ADAPTIVE NETWORK TRAFFIC REDUCTION WITH PROGRAMMABLE DATA PLANES

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Introduction

- Industrial networks use standard real-time communication protocols, e.g.: ProfiNet
  - Cyclic data exchange between IO devices and PLCs
  - IO devices report at predefined frequency
    - Unchanged device state is a life signal
- The traffic generated by a single device is insignificant, but in an industrial site with hundreds of such devices, the number of packets to be transmitted adds up

Cloud-assisted industrial environment

- Data communication between IO devices (sensors and actuators) is deployed in the industrial site
- Software PLCs running in the cloud
- The industrial site has a 5G radio access to connect
  - software PLCs
  - IO devices

Problem statement

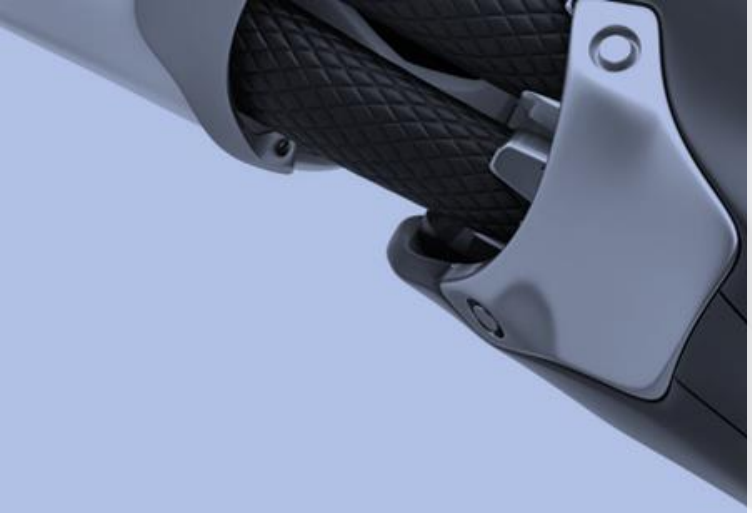
Connecting PLCs and IO devices via 5G is challenging

- Sensors and PLCs send status signals with predetermined frequencies usually between 1 and 1000 Hz
- High overhead affecting both spectral and energy efficiency

Big percentage of the data is redundant

- No new sensor information
- PLCs and IO devices are sensitive to packet loss and jitter

Packet filtering is not an option



Active – Passive phases

Active phase

- Reported IO data continuously changes
  - Robot arm performs an industrial task
  - Temperature sensor environment is not static

