Technology Reports

MBH SR-MPLS TI-LFA

SR-based Routers in 5G MBH

Radio Access Network Development Department Yoshio Igaue Takumi Harada
Yuki Matsuda Hiroaki Ogawa

In the 5G era, mobile networks have new requirements in addition to the conventional ones. It is becoming increasingly difficult for the MBH to meet the requirements for more efficient network construction and operation, higher reliability, large-capacity networks to meet the increased traffic in the 5G era, and for networks that can flexibly support a variety of services (low latency, guaranteed bandwidth, etc.) using only the connection method conventionally adopted for the MBH. Therefore, the MBH urgently needs further upgrades. As one solution, NTT DOCOMO has been considering a network design with a new connection method using SR technology. This article provides an overview of the newly commercially introduced SR-based router and its elemental SR technology.

1. Introduction

On a mobile network, the section connecting base stations and the core node*1 is called the "Mobile BackHaul" (MBH). The MBH needs to efficiently connect the base stations installed over wide areas to expand the areas available to users to the core node. Although the conventional MBH has had network design for excellent efficiency in traffic accommodation and reliability in case of device failure, with the coming of the 5th Generation mobile communications systems (5G) era, the MBH will require new design to cope with increased traffic and achieve 5G requirements for high speed and large

*1 Core node: A node such as an exchange or subscriber information management unit.

capacity (eMBB: enhanced Mobile BroadBand), low latency (URLLC: Ultra Reliable and Low Latency Communications), and massive terminal connectivity (mMTC: massive Machine Type Communications). To efficiently accommodate base stations in the MBH for these new requirements, it is assumed that issues below will be difficult to address with the equipment for the Ethernet method [1] that NTT DOCOMO has been operating so far.

(1) Providing a high-capacity network to meet the increased traffic in the 5G era (existing equipment has a maximum of 10GbE (Gigabit Ethernet))
(2) Improving efficiency of network construction/operation and further enhancing network reliability
(3) Realizing routing to flexibly respond to various Service Level Agreements (SLAs)*2 (low latency/bandwidth guarantees, etc.)

To solve issue (1), it is necessary to expand the interfaces of the equipment itself. Therefore, we considered expanding the physical interfaces of the equipment from the current maximum of 10G to over 100G. To deal with issue (2), we considered the support for the Segment Routing (SR) method. To solve both issues (1) and (2), we introduced a new MBH system using SR-based routers. To solve issue (3), we are also considering how to achieve routing that satisfies SLAs suitable for various services across the entire mobile network and to improve the efficiency of the network and operations by collaborating with the SR controller*3.

This article introduces an overview of SR-based router commercially deployed since 2020, the network configuration of an Access Router Network (hereinafter referred to as an "ARN"), which is a new MBH using SR-based routers, a functional overview and advantages of SR, which is the elemental technology that comprises an ARN, and the fault detection functions of the equipment. Finally, the article describes the future functional enhancement of the MBH.

2. Devices Comprising an ARN and Network Design

2.1 ARN Overview

An ARN consists of two types of Network Elements (NEs)*4, one called an "Area aGgregation Router" (AGR), the other called an "Area aCcess Router" (ACR), and an NE Operation System (NE-OpS)*5 which is responsible for monitoring, controlling, and configuring the NEs. An overview of an ARN configuration is shown in **Figure 1**.

We can install multiple line cards*6 with 100GbE and 10GbE or 1GbE physical interfaces in AGRs/ACRs, and construct facilities to guarantee transmission capacity according to the required bandwidth for the network using a Link Aggregation Group (LAG)*7 (**Table 1**).

ACRs are located near base stations and are responsible for aggregating multiple base station areas and their communications, and connecting them to AGRs. When ACRs connect to AGRs, the network topology is not only the star*8 type, but also enables ACRs to connect directly to neighboring ACRs without going through AGRs, which avoids the need to construct long-distance transmission lines through buildings. This reduces the cost of transmission lines and enables the network topology to be flexibly and easily expanded when

*2 SLA: A guarantee of the quality of a provided service.
*3 Controller: A device responsible for controlling NEs (see *4).
*4 NE: A generic term for equipment that makes up a network.
*5 NE-OpS: A general term for a system that monitors and controls NEs.
*6 Line card: A module installed in a chassis-type router device, on which physical interfaces are installed.
*7 LAG: A function that treats multiple physical circuits as a single virtual circuit.
*8 Star topology: A type of network topology. A network structure in which multiple communication devices are connected to a central communication node.

