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CENTRALISED SOFTWARE AND ZONAL ARCHITECTURES FOR FUTURE INNOVATIVE AMBIENT LIGHTING ENABLED BY E²B 10BASE-T1S

BMW & ANALOG DEVICES

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IEEE AUTOMOTIVE ETHERNET & IP TECH DAY

AGENDA.

1

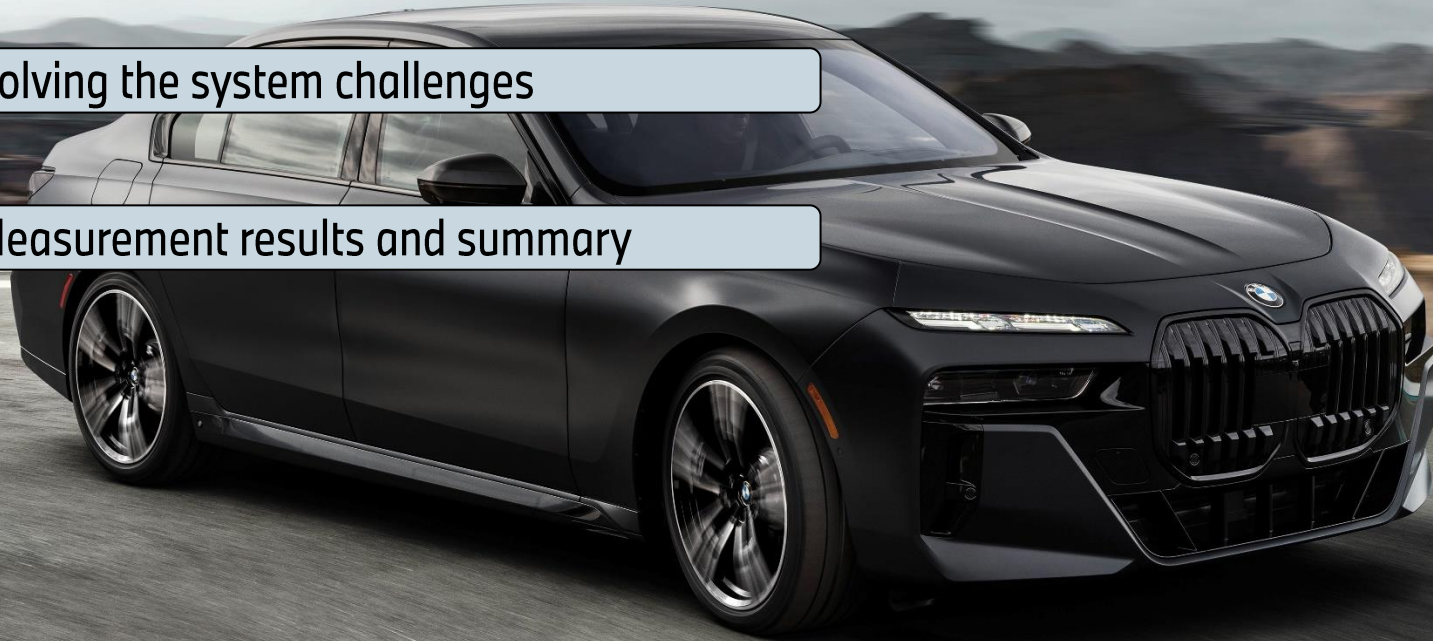
Ambient Lighting future needs

2

Solving the system challenges

3

Measurement results and summary



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STRATEGY FOR FUTURE INNOVATIVE AMBIENT LIGHTING

THE NEXT LEVEL EXPERIENCE ENABLED BY LIGHT FUNCTIONS

- INTELLIGENT
- LIVE
- DYNAMIC
- MODERN



- CUSTOMER EXPECTATION FOR LIGHT SYSTEMS ARE INSPIRED BY HOME AND BUILDING ARCHITECTURES

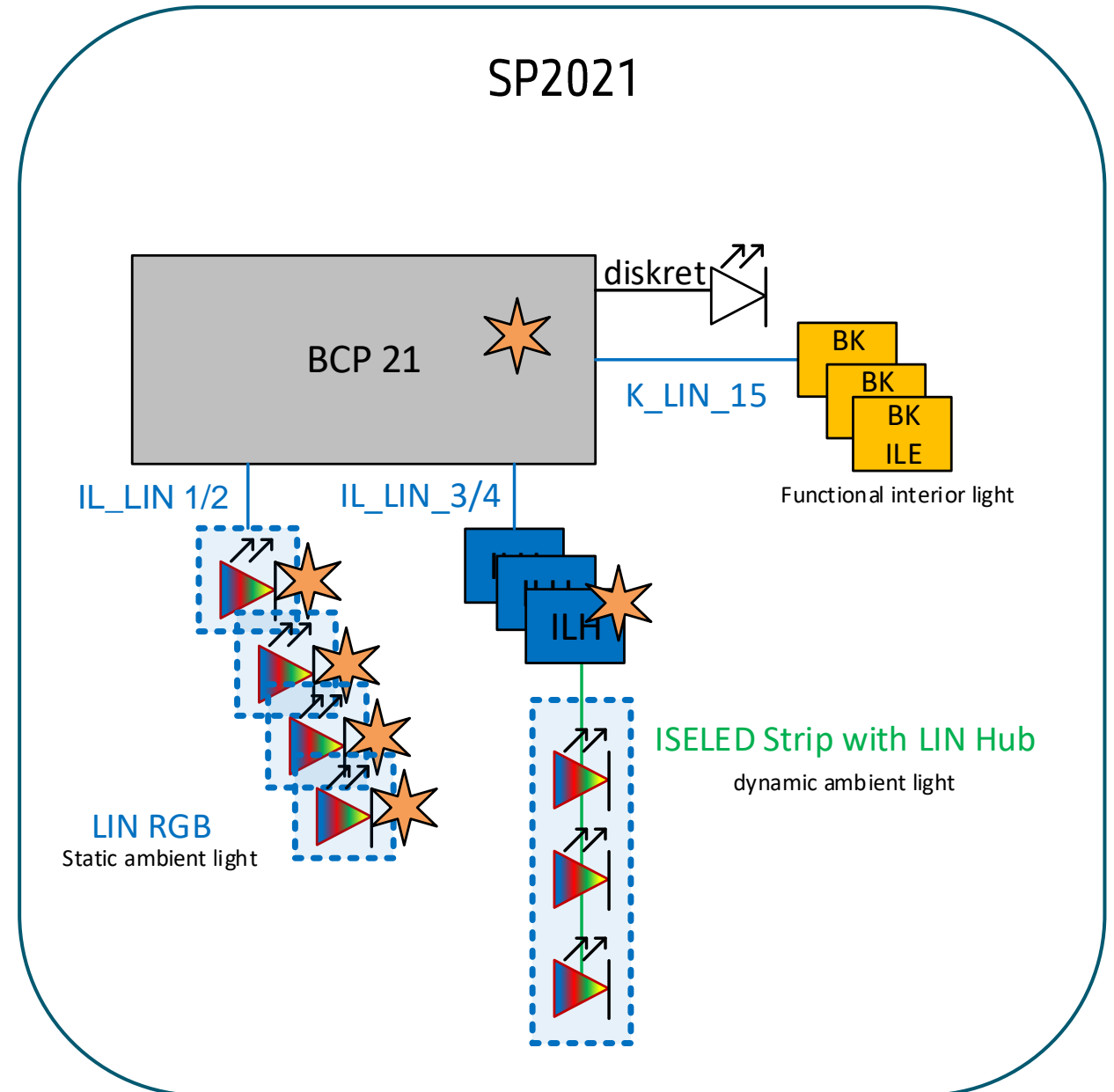
STATE OF THE ART SP2021

OVERVIEW

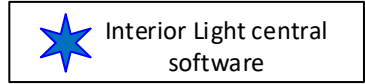
- Distributed & heterogeneous System (Synchronisation)
 - Complex integration of different technologies
 - Software (LIN Hubs/LIN RGBs/ Central ECU)
 - Static, dynamic and functional light (5 LINs)
- Limited System
 - Limited animation and appearances due to LIN
 - Fixed number of LEDs in the whole system
 - Maximum number of LEDs in a strip 63
- Not aligned to zonal architecture
- Difficult to update

TOPICS FOR 2025 ARCHITECTURE

- Investigation of other Bus technologies (CAN/Flexray ...)
- SW partitioning (AUTOSAR vs. LINUX)
- Synchronisation of the whole System
- 20ms update of each LED (jitter)



