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Ethernet TSN as Enabling Technology for ADAS and Automated Driving Systems

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Automotive Ethernet Began its Path of Success

- IEEE 802.3 standards for 100BASE-T1, 1000BASE-T1, and beyond, will address automotive industry needs in bandwidth and physical layer characteristics required by automotive operational environments
- IEEE 802.1 TSN standards will address most automotive IN-Vehicle Ethernet communication needs of precise time synchronization, latency guarantees and predictability, ultra-low latencies, fault tolerance, and dependability
- TSN will enable substantial simplification of the challenging implementation of safety-critical automated driving systems

Agenda

- *Driving automation definition*
- Communication requirements and role of TSN standards
- Example architectures using TSN features
- Concluding remarks

Key Use Case: Driving Automation

- Driving automation levels classify and categorize automotive features based on their capabilities in performing the driving task:
  - **Operational behaviors** (longitudinal and lateral control, object/event detection and response (OEDR)
  - **Tactical behaviors** (speed/lane selection, maneuver planning)
  - **Strategic behaviors** (destination/route planning)

Dynamic Driving Task (DDT)

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Driving Automation Levels

1. **Driver Assistance.** Sustained longitudinal OR lateral control relative to external objects and event (e.g., ACC).
2. **Partial automation.** Longitudinal AND lateral control for a given Operational Design Domain (ODD). Driver must supervise, and perform remainder of DDT.
3. **Conditional automation.** Complete DDT within a given ODD, providing appropriate response to relevant objects and events. Require the driver to take control if the system is about to exit its ODD or in case of system failure.

Note: Driving automation levels are defined in SAEJ3016

Driving Automation Levels

4. **High automation.** Complete DDT within a given ODD. Automatically bring the vehicle to “minimal risk condition” without reliance on the driver if the system is about to exit its ODD or in case of system failure, or in case of vehicle base failure (e.g., flat tire)
5. **Full automation.** Complete DDT under all on-road driving conditions in which the operator is legally permitted to operate a vehicle (no prescribed ODD)

Note: Driving automation levels are defined in SAEJ3016

Summary of Automation Levels

The level depends on the system's capability of performing the following functions within the context of a given Operational Design Domain:

- Primary subtasks of the Dynamic Driving Task
  - Lateral control
  - Longitudinal control
  - Object and Event Detection and Response
- Fallback capability

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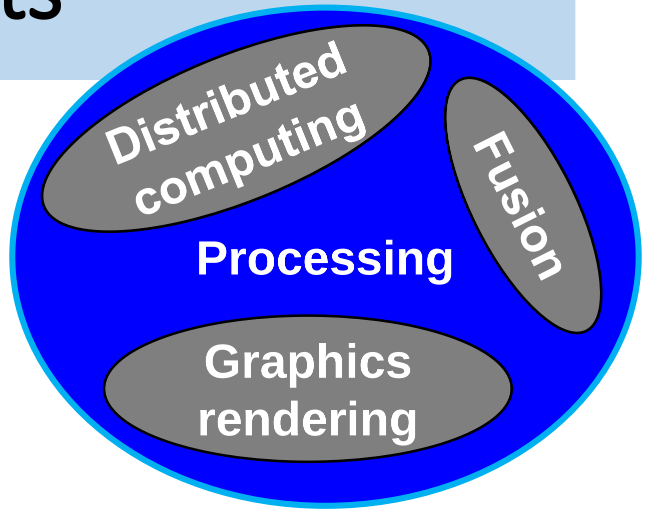
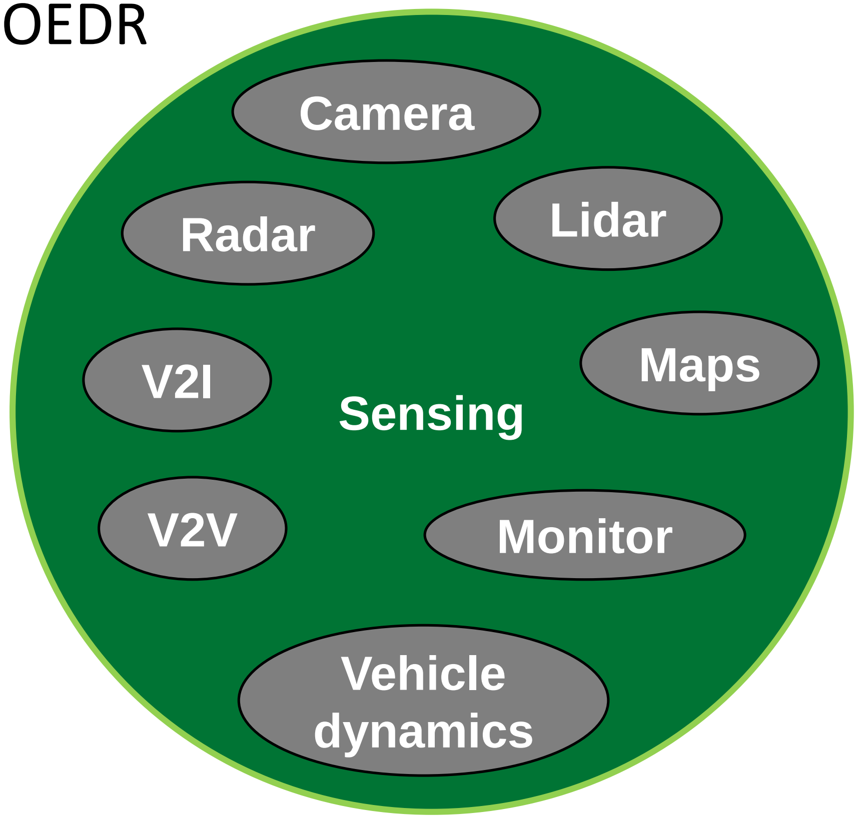
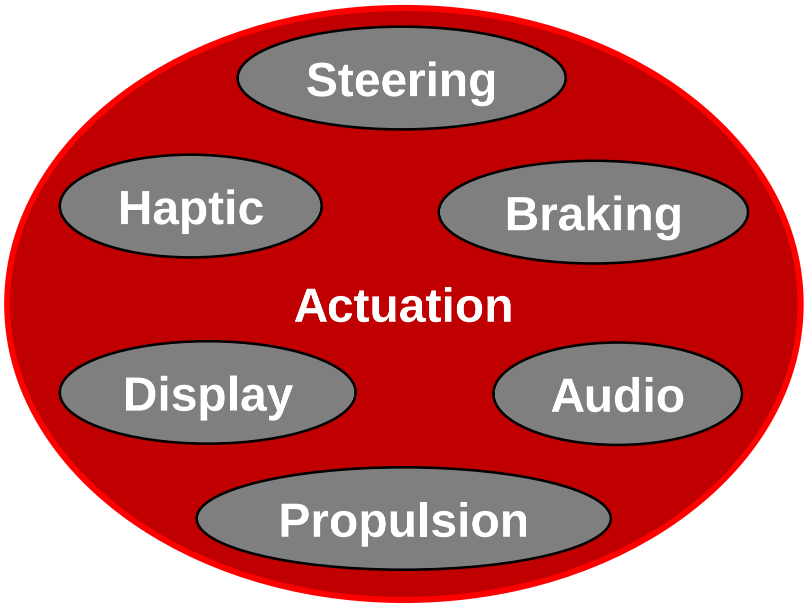
Communication Requirements

