Centralized ultra-precision service control system for providing ultra-precision services in large-scale deterministic networks

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***Abstract*— In the future, it is necessary to provide ultra-precision services that can provide immersive feeling without distance restrictions, such as ultra-realistic interactive services such as AR/VR/XR and high-precision services such as remote control of drones and robots. However, the current technology is difficult to provide remote ultra-precision services through an internet-scale wide area network. In order to provide an ultra-precision services, an in-time packet forwarding method and an on-time packet forwarding method must be provided as time-determined packet forwarding types. Therefore, this paper proposes a centralized ultra-precision service control system that can provide in-time packet forwarding method and on-time packet forwarding method in a large-scale deterministic network to provide ultra-precision services.**

***Keywords*— ultra-precision service, in-time packet, on-time packet, , large-scale deterministic network, service control system**

I. INTRODUCTION

In the future, it is necessary to provide ultra-precision services that can provide immersive feeling without distance restrictions, such as ultra-realistic interactive services such as AR/VR/XR and high-precision services such as remote control of drones and robots. However, the current technology is only to the extent that 5G ultra-low latency service is provided only in the wireless access section centered on mobile edge computing (MEC) service, and it is difficult to provide remote ultra-low latency service through an internet-scale wide area network. In order to achieve the goal of providing an ultra-low latency service, research on a highly reliable ultra-low latency network with limited latency and low jitter is being conducted on the network infrastructure. The IEEE standardization organization focuses on the TSN (Time Sensitive Networking) standard, and the IETF standardization organization focuses on the DetNet (Deterministic Networking) standard. Since TSN is limited to Layer 2, network scalability is small, but standards adopted for specific use cases are specified, so the standardization stage is mature, whereas DetNet is expandable to Layer 3 or higher, so network scalability is large but standards are currently in the development stage [1]. So, for a large-scale ultra-low-latency end-to-end service in a remote location, the network infrastructure must support time-determined services such as DetNet service. In order to provide an ultra-precision service, an in-time packet forwarding method and an on-time packet forwarding method must be provided as time-determined packet forwarding types. The in-time packet forwarding method is a method in which packets must be delivered as quickly as possible in a way that guarantees within the maximum latency requirements of ultra-precision services. The on-time packet forwarding method is a method in which packets must be delivered at a desired time in a way that guarantees within the latency variation (jitter) requirements of ultra-precision services.

Therefore, this paper proposes a centralized ultra-precision service control system that can provide in-time packet forwarding method and on-time packet forwarding method in a large-scale deterministic network to provide ultra-precision services.

II. RELATED WORKS

The DetNet architecture can be applied to campus networks and private WANs, including large-scale ISPs such as 5G networks. In order to provide ultra-realistic/high-precision services to large-scale ISP networks, it is essential to apply DetNet. The demand for ultra-low latency exists in both L2/L3 networks and small/large-scale networks, and providing DetNet services in large-scale networks is a new challenge. To solve this challenge, the IETF DetNet working group is proposing a new method for latency deterministic forwarding through a large-scale network called LDN (Large-scale Deterministic Network) [2]. In addition, in order to provide ultra-realistic/high-precision remote control service, a standardization study on DetNet segment routing IPv6 technology (DetNet SRv6) has been proposed by the IETF DetNet working group [3].

III. ULTRA-PRECISION SERVICE PROVISION SCENARIO

Figure 1 shows a reference model of a centralized ultra-precision service control system supporting ultra-precision services. In order to provide the ultra-precision service, the centralized ultra-precision service control system is composed of a network node, an ultra-precision service control system, an ultra-precision service terminal, and an ultra-precision service application server. The network node forwards in-time packets and on-time packets. The ultra-precision service control system centrally controls in-time and on-time packet delivery information so that network nodes can deliver according to in-time and on-time packet characteristics. The ultra-precision service terminal requests the start of the ultra-precision service, and the ultra-precision service application server provides the ultra-precision service.

