Application Note DK9322-0110-0024
TwinCAT

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Real-time Ethernet
Network variables
TwinCAT
Multimaster
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Publish-Subscribe
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Real-time Ethernet with TwinCAT network variables

This Application Example describes the function and application of TwinCAT network variables based on the publish/subscribe principle. These network variables can be used to exchange data between controllers in real-time based on real-time Ethernet. In contrast to the master-slave principle, publish/subscribe has no fixed hierarchical structure so that the system can respond flexibly to dynamic changes during runtime. Since the network variables are transported via standard protocols (TCP/UDP), an existing Ethernet infrastructure can be used (office or corporate network).

Communication at process control level

The process control level is the communication level at which the controllers of a system exchange application-related data. In many cases it is not desirable to have a fixed hierarchical structure between the individual controllers (as in master-slave process data communication), because they act independent of each other and in different configurations, depending on the process status. This is where the publisher-subscriber principle using deterministic real-time Ethernet comes in useful.

Publisher-subscriber instead of master-slave

In contrast to the master-slave principle, which is often used in conventional fieldbus systems, the publisher-subscriber method has no central master for processing the process signals and controlling the communication. A controller (publisher) offers its data in the network, and devices (subscribers) can subscribe to them. Each controller can therefore act as publisher and subscriber at the same time.

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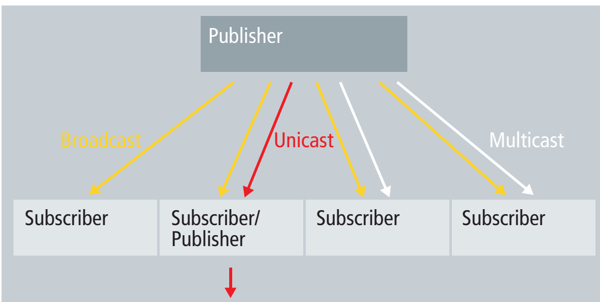

Fig. 1 Broadcast, multicast and unicast as communication modes

The publisher can send its data in different modes. Broadcast, multicast or unicast can be used. All services are unacknowledged, i.e. the sender does not verify correct reception of the data. This makes the whole communication very lean and significantly increases the usable data rate.

Advantages of TwinCAT network variables (publisher-subscriber)
The communication is only monitored in the subscriber. Mutual publisher-subscriber relationships permit bi-directional and multi-directional communication. The data traffic flows between the associated devices. This means they can communicate directly with each other, without having to go via a central instance, i.e. a master. This not only eliminates the need for buffering, it also makes the communication very flexible: the number of users can change during runtime, without affecting the communication process.

The use of real-time Ethernet enables all benefits offered by Ethernet to be utilised for industrial applications:
- application of standard hardware components
- no fieldbus-specific interface required – only an Ethernet port
- Standard protocols (TCP/UDP etc.) can be used in parallel.
- Data transmission rates are comparatively high.
- Remote maintenance and diagnostics are possible in parallel.

In summary, real-time Ethernet with TwinCAT network variables is deterministic, fast, cost-effective and enables real-time capability with parallel application of fieldbus communication in a control system.

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Real-time Ethernet and TwinCAT

The use of real-time Ethernet is based on a conventional Ethernet port which accesses the same driver that is also for the EtherCAT communication. The TwinCAT real-time Ethernet driver (also referred to as Y driver) requires no further configuration, since the TwinCAT communication structure is used. This means an existing infrastructure can be used to distribute a non-event-driven cyclic data stream via the TwinCAT network variables. Acyclic communication („on demand") via real-time Ethernet is also possible. In this case ADS is used, as usual for TwinCAT (‚ADS over real-time Ethernet'). Further informations about **real-time Ethernet** and **TwinCAT network variables** in the Beckhoff Information System! The corresponding links can be found at the end of this document.

