Multidrop Ethernet for In-cabinet Applications

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Purpose

- The purpose of this presentation is:
  - To present the potential use case of multidrop Ethernet for In-cabinet Applications within Industrial Automation
    - This does not exclude point-point usage for critical applications
  - To discuss technology and concerns relevant to multidrop (not a proposal)

Relevant types of In-cabinet components

- Circuit protection
  - Disconnects
  - Breakers
- Motor control and protection
  - Contactors
  - Overload relays
  - Soft starters
  - Drives
- Operator interface
  - Pilot devices
    - Pushbuttons, selector switches, indicators…
  - Signaling devices
    - Tower or stack lights,

Largest volume

Market estimate

- Derived from: IHS Technology, “Low Voltage Contactors & Overload Protection Devices – World – 2014”, February 2014
- 426M
  - 2019 extrapolation + 10% other components
- Assume 15% penetration
  - 64M

Typical panel assembly

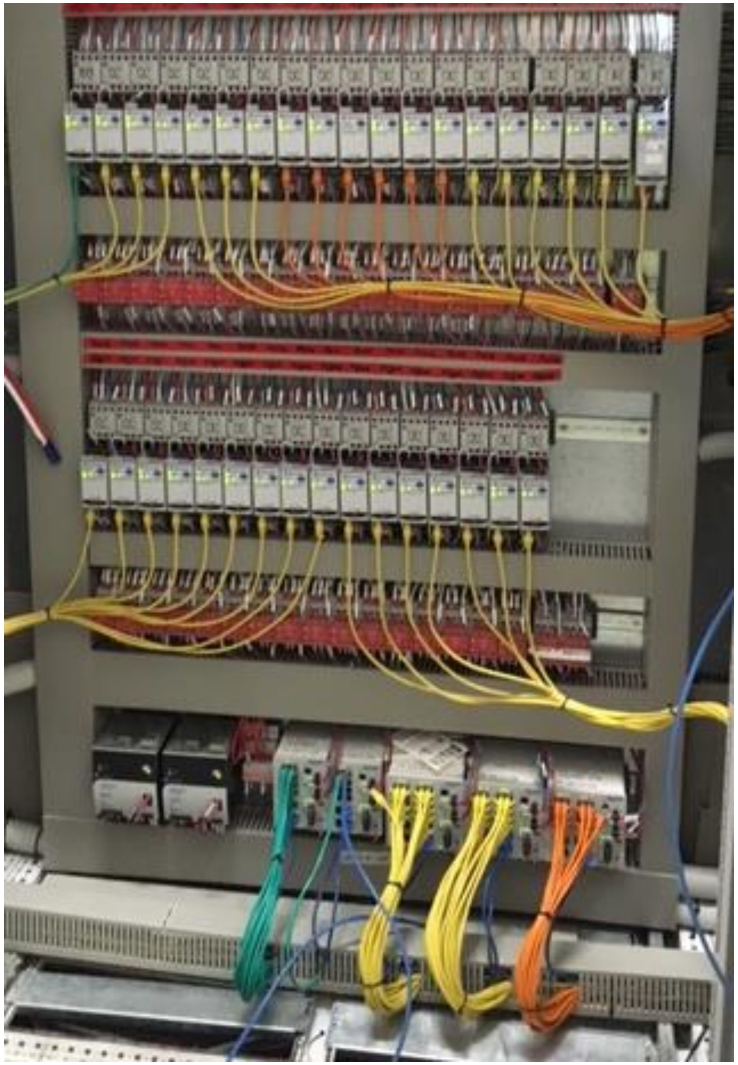
- Components are snapped into place in rows on DIN rails
- Component wiring is placed in channels
  - Load connections
  - Device power
  - Communication or wired logic

