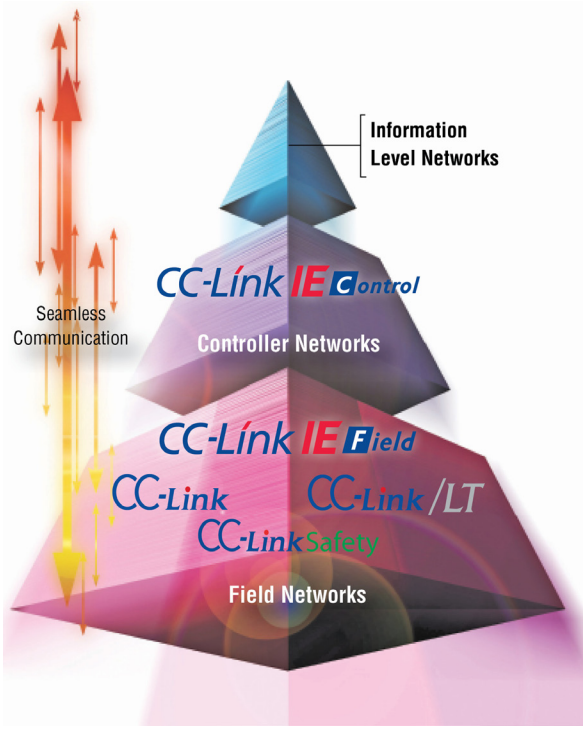
1 Gigabit Industrial Ethernet field network delivers determinism and accommodates 10/100/1000 Mb TCP/IP field devices

The continuing drive to improve productivity will encourage more automation networking. The driving factors behind this expected growth include lean working, increased traceability legislation, product lifecycle management production (PLM), and improvements in manufacturing cycle times. This requires connecting the factory floor to the corporate offices where enterprise resource planning (ERP) systems make information available backwards into the supply chain, as well as forward to customers. Simply put, everyone wants to see what's happening. As a result, networks and the information they handle are becoming as important as the industrial control functions they manage.

CC-Link IE Field

This white paper describes the open CC-Link IE Field network, an Industrial Ethernet technology, which operates at 1 Gigabit/sec. This data rate is 10 times faster than other Industrial Ethernet technologies in order to provide highly responsive control system communications, while at the same time allowing connection to field devices (RFID readers, vision systems, etc.) that have TCP/IP Ethernet ports communicating at slower 10Mb or 100Mb data rates.

The CC-Link Partner Association (CLPA), drawing on a decade of accumulated knowledge, developed the CC-Link IE Field network. CC-Link IE Field is the newest addition to the family of CC-Link networks. CC-Link networks are designed to allow seamless movement of data through one or more network levels.



Ease-of-Use and Determinism

CC-Link IE Field is a Gigabit Industrial Ethernet network that conforms to the IEEE 802.3 standard and it provides inherent deterministic communications which are critical for reliable industrial control systems. The CC-Link IE Field network architecture was designed to allow a Plant Engineer with little or no knowledge of the complexities of Ethernet to configure and maintain an Industrial Ethernet networking system. Rather than using complicated IP addressing, Object Oriented Programming, specialized physical layer configurations and other complications, the CC-Link IE Field node addressing uses simple station numbering (1 to 121). All the complex Ethernet addressing and communications are automatically completed in the background. In addition,

the requirement to employ complex switches to achieve deterministic behavior in an Industrial Ethernet network is eliminated.

End-users have seen office TCP/IP Ethernet as a way of communicating shop floor data to the top floor ERP/information systems. As a model, Enterprise IT with its TCP/IP network backbone is what attracted plant managers to consider a similar approach for their industrial and manufacturing applications. However, unlike the popular fieldbus automation networks such as the original (RS485 based) CC-Link and others, office TCP/IP Ethernet cannot deliver the performance necessary for modern complex manufacturing processes. This is especially true for applications that require deterministic control for proper operation. There are many different ways to provide determinism using Ethernet and this may explain the rash of Industrial Ethernet protocols introduced over the last several years. Some argue that Industrial Ethernet does not need to be deterministic for most situations if enough bandwidth is provided. However, determinism is certainly required for many applications, so it makes sense to use a deterministic network in order to guarantee proper control operation.

