RUGGEDISED
Designing smart, resilient cities for all

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Contents

Introduction

This report describes both the roll out of LoRa for the radio environment as the activities to develop use cases within RUGGEDISED. LoRa is a new “Low Power Long Range” (M2M) network that will cover the need of the RUGGEDISED project in the Heart of South area.

Executive summary

KPN is the Dutch incumbent with its own fiber and copper networks in the fixed domain and 2G/3G/4G networks in the mobile domain. LoRa will act individually and alongside the other mobile networks and is especially suited for Internet of Things (IoT) and Smart City solutions.

KPN is Dutch market leader on both mobile and fixed connections within the business market and consumer market.

KPN provides millions of clients with different products and services and takes in an enabling position in the Internet of Things and Smart City marketplaces. With its focus on collaborating with ecosystem parties (from start-ups to corporates) and matching demand and offer in the market, from niche players and specific unique customer demands to general solutions and maturing market opportunities, KPN has a dominant local presence in all customer segments in The Netherlands and therefore is the Dutch go-to party that boosts the Internet of Things and Smart City marketplace in The Netherlands.

The team from KPN promised in RUGGEDISED the introduction of a LoRa operated network which makes transport of data far more efficient and easy.

This LoRa network has been made ready and is optimized by the KPN team for the RUGGEDISED project. It makes all kinds of sensor techniques possible in the Heart of South area e.g. the calculation of the optimal routes for (waste) collection services within the City of Rotterdam, the remote switching of street and other lighting or for remote opening and closing doors.

The roll out of the LoRa network makes further innovations possible. Both the city of Rotterdam as well as private (consortium-) parties can and will use the LoRa network for new applications. All at low costs, because the used technique ensures that therefore Wifi or nowadays still expensive 4G is not required and needed.

Use of LoRa within the RUGGEDISED project

While LoRa could have been used for solution R11 (smart lighting) & R13 (smart waste management) it turned out not to be the desired connection type for both cases.

R11 Smart Lighting

While smart lighting has a connection to the power grid the need for low power connectivity is not a priority. The specific use of telemanagement dictates the size of data streams. The data stream required in the telemanagement solution selected by Rotterdam surpasses the tresholds of LoRa WAN.

Street light fixtures are being connected, also in the City of Rotterdam. Some suppliers use LoRa WAN, others use 2G, NBIoT or 4G. The logic to connect street light fixtures is there. Being able to communicate with light fixtures in order to dim or simply to check systems has proven to be valuable to city managers. Fact is that what seems logical in theory may not be in real life. The delivery of street lighting services is a fragmented one. From the producer of the light pole, the fixture, the management system to the contractor, they all have their own interests and so does the street light manager of the municipality. KPN is eager to connect Rotterdam light fixtures however, KPN is depending on the requirements laid down by the city procurement and the company winning the bid to supply. KPN has not been able to convince the authorized civil servants to request LoRa WAN connectivity and therefore it has not been used in the Heart of South.

R13 Smart Waste Management

During the procurement process of Smart Waste systems by Rotterdam, the city overlooked the possibility of stating that the use of the LoRa-network is mandatory for the smart waste system. The chosen software provider uses 4G instead, which was unforeseen by the responsible department for waste management. If a city chooses to use a particular network such as LoRa, it should be a requirement in the procurement phase.

LoRa network for new applications

Although the network is ready to receive the input of sensors and diverse data from other smart solutions, there are no use cases or solutions using LoRa as connectivity so far. Smart Waste and Smart Street Lighting were originally planned to be equipped with LoRa connectivity. But this will not happen due to the final terms of the public tender of these solutions.

What may seem odd is that at this moment certain departments within the municipality are in fact working on pilots with LoRa WAN. These pilots concern ground water level measurements and rodent traps. Unfortunately it has proven to be difficult to match projects within the city organization with the RUGGEDISED objectives.

KPN has organized workshops with civil servants of the city of Rotterdam to determine possible other use cases that benefit from LoRa WAN connectivity. These workshops have also been attended by employees of partner organizations such as Ahoy, Heijmans, Eneco and RET. The meetings have led to possible utilization of LoRa WAN.

Outcome workshop | Vote on preferred IoT pilot

Which solution is best match with objectives Ruggedised? Stakeholders selection

Proposal	Match Ruggedised	LoRa Value	Prio (1,2,3)	Rtdm	RET	Ahoy	Heijmans	KPN
Air quality	++	++					3	1
Noise measurement	++	++		1				2
Public lighting	++	+		2		2	2	
Parking capacity	++	+					1	3
Last Mile	++	?			1	1		
Construction trace	+	+						

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Unfortunately, due to different interests, each idea was received with objections from one or another party. Some were afraid what measurements of city services or even air pollution would lead to too much discussion in the public arena.