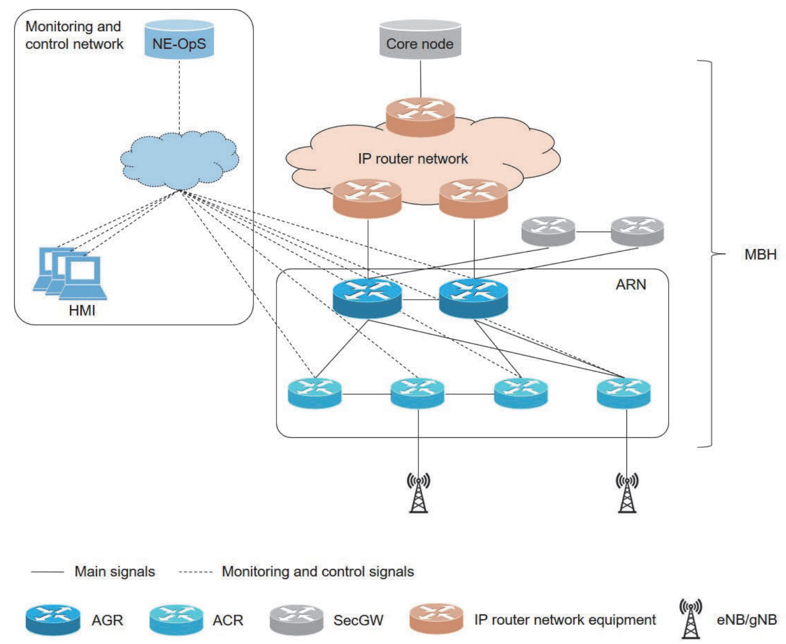
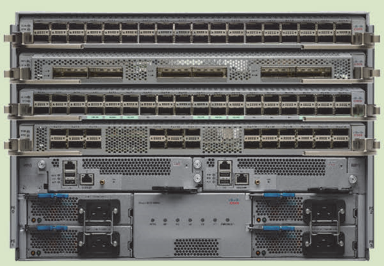
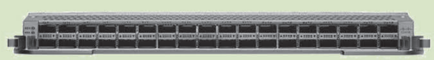


Figure 1　ARN configuration

Table 1　ARN equipment

	AGR	ACR
Chassis		
Line card (100G module)		

incorporating new ACRs. Also, when connecting to AGRs, by making physical lines redundant as necessary, we can construct a reliable network.

AGRs are routers that aggregate communications from the base stations constructed in each area and connect them to the IP router network [2]. Since high reliability is required, these routers are made redundant as network topology, which allows communications to continue without affecting services even if a router fails. As well as aggregating communications, they also connect to Security GateWay (SecGW)*9 for encrypting communications in the backhaul section and the monitoring and control network.

A NE-OpS is connected to NEs via a monitoring and control network, which allows remote monitoring, control and configuration of all NEs.

2.2 ARN Characteristics

1) Flexibly Designable According to Various User and System Requirements

On an ARN, by applying Virtual Private Networks (VPNs)*10 to system units such as cellular systems including 5G, and wireless LAN systems, various services can be accommodated on the same physical network. This allows optimization of routing, Quality of Service (QoS)*11, security and latency for each user, and also ensures operational independence among users.

2) Route Aggregation

In a cellular system, a huge amount of routing information is distributed between an ARN and the IP router network, which is the upper layer network. Therefore, AGRs, which are the connection devices to the upper layer network, aggregate the routing information and broadcasts it to the upper layer (IP router network) to reduce the amount of routing information entered into the routing table maintained by AGRs and the IP router network. This reduces the load when resetting the routing table, learning the routing information again and entering it into the routing table with increased routing information on the entire network and thus enables stable network operations when a failure occurs.

3) Shaping*12

Since the base stations connected to an ARN cannot guarantee enough bandwidth (there are many cases using 1GbE connection when connecting a base station and an ARN), the shaping target downlink traffic coming from the IP router network is flagged at the AGRs, which are the entrances to the ARN, and shaping is applied to the flagged traffic at the ACRs, which are the exits from the ARN, to adjust the transmission bandwidth according to the transmission path. Even for narrow-band sections, this makes it possible to reduce congestion*13 and its resulting packet loss by reducing the traffic load in the ARN.

