White Paper

Accelerate smart factory construction with TSN technology

CC-Link IE TSN

Development background, features, and future developments

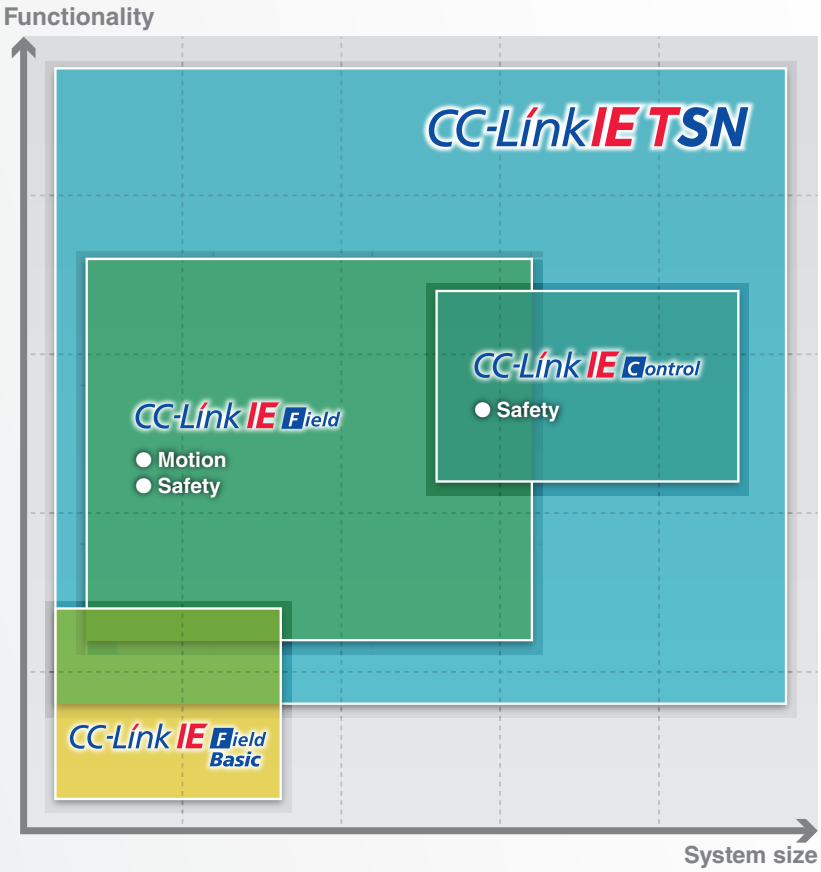
1. Introduction

The CC-Link Partner Association has created a new industrial open network specification "CC-Link IE TSN" as the next generation CC-Link IE network.

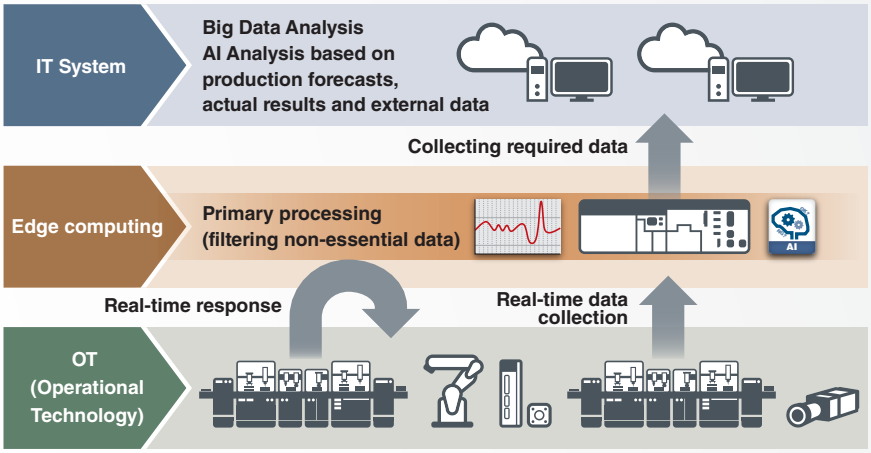
CC-Link IE was introduced in 2007 as the first industrial open network in the industry based on 1 Gbps Ethernet. CC-Link IE is available in several different types. "CC-Link IE Control" is a trunk network that connects controllers within a factory, while "CC-Link IE Field" covers general input/output control, connecting controllers with a wide variety of field devices. Functionality and scope have also been expanded with "CC-Link IE Field Motion" (for motion control) and "CC-Link IE Safety" (for safety control). In 2016, "CC-Link IE Field Basic" was added to the lineup to extend compatibility to 100Mbit devices.

