IEEE 802.3da SPMD TF: 10BASE-T1S multidrop Low-Power Wake Proposal

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Previously on "Multidrop Energy Saving"

- **July 2023 – Berlin**
  - Introduced the low-power wakeup mechanism specified by OPEN Alliance for 10BASE-T1S
  - Provided initial baseline text based on the
  - Intention was to use it to emulate EEE for Multidrop

A new direction…

- **Initial thought was OPEN Alliance Wake/Sleep specification could be used to plug into Clause 78 EEE, but there are issues…**
  - EEE can bring the link back up FAST
  - Waking a full mixing segment from a low-power state is much slower
    - Must wait for other devices to stop transmitting, or
    - Wait for PLCA Transmit Opportunity
    - Unique to multidrop; Point-to-point topology has it easier

- **Rather than plug into EEE, let's instead define it as a new power management client and mechanism for mixing segment low-power wake-up**

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Summary

- **The system may not need all nodes on the mixing segment to be always active**
- **OPEN Alliance goal was that devices not needed are put in a minimal power state**
- **OPEN Alliance solution:**
  - Application layer determines when devices go to low-power state
    - Generation of wake/sleep requests is out of scope
  - Specify a global wake mechanism to exit low-power state
    - All nodes on the mixing segment wake up
    - No selective wake; wake isn't addressable
    - Nodes in low-power state must not be falsely awakened by normal DME traffic from active nodes
    - Use of out-of-band signaling implemented with only passive analog circuits
      - VERY low power – Target <120 μW

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Wake-Up Tone (WUT)

- **Partial Networking on a Mixing-Segment (Beruto, 20/1/2020)**
  - There's a sweet spot in the frequency range between 500 KHz and 1 MHz where a signal could be distinguished (by analog means) from the DME (Differential Manchester Encoding) which is used for normal 10BASE T1S data.
    - This could be used for the wakeup signal!

- **WUT defined as 12 periods (19.2us) of 625 kHz tone**
  - Decade lower than lowest DME fundamental (all zeros, 6.25MHz)
  - Detectable by simple low-power analog circuitry

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Interoperability with Active Nodes

- **Transmitting the WUT shall NOT disrupt traffic of active nodes**

- **The WUT <u>must</u> be compatible with PLCA and CSMA/CD**
  - PLCA: Send the wake-up signal during node's TO

- **But – the 625kHz WUT will <u>not</u> assert a carrier sense**
  - WUT would collide with active nodes

- **We must create a period of silence on the mixing segment in which to transmit the WUT so it is always detectable by nodes in the low-power state**
  - Without causing collisions in PLCA
  - Allowing only <u>initial</u> collisions in CSMA/CD

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SUSPEND coding

- **Six DME encoded 'T' symbols are sent by the PHY prior to WUT**
  - Will be detected as carrier
    - Makes both PLCA and CSMA/CD nodes enter a receive state
  - Special symbol encoding to suspend the PLCA state machine, holds present TO despite carrier sense going low during WUT

- **PCS detects receives 'TT' as a SUSPEND receive command**
  - Similar to BEACON (NN), COMMIT (JJ), and start of frame (JJHH)

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SUSPEND coding and PLCA

- **PLCA RS receives SUSPEND and "pauses" the TO Timer**
  - Control state diagram will enter the RESYNC state - will not transmit
  - Data state diagram will accept transmit data from the MAC placing it in the PLCA delay line
    - If filled, will generate a normal PLCA logical collision to the MAC

- **PLCA will remain paused until expiration of a "resume timer" when it will continue with the TO where it left off**
  - Wake-up sequence will not cause excess delay to high TO devices

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SUSPEND coding and CSMA/CD

- **The SUSPEND signaling on the wire will assert carrier sense causing CSMA/CD MAC to defer**

- **There is a small window in which a device may collide with the SUSPEND**

  - WUT is specified sufficiently long enough for the device to collide and JAM, with enough remaining WUT being transmitted "in the clear" to still be detected by all low-power devices

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SUSPEND coding

- **Why the 'T' symbol?**
  - Maximize auto-correlation properties for detection
  - Minimize cross-correlation with existing coding (BEACON, COMMIT, and start-of-frame 'JJHH')
  - Currently used as the End-of-Stream Delimiter (ESD) but can be reused

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Closing out the WUT

- **After the WUT is sent, a period of COMMIT 'J' symbols are sent**
- **Clause 147 PCS always ends COMMIT followed by ESD/ESDOK**

- **This sequence asserts carrier sense on all nodes again and resynchronizes PLCA**

