

PACKET FORWARDING METHOD, APPARATUS, NETWORK DEVICE AND STORAGE MEDIUM

Technical field

5 The present disclosure relates to the technical field of communication, in particular to a packet forwarding method and an packet forwarding apparatus, a network device and a storage medium.

Background

10 Internet Protocol Version 6 Segment Routing Traffic Engineering Policy (SRv6 TE Policy) is a new tunnel drainage technology developed on the basis of Internet Protocol Version 6 Segment Routing (SRV6) technology. With this tunnel drainage technology, a service packet can be directed to an appropriate SRv6 TE Policy, and then be forwarded by using a forwarding path in the SRv6 TE Policy.

15 In order to enhance the reliability of forwarding paths, a controller will deploy multiple candidate paths on a source node at the same time, and when all the primary candidate paths with high preference are unavailable, switching to the standby candidate paths with low preference can be performed.

Summary

20 In view of this, the present disclosure provides a packet forwarding method and an packet forwarding apparatus, a network device and a storage medium, in order to obtain the minimum available bandwidths of nodes on a forwarding path in time. The specific technical solutions are as follows.

 In a first aspect, an example of the present disclosure provides a packet forwarding method applied to a first node, including:

25 acquiring a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and

all previous-hop nodes of the first node;

sending the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

5 In a possible implementation, when the first node is a source node, acquiring the first packet includes:

receiving a second packet;

acquiring a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

10 carrying the first bandwidth into the first IPv6 option header, and encapsulating the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

In a possible implementation, when the first node is an intermediate node, acquiring the first packet includes:

15 receiving a third packet, wherein the third packet includes a second IPv6 option header, and the second IPv6 option header includes a second bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the first node;

20 if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintaining the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, updating the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

25 In a possible implementation, the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate

node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

In a possible implementation, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

- 5 In a possible implementation, the second packet is a data packet or an active performance measurement packet.

In the second aspect, an example of the present disclosure provides a packet forwarding method applied to a second node, including:

- 10 receiving a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6 forwarding path;

- 15 reporting a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

In a possible implementation, a data packet is encapsulated in an inner layer of the first packet; reporting the third bandwidth includes:

- 20 if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among the minimum available bandwidths of all nodes in the SRv6 forwarding path, reporting the third bandwidth to a controller; or,

- 25 if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, sending an IP packet including the third bandwidth to a source node.

In a possible implementation, an active performance measurement packet is encapsulated in an inner layer of the first packet; reporting the third bandwidth includes:

5 sending a response packet for the active performance measurement packet to a source node, wherein the response packet includes a TLV structure which is used to carry the third bandwidth.

10 In a possible implementation, the active performance measurement packet is a STAMP packet, and the TLV structure includes STAMP TLV Flags, a Type field, a Length field and a minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags include a U flag with a value of 1.

In a possible implementation, the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

15 the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

In a possible implementation, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

20 In a third aspect, an example of the present disclosure provides an packet forwarding apparatus applied to a first node, including:

an acquiring module, to acquire a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node;

25

a sending module, to send the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes

in the SRv6 forwarding path.

In a possible implementation, when the first node is a source node, the acquiring module is specifically to:

receive a second packet;

5 acquire a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

carry the first bandwidth into the first IPv6 option header, and encapsulate the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

10 In a possible implementation, when the first node is an intermediate node, the acquiring module is specifically to:

receive a third packet, wherein the third packet includes a second IPv6 option header, and the second IPv6 option header includes a second bandwidth which is a minimum value among minimum available bandwidths of all the previous-hop nodes
15 of the first node;

if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintain the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, update the second bandwidth to the minimum available bandwidth of the
20 first node to obtain the first packet.

In a possible implementation, the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate
25 node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

In a possible implementation, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and

the minimum available bandwidth field is used to carry the first bandwidth.

In a possible implementation, the second packet is a data packet or an active performance measurement packet.

In a fourth aspect, an example of the present disclosure provides an packet
5 forwarding apparatus applied to a second node, including:

a receiving module, to receive a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6
10 forwarding path;

a reporting module, to report a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

In a possible implementation, a data packet is encapsulated in an inner layer of
15 the first packet; the reporting module is specifically to:

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, report the third bandwidth to a
20 controller; or,

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, send an IP packet including the
25 third bandwidth to a source node.

In a possible implementation, an active performance measurement packet is encapsulated in an inner layer of the first packet; the reporting module is specifically to:

send a response packet for the active performance measurement packet to a source node, wherein the response packet includes a TLV structure which is used to carry the third bandwidth.