The newly established CC-Link IE TSN specification is the first to combine gigabit Ethernet bandwidth with time sensitive networking (TSN). TSN is an addition to the IEEE Ethernet related standards and is starting to become popular for industrial networks. TSN's key benefit is that it allows the combining of real-time control communication with non-real time information communication while maintaining deterministic performance. This is not possible with conventional Ethernet.

CC-Link IE TSN adds TSN to increase openness while further strengthening performance and functionality. It also supports more development methods, enabling easier implementation on a wider range of equipment and increasing the number of compatible products and is expected to accelerate the construction of smart factories using the IIoT.



2. Development Background



As customer needs grow more diverse and advanced, there is a growing trend in manufacturing industry toward automation, reducing TCO (Total Cost of Ownership) and improving quality, together with embracing new manufacturing methods such as mass customization. The information-driven society fueled by IT-based data continues to develop, with the development of sensing technology, higher-speed networks, the spread of cloud/edge computing, and the development of AI (artificial intelligence).

We are also seeing the appearance of global mega-trends moving toward the use of the IIoT in manufacturing industry, such as Industry 4.0 in Europe, the IIC (Industrial Internet Consortium) in the US, Intelligent Manufacturing in China, and Connected Industries in Japan. All of these share a common goal: the creation of "smart factories" in which everything is connected, data is used to the fullest, and optimized manufacturing takes place autonomously.

In order to create smart factories, essential issues include gathering real-time information from production processes, processing it via edge computing, and then transmitting it seamlessly to IT systems. Toward that end, one crucial need when making the most of production site data is a network capable of high-speed, stable control communication as well as large-volume information transmission to IT systems. In other words, it is important to combine industrial networks at production sites with IT system networks.

A wide variety of industrial networks are currently in use. However, it is difficult to achieve interoperability between them, leading to "islands" of automation that decrease process transparency. Demand for TSN support will therefore increase, as this technology makes it possible to mix different networks on the same trunk line and provide real-time communication through time synchronization.

CC-Link IE TSN was developed to meet this demand. CC-Link IE TSN enables seamless, smooth connection from upper level IT systems to OT systems at production sites, allowing the expanded use of a wide variety of applications in manufacturing industry.

In order to realize smart factories, productivity improvement through higher equipment performance and functionality is essential, along with advanced motion control. This is especially true in advanced industries such as semiconductor and battery manufacturing.

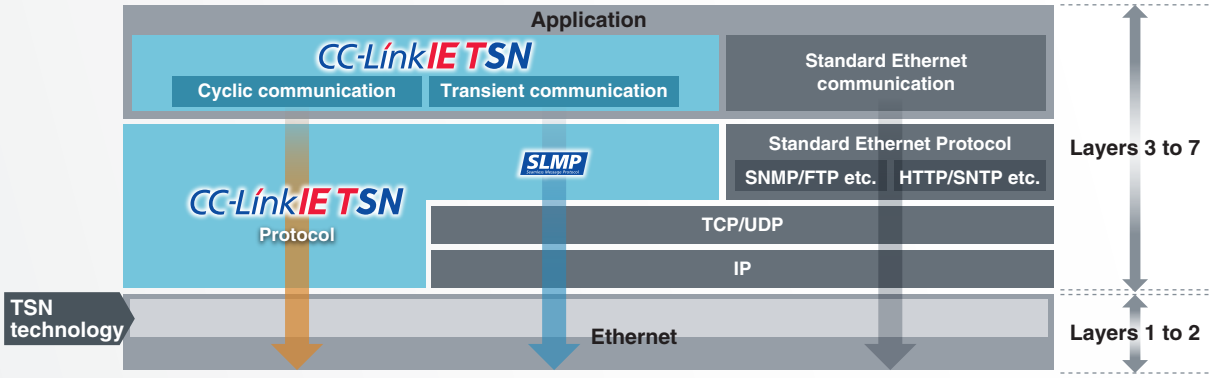
CC-Link IE TSN builds on the benefits of CC-Link IE by improving communication functions and synchronization accuracy. Thus the motion control capabilities have been significantly enhanced.

