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mySMART Life

Deliverable due date: 30.11.2019 – Month 36

D3.9 Parking Space Detection

WP3, Task 3.7

Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Project Acronym	mySMARTLife		
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**		
Project Duration	1st December 2016 – 30th November 2021 (60 Months)		
Deliverable	D3.9 Parking Space Detection		
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Due date	30/11/2019		
Work Package	WP3		
Lead beneficiary	Free and Hanseatic City of Hamburg, HAM		
Contributing beneficiaries	SNH		
Task description	TASK 3.7.6: Non-technical actions to foster sustainable mobility. A system for parking space detection for e-car charging stations will be designed and implemented by SNH (LTP of HAM) to prevent parking of non-e-cars on parking spots at charging stations.		
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Abbreviations and Acronyms

Acronym	Description
AC	Alternating Current
APP	Application
CCS	Combined Charging System
DC	Direct Current
EMP	Electromobility Provider
EV	Electric vehicle
FHH	Free and Hanseatic City of Hamburg
LoRaWAN	Long Range Wide Area Network
PSD	Parking space detection
RFID	Radio Frequency Identification
SMS	Short Message Service
SNH	Stromnetz Hamburg GmbH

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1. Executive Summary

In order to maintain and strengthen its leading role in the automotive and supplier industry as well as in research, Germany has set the goal to become the leading supplier and home to the lead market for electric vehicles (EV) (NPE, 2014). Electromobility is the driving force behind sustainable, climate-friendly transport. Therefore, it can be assumed that the market for electromobility will grow rapidly in the upcoming years. Despite all efforts however, the market ramp-up of EVs did not progress as planned, but is now on the verge of a breakthrough.

A frequently presented challenge in the field of electromobility is the lack of sufficient publicly accessible charging stations for EVs. Often, parking spaces at charging stations are blocked by other drivers, precluding arriving EVs from charging. Possible reasons for this are the low acceptance of electric mobility in general, limited visibility of charging locations and ignorance of regulations and laws concerning electric mobility. In order to solve this problem, the number of incorrectly occupied parking spaces at charging stations must be reduced. Within the framework of the project mySMARTLife, differentmeasures to increase the usability of electric charging stations are evaluated and a focus is laid on the development of a technical concept for the detection of the availability of charging points. In this context, it is not the intention of the Stromnetz Hamburg GmbH (SNH) to take over the role of the police, to control illegal parking cars at charging points. Instead, SNH wants to contribute to strengthening the confidence of EV drivers in the efficiency of the charging infrastructure and to systematically combat the so-called "fear of range" which unfortunately still exists. Charging point search traffic will be actively reduced and often even completely prevented.

The Stromnetz Hamburg GmbH (SNH) has faced the problem of misallocation of charging points at the charging points in Hamburg by using ground sensors. The developed system in mySMARTLife will soon be able to reliably locate available parking spaces at the 1,000 publicly accessible charging points in Hamburg in real time and provide users with this information online via an app. For this, LoRaWAN (Long Range Wide Area Network) technology will be used in Hamburg to monitor the parking sensors.

Due to the high range and very good building permeability, other applications can also be addressed. One example is a cross-divisional, remote reading of meter values without the need for additional on-site work.

In addition, a full-coverage LoRaWAN wireless network is to be developed in cooperation with other municipal companies. A Germany-wide cooperation has been established in order to promote joint technological development to unlock the technology's idle potential. By implementing LoRaWAN transmission, additional sensors can be easily integrated into the network. As a result, further synergy effects can be systematically leveraged. Exactly these potentials point the way of Hamburg as an innovative "Lighthouse City" in Europe and clearly show the possibilities of an innovative "Urban Transformation Strategy".

2. Introduction

2.1 Purpose and target group

This deliverable describes the strategic approach and the technical concept of implementing a parking space detection at the public charging stations for electric vehicles in the Free and Hanseatic City of Hamburg.

For this purpose, the development of the public charging infrastructure will be described in detail in the context of the "Master plan for the improvement of the publicly accessible charging infrastructure for electric vehicles in Hamburg". This will create a deeper understanding of the challenge of misoccupancy wrongful occupancy at the public charging points in Hamburg (Chapter 3).

Afterwards, the presented work points out the systematic implementation of the steps required regarding the design of a parking space detection in detail (Chapter 4).

In addition, the potential of using the LoRaWAN (Long Range Wide Area Network) transmission standard is explained and the reason for choosing this technology is explained.

2.2 Contributions of partners

The following table shows the main contributions from participating partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
SNH	Chapter 1-7
HAM	Chapter 2.2, 2.3, 3.3 and overall coordination

2.3 Relation to other activities in the project

This deliverable is allocated in Task 3.7 “Sustainable Mobility and Electrical Mobility” and describes a result of subtask 3.7.6 “Non-technical Actions to foster sustainable Mobility”, in particular the results of the project action 35: “Parking space detection at charging points”.

This deliverable provides an overview of a technical concept of a system for parking space detection in front of public charging stations in the City of Hamburg and provides an outlook on future developments.

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Table 2: Relation to other activities in the project

Deliverable Number	Contributions
D3.8	“New Mobility Services” – This deliverable provides an Overview about the development about charging Infrastructure in Hamburg and Charging solutions for special use cases.

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3. Public Charging Structure in Hamburg

3.1 Background and Motivation

As the owner and operator of the electricity distribution network and the associated cables, switching and transformer plants in Hamburg, ensuring electricity supply for the city of Hamburg is the mission of SNH. Every year, around 13 KWh of electricity flows through Hamburg's electricity network, supplying around 1.3 million households.

SNH is responsible for planning, building, operating and expanding the distribution network for electricity with cables, switching and transformer plants. Its tasks include grid connection, processing grid use and providing and reading metres. It also includes grid development, fault management and the maintenance and expansion of the Hamburg electricity distribution grid, including the infrastructure for electromobility.

But, a switch to electromobility requires user acceptance. When assessing electric mobility in comparison to conventional vehicles, the criticisms include too little range, charging takes too long and insufficient charging infrastructure. In addition, the existing charging stations are often occupied by parking offenders and access is thus blocked.

The development of a nationwide charging network is mainly driven by politics. In addition to the expansion of the charging infrastructure, the usability of the existing charging stations must also be increased. Despite the evident increase in technological maturity on the part of both, the vehicles and the charging infrastructure, there is still a fundamental scepticism and subjective "fear of range" among the ev-drivers. This can only be countered effectively with a systematic and methodologically based approach to the implementation of a coherent network of charging infrastructure (as in Hamburg). Once this step has been taken, confidence must be created in a functioning utilisation conceptand and the parking space detection is an indispensable component here. In many places the signage is not yet uniform and the charging area is not clearly recognisable. Due to a shortage of parking space, the space is often left empty despite the obvious charging station. The usability of the charging infrastructure is limited by such parking abuse, which occurs regularly in practice.

For this reason, the mySMARTLife project is focused on measures to ensure that a charging station can actually be used and not be prevented from doing so, due to a non-electric vehicle parking in the space. The focus is on spatial access to the charging station, i.e. the prevention of impairments such as incorrect parking by setting up a parking space detection system.

