MONROE: A Distributed Platform for Mobile Broadband Measurements

Özgü Alay

Simula Research Laboratory AS

June 19, 2017

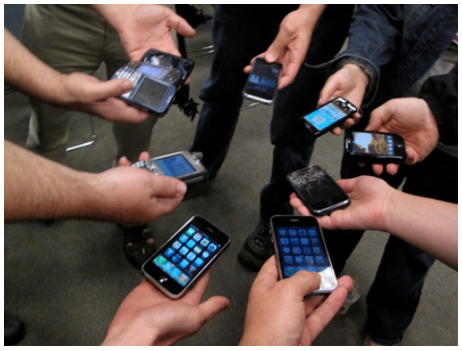
Mobile broadband (MBB) networks

- Underpins a lot of vital operations of the modern society

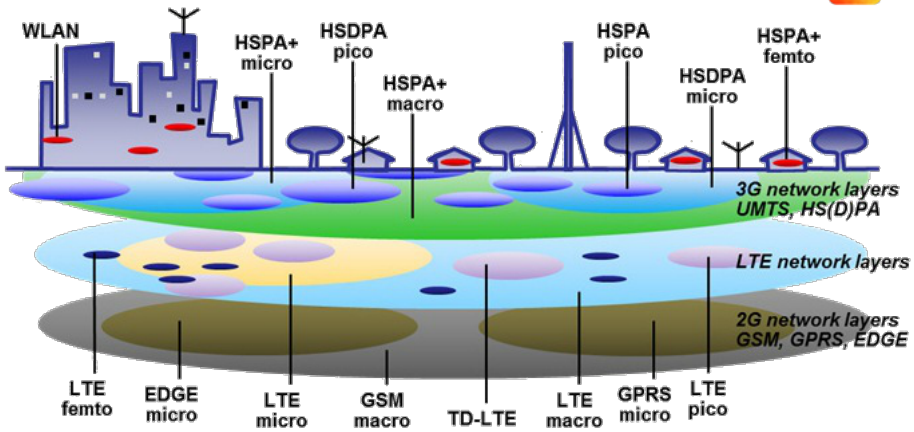



Mobile broadband (MBB) networks

- The popularity of mobile devices combined with high-capacity 3G and 4G mobile networks, has radically changed the way most people access and use the Internet.



Mobile Ecosystem



- Very complex!
- Theory does not tell it all. Hard to isolate different layers.
- Need for objective end-to-end measurements!

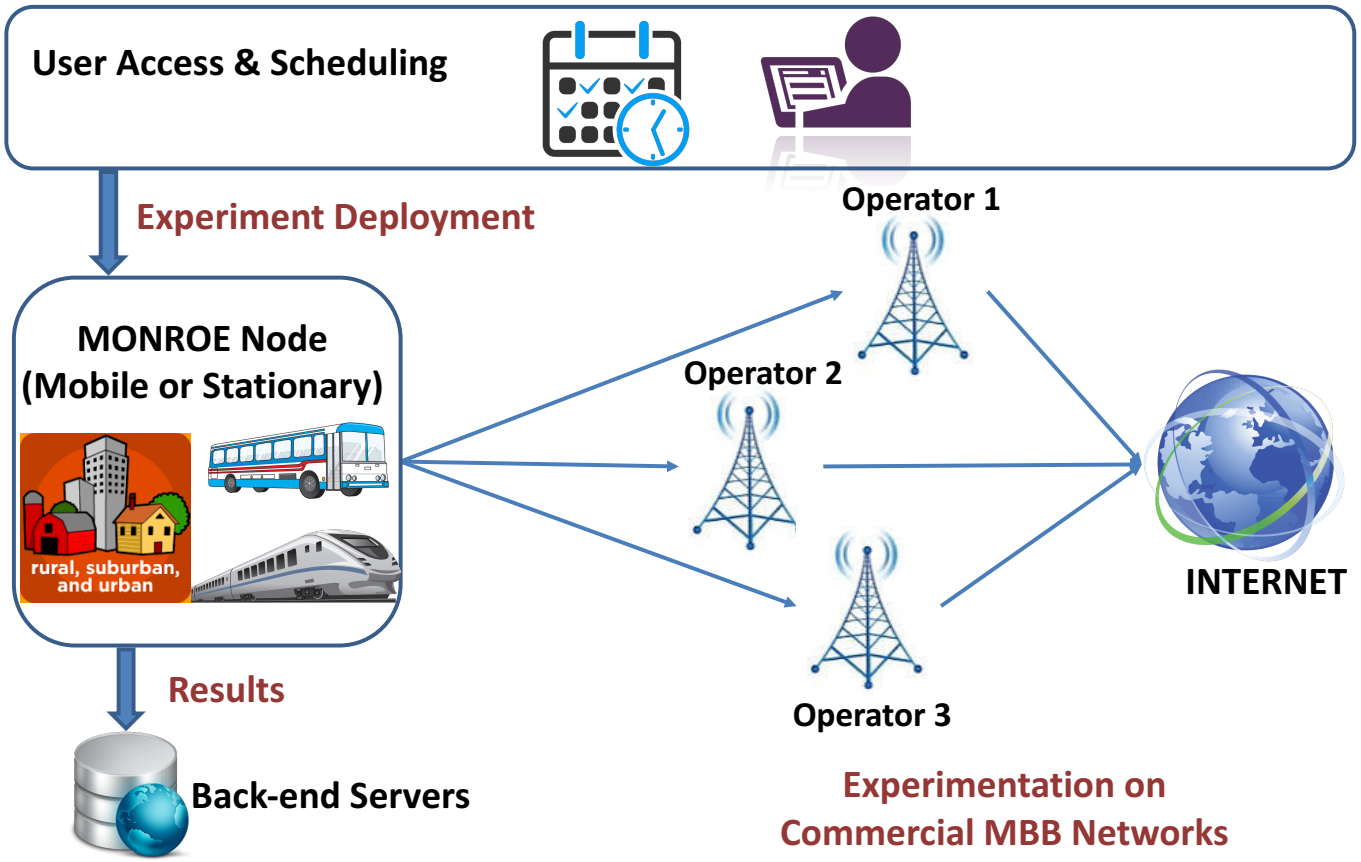
MONROE: a unique platform for measurements and experiments in operational MBB networks

- Design, build and operate an **open**, **European-scale**, and **flexible** platform to run experiments on operational 3G/4G Mobile Broadband networks with WiFi connectivity
- Use the platform for:
  - identification of key MBB performance parameters, thus enabling **accurate**, **realistic**, **persistent** and **meaningful** monitoring and performance assessment
  - examination and evaluation of **innovative protocols and services** for MBB networks

MONROE

- Coverage to 4 European Countries (Norway, Sweden, Spain, Italy)
- Nodes on buses, trains and trucks
  - Impact of mobility
- 3MBB operators and WiFi
  - Experimenting on different access technologies
  - Explore new ways of combining them to increase performance and robustness

MONROE System Overview



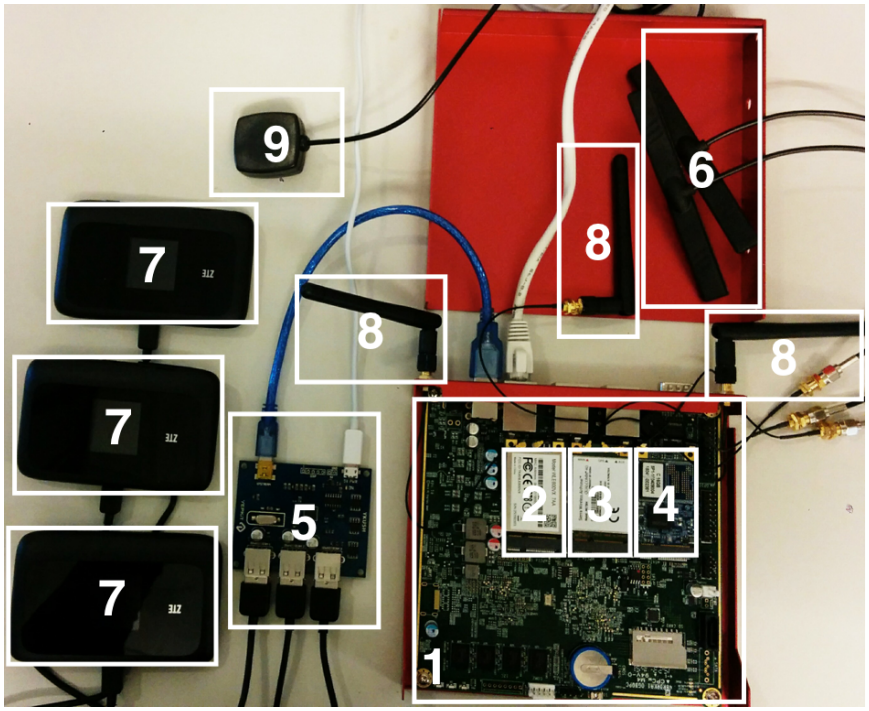
"Experience: An Open Platform for Experimentation with Commercial Mobile Broadband Networks", to appear in ACM *MOBICOM*, 2017

