

# Embedded reconfiguration of TSN

ECRTS 2024

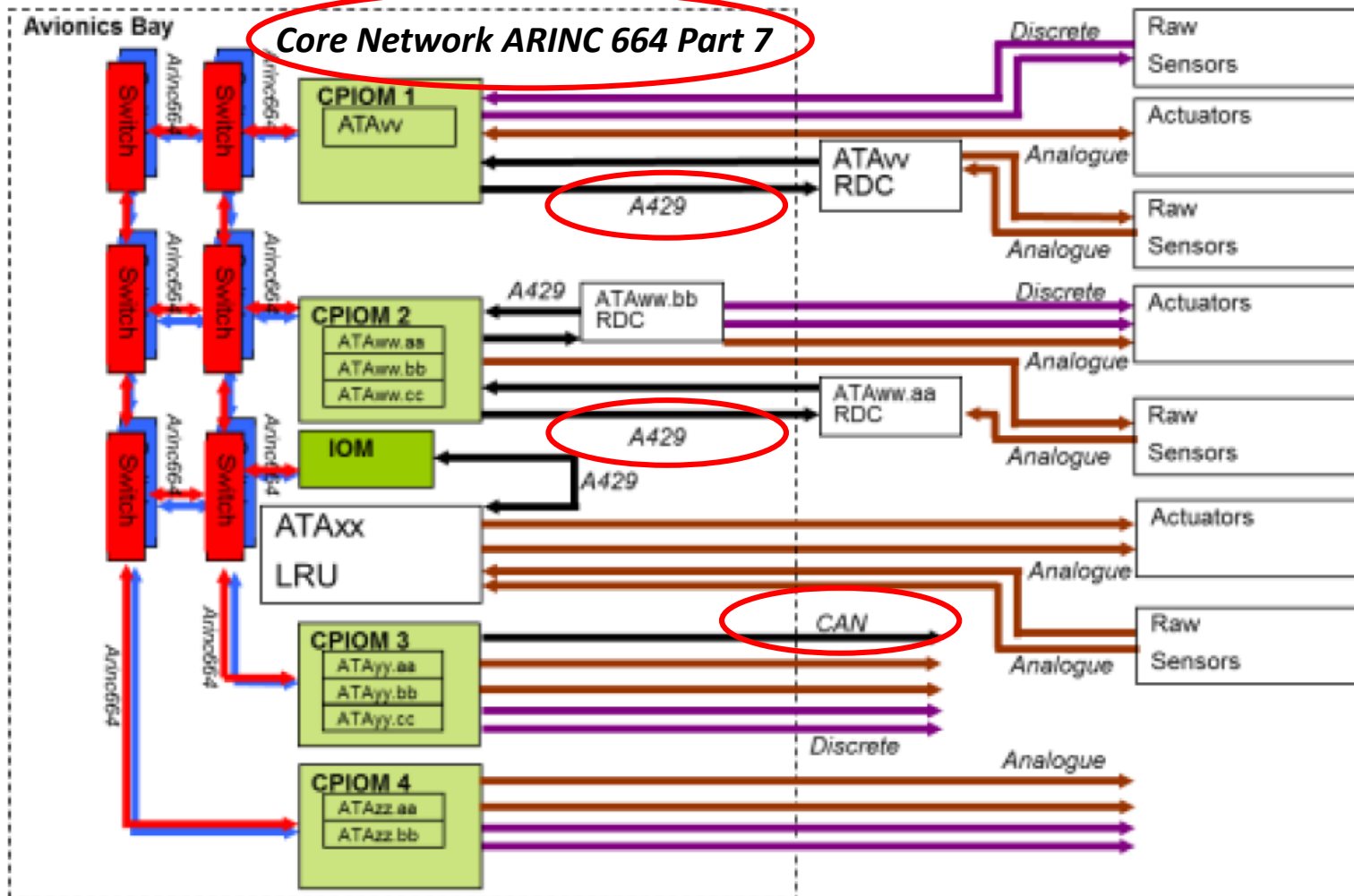
Industrial Challenge session

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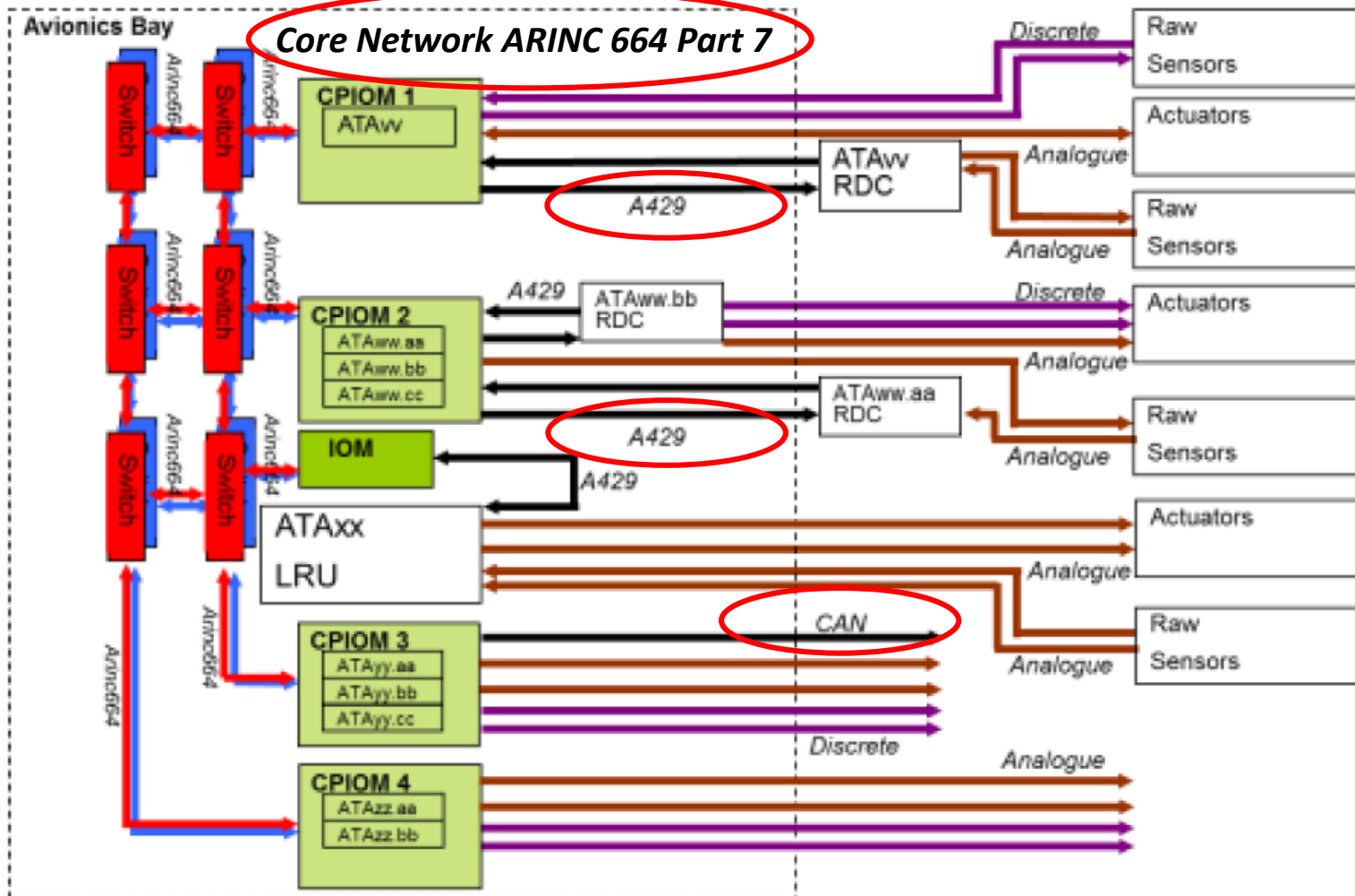
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# Global context

