Development of Network Redundancy Technology – Parallel Redundancy Protocol (PRP)

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Abstract

We are currently providing industrial equipment and network systems for general infrastructures. Infrastructure networks require a high level of redundancy to ensure that communications can continue even if a failure occurs. For digital substations where system reliability is strictly demanded, it is possible to realize a high reliability network with a feature of no downtime even upon the occurrence of any system error, provided that the Parallel Redundancy Protocol (PRP) specified by the International Standard is applied. The PRP can offer a high reliability for a variety of network not limited to substation systems.

We developed PRP network redundancy software that complies with IEC international standard and evaluated a prototype industrial switching hub product that installs the software.

1 Preface

Power companies in Japan are promoting digitalization of substations in accordance with the International Standard, IEC 61850. As a practical means to realize a robust network for digital substations, application of the Parallel Redundancy Protocol (PRP) is under study. The PRP is a standardization protocol defined by IEC 62439-3. This protocol is suitable for the digital substation network where a variety of equipment produced by various different manufacturers is connected together. There are multiple standardized redundancy protocols such as the Rapid Spanning Tree Protocol (RSTP). Many of these protocols, however, are vulnerable to a short downtime when a system error occurs. For the PRP, the network is established in a redundant circuitry so that the same packet is simultaneously transferred through the duplex circuits. In such a scheme, communications can be continuously maintained without interruption even though either circuit is out of order. When the PRP is adopted, it is possible to establish a no-downtime network, and such a system is particularly advantageous for any mission critical network infrastructure. This paper introduces the result of practical evaluation on a switching hub where the PRP network redundancy software developed by our company is installed.

2 Overview of PRP

2.1 Basic Principle

Fig. 1 shows a concept of the PRP. An ETHERNET frame is duplicated at the start-point node and transmitted through the physically different routes. At the end-point node, either frame of them is used or narrowed down, and transferred to the destination. Even though one of the duplicated ETHERNET frames is lost, another one is delivered to the destination and there is no loss of ETHERNET frame as seen from the end host. Fig. 2 shows an example of the Redundancy Box (RedBox) configuration. The node intended to support the PRP is called the Doubly Attached Node implementing PRP (DANP). In contrast, general nodes (such as ordinary PCs) that do not support PRP are called Singly Attached Nodes (SANs). The two duplicated ETHERNET frames are attached with the same sequence number. At the DANP on the ending side, the sequence number attached to the delivered frame is checked. Out of the ETHERNET frames attached with the same sequence number, the leading frame is transferred to the destination and the follower frame is discarded. Redundancy is realized by the PRP when the RedBox takes a role of the DANP in place of the SAN.

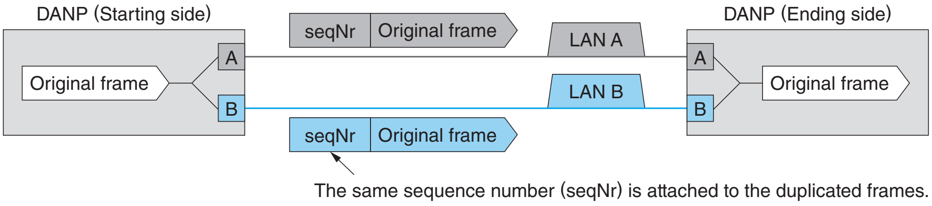

Fig. 1 Concept of PRP

The frame is replicated at the starting node and forwarded to the duplicate route. At the end node, only the first frame to arrive is forwarded to the destination. Even if one frame is lost, the other frame will reach the destination, so no frames are lost.

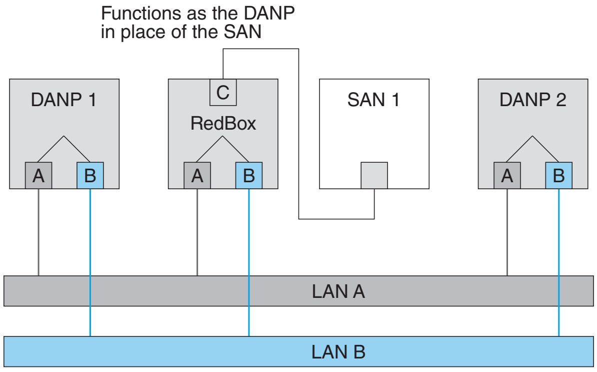

Fig. 2 Example of Redundancy Box (RedBox) Configuration

Since the RedBox functions as the DANP in place of the SAN, the SAN can be connected to the PRP network.

