Node Count Analysis in 10Base-T1S Ethernet

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By:

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Today's Presentation Agenda

01 – Factors affecting node count in a network

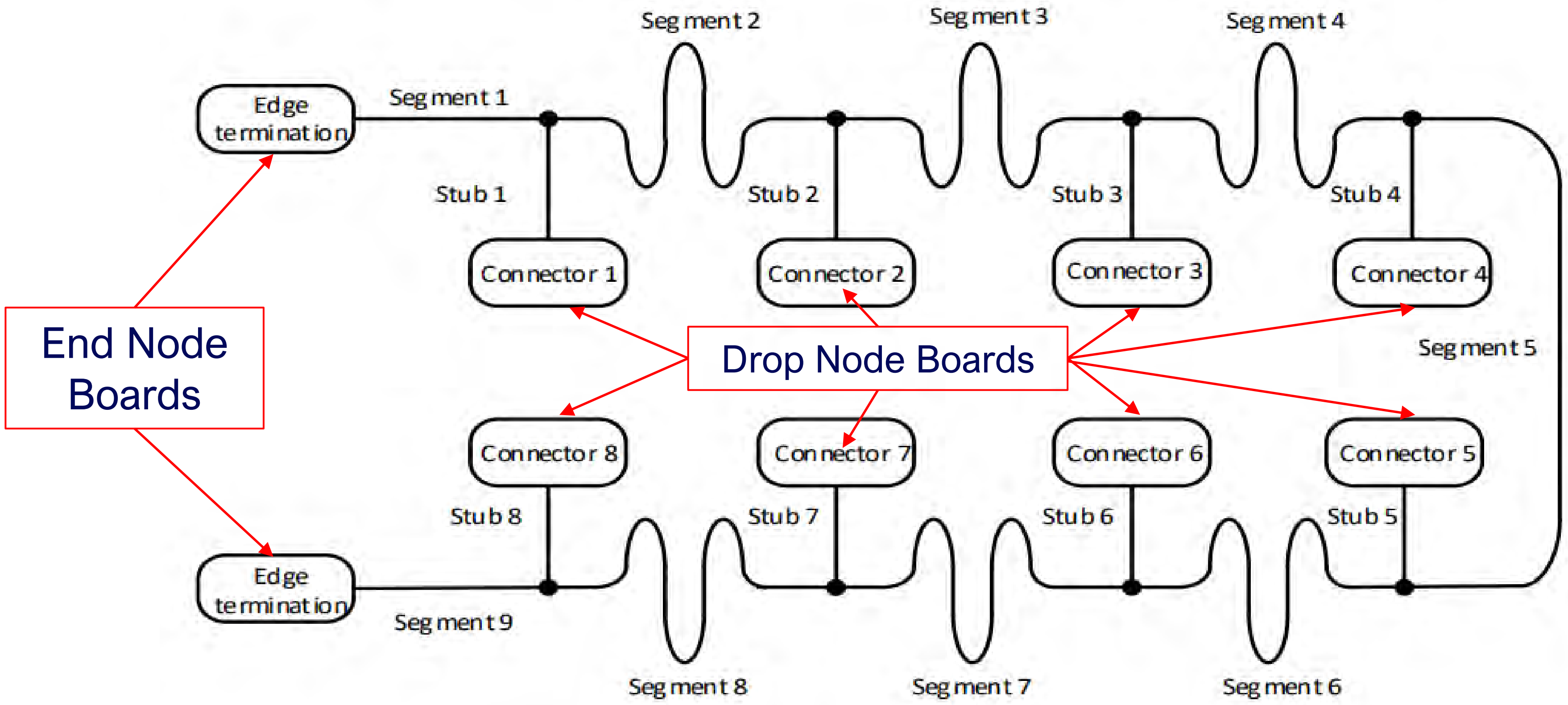
02 – Analysis of Lab measurements

03 – Node count conclusion based on electrical analysis

04 – System Level latency considerations for various topology designs

05 – Conclusion

Background Information



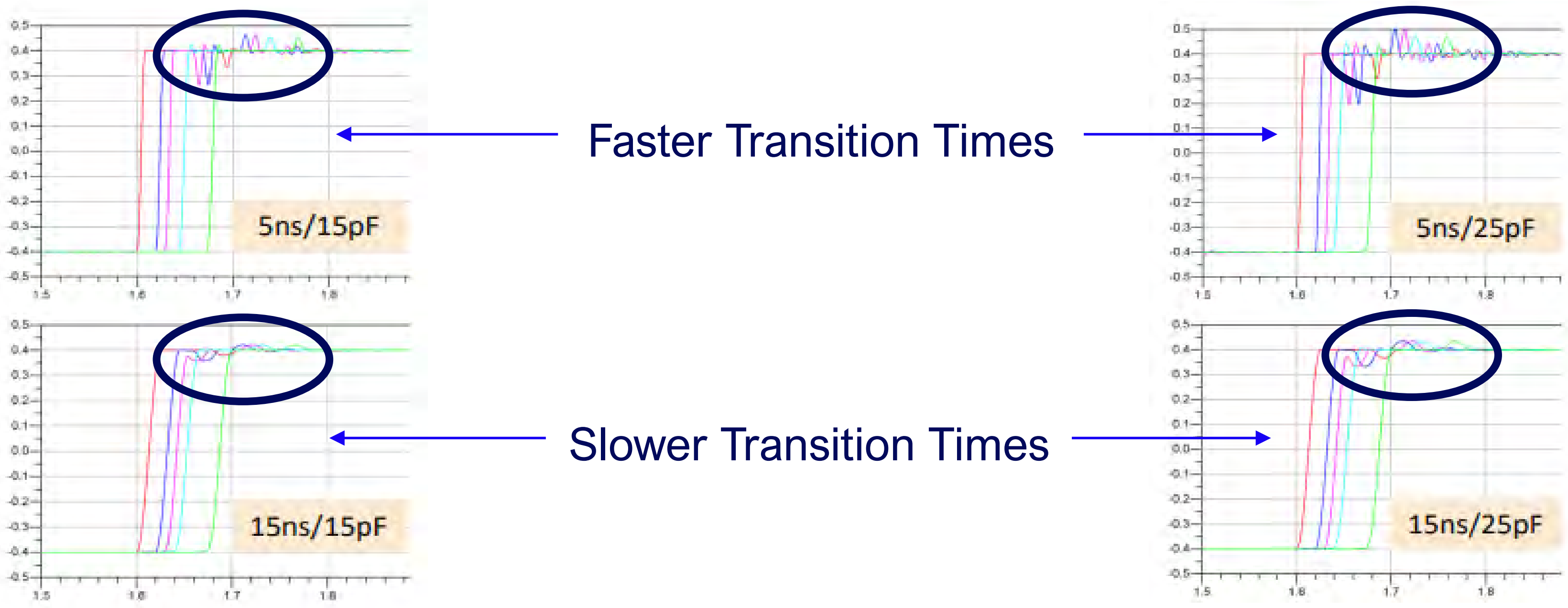
- **The IEEE 802.3cg standard and hence the PHY solutions were developed assuming the following**
