ASSISTANCE

Adapted situation awareneSS tools and taIlored training curricula for increaSing capabiliTies and enhANcing the proteCtion of first respondErs

European Commission

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Author / Organisation	Davor Todorovski (VIASAT) Rayco Pérez (VIASAT)

Deliverable D5.3

Robust Land Mobile Communications Infrastructure Development

07/01/2021

[1] PU: Public; PP: Restricted to other programme participants (including the EC services); RE: Restricted to a group specified by the Consortium (including the EC services); CO: Confidential, only for members of the Consortium (including the EC services).

ASSISTANCE

Nowadays different first responder (FR) organizations cooperate together to face large and complex disasters that in some cases can be amplified due to new threats such as climate change in case of natural disasters (e.g. larger and more frequent floods and wild fires, etc) or the increase of radicalization in case of man-made disasters (e.g. arsonists that burn European forests, terrorist attacks coordinated across multiple European cities).

The impact of large disasters like these could have disastrous consequences for the European Member States and affect social well-being on a global level. Each type of FR organization (e.g. medical emergency services, fire and rescue services, law enforcement teams, civil protection professionals, etc.) that mitigate these kinds of events are exposed to unexpected dangers and new threats that can severely affect their personal safety.

ASSISTANCE proposes a holistic solution that will adapt a well-tested situation awareness (SA) application as the core of a wider SA platform. The new ASSISTANCE platform is capable of offering different configuration modes for providing the tailored information needed by each FR organization while they work together to mitigate the disaster (e.g. real time video and resources location for firefighters, evacuation route status for emergency health services and so on).

With this solution ASSISTANCE will enhance the SA of the responding organisations during their mitigation activities through the integration of new paradigms, tools and technologies (e.g. drones/robots equipped with a range of sensors, robust communications capabilities, etc.) with the main objective of increasing both their protection and their efficiency.

ASSISTANCE will also improve the skills and capabilities of the FRs through the establishment of a European advanced training network that will provide tailored training based on new learning approaches (e.g. virtual, mixed and/or augmented reality) adapted to each type of FR organizational need and the possibility of sharing virtual training environments, exchanging experiences and actuation procedures.

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Disclaimer

List of Authors

Organisation	Authors
VIASAT	Davor Todorovski
VIASAT	Rayco J. Pérez
VIASAT	Alessandro Pelosi
VIASAT	Stephane Provost

Change control datasheet

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2.0	Clarification regarding the on-field demonstrations	5	61	07/01/21

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Acronyms

ASSISTANCE	Adapted situation awareneSS tools and taIlored training curricula for increaSing capabiliTie and enhANcing the proteCtion of first respondErs
PC	Project Coordinator
D#.#	Deliverable number #.# (D1.1 deliverable 1 of work package 1)
DoA	Description of Action of the project
EC	European Commission
EU	European Union
GA	Grant Agreement
H2020	Horizon 2020 Programme for Research and Innovation
IPR	Intellectual Property Rights
M#	#th month of the project (M1=May 2019)
WP	Work Package
IPR	Intellectual Property Rights
PSC	Project Steering Committee
PIC	Project Implementation Committee
PSB	Project Security Board
AB	Advisory Board
TL	Task Leader
WPL	Work Package Leader
MANET	Mobile Ad Hoc Network
AMR	Adaptive Multi-Rate
AES	Advanced Encryption Standard
MJPEG	Motion Joint Photographic Experts Group
LTE	Long Term Evolution
GSM	Global System for Mobile Communications
GPS	Global Positioning System
RSA	Rivest–Shamir–Adleman
SHA	Secure Hash Algorithms
SMA	SubMiniature version A
PTZ	Pan-Tilt-Zoom
SOAP	Simple Object Access Protocol
MIMO	Multiple-Input and Multiple-Output
SIMO	Single-Input and Multiple-Output
KaLMA	Ka-band Land Mobile Antenna
UL/DL	Uplink/Downlink

1. Introduction

1.1. Executive Summary

This deliverable presents the practical development and implementation of the mobile communications infrastructure proposed by Viasat for the ASSISTANCE project. It contains a detailed description of the Viasat land vehicle (communication hub) with its components and technical specifications. In addition, this deliverable contains descriptions and results of the tests performed in the previous months in order to evaluate the performance and capabilities of the system.

1.2. Purpose of the Document

The purpose of this document is to provide to ASSISTANCE a complete description of the communications infrastructure with all its components and functionalities. In addition, the deliverable provides a description of the performed system tests in order to provide visibility to all the partners of the way the system fulfils the ASSISTANCE requirements.

1.3. Scope

The scope of this deliverable covers:

- Viasat land vehicle (communication hub) presentation
- Communication hub functional description
- Communication hub components description
- System tests description
- System tests results analysis
- MANET tests description
- MANET tests results analysis

2. ASSISTANCE Network Architecture Overview

One of the main goals of ASSISTANCE is to establish reliable and secure connectivity between the field units, field commanders (operational level) and the C2 centres (tactical level). The overall ASSISTANCE communication solution is based on a secure hybrid network approach that will provide high availability in remote areas outside of the coverage area of traditional communication networks or areas where these networks have been disrupted due to an emergency. The hybrid network will provide the necessary availability and data rates within the latency constraints in order to support the large set of interactions between the field units and C2 centres in time-critical missions.

The proposed network architecture for ASSISTANCE consists of three main segments:

- **Command and Control centre** is the unit that has a global view and control of all the components of the ASSISTANCE project.
- **Radio network** presents the last-mile network that connects the field units and UxVs to the communication hub.
- **Viasat Land Vehicle** that acts as the backhaul to the radio network, i.e. the communication node which connects the radio network to the C2 centre. The Viasat Land Vehicle has three main functionalities:
    - **Communication hub** - The main goal of this nomadic communication hub is to provide network coverage to areas where the ordinary land communication systems are not available due to lack of coverage, unreliability or disruption.
    - **On-board camera** – The vehicle will be mounted with an IP camera that will stream a real time video and can be controlled both by an operator inside the vehicle.
    - **Ground control station** – The vehicle can host an operator of the camera, as well as an officer who has situational awareness and can coordinate and provide support for the on-field units.

The more detailed description of the network architecture has been presented in the deliverable "ASSISTANCE D3.3: Robust Mobile Communications".

3. Communication Hub Architecture

This section describes each of the components of the communication hub and their functionalities in the setup. The detailed diagram of the setup inside the communication hub is illustrated in Figure 1. The communication hub connects the radio network to the C2 centre by using two different networks: LTE network and satellite network. This allows the communication hub to use the LTE network with low latency when the vehicle is in LTE coverage area and switch to using the Viasat satellite network in cases when there is no LTE coverage, which is very common for the use cases in the ASSISTANCE project. This will ensure high reliability and availability even in rough terrains and changing conditions. The components in the communication hub are described in the following subsections.

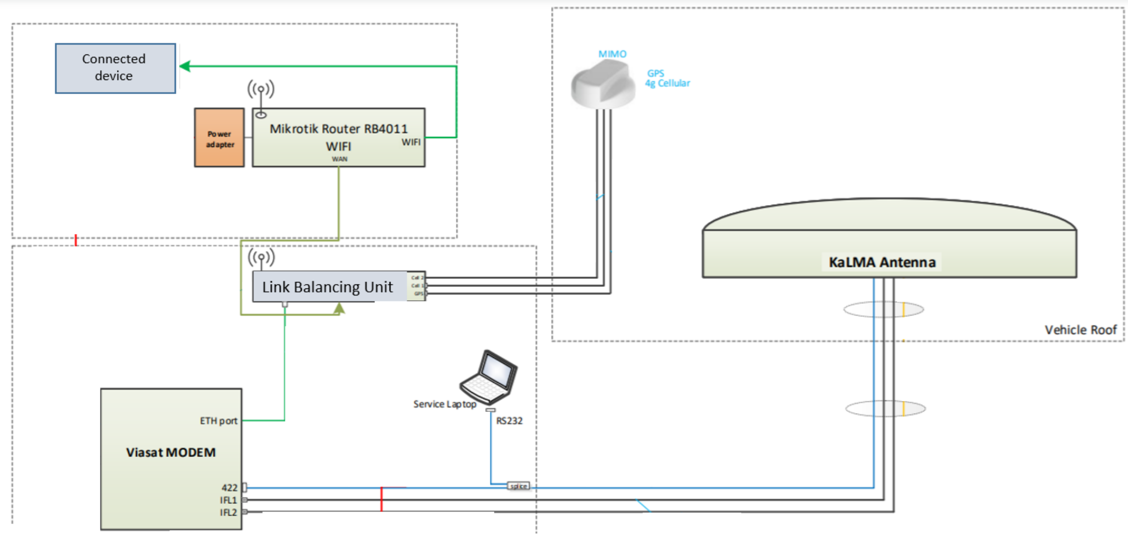


Figure 1 - Communication hub diagram

3.1. Network Camera

The camera mounted on the vehicle is an IP surveillance camera – “AXIS Q6215-LE PTZ” which is robust network camera specially designed with high precision pan, tilt and zoom and long-range IR to cover wide and long-distance surveillance. The camera can recognise and identify objects in large open areas even in poor light or complete darkness which makes it very useful for the use cases covered in ASSISTANCE.

The real time video stream from the camera can be played by accessing the Axis web interface with HTTP through the IP address of the camera. The user can modify all the parameters of the camera and configure the RTSP stream on the camera such that it can be played by any video player hosted on a device which has access to the camera’s subnet.

Figure 2 - AXIS Q6215-LE PTZ network camera

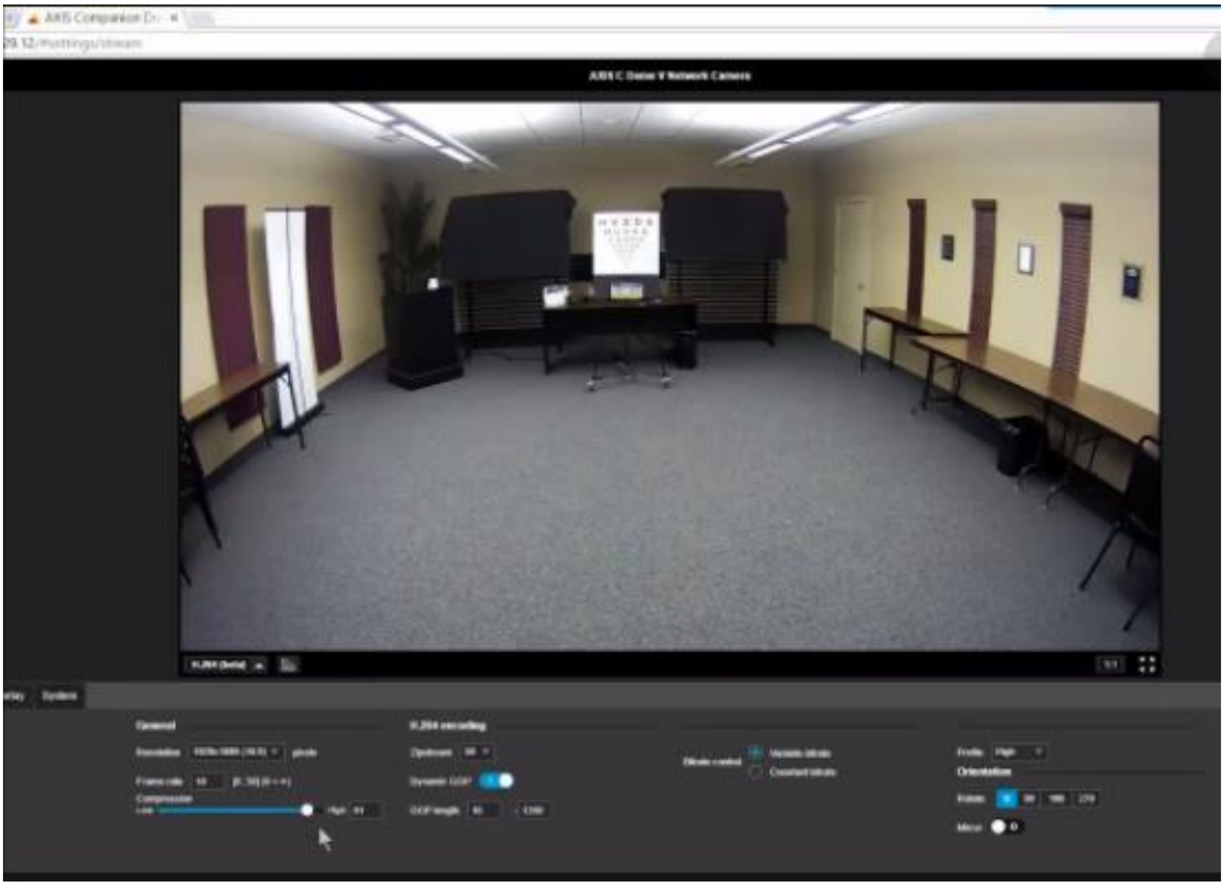


Figure 3 - Axis web interface

Figure 4 - Axis network camera mounted on the communication hub

3.2. MikroTik RB4011 Router

The MikroTik RB4011 router is used in the communication hub to interconnect all the devices. In addition, it provides Wi-Fi connectivity to users and devices located in a close proximity to the communication hub. The router and its detailed schema are illustrated in Figure 5.

Figure 5 - MikroTik RB4011 router

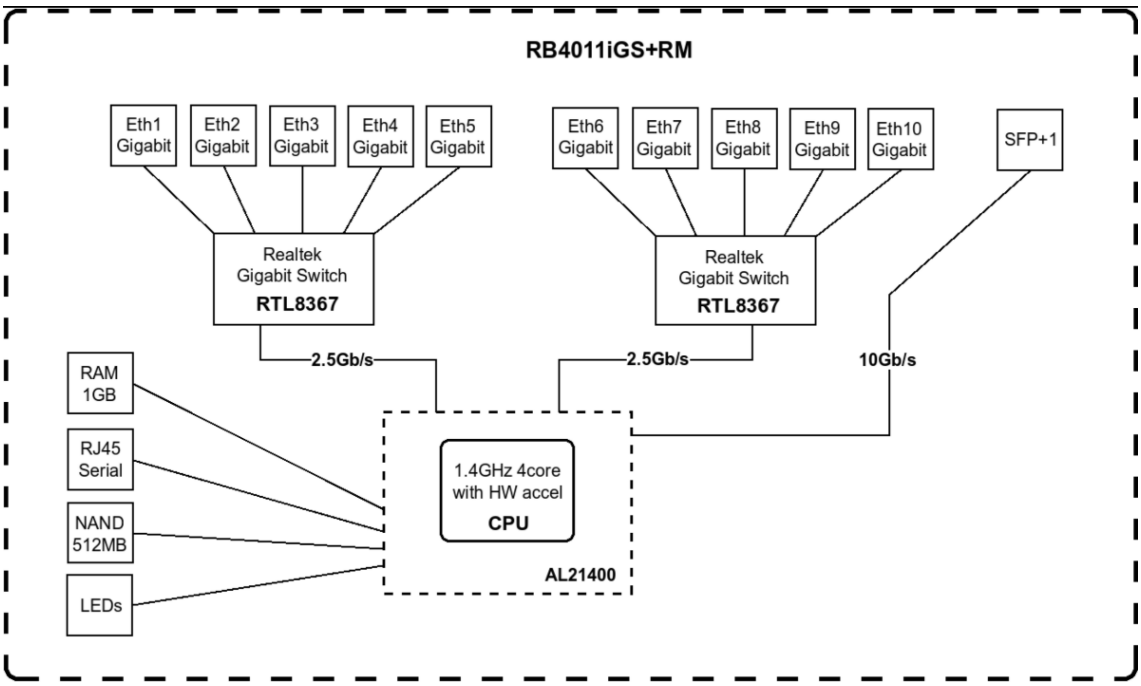


Figure 6 - MikroTik RB4011 schema

3.3. Link Balancing Unit

The link balancing unit has the functionality of utilizing several links to connect the on-field agents and the C2 centre. In the current setup, the link balancing unit utilizes two backhaul links (satellite and LTE). In order to ensure reliability and availability in different network scenarios, two separate VPN tunnels (one over LTE and the other over the satellite link) are established between the Link Balancing Unit on-board the Viasat communication hub (vehicle) and the VPN concentrator hosted in a virtual private cloud which terminates the VPN tunnels. The Link Balancing Unit and VPN concentrator manage the VPN tunnels to provide Active/Standby failover between the two links (LTE and satellite). The VPN tunnels act as a single logical VPN tunnel by performing packet-based fail-over between the links.

Figure 7 - Link Balancing Unit

The communication hub can establish the satellite link by utilizing the self-pointing Viasat “KaLMA” satellite antenna or the Dawson “Dawson SC Zero 70 KA-SAT” fully automated system.

