



MICROCHIP

**TIME SYNCHRONIZED COLLISION
AVOIDANCE IN MULTIDROP
NETWORKS**

**Further investigations on the usability of TSN standards 802.1AS and
802.1Qbv for collision avoidance in multidrop networks (802.3cg)**

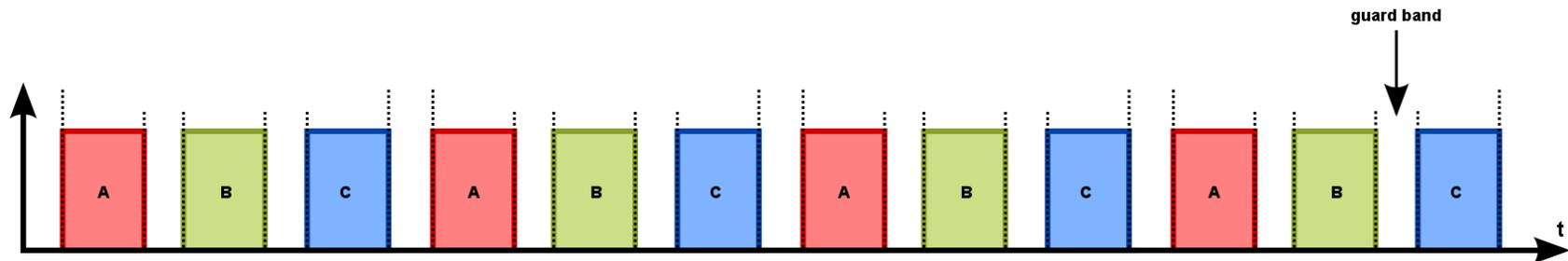
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October 2017**

INTRODUCTION

- **Further investigations on the usability of TSN standards in short-range CSMA/CD multidrop networks (802.3cg)**
- **Previous 3cg presentations about this topic**
 - “802.1 Time-sensitive Networking on 802.3cg Multidrop Networks”, Craig Gunther (Harman), Sep 2017
 - “10SPE@15m multidrop and TSN”, Kirsten Matheus (BMW), May 2017
- **Intention is to avoid collisions on a shared medium to reduce latencies and grant deterministic behavior, e.g. for streaming or QoS applications**
- **Appropriate TSN standards**
 - 802.1Qbv for scheduled traffic
 - 802.1AS for time synchronization