While the majority of Industrial Ethernet protocols will meet the network performance needs of most users, they frequently bring unwanted complexity as part of the package. The required skills base can adversely affect downtime, maintenance and the ability to make network configuration changes. Perhaps this partly explains why some users have been reluctant to move from traditional fieldbus to an Ethernet-based equivalent. Experienced and skilled Control Engineers are increasingly rare on the shop floor. For many companies, having a shortage of skilled Engineers to handle advanced automation equipment will likely lead to serious problems in the future. Few companies can afford a staff of Specialist Engineers to maintain their automation networks. The trend is to employ general Control Engineers and bring in Automation experts when required. Often these experts are the support engineers from equipment suppliers, and even these engineers may not be expert network specialists. Such support engineers may also be quite expensive. To prevent production shutdowns and delays in implementing effective control systems, the networking technology must be designed to be easy to use and maintain from the start. New plant and equipment needs to be as simple as possible, with easy-to-use field devices requiring little or no personnel training. For quick response to problems, easy system self-diagnostics and problem identification that doesn't rely on an Engineer's intuition or experience are crucially important.

Gigabit speed, coupled with the inherent deterministic operation described below, ensures effective control communications. To assist in eliminating the complexities normally associated with Ethernet networks, the CC-Link IE Field network uses a token passing scheme for Ethernet communications (see Token Passing scheme figure). This token passing scheme eliminates data collisions resulting in greater communication throughput. This also provides deterministic data exchange and a constant link scan time. Network nodes exchange the token by receiving and transmitting a token frame based on the token passing route established by the Master station during initialization. The token passing route indicates the node order in which token passing is to be executed. The structure of the token passing route is independent of topology and forms a logical ring made up of nodes that is independent of the physical layout of the network. Using this token passing scheme, only the node holding the token has initial data transmission authority, all other nodes simply forward the transmission. In token passing, all stations on the network receive the data but only the station holding the token is allowed to transmit original data and messages. Once the token is passed to the next station, only then can that specific

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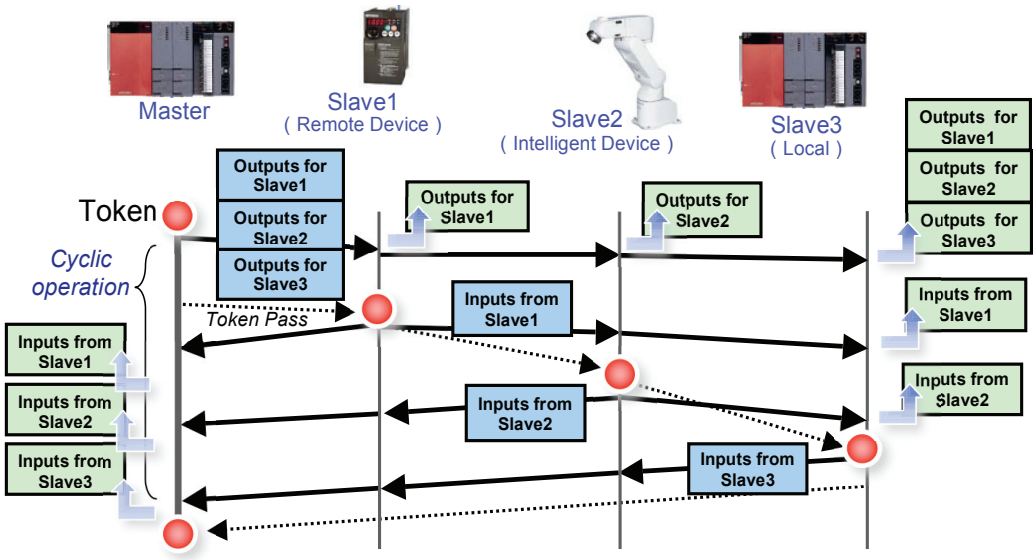
station transmit original data and messages. In this token passing scheme, each station has the ability to transmit original data and messages once during each cycle of network communications

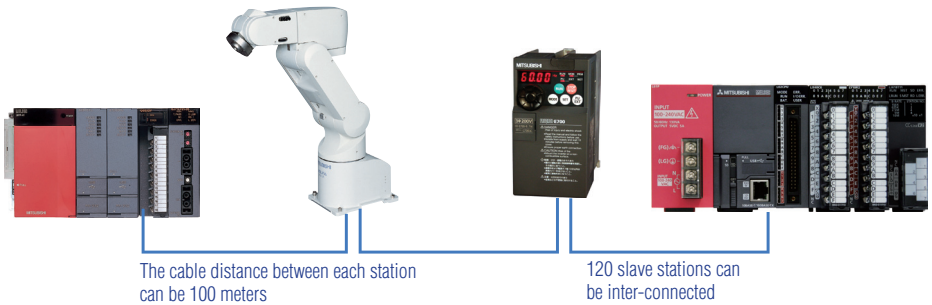
TOKEN PASSING SCHEME



Network Topology

Additional features incorporated into CC-Link IE Field, include the ability to design the most efficient and effective application layout then designing the automation network to fit that application (not the necessity to fit the application to the network). This is a very important feature, because in general, most Industrial Ethernet networks require the application to be wired in a specific manner - especially if you want the network to operate in the most efficient manner. With the CC-Link IE Field network, the application network can be connected in a line (daisy chain), star, ring or any combination of line and star topologies. When using line or ring configurations, Cat5e Ethernet cables connect CC-link IE Field devices (nodes) in a daisy chain fashion. No Ethernet switches are required. This implementation reduces the cost and complexity of the network installation.

