Topology Discovery
Feature for 10BASE-T1S Multi-Drop Networks

A method for locating and enumerating potentially identical devices without pre-installed configuration

IEEE-SA Ethernet & IP @ Automotive Technology Day

November 2022

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Agenda

- Problem statement
  - How to unambiguously identify identical nodes on a multi-drop network?
  - Why is it important?
- Typical use cases for Topology Discovery
  - Examples
- How Topology Discovery works
  - Technical details
- Measurements & Results
- Conclusions

Outline

- 10BASE-T1S brought multi-drop back to the Ethernet world
  - one single-pair cable connecting multiple devices
  - only one PHY per device
  - no need for large switches or gateways to bridge other IVN technologies
  - real-time performance (PLCA)
  - a big saving in system costs and power compared to P2P
- Multi-drop also brings in new challenges, like assigning addresses, IDs, and roles to identical nodes
  - e.g., IP numbers, PLCA IDs, or even MAC addresses
- In P2P, a device location is known from the switch port it is connected to
  - but what about multi-drop?
- That is where the Topology Discovery feature comes in handy!

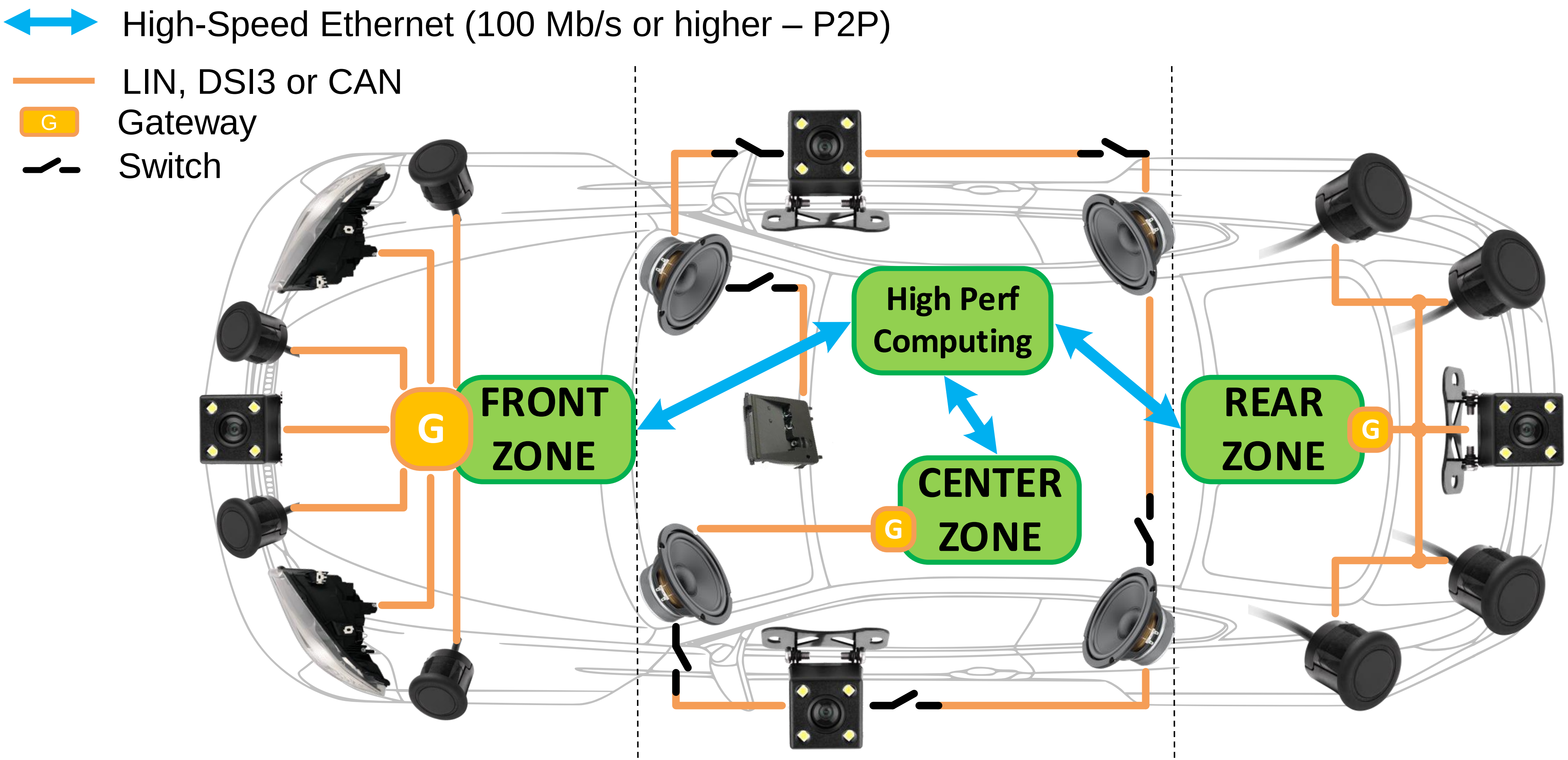
Use Cases

Examples

Basic Examples

- Example #1: car assembly
  - install identical radars on the same bus line
  - later, have the SW automatically assign their roles based on position
- Example #2: servicing the car
  - replace or add a device by picking a new part out of the box
    - no need to pre-configure the device
  - press a button and have the SW configure the new device based on its position
- Avoid error-prone procedures
- Save time → save money!

Existing addressing solutions



Hardware solution using point to point

Daisy chain with switches (or equivalent) at each node

Proprietary solutions, often requiring additional hardware and software

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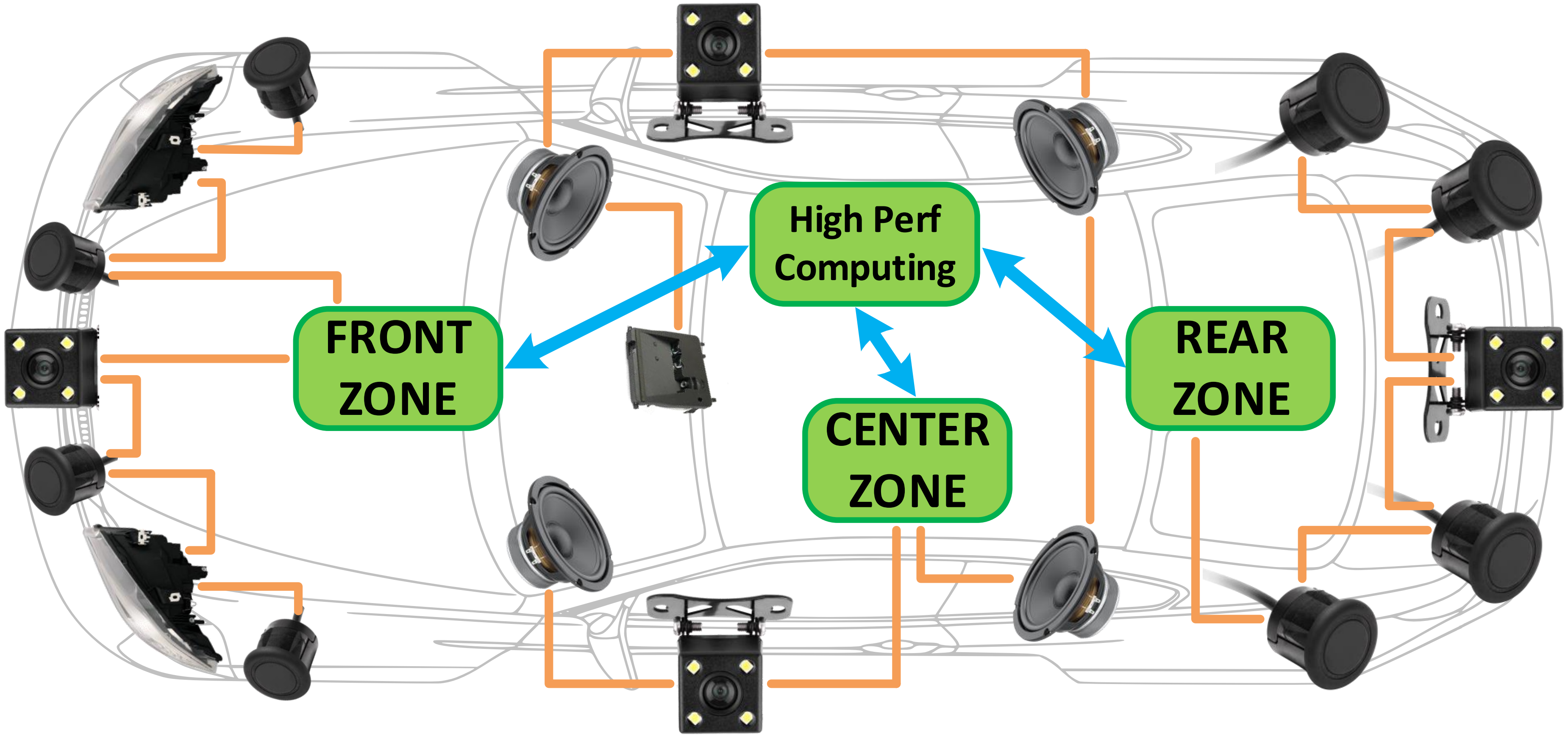
Topology Discovery Solution