Comments stakeholders on proposals

Due to different stakes no consensus was reached on any of the proposed LoRa solutions

Rotterdam
"My preference is to present sustainability in the area. We have to think about a basic infrastructure that we build and then feed on information from measurements."

Ahoy
"Parking capacity has already been included in the signage infrastructure in the area."

Rotterdam
"For Ruggedised it is practical that noise measurements are taken at Ahoy and agreements are made with Ahoy on how to deal with this.."

Ahoy
"As said, I dread communication about noise and emissions."

Ahoy
"Last mile communication has value for Ahoy, as well as solution with public lighting."

Rotterdam
"However, I want to avoid getting into trouble with the measurements. So if, for example, the area gets busier and the air quality deteriorates, we then have to solve this difficult problem as a team."

RET
"... the essence must be to entice visitors into alternatives to 'parking in front' by providing transparent and up-to-date information."

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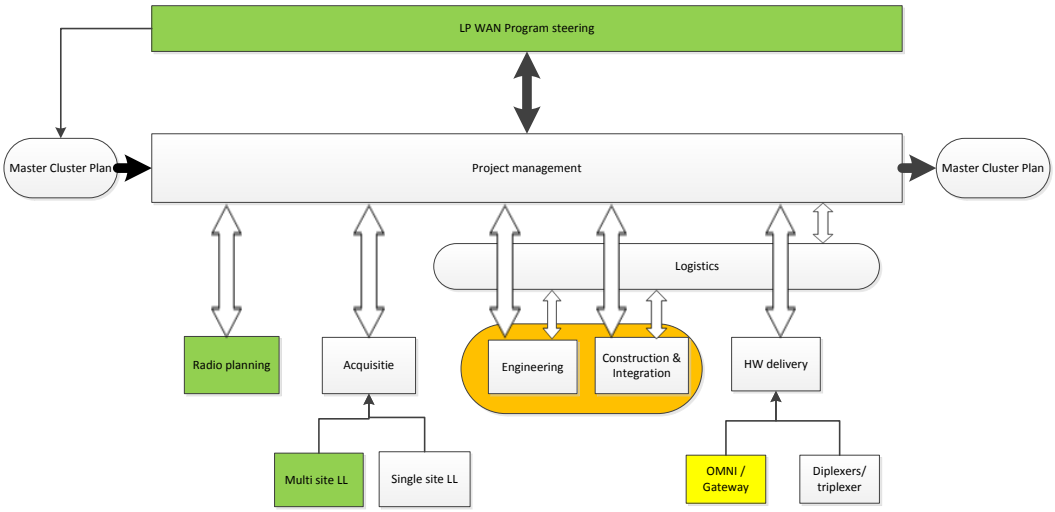
Organization of the LoRa network implementation project

For the RUGGEDISED project we set up an organisation to implement a LoRa network. In this project we directly set up a blueprint for future roll out of LoRa nation wide. In the picture below the set up of the organisation is presented.



Design – Brief service description

Before we start the description of the design process an principles let us have a (Brief) Service Description.

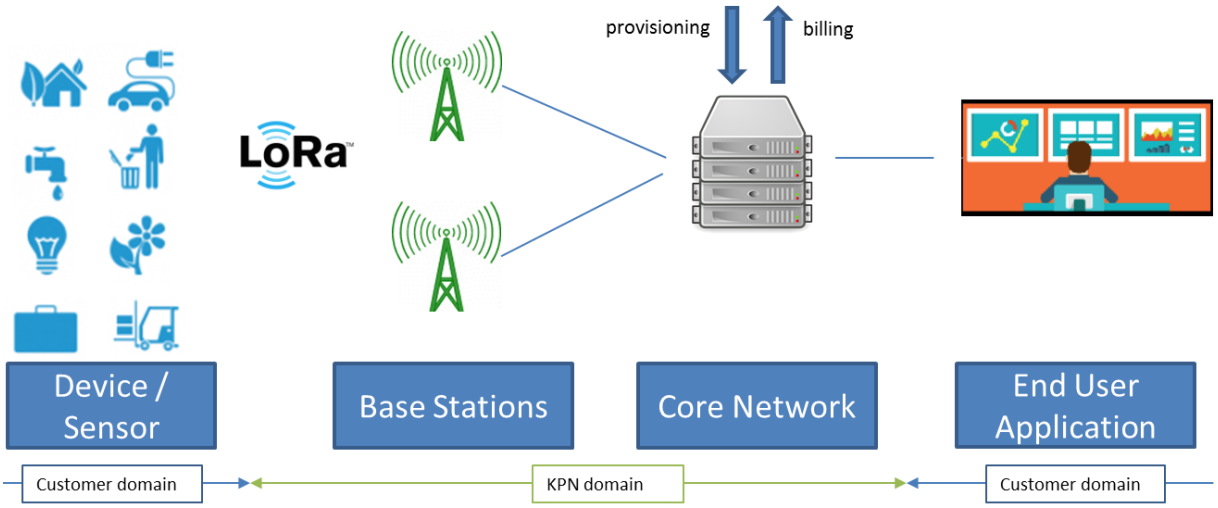
LoRa ia a **Low Power Wide Area Network (LPWAN),** a telecommunications network specially designed for the Internet of Things (IoT), machine-to-machine market.

