Technische Universität Braunschweig

INSTITUTE OF COMPUTER AND NETWORK ENGINEERING

Safe reconfiguration of automotive TSN networks

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2023-09-27

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Work Group:

- Design of Embedded and Cyber-physical Systems (Prof. Dr.-Ing. R. Ernst)

Research focus on Vehicles and Avionic:

- Adaptive, Autonomous, Real-time Embedded Systems
- Computer Engineering and Hardware architectures
- Communication Systems
- Functional Safety dependability and robustness

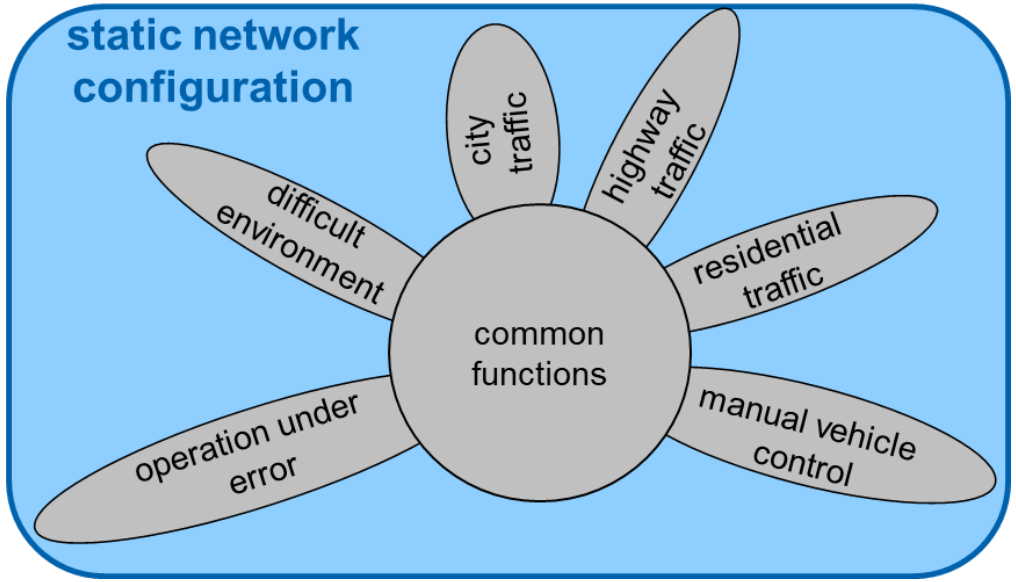
https://magazin.tu-braunschweig.de/m-post/20-millionen-euro-fuer-gebaeudesanierungen-der-tu-braunschweig/

Agenda

- In Vehicle Networks
- Network Management
- Example Scenarios
- Conclusion

In Vehicle Network

- **vehicle network challenges**
  - Increasing sensor data traffic with high requirements on bandwidth, latency
  - Complex mix of small and large data objects, mixed criticality, V2X data transport, fail operational, …
  - Dynamic connections across vehicle network



- **SoA: static vehicle network management**
  - static parameter adjustment at design time
  - many parameters TSN, AVB: priority, shaping, access control, TAS
  - Must be designed for the worst case and cover all combinations

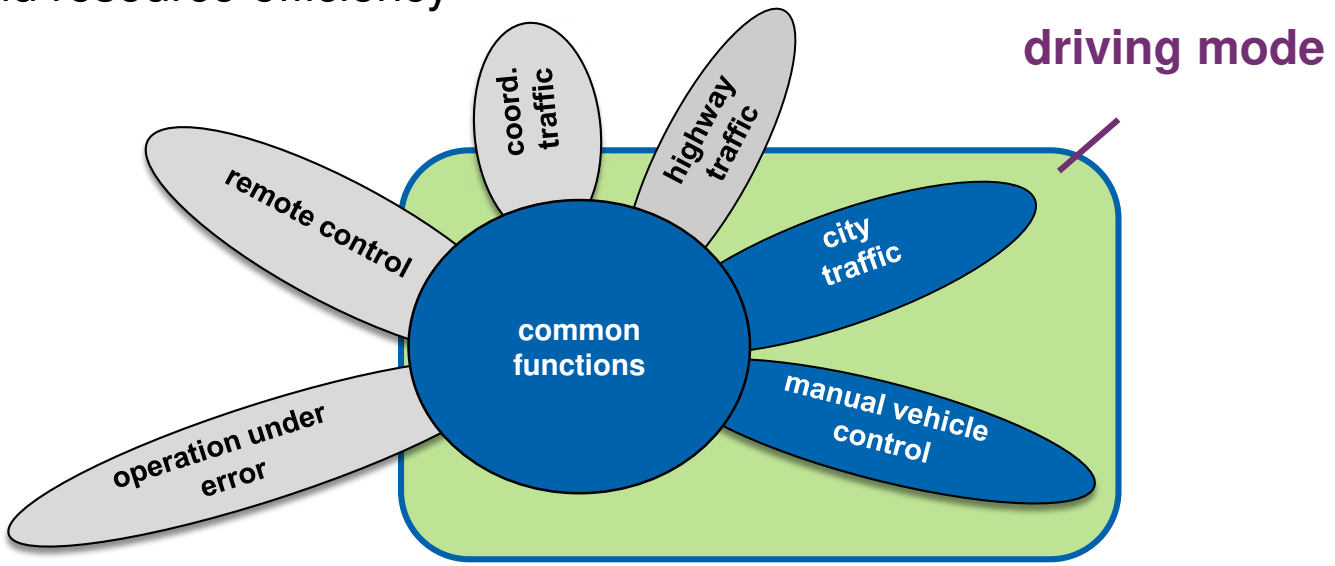
  →complex and challenging design process

  →Inefficient and inflexible resource utilization

Application Aware Dynamic Network Management

- parameter adjustment during runtime
- application and situation aware network adaptation
- can be applied to subset of network nodes, parameters, and applications
- more flexible design process – individual planning of situations and applications

- higher system performance (latency, bandwidth) and resource efficiency
- flexible network architecture
- enables data intensive V2X applications