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3.2 Establishing and Expanding the Public Charging Infrastructure

Hamburg has been expanding the public charging structure for several years. Both in terms of the number of battery-powered electric vehicles and the density of the charging infrastructure in public areas, Hamburg is among the pioneers in Germany.

On 26 August 2014, the Hamburg Senate approved the “Master Plan on the Further Development of the Publicly Accessible Charging Infrastructure for Electric Vehicles in Hamburg” (FHH, 2013), on the basis of which the establishment and expansion of charging stations in the Hamburg municipal area has been implemented in recent years, and is still continuing. The Master Plan provides for a needs-based expansion of the charging infrastructure on the basis of the expected number of vehicles in Hamburg. In the run-up phase in line with the Master Plan, as a partner to the City of Hamburg, SNH plays a central role in the coordination and implementation of the installation and operation of the charging infrastructure.

Targets will be set for a needs-based expansion of the charging infrastructure. By early 2020, the number of charging points is to be expanded to 1,000 (around 500 stations) publicly accessible charging points.

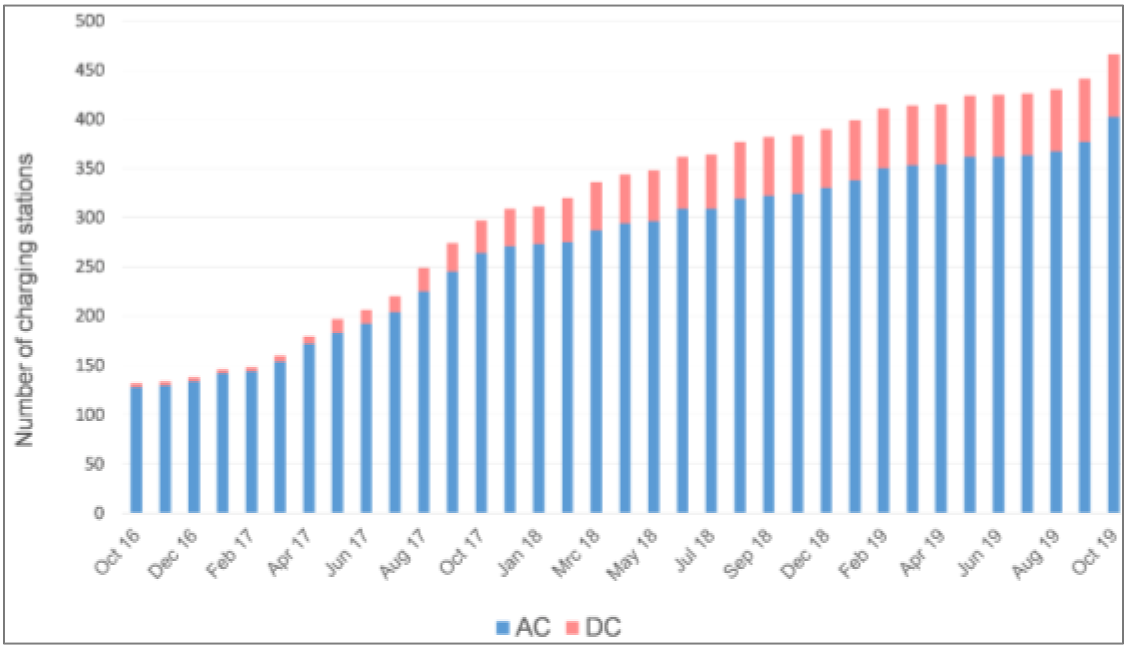

Figure 1: Number and expansion of public charging stations (Source: SNH’s own representation)

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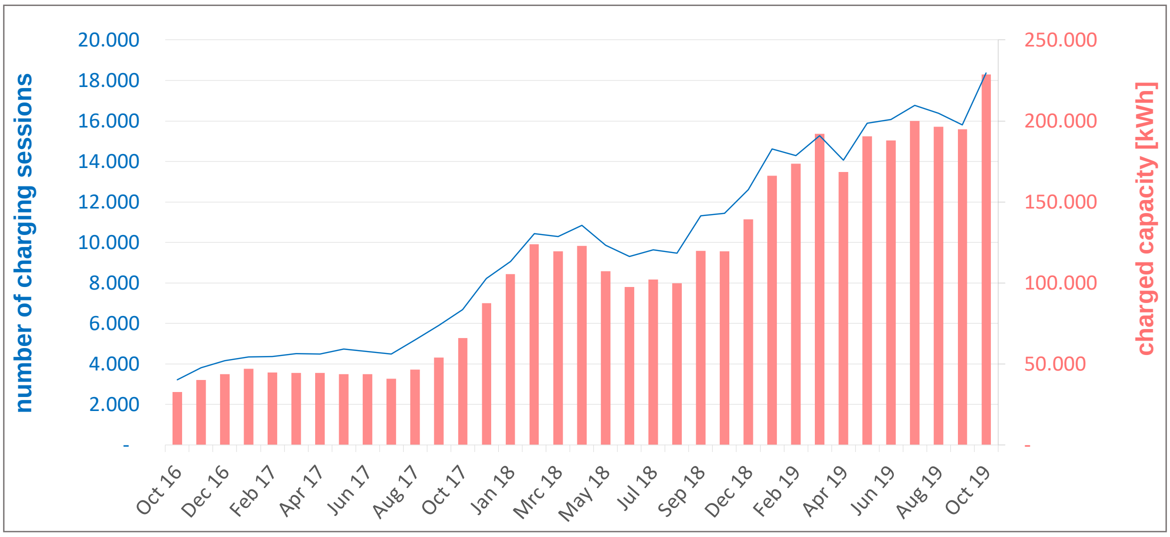

Figure 2: Utilisation of public charging infrastructure (Source: SNH's own representation)

3.3 Legal Basis

The e-mobile parking spaces in the city of Hamburg are marked by special signs (see Figure 3). A license plate for electric vehicles is required to use an e-mobile parking space. This license plate can be obtained from the registration authority. In addition, the maximum parking time must be observed during operation and a parking disc must be stored in the vehicle (LBV, 2018)

Figure 3: Typical signs at e-mobil parking space (Source: LBV, 2018)

The parking time is generally limited to two hours for AC charging stations and one hour for DC fast charging stations. This limitation applies during the specified operating time (9 am to 8 pm on working days) to allow a large number of vehicles to use the charging station. During this time it is allowed to park there for two hours with a parking disc. Outside of the operating time, parking for electric vehicles is permitted for an unlimited period. Vehicles with combustion engines may not use a special parking space for electric vehicles at any time. If someone parks the vehicle nevertheless, they must expect the vehicle to be towed away. In addition, a warning or fine will be levied (LBV, 2018).

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Finally, it should be mentioned that the Hamburg infrastructure of course also meets the requirements of the national charging station regulation (BMWI, 2016).

