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MONROE

Measuring Mobile Broadband Networks in Europe

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Deliverable D2.2
Node Deployment

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Abstract

This report describes the logistic procedures designed to purchase the hardware equipment, install and configure the software operating system, assemble the MONROE nodes and finally ship the nodes to the responsible partners for the deployment. Testing procedures for the assessment of the correct functional working of both stationary and mobile nodes are also presented in the form of test cards. Deployment strategies for selection of hosts and node installations are also described. The document is an update of the original deliverable D2.2, and reports the upgrade to the MONROE logistics, assembly and deployment procedures according to the new node design.

Keywords

Participant organisation name	Short name
SIMULA RESEARCH LABORATORY AS *(Coordinator)*	SRL
CELERWAY COMMUNICATION AS	Celerway
TELENOR ASA	Telenor
NEXTWORKS	NXW
FUNDACION IMDEA NETWORKS	IMDEA
KARLSTADS UNIVERSITET	KaU
POLITECNICO DI TORINO	POLITO

1 Introduction

The MONROE project aims to build and operate a novel platform to perform measurements and experiments in the operational mobile networks (MBBs). The main objective of the project is to design and implement an European transnational open testbed for independent, multi-homed, large-scale monitoring and assessment of performance of MBBs networks in heterogeneous environments.

This document is an upgraded version of the original deliverable D2.2, and provides the needed updates to the MONROE logistic, assembly and deployment procedures in light of the new dual-APU node design. Indeed, the upgrade of the MONROE platform to the new node desing has required the engineering of the new procedures for the realization of a new set of dual-APU nodes. It is important to highlight that the upgrade of the MONROE platform has been carried out following the principle of re-using as much as possible available material and components from the old nodes.

This deliverable describes those MONROE logistic procedures which aimed at analyze the hardware requirements of the platform against the components available in the market. The main goal has been the acquisition of equipment and various material for the MONROE nodes following a principle of best trade off among several aspects, including availability, delivery time and equipment cost. Based on these, specific suppliers have been selected for each of the components to fully match the MONROE platform requirements. As a consequence of the upgrade to the new node design, the total number of nodes for the MONROE platform has been revisited to target a total of 135 nodes (plus 20 for testing) distributed per country as following:

- Norway: 35 deployed nodes (25 mobile and 10 stationary), 5 testing nodes
- Sweden: 45 deployed nodes (30 mobile, 15 stationary), 5 testing nodes
- Italy: 45 deployed nodes (25 in public transport vehicles, 15 in delivery trucks, 5 stationary), 5 testing nodes
- Spain: 10 deployed nodes (all stationary), 5 testing nodes

Nextworks has been the main responsible for the collection of the spare equipment and materials from the suppliers. Aiming to simplify and ease the assembly procedures, the Nextworks' warehouse infrastructure has been enhanced to store and catalogue in an efficient way all the items in the depot. In this way, all components have been made accessible during the assembly phases. Moreover, a reference MONROE courier has been selected for the shipment of the nodes to the partners in Spain, Italy, Sweden and Norway. The courier has guaranteed a short shipping time together with a competitive price.

The core part of this document focuses on the description of the MONROE node assembly procedures, for both stationary and mobile nodes. In short, the workflows for APUs software installation and configuration, as well as interconnection of equipment and components into assembled box, are fully described. Specific customization required for different partners (in different deployment countries) are also considered. The description of the MONROE assembly procedures is augmented with a set of test cards which are used by assembly team to validate the correct functional operation of the nodes.

This document also describes the MONROE node deployment strategies, which basically provide information on the selected hosts and locations for the deployed stationary and mobile nodes. The goal here has been to build a distributed and heterogeneous platform in terms of environmental conditions. The description of the MONROE node deployment included in this document covers a part of the whole set of planned stationary and mobile nodes. A further update to this document will be released to provide the full information on the MONROE deployed nodes.

2 Logistics

This section describes the MONROE **logistics procedures**, which are composed by a coordinated collection of complex operations for the management of the flow of node components from the *point of origin* to the *point of consumption*. The point of origin is basically the location of a given individual component at the moment of the order, i.e. the supplier warehouse. On the other hand, the point of consumption is the final destination of a MONROE assembled node, i.e. the locatin of a given host (bus or train company, a MONROE partner, etc.). The logistics procedures include the purchasing of the selected goods, the inventory, the storage in a proper warehouse, the material handling to assemble and realize the MONROE nodes and finally the packaging and shipment to the partners for the final deployment. Figure 1 provides an overview of the MONROE logistics workflow, in the specific example case of GTT as point of consumption for deployment of mobile nodes on Turin city buses. The overall workflow can be summarized as follows:

- Nodes hardware components are ordered from the selected suppliers. This phase involve the order of modems, antennas, APUs, disks, etc, each from the best available supplier, in terms of delivery cost and time.
- Upon order, the hardware suppliers ship the components to Nextworks (Pisa). Here all the received material is stored, catalogued in inventories and stored in the warehouse.
- Nextworks takes care of ordering additional assembly material and consumables, needed to produce MONROE nodes.
- Nextworks assembly team prepares the nodes, which basically includes software installation and configuration for APU nodes, and assembly of the whole node components into a box.
- When ready, a set of assembled MONROE nodes (normally in sets of 10 to 15 units) are shipped with the reference MONROE outbound courier towards the final destination
- Upon arrival of the nodes at destination, the MONROE nodes can be subject to further tests and validations from the host deployment team
- The nodes are deployed in the given location (bus, train, etc.) and installed to be used as part of the MONROE platform.

More details on each of the above MONROE logistics activity are provided in the following sections.

2.1 Inbound: purchase and storage the goods

In the deliverable D2.1, we have introduced the basic prerequisites of the MONROE system and its hardware components. We have also presented the main devices that form the core of the node, i.e the APU system board, the internal WiFi modems, the GPS receiver, etc. Moreover the tests to verify their characteristics have been reported. In short, the *bill of materials* has been fully defined and this can be considered as the starting point for the logistic and deployment phase of the project.

One of the first activities carried out in the Task 2.2 was the selection of the best suppliers available in the market which can guarantee the large amount of materials and a short delivery time. In this context, we have created relationships directly with the device producers in order to avoid the intermediation of suppliers or retailers. It is worth noting that these contacts allowed us to have technical discussions to solve problems or to enhance the final product. For example, the case of the APU board is a customisation of the

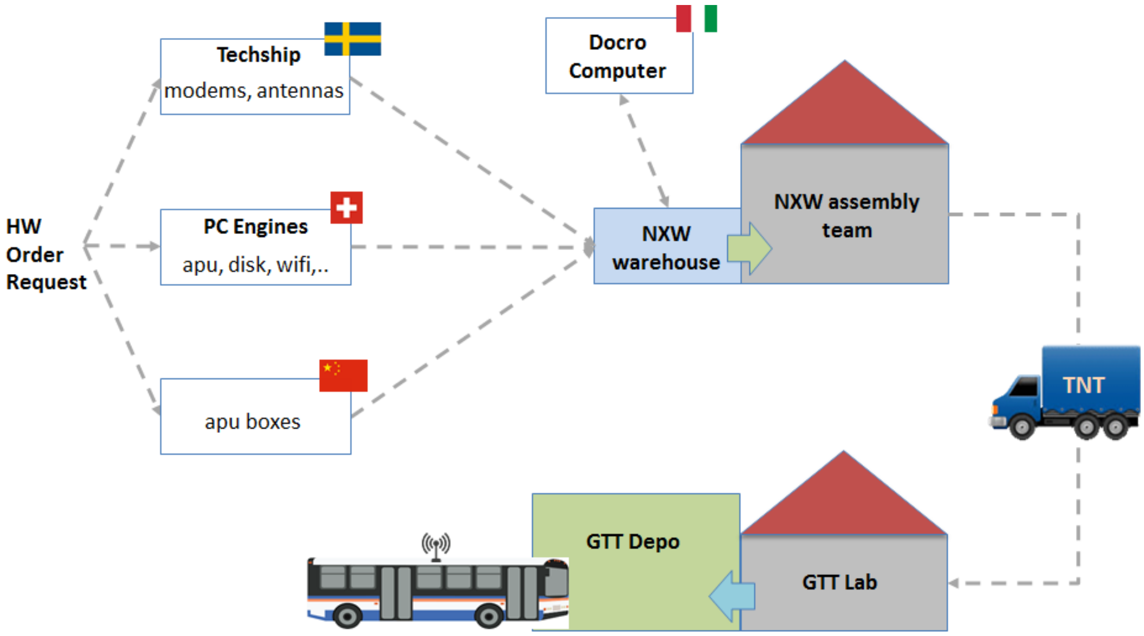

Figure 1: *Overview of MONROE logistics workflow.*

standard case produced by the PC Engine. In fact we asked four side holes to speed up the usage of the SMA connectors for the LTE and WiFi antennas. A special mention is required on the converters that are used to power the devices with different ingress voltages. These components have been first selected by analyzing the technical specifications, then some samples were purchased and tested in our laboratory. At the end, the converters have been ordered directly from the producers. On the other hand, several easily available and cheap components have been acquired directly from local distributors, i.e cables, adapters, standard connectors, boxes, etc. The price of these goods is so low to require further actions.

