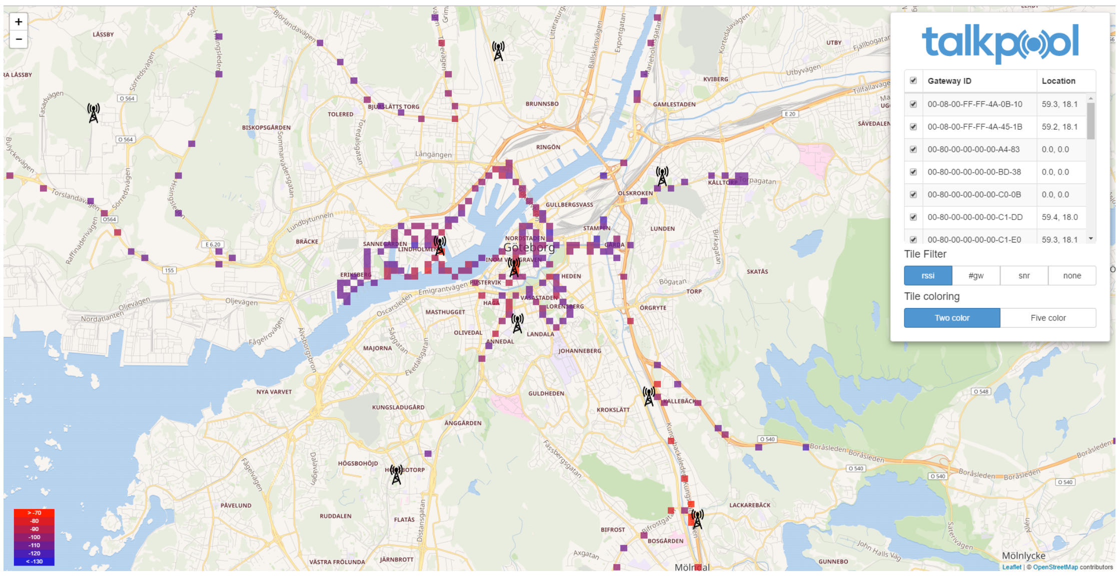

✓	Gateway ID	Location
✓	00-08-00-FF-FF-4A-0B-10	59.3, 18.1
✓	00-08-00-FF-FF-4A-45-1B	59.2, 18.1
✓	00-80-00-00-00-00-A4-83	0.0, 0.0
✓	00-80-00-00-00-00-BD-38	0.0, 0.0
✓	00-80-00-00-00-00-C0-0B	0.0, 0.0
✓	00-80-00-00-00-00-C1-DD	59.4, 18.0
✓	00-80-00-00-00-00-C1-E0	59.3, 18.1

Tile Filter: [✓ rssi] #gw snr none

Tile coloring: [✓ Two color] Five color

LoRa Network - Analysis and Monitoring

Bachelor's thesis in Computer Science and Engineering

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Cover: Frontend Dashboard built in project, showing a map with gateways and sample measurements.

Abstract

This report explores a solution to a maintenance problem of internet of things based networks where a lack of tools for visualization of the coverage is present. It argues for different software libraries and frameworks, their benefits and drawbacks for the task. The process starts with a prestudy to define the scope and is followed up by an implementation based on the prestudy. The result is concluded as a frontend-backend solution that visualizes the coverage on a earth map using a grid based heat map.

Sammanfattning

Denna rapport utforskar en lösning för ett underhållsproblem av ”Internet of Things” nätverk där det för tillfället inte finns något verktyg för att visualisera täckning. Argument för olika mjukvarulösningar såsom ramverk och bibliotek tas upp samt väger för- och nackdelar mot varandra. Projektet börjar med en förundersökning för att definiera funktionella krav på applikationen vilket sedan implementeras. Resultatet är en ”frontend-backend” lösning där användargränssnittet består av en webbsida med en karta samt ett rutnät ovanpå som visualiserar täckningen över ett specifikt område.

Acknowledgements

We would like to thank Cybercom for providing the opportunity of doing a bachelor thesis in a new and growing concept, Daniel Öhlund and Andreas Lindmark for guidelines in the process of development and defining scopes, Mina Alibeigi for always covering our backs, Gabriel Ibanez for providing administrative solutions and finally Tanner Yavuz for providing a good social atmosphere at the office.

TalkPool is the customer which had interest in the platform and provided technical guidelines and requirements that made the project possible at all, thanks to Stefan Lindgren and Bertil Moberg for this opportunity.

Finally we would also like to thank Chalmers for the whole educational programme and Uno Holmer who was the supervisor for this project from Chalmers and our former lecturer, Peter Lundin the examiner for the generous grades he will give.

Alexander Erenstedt, Philip Laine

Gothenburg 04/06/17

Contents

Abbreviations

API - Application Program Interface

DOM - Document Object Model

GPS - Global Positioning System

IoT - Internet of Things

JAX-RS - Java API for RESTful Web Services

JSON - JavaScript Object Notation

LoRa - Low Power Wide Area Network

MVC - Model View Controller

MQTT - Message Queue Telemetry Transport

OSM - Open Street Map

PNG - Portable Network Graphics

REST - Representational State Transfer

RSSI - Received Signal Strength Indication

SNR - Signal to Noise Ratio

UI - User Interfaces	
VM - Virtual Machine	

1

Introduction

TalkPool is a provider of Low Power Wide Area Network (LoRa). TalkPool has currently deployed LoRa networks across the globe and the network is advertised as a automated wireless method of collecting data. An example of usage could be a landlord who wants to monitor temperature and humidity in their buildings where conventional methods would require traveling to the location.

1.1 Problem statement

TalkPool currently lacks an efficient way of measuring and determining the state of their LoRa network which makes the process of maintenance rather dull. Cybercom has partnered with TalkPool to develop a solution to simplify the analysis of TalkPool's LoRa network coverage through visualization. This would allow for easier detection of problems and errors with specific gateways. It would assist in determining the feasibility when deploying new devices or gateways.

The developed application will primarily be used internally by TalkPool to get a broad understanding of their network. In a later stage the application could be useful for end user to assist in troubleshooting issues with their devices aswell.

This report aims to explore a possible solution to process, store and visualize location based data. Focus will be on discussing the different options of implementation for a user interface regarding performance, time frames and compatibility. The solution will consist of three main components which are:

- Data receiving and processing
- Data storage and delivery
- Data visualization

The goal is to evaluate each component as if they would be used in production. Aspects such as scalability and mutability will be observed to create the final verdict. Aspects of this report will discuss the different possibilities to store and process geo-location data. It will look at different options and problems which can arise when attempting to store and query larger sets of data based on position.

Focus is given to setting up a data processing and storing system, suited for location based visualization. Allowing for further features to be developed at a later time without having to do the data collection again.

1.2 Purpose

The purpose is to develop a prototype application which visualizes location based network coverage through the use of a heat map. The end result is a proof of concept showing the possibilities and usefulness of visualizing a heat map through a grid based system.

1.3 Delimitations

- Legacy systems support is not a requirement when selecting tools such as web browsers.
- Data will be supplied by TalkPool and will be generated during the project.
- Hosting will be done through Azure.
- The database is built based on the assumption that the Gateways will not change.
- Data is not expected to be received from any of the poles.

2

Theory

This chapter will explain key concepts used in the development and deployment of this projects. Focus is put on protocols and standards needed to understand the project, but some tools and languages will also be explained.

2.1 Agile Development

Agile development is a principle which allows projects to quickly and painlessly adapt to requirement changes. Work is divided up in sprints, where each sprint is to be done within a set time. Each sprint gets estimated with a set of tasks, which are expected to be completed within the sprint. These tasks are repeatedly synchronized and prioritized in collaboration with stakeholders each sprint to ensure a solid final product. When tasks are done they will be queued for review which is supposed to be reviewed by someone else than the person who executed the task. There will be daily stand up meetings to update everyone in the team on what is under progress and problems that could hinder progress.