Wiring practice - discrete

- Discrete wiring is the most common practice

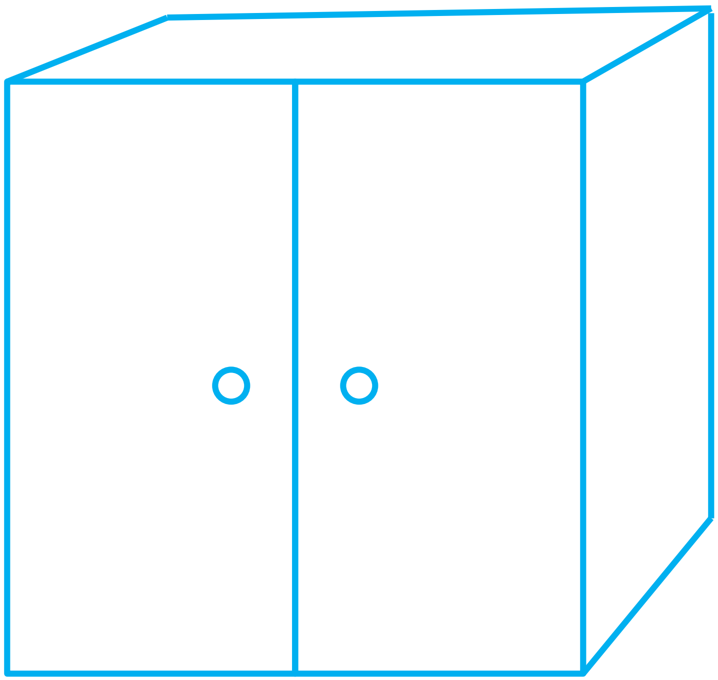
Wiring practice - networking

- High-end components have already adopted Ethernet
- For the bulk of the devices, dual-port Ethernet exceeds the cost of the discrete wired device



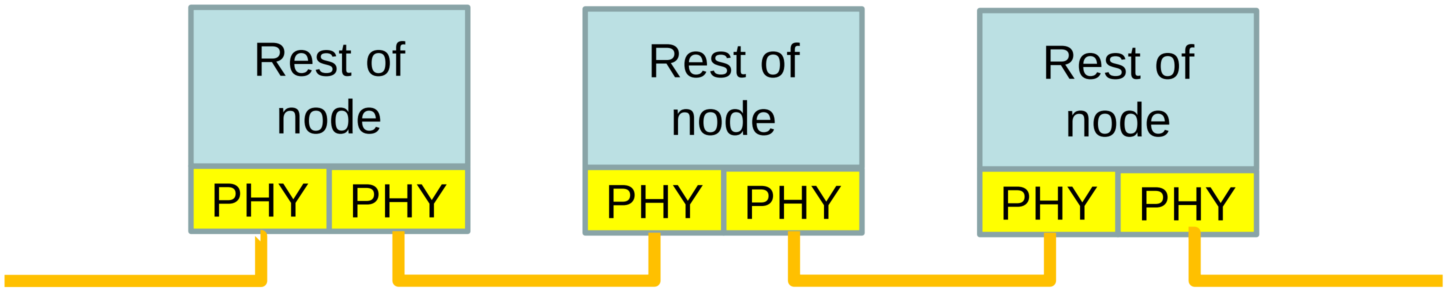
Enclosures

- Typical enclosures
  - https://www.pentairprotect.com/wcsstore/AuroraStorefrontAssetStore/UserDownloads/Downloads/Bro-00218.pdf
- Large
  - Height = 2.2 m
  - Width = 1.8 m
  - Depth = 1 m