CC-Link IE TSN has thus been created as a next generation industrial open network to accelerate the construction of smart factories.

3. Technical overview and utilization of open technology

1 TSN technology and protocol layers

CC-Link IE TSN's protocol uses layers 3 to 7 of the OSI reference model, building on the TSN technology located in layer 2.



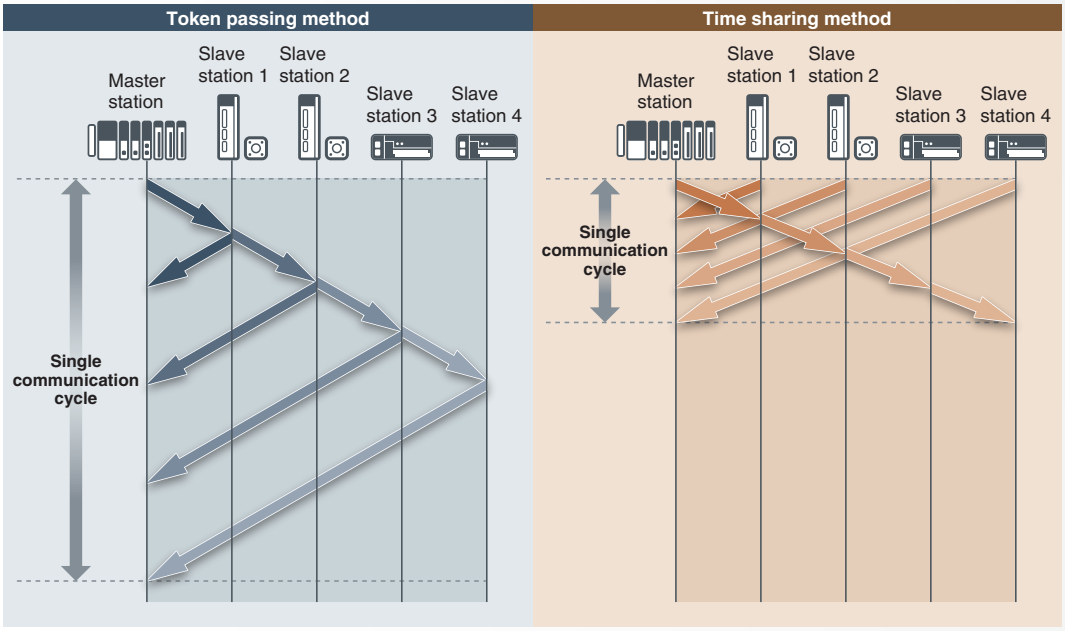
TSN consists of multiple international standards. The major standards are IEEE802.1AS (which defines the time synchronization method) and IEEE802.1Qbv (which defines the time sharing method). Combining these to the Ethernet standard enables punctuality, ensuring transmission within a given period of time, and mixed implementation with other communication protocols.

The Ethernet standard protocols that can be used are IP at the third layer and TCP/UDP at the fourth layer. Protocols such as SNMP, HTTP, and FTP can also be used in the upper levels. This provides for more flexible network administration, as general purpose Ethernet diagnostic tools can be used for network diagnosis.

2 Communication method

CC-Link IE TSN uses the time sharing method, a revolutionary cyclic communication concept. Conventional CC-Link IE uses a token passing method. A station transfers transmission rights to the next station after transmitting its own data by transfer of the token.