- Avionics networks
  - ARNIC 664 Part 7 (AFDX)
  - ARINC 429
  - ARINC 629
  - ARINC 825 (CAN)
  - MIL-STD-1553
  - Commercial Ethernet
  - ...

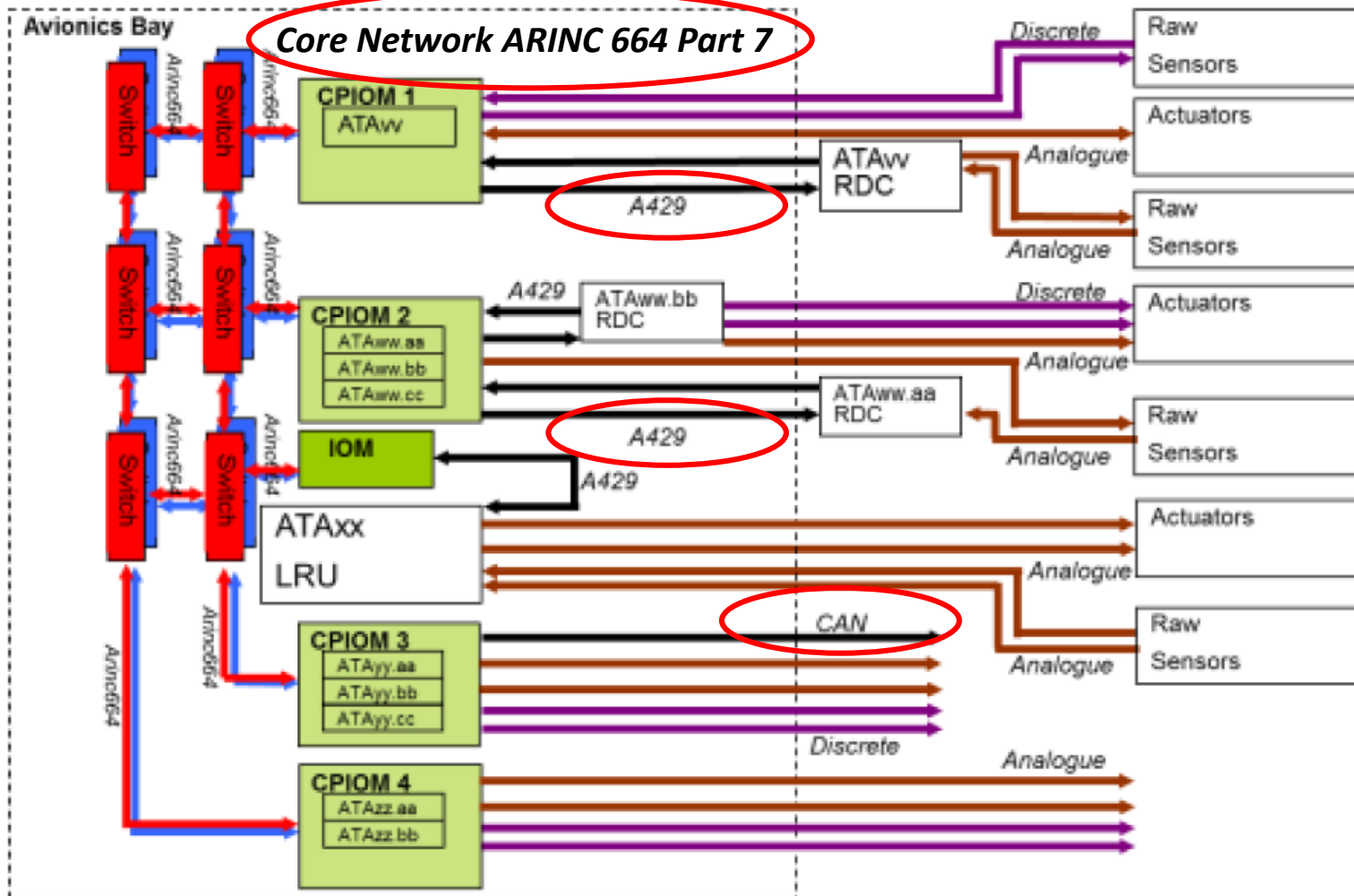


# Global context

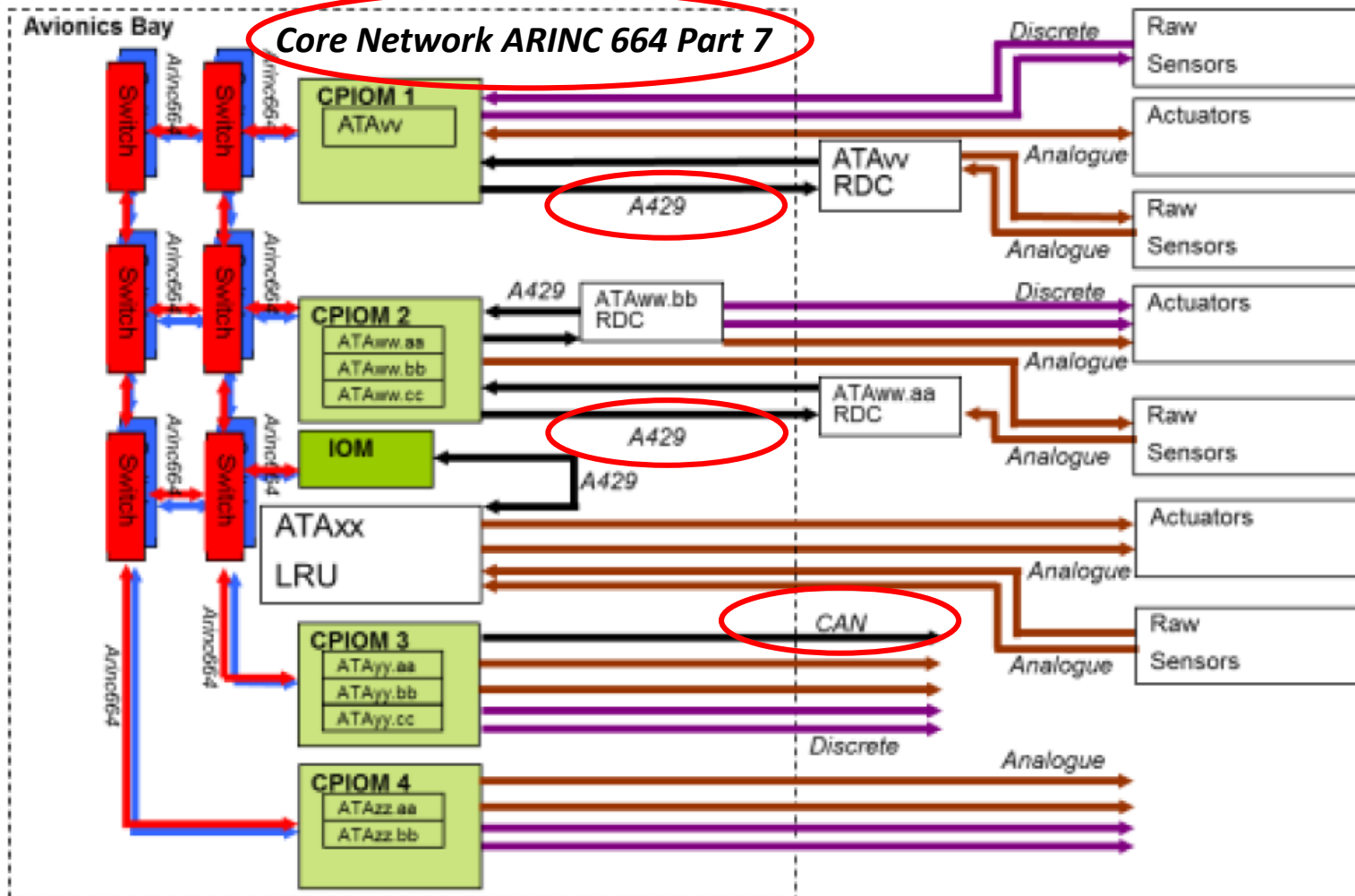


- Avionics networks
  - ARINC 664 Part 7 (AFDX)
    - High critical comm.
    - 4 priority levels
    - Up to 100 Mbps
    - Computers > 100
    - Duplicated to increase the fault tolerance
  - ARINC 429
  - ARINC 629
  - ARINC 825 (CAN)
  - MIL-STD-1553
  - Commercial Ethernet
  - ...

- Avionics networks
