



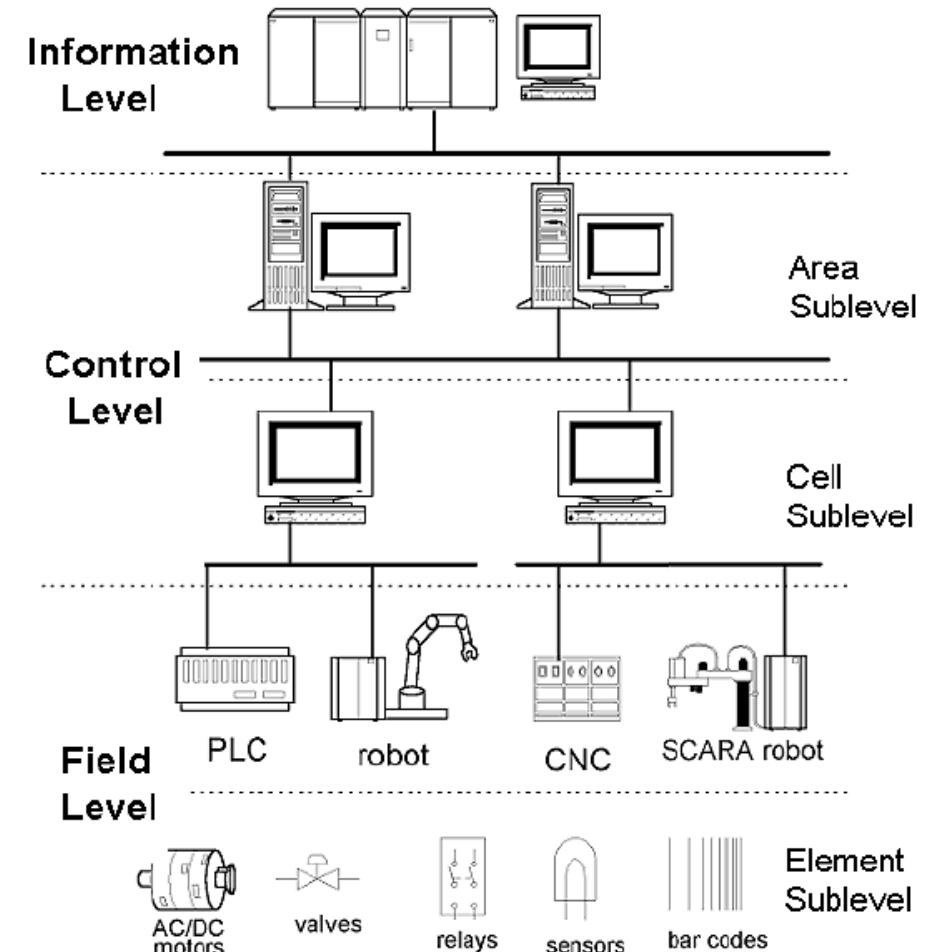
# **New Ethernet Applications – Industrial Networking Requirements**

