AUTOMOTIVE TIME SYNCHRONIZATION – USE CASE

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AGENDA

AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

Scope of this presentation:

- Provide goals and “level set” concerning use of time synchronization
- Description **of a few** Automotive constraints and requirements
- Suggested Automotive Time Synchronization profiles
- Use case based on simple common architectural OEM design
- A single specific use case (out of many…), with focus on working clock time synchronization requirements in the network

Not scope of this presentation:

- Provide a pre-selection of IEEE 802.1AS-REV and 1588 v2.1 mechanisms “one size fits all” solution representing the whole automotive industry or Time Synchronization profiles
- Representation of different OEM opinions and additional architecture designs

AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

Need:

- ADAS message interleaving/seaming together of multiple sensor data
- Adjust for clock offsets between sensors based on different startup times
- Adjust for added time differences due to local clock frequency Remove/minimize margin of error of ADAS processing node to interpret sensor recordings of object data
- Without required precision sensor provided data can become “out-of-order” (e.g. Sensor_A indicates it’s data was recorded before Sensor_B because Sensor_B clock has deviation to Sensor_A clock)
- Reduce sync startup time on ignition cycles and activation off sleep modes to <100ms (e.g. based on Controller Area Network (CAN) typical startup)
- HAS TO MEET FUNCTIONAL SAFETY REQUIREMENTS FOR ASIL COMPLIANCE

AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

Goals:

- Provide a common system level time base
- Provide a standards based time synchronization method for redundancy based on functional safety requirements where required
- Provide safety critical Electronic Control Units (ECUs) with the same real-time precision view of time (e.g. Ability to support high accuracy and precision/resolution levels
- Solution is easy to implement and cost effective

LEVEL SET:

Focus of this Presentation is on Working Clock with shorter synchronization startup times:

Wall Clock

- OS System Time
- Timestamp sequence of events
- Timestamp production data
- Timestamp sampled values
- Clock Source: GPS/NTP (e.g. not always available)

Working Clock

- Synchronize applications
  - Sensors, actuators, control unit
- Used for scheduling traffic to synchronize
  - Time based transmission in end stations
  - Time aware shapers
- Used for precision/accuracy of transmission
  - 1us with sync 32ms interval
  - Redundancy options (i.e. GM's)
  - Clock Source: free running crystal oscillator(s)

Focus on IEEE Std 802.1AS-REV as a profile of 1588 v2.1

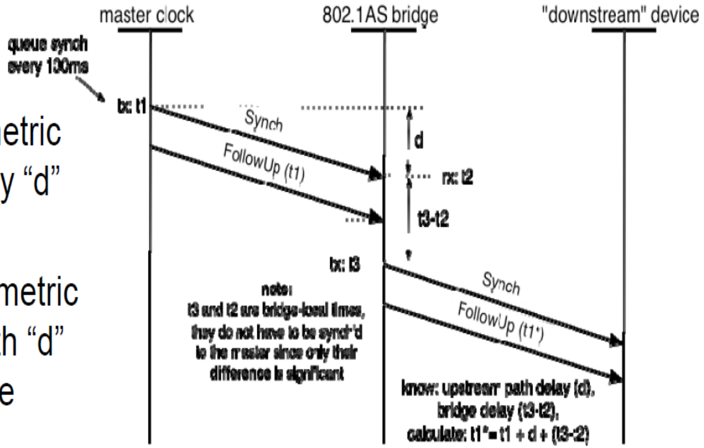
LEVEL SET:

Offset Calculations

- Needed to account for sync frequency time drifts between Master/Slave clocks
- Used to calculate neighborRateRatio

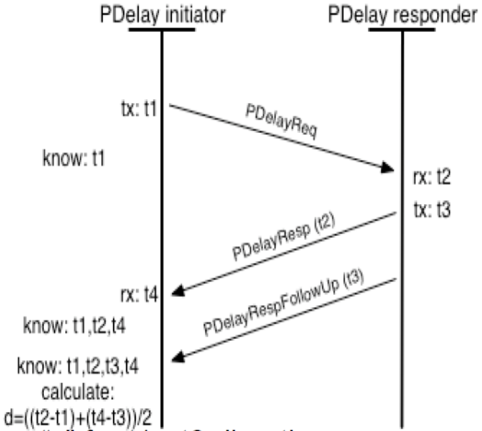
Path Delay Calculations

- Propagation time through the cable
- Needed for Slave to calculate for peer delay