The storage of the goods has been an important activity that we fully adopted. In particular, the ingress components have been checked and counted (if necessary) and then introduced in our centralized system for the management of the depot. The database has been updated with the MONROE materials which have been uniquely identified by an internal code. In every moment of the production, the system has tracked the place and quantity for each device.

Table 1 summarizes the *bill of materials* with details of the product code, the description, the producer or supplier and the place of the depot in which the component is (or has been) stored.

2.2 Assembly procedures

The MONROE platform consists of two different types of node:

- *Stationary Nodes:* deployed in labs, offices and houses
- *Mobile Nodes:* deployed in buses, trucks and trains

As described in the following subsections, both types of nodes are, from and assembling point of view, very similar. The only difference resides in the in the power supply and voltage constraints required from different devices, depending on the deployment environment.

Code	Description	Supplier	Storage at warehouse
apu1d4	APU.1D4 system board 4GB	PC Engine	LABMONROE-0-1
apu2d4	APU.2D4 system board 4GB	PC Engine	LABMONROE-0-1
case1d2redu	Custom red case	PC Engine	LABMONROE-0-1
ac12veur2	AC adapter 12V 2A euro for IT equipment	PC Engine	LABMONROE-0-1
sma-cable	Interface cable SMA/IPEX 15cm	PC Engine	LABMONROE-0-1
msata16d	SSD M-Sata 16GB MLC Phison	PC Engine	LABMONROE-0-2
wle600vx	Compex WLE600VX miniPCI express card	PC Engine	LABMONROE-0-2
mc7304	Sierra wireless MC7304 data (CAT3)	PC Engine	LABMONROE-0-2
sim7100E	SIMCom SIM7100E (CAT3, embedded sim slot)	PC Engine	LABMONROE-0-2
mc745504	Sierra wireless MC7455 data (CAT6)	PC Engine	LABMONROE-0-2
wifi-antenna	Wifi rubber antenna 2.4-5.8 GHz	.	LABMONROE-0-2
lte-antenna	External T-blade LTE antenna	.	LABMONROE-0-2
gps-antenna	External passive GPS antenna	.	LABMONROE-0-2
gsm-socket	GSM smart plug	.	LABMONROE-0-4
accessories	Outlet extensions, fuses, metal clamps, spare materials	DOCRO Computer	LABMONROE-0-4
gewiss-box	Gewiss IP55 enclosure	Gewiss	LABMONROE-1-0
k2413	DC-DC converter from 24V to 12V	Alcapower	LABMONROE-1-1
rsd-100c-12	Railway Single Output DC-DC Converter from 48V to 12V	MW mean well	LABMONROE-1-1
rsd-100d-12	Railway Single Output DC-DC Converter from 110V to 12V	MW mean well	LABMONROE-1-1

Table 1: Storage of the MONROE components.

2.2.1 Common assembly procedure

Each MONROE node contains two APUs (Accelerated Processing Unit, see table 1), directly connected via Ethernet, which represents the core of node itself. Due to this, it's worth providing a general overview of the APU motherboard. Both of APUs listed in table 1 are used in MONROE platform. Here we provide a description of apu2d4, the most used, while a description of apu1d4, in terms of differences with apu2c4, will be provided further on in this section. The APU motherboard is equipped with:

- 3 slots for PCIe cards;
- 2 slots for SIM cards;
- 2 USB 3.0 ports
- 3 Ethernet ports
- 1 serial port

One PCIe slot is always reserved to mSata SSD, wich will contain the Operating System and the software for the exepriments, while the remaining ones are used to host LTE/GPS modems or WiFi receiver cards. WiFi and LTE/GPS modules are connected to the proper antennas via SMA connectors. Finally, the antennas are fixed to the APU chassis. USB ports are leaved free for future use: they can be used to install the Operating System. The Etherent ports are used to provide an wired access towards Internet (Eth0) and to interconnect together both APUs (Eth1 and Eth2). For managements reasons, we distinguish two roles concerning the single APU in dual-APU system, HEAD or TAIL. As explained below, HEAD and TAIL differ in two aspects: the PCIe cards and the number of SIMs installed.

In TAIL APU, the two free PCIe slots host 1 LTE/GPS modem and 1 WiFi receiver respectively. Since only one LTE/GPS modem is installed, the TAIL APU will contain only one SIM card, which will be inserted in one of the slots in the motherboard. The figure 2 depicts the main building blocks of the TAIL APU system and how they are assembled on the motherboard.

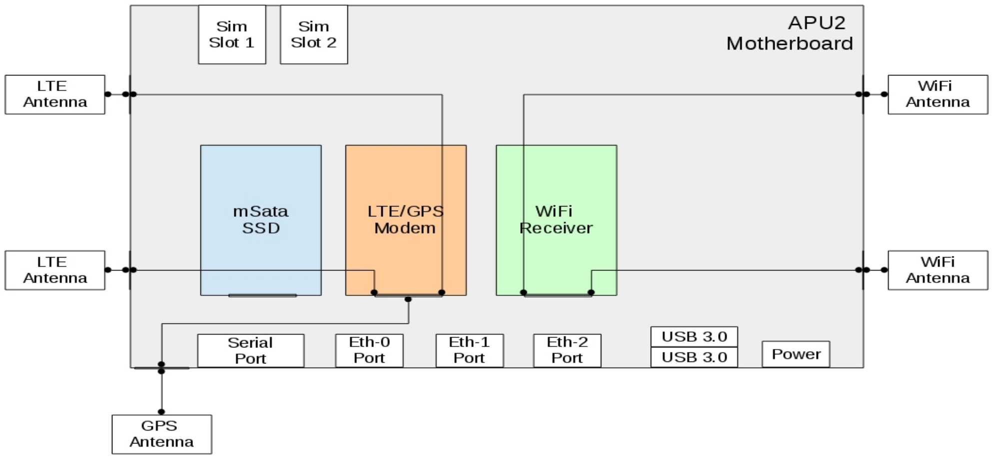

Figure 2: Building blocks of TAIL node.

The configuration of HEAD APU constists of 2 LTE/GPS modem (no WiFi receiver) and two SIM cards. The figure 3 depicts the main building blocks of the HEAD APU system and how they are assembled on the motherboard.

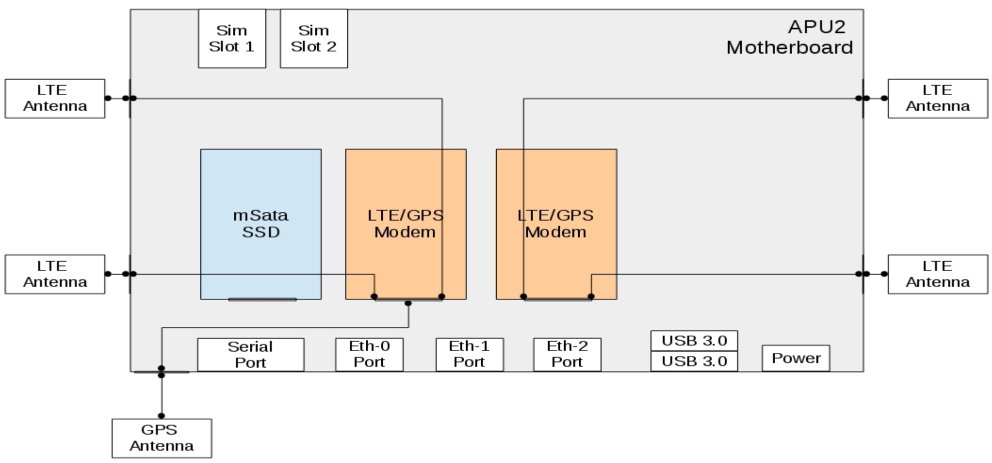

Figure 3: Building blocks of HEAD node.