In contrast, CC-Link IE TSN uses common time synchronized across the network. The input and output communication frames are simultaneously transmitted in both directions in a fixed time. Combining this method with TSN technology shortens the network cyclic data update time



Link scan is completed when token makes 1lap

Completion of the link scan is done when the I/O communication frames are transmitted simultaneously in both directions at a predetermined time by utilizing network time synchronization.

3 Increased profile support & diagnostics

The CC-Link Partner Association has defined CSP+ (Control & Communication System Profile) in order to make it easier to start up, operate, and maintain devices compatible with the CC-Link family. By using CSP+, CC-Link IE TSN has added support for CANopen device profiles. For example, communication using international standard IEC61800-7 (CiA402) is possible.

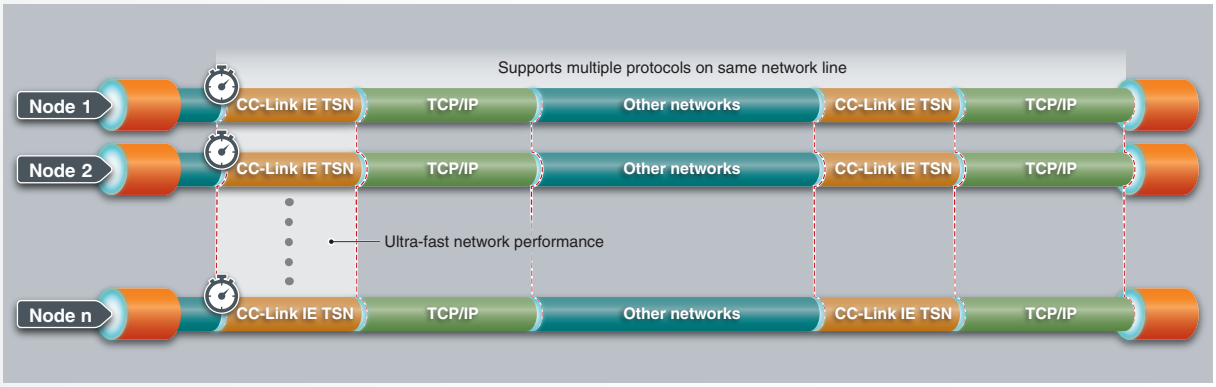
4 Support for general-purpose network diagnostic functions

CC-Link IE TSN network devices can be examined using SNMP (Simple Network Management Protocol), which is widely used for monitoring IT networks. CC-Link IE TSN component information and statistical information are defined as extended MIBs (Management Information Bases), allowing general purpose SNMP tools to be used for network diagnostics.

4. Features

CC-Link IE TSN offers four major features.