3.4 Technical Basis

The charging stations installed must fulfil certain criteria, which are laid down in the Master Plan (Hamburg, 2014). AC charging stations are each equipped with two charging points at which both type 2 and Schuko plugs can be charged, so that smaller electric vehicles and pedelecs can also charge there. Charging stations are mainly equipped with three-phase with AC, so vehicles can be charged up to 22kW charging capacity. AC charging systems with a maximum charging capacity of 11kW can only be fitted and used in semi-public spaces, e.g. in multi-storey car parks or on park-and-ride areas.

The connection to the IT backend and the desire for the shortest possible charging times and high energy transmission represent further technical challenges for the charging stations. In addition, public access leads to specific safety requirements. The technical structure of the charging stations referring to Hamburgs Master Plan is explained below and the differences between the different charging station types are shown. The minimum technical requirements for charging stations are defined in EU Directive 2014/94/EU, which stipulates certain connectors as standard (EU 2014), e.g. for reasons of interoperability. Other requirements that apply only in Hamburg, such as accessibility and design requirements, are defined and laid down in the official Master Plan.

The criteria specified by the city, which are met by the charging infrastructure: Users gain access to the charging stations via an RFID card, which is used for identification purposes. As a component for non-discriminatory access, an additional direct-pay option is available at the charging stations. This allows customers at all SNH master plan charging stations to pay either by SMS or app, even without having signed a contract with an electric mobility provider (EMP) beforehand. All charging stations are supplied with certified green electricity, i.e. electricity from renewable sources, in accordance with the specifications of the City of Hamburg. DC charging stations are also each equipped with two charging points. The so-called Multi-Chargers or 3-in-1 system solutions offer a DC charging point at which either a CCS or CHAdeMO plug can be charged and an AC charging point for charging with a Type 2 plug (three-phase). Current electric vehicles have to charge for about 30 minutes to reach up to 80% of their battery capacity (HMWEVW, 2017). The aim is to be able to charge quickly throughout Hamburg in the future, i.e. to provide charging capacities of more than 20 kW with DC and AC charging stations.

The publicly accessible charging stations have a uniform FHH design (red/grey) including an urban electric mobility icon. This increases the recognisability and awareness of the charging stations and the compatibility with the city corporate image is maintained. Information about the charging stations

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(location, equipment, occupancy of the charging points) can be found on the SNH and the City of Hamburg websites (SNH, 2019) as well as via the "E-Charging Hamburg" app.

3.5 Parking abuse at public charging stations

Three influencing factors come into play with parking abuse: the area around the charging station, the compatibility of the connection options, and illegal parking in the spaces.

Visual measures have been developed to prevent illegal parking in the spaces at charging stations. These measures must be implemented at short notice and uniformly within the Hamburg charging infrastructure or are already being implemented. A review of the use of charging infrastructure with and without marking on ground has shown that the ground marking has a positive effect on the number of charging operations. In the city centre in particular, marking on the ground has a big effect. In the outer areas of the city, this effect is significantly lower or in some cases not discernible. In order to prevent unauthorised vehicles from parking illegally at the public charging infrastructure as far as possible, the recommendation should not only include clear signs at charging stations, but also markings on the ground at the charging stations.

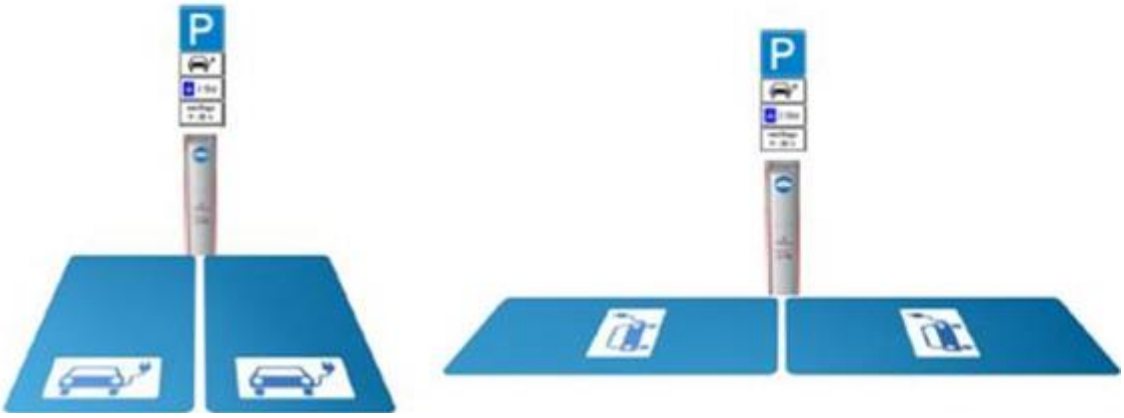

Figure 4: Ground marking and signage concept in Hamburg (Source: SNH's own representation)

In principle, a clear parking space is a prerequisite for spatial access to a charging station. Analyses have shown that at certain times more than half of the parking spaces at charging stations are blocked illegally. In addition, it was found that especially in areas with severe pressure on parking, additional ground marking leads to higher usage figures.

In the mySMARTLife project, a decentralised parking space detection system was developed to optimise infrastructure use and parking space monitoring. This system can be integrated into the existing charging infrastructure both in terms of hardware and software and provides the user with a reliable indication of the availability of the charging infrastructure.

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So far, only the charging connector lock has been interpreted (not plugged in/ plugged in). This meant that occupancy by non-charging electric vehicles or misuse by combustion vehicles could not be reliably detected. Finally, it should be noted that the following three measures must be carried out to prevent incorrect occupancy of the charging stations.

Figure 5: Measures to reduce the number of parking abuse at public charging points in Hamburg (Source: SNH's own representation)

The signs and floor markings are already rolled out everywhere in the city. The design of the ground sensors and the associated sensor technology will be examined in more detail in the following section.

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4. Technical concept for parking space detection

4.1 Framework and task

To date, the charging stations in Hamburg have not been widely equipped with sensors for parking space monitoring. Within the framework of the project, however, all conceptual preparations, determinations and interpretations were carried out in order to realise a comprehensive roll-out of the detection technology, as well as validation tests. The status of the individual charging points can be displayed in apps and on websites, so that users can see which charging stations they can currently use. If a charging point is displayed as free at the current state, this means that no electric vehicle is currently connected to the charging point. If a user drives to the supposedly free charging point, it is still possible that a vehicle is parked in the sparking space and has not connected to a free charging point. This can be prevented by the ground sensors. By means of ground sensors, the occupancy of the parking space can be recorded in addition to the occupancy of the charging point. For this purpose, ground sensors are attached to charging stations at both parking spaces. The IT backend can therefore be used to specify more precisely whether a charging point is currently usable or occupied. It is foreseen that this information is also transmitted to operators of apps, websites and navigation service providers. This allows a user to see more precisely which charging point he can use. Parking times can also be recorded. Exceeding of maximum parking durations can thus be determined directly.

The technical implementation of the measure requires a technical concept and a pilot test. The connection of ground sensors to the SNH IT backend need to be tested. There are no legal obstacles to the implementation of the measure. It is only necessary to apply for and set up stopping restrictions for the work.