The dual-APU sistem guarantees the possibility of perform measurements concerning 3 different mobile operators (HEAD and TAIL together can host 3 SIM cards), furthermore, as TAIL is accessible via Ethernet from HEAD, it's possible to handle whole dual-APU system accessing the HEAD APU.

For the assembly of the MONROE nodes, we have implemented a simple procedure composed of these basic steps:

1. Mount heatsink to the motherboard;
2. Fix motherboard to the APU chassis;
3. Plug the hard disk on the motherboard;
4. Plug the LTE/GPS and/or WiFi PCIe cards on the motherboard and use proper SMA connectors for linking the cards to the APU chassis;
5. Put the management SIM card(s) in the proper slot(s);
6. Close the APU chassis and mount all the antennas, i.e WiFi, GPS and LTE;
7. Install OS via USB
8. Tests as in Section 2.3
9. Build the power supply system (depending on the node typology);
10. Assemble the components and devices in the Gewiss box.
11. Repeat tests as in Section 2.3

The figure 4 shows two photos as example of a HEAD and TAIL APUs:

2.2.2 Stationary nodes

Stationary nodes are directly connected to the electric power distribution in the 220-240 volt range. In short, they use the general-purpose alternating-current (AC) electric power supply with a voltage of (nominally) 230V and a frequency of 50Hz, here in Europe.

As the main components of the system work in direct current, an AC/DC transformer is required. In the Gewiss box, there are different power sockets linked in sequence. The first one is a programmable GSM socket that allows us to switch on/off the MONROE node using a SMS from a remote cellular phone. Then there is an outlet power strip used to connect the plugs of the APU system and the USB hub.

The figure 5 depicts the main building blocks of the stationary nodes and their interconnections.

Figure 4: Examples of HEAD (left) and TAIL (right) APUs.

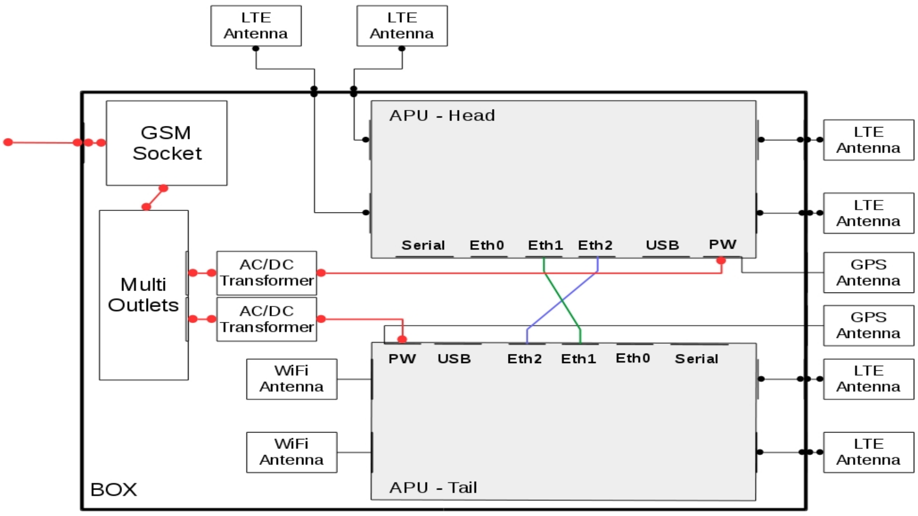

Figure 5: Building blocks of the stationary nodes.

2.2.3 Mobile nodes

MONROE mobile nodes are placed on trucks, buses or trains in Italy, Sweden and Norway. Consequently, they are supplied from the inner power grid of the transport vehicles that host them. The power grids in trucks, buses and trains are identified to work in DC mode at 24, 48 or 110 Volts. Therefore, it is necessary to mount DC-DC converters in order to translate the ingress power supply to the one used by the internal node devices, i.e 12V for the APU board. Consequently, a 24,48,110V to 12V converter is directly connected to the transport power grid and decreases the ingress voltage down for the APU system;

For the mobile nodes we could not use the GSM socket since there is no alternative that works with DC voltage, except for some trains that can support DC voltage. However, the vehicles power off regularly resulting in a reboot of the node.

The figure 6 shows the main building blocks of the mobile nodes and their interconnections.

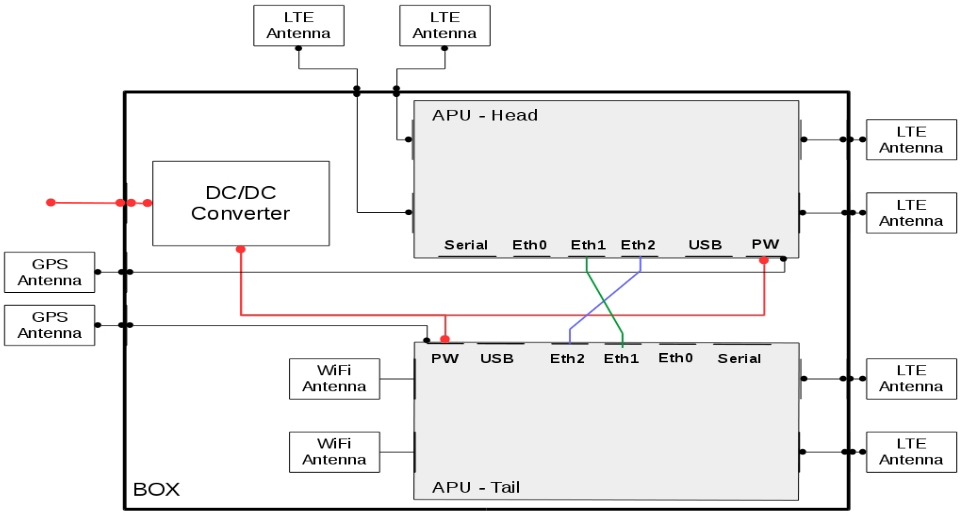

Figure 6: Building blocks of the mobile nodes.

Mobile nodes in Italy

The nodes deployed in Italy are equipped with a 24 to 12 volts converter as 24 volts is the standard voltage used in the Italian public transports. There is a difference between the mobile nodes deployed in buses with respect the ones deployed in trucks. The dual-APU system installed in nodes which are deployed in the trucks consists of a couple of apu1d4 (APU1) instead of apu2c4 (APU2), similar from an external point of view, but internally different. The HEAD/TAIL configuration it's the one described above but, since APU1 offers only one slot for SIM cards, one of the LTE/GPS modem in the HEAD is a **sim7100E**, which offers an embedded SIM slot. All LTE/GPS modem in truck nodes are CAT3 instead of CAT6 as the ones in the buses: they are enough to perform measurements in rural areas, in which often the only mobile transmission technology available is 2G/3G. There are other differences between the two types of APUs (different CPUs, USB 3.0 in APU2 and 2.0 in APU1, etc) but they don't affect the node configuration and will not be treated.

Mobile nodes in Sweden

Swedish nodes are identical to the ones deployed to the buses in Italy. The only difference in the assembly procedures is related on the support of the Gewiss box. In fact, the Italian nodes lie on four silent blocks whereas the Swedish are mounted on a plywood plate.

The figure 7 shows two examples of these nodes.