This network allows connected objects to remotely communicate and be remotely controlled through applications. Its best suited to support services and use cases which need long range communication and depend on a low power consumption (battery operating sensors / devices). This network operates at a relatively slow speed (range from 0.3 kbps to 50 kbps).

Our LPWAN solution is based on the LoRa-Wan specs. LoRa is a proprietary radio protocol developed by Semtech using license free spectrum (868 Mhz) .

With LoRa, every customer has a number of end-devices (complying to the LoRa WAN standard) that are communicating with an application server at the customer premises.

The network operator, KPN, offers the business customer a secure access service enriched with a number of value added services (e.g. localization)



An end-device, e.g. a temperature sensor, wakes-up to transmit its measurement. The LoRaWAN radio frame will be received by all nearby base stations. The device then immediately goes to sleep for a specified amount of time, by default 1 second, in order to preserve the battery.

After the exact sleep time, the End-device wakes up to receive a potential downlink communication from the network. The downlink communication may be an ACK from the network if the End-device had sent a confirmed LoRaWAN frame, or it may be a command.

After this brief description let us look at the designs of the LoRa network and transmission. The designs were described by the team at high level in the first place to get more detailed afterwards.

Network design

In the project the team started with the set up of the different designs. The team discussed the requirements and agreed on a few important design principles regarding the network design:

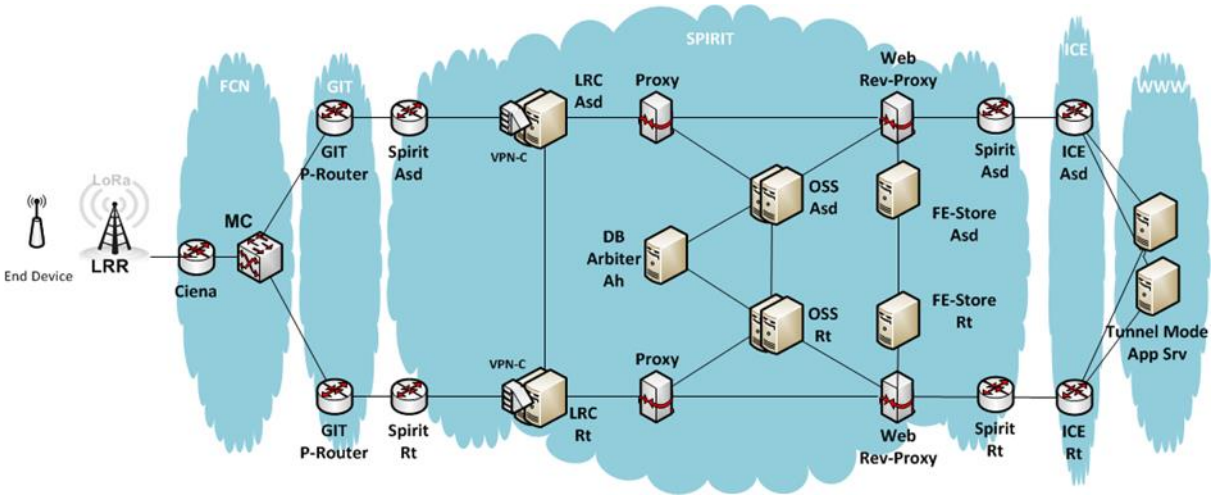
Required:

- It is required that 3 sites cover the user equipment. This is needed for location determination. The coverage has to be comparable with the GSM coverage. This is taken in account in the radio plan.

Design principles:

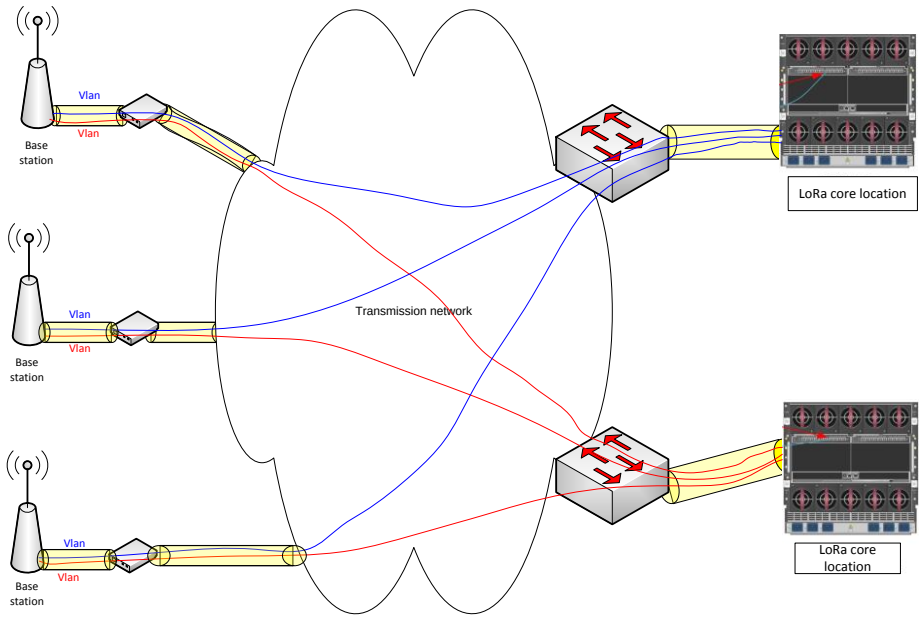
- It has been agreed to install the Gateway near the antenna as much as possible.
- After 3 installations the experiences will be evaluated if this construction in the tower is the best one.
- The team decided on the the principle that an OMNI antenna is combined with a Gateway and POE at site. *In some cases later on during national roll out the LTE antenna's will be used. Then the LoRa signal must be separated from the GSM/GSM and LTE signal.*
- Every installation, omni or reuse LTE antenna, must be protected for lightning
- Every site will have a Gateway which will be connected to the Core environment.
- Back up is covered via 4G

The core environment design became a virtualized environment. The picture below gives an overview:



Transmission design

One of the design principals was that every site will have a Gateway which will be connected to the LoRa core environment - transmission. In several sessions the network path is discussed based on this principal. The picture below gives an overview of the transmission in radio.



Gateway roadmap and used versions

The team needed gateways and started a selection proces.

A gateway by the way is a transparent bridge relaying messages between end-devices and a central network server in the backend. Gateways are connected to the network server via standard IP connections while end-devices use single-hop wireless communication to one or many gateways

For chosing the right gateways we as a team discussed the roadmaps of versions to be used. For the sites omni-directional antennas were chosen (initially that was IoT Station v0 shown in the picture below).

Later on we more and more discovered the missing of localization services. The gateway needs GPS reception for this and for that reason the IoT Station v0 were replaced later on by the team for the IoT Stations v3 which do support localization.

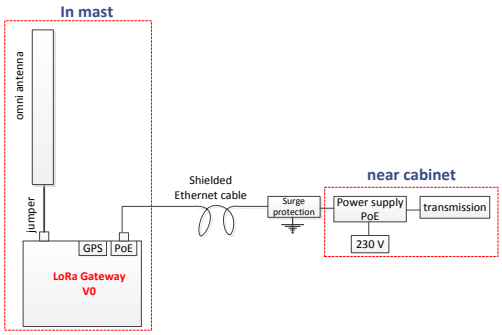
Figure 3 : LoRa IoT Station casing - external view

In the picture the principle at site is shown.

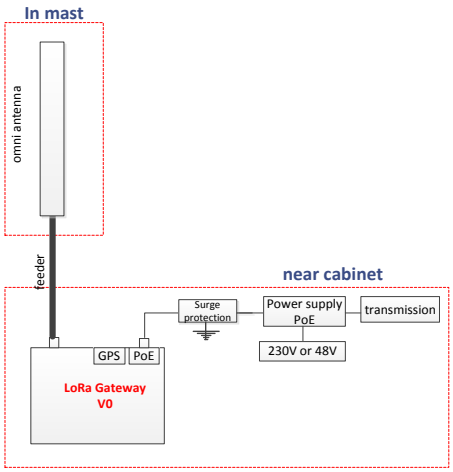
No 5 is the OMNI antenna
No 1 is the Gateway

Figure 4 : POE injector (example)

No7 is the POE this unit combines power and transmission and will be connected with the Gateway via RJ45 cabling.



Gateway near the Mast



Gateway near the cabinet.

Tooling used and registration

As mentioned before we as a team directly set up a blueprint for future roll out of loRa nation wide. The choise of tooling is important for providing seamless services to users and so this became a stream in our project as well. In this chapter we give an overview of the tooling that was chosen by the team to perform this project.

Asset
In Asset a radio layer was made for LoRa. This tool is needed to visualize the functionalities of LoRa.

LoRa Master Planning
In this tool the radio planners stored the radio information like antenna, height etc. This tool also created a planning sheet so the progress can be monitored, the delivery of the transmission etc. From this tool information was transferred to the Master Cluster Planning MCP.

