ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Intelligent user plane for the manufacturing sector

(one6G) Open Lecture 7 – In Network Computing and Intelligent User Plane for 6G

March 21, 2024

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Industry 4.0 and OT networking

- OT systems have some peculiar characteristics when compared to IT

- Operational continuity
  - OT must not stop, because an unwanted stop will result in an economic loss, therefore experiments, assessments etc. must be done in vitro
- Interaction with the physical world
  - A malfunction or an attack to the OT may result in real damages to people and goods
- Lifecycle
  - OT systems have life cycles that are typically much longer than IT, i.e. in OT it is common to find not up to date legacy devices and software components

Industry 4.0 and OT networking

In OT we can not rely on solving networking issues at the end-points as much as in IT

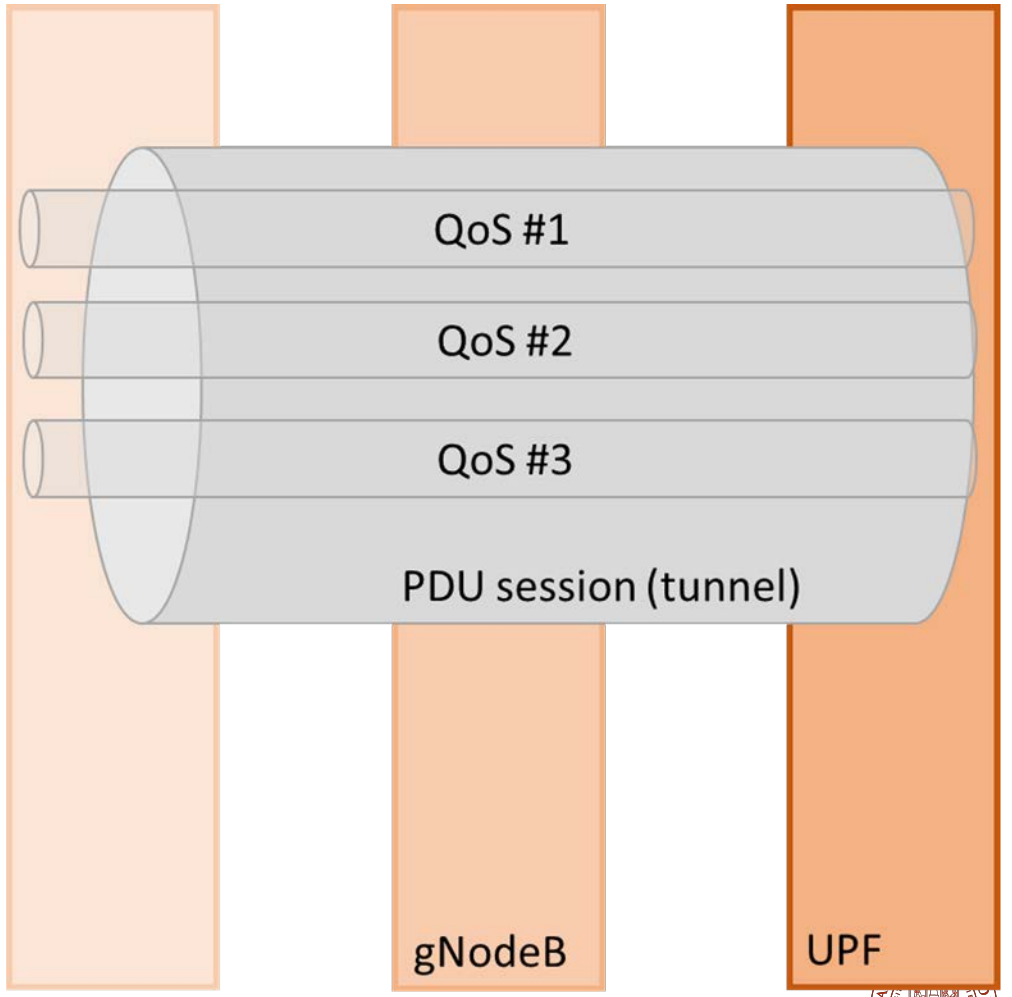
Intelligent user plane and in-network computing can play an important role in solving this

PDU sessions and QoS for remote maintainance

In 5G the communication between end users is implemented as bit pipe mapped over a PDU session. The PDU session is the logical bit pipe providing the connectivity to an external data network.

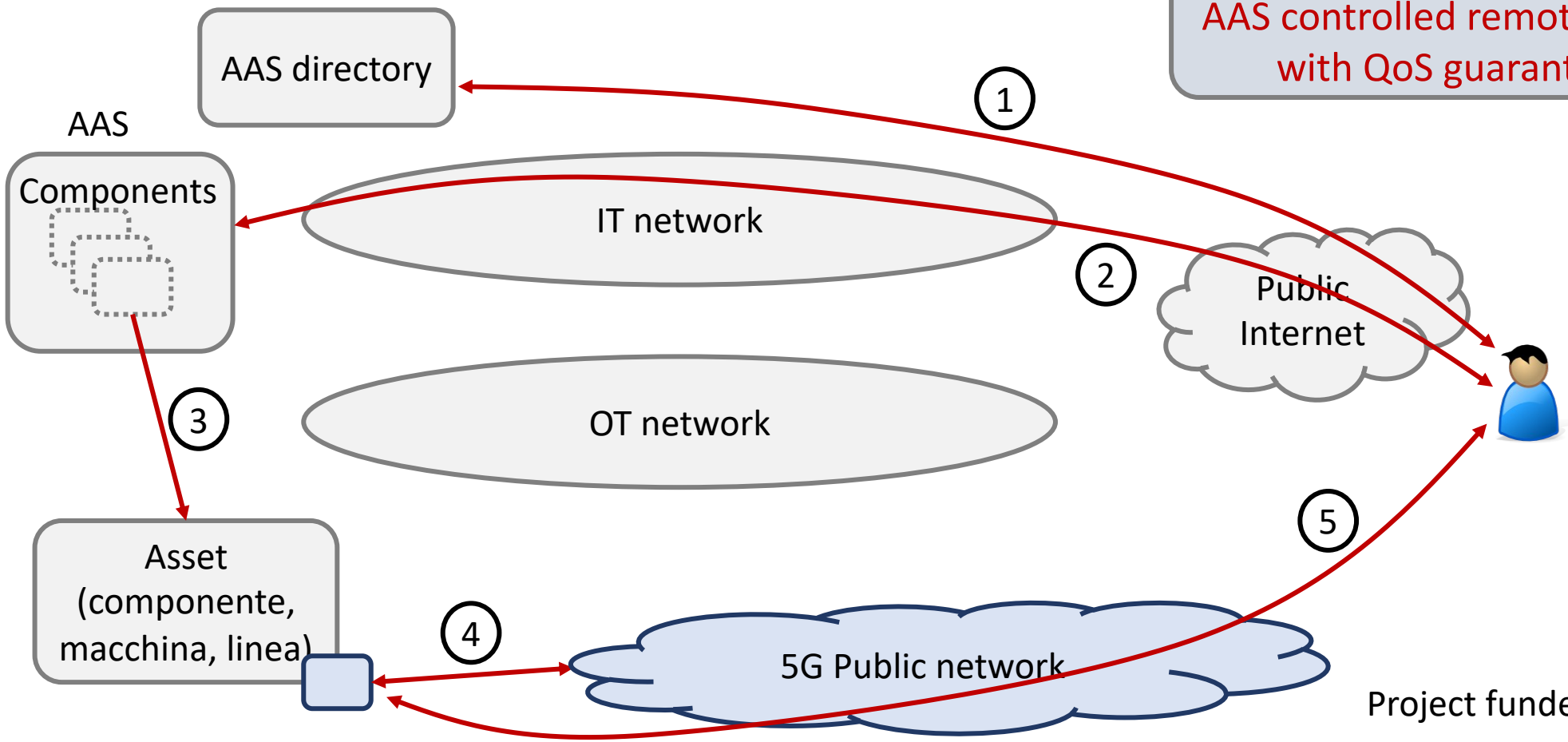
- PDU session: data flow between User equipment and network
- Multiple traffic flows can be defined within the same PDU session with different QoS requirements

