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WiSHFUL

CONTEXTUAL INFERENCE OVER IOT NODES

- UNITE -

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Concept (1/2)

- UNITE proposes an enhanced, two level monitoring scheme for transforming the WiSHFUL nodes to local processing mechanisms and knowledge producers
- UNITE can proactively identify network performance abnormalities through:
  - **localized context prediction**: gives an insight on future performance trends for a set of network performance parameters
  - **learning**: undertakes the responsibility of revealing the hidden distribution of the observed parameters
  - **Inference**: decides if QoS violations are impending.

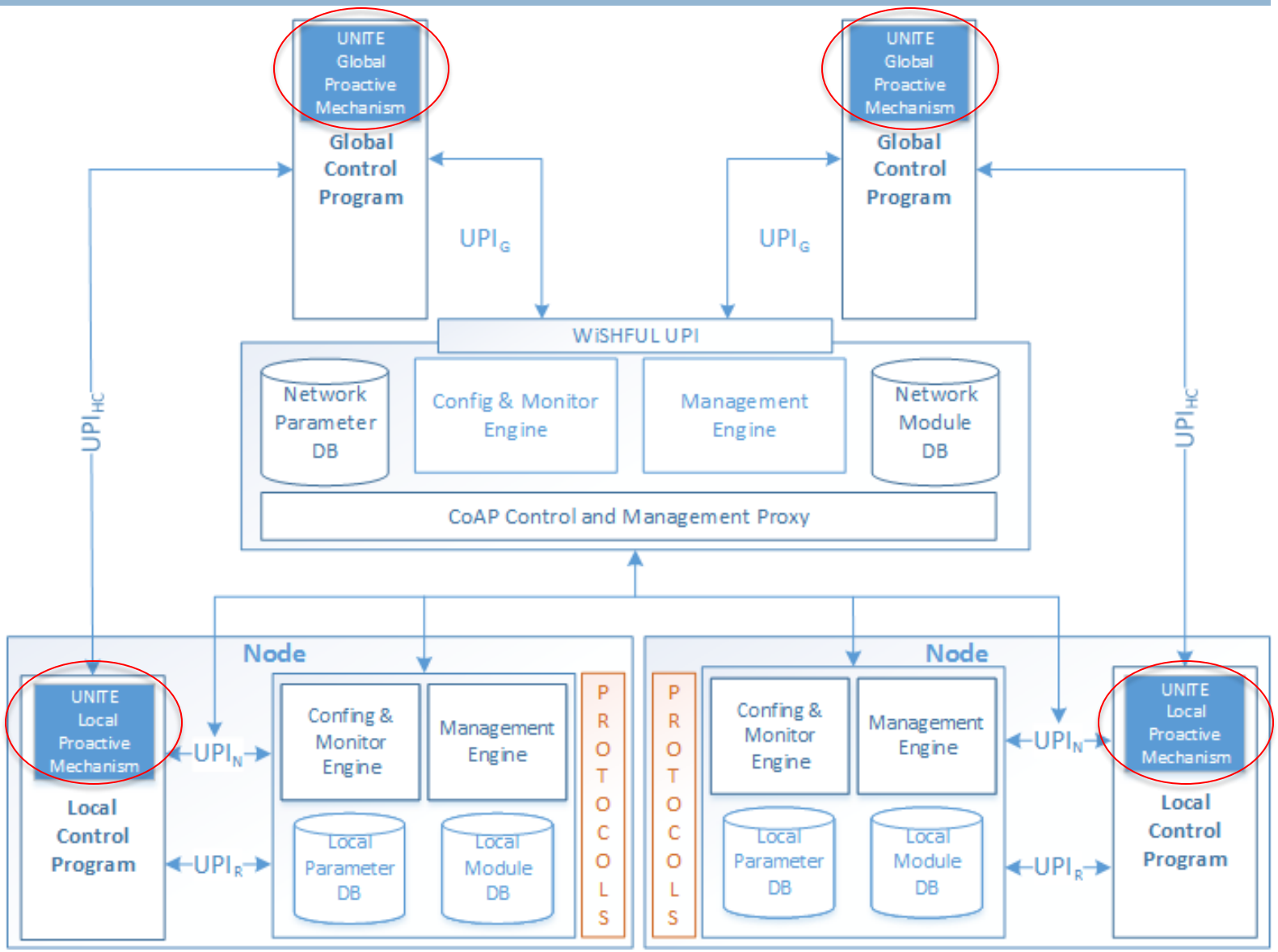
Concept (2/2)

- UNITE handles the uncertainty about the future, possible, presence of QoS violation events
- It provides a ***two layer*** scheme:
  - A module is placed in the local control module in WiSHFUL nodes
  - A module is placed in the global control module of the WiSHFUL platform