Mobile Access Registration Temporary Tool
This tool was a temporary tool because the definite tooling cold not be adapted in time for LoRa roll out. This tool made it possible to order the transmission. The information registration of LoRa and also the relevant inventory information was stored in the tool

Netcool
In Netcool the alarms are presented that were generated.

Network Management Portal - NMP
The NMP is managing the Radio and the Core environment.

ECM4Sites
In this tool all relevant information needed for building, integrating and acceptance of sites is stored like the Functional Design and measurements (when needed).

LoRaMote
LoRaMote is the test tool that was used after activation of the Gateway. With this tool the Lora site was basicly tested.

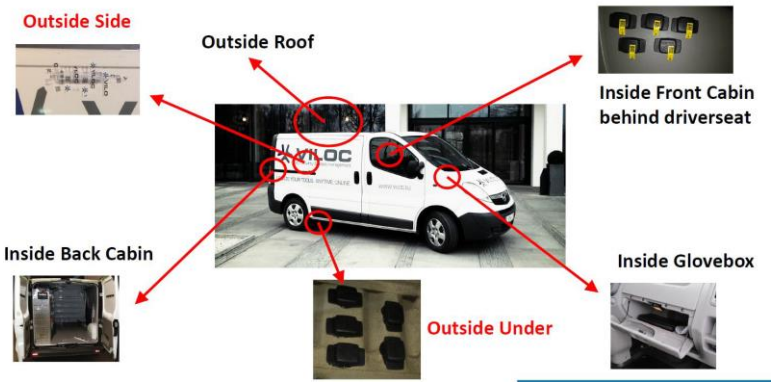
LoRaMote

LoRaMote: Coverage Testing Device

- The LoRaMote is a special device that allows testing the LoRa Network Coverage.
- The LoRaMote has a LoRa Modem inside to send LoRa messages/frames to the LoRa BST.
- The LoRaMote is programmed to send every 5 or 10 or 60 seconds LoRa messages automatically.
- Works on 9V battery (not rechargeable) or powered via USB cable.
- LoRaMote has multiple sensors onboard that function all the time when switched on.
- The device is not power efficient and remains ON all the time = battery drains after ~12h.

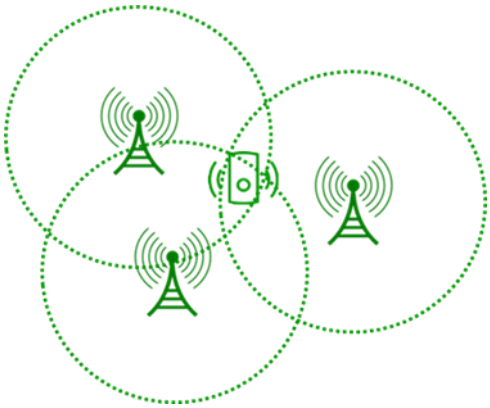
VILOC bus

As mentioned we had to optimise localization after building the LoRa network. For optimisation of the localization feature we tuned the network using the VILOC bus stuffed with sensors. We drove arround measured and tuned and tweaked unill localization was acceptable.



Selection of the LoRa sites

The localization technique is based on triangulation which means that the uplink signal of the device must be received by at least three gateways. We as a team selected the locations for our gateways by using the coverage requirements that were relevant. The definition of the right locations was an action by the radio planning.



We found

- Veerlaan 30-54 Rotterdam
- Pascalweg 41 Rotterdam
- Anthony Fokkerweg 40 Rotterdam

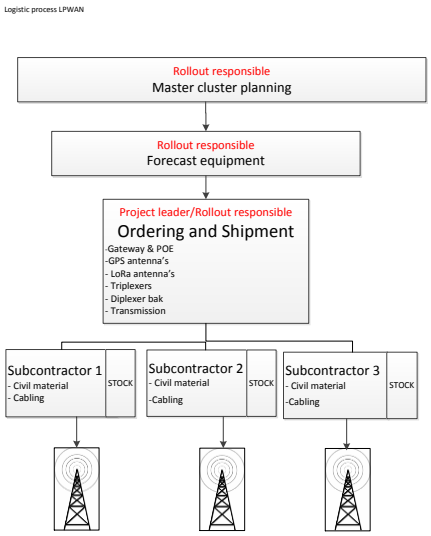
Veerlaan 30-54 Rotterdam

Pascalweg 41 Rotterdam

Anthony Fokkerweg 40 Rotterdam

Rollout of the LoRa sites

After the designs were made, tools defined and the locations selected we started defining the roll out plan. We set up a logistic process as the basis for the order delivery to the subcontractors and the integrator.



Transmission ordering LoRa

The transmission design was described and the LoRa service was executed in the beginning of the rollout. In the roll out we ordered the designed transmission path.