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WUP – Wake-Up Pulse

- **Therefore, the full 32.4 μs Wake-Up Pulse (WUP) sent consists of the following:**
  - SUSPEND - 6 DME encoded 'T' symbols
  - 12 periods of 625 kHz Wake-Up Tone (WUT)
  - COMMIT - 25 DME encoded 'J' symbols
  - DME encoded ESD, ESDOK
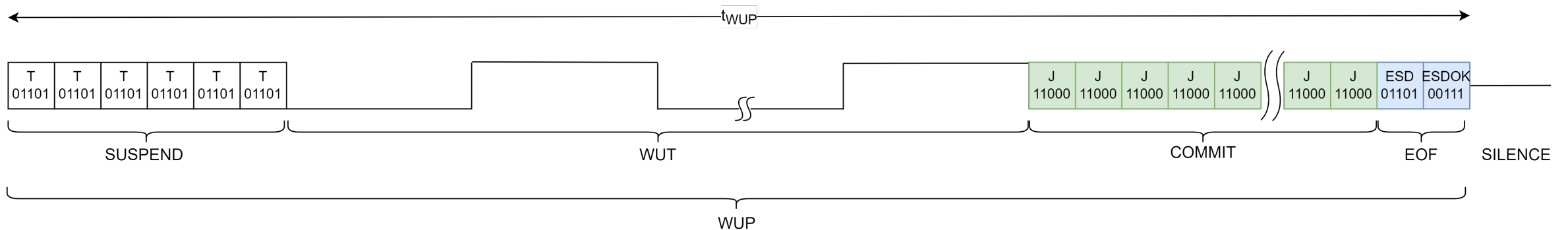
New PMA WUT request/indication

- **PMA_WUT.request**
  - When asserted, causes the PMA to transmit 625kHz WUT

- **PMA_WUT.indication**
  - Asserted when the PMA detects a WUT causing implementation to exit low-power state
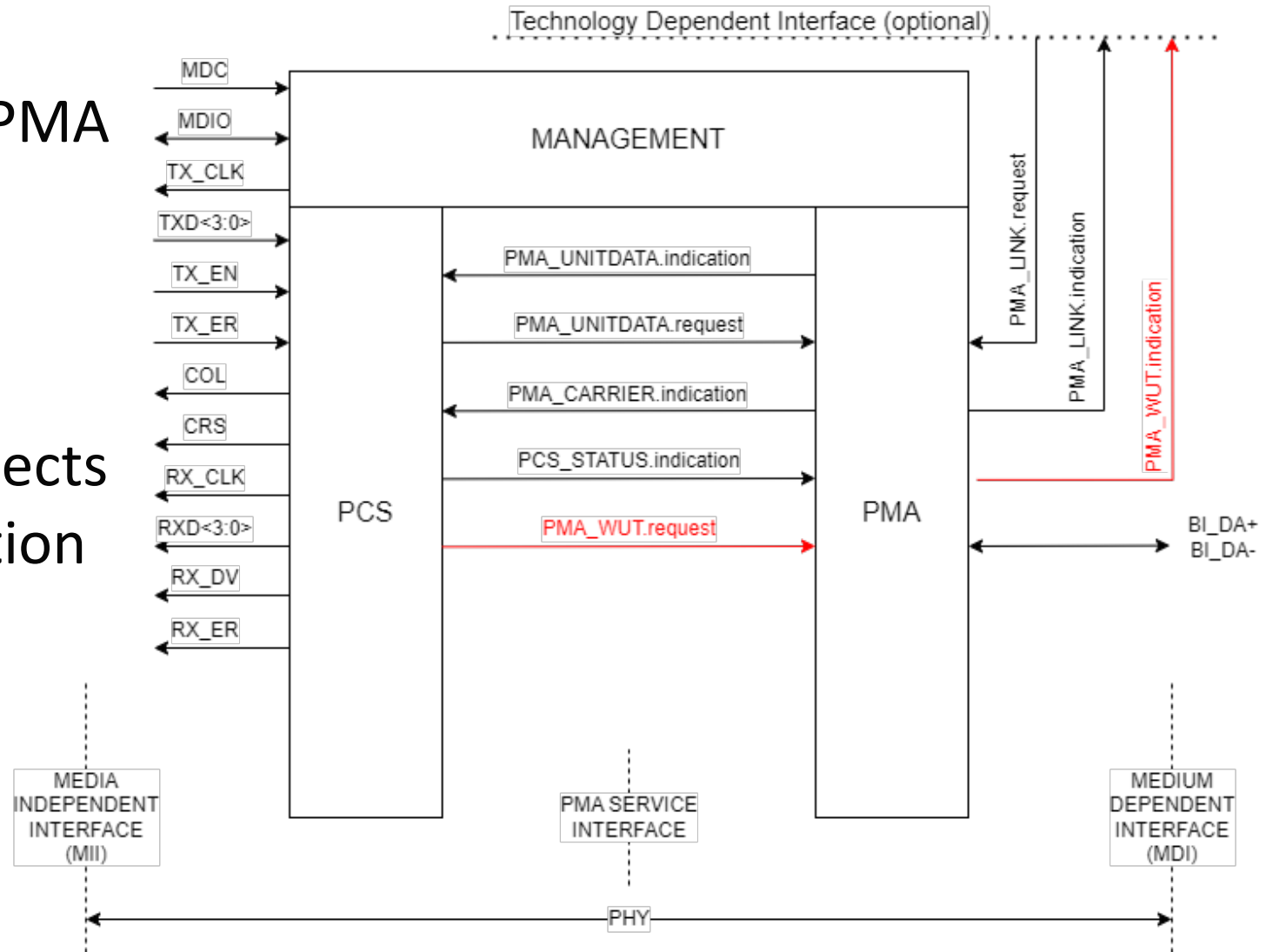
PMA Architectural Changes

