Leveraging 5G Networks & EtherNet/IP: Unleashing the Power of TSN, Clustered Networks, and Deterministic Connectivity for Sensor-to-Cloud Architecture

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Outlines

• Smart Manufacturing & OT–IT Convergence
• 5G in Smart Manufacturing
• 5G & Relevance of ISA–95 Purdue Model
• Typical Network Architecture for EtherNet/IP + Private 5G
• Integrating EtherNet/IP with 5G
  • OSI Layer Breakdown
  • Blended Architecture
• MVP for 5G Testing
• Reference Design
  • Hardware Architecture
  • Functional Architecture
• EtherNet/IP with Private 5G – Use Cases & Applications
• Conclusion
Smart Manufacturing & OT-IT Convergence

Level 4
Enterprise & Business Intelligence

Level 3
Plant Operation & Management

Level 2
Supervisory Control

Level 1
Process Control

Level 0
Field Devices

ANSI / ISA-95 (ISO 62264) MODEL

• Digital Transformation (Profitability, Flexibility..)
• Data view at enterprise level
• High upgrade cost
• Cyber not designed, No common platform for cyber monitoring

OT+IT

Microservices/ TCP/IP/ Ethernet/ Wi-Fi/ 5G/ OPC/ MQTT/ Data Diode ......

IIoT / CLOUD / SERVICES INTEGRATION

• Digital Transformation (Profitability, Flexibility..)
• Data view at enterprise level
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Technical Track
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2023 Industry Conference & 22nd Annual Meeting
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The 5G specifications defined by 3GPP include the following elements that make it the next big thing for intelligent factories:

1. **QoS (Quality of Service):** 3GPP has defined four parameters for 5G based on the types of traffic,
   - Periodic Deterministic Traffic: Stringent requirements are defined.
   - Aperiodic Deterministic Traffic: No pre-set sending time, but stringent requirements in terms of timeliness and availability are defined.
   - Non-Deterministic Traffic: Specifying lesser stringent requirements.
   - Mixed Traffic: Minimum stringent requirements.

2. **End-to-End Latency:** As less as 0.5 millisecond that goes up to 500 milliseconds

3. **Data Rate:** Up to Gbits/second

4. **Communication Service Availability:** 99.9% to 99.999999%

5. **Seamless integration** with wired technologies on the same machines

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**High-band or millimeter wave (mmWave) 5G**

High speed but short range. High band 5G frequencies range from 24 GHz to 100 GHz, making it incredibly fast – enabling multi-gigabit per second speeds. But these high frequencies cause trouble going through buildings and walls, making it useful only for short distances.
5G & Relevance of Purdue Model
Typical Network Architecture for EtherNet/IP + Private 5G

- A typical Ethernet-IP device has an EtherNet/IP Slave Device; for example, Motion Control Driver, the EtherNet/IP Object will be Motor Object.

- The same EtherNet/IP setup is referred to for bringing in 5G Integration.
OSI Layer Breakdown – Integrating EtherNet/IP with 5G

- Drive object
- CIP Application
- Implement IO
- UDP Packets
- Physical Layer

USER LAYER

APPLICATION LAYER
- Application/Service
- Open Transfer Protocol
- Network Layer
- Open Wireless Architecture

APPLICATION LAYER
- PRESENTATION LAYER
- SESSION LAYER
- TRANSPORT LAYER

NETWORK LAYER
- DATA LINK LAYER
- PHYSICAL LAYER

TRANSPORT & DATA LINK LAYER

PHYSICAL LAYER

STANDARD ETHERNET PHY
Blended Architecture – Integrating EtherNet/IP with 5G

APPLICATION
- Motion Control Ethernet / IP Objects
- Implicit I/O Message
- Common Connection Object CIP Application
- UDP Protocol
- Addressing
- Signaling & Low-Level Comms

TRANSPORT

NETWORK

PHYSICAL

STM 32

SPI

5G Modem
Blended Architecture – Integrating EtherNet/IP with 5G

- Device Profile
- Explicit/Implicit Communication
- Connection Management

- UDP / TCP
- (IP)

- Ethernet MAC
- Ethernet Physical

CIP Layer
SOC-1

UDP
Wireless SOC-2

5G Modem MTP
Blended Architecture – Integrating EtherNet/IP with 5G

STM32 Ethernet/IP Stack

5G Modem

IO Device

5G MODEM

PC Based Host OR HMI
WITH ETHERNET/IP MASTER

P5G BASE STATION
MVP for 5G Testing

Private 5G Network

- 5G Modem
- MCU
- NODE-1
- NODE-2
- NODE-N

- Modem Driver
- Ethernet IP Slave Device
- I/O Controller Python Application
- Motor Control Application

PC Application EtherNet-IP Master

Micro PCI
Reference Design – Hardware Architecture
The above architecture describes the high-level software/firmware architecture of a 5G-based Ethernet/IP Device, which can control a DC motor’s speed and handle some of the I/O functions.

- Encapsulation for EtherNet/IP to work with 5G.
- This architecture describes the message handling between the two SoCs.
- The two SoC hardware are interconnected over an SPI bus to have a maximum 10mbps connection.
- Inter-chip connection over serial (UART) interface with a USB-CDC connection device class was used to configure the SoCs.
EtherNet/IP with Private 5G – Use Cases & Applications

- EtherNet/IP Controller
- Motor Controller
- EtherNet/IP Controller
- I/O Module
- EtherNet/IP Master
- TSN Grand Master Clock
- Private 5G Network
- Cloud

Applications:
- Motion Control & Robotics
- Automated Guided Vehicles
Conclusion

• The amalgamation of 5G networks with EtherNet/IP represents a pivotal advancement in industrial automation, further bolstered by the potential of Time-Sensitive Networking (TSN).

• This synergy promises ultra-responsive, deterministic, and broad bandwidth communication platforms uniquely suited to the multifaceted requirements of modern industrial ecosystems.

• Drawing upon collaborative insights from leaders like Rockwell Automation, Ericsson, Qualcomm, and Verizon, this integration crafts a foundational pathway for organizations aiming to exploit the full spectrum of real-time data communication.

• The outlined hardware and software architectures not only facilitate streamlined MVP developments but also position industries at the vanguard of a burgeoning digital evolution.