Elastic Ethernet Networking for Industry

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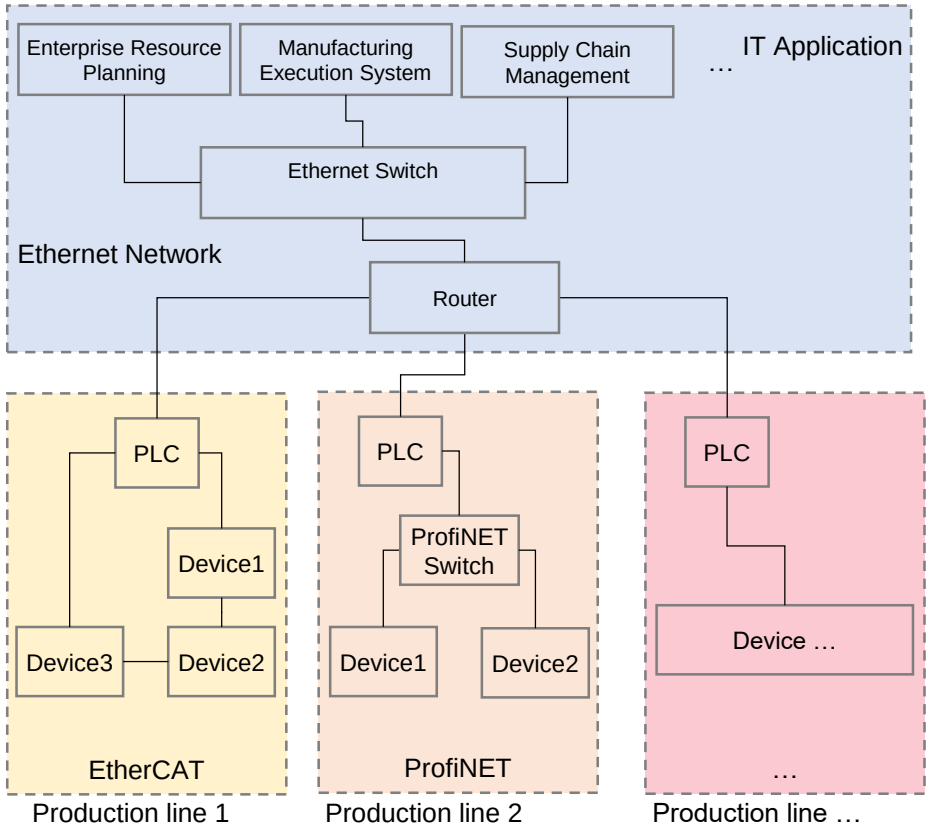
Background

- Industrial network has been discussed in IEEE 802.
  - New Ethernet Applications – Industrial Networking Requirements (https://www.ieee802.org/3/ad_hoc/ngrates/public/18_03/woods_nea_01_0318.pdf) discussed smart factory challenges and corresponding networking requirements for **convergence**, **performance** etc., stressing the need for controlling accumulated latency.
  - IEEE 802 Nendica Report – Flexible Factory IoT: Use Cases and Communication Requirements for Wired and Wireless Bridged Networks (https://ieeexplore.ieee.org/document/9068511), presented communication requirements including **variable-type**, **variable-volume** production, and **rapid customization** in a factory.
  - Low Latency Discussion for Ethernet Networking (https://mentor.ieee.org/802.1/dcn/21/1-21-0072-00-ICne-low-latency-discussion-for-ethernet-networking.pdf), discussed industrial scenarios with **low latency** requirements.
- As these contributions mentioned that the diverse demands of industrial production is the trend, and pushing Ethernet network down to device level of factory. Challenges and potential requirements were also discussed.
- This presentation starts discussion with current industrial networks, and proposes a way that Ethernet network moves forward.
  1. To discuss the current silo industrial networks and corresponding disadvantages.
  2. Intends to propose some enhancement aspects for Ethernet network.

