EEE Scenarios for Automotive Links

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Agenda

- EEE Mechanism Summary
  - What it is, and what it is not
- EEE Modes in 802.3 Standards
  - Modes and principles of power savings
- Automotive Use Case Scenarios for 802.3cy PHYs
  - Possible EEE enhancements and relation to PHY function
  - Key questions

EEE Mechanism – what it is & what it is not

- EEE enables the PHY to asymmetrically go into Low Power Idle Mode
    - "provides a protocol to coordinate transitions to or from a lower level of power consumption and does this without changing the link status and without dropping or corrupting frames. The transition time into and out of the lower level of power consumption is kept small enough to be transparent to upper layer protocols and applications." (IEEE Std 802.3-2018 Cl 78)
  - Transmitting MAC signals that traffic won't be coming without advance notice
    - Transmitting PHY is required to send minimal signals after transition (defined for the PHY)
  - Receiving PHY signals receiving MAC that traffic won't be coming
    - PHY may ignore transmissions until wake is signaled (defined for the PHY)
- EEE signals at the xMII indicate contract not to give or expect data without advance notice
  - EEE conceptually isn't tied to the amount of time advance notice is given, these are specified per PHY and mode
  - Mechanism for EEE isn't tied to what signaling is present on the line, but PHYs specify this
  - PHY clauses define transmitted signals on the line to aid receiver tracking and recovery (e.g., quiet/refresh), but this is phy-specific, not part of the EEE mechanism itself

EEE Parameters to Constrain

- How fast do the phys need to return to full data mode?
  - This determines how much tracking / keep-alive needs to happen
- Other than that, the less we constrain, the more freedom designers have to reduce power/complexity
  - Do we constrain when a PHY goes to sleep?
    - This can make alignment with framing and other functions simpler (see, e.g., 802.3ch)
  - Do we need to constrain how a transmitter transitions
    - Other than not transmitting WAKE or interfering with refresh/tracking operations, there is no need

EEE Modes in IEEE 802.3 Standards

- All EEE mechanisms provide for signalling to hold back transmitted data, but differ in transmitter activity & wake time
  - Deep sleep / low-power-idle
    - For BASE-T this normally goes between a quiet state and periodic transmissions to refresh equalizers and timing
  - Fast Wake
    - For optical transceivers, this keeps the transmitter alive to allow faster recovery
  - Slow Wake
    - Defined for Clause 149 PHYs, lengthens the wake-up time
- WE CAN DEFINE MORE, BASED ON WHAT WE NEED

Underlying Principles of Power Savings

- Implementation power savings increases with time between activity
  - Not just wake time for data, but also time between ANY TX or RX, including refresh
- Fitting the assumptions to the use case is important for an efficient solution
- Within the PHY, key low-power-state power usages are:
  - Circuit settling/keep-alive currents (~msec-level time constants)
  - Managing timing drift – depends on tracking loop design and pull in time
    - Traditional PHY model sets refresh based on this
  - Monitoring for alert/refresh OAM
    - Traditional PHYs do loop timing and ALERT reception with ordinary data path, NOT a requirement of EEE (we have flexibility here)

Automotive Use Case Scenarios for 802.3cy PHYs / EEE

- Bursty, intermittent traffic between switches
  - Normal EEE scenario – desire fast wake, keep buffers small
- Backup link
  - Quiet until a fast-startup is required
- Asymmetric link with low-rate control traffic
  - One direction on constantly at full rate, other has low average rate – occasional short control frames (not really continuous low-rate)

Bursty, intermittent traffic

- EEE models developed for data center / web traffic
  - See, e.g., http://www.ieee802.org/802_tutorials/07-July/IEEE-tutorial-energy-efficient-ethernet.pdf slides 8 through 11
- Automotive networks are largely machine-to-machine control networks
  - Burst characteristics of traffic on these networks are influenced by and under study in 802.1 TSN standards
- Recommendation – ask 802.1dg experts for pointers to traffic statistics to determine proper fast-wake timing

Backup link

- Link primarily serves to provide redundancy for functional safety
  - Generally not used in packet forwarding until other link fails
- Link can remain off, but activated on ‘hot standby’
  - Essentially this is a ‘fast-startup’
  - Perhaps aided by pre-configuration
- Need to consider how the switchover is implemented at higher layers in order to consider wake time

Asymmetric link with low-rate control traffic

- One direction on constantly at full rate, other has low average rate
  - Can be scheduled, low-rate may be queued and managed by 802.1
  - Occasional short control frames (not really continuous low-rate) / Reverse asymmetry mode for updates (could be full rate)
  - Time sensitivity isn’t symmetric either
- Different than normal EEE PHY assumptions at all layers
  - One active direction may be used to keep timing
- Recommendation – define a new EEE mode with longer than ‘slow-wake’
- Key questions:
  - How time-sensitive is the low-utilization direction (msec, or microsec?)
  - How much data can be buffered and bursted in the low-utilization direction
  - Does the high-rate stream use 100% of the rate, or can it be interrupted (and queued)?

Recommendations

- Inquire to 802.1dg for fast-wake timing (can we JUST do slow-wake?)
- Consider additional EEE mode for Asymmetric link
  - Nature of traffic is different
  - How much scheduling can be done?
- Consider needs of the backup link
  - Is this a EEE application, or a fast-startup application
- Specify as little as necessary
  - Allow transmitter/receiver designers flexibility to save & invent