This action provides for the occupancy of parking spaces at charging stations to be recorded. This will provide users with a much clearer indication of which charging points they can use, but will not directly address the problem of parking abuse. It becomes apparent if a parking space is occupied for too long, exceeding the maximum parking period, but not if the parking space is occupied by an electric vehicle or another vehicle. If a charging point is free and the corresponding parking space is occupied, one can only assume that a combustion vehicle is standing in the parking space without permission. But, it could also be an electric vehicle that is just using the parking space, but not the charging station. Nevertheless, the impact of the measure is assessed as high due to the visibility of the occupancy for users.

However, as even after this measure, unauthorised vehicles will continue to be parked at the charging points, albeit to a lesser extent, the user of the charging points should be informed about

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whether a site is occupied or not. A system that will be rolled out is a floor sensor with LoRaWAN connection. At present, charging point assignments are only detected by their use. With the floor sensor, an AND/OR query in the APP charging station can be used to indicate whether a charging station is actually occupied or not.

In order to find the suitable parking space monitoring system, five planning and implementation steps were carried out. The objective is the technical design and specification of a technology for the sensory recording of the occupancy and for the recording, processing and utilisation of the data. In the course of the implementation of this project it became apparent which potentials lie in a wireless network to be created. Therefore, chapter 5 is dedicated to the possibilities that could be opened up for Hamburg through these mySMARTLife activities.

The following planning and implementation steps will be explained below:

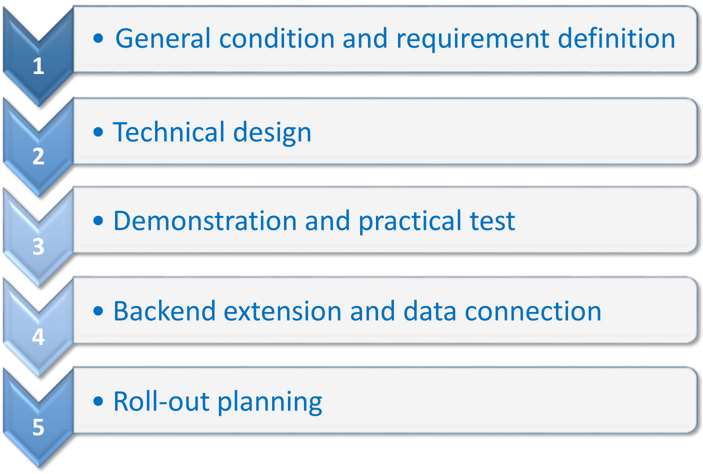

Figure 6: Planning and implementation steps in the SNH sub-project (Source: SNH's own representation)

4.2 General condition and requirement definition (step 1)

First of all, it is important to consider the general technological framework. In the analysis, sensor/detection technologies for the detection and identification of parking space occupancy statuses as a possible component of the existing system, the solution will be limited to single spaces. Since the charging stations are isolated and decentralised, there is no need to consider multiple detection. This may become relevant in the future if charging parks are to be set up and detected. The consideration of the system solutions refers not only to the detection of parking space occupancy, but also to data transmission (see section 4.5) and communication (see section 4.3) with the existing SNH backend. The following overview shows the various applications:

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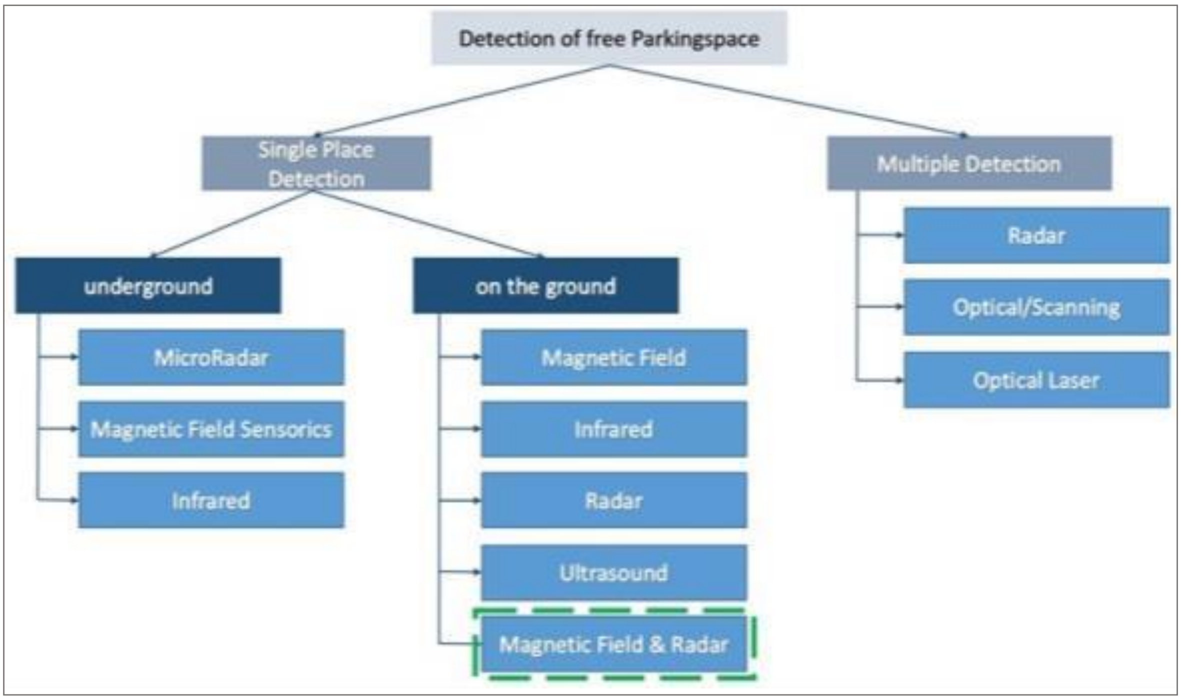

Figure 7: Overview of the relevant technological options in the field of parking space detection (Source: SNH's own representation)

Technologies for multiple detection, for example of freely accessible parking spaces at the side of the road ("on street") or closed parking areas off the road ("off street"), are not included in the product identification, as this is not part of the charging infrastructure application.

In the case of single site detection, detection from underground/side or from above (above ground) is possible by installing a sensor above the sites. In general, civil engineering intervention in the parking areas is necessary for detection from below, which must be minimised during product identification. A "top-down detection" requires a separate and raised fixing point, which runs counter to the requirement of a one-piece charging infrastructure - as installed in Hamburg. For this reason, this detection technology is also not taken into account in the further consideration.

The task was, therefore, to find a detection technology that would detect individual parking spaces above ground. The following basic techniques are evaluated.

Radar technology

In radar technology, radar detectors generate an electromagnetic signal. This signal is bundled and emitted by an antenna. When vehicles pass the radiation, the radar radiation is reflected and received again by the antenna. Due to the reflected radar radiation there is a frequency change. While Doppler radars can only detect flowing traffic, radars can also detect stationary vehicles. In contrast to optical sensors, radar technology works in a weather-independent frequency spectrum.

