Differentiated Services

(Modulo Operation based Diff Serv)

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2026 August 27, Teleconference ad hoc

Setting the stage

- Will assume: Audience familiar w CFI presentation
  https://www.ieee802.org/3/cfi/0726_1/CFI_01_0726.pdf
- Will limit repetition of CFI content to a minimum:
  - Problem statement
  - Simulation slide
- Will focus on one method for PLCA Multidrop Latency & Jitter Enhancements: **Modulo Operation based Differentiated Services**
- Method was presented during a NEA meeting in 10/2025
  https://www.ieee802.org/3/ad_hoc/ngrates/public/calls/25_1009/2025_10_09a_NEA_Differentiated_Services_10BaseT1S-v1-no-backup.pdf

Problem Statement (1 of 2)

Mixed criticality traffic:

- Different devices in automotive networks frequently have traffic with different application specific latency requirements.

  Example: Closure modules (door, trunk) with best effort traffic, Propulsion related control loops with low latency requirements.
- Even on a single station we often have traffic with different latency requirements.

PLCA characteristics:

- PLCA provides **fair and equal access** to all stations (*1)
- The resulting PLCA **worst-case latency is too high** for control applications with low-latency requirements.(*2)
- PLCA's variable cycle length leads to **high latency jitter** (lack of sufficient determinism). (*2)
- PLCA has **no mechanisms that enable tailoring latency and jitter** to meet traffic requirements.

(*1) As of today, bursts are the only IEEE standardized provision for 'unequal' access in PLCA based networks.
(*2) We demonstrated high latency/high jitter for realistic automotive network traffic/networks via simulations in the CFI presentation.

Problem Statement (2 of 2)

Scalability:

- Automotive networks are engineered, but over time networks evolve. Traffic changes due to over-the-air updates or because new features are added from model year to model year.

PLCA characteristics:

- 10BASE-T1S/M segments can be engineered to meet latency requirements
- But **when traffic is added** to a previously engineered segment, it **impacts latencies and jitter in unpredictable ways** (scalability concern) (*1)

(*1) We demonstrated the impact adding traffic to a pre-existing network can have on latency and jitter. See CFI presentation for details.

Differentiated Services Concept (1/4)

Desired behavior:

- Differentiate between nodes with different latency requirements
- Example:
  - Low Latency nodes can send frequently (e.g., in every cycle)
  - Medium latency nodes send less frequently (e.g., in every other cycle)
  - Best effort nodes send infrequently (e.g., in every fourth cycle)

cycle	Node N0	Node N1	Node N2	Node N3	Node N4	Node N5	Total
1	X	X			X		3
2	X		X	X			3
3	X	X				X	3
4	X		X	X			3
5	X	X			X		3
6	X		X	X			3
7	X	X				X	3
8	X		X	X			3
9	X	X			X		3
10	X		X	X			3
11	X	X				X	3
12	X		X	X			3
13	X	X			X		3
14	X		X	X			3
15	X	X				X	3
16	X		X	X			3

Low Latency Node | Medium Latency Nodes | Best Effort Nodes

Key idea:

- Limit the number of nodes that can send in any cycle to a small constant number !
- Latency is no longer a direct function of the number of nodes on the network.

Differentiated Services Concept (2/4)

Differentiated Services (per node):

- Each node N_i has 2 config parameters: m_i, o_i
- A node Ni has permission to send if:
  - It's TO is available, and
  - $(cc_i + o_i) \bmod m_i = 0$
- Observation:
  The pattern repeats every 4 cycles (hypercycle).
  In general: Every lcm(m_1, m_2, m_3, …,m_n) cycles.

m_i	1	2	2	2	4	4
o_i	0	1	0	0	3	1

cc_i	N0	N1	N2	N3	N4	N5	Total
1	X	X			X		3
2	X		X	X			3
3	X	X				X	3
4	X		X	X			3
5	X	X			X		3
6	X		X	X			3
7	X	X				X	3
8	X		X	X			3
9	X	X			X		3
10	X		X	X			3
11	X	X				X	3
12	X		X	X			3
13	X	X			X		3
14	X		X	X			3
15	X	X				X	3
16	X		X	X			3

Low Latency Node | Medium Latency Nodes | Best Effort Nodes

Differentiated Services Concept (3/4)

Differentiated Services (per class of service)

- Node can have mixed latency traffic.
- Example Node Na:
  PCP=7 low latency (PLCA ID = 0)
  PCP=4 medium latency (PLCA ID = 1)
- Example
  - The max number of frames that can be send in any given cycle is constraint to an upper bound of 5
  - Low latency frames: Every cycle
  - Medium latency frames: Every other cycle
  - Best effort frames: Every 4th cycle
- Requires:
  - Ability to assign multiple PLCA IDs to a node
  - Nodes with multiple transmit queues (mapped to PCP codes)
  - Parameters m, o for each used (PCP per Node) combination.

m_i	1	2	1	2	2	4	4	1	
o_i	0	1	0	1	0	2	0	0	
cc_i	Na ID = 0 PCP=7	Na ID = 1 PCP=4	Nb ID = 2 PCP=7	Nb ID = 3 PCP=4	Nc ID = 4 PCP=4	Nc ID = 5 PCP=0	Nd ID = 6 PCP=0	Ne ID = 7 PCP=7	Total
1	X	X	X	X				X	5
2	X		X		X	X		X	5
3	X	X	X	X				X	5
4	X		X		X		X	X	5
5	X	X	X	X				X	5
6	X		X		X	X		X	5
7	X	X	X	X				X	5
8	X		X		X		X	X	5
9	X	X	X	X				X	5
10	X		X		X	X		X	5
11	X	X	X	X				X	5
12	X		X		X		X	X	5
13	X	X	X	X				X	5
14	X		X		X	X		X	5
15	X	X	X	X				X	5
16	X		X		X		X	X	5