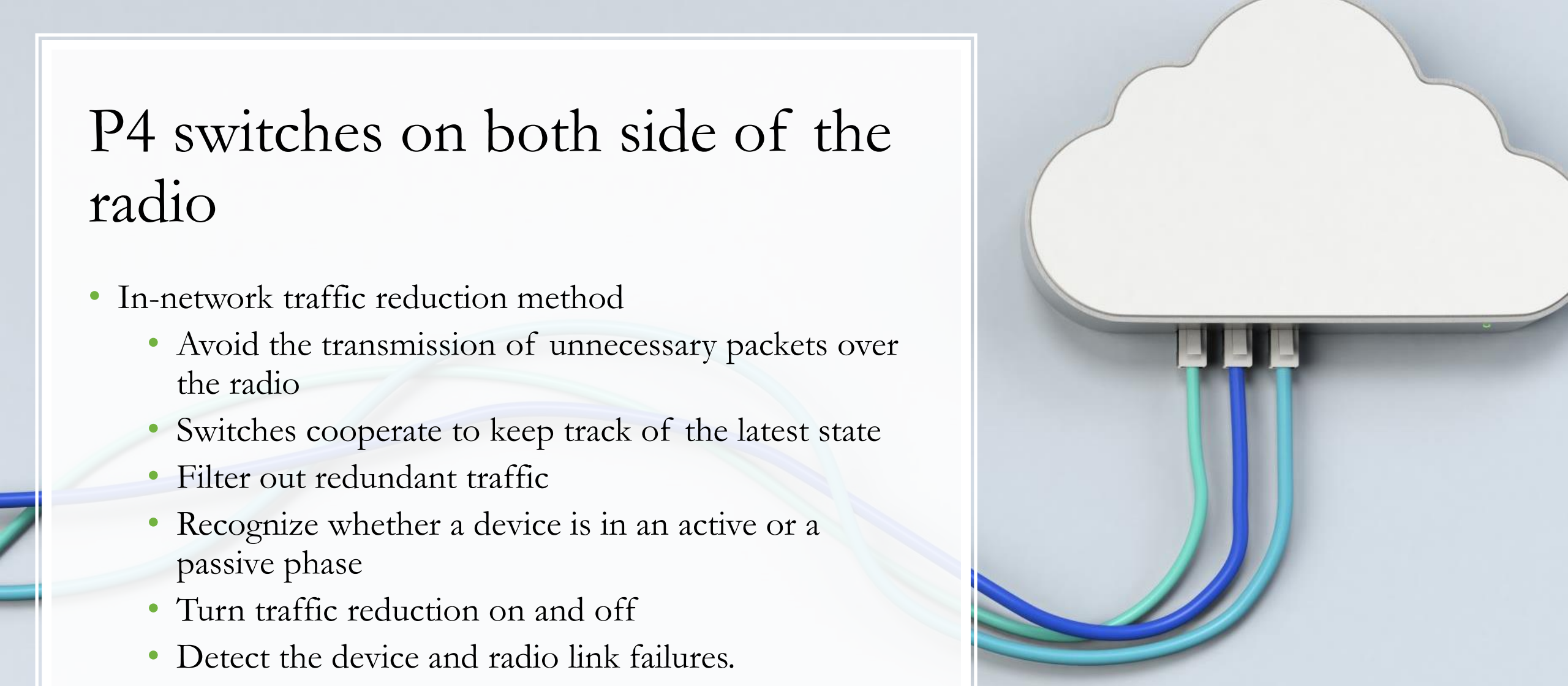
Passive phase

- IO device is in an idle state
  - robot arm waiting for the next product
  - Temperature sensor environment is static
- Network traffic with constant IO data.

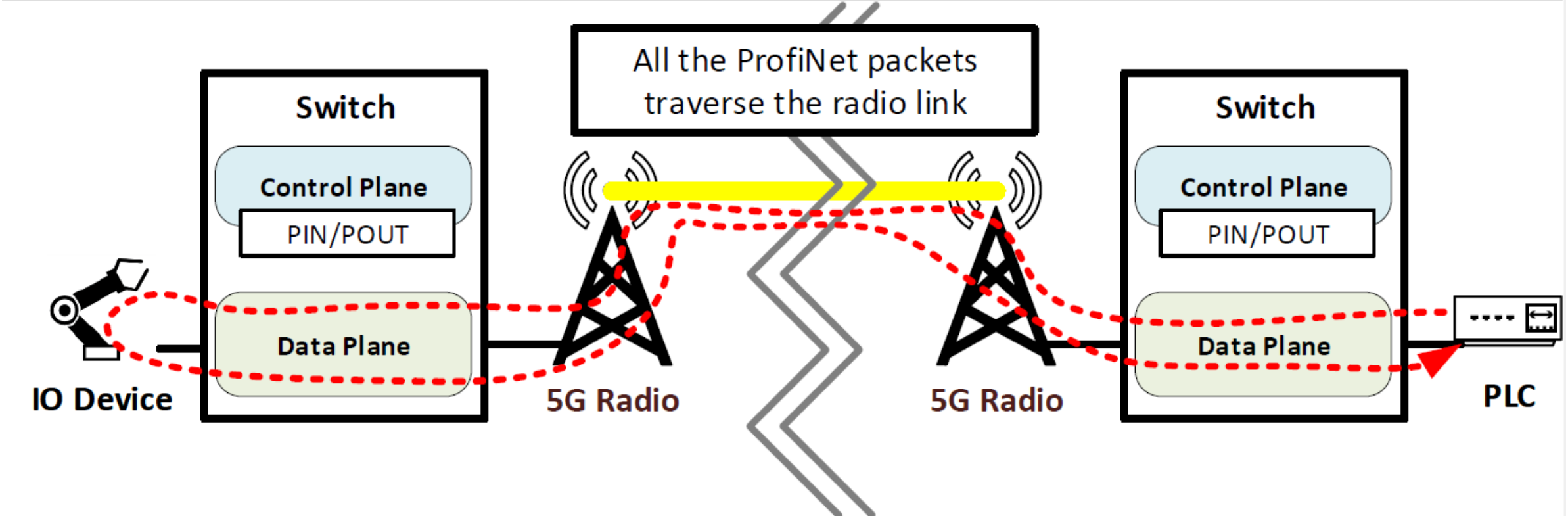
Passive and active phases alternate with each IO device

