PonCAN – A New Generation Fiber Optic Network

Application: Industrial Control
(Rev. B)

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Chapter 1 PREFACE

As the continuous integration of Information Technology (IT) and Operation Technology (OT), the demand for a unified network architecture becomes imperative. The development of smart manufacturing, industrial internet of things, and big data has made this integration more pressing. However, the different communication requirements of IT and OT have created a major obstacle for the integration of these two fields for a long time. The data in the Internet and informatization fields require more bandwidth, while real-time and determinism are the key issues for industry. These data are often unable to be transmitted over the same network. Therefore, finding a unified solution has become a necessary requirement for industry integration.

After 2014, with the advent of Industry 4.0, the demand for industrial IoT and smart manufacturing has become increasingly urgent, and the demand for connection has changed. Real-time communication technology in the industrial control field has gradually developed from the fieldbus stage to the real-time Ethernet stage based on standard Ethernet expanded by various manufacturers. However, this specific definition of industrial real-time Ethernet and standard Ethernet cannot transmit data in the same network. For the global optimization of edge computing, industrial IoT, and smart manufacturing, real-time data needed for manufacturing site control and non-real-time data needed for production management and optimization must be centralized through a unified network, processed and analyzed on a unified data platform, and then sent to various controllers to execute. Some global optimization work does not need to go through hierarchical controllers, but instead wants to go directly to the edge or the cloud. This makes the need for a unified network urgent.

A Deterministic Network is used to provide real-time data transmission, ensuring a guaranteed communication service quality, such as ultra-low upper bound latency, jitter, packet loss rate, bandwidth that is upper and lower bound controllable, and ultra-high lower bound reliability. Time Sensitive Network (TSN) is one of the new industrial communication technologies that is actively promoted in the industry, however, TSN protocols are very complex and currently, the products in the market only support a small part of them. The cost is high, the usage is complicated, and interconnectivity is very difficult to achieve. Furthermore, the increasing number of ports requires higher processing capabilities from the switch.

Vulcan has introduced a cutting-edge industrial control network bus architecture that utilizes fiber transmission technology for the next generation. It integrates high-speed data transmission of passive fiber communication, ultra-low latency, and high reliability control functions, providing high security, easy wiring and full network synchronization features, as well as a highly secure, scalable, and reliable end-to-end industrial data transmission solution. The introduction of fiber transmission technology into control area networks brings the bandwidth advantages brought by fiber connectivity to nodes, enabling OT/IT integration at a very low cost, empowering the network requirements of the intelligent manufacturing era.

Chapter 2 TECHNICAL OVERVIEW

The PonCAN network is an innovative, end-to-end and unified new industrial control deterministic network. It integrates traditional CAN networks, sensor device networks, Ethernet switches, extended PCIe networks, CPU access and multi IO device control management networks into one network, using a fiber tree structure or flexible daisy-chain structure to integrate networks within multiple copper or optical domains, forming a high-efficiency real-time large data transmission industrial control network. Its main components include:

- Core switch: Core switching engine
- Core (OLT Root): Core Station (OLT)
- Gate (Gate relay): Contains downstream OLT Root and upstream ONU
- Node (ONU Node): Client/Edge Station (ONU station)

- Optical Fiber or Copper cable connecting stations in single or multiple domains

PonCAN architecture chips deploys flexible network topology, integrate multi-functional and provide flexible IO interfaces such as PCIe 3.0, USB 3.0 and flexible Ethernet (including 10G/25G/1.25G bps fiber node) interfaces for user applications.

Chapter 3 TECHNICAL CHARACTERISTICS

The unique technical features of PonCAN network include:

- High determinism, bandwidth and low latency network behavior;
- High functional safety and reliable communication;
- OT (Operational Technology) and IT (Information Technology) network convergence, a single network supports different service properties;
- Low-cost, low-power, long-distance, and long-life network infrastructure;
- Strong security;
- Centralized network management, flexible network configuration. Strong remote diagnosis and debugging functionality, software-defined network architecture;
- Smooth migration of existing ecosystems;
- Seamless integration with 5G URLLC-based wireless.

3.1 High bandwidth, high determinism and low latency

- Bandwidth and Bandwidth Utilization
    - The first generation product supports 10Gbps bandwidth, future products can be smoothly upgraded to 25G/50G/100G/…
    - The network bandwidth effective utilization rate is greater than 85%
- Latency Characteristics
    - Maximum latency limits can be configured with different latency boundaries, typically the guaranteed end-to-end maximum latency is less than 100us
    - Critical messages can be guaranteed to have latency less than

10us

- High-precision full network synchronization
    - Synchronization accuracy performance can reach 8ns, synchronization jitter within +/- 20ns range
    - All nodes in the network share a global timestamp
    - Precise full network remote transmission with 1pps accuracy
- Hard real-time network scheduling
    - No network congestion, efficient and flexible service flow plasticity
    - High priority service flows can overtake low priority service flows, forming the foundation for IT/OT integration.

