PROFINET IRT

The Solution for Synchronous Real-time Applications

Introduction

PROFINET employs various communication channels to deliver data with the appropriate speed and determinism. The PROFINET Isochronous Real-Time (IRT) communication channel is designed to fulfill the most demanding high-speed motion control applications.

This White Paper explains PROFINET IRT mechanisms, such as Bandwidth Reservation, Scheduling, and Synchronization. Also, it covers an overview of how to implement PROFINET IRT, including topology and media options.

PROFINET Mechanisms

PROFINET is the world's most advanced Industrial Ethernet solution. It is a communication protocol to exchange data between controllers and devices. PROFINET can operate in demanding industrial environments and can deliver the speed and precision required by manufacturing plants. To ensure appropriate performance, PROFINET delivers data through the following communication channels:

1. TCP/IP (or UDP/IP)
2. PROFINET Real-Time (RT)
3. PROFINET Isochronous Real-Time (IRT)
4. Time Sensitive Networking (TSN)

PROFINET employs TCP/IP (or UDP/IP) communications for specific non-time-critical tasks, such as configuration, parameterization, and diagnostics. Processing data packets through the IP stack generates latency and jitter. Therefore, IP-based communication with PROFINET is unsuitable for time-critical tasks.

PROFINET RT handles time-critical data exchange. An arriving PROFINET RT Ethernet frame has the PROFINET EtherType: 0×8892. Upon arrival at the destination node, the frame is directed straight from Ethernet (Layer 2) to the PROFINET application (Layer 7) [1]. The frame skips the TCP/IP layers and avoids the variable time it takes to be processed. Thus, communication speed and determinism improve significantly.

PROFINET RT meets the vast majority of industrial automation timing requirements, and almost all PROFINET frames are sent via this method. PROFINET can use additional techniques for even faster performance with the PROFINET IRT channel. PROFINET IRT is a step beyond PROFINET RT.

Unavoidably, under high network traffic, some time-critical messages can gain jitter. PROFINET IRT eliminates variable data delays by enhancing the rules employed to switch Ethernet traffic and creating special rules for PROFINET traffic. It fulfills all synchronization requirements and allows deterministic communication with cycle times down to 31.25 µs and1 µs of jitter.

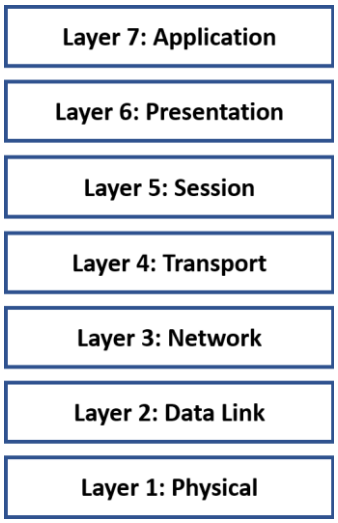

Figure 1 - ISO/OSI Model

[1] The layers refer to the ISO/OSI model, a seven-layer model that generically describes the abstraction layers of a communication system.

The latest PROFINET specification (V2.4) introduces a fourth communication channel: PROFINET over TSN. Since PROFINET over TSN has yet to be implemented in PROFINET components, this White Paper won't cover the topic. Information on PROFINET over TSN is available at https://us.profinet.com/digital/tsn

PROFINET Conformance Classes and PROFINET IRT

Most industrial applications do not require IRT performance. Therefore, not all PROFINET devices have IRT capabilities. The functionality of PROFINET components varies.

Every PROFINET device has a defined set of features that are mandatory based on its Conformance Class (CC). The table below summarizes the characteristics of CC-A, B, and C.

