# SLA-aware Real Time Control Technology across Optical and Mobile Networks

**Hiroshi Ou, Kota Asaka, Tatsuya Shimada, and Tomoaki Yoshida**
*NTT Access Network Service Systems Laboratories, NTT Corporation, 1-1 Hikarinooka, Yokosuka, Kanagawa 239-0847, Japan*
*Author e-mail address: hiroshi.ou.dg@hco.ntt.co.jp*

**Abstract:** Low latency services such as remote drone control are expected to be provided by future optical and mobile networks. This paper covers the issues and possible technology candidates to resolve them. © 2022 The Author(s)

## 1. Introduction

Thanks to 5G, growing expectations are being placed on the network to accommodate various services that have strict requirements such as ultra-low latency services like factory automation or drone control, and massive connection numbers like various Internet of Thing (IoT) equipment, in addition to the expansion of current broadband services. Since the network requirements of upper-layer services are decided by the End-to-End quality, it is important to deploy/design a high quality E2E network including both wireless (mobile) and wired (optical) networks. This enables the accommodation of services that have even stricter requirements.
The decrease in working population is one of the biggest issues in Japan and indeed most developed countries. Increasing the number of network-supported services is expected to reduce workforce demands.
Furthermore, lower power consumption is also demanded to control global warming.
To respond to the demands above, Innovative Optical and Wireless Network (IOWN) All Photonics Network (APN) has been studied [1]. IOWN APN is an optical network that has the advantages of ultra-large bandwidth, ultra-low latency, and ultra-low power consumption compared with the conventional network by eliminating electrical processing from user plane transport and connecting the optical path directly from end to end. In 2020 NTT and partners established IOWN Global Forum (IOWN GF) to realize the vision of IOWN. IOWN GF continues to publish use cases and technology outlooks of IOWN as interim results [2-4].
Fig. 1 shows a typical use case of the future network utilizing IOWN APN. This use case is to control drones remotely to inspect and repair facilities with live-video streaming. IOWN APN will enrich the complicated control such as the cooperation of multiple drones by fully utilizing the advantage of low latency, while high-resolution live-video streaming is realized by large capacity. This enables dispatch-less operation which leads to lower operation cost and fast/flexible operation. The APN controller controls and provides small latency optical paths between terminals and the drone control application, which is set on an edge close to a photonic gateway (Ph-GW), by switching Ph-GW routing information. The Ph-GW is an access node for APN, and handles the optical signals incoming from / outgoing to the access fiber; it can support various topologies, such as a star, a point-to-point, and a loop.
In this paper, we will introduce issues that appear likely when realizing remote drone control, especially from a latency point of view, and introduce the SLA-aware real time control technology that resolves the issues.

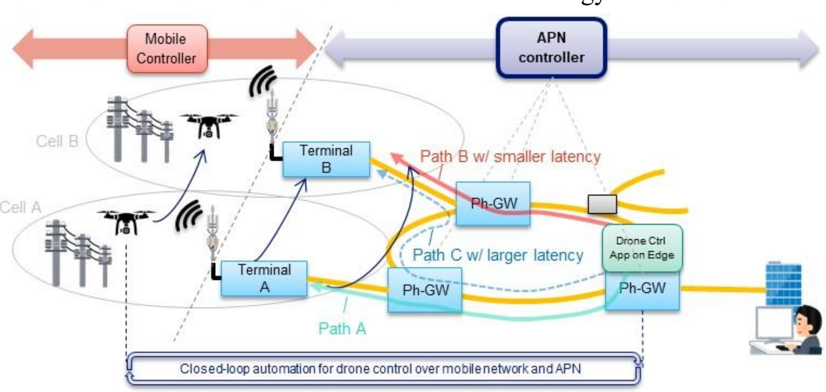


Fig. 1. Remote drone control: a typical use case utilizing IOWN APN

## 2. Issues for realizing remote drone control

Latency is one of the strictest requirements that must be considered for remote drone control. When controlling drones remotely, network round-trip times must be less than 20ms (including air-interface and optical network latency) [5]. Utilizing IOWN APN, latency on the optical access and core network is small enough to meet this requirement. The one-way latency on air-interface would be 4ms even with 5G eMBB, in ideal case, which is also small enough. However, considering the operation of multiple drones in a cell, it becomes difficult to satisfy the requirement as the scheduling delay on air-interface may become significant.

Scheduling delay can be decreased by splitting and narrowing the cells, but this increases the number of optical fibers for mobile fronthaul and backhaul. This leads to concerns such as higher equipment cost to support larger numbers of wavelengths and wavelength resource shortages.

Therefore, we consider the approach of linking wavelengths to users dynamically, instead of allocating wavelengths statically to all cells. As drones may not be active in some cells, the dynamic allocation of wavelengths would be beneficial in reducing the number of wavelengths needed thanks to the statistical multiplexing effect.

Two issues should be addressed for the dynamic allocation of wavelengths. One is automating the operation of wavelength allocation and path routing. It is not realistic for operators to do these manually as the needs of assigning wavelengths to cells will vary dynamically. The other one is real-time switching of optical paths. The allocation of wavelengths and optical paths should accommodate drone mobility while satisfying the requirements. We are studying an SLA-aware real time control technology to resolve these issues.

To realize SLA-aware real time control, high-speed processing is needed for (1) the collection of network quality information, (2) analysis of optical path routing, and (3) control of optical paths according to the analysis results as shown in Fig. 2. The target of processing in the controller is less than 10ms. As we assume the adoption of 5G eMBB, LTE would consume most of the delay budget, whose one way delay is 8ms. The switching time of Ph-GW is assumed negligible, as there already exist optical switch products with nano-second speeds at the device level.