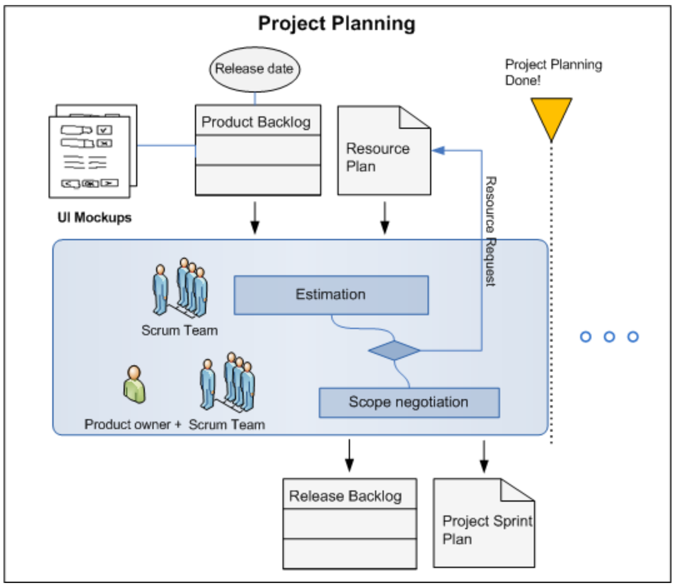


Figure 2.1: Agile project planning process

2.2 Docker

The Docker solution is based on containers and operates similar to how virtual machines work. This simplifies deployment and development since it isolates applications from each other by running them separately in different containers. This causes each application to have its own OS and which is unified across all different platforms. This requires a implementation of Docker on different platform but allows development towards all these platforms without any specific consideration, similar to how Java is implemented with its virtual machines.

2.3 IoT

The Internet of Things (IoT) is defined ”as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.” [2] IoT includes all devices which are connected to the internet for the purpose of transmitting information, this can be anything from a truck to a trashcan.

2.4 MQTT

Message Queue Telemetry Transport (MQTT) is a light weight communication protocol meant for device to device communication. The protocol is widely used by IoT devices which require a simple solution to send small amounts of data between devices. Devices communicate through a publish-subscribe pattern where a broker is required to receive messages and forward them to devices which are interested in receiving them. This pattern allows for multiple devices to receive the same message, and for a device to publish a message which no device listens to.

2.5 LoRa

Lora is a wireless communication technology developed for applications in IoT devices. Communication is done through gateways which relay the data to a conventional network, as shown in figure 2.2. It is geared towards battery powered devices such as sensors due to its low power use, making it possible for devices to run for years before needing to change its battery. LoRa is limited by its low bit rate in comparison to other conventional cellular technologies which focuses on transmitting vast amounts of data. The network is based on devices and gateways where the gateways is the connection to the internet for the devices.

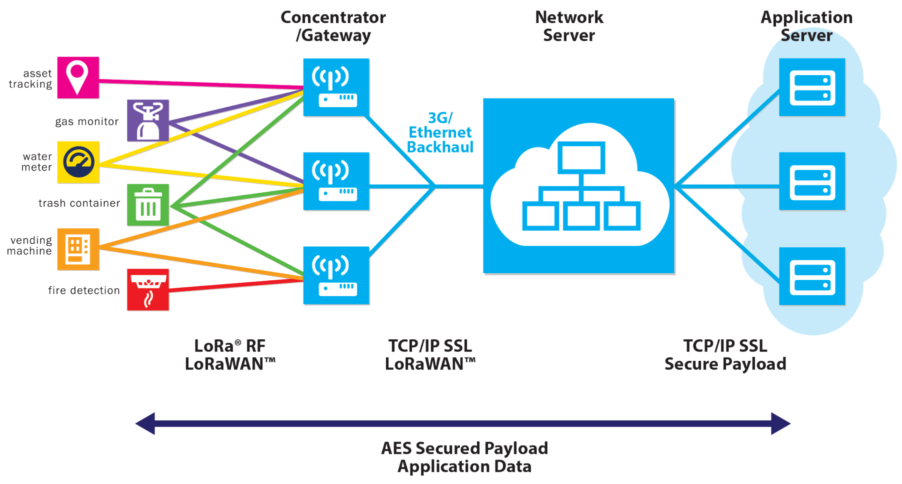


Figure 2.2: LoRa network diagram

2.5.1 RSSI

Received signal strength indication (RSSI) is the measure of signal power between a device and a gateway in dB. The further away a device is from the receiver the lower the RSSI is expected to be as the power diminishes. High RSSI values means that the signal strength is good and the connection will be reliable. While low values means that the connection will be more susceptible to interference from other devices, causing connectivity issues.

2.5.2 SNR

Signal to noise ratio (SNR) is the ratio between the signal power and the amount of background noise interfering with the signal. The ratio is important as data must be transmitted well above the noise floor for it to be received and decoded. Large amounts of noise would also cause the need to transmit with more power, to stay above the noise floor.

2.6 ReactJS

React is a programming concept which simplifies building User Interfaces(UI)[3], supposedly replaces the view part of the Model-View-Controller (MVC) template[4]. It aims to be simple, efficient, interactive and as the title suggests, reactive, mostly to changes in the UI[3]. It is currently mainly maintained by Facebook and is licensed as open source under Berkeley Software Distribution(BSD) however with some extra clauses [1]. ReactJS is based on a component logic which is arranged in a tree structure, parent and child relations. The data flow between components is uni-directional which means that the data flow is just in one direction, most often from parent to child. This characteristic is probable to cause some confusion on how components are supposed to communicate, especially when two components that does not have a parent-child relation requires data exchange.

2.6.1 React-Redux

Redux is a tool inspired by the Flux pattern and built to be combined but not limited to React. It is built to solve the issues where React crumbles in the sense of data flow. Redux offers a solution where each component in React can subscribe and dispatch data into a global store, this removes the logic requirements from components in React to handle each other and can simply be implemented towards the store instead.

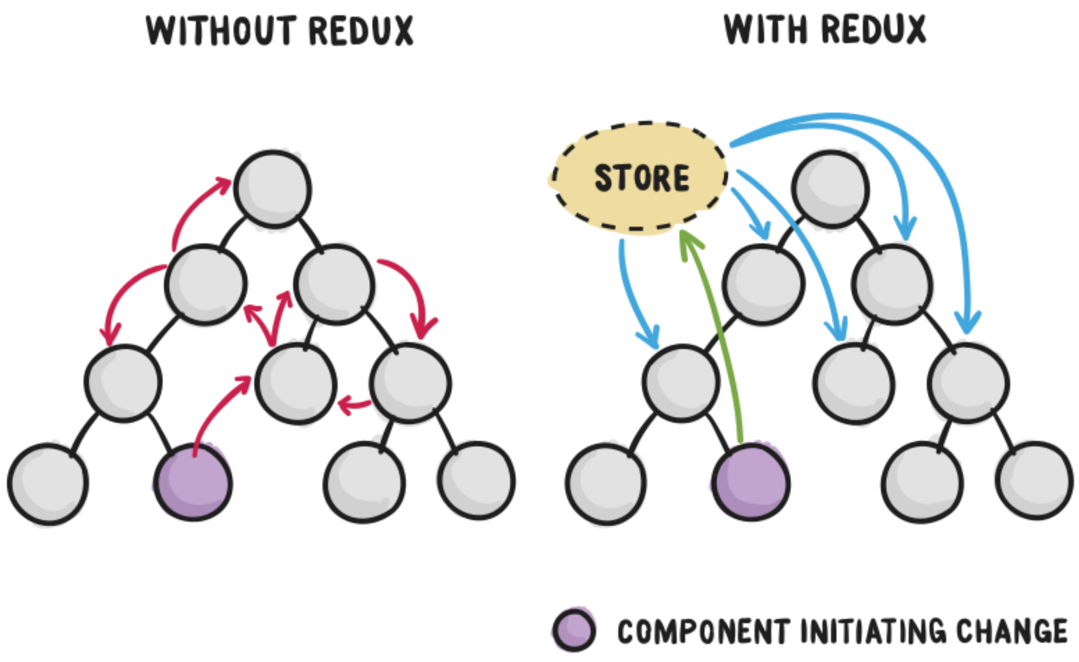


Figure 2.3: React with and without Redux visualization

2.7 GeoJSON

”GeoJSON is a geospatial data interchange format based on JSON. It defines several types of JSON objects and the manner in which they are combined to represent data about geographic features, their properties, and their spatial extents.” [2]

2.8 Heat map

Heat maps is basically a visualization of a grid with some kind of values. There is multiple types of color schemes used and there is not a defined standard but blue and red is a more conventional way of showing polarities.

2.9 Leaflet

Leaflet is a lightweight library for using interactive maps. Leaflet implements different components for the maps such as markers, rectangles, layer controllers and much more. The core element, the map, requires a tile provider which has the task to send the map as images based on current view bounds and zoom level. Leaflet has support for drawing figures on the map from GeoJSON data.

2.10 Big Data

Big data is a term which describes data that is too large to be handled by conventional methods, it is often defined with the three V's [3].