  - Supports up to at least 8 Nodes
  - Maximum Length (end to end): 25 meters

Factors affecting the node count in a network

- Node Count is a func(electrical_signal_quality)
- Major Factors affecting Node Count are:
    1. PHY transition time (rise/fall times)
    2. External noise due to vehicular electronics
    3. Overall system capacitance
    4. Node-to-Node Distances
- Acceptance Criteria for a Good Topology, based on performance of:
    - ✓ Eye Height
    - ✓ Jitter

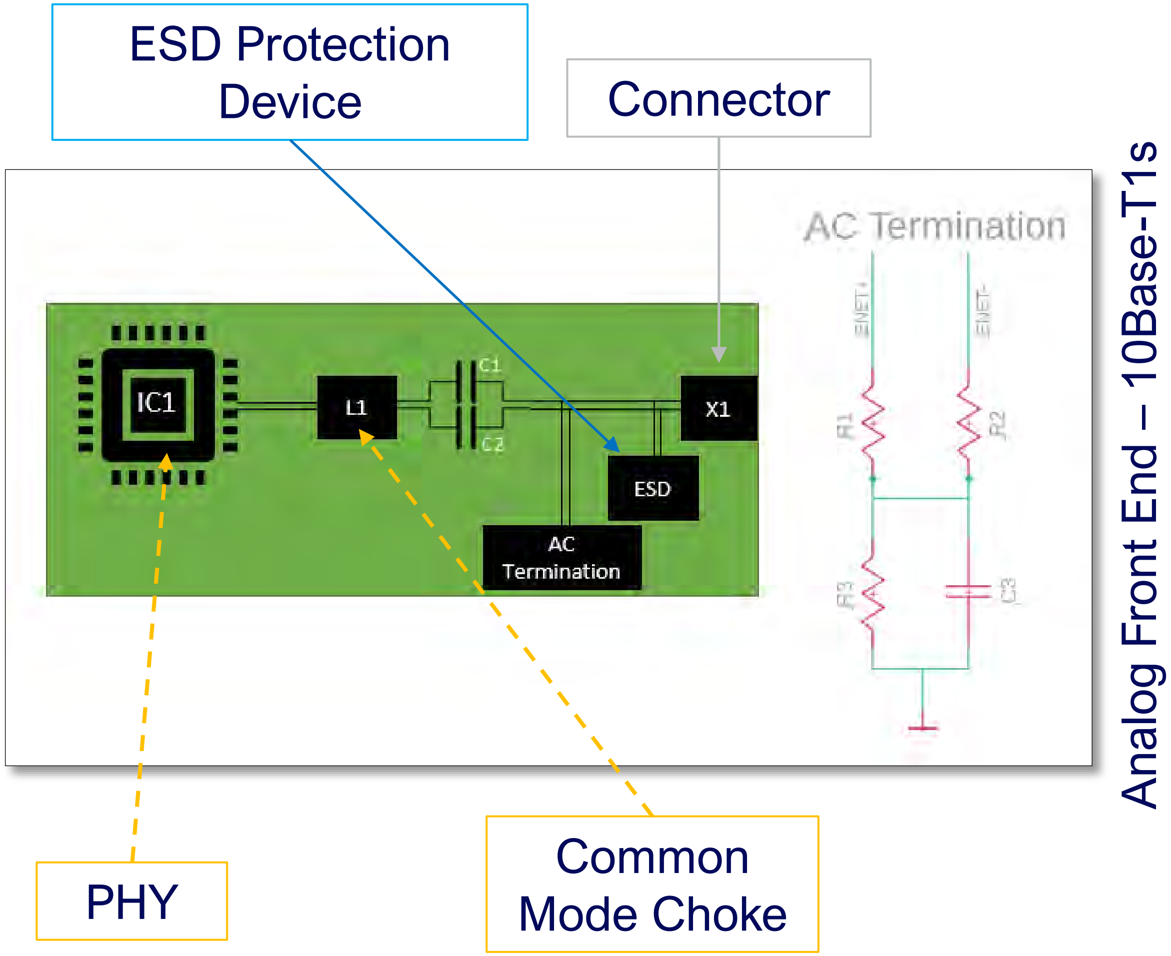
Explanation of Factors (#1, # 2): RISE/FALL TIME & EMC NOISE

