MIDDLEWARE FOR SAFE SOFTWARE-DEFINED CARS

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SECURE CONNECTIONS
FOR A SMARTER WORLD

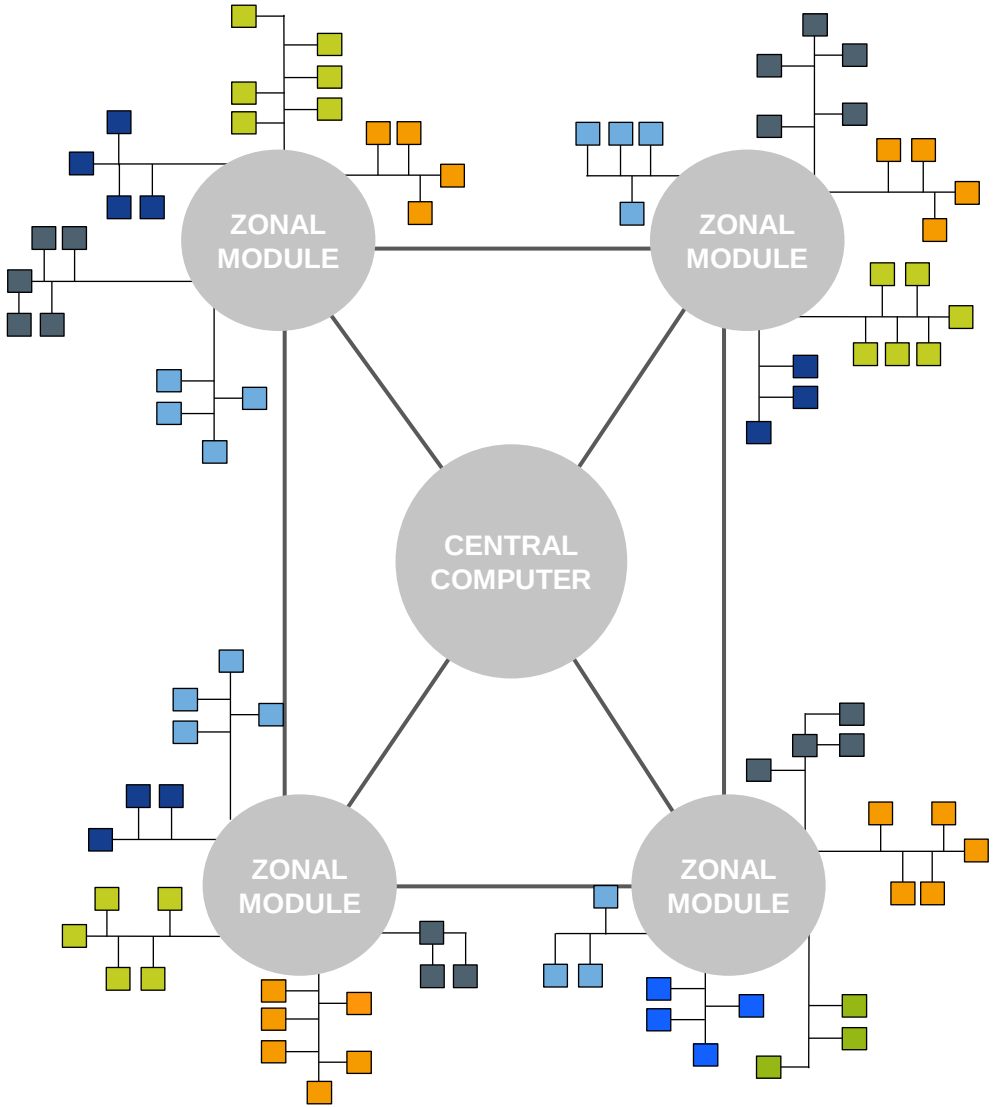
AUDIENCE SURVEY

1. Who works in the automotive industry?
2. Who knows benefits of the zonal architecture?
3. Why do we need Time-Sensitive Networking?
4. Who worked with ROS, SOME/IP or MQTT?

OUTLINE

1. What is middleware doing in the software-defined car?
2. Survey of middleware protocols and software stacks
3. Proof-of-concepts: DDS-TSN integration and DDS-based safe fail-over design
4. Conclusions and further reading