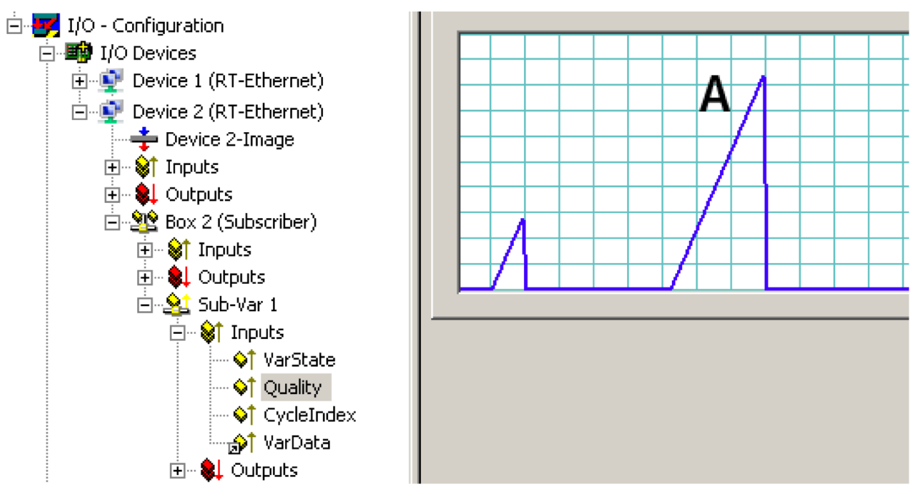

Fig. 2 TwinCAT System Manager with diagnostic function for viewing the latency times of the individual variables.

The publisher controller in the System Manager enables flexible responses to dynamic changes: Target addresses or variable IDs for the individual transmissions can be modified during runtime. TwinCAT diagnostics enable conclusions to be drawn regarding current latencies and the network load at any time. Since verification only takes place in the subscriber, the corresponding variable can be called up in the subscriber box of the TwinCAT System Manager in order to view the refresh rate of the variable under Quality – Online. In the preceding figure 2 the connection was interrupted for approx. 2.5 s at point A.

In contrast to the widespread TCP/IP and UDP/IP protocols (Fig. 3 left), which are used worldwide for sending individual Ethernet frames, real-time communication with network variables (Fig. 3 right) only requires the hardware addresses of the network cards within a local subnet. The overhead resulting from TCP/IP and UDP/IP is eliminated within a subnet, and therefore layers 3 and 4 in the ISO-OSI model. The devices are addressed directly via the hardware addresses (MAC ID) of the network cards (layer 2).

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The operating system of the PC is not involved in the data transfer, so that far higher deterministic is achieved and response times can be guaranteed. Real-time Ethernet eliminates the Windows stacks cycle times required for TCP/IP, thereby achieving high transfer speeds. In addition to fast transfer, real-time Ethernet also offers very high usable data rates: for each publisher a complete Ethernet frame is available whose 1480 bytes can be used entirely for transporting the process data.