3.4. Dawson Satellite Antenna System

The Dawson SC Antenna is a fully automatic flyaway antenna system that operates on the satellite Eutelsat KA-SAT as well as other Viasat networks around the world. Figure 9 presents the system in a lab setting and is used solely for illustration purpose (the system shown in the figure is not powered on). The full system specifications are presented in Figure 10Figure 9.

Dawson produces in partnership with Viasat Inc. a set of auto pointing antennas for outdoor nomadic applications.

These antennas come on two different setups:

1. Vehicle mounted, equipped with all the necessary kit to be setup on top of a van or any other capable vehicle. It has advanced stowing capacities to reduce the stow size and reduce aerodynamic drag.
2. Ground based, with appropriate tripod for field deployment, this antenna can be disassembled in parts and can be carried in appropriate flight cases for remote site setup.

This antenna set, also, can be accompanied by an appropriate energy module able to provide electrical power in quantity sufficient for 24h operations on locations where no other source is available.

The antenna pointing system is able to discover the given satellite position dialoguing directly with the SATCOM modem and getting the relative information from the standard “satinfo” file available on the modem file system.

Figure 8 - Dawson antenna system deployed in the EMSA project

The antenna control unit is able to dialogue with both the TRIA module and the modem to ensure correct pointing and beam selection, plus is able to keep memory of the latest position where the satellite had been fund in order to speed up the antenna pointing in case the vehicle/field of operation had not been moved. (E.g: multi day operation with overnight stowing)

Some application for this antenna:

- Provide field internet connectivity to a mobile pilot station to operate an UAV from a remote and unconnected field. (Project "Viadrone").
- Provide connectivity to an emergency deployed control station to operate "on field" remote sensor image treatment to prevent pollution in the Mediterranean Sea caused by illegal oil tanker spill (Project EMSA shown in Figure 8).

Figure 9 - Dawson SC Zero 70 KA-SAT antenna system in the Viasat lab (powered off)

Section	Item	Specification
Power requirement	**Prime power** **Power consumption**	220 V AC (12 V DC optional) Approximately 100W
Physical	**Antenna box** **Equipment box** **Positioner box**	850 H x 820 W x 180 D (mm) Wt 14 Kg 240 H x 560 W x 620 L (mm) Wt 19 Kg 410 H x 360 W x 1120 L (mm) Wt 34 Kg
Operation	**Set up / Pointing time** **Pointing system**	<4 minute typical Fully automatic Manual over ride and emergency stow
Environmental	**Temperature (use)** **Wind speed** **Rain**	Minus 40 to Plus 60 C 70 Kph use 160 Kph stow (with ballast) Fully waterproof in use
Construction	**Antenna system** **Reflector** **Base**	Aluminium and stainless steel ViaSat OEM part Stainless steel tripod
Positioner	**Elevation range** **Azimuth range** **Polarisation range**	10 - 90 Degrees fully motorised 200 degrees +/- fully motorised Automatic switching of polarity
Performance	**BUC size** **Data rate TX** **Data rate RX**	Standard ViaSat E TRIA KA-SAT services supported KA-SAT services supported
RF	**Antenna**	Eutelsat KaSat
	Frequency	KaBand
	Compatibility	Eutelsat KA-SAT
	Antenna size **Feed**	75 cm nominal Circular Polarised KaBand

Figure 10 - Dawson SC Zero 70 KA-SAT technical specifications

3.5. KaLMA satellite antenna

The KaLMA antenna is a self-pointing Ka-band satellite antenna mounted on the communication hub (Viasat Land Vehicle). This antenna is used to establish a link to the satellite, thus creating the backhaul link through the Viasat core satellite network.

The Kalma antenna solution is based on fixed beam radiating panels mounted on a 2-axis mechanically steerable platform that is oriented toward the satellite by means of 2 electrical motors (Elevation and Azimuth). The radiating aperture utilizes a proprietary planar array antenna design. The antenna is designed to interface with standard SurfBeam-2 RF components and modem but can be integrated with third party components.

The radiating aperture is based on two distinct rectangular arrays, one for Transmit and one for Receive that interface with the SurfBeam-2 electronics. The antenna electronics is controlled by onboard electronic based on the information of embedded attitude sensors and signal quality information coming from the SurfBeam-2 modem. The antenna is enclosed in a composite frame suitable for Ka-band radiation and allowing the use of the antenna in outdoor conditions. The frame is equipped with brackets for mounting on ground vehicles. This antenna can be easily installed on different type vehicles and has demonstrated high satellite tracking capabilities while on-the-move.

Specifications:

- KA SOTM Antenna Terminal – Operates while vehicle is moving
- Automatic satellite acquisition and tracking
- Operates in emerging Ka-band services worldwide
- Low profile Antenna <33 cm in height with Look angles 10°-90°
- Compliant with FCC and ITU for Mobile VSAT
- Affordable Rugged and Highly Reliable
- Operational wind speed of 115 mph or better
- Compliant with ViaSat HTS and similar Ka-band networks.
- Antenna dimension: L: 51.2” - W: 51.2” H: 13”
- Weight: 88 lbs

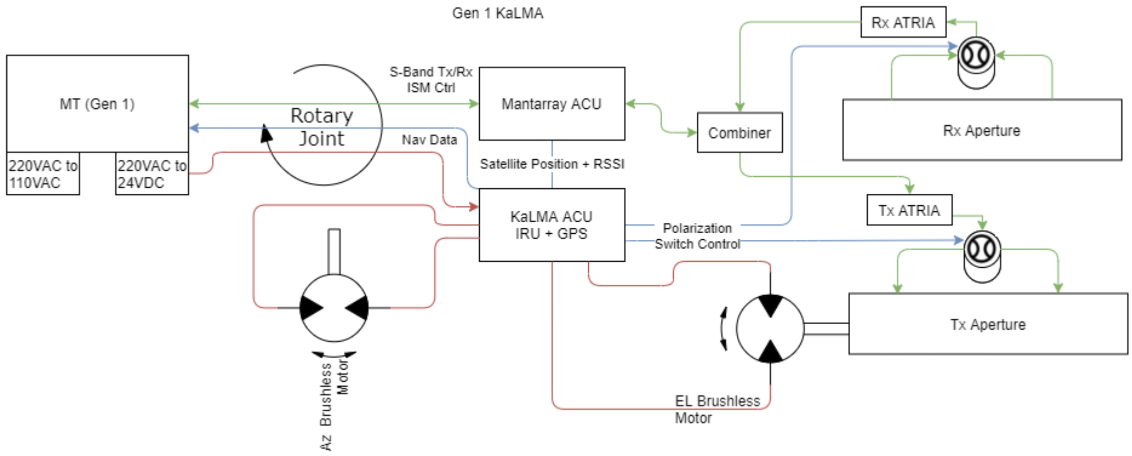


Figure 11 - Architecture diagram of the KaLMA antenna

Figure 12 - KaLMA antenna mounted on the roof of the Viasat Land Vehicle

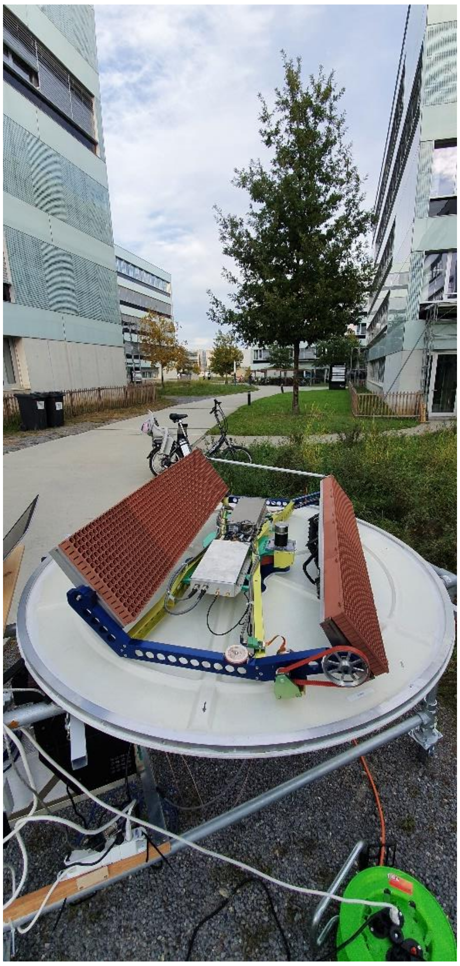


Figure 13 - Testing with the KaLMA antenna

Figure 14 - Viasat mobile terminal (modem) and ACU power source

3.6. Panorama MIMO Antenna

The LGMMFFR-7-27 is a high performance MIMO antenna covering 698-2700MHz mounted on the roof of the communication hub (Viasat land vehicle). The LGMMFFR-7-27 consists of up to 5 elements; two isolated high performance antenna elements covering 698-2700MHz offer MIMO/diversity at cellular/LTE frequencies, up to 2 optional dual band elements covering 2.3-2.7 & 4.9-6GHz support MIMO/diversity operation for WIFI and WiMAX and a high performance GPS antenna with an integrated 26dB gain LNA.

Figure 15 - Panorama LGMMFFR-7-27 antenna in the lab

Electrical Data	
LTE Frequencies	698-960/1710-2700MHz
Global Positioning	Optional GPS L1 1575; GPS L1 1575
Wifi Frequencies	MiMo - 2.4/5.0GHz - (Optional)
Peak Gain (dBi)	5
LTE MiMo	2x2
WiFi MiMo	Optional 2x2;
Max Input Power (W)	20
Pattern	Omni-directional
Ground Plane Independent	Yes

Figure 16 - Panorama LGMMFFR-7-27 technical specifications

4. System tests

4.1. Long driving tests

This section presents the tests that have been performed with the presented system and the obtained results. The goal of the test was to drive along pre-defined routes with the communication hub for 72 hours in order to evaluate the performance of the system during a long period of active use. The routes for the testing are presented in Figure 17, Figure 18 and Figure 19 respectively.

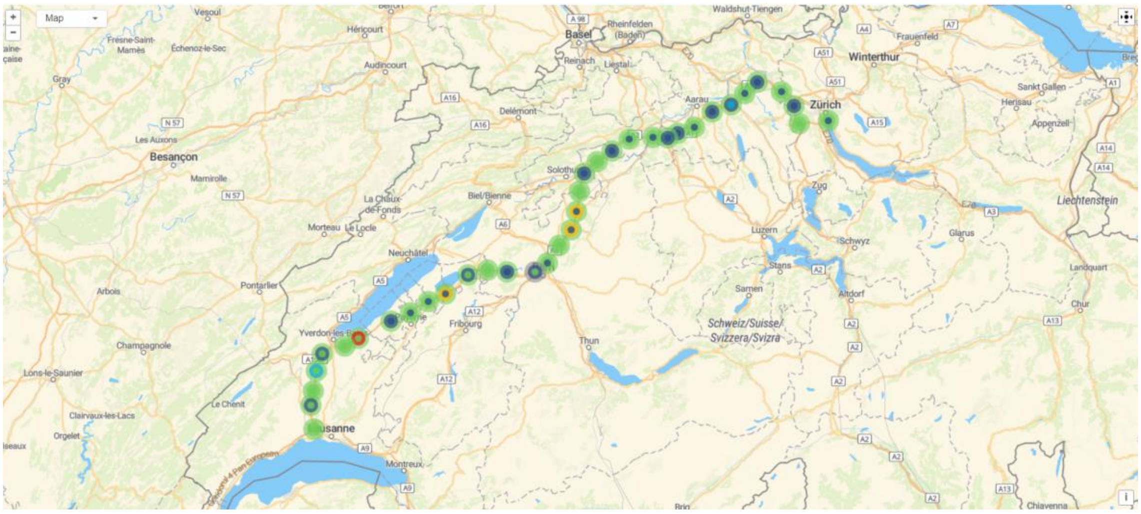


Figure 17 - Driving route taken on 13.11.2020 (230 km)

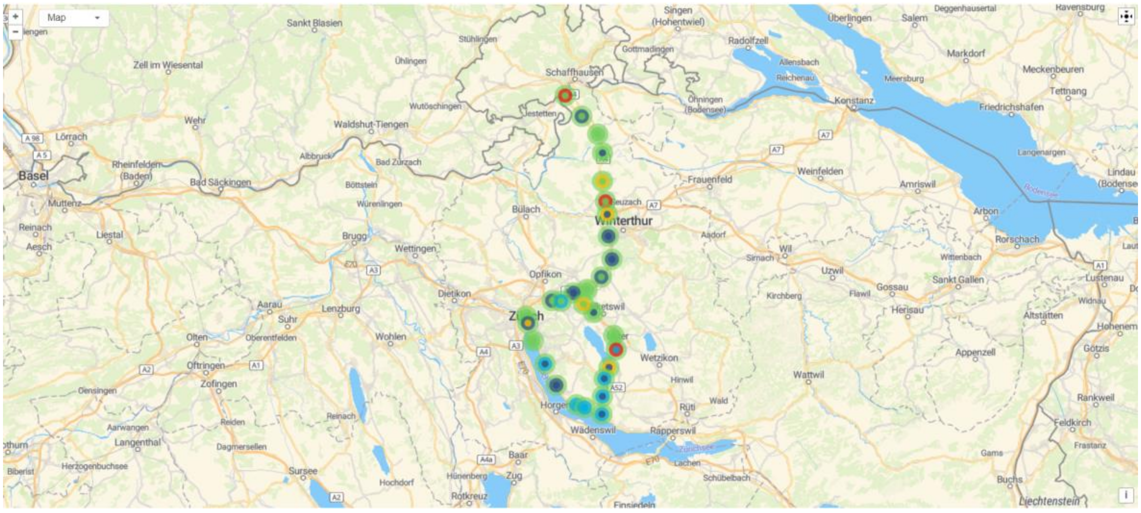


Figure 18 - Driving route taken on 14.11.2020 (40 km)

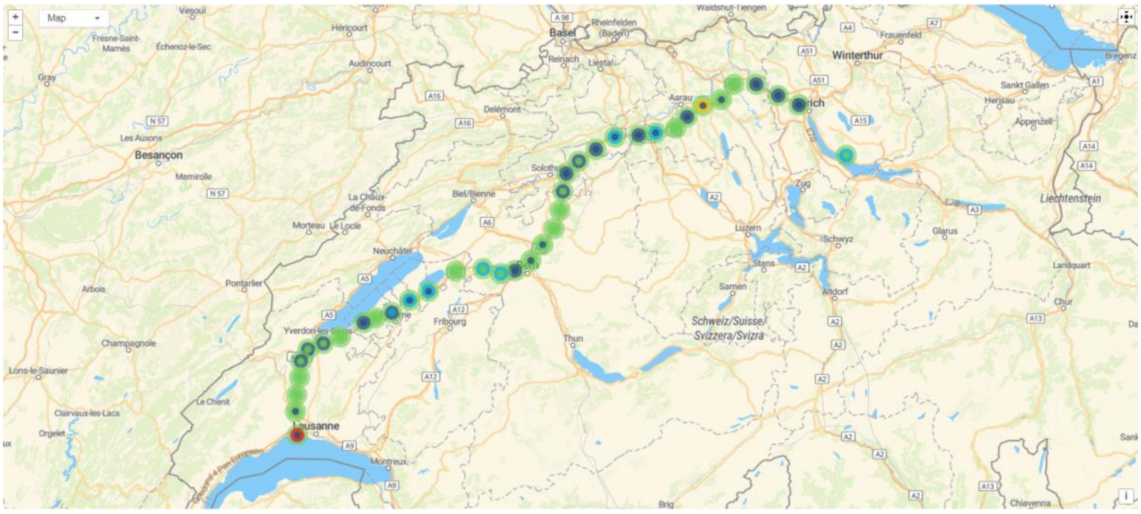


Figure 19 - Driving route taken on 15.11.2020 (230 km)

4.1.1. Link quality monitoring

One of the main goals of the test was to monitor the quality of each link (satellite and LTE) at every 10 seconds along the test route and evaluate the dependence between the quality of the links and the performance of the system. The link balancing unit has the ability to monitor each link with its signal parameters at an interval of 10 seconds. This provides us with the ability to observe the quality of the links in near real-time, as well as store the obtained results for further analysis.

LTE link

The system can record the following parameters on the LTE link:

- SNR – The signal-to-noise ratio of the given signal.
- RSRP – The average power received from a single reference signal, and its typical range is around -44dbm (good) to -140dbm (bad).
- RSRQ – Indicates quality of the received signal, and its range is typically -19.5dB (bad) to -3dB (good).
- Represents the entire received power including the wanted power from the serving cell as well as all co-channel power and other sources of noise.

