2023 ODVA

Industry Conference and 22nd Annual Meeting

Expanding Constrained EtherNet/IP to On-Machine Sensors

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Self-Claim

- All concepts presented here are research outcomes, shall not be directly used or interpreted as recommendations for product implementations.

- The concepts might be good or bad. We present concepts here to spur discussions and further work on the topic.   It is up to the community here to determine the good or bad in the end.

Abbreviation and Definition

- **APL**: Advanced Physical Layer
- **DHCP**: Dynamic Host Configuration Protocol
- **DLR+**: Enhanced Device Level Ring
- **DTLS**: Data Transport Layer Security
- **HAL**: Hardware Abstract Layer
- **LLDP**: Link Layer Discovery Protocol
- **LNDC**: Linear Network Discovery and Commissioning
- **MPE**: Multiple Pair Ethernet
- **OMSPE**: On-Machine Single Pair Ethernet
- **SPE**: Single Pair Ethernet
- **SPI**: Serial Peripheral Interface

- **Compute Entity**: It is an abstract entity that could represent HMI, Workstation, Edge Device for Cloud, or alike device, which has data acquisition, aggregation, analysis, or visualization capabilities.
- **Powered SPE**: The SPE pair is also used to deliver the power to the device. The power is coupled/decoupled to/from the SPE pair with the power coupler/decoupler. It does not support power detection and classification as IEEE Power over Data Line specifies.

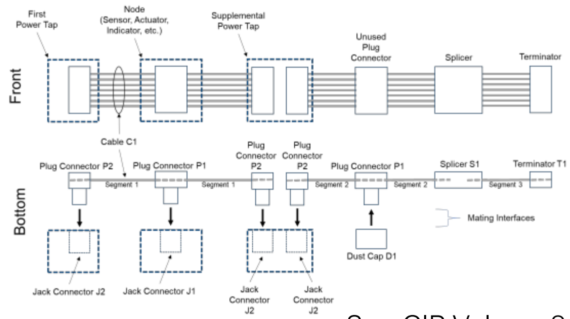
Agenda

- **Background**
- OMSPE sensor network
  - Add EtherNet/IP Connectivity to on-machine sensors
- DLR+ with LNDC functions
  - Simplify OMSPE sensor network commissioning and diagnosis
- Summary and outlook

Background

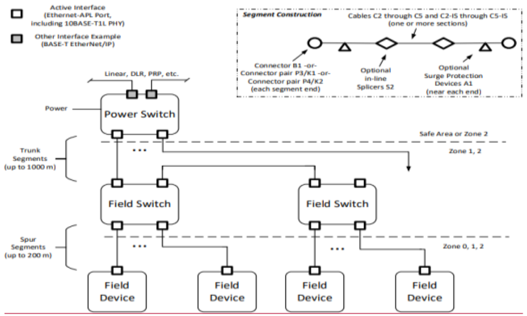
- IEEE802.3cg
  - 10BASE-T1S
  - 10BASE-T1L
- In-cabinet EtherNet/IP Usage Profile
  - Based on 10BASE-T1S Ethernet technology
  - Cost effective UDP-only EtherNet/IP device
  - Extra wires to carry device power
- Instrument EtherNet/IP Usage Profile
  - Based on 10BASE-T1L Ethernet technology
  - Star topology and powered SPE