1. PHY transition time (Tr/Tf): The PHY must have a signal transition time of <= 15ns



2. External EMC Noise: In typical scenario, this will close the eye by a minimum of $200mV_{p\text{-}p}$

Explanation of Factor (#3): NODE CAPACITANCE



- Typical Capacitance of each component
  1. ESD: <1pF
  2. Common Mode Chokes: < 10pF (Class III)
  3. PHY: < 9pF
  4. Trace: ~1pF/inch

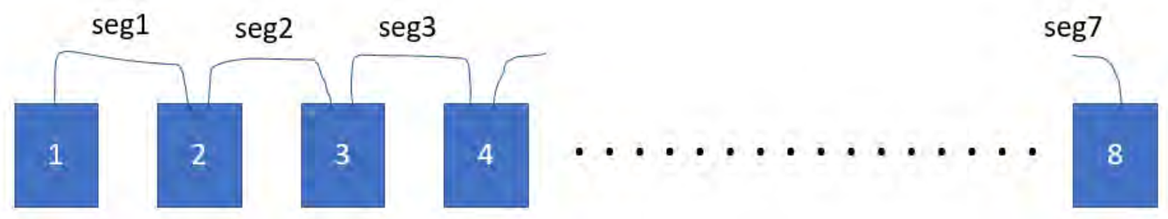
- Total Node Capacitance ranges from 18-25pF

- The 8 node/25 meter in the standards: 25 pF/node capacitance requirement

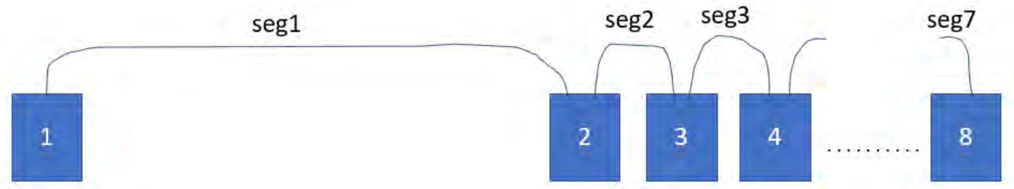
Explanation of Factor (#4): NODE-to-NODE DISTANCE

- Node-to-Node stacked very close (within 1 meter): can lead to stacked capacitance effect, which limits the Node Count

Setup #1



Setup #2



- Keeping all the system parameter constant between the two topologies, Setup #1 will yield better signal quality than Setup #2

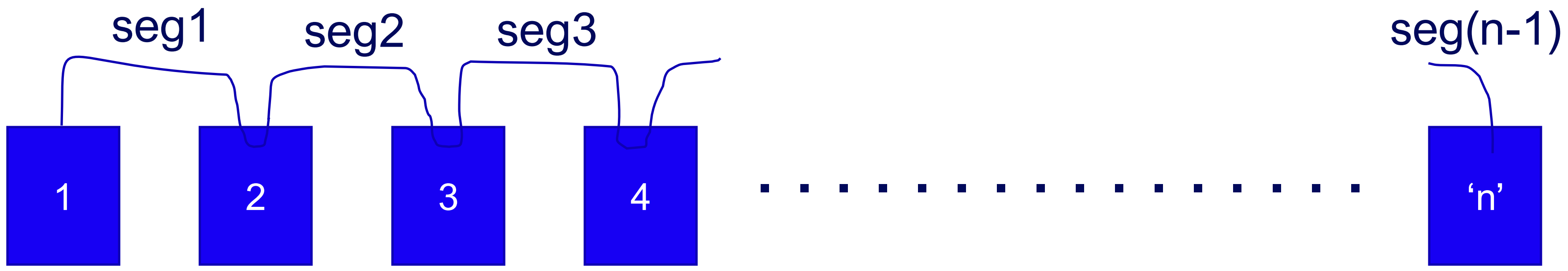
Factors that System Designers can control

- Factors under System Designers control:
  - ✓ Node capacitance
    - + PHY, ESD and CMC Selection
  - ✓ Placement of Nodes
    - + Distance between the nodes

- Hence in our lab measurements, we vary these 2 factors
  - + System Capacitance : By increasing / decreasing Node Count
  - + Node-to-Node Distance : By increasing / decreasing Node-to-Node distances