  - ARNIC 664 Part 7 (AFDX)
    - Duplicated to increase the fault tolerance and ensure that data transmission even in the event of a failure or disruption in the network
  - ARINC 429
  - ARINC 629
  - ARINC 825 (CAN)
  - MIL-STD-1553
  - Commercial Ethernet
  - ...

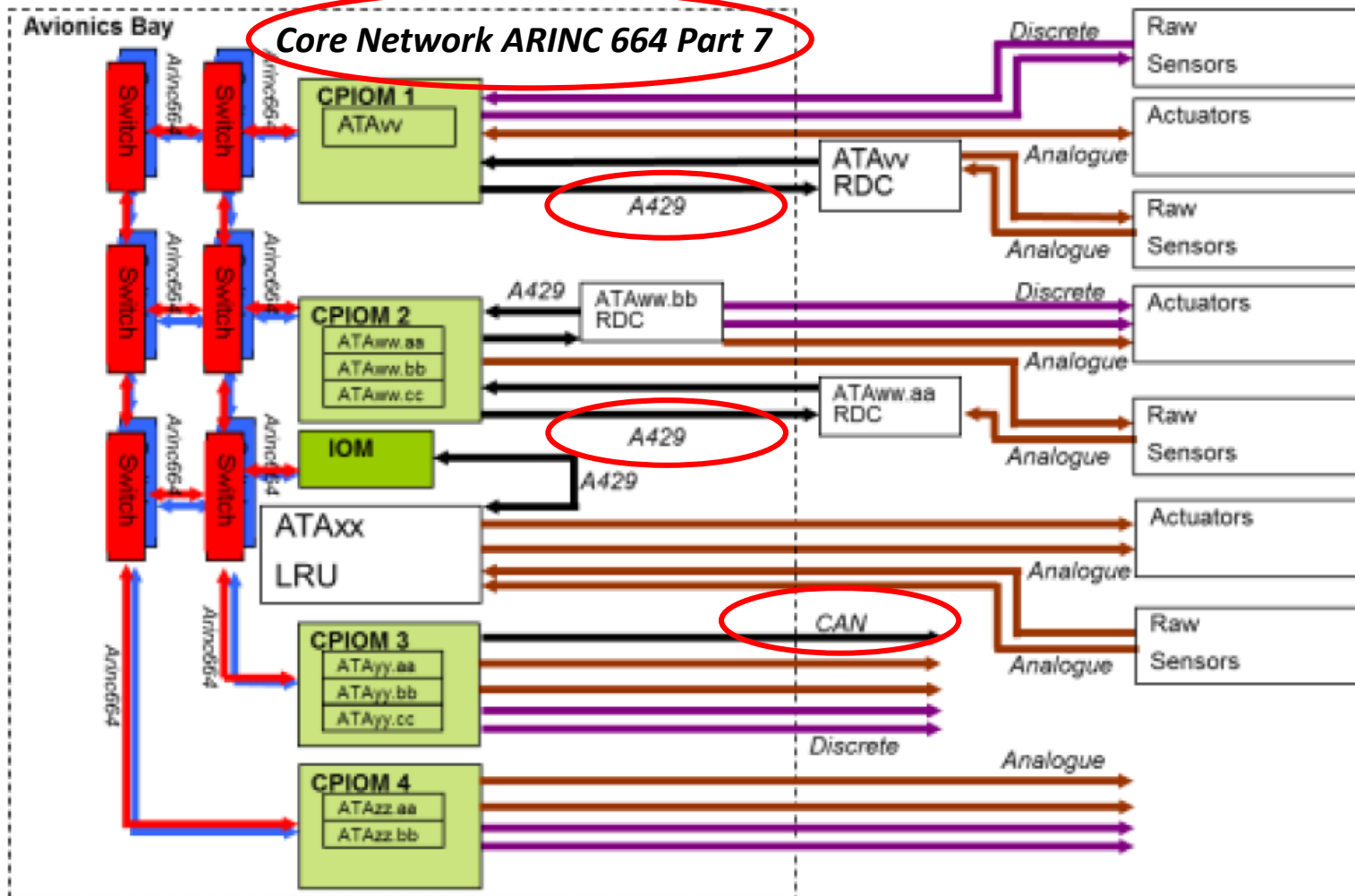


# Global context



- Avionics networks
  - ARINC 664 Part 7 (AFDX)
  - ARINC 429
    - Connecting sensors and actuators
    - Up to 100 Kbps
    - Computers < 20
  - ARINC 629
  - ARINC 825 (CAN)
  - MIL-STD-1553
  - Commercial Ethernet
  - ...