4) micro-Bidirectional Forwarding Detection (micro-BFD) and Border Gateway Protocol-Prefix Independent Convergence (BGP-PIC) Functions

In the event of network failure, in addition to redundant routers as described above, an ARN can be configured using technologies such as micro-BFD and BGP-PIC, described below, to quickly complete the process from failure detection to rerouting.

(a) micro-BFD

The AGR to AGR links, AGR to ACR links, and AGR to IP router network links are connected with multiple 100GbE interfaces for line redundancy, and are operated as one logical interface by applying a LAG. This function sends and receives keepalive packets at a high frequency on each physical interface that constitutes the LAG, which enables fast rerouting by detecting failures promptly.

(b) BGP-PIC

Since there are tens of thousands of routes

---

*9 SecGW: A communication device that terminates encrypted communication to/from a base station

*10 VPN: A virtual network logically structured for each service.

*11 QoS: A quality specification on a network for controlling the bandwidth used, the amount of latency and the discard rate, etc.

*12 Shaping: A type of bandwidth limitation method. A technology that buffers and transmits data when the data volume exceeds the threshold set in the device.

*13 Congestion: Impediments to communications services due to communications requests being concentrated in a short period of time and exceeding the processing capabilities of the service control server.

broadcasted in a cellular system, it takes seconds to find a backup route (lookup) in the event of a failure. BGP-PIC improves the calculation efficiency of the backup route lookup, and the time lag between failure detection and rerouting can be shortened.

2.3 Operation and Maintenance of an ARN

The NE-OpS manages, monitors, controls and configures the NEs. The system achieves efficient maintenance and operations through centralized management of ACRs and AGRs located in many locations. Communications between NE-OpS and NEs is via the ARN. As mentioned, the design minimizes the impact on operations even if a failure occurs in the ARN, and the network configuration has little impact on management and monitoring of the NEs (ACRs/AGRs), so that maintenance and operations can be continued even if a failure occurs.

3. SR Functions

This chapter provides an overview of the main SR functions operating on an ARN.

3.1 SR Overview

In general, router devices determine the next-hop router based on the destination IP address of the packets. In case of SR, the next-hop is determined with "segment". This architecture enables simpler and more flexible control than the conventional Multi-Protocol Label Switching (MPLS)*14-based forwarding. While there are several types of segment, an ARN mainly uses the Interior Gateway Protocol (IGP) – Prefix Segment and IGP-Adjacency Segment. An overview of the SR forwarding operation is shown in **Figure 2**.

1) Prefix-SID (IGP-Prefix Segment ID)

Prefix-SID is a unique value on the SR domain and is used for basic forwarding control. The Prefix-SID corresponding to the IGP-Prefix (e.g., loopback address*15) used for a single node is called the "Node (IGP-Node Segment) - SID". SR-based routers can use it to uniquely designate a node in a domain.

2) Adj (IGP-Adjacency Segment) - SID

This is a unique value within each SR router, is assigned to each link to neighboring IGP nodes, and is used in special forwarding control. An SR node forwards packets with its own Adj-SID through the corresponding link, without any IP shortest-path consideration.

3.2 SR Characteristics

An ARN uses the SR-MPLS, which applies SR to the MPLS data plane*16 and has the following features.

1) Data Plane

In SR-MPLS the conventional MPLS data plane can be used as it is. The segment is also represented by encoding the SID in the Label field of the MPLS header.

2) Control Plane*17

The following three options are available to implement SR control plane.

- Distributed, in which the segments are allocated and signaled only by extended routing protocols (such as Open Shortest Path First (OSPF)*18). This method does not require label distribution-specific protocols (Label

*14 MPLS: A packet forwarding technology that uses labels instead of IP addresses.

*15 Loopback address: An IP address assigned to a node to indicate the node itself.

*16 Data plane: A routing table and its logic used by routers to forward traffic.

*17 Control plane: A routing protocol used by routers to control traffic forwarding.

*18 OSPF: A protocol that allows routers to select routes based on adjacent connection information.

*19 LDP: A kind of label exchange protocol. Label information exchange enables the establishment of a session between NEs.