Primary subtasks of DDT

- Lateral control
- Longitudinal control
- OEDR







Communication Requirements

Primary subtasks of DDT

- Lateral control
- Longitudinal control
- OEDR

TSN support

Mixed real-time traffic and **mixed** latency requirements

- 802.1Q priorities and credit-based shaper (AVB)
- 802.1Qch cyclic queuing and forwarding
- 802.1Qbv scheduled traffic
- 802.1Qbu preemption
- 802.1Qcc stream reservation and configuration
- UBS: Urgency Based Scheduler (not yet a TSN project)

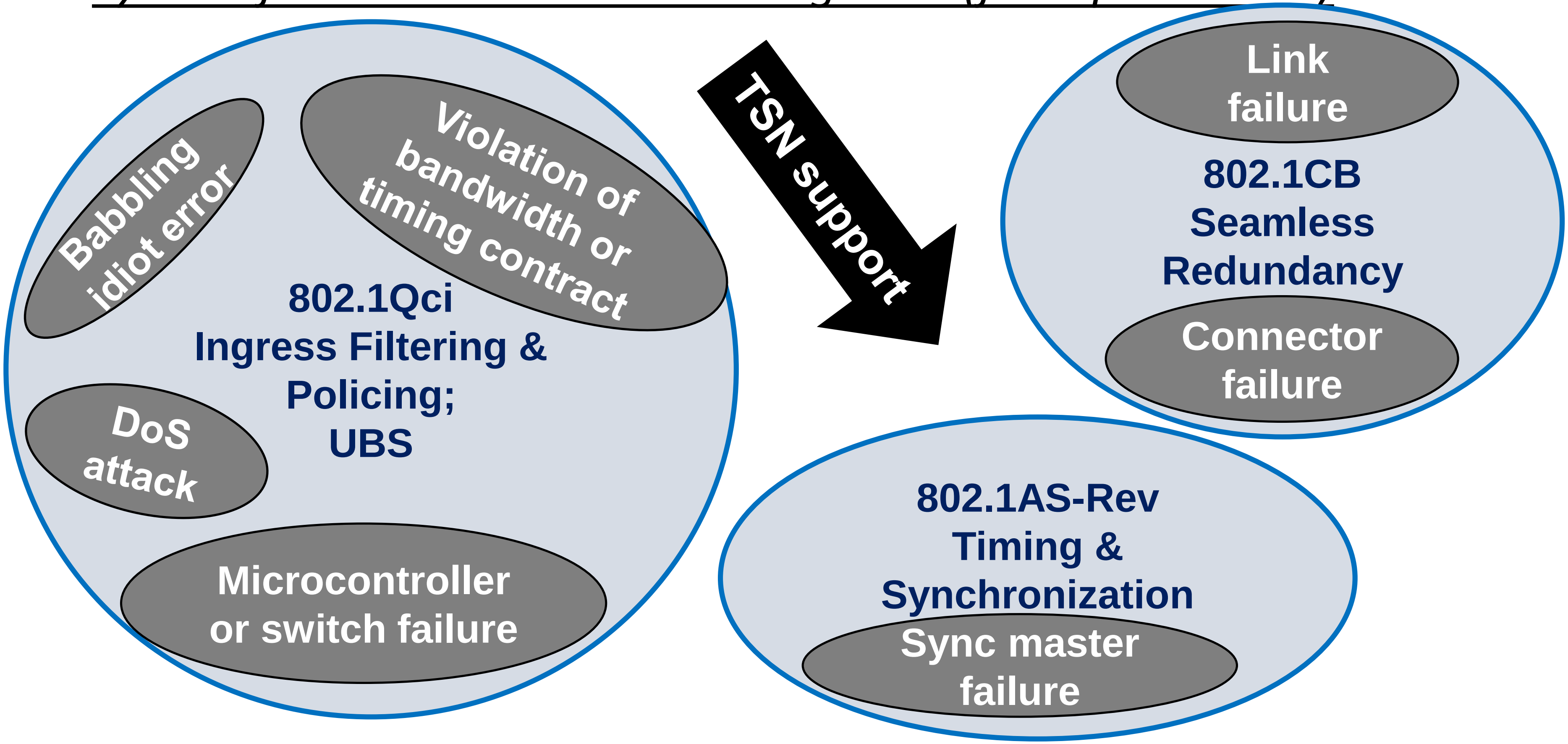
Common notion of time

- 802.1AS(-Rev) timing and synchronization

Communication Requirements

Fallback capability

- ODD boundary detection (same as previous slide)
- *System failure detection and mitigation (fail-operational)*