High-Speed Ethernet (100 Mb/s or higher – P2P)

10BT1S network (Daisy Chain)

NEW



- Yields the same benefits as the “daisy chain” sequential startup, without extra cables/switches
- Measuring node position with high accuracy (less than ± 5 cm)
- Full Ethernet solution: standard, no need for gateways or extra cables

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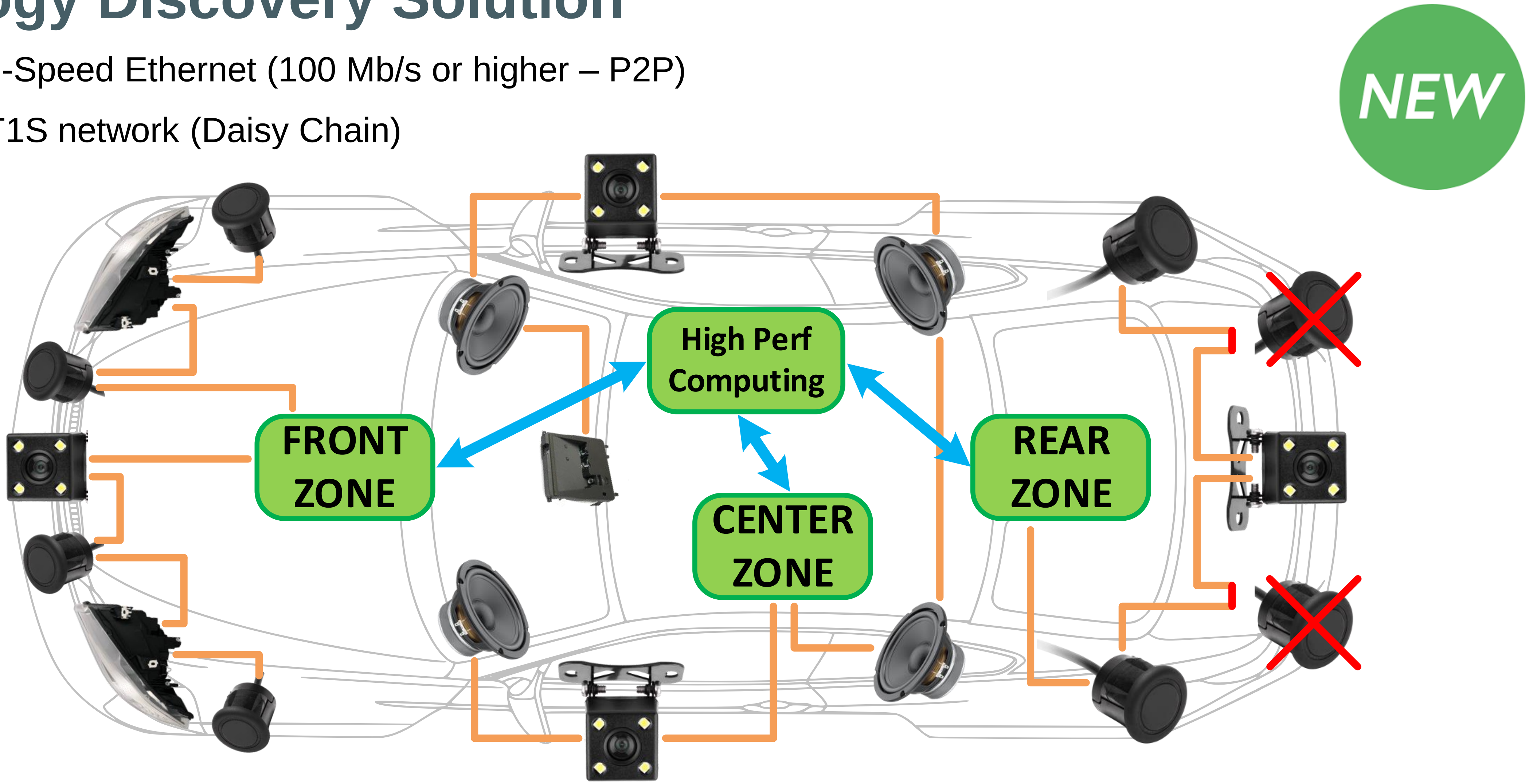
Topology Discovery Solution

High-Speed Ethernet (100 Mb/s or higher – P2P)

10BT1S network (Daisy Chain)



- Enables network flexibility and scalability by distance measurement compared to sequential node ID assignment (allows removing or adding nodes without side effects)

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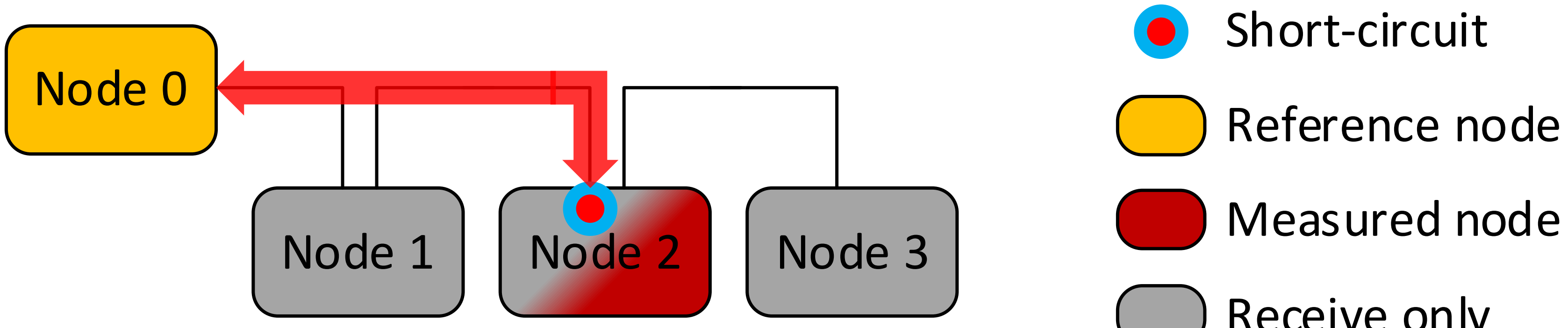
How Topology Discovery Works

