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Switch Design for data exchange in I&C Safety Systems

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1. Introduction

According to a digitalization of the Instrumentation and Control (I&C) system of a Nuclear Power Plant (NPP), a Data Communication System (DCS) is required for digitalized data exchanges between different equipment. In a DCS, interconnection equipments are necessary to provide connection points for safety systems or safety networks. Among interconnection equipments, a switch is selected because it provides point-to-point connections and it is operated based on the OSI(Open System Interconnection) data link layer (Layer 2) MAC address. In this paper, the design concepts of a switch structure for data exchanges are proposed based on commercial design techniques, applicable acceptance criteria and guidelines.

2. Acceptance criteria and guideline

In this section the operation procedure and structure of a switch are presented. And applicable acceptance criteria and guidelines in NPP I&C systems are presented.

2.1. Commercial switch

Usually, the operation procedure of a switch is as follows[1]. As a frame comes into a switch, the switch saves the originating MAC(Medium Access Control) address and the originating port in the switch's MAC address table. The switch then selectively transmits the frame from specific ports based on the frame's destination MAC address. If the destination MAC address is known, the frame is forwarded only to the corresponding port in the MAC address table. If the destination port is the same as the originating port, the frame is filtered out and not forwarded.

The structure of a general switch consists of four parts[1]; input port module, output port module, switching fabric module and a processor module. Input port modules and output port provides the separate connections of the physical layer and the MAC layer and a buffering function, a lookup and forwarding function of a frame. If a processor module decides on a path based on a MAC address table, the switching fabric module transmits a frame to the destination by connecting it to an actual path. Also a processor module runs the network management function and the routing function etc.

Usually, switches are categorized based on internal architectural characteristics such as the position of a memory (buffer) and the type of a switching fabric module. Because the performance of a switch varies as internal architectural characteristics, a switch should be designed by considering the position of a memory and the type of a switching fabric module.

2.2. Criteria and Guidelines

In NPP I&C systems, a safety requirement has a higher priority than a performance requirement. A high safety is the most important requirement among the requirements of NPP I&C systems. Therefore, a switch used for a safety network in NPP I&C systems should secure a safety requirement and a reliability requirement [2, 4].

It is important to satisfy an independence requirement and an electrical isolation requirement lest a failure should be delivered between safety systems [2,4].

To warrant the recognition and collision protection of a data transmission between channels and to warrant the integrity of the safety functions, a switch should satisfy a communication independence requirement [2].

Also, a switch for a safety network should be designed to have a suitable performance by considering the following guidelines in NPP I&C systems [3].

- Correct layout: Before detailed design begins, an accurate layout of the communication network should be presented, but otherwise accurate performance modeling is impossible.

- Deterministic data communication: A deterministic data communication means that it is possible to calculate the maximum delay which a frame offered for a transmission encounter before it arrives at its destination.

- Transmission media: A transmission media is an important component in a DCS, because it provides an actual path instead of a hard-wired connection. Some of the important factors of transmission media are an isolation, noise immunity, bandwidth, low bit error rate, etc.

3. The Design concept of a switch

Recently, the study of a MEMS(Micro-Electro-Mechanical System) switch has been accomplished for the electrical isolation requirements. But we determined to use the architecture of a shared bus switch, because the MEMS switch technology was immature and its switching time required several milliseconds.

Based on the technology of commercial switches, applicable acceptance criteria and guidelines, the design concepts of a switch structure are derived. Table 1 shows the design concepts of a switch. Figure 1 shows the structure of a switch based on Table 1.

Table 1. The design concepts of a switch.

Criteria & Guideline	Design concept
Safety/Reliability	Redundancy of Processor module
	Hot-swap technology
	Watch-dog timer
Independence/ Isolation/Separation	Separation between Input and output port
	Non-interruptible for processor module
	Simplex transmission
	Single mode optic fiber
Communication independence	Buffering circuit in input and output port
Layout	Star topology
Deterministic data communication	Point-to-point connection : no collision occur
	Use shared bus switch

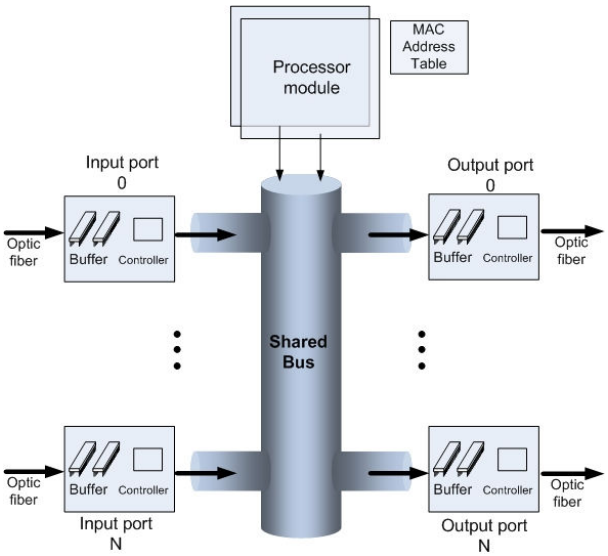

Figure 1. The structure of a switch based on the design concepts.

Redundancy methods and hot-swap methods are used for the safety/reliability requirements. To satisfy the independence/isolation requirements, a switch is designed to be non-interruptible for a processor module and to use an optic fiber cable for an electrical isolation. The separation between the input and output ports and between the cables for a one-way communication respectively satisfies the communication isolation requirements. Also the controller and buffers in a switch satisfy the communication independence requirements.

Using shared bus switch and point-to-point connection satisfy the deterministic data communication requirements. A shared bus switch is a structure where a data bus of a high speed is linked between an input port and an output port. Because this bus can handle the maximum transmission speed of each port at the same time and have non-bottleneck of the data path, a shared bus switch have low propagation time.

4. Conclusion

In this paper, the design criteria and guidelines for a switch are presented, which are the essential requirements to develop a switch for a safety network in NPP I&C systems. Based on these results, the design concepts of a switch were proposed. The proposed design concepts of a switch have a star topology, redundancy in a processor, separation between an input and output ports, an optic fiber and a simplex transmission. Currently based on these design concepts, the prototype of a switch with a VMEbus(Versa Module Eurocard bus) is in the process of a developments and testing.

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