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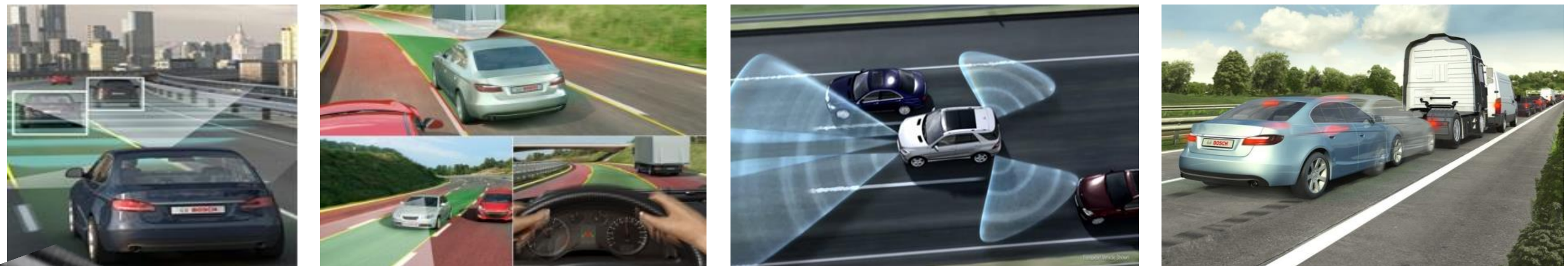
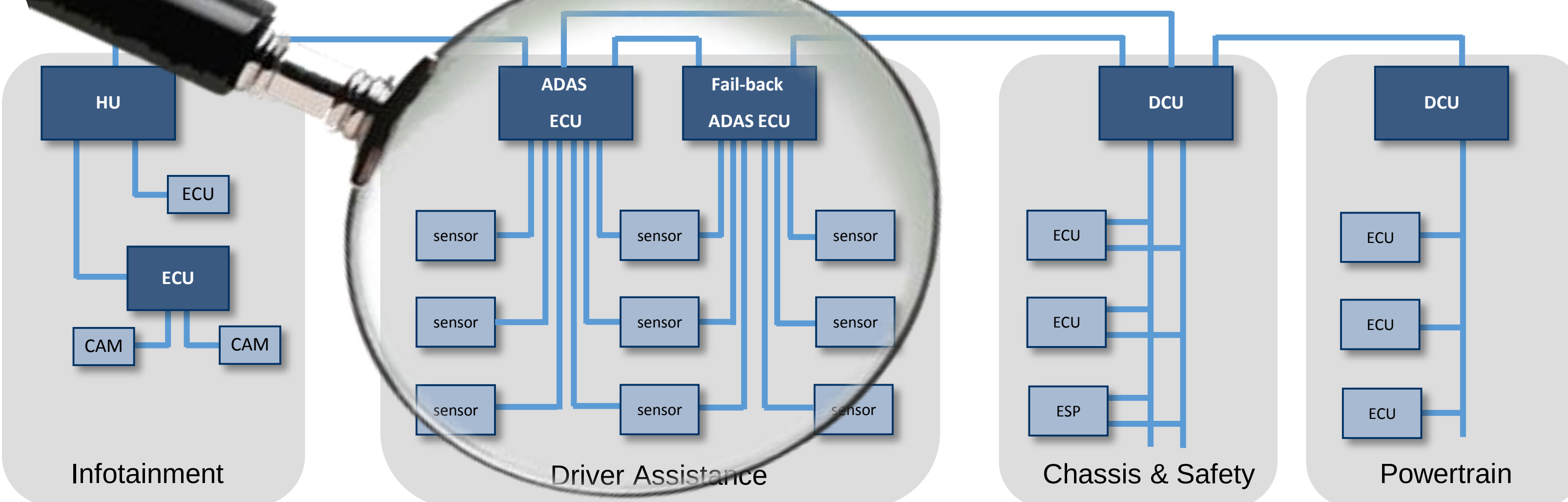
System Overview and Use Cases

Improvements on Sophisticated Automotive Advanced Drivers Assistance Systems (ADAS) like:

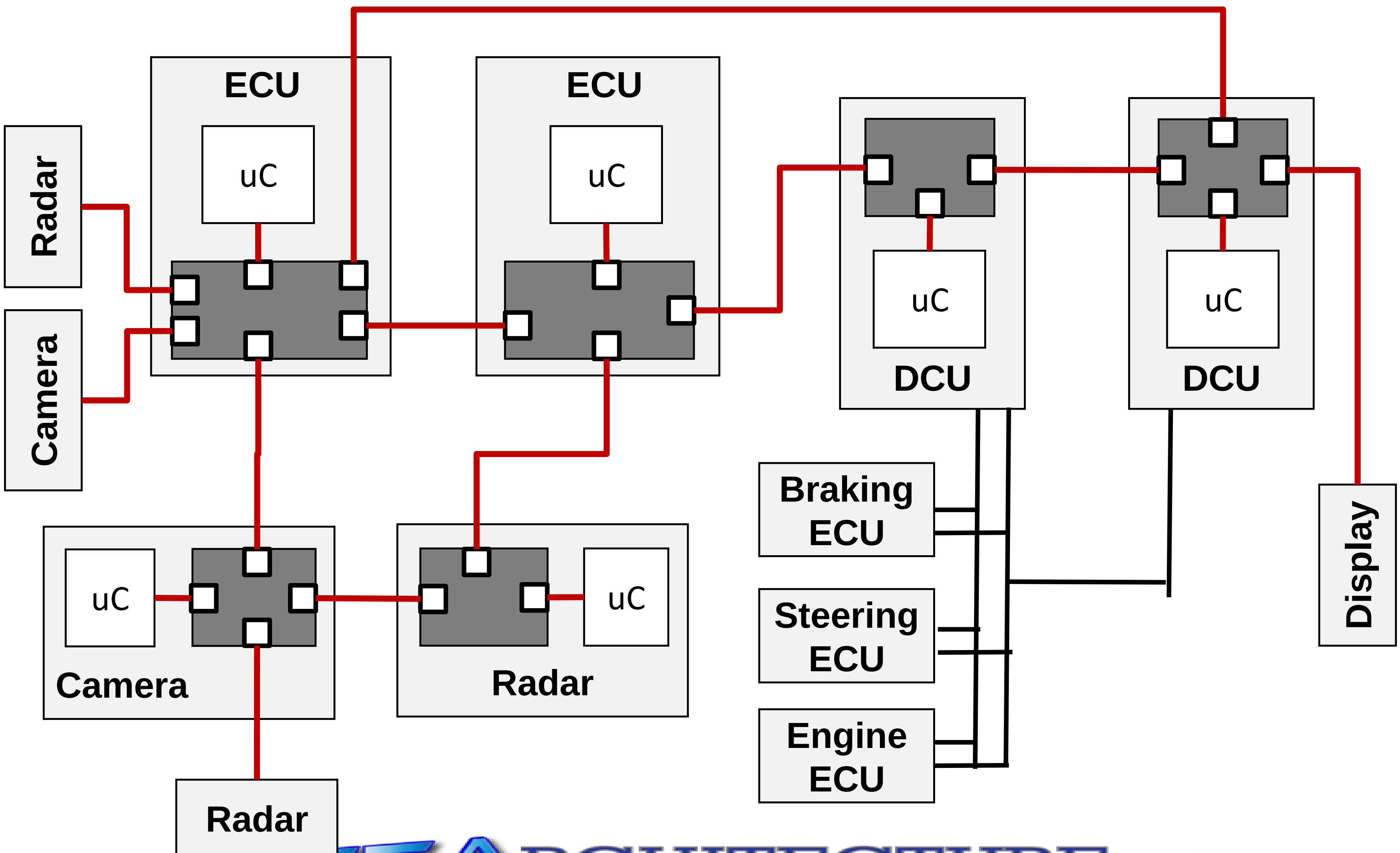


ise Control | Lane Departure Assist | Blind Spot Assist | Brake Assist

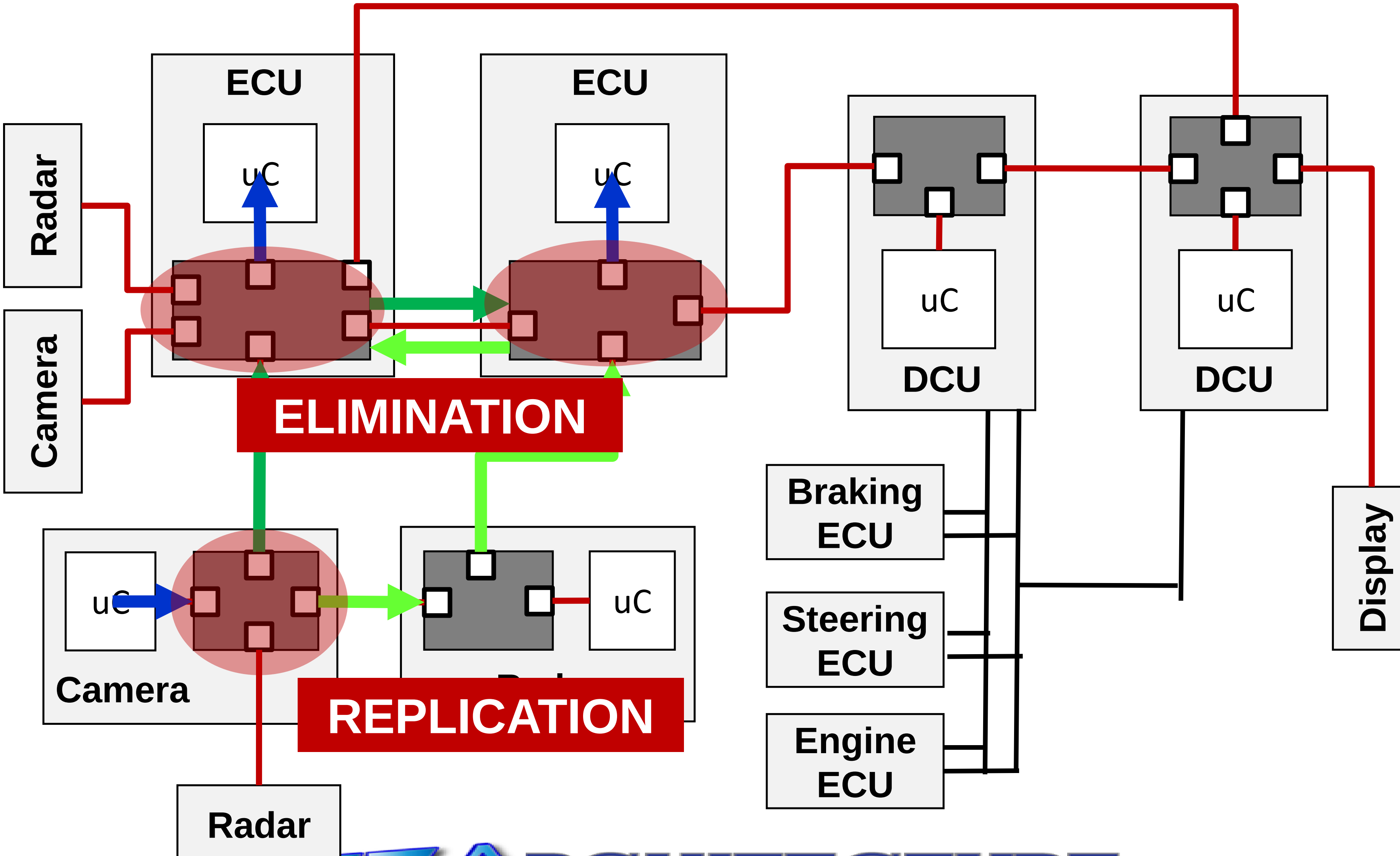


Fictive example of an in-vehicle E/E architecture

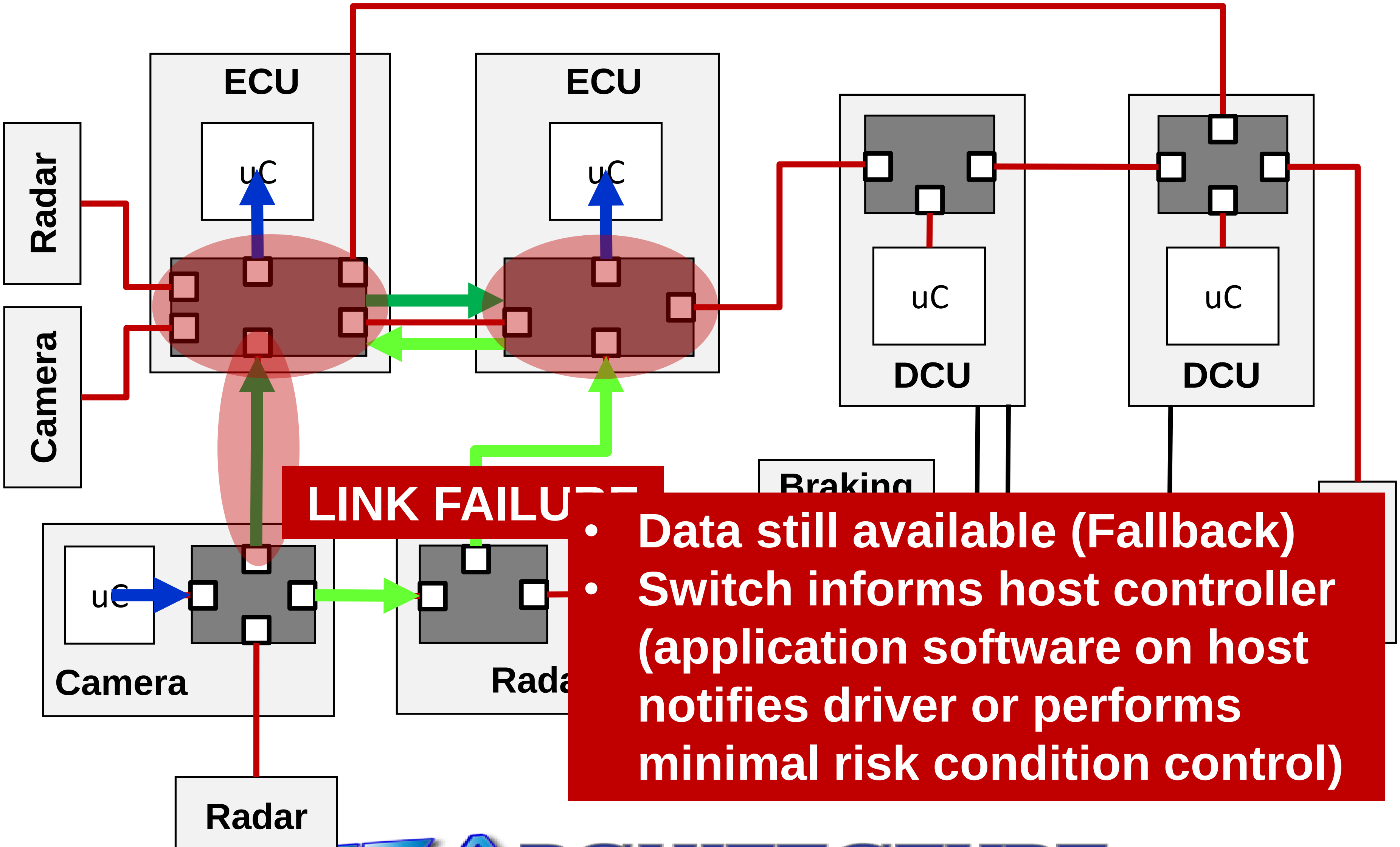
E/E Architecture Example



