WP2: Experimentation: Middlebox Modeling and Testing

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measurement and architecture for a middleboxed internet

measurement | architecture | experimentation

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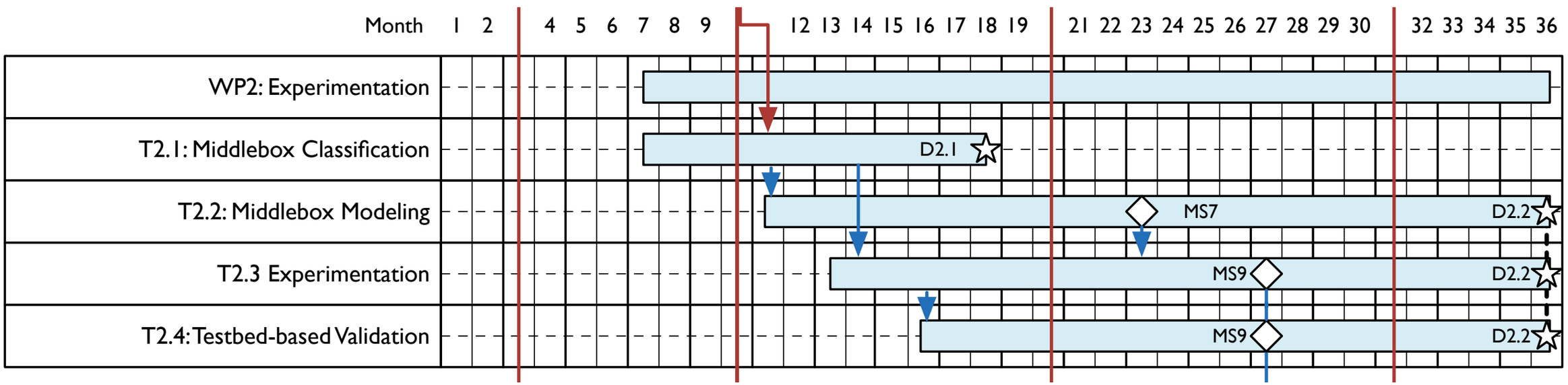
WP2 Objectives and Tasks

- Development of a middlebox taxonomy, based on WP1 measurements
- **Development of a middlebox model** for testing and experimentation
- **Evaluation** of use cases applicability and deployment feasibility **of protocols / protocol extensions from WP3**



Overview - Who did what?

Partner	Task 2.1 Middlebox classification	Task 2.2 Middlebox modeling	Task 2.3 Model/NFV-based experimentation	Task 2.4 Testbed-based validation of approach
ETH			✓	✓
TID		✓	✓	
ULg	✓	✓		
UoA	✓			✓
SRL	✓			✓
NOKIA				✓

Deliverables summary

D2.1	Middlebox Classification and Initial Model	M18
D2.2	Final Middlebox Model, Experimentation and Evaluation Report	M36

WP2 activities in the reporting period

- Modular middlebox simulator (T2.2)

- Experimental evaluation of protocols or protocol extensions, based on explicit path-to-sender or sender-to-path signaling (T2.4)
  - Datagram Packetization Layer Path MTU Discovery
  - Passive latency measurement approaches
  - Loss-Latency trade-off

- MAMI components for virtualised deployments (T2.3)
  - Extensions to the Network Modelling (NEMO) language

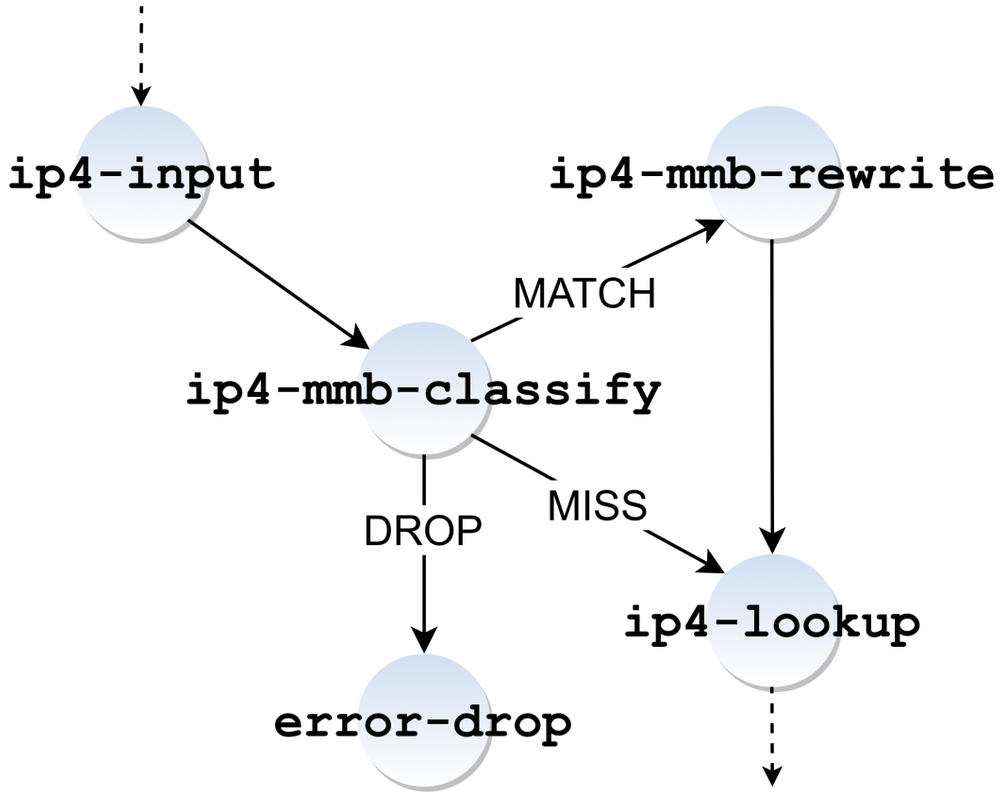
Modular middlebox simulator (mmb)

