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Leveraging SOA Communication Middleware with TSN for Software Defined Vehicles

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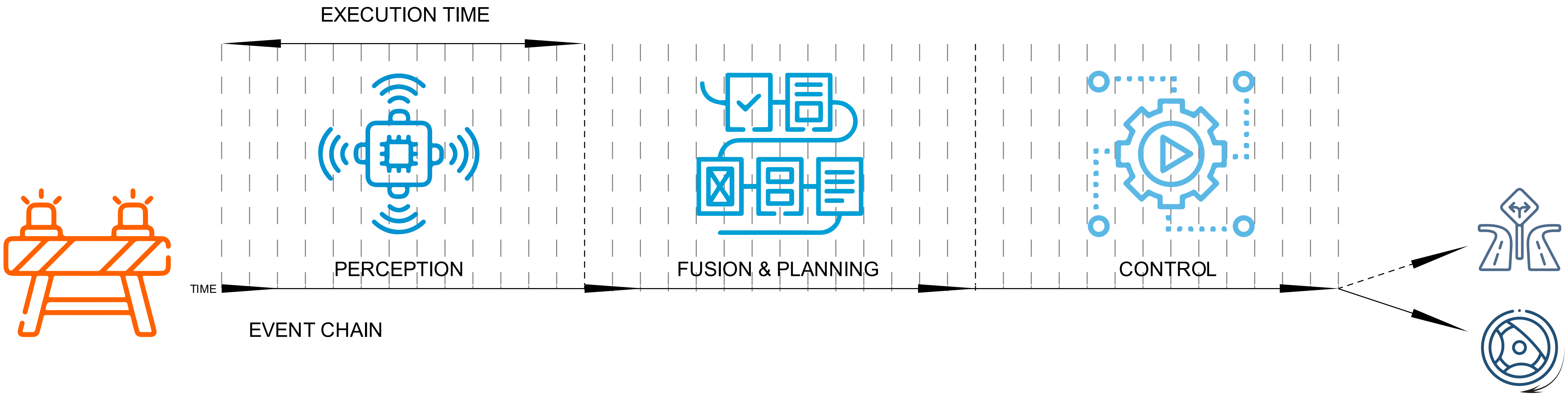
TTTech Auto AG

Typical single-ECU functions

Control loops with strict timing requirements (event-chains)

Sensor Input > Pre-processing > Compute > Control



Requirement A: vehicle stops within **x ms** at speed of **y kph** if **event z** happens

(Sub-)System X needs to detect **event z** within **a ms** and trigger reaction of (sub-)system Y within **b ms**

Zonal Architectures and Software Defined Vehicles

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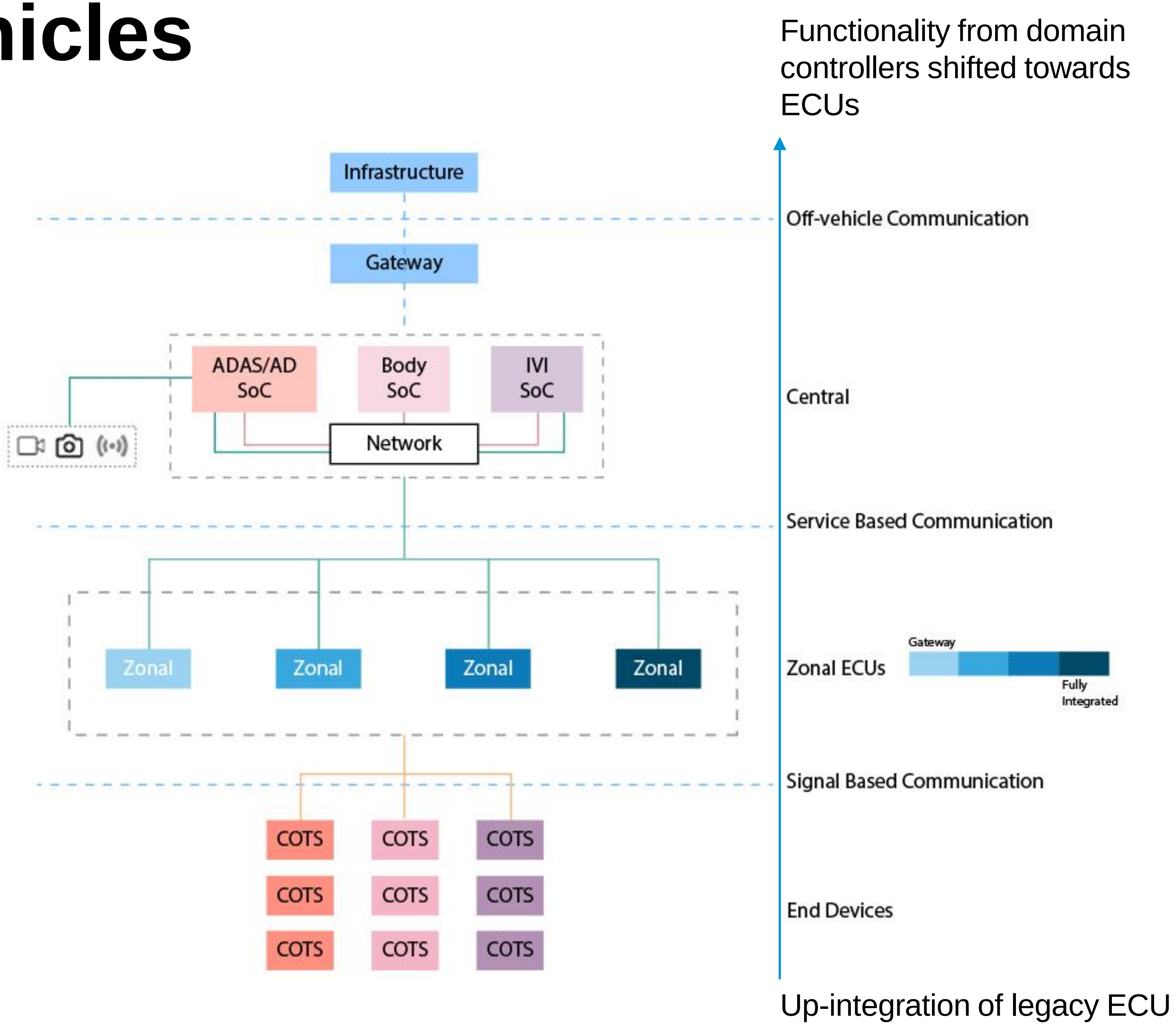
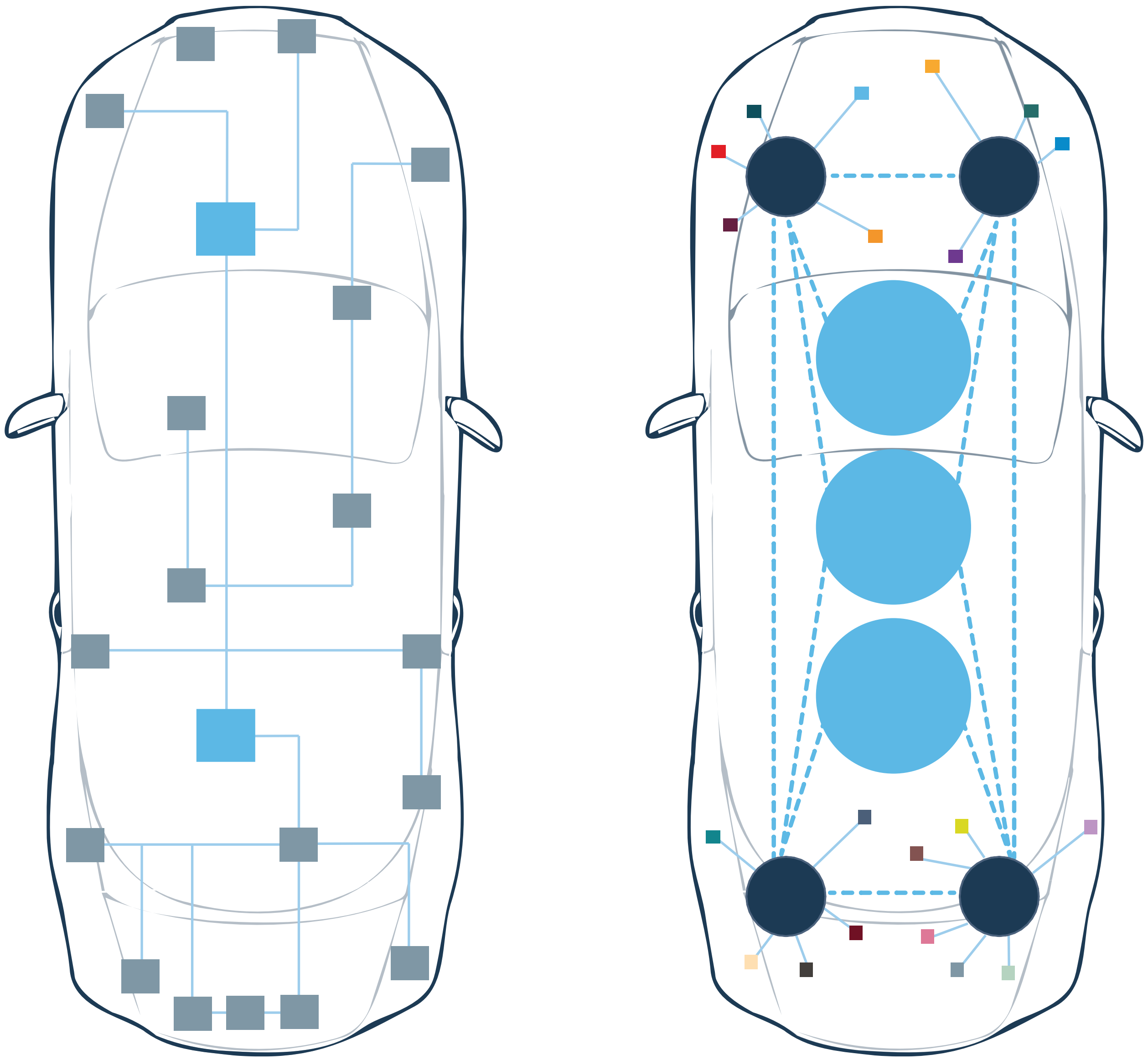
- From single-ECU design to vehicle-wide multi-ECU designs
- Higher integration, no more isolated execution on SoCs/ECUs
- Cover distinct HW platforms, not just variants
- Consolidate and optimize hardware and communication paths
- Continuous updates to SW in a changing HW environment



