



MONROE

Measuring Mobile Broadband Networks in Europe

H2020-ICT-11-2014

Project number: 644399

First MONROE Open Call for Experiments and Extensions

1 Call objectives

Building and operating a mobile broadband (MBB) testbed is the key goal of the MONROE project. Such a testbed, however, cannot be built without the feedback of the experimenters who will be the main users of it. Therefore, external users are in the core of the MONROE project. Through the first competitive open call, MONROE aims to involve the external users in the design process of the testbed to create a platform that meets the expectations of its users.

The experimenters selected through the first open call will access to the prototype platform. They will be allowed to run active/passive measurements as well as propose protocol experiments, which require active traffic generation and SW support from the MONROE consortium. They can further propose SW extensions to the platform as well as HW extensions to the infrastructure. Since the experimenters will have access to the prototype system, they are expected, as their contribution, to provide feedback that will be used to refine the platform to its final version.

2 Call information

Project full name:	MONROE– Measuring Mobile Broadband Networks in Europe
Project number:	644399
Call identifier:	MONROE-OC1
Call name:	First MONROE Open Call for Experiments and Extensions
Total budget:	€1,800,000
Number of proposals to be funded:	up to 12
Maximum funding per proposal:	€150,000
Number of partners per proposal:	The target number of participants per proposal is maximum 2.
Type of participants:	The profile of participants is academics, industry or SMEs active in research and/or development of mobile broadband technologies, protocols and/or applications. The rules of participation are the same as for any H2020 proposal.
Duration of the experiment:	The maximum allowed duration of each experiment is 18 Months
Language of the proposal:	English
Format of the proposal:	Proposals must follow the provided template, available at www.monroe-project.eu/firstopencall/
Proposal submission:	via email to info@monroe-project.eu
Call deadline:	Tuesday, March 15, 2016 at 17:00h CET (Brussels time)
Notification of acceptance:	Monday, May 2, 2016
Starting date:	June, 2016
Contact:	info@monroe-project.eu

3 Eligibility criteria

Requirements for the eligibility of proposals:

- Parties eligible for participation in the EC Horizon 2020 Framework Programme. Rules for eligibility can be found at: http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-a-countries-rules_en.pdf

- Single proposals or a maximum of 2 Participants per proposal.
- In case of 2 participants, one of the participants is expected to be an industrial or SME partner. For proposals with 2 participants, the synergy from the combined expertise shall be addressed in the application.
- A party is entitled to submit multiple proposals. However, a party can only be selected for funding for one proposal, selected as best ranked among all submissions for this Party and approved through the evaluation process.

Successful applicants must confirm that they have the necessary personnel and financial resources to perform the proposed experiments. For details about this Open Call funding payment see Section 9 of this document.

4 Overview of MONROE

MBB networks underpin a lot of vital operations of the modern society and are arguably becoming the most important piece of the modern communications infrastructure in the world. The immense popularity of mobile devices like smartphones and tablets, combined with the availability of high-capacity 3G and 4G mobile networks, has radically changed the way most people access and use the Internet. Given the importance of MBB networks, there is a strong need for objective information about their performance, particularly, the quality experienced by the end user. Such information is very valuable for many parties including operators, regulators and policy makers, consumers and society at large, businesses whose services depend on MBB networks, researchers and innovators. MONROE proposes to design and operate the first European transnational open platform for independent, multi-homed, large-scale monitoring and assessment of performance of MBB networks in heterogeneous environments.

MONROE is building a dedicated infrastructure for measuring and experimenting in MBB and WiFi networks, comprising both fixed and mobile nodes distributed over Norway, Sweden, Spain and Italy. The mobile nodes will be placed on trains, busses and trucks, and they will play a key role to understand the MBB performance under mobility. They will also help to cover both urban and rural areas. In total, 150 mobile nodes and 100 stationary nodes will be deployed. The distribution of the nodes are displayed in Table 1.

Country	Region	Number of Nodes	Mobile/Static	Urban/Rural
Norway	Oslo	10	Static	Urban
	Bergen	10	Static	Urban
	Trains in Norway	40	Mobile	Urban/Rural
Sweden	Västerås	10	Static	Urban
	Stockholm	10	Static	Urban
	Karlstad	10	Static	Urban
	Busses in Karlstad and Värmland	50	Mobile	Urban/Rural
Spain	Madrid	20	Static	Urban
Italy	Turin	10	Static	Urban
	Pisa	10	Static	Urban
	Buses in Turin	40	Mobile	Urban/Rural
	Trucks in Tuscany	30	Mobile	Urban/Rural

Table 1: MONROE Node Distribution

The MONROE nodes are designed such that they are flexible and powerful enough to run most measurement and experiment tasks, including demanding applications like adaptive video streaming. The nodes are equipped with GPS for tracking the location of mobile nodes. Further technical details on the MONROE node are provided in the fact box to the left and in Annex A.

MONROE will design experiments that measure the characteristics of MBB networks both in terms of performance and reliability. Furthermore, MONROE will allow experimenting novel services and applications on MBB networks. All nodes will be connected to three MBB providers, and often also to WiFi. This makes MONROE particularly well suited for experimentation with methods that exploit multiple links. In addition to information about network, time and location for experiments, MONROE nodes have built-in support for collecting metadata from the externally connected modems such as cell ID, signal strength, connection mode etc. MONROE provides a messaging API that relays the metadata about node, network events and modems to experimenters through ZeroMQ and JSON format.