- **Volume** is used to describe sizes of captured data, terabytes, petabytes and sometimes exabytes of data.
- **Variety** defines the problems where data can be collected from different places in different formatting and structure. The three types of data that are often mentioned: the structured, unstructured and the combination of these which is called semi-structured.
- **Velocity** refers to the speed of processing and generating data.

3

Development Approach

This chapter will cover the ways of working and a prestudy that was made to define the scope of the project. The work flow follows the agile development approach to ensure common goals with every stakeholder.

3.1 Prestudy

A prestudy defines the technical requirements, questions yet to be answered when the project starts, assumptions and a brief plan of how the system will be designed. Cost calculations is also usually included but in this case a rather small component, where some hosting costs are considered. The broad but exact purpose of the prestudy is to define the scope of the project, to define what resources is available and required.

The prestudy is done in collaboration with TalkPool to ensure common requirements on functionality and to synchronize the grasp on the scope of the project. The process of prestudy consists of defining user stories based on TalkPool's idea of usage where those defines the core functionality that will be implemented. The user stories is afterwards broken down to facilitate work and thereby time estimations. Mockups of the project should also be presented and agreed upon to ensure that all involved parties is satisfied with the development direction of the project. The final mockup based on the technical specifications is shown in figure 3.2.

3.2 User Stories

The technical requirements is defined in the prestudy with user stories, they are defined such as: ”As a <type of user>, I want <some goal> so that <some reason>”. This ensures that there is value for someone or something when functionality is achieved, following is the most defining user stories of the collection:

1. As a network admin, I want to see the position of the gateways on the map so that I can assume the network coverage.
2. As a developer, I want to have a grid on the map so that I can later draw a heat map with it.
3. As a network admin, I want to see coverage based on different properties (RSSI, SNR and number of gateways) so that I can differ between interference and low signal strength.
4. As a network admin, I want to see a legend with threshold values so that I can understand the different colors in the heat map.

In the first user story the user would be a network admin, someone who has responsibility to ensure stability and reliability of the network. This user needs aid in making decisions on for example, where to place a new gateway to maximize the coverage or simply where the network currently is weak. This user story is rather pointless in its own and is merely one step towards the final product of this project but yet utterly important for the complete visualization of the network status.

The second user story follows a similar pattern as the first, does not contribute much in its own but when combined, in this case number three, it produces a significant amount of value for a network admin.

3.3 Technical Requirements

3.3.1 Data Processing

The incoming messages will have the same JSON format, but the type of data sent will differ between device types. Both the type of data sent and the method of encoding the data can differ between devices. A example of a typical message sent from a tracking device is shown in figure 3.1, where the data will be the position of the tracking device.

```
{
    "deviceEui": "A2-3D-47-65-35-98-74-2B",
    "appEui": "C8-03-A1-4C-E4-2B-E8-A2",
    "seqno": 5,
    "port": 4,
    "data": "gFIaiwh6hA",
    "time": "2017-05-03T09:32:41.150Z",
    "deviceTx": {
        "sf": 12,
        "bw": 125,
        "freq": 867.5,
        "adr": false
    },
    "gatewayRx": [
        {
            "gatewayEui": "72-76-FF-FF-FE-01-03-33",
            "time": "2017-05-03T09:32:41.150Z",
            "isTimeFromGateway": true,
            "chan": 2,
            "rssi": -112,
            "snr": -12.0
        },
        {
            "gatewayEui": "72-76-FF-FF-FE-01-03-33",
            "time": "2017-05-03T09:32:41.150Z",
            "isTimeFromGateway": true,
            "chan": 18,
            "rssi": -111,
            "snr": -14.0
        }
    ]
}
```

Figure 3.1: MQTT message JSON format

Devices are limited to tracking devices which have GPS modules as the goal is to correlate signal quality with a specific location. The data when received needs to be processed as there only certain parameters are needed, and values such as RSSI must be normalized. The following parameters are needed to be able to properly visualize the heat map.

- Location
- RSSI
- SNR
- SF
- Receiving Gateway

The received location data should be translated into a grid system to simplify the storage and reduce the database size which helps indexing and accessing specific information faster. Grouping of location data also requires the measured values to be grouped in a similar fashion. The suggestion from TalkPool was to use a rolling window where new measurements affects the value by a predefined percentage where this percentage should be based on how fast or slow old values should be phased out.

3.3.2 Filtering

The filtering options changes the displayed data by the heat map, which will update in real-time as settings are selected.

- Selecting specific gateways
- Measurement value types (RSSI, SNR, number of gateways, packet loss)
- Scenario (Outdoor, Indoor, Deep-Indoor)
- When there are measurements from one gateway for a position the average of all the values through time is used
- When there are measurements from multiple gateways for a position the maximum of the average values is used

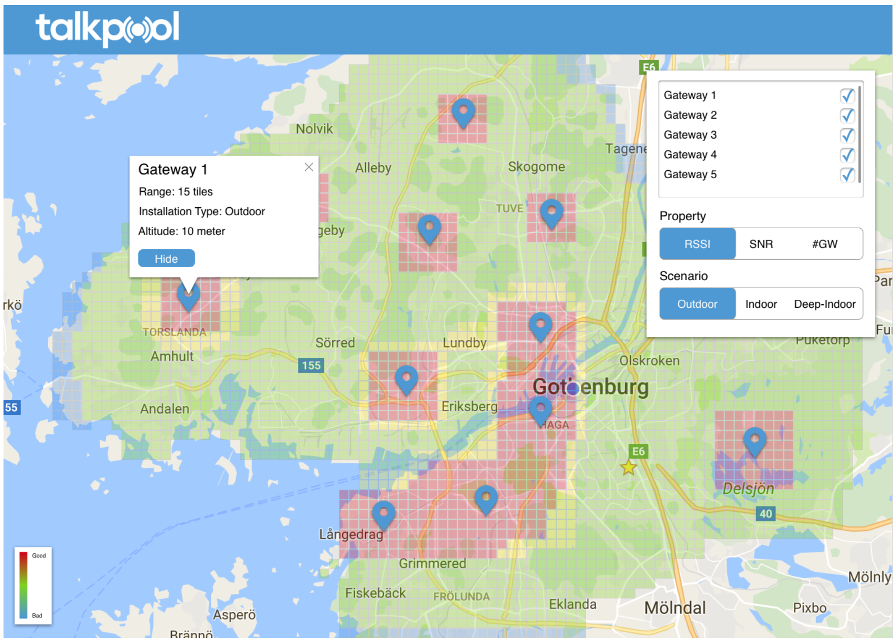


Figure 3.2: Final prestudy mockup for the frontend

4 System Design

Figure 4.1 shows the general data flow and design of the platform. The data flow starts from TalkPool's application servers which publishes messages received from tracker devices to a MQTT broker hosted on Azure. There is a MQTT client which runs alongside the broker, that subscribes to the messages published by TalkPool on the broker. The client will then parse the data in the message and extract the necessary data from the message, which it then posts to the backend. The data from TalkPool can come in many different formats, depending on the version and device where the message originates from. Figure 3.1 shows an example of the received message format. It is necessary to standardize the format received by the backend as many different applications may communicate with the backend in theory.

The backend will then update the records in the DB or insert a new record, depending on the specified location. The frontend is served from a static HTTP server to the end user client, which the queries the backend for data. The backend provides data such as the gateway position and tile values that the client then displays to the end user.

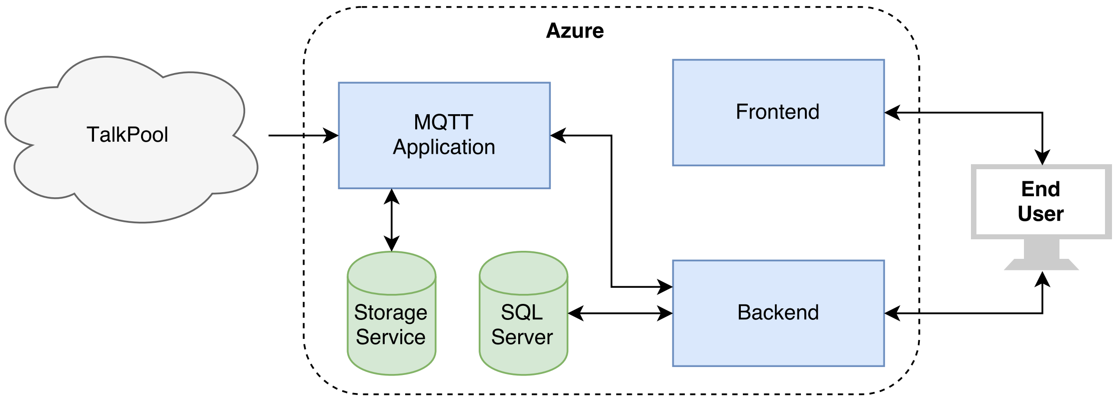


Figure 4.1: Network design for the platform

4.1 MQTT Application

The MQTT application consists of both a broker and a client. The broker is required to allow remote clients can connect and publish to it, additionally the broker authenticates clients so that random messages cant be published. The client runs in the same application and subscribes to a set of topics on the broker. The client will for every message it receives, store it as text, and try to parse it to an expected format. All messages which are in the expected format will be posted to the backend. The storage service serves the purpose of acting as a backup in the case where new data formats are supported, allowing for old data to be replayed to the MQTT application.