BENEFITS OF INTERIOR LIGHT ARCHITECTURE E/E SYSTEM 25

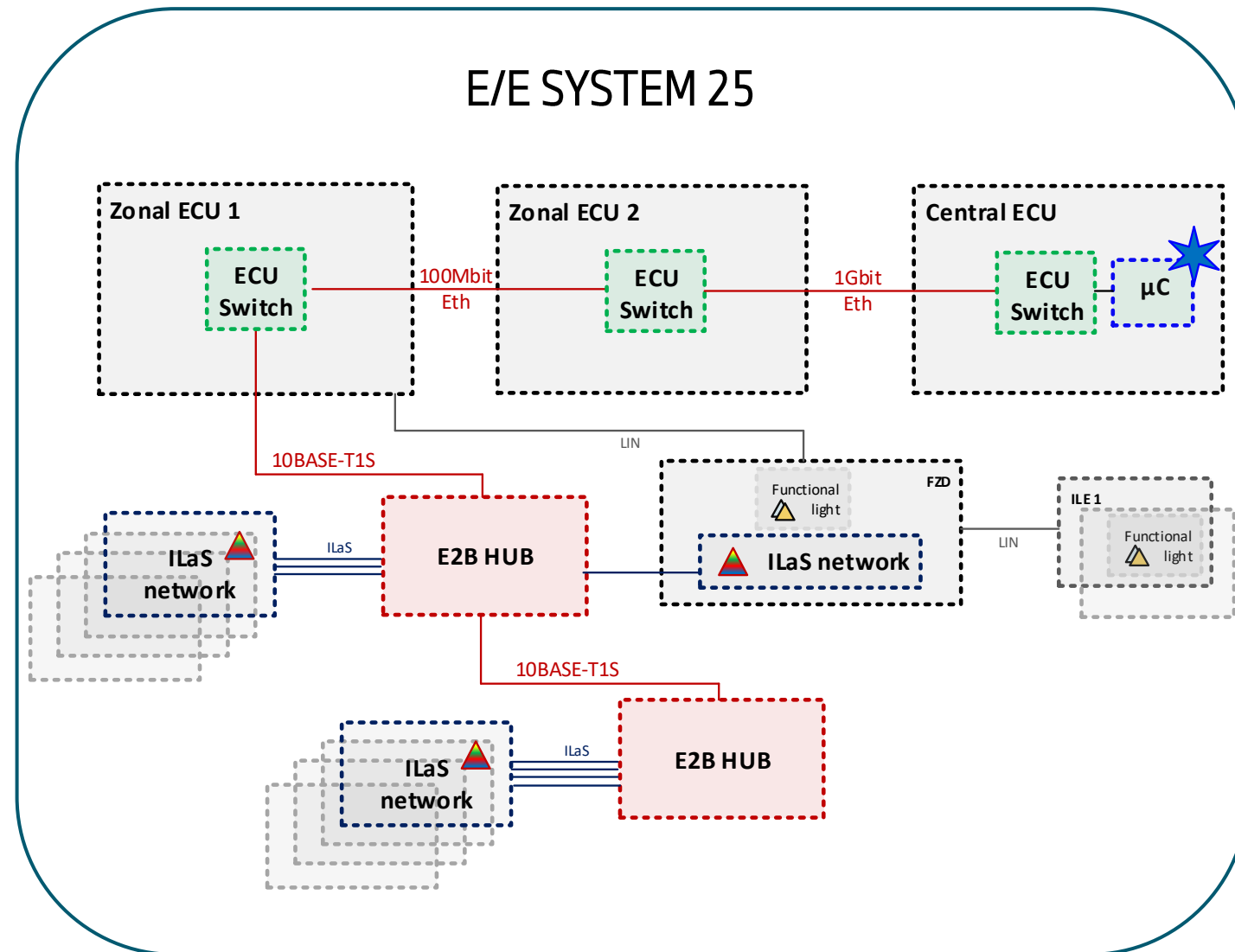


FUNCTIONAL BENEFITS

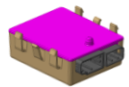
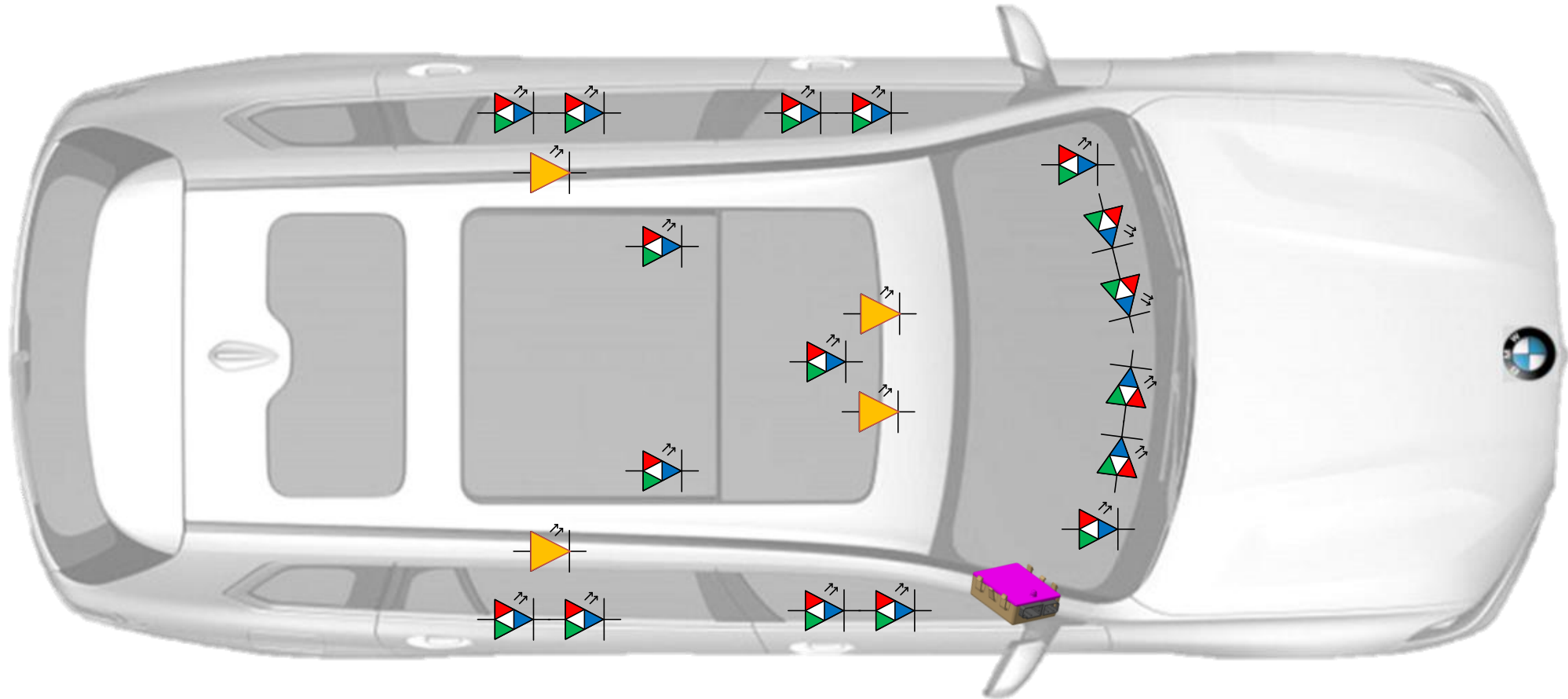
- "Realtime" light functions
- Dynamic projection
- Multi-dimensional lighting experience (2D effects)
- Interaction with customer / personalisation
- Dynamic light functions responding to real-time input
- Synchronus control of all lighting components
- Central logic (also advantages for Function on Demand, Always fresh)

COMPONENT BENEFITS

- Wiring Harness optimization
- Elimination of wiring harness splices
- Zonal architecture
- Elimination of SW (only HW components)



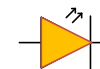
COMPONENTS AND SCALING E/E SYSTEM 25 - OVERVIEW



▪ E2B Hub (10BASE-T1S to ILaS)