- Based on prior MAMI work on middlebox policies taxonomy (D2.1)

- Stateless and stateful packet classification and rewriting
  - Stateless packet matching based on any combination of constraints on network or transport header fields
  - Stateful TCP and UDP flow matching
  - Packet mangling or dropping
  - Bidirectional mapping

Modular middlebox simulator (mmb)

- Implemented as a Vector Packet Processor (VPP) plugin
- Two nodes added to VPP processing graph:
  - Classification
  - Rewriting
- Middlebox policies specified / configured via CLI



Modular middlebox simulator (mmb)

- Example
  - Drop everything but TCP:

match

```
vpp# mmb add ip-proto != tcp drop
```

stateless rule

protocol header field => can be IPv4, IPv6, ICMPv4, UDP, TCP (both fixed header and options)

condition

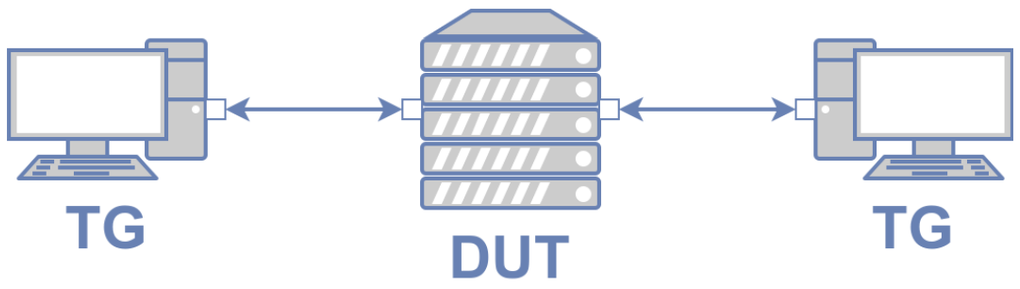
value

target => action to be taken if packet matches rule

Modular middlebox simulator (mmb)

- Performance measurements
  - mmb configured as firewall, all traffic should pass
    - Simple stateless rules, 5-tuple matching (only fast path used)
    - Parameter: # of rules that have to be evaluated
    - KPI: max throughput achieved

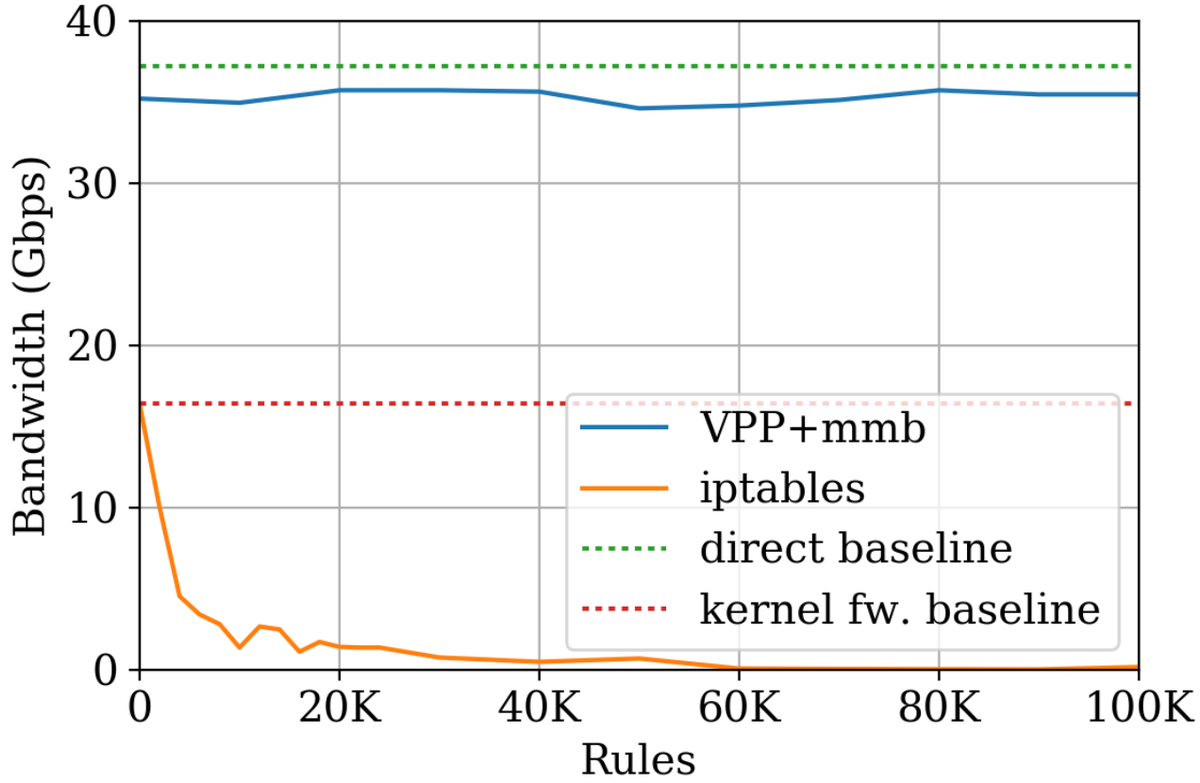
(1) calibration (direct baseline)



(2) middlebox = DUT using either mbb, iptables, or direct kernel forwarding

Modular middlebox simulator (mmb)

- Performance measurements
  - mmb configured as firewall, all traffic should pass