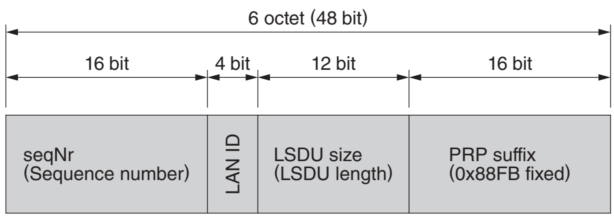

Fig. 3 RCT Configuration

The RCT includes 4 types of information and its total size is 6 octets.

2.2 Redundancy Check Trailer (RCT)

In addition to the sequence number for the ETHERNET frame, the PRP is attached with supplementary information, which is called the RCT. Fig. 3 shows the RCT constitution and Table 1 shows items of the RCT configuration.

Since the total RCT size is 6 octets, the frame size after the attachment of RCT will exceed the Maximum Transmission Unit (MTU) if the ETHERNET frame size with RCT is already at the level of MTU or the remaining size to the MTU level is less than 6 octets. As a result, the data cannot pass through the LAN and certain countermeasures must be taken. Fig. 4 shows concept of countermeasures for MTU excess. As a remedial measure, the MTU of the RCT domain where the RCT-attached ETHERNET frame passes through is set larger than 6 octets. In such a setting, there is no problem because the MTU is never exceeded even though the RCT is attached. This MTU-related problem cannot, however, be detected unless confirmation of communication in MTU size is implemented. For this reason,

Table 1 Items of RCT Configuration

The RCT is composed of 4 types of items; sequence number, LAN ID, LSDU size, and PRP suffix.

Item	Contents
seqNr (Sequence number)	Serial number to confirm the identity of two frames caused by duplication.
LAN ID	For the route identifier of the passing LAN (A or B) and the duplex frames sent from LAN A, 1010 (0xA) is set. For the frame sent from LAN B, 1011 (0xB) is set.
Link Service Data Unit (LSDU) size	Payload length of the duplex frames is stored here.
PRP suffix	This is an identification number to examine whether the RCT is attached to the frame, and its value is 0x88FB.

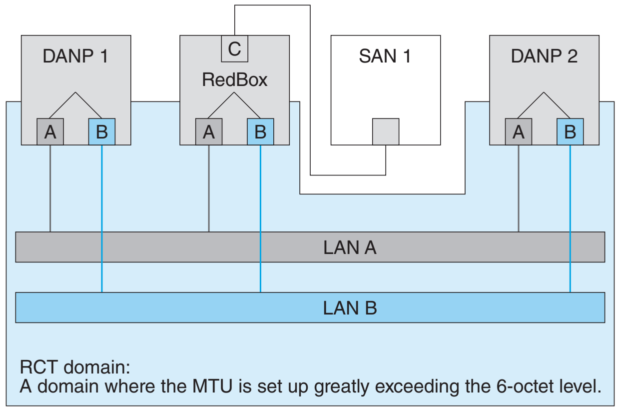

Fig. 4 Concept of Countermeasures for MTU Excess

To control the frame size not to exceed the MTU level, it is necessary to set the RCT domain MTU greater than the 6-octet level that is the size of a regular domain.

it is necessary to note a fact that it is impossible to accomplish communication confirmation for a small-sized frame such as ping (packet internet groper).

3 Installation of Our Company's PRP

3.1 Basic Policy

For the development of our technology, we installed all PRP-related items in our software prototype which conforms to IEC Standard 62439-3. All items like a node table were installed though these are optional for the IEC Standard.

3.2 Node Table

The node table is a data store where the result of network monitoring is recorded. In the node table, each remote node detected by network monitoring is registered as a data entry. The remote node is a node, e.g. DANP, RedBox and SAN, connected to the network. The received multiple frames are checked and the contents of entry are updated. Table 2 shows contents of node table entries. By examining node tables, it becomes possible to confirm the status of connection with each node.

