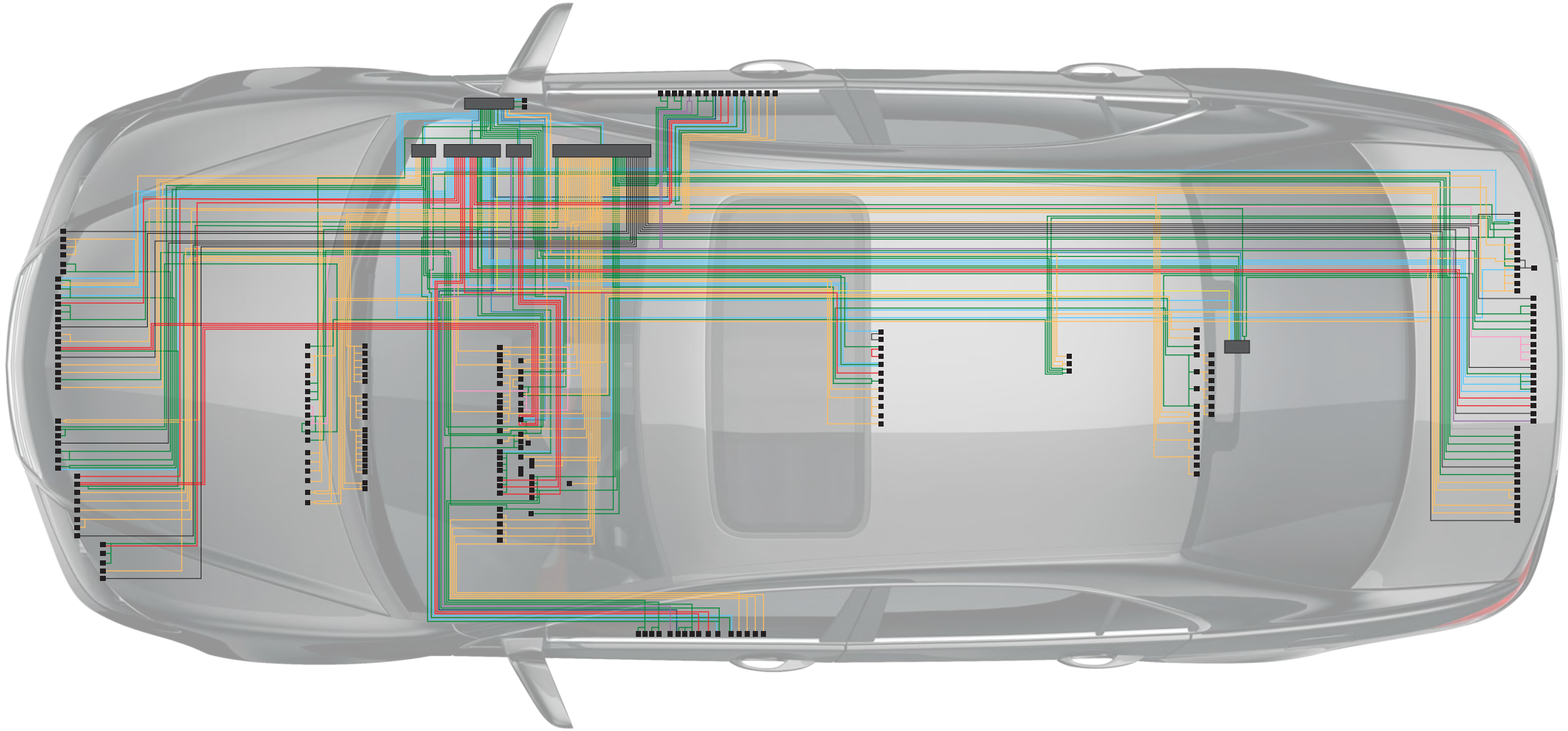
Fundamental Concepts

- Next-hops
  - next forwarding node
  - or ultimate destination
- Tunnels
  - conveying packets within packets

The Objectives

- Maximize efficiency
  - increase performance
  - decrease cost
- Simplify
- Enhance flexibility
- Improve security
- Improve resilience