3.2 Functional safety

- Communication Reliability
    - Fiber communication itself can provide BER less than 1e-12
    - Messages with high reliability requirements
        - Provides end-to-end ACK mechanism
        - Automatically retransmission mechanism implemented at physical layer to minimize extra retransmission latency
        - Total equivalent BER less than 1e-19
    - Strong resistance to environmental electromagnetic interference and minimum interference to environment emission
    - System Resilience
        - PonCAN can support fully redundant network design
        - Real-time detection of network failure (fiber, devices, equipment)
        - Automatic protection switchover within a very short time

3.3 Convergence of IT and OT

- A fully controlled and managed network
    - Precise full-network synchronization
    - Precise full-network service scheduling with no service blocking or collisions
    - Preemptive service scheduling, OT flows can effectively preempt IT flows
    - Each node can support 8 different priority levels of service
    - One network supports 128 nodes and 4096 service flows

  - Multiple networks can be cascaded to form a larger network
- Software-defined network
  - Software can define each service flow and change service exchange rules in real-time
  - Software defines sub-networks and isolation between sub-networks, changing the logical topology of the network
  - Provides enough counter MIB information for network diagnosis and tuning
- Seamless connection between edge cloud and machine devices

3.4 Security defense

- Unique three-layer security defense system
  - Component level
  - Trust root embedded inside chip
  - Trusted secure boot and OTA update
  - SE API provided to upper layer software
- Network level
  - Pre-authorization of node registration
  - Real-time authentication required for each node to access the network
  - Periodic re-authentication required for each node in the network
  - Real-time AES encryption of all services in the network
- Behavioral level
  - Non-intrusive real-time monitoring of all node behavior patterns, building behavior models, identifying abnormal behavior
  - Detecting hardware aging or failure
  - Detecting hacker intrusion

3.5 Ecosystem

The ecosystem of the PonCAN network is highly user-friendly, reflected in:

- Zero modification of existing devices to access the PonCAN network
- The PonCAN SoC provides interfaces for various standard industrial devices: Ethernet, PCIe, USB, MIPI, CAN, RS485, and rich GPIO
- PonCAN network passes various different protocols and packets, and different protocols can coexist on the PonCAN network. If necessary, the PonCAN Soc can perform protocol conversion to achieve full or partial network uniform protocol

Path 1:

- The original protocol of the device is transmitted on top of the PonCAN protocol
- Communication between devices with different protocols is achieved through the original protocol gateway

Path 2:

- The various different protocols of the device can be converted into a unified network protocol, such as OPC UA, DDS, TCP/IP, etc.
- Direct communication between device nodes