Comparison # 1

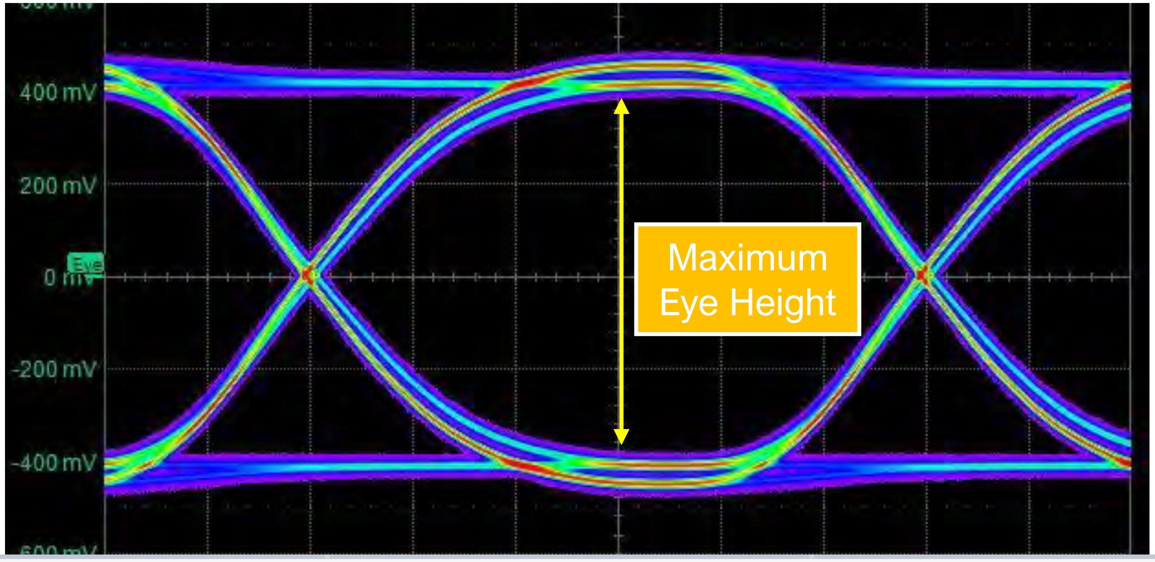
Vary the number of nodes



n = total number of nodes = 8, 10, 12, 15

Total Nodes	Setup 1	Total End-End Distance
8	All segments = 0.75m	5.25 meters
10	All segments = 0.75m	6.75 meters
12	All segments = 0.75m	8.25 meters
15	All segments = 0.75m	10.50 meters

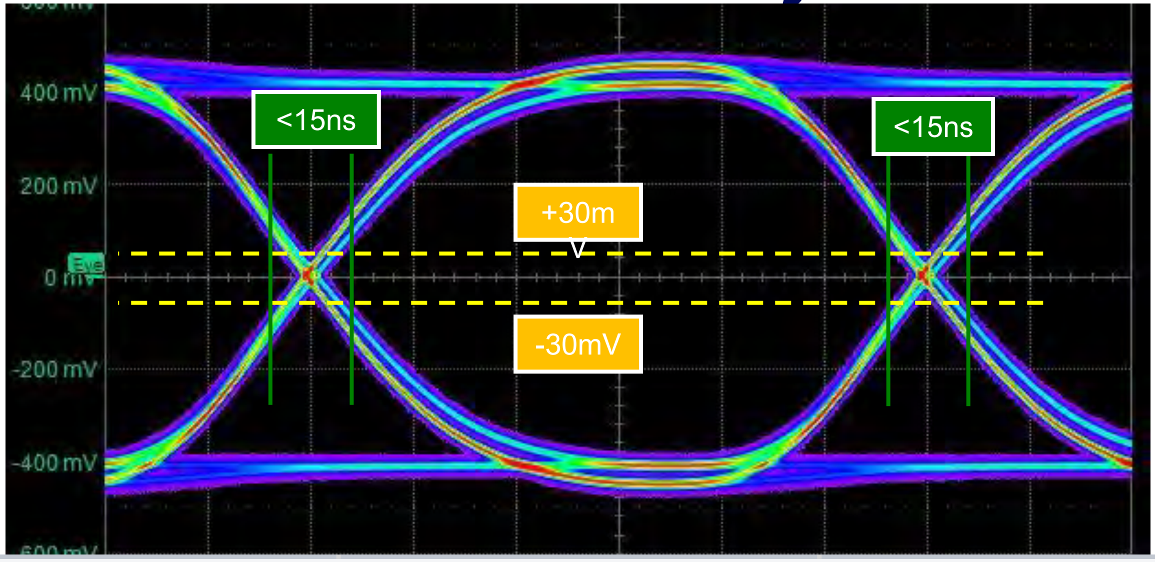
Signal Waveform Analysis – Maximum Eye Height



Eye Height gets worse

Number of Nodes	Maximum Eye Height (mVp-p)(should be ≥ 500mV)			
	On Transmitting Node	Middle Node 1	Middle Node 2	Far End node
8 nodes	718	540	575	695
10 nodes	598	580	565	570
12 nodes	585	465	531	531
15 nodes	575	520	485	512