# Global context

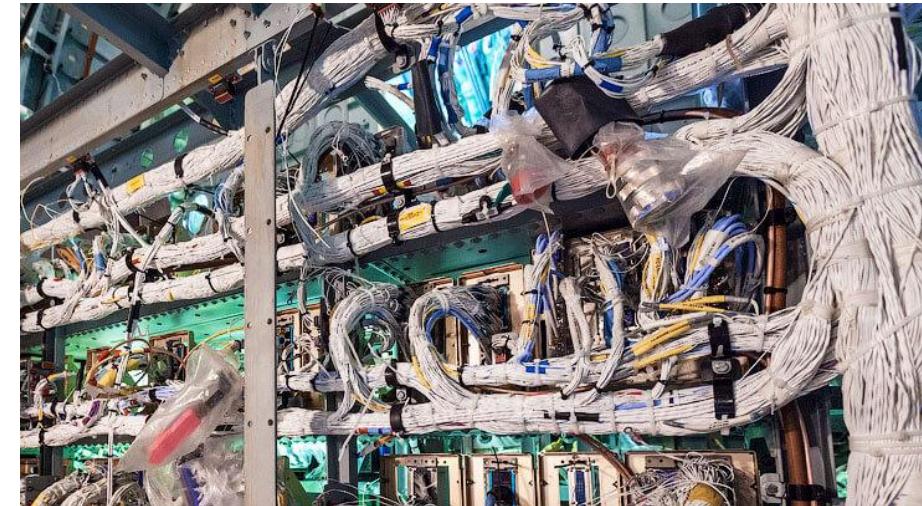


- Avionics networks
  - ARINC 664 Part 7 (AFDX)
  - ARINC 429
  - ARINC 629
  - ARINC 825 (CAN)
  - MIL-STD-1553
  - Commercial Ethernet
    - In-flight Entertainment & Connectivity (BE traffic)
    - Over 1 Gbps
  - ...