Technical site survey - TSS

We started the fysical roll out with a TSS on the selected gateway locations. During this visit of the site the following items were being checked by the team:

- Configuration
- What the current situation at site is
- What equipment is needed (cabling, Antenna materials etc.)
- Construction impact
- Power supply
- Cables
- Proposal for site configuration (standard choices)
- What will be the approach to adapt the site for LoRa
- Crane location when relevant.
- Take in account the other OLO's (Telco operators on the same site), it could be that courtesy must be requested.
- Check on manco's that will remain after LoRa activities

After the TSS it was possible to continue and make:

- The checklist filled in with all relevant items for the Functional Design
- Photo document
- Drawings
- A list of hardware need to be ordered.

- Calculation of the Attenuation and the delay when an OMNI is used also the height of the LoR antenna and the feeder length must be collected. This can be calculated with the information below:

    - The drawings and result of TSS were checked by Radio planning. When agreed this information must led to execution in the next step is “create the order”.
    - When the result of the TSS is different than expected the site radio design must be changed. This is only valid for Radio planning issues. The team mitigated on this issue and let the radio planner join the TSS.

Note
During the LoRa activities contractual issues and requests for changes occured. The team together with acquisition party solved these issues. It however can also be the case that technical or civil issues arise at site. This can be in relation with the landlord or due to construction difficulties.

Acquisition and Functional Design

During the process in which the TSS was developed as described. We were able to execute the acquisition of the selected sites with the landlords. When the acquisition is agreed also the Functional Design could be finalised needed to start the next phase -creating the orders.

Create the orders

When the Functional Design was accepted the information was stored and the orders generated. After this moment it became possible to create a site plan with the additional installation.

Logistic process

For building the site many materials are needed. The materials are coming from different suppliers and this all have to be deliverd in time to execute the civil work. During the TSS an inventory was already made of the needed hardware.

Building / Integration activities

Before the activities at site could start by our installation partners the outage procedure must be executed. This is procedure where the engineering calls with the NOC to announce the planned work. The locking of the site, if needed, will be done by Network Operation Center - NOC.

When the actual activity start on a specific site the LoRa implementation the engineer on site contacts the NOC again.

Now the outage procedure is executed the work at site can start.

End results of building

_Location Veerlaan 30-54 Rotterdam

Location Pascalweg 41 Rotterdam


Location Anthony Fokkerweg 40 Rotterdam

Status update KPN by the integrator

After the successful integration of a site it is important to exchange data about the integrated site. The team received all relevant information of the sites/ network from the integrator which was a subcontractor as well.

Request for acceptance

When the base station was integrated, tested and the exchange of information has taken place the acceptance procedure was started.

There are several scenarios that must be accepted:

- The Lora installation with OMNI
- The Lora installation on existing antennas so called sectorized
- A Lora installation with impact on the current antenna installation.

Communications during roll out

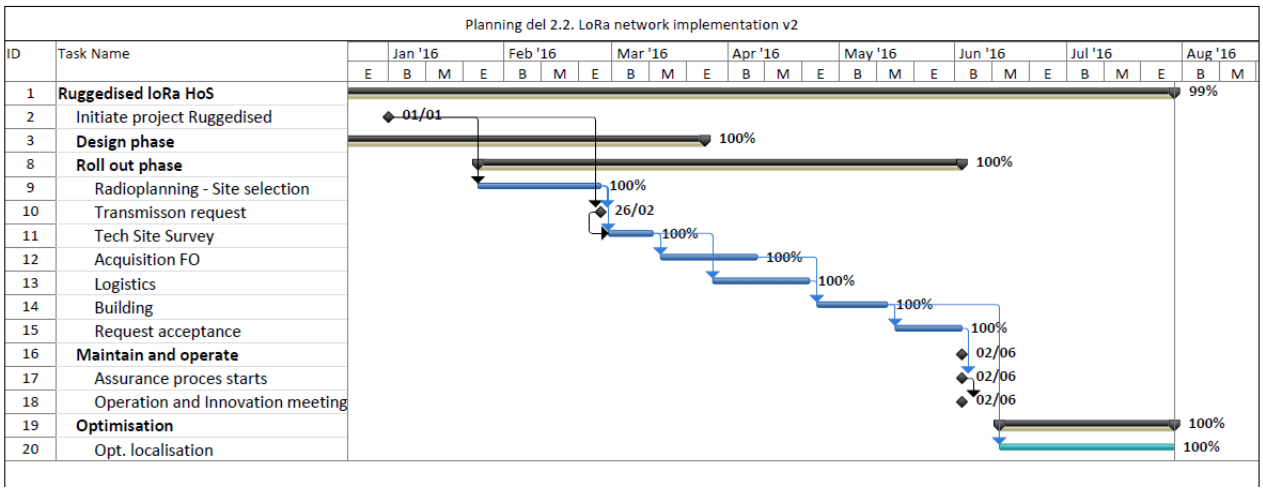
To assure the roll out, the roll out per location was discussed in weekly held meetings where the progress of the clusters are discussed with:

- Eventual changes.
- The readiness of the clusters (building / integration)
- HW availability/ transmission delivered
- **Go/ NoGo**. When the detailed locationcluster had a go. The team started the ordering process and bulk import

After the successful integration of a site it is important to exchange data about the integrated site. The team received all relevant information of the sites/ network from the integrator which was a subcontractor as well.