Since Switzerland is relatively well covered when it comes to LTE, we can observe in Figure 20 that the LTE signal quality (indicated by the blue and green circles) is high along the test route with very few drops in quality in some spots. This can be confirmed by observing the timeline graph of the LTE signal parameters in Figure 21. The graph shows a very brief time interval of 5 minutes where the LTE signal drops and the LTE connection is completely lost which is shown in Figure 22. The map with the exact location of the signal drop is illustrated in Figure 23 showing the values of the LTE signal parameters before the signal is completely dropped and the location where the LTE signal is regained a few minutes later. It is important to note that when the LTE signal was dropped, the system performed a failover to the satellite link without any disruption to the performance of the system.

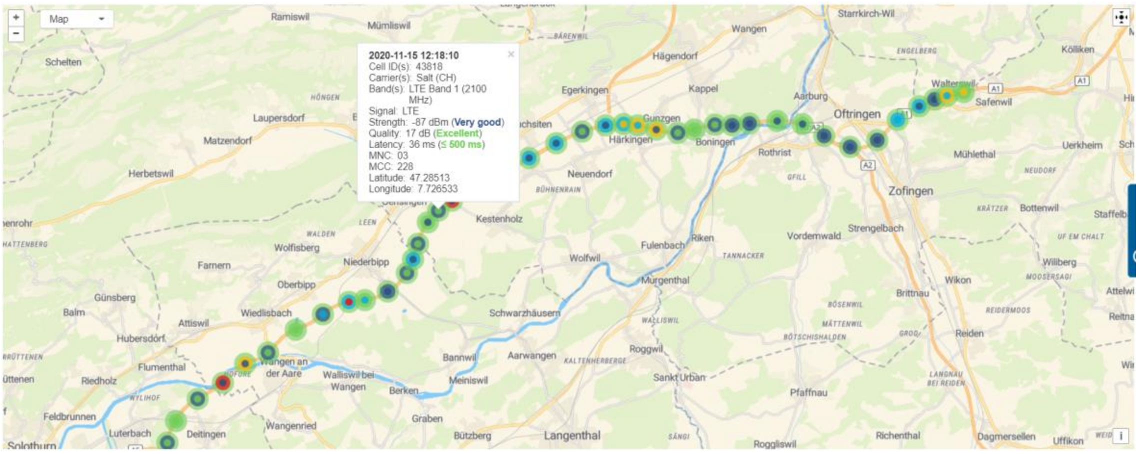


Figure 20 - Map of the LTE link quality during the long driving test

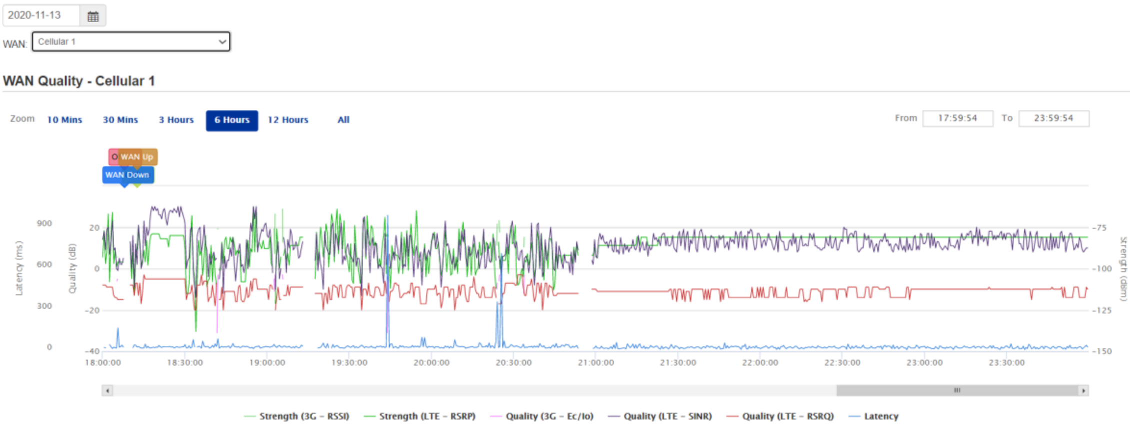


Figure 21 - Timeline graph of the LTE signal parameters

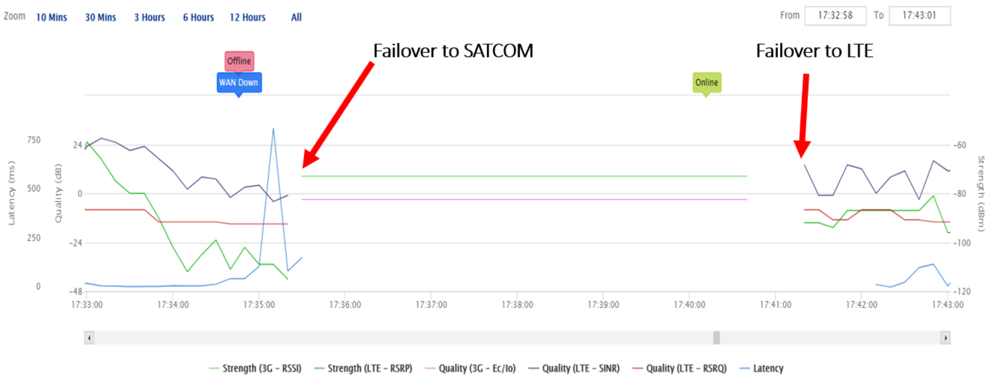
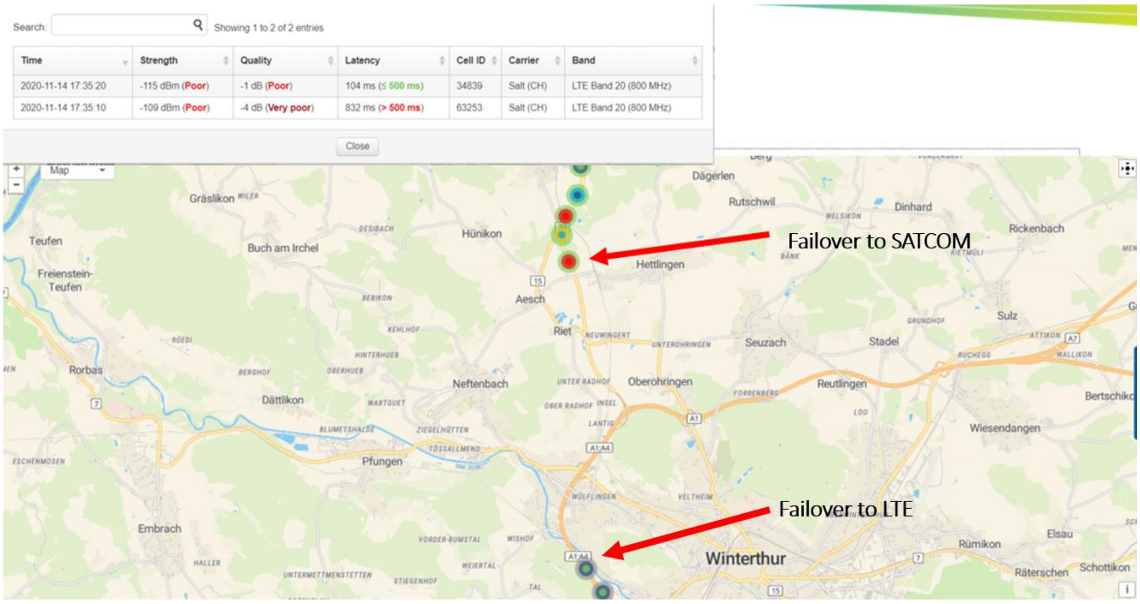


Figure 22 - Timeline graph of the LTE signal drop



Time	Strength	Quality	Latency	Cell ID	Carrier	Band
2020-11-14 17:35:20	-115 dBm (Poor)	-1 dB (Poor)	104 ms (≤ 500 ms)	34839	Salt (CH)	LTE Band 20 (800 MHz)
2020-11-14 17:35:10	-109 dBm (Poor)	-4 dB (Very poor)	832 ms (> 500 ms)	63253	Salt (CH)	LTE Band 20 (800 MHz)

Figure 23 - Map of the LTE signal drop

Satellite link

Similar to the LTE link, we have also observed the satellite link status at intervals of 10 seconds. The map shown in Figure 24 illustrates the status of the Satellite link along the test route during the long driving test. The red circles on the map show the location where the satellite link was active and the system is using the link as backhaul. It is important to note that each circle on the map corresponds to approximately 10 data points since each data point is taken at an interval of 10 seconds and not every data point can be shown on the map when it is not zoomed in. The map shows that the satellite link is active along most of the test route with some disruptions due to the many physical obstacles on the road that prevent the KaLMA antenna from maintaining LOS with the satellite. The timeline graph of the latency on the satellite link corresponding to the map shown in Figure 24 is illustrated in Figure 25. The timeline graph shows only the latency measurements when the satellite link is active meaning that the blank spots correspond to the points in time when the satellite link was down. During those points in time, the system performs a failover to the LTE link with no loss of data.

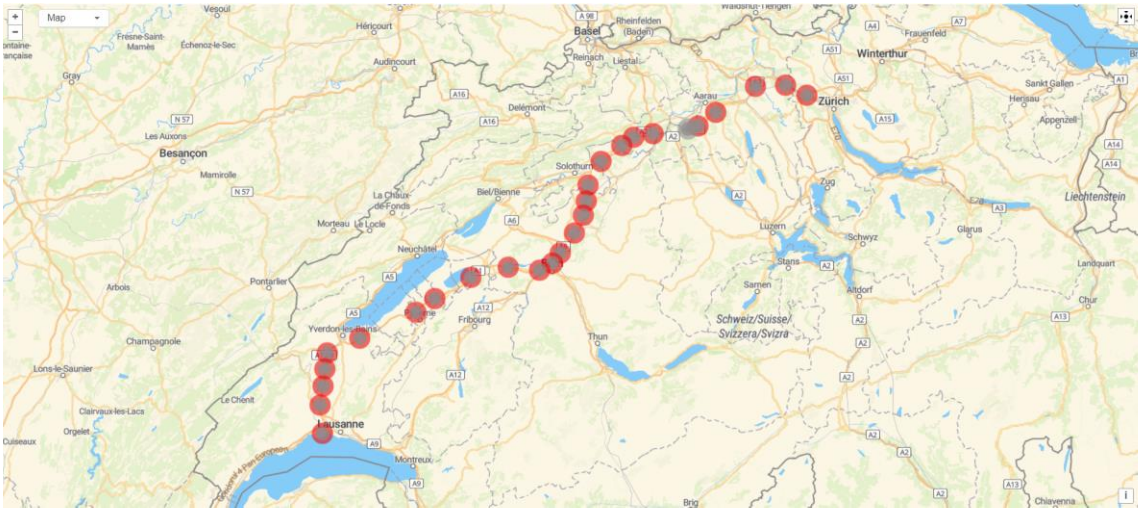


Figure 24 - Map of the Satellite link status during the long driving test

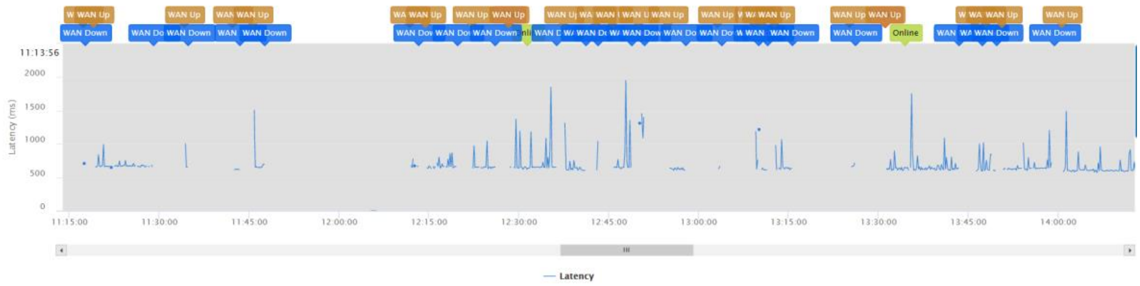


Figure 25 - Timeline graph of the latency on the Satellite link during the long driving test

4.1.2. Deployment Test

This subsection presents a testing scenario where the communication hub is deployed to the field of operation and remains static during the mission. To simulate this scenario, we have monitored the system during driving before stopping at a pre-defined location for 1 hour in order to analyse if the system performs in a stable manner after the deployment. The map of this test is illustrated in Figure 26 where we can see the route taken to reach the deployment location, as well as the location of the deployment with its 302 entries for the latency measurements. The corresponding timeline graph is presented in Figure 27 where we can observe the satellite link latency during the test. We can observe that the satellite link is going back and forth between online and offline during the driving to the deployment location which is expected due to the physical obstacles encountered along the route. It is important to point out that the satellite link is stable after the communication hub reaches the defined location and while the communication hub is no longer moving. This shows that the communication hub provides a reliable backhaul link in the scenario where it needs to be deployed in an area outside of cellular coverage.

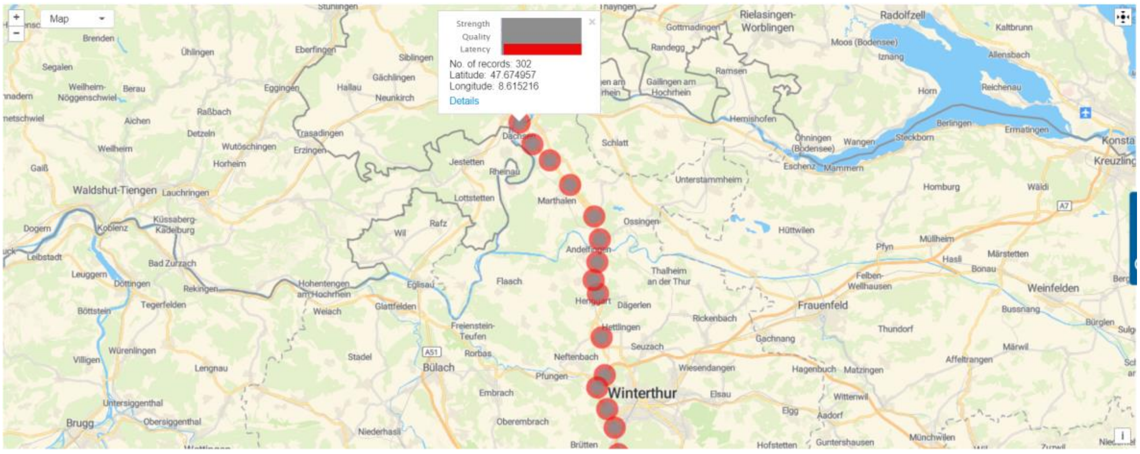


Figure 26 - Map of the deployment test

Figure 27 - Timeline graph of the satellite link latency during the deployment test

4.1.3. Failover Tests

This subsection presents the tests focusing on evaluating the ability of the system to perform failovers between the two links without affecting the performance of the system. Therefore, we have configured the satellite link as the priority link meaning that it will be used when both links are active. The goal is to observe the performance of the system when the satellite link is offline and the system needs to perform a failover to the LTE link. In addition, the system needs to be able to perform another failover back to the satellite link once the satellite link is back online.

The map of the first failover example is shown on Figure 28 where the red circles represent the locations where the satellite link is active and the blank spots represent the locations where the satellite link is down and the system has performed a failover to the LTE link. The same map representing the LTE link signal parameters during the same time is shown in Figure 29 where we can observe that the LTE link is online during the whole time interval.