Signal Waveform Analysis – P-P Jitter

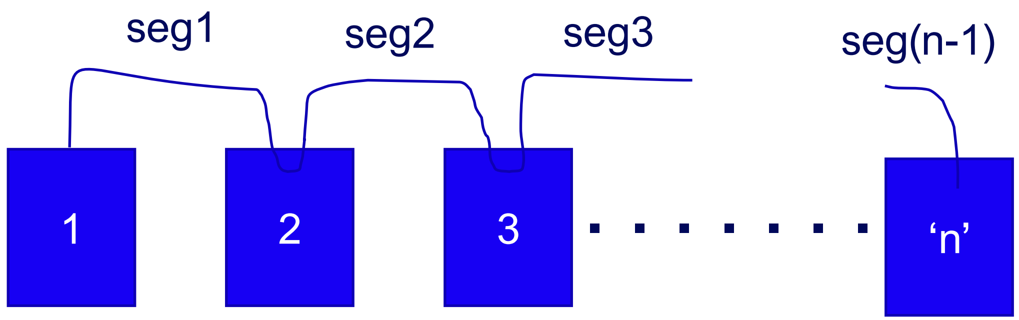


Jitter gets worse

Number of Nodes	Maximun Jitter (ns) (should be ≤ 15ns)			
	On Transmitting Node	Middle Node 1	Middle Node 2	Far End node
8 nodes	3.75	4.56	4.96	5.37
10 nodes	6.03	8.17	8.71	7.04
12 nodes	7.24	9.45	8.91	7.25
15 nodes	7.5	8.35	9.02	6.96

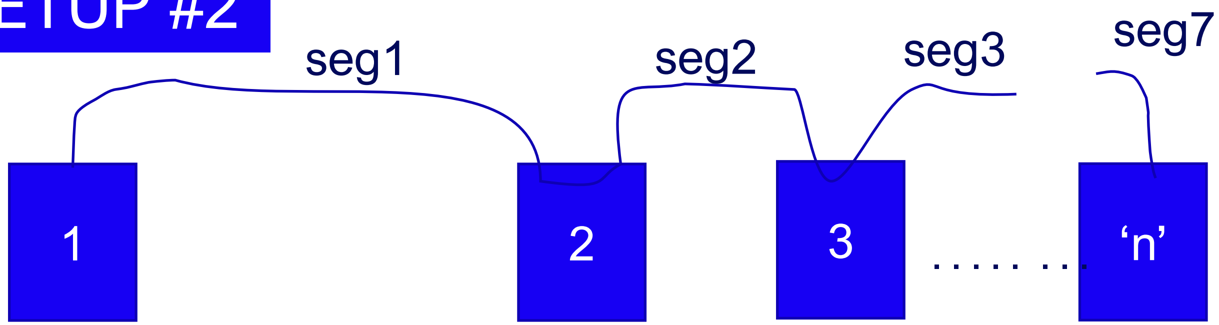
Comparison # 2: Stacked up Nodes

SETUP #1



Nodes	Setup 1	Total End-End Distance
8	All segments = 3m	21.5m
10	All segments = 3m	27m

SETUP #2

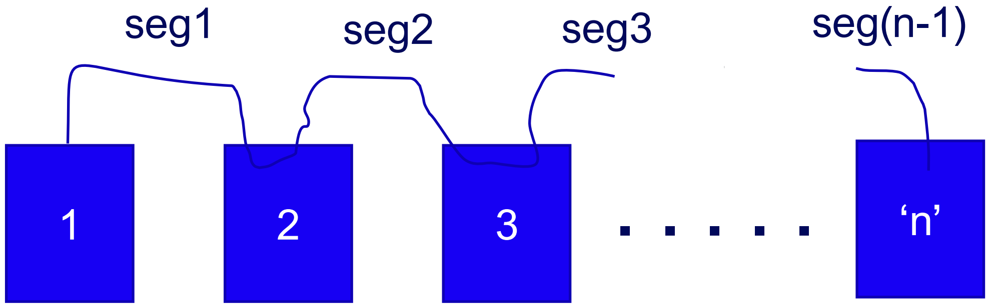


Nodes	Setup 2	Total End-End Distance
8	Seg1 =17, Remaining = 0.75m	21.5m
10	Seg1 = 21m, Remaining = 0.75m	27m

TREND: Nodes that are spread out have better performance,
Closely spaced nodes have stacked capacitance effect

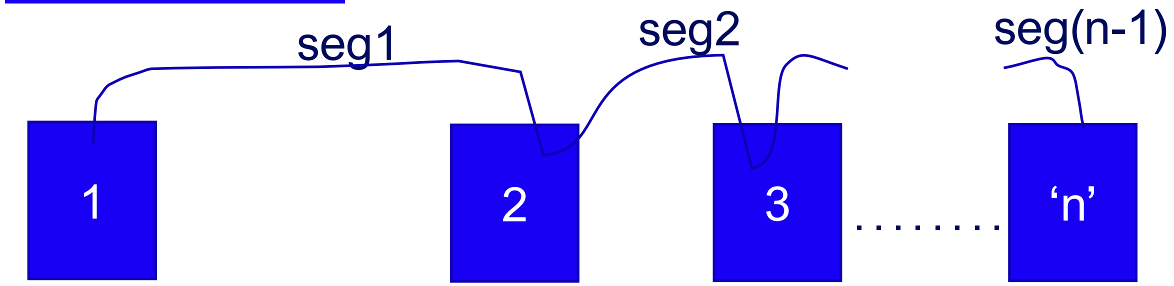
Comparison # 3: Increased End-to-End Cable Length

SETUP #1



Nodes	Setup 1	Total End-End Distance
8	All segments = 0.75m	5.25m
10		6.75m
12		8.25m
15		10.50m

SETUP #2



Nodes	Setup 2	Total End-End Distance
8	Seg1 =3m, Remaining = 0.75m	7.5m
10		9.0m
12		10.50m
15		12.75m

TREND: Additional Cable length have more affect on the eye height than the jitter performance