To make it simple: select the perfomance guarantee for the PDU session



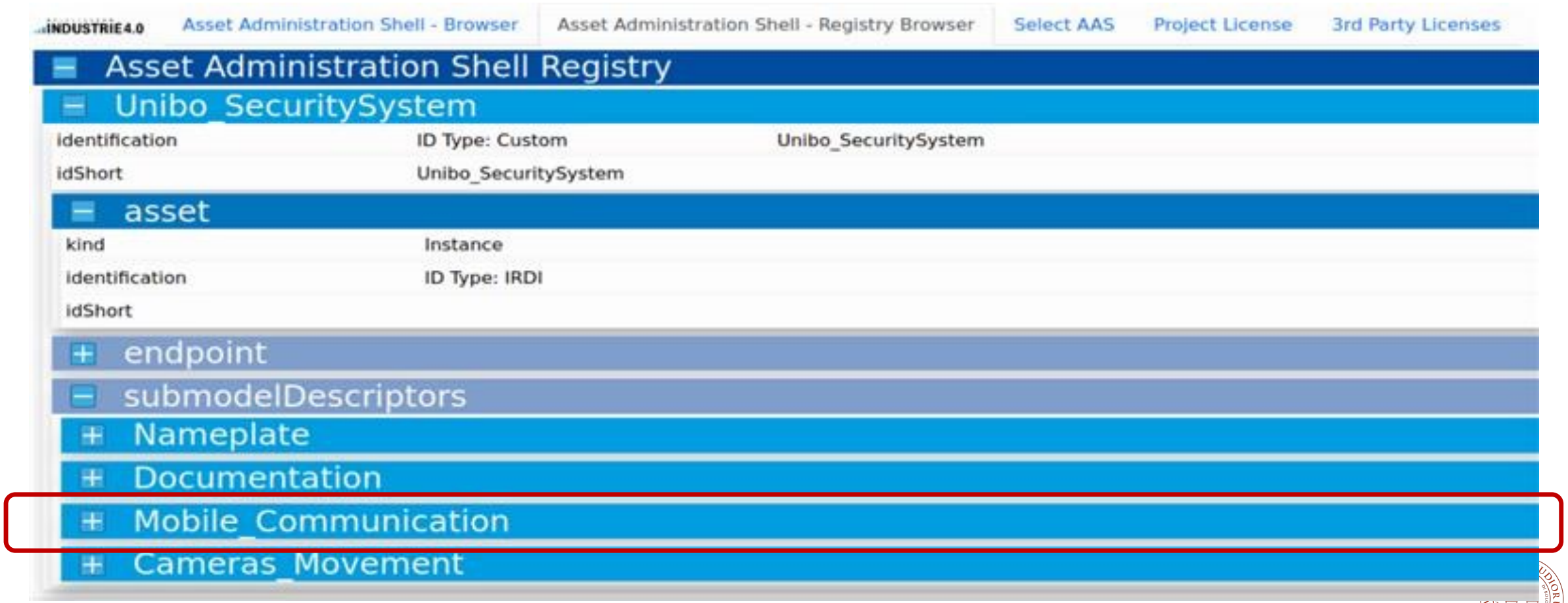
5GCONNECT

Use case:
AAS controlled remote maintainance with QoS guarantee over 5G



Project funded by: bi-REX Big Data Innovation & Research Excellence

AAS registry



Manage 5G PDU via AAS

Operation: activatePduSession

idShort	activatePduSession

parent

kind	Instance

inputVariable

Property: sst

idShort	sst
category	VARIABLE
kind	Template
value	1
valueType	integer

Property: sd

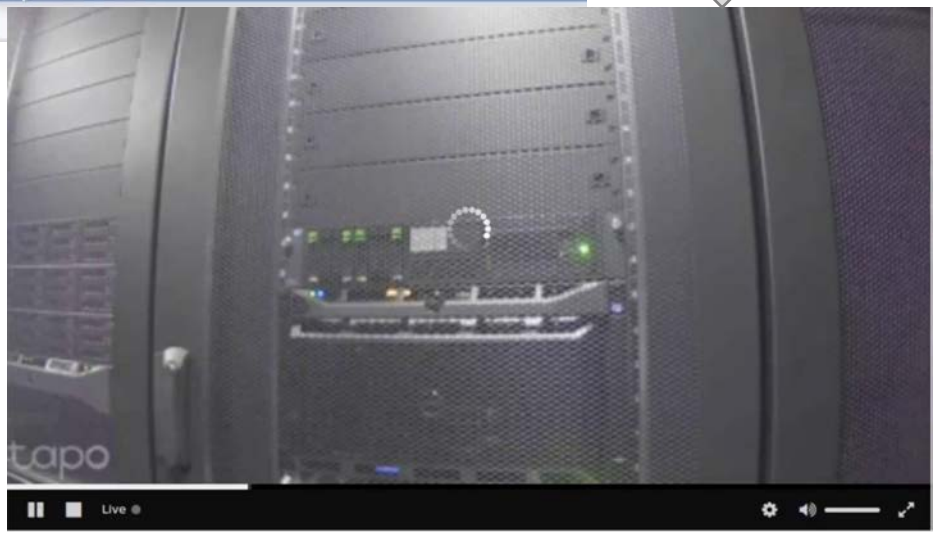
idShort	sd
category	VARIABLE
kind	Template
value	000001
valueType	string