- For symmetric paths, only "d" is needed
- For asymmetric paths, both "d" and "x" are needed:
  - t1* = t1 + d + x +(t3-t2)
  - (note that "d" is the delay from ingress, while "x" is the offset from egress)

- Process requires t1, t2, t3 and t4 *and* that the propagation time in both directions is the same
  - or the offset between the two is known



- For known fixed extra delay "x" for t1->t2 direction:
  - $d=((t2-t1-x)+(t4-t3))/2$

AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

Automotive Considerations and Requirements:

Safety/ISO 26262 (uses Automotive Safety Integrity Level (ASIL) compliance for Hazard Analysis & Risk Assessment)

- Keep data integrity high (e.g., account drifting)
- Allow E2E protection (e.g. security of time sync messages)
- Keep communication network "robust"/avoid unnecessary single points of failure
- Dual Plausible failure requirements
- Allow for network validation and verification

Configuration

- Maintain standardization amongst suppliers and other implementation standards (e.g. AUTOSAR)
- Allow simple configuration for integrators and OEM tools chain process (e.g. Vector, Mentor, etc.)
- Allow distributed network development (i.e., different divisions, different suppliers)
- Validatible

Topologies

- Support for single and multiple time domains
- Allow redundant transmission (IEEE 802.1CB FRER, dynamic structural redundancy, partial network replication, time redundancy, etc..), where needed (cost vs. safety)
- Provide a pre-selection of IEEE 802.1AS-REV and 1588 v2.1 mechanisms "one size fits all" solution representing the whole automotive industry
- Representation of different OEM opinions

AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

Automotive Considerations and Requirements: (con't)

Bandwidth

- Keep wire speed low (PHY & common chokes costs)
- Keep net bandwidth high/overhead low (e.g. minimize # of transmissions)

Traffic

- Minimize number of traffic transmissions (e.g. Sync msg sent with inserted Pdelay_resp_Followup or TLV)
- Maximize performance accuracy by minimizing synchronization error margin <1us based on environmental factors of AEC-Q100 Grade 1 -40°C to +125°C and 75% Bandwidth network load
- GPS is not always available during startup(s) or operation

Endpoints

- Integrate with AUTOSAR or OEM developed Implementation std modules (e.g. StbM, EthTsync, etc.)
- Integrate with automotive grade communication stacks
- Keep performance limitations of µCs into account
- Assume slave local reference clock <100PPM (NOTE: GrandMaster reference free running oscillator crystal with a frequency tolerance of <±10PPM @ 30°C and <±30PPM @ approx. -40°C to +125°C