Chapter 4 SYSTEM ARCHITECTURE

4.1 PonCAN system architecture

PonCAN-Based Smart Manufacturing

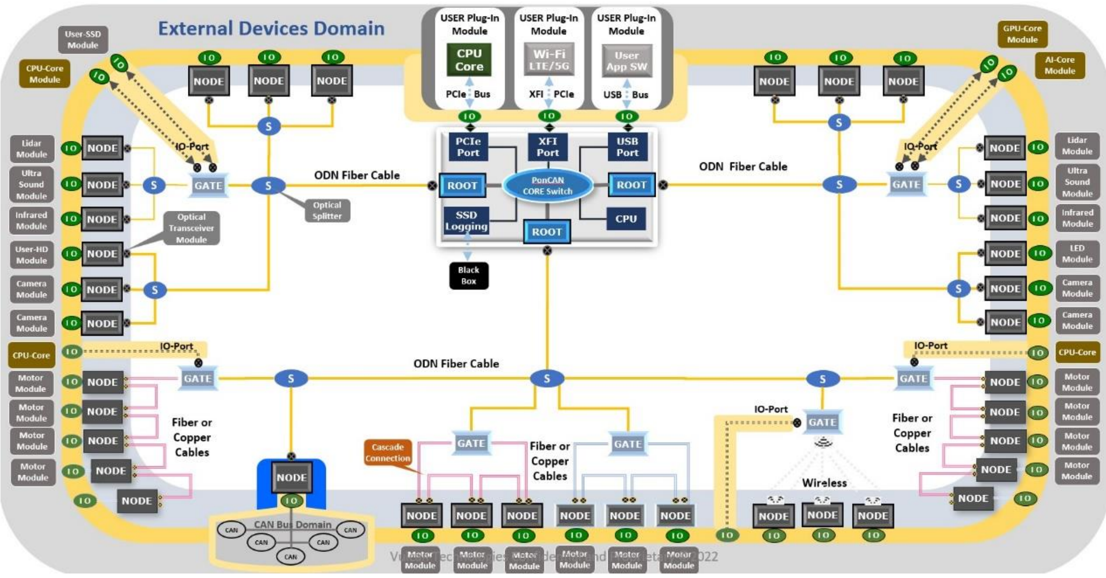


Figure 1 PonCAN network system architecture

As shown in Figure 1, the typical PonCAN network system architecture consists of the following main components:

- Core node (OLT Core)
- Gateway relay (Gate Relay)
- Front-end node (ONU Node)

- Fiber, Splitter and/or copper cable

By combining the network components above, standalone or multi-level optical or copper device systems can be integrated into a PonCAN network for efficient unified control.

Chapter 5 APPLICATION SCENARIOS

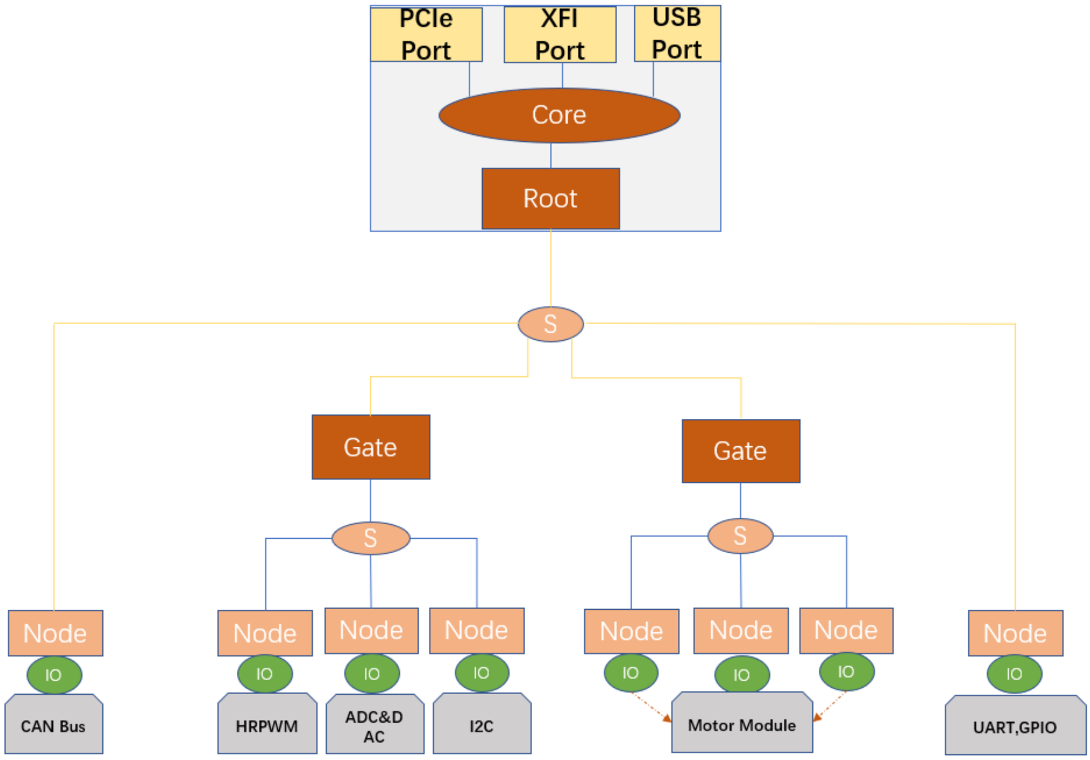
The development of industrial control networks must prioritize the resolution of enterprise difficulties and industry pain points. Industrial control networks face new demands and challenges, such as requirements for network delay, jitter, security, bandwidth, and network convergence in terms of deterministic networks. Through the introduction of the previous sections, we already know that PonCAN networks can perfectly address these pain points and provide a safe and reliable network transmission solution for industrial control network fields such as smart manufacturing and automated factories.

From an application perspective, the large-scale implementation of industrial control networks with deterministic network technology can drive the network and intelligent upgrading of various industries in the industrial sector, such as smart manufacturing (intelligent factories, automated workshops, equipment maintenance, etc.). For industrial control scenarios, the table below shows the typical requirements for deterministic service quality for various services carried by the network in different applications.