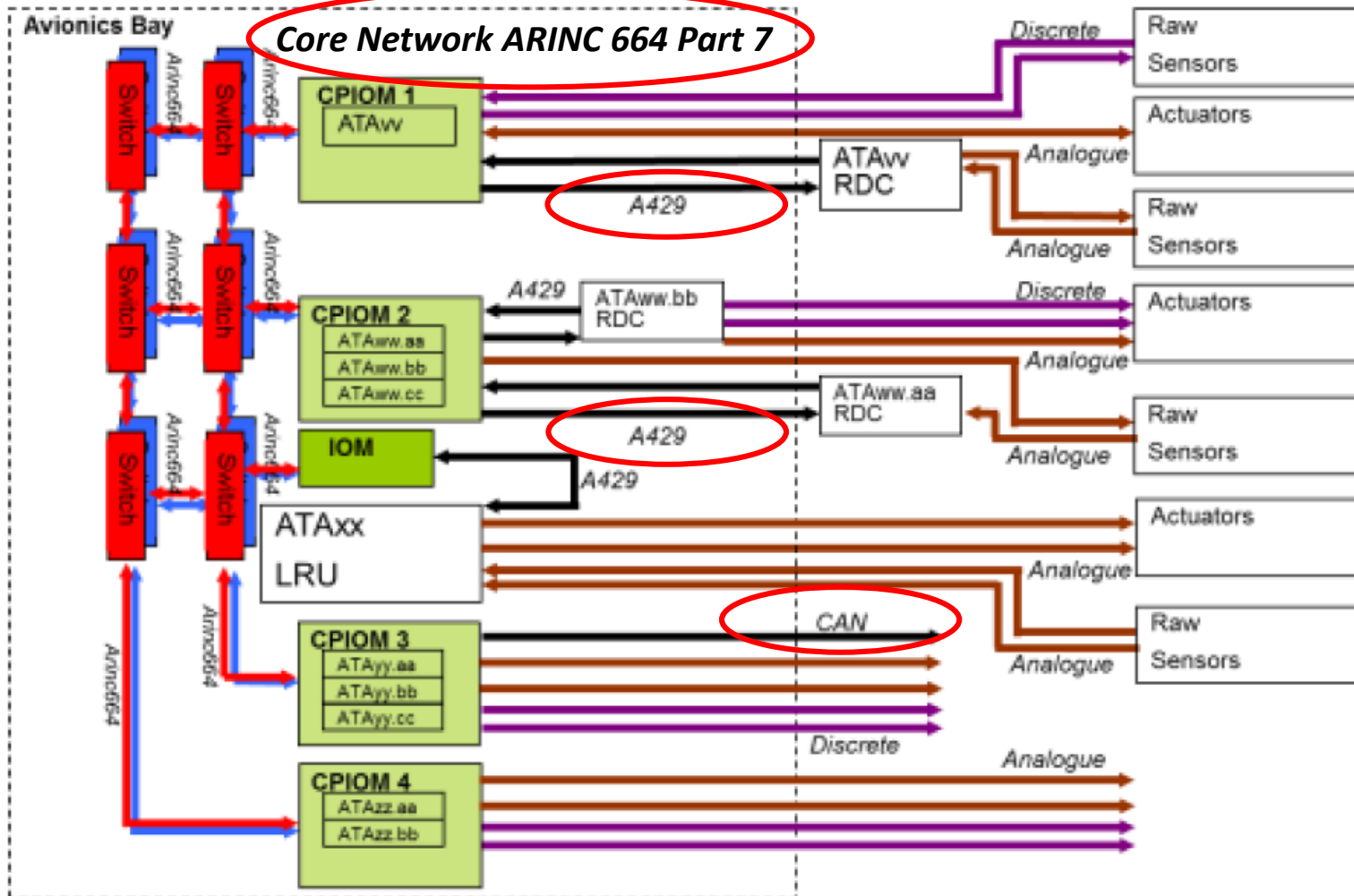


# Global context

- Avionics networks
  - A380: 100,000 different wires, totaling 530 kilometers

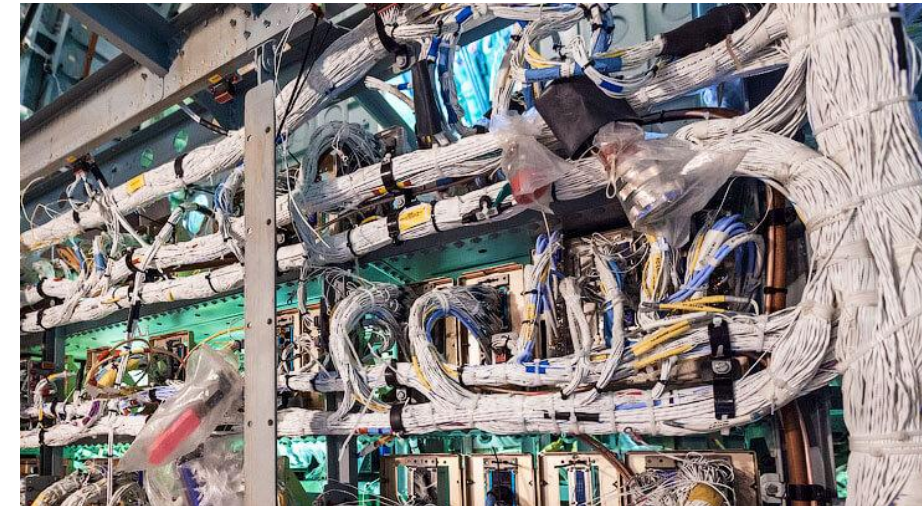


*Aircraft cabling*

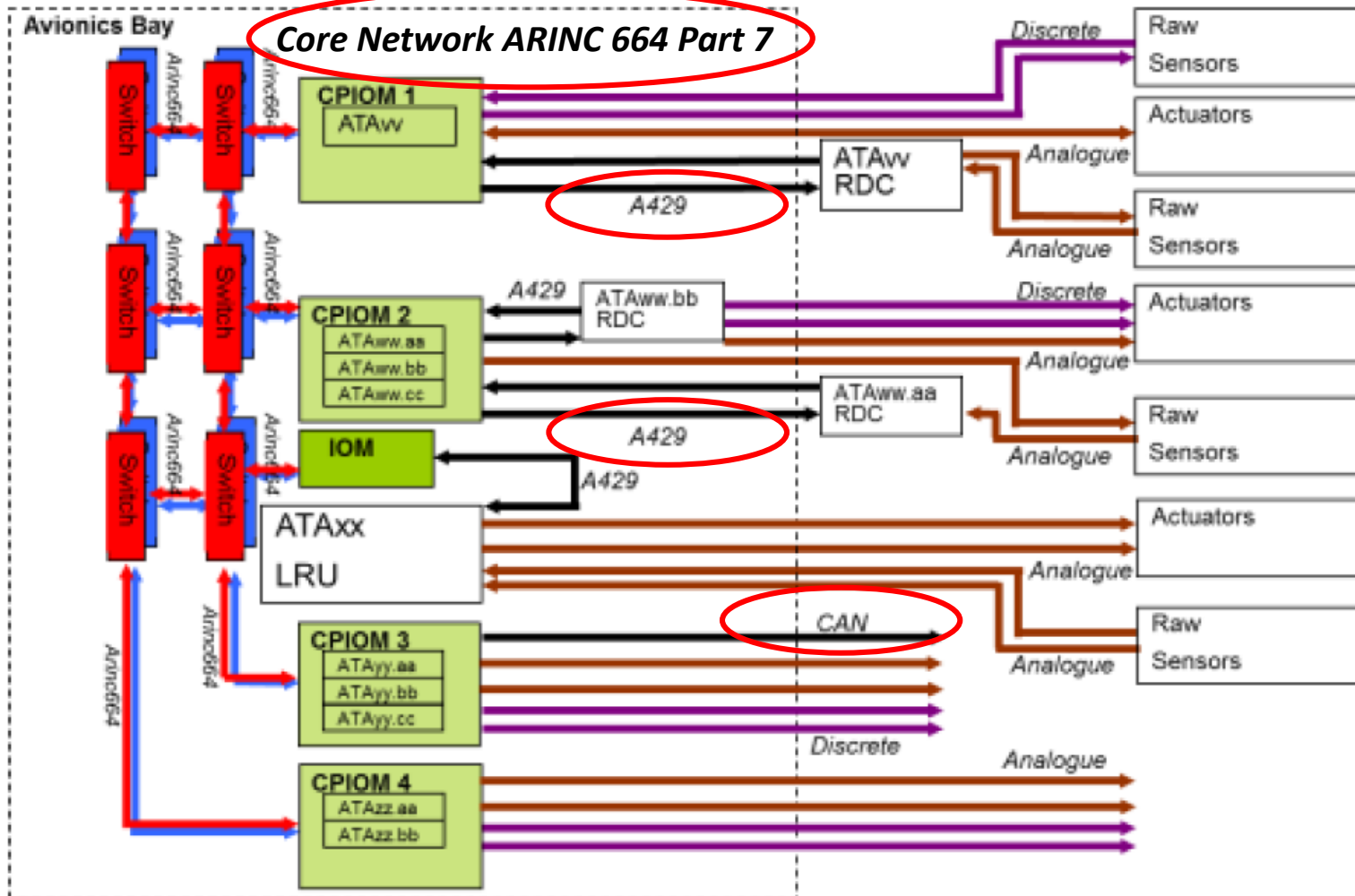


# Global context

- Avionics networks
  - Challenges: reduce SWaP (Size, Weight and Power), maintenance and certification costs