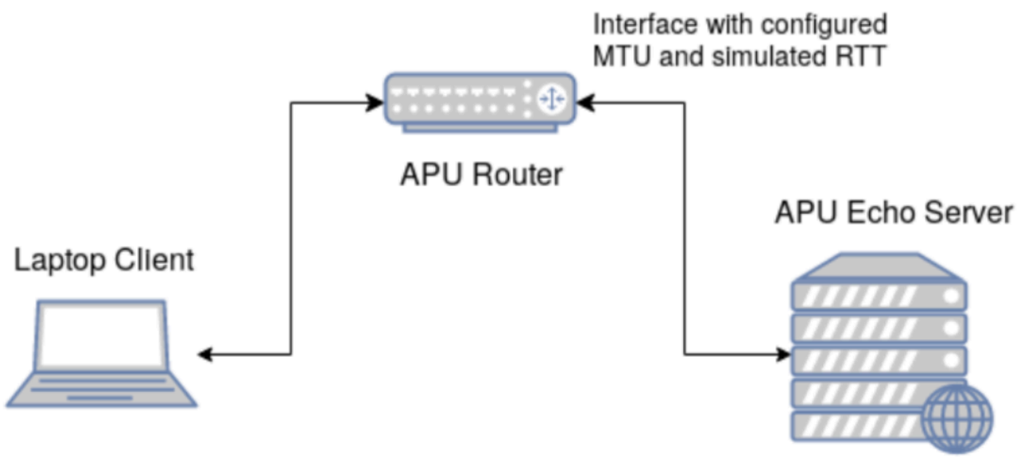


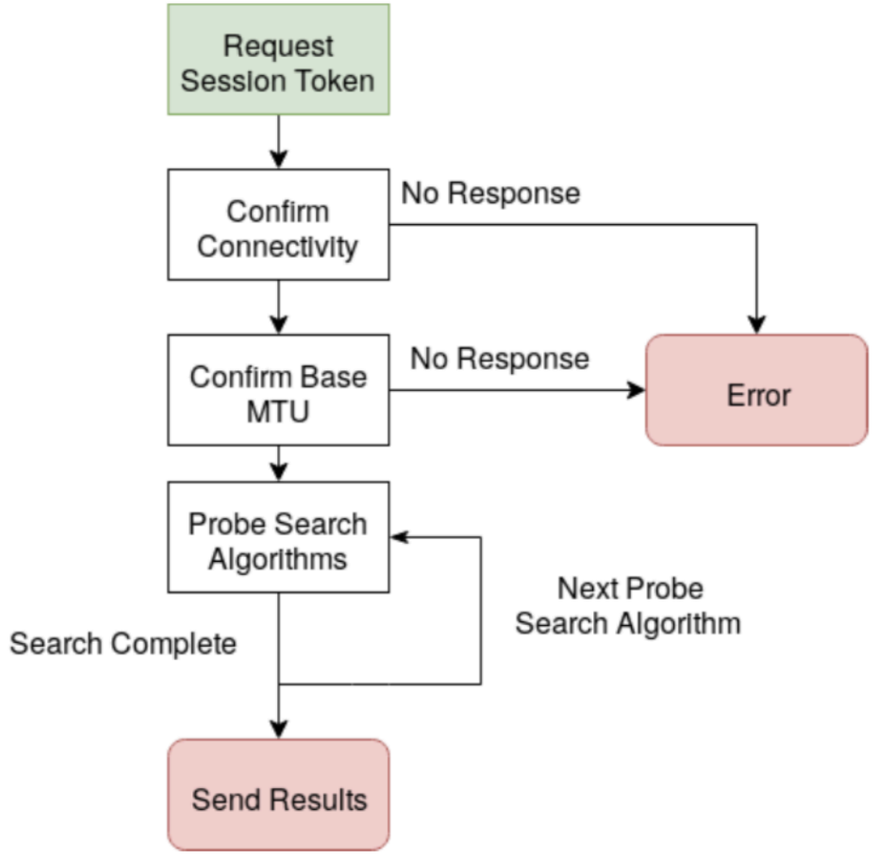
Datagram Packetization Layer Path MTU Discovery (DPLPMTUD)

- Adds PMTU discovery to datagram protocols
- Experiments to:
  - demonstrate it works as expected
  - evaluate different PMTU search methods
- Different test setups
  - Controlled lab environment and real-world paths
  - With / without support for ICMP Path Too Big (PTB) messages

Datagram Packetization Layer Path MTU Discovery (DPLPMTUD)

- Client implementing draft-ietf-tsvwg-datagram-plpmtud + either of 3 search methods:
  - step size
  - binary
  - table-based (based on common PMTU values found in WP1 experiments)





Datagram Packetization Layer Path MTU Discovery (DPLPMTUD)

- Summary of results
  - Algorithm works without PTB support – or absence of valid PTB messages
    - PTB enabled => faster search (as expected – avoidance of a black-hole timeout)
  - No method is a clear winner, results dependent on network configuration – QUIC is implementing the simplest method

Search Type	Probes Received	Time to complete (s)	MPS found	Estimated RTT (ms)
Step Size 1	273	24.2	1472	88.2
Step Size 50	6	0.5	1450	88.2
Derived Table	7	0.7	1472	88.2
Binary Search	1	0.07	1472	88.2

Table 5: Results of tests of the DPLPMTU test tool in a real world environment with each of the four search algorithms. The test network did not generate any ICMP PTB messages.

