

The DAEMON Network Intelligence stratum and RAN services

The 6G series workshop by Hexa-X and Hexa-X-II
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ICT52 DAEMON Project

Network intelligence for aDAptive and sElf-Learning MObile Networks

Designing a NI-native architecture for B5G systems

Guidelines to
define and
design NI

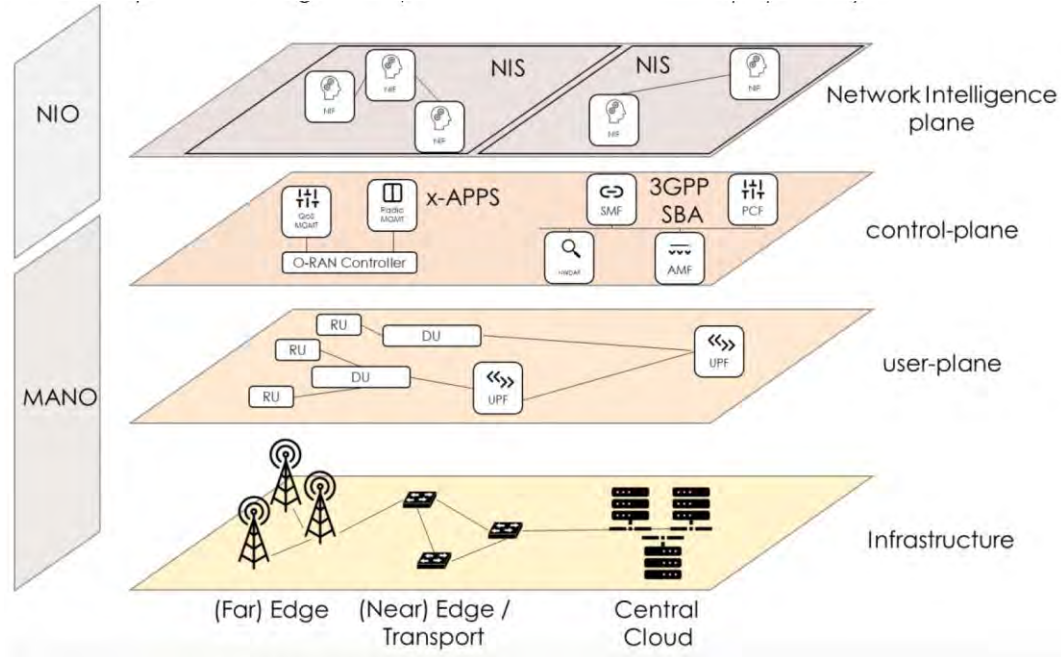
NI Native Architecture

- The defined requirements for the DAEMON's **NI Plane** help to remove the current barriers and enable full support for all aspects not necessarily covered by current frameworks.
- NIP goes beyond the state of the art
 - 7th state-of-the-art frameworks, architectures, and implementations were reviewed in Y1
 - Edge computing
 - Network function virtualization
 - Management and Orchestration
 - Radio Access Networks
 - Core networks
 - Machine learning

Framework	Provide a methodology to define AI-based functionalities	Provide mechanism to manage lifecycle of AI-based functionalities	Provide mechanism to coordinate intelligence across different network segments	Decentralized and unified data management for NI
ETSI MEC	No	No	No	No
ETSI NFV-MANO	No	No	No	No
ETSI ENI	Yes	No	No	No
O-RAN	Yes	Partially	No	No
OSM	No	No	No	No
3GPP	No	No	No	No
ONAP	No	No	No	No
NIP	Yes	Yes	Yes	Yes

[3] M. Camelo *et al.*, "DAEMON: A Network Intelligence Plane for 6G Networks," 2022 *IEEE Globecom Workshops (GC Wkshps)*, Rio de Janeiro, Brazil, 2022, pp. 1341-1346, doi: 10.1109/GCWkshps56602.2022.10008662.