**March 6, 2018**

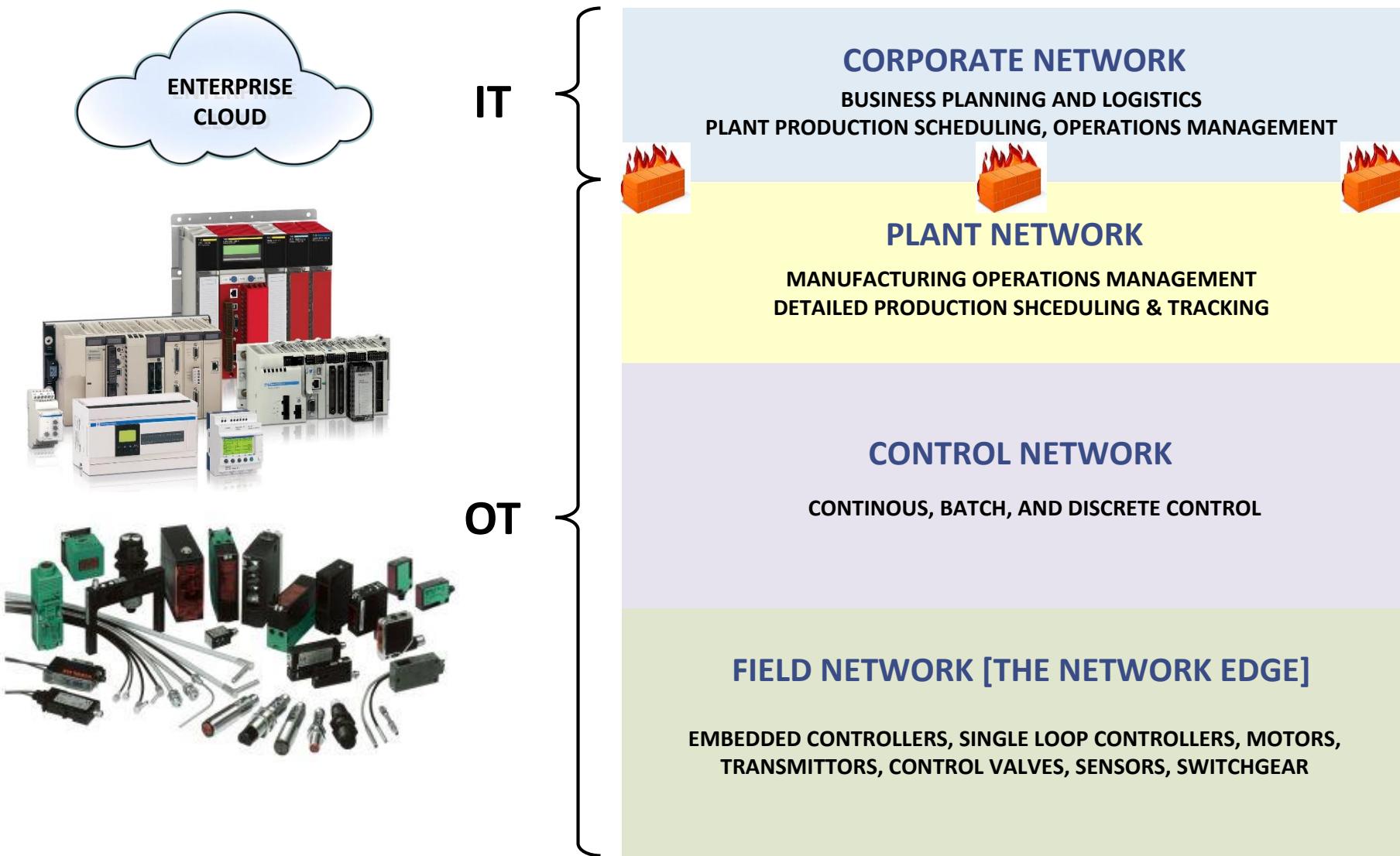
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# Today's Factory: Operations are Hierarchical