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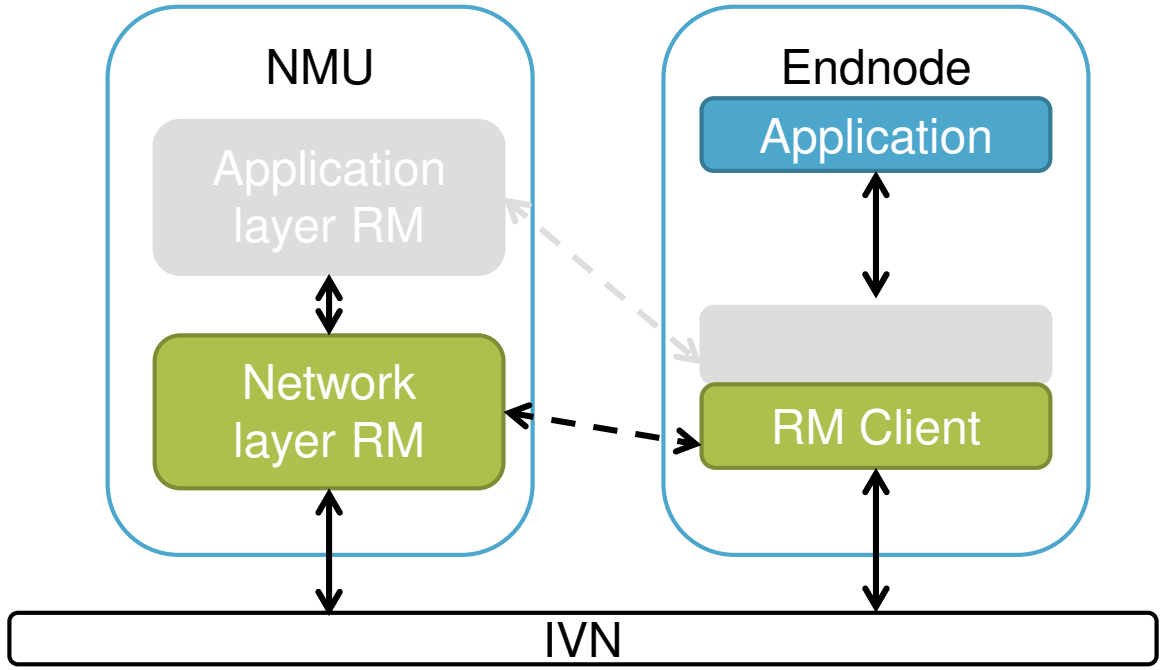
Network Management Unit

- **NMU** with Network Layer Resource Manager (nRM)
- **Resource Manager Client** on all network devices (Switch and Endnode)

- **nRM:**
  - Monitor of all network resources
  - Fault detection

- **Effect**:
  - Coordinates application access to IVN
  - Change parameter set of network devices
  - Safe mode change

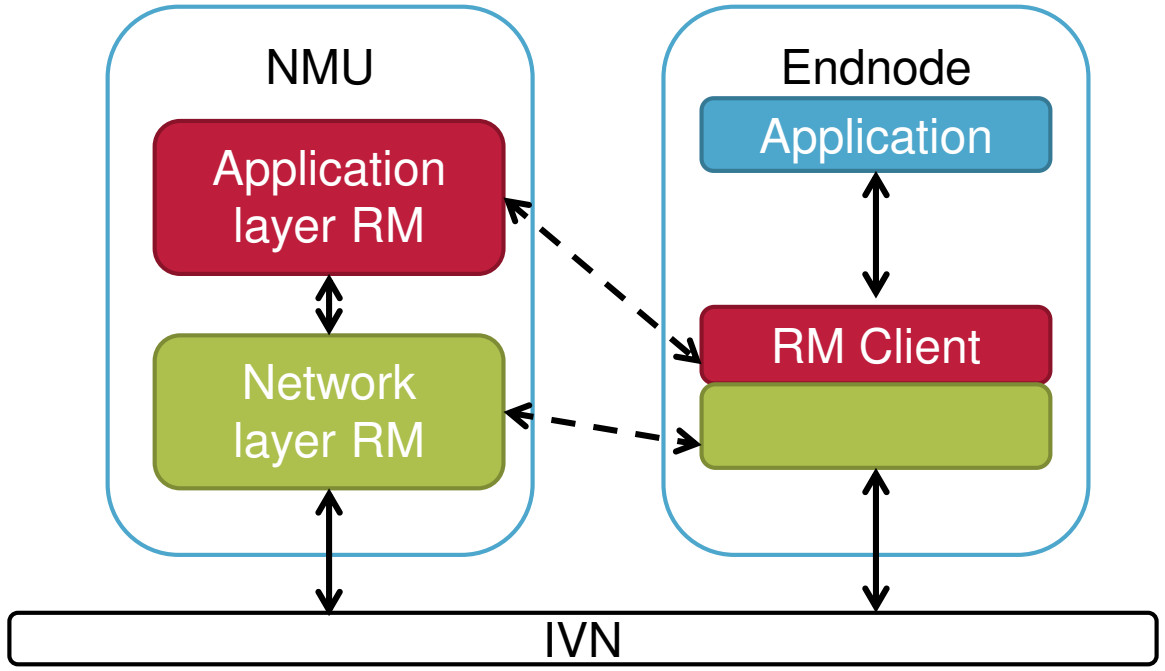


Application Aware Network Management

- **NMU** with Application layer Resource Manager (aRM)

- **aRM:**
  - Monitor of application demands
  - Coordinates and orchestrate applications
  - Bundles demands of applications and forward to nRM

- **Effect**:
  - Knowledge of data leads to better management
  - Enables application/object based scheduling
  - Improve safety for mode change



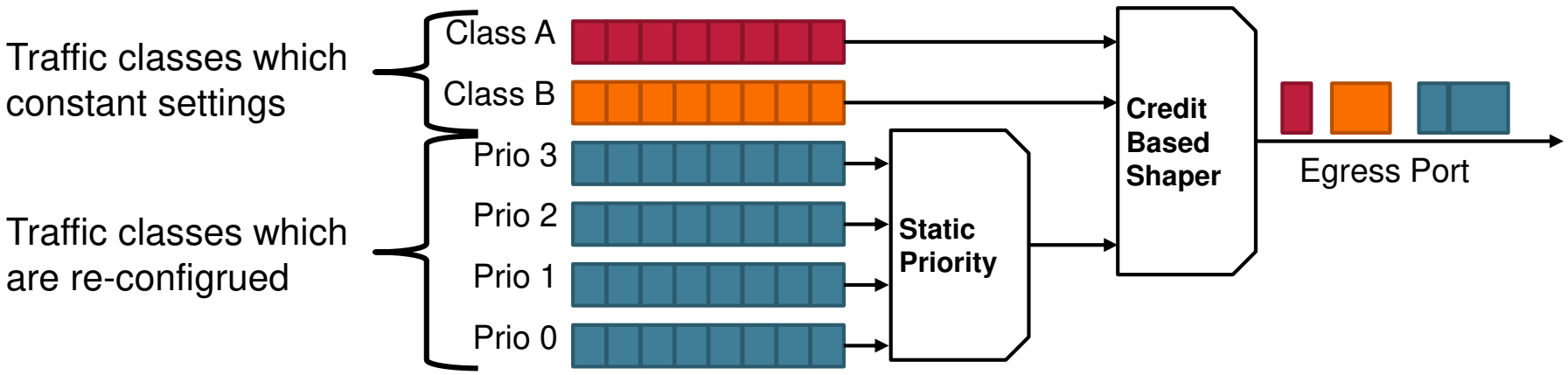
Partial Re-Configuration

- Traffic streams with the **highest priority** may have very tight **deadlines** and are **interference-sensitive**

