2021 IEEE Standards Association (IEEE-SA) Ethernet & IP @ AUTOMOTIVE TECHNOLOGY WEEK

Reimagining Vehicular Communication using Programmable Data Plane Technologies

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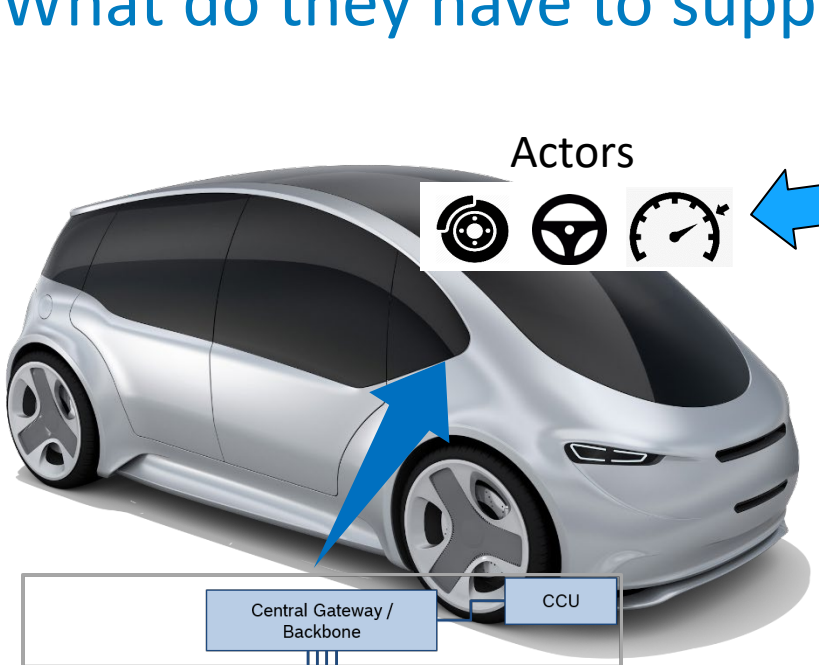
BOSCH

Agenda

1. Need for flexibility in Automotive Networks
2. Status Quo
3. Programmable Data Plane (PDP) Technologies
4. Service Oriented Communication with PDP
5. Open Challenges
6. Outlook

Automotive Networks of the Future

What do they have to support?



Autonomous Driving

Fail-over

Graceful Degradation

Tri-modular Redundancy

Fail-Operational

Lockstep

Strict QoS requirements

Automotive Networks of the Future

What do they need?

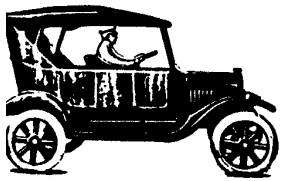
- We need more bandwidth

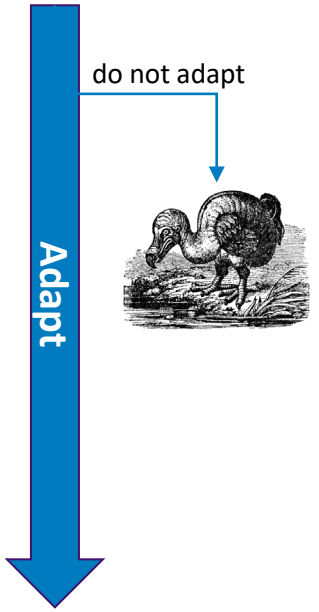
AUTOMOTIVE ETHERNET ✓

- We need freedom from interference

IEEE TSN ✓

- We need to adapt to changing communication patterns in the field ?