	CC-A	CC-B	CC-C
Real-time data exchange	✓	✓	✓
Alarms and diagnostics	✓	✓	✓
Network topology support	✓	✓	✓
SNMP support		✓	✓
Isochronous real-time data exchange			✓

All PROFINET devices support real-time data exchange, standardized alarms and diagnostics, and network topology support. PROFINET devices have built-in standard diagnostics and alarms with specific PROFINET errors, such as invalid read/write area, device not accessible, and data length error. Also, PROFINET devices have built-in network topology support. The user can read out topology information with standard PROFINET tools.

Aside from the standard diagnostics and topology support in all PROFINET devices, CC-B devices support Simple Network Management Protocol (SNMP). With SNMP support, users can employ standard SNMP tools to read out topology information, network statistics, and other related network details.

In addition to SNMP, CC-C devices also support PROFINET IRT. Only CC-C PROFINET components support the IRT functionality and are therefore required to implement IRT configurations.

PROFINET IRT Overview

PROFINET RT meets the majority of industrial automation timing requirements. Most PROFINET networks can solely rely on PROFINET RT for all cyclic data exchange. PROFINET IRT is optional and only required in specific high-performance applications, like, for example:

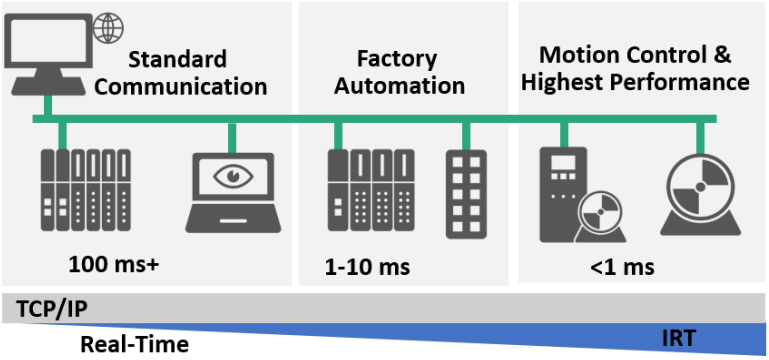

Figure 2 -Timing performance requirements

- Packing machines
- Printing presses
- Plastics injection molding machines
- Wood-processing machines
- Glass-processing machines
- Ceramic-processing machines

Mechanisms and Performance

PROFINET IRT provides fast and deterministic data exchange for the most demanding applications. It employs three mechanisms to achieve the desired performance:

Synchronization: All devices involved in the synchronous communication must have a common clock to ensure a maximum cycle time deviation of 1 µs. A clock master uses synchronization frames to synchronize all local clock pulse generators of IRT devices within a clock system to a common clock.

Bandwidth Reservation: The cyclic data packets are transferred as synchronized packets on a reserved bandwidth. All other data packets, such as packets for diagnostics or IP traffic, share the rest of the Ethernet bandwidth. The reserved bandwidth protects time-sensitive data from delays caused by other data. Also, it allows for the highest level of determinism.

Scheduling: To communicate in real-time, the controller creates a schedule for IRT communication. The schedule is like a timetable that indicates precisely when each frame must be sent out.

IRT-capable devices offer fast update times of 250 µs. But, a subset of IRT devices offer even faster performance. With appropriate hardware, it is possible to reduce the minimum update time to 31.25 µs. Such specialized components employ three additional mechanisms:

Fast-forwarding: Every Ethernet frame has an ID built-in. The ID tells a node if the packet is intended for it or another device on the network. Fast-forwarding moves the ID to the beginning of the frame. Then, devices can decipher sooner whether they should process the data or forward the frame.

Dynamic Packing: Instead of sending individual frames for each node, a summation frame is used. It contains all data for devices in a line. Once a device processes its part of the frame, the processed data stays in the respective device, minimizing the remaining packet's size.

Fragmentation: Standard TCP/IP traffic can coexist on the same wire as PROFINET traffic. With fragmentation, large TCP/IP frames are split up into smaller frames. Then, more PROFINET data can be transmitted.