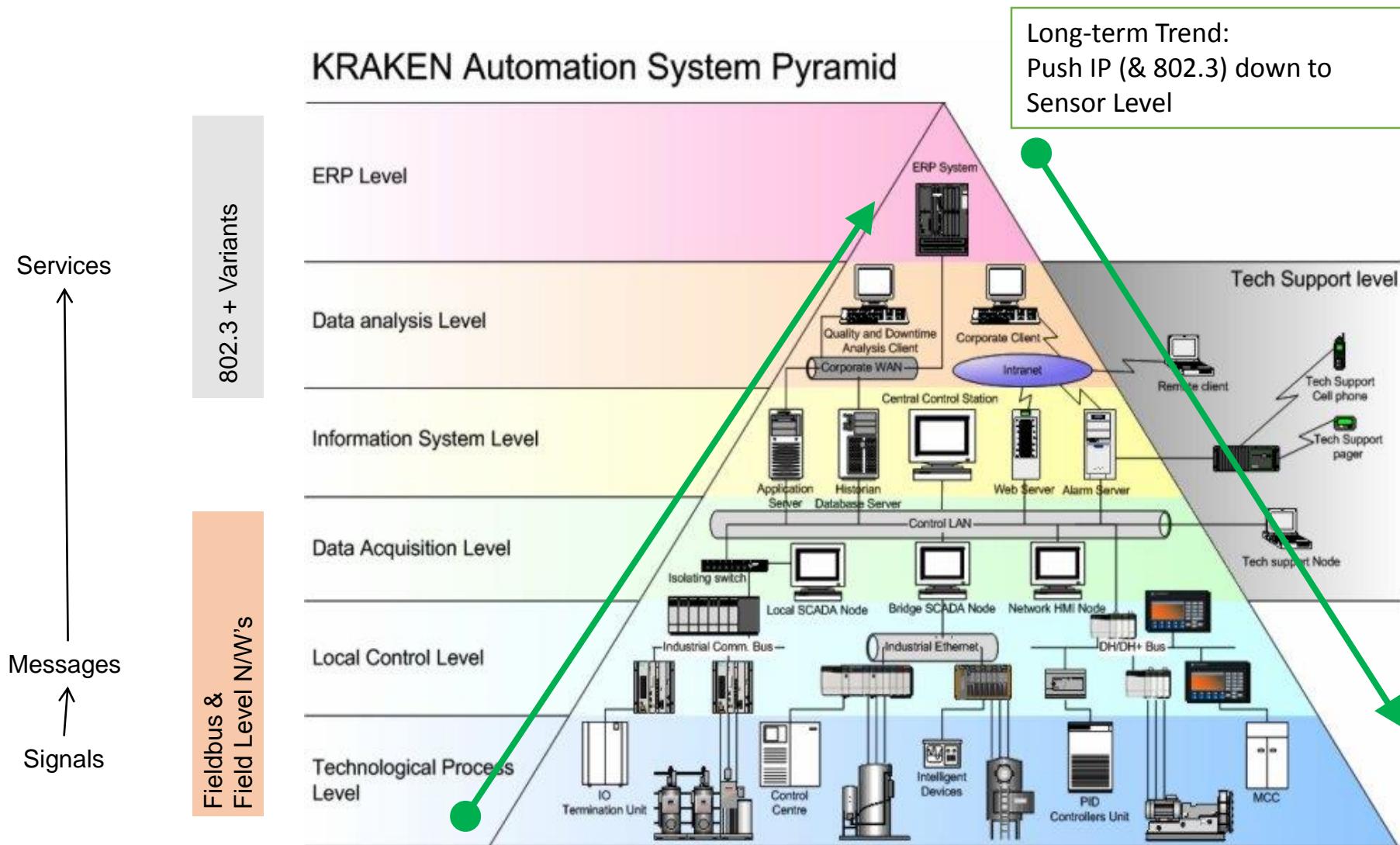
- **Information Level**
  - Top Level of Plant or Automation System.
  - Ethernet-Based Communication
- **Control Level**
  - Typically Peer-To-Peer Networks between Controllers (PLCs).
  - Deterministic Ethernet Communication (often proprietary layer 2)
- **Cell Sublevel**
  - Cells combined in Application Oriented Groups.
  - Deterministic Ethernet Communication (often proprietary layer 2)
- **Field Level**
  - Typically binary and analog field devices.