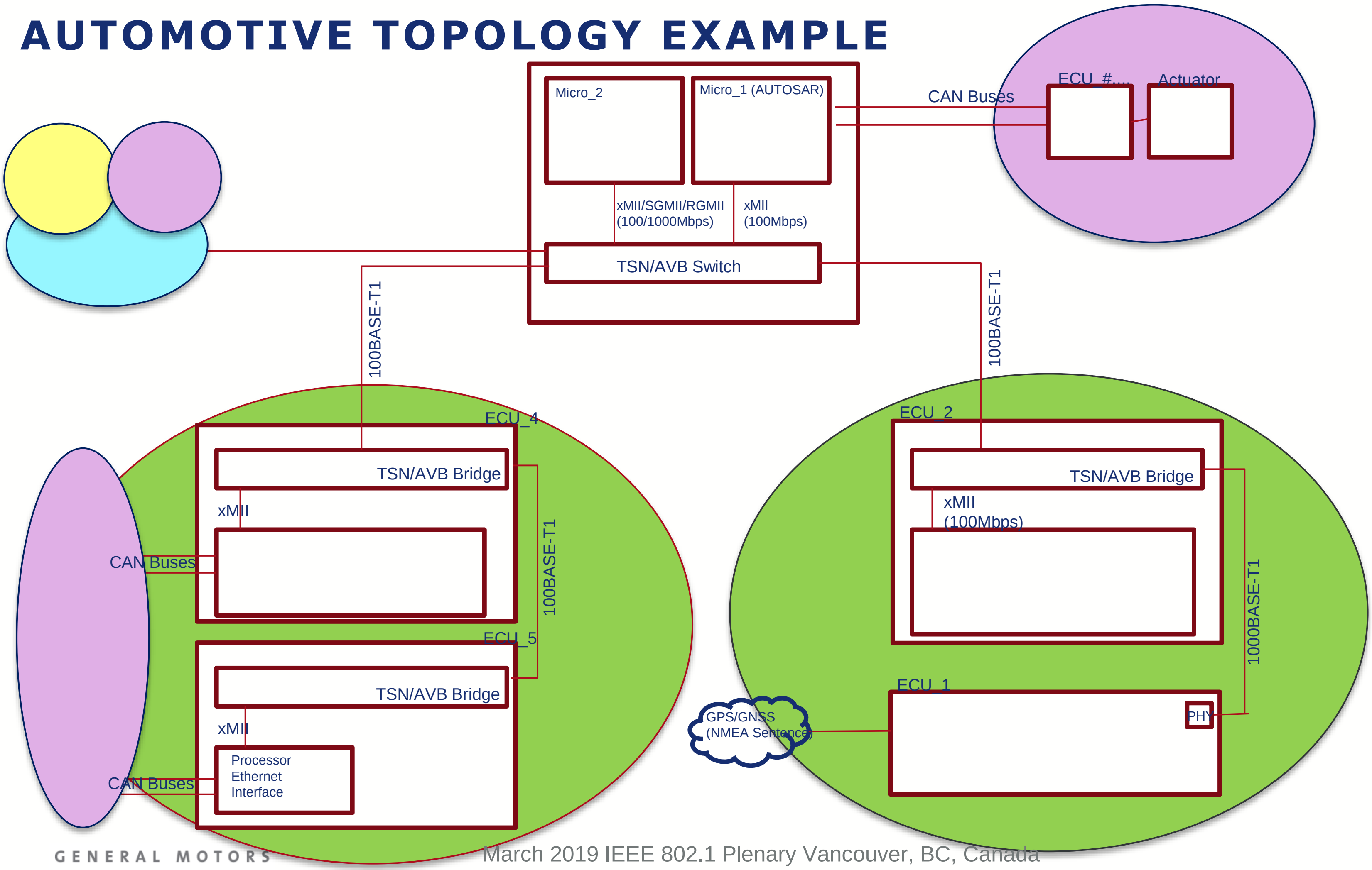
AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

Automotive Considerations and Requirements: (con't)