Network Intelligence Plane

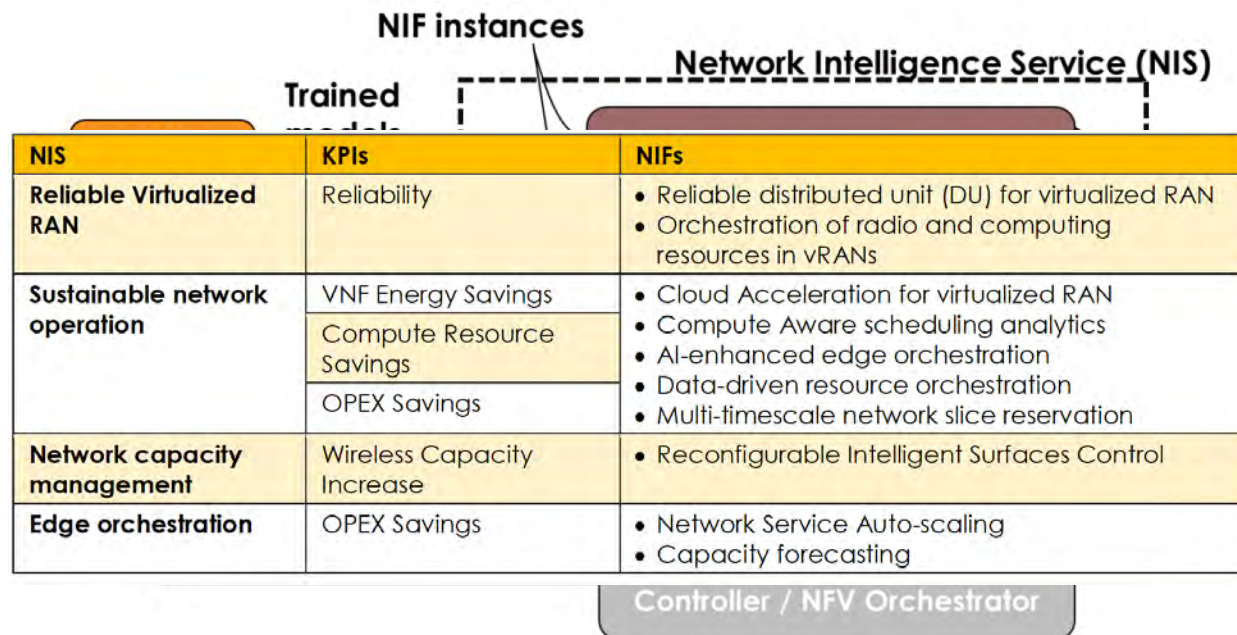


- The **Network Intelligence plane (NIP)** integrates the functions related to network intelligence, such as the ones detailed in D3.1/D3.2 and D4.1/D4.2, in the network architecture.
- The Management and Orchestration (MANO) of the compound network is performed by two elements:
 - The traditional MANO for non-NI functions, and the
 - **Network Intelligence Orchestrator (NIO)**

[3] M. Camelo *et al.*, "DAEMON: A Network Intelligence Plane for 6G Networks," *2022 IEEE Globecom Workshops (GC Wkshps)*, Rio de Janeiro, Brazil, 2022, pp. 1341-1346, doi: 10.1109/GCWkshps56602.2022.10008662.

[6] M. Gramaglia *et al.*, 6G Architecture Landscape – European Perspective, A white paper from the 5G Architecture Working Group, Version 6.0, February 2023

Network Intelligence Plane: Taxonomy of NIP operations



• Network Intelligence Function (NIF):

- Functional block in a network intelligence instance that implements a decision-making functionality to be deployed in a controller, NFV orchestrator, or NF

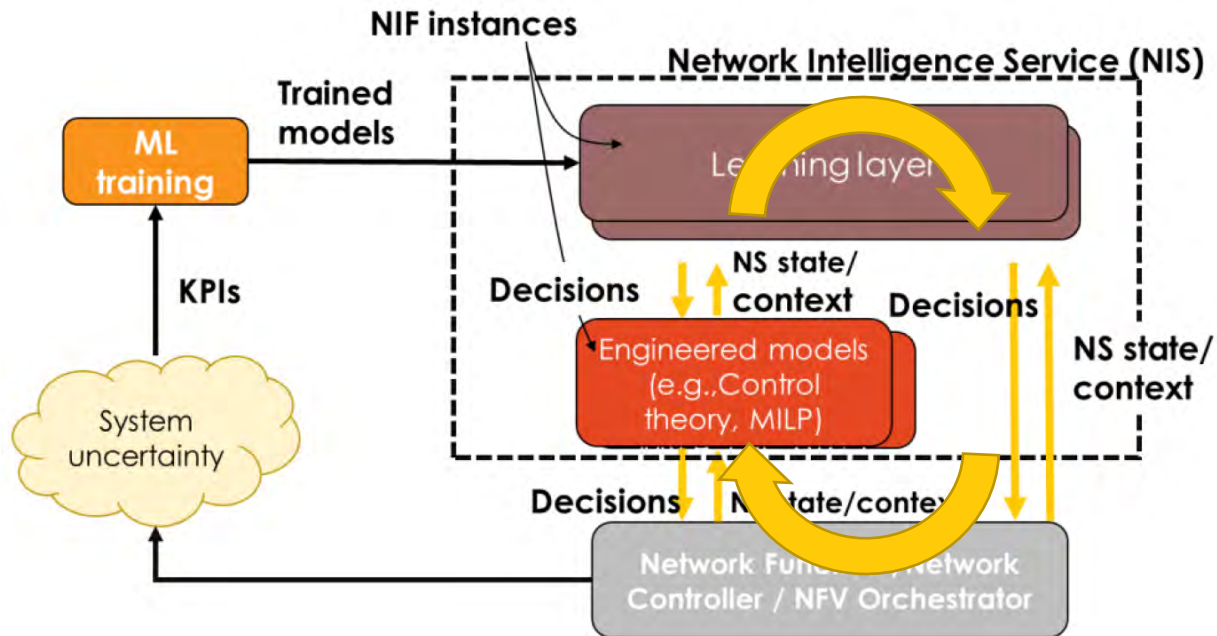
Network Intelligence Service (NIS).