Topology

There are no topology restrictions for PROFINET IRT. The user can implement line, star, tree, or ring configurations. The only requirement is that all IRT nodes have to be interconnected on the same domain or network section. Other PROFINET or Ethernet nodes can be connected as well, but must not interrupt direct connection between IRT devices. All switches in the IRT domain must support IRT. The diagram below illustrates the concept.

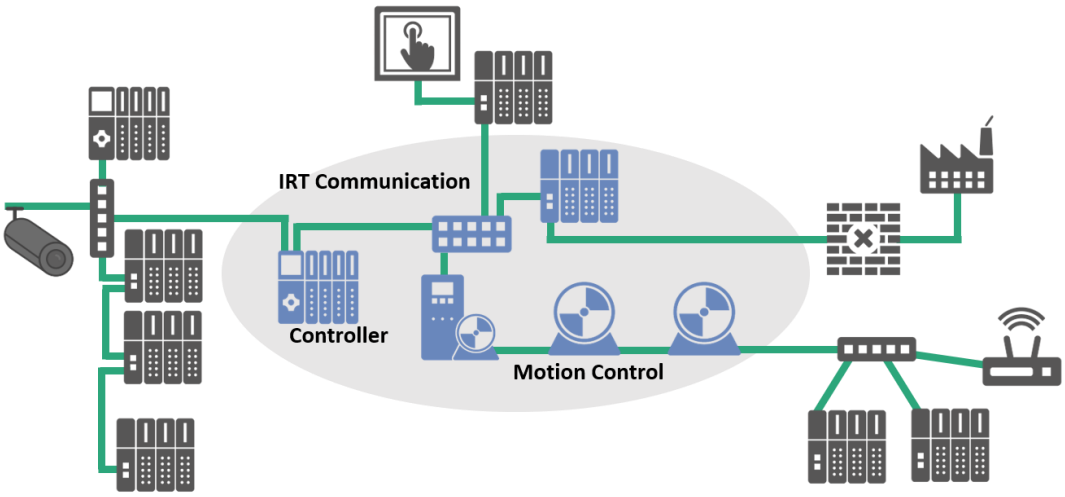

Figure 3 - PROFINET IRT configuration

The blue components make up an IRT domain between an IRT-capable controller and IRT-capable devices. Within one network, there can be multiple independent IRT domains.

Media Considerations

There is no need for specialized cables or connectors in a PROFINET network. Even when employing IRT, the communication medium is standard unmodified Ethernet. As a result, users can utilize standard Ethernet cables and connectors. Copper and fiber optic Ethernet cables are suitable media.

Wireless communication is a feature of PROFINET. Messages can be transmitted wirelessly via Wi-Fi or Bluetooth, as defined by the PROFINET specification. Unfortunately, due to the variable time it takes to convert wired signals to wireless signals, wireless connections are unsuitable for PROFINET IRT applications.

Implementation

The first step to implement PROFINET IRT is selecting the appropriate components. PROFINET components that provide IRT capabilities are always Conformance Class C. To implement PROFINET IRT, controllers and devices that require IRT performance, and every Ethernet switch linking those components must be certified according to PROFINET's Conformance Class C.

The user must then configure the IRT synchronization domain; they must specify the cycle times for the devices. Then, the controller calculates the amount of bandwidth needed for the IRT operation. Finally, the network topology must be defined in the controller to optimize the IRT transmission schedule within the IRT time bands. The whole process is only slightly more involved than setting up the rest of the network.

Summary

PROFINET users have the option to employ PROFINET RT or PROFINET IRT for cyclic data exchange. PROFINET RT provides suitable performance for most automation tasks. Still, some applications require faster speeds and a higher degree of determinism. PROFINET IRT ensures messages are delivered in a fast and highly deterministic fashion regardless of external Ethernet traffic.

Implementing PROFINET IRT requires prior planning by selecting the appropriate components. However, a PROFINET IRT configuration is not restricted to specific topology or media options. Also, PROFINET networks continue to be open networks that allow for coexistence with other Ethernet traffic.

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