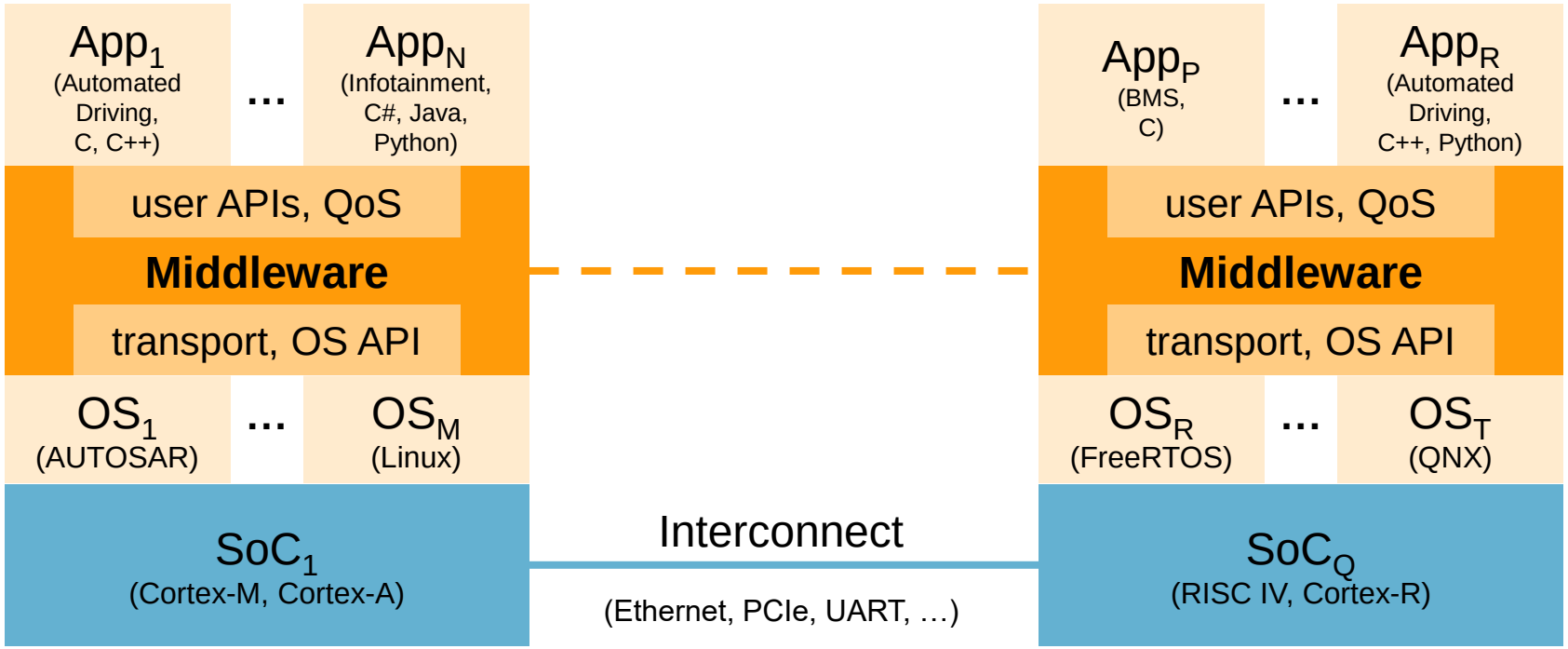
DISTRIBUTED PROCESSING: THE TREND IN AUTOMOTIVE SYSTEM ARCHITECTURE (HARDWARE PERSPECTIVE)



- Physical consolidation to reduce wiring
- Central computer for number crunching
- Zonal modules have to safely and securely:
  - aggregate
  - forward
  - convert
  - process
- A PCB or SoC has distributed processors to boost efficiency and modularity
- Complex requirements on networking devices

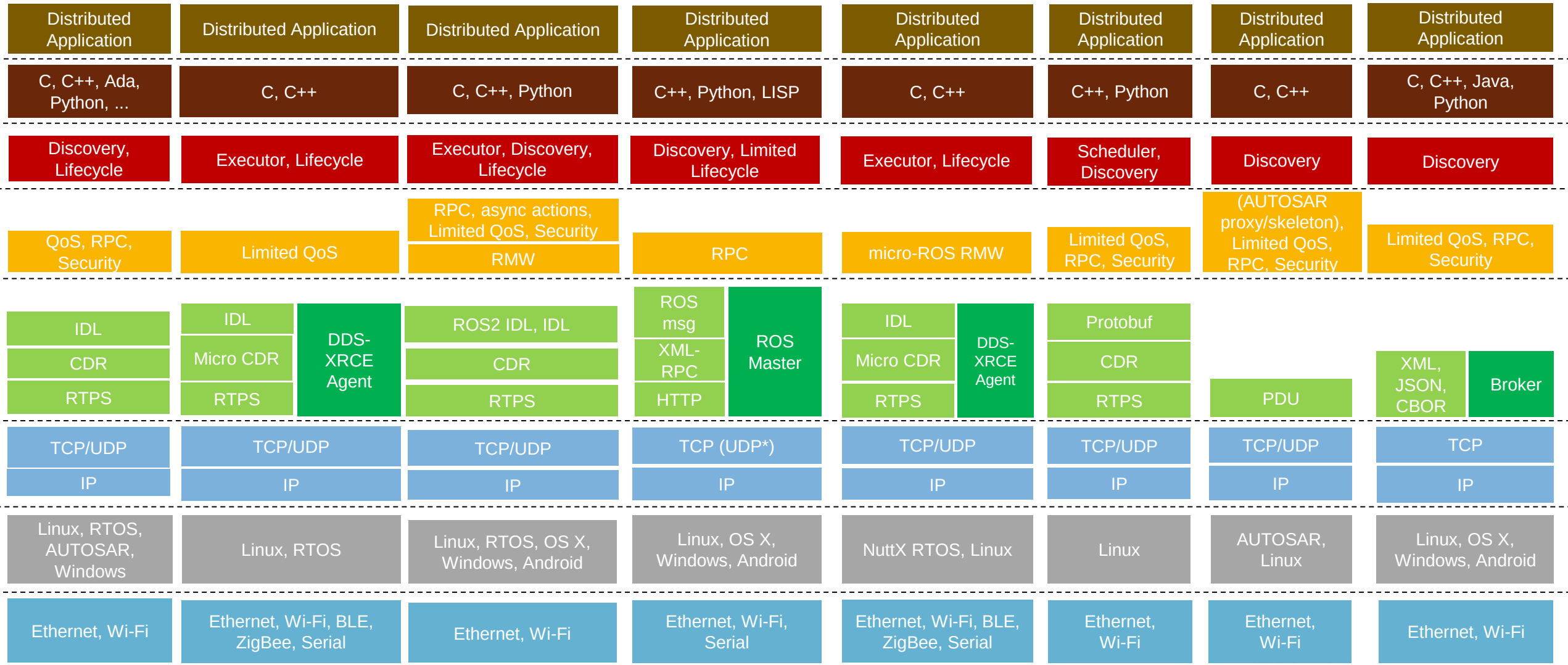
DISTRIBUTED PROCESSING: THE TREND IN AUTOMOTIVE SYSTEM ARCHITECTURE (SOFTWARE PERSPECTIVE)

