5G positioning on Interactive map

Project 5G Hub Vaasa

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Introduction

5G, the fifth generation of wireless communication technology is a step forward in connectivity, speed and capacity compared to its predecessors. One of the areas the 5G specification has developed is in device positioning accuracy, used when tracking smartphones, cars, or other User Equipment (UE). The 5G specification introduced new signals used in positioning (the Positioning Reference Signal), improved existing signals (the Sounding Reference Signal), and uses a larger bandwidth to allow for improved tracking accuracy at millimetre wave frequencies (mmWave).

In addition to the standard user equipment tracking, which is expected today, 5G tracking may become relevant in the future when used together with autonomous drive and driver assisted services, as well as for autonomous drones, robots, and other upcoming technologies.

Project workers in the 5G Hub Vaasa project started development on an interactive map for the Technobothnia laboratories to be used for local GNSS and 5G positioning. The aim of this use case is to offer a framework that will showcase and track 5G positioning data once it becomes available. Until then, the map can be deployed to track the location of User Equipment (e.g., smartphones, tablets etc.) using standard Global Navigation Satellite System (GNSS) tracking. The interactive map provides a convenient demonstration and display of positioning data.

5G positioning signals

Project workers researched various methods by which 5G networks could assist in device positioning which are not otherwise offered by 3G, 4G and LTE networks.

5G networks provide and improve two types of signals that can be used for spatial positioning: the Sounding Reference Signal (SRS) and the Positioning Reference Signal (PRS).

The Sounding Reference Signal is transmitted via the uplink from User Equipment (e.g., phones) to the base station. The SRS has been utilized for positioning since the introduction of 3GPP Release 16.

On the other hand, the Positioning Reference Signal is sent via the downlink from the base station to the User Equipment. This signal was specifically designed to provide high accuracy in positioning.

Both signals were incorporated into the 5G New Radio specifications. As quoted from Ericsson (n.d.), *"To enable more accurate positioning measurements than LTE, new reference signals were added to the NR specifications. These signals are the positioning reference signal (NR PRS) in the downlink and the sounding reference signal (SRS) for positioning in the uplink."* (Ericsson, n.d.)

The Sounding Reference Signal serves as an uplink reference signal in both 5G New Radio (NR) and LTE. In both systems, its primary purpose is for the base station to estimate the uplink channel quality. In 5G NR, the SRS becomes more important due to the dominant use of Time Division Duplexing (TDD) as a deployment mode (Sharetechnote, n.d.).

The Positioning Reference Signal was specifically designed for positioning. With PRS-based positioning, signals from multiple base stations are collected by the User Equipment, which then locally calculates the arrival time difference to estimate its own position (Mathworks, n.d.).

The Amarisoft Callbox Classic available in the 5G laboratory in Technobothnia has built-in support for both the PRS and SRS signals.

5G laboratory positioning limitations

Our Amarisoft Callbox Classic base station supports both SRS and PRS signals, the two signals which can be used for positioning in 5G networks. However, to pinpoint the precise location of a user device using either signal typically requires data from multiple base stations. This is because the triangulation process which determines a device's position works by measuring the signal's travel time between the base station and the device (see figure 1 and 2). This method requires data from multiple base stations (Technology, n.d.).

In our 5G laboratory, we operate with a single base station with a limited communication range, making triangulation challenging. With data from just one base station, we can only determine the radial distance of the device from that single base station, but we cannot pinpoint its exact position in two-dimensional or three-dimensional space. For accurate 3D triangulation, at least four base stations are typically required. This means we can determine a sphere of possible locations around the base station where a user device might be, but not a specific point on that sphere. In addition, Positioning with a single base station is also more susceptible to interference and noise.

This assumption is excluding some more novel approaches which would allow triangulation using a single base station (Technology, n.d.). Some of these methods take advantage of antenna arrays in MIMO configurations.