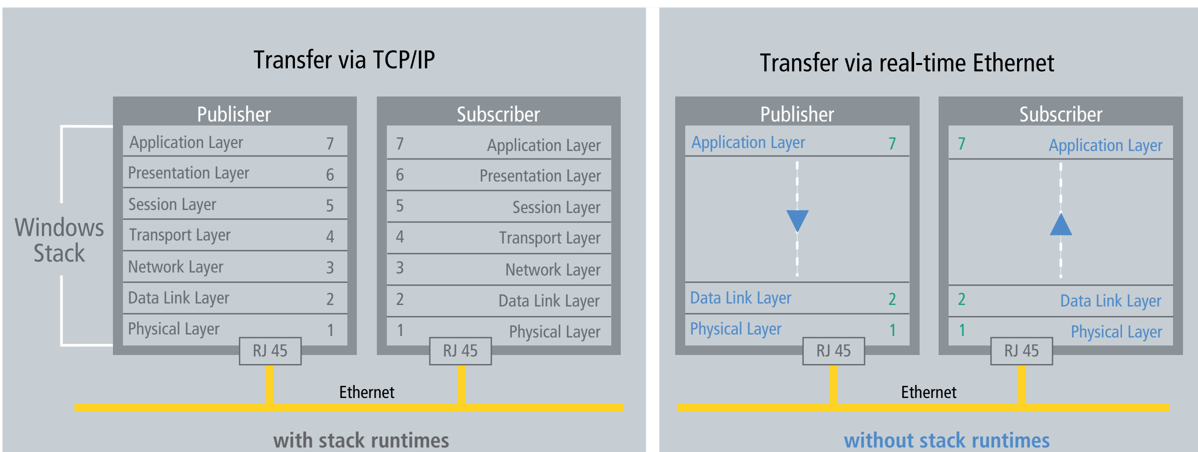

Fig. 3 Realtime-Ethernet: Transfer without stack runtimes, in contrast to TCP/IP

If processing outside the local subnet is required, the network variables can be transported via standard protocols such as TCP and UDP as an alternative to real-time Ethernet. Please note the following in order to use the network variables within an existing office infrastructure based on Ethernet (UDP and TCP): the network components must be equipped with an Intel® chip, and the communication must not take place via a router. The reaction of broadcast telegrams must be taken into account with regard to the traffic. The communication should therefore ideally take place within a segment.

Example applications

Real-time Ethernet based on TC network variables is used in many applications. Three applications are described below as examples, in order to illustrate the use of real-time Ethernet:

- A Distributed Motion Control
- B Distributed Safety
- C High-speed inter-PC communication

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A Distributed Motion Control

Control concepts with distributed intelligence are used in complex systems that are to be subdivided into logical units. The individual parts can then be configured and commissioned separately.

Once the individual parts are interlinked, communication takes place at two levels:

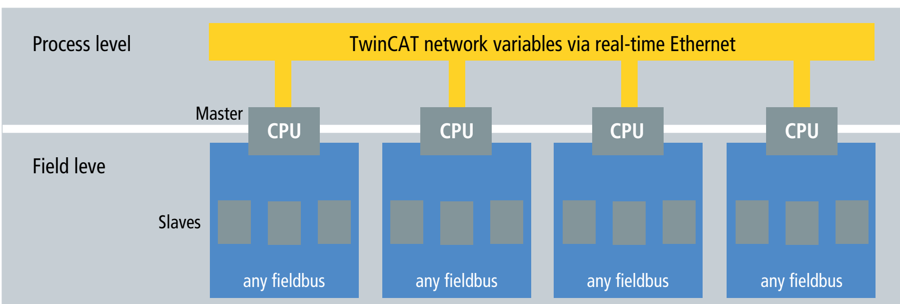

Fig. 4 Different communication channels at the field and process level

Fieldbus level:

Each individual controller acts as a master within an independent fieldbus environment and cyclically exchanges data with the connected slaves based on any fieldbus.

Process level:

The individual controllers (masters) exchange the data and parameters that are relevant for the application via a common communication channel (backbone) in the form of network variables. They are cyclically communicated between the controllers. Real-time Ethernet serves as transport medium for the network variables.

A fixed hierarchical structure between the controllers, as it is common at the fieldbus level as a master-slave relation, does not make sense. The system is therefore configured using several masters (cf. Fig. 5) with TwinCAT network variables via real-time Ethernet, in order to network the controllers at a higher level.

