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Time-sensitive control data streams in service-oriented architecture based on Automotive Ethernet

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Rettungsgasse – ad hoc emergency lane in case of a traffic jam

Mandatory on highways in Germany and Austria

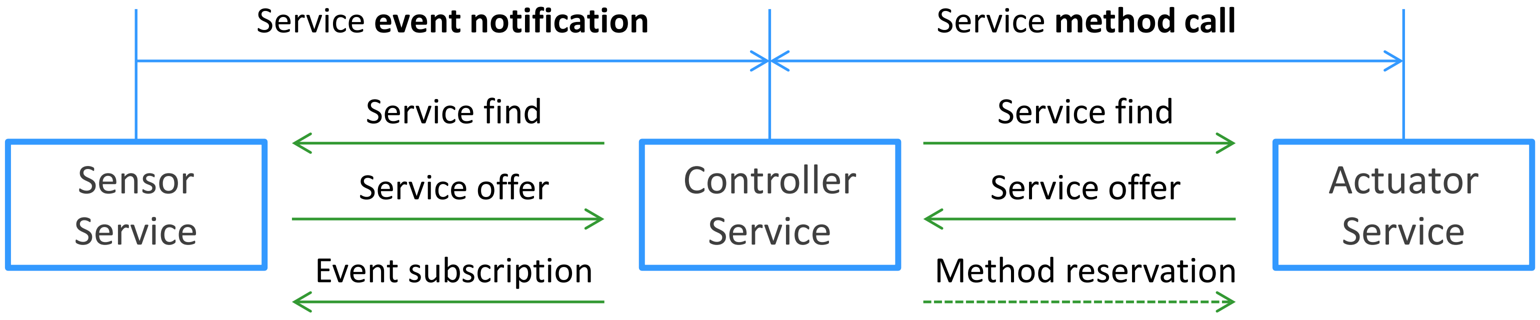
Give way to important things –
that´s what we also need for time-critical applications …

Service-Oriented Architecture (SOA)

Brief overview

- **Service** = discrete unit of functionality that can be accessed remotely and updated independently
- Applications are built by combining services, e.g. control loop built out of Sensor, Controller, Actuator

Server offers and provides service events and methods



Client finds services and
- subscribes/consumes events
- reserves/calls methods

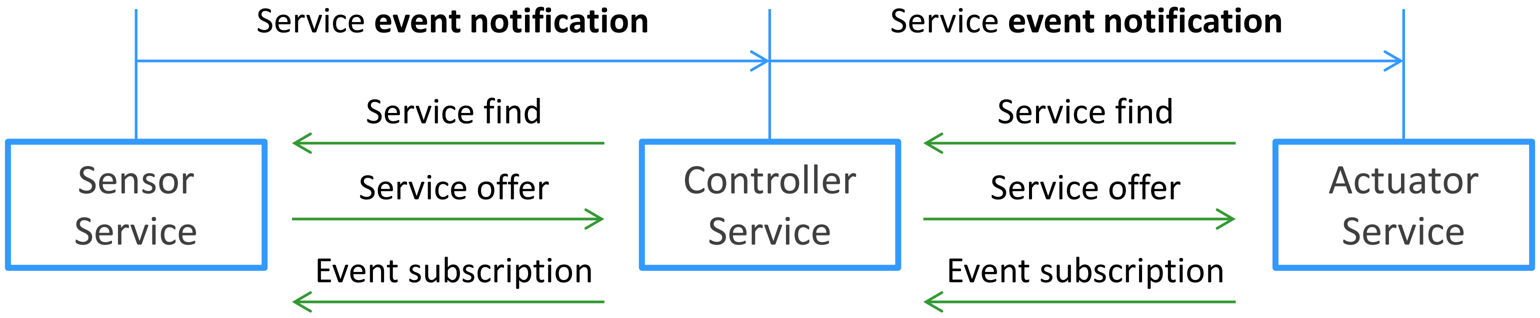
- **Binding** between **server** (service provider) and **client** (service user) is established dynamically via **service discovery**
- Provides scalability and allows adding new service users without any adaptation of existing service providers

Service-Oriented Architecture (SOA)

Brief overview

- Interaction between Controller and Actuator Service can also be realized via service events (instead of methods)
- In this case client/server roles are swapped between Controller and Actuator

Server offers and provides service events



Client finds services and subscribes and consumes service events

Note:

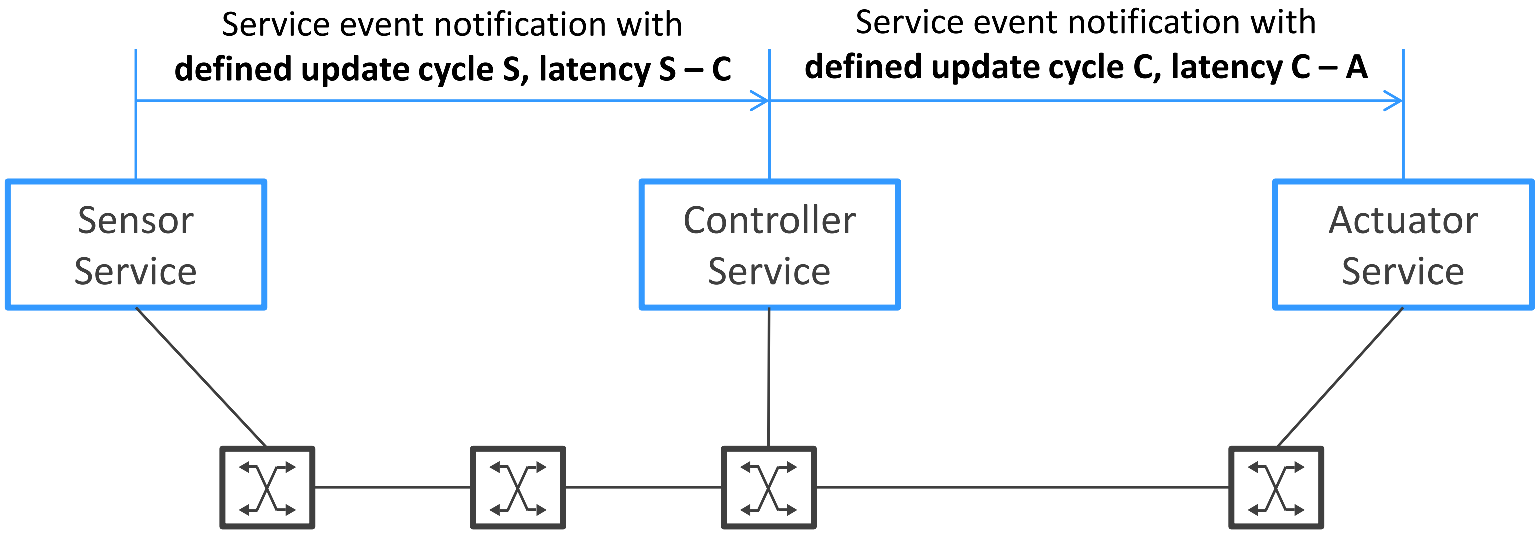
- The examples in this presentation focus on the scenario with service events
- The concept shown also applies to service methods (with some adaptations)