- **Clause 147 PMA changes to support WUT transmission request and detection indication**

  - The WUT DETECT block always powered in the low-power state
  - The PMA TRANSMIT block definition is updated for 625kHz tone transmit capability
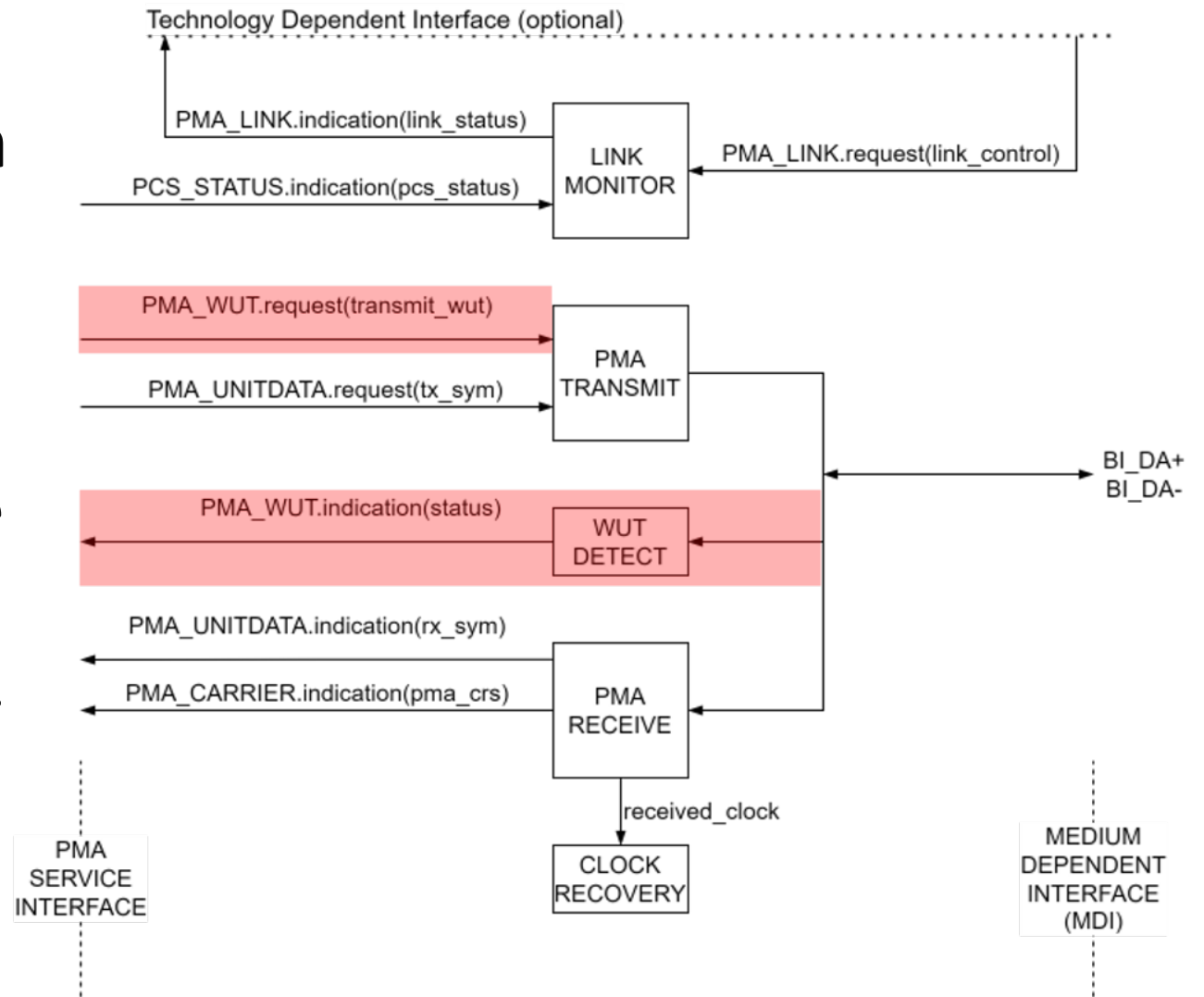
New Power Management Client