▪ Ambient interior light

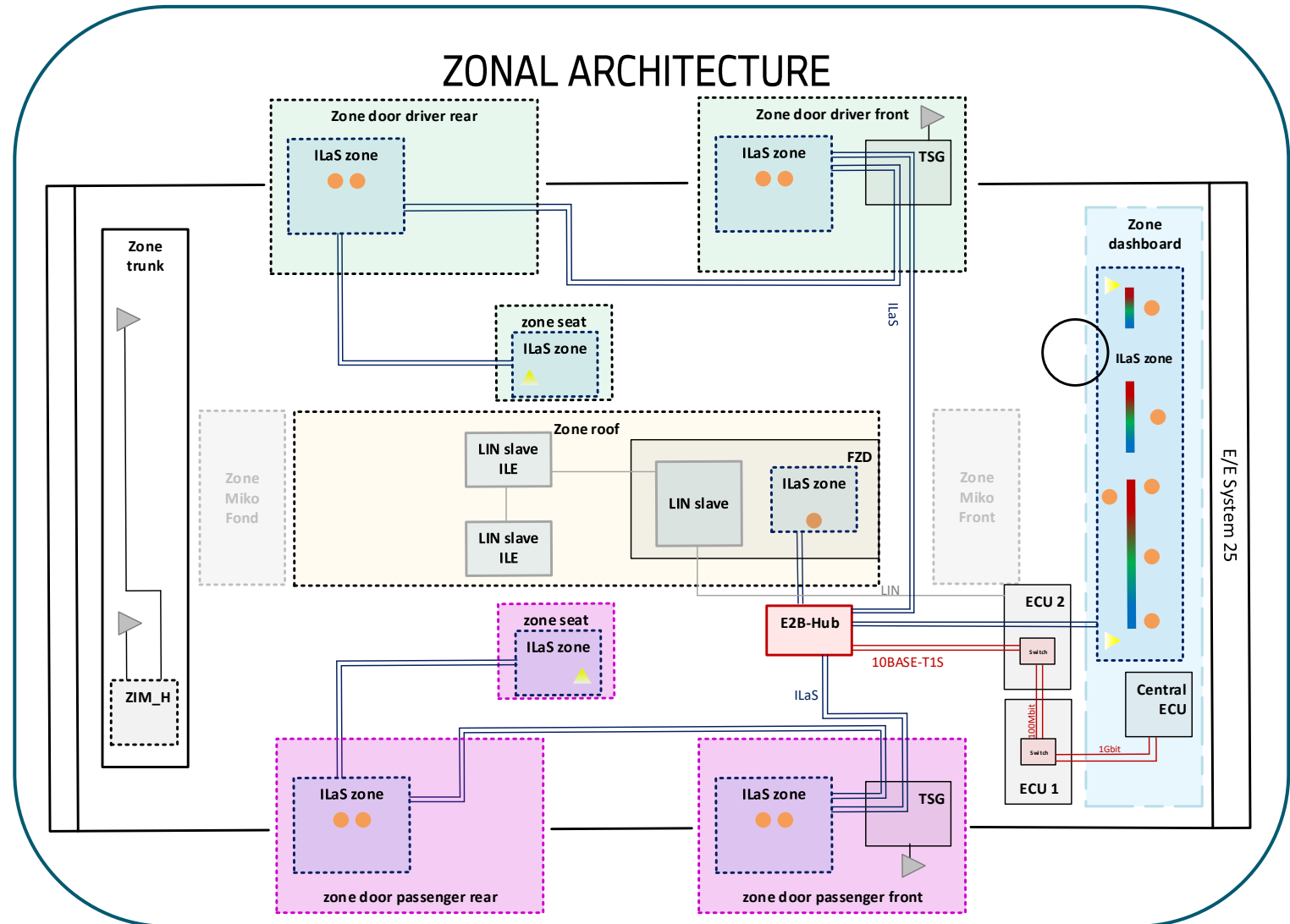


▪ Functional interior light

OVERVIEW INTERIOR LIGHT ZONAL ARCHITECTURE

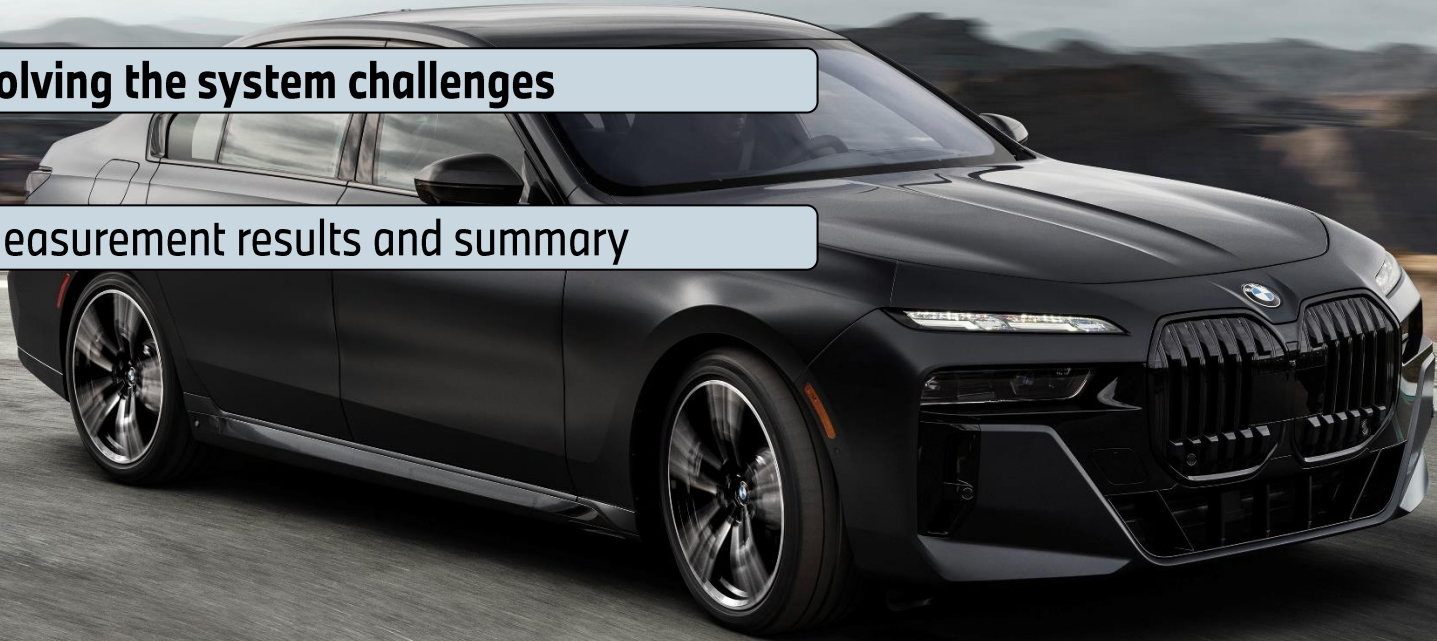
ZONAL ARCHITECTURE

- E2B Hubs all hardware implementation which communicates over 10BASE-T1S Ethernet and translate the signals to ILaS
- ILaS is offered in different zones (e.g. dashboard)
- Power supply is provided by zonal ECUs and looped through by the components
- ILaS is looped through the light components
- For small cars one E2B hub is sufficient
- For fully equipped cars additional E2B hubs can also be added



AGENDA.

- 1 Ambient Lighting future needs
- 2 Solving the system challenges
- 3 Measurement results and summary



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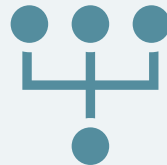
APPLICATION AND SYSTEM CHALLENGES CREATE OPPORTUNITIES TO INNOVATE

- ADI engaged early with BMW to understand upcoming system requirements and address the following key challenges:



Software Defined

Upgradable, Flexible and Adaptable Lighting System



Zonal Architecture

Align to Zonal Architecture



System Optimization

Enable an optimized edge node implementation



Synchronized Animation

Provide cross-lighting and cross application Synchronisation

- The advanced requirements of the BMW's Ambient Lighting solution drove a different approach and opportunity for system level innovations utilising the latest available technologies