Time-Sensitive Control Data Streams in SOA

Motivation and overview

- Advanced driver assistance and automated driving functions as well as chassis applications are time-critical systems using time-sensitive control data streams.

Server provides service events with a defined **update cycle**



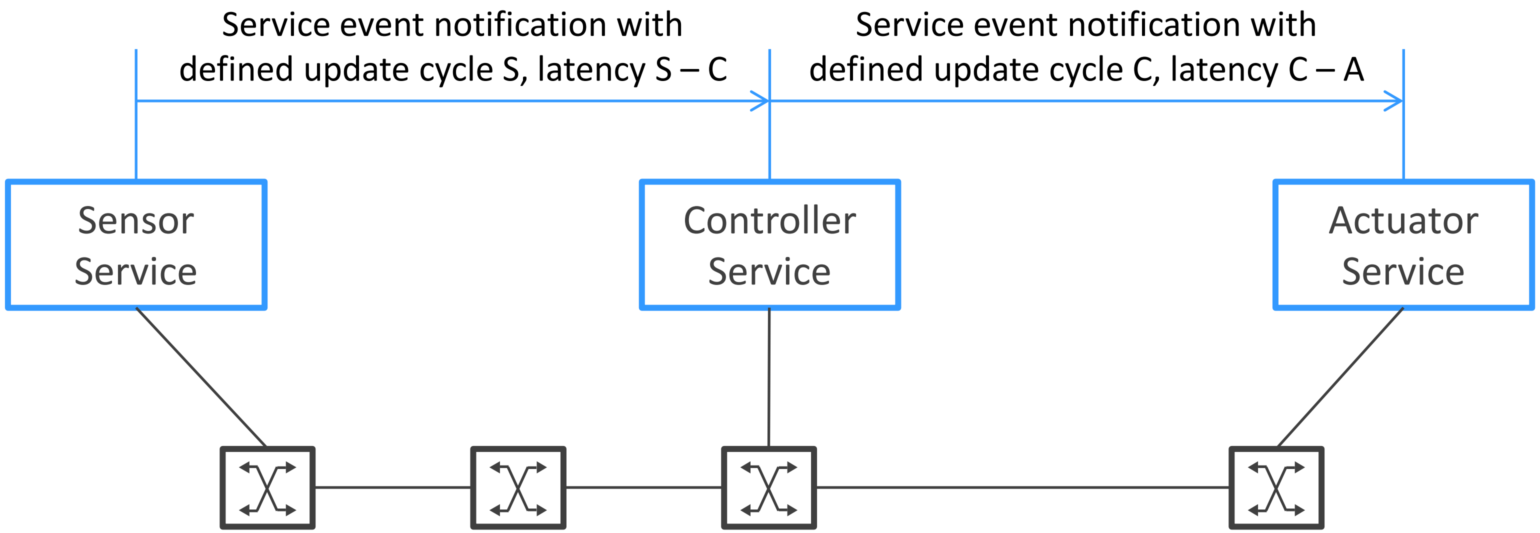
Client needs service events with a defined **update cycle** and **max bounded latency**

Automotive Ethernet network with TSN can **guarantee maximum bounded latencies** for control data streams by separating the streams into up to 8 traffic classes and applying traffic shaping

… Ethernet switch

Time-Sensitive Control Data Streams in Service-Oriented Architecture

Introducing further layers



Time-Sensitive Control Data Streams in Service-Oriented Architecture

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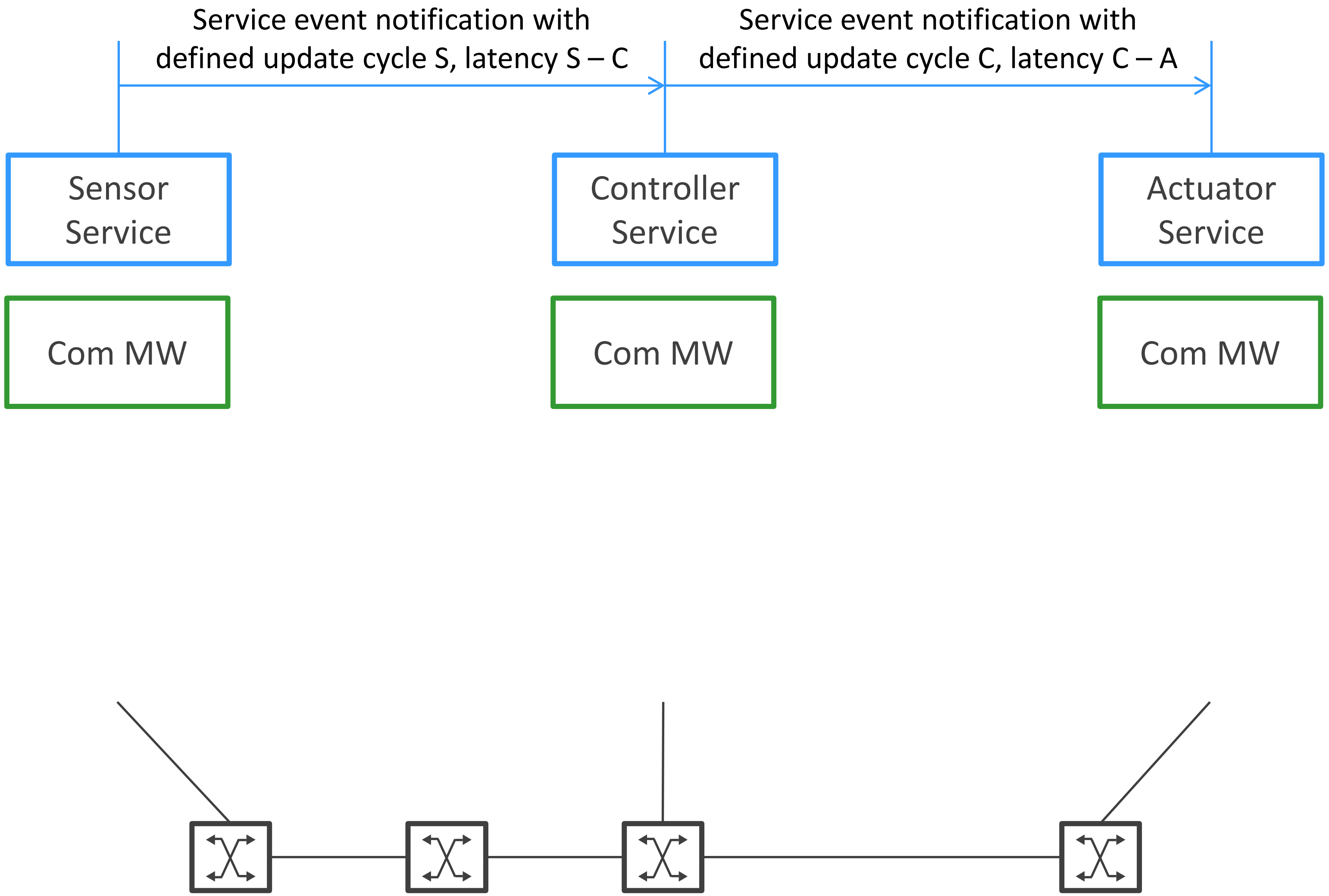
Introducing further layers – Communication Middleware