LINE TOPOLOGY When using line topology, each CC-Link IE Field network station has two RJ45 ports and is connected in a daisy-chain fashion to the adjacent stations using Cat5e cable. This topology does not require the use of any Ethernet switches. This reduces the cost and complexity of the network installation.



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When using the Star connection method a non-managed Ethernet Layer 2 Switch must be used to act as a central connection point. Multiple Layer 2 Switches may be incorporated into the application, providing for a diverse implementation.

STAR TOPOLOGY An alternative topology is the Star. This is accomplished by using one or more Layer 2 Ethernet switches. (Managed switches are not required.) The CC-Link IE master is connected to the switch, as is each of the slave stations.

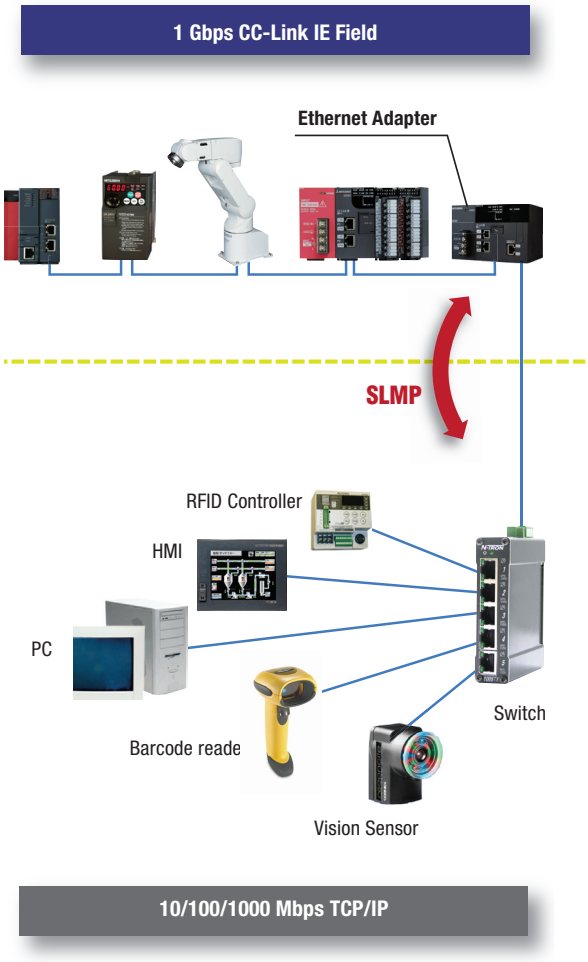
Only an unmanged Layer 2 switch is needed for star configurations. CC-Link IE Field does not require the use of more expensive and complex switches that employ Internet Group Management Protocol (IGMP) snooping and other complex configuration requirements. Up to 121 devices (1 master and 120 slave stations) can be interconnected on each CC-Link IE Field network with up to 100 meters between devices. This allows a total network distance of up to 12km, without the use of repeaters.

Connectivity is completely flexible with devices being able to be placed freely anywhere on the network. This includes the use of the aforementioned switches in addition to media converters and repeaters. These additional physical layer devices can aid with installation and with no limit on the number of branches, stacking of multiple switches can also be incorporated. This feature aids in the installation of more complex applications. When adding stations to the CC-Link IE Field network, they can be connected freely, either to an empty port on a device or on an unmanaged Ethernet Layer 2 Switch. This enables the flexibility of adding stations without taking into account the physical location or order of station connections. Flexibility is enhanced by the use of standard Ethernet IEEE802.3 1000Base-T physical layer equipment - Cat5e cable and RJ-45 connectors. As with most industrial installations, a dual shielded Cat5e cable is recommended, especially in harsh EMI environments.