RESULT – COMPLETELY NEW, INNOVATIVE SYSTEM APPROACH



Software Defined

- All **software** (Application layer to edge node driver) is **centralized**



Zonal Architecture Support

- Ethernet-based switch ECUs



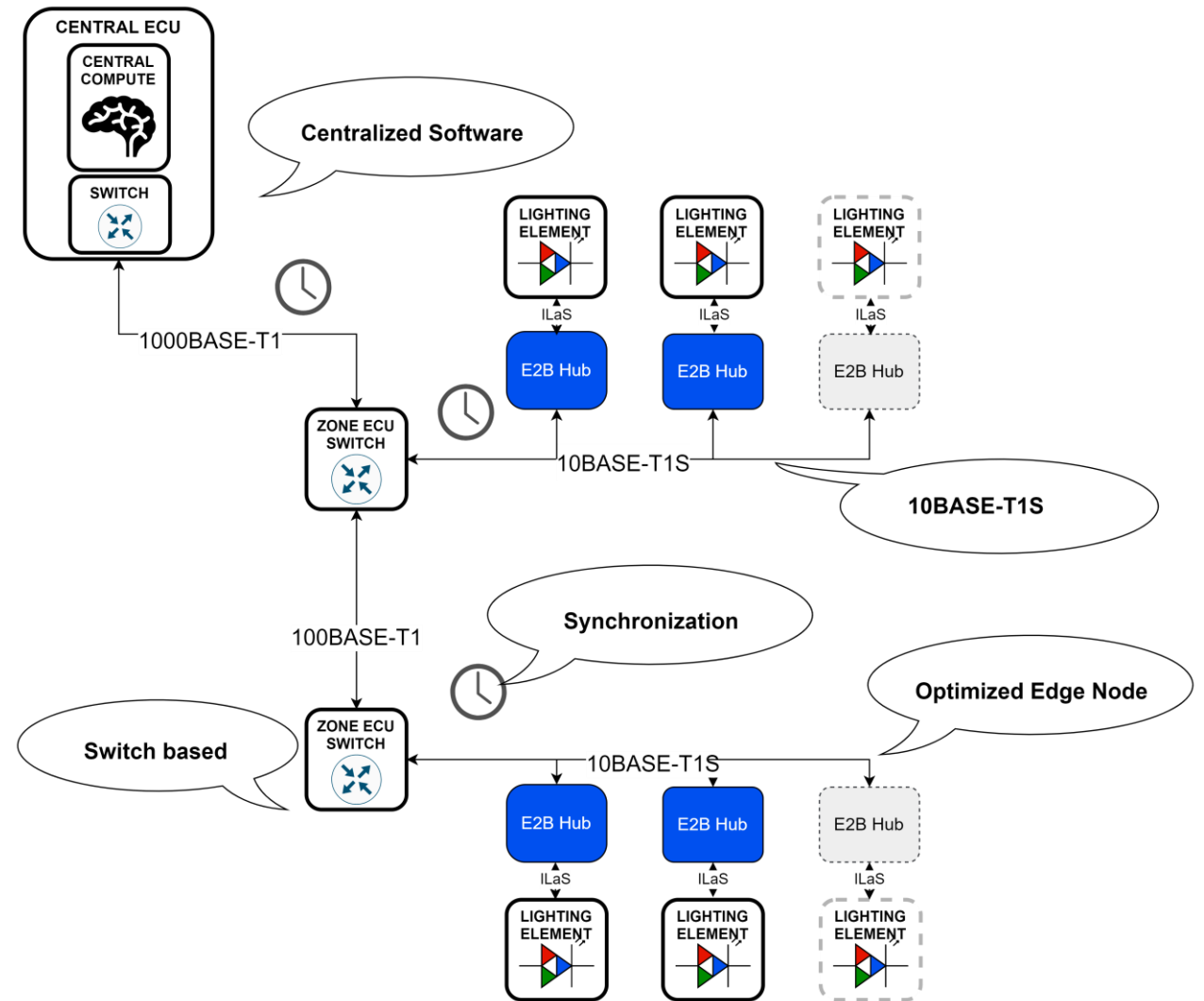
System Optimization

- 10BASE-T1S-based Hardware only Edge node
- ILaS interface to LED



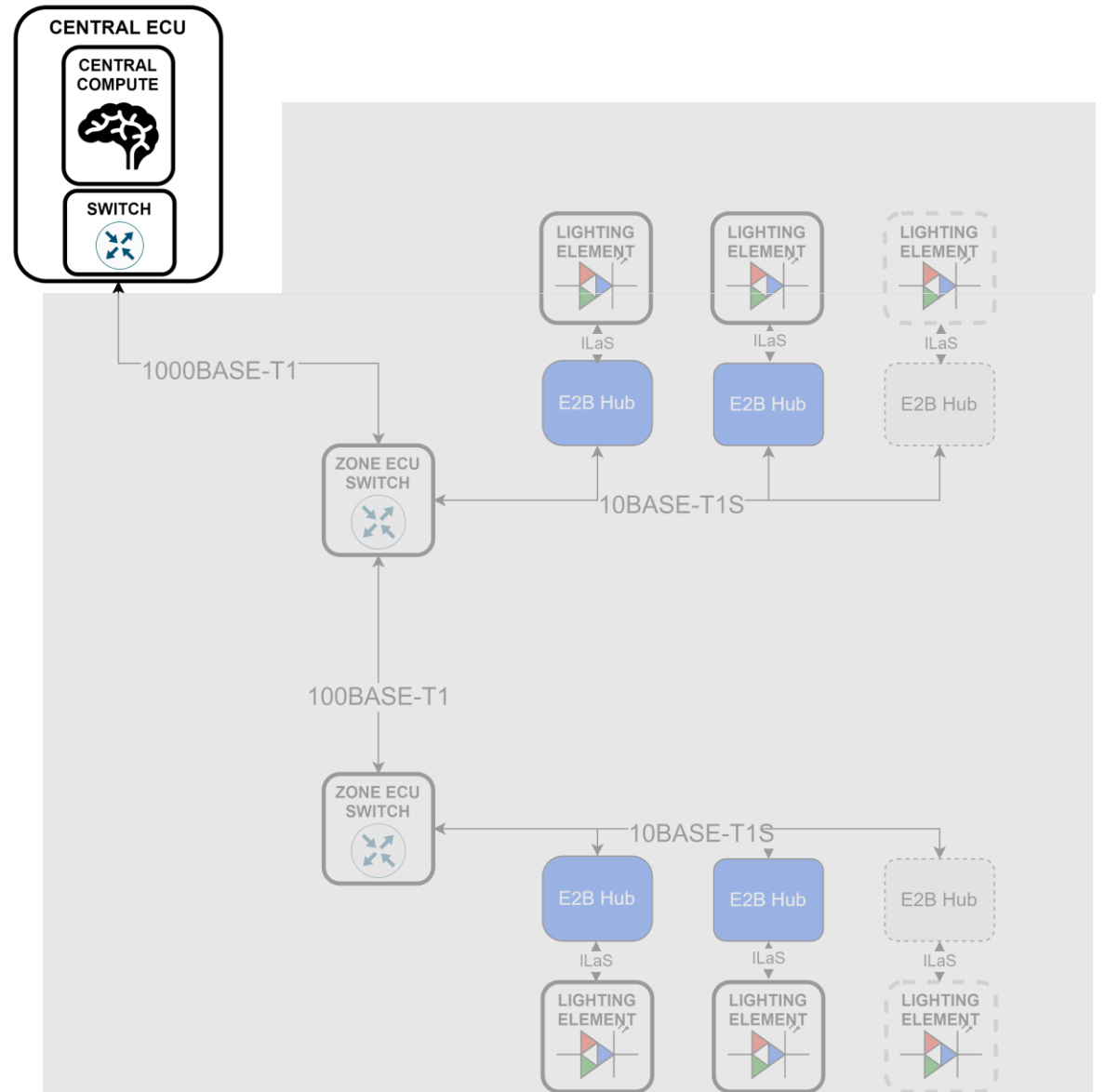
Synchronized Animation

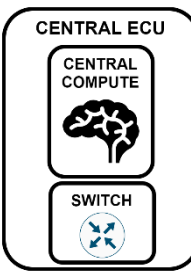
- TSN support



1. SOFTWARE DEFINED: REQUIREMENTS

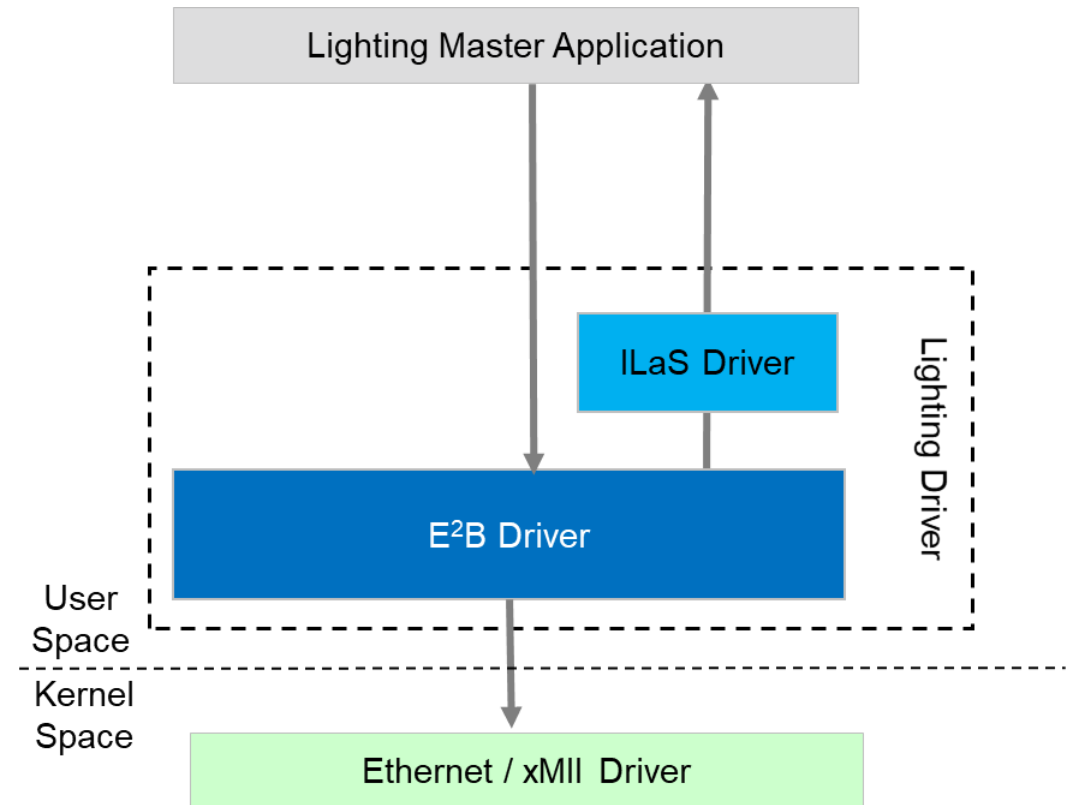
- Support full **OTA** updates
- Software located in the **User Space**
- Easy to Update and maintain
- Support **advanced animation** routines
- Provide **Cross-application synergy**





1. SOFTWARE DEFINED: THE SOLUTION

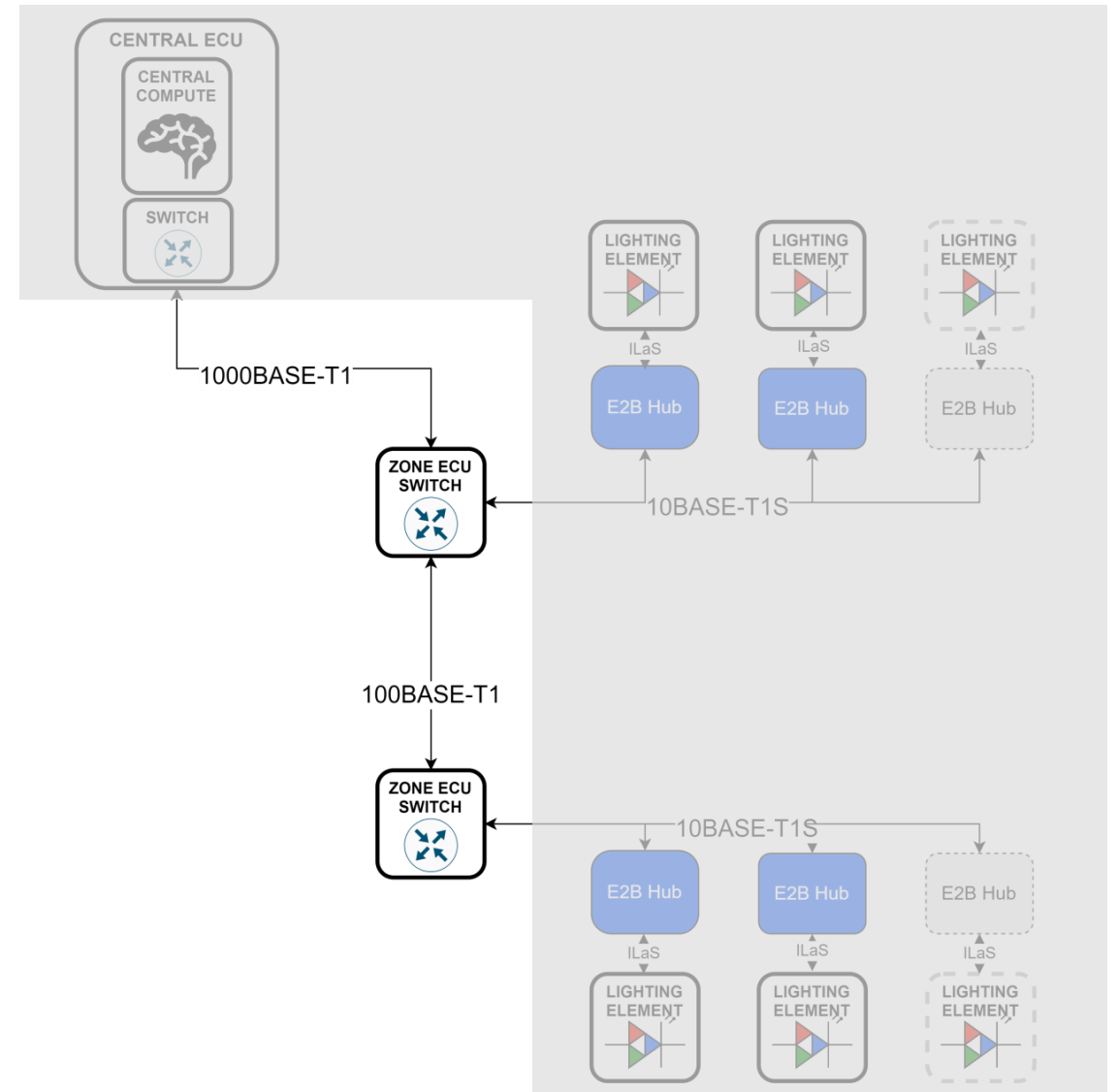
- All lighting software integrated and runs in a single location on Central ECU
 - Lighting Master Application
 - Lighting Driver
 - ILaS Driver
 - ISELED Light & Sensor Network protocol
 - E²B Driver
 - Ethernet to the Edge Protocol



Software from edge nodes removed and centralized in Central ECU

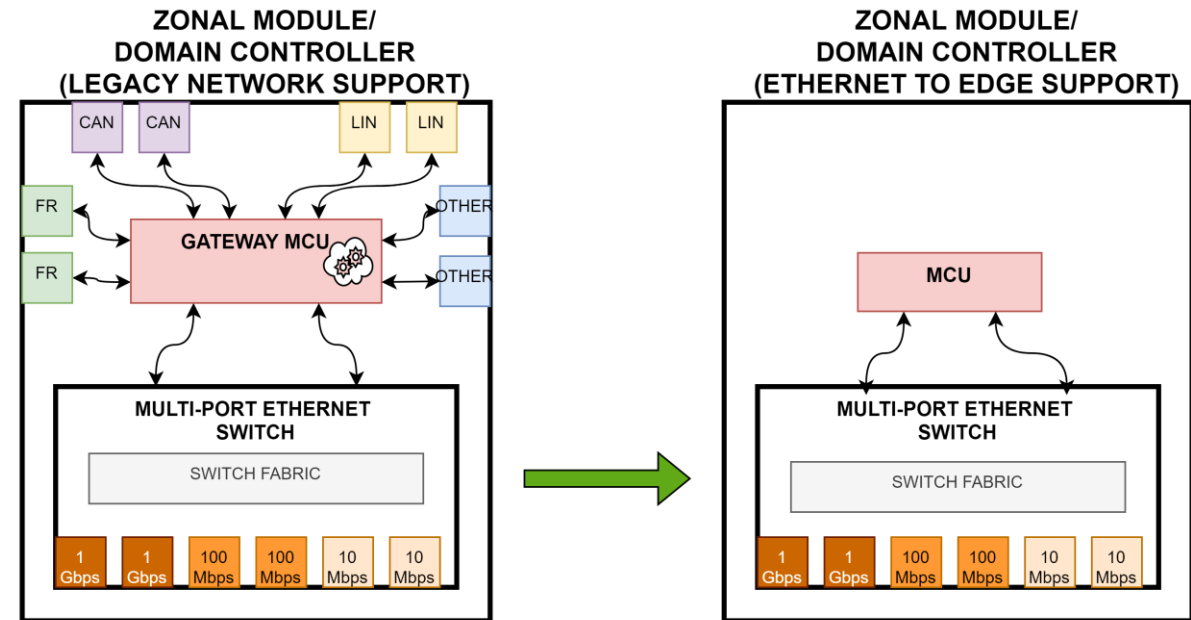
2. ALIGN TO ZONAL ARCHITECTURE: REQUIREMENTS

- Support connectivity to Zonal ECU's
 - Easily **upgradable** network
 - Scalable Network
 - Ability to **easily add nodes**
 - Qualification of Network
 - **Minimum re-qualification** effort when network updates are made
 - Reusability of Network
 - Previous designs **reusable** to minimize effort/cost