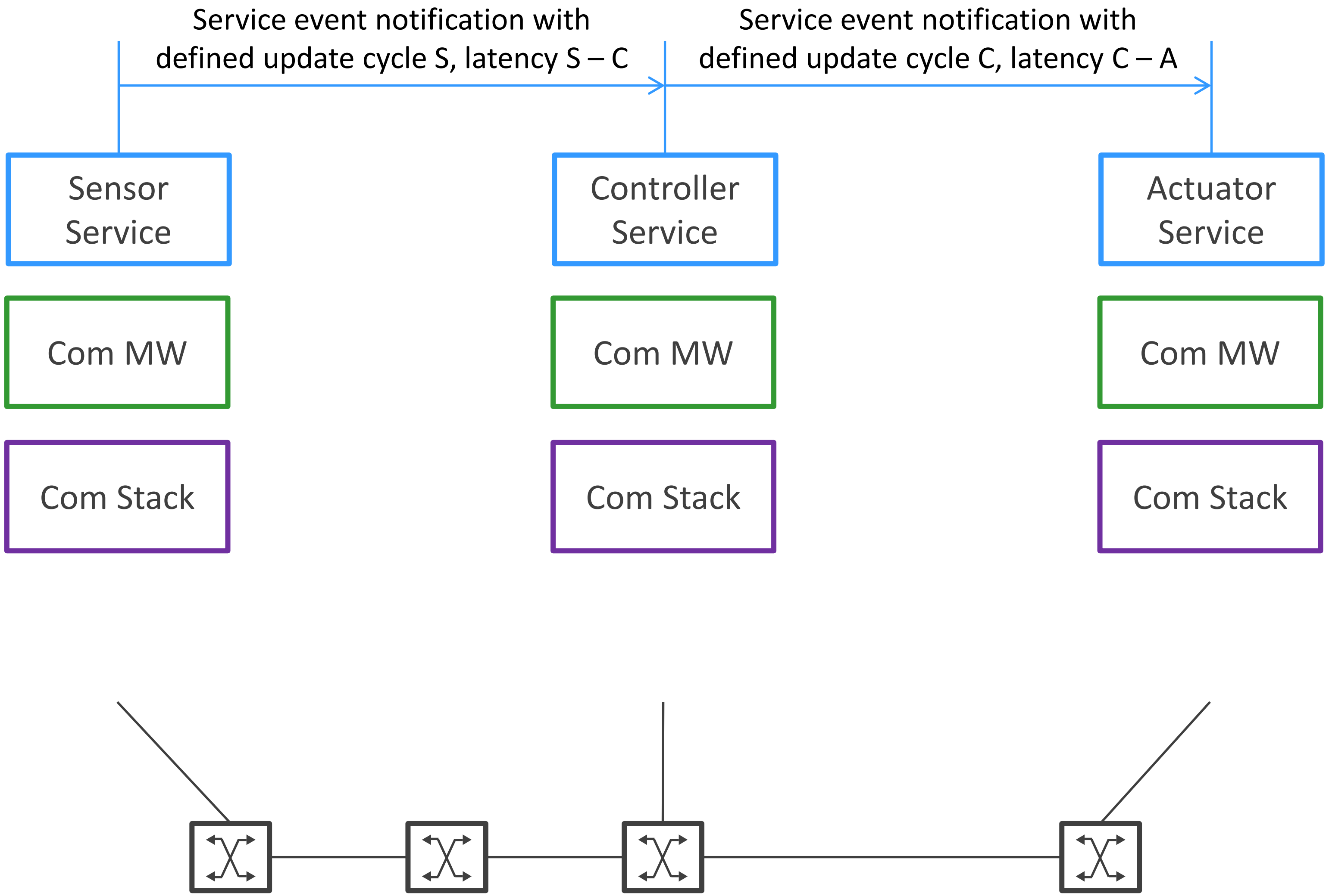


Communication Middleware

- **implements** OSI Layer 5 – 7
- **negotiates** service event update cycle and latency dynamically
- **provides** environment for prioritized channels
- **selects** Tx/Rx priority based on max latency
- **checks** if selected prio is supported
- **requests** bandwidth reservation at all involved network elements
- **reports** success/failure to Client