MONROE will make it easy to access the system and deploy experiments on all or a selected subset of the nodes. The user access and experiment management system will be adapted from FED4FIRE project to make MONROE compliant with all other FIRE facilities. A scheduling system will reserve and provision experiments ensuring fairness among different experimenters. An experimenter will be allowed to run experiments in a Linux container (Docker), or in virtual machines in case kernel access is required, running on a Debian Linux operating system. Experiments can be implemented and configured using any programming/scripting language, as long as it runs within these constraints and respects the resource limits of the node. The experimenters can deploy their experiments through MONROE's user access and scheduling interface (i.e. experimenters will not be given SSH access to the node). MONROE will provide a template experiment and test environment to the experimenters to get them started. Furthermore, the experimenters will be provided a local machine and a MONROE node to test their experiments. Results of experiments can be written to a disk and will be transferred to a MONROE repository automatically, or they can be transferred/streamed by the experimenter to his/her preferred location using his/her own technology. The MONROE system design is further detailed in Annex A.

The main objectives of MONROE are:

- To build an open and large-scale measurement and experimental platform, targeting MBB and WiFi networks, distributed over multiple European countries, with multi-homing capabilities.
- To operate this large-scale platform by providing both maintenance and external user support.
- To use the platform for the identification of key MBB performance parameters, thus enabling accurate, realistic and meaningful monitoring and performance assessment of such networks.
- To achieve a user-oriented closed-loop system design in which the experimental platform is open to external users, and where users are incorporated early on in the experimental design process.
- To provide Experiments as a Service (EaaS), thus lowering the barrier for using the platform to external users, by providing well-documented tools and high-level scripts to execute experiments, collect results, and analyze data.

The current MONROE node is an apu1d4 from PC Engines with AMD 1GHz dual core 64 bit processor and 4GB DRAM. It has 3 RJ45 ports, 2 USB 2.0 ports, mSATA SSD and SD card reader. The node has 3 ZTE MF910 MiFis attached, connected to 3 different MBB operators. In addition, it has built-in dual band AC WiFi card, and GPS with external antennas.

Node Technical Facts

- To develop models for sustaining and extending the platform and its usage beyond the project budget and project ending.

MONROE will not only support the external users throughout their experiments (by providing experimental scripts as well as technical support) but also involve them early on in the design process of the testbed to create a system that meets the expectations of its users. The process for involving external users are through open calls.

5 Scope of the Present Call

The target of the first open call is the experimenters who will leverage the MONROE platform to provide innovative solutions for MBB networks. The experimenters selected through the first open call will get access to the prototype MONROE platform. They will be allowed to run active/passive measurements as well as propose protocol experiments. Both proposals targeting scientific excellence as well as industrial innovation are welcome. Potential use cases include but are not limited to: (i) Key MBB Metrics, (ii) Application Performance and (iii) Innovative Protocol and Services. More details on these use cases and other potential use cases are provided in Deliverable 1.1, available in MONROE's website.

The experimenters can further propose SW extensions to the platform as well as HW extensions to the infrastructure. For the SW extensions: one can add new SW functionality to the MONROE platform or advance the current MONROE SW modules. In case of SW extensions, the source code of the extension, together with the documentation on the use of the extension, must be posted on the MONROE project website. The SW must be made available as open source together with other MONROE SW through MONROE's git repository. For the HW extensions: one can deploy additional MONROE nodes to areas where there are currently no MONROE nodes or extend the functionality and the capabilities of the platform with additional equipment that is compliant with the MONROE platform. In case of HW extensions, the extensions must be made available to external users through the MONROE scheduling system. Further details on the MONROE SW and HW design is available in Annex A.

Since the experimenters will have access to the prototype system, they are expected, as their contribution, to provide a feedback report that will be used to refine the platform to its final version (see Section 10). Each experimenter will get access to the platform for no more than 18 months and they will be funded with up to 150k Euros.

6 Role in the Consortium

Participants from selected proposals in this first open call will not become official partners in the MONROE project and will not receive funding from the European Commission. Once a participant is selected to perform the proposed Experiment, he/she will become a Third Party using Cascade Funding (also known as sub-granting), and to this end he/she will be acknowledged by the project coordinator (Simula) as 'Associated Partner'. In the remainder of this document a 'Third Party using Cascade Funding' is referred to as 'Associated Partner'. Successful applicants will be listed in the MONROE's website under the page 'Associated Partners'.

The administrative load for the Associated Partner will be minimal. Only a first feedback report and a final report describing the tasks performed and the results achieved are required (see Section 10). An invoice needs to be submitted to Simula together with the final report. This final report will be required before payment will be carried out. In case the Experiment involves a SW Extension to MONROE, the code of the

Extension, together with the documentation on the use of the Extension, must be posted on the MONROE project website, before payment will be carried out. For the HW extensions, all HW components needs to be integrated with the MONROE platform and the HW should be made available to other experimenters before payment will be carried out. 25% of the requested funding will be provided after the first feedback report that is due September 2016. A payment of up to 50% of the requested funding will be carried out by the project coordinator based on the evaluation of the final report, code and documentation. The remaining 25% will be paid following a formal approval of the report and the work at a technical project review by the European Commission (EC). More details on the payment scheme are given in section 9.