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Magnetic field sensors

With magnetic field sensors, the relative change in the earth's magnetic field is monitored. The latter is changed by the movement or presence of metal parts (e.g. vehicle). These changes in the earth's magnetic field, which are expressed by changes in the magnetic flux density, are registered by the detectors. Earth magnetic field detectors can be both wired and wireless systems. They can be placed in the ground or used for detection from above or from the side (e.g. by attaching them to the charging point or kerb stone). Magnetic field sensors are very sensitive to interference from neighbouring car parks. They can also be disturbed by surrounding metal parts such as reinforced concrete (Park&Ride car park application).

Infrared technology

In passive infrared technology, the sensors react to changes in the thermal radiation of the object being measured, i.e. the charging location. The vehicles are detected on the basis of their thermal radiation. Infrared sensors are less sensitive to fog than optical image detection, but more susceptible to heavy rain and snow.

Magnetic field and radar

This is a technology that represents a combination of magnetic field and radar. So both sensors (see above) are installed. If a vehicle drives onto the parking space to be detected, the magnetic field sensor detects this change in condition in a battery-saving manner. Subsequently, the radar sensors are "woken up" and an active measurement takes place by means of radar technology.

Appraisal

A systematic recording and evaluation of the technological requirements for a parking space detection sensor system was carried out. The table below shows this requirement evaluation.

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	Radar	Magnetic field	Infrared	Magnetic field and radar
No false alarms on free spaces by vehicles on neighbouring spaces	✓	✗	✓	✓
Robust RF performance	✓	✗	✗	✓
Ignores overlapping and double occupancy	✓	✗	✓	✓
Unaffected by dirt, dust or oil on the sensor	✓	✓	✗	✓
Immune to electromagnetic interference	✓	✗	✓	✓
Consistent performance in all lighting situations	✓	✓	✗	✓
Correct reporting results, even during permanent occupancy	✓	✗	✓	✓
No disruptive influences from slow-moving queues of vehicles in the vicinity	✓	✗	✓	✓
Battery performance	✗	✓	✗	✓

Figure 8: Selected performance indicators of parking sensors (Source: SNH's own representation)

On the basis of the fundamental assessment carried out, a specific product must be sought, which combines magnetic field and radar technology.

4.3 Technical design (step 2)

First of all, it is important to identify the relevant partial pieces of the transmission and processing chain in order to make the technical design and decisions for the relevant components. Six components have been identified:

- **Sensor**: First of all, LoRaWAN ground sensors are installed at every charging point for the purposes of detecting vehicles parking. This is to inform the customer/user whether a parking space really is free or not. Although it does not completely prevent illegally parked vehicles from continuing to occupy the parking spaces at the charging points, it can avoid unnecessary journeys in advance (see above).
- **Gateway**: The changes in status are therefore detected by the sensor and transmitted to the gateway, which is installed in the charging station.
- **Element**: Transmission of the measured value to the element in the SNH data centre via a gateway, which is installed inside the charging points.
- **PSD application**: Preparation of the measured values and transfer to the external car park application. Further assignment of the measured value to the corresponding charging points
- **E-mobility backend**: Passing on all information to the SNH E-Mobility Backend.

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- **User interface:** After the last evaluation by the backend, the information is to be made available to end customers and users of the public charging infrastructure in Hamburg via an e-Charging App. It is also planned to make the data available to other market partners.

The table below illustrates the six elements of the processing chain.

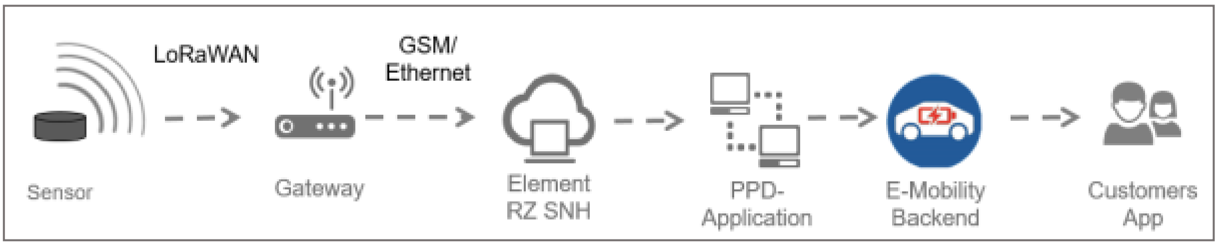

Figure 9: Transmission and processing chain of parking space detection in Hamburg (Source: SNH's own representation)

On the basis of including all relevant departments and in the context of future challenges, the LoRaWAN transmission standard was decided upon. This standard is a "Low-Power-Wireless" network protocol, whose specifications are laid down by the (LoRa Alliance LoRa Alliance®, 2019). The protocol is freely available and uses a patented process for data transmission. LoRaWAN is thus a non-proprietary and standardised system. LoRaWAN uses the standard AES 128 bit encryption. AES 128 bit is a symmetric encryption, wherein the key space has a size of 2^128. According to today's standards of encryption, this is considered to be safe. In addition, LoRaWAN offers a high level of protection against various forms of hacker attacks, such as side- Channel Attacks, Package Forgery or Replay Attack (Schulz, 2019).

Considering the background of the processing chain explained and the application of e-mobility, as well as the decision for LoRaWAN technology, the focus was put on the following requirements when selecting ground sensors (see Table **3**):

Table 3: Selected performance indicators of parking sensors (Source: SNH's own representation)

No	Category	Performance indicators
1	Battery performance	Long service life, economic efficiency
2	Data communication	Standardised data transmission, Open Source protocol
3	Security	AES 128 bit encryption
4	Assembly (one-piece/multi-piece)	Mechanical connection to the substrate, multi-part system for easy maintenance
5	Degree of maturity	Series maturity
6	Dependence of network operators	Own network possible, no proprietary system
7	Company/references	Comparable reference projects

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8	Case	Weather resistance
9	Operating information	Status information is transmitted

In addition to the listed performance indicators, particular attention was paid to supplier-independent compatibility of the sensors with the charging hardware. The result of the explained project steps is the agreed cooperation of SNH with Zenner IoT Solutions GmbH and Bosch Connected Devices and Solutions GmbH. Zenner IoT Solutions provides the network software "Element" which is necessary for the operation. This software is used to assign and translate the data of the ground sensor transmitted by the radio technology "LoRaWAN". The floor sensor called "Parking Lot Sensor" by Bosch is the hardware component in this system. This 15cm wide sensor is installed centrally on each parking space at the charging stations. This sensor is distinguished by its simple mounting, maintenance-free operation and the accuracy of the detection of the parking space status. KERLINK - Wirnet Station 868 was selected as the gateway technology.

The special feature of the Hamburg solution is the integration of the gateway hardware into the charging station. In this context, the SNH focuses on a **divergent and complementary technology**.

The integration of the gateways into the charging device takes place without any intervention in the existing charging system. Both certification and warranty are retained. The following key points deserve special mention:

- The gateway is an independent component that is integrated into the charging station via Plug&Play.
- There is a separate communication path from the gateway to the backend (the GSM connection of the charging station does not have to be used).
- The gateways are mounted without tools.
- Service socket in the charging infrastructure provides the necessary energy, therefore no separate laying of cables is necessary
- Both existing and new charging stations can be used. So the existing huge charging network is used for a fast and efficient detection via LoRaWan.