Time-Sensitive Control Data Streams in Service-Oriented Architecture

Introducing further layers – Communication Stack

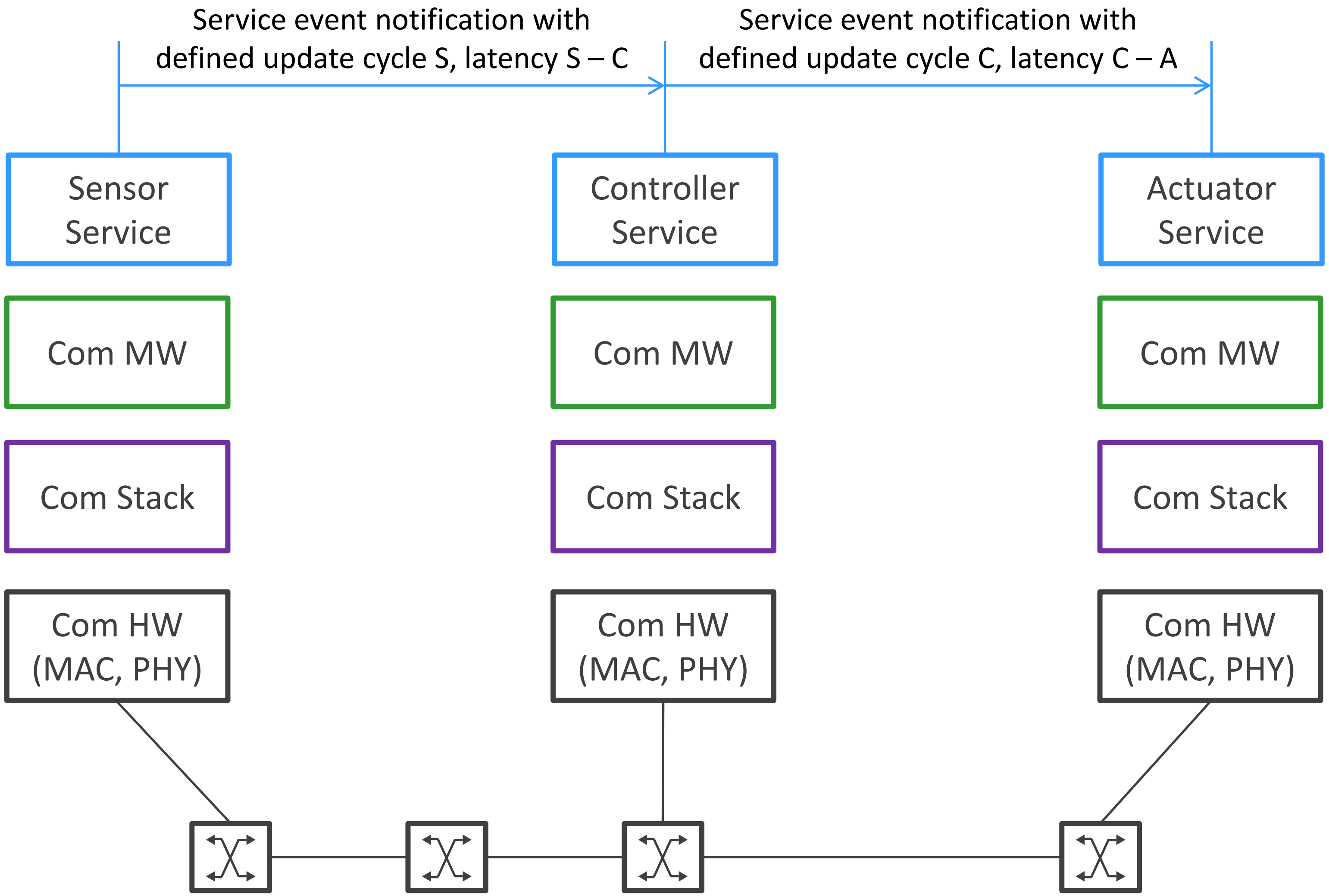


Communication Stack

- **implements** OSI Layer (2), 3, 4
- **consists** of Network stack and drivers
- **provides** environment for prio channels
- **sets** VLAN PCP field based on priority
- **selects** Tx/Rx priority queue of Com HW