The Terms of Service (TOS) for the MONROE platform are available in Annex B of this document. To declare their acceptance of the conditions stipulated in the TOS and of applicable EU regulations, participants from selected proposals must sign a 'Certification and Declaration on Honour', available in Annex C of this document, before being accepted as Associated Partners.

7 Access to Foreground Information from the Project

As indicated by the EC Guidelines, an Associated Partner is paid in full for its contribution made to a project by the beneficiary with whom it has a contract. As a consequence Associated Partners do not have any IPR rights on the foreground of the project. All source code developed in MONROE will, however, be released as open source and as such will be available to the Associated Partner. The MONROE Consortium will claim no IPR rights over material developed by Associated Partners.

8 Support During the Experiment

Learning and getting used to a new tool is always a time-consuming task. Furthermore, designing experiments, especially for large-scale complex systems such as MBB networks, requires experience and time. Therefore, one fundamental objective of MONROE consists in taking all necessary steps to have external users start using the testbed as soon as they get access to the platform (i.e., in June 2016 for users from the first call).

MONROE will provide a user manual and suitable training material to assist the external use of the platform. The manual and training material will introduce the capabilities of the platform and detailing the high level scripts used to run simple experiments and the tools to analyze the results. The designed experiments will cover several different use cases, and the external users can directly learn from them, and modify the provided tools to meet their needs.

MONROE will organize workshops for external experimenters to provide them hands on experience on the platform. The first workshop will be arranged in May 2016, just before the experiments from the first call start.

To ensure that each external experimenter that is granted funding through the MONROE open calls gets adequate and easily accessible user support, each user will also be assigned a patron that is responsible for providing support. This includes to help resolve any issues related to the use of the platform that may come up during the experiment.

Providing examples, well-documented scripts and tools with the training/workshop material, MONROE will shorten the time from starting to use the testbed to running the first experiment for external users. A Wiki/blog like platform will collect all information, where external users will be asked to contribute with

documentation on the software they developed. MONROE partners will strictly check the quality of this material to provide useful and easy access to this information.

9 Funding Scheme for Experimenters

As the selected applicants will be linked to the MONROE consortium as Third Party using Cascade Funding, referred to as Associated Partner to MONROE, specific arrangements exist with respect to financial costs and payment schemes:

1. The maximum requested funding for a proposal in this Call is set at €150,000.
2. As an Associated Partner, the applicant needs to include an overview of the estimated costs in its proposal at the time of submission. Costs consist of personnel costs, direct costs (such as travel, equipment, etc.) and indirect costs. The costs of an Associated Partner have to comply with the rules and the principles mentioned in Section I, Article 6 (Eligible and ineligible costs) of the H2020 AGA – Annotated Model Grant Agreement (see http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/amga/h2020-amga_en.pdf), in the same way as the beneficiaries, and must be recorded in the accounts of the Associated Partner. In other words, the rules relating to eligibility of costs, identification of direct and indirect costs and upper funding limits apply. Equally those concerning controls and audits of Section I, Article 22 of the H2020 AGA.
3. As an Associated Partner, the selected experimenters need to submit two reports as detailed in Section 10, a first feedback report in September 2016 and a final report. The final report must include an overview of the costs incurred and will be accompanied by an invoice to the project coordinator, in this case Simula.
4. The reports and the declared costs will be evaluated by the MONROE consortium.
5. 25% of the requested funding will be provided after the first feedback report that is due September 2016.
6. Based on the evaluation of the final report, a payment of up to 50% of the requested funding will be carried out by the project coordinator.
7. The remaining 25% will be paid following a formal approval of the final report and the work at a technical project review by the European Commission (EC).
8. For Open Call 1, two planned review meetings with the EC are of importance, the year two review, expected in May 2017, and the final review, expected in May 2018. At the review meetings, the results of the experiment and/or HW/SW extension need to be presented. Either the Associated Partner or the corresponding beneficiary has to present the final results. In the latter case, the corresponding beneficiary should be well informed, as 25% of the payment depends on the formal approval of the work at the final review meeting.

10 Reporting

As the selected experimenters will be linked to the MONROE consortium as an Associated Partner, no input will be required for any of the regular project reports, which the MONROE consortium needs to submit to the EC.

Each Associated Partner needs to submit two reports: A first feedback report in September 2016 and a final report after completion of the experiment or extension. A specific template needs to be used and will include:

Part A. Summary

The information provided in the summary is intended for use in public documents and reports by the MONROE project.

Part B. Detailed description

This section describes the details on the experiment/extension. It includes:

B.1 Concept and Objectives

B.2 Experimental Set-up and Results

B.3 Lessons learned

B.4 Impact

Please note that for experiments, section B.4 should focus on the scientific and/or business impact of the experiment. For SW and HW extensions, the impact should give a clear description of the potential use of the extension by future experimenters.

Part C. Feedback to MONROE

This section contains valuable information for the MONROE consortium and describes the Associated Partner's experiences while performing the experiment or while implementing the extension starting from the available software and hardware. Note that the production of this feedback is one of the key motivations for the existence of the MONROE open calls. It includes:

C.1 Resources & tools used

C.2 Feedback on experimenting in / implementing extensions within MONROE

C.3 Why MONROE was useful for the Associated Partner

These reports will not only serve as an evaluation tool to judge payment of the experimenter, but will also serve as (1) input to the evaluation of the user-friendliness of the MONROE system, both in terms of hardware and software, and (2) identification of missing gaps in both node design and software tools. The information is solicited in order to refine and improve the platform and its tools.