# Today's Factory: Networks are Hierarchical



# Vanishing Hierarchy: Industry is Pushing IP to the Edge

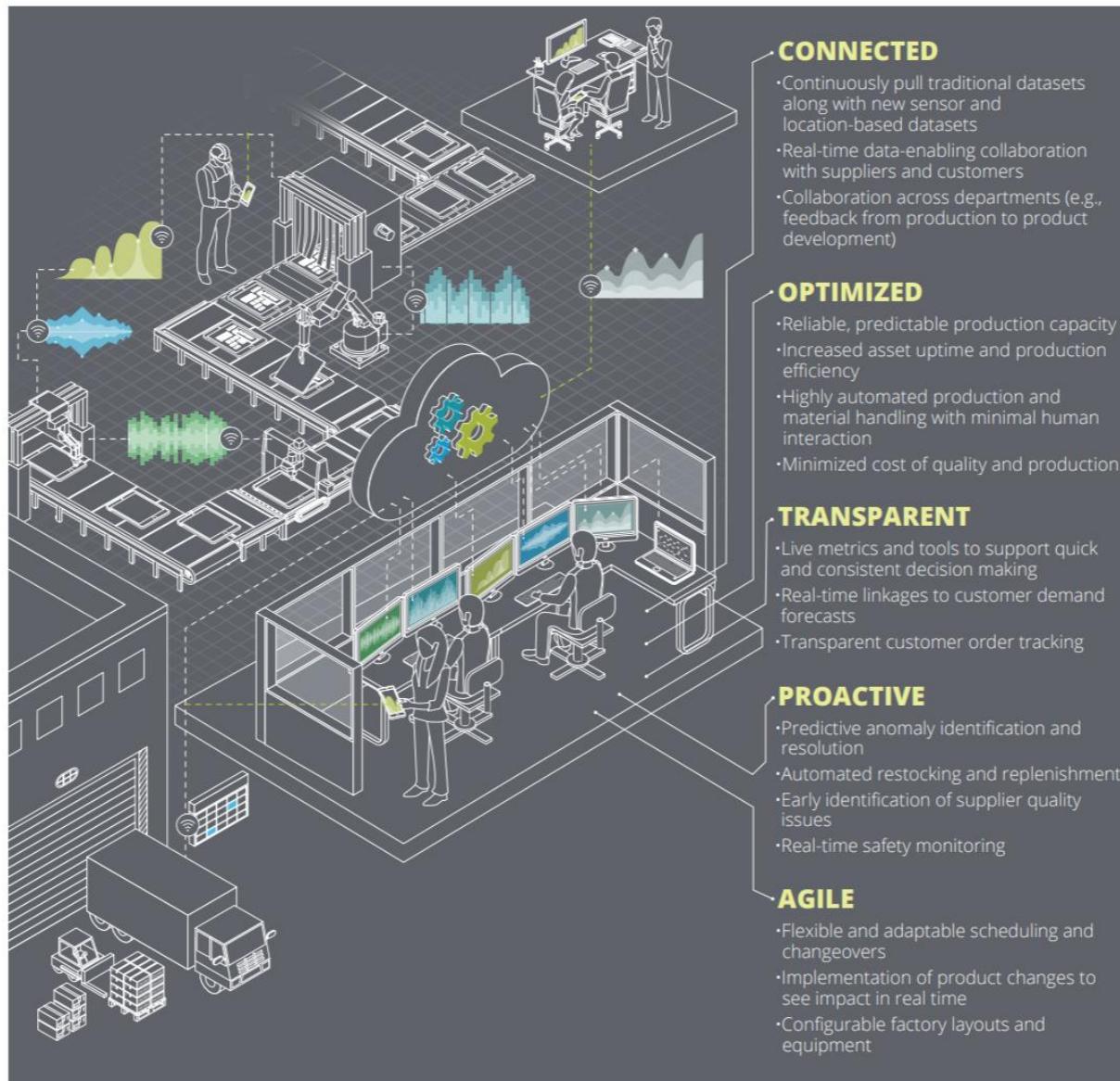


# Smart Factory: Goals

- Ensure consistent quality and performance across global operations
- Balance manufacturing with demand to optimize material usage and asset utilization
- Improve and meet regulatory compliance
- Implement more flexible and agile manufacturing operations to respond to rapidly changing market conditions
- Meet demanding requirements and metrics for on-time delivery through reduced mean-time-to-repair (MTTR) and increased overall equipment effectiveness (OEE)
- Reduce the cost of design, deployment, and support of manufacturing and IT systems at global manufacturing plants.
- Improve response to events that occur on the plant floor, regardless of location.
- **Industrial Automation Control System (IACS) manufacturers are currently falling short of these objectives. The key to resolving this problem is better access to information.**

# Requirements for the Smart Factory

- The smart factory is a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes.



# Smart Factory: Challenges

- **Reliability**—As manufacturing operations become globally integrated, manufacturers are challenged to provide consistent access to data while making the manufacturing environment flexible. Security, availability, and asset use are critically important to manufacturing companies because IACS equipment is mission-critical, and efficiency is important to remain competitive.
- **Cost**—Legacy IACS, although often fully depreciated in existing manufacturing environments, can be difficult to integrate with the enterprise and can be costly to operate due to the multiple networks in use that require management, training, integration, gateways, spares, etc.
- **Product Design Integration**—Limited access to local subject-matter experts constrain collaborative manufacturing, impacting the ability to quickly respond to events, collaborate with engineering on new products and increasing cost to resolve problem.
- **Service Integration**—In an effort to provide differentiated service, manufacturers are struggling to create systems to capture and incorporate genealogy data about their products.
- **Data Interaction and Management**—Incorporating real-time plant productivity and operational data into manufacturing execution systems (MES), customer relationship management (CRM), supply chain management (SCM), and other enterprise resource planning (ERP) systems restrict and constrain the ongoing move to service-oriented architectures.
- **Partner Connections**—With an aging and decreasing workforce and increased manufacturing complexity, manufacturers are trying to find ways to leverage relationships with IACS vendors to support their plant floor applications.