→This could prevent the re-configuration

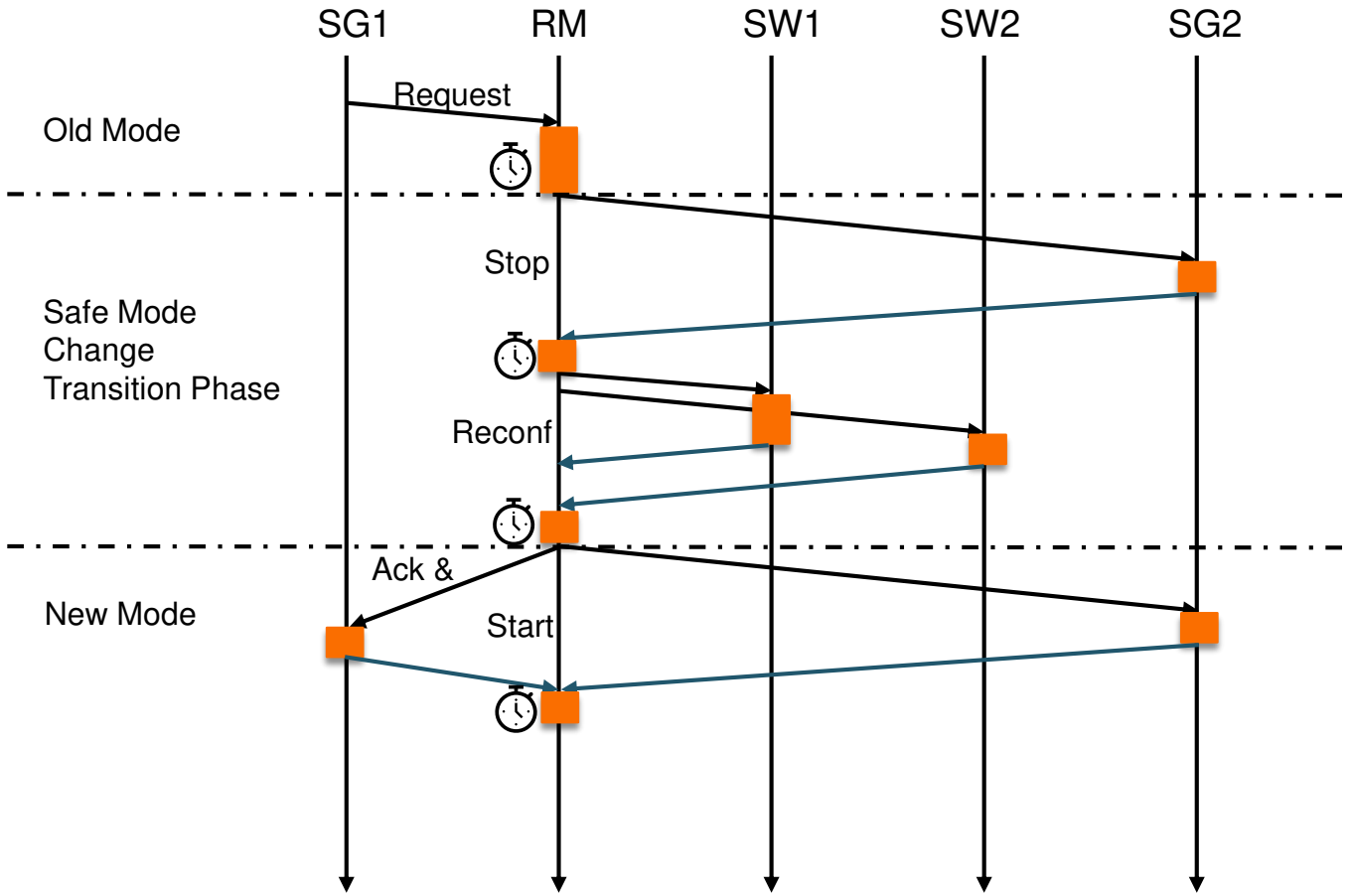
- nRM allows to re-configure only the selected traffic classes
- Without affecting higher priority traffic

→ only affected **entities** of the network or **streams** are reconfigured



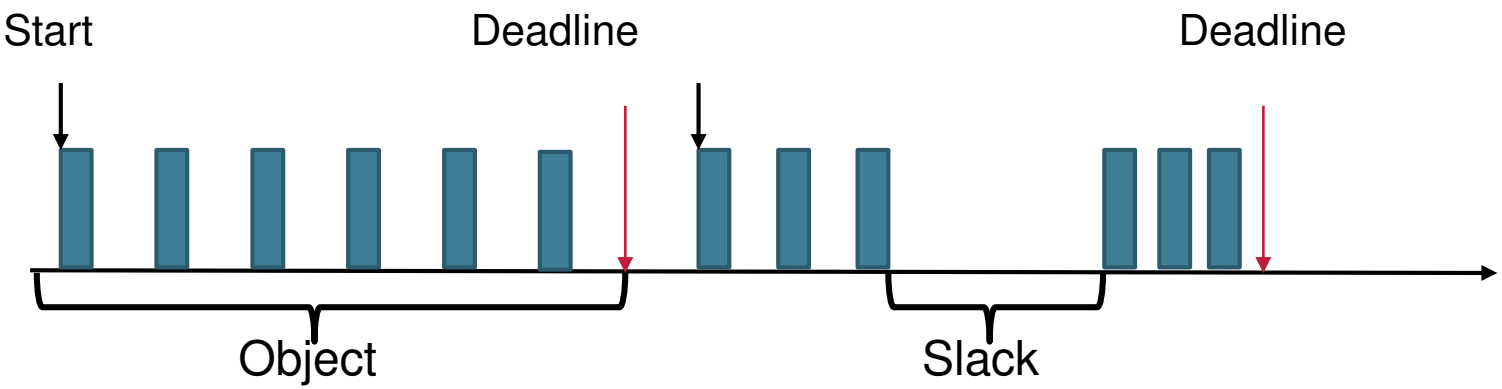
Safe Mode-Change

- Three step reconfiguration
  - Stopping all affected transmissions
  - Reconfigure routes (Switches) and parameters (Applications)
  - Start transmissions with new parameter set