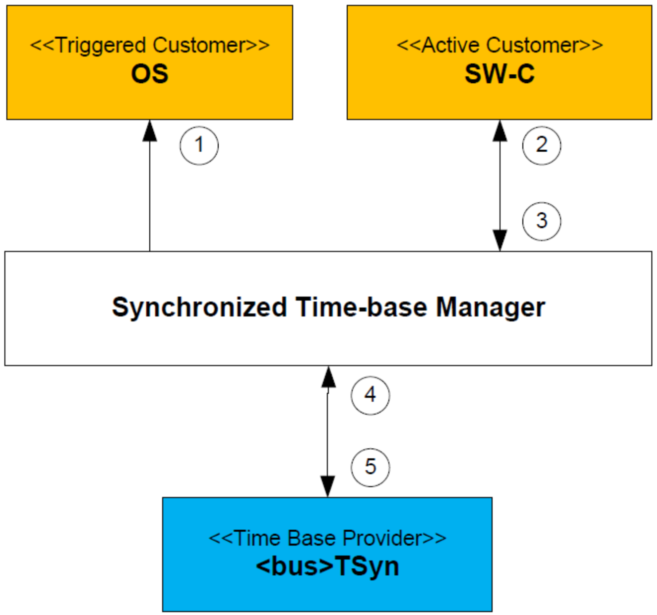
Overall System

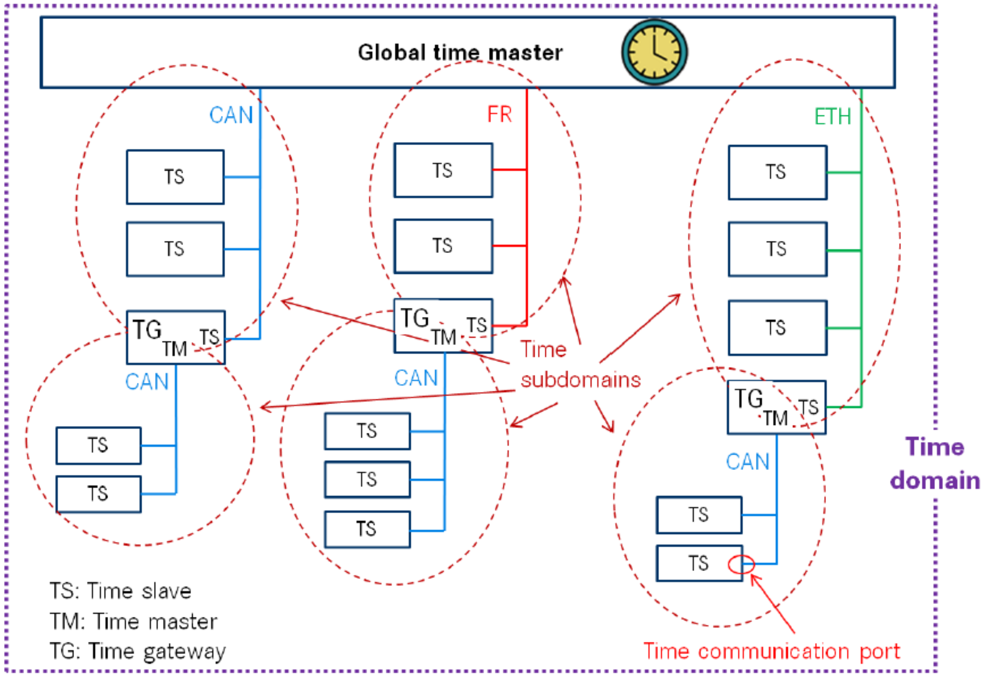
- Startup fast (<100 ms)
  - Store (default) configurations in endpoints wherever possible to eliminate additional communication and convergence times at startup (e.g.. MSRP cannot be effectively used)
  - If clock sync is needed:
    - Let it startup before real-time streams are emitted without congestion by streams
    - Multiple sync messages needed at startup for consistency
    - Fast intervals needed for startup
- Power considerations:
  - Fast re-integration after standby/sleep
- Validation/diagnostic considerations:
  - Verify sync messages were received in specified intervals
  - Verify time was adjusted by µC based on provide offset/pdelay BEFORE traffic sent
  - Adjust/Verify "timejump" drift is adjusted based on "phase-lock" loop between local clock and reference clock based on slew rate of <50ms
  - Simple defined registry entries to act as triggers to Diagnostic Trouble Codes (DTCs)
  - System_Init process to avoid triggering DTCs

