The dynamics of community innovations

A socio-technical analysis of the shaping of The Things Network – an Internet of Things community network

Master Thesis

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Graduation date: August 29, 2017

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Summary

Historically, innovation was considered to be carried out by manufacturers only, who keep innovations for themselves, protected by patents and copyrights. However, Von Hippel and colleagues have argued that in practice, innovation is also carried out by users, often, but not necessary in the form of a community. In their research on innovation communities, they mainly focus on the exchange of information. STS scholars further develop the notion of innovation communities, by introducing concepts of co-shaping socio-technical configurations, agency of technological artefacts and user diversity. This research aims to add to the current body of work on the dynamics of bottom-up innovation communities, by examining The Things Network, a community that aims to develop a global ICT-network infrastructure. Current work on innovation communities doesn't include communities building global network infrastructures, as they only focus on local infrastructure, or global communities developing open source software. Another reason why The Things Network is an interesting case study is commercialization, as it is a recurring topic within innovation communities. Several scholars have shown that there often is tension between community and commercial aspects, which sometimes leads to splits or disintegration of the community. Within The Things Network, they have – until now – maintained a constructive balance between commercial and community values and interests. This led me to define the following research question: *How can we understand the socio-technical dynamics of The Things Network as a local and global innovation community?*

In this thesis, I have build forth on the research of Verhaegh, who conceptualizes innovation communities as a socio-technical heterogeneous network consisting of a variety of diverse human and non-human actors. He introduces the notion of 'alignment work', as the work involved in shaping heterogeneous networks. However, as Verhaegh did not further conceptualize the dynamics of alignment work itself, I further structured these dynamics using a framework of Callon, the sociology of translation. This framework introduces four phases by which heterogeneous networks are shaped: problematization, interessement, enrolment and mobilization, which have allowed me to analyze the alignment processes in The Things Network in more detail. Callon further refines these phases by developing several related notions: problem definition, actor definition and obligatory points of passage (problematization); interessement devices (interessement); representation (mobilization); translation and displacement (overall). Throughout my study, I have refined and enriched Callon's vocabulary, by developing three new notions, namely 'sub-problematization', as a refinement of the problem definition, 'alignment device', as an addition to the interessement device and the notion of 'placement' of newly developed actors.

I have described and analyzed my case study with this conceptual lens, which has led to the identification of four different alignment dynamics, namely 1) continuous alignment, 2) iterated alignment, 3) de- and re-alignment, and 4) consecutive alignment. Furthermore, The Things Network is a multi-scalar network, where actors form their own nested heterogeneous networks. In these networks, actors, focus on addressing localized problems, aimed at contributing to the global goal of The Things Network. Finally, the initiators of The Things Network aim to strengthen the bonds between the involved actors, through open communication and inclusion of local actors in dynamics on the global level, as well as aiming to incorporate the interests of the different actors – both commercial and non-commercial – in the global infrastructure, in such a way that commercial actors and non-commercial actors reinforce each other in creating a global crowd-sourced infrastructure.

These conclusions are translated into six lessons, aimed at creating and strengthening innovation communities.

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1 Introduction

It can be said that we live in the `technological age', or in the `digital' age, an age where we shift from traditional industry, towards a world of digital technology and digital information transfer. In our daily lives, (digital) technology is all around us. Social media connected us digitally to other people, but recently our devices also become more and more connected. The whole of these connected devices is also called an 'Internet of Things' (IoT). These things can be almost anything, for example a heart monitor implant, a sensor that reports when the pressure of your car's tires is low, sensors in bridges that report if the bridge is structurally failing, a thermostat that can be controlled remotely, just to name a few examples (Burrus, 2014; NEST, 2015; van Noort, 2015).

These technologies require a wireless network with which they can connect. Some devices rely on already existing networks, like Wi-Fi, Bluetooth, or GSM networks. However, existing technologies are not made to be used by IoT devices and generally have important drawbacks, like a limited range (several tens of meters) or high power consumption. Several new protocols have been developed to overcome these drawbacks and build networks specifically aimed for IoT devices. These protocols are generally grouped under the name ‘Low Power Wide Area Networks’, or LPWAN[1]. Generally, the aim of LPWAN protocols is, like the name implies, to create a low power, wide area network. One of the most important and interesting LPWAN protocol is LoRaWAN, an open protocol built on the proprietary LoRa® chips technology[2]. LoRa chips arrange the transmission and reception of data and the LoRaWAN protocol is a standard with which to build a complete network on LoRa. It specifies data formats and encryption, and also which radio frequencies should be used. Generally, a LoRaWAN network consists of gateways, which provide coverage and receive the messages sent by IoT devices, and a backend. The gateways forward the messages they receive to the backend via the internet, and the backend sends the messages to their destinations[3].

Today, LoRaWAN networks are being built by different parties, most of which are commercial[4]. The commercial actors tend to build closed networks with a subscription-based revenue model. In other words, if you want to use their network, you have to pay for it. However, as LoRaWAN is an open standard, it also allows building an open source and free network. This is precisely what the non-profit foundation ‘The Things Network’ (TTN) aims to do: to create a community LoraWan network that that can be used for free by everyone. The software TTN develops is released under an open-source license. The ultimate goal of TTN is to have a set of networks that together cover the whole world (The Things Network, 2016), but they started small. Initially, TTN started with a proof-of-concept network in Amsterdam, The Netherlands, where they built

[1] For an overview of different LPWAN technologies, see e.g. https://iot-for-all.com/comparison-of-lpwan-technologies/

[2] Source: (Petersen, 2015) and https://www.lora-alliance.org/What-Is-LoRa/Technology

[3] For more information on LoRaWAN, see Appendix A.

[4] Most parties are united under the flag of the LoRa-Alliance, with members like IBM, Cisco, ST and KPN. For a full list see: https://www.lora-alliance.org/The-Alliance/Member-List

their own software for a backend and crowd-sourced the gateways: local companies and organizations paid for the gateways and put them on their roof.

After this first network was deemed successful, the members of The Things Network started working on their global aspirations. Instead of working from a single community to create coverage, they argued for a model with a central team, and lots of local communities. This central team would consist of the team then working in Amsterdam and would continue to work on the backend and provide centralized communication media. Local communities on the other hand, would work on placing gateways in their area, and create applications which could be used on the network. In contrast to the network itself, these applications do not have to be open: from the start, the initiators of TTN established that everyone is free to develop commercial and non-commercial applications on the network, without ever having to pay for use of the network.

The Things Network is working on new innovations, from creating their own backend to applications on the network. As such, TTN can be considered an '*innovation community*'. The concept of innovation communities has first been developed by Von Hippel and colleagues in Innovation Studies. It is rooted in earlier research by Von Hippel into user innovators. He argues that not only manufacturers innovate, but also users. Collaborating user innovators are considered by Von Hippel as an innovation community when they regularly exchange information about their innovations (Von Hippel, 2005a). Generally, the innovators are working non-profit, as volunteers. However, the innovations they develop are often commercialized, either by members of the community or external manufacturers (see e.g. Franke & Shah, 2003). In these types of innovations, the product is not inherently linked to the innovation community (Von Hippel, 2005a).

Later, scholars from STS interested in the active role of users in technology development, also contributed to the understanding of the phenomenon of innovation communities (e.g. Verhaegh 2010, Soderberg 2011, Hyysalo 2007) The STS perspective conceptually enriched the analysis and understanding of the dynamics of innovation communities. Whereas scholars from Innovation Studies focus on exchange of information, STS scholars introduce concepts of co-shaping socio-technical configurations, agency of technological artefacts and user diversity.

Verhaegh (2010) conceptualizes innovation communities as hybrid socio-technical collectives. He argues that innovations are inherently linked to their innovation community. He analyzed the case of Wireless Leiden, a community concerned with creating and maintaining an innovative city-wide wireless infrastructure, which is mainly used to provide free internet to the residents of Leiden, a city in the Netherlands. Verhaegh argues that without the community, there would be no innovation, as a lot of work is involved in creating and maintaining the innovation, ensuring that it keeps working. Furthermore, without the innovation, there would be no community, as the only reason for the existence of the community, is the network. In other words, the community and the innovation are co-produced. By emphasizing this dynamic, Verhaegh introduced the notion of *Community Innovation*.

The second conceptual STS lense concerns the role of technological artefacts. In STS studies, technological artifacts have *material agency* in addition to their enabling and constraining influence, limiting or enabling possibilities within innovations (Callon, 1980; Callon & Law, 1982; Oudshoorn & Pinch, 2003). Verhaegh (2010) argues that scholars of Innovation Studies generally do not include technology as an actor in the innovation process. One notable exception to this is a study by Von Hippel and Finkelstein (1978), who explored how artifacts could enable or restrain processes of user innovations.

The third characteristic STS lense is '*user diversity*'. User-oriented STS studies have shown that often several different types of users are involved in the development of new products, potentially with different interests and agendas (e.g.Oudshoorn et al., 2005). Both Hyysalo (2007) and Verhaegh argue that research of Innovation Studies does not take into account this diversity of users.

In his study of Wireless Leiden, Verhaegh choose to focus on four different types of work carried out in innovation communities, to ensure the different types of actors (human as well as non-human) involved in the community are rendered visible. These four types are: alignment work, domestication work, care work and coordination work.[5] At the start of a community, actors will have to be brought together, in order to successfully realize the goals of that community. In the case of Wireless Leiden, work revolved around changing Wi-Fi from a low-range indoor technology to a long-range outdoor technology, the alignment of actors who could help realize this change and other actors who would help expand and maintain the community (network). Domestication work describes the process by which Wireless Leiden is brought to the homes of Leiden residents. Care work describes the work involved in maintenance of the different parts of the network. The last type of work, coordination work, describes the "[..] *activities involved in keeping the hybrid collective of Wireless Leiden coherent and preventing it from falling apart [..]" (Verhaegh, 2010, p. 128).* In his case study, Verhaegh highlights two dimensions of potential conflict in the dynamics of innovation communities: *commercialization and professionalization*. On these two dimensions, different actors on the network have conflicting interests, which result in (heated) discussions on the path Wireless Leiden is to take. The first conflict is resolved internally, while the second one results in a fracture, with some members leaving the initiative.

Commercialization is a recurring topic in innovation communities. Von Hippel has shown that there is often a tension between the non-commercial and commercial aspects in the network. This tension is especially visible in another case study by Söderberg (2011), namely the Ronja community in the city of Prague. The Ronja community developed an innovative local ICT-infrastructure based on sending data over visible, red light. Söderberg (2011) describes the value conflict which emerged in this community. In his research, he describes how the Ronja community slowly fell apart. The community was initially concerned with creating a 'user-controlled technology': everyone, including those lacking previous knowledge of electronics, should be able to build the device. In the Ronja project, they aimed to realize this by enabling lay users to understand and build the technology, as well as using generally available and relatively cheap components. This collective vision encouraged community members to share their modifications, with a focus on making it easy for new users to understand and build Ronja devices themselves. Sometimes,

[5] For an elaborate description of the different theoretical concepts mentioned in the introduction, please see Section 2. Theoretical Framework.

innovators would abandon their improvements, because they proved to be too complex, or unreliable. However, after some time, some community members were unsatisfied by the basic nature of Ronja devices and wanted to improve them substantially. They stopped sharing their designs, thereby abandoned the principles of a user-controlled technology, and started to market their improved devices commercially. This tension between interests slowly drove the community apart, resulting in its disintegration.

In this thesis I aim to contribute to the current body of studies on the dynamics of Innovation Communities by using The Things Network (TTN) as case. The Things Network is an interesting case study as it is an innovation community concerned with building a global network infrastructure. Earlier STS case studies focused primarily on communities developing physical ICT infrastructures on a local level, like the previously mentioned Wireless Leiden (Verhaegh, 2010) and Ronja community (Söderberg, 2011). Within Innovation Studies global communities are studied, but mainly those that focus in open source software innovations, like the Apache web server software (Franke & Von Hippel, 2003) and Fetchmail (Von Hippel, 2005a). Another reason that The Things Network is an interesting case study is that TTN has developed –until now – a constructive balance between commercial and community values and interests.

This results in the following research question:

How can we understand the socio-technical dynamics of The Things Network as a local and global innovation community?

This thesis contains a total of 7 chapters and is structured as follows: In Chapter 2, I will elaborate the conceptual framework for analyzing the case study and reformulate my main research question into theory-informed sub-questions. Chapter 3 describes the methodology I used to answer these research questions. In chapters 4, 5, and 6, I will analyze the case study: Chapter 4 contains an analysis of the start of TTN as a local community building a network in Amsterdam. In chapter 5, I will focus on the transformation to a global community and the resulting alignment work on the global level. In chapter 6, I will elaborate on the dynamics of two Dutch local communities, the alignment work within these communities and the dynamics between the global and local level of the communities. In chapter 7, I will summarize my main findings related to the initial research questions and discuss and compare my findings with the earlier case studies on innovation communities, most notably the study on Wireless Leiden by Verhaegh (2011). Finally, I will draw conclusions and elaborate recommendations for further research.

2 Theoretical Framework

In this section, I will elaborate on the theories and concepts that I already shortly addressed in the introduction. In section 2.1 I will discuss more extensive the research carried out in Innovation Studies, focusing on users as innovators and innovation communities. In the next section, 2.2, I will elaborate on the STS concepts relevant for the analysis of the dynamics of innovation communities as a heterogeneous network, namely user agency in the shaping of technology, the user diversity and, last but not least, the agency of material actors in the shaping of technology. Next, in section 2.3, I will elaborate on two frameworks for analyzing the dynamics of shaping heterogeneous networks. The first framework is based on the work by Verhaegh (2010), with an emphasis on the first type of work, alignment work, as the other types of work – domestication work, maintenance work and coordination work are less relevant for TTN. The project is still in the phase of building the network. By using a second framework, based on the sociology of translations as developed by Callon (1986b) I aim to conceptually enrich the dynamics of alignment work. In the last section 2.4 I will elaborate on the theory induced reformulation of the main research question into sub-questions.

2.1 Innovation Studies

In this section, I will elaborate on the research done by scholars in Innovation Studies, most notably Von Hippel. In the first sub-section I will focus on users as innovators, and in the second I will focus on the work of Von Hippel and colleagues on innovation communities.

2.1.1 Users as innovators

In the traditional, manufacturer-centric model of innovation, innovation is carried out by (research departments of) manufacturers, who develop new products and services, keeping the innovations for themselves, protected by patents, copyrights and other means to prevent others from profiting from them. The resulting products are brought to the market, where the user is seen as the passive recipient, only there to have needs which are partly satisfied by these new products (Von Hippel, 2005b, p. 4).

While studying the innovation process Von Hippel and others found that, contrary to the traditional model, innovation is often carried out in collaboration with, or by users[6] (Shah, 2000; Tuomi, 2002; Urban & Von Hippel, 1988; Von Hippel, 1976). Examples of user innovations can be found in for example the development of high-performance windsurfing equipment. At the time of the first Hawaiian World Cup for windsurfers, a small group of windsurfers started to jump with their surfboards. However, while attempting to jump, they would often lose control of their surfboards, as they flew off in mid-air, having nothing to stay standing on the board. One of the windsurfers recalled making a board with foot straps. Using this board made it possible to control the board in mid-air and land without hurting himself or damaging the equipment. Within a few days several others also added foot straps to their boards and they started competing on who could make the nicest/highest jumps (Shah,

[6] It is important to note here that `users' in the terminology of Von Hippel are those who use products designed by others. An airplane factory produces airplanes, but they are users of eg. metal working machines. So, the term users dos not only include individuals, but alco companies and other organizations (Von Hippel, 2005a, p. 3).

2000). Von Hippel (1986) argues that there is a specific type of user who is most likely to innovate, which he calls the 'lead user'.

According to Von Hippel, lead users differ from other users by two defining characteristics. The first of these is that lead users are at the leading edge of a market trend, in other words they are experiencing new needs to which no previous attention has been paid and are not yet experienced by the bulk of the market. Secondly, lead users expect to benefit from a solution to these new needs. The higher this benefit is, the more incentive the user has to obtain a solution, either by developing or purchasing one (Von Hippel, 2005a, p. 22). These properties can be clearly seen in the previous example of the windsurfers. They were experiencing a problem, where they couldn't jump without flying off the board in mid-air. The solution one of the servers came up with served as a solution for this problem and even enabled one to not only fly in the air and land, but also change direction in mid-air. In this case, the solution was already present, without the need to develop something new. In other cases, several innovators work together to create solutions for the problems they perceive. This kind of collaboration can be largely informal, where innovators occasionally help each other. Another form of, more organized, collaboration occurs when innovators come together in what Von Hippel calls an innovation community (Von Hippel, 2005a).

2.1.2 Innovation Communities

Information communities are groups where user innovators work together in a formalized group (eg. the Linux open source communities). Von Hippel (2005a) defined `innovation communities' as meaning ``nodes consisting of individuals or firms interconnected by information transfer links which may involve face-to-face, electronic, or other communication'' (p. 96). Members of innovation communities are both (lead) users and manufacturers (individuals as well as firms). Lead users might receive support from other users and manufacturers may create commercial products based on the information revealed in the community. This form of commercialization is especially visible in extreme or very specific sports (Franke & Shah, 2003).

A crucial aspect of innovation communities is their way of handling information about innovations. Von Hippel (2005a) argues that innovation communities can only flourish when at least some of its members innovate and freely reveal their innovations and others find the information revealed to be of interest. This can be seen in communities of individuals (see eg. Franke and Shah 2003, on extreme sports) as well as in communities where firms are involved (sometimes in collaboration with individuals). Examples include freely revealed information to competing firms on furnace improvements for the English iron ore industry (Allen, 1983), improvements on steam engines used to pump water out of mines in the 1800s (Nuvolari, 2004) and, more recently, in the embedded software business. Henkel (2003) analyzed practices on developing 'embedded Linux', which is a collection of different Linux operating systems, modified to run on small embedded systems and based on the Linux Kernel or non-embedded Linux Operating Systems. Recently, more and more devices are equipped with microprocessors and software, ranging from small devices, like a tv, tv-remote and coffee machine, to large industrial machines and airplanes. The software running in these machines is often some form of embedded Linux[7]. Due to the wide range of embedded devices, there is no standard embedded Linux available, but rather a set of modules and extensions that make Linux suitable for embedded systems. These modules are developed by commercial (competitive) firms, who often work together and freely reveal parts of their software, so others can use them. This form of collaboration offers several benefits: it results in an improved version of what Henkel calls 'standard Linux'[8], re-using code to speed up development, learning from code written by others and getting support from other developers from potentially competing firms.

Another set of characteristics of innovation communities is related to social interactions in communities. The first of these is that apart from functional interaction, users often connect on the social level, where ``networks of interpersonal ties that provide sociability, support, information, a sense of belonging, and social identity'' (Wellman et al. 2002, p. 4; in Hippel 2005a) are established. These social networks are more apparent in user innovations outside of firms. Secondly, innovators are often more involved in their respective communities. In their research on innovation in extreme sports communities, Franke and Shah (2003) found that innovators within the sports communities are more involved in these communities as they spend more time with other community members and are, generally, involved longer in the community than non-innovators. Finally, members of innovation communities tend to help others, not only by distributing and evaluating completed innovations, but also help with innovations-in-progress. Users offer their knowledge and competencies to other users, to help them innovate. They also assist innovators by referring them to non-community members who might be able to help them with other skills not available in the community (Franke & Shah, pp. 164-165).

The last characteristic of innovation communities can be found in its tension between its commercial and non-commercial aspects. Generally, as we have seen, work done in innovation communities is non-profit, voluntary work, carried out by individual users, or firms. In other words, communities are based around a gift economy, exchanging information (about innovations) rather than money. On the other hand, innovations themselves might be commercialized, in two different ways: if firms are involved, they often receive commercial benefits from the developments in the community by incorporating them in their own products. Furthermore, the innovations developed in the communities might be commercialized by manufacturers, who can be both user manufacturers (Baldwin & Von Hippel, 2011) or firm manufacturers. These manufacturers are often part of the community (Von Hippel, 2005a).

Clearly, Von Hippel and his scholars have contributed greatly to putting user innovation and innovation communities on the research agenda. Yet I agree with Oudshoorn and Pinch (2003) and Verhaegh (2010) that the IS perspective is limited. It does not address the role of material actors in

[7] Currently, in 2017, almost all embedded consumer products (eg. Phones, cameras and televisions) use some form of embedded Linux. For a non-exhaustive list of earlier consumer products using embedded Linux, see: http://elinux.org/Products

[8] The term standard Linux is not known in Linux communities. Henkel probably refers to the Linux Kernel, which is the basis used in all Linux operating systems.

the dynamics, nor does it pay attention to user diversity. STS studies conceptually elaborated these aspects.

2.2 Science, Technology & Society Studies

In this section, I will focus on three different core concepts in STS. I will start with user agency, which is followed by work on user diversity. Finally, I will elaborate on research on the role of technology.

2.2.1 User agency in STS

From the 1980s onwards, scholars in STS began to consider the role of users in the development of new technologies, and along with it, different models of innovation[9]. In their seminal work, Oudshoorn and Pinch (2003) trace the roots of user agency in STS to two strands of research. The first of these is the studies undertaken by feminist scholars in the area of history of technology. Oudshoorn and Pinch state that historians of technology initially focused only on the design and production of technologies, an area of development that was dominated by men. Feminist scholars argued that historians of technology should include the use and users of technology in their research, which also served as a way of looking at technology beyond male dominated studies. Slowly, users were introduced in research on history of technology, first only as passive recipients of technology and later as active participants in technological change (Oudshoorn & Pinch, 2003, pp. 4-5). Oudshoorn and Pinch (2003) mention the relevance of the research done by Ruth Schwartz Cowan as one of the earliest works addressing the active role of users in technology development by introducing the notion of ‘consumption junction’, as “*the place and time at which the consumer makes choices between competing technologies*” (Cowan 1987, p. 263, as quoted in Oudshoorn & Pinch 2003, p. 4).

The second strand of research revolves around the scholars Trevor Pinch & Wiebe Bijker, who developed the social construction of technology (SCOT) approach (Pinch & Bijker, 1984). Central to the SCOT approach is the role of users in technological development. When a new technology is developed, different groups of users are involved, who might have very different needs. In turn, innovators might address one (or more) of these needs in product development, resulting in different revisions of one technological idea.

Different groups of users might have very different needs, leading to different developments of the same technology. As a result, technology development follows an often-forked path, with many different strands. In the SCOT theory, Pinch and Bijker (1984) argue that, sooner or later, development will converge to one strand, and a dominant technological meaning emerges. A well-known example of this is the development of the bicycle, which went from the high-wheeled bicycle via many detours and alternatives to the safety bicycle as we know today. Later, the concept of users as 'agents of technological change' has been added to SCOT, which accounts for later developments of a technology, when users find new uses for a technology, after it has been stabilized (Kline & Pinch, 1996).

[9] In contrast to the traditional linear model of innovation, as mentioned in the previous chapter

Both feminist scholars and the SCOT approach show that users play an active role in technological change and that there are different (groups of) users, each with their own needs and agendas. This concept has been introduced by (Cowan, 1987) as 'user diversity'.

2.2.2 User diversity

The relevance of user diversity for understanding technology dynamics was addressed by early feminist scholars who aimed to make visible on the active role of women in shaping new technology (Oudshoorn & Pinch, 2003), by emphasizing their autonomy and influence on technological development. Cowan (1987) showed that there are a lot of different kind of users. Similar like Pinch and Bijker (1987) show in their work on SCOT, there are a lot of different groups of actors. In medical technologies for example, one can find, amongst others, health professionals, patients, hospital administrators, nurses and patients' families. Within these groups, one can find more variety: user groups consist of people of different gender, age, socio-economic and ethnic situation, which might all be relevant for their view on or role in the development and use of a technology. Because of this heterogeneity amongst users, not all users will find themselves in the same position in relation to a specific technology (Oudshoorn & Pinch, 2003, p. 6).

In Innovation Studies, not much attention has been paid to the diversity of users (Oudshoorn & Pinch, 2003, 2008). Hyysalo (2007) argues that the focus on lead users diminishes the role of other users. He argues that local modifications and adaptations by non-lead users can be crucial to the diffusion of innovation.

It is no trivial task to identify all these different groups. The very act of trying to identify groups and individuals as users might already change the actual roles of these people in technological development. Groups involved in the development of a new product may have different views on who the users are, or will be, and may employ different resources to steer the design of the new technology, so it fits their view (Oudshoorn et al., 2005).

2.2.3 Agency of Technological artefacts

Another important strand of work found in STS studies, is that of the role of technological artefacts in the development and use of (new) technologies, of which the fundamental work was carried out by Callon, Latour, Law and others, when they developed Actor Network Theory (ANT) (e.g.Callon, 1986a; Law, 1992). ANT scholars build on the work of semiotics, which is the study of how meanings are built, and extend it to include technology. They argue that actors are brought into existence relationally: there is no individual actor (human or non-human) which can exist without a relation to another actor. It is precisely these relations between the different actors, which constitutes these actors themselves. An important notion in the relation between humans and non-humans is the idea of a 'script'. Akrich (1992) argues that all designers base their design on an envisioned set of users and specific use situations. The materialized presentation of this envisioned use can be seen as a script of the technology. When the technology is used, or, in semiotic terms, the script read, it is adapted to a new environment, in which the uses, meanings, and products themselves can be changed.

STS scholars thus find that material actors play an active role in its development and use. Drawing on earlier research, (Verhaegh, 2010) argues that innovation communities are inherently socio-technical, forming a hybrid collective, in which both human and non-human actors together shape technological development. As a result, he defines innovation by user collectives as *"a process of building heterogeneous networks among and between humans and non-humans"* (Verhaegh, 2010, p. 19). These networks are never really stable, requiring continuous work, to make sure the network doesn't fall apart.

In this thesis I will start my analysis based on the above discussed STS perspective, conceptualizing an innovation community as a socio-technical heterogeneous network consisting of a variety of diverse human and non-human actors. In the next section I will elaborate on a framework for analysing the dynamics by which these heterogeneous networks come into being and how these networks grow in a process of co-shaping the community and the innovation.

2.3 Alignment dynamics in shaping heterogeneous networks

Verhaegh (2010) distinguished four types of work to understand the process of building and maintaining these heterogeneous networks: alignment work, domestication work, maintenance work and coordination work. For my study the first type of work is the most relevant as my case of TTN is still in the phase of developing the infrastructure and has hardly any users until now. He defined alignment work as focused *"on the work involved in creating alliances and building connections between the heterogeneous elements of the network"*. (Verhaegh, 2010, p. 26). He separates alignment work in Wireless Leiden in two different phases: the first phase of 'user-initiated innovation as collective re-engineering' (Verhaegh, 2010) and the second phase, which is featured by 'The growth of Wireless Leiden as community innovation' (Verhaegh, 2010).

In the first phase, the Wireless Leiden initiators work on re-engineering Wi-Fi, from a device providing wireless internet access in people's homes to an outdoor, long-range device as part of a network infrastructure. Verhaegh argues that the work needed to re-engineer Wi-Fi is shaped by two different actors, namely the (original) script of Wi-Fi, and the envisioned user and use situation. Furthermore, in describing the work involved in increasing the range of the devices, Verhaegh describes one limiting actor, namely the law, which restricts the maximum amount of power Wi-Fi devices can use to send data. As such, re-engineering can be understood as a (possible) process in the dynamics of an innovation community, focusing on the work necessary to align technological artifacts to the heterogeneous network.