802.1CB and Ring Topologies

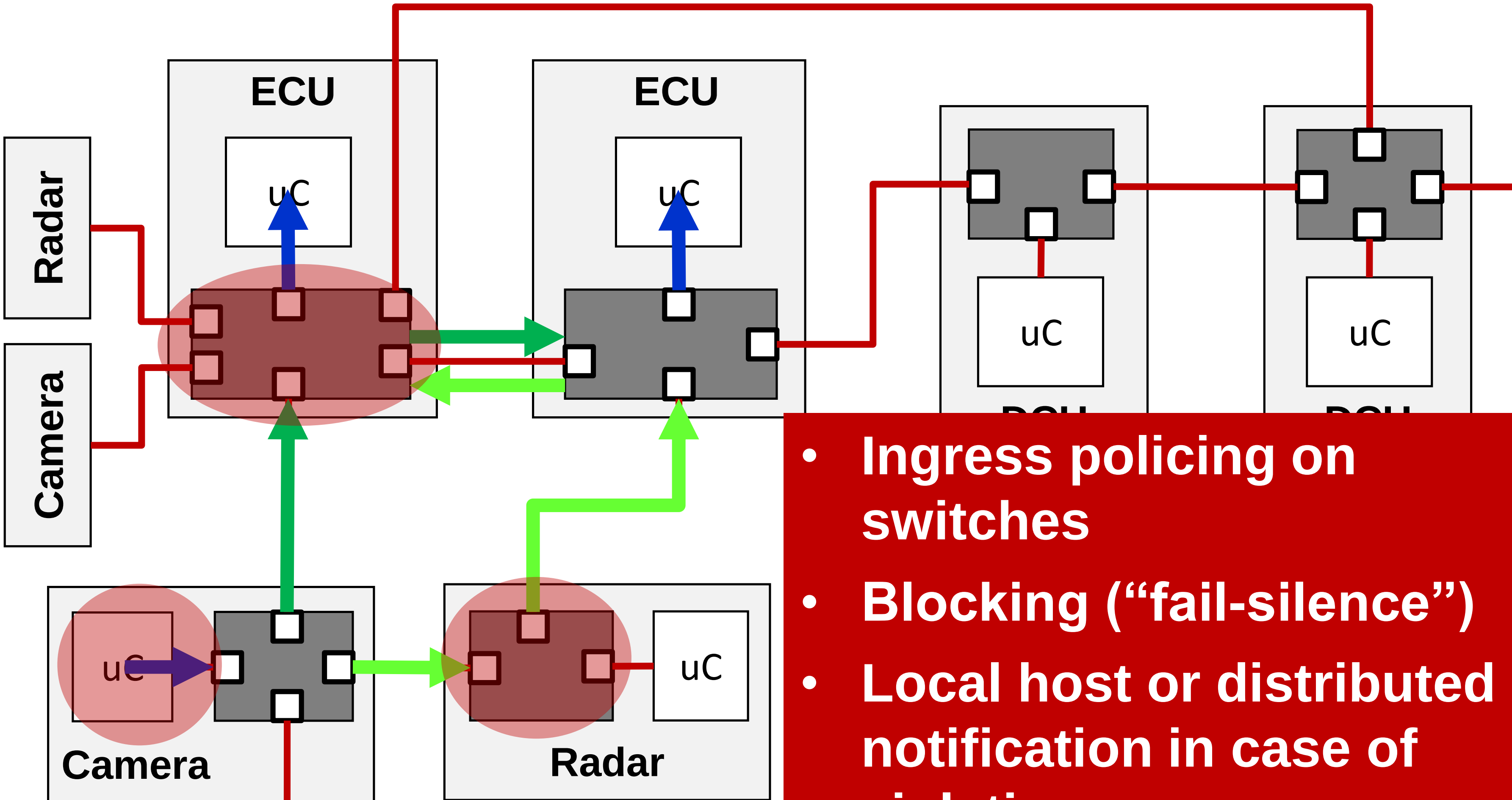


802.1CB and Failures



- Data still available (Fallback)
- Switch informs host controller (application software on host notifies driver or performs minimal risk condition control)