802.1QBV SCHEDULED TRAFFIC

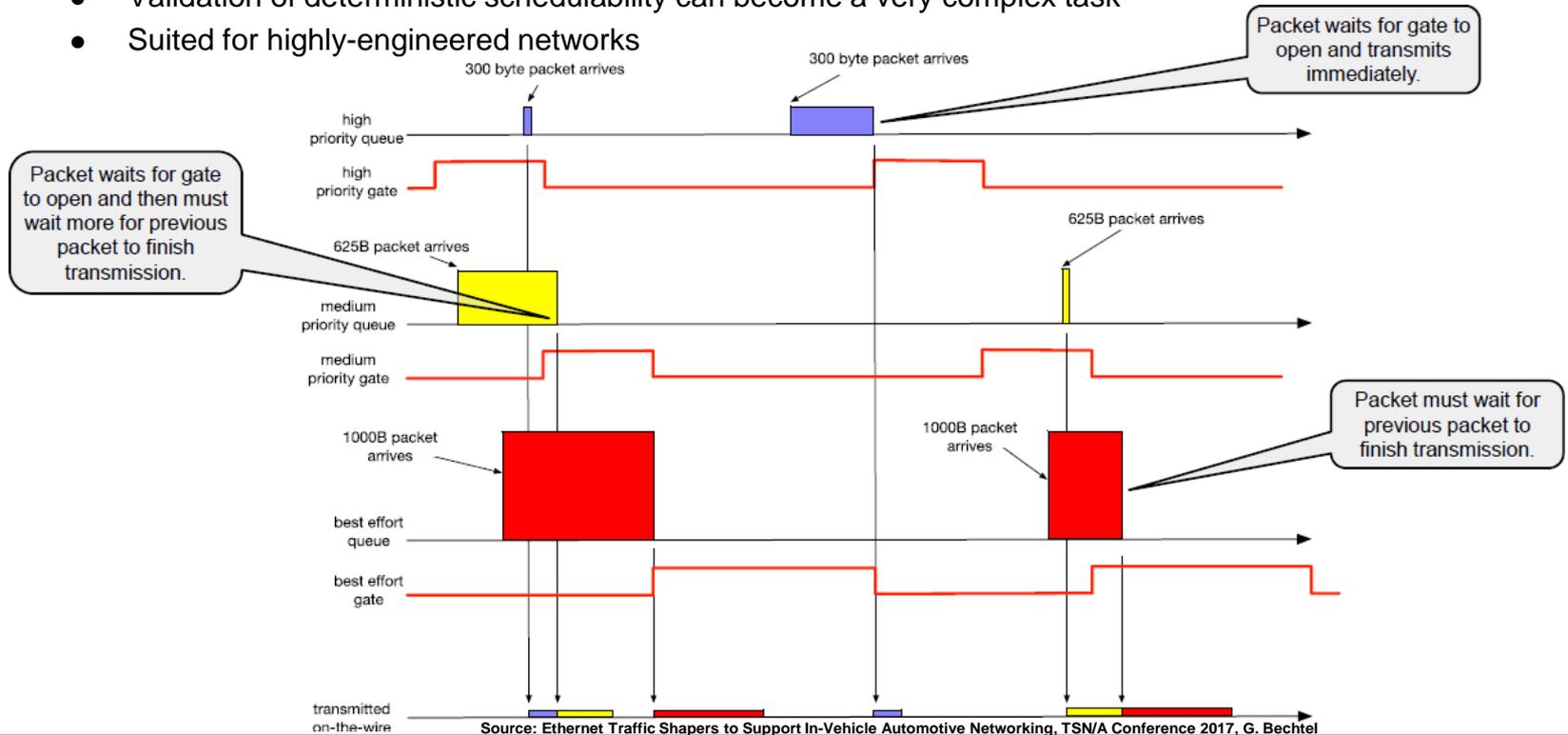
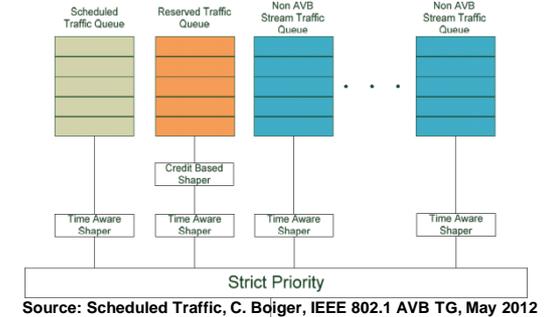
- **Arbitration on a periodically repeated time schedule**
 - Time Division Multiple Access (TDMA) or Synchronous Time Division (STD) like strategy
 - Scheduler can grant the exclusive transmission right (transmission window) to each node
 - Will work with standard PHYs, but requires MAC hardware support
 - Bandwidth of unused transmission windows will be lost
 - Sufficient to avoid collisions on a multidrop network if time is well synchronized
- **Requires time synchronization**
 - Scheduler is only available after time synchronization was established
 - If not established or lost, a multidrop network node is not allowed to transmit
 - Any collision decreases efficiency and is able to break determinism → **unwanted behavior**
 - Synchronization must be established before the first transmission (affects startup time)
 - Master node has exclusive transmit right during the startup phase (time until all nodes was initially synchronized and scheduled traffic becomes available)
- **Qbv defines the Time Aware Shaper (TAS)**