- Composition of Network Intelligence Functions (NIFs) that has a specific target, usually related to a specific set of target KPIs

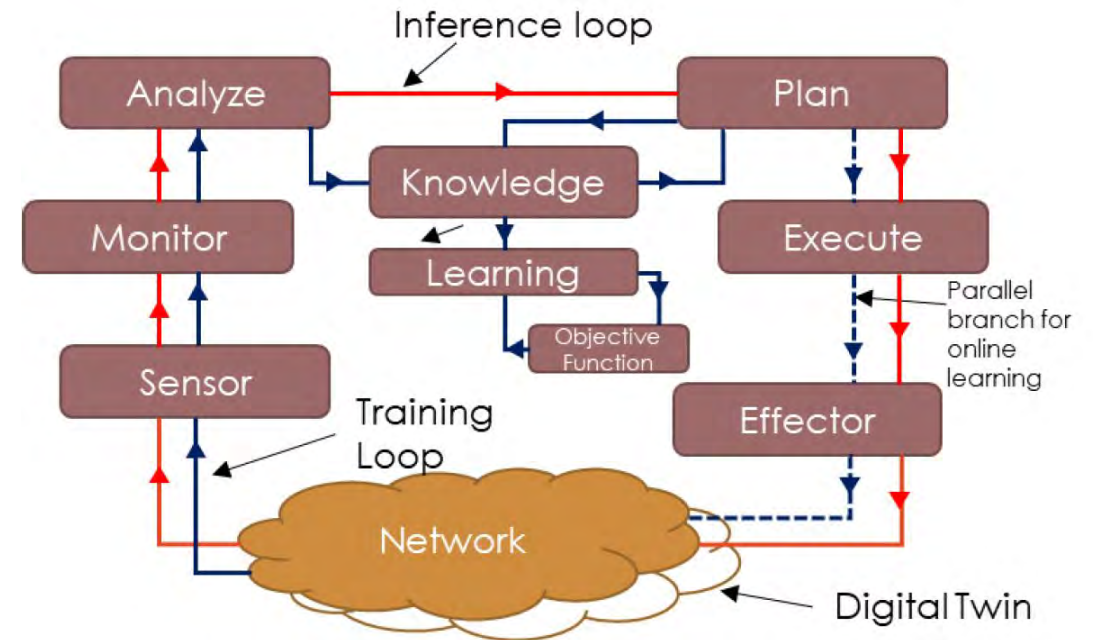
[3] M. Camelo *et al.*, "DAEMON: A Network Intelligence Plane for 6G Networks," 2022 *IEEE Globecom Workshops (GC Wkshps)*, Rio de Janeiro, Brazil, 2022, pp. 1341-1346, doi: 10.1109/GCWkshps56602.2022.10008662.

Network Intelligence Plane: NIF representation

Taxonomy of NIP operations



NIF representation framework (N-MAPE-K)