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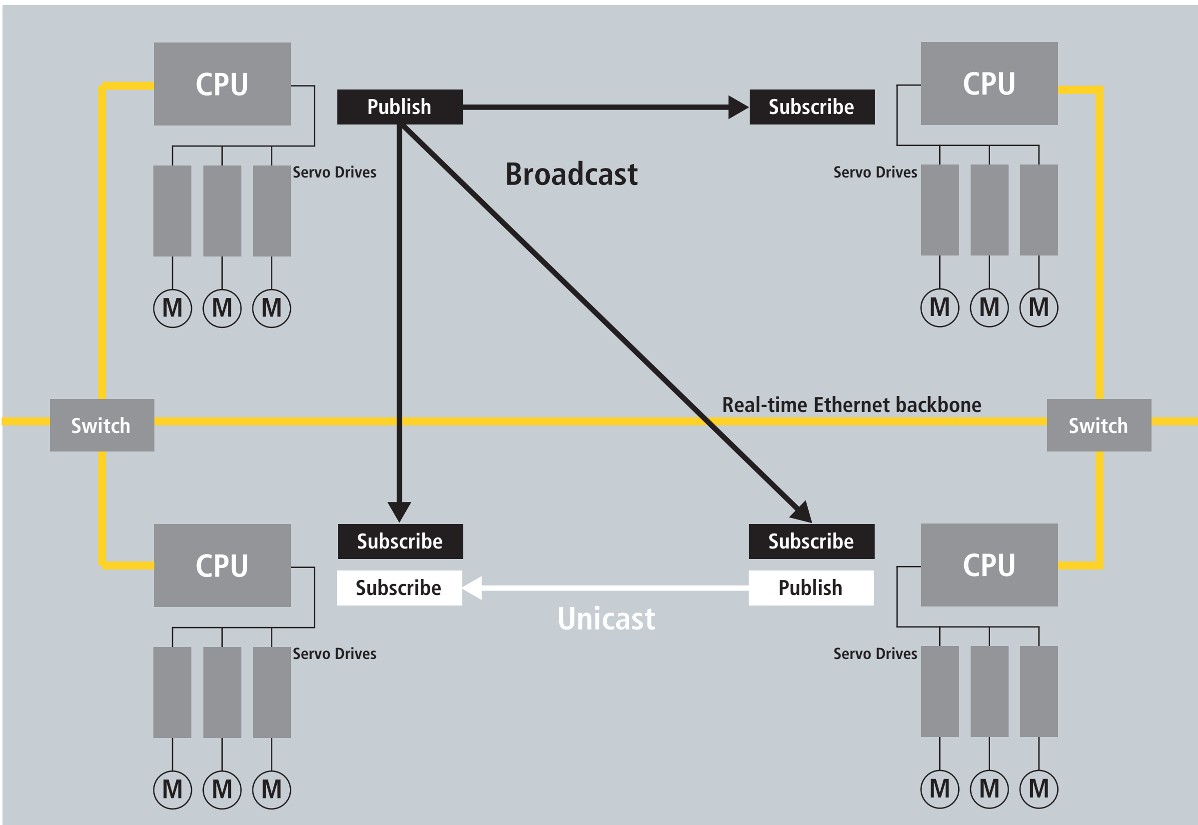

Fig. 5 Multimaster communication via TwinCAT network variables and a real-time Ethernet backbone

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B Distributed Safety

TwinCAT and NV based on real-time Ethernet offers cost-effective networking of safety controllers in modular machine construction systems. If an emergency stop is triggered within a segment, the segment before and after should be switched off. Via real-time Ethernet and TwinCAT network variables the emergency off functions of the segments are published via unicast, and the two adjacent segments are entered as subscribers.