- Past: weakly programmable ECUs, each performing one mostly isolated function
- Present: consolidated ECUs running flexible software with complex control and advanced functions
- Future: *software-defined cars* with easy-to-program distributed interoperable software services; the corresponding system architecture is commonly referred to as Service-Oriented Architecture
- **Middleware** is a collection of software libraries for distributed processing simplifying development of composable modular systems; the middleware is a key building block of the service-oriented architecture
- Middleware examples: ROS, DDS, SOME/IP, MQTT, Cyber RT, Apex.Middleware, Iceoryx, ...



component examples are in brackets

MIDDLEWARE SOFTWARE STACKS COMPARISON



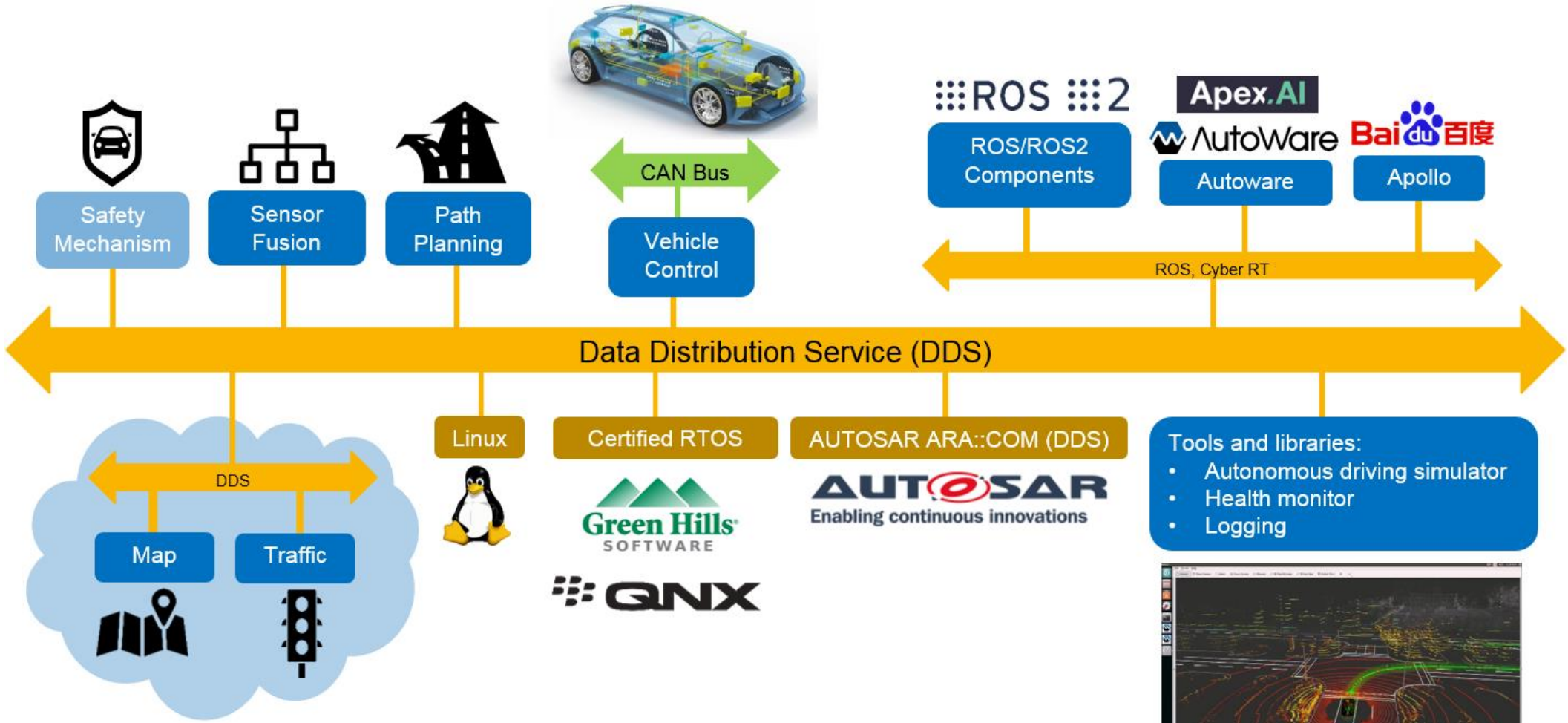
COMPARISON OF POPULAR (AUTOMOTIVE) MIDDLEWARE PROTOCOLS

Communication Protocol Characteristics	**DDS**	**ROS1**	**Cyber RT**	**uORB**	**SOME/IP**	**UAVCAN**	**POSIX Socket**	**OpenAMP + RPmsg (channel)**	**AMQP**	**ZeroMQ**
Publish-Subscribe pattern	Y	Y	Y	Y	Y	Y	Y (limited)	N	Y	Y
Real Time Publish-Subscribe (RTPS)	Y	N	Y	N	N	N	N	N	?	N
Remote Procedure Call (RPC)	Y	Y	Y	?	Y	Y	N	Y	Y	Y
On-chip communication	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Inter-chip communication	Y	Y	?	N	Y	?	Y	Y	?	?