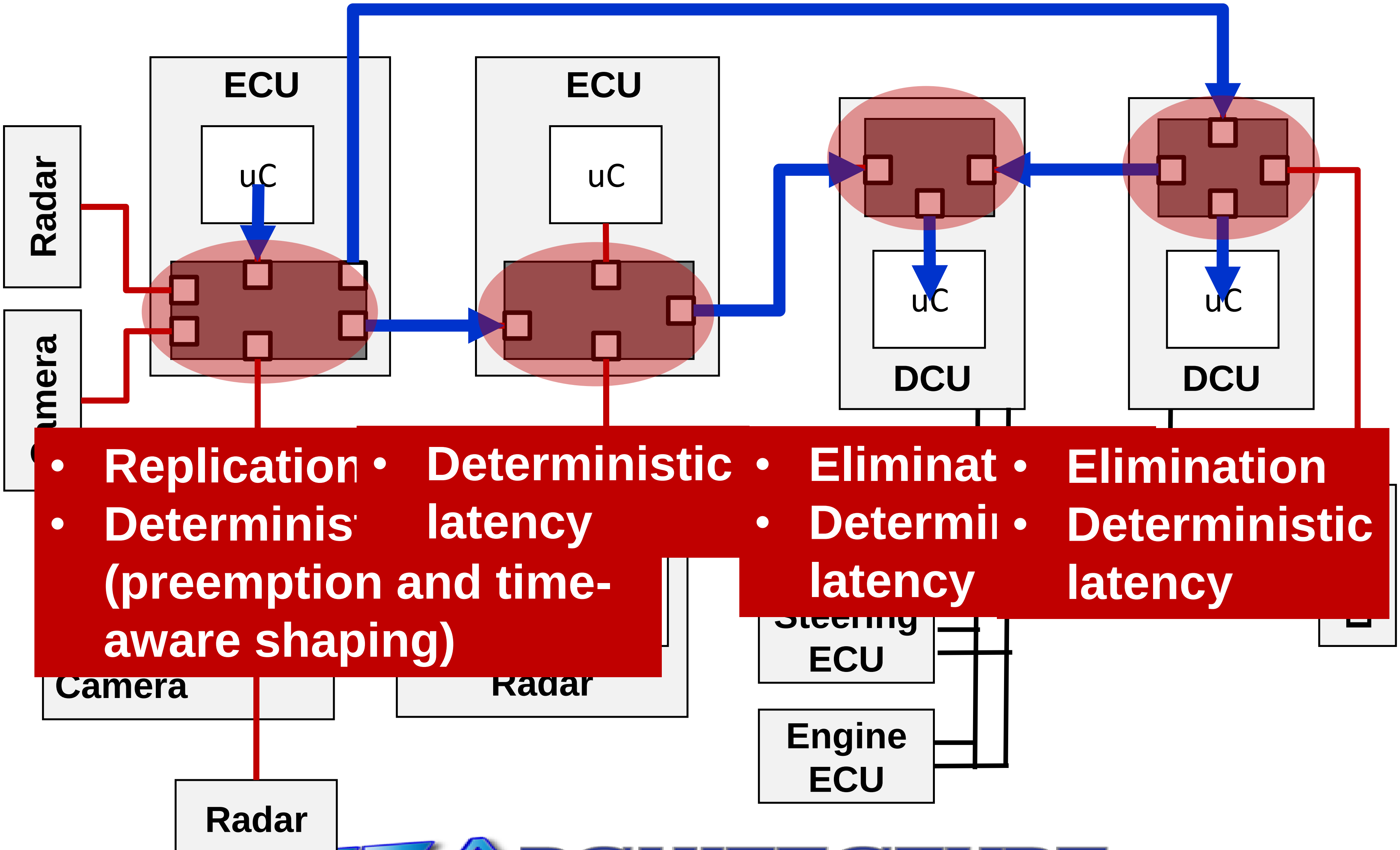
802.1Qci Ingress Filtering and Policing



Exceeds predefined rate

- Ingress policing on switches
- Blocking (“fail-silence”)
- Local host or distributed notification in case of violations
- Fallback capability

802.1CB/Qbv/Qbu – Backbone and Actuation



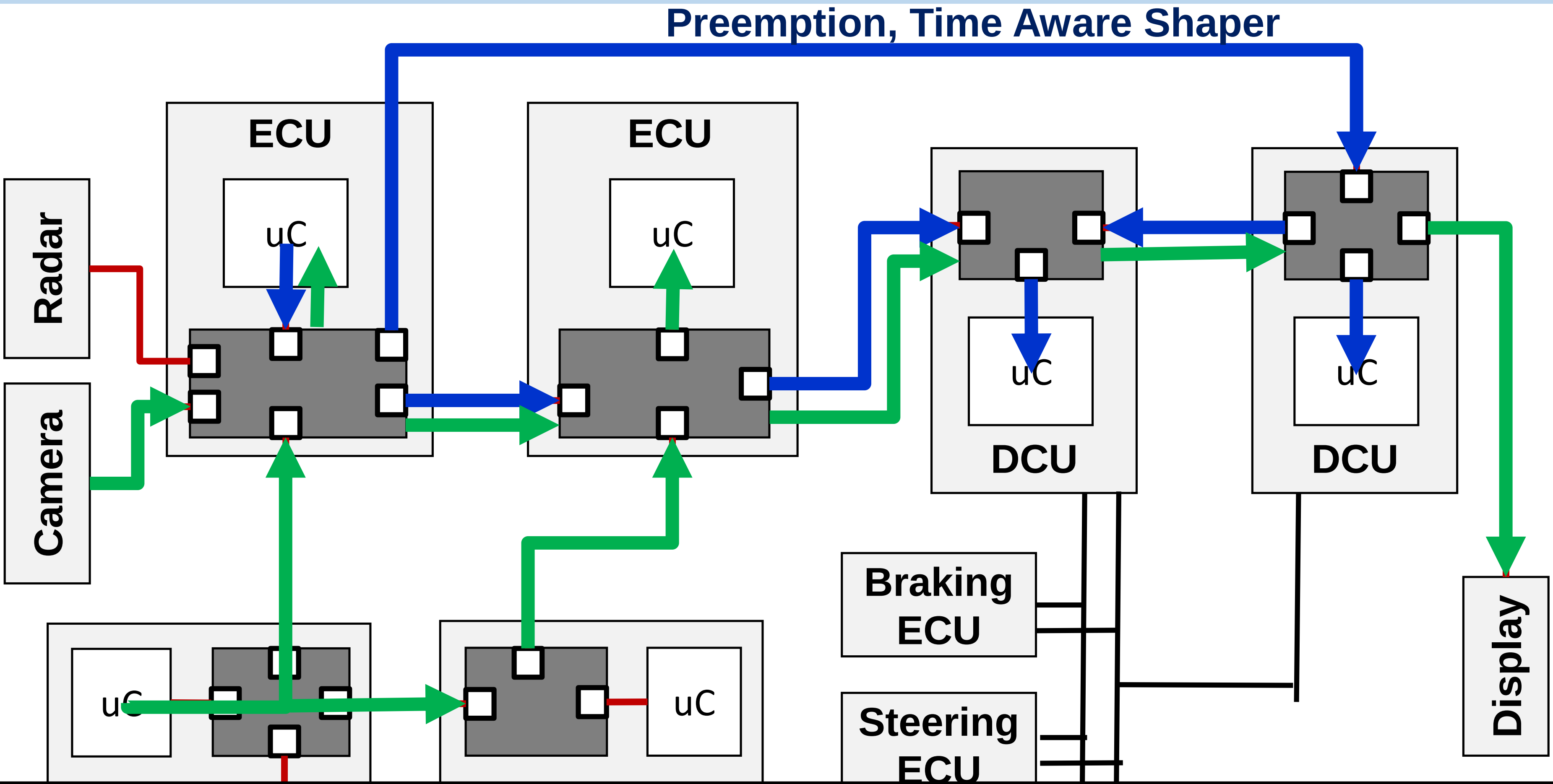
- Replication
- Deterministic latency (preemption and time-aware shaping)