4.2 SQL Server

There are three tables in the SQL database, tiles, gateways and measurements. The measurements has a tile and a gateway as a foreign key combined with measurement values such as RSSI and SNR. This enables a tile to have multiple gateways referenced with different RSSI and SNR values for each gateway since it is a many to one reference.

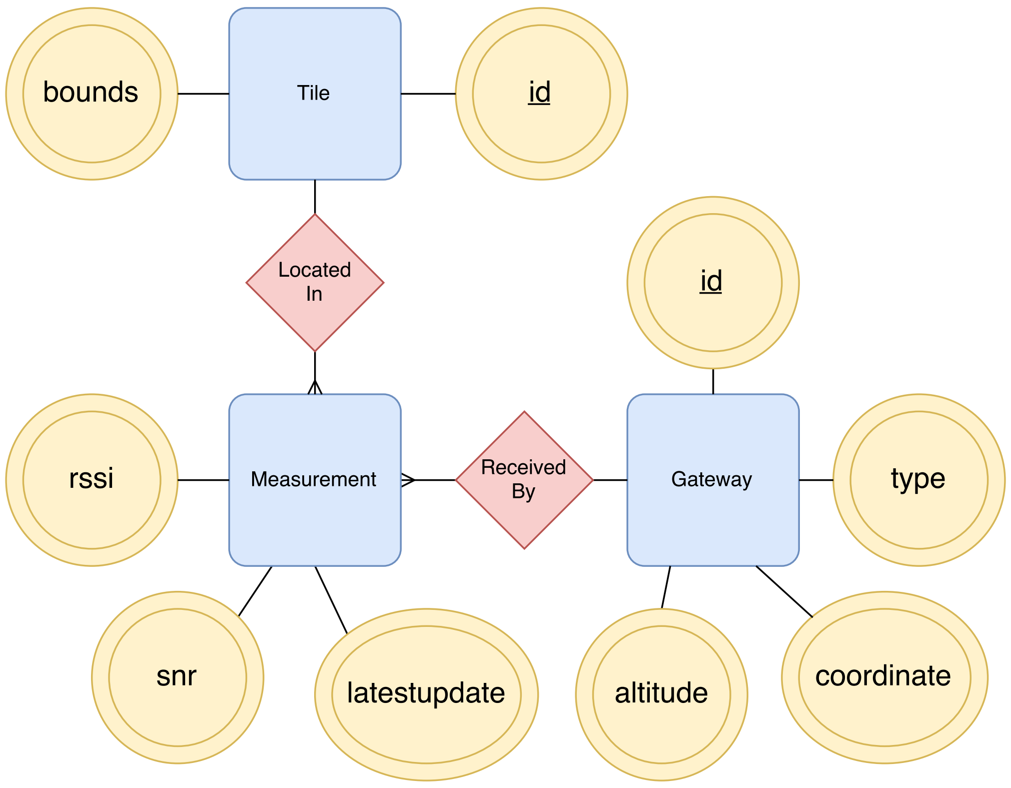


Figure 4.2: ER-diagram of the database design in SQL

4.2.1 Grid

The grid is defined in the backend Java layer with an algorithm which calculates each tile that forms the grid. The grid only exists as an algorithm which means that tiles are generated only upon new received data and empty tiles simply does not exist at all until data was received in that location. Tiles are represented as a polygon using GeoJSON and is defined from a method which receives a point and then calculates which tile it is inside of, illustrated in figure 4.3.

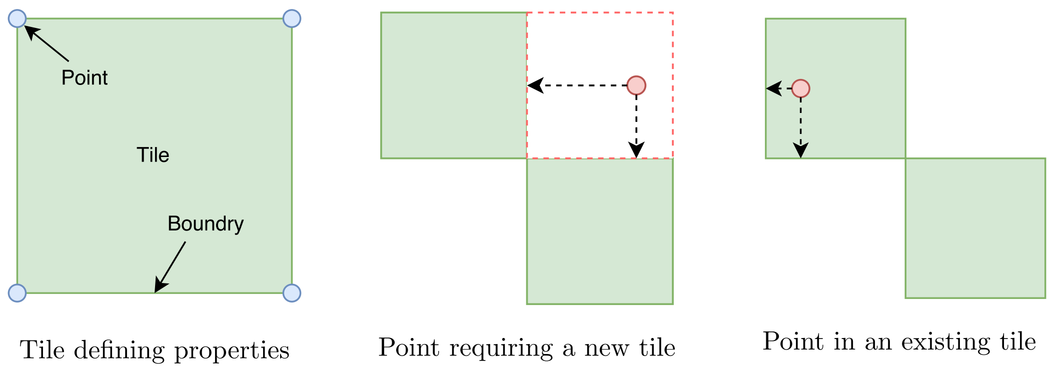


Figure 4.3: Visualization of tile definition and creating.

The tiles are stored in a (x, y) coordinate fashion and since defined coordinates on the earth is usually represented as (latitude, longitude) the order is reversed compared to the storing procedure. The solution for this is to switch the order of the presented coordinates where the information is accessed from a user perspective.

4.3 Backend

The backend was built following the REST style with the Jersey library. The main benefit with Jersey is that it follows the JAX-RS specification, which is a Java API specification for REST web services. This means that it would allow moving to another library that follows the same specification with very little change in the code. REST is a design style which defines the methods of interactions between a client and a server [4]. In the case of the platform this would be the backend and the frontend running in a web browser. This decouples the two components as there is a predefined set of responsibility for who does what. As an example the following path would be used to fetch a specific gateway resource with the matching id, which would then return a JSON response.

```
GET /gateways/00-80-00-00-00-4A-05-1C

{
  "id": "00-80-00-00-00-4A-05-1C",
  "type": "Indoor",
  "coordinate": {
    "type": "Point",
    "coordinates": [
      12.006403,
      57.718481
    ]
  },
  "altitude": 10
}
```

Figure 4.4: Sample gateway JSON format.

Adhering to this format would allow other applications to be developed using the same backend, without any changes being made. Additional resource paths or filtering options could be added if needed without affecting other applications using the same backend.

4.4 Frontend

The frontend is the interface for the users, it is mainly built with JavaScript and the library ReactJS. Since React is mostly a programming mindset for visualizing, there is other libraries that complements well such as Redux which standardizes the data flow between components in React. This library was considered and researched upon but the choice was to skip it since the purpose of this project was to create a rather simple prototype and the inclusion of Redux was estimated to consume to much time compared to the benefits which would be easier reading and coding.

Different components in the frontend communicate through callback functions in the main component which is tasked with supplying its children with correct state updates and props.

ReactJS has multiple libraries for UX styling, this project include the React-bootstrap which has lots of different functional and styled components such as buttons and forms. The map rendering library used is Leaflet where the tile provider is WikiMedia.