Property: dnn

idShort	dnn
category	VARIABLE
kind	Template
value	security_system
valueType	string

outputVariable

Call



Operation: activatePduSession

idShort	activatePduSession

parent

kind	Instance

inputVariable

Property: sst

Property: sd

idShort	sd
category	VARIABLE
kind	Template
value	000002
valueType	string

Property: dnn

outputVariable

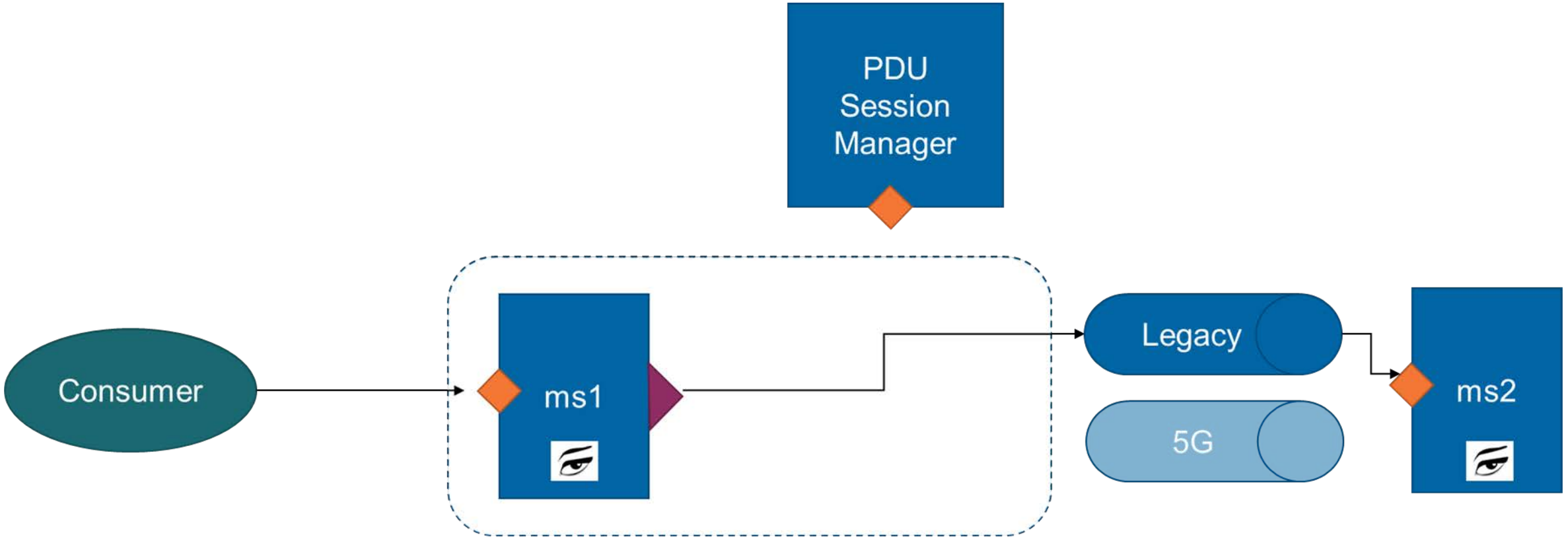
Call

Toward composable enterprise - a look into the future

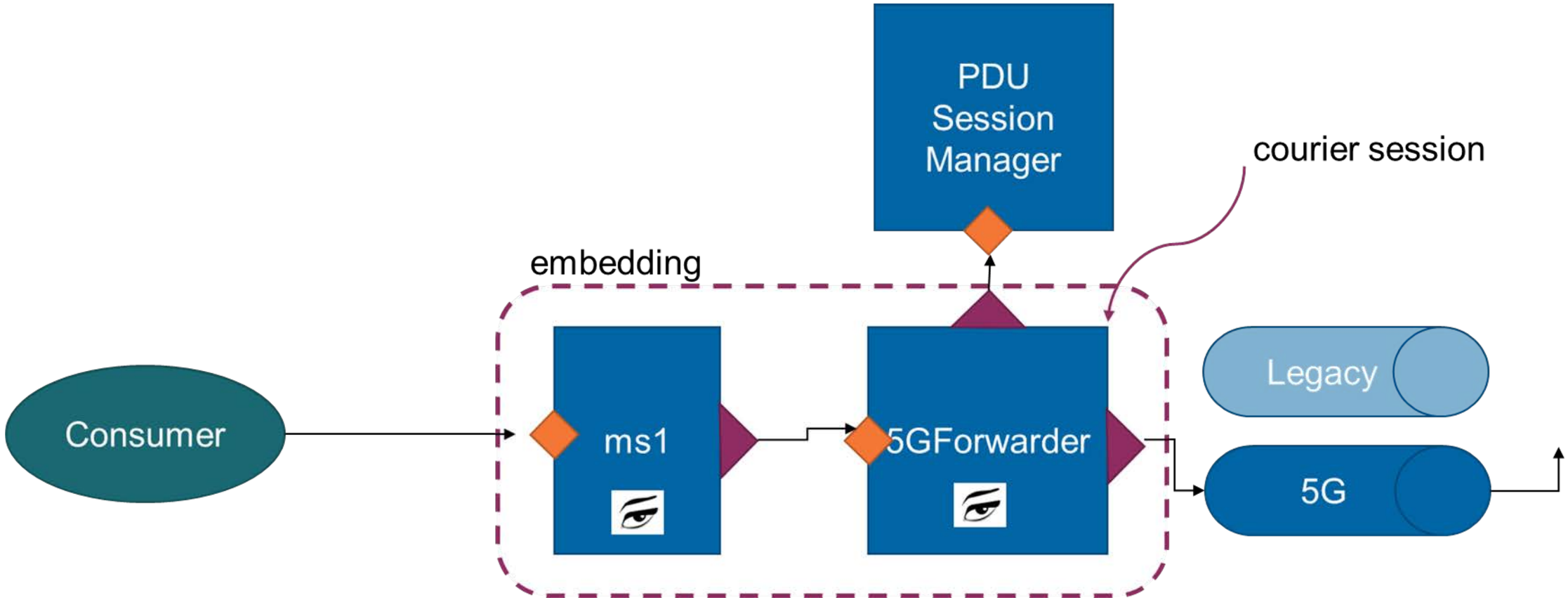
- “An organization that delivers business outcomes and adapts to the pace of business change” (Gartner)

- Composable enterprises relies on the assembly of interchangeable application building blocks:
  - Applications as a set of loosely coupled services → Microservice architecture
  - These services must communicate with each other and can do so through different means (LAN, WAN, LTE, 5G…)
  - Ideally when developing a microservice you want to focus on the business logic while abstracting from other aspects such as connectivity.