Figure 8-10.1 In-cabinet Cabling and Devices



Src: CIP Volume 2

Figure 8-11.1 Three-tier System Overview Diagram



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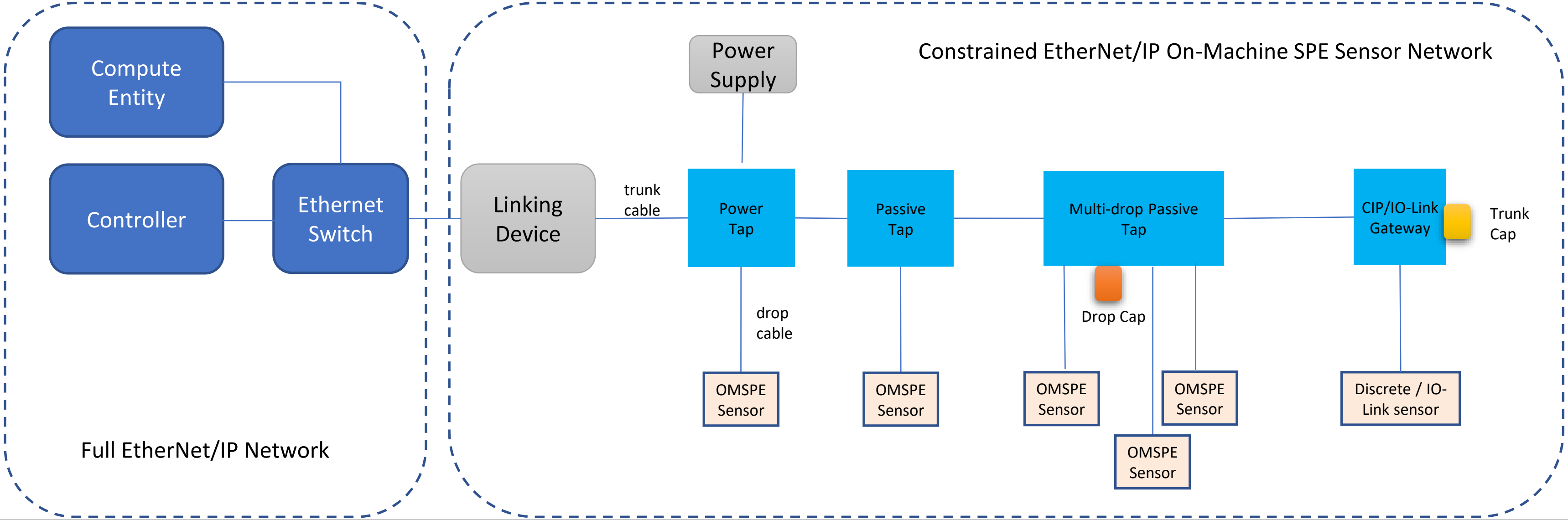
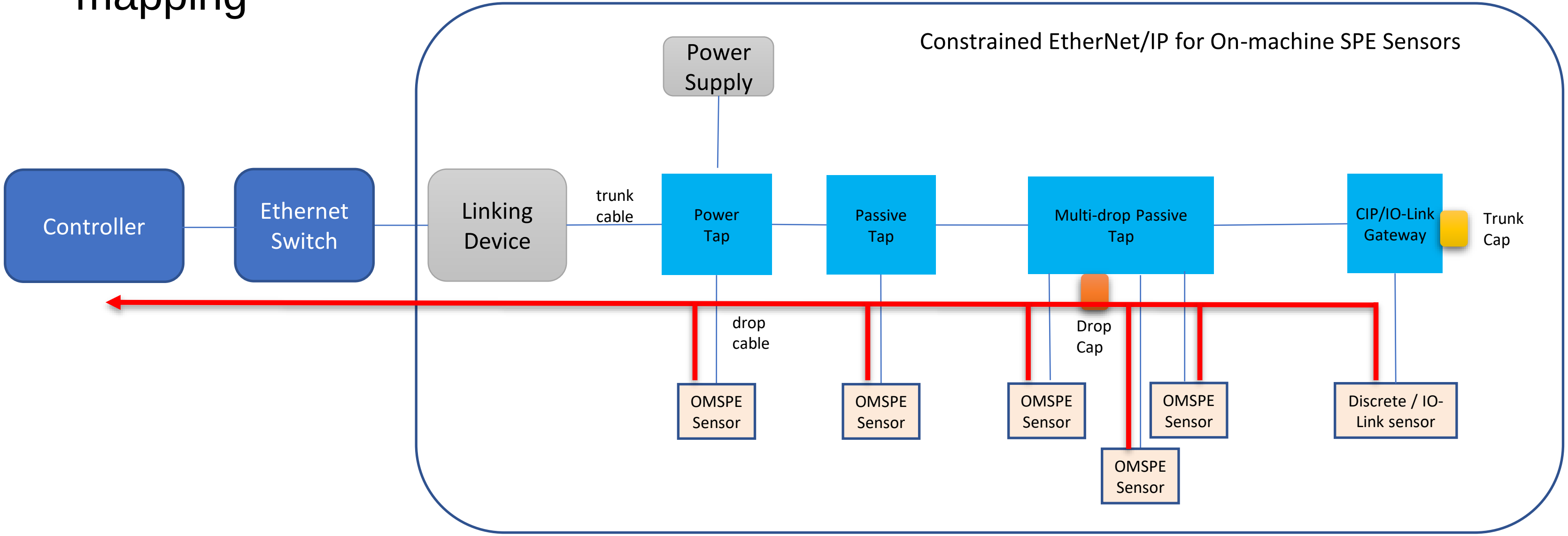
The OMSPE Sensor Network

- A further step to expand constrained EtherNet/IP to on-machine sensors
- A combination of merits of APL/T1L (powered SPE, long distance) and In-cabinet T1S (Constrained EtherNet/IP) to solve the constrained OMSPE sensor use cases



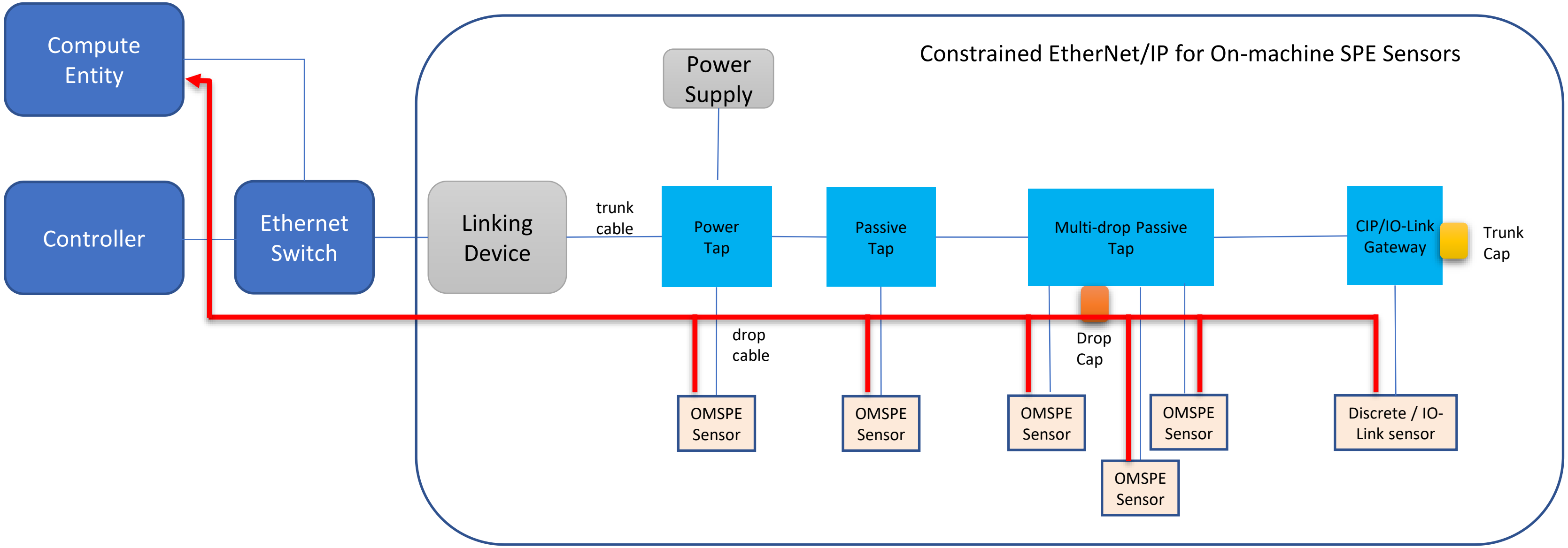
Sensor to Controller Communication

- Sensor to controller EtherNet/IP communication as part of integrated control
- Remove the complexity of the application protocol translation and data mapping