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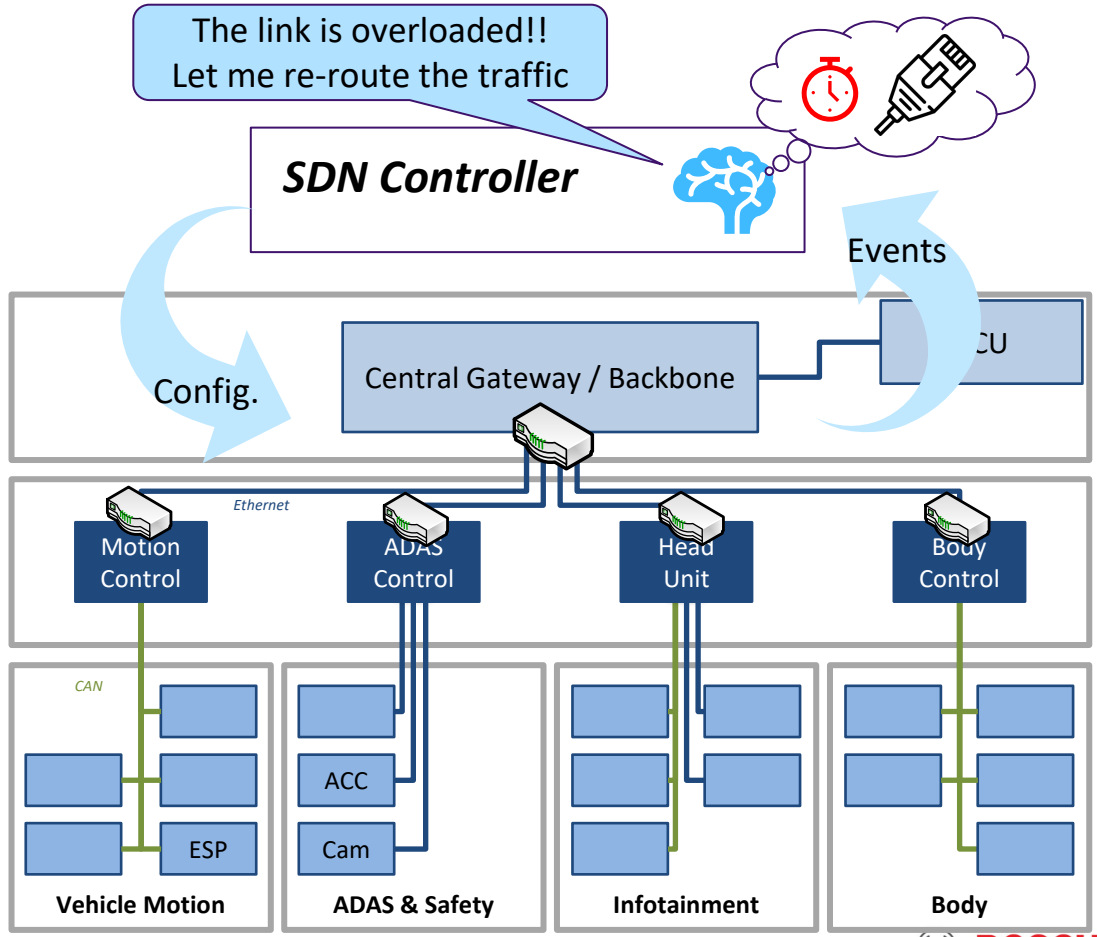
Automotive Networks of the Future

How to make them flexible?

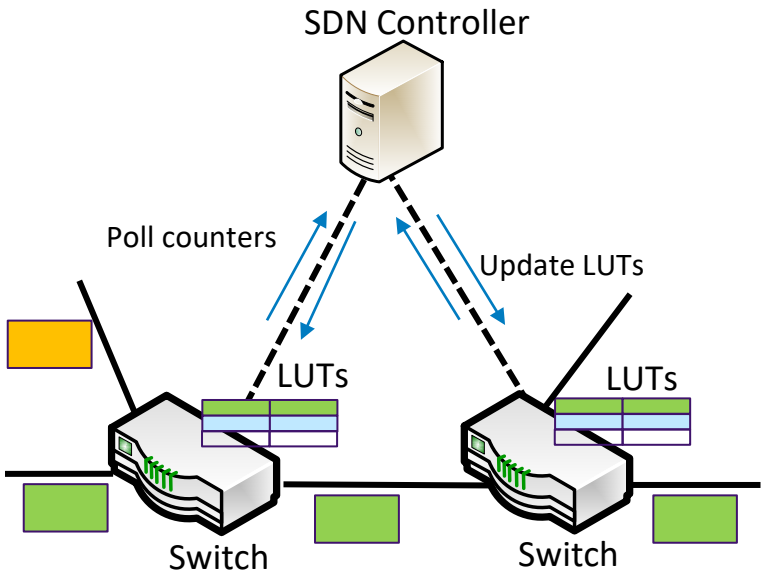
Software-defined Networking (SDN)

- Separation of the network control plane from the data plane
- Logically centralized control plane
- Network Management using well-defined interfaces (e.g. OpenFlow)
- Can be used for managing TSN



Automotive Networks of the Future

What is missing with SDN?