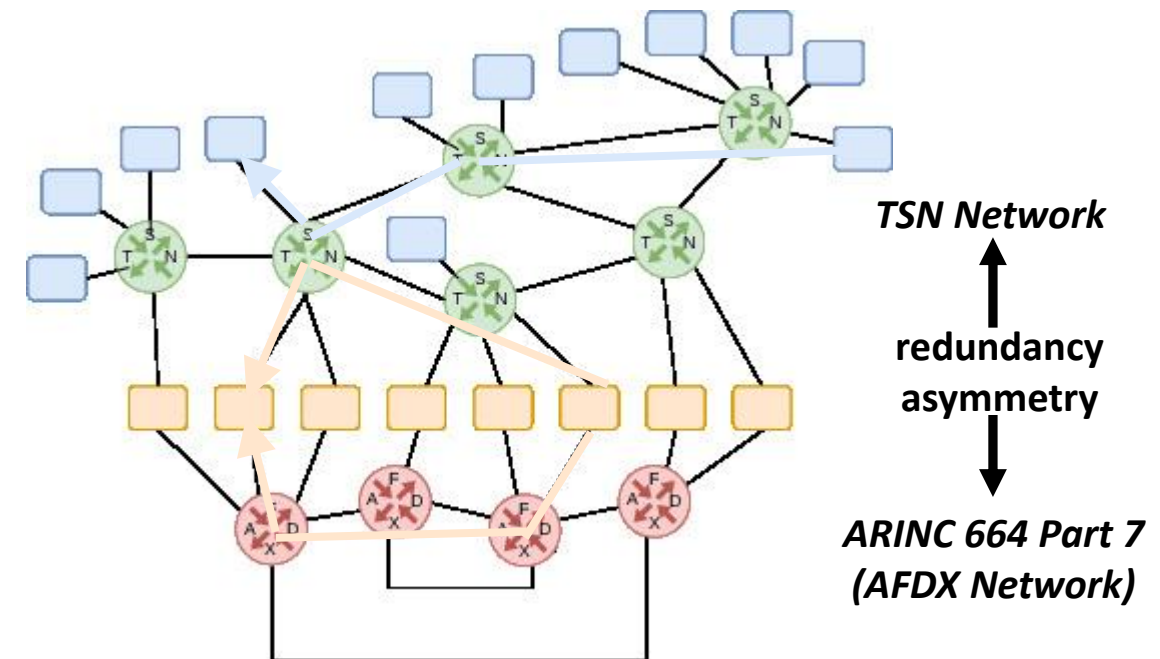
*Aircraft cabling*





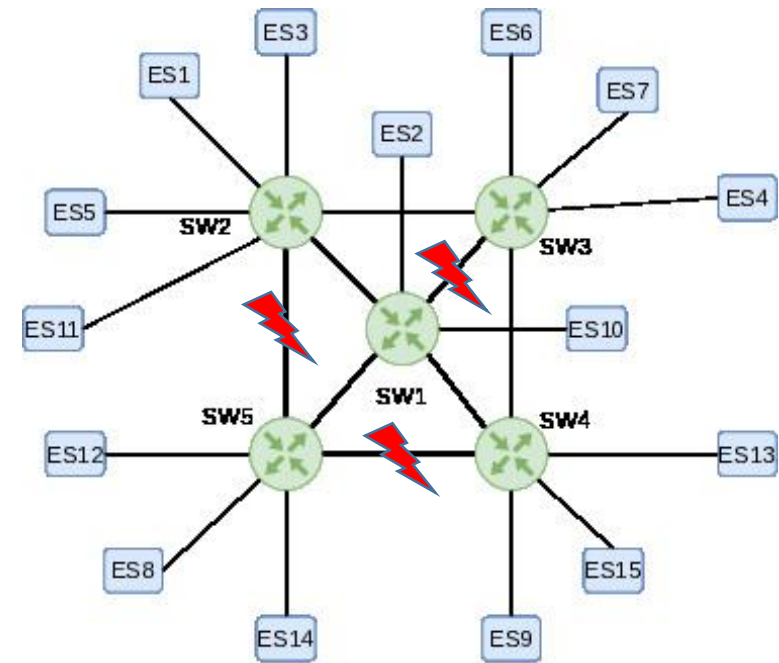
# Global context

- TSN: the new real-time Ethernet
- Candidate as future avionic data backbone
- Hosting both
  - Critical data flows (in redundancy with legacy AFDX)
  - And non-critical data flows



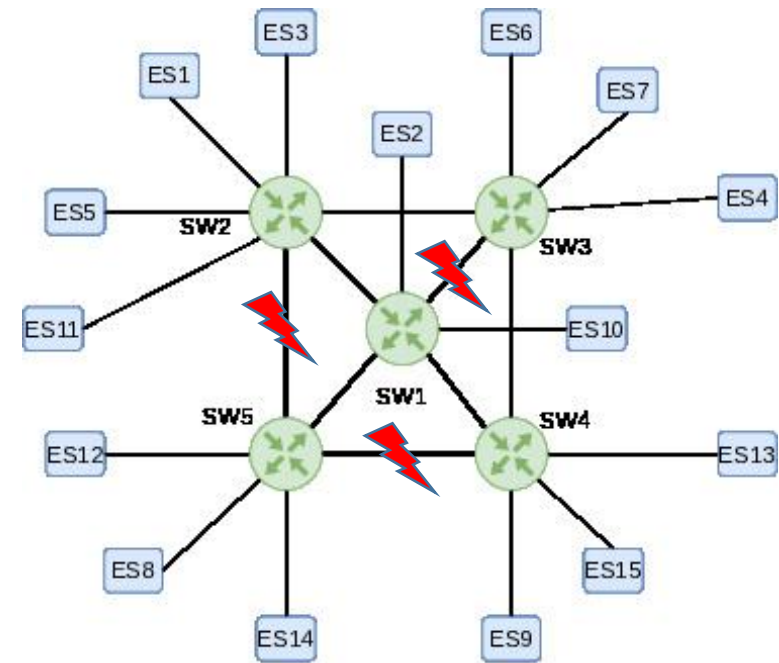
# Challenge context

- TSN-only
- Set of real-time data flows (*streams*)
- Initial static configuration
- Possible faults



# The challenge itself

- In case of faults
  - Computing a new configuration
  - Still ensuring real-time guarantees
  - At least for most critical flows
    - Notion of flow utility/criticality
  - In short amount of time
  - Using embedded resources
  - While maintaining service



# The challenge limits

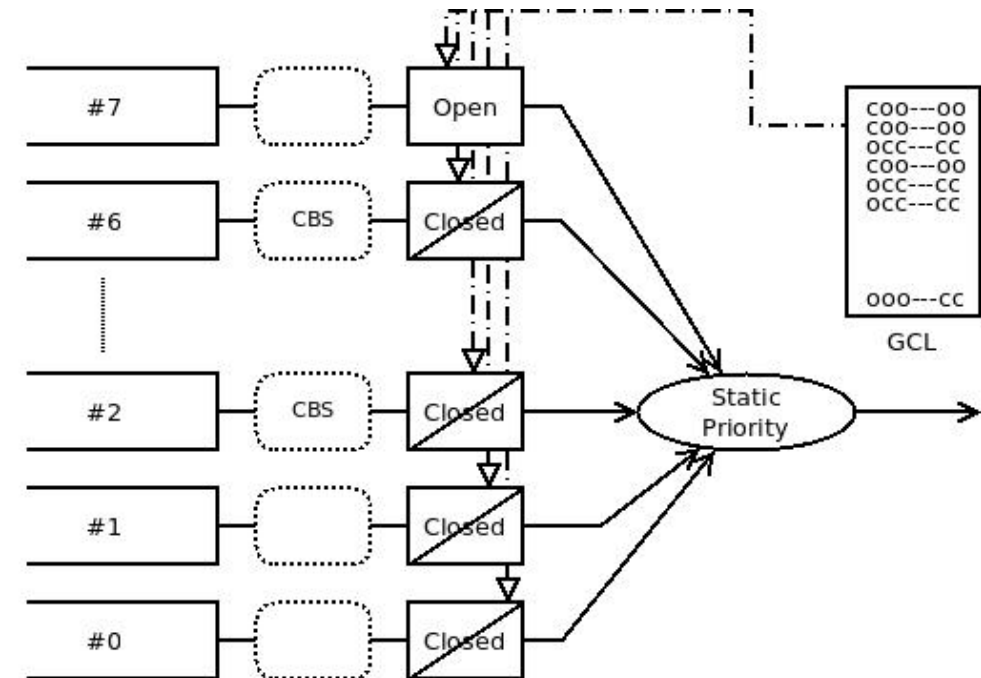
A subset of TSN

- One Time Aware Shaper queue (#7)
- A few Credit-Based-Shaper queues (#6-#2)
- Best-effort traffic