Focus on 5G forwarder (1)

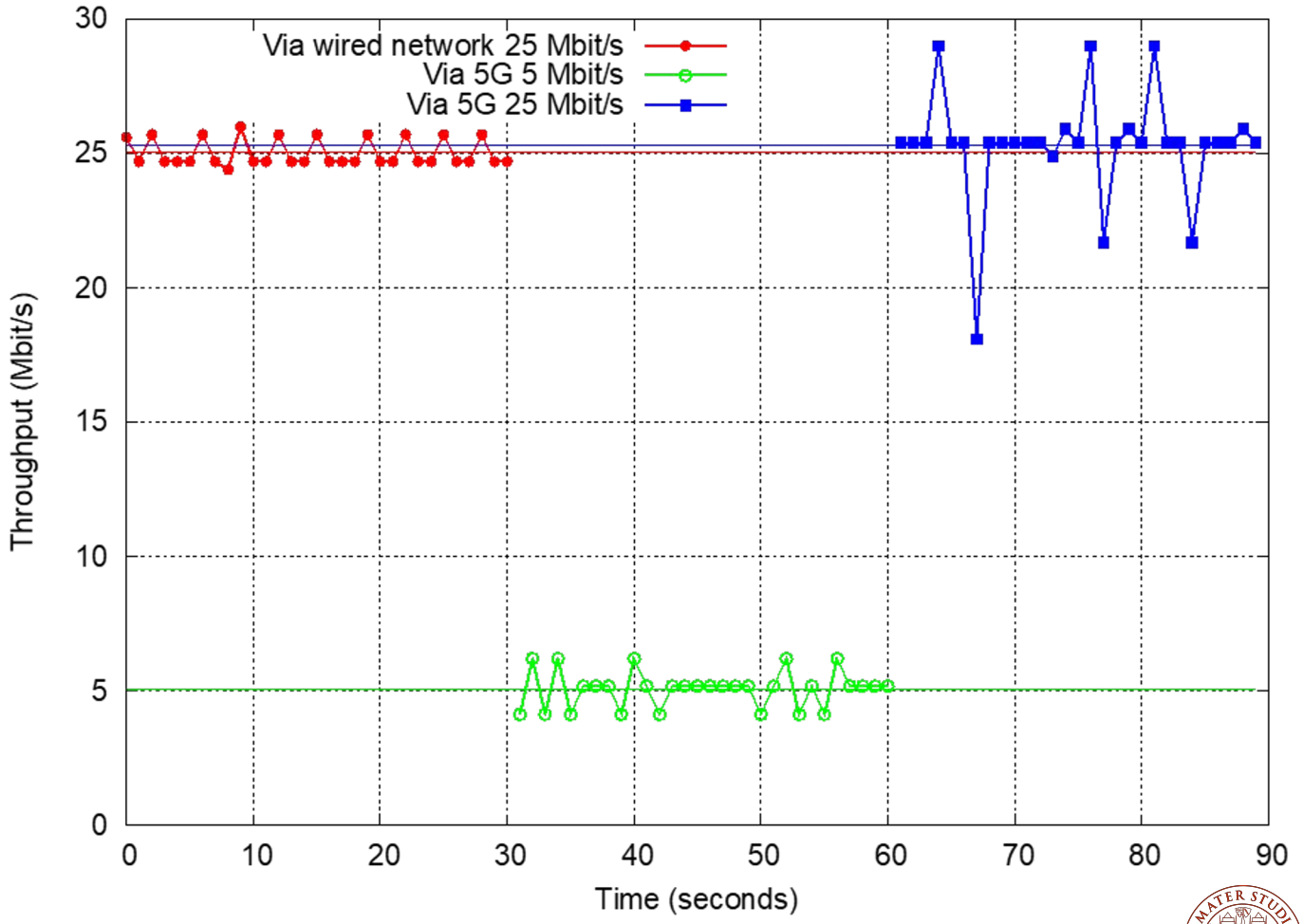


Focus on 5G forwarder (2)



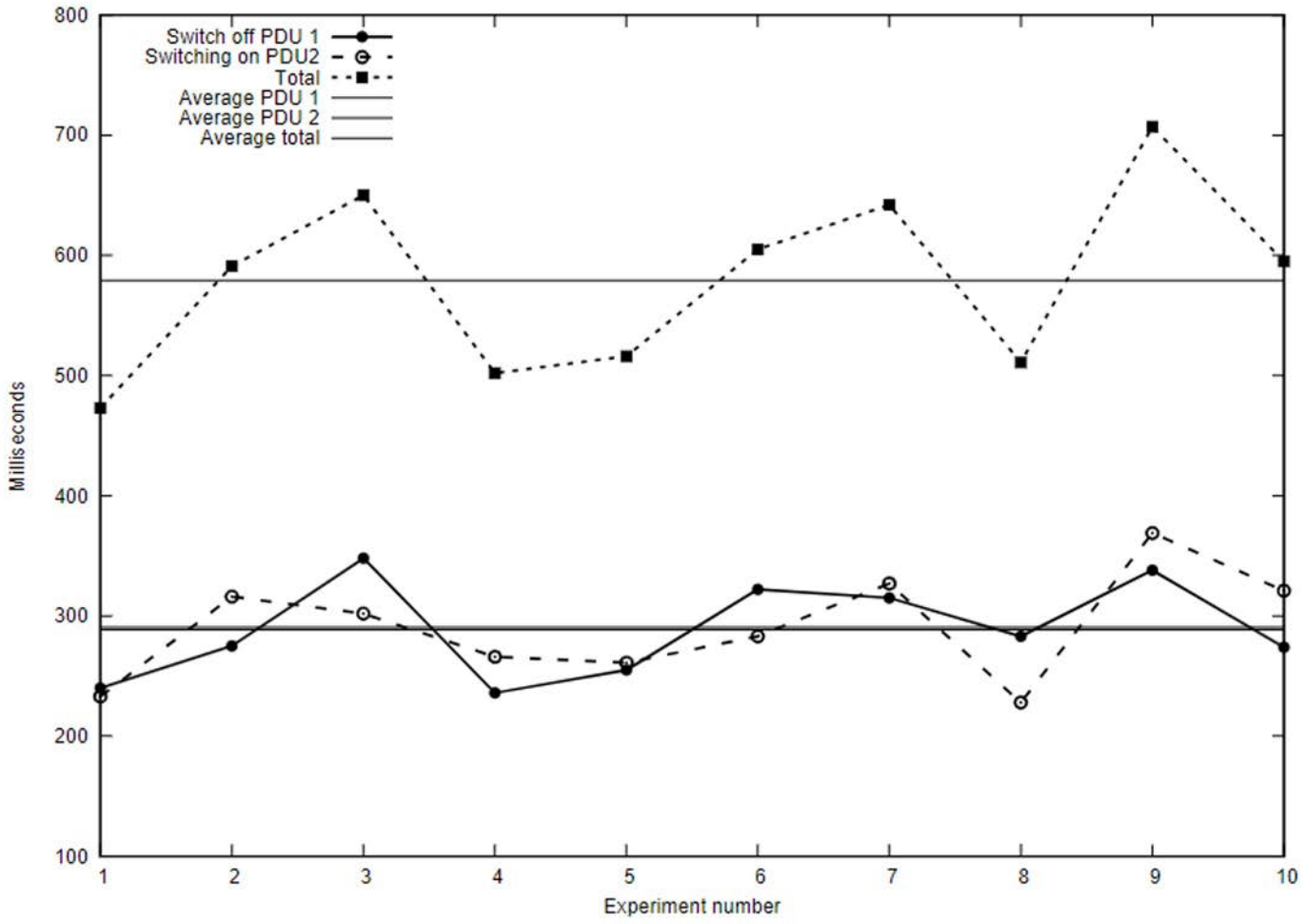
Results - Network characteristics on-demand

