OpenCNC

A software-defined control plane for automating TSN network configuration

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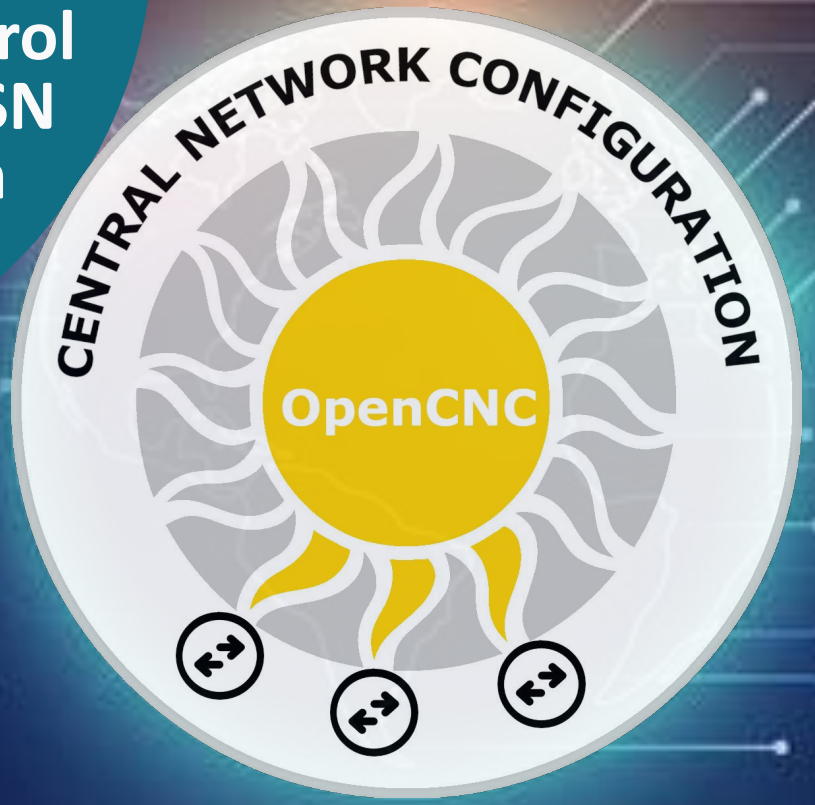
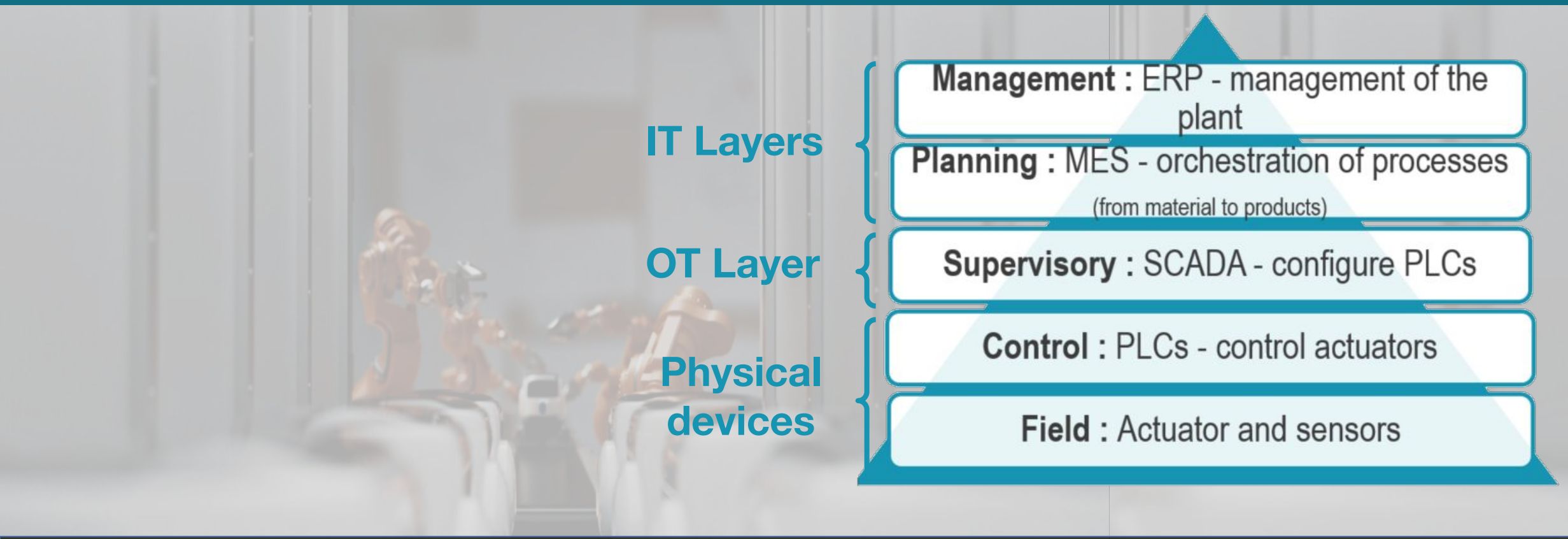


Agenda

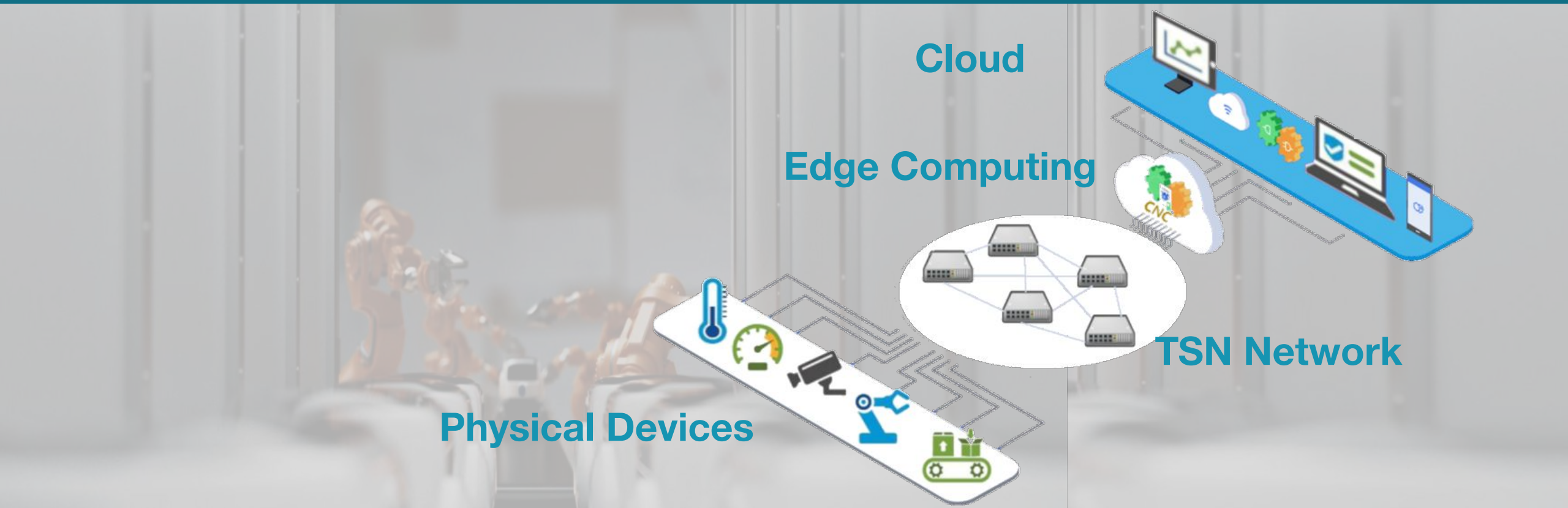
1. Introduction
2. OpenCNC design
3. TSN Network optimization
4. Conclusion

Connected Cyber-Physical Systems Now



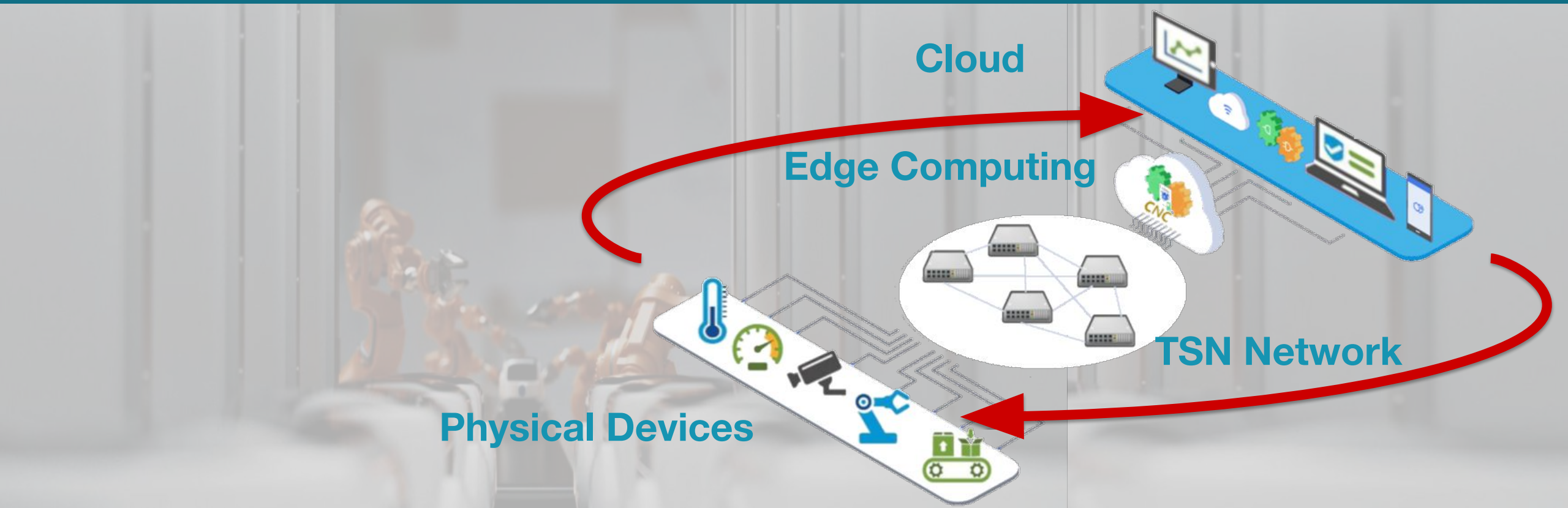
- **Needs/Trends:**
  - Collecting and Making use of billions of sensor data IoT
  - Analyzing data and acting upon it in Real-time Analytics
  - Autonomous Decisions guided by algorithms ML

