On-demand Photonic Multipoint Connection Technology Supporting High-presence Communications Services

Hirotaka Yoshioka, Takamitsu Narumi, Masahiro Nakagawa, and Kenichiro Matsumoto

Abstract

Aiming for the next generation of high-presence communications services, this article presents a multipoint connection technology to provide a user-specific photonic communications network on demand for specific applications and requirements by constantly monitoring and linking/controlling various technical elements of the All-Photonics Network, such as the user interface, communication bandwidth, low latency, and local high-precision time keeping.

Keywords: high-presence communication, on-demand, photonic multipoint connection

1. Achieving a world of high-reality experiences for many people

The world where people used to meet each other, gather in large groups, and enjoy on-the-spot conversations and events is changing to one where people gather remotely from various locations to participate in meetings and events. People who are far away can easily meet each other via a display, and events that used to be difficult to experience due to capacity limitations are now easier to participate in, offering new ways to have fun. However, people may still feel a lack of realism. This is probably because many people feel uncomfortable due to unstable and highly variable communications quality, e.g., communications slowing down when talking to a friend or cheering for their favorite entertainer.

High-quality communications are also very expensive, takes several months for services to become available, and is a privilege only for a limited number of people. This is due to the limitations of current communications network technologies (**Fig. 1**). To achieve both *high-speed and broad bandwidth* as well as *low cost and immediate use*, NTT is collaborating with many partners and using All-Photonics Network (APN) technology to research and develop on-demand photonic multipoint connection technology called Photonics On-demand. We will add service technologies, such as the advanced next-generation video service platform called Photonic Direct Multipoint Connection Service Platform, to this communications technology to deliver high-presence communications to many of customers even in remote environments and making the Remote World a reality.

2. Service overview: A remote communications network that connects the world on demand

The key to solving the current network issues with remote communications, which will be achieved with Photonics On-demand, is how to make the smallest unit (one optical wavelength, commonly known as λ) of an optical communications path, which is high-speed but expensive and has limited applications,

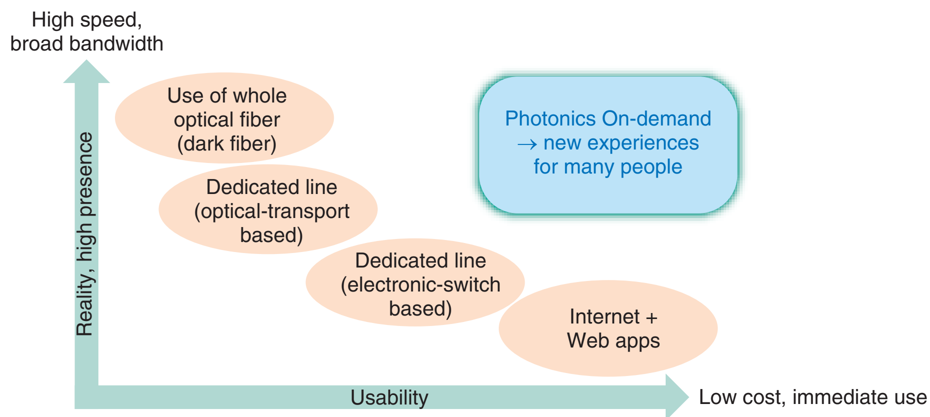

Fig. 1. Relationship among current services and target area for new technologies.