Time-Sensitive Control Data Streams in Service-Oriented Architecture

Introducing further layers – Communication Hardware

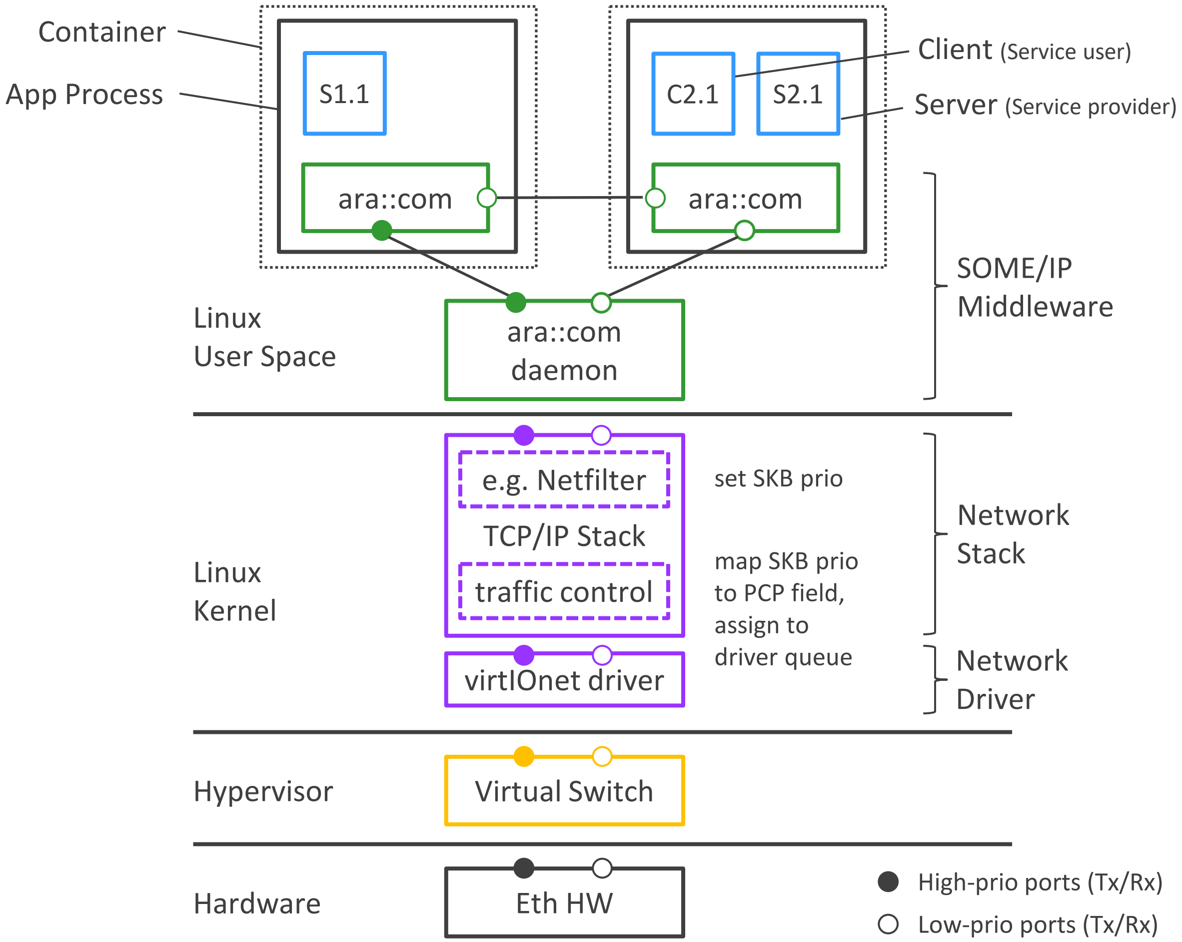


Com HW

- **implements** OSI Layer 1, 2
- **consists** of multiple network elements: switches, source and destination nodes
- related TSN standards:
  - 802.1AS Timing and Synchronization
  - 802.1Q - Forwarding and Queuing Enhancements for Time-Sensitive Streams (FQTSS): Priority, CBS
  - 802.1Q - Enhancements for Scheduled Traffic: TAS
  - 802.1Q - Asynchronous Traffic Shaping
  - 802.1Q - Stream Reservation Protocol (SRP)
  - 802.1Q - Per-Stream Filtering and Policing
  - 802.1Q - Cyclic Queuing and Forwarding
  - 802.1Q - Frame Preemption

Communication SW Architecture of a Vehicle Server (HPC)

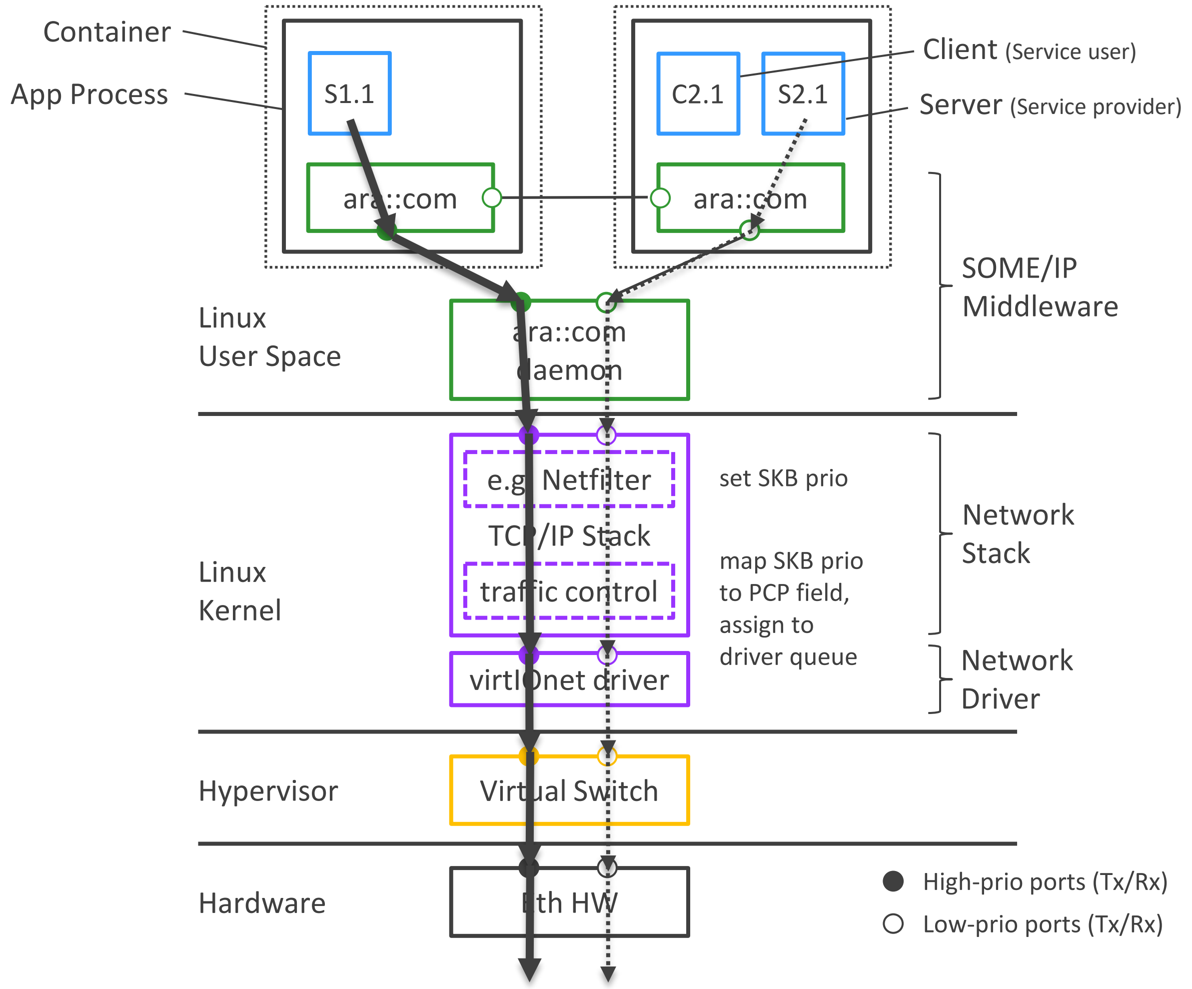
Latency and prioritization measures on the different software layers



- **Com Middleware**
  - ara::com daemon providing a priority and a best effort channel
  - separate IPC sockets and processing threads with different priority (within same prio: weighted round-robin, between prios: strict priority)
- **Network stack**
  - Maps MW prio channel to related UDP socket; set SKB prio accordingly (`setsockopt(…, SO_PRIORITY, …)`)
  - traffic control sets PCP field and selects driver queue (congestion resolution: Qdisc MQPRIO (multiqueue priority))
- **Network driver**
  - Maps driver queue of a VM to Virtual Switch queue
- **Virtual Switch (Hypervisor)**
  - Maps Virtual Switch queue to Eth HW queue
  - Frame processing acc. to strict priority and via interleaved weighted round robin algorithm within the same priority
- **Ethernet hardware** queues
  - Two queues: priority and non-priority