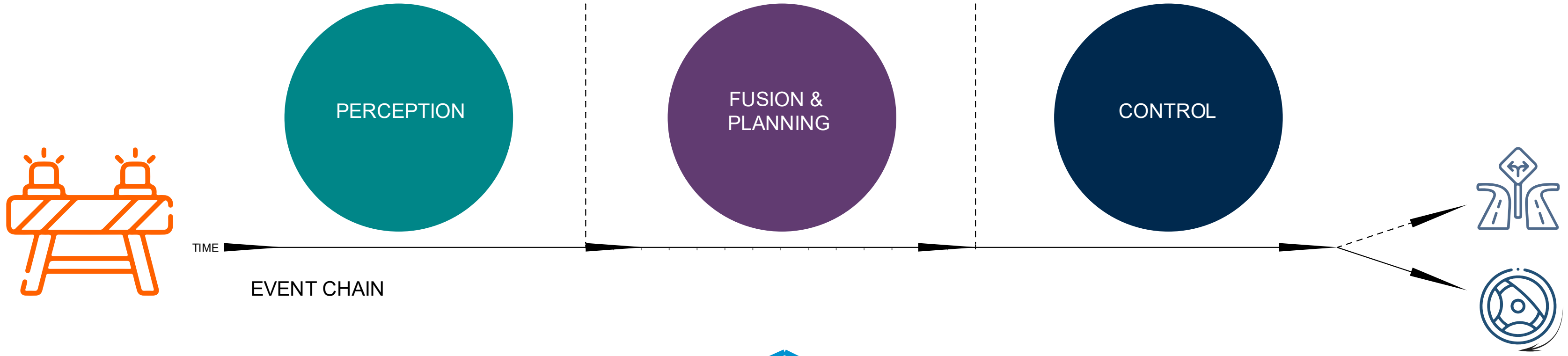
Zonal Architecture Evolution

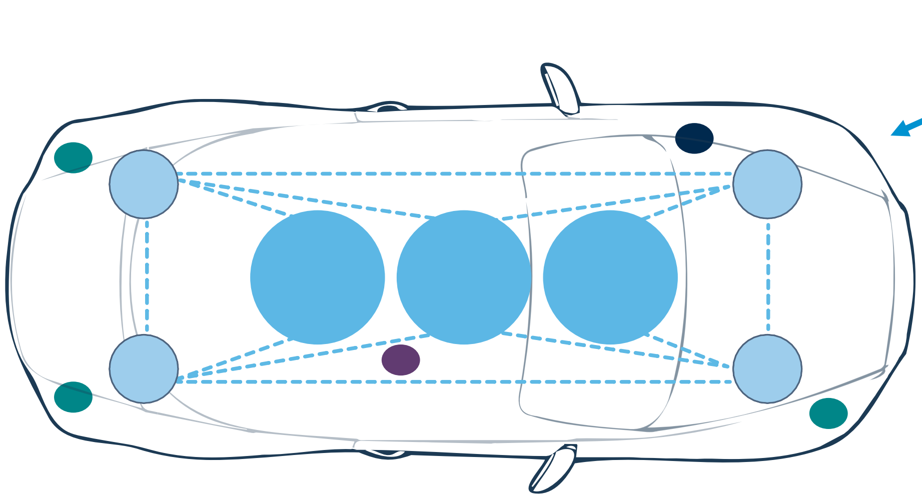
- Up-integration for new architectures: functionality increasingly realized in software
- Enables sharing of resources provided by different ECUs
- Enables optimization of communication flows and compute platforms
- Cloud/Edge connectivity becomes relevant



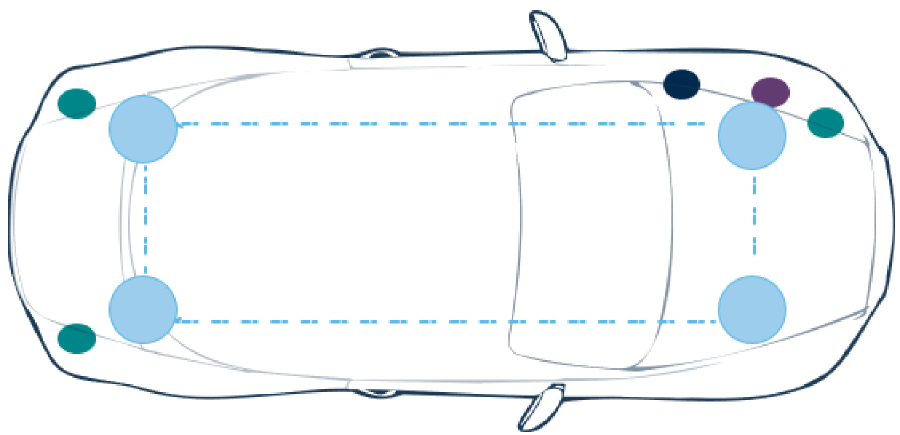
Software Defined Vehicle

Realizing functionality mainly in Software enables evolution and consolidation of the Hardware platform and legacy systems!