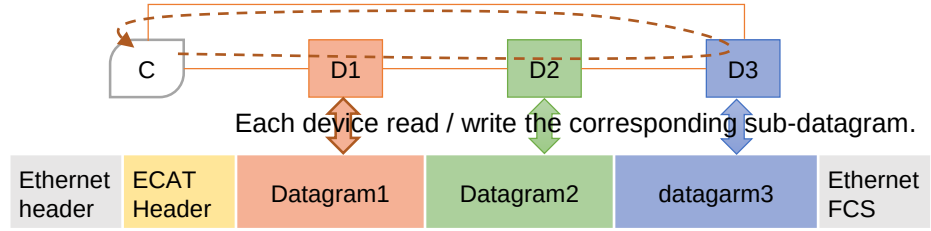
Now: Multiple Silo Industrial Ethernet Networks Coexist

- **Silo network:** specific industrial ethernet networks (evolved from industrial field bus) were built for specific vendor's controller / device and connects to IT network independently.
  - **Evolve & extend independently** due to different technical mechanism including different topology / forwarding mode, etc.
  - Independent & different management / control, it's **hard for overall schedule** according to global manufacturing operations, and **cannot quickly respond** to rapidly changing market conditions .



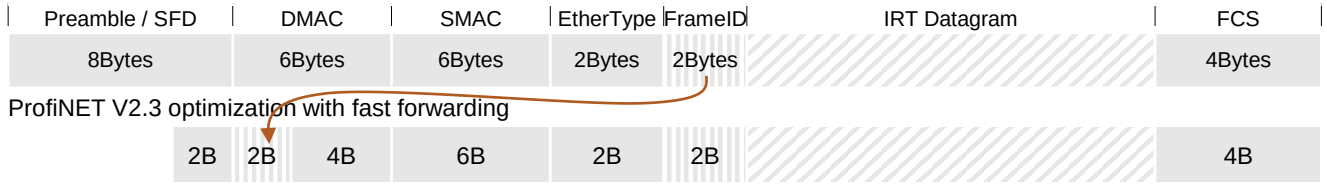
Main features of **EtherCAT** can be summarized as summation frame packaging, logical addressing.

1. **Summation frame packaging:** All device data is carried within one single summation datagram to optimize the bandwidth efficiency. So, in **one cycle**, only **one datagram** is refreshing on the fly.
2. **Logical addressing:** The Datagram from Controller is **passed through via devices one by one in a logical ring routing** and returning to Controller in the last hop according to logical addressing.



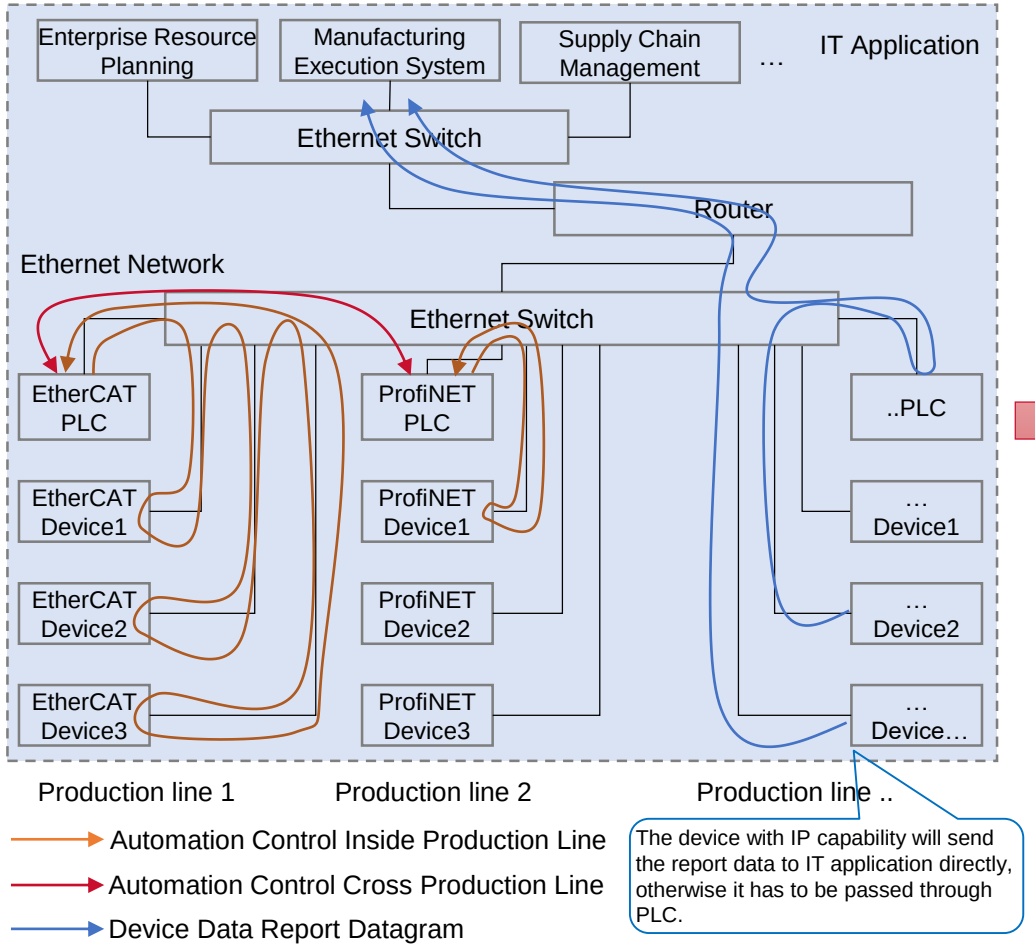
Comparing to EtherCAT, **ProfiNET IRT** (Isochronous Real-Time, described with class number Real-Time Class 3) is the top performance class.