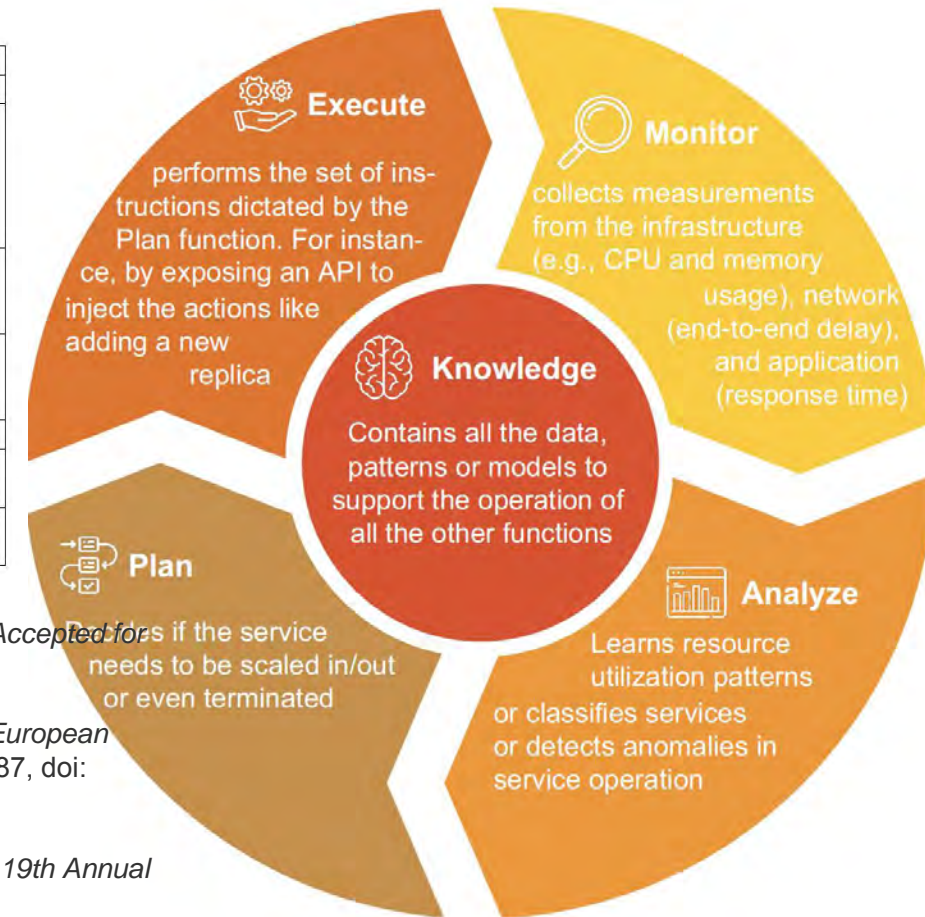
Each NIF can be further split into atomic **NIF Components (NIF-C)**

[3] M. Camelo *et al.*, "DAEMON: A Network Intelligence Plane for 6G Networks," 2022 *IEEE Globecom Workshops (GC Wkshps)*, Rio de Janeiro, Brazil, 2022, pp. 1341-1346, doi: 10.1109/GCWkshps56602.2022.10008662.

Network Intelligence Plane: NIF Representation: NIF - computing scaling algorithms

MAPE-K DECOMPOSITION OF DIFFERENT SCALING METHODS

MAPE-K Component	Scaling Method			
	Threshold-based	Control-based	SL-based	RL-based
Monitor	Resource State: CPU utilization Network State: service latency, E2E delay	Network State: service latency, E2E delay	Traffic Demands: Traffic load Resource State: CPU utilization, number of replicas Network State: service latency, E2E delay	Resource State: CPU utilization, number of replicas Network State: service latency, E2E delay
Analyze	Comparison between the monitored variables and the predefined thresholds	Computation of how the control variable needs to be changed as a weighted sum of an error term and a trend	The monitored variables are passed by a time series forecasting algorithm to learn hidden patterns	The monitored variables are averaged to compose the State.
Plan	Predefined actions according to the thresholds		Apply a mathematical formula to translate future patterns into scaling decisions	An agent takes the best action according to the learned strategy and current network state
Execute	An API to the MANO platform to communicate scaling decisions			
Knowledge	External: Human knowledge to define the threshold	Control terms' values	Model of the expected traffic load	Strategy with the actions to be taken according to the network state
Training Loss State/Actions/Rewards	N/A		Cross-Entropy	States: Avg CPU utilization, Avg latency Rewards: Resource utilization tolerance



[4] P. Soto *et al.*, "Network Intelligence for NFV scaling in closed-loop architectures," *IEEE Communication Magazine*, Accepted for publication, 2023.

