Enhanced PLCA (EPLCA) – Technical Feasibility Study For Predictable Max Latency

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Feasibility Study Options

- Option-1: Limit Max-Packet size to 256-bytes and no bursting
- Option-2: High-Priority and Normal-Priority traffic types
- Option-3: High-Priority and Normal-Priority Nodes/Node-Counts

Option-1 – Limit Max Packet size to 256-bytes & No Burst

- Application Layer Restriction: Limit Max packet size to 256-bytes and no burst
  - Most Nodes currently send small packets
  - Note: Bursting does not improve bandwidth utilization (because header overhead); only helps the bursting Node to get more bandwidth over the other non-bursting Nodes
    - PLCA by design allows a Node to have more bandwidth if other Nodes are not using the bandwidth, hence bursting is not good for fairness
    - Large packet size is good for bandwidth utilization only when single Node is doing most of the traffic.
- No changes to the existing PLCA and DPLCA; avoids new protocol/device development
- Predictable Reduced Latency & Jitter; latency depends on the number of Nodes*
  - Maximum Latency = 8-Nodes * 256-Bytes * 8-bits * 100 ~= 1.64ms [2.46ms with 12 Nodes]
  - Latency Jitter: Just one Node active (vs) all 8 Nodes active ~= 0.21ms (vs) 1.64ms [0.32ms (vs) 2.46ms with 12 Nods]
- Clean solution, in line with CAN/LIN protocol based earlier automotive applications; which do only small packet transfers
- DPLCA: For predictable latency, at least send one commit per age cycle; not to lose it's TO
- Variation: Breaking a larger packet into smaller sub-burst packets in PLCA layer and reassembling back in PLCA layer for better utilization - Current MAC MII interfaces does not allow this

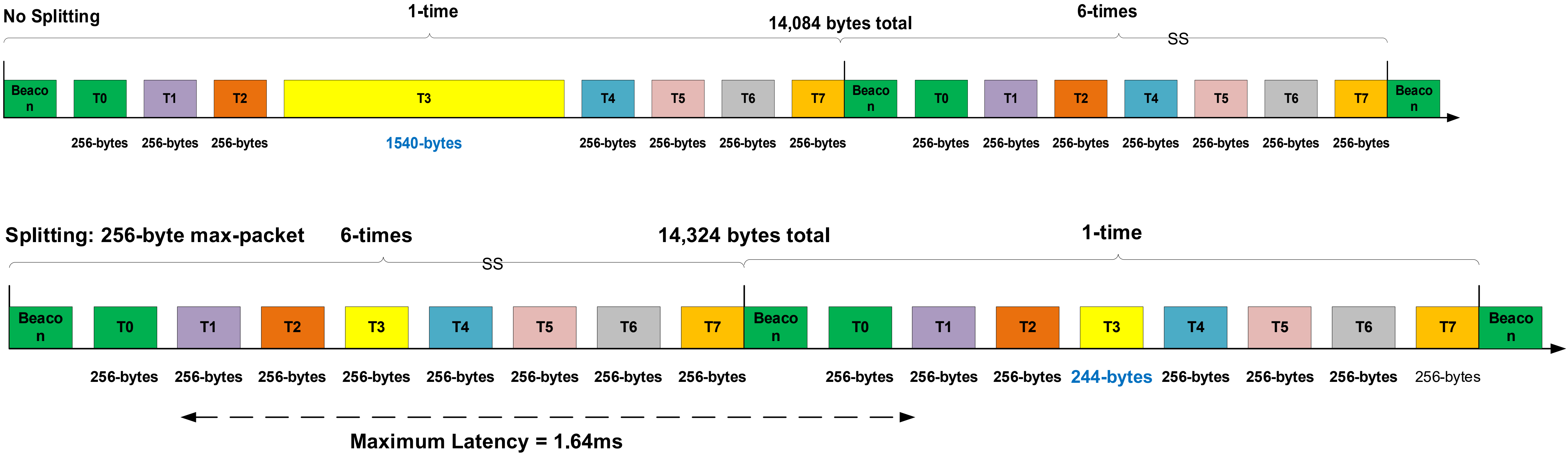
*Note: Beacon overhead is small and not factored here