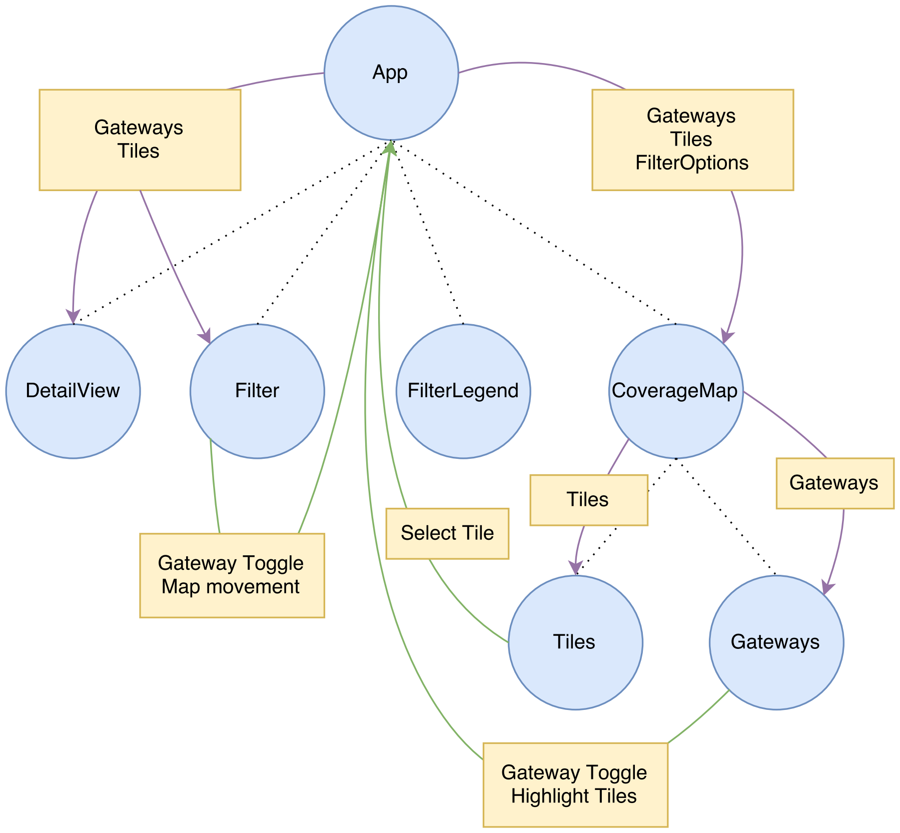


Figure 4.5: Data flow of frontend simplified

The heat map drawn in based on the tiles and values provided from the backend. A tile consists of a list of measurements and a polygon that uses five points which forms a rectangle. The measurements comes from each gateway that have coverage of the specific tile which causes it to exist multiple measured values for each tile. The values drawn on the tiles in the heat map is based on the best measurement. Figure 4.6 shows a sample of a tile sent from the backend to the frontend.

```
[
    {
        "id":"017809bf28be5f9796d4f11a846f1df5",
        "bounds":{
            "type":"Polygon",
            "coordinates":[
                [
                    [
                        11.942,
                        57.71
                    ],
                    [
                        11.944,
                  57.71
               ],
               [
                  11.944,
                  57.711
               ],
               [
                  11.942,
                  57.711
               ],
               [
                  11.942,
                  57.71
               ]
            ]
         ]
      },
      "measurements":[
         {
            "gateway":{
               "id":"72-76-FF-FF-FE-01-03-33",
               "type":"Roof-top",
               "coordinate":{
                  "type":"Point",
                  "coordinates":[
                     11.957764,
                     57.73824
                  ]
               },
               "altitude":10
            },
            "rssi":-115,
            "snr":-13.1,
            "latestupdate":1495441992700
         }
      ]
   }
]
```

Figure 4.6: Sample Tile JSON format.

The color scaling of tiles in the heat map is implemented on a two and five color basis where both implementations uses red as a high or good value and the blue represent a worse or low value. The color scales are shown in figure 4.7 and the the legends which maps the color of a tile to a value are shown in 4.8

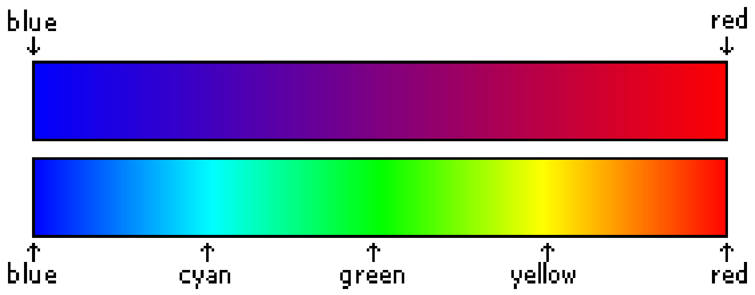
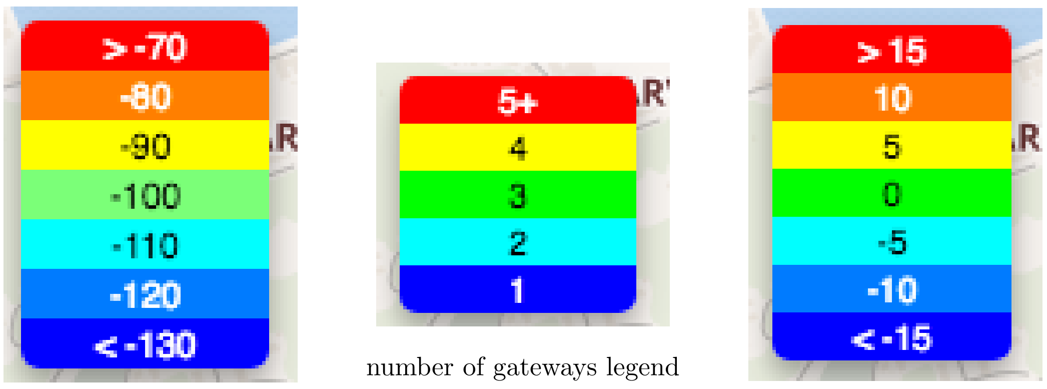


Figure 4.7: Color scaling used for tiles



RSSI legend

number of gateways legend

SNR legend

Figure 4.8: Five color scaling on legends from the dashboard

Most of the look ups in the frontend are based upon hash maps to ensure constant timings when accessing data. However, some loops will be required when for example drawing all tiles or gateways. These are expected to be the bottleneck from a performance point of view. One example of a implemented optimization is that the tiles are fetched dynamically based on the current view of the map, this would cause a cost of loading the network more but benefits in reducing the amount of tiles stored and rendered.

4.5 Deployment

The hosting for all the different resources was done through Azure, as defined earlier in the delimitation of the report. There were no other limitations on the hosting of deployment methods, leaving a lot of different possible solutions many of which can be considered correct. Azure offers a lot of functionality as services through their platform, but after some considerations they were ignored in favour of running everything on one Ubuntu VM. This was partly due to time constraints favouring known tools and the lack of specific features which would have needed to be customized to expand the services. All three components were run as separate Docker containers, allowing for the use of one VM to host all the needed resources. An additional benefit would be that deployment on the customers own platform would be simplified, as everything could be setup on one single Linux machine. This could reduce the hosting cost as the cheapest option could be chosen, or an option which could provide more up time in comparison to Azure.

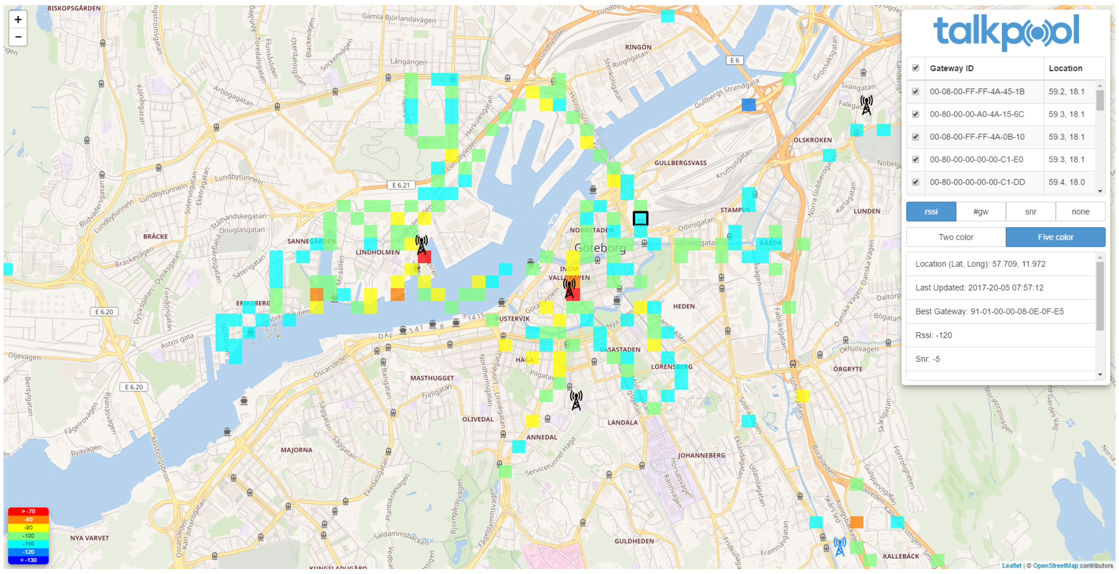
5

Result

The data flow of the prototype is an MQTT application receiving and processing data into the backend, the layer above the SQL database, and a storage service where messages are stored without modifications. The frontend ensures that data from the database is rendered and fetched properly for the user, all this is visualized in figure 4.1

5.1 Features and Functionality

The final result of the frontend shows a map with values from sensors drawn on a heat map and enables filtering of sensor data such as RSSI, SNR and amount of gateways with coverage. It is also possible to view details of specific nodes and to remove single or multiple gateway's contributions to tiles.