AUTOMOTIVE TOPOLOGY EXAMPLE



IEEE 802.1AS SYSTEM TIME SYNCHRONIZATION W/AUTOSAR





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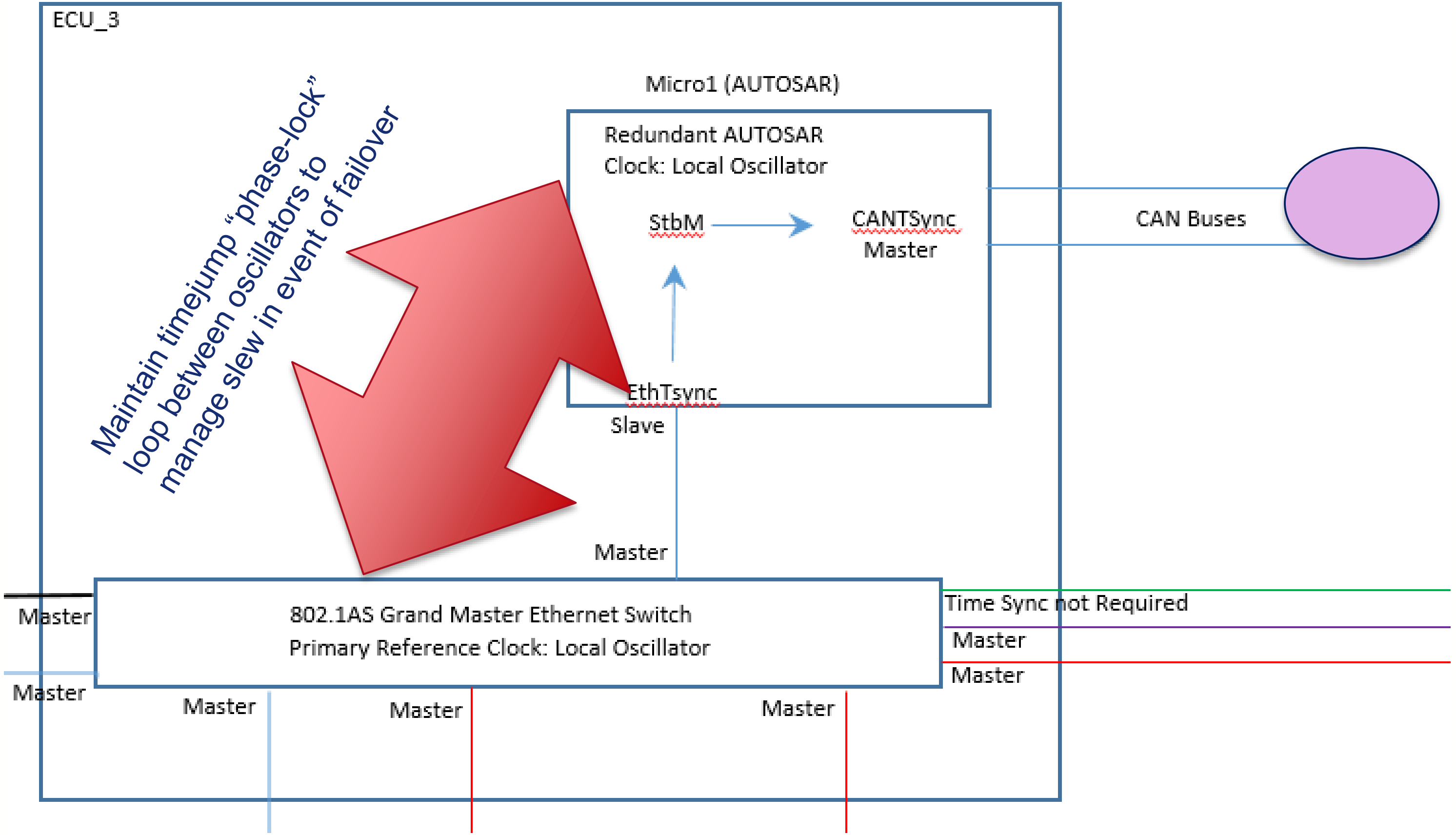
IEEE 802.1AS SYSTEM TIME SYNCHRONIZATION W/AUTOSAR



SUMMARY
AUTOMOTIVE TIME SYNCHRONIZATION– USE CASE

- Automotive constraints must be taken into consideration (e.g. safety, design and cost requirements)
- Standardization required to be supported by AUTOSAR and other OEM implementation standards
- A common SYSTEM level time synchronization is required for E2E accuracy, precision and resolution
- Implementation/configuration requirements given to integrators **HAS** to be:
    - Documentable
    - Simple to implement w/o custom coding
    - “Compartmentalized”
    - Validatible

- Is it an IEEE 802.1 “one size fits all” solution or a profile choice based on ASIL compliance (e.g. ASIL D/B/QM)

ADDITIONAL CONTRIBUTIONS ARE WELCOMED
THANK YOU