MONROE Nodes

- Small, affordable, robust, sufficiently powerful HW supporting the mainline Linux kernel.
  - Single Board Computers (SBCs) due to size and price constraints
- Selected: PcEngines APU
  - 1Ghz 64 bit quad core processor, 4GB of RAM, 16GB HDD.
  - 3 PCI-e slots, two of which support 3G/4G modems

Initial Node Design

- APU
- Yepkit self-powered USB hub
- 3 USB-based CAT4 MF910 MiFis
- 1 WiFi card

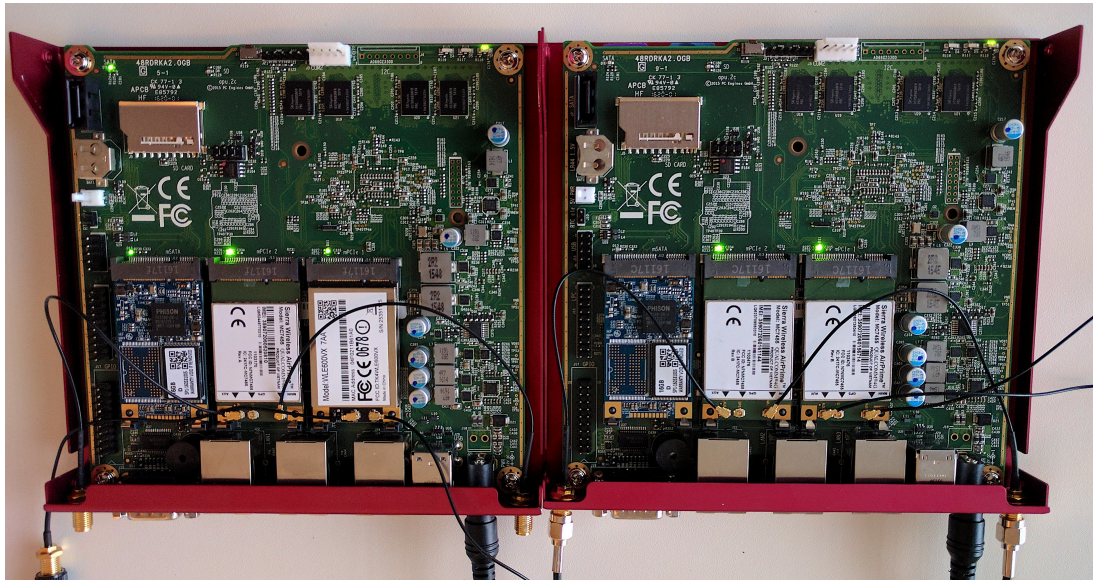


Experience

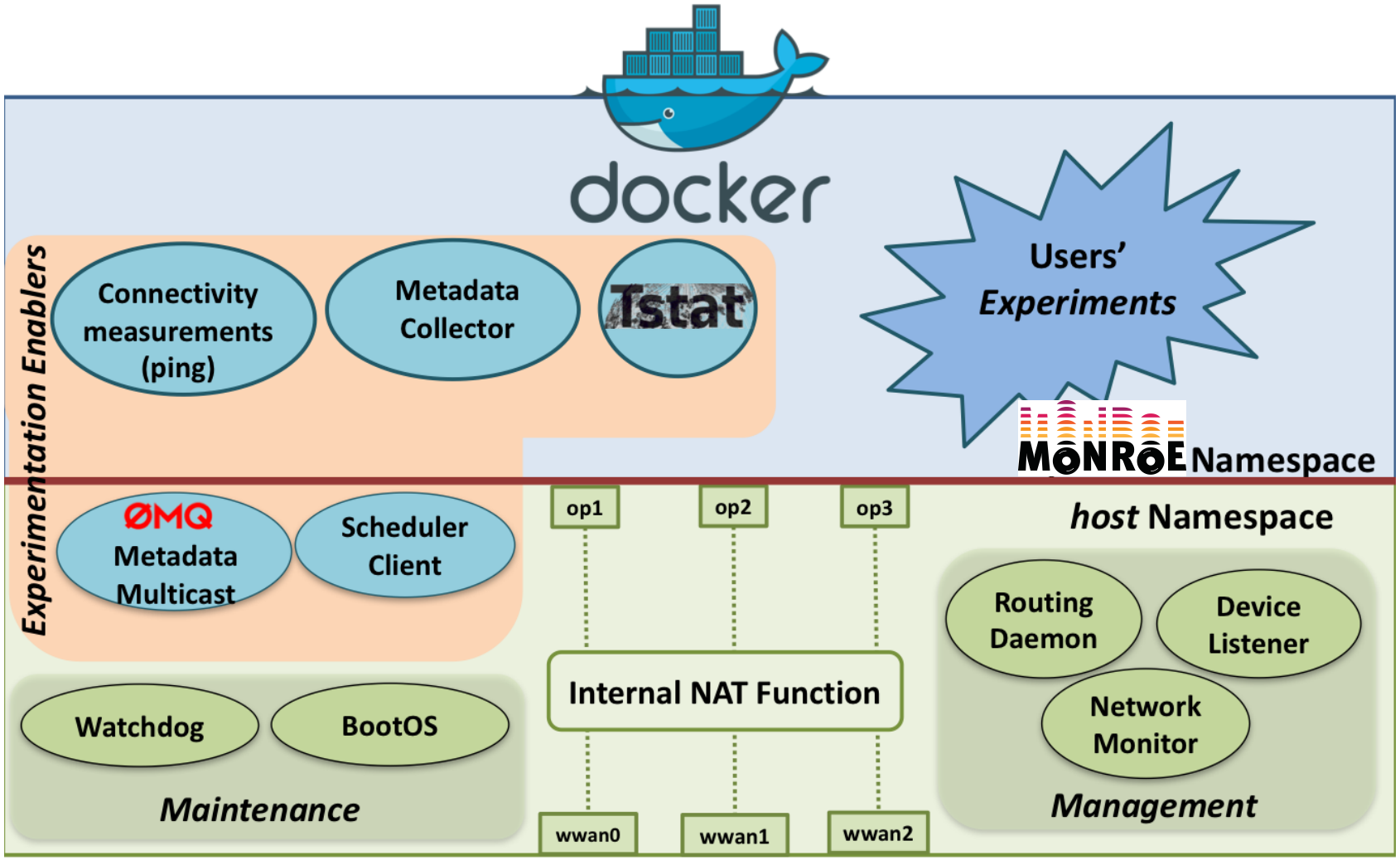
- APUs proved to be very stable
- Mifis proved more challenging than expected:
  - A forced update to the firmware made all our MiFis became inaccessible
  - MiFis themselves were prone to enter a working state (transparent PPP) from which we could only restore them by draining their batteries, or perform a manual reboot by pushing the power button
  - Some of the MiFis showed clear signs of bloated batteries

Final Node Design

- Dual-APU
- Head: 2 PCI-e CAT6 modems
- Tail: 1 PCI-e CAT6 modem and a Wifi card