✓	Gateway ID	Location
✓	00-08-00-FF-FF-4A-45-1B	59.2, 18.1
✓	00-80-00-00-A0-4A-15-6C	59.3, 18.1
✓	00-08-00-FF-FF-4A-0B-10	59.3, 18.1
✓	00-80-00-00-00-00-C1-E0	59.3, 18.1
✓	00-80-00-00-00-00-C1-DD	59.4, 18.0

Location (Lat, Long): 57.709, 11.972

Last Updated: 2017-20-05 07:57:12

Best Gateway: 91-01-00-00-08-0E-0F-E5

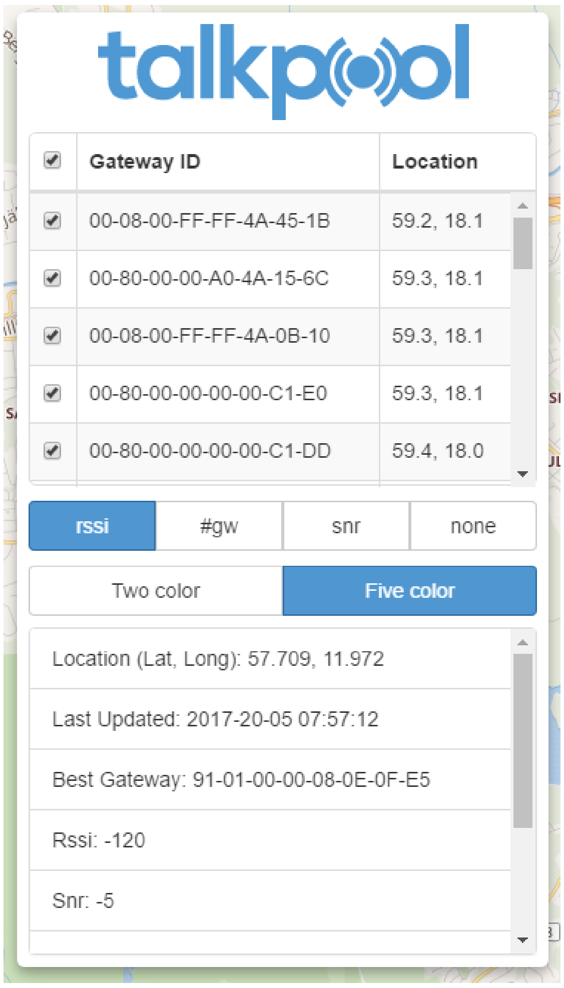
Rssi: -120

Snr: -5

Figure 5.1: Screenshot of the frontend

The panel consists of a gateway list where gateways are listed with their ID and coordinates, filtering options and a detailed view of tiles. The detailed view is based on the current selected tile which has a black border around and displays the following information about the tile, also shown in figure 5.2:

- **Coordinate(Lat, Lon):** Coordinates of the tile
- **Last Updated:** time stamp from latest update
- **Best Gateway:** id of the gateway with best reported RSSI value
- **RSSI:** highest collected RSSI value of the tile
- **SNR:** highest collected SNR value of the tile
- **#GW** The amount of gateways with coverage of the tile
- **Enabled/Disabled Gateways(<amount>):** IDs of the gateways that have collected data from the tile grouped by their current visible status



✓	Gateway ID	Location
✓	00-08-00-FF-FF-4A-45-1B	59.2, 18.1
✓	00-80-00-00-A0-4A-15-6C	59.3, 18.1
✓	00-08-00-FF-FF-4A-0B-10	59.3, 18.1
✓	00-80-00-00-00-00-C1-E0	59.3, 18.1
✓	00-80-00-00-00-00-C1-DD	59.4, 18.0

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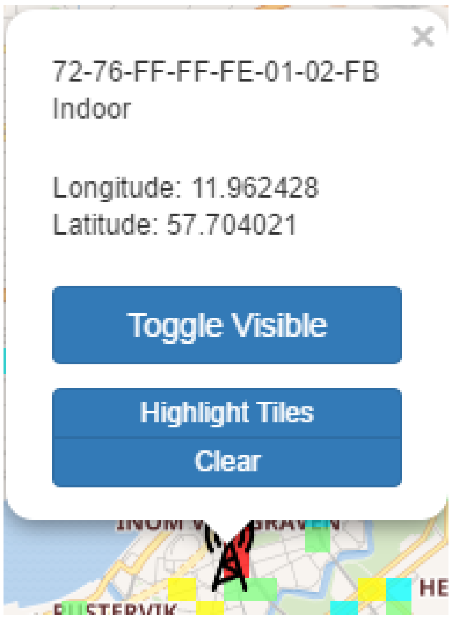
Snr: -5

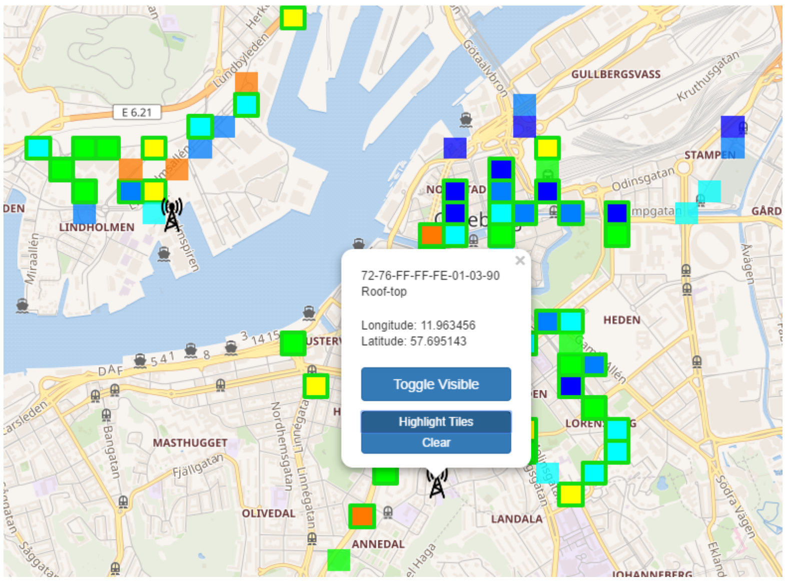
Figure 5.2: Panel from the dashboard

Clicking on a gateway opens a pop-up which gives more information about that specific gateway and buttons interact with the gateway, shown in in figure 5.3. In the pop-up the buttons can toggle the visibility of the gateway or highlighting of the tiles where this gateway has the best RSSI value as illustrated in figure 5.4. Toggling a gateways means that the gateway will not contribute with values towards the tiles and for example if a tile only has reported values from a invisible gateway the tile will not be drawn.


72-76-FF-FF-FE-01-02-FB
Indoor

Longitude: 11.962428
Latitude: 57.704021

Figure 5.3: Gateway popup from the dashboard


72-76-FF-FF-FE-01-03-90
Roof-top

Longitude: 11.963456
Latitude: 57.695143

Figure 5.4: Gateway with highlighted tiles from the dashboard

The grid visualized on the map is exclusively based upon collected data which means that tiles without data is not shown at all and therefore gaps are likely to exist in the grid. The grid is based upon GeoJSON sent from the database (tile package shown in figure 4.6) and is but not limited to rectangles.

The grid heat map is drawn with a five or two color scale and values is explained on the dashboard with a legend (figure 4.8) and a comparison of the two scales is visualized in figure 5.5.

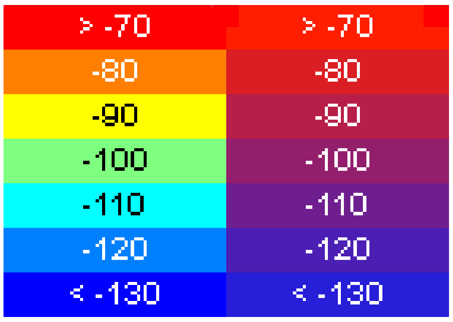


Figure 5.5: RSSI legends compared with the two scales

5.2 Performance

Few tests have been made with substantial amounts of data and the performance is expected to be linear in relation with the amount of nodes. The maximum amount of nodes used in tests was near 10000 and it turned out to be functional but slow. Somewhere around 5000 nodes should be fine performance wise depending on the hardware. However, it is most likely the amount of tiles that could become overwhelming, rather than the amount of gateways.