# Smart Factory: Benefits

- These challenges are pushing manufacturers to adopt standard Ethernet and IP network technologies throughout the manufacturing environment. By moving to standard network technologies, manufacturers can:
  - **Realize Significant Cost Savings**
    - Broader supply base
    - Lower total cost-of-ownership (TCO).
  - **Simplify Maintainability**
    - Legacy IACS network technology is becoming more complex
    - Resources competent in standard Ethernet and IP networking technologies more readily available,
  - **Enhance Flexibility**
    - Standard Ethernet and IP technology provides higher availability and better performance than legacy networking technologies.
    - New functionality and evolving capabilities in the IACS are focused on standard networking technologies.
  - **Increase Efficiency**
    - Standard Ethernet and IP technology improves visibility for business decisions

## Benefits of the Smart Factory



Asset  
Efficiency



Improved  
Quality



Reduced Cost



Worker Safety



Environmental  
Sustainability



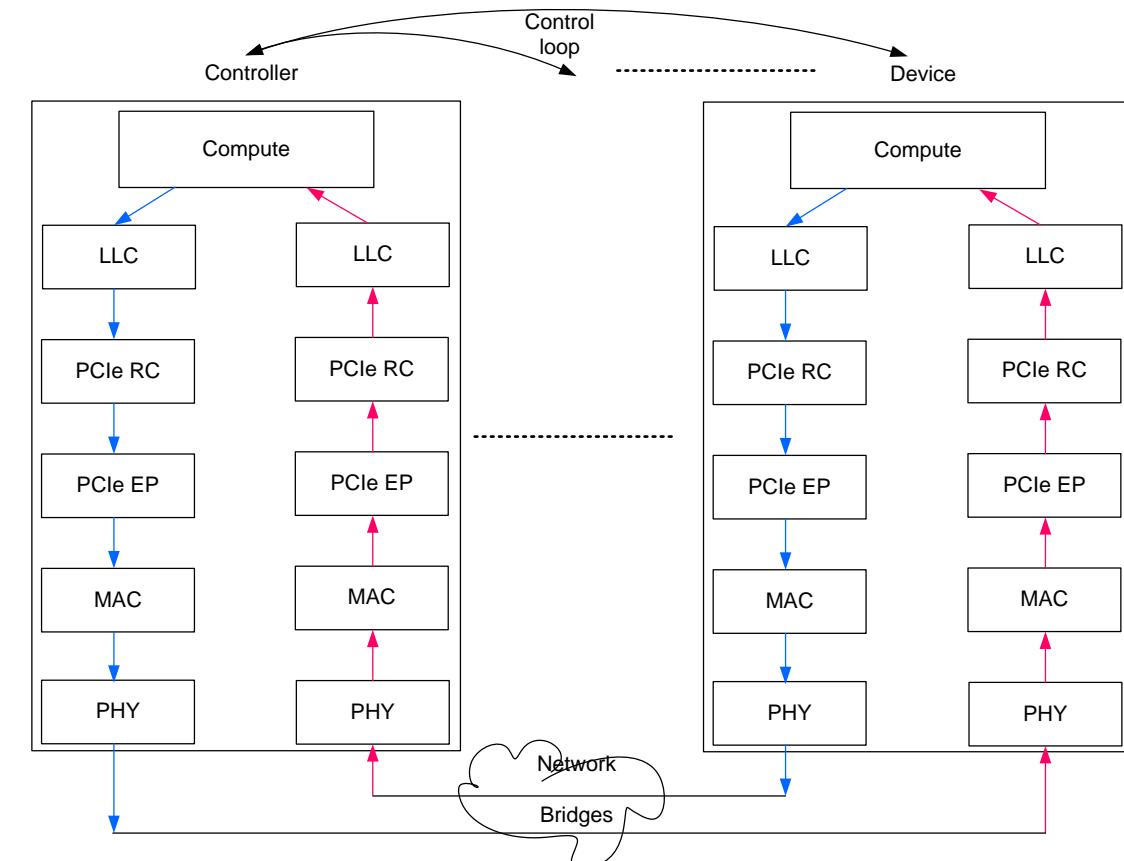
Agility of  
Production

# Networking Requirements: General

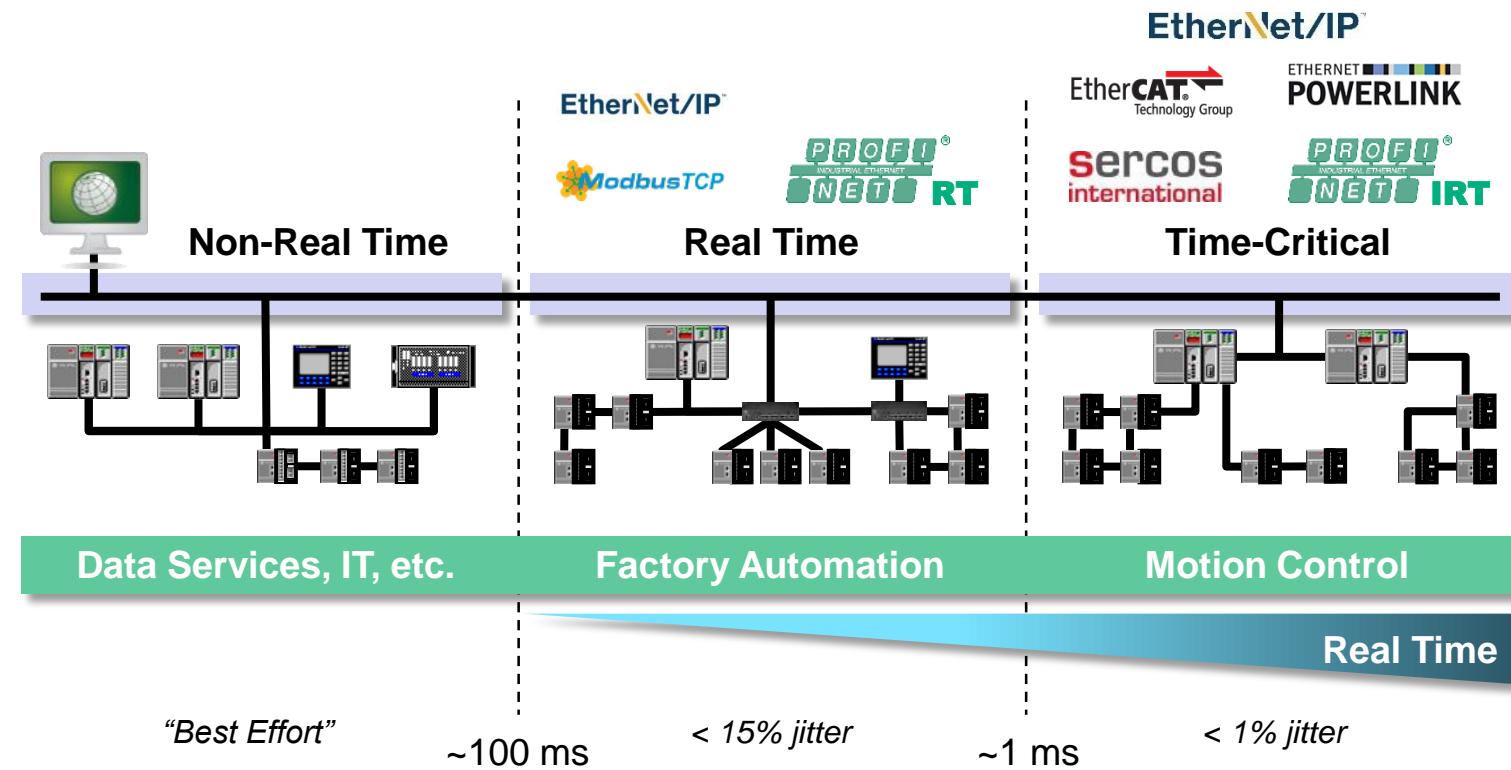
- **Scalability**
  - Bandwidth – 10 Mbps to 1 Gbps (2.5 / 5 / 10 Gbps for network infrastructure)
  - Network size – from tens of infrastructure devices to hundreds of infrastructure devices
- **Convergence**
  - Blending of existing non-scheduled technologies and products within a new, deterministic technologies
  - Manage low priority or interfering traffic to ensure on-time delivery of high priority traffic
- **Security**
  - Protect the integrity and availability of data
  - Tested and Validated Architectures
- **Performance**
  - Able to support from human response times to hundreds of axes of motion (drives)
- **Flexible Topologies**
  - Ring, line, star, redundant star to address physical constraints
- **Low/Bounded Latency**
  - Able to support ~1ms for motion

# Networking Requirements: Principle Data Path (Control Loop)

- Principle data path between the controller and a device :
  - The entities which are involved into the guaranteed latency transmission for the control loop are depicted
  - Latencies for link layer control, bus interface, MAC/PHY are incurred at the controller and the device
  - Combined store & forward, bridge delay and PHY delay accumulate at each hop in the network.