MONROE Software Ecosystem



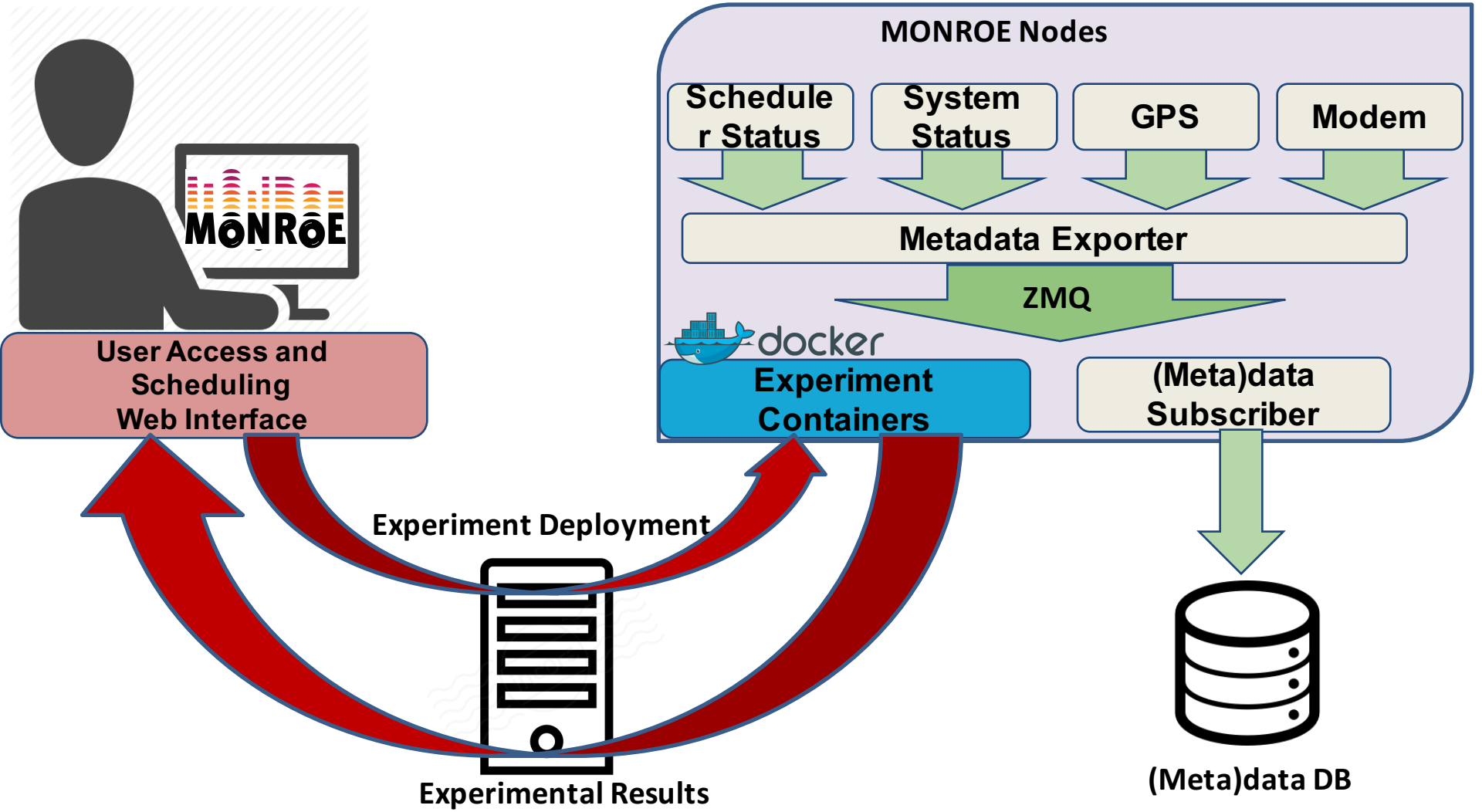
Internal NAT Function

- MONROE namespace ensures the minimum impact of user experiments gone wrong
- For each physical interface, a virtualized ethernet (veth), interface pair is created
  - one end in host namespace and one end in MONROE namespace
- Routing rules are added in the network namespace to allow routing by interface.
- Define internal internal Network Address Translation (NAT) function to allow communication between host namespace and MONROE network namespace
- Use iptables NAT masquerading rules in the host namespace to configure the NAT function.

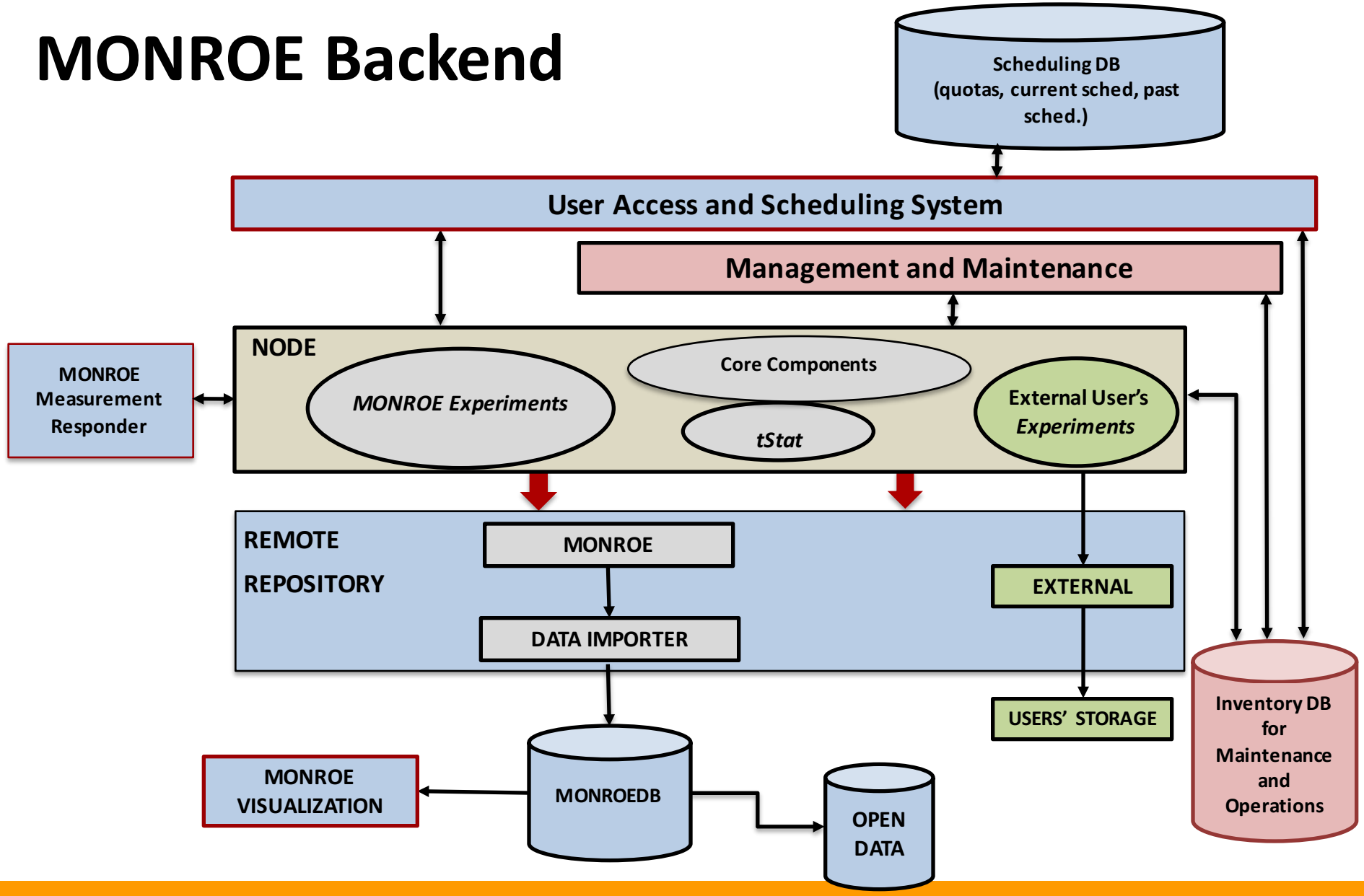
Docker Virtualization

- Each experiment runs inside a virtualized environment (Docker container) to ensure separation and containment of processes
- Docker containers are based on a layered file system
  - Default base image for the experiment containers integrates the base operating system installation with default tools
  - Containers provide just the contents that are unique for the particular experiment
    - significantly reducing the download and deployment time overhead and accountable traffic volume
- Experiments running inside a container
  - have access to the experimental network interfaces
  - can read and write on their own file system, overlaid over that of the base MONROE image
  - write their results to (e.g., /MONROE/results/) to be automatically transferred to the MONROE servers