The Challenges



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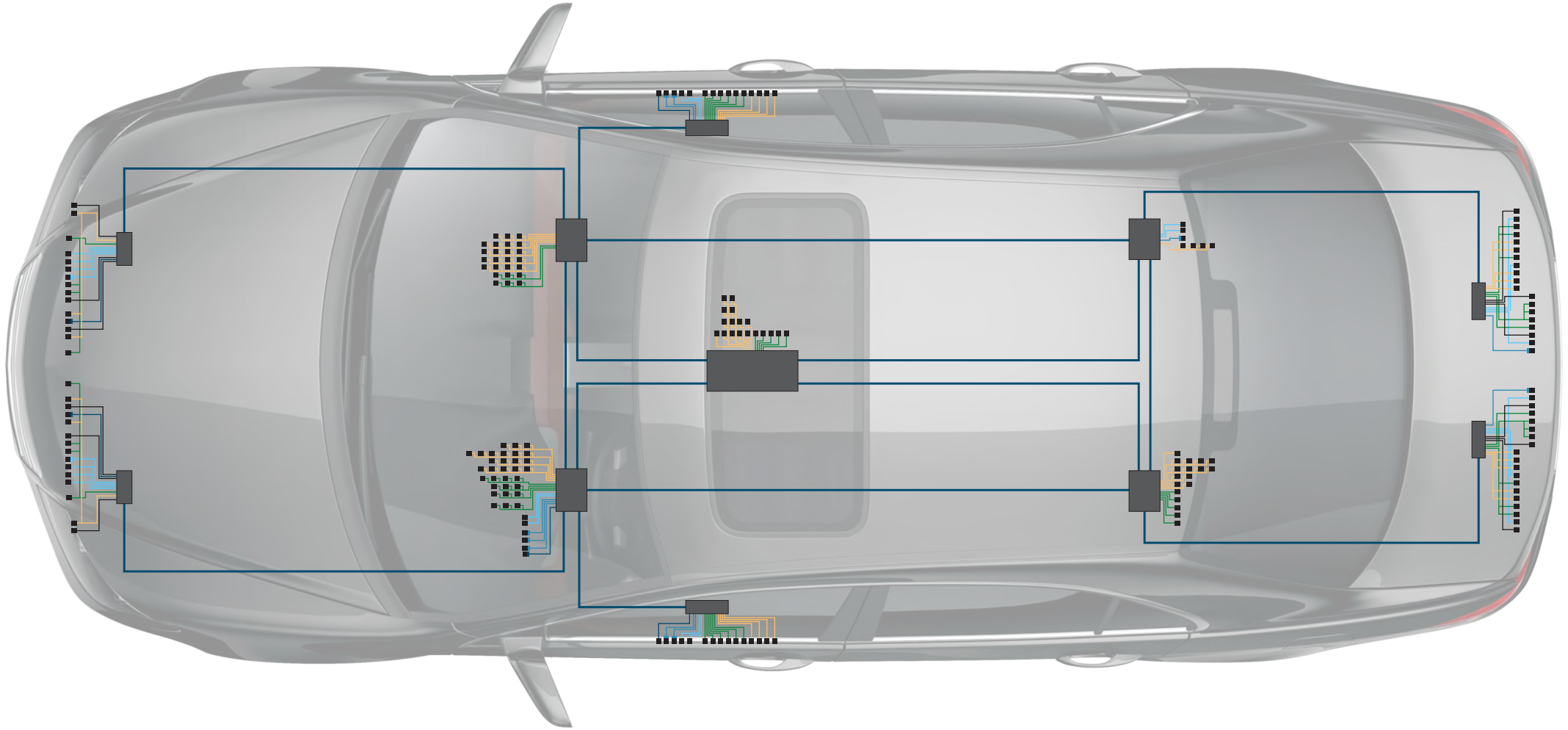
The Challenges



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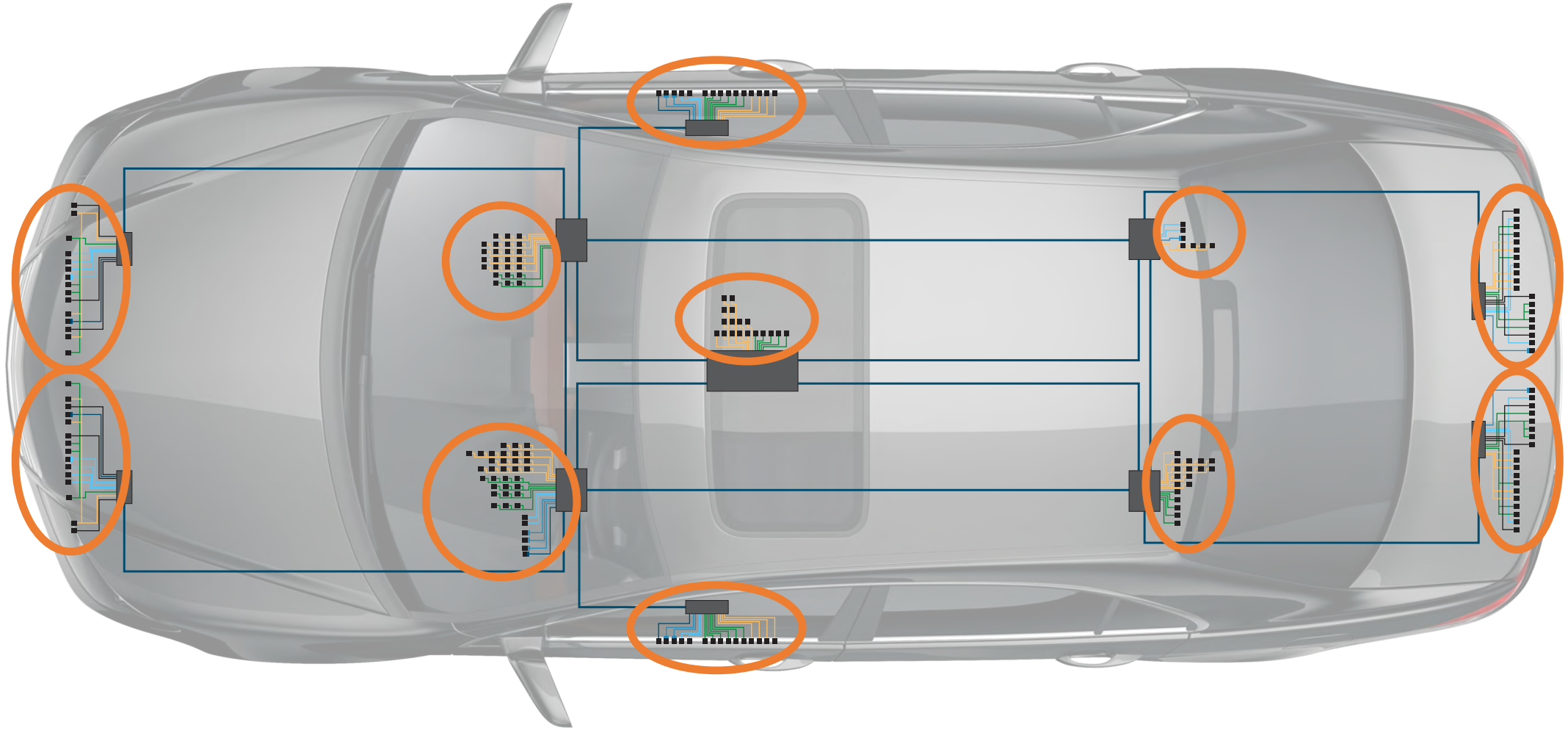
One Particular Challenge