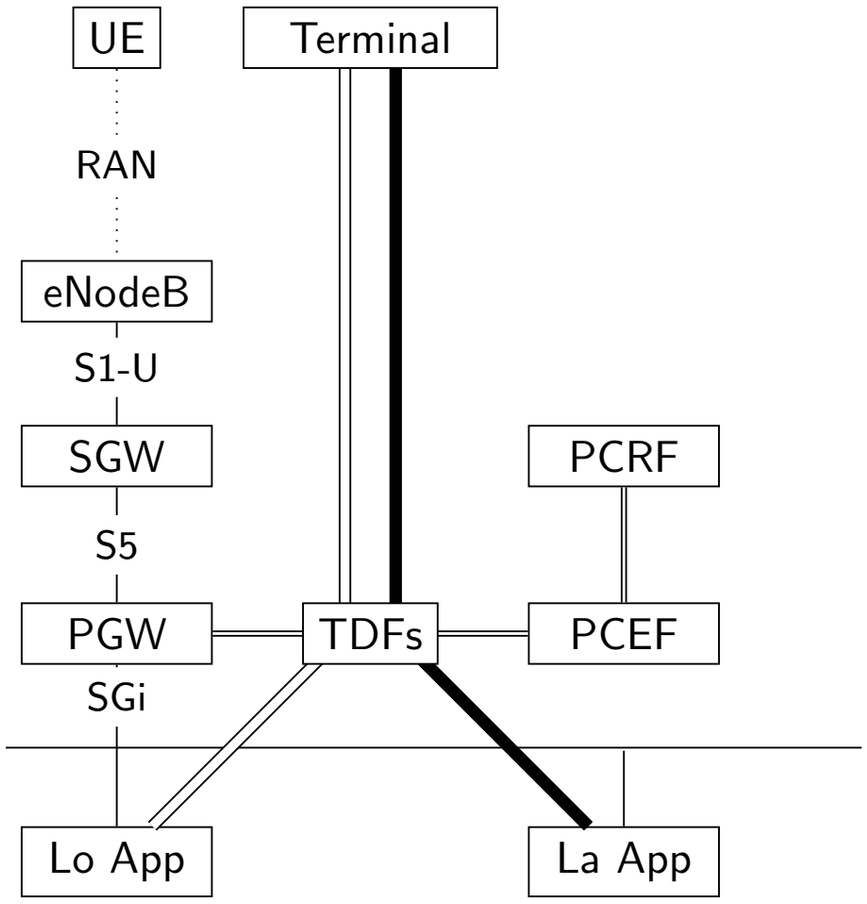
Loss-Latency Trade-off (LLT)

- Experiments to:
  - Evaluate the LLT Signal for Mobile Networks
    - Packets marked with DiffServ Code Points (DSCPs) as defined in draft-you-tsvwg-latency-loss-tradeoff
    - Mapping to either of two LTE bearers: default or low-latency
  - Verify there are no incentives for cheating

- Simulation-based (ns-3) evaluation
- Testbed setup based on a set of VNFs prepared and deployed in 5TONIC (but eventually could not be used within the project)

Loss-Latency trade-off (LoLa)

- Simple scenario: two competing flows
  - TCP large file download (prefers low loss)
  - Real-time 64 kbps audio flow (prefers low latency)
  - Baseline = no marking, i.e., both on the same (default) bearer

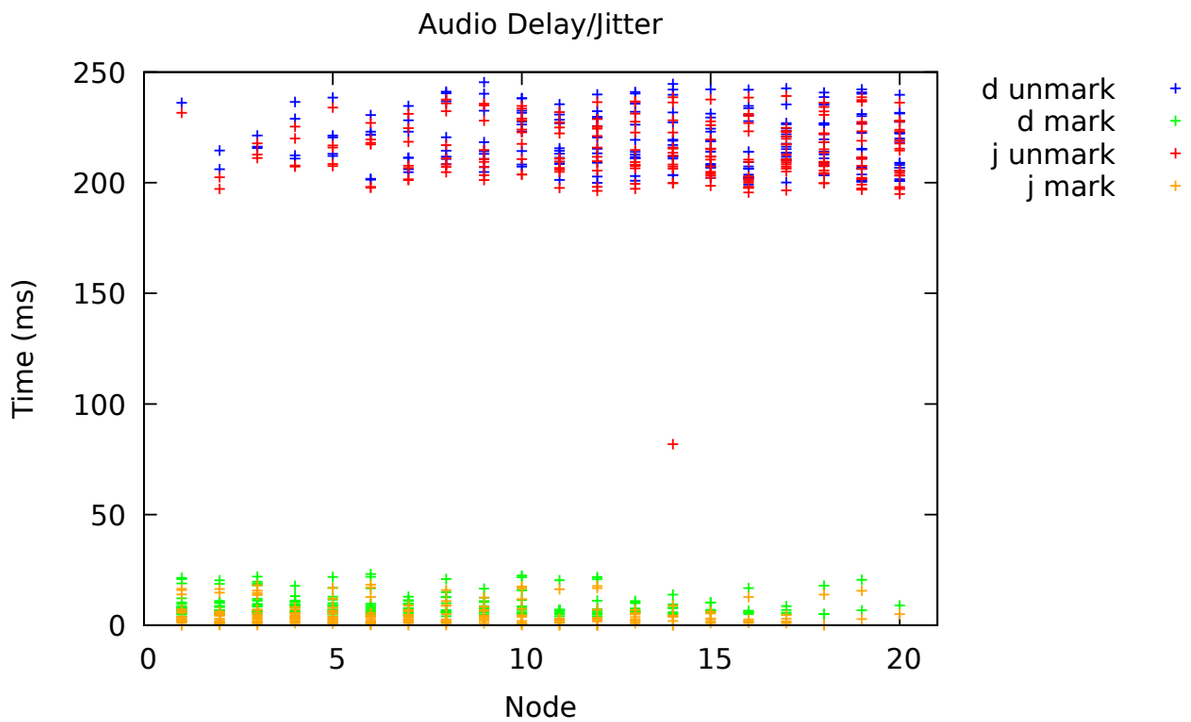


Loss-Latency trade-off (LoLa)

