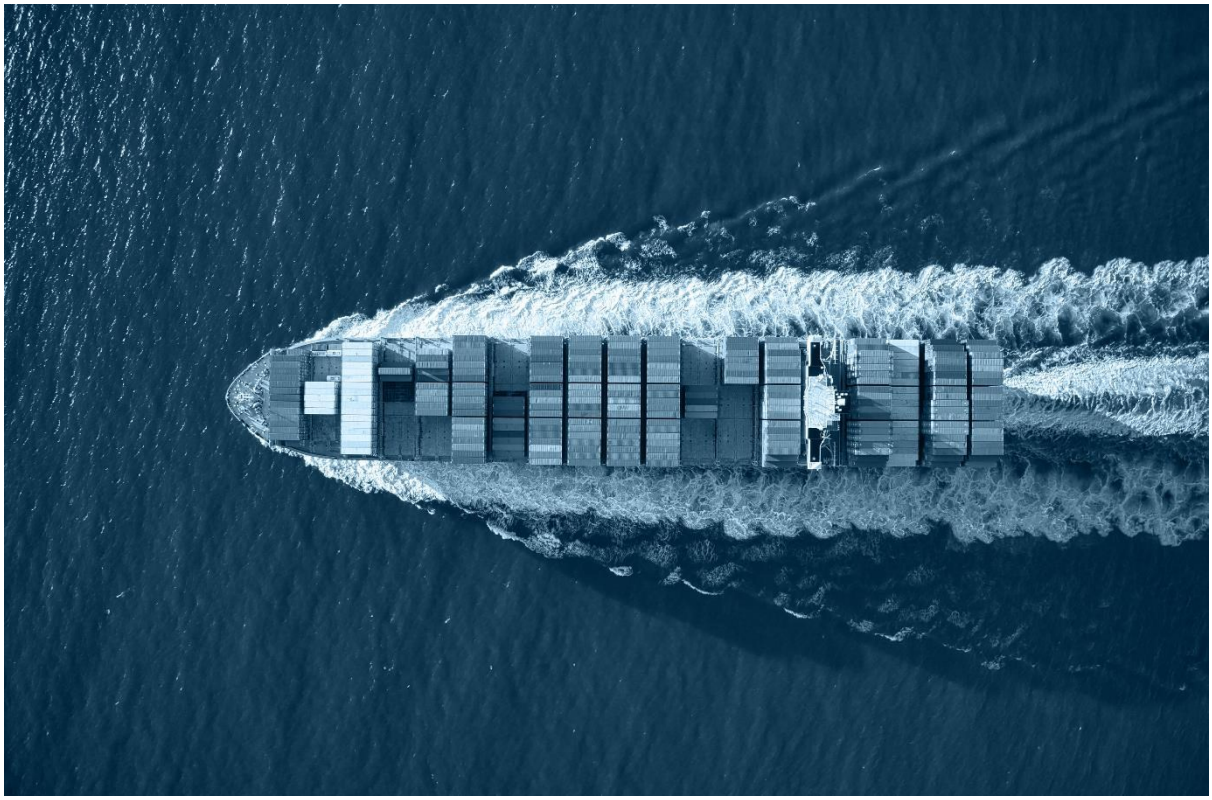
TURKU AMK
TURKU UNIVERSITY OF APPLIED SCIENCES

BUSINESS FINLAND

ADMO DELIVERABLE 2.3 - 5G NETWORK QUALITY OF SERVICE EVALUATION IN MARITIME ENVIRONMENT: A CASE STUDY OF BASE STATION PERFORMANCE IN THE ÅLAND ARCHIPELAGO



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1. INTRODUCTION

To evaluate the quality of service requirements for 5G Advanced (5GA) maritime deployments, it is essential to first understand the current network usage patterns and challenges in maritime environments. This study analyzes two operational base stations in the Åland archipelago to establish baseline performance metrics and identify specific maritime use cases that would benefit from 5GA capabilities. The findings will inform the development of 5GA networks that can better serve both residential and maritime users while meeting the demanding requirements of digitalized maritime services.

Mobile networks covering archipelago and the sea routes may have two kinds of users. There are the local residential users and when ships are passing by there could be a high number of temporary users from the ship. One example is the route between Turku/Naantali and Stockholm/Kapellskär, Sweden. One part of the route is passing two Ålcom 4G base stations at the islands of Sottunga and Jyddö. During the ADMO-project we were able to get data of these two base stations from Ålcom, one of the steering group members of the project.

First data was from Saturday 13.1.2024 14:00 to Monday 15.1.2024 14:00, and the second data from Monday 29.4.2024 00:00 to Thursday 2.5.2024 24:00. The first set is from “quiet” winter period, but the second set includes “Vappu” festivities.

2. SOTTUNGA AND JYDDÖ BASE STATIONS

The Sottunga and Jyddö base station locations are shown in Figure 1. The track of the ships is shown in red. As a ship is approaching from Turku, it is first connected to Sottunga sector B, then switches to sector A and at some point to Jyddö C and then to Jyddö B. These points are marked with black dots in Figure 1. When individual ship movements are analysed, it is enough that we know the time each ship is in any of these points. As points are spread from west to east, it is enough to check the longitude.