Information Flow



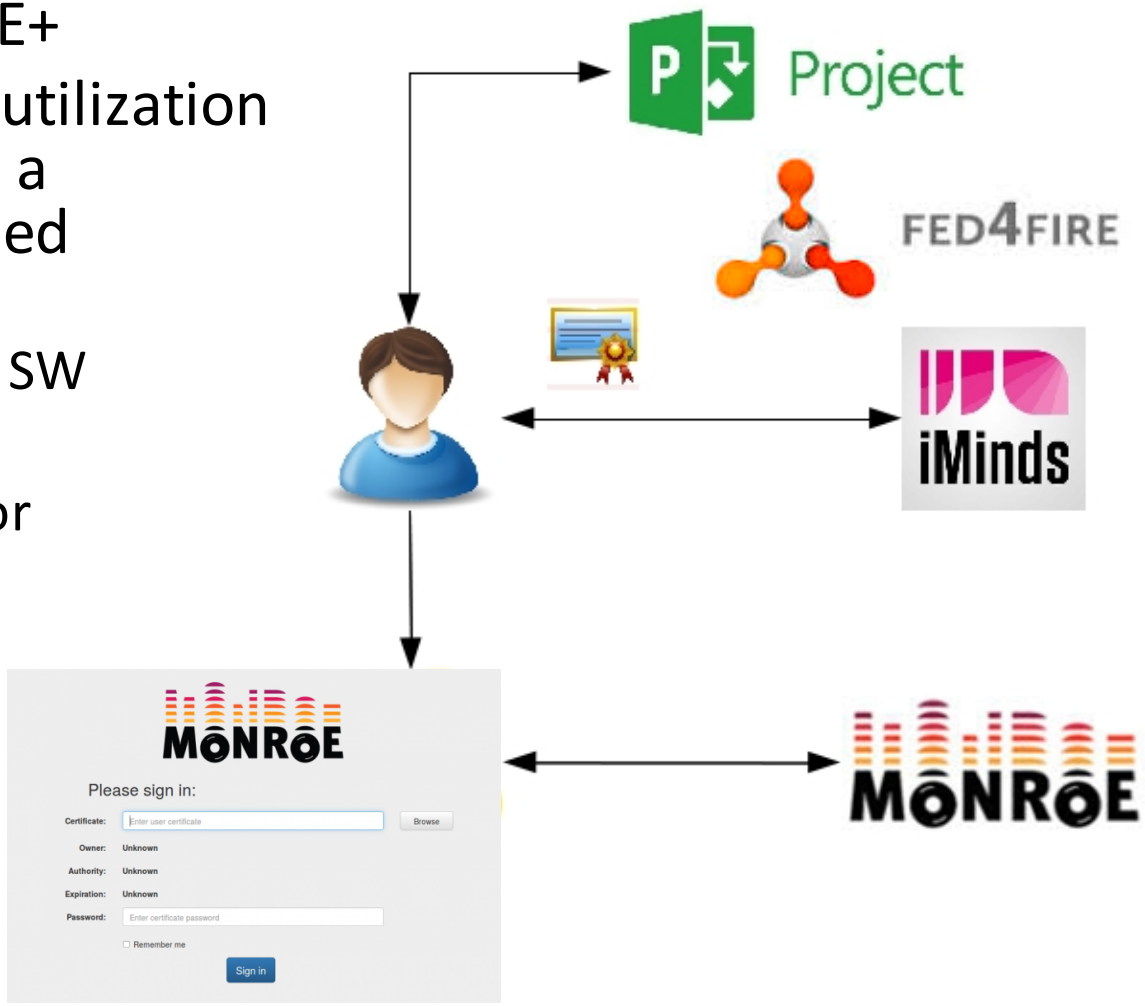
MONROE Backend



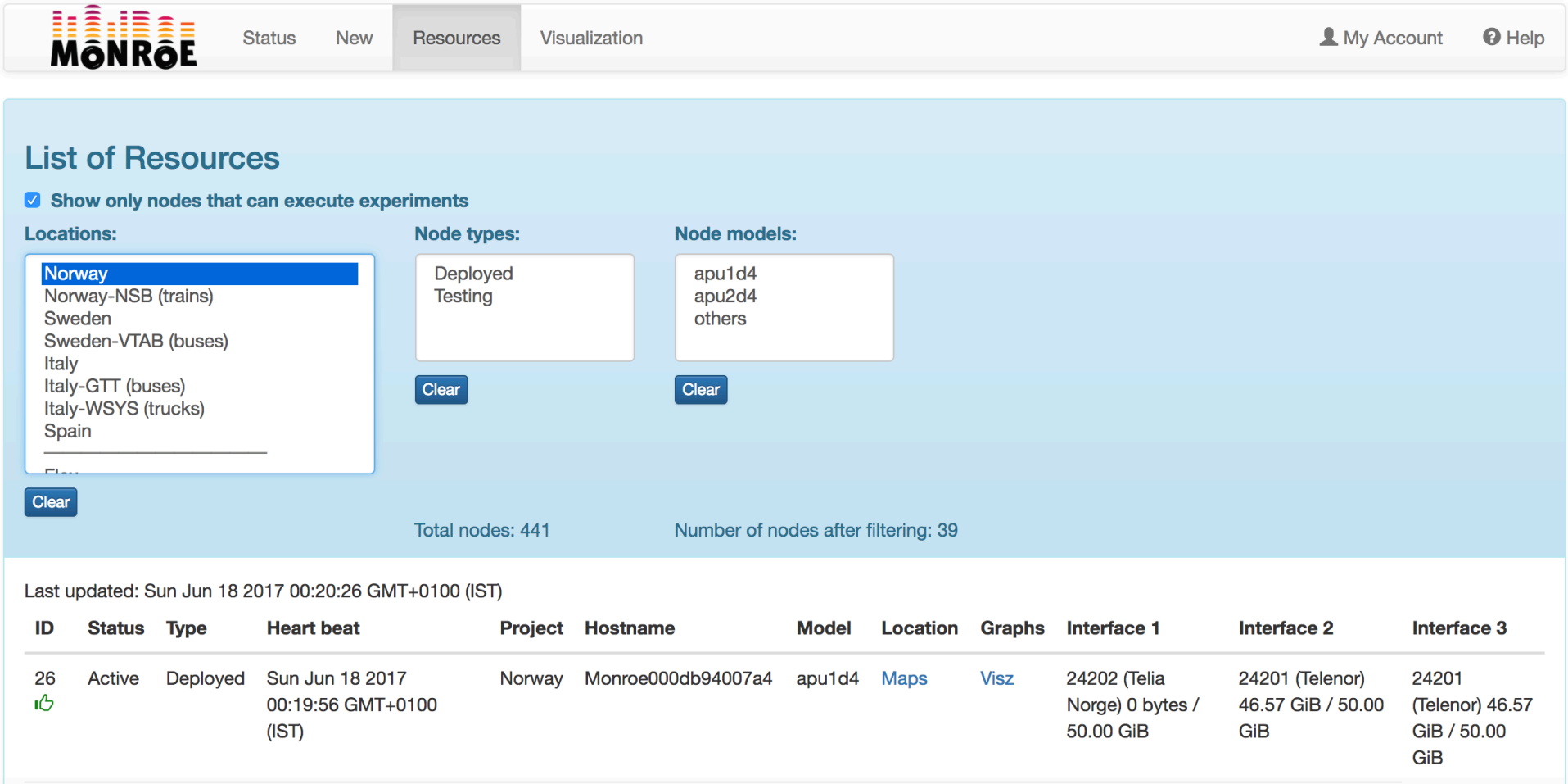
User access

Federation with FIRE/FIRE+

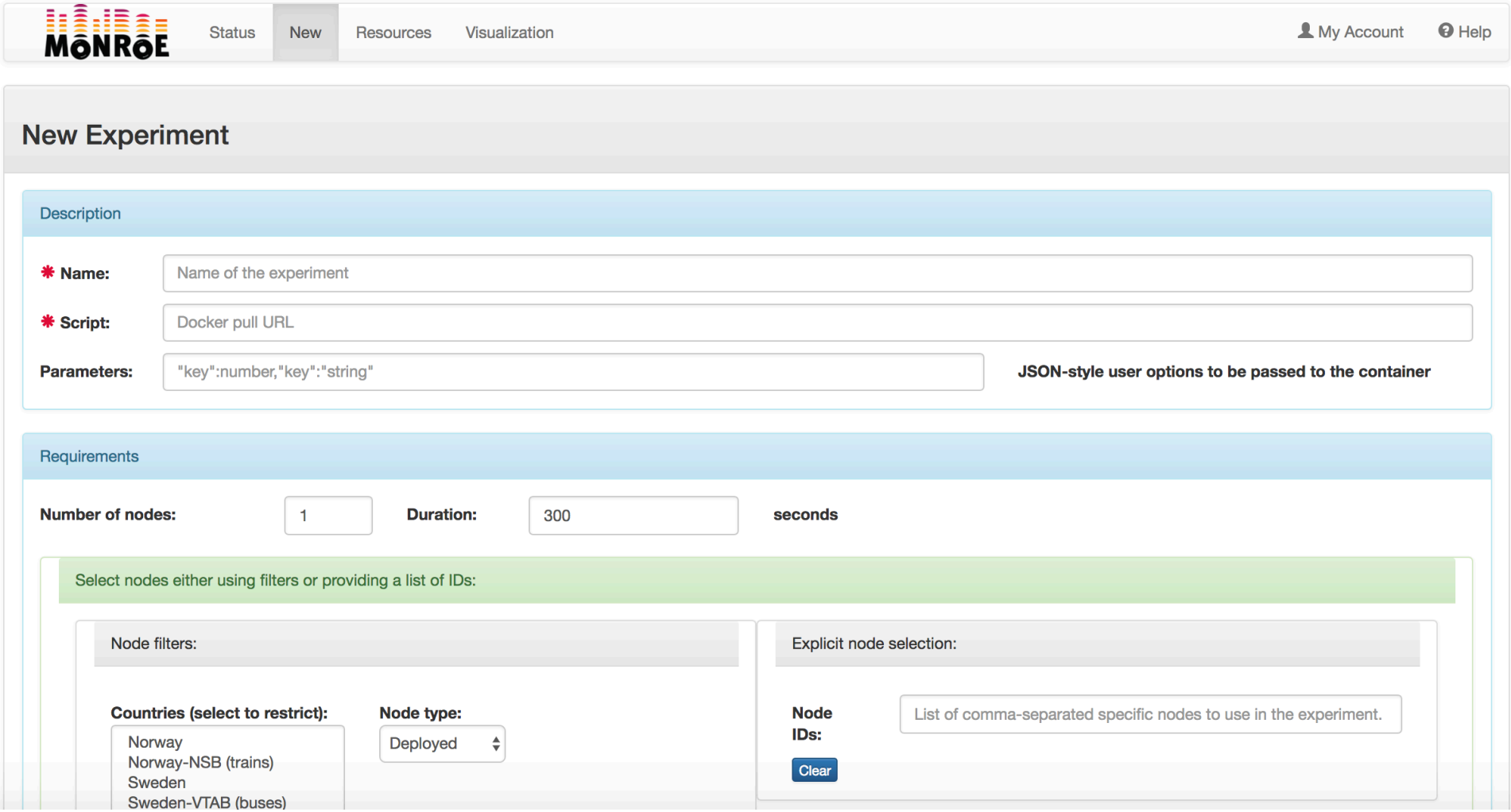
- User access and node utilization managed according to a standardized and unified approach
  - Reuse Fed4FIRE open SW
  - GENI API v.3
  - REST as parallel API for development