Connected Cyber-Physical Systems □ In Future



- **Characteristics and Benefits**
  - In software, virtualized, programmable, upgradable, commodity infrastructure, open, interoperable, customizable, Intelligence
  - Increase flexibility, reduce deployment time and cost

Connected Cyber-Physical Systems □ In Future



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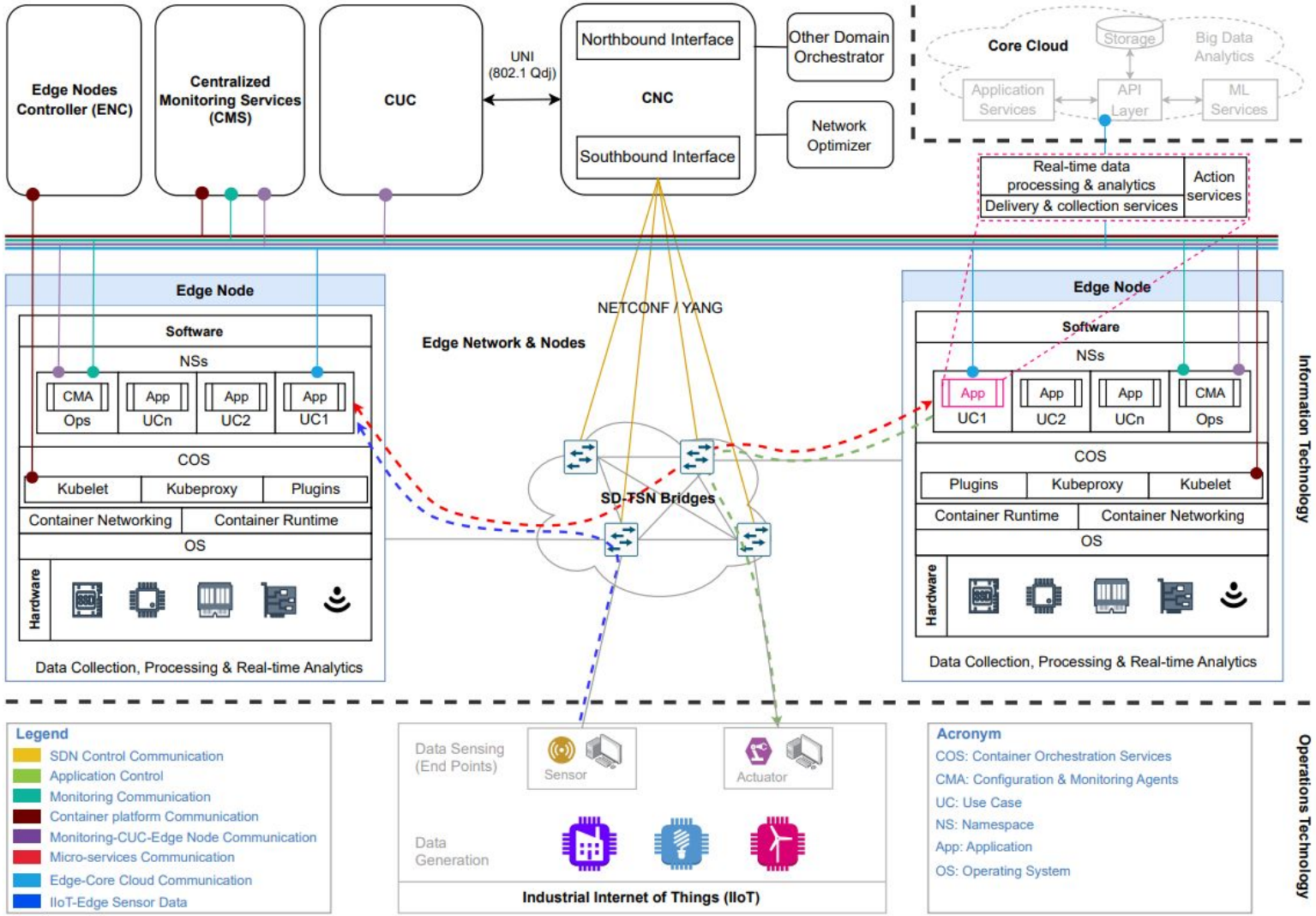
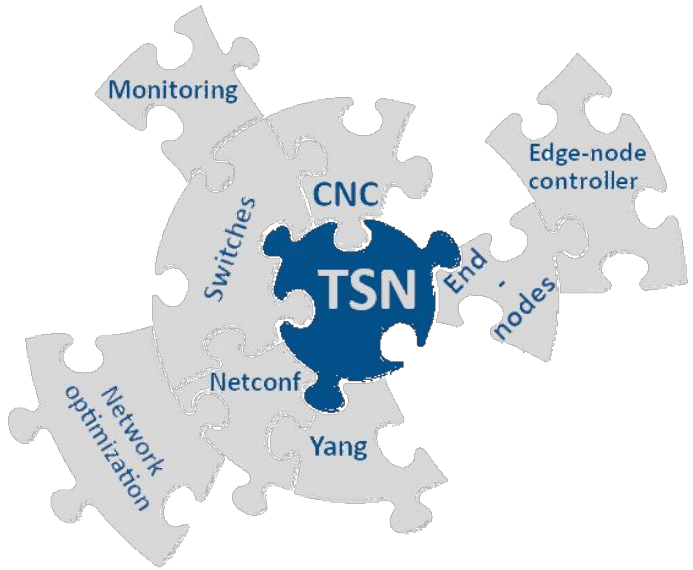
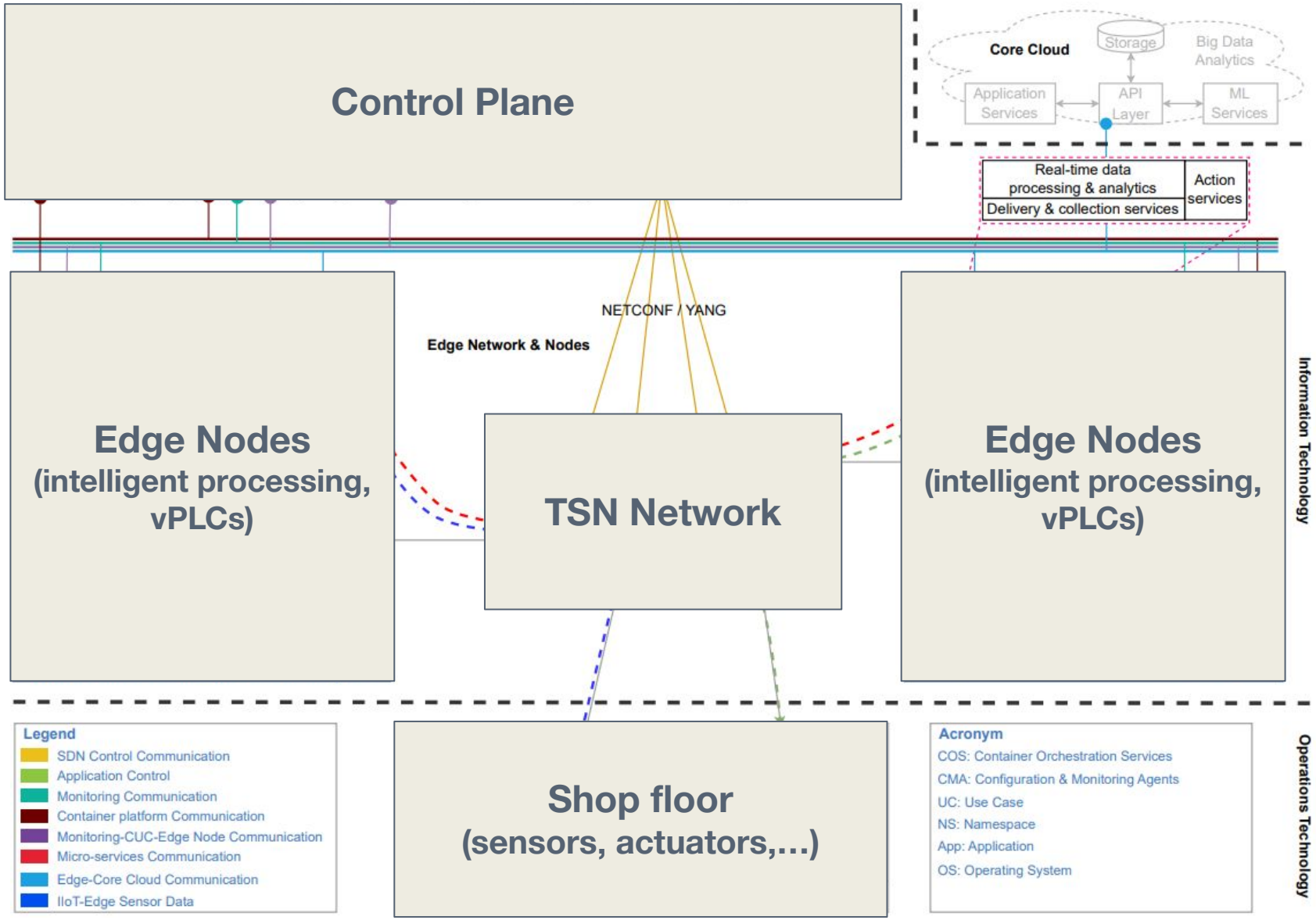
Introduction: AIDA - A Holistic AI-Driven Networking and Processing Framework