Technical Details

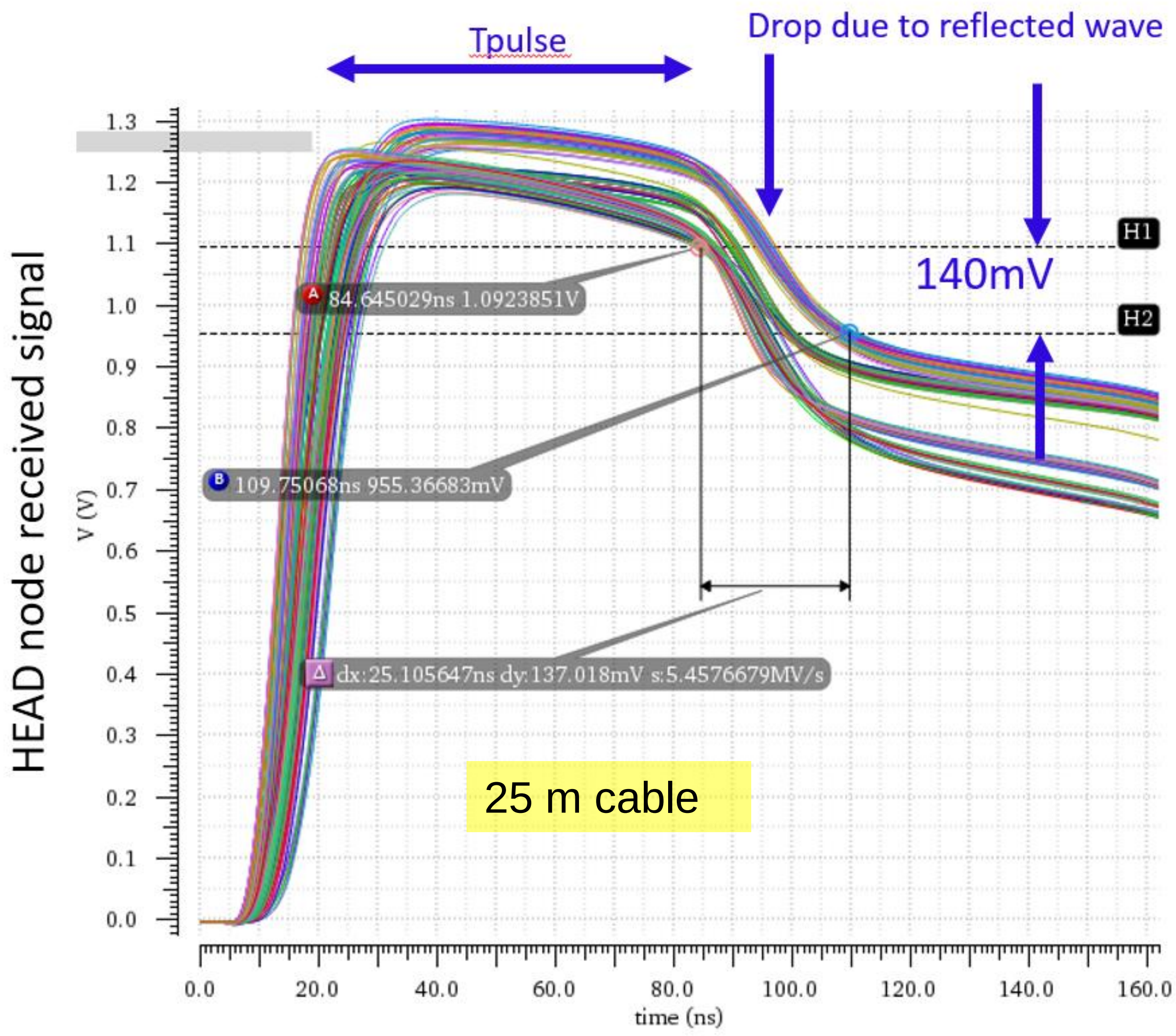
Can TDR work on a multi-drop bus?

- Traditionally, measuring distances can be achieved using Time Domain Reflectometry (TDR) techniques
- In multi-drop, we would need the node under measurement to create a low-impedance reflection point at the MDI



- However, on a mixing-segment the impedance seen by the incident and reflected waves (looking from/to the MDI) is not the same
  - This creates a significant attenuation of the reflected pulse, which leaves a **very low SNR margin** for measuring the round-trip time

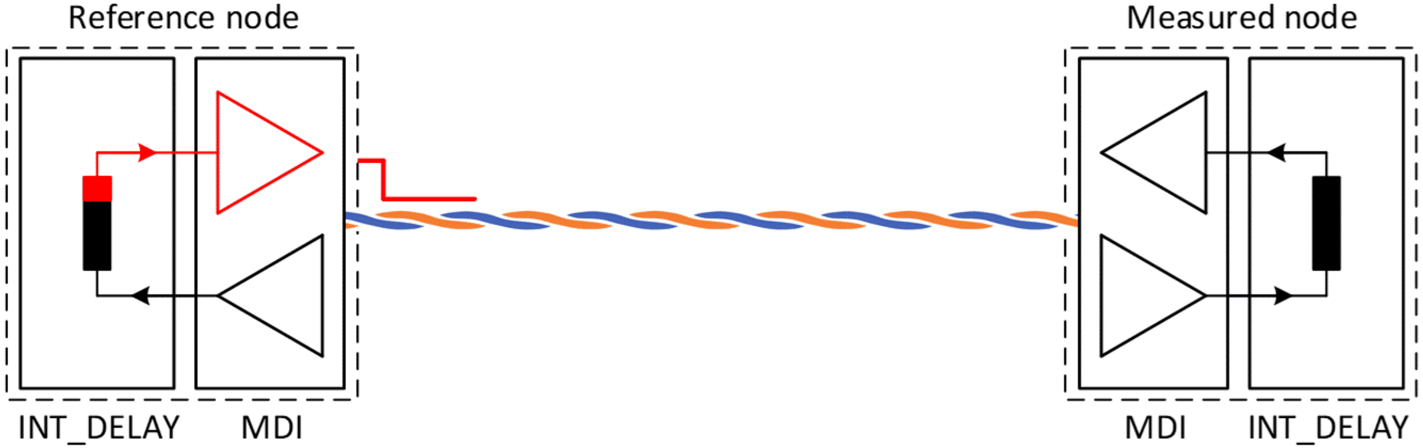
TDR simulation results



- The margin for detecting the reflected wave may be very low
- The impedance mismatch also creates multiple reflections and ringing that further decrease the SNR
- Creating a short circuit at the MDI creates additional challenges when the common-mode disturbance is significant (e.g., during a BCI/DPI test)
- TDR usually implies the use of high-speed ADCs and fast/precise clocks → cost increase

Topology Discovery – Distance measurement

- Transponder solution (reuse of existing blocks → same EMC performance as DATA)
- Measurement is done between two nodes at a time: reference (R) and measured (M)
- Pulses are sent back and forth (ping-pong) for a predefined time (TMEAS), and the number of received pulses (NPULSES) is counted



