Revitalizing Industrial Networking with Programmable Data Planes

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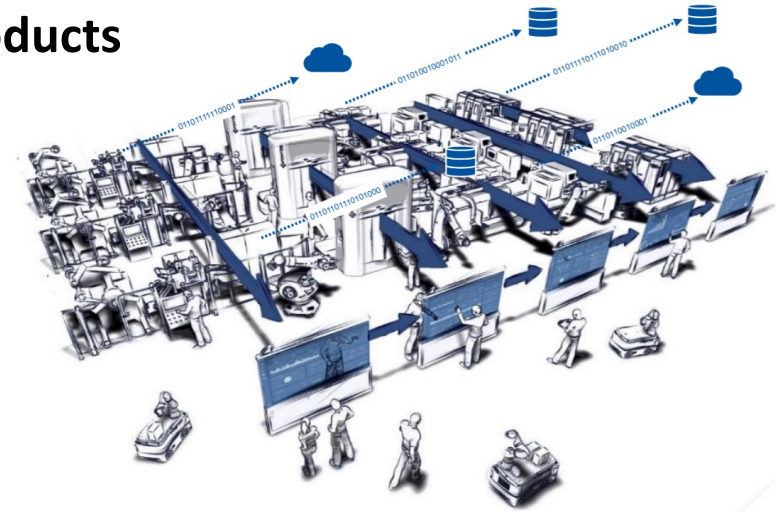
Industry 4.0
Highly integrated smart production

- **Increasing need for more customized products**



- **Flexible production lines are needed**
  - Cost effective personalized production
  - Fast reconfiguration
  - Agile behavior

- Softwarization has already started, but it is **slow and painful** process

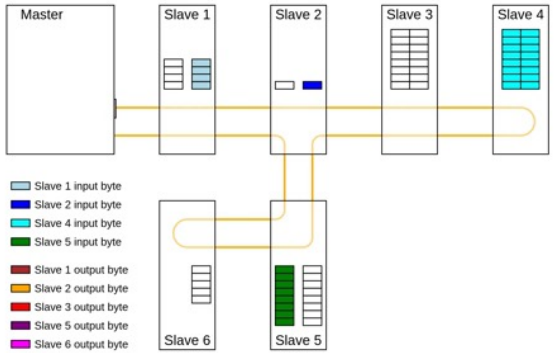
Why softwarization is difficult?

- Industrial applications have **strict requirements**
  - Availability, security and timeliness
- **Most devices are designed for long term operation (>10years)**
  - High cost of acquiring devices
  - Protocol updates are generally not possible
  - Replacement with smarter alternatives is unrealistic
- Industrial protocols designed for **closed industrial networks**
  - Assuming low latency, almost zero loss, reliable (wired) links
  - **Ensuring the integration of various field devices**

Two industrial protocol examples

- **ProfiNet**
  - E2E communication
  - Cyclic IO data exchange between each IO device and a responsible controller
  - Predefined cycle time/update period (1ms-10sec in general)
  - Packets even if the state (IO data) is not changed

- **EtherCAT**
  - Daisy chain communication
    covering a master and several slaves
  - Master periodically sends EtherCAT frames
  - Each slave reads/writes a spec. part of the same frame

