Trouble Shooting Method for Intermittent Interruption of Communication Between Networks in NPPs

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1. Introduction

The I&C system network of nuclear power plants (NPPs) consists of complex networks with various equipment and protocols, complicated network structures, and regional distribution as they have developed from partially applying digital technology in OPR1000 to fully adopting digital technology in APR1400.

In this study, we present a trouble shooting methods for intermittent interruption of communication that often occurs in NPPs using case of communication interruption between the Man-Machine Interface System (MMIS) and the Turbine Control & Generator Monitoring System (TCGMS) at BNPP Unit 3.

2. Methods and Results

2.1 Failure Modes

Failure modes of intermittent communication interruption that may occur between or within networks are an important issue for troubleshooting. In order to facilitate trouble shooting, we have classified possible failure modes related to intermittent communication failures in Table I as follows: hardware, software, too much traffic, and packet.

Each fault mode can be identified through basic inspection such as cable diagnostics, ping test, and packet analysis.

Table I: Failure Modes of Communication Interruption

Classification	Failure Modes
Hardware	Decreased Communication Chip Function Decreased Communication Interface Decreased Optical Module Light Intensity Poor Connection
Software	Incorrect Setting Software Setpoint Error Insufficient Error Checking Algorithm Application Software Error
Too much Traffic	Increased Processor Utilization Response Time Delay
Packet	Packet Transformation Packet Transmission Delay

2.2 Troubleshooting Process

In case of communication failure, the troubleshooting process involves checking network configuration, selecting inspection points, performing basic inspections, packet acquisition, and analyzing packets in that order.

2.2.1 Checking Network Configuration

The network configuration of the APR1400 MMIS is complex as multiple heterogeneous networks are connected together. Therefore, it is necessary to confirm the topology (tree, ring, bus, etc.) and communication line connections, and verify the IP/MAC addresses of the target network servers, switches, controllers.

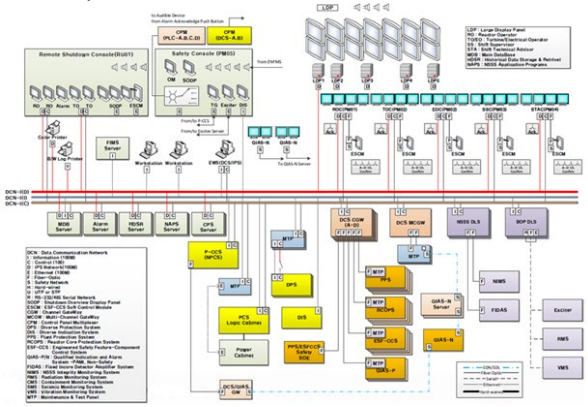

Fig. 1. Network Configuration for APR1400

2.2.2 Selecting Inspection Points

To select inspection points, first we need to identify the flow of packets. The packets between BNPP Unit 3 MMIS and TCGMS are connected as shown in Figure 2, from MMIS OIS to TCGMS Controller.
Select inspection points in each network that can be inspected for fault modes.

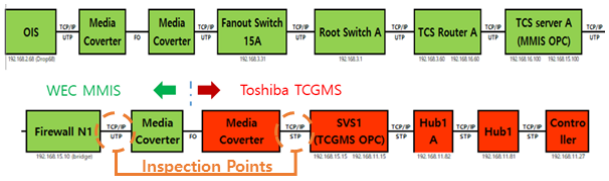

Fig. 2. Flow of packets between BNPP Unit 3 MMIS and TCGMS and selected inspection points

2.2.3 Basic Inspection

Basic inspections include verifying physical connections such as cable integrity using an LAN cable tester and TDR/OTDR, inspecting optical cables such as surface damage check, and confirming data loss rate and transmission delay through fault segment ping test. Additionally, network equipment status can be checked by examining LEDs and monitoring system server's network, processor and memory utilization rates, etc.

2.2.4 Packet Acquisition

There are several methods to acquire packets such as In-Line, Hubbing-Out and Switch Mirroring. While In-Line and Hubbing-Out methods are accurate, they require separation of communication lines which makes them unusable during normal operation. Therefore, the primary method used is Switch Mirroring.

2.2.5 Packet Analysis

The acquired packets can be analyzed using an analysis program (e.g., Wireshark). The methods of analysis include normal/abnormal comparison analysis and abnormal state packet analysis.

Normal and abnormal comparison analysis compares delay time, packet size, number of packets per second for each data packet under normal and abnormal conditions.

Abnormal analysis analyzes error control (ACKs), sequence control (out-of-order, duplicate, lost segment), and flow control (window size) in data packets.

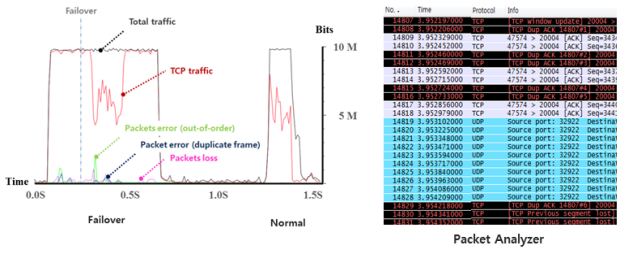

Fig. 3. Case of Abnormal Packets Analysis

3. Conclusions

The NPPs I&C system network requires high reliability and thorough traffic management compared to general industrial networks, and has various network structure due to different system architectures, network equipment and multiplexing configurations among suppliers.

Due to intermittent interruption of communication in the Ethernet-based network of an operational NPPs, there is a need for troubleshooting guidelines. Therefore, we have compiled fault modes based on experience data and confirmed inspection methods by each fault mode. This study is expected to be an effective guide for troubleshooting network failures in NPPs.

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