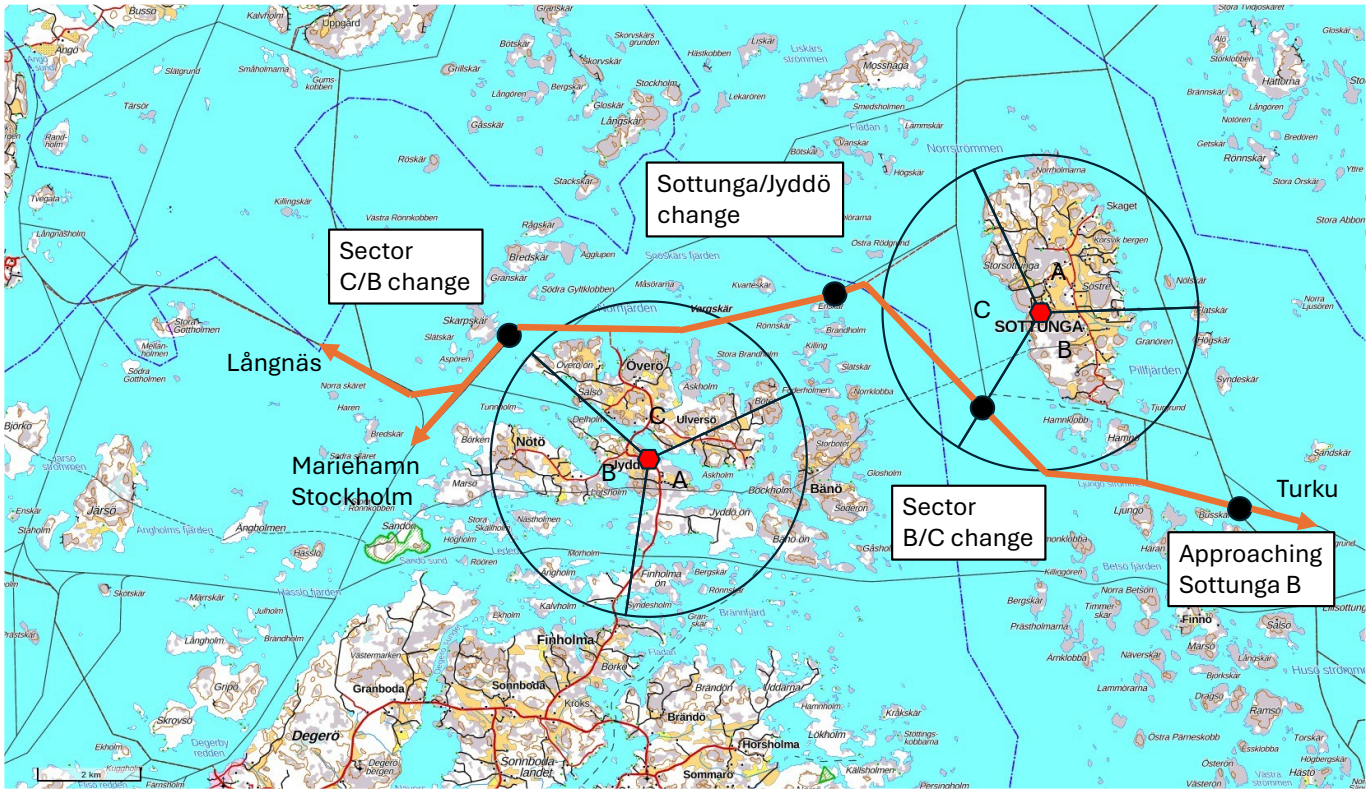

Figure 1 Sottunga and Jyddö BS Sectors and Points of Interest

3. SHIPS

There are 5 big ships that use this route daily with a fixed timetable. In addition, there are a couple of smaller ferries, but they were not found to have any impact on the base stations. In the first data set, the second Finnlines ship was the older FinnSwan with less emphasis on passengers, but the second data set included a new ship FinnCanopus, a sister ship of FinnSirius with much larger passenger facilities.

Viking Grace

Viking Glory

Baltic Princess

FinnSirius

FinnSwan

Small Ferries
Gudingen
Viggen

Figure 2 Ships on the route

For each ship we had the AIS-data available so that we could see when the ship was at any of the points we were interested.

4. SET 1 JANUARY 13.-15.2024

The number of users for each base station and each sector is shown in Figure 3 (Sottunga) and Figure 4 (Jyddö). Sottunga A seems to have only residential traffic as the number of users at 800 MHz is 0, 1 or 2 and at 1800 MHz around 8 with no spikes. For Sottunga B and C the situation is clearly different. There is a basic load of few users, but we can also see spikes of tens and even more than 100 users. For Jyddö the A sector has also clearly residential users at 1800 MHz and just a few users at 800 MHz except a few spikes. The B and C sector has some basic load of few users, but quite high spikes of tens or more than 100 users.

Overall, it seems that for effects of the ships we should study the Sottunga B and C sectors and Jyddö C and B sectors. When the ship movements are compared to the found spikes in the number of users we see a clear correlation between a spike and a ship. The overall situation is shown in Figure 5. All the ship movements can be seen on the user statistics.