- **Enables power savings during periods when one or more nodes on the mixing segment are not required to be active.**
- **Communication of PM Client to upper application layers is implementation specific**
  - Defined as generic request/indication signals
  - However, a few Clause 30 PM Actions/Attributes are proposed
- **PM Client communicates to the PHY through the PLCA RS in Clause 148**
- **"Low-Power" definition is *implementation dependent***

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Optional Power Management Client
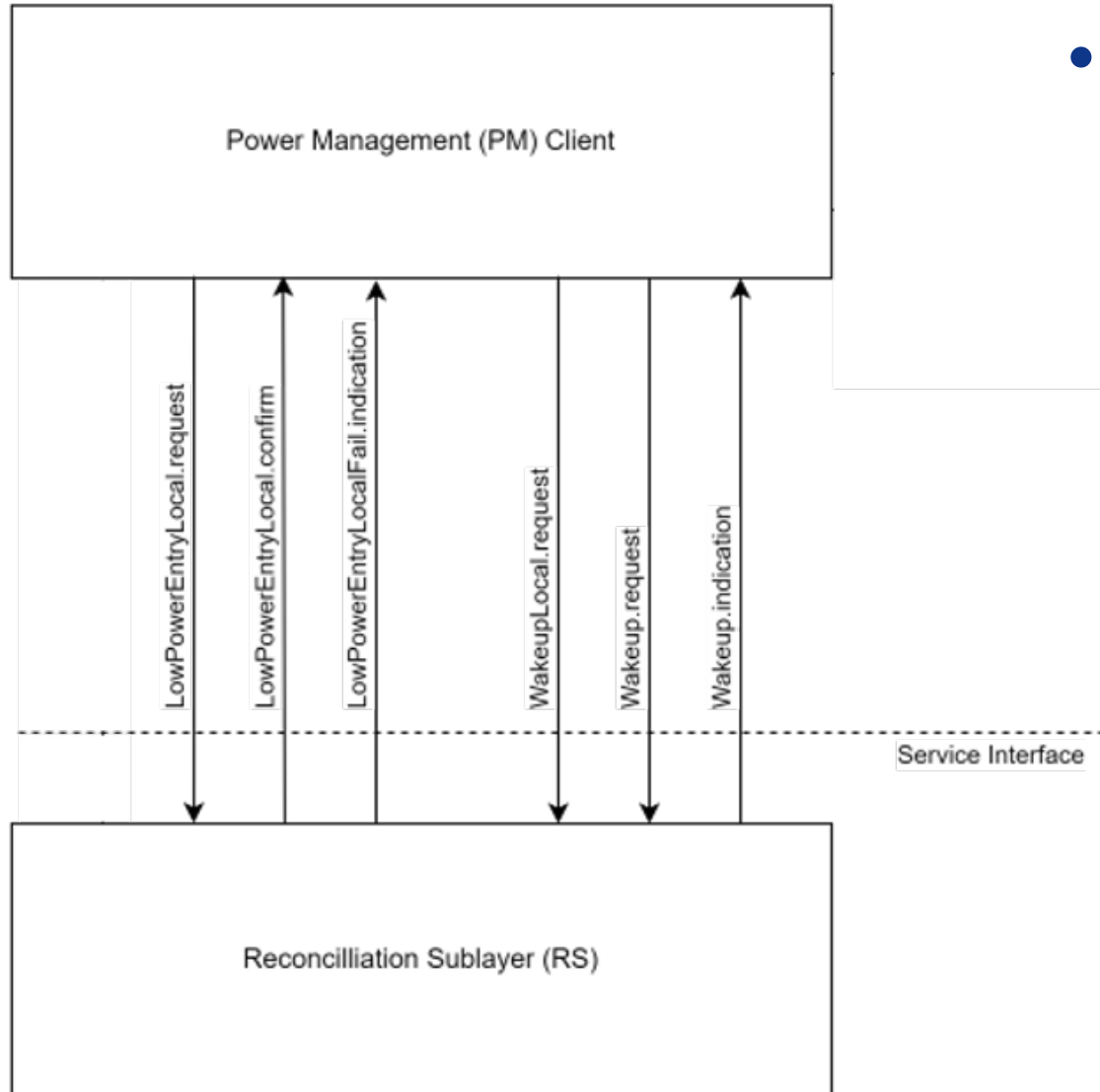
- ## **Primatives**
  - LowPowerEntryLocal.request
    - Request the local PHY to enter low-power state
  - LowPowerEntryLocal.confirm
    - Acknowledge when the local PHY has entered requested low-power state
  - LowPowerEntryLocalFail.indication
    - Indicate an unsuccessful attempt to put the local PHY into requested low-power state
  - WakeupLocal.request
    - Transition the local PHY from a low power state
  - Wakeup.request
    - Request WUP to be transmitted to all nodes on the mixing segment; sets PLCA wur←TRUE
  - Wakeup.indication
    - Indicates a detected wake-up event on the mixing segment