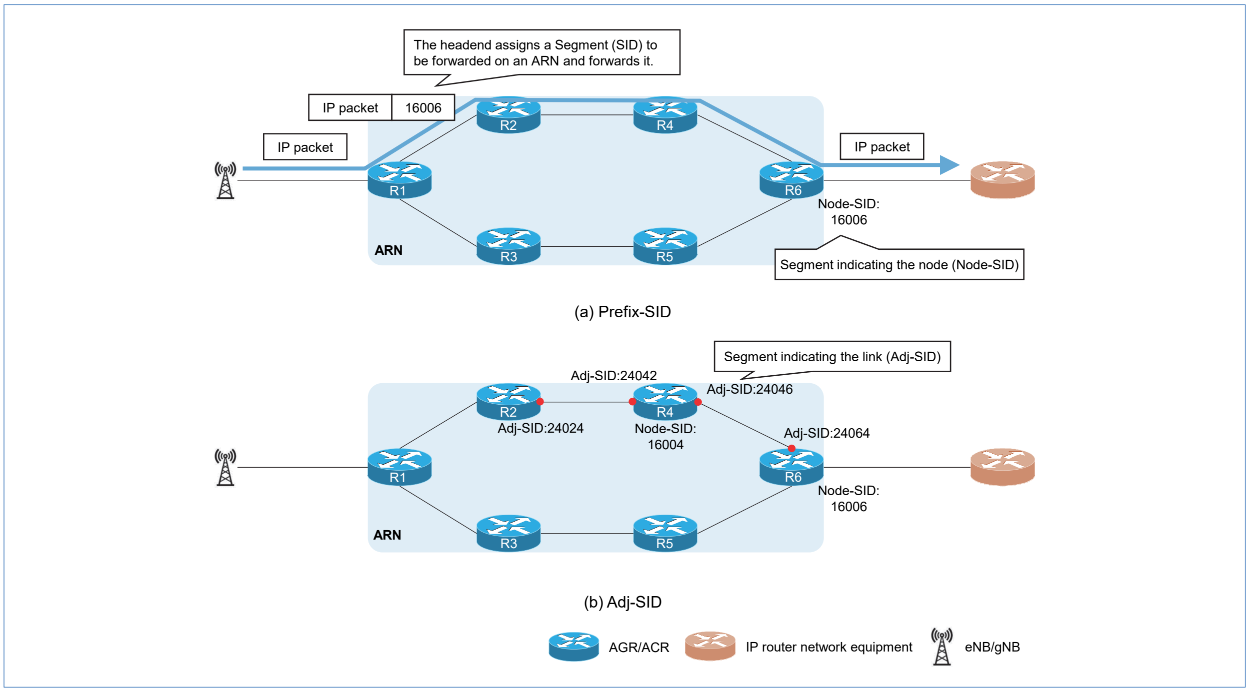


Figure 2 Overview of SR transfer operation

Distribution Protocol (LDP)*19 or Resource reSerVation Protocol (RSVP)*20), making it simpler than conventional MPLS (OSPF uses this method in an ARN).

- Centralized, in which the segments are allocated and instantiated by the SR controller.
- Hybrid, which is based on the distributed control plane with the SR controller

3) Source Routing

An ingress SR node can steer a packet through an SR-policy*21 instantiated as an order list of instructions. A transit SR node determines the next-hop following the SR-policy. In addition, the architecture is highly compatible with a Software Defined Network (SDN)*22 (enabling easy centralized control with a controller) and can provide optimized routing operations for each user, such as low latency and guaranteed bandwidth.

4) Fast Failover

Since an ARN deals with the C-Plane*23 of cellular communications and voice services, it requires a high level of availability. An ARN must be designed to minimize packet loss with quick rerouting in the event of any failure. As shown in **Figure 3**, in conventional MPLS, there is a concern that, depending on the topology, a packet rerouted once may end up heading toward a failure point again, resulting in a loop (Fig. 3(b)). However, in SR-MPLS, loops can be avoided by strictly specifying the forwarding backup route using the MPLS label stack (Fig. 3(c), (d)). This is called "Topology Independent Loop Free Alternate" (TI-LFA), and is a function that enables fast rerouting for failures on the IGP (OSPF) network. Conventional IP fast reroute such as LFA and remote LFA (rLFA) cannot install

*20 RSVP: A protocol to secure necessary QoS for services such as data requiring real-time communication by reserving in advance end-to-end bandwidth on an IP network.

*21 SR-policy: A policy that specifies a forwarding route on an SR network.

*22 SDN: Software control of the configuration and operation of devices comprising a network.

*23 C-Plane: A protocol for transferring control signals for establishing and disconnecting cellular communications.