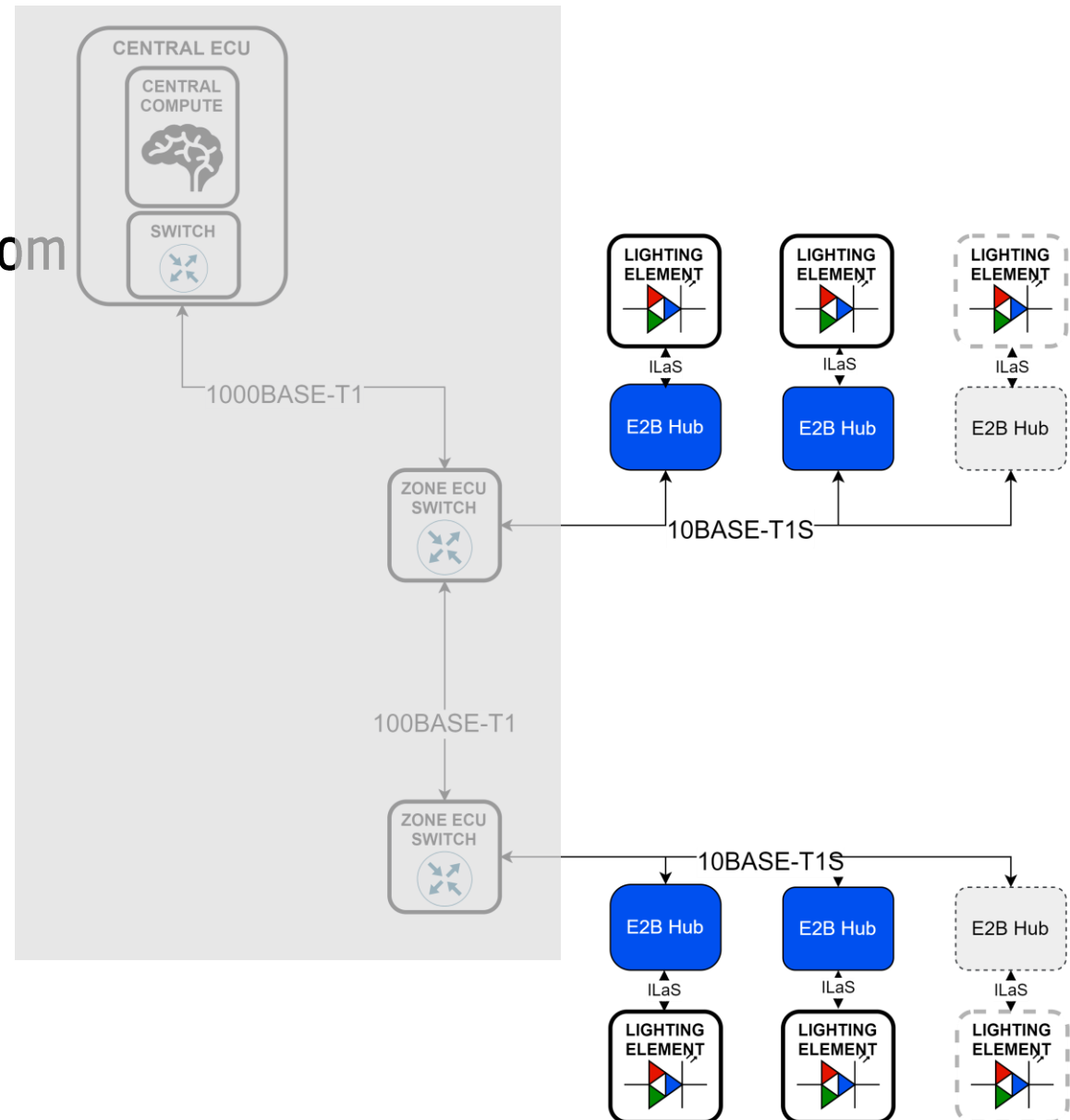
2. ALIGN TO ZONAL ARCHITECTURE: THE SOLUTION

- Switch based ECUs extending **Ethernet to the Edge to simplify** networking solution
 - Gateways eliminated
 - Ethernet frames handled directly in switch
 - Switch MCU available for other tasks or scaled down
 - Unified solution suite across the network
 - Security, TSN, Routing, Wake/Sleep, etc.



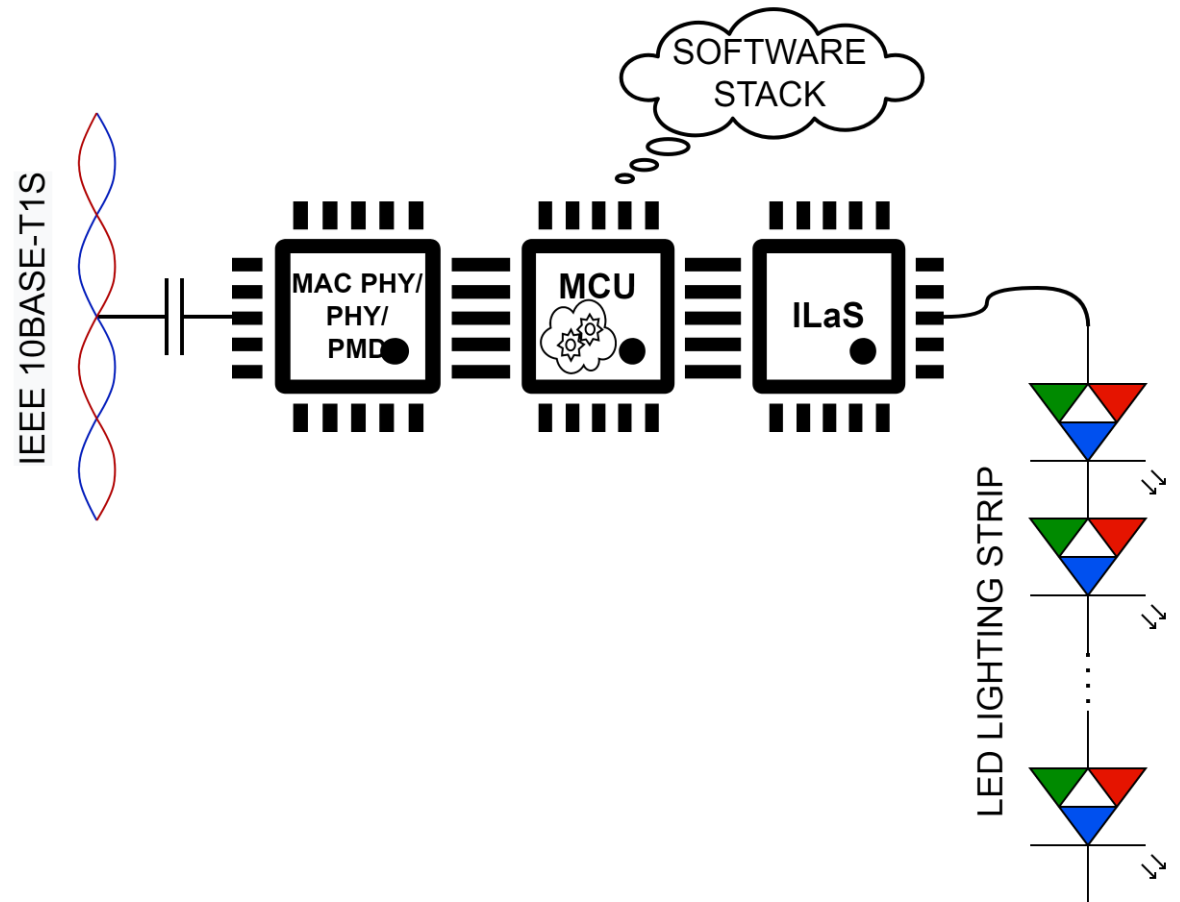
3. OPTIMISED EDGE NODES: REQUIREMENTS

- Ease of implementation
- **Identical performance** across all nodes from multiple suppliers
- **No Software Qualification**
- **Synchronisation/Determinism**
- Small Form factor



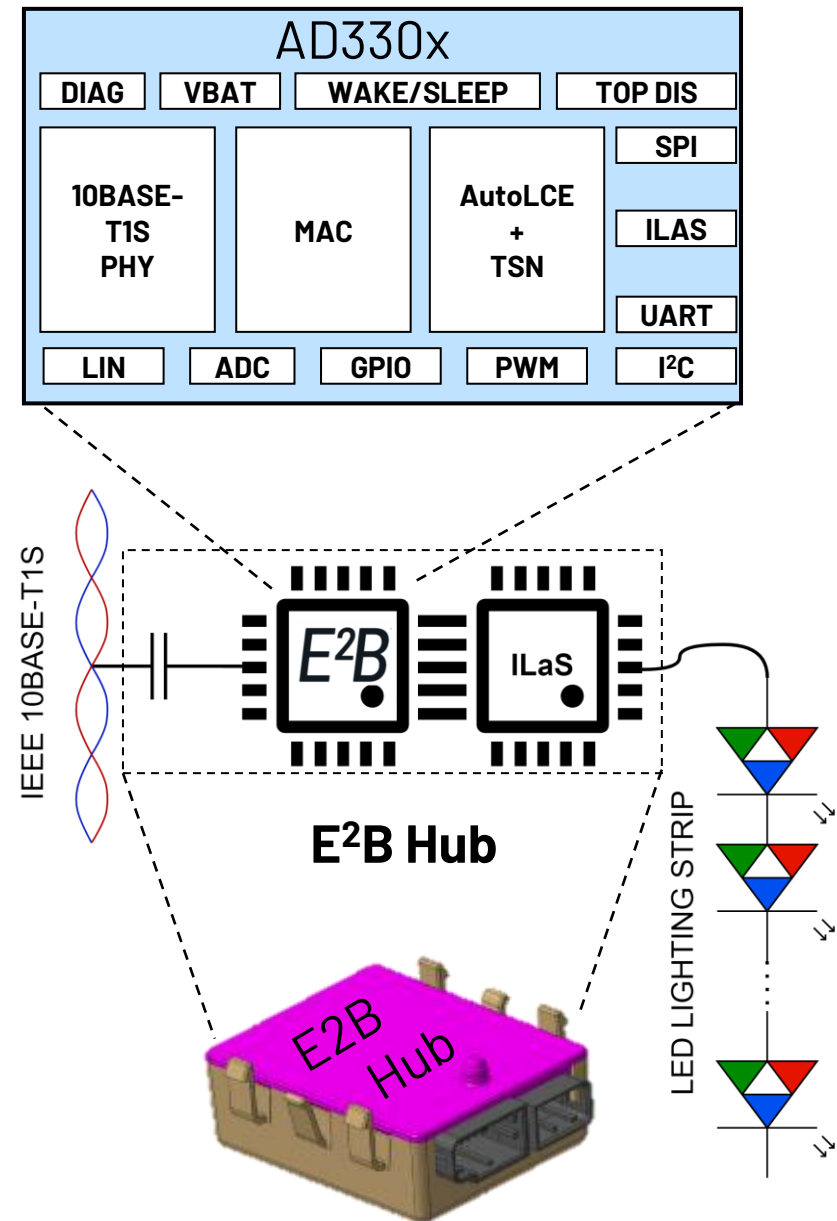
3. OPTIMISED EDGE NODES: THE CONCERN

- Existing Ethernet Based Edge Nodes
 - **Added complexity** for simple edge nodes
 - Examples : Lighting, Body Control, Drive-train, ...
 - Reluctance to adapt Ethernet for these applications
- Ethernet Software Stack at the edge node requires dedicated MCU
 - Significant overhead of SW qualification
 - Identical performance from multiple suppliers is difficult to achieve



