Remote control of the industry processes. POWERLINK protocol application

A Wróbel¹, D Paruzel² and B Paszkiewicz³
¹,²,³Silesian University of Technology, Faculty of Mechanical Engineering, Konarskiego 18a Street, 44-100 Gliwice, Poland

E-mail: andrzej.wrobel@polsl.pl

Abstract. The present technological development enables the use of solutions characterized by a lower failure rate, and work with greater precision. This allows you to obtain the most efficient production, high speed production and reliability of individual components. The main scope of this article was POWERLINK protocol application for communication with the controller B & R through communication Ethernet for recording process parameters. This enables control of run production cycle using an internal network connected to the PC industry. Knowledge of the most important parameters of the production in real time allows detecting of a failure immediately after occurrence. For this purpose, the position of diagnostic use driver X20CP1301 B&R to record measurement data such as pressure, temperature valve between the parties and the torque required to change the valve setting was made. The use of POWERLINK protocol allows for the transmission of information on the status of every 200μs.

1. Introduction
Production speed and reliability - these two play a key role in the world of industrial automation. The development of technology enables you to make any object faster and faster with greater accuracy. Each production process consists of several components whose respective assembling and scheduled work is important for proper implementation of the element. Often, the information between the components of the production line must be transmitted immediately in real time to ensure the correctness of the cycle. Many existing solutions are based on copyrighted data transfer protocols forcing consumers to purchase parts of individual businesses, since implementation of other data protocols is not possible. B & R has gone from building its own data transfer system and has based its POWERLINK solution on Ethernet.

2. POWERLINK
2.1. Description
Created on the valid standards POWERLINK is an IEEE 802.3 Ethernet enhancement with mixed polling and time quantization. This solution enables critical data to be transmitted in very short and precise isochronous cycles whose duration can be configured. Lower priority data is sent by the reserved asynchronous channel. This involves distinguishing real-time domains and non-real-time domains as it shows figure 1. Lower priority information is distributed between the real-time domain and the real-time domain using standard IP frames.
This solution increases the occurrence of damage caused by the transmission of erroneous data or hacker attacks on the machine level is prevented. The clear boundary between the machine and the company network protects against security flaws while maintaining data transparency.

POWERLINK protocol is based on the model layer ISO / OSI and supports depending on the type of client-server and producer-recipient. The foundation is IEEE 802.3 standard layers with current physical layer 100BASE-X. In the future this may be the development of layers of faster Ethernet variants for example Gbit Ethernet. The protocol uses a MAC addressing system, so each device on the network receives a unique MAC address. Nodes in the real-time domain receive additionally EPL node identifiers. Ethernet POWERLINK also allows standard IP addressing, so that real-time devices are monitored from anywhere in the world via the Internet. POWERLINK binds the device address to the node selection switch on the front of the enclosure so that when replacing devices their IP addresses are retained and there is no need to reenter them. This protocol is integrated into the CAN open of communication profiles and device profiles, enabling the transfer of applications from the CAN bus used to Ethernet-based environments.

The isochronous phase can distinguish between transfer slots dedicated to particular nodes, which have to send their data in every basic cycle, and slots shared by nodes to transfer their data one after the other in different cycles as it shows figure 2.

**Figure 1.** Network Structure.
2.2. Why Ethernet?

Today, the main criteria when implementing modern technology is their price and reliability. One of the most commonly chosen standards for industrial communications is Ethernet, a technology that was developed more than 40 years ago and is constantly evolving. It provides long-term stable performance, fast and reliable device-level communication such as I/O modules, sensors, operator panels, drivers. One of the biggest advantages of Ethernet is the flexibility and openness that makes it easy to integrate multiple types of devices from different manufacturers. Knowledge of Ethernet technology is widely recognized today as a matter of common knowledge that it is a well-known technology whose price-to-ability ratio is low. This technology is based on the idea of nodes connected to one source. Each node sends and receives messages (frames). There are many versions of Ethernet that present (table 1).

| Type            | Name              | Kind of cable                  | Range |
|-----------------|-------------------|--------------------------------|-------|
| Fast Ethernet   | 100Base - TX      | 2 pairs of 4 couplet twisted    | 100 m |
| 100 Mb/s        |                   | fiber category 5               |       |
|                 | 100Base - FX      | Multimode                      | 2 km  |
|                 |                   | Fiber optical fiber            |       |
| Gigabit Ethernet| 100Base - LX      | Fiber optical fiber            | 10 km |
| 1 Gb/s          |                   |                                |       |
|                 | 1000Base - T      | Copper cable – twisted pair     | 100 m |
|                 |                   | category 5/5e                  |       |
|                 | 1000Base - SX     | Optical fiber                  | 550 m |
The high bandwidth of the network allows for the transmission of more data and connectivity at the information level of computers. With POWERLINK, Ethernet operates with a cycle time of 200 μs, and its precision is microsecond.

2.3. POWERLINK frame

POWERLINK protocol is embedded in the second Ethernet frame. IEE802.3 complies with frame rates between 64 Bit and 1518 Bit. The MAC Address and CRC size is 18 bits, leaving a free range of 46 Bit - 1500 Bit.