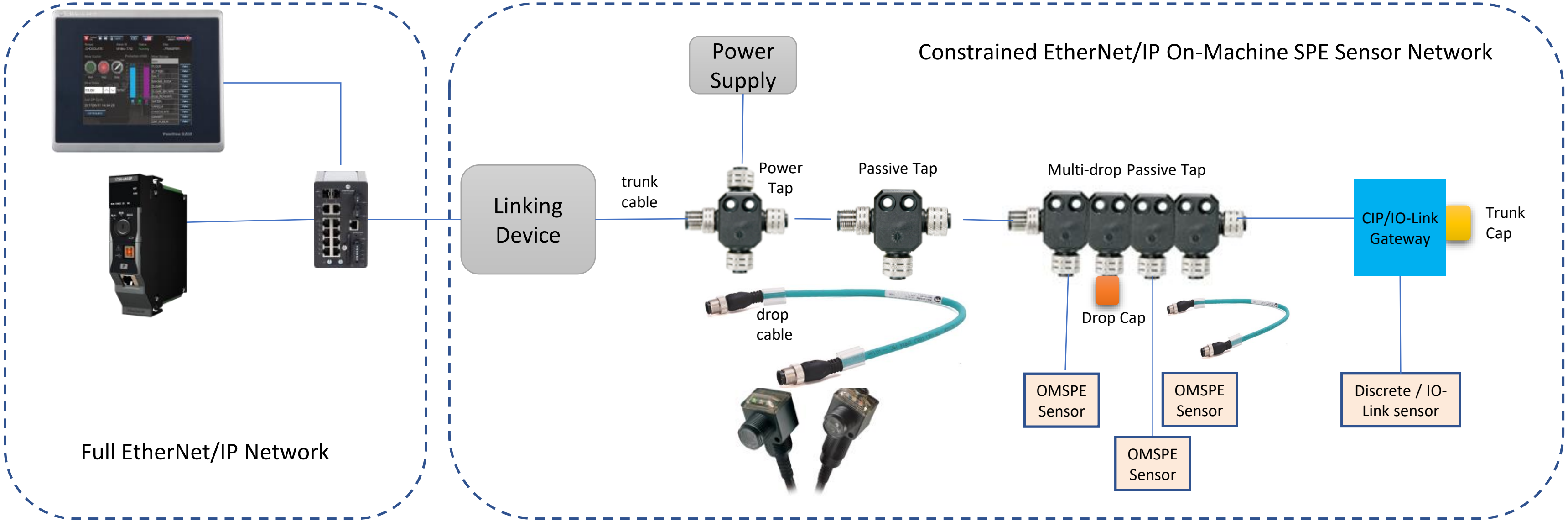
Sensor to Compute Communication

- Direct access to rich sensor information (identity, configuration, run-time data, diagnostics) enables new data analytic use cases



Main Design Objectives of The OMSPE Sensor Network

- "**Low system cost**" to be competitive on the market
- "**Ease of use**" in every stage of the network life cycle