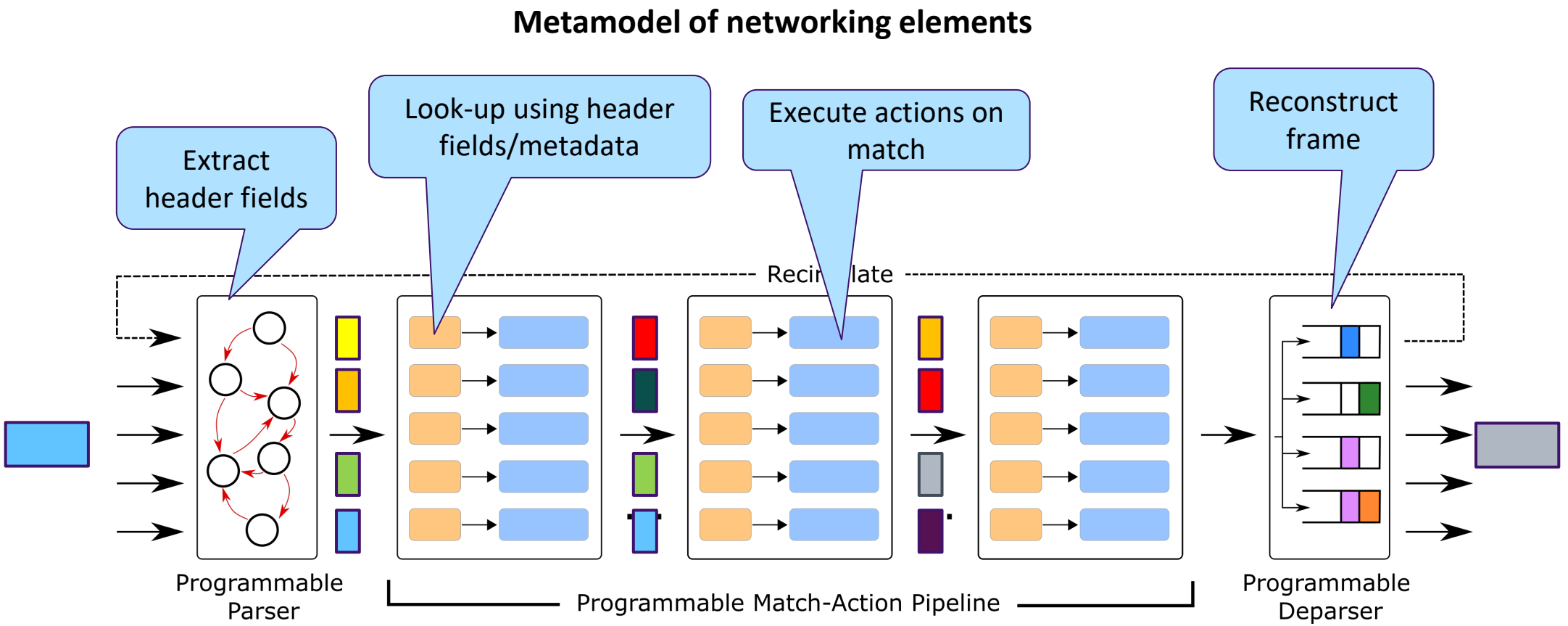


- Limited programmability in the data plane
  - Pre-defined look-up tables (LUTs)
  - Packet and event counters
- No influence on packet processing
- Need to go beyond what a switch can do?
  - Go to the switch CPU (slow and painful)
  - Include reconfigurable hardware (e.g. FPGA)

Programmable Data Planes (PDP)

Reconfigurable Match-Action Pipeline

Based on the P4_tutorial.pptx from P4.org



Programmable Data Planes (PDP)

P4: Modelling Network Forwarding Functions

Based on the P4_tutorial.pptx from P4.org

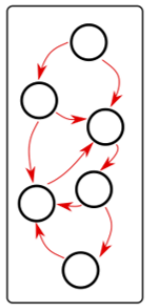
```
#include <core.p4>
#include <v1model.p4>
struct metadata {}
struct headers {}
```