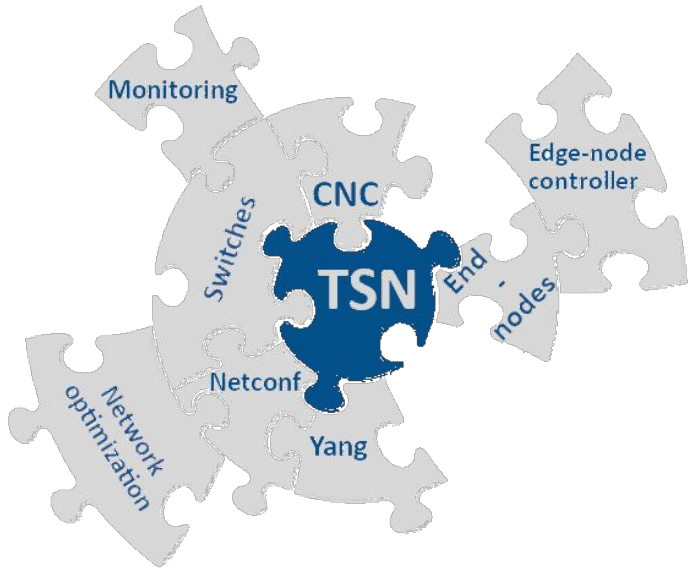




Publication: Chahed, Hamza, et al. "AIDA—A holistic AI-driven networking and processing framework for industrial IoT applications." *Internet of Things* 22 (2023): 100805.

Introduction: AIDA - A Holistic AI-Driven Networking and Processing Framework

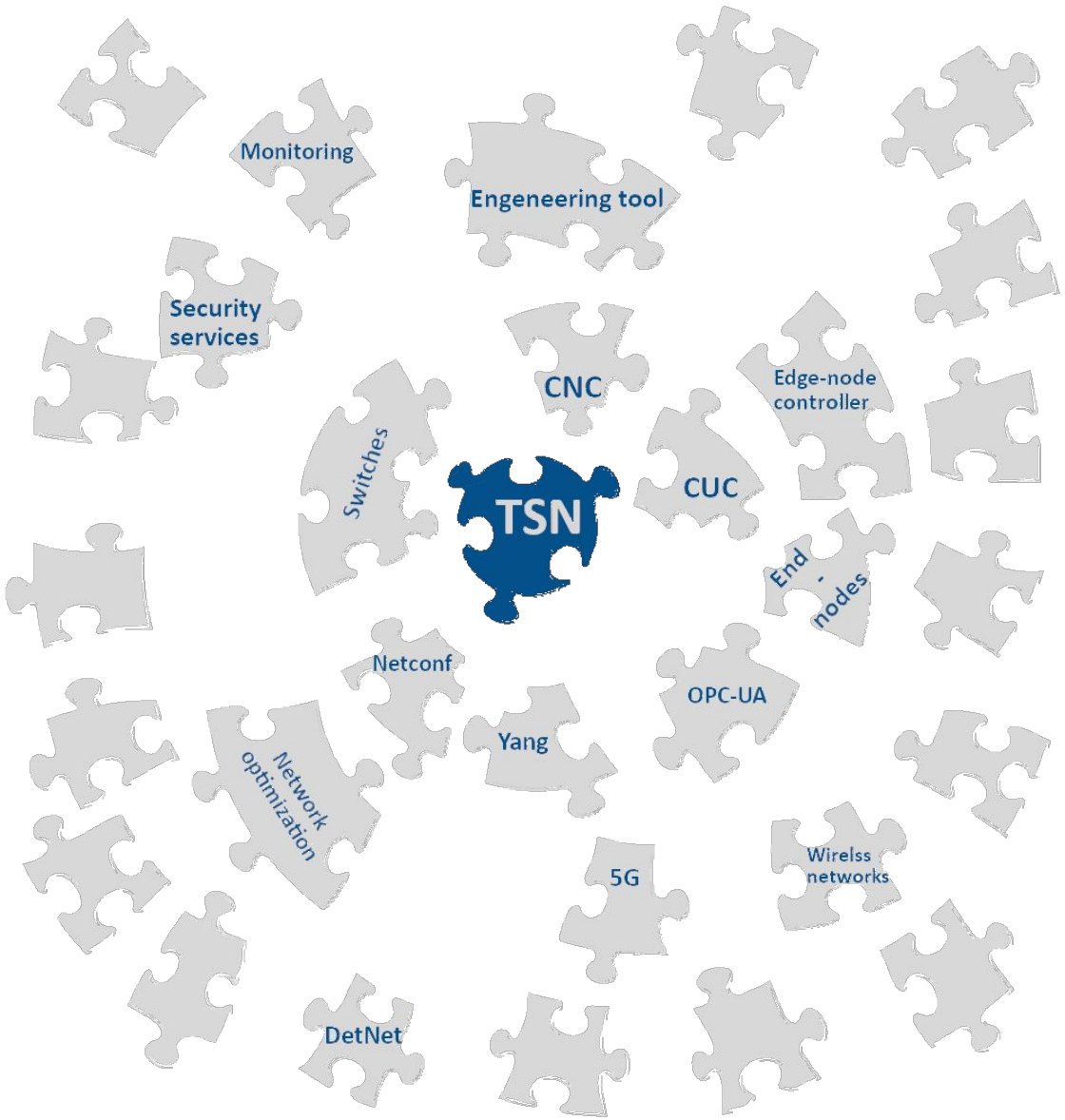




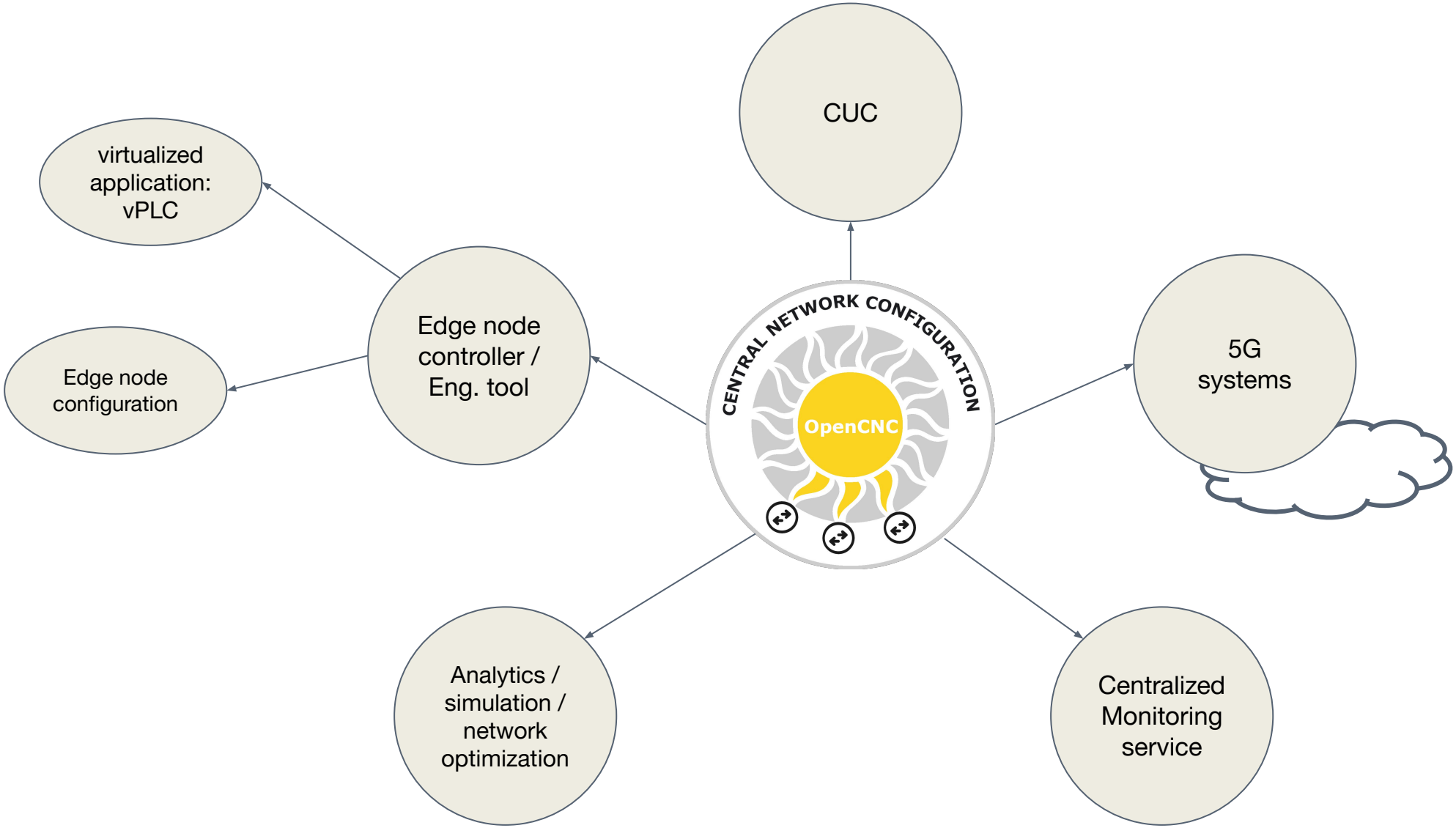
Big picture

- TSN: Converged Real-Time Networks
- Rich eco-system
  - Multiple networking technologies e.g. 5g, DetNet...
  - Multiple standardization bodies
- Diverse applications and solutions
  - Diverse end-systems, Virtualisation…
  - Many projects treating different parts of the TSN world e.g. **AIDA**
- Standardization advancing but gaps exist