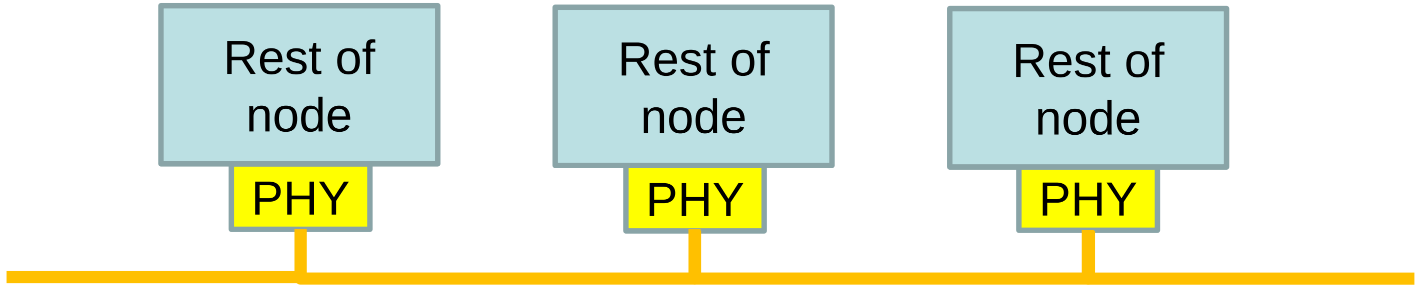


Topologies

Linear
Switched
Topology

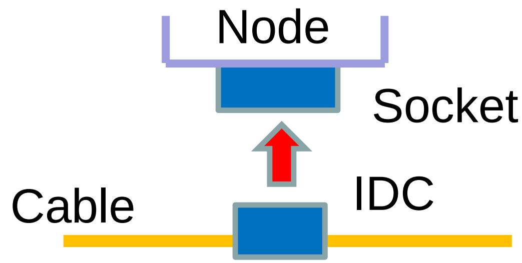


Linear
Bus
Topology



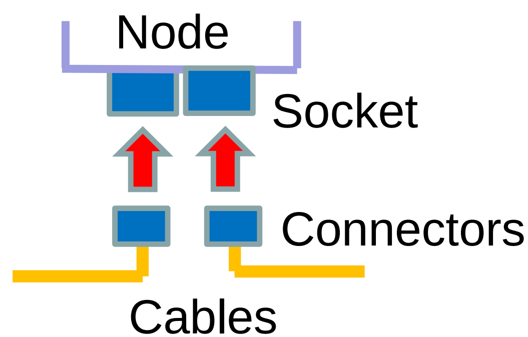
Various bus attachment methods

Insulation Displacement Connectors



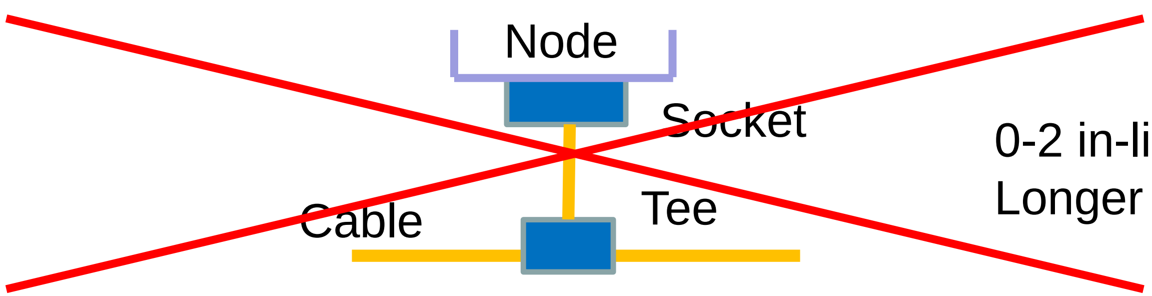
No in-line connectors
Minimal stub

Jumper Cables



2 in-line connectors
Minimal stub inside node

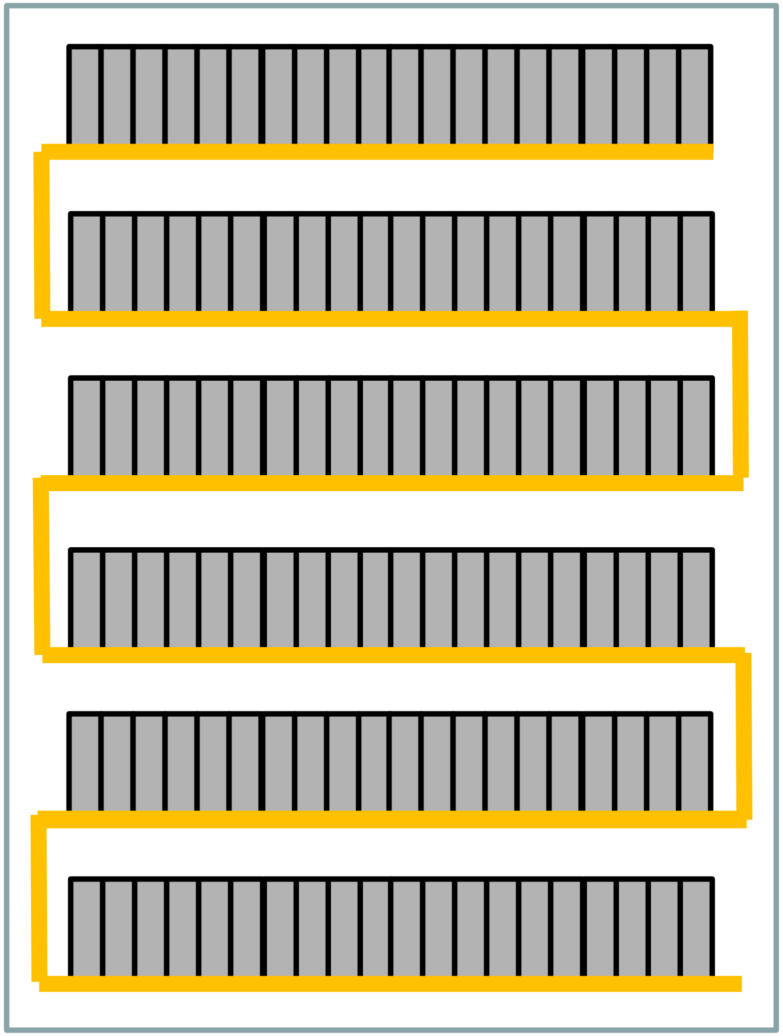
Tee



0-2 in-line connectors
Longer stubs

Estimates for linear bus topology

- A single bus covers back panel and doors
- Length
  - 6 rows @ 1.8 m
  - 2.2 m height