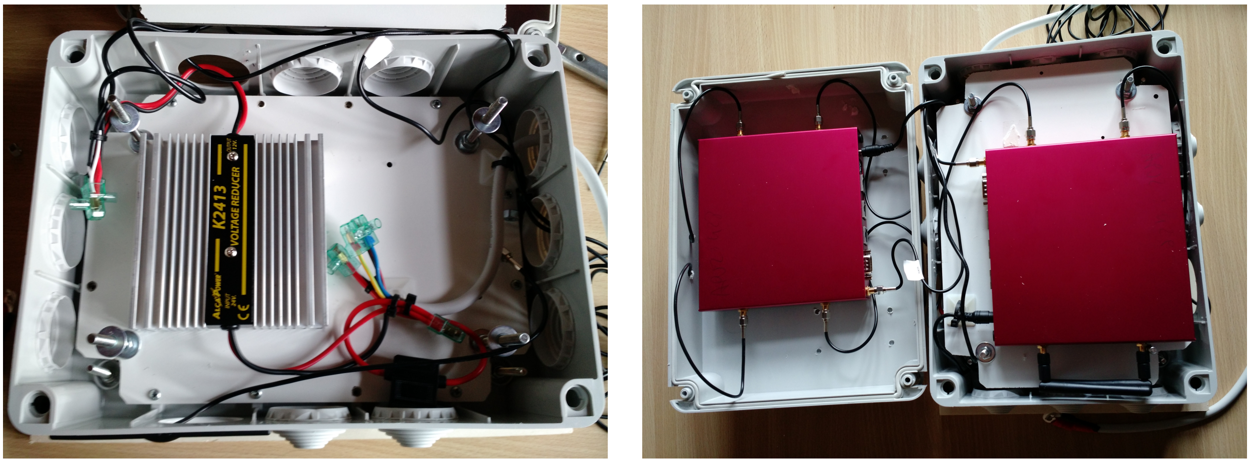

Figure 7: Examples of assembled mobile nodes in Italy and Sweden.

Mobile nodes in Norway

Norwegian mobile nodes differ from Italian and Swedish for the input DC converters because the Norvegian transports can use a 48V or 110V DC power grid. Therefore, different converters are used for this category of mobile nodes. Furthermore, in some trains, there is a support for DC voltage, in which case we deploy regular stationary nodes to these trains.

2.3 Test procedures

This section details the design of the tests on the hardware and software parts of the MONROE nodes.

The tests have been executed to validate the main functionalities of the devices in order to safely proceed with the final deployment in the selected hosts. The tests are presented in the form of **test-cards**. Each test-card includes a detailed description, the objectives and the steps to execute and replicate the test. At the end of each step the expected results are also provided.

2.3.1 Power on the node through the GSM socket

The test GSM-SOCKET-STATIONARY-001 (Table 2) can be only applied to the stationary nodes which are equipped with a GSM socket (with only exception of some nodes on the trains in Norway).

Test Card	GSM-SOCKET-STATIONARY-001	**Status**	Passed / Failed
Test Name	Power on the node through the GSM socket		
Objectives	Verify the possibility to power-on the device using a SMS to the GSM socket		
Dependencies	None		
Comments	A node fully assembled equipped with the SIM cards. The node must be powered off		

Steps Description

Step	Description	Results	Status
1.	Connect the Schuko plug of the node to the power supply	Verify that two lights of the GSM socket are on, i.e the power light (fixed) and the status light (blinking)	Passed / Failed
2.	Use a mobile phone to send a SMS to the SIM number of the GSM socket with this message 123456#1#	Wait for some seconds or minutes (it could depend on your network connectivity). After that, you should get a long buzzer sound and a third light should be on (calling light)	Passed /Failed
3.	Get the box and take a look at the lights	You should see the power green led on each APU turned on, that means that the device is powered on	Passed / Failed

Table 2: GSM-SOCKET-STATIONARY-001

2.3.2 Power off the node through the GSM socket

The test GSM-SOCKET-STATIONARY-002 (Table 3) can be only applied to the stationary nodes which are equipped with a GSM socket.

Test Card	GSM-SOCKET-STATIONARY-002	**Status**	Passed / Failed
Test Name	Power off the node through the GSM socket		
Objectives	Verify the possibility to power-off the device using a SMS to the GSM socket		
Dependencies	GSM-SOCKET-STATIONARY-001		
Comments	The node should be up and running		

Steps Description

Step	Description	Results	Status
1.	Use a mobile phone to send a SMS to the SIM number of the GSM socket with this message 123456#2#	You should get a long buzzer sound and the calling light should be off	Passed / Failed
2.	Get the box and take a look at the lights	The node must switch off	Passed / Failed

Table 3: GSM-SOCKET-STATIONARY-002

2.3.3 Verify the GPS signal

The test GPS-SIGNAL-TRACES-001 (Table 4) can be applied to both stationary and mobile nodes. This test is intended to be **per-apu**.

Test Card	GPS-SIGNAL-TRACES-001	**Status**	Passed / Failed
Test Name	Verify the GPS signal		
Objectives	Verify the possibility to receive the GPS signal for monitoring the position of the node		
Dependencies	None		
Comments	The node must be up and placed in a coverage area for the GPS antenna		

Steps Description			
Step	Description	Results	Status
1.	Access APU via serial port	You must receive the login request	Passed / Failed
2.	Provide user and password for superuser (MonroeSA)	You must receive the prompt of the node. Also you should be able to see the hostname of the node	Passed / Failed
3.	Retrieve the logs and see the traces of the GSP antenna. Run the command 'metadata | grep GPS'	The traces must flow in the screen	Passed / Failed

Table 4: GPS-SIGNAL-TRACES-001

2.3.4 Run the system self-test procedure

The test SYSTEM-SELF-TESTS-001 (Table 5) can be applied to both stationary and mobile nodes. This test is intended to be **per-apu**.

It is worth noting that this test is scheduled to run periodically inside the node every 20 minutes.

If three green lights are seen, then the system self-test has succeeded. Otherwise, it could be possible that the test may not have run yet and you have to wait 20 minutes more. In some cases, it is also possible that it may not have run because a previous step has failed, or the self-test may have failed. In all these cases, however an error-tracking procedure should be started to identify the problem(s).

Test Card	SYSTEM-SELF-TESTS-001	**Status**	Passed / Failed
Test Name	Automatic system self-test procedure		
Objectives	Run the system self-test procedure to verify error conditions		
Dependencies	None		
Comments	The device must be up and running		
Steps Description			
Step	Description	Results	Status
1.	Enter in the node. You can reuse the steps 1 and 2 of the test-case GPS-SIGNAL-TRACES-001		Passed / Failed
2.	Run the command biteback -f	You must see a trace with something like "26/26 success". In any case no errors are expected. You must also see three green lights on in the APU	Passed / Failed

Table 5: SYSTEM-SELF-TESTS-001

2.3.5 Run the ping through the WWAN interfaces

The test PING-WWAN-001 (Table 6) can be applied to both stationary and mobile nodes. This test is intended to be **per-apu**.

This test is **optional** in the sense that it is already covered by the SYSTEM-SELF-TESTS-001. In any case, you can use the steps for an analysis of the root causes of the connectivity problems of the network devices.

Test Card	PING-WWAN-001	**Status**	Passed / Failed
Test Name	Ping through the WWAN interfaces		
Objectives	Verify that all the three Modem Wifi are correctly installed and configured		
Dependencies	None		
Comments	The node must be up and running		
Steps Description			
Step	Description	Results	Status
1.	Enter in the node. You can reuse the steps 1 and 2 of the test-case GPS-SIGNAL-TRACES-001		Passed / Failed
2.	Verify that WWAN interfaces are configured: 1 for TAIL, 2 for HEAD. Run the command ifconfig | grep wwan	Interface wwan0 must be configured. In case of HEAD, wwan2 must be present too.	Passed / Failed
3.	Verify that you can ping the 8.8.8.8 address from the wwan0 interface. Run the command ping -I wwan0 8.8.8.8	You must receive valid results. Please see the note below in case of errors	Passed / Failed
4.	Repeat the step 3 for the wwan2 if present		Passed / Failed

Table 6: PING-WWAN-001

The main and common causes of errors in the ping tests are related to problems with the SIM cards, e.g. the SIM is not correctly placed in the slot or it is still blocked by its PIN/PUK code. In this latter case, the MONROE system is already equipped with a database that stores the PIN of the provided SIM cards. It is possible that some configuration problem exists within the database. Alternatively, there might be some issues with the provider or operator, i.e. a very low quality of the signal. In this case, the node should be moved in a better coverage area.