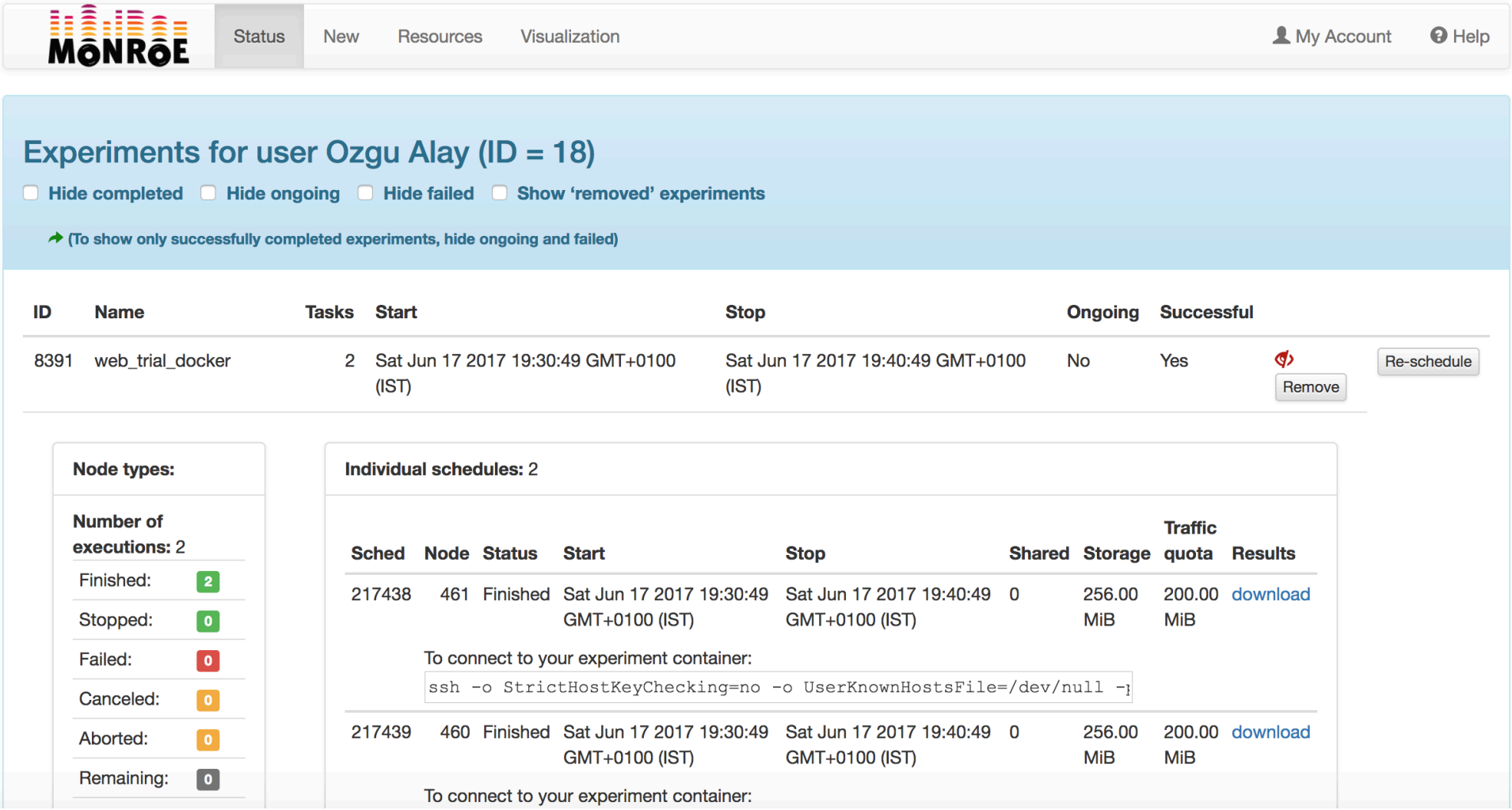
MONROE Web Interface: Resources



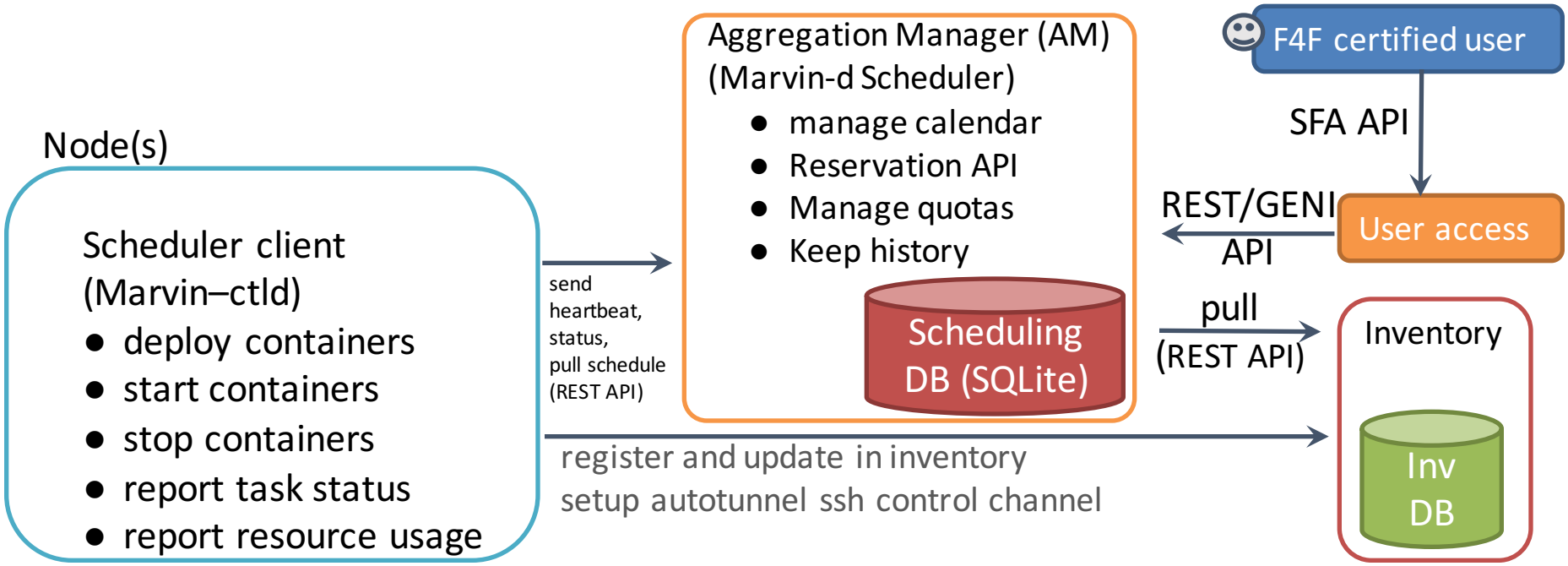
MONROE Web Interface: New



MONROE Web Interface: Status



Scheduling


Node(s)
Scheduler client
(Marvin–ctld)
deploy containers
start containers
stop containers
report task status
report resource usage
send
heartbeat,
status,
pull schedule
(REST API)
Aggregation Manager (AM)
(Marvin-d Scheduler)
manage calendar
Reservation API
Manage quotas
Keep history
Scheduling
DB (SQLite)
F4F certified user
SFA API
REST/GENI
API
User access
pull
(REST API)
Inventory
Inv
DB
register and update in inventory
setup autotunnel ssh control channel