5 In a possible implementation, the active performance measurement packet is a STAMP packet, and the TLV structure includes STAMP TLV Flags, a Type field, a Length field and a minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags include a U flag with a value of 1.

10 In a possible implementation, the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

15 In a possible implementation, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

In a fifth aspect, an example of the present disclosure provides a network device, which is applied to a first node, the network device including:

20 a processor;
a transceiver;

a machine-readable storage medium having stored therein machine-executable instructions that can be executed by the processor, wherein the machine-executable instructions cause the processor to:

25 acquire a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node;

send the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

In a possible implementation, when the first node is a source node, the
5 machine-executable instructions further cause the processor to:

receive a second packet;

acquire a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

10 carry the first bandwidth into the first IPv6 option header, and encapsulate the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

In a possible implementation, when the first node is an intermediate node, the machine-executable instructions further cause the processor to:

15 receive a third packet, wherein the third packet includes a second IPv6 option header, and the second IPv6 option header includes a second bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the first node;

if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintain the second bandwidth to obtain the first packet;

20 if the second bandwidth is greater than the minimum available bandwidth of the first node, update the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

In a possible implementation, the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all
25 the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

In a possible implementation, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

5 In a possible implementation, the second packet is a data packet or an active performance measurement packet.

In a sixth aspect, an example of the present disclosure provides a network device, which is applied to a second node, the network device including:

a processor;

a transceiver;

10 a machine-readable storage medium having stored therein machine-executable instructions that can be executed by the processor, wherein the machine-executable instructions cause the processor to:

receive a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value
15 among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6 forwarding path; and

report a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

20 In a possible implementation, a data packet is encapsulated in an inner layer of the first packet; the machine-executable instructions further cause the processor to:

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available
25 bandwidths of all nodes in the SRv6 forwarding path, report the third bandwidth to a controller; or,

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth

is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, send an IP packet including the third bandwidth to a source node.

5 In a possible implementation, an active performance measurement packet is encapsulated in an inner layer of the first packet; the machine-executable instructions further cause the processor to:

send a response packet for the active performance measurement packet to a source node, wherein the response packet includes a TLV structure which is used to carry the third bandwidth.

10 In a possible implementation, the active performance measurement packet is a STAMP packet, and the TLV structure includes STAMP TLV Flags, a Type field, a Length field and a minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags include a U flag with a value of 1.

15 In a possible implementation, the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

20 In a possible implementation, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

25 In a seventh aspect, an example of the present disclosure provides a machine-readable storage medium having stored therein machine-executable instructions which, when called and executed by a processor, cause the processor to carry out the method in the first aspect.

In an eighth aspect, an example of the present disclosure provides a computer program product containing instructions which, when run on a computer, cause the

computer to perform the method in the first aspect.

With the technical solutions, the first packet acquired by the first node includes the first IPv6 option header and the second packet, wherein the first IPv6 option header includes the first bandwidth, the first bandwidth is a minimum value among
5 minimum available bandwidths of nodes in the SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node. Further, the first packet is forwarded according to the SRv6 forwarding path, so that a tail node can know a minimum value among minimum available
10 bandwidths of all nodes in the SRv6 forwarding path, and thus can report the minimum value. In this way, the controller or the source node is allowed to acquire the minimum value among the minimum available bandwidths of all nodes in the SRv6 forwarding path in time. This minimum value can reflect the minimum available bandwidth of the SRv6 forwarding path, and further the problem of packet
15 loss caused by the inability to sense the minimum available bandwidth of the SRv6 forwarding path can be avoided.

Brief Description of the Drawings

The accompanying drawings described herein are used to provide a further understanding of the present disclosure and constitute a part of the present disclosure. The illustrative examples of the present disclosure and the descriptions thereof are
20 used to explain the present disclosure and do not constitute an improper limitation on the present disclosure.

Fig. 1 is an exemplary schematic diagram of a process for forwarding SRv6 packet provided by an example of the present disclosure;

Fig. 2 is a flowchart of a packet forwarding method provided by an example of
25 the present disclosure;

Fig. 3 is a schematic diagram of an IPv6 option header provided by an example of the present disclosure;

Fig. 4 is a flowchart of another packet forwarding method provided by an example of the present disclosure;

Fig. 5 is a schematic diagram of a TLV structure provided by an example of the present disclosure;

Fig. 6 is a schematic diagram of a multipath scene provided by an example of the present disclosure;

5 Fig. 7 is a schematic structural diagram of an packet forwarding apparatus provided by an example of the present disclosure;

Fig. 8 is a schematic structural diagram of another packet forwarding apparatus provided by an example of the present disclosure;

10 Fig. 9 is a schematic structural diagram of a network device provided by an example of the present disclosure;

Fig. 10 is a schematic structural diagram of another network device provided by an example of the present disclosure.