(Re)discovery	Y	Y	Y	?	Y	Y	N	Y	Y	N
Real-time	Y	N	Y	N	?	Y	Y	Y	Y	Y
Multi-OS support	Y	Y	?	Y	Y	Y	Y	Y	Y	Y
Security	Y	N	Y	N	Y	Y	N	Y	Y	Y
Quality of Service (QoS)	Y (rich)	N	Y (limited)	N	Y (very limited)	Y?	Y (limited)	?	Y	Y
Standard API	Y	N	N (Apollo-specific)	?	Y (AUTOSAR-specific)	Y	Y	N	?	Y
Safety certification	Y	N	N	N	?	N	N	N	N	N
License	Open source & Commercial	Open source	Open source	Open source	Open source	Open source	Open source	Open source	Open source	Open Source

Data Distribution Service middleware meets requirements of autonomous driving systems:

- Safe and reliable
- Secure
- Automotive certification
- Ethernet (UDP, TCP), Shared memory, UART, PCIe

- DDS-TSN (Time Sensitive Networking) integration
- Resource-constrained safety core (RTI Micro, DDS-XRCE)
- Quality of service for different data streams
- Large ecosystem of tools and libraries



Reference: https://www.rti.com/industries/automotive/autonomous-vehicles-production

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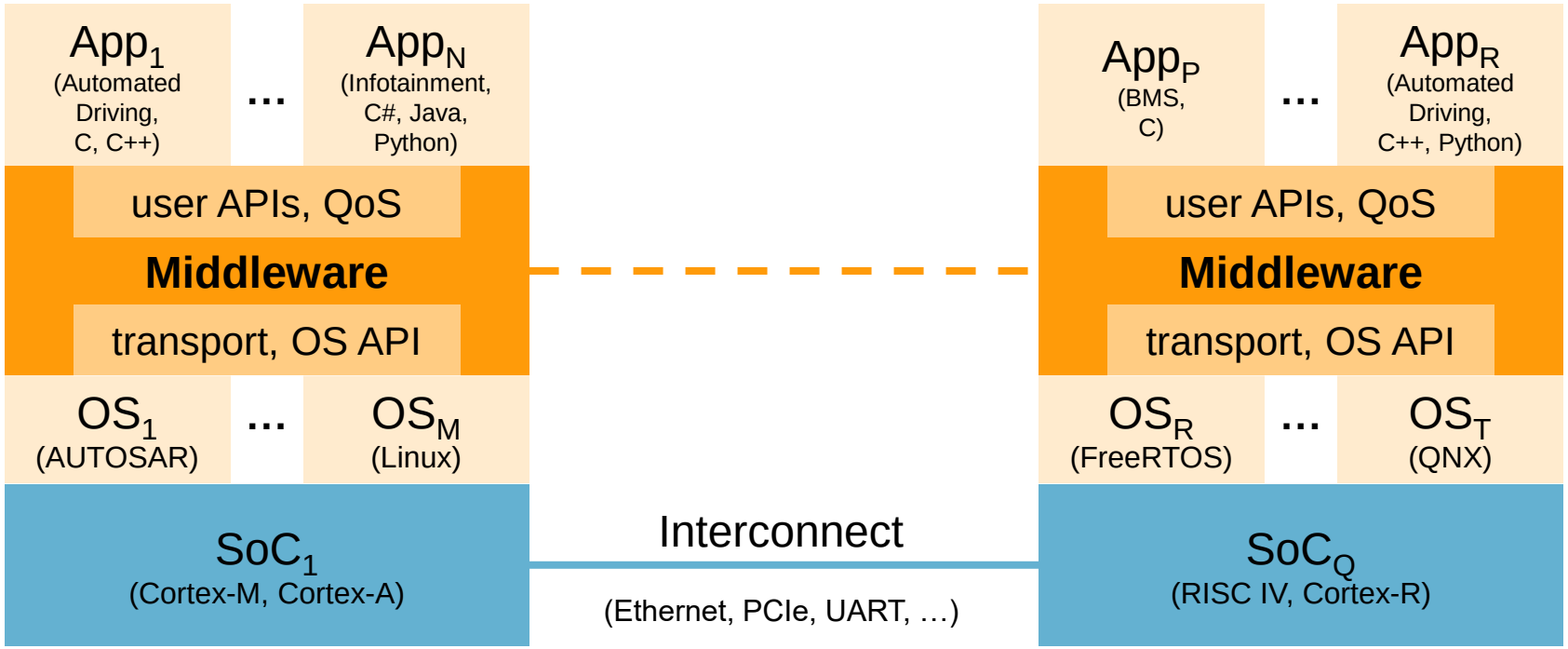


DDS-TSN INTEGRATION PROOF-OF-CONCEPT (URL)

AUTOWARE.AUTO

automated driving simulator

drive-by-wire (simulator) interface
camera service for telematics
RTI Connext® DDS
S32G, SJA1110