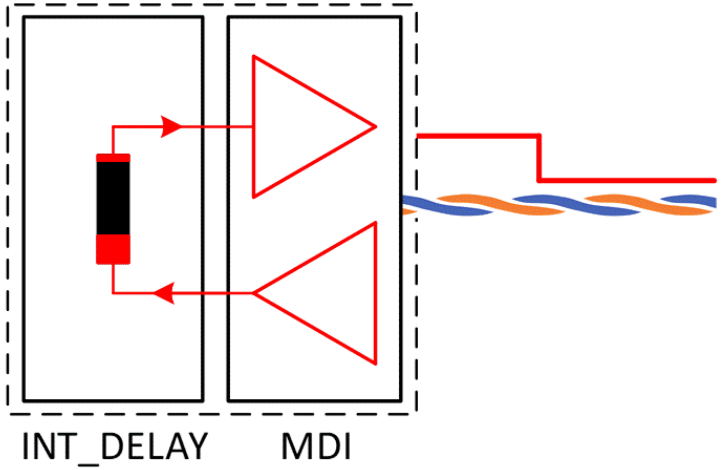
$$t_P = \frac{1}{2} \cdot \left(\frac{TMEAS}{NPULSES} - INT\_DELAY_R - INT\_DELAY_M \right)$$

- To calculate the propagation delay of the line (t_P), we need to know the duration of the internal delay (INT_DELAY)

Topology Discovery – Internal delay measurement

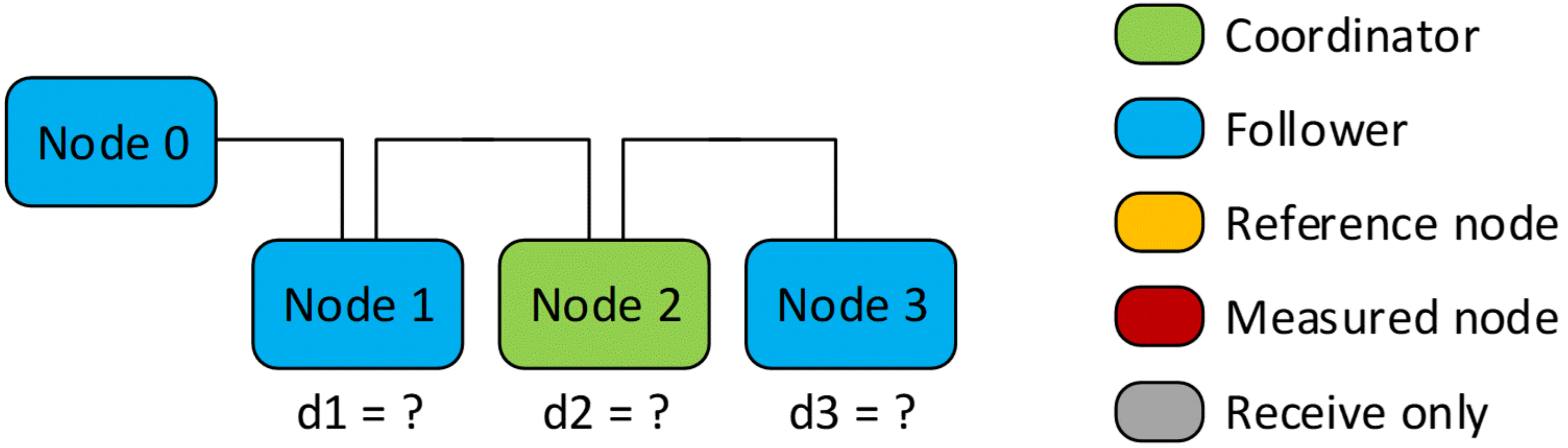
- Re-use of the distance measurement principle
- For a predefined period, each node in turn sends pulses repeatedly while receiving them back in a loop
- The number of received pulses is proportional to INT_DELAY
  - INT_DELAY must be longer than the maximum pulse width
  - There is no need for the nodes being measured to report their INT_DELAY back to the reference node (automatic mode)

$$INT\_DELAY = \frac{TMEAS}{NPULSES}$$



Topology Discovery – Procedure (Example)

- The reference node puts the network into topology discovery mode using normal data communication, having all nodes go into “receive-only” mode
- Each measured node, in sequence:
  - initiates INT_DELAY measurement (upon request)
  - enters transponder mode for looping back the pulses
  - goes back to receive-only mode