Same SW function
Deployed in different
physical architectures



Consequences of Zonal Approaches

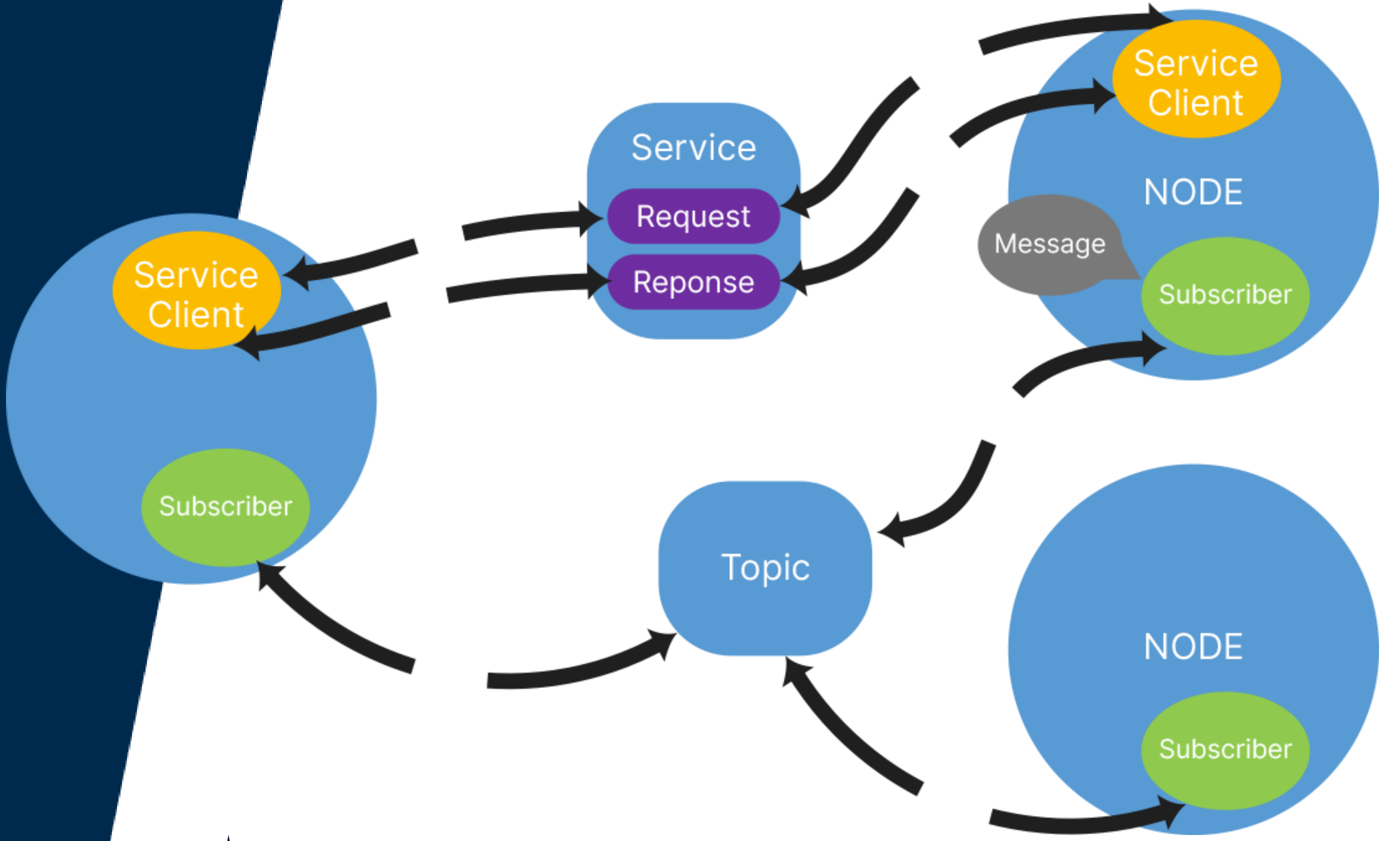
- Integration of applications from Classic AUTOSAR, POSIX, ...
- Maintain **real-time guarantees for communication** and **FFI for safety-critical applications** in a **heterogenous and distributed mixed-criticality environment**
- Software is continuously upgraded and improved:
  - Embedded Applications & Tooling
  - Increased integration of off-board systems
  - **Maintaining SW functionality in a changing hardware environment requires decoupling of SW provided functions from physical deployment = Location Transparency**
  - Switching from Signal-oriented to SOA is just one aspect

``with SOA, we got the worst of both worlds ..."

Technology Selection

From Prototype to Series Deployment

- Frameworks like ROS2 are superb for prototyping; typically, such prototype systems must be re-implemented using 'series quality technology'.
- With DDS/Zenoh there exists a clear and defined path from prototype development to series deployment; no switch of design methodology or technology is needed.



Tooling Perspective

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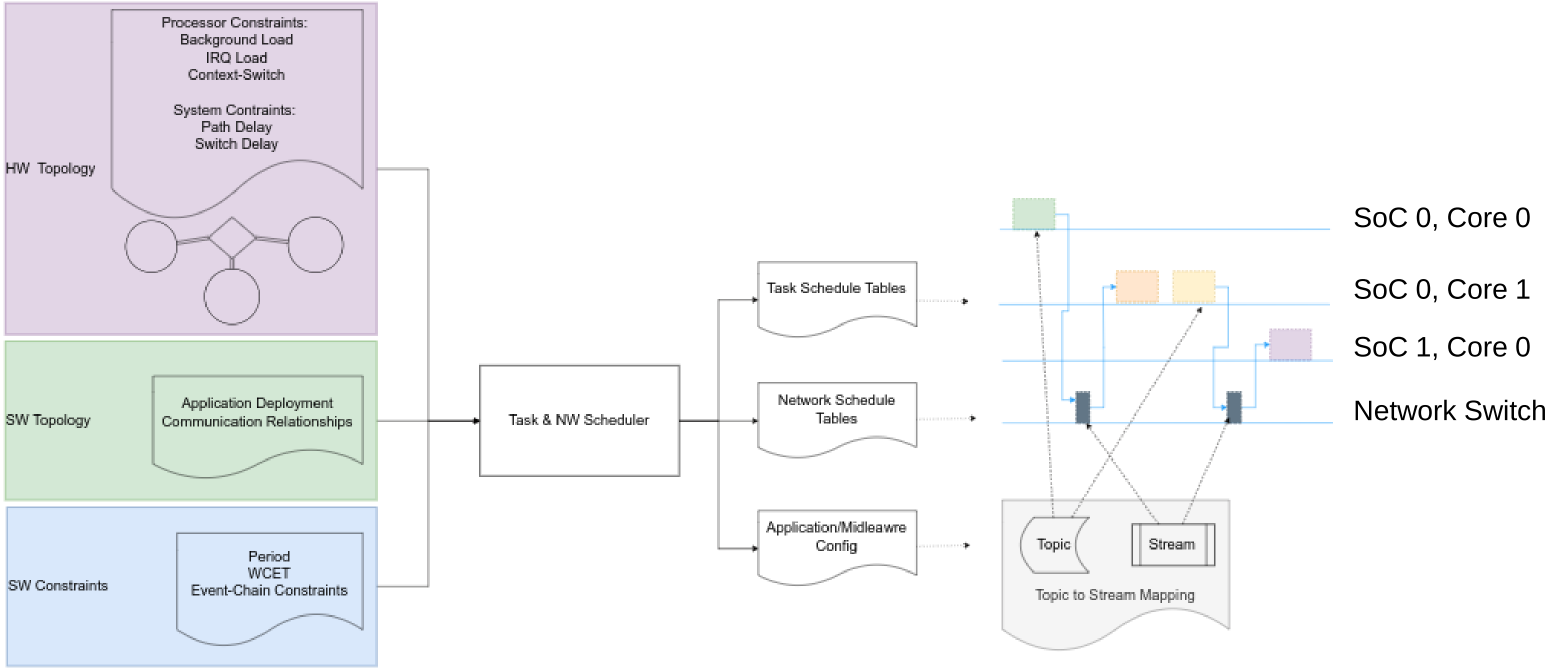
- DDS allows to seamlessly transition from loosely coupled to defined topology
- SW Functionality is not at all impacted by the transition
- Integrator and Developer can specify/adapt application QoS (SW Constraints) and SW topology
- Guarantees (Timing, FFI) are configured in a fully automated scheduling step



Transparent to application layer

Finzi, A., Craciunas, S. S., & Boyer, M. (2022). A Real-time Calculus Approach for Integrating Sporadic Events in Time-triggered Systems. *arXiv preprint arXiv:2204.10264*.