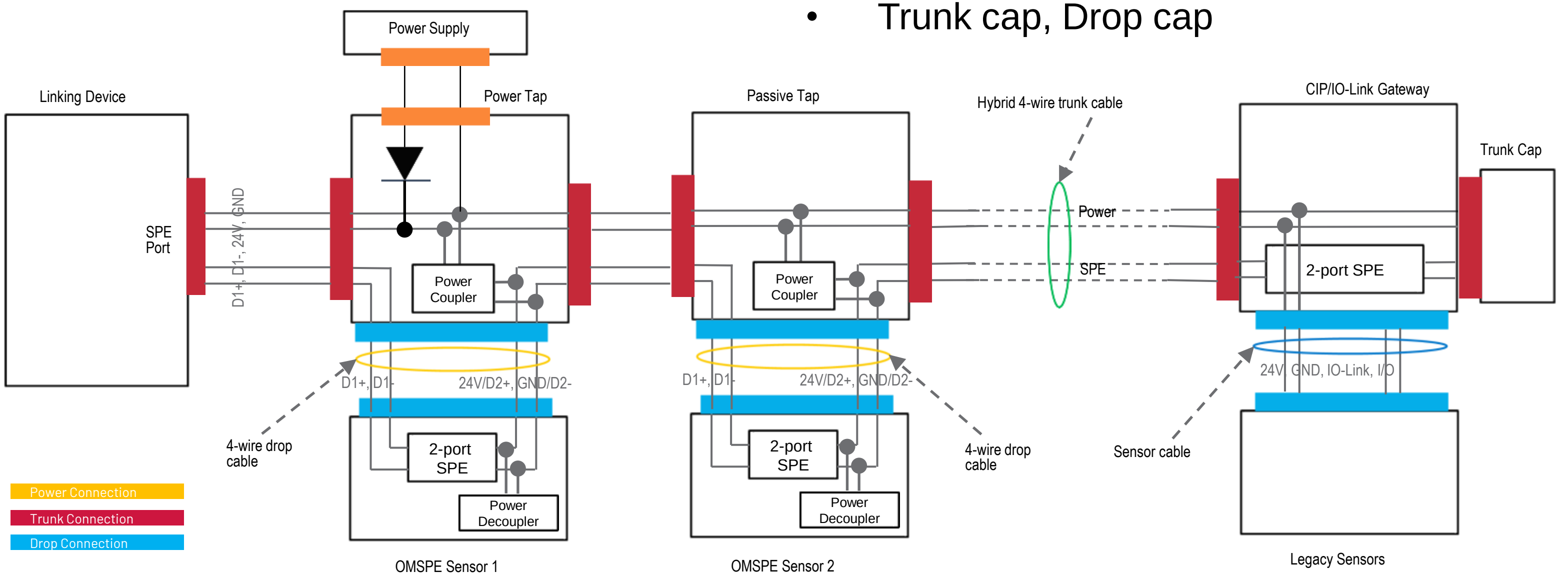
OMSPE Sensor Network Architecture

Topology

- Trunk-drop physical topology
- Linear SPE network, Bus power network

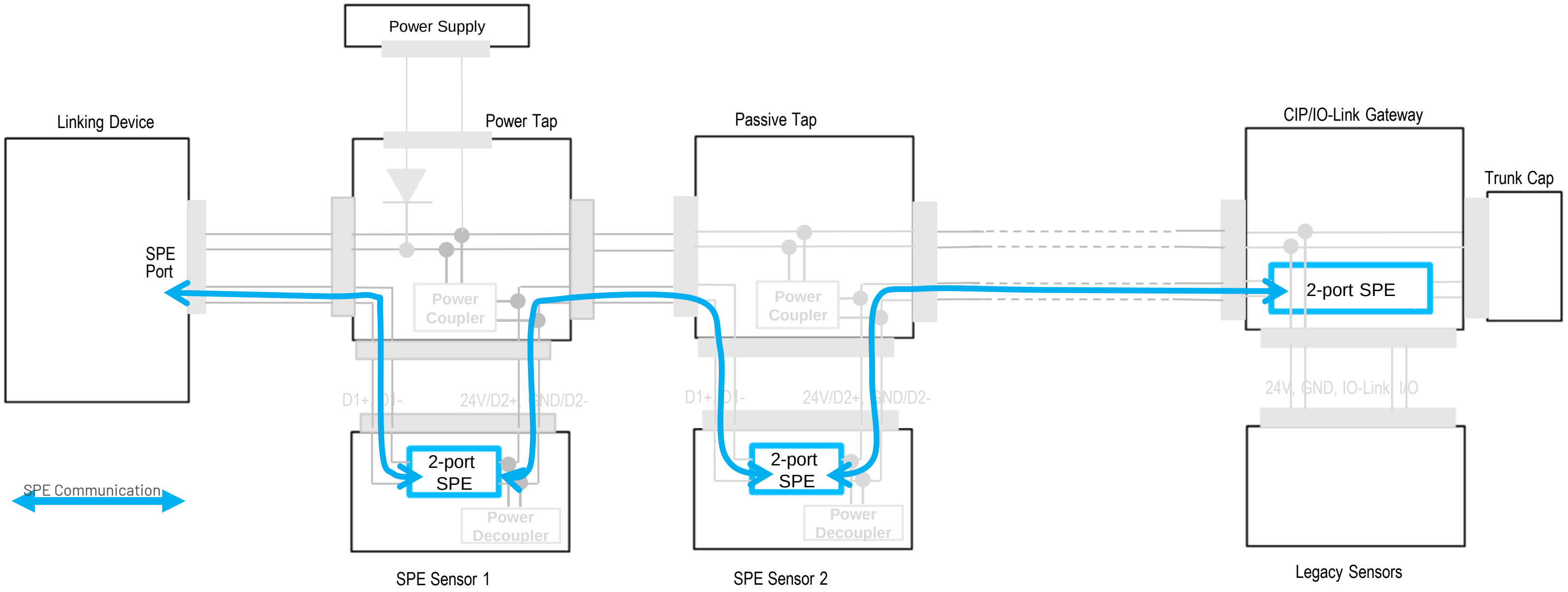
Components

- Linking Device, OMSPE Sensors
- Power Tap, Passive Tap, CIP/IO-Link GW
- Trunk media, Drop media
- Trunk cap, Drop cap