6

Conclusion

This chapter will discuss different problems encountered and their solution. Challenges were inevitable but there are many ways to face them. Using the initial technical requirements will simplify judging if the end goal was completed, which was discussed in the previous chapter. Instead focus will be put on analyzing the choices made during the project.

6.1 Final result

The project overall turned out alright, the customer TalkPool was pleased with the results and mentioned that they found a it usable even during development. The method with a prestudy and then following an agile development approach turned out to be a winning move. One could argue that the performed prestudy was quite successful since only a few changes were made in the sprint meetings, a re-prioritization of some user stories for the final sprint. Some extra features were implemented in the frontend for a better user experience such as relocating the map to gateways or multiple color scaling on the grid, they were rather minor but is likely to give the user a better experience and result from usage. The plan was to have daily stand up meetings which was not consistent but somewhat maintained, the average per week ended up close to three.

Considering the mockup created in the prestudy and the final result (figure 3.2 and 5.1) the similarities are quite substantial which argues for a good outcome and result of the project. The positive differences are the color scaling of tiles, the detailed view of tiles, interact ability with the pop-up of gateways. What was not included from the mockup was the filtering on different types of gateway placements which is mentioned as scenario in the mockup.

6.2 Biggest Issues

A performance issue were encountered during early development when tests with different amount of tiles were tested. The amount of tiles where doubled up to a amount of ten thousands where the tests stopped since the frontend ran very slow. The rendering times with ten thousands of tiles could take a couple of seconds which is unacceptable but still the system was usable. Workarounds such as the dynamic fetching of tiles is a precaution for the fact that it is a reasonable scenario in the future if data is collected over a long period of time with a variation of locations.

The fact that different systems stores location data differently caused headaches where most of the UI based libraries present the location as Latitude, Longitude which would be Y, X in a regular coordination system in contrast to most systems which stores them as X, Y. The rather late conclusion was to store everything everywhere as X, Y and only when presented for users switch the order into Y, X or Latitude, Longitude, since this is the standard of how coordinates on the earth is presented. There was a situation because of a misunderstanding where both the frontend and backend had the coordinates reversed which caused everything to be presented correctly but in the sense of creating readable and mutable code this it had to be fixed.

6.3 Frontend Technology Choice

The choice of ReactJS was mostly because its fast since it uses a virtual rendering system and compares it to the latest render, then updates what is necessary instead of re-rendering everything. Results from a rather simple and arguably effective test is shown in figure 6.1 and 6.2. The test consists of rendering a list with a thousand elements bound with a ”onClick” method [5]. The test itself does not have a solid scientific approach but the results proposes that there likely is a advantage of using the virtual DOM rendering.

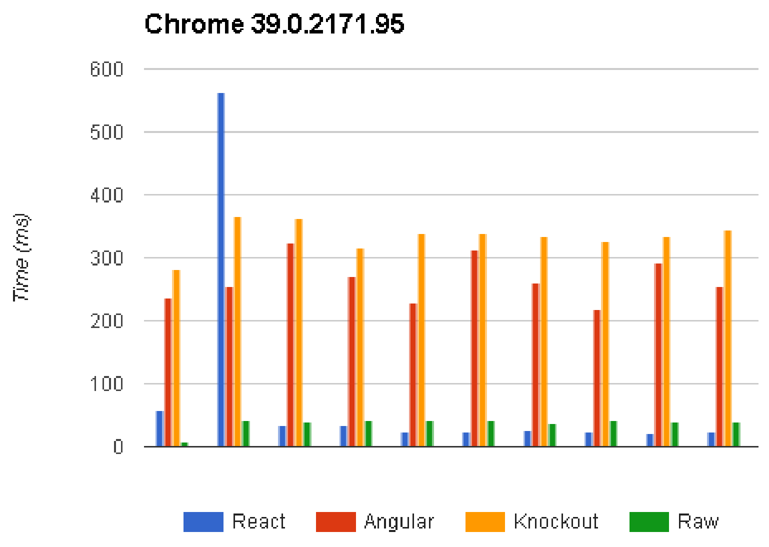


Figure 6.1: Results from comparing different browser with different frameworks [5]

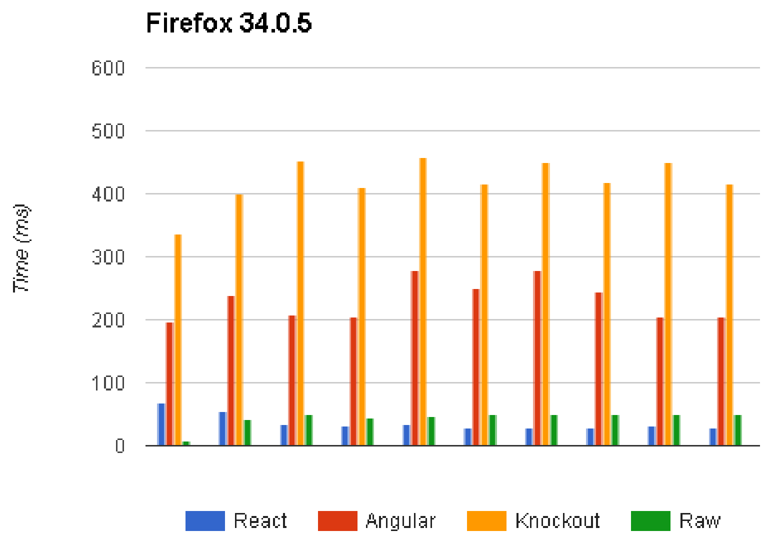


Figure 6.2: Results from comparing different browser with different frameworks [5]

ReactJS is not really comparable to other choices that solves similar problems since in most of them React would simply be one component of many, for example it is often compared to the View part in a MVC pattern and most other libraries or frameworks consists of the whole package of MVC. ReactJS is meant to be paired with a data flow control of some sort, the Flux pattern is often mentioned and Redux is the rather obvious choice for this since it is designed primarily for ReactJS but not limited to it. The choice was to skip Redux and this is probably one of the bigger mistakes in the project. The data flow in the final project turned out to be rather complex and hard to keep track of. The app component was what held most of the states and fills a similar function as a set of stores would do in a Redux implementation, but it also full filled the role of being the root node where both requires logic. This caused the fact that the app component is huge and an inclusion of Redux would solve this by lifting out the states and data flow, similar to what is shown in figure 2.3.

During implementation of the later features the conclusion was made that a rewrite with React-Redux would likely solve issues on further scaling the frontend with new features more consistent. The callback functions started getting larger and the data flow between components was more complex. A rewrite in combination with Redux is likely to solve these issues but a prediction of new problems that might occur is a rather obnoxious task but the existence of new complications is almost certain. Redux would solve some of these issues by extracting the logic out of the ReactJS, handling the data flow and logic with reducers, actions and stores. The decision in this project was to skip it since the research time would be to demanding and the skill curve of using the library seemed to be rather steep in comparison to just running with the ReactJS. Looking at this decision post project it is certainly hard to argue if it was right or wrong since the fact that the project still had a good outcome. When considering the knowledge loss from skipping Redux it might be a loss on a long term goal from the members perspective but it is likely that an inclusion would not have affected the final products sum of functionality a whole lot.

6.4 Map Solution

There is a whole lot of map services and libraries that is feasible in a project like this, the choice made was mostly based upon free to use and open source licenses. Leaflet was a great candidate and chosen because of its simplicity and the fact that it is lightweight [6]. Competitors to the choice of leaflet were Google maps, Open layers and MapBox. All of these would all be viable choices but since Google maps and MapBox had costs when reaching high amounts of usage they were discarded as options [7][8]. Open layers seems to be the more advanced library and probably would be more suitable for a complex frontend, in this case the functionality of the frontend did not have excessive requirements, partly because it is a prototype but also since the interaction with the user was defined as rather limited. The combination of this and the fact that similartech.com keeps track on the usage of these libraries and presented statistics on leaflet being the superior choice for more solutions[9].

6.5 Compatibility

There is multiple different web browsers and during the development Google Chrome was the only browser used. When the project was wrapping up a simple compatibility test was done and the conclusion was made that most standard browsers could run the site except for Internet Explorer which is reasonable since it is no longer supported by Microsoft [10]. The tested web browsers is Google Chrome, Firefox, Safari, Internet Explorer, Edge and Opera.