Series deployment

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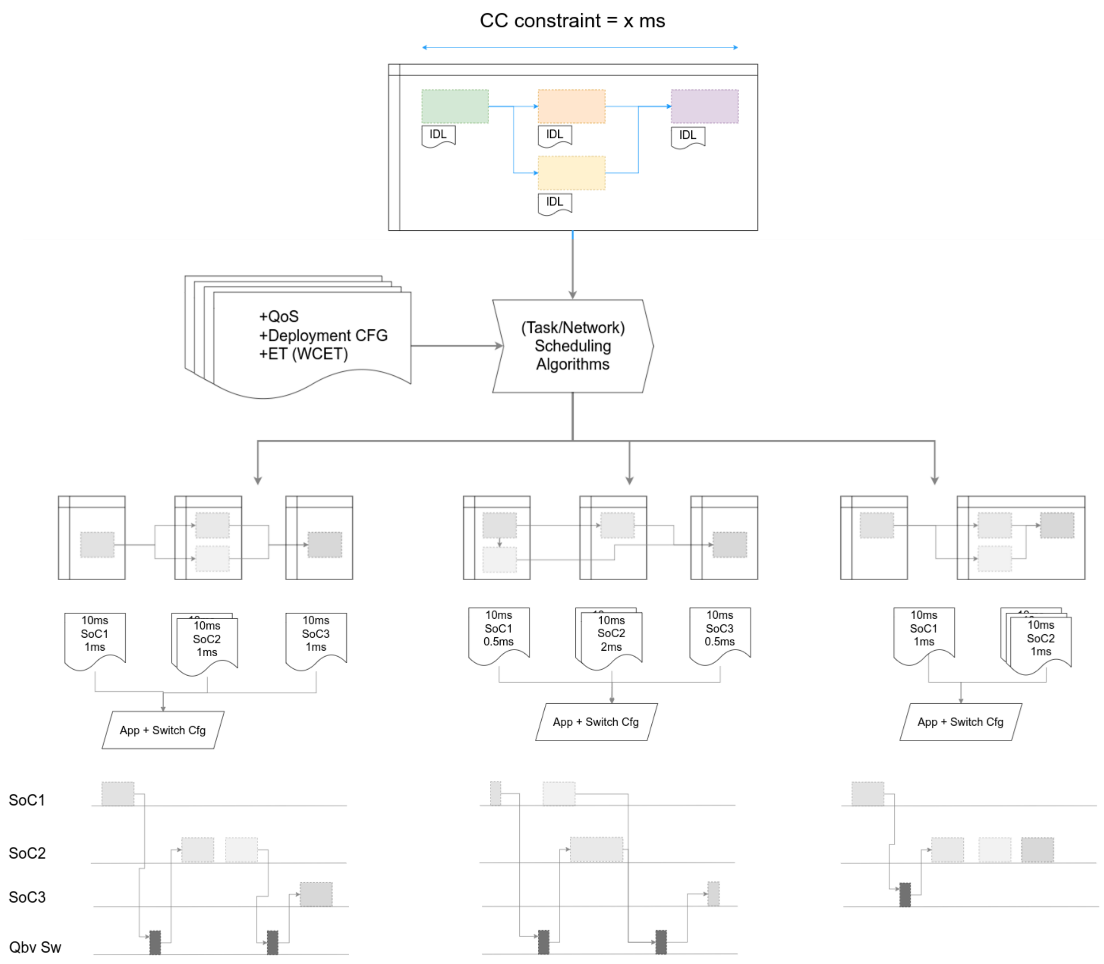