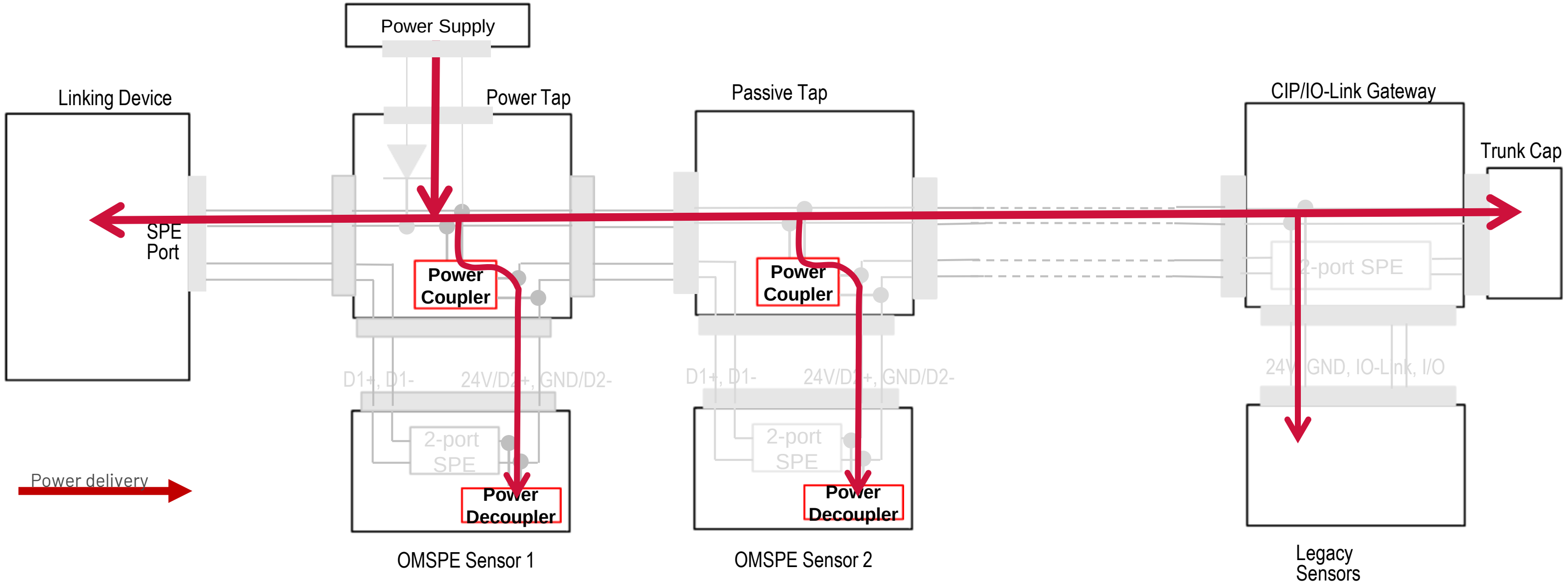
Communication Architecture

- Linear/ring SPE network
- Location-based network discovery, commissioning and diagnosis (DLR+ protocol)



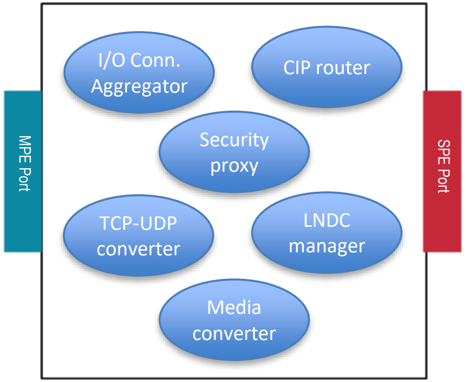
Power Architecture

- 24VDC 4A power supply, 0.5W device
- Dedicated power pair on trunk and Powered SPE on drop



Linking Device

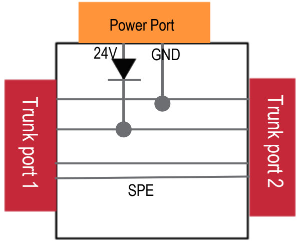
- Media converter
- LNDC manager
- TCP-UDP converter
- Security proxy
- CIP router
- I/O connection aggregator



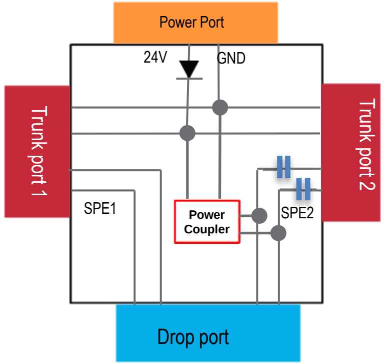
Linking Device

Power Tap

- Inject power to an OMSPE sensor network
- Allow multiple power taps on an OMSPE sensor network
- Basic and advanced Power Taps



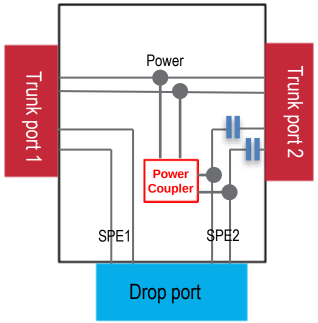
a) Basic Power Tap



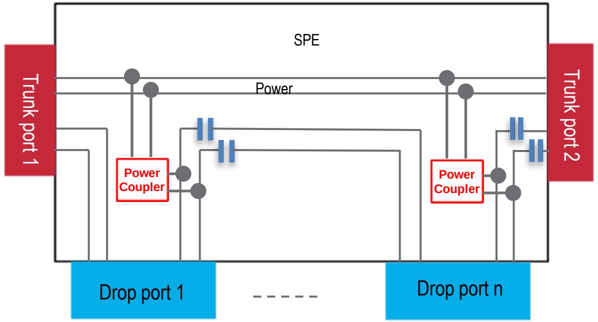
b) Advanced Power Tap with a drop port

Passive Tap

- Connect OMSPE sensors to an OMSPE sensor network
- Couple power from the trunk power pair to the drop SPE pair
- Single drop port or multiple drop ports