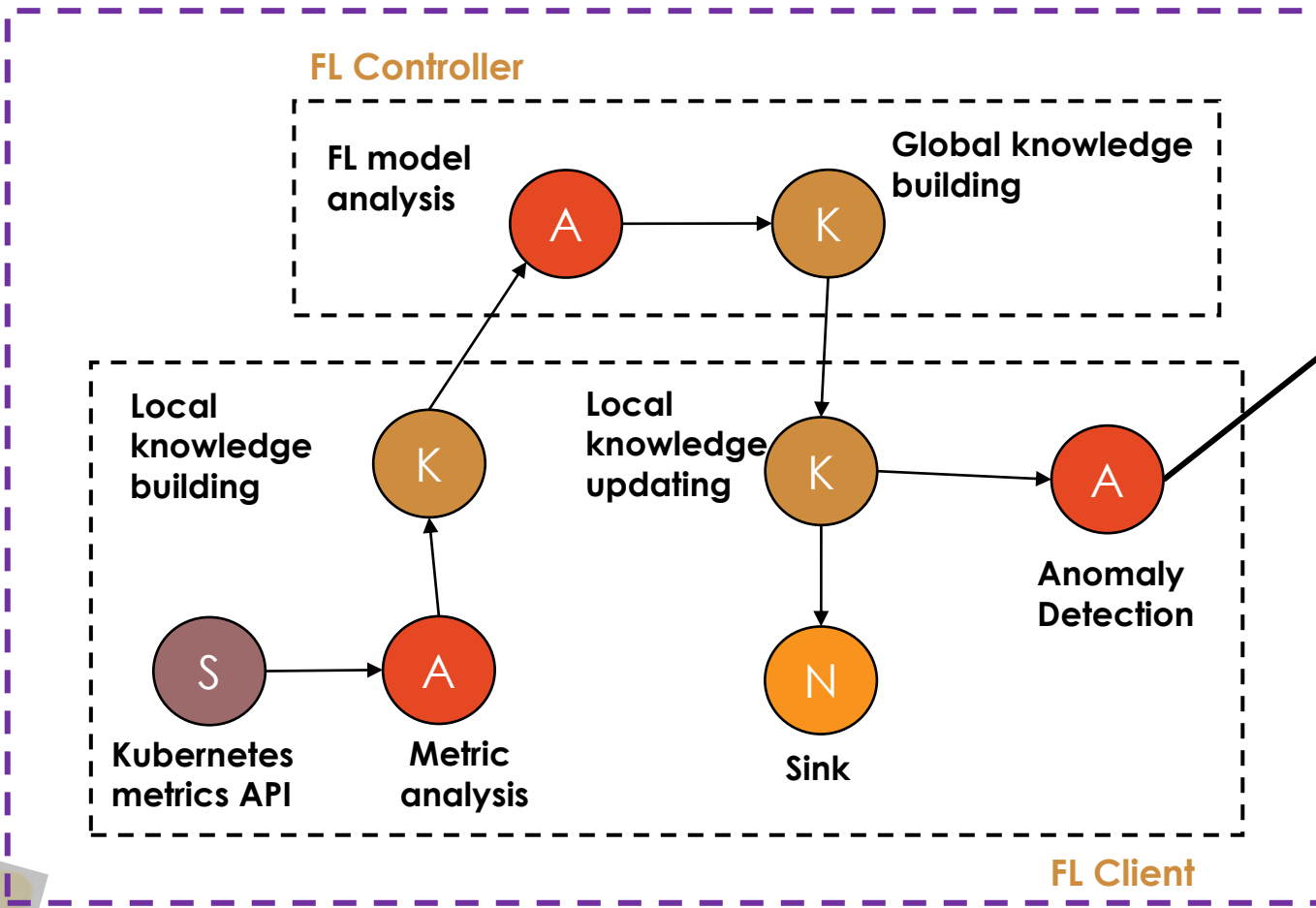
[5] M. Gramaglia *et al.*, "Network Intelligence for Virtualized RAN Orchestration: The DAEMON Approach," *2022 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*, Grenoble, France, 2022, pp. 482-487, doi: 10.1109/EuCNC/6GSummit54941.2022.9815816. (vRAIn and SBP-vRAN)

[2] M. Camelo *et al.*, "Requirements and Specifications for the Orchestration of Network Intelligence in 6G," *2022 IEEE 19th Annual Consumer Communications & Networking Conference (CCNC)*, Las Vegas, NV, USA, 2022, pp. 1-9, doi: 10.1109/CCNC49033.2022.9700729. (vRAIn vs. ATARI)