4.4 Demonstration and practical test (step 3)

In the course of two practical tests, the technology definition described above, which led to the use of the combined technology, was once again substantiated. The first took place in 2017 and was carried out with the installation of four ground sensors in front of a building at the Bramfeld depot of SNH.

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Further tests were also carried out on selected charging infrastructures. The AC charging pillar type was chosen, which was installed in the public space.

Figure 10: Selected ground sensors in practical test (Source: SNH'own photo)

4.5 Backend extension and data connection (step 4)

The previous availability message (and resulting graphic representation in the charging point card) is triggered by the potential-free contact of the charging plug lock at the charging point. The system can therefore detect two statuses, namely whether a vehicle is connected to the charging infrastructure (A) or not (B) (see A and B).

Ⓐ

The following "status" of the charging point can thus be displayed:

→ "not occupied" = no vehicle connected to the charging point,

→ "occupied" = vehicle connected to the charging point

In order to reliably detect occupancy by non-charging electric vehicles or misuse by combustion vehicles, an "and" link must be established with the sensor message. Therefore, the data field "Parking" was added to the frontend in addition to the "Status" as part of the extended visualisation.

Ⓑ

When the parking sensors are rolled out and provide data, the following information is displayed (currently this information is shown as "unknown"):

→ "Parking space occupied" = parking space in front of the charging point is occupied

→ "Parking space not occupied" = parking space in front of the charging point is free

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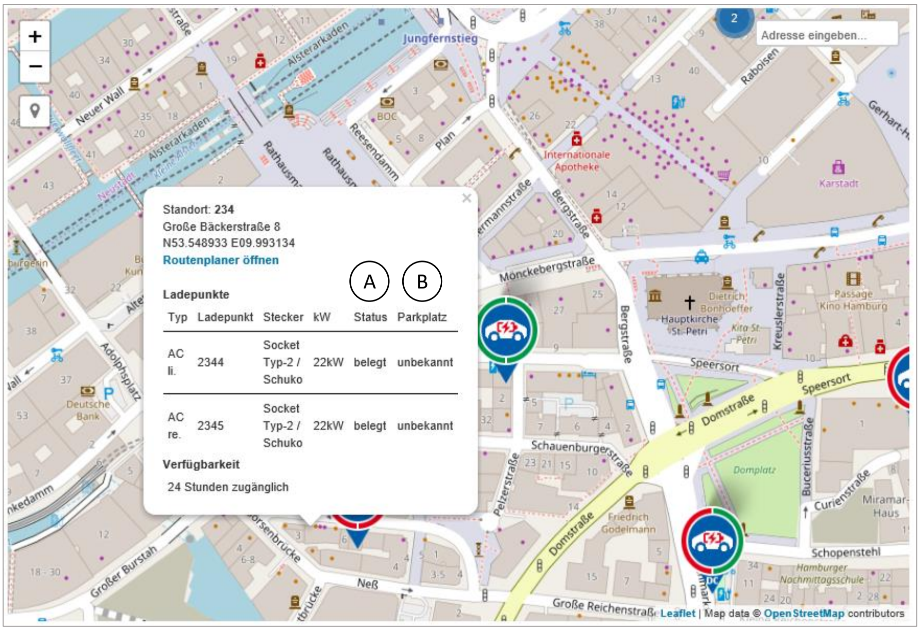

Figure 11: Screenshot of the future presentation for the user software (Source: IT-Backend Screenshot SNH)

Even if the displayed data fields are already implemented, the roll-out will lead to a further visual adjustment and thus to a significant increase in user friendliness and usability. This adjustment has already been prepared in anticipation of the forthcoming roll-out. The following figure shows this planned further development of the user front end. As this "screen" is still being agreed, it is currently available in German. An English version can then be added to the internationally available app.

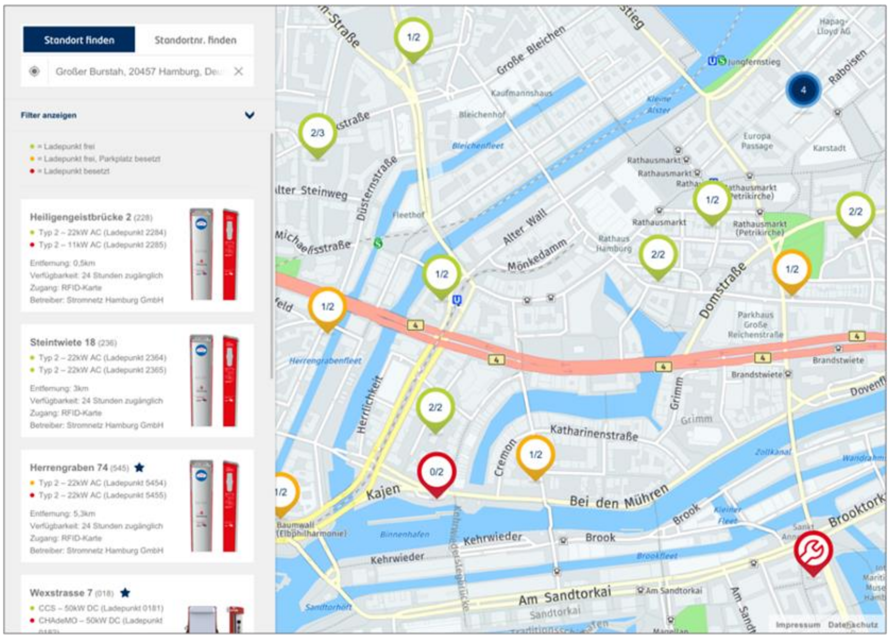

Figure 12: Screenshot of the occupancy data fields in the future e-charging software (Source: IT-Backend Screenshot SNH)

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The Technology Readiness Level (TRL) is a scale for evaluating the development status of new technologies on the basis of a systematic analysis. It indicates on a scale from 1 to 9 how advanced a technology is. This degree of maturity has developed into a standard in other areas of future technologies. The starting point for the parking space detection was a TRL of 6. If one follows this system, the result of the project can be described when the TRL 8 is reached.

4.6 Roll-out planning (step 5)

In the future, the system described above will reliably detect available parking spaces at the upcomining 1,000 publicly accessible charging points in Hamburg in real time and make this information available to users online. The system components have been selected, the installation of the sensors has been extensively tested, the processes are planned and the roll-out of the ground sensors can begin shortly after approval by the Free and Hanseatic City. The application of the gateways has already started within the framework of a pilot phase one. The following figure shows the status quo of network coverage in Hamburg without charging point gateways.