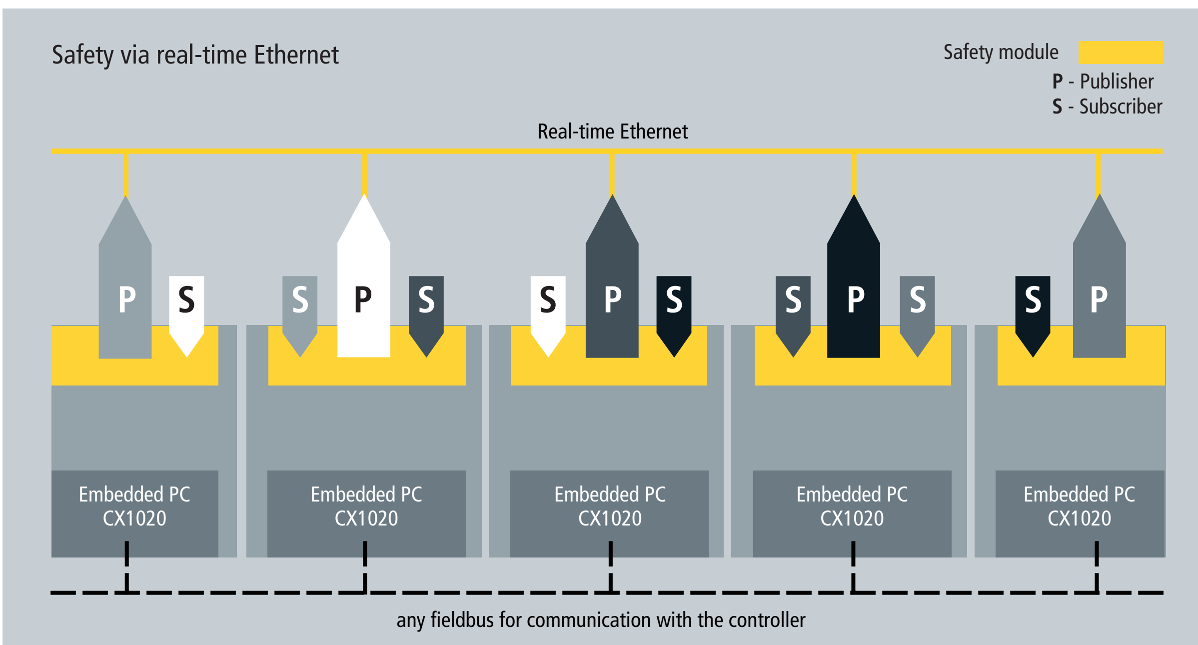

Fig. 6 Distributed Safety via real-time Ethernet within a modularised production line

This concept offers high deterministics, low infrastructure costs (Ethernet ports and cables) and fast transfer of large data quantities.

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C 50-µs inter-PC communication

In contrast to the applications described above, the following example focuses not on comprehensive networking between different devices, but on short cycle times.