- Summary of results
  - Is it worth cheating? (TCP greedy flow marked as “low-latency”)
    - Answer: **no**
    - Self-inflicted higher loss & lower throughput, as expected

Loss-Latency trade-off (LoLa)

- More complex scenario: multiple UEs connected to one e-Node B
  - One audio or video CBR stream + a large file download per UE
  - In each run, some UEs use LLT marking (i.e., ≠ bearers), some don't

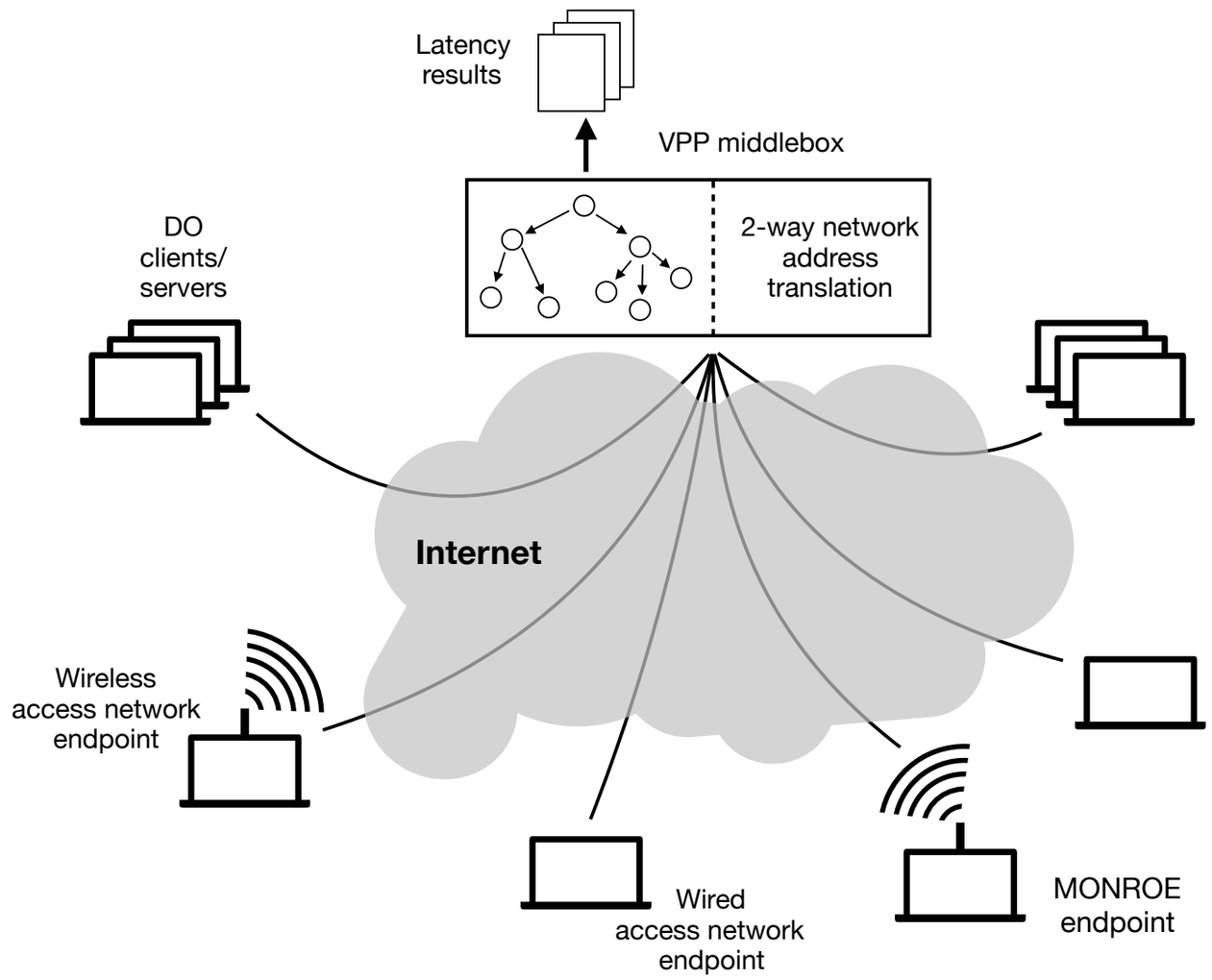


Passive latency measurement approaches

- VPP-based measurement box developed for latency measurements
- Experiments to:
  - Evaluate **latency spin signal**
    - Both in QUIC, TCP and PLUS
  - Compare with other approaches
    - TCP timestamps
    - PLUS Packet Serial Number (PSN) and Packet Serial Echo (PSE)
- **Latency measurement demo** to follow this presentation