  - 2 m to doors + 1.8 m backtracking
  - 6 rows @ 1.8 m on door
  - Total > 27.6 m
- Nodes
  - 20 across * 5 rows
  - Total > 100 nodes



Node count – termination load

- Point-point Ethernet terminates with 50 ohms on each end
  - 1 Vp leads to 20 mA
- 8 nodes (one automotive request) leads to 160 mA
- 100 nodes leads to 2 A

- This amount of drive current becomes <u>excessive</u>

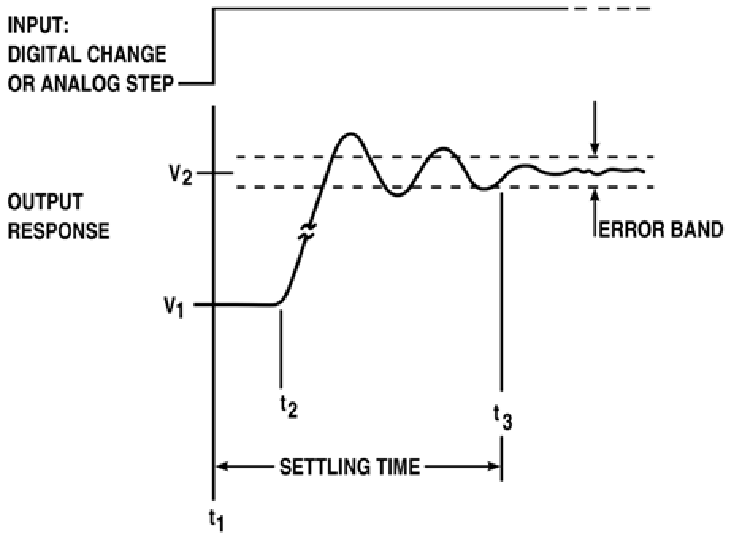
Node count - legacy solutions

- The most common way RS485, CAN, and other buses support multiple nodes is by:
  - Making the termination external
  - High impedance transceivers
    - 3-state transmitters