Figure 3 Sottunga A B C number of users

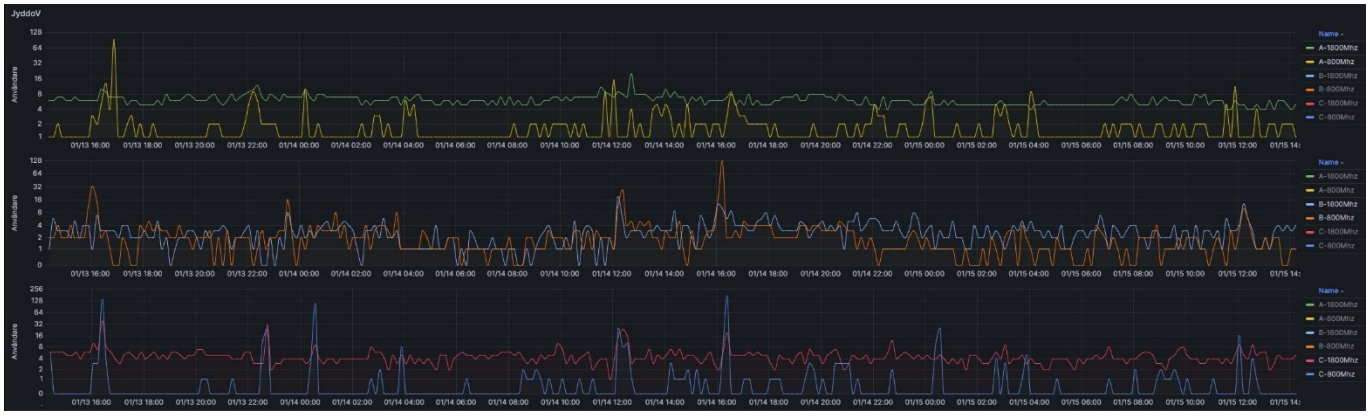

Figure 4 Jyddö A B C number of users

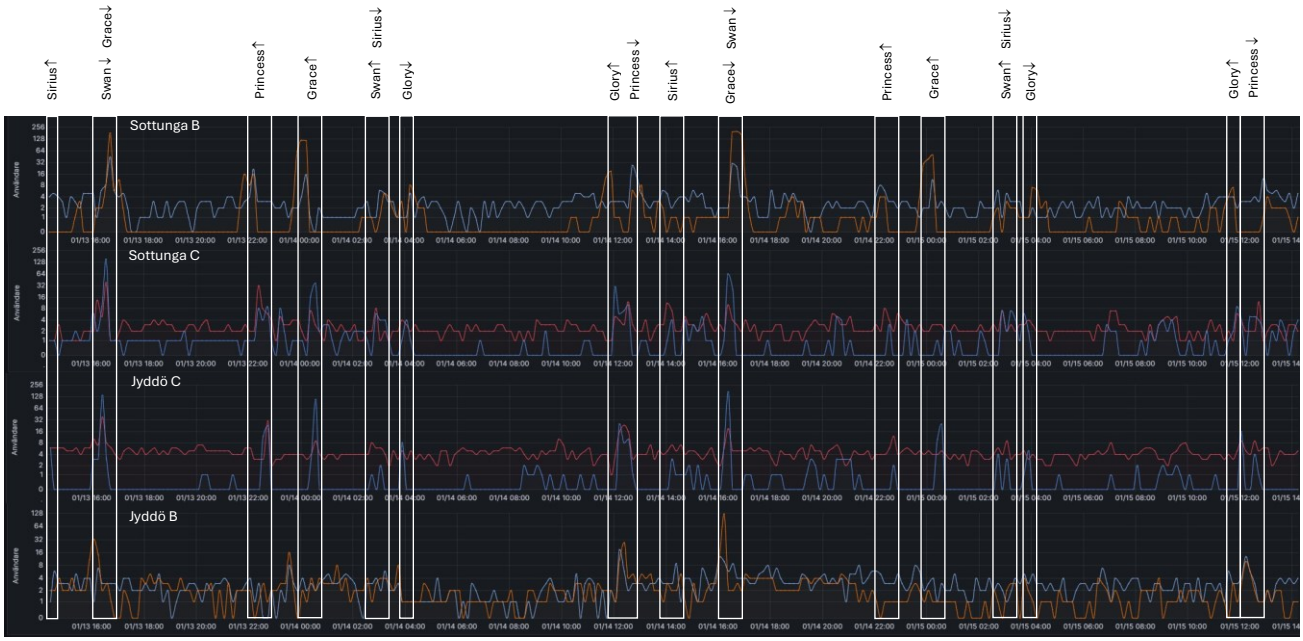

Figure 5 Number of user spikes and ships

On individual ship movements let's take here a couple of examples in a more detailed study. We can first look at Viking Grace on the 13.1. on the way from west to east, shown in Figure 6. The spike is first on Jyddö B, then moves to Jyddö C, then to Sottunga C and finally to Sottunga B. So from the base station user data we can see which way the ship is moving. The height of the spike is smaller in Jyddö B than at the other sectors, probably due to the fact that there are also some other base stations.

