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First Demonstration of Real-Time Optical Path Control Scheme with AMCC Telemetry

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Abstract *To ensure stringent SLA requirements in the 5G/6G era, we propose and demonstrate real-time performance collection, analysis and control of optical path scheme based on commercial and open-source products. We verified that the automatic optical path control can perform the aforementioned tasks within 20 milliseconds. ©2022 The Author(s)*

Introduction

As advancements are made in networks, such as 5G/6G, network requirements are becoming stricter and more diverse. Networks are expected to provide various high-quality communication services that utilize AI/ML cost-effectively, which were traditionally operated within a standalone or local network due to its stringent requirements for capacity, latency, etc. We previously introduced a remote drone control for inspecting and repairing facilities [1]. The Innovative Optical and Wireless Network-All Photonic Network (IOWN APN) [2] is a promising ultra-large capacity and ultra-low latency network as it connects the optical path directly, though the quality of wireless access network should be considered as well. In other words, the network quality should be ensured from end to end as future networks should be heterogeneously and entirely controlled in optical and wireless aspects.

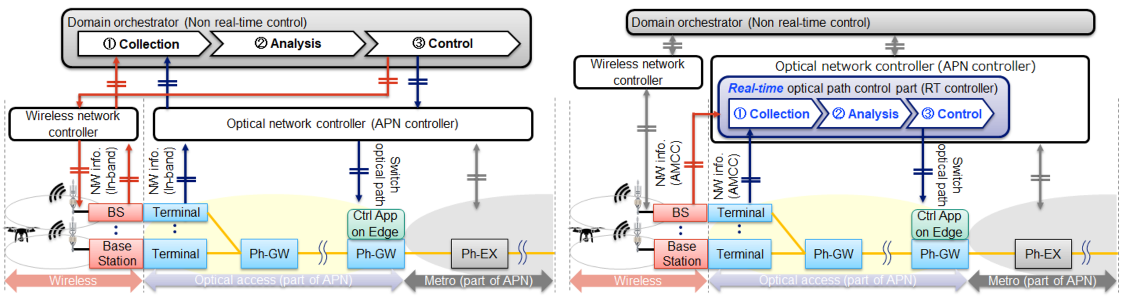
Real-time control is another requirement for future networks. Network quality varies with user mobility, congestion, etc. To guarantee optimal network performance, it is essential for network information to be acquired in real time and for the network to be controlled quickly and appropriately. Because the remote drone control requires a total processing time of within 10 ms for its real-time characteristics [1], fast and protocol independent telemetry is crucial.

The automatic switching of optical paths has been implemented for network protection [3,4]. However, they require a switching time of 50 ms. Moreover, the protection scheme is implemented in dedicated hardware to meet the fast path recovery requirement. There is no room to consider complex situations and select the control policy. Meanwhile, network control technologies based on telemetry have been also studied [5-8]. They have shown to be useful for analysing various network situations. However, they are in-band based and do not focus on path flexibility or processing time.

In this paper, we propose a system with a real-time optical path control scheme aimed at the realization of the remote drone control. We evaluated the feasibility of the system in terms of processing time for the first time. Then we analyse the gap between the requirement and result and discuss the gap with the requirement of the remote drone control.

Real-time optical path control scheme

Fig. 1 shows (a) a traditional network architecture and (b) our proposed architecture that integrates optical and wireless systems compared with. IOWN APN is utilized for the optical network. The control application for the remote drone is deployed on the network edge. For the wireless network, the coverage area of each cell in 5G/6G is small, so the connected cell will change as the drone moves. Both architectures collect and analyse the network quality information, and then control the network on the basis of the analysis results. The network quality information includes the latency of the optical and wireless networks, such as transport and scheduling latency. The quality information of the activated path is



(a) Traditional architecture (b) Proposed architecture with real-time optical path control scheme

Fig. 1: Architectures of, (a) traditional network and (b) proposed real-time optical path control scheme.