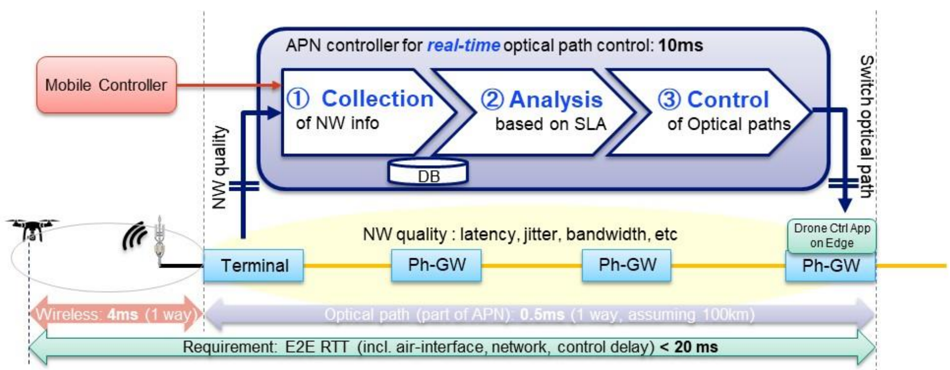


Fig.2 SLA-Aware Real Time Control

## 3. Technology Candidates for SLA-Aware Real Time Control

In this section, we explain technology candidates that are anticipated to provide SLA-aware real time control.

### *3.1. Real-Time and Protocol-Free Performance Measurement and Collection*

Real-time and protocol-free measurement and collection technologies are essential. For the real-time collection technology within single digit ms, streaming telemetry [6] would be a candidate, while conventional SNMP is not suitable for real-time use as its collection interval can exceed 1min. Not only latency but also jitter, bandwidth, etc. may be in scope as well, depending on drone tasks.

Protocol free is also essential so that performance measurement and collection does not affect to user data transmission; fortunately, it is one of the features of IOWN APN. AMCC [7] may be a candidate for protocol-free measurement and collection. However, how to utilize AMCC for telemetry must be studied as AMCC is originally a low bit rate channel for management and control. As AMCC was originally specified for 1:1 communication, it must be studied how to extend to 1:n communication to measure and collect data from multiple Ph-GWs,.

For the collection of wireless system data, it is expected to use Cooperative Transport Interface (CTI). CTI is an interface between passive optical network (PON) and mobile systems, and enables PON to perform cooperative DBA by obtaining mobile scheduling information to reduce upstream latency [8], as shown in Fig.3.

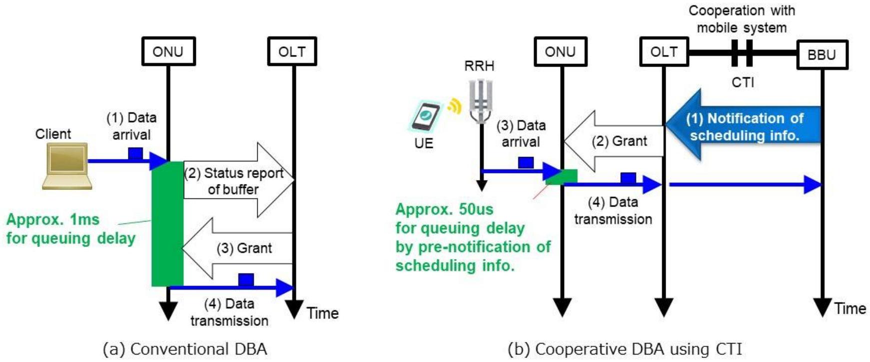


Fig.3. Uplink procedure by cooperation between PON and mobile system

The extension of CTI is also required, as CTI is defined for cooperation with LTE standard systems. One approach is to extend it to support short TTI for 5G and beyond. Another is to study new optical-wireless cooperation technology for lowering latency and jitter not limited to TDM network.

### *3.2. Real-time and flexible analysis*

Analysis to find a new optical path that satisfies SLA should be performed within single digit ms. FPGAs and GPUs may be used to accelerate the processing for quickly finding the new path. Prediction based on artificial intelligence (AI) is another approach for real-time control.

Flexible analysis by APN controller must also be considered. Some services may emphasize optical span quality, while others quality of the optical plus wireless span. Some may require latency, while others may require bandwidth, etc. Therefore, the analysis of network quality in terms of satisfying the requirement should be done on a service basis. It is not practical to implement hardware-based analysis function from scratch per service, thus it is desirable to be realized by a combination of software-based components. Microservices, such as Kubernetes, based architecture is one of the possible implementation methods, but it must be studied how to achieve both the flexibility and the adequate high-speed processing to support real-time control at the same time.

### *3.3. Real-time and open control of Ph-GW*

Ph-GWs are controlled according to the result of the analysis within single digit ms. It is desirable to use an open and common interface and data model to control various types and versions of Ph-GWs. Netconf or Restconf may be candidates as the interface to switch optical paths. OpenConfig or Open ROADM may be candidates as the data model. Cooperation of wireless and optical switching should also be studied to minimize the switching time in system level.

## 4. Conclusion

This paper introduced remote drone control as a typical use case of a future network based on IOWN APN. SLA-aware real time control must meet strict latency requirements for drone control. It also covered technology candidates as further study subjects. We are currently studying these issues and are prototyping a controller.

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