- Deterministic latency

- Elimination
- Deterministic latency

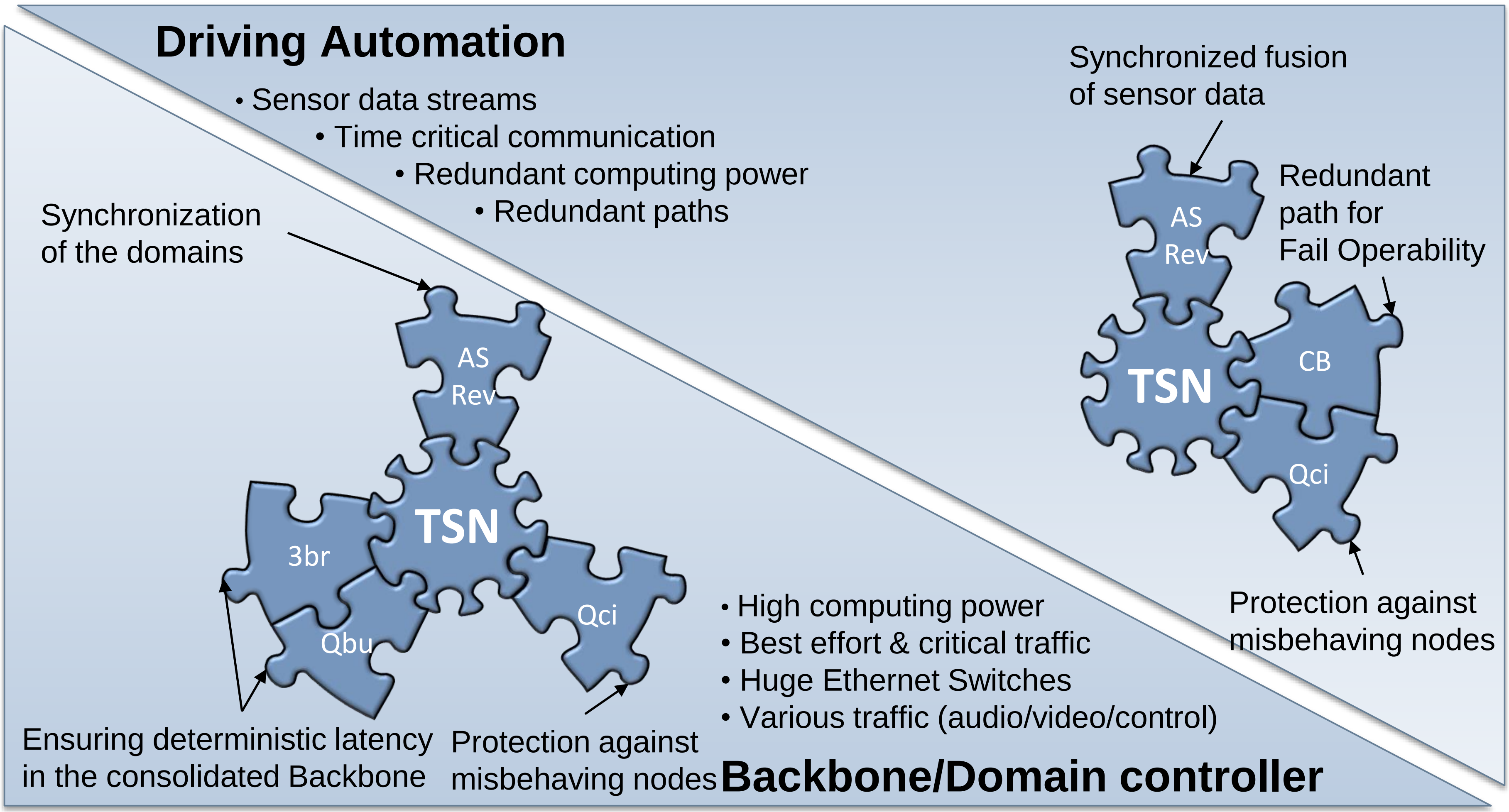
- Elimination
- Deterministic latency

802.1CB/Qbv/Qbu – Backbone and Actuation



TSN enables dependable and deterministic low-latency communication in presence of bandwidth-consuming communication like ADAS sensors and audio/video