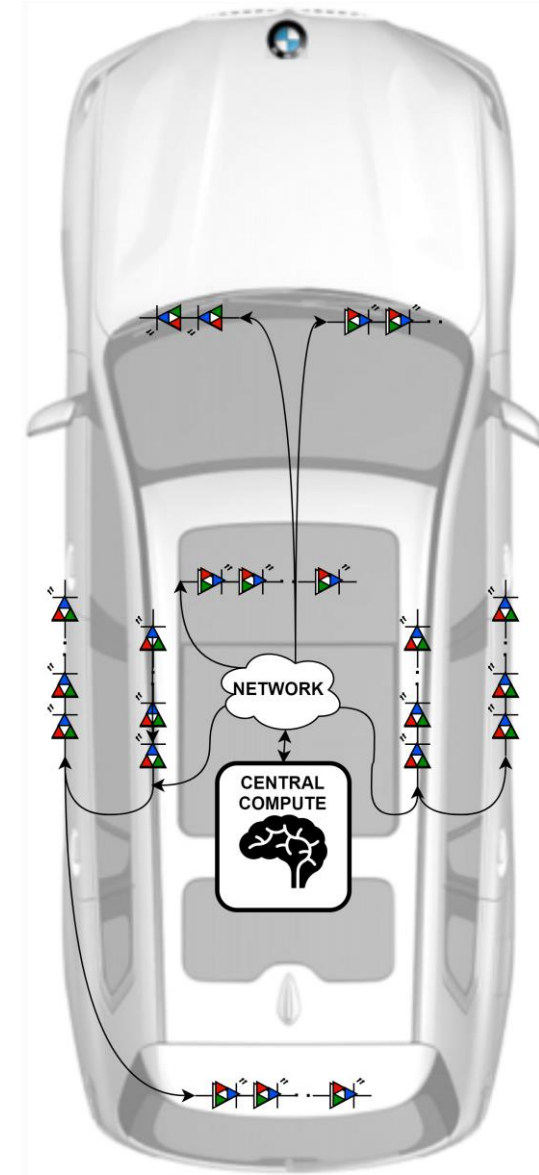
3. OPTIMISED EDGE NODES: THE SOLUTION

- **E²B** provides a highly optimized yet flexible hardware-based Ethernet edge node enabling:
 - **Removal of Software/Software Qual:** Hardware only edge node
 - **Simplified OTA:** No requirement of OTA to edge node
 - **Determinism:** Hardware implementation provide fully deterministic Lighting interface
 - **Diagnostics:** Handled in the central ECU, all connectivity diagnostics enabled in hardware
 - **Security:** Hardware based approach reduces possible attack surfaces



4. SYNCHRONIZED ANIMATION: REQUIREMENTS

- Lighting Animation synchronization
 - Must be **stable** < 1-2ms jitter
 - Must be **accurate** to 20ms of precision
 - Configurable to match lighting strip length
- Cross-application synchronization
 - Delay must be < 150ms for HMI interaction
 - Easily adjustable to **align with other functions**
 - Ambilight Display
 - Hazard indication – safe exit indication



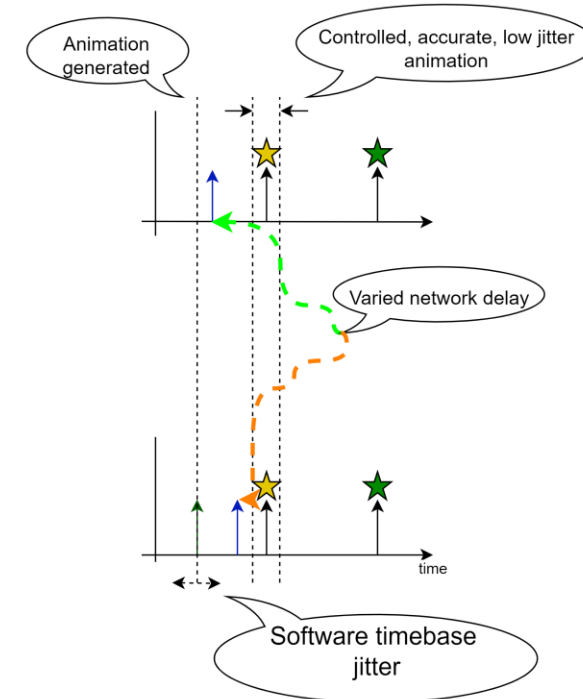
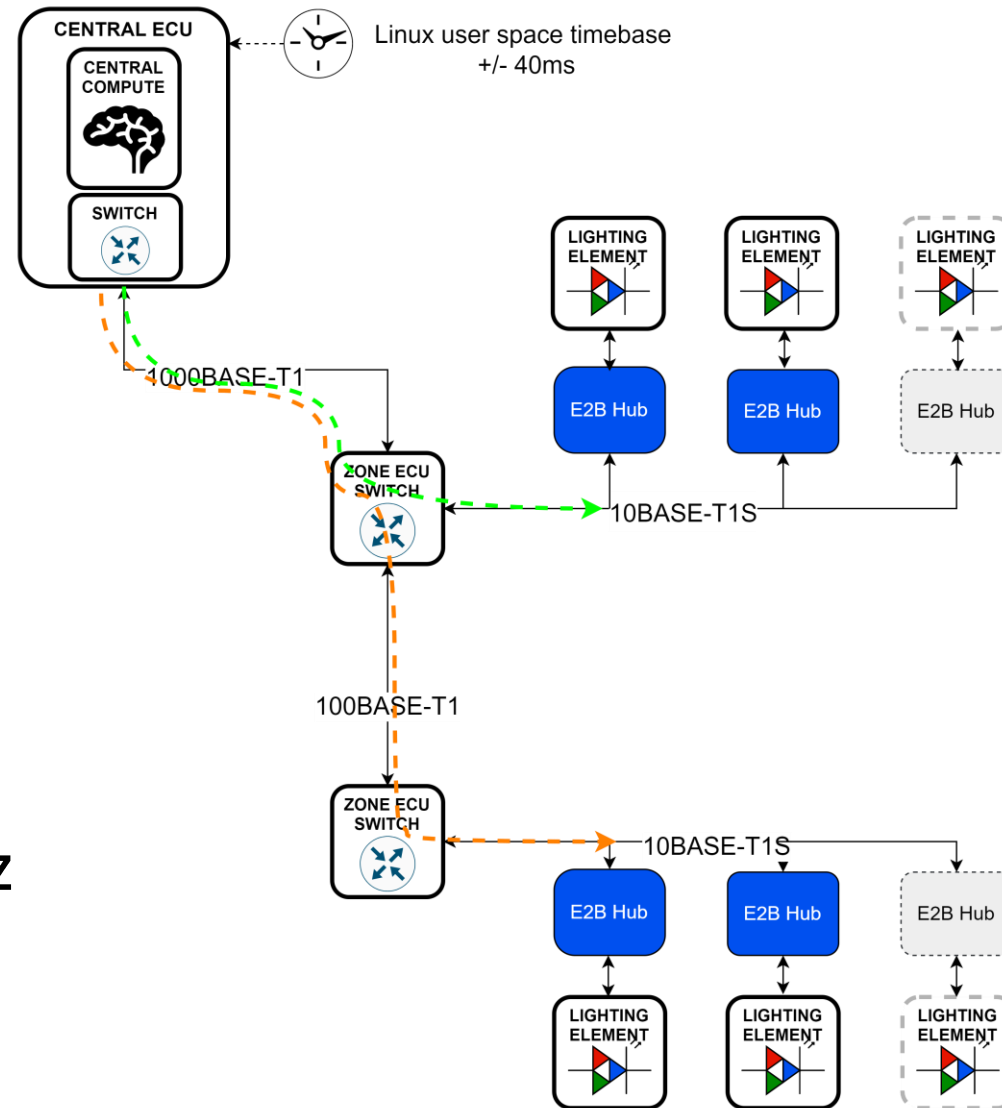
4. SYNCHRONIZED ANIMATION : ERROR SOURCES