Objectives

- Offer a layered architecture capable of identifying QoS violations either locally or globally
- Collect, process and forecast future trends of specific network performance parameters to support a proactive response mechanism for any temporal network performance abnormalities
- Perform statistical estimate and inference over the unknown distribution of the performance metrics measurements
- Perform uncertainty management for events identification
- Perform global inference for the management of groups of WiSHFUL nodes

Architecture



Local Decision Making

- UNITE aims to process multiple network performance parameters collected by nodes
- It aims to identify events related to the ***Possibility of Violation*** (PoV) of QoS
- PoV consists of the local knowledge for each node
- The PoV is the result of a complicated, yet, speedy process that involves:
  - *localized context forecasting*
  - *localized statistical learning*
  - *localized context inference*

Context Forecasting (1/2)

- UNITE involves a set of estimators and an ***ensemble forecasting scheme***
- The proposed mechanism involves time series (context) prediction
- The following list reports on the adopted estimators:
  - Cycle estimator
  - Moving average estimator
  - Geometric moving average estimator
  - Triangular moving average estimator
  - Parabolic average estimator
  - Linear regression estimator
  - Round average estimator
  - Seasonal Naïve estimator
  - Exponential estimator
  - Drift estimator
  - Linear estimator
  - Polynomial estimator

Context Forecasting (2/2)

- The ensemble forecasting scheme consists of the aggregation of the results
- Results reported by each estimator are collected and, accordingly, an outlier detection process is applied
- The aim is to eliminate the outlier estimators, i.e., estimators that considerably deviate from the rest
- The final result is calculated on top of the remaining (non-outlier) estimations
- We apply an averaging mechanism in the remaining (filtered) estimations

Statistical Learning

- The ***localized statistical learning*** aims to reveal the hidden characteristics of each parameter
- The probability density function (pdf) of a contextual parameter is unknown
- UNITE relies on the incremental estimation of the pdf
- We adopt the widely known ***Kernel Density Estimator*** (KDE)
- The KDE returns the probability of having the performance measurements below a threshold
- If this threshold is violated, an indication of a possible QoS violation is obtained

Context Inference (1/5)

- The ***localized context inference*** module is responsible to derive decisions on top of the results of the aforementioned components
- Decisions are made through the use of a ***Fuzzy Logic System*** (FLS)
- It is based on a set of ***Fuzzy Inference Rules*** (FIRs)
- Each FIR reflects the PoV for a specific event

Context Inference (2/5)

- We consider two types of performance metrics, i.e.,
  - proportional
  - non-proportional
- Proportional metrics depict an increase in the QoS when they are also increased
- The opposite stands when we consider non-proportional metrics

Context Inference (3/5)

- Each FIR takes into consideration:
  - the fused estimation as delivered by the ensemble forecasting scheme (fused_estimation)
  - the results of the statistical inference process (kde_result)
  - the current measurement for each performance parameter (current)
- The outcome of each FIR is the PoV
- The adopted linguistic values are low, medium and high
- Membership functions are triangular

Context Inference (4/5)

- FIR examples for proportional metrics (27 rules in total):

No	fused_estimation	kde_result	current	PoV
1	low	low	low	high
2	low	low	medium	high
3	low	low	high	high
4	low	medium	low	high
5	low	medium	medium	high

Context Inference (5/5)

- FIR examples for non-proportional metrics (27 rules in total):

No	fused_estimation	kde_result	current	PoV
1	low	low	low	low
2	low	low	medium	low
3	low	low	high	high
4	low	medium	low	low
5	low	medium	medium	low

Global Inference (1/2)

- UNITE also offers a ***global inference process*** for group management
- Each node, after calculating the PoV, notifies accordingly, the global control program
- UNITE adopts incremental clustering
- The process is repeated at each ***clustering era*** executed periodically
- After the formation of clusters, each group is classified in a set of pre-defined categories

Global Inference (2/2)

- The reported PoVs are fused / aggregated in each group, e.g., through an averaging mechanism
- A group that is characterized by an increased aggregated PoV is instructed to change the configuration parameters
- We rely on the ***time interval*** when the packets are sent and the ***packet size*** (as those may be adopted in the WiSHFUL platform for our purposes)
- The UNITE mechanism can be easily extended to include more parameters

Technical Aspects (1/2)

- We deploy each node with our custom image, **unitev1**, based on the Ubuntu 16-64-STD
- The image includes additional pre-installed python libraries, ubuntu packages, and Unite's Zolertia firmware
- We devote a node to execute the UNITE's global control program, while the others execute the simple agent program
- The agent code is based on the default WiSHFul agent script, found in the official github repository