In the second phase, Verhaegh characterizes Wireless Leiden as a 'community innovation' where a variety of both human and non-humans actors are inextricably interwoven in the development of Wireless Leiden as a network infrastructure, co-shaping each other and themselves.

Both phases clearly give some insight in the dynamics of shaping community innovations. However, Verhaegh did not further conceptualize the dynamics of alignment work itself, e.g. on phases in alignment work, or the different dynamics in aligning different types of actors.

The shaping of heterogeneous networks can also be understood as a translational process. According to Latour (1987) the translation process is a process where actors enroll allies in the actor network and align the

interests of those allies in a continuous process of renegotiation. The interests of the allies are translated in such a way that they coincide with the goals of the actors. In this process, he doesn't differentiate between human and non-human actors.
Callon (1986b) conceptualizes this process of translation in four specific moments or phases of translation: *problematization, interessement, enrolment and mobilization*. He elaborated these concepts based on the analysis of a specific case study. He follows three researchers in their work on aligning different actors, to find the answer to the question: Do the scallops (Pecten Maximus) at St. Brieuc Bay anchor?

Although the scallops case is quite different from community innovations like TTN, I expect that this elaboration of four phases can refine Verhaegh's general concept of alignment work. Callon analyses the scallops case from the perspective of the researchers, whereas innovation communities are initiated by a quite different type of actor, the lead users. Yet most innovation communities have a lead user as initiator[10], and in the first phase of understanding the rise of a new innovation communities, the perspectives of these initiators are core elements in the dynamics. Below the four phases are described and illustrated by the scallops case.

The first phase in translation is '*problematization*', which Callon defines as follows: "*They determined a set of actors and defined their identities in such a way as to establish themselves as an obligatory passage point in the network of relationships they were building. This double movement, which renders them indispensable in the network, is what we call problematization*" (Callon, 1986b, p. 6). In this process, the initiating actors start by describing a problem, or question as a first step in building the network of relations. In the case of the scallops at St. Brieuc bay, it is the above-mentioned question. For years now, the stock of scallops in France has been dwindling. The three researchers have recently visited Japan, where they observed a new method on scallop cultivation. They want to bring this method to France, or more specifically, St. Brieuc bay, to restore the dwindling stock of Scallops. However, to confirm whether the Japanese methods work, they have to find out whether the scallops at St. Brieuc anchor.

The next phase in the process is 'interessement', the definition of relevant actors and their interests, in such a way that the interests align with the question. In order to satisfy these interests, the actors have to accept the problem and *"recognize that their alliance around this question can benefit each of them"* (Callon, 1986b, p. 8), establishing the problem/question, and by extension, the three researchers, as obligatory point of passage. Consider for example the definition of the fishermen of St. Brieuc bay by the three researchers. They argue that these fishermen were fishing all scallops from the bay for large short term profits. In the long run however, this would ruin the business of the fishermen, as there would be no scallops left to fish. The researchers argued that the fishermen were aware of this problem and would thus be interested in restocking the bay. Before restocking the bay is possible however, they first need to answer the question whether the scallops anchor, defining this question and the three researchers bent on answering it, as an obligatory point of passage.

[10] For example: The lead user for Wireless Leiden was Koolhaas, and Karel Kulhavy was the lead user for Ronja.

In this phase, the researchers have to align the different actors with their definition, or in Callon's words: *"Interessement is the group of actions by which an entity attempts to impose and stabilize the identity of other actors it defines through its problematization. Different devices are used to implement these actions"* (Callon, 1986b, p. 8). Callon calls these devices '*interessement devices*', which can be virtually anything. Interessement devices are placed between the actor to be interested and all other entities, preventing them from creating a link with the two actors. In Figure 1, the two actors are represented as A and B. The interessement device, the large arrow, prevents C,D and E from aligning with B and promotes the connection with A.

An example is the device used by the three researchers to interest scallops. It is the same device as used by the Japanese to cultivate scallops. It is a towline with collectors to which scallop larvae anchor and which protects from predators and other dangers. The towlines are meant to confirm the theories of the actors, showing that Pecten maximus does anchor, while at the same time keeping predators, influence from currents and fishermen at bay.

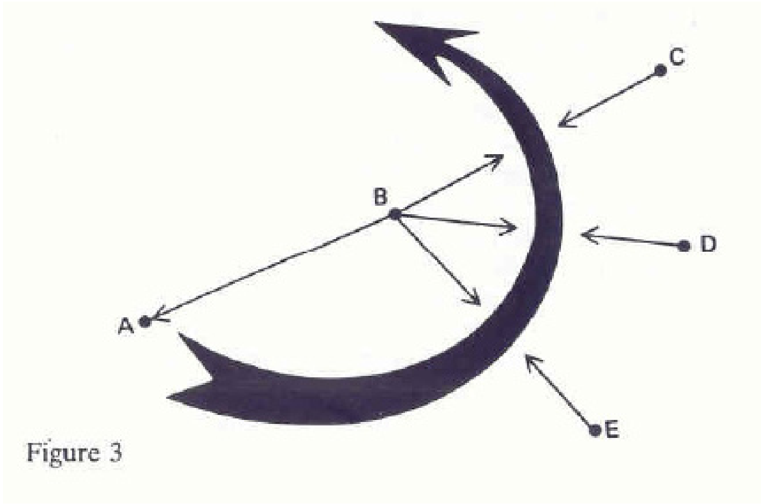

Figure 1- Interessement device - (Callon, 1986b)

Enrolment describes the actual process by which the actors are aligned: "*To describe enrolment is thus to describe the group of multilateral negotiations, trials of strength and tricks that accompany the interessements and enable them to succeed*" (Callon, 1986b, p. 10). Callon captures enrolment by describing the negotiations with the scallops: In the negotiations of the three researchers with the scallops, several changes to the interessement device are needed to show that the scallops at St. Brieuc actually anchor: The researchers experiment with different materials as well as the height at which to place the towlines, with varying success: Some materials, like straw, broom or vegetable horsehair prove to be less successful than others. In the end however, they are convinced that Pecten maximus does in fact anchor.

The final phase, mobilization, has two aspects: representation and displacement. Representation concerns the amount of actors actively involved in the network, compared to all actors in the group: Not every entity in the different actor groups is involved, but are rather represented by a limited subset of these actors. The total population of scallops is represented by their anchoring brethren; the scientific community is represented by those scientists who read the publications of the three researches and visit the conferences; the fishermen have appointed representatives. These representatives have given green light and their support to the experiments by the scientists and restocking the bay.

The second aspect of mobilization, displacement, is used in conjunction with transformation: In a heterogeneous network, displacements take place continuously: goals and interests of actors are displaced to the interests as defined by the three researchers. Instead of fishing for short-term benefits, the fishermen "*were invited to change the focus of their preoccupations and their project in order to follow the investigations of the researchers*" (Callon, 1986b, p. 18). These displacements renders actors mobile: "*To mobilize, as the word indicates, is to render entities mobile, which were not so beforehand*" (Callon, 1986b, p. 14). Or, in other words, actors who were previously not included in the heterogeneous network, are now becoming part of the network. Originally, Callon's analysis does not include the creation of new actors, but it is easy to see that mobilization could also include the shaping of new actors, not just displacing them, but developing (implying a separate translation process) and placing them in the network.

To summarize, Callon's phases of translation can be a valuable conceptual elaboration of Verhaegh's notion of alignment work. The processes and concepts of problematization, obligatory point of passage, interessement and interessement devices, enrolment and mobilization (displacement and representation) allow for a more detailed analysis of alignment work. Yet it is likely that there are limitations as well as Callon's case is written from the perspective of traditional actors (scientists) whereas in my case community actors and users are core actors. Another limitation of Callon's vocabulary can be the limited analytical power to understand the dynamics behind the shaping of new innovative technological actors rooted in user innovation.

2.4 Research questions

In chapter 1, I defined the main research question as follows:

How can we understand the socio-technical dynamics of The Things Network as a local and global innovation community?

In light of the literature discussed in this section and the main research question, it is possible to further specify the goals of this research. I thus have derived the following sub-questions:

1. How can the rise of The Things Network be understood in terms of aligning and translating human and non human actors in a new heterogeneous network ?
2. What heterogeneous actors – human and non-human – are aligned and translated into the TTN network as global innovation community?
3. What heterogeneous actors – human and non-human – are aligned and translated into local TTN innovation communities?
4. How do local and global dynamics influence each other?
5. How are community and commercial interests co-aligned in the above global and local dynamics?

3 Methodological approach

In this chapter, I will first elaborate on my choice for a single case study. Afterwards I will describe the methodology used to answer the research questions.

3.1 Case study approach

The empirical and orienting nature of this research has led me to use a qualitative approach, based on an in-depth case study (Yin, 2006). This kind of qualitative approach enabled me to make a detailed analysis of the dynamics of community innovations, while staying within the time limits for this thesis. The main drawback of a single case study is that it isn't possible to directly extrapolate the results to general findings. To overcome this limitation, I will discuss and compare my findings in relation to similar studies, most notably Verhaegh's (2010) study of Wireless Leiden. The case study to be analyzed is the community around 'The Things Network'; a community concerned with the development of a LoRaWAN based infrastructure. The Things Network officially launched on August 21, 2015, after the initial team created a local infrastructure covering the city of Amsterdam. After the launch, the community quickly became a global community, with local communities creating coverage and a global team steering the direction of TTN and work on global elements of the infrastructure. In roughly two years, the community, initially comprised of 9 members, grew to more than 20.000 members, spread over 450 communities in more than 80 countries. Together, these communities placed more than 1000 gateways, providing (localized) coverage all around the world.

In this thesis, I focused on the global team and two local communities, due to the limited time and space available. The two local communities, TTN Enschede and LoRApeldoorn are both situated in The Netherlands. The geographical location of these communities allowed me to attend their meet-ups and be flexible when having to travel for interviews, enabling me to conduct a more in-depth analysis. A potential drawback of analyzing two communities which are relatively close is that they do not necessarily compare to other local communities in different countries, where not only local laws differ, for example regarding privacy, data retention and frequency usage, but also have a different culture, which might have its own effects on local communities. Such a comparison between local communities is outside the scope of my thesis, but might constitute a relevant topic for further study.

3.2 Research Methodology

I used semi-structured qualitative interviews as the main method for collecting empirical data. I interviewed in total nine actors from the global team and the two local communities (see table 3.3). The interviewees of TTN Enschede were mainly identified through a snow-ball method, where one interview led to the other. Unfortunately, the Enschede community became inactive shortly after I started working on my thesis, which left me with 3 interviews. In LoRApeldoorn, I briefly elaborated on my research in one of the meet-ups, after which I interested 5 local members for an interview. In both communities, I interviewed (one of) the initiator(-s) and several local community members. It proved to be more difficult to interest members of the global team for an interview: I initially hoped to interview the two founders of The Things Network, however, after repeated requests, they were not available for an interview, which limited my interviews of global team members to one of the two community managers.

The interviews with local community members were informed on my conceptualization of shaping heterogeneous networks, presented in section 2.3 and the resulting sub-questions, presented in section 2.4. focussing on gaining insight into alignment and translation dynamics in the local communities. The interviews addressed the background of the interviewed actors; the process by which they joined The Things network; their relation to and perception of other actors involved in the network; their personal interests and their perception of the interests of the founders of The Things Network; the dynamics of shaping the LoRaWAN-infrastructure; and the work done on creating applications for The Things Network. These topics were translated into 9 sets of questions. These questions were pre-structured but open. During the interviews, I stimulated the interviewee to tell more by using prompting techniques. The interview with the global team member is structured similarly, but emphasized the dynamics on the global level, as well as the relation between dynamics on the global and local level. An overview of the different interviews can be found in table 1 and the schematic for the different interviews is attached in Appendix B.

To complement these interviews, I collected data from several other sources. First, I attended several meetups of the two local communities, as well as a meetup for community initiators in the Netherlands, hosted by the global team. I made notes of these meetings and used some of the information to sharpen the interviews. An overview of these meetings can be found in table 2. Secondly, I used some existing online recordings of other meetups organized by the global team, as well as two online meetings. Thirdly, I used a set of public interviews with Wienke Giezeman, who was interviewed by several different media. Fourthly, I studied several design documents and specifications, including the LoRaWAN specifications and documents provided by TTN on their architecture. An overview of all the attended meetings can be found in table 2. The other sources are listed in table 3. Finally, I've studied several media outings by The Things Network, most notably their e-mail updates and the website, as well as the global forum.

The empirical data is analyzed within the two concepts of shaping heterogeneous networks: alignment work and translation processes. All non-written sources have been transcribed, and the data is analyzed and structured using coding software (Atlas.ti). In the initial round of coding, different actors (human and non-human), the defined and actual interests of these actors, the visions and strategies of actors, and the (changing) actor relations, were identified. This resulted in the identification of several different processes in shaping the heterogeneous network. In a second round of coding, these processes were coded based on the actors involved, their problematization, the interessement devices, discrepancies between defined and actual interests, the negotiations of these interests and the results.

3.3 Tables : Overview of interviews and meetups

Interviews			
User Role	**Name**	**Interview date**	**Reffered to as**
Initiator TTN Enschede	Timothy Sealy	November 10, 2016	Sealy
Community member TTN Enschede	JP Meijers	October 24, 2016	Meijers
Initiator TTN Almelo	Lex Bolkesteijn	January 12, 2017	Bolkesteijn
Initiator LoRApeldoorn	René van der Weerd	February 20, 2017	Van der Weerd
Community member LoRApeldoorn	Jeroen van Bussel	January 13, 2017	Van Bussel
Community member LoRApeldoorn	Remko Welling	January 13, 2017	Welling
Community member LoRApeldoorn	Frank Woutersen	January 16, 2017	Woutersen
Community member LoRApeldoorn	Maarten Westenberg	February 27, 2017	Westenberg
Community manager Global team	Laurens Slats	January 27, 2017	Slats

Table 1 - List of interviews

Meetups			
Community	**Content**	**Date**	**Referred to as**
TTN Enschede	KiTT Lab Special – LoRaWAN presentation – Application presentation	March 31, 2016	(Meetup KiTT, 2016)
TTN Enschede	Social meetup	June 28, 2016	Social meetup, TTN Enschede, 2016
TTN Enschede	Workshop (presentation) build your own antenna	Sep 14, 2016	Antenna meetup, TTN Enschede, 2016
LoRApeldoorn	Workshop, build your own single-channel gateway	November 17, 2016	Gateway Workshop, LoRApeldoorn, 2016
Global	National initiator meet	February 14, 2017	(Initiator meetup, 2017)

Table 2 - List of visited meetups

Other sources		
Document type	**Content**	**Source/Referred to as**
Document	Mission statement of The Things Network. Written in July 2015.	https://github.com/TheThingsNetwork/Manifest/blob/master/Mission.md The Things Network Mission
Document	Manifesto of The Things Network. Written in July 2015.	https://github.com/TheThingsNetwork/Manifest The Things Network Manifest
Document	LoRaWAN specifications v1.0.2, which contains a list of changes from previous versions.	(LoRa Alliance, 2017a)
Document	LoRaWAN regional parameters v1.0, which contains a list of differences between regions.	(LoRa Alliance, 2017b)
Interview	First interview with Wienke Giezeman by Fast Moving Targets, on Sept. 2, 2015.	https://youtu.be/QFaiiaGQVw0 (Interview FMT, 2015)
Interview	Second interview with Wienke Giezeman, by Fast Moving Targets, on June 9, 2017.	https://www.youtube.com/watch?v=At00HOt-afY (Interview FMT, 2017)
Recording	Recording of the first presentation of The Things Network, on 15 July 2015.	https://www.youtube.com/watch?v=SIRcMjocUwE First presentation of The Things Network, 15 July 2015
Recording	Recording of a meetup, in which Giezeman presents the status of The Things Network	https://www.youtube.com/watch?v=RXnqqMSNUzI Status of The Things Network, 21 Oct. 2015
Recording	Recording of the TTN launch event, held on 21 august 2015.	https://www.youtube.com/watch?v=L1TOZuK5LBM and https://www.youtube.com/watch?v=va4E2e5afU0 TTN Launch event, 21 August 2015
Recording	The Things Network, 'ask me anything' session, with Giezeman and Stokking, on May 29, 2017.	https://www.youtube.com/watch?v=CFynqvmhKOw The Things Network AMA, 29 May 2017
Webinar	LoRa crash course by Thomas Telkamp – Webinar by global team member, focused on the technical side of LoRa and LoRaWAN.	LoRa crash course, 2016.
Website article	The Things Network: Building a global IoT data network in 6 months – Article by Wienke Giezeman, looking back on the first six months of The Things Network.	https://medium.com/@wienke/the-things-network-building-a-global-iot-data-network-in-6-months-adc2c0b1ae9b (Giezeman, 2016)
Interview	Interview with Wienke Giezeman by 7Ditches.tv, on may 2, 2016.	https://www.youtube.com/watch?v=G4njJEkkI3s (Interview 7Ditches.tv, 2016)

Table 3 - List of other sources

4 Rise of The Things Network

In this chapter, I will analyze the first phase of The Things Network, in which they start as a local grass-roots initiative building a local network in Amsterdam. I will start by describing how Giezeman, the initiator, started The Things Network in section 4.1. In the subsequent sections, I will analyze this start and further rise of The Things Network, based on Callon's phases of translation. In section 4.2, I will describe the initial problematization of The Things Network: the problem definition, defined actors and obligatory point of passage. In section 4.3 I will analyze the interessement and enrolment of the different actors and their relation to the initial defined actors. Section 4.4 describes the mobilization of the different actors at the official launch, the chain of translations leading up to that point. Finally, this section is followed by the concluding paragraph (4.5).

4.1 Initiating the Things Network

The first ideas for an open IoT community infrastructure started when Wienke Giezeman, the initiator of TTN, met Jonathan Carter[11] in June 2015. At a Hackerspace in Amsterdam, Carter showed a first version of a LoRaWAN gateway. After getting to know some of the preliminary specifications, like connecting thousands of devices within a 10 kilometer range, for the cost of 1200euro, Giezeman was immediately interested. He saw the map of Amsterdam covered by 10 circles in his mind, representing 10 gateways and their range and was inspired to build such a network (Interview FMT, 2015).

After some initial investigation on how other parties are using the technology, Giezeman found out that it is mainly used by telecom operators to build proprietary closed networks with a subscription-based revenue model. Giezeman himself thought of another idea, namely to make an open crowd-sourced network, where users would buy a gateway and connect it to their own internet connection. These gateways can then be connected with open source software. This idea is based on how the internet was built: *"Basically, from the point of view of how the internet emerged. Oh, you had a network, I have a network. I can use your network, and you can use my network, we won't fuss about it, because there is a synergy. You can do the same for this, where you can use each other's masts"* (Interview FMT, 2015).. Giezeman thought that the model by which Telecom Operators build their networks wasn't applicable to a LoRaWAN network: in the traditional model, the telecom operators would build a network and its users would pay a fee to use the network. While with LoRaWAN, the costs are mostly in setting up the network, running costs are not much in comparison. Instead of building a centralized network with a 'gatekeeper', Giezeman wanted to build a de-centralized network. A gatekeeper network has a single point where all traffic comes together. The gatekeeper then checks if the owner of the traffic paid for it and only allows packets through where this is the case. A de-centralized network on the other hand, has no single point where all traffic comes together. It is distributed amongst different parts of the network, which are set-up redundant, to distribute loads and prevent a single point of failure. If one of the parts of the network goes offline, the other, redundant, parts can take over.

[11] Co-founder of Glimworm IT, Glimworm Beacons and ParkShark , IoT professional and maker.

Furthermore, Giezeman believes that eventually, almost everything will be connected to the internet. It would be disastrous if a single actor were to gain control over the network with which these devices connect. As such, such a network should be de-centralized, distributing control over as many people as possible. LoRaWAN specification is not aimed at building such a de-centralized network, but doesn't enforce a centralized network either.[12] Giezeman talked about this idea with a friend, Johan Stokking, with whom he used to share a co-working space at his previous company. Johan Stokking quickly caught on to the idea and they decided to collaborate, with Giezeman focusing on the social community aspects and Stokking working on the technological elements. At this point in time, there is a commercially available gateway. However, there is no ready-made backend or application, so these will have to be developed (Interview FMT, 2015; Giezeman, 2016).

4.2 Problematization

As I have shown in the theoretical section, the problematization phase consists of three different elements: a problem definition, the definition of actors and the definition of obligatory passage points. In order to elaborate on the first point, I will first give a description of the Problem definition

As it can be seen from above description, Giezeman wants to build a Things Network as a de-centralized network, opposed to more traditional network architecture, which is used by Telecom Operators to build IoT networks. He first publicly pitches this idea at an IoT meetup group, called 'Sensemakers'. The group meets once a month in Amsterdam. The meetups involve presentations, discussions and hands-on workshops dedicated to a variety of topics: "*creative, advanced and human-centered Internet-of-Things, sensor(networks), electronics/hardware, open hardware/source and hardware start-ups*"[13]. Everyone who is interested in these topics is free to join the meetups. In these meetups, there is also time for start-ups and other new organizations to present their ideas and products. On 15 July 2015, Giezeman is one of the presenters[14], where he presents The Things Network. His presentation is announced on the meetup page as a 'top secret project'[15]. It will prove to be the kick-off for TTN, as I will show further in this chapter. In his presentation, he defines the goal of TTN as follows: *"Our mission is to build a decentralized, open and crowd sourced IoT data network. Owned and operated by its users."* [16]

In a later meet-up, Giezeman and Stokking show how they identified several hypotheses which had to be verified before such a network could become reality. They separated the hypotheses in three logical steps, each with their own set of hypotheses. They addressed one step at a time.

1.
   1.1. An open LoRaWAN network can be crowd-sourced

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[12] See section 5.2.1 for a more elaborate description.

[13] Source: http://sensemakers.info/

[14] Although Stokking was already involved, he was not present at the meeting, as he was in Barcelona at the time.

[15] Source: https://www.meetup.com/sensemakersams/events/219760920/

[16] Source: First presentation of The Things Network, 15 July 2015

1.2. We can build a LoRaWAN network in **one** city

2.

2.1. We can communicate the message around the world

2.2. We can encourage [local] communities to do a similar thing

2.3. We can imagine an architecture that fully implements our mission

3.

3.1. We can crowd source a network in another city than Amsterdam with the community

3.2. We can crowd source the OPEX[17] part of a community owned network

3.3. We can support a global community[18]

In the first phase of The Things Network, Giezeman and Stokking work on conforming the hypotheses listed under 1. In order to address these hypotheses, they decided to first build a local network in Amsterdam, The Netherlands, in 6 weeks.

To summarize**,** the central problem definition is: How can a de-centralized network infrastructure be created, in such a way that no single entity can leverage parts of the network to gain control over others? Giezeman and Stokking further developed this question, by translating it to a set of hypotheses, or sub-problems. They decide to address these problems in order, starting with the first set: crowd-sourcing the necessary LoRaWAN infrastructure and building a network in one city .

4.2.1 The interdefinition of the actors

In contrast to the researchers in the scallops case described by Callon, Giezeman did not explicitly define actor groups and their interests in writing. However, at the first presentation of their idea, at an IoT meetup group, called 'Sensemakers', which has its base in Amsterdam, Giezeman shortly described 5 different groups of actors which they would like to align to the to-be-formed community[19]:

1) Architects – In order to build the infrastructure necessary for the network, the initiators would like to get in touch with computer architects to exchange ideas on the network architecture and their help in building the network.

2) Device makers and 3) Entrepreneurs – Two groups of actors who together build applications on the network: entrepreneurs who think about use cases for the network and device makers to implement these use cases in the form of devices and applications on The Things Network.

4) Philosophers –Philosophers can help formalize the mission of The Things Network, making sure that the to-be-written guidelines adhere to the ideas of de-centralization.

5) Pledgers – Pledgers, or sponsors, who are willing to pay for gateways and place them at their homes or companies.

[17] OPEX costs are operating expenses, or, in other words, the costs to keep the network running.

[18] These hypotheses were presented at a meetup on 21 oct, 2015. Giezeman argued that they had already verified the first two sets of hypotheses. Based on this argument, it is reasonable to assume that the hypotheses were formulated beforehand, it makes little sense to formulate these hypotheses ex-post. Source: Status of The Things Network, 21 Oct. 2015

[19] Source: First presentation of The Things Network, 15 July 2015

The definition of these actors is very broad. In the case of the scallops, two of the three defined actors clearly belong to a certain group: the scallops and the fishermen are bound to a location: St. Brieuc bay. The scientific colleagues are less defined: any scientist who might be interested in the scallops at St. Brieuc Bay can be considered a colleague. Similarly, the actors of The Things Network are defined very broad: all actors represent large human groups, spread around the globe. We can limit the potential actors from this group to Amsterdam and surroundings, as the founders aim to build an initial local network in Amsterdam.

Next to these human actors that Giezeman defined in the IoT meeting, he also presents the non human actors needed to create a LoRaWAN infrastructure capable of sending messages. He starts by presenting a **node**, which can send messages using LoRa. The node itself is a demo node, made by Semtech, the developer of LoRa, to show the possibilities of the LoRa-based infrastructure. Next, he presents a commercially available **gateway.** Gateways receive the messages sent by nodes and forward them to the right destination: *"It receives the signal, there is a little computer in there, and the computer sends it to whatever you want: the cloud, it stores it locally, and you can do something with it."*[20] Finally, for a crowd-sourced network, where gateways are owned and operated by the users, he argues the need for a **routing mechanism**: gateways need to know where to send all the messages, which can easily be configured for gateways that are owned by the user that placed the nodes. However, gateways also need to know where to send the messages if the nodes that sent them are not from the same owner. He presents these parts as essential elements which together make up the infrastructure.[21]

Finally, Giezeman also describes what his reason, his motivation for starting The Things Network is: "*The biggest thing for me why I do this is, this is a de-centralization experiment. And, that's why I wanna, I wanna share it with you guys and hope you get in touch with me if you have ideas about this, because I would like to discuss how we can truly embed de-centralization in this, how can we truly make sure there is never a single entity that holds any type of control that results in whatsoever leverage that can compromise the common goals you have as a community.*"[22]

To summarize**,** in his initial presentation of The Things Network, the initiating actor Giezeman describes the role of several different actors. He describes five different roles for human actors, who could help create and expand the network, namely: architects, device makers, entrepreneurs, philosophers and pledgers. Furthermore, he mentions three non-human actors: nodes, gateways and a routing mechanism, which he defines as necessary for creating a Lorawan infrastructure and applications which make use of this infrastructure.

4.2.2 The definition of obligatory passage points

In the initial problematization, Giezeman aims to create a network infrastructure, devoid of any single point of control, in contrast to traditional gatekeeper infrastructures, built by the telecom industry. As I

[20] Ibid.

[21] Ibid.

[22] Ibid.

have shown above, the solution he envisions is a crowd-sourced network, where a lot of different actors will have control over a small, redundant part of the infrastructure, together forming a global infrastructure. In that way, one, or several actors can leave or change the part they control, without it impacting the infrastructure as a whole.

In order to reach this goal, Giezeman has defined several hypotheses, which he takes as progressive steps TTN has to move through to create a global infrastructure. These steps can be seen as obligatory passage points: Only by displacing the actors, defined above, in such a way that the hypotheses can be confirmed, will The Things Network be successful.

Initially, he aims to address the first set of hypotheses, by creating a local infrastructure. At the first presentation, he presents himself as an obligatory passage point for reaching this goal: He is the sole contact for any actor who is interested in the community and wants to join. However, Giezeman can only be considered a passage point for TTN itself. If anyone wants to create a similar infrastructure, based on the same principles, they can do so without getting involved with The Things Network. They would, similarly to TTN, have to develop some parts, but the basis, LoRaWAN, is open source and free to use.