Part of these reports may be used by the MONROE consortium for inclusion in their reporting documents to the EC and in public presentations. Inclusion of confidential information should therefore be indicated and discussed with the MONROE consortium.

The reports will also be used for the formal reviews by the European Commission. Each Associated Partner should be prepared to attend these formal review meetings with the EC, upon request by the MONROE consortium. The review meetings are expected for May 2017 and May 2018.

The template for reporting will be available at the start of the experiment. The same template will be used for both reports, but part of the information in Part B of the report will be less extensive for the first feedback report.

11 Proposal Template

Applicants must use the proposal template available at www.monroe-project.eu/firstopencall/. In the document, applicants will find instructional texts specifying the type of information expected per section. Each section has indicated limited number of pages. The applicants are sole responsible for completing all required fields in the template according to the instructions.

12 Criteria for Evaluation

Applications to open calls will be evaluated by a committee of 2 researchers and 2 industry delegates selected by the Project Board and approved by the Advisory Board. The European Commission through internal or external experts might monitor this process.

The evaluation of received proposals will be ranked according to the following criteria:

Excellence (0 to 5 points): *relevance/alignment to the MONROE's objectives and soundness of the experiment and/or extensions.* The experiment should be scientifically and/or technically sound. There should be a clear problem statement in relation to the the state of art, a solid experiment design and a good methodology (Section B.1 and B.4 in the proposal template). For HW/SW extensions, the applicant should clearly indicate the usefulness and the feasibility of the extensions. The applicant should exhibit prior research/development experience and the necessary qualifications to perform the experiment or implement the SW/HW extensions (Section E in the proposal template). **Minimum score to pass the evaluation: 3.**

Impact (0 to 5 points): *effectiveness of the proposed experiment to advance the current MBB networks.* The score covers scientific or industrial impact (Section B.2 in the proposal template). For scientific impact, the score reflects the extent to which the broader scientific community can benefit from the proposed solution or the extension. Furthermore, the expected results of the experiment should have potential for publication in high-impact scientific journals and/or for presentation/demonstration of the results on major scientific conferences. For the industrial impact, the score reflects the potential for exploiting the results of the experiment in commercial solutions and the expected results should have potential for demonstration on relevant events (exhibitions, congresses, technical seminars, networking events, user group events, etc.). For HW/SW extensions, the applicant should clearly indicate how the extensions complements the current MONROE platform. Sustainability of the platform is one of the main objectives of MONROE project. Therefore, the applicant should indicate how the proposed experiment and/or extension can help sustain the MONROE platform and it's usage beyond the project budget and project ending. Furthermore, the applicant should clearly indicate the expected impact that the MONROE consortium can expect from the use of its platform after carrying out the experiment or extension (Section D in the proposal template). **Minimum score to pass the evaluation: 3.**

Innovation (0 to 5 points): *novelty and necessity of the proposed experiment/extension.* The score reflects the scientific or industrial innovation (Section B.3 in the proposal template). For scientific innovation, we expect an experiment/extension to push the boundaries of its domain. In order to demonstrate this criterion, the applicant is expected to clearly motivate the experiment/extension and indicate the State of the Art in the appropriate field. For industrial innovation, we expect to see a clear indication to which extent the proposed solution is different and innovative compared to existing and/or competing commercial solutions. In order to demonstrate this criterion, the applicant is expected to clearly moti-

vate the experiment/extension and compare the proposed solution with existing solutions in the field.

Minimum score to pass the evaluation: 3.

Minimum total score to pass the evaluation: 10.

Socio-economic and other relevant non-technical aspects will also be considered. For the first call, a diversity in the selected experiments will also be emphasized to provide feedback on the full potential of the MONROE experimental platform. A number of top-ranked proposals will be selected to achieve the target budget of the call.

13 Submission

Proposal submission deadline:	March 15, 2016 at 17:00h CET (Brussels time)
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Proposals must be written in English and be submitted via email to info@monroe-project.eu. The notification of reception emails will follow the next day.

Updates to a submitted proposal are allowed until the call deadline. If you submit an update to your proposal, please clearly indicate this in the subject line of the mail.

Annex A: MONROE System Design

The main components of the MONROE platform are described in what follows.