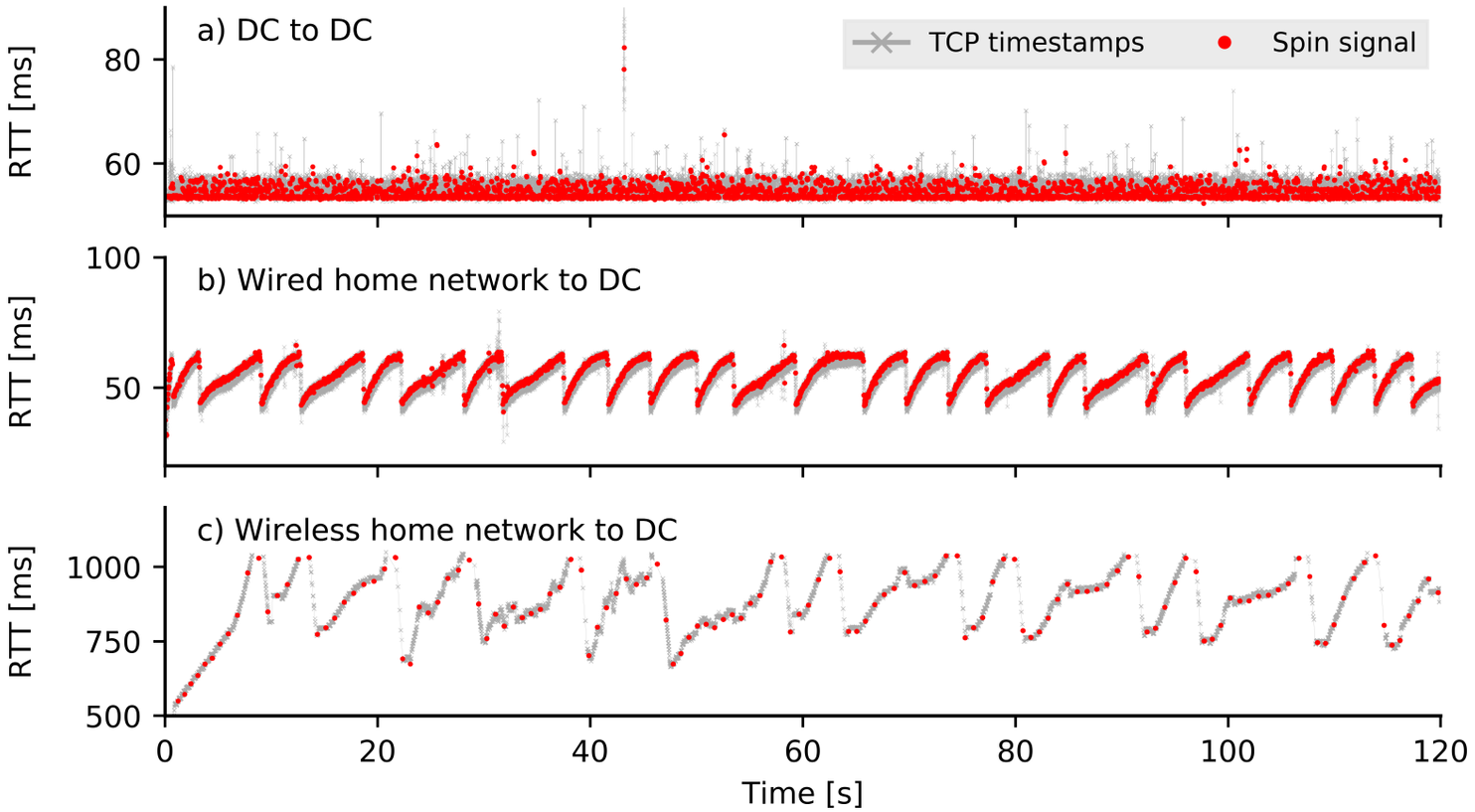
Passive latency measurement approaches

- TCP and PLUS experiments: Internet paths, hosts in:
  - MONROE testbed
  - Digital Ocean
  - wireless home
  - wired home