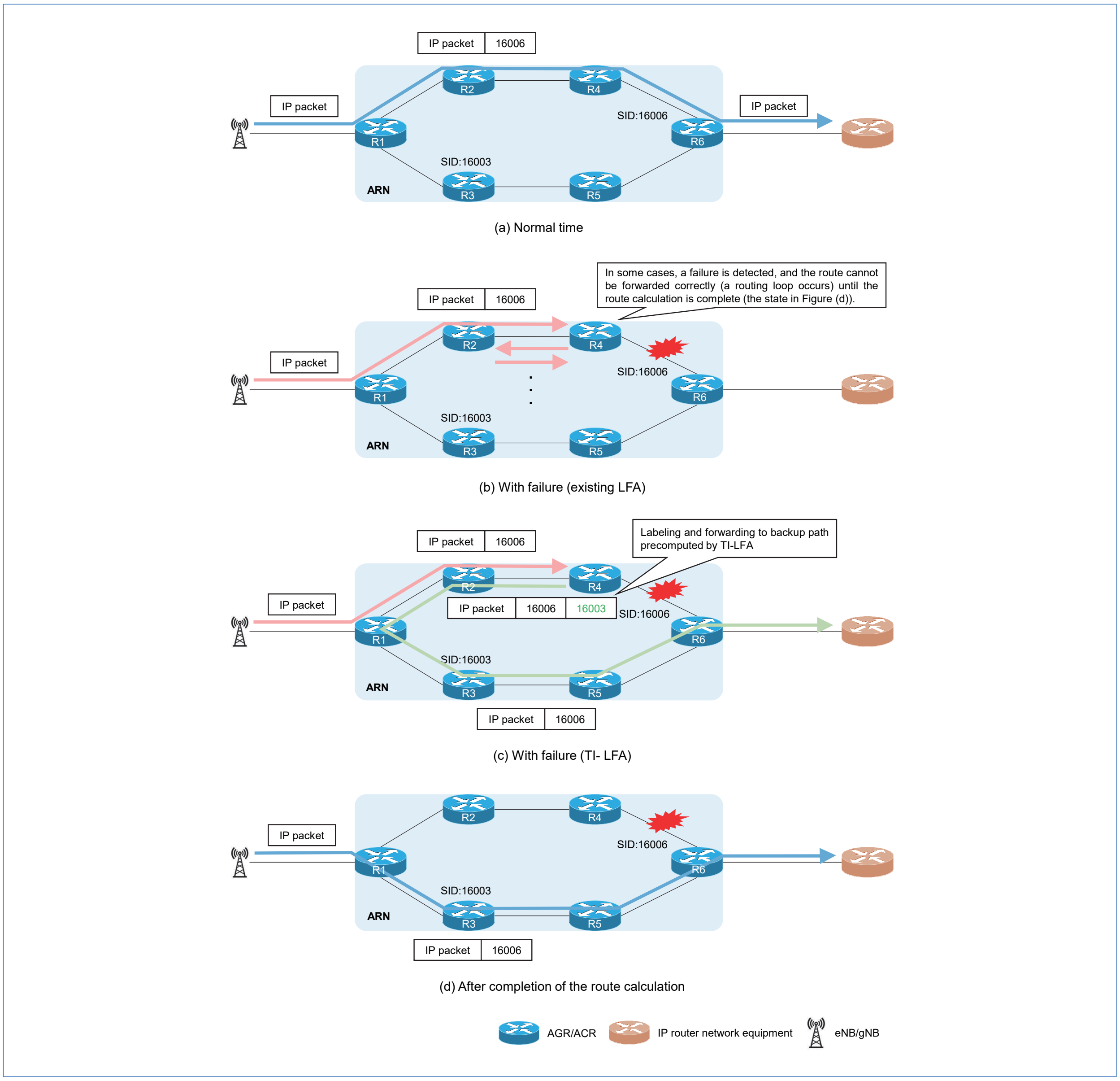


Figure 3　Summary of failure actions and TI-LFA actions on the ARN

a loop-free reroute depending on the topology.

5) Operation And Maintenance (OAM)*24 Functions

SR-based routers have several OAM functions.

First of all, as basic OAM functions, ping*25 and traceroute*26 can be used to check reachability to neighboring nodes within an IGP network.

Next, Virtual Routing and Forwarding (VRF)-ping/traceroute can be used to check the reachability and forwarding route to any destination on the VPN. The destination does not have to be on the ARN, and the function can also be used to

*24 OAM: Functions for maintenance and operational management on a network.