Communication SW Architecture of a Vehicle Server (HPC)

Latency and prioritization measures on the different software layers



Test Setup:

- Server S1.1 transmits data with high priority (bold line)
- Server S2.1 transmits data with low priority (dotted line) and might be blocked by interfering traffic
- Traffic generator that can be activated to produce a lot of interfering traffic on a low priority socket
- Used Software: EB corbos AdaptiveCore, EB corbos Linux, EB corbos Hypervisor, EB corbos virtual Switch

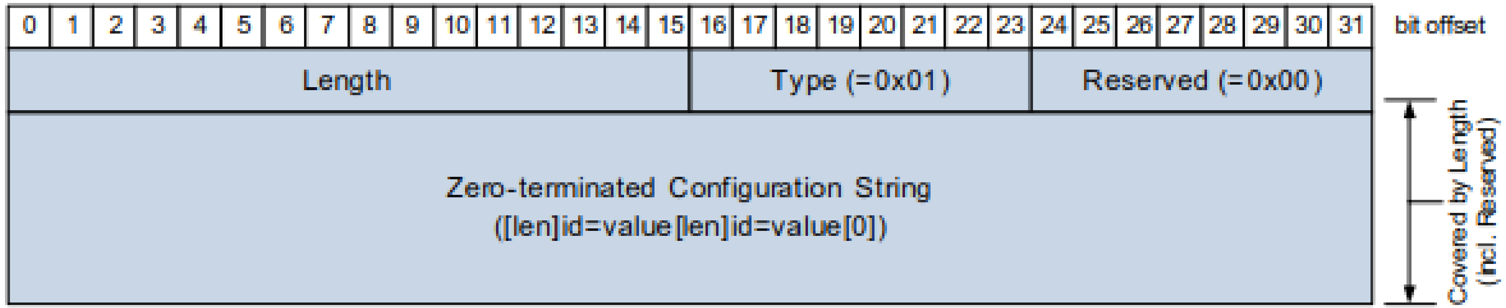
Results:

- Service events from S1.1 are always transmitted without any frame drops or latency violations (independent of interfering traffic)
- Service events from S2.1 are transmitted incompletely (frame drops, increased latency depending on interfering traffic)

AUTOSAR SOME/IP QoS Extension (Update Cycle, Latency)

COM Middleware mechanism to negotiate Update Cycle and Latency - Overview

- Negotiation can be done via existing SOME/IP-SD feature
  - Configuration options (a.k.a. capability records) – may carry arbitrary additional information for a service interface



Ref. AUTOSAR

Key/value pairs (like DNS-SD TXT records according to IETF RFC 6763)

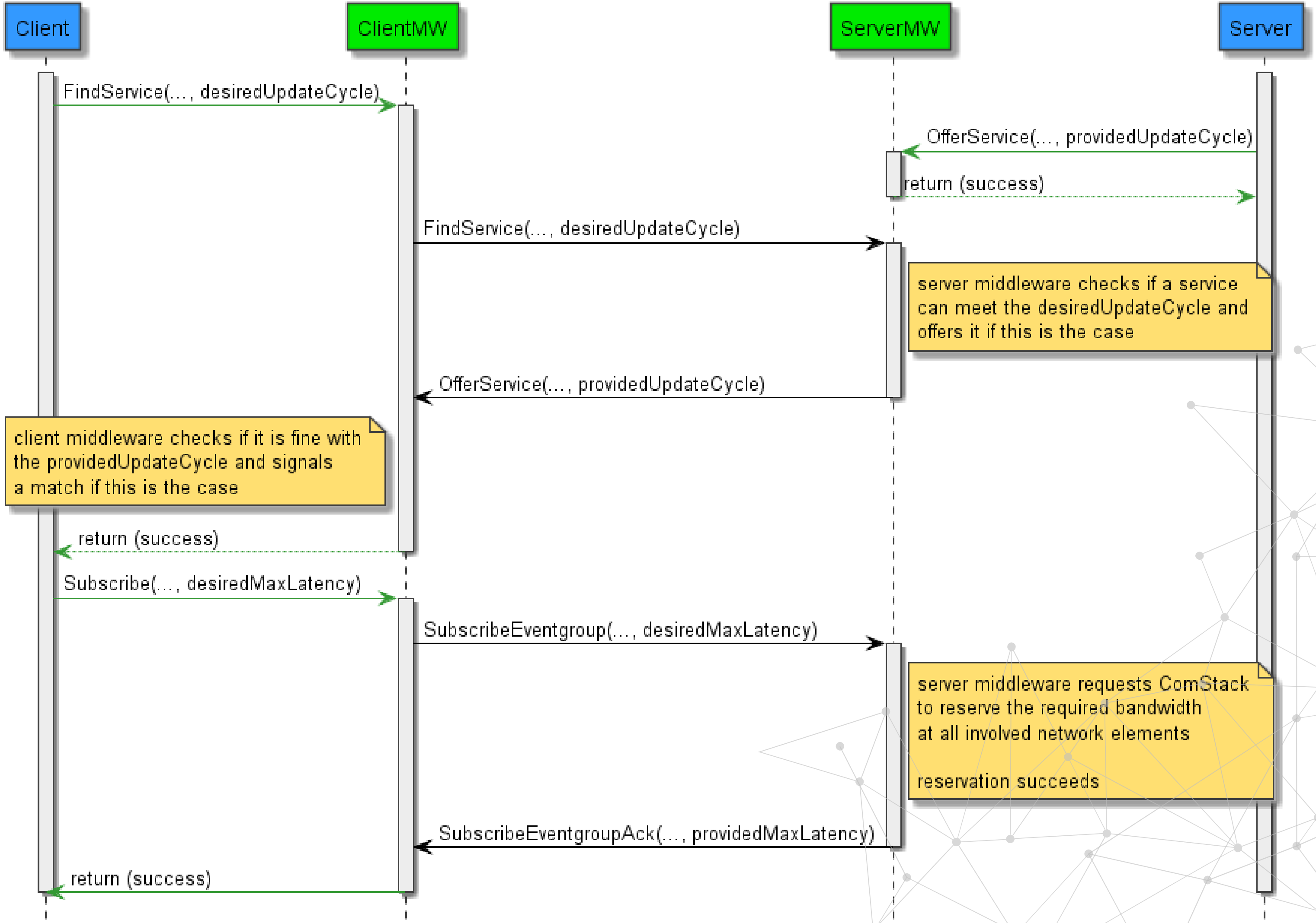
  - Use these configuration options in *OfferService*, *FindService*, *SubscribeEventGroup*, *SubscribeEventGroupAck* SOME/IP-SD message entries to transport QoS attributes, introduce standardized keys (**`max_latency`**, **`update_cycle`**)
- Interface extension for using these config options
  - Variant 1: QoS attributes are configured statically per service interface, e.g. AP ara::com Manifest (configuration)
  - Variant 2: QoS attributes are provided by the application during run-time, e.g. AP ara::com API (additional arguments)