1. **Strict scheduling:** No delays can happen within this Real-Time communication class. Switches forward frames looking only at the time schedule and frame ID, not MAC address.
2. **Fast forwarding:** To shorten forwarding delays with rearranged frame structure by reducing the size of preamble section and copying Frame ID (2Bytes) to the destination MAC.



Future: Elastic Industrial Ethernet Network to be Shared by Different Industrial Production Lines / Systems

- **Elastic Industrial Ethernet Network:** A converged Ethernet network **serves different services**, provides **elastic adjustment** according to global coordination of manufacturing operation, and **quick responds** to rapidly changing market conditions.



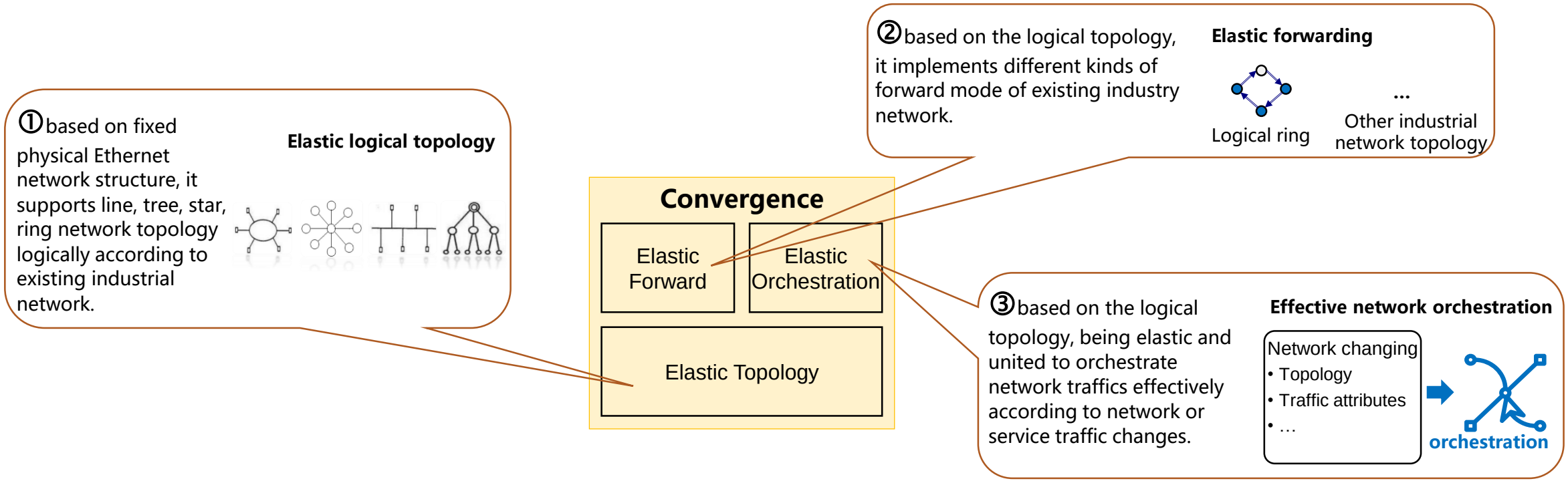
Compatible	One shared and **convergent** Ethernet network connects to all the production lines / devices and serves different services: • Compatible to existing service flow & technical mechanism • Network **performance** to satisfy the QoS of existing service
Elastic	The elastic Ethernet network supports agile adjustment: • Elastic Ethernet network unified orchestration to support global scheduling. • All devices connected as a whole pool to support global production line coordination & extension.
Efficient	One Ethernet network infrastructure fully connects to all systems, devices: • Quick network adjustment to rapidly changing market conditions. • Proper traffic flow path to improve overall network efficiency.

