Innovative Optical and Wireless Network (IOWN) for a Sustainable World

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Abstract: IOWN is a next generation communication and computing infrastructure which enables both high-performance and low-power consumption for the Sustainable Development Goals by IOWN's capabilities of an all-photonics network and a data-centric infrastructure.

1. Introduction

Latest services become more sophisticated by AI/ML and IoT technologies. AI/ML requires a vast amount of processing power. IoT based services require a lot of data from diverse sensors. As a result, the required data-volume and processing-power is increasing exponentially. This causes ever increasing power consumptions for data transmitting and processing. For example, it is difficult to find a location to build a hyper-scale data-center due to difficulty of securing enough electricity. For our sustainable growth, we have to pursue both improving performance and reducing environmental impact.

2. Innovative Optical and Wireless Network

NTT believes the photonics technologies could contribute to solving the issue. NTT has long history of research on optical technologies since 1960's [1]. In recent years, NTT has made a series of inventions on a field of photonics electronics convergence technology [2], [3], [4], [5]. They enable both high-performance and low-power consumption. Introducing photonics technologies into diverse area of communication and computing makes it possible to improve the performance and to reduce environmental impacts. This is the origin of Innovative Optical and Wireless Network (IOWN). By using photonics technologies, we would like to develop next generation communication and computing infrastructures for our sustainable society.

2.1. All-Photonics Network (APN)

All-Photonics Network (APN) provides an end-to-end and a flexible photonics wavelength path without any routing and electric-photonic/photonic-electric exchanging procedures among the photonics-path. Current packet networks can provide flexible and inter-operable communication infrastructures like the Internet. Multi-hop IP routing is one of the core features of the packet network for the above advantages. However, such a multi-hop routing requires many electric-photonic/photonic-electric exchange and routing operations. It consumes electricity and processing time. Another issue of current packet network is duration of latency. Since the packet network is a best-effort network, the variation of latency is not stable. The latency is not predictable.

n comparison with current packet network, APN requires neither electric-photonic/photonic-electric exchange nor routing process during its photonics-path. In other words, the current packet network is similar to the public transportation using various types of trains such as subways, local trains, and express trains. It requires extra times when the user exchanges from a train to another train. The user is also tried on the exchanges. APN is similar to a direct express train. It does NOT require any exchanging trains during the travel. The user just sit on his/her seat without any extra time or extra work for exchanging trains. (Fig. 1)

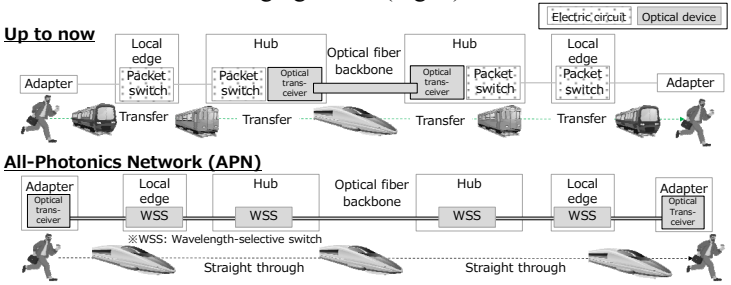

Fig. 1 All-Photonics Network (APN)

As the result, the target of APN is two-digit level improvement in bandwidth, latency, and power efficiency in 2030. In addition, APN enables static milliseconds level latency and hundreds Gbps level communication capacity.

The dark-fiber can provide both low-latency and zero-duration of latency. However, it cannot provide dynamic communication path, since it is a physical connection between end-points. The dark-fiber has no flexibility. In comparison with that, the APN's Wavelength-Selective Switch can provide dynamic photonics path between selected endpoints without any packet routing processes.

2.2. Photonic Disaggregated Computing

The current major computing architecture is "CPU-centric." The Central Processing Unit (CPU) controls all transmitting and processing of data. However, the latest AI/ML technology requires simple but a lot of processing that GPU is more fit than CPU. Therefore, we should consider a new computing architecture of "Data-Centric" rather than "CPU-Centric." Photonics technologies could contribute to develop this new architecture. Introducing small-sized and low-power consumption photonics-electric interface into each computing equipment such as GPU, DPU, and memory, could provide direct photonics path between them. This computing architecture can provide one computing equipment level connection and precise energy saving control. It enables both flexible scalability and power efficiency. With this architecture, we would like to develop 20 times power efficient computing infrastructure in 2030. (Fig. 2)

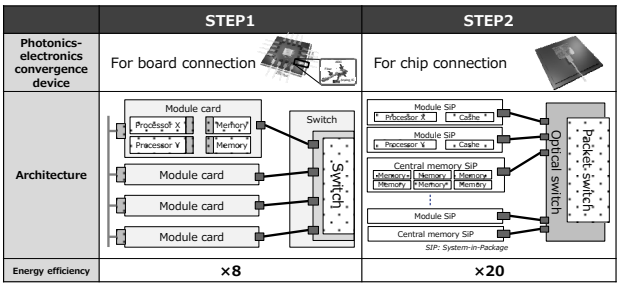

Fig2. Photonic Disaggregated Computing

3. Contributions to a Sustainable World

Those major technologies of IOWN can provide high-performance and flexible capabilities with a low-power consumption. In diverse industries, those features value for the sustainability.