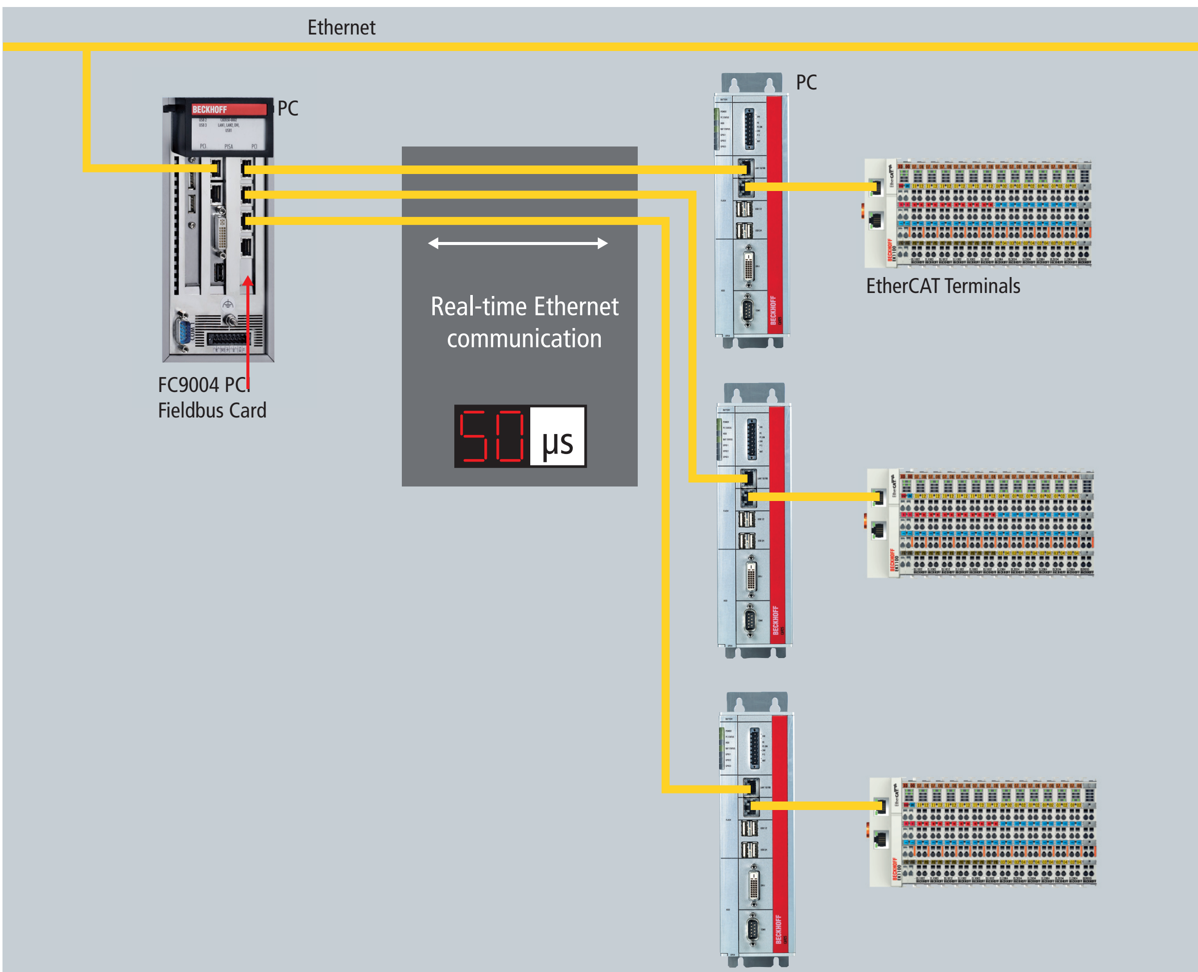

Fig. 7 Ultra-fast communication between several PCs via FC9004

High cycle times can be achieved for exchanging data between a central PC and three connected PCs due to lean protocol and direct access. The PCs are connected with the central PC via a FC9004 PCI fieldbus card without further switches. Bidirectional communication structures are implemented in TwinCAT configuration based on TwinCAT network variables. The following figure 8 shows a screenshot of the TwinCAT System Manager with a real-time Ethernet connection at a transfer rate of 20,026 frames per second in send and receive direction, i.e. a cycle time of 50 µs.

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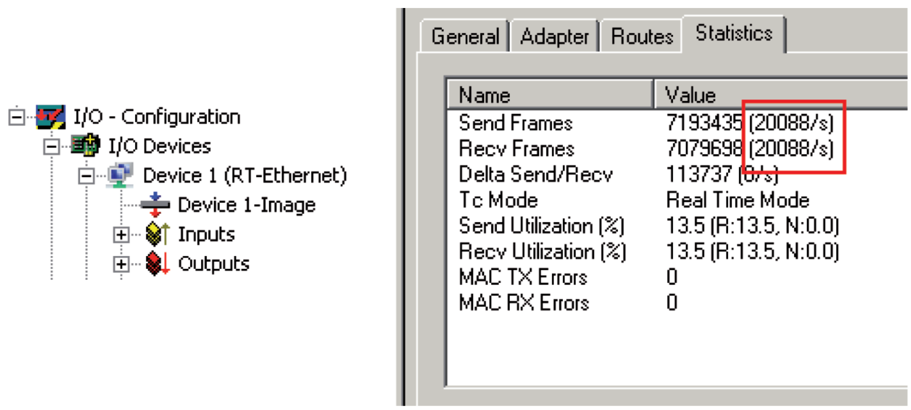

Fig. 8: 50-µs inter-PC communication

– PLC and Motion Control on the PC **www.beckhoff.com/TwinCAT**

– PCI Fieldbus card for Ethernet **www.beckhoff.com/FC9004**

– Beckhoff Information System **http://infosys.beckhoff.com**

– TwinCAT network variables at Beckhoff Information System

http://infosys.beckhoff.com/content/1033/tcsystemmanager/netvars/bt_el66 xx_beckhoff_network_var_settings.htm

– Real-time Ethernet at Beckhoff Information System

http://infosys.beckhoff.com/content/1033/tcrtethernet/html/tcrtethernet_configuration.htm