Includes & defines

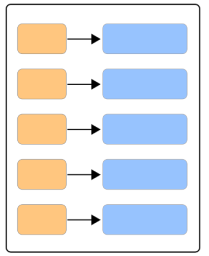
```
state start {
    transition parse_ethernet;
}

state parse_ethernet {
    packet.extract(hdr.ethernet);
    transition select(hdr.ethernet.etherType) {
        TYPE_IPV4: parse_ipv4;
        default: accept;
    }
}

state parse_ipv4 {
    packet.extract(hdr.ipv4);
    transition accept;
}
```

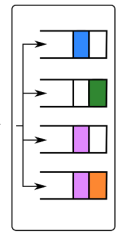


```
table ipv4_lpm {
    key = {
        hdr.ipv4.dstAddr: lpm;
    }
    actions = {
        ipv4_forward;
        drop;
        NoAction;
    }
    size = 1024;
    default_action = drop();
}
```



```
action ipv4_forward(macAddr_t dstAddr, egressSpec_t port) {
    standard_metadata.egress_spec = port;
    hdr.ethernet.srcAddr = hdr.ethernet.dstAddr;
    hdr.ethernet.dstAddr = dstAddr;
    hdr.ipv4.ttl = hdr.ipv4.ttl - 1;
}
```

```
control MyDeparser(packet_out packet, in headers hdr) {
    apply {
        packet.emit(hdr.ethernet);
        packet.emit(hdr.ipv4);
    }
}
```



Fully Programmable Networks
PDP with SDN

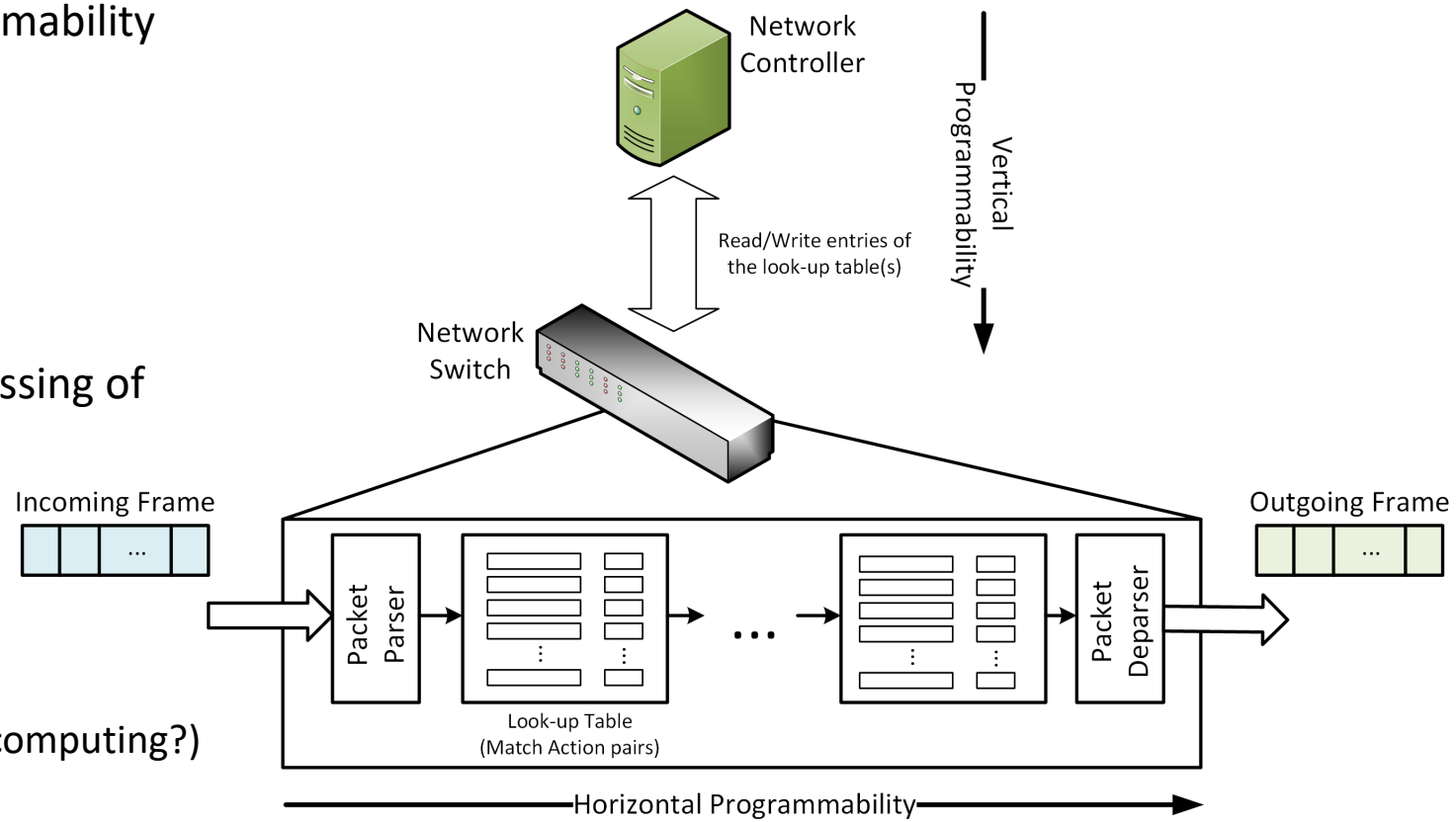
- SDN enables only vertical programmability