4.3 Interessement and enrolment

The first group of actors is interested and enrolled at the previously mentioned presentation at Sensemakers, where Giezeman pitches his vision of The Things Network. At the end of his presentation, Giezeman asks the people[23] present at the meeting if they are interested in joining Stokking and himself in creating such a network in Amsterdam. Several people responded positively, resulting in a group of 7 makers[24] joining the community (Giezeman, 2016). This initial group doesn't coincide with the definition of the 5 actors presented earlier: Makers were not included. In practice, as I will show in the next section, the group of 7 makers, together with Giezeman and Stokking, will take on roles 1 through 4 from the earlier definition. So, in enrolment, the actor roles as initially defined were revised.

The tool Giezeman uses to interest these actors to TTN, the presentation, could be considered as an interessement device, in the sense that it aims to strengthen the actor identity as defined in the problematization. Yet, I do see also a difference with how Callon (1986) describes the working of an interessement device in his scallops case. Figure 1 (chapter 2) illustrates how Callon defines the working of an interessement device: the relation between A and B is strengthened by preventing actors C, D etc. from aligning with actor B. However, the difference is that in the case of TTN, the relation itself first has to be established, before it can be strengthened. The presentation of TTN's vision is not primarily aimed at preventing those present from aligning to other actors (or vice versa), but

[23] A total of 82 members RSVP'd that they would be at the meeting. It is not known how many actually went (2 notified in advance that they wouldn't be able to come).
[24] Makers is a term from the maker culture, or maker movement, which refers to people who embrace principles such as learning-by-doing and concern themselves with 'building devices'.

rather at creating a *new* relation between TTN and the actors present. This is why I propose to use the term '***alignment device***' to describe these devices that are aimed to establishing a *new* relation, rather than interessement device.

In the few weeks after the presentation, Giezeman aims to align a 2nd group of actors, namely the pledgers, or sponsors, as defined in role 5 earlier, who are willing to pay for and place a gateway on their roof. Giezeman approached companies and non-profit organizations with an office in Amsterdam, to ask them to sponsor a gateway. He manages to convince them with the same story he presented earlier, focusing on the TTN mission in addition to the companies acknowledging that they could get some media attention if they sponsor a gateway. Giezeman convinced several companies to sponsor and host a gateway[25], which were configured by members of the initial team. Additionally, some of the enrolled actors wanted to do more: the Next Web, for example, promoted The Things Network when they officially launched, Deloitte helped with security audits on the network, KPMG helped with global expansion and Rockstart provided space for TTN events. These new roles emerged in the process of enrolment and were not foreseen in the initial problematization. Enrolment here, again lead to a revision of actor roles.

To summarize**,** the process of enrolling the first groups of actors diverts from Callon's conceptualization: Instead of interessement, using an interessement device to align an actor, they are interested by use of an alignment device, which is focused on creating a relation between the initiators and the interested actor, rather than preventing other actors from aligning the interested actor.

In this section, I have also shown how, during the process of interessement, Giezeman moves away from the initial actor definition: Rather than interesting these groups, Giezeman enrolls a group of seven makers, or tinkerers, who, in practice, take on role 1 through 4. Furthermore, in the negotiations during enrolment of the last group of actors, the pledgers, new roles were constructed, displacing pledgers not only as sponsors of gateways, but also in several different roles, where the sponsors want to actively help promote and shape The Things Network.

4.3.1 Shaping new actors

In the second iteration of interessement and enrolment, the newly aligned group of makers, together with Giezeman and Stokking, start working on shaping new actors. Just two days after the initial presentation, on July 17, 2015[26], the group started working on formalizing the mission and creating a manifesto. With these documents they revisit and refine the problem definition, further outlining how the network

[25] Aligned actors include: Rockstart, Bovendebalie, The Next Web, KPMG, We Share Solar, de Waag, Glimworm, Deloitte, Non-red, Disruptor, Trakkies, The Smiths, Port of Amsterdam, and Beurs van Berlage.

[26] https://github.com/TheThingsNetwork/Manifest/network shows that first work on the manifesto started on July 17, 2015 and initially completed on July 21, 2015 after several grammatical and spelling revisions. In the period that follows, several other spelling mistakes are removed and the documents are translated to Greek.

should look like. In the mission document, they outline their vision, mission and plan. Their vision is based on their idea of how the internet is formed: "*People connecting their networks and allowing traffic from, to, and over their network free passage created the Internet. In doing so they created synergy, whereby the whole could grow past the sum of its parts*."[27] They aim to do the same for the *"IoT network of the future"*[28]. The main principles of such a network are outlined as follows: 1) All data will be end-to-end encrypted and will only belong to the owner. 2) All data is treated equally and 3) Technology developed in the stack is made open source. And 4) Access to the network will be free. At the heart of this mission is the idea that they want to prevent any single entity from controlling the network (and possibly violating the community goals). This last idea is further formulated in the manifesto: *"Controlling the network that makes this possible means controlling the world. We believe that this power should not be restricted to a few people, companies or nations. Instead this should be distributed over as many people as possible without the possibility to be taken away by anyone. We therefore founded "The Things Network"."*[29]

A second activity that the initiators realized with writing the manifesto is defining the properties The Things Network should have to achieve this goal: The first of these properties is that the network is an open source, free initiative. Secondly, everyone should be able to help setup and use the network, be that by using nodes to connect to the network, placing gateways or setting up a backend. Thirdly, these different backends will be connected together in a decentralized manner, so there is no single point of control in the network. In the fourth point, they argue that the network shall be protocol agnostic, and every protocol can be used, as long as these protocols are not proprietary, open source and free of rights. Fifthly, everyone who sets up a "gateway, or a backend shall do so free of charge for all connecting devices and servers." [30] Sixthly, everyone who makes use of the network should realize it is an as-is network, where its services may be terminated for any reason at any moment. Finally, there are no restrictions to applications running on the network. They may be commercially based or free and open. As we will see later in this thesis, the manifesto itself will have an active role in the further shaping of the socio-technical network.

In this manifesto, the first linking of a new actor role, that of the commercial or business user, also becomes visible: everyone is allowed to create an application, making it possible to exploit commercial applications on the network infrastructure. In section 6, I will elaborate on the negotiations required to align this role to the community, as well as its influence on the shaping of the network.

After creating the manifesto and mission, the initial team started working on realizing a proof-of-concept network. As I described in the previous section, Giezeman already started to approach companies to place gateways. The rest of the team (the 7 makers and Stokking), start working on the routing mechanism. They do so by introducing two new actors, a

[27] Source: The Things Network Mission
[28] Ibid.
[29] Source: The Things Network Manifest

[30] Ibid.

backend and application servers.
Both actors are already defined in the LoRaWAN protocol[31].
Application servers are the end-points for the data send by the nodes. Application servers and nodes together form applications. The backend receives all data from the gateways and ensures that it is sent to the appropriate application server (by user configuration).

They built this Lorawan network in roughly six weeks, implementing a rudimentary backend, creating a proof-of-concept network which only implements the necessary features to get messages from the node to the application server, without implementing any security measures or the more sophisticated mechanisms of LoRaWAN[32]. Furthermore, in this stage, the backend is implemented as a centralized server, in direct conflict with the problematization: The owners of this central backend, in this case the initial team, are in control of the network. Later, they start working on de-centralizing the backend. I have analyzed this process in section 5.2.

The application that TTN team initially developed was a commercial application, which they developed together with HoosJeBootje[33]. HoosJeBootje is a small Amsterdam based company which helps boat owners in Amsterdam to remove water which got into their boats.

[31] I will elaborate on the role of the LoRaWAN protocol in section 5.2. A description of a LoRaWAN-based infrastructure as advocated by the LoRaWAN alliance can be found in Appendix A.
[32] In section 5.2 I will elaborate on the work and actors involved in shaping the backend.
[33] Source: (Interview FMT, 2015) and http://www.hoosjebootje.nl.

Originally, boat owners had to keep an eye on their boat themselves, to see whether any water got in their boats. The application TTN developed together with HoosJeBootje consists of a LoRaWAN based sensor which boat owners could place in their boats. If any water is detected, the sensor would send a message through TTN to the application server. The server then sends a SMS message to the boat owner. If he responds by replying 'hoos'[34], HoosJeBootje would come and empty the boat. This application was mostly used to promote the network during and immediately after launch, as an example of what is possible on the network (Giezeman, 2016).

To conclude**,** in the second iteration of enrolment, the newly aligned actors define and shape several new actors: They first revisit the problem definition, by creating a manifesto and mission, that further refine the goals of The Things Network and describe properties the infrastructure should have. In the proof-of-concept infrastructure, not all of these properties are incorporated, creating tension between problematization and actual enrolment.
Secondly, they incorporate the LoRaWAN structure as advocated by the Lora Alliance in the network by defining and shaping two actors, the backend and application servers.
Thirdly, the redefinition of the initial problem statement also opens the door for a new user role, that of the business user, by arguing that applications on the network can be both for-profit and non-profit. The first business user aligned to the network is HoosJeBootje. The initial

[34] Hoos, or hozen, is Dutch for 'empty(-ing) a boat'.

team creates an application where boat owners place a device in their boat, which notifies them when it detects water. They then link this application with HoosJeBootje, a company which offers several services to boat owners, including emptying water from boats. The user of the application can choose whether they want to let the application notify HoosJeBootje, or arrange something themselves. As such, this application functioned as an alignment device, aligning HoosjeBootje to the network.

Another aspect to consider is that not all actors enrolled in this phase existed yet. Some of the actors, for example the backend had to be created from scratch: they only existed as a concept in the way they were defined. This aspect is not visible in Callon's analysis where all described actors involved in the network already existed in some form. Callon argues that these existing actors are *dis*placed: they are taken from their original environment and, through negotiations, translated in such a way that they are aligned with the problem definition of the heterogeneous network[35]. Shaping new actors on the other hand, doesn't involve a movement from one place to another, but rather only a movement towards placing a newly created actor in the network. Therefore, I want to introduce, next to *dis*placement, the notion of ***placement***.[36]

[35] Not only the interested actor is translated in this process. As I have shown, newly enrolled actors can also translate the goals and problematization of the network itself, in this case by creating a manifesto and mission.

[36] I realize the creating of a new artefact is in itself a complex translation and displacement of various other actors, yet, in describing the dynamics of a particular actor network (here the one that shapes TTN) a newly created actor cannot be understood in term of displacement as it had no prior place because of its non-existence.

4.4 Mobilization

In the mobilization phase of the translation dynamics, representation and displacement are core processes. From each actor group, often quite diverse representations are made based on a limited subset. This process has the danger of making diversity in an actor group invisible. It also can strengthen a particular sub-group if the representation is based on this group.

On august 21, 2015, Giezeman and Stokking officially launch The Things Network, during an event called 'The Things Network LoRa Conference Amsterdam', organized by the initial team.[37] In his presentation, Giezeman recalls the (dis-)placements necessary to create the local infrastructure: He introduces LoRaWAN as an actor, how he came up with the idea, the goal of The Things Network, the human actors involved and the sponsors. He further presents the use case, the HoosJeBootje application, as an application that proofs that the infrastructure works and is useful for the people.[38] HoosJeBootje, thus represents the actor group commercial users. Later, in chapter 6, I will discuss that Giezeman 'regretted' this representation as HoosJeBootje was a small start-up company and this representation excluded bigger commercial players.

[37] Source: TTN Launch event, 21 August 2015

[38] Ibid.

Finally, Giezeman also presents a map (see figure 2), that represents the infrastructure: Gateways are represented by icons of its sponsor, while circles surrounding it represent the coverage the gateway provides. These circles are layered on top of a map of Amsterdam, and together cover the city centre. The map itself becomes the actor that represents the success of creating a local, crowd-sourced infrastructure, as Giezeman announces: *"Hereby I present you the first crowd-sourced Internet of Things data network, here in Amsterdam."*[39] Yet, in the map, the TTN infrastructure is rather represented through quite some commercial sponsor actors, rendering various other involved actors, e.g. the makers, and other involved citizens invisible.

Figure 2 - Map of Amsterdam infrastructure

[39] Ibid.

4.5 Conclusions

In this chapter, I have shown how Giezeman initiates The Things network and the following processes leading to the successful creation of a proof-of-concept infrastructure and application. I have done so by analyzing these processes by means of the concepts introduced by Callon. In general, the different concepts are useful tools in analysis: By analyzing the work and negotiations carried out in the process of interesting and enrolling users, and the relation of these processes to the initial problematization, makes it possible to place the alignment process in context. This process is not linear, but rather consisted of several iterations, where, in the process of enrolling new actors, earlier phases are revisited and modified, which leads to new processes of interessement and enrolment.

I have however, identified two elements that do not immediately fit in Callon's concepts. The first of these elements is found in the process of enrolment, where actors are not enrolled using interessement, but rather a different process. Interessement is supported by interessement devices, which are placed in-between the interested actors and outside influences. The process described in the previous sections however, showed that actors were enrolled by focusing on creating a relation between the to-be-aligned actor and the heterogeneous network: devices are used which are aimed at the relation between the involved actors themselves, instead of trying to keep unwanted actors from preventing enrolment. I have called the devices used or this process 'alignment devices'. The second element is the shaping of new actors: Rather than enrolling materially existing actors in the defined actor roles, new actors are shaped. This results not in *dis*placement of actors, but rather in *placement.* Actual enrolment of these actors, still requires lots of work, as we will see in Chapter 5.

The different alignment processes in this phase of the network are all aimed at creating a proof-of-concept network in a single city, which is successful. In the first iteration, two different actor groups are aligned to make this possible: A group of 7 makers, who, together with Stokking, work on shaping the first backend and an application, and a group of pledgers, who sponsor a gateway and location.

The initial team introduces three new actors in the iteration of enrolment. The first, the mission and manifesto, already show that the process of alignment, as structured by the four phases of translation, is not a linear process. The team redefines the initial problem definition, which also opens the path for a commercial interests and a corresponding actor: The business user. This is already visible with the shaping of the HoosJeBootje application, where the team aligns HoosJeBootje, a commercial actor, to the network through an application. The first signs of a community in which both commercial and community interests exist at the same time.

Development and enrolment of these actors is done in several weeks, resulting in the successful shaping of a local infrastructure, which Giezeman presents at the TTN Launch event. In his presentation, Giezeman presents HoosJeBootje as a representative for business users. Furthermore, he presents the local map – which prominently features the gateway sponsors – as a representation of the infrastructure, rendering other involved actors, such as the makers and the backend, invisible.

5 Global alignment dynamics

After confirming the first two hypotheses at the global launch event, the initial team starts working on the second and third set of hypotheses, aiming to create a global infrastructure. They transform the roles of the different involved actors, to reflect this change in focus: the initial team becomes the 'global team' focusing on further shaping the backend and global infrastructure of The Things Network. The proof-of-concept infrastructure, especially the translation process of aligning sponsors and placing gateways gets two new roles: The proof-of-concept network serves as an alignment device, interesting potential actors by showing that it is possible to create a crowd-source infrastructure. They also defined several new actors, aimed at creating more local infrastructures: The global team aims to enrol local actors, who want to create infrastructure in their local area. Or, in Giezeman's words: they want to *"recruit people who want to run a campaign in their own geographic."* [40] The proof-of-concept infrastructure serves as a role model for these communities, they can follow the same process as by which the infrastructure in Amsterdam was shaped. Furthermore, they aimed to create a new actor: a cheap, user-friendly gateway.

In this section, I will elaborate on the enrolment and shaping of the new actors and the reshaping of existing actors. In the first section I will elaborate on the enrolment of local communities and the creation of a global community. In section 5.2 I will elaborate on the reshaping of the backend: they continue implementing LoRaWAN features and start working on decentralization. Next, in section 5.3 I will analyze the shaping of the 'cheap and user-friendly gateway'. The global team, together with Tweetonig, a product development company, aims to develop a new gateway, to make it easier and cheaper for community members to create coverage. Finally, in section 5.4 I will present my conclusions.

[40] Source: TTN Launch event, 21 August 2015

5.1 Shaping a global community

In this section, I will elaborate on the enrolment of several human actors. I will start by describing the dynamics within the global team itself, then turn to the later constructed business user and finally to local community members.

5.1.1 Global team

The global team first started as a group of volunteers, which emerged from the reshaping of the initial team, which was formally announced on August 21, 2015. Roughly a month later, Giezeman and Stokking create The Things Network Foundation. The Things Network Foundation is a non-profit entity, which supports the mission and manifesto as mentioned in Chapter 4. They did this for two reasons: The first is that they wouldn't be personally liable for The Things Network and 2) so they would have a legal entity which could form the backbone of the network. With this legal entity, it is easier to raise funds and declare ownership[41].

[41] Source: Status of The Things Network, 21 Oct. 2015

A few months later, on 9 December 2015[42], Giezeman and Stokking registered a for-profit company, next to the non-profit foundation, called The Things Industries. In one of his first interviews after the launch of The Things Network, on September 2 2015, (FMT, 1st interview), Giezeman explains that he set up The Things Network Foundation as a non-profit organization, while, at the same time, he also is an entrepreneur who wants to make money. He indicated that he, at the time, had no idea how to do that with the network, but that they would probably offer some services on the network. He was very firm on stating that the base network should remain free and open, which is reflected in the manifesto, and supported by the foundation.

The relation between TTNF and TTI becomes deeper when the global team moves from a team of volunteers to a team of paid employees. The members are employed by TTI, as Giezeman argues: "*Within Dutch regulations it is not so responsible to hire people in a foundation, so we have all the people there*"[43]. Within the global team, roles are more clearly separated in application developers, backend developers, web developers, and community managers. While the first actor roles are formalizations of roles they already had, the role of community manager is newly defined. The role of the two community managers is to assist local communities, in everything they could struggle with: from finding suitable locations and gateways, to helping make the community more active, help with pr, and others (Interview Slats). The rest of the global team continues working on developing the backend and web-interfaces to connect to the backend. Initially, all software they develop is released under an open source license and donated to the TTN Foundation. However, as I will elaborate in section 5.2, the global team introduces new components to the backend, which aren't made open source, but are crucial to connect to the, still centralized, backend of The Things Network. The Things Industries also manages this backend.[44] As such, the Foundation becomes dependent on The Things Industries, without TTI, there would be no running backend, which is the core of the infrastructure. The reverse also holds: TTI started developing commercial services as extra layers on the community infrastructure. TTI needs the community build infrastructure to sell their services, without it, they would have no right of existence. As the community grows, their potential offset market grows as well. Furthermore, the services themselves are constructed from development of the community: As the community grows, TTI gains insight into possible commercial ventures, for example offering private backends as a service. Most of these commercial ventures are aimed at business users. As such, the community, represented by The Things Network Foundation, and The Things Industries develop in a symbiotic relation, mutually dependent on each other.

5.1.2 Business users

As I have shown in Chapter 4, the first inkling of the role 'business user' became visible in the shaping of the Manifesto. Over time, the interests

[42] Source: https://www.opencompanies.nl/dienstverlening-the-things-industries-bv-amsterdam-64725189
[43] Source: The Things Network AMA, 29 May 2017
[44] Source: https://www.thethingsnetwork.org/forum/t/the-things-network-roadmap-2016-q3-2017-q2/3393/12

this type of user has, has become more visible: They are mainly interested in a stable, backwards-compatible network, on which they can sign SLAs, or Service Level Agreements, which are contracts based on up-time: In these contracts, the up-time (availability) of the network is guaranteed, if that arrangement isn't met, fines follow. However, this kind of arrangement isn't possible for the community infrastructure, it is offered as-is, without any guarantees. The global team aims to incorporate the interests of the users together with de-centralization of the backend: Business users can set-up their own private backend, connected to the community infrastructure. In this way, they themselves are responsible for the up-time of the backend, rather than relying on the community infrastructure. To be completely independent from the community infrastructure, the business user also has to deploy their own gateways, as community gateways are not guaranteed to be always working[45]. The idea is to connect both gateways and backend to the community infrastructure, so they can reinforce each other. [46] This type of integration is also used by The Things Industries to offer one of their first commercial services: TTI offers commercial private backends with uptime guarantee.

5.1.3 (Local) community actors

As I argued in the introduction, Giezeman and the rest of the global team revisit problematization to define a new group of actors: local community members. They have two separate roles in mind for these community members: creating coverage[47] and creating applications (interview Slats). A further, implicit role given to community members is to provide feedback on the plans of the global team. Before the global team introduces a new feature, they regularly ask for feedback from the community. Furthermore, in several mailings, they also encourage community members to take up the role of backend developer: they are invited to help program the backend.

The global team aims to enroll these members using (news) media. They want to spread information of The Things Network, focusing on its mission, as far and wide as possible, seducing people to join the network, which they can do by registering on the TTN website. The media, in this translation process, function as an alignment device, connecting members from all over the world to The Things Network. The global team aimed to spread the message further using the Launch Event, after which Giezeman was invited for several media, including the Dutch national news[48], as well as their Kickstarter campaign (see section 5.3).

Important to note here is that (newly aligned) community members do not have to become a member of a local community, there is no device forcing them to do so. Some of the roles, most notably the role of 'creating coverage', is taken up by many of the community members: coverage is necessary to work with the infrastructure, so practically all

[45] In the future, Giezeman hopes this will be solved by redundancy: if enough gateways cover the same area, it is no problem if one, or several, go offline (Interview FMT, 2017).

[46] At the moment of writing, this kind of integration is not yet possible. Source: https://www.thethingsnetwork.org/article/the-things-network-architecture-1

[47] Sources: TTN Launch event, 21 August 2015 and https://www.thethingsnetwork.org/start-a-community

[48] Source: https://www.thethingsnetwork.org/wiki/External/Media

members that don't have coverage where they need it, work on creating coverage, be it only a small section, for themselves, or a large area (e.g. Interview Welling, v. Bussel, Meijers). Members are forced, due to the lack of coverage, to enroll the necessary actors to create coverage themselves. Even when there already is coverage, some members continue to work on improving that coverage (Interview Sealy, Bolkesteijn). Not as many users take up the other roles however: several community members are enrolled as application developers (interview Meijers, Westenberg, Woutersen, Sealy), while others rather like to tinker with the hardware and are not necessarily involved in creating applications (Interview Bolkesteijn, Welling). Finally, members are only enrolled in the last two roles sporadically: the calls for feedback and help programming the backend don't bear much fruit: feedback topics mostly receive no more than a few responses, some don't get any. A rare few topics receive a lot of responses. Finally, as I will analyze in section 5.2.3, there are also just a few community members who help the global team shape the backend.

During problematization, the global team created a separate role for so-called 'local initiators': members who want to initiate a local community, by gathering local community members who want to create coverage and applications. Their role has been further specified on a webpage on the TTN website, made by the global team, and dedicated to initiators: *"Community initiators can always count on our full support and can carry the title "Initiator". In return we ask initiators to respect the manifest, keep the community page up-to-date[49], make sure local meetings are organized and be approachable for people to connect to."[50]* The process of aligning local initiators starts similar to that of other community members. As community manager Slats explained: *"We are not actively searching [for community initiators], people find us, in one way or another"* (Interview Slats). He argues, that by spreading the message of TTN, via social media and their website, people come to the global team out of their own volition. Initially, people interested in becoming an initiator had to e-mail Giezeman, with whom they could discuss details and get a community page. Later, the global team introduced a form on the website, which members interested in becoming an initiator can fill. This form contains questions about e.g. location, background of the initiator, plans and ambitions as well as questions on how the global team can support the initiator. Afterwards, one of the two newly appointed community managers will contact the member and together they go through the details of work necessary to start a community (Interview Slats). So, alignment goes on a person-by-person basis, where each individual initiator is enrolled in their communication with one of the community members. Slats argues that these initiators serve as ambassadors, representing the network, and enrolling a lot of community members via mouth-to-mouth advertising (Interview Slats).

[49] Each community has its own community page on the TTN website, where the community is represented: it offers a map of community gateways, as well as a list of activities, community initiators and members and can be linked to communication media used by the local community.
[50] https://www.thethingsnetwork.org/start-a-community

The process of creating and developing a community, proved to be difficult for some initiators. In august 2016, one of the global community managers announced that they were getting more and more questions on how to start and organize a community[51]. In order to help initiators, he introduced the concept of 'unleash your city', which was implemented in November 2016 and features on each community's webpage. The concept features a set of requirements which communities have to go through before they can become 'official', now differentiating between normal and official communities. These requirements are, from the viewpoint of the global team, necessary elements to successfully create a community: these requirements represents the steps a local community has to go through, before the global team considers the community enrolled in the network. At the same time, these requirements were meant to guide and motivate initiators to further develop their respective communities[52]. Between November 2016 and August 2017, around 70 communities fulfilled these requirements, officially becoming a part of The Things Network[53].

In this section, I have shown how Giezeman and Stokking worked on aligning commercial interests in the network, which they did through shaping The Things Industries. TTI is intricately interwoven in the community, creating a symbiotic relation between the two, where they both depend on each other. Secondly, the global team created a new set of roles, focused on creating coverage and applications. In their communication with these community members, the global team implicitly constructed two more roles, in calls for feedback and several outings aiming to enroll members as backend developers. Thirdly, the global team defined another role, that of local initiator. Local initiators are meant to stimulate TTN in their area, create local communities and act as local ambassadors who enroll actors and actively work on creating coverage and expanding the community. These roles were later formalized in several requirements, which had to be fulfilled before a community could become ' official' . These requirements were meant as an alignment device, motivating and guiding initiators towards a well-developed community.

Finally, we can see differences between the process of interessement enrolment as defined by Callon and the alignment processes visible in this chapter. Similar to the processes in chapter 4, members are not aligned by interessement devices, aimed at preventing them from aligning with other actors, but rather through alignment devices, mainly media, aimed at creating a link between potential actors and the heterogeneous network. There is however an important difference between enrolment in the initial phase of TTN and its second phase: In the initial phase, Giezeman explicitly tried to align certain groups of actors (those present at the first presentation, at Sensemakers, and local businesses and other organizations in Amsterdam). However, in this phase, potential members come to The Things Network of their own volition and no specific actor group is addressed: The alignment devices seduce them to come to The Things Network. These actors enrolled in the network with varying

[51] https://www.thethingsnetwork.org/forum/t/unleash-your-city-challenge-call-for-feedback/2995
[52] https://www.thethingsnetwork.org/forum/t/become-official-unleash-your-community/4014
[53] Both local communities I included in my research are official communities. Source: https://www.thethingsnetwork.org/community

success: Some roles are taken up by virtually all users (creating coverage), while only a few users are enrolled in other roles: providing feedback and as backend developers.

5.2 Translating the backend

In this section, I will elaborate on the translation processes focused on aligning the backend to its role envisioned in problematization. As I argued in chapter 4, the first iteration of the backend only implemented a few LoRaWAN features and it is not aligned to its previously defined role. In order to analyze these processes, we must first turn to three other actors, who all influence the shaping of the backend, namely: Semtech, the owner of LoRa, the Lora Alliance, who develops the LoRaWAN specifications and finally, national laws. These external actors all impose restrictions and requirements regarding the development of the infrastructure, which the global team has to work around or incorporate in order to successfully create a de-centralized infrastructure.

