Wireless Networking Technology for Real-time Remote Control of Factory Equipment: Wireless ExpEther

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Abstract

NEC has developed the "wireless ExpEther", a networking technology that allows remote computers to perform real-time centralized control in the wireless environments of I/O devices such as sensors, actuators and displays at production sites. The production sites of factories are a harsh environment for wireless remote control because radio waves are often reflected or attenuated by metallic objects, which leads potentially to communication losses (en-route packet losses). Even in such environments the technology discussed below ensures stable wireless network connection between computers and I/O devices by means of "rateless coding." This technology is capable of transmitting control signals and data between devices correctly and its development is expected to enable implementations of new functions based on merging industrial equipment and IT devices.

Keywords

ExpEther, factory equipment, real-time, remote control, wireless networking technology

1. Introduction

Recent trends in IoT dissemination, has indicated that a need to connect a huge number of sensors and production equipment devices to the network and to control them in real time is becoming evident at factory production sites, etc. In order to deal with this trend NEC is deploying activities to propose and popularize a technology for networking I/O devices such as sensors, actuators and displays called ExpEther (Express Ethernet). This strategy makes it possible to connect and control multiple devices remotely.

Besides, the need for wireless network connection is also on the increase because the wired connections of sensors and devices tend to deteriorate work efficiency and the frequent modifications to production lines make it difficult to use wired connections. We are therefore also tackling the wireless implementation of ExpEther.

In this paper, we describe the NEC-original ExpEther technology and discuss the technologies that can be realized via its wireless implementation.

2. ExpEther Enabling Real-time Remote Control of IoT devices

The PCI Express serial bus standard is usually used inside the computer cabinet, however, NEC's "ExpEther" networking technology makes possible to use the standard outside the computer cabinet via wired Ethernet in order to connect computers and I/O devices. This procedure enables the connection of remote sites with low delay. It enables the installing computers including servers and workstations at a single location, such as in a server room and other devices in the production sites where they are connected via wired Ethernet. The real-time remote control of equipment is then realized.

Currently, the introduction of IoT devices is advancing at production sites such as in factories. Introduction of IoT requires installation of high-performance servers for use in collecting information from sensors and for processing AI analyses in the field. However, ordinary IT devices present various issues that complicate installation of I/O devices in the field, such as those caused by unfavorable environments due to dust and heat, installation footprints and maintainability. Even in such cases, ExpEther can solve problems because; 1) since only those I/O devices for use in information collection and control should be installed in the field, the environmental resistance can be secured, and; 2) computer devices such as servers that are usually incompatible with harsh environments can be installed outside the production site.

While industrial equipment is currently advancing by adopting AI, etc., it is not easy to add IT functions to it because of the configurations that are optimized for specific functions. Even in such cases, if ExpEther is integrated into the industrial equipment, it is possible to connect the GPU and storage, etc., to the network as required and to add IT devices to networks for the implementation of new functions, based on merging industrial equipment and IT devices.

3. High-Reliability Wireless Technology Enabling Wireless Implementation of ExpEther

3.1 Issues of Wireless ExpEther Implementation

Computer devices are generally connected directly to a host computer, and this presupposes that no packet loss or time-out occurs in the communications between the devices and the host. To make sure of this, a time-out restriction (typically 50 ms) is set in the computer bus protocol in order to detect physical failures of devices. If a packet loss or time-out occurs counter to this restriction, an error or system down occurs on the host. Such a time-out restriction must also be met by ExpEther that virtualizes the computer bus communication in the network.

ExpEther achieves loss-less computer bus communications by performing retransmission if a packet loss occurs in the network. If a packet loss occurs in the retransmission, the lost packet is retransmitted. This control presupposes a network with a low packet loss rate and low delay, such as the wired Ethernet. Since the packet loss rate of a wired network is less than 10-4 and the delay less than a few hundred μs, the time-out restriction of the computer bus communication is not exceeded, even in cases when multiple retransmissions are performed.

On the other hand, the packet loss rate of wireless networks is known to be more than 10^{-3} and the delay is a few ms. In communications in an environment like a wireless network, a loss-less communication using the retransmission control is expected to have multiple occurrences of packet retransmissions. Such an environment has issues with the incapability of meeting the time-out restriction on computer bus communications due to an increase in the packet arrival delays. Therefore, to use ExpEther in a wireless network, a new transport system is needed that can meet the loss-less requirement and time-out restriction, even in networks with high packet loss rates.