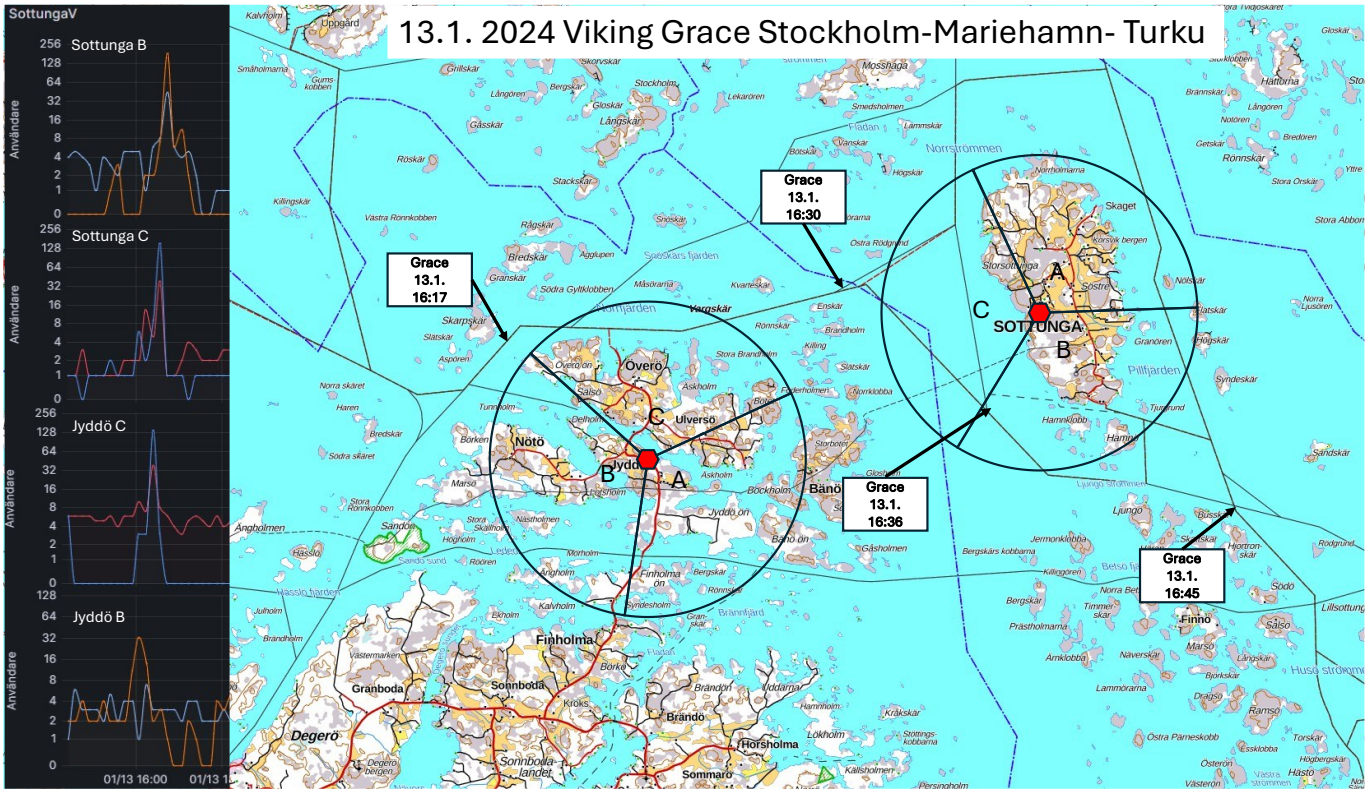

Figure 6 Viking Grace 13.1. 2024

The second case is Viking Glory and Baltic Princess on the 14.1. shown in Figure 7. This is interesting as the ships are moving in different directions, Viking Glory from east to west and Baltic Princess from west to east. In Sottunga B the two spikes are clearly separated by roughly one hour as Glory comes to B sector 11:48 and Princess leaves B sector 12:51. In Sottunga C sector the spike separation is smaller, but we can still see two spikes as the ships are in the area roughly 30 minutes apart. When we move to Jyddö C the spikes are almost overlapping as the separation between ships is smaller and finally in Jyddö B we see the spikes starting separate as the ships have passed by. It is also noticeable that one ship is mostly in 800 MHz band and the other at 1800 MHz band. The reason for this is unknown.