Unit Loads	Nodes	Value
1	32	12k ohm
1/2	64	24k ohm
1/4	128	48k ohm
1/8	256	96k ohm

Length – reflections (1)

- Rules of thumb
  - Lumped element: Ignore reflections if rise and fall times are less than the Round Trip Time (RTT)
  - Arrange termination to absorb reflections within RTT, sample after RTT



https://commons.wikimedia.org/wiki/File:High_accuracy_settling_time_measurements_figure_1.png

Length – reflections (2)

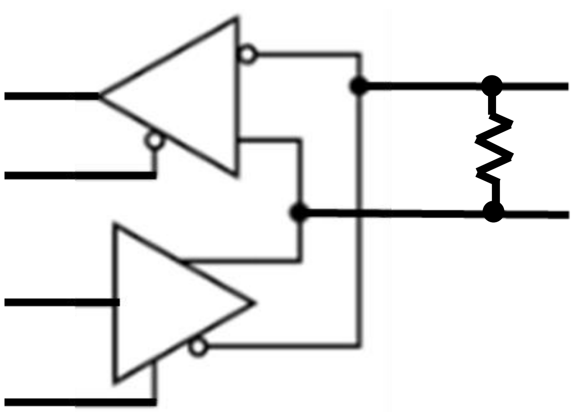
- Assume 0.66Vp or 5ns/m
- 10 M => 100 ns/bit
  - Stable sample point at 80% of symbol

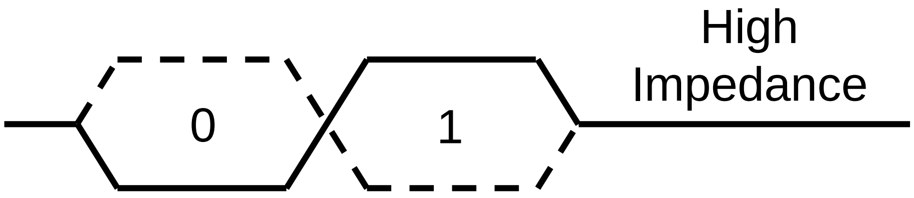
Length	RTT	Symbol period	Bits/symbol	Sample point
8 m	80 ns	100 ns	1	80-100 ns
15 m	150 ns	200 ns	2	180-200 ns
25 m	250 ns	300 ns	3	280-300 ns
30 m	300 ns	400 ns	4	380-400 ns

- Best solution is to pick a topology that minimizes reflections and then to tolerate them