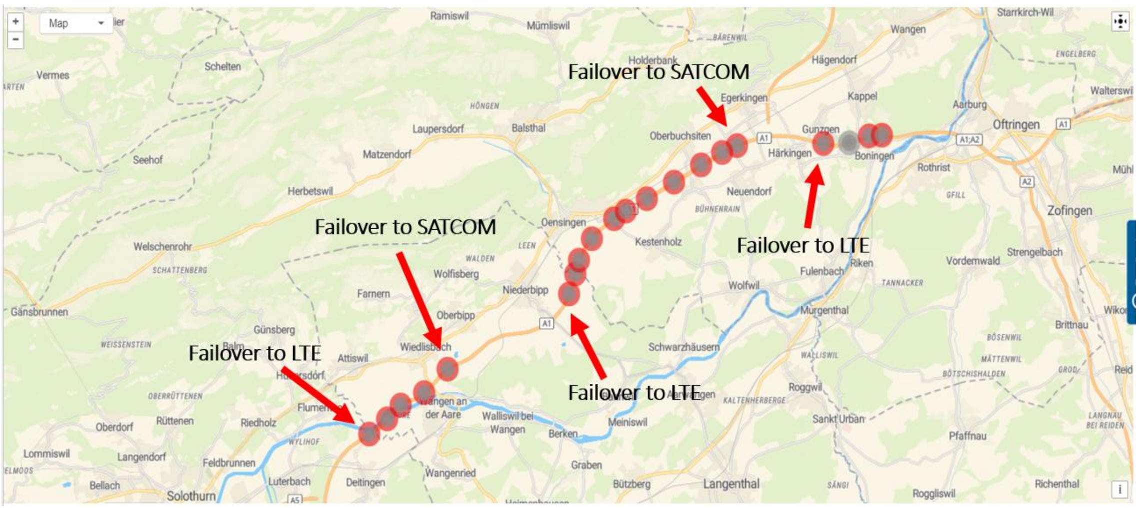


Figure 28 - Map of the Satellite link latency during the failover

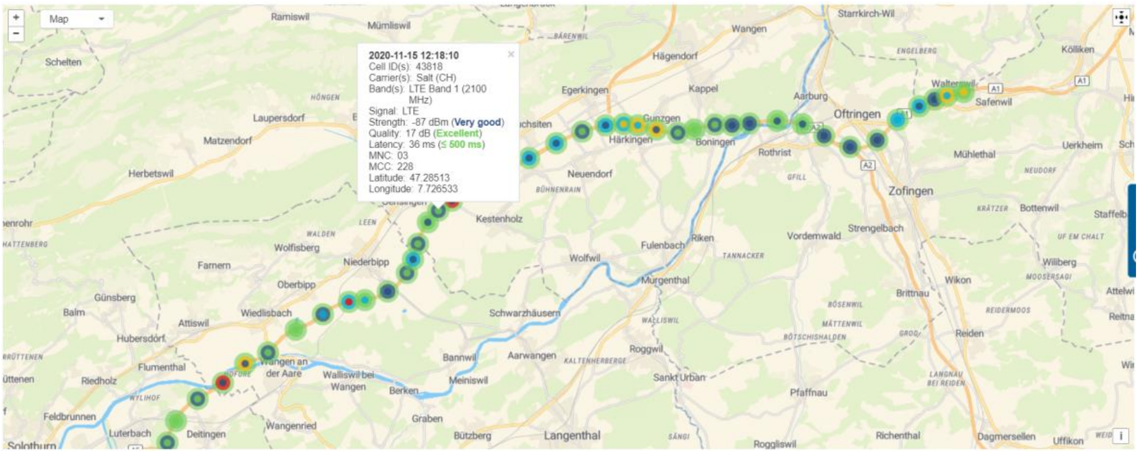


Figure 29 - Map of the LTE link signal parameters during the failover

The data rates on both links during the time interval of 24 minutes (each block on the graph corresponds to 4 minutes) is shown in Figure 30. The upper graph represents the data rate on the satellite link and the lower graph shows the data rate on the LTE link. As shown in the graph, the system performs several failovers between the links depending on the availability of the satellite link since it has priority. The conclusion of these tests is that the system is able to perform failovers between the links without any degradation in performance which ensures that the system provides high availability and reliability.

Figure 30 - Data rates on the satellite and LTE link

4.1.4. Long activity Test

The goal of this test is to test the performance of the system using the satellite link during an interval of 12 hours. The test consists of keeping the system to be active for 12 hours while downloading at a constant rate of 750 kbps in order to observe whether the system will experience any disruptions. The SNR measured on the upstream and downstream link of the KaLMA satellite antenna during the 12 hours of active use is shown on Figure 31.

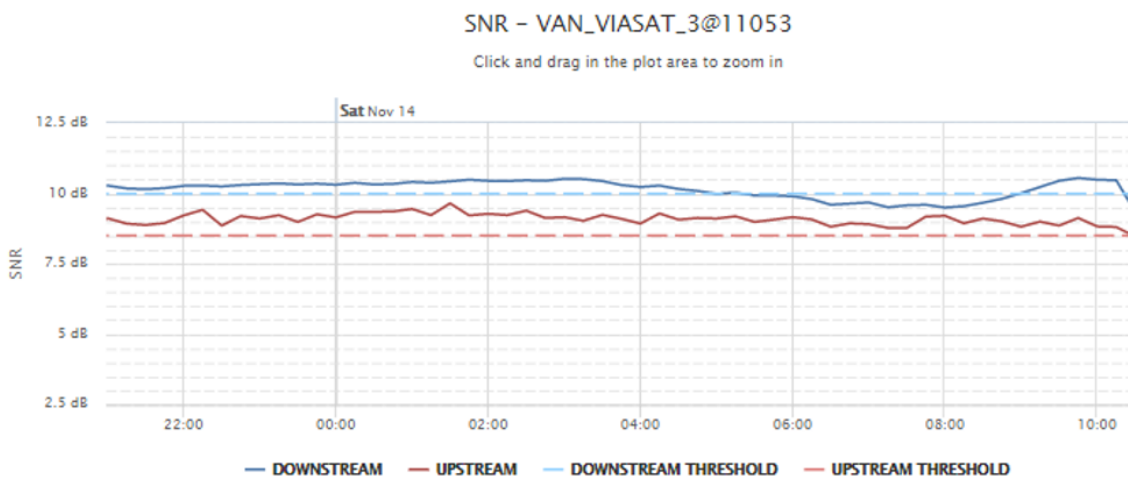


Figure 31 - SNR on the upstream and downstream link on the KaLMA

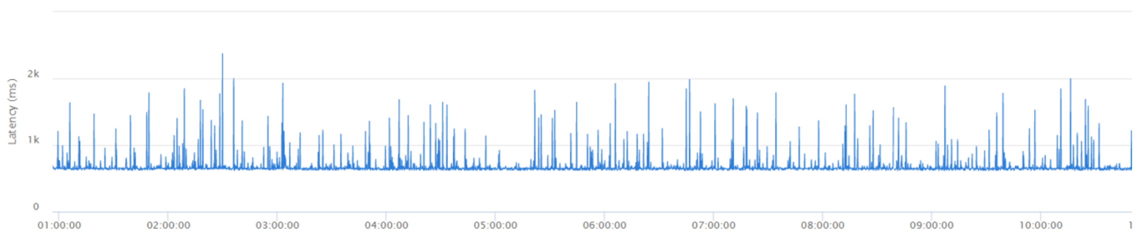


Figure 32 - Timeline graph of the satellite link latency during the long activity test

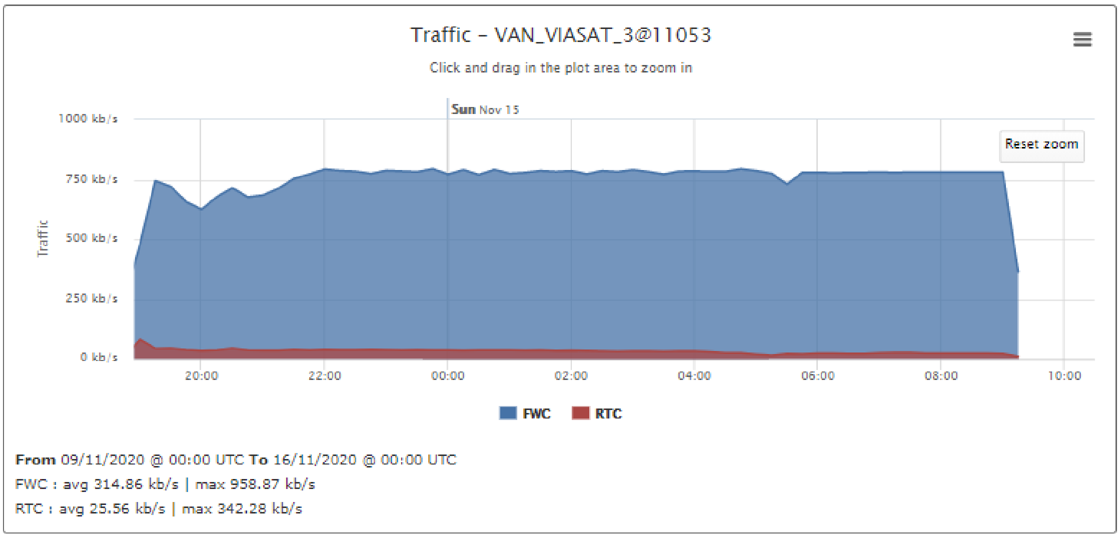


Figure 33 - Download data rate on the satellite link during the long activity test

We can observe that the SNR is stable during the whole time interval except for a brief drop on the upstream link in the morning which is quickly regained. The timeline graph of the satellite link latency illustrated in Figure 32 shows that the satellite link is stable during the whole 12-hour time interval. Furthermore, we can observe in Figure 33 that the download data rate on the satellite link is stable at the desired 750 kbps during the whole time interval. This set of tests proves that the system ensures stable performance during a long period of activity.

4.2. Short Driving Tests

This section presents the tests performed by driving around in the communication hub (Viasat Land Vehicle) with the KaLMA antenna mounted on the roof of the vehicle. The antenna's control unit (ACU) is able to log up to 150 parameters at an interval of 0.1s which can then be illustrated on a map, thus allowing the visualization of the major antenna parameters at every point in the test path. The screenshots presented in this section use the colour of the icon (in this case a circle) to represent the RSSI of the antenna at the given point with green colour representing a high RSSI (above 8 dB) and orange and red representing lower RSSI values respectively. The goal of this test is to evaluate the pointing capabilities of the antenna and observe which specific scenarios cause the RSSI to drop.

The screenshots illustrate two different routes, but the same conclusions can be drawn from both scenarios. The antenna is able to maintain a high RSSI despite a lot of sharp turns along the paths with some instances of decreased RSSI mostly due to physical obstacles at the given location.

4.2.1.1. Test at EPFL campus – Lausanne

The same tests were performed by driving around the EPFL campus in Lausanne, Switzerland. Figure 34 illustrates the RSSI at every point along the path where it is clear that the RSSI drops at the points where tall objects like buildings and trees block the satellite signal thus resulting in a very low RSSI. However, the KaLMA antenna is able to quickly recover the signal once LOS with the satellite is established.

Figure 34 - RSSI at every point along the path

Figure 35 - Connectivity at every single point along the path

In order to evaluate the relationship between the RSSI and the connectivity (status of the connection) of the modem, we observe Figure 35 where the network status is illustrated. The modem has 4 different states:

- **Scanning** which means that the KaLMA antenna is tracking the satellite in order to establish the link.

- **Network entry** which means that the antenna has established a link with the satellite with a satisfactory RSSI and the modem is negotiating the network entry with the satellite core network.
- **DHCP** which means that the core satellite network is assigning an IP address to the modem.
- **Online** which means that the system is online and data can be transferred using the satellite network.

We can see from both Figure 34 and Figure 35 that there is a clear alignment between the connection status and RSSI since the system is in Scanning state when the RSSI is low meaning that the KaLMA antenna is still tracking the satellite. Once the antenna establishes the link with the satellite, the system goes to the status Network entry and if it is successful, the system proceeds with DHCP and after receiving an IP address, the system is Online.

Figure 36 and Figure 37 illustrate the relationship between the driving speed of the vehicle and the RSSI obtained by the KaLMA antenna. The plots show that the driving speed does not affect the satellite tracking of the KaLMA antenna which is able to establish and maintain the satellite link at variable driving speed.

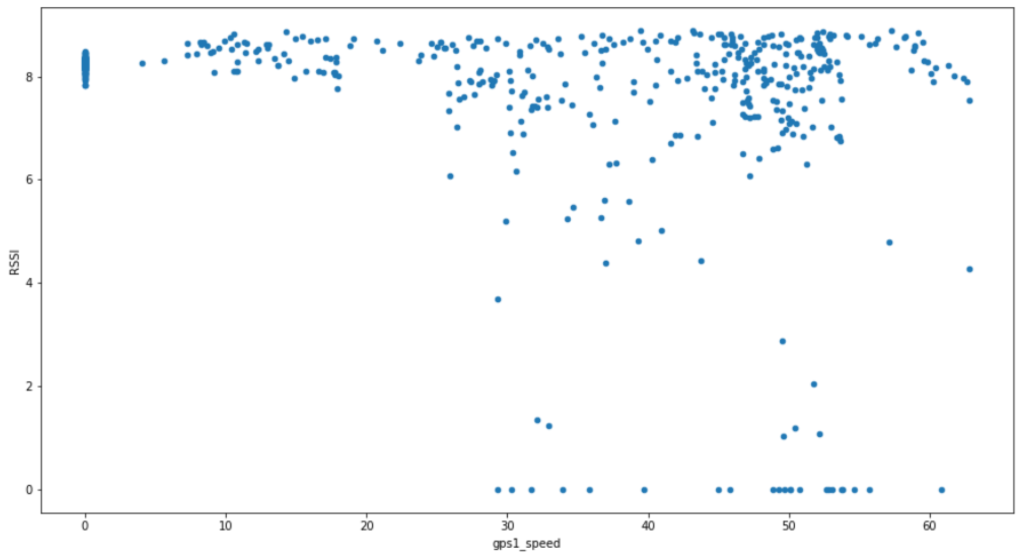


Figure 36 - Relationship of the driving speed (kmph) and the RSSI (1)

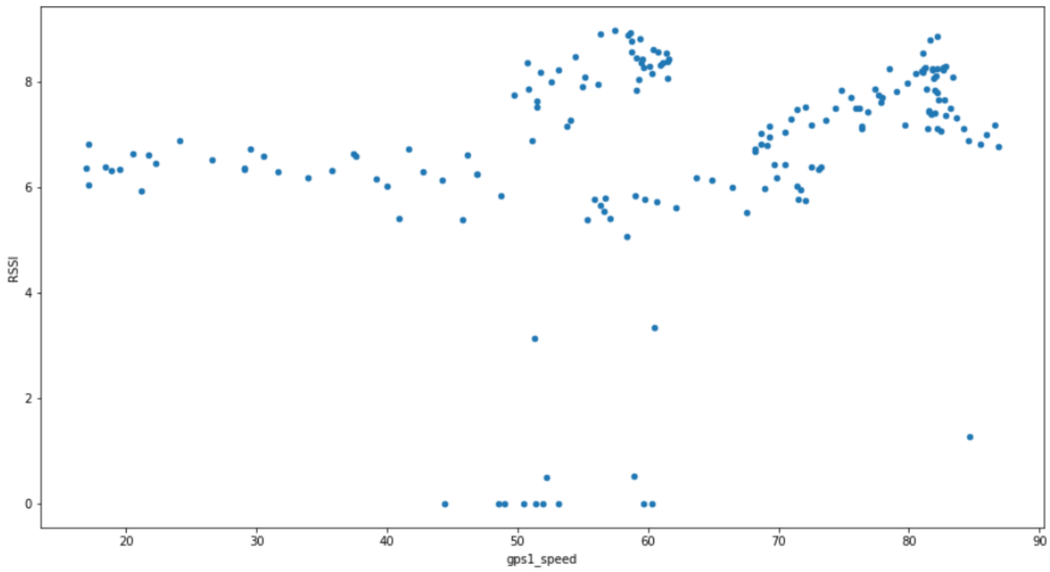


Figure 37 - Relationship of the driving speed (kmph) and the RSSI (2)

4.3. Trellisware Tests

Test description

Trellisware radio terminals create a self-forming, self-healing, infrastructure-less tactical Mobile Ad-hoc Network (MANET) capable of connecting a large number of devices across a large area. In addition to the audio channels, each radio module supports H.264 video streams. Depending on the model of the radio terminal and the resolution of the video streams, the MANET can support multiple video streams simultaneously. Furthermore, the Trellisware radio terminal can act as a relay to other radios in range, thus creating a mesh radio network with a large range. The radio modules (equipped on first responders and UAVs) will send or relay all the data streams to the communication hub where the traffic will be routed to the C2 centre.

Figure 38 - Trellisware testing setup

The goal of these tests is to evaluate the range and throughput of the Trellisware MANET in different scenarios in order to have an insight into the capabilities and limitations of the radio terminals, as well as to verify the integration of the Trellisware MANET into the developed hybrid network infrastructure.

1. **TST_TRLS_001**: Test the connectivity between two 'Cub' terminals in lab conditions.
2. **TST_TRLS_002**: LOS range test between two 'Cub' terminals.

The rest of the tests with the MANET have been presented in the deliverable "ASSISTANCE D3.3: Robust Mobile Communications".