TSN is a Flexible Protocol Set Supporting …



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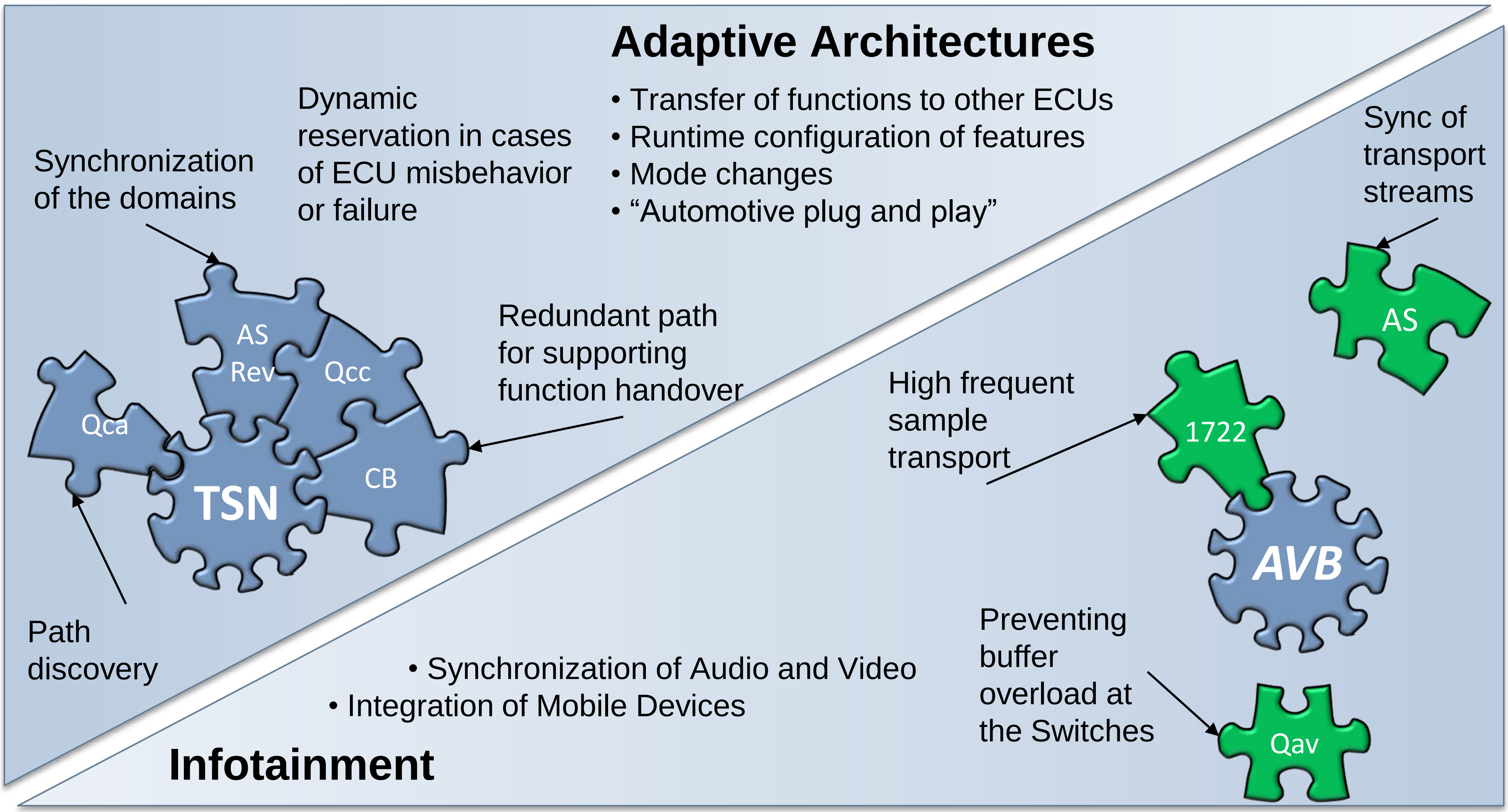
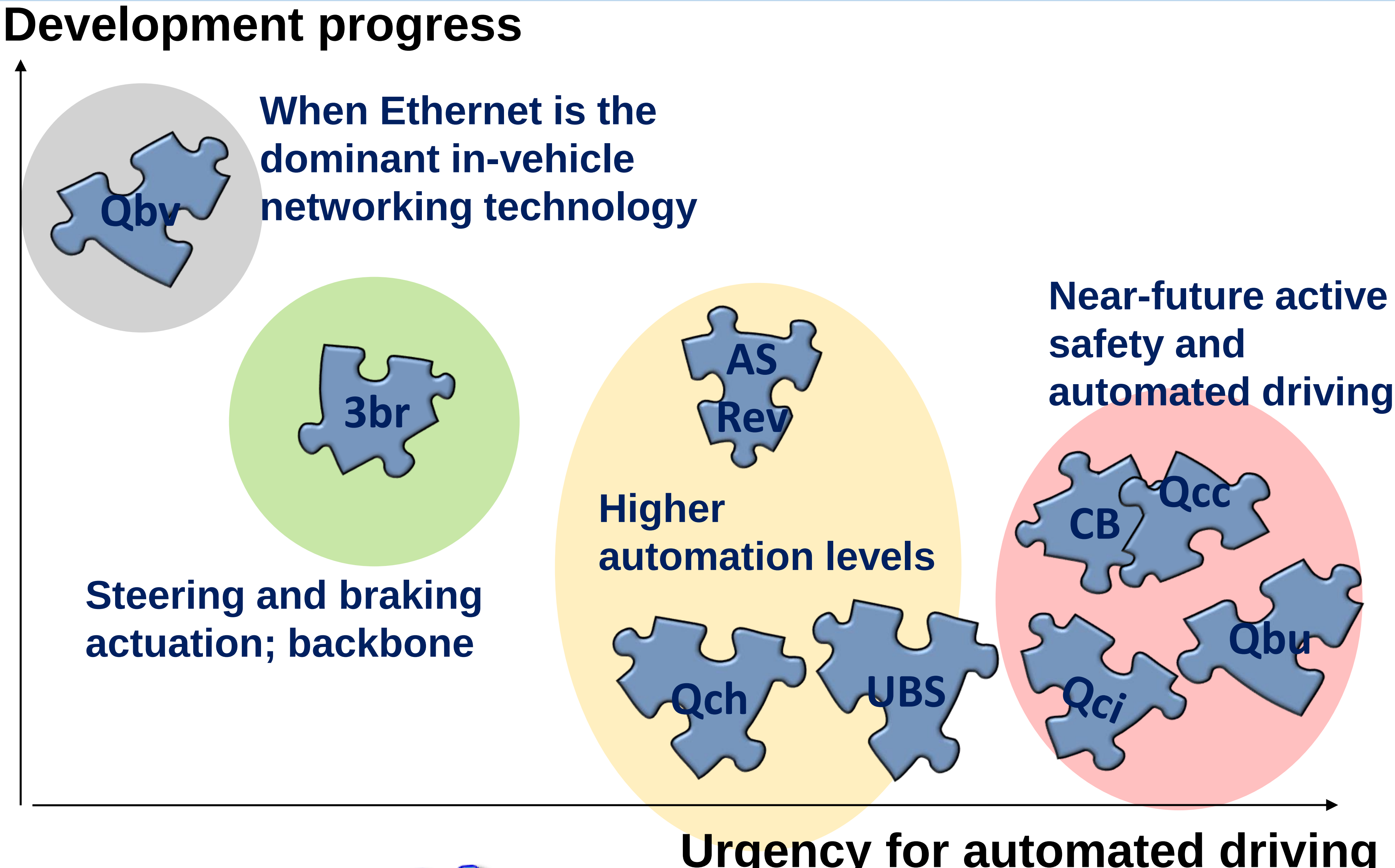


TSN Progress vs. Automotive Deployment



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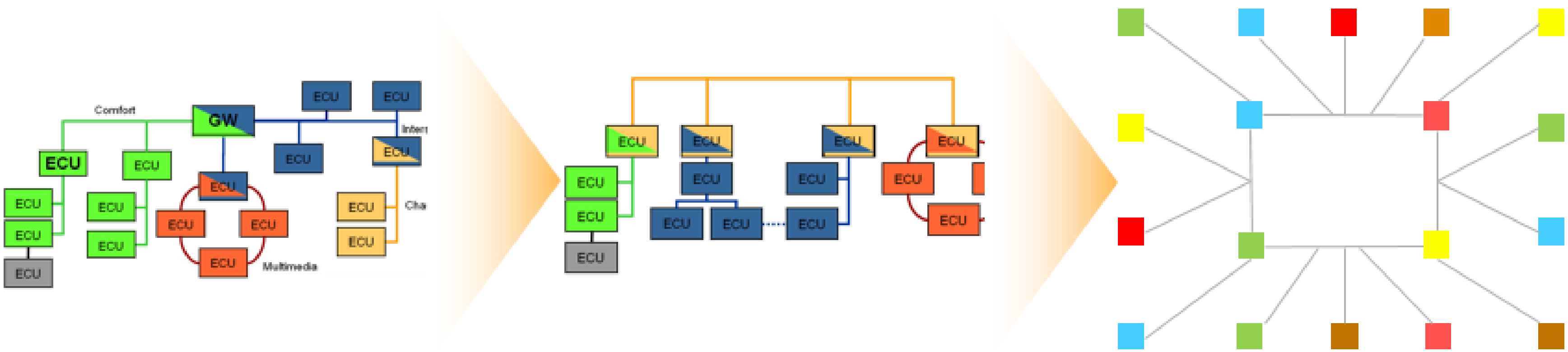
Challenges

Distributed Current Approach | **Organized Domain Approach** | **Disruptive Cloud Approach**



- *Keep it Simple*
- *Keep it Flexible*
- *Keep it Reliable*
- *Keep it Robust*
- *Keep it Inexpensive to Implement*
- *Availability*

Conclusions

- The TSN standards address very important engineering problems in the development of driving automation systems

- TSN will help the automotive industry in complying with functional safety requirements (ISO 26262)

- TSN adds Layer 2 solutions for real-time and dependability in switched Ethernet, all of which are instrumental in the automation of the Dynamic Driving Task and Fallback Capability