- Communications via legacy wired network @ 25Mbps
- Network communication via mobile 5G connection with low bandwidth PDU session @ 5 Mbps
- Network communication via mobile 5G connection with high bandwidth PDU session. @ 25 Mbps



Results - Switch time between PDU configuration

- Time needed to switch from a low-speed PDU to a high-speed one.
- The Figure shows the switch-off time, the switch-on time, and the total, with related averages computed over 10 samples.
- The average downtime is always under 800 ms.

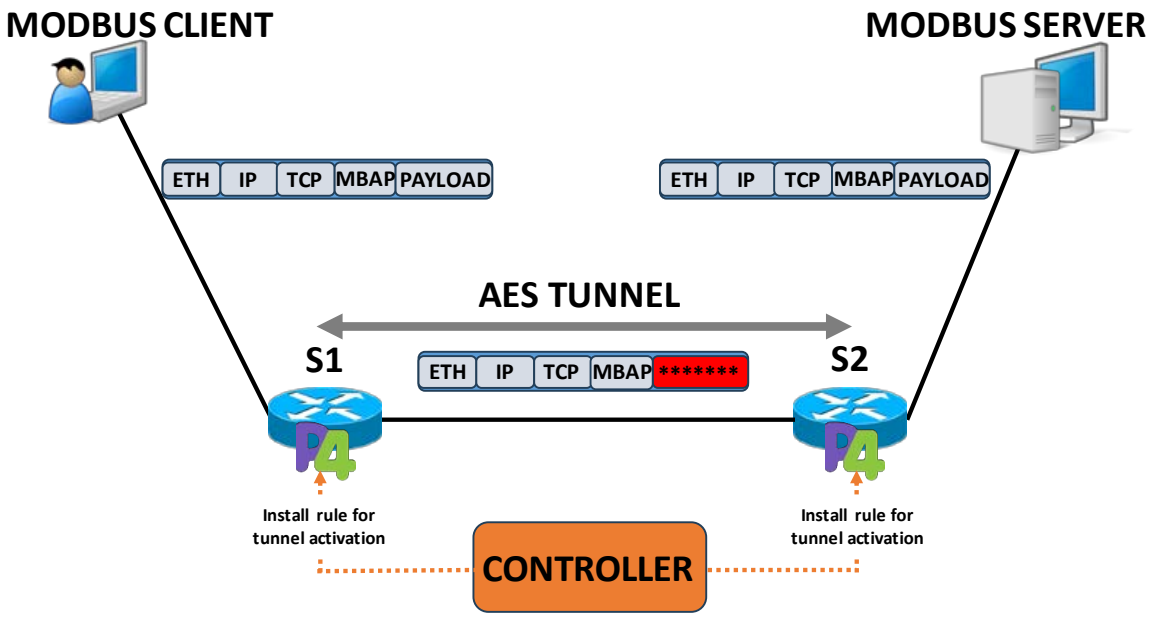


In network computing with P4 programmable switches

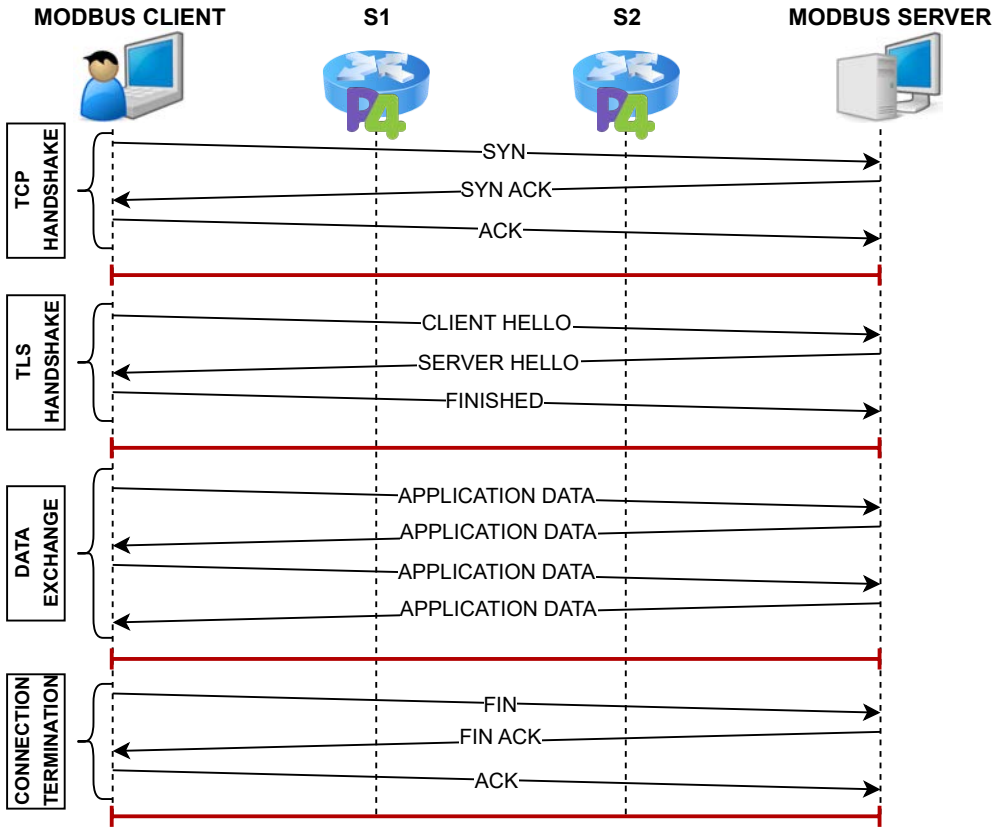
- Legacy OT applications use legacy protocols with limited support for advanced networking features
- The use case is cybersecurity which may affect
  - Operational continuity
    - A cybersecurity attack, in particular denial of service may stop the production line
    - A data breach on OT comunication may damage the production process
  - Interaction with the physical world
    - An attack to the OT may result in real damages to people and goods