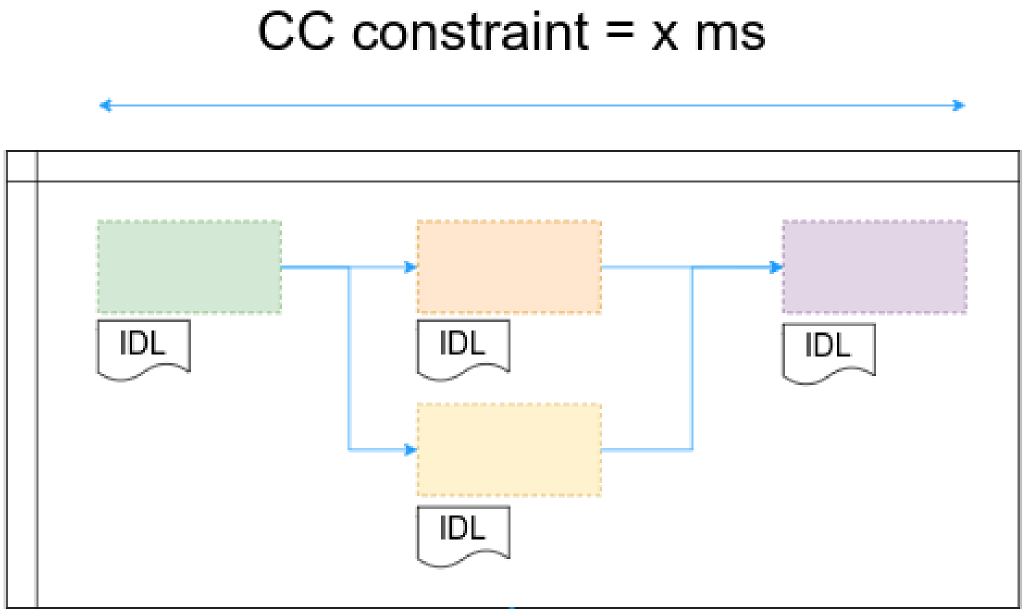
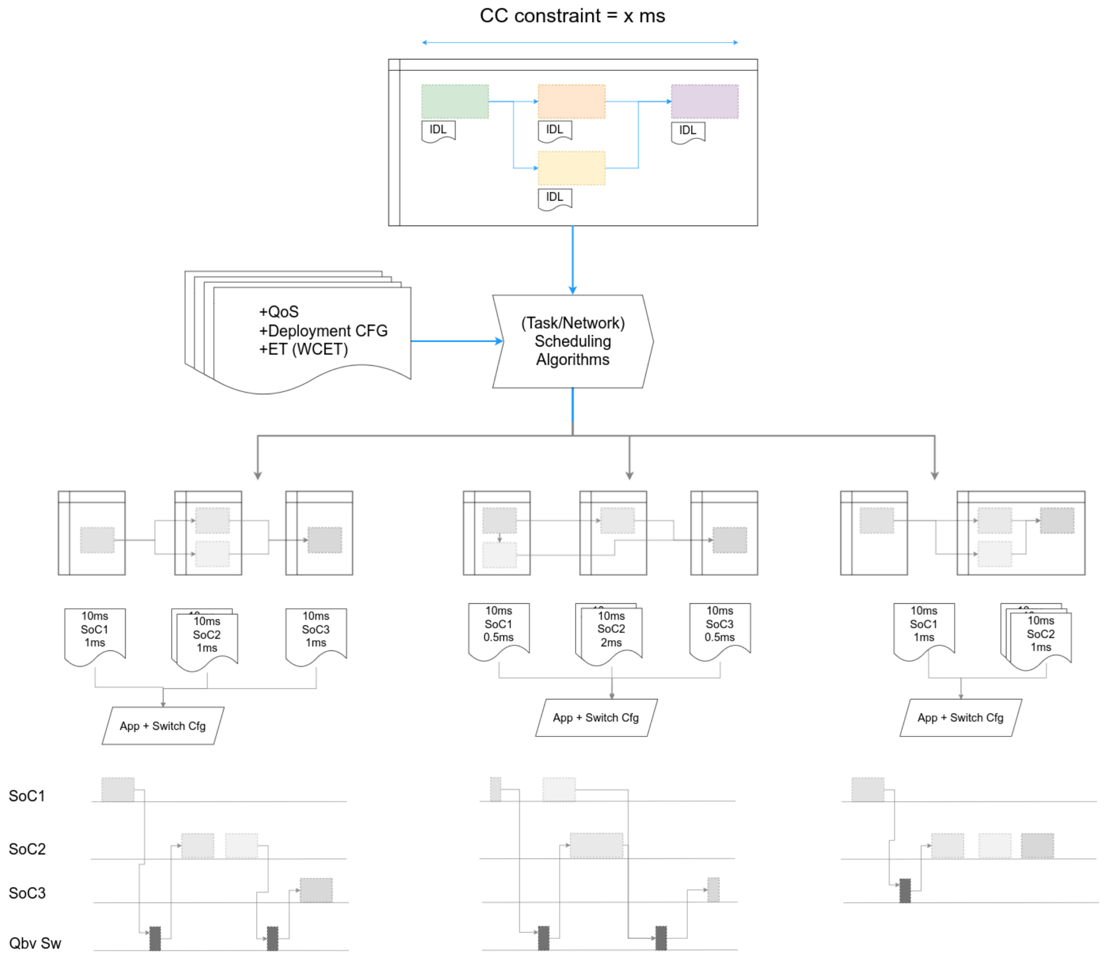
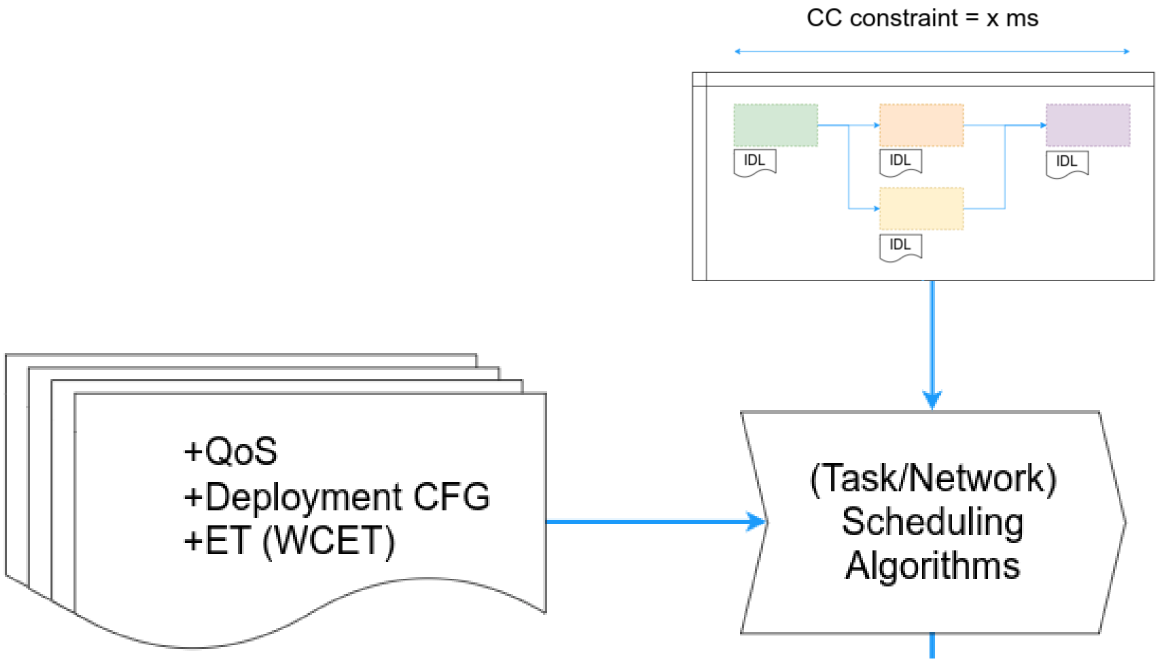