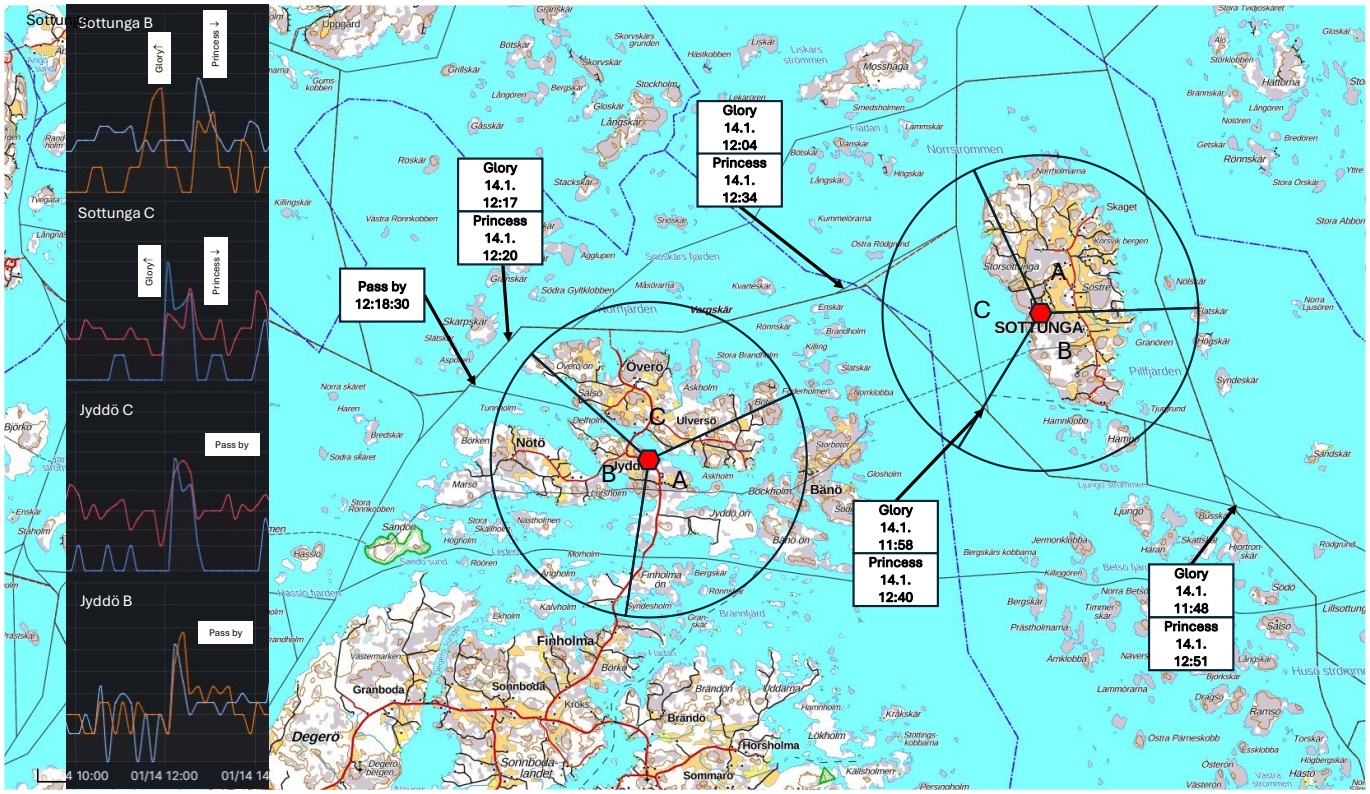

Figure 7 Viking Glory and Baltic Princess 14.1. 2024

5. SET 2 APRIL 29. 00:00 TO MAY 2. 24:00

The number of users for each base station and each sector is shown in Figure 8 (Sottunga) and Figure 9 (Jyddö). Note that the scale is different from the set 1 which had log2 scale (2, 4, 8, 16, 32, 64 etc.), set 2 having linear scale.

We can again see that Sottunga A sector is clearly residential having fairly constant number of users. Interestingly there are more users than in set 1 in January. Now around 20 at 1800 MHz and around 8 at 800 MHz. There are no spikes for ships.

Sottunga B and C sectors have fairly flat base of local users with perhaps less than 10 users on average. It is difficult to see more precisely as the scale is linear to 200. However, there are clear spikes which can easily be distinguished from the flat base. When the spikes are compared to the movements of the ships, we notice that each spike is caused by a ship passing by.

Jyddö A, B and C look all very similar than Sottunga B and C. Jyddö A seems to have more local users than B and C, about 15 to 20 at 1800 MHz and about 5 at 800 MHz. Spikes are now seen on all sectors A, B and C, and they correlate well with the spikes on Sottunga B and C and with the ship movements.

All the ship movements and user statistics of both Sottunga and Jyddö have been collected to Figure 10.