In network encryption for secure OT communications

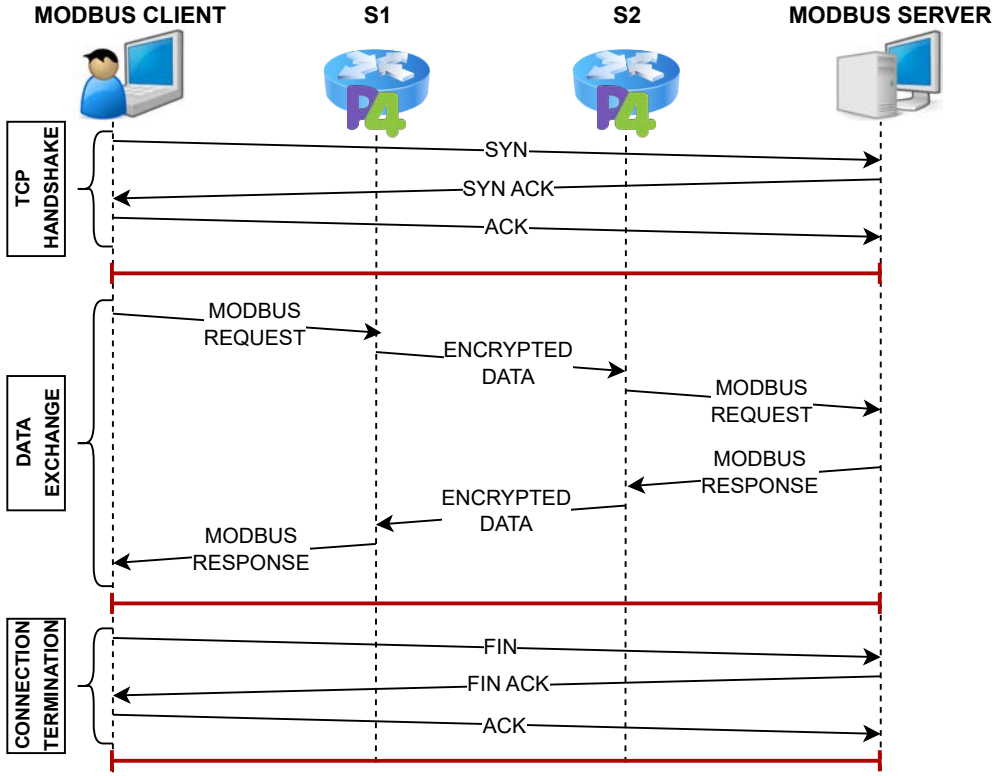
- Modbus as an example of a very popular OT protocol
- P4 switches as network nodes with processing capabilities
- Communications secured over the relevant network section with end nodes fully unaware