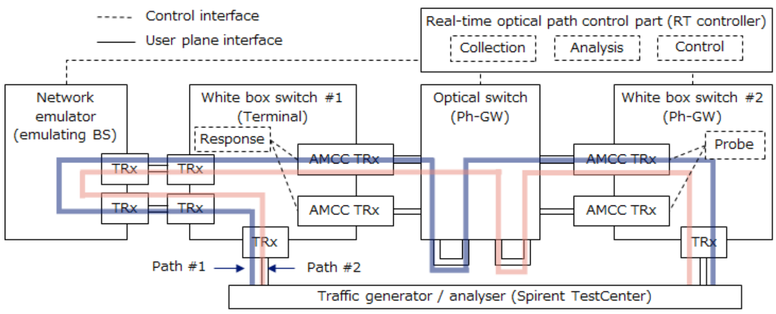


Fig. 2: Experimental setup for the feasibility study.

collected, as well as that of one or more backup paths and cells.

In the traditional architecture shown in Fig. 1 (a), a domain orchestrator plays a role of network control and gives directions to an optical network controller and a wireless network controller. This architecture is not suitable for real-time control as the collection is done by two hops and the analysis covers the whole network including metro/core. However, it is enough only to cover wireless and optical access as the control area because the control application for the remote drone is deployed on the network edge.

With the proposed architecture shown in Fig. 1 (b), we add a Real-Time (RT) optical path control part (RT controller) to the APN controller. The RT controller collects network quality information from APN as well as from base stations directly, not through the wireless network controller. Auxiliary Management and Control Channel (AMCC) [9] is used as a telemetry method that is independent of user-plane protocol. In the proposed architecture, wireless and optical access are covered as the control areas for the real-time optical path control part. The controller should be an open model (rather than vendor native model) for cost-effectiveness and flexibility. However, an open model raises the concern of control speed. In this paper, we prioritize open model implementation over control speed, and we use OpenConfig, a common data model. Each function in a real-time optical control part is implemented in the microservices architecture for flexibility.

One of the objectives of our proposed system is to only allocate the optical path/wavelength dynamically to the cell which has active users (drones) on the basis of the user mobility. This makes it possible to build a low-cost network as equipment is not required to support an enormous number of wavelengths. However, the feasibility of the proposed system needs to be studied to determine whether it can perform within 10ms, which is the required processing time.

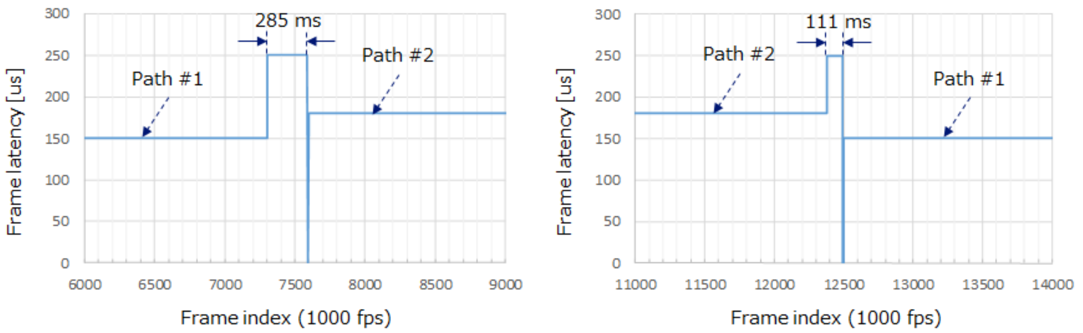
Experimental setup of real-time controller

To confirm the feasibility of our proposed system, we conducted an experimental study of processing times for collection, analysis and control in the RT controller, which is based on commercial and open-source products. Fig. 2 shows the experimental setup.