Big potential for TSN, many pieces but no complete image



TSN Network Control and Management plane



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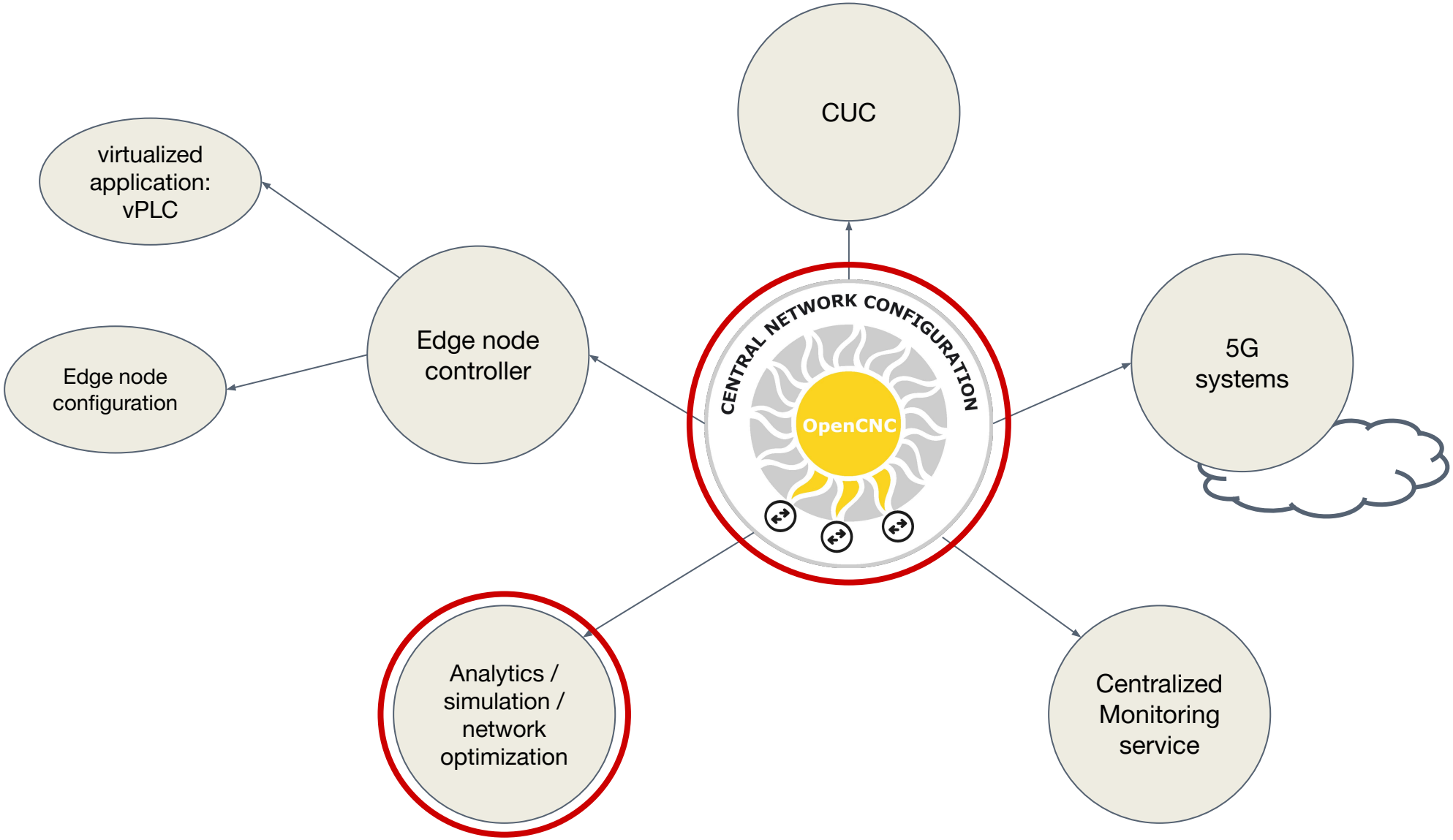
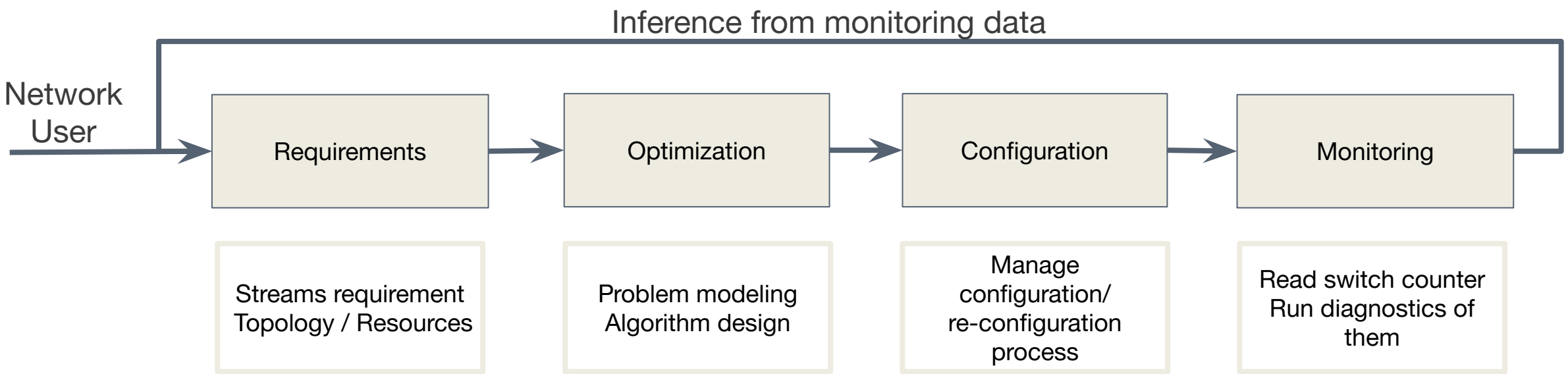
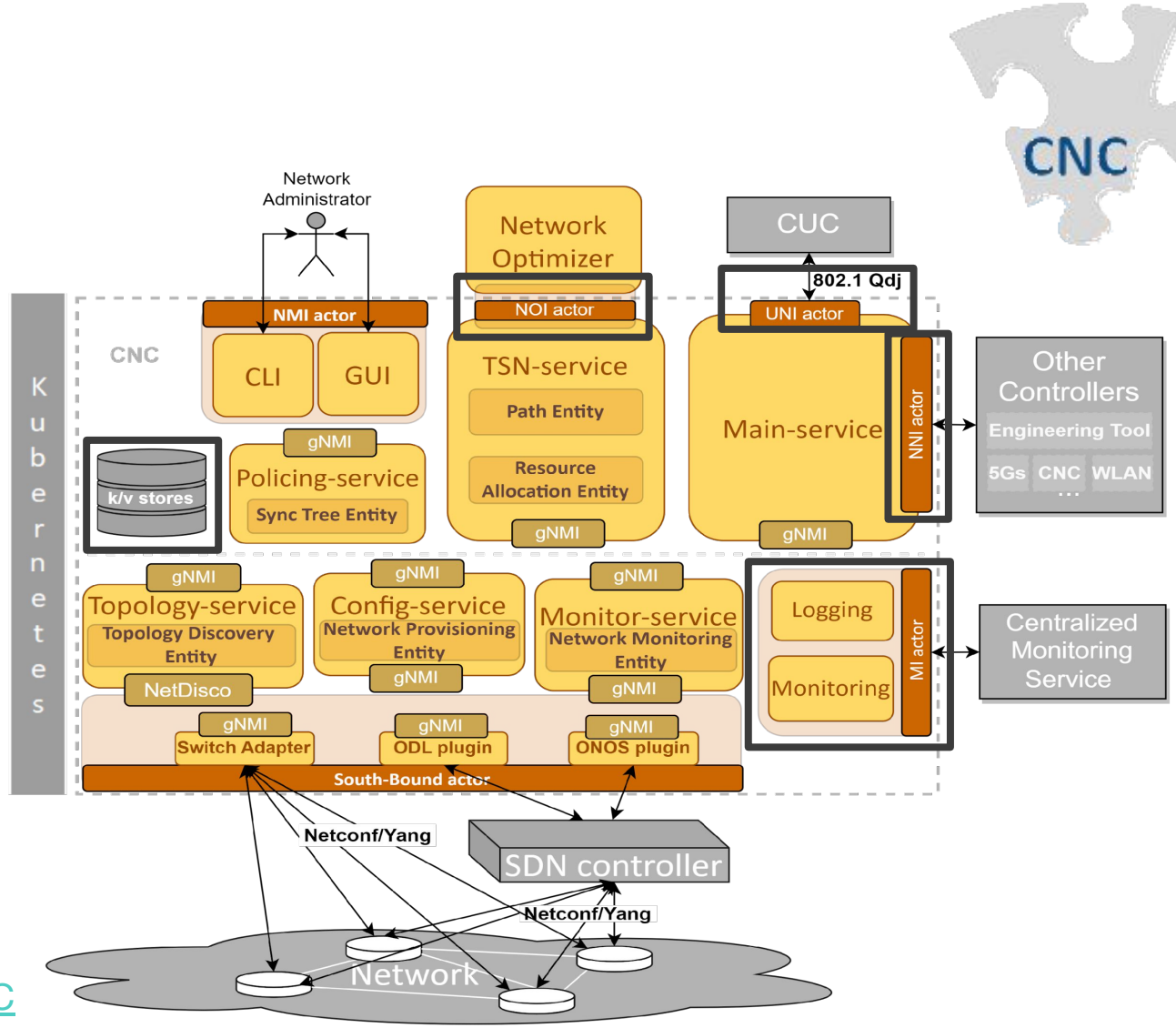