4.3.1. **TST_TRLS_001**: Test the connectivity between two 'Cub' terminals in lab conditions

Test case ID	
TST_TRLS_001	
Test description	Test the connectivity between two 'Cub' terminals in lab conditions.
Test Scenario	
The goal of this test is to evaluate the connectivity and throughput between two 'Cub' terminals in lab conditions. In order to do this, two laptops are connected to a separate Trellisware 'Cub' radio terminal and a TCP session is established between the laptops using Iperf. The same test is also performed for UDP messages. The test was performed in the communications lab in Viasat's Lausanne office.	
Test Results	
Link SNR	52 dB
Bandwidth	TCP: 3.31 Mbps, UDP: 8.02 Mbps
Packet losses (UDP)	0.012%
Latency	Minimum = 67ms, Maximum = 391ms, Average = 142ms

4.3.2. **TST_TRLS_002**: LOS range test between two 'Cub' terminals

Test case ID	
TST_TRLS_002	
Test Scenario	
The goal of this test is to evaluate the range, throughput and latency between two 'Cub' terminals by placing them at various distances from each other ensuring LOS. In order to do this, we keep one radio terminal at a fixed position and move the other radio to different positions relative to the first. At each designated distance, we evaluate the throughput and latency of the connection between the two radios. We repeat the tests for the following distances between the radios: 50m, 100m, 1km, 3km, 5.5km, 10km. The tests presented in this table have been performed in "Zmeevo military base" in Bulgaria from 09.09.2020 until 12.09.2020 with the support of the Bulgarian Defence Institute "Professor Tsvetan Lazarov".	
Test Results	
50m	
Link SNR	53 dB

Bandwidth	TCP: 3.24 Mbps, UDP: 7.92 Mbps
Packet losses (UDP)	0.13%
Latency	Minimum = 82ms, Maximum = 380ms, Average = 157ms
100m	
Link SNR	52 dB
Bandwidth	TCP: 3.12 Mbps, UDP: 8.04 Mbps
Packet losses (UDP)	0.21%
Latency	Minimum = 73ms, Maximum = 305ms, Average = 135ms
1.3km	
Link SNR	53
Bandwidth	TCP: 2.56 Mbps, UDP: 6.75 Mbps
Packet losses (UDP)	2.3%
Latency	Minimum = 92ms, Maximum = 396ms, Average = 178ms
3km	
Link SNR	53 dB
Bandwidth	TCP: 2.31 Mbps, UDP: 7.12 Mbps
Packet losses (UDP)	3.7%
Latency	Minimum = 74ms, Maximum = 297ms, Average = 133ms
5.5km (over lake)	
Link SNR	34 dB
Bandwidth	TCP: 3.23 Mbps, UDP: 8.02 Mbps
Packet losses (UDP)	0.041%
Latency	Minimum = 67ms, Maximum = 282ms, Average = 128ms
10km	
Link SNR	6 dB
Bandwidth	TCP: 1.02 Mbps, UDP: 2.48 Mbps
Packet losses (UDP)	6.7%
Latency	Minimum = 70ms, Maximum = 292ms, Average = 138ms

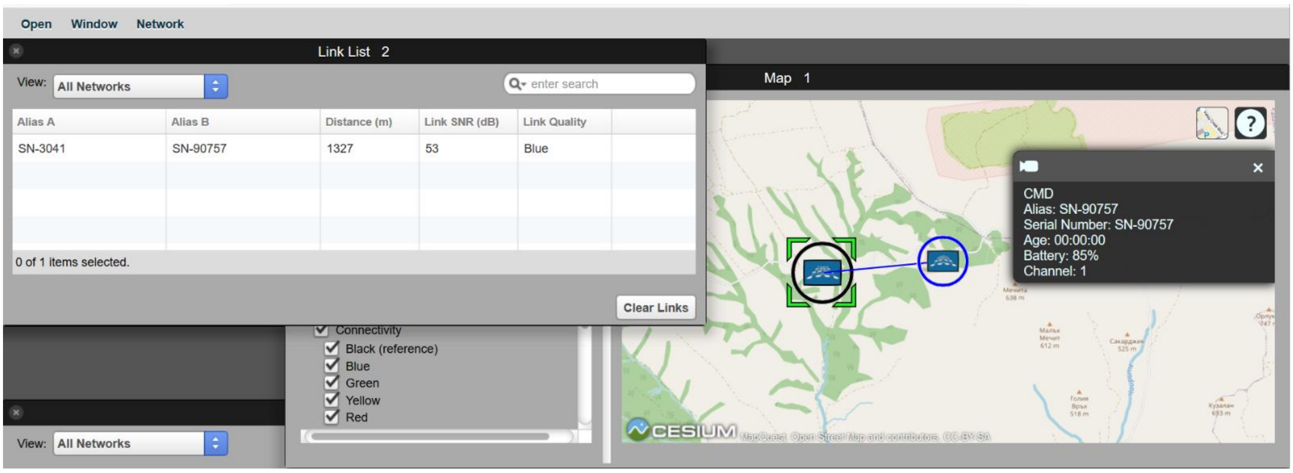


Figure 39 - Range test at 1.3 km (map)

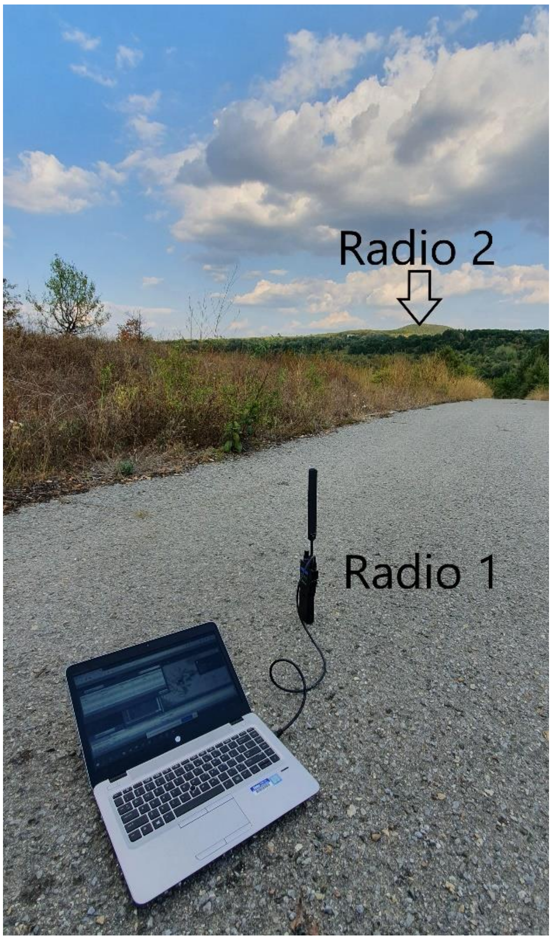


Figure 40 - Range test at 1.3km (terrain)

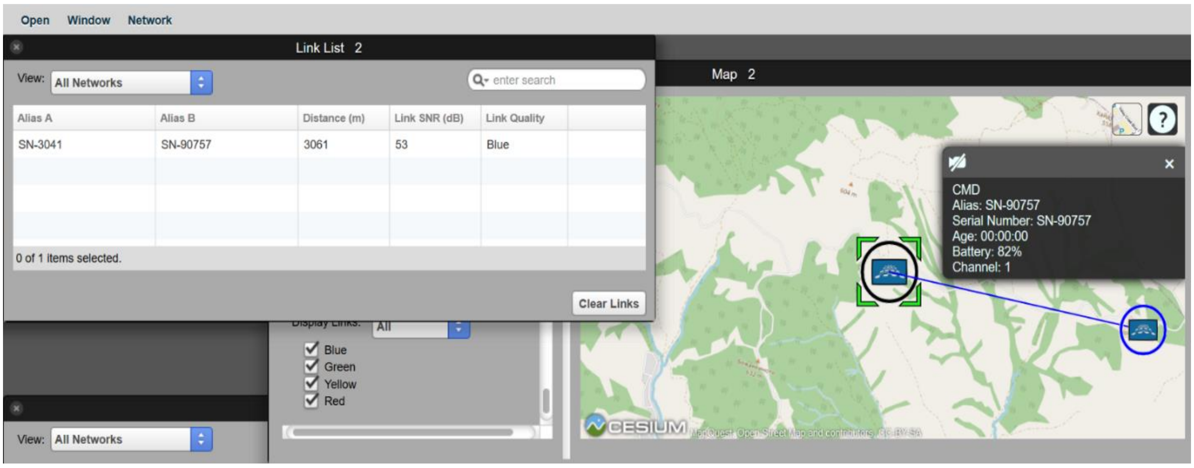


Figure 41 - Range test at 3 km (map)

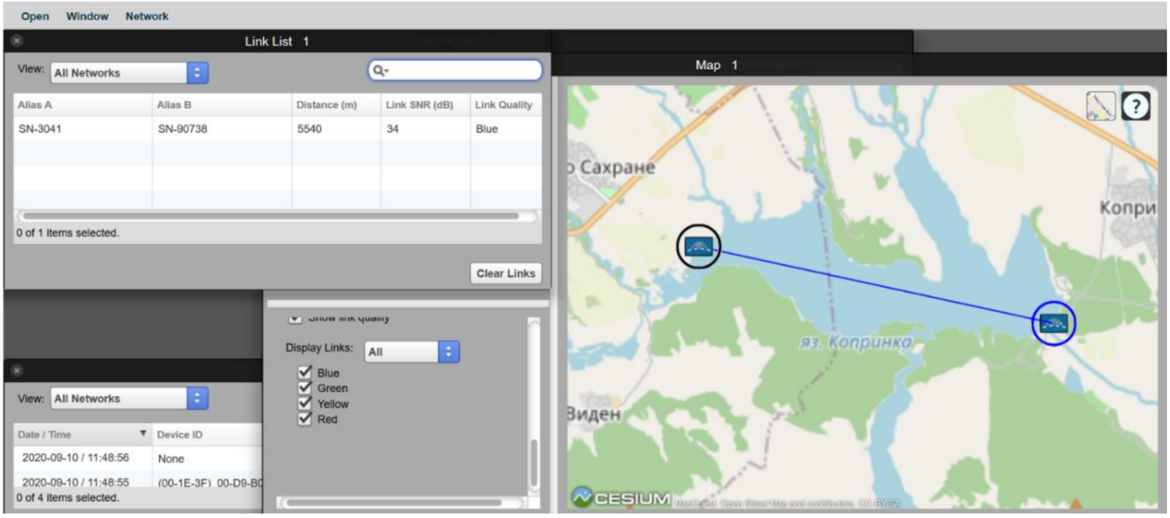


Figure 42 - Range test at 5.5 km (map)

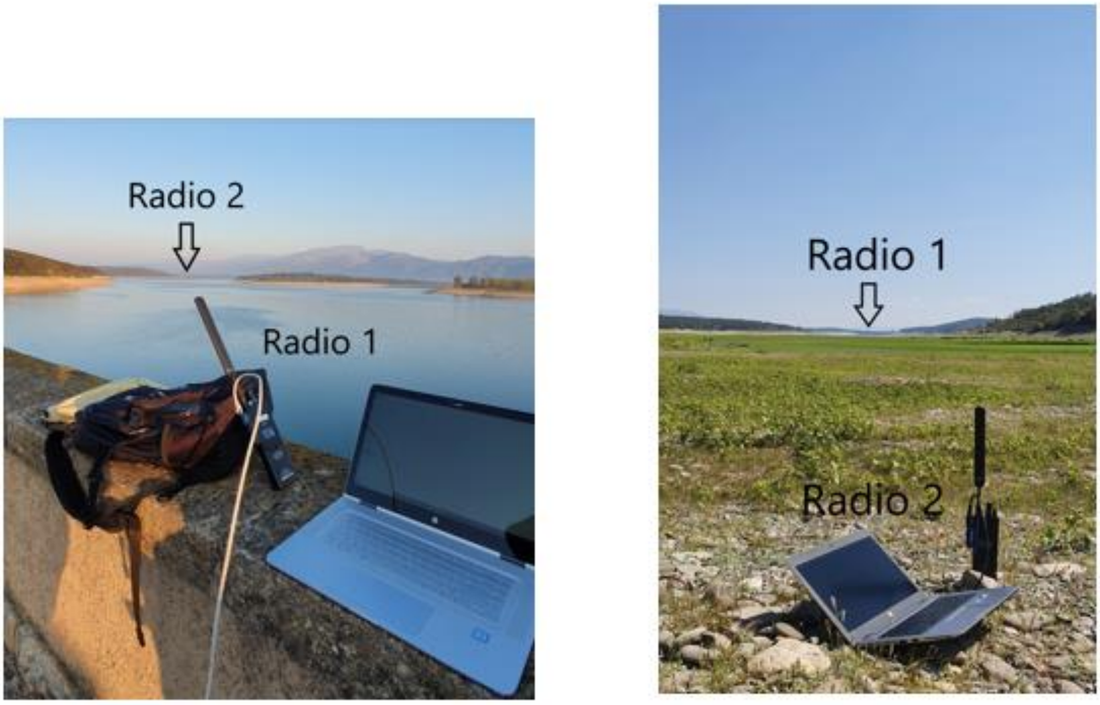


Figure 43 - Range test at 5.5 km (terrain)

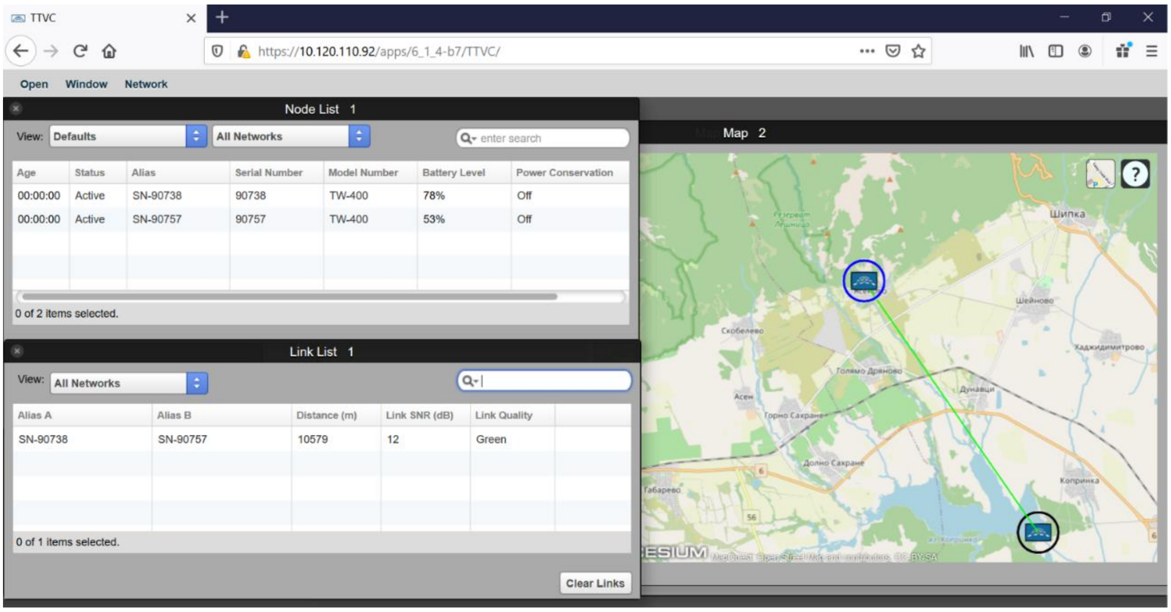


Figure 44 - Range test at 10km (map)

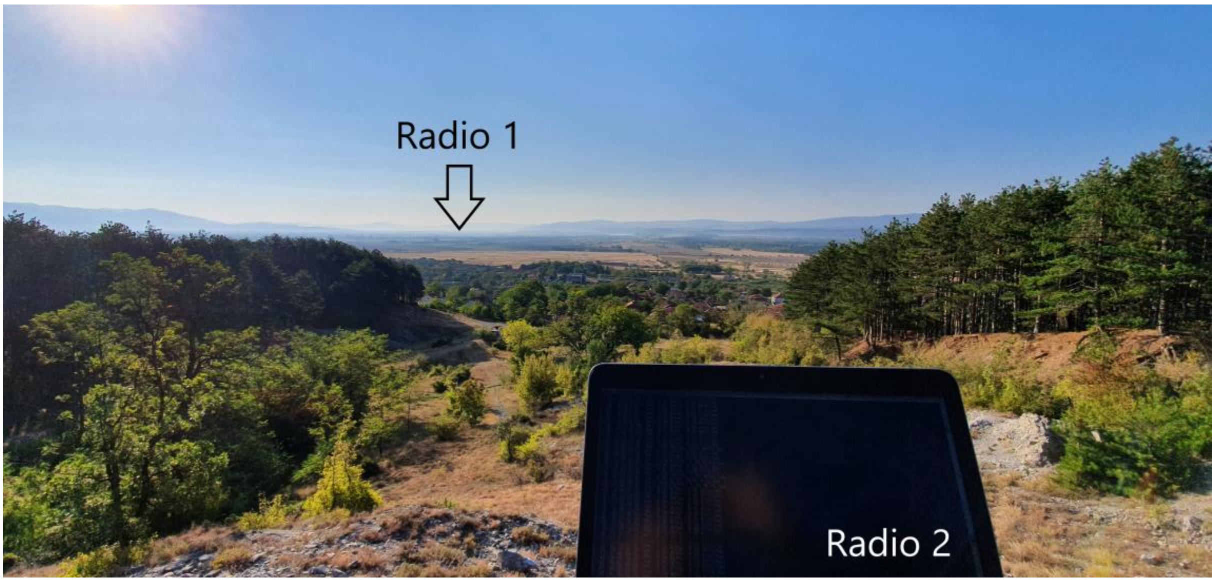


Figure 45 - Range test at 10km (terrain)