SW platform

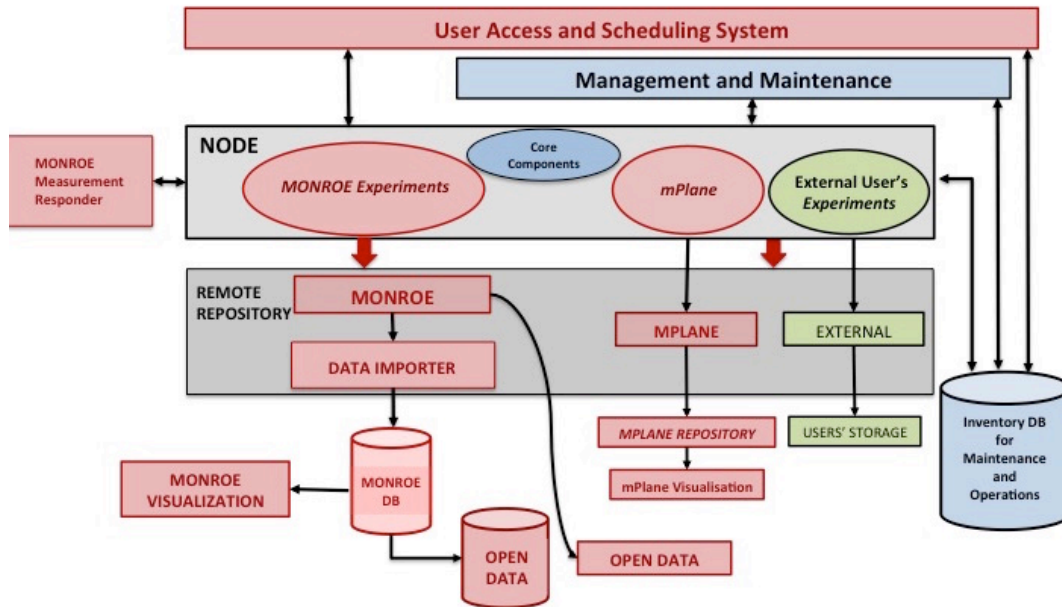


Figure 1: Building Blocks of MONROE System

We summarize the initial system design for MONROE in Figure 1. The system is composed of 5 main parts: (i) User Access and Scheduling System, (ii) Management and Maintenance System with Inventory, (iii) Node, (iv) Repositories and Data Importer (v) Database and Visualization. We will provide an overview of each part and discuss the communication between them. All the blocks are color coded as follows:

- Blue: These are components that are provided as background to MONROE. They are not available as open source.
- Red: These are the components that will be developed during the project and will be made open source.
- Green: These are the components that the external users are responsible for developing. Templates will be provided as open source.

Next, we will provide more details on each component.

User Access

The Fed4FIRE Portal is the common tool where registered users can select and access the MONROE platform. Figure 2 provides the workflow that all new users must follow when they want to join MONROE and run an experiment. This include users belonging to MONROE partner institutions, users of granted projects trough open calls, and external (non-funded) users. A summary of required steps is the following:

- *Read Documentation:* The user must be familiar with terminology and tools of the Fed4Fire federation and, in particular, with the MONROE testbed.

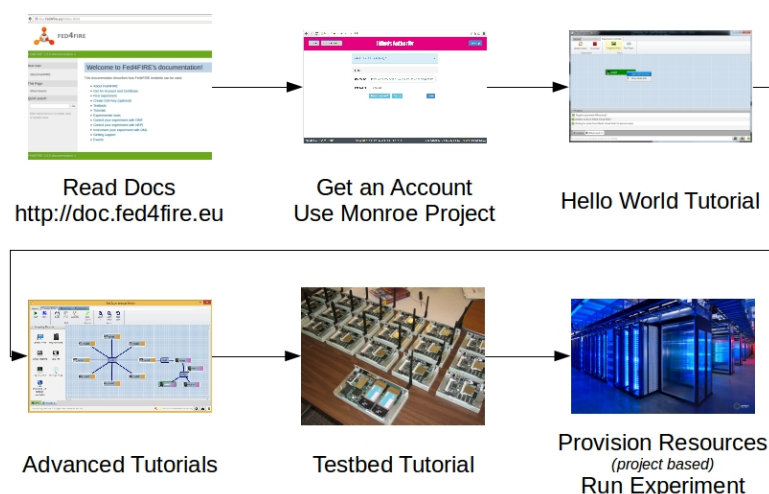


Figure 2: Experimenter Workflow

- *Get a valid account:* The user has to apply for a valid Fed4Fire account and download the corresponding certificate. All accounts must be associated to an existing MONROE project.
- *Perform tutorial:* Follow the introductory tutorial to gain knowledge about the basic tools.
- *Perform the advanced tutorial:* Follow the advanced tutorials, which cover advanced topics like scheduling, large deployments, batch processing, etc.
- *Perform the MONROE tutorial:* Perform the MONROE tutorial, which describes those elements that are specific to the MONROE testbed.
- *Provision Resources:* During the final step the user should ask for resources to run the experiment to the MONROE managers.

MONROE will adhere to the Fed4FIRE Authentication and Authorization schemas:

- **Fed4FIRE AAA.** Fed4FIRE works with X.509 certificates to authenticate and authorize experimenters (users) on testbeds. Testbeds can decide which certificates from which authorities they accept. A federation is a collection of testbeds that share, and trust, the same certification authorities and user certificates. For example, Fed4FIRE is one of these federations. The current authority which can be used in the Fed4FIRE federation is located at iMinds.
- **MONROE AAA.** MONROE share and trust the certificates generated by the iMinds authority, and therefore, is a member of the Fed4FIRE federation. Other certification authorities, and other federations, like GENI, are not supported by MONROE.

The access to MONROE will be granted by means of a client developed in MONROE using AngularJS. The client provides the experimenters with a list of resources, configuration options and configuration tools, including a calendar for experiment scheduling.

Scheduling System

A MONROE scheduler ensures that there are no conflicts between users when running their experiments. The scheduler takes into consideration the node resources, the experiment description and measurements needed, and assigns a time-slot and a subset of the nodes to each user.