Cable length leads to DC resistance loss

Conclusion for NODE COUNT Analysis

Number of Nodes	Minimum Node-to-Node Distance
<= 8	>0.5 meters
8 < nodes <= 10	>0.75 meters
10 < nodes <= 15	>1.0 meters
15 < Nodes <= 20	>1.5 meters
Nodes > 20	Needs Further Testing and Investigation

NOTE: Node System Capacitance of <= 20pF

10BaseT1S Network Background Motivation

- Bit-rate gap between CAN-FD (2Mbps) and 100Base-T1 Ethernet (100Mbps)

- Provide high bandwidth traffic for zonal implementations, over a single twisted wire

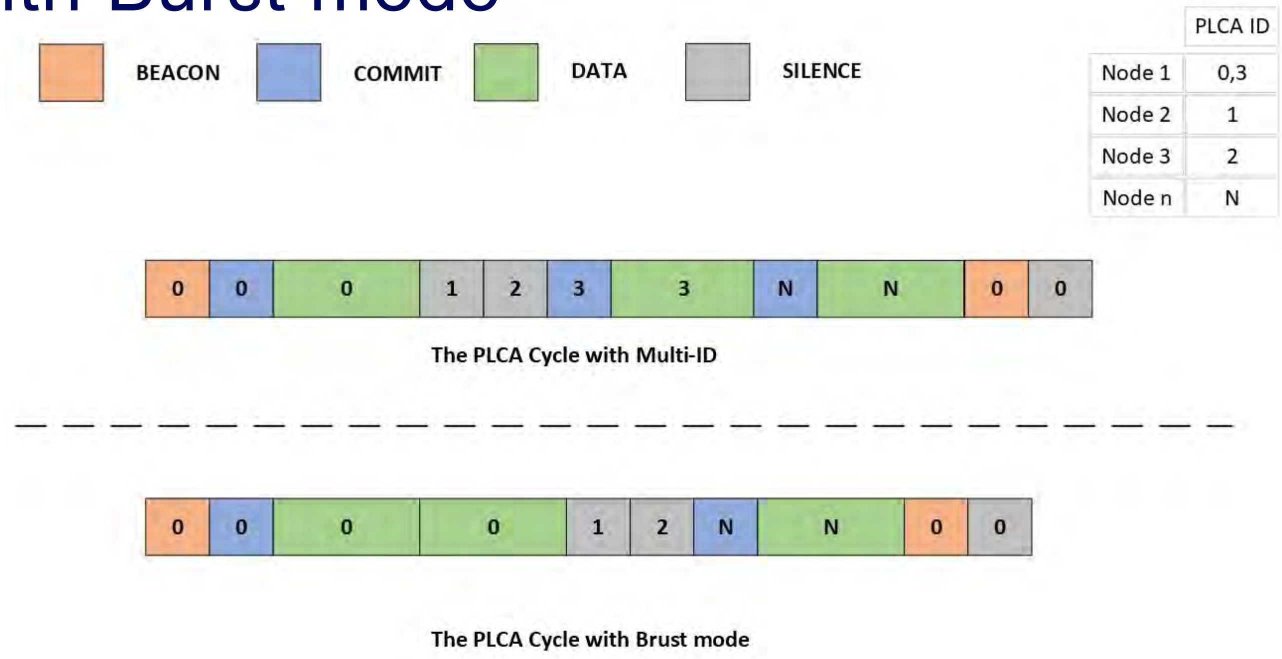
- Allow IP based network integration

- Deterministic communication Nodes can transmit only in its Transmit Opportunity (TO)

Solutions for Overcoming Latency Concerns

Possible Solutions: reduce the latency (PLCA features)

- Multiple Node ID: Node assigned two or more PLCA ID
- Multiple Message in same TO: Burst mode
- Combined: Multiple NodeID with Burst mode