5.2.1 Semtech and the LoRa Alliance

LoRa is proprietary hardware that is developed by Cycleo SAS, a French company. In 2012, Semtech Corporation, a US based electronics company, acquired Cycleo SAS for $5M. With this acquisition, SemTech also acquired all intellectual property rights for LoRa. Since then, SemTech sold licenses to two other companies, MicroChip and STMicroelectronics, for producing LoRa hardware. LoRa's intended use is in wireless IoT devices, able to transmit a small amount of data over a distance of several kilometers (0-14) while using the least amount of energy possible[54]. Semtech is the single owner of LoRa and sets the price for LoRa chips, determining, for a mayor part, the cost of LoRa-based devices.

Built on top of LoRa is the open source software protocol LoRaWAN™, which defines a way of building an IoT network using LoRa. LoRaWAN is developed by the LoRa Alliance, an open non-profit association of members, which was established on Feb 19, 2015. Its founding members include Semtech and other network companies like Actility, Cisco, IBM, Kerlink and Microchip Technology, as well as telecom operators like: KPN, SingTel and Proximus[55]. Currently, the LoRa alliance includes more than 500 members, companies as well as a few non-profit associations, like The Things Network[56]. The Lora Alliance forms their own heterogeneous network, whose members strive to:*"[..]drive the global success of the LoRa protocol (LoRaWAN), by sharing knowledge and experience to guarantee interoperability between operators in one open global standard*." [57] They aim to interest actors with LoRaWAN itself, as 'the standard' for IoT networks. The LoRaWAN specification documents define the LoRaWAN procotol, divided in a set of compulsory features and a set of non-compulsory features. In order for a network to be LoRaWAN compliant, all compulsory features have to be implemented.

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[54] http://www.semtech.com/wireless-rf/internet-of-things/what-is-lora/
[55] http://www.itworldcanada.com/article/cisco-ibm-others-band-together-to-standardize-iot-networks/100998
[56] For a full list of all the members, see: https://www.lora-alliance.org/The-Alliance/Member-List
[57] https://www.lora-alliance.org/The-Alliance/About-the-Alliance

The specifications of LoRaWAN define various aspects of how a things network build on this technology should look like: Firstly, this standard specifies various aspects of a LoRa network: how the different parts should communicate and what data encryption should be used. Secondly, it specifies on which radio-frequencies (bands) LoRa networks should operate, depending on their geographical location. Currently appointed frequencies all fall in the ISM Band. The ISM band is part of the frequency spectrum that is free to use without requiring any license, but with limitations, set by national law. Thirdly, LoRaWAN also specifies the amount of data which can be sent in a single transmission, the data transfer speed and the number of messages an end device is allowed to send. Fourthly, LoRaWAN specifies a set of minimum hardware requirements to which devices in the network have to comply. Finally, the LoRa Alliance promotes the deployment of a LoRaWAN network in a so-called star-of-stars layout. In this layout, all connected gateways connect to a single backend, providing a centralized structure (LoRa Alliance, 2017a; 2017b).

The LoRaWAN specifications have not yet been finalized. Up until now, three versions have been released, each correcting (typographical) errors from the previous version and/or implementing new features. Simultaneously, the LoRaWAN standard has also been updated to include regional requirements based on national laws.

5.2.2 National law

The final actor relevant in shaping the network infrastructure are national laws. LoRa operates in different ISM bands, depending on local frequencies: Not every country has the same ISM bands with the same limitations. In the latest version of the LoRaWAN specifications currently available, the Lora Alliance acknowledges 9 different sets of regulations (LoRa Alliance, 2017b) , of which The Things Network currently implements 7 (only 1 EU band and 1 China band are not supported. Both EU and China are covered by other bands). The regulations differ on what frequencies you are allowed to use as ISM band, the amount of power with which you are allowed to send and the amount of time you are allowed to send. A defined frequency range can be split into multiple smaller bands, with different regulations regarding to power and send time.

5.2.3 (Re-)shaping the backend

The first version of the backend, developed by the initial team, is a proof-of-concept backend, that only implements rudimentary features of a LoRaWAN network: it enabled end devices to send messages over the network to their application server. The messages were not encrypted and many required LoRaWAN features were not yet implemented. The backend was also built according to the star-of-stars typology, as recommended by the Lora Alliance. The star-of-stars layout features a central backend, rather than a de-centralized one, all gateways connect to the same, single backend. Within the TTN community, this backend is known as v0, or Croft.

The main factor that is holding the global team back in implementing a de-centralized network is its complexity. In a centralized network, the answer to the question 'Where does this packet (send by a node) go?' is very simple, as there is one centralized server which holds all information on where a packet needs to go. In a de-centralized environment however, the answer becomes very complex. While there are different implementations possible for a decentralized network, the LoRaWAN specifications do not allow for most of them: As mentioned before, in the LoRaWAN specifications, it is argued that LoRaWAN networks are typically

"*[..]laid out in a star-of-stars topology in which* ***gateways*** *relay messages between* ***end-devices*** *and a central* ***network server*** *at the backend.*"[58] The rest of the LoRaWAN protocol is based on this assumption, necessitating the use of a network server. These specifications force the global team in a specific translation process: Their only option left is to de-centralize the network server itself, by having not only one server, but several running at the same time.

Stokking, one of the two founders and tech-lead of the global team, already presented a rough version of this idea, where multiple backends would form the de-centralized core of the infrastructure, at the global launch event on 21 august 2015. In the period that follows, the global team continues working on their plan to de-centralize the backend, while developing the next iteration of the backend. In the period between November 2015 and April 2016, the global team, with the help of the *"expertise of many community members"*[59] publicly worked on a new backend, called v1, or staging, which was released on April 18, 2016[60] and implemented many of the required LoRaWAN features to become LoRaWAN compliant, further aligning TTN to the Lora Alliance. This backend was not without its flaws, as it had several bugs and some features were not implemented yet, as it, for example, did not have support for one of the two ISM bands in Europe, or the American, Chinese and Australian bands.

In this version of the backend, the global team also implemented the step in translating towards a de-centralized backend. In this first iteration, they divided the tasks of the backend across three different services, namely the router, broker, and handler. The idea was that all these components could be multiplied, distributing the work over several instances, which could be hosted by others, and not only by The Things Network Foundation[61], bringing the backend one step closer to its envisioned role in the problematization phase.

After the release of Staging, work continued on implementing the next iteration of the backend. The global team worked on further aligning TTN to the LoRaWAN specifications and the Lora Alliance, while also developing new services. The architecture of this third iteration of the backend, called v2, or production, was also the first version where the commercial incentives of The Things Industries became visible. Stokking first announced the plans for the new backend, on September 6, 2016, where he stated that not all parts of the new backend would be open source. The core of the backend, which routes the messages from the gateways to the applications, would be open source and several additional services, namely the account server, NOC, dashboard, and

[58] Emphasis as in original. Source: (LoRa Alliance, 2017a). The term 'network server' in this quote refers to the same device as the term 'backend', used throughout this thesis.

[59] https://www.thethingsnetwork.org/forum/t/announcing-staging-environment-of-ttn-back-end-1-0/1852/10

[60] Ibid.

[61] Source: The Things Network Staging Wiki: http://staging.thethingsnetwork.org/wiki/Backend/Overview (Accessed: May 2016).

integration controller would remain closed source, but free to access[62]. These services are not required, but rather from a layer of ease-of-access on top of the backend: they are aimed at lowering the barrier for application developers and gateway owners: In previous versions of the backend, nodes and gateways could only be enrolled via command-line interfaces and there were no monitoring services available. The newly developed services include a monitoring tool and all have graphical user-interfaces, simplifying the enrolment process of nodes, gateways and applications services. Stokking has two arguments for developing the backend as a hybrid of open- and closed-source software: *"For some services, we publish more questions than answers by making them open source, in some services we invest a lot of time, money and risk, and some services are only usable and useful in the public community network and not in private networks. What we will do, however, is to make the interfaces public, stable and documented so that everybody can develop services that suit their needs, e.g. a dashboard, account server, integration controller and NOC. We might come up with simple reference implementations of these services."*[63]

Initially, there are no questions posted on the forum regarding this duality. Only later, on February 18, 2017, a single question is asked on the forum. A community member, who goes by the name 'heida' asks, after learning that parts of the backend are closed source: *"**@arjanvanb**, does this mean that TTN is moving away from its manifesto? It states 'The Things Network is an open source, free initiative'"*[64]. As a response, 'arjanvanb', another local community members responds by repeating Stokking's argument, adding: *"Bummer, but all considered I still support TTN's decision to keep some nice-to-haves closed. Open Source projects need funding to be sustainable. If large organisations that need Console on their own servers are paying for that through some commercial counterpart of the foundation, then that benefits all."* A final reply from Stokking confirms the story of arjanvanb, after which the conversation ends. Work continues on the Production backend, which is released on December 14, 2016 and mainly focused on ease of access, providing access via graphical web interfaces instead of command line interfaces, as well as preparatory work for de-centralization, better documentation and integration with several 3rd party IoT frameworks, the latter also being closed source, but free to use.

On May 22, 2017, Giezeman announced that they had done most of the work for decentralization, and that it was now possible to create your own private backend. However, connection with the community network is not yet fully implemented[65]. While it is already possible to decentralize one of the three components, the handler, it is not possible to connect a complete, privately hosted, backend. The main advantage of hosting your own handler is that the packets send don't have to be decrypted in the community network, providing better security. If you use the community

[62] Figure 3 presents an overview of the backend structure.
[63] Source: https://www.thethingsnetwork.org/forum/t/the-things-network-roadmap-2016-q3-2017-q2/3393

[64] Source: https://www.thethingsnetwork.org/forum/t/where-is-the-code-for-console/4941/4
[65] Source: https://www.thethingsnetwork.org/article/no-permission-required-founders-letter and https://www.thethingsnetwork.org/wiki/Backend/

handler, the network has to decrypt your message in order to send it to the application server. Although this new iteration further translates the backend, by displacing it in such a way that it comes closer to its original definition, there are still two more hurdles to overcome before the network can be called decentralized: The first of these is communication between privately hosted backends and the community network, represented by the dotted lines in figure 4. The current plan to implement this is, is also the second hurdle: They aim to solve the problem by using a single, centralized discovery server, which has a list of all the decentralized backend components, together with a network server. Only by successfully displacing the functions of the discovery server to a decentralized service, can the backend be fully aligned to its envisioned role. Figure 4 shows the global teams vision of a de-centralized backend, integrating public de-centralized backend and private backends, without a centralized discovery server.

5.2.4 Contribution of community members

In this section, so far, I have mainly focused on the work done by the global team to align the interests of the different actors end translating the backend. In this subsection, I will focus on the role of other community members in shaping the backend. Local community members, as shown earlier in this chapter, were urged to help in programming the backend. However, there are just a few users who have contributed a little to the backend by means of writing code[66].

However, users do contribute in other ways. For example JP Meijers, a TTN Enschede community member, who has developed an application called TTNMapper. This application can be used to measure coverage of The Things Network[67]. In order to map coverage, he needs some information from deployed gateways, most notably their location. In the first version of the backend, this kind of information was publicly available. In the second version, Staging, however, there was no public interface through which he could get this information. This led to a collaboration between TTI and Meijers, where they worked together on some of the features the (closed-source) NOC should have. As such, they worked together to keep TTNMapper aligned to the network.

5.2.5 Constructing value

One of the members of the global team, Jan Kramer aims to make value visible on the network. By value, he means the use of airtime by nodes, and, by setting up gateways, contributing to making more airtime available. Currently, value is measured by the data transmitted over the network. If you have your own gateway, then a high amount of data that others send via your gateway (so not your own messages) is considered positive. The messages you send with your own nodes are negative airtime. The main incentive to make value visible is to investigate skewed balances on the network. Some members might contribute a lot more than they consume, while others might consume a lot more than they

[66] Github provides information on activity of users by means of lines of code written. On a total of a several hundred thousand lines of code, only a few thousand have been written by local community members. See: https://github.com/TheThingsNetwork/ttn/graphs/contributors

[67] See section 6.3.4 And http://www.ttnmapper.org

contribute. They are thinking of implementing measures if there are big discrepancies on the network, so those who consume a lot have more incentive to place gateways, preventing them from leeching of the network. This does however, in principle, clash with the free nature of the network, as defined in the manifesto. When this idea was first pitched to community initiators the general reception was positive (Initiator meetup, 2017).

In conclusion, the global team has continued working on the backend, slowly incorporating interests of other actors in several iterations. They aim to align the backend to the LoRaWAN requirements as well as incorporating the needs of business users in the infrastructure. In these developments, changes to the infrastructure led to partial de-alignment of TTNMapper, an application developed by a community member. The global team addressed this by enrolling the developer as a member of the development team: he was asked to provide his input on what he needs, so it could be integrated in the next version of the backend. By de-centralizing the backend, the global team also hopes to create a hybrid commercial/non-commercial infrastructure: they aim to integrate private networks run by business users in the network, where business users can use the community network and vice-versa. If this becomes successful, they have successfully enrolled a new user in the heterogeneous network, strengthening it.

In the meantime, the team also works on closing the gap between the backend and its envisioned role: over several translation iterations they prepare de-centralization of the backend. At the same time, they also move away from one of the core principles of the network: instead of making all elements of the infrastructure open source, the global team keeps part of the backend private, arguing that 1) they are only services on the backend and not necessary in the infrastructure and 2) they also want to protect their own interests, as they invested lots of money and time in the different components, who are only useful in the community infrastructure, so there is no need to make the open source. These changes are accepted with little resistance, only one community member, half a year after the presentation of these plans, openly questions the move from an open-source infrastructure, to a partially closed infrastructure. The members seem to accept a redefinition of the backend (and the rest of the infrastructure), as not being completely open-source.

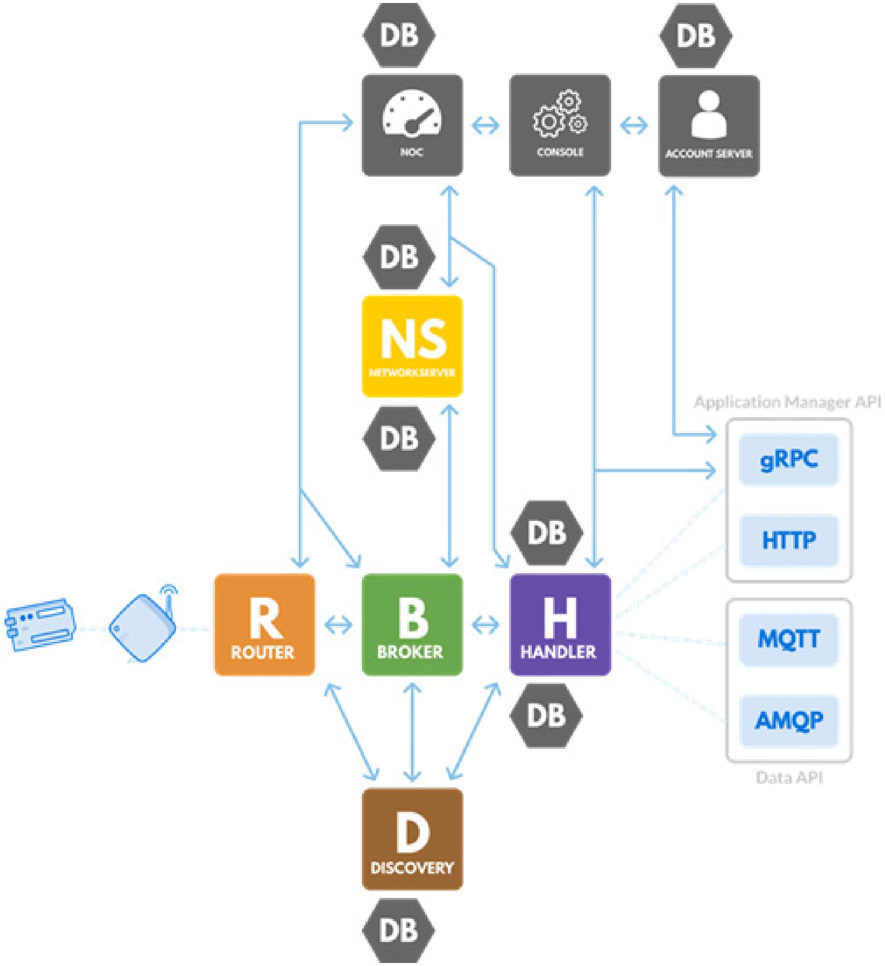

Figure 3 - Overview of the TTN Backend, greyed elements are closed-source.
Source: https://www.thethingsnetwork.org/article/the-things-network-architecture-1

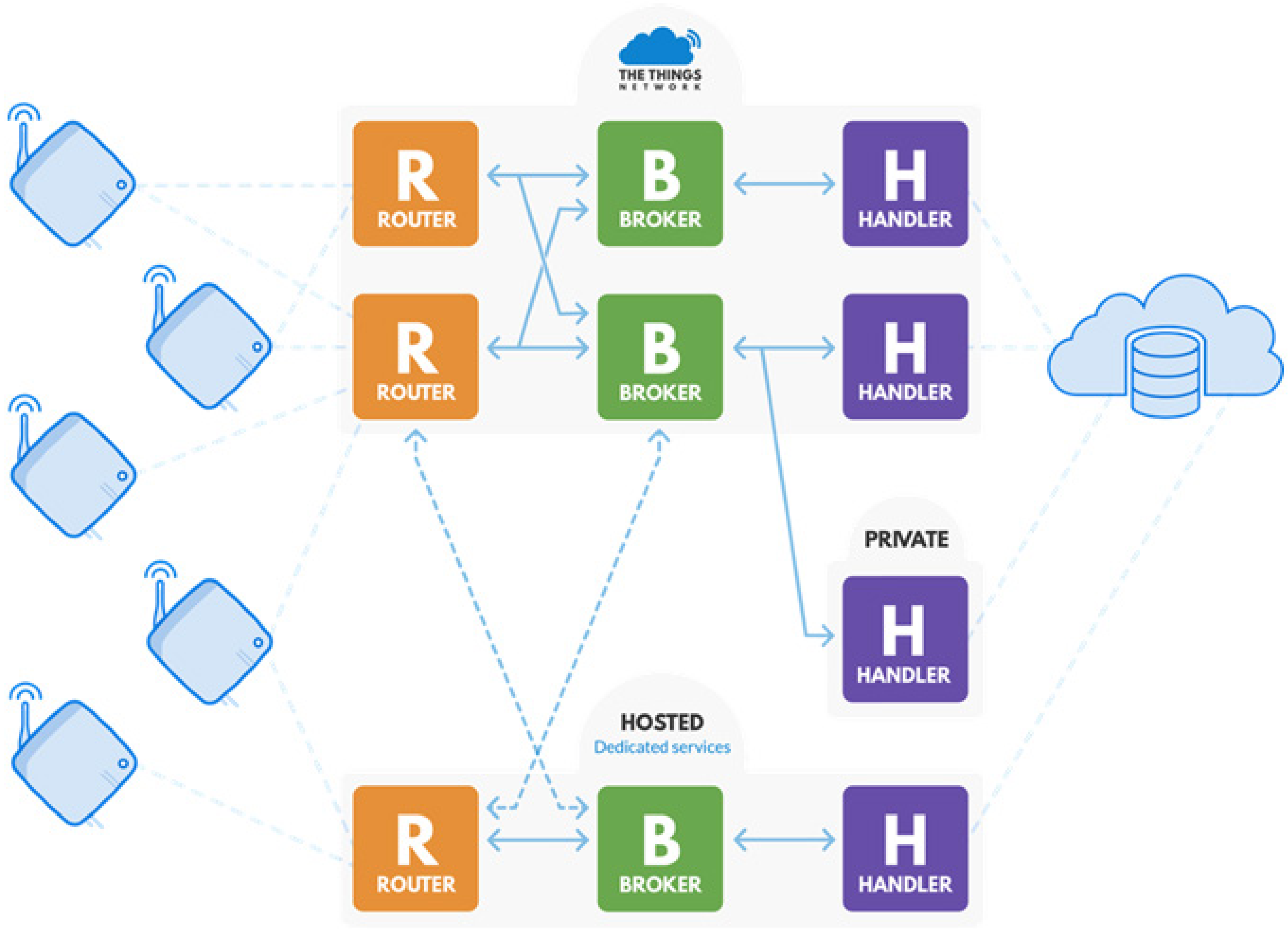

Figure 4 - Structure of the de-centralized network.
Source: https://www.thethingsnetwork.org/article/the-things-network-architecture-1

5.3 Shaping a cheap, user-friendly gateway (through Kickstarter)

As discussed in section 5.2, the global team made a promise of shaping a cheap, user-friendly gateway, in order to enroll local community members. The global team asked Tweetonig, a development company from Rotterdam to start developing a 'cheap, user-friendly gateway' and two different nodes, which developers can use to make their own applications on the network.

Giezeman, Stokking and Tweetonig decided to use Kickstarter[68], a platform which helps developers raise money, to pre-fund further development and production of the devices. As such, Kickstarter functions as an alignment device, bringing together development initiatives with those who are willing and have the money to fund development and production, as well as setting up local community members as gateway sponsors and infrastructure builders. Giezeman, Stokking and Tweetonig created a Kickstarter campaign, which would run for 30 days, through which they offered several different levels of funding. These levels ranged from a donation of €5 via a single gateway (€200) to a 'city starting pack' (€6000). Instead of focusing purely on these products (the gateway and nodes), Giezeman and Stokking focused on selling their vision, "*[t]elling the story about an open and free Internet of Things data network*" (Giezeman, 2016) via the Kickstarter campaign. In order to further support their point, the global team created an introduction video, which not only focused on the Kickstarter and its products, but also incorporated other alignment devices, such as the previously built local network and HoosJeBootje. As such, the backers, as those who spend money on Kickstarter are called, were not only buying a product, but also buying the vision of and enrolling themselves to The Things Network.

The campaign was shaped in such a way that that it had a huge attractivity in aligning new actors. Firstly, the gateways were promised to be sold at 20% of the price of a regular gateway (compared to commercial gateways available during the Kickstarter campaign), were promised to be easy to use and open source. These promises would lower the hurdle of buying and setting up a gateway, by lowering the cost and technological knowledge needed.

Secondly, Giezeman and Stokking used - with the help of community member Marcus Kirsch - several strategies to increase media coverage for the Kickstarter campaign. They started by creating a page that would show contributors an estimate of how many people they would (potentially) reach when placing a gateway at a certain location. This would help potential contributors see that funding the Kickstarter campaign would not only help (creating coverage for) themselves but also have a positive impact for the people living nearby. Before they started their Kickstarter campaign, they already created another alignment device, a mailing list, for which members could subscribe via the TTN

[68] Kickstarter is a funding platform, where developers can get funding for their products, while they are still in (pre-)development. These products range from media products (eg. a new music album) to technological devices like the TTN gateway. The general public funds these projects by pledging a certain amount of money. Depending on the amount of money pledged, contributors will get a different reward. In the case of the TTN Kickstarter, rewards can include one or more gateways or nodes possibly combined with a workshop. As the product being sold is generally still in development, there are no guarantees when backing a project. The development process might be delayed, or cancelled entirely. In the latter case, it is not certain that contributors will get their money back.

website. The global team would provide updates on their soon-to-be Kickstarter campaign via this mailing list and those who were considering buying a Kickstarter gateway could sign up. Giezeman and Stokking unofficially started the campaign an hour earlier via this mailing list, which by now had over 900 members. This action led to an early group of backers who already pledged a substantial amount of money.

The official launch of the Kickstarter Campaign took place on purpose during the crowd-sourcing week in Brussels, on the 21st of October 2015, which provided them with an additional media platform. Combining these alignment strategies led to the alignment of a lot of different news media: *"In the following weeks we were in the top 10 on Product Hunt (thanks Milan van den Bovenkamp) and Hacker News. On a ton of major blogs. Even invited to come speak at SXSW 2016. We got invited for TV shows and we were on the national news"* (Giezeman, 2016)[20]. After the enrolment of these actors, they functioned as alignment devices, which helped spread the story of The Things Network around the world, reaching more (potential) community members.

The Kickstarter campaign acted as a successful alignment device, raising nearly twice the required amount of money, pledged by 934 contributors[69]. In total, 1489 gateways were sold, to a variety of different actors, amongst which a lot of (new) local community members, businesses and three Dutch provinces. Internet entrepreneurs Mark Vletter and Joshua Peper convinced the provincial government of Groningen, Friesland and Drenthe, to make a completely covering network in their province with Kickstarter gateways.

To conclude, the global team started a Kickstarter campaign to shape a 'cheap and user-friendly gateway', based on feedback from community members: they find current gateways to expensive and difficult to configure. The new gateway should lower these barrier, allowing more community members to enroll gateways and create coverage. At the same time, the global team aims to use Kickstarter as an alignment device, not only aimed aligning new actors, including governments, businesses and individuals into the network as gateway sponsors, but also aimed at aligning several different media, who could promote The Things Network, and function as alignment devices aligning more people to the heterogeneous network. Yet, after this phase of successful alignment of backers and sponsors, the next phase in the shaping of the new gateway encountered quite some dynamics of mis-aligmnent, de-alignment and re-alignment.

5.3.1 (Delays with) shaping the gateway

After the Kickstarter campaign, Tweetonig - in collaboration with Giezeman and Stokking - started working on the development and production of the different devices. However, aligning the different actors in this process didn't go as expected. During the Kickstarter campaign Giezeman promised that, even though they couldn't take all variables into account, they would deliver the gateways and nodes around June 26, 2016[2]. However, by July 2017, more than a year later, the devices are still not delivered. In this section, I will describe the process of shaping the Kickstarter gateway, focusing on the delays and problems encountered as well as the response from the community.

[69] Source: https://www.kickstarter.com/projects/419277966/the-things-network. Visited on Jan 18, 2017.

The main method of communication on Kickstarter is through the use of 'Updates'. These updates are posted on the campaign page and e-mailed to backers. Only three weeks before the promised delivery date, Giezeman announced, at the very bottom of the 10th update, posted on June 6, 2016[70], that there would be a delay of about a month. The main body of the update was focused on positive news: It contains photos of a prototype of the gateway, and a call for input about the design (thoughts and questions). As the cause for the delay, Giezeman stated:"*We are also still in the process of find the perfect partner for our production and future distribution.*"[71].

On July 8, 2016, Wienke Giezeman said in a post on the comment section that the delivery date was pushed back to September 2016, arguing that was said in last update, while in fact, the last update said the delivery date would be end of July 2016. One backer, on Kickstarter known under the name "Pieter" commented that he was "*unpleasantly surprised*" by the further delay.

In an update[72] (#11) on July 12, 2016, Giezeman formally announced the expected delivery date was pushed to September, without any further explanation. The remainder of the update focuses on things the TTN global team was working on. In a comment on this update, another actor expresses his dissatisfaction of the delays:

"I'm quite disappointed by the delivery dates being pushed so much, to September, when I'm also getting updates that the TTN team is travelling all around the world... Respectfully, if you really "can't wait" to launch, please do try to make sure that this is the final delay in production.
The UI and UX look great, by the way! :)"

Wienke responded to this comment, stating:

"Thanks for you[r] comment, Ido! And thanks for the compliment!
We share the disappointment with you. We would love to have it out this month as well as you can imagine. We don't see any risk in the team being all over the world with regards to this. To give you some insights. These are all workshops we give. And every workshop we learn from developers getting their hands on the products and we get a ton of feedback. We also experience how [our] network is behaving with all the increasing traffic we have. So we see these as small tests for the big launch when we ship the products. And the products and the developer experience gets better every time.
Thank again for being a backer and joining us in the challenges and risks it takes for bringing this product at this price point and with these capabilities to the market so we can build a global Internet of Things data network together! (aka u rock! :))".