Scheduling policies

- Schedule an experiment on **n** nodes of **type t** at given **time (start, end)**
  - type selectors: deployed, testing, mobile, static, country X, operator Y
- Only one active measurement experiment may run at a time (marked as exclusive)
- Several passive experiments may run at a time
- Quotas enforced in terms of storage, volume of data exchanged

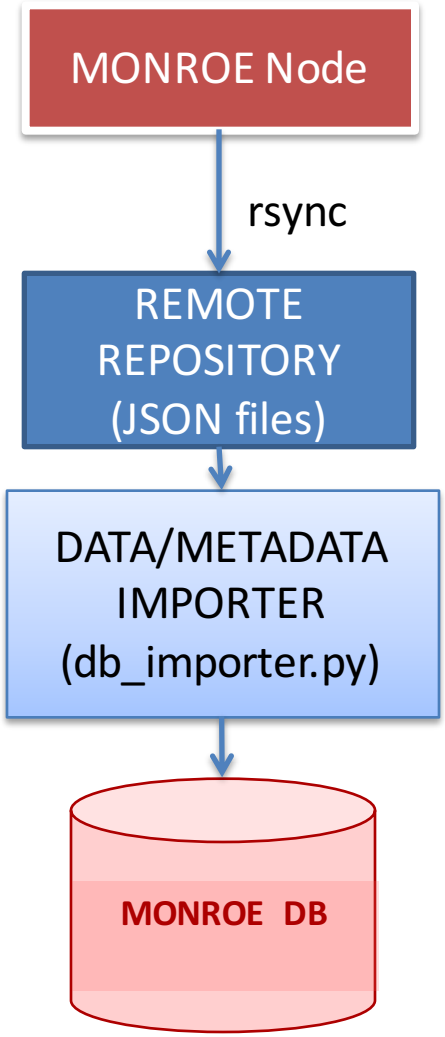
- Priority translates into pre-booking periods, else FCFS.

Data and Metadata Importer

- Local files are exported to the remote repository
  - Connection status to the remote repository:
    - Connection exists:

      Every 2 minutes this file rsync'ed
    - Connection does not exist:

      Continue local logging until connection comes up or disk is 90% full.
- On the remote repository
  - Parse and injected into the DB every 20 secs
  - Daily backup (with compressed JSON files)