3 categories of requirements to be addressed for elastic industrial Ethernet network.

- **Convergence**
- **Performance**
- **Adaptability**

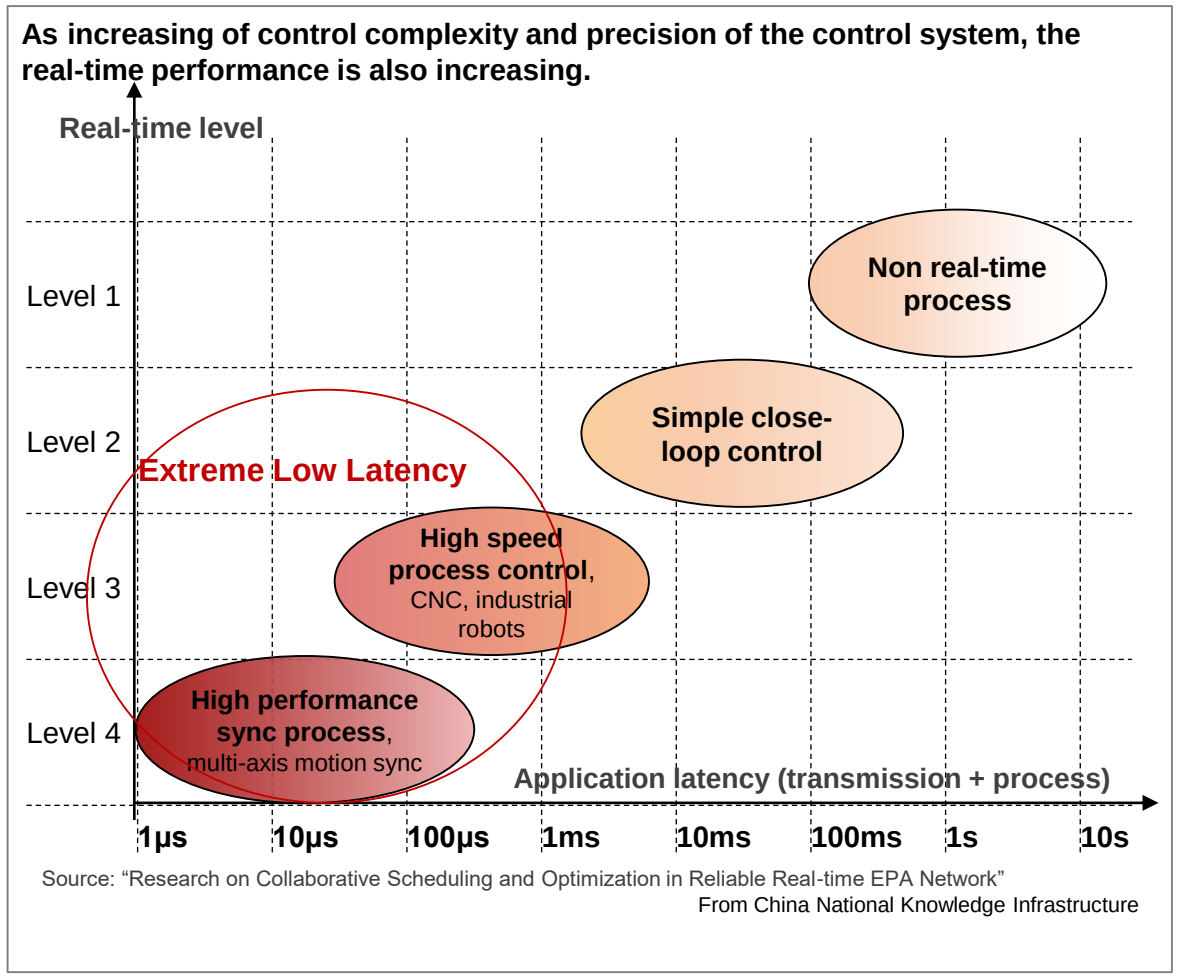
Requirement Category 1: Elastic Forwarding & Orchestration to Support Different Industrial Services Running on Shared/Converged Ethernet Network