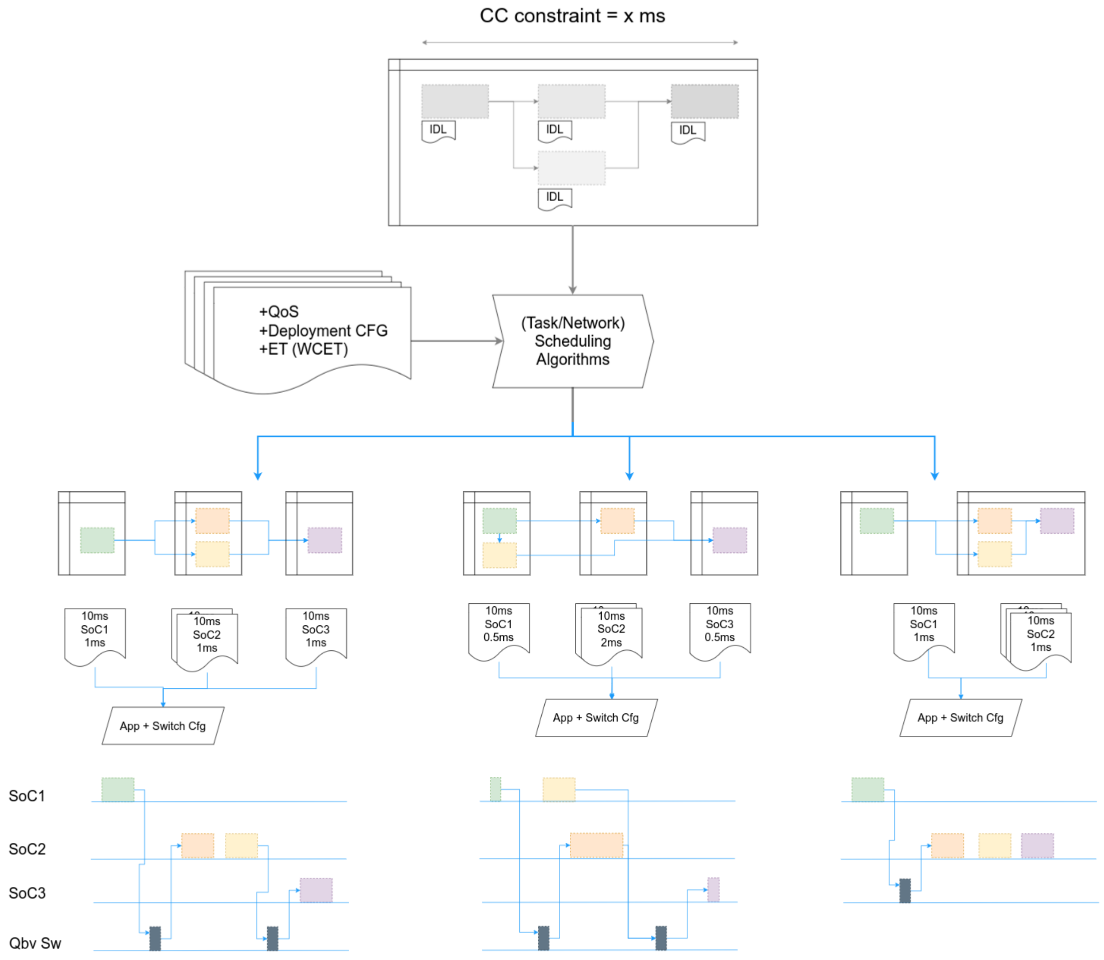


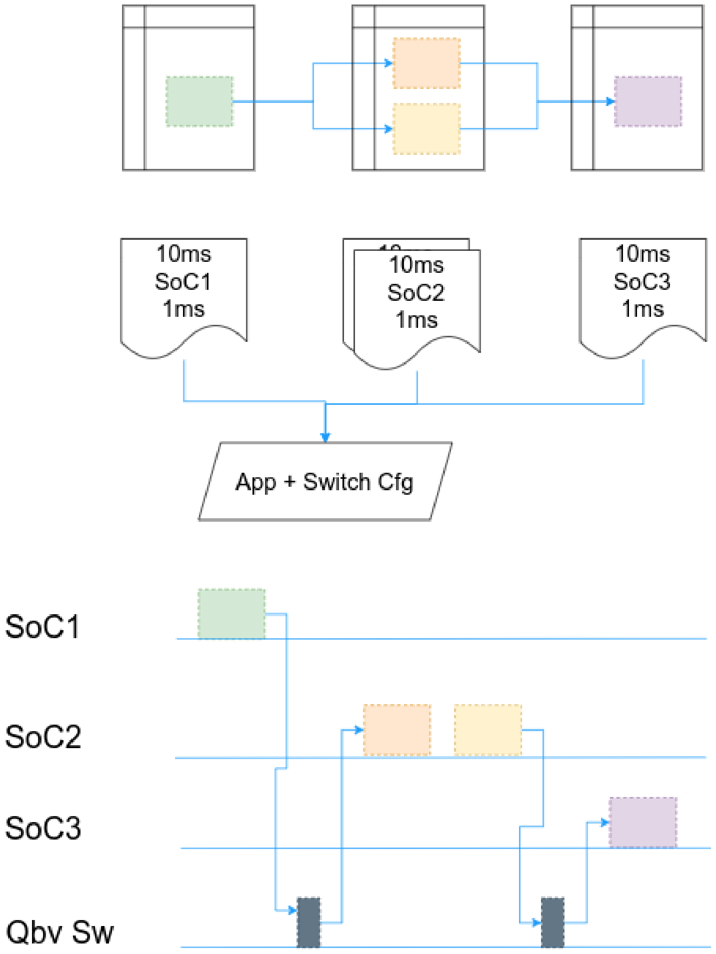
Series deployment





Series deployment

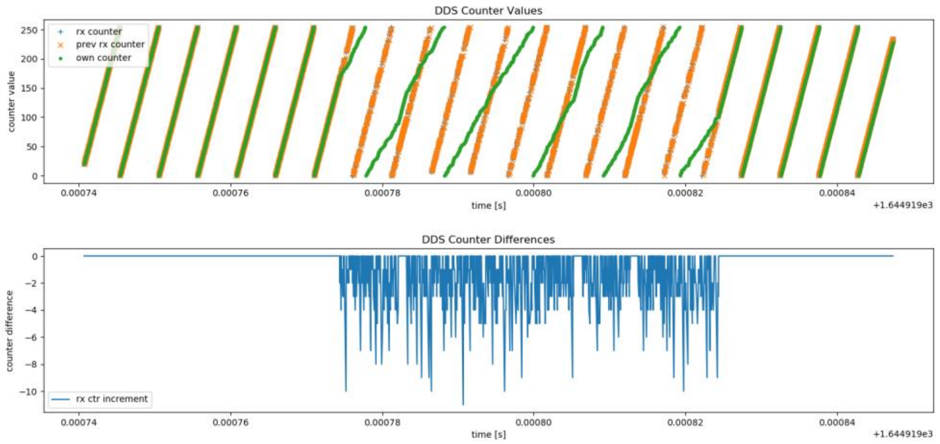


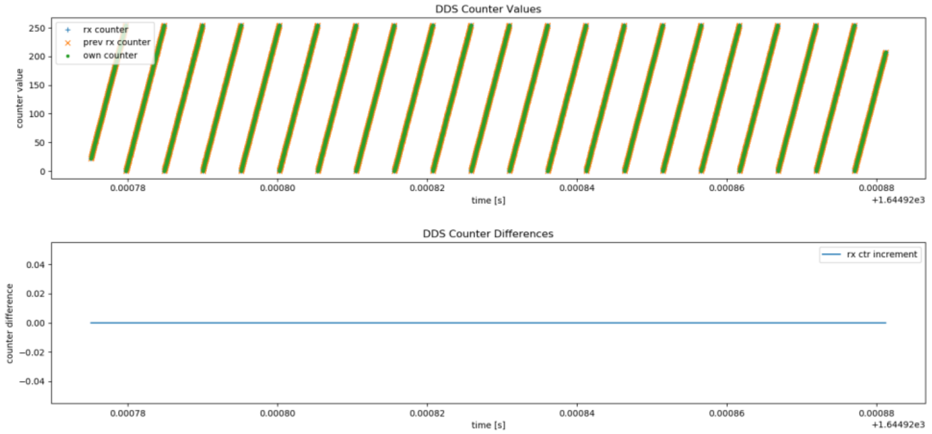


Deterministic communication with DDS

Prototype integration of DDS with Task and Network Scheduling shows improved determinism

- Explicit scheduling of tx and rx threads on task level
- Mapping of DDS QoS Parameters to TSN
- Example: Stream isolation properties against low-prio/best-effort traffic