  Control Plane → Data Plane

  - Dynamic Network Management

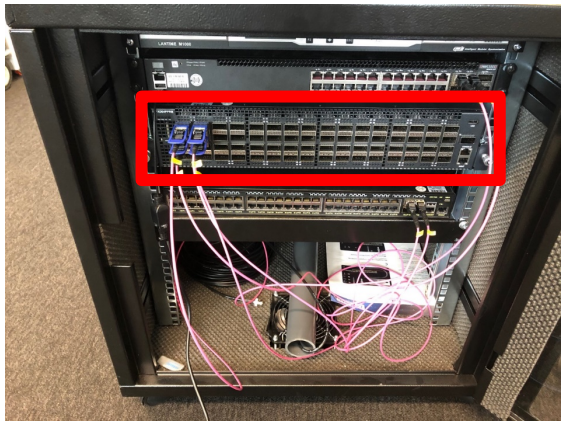
- Horizontal programmability: Processing of packets in data plane devices

  - New protocols & features
  - Faster innovation
  - Application specific networking (& computing?)

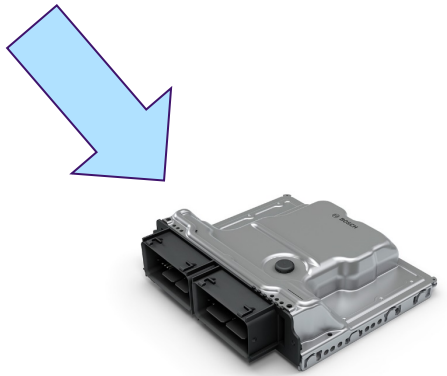


Programmable Data Planes (PDP)
Could it add value to automotive networks?

- Status Quo – PDP
  - Data center origins
  - Provisioned for high throughput
  - Limited real-time considerations

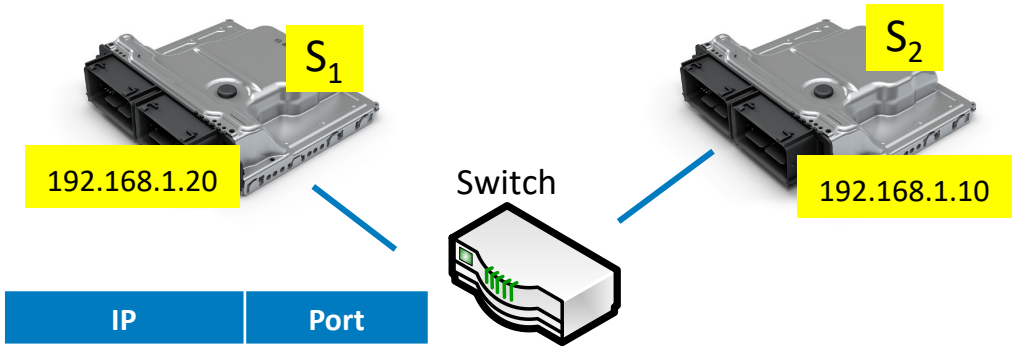


- For Automotive Networks
  - Moving towards service-oriented communication
  - Safety & security considerations
  - TSN for freedom from interference



Service Oriented Communication (SoC) in Automotive
Usecase for PDPs?