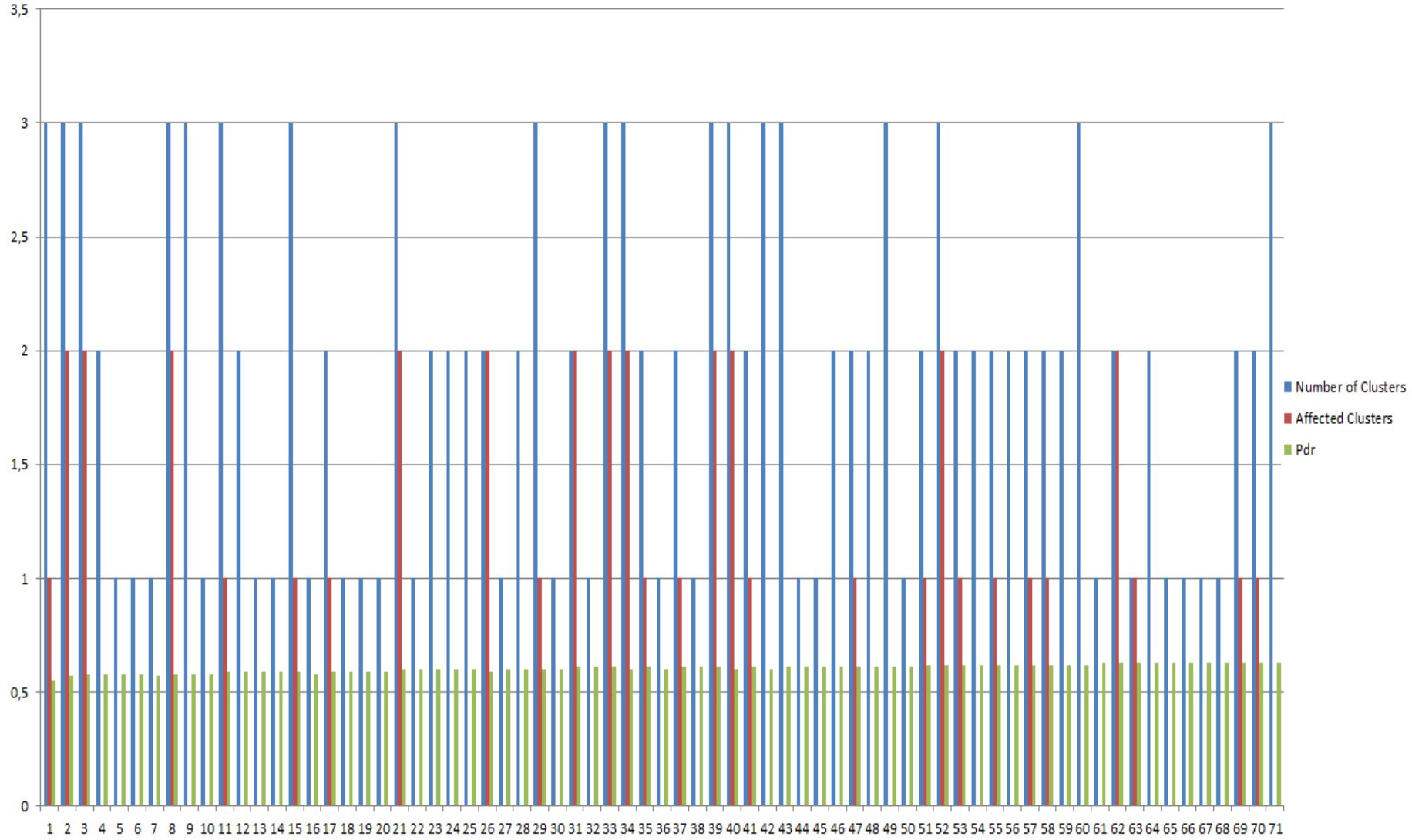
Technical Aspects (2/2)

- The unite_local_control program, runs locally in each client node
- Each client waits until the global control program enables it
- When that happens, the udp_stats parameters are received from the Zolertia node and calculates the PoV
- Nodes, by utilizing WiSHFUL UPI functions, send the calculated value to the global control program

Validation (1/4)

- We adopt the **wilab1** testbed
- We rely on the packet delivery ratio (pdr) for the identification of possible increased traffic
- UNITE manages to identify 2-3 clusters - 2 of the 3 are affected by low QoS
- In the beginning of the process, the pdr is at low levels (i.e., 0.55)
- Nodes are instructed to take measures (i.e., to decrease the ***packet size***)
- After 70-71 rounds, the pdr is observed to be equal to 0.63