2.3.6 Verify the DNS settings

The test DNS-SETTING-001 (Table 7) can be applied to both stationary and mobile nodes. This test is intended to be **per-apu**.

This test is also **optional** in the sense that it is already covered by the SYSTEM-SELF-TESTS-001. In any case, one can use the steps for an analysis of the root causes of the network connectivity problems.

Test Card	DNS-SETTING-001	**Status**	Passed / Failed
Test Name	Verify the DNS settings		
Objectives	Verify that the DNS is correctly configured		
Dependencies	None		
Comments	The node must be up and running		
Steps Description			
Step	Description	Results	Status
1.	Enter in the system. Reuse the steps 1 and 2 of the test-case GPS-SIGNAL-TRACES-001		Passed / Failed
2.	Run the command ping www.google.com	You must be able to resolve this address and obtain valid results	Passed / Failed

Table 7: DNS-SETTING-001

2.3.7 Verify the status of the node in the repository

The test REPOSITORY-STATUS-001 (Table 8) can be applied to both stationary and mobile nodes. This test is intended to be **per-apu**.

Test Card	REPOSITORY-STATUS-001	**Status**	Passed / Failed
Test Name	Status of the node in the repository		
Objectives	Verify that the HEAD and TAIL is correctly registered in the inventory		
Dependencies	None		
Comments	Obtain the identifiers of HEAD and TAIL (hostname or ID)		

Steps Description			
Step	Description	Results	Status
1.	Connect your browser to the address https://monroe.celerway.no/login.php		Passed / Failed
2.	Provide your credentials (username and password)	You must be able to login in the inventory web pages	Passed / Failed
3.	Search the node using its hostname (or identifier)	Verify that the APU has a green state (green radio button)	Passed / Failed

Table 8: REPOSITORY-STATUS-001

2.3.8 Verify the status of the interfaces in the repository

The test REPOSITORY-STATUS-002 (Table 9) can be applied to both stationary and mobile nodes. This test is intended to be **per-apu**.

Test Card	REPOSITORY-STATUS-002	**Status**	Passed / Failed
Test Name	Status of the interfaces of the node in the inventory		
Objectives	Verify that the interfaces of HEAD and TAIL are correctly working		
Dependencies	REPOSITORY-STATUS-001		
Comments			
Steps Description			
Step	Description	Results	Status
1.	Click on the (green) radio button	You should have a popup with the node details	Passed / Failed
2.	Verify the status of the interfaces	The interfaces must be labelled with the proper operator and the type of the network currently connected (e.g. 3G, 4G or LTE). Also, the status must be a green bar	Passed / Failed

Table 9: REPOSITORY-STATUS-002

2.4 Outbound: shipment to the partners

When (and if) assembled nodes pass all the planned tests previously described, they are accurately packed for a safe shipment and to prevent damages or faults during the transportation. The selection of a reference courier for the MONROE nodes shipment has been carried out in the first months of the project, and had the main aim to have a unique contanct point for the delivery process, while trying to reduce the overall costs. Several couriers have been contacted to receive quotations and delivery times for the four countries involved in the MONROE nodes deployment, i.e. Spain, Norway, Sweden and Italy.

Nextworks, as main responsible for the logistics arrangements, collected best offers from *Bartolini*, *DHL Express*, *Macros* and *TNT* couriers. At the end, **TNT** was selected as it guaranteed the best trade off between delivery cost and time. TNT offered delivery time for Italy in one business day, and within one week in the rest of Europe (no more than five working days). Table 10 summarises the main outbound logistics information related to the shipment process of MONROE nodes, i.e the destination, address, selected courier and the expected delivery time (in days). Note that since all the nodes have been assembled directly in Nextworks (Pisa), we have not used any courier for the shipment of stationary and mobile nodes in the Tuscany area.

3 Deployment of the nodes

MONROE has the main objective to build a dedicated infrastructure for measuring and experimenting in commercial mobile broadband (MBB) and WiFi networks, setting up a platform composed by stationary and mobile measurement nodes.

As said, this document upgrades the original deliverable D2.2 and provides those updates related to the new MONROE node design. Concerning the deployment, the upgrade of the MONROE platform to the new required an update of the target of deployed nodes across Europe. In particular, the new total number of

Destination	Address	Courier	Delivery time
Sweden - Karlstad	UNIVERSIT ETSGATAN 2, KARLSTAD 65188, Sweden, SE 202100312001	TNT	5
Spain - Madrid	Avenida del Mar Mediterraneo, 22, 28918 Leganes (MADRID), Spain	TNT	5
Italy - Turin (GTT)	Corso Bramante, 66, 10126 Torino, Italia	TNT	1
Italy - Turin (POLITO)	Dipartimento di Elettronica e Telecomunicazioni - Corso Duca degli Abruzzi, 24, 10129 Torino	TNT	1
Norway - Oslo	MARTIN LINGES VEI 17, SNAROYA 1367, Norway, NO984648855	TNT	5

Table 10: Shipment of the MONROE nodes.

deployed nodes is 135, augmented with 20 test nodes. Among these, 95 are mobile nodes spread across Norway, Sweden and Italy, mostly installed on trains, buses and deliveray trucks.

Table 11 provides an overview of the new MONROE nodes distribution per-country.

Country	Partners	Mobile Nodes N.	Stationary Nodes N.	Tesing Nodes N.
Norway	SRL	**25**	**10**	**5**
Sweden	KAU	**30**	**15**	**5**
Italy	NXW, POLITO	**40**	**5**	**5**
Spain	IMDEA	**–**	**10**	**5**

Table 11: Updated MONROE deployment strategy

It is worth to mention that in addition to these above nodes planned for the four original project countries, additional mobile and stationary nodes have been assembled for the MONROE Open Calls users. Aiming to involve external users as soon as possible, while to anticipate the validation and exploitation of the MONROE platform, both first and second Open Call users nodes have been prioritized in the assembly and deployment workflows.

The following sections provide details on the MONROE deployment strategies and locations, with per-country information on nodes locations and operation environments.

3.1 Deployment strategy

One of the main goals of the MONROE project is to set up an infrastructure to allow users and experimenters to run their experiments in operational MBB networks across Europe.

Therefore, the MONROE testbed deployment strategy aims to fulfill a set of objective that enable users to deploy their experiments and perform meaningful and representative measurements.

- **Platform Stability**. We designed the MONROE nodes to be stable over time, both from the point of view of hardware components and software modules. However, since issues are likely to appear, we have designed a series of monitoring and maintenance routines aimed to keep the nodes operational and minimize the impact on the platform users. This is a continuous ongoing effort and it builds upon our experience with operating and providing support for MONROE.
- **Diversity**. Diversity is one of the main features of the MONROE infrastructure. Each MONROE node connects to three different operators, making the platform particularly well suited for experimentation with multi-homing and operator aggregation techniques. At the European level, MONROE covers four

countries (Norway, Italy, Sweden, Spain) with around 150 measurement points and enables the analysis of 12 different major MBB operators through commercial-grade subscriptions, which are normally accessible to clients. MONROE allows for testing in mobile nodes in three countries (Norway, Italy and Sweden) using three MBB operators simultaneously in each country. Through the mobile nodes, experimenters test in both urban and wide rural areas. In light of the latest roaming agreements between MBB operators at the European level, MONROE activated several measurement nodes operating on international roaming subscriptions in Spain (operating with subscriptions from native Italian operator) and Norway (operating with subscriptions from native Swedish operator).