TSN Network Control and Management workflow



OpenCNC: overview

- Modular (μServices-based)
- Cloud-native (Kubernetes)
- Easy to scale up and out
- Adaptive to the needs of the network administrator
- Part of a holistic AI-driven networking and processing Framework (AIDA)



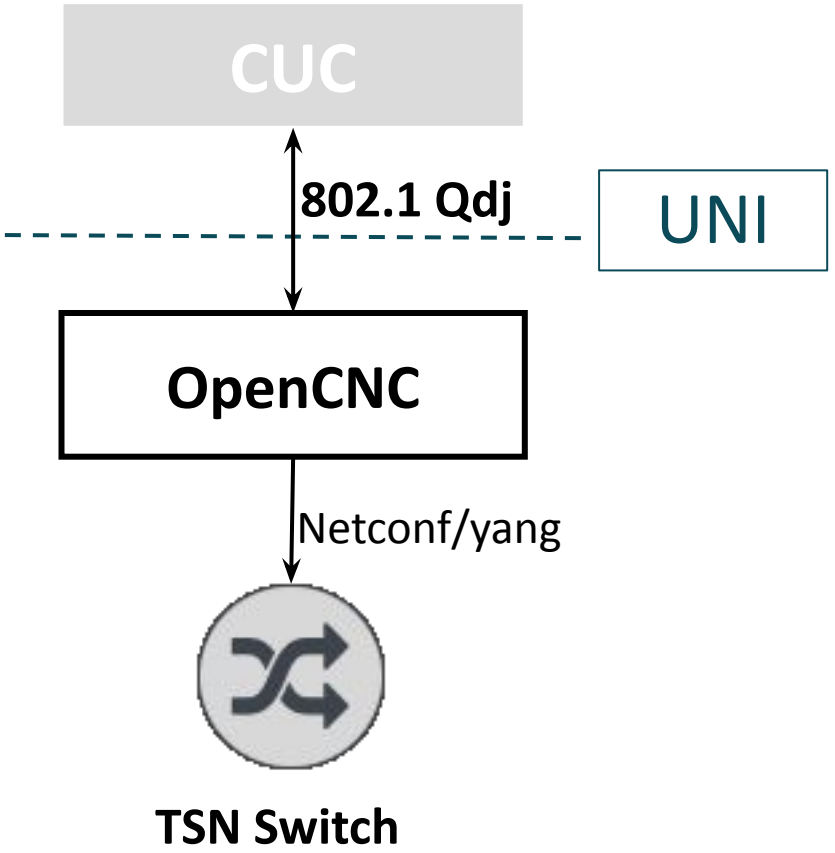
Link to OpenCNC: https://github.com/AIDA-KAU/OpenCNC

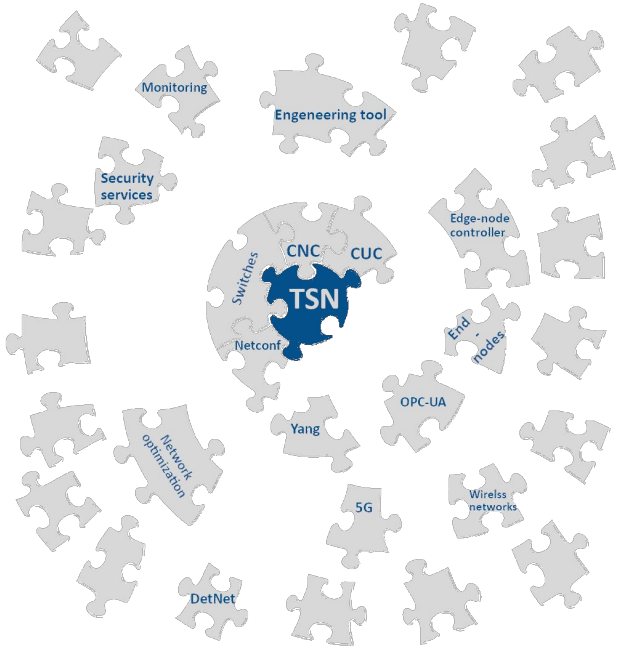
UNI interface

Add_talker

Join_stream

Register_talker
Register_listener



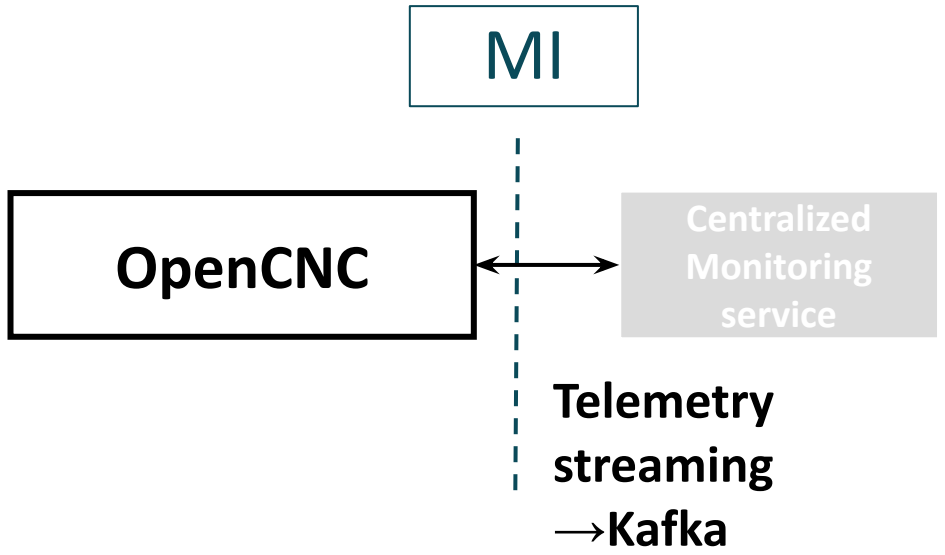


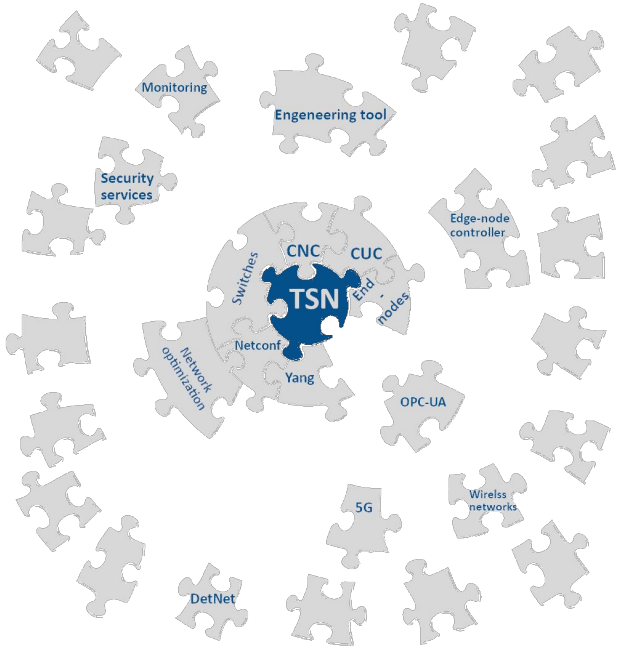
Contribution to the conference TSN/A 2022: Towards Viable Open Source TSN - From Endpoint to Network Configuration

Monitoring interface

Log data from **all the microservices** about **all the internal processing**

Network monitoring data: **all counters** from **all the switches** in the network