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Clause 22 changes

- **The following changes are needed to allow Power Management control between the PLCA RS and the PHY**

 - MII Transmit Data – Request PHY Transmit Wake-Up

TX_EN	TX_ER	TXD<3:0>	Indication
...			
0	1	0100	WakeUp Request (WUR)
0	1	~~0100~~ 0101 through 1111	Reserved
...			

  - MII Receive Data – Received SUSPEND from PHY

 | RX_DV | RX_ER | RXD<3:0> | Indication |
    |---|---|---|---|
    | ... | | | |
    | **0** | 1 | 0100 | SUSPEND indication |
    | **0** | 1 | ~~0100~~ 0101 through 1111 | Reserved |
    | ... | | | |

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Causing a Wakeup on the network - 1

- **When the PM Client needs to send a wake-up to the segment:**

  - Asserts Wakeup.Request to the PLCA RS setting the PLCA wur=TRUE

 - PLCA RS then sends a WUP Request (WUPRQ) to PHY via new MII encoding

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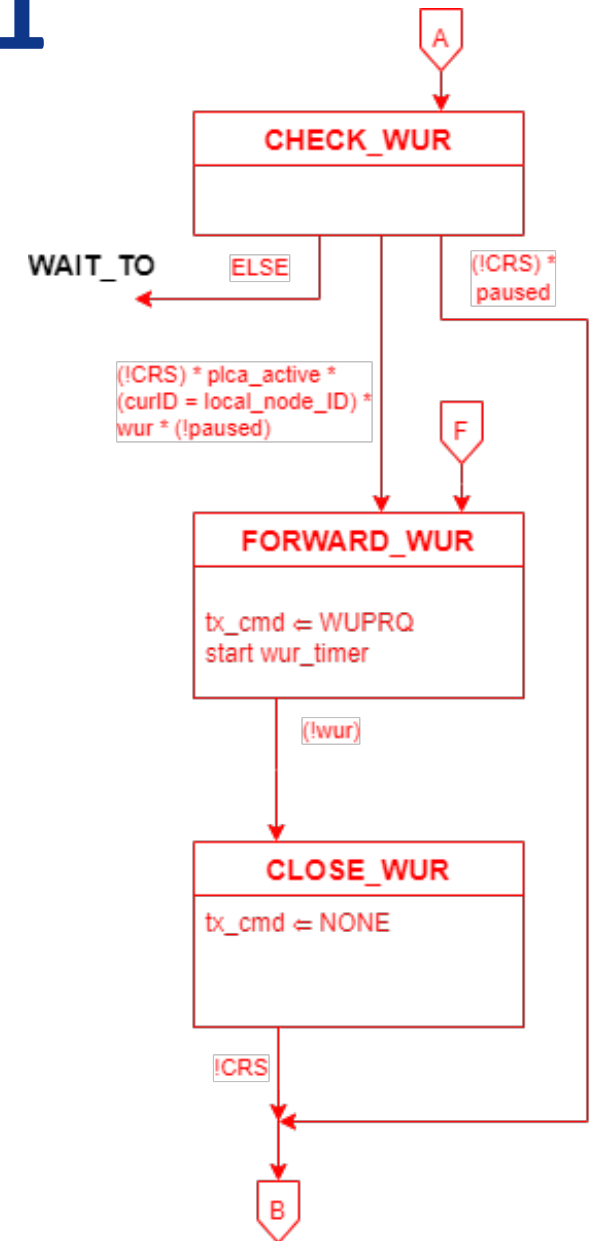
Causing a Wakeup on the network - 2

- **When the PHY receives tx_cmd=WUPRQ from MII, PCS transmits:**
  - SUSPEND symbols

  - Sets wut_transmit←TRUE asserting PMA_WUT.request to PMA
    - Causes PMA to transmit 625kHz tone