TAS / TT  
/ TDMA

CBS

BE





# Is it really a challenge?

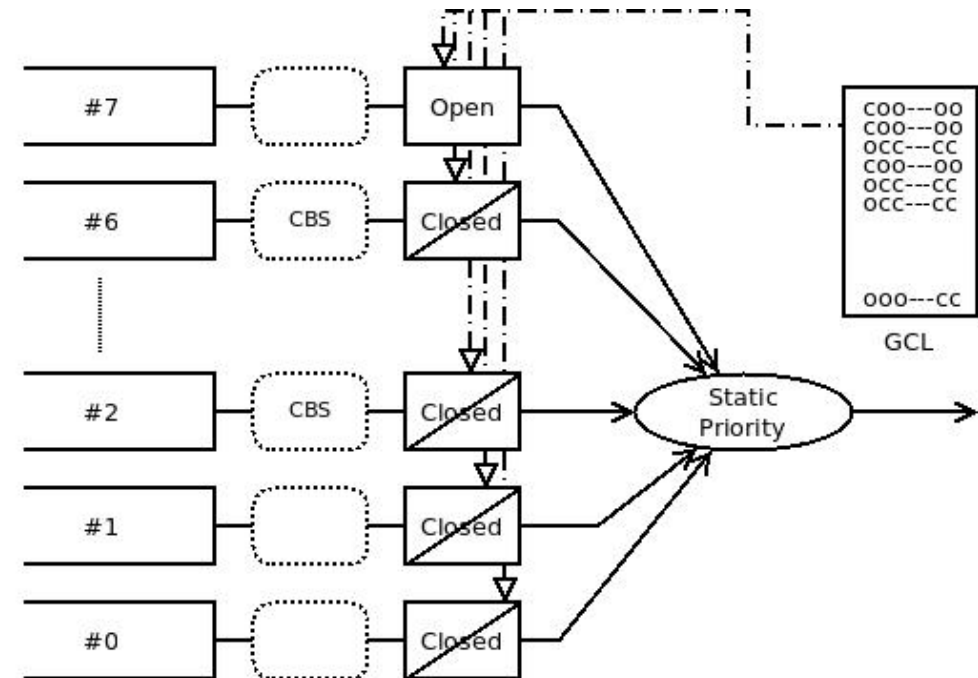
# TAS configuration challenge

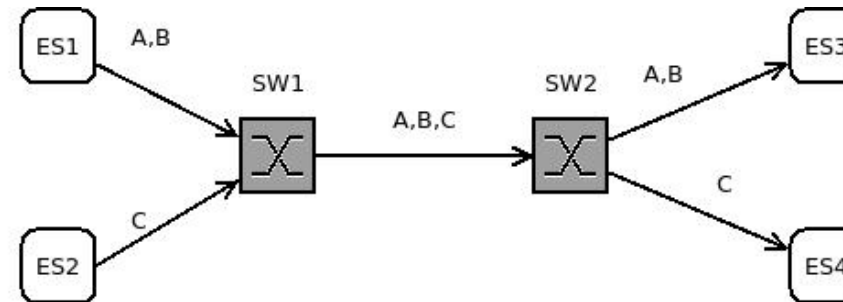
- TAS : Time Aware Shaper Hard
- Basic idea: Time-Triggered schedule
  - Cyclic behavior
  - One time window = one frame
- End-to-end schedule
  - Alignement of windows allong the path
- TAS with TSN: queuing semantics
  - Based on gate schedule
  - Sends the head of queue Harder

TAS / TT  
TDMA

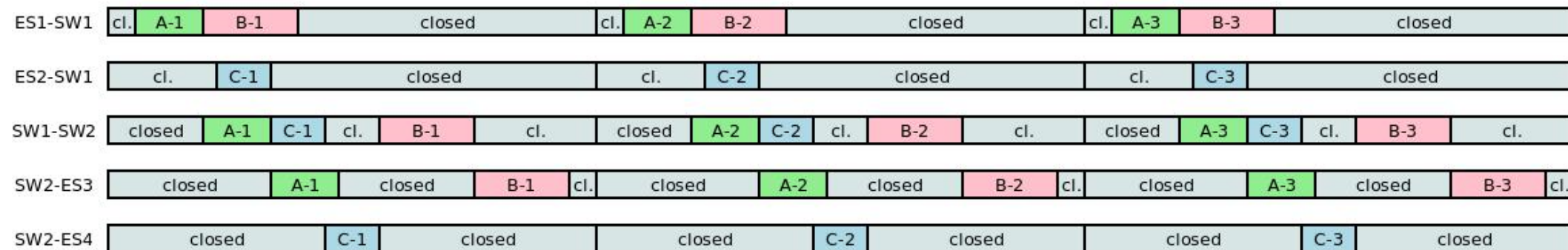
CBS

BE

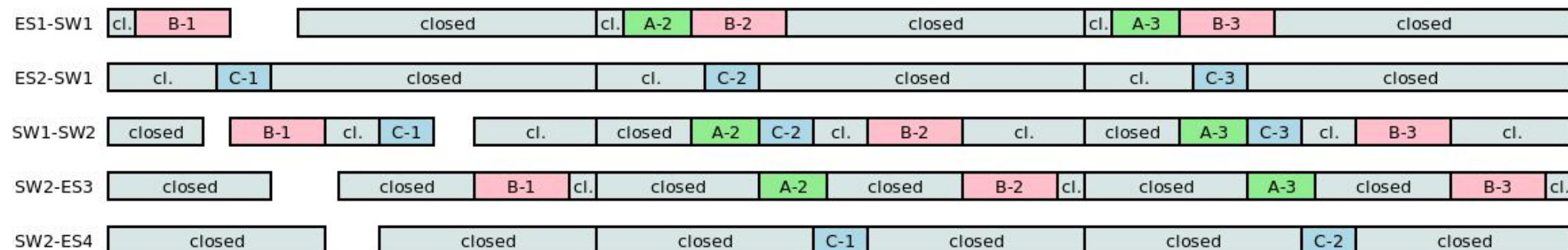




Nominal TAS behavior



Loss impact



# TAS re-configuration challenge

- Short configuration time (s – mn)
- Incremental schedule (keep existing windows, as much as possible)
- But re-schedule based on utility
  - Ex: route of flow  $f$  is broken
  - No (route,schedule) is found
  - Some lower utility flows can be removed: which ones? How many?
- The coherence problem ....