1 Integration of control communication and information communication



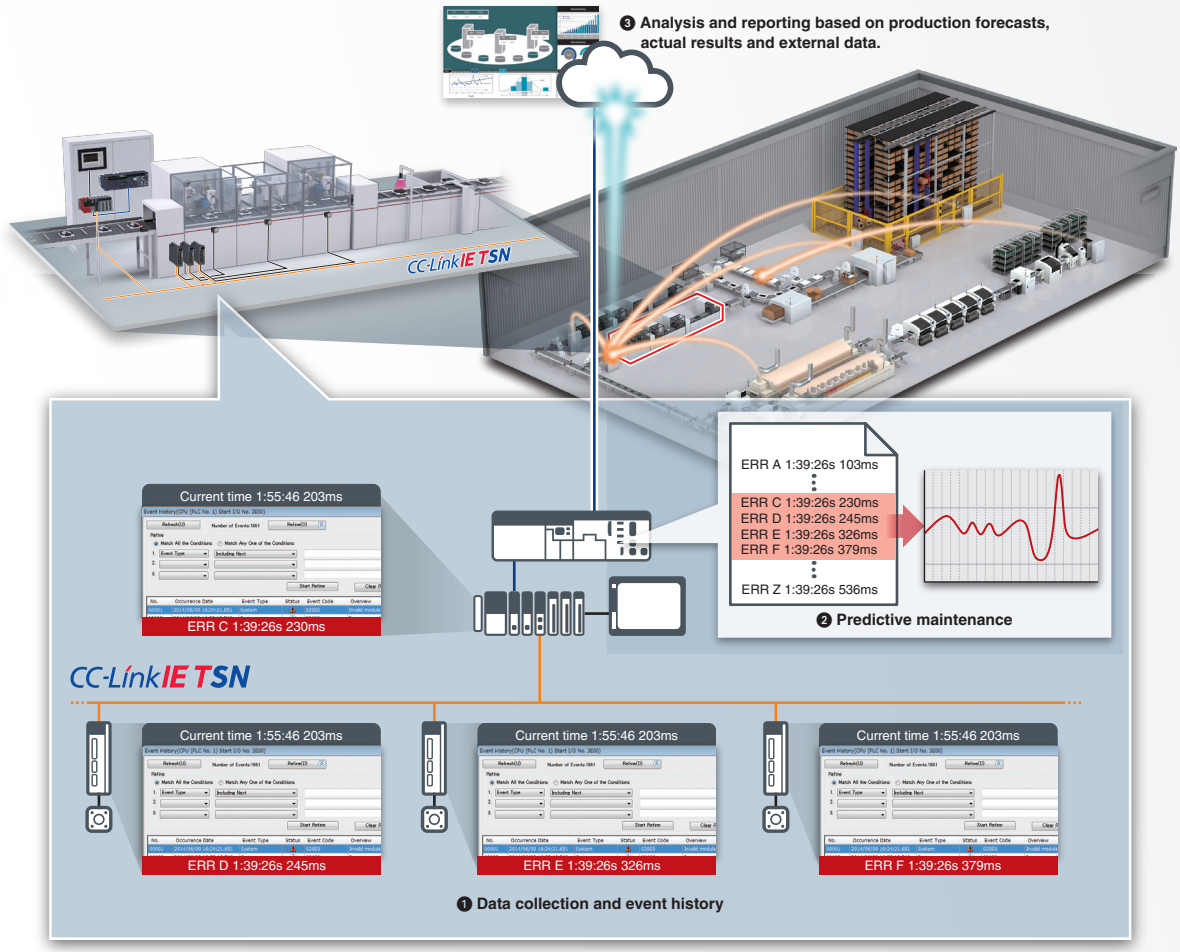
By giving a high priority to cyclic communication for device control and by allocating bandwidth preferentially over information communication, CC-Link IE TSN offers a network environment that communicates information with IT systems while controlling system devices with real-time cyclic communication. This mixture with information communication means that devices using UDP or TCP communication (such as machine vision systems) can be connected to the network for high accuracy monitoring, diagnostics and analysis.

2 Rapid system setup and advanced predictive maintenance

CC-Link IE TSN is also compatible with SNMP, enabling easier diagnosis of network devices. Until now, special tools were required when collecting device status information. However, general purpose SNMP monitoring tools can now be used to gather and analyze data from devices compatible with either CC-Link IE TSN or IP communication (such as switches and routers). This allows quicker system startup times, and can reduce the amount of time and effort spent on system administration and checking the operating status of devices during maintenance.

The time synchronization protocol regulated by TSN is used to calibrate time differences between devices compatible with CC-Link IE TSN, keeping them synchronized with high accuracy. Time information stored in both master and slave devices is kept synchronized to the microsecond. If a network error occurs, this makes it possible to check operation logs and accurately trace events up to the error in chronological order. This can help to identify problems and can lead to quicker recovery.

It is also possible to provide production site information and accurate time information to IT systems. This will allow AI enabled data analysis to provide further process improvement via predictive maintenance.