- **Mobility Scenarios**. Mobile scenarios are of utmost interest to both academia and industry because of their challenging nature. Testing under mobility in MONROE provides useful insights and gives unprecedented access to data on commercial MBB networks. Therefore, around 100 out of 150 new nodes are operating aboard buses, trains and trucks in Norway, Italy and Sweden. We have established contacts with public transport companies in all of these countries (NSB and Netbuss in Norway, GTT in Italy and VL in Sweden) and, after thorough testing of node functionality and stability, nodes have been installed in the transport vehicles. This has proven to be a very long and difficult process because of the many restrictions and the complex environment where the nodes need to operate.
- **Wide geographical coverage**. The nodes are widely distributed across Norway, Sweden, Italy and Spain. In this context, we can collect measurements under heterogeneous environment conditions, from major cities to remote rural areas. The testbed covers with stationary nodes several main large cities (i.e. Oslo, Karlstad, Madrid, Torino and Pisa) giving a detailed view of the network conditions in the urban areas. We deployed several of the nodes in busy areas, such as university campuses (Madrid, Karlstad, Torino, Oslo, Bergen, Trondheim) or train stations (Oslo). Additionally, we cover residential areas through nodes voluntarily hosted in homes. At the same time, the mobile nodes can cover both rural and urban areas since buses, trains and trucks work in the city-centre as well as inter-city areas. For example, in Norway the nodes we deployed on trains operate on 4 inter-city routes and cover over 2,500km across challenging geographical areas.
- **Large-scale**. The MONROE platform consist of around 150 MONROE nodes. This large number of devices makes it possible to give a representative view of the characteristics of MBB networks.

3.2 Deployment Locations of the Nodes

This section provides details on the deployment of the MONROE nodes in the different target countries, namely Italy, Spain, Sweden and Norway. Deployment locations for mobile and stationary nodes are presented, as well with a report on the deployment status at the time of writing.

3.2.1 Nodes in Italy

NXW and POLITO are responsible for the deployment of the nodes in Italy. The target for the nodes to be deployed in Italy, considering the new MONROE node design and updated distribution, is the following:

- **40 mobile nodes**
  - **25 nodes** on buses in the city of Turin, operated by the local transport company GTT (Gruppo Torinese Trasporti)
  - **15 nodes** on trucks in the Pisa suburban area, operated by the local company Bettarini

- **5 stationary nodes**, all deployed in the Turin city area around the Politecnico di Torino campus
- **5 testing nodes**, all deployed in the Politecnico di Torino campus

As said, mobile nodes in Italy are deployed on two different hosts, *GTT* and *Bettarini*.

NodeIDs	N.	Partner	Address	Notes
(308-309), (310-311), (312-313), (314-315), (316-317), (318-319), (320-321), (326-327), (340-341), (352-353), (342-343), (344-345), (346-347), (348-349), (350-351), (334-335), (336-337), (338-339), (354-355), (388-389), (390-391), (392-393), (398-399), (404-405), (330-331)	**25 dual-APUs**	GTT/NXW	GTT, Corso Bramante, Torino (Italy)	Urban buses move around the Turin area
(144-145), (150-151), (146-147), (152-153), (148-149), (266-267), (274-275), (264-265), (258-259), (173-293)	**10 dual-APUs**	NXW	Bettarini Group, Via F. Pera, Livorno (Italy)	Trucks move around Tuscany and center-north of Italy
(270-271), (268-269), (272-273), (128-129), (136-137)	**5 dual-APUs**	NXW	Bettarini Group, Via F. Pera, Livorno (Italy)	Still to be deployed on trucks at the time of writing

Table 12: Mobile nodes deployment in Italy.

GTT is the Turin city local transport company, and runs buses, trams and metro. The MONROE mobile nodes planned for GTT, in the total of 25, are deployed on urban buses. Figure8 shows a GTT bus and the node installed over the driver seat. At the time of writing, 15 of the 25 GTT mobile nodes are deployed on buses. The last 10 are in the GTT installation queue in Turin. Bettarini is a truck company in Livorno (a city in Tuscany closeby Pisa), and provides rental services for different types of trucks, including, tippers, crane and rigids among the others. In particular, MONROE nodes are installed on rigids and cranes as illustrated in Figure9. At the time of writing, 10 out of 15 mobile nodes for Bettarini have been installed on trucks. The last 5 have been assembled and tested in Nextworks and will be deployed during July 2017. Figure10 shows GPS tracking plots as collected by two MONROE mobile nodes deployed on a Bettarini truck (moving in west coast of Tuscany in Italy), and a GTT bus (moving in Turin urban area).

Figure 8: MONROE nodes on GTT buses

Figure 9: MONROE nodes on Bettarini trucks

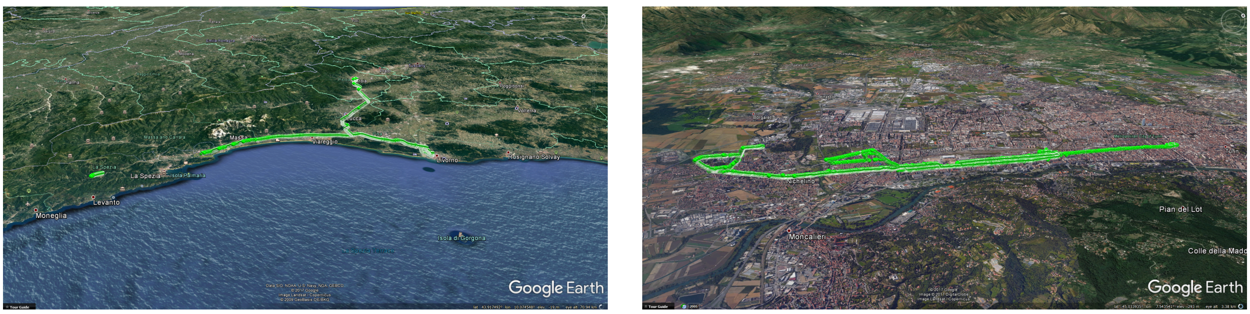

Figure 10: GPS tracking of Bettarini truck (left) and GTT bus (right)

On the other hand, the current status of distribution of stationary nodes in Italy is reported in Table 13. Currently, a total of 7 stationary nodes are depolyed in Turin by POLITO including 5 old nodes (still operational and working), and 2 new dual-APU testing nodes.

NodeIDs	N.	Partner	Address	Notes
38,39,110,111,119	**5 old nodes**	POLITO	Corso Duca degli Abruzzi, Torino	Politecnico di Torino areas
——	**5 dual-APUs**	POLITO	Corso Duca degli Abruzzi, Torino	To be deployed in Politecnico di Torino areas

Table 13: Stationary nodes deployment in Italy.

In Figures 11 and 12, the locations of the stationary nodes in Turin are highlighted. In particular, they are deployed around the Politecnico di Torino university campus area, as it is one of the MONROE target areas of analysis and measurement, due to the high concentration of people. Blue pins in Fig. 12 show the exact position of the 5 old stationary nodes still running. According to the deployment target for Italy, the plan is to deploy the 5 dual-APUs stationary nodes in the Turin city area, in the locations marked by red points in Fig. 12.

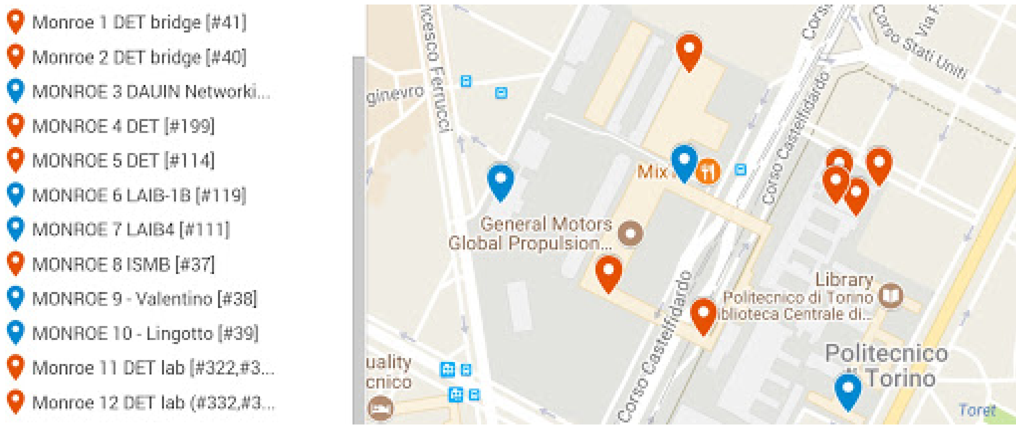

Figure 11: Map of the nodes in Turin (Politecnico di Torino areas) .