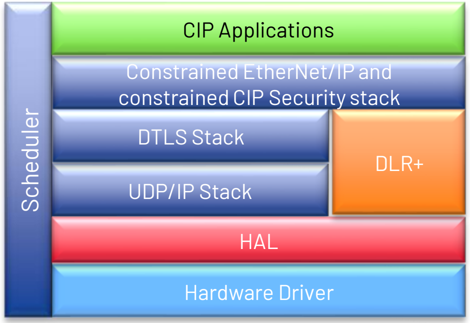
a) Single-drop Passive Tap

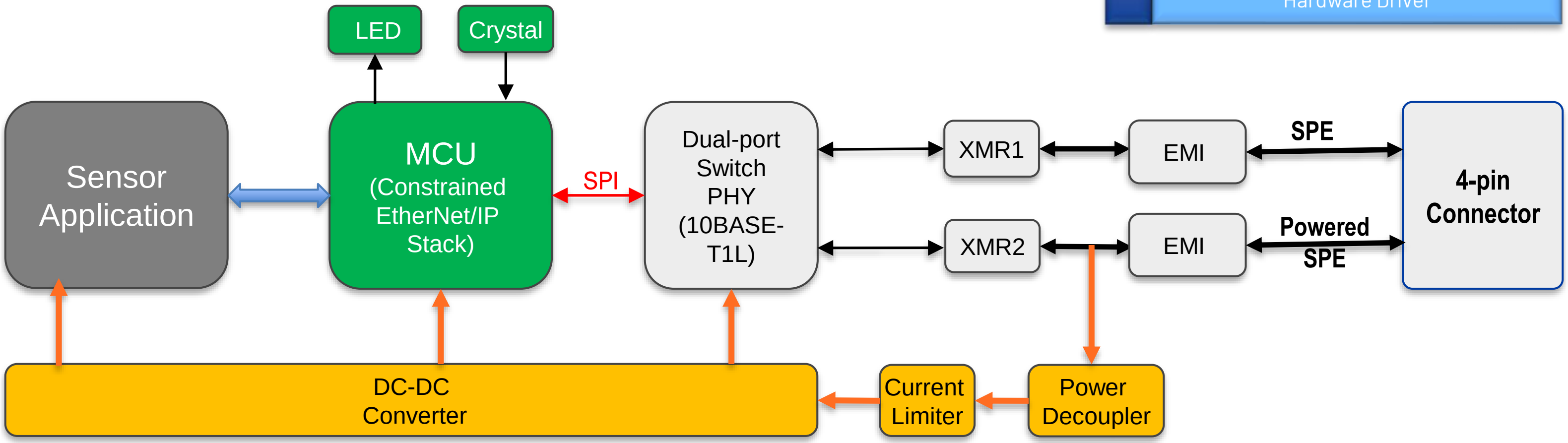


b) Multiple-drop Passive Tap

OMSPE Sensor

- Dual-channel SPE (Connector, EMI, XMR, PHY Chip)
- Powered SPE
- Low-cost non-Ethernet MCU
- Constrained EtherNet/IP stack





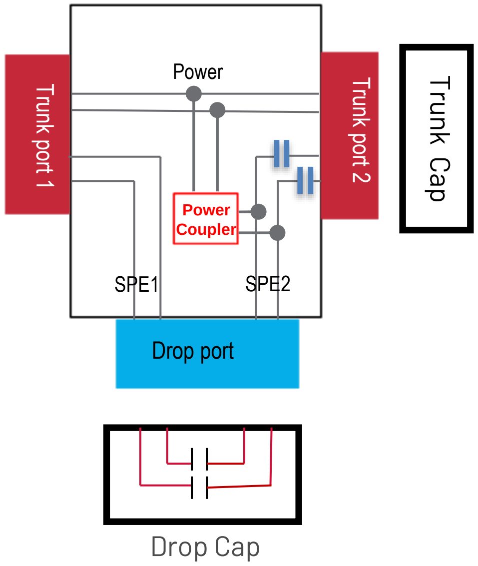
Trunk Media and Drop Media

- Hybrid Trunk media
  - Between taps
  - Unshielded/shielded cable
    - One power pair (24VDC, 4A)
    - One SPE pair
  - M12/M8 connector
  - Up to 200m

- Standard Ethernet drop media
  - Between taps and OMSPE sensors
  - Unshielded Ethernet cable
    - One SPE pair
    - One powered SPE pair
  - M12-D Ethernet connector
  - Up to 20m

Trunk Cap and Drop Cap

- Trunk cap
  - A dust cap, no electronics
- Drop cap
  - An electronical cap, connecting two SPE pairs via capacitors in the drop cap



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LLDP and DHCP

- LLDP is a Link Layer Discovery Protocol, which is used for the network topology and device capabilities discovery.
- DHCP is a Dynamic Host Configuration Protocol, which is used for the device IP and network configuration.

- Challenges on using “LLDP+DHCP” for the OMSPE sensor network discovery and commissioning.
  - Difficult to discover the sensor location.
  - Difficult to generate the topology information.
  - Difficult to detect the network change for the network diagnosis.
  - Difficult to adapt to the network change for the network upgrade.

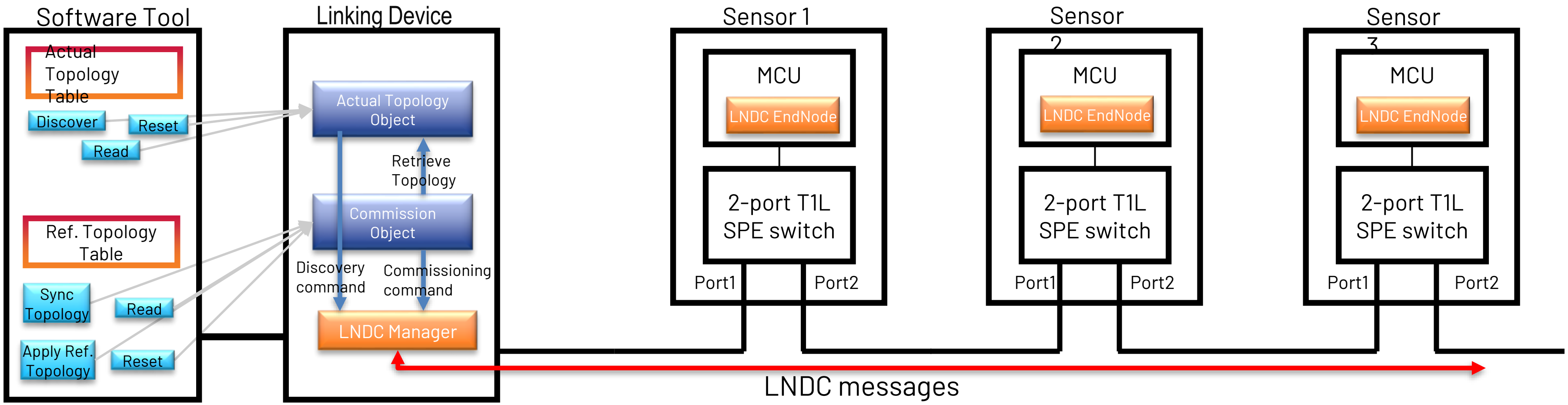
DLR Plus (DLR+) Protocol

- Enhance DLR with new capabilities of linear network discovery, commissioning and diagnosis (LNDC)
  - Discover network topology and apply it as reference topology
    - Device location information
  - Commission the network easily
    - Initial configuration of network
    - Device replacement
  - Diagnose the network quickly
    - Location-based node insertion, removal and change