P4 switches on both side of the radio

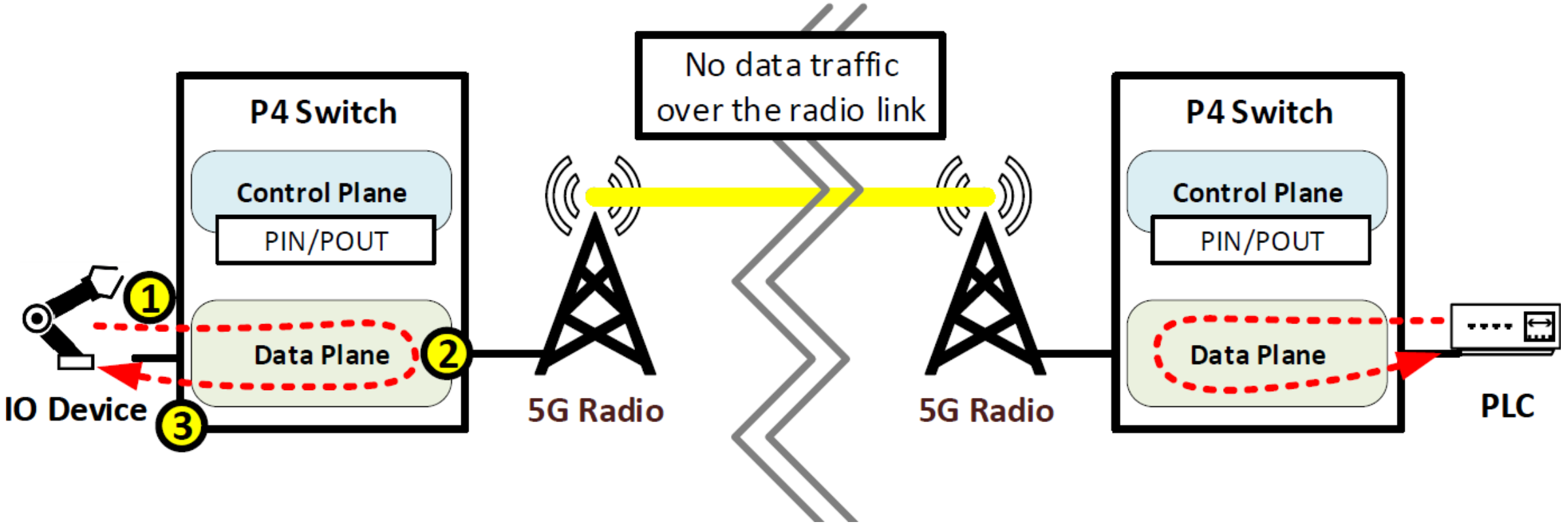
- In-network traffic reduction method
  - Avoid the transmission of unnecessary packets over the radio
  - Switches cooperate to keep track of the latest state
  - Filter out redundant traffic
  - Recognize whether a device is in an active or a passive phase
  - Turn traffic reduction on and off
  - Detect the device and radio link failures.
- No modification in the IO devices or in the protocol