In the period that follows, from July 8 2016, until May 4, 2017, Giezeman notifies the backers, in 8 different updates, of further delays. Sometimes giving a cause for the delays, ranging from delays in component delivery and bugs in the software to delay in finding a manufacturer, who would

[70] Source: https://www.kickstarter.com/projects/419277966/the-things-network/posts/1592939. Visited on Jan 20, 2017
[71] Ibid.
[72] Source: https://www.kickstarter.com/projects/419277966/the-things-network/posts/1626915. Visited on Jan 20, 2017

"deliver the products at the right price, with the quality we want and future market availability."[73]

In the earlier updates, Giezeman is rather vague about where they are in the process of shaping the gateway and getting it out to backers and he only roughly describes the problems they encounter. On a meetup for TTN Initiators in Utrecht, on 14 February 2017, he elaborates on two problems they encountered, starting with the remark: : *"If you want to get 5 years older in 1 year, you should do a Kickstarter"* (Initiator meetup, 2017) arguing that he got e-mails announcing further problems with the development of the gateway almost every day. He continues by highlighting two of the problems that occurred during the production of the Kickstarter gateways. The first of these is a logistical problem. He said they shipped a set of parts, together worth €90.000,- to China with DHL. After a while, DHL announced that the parts were delivered. However, the receivers, a factory in China, said that they didn't receive the parts. Giezeman didn't further explain what caused this problem or how they solved it however. The second problem was that upon inspection, a certain component had weird spots on it. After communication with the factory that produced these parts, they found out that the wrong ink was used for the quality control stamp. This ink left a mark on the components, but didn't affect its functioning.

In the latest set of updates, posted between March 20, 2017 and May 22, 2017, Giezeman further informs backers of a delay caused by certification. Due to a change in regulations, the gateway has to go through a new certification process, which they didn't account for. No test houses have set up processes for testing compliance to these regulations yet, which causes further delays. Giezeman also informed backers that a problem with a connector caused further delay. The connector on the production boards was different than the connector on the samples received earlier. This caused a bad connection between two components.

In the meantime, a community member, known under the nickname "bluejedi" opens a topic on April 10, 2017 on the TTN forum, titled: "Is the TTN Gateway Vaporware?"[74] What follows is at first a short discussion on the current status of the gateway by community members who argue that despite the delays, it certainly is no vapourware. After a digression to several other subjects and a response by Wienke Giezeman with photos showing the production of (components of) the gateway, another user "mikeyking" expresses his disappointment: *"The amount of emails building up hope "we're almost there" to then have "oh, found a firmware issue, it'll be in a few months time" - it all wears thin in the end, no matter of how many lovely photos you have of something on the production line that hasn't actually made it to me yet."* Several posts later, Giezeman responds to this message, emphasizing that the TTN team shares his frustration, but the only thing they can do is move through the challenges. He ends his post with: "*Hope you can imagine we have the same frustration and are with you and doing everything we can to get the*

[73] Source: https://www.kickstarter.com/projects/419277966/the-things-network/posts/1658574

[74] Source: https://www.thethingsnetwork.org/forum/t/what-is-the-status-of-the-ttn-gateway-formerly-is-the-ttn-gateway-vaporware/6598/

products with you. We hope that through continuous communication and updates we keep everyone informed." This is however not an end to the discussion. In a later post in the same topic, Giezeman asks whether the title of the topic can be changed to a more neutral question, as this title "*does not really respect the hard work by the team and our partners."* Another community member "Ajj" responds: "*Yes we do mind! Keep it as it is, please! Working hard in itself is not a virtue, the only thing that counts is getting results which means in this case getting out to the Kickstarter backers. Complaining about the amount of money that has to be poured into this adventure does not make your case stronger. Do you think that in a commercial setting you would be allowed to over-run a project for more than a year? You would be out of your job long before!! Come on, Wienke, you made such a big splash of TTN before you were anyway near sure that you could really deliver what was promised. Shit happens, this is not what you had wished or hoped for but be a man and make sure that TTN does not sink like your previous enterprise. We are running terribly out of time!!"* This post solicits a final response from Giezeman, who replies with "This is motivating" at the same time quoting the last two sentences of Ajj's post.

Failed enrolment?

Above excerpts show that a myriad of different actors, both human and non-human are involved in shaping the Kickstarter gateway. From shipping companies and (LoRa chip) manufacturers, to firmware writers and certification houses. All these actors together, have to form their own heterogeneous network, centred around the gateway. This network is nested in the heterogeneous network that forms TTN and connected through the promise of a cheap, user-friendly gateway. However, enrolment of the necessary actors in this process is difficult: sometimes, enrolment seems to be a success, but proves to be otherwise, as can be seen with the connector, while in other cases, enrolment is successful, but delayed. It has also been necessary to align new, previously undefined actors, in the network. The team only learned in early 2017, that the gateways would have to pass a new set of regulations, which required them to test the gateways using new certifications processes. They now had to enrol a certification agency into the network. Furthermore, as the regulations are new, no standard certification process is ready yet. The shaping and enrolment of a certification procedure leads to further delay. The heterogeneous network itself is unstable, where actors have to work continuously to enrol actors and preventing the network from falling apart.

Influence on the heterogeneous network

The delays of the Kickstarter impact The Things Network in several ways. The first of these is visible in coverage on the network. Currently, there are about 1800 gateways in the world, providing coverage for The Things Network[75]. During the Kickstarter, 1489 gateways were sold. If these gateways were delivered, they would almost double the amount of gateways currently in operation, vastly increasing coverage of The Things Network. Several other problems were addressed at a meetup of LoRApeldoorn, by local community members[76]. One of the conversations that evening between several community members was centred around the Kickstarter delay, and during their discussion, they argued that three

[75] http://ttnmapper.org/

[76] Gateway Workshop, LoRApeldoorn, 2016

things could happen: 1) TTN/LoRa is overtaken by new protocols/technologies. LoRa is not the only long range IoT technology being developed, and several major actors are working on their own technologies and protocols. 2) It is now possible to build your own multi-channel gateway for the same price as the TTN Kickstarter gateway[77]. 3) It is bad for the reputation of TTN. Backers are getting impatient and lose their trust in The Things Network.
The meetup itself was also a result of the Kickstarter delays. The LoRApeldoorn community initially wanted to create coverage using Kickstarter gateways. Due to the delays, there was only limited coverage available, created by members who used other gateways. Several members were eagerly waiting for coverage, so the community organized a meetup where members could build their own single-channel gateways[78]. The organizers argued that, instead of waiting on the delivery of the Kickstarter gateway, it would be better to build your own gateway. The delayed enrolment of the Kickstarter gateway contributed for a great part to the development and enrolment of the single-channel gateway.

To summarize, the shaping of the Kickstarter gateway has proven to be a difficult process, quickly becoming a complex agglomeration of partially enrolled actors, where conflicts popped up almost every day: actors who the global team thought were aligned, betray the network, for example, deliveries are delayed, and produced components are different from their prototype. Often, alignment turns out to be mis-alignment, or even results in failed alignment, where components have to be sent back to be modified.

All actors together form their own, unstable, heterogeneous network, focused on the problem of shaping a cheap, user-friendly gateway. This network is nested in the larger heterogeneous network, as the gateway should become part of the TTN infrastructure. However, due to all problems, this enrolment is delayed, as the gateways haven't been realized yet.

The enrolment problems also rub off on the global community: creating coverage is delayed, as over 900 members are waiting for delivery of the gateway by which they aim to do so. Some backers however, take matters in their own hand and start shaping their own gateways, rather than continue waiting: they start their own translation processes, leading to alternative devices, by which they aim to creating coverage. In chapter 6, I have analyzed these dynamics.

5.4 Conclusion

In this chapter, I have shown how the global team transforms The Things Network from a local community, to a global community with over 450 local communities. In this process they revisit the problematization, where they define new actor roles, both on the local level as well as the global level: locally, they defined infrastructure builders creating coverage, applications builders and backend developers. On the global level, the team formalized roles already in existence, as backend developers and web developers, and introduce a new role, the community manager, who focuses on supporting local communities. They

[77] I found that, while it might be the same price, it is certainly not as user-friendly. See section 6.3.2 for an analysis of the different types of gateways that are shaped and used in The Things Network
[78] See section 6.3.2 for my analysis of the shaping and enrolment of Single-channel gateways.

also work on reshaping the backend, in an iterative process, bringing it closer to its envisioned role. Furthermore, they define a ' cheap, and user-friendly gateway', which should help community members successfully enroll the actors needed to create coverage.

The alignment process by which local actors are aligned, differs from the process of interessement as defined by Callon. Similarly to chapter 4, members are enrolled with alignment devices, aiming to create a link between potential members and the heterogeneous network. There is however, an important difference. In the initial phase, Giezeman aimed to align specific groups of actors. In this phase, the group of potential actors is not defined in such a way: the global team aims to get their vision heard around the world, seducing potential actors around the world to join The Things Network. This also makes it more difficult to enroll this group of actors in a specific role: some roles are taken up by almost everyone who enrolls in the network, while members are barely enrolled in others.

At the same time, the global team continues working on the backend. Although they already have a first version, there is quite the gap between its envisioned and current role, most notably as it currently is a centralized backend, rather than a de-centralized backend. In several iterative translation processes the team reshapes the backend, slowly closing the gap. However, at the same time, they introduce a new gap: the manifesto argues that all infrastructure components will be released under an open-source license. With the introduction of several closed-source elements, the global team moves away from this statement, creating tension between the backend and manifesto, and possible, within the whole heterogeneous network. The latter however, seems not to be an issue, only one member questions the move to closed-source components, other members seem to accept it as a means of attaining money for the global team; money necessary to sustain The Things Network. As such, they redefine the backend, translating it from an open-source infrastructure component, to a partial open- and partial closed-source component. Apart from working on de-centralization, the global team also works on integrating the requirements and interests of several other actors in the network, amongst which the Lora Alliance, national laws and wishes from local community members.

Finally, the team works on shaping the cheap, user-friendly gateway. They first aim to enroll actors as sponsors using Kickstarter, which is highly successful. They get nearly twice the amount of money they deemed necessary to develop the gateways. In the actual process of shaping the gateway, the global team creates a separate heterogeneous network, which is connected to the larger network with the promise of shaping a new gateway. Shaping of this network is not a success story, but rather a long and arduous road, filled with setbacks, failed alignment processes, betrayal and much work on (re-)aligning involved actors. A complete heterogeneous network is slowly formed, but it is highly unstable, resulting in serious delays: Initially, the gateways would be delivered at the end of June 2016. However, by July 2017, the gateways are still in the development process. These delays influence the network: delays of the Kickstarter gateway result in delays in creating coverage: members were depending on timely delivery of these gateways, to create coverage in their area. As a result, some backers start creating their own gateways, as they are tired of waiting on the Kickstarter.

6 Local alignment dynamics

With its global aspirations, The Things Network's global team encouraged others to start their own local communities. As I have shown in chapter 5, these communities are to create coverage for TTN in their own area as well as develop use cases for applications on the network. In this chapter, I will elaborate on the alignment processes of two local communities, on their work on these goals. These communities, TTN Enschede and LoRApeldoorn are both situated in The Netherlands. In the first section, I will elaborate on the rise of these two communities, describing how the initiators were interested and enrolled, and their work on creating and expanding their local communities. In the next two sections, I will focus on creating coverage (section 3) and creating applications (section 4) . In section 5, I will conclude this chapter.

6.1 TTN Enschede[79]

TTNEnschede is the local community centred on Enschede and Hengelo, two neighbouring cities in the east of the Netherlands. The initiator for this community is Timothy Sealy. Sealy got to know about TTN by reading an article on a Dutch tech site about The Things Network in Amsterdam, which was posted on 19 august 2015. He recalls his interest piqued after reading that the TTN team managed to build the network in Amsterdam in six weeks. He figured, that they could do it faster in Enschede, as it is a much smaller city. Sealy decided to pitch the idea of creating a similar network in Enschede to his employer: "*[I]f it takes them 6 weeks to build a network in Amsterdam, we should be able to do it in a week in Enschede*".

His employer wasn't immediately convinced: All data going over the network could be read by the TTN global team, as all data passes through the centralized backend[80]. The open character of the network on the other hand, proved to be the crucial, decisive reason for his employer to continue with it. Sealy worked at that time at Innovalor, where they believe in 'open innovation': "*That means that you work together, and innovation comes from networks where you work together.*" He further argues that this collaboration should be completely open, from the infrastructure to the data, making innovation independent of the amount of money you can invest. The open character of The Things Network thus functions as an alignment device, persuading Sealy's employer: the open character of the network lowers the entrance barrier. Sealy's employer decides to financially support The Things Network, Innovalor sponsors a gateway.

However, Innovalor cannot offer a suitable location and Sealy continues enrolling actors, to realize coverage for Enschede. He successfully does so: the gateway was placed on January 29, 2016[81], creating coverage for Enschede's city centre, and most of the surrounding neighbourhood. In the meantime, on a newly-created mailing list for LoRaWAN enthusiasts in Enschede (of which Sealy was also a member), the first messages (January

[79] This section is based on my interview with Timothy Sealy, November 10, 2016.

[80] As I have shown in Section 5, the global team introduced end-to-end encryption on May 22, 2017, over a year after the start of TTN Enschede. With complete end-to-end encryption, it should be impossible for anyone, including the global team, to read data belonging to someone else.

[81] Source: IoThings_Enschede mallist: http://opengesprekken.nl/pipermail/things_enschede_opengesprekken.nl/2016-January/000012.html

28,2016) concentrated on the organization of a meet-up: Several of the mailing list members argued it would be nice to gather together and exchange information. In this mail exchange, a date was quickly decided: 4 February 2016, at a local café. This meetup marked the start of TTN Enschede. The community has since grown to a community with about 20 core members, all with a technological background and 20 to 30 more who are interested but not active in the community (Interview Sealy).

In the period of March – Sept 2016, Sealy organized (together with others) four more meetups[82]. The meetups in general, functioned as alignment devices, enrolling actors in the TTN Enschede community. The meetups had a variety of topics: KiTTLab[83], a local non-profit organization which provides members with tools to create their own products, hosted a meetup, focusing on introducing LoRa/The Things Network and exchange of knowledge and information. On May 21, 2016, TTNEnschede organized another meet-up. The core of this meet-up was a workshop on how to build your own node, complete with the firmware needed to start mapping gateway coverage with TTNMapper[84]. The node was developed by one of the community members, who created a custom board on which you could solder a node chip, as well as a small micro-computer.

Sealy planned another informal meet-up on June 28, 2016. On the terrace of café Jansen en Janssen, TTNEnschede members met with members from the TTN Community in Münster and talked about a variety of topics, ranging from different nodes, how to build them, gateway coverage and other TTN related topics, to social chitchat.
The latest meet-up was held on September 14, 2016 at the work place of one of the community members. The topic of the evening was 'Building your own LoRa antenna', a presentation given by Lex Bolkesteijn, the TTN Almelo community manager.

In these meetups Sealy tried to put more emphasis on the creation of applications. He argues that most of the community consists of technical people who find the workings of LoRaWAN interesting. However, he himself is more interested in applications, what can we do with it? One of the meetups, the node-building workshop was centred around this theme: having a node is crucial for developing your own applications, as such, building a node with the community lowers the barrier for community members to work on their own applications. However, Sealy argues that this wasn't very successful, as none of the members who built a node created an application. In the meetup on September 14, 2016, Sealy again tries to encourage the community to work on applications and to share what they are working on, so others can use it as inspiration and might help to develop the application.

Apart from information exchange during the meetups, the TTNEnschede community members also use an online communication platform. Initially, they used the mailing list IoThings_Enschede which I mentioned earlier. This mailing list was quickly abandoned in favour of Slack. Even though there already was a global Slack group available, initiated by the global team, TTN Enschede members created their own group. One community member thought that it would be better to use a group on the global Slack, as this would strengthen the relation between the TTN Enschede community and the global community. Following up on his

[82] TTN Enschede had no meetups in the period of Oct 2016 – April 2017
[83] Source: http://www.kittlab.com/
[84] I will elaborate on the role of TTNMapper in alignment later in this chapter.

words, he created a channel on the global slack group on Jan. 17, 2017. He then tried to convince the local community members to move over to the new Slack channel. Initially, this transition seemed to work, as TTN Enschede members started using the newly created channel for communication. However, after a while, they went back to their own Slack group, abandoning the channel created on the global Slack group[85]. The interessement device used, the argument made by the community member, proved unsuccessful: it failed to permanently displace the actors.

To summarize: The TTN Enschede community is initiated by Timothy Sealy. He first started by creating coverage in Enschede, aligning several actors, including his employer. Using the open character of The Things Network as alignment device, Sealy convinced his employer to sponsor a gateway. In the process that followed Sealy aligned the gateway to TTN by enrolling several actors. At the same time, a meeting was organized by members of a mailing list focused on the Internet of Things. This meetup marked the start of TTN Enschede. In the period after, Sealy co-organized four more meetups, aimed at aligning new actors, both human and non-human. In these meetups he focused on creating applications, motivating users to become application developers and share their applications.

One community member tried to strengthen the bond between TTN Enschede and the global community by creating a channel on the global Slack group, one of the two communication platforms for the global community. Initially, he seemed successful: he convinced several community members to move over to the new channel, enrolling actors to the global Slack group. However, after a while, this channel was abandoned, and community members returned to their own Slack group. The relation between the local group and the community proved to be stronger: Although the argument to move at first seemed to be a successful interessement device, in the end it failed to permanently displace the actors.

[85] The last message on the global slack channel was sent on May 10, 2017.

6.2 LoRApeldoorn[86]

LoRApeldoorn is a local community for Apeldoorn and surrounding villages. According to community member Maarten Westenberg, LoRApeldoorn has that name because it is not inherently solely focused on The Things Network, but rather on LoRa/LoRaWAN in general (Interview Westenberg). However, in practice, the focus of LoRApeldoorn is actually on (creating coverage for) The Things Network. They also profile themselves on the website of The Things Network as a local community.

The idea of creating LoRa coverage originated when René van der Weerd started the Permanent Future Lab, *"[…] a publicly accessible location where the newest technology is being shared."*[87] At the opening of the lab, René announced that he wanted to have LoRa coverage in Apeldoorn in one year. Amongst the alternatives, René said he wanted to go for TTN, because: *"Well, the idea behind The Future Lab is open source, and an open network for everybody matches well."* (Interview: Initiator

[86] This section is based on my Interview with René van der Weerd, on February 20, 2017

[87] Source: https://permanentfuturelab.wiki/wiki/ Permanent_Future_Lab_Wiki

LoRApeldoorn). The open character of the Things Network this time functions as an interessement device, preventing alignment to other networks and enrolling v.d. Weerd in The Things Network. TTN also fulfilled a secondary role: combining TTN with the Future Lab, allowed René to gain more traction for The Future Lab as well as more exposure (Interview: Initiator LoRApeldoorn).

René invited people for a first meeting, and made it public by organizing it via the platform 'Meetup.com', an online platform for communities to publicly host their meetings. At this meetup, Laurens Slats, one of the two global community members, was also present. The LoRApeldoorn community grew to about 10-15 members that visit regularly, 20-25 who visit occasionally, and 30 more who enrolled in the meetup group, but never joined an event. The members mainly communicate at their meetups, and only occasionally, in contrast the the TTN Enschede community, use their Slack group, made for them by Slats (Interview v. Bussel, interview Welling). Similarly to TTN Enschede, a LoRApeldoorn member, Remko Welling created a channel for Apeldoorn in the global slack group, on December 16, 2016 to strengthen the bond between LoRApeldoorn and the global community. However, this wasn't successful: the community kept using their own local Slack, and the channel on the global group remained unused: Welling lacked an interessement device that would displace the actors to the new channel.

The members of LoRApeldoorn organized more meetings than TTN Enschede, having meetups roughly once every month, starting in April 2016, for a total 10 until January 2017. The meetups were fairly similar to those organized by the TTN Enschede community, with one notable difference. V.d. Weerd would invite everyone to join for dinner before the meetup officially started. The dinner functioned as an alignment device, strengthening the bond between the community and its members. At the beginning of each meetup, they would discuss their progress on creating coverage. Apeldoorn didn't have any coverage until late 2016, making it a priority for community members, as without coverage, they couldn't do anything with the infrastructure (Interview v. Bussel). This lack of coverage encouraged one community member to start building his own gateway. Three community members later organized a meetup, where other members could also build this gateway[88]. The content of the other meetups ranges from network updates, application brainstorms and presentations, to a build evening where members could build their own nodes.

Summarizing, the LoRApeldoorn community is fairly similar to TTN Enschede, organizing similar meetups. They are however more active, having organized 10 meetups, while TTN Enschede only had 5. Furthermore, the lack of coverage in Apeldoorn, led community members to organize meetups focused on creating coverage, in either brainstorm sessions or hands-on workshops, constructing gateways.

6.3 Creating coverage

Both local communities worked hard on creating coverage in their local area. The most important factor in creating coverage is the location of the gateway. Due to the nature of radio-waves, they reach the furthest when there are no obstacles in the way. For the frequencies that LoRaWAN uses, the most impeding objects are large buildings and other large metal

[88] In section 6.3.2 I will further elaborate on this gateway and its role in shaping the heterogeneous network.

structures, as well as trees. In order to prevent obstructions, gateways are preferably placed as high as possible, on locations where there are little to no obstructing objects. This type of location is central in the first of two different processes of creating coverage, where community members aim to place (sponsored) gateways on the roofs of high buildings; locations which are generally managed by third parties.

The second process revolves around personal gateways: Community members fund their own gateways, which they place indoors or outdoors on locations they manage or own (their own house, or company for example). Both these processes revolved around the problem of 'creating coverage': How can we create coverage in our area? However, they involved different actors. In this section, I will first elaborate on community gateways, then on personal gateways and I will end with three bottom-up innovations, which emerged from the process of creating coverage.

6.3.1 Community gateways

Both LoRApeldoorn and TTN Enschede currently have two community gateways. In this section, I will further elaborate on the strategies both communities employed and their work on creating coverage and compare them to each other.

Enschede

As discussed earlier, the employer of the TTN Enschede initiator decided to sponsor a gateway. However, Sealy still had to find a suitable location for the gateway. His goal for this gateway was to cover as most of Enschede as possible, so the building had to be high and well-situated, close to the city centre. The first building he had in mind belongs to an educational institution, the Saxion, a University of Applied Sciences. They have a fairly high building, located close to the city centre, without many obstacles in the vicinity; an ideal location Sealy managed to align this building by convincing the board of the Saxion, via one of his contacts. Sealy already knew some members of one of the educational departments of the Saxion, a department focused on the Internet of Things and smart cities. He aligned them by arguing that TTN could be a nice 'proeftuin': An experimental infrastructure, which could be used in, amongst others, smart city projects. Members from this department forwarded the request to the executive board, who were successfully enrolled: They would allow Sealy to place the gateway on the roof of the Saxion. This displacement led to a successful translation of the Saxion building from housing an educational institution to providing a location for the gateway. The next step in the process is actual placement of the gateway on the roof, for which Sealy has to find a mounting point, if there is any. The building features a railing along its edges. This railing is used to mount the gateway, using the mounting equipment provided with the gateway and a few tie-wraps. The railing, mounting equipment and tie-wraps together serve as an interessement device, preventing other actors, such as the weather (storms), from de-aligning the gateway.
The next step is to connect the gateway to power and internet, which which was already available on the roof of the Saxion. Using an Ethernet cable as alignment device, power[89] and internet are enrolled in the network and the gateway is successfully connected. After this is done, Sealy can configure the gateway to connect it to the TTN backend. After

[89] Power is provided through so-called Power over Ethernet, where, as the name implies, both power and Ethernet are provided over the same cable.

displacement of this final actor, the heterogeneous network is complete. All actors are translated to form a heterogeneous network which provides coverage for the city centre and most of the rest of the city.

After placement of the initial gateway, Sealy wanted to increase coverage to a neighboring city (Hengelo), by bridging the area in between the two cities, as well increasing coverage on the other city, where the Saxion gateway couldn't reach. The first of these was realized when a local company, KiTT Engineering, decided to host their own gateway. They are situated at a business area at the border of Enschede, near Hengelo. For the second area, Sealy already found a suitable location: a high flat, located on the east part of the city centre. They first tried to figure out who lived on the upper floors of the flat, which wasn't very successful. Later, they managed to get in contact with the association of owners of the building. Sealy again pitched TTN as a 'proeftuin' and requested permission to place a gateway on the building's roof. The owners association however, had its doubts and it took several meetings to convince them: finally, Sealy was allowed to place a gateway on the roof, and power and internet costs would be covered by the owners association.

The gateway that had to be placed on the roof is a Lorank8, a cheaper gateway, meant for indoor use, and doesn't come in a waterproof enclosure, like the gateway used on the Saxion. An extra interessement device, a waterproof casing, had to be used to prevent the weather from de-aligning the gateway. In the next step, they faced another challenge: there was no mounting point available on the roof, and the gateway didn't come with any mounting equipment. To solve the problem, they brought in another interessement device, a steel frame base, used to mount antennas on a roof. It is free standing and held in place by heavy stone tiles, preventing the gateway from disappearing in e.g. a storm. Two further challenges had to be solved: the gateway didn't come with an antenna, used a commercial version of an earlier proven design[90], had to be connected with a so-called pig-tail cable. The ordered cable was too long and some attempts were made to shorten it. Another local community member visited the local radio amateur club, but due to the short time available and lack of components, it wasn't possible to shorten the cable. Secondly, there was no internet access or power available on the roof. They had to use long cables as an alignment device, and route them through several ducts to connect the gateway (Interview follow-up, Sealy). The location required more, and different, interessement and alignment devices, compared to the gateway at the other location.

Apeldoorn

The LoRApeldoorn members, in first instance, wanted to use the Kickstarter gateways to provide coverage in Apeldoorn. At their second meetup, in May 2016, they made preparations to deploy the Kickstarter gateways. However, after it became clear that the gateways were delayed, they became aware of their eagerness to start with TTN as soon as possible[91] and they figured creating the infrastructure was the most important thing to do, even without the Kickstarter gateways. In the next meetups, they came up with two different strategies. The first concerned using a few gateways at a high location to cover a large area. They figured that not much money would be needed for this strategy, as it involved

[90] See section 6.3.3 on antenna experiments
[91] Source: https://www.thethingsnetwork.org/community/apeldoorn/ post/our-ttn-gateway-story-part-1

only a few gateways. Furthermore, a small community team could develop and operate such a network. The second strategy would involve many smaller gateways that are operated by community members. If there were enough gateways, spread evenly, coverage might be consistent. A large number of community members were needed for this strategy, that would thus have been more expensive and members should be willing to maintain their own gateways.

In order to get coverage, they aimed for both strategies. The second was addressed in a number of meetups, which I will cover in the next sub-section. For the first strategy, the community initiator, van der Weerd, argued that when the community would grow larger, companies would contact the local community on their own. One of the companies they got in contact with was the Kadaster, a governmental agency. In a meeting on how they could help each other, Kadaster agreed with placing a gateway on top of their building, as a 3-week pilot, as the engineers from Kadaster first wanted to confirm that LoRaWAN wouldn't interfere with the other antennas on the roof. The gateway itself was sponsored by Wireless Things België. A member of Wireless Things is a regular visitor at the LoRApeldoorn meetups, roughly driving 200 kilometers from the neighboring country, Belgium. The gateway was placed by two community members at the end of November, 2016. One of them, a radio amateur, brought a fold-up mast on which to place the gateway, as there was no mounting point available. Getting internet to the gateway proved more difficult: the gateway couldn't be connected to the regular internet connection of the Kadaster building, as that would compromise the security of their internal network. However, the engineers from Kadaster promised there would be an internet connection available: using a router as an interessement device, placed between the gateway and Kadaster's internet connection, it should have prevented connection between the internal network and the gateway. However, the router was misplaced, and the gateway was rejected internet access by the devices controlling the internal network. A week later, the engineers managed to correct this problem: the router now functioned correctly, enrolling the internet connection in the heterogeneous network. With the chain of translations now complete, the gateway went online and provided coverage for a large part of Apeldoorn. After 3 weeks, the experiment was deemed successful: the gateway didn't interfere with the other antennas on the roof of the building, and the gateway is still up and running[92].