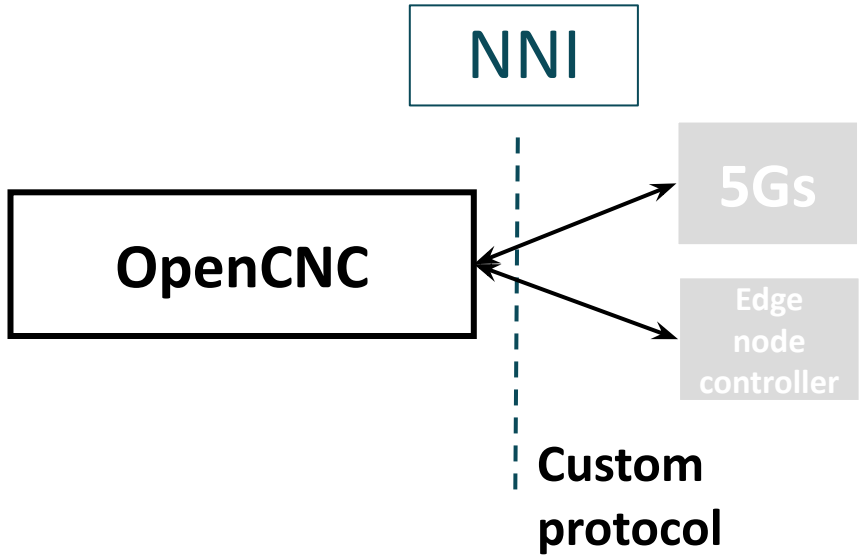
Contribution to the conference TSN/A 2023: Closing the configuration loop with OpenCNC and ControlTSN Frameworks

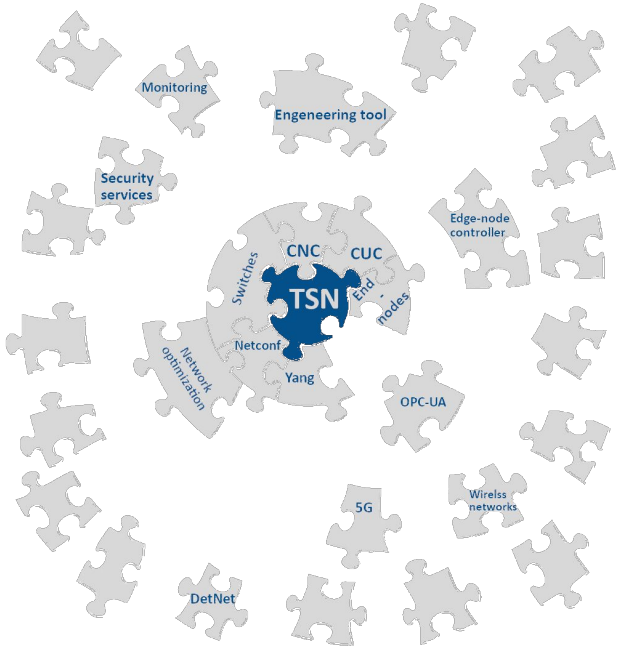
NNI interface

get_streams: returns **all configured streams**

get_talkers: returns **all registered talkers**

get_listeners:returns **all registered listeners**





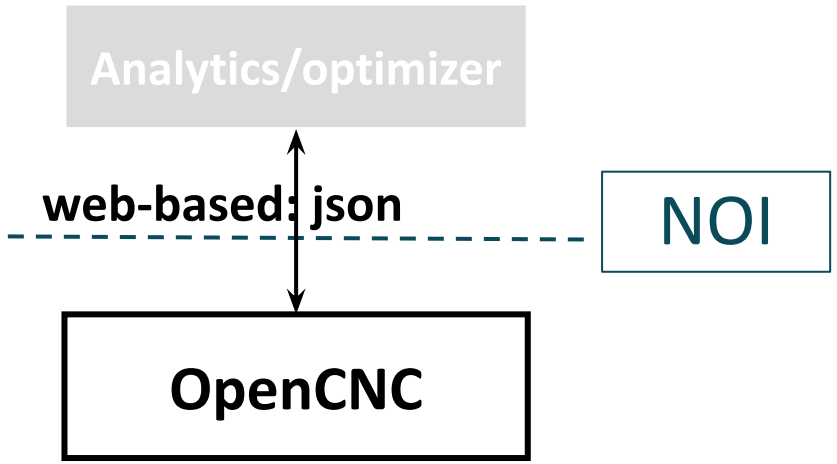
Contribution to the conference TSN/A 2023: Closing the configuration loop with OpenCNC and ControlTSN Frameworks

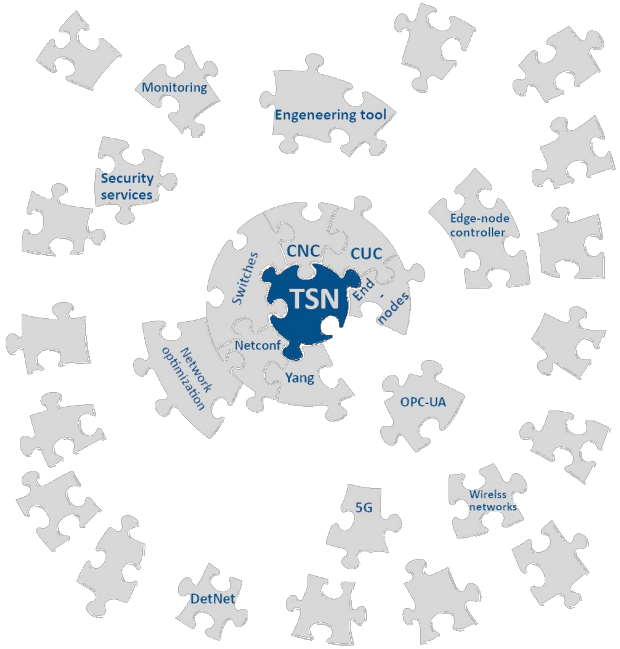
Network optimization interface

Optimize the network configuration

Check the quality of the schedule

Simulate the network





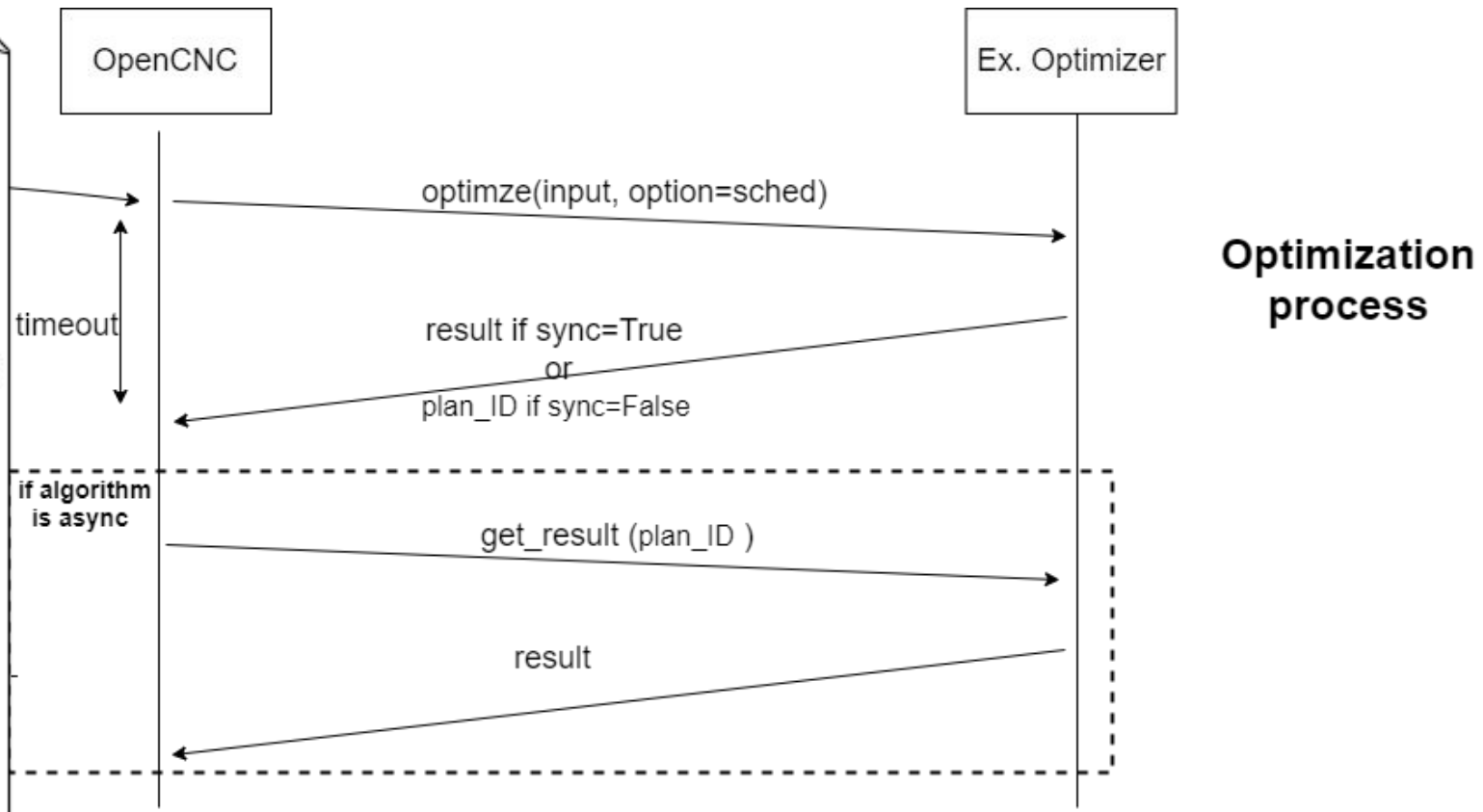
Contribution to the conference TSN/A 2023: Closing the configuration loop with OpenCNC and ControlTSN Frameworks