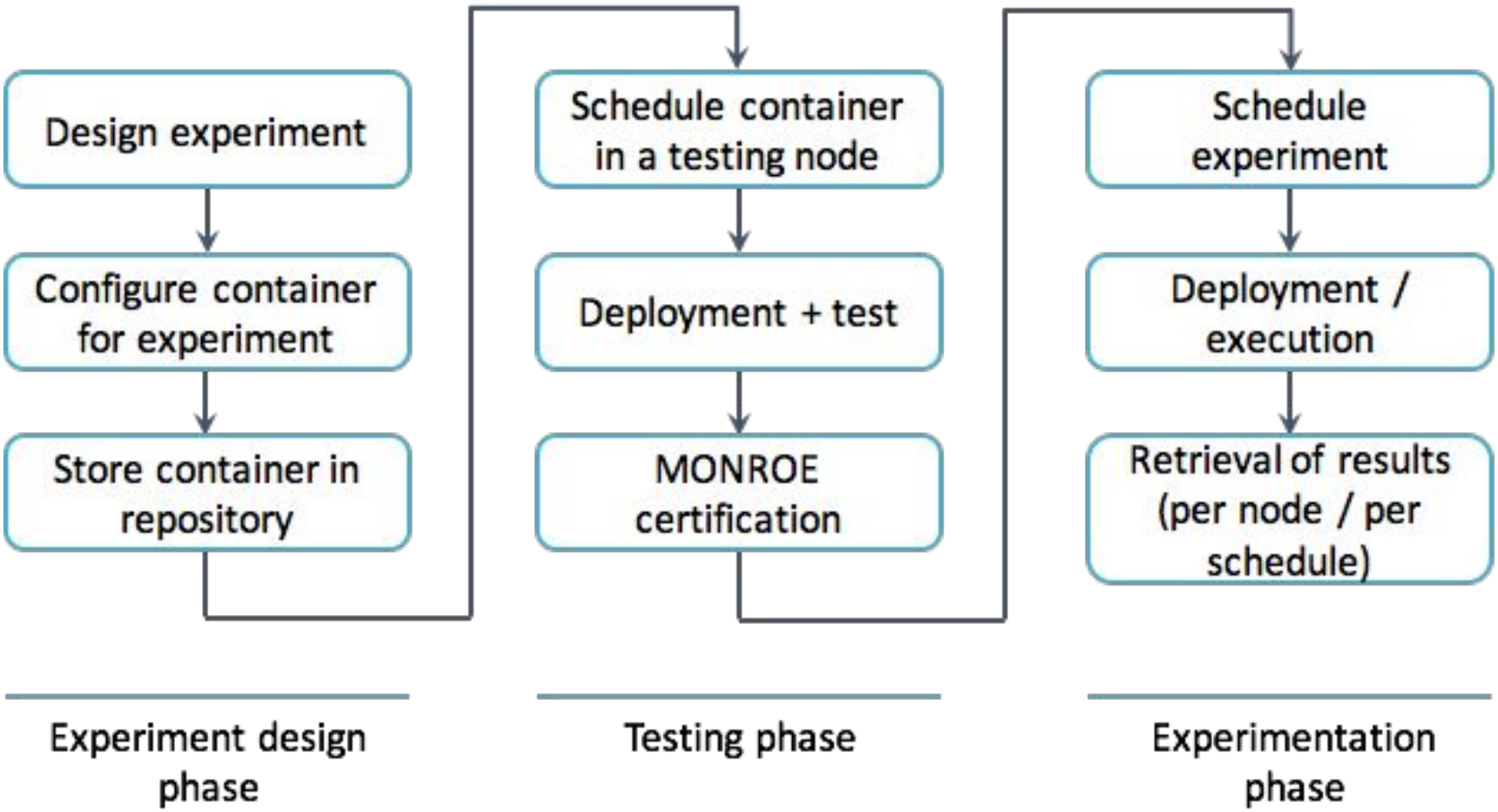


MONROE DB

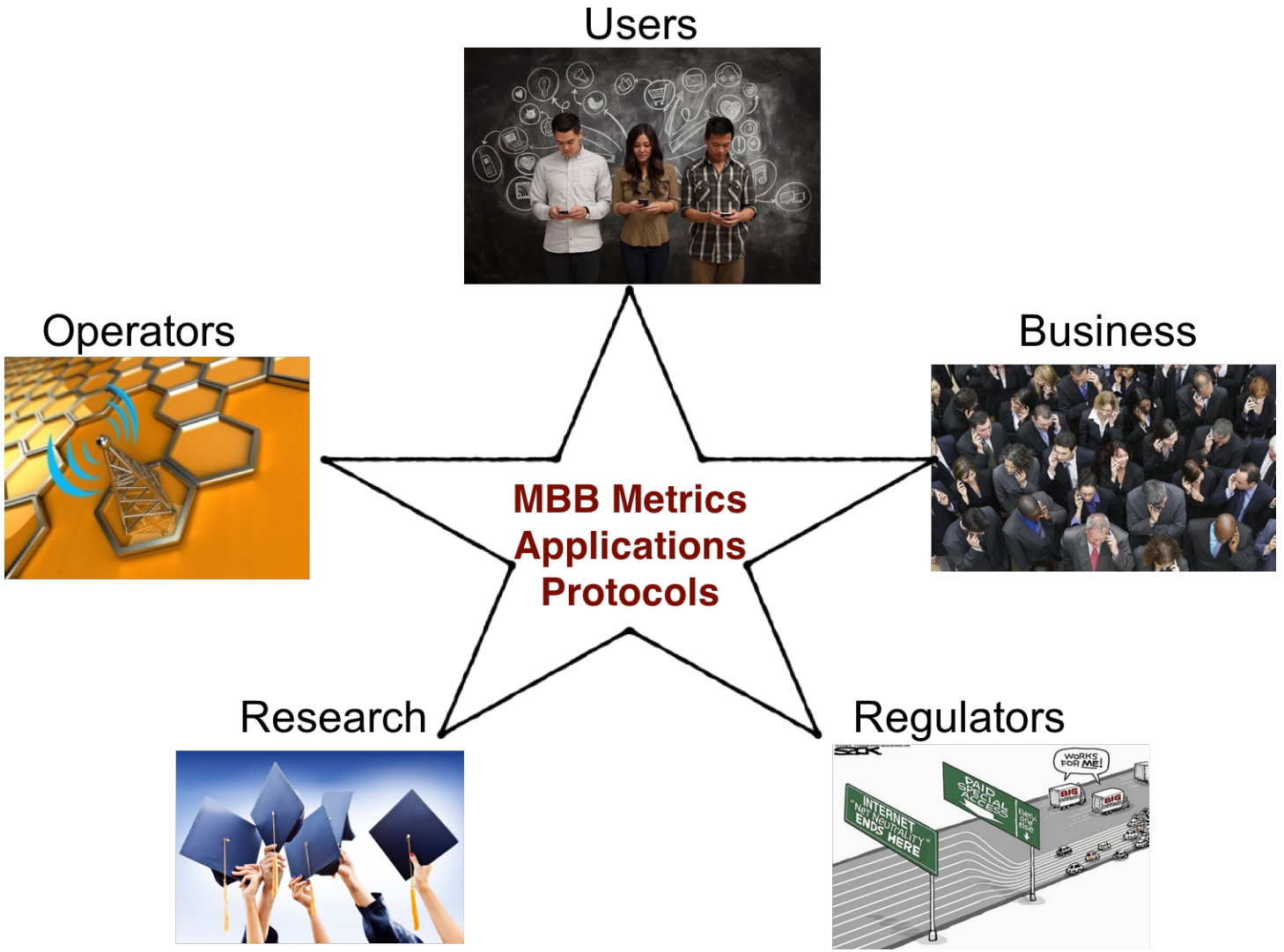
- Used to store:
  - Measurements (RTT, throughput, packet loss, DL time, ….)
  - Metadata (signal strength, connectivity type, GPS, …)
- For data and metadata use a big data solution
  - Friendly for parsing long time series
  - Scales much better than a relational data base
- Data accessible with tools specialized for Big Data analysis

MONROE uses a NoSql database (Apache Cassandra)

Experimentation Process



MONROE Measurements and Experiments



MONROE Use Cases

- ***Key MBB Metrics***
  - *Network tomography*
  - *Traffic analysis with Tstat*

Tstat

- ***Application Performance***
  - *Video applications*
  - *Web services*

- ***Protocol Innovation***
  - *Internet Path Support*
  - *Multipath protocols*
  - *Traffic Offloading*

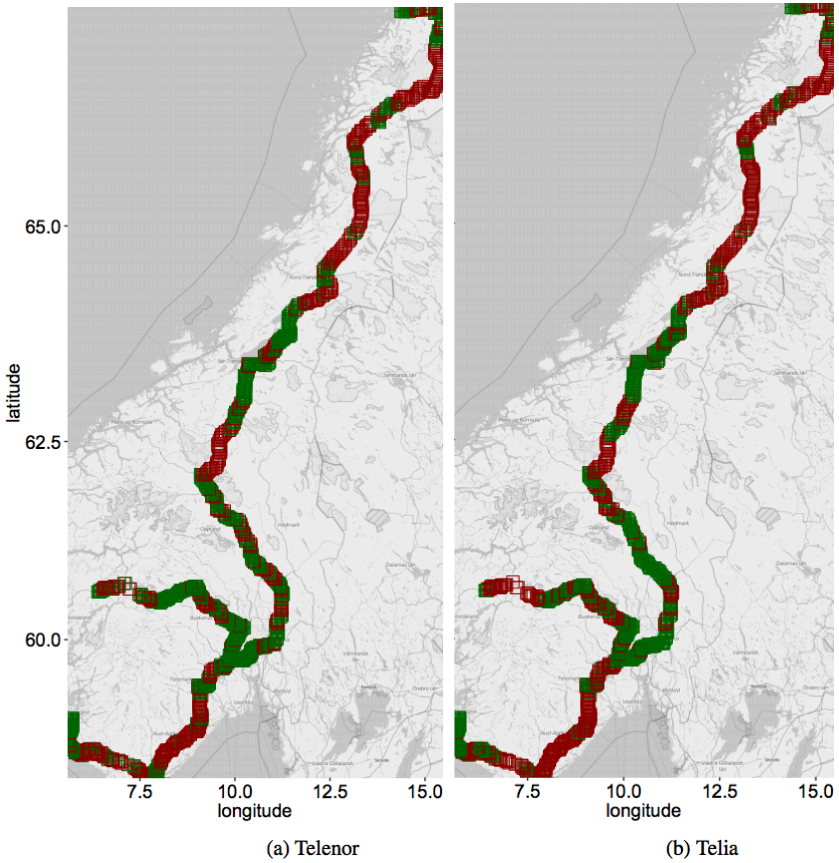
Use Case 1: KEY MBB Parameters

Performance assessment and monitoring of mobile broadband (MBB) networks

- Network Tomography: Performance and Reliability Parameters
  - Latency, packet loss, bandwidth, etc…
- Traffic analysis
  - Monitor and report live traffic statistics
- Route analytics: Network Topology Inference / Analysis
  - Path dynamics, Internet routing data, prefix geolocation

Building reliable coverage maps

- Built coverage maps of different operators based on the rich modem metadata



(a) Telenor (b) Telia

- "Profiling mobile broadband coverage", Traffic Monitoring and Analysis (TMA), 2016 (best paper award)
- "ZipWeave: towards efficient and reliable measurement based mobile coverage maps", in INFOCOM 2017

Tstat monitoring

- Deployed Tstat on all MONROE nodes
- Analyzed the log files together with the metadata, used Tstat passive traces to identify the proxies in MBB's infrastructure

Country	Operator	Private IP & NAT	$\widehat{G}$ mismatch on port 80	L4 Mangling	Connection (percentage) Type
Italy	op0	Yes	Yes*	All	3G (0.46), 4G (0.54)
	op1	Yes*	Yes	All	3G (0.15), 4G (0.85)
	op2	No	Yes	All	2G (<0.01), 3G (0.08), 4G (0.92)
Sweden	op0	Yes*	Yes*	All	4G (100)
	op1	No	Yes	All	3G (<0.01), 4G (0.99)
	op2	No	Yes*	All	3G (0.37), 4G (0.63)
Spain	op0	Yes	No	All	4G (100)
	op1	Yes	No	All	3G (0.16), 4G (0.84)
	op2*	No	Yes	All	3G (0.07), 4G (0.93)
Norway	op0	No	Yes*	All	4G (100)
	op1	Yes*	Yes*	All	3G (0.08), 4G (0.92)

"Speedtest-like measurements in 3G/4G networks: the MONROE experience", to appear in ITC'17