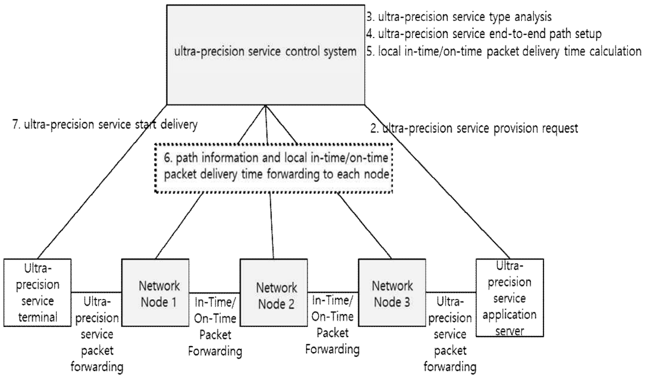

Figure 1. Reference model of centralized ultra-precision service control system

The ultra-precision service control system collects node and link information from each node before providing the ultra-precision service and stores it in the ultra-precision service control information repository. Then, when the ultra-precision service control system receives the ultra-precision service start request from the ultra-precision service terminal, it requests the ultra-precision service provision request to the ultra-precision service application server. When the ultra-precision service control system receives a response from the ultra-precision service application server, it analyzes the type of the ultra-precision service received from the ultra-precision service terminal. In addition, the ultra-precision service control system establishes an end-to-end path composed of network nodes passing from the ultra-precision service terminal to the ultra-precision service application server for the delivery of the corresponding ultra-precision service packet.

In the case of an in-time service, a local in-time packet delivery time is calculated, and in the case of an on-time service, a local on-time packet delivery time is calculated according to the type of the received ultra-precision service. Then, the ultra-precision service control system delivers the established path information and local in-time packet delivery time or local on-time packet delivery time to each network node. When the ultra-precision service control system transmits the start of the ultra-precision service to the ultra-precision service terminal, the ultra-precision service terminal delivers the ultra-precision service packet to the network node. The network node that has received the ultra-precision service packet delivers the in-time packet or the on-time packet to the next connected network node according to the type of the ultra-precision service. Then, the network node connected to the ultra-precision service application server converts the in-time packet or the on-time packet into an ultra-precision service packet and delivers the converted ultra-precision service packet to the ultra-precision service application server. Therefore, in a large-scale deterministic network, the ultra-precision service control system tightly coupled with the network nodes can stably provide ultra-precision services of the in-time packet delivery method and the on-time packet delivery method.

IV. CENTRALIZED ULTRA-PRECISION SERVICE CONTROL SYSTEM

As shown in Figure 2, the centralized ultra-precision service control system is composed of the ultra-precision service control system and network nodes. The ultra-precision service control system consists of a network node topology processing function, an ultra-precision service control information repository, an ultra-precision service control function, an ultra-precision service path setting function, an in-time packet delivery time processing function, and an on-time packet delivery time processing function. Network node consists of an ultra-precision service control agent function.

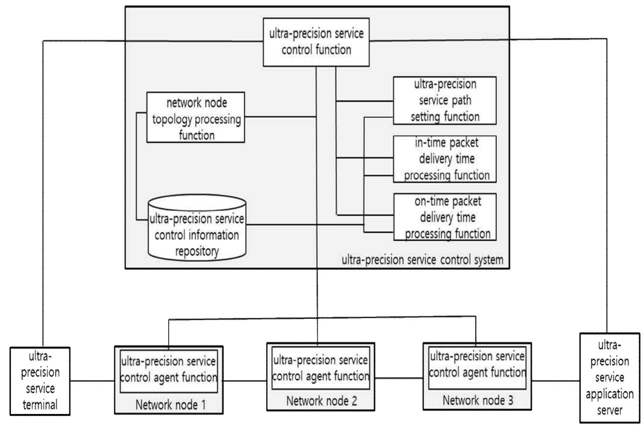

Figure 2. Architecture of centralized ultra-precision service control system

The network node topology processing function collects node information and link information with adjacently connected nodes from the ultra-precision service control agent function of each network node. In addition, the network node topology processing function configures ultra-precision service network topology information based on the collected node and link information, and stores the configured ultra-precision service network topology information to the ultra-precision service control information repository.