*25 Ping: A command to check the reachability of a node on an IP-network.

*26 Traceroute: A command to check the network route to a node on an IP-network.

check the reachability to base stations and core nodes.

In addition, MPLS-Ping can be used to check reachability of an IGP network, etc. on the MPLS data plane. This is used to check for special issues such as failure to exchange SID information.

One of the features of SR-based routers is Data Plane Monitoring (DPM), a function that detects silent failures*27. As shown in **Figure 4**, DPM enables periodic checking of the liveness of the network.

4. Evolution of the MBH in the 5G era

4.1 Overview of SR-TE

Applying SR technology to Traffic Engineering (TE), which can explicitly specify routes in an ARN, makes it possible to achieve even more flexible routing to meet each service requirement. Similarly, in the MBH, SR-TE can provide highly detailed network control to meet the various needs of users. On the mobile network, communications from user mobile phones to the core node are the target of SR-TE in our network.

With the launch of 5G services, a variety of requirements with lower latency, higher capacity, and more simultaneous connections to many devices than ever before must be accommodated. We require even more flexible network design that considers the characteristics of each network providing these services.

An overview of SR-TE is shown in **Figure 5**. In SR-TE, the route of packet forwarding is determined by source routing as described in Chapter 3 so

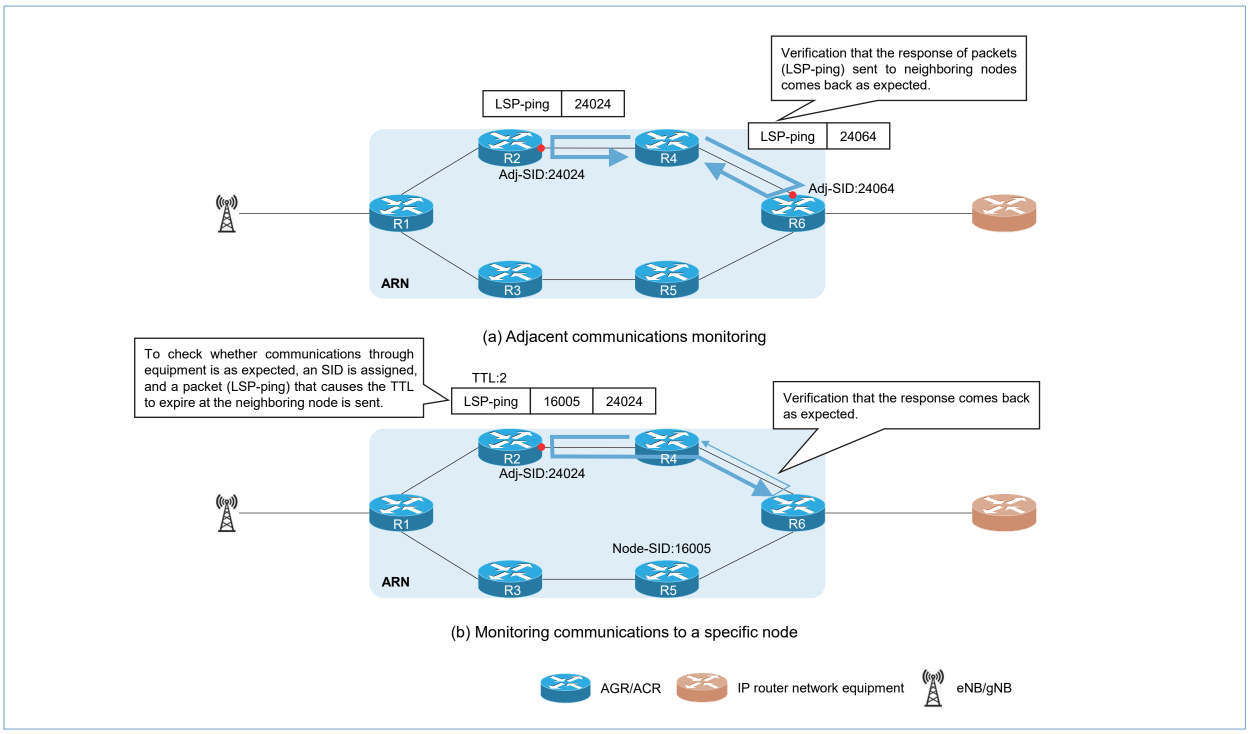


Figure 4 Overview of DPM operations

*27 **Silent failure:** A failure that cannot be detected by NE-OpS.