Option-1 – Limit Max Packet size to 256-bytes & No Burst

- Framing overhead per packet – 40 bytes
  - 8-byte Preamble & SFD + 6-byte Destination MAC + 6-byte Source MAC + 2-byte Type/Length + 4-byte Frame Check Sequence (FCS) + 2-byte (ESD & ESDOK) + 12-byte Inter Packet Gap (IPG)
- For a 1500-byte data packet, the framing overhead is (40/1500) * 100 ~= 2.7%
- When a 1500-byte data packet is broken into seven packets (6 * 216-bytes + 1 * 204-bytes), the overhead is = (40*7/1500) * 100 ~= **18.7%**
- It is not as bad as it looks when multiple Nodes are active in a PLCA cycle ….
  - Example: 8 Nodes are active and all are sending data of 256 bytes packets except one Node sending 1540 bytes
  - Bandwidth overhead during 7 PLCA cycles when a Node sends 1540-byte packet in 1-plca cycle (and idle in later plca cycle) versus it splits into 256 max packets:
    - No-splitting: 7-Nodes * 7-plca-cycles * 256-bytes + 1-Node * 1-plca-cycle * 1540 = 14,084 bytes
    - With splitting: 7-Nodes * 7-plca-cycles * 256-bytes + 1-Node * 6-plca-cycles * 256 + 1-Node * 1-plca-cycle * 244-remaining-bytes = 14,324 bytes
    - The spitting overhead = ((14,324-14,084)/14,084) * 100 ~= **1.7 % (**Not too bad!)

Option-1 – Limit Max Packet size to 256-bytes & No Burst

Number of Nodes=8



Splitting Overhead = ((14,324-14,084)/14,084) * 100 ~= 1.7 %

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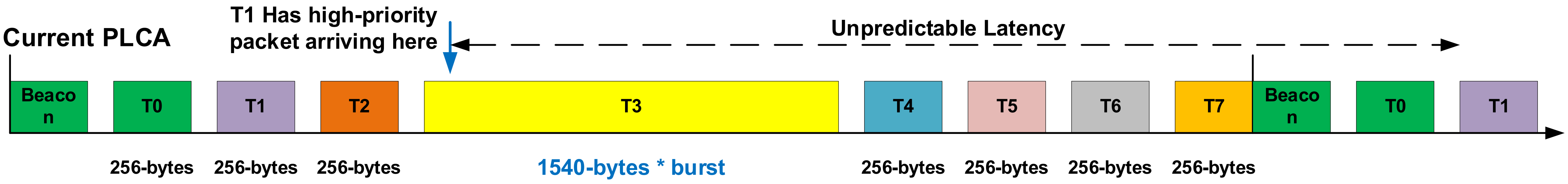
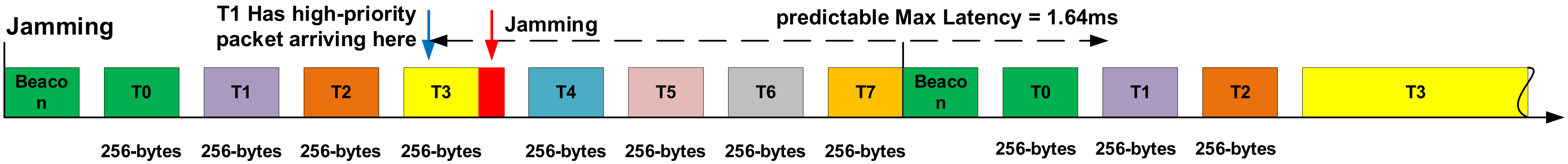
Option-2 – Define High-Priority and Normal-Priority Traffic Types

- A Node could have normal-priority and/or have high-priority traffic types
  - Application depended, only the Node knows about traffic types and transparent to other Nodes
- Assumptions:
  - High-priority traffic max packet size limit is 256
  - Only a few Nodes do high-priority traffic
  - High-priority traffic does not happen very often, and they only require predictable latency
- When a Node has high-priority traffic, it can jam another Node’s packet when a Node’s packet size exceeds 256-bytes
  - If all the Nodes packets are <=256-bytes, no jamming
  - The latency is same as in proposal-1
  - Jamming happens once in a while and recovers as ethernet supports 16 backoff retry attempts
- Smaller change in PLCA/DPLCA design for the jamming, otherwise PLCA/DPLCA remains same
- Not scalable when there are large number of high-priority traffic and large number of >256-byte packet traffic mix.
- Latency depends on the number of Nodes