The first step to prepare and execute the experiments consists in testing and monitoring the resources of each experiment. For this, a system image of the experiments provided by the user will be loaded onto a testing node. The experiment will be run, and its resource usage will be monitored. If the usage is within defined constraints, the system image will be approved (e.g. by means of a cryptographic signature). Only then, the experiment image will be loaded onto the node. This is important especially in terms of data since MBB subscriptions have data quotas.

At the given start time, a script defined by the experiment will be run. During the runtime of the experiment, resources will be monitored and constraints will be enforced according to the reservation. At the defined stop time, all processes belonging to the experiment will be canceled. These four actions can be implemented by a node controller, if the scheduling solution provides an interface to start the actions at the appropriate time.

In terms of scheduling, MONROE further defines some policies in order to resolve potential conflicts:

- An active experiment where traffic is generated is marked as *exclusive* and only one such experiment may run at a given time on a node.
- A passive experiment where traffic is monitored is marked as *passive* and a given number of such experiments may run at a time
- User experiments may be scheduled to be periodic, continuous (not bandwidth demanding) or one-time.
- MONROE reserves fixed time slots for experiments and these time slots may be overridden by advance booking. Only experiments for which a time slot has been booked in advance may be run.
- Nodes may be of different types (static, mobile, urban, rural, certain area, etc...) defined by the MONROE project.
- A booking over several nodes or several time periods is treated as atomic. I.e. if one of the booking periods or nodes is unavailable, the entire booking is rejected. Several bookings over different nodes or time periods may be linked to an atomic unit.

Management and Maintenance

The Management and Maintenance System will be used mostly by the operations team to manage and maintain the MONROE testbed and has mainly 4 different components:

Software Configuration Agent talks to the inventory to retrieve node specific configurations and grabs configuration files and job instructions from the Software Configuration Server.

Monitoring Agent monitors and reports the health of the system including logging, performance monitoring, self checks for services etc. that extends beyond basic watchdog functionality.

Status Visualization and Management Interface is the main point for editing node details and tracking availability for operations teams. Log and monitoring systems will be available through this portal.

Inventory keeps all the information required for operations and maintenance. This involves the status of each node, status of different connections, location of the nodes, etc. This data is kept in a relational database and an API is provided to retrieve data from the inventory DB.

Since these modules mostly considers the operations and maintenance, we will inherit from the Nornet Management and Maintenance System already available at Simula and will provide an interface to MONROE.

Node

The Node represents all the software running on the MONROE node as illustrated in Figure 3 and has two main parts: Core Components and Experiments.

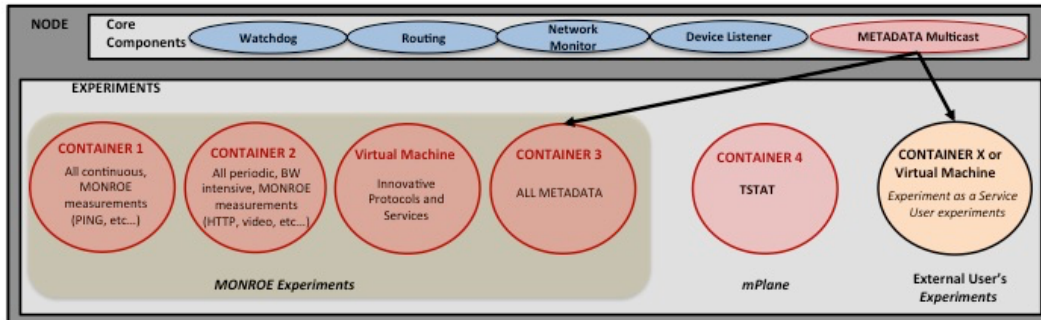


Figure 3: SW running on the node

The **Core System Components** include the main software running on the node and make sure that the node is up and running. These include the following software modules:

- *System-wide Watchdog* is responsible for ensuring all core services are running.
- *Routing Daemon* is responsible for routing which is required when connected to multiple interfaces simultaneously.
- *Network monitor* monitors connectivity of the different interfaces. In order to do this, it performs some of the core measurements (ICMP, DNS and time to first byte). In addition, the tool supports IPv4/IPv6 and makes sure that the route for unbound traffic goes through a *good* interface.
- *Device Listener* is responsible for detecting and connecting to the 3G/4G modems and WiFi dongles.
- *Metadata Multicast* multicasts the metadata such as node status, connection technology and GPS. Different experiments can subscribe to specific relevant information, for example to correlate GPS/operator with a throughput measurement. Metadata is distributed using the Zero MQ multicast publishing system.

The **Experiments** constitute all the measurements running on the node. These include the experiments run by the consortium as well as the external users. The node runs applications inside light-weight virtualization containers to provide isolation and resource management. For experiments that require kernel changes, the node will also support full virtualization through Virtual Machines (VMs).

Containers and VMs will be used to initialize, execute and finalize the experiments. In Figure 3, Containers 1-4 are run and controlled by the consortium to determine the key MBB parameters. Container 1 will collect all the continuous MONROE measurements such as ping test. Container 2 is allocated to run periodic bandwidth intensive applications such as web services and video streaming. Container 3 is responsible for collecting all the metadata. Container 4 is dedicated to `Tstat`. The experiments that will be run by the consortium on innovative protocols and services will be run in a VM. Container X and external user's VM will be used by the external users to run all other experiments.