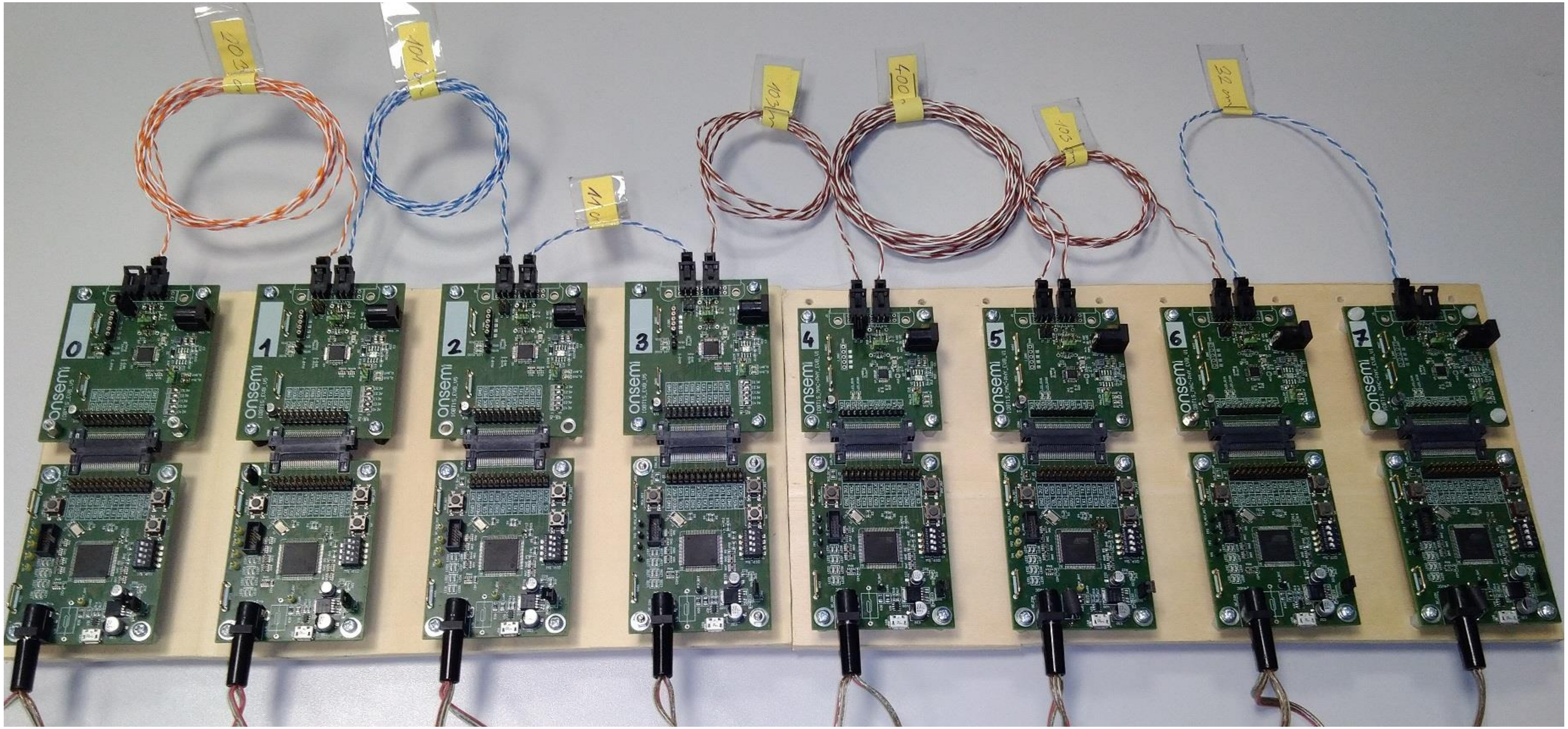


Measurements

Results

Measurement - Setup

4 PHY and 4 MAC-PHY devices connected via cables of different lengths



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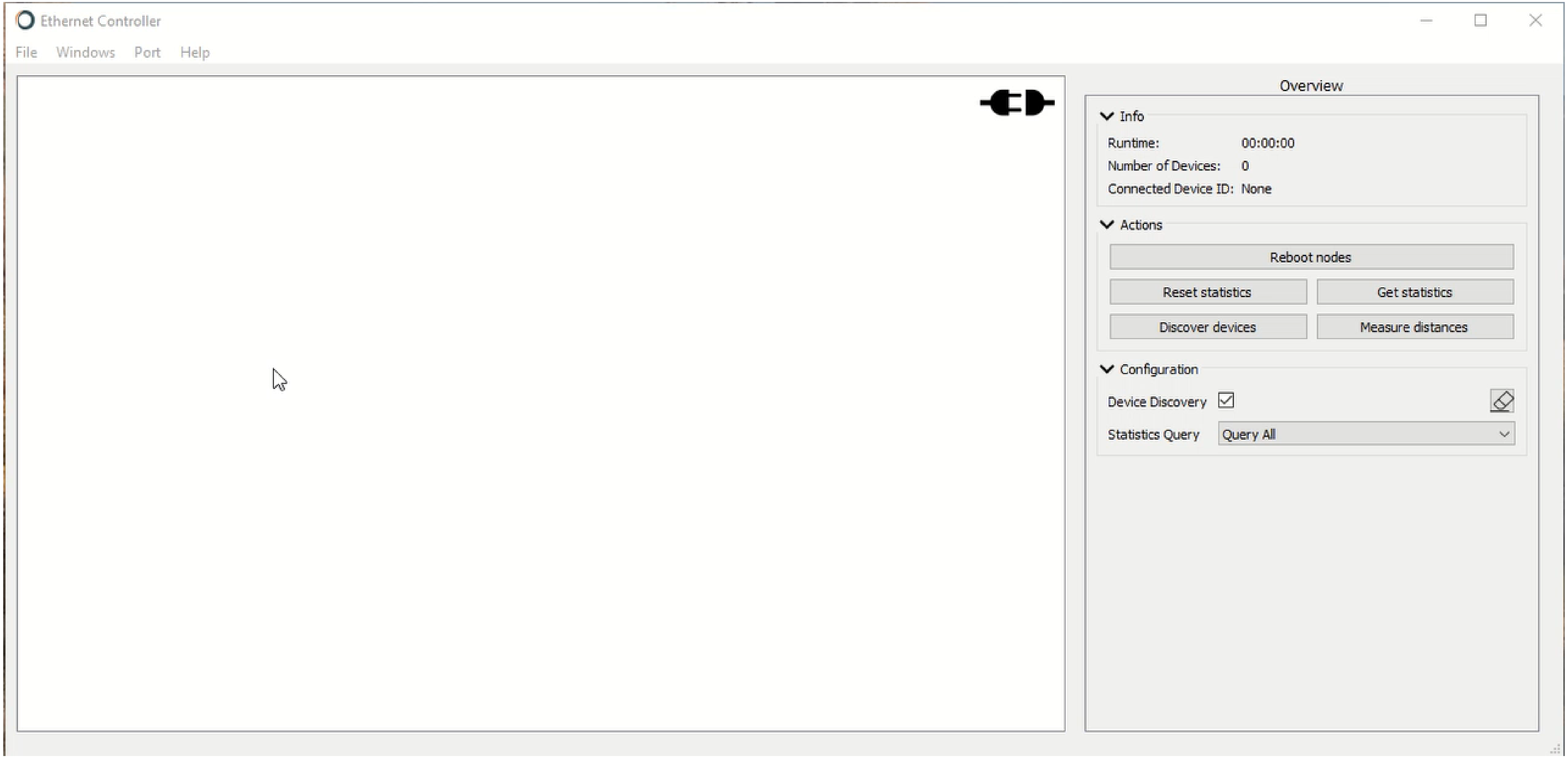
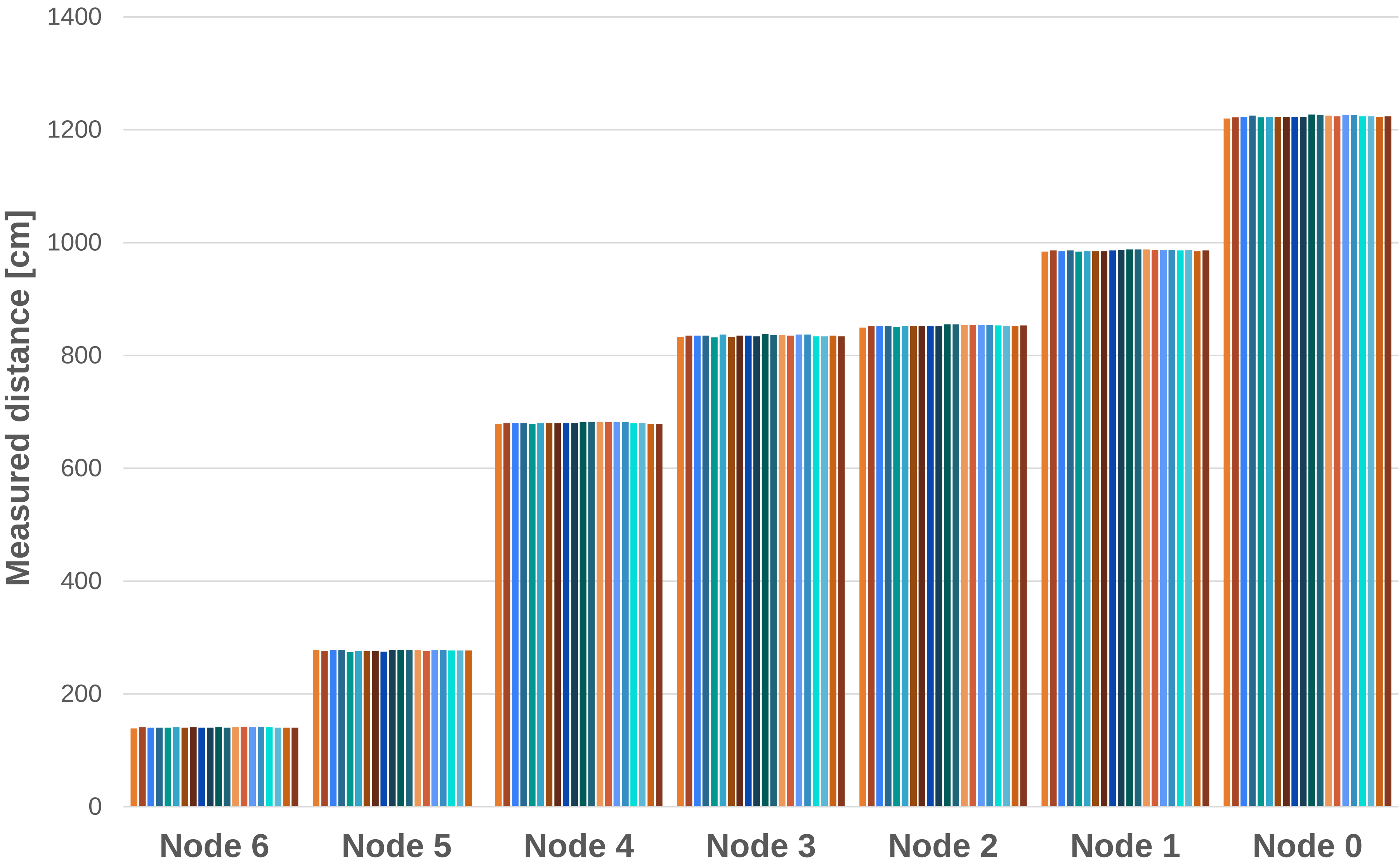
Measurement – Video