802.1QBV TIME AWARE SHAPER

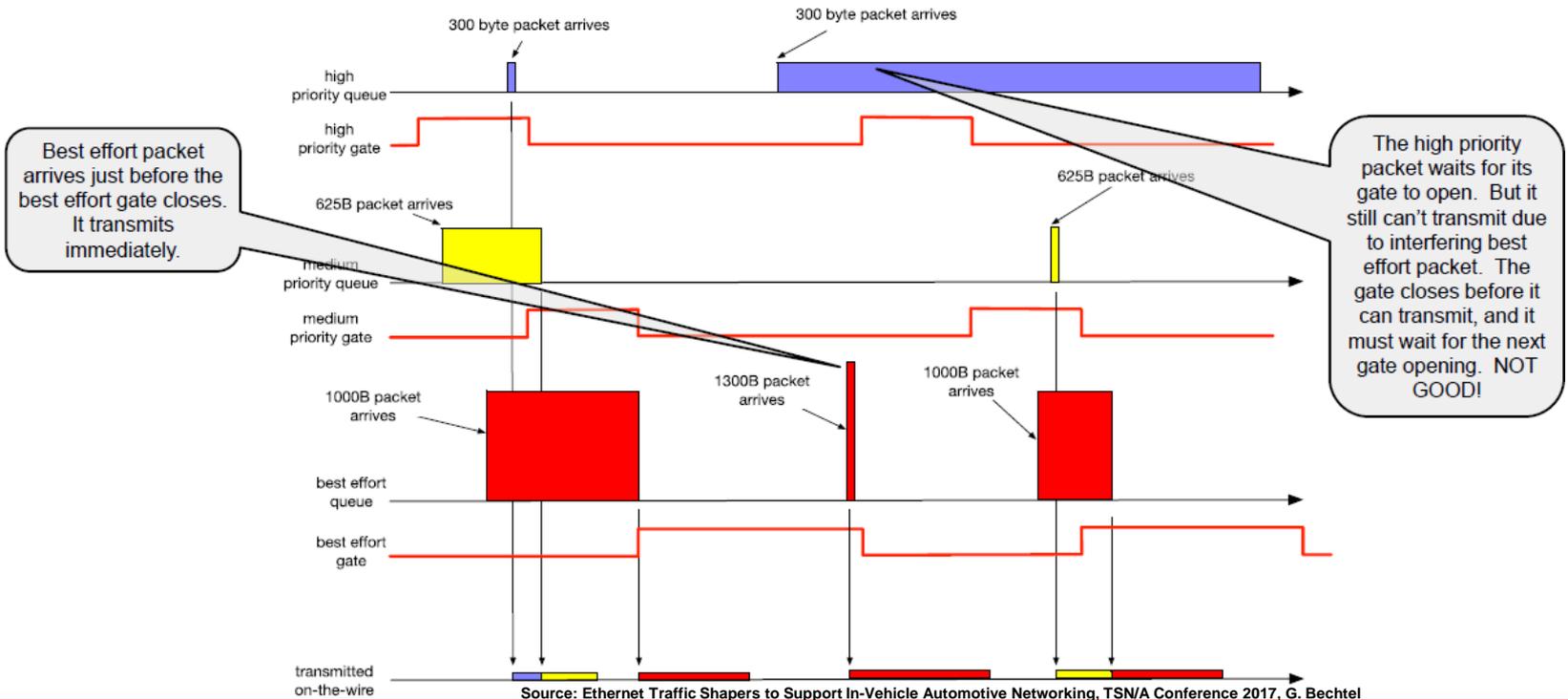
- **Time Aware Shaper (TAS)**

- Establishes a periodically repeated time schedule of transmission windows
- Each transmission window is assigned to a priority queue
- Transmission windows are of configurable width (gate control)
- Requires HW support for queues and transmission gate control in the MAC
- Best for small packets at regular periodicity
- Validation of deterministic schedulability can become a very complex task
- Suited for highly-engineered networks



802.1QBV TAS EFFICIENCY

- **TAS requires high engineering effort to be efficient**
 - “Slot Slop” issue must be avoided by engineering
 - Worst-case packet sizes must be considered
 - Add/Increase guard band/slot → reduces network efficiency
 - Avoid non-engineered traffic if possible → keep packets as small as possible
 - Customized gate scheduling strategies
 - Engineering must exactly match the network requirements
 - Frame preemption (802.3br and 802.1Qbu) may reduce guard bands