Test Logs

```
Pinging 10.120.254.84 with 32 bytes of data:
Reply from 10.120.254.84: bytes=32 time=239ms TTL=128
Reply from 10.120.254.84: bytes=32 time=207ms TTL=128
Reply from 10.120.254.84: bytes=32 time=180ms TTL=128
Reply from 10.120.254.84: bytes=32 time=177ms TTL=128
Reply from 10.120.254.84: bytes=32 time=131ms TTL=128
Reply from 10.120.254.84: bytes=32 time=116ms TTL=128
Reply from 10.120.254.84: bytes=32 time=92ms TTL=128
Reply from 10.120.254.84: bytes=32 time=74ms TTL=128
Reply from 10.120.254.84: bytes=32 time=84ms TTL=128
Reply from 10.120.254.84: bytes=32 time=111ms TTL=128
Reply from 10.120.254.84: bytes=32 time=79ms TTL=128
Reply from 10.120.254.84: bytes=32 time=143ms TTL=128
Reply from 10.120.254.84: bytes=32 time=130ms TTL=128
Reply from 10.120.254.84: bytes=32 time=99ms TTL=128
Reply from 10.120.254.84: bytes=32 time=101ms TTL=128
Reply from 10.120.254.84: bytes=32 time=83ms TTL=128
Reply from 10.120.254.84: bytes=32 time=74ms TTL=128
Reply from 10.120.254.84: bytes=32 time=102ms TTL=128
Reply from 10.120.254.84: bytes=32 time=107ms TTL=128
Reply from 10.120.254.84: bytes=32 time=99ms TTL=128
Reply from 10.120.254.84: bytes=32 time=110ms TTL=128
Reply from 10.120.254.84: bytes=32 time=103ms TTL=128
Reply from 10.120.254.84: bytes=32 time=237ms TTL=128
Reply from 10.120.254.84: bytes=32 time=176ms TTL=128
Reply from 10.120.254.84: bytes=32 time=113ms TTL=128
```

Figure 46 - Latency test at 3km

```
Connecting to host 10.120.254.84, port 5201
[  4] local 10.120.160.139 port 57166 connected to 10.120.254.84 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.01   sec   256 KBytes  2.10 Mbits/sec
[  4]   2.01-3.01   sec   256 KBytes  2.10 Mbits/sec
[  4]   3.01-4.01   sec   256 KBytes  2.10 Mbits/sec
[  4]   4.01-5.01   sec   128 KBytes  1.05 Mbits/sec
[  4]   5.01-6.00   sec   256 KBytes  2.10 Mbits/sec
[  4]   6.00-7.00   sec   128 KBytes  1.05 Mbits/sec
[  4]   7.00-8.00   sec   128 KBytes  1.05 Mbits/sec
[  4]   8.00-9.00   sec   256 KBytes  2.10 Mbits/sec
[  4]   9.00-10.00  sec   128 KBytes  1.05 Mbits/sec
[  4]  10.00-11.00  sec   256 KBytes  2.10 Mbits/sec
[  4]  11.00-12.00  sec   256 KBytes  2.09 Mbits/sec
[  4]  12.00-13.02  sec   128 KBytes  1.04 Mbits/sec
[  4]  13.02-14.02  sec   128 KBytes  1.04 Mbits/sec
[  4]  14.02-15.02  sec   256 KBytes  2.11 Mbits/sec
[  4]  15.02-16.02  sec   256 KBytes  2.10 Mbits/sec
[  4]  16.02-17.02  sec   128 KBytes  1.05 Mbits/sec
[  4]  17.02-18.01  sec   128 KBytes  1.05 Mbits/sec
[  4]  18.01-19.01  sec   256 KBytes  2.11 Mbits/sec
[  4]  19.01-20.01  sec   128 KBytes  1.05 Mbits/sec
[  4]  20.01-21.01  sec   128 KBytes  1.05 Mbits/sec
[  4]  21.01-22.01  sec   256 KBytes  2.10 Mbits/sec
[  4]  22.01-23.01  sec   128 KBytes  1.04 Mbits/sec
[  4]  23.01-24.01  sec   128 KBytes  1.05 Mbits/sec
[  4]  24.01-25.01  sec   256 KBytes  2.10 Mbits/sec
[  4]  25.01-26.01  sec   128 KBytes  1.05 Mbits/sec
[  4]  26.01-27.00  sec   128 KBytes  1.05 Mbits/sec
[  4]  27.00-28.00  sec   256 KBytes  2.10 Mbits/sec
[  4]  28.00-29.00  sec   128 KBytes  1.05 Mbits/sec
[  4]  29.00-30.00  sec   256 KBytes  2.10 Mbits/sec
```

Figure 47 - TCP test at 3km

```
Connecting to host 10.120.254.84, port 5201
[  4] local 10.120.160.139 port 64354 connected to 10.120.254.84 port 5201
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.02   sec   896 KBytes  7.23 Mbits/sec  112
[  4]   1.02-2.01   sec   976 KBytes  8.03 Mbits/sec  122
[  4]   2.01-3.01   sec   984 KBytes  8.10 Mbits/sec  123
[  4]   3.01-4.00   sec   976 KBytes  8.03 Mbits/sec  122
[  4]   4.00-5.00   sec   968 KBytes  7.92 Mbits/sec  121
[  4]   5.00-6.01   sec   984 KBytes  8.00 Mbits/sec  123
[  4]   6.01-7.00   sec   976 KBytes  8.06 Mbits/sec  122
[  4]   7.00-8.00   sec   976 KBytes  8.00 Mbits/sec  122
[  4]   8.00-9.01   sec   976 KBytes  7.90 Mbits/sec  122
[  4]   9.01-10.01  sec   984 KBytes  8.09 Mbits/sec  123
[  4]  10.01-11.00  sec   968 KBytes  7.97 Mbits/sec  121
[  4]  11.00-12.01  sec   976 KBytes  7.99 Mbits/sec  122
[  4]  12.01-13.01  sec   984 KBytes  8.03 Mbits/sec  123
[  4]  13.01-14.00  sec   968 KBytes  7.97 Mbits/sec  121
[  4]  14.00-15.00  sec   976 KBytes  8.01 Mbits/sec  122
[  4]  15.00-16.02  sec   984 KBytes  7.97 Mbits/sec  123
[  4]  16.02-17.00  sec   976 KBytes  8.10 Mbits/sec  122
[  4]  17.00-18.01  sec   976 KBytes  7.94 Mbits/sec  122
[  4]  18.01-19.01  sec   992 KBytes  8.08 Mbits/sec  124
[  4]  19.01-20.01  sec   960 KBytes  7.90 Mbits/sec  120
[  4]  20.01-21.00  sec   976 KBytes  8.05 Mbits/sec  122
[  4]  21.00-22.01  sec   976 KBytes  7.94 Mbits/sec  122
[  4]  22.01-23.01  sec   984 KBytes  8.09 Mbits/sec  123
[  4]  23.01-24.00  sec   968 KBytes  7.96 Mbits/sec  121
[  4]  24.00-25.00  sec   976 KBytes  7.99 Mbits/sec  122
[  4]  25.00-26.01  sec   984 KBytes  8.03 Mbits/sec  123
[  4]  26.01-27.00  sec   968 KBytes  7.95 Mbits/sec  121
[  4]  27.00-28.01  sec   984 KBytes  8.01 Mbits/sec  123
[  4]  28.01-29.01  sec   984 KBytes  8.04 Mbits/sec  123
[  4]  29.01-30.00  sec   968 KBytes  8.02 Mbits/sec  121
```

Figure 48 - UDP test at 3km

```
Pinging 10.120.162.105 with 32 bytes of data:
Reply from 10.120.162.105: bytes=32 time=187ms TTL=128
Reply from 10.120.162.105: bytes=32 time=149ms TTL=128
Reply from 10.120.162.105: bytes=32 time=129ms TTL=128
Reply from 10.120.162.105: bytes=32 time=67ms TTL=128
Reply from 10.120.162.105: bytes=32 time=137ms TTL=128
Reply from 10.120.162.105: bytes=32 time=91ms TTL=128
Reply from 10.120.162.105: bytes=32 time=119ms TTL=128
Reply from 10.120.162.105: bytes=32 time=101ms TTL=128
Reply from 10.120.162.105: bytes=32 time=114ms TTL=128
Reply from 10.120.162.105: bytes=32 time=94ms TTL=128
Reply from 10.120.162.105: bytes=32 time=68ms TTL=128
Reply from 10.120.162.105: bytes=32 time=111ms TTL=128
Reply from 10.120.162.105: bytes=32 time=282ms TTL=128
Reply from 10.120.162.105: bytes=32 time=248ms TTL=128
Reply from 10.120.162.105: bytes=32 time=236ms TTL=128
Reply from 10.120.162.105: bytes=32 time=257ms TTL=128
Reply from 10.120.162.105: bytes=32 time=237ms TTL=128
Reply from 10.120.162.105: bytes=32 time=201ms TTL=128
Reply from 10.120.162.105: bytes=32 time=223ms TTL=128
Reply from 10.120.162.105: bytes=32 time=146ms TTL=128
Reply from 10.120.162.105: bytes=32 time=126ms TTL=128
Reply from 10.120.162.105: bytes=32 time=99ms TTL=128
Reply from 10.120.162.105: bytes=32 time=130ms TTL=128
Reply from 10.120.162.105: bytes=32 time=114ms TTL=128
Reply from 10.120.162.105: bytes=32 time=87ms TTL=128
Reply from 10.120.162.105: bytes=32 time=78ms TTL=128
Reply from 10.120.162.105: bytes=32 time=120ms TTL=128
Reply from 10.120.162.105: bytes=32 time=79ms TTL=128
Reply from 10.120.162.105: bytes=32 time=113ms TTL=128
Reply from 10.120.162.105: bytes=32 time=100ms TTL=128
Reply from 10.120.162.105: bytes=32 time=79ms TTL=128
```

Figure 49 - Latency test at 5.5km

```
Connecting to host 10.120.162.105, port 5201
[  4] local 10.120.160.139 port 56031 connected to 10.120.162.105 port 5201
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.01   sec   256 KBytes  2.08 Mbits/sec
[  4]   1.01-2.00   sec   256 KBytes  2.11 Mbits/sec
[  4]   2.00-3.00   sec   384 KBytes  3.14 Mbits/sec
[  4]   3.00-4.00   sec   384 KBytes  3.16 Mbits/sec
[  4]   4.00-5.01   sec   512 KBytes  4.16 Mbits/sec
[  4]   5.01-6.00   sec   256 KBytes  2.12 Mbits/sec
[  4]   6.00-7.01   sec   384 KBytes  3.12 Mbits/sec
[  4]   7.01-8.01   sec   384 KBytes  3.15 Mbits/sec
[  4]   8.01-9.01   sec   512 KBytes  4.17 Mbits/sec
[  4]   9.01-10.01  sec   384 KBytes  3.17 Mbits/sec
[  4]  10.01-11.04  sec   384 KBytes  3.04 Mbits/sec
[  4]  11.04-12.01  sec   384 KBytes  3.25 Mbits/sec
[  4]  12.01-13.01  sec   512 KBytes  4.18 Mbits/sec
[  4]  13.01-14.02  sec   384 KBytes  3.14 Mbits/sec
[  4]  14.02-15.00  sec   256 KBytes  2.12 Mbits/sec
[  4]  15.00-16.01  sec   512 KBytes  4.18 Mbits/sec
[  4]  16.01-17.01  sec   384 KBytes  3.12 Mbits/sec
[  4]  17.01-18.02  sec   256 KBytes  2.09 Mbits/sec
[  4]  18.02-19.00  sec   384 KBytes  3.19 Mbits/sec
[  4]  19.00-20.01  sec   384 KBytes  3.13 Mbits/sec
[  4]  20.01-21.00  sec   384 KBytes  3.16 Mbits/sec
[  4]  21.00-22.00  sec   384 KBytes  3.14 Mbits/sec
[  4]  22.00-23.02  sec   384 KBytes  3.11 Mbits/sec
[  4]  23.02-24.01  sec   384 KBytes  3.16 Mbits/sec
[  4]  24.01-25.02  sec   384 KBytes  3.13 Mbits/sec
[  4]  25.02-26.01  sec   384 KBytes  3.17 Mbits/sec
[  4]  26.01-27.01  sec   512 KBytes  4.18 Mbits/sec
[  4]  27.01-28.02  sec   384 KBytes  3.14 Mbits/sec
[  4]  28.02-29.02  sec   512 KBytes  4.19 Mbits/sec
[  4]  29.02-30.01  sec   256 KBytes  2.11 Mbits/sec
```

Figure 50 - TCP test at 5.5km

```
Connecting to host 10.120.162.105, port 5201
[  4] local 10.120.160.139 port 50626 connected to 10.120.162.105 port 5201
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.01   sec   912 KBytes  7.38 Mbits/sec  114
[  4]   1.01-2.00   sec   968 KBytes  8.01 Mbits/sec  121
[  4]   2.00-3.01   sec   976 KBytes  7.93 Mbits/sec  122
[  4]   3.01-4.00   sec   968 KBytes  7.99 Mbits/sec  121
[  4]   4.00-5.00   sec   984 KBytes  8.06 Mbits/sec  123
[  4]   5.00-6.00   sec   968 KBytes  7.91 Mbits/sec  121
[  4]   6.00-7.01   sec   976 KBytes  7.96 Mbits/sec  122
[  4]   7.01-8.01   sec   984 KBytes  8.08 Mbits/sec  123
[  4]   8.01-9.01   sec   976 KBytes  7.98 Mbits/sec  122
[  4]   9.01-10.01  sec   984 KBytes  8.05 Mbits/sec  123
[  4]  10.01-11.02  sec   968 KBytes  7.86 Mbits/sec  121
[  4]  11.02-12.01  sec   976 KBytes  8.07 Mbits/sec  122
[  4]  12.01-13.00  sec   984 KBytes  8.10 Mbits/sec  123
[  4]  13.00-14.00  sec   968 KBytes  7.96 Mbits/sec  121
[  4]  14.00-15.00  sec   984 KBytes  8.03 Mbits/sec  123
[  4]  15.00-16.00  sec   968 KBytes  7.93 Mbits/sec  121
[  4]  16.00-17.00  sec   976 KBytes  8.00 Mbits/sec  122
[  4]  17.00-18.02  sec   976 KBytes  7.83 Mbits/sec  122
[  4]  18.02-19.00  sec   984 KBytes  8.25 Mbits/sec  123
[  4]  19.00-20.00  sec   976 KBytes  7.98 Mbits/sec  122
[  4]  20.00-21.00  sec   976 KBytes  8.00 Mbits/sec  122
[  4]  21.00-22.00  sec   976 KBytes  7.99 Mbits/sec  122
[  4]  22.00-23.00  sec   984 KBytes  8.05 Mbits/sec  123
[  4]  23.00-24.00  sec   968 KBytes  7.95 Mbits/sec  121
[  4]  24.00-25.00  sec   976 KBytes  7.99 Mbits/sec  122
[  4]  25.00-26.01  sec   976 KBytes  7.96 Mbits/sec  122
[  4]  26.01-27.00  sec   976 KBytes  8.03 Mbits/sec  122
[  4]  27.00-28.00  sec   976 KBytes  8.01 Mbits/sec  122
[  4]  28.00-29.00  sec   984 KBytes  8.06 Mbits/sec  123
[  4]  29.00-30.00  sec   976 KBytes  7.98 Mbits/sec  122
```

Figure 51 - UDP test at 5.5km

4.3.3. **TST_TRLS_003**: Test the connectivity between three 'Cub' terminals on the field using radio relaying

Test case ID	
TST_TRLS_003	
Test Scenario	
The goal of this test is to test the radio relaying capability of the Trellisware Cub radio terminal. This functionality allows the radio terminal to act as a relay for two radios that are out of range of each other but within range of the radio acting as a relay. Therefore, this functionality of the Trellisware Cub allows it to drastically increase the range of the Trellisware MANET since it can support up to 8 hops between radio relays in the MANET. The test was performed by placing two radios at the distance of 10 km with established LOS (same as in TST_TRLS_002) and a third radio at the distance of 100m and LOS to the second radio, without LOS to the first radio. This means that the second radio will act as a relay for the communication between the first and third radio.	
Test Results	
Radio 1 : Radio 2	
Link SNR	6 dB
Bandwidth	TCP: 1.16 Mbps, UDP: 2.14 Mbps
Packet losses (UDP)	4.2%
Latency	Minimum = 82ms, Maximum = 302ms, Average = 142ms
Radio 2 : Radio 3	
Link SNR	51 dB
Bandwidth	TCP: 3.12 Mbps, UDP: 7.83 Mbps
Packet losses (UDP)	0.21%
Latency	Minimum = 76ms, Maximum = 387ms, Average = 147ms
Radio 1 : Radio 3	
Link SNR	No direct link
Bandwidth	TCP: 0.78 Mbps, UDP: 1.97 Mbps
Packet losses (UDP)	6.4 %
Latency	Minimum = 81ms, Maximum = 343ms, Average = 147ms