Application / Sample-Based Scheduling

- Automotive applications are designed around samples
  - Sensor data e.g. LIDAR or Camera frames or DDS or SOME/IP objects
- Samples are converted in to multi-packet transmissions
  - Bursts of UDP packets per object
- Sample data is only meaningful when the whole object arrives in time
  - Mostly fixed deadline (burst latency and jitter). e.g. 30 frames per second



- Slack can be used to reconfigure network without data loss and deadline violations

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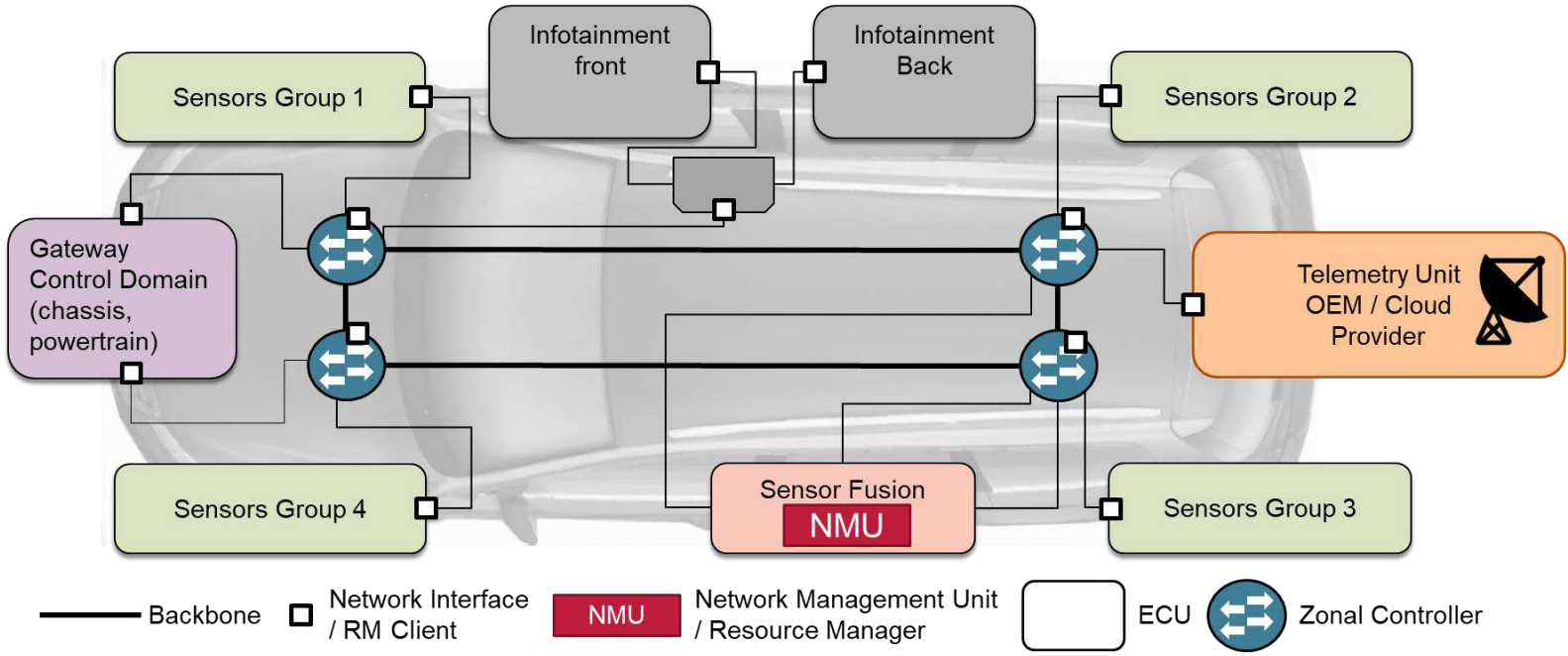
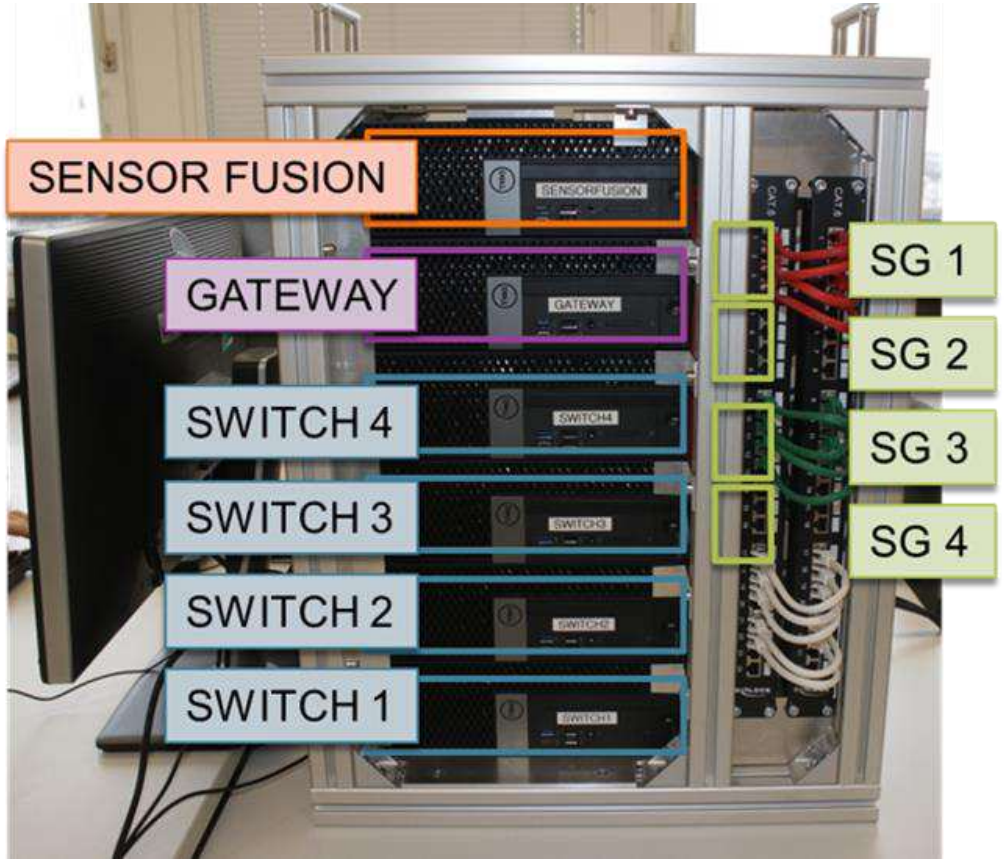
Dynamic Vehicle Network – Demonstrator