- Next generation of automotive softwares
  - Loose collection of services
  - Runtime discovery & middleware-based communication
  - SOME/IP, DDS etc.
- Designed for an IP-Overlay
  - Agnostic to network topology
  - No service-awareness in networks
  - May result in bottlenecks
- Can we do better with PDPs?



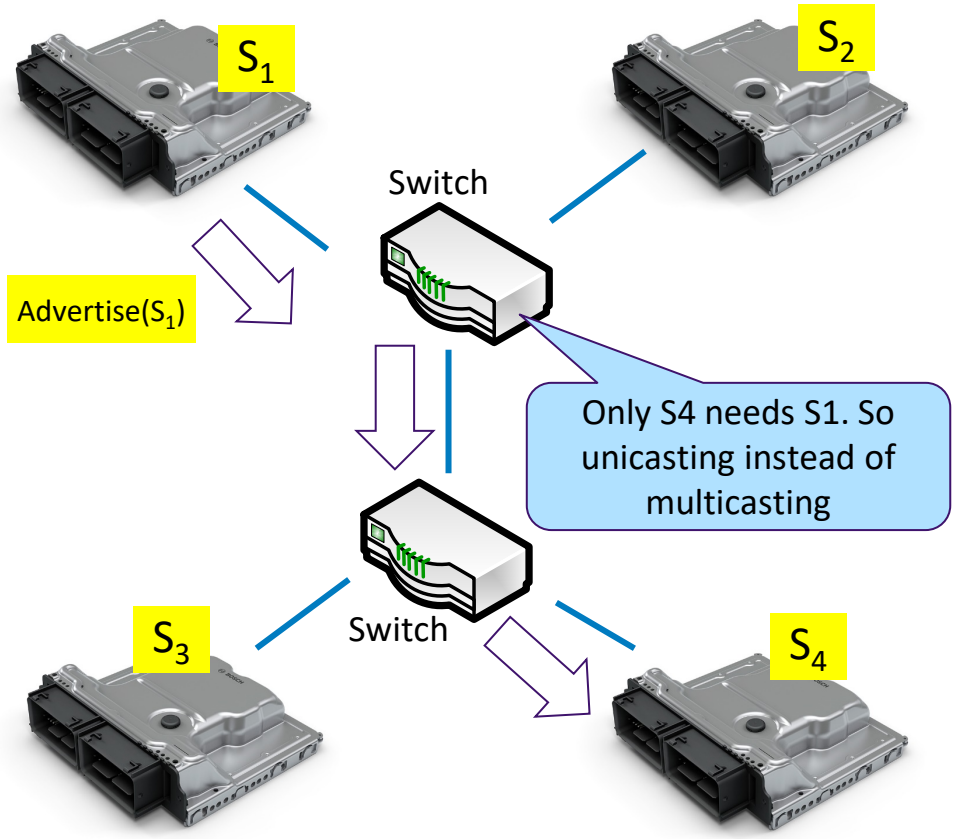
IP	Port
192.168.1.10	Port 2
192.168.1.20	Port 1

Service	Port
S_1	Port 2
S_2	Port 1

PDPs in Automotive
Runtime Service Discovery

- Fully Decentralized Service Discovery in Automotive SoC S
  - Based on UDP Multicasts
  - Discovery overhead scales quadratically
  - Forwarding decoupled from service discovery

