（2）英文要約

Title:

Project for Innovative AI Chips and Next-Generation Computing Technology Development
Development of Next Generation Computing Technologies
Research and Development of High Speed and Low Power Data Transfer System Using Photonic & Electronic Hybrid Switch for Next Generation Datacenter with Disaggregation Architecture
(FY2018-FY2022)

< Photoelectric hybrid switch (SW) control technology >

To achieve high-speed switching in the photoelectric hybrid SW system, it is important to hold link-up status of ethernet switch ports when the optical transmission line is switching. In this study, we developed the link-up hold method, the control procedure for the photoelectric hybrid switch systems by using EtherCAT and OpenFlow function. Furthermore, the change timing of the TOS (Type of Service) value of the IP packet not to cause packet loss was clarified.

< Photoelectric hybrid SW control Algorithm>

A traffic engineering algorithm and a fast control plane technique for network controllers have been developed to achieve effective traffic engineering for next-generation datacenter with disaggregation architecture. The main results are as follows: (1) As a traffic engineering algorithm, we have investigated two approaches, service-driven and data-driven, and a traffic engineering algorithm suitable for the photoelectronic hybrid switch system has been developed to improve the execution time of large-scale distributed deep learning applications. (2) A fast control plane technology has been developed. It is scalable up to 1000 racks and allows optical switches to be configured in 100 μs. (3) A model for describing the functionality and status of optical components has been developed for resource management of the photoelectric hybrid switch system. Finally, the proposed network controller that integrates the above functions has been demonstrated the effectiveness on a photoelectronic hybrid switch system.

<Performance maximization of optical SW network architecture>

Next-generation computing is expected to have a wide range of applications, including various AI-related services and cloud-related services. We developed an efficient optical switch network architecture that can be optimized for various applications and computing environments including disaggregation type next-generation data centers. In order to achieve the low power consumption, high performance, maximization of economic efficiency, optimization is required according to the applications. Scalability (pay-as-you-grow) is also important for the economical introduction of large-scale switches. We realized an optical switch architecture that can optimize the modulation format, number of ports, space/wavelength switch function configuration. As for the future expandability, we have demonstrated that it can be expanded to more than 7,000 ports by the optical switch transmission experiments using newly developed devices. Regarding the capacity, we developed new optical switch architectures utilizing space division multiplexing, ultra-wideband transmission, and ultra-high density wavelength division multiplexing, and realized a switch capacity exceeding one petabit per second. Furthermore, we proposed a method to greatly improve the latency characteristics of data centers and verified its effectiveness through the control network experiments.

<Optical ToR switch & Optical wavelength transmitter and receiver>

To develop the Optical wavelength transceiver, the optical burst signal receivers in digital coherent optical communication system are studied. Targeting fast wavelength switching, a Proportional-Integral-Differential controller of a tunable laser is developed. As a result, the wavelength switching time of 100 μs is expected to be achieved. Moreover, an optical burst receiver is considered. By providing an intradyne coherent receiver with gain control voltage at the same time as wavelength switching, optical burst signal receiver is achieved. Optical wavelength transceiver is fabricated by implementing the above technologies and Burst-mode multi-level-modulation processor. Finally, Optical ToR switch with Optical wavelength transceiver, Electrical-switch interface and EtherCAT, which is used as an external control interface, is prototyped and evaluated. The wavelength switching time is less than 100 μs, and the error-free operation is achieved with a Forward Error Correction in 400 Gbps mode. Also, the operation of Photoelectric hybrid switch incorporating this Optical ToR switch has been demonstrated with an external control of EtherCAT.

<Burst-mode, multi-level-modulation processor>

Burst-mode, multi-level-modulation processor is one of the components of an optical wavelength transmitter and receiver. It is a digital signal processing circuit that generates a multi-level signal for generating a multi-level coherent optical signal on the transmitter side and demodulates the received optical burst signal on the receiver side. We developed some prototypes of the burst-mode, multi-level-modulation processor step by step in order to simultaneously realize optical multi-level modulation/demodulation that expands transmission capacity and high-speed response that can handle optical burst signals with short signal durations and non-uniform timings. In the evaluation using a final prototype chip, we achieved the target high-speed response time of 100 μs or less in both transmission speed modes of 200 Gbps and 400 Gbps. Furthermore, the final prototype chip was incorporated into an optical wavelength transmitter and receiver, and through system verification, it was verified that it could operate in an optoelectronic hybrid switch system, and burst-mode, multi-level-modulation processor technology was established.

< Optical core SW>

We have designed and the implemented prototype equipment for the principle verification of the switching system consisting of more than 1,000 I/O ports and having the capability of short switching time of less than 100 μs. And also the functional basis of cooperative operation with other functional parts, namely the optical ToR switch, the optical wavelength transmitter and receiver, and the SW controller was implemented. Following three points were regarded as important points: (1) Design from the viewpoint of optical signal transmission such as optical level diagrams and optical signal-to-noise ratio diagrams. (2) Design from the viewpoint of implementation such as the total equipment size when fully implemented. (3) Design from the viewpoint of cooperation with other functional parts. In addition, we have also verified the high-speed switching operation at the optical physical layer utilizing the developed high-speed spatial switch and the high-speed wavelength tunable laser.

< International standardization>

We had two objectives on this activity. For the "system control program", we conducted the open-source strategy, and gave the presentation at the international conference. Source code can be downloaded through the specific site. For the parts technologies, we keep those parts technology information secret rather than disclose them through patent strategy.

<Photoelectric hybrid SW system verification>

A verification system by using a developed optical core switch, optical wavelength transmitters and receivers and burst-mode, multi-level-modulation processors was bult to demonstrate the system functions. Transmission line switching time less than 250 μs was achieved by cooperation control using EtherCAT. And it was demonstrated that there was not a packet loss when transmission line is switched. Furthermore, the demodulation for 400 Gbps optical burst signal was showed by using the experimental boards that burst-mode, multi-level-modulation processor was implemented.