AUTOSAR SOME/IP QoS Extension (Update Cycle, Latency)

Negotiation of Update Cycle and Latency – Sequence Diagram: Success Scenario

Scenario description

- Client looks for a service event with a desired
  - update cycle and
  - maximum latency
- Server offers a service event with a provided update cycle that is **lower** than the desired one of the Client
- Server middleware requests ComStack to reserve bandwidth to guarantee the desired maximum latency and reservation **succeeds**

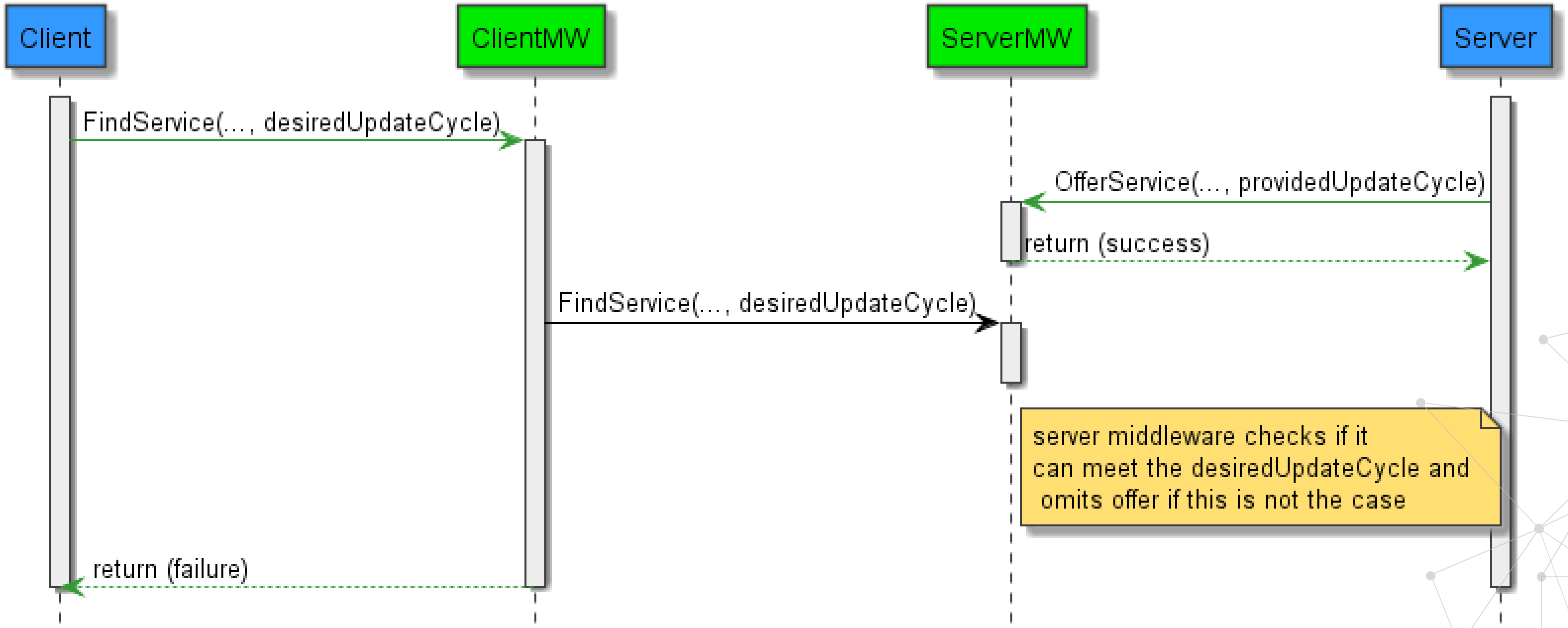


AUTOSAR SOME/IP QoS Extension (Update Cycle, Latency)

Negotiation of Update Cycle and Latency – Sequence Diagram: Failure Scenario (Update Cycle Mismatch)

Scenario description

- Client looks for a service event with a desired
  - update cycle and
  - maximum latency
- Server offers a service event with a provided update cycle that is **larger** than the desired one of the Client