3.2 High-reliability, Short-delay Communication Technology Using Rateless Codes

To satisfy the time-out restriction even in an environment with frequent packet losses, such as a wireless network, NEC proposes a highly reliable wireless communication technology that uses rateless coding, which is one of the redundant encoding methods. **Fig. 1** shows the outline scheme of the proposed method. The rateless coding generates encoded packets by selecting packets randomly from a certain number of packets and XORing. Decoding becomes possible when the receiving party has received more encoded packets than the number of packets used in the encoding. With this method, the sender party generates packets, codes a certain number of them by rateless coding and outputs the encoded packets successively to the receiver until the response packet (ACK) is received from the receiver. As the receiver receives packets until a certain number of packets can be decoded, all the packets can arrive without a retransmission request and communications are possible with low delay. Additionally, to ensure the packet arrivals within the time-out period of the computer bus, the packet arrival delay from the sender to the receiver of the computer bus is expressed with a queuing model and the maximum arrival delay is mathematized to adjust the number of packets subjected to encoding. Specifically, the packet loss rate/delay of the wireless Ethernet and the maximum queue length of the computer bus are entered in a mathematical model and the number of packets coded together by rateless coding is determined in order to guarantee the transmission delay that can

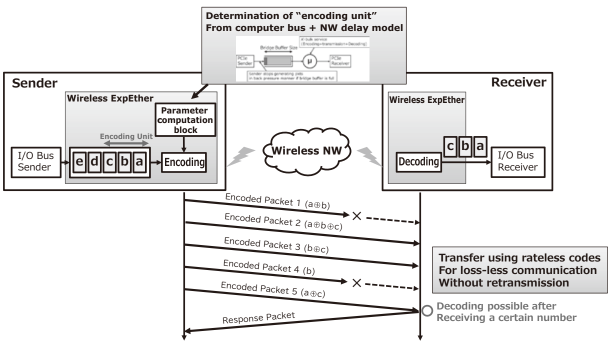

Fig. 1 Outline of proposed system.

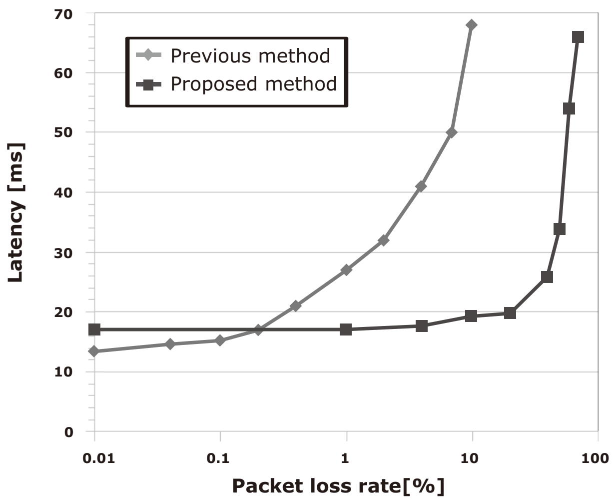

Fig. 2 Latency evaluation.

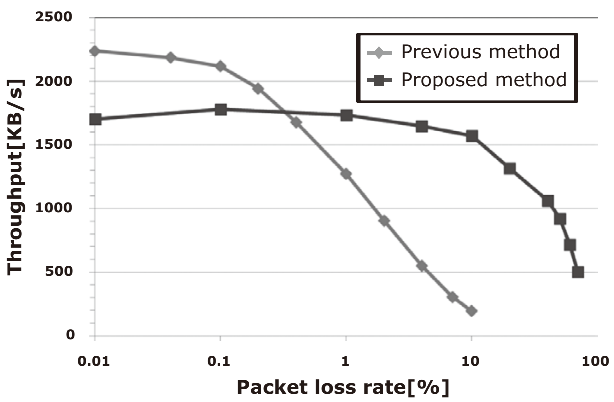

Fig. 3 Throughput evaluation.

meet the delay requirement of the computer bus.

Fig. 2 and **Fig. 3** show the results of an experiment varying the packet loss rate. With this experiment, we connected an SSD as an I/O device and evaluated the storage access latency and throughput. We also compared the results with those of the traditional communication method based on retransmission control.

Fig. 2 shows the results of evaluation of the maximum latency. As seen here, the proposed method can transfer packets with shorter delay when the packet loss rate is 1% or more. The experiment also confirmed that the previous method brings on an I/O device disconnection when the packet loss rate exceeds 5% (because the delay exceeds 40 ms) and that the proposed method can retain the I/O device connections even when the packet loss rate is 40% or more. These results suggest that a computer bus communication is possible even with a wireless network with a high packet loss rate.

Fig. 3 shows the results of evaluation of the throughput. Similarly to the results of the maximum latency evaluation, the proposed method can retain a higher throughput when the packet loss rate is 1% or more and the improvement in performance is 8 times greater at maximum. This improvement in the throughput performance is regarded as being because the proposed method can execute the computer bus transactions at higher speeds, thanks to the lower delay than the previous method. These results indicate that the proposed method can implement communications with low delay and high throughput even in a network environment with a high packet loss rate.

4. Future Perspectives

Since the ExpEther Consortium was established in 2008 with the aim of disseminating the ExpEther technology. The ExpEther was then released in 2012 first in the world market and the technology is now used in various domains, including particularly in social infrastructures. Because the recent applications of IoT and AI perform data collection and control in real time, the establishment of a wireless technology featuring low delay and high reliability is needed in environments without network infrastructures. It is also needed in environments where a high degree of freedom of installation is required, such as in factories. In the future NEC intends to advance the R&D of this technology in order to support its practical implementation. Reliability will be improved by multi-link redundant transfers using several wireless circuits and by evaluating the performances of actual environments.

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