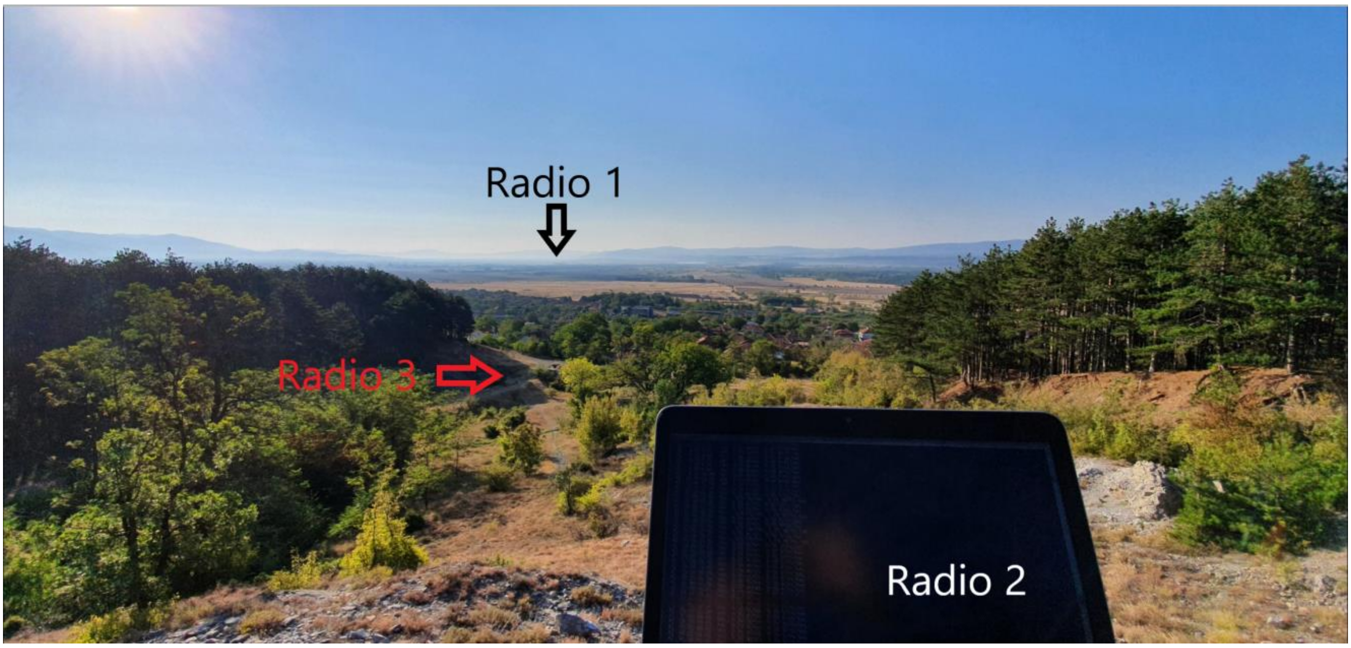


Figure 52 - Radio relay test (Radio 2 Point of View)

Figure 53 - Radio relay test (Radio 3 Point of View)

4.3.4. **TST_TRLS_004**: LOS range test between two ‘Cub’ terminals over sea

Test case ID	
TST_TRLS_004	
Test Scenario	
The goal of this test is to evaluate the range, throughput and latency between two ‘Cub’ terminals by placing them at various distances from each other ensuring LOS over the sea in order to evaluate the effect of the water surface and waves on the radio transmission. In order to do this, we keep one radio terminal at a fixed position and move the other radio to different positions relative to the first. At each designated distance, we evaluate the throughput and latency of the connection between the two radios. We repeat the tests for the following distances between the radios: 50m, 2.3km, 5.5km, 7.5km and 10km. The tests presented in this table have been performed in The Portuguese Navy base in Lisbon, Portugal from 30.09.2020 until 02.10.2020 with the support of the Portuguese Navy (Marinha Portuguesa).	
Test Results	
2.3 km	
Link SNR	35 dB
Bandwidth	TCP: 3.45 Mbps, UDP: 7.96 Mbps
Packet losses (UDP)	0.11%
Latency	Minimum = 82ms, Maximum = 387ms, Average = 159ms
5.5 km	
Link SNR	24 dB
Bandwidth	TCP: 3.12 Mbps, UDP: 7.68 Mbps
Packet losses (UDP)	0.27%
Latency	Minimum = 73ms, Maximum = 317ms, Average = 145ms
7.5 km	
Link SNR	26 dB
Bandwidth	TCP: 2.56 Mbps, UDP: 6.75 Mbps
Packet losses (UDP)	2.3%
Latency	Minimum = 92ms, Maximum = 396ms, Average = 178ms
10 km	
Link SNR	16 dB
Bandwidth	TCP: 1.72 Mbps, UDP: 6.23 Mbps
Packet losses (UDP)	4.7%
Latency	Minimum = 74ms, Maximum = 291ms, Average = 142ms

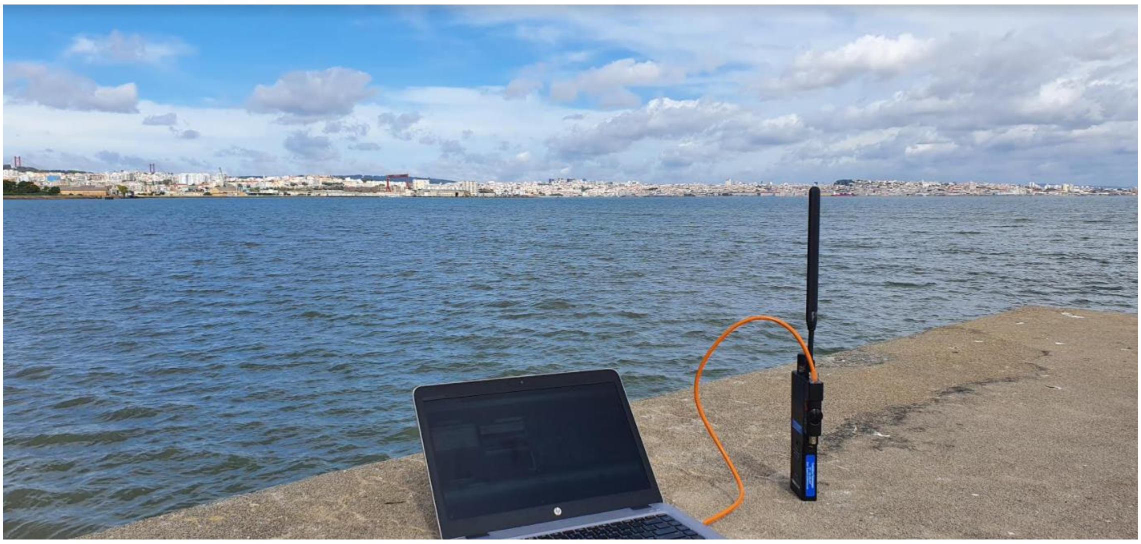


Figure 54 - Range test at 2.3 km (terrain)

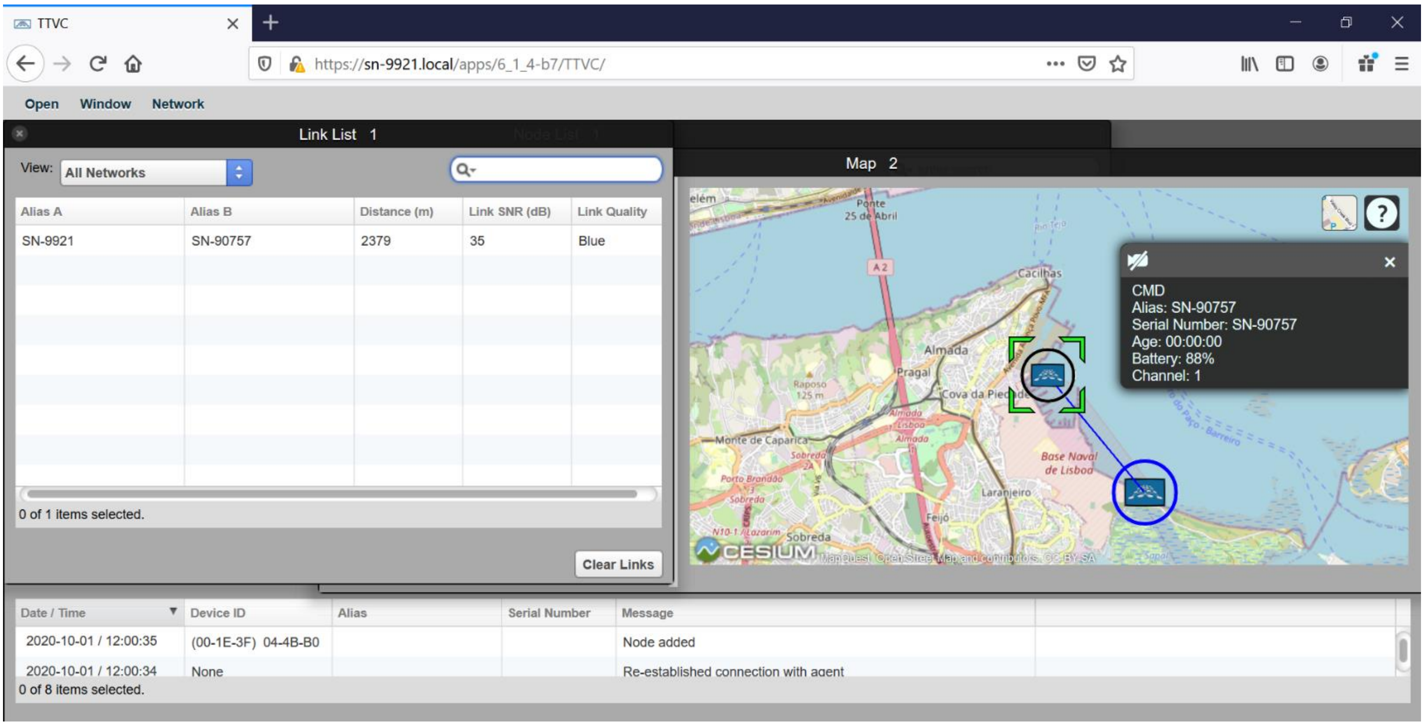


Figure 55 - Range test at 2.3 km (map)

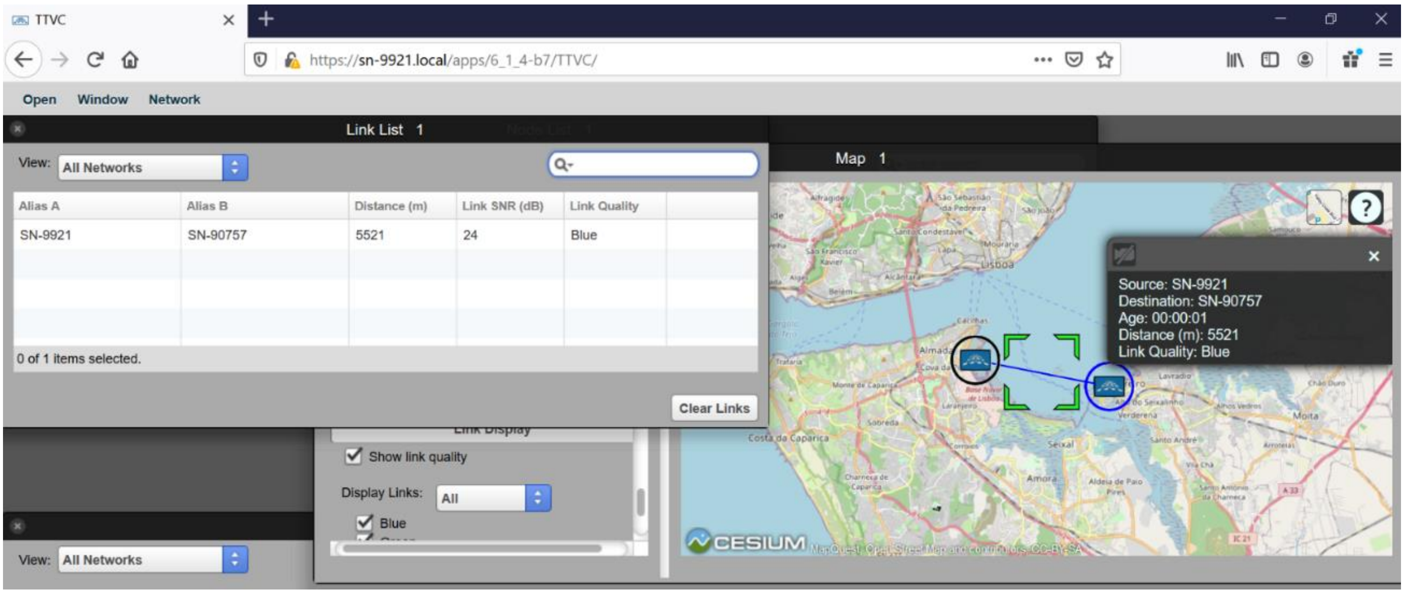


Figure 56 - Range test at 5.5km (map)

Figure 57 - Range test at 5.5km (terrain)

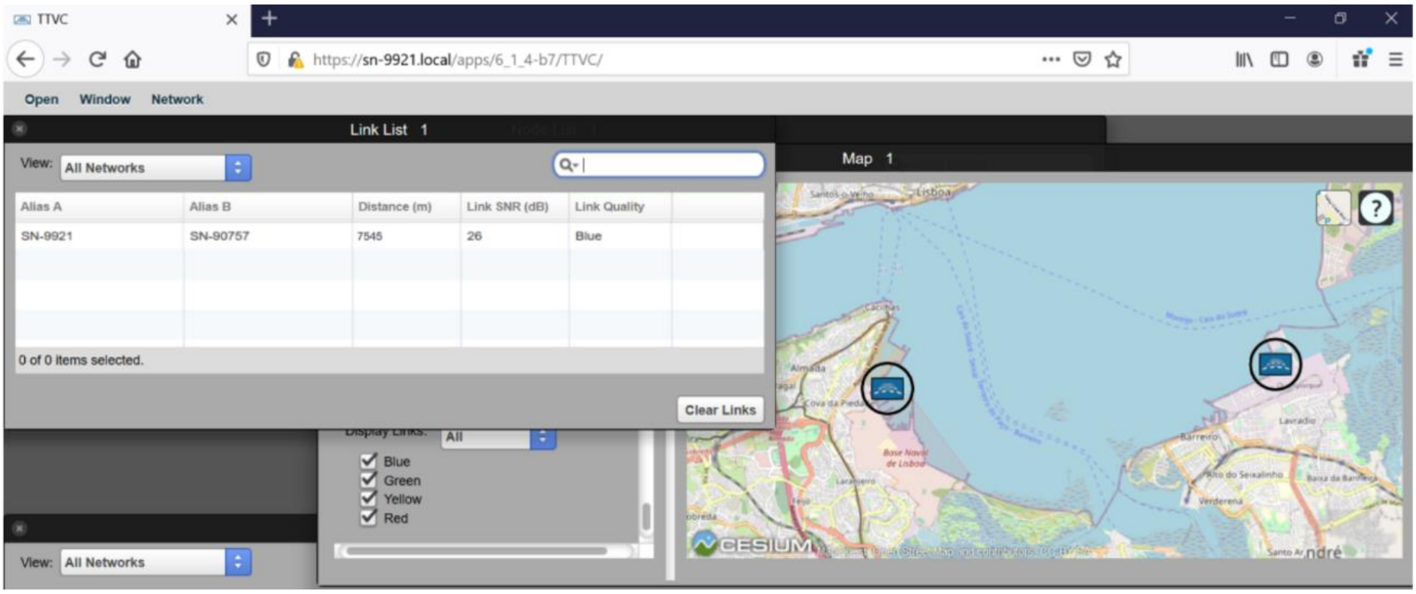


Figure 58 - Range test at 7.5km (map)

Figure 59 - Range test at 7.5km (terrain)