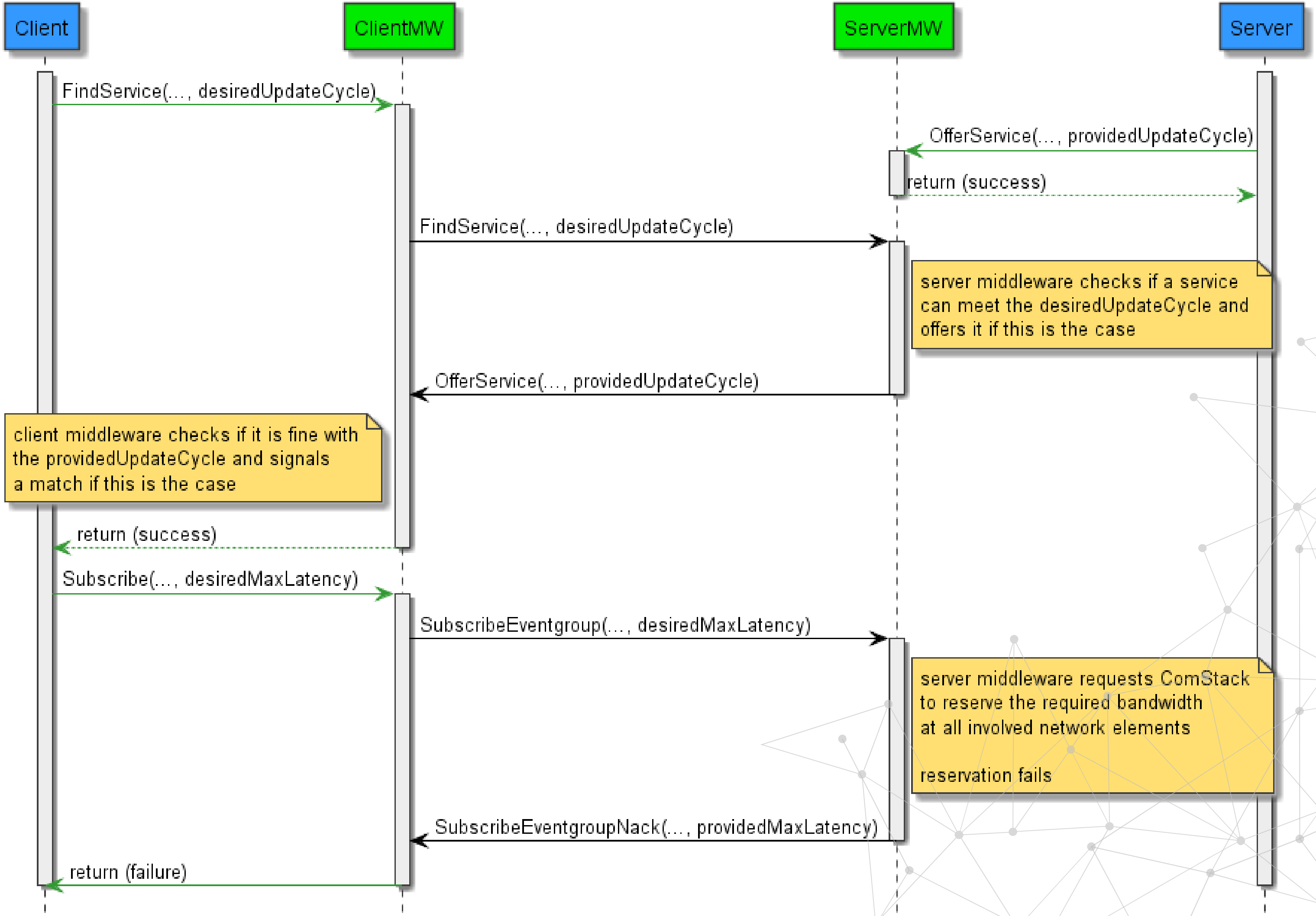


AUTOSAR SOME/IP QoS Extension (Update Cycle, Latency)

Negotiation of Update Cycle and Latency – Sequence Diagram: Failure Scenario (Latency Violation)

Scenario description

- Client looks for a service event with a desired
  - update cycle and
  - maximum latency
- Server offers a service event with a provided update cycle that is **lower** than the desired one of the Client
- Server middleware requests ComStack to reserve bandwidth to guarantee the desired maximum latency and reservation **fails**



Configuration and Bandwidth Reservation of Network Elements

COM Stack mechanism for configuration and bandwidth reservation – some alternative options

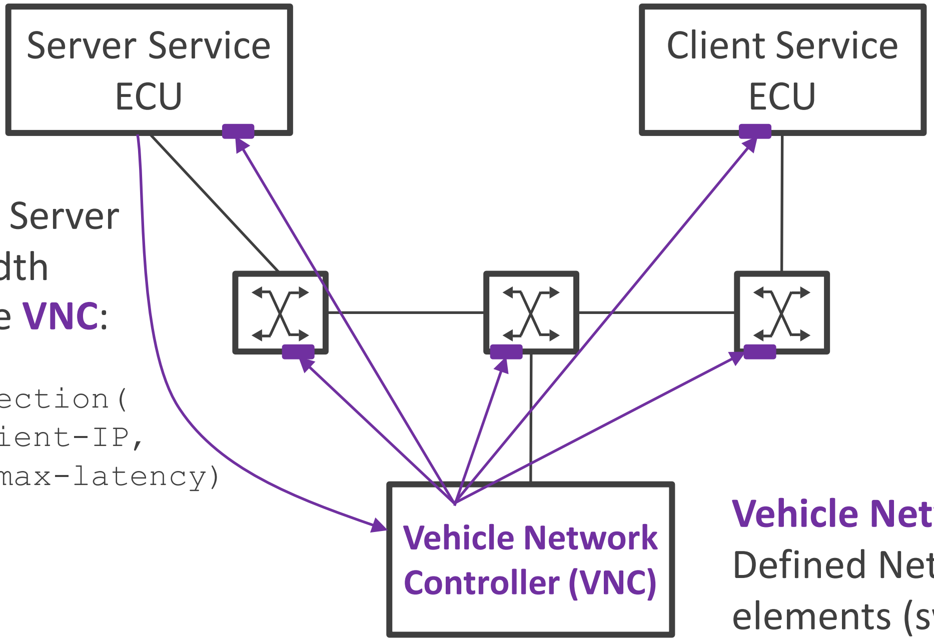
(1) **Static configuration** using virtual reservations based on a-prio known communication relationships

(2) **Stream Reservation Protocol (SRP)** according to IEEE 802.1Q

(3) Central **Vehicle Network Controller (VNC)** based on Software-Defined Network (SDN) Architecture as shown below

Com Stack at the Server requests bandwidth reservation at the **VNC**:

```
requestL3Connection(
server-IP, client-IP,
data-length, max-latency)
```



- Standardized remote configuration interface (e.g. NETCONF/YANG) to switches and end nodes

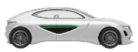
Vehicle Network Controller (VNC) is basically a Software-Defined Network (SDN) controller that manages all network elements (switches, end nodes)

Summary

Time-sensitive control data streams in service-oriented architecture are **service events with a defined update cycle and maximum bounded latency**.

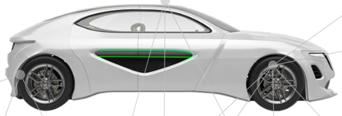
Communication middleware needs to support dynamic negotiation of update cycle and latency.
Related **extension for AUTOSAR SOME/IP QoS support** has been shown.

For QoS the whole data path on the network and from network interface to the application need to be covered.
Concrete measures have been described **for the different communication layers** (e.g., priority and a best effort channels, dedicated processing threads, virtual switch priority queues, interleaved weighted round robin)



Experiences from the **QoS implementation of a Vehicle Server (HPC)** based on EB´s products have been shared.
Time-sensitive control data streams in SOA are fully supported along the complete communication path.

Thank you for your attention!!



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