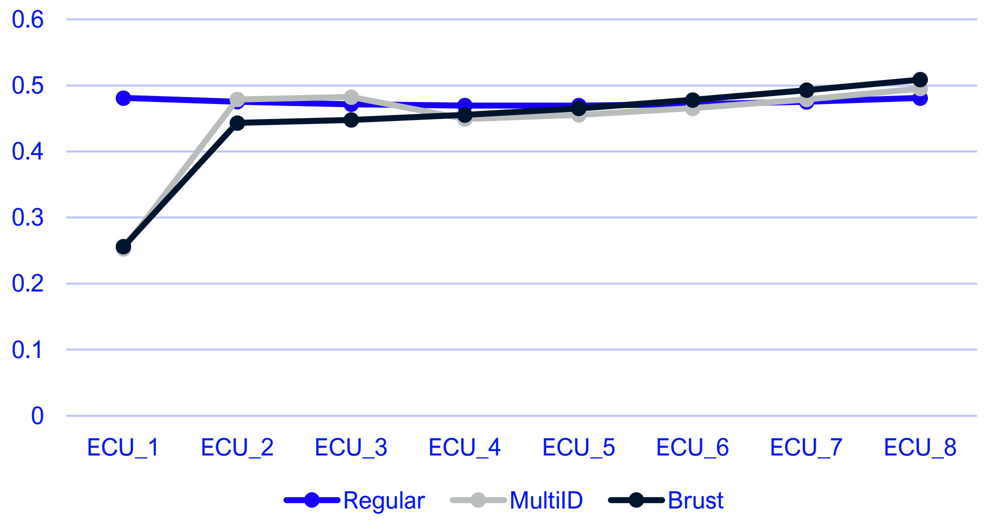


Measurement Results

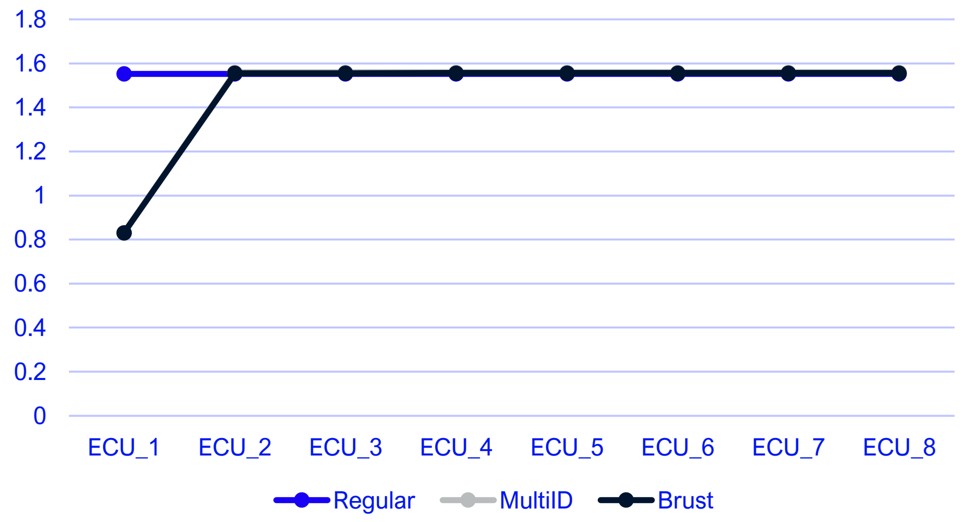
Compare ECU_1 with 2 IDs and ECU_1 with Burst mode (1 Burst count)

Unit: msec

STD Latency



Worst Latency

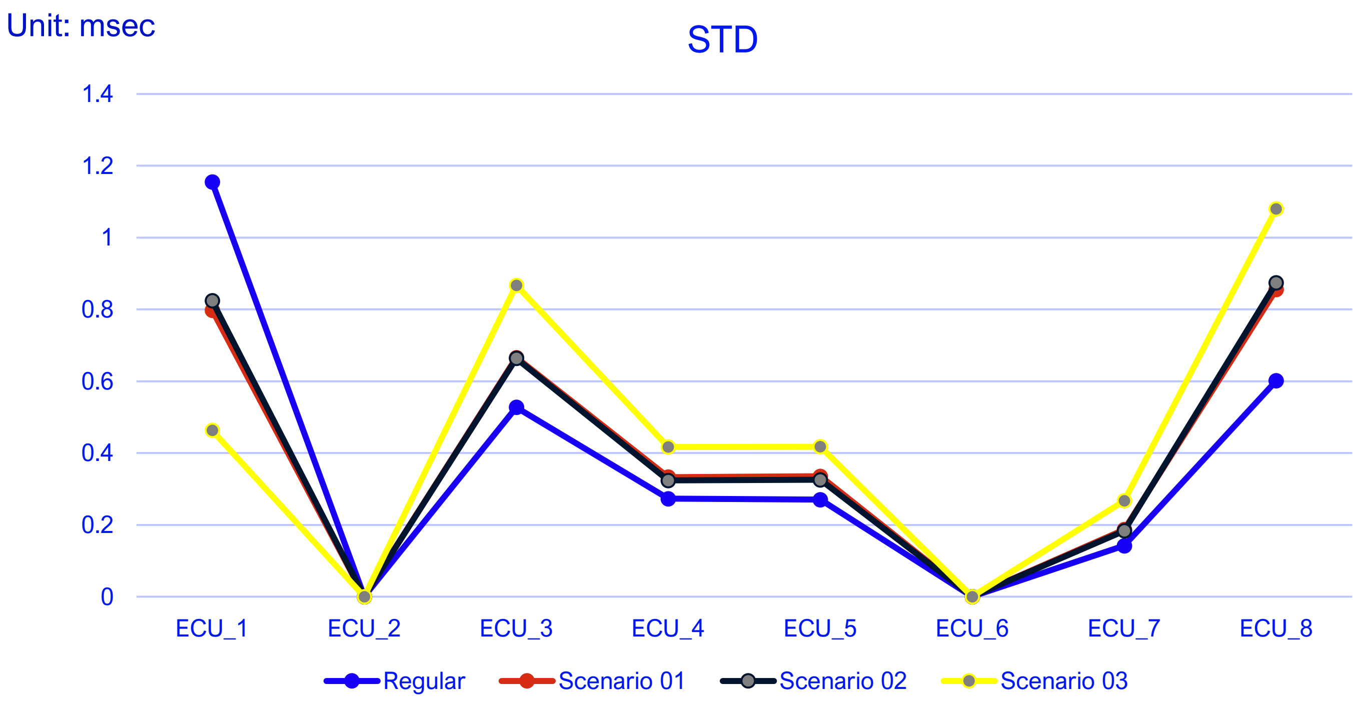


STD Latency

Unit: msec

	ECU_1	ECU_2	ECU_3	ECU_4	ECU_5	ECU_6	ECU_7	ECU_8
Busload	10.4%	10.4%	10.4%	10.4%	10.4%	10.4%	10.4%	10.4%
Regular	0.480	0.475	0.471	0.469	0.469	0.471	0.475	0.480
Multi-ID	0.252	0.478	0.482	0.449	0.45	0.465	0.478	0.495
Burst	0.256	0.443	0.447	0.455	0.46	0.478	0.492	0.508