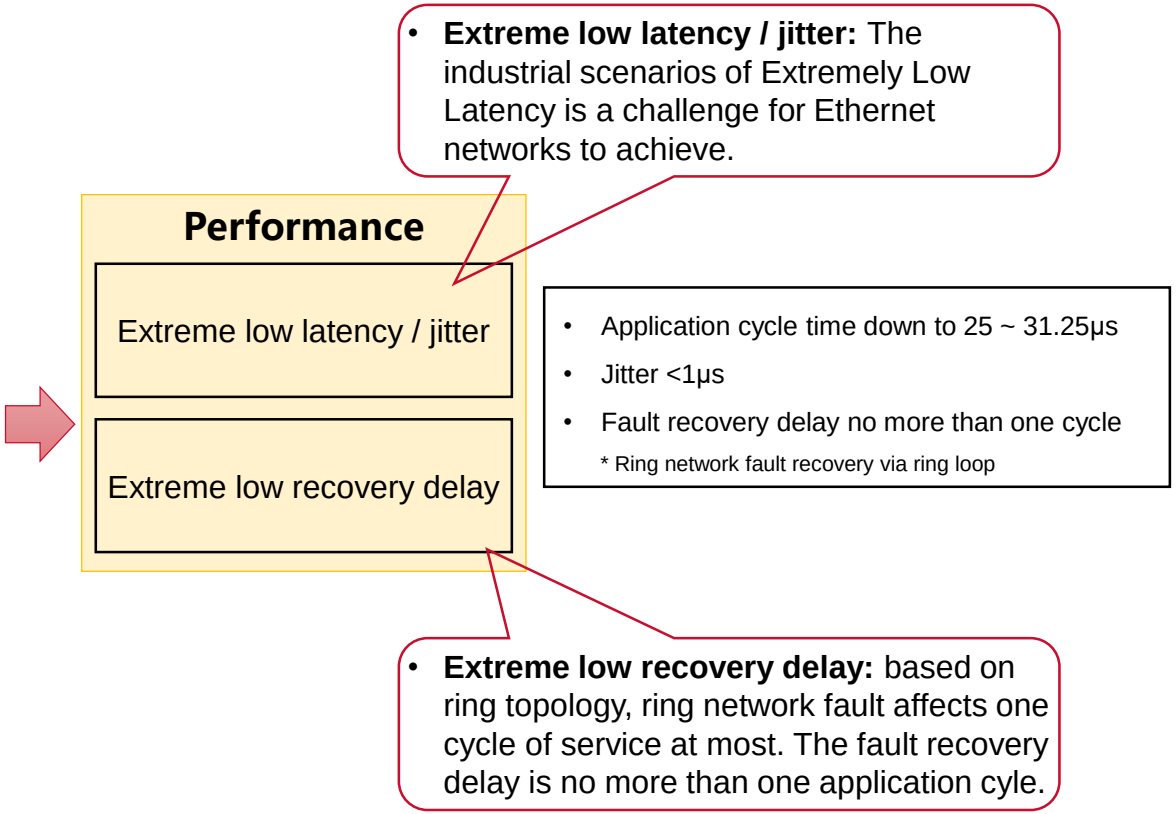
- **Convergent** industrial network for multi-service & **elastic** adjustment to changes and overall coordination
  - ① **Elastic logical topology** based on fixed physical Ethernet network topology to support different kinds topology of existing industrial networks
  - ② **Elastic forwarding** to simulate and be compatible with existing forwarding mode of current industrial networks
  - ③ **Elastic orchestration** via adjusting and scheduling to quickly match the network or service changes.



Requirement Category 2: Extreme Performance to Match Industrial Scenarios

- **Performance**: extreme low latency / jitter to satisfy industry scenarios, and extreme low recovery delay to keep service available.