Time-Sensitive Networking
SJA1110s

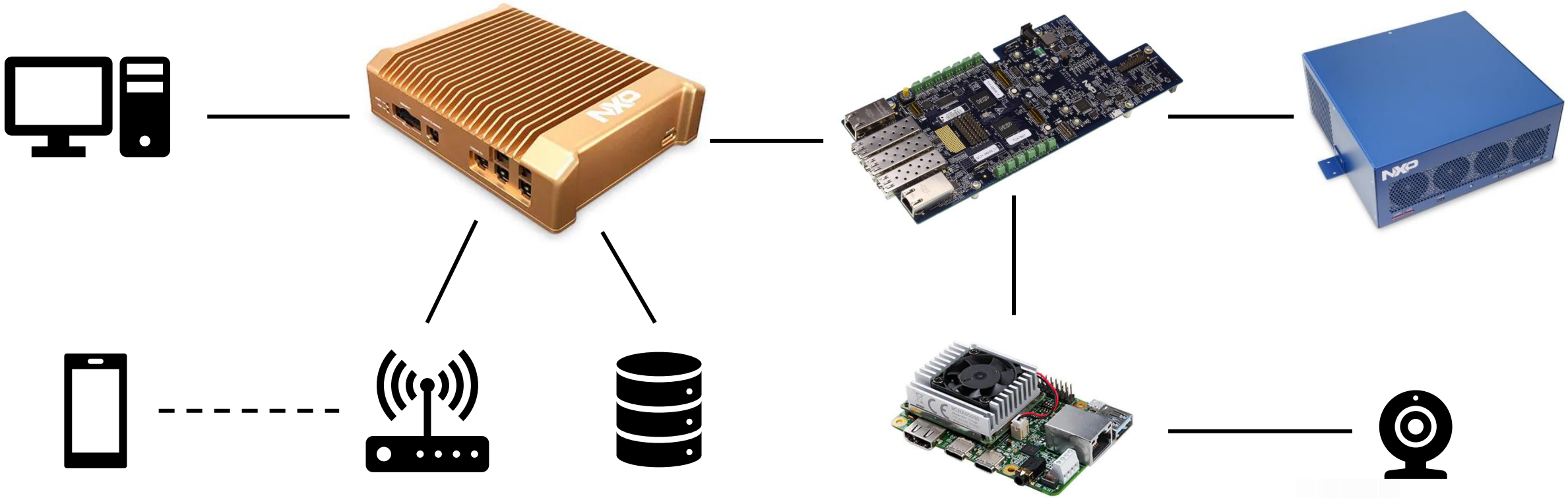
Autonomous Valet Parking
RTI Connext® DDS
LS2084