- Zonal architecture

- Varied network paths to lighting elements must be equalized

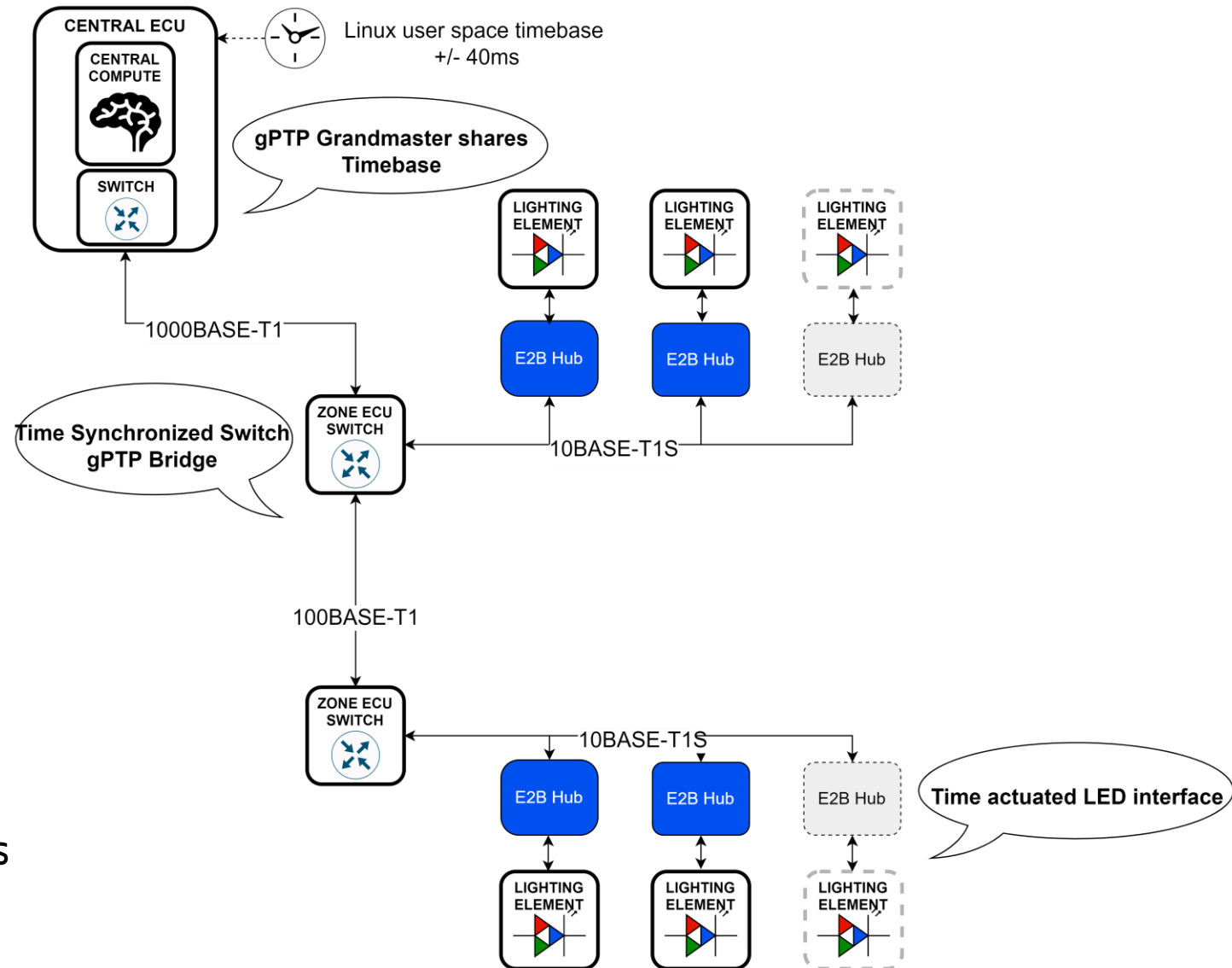
- Central compute

- Lighting drivers run in Linux user space
- e.g. Linux +/- 40ms accuracy
- Refresh rate minimum of 50Hz for smooth animation



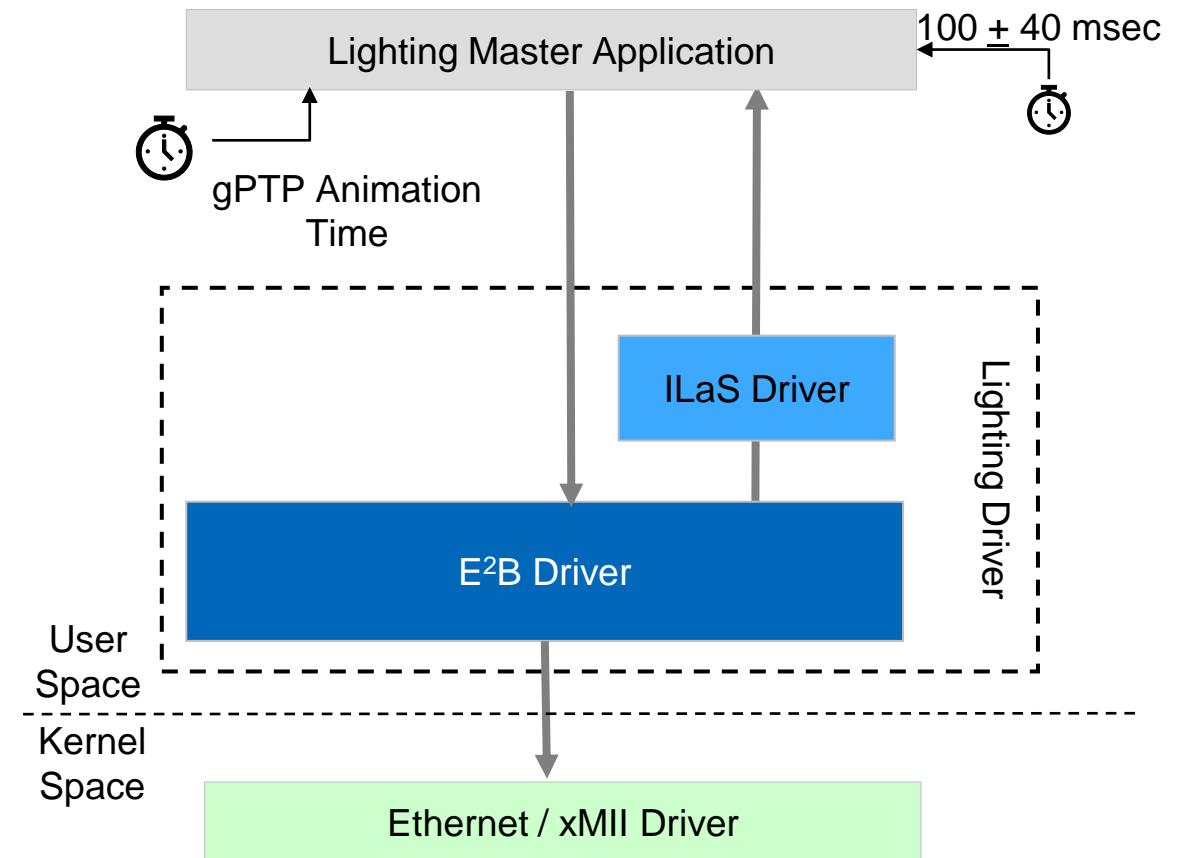
4. SYNCHRONIZED ANIMATION : THE SOLUTION

- Lighting synchronized via gPTP
 - All nodes **synchronized to gPTP timebase**
 - IEEE 802.1AS
 - Presentation time used to control actuation
 - MAX_TRANSIT time accounts for worst case
 - Software timebase uncertainty
 - Network delay
 - Fixed deterministic latency of E²B end node guarantees accuracy to endpoint (e.g. LED)
- Cross-application solution
 - **Timebase shared with all Ethernet nodes**
 - Synchronized orchestration of all sensor/actuators
 - Easier to achieve/maintain/scale than with legacy network technologies



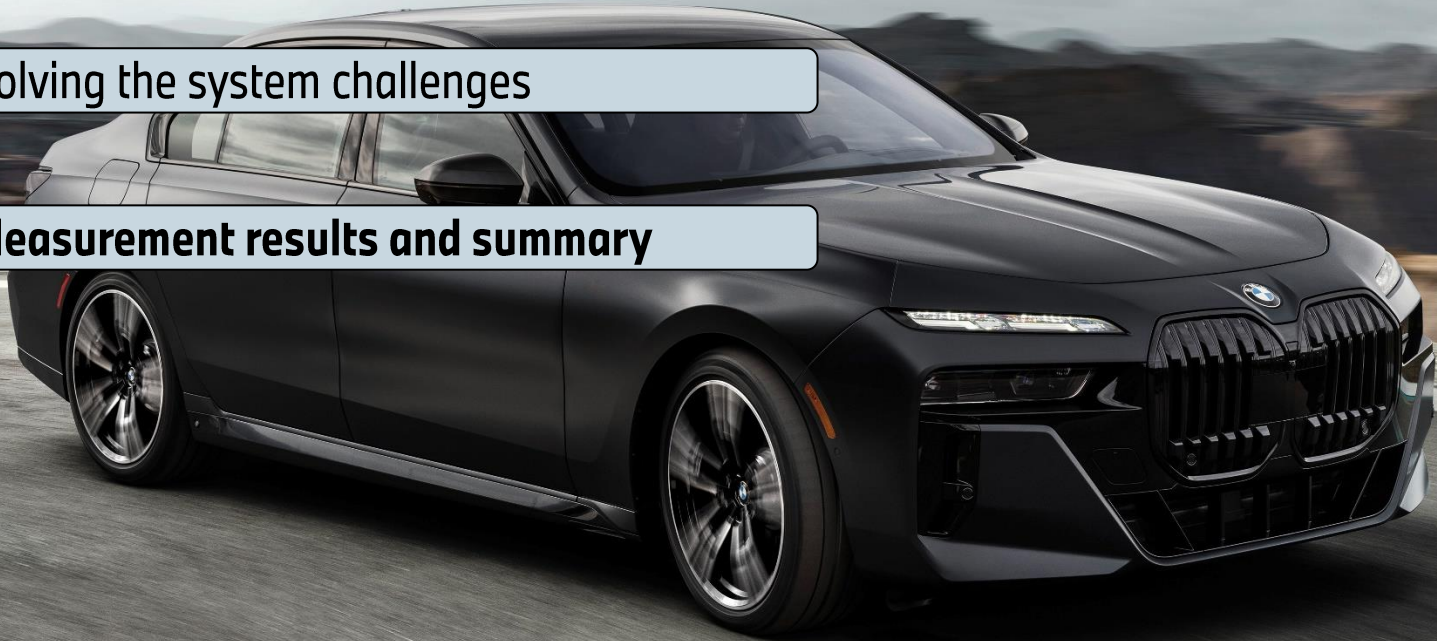
4. SYNCHRONIZED ANIMATION : THE SOLUTION

- Direct drive from 'User Space' will not achieve required animation accuracy
- Embed **animation presentation time** in updates
 - gPTP time based
 - Synchronized actuation at edge nodes
 - Animation time incremented to achieve desired refresh rate
- Lighting application can **schedule multiple animation updates**
 - Animation updates queued in the HW FIFOs on Edge Nodes
- **Edge nodes actuate updates** at embedded animation time