- Redundant TSN zonal backbone architecture of future vehicle
- IEEE 802.1Qav and IEEE 802.1QAS
- Represents main traffic and modules of an automated vehicle
  - Four sensor groups e.g., LIDAR, RADAR, or cameras
  - Gateway to legacy bus components (e.g., (electric) powertrain, chassis)
  - Sensor fusion unit processing data from the sensors and ECUs
  - Infotainment domain (AV + HMI)
  - Telemetry unit for V2X
- Network Management Unit (NMU) in Sensor Fusion



Scenarios

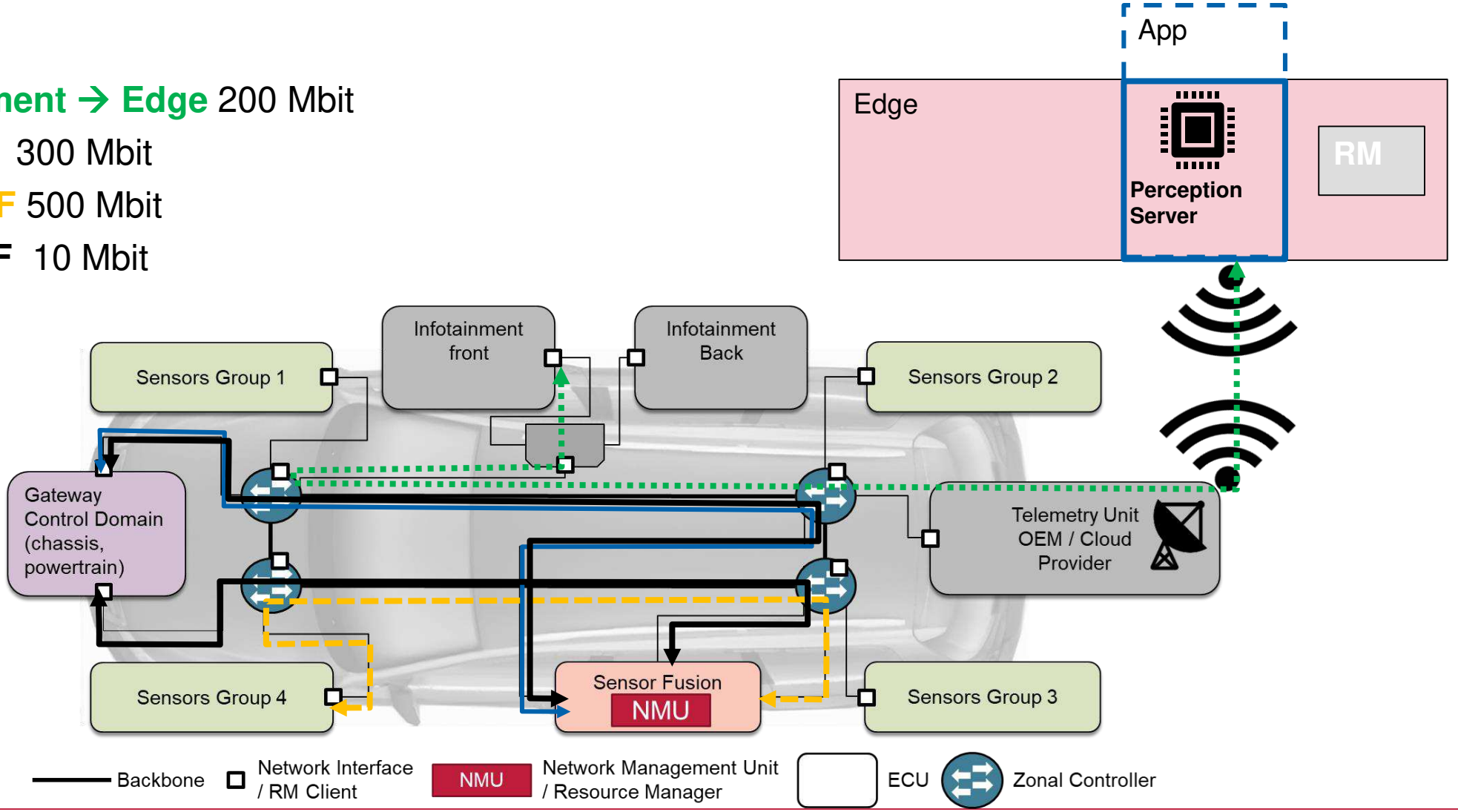
- **Scenario 1:** State-of-the-Art
  - Static Configuration
  - Cloud connection is treated as best effort
- **Scenario 2:** Dynamic Network Re-configuration
  - Extra bandwith available for edge/cloud for communication
- **Scenario 3:** Operation Under Error
  - Detection and Re-configuration



State-of-the-Art

Streams:

- Low-Prio **Infotainment → Edge** 200 Mbit
- Mid-Prio **CD → SF** 300 Mbit
- Mid-Prio **SG4 → SF** 500 Mbit
- High-Prio **CD → SF** 10 Mbit