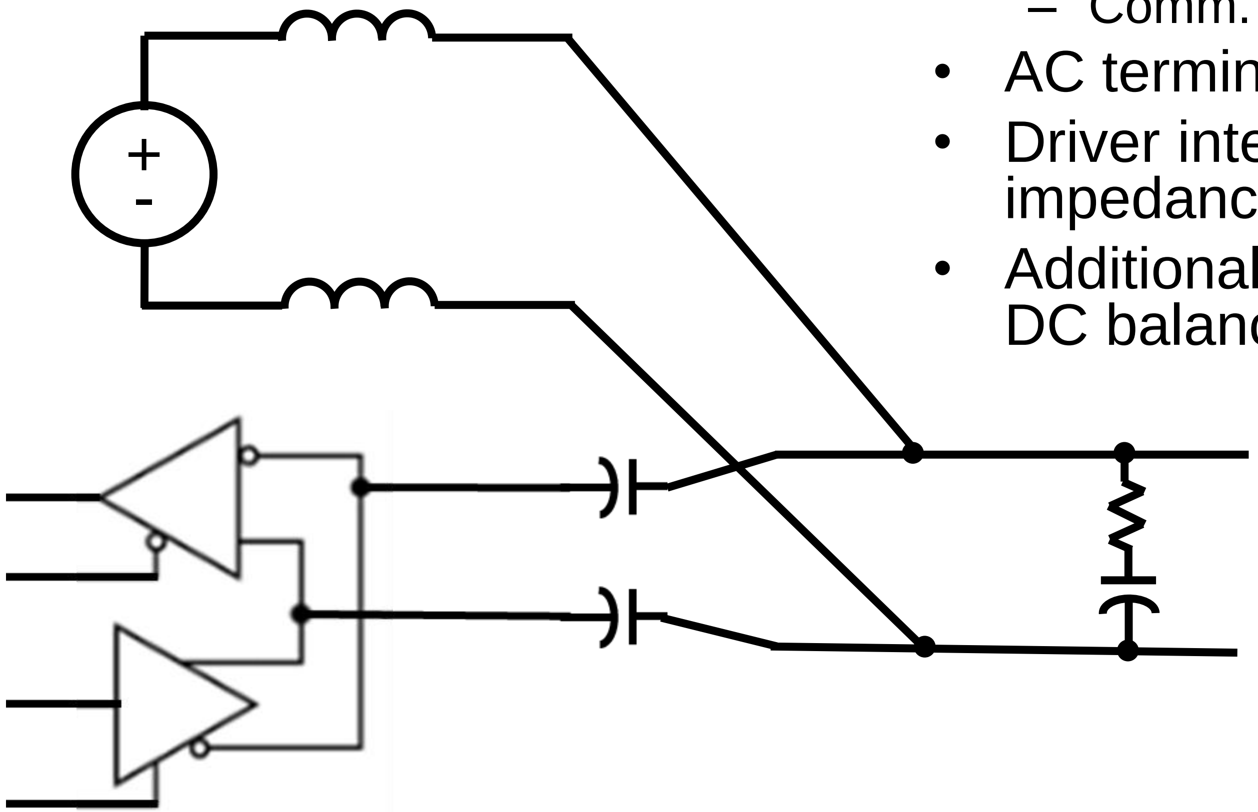
Line interface - typical

- Differential driver and receiver
- Impedance of 60 Ω to match midline connection of 120 Ω in each direction
- Referenced to a local power supply
- Normally DC coupled to line
- Limited common mode range





Line interface - power



- AC coupling for optional power
  - Comm. isolation
- AC termination
- Driver internal impedance of 50 Ω?
- Additional encoding for DC balance