TLS vs in network encryption



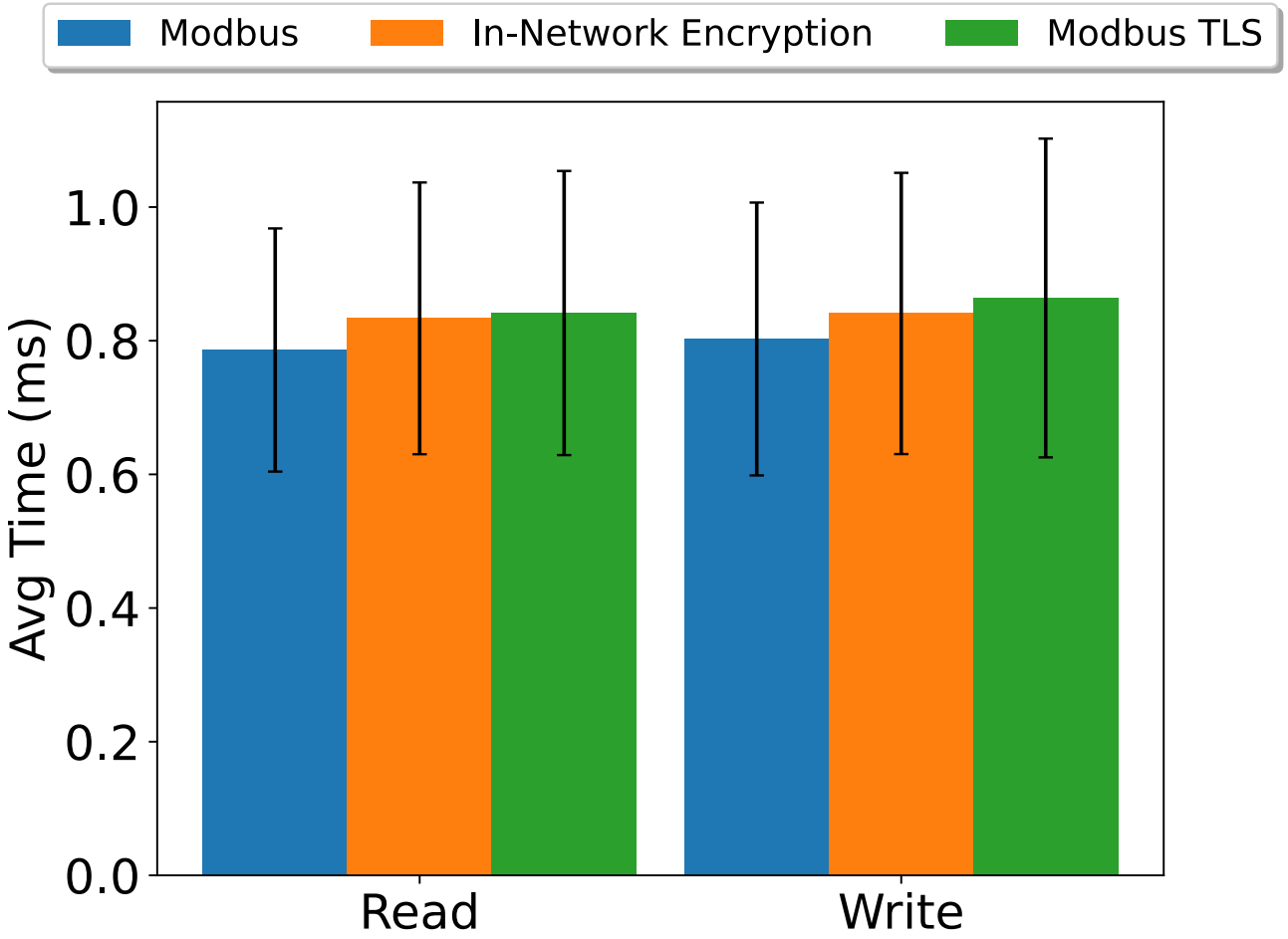
Modbus with TLS



Modbus with in network encryption

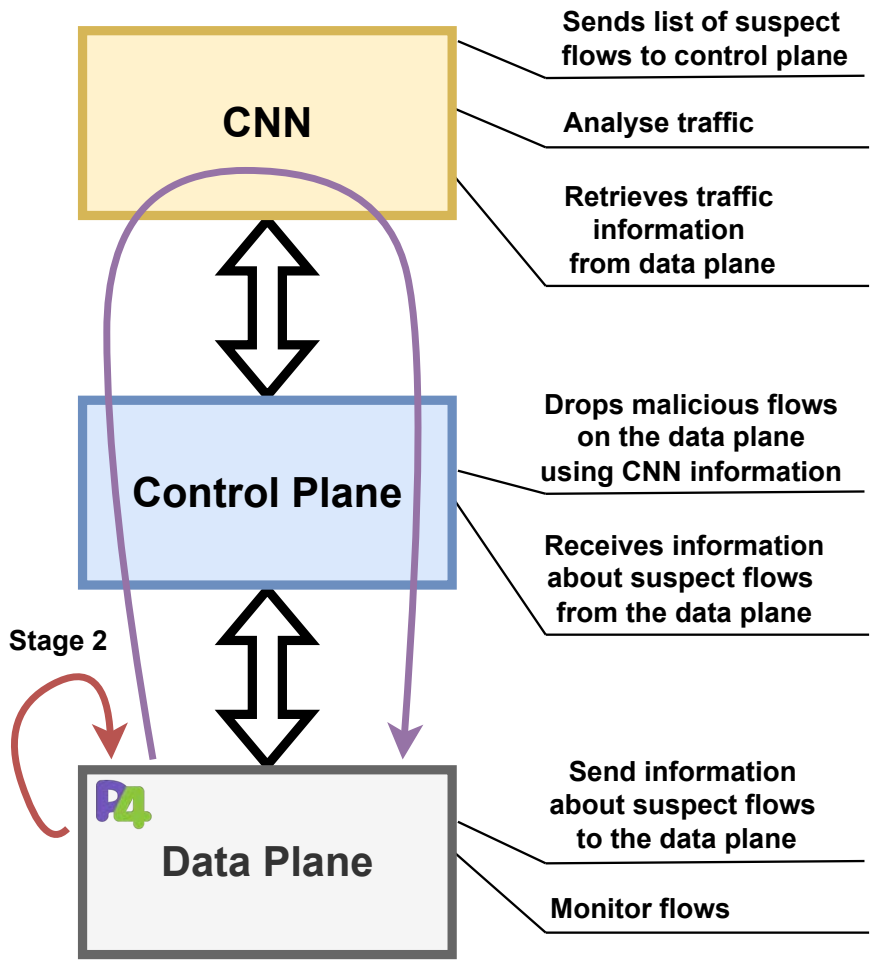
Performance

- Virtualized set up (P4 switches are implemented with bmv2 software switch)
- Comparison of the three solutions for read and write Modbus operations
- In network encryption proves very effective, sligthly better than TLS but not significantly worse than unencrypted communications

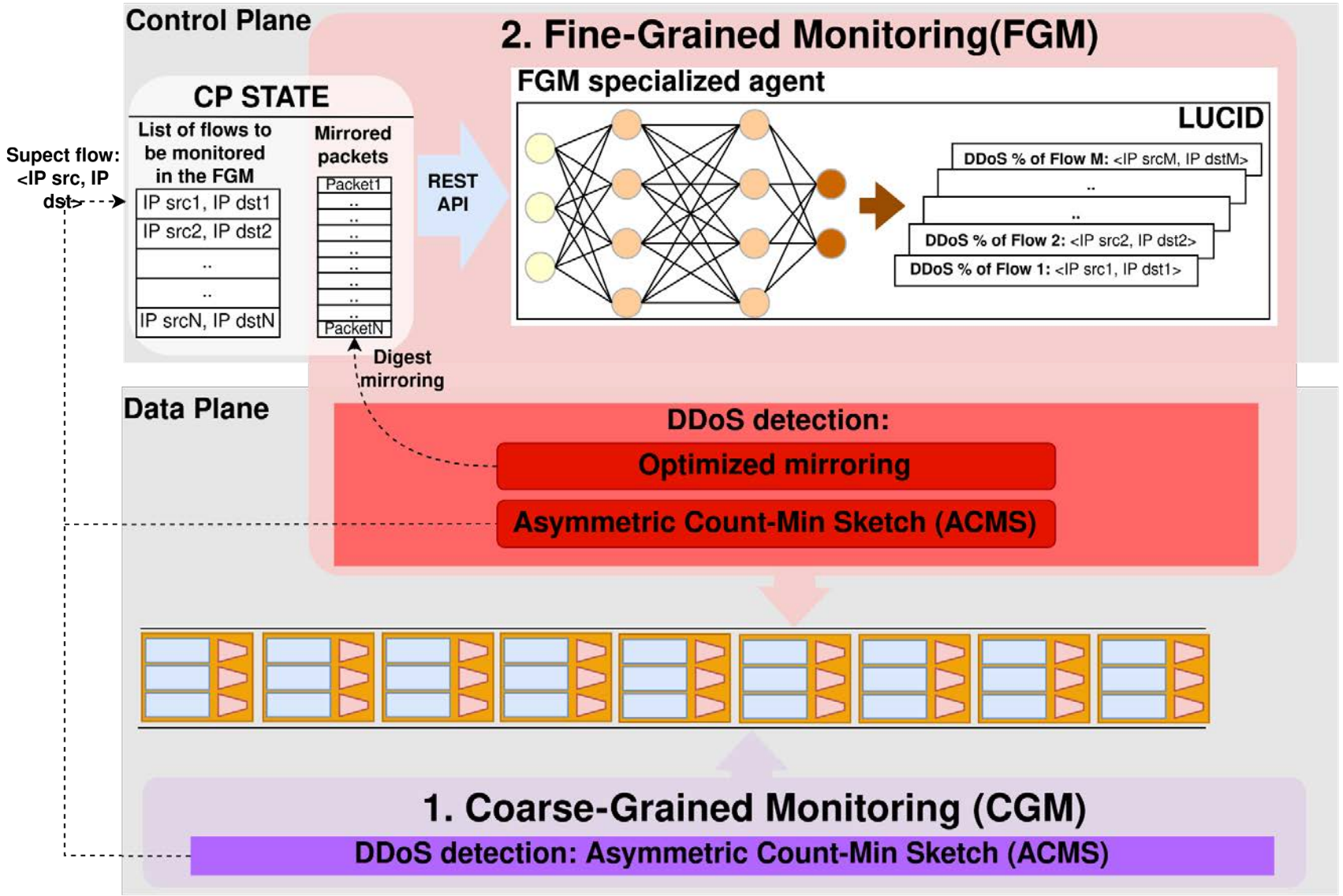


Programmable network for monitoring and mitigation

- Integrate monitoring tools into programmable switches (P4)
- Detect anomalies with coarse analysis
- Duplicate traffic towards the control plane for detailed AI analysis (avoid false positives)
- Identify malicious traffic and select mitigation technique
- Trigger the control plane to re-program the data plane to implement mitigation