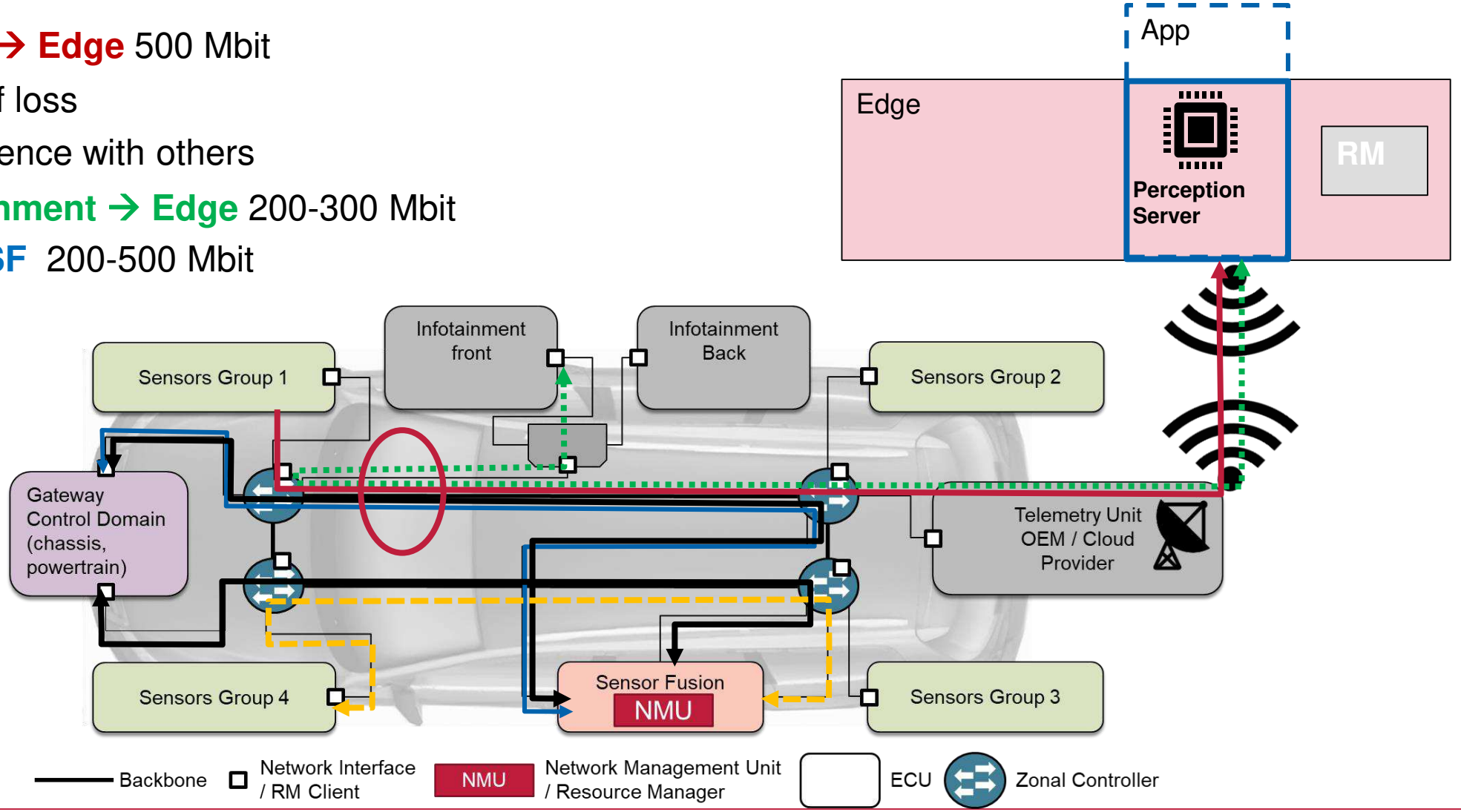
State-of-the-Art

New connection **SG1 → Edge** 500 Mbit

→If best effort lots of loss

→If Mid-Prio interference with others

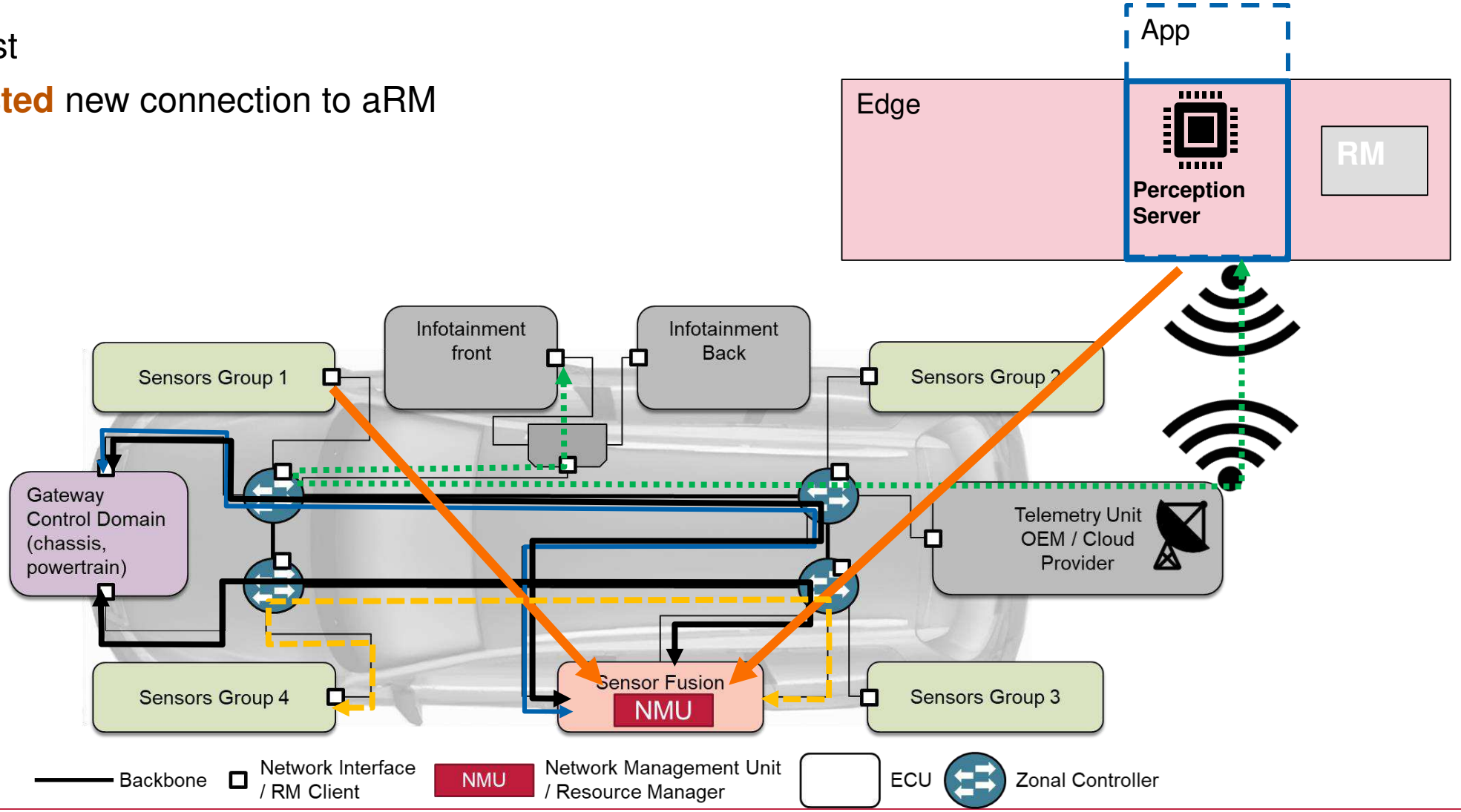
- Low-Prio **Infotainment → Edge** 200-300 Mbit
- Mid-Prio **CD → SF** 200-500 Mbit