802.1AS TIME SYNCHRONIZATION

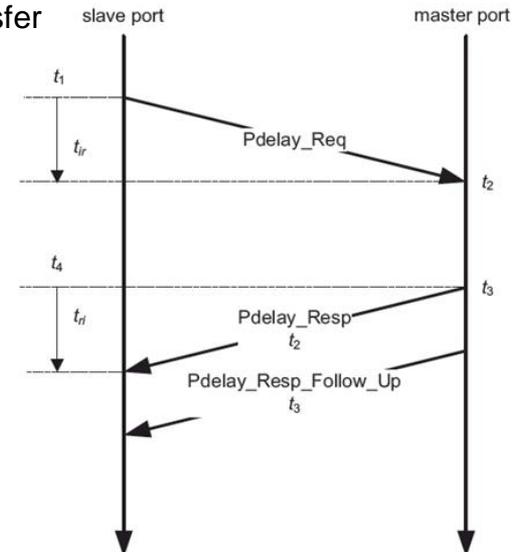
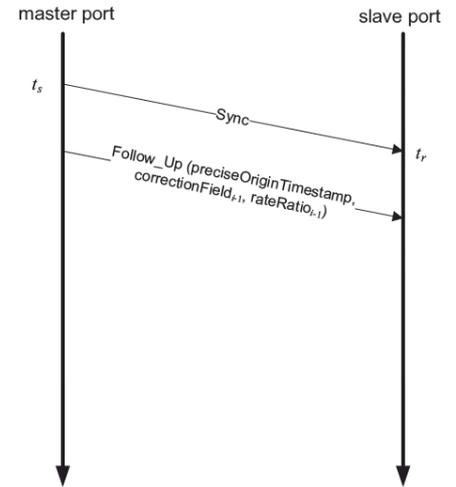
- **Key components of 802.1AS Time Synchronization**

- Sync

- Distributes the grandmaster time
- Periodically sent from master to slave
- Multidrop master needs a transmission window for sending this message, except for the startup phase
- Collisions during the startup phase will delay startup, but won't break the Sync mechanism
- Requires hardware timestamping as defined by IEEE1588
- Sync message can be broadcasted to all slaves in a single transfer

- Pdelay

- Measure link propagation delay between peers
- Periodically sent from slave to master



802.1AS PROPAGATION DELAY

- **802.1AS propagation delay measurement**

- Propagation delay may be negligible for small cable distances
- But Pdelay is also used to determine the **neighbor rate ratio** for clock syntonization in 802.1AS
- Defined for full-duplex, point-to-point links
- For multidrop networks, the Pdelay messages must be sent inside scheduled transmission windows
- But scheduled traffic is not available unless all nodes are time synchronized **and** 802.1AS requires the Pdelay to establish time synchronization (**neighbor rate ratio** is necessary)

- **Potential collisions caused by Pdelay messages**

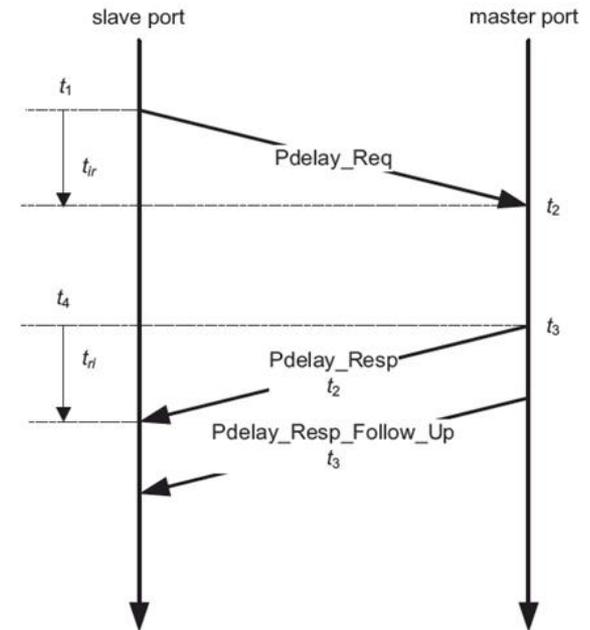
- We can tolerate collisions for the startup phase (time until all nodes was initially synchronized and scheduled traffic becomes available)
- But think of a scenario where one node goes through reset or lost sync, while all other nodes are still functional

Transmissions from unsynchronized nodes are a source of potential collisions on the network

→ Unsynchronized nodes must stay passive (listen only)

- **Proposal: Eliminate 802.1AS Pdelay mechanism**

- Replace propagation delay by constant t_{ir} and t_{ri} values, depending on PHY metrics and cable length
- **Neighbor rate ratio** must be measured in a different way