3.3 Conformance Test

According to IEC 62439-3, implementation of conformance test is specified to confirm whether the machine meets the requirements of the Standard. For the conformance test, a single unit of DANP or RedBox is tested. A testing to check a combination of multiple machines is not stipulated. Even in the case of testing on the RedBox as a machine under test, only DANP functions are tested. Fig. 5 shows the system configuration for the conformance test. A test frame, unicast or multicast, is transmitted from the PRP frame generator via the RedBox to the machine under test. The transmission delay unit is connected to Port A and Port B of the RedBox. The bridges on LAN A and LAN B are not relating to PRP communication itself, but they are installed for the purpose of making the machine under test receive a signal from the Bridge Protocol Data Unit (BPDU) so that the resultant reaction can be examined.

A conformance test was carried out on a switching hub product equipped with the PRP software prototype, and it was confirmed that the product complies with the standard. Meanwhile, since the prototype switching hub does not support PTP (Precision Time Protocol), the PTP frame processing item was excluded.

Table 2 Contents of Node Table Entries

The node table includes 10 items, such as MAC address of remote node.

Item	Contents
MacAddress	MAC address of remote node
RemNodeType	Enumeration value to express remote node classification
CntReceivedA	Frame number from a remote node received at Port A
CntReceivedB	Frame number from a remote node received at Port B
CntErrWrongLanA	Frame number whose LAN ID is not 1010, out of the frames received at Port A
CntErrWrongLanB	Frame number whose LAN ID is not 1011, out of the frames received at Port B
TimeLastSeenA	Final time when a frame sent from this remote node is received at port A
TimeLastSeenB	Final time when a frame sent from this remote node is received at port B
SanA	Decided to be True when this remote node is SAN on LAN A
SanB	Decided to be True when this remote node is SAN on LAN B

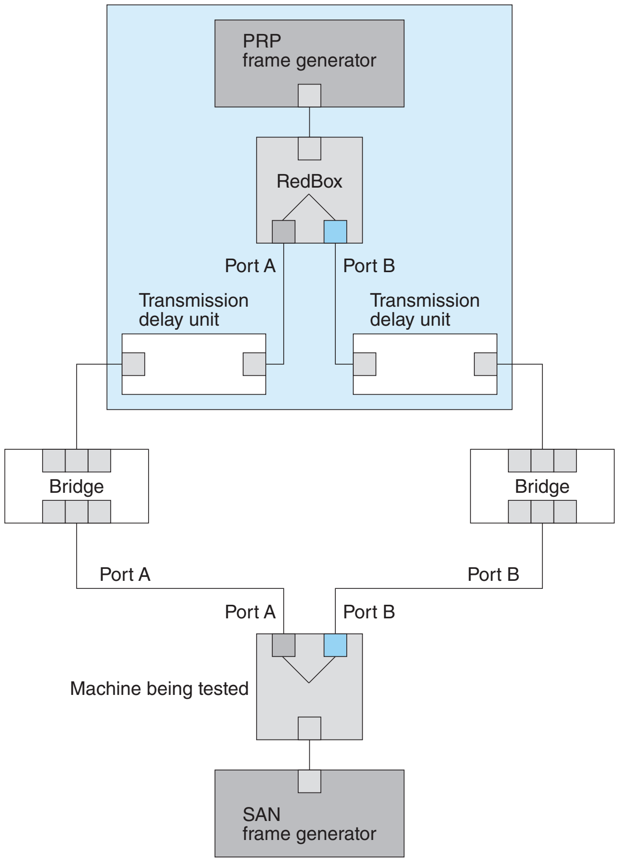

Fig. 5 System Configuration for Conformance Test

The DANP functions of machines under test are checked by means of frame generator, RedBox, and transmission delay unit.

4 Postscript

This paper introduced an overview of the development of network redundancy software that complies with the international standard on PRP. By applying this software to industrial equipment and building a PRP network, it is possible to realize a network that can continue communication without data loss even when a failure occurs.

Going forward, we will continue providing products that contribute to robust network systems by further improving reliability.

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