Dynamic Network Re-Configuration

Step 1: service request

- application **requested** new connection to aRM



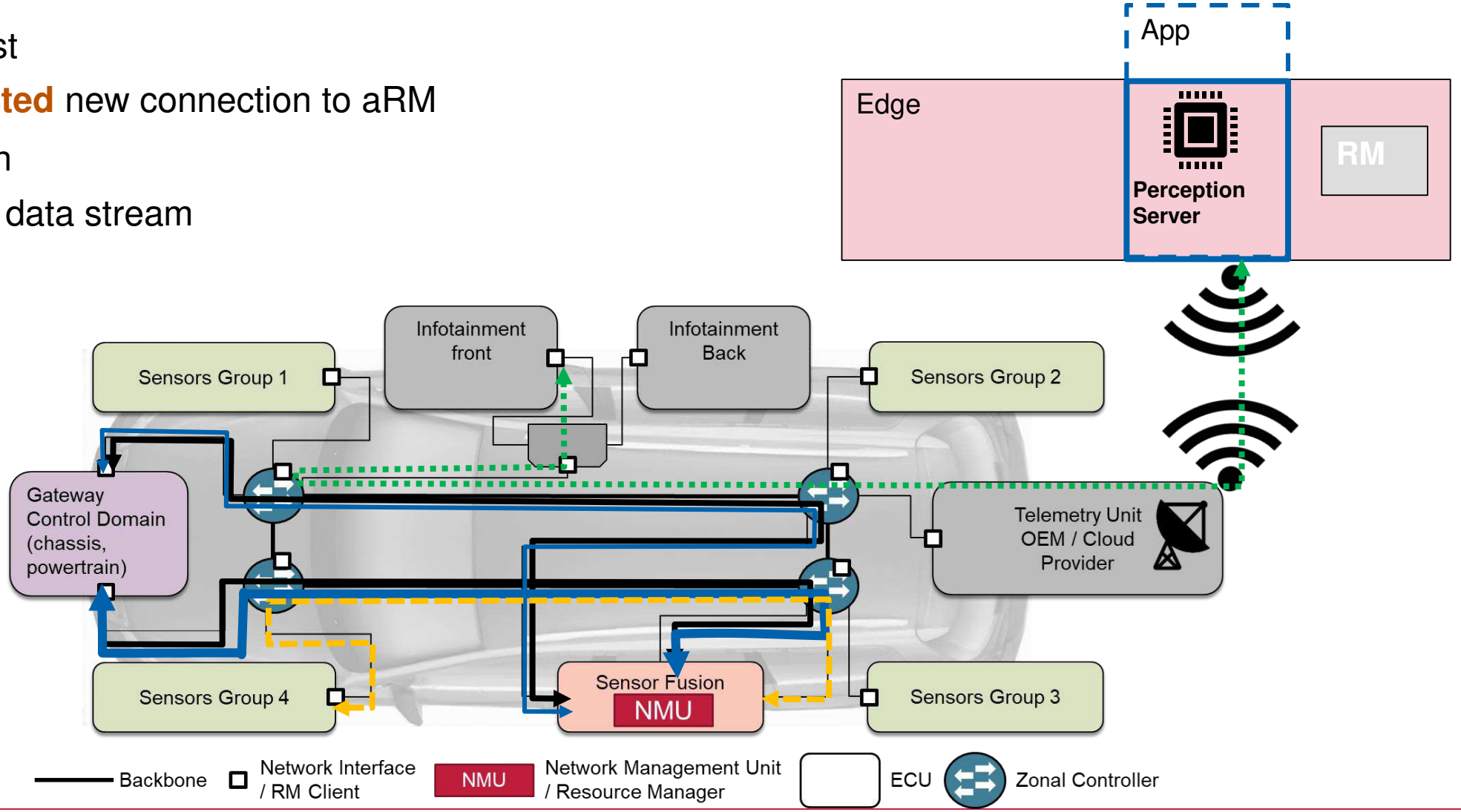
Dynamic Network Re-Configuration

Step 1: service request

- application **requested** new connection to aRM

Step 2: reconfiguration

- new route for **blue** data stream



Dynamic Network Re-Configuration

Step 1: service request

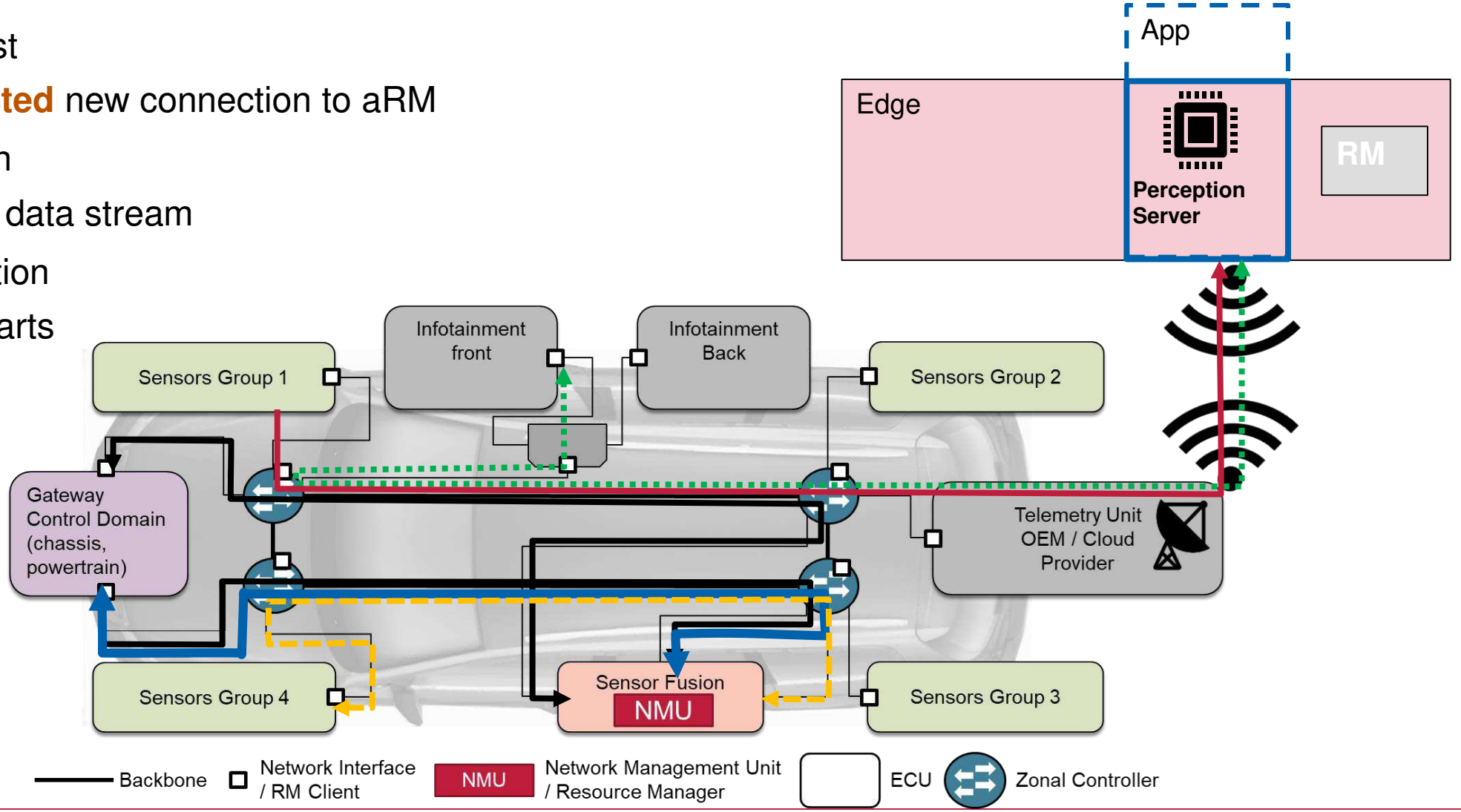
- application **requested** new connection to aRM

Step 2: reconfiguration

- new route for **blue** data stream