Repeatability of the measurement

20 measurements in a row, 4 different MAC-PHYs used as the reference node



Node	Max. Δ [cm]
6	3.1
5	4
4	3.1
3	6
2	5.6
1	4
0	7

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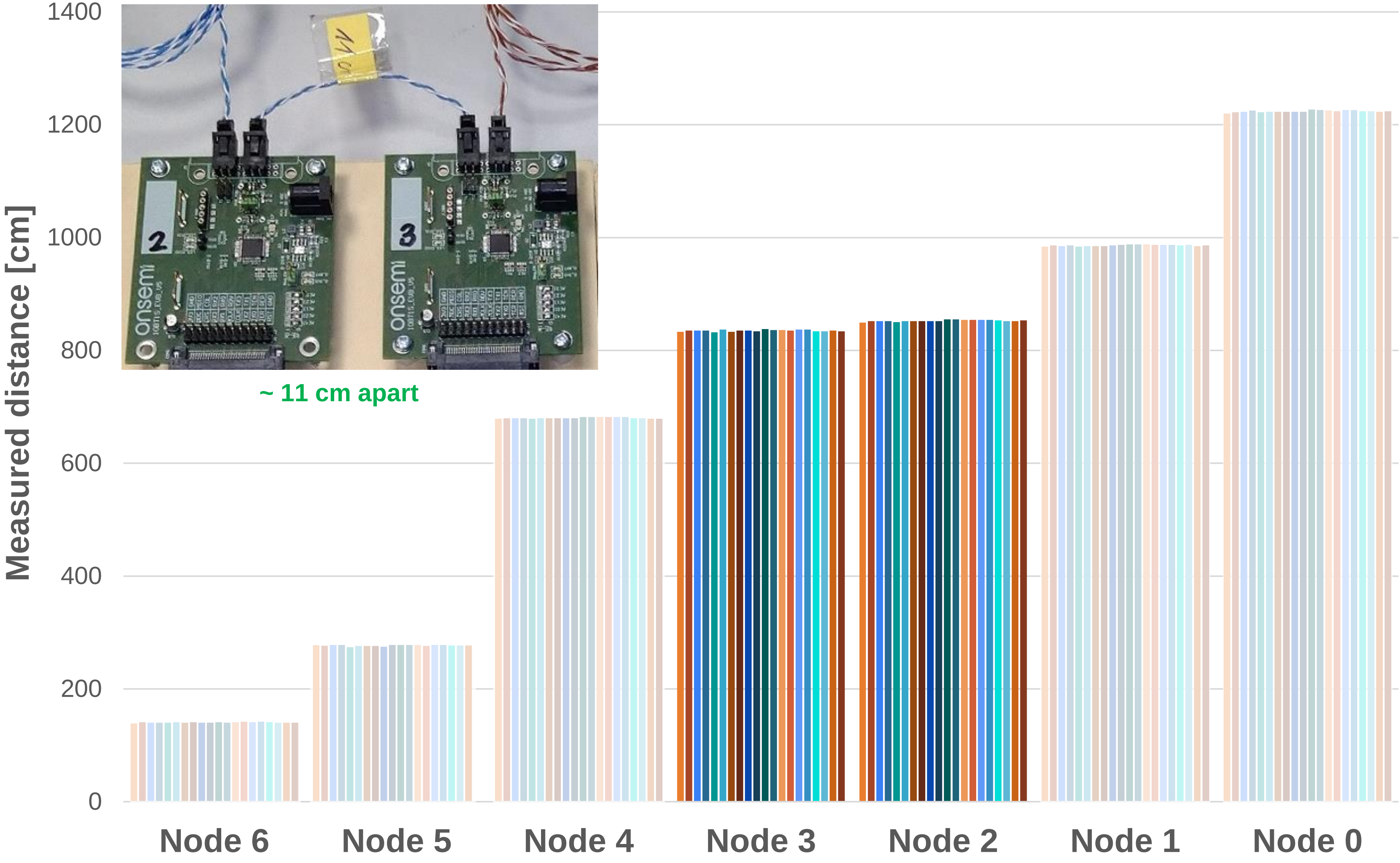

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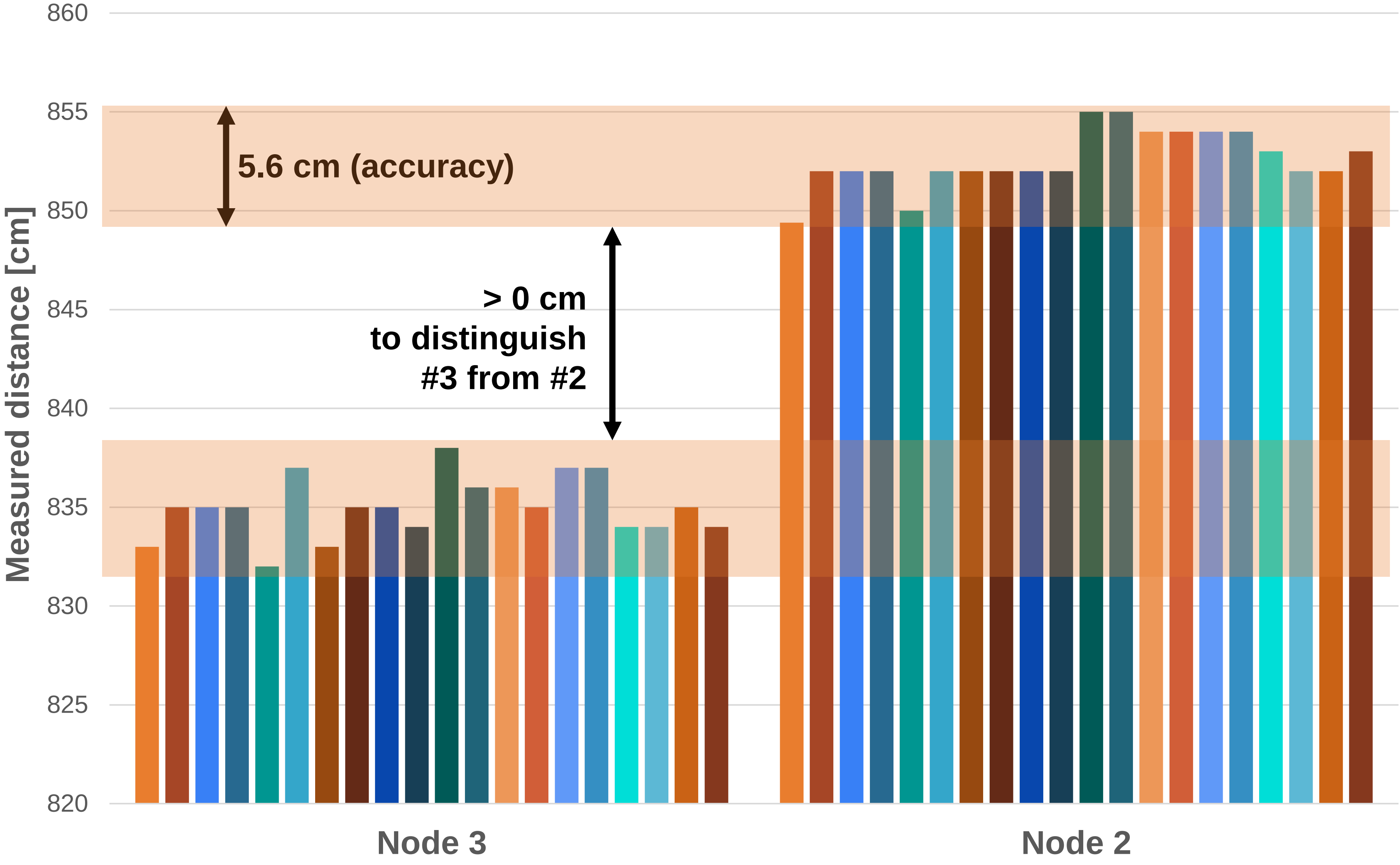