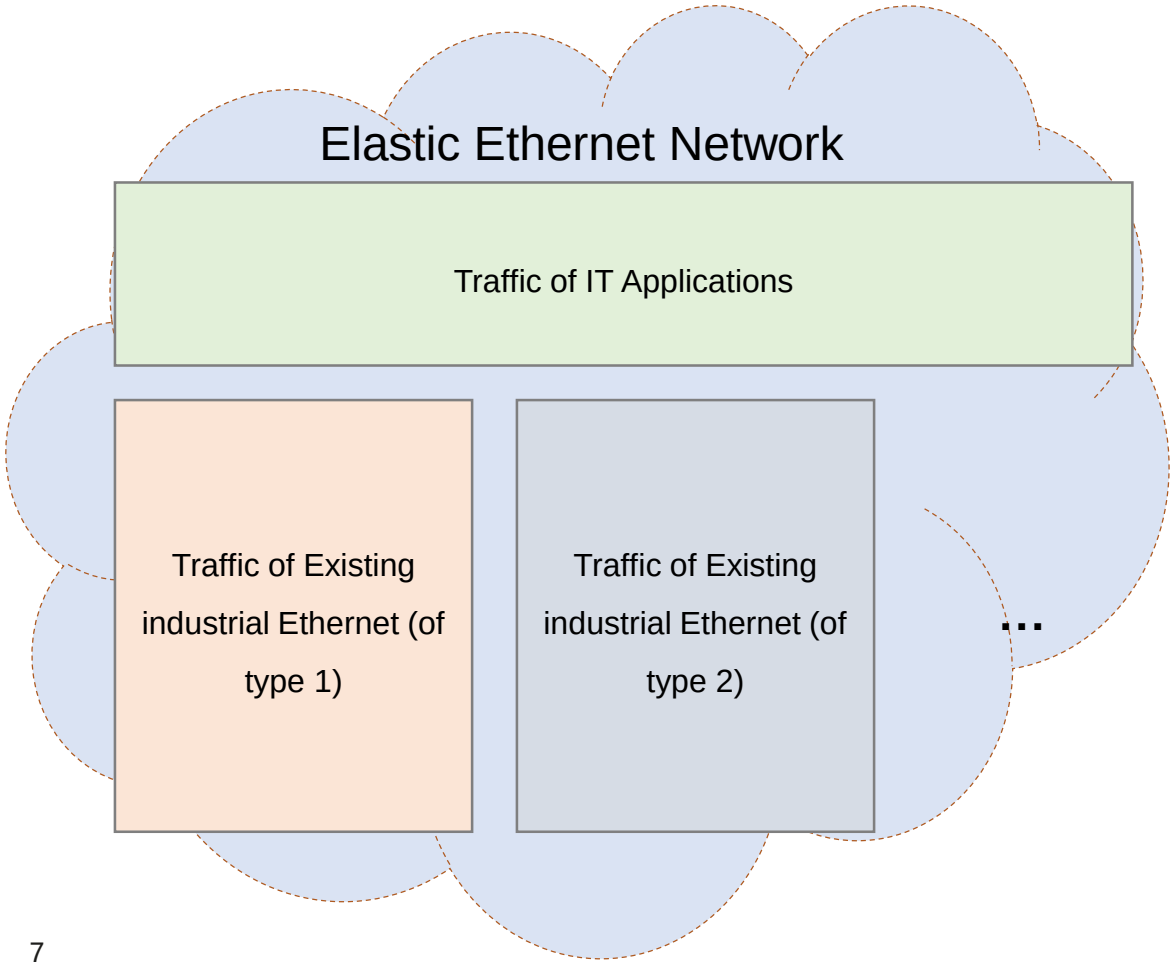




Refer to : Low Latency Discussion for Ethernet Networking (https://mentor.ieee.org/802.1/dcn/21/1-21-0072-00-ICne-low-latency-discussion-for-ethernet-networking.pdf)

Requirement Category 3: Adaptive to Different Traffic based on the Shared Network

- **Adaptability**: adaptive to different traffic of industrial services and IT applications sharing the network.