workstation

(zonal) gateway

network

high-performance computer



phone, cloud

telematics

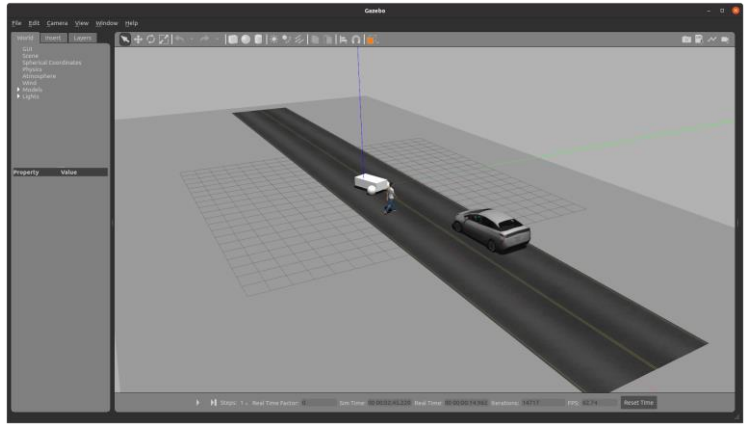
storage

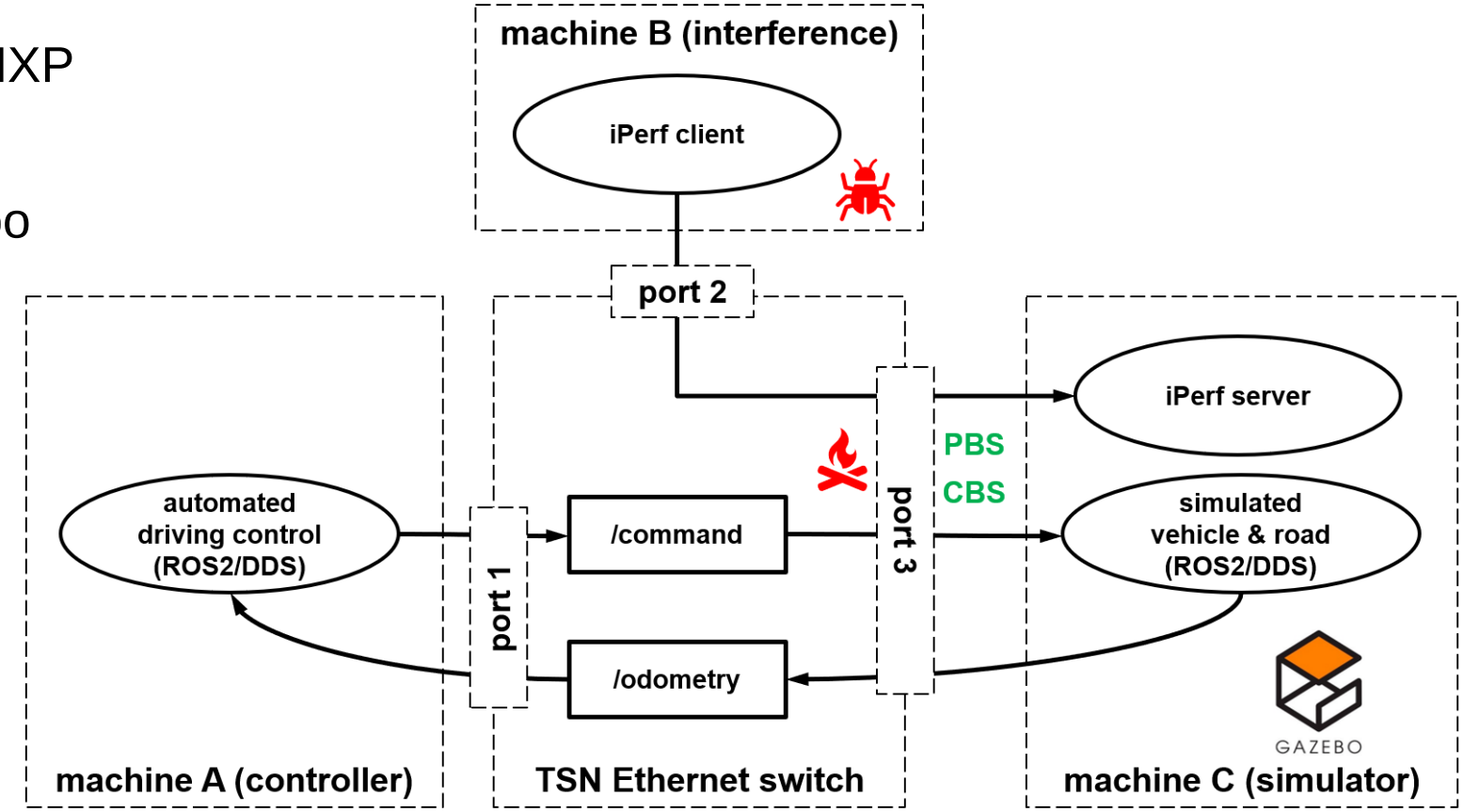
i.MX8 infotainment

camera

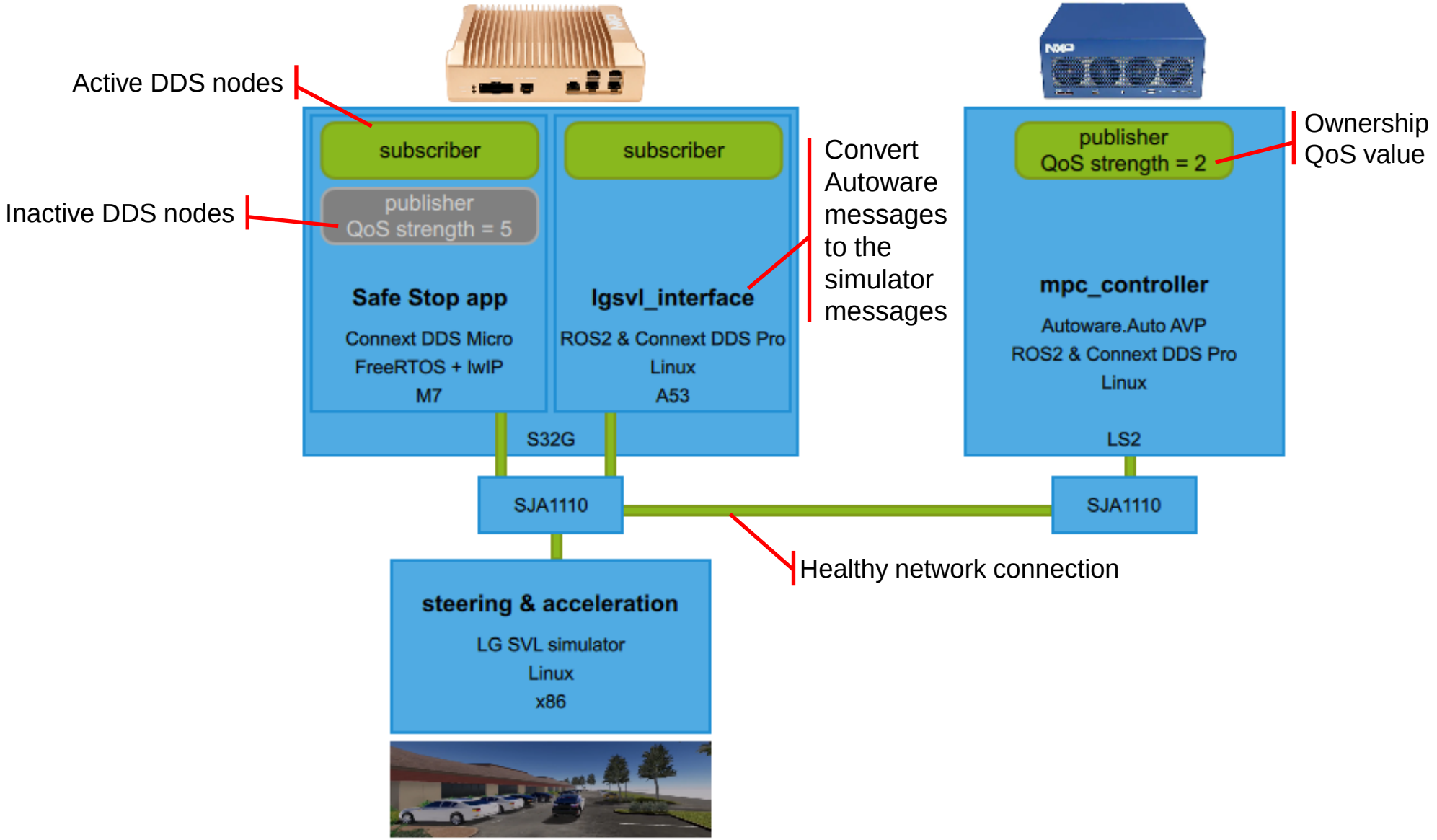
OPEN-SOURCE DEMO TO PROMOTE DDS AND TSN INTEGRATION

- Goals:
  - illustrate and popularize advantages of the DDS and TSN integration
  - simple evaluation with open-source ROS tools and consumer devices
- Implementation:
  - application code from scratch at NXP
  - automotive use-case: moose test
  - based on ROS 2 Foxy and Gazebo
  - Published on GitHub: https://github.com/NXP/dds-tsn