Experiment data is produced and collected in different ways depending on the tools in use. This data (including the metadata) is then reformatted into JavaScript object notation (JSON) files. For example ping RTT

experiments use text output logging from a ping command, which is reformatted into JSON file format. Using the same data format enables efficient reuse of software tools and processing. JSON files are transferred at periodic intervals (on the scale of 30-60 seconds) to a remote repository. If no Internet connection is available, files will be cached on the node until the next transmission attempt. At the repository only completely received files are processed.

The experiments will be run towards a MONROE measurement Responder. For example, for the simple ping test, this responder will become the *echo server*. For different type of tests, the responder can be configured.

Remote Repositories, Data Importer and Database

The MONROE Remote Repository is composed by 3 repositories as illustrated in the Figure 1: MONROE repository, mPlane repository and external user repository.

- MONROE repository will collect all the continuous/periodic measurements including the metadata from Containers 1-3. Some of this data will be visualised in near real-time, therefore, we need a periodic synchronization between the nodes and the MONROE repository, based on `rsync`.
- mPlane repository will collect all the `Tstat` output. This data will further be fed into the mPlane project repository and be visualised through the mPlane GUI.
- External repository will collect all the other measurement and experiment results (ContainerX).

The data and metadata that is collected in the node and transferred to the repositories, need to be stored (imported) in a central database. The files copied by `rsync` arrive to a specific directory. At periodic intervals (which may be much shorter than the transfer interval time) the incoming directory is scanned for new JSON files. These are parsed and inserted into the MONROE database according to a database schema.

As concerns the database, MONROE uses a non-relational Cassandra approach in which data are stored to optimize the queries of the visualisation tool described in what follows.

Visualisation

The visualisation tool of MONROE draws data from the database and graphically presents important statistics and other knowledge from the data. The designed visualisation solution is based on javascript technologies such as AngularJS (for the front-end) and NodeJS (for the back-end). It also uses Tornado web server technology based on python. It is composed of 2 layers. The upper layer manages the graphical representation of the web pages and the contents. The lower layer is in charge of retrieving monitoring data from the measurement system or the database. Specifically, the visualisation system includes different components:

- The login page with the logos of the project and partners.
- The map of the nodes on the globe. This is based on the open source WebGL Earth 3D library¹.
- A table with the node capabilities.
- Multiple charts based on the Highcharts library². For example, RTT as a line chart, the packet loss as a speedometer gauge, connection type as a pie chart and the signal strength as a column chart.
- Time series analysis of selected nodes and selected parameters to certain users.

¹<http://www.webglearth.org>

²<http://www.highcharts.com/products/highcharts>

HW platform

The following HW components have been selected for use in MONROE.

Node: APU1d4 from PC Engines³ with AMD 1GHz dual core 64 bit, 4GB DRAM, SD card reader, 3 RJ45 WAN/LAN, 2 USB ports, MiniPCI mSATA SSD, 2 MiniPCI for WiFi/LTE and SIM card reader. We use a custom-made casing from PC engines since we need 6 antennas.

Built-in miniPCI LTE modem for management: Sierra Wireless MC7304⁴ (LTE cat4), 2 external LTE antennas - External T-blade LTE Antenna⁵ and 1 external GPS antenna⁶ (or interface to bus/train)

Built-in miniPCI WiFi: Sparklan WPEA-352ACN⁷ (AC dual band) and 3 external antennas - WiFi rubber swivel antenna 2.4/5.0 GHz⁸

USB hub: YEPKIT YKUSH 2.0 having 3 ports with individual port control (6 Amp)⁹

3 x USB modems/MiFis: We currently support most available modems/MiFis. In our nodes we will deploy ZTE MF910 CAT4 USB MiFis.

GSM socket: Wolf-Guard GSM Smart power switch¹⁰

Box: This component will be based on specification for individual busses and trucks

Converters: They will be based on specification for individual busses and trucks

Cost of a node

We estimate the cost for a complete node to be about 800 EUR. Special equipment for busses and trucks will add about 100 EUR to this. Note that this is a conservative estimate considering only the cost of different components to build one node.

Subscriptions - SIM cards

In terms of subscriptions, 3 SIM cards from 3 different operators will be used for the MiFis, 1 SIM card for built-in miniPCI modem for management and 1 SIM card for the GSM socket where such is used. The SIM cards for management and the GSM socket can be from any of the above-mentioned operators. For our subscriptions, we try to maximize bandwidth and data quotas on the subscriptions.