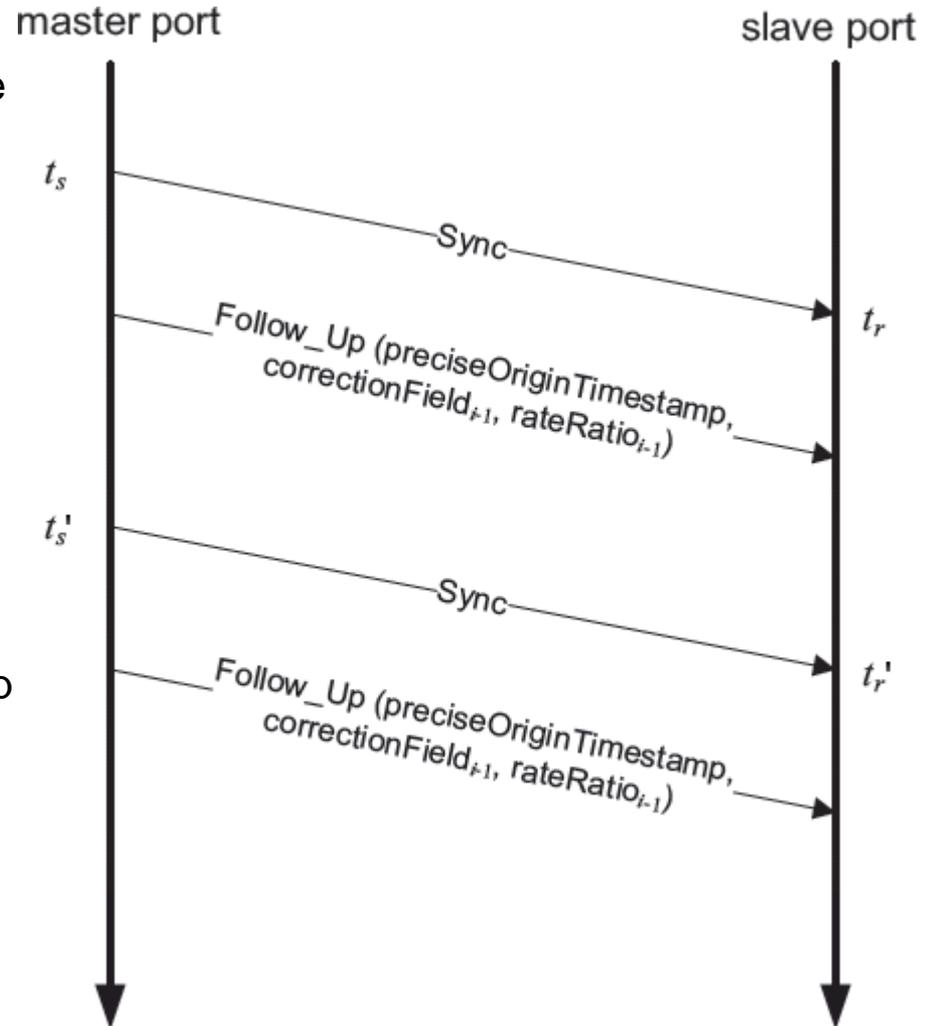
CONFLICTS WITH NO-COLLISION REQUIREMENT

802.1AS NEIGHBOR RATE RATIO

- 802.1AS Sync message can be used as an alternative approach to calculate the clock ratio between master and slave nodes

$$\text{ratio} = (t_s' - t_s) / (t_r' - t_r)$$

- Requires a constant link delay in master-to-slave-direction
- Pdelay mechanism will finally be eliminated
- Requires to adapt the 802.1AS standard for multidrop networks
- Most parameters of the Sync-FollowUp message are of no importance for a multidrop network
→ can be abolished if the Sync message already transfers the previous t_s timestamp



SUMMARY

- **802.1Qbv is suitable for TDMA-like collision avoidance**
- **TAS is very difficult to utilize (e.g. Slot Slop issue)**
- **Latency variations can be reduced (depending on the chosen window and guard band sizes), but often with negative impact on efficiency**
- **Unused transmission windows will be lost, but it may be viable to adapt the TAS gate control during runtime**
- **802.1AS standard is defined for point-to-point networks and needs customizations for multidrop network links**
 - Eliminate propagation delay measurements
 - Adapt Sync mechanism
- **Time synchronization may also be important for other applications**
- **Works with standard PHYs, unlike the PLCA approach**
- **Hardware support is necessary on MAC level**
 - RTC and hardware timestamping (IEEE1588)
 - TAS shaper extensions
 - Priority Queues

THANK YOU!