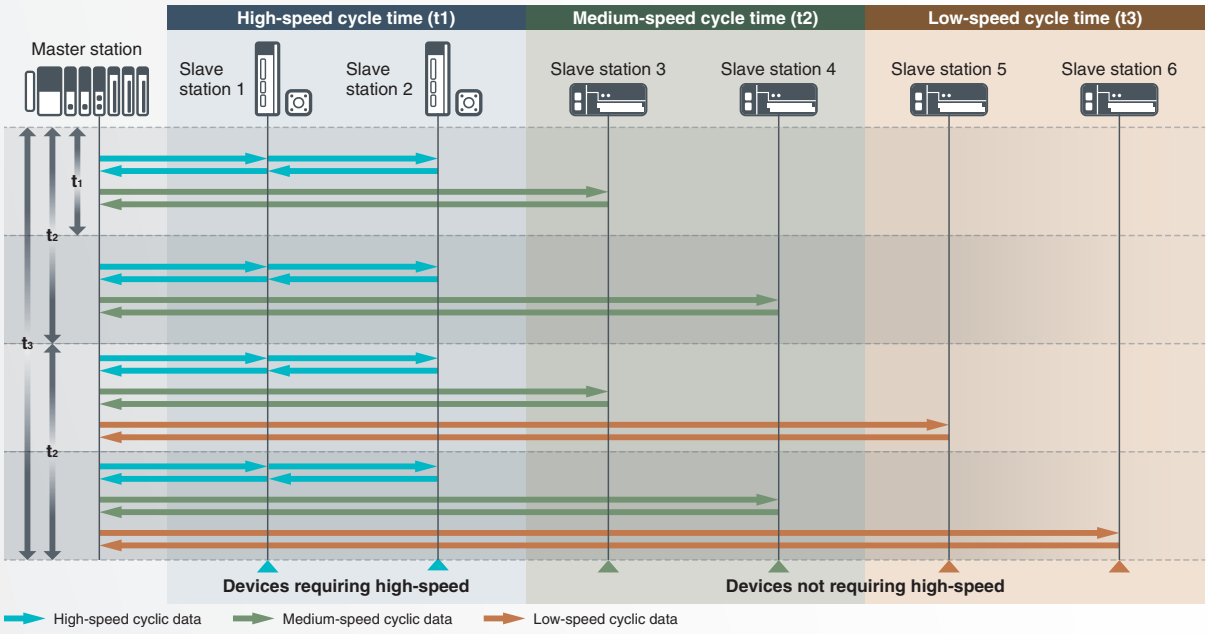


3 Maximize the performance of motion control and reduce cycle time

CC-Link IE TSN uses the time sharing method with time trigger and bidirectional simultaneous communication to achieve a cycle time of 31.25 μs or less. Adding sensors or increasing the number of servo amplifier axes required for control to expand a production line has minimal effect on overall cycle time in systems operated with CC-Link IE TSN. Cycle time may even be reduced compared with systems operated with conventional networks. This is achieved in the following way.

CC-Link IE TSN allows equipment with different communication cycles to be used together according to the performance of each device. Until now, devices connected to the same master station had to be operated using the same cyclic communication cycle (link scan time) throughout the entire network. CC-Link IE TSN allows for multiple communication cycles to be used within the same network.

This makes it possible to optimize communication cycles depending on the characteristics of each device. For example, devices (such as remote I/O) not requiring a high speed communication cycle can be connected while still maintaining the performance of devices requiring high performance communication cycles (such as servo amplifiers). This can also maximize the potential of slave devices on the network and improve productivity throughout the entire system.



4 More options for device vendors

In order for conventional CC-Link IE to make effective use of its 1 Gbps bandwidth, device development vendors had to implement both master and slave device functions with hardware, using dedicated ASICs or FPGAs.

CC-Link IE TSN supports implementation on both hardware and software platforms. ASIC and FPGA based hardware methods are supported. Moreover, development with software protocol stacks on a general purpose Ethernet chip is also possible for both master and slave devices. In all cases, 100Mbit and 1Gbit physical layers are supported.