³<http://www.pceingines.ch/apu.htm>

⁴<https://techship.se/products/sierra-wireless-mc7304-data/?signature=1167>

⁵<https://techship.se/products/external-t-blade-lte-antenna/?signature=9759>

⁶<https://techship.se/products/external-gps-antenna/?signature=2517>

⁷<https://techship.se/products/sparklan-wpea-352acn/?signature=8496>

⁸<https://techship.se/products/wifi-rubber-swivel-antenna-24ghz-50ghz/?signature=10>

⁹ <https://www.yepkit.com/products/ykush>

¹⁰<http://www.chinawolfguard.com/WIFI-GSM-Wireless-Smart-power-Switch-58.html>

Annex B: MONROE Terms of Service

Your registration and access to MONROE as Experimenter is conditioned on your acceptance and compliance to this Terms of Service ("TOS"). By using the MONROE platform (the "Service"), you agree to be bound by the TOS and you agree that this constitutes a binding, formal agreement between the MONROE Consortium and you. The TOS apply to every Experimenter using the MONROE platform. You can review the most current version of the TOS at any time at: <https://www.monroe-project.eu>. It is the Experimenter's responsibility to remain aware of all applicable regulations. If you have any questions regarding this Terms of Service or if you wish to discuss the terms and conditions contained herein please contact the MONROE Consortium at [info \[at\] monroe-project.eu](mailto:info@monroe-project.eu)

Description of Service: MONROE is a Platform-as-a-Service (PaaS) application delivered by the MONROE Consortium designed for you, the Experimenter, to perform measurements and experiments connected to mobile broadband networks. As part of the Service, you will get access to one or more SIM cards issued by telecom operators.

Eligibility: You, being an individual, company or organisation, must provide your current, accurate identification, contact, and other information that may be required as part of the registration process and/or continued use of the Service. You are responsible for maintaining the confidentiality of your Service password and account, and are responsible for all activities that occur thereunder.

Proper Use: You agree that you will use the Service in compliance with all applicable local, state, national, and international laws, rules and regulations, including any laws regarding the transmission of technical data exported from your country of residence. You shall not agree, authorize or encourage any third party to: use the Service to upload, transmit or otherwise distribute any content that is unlawful, defamatory, harassing, abusive, fraudulent, obscene, contains viruses, or is otherwise objectionable as reasonably determined by the MONROE Consortium.

In particular, you will be liable for the usage, authorized or not, of the SIM by third parties, and you are obliged to prevent third parties from using the SIM for illegal purposes and in illegal ways. Furthermore, you are obliged to keep the MONROE Consortium and the SIM card providers indemnified from any consequences of such usage. The MONROE Consortium or SIM card provider shall not be liable for the content of messages, documents or any other data sent and/or received with the SIM, through the telecom operator issuing the SIM, or any other operators. Furthermore, you shall use the SIM for your own experimentation purposes and shall not, in any way or any form, resell the usage of the SIM to third parties.

All other use of the Service by the Experimenter than the use explicitly contained in the Experiment is not permitted.

Intellectual Property Rights: You acknowledge that the MONROE Consortium owns all right, title and interest in and to the Service, including without limitation all intellectual property rights, and that such rights are protected by intellectual property laws. The MONROE Consortium claims no intellectual property rights over the material you provide to the Service. The Experimenters shall deliver a final report on the Service, which can be made public by the MONROE Consortium with the objective of further promoting the Service. The report can be kept confidential if the Experimenter claims commercial interests that limit publication. In the particular case of software extensions to the Service provided by Experimenters, Experimenters acknowledge that correspondent code and documentation must be available as open source following MONROE's policy.

Warranties and Liability: The Service is provided to you strictly on an "as is" basis. All conditions, representations and warranties, whether express, implied, statutory or otherwise, including, without limitation, any implied warranty of merchantability, fitness for a particular purpose, or non-infringement of third party

rights, are hereby disclaimed to the maximum extent permitted by applicable law. You agree that the MONROE Consortium shall not be liable for any direct, indirect, incidental, special, consequential or exemplary damages, including but not limited to, damages for loss of profits, goodwill, use, data or other intangible losses (even if the MONROE Consortium has been advised of the possibility of such damages), resulting from your usage of the Service. Experimenters shall be liable for actions performed on the Service.

Indemnification: You agree to hold harmless and indemnify the MONROE Consortium and SIM card providers from and against any third party claim arising from or in any way related to your use of the Service, including any liability or expense arising from all claims, losses, damages (actual and consequential), suits, judgments, litigation costs and attorneys' fees, of every kind and nature. In such a case, the MONROE Consortium will provide you with written notice of such claim, suit or action. The failure of the MONROE Consortium to exercise or enforce any right or provision of the TOS shall not constitute a waiver of such right or provision. The TOS constitutes the entire agreement between you and the MONROE Consortium and govern your use of the Service, superseding any prior agreements between you and the MONROE Consortium (including, but not limited to, any prior versions of the TOS).

Annex C: MONROE Certification and Declaration on Honour¹¹

I certify that

1. our organisation is committed to be contracted as an Associated Partner in the project Measuring Mobile Broadband Networks in Europe (MONROE);
2. the information relating to our organisation set out in the Open Call forms is accurate and correct;
3. the estimated costs meet the criteria for eligible costs for the MONROE project and the normal cost accounting principles of our organisation, and that they reflect the estimated costs expected to be incurred in carrying out the work described in the proposal;
4. our organization accepts the conditions set in the Terms of Service in Annex B of the document "First MONROE Open Call for Experiments and Extensions".

I declare on my honour that our organisation fully satisfies the conditions specified in Article 15 (Financial support to third parties) of the H2020 General Model Grant Agreement. I also certify that our organisation will comply to the obligations specified under Art 35 (Conflict of interest), 36 (Confidentiality), 38 (Visibility of EU funding) and 46 (Liability for damages) also apply to the third parties receiving financial support.

Signature

Name First name(s)

Full Legal Name of organisation

Date

Signature of the legal representative of the organisation

Stamp of organisation

¹¹In case of consortia, one certification per participant should be signed.