The ultra-precision service control function, upon receiving a request to start the ultra-precision service from the ultra-precision service terminal, makes a request to provide the ultra-precision service to the ultra-precision service application server and analyzes the received ultra-precision service type. And when the analyzed ultra-precision service is an in-time service, the ultra-precision service control function requests the ultra-precision service path setting function to set up an end-to-end network path and get the set path information for in-time service packet delivery. In addition, the ultra-precision service control function transfers the in-time time received from the ultra-precision service terminal to the in-time packet delivery time processing function to obtain the local in-time packet delivery time of each network node. Then, the ultra-precision service control function transmits the set in-time packet forwarding path information and the local in-time packet forwarding time to the ultra-precision service control agent function in each network node. On the other hand, if the analyzed ultra-precision service is an on-time service, the ultra-precision service control function requests the ultra-precision service path setting function to set the end-to-end network path and get the set path information for on-time service packet delivery. In addition, the ultra-precision service control function delivers the on-time time and allowable delay variation time received from the ultra-precision service terminal to the on-time packet delivery time processing function to obtain the local on-time packet delivery time of each network node. Then, the ultra-precision service control function delivers the set on-time packet forwarding path information and the local on-time packet forwarding time to the ultra-precision service control agent function in each network node. The ultra-precision service path setting function uses the topology information of the network node stored in the ultra-precision service control information repository to establish an in-time packet forwarding path or an on-time packet forwarding path from the ultra-precision service terminal to the ultra-precision service application server. Then, the ultra-precision service path setting function provides the set in-time packet forwarding path or the on-time packet forwarding path to the ultra-precision service control function, and stores the set in-time packet forwarding path and the on-time packet forwarding path in the ultra-precision service control information repository.

The in-time packet delivery time processing function subtracts the delay time required for nodes and links from the in-time time desired by the ultra-precision service when receiving the in-time time desired for the ultra-precision service and the set in-time packet delivery path from the ultra-precision service control function. This subtracted difference value becomes the total allowable delay time of the set in-time packet delivery path. Then, this total allowable delay time is divided by the number of network nodes included in the in-time packet forwarding path to obtain the allowable delay time at each node. By summing the obtained allowable delay time and the delay time of each node itself, the local in-time packet delivery time of each node is obtained. The in-time packet delivery time processing function provides the obtained local in-time packet delivery time of each node to the ultra-precision service control function and stores it in the ultra-precision service control information repository.

The on-time packet delivery time processing function subtracts the delay time required for nodes and links from the on-time time desired by the ultra-precision service when receiving the desired on-time time, the allowable delay variation time for the ultra-precision service and the set on-time packet delivery path from the ultra-precision service control function. This subtracted difference is the total buffering delay time of the on-time packet delivery path. Then, this total buffering delay time is divided by the number of network nodes included in the on-time packet forwarding path to obtain the local buffering delay time at each node. And the allowable delay variation time of the received ultra-precision service is divided by the number of nodes included in the on-time packet forwarding path to obtain the local allowable delay variation time at each node. Then, the local buffering delay time of each node, the local allowable delay variation time, and the delay time of each node are summed to obtain the local on-time packet delivery time of each node. The on-time packet delivery time processing function provides the obtained local on-time packet delivery time of each node to the ultra-precision service control function and stores it in the ultra-precision service control information repository.

The ultra-precision service control information repository stores network node topology information, ultra-precision service (in-time service and on-time service) path information, in-time packet delivery time information of each network node, and on-time packet delivery time information of each network node. The ultra-precision service control agent function transmits its own node and link information and information of neighboring nodes to the network node topology processing function. In addition, the ultra-precision service control agent function receives the ultra-precision service (in-time service and on-time service) path information from the ultra-precision service control function and sets the corresponding path in its own node. In addition, the ultra-precision service control agent function delivers the in-time and on-time packets to the connected sub-network nodes according to the received in-time packet delivery time and on-time packet delivery time.

V. CONCLUSION

In this paper, we proposed a centralized ultra-precision service control system that can deliver ultra-precision service packets such as in-time packet and on-time packet to a large-scale deterministic network. The centralized ultra-precision service control system provides an ultra-precision service control system that is tightly coupled with the network node that delivers the ultra-precision service packet. So, the ultra-precision service control system can provide the in-time type service and the on-time type service, which are characteristics of the ultra-precision service, in an optimal way, thereby increasing the efficiency of providing the ultra-precision service. Therefore, it is expected that the centralized ultra-precision service control system will provide an ultra-precision network infrastructure environment that supports immersion feeling without distance restrictions, such as ultra-realistic interactive services such as AR/VR/XR, and high-precision services such as remote control of drones and robots.

ACKNOWLEDGMENT

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