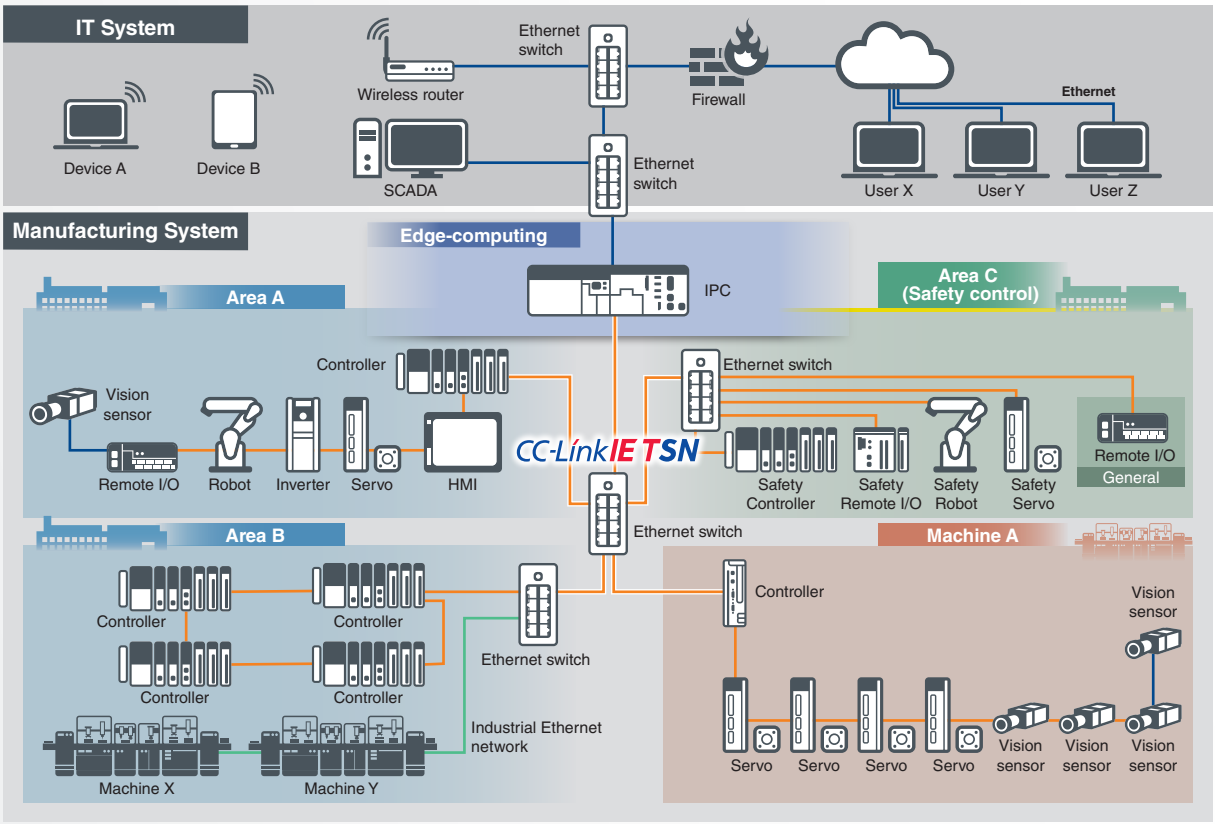
Device development vendors, given these options for implementation (hardware or software) and communication speed (100 Mbps or 1 Gbps), can now use the ideal development method for devices compatible with CC-Link IE TSN. This will also benefit users by rapidly expanding the range of compatible devices.

Development method*1			CC-Link IE TSN
Communication speed	Master	Slave	
1Gbps	Hardware	Hardware	Supported
	Software		
	Hardware	Software	
	Software		
100Mbps	Hardware	Hardware	
	Software		
	Hardware	Software	
	Software		

*1. Hardware: Development with dedicated ASIC or FPGA.
Software : Development with software protocol stack (standard Ethernet chip).

