Smart Factory with Intelligent Edge Control Enabled by Deterministic IP based Networking

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Evolution of Automation Pyramid

Decentralization of cloud functions down to the Edge

Centralization of control and computing up to the Edge
Edge Computing Architecture

**Today**
- PC
- PLC
- Smart Devices
- I/O

**Edge Gateway**
- Cloud
- Edge Box
- PLC
- Smart Devices
- I/O

**Edge Compute**
- Cloud
- Edge Compute
- PLC
- Smart Devices
- I/O

**Real-Time Edge Compute**
- Edge Compute with Real-Time
- I/O

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Network Communication Determinism
Use Case “Deterministic IP Enabling Intelligent Edge Control”

- Reduce CAPEX and OPEX
- Increase flexibility: Massive PLC virtualization on edge/cloud infrastructure for flexible, elastic and on-demand automation.
- Enable machine learning and (real-time) big data analysis
- Transparent to existing Industrial Ethernet communication protocols
- Work seamless with 5G
- Support IT&OT convergence: It can carry control, video, data and other heterogenous traffic in one network
- Support large-scale deterministic communication
## Ethernet Based Deterministic Networking Technologies

<table>
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<tr>
<th>OSI Layer 3 Technology</th>
<th>Deterministic IP for large-scale Deterministic Network</th>
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<tr>
<td></td>
<td>– Beyond hop-limit, adapt to large scale networking</td>
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<tr>
<td></td>
<td>– Performance: 10µs latency per hop, 20µs jitter E2E</td>
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<td>– Being standardized in IETF DetNet workgroup</td>
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<th>OSI Layer 2 Technology</th>
<th>TSN (Time-Sensitive Networking) and Industrial Ethernet Tech.</th>
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<td>– Performance: 1-5µs low latency, &lt;1µs jitter E2E</td>
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<td>– Well recognized and accepted among OT players</td>
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<td>– Standardized in IEEE 802.1</td>
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<th>OSI Layer 1.5 Technology</th>
<th>XE (X-Ethernet)</th>
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<td>– Work on layer between PHY and MAC, bit-block exchange</td>
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<td></td>
<td>– Performance: 1-2µs ultra low latency, 50ns ultra low jitter</td>
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<td></td>
<td>– Capable of carrying industrial Ethernet protocols transparently, such as industrial Ethernet implement, PROFINET, EtherCAT, EtherNet/IP</td>
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- Suitable for large-scale network
- Good for small-scale network
Large-scale Deterministic Networking

The large-scale deterministic networking focuses on deterministic data paths that operate over Layer 2 bridged and Layer 3 routed segments, where such paths can provide bounds on latency, loss, and packet delay variation (jitter), and high reliability.

It supports massive nodes to achieve deterministic forwarding jitter at microsecond level. It is being standardized in IETF, and compatible with 5G seamlessly.
① Dispatcher divides time into same length “coaches”, and send out packets in cyclic coaches

1. coach’s size is 10 us, different flows’ packets co-exist in a single coach

2. Send LDN packets first, and the remaining space can be used by BE packets

② Each pair of nodes have a stable cycle mapping relationship, which determines packets forwarding time

(X, Y)’s cycle mapping is 0→ 2
Accordingly, cycle 1’s packets of X will map to cycle 3 of Y

③ Once the sending cycle at X is determined, according to a serials of cycle mapping relationship, then the receiving cycle at W is determined. E2E jitter < variance in sending cycle + variance in receiving cycle = 20 us

Send out packets in 10 us cyclic pattern

X Send

Link propagation

Y Send

cycle mapping of (X, Y) is 0→2, before Y’s cycle 2, all packets sent from X at cycle 0 can be received.

Y Receive

Link propagation

Z Receive

Constrained by a stable cycle mapping relationship. Once the sending cycle is determined, then the receiving cycle is determined.

Z Send

W Receive
Large-scale Deterministic Network Solution Overview

Four Functional Components:

I. UNI-describe users’ deterministic service requirements to network

II. Reservation Signaling-reserve resources for deterministic applications

III. LDN Forwarding-provide IP based deterministic service

IV. OAM-a fine-grained visualization OAM toolset provided for user
Smart Factory Vision Enabled by Deterministic IP based Network

Private Cloud
(ERP, MES, AI...)

Factory A

Factory B

DIP based Network

TSN

Local IPC
Collaboration with Beckhoff – HMI 2018

Beckhoff IPC controls a servo motor at a cycle time of 2ms over a deterministic IP network (emulated by 2 DIP routers)
Huawei Connect Europe 2019: Joint Demonstration with FESTO

https://twitter.com/HuaweiEntDE/status/1218082995187351553?s=20
https://www.facebook.com/HuaweiEnterpriseDE/photos/a.460953657400687/1484497385046304/?type=3&theater
https://www.linkedin.com/posts/huawei-enterprise_smartmanufacturing-activity-6623853804985077760-EFqq
Any Questions?
Thank You!