Timelines

It was important to report the progress to our stakeholders since this implementation was new to our organisation as well. The planning on headlines was:



Assurance processes an roles

After implementation assurance and maintenance started. These processes were described as mentioned in a parallel stream but needed ot be ready to perform seamless services aftre implementing. They were implemented and executed in the different departments.

Roles in the assurance processes

- **KPN SQC NOC** became responsible for the alarms & customer complaints. They analyse operation problems as they occur.

- **FM processes** is a problem solving party. The are available to solve problems in the LoRa network. Part of this FM process is the support ticketing system, made available by our partner.

- **Network management** is executed in different departments depending on their role in the chain of delivery.

- **Element management Fieldforce** It will happen that the Gateway, antenna, cable or transmission will get out of order. In this case a field engineer have to go to site to repair. A centralized location from where the regional stocks will be supplied was set up and the swap & repair process (RMA).

- **SW Upgrades and Testing** There will be SW upgrades that have to be made (radio/ core part), tested and rolled out in the network. The SW upgrades will repair bugs and add new capabilities. This is organized in KPN and Actility.

  For all SW upgrades a rollback principle has to be available.

- **Capacity management** The following KPI's are being measured per gateway and per frequency, preferably busy hour values:
  - downlink channel usage
  - uplink channel usage
  - uplink channel interference

  For each of the KPIs thresholds were determined in the project.

Processes out of scope for the project but essential to have to deliver seamless services

- **Be alert process** If a big disturbance occurs it is important to start the Be alert process. This is a standard KPN process we use.
- **Biling proces**

Recommendations

Operation and Innovation meetings

Innovation never stops. The best recommendation we have is to organise Operation and Innovation meetings from the start. The LoRa network is a cooperation between different parties, therefore it is important to organize meetings to stay aligned. Also the Innovation progress must be exchanged between parties. Directly start Operation and Innovation meetings where the following topics are discussed:

- Innovation announcements
- Roadmap of software improvements
- Rollout of software upgrades
- Functional Maintenance handling (ticket process)
- Share maintenance issues
- Report of Quality (when available)
- Cooperation between parties
- Make and maintain the ServiceLevelAgreement

Technical recommendations

Concerning the use of LoRa within the RUGGEDISED project,

While LoRa could have been used for solution R11 (smart lighting) & R13 (smart waste management) it turned out to be not the desirable connection type for both solutions.

R11 Smart Lighting in specific. While smart lighting has a connection to the power grid, it doesn't need to save on power usage by sending data. Besides the amount of data send by the smart lighting used in R11 is exceeding the capacity LoRa can offer.

Concerning the network itself

Gateway installation

Install the Gateway near the antenna as much as possible. Meaning construction in the tower is the best one.
After 3 installations the experiences was evaluated:

Pro's

- *More capacity*
- *Better coverage in case 2dBi (and 5dBi) omni-antennas are used*
- *4G access better covered*
- *Less construction work during the swap from v0 to v3 (no feeder construction to add or remove.*

Cons

- *There is a risk for maintenance (restarting is however possible by removing the power over ethernet cable. And becomes an issue when placed in a gateway position which is out of reach of maintenance teams.*

Secure and reliable

The team looked at Sigfox (a long-standing IoT network, in the Netherlands, for example via Tele2 represented) as well. Since data traffic runs through the Sigfox data centers in France and moreover it will then be decrypted there. The data in the chosen solution is handled via KPN's own data centers and network. In this way KPN has full control over data privacy. The choice for LoRa as an IoT network was made fairly quick based on that.

The team also had a discussion about ABP versus OTAA. In some cases you might need to hardcode the DevAddr as well as the security keys in the device. This means activating a device by personalization (ABP). This strategy might seem simpler, because you skip the join procedure, but it has some downsides related to security. KPN choose to use Over-the-Air Activation (OTAA) which is supported by the LoRa Alliance and is the preferred and most secure way to connect with the back end of the KPN Network.

Commercial recommendations

Support for innovation projects

LoRa is complementary - KPN's Low Power Long Range (LoRa) network service is based on a relatively new LPWAN protocol for IoT and supplements existing 3G and 4G networks. LoRa should not become a substitute for the existing Machine to Machine (M2M) technology, which works with a SIM card. M2M works through it regular mobile network and for more data-intensive applications, such as a smart car or a smart meter for regular use passing on electricity consumption from households. M2M needs more energy but still are a good alternative if these objects generate electricity or electricity is available.