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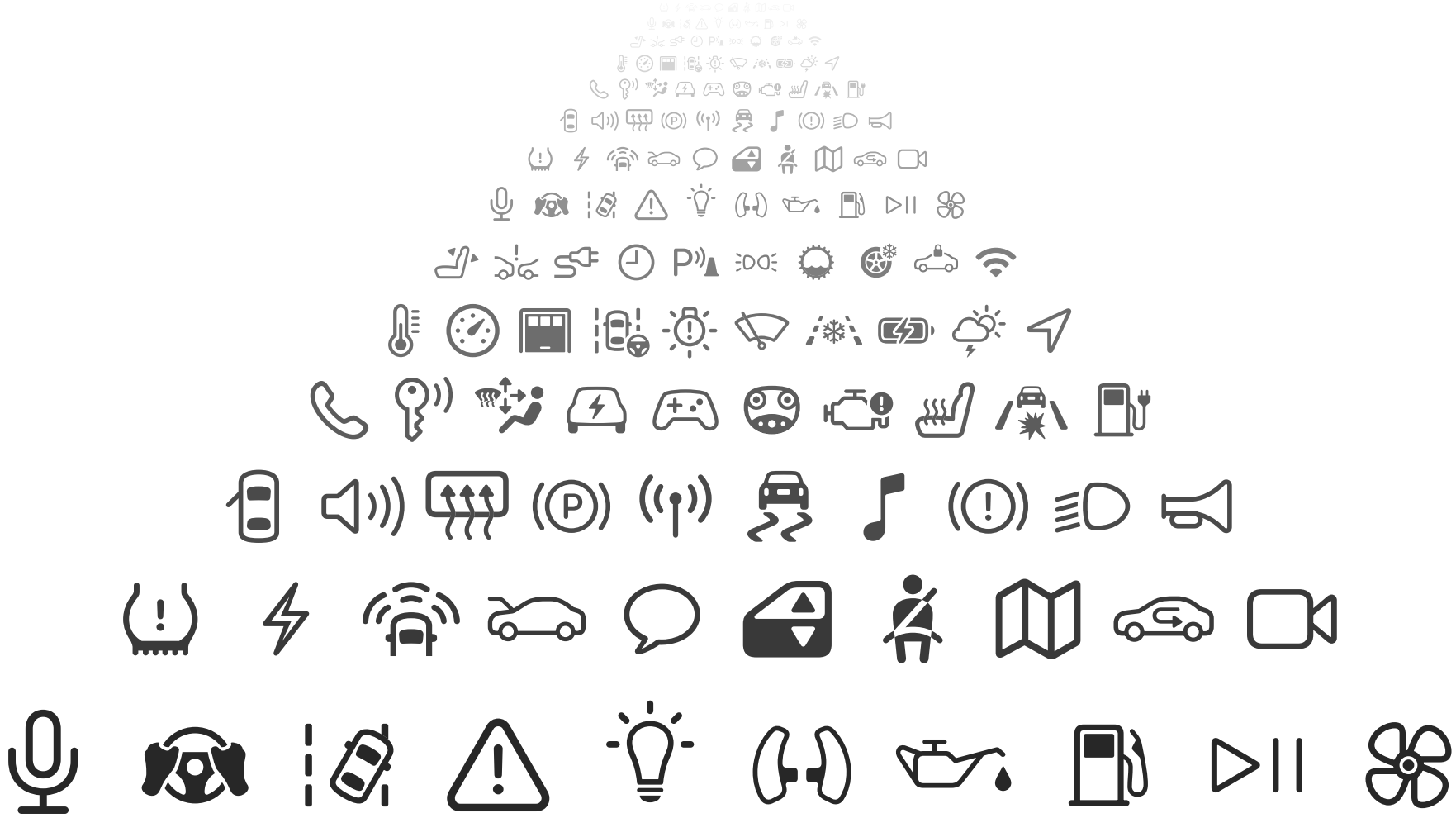
Sensors and Servos

- Sensors—inputs to ECUs
  - temperature, pressure, radar, cameras, etc.
- Servos—outputs from ECUs
  - solenoids, lights, video displays, etc.