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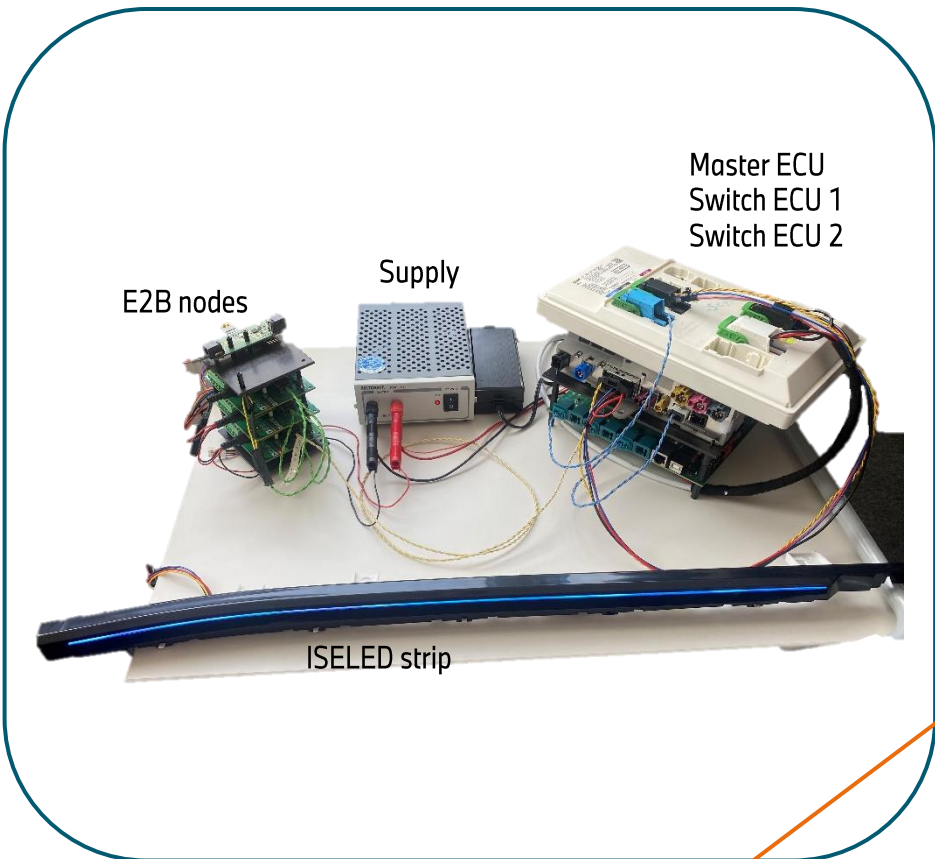
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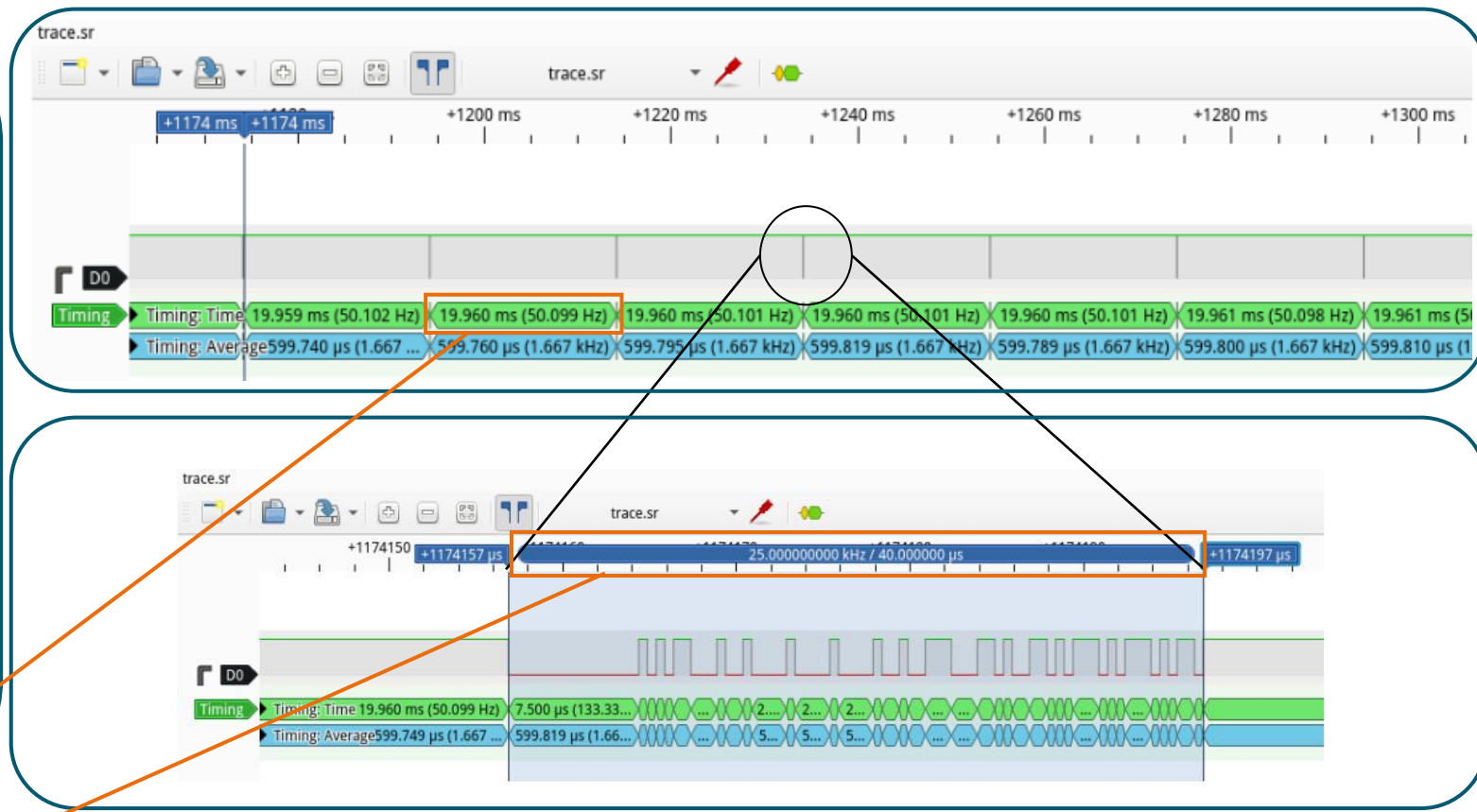
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MEASUREMENT SET-UP AND RESULTS

MEASUREMENT SET-UP

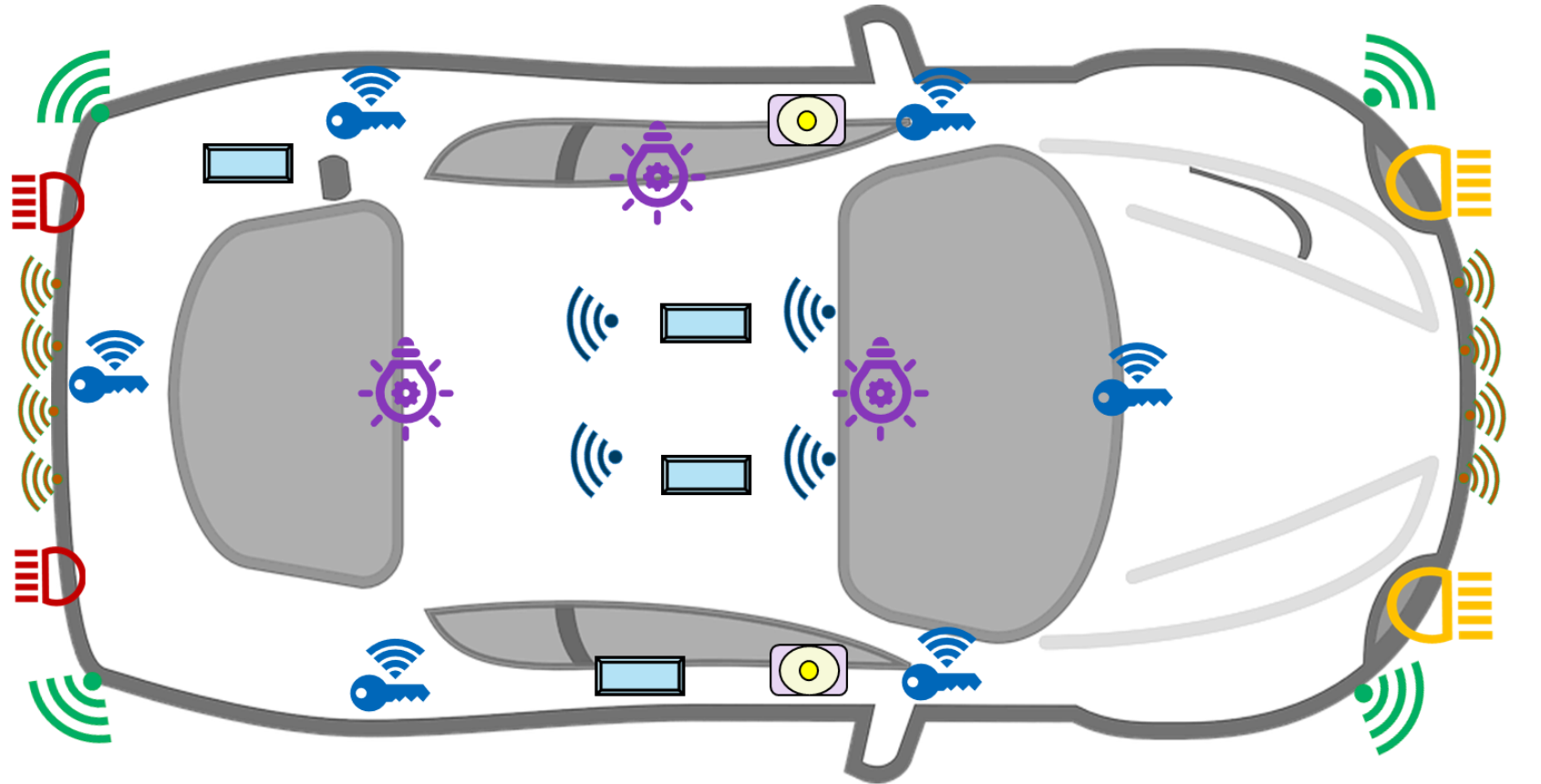


MEASUREMENT RESULTS



- Update of each ISELED = $19,960\text{ms} + 40\mu\text{s} = 20\text{ms} == 50\text{ Hz}$

10BASE-T1S E²B – EXCELLENT FIT FOR BROAD RANGE OF APPLICATIONS



Front
Headlights

Rear
Lights

Keyless
Entry

Ambient
Lighting

Short Range
Radar

Ultrasonics

Sub ECU e.g.
Door/Seat

Interior
Radar

Projector

And many
more.....

SUMMARY

- Ambient lighting is undergoing a significant change
- Leveraging the Ethernet Ecosystem (switches/TSN etc) simplified the system implementation
- The availability of 10BASE-T1S further eased the system design bringing Ethernet to the edge
- Use of E2B, enabling an all hardware edge node, further reduced the complexity of the edge node and enabled centralisation of the software
- 10BASE-T1S is ready for production rollout