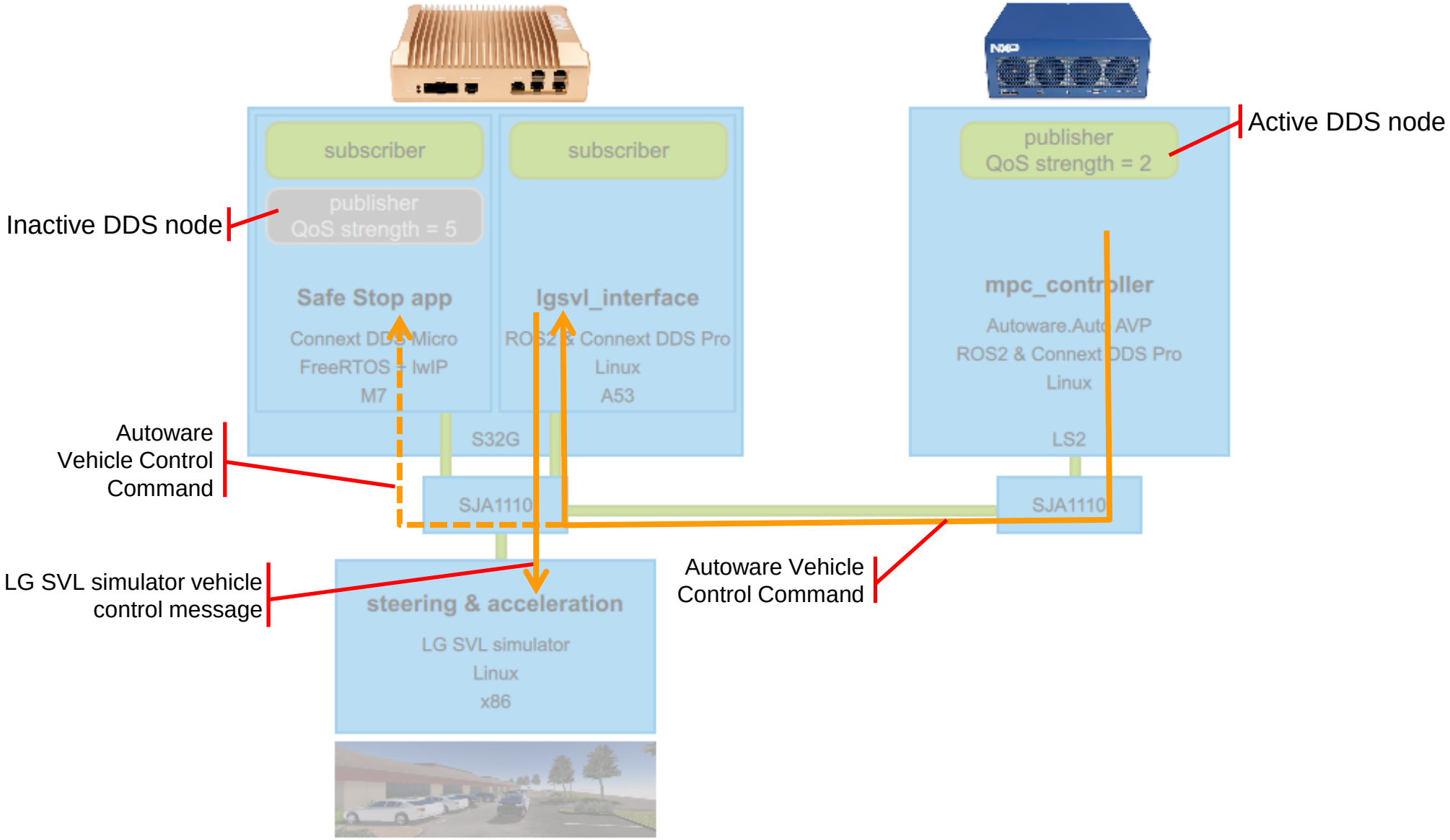




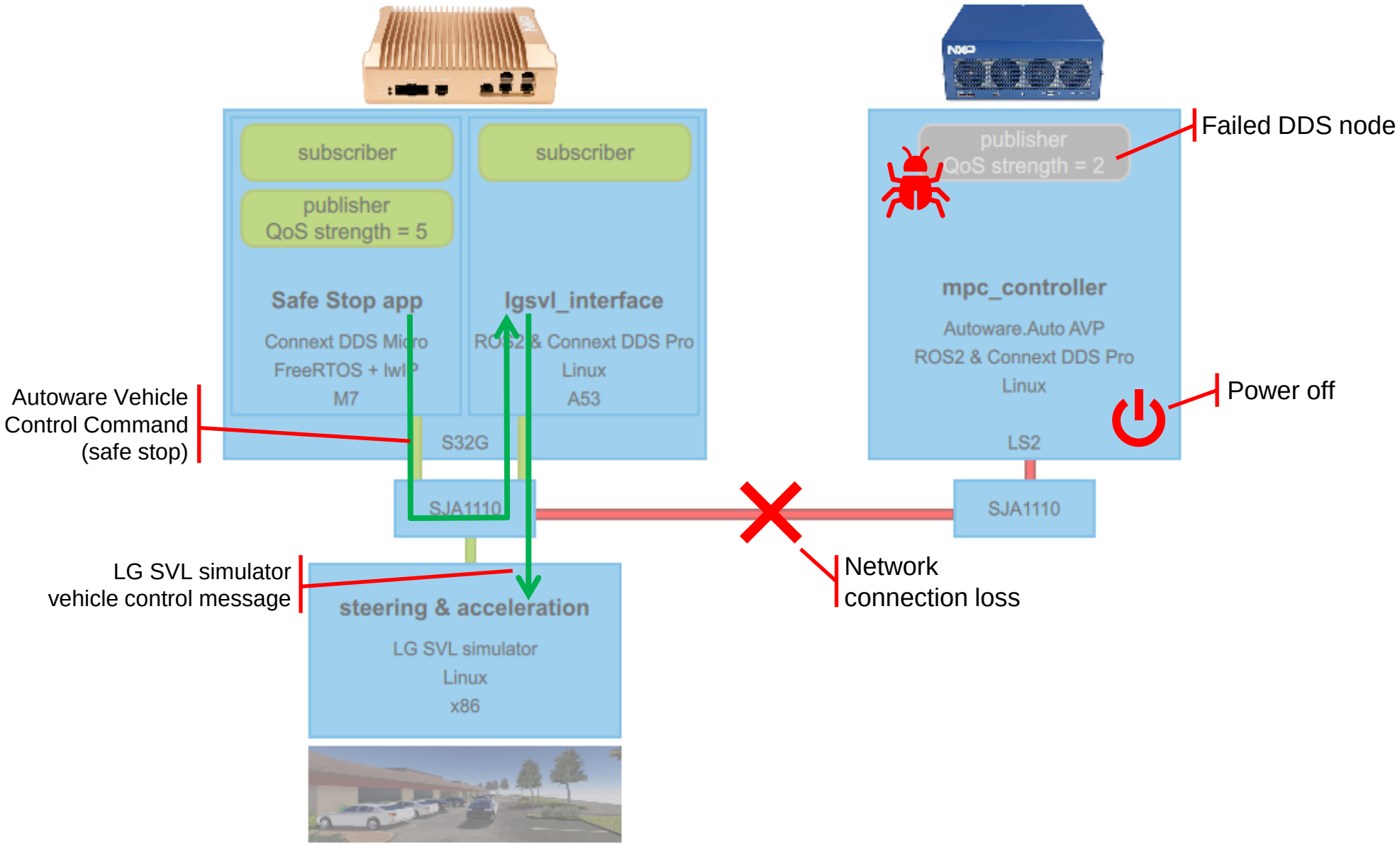
FAIL-OVER AND TAKEOVER SAFETY MECHANISMS BASED ON DDS [PUBLIC URL]



DATA STREAMS



FAULT MITIGATION



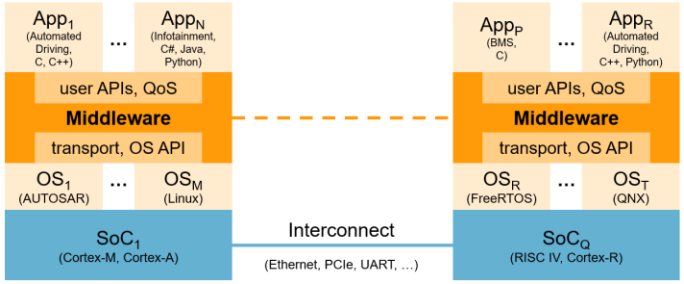
CONCLUSIONS

- Software becomes the key differentiator, supported by cost-effective programmable reliable chips
- Middleware software enables safe distributed processing in a software-defined car

- Applications demand from middleware:
  - modular and composable component API with various language bindings
  - *various Quality-of-Service policies (redundancy, real-time, reliability)*
  - rich ecosystem of libraries, tools, documentation
  - certifications, community or commercial support

- Platform demands from middleware:
  - *ability to run on various OSes and processors (RTOS, lock-step resource-constrained cores)*
  - *mapping of DDS topics and QoS policies to TSN Ethernet streams and protocols*
  - support for various transport media (TSN Ethernet, PCIe, shared memory)

- DDS meets many requirements of automotive applications and platforms



FURTHER READING

1. NXP and RTI on **DDS-TSN** integration webinar
2. TSN and middleware integration at NXP TechDays
3. Open-source DDS-TSN integration example on NXP **GitHub**
4. NXP webinar "Transition to **Zonal Architectures**: Challenges and NXP Solutions"
5. NXP trainings on **service-oriented gateway S32G**
6. "Choosing the Right **TSN Tools** to meet a Bounded Latency" by Don Pannell (2nd link)
7. "**DDS and TSN**: the future of real-time data exchange?" blog post by RTI
8. GuardKnox on **zonal** architectures , SOA and software-defined cars
9. McKinsey report on **automotive software and electronics** through 2030
10. A DDS-TSN integration white paper is coming up, let me know if you are interested

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