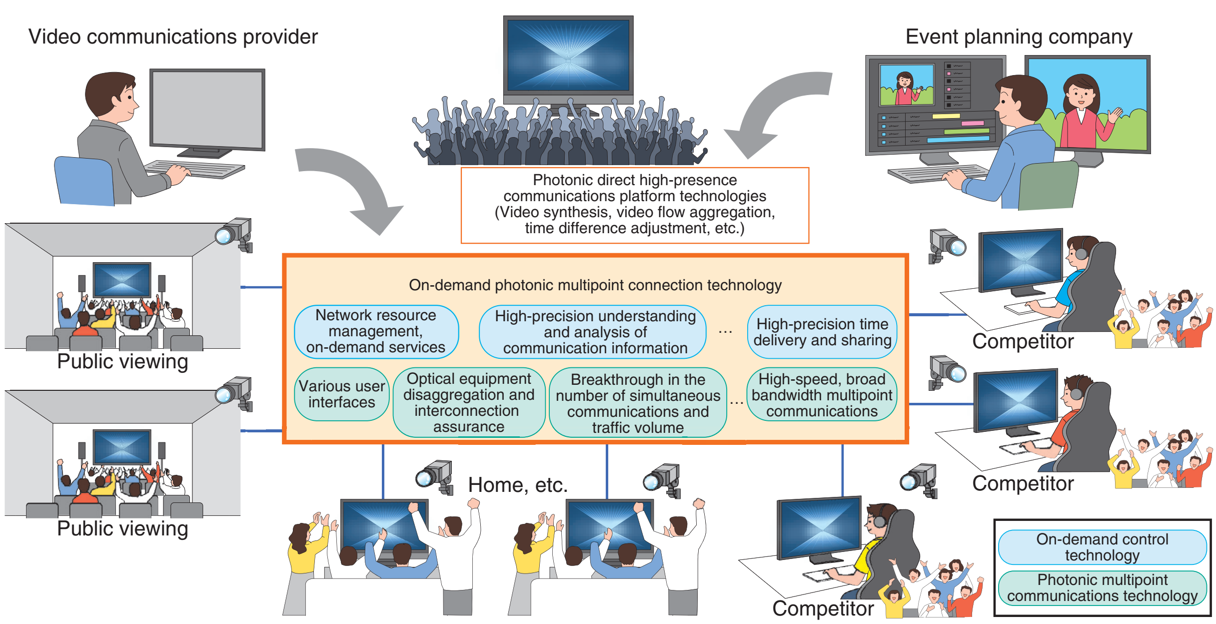

Fig. 2. A service provided by a remote communications network that connects the world on demand and key technologies.

available to a large number of people at low cost. To achieve this, the key is to increase the number of λs that can be used with a single optical fiber and achieve on-demand using the optical resources only when necessary and minimize use to only the amount of time needed.

It is also important to greatly expand service menus, which currently have little variety, to meet a wide range of user needs on the same network, and superimpose networks that can be provided to each user. This service is illustrated in **Fig. 2**.

3. Key technologies supporting services: Innovative technologies and total coordination

In this section, we introduce the key technologies that support Photonics On-demand.

3.1 Various interface types: Varied protocol support and flexible bandwidth selection

To enable users to use their own assets and the network freely, it is important to have a variety of interfaces to connect devices. We aim for various types of communications such as uncompressed video transmission (e.g., via serial digital interfaces) and analog optical signals essentially without the need for conventional protocols such as Ethernet or TCP/IP (Transmission Control Protocol/Internet Protocol). We will also use technology that divides a λ into time-domain elements and/or treats multiple λs as a group to provide communications with optimal quality and speed at all times.

3.2 Vendor-agnostic photonic device connection: Disaggregation and multi-vendor interconnection

To enable users to use a variety of interfaces, it will be necessary to expand the choice of connectible user devices and guarantee a variety of network combinations. However, since optical transmission equipment is conventionally provided by a single vendor in an end-to-end (E2E) manner, it will be necessary to disaggregate such equipment by function and freely interconnect different vendors. This type of disaggregation between hardware functions is called *horizontal disaggregation*. NTT is promoting this through global communities such as Metro Ethernet Forum, Open Networking Foundation, Telecom Infra Project (TIP) [1], and OpenROADM. The Innovative Optical and Wireless Network (IOWN) will further accelerate these interconnections.

3.3 Improving network utilization efficiency: Expanding network capacity and number of available wavelengths

The key to providing highly realistic services at low cost is a dramatic increase in the number of users using the network. To achieve this, we aim for a 125-fold increase in transmission capacity. This will be achieved by expanding the number of wavelength bands (introducing multiband transmission technology for stable, long-distance transmission [2]), by increasing the capacity per λ and exploiting the spatial dimension (e.g., space division multiplexing transmission). To meet diverse user needs, we will also establish technology that divides a single λ into the time-domain elements while guaranteeing long-distance transmission to provide services to even more users [3].