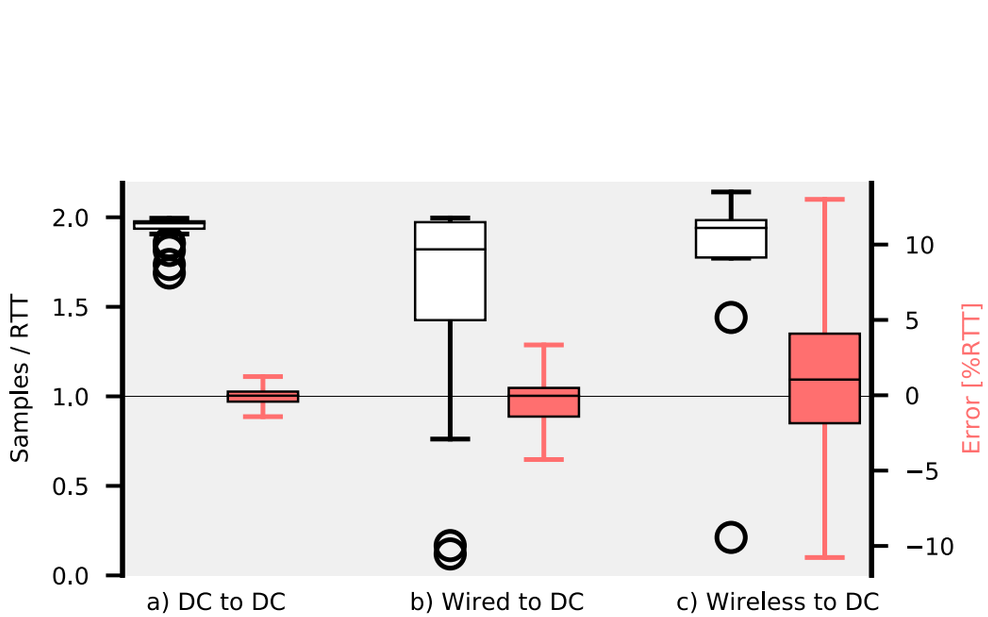


Passive latency measurement approaches

- Spin signal vs. TCP timestamps

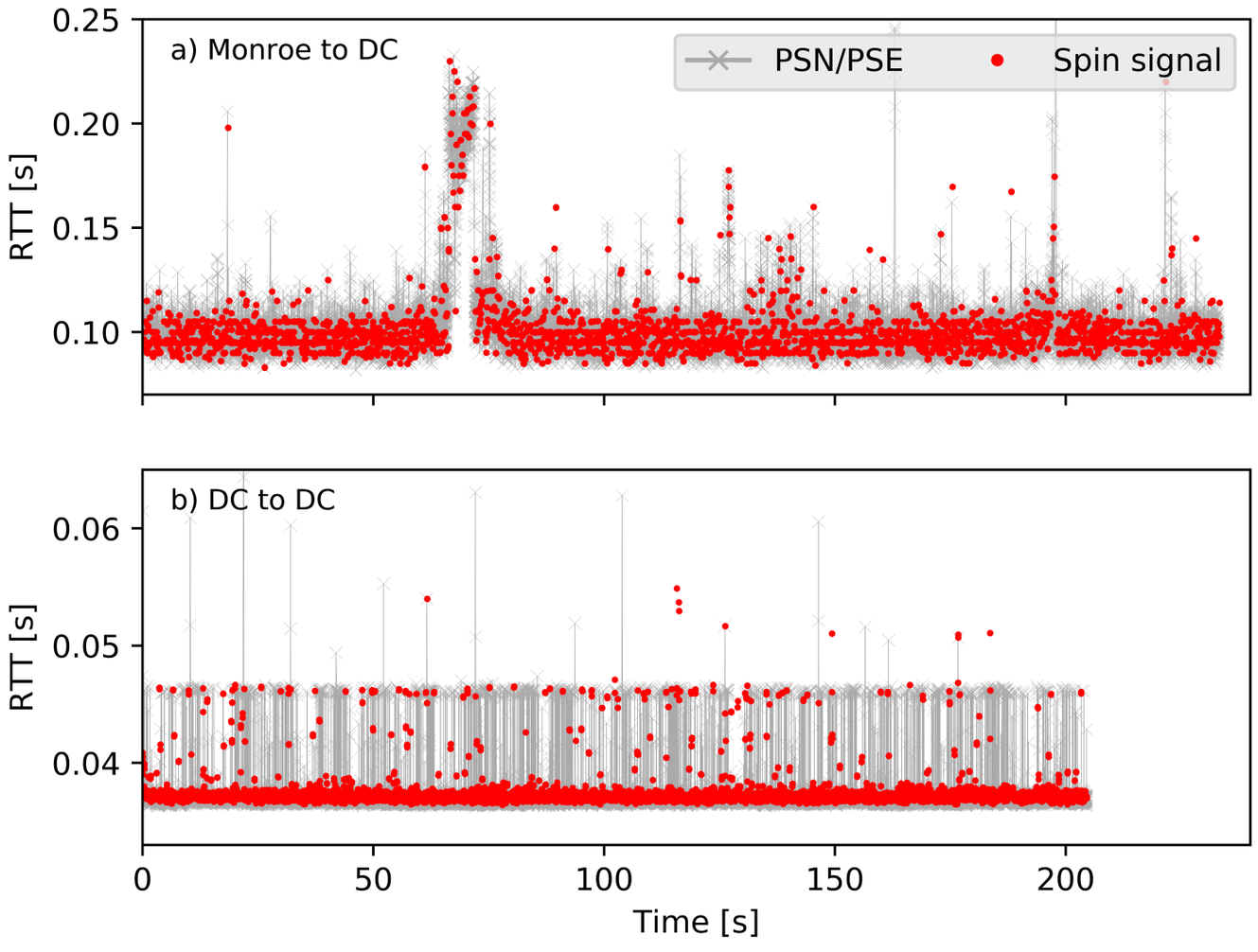


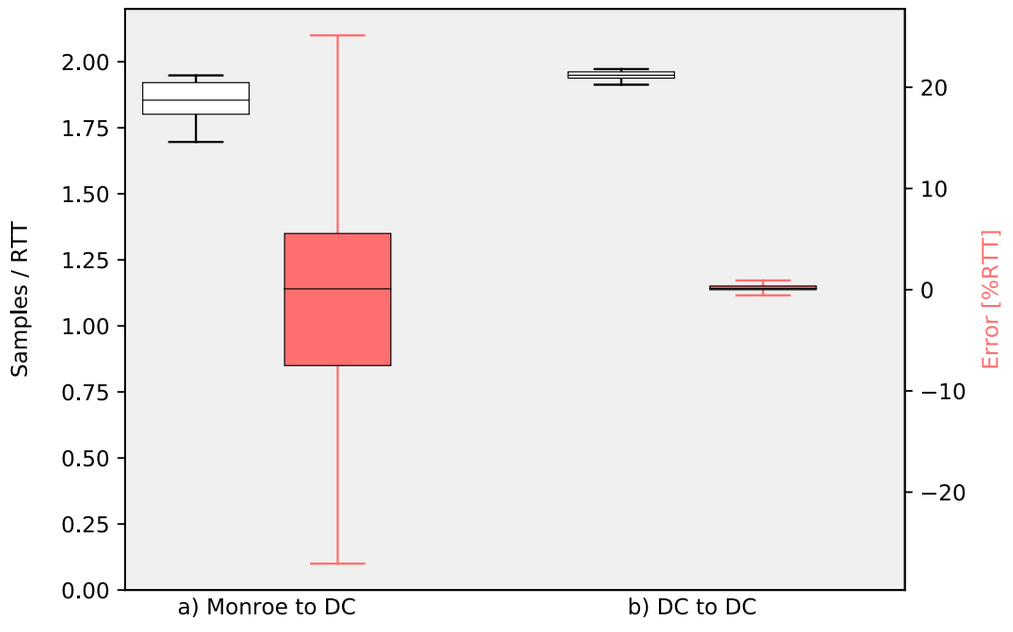
Example traces



Passive latency measurement approaches

- Spin signal vs. PLUS PSN/PSE

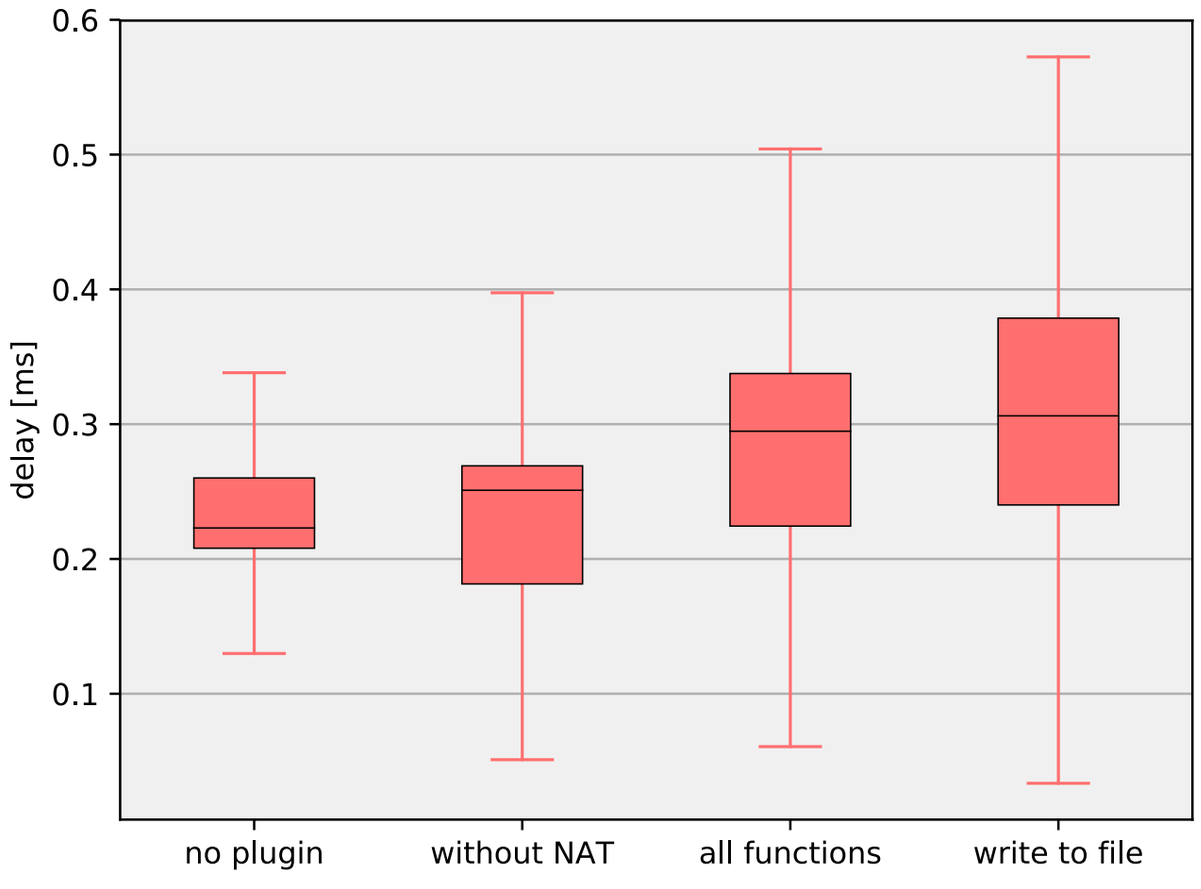




Example traces

Passive latency measurement approaches

- Performance of VPP-based latency measurement
  - Delays introduced by the plugin are small



MAMI components for virtualised deployments

- Measurement and experimentation components prepared for virtualised deployments
  - cloud-init configuration templates for:
    - PATHspider (used for path transparency measurements in WP1)
    - VPP-latency-mb (used for passive RTT measurement experiments in WP2)
  - VNF components and service descriptors templates for VPP-latency-mb
  - Experimental setup deployed in the 5TONIC 5G testbed

- Extensions to the Network Modeling (NEMO) language to accommodate recursive VNF Descriptors
  - Internet Draft draft-aranda-nfvrg-recursive-vnf

Summary of WP2 achievements

- Middlebox taxonomy and model **published,** middlebox simulator (mmb) **released as open-source software**