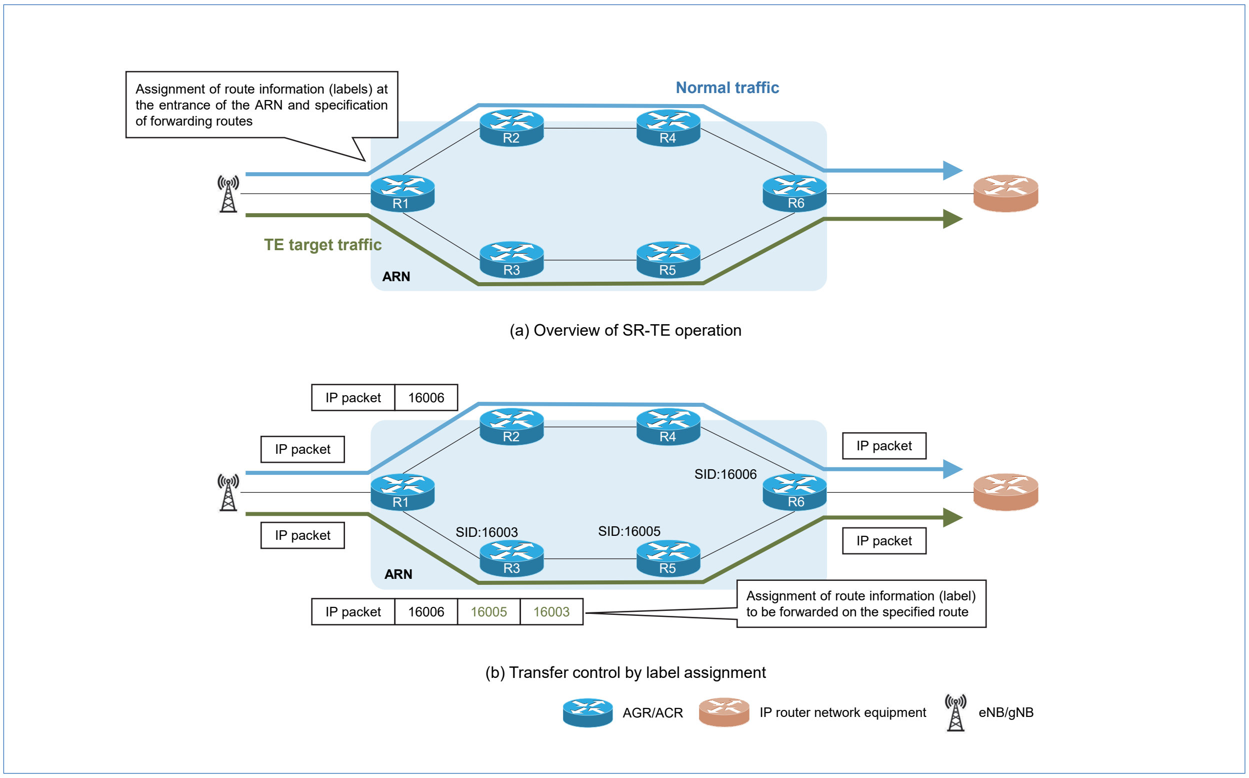


Figure 5　Overview of SR-TE control

that the route through the MBH can be explicitly specified at the entrance to an ARN. When packets flow into the MBH, route of packet forwarding is specified using the identifiers assigned to each service, making it possible to operate routes as logically separate networks. For example, IP addresses, port numbers, and Differentiated Services Code Point (DSCP) values*28 can be used as identifiers to sort services, and control methods can be tailored to the nodes to be connected.

For example, when providing low latency services, it is possible to calculate the forwarding path using the amount of delay between nodes and set the shortest path, which is the result of the calculation, to each piece of network equipment. It is possible to construct the MBH more flexibly than in the past by using routes determined by route calculation using path cost*29 such as OSPF and routes determined by route calculation using the amount of delay.

4.2 Towards the Realization of Network Slicing in E2E

Designing the network through the SR controller will make it possible to optimize routes not only for the MBH but also for other networks connected to the MBH, which holds promise for the realization of End-to-End (E2E) flexible routing. Slicing in E2E is expected to provide users with networks that are even more in line with the requirements of each service unit.

The network topology through the SR controller

*28 DSCP value: A value indicating priority level when controlling the priority of packets.