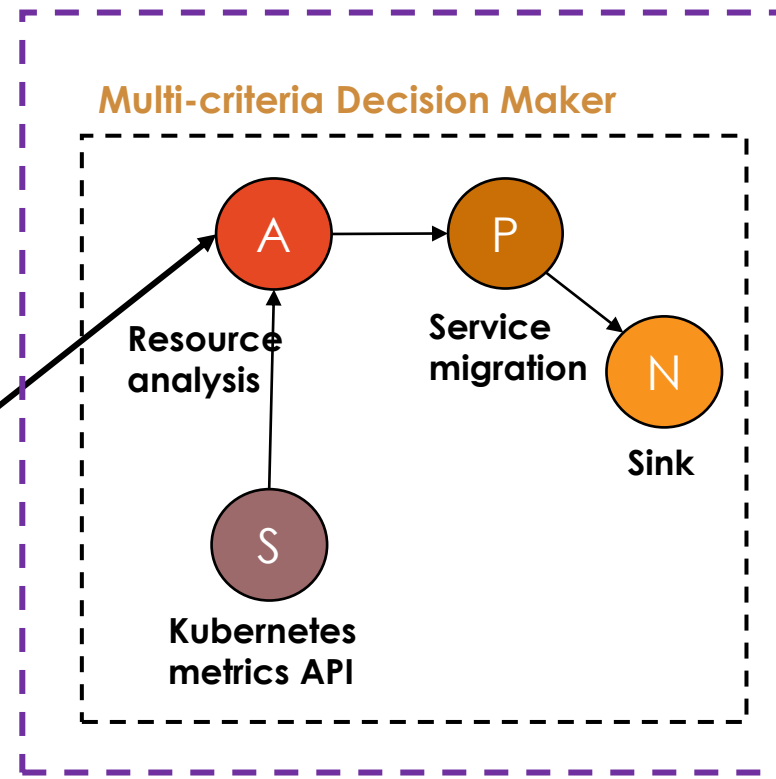
Network Intelligence Plane

NIF Representation: NIS

NIF1: Federated Learning Powered Anomaly Detection



NIF2: Service Relocation



NIS: Federated Learning Powered Anomaly Detection and Service Relocation

- Includes NIF1 and NIF2
- Zenoh as our data framework

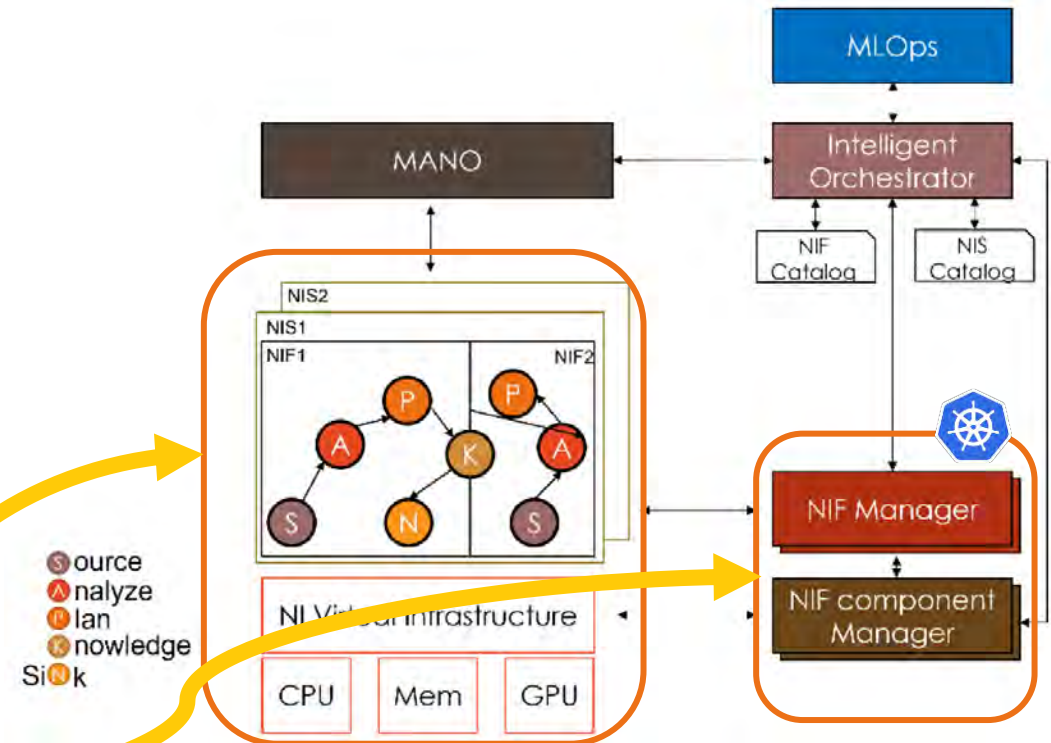
NIF-Cs: S Source A Analyze P Plan K Knowledge N Sink

Cloud

Edge

Network Intelligence Plane Network Intelligence Orchestration

- **NIF Component Manager.** The NIF Component Manager oversees handling the lifecycle of the NIF-Cs.
- **NIF Manager.** The NIF Manager, instead, has a global view of the set of NIF-C that compose every NIF.
- **Intelligence Orchestrator.** It oversees the lifecycle management of the NIS, by properly coordinating the NIFs that build each of them