3.4 High-speed distribution of large-volume content to multiple locations: Multipoint simultaneous connection and photonics multicast

E2E communications leveraging optical transport technology alone are generally point-to-point (P2P), one-to-one connections. By grouping these and providing frame multiplexing and other features required by users, simultaneous connection of multipoint users can be achieved as function dedicated networks (FDNs). An FDN is a dedicated logical network that is independent for each user. These networks enable a large number of separate service levels that do not interfere with each other. It could be said that this is the network slice in which optical layer is the core, in contrast to the slicing technology currently accelerating around 5G (fifth-generation mobile communications systems). P2P connections alone also require servers to provide services and large numbers of optical λs to be handled at all times. However, APN optical components can copy and branch the same data to deliver them to multiple locations at high speed while maintaining quality.

Next, we introduce the core technologies to provide services on demand according to user requirements.

3.5 On-demand connection: FDN controllers

The most important technology in Photonics On-demand—and in all FDN services—is the FDN controller. With facility planning based on network design technology and usage forecasting based on macro information, which had been mainly adopted by telecommunications carriers, it is assumed that optical paths will be used on a fixed basis, but construction requires a long time and network resources are occupied even during periods of non-use, resulting in the inefficient use of these resources. Photonics On-demand enables high-efficiency usage of network resources by precisely allocating physical and logical network resources only when users need them, contributing to the provision of cost-effective, high-presence services. The key points are the management of network resources, creation and release of logical networks optimized for the required service level, and provision and maintenance of service levels. NTT laboratories are working with the above-mentioned global communities to demonstrate and promote the use of existing and new transport equipment.

By coordinating the innovative technologies provided by IOWN, we are working on the demonstration and establishment of workflows and the practical application of FDN controllers to shorten the time of providing optical communications paths from several months of construction to tens of minutes, and a few minutes shorter in the future, in line with the development of APN technology. By securely and reliably managing network resources on a per-user basis, an enormous number of services can be provided on a single network (hundreds to tens of thousands of connection points per service, provision of tens of thousands of simultaneous services, etc.).

3.6 Real-time and detailed understanding and adjustment of networks: Network monitoring, latency adjustment

With on-demand resource utilization, it is important to accurately determine the state of the vast amount of disaggregated network resources in real time. Specifically, it is important not only to monitor equipment-failure states but also guarantee the various network conditions and their strict service levels when each resource is linked. To achieve this, high-precision E2E service monitoring and network control are required. Although NTT has been working on monitoring technology at the transport layer, we are also working on the basic technologies to manage optical resources, measure communication speeds, and adjust latency according to service requirements.

3.7 Network-wide high-precision time synchronization

The low-latency network brought about by IOWN/APN will come into its own with more accurate time management and synchronization between devices. For example, for stock trading and professional remote e-sports, where fairness is key, we are working on high-precision time-synchronization technology to deliver more accurate clock time across the country without compromising accuracy and precisely adjust the timing between devices. Embedding highly accurate timestamps of communication locations in communication data enables services to conduct highly accurate and fair data timing correction. Increasing the accuracy of frequency sources will also make it possible to provide even more accurate clock time in the future.

3.8 Usability improvements: Photonic direct high-presence communications platform

To make Photonics On-demand available to as many service providers as possible, we have started to study a photonic direct high-presence communications platform—a video platform to provide more convenient user interfaces. Video communications include functions such as rendering, video composition, video-flow aggregation, compression/decompression, and time-difference adjustment. These technologies are provided as a platform through batch control by the controller. Users can combine these functions in the order in which they actually want to carry out processing and add content such as captured video and audio that they want to use with each function. Inter-site communications of services and video functions can be combined with a Photonics On-demand FDN, while connecting to a minimum of video equipment makes it possible to provide high-presence video communications, connecting to any point freely at any time.

Figure 3 shows the workflow for the current service provision. Many technologies can be used on-demand with advanced management control by using the Cognitive Foundation (CF) and FDN controllers.

