Advanced Sleep and Wakeup concept for Automotive Ethernet

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Outline

- Introduction
- Sleep/Wakeup objectives
- Partial Networking concepts
- Transition Sleep and Wakeup process
- PHY Power Moding
- Encoding LPS and WUR
- Conclusion
- NXP progress with TJA1100
Glossary

- **SSD**: Start Stream Delimiter
- **ESD**: End Stream Delimiter / Electrostatic Discharge
- **LPS**: Low Power Sleep
- **NM**: Network Management
- **WUP**: Wakeup Pattern
- **WUR**: Wakeup Request (encoded in Idle stream)
- **RTPGE**: Reduced Twisted Pair Gigabit Ethernet
Introduction

Automotive Ethernet success factors

- System costs competitive against peer technologies (MOST, LVDS)
- EMC and ESD
- Interoperable PHYs available
- Converged network traffic (TSN standardization in IEEE)
- System scalability (bandwidth, number of network nodes)
- Software stacks automotive qualified (functional safety)
- and ... Sleep/Wakeup concept (partial networking, energy efficiency)

Every saved mA means less fuel consumption and longer reach for e-vehicles.
Objectives

Sleep/Wakeup concept

- Enables partial networking
- Node/cluster wakeup within less than 250ms
- Sleep current consumption per port less than 10μA
- No unwanted wakeup in presence of interference noise
- No change to MAC layer
- Allows integration in Autosar network management
- Concept extendable to Gigabit Ethernet
- No additional hardware needed
- Open standard
Partial Networking concepts

1. Selective wakeup

1. System in Sleep
Partial Networking concepts

1. Selective wakeup

1. System in Sleep
2. Wakeup and Link-Up
Partial Networking concepts

1. Selective wakeup

1. System in Sleep
2. Wakeup and Link-Up
Partial Networking concepts

1. Selective wakeup

1. System in Sleep
2. Wakeup and Link-Up
Partial Networking concepts

1. Selective wakeup

1. System in Sleep
2. Wakeup and Link-Up

Diagram:

- PHY
- Switch
- uC

Link up

Wakeup
Partial Networking concepts

2. Global wakeup with activation line

1. System in Sleep
Partial Networking concepts

2. Global wakeup with activation line

1. System in Sleep
2. Activate wakeup line

Wakeup
Partial Networking concepts

2. Global wakeup with activation line

1. System in Sleep
2. Activate wakeup line
3. Global WU and link startup

- Switch
  - PHY
  - PHY
  - PHY

- uC

Funct. Cluster A
Funct. Cluster B
Funct. Cluster C
Partial Networking concepts

2. Global wakeup with activation line

1. System in Sleep
2. Activate wakeup line
3. Global WU and link startup
4. Selective Sleep Cluster B,C

Switch

PHY

Switch

PHY

Switch

PHY

Funct. Cluster A

Funct. Cluster B

Funct. Cluster C
Partial Networking concepts

3. Global wakeup via Ethernet line

1. Funct. Cluster B awake
Partial Networking concepts

3. Global wakeup via Ethernet line

1. Funct. Cluster B awake
2. Link wakeup
Partial Networking concepts

3. Global wakeup via Ethernet line

1. Funct. Cluster B awake
2. Link wakeup
3. Distribute wakeup signal

- WUR encoded in Idle
- WUP encoded in Idle
Partial Networking concepts

3. Global wakeup via Ethernet line

1. Funct. Cluster B awake
2. Link wakeup
3. Distribute wakeup signal
4. Global WU and link startup
Partial Networking concepts

3. Global wakeup via Ethernet line

1. Funct. Cluster B awake
2. Link wakeup
3. Distribute wakeup signal
4. Global WU and link startup
5. Selective Sleep Cluster C
Wakeup Process

Wakeup phase introduced, sending WUP!
Sleep Transition

Handshake mechanism between link partners!
PHY Power Moding

- **NORMAL**
  - cmd_NORMAL
  - cmd_STANDBY

- **SLEEP REQUEST**
  - cmd_SLEEPPREREQUEST
  - cmd_NORMAL
  - cmd_SLEEP

- **STANDBY**
  - cmd_NORMAL
  - cmd_STANDBY
  - Wakeup detected

- **SLEEP**
  - cmd_SLEEP
  - timeout
  - WUP detection active

Sending LPS codes
LPS Encoding

- Reserved code-groups defined in BroadR-Reach spec:
  - SSD: (0,0), (0,0), (0,0)
  - ESD: (0,0), (0,0), (1,1)
  - ERR_ESD: (0,0), (0,0), (-1,-1)

LPS code-group: (0,0), (0,0), (1,-1), (1,-1)

IDLE | SSD | FRAME | ESD | IDLE
--- | --- | --- | --- | ---
IDLE | LPS | IDLE | LPS | IDLE | ...
WUR Encoding

- \( S_d[n][2] = S_c[n][2] \oplus tx\_data[n][2] \)
  \[ \begin{align*}
  &= S_c[n][2] \oplus 1 & \text{if } (tx\_enable[n-3] = 1) \\
  &= S_c[n][2] & \text{else if } (loc\_rcvr\_status=OK) \\
  &= S_c[n][2] & \text{else} \\
  \end{align*} \]

- \( S_d[n][1] = S_c[n][1] \oplus tx\_data[n][1] \)
  \[ \begin{align*}
  &= S_c[n][1] \oplus 1 & \text{if } (tx\_enable[n-3] = 1) \\
  &= S_c[n][1] & \text{else if } (WUR=TRUE) \\
  &= S_c[n][1] & \text{else} \\
  \end{align*} \]

- \( S_d[n][0] = S_c[n][0] \oplus tx\_data[n][0] \)
  \[ \begin{align*}
  &= S_c[n][0] & \text{if } (tx\_enable[n-3] = 1) \\
  &= S_c[n][0] & \text{else} \\
  \end{align*} \]

The WUR signal can be encoded in the Idle stream in the same way as the \( loc\_rcvr\_status \).
Conclusion

- Global wakeup via Ethernet line is the preferred solution to enable partial networking
- Main advantages are
  - Cluster wakeup within less than 250ms
  - No additional hardware needed
  - Concept is extendable to Gigabit Ethernet
- Sleep/Wakeup concept can be seen as extension to BroadR-Reach spec
- Alignment on WUP needed
- NXP will publish Sleep/Wakeup concept spec and drive standardization process in OPEN alliance
NXP Progress with TJA1100

Status in 2012
- Product Concept Sheet available
- Specification frozen
- Transmitter Test chip available

Status today, 2013
- Engineering Samples working
  - NXP-NXP link stable
  - NXP-Broadcom link working
  - First EMC results promising
  - Sleep/Wakeup implemented
- Data Sheet, Application Hints available
- Evaluation and further optimization ongoing
You are all invited to come to our booth
to convince yourself of the interoperability
between the TJA1100 and the Broadcom PHY.

Thank you!
Backup Slides
Sleep Transition

No confirmation from link partner within a certain time.