Sensors and Servos



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Sensors

- High data rate
  - e.g., video cameras

Sensors

- High data rate
  - e.g., video cameras
- Medium data rate
  - e.g., speed sensors

Sensors

- High data rate
  - e.g., video cameras
- Medium data rate
  - e.g., speed sensors
- Low data rate
  - e.g., buttons & switches

- 12 Cameras
- 60 fps
- 720 interrupts/sec
- Sync’d cameras:
  - 60 interrupts/sec

Sensors

- High data rate
  - e.g., video cameras
- Medium data rate
  - e.g., speed sensors
- Low data rate
  - e.g., buttons & switches

Medium Data Rate, Big Overhead

- 100 sensors
- × 100 transmits per second
- = 10 000 frames per second
- or, 100 µs between interrupts

Contributions to Overhead

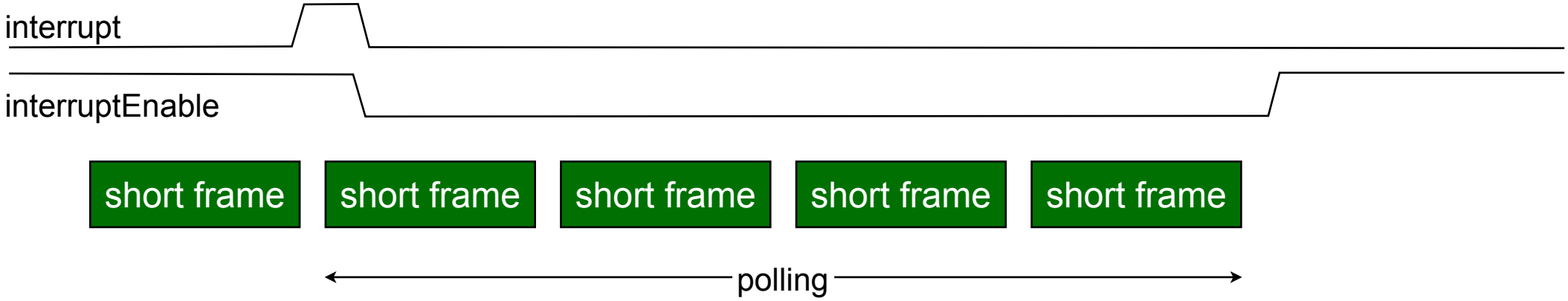
- Interrupt signal
- Context save/restore
- Cause determination
- Work scheduling
- Event/work/completion queue processing
- Handling-function dispatch

What Can Be Done?

Interrupt Coalescing

Interrupt Coalescing

- Disable
- Poll
- Loop
- Re-enable
- Software solution



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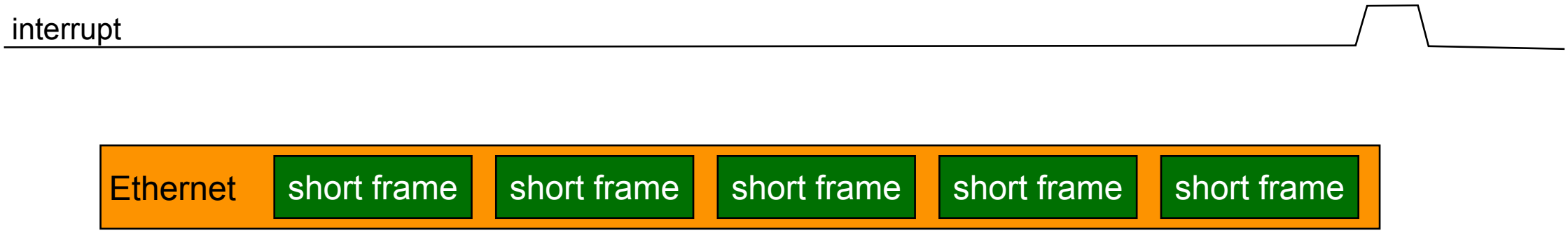
Interrupt Coalescing

- Interrupt signal ✓
- Context save/restore ✓
- Cause determination ✓
- Work scheduling ✓
- Event/work/completion queue processing ✗
- Handling-function dispatch ✗

Frame Coalescing

Frame Coalescing

- Delay transmission
- Group by next hop
- Pack into Ethernet
- Also interrupt coalescing



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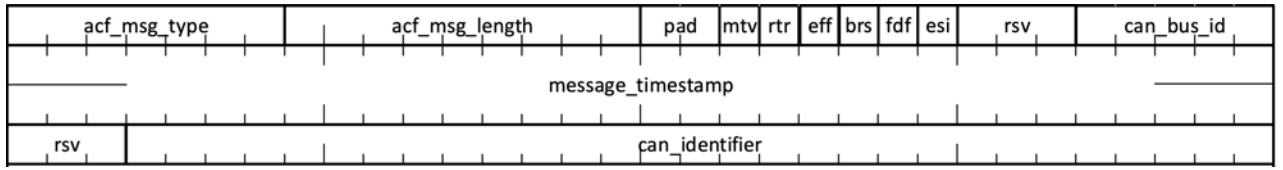
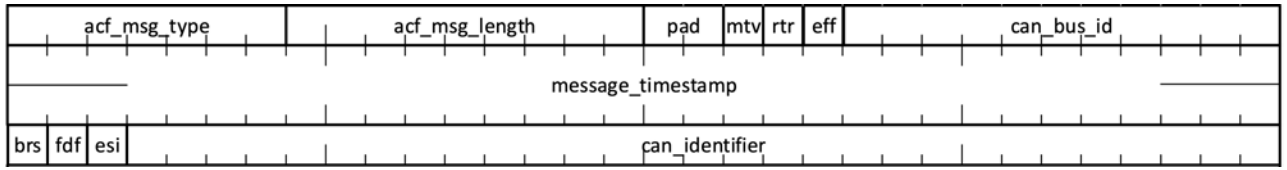
Frame Coalescing