Line interface - polarity

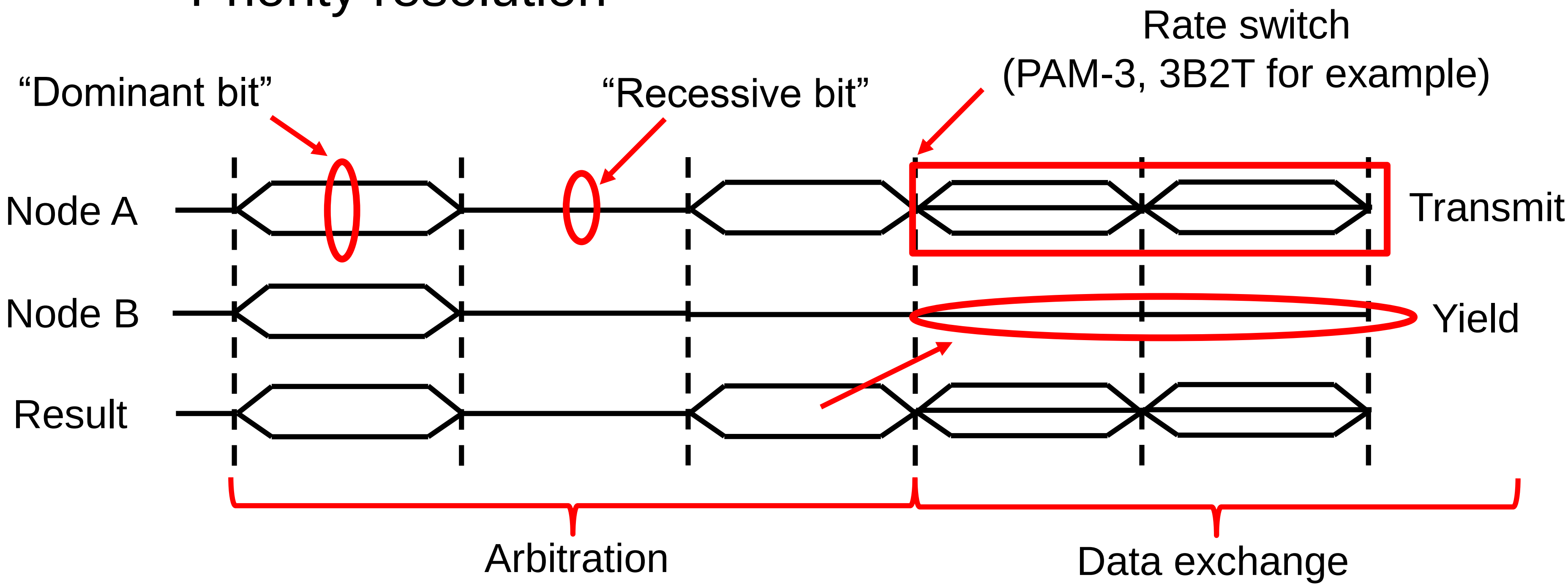
- Possibility of polarity insensitivity
  - Communication depends on signaling method
    - Limits access methods
  - Power requires diode bridge
    - Adds loss

Collision management (1)

- CSMA/CD
  - Random backoff issue
  - Legacy question
- EPON-derivative
  - Complexity
  - Requires new parts
- TSN
- Something new?

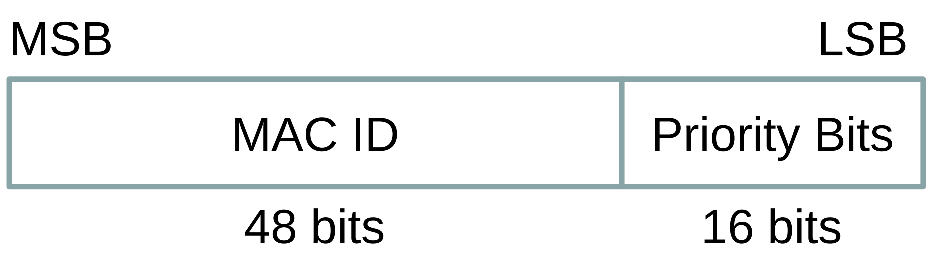
Collision management (2)

- CAN-like method?
- Non-destructive bit-wise arbitration
  - Random access
  - No collisions, no loss, no random backoff
  - Priority resolution