Deterministic communication with DDS

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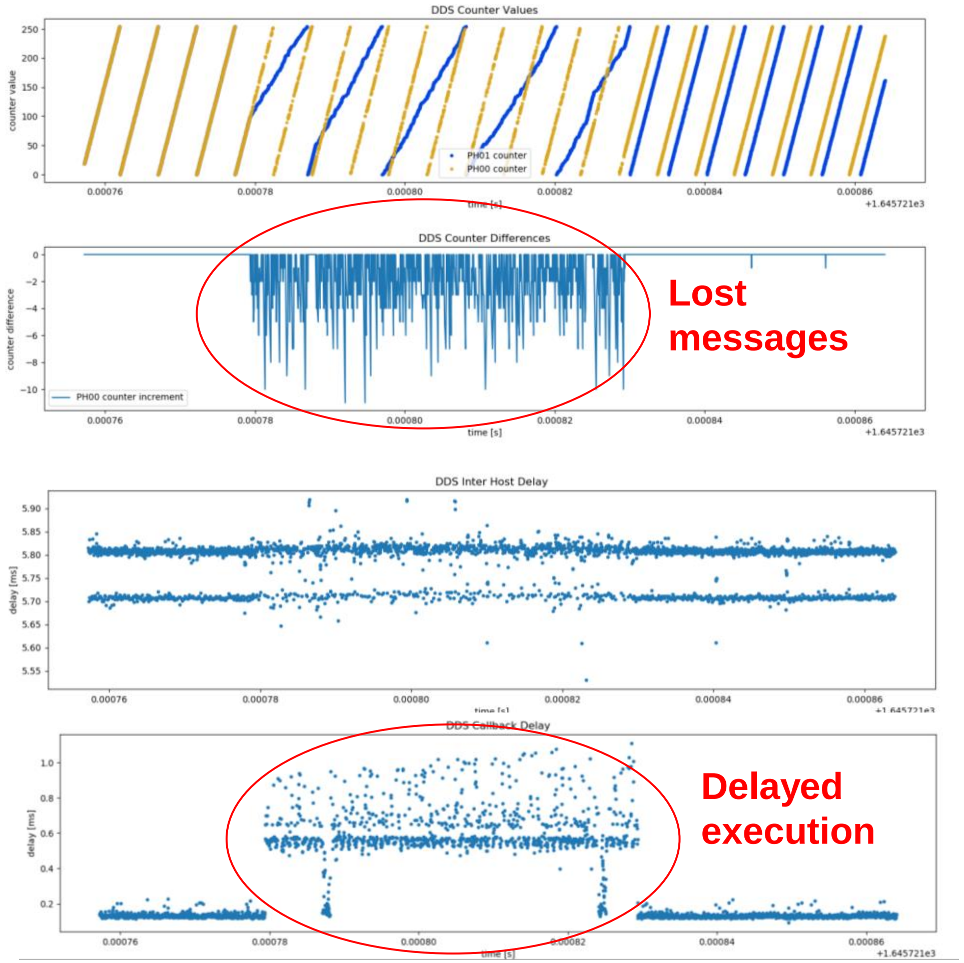
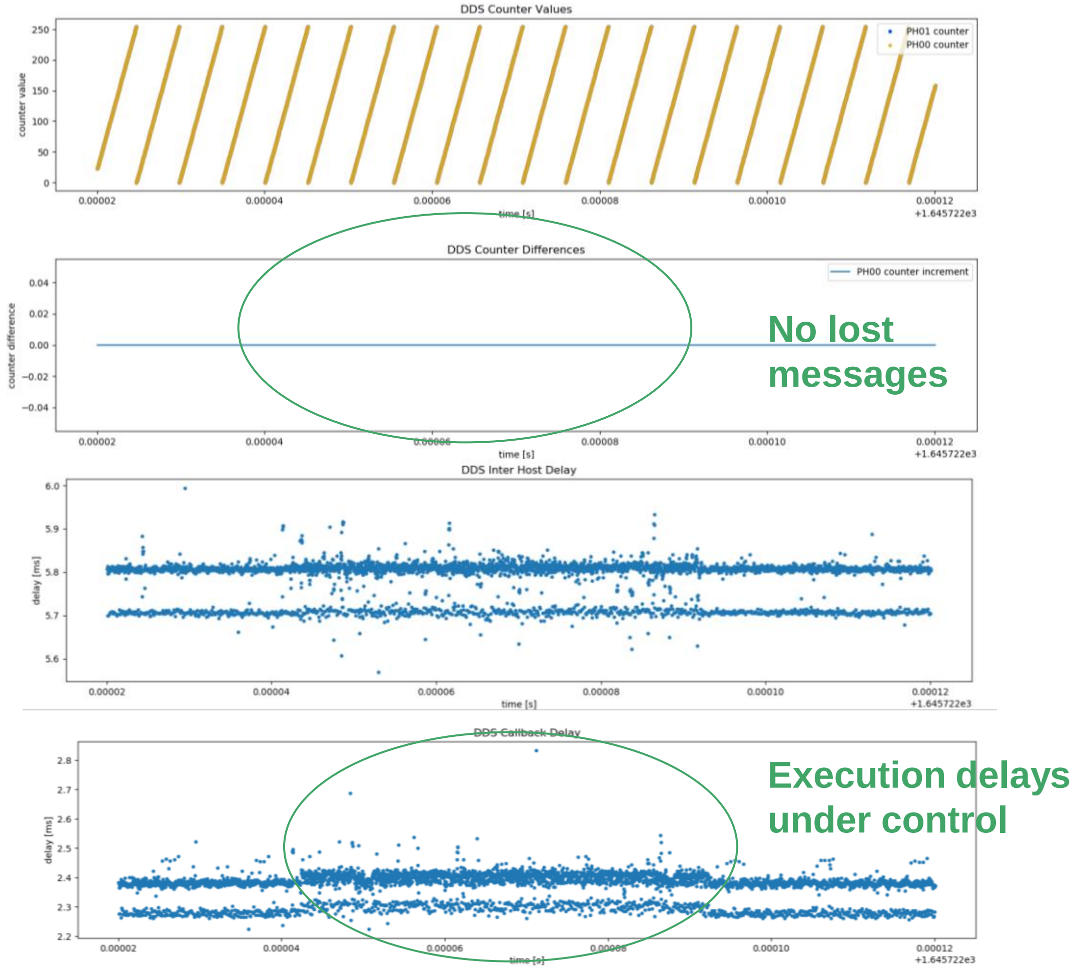
BEST EFFORT



vs.