5. Use cases

1 Smart integration of control and information communication

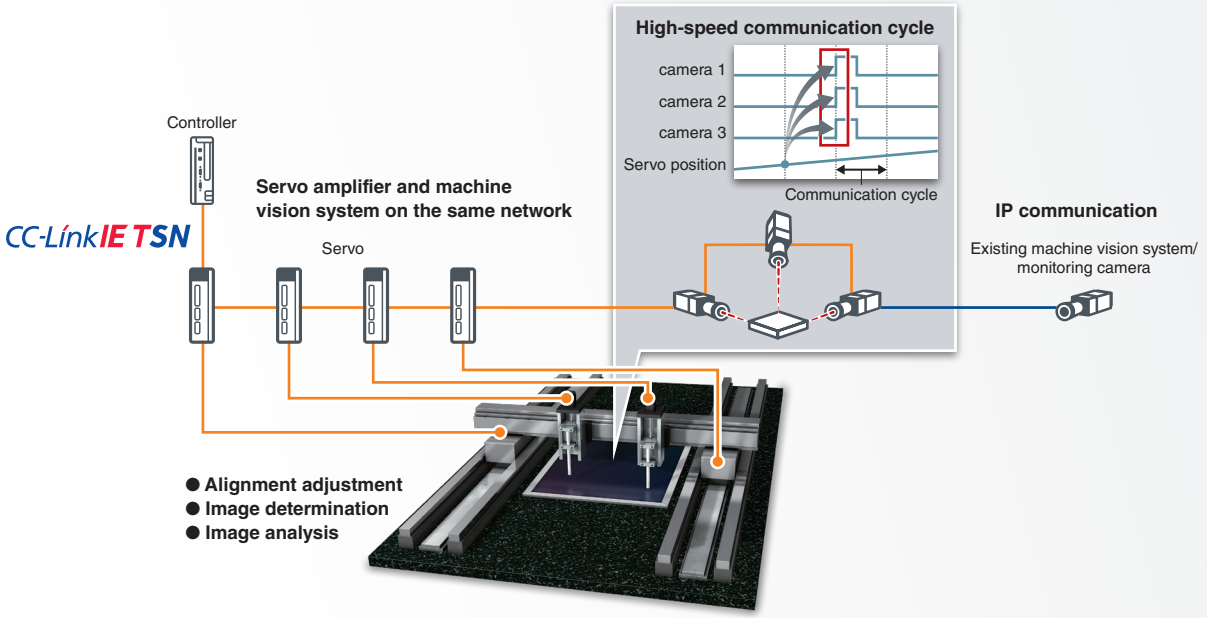


Achieve smart factories by integrating IT system information communication and other open protocols on the same network while running real time control.

2 System using general-purpose IP communication devices and high performance motion control

In the current system, the servo motor is momentarily stopped during alignment operation, and then the workpiece position is accurately measured by vision. A servo amplifier and vision sensor compatible with CC-Link IE TSN could be used at this point to allow time synchronization, which would enable the vision sensor to accurately determine the position of the workpiece while being moved by the servo motor. This could significantly improve cycle time and reduce wiring.

The large volume of image data from the vision sensor can be transmitted via IP communication, allowing construction of a single network system with reduced wiring and yet with no impact on servo control performance.



6. Future Developments

The new CC-Link IE TSN specification uses TSN technology to enable time sharing communication over Ethernet, making it easy to use Ethernet devices. The protocol has also been redesigned for high-speed cyclic communication, significantly improving performance and functionality for general control and motion control in the OT field.

Development will continue with the goal of further expanding the fields in which it can be used as follows.

- CC-Link IE safety communication function support development to address applications requiring safety communication
- Optical cable support for applications requiring long distances or high noise resistance

We also plan to acquire international standards, such as IEC61784 (which has already been obtained for CC-Link IE), the SEMI semiconductor/FPD industry international standard, and national standards in countries such as China and South Korea.

We will also work toward the use of TSN technology to enhance interconnectivity with other industrial open networks, to make the best use of data through overall connection.

This will allow CC-Link IE TSN to expand into more fields and grow as an industrial open network, serving as the foundation for "intelligent factories" that aim at autonomous, optimized manufacturing.

Issued by

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