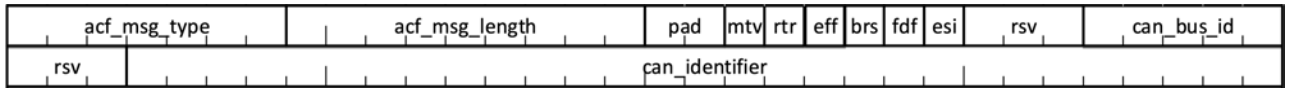
Frame Coalescing



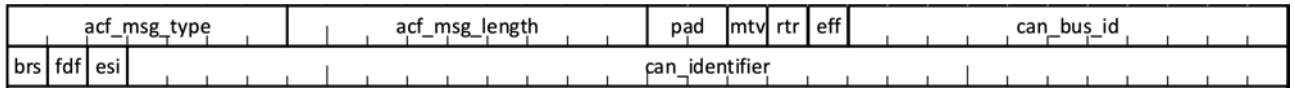
CAN/CAN FD



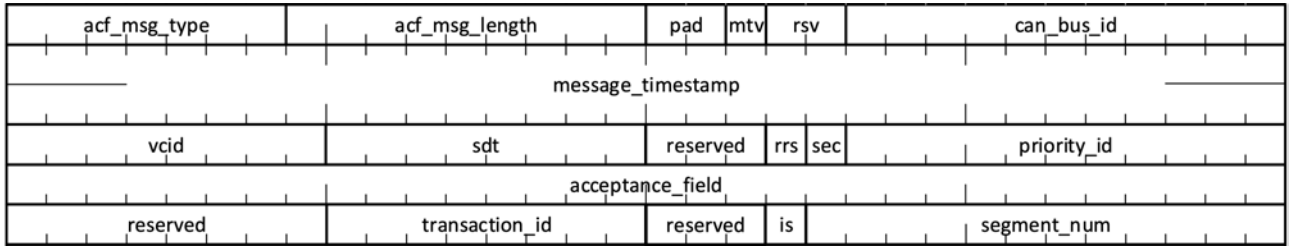
CAN/CAN FD, v2



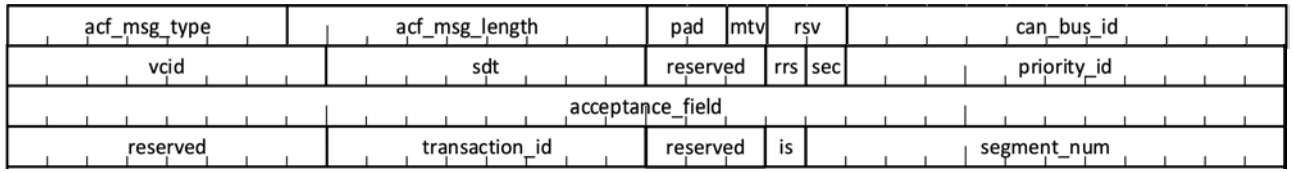
CAN/CAN FD, brief



CAN/CAN FD, brief, v2



CAN XL



CAN XL, brief

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Frame Coalescing

- Ethernet + VLAN: 18 bytes
- AVTP header: 24 bytes
- ACF (brief) header: 8 bytes
- CAN payload: 8 bytes
- Ethernet payload: 46–1500 bytes
- CAN frames per Ethernet: 1–92
- Network bandwidth savings: 0%–80%

Frame Coalescing

- Interrupt signal ✓
- Context save/restore ✓
- Cause determination ✓
- Work scheduling ✓
- Event/work/completion queue processing ✓
- Handling-function dispatch ✗

Functional Coalescing

Functional Coalescing

- Interrupt signal ✓
- Context save/restore ✓
- Cause determination ✓
- Work scheduling ✓
- Event/work/completion queue processing ✓
- Handling-function dispatch ✓