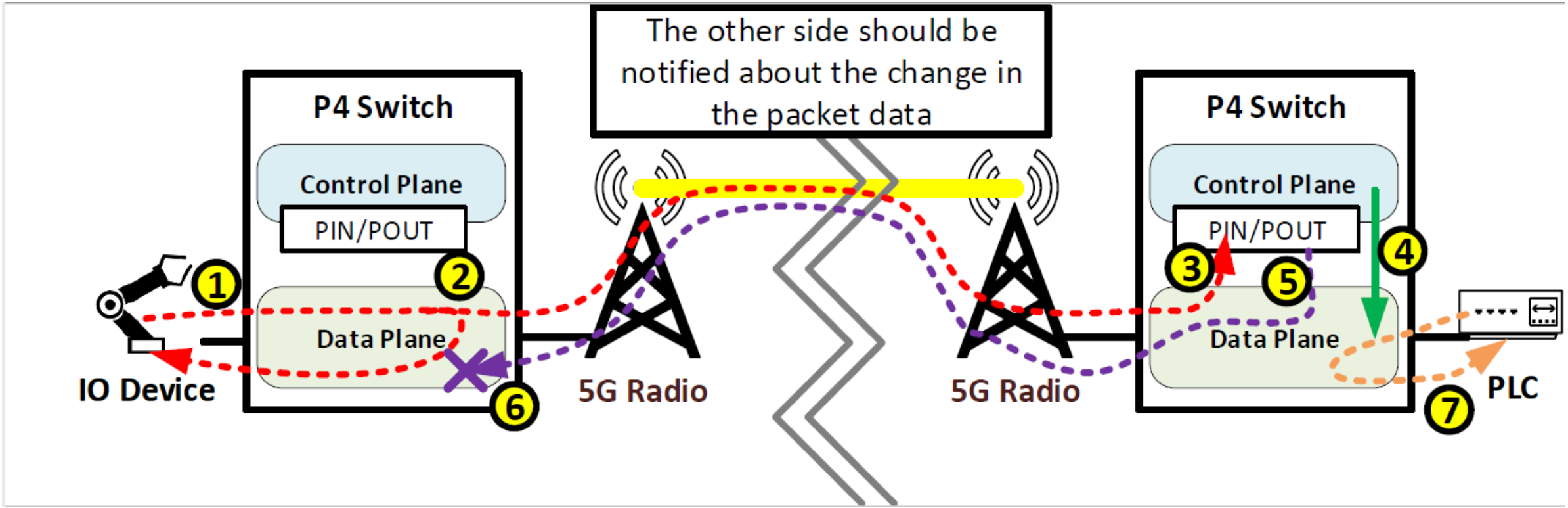
System overview – Simple forwarding



System overview – Traffic reduction (Data const.)



System overview – Traffic reduction (data changes)