6.6 Heatmap Rendering

The heat map rendering was solved through translating the given bounds for each tile to an entity which is then added to the map Document Object Model (DOM). Every tile would therefore produce one entity, which leaflet would need to keep reference to and redraw when the map moves and a tile appears within the viewing bounds. As mentioned in the result there is a limit to the amount of tiles which both Leaflet and the web browser can render before the FPS count becomes to low and the frontend appear sluggish. This problem is for the most part avoided through tiles only being loaded for the currently visible area of the map, forcing the previously fetched tiles to be released from memory leading to them not being drawn. Request to the backend could be considered relatively cheap and as long as they are fast enough will not be noticed by the end user. Such a logic will work as long as there are not too many tiles in a specific area, which could be the case further down the road when large amounts of data has been collected covering an area. This is expected to happen at a certain point and was considered but beyond the scope of the project.

6.7 Sustainability

The application itself has little to none impact on the environment. However, it could help the technicians to reduce the amount of traveling that is required since it collects and presents the data that otherwise would be obtained from local location. Considering an ethical approach these devices could in fact report personal data which means that security in the sense of encryption and access limitations should be implemented.

7

Continuation

This chapter will cover possible new features and improvements of existing ones for the application. It covers some optimization methods that could be used when the data set gets substantially bigger which currently would slow down the application. The features discussed are considered out of the scope, or additional features which could be implemented if time allowed for it.

7.1 Tile Optimization

There are a couple of possible solutions to this inevitable issue, due to the fact that there is a threshold for the amount of simultaneous tiles being displayed. One very simple solution would be to cluster tiles together into groups of 4 or 8, and averaging the values across the cluster. It would reduce the resolution of the heat map, but would greatly improve performance as it would reduce the amount of tile by a factor of 4 or 8. An example of this process is shown in 7.1. On the other hand lower resolution is beneficial when zoomed out, as it would be impossible to see color information when tiles become very small.

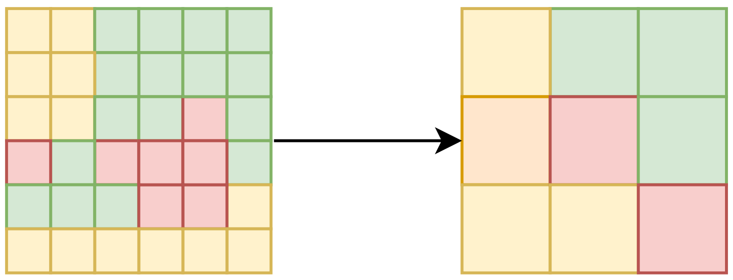


Figure 7.1: Grouping multiple tiles in to one larger tile

7.1.1 Grouping Options

One assumption made is that tiles are so dense that grouping neighbouring tiles is possible. A worst case scenario would be tiles scattered in a checkerboard pattern, only allowing fora tile reduction of 50%. This solution would require a certain amount of pre-processing,which would require the complexity of the grouping algorithm to be relatively small for the added loading time to be negligible. The worst case scenario is that the processing time would be so large that the sluggishness of the visualization has just been moved to an earlier time in the loading process. Pre-processing could be avoided through offloading the work to the backend, allowing it to return tiles that are larger than those stored.Allowing the database to do the grouping would be a lot more efficient, and would probably have a negligible effect on the data fetching time from the backend. Such an alternative would have little effect on the frontend implementation as it does not distinguish between different tile sizes, and if or when the overlap with each other.

There would be two options when determining if and by how much to group the tiles. The zoom level of the map or the amount of tiles expected to be returned without grouping.One would require the frontend to pass a scale value based on the current zoom level in the map, which would be minimal effort to implement. This solutions could still lead to issues in very tile dense areas and has no real guarantee that grouping would solve the performance issue, or just reduce the resolution. The other would be to calculate threshold values for when to group tile. A benefit of this method would be that simple calculations on how close the tiles are to each other could be done, which could help determine when grouping is a effective method. Further testing would be required to measure the complexity of the query, but could have a large impact on the frontend performance when the heat map coverage becomes denser.

7.1.2 Tile Server

The two proposed solutions would require smaller changes to the frontend logic, but there is a third alternative which could be considered in the future that can be combined with tile grouping concept. This option would be to have a separate tile server to generate the tile layer, which would be displayed on top of the map. This would allow for quick loading as tiles are loaded in smaller chunks, and the map would process caching the view itself. The benefit would be that the rendering time for the layer would be a lot faster, but there would be some issues that would need to be solved. Data would need to be passed through a separate method as the tile server would only output PNG images for the tiles. This would make user interactions and data highlighting a lot harder to implement, and maybe even impractical to. The question would be if the performance benefits would outweigh the problems faced with user interactions.

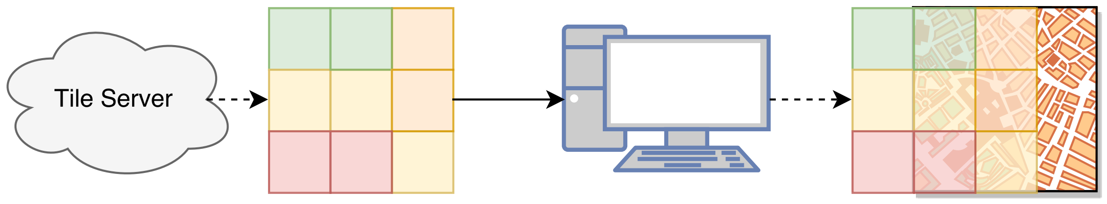


Figure 7.2: Process of genereating tiles serverside

7.2 SQL Flavour

The backend stores the each tile as a spatial geometry object. A geometry is defined by a list of point where the starting point and ending point are the same, resulting in a enclosed area. This SQL data type is based on ISO 19125 resulting in many SQL flavours, adding the possibility to migrate to other DB as the behaviour is expected to be the same [10]. It would be possible to store the tile position with other methods such as a index value which could then be translated to a position when needed. This would decrease the amount of data needed to be stored, but would require to predefined the grid size with triggers. Storing the tile position as spatial data also allows for indexing and quick filtering based on the tile location and boundary. A lot of the fetching from the DB requires spatial filtering, such as when fetching a set of tiles within a boundary, or when checking if a position is within an already existing tile. Such query can become very slow as the amount of tiles increases, requiring the underlying functions to be effectively implemented. Storing the tile boundary in any other format would in the end still require translation to a geometry object, adding an extra cost to queries.

7.3 Additional Features

7.3.1 Filtering Options

Filtering of time frames would certainly be a feature which would bring value to the frontend, although this was not implemented it was considered at an early stage but concluded to require a substantial amount of work and therefore was not prioritized. The frontend would be required to accept user input and request data accordingly from the backend where new paths and queries would require implementation.

Each gateway has a setting property denoting the how it is placed. This could be indoor, outdoor or in a tower. The setting has an effect on the messages being picked up, as a gateway placed high up will pick up messages very far away, but record a low RSSI. The setting property is not used when filtering data, but could be to better visualize the coverage. As it may be an indicator to why signal coverage is poor close to a gateway, due to its setting.

7.3.2 New Devices

The final product is designed for the GPS trackers but a few modifications should enable new devices to be displayed. For devices that does not send their location in messages a separate meta data table or database would have to be established. This however requires the devices to be static and not moved which requires continuous maintenance of the database if devices actually moves frequently. One possibility to solve this is to triangulate the positions based upon different gateways receiving the same message, this however requires that there is overlapping gateway coverage of at least three and preferably more.

7.3.3 Alternative Applications

The developed system is suited for once special case but minor adjustments could be done to change the nature of the platform substantially, it could be used for anything that has some sort of value and a position that needs a visual representation. One example would be when orienteering competitions are held where you might want to be able to track the competitors which this system should be competent of with some slight modifications such as not saving data and just visualizing the latest position of each device on the map. This could be done by skipping the database entirely and let the MQTT client send the data straight to the frontend, the grid system probably is a waste in this case and since its defined in the database and the frontend simply displays the data it should be a quick fix. It is likely that new trackers would have to be designed for this since the time resolution is rather small with thirty seconds interval of messages.

7.3.4 Machine Learning

A implementation of machine learning on collected data could help analyze and predict new positions of gateways or where devices is likely to fail transmissions, however, it is reasonable to assume that the implementation of this would give little value compared to the cost of development.

7.3.5 Big Data

The initial plan was to have a project around the Big Data concept, however, TalkPool rather wanted a prototype of a tool to ease the maintaining of their networks. Big data analysis is probably applicable on a production version and is somewhat prepared since all messages are stored raw in a special storage, where the reason for this storage was exactly to collect all data for a big data analysis. A big data analysis would likely be able to add value to the product but would require thorough knowledge of the LoRa network which is beyond the scope of this project.

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