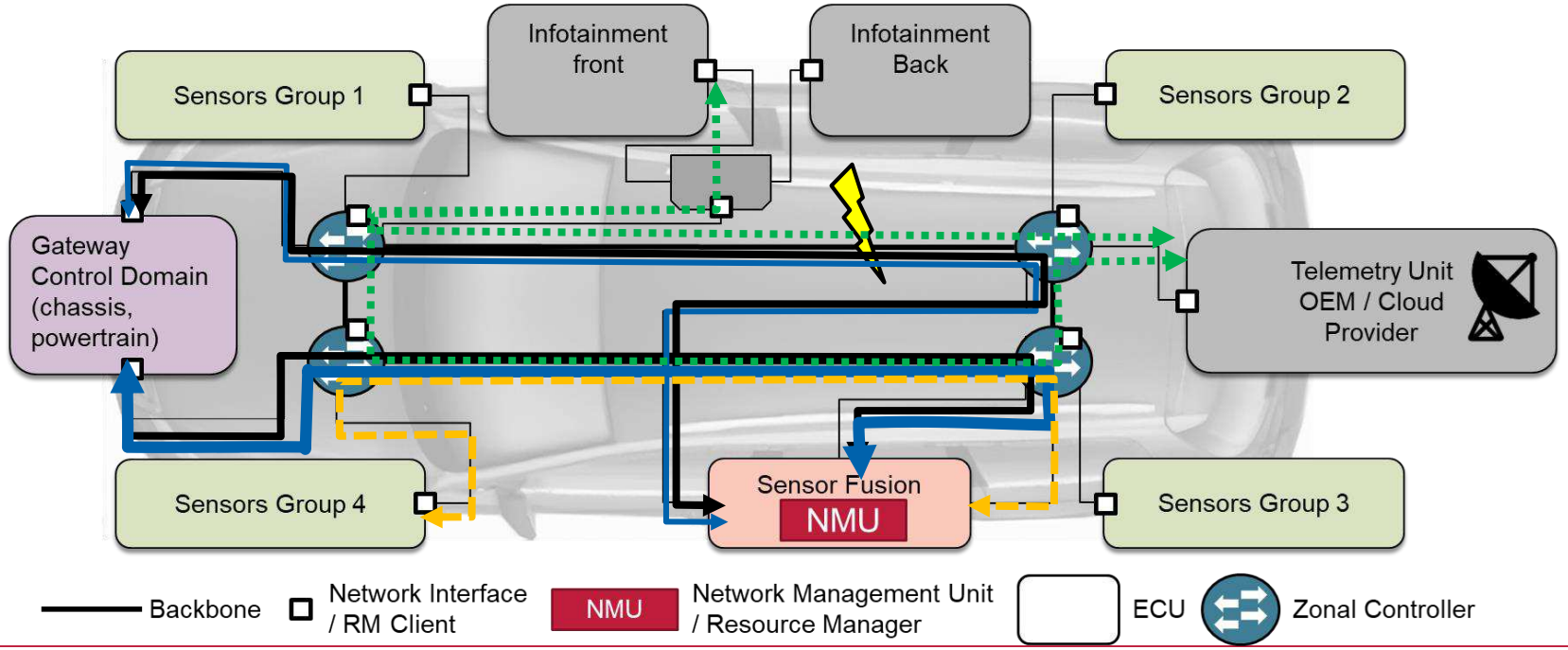
Step 3: service activation

- **red** data stream starts



Operation Under Error

- **Re-configuration in case of Failures**
- **Detect failure with monitors**
- **NMU change mode**
  - Stop data connections if necessary
  - Reroute data streams to remaining resources



Conclusion

- **Network Management Architecture**
- **Mechanisms for safe re-configuration**
  - Partial re-configuration
  - Three step mode change
  - Object slack
- **Example Scenarios**
  - Dynamic reconfiguration protocol
  - Operation under error

Questions?