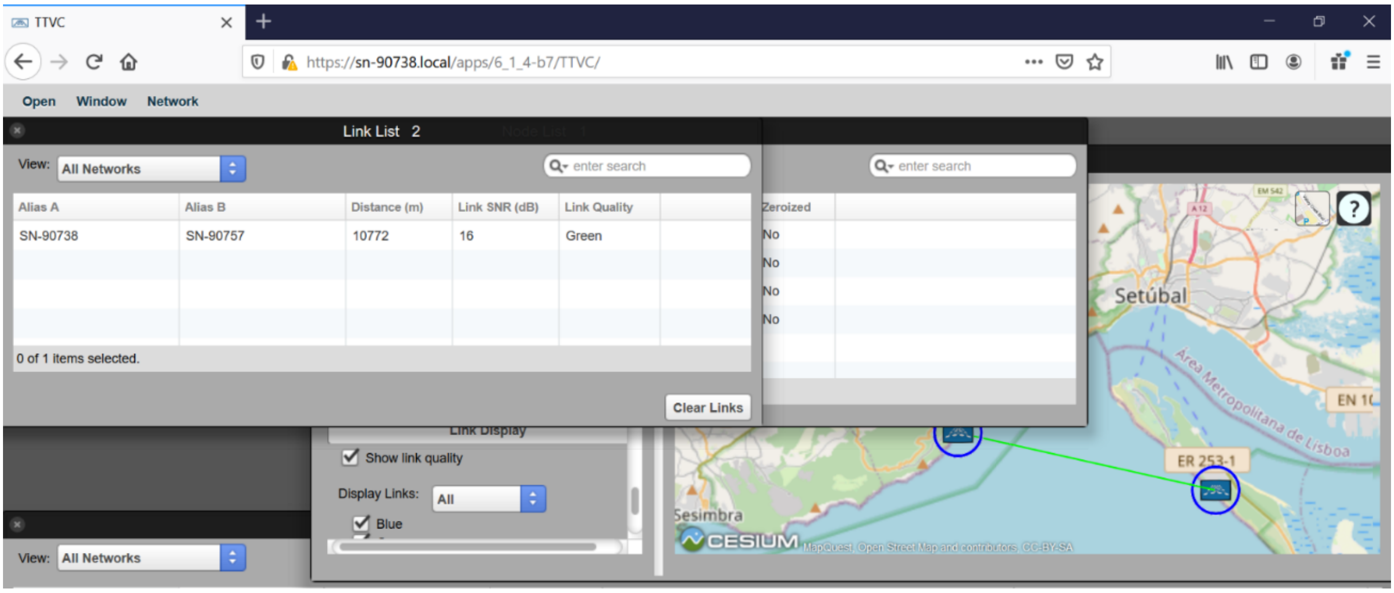


Figure 60 - Range test at 10km (map)

Figure 61 - Range test at 10km (terrain)

Test Logs

```
Pinging 10.120.254.88 with 32 bytes of data:
Reply from 10.120.254.88: bytes=32 time=71ms TTL=128
Reply from 10.120.254.88: bytes=32 time=106ms TTL=128
Reply from 10.120.254.88: bytes=32 time=101ms TTL=128
Reply from 10.120.254.88: bytes=32 time=91ms TTL=128
Reply from 10.120.254.88: bytes=32 time=83ms TTL=128
Reply from 10.120.254.88: bytes=32 time=116ms TTL=128
Reply from 10.120.254.88: bytes=32 time=106ms TTL=128
Reply from 10.120.254.88: bytes=32 time=98ms TTL=128
Reply from 10.120.254.88: bytes=32 time=127ms TTL=128
Reply from 10.120.254.88: bytes=32 time=275ms TTL=128
Reply from 10.120.254.88: bytes=32 time=80ms TTL=128
Reply from 10.120.254.88: bytes=32 time=269ms TTL=128
Reply from 10.120.254.88: bytes=32 time=251ms TTL=128
Reply from 10.120.254.88: bytes=32 time=191ms TTL=128
Reply from 10.120.254.88: bytes=32 time=166ms TTL=128
Reply from 10.120.254.88: bytes=32 time=147ms TTL=128
Reply from 10.120.254.88: bytes=32 time=167ms TTL=128
Reply from 10.120.254.88: bytes=32 time=127ms TTL=128
Reply from 10.120.254.88: bytes=32 time=149ms TTL=128
Reply from 10.120.254.88: bytes=32 time=90ms TTL=128
Reply from 10.120.254.88: bytes=32 time=84ms TTL=128
Reply from 10.120.254.88: bytes=32 time=116ms TTL=128
Reply from 10.120.254.88: bytes=32 time=81ms TTL=128
Reply from 10.120.254.88: bytes=32 time=111ms TTL=128
Reply from 10.120.254.88: bytes=32 time=113ms TTL=128
Reply from 10.120.254.88: bytes=32 time=108ms TTL=128
Reply from 10.120.254.88: bytes=32 time=84ms TTL=128
Reply from 10.120.254.88: bytes=32 time=77ms TTL=128
Reply from 10.120.254.88: bytes=32 time=74ms TTL=128
Reply from 10.120.254.88: bytes=32 time=159ms TTL=128
```

Figure 62 - Latency test at 5.5km

```
Connecting to host 10.120.254.88, port 5201
[  4] local 10.120.160.139 port 52887 connected to 10.120.254.88
[ ID] Interval           Transfer     Bandwidth
[  4]   0.00-1.00   sec   256 KBytes  2.10 Mbits/sec
[  4]   1.00-2.00   sec   384 KBytes  3.14 Mbits/sec
[  4]   2.00-3.00   sec   384 KBytes  3.15 Mbits/sec
[  4]   3.00-4.00   sec   384 KBytes  3.15 Mbits/sec
[  4]   4.00-5.00   sec   384 KBytes  3.15 Mbits/sec
[  4]   5.00-6.00   sec   384 KBytes  3.14 Mbits/sec
[  4]   6.00-7.00   sec   256 KBytes  2.10 Mbits/sec
[  4]   7.00-8.00   sec   512 KBytes  4.18 Mbits/sec
[  4]   8.00-9.00   sec   512 KBytes  4.20 Mbits/sec
[  4]   9.00-10.00  sec   256 KBytes  2.10 Mbits/sec
[  4]  10.00-11.00  sec   512 KBytes  4.20 Mbits/sec
[  4]  11.00-12.00  sec   256 KBytes  2.10 Mbits/sec
[  4]  12.00-13.00  sec   384 KBytes  3.14 Mbits/sec
[  4]  13.00-14.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  14.00-15.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  15.00-16.00  sec   384 KBytes  3.14 Mbits/sec
[  4]  16.00-17.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  17.00-18.00  sec   512 KBytes  4.20 Mbits/sec
[  4]  18.00-19.00  sec   256 KBytes  2.10 Mbits/sec
[  4]  19.00-20.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  20.00-21.00  sec   256 KBytes  2.09 Mbits/sec
[  4]  21.00-22.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  22.00-23.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  23.00-24.00  sec   384 KBytes  3.14 Mbits/sec
[  4]  24.00-25.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  25.00-26.00  sec   384 KBytes  3.15 Mbits/sec
[  4]  26.00-27.00  sec   384 KBytes  3.14 Mbits/sec
[  4]  27.00-28.00  sec   512 KBytes  4.19 Mbits/sec
[  4]  28.00-29.00  sec   384 KBytes  3.14 Mbits/sec
[  4]  29.00-30.00  sec   384 KBytes  3.15 Mbits/sec
```

Figure 63 - TCP test at 5.5km

```
Connecting to host 10.120.254.88, port 5201
[  4] local 10.120.160.139 port 63883 connected to 10.120.254.88 port
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.00   sec   912 KBytes  7.47 Mbits/sec  114
[  4]   1.00-2.00   sec   976 KBytes  8.00 Mbits/sec  122
[  4]   2.00-3.00   sec   960 KBytes  7.86 Mbits/sec  120
[  4]   3.00-4.00   sec   984 KBytes  8.06 Mbits/sec  123
[  4]   4.00-5.00   sec   976 KBytes  7.99 Mbits/sec  122
[  4]   5.00-6.00   sec   968 KBytes  7.93 Mbits/sec  121
[  4]   6.00-7.01   sec   992 KBytes  8.05 Mbits/sec  124
[  4]   7.01-8.00   sec   960 KBytes  7.94 Mbits/sec  120
[  4]   8.00-9.01   sec   984 KBytes  7.95 Mbits/sec  123
[  4]   9.01-10.00  sec   976 KBytes  8.11 Mbits/sec  122
[  4]  10.00-11.00  sec   984 KBytes  8.06 Mbits/sec  123
[  4]  11.00-12.00  sec   968 KBytes  7.93 Mbits/sec  121
[  4]  12.00-13.00  sec   976 KBytes  7.99 Mbits/sec  122
[  4]  13.00-14.00  sec   992 KBytes  8.13 Mbits/sec  124
[  4]  14.00-15.00  sec   960 KBytes  7.86 Mbits/sec  120
[  4]  15.00-16.00  sec   976 KBytes  8.00 Mbits/sec  122
[  4]  16.00-17.00  sec   984 KBytes  8.06 Mbits/sec  123
[  4]  17.00-18.00  sec   968 KBytes  7.92 Mbits/sec  121
[  4]  18.00-19.00  sec   992 KBytes  8.13 Mbits/sec  124
[  4]  19.00-20.00  sec   984 KBytes  8.06 Mbits/sec  123
[  4]  20.00-21.00  sec   976 KBytes  8.00 Mbits/sec  122
[  4]  21.00-22.00  sec   960 KBytes  7.86 Mbits/sec  120
[  4]  22.00-23.00  sec   992 KBytes  8.13 Mbits/sec  124
[  4]  23.00-24.00  sec   968 KBytes  7.93 Mbits/sec  121
[  4]  24.00-25.00  sec   976 KBytes  8.00 Mbits/sec  122
[  4]  25.00-26.00  sec   984 KBytes  8.06 Mbits/sec  123
[  4]  26.00-27.00  sec   960 KBytes  7.85 Mbits/sec  120
[  4]  27.00-28.00  sec   976 KBytes  8.01 Mbits/sec  122
[  4]  28.00-29.00  sec   992 KBytes  8.13 Mbits/sec  124
[  4]  29.00-30.00  sec   968 KBytes  7.93 Mbits/sec  121
```

Figure 64 - UDP test at 5.5km

4.3.5. **TST_TRLS_005**: NLOS range test between Trellisware terminals with radio relaying using an aerostat

Test case ID
TST_TRLS_005
Test Scenario
The goal of this test is to test the radio relaying capability of the Trellisware Cub radio terminal. This functionality allows the radio terminal to act as a relay for two radios that are out of range of each other but within range of the radio acting as a relay. Therefore, this functionality of the Trellisware Cub allows it to drastically increase the range of the Trellisware MANET since it can support up to 8 hops between radio relays in the MANET. The test was performed by placing a stationary Trellisware Cub radio at the ground (football pitch) and mounting a radio relay (Trellisware Ghost terminal) on an aerostat flying over the football pitch at a height of 35m. The third radio is a Trellisware Cub radio terminal mounted on a vehicle which is driving along a path with many obstacles that ensures that the two Cub radios do not have LOS. We evaluate the throughput and latency of the connection between the two Trellisware Cub radios using the Trellisware Ghost mounted on the aerostat as relay at the following distances: 100m, 230m, 600m and 1.2km.

Test Results	
100 m	
Link SNR (Cub-Ghost)	48 dB
Bandwidth	TCP: 2.38 Mbps, UDP: 6.34 Mbps
Packet losses (UDP)	0.29%
Latency	Minimum = 72ms, Maximum = 487ms, Average = 171ms
230 m	
Link SNR (Cub-Ghost)	41 dB
Bandwidth	TCP: 2.1 Mbps, UDP: 5.32 Mbps
Packet losses (UDP)	0.37%
Latency	Minimum = 73ms, Maximum = 317ms, Average = 195ms
600 m	
Link SNR (Cub-Ghost)	40 dB
Bandwidth	TCP: 1.67 Mbps, UDP: 5.75 Mbps
Packet losses (UDP)	1.3%
Latency	Minimum = 92ms, Maximum = 396ms, Average = 178ms
1.2 km	
Link SNR (Cub-Ghost)	36 dB
Bandwidth	TCP: 1.49 Mbps, UDP: 4.78 Mbps
Packet losses (UDP)	3.7%
Latency	Minimum = 91ms, Maximum = 491ms, Average = 212ms

Figure 65 - Radio relay test with aerostat (map)

Figure 66 - Setting up the aerostat

Figure 67 - Aerostat flying at the height of 35m

Figure 68 - Aerostat flying at the height of 35m after the set-up

5. On-field demonstrations

This section summarizes the technical specifications, limitations and regulations for the on-field demonstrations in the ARESIBO project. There is a distinction between the specifications and the setup for the on-field demonstrations and the eventual operational solution.

5.1. Technical specifications

Table 1 Technical specifications of the last mile solutions

Setup	On-field demonstration		Operational	
Last mile solution	Wi-Fi	MANET	Wi-Fi	MANET
Number of users	20	4	60 (to be tested)	60 (to be tested)
Total bandwidth	LTE: 20 Mbps; SATCOM:2 Mbps	LTE: 20 Mbps; SATCOM:2 Mbps	LTE: 40 Mbps; SATCOM:20 Mbps (to be tested)	LTE: 40 Mbps; SATCOM:20 Mbps (to be tested)

There are several notes concerning the on-field demonstrations:

- The usage of an aerostat (as presented in Section 5.3.5) is dependent on the weather conditions as the aerostat might face operational difficulties in severe weather.
- Both nomadic and mobile solutions will be presented to the ASSISTANCE reviewers and we will explain the situation and our preference to run the onsite demonstrations with the nomadic system. However, if the decision is that Viasat needs to bring the full mobile system to at least one of the demonstrations, we will do it and bring it to the nearest one.
- The number of users and total bandwidth for the operational solution are based on estimations and require further testing.

6. Brazil test campaign

Viasat is planning to perform extensive tests of the system as part of an internal project in Brazil. Viasat has identified both a technical and commercial potential on running tests in Brazil. Viasat currently operates the government satellite SDGC1 owned by the public entity Telebras. Telebras has expressed a strong interest in our mobile communication hub for public first responder applications and other public safety agencies. These synergies combined with the challenging environmental will help to take a significant step forward towards validating both the technical and commercial viability of our solution. These tests can be extended and adapted to the ARESIBO setup and provide valuable insights into the system performance in conditions that cannot be tested in Switzerland, but can be met by some partners in ARESIBO during their operations. These conditions and their effect on the system are explained in more detail in this section.

Antenna angle of elevation

Due to the lower latitude of the testing locations in Brazil and their relative position to the satellite, the KaLMA antenna will have to perform with a higher angle of elevation compared to Switzerland when pointing to the satellite. The goal of these tests is to evaluate the capability of the system to maintain a high level of performance while constantly pointing at a higher angle of elevation. These tests are relevant for the ARESIBO project since there are partners in ARESIBO operating in locations with different latitudes and these tests will provide an answer whether the angle of elevation of the satellite antenna has an effect on the system performance.

Weather conditions

The weather conditions in Brazil are vastly different to the ones in Switzerland, mainly in terms of the temperature and humidity. Therefore, the goal of this test is to evaluate the effect of the weather conditions (mostly temperature and humidity) on the satellite antenna and the whole system. This test is relevant for the ARESIBO project as it will provide valuable insight on the system performance for partners that operate in similar weather conditions.

Beam handovers

Since Brazil covers a significant land area, there is a large number of satellite beams used to provide coverage to the whole area of Brazil. Therefore, having a mobile communication hub would require the system to perform many handovers between different beams. This test will focus on observing the impact of the beam handovers on the overall system performance and it will be relevant for ARESIBO since there are many beams over Europe and handovers will be very common in the ARESIBO use-cases.

Availability and reliability

The tests in Brazil will require the system to be active for long periods of time (i.e. weeks of uninterrupted activity) which will provide valuable insight into the system's availability and reliability. This test will is relevant for the ARESIBO project since the use-cases defined in ARESIBO require the system to be operational for long periods of time.

7. Conclusions

The goal of this activity has been reached at this point of the program. VIASAT has deployed and tested the Mobil Communication Hub and the technology is ready for a field demonstration.

This system has three key elements: KALMA mechanical steering horn array antenna, Seamless Failover System and Last Mile Radio System. To the main communication features, some security features have been added as explained in D3.3, considering this as a relevant system characteristic to enable the system to be commercialized in near future.

We have first deployed and tested the system in our lab premises. Each of the individual components has been tested and verified as well as the full integrated system. After that first phase, we have set up the System in a test vehicle and run with it 3 test campaigns: short ride, long ride and last mile. Few more testing activities are planned to validate the system in lower latitudes and extreme environmental conditions for potential commercialization purposes.

At this point we can state that we have deployed and tested the Robust Mobile Communication System that was presented in D3.3. Even if some tests and system optimization is still on going, the solution is ready today.