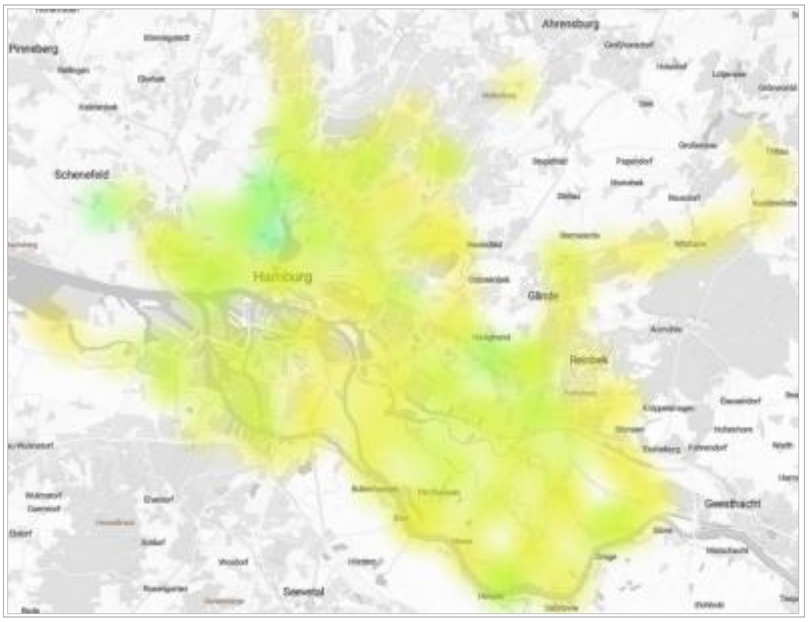

Figure 13: Status quo of gateway network coverage in Hamburg (Source: SNH's own representation)

Currently (10/2019), 244 charging stations in Hamburg are equipped with gateways for LoRaWAN connection. Due to the good network coverage in the Hamburg area, smooth communication is guaranteed.

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Figure 14: Planning of gateway network coverage by public charging points in Hamburg (Source: SNH’s own representation)

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5. Outlook/Perspective

5.1 Future innovations through LoRaWan and potential for Hamburg

As a former European Green Capital, Hamburg is particularly committed to the principle of sustainability and is continuously working to improve the social, economic and environmental conditions of the city's citizens - in line with the urban development strategy "Green, fair, growing city by the water" by 2030. (Hamburg, 2014).

While the mySMARTLife project initially focused on the detection parking spaces at the Hamburg charging stations and the associated increase in user-friendliness, the further progress of the project quickly showed that there is a very high innovative potential, particularly in the choice of transmission technology.

In the course of transformation into a smart city, data and its transmission are the most important key elements. Because smart city applications can improve the quality of life in large cities: They can, for example, record cross-divisional meter readings, measure traffic volumes and thus reduce CO2 emissions or make the disposal of waste more effective and efficient. This requires a communication and network infrastructure that is able to transmit data over long distances without interference from cables and without cellars or walls preventing interference-free transmission. The selected transmission standard LoRaWAN can offer this added value. If a network of gateways is installed across the whole area, a large number of sensors can be integrated into this network. For this reason, SNH and its partners are working together to set up an efficient wireless network covering the Hamburg metropolitan area, using the charging infrastructure for electric vehicles. The future applications seem to be limitless.

Stromnetz Hamburg relies on close cooperation with municipal partners in order to leverage synergies hand in hand. Gateways are thus not only built on SNH properties, but also decentralised by partner companies. SNH also builds on partner sites in order to expand the network. The decentrally generated sensor data will then have to be forwarded to SNH’s central platform. At this point data are evaluated and made available for applications. This cooperation was initiated by eight Hamburg companies (SNH press, 2019). These eight companies are caracterized as strategically important companies in the urban context for the LoRaWAN use case: Gasnetz Hamburg GmbH (gas network operator), Hamburg Energie GmbH (municipal energy supplier), Hamburger Hochbahn AG (public transport), Hamburger Verkehrsanlagen GmbH (hamburg traffic facilities), Hamburger Wasserwerke GmbH (hamburg water company), Landesbetrieb Schulbau Hamburg (school construction hamburg), Stadtreinigung Hamburg AöR (waste management and city cleaning), Stromnetz Hamburg GmbH (electricity grid operator).

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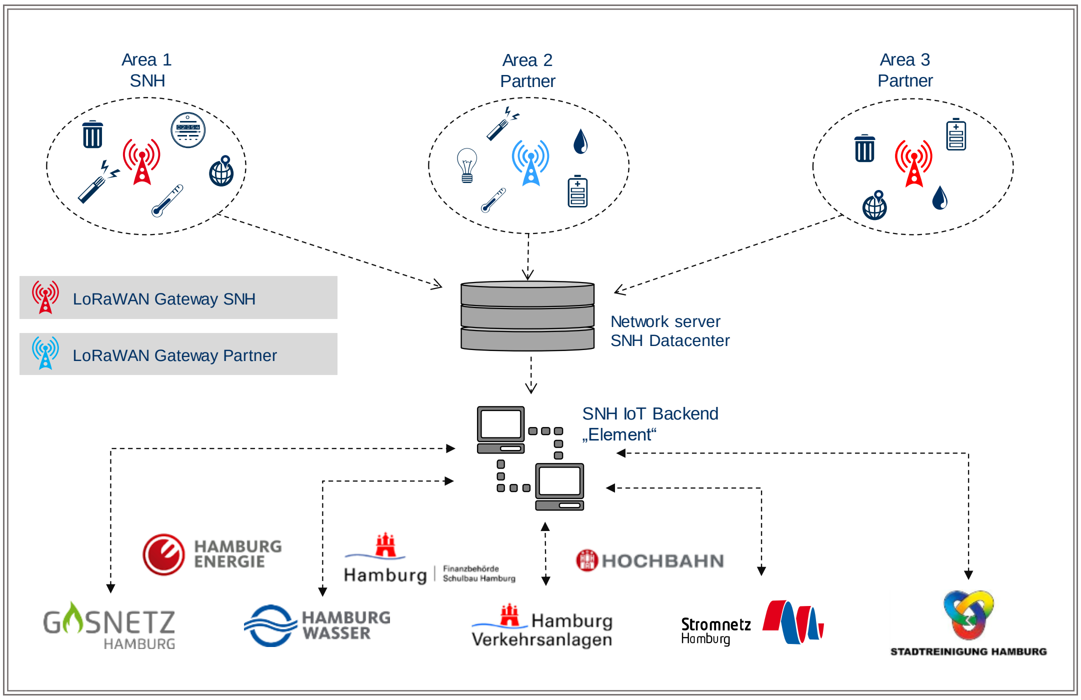
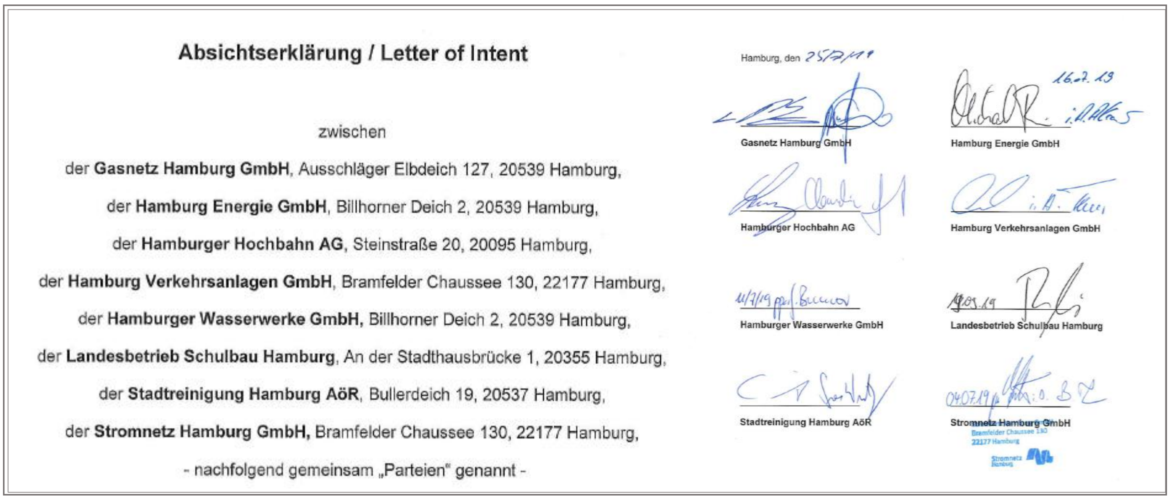