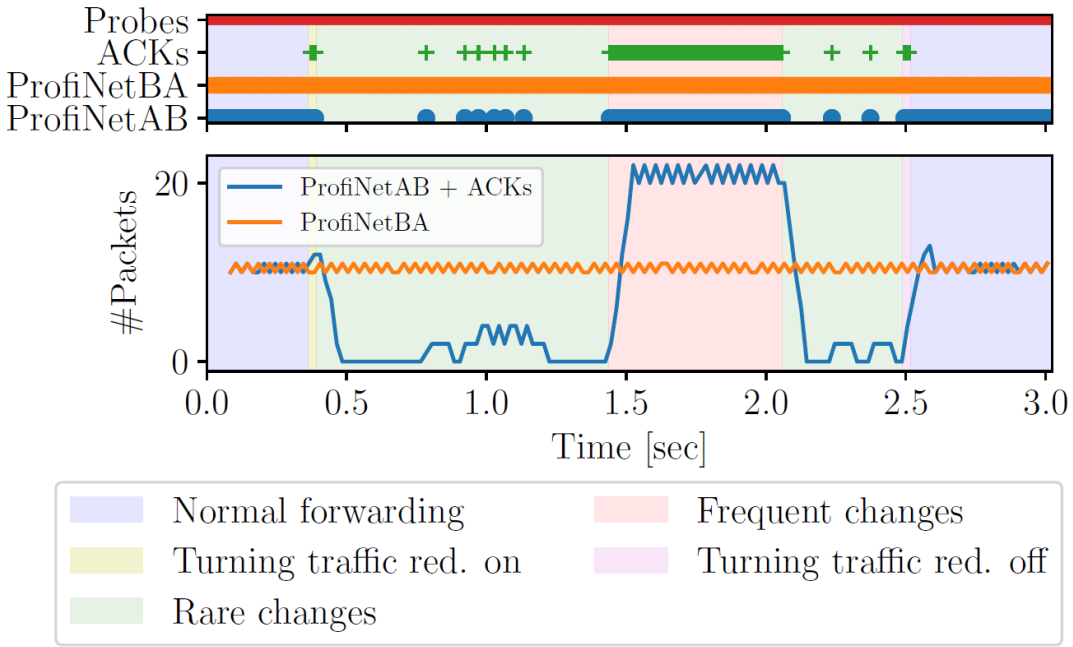
Missing Event Detection

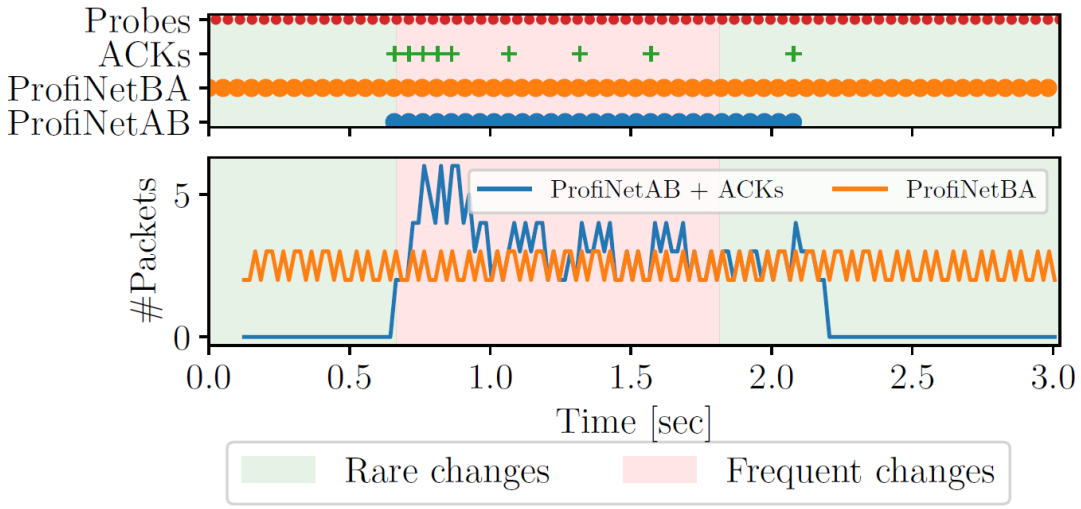
- React to failures as soon as possible
  - A packet generator engine generates probe packets at a predefined frequency
  - The probe filled with the status bitmap of IO devices
  - The probe sent over the radio link (TTL-1)
  - Probe received from the other side of the radio (TTL reset)
  - The bitmap of device states is refreshed according to the received information, and the probe packet is dropped.
- If failure is detected, the automatic responses stop
  - Original behavior of the industrial network

Adaptivity

- In active phase
  - Traffic reduction method doubles the load on the radio link
  - Overhead of CP-ACK and Probe packets
- Dynamically enable and disable traffic reduction
- 3 possible options upon arrival of an IO data packet
  - Turn off traffic reduction
  - Turn on traffic reduction
  - Learn the new IO data, don't turn on traffic reduction yet
- Action is selected based on how frequently the IO data of a given device changes

Evaluation


Probes
ACKs
ProfiNetBA
ProfiNetAB
#Packets
20
0
ProfiNetAB + ACKs
ProfiNetBA
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time [sec]
Normal forwarding
Turning traffic red. on
Rare changes
Frequent changes
Turning traffic red. off


Probes
ACKs
ProfiNetBA
ProfiNetAB
#Packets
5
0
ProfiNetAB + ACKs
ProfiNetBA
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time [sec]
Rare changes
Frequent changes

Results

- Adaptive Network Traffic Reduction on the Fly with Programmable Data Planes
- IEEE ACCESS – Under revision
  - Györgyi Csaba, Vörös Péter, Kecskeméti Károly, Laki Sándor, Szabó Géza (Ericsson)

- Radio Propagation Digital Twin Aided Multi-Point Transmission with In-network Dynamic On-Off Switching
- IEEE JSAC Special Issue on Digital Twins for Mobile Networks – Waiting for review
  - Györgyi Csaba, Vörös Péter, Laki Sándor, Szabó Géza (Ericsson)

Thank you for your attention!

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Hungary

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