- **Experimental validation** of middlebox cooperation and path signaling mechanisms
  - Validation of a new Path MTU Discovery mechanism for UDP (under standardisation)
  - Validation of a new method for passive latency measurements, based on the spin signal
  - Preliminary validation (by simulation) of the LoLa approach, and preparation for experiments in a 5G testbed

WP2-related scientific publications and standardisation

- Additional papers (not mentioned earlier)
  - Under submission
    - K. Edeline, J. Iurman, C. Soldani, and B. Donnet. “mmb: Flexible High-Speed Userspace Middleboxes”. Submitted to *USENIX Annual Technical Conference (ATC)*, January 2019.
  - Published
    - K. Edeline and B. Donnet, “An Observation-Based Middlebox Policy Taxonomy”. In *ACM CoNEXT Student Workshop*, December 2017.

- Posters and presentations
  - T. Bühler, M. Kühlewind, and B. Trammell. “Enhancing encrypted transport protocols with passive measurement capabilities”. Poster at *ACM IMC*, November 2017.

- Internet Drafts (IRTF)
  - P. Aranda Gutierrez, D. Lopez, S. Salsano, and E. Batanero. “High-level VNF Descriptors using NEMO”. Internet draft draft-aranda-nfvrg-recursive-vnf. August 2018.

Q & A

mami

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