Figure 8 Sottunga A, B and C number of users 29.4.-2.5.2024

Figure 9 Jyddö A, B and C number of users 29.4.-2.5. 2024

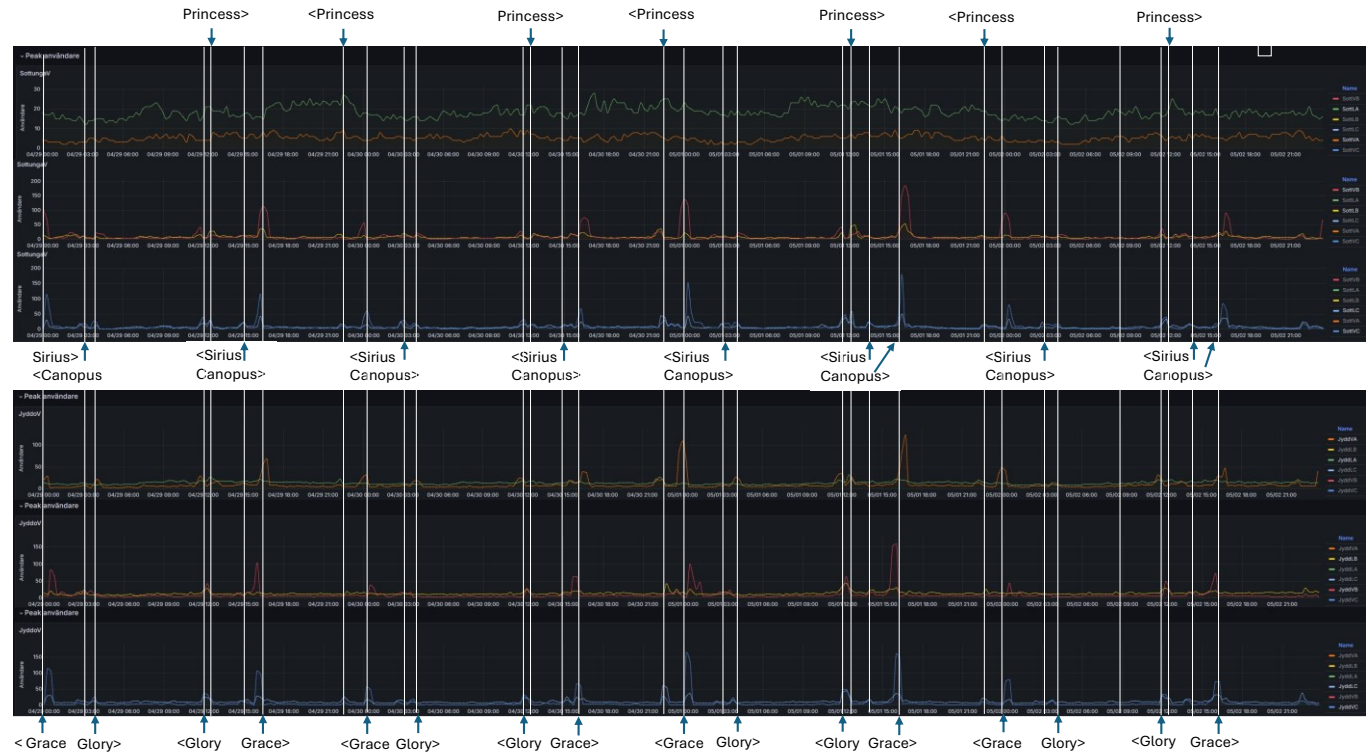

Figure 10 Ship movements and number of users 29.4.-2.5.2025

For the set 2 we also had available the used data for the whole BS (dataförbrukning) as one part of the data set. This can be compared with number of users and ships. This is done here separately for each day for Sottunga B and C sectors (Jyddö would be very similar).

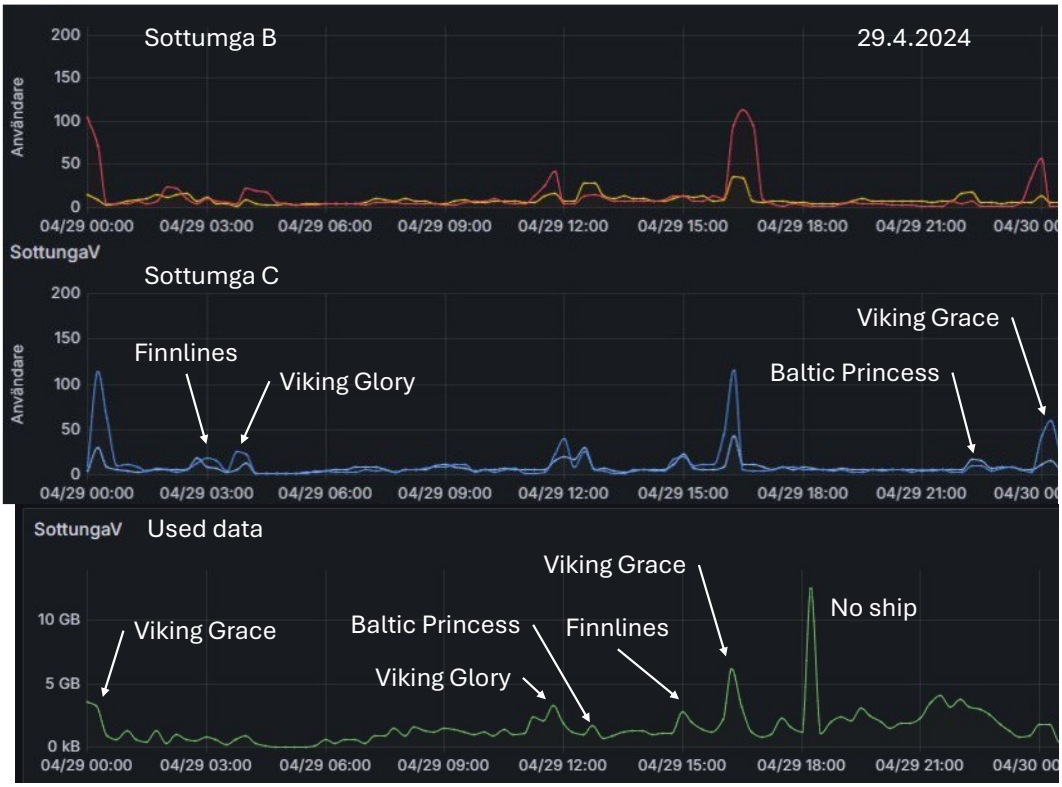

Figure 11 Number of users at Sottunga B and C and total data usage of the site 29.4.2024

Figure 11 shows the situation on Monday 29.4.2024. The various ships can be identified from the spikes on the number of users and on the used data curve. It is interesting to note that the number of additional users and the used data do not directly correlate. Typically, nighttime data usage is smaller than daytime data usage. The highest number of users is with Viking Grace (also on other days) but the nighttime pass (00:00) uses less data than daytime (16:30). The highest amount of used data at around 18:00 is not caused by any ship but must be a residential or some other user. Overall, more data is used in the evening, but there is only one ship, Baltic Princess 22:30, so this comes from other users.

Figure 12 shows Tuesday 30.4.2024 “Vappuaatto”. Less data is used by the ships than previous day and there is a high spike at 21:30, which is not coming from any ship. Number of users at 24:00 with Viking Grace is very high, but additional data usage is fairly low.

Figure 13 shows Wednesday 1.5.2024 “Vappu”. Much more data is used by the ships than the previous day. Maybe people were celebrating more on “Vappuaatto” and “Vappu” was then more peaceful, and more content was used. Number of users was the highest of all days.