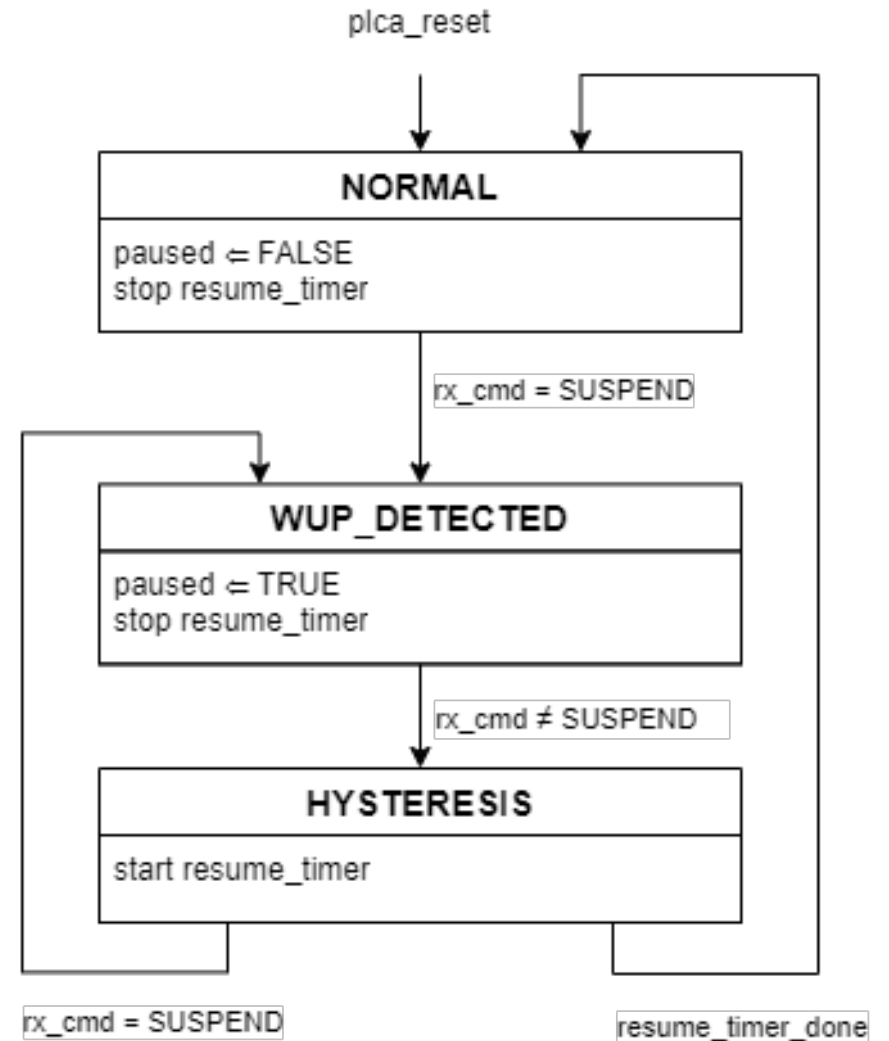 - Transmits COMMIT symbols until tx_cmd!=WUPRQ
    - Finalizes with ESD/ESDOK
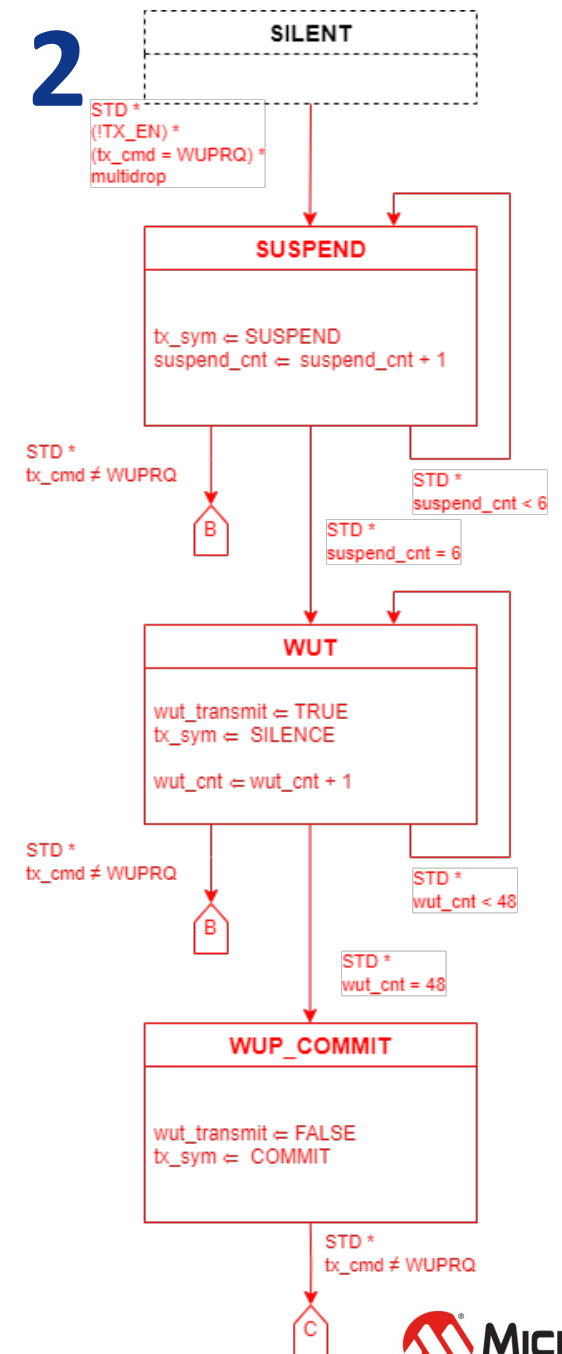
Receiving a SUSPEND from the network - 1