KPN has not been able to convince the authorized civil servants to request LoRa WAN connectivity and therefore it has not been used in the Heart of South. Authorized civil servants within the municipality should support innovation projects like RUGGEDISED.

Time to market

The LoRa network uses existing mobile sites (mobile masts) and the network on which it works. That helpes with a quick 'time-to-market.

Frequency

In addition to the time to market. The frequency spectrum was still fairly clean, so that a network could be set up on this frequency fairly quick.

As far as the LoRa frequency is concerned - license-free (868 MHz), the question can be asked whether this does not start to become full after a period of time and therefore interference. Alternative research is a necessity if realization of the chosen ferquencies at large-scale use of the LoRa networks could cause problems such as interference in the near future.

Organisational recommendations

Concerning the use of LoRa within the RUGGEDISED project,

As said LoRa could have been used for solution R11 (smart lighting) & R13 (smart waste management) it turned out to be not the desirable connection type for both solutions.

Specific on R11 Smart Lighting - Street light fixtures are being connected, also in the City of Rotterdam. Being able to communicate with light fixtures in order to dim or simply to check systems has proven to be valuable to city managers. Fact is that what seems logical in theory may not be in real life. The delivery of street lighting services is a fragmented one. From the producer of the light pole, the fixture, the management system to the contractor, they all have their own interests and so does the street light manager of the municipality. KPN is eager to connect Rotterdam light fixtures however, KPN is depending on the requirements laid down by the city procurement and the company winning the bid to supply.

Specific on R13 Smart Waste Management - During the procurement process of Smart Waste systems by Rotterdam, the city overlooked the possibility of stating that the use of the LoRa-network is mandatory for the smart waste system. The chosen software provider uses 4G instead of LoRa, which was not foreseen by the department responsible for the smart waste containers. Which network to exploit should be mentioned in the procurement phase.

LoRa network for new applications

The LoRa network is ready to receive the input of sensors and diverse data from other smart solutions, still there are no use cases or solutions using LoRa as connectivity so far. Smart Waste and Smart Street Lighting were originally planned to be equipped with LoRa connectivity. But this will not happen due to the final terms of the public tender of these solutions.

What may seem odd is that certain departments within the municipality are in fact working on pilots with LoRa WAN. These pilots concern ground water level measurements and rodent traps. Unfortunately it has proven to be difficult to match projects within the city organization with the RUGGEDISED objectives.

KPN has even organized workshops with civil servants of the city of Rotterdam to determine possible other use cases that benefit from LoRa WAN connectivity. These workshops have also been attended by employees of partner organizations such as Ahoy, Heijmans, Eneco and RET. The meetings have led to possible utilization of LoRa WAN. Unfortunately each idea was received with many objections. Some were afraid what measurements of city services or even air pollution would lead to in the public opinion, be disruptive within constraints.

Concerning the network itself

Landlord

When the Technical Site Survey is executed sometimes landlord issues can appear. Of course also later in time this is possible. How to deal with the landlord issues technical and contractual.

It can be the case that technical issues arise at site. This can be in relation with the landlord or due to construction difficulties. Sometimes the issues will solve between parties by itself but in some occasions it could be required a change request for the technical solution must be made.

During the LoRa activities also contractual issues or requests for changes can occur. The acquisition party must get involved to solve these issues as much as possible.

Fail fast

Go for the Minimal Viable Product and fail fast. Don't be distracted and focus on priorities to improve your network after first rollout. In our case we as a team started small as well and improved our network afterwards. We for instance improved on localization afterwards after LoRa coverage was delivered.

When you connect to existing unused interfaces on legacy systems they might become part of your projectscope. Since these interfaces become part of your solution the must be PENtested as well. In some situations they even must be upgraded to become secure. You will have to find budget and time.

Customer Engagement

Our conclusion is that a IoT network provider needs to have the items mentioned below to have a good engagement with a customer fullfilling there usecase:

- An accesible multipurpose network must evolute with the usecases. Accuracy was essential to fullfil the first usecases in tracking and tracing. GEOlocation decribed in this report needed optimisation.
- As a connectivity provider you don't have the specific domain expertise, but having just an accesible multipurpose network is simply not enough to get upto speed. You must have usecases.
- While engaging with a client you should not build POC's and POC's only. Please search for the real problem to solve in the usecase, search for the snakebite". Search for usecases that make a difference in the business you want to be in. In this way you'll get the attention you deserve.
- In the proces to get engaged and work out a usecase/ develop a solution there are different roles to fill in. There are role for data providers the parties who ingest sensordata into your LoRa network, but there are also roles for information producers to make information out of sensordata and application builders to really have an effect and fullfill a usecase. Get resources who can fill in these rolls onboard.

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