The construction of the Powerlink protocol frame is different – figure 3. The first part - Header, identifies the message type and contains addressing information. Second part - Payload, is dependent on the actual message type. Message types are shown in (table 2).

![Figure 3. Ethernet and Powerlink frame.](image)

| ID   | Abbreviation | Name        | Purpose                                                                 |
|------|--------------|-------------|-------------------------------------------------------------------------|
| 01h  | SoC          | Start of Cycle | Determines the start of a new cycle and synchronizes all nodes in the network |
| 03h  | PReq         | PollRequest  | Requests a node to send a PollResponse. Sends isochronous data to this node. |
| 04h  | PRes         | PollResponse | Response to a PollRequest. Sends isochronous data to the network.          |
05h  SoA  Start of Asynchronous  Determines the start of the asynchronous phase. May also assign an asynchronous slot to a node.

06h  ASnd  Asynchronous Send  Transports asynchronous data via the POWERLINK/ASnd protocol (e.g. NMT commands).

07h  AMNI  Active Managing Node Indication  Indicates the active MN to the network (used by EPSG 302-A - High Availability)

0Dh  AInv  Asynchronous Invite  Assigns an asynchronous slot to a node (used by EPSG 302-B - Multiple ASnd)

2.4. Work modes
POWERLINK-enabled devices can work in basic Ethernet mode and POWERLINK mode. First of them work directly on an existing Ethernet network that does not require real-time data transmission. POWERLINK mode is based on real-time operation, where the cycle time depends on the amount of isochronous and asynchronous data as well as the number of network nodes. The basic cycle is divided into three phases:
1) Start phase - all nodes in it synchronize with the management node
2) Isochronous Phase - The management node allocates a fixed width time window to each node for critical time data transmission. It is possible to listen for all data sent by the other nodes
3) Asynchronous phase - the management node releases the network for that node so that it can transmit non-critical data in time through standard IP protocols and IP addressing.
Depending on the length of the total cycle time, the quality of real-time work may be different. The length of individual phases can be freely configured, but must not exceed the basic cycle length.

3. Station
Figure 4 shows the schema of the physical process parameters recorder such as pressure, temperature and torque. This recorded was connected to X20CP1301 PLC driver which allows direct connection of 250 I/O modules what gives about 3000 channels. The POWERLINK X20IF1082 interface was included in the controller. This interface has two RJ45 jacks for configuring the POWERLINK connection. The Visualization of the physical parameters of the station was performed using the B & R Automation studio environment and displayed on the HMI Power Panel C70 from B & R.

The recorder with the POWERLINK protocol enables the transfer of variables between drivers in real time.
The station realizes pressure measurement on both sides of the valve, temperature and torque on the valve knob. Data from the pressure, temperature and torque sensors are synchronized in milliseconds. A torque sensor of 0-200 Nm is attached to the valve located in the central part of the process parameters recorder. The temperature sensor range is between -50°C to 150°C, while the pressure measurement is in the range of 0-10 bar. All sensors have an analog output of 0-10V range. The station is designed to optimize the timing of valve settings changes according to the torque value generated on the torque sensor and to ensure the safety of the entire system by short response times to the increased value of one of the measured parameters.

4. Network structure
The ability to transfer data between a physical parameter recorder registered with a B & R X20 CP1301 PLC and the rest of the network plays a key role. The network structure used in this workstation is based on the POWERLINK communication protocol.

Figure 5. Structure of the workstation network.

Figure 5 shows the structure of the workstation network in which a clear combination of each measurement element with the PLC is visible, and then using the X20IF1082 interface, the HMI display has been accessed to obtain all real-time measurement values. Knowledge of the process parameters in real time allows generating the appropriate torque on the valve according to the purpose of the station, performing this operation within 0.2 seconds. The network structure at any time can be
extended with additional components working in real time or outside real time depending on the priority of the data being transmitted.

Joining The POWERLINK protocol allows you to register those parameters that are relevant from a technological point of view, updating other values at a certain time, rather than with each cycle. This saves information transfer time, as well as the memory of the data processing device.

Fast response time greatly improves the safety of the process and the quality of the operation.

5. Conclusion
The POWERLINK is a real-time protocol for a new generation of machines that require real-time response and high performance. Industry is facing with more and more difficult tasks based on the increasing complexity of systems, increasing the number of machine axes and striving for the highest possible speed and accuracy. For this purpose it is necessary to coordinate all working axes, most often with respect to one base coordinate system. High-speed printing machines and the sampling frequency of traceable sensors spanning a few microseconds significantly hamper real-time machine communication. POWERLINK handles modern problems with its main features. The first feature is the cross traffic support, so that all drives on the network receive data directly from the network node at the same time. There is no need for data transfer by the master to allow for immediate response of the drives. This protocol also uses multiplication of slave nodes - not every node must react in the same cycle, thus reducing cycle times even in multi-axis machines. Another aspect in favour of the POWERLINK protocol is its price. Thanks to the use of FPGAs, the cost of industrial Ethernet interfaces is so within the limits of classic fieldbus solutions, but their wide range of applications is working to their advantage. Due to the rapidly growing automation processes, the use of the protocol in the industry will greatly improve response time and product quality. The development of Ethernet will enable the development of the POWERLINK protocol and the provision of space.

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