**Project level demo @
DAEMON booth**

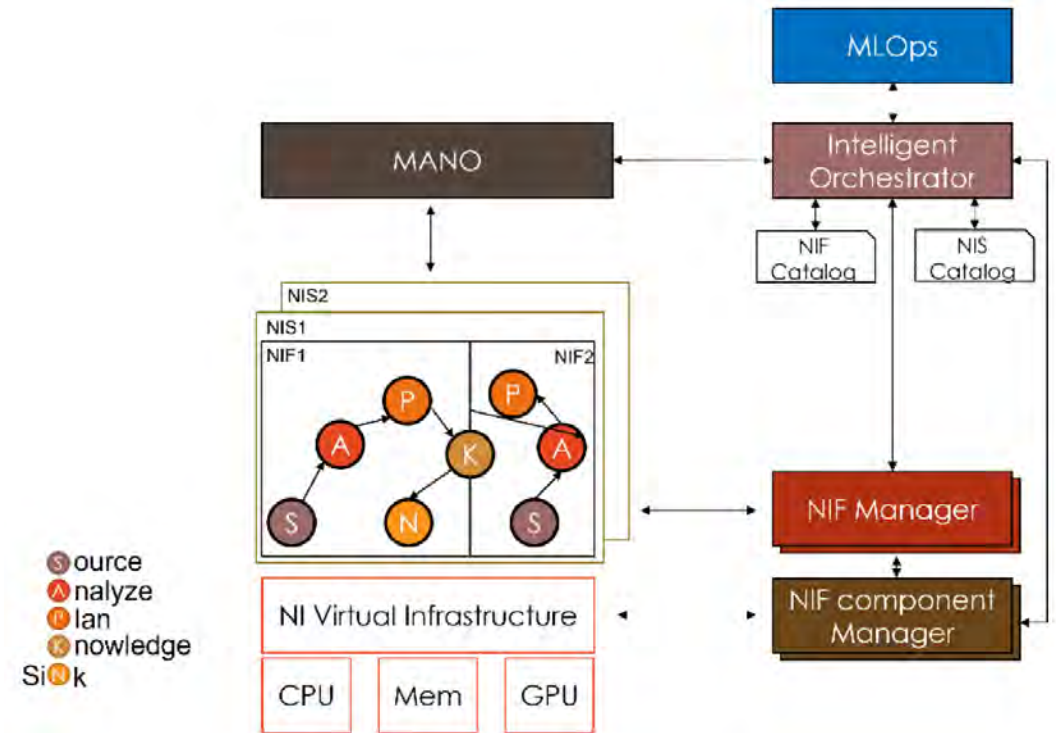


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Network Intelligence Plane Intelligence Orchestrator

- The selection of the **Network Intelligence Functions (NIF)** that come together to build a **Network Intelligence Service (NIS)**
- The Monitoring of Nif/NIS KPIs (e.g., accuracy) and specific actions that may be taken to optimize them.
- The specific training procedures in the case of learning models.
- The interaction with the MANO to handle service and resource orchestration.