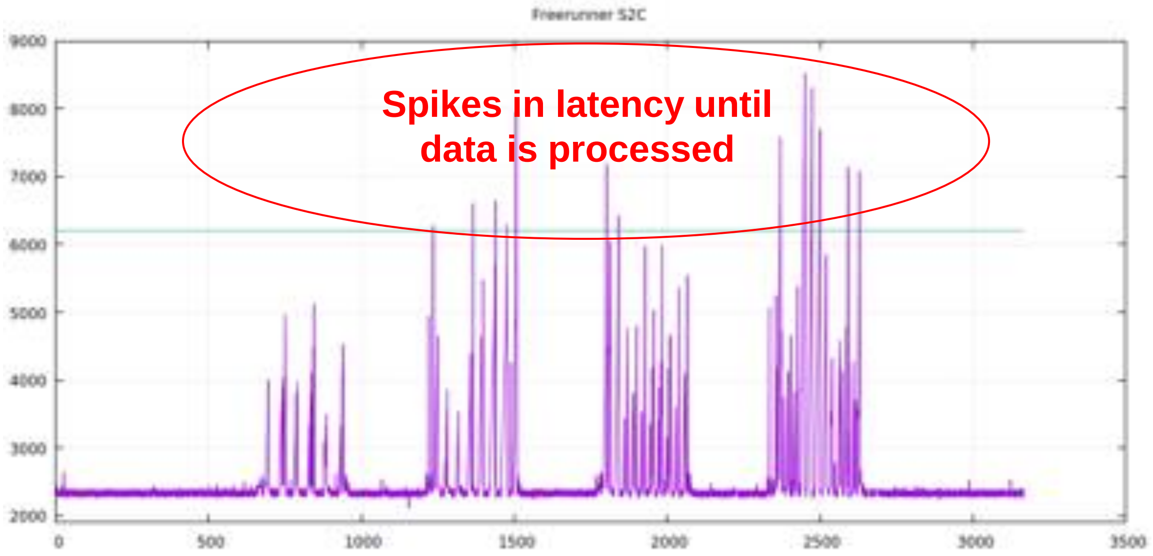
DDS+TSN



Scheduling Performance

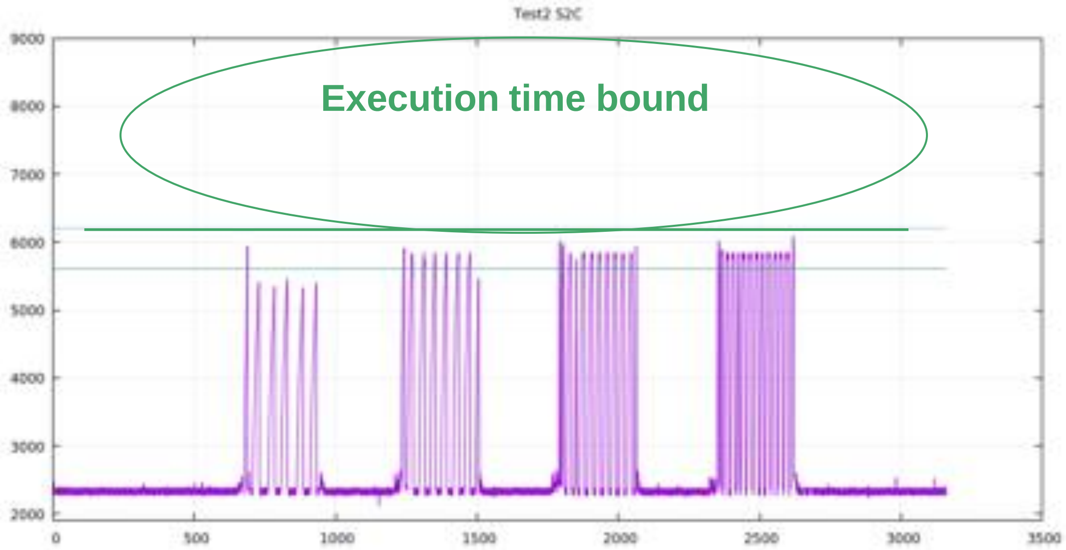
Results

FREE RUNNING



Load 30% 40% 50% 60%

TASK + NETWORK SCHEDULER



Load 30% 40% 50% 60%

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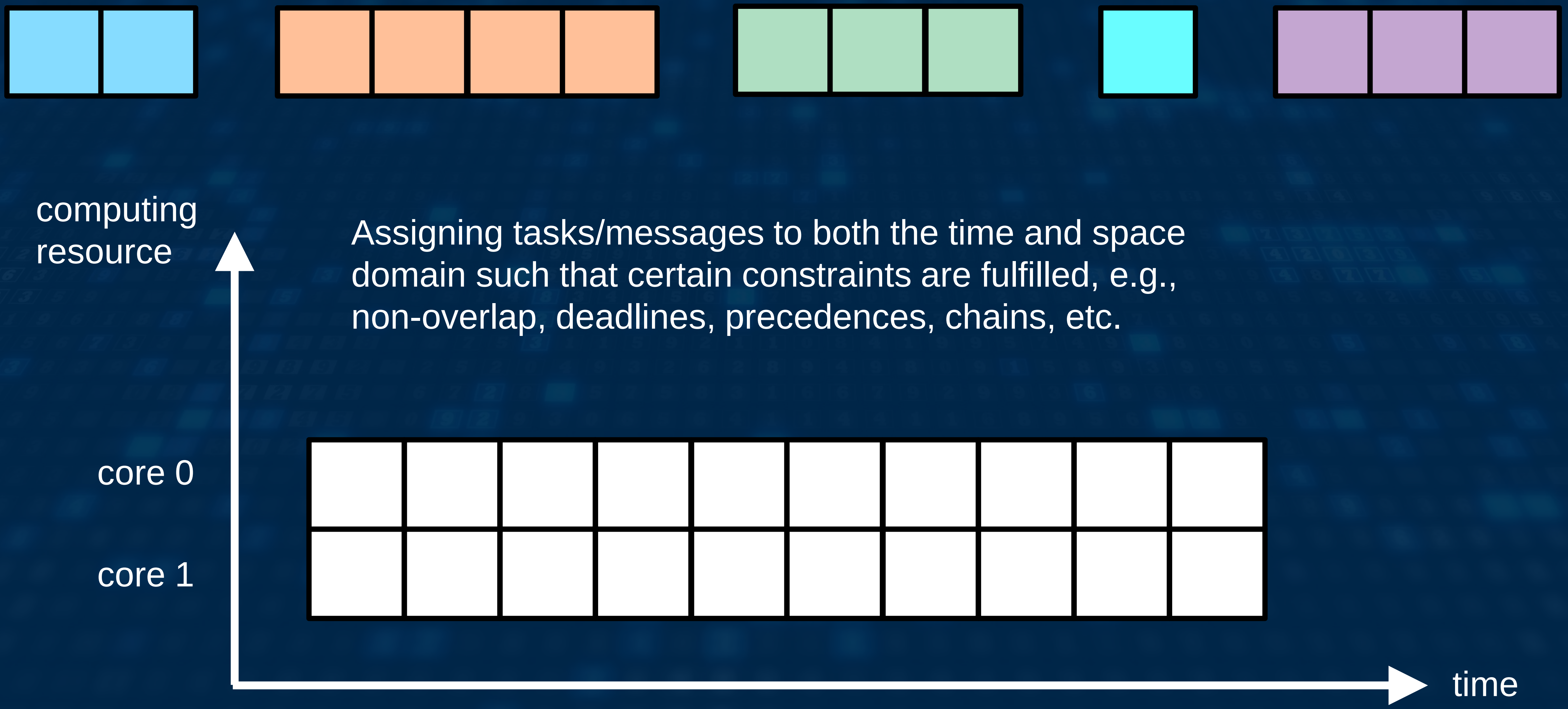
The scheduling problem



Assigning tasks/messages to both the time and space domain such that certain constraints are fulfilled, e.g., non-overlap, deadlines, precedences, chains, etc.

Tooling Workflow

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1

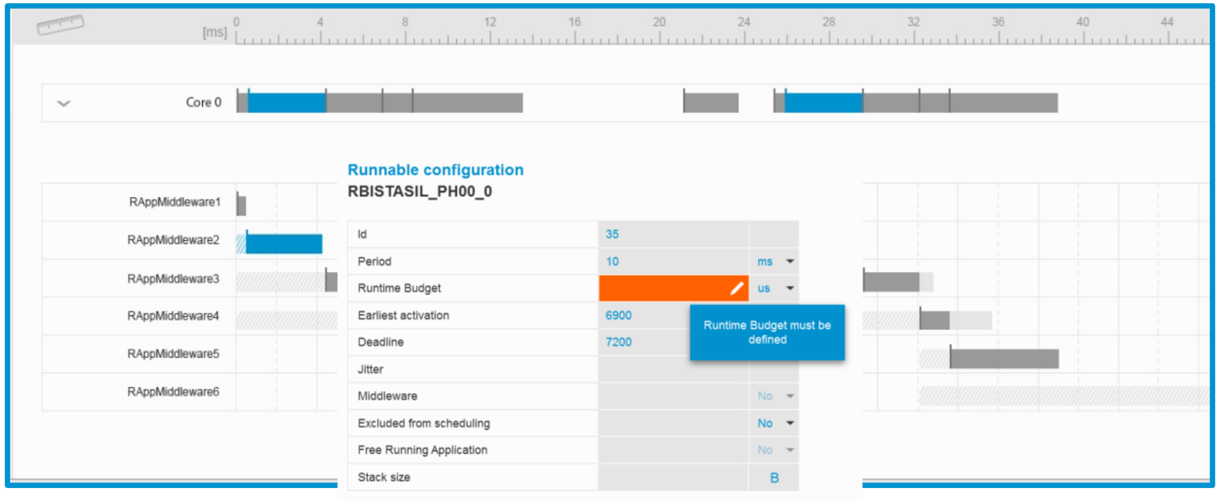
System Definition

- Number of Tasks
- Periods
- Host Affinity
- Resources

2

Scheduling Suite Configuration

- Timing Budget
- Core Affinity
- Jitter
- Category (Time/Event/Data Driven)
- Free Running App
- Computational Chains



3

Task Mapping & Comp. Chain Scheduling Tool

4

Network Scheduling Tool

Scheduling Core Configuration
- AUTOSAR
- RTOS
- Linux

Network Schedule Configuration

5

Task Schedule Visualization

ECU

Switch