The 2nd community gateway of LoRApeldoorn was placed roughly half a year later. The location was arranged by Welling, the radio-amateur who was also involved in placing the 1st gateway. He got in contact with a group of radio-amateurs who operate a repeater station, an autonomous station which repeats the signals it receives to make them propagate further. This station is placed on the roof of the 'Mheenflat' a high building in Apeldoorn. The gateway was sponsored by a company situated in Apeldoorn called INCAA Computers, who developed their own LoRaWAN gateway. Due to restrictions at the site, the gateway wasn't allowed to be placed outdoors, requiring a different chain of translations than with the other gateways: the gateway was placed indoors in a lockable enclosure, so others couldn't tamper with the equipment; the enclosure functions as an interessement device, keeping unauthorized

[92] Source: Interview Welling, Interview v. Bussel, Interview de Weerd and https://www.thethingsnetwork.org/community/apeldoorn/post/our-ttn-gateway-story-part-1

people away. From there, a 14-meter long cable aligned the outdoor antenna to the gateway. The antenna itself was mounted on an existing mast, which also hosts several other antennas. Finally, there is no wired internet connection available, only a Wi-Fi connection. This poses a problem, the gateway used can only connect via GSM or a wired internet connection: an old router is modified and displaced to function as an access point, converting the Wi-Fi signal to a wired connection, aligning the internet and the gateway. This chain of translations, (dis-)placing the actors in a specific role, led to the creation of more coverage: The 'Mheen' gateway provides coverage for a previously uncovered part of Apeldoorn and vicinity and redundant coverage for the rest of Apeldoorn[93].

Comparison
In the above section, we have seen how local communities work on solving the problem of lack of coverage: Both communities want to create coverage for The Things Network in their own region.
In order to do so, they had to align several human and non-human actors, creating a small heterogeneous network around each gateway: with a complete chain of translation, where all actors are successfully displaced, the network could provide coverage for most of the local area. Initially, both communities employed different strategies to shape these heterogeneous networks. The LoRapeldoorn community initially wanted to wait for enrolment of the Kickstarter gateway, where TTN Enschede didn't. With the delayed enrolment of the Kickstarter gateways, Apeldoorn adjusted its strategy to one similar in Enschede: Placing a few gateways on strategic locations to maximize coverage. Still, their strategy in enrolling actors is, initially, different: Sealy had a pro-active attitude and tried to enroll actors who were not yet involved. For the first LoRApeldoorn gateway, it was different: The community already had contact with the Kadaster. In a meeting between engineers from Kadaster and local community members, the first ideas for placing a gateway on the roof of the Kadaster building emerged. The enrolment of actors for the 2nd LoRApeldoorn community gateway followed a process similar to that of TTN Enschede.

The rest of the process is, at first glance, similar in both communities: They had to align different human and non-human actors, for which they employed similar interessement and alignment devices. For example, the gateway had to be aligned to the roof of the building: Both communities had to place a mast on one of the two locations and could mount the gateway to existing mounting points on the other. These interessement devices were used to make sure the gateway will remain aligned to the roof, instead of e.g. disappearing in a storm. Another example is the alignment of the gateway to the backend, which is accomplished by connecting the gateway to the internet, either by using a cable or Wi-Fi devices as an alignment device.

When looking at the processes in more detail, small differences become visible: For example, on all 4 locations, a different gateway brand is employed, each of them requiring and enabling slightly different processes. The Kerlink gateway employed on the Saxion building comes with mounting equipment and an antenna, making gateway placement a

[93] Source: https://www.thethingsnetwork.org/community/apeldoorn/post/incaa-computers-sponsored-lorawan-gateway and https://www.thethingsnetwork.org/community/apeldoorn/post/community-gateway-de-mheen-online

lot easier, similar to the gateway deployed on the Kadaster. The LoRank8 gateway deployed on a private flat in Enschede, is originally not meant for outdoor use. An extra interessement device, a waterproof casing, had to be used to prevent the weather from de-aligning the gateway. Furthermore, each gateway has its own configuration procedure.[94] Another example is the roof: It may or may not have a mounting point available and differ in how internet and power can be provided. These differences between each location, and the differences in technical requirements, ensure that the process of creating the heterogeneous networks is different every time, resulting in a different chain of translation. However, if successful, the translations still lead to a similar outcome: the heterogeneous networks provide coverage for The Things Network.

6.3.2 Personal gateways

As I will show, the process of placing personal gateways is similar, although a bit simpler: The person placing (and sponsoring) the gateway, is also in charge of the location it is placed, as such, he doesn't need any permission. Most of these personal gateways are placed indoors, where it is easier to align internet and power to the network. There is however more variety visible in the dynamics involving personal gateways in comparison to community gateways. The most important reason for this is the Kickstarter: With the delayed enrolment of the Kickstarter, community members, together with those that didn't back the Kickstarter, started to look for alternative methods of creating coverage.

[94] Source: https://www.thethingsnetwork.org/wiki/Hardware/Gateways/

As there is no direct alternative for a cheap, user-friendly gateway, they went for either of these options: Some community members bought commercial gateways, which are, although more expensive, still relatively user-friendly. Others decided to build their own gateways, which is cheaper, but requires a lot more technical skills.

Commercial gateway

Both LoRApeldoorn members and TTN Enschede members bought their own commercial gateways. One LoRApeldoorn member decided to buy commercial gateways[95], as he wanted some professional devices to create coverage for his company. He initially bought them to place at higher points, but with the Kadaster community gateway, he no longer deemed it necessary.

The TTN Enschede member who bought a commercial gateway had an agreement with his employer, who would sponsor the gateway, as an exchange for company related work he does in his free time. Initially, he wanted to buy a Kickstarter gateway when it became available[96], however, it soon became clear that the gateways were delayed and he convinced his employer to sponsor a slightly more expensive Lorank-8, which is meant for indoor use. He initially placed the gateway on the window sill on his dormer, which didn't result in good coverage. He soon decided to create a new antenna[97] and place it outdoors, to increase

[95] He also has multiple home-built gateways

[96] It was announced that the Kickstarter gateway would be for sale (for a higher price) after they were delivered to Kickstarter backers.

[97] See section 6.3.3 for the alignment work carried out to create and align new antennas.

coverage. In order to accomplish it, he had to re-align his dormer and align the antenna mast he already had on his roof: In order to bring the antenna cable outside, he had to drill a hole in the side of his dormer. He also had limitations on where to place the antenna. As a radio-amateur, he already had an antenna mast on his roof, where little space was left for another antenna. After some testing it proved impossible to enroll this mast for gateway placement: The antenna would physically clash with his other, rotating, antennas in the mast. For him, these antennas were first priority, preventing alignment of the mast. To solve the problem, he placed the antenna on the other side of the dormer, on its own separate mast. Still, the placement is not ideal: If he is using his radio amateur equipment and sending with a lot of power over a frequency close to LoRaWAN, the gateway crashes, de-aligning it from the network. He has to reset it, before it works again.

Home-built gateway

Apart from using commercial gateways, TTN members have also started to create their own gateways. These gateways fall into two categories: Those with the same functionality as commercial gateways and those that don't. Devices of the first category are almost always based on the IMST iC880A, a LoRaWAN compatible[98] concentrator board. The concentrator board forms the heart of a LoRaWAN gateway and contains all LoRa parts necessary for a gateway. Several other components have to be added to make it a complete gateway, for which you need technological skills: Parts have to be soldered on, a micro-controller needs to be added and configured, you need to build your own enclosure, and an antenna has to be connected. As such, community members without the necessary technical skills were excluded from creating their own gateways. Several TTN community members tried to lower this barrier, by writing guides on creating a gateway, and publishing them on the TTN website, in a section (the Lab) dedicated to tutorials and guides: the guides function as alignment devices, aligning gateways and less technical skilled community members.

The second type of gateways are so-called 'single-channel gateways' (SCG). The first SCG has been developed by a global team member, Telkamp, as a proof-of-concept: The single-channel gateway was meant to be used for development and node testing. A LoRApeldoorn member, Westenberg, was inspired and designed a new SCG, based on different, cheaper hardware. He displaced several commercially available parts: At its core, the SCG has a chip normally used in nodes, which is now displaced to function as a gateway chip. These chips only cost a few euro, which is very cheap in comparison to the concentrator board, which costs around €130,-. It is combined with a very cheap and popular Wi-Fi chip and micro-controller, the ESP-8266. His main incentive for creating this gateway, was so that community members could build a much cheaper (€15,-), limited functionality gateway. This enables members who don't have the money for a full multi-channel gateway, and especially those who already invested in a Kickstarter gateway, to create coverage for themselves and their immediate environment. Westenberg freely published the design and software for these gateways so others could

[98] The LoRaWAN specifications specify a minimum set of requirements for gateways, amongst which a minimum amount of 'channels': Frequencies on which the gateway can receive messages at the same time. The minimum for LoRaWAN compatibility is 3 (LoRa Alliance, 2017a), but most commercial gateways, and this concentrator board, have 8 .

build them as well. Over time, he has added more features to these gateways, by publishing new firmware.

On November 17, 2016, Two TTN Apeldoorn members, Jeroen van Bussel and Remko Welling (assisted by Westenberg) hosted a workshop on building a single-channel gateway: They had a total of 15 kits available, which attendees could buy for cost price. Van Bussel and Welling argued that the Kickstarter gateways were delayed too much and they wanted to be able to build and test a network without spending much money again (having already invested in the Kickstarter gateways). Jeroen van Bussel arranged the hardware for the gateway and the build manual and Maarten Westenberg built the software for it. The final part of the workshop consisted of building an antenna. Remko Welling, a HAM-radio amateur arranged the materials, a construction manual and the test equipment for calibrating the antenna's. Workshop attendees came from all over the NL's; with even someone from Antwerp joining.

There is however, a caveat for using single-channel gateways: The gateways currently work on the TTN network, but they are not LoRaWAN compatible. Regular gateways can listen on 8 channels at the same time, while single-channel gateways, as their name implies, only listen on one. As such, if there is only coverage from an SCG, only 1/8th of the messages send by nodes are received and propagated to the rest of the network[99]. The global team doesn't really know what to do with these gateways: They regularly announced on the forums that they would allow these devices for now, but maybe not in the future: In June 2016, a global team member says: *"There's still discussion about whether we even want to support these type of devices in the public community network, as they do not provide the expected features (only able to receive on a specific data rate, no downlink possible)."*[100] In a later post on the same topic, he argues*:* *"We don't want this for the production environment, therefore, on the production environment, we will probably not support single channel gateways. This way, people can test their nodes with a cheap single-channel gateway on the staging environment, while we keep the production environment fully functional (so with support for OTAA and reliable downlink)."*[101]

In Oct 2016, a global team member reported a new way of handling SCGs: *"For the time being, we're allowing single-channel gateways on TTN, but in order to keep confusion to a minimum, we will hide them from the maps (or somehow indicate that they're not real gateways)."*[102] At around the same time, the team revealed they had problems with single-channel gateways on the backend: Most single-channels don't support a certain feature: 'over-the-air-activation' (OTAA), while the backend expects every gateway to be able to do so, as it is necessary for LoRaWAN compliance.

[99] Normally, a node uses all 8-channels: each time it sends, it uses a different channel. They can however be configured to only send on one channel (interview Westenberg).

[100] https://www.thethingsnetwork.org/forum/t/how-are-single-channel-gateways-recognized/2454

[101] Ibid.

[102] https://www.thethingsnetwork.org/forum/t/affordable-esp8266-based-gateway-build-instructions/3837/2

Despite these messages, SCGs are still visible on the map, and compatible with the newest backend. In December 2016, the global team introduced the production backend, with continued support for single-channel gateways and also solving the earlier problems of OTAA, by disabling it for SCGs in the backend. On April 6, 2017, a global team member announced that an update to the backend inadvertently caused problems with "*some Single-Channel gateways*"[103]: The messages from certain single-channel gateways were discarded by the backend. He finished his post by arguing that SCGs are not officially supported on the network: "*P.S. please note that single-channel gateways are not LoRaWAN compliant and not officially supported by TTN.*" The announcement started a discussion amongst TTN members on the importance of single-channel gateways. One community member notes that without these SCG's, there would be less coverage, de-aligning members:

*"**This is pretty bad.** Single channel gateways are used as a proof of concept with a couple of nodes. "full gateways" are in many cases too expensive just to experiment with. There are huge areas, even in The Netherlands, with no TTN coverage for these projects a single channel gateway is the only option."*[104] Finishing his post with: "*If TTN want more grassroots projects and more people experimenting they will need to be flexible there. Single Channel Gateways are a way to for TTN to grow, killing existing and working setups will erode support for TTN.*"[105]

Other community members either stress the problems non-LoRaWAN-compliant gateways cause on the network, looking for a solution to keep single-channel gateways, while mitigating these problems. On April 10, 2017 a global team member proposed a new way of handling single-channel gateways, and asks for feedback from the community, in a topic called "The future of single-channel gateways"[106]. The team member proposed to push the developers of single-channel gateways to add downlink support and to define a different band-plan for single-channel gateways: These gateways would operate on a different frequency from LoRaWAN compliant devices, and won't harm the rest of the network: instead of overloading one of the available channels, they would operate on another. In the following discussion, the first proposal is readily accepted, but the second raises issues: Some members see it as an excellent plan, while others do not agree using a separate frequency, for three reasons: 1) In for example Australia, there is no spare bandwidth that could be used for SCGs. 2) SCGs are significantly cheaper than any other gateway and are continuously modified to become more and more compliant. One future option might be to combine three single-channel gateways to create one compliant gateway. 3) The problem statement that single-channel gateways cause heavy loads on one channel is attributed to the wrong actor: the SCG doesn't cause these loads, but it is

[103] https://www.thethingsnetwork.org/forum/t/resolved-some-single-channel-gateways-stopped-working/6529
[104] Ibid.
[105] Ibid.
[106] https://www.thethingsnetwork.org/forum/t/the-future-of-single-channel-gateways/6590

rather nodes, modified to function on one channel. Furthermore, he presents a use case where SCGs reinforce the infrastructure, rather than impede it.

What we can see in this discussion, is that the main argument revolves around who/what is excluded/harmed and who/what is enabled, as well as the importance of the involved actors. These differences in including/excluding actors can be seen in all types of gateways. The first, commercially available gateways, might have been cheap from the viewpoint of other wireless infrastructure (Interview Sealy; FMT, interview Giezeman, 2015), local community members still found them too expensive. In response, the global team promised to shape a cheap and user-friendly gateway, with the help of another company and funded through Kickstarter. It was aimed at lowering two barriers: the money needed to buy a gateway and the skills needed to configure it. A lot of the members who backed the Kickstarter were aiming to place these gateways in their own homes, enrolling all actors necessary for personal gateways; rather than aiming at placing community gateways. However, the delay of the Kickstarter gateways had an opposite effect: instead of enabling members to create coverage, it postponed coverage creation: members where waiting and not willing to spend even more money on another gateway (Interview Welling).

In the meantime, cheaper commercial gateways became available, as well as parts for making home-build gateways. The new commercial gateways were roughly double the price of a Kickstarter gateway and home-building a multi-channel gateway cost about the same as a Kickstarter gateway. However, home-build gateways require members to have certain technical knowledge in order to successfully combine the parts to create a gateway, which excluded members without sufficient technological knowledge. Home-built gateways have been used for both community and personal gateways (Interview Meijers).

Some Kickstarter backers decided to use one of the above gateways, while others created their own single-channel gateways. SCGs are very cheap, especially when compared to other available gateways, enabling users who didn’t want, or couldn’t spend much money on LoRaWAN, to create coverage and start working on their projects. On the other hand, SCG’s also bring conflict into the network. They are not aligned to the LoRaWAN specifications, as they have just one channel instead of the minimum of three. Furthermore, in several updates to the backend, implementing new features, these features led to temporary de-alignment of some single channel gateways. This led to a discussion between the advantages (including more actors) and the disadvantages (risks and incompatibility) of single-channel gateways. The discussion ended without a conclusion.

In this section, I have identified several dynamics on creating coverage by local community members, focusing on personal gateways. The members use different types of gateways, namely: commercial gateways, home-build multi-channel gateways and home-build single-channel gateways. These gateways have certain properties which results in inclusion and exclusion of actors. In order, these gateways range from more expensive to very cheap. It is exactly the other way around for technological knowledge required: commercial gateways are relatively easy to set-up, especially when compared to the home-build gateways. Single-channel gateways not only exclude those without technological knowledge, but also conflict with the LoRaWAN requirements, creating tension in the network. Several solutions have been proposed, but there has been no clear outcome from the discussion.

The single-channel gateways were developed by a local community members. His bottom-up innovation slowly diffused to the network, becoming a popular type of gateway to use.

6.3.3 Antenna experiments

The second bottom-up innovation stems from antenna experiments of one TTN Enschede community member: Bolkesteijn. After deciding he wanted to improve the coverage of his gateway, he defined a new actor, an outdoor antenna, which he wanted to create himself. As a radio-amateur, Bolkesteijn had some knowledge on DIY-antennas and adapted an earlier designed "Collinear antenna"[107], which was originally intended to be used on Wi-Fi frequencies, to use on the LoRa frequencies. For this antenna, he displaced a copper wire, soldered on an antenna connector, made a mounting plate from a small metal plate and a u-bolt and finally, enclosed it all in a waterproof PVC-tube. Afterwards, when he tested the antenna, the results were promising: The coverage for his gateway increased significantly. While building his antenna, he took some photos and shared the design process on the TTN forum. When another community member also built the antenna, based on the instructions Lex Bolkesteijn posted, he was expecting an increase in range by using the new antennas. However, in practice, the antenna performed poorly, reducing the effective coverage of the gateway. In order to find out what went wrong, Lex Bolkesteijn decided to build a second antenna, with some minor changes. These minor changes should help increase the range even further. However, in further tests with his two antennas, Bolkesteijn discovered that the length of the cable and the location of the antenna (mounted on a metal tube, metal roof underneath etc) had a major, often negative, impact on its performance. The metal tube and roof materials emerged as relevant actors, while Bolkesteijn previously did not consider them. Only by enrolling these actors (and the previously considered but problematic cable) for every location can working collinear antennas be built. (interview Bolkesteijn, TTN Enschede community member).

Even before he found out this problem, Lex decided to make a new antenna, by utilizing another existing antenna design, namely the ground-plane antenna. He shared the design process with the community, much like his previous antenna experiment. After the design was complete, he created a guide for other to also make their own ground-plane antenna and posted it on the Labs section of the TTN website. The antenna itself is easy to build, and had good results, coverage was similar to the first antenna he built, but wasn't influenced by other actors, like the collinear antenna: cable length, metal tube and roofing materials do not (significantly) impact coverage. The antenna design was later used on two separate occasions: First, it was used in a LoRApeldoorn meetup, where attendees could build their own gateway and a ground-plane antenna. Secondly, this antenna design was also featured in a presentation by Thomas Telkamp, a global team member, in a live seminar called "LoRa crash course by Thomas Telkamp"[108]. Several users reported that their home-built antenna, using Bolkesteijn's guide, worked well. Other

[107] https://www.thethingsnetwork.org/forum/t/diy-external-antenna-for-gateway/3011

[108] Source: LoRa crash course, 2016.

community members bought commercially available ground-plane antenna's, suitable for the LoRaWAN frequency.

For his third (and up to now, last) antenna experiment, Bolkesteijn worked together with a fellow HAM, who wondered whether another design, the J-Pole antenna, would also work for LoRa. In contrast to the other two designs, it is more difficult to build, as the location of the connector that connects the cable to the antenna needs to be placed in a very specific location. In field experiments, this antenna has proven to be '[...] almost as good as the groundplane […]'[109]. Another community member also built a J-pole antenna, but acknowledged it might not be possible to interest and enroll the different parts to create a good J-pole antenna without the proper (expensive) testing equipment: only actors who can successfully enroll the necessary equipment will be able to build such an antenna.

In this section, I have analyzed how Bolkesteijn, aiming to increase coverage of his gateway, defined a new actor, an outdoor antenna and aimed to shape it himself. Initially, his first iteration, the collinear antenna seemed successful: after some tests, he installed the gateway on his roof, for which he initially wanted to enroll his already existing antenna masts. However, as there was not enough space in the mast, Bolkesteijn enrolled a new actors and redefined an existing one: he attached a small mast at the other side of his dormer, so it wouldn't conflict with the existing antenna's and he had to displace the dormer: he had to make a hole in its side so an antenna cable could be fed through. His enrolment of this antenna has proven successful, however, other members had problems with the design, it lead to a reduction of coverage rather than an increase. After some experiments Bolkesteijn discovered that roof materials, tubing and antenna cable length had a significant impact on the antenna performance: three actors he didn't take into account but have to be enrolled for an antenna of this design to be successful.

[109] Source: https://www.thethingsnetwork.org/forum/t/antenna-experiment-868mhz-j-pole/3620

Bolkesteijn created to further antenna's, one of which was deemed too difficult to built for members who couldn't enroll the right equipment, while the other was successful: The antenna operates well, fairly independent of its surroundings, making enrolment easier. This antenna design diffused through the community, via several communication channels, most notably the Lab section on the website, which featured a guide on how to build such an antenna, and the respective forum topic, where Bolkesteijn shared his experiments. His design is incorporated in diy antennas used by several communities, and featured in one of the seminars given by a global community member.

6.3.4 Visualizing coverage

Another TTN Enschede member, Meijers, created another translation dynamic by problematizing the visibility of coverage: he wanted to be able to visualize coverage of currently installed gateways, so members know where a gateway is needed. He had previously worked on visualizing coverage of another network for wildlife monitoring, for similar reasons: he needed to know whether he had coverage or needed to place more gateways (Interview Meijers).

He created an application which could be used on mobile phones, in conjunction with a node, to map coverage of gateways. The results are shown on a map on the website, TTNMapper.org. The map shows the locations of gateways as well as their reach and signal quality, if it has been mapped. Finally, the map shows where members are currently mapping, by marking them on the map as a little bicycle.

In order to realize this application, he had to align several different actors: First, he needed information from the backend: He needed to know which gateway received his packets and with how much power. This information was publicly available in the first version of the backend, however, in the second backend, this data was not (publicly) available[110]. After mentioning this issue to the global team, he was asked to help design and develop the backend, so his needs could be incorporated (interview Sealy). Secondly, he had to align smartphones, which received the data from the backend, marked it with a gps location and sent it to his web server, which would plot the data on a map.

Meijers took a few printouts of his map to the first TTN Enschede meetup, showing that, with the newly installed gateway on the roof of the Saxion, Enschede already had excellent coverage. This convinced several members to buy their own hardware and start experimenting.

Conceptually speaking, the visualization print-outs functioned as a spokesperson for the network: the lines on the map represented coverage, and by extension, all actors in the network. At the same time, the map functioned as a device that made the gateway visible again: after enrolment of all actors, the heterogeneous network around the gateway (including the gateway itself) has become invisible. Only through representation by the map on the local community page on the website, does one actor become visible: the gateway itself. This map would show the location of the gateway in the centre of a circle representing its coverage. This representation however is not accurate, as coverage of gateways is almost never circular. TTNMapper on the other hand, works with actual measurements, providing more accurate representation of coverage.

Coverage mapping itself also helped to strengthen the bond between community members, and align new members: If one of the members saw that someone else was mapping coverage in their region, they would often join and start mapping together. They also tried to find placement of gateways (if not known) and ring the door, asking if a gateway is there. If they found a gateway owner using this method, they tried to enroll the owner in the local community (if he wasn't already a member). It also served as a tool which incited competition to get the longest range possible (measured over 180 kilometers) (Interview Sealy, Interview Meijers).

At first, TTNMapper was only used by the Enschede community. However, it spread quickly and is now used by members all over the world[111].

[110] The first and second version of the backend were online simulataneously. Meijers could still use the information provided by the first backend. (Interview Sealy)

[111] Source: http://ttnmapper.org

6.4 Creating applications

Apart from creating coverage, the global team also delegated the role of creating applications to local communities and their members. Initially, the focus was on creating a ‘killer app’ for consumers, which would validate the existence of the network in itself: Without applications, TTN doesn’t have any value, rendering both the infrastructure and the community obsolete (interview Sealy; Interview 7Ditches.tv, 2016).

Local communities tried to promote application creation, for example by hosting workshops on creating your own node, which would help community members with the hardware needed to develop applications. TTN Enschede initiator Sealy also paid special attention to application creation during meet-ups. He isn’t so much interested in the technology itself, and how it works, but rather what you can do with it. He tried to interest the local municipality to develop use cases and help developing the infrastructure, but enrolment failed: The local municipality was interested, but couldn’t find someone who could be responsible and didn’t have budget available. Sealy also regularly asked at meetups whether anyone was developing an application and willing to share. At one of those meetups, Adri Wischmann responded by explaining about his application to help monitor his father: The application monitors whether his father steps on the doormat in front of his bathroom door. If there has been no activity for a long time, a signal is sent to the neighbour to check on Wischmann’s father. It might of course be the case that Wischmann’s father isn’t home: For those moments, Wischmann created a cube with different symbols on its sides, like a little shopping icon. Whenever his father goes out the door, he has to put the cube with the right side up. In this way, the system knows when his father is out, so it doesn’t send a message to the neighbours unnecessarily.

However, no ‘killer app’ was developed for TTN. Giezeman and Sealy both give a reason why this is the case. Giezeman argues that the initial focus on creating consumer applications is wrong, a focus they also had by creating the HoosJeBootje application. He argues that currently, IoT applications are mostly useful for businesses and other organizations (Interview 7Ditches.tv, 2016). Sealy argued that the approach to find applications for TTN is wrong: Application developers try to find a problem to the solution ‘TTN’ instead of the other way around, where a problem is identified, and a potential solution is thought out. If this potential solution includes a (LoRaWAN) IoT infrastructure, developing an application on The Things Network might be the answer (Interview Sealy).

This also asks for a different approach. Instead of developing applications from within The Things network, TTN itself has to become an actor in another heterogeneous network, revolving around a different problem. The Things Network will be an actor that has to be aligned to the problem and the defined role, and might have to be adapted to fit this role. LoRApeldoorn community member Westenberg illustrates this problem. He has his own company and has deployed several applications which operate on The Things Network. From his view as a business user, he would like the global team to focus on backwards compatibility and stability: Stability is important the guarantee the uptime of the network. At one point in time, the network has been offline for almost a week, because there were some problems with the backend, and the only global team member who could solve it was on the other side of the world. There had been no information from the global team, that the network was done, nor any information about when the problem would be solved (Interview Bussel). Backwards compatibility is also important, as that would ensure his nodes keep working on the network. Recently, he had to recall all his nodes to apply an update, as the backend of TTN was changed, so that the nodes wouldn't work anymore. Luckily his customer didn't make a big deal out of it, but it was an expensive operation. According to Westenberg, the team focuses too much on innovation, introducing new features, like integrations with different IoT platforms, instead of focusing on backwards compatibility and stability. As a result, Westenberg started thinking about moving to another LoRaWAN provider, de-aligning from The Things Network (Interview Westenberg).