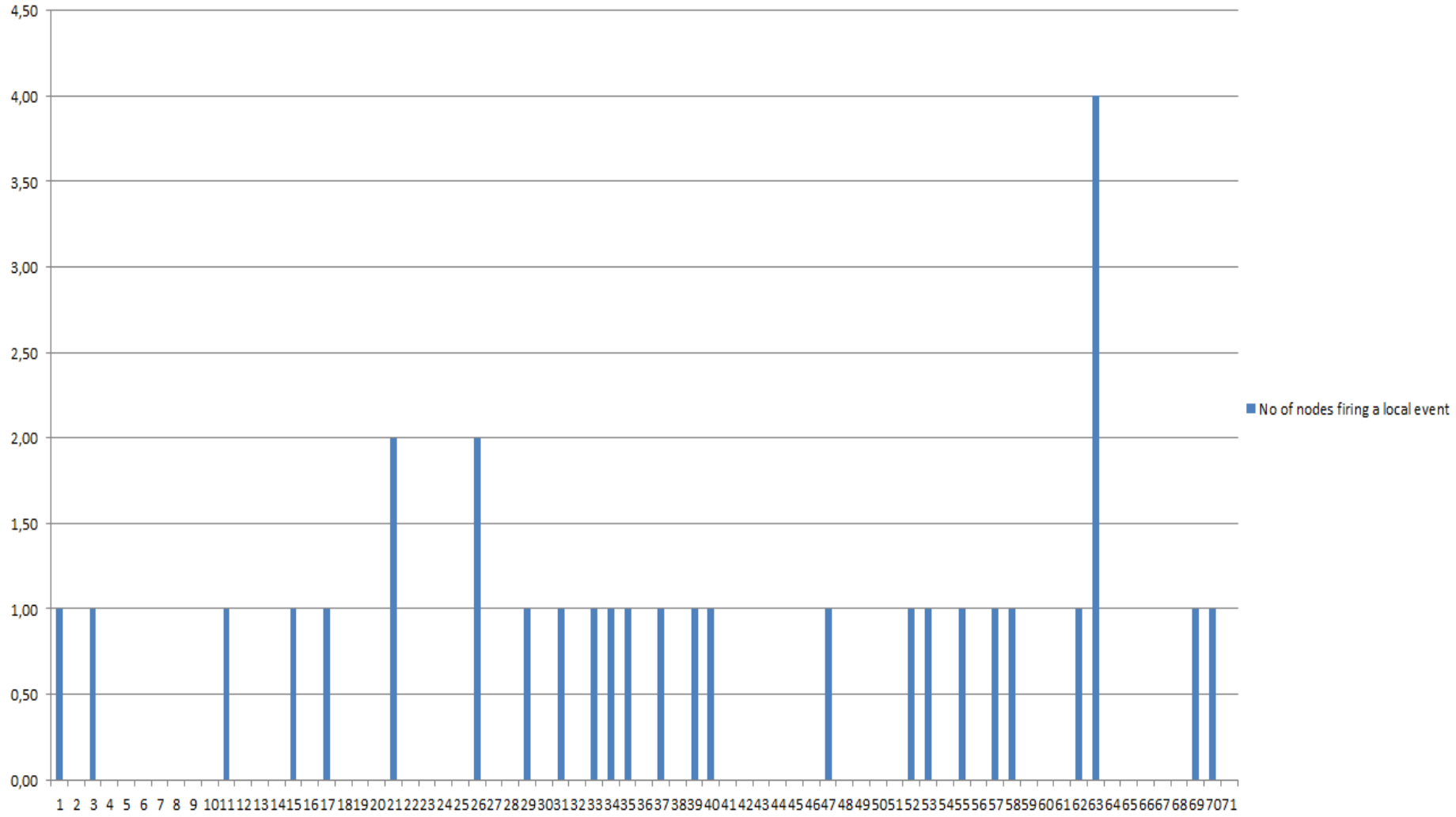
Validation (2/4)



Validation (3/4)

- UNITE modules are also capable of identifying QoS violation events locally
- Every node that identifies any performance violation, it updates the ***time interval***

Validation (4/4)



UPIs Used

- UPI_R interface is adopted to discover all the available radio platforms of a node
- The network interface (UPI_N) is highly used to configure the routing behaviour of the network by changing the appropriate parameters
- UPI_G interfaces are adopted to update the control of behaviour of the problematic group of heterogeneous devices

UNITE-WiSHFUL Benefits

- The global/local control programs architecture was sufficient to enable advanced experimentation and provided the needed control functionality
- The Time-Annotated Instruction Set Computer (TAISC) and Generic Internet-of-Things ARchitecture (GITAR) could be the most valuable components as they consist of the basis for retrieving network data
- Their functionalities are efficiently exposed to the upper layers and the UNITE solution

Thank you!