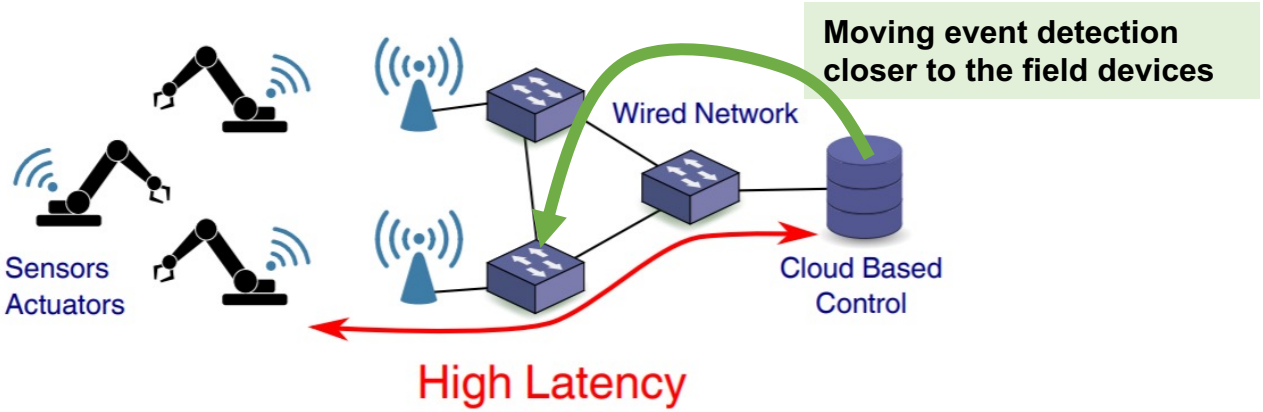


Source: wikipedia.com

Towards increased flexibility

Trend & Challenge 1

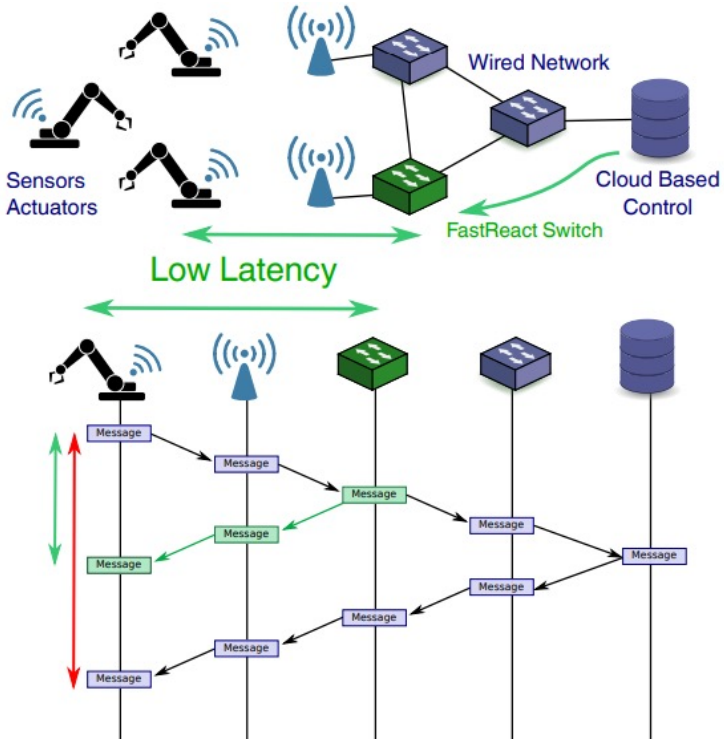
- **Cloud-based industrial controllers** (e.g., SoftPLCs)
  - **PRO: Software-based alternatives to hardware solutions**
  - **CON: Larger latency - e.g., slow reaction to emergency situations**
    Sensors may generate large amount of data to be transmitted (esp. imaging)
  - **IDEA: moving time-critical computations closer to the field devices**
- Example: **In-network event detection with FastReact**



In-network event detection with FastReact*

- **Local Decision Making** instead of centralized control
  - Early reaction reduces time required for processing
  - Reduces network data rate
  - Fewer devices that can fail
- **FastReact**
  - Implemented in P4 data plane programming language
  - Reconfigurable rules in runtime using BNF
  - Trigger local actions based on locally stored data

```
if (sensor1 > 50) && (sensor2 < 25):
    trigger_actuator(<portno>)
```

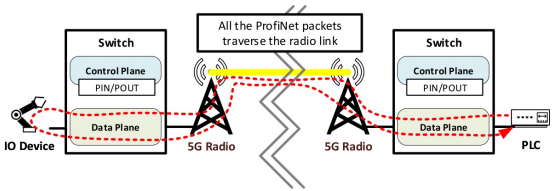


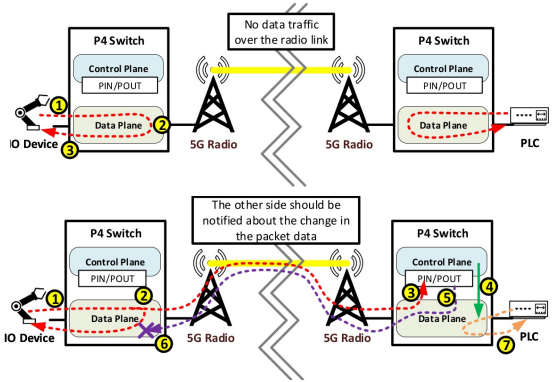
* *J. Vestin, A. Kassler, S. Laki, G. Pongrácz:* ***Towards In-Network Event detection and Filtering for Publish/Subscribe Communication using Programmable Data Planes****, In IEEE Transactions on Network and Service Management (IEEE TNSM), Volume: 18, Issue: 1, Page(s): 415 - 428, March 2021*

Towards increased flexibility

Trend & Challenge 2

- **Wireless links between field devices**
  - **PRO: Recabeling is a significant cost factor in the reconfiguration of prod. lines**
  - **CON: spectrum efficiency issues and larger energy consumption**
    - Industrial protocols not designed for wireless transmission, e.g. (cyclic IO data packets pollutes the radio link with tiny packets, daisy chaining over wireless links...)
  - **IDEA: reducing unnecessary traffic over radio links**
- Example: **ProfiNet traffic reduction over a radio link with in-network caching and filtering***





** Cs. Györgyi, K. Kecskeméti, P. Vörös, G. Szabó, S. Laki: **In-network Solution for Network Traffic Reduction in Industrial Data Communication** [Accepted], IEEE Int. Conference on Network Softwarization 2021 (IEEE NetSoft'21), 28 June-2 July 2021*

Conclusion

- Programmable data planes have **many practical benefits for industrial nets**
  - Enables incremental improvements in the network
  - Without any modification in the field devices and the used protocols
- **Accelerating the deployment of new technologies**
  - Cloud-based industrial control
    - Offloading latency sensitive decisions into the network dataplane itself
  - Wireless setups (e.g., 5G radio)
- **Further areas not covered in this talk**
  - Cloud robotics
  - P4 for TSN data plane mechanisms (redundancy, frame preemption,…)
  - Real-time control in cloud or edge-cloud

Thank You

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