Application	**Latency**	**Jitter**	**Reliability & Bandwidth**
Remote control	5 ms	-	99.999%, up to 10 Mbps
Discrete automatic motion control	1 ms	1 µs	99.9999%, 1 to 10 Mbps
Discrete automation	10 ms	1 ms	99.99%, 10 Mbps
Process automation remote control	50 ms	20 ms	99.9999%, 1 to 100 Mbps

Process automation monitoring	50 ms	20 ms	99.999999%, 1 Mbps

The simplified topology of the PonCAN network in the industrial control field is shown in Figure 2, which includes the three main components of the PonCAN network system: Core Root OLT, Gate Relay, and front-end ONU Node, where the Node has the flexible and convenient multi-type IO interface required for industrial control field device access, greatly facilitating the promotion and application of the PonCAN system in the industrial control field.



PonCAN network in the field of industrial control

In the subsequent sections of this chapter, two scenarios of industrial control field application will be introduced in detail.

5.1 PonCAN in Factory Automation

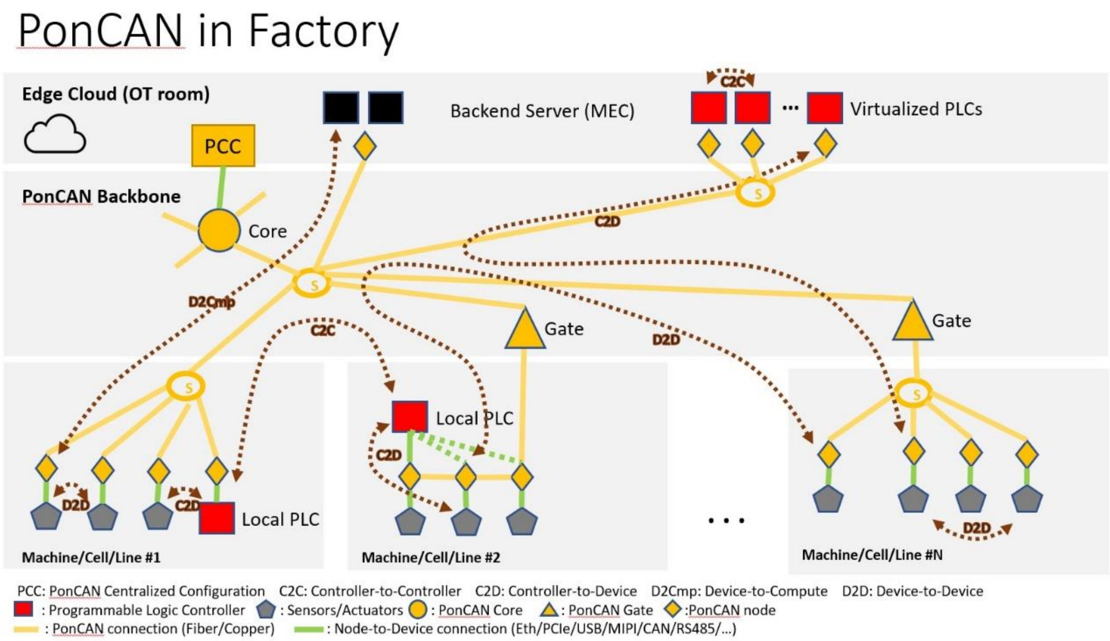


Figure 3 PonCAN factory automation application block diagram

In the current process of transforming actual factories into automation control, in addition to the deterministic network and network integration problems described in the previous chapter, there is also a practical problem of deployment implementation. If a TSN-like network technology is adopted, many Ethernet switches and copper cable networks will still be unavoidable. If the factory area is too large or if the devices that need to be integrated into one network have many different manufacturers or protocols, it will cause complicated deployment and compatibility issues, and cannot fully utilize the advantages of TSN network technology. However, by adopting PonCAN network technology, the above problems are perfectly solved. The entire process uses one fiber optic cable to integrate into one network.

As shown in Figure 3, through the PonCAN network core nodes Core, Gate, and Node, various front-end devices (various sensors, actuators, etc.), PLC controllers with various local protocols, and centralized virtualized PLCs in the factory automation production scenario are integrated into a PonCAN data transmission network with a single fiber optic cable and corresponding optical splitters. This can be controlled from the edge cloud center, realizing high-speed, real-time, secure, and high-bandwidth transmission and control of information data flow and operational processes.