- **When the PCS receives two SUSPEND symbols, it drives a SUSPEND indication on MII to the PLCA RS**
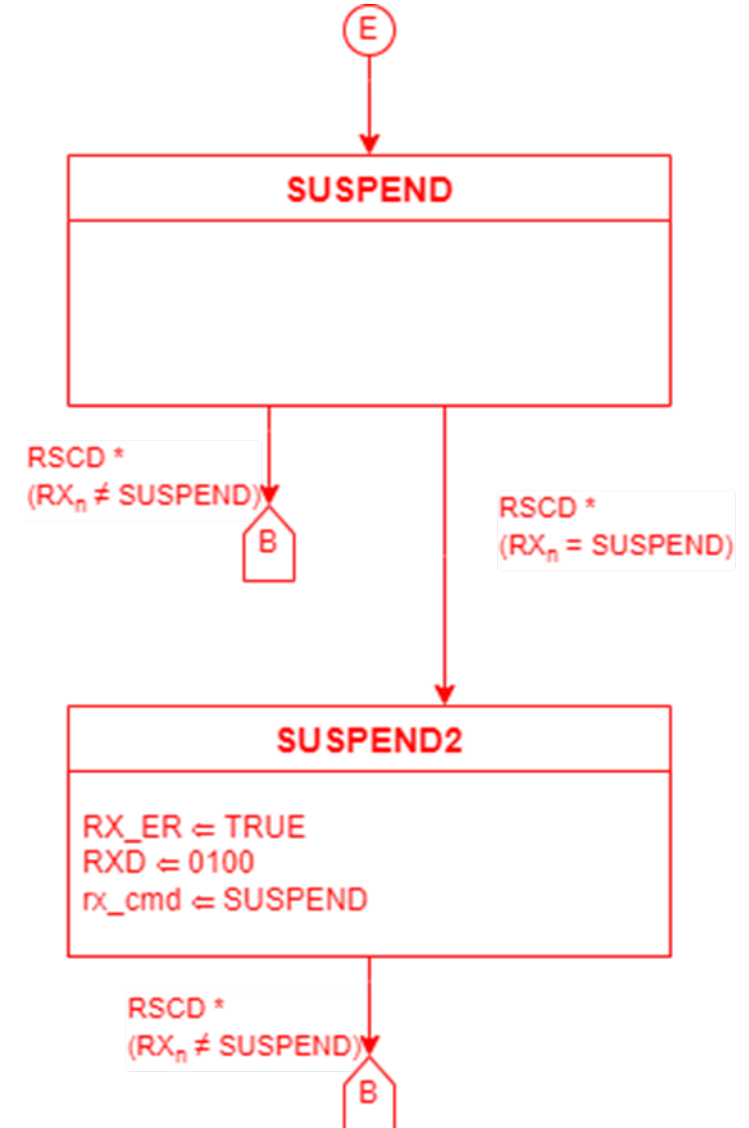
Receiving a SUSPEND from the network - 2

- **PLCA receives rx_cmd=SUSPEND**

- **Sets PLCA paused←TRUE**

- **PLCA remains paused for duration of WUP (resume_timer)**

plca_reset

NORMAL

paused ⇐ FALSE
stop resume_timer

rx_cmd = SUSPEND

WUP_DETECTED

paused ⇐ TRUE
stop resume_timer

rx_cmd ≠ SUSPEND

HYSTERESIS

start resume_timer

rx_cmd = SUSPEND

resume_timer_done

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Receiving a SUSPEND from the network - 3

- **With PLCA paused=TRUE, control state diagram transitions into RESYNC and stays until !paused**
- **When !paused, return to normal PLCA operation through SEND_BEACON or EARLY_RECEIVE**

Thank You!