Using TCP/IP Ethernet Devices

A large number of Ethernet-capable field devices use the TCP/IP protocol. These TCP/IP (and UDP/IP) compatible devices include products such as RFID readers, bar code scanners, etc. One feature that can expand the use of the CC Link IE Field network includes the ability to incorporate TCP/IP (or UDP/IP) compatible devices into an application. These TCP/IP (or UDP/IP) compatible devices only require a slight firmware modification, no hardware changes are necessary. This firmware modification is the incorporation of the Seamless Messaging Protocol (SLMP). This Seamless Messaging Protocol (SLMP) is a simple client and server type protocol used to allow the communication between these TCP/IP (or UDP/IP) compatible devices and the CC Link IE Field network devices [via the TCP/IP or UDP/IP protocols].

The Seamless Messaging Protocol (SLMP) firmware modification is the incorporation of these TCP/IP (or UDP/IP) commands. Not all of these commands are required, some are optional. Depending upon the features to be incorporated in the TCP/IP field device, the device manufacturer would select the appropriate commands from the following listing.



Device Read	Memory Read	Read Directory/File
Device Write	Memory Write	Search Directory/File
Device Read Random	Extend Unit Read	New File
Device Write Random	Extend Unit Write	Delete File
Device Entry Monitor Device	Clear Error	Change File State
Device Execute Monitor	Remote Run	Change File Date
Device Read Block	Remote Stop	Open File
Device Write Block	Remote Pause	Read File
Remote Read Type Name	Remote Latch Clear	Write File
Copy File	Remote Reset	Close File

Once the TCP/IP (or UDP/IP) compatible devices contain the necessary SLMP commands, connecting them to the CC-Link IE Field network is accomplished through the use of an Ethernet Adaptor. Once connected, they will be able to communicate with CC-Link IE Field devices.

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Data Capacity

The capacity of the CC-Link IE Field network includes up to 32768 Bits (flags) and 16384 Words (32768 octets). Bits are 1-bit data registers represented as either 0 (zero-OFF) or 1 (one-ON). Words are 16 bit data registers capable of storing numerical values. Each 16 bit word can represent a signed decimal (-32,768 — 32,767), an unsigned decimal (0 — 65535) or a hexadecimal (0 — FFFF) value. Therefore a Master Node on the CC-Link IE Field network must have enough memory to accommodate all of this information. The Master Node acts as a master during initial set up phases of the network, establishes the Ethernet token passing route and controls the initial token management. Other devices on the network can include a

- Local device (up to 4096 bits and 2048 words per device),
- Intelligent Device (up to 4096 bits and 2048 words per device),
- Remote Device (up to 256 bits and 128 words) and a
- Remote I/O device (up to 128 bits).

Input bits are internally designated Rx and Output bits are designated Ry. 16 bit output data registers are designated RWr and the 16 bit input data registers are designated RWw. Internal to the Master station there are also a number of additional special words and bits which are used in the comprehensive diagnostics of the network. These are designated SB for Special Bits and SW for Special Words.

Transmission Types

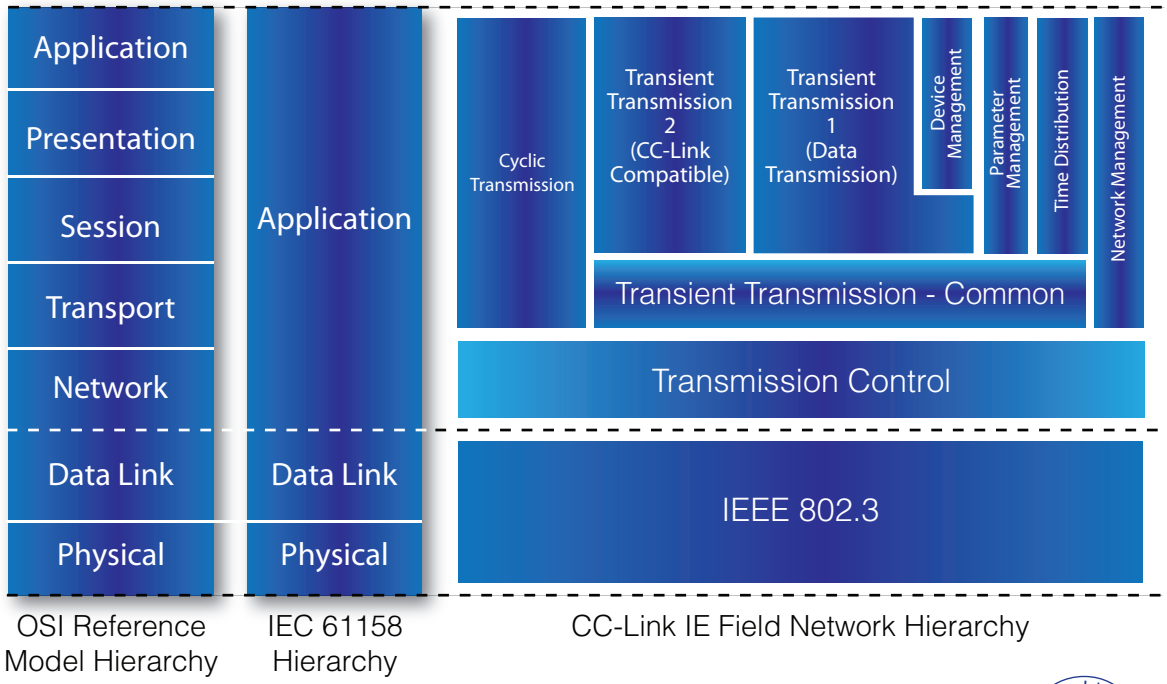
The CC-Link IE Field network offers the following three types of communications:

a) Transmission and reception of message frames related to transmission control (including network management and token control)

b) Transmission and reception of message frames for cyclic transmission

c) Transmission and reception of message frames for transient transmission

The network management function provided by the CC-Link IE Field network is achieved by combining the above three transmission types.



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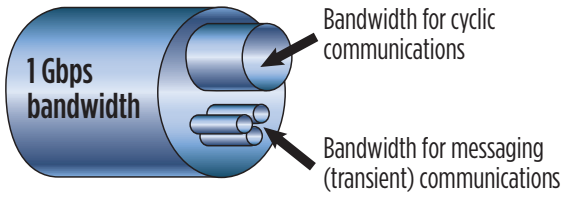
Transmission Hierarchy

Cyclic transmission refers to the constant periodic data transmissions between the Master and each slave station. The slave stations send cyclic data to the master station according to the command of the master station and the network token. CC Link IE Field network performs cyclic communication at a communication speed at 1Gbps, therefore the control data for each station can be updated in real time. If slave stations wish to communicate to other stations apart from the master they use transient communications.

Transient transmission is a function that executes non-cyclic communication when there is a request for communication between nodes (Master to Slave or Slave to Slave). There are two types of transient transmissions: a request/response type in which the server responds to a request from the client, and a request type in which the server does not send a response to a request from the client. In CC-Link IE Field network there is simultaneous use of cyclic communication and transient communications. Both cyclic and transient messages have separate message bands which are guaranteed independently. Even if the traffic of the transient message communication increases, stable high-speed control can be kept without affecting the traffic of the cyclic transmission. This is accomplished through the use of a transient transmission count. The transient transmission count restricts the number of transient transmission frames transmitted per link scan. As a result, the deterministic behavior of the cyclic transmissions is ensured, as well as providing transient transmission opportunities to each node, thereby preventing a portion of nodes from not having the opportunity of performing transient transmissions.

So as to guarantee a stable data transfer cycle for cyclic real-time information, CC Link IE Field assigns a transmission bandwidth for transient message communication without adversely affecting cyclic communication. This assures high-speed determinism for high quality production operations, while still allowing for significant amounts of non-real-time messaging. This method also supports predictive maintenance programs and online diagnostics. The following figure is a representation of bandwidth allocation.

REPRESENTATION OF BANDWIDTH ASSIGNMENT



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The CC-Link Partner Association incorporated all of these features, and more, into the Industrial Ethernet CC-Link IE Field network to allow that Plant Engineer the ability to install and maintain a communication system that will be the center point of a manufacturing or processing application. This is done without the detailed intricate knowledge of Ethernet and its complexities.

CC-LINK IE FIELD SPECIFICATIONS

Ethernet Standard	IEEE 802.3ab (1000Base-T)
Communication Speed	1Gbps
Cable	Shielded Copper Cable (ANSI/TIA/EIA-568-B Cat. 5e)
Connector	RJ-45 8P8C Connector
Media Access Control	Token Passing
Network Topology	Star/Line/Ring / Mixture of Star and Line
Number of Stations	254 (current implementation allows up to 121 stations)
Number of SLMP-TCP/IP Devices Through Ethernet Adapter	Maximum 3840 (up to 32 SLMP-TCP/IP devices per Ethernet Adapter and up to 120 Ethernet Adapters per network with current implementation
Maximum Cable Length Between Stations	100 meters between each station
Cyclic Transmission (Master/Slave Communications)	Max. 32,768 bits (4,096 bytes) Max. 16,384 words (32,768 bytes)
Transient Transmission (Peer to Peer)	Message size: Max. 2048 bytes
Maximum Number of Interconected Networks	239

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