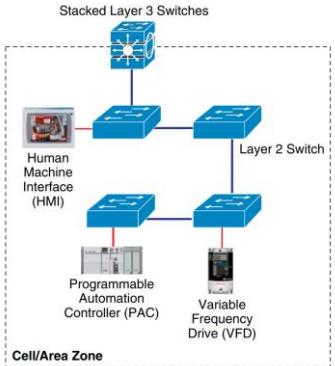
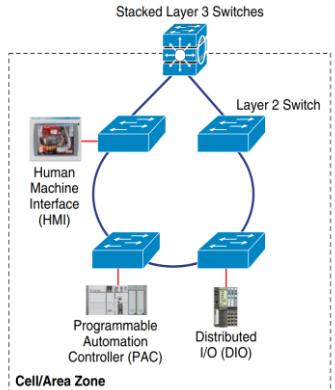


# Networking Requirements: Performance



- In order to sense and take action in automation, Ethernet messages must arrive "on-time"

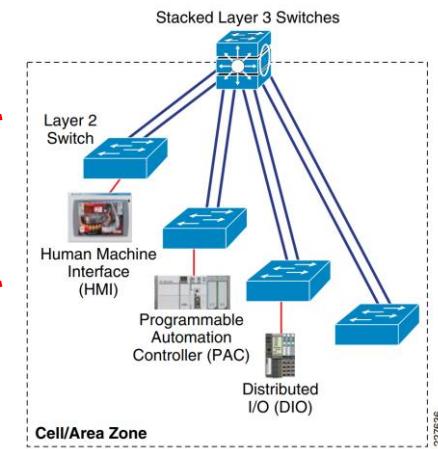
# Networking Requirements: Flexible Topologies



Long, Low-Latency  
lines and rings to  
suit physical  
constraints



Redundant Star  
topologies for high  
reliability



# Why Line Topologies?



- Physical constraints make cabling for star topologies impractical
- The construction of the application naturally lends itself to point-to-point connectivity
- They are, after all, assembly “lines”