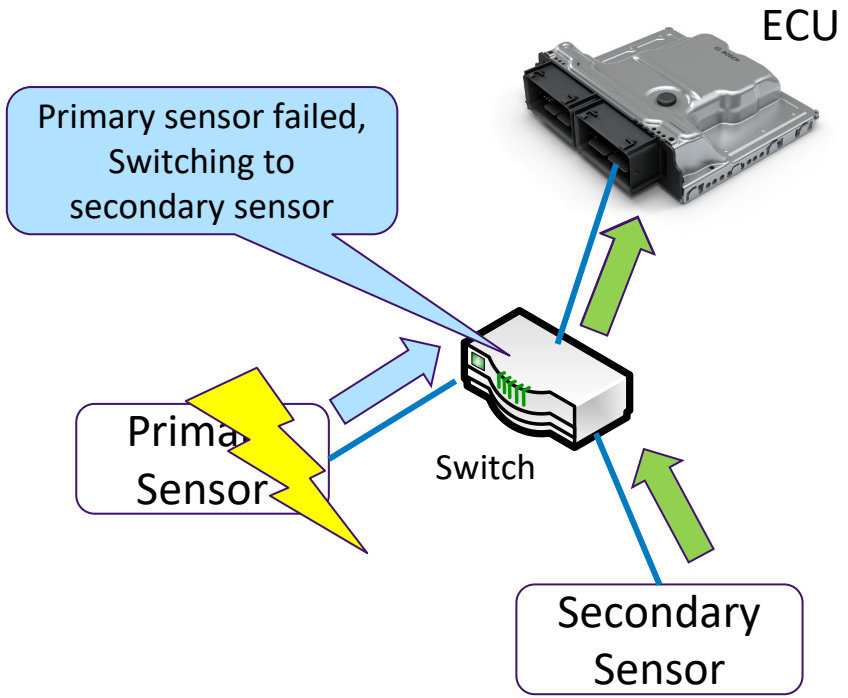
- More Discovery Options with PDP
  - Decentralized Discovery in Network
  - Centralized Discovery
  - Hybrid Mechanisms



PDPs in Automotive
Application Layer Fault Tolerance

- Application-level fault tolerance built inside services
  - Redundant deployment of services
  - Switching to secondary services on failure
  - Failure detection in application layer

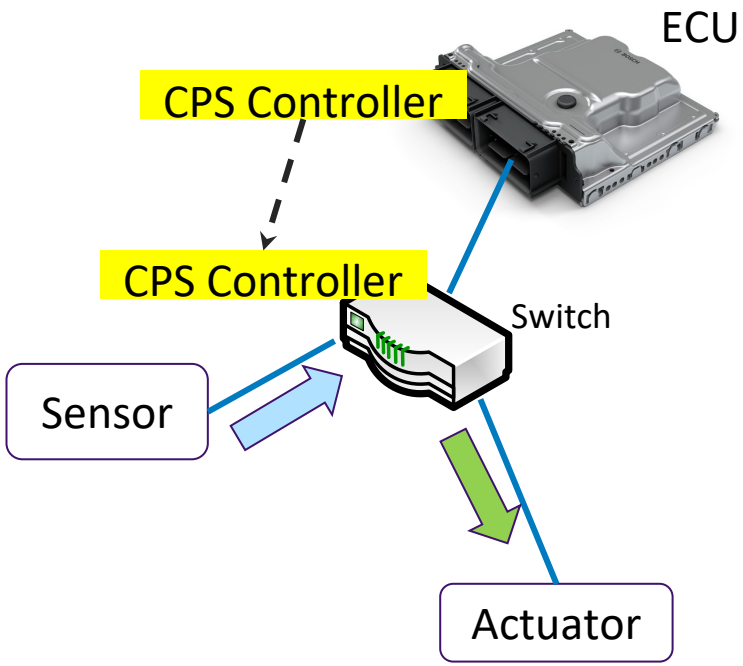
- Faster fail-over times
  - Detection in network[1]
  - Fail-safe/fail-operational
  - Useful in autonomous vehicles



[1] Published at IFIP Networking: https://ieeexplore.ieee.org/abstract/document/9142735

PDPs in Automotive
Application Specific Computing

- PDPs to execute computations on data stream
  - E.g. Cyber-physical System (CPS) Controller processing sensor data stream to steer actuators
- Offload control algorithm to the network from the ECU
  - E.g. PID Control
  - Lower control loop latency & jitter
  - Better quality-of-control
- ECU only updates setpoints and executes error handling



Automotive Programmable Data Plane
Open Questions and Challenges

- Safety considerations for hardware (and the accompanying toolchain)
  - ISO26262, ASIL, etc.
- Security & Encryption
  - Handling encrypted header fields
  - Verifying integrity
- Interplay with TSN
- Standards for automotive

Automotive Programmable Data Plane
Conclusion & Outlook

- PDP as a networking technology
  - Primarily for datacenters
  - Enable fully programmble networks
- An automotive variant for PDP – perhaps less flexible, targeted towards automotive service-oriented communication
  - Efficient service discovery
  - Application layer fault tolerance within the network
  - Improved application split between compute & network
- Plenty of open challenges including standards for automotive

CURIOUS!! GET IN TOUCH

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