Bringing It All Together

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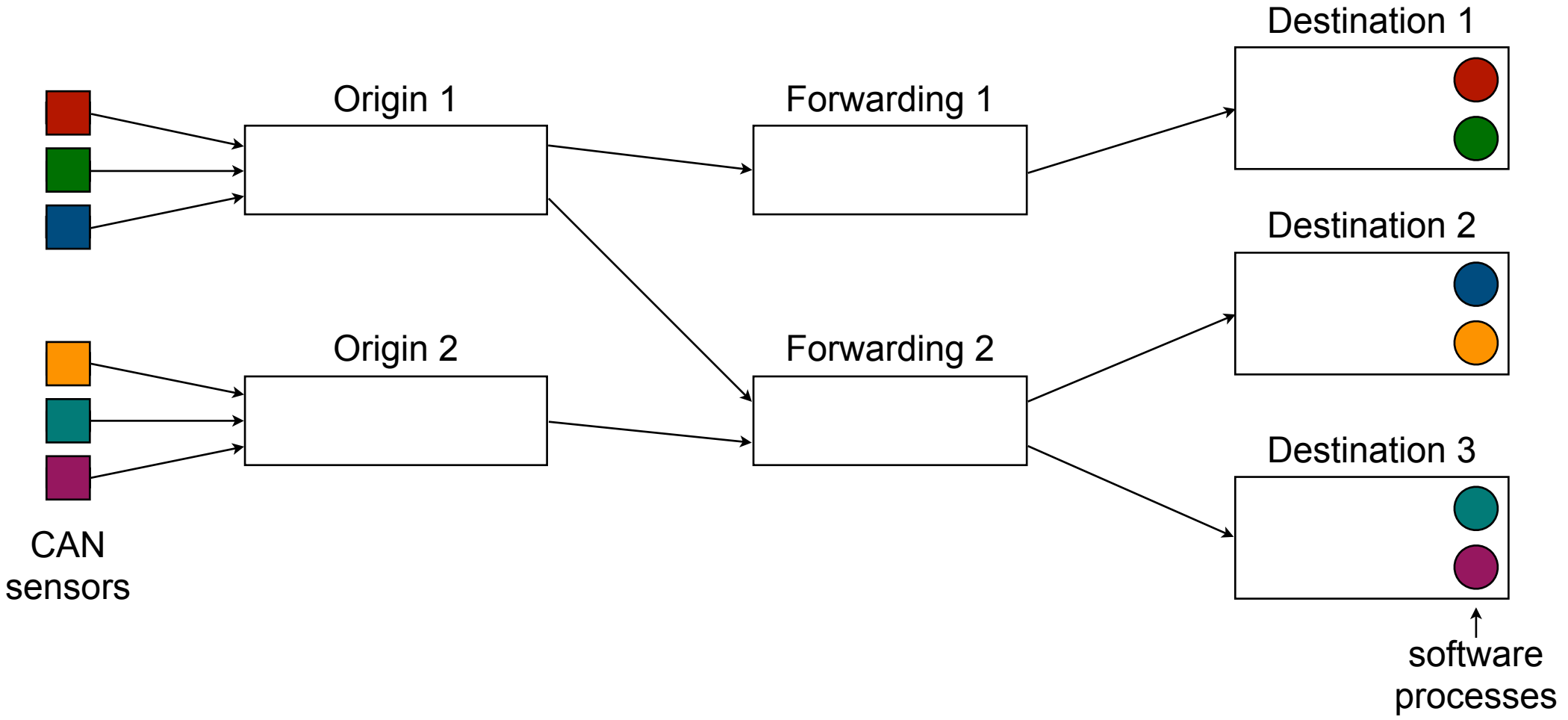
Bringing It All Together



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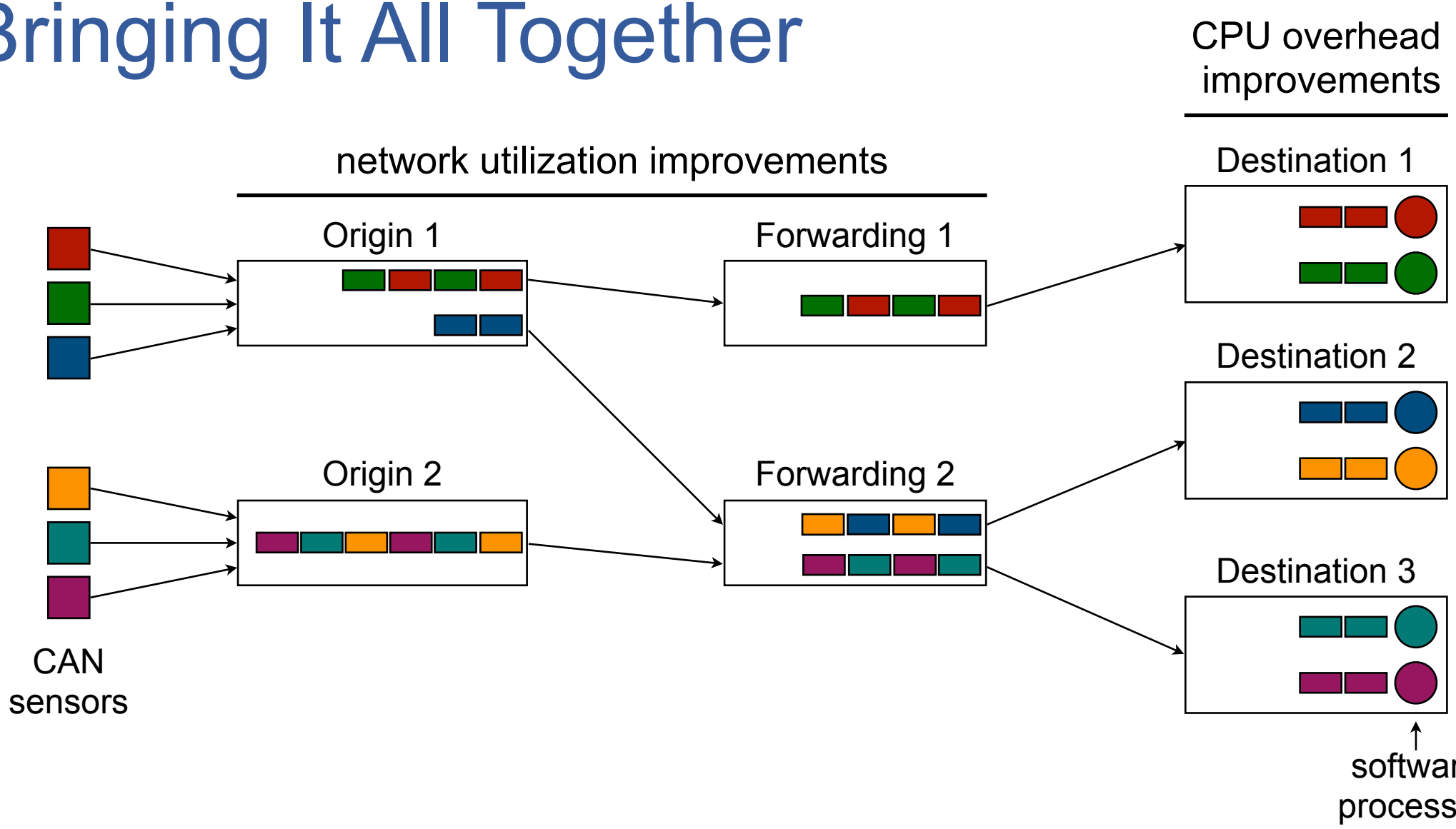
Bringing It All Together