Option-2 – Define High-Priority and Normal-Priority Traffic Types

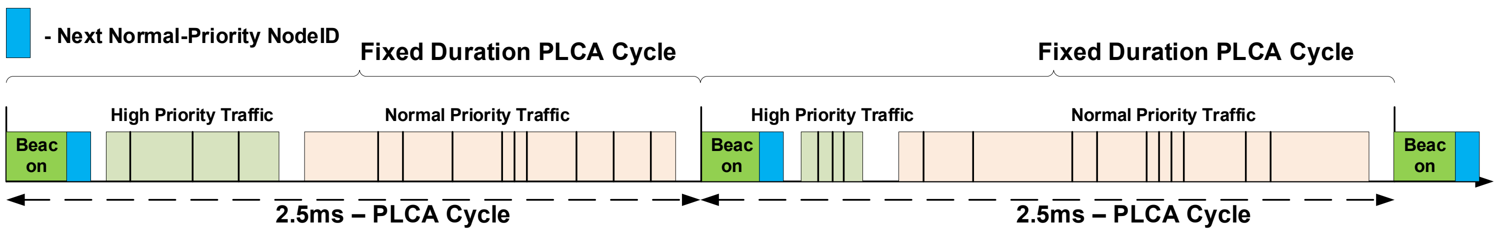


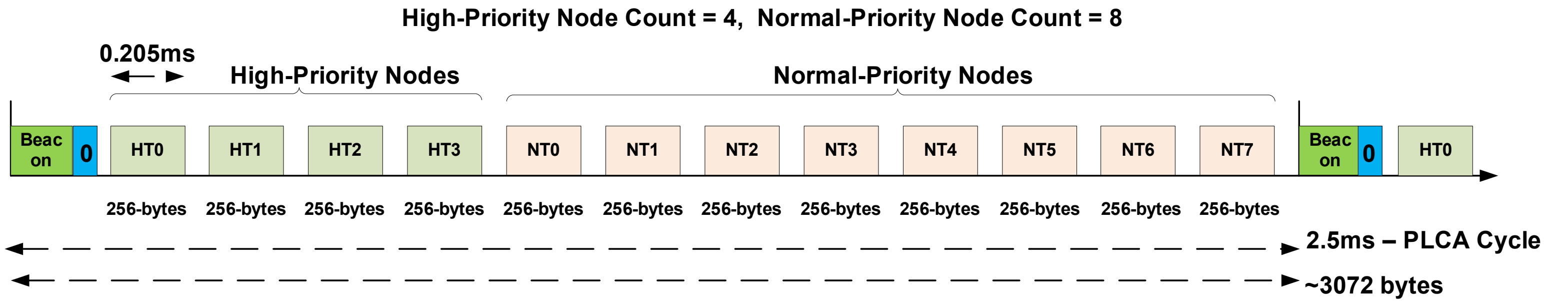


Option-3 – High-Priority and Normal-Priority Node Counts

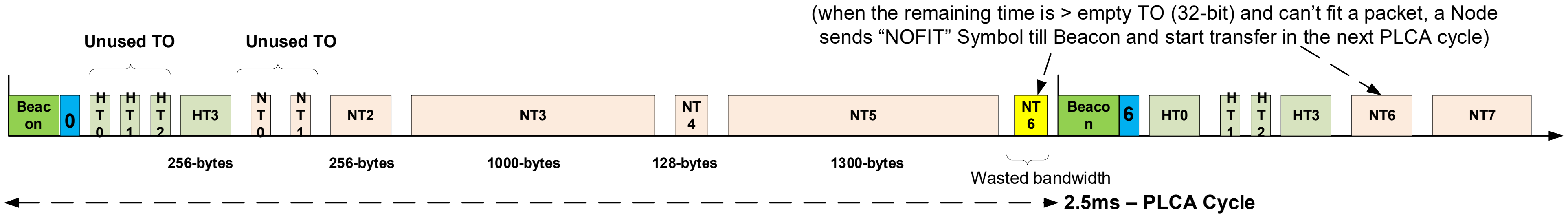
- Define two Node-Counts
  - High-Priority Node-Count: Max Packet Size 256
  - Normal-Priority Node-Count: Max Packet Size 1540, No Burst
- The PLCA Cycle duration is fixed
  - Example 2.5ms (should have space for at least one 1540-byte packet after High-Priority packets).
  - Along with Beacon, coordinator sends Next-Normal-Priority NodeID (NNPNID), so a Node which joins later knows it's place.
- The High-Priority Nodes do transfer first, and Normal-Priority Nodes next if time left in a PLCA cycle, else in the next PLCA cycle. A Non-Priority Node could do more 0, 1, or more transfer in a PLCA cycle.
- The High-Priority and Normal-Priority Nodes still follow the round-robin based arbitration
- Example: In a 4 High-Priority Node configuration, if none of the High-Priority Nodes do transfer, then the bandwidth wastage is = ((4* 32 *100[TO] - 12*8*100[IPG])/2.5ms*1000,000) * 100 ~= 0.13%
- If a 1540-byte Normal-Priority packet just could not fit by a small margin, the bandwidth wasted is = (1539*8*100/2.5ms*1000,000) * 100 = 49.25%
  - Maximum Bandwidth wastage with 256-byte packets = (255*8*100/2.5ms*1000,000) * 100 = 8.16%
  - Reinforces that the packet size should be small to avoid bandwidth waste; limit packet size to 256-bytes
- The latency remains same irrespective of the number of Normal-Priority PLCA Nodes