Network optimization interface

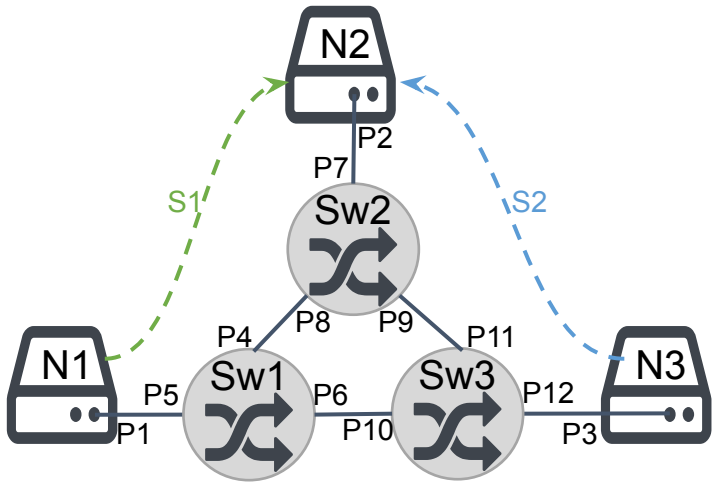
```
capabilities: {sched:"this algo does...",
    sched/route: "this algo does...",
    sched/route/embed:"this algo does..."}
Inputs: {JSON_UC: expFile,
         CSV_PLAIN: expFile}
Outputs: {JSON_FINISHED_UC: expFile}

External_optimizers:
  - optimizer_ip: 192.168.0.1
    optimizer_name: reconf_GA
    port: 55555
    description: "this algorithm does..."
    capabilities: [sched, sched/route, sched/route/embed]
    input: JSON_UC
    output: JSON_FINISHED_UC
    max_response_time[s]: 300
    sync : True

  - optimizer_ip: 192.168.0.2
    optimizer_name: conf_RL
    port: 55555
    description: "this algorithm does..."
    capabilities: [sched]
    input: JSON_UC
    output: JSON_FINISHED_UC
    max_response_time[s]: 1500
    sync: False
```