- The LNDC function enhancement of DLR is motivated by simplifying the OMSPE sensor network discovery, commissioning and diagnosis, but is applicable to a general linear EtherNet/IP network

LNDC Architecture

- LNDC Software Tool providing user interfaces including actual and reference topology information
- LNDC Services provided via Actual Topology object and Commissioning object in Linking Device
- LNDC Entities: LNDC Manager and LNDC End Node
- LNDC Messages: Discovery and Commissioning

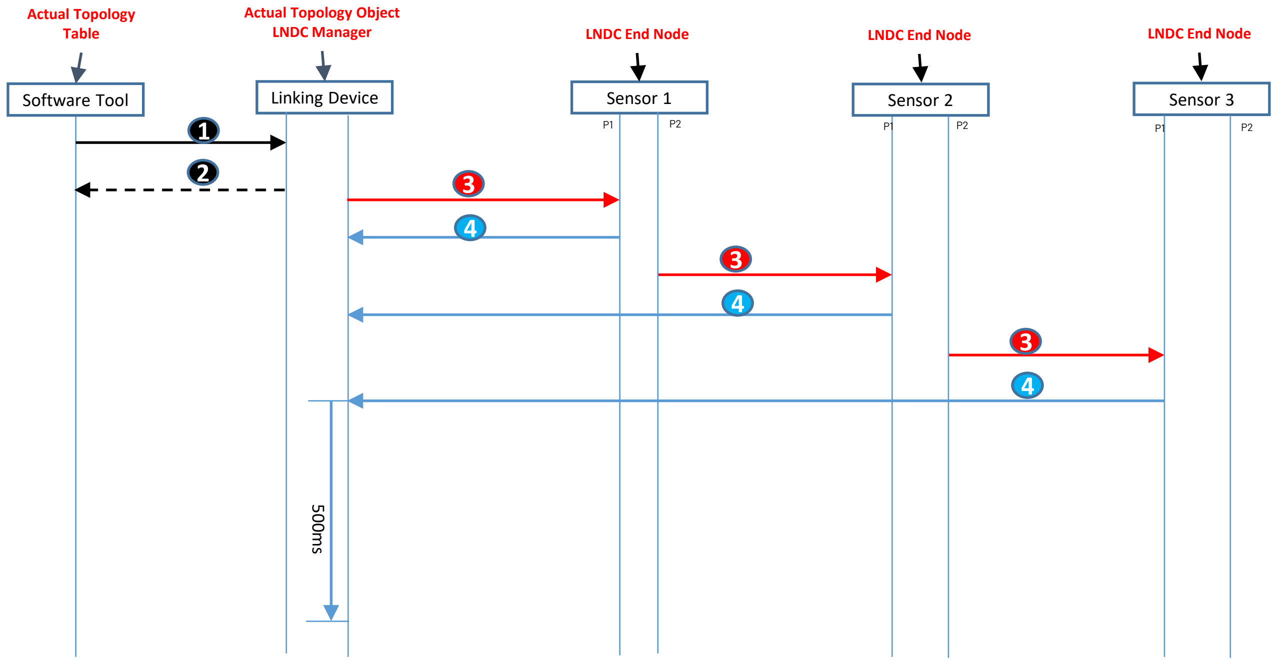


LNDC Messages

- Use Ring EtherType (0x80E1)
- Use Ring protocol Subtype (e.g., 0x02)
- Define new messages for LNDC functions

Frame type	Frame Type ID	Dest. MAC Address	Direction
Discover Topology Request	0x10	01-21-6C-00-00-02	Manager -> End Node
Discover Topology Response	0x11	Manager MAC address	End Node -> Manager
Commissioning Request	0x12	End Node MAC address	Manager -> End Node
Commissioning Response	0x13	Manager MAC address	End Node -> Manager