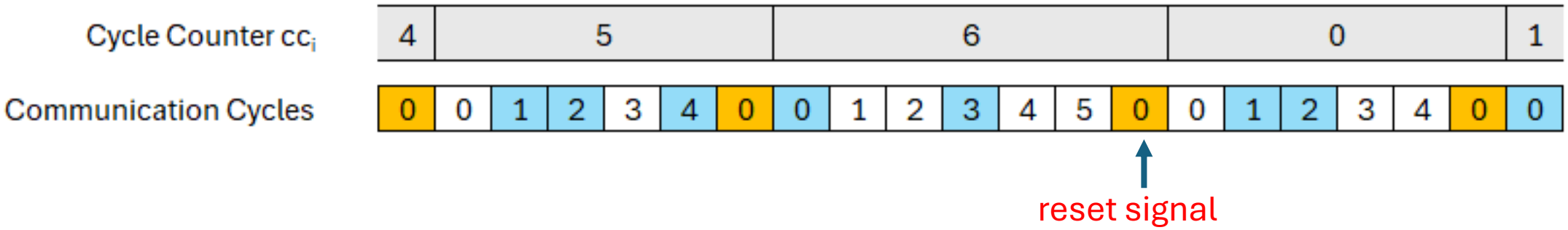
Na: low, med | Nb: low, med | Nc: med, BE | Nd: BE | Ne: low

To keep the table short, we picked small m_i values in the range of 1 to 4. Picking larger m_i values (e.g., 8, 16, 32) for medium latency and best effort and small values (e.g., 1, 2) for low latency frames can keep the maximum number of nodes transmitting in a cycle to a smaller constant than in our example (e.g., 2 or 3 instead of 5).

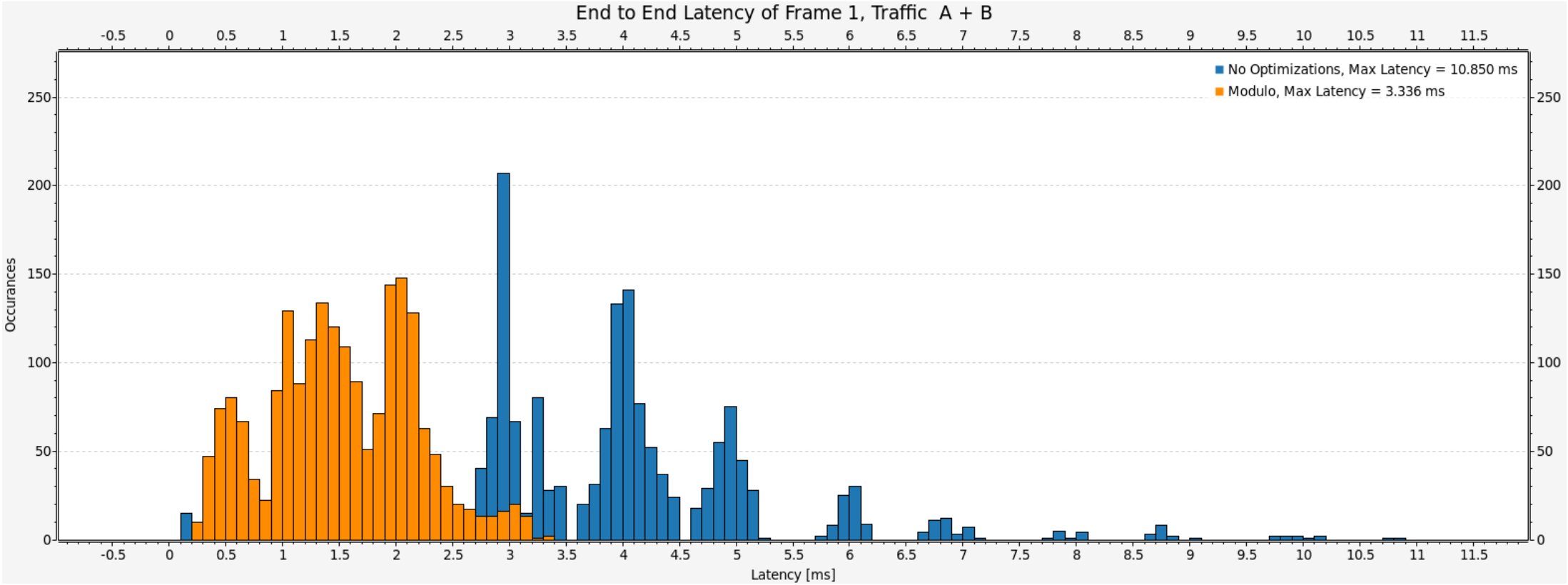
Differentiated Services Concept (4/4)

Cycle Counter:

- Node names: N0, N1, …, Nn
- Each node N_i has a local notion cc_i of a global cycle counter
- Node N_i increments cc_i upon reception of Beacon
- Coordinator periodically sends reset at the end of a hypercycle
  (enables nodes that power-on late to join and know the cycle counter value after observing the next reset)
- Options for reset signal coding needs exploration.
  One option to explore: Double beacon (backwards compatible) signals the cycle start and a reset.
  Btw: Missing a small number of resets due to some fault will not throw off the schedule .



Modulo based Diff Services can reduce latency and jitter for critical traffic



See CFI presentation for details on simulation experiments.

Thank You for Joining