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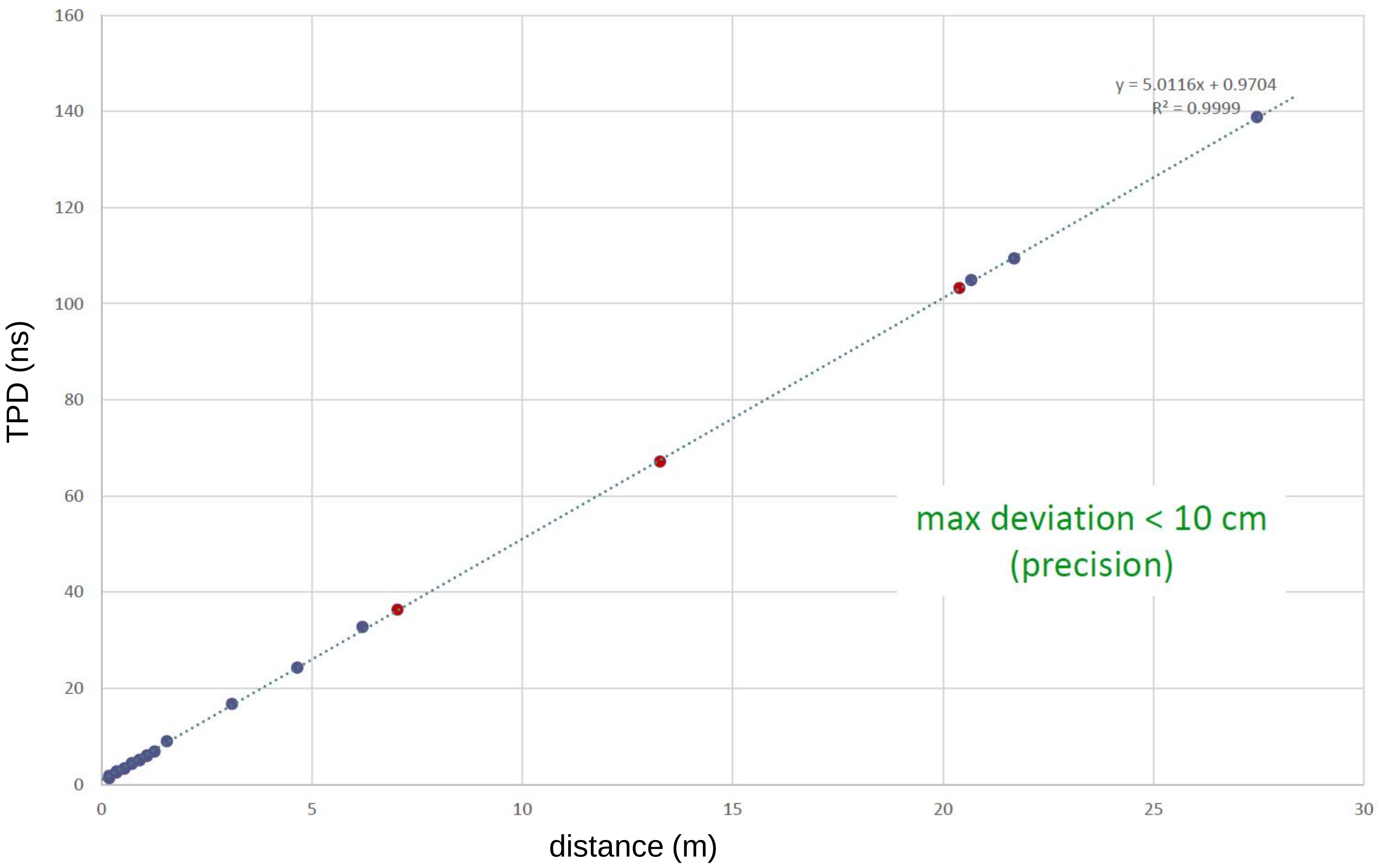
Linearity

8 nodes network (different setup)



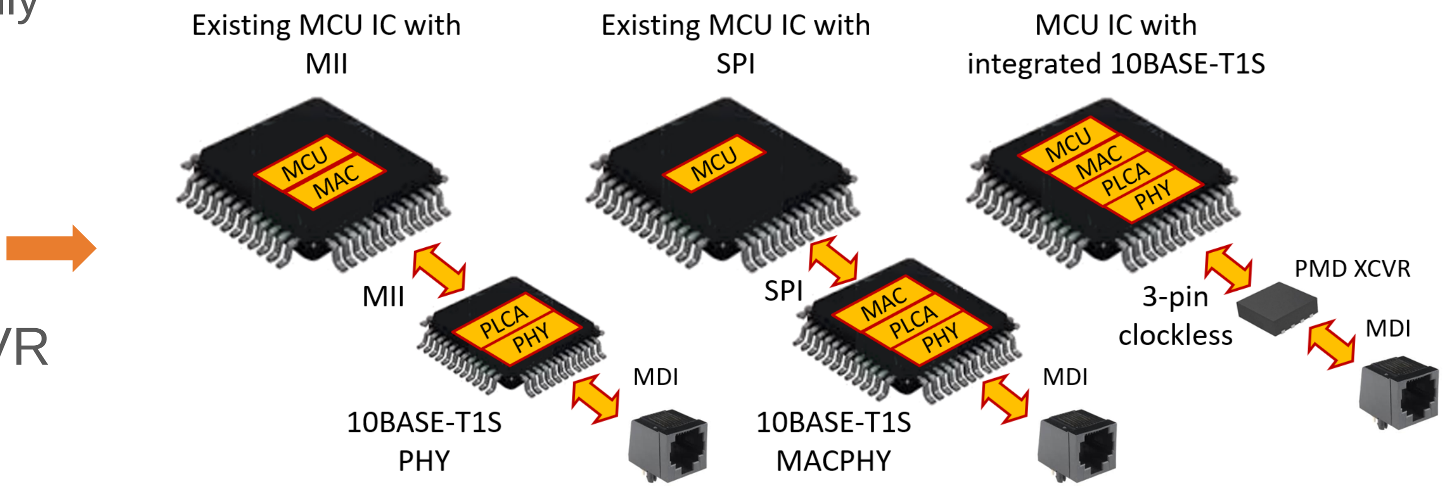
- multiple nodes in various configurations
- 7, 13, and 20 m “axon” +
  - 8P, 1.2 m
  - 5P, 4.5 m
  - 2P, 16 cm stub

Picture courtesy of Canova Tech

Conclusions

Conclusions on Topology Discovery

- Allows detecting the position of nodes connected on a multi-drop bus
  - measuring the distance between nodes with an accuracy of less than ±5 cm
- Standardized in OPEN TC14 to guarantee interoperability
- Significantly reduces system costs (e.g., no large switches or gateways)
- Flexible and scalable solution
  - you can add or remove nodes dynamically
- Works with all three flavors of T1S
  - Classic MII PHY
  - MAC-PHY with SPI interface
  - 8-pin and 14-pin PMD CAN-like XCVR
- Proven by real measurements
- Opens the door for additional use cases



Q&A

Thank You!