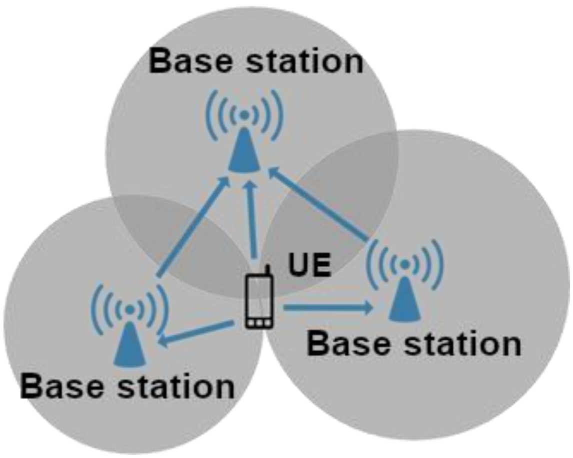

Figure 1 SRS Triangulation

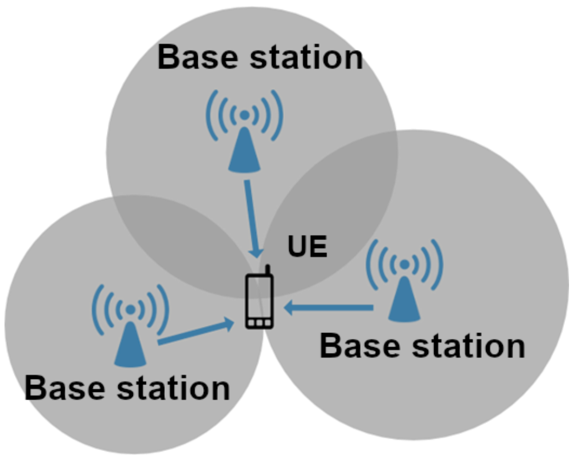

Figure 2 PRS Triangulation

Development process

After thoroughly researching all the tracking possibilities available to us, we started the development of an Interactive map application initially based around the Technobothnia premises. The primary objective of this application was to track, summarize, and display positional data received from local smartphones and other user devices and to display and produce density heatmaps based on historical tracking data. More advanced forms of data analysis were planned.

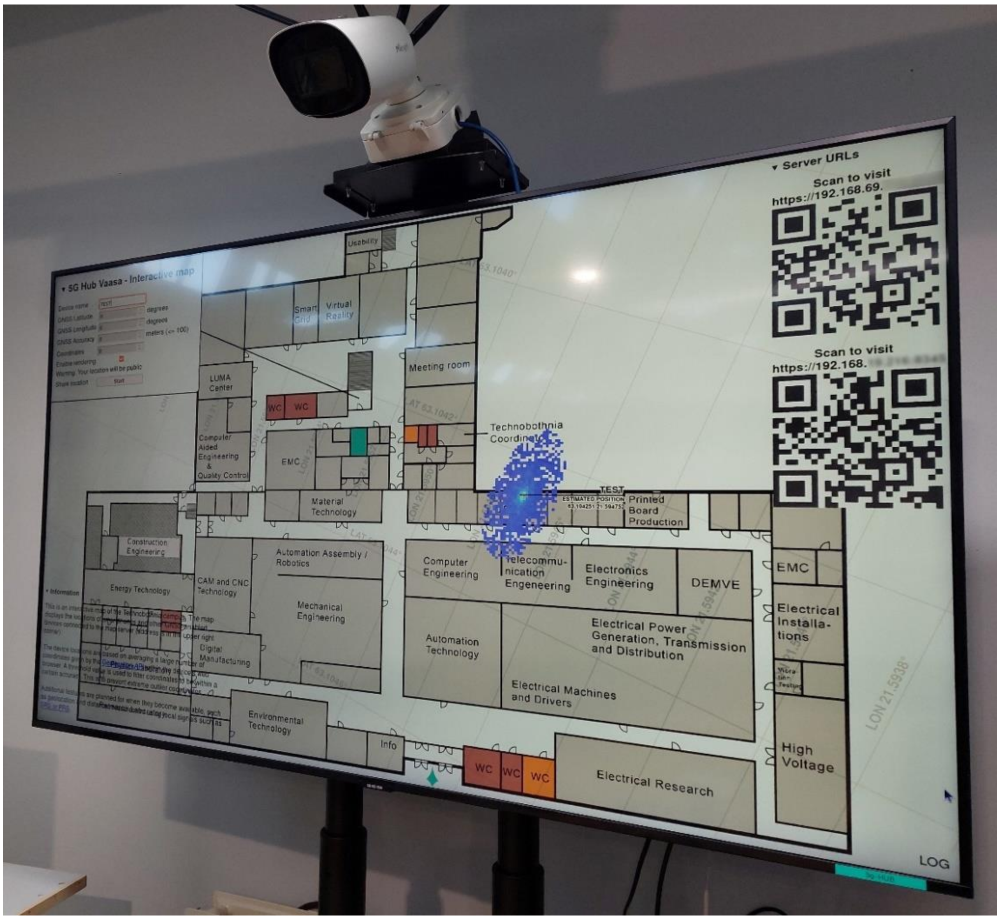

Figure 3 Interactive map web interface

Node.js server

The server component consists of both the tracking data database and the static web server that displays the map interface. We wrote the server in JavaScript using Node.js. It leverages Express.js to serve public website files.

A notable feature of the web server was its ability to generate encryption certificates, or SSL certificates, for the client. This security measure is prevalent as most web browsers on mobile devices mandate that GNSS tracking can only be accessed via a secure, encrypted connection. This is indicated by the lock symbol in the address bar. A self-signed certificate requires manual acceptance.

The server itself is otherwise relatively simple. It keeps a list of connected clients, client names and their reported locations. These details are then relayed to all the other connected clients, allowing all the clients to see each other's locations and for the data to be displayed on a shared map interface.