Figure 15: Hamburg cooperation approach of a LoRaWAN network (Source: Own representation)



Absichtserklärung / Letter of Intent

zwischen

der **Gasnetz Hamburg GmbH**, Ausschläger Elbdeich 127, 20539 Hamburg,

der **Hamburg Energie GmbH**, Billhorner Deich 2, 20539 Hamburg,

der **Hamburger Hochbahn AG**, Steinstraße 20, 20095 Hamburg,

der **Hamburg Verkehrsanlagen GmbH**, Bramfelder Chaussee 130, 22177 Hamburg,

der **Hamburger Wasserwerke GmbH**, Billhorner Deich 2, 20539 Hamburg,

der **Landesbetrieb Schulbau Hamburg**, An der Stadthausbrücke 1, 20355 Hamburg,

der **Stadtreinigung Hamburg AöR**, Bullerdeich 19, 20537 Hamburg,

der **Stromnetz Hamburg GmbH**, Bramfelder Chaussee 130, 22177 Hamburg,

- nachfolgend gemeinsam „Parteien" genannt -

Hamburg, den

Gasnetz Hamburg GmbH

Hamburg Energie GmbH

Hamburger Hochbahn AG

Hamburg Verkehrsanlagen GmbH

Hamburger Wasserwerke GmbH

Landesbetrieb Schulbau Hamburg

Stadtreinigung Hamburg AöR

Stromnetz Hamburg GmbH

Figure 16: Signing of a Letter of Intent for the establishment and further development of the Hamburg LoRaWAN network (Source: SNH's own representation)

5.2 Cooperation approaches and supra-regional cooperation

In addition to the regional approach described above, SNH initiated further national cooperation. Six municipal companies from Germany are cooperating to use the LoRaWAN radio communication system. The companies see great potential in this technology for developing and linking very different applications. Together with the municipal companies, a comprehensive LoRaWAN wireless network is to be created that can be used individually. The partners contribute different applications to the

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cooperation (SNH press2, 2019).

Stadtwerke Münster (engl.: Münster municipal utility) successfully completed the first operational tests for monitoring district heating shafts via LoRaWAN and developed concepts for LoRaWAN applications in urban areas for the city of Münster, e.g. for reducing traffic searching parking spaces.

Westfalen Weser Netz (engl: Westphalia Weser Grid) as a regionally active company plans to use the technology promptly to control street lighting or to provide messages for network operation in the entire region. Other municipalities in WWN's network area can also benefit from the pilot projects at a later date.

For the City of **Delbrück**, the focus is on the digital transmission of data from urban processes, such as the water and sewage works, the building yard or schools.

Paderborn ASP (engl.: City Cleaning and Parking Paderborn) intends to completely digitise parking space management in Paderborn by using sensors embedded in the ground and linking it with the existing data from the multi-storey car parks. This makes it possible to direct guide users to free parking spaces throughout the city centre.

But practical applications are also conceivable, such as the transmission of information on whether doors and windows in public buildings are closed. From the perspective of the cooperation partners, LoRaWAN technology is an important building block on the way to the development of "Smart Cities".

That is why the partners have now signed a Letter of Intent. In the Letter of Intent, the companies express their interest in jointly developing concepts for organisational and technical structures for the application of LoRaWAN. As municipal companies, the partners have regional expertise and the flexibility required for the timely expansion of the technology. In addition, they are already operating or planning their first pilot applications in the field of LoRaWAN and are therefore very interested in a joint and regular exchange of experience as well as in the development of technologies and applications.

In concrete terms, it was agreed to jointly develop concepts for applications such as parking space monitoring, street lighting, error and fault message collection, level measurement and energy data acquisition. Individual components of the LoRaWAN network such as sensors/actuators, gateways or server operation are also to be tested.

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6. Conclusion

The problem has been known for some time and has constantly been an emotional criticism of Hamburg's public charging infrastructure: The incorrect occupancy of the parking spaces for charging electric vehicles. Customers often drive up to a charging station with batteries that are already heavily discharged, only to discover that both spaces are occupied. Charging is therefore not possible. Previously, the Stromnetz Hamburg e-Charging App was used to determine in advance whether another electric vehicle was already connected to the charging point in question. This does not warn, however, that the parking space may be blocked by a vehicle with another vehicle in contravention of the regulations and that the journey is therefore in vain. A signage system and ground markings have already significantly improved the situation of illegal parking in the charging lots. The use of new ground sensors in Hamburg will now solve this problem: a sensor installed on the ground will detect at any time whether the parking space is free or blocked by another vehicle.

This information will be in the future also displayed to the user in the app. The special feature of the Hamburg solution is the integration of the gateway hardware into the charging station. In this context, the SNH focuses on a divergent and complementary technology.

In this context, it is not the intention of the Stromnetz Hamburg GmbH (SNH) to take over the role of the police, to control illegal parking cars at charging points. Instead, SNH wants to contribute to strengthening the confidence of EV drivers in the efficiency of the charging infrastructure and to systematically combat the so-called "fear of range" which unfortunately still exists. Charging point search traffic will be actively reduced and often even completely prevented.

However, the technology will not only be used for reading parking sensors at charging points, but also offers further innovative future fields of action. In the course of the conceptual work on this action very large innovative potentials could be identified. These go far beyond the application of electromobility: By means of the employed LoRaWAN transmission technology, further sensors can be integrated into the network and in this way further synergy effects can be systematically leveraged. The technology offers the widest variety of use cases and the possibility to combine data transfer to an economic attractive price. Exactly these potentials strengthen Hamburg's path as an innovative "Lighthouse City" in Europe and indicate possibilities of an innovative "Urban Transformation Strategy" to support the follower cities in developing their own approach for a Smart City.

In order to expand, support and further develop the LoRaWAN network and the technology itself, Hamburg relies on strong cooperations. On the one hand, through the establishment of a Hamburg cooperation network and, on the other, through supraregional cooperation. In this sense, also, the mySMARTLife project was thus able to make a major contribution to supporting the Hamburg way to a Smart-City.

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