Option-3 – High-Priority and Normal-Priority Node Counts

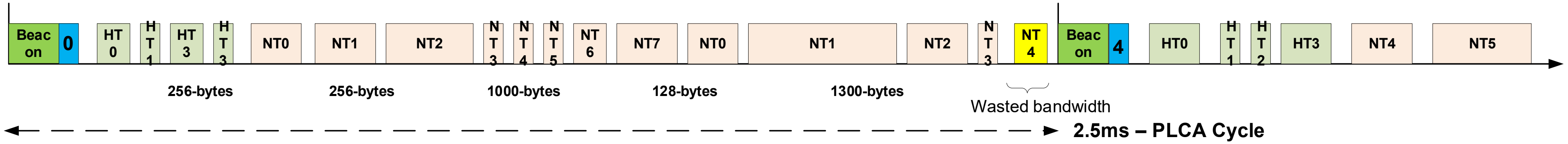




Traffic Example-1: All the Normal-Priority Nodes get chance to do transfer in a PLCA



Traffic Example-2: Not all Normal-Priority Nodes get chance to do transfer in a PLCA cycle



Traffic Example-3: Some Nodes get chance to do more than one transfer in a PLCA cycle

Comparison Of Options

	Option-1	Option-2	Option-3
Changes to PLCA or DPLCA Needed	No	Yes	Yes (No DPLCA Support)
Interop with existing PLCA devices	Yes	Yes	No
Latency	Depends on the number of Nodes	Depends on the number of Nodes	Fixed
Bandwidth Wastage	No	Some due to Jamming. Large if there are many large-packet Nodes	Some at the end of the PLCA cycle. Large if there are many large-packet Nodes
Scalable/ Predictable	Yes	No	Yes
Strength	No change in PLCA (only application change)	Smaller change to PLCA	Scalable for higher Nodes-Count

Backup

Automotive Packet size Usage – Google Gemini Data

Real-World Usage Data & Packet Size Distribution

In practical automotive zonal architectures (connecting sensors, actuators, radar, microphones, and headlights), network traffic is split into distinct packet size buckets:

Packet Size (Total Frame)	Typical Real-World Workload / Application	Approximate Share of Network Traffic
64 Bytes *(Minimum)*	**CAN-to-Ethernet Bridging & Actuators** Carries small control signals (e.g., window motors, smart lighting, fluid sensors, seat buttons) translated from legacy CAN.	**~70% to 80%**
128 – 256 Bytes	**Time-Critical Sensor Streams** Time-Sensitive Networking (TSN) data, highly periodic wheel-speed data, and IMU inertial sensors.	**~10% to 15%**
512 – 1,024 Bytes	**Compressed Audio & Local Diagnostics** Inter-ECU communication profiles, infotainment mic/speaker channels, and real-time powertrain sensor aggregation.	**~5% to 10%**
1,518 Bytes *(Maximum)*	**OTA Firmware Updates & Flash Logging** Used almost exclusively during vehicle servicing or Over-The-Air (OTA) software download cycles to maximize throughput.	**< 5%** *(Except during system updates)*

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