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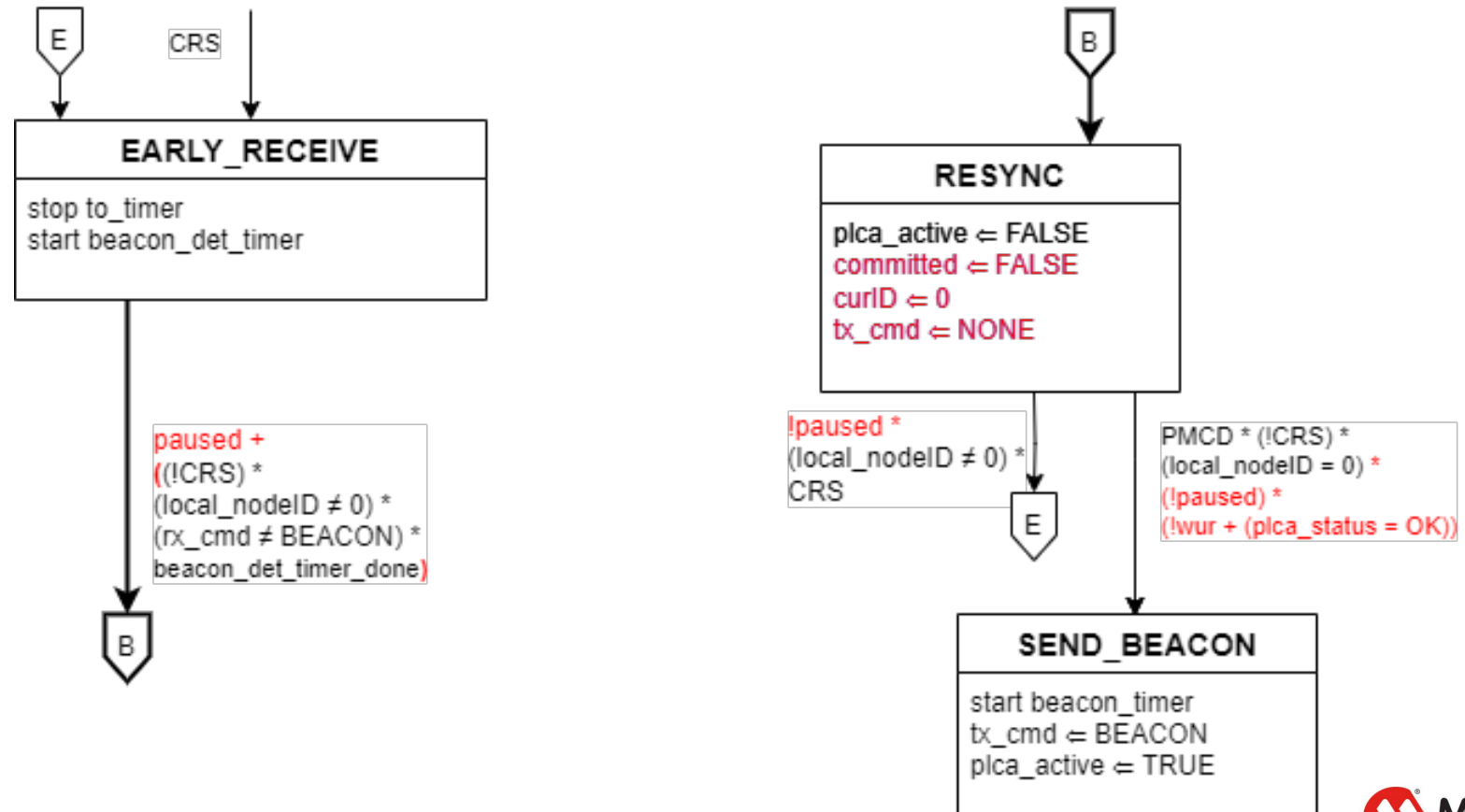
References

- **10BASE-T1S multidrop EEE proposal**

    10BASE-T1S multidrop EEE proposal (Baggett, 12/6/2023)

- **IEEE P802.3da Objectives**

    7. Specify improvements for Energy Efficient Ethernet compared to current 10Mb/s multidrop single balanced pair networks

    Partial Networking on a Mixing-Segment (Beruto, 20/1/2020)

    Thoughts on Energy Efficient Multidrop Systems (Zimmerman, 30/6/2021)

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