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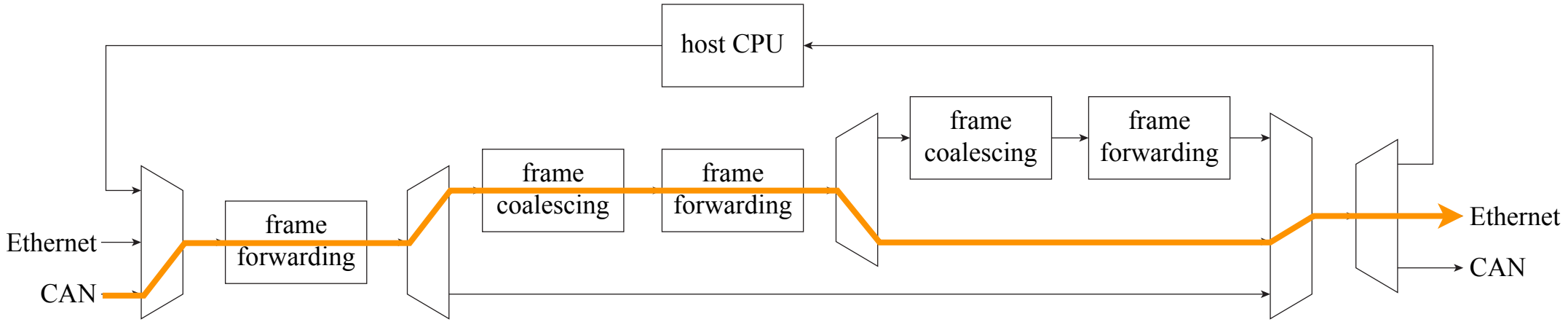
Bringing It All Together



CAN-to-Ethernet Destination Coalescing

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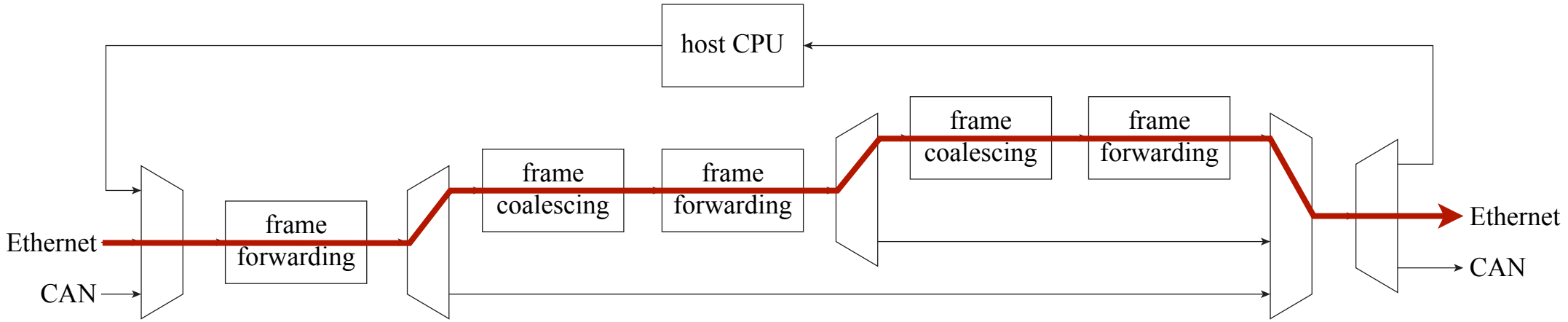

Network Midpoint Destination Coalescing

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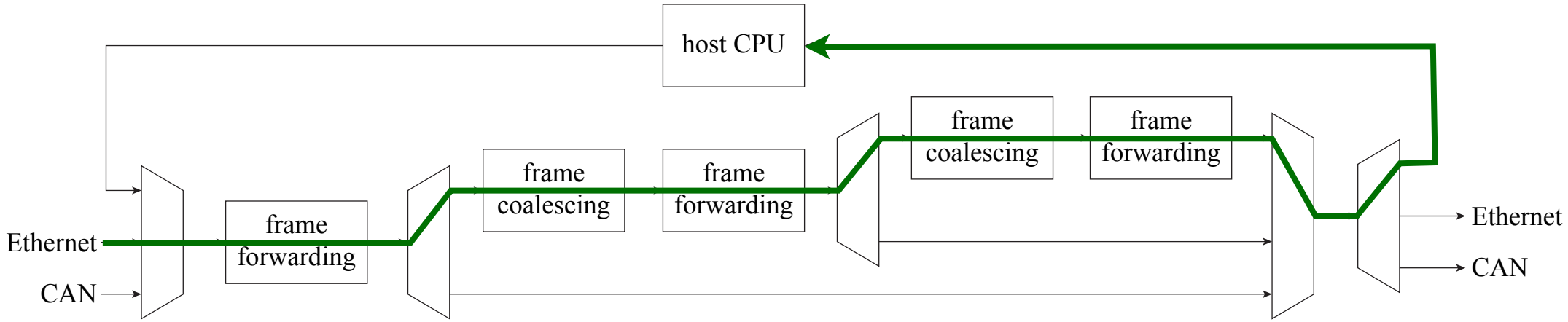