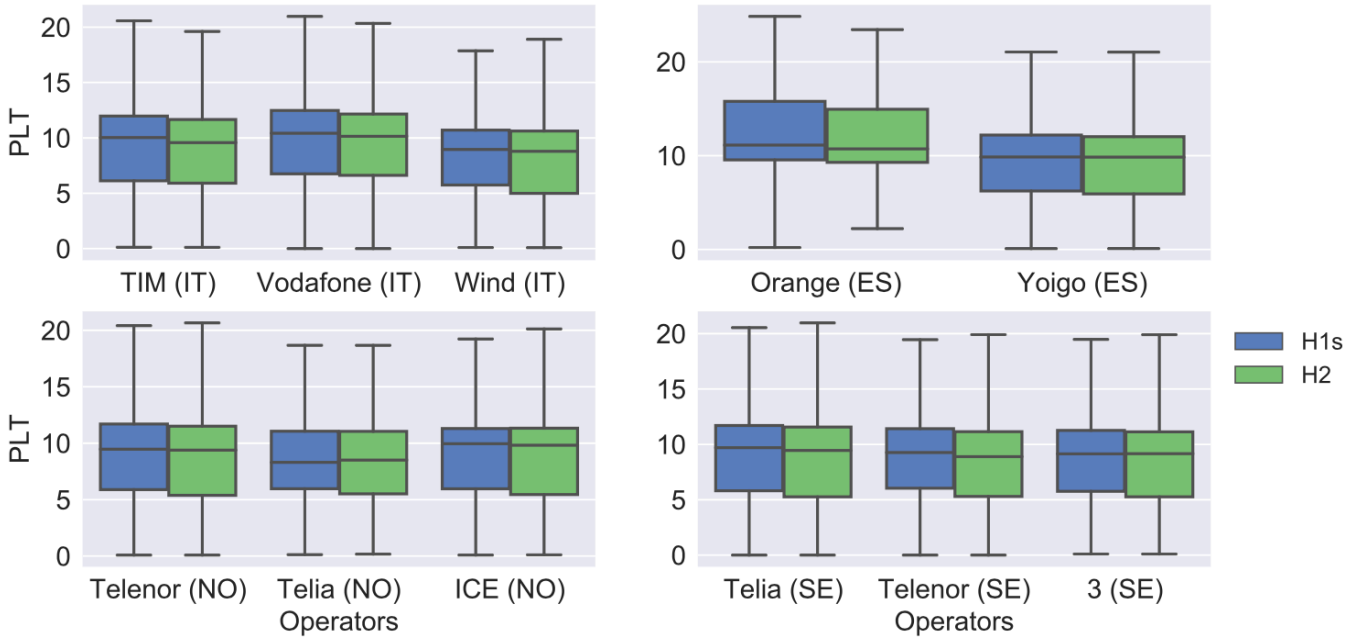
Use Case 2: Application Performance

Service-oriented measurements

- Performance Measurement for Video on Demand and Video Conferencing Systems
- Performance measurements of Web traffic
- Assessment of Online Gaming performance
- Effect of the background traffic on the application performance
- Study how Quality of Experience (QoE) can be estimated from objective metrics

Web Performance

- Developed a web performance measurement tool
- Analyzed web performance over different operators as well as over different protocols



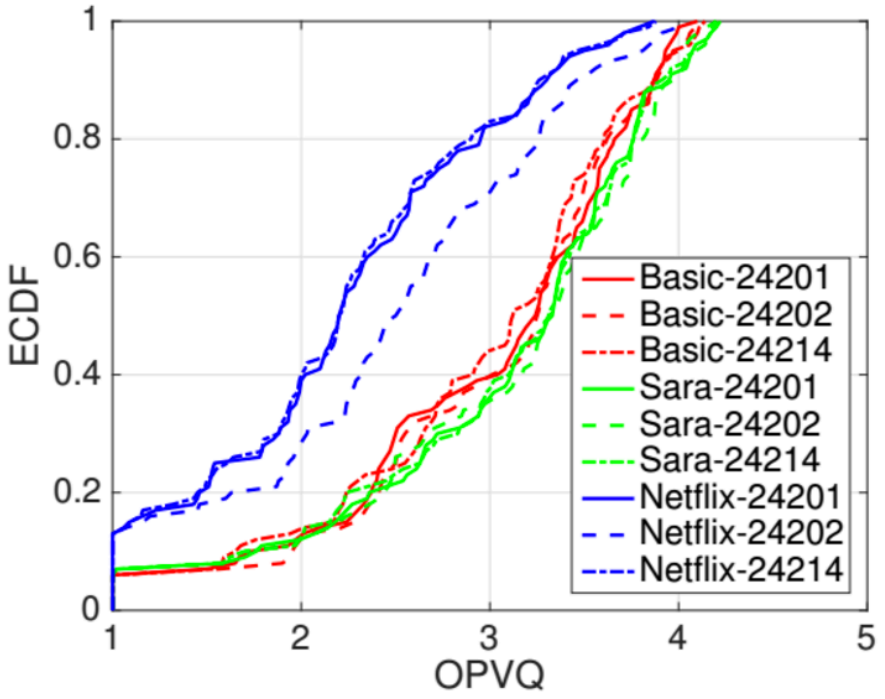
Video Streaming with DASH

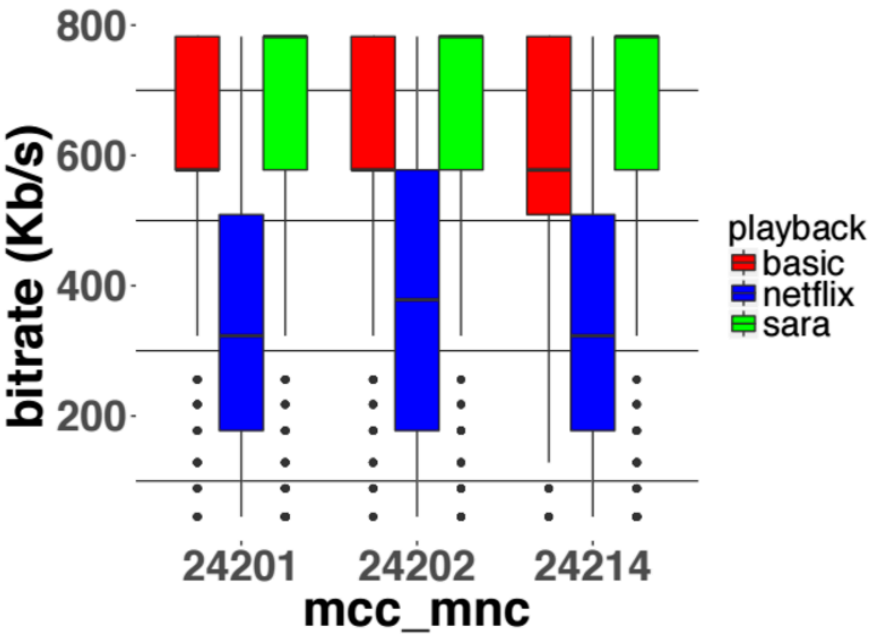
- Developed a DASH measurement tool
- Analyzed the performance of different DASH rate-adaptation algorithms over different operators

Basic — throughput-based

SARA — hybrid

BBA (Netflix) — buffer-based





Use Case 3: Novel Services and Protocols

Examination and evaluation of innovative protocols and services for MBB networks

- Evaluation of path support for MPTCP, ECN, TCP Fast Open, etc.
- Protocol Performance Optimizations
- Traffic offloading between MBB and WIFI
- Multipath Performance Measurements

Path support for IP and TCP

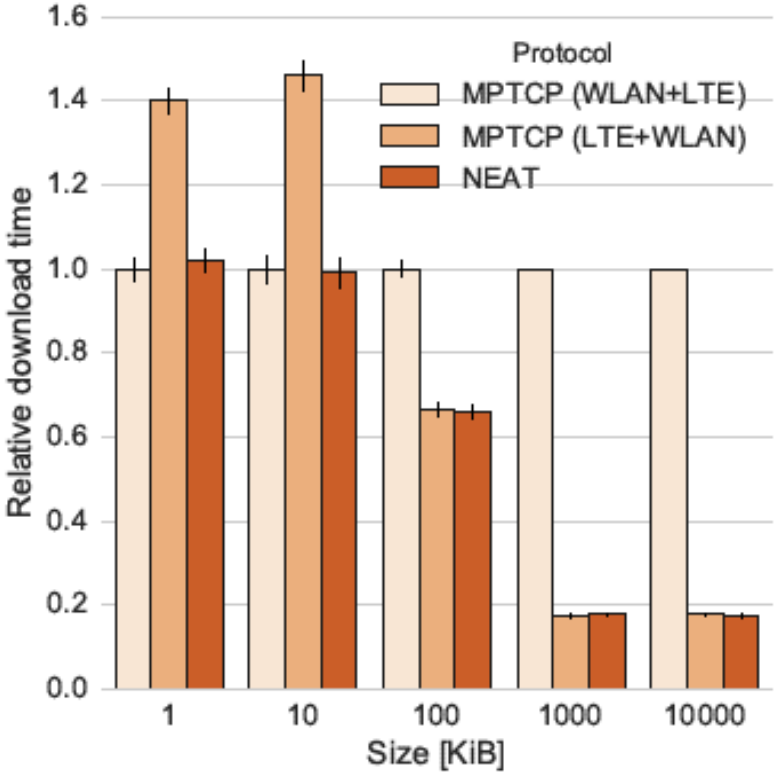
- Test path support for IP and TCP, e.g., MPTCP, ECN, TCP Fast Open
- Customized PATHspider to measure across multiple paths

- We carried out a large scale path support measurement campaign over mobile networks

"Path transparency measurements from the mobile edge with PATHspider", accepted by IEEE/IFIP MNM Workshop 2017
"Exploring DSCP modification pathologies in mobile edge networks", accepted by IEEE/IFIP MNM Workshop 2017

MPTCP: intelligent interface selection

- Implemented NEAT transport architecture in MONROE
- Experiments over MPTCP
- Uses metadata to make a decision on the paths and selects them accordingly



Relative download performance using MPTCP with different primary path configuration and NEAT

"A NEAT approach to mobile communication", accepted by SIGCOMM 2017, MobiArch workshop


WHO
WHAT
WHERE
WHEN
WHY
HOW
QUESTIONS
ANSWERS