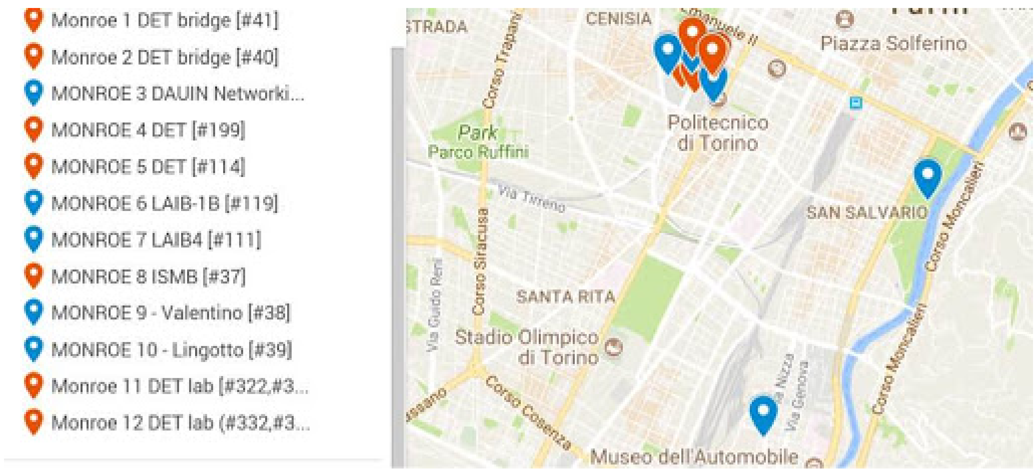

Figure 12: Map of the nodes in Turin.

3.2.2 Nodes in Spain

IMDEA is responsible for the deployment of the nodes in Spain. We are currently in the process of substituting the old nodes for 15 new APU2 ones, of which 10 will be deployed for experiments and 5 will be used as testing nodes for users. At the time of writing, 2 out of 5 dual-APU testing nodes are up and running in IMDEA premises. The deployment of the rest of stationary nodes is still undergoing and expected to be completed during September 2017. These new nodes will be deployed in the greater Madrid area, targeting specifically the University Carlos III campus in Leganés and Madrid city center. Moreover, 7 of the old nodes are still operational at the IMDEA Networks lab and usable as additional testing nodes (the rest were decommissioned after showing failures).

NodeIDs	**N.**	**Type**	**Partner**	**Address**	**Notes**
57, 59, 62, 194, 195, 196, 203	**7 old nodes**	Stationary	IMDEA	IMDEA (Leganés)	APU1

Table 14: Deployment in Spain.

3.2.3 Nodes in Sweden

KAU is responsible for the deployment of the nodes in Sweden. We summarize the ongoing deployment of the stationary nodes in Sweden in Table 15. In total 15 stationary nodes will be deployed in the new deployment. When finalized, two of the nodes will be on the KAU campus, six nodes will be distributed in the Karlstad city area, three nodes will be in the Karlstad greater surrounding area, two nodes will be deployed in Stockholm and two nodes in Västerås. The nodes in Stockholm and Västerås are deployed in collaboration with Swedish Institute of Computer Science (SICS) and Mälardalen University (MDH), respectively. In addition, five testing nodes will be deployed on the KAU campus. The node IDs of the six already deployed nodes are indicated in Table 15 and the nodes that are planned to be deployed are marked with −− in the table. Node deployment on the KAU campus and in Stockholm is complete whereas deployment for the other locations will be completed in August. However, note that most of the nodes that are not deployed are currently operational in KAU campus. The planned locations of the nodes in Karlstad city area are illustrated in Figure 13.

NodeIDs	N.	Type	Partner	Address	Notes
400-401, 402-403	**2 dual-apu**	Stationary	KAU	Universitetsgatan 2, Karlstad	KAU campus
484-485, ——, ——, ——, ——, ——	**6 dual-apu**	Stationary	KAU	Karlstad city area	KAU employee's houses and partner offices
480-481, ——, ——	**3 dual-apu**	Stationary	KAU	Karlstad surrounding area	KAU employee's houses
476-477, 478-479	**2 dual-apu**	Stationary	KAU	Isafjordsgatan 22, Kista	Offices in Electrum
———- , ———-	**2 dual-apu**	Stationary	KAU	Högskoleplan 1, Västerås	Mälardalen University (MDH) campus

Table 15: Deployment plan for stationary nodes in Sweden.

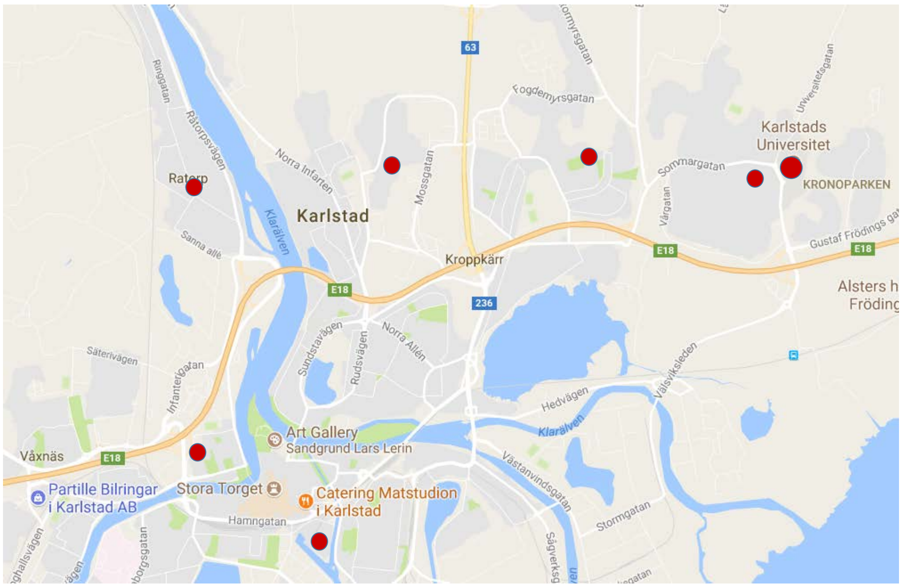

Figure 13: Map of the planned node locations in the Karlstad city area.

Concerning the mobile nodes, a total of 30 mobile nodes will be deployed in Sweden, 25 of them will be deployed in buses from Värmlandstrafik and five of them in buses from Karlstadsbuss. Värmlandstrafik is the regional bus company serving Karlstad and the region of Värmland in which Karlstad is located. Having nodes deployed in their buses thus gives the possibility to cover both city conditions and rural areas. Karlstadbuss provides bus services within the city of Karlstad, and the nodes in their buses will stay within the city of Karlstad. So far, most of the nodes targeted for the buses from Värmlandstrafik have been deployed. A summary of the deployment is given in Table 16. The remainder of the mobile nodes will be deployed after the summer. Figure 14 shows GPS tracking plots as collected by two MONROE mobile nodes deployed on VTAB buses in the Kristinehamn (#3288) and Filipstad/Karlstad (#3343) area.

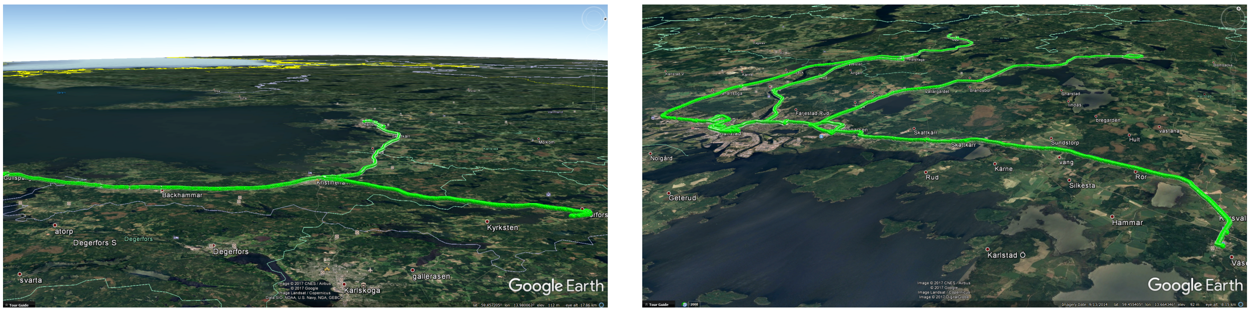

Figure 14: GPS tracking of VTAB bus #3288 (left) and #3343 (right)