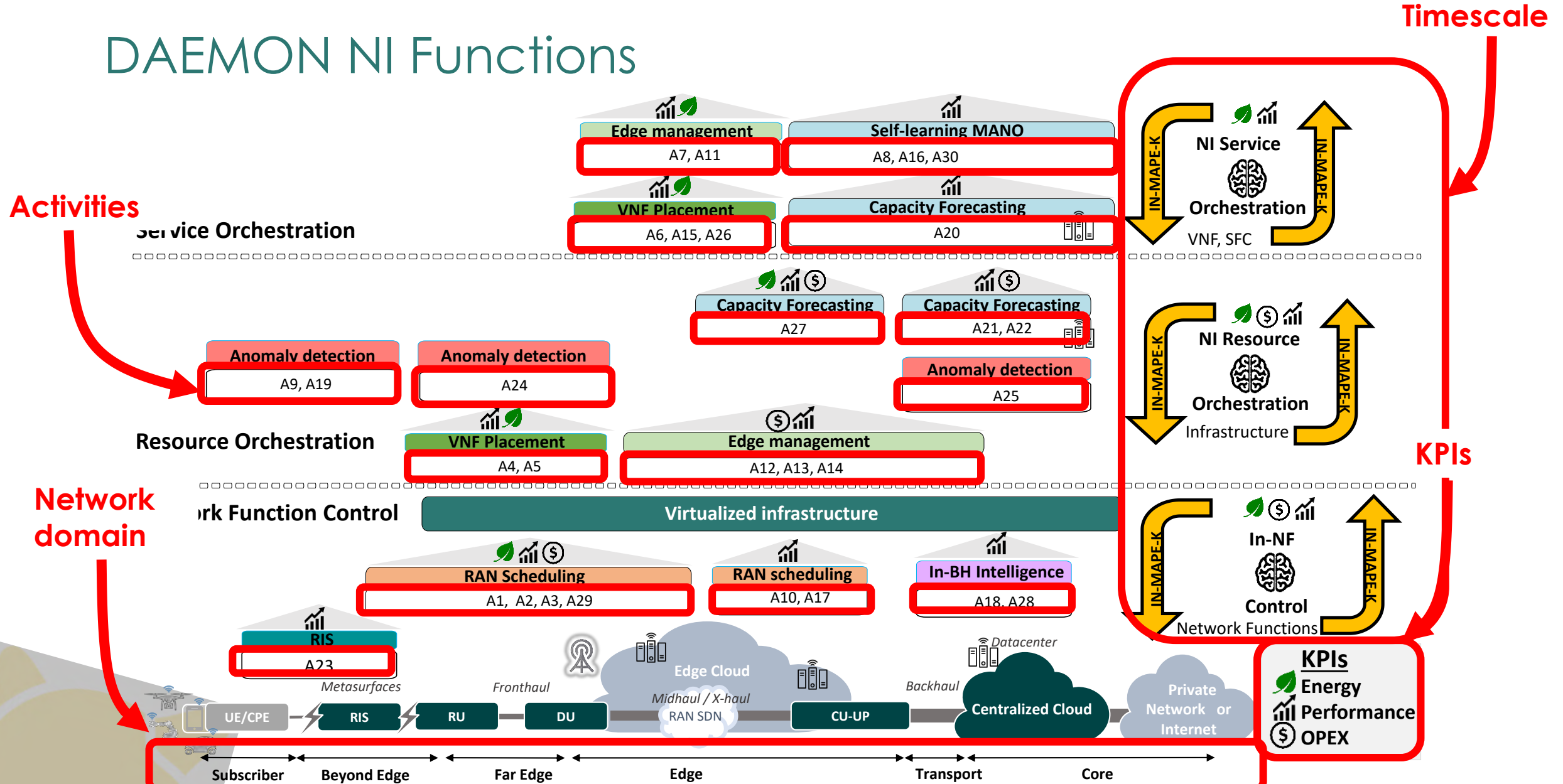


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Network Intelligence Plane: NIP and MLOps

MLOps workflows	MLOps Component	DAEMON NI Plane component exposing such functionality	Description
Build	ML pipeline	ML pipelines	Creation, training and registration of training models.
Deploy	Testing and Release	NI Orchestrator	Selection and trigger NIS deployment (testing/release)
		NI Orchestrator	Runtime and lifecycle management of deployed NIS
Monitor	Monitor	NIF Manager	Capture and expose performance metric of the ML model
	Analysis	NI Orchestrator	Determine the performance of the ML model(s) in the NIS. May include explainability functionalities to keep accountability of ML models.
	Governance	NI Orchestrator	Send alerts and trigger actions based on the model's performance such as conflict resolution, trigger a new retraining phase, change the model,

DAEMON NI Functions



Conclusions

- **NI plane (or stratum)** allows us to homogeneize intrinsically heterogeneous Network Intelligence to ease lifecycle management and coordination
- DAEMON has or is designing 30 NIFs providing 8 NI Services across different network domains, timescales and goals

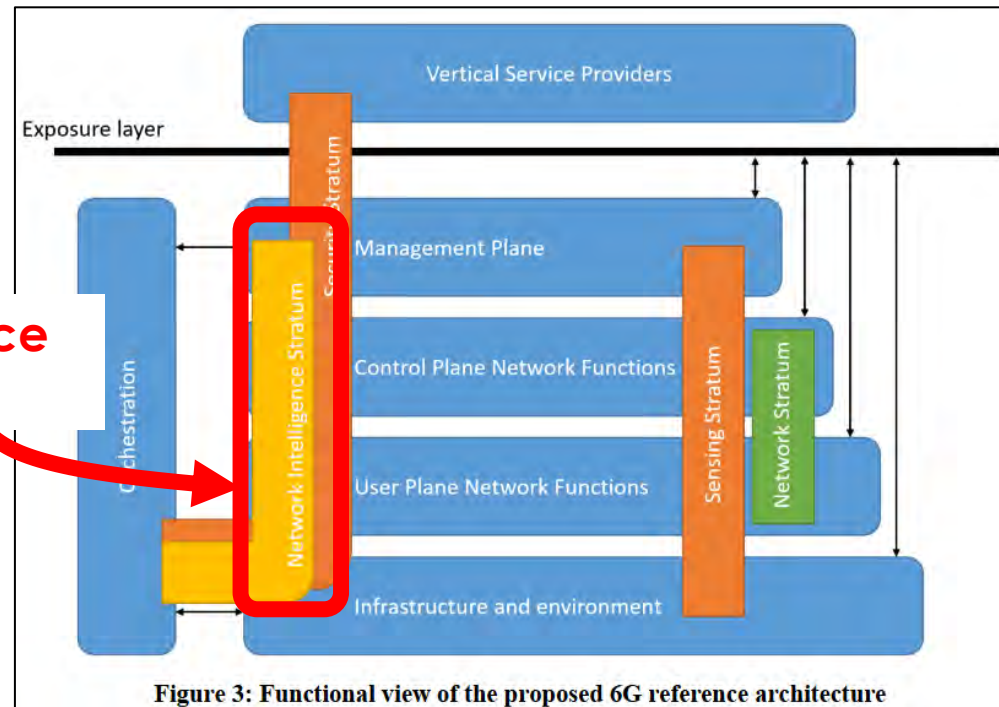


Figure 3: Functional view of the proposed 6G reference architecture