LNDC - Network Discovery



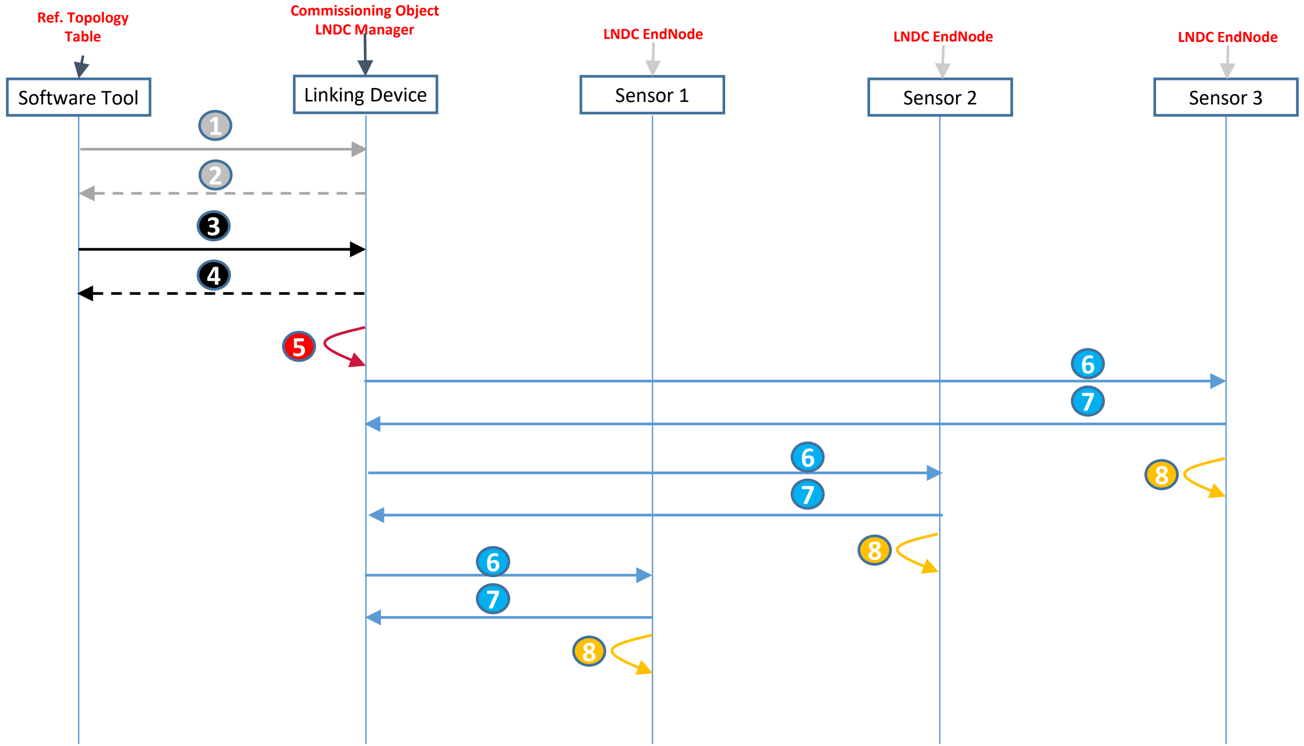
1. CIP Request: Discover Topology Request of Actual Topology Object

2. CIP Response: Discover Topology Response of Actual Topology Object

3. LNDC message: Discover Topology Request

4. LNDC message: Discover Topology Response

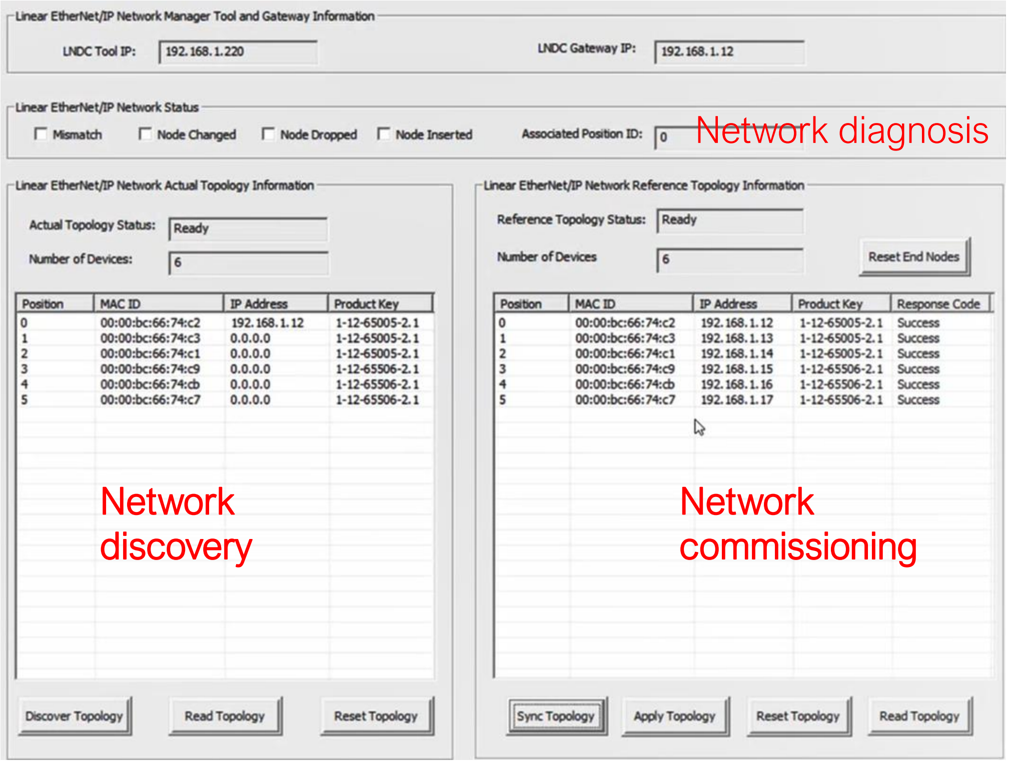
LNDC - Network Commissioning



Note: Sync Topology service is optional. Apply Reference service shall be executed only after a reference topology is ready in Linking Device.

1. CIP Request: Sync Topology Request
2. CIP Response: Sync Topology Response
3. CIP Request: Apply Reference Request
4. CIP Response: Apply Reference Response
5. Allocate IP addresses to End Nodes automatically
6. **LNDC message:** Commissioning Request
7. **LNDC Message:** Commissioning Response
8. Internal processing: apply IP address and restart

LNDC Software Tool Research Prototype



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Summary and Outlook

- An OMSPE sensor network to enable the EtherNet/IP connectivity from sensor to controller and compute
  - A cost-effective network architecture to support “low system cost” objective
- An DLR+ protocol with enhanced LNDC functions to simplify the network discovery, commissioning and diagnostic
  - Enable “easy of use” user experience

- Optimization of design for product implementation
  - Expect collaborations within ODVA community
- Specification enhancements on On-machine sensor EtherNet/IP usage profile

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Question?