In February 2017, the global team announced that they would integrate the wishes of business users by allowing them to host their own private network (or hosting it for them), which is connected to the community infrastructure. Their goal is to be able to integrate the wishes of business users, enrolling them in their networks, and improve the community infrastructure at the same time.

To conclude, applications show the validity of building the TTN infrastructure, as without applications, the infrastructure would have no use. In the two local communities I focused on they tried to promote community members to start working on applications. For example by offering node building workshops, but also presentations on sensors and applications designed by members. Although several applications were developed, it didn't lead to a 'killer app', an application that would immediately validate the existence of a global infrastructure. Giezeman argues that initially, application builders mostly focused on consumer applications, something also shown by the HoosJeBootje app they developed earlier. Instead, The Things Network is more useful for business applications. Sealy argued that the approach to find applications is wrong: application developers try to find a problem to the solution 'TTN', instead of having a problem and considering whether TTN should be part of the solution.

By extension, I have hypothesized that this also asks for a different approach, where applications are not developed from within the TTN network. Rather, applications are created from a different heterogeneous network, with its own problem definition and defined actors. If TTN is deemed useful for this problem, it needs to be enrolled. However, TTN might not fit this role and needs to be displaced. I have illustrated this by showing the interests of an application developer, a LoRApeldoorn community member, who defined a role for TTN that doesn't coincide with TTN's current interests. TTN focuses on innovations, introducing new features for the infrastructure, while the developer would rather see them working on stability and backwards compatibility. This gap in interests has led to temporary de-alignments where the developer had to recall his nodes and modify their software, so they could re-align to The Things Network. The continued existence of this gap has led the developer to re-consider his alignment to The Things Network.

6.5 Conclusion

In this chapter, I have focused on analyzing the dynamics at the local level, which are centered around community building, creating coverage and creating applications.

The main process of creating a community revolves around organizing activities and connecting members. The meetups of both communities interested different actors from the local area, all with a technological background. The meetups were focused on social gathering and exchanging knowledge, creating nodes and presentations on applications and other aspects of The Things network. With the meetups as an alignment device, both communities mobilized between 10 and 20 people who formed the core of their community. There is a slight difference in focus in the meetups, as LoRApeldoorn focused more on creating coverage, something that was realized at TTN Enschede even before the community officially started. The initiator for TTN Enschede tried to encourage members to focus on application development, and in the Enschede meetups, creating applications was more central than creating coverage.

I have shown that creating coverage is a multi-faceted process which requires the interessement and enrolment of several human and non-human actors. The work done closely resembles the work done in Wireless Leiden, co-shaping the (local) community and the infrastructure. The main difference is that local communities are embedded in TTN, where the global team is dependent on local communities to create a global infrastructure and local communities depend on the global team for the backend, creating a more complex heterogeneous multi-scalar network.

Both communities recognized the key role the infrastructure had in developing the community, but initially employed different strategies in creating coverage. TTN Enschede started right of the bat with a community gateway with large coverage, later adding to it with personal gateways and another community gateway. LoRApeldoorn initially thought to use the Kickstarter gateways to create coverage. After a while, it became clear that these gateways were delayed, so they employed two different strategies: Creating simple single-channel gateways so they could start working with TTN, while also aiming to place a few gateways on high buildings in the city. They initially employed a 'strategy of opportunity' for the first gateway: The initiator argued that when the community grew, interested parties would enroll in the local network, and opportunities would arise to place a community gateway, which is what happened with the Kadaster gateway. For their second community gateway, a community member took a pro-active role and arranged a location. The other actors interested and enrolled by the two communities are similar: they had to deploy their own mast at one of the locations, arrange internet and power, place the sponsored gateways and configure them.
Although all processes are similar, the differences in technical features (non-waterproof vs. waterproof gateway) and differences in site layouts required different actors and different translation processes, each displacing actors differently. The end result remains the same: the two communities both successfully translated two sets of actors who now provide coverage for their respective area.

Deployment of personal gateways is similar, although placement is often simpler and no permission is needed from the location owner. There is a wide variety of different gateways in use by community members, most notably a range of home-built devices. One of them, the single-channel gateway, is a bottom-up development, introduced by a global team member and taken over by a LoRApeldoorn community member. His development of single-channel gateways flowed back into the community, where more and more community members started building these gateways.

In the work on gateways, two more bottom-up innovations emerged: The first of these are the antenna experiments carried out by a TTN Enschede community member: With his experiments he created a cheap, good-working antenna, which widely diffused in the global community. Finally, another community member developed TTNMapper, a tool with which to map coverage of gateways. TTNMapper both stimulated community members to start actively work with TTN as well as being used around the globe to map and optimize gateway coverage.

In this chapter, I have described, how – using Callon's vocabulary – these bottom-up innovations come into existence, solving a problem perceived by their developers. In several iterations, work on shaping these actors, enrolling them after a chain of translations. After their enrolment, the new devices don't stay on the local level, they slowly diffuse through the community, where more and more members start using the newly developed actors, or create their own, based on the guides available. In this process, the devices slowly start to influence global dynamics, which can for example be seen in the friction SCGs cause.

Furthermore, I have shown how the bottom-up innovation TTNMapper functioned as a representative of gateways, and the coverage created by the small heterogeneous network, of which are gateways are one part. These small networks become invisible once all actors are enrolled and they start creating coverage. Only gateways themselves, and coverage, are represented, in two different places. On the community page of the TTN website, a small map shows the gateways placed by the community and an estimation of coverage of these gateways is made, by placing a circle around the gateway. Yet, in practice, coverage of gateways differ between gateways and also in direction. As such, TTNMapper provides a similar, but more accurate representation of gateways and their coverage, as it shows measured coverage, rather than estimated coverage.

Finally, in the section on creating applications I have hypothesized that applications should not be built from within the community, but rather from separate heterogeneous networks. These networks revolve around a different problem definition and might require TTN to change focus, as their current interests might not align with those of the separate network. One LoRApeldoorn community member, who develops commercial applications, argues that The Things Network doesn't focus on what he finds important as a business user, namely stability and backwards compatibility. Instead, TTN focuses on innovation, developing new features. This gap in interests lead the developer to reconsider his alignment to The Things Network.

7 Discussion & conclusion

In this thesis I focused on describing and analyzing the dynamics of community innovations within a single case study, to gain more insight in their development. This research aims to add to the current body of work on the dynamics of bottom up innovation communities, by examining a community that aims to develop a *global* ICT-network infrastructure. In chapter 1, I defined the following research question: *How can we understand the socio-technical dynamics of The Things Network as a local and global innovation community?*

As elaborated in the theoretical framework (chapter 2), I analyzed the dynamics of innovation communities as a process of shaping heterogeneous networks, in which both human and non-human actors play important roles. Theoretically, I built on Verhaegh's notion of 'alignment work'. However, as Verhaegh did not further conceptualize the dynamics of alignment work itself, I also used an earlier developed framework of Callon (1986b), the sociology of translation, which introduces four phases by which heterogeneous networks are shaped: problematization, interessement, enrolment and mobilization. I have described and analyzed my case study with this conceptual lense aiming to come to a better understanding of the socio-technical dynamics in innovation communities. In this academic endeavor, I also aimed to enrich the conceptual vocabulary fruitful to understand the community innovation dynamics.

This thesis thus has a double role: understanding the dynamics in The Things network, and further conceptualizing these dynamics. In the first five sections of this chapter, I have respectively addressed the 5 sub-questions as formulated in Chapter 2. For each question I will summarize the main findings and also reflect on the theoretical conceptualization. Finally, section 7.5 provides an overall conclusion, reflection on the theoretical framework, lessons for community innovations and recommendations for further research.

7.1 Rise of The Things Network: Partial problematizations and alignment devices.

In this section, I will answer the first sub-question: 'How can the rise of The Things Network be understood in terms of aligning and translating human and non human actors in a new heterogeneous network?'

In the beginning of TTN, Giezeman - the initiator - had to define and align various actors. In the early problematization phase, Giezeman developed a vision of a to-be-created infrastructure, based on LoRaWAN, a newly developed protocol meant for IoT infrastructures. He wanted to create an infrastructure where no single actor can gain leverage and control other actors in the network, which makes it necessary to de-centralize all components of the infrastructure. Giezeman can be characterized as a lead user who wanted to develop something that doesn't yet exist. The role of Giezeman as initiating lead user with visionary and managerial competences is also found in other community innovations (e.g Koolhaas in Wireless Leiden (Verhaegh, 2010) and Karel Kulhavy in the Ronja case (Söderberg, 2011)). Clearly these lead users are likely to fulfill a core role in the initiating phase.

In the early phase Giezeman successfully enrolled an actor with technological competences, Johan Stokking, to join him in leading this new venture. Together, they redefined the problematization by splitting it in smaller sub-problems. Each partial problematization was formulated as a 'hypothesis' serving as subsequent challenges to enroll specific actors into the network. Each hypothesis acted as an obligatory points of passage in the ***process*** towards a - in the actors definition - successful LoRaWAN infrastructure, and in my analyst position - stable heterogeneous socio-technical network. These partial problematizations formed a strong guidance for the early alignment actions of the initiators.

In order to realize the first hypotheses, crowd-sourcing and building a local LoRaWAN infrastructure, the initiators defined eight actor groups – human and non-human - and their envisioned roles in the TTN network: architects, device makers, entrepreneurs, philosophers, pledgers, nodes, gateways and a routing mechanism. In the first problematization, all these actors, human and non human, had to be aligned.

The second and third phase in the sociology of translation, are aimed at interessing, aligning and enrolling these actors: In a process of negotiations, the actors are displaced, or translated into the network, in such a way that they take up these roles. In Callon's theorization, the core notion in the second phase is interessement, a process that aims to strengthen the particular identity and role of the actors as defined in the problematization. Interessement devices, that are used to actually implement these processes, are primarily directed at weakening or preventing relations of the involved actor groups with other entities. However, in the actual empirical dynamics in the TTN case process, I also encountered alignment processes that, in my opinion, cannot be adequately described as interessement with interessement devices at work. Some actors are aligned in the network in a direct relation, created between the network and the to-be-aligned actor (rather than preventing other, outside actors aligning to the to-be-aligned actor), using another type of device, which I have conceptualized as '*alignment device*'. In this case, the alignment device took the form of a presentation: at the time Giezeman first presented his plans to the public, he asked those present who would want to help him (and Stokking) create the infrastructure. This is also the first moment Giezeman departs from problematization: instead of aligning one of the previously defined actor groups, he aligns a group of 7 makers, who are displaced in such a way that they take up the roles earlier attributed to the first 4 defined actors.

In the process that follows, Giezeman aims to align pledgers, or gateway sponsors. This process is also different than envisioned: although he aligns several sponsors, using the same arguments as in the presentation as alignment device, new actor roles emerge in the negotiations: Some of the aligned actors want to do more than become a sponsor, by for example performing security audits on the infrastructure. So, here we see a dynamics, that the newly enrolled actors redefine their own role and identity in the network.

Next follows a second iteration of the previous phase(-s): The newly aligned team, together with Stokking and Giezeman created three new actors: A manifesto and mission, with which they again revised the problem definition. It contains more details about how the infrastructure should look like and what they aim to achieve. In the manifesto, they also open the door for a new type of user, the business user, as they argue that applications developed on the network can be both non-profit and for-profit. Secondly, they have to engineer a backend, a crucial component in a LoRaWAN infrastructure, which takes on the role of the routing mechanism. This initial backend, together with the placed gateways, becomes the proof-of-concept infrastructure, only implementing the necessary features to create a functioning infrastructure. The infrastructure is not de-centralized and extra features like encryption are not implemented. The third actor is an application running on the infrastructure, which checks whether water gets into boats, informs the boat owners and asks whether they want to have HoosJeBootje, an Amsterdam based company, come and empty their boat. The (concept of the) application functions as an alignment device, aligning the first business user, HoosJeBootje, in the network.

This new iteration, again does not completely fit in Callon's (1986b) concepts of interessement and enrolment, which is described by the displacement of actors, which assumes that these actors already exist, in some material form. To better describe this process, I have introduced the concept of '***placement***' to describe the process by which these new actors - to be enrolled in the network - need to be actually shaped, to first get a new place, where after they will become subject to displacement.

In the final phase, mobilization, Giezeman represented the whole heterogeneous network, at the launch event of The Things network, eight and a half weeks after his initial presentation. The HoosJeBootje application is displaced as an example showing that the infrastructure works, together with a map, showing coverage of the network, represented as circles. The centers of the circles prominently feature the gateway sponsors, rendering the other actors involved, e.g. the makers and backend, invisible. Finally, the seven makers are translated into actors who helped create the first local Lorawan infrastructure. Giezeman speaks for all actors when he says: *"Hereby I present you the first crowd-sourced Internet of Things data network, here in Amsterdam."*[112]

[112] Source: https://www.youtube.com/watch?v=L1TOZuK5LBM

7.1.1 To conclude

In this section, I aimed to answer the following sub-question: 'How can the rise of The Things Network be understood in terms of aligning and translating human and non human actors in a new heterogeneous network?' by framing the dynamics using Callon's sociology of translation. In the first phase, problematization, Giezeman develops a vision of creating a de-centralized network infrastructure. Later, Giezeman and Stokking redefine problematization by splitting in up into sub-problematizations. By doing so the initiators created sequential Obligatory Points of Passage that guided their alignment activities. They further defined a set of eight actors, who they deem necessary to solve the problem. In two iterations, actors are aligned to the network: in the first iteration, actors are enrolled using alignment devices, aimed at creating a bond between to-be-enrolled actors and the heterogeneous network. The actors enrolled in this process don't necessarily overlap with the roles defined in problematization. We have seen how 1) a different group of actors have been enrolled, who take up several of the earlier defined roles, and 2) new roles are constructed in the enrolment process.

In the second iteration, the involved actors revisit problematization, further defining the goals and structure of The Things Network. Furthermore, new actors are shaped and placed in the network. In the final phase, all actors are translated, so that Giezeman can speak for all of them when he argues that the first phase of The Things Network has been successful. In this process, certain actors are rendered invisible, while others are prominently featured.

Clearly, Callon's vocabulary on building heterogeneous networks allowed me to analyze the alignment processes in the TTN case in more detail, compared to Verhaegh's notion of alignment as socio-technical reconfiguration. Yet, the empirical richness and detail of the TTN case also allowed me to refine and enrich Callon's conceptual vocabulary. I thus developed the notions of 'sub-problematization', 'alignment device', as an addition to the interessement device, and the notion of 'placement' of newly developed actors, prior to displacement of actors.

7.2 Global alignment dynamics: iterated alignment, de-and re-alignment and nested networks

In this section, I aim to answer the second sub-question: 'What heterogeneous actors – human and non-human – are aligned and translated into the TTN network as global innovation community?'.

The alignment dynamics in the second phase of The Things Network roughly follow the same process as described above. The initial team revisits problematization, as they change the scope of The Things Network from a local initiative, to a global initiative. The main problematization, the creation of a de-centralized infrastructure remains, but they now aim to create global coverage. To realize this, they define several new actors, in new roles: They define local communities, led by local initiators, where community members are given the roles to create coverage and develop applications. Furthermore, they continue working on the backend and start shaping a cheap, user-friendly gateway.

The dynamics by which the community members, initiators, backend and gateway are aligned are all different. Community members are mainly enrolled using (news) media as alignment device. During the launch event and the Kickstarter, The Things Network gains enough publicity to align several news media, which further spread the story of The Things Network, seducing people to join. Community members often join local communities, if there are any in their area, but they don't have to: after registration on the TTN website, they already are full members of the community.

The process of aligning local initiators also first uses the media as an alignment device. There are however, a few more steps in the enrolment process. Initially, people had to contact Giezeman if they were interested in starting a local community. Later, the global team introduced a form on the TTN website, which members could fill. Afterwards, one of the global community managers would contact that member and would together go through the details of becoming a local initiator. In November 2016, the global team introduced a new alignment device: a set of requirements which local communities had to fulfill before they could officially become a part of The Things Network. These requirements were aimed at motivating local initiators to further develop their communities. By June 15, 2017, local initiators created over 450 communities, of which 67 are official.

The two alignment processes described above, where community members and initiators are enrolled in the network, are *continuous* processes. Rather than aiming at aligning a pre-defined set of actors, the alignment devices in these processes enroll new members every day, constantly increasing the size of the heterogeneous network. The enrolment process of the backend is different: the global team works to close the gap between problematization and enrolment in several iterations. They slowly implement features they deem necessary before it can be de-centralized, as well as integrating all features from the

LoRaWAN specifications and interests of different types of users[113], while taking into account the restrictions from different laws all around the world.

Finally, the global team aimed to align an actor that does not exist yet – a cheap, user-friendly gateway. The first problematization was to find funding for the costs of developing this new type of gateway. Kickstarter, a crowd-funding platform, was used as enrolment device to align funders for the new gateway development. However, these funders were aligned and successfully enrolled in multiple roles: not only as funders but also as gateway sponsors and coverage creators. The alignment of funders into the network went relatively easy and fast as the promises of an open things network acted as a strong alignment device.

However, the next dynamics revolving around the actual shaping the gateway was extremely tedious and triggered a lot of instability in the evolving network. The global team, together with a small company Tweetonig started shaping a nested heterogeneous network, in which a myriad of actors have to be enrolled to create the Kickstarter gateway. This process turns out to be long and arduous, full of mis- and de-alignment, resulting in a complex agglomeration of partially aligned actors, a highly unstable network. In this process, the team for example encounters problems with delivery delays, missing shipments, stained components and mis-representation: prototypes that differ from production versions. Finally, unexpected actors announce themselves, as new regulations require the gateways to be verified in a new certification process, which the team didn't take into account. All these factors together, delay enrolment of the gateway for, by now, over a year, as the gateways still haven't been delivered. This (until now) failing of enrolling the new gateway, created serious instabilities in the network. Other actors, especially local community members wanting to realize coverage, were disappointed and initiated local actions, like building simple gateways themselves, that de-stabilized linkages with other actors in the global network, e.g the global team and the backend.

[113] I have discussed the latter in Section 6.5, as this is a process where mostly commercial interests are integrated in the network.

To conclude

In this section, I have further studied the dynamics shaping the heterogeneous network, by analyzing the alignment processes and identifying the different actors involved on the global level. In the transformation of The Things Network, from a local initiative to a global community, the problematization is revisited and new actors are defined, namely local community members, in the roles of coverage creators, application developers and local initiators, and a new cheap and user-friendly gateway, aimed at lowering the costs for community members to create coverage.

To better described the different alignment dynamics, I conceptually elaborated three different forms of alignment: **1) continuous alignment:** New local community members are continuously aligned through the use of media as an alignment device. Every day, citizens all over the world, are enrolled and displaced as members of local TTN communities. Yet, the alignment devices also exclude groups of citizens, (e.g. women and elderly) through biases in the media (technical fora's). **2) iterated alignment**: In several iterations of translations, the global team works on closing the gap between the definition and current role of the backend. **3)**

de- and re-alignment: The Kickstarter gateway, is a new, still to be developed and to be placed actor. Here we see that a whole new actor network needs be created (one could see this as a nested heterogeneous network) by the global team. The dynamics of this nested actor network, is an arduous process, plagued by - amongst others - betrayal, where shipments go missing and prototype examples are unexpectedly different from the final production version, leading to multiple forms of **de-alignment.** The global team has to continuously try to keep this unstable network together, by aligning new actors and **re-aligning** existing actors. The unstable nested network and continuous de-alignments lead to delays in enrolment into the TTN community innovation network.

7.3 Local alignment dynamics: Sequential alignment, gateway diversity and enrolment in other networks

In this section, I aim to answer the third sub-question: 'What heterogeneous actors – human and non-human – are aligned and translated into local TTN innovation communities?'. I have based my analysis on the study of dynamics in two local TTN communities, namely LoRApeldoorn and TTN Enschede. These communities form their own heterogeneous networks, nested in the global community. They operate relatively independent, but the local communities depend on the global community and vice-versa. The local communities for example need the backend developed by the global team for the local infrastructure to work, and the global community needs local communities to create worldwide coverage.

Both communities focus on creating coverage and applications, yet their alignment strategies show differences as well. At the start of the TTN Enschede community, the initiator already placed a community gateway, providing coverage for most of Enschede. Furthermore, he himself is more interested in the possible applications of the infrastructure, rather than the infrastructure itself. As such, he aims to steer the community to enroll more actors as application developers, who share what they are doing. LoRApeldoorn on the other hand, were initially waiting on the Kickstarter gateways to create coverage. As these were delayed, they mainly focused on creating coverage using alternative strategies. Both communities used the meetups to enroll new actors and align them with the roles each community respectively focused on.

7.3.1 Creating coverage: diversity of gateways

Within the dynamics of creating coverage, I have shown that coverage is created by shaping smaller heterogeneous networks, revolving around a combination of a gateway and location. These dynamics can be described in two different processes, creating coverage using community gateways and personal gateways. Community gateways are placed on high buildings, which are generally managed by third parties. High locations are important due to the nature of radio-waves: When there are less obstacles like trees and other buildings in the way, the radio-waves propagate further. High buildings tend to have less obstacles in the direct vicinity, increasing the range a single gateway can cover. Globally, the chain of translations necessary for enrolling community gateways is similar. It is a sequential process of aligning actors using a combination of alignment and interessement devices, gateway sponsors, buildings and their owners, gateway mounting equipment, power and internet. In each step, one of these actors is aligned sequentially, eventually leading to coverage for The Things Network.

The different processes differ when one looks at the details, as different site layouts and technical properties of the gateways require different translations and different alignment and interessement devices. For example, one of the community gateways placed by TTN Enschede didn't come in a waterproof enclosure, as it was meant for indoor use. The community had to displace this actor using a waterproof enclosure as interessement device. Another example is a community gateway placed by LoRApeldoorn. Due to site restrictions they weren't allowed to place the gateway outdoors. As the gateway was now accessible for others, they had to place it in a lockable enclosure, so others couldn't tamper with it.

The chain of translations for personal gateways is similar but somewhat simpler: personal gateways are usually placed indoors, in the home of the community member, who usually also pays for the gateway. Furthermore, internet access and power is usually easily available in these locations. There is however, a large variety in the types of gateways community members use, each including and excluding different actors: the more expensive, commercially available gateways are easier to configure, thus requiring less technological expertise. Home-built gateways on the other hand, which come in two varieties, multi-channel and single-channel are cheaper, but more difficult to configure, as one has to assemble it themselves, translating the parts to a functional gateway. Single-channel gateways are the most difficult to configure, as they require translation of nodes to function as gateways, different from their intended use.

The chain of translations necessary for both personal and community gateways is thus partially determined by the type of gateway used, and, in the case of community gateways by the site layout.

7.3.2 Creating applications: need to penetrate into another heterogeneous network

After the transformation of TTN to a global community, the global team delegated the role of creating applications to local community members, where they initially hoped, someone would create a 'killer app', an application that would at once validate the existence of the heterogeneous network. Without applications, TTN wouldn't have any added value, rendering both the community and infrastructure obsolete. However, up until now, no killer app has been developed for TTN. Sealy, the initiator of TTN Enschede argues that current process with which application developers approach development is wrong: they try to find a problem with the solution TTN, instead of the other way around, where the first step is the identification of a problem, and only afterwards investigating whether TTN could prove part of the solution. Or, in terms of the sociology of translation, application developers are currently aiming to enroll other actors in the TTN network, where they use applications as alignment devices. Yet, I hypothesized that the enrolment of application actors might constitute a different dynamics where TTN has to present themselves as an actor (solution) into a completely different heterogeneous actor network rooted in the application domain with actor making their own problematization. TTN itself then becomes an actor in another heterogeneous network, revolving around the problem the leading actors in that network aim to solve. Every problem has its own problematization, where certain actor roles are defined, and actors displaced in these roles. As TTN is not the leading actor in these problems, but rather part of the solution, they are another actor which has to be aligned in the defined role, where they initially might not fit. The Things Network might have to adapt themselves to the interests defined in the heterogeneous network, which they aim to become part of, instead of translating actors in their own heterogeneous network.

7.3.3 Comparison to Wireless Leiden

In this section, I will compare my findings on the dynamics within The Things Network to Verhaegh's (2010) analysis of Wireless Leiden. Wireless Leiden, can be split into two phases, similar to The Things network. In the initial phase, the dynamics visible in both communities are similar: both communities were initiated by a lead user, aiming to create a network infrastructure. In order to realize their goal, they both aligned a group of tinkerers, with whom they start developing the devices necessary to create their envisioned infrastructure. The main difference in this process stems from the devices each community aims to use. The Wireless Leiden community focuses on an existing technology, re-engineering it to align it to its envisioned use, or defined role. The Things Network on the other hand aims to use LoRaWAN, a protocol that, at the time, wasn't completely developed yet. Although gateways were readily available, the backend needed to create an infrastructure still had to be developed. Only after shaping the backend could they work on further aligning it to its defined role. Furthermore, in contrast to The Things Network, Wireless Leiden only start creating their infrastructure after re-engineering of Wi-Fi is successful.

The second phase of alignment work in Wireless Leiden can be best compared to local communities in The Things Network, as both aim to create local coverage for their communities. In this second phase, which Verhaegh characterizes as 'The growth of Wireless Leiden as community innovation' he focuses on the diversity of users involved in Wireless Leiden. He identifies four different types of users, in specific roles. Two of these roles are also visible in The Things Network. The first role, the 'organizational user as sponsor' is similar to the role of gateway sponsors in The Things Network. They are companies and other users who sponsor gateways[114]. The second type of user is the 'volunteer user': they are users with a technological background who for example help with development and placement of gateways, maintaining the website and writing software code. Similar roles are visible in The Things Network, but spread over different actors. Some of the roles, such as maintaining the website are attributed to the global team. Other roles, such as placement of gateways have been taken up by local community members.

The other two types of users, 'home users' and 'maintenance users' are not visible in The Things Network, yet, some of the roles of these members are. The term home users refers to users, generally without technological knowledge, who used Wireless Leiden to gain internet access. This type of user was first aligned to the network after the enrolment of an Internet Service Provider into Wireless Leiden. The Wireless Leiden community decided to provide free internet access for Leiden residents, in the areas where there was coverage. Furthermore, one of the Wireless Leiden residents developed a commercial client, called Wandy, with which home users could connect to the infrastructure: through Wandy, users without relevant technical knowledge where included in the network. Not all potential home users initially had coverage of Wireless Leiden. Some home users, together with an experienced volunteer with technical knowledge, created coverage

[114] Within Wireless Leiden, the term node was used for devices with a similar function to gateways in The Things Network. To avoid confusion, I relabeled Wireless Leiden nodes to gateways.

themselves, in a process similar to creating coverage for The Things network.

The final type of user, the maintenance user only emerged later, when Wireless Leiden had grown substantially. The volunteer users within the community were unable to keep up with placement and maintenance of the nodes, which led to the delegation of the latter role to the newly developed 'node adoption volunteer'; home users who would, with the help of a checklist, check and maintain gateways. Within The Things Network, there is no separate role for gateway maintenance, it is usually carried out by the member(-s) who placed the gateway.

T o conclude, Wireless Leiden has a larger user diversity than The Things Network, which doesn't have actors without a technological background. However, some of the roles of the non-technical actors in Wireless Leiden are similar to roles of technical users in The Thing network, for example the work on creating coverage, or maintaining gateways. The dynamics visible in both communities have many similarities: Both communities start with an initiator who enrolls a group of tinkerers, who aim to create a local infrastructure. Furthermore, in both communities are the media the main alignment device used to align local members.