*29 Path cost: The accumulated distance (weighting) on the path to the destination.

is shown in **Figure 6**. Since the SR-based router alone cannot collect the network configuration information other than the ARN, it is necessary to obtain the network configuration via the other controller for the destination network. Path computation is not performed only by the routers on the ARN section and the SR controller for the ARN, but also in cooperation with the other network controller, sharing other network configuration information necessary for routing and performing path computation.

Coordinating between each controller and configuring each router under each controller in this way makes it possible to apply a consistent routing policy in E2E and configure logical networks to meet various service requirements. In this case, the SR-based router will realize routing in cooperation with the controller, making it possible to provide flexible network design for a variety of services and requirements.

5. Conclusion

This article has described an overview of the SR-based router to support the 5G era, its network configurations, and MBH evolution that will be realized in the future.

As discussed, the introduction of the SR-based router enables a significant increase in network capacity and efficient network bandwidth utilization, and also increases network reliability in the event of failures due to fast failover and improved failure detection.

Going forward, we will continue to consider the enhancement of functions to flexibly support a wide variety of 5G services through linkage with

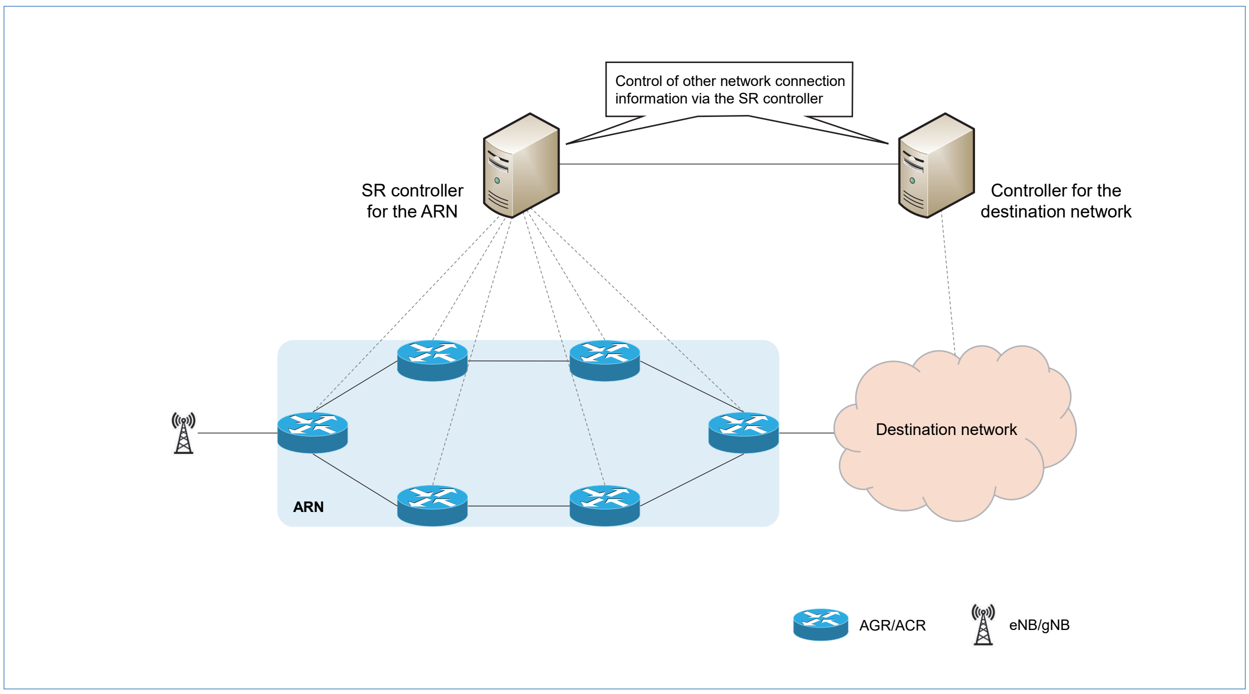


Figure 6　Network topology through the SR controller

the SR controller.

REFERENCES

[1] K. Morita, et al.: "Ethernet Transmission Equipment ERP-SW for All-IP Transmission Paths," NTT DOCOMO Technical Journal, Vol.12, No.3, pp.56–60, Dec. 2010.

[2] K. Osaki, et al.: "Configuration Technology for "IP Router Network" – Overview of L2/L3 Integrated VPN Backbone –," NTT DOCOMO Technical Journal, Vol.12, No.1, pp.57–63, Apr. 2004 (In Japanese).