Map interface website

The server's static website component is built using HTML, CSS, and Vanilla JavaScript. This interface is delivered to the connected clients, displaying a draggable map with a heatmap overlay representing the location of other connected devices. We sourced the Technobothnia background image from the official Technobothnia website. The map is interactive, allowing users to drag it using either mouse or touch input. Each piece of User Equipment is labeled on the map to assist users in distinguishing between different devices. The map also features a latitude and longitude grid.

The overlaid heatmap provides an approximation of the positional accuracy of the tracking for each user device. A more dispersed positional distribution indicates decreased tracking accuracy. The heatmap also approximates the center of mass of the position distribution.

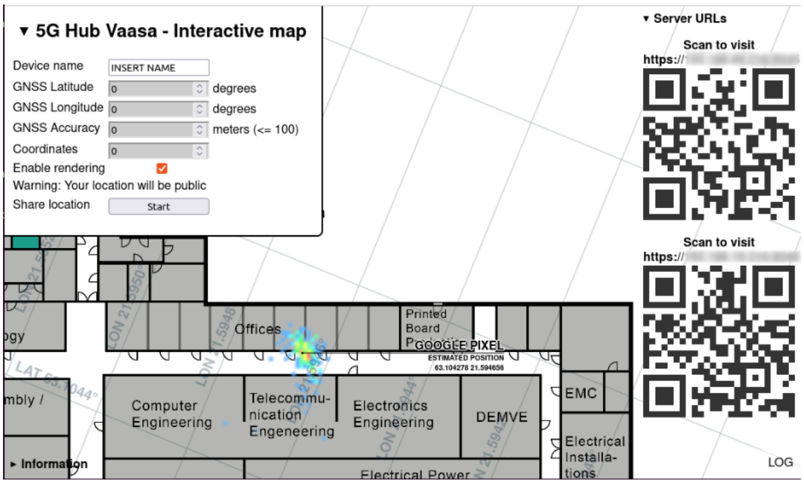

Figure 4 Heatmap centred in the 5G laboratory

To make the interface easier to access, we automatically generate QR codes displayed on the map interface. Clients can scan these with their cameras to directly access the serve.

Websockets

Upon connecting to the website, clients automatically establish a WebSocket connection to the server. Through this connection, they can transmit positioning data and other relevant statistical data to the server in real-time. This data is then relayed by the server to all other clients viewing the map interface. Each mobile device connected to the server gets its position tracked using its built-in Geotracking API, which then gets displayed on the map. Users have the option to attach a name to their device's representation.

Android application

To collect tracking information from the client devices, an additional client application was required. While our initial efforts focused on creating a native Android application, we later transitioned to a completely web-based approach, using the capabilities of the browser's Geolocation API.

Initially, we created a separate tracking app in native Android. We tried several different Android frameworks, looking for the easiest one for future developers to learn and use. The following frameworks were tested:

• **Flutter**: Flutter is an open-source UI software development toolkit created by Google, allowing developers to craft natively compiled applications for mobile, web, and desktop from a single codebase.

• **Capacitor**: Capacitor is a cross-platform runtime that enables web apps to run natively on iOS, Android, and the web.

• **Cordova**: Cordova, previously known as PhoneGap, is an open-source mobile development framework that allows for the creation of mobile apps using HTML, CSS, and JavaScript, wrapped within a native container.

• **Native Kotlin**: Using the Kotlin programming language for developing platform-specific applications without a framework.

After some trial and error, we chose to build a Native Android app in Android Studio using the programming language Kotlin. One critical consideration in our decision-making process was the limitations faced with the frameworks, especially concerning low-level access to tracking APIs/hardware.