NodeIDs (Bus no.)	N.	Type	Partner	Address	Notes
412-413 (#3281), 418-419 (#3262), 426-427 (#3465), 428-429 (#3264), 430-431 (#3255), 434-435 (#3279)	**6 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Karlstad Area
380-381 (#3288), 378-379 (#3289), 372-373 (#3291)	**3 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Kristenhamn Area
436-437 (#3251), 382-383 (#3343), 384-385 (#3249)	**3 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Filipstad Area
374-375 (#3366), 406-407 (#3364)	**2 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Sunne Area
408-409 (#3358), 410-411 (#3357)	**2 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Årjäng Area
386-387 (#3344), 414-415 (#3345)	**2 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Hagfors Area
420-421 (#3426)	**1 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Säffle Area
422-423 (TBD), 424-425 (TBD)	**2 dual-apu**	Mobile	KAU	Värmlandstrafik (VTAB, #bus no.)	Unknown Area
416-417 (TBD), 432-433 (TBD), 502-503 (TBD), 504-505 (TBD), 506-507 (TBD), 508-509 (TBD), 510-511 (TBD), 512-513 (TBD)	**8 dual-apu**	Mobile	KAU	Host TBD upon deployment	Depending on the host

Table 16: Mobile node deployment in Sweden.

3.2.4 Nodes in Norway

SRL is responsible for the deployment of the nodes in Norway. We summarize the ongoing deployment of the stationary nodes in Norway in Table 17. In total 10 stationary nodes are deployed to university campuses in 2 largest cities in Norway (Oslo and Trondheim). We further placed 2 nodes on the main train station in Oslo and other nodes are distributed to provide further diversity. The locations of the nodes in Oslo are illustrated in Figure 15.

NodeId(s)	N.	Type	Partner	Address	Notes
438-439, 444-445, 446-447, 452-453, 454-455, 470-471, 472-473,	**7**	Stationary	SRL	Oslo Area	houses and train station
358-359, 360-361 362-363,	**3**	Stationary	SRL	Norwegian University of Science and Technology	offices in the campus (+1 testing node)

Table 17: Deployment in Norway.

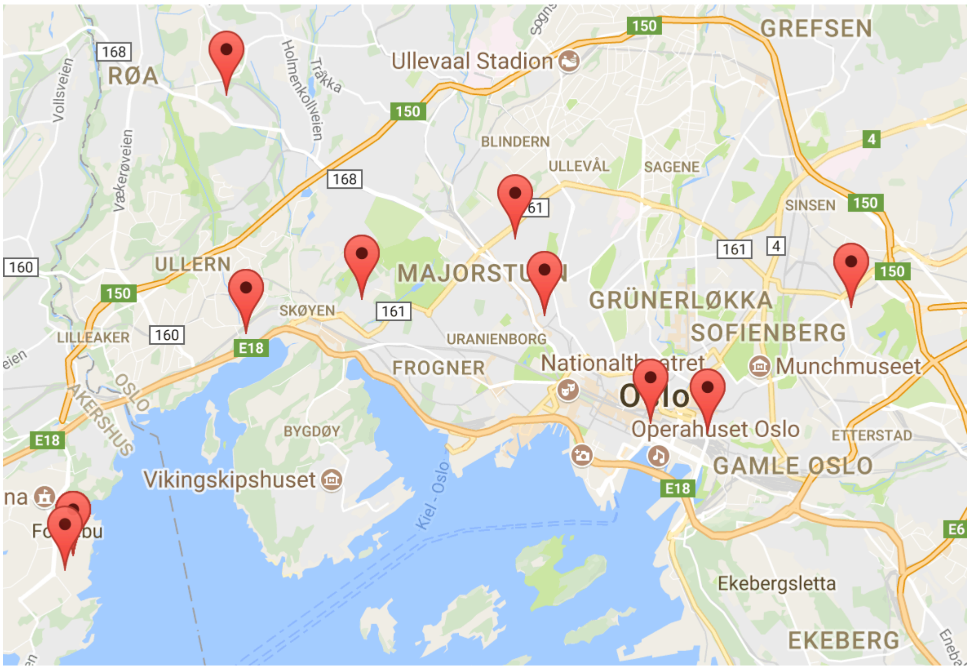

Figure 15: Map of the nodes in Oslo area.

Figure 16: Node Deployment in trains in Norway (Type 75).

Concerning the mobile nodes, a total of 25 mobile nodes will be deployed on the regional trains in Norway in collaboration with NSB. The trains cover both city and rural areas. A summary of the deployment is given in Table 18. Different trains have different settings to host MONROE nodes. We illustrated two different node deployment in trains: one with an AC plug in Figure 16 and one with a 110V DC voltage in Figure 17. Currently, 15 nodes have been deployed, and the remainder of the mobile nodes will be deployed during the summer. However, note that the nodes that are not deployed are currently operational in SRL lab. Figure 18 shows GPS tracking plots as collected by 5 MONROE mobile nodes deployed on NSB trains. The figure further illustrates the observed mobile coverage profiles.

Figure 17: Node Deployment in trains in Norway (Type 73).

4 Conclusions

This deliverable is an update of the original D2.2 submitted during the second year of MONROE on in September 2016, and includes the upgraded logistics, assembly and deployment procedures required with the tranistion of the MONROE platform to the new node design presented in deliverable D2.1 (i.e. its updated version).

The new dual-APU MONROE node design opened the need of a re-engineering of part of the logistics procedures, mostly related to collection of old nodes to be upgraded, including the acquisition of new material and components needed to assembly the new nodes. These have been defined with the aim of re-using as much as possible material and components from already assembled and deployed old nodes. Moreover, the new design required the definition of updated assembly procedures to cope with the new set of components building each MONROE node, in particular the presence of two APUs and the removal of the MiFi modems. The new MONROE node implementation is much more robust and stable than the original one, it is also more expensive mostly due to usage of a dual-APU design. This impacted the total number of nodes initially planned to be deployed in the MONROE testbed. Currently, the distribution of nodes per country is the following:

- Norway: 35 deployed nodes (25 mobile and 10 stationary), 5 testing nodes
- Sweden: 45 deployed nodes (30 mobile, 15 stationary), 5 testing nodes

NodeIDs	N.	Type	Partner	Address	Notes
228-229, 254-255, 289-290	**3 dual-apu**	Mobile	SRL	NSB type 5 trains	Regional Trains
206-292, 257-258	**2 dual-apu**	Mobile	SRL	NSB type 7 trains	Regional Trains
261-291, 296-297, 304-305, 368-369, 366-367, 448-449,	**6 dual-apu**	Mobile	SRL	NSB type 73 trains	Regional Trains
460-461, 456-457,	**2 dual-apu**	Mobile	SRL	NSB type 75 trains	Regional Trains
462-463, 212-213,	**2 dual-apu**	Mobile	SRL	NSB type 74 trains	Regional Trains
257, 212,	**2 old nodes**	Mobile	SRL	Old nodes to be replaced	Regional Trains
298-299, 300-301, 362-363, 364-365, 370-371, 440-441, 442-443, 464-465, 466-467, 468-469,	**10 dual-apu**	Mobile	SRL	Nodes prepared and to be deployed	Regional Trains

Table 18: Mobile node deployment in Norway.

- Italy: 45 deployed nodes (25 in public transport vehicles, 15 in delivery trucks, 5 stationary), 5 testing nodes
- Spain: 10 deployed nodes (all stationary), 5 testing nodes

In addition to these above nodes planned for Norway, Sweden, Italy and Spain, more nodes have been prepared for the MONROE external users. The assembly and deployment of these nodes have been prioritized when possible to involve Open Calls users and get feedbacks on the MONROE platform as soon as posible.

All the new mobile nodes have been assembled. Most of them are already deployed, and few nodes remains to be installed on trucks and trains in Italy and Sweden. For the stationary nodes, they have been mostly deployed in Sweden and Norway, while those planned for Spain and Italy are under finalization. The overall plan is to have the full set of MONROE stationary and mobile nodes deployed during September 2017.

Figure 18: The train routes covered in Norway (color coded with the mobile coverage).

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