Both communities use the same type of alignment device, namely the media, to enroll new users in the network.

7.3.4 To conclude

The dynamics in local communities are centered around three processes: developing the community, creating coverage and creating applications. Both TTN Enschede and LoRApeldoorn mainly aim to align members using their meetups as alignment device, also aimed at steering community members towards one of the two problems. Both communities are nested heterogeneous networks which address both roles, but focus on one of them: The initiator of TTN Enschede aims to push members to create applications. LoRApeldoorn has no coverage yet, which leads them to focus on creating coverage.

Coverage is created by separate, nested heterogeneous networks, **consecutively aligning** new actors to the network. These processes can be separated into two categories, community gateways and personal gateways. The process of enrolling different community gateways is globally the same, though technical requirements for different types of gateways and the restrictions of different site layouts determine different chains of translations, where different alignment and interessement devices are necessary to displace all actors. The creation of personal gateways is mainly influenced by the type of gateway: the three different gateway types all include/exclude certain actors: they vary in price and in skill needed to assemble and configure them.

Finally, I have hypothesized how, in the process of creating applications, TTN has to align itself to other networks, instead of aiming to enroll the actors involved in The Things Network. In this process, TTN might have to be displaced, to fit the defined actor role, as inspired by the problem definition.

7.4 Global-local interactions and influences: participation and conflict

In this section, I aim to answer my fourth sub-question: ‘How do local and global dynamics influence each other?’.

Throughout the development of The Things Network local communities operate relatively independent from the global community, as their focus lies within their local environment. The global and local communities are mutually dependent however, as local communities depend on e.g. the backend, developed by the global team, and the global community depends on the local communities for creating world-wide coverage. As such, it is also possible to identify several processes in which the global and local dynamics influence each other. First of all, the global community, as led by the global team, has a mayor influence on the dynamics of the local level. The global team controls the backend and related services, where they determine how and which actors can enroll in the network: they write the connectors to connect gateways and application servers to the backend, where the global team continues to develop more connectors for different services which can function as application servers, potentially including more actors in the network.

The global team also controls which nodes are allowed on the network, as well as gateways: At one point in the development, they temporarily disconnected a set of single-channel gateways. As such, the global team acts as OPP for local gateways and nodes. They control which actors the local communities can enroll in the network. Yet, their actions are not solely top-down, they regularly consult a small, set group, consisting of community members around the world - moments where local members can influence the dynamics on the global level - to provide feedback before the global team publishes their ideas on the forum. Once published on the forum all community members can in principle provide feedback on their plans. The global team aims to be open about what they do and communicate with local communities about their plans, in order to keep both the global team and local communities aligned to each other. In this process, they aim to enroll local community members as actors on the global level, co-determining global dynamics.

In this thesis, I have identified three other moments in which local community members influence global dynamics. The first of these is through bottom-up innovations. In section 6.3, I have shown how three community members develop new actors, namely the single-channel gateway, three different home-made antennas and TTNMapper. Although all three actors influence global dynamics, the single-channel gateways are particularly visible in global dynamics. Single-channel gateways are not LoRaWAN compliant, which has led to problems with the backend: the single-channel gateways weaken the network on the global level. On the other hand, local community members argued that single-channel gateways are essential in some local communities, as they are the only affordable option to start experimenting on The Things Network. Without single-channel gateways, many members would not have enrolled.

The second moment where local community members have influenced global dynamics is the Kickstarter. Local users are interested in a cheap, user-friendly gateway, as they argue that currently available gateways are difficult to set-up and expensive. This interest is translated by the global team, who aim to create such a gateway through a Kickstarter campaign, aiming to incorporate the wishes of local community members into the network.

Finally, after the role of the business user emerged in the network, it became clear that they had interests that didn't align with TTN. Business users wanted a stable, backwards compatible network, both of which couldn't be offered by the community infrastructure. The global team aimed to incorporate these interests, as they found it important to enroll business users in the network. The dynamics visible are very similar to those in the creation of the Kickstarter campaign: the interests of local members led to dynamics initiated by the global team, who aimed to incorporate these interests in the network.

7.4.1 To conclude

In this section, I have shown how the global team, in its role as developers of the backend, are in control of the network, functioning as an obligatory point of passage for local gateways and nodes. This kind of control creates tension, as it is in direct contrast with the manifesto, and overall goal of TTN where they argue they want to make sure that no actor can exercise control over others in the network. Their role as an obligatory point of passage might change in the future, when the current, centralized infrastructure, is successfully translated to a de-centralized infrastructure. At the same time, they aim to include the opinions of local community members in their decisions, where, through open communication and feedback moments, aiming to prevent creating a gap between the global and local communities.

Local communities influence the global community through bottom-up innovations. In the two communities I have analyzed, three bottom-up innovations are visible, which dispersed through the global community. One of these innovations, the single-channel gateway, sparked discussions as it strengthened local communities, but weakened the global infrastructure. Finally, as I will show in the next section, interests of local business users are to be translated into the network, at the global level.

7.5 Community versus commercial interests: Tension and synergy

In this section, I aim to answer my last sub-question: 'How are community and commercial interests co-aligned in the above global and local dynamics?'

As we have seen in this thesis, the co-alignment of community and commercial interests is particularly visible on the global level, in the double role of the global team, as representing both community and commercial interests and their work on enrolling the backend, where they aim to integrate community interests, and the commercial interests of the global team itself and business users. Initially, the global team started as a group of volunteers. Over time, the commercial interests of Giezeman and Stokking became visible. Apart from starting The Things Network Foundation, representing the community side, they start The Things Industries, a commercial venture. They aimed to create commercial services on top of the infrastructure, while the infrastructure itself would remain open source and free to use. The group of volunteers is translated to a group of paid employees, under The Things Industries, at the same time representing commercial and community interests. The first moment the commercial interests of TTI become visible is in the development of the backend. Instead of releasing the complete backend under an open source license, the global team decides to keep certain parts closed source. Most of these parts are extra services on the infrastructure, and not necessary for running the backend. One service however, the account server, is crucial: without it, the backend wouldn't work. As such, the team moves away from the problematization, creating a gap between problematization and enrolment, where community and commercial interests conflict and are not co-aligned. Local community members don't seem to mind this development, as only one user openly questioned it.

As time continues, a new user role is constructed, the business user. Business users are actors in a different role, that mostly emerged some time after The Things Network became a global community. The door to users enrolling as business user was opened in the manifesto, as argued before. According to business user Westenberg, the interests of business users and TTN don't align on two aspects: first, business users want a stable infrastructure, that is guaranteed to be online. However, the TTN community only offers an as-is network, without any guarantees, which has been offline from time to time, with the longest period almost a week. Secondly, backwards compatibility is important for business users, so they don't have to recall deployed applications to update them. However, the iterative updates of the backend are often not backwards compatible: the global team argues they make such drastic changes between versions, that backwards compatibility is impossible. Although the community and commercial interests seem incompatible, the global team still aims to align these interests in the network, by incorporating it into the decentralization of the backend. They argue that business users could set up their own, so-called, private backend, and deploy their own gateways, for which they can guarantee uptime themselves. This private network could then be enrolled in the community infrastructure: messages from members of the community could then be received via the private gateways and forwarded to one of the community backends and vise versa: business users can use the coverage created by community gateways as an extension of their network (without guarantees). Messages received by a community gateway could be forwarded to the private backend. The global team argues that in this way, private and community networks can reinforce each other, without a conflict of interest. Although some of the work needed to realize this form of decentralization has been done, it is not yet possible to connect private infrastructures to the community infrastructure.

To conclude

In this section, I have described two processes in which community interests and commercial interests come together, both in the enrolment of the backend. In the first, commercial interests lead the global team to create a gap between problematization and enrolment: they keep some elements of the backend closed source, in contrast to what has been described in the manifesto.

This tension is similar to the tension visible in the Ronja community. The Ronja community, as I described in chapter 1, was a community aimed at developing 'Ronja', a device that sends data over visible, red light, with which members can build local ICT-infrastructures. Initially, the community collectively worked on realizing Ronja as a user-controlled technology - a device which everyone, including those without knowledge of electronics, should be able to build. However, later, other members joined with a commercial incentive: instead of sharing their improvements - aimed at improving the technology, rather than making it user-friendly – they kept the designs for themselves and developed commercial devices based on the improvements. This tension slowly led to disintegration of the community.

Within TTN, the tension hasn't led to any conflict yet. This might partly be because of the difference in the community structure: in the Ronja community, development of Ronja devices was de-centralized and the work was spread over many different users. Within The Things Network, development of the backend is done centrally, by the global team. Furthermore, as the infrastructure of The Things Network is still centralized, and the closed source elements can be freely accessed, there is no incentive for members to create a conflict. De-centralization of the backend on the other hand, would require members to be able to deploy at least some of the closed-sourced elements of the backend, which is currently impossible. In the future, the currently existing tension might grow into a conflict.

In the second process, the global team aims to create a synergy between the interests of business users - driven by commercial incentive – and the community interests. They argue that business users could create their own infrastructure, which they manage themselves, making it possible to guarantee stability and backwards compatibility. These private infrastructures could then be connected to the community network, so they can mutually reinforce each other, instead of creating tension.

7.6 Conclusions & recommendations

In the previous paragraphs, I have focused on the dynamics of The Things Network, as a global and local community, where I have described several different alignment processes. I have studied how The Things Network has grown from a local initiative to a global initiative with over 450 local communities. This can be separated in two phases, based on the sub-problematizations defined by the initiators. In the first phase, the initiators aimed to create a local, crowd-sourced infrastructure, by enrolling and creating actors in two iterations. In the first iteration they focused on enrolling gateway sponsors and actors who could help shape new actors. In the enrolment process, several new actor roles where defined and included in the network.

In the second phase, the team revisited the problematization, now aiming to create a global infrastructure, led by a global team. They aimed to enroll local initiators who would start local communities focused on creating coverage in their area, and creating applications. Community members and initiators were enrolled using the media as an alignment device, in a process of continuous alignment, where new members – limited to those with a technical background – join the network every day. The global team itself continued on working on the backend, aiming to align community and commercial interests in such a way that a synergy would emerge, where the community infrastructure would support private infrastructures and vise-versa. I identified this process as a form of iterated alignment, where each iteration brings the backend closer to its defined role, as well as further integrating other members' interests.

Furthermore, the team worked on creating a cheap, user-friendly gateway, via a Kickstarter campaign. The campaign itself proved to be a powerful alignment device, aligning many members as pledgers, gateway sponsors and potential coverage creators. After the campaign the team started working on developing the gateway, where they had to create a whole new heterogeneous network, which has proven to be an arduous process, plagued by – amongst others – betrayal, where actors de-align, leading to a highly unstable network. The global team had to work continuously to keep the network together, by aligning new actors and re-aligning existing actors.

Local communities, on the other hand, mainly focus on the two roles defined by the global team: creating coverage and creating applications. In their process on creating coverage, local community members shape small heterogeneous networks where they consecutively enroll the actors necessary for creating coverage. This process is mainly influenced by specific technological requirements and properties of gateways as well as restrictions in site layouts, which require different alignment and interessement devices to align all actors. In their work on creating applications, community members often take TTN as the starting point, and try to find a problem fitting to TTN as a solution. I have hypothesized how this might be the wrong approach, rather than aiming at enrolling applications from within the community, it might be necessary for TTN to align to other networks and adapt itself to the roles defined in that network.

Finally, I have also identified two potential conflicts on the network: The first potential conflict emerged when the global team created a gap between problematization and enrolment by keeping some elements of the backend closed source, of which one is necessary to run a backend. Currently, this has not led to any conflict, but that might be different when the backend is de-centralized. The second conflict emerged through a bottom-up innovation, the single-channel gateway, which reinforces local communities, but weakens the global infrastructure.

7.6.1 Reflection on the theoretical framework

In this thesis, I have used Callon's (1986b) Sociology of Translation to further structure dynamics within The Things network. Callon's vocabulary proved particularly useful to analyze the alignment processes in the TTN case in more detail, compared to Verhaegh's notion of alignment work. The dynamics made visible by comparing actual enrolment of actors to the actor roles defined during problematization have proven to be essential for developing my argument; they allowed me to identify different alignment processes visible in The Things Network. Yet, Callon's vocabulary couldn't adequately capture all dynamics visible in The Things Network. The empirical richness and detail of TTN allowed me to refine and enrich Callon's concepts, by developing three new notions: 1) 'sub-problematization', where Giezeman and Stokking divided the problematization in several 'hypotheses', which they aimed to address one by one. 2) 'alignment device', as an addition to the interessement device. Interessement and interessement devices are aimed at enrolling actors by weakening or preventing relations of the involved actors with entities outside of the network. Alignment devices on the other hand, aim to enroll actors by creating a direct relation between the involved actors. 3)The 'placement' of newly developed actors, by which new actors are shaped, to first get a place in the network, where after they can be displaced.

7.6.2 Lessons for strengthening community innovations

In the previous paragraphs, I have focused on the dynamics of TTN, where I have described several different alignment processes and potential conflicts in these processes. I have translated these conclusions to the six following lessons, aimed at starting and strengthening innovation communities:

1) The competences of the initiator(-s) are of vital importance for the success of the network. Within The Things Network (and other innovation communities), initiators have visionary and managerial competences, essential for successfully creating a community.
2) Divide the mission, or problematization, in sequential sub-problems. This allows the community to tackle smaller, easier problems, while at the same time, the overall goal is brought closer step by step.
3) The leading team should openly communicate about their decisions and involve (local) community members in the decision

making process. Doing so will allow global members to better align the interests of local community members, preventing de-alignment of actors.

4) Focus on incorporating and balancing interests of different actors in the network. Incorporating interests, in conjunction with open communication, is important to align new actors and prevent their de-alignment. Furthermore, balancing these interests, especially commercial and community values, is important to prevent conflict within the network, as for example happened in the Ronja community.
5) Innovators should actively stimulate and facilitate local innovation to encourage community members to innovate and actively support the growth and stabilization of the network.
6) Allow for a diversity of actors to emerge and enroll on the local level. In the latter part of my conclusions, we have seen how the diversity of gateways, led to the enrolment of more actors on the local level. Especially, single-channel gateways have been deemed crucial by local community members. However, they also created a conflict in the global community: global team members argued that they were weakening the infrastructure. However, rather than aiming to de-align single-channel gateways, they have been searching for ways to accommodate for the diversity of gateways withing the infrastructure.

7.6.3 Recommendations for further research

In this section, I will provide three recommendations for further research. The first of these stems from my selection of actors for the case study. In my thesis, I included two local communities, both situated in the same country. Although it provides a good initial vie of dynamics in local communities, it also is a rather one-sided view of the communities involved in The Things Network. There are currently over 450 communities in The Things Network, spread over more than 80 countries, each with their own local cultures and laws. I expect there will be plenty variations in the 450 communities spread over more than 80 countries. It would be interesting to select a group of communities in several different parts of the world, and compare them to each other and the communities analyzed in this thesis.

My second recommendation relates to the three bottom-up innovations, which emerged from the work on creating and improving coverage. I have been able to analyze how these innovations were brought into existence, as well as their influence on the network, using Callon's vocabulary. Yet, his framework doesn't include notions on how these bottom-up innovations diffuse: In their initial enrolment, they were only enrolled in a local setting by a single user. Over time, these innovations diffused and spread from their local community to other local communities and finally, the global community. Unfortunately, it was outside the scope of this thesis to further analyze the dynamics by which these innovations diffused in the network.

My final recommendation covers the time slot within which I collected my empirical data. I have aimed to collect empirical data, covering the time period from its initial start in July 2015 up until May 2017. This has provided me with a very rich and extensive amount of empirical data, which I've used to perform my analysis. Over this time period, The Things Network has emerged as a global community, sporting over 20.000 members, spread all over the world. Right now, The Things Network still continues to grow and expand, rather than stabilize, with many ongoing developments. In the (near) future, delivery of the Kickstarter gateways as well as de-centralization of the infrastructure, might prove to be important dynamics in the further development of the network. As such, it would be interesting to do a follow-up research of The Things Network.

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9 Appendix A

Figure 5 provides a schematic overview of a complete LoRaWAN network. Such a network consists of four types of components, divided into two categories: *The infrastructure*, consisting of gateways and a backend and *the applications*, which include end nodes and application servers. **End nodes** are the small devices that generate data: They can for example have sensors to monitor things happening in their environment, like measuring air/water quality. Periodically, they will send their data, using LoRa, wirelessly. If there are one or more **gateways** within range, they will receive this data and send it to the **backend**, either via 3g, 4g, Ethernet or Wi-Fi. The backend on its turn, manages the network. It eliminates duplicate packets and manages security. Above all, it knows where packets should go, or in other words, which node belongs to which **application (server)**. Application servers are devices which interpret the data send by the end nodes. End nodes are always made for an application, and their data typically ends up at one server, the server that was made for that application.

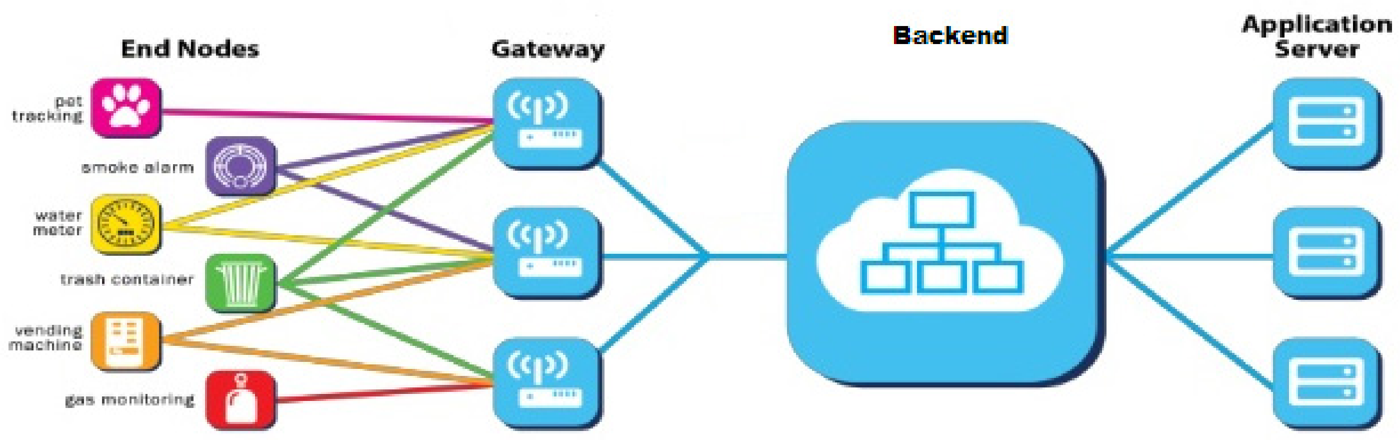

Figure 6 - LoRaWAN layout. Source: LoRa Alliance, retrieved from: https://www.lora-alliance.org/technology

10 Appendix B

Interview questions – TTN – Local community members

Basisvragen:

- Naam
- Leeftijd
- Opleiding
- Werk

- Community
- Persoonlijke ervaring – op het eerste moment
  - **Kan je iets vertellen over hoe en wanneer je bij TTN terecht bent gekomen?**
    - Hoe heb je er van gehoord?
      - Van wie?
  - **Waarom ben je actief geworden in deze community?**
  - **Wat sprak je aan?**
    - Wat voor mogelijkheden zag je?
      - Technologisch, Sociaal, maatschappelijk
  - **Had je al een idee wat je wou gaan doen?**
- Persoonlijke ervaring – nu
  - **Je bent nu dus al <tijd> betrokken bij TTN, is in de tussentijd je beeld van TTN veranderd?**
    - De mogelijkheden die je toen zag, zijn die er nog?
    - Ben je aan de slag gegaan met de ideeën die je toen had?
- Beeld van de lokale community
  - Hoeveel mensen zijn betrokken bij <naam lokale community>?
    - Zijn het voornamelijk mannen, of zijn er ook vrouwen?
    - Heb je een beeld van de leeftijd van de betrokken mensen?
    - En van hun achtergrond? (Technologisch/business/iets anders?)
    - Hoeveel mensen zijn er actief in de community?
    - Zijn er leiders in de communitie? (initiatiefnemers, kartrekkers)
  - **Als community komen jullie ook wel eens samen. Kan je daar iets meer over vertellen?**
    - Hoe vaak komen jullie samen?
    - Wat zijn dan zoal onderwerpen van deze bijeenkomsten?
      - Technisch/sociaal/?
      - Demonstraties/workshops/?
        - Samenwerking
    - Komen jullie buiten de "officiële" bijeenkomsten ook wel eens bij elkaar?
      - Wat doen jullie dan zoal?
- Network : community
  - **Jullie community is voornamelijk actief in <regio>.**
  - **Zijn jullie als community bezig een dekkend netwerk te creeëren in deze omgeving?**
    - Stel je voor dat je in een bepaalde wijk geen dekking hebt, wat is jullie strategie om wel dekking te krijgen?
    - Hoe doen jullie dat?
  - **Hoe goed is de dekking nu?**
  - **Hoeveel gateways zijn er?**
  - **Van wij zijn deze gateways?**
    - Wie doet het onderhoud aan de gateways?
  - **Hoe snel gaat het uitrollen van het netwerk?**
- Network
  - **Heb je zelf een (of meerdere) gateways?**

- Waar is deze geplaatst?
- **Wat voor gateway is het?**
    - Zelfgebouwd, kant en klaar?
- **Waarom heb je deze gateway aangeschaft?**
    - Zelf experimenteren
    - Voor de community
    - iet anders...

- Personal Projects/applications
    - **Ben je zelf ook bezig met een project binnen TTN? Wat voor soort project?**
        - Zo ja, waar ben je mee bezig?
    - **Je zei aan het begin van het interview dat je .. achtergrond hebt, (hoe) gebruik je deze kennis in jouw project?**
    - **Werk je er alleen aan, of werken anderen er nog aan mee?**
        - Heb je deze mensen gevraagd om mee te helpen?
            - Waarom?
        - Welke skills brengen ze mensen mee?
    - **Als het een toepassing is:**
        - Heb je (een) specifieke doelgroep(-en) in gedachten bij je toepassing(-en)?
        - Waarom deze doelgroep(-en)?
        - (Hoe) betrekken jullie deze doelgroep(-en)?
    - **Wordt jij zelf ook wel eens gevraagd door iemand om mee te helpen?**
        - Door wie/voor wat?
    - **(Hoe) deel jij je eigen kennis/ervaringen met TTN?**
- Community projects/applications
    - **Zijn er projecten die met de community gedragen/ontwikkeld worden?**
        - Zo ja, wat voor projecten?
        - Wie werken eraan mee?
            - Ook mensen van buiten de local community?
        - Welke skills brengen deze mensen mee?
        - Hebben jullie zelf alle kennis in huis?
        - Is er één iemand, of zijn er meerdere mensen, die de kar trekken?
    - **Zijn jullie ook bezig met het maken/bedenken van toepassingen?**
    - **Hebben jullie daar als community een strategie in? Zoja, wat voor strategie?**
    - **Hebben jullie (een) specifieke doelgroep(-en) in gedachten bij jullie toepassing(-en)?**
    - **Waarom deze doelgroep(-en)?**
    - **(Hoe) betrekken jullie deze doelgroep(-en)?**

- TTN Stichting & Ideologie
    - **Aan het "roer" van TTN staat de stichting van TTN. Op hun website is op diverse plekken (forum, labs) informatie te vinden, maak je daar wel eens gebruik van?**
        - Deel je daar zelf informatie?
    - **Op de website van TTN staat een kort filmpje waarin ze het doel van TTN als volgt uitleggen: "Imagine an Internet of Things data network. That is created by the people and free and open to use."**
    - **Zijn deze elementen (gratis, crowd sourced, open source, globaal) belangrijk voor jou? Waarom wel (of niet)?**
    - **Denk je dat het netwerk van TTN, met deze elementen, de wereld beter maakt?**
        - Vind je dat belangijk?
    - **Zijn er volgens jou nog andere belangrijke elementen?**
    - **Wienke zelf onderschrijft dat de manier waarop TTN is opgezet, ruimte bied voor innovatie, voornamelijk omdat het een open, gratis toegankelijk netwerk is. Wat is jouw mening hierover?**
        - Naast TTN is KPN ook bezig met een LoRa netwerk. Zie je deze ontwikkeling als een bedreiging, of kunnen ze goed naast elkaar bestaan?
    - **Op dit moment is al het werk voor TTN vrijwilligerswerk, denk je dat dit zo kan blijven? Waarom?**
- TTN & Toekomst
    - **Hoe zou je willen dat TTN eruit gaat zien? Spelen de eerder genoemde elementen een belangrijke rol? (gratis, crowd sourced, open source, globaal).**
    - **Hoe realistisch is dit toekomstbeeld?**
    - **Denk je dat TTN zo hard blijft groeien als het nu doet, of verwacht je dat er ook mensen af zullen haken?**

Dit waren mijn vragen. Ik weet niet of je nog aanvullingen hebt?

Interview questions – TTN global team –community manager

- *Persoonlijke ervaring*
  - **Kan je iets vertellen over hoe en wanneer je bij TTN terecht bent gekomen?**
    - Hoe heb je er van gehoord?
      - Van wie?
  - **Waarom ben je actief geworden in deze community?**
  - **Wat sprak je aan?** *(ideologie)*
    - Wat voor mogelijkheden zag je?
      - Technologisch, Sociaal, maatschappelijk
  - **Wat zijn je belangrijkste motieven om dit te blijven doen?**
    - Vernieuwend, ideologisch, ..?
- *Global team*
  - **Wat weet je van de ontwikkeling van het global team?**
    - Hoe is dit team tot stand gekomen?
      - (Eerste team dat netwerk A'dam heeft gebouwd?)
    - Waar komen deze mensen vandaan?
    - Hoe zijn ze betrokken?
    - Waarom zijn ze betrokken? *(ideologie)*
    - Hoe verloopt de aansturing van dit team? *(Ideologie)*
  - **Werkt iedereen fulltime aan TTN?**
  - **Vrijwilligerwerk**
  - **Paar vragen over Wienke:**
    - **Wat is de rol van Winke binnen TTN?**
    -
- *Local communities*
  - **Jij bent community manager, kan je iets vertellen over je werk?**
    - Forum/Slack/lokale communities
      - (Hoe) houd je je als community manager ook bezig met ..?
  - **Hoe komen lokale communities tot stand?**
    - Nemen jullie initiatief, komen ze naar jullie?
      - Rol van (social) media?
  - **Hoe is het contact met lokale communities?**
    - Faciliterend, sturend, informerend?
  - **Wat vinden lokale communities belangrijk?** (*ideologie)*
- *Technologie (Kickstarter)*
  - **Naast communities is ook technologie een belangrijke factor in jullie community. Kan je een voorbeeld geven van iets wat goed gelopen is, en iets wat spanning geeft/heeft gegeven?**
    - Kickstarter vertraging, initiatieven lokale communities
  - **Kickstarter backers, wie zijn dat?**
    - Private (Bedrijf, NGO), Public (overheid), civiel (geld/communitie)
  - **Ik hoor weinig over toepassingen die werken op het TTN netwerk. Houden jullie je bezig met deze toepassingen?**
    - Hoe/waarom wel/niet?

- *TTN & Toekomst*
  - **Hoe zou je willen dat TTN eruit gaat zien?**
  - **Delen de andere leden van het global team deze visie?**
  - **(Wat zijn voorwaardes om tot de realisatie van dit toekomstbeeld te komen?)**