Measurement Results



#	Busload
ECU_1	48.5%
ECU_2	0%
ECU_3	10.4%
ECU_4	0.03%
ECU_5	0.03%
ECU_6	0%
ECU_7	0.01%
ECU_8	20.5%

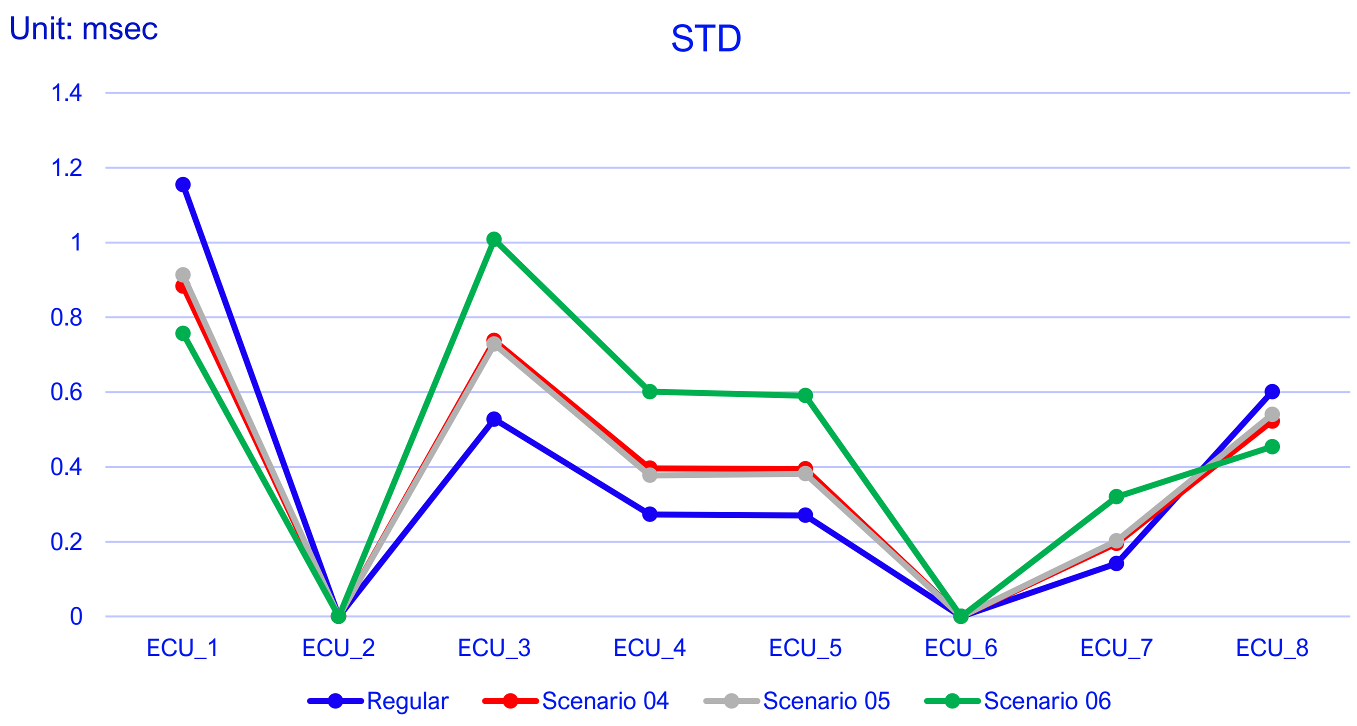
Regular: Normal configuration each node has a unique PLCA ID without Burst mode.

Scenario 01 : ECU_1 with Burst mode (addition one Ethernet Frame)

Scenario 02 : ECU_1 has two PLCA ID.

Scenario 03 : ECU_1 has two PLCA ID with Burst mode (addition one Ethernet Frame.)

Measurement Results



#	Busload
ECU_1	48.5%
ECU_2	0%
ECU_3	10.4%
ECU_4	0.03%
ECU_5	0.03%
ECU_6	0%
ECU_7	0.01%
ECU_8	20.5%

Regular: Normal configuration each node has a unique PLCA ID without Burst mode.

Scenario 04 : Both ECU_1 and ECU_8 with Burst mode (addition one Ethernet Frame)

Scenario 05 : Both ECU_1 and ECU_8 have two PLCA ID.

Scenario 06 : Both ECU_1 and ECU_8 has two PLCA ID with Burst mode (addition one Ethernet Frame.)

Key Takeaways - Latency

- Key Takeaway # 1 - Both Multiple IDs and Burst mode can reduce the individual Node's latency, also will increase Nearby Node's latency.
- Key Takeaway # 2 – For Nodes with high Network Utilization, Multiple IDs with Burst mode might be good to reduce latency.

Overall Presentation Conclusion(s)

Max Node Count of a 10Base-T1S network design depends on:

1. Node placement and node capacitance play a critical role in determining the signal quality, our guidance:
    1. Node Capacitance <= 20pF
    2. Node-to-Node min distance varies on Node Count

2. We recommend SI analysis at each Node(s)

3. For node’s frame latency, the balancing act is required, where the network implementers should consider total node and nearby node’s latency.

Acknowledgements
Contributors: Mr. Ajeya Gupta

Thank you for your attention

QUESTIONS??