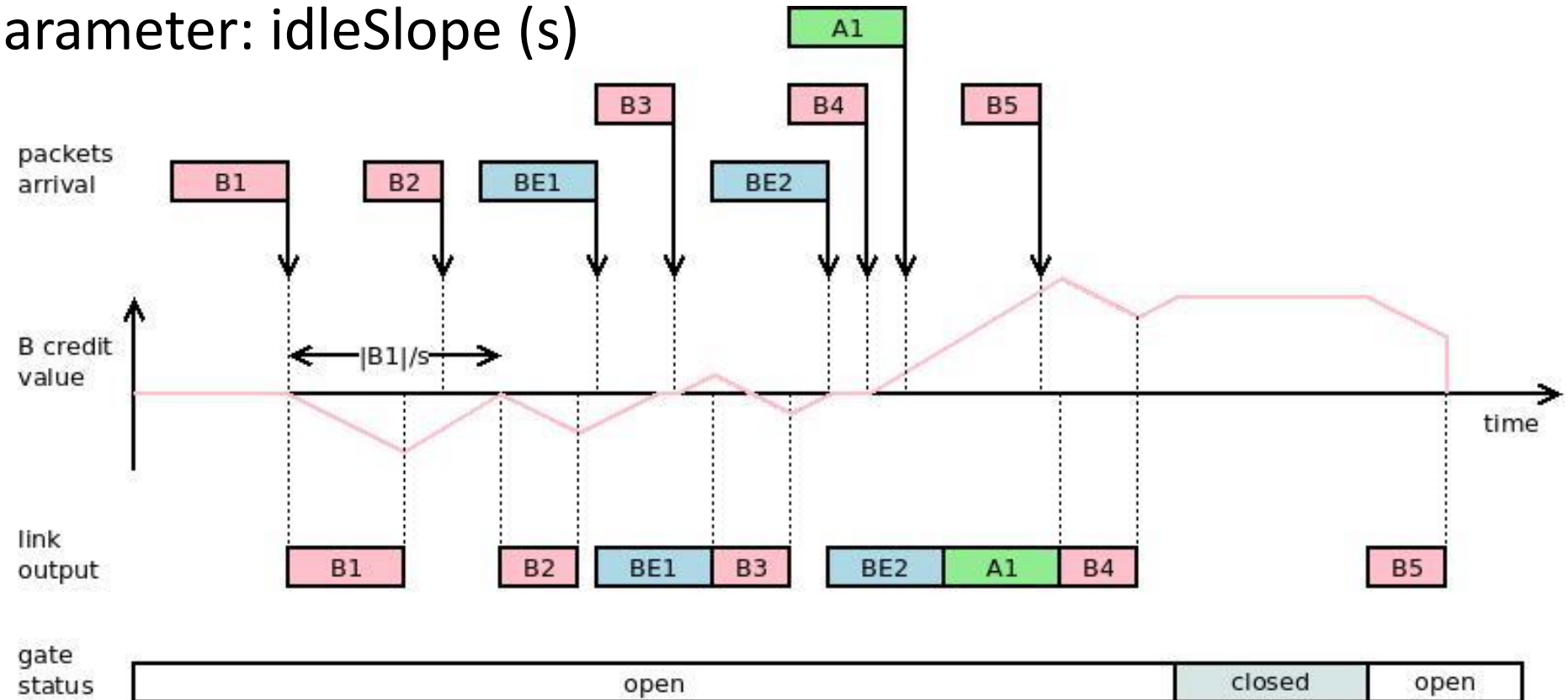


# The coherence problem

- Removing a flow: cf. loss and queueing semantics
- Adding a flow (because of re-routing)
  - Need add of dedicated time window
  - In each node along the path
- Problem: deployment of new configuration along all paths

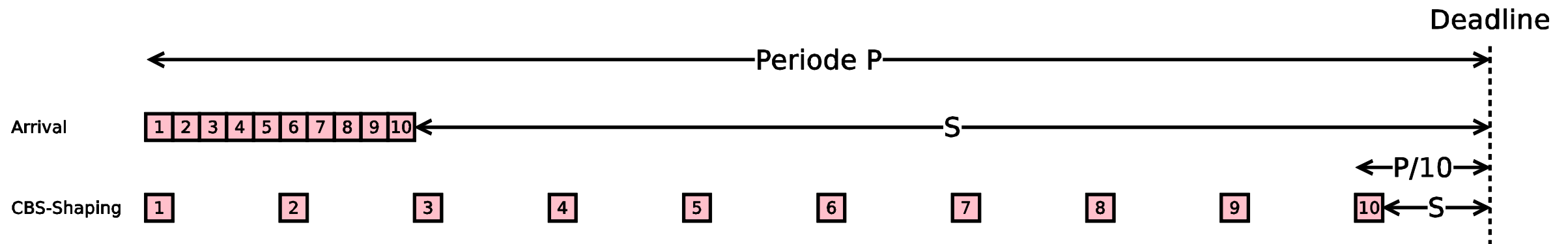
# CBS configuration challenge

- CBS: Credit-based Shaper / Based on evolution of a credit
- Per queue parameter: idleSlope (s)



# CBS configuration challenge

- Configuration: set one slope per queue along the path
- The trivial (false) idea:
  - Let  $r_i$  the throuput of flow  $i$
  - Let  $F(p)$  be the set of flows crossing port  $p$
  - Set  $s(p) = \sum_{i \in F(p)} r_i$
- Exemple: 10 flows, same (source, dest, size, period), implicit deadline



# CBS configuration challenge

## Configuration main steps

- Assign a local deadline per queue (same for all flows in the queue)
- Evaluate interferences of
  - Higher priority flows
  - Gate closing (TAS interference)
- Compute a slope



# CBS re-configuration challenge

## Configuration main steps

- Assign a local deadline per queue (same for all flows in the queue)
- Evaluate interferences of
  - Higher priority flows
  - Gate closing (TAS interference)
- Compute a slope
- In short amount of time

# Conclusion

# How to contribute?

- [github.com/ecrtsorg](https://github.com/ecrtsorg)
  - Textual description of the challenge
  - Full Data set (topology, flows characteristics)
  - Mailing list