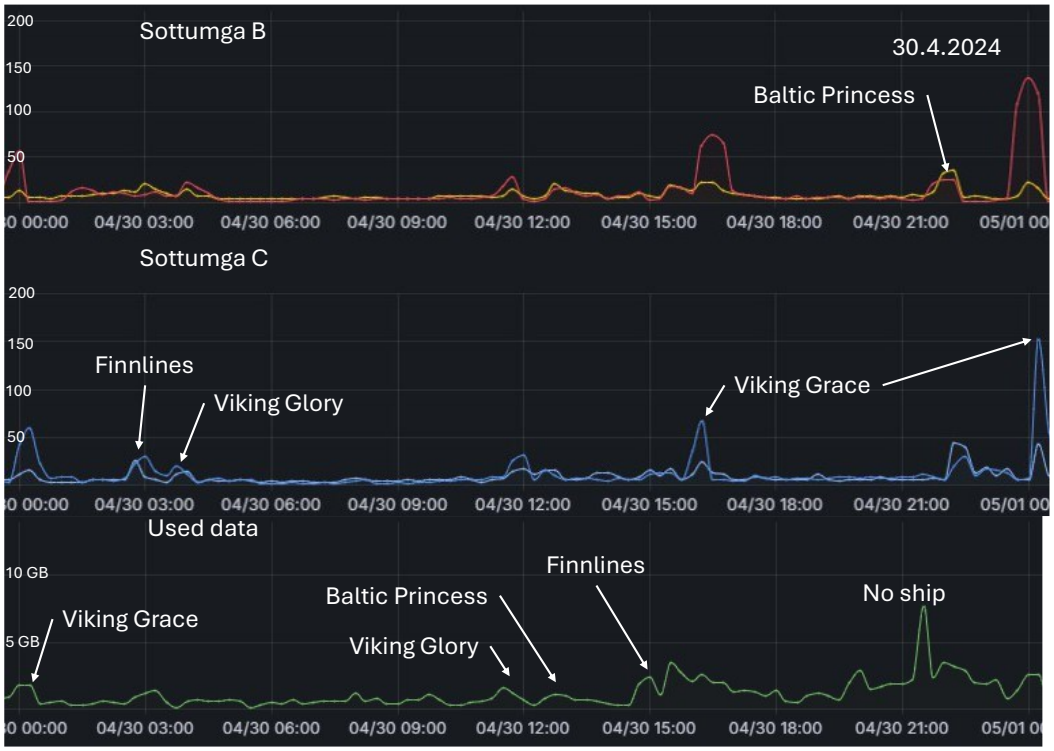

Figure 12 Number of users at Sottunga B and C and total data usage of the site 30.4.2024

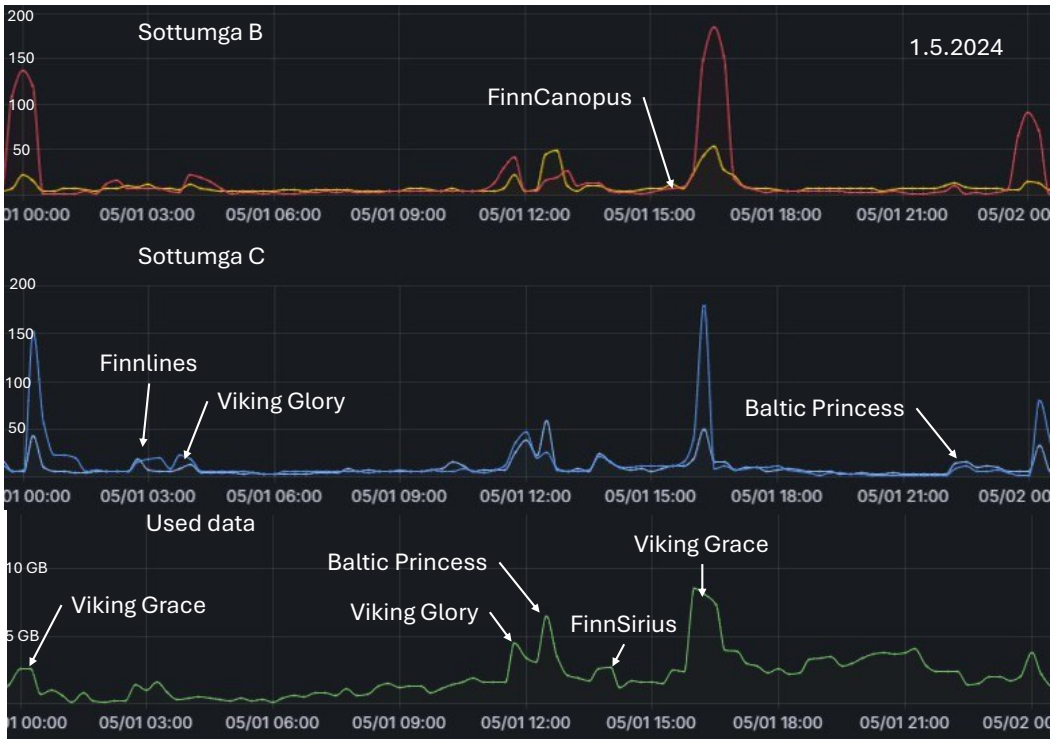

Figure 13 Number of users at Sottunga B and C and total data usage of the site 1.5.2024