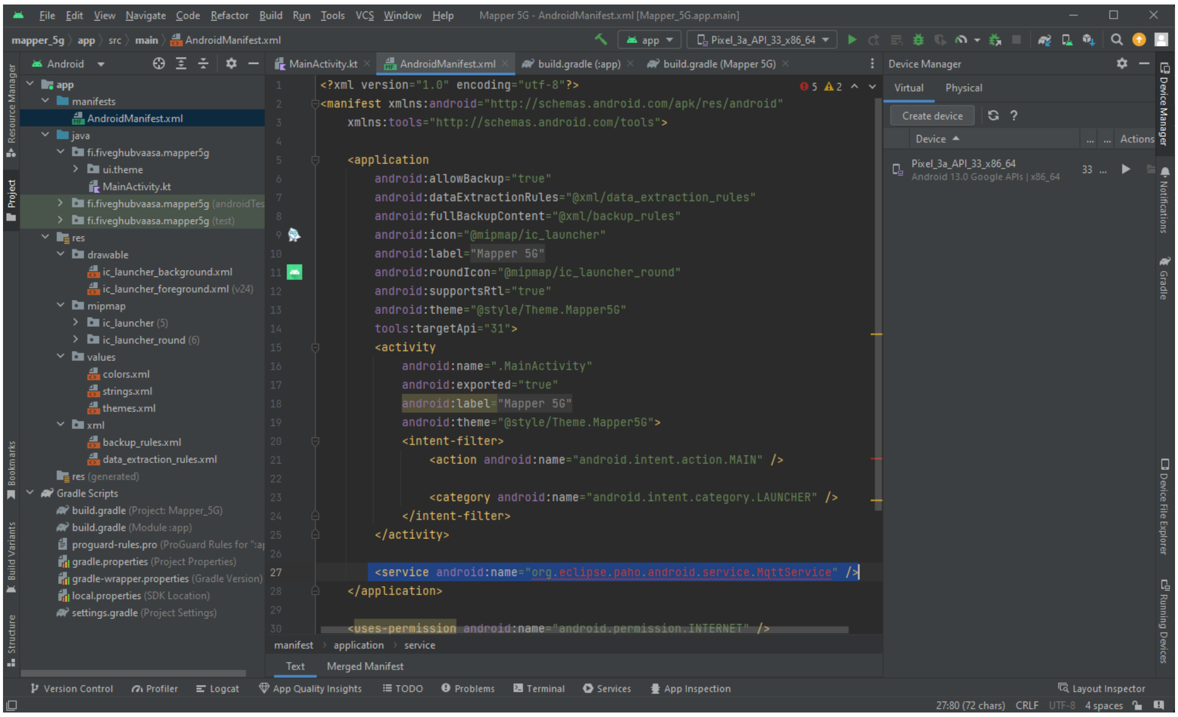

Figure 5 Android Studio

Web based client

The web-based client was later developed as a temporary more easily manageable alternative to the rather complex Native Android client. Since it is a web-based interface. Being web-based, it provided the added advantage of integrating the client application directly with the map interface.

However, the limitation of the web-based client lies in its inability to tap into the lower-level hardware functionalities required for more advanced tracking techniques (such as reading signals from the Radio hardware). This limitation arises because Android web browsers, and often the operating system itself, do not provide access to such low-level hardware components.

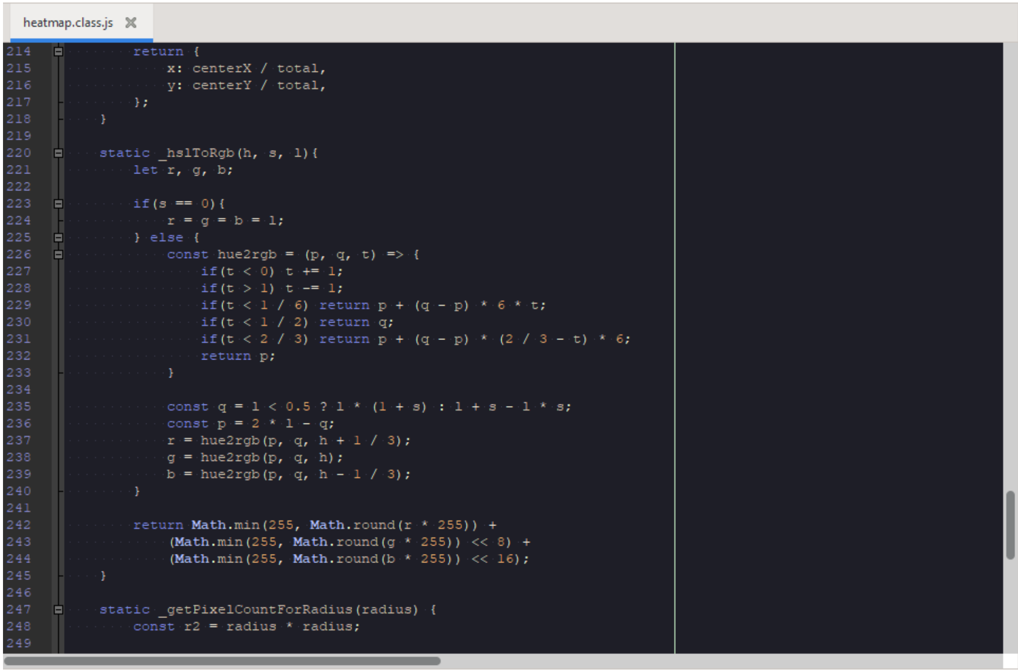

Figure 6 JavaScript development in Geany

Conclusion

The map interface we developed effectively facilitates GNSS tracking. The map shows density distributions of tracking data from smartphones and other user equipment within the 5G laboratories and Technobothnia.

While our current setup does not yet support tracking with 5G-based positioning signals, the system is designed with adaptability in mind, making it feasible to integrate this functionality in the future.

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