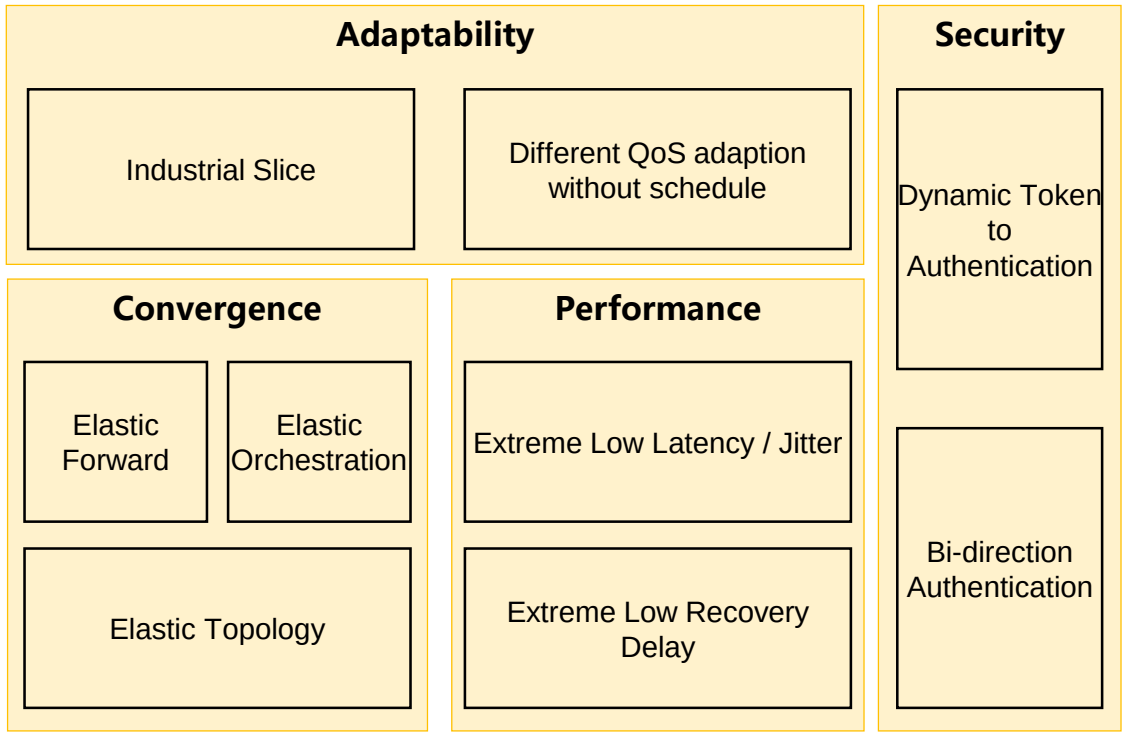
- Adaptive to different kind of existing service traffic for normal running
  - ① **Network slicing** with logical isolation to avoid interfering and make full use of the bandwidth.
  - ② **Different kinds of traffic with different low latency / jitter requirements** are running on the same Ethernet network, it's necessary to assure these traffics' QoS without scheduling.
    - Application cycle 1ms, jitter < 1%
    - ….
    - Application cycle 100ms jitter < 15%

Adaptability

Industrial Slicing	Different QoS adaption without schedule

Framework of Elastic Ethernet Networking for Industry Sharing one Network

Elastic Industrial Ethernet Network supports to **Full Coverage** industrial scenarios.



1. **Implement network convergence**
   - ✓ Share the same network infrastructure
   - ✓ Elastic topology adjustment & forwarding logically
   - ✓ Ease for unified orchestration according to changes
2. **Assure network performance**
   - ✓ Extreme low latency & jitter
   - ✓ Extreme low recovery delay of ring network fault
3. **Build service adaptability**
   - ✓ Industrial slicing to avoid interfering
   - ✓ Different QoS adaption without schedule
4. **Security mechanism**
   - ✓ Dynamic token & bi-direction to authentication to assure security

Next Steps

- Consider to initiate a new study item for further discussion toward possible work item.
- Potential topics include:
  - Explore detailed requirements & use case according to these aspects (convergence, performance, adaptability …)
  - Explore related technologies to be leveraged or gaps to be addressed
  - Explore the framework of elastic industrial Ethernet networks
  - Explore potential technology points
    - ✓ Elastic topology / forwarding based on fixed physical topology
    - ✓ Elastic and united orchestration for different services
    - ✓ High performance making use of full Ethernet network bandwidth
    - ✓ Support QoS and other service requirements of existing services

Thank you.