5.2 PonCAN in 5G Convergence

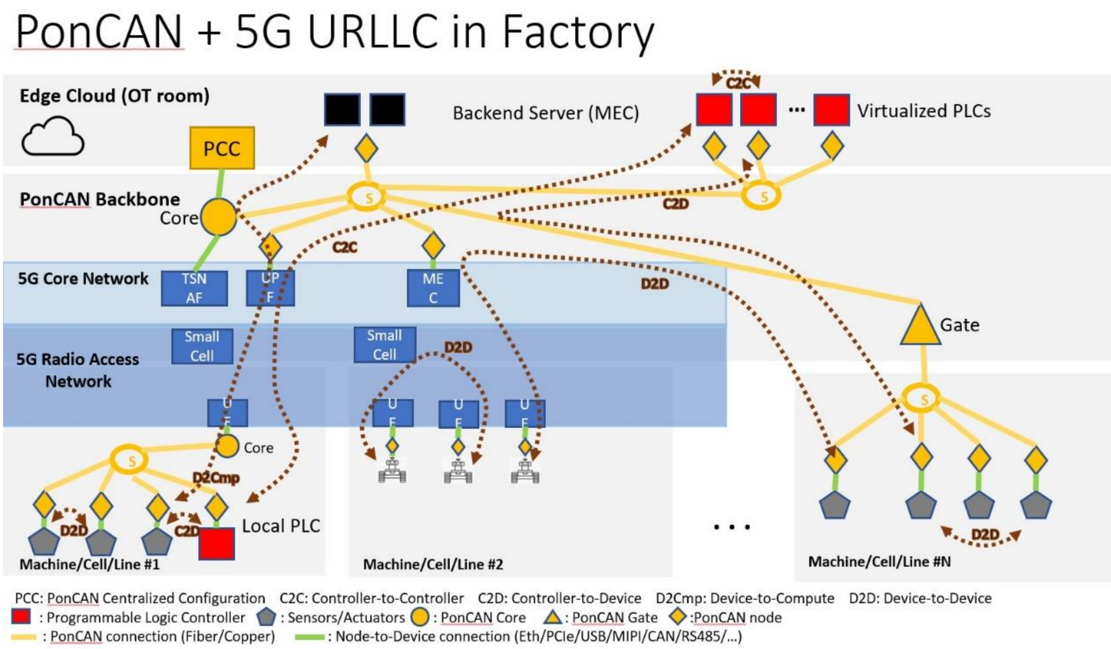


Figure 4 The integrated network of PonCAN and 5G

With the rapid development of 5G technology and its increasingly extensive applications, the integration of PonCAN with 5G technology is an inevitable trend. In some industrial control network scenarios, there may be a need for data transmission across regions and networks, in which case the PonCAN network supports integration with the 5G core network to meet these needs.

In the 5G URLLC scenario, 5GS supports the processing of 1588-based PTP packages and is capable of measuring the extra delay of 1588 packages within the 5GS system, allowing for seamless integration with PonCAN. In this case, 5GS is a time-sensitive subsystem. The integration of PonCAN and 5G URLLC does not require 5GS to support other TSN features. PonCAN itself can schedule and shape traffic. If 5GS supports TSN features, the integration of PonCAN and 5G URLLC can achieve more detailed service control, but this is not necessary. Therefore, 5G URLLC can be seen as a virtual time-sensitive subnetwork within the PonCAN network, and whether 5GS supports TSN or not, it is enough to seamlessly integrate with PonCAN. PonCAN and

5G URLLC are two highly complementary technologies that cannot be replaced by each other and can work well together.

Chapter 6 CONCLUSION

In summary, the advantages of the PonCAN network in the field of industrial control are mainly:

- High bandwidth, guaranteed ultra-low latency, high real-time and synchronous determinism, with all the network performance features required for Ethernet determinate networks, and even better.
- Multiple industrial control interfaces, which can save a lot of peripheral devices, such as high precision HRPWM, ADC & DAC, CAN-FD, UART and other high and low-speed control interfaces, which simplifies system design and saves cost.
- A unified network architecture perfectly solves the integration of IT and OT.
- Reliable and secure fiber communication with a redundant and elastic system ensures high reliability in system operation.
- Complete network security guarantee at the system level.
- Optical fiber's long transmission distance, long life, low maintenance cost, and various network topologies perfectly meet the application requirements of factory control network deployment, bringing low power consumption, low cost, and anti-electromagnetic interference advantages.
- Support for joint network deployment with 5G URLLC, seamlessly combining high-speed wired and wireless networks to meet the needs of industrial control transmission network deployment across network domains.

The upcoming new generation of industrial networks will be a network that coexists and complements wireless, copper wire and fiber optics. Vulcan is committed to the cutting-edge technology of fiber optic network industrial communication protocols, promoting the realization of "*light in and copper out*" in the industrial field.