3.1. Flexible Mobile Fronthaul

The capacity of mobile network is continuously increasing. And high-frequency wireless band usage requires large number of Radio Units. The current network between Distribute Unit (DU) and Radio Unit (RU) is provided by static dark-fiber. However, the ratio of mobile network utilization varies due to the user density of the area. For example, a number of users in a RU area is dramatically different in daytime and night-time in the metropolitan area. There are a lot of office workers in daytime, but only few users in night-time. Since the current mobile fronthaul provided by dark-fiber is static, all DU should be operated through all day. On the other hand, APN can provide flexible optics path between RU and DU. APN can switch optical path from a RU to another DU dynamically. With this feature, only some DUs are operated to control all RUs in night-time and other DUs could be shutdown. Therefore, APN enables power optimized mobile fronthaul. (Fig. 3)

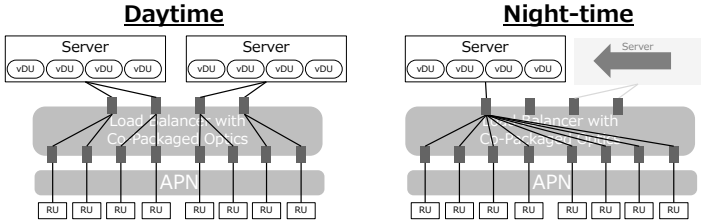

Fig. 3 Flexible Mobile Fronthaul with APN

3.2. Distributed Datacenter

APN provides photonics communication path with low and stable latency. APN path between data-centers enables virtual one computer with inter-data center equipments. This means that we can use several numbers of distributed middle-sized data-centers instead of a hyper-scale data-center. Since the hyper-scale data-center requires a vast amount of electricity, only a large-scale thermal power plant or nuclear power plant provides enough electricity. Sustainable energy cannot provide such a concentrated and large-scale electricity. One the other hand, if we can use distributed middle-sized data-centers, we can use area distributed sustainable energy more. (Fig. 4)

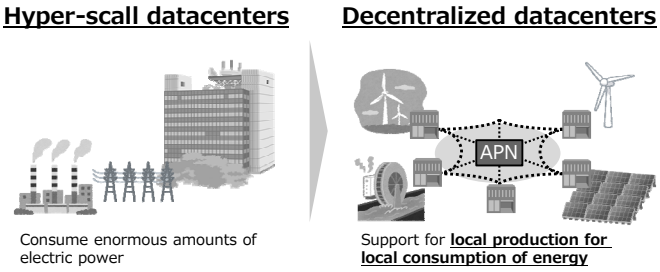

Fig. 4 Distributed Datacenter

4. IOWN Global Forum

The target of IOWN is challenging one. It requires a lot of innovation from diverse industries. To enable IOWN supported sustainable society, IOWN Global Forum (IOWN GF) was established in January 2020. One of the important characteristics of IOWN GF is to contribute to sustainable world by innovative technologies since its establishment. For this challenging goal, over 100 members work together to develop both technologies and use cases. There are both tech-companies and user-side companies who would like to use IOWN technologies to improve their businesses. Under COVID-19, IOWN GF has been able to arrange only online meeting over two years. However, it enables IOWN GF to set online meeting frequently. With this close work, IOWN GF has developed and published a series of deliverables. From 2022, IOWN GF tries to start its PoC activities to proof the value of IOWN GF technologies and use cases with members from diverse industries.

5. Contributions to Sustainable Development Goals

IOWN intends both high-performance and power efficiency with innovative communication and computing technologies. These features can obviously contribute to “#8 Decent Work and Economic Growth”, “#7 Affordable and Clean Energy,” and “#9 Industry, Innovation and Infrastructure” of SDGs. IOWN GF is a global collaboration forum to develop a next generation sustainable communication and computing infrastructure. This is related to “#17 Partnerships for the Goals.” The sustainable growth is critical for all industries and organizations. We believe the innovation should contribute to both economic growth and a sustainable society.

6. Conclusion

IOWN is the next generation communication and computing infrastructure. With utilizing photonics technologies in diverse areas, IOWN pursues both high-performance and energy efficiency. IOWN has possibilities to contribute to SDGs in diverse perspectives. The goal of IOWN is to provide the next generation IT infrastructure for a sustainable society.

[1] T. Izawa, S. Sudo, and F. Hanawa, “Continuous Fabrication Process for High-Silica Fiber Preforms,” Trans. IECE Japan, vol.E62, no.11, pp.779-778, Nov. 1979.

[2] K. Nozaki, S. Matsuo, T. Fujii, K. Takeda, A. Shinya, E. Kuramochi, and M. Notomi, “Femto-farad optoelectronic integration demonstrating energy-saving signal conversion and nonlinear functions,” Nature Photonics, vol. 13, pp. 454-459, 2019

[3] M. Ono, M. Hata, M. Tsunekawa, K. Nozaki, H. Sumikura, H. Chiba, and M. Notomi, “Ultrafast and energy-efficient all-optical switching with graphene-loaded deep-subwavelength plasmonic waveguides,” Nature Photonics, DOI: 10.1038/s41566-019-0547-7, 2019

[4] S. Kita, K. Nozaki, K. Tanaka, A. Shinya, and M. Notomi, “Ultrashort low-loss Ψ gates for linear optical logic on Si photonics platform,” Communications Physics, Vol. 3, No. 33, pp.1-8, 2020.

[5] S. Yamaoka, N. Diamantopolos, H. Nishi, R. Nakao, T. Fujii, K. Takeda, T. Hiraki, T. Tsurugaya, S. Kanazawa, H. Tanobe, T. Kakitsuka, T. Tsuchizawa, F. Koyama, and S. Matsuo, “Directly modulated membrane lasers with 108 GHz bandwidth on a high-thermal-conductivity silicon carbide substrate," Nature Photonics, DOI: 10.1038/s41566-020-00700-y, 2020.