The RT controller is implemented on a Fujitsu PRIMERGY RX 1330 M4 with Xeon E-2286G CPU, 16GB x 2 RAMs and 960GB x 2 SSDs. Inventec D6254QS is used for white box switches, one to simulate terminals and the other to simulate a part of a Ph-GW. Here, the Ph-GW is an optical node equipped with an optical switch to support various optical functions [10]. The Polatis series 6000 8x8 is used for optical switches. We used one switch to simulate two logical switches by hard splitting port groups. For the transceivers between white box switches, AMCC transceivers by MEL Telecom are used. An XGEM 10 Gigabit Ethernet Multi-Profile Emulator by Anue systems is used for network emulator, which simulates the latency variation in wireless. Two paths are assumed, one is an activated path and the other is a backup, by changing cross connect of the optical switch and the latency value in the network emulator. Spirent TestCenter is used as a traffic generator/analyser to measure the latency of the activated path. The measurement traffic is sent at 1000 fps in a clockwise direction from the traffic generator.

The collection, analysis, and control functions of the RT controller are implemented as Docker containers based on Kubernetes 1.21.1 with Java 1.8 over CentOS 7.9.

The white box switches utilize a probe and response function using AMCC to measure the latency between white box switches for the both activated and the backup paths. The probe function sends a probe signal to the response function. The response function returns the response signal as soon as receiving the probe signal. When receiving the response signal, the probe function calculates the latency as the round trip time from when the probe signal is sent to when the response signal is received. The probe



(1) Path switching to path #2 (180 ms latency) after latency of path #1 increased (150 ms → 250 ms).
(2) Path switching to path #1 (150 ms latency) after latency of path #2 increased (180 ms → 250 ms).

Fig. 3: Evaluation results, which show frame index v.s. frame latency. Frame rate is 1000 frames per sec.

signal is sent from the probe function to the response function every 1800 ms due to the limitation of AMCC transceivers. As soon as the latency is measured, it is reported to the RT controller. The probe and response function are also used to simulate the information collection from a base station through the terminal. In other words, the information on wireless latency variation is reflected in the controller when it receives the report from the white box switch, though the value is directly collected from the network emulator to the controller.

The analysis function in the RT controller is implemented with a simple algorithm. It calculates the latency of the activated path as the sum of the latency between white box switches and the latency of the network emulator. Then, the calculated latency is evaluated whether to exceed a pre-configured threshold. When the latency exceeds the threshold, the function calculates another path that satisfies the threshold. In this study, it is assumed that the backup path always satisfies the threshold. The analysis is performed every 100ms, which is set to be sufficiently larger than the expected processing time.

Finally, the control function is implemented in two steps. First, the function creates an OpenConfig data model as a common data model after the analysis function chooses to switch the optical path. Then the OpenConfig data model is converted to a vendor-specific model and sent to the optical switch.

Performance evaluation and discussion

For the evaluation procedures, we first set the initial condition, and then increase the latency of activated path to exceed the threshold. In the experiment, the threshold is set as 200 ms, while the latency of the activated path is increased to 250 ms from 150 or 180 ms by changing the latency value for the path of the network emulator.

Fig. 3 shows the measured latency per frame index. We determined that the path automatically switched to the new one after the latency of the original path increased.

Tab. 1: Detailed processing time within RT controller. The processing time of Control function is dominant.

Function		Ave. proc. time
Collection		2.152 ms
Analysis		0.214 ms
Control	Create Open-Config data model	11.774 ms
	Convert to vendor-specific model	5.527 ms

Tab. 1 shows the detailed processing times of the RT controller. We determined that the total of the average processing time of collection, analysis, and control functions were within 20 ms. The collection and analysis functions performed sufficiently faster than 10 ms. On the other hand, the processing time of the control function is longer, and needs to be improved by one digit.

The time to switch paths from latency increased varies in Fig.3 because of the periodic processing of the collection and analysis. In other words, it is due to the performance limitation of the AMCC transceivers, which is not an essential part of the proposed system.

From the above results, we found that the proposal can perform the real-time control around 20 ms. To realize remote drone control use case, the processing of the control function needs to be accelerated by one digit.

Conclusions

We have proposed a real-time optical path control scheme that performs collection, analysis, and control in a network controller with protocol-independent telemetry to ensure stringent requirement of low-latency services such as remote drone control. After the evaluation, we determined that the collection and analysis can be performed in a single-digit ms, which is fast enough, while the control needs to be improved to realize the remote drone control.

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