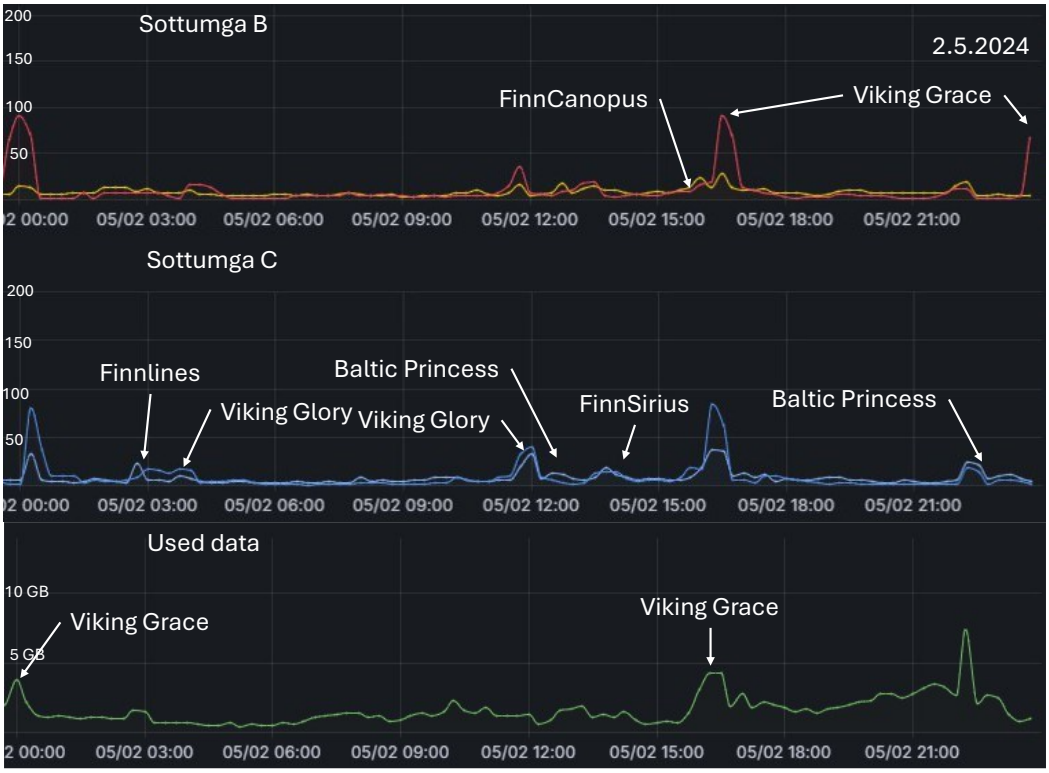

Figure 14 Number of users at Sottunga B and C and total data usage of the site 2.5.2024

Figure 14 shows Thursday 2.5.2024, which is back to normal after the “Vappu”. Still Viking Grace is quite noticeable and especially Baltic Princess 22:30 has high data peak even if the number of users is not very high.

From the user statistics of both Sottunga and Jyddö the highest number of connected users from each ship pass can be roughly estimated. This was done so that for each ship pass either one of the Sottunga sectors or one of the Jyddö sectors value was selected, whichever was the highest. As each ship has two passes per day, these are added to get the daily number. This is shown in Table 1.

Table 1 Number of users attached to base stations each day

Ship	Number of user/day				
	29.04.2024	30.04.2024	01.05.2024	02.05.2024	Total
Viking Grace	310	175	440	250	1175
Viking Glory	100	90	120	100	410
Baltic Princes	80	110	115	70	375
Finnsirius / Finncanopus	70	80	90	110	350

Probably the numbers reflect to some extent the popularity of the ship or suitability of the timetable, but there could also be other reasons. A ship can have windows with metal coating so that signal levels are reduced and less UEs are connected to the base stations. Also, a ship can have good internal WiFi, which is then used by the passengers instead of the mobile

networks. Obviously, the ship should have in this case the connectivity from somewhere, but this does not show to the mobile networks as many users although the data load can be high. The ship can also use satellite connectivity, but this is typically more costly.

From the used data curves of the Sottunga base station in Figure 11 to Figure 14 we can roughly estimate the additional peak data usage per ship. This is shown in Table 2. It has similar characteristics as the number of users Viking Grace having the highest data peaks.

Table 2 Peak used data at Sottunga BS for each day

Ship	Peak used data at Sottunga BS [GB]				
	29.04.2024	30.04.2024	01.05.2024	02.05.2024	Total
Viking Grace	10	6	11	8	35
Viking Glory	5	1	5	0	11
Baltic Princes	1	3	6	5	15
Finnsirius / Finncanopus	3	3	5	3	14

6. CONCLUSIONS

Analysis of two base stations in the Åland archipelago revealed distinct patterns in mobile network usage between residential and maritime users. The residential user base remained stable at 5-20 users per sector, while ship passages created predictable, short-duration spikes of up to 100+ users. These usage patterns highlight specific challenges that 5GA networks will need to address in maritime environments.

The relationship between user numbers and data consumption showed interesting variations that have implications for 5GA network planning. Peak user numbers from ships did not necessarily correspond to high data usage, suggesting that 5GA networks will need sophisticated resource allocation mechanisms to efficiently serve maritime traffic.

While the current infrastructure demonstrated robust performance throughout the study period, several areas for 5GA enhancement were identified:

1. Need for more dynamic resource allocation to handle rapid user number fluctuations from passing vessels
2. Opportunity for predictive resource management based on known ship schedules
3. Potential for dedicated maritime slicing to better serve ship-specific applications
4. Requirements for enhanced uplink capabilities to support emerging maritime use cases

These findings provide valuable insights for 5GA network planning in maritime environments. Future 5GA deployments should focus on implementing adaptive resource allocation, enhanced coverage solutions, and specialized maritime service features. The observed usage patterns suggest that 5GA networks will need to be dimensioned differently from traditional terrestrial networks to effectively serve both residential and maritime users while meeting the quality of service requirements for advanced maritime applications.