Network Optimization



No overlap

No looping

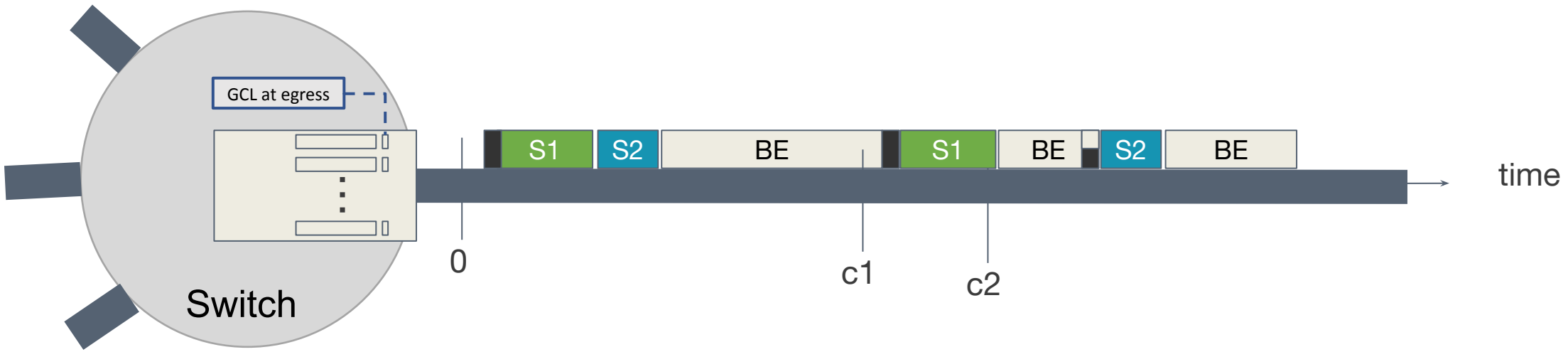
minimum jitter

stream sequencing

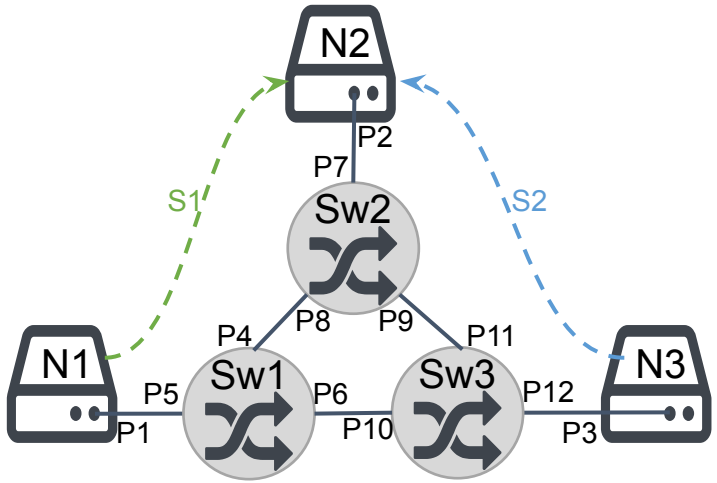
Respect Qos requirement e.g. latency

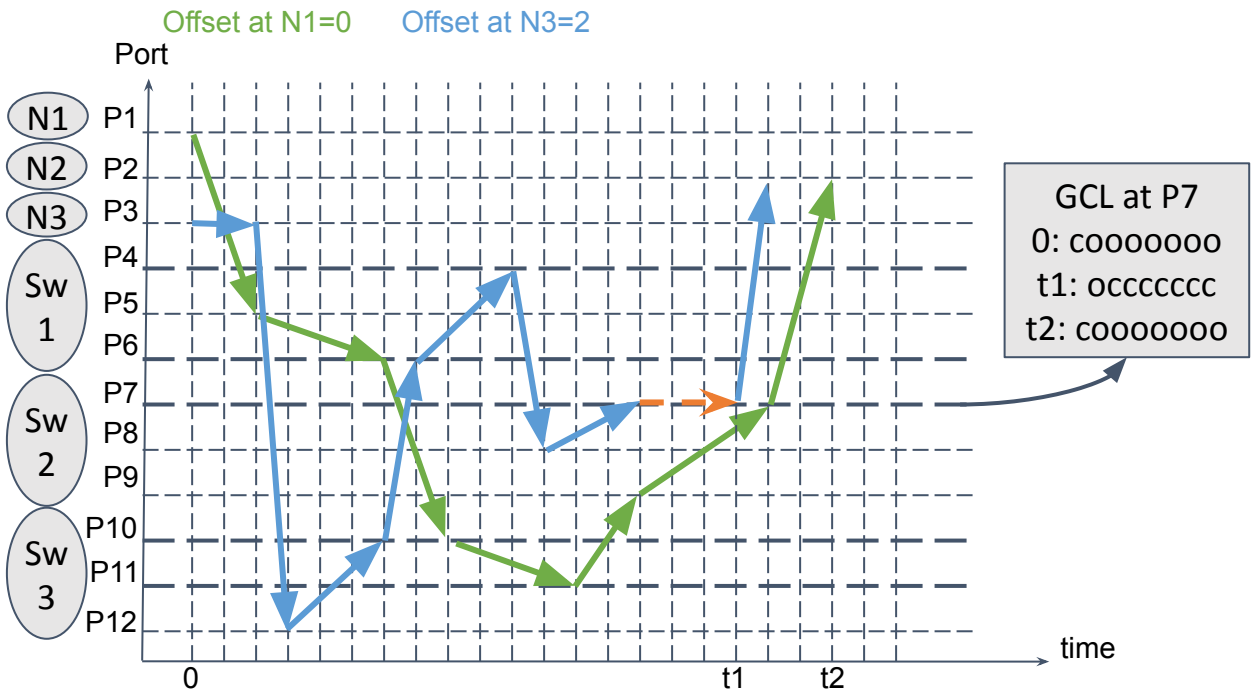
Flow conservation

Traffic is cyclic

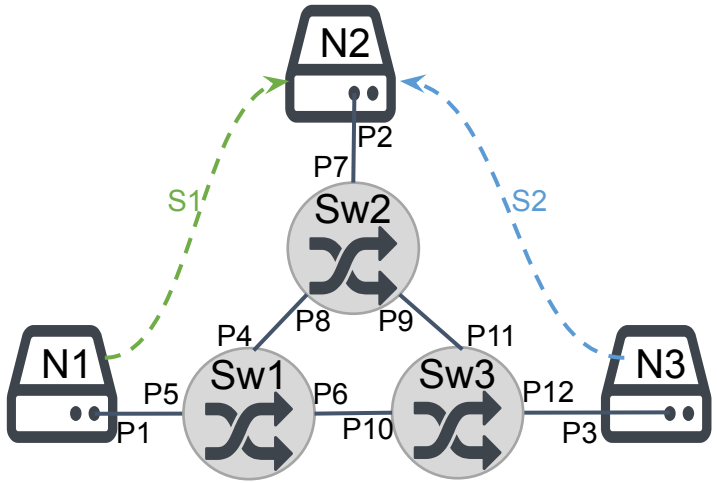


Network Optimization



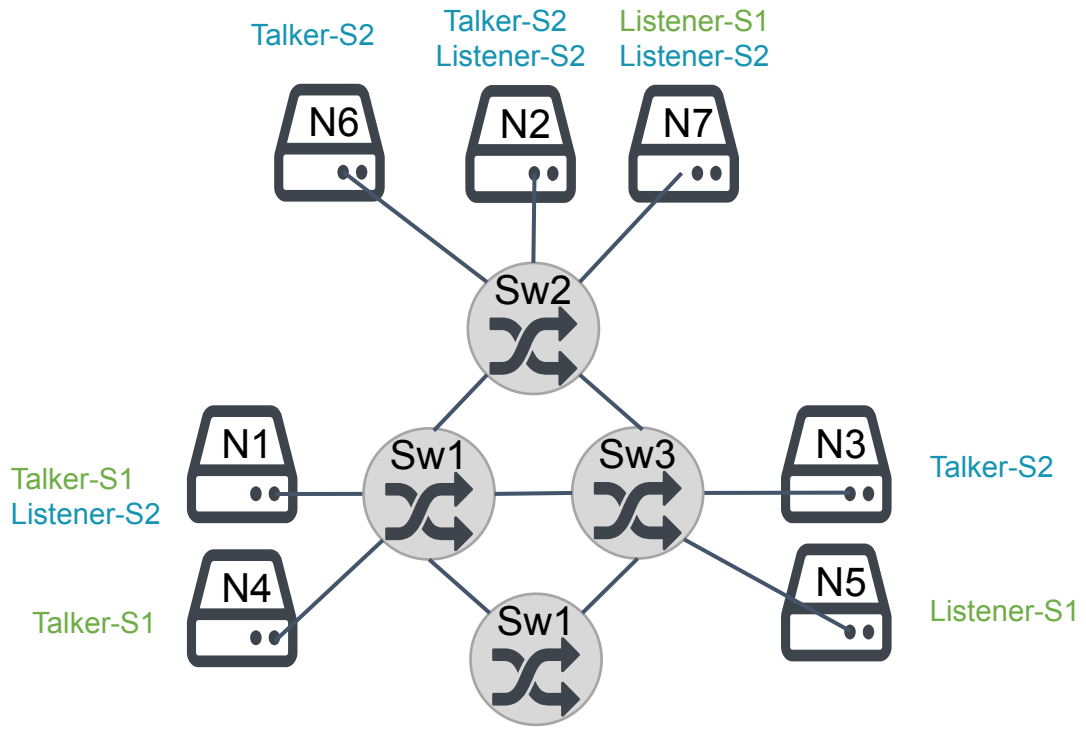


Problem extensions



Network Configuration extended to:

- Task placement
- Routing
- Scheduling



Techniques

ILP formulation + of-the-shelve solve

AI: reinforcement learning

Heuristics e.g. Genetic algorithms

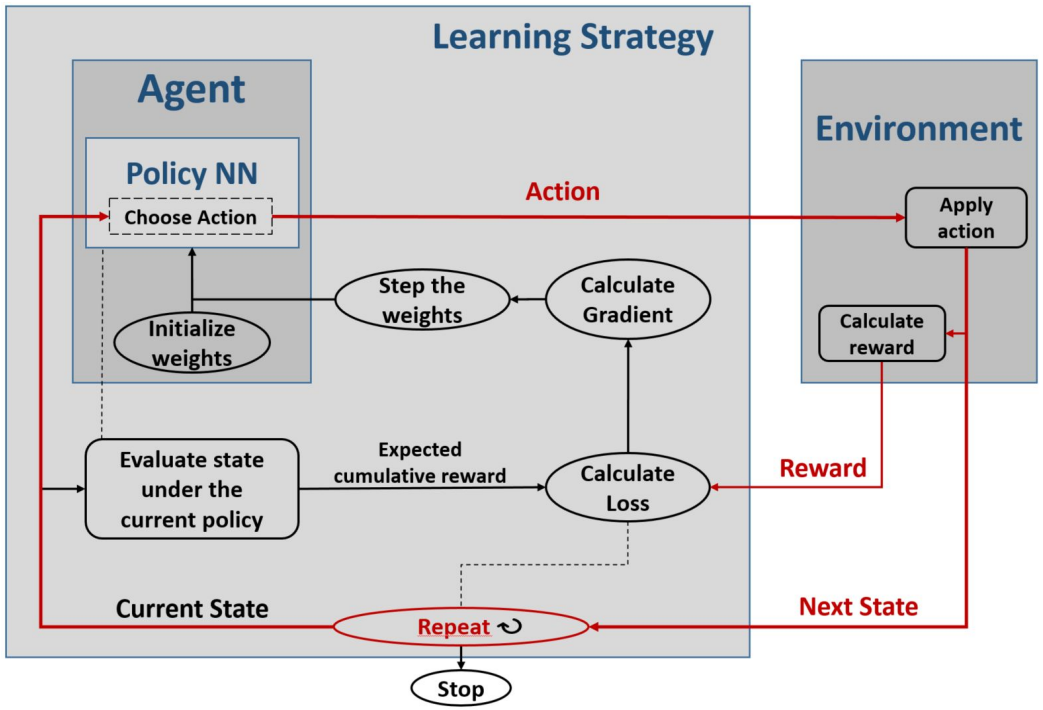
Notation	M
$x^{s,i}_{m,(b_i,b_j)} = \{0,1\}$	0-1 variable about the reservation of a transmission window time
	Decision Variables

Constraint	No
single talker placement	$\sum_{t\in T_s}\sum_{m\in[1,M_s]} x^{s,i=}_{m,(t}$
single listener placement	$\sum_{l\in L_s}\sum_{m\in[1,M]} x^{s,i=}_{m,(b}$
talker and listener placed in different nodes	$\sum_{m\in[1,M_s]} x^{s,i=0}_{m,(n,b)} + \sum_{m\in[1,M]} x^{s,i=}_{m,(b}$
Flow conservation	$\sum_{m\in[1,M]} x^{s,i=0}_{m,(b1,b)} - \sum_{m\in[1,M]} x^{s,i=}_{m,(}$
No looping: traffic enters a bridge maximally once	$\sum_{\beta\in B_b}\sum_{m\in[1,M]} x^{s,i=}_{m,(\beta}$
Bridge sends traffic only after receiving it	$\sum_{m\in[1,M]} m.x^{s,i=0}_{m,(b,b1)} - \sum_{m\in[1,M]} m.x^{s,i=0}_{m,(b2,b}$
Cyclic traffic	$x^{s,i=0}_{m,(b,\beta)} - x^{s,i}_{m+i*M_s,(b,\beta)} = 0, \forall m \in [1$
No overlapping between windows	$x^{s,k}_{t,(b,\beta)} + \sum_{\sigma\in S\setminus\{s\}}\sum_{m=t}^{t+w_{s,(b,\beta)}}\sum_{i=0}^{\frac{M}{M_\sigma}} x^{\sigma,i}_{m,(b,\beta)} \le 1,$
Maximum latency constraint	$t*x^{s,i=0}_{t,(b2,n2)} - m*x^{s,i=0}_{m,(n1,b1)} + w_{s,(b2,n2)} \le ML_s, \forall s \in S,$
Maximum bandwidth per link	$\sum_{m\in[0,M]}\sum_{s\in S} w_{s,(b,\beta)} * x^{s,i=}_{m,(b}$
	Constraints

Techniques

ILP formulation + of-the-shelve solvers

AI: reinforcement learning



Heuristics e.g. Genetic algorithms

Techniques

ILP formulation + of-the-shelve solvers

AI: reinforcement learning

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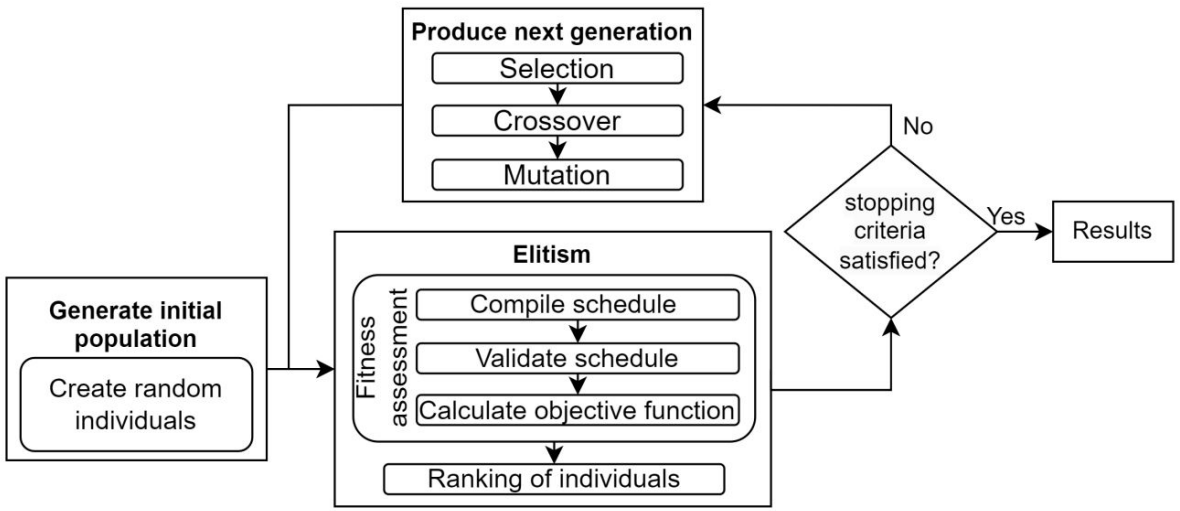
Under submission: “Optimizing TSN Routing, Scheduling, and Task Placement in Virtualized Edge-Compute Platforms”



Thank you for you attention

Questions?