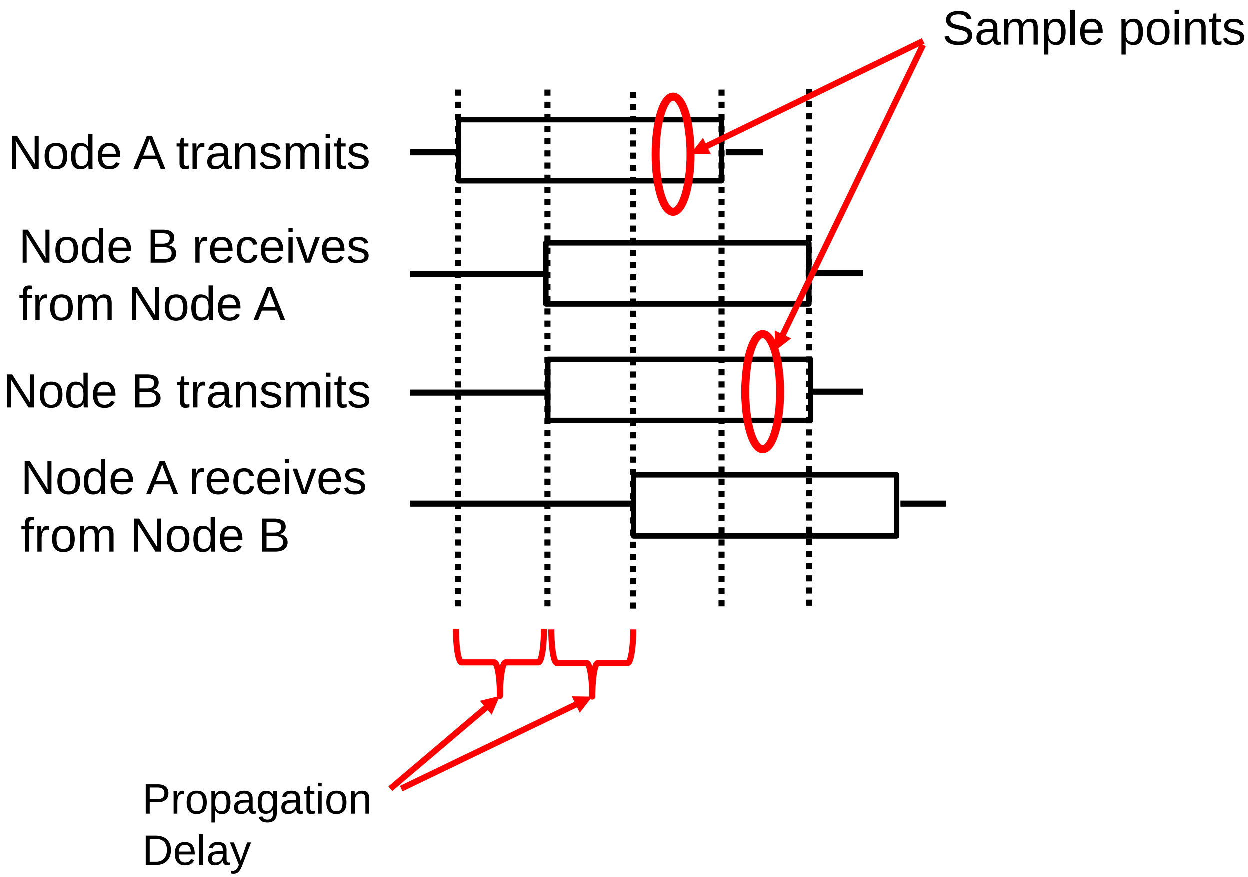
Collision management (3)

- CAN-like method?
- Arbitration ID
  - Priority bits sent first
  - MAC ID is a tie breaker in case of matching priority (avoids collisions)



Collision management (4)

- Timing for 2 nodes at far ends of channel



Collision management (5)

- CAN-like method?
- Issues:
  - Polarity is fixed
    - Requirement?
  - Adds access delay
    - 64 bits => 6.4 us

TSN compatibility

- A bus (like wireless) is a shared medium
  - IEEE 802.11v provides an example of accurate time synchronization
- Each node has the ability to queue packet delivery and support
  - 802.1Qbv Scheduled Traffic
  - 802.1Qbu Frame Preemption

Conclusions

- In-cabinet industrial automation applications could benefit from a multi-drop Ethernet option
- Technical solution could draw from and extend existing techniques
  - Challenges exist – especially reflections