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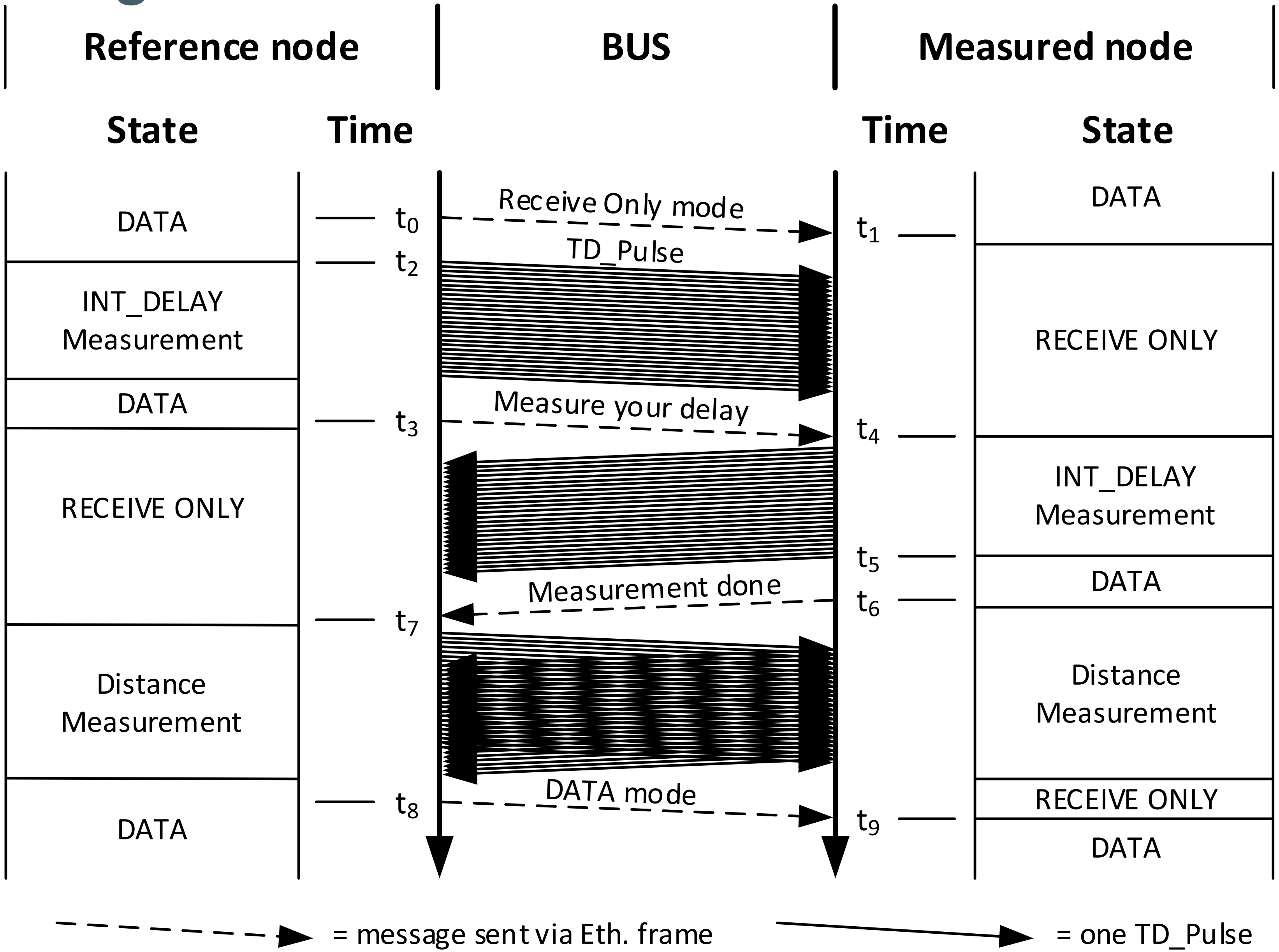
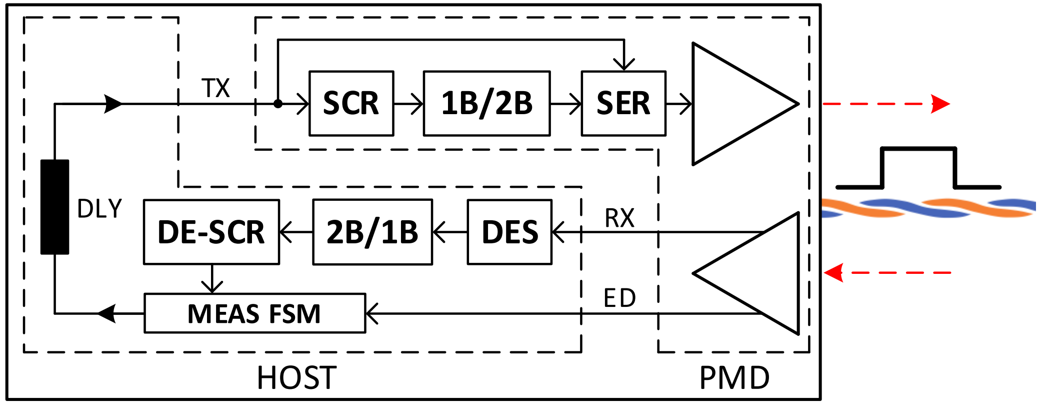
Sequence diagram

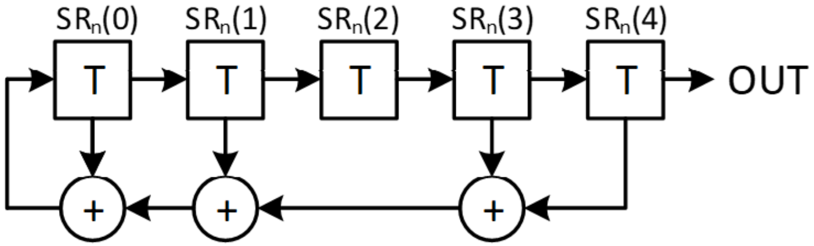


Topology Discovery – Scrambler

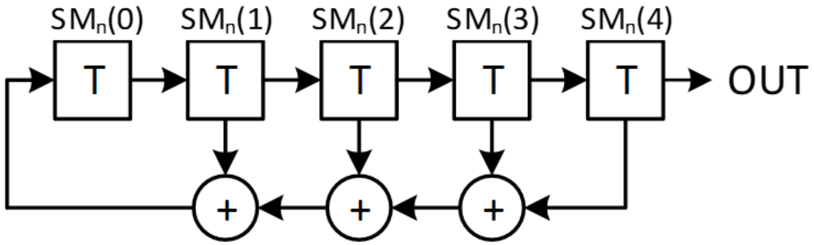
- A specific sequence of pulses polarity allows validation of the measure
  - the receiver expects a specific sequence that breaks if “alien” pulses hit the line
- The polarity of pulses defined by the output of the scrambler and 1B/2B coding
- The scrambler is updated once every two transmitted pulses
- The descrambler checks the polarity of the received pulses vs the defined polynomial

Reference / Measured node





Additive scrambler - Reference node



Additive scrambler - Measured node

Scrambler 1B/2B encoding

Scrambler output [B]	Transceiver output [B]
1	{-1, +1}
0	{+1, -1}

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Sensitivity

short increments of the distance in between nodes