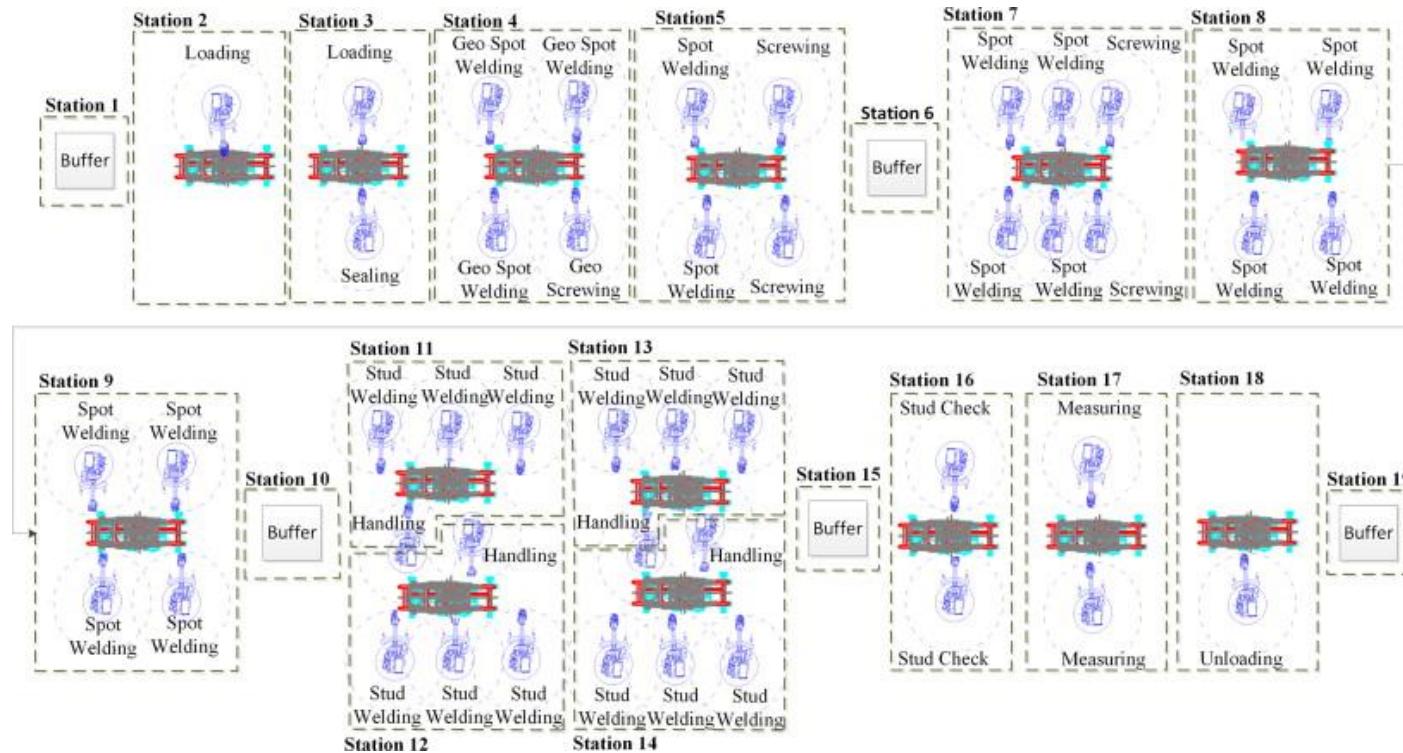


# Networking Requirements: Brownfield Migration

- Brownfield is the name given to extending or expanding automation environments that already exist.
  - There are more brownfield installations in industrial automation than greenfield installations.
  - Industrial automation is slow to move to new technology
  - Some equipment is used for 40 years or more.
  - It is unlikely that any networking technology will gain either rapid or widespread adoption if it fails to support existing applications with no deterioration (or change) in performance.
  - “On-ramps” need to be provided for existing applications to migrate to new networking technologies.



# Networking Requirements: Brownfield Migration



- A single line consists of many different sections of machinery
  - Sections may be delivered via different OEMs
  - Some sections or cells are likely legacy (Brownfield), Ethernet technologies provide the “on-ramp” between old and new.
  - Accumulated latency must be as low as possible.

# Networking Requirements: Lines and Rings

- **Scalability** – Well addressed by IEEE802.3 and IEEE802.1.
- **Convergence** – Well addressed by IEEE802.3 and IEEE802.1.
- **Security** – On-going work in IEEE802.1, IETF, IEC and other organizations shows promise for these applications.
- **Performance** – Addressed by emerging IEEE802.1 TSN work.
- **Flexible Topologies** – Well addressed by IEEE802.1
- **Low-Latency** – Accumulated Latency remains a challenge in industrial applications.

# Networking Requirements: Low-Latency

- Industrial applications, such as machine control, are typically built in long line configurations. For these installations, to minimize wiring cost and complexity, typical installation uses “daisy chain” where each node has (2) external switched ports and an internal port that goes to the end-node.
- A common application is motion control where fast loop times are required. 125  $\mu\text{s}$  cycle rate is common for 100 Mbps. Even lower rates ( $62.5\mu\text{s}/31.25\mu\text{s}$ ) are desired for 1 Gbps. To support this, low latency for messages through the network is a high priority.
- Even Gigabit data rates are not sufficient to solve this problem. Combined store & forward, bridge delay and PHY delay exceed timing budgets. For instance, in a line topology of 64 hops, accumulated latency would exceed a 100  $\mu\text{s}$  control loop even at Gigabit speeds.
- These systems often also have high EMC and there is a desire in some applications to support brown-field wiring. Often, these devices are resource, power and cost-constrained. For these applications 100Mb/s rates are desired.

# Conclusion

- Ethernet provides a nearly ideal networking solution for the factory of the future.
  - Already commonly deployed in automation
  - Scales to future needs
- Emerging work in IEEE802.1 and IEEE802.3 further addresses these needs.
- Accumulated Latency remains a challenge in industrial applications.
- Today, industrial networks solve these problems using a variety of techniques.
  - In many cases, these techniques violate IEEE802.3 and IEEE802.1 standards.
  - Therefore it seems prudent that IEEE802.3 and IEEE802.1 consider these use cases to ensure an approach consistent with IEEE standards.

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