4. Prospects for the future: Deployment of usable technologies to the market and sustainable development of services

Although APN innovative technologies are needed to complete the establishment of on-demand photonic multipoint connection technology (its culmination is targeted for 2030), the key on-demand connection technologies can be used on existing optical networks. In the early stages, we will work on using the high-level control and network monitoring functions to provide a more cost-effective optical path.

To show the latest technology at Expo 2025 Osaka, Kansai, we will work together with partners to research and develop fundamental technologies to achieve the Remote World. Going forward, we will improve the real-time functionality of service delivery and scale of concurrent usage to bring more affordable services to more people. This technology, when used in conjunction with IOWN's new radio technology, will also contribute to increasing the effectiveness of extreme NaaS (network as a service).

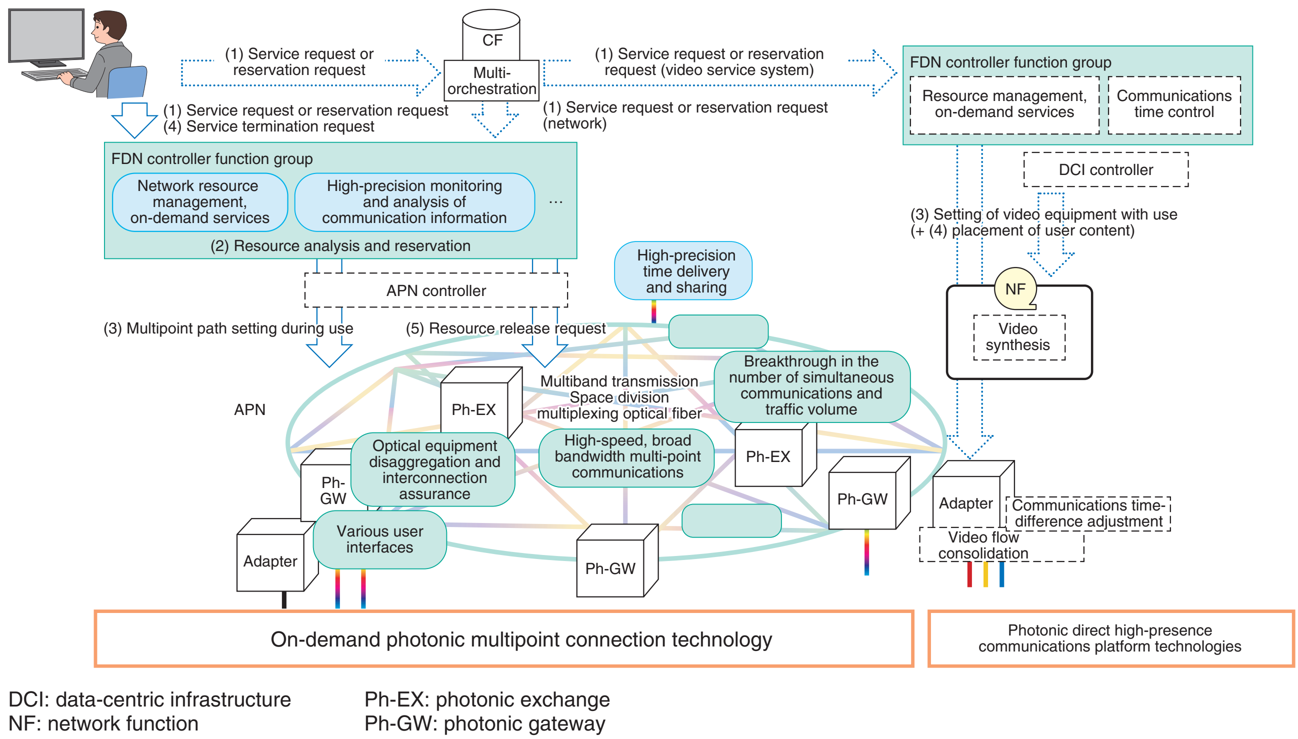

Fig. 3. On-demand photonic multipoint connection technology workflow.

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