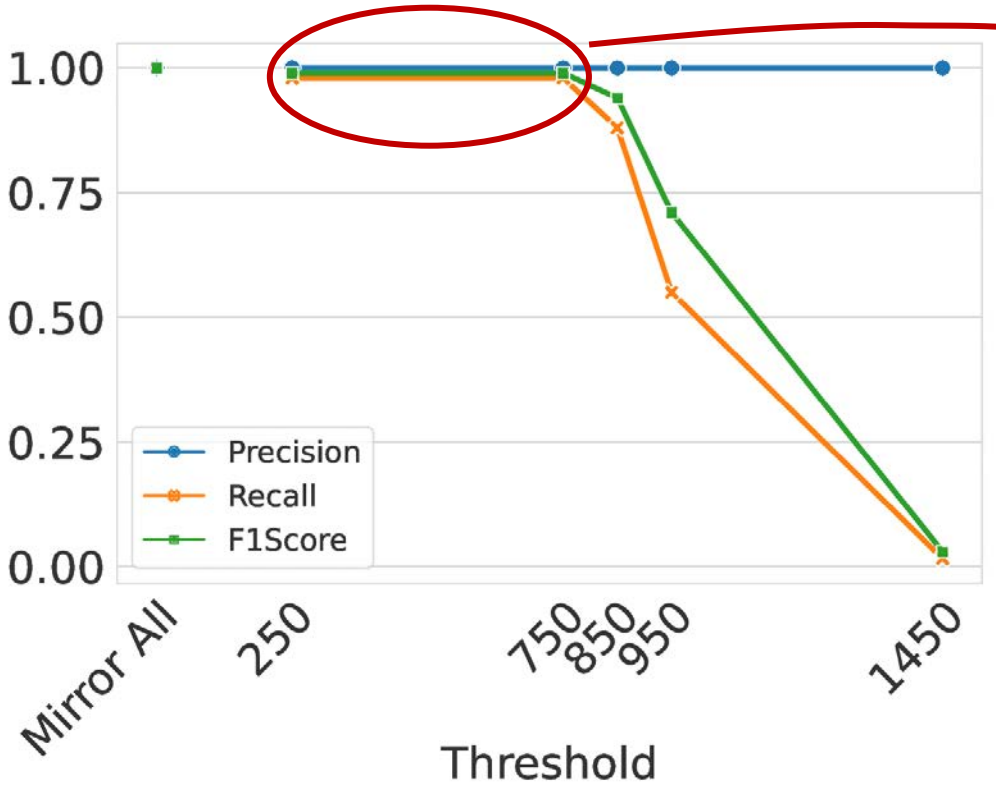
System Architecture

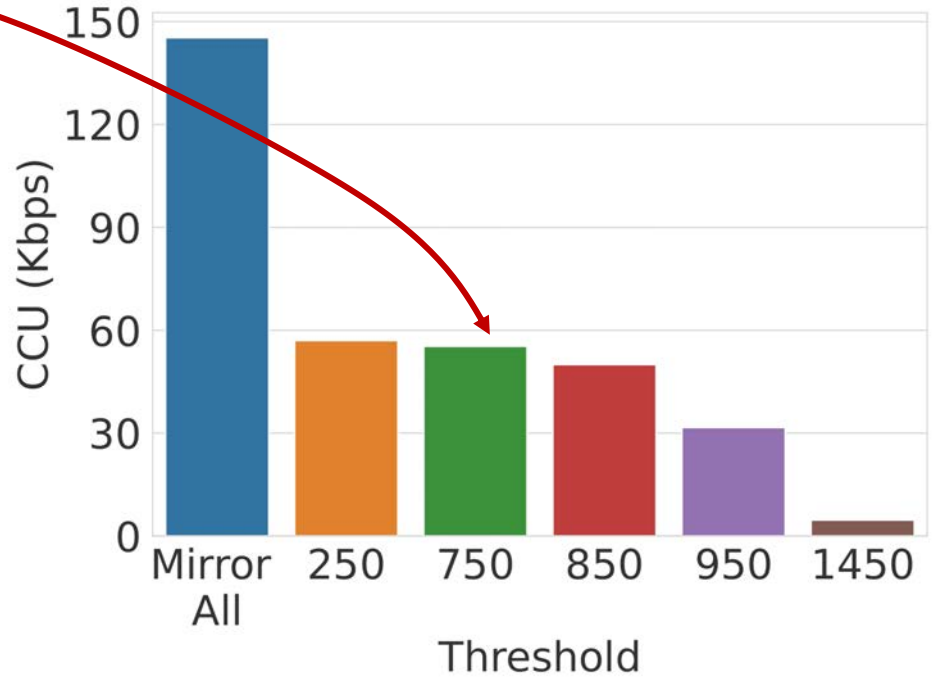


Performance

Goal - achieve at once
- good detection capability
- limited load on the control plane

- Thanks to the coarse detection in the data plane the amount of traffic to be sent for detailed checking is reduced significantly





Conclusions

OT is a very interesting vertical use case

- Interest towards intelligent user plane is starting in manufacturing
- In network computing may provide solutions for a smoother transition towards the connected factory

- Take away message
  - Enable end users with customizable in network primitives

Thanks to

The works presentated here are the outcome of joint research with many colleagues and students that I must thank for their contributions:

Prof. Marco Prandini, Prof. Andrea Melis

Mr. Amir Al Sadi, Mr. Davide Berardi, Ms. Chiara Grasselli, Mr. Lorenzo Rinieri, Mr. Daniele Rossi, Mr. Giacomo Tontini

Some relevant publications:

A. A. Sadi, M. Savi, A. Melis, M. Prandini and F. Callegati, "Unleashing Dynamic Pipeline Reconfiguration of P4 Switches for Efficient Network Monitoring," in IEEE Transactions on Network and Service Management, doi: 10.1109/TNSM.2024.3377538.

A. A. Sadi, M. Savi, D. Berardi, A. Melis, M. Prandini and F. Callegati, "Real-time Pipeline Reconfiguration of P4 Programmable Switches to Efficiently Detect and Mitigate DDoS Attacks," 2023 26th Conference on Innovation in Clouds, Internet and Networks and Workshops (ICIN), Paris, France, 2023, pp. 21-23, doi: 10.1109/ICIN56760.2023.10073501.

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