Destination Endpoint Functional Coalescing

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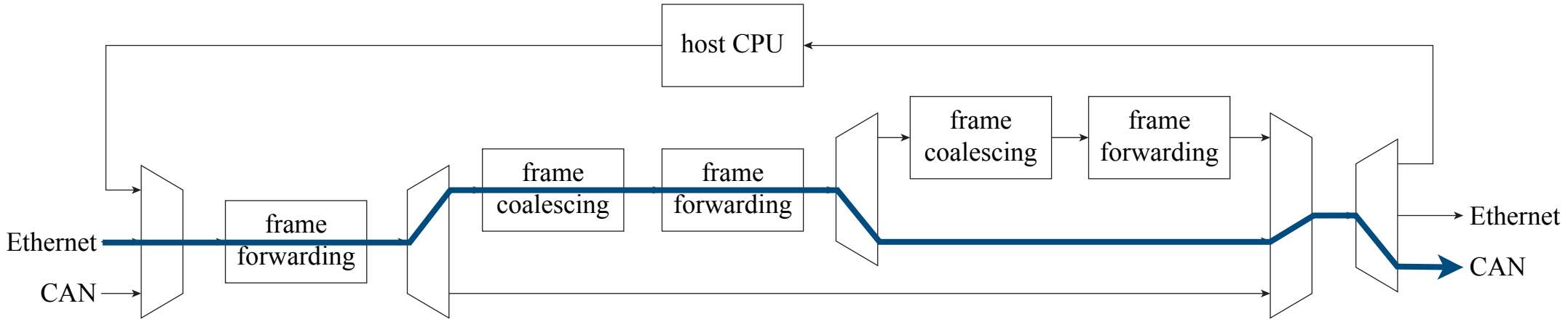

Ethernet-to-CAN Distribution

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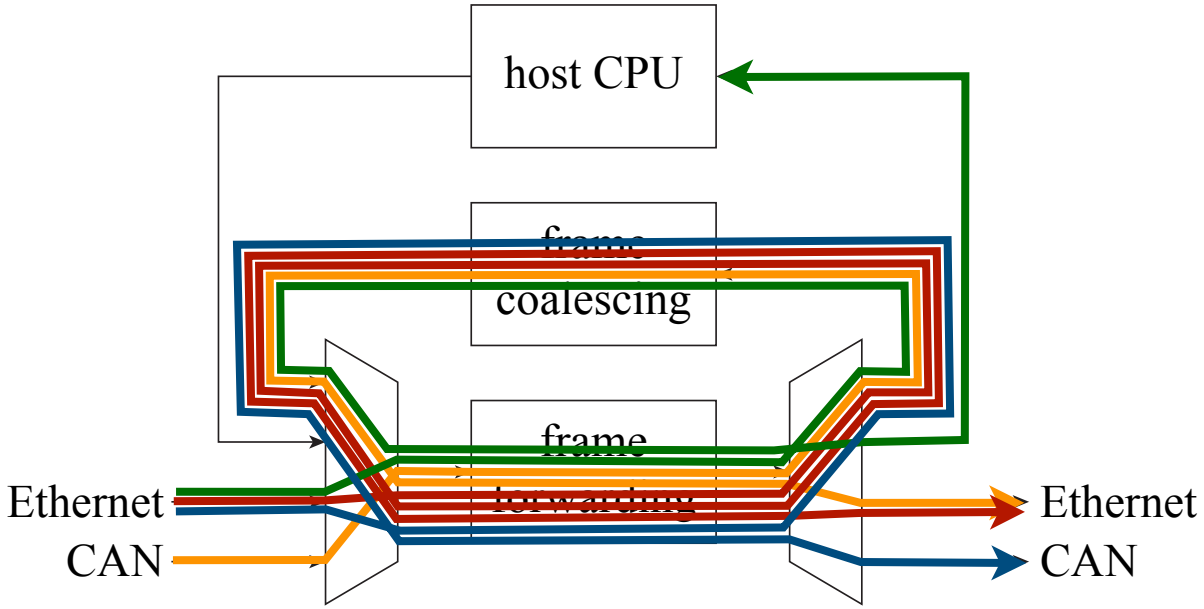
Bringing It All Together



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What About Transmit?

What About Transmit?

- Lower overhead than receive
- Still significant
- Frame coalescing at source
- Frame distribution at destination

There’s More…

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10Base-T1S

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10Base-T1S

Concluding Thoughts

Concluding Thoughts

- It’s a real issue
- Interrupt and frame coalescing:
  - good first steps
- Next-hop coalescing at origin or midpoint:
  - some benefits
- Functional coalescing at destination hop
  - big benefits
- Must be done in hardware
  - that’s the whole point

[October 2024]