Detailed Description

15 In order to make the purpose, technical solutions and advantages of the present disclosure more clear and more understandable, the present disclosure will be further described in detail with reference to the accompanying drawings and examples. Obviously, the described examples are only some, and not all, of the examples of the present disclosure. All other examples acquired based on the examples in the present disclosure by those ordinary skilled in the art fall into the scope of protection of the present disclosure.

For the convenience of understanding, the related concepts involved in the examples of the present disclosure are explained.

1. Introduction to SRv6.

25 The development of cloud computing poses new challenges to wide area network, and requires changes in the traditional wide area network. As the core technology of reconstructing wide area network, software-defined networking in a wide area network (SD-WAN) accelerates network delivery, optimizes application experience, improves bandwidth utilization, simplifies network operation and maintenance by

means of automatic deployment, centralized control, intelligent scheduling and visualization and so on, thereby meeting the requirements of cloud computing for WAN. Intelligent scheduling is a key capability of the new generation WAN, which is very important for ensuring the application quality and optimizing the bandwidth resources. Existing traffic engineering technologies such as Multi-Protocol Label Switching (MPLS) and Resource Reservation Protocol-Traffic Engineering (RSVP-TE) can meet the requirements of applications for differentiated bandwidth guarantees. However, it has problems of multiple protocol types, complex deployment, difficulty in management and poor scalability, etc., which cannot meet the requirements of the new generation of WAN for dynamic deployment, flexible scheduling, fast and scalability, etc. Therefore, a new protocol of Segment Routing (SR) appears.

SR adopts the source node path selection mechanism, which encapsulates, in the source node, a Segment identifier (SID) of a segment to be passed by a forwarding path in advance. When a packet passes through a SR node, the SR node forwards the packet according the SID of the packet. Other nodes other than the source node do not need to maintain the path state.

Segment Routing IPv6 (SRv6) refers to the implementation of SR based on the IPv6 forwarding plane. The source node of SRv6 can insert a routing extension header, i.e., a Segment Routing Header (SRH), into an IPv6 packet, and add, in the SRH, SIDs of all segments to be passed through by the forwarding path, i.e., a SID list, , so as to explicitly specify the forwarding path of the IPv6 packet. SRv6 provides a flexible and efficient control means for SD-WAN, which is characterized by simple deployment and easy expansion, and allows to better schedule traffic and optimize path, to ensure the quality of key services, balance traffic distribution, improve the utilization rate of dedicated lines and reduce line costs.

Nodes in the SRv6 network are divided into the following roles according to different functions:

Source node: responsible for inserting a SRH into an IPv6 header of an IPv6 packet, or encapsulating the IPv6 header in the outer layer of packet and inserting a

SRH. The source node is used to direct the packet flow into a SRv6 path defined by a Segment List in SRH.

Transit node: located on the SRv6 path of the packet. The transit node does not participate in the SRv6 processing, and only performs an ordinary forwarding of the IPv6 packet. The transit node can be a node that supports SRv6 or a node that does not support SRv6.

Endpoint node: if an IPv6 destination address of the received SRv6 packet is a SRv6 SID configured on the Endpoint node, it will be processed according to instructions of the SRv6 SID and the SRH will be updated.

10 Tail node: the last Endpoint node of the SRv6 forwarding path.

The same node can play different roles in different SRv6 paths. For example, a node is a source node in a SRv6 path and can be a transit node or an Endpoint node in other SRv6 paths.

2. The process of forwarding the SRv6 packet.

15 As shown in Fig. 1, device A in Fig. 1 is a source node, device C and device E are Endpoint nodes, and device B and device D are transit nodes. The process of forwarding the SRv6 packet includes the following steps:

Step 1: After receiving an IPv6 packet, device A, as a source node, encapsulates the SRH and IPv6 header in the IPv6 packet, and then looks up a routing table according to a destination address in the encapsulated IPv6 header, so as to forward the encapsulated packet to device B.

Since a path from device A to device D needs to pass through two Endpoint nodes, namely device C and device E, SL in the SRH is 2-1, that is, SL=1, and the SID list encapsulated in the SRH includes Segment List [0]=E and Segment List [1] = C.

The source address in the IPv6 header is an address of device A, and the destination address in the IPv6 header is an address indicated by SL, that is, an address of Segment List [1] indicated by SL=1, that is, an address of device C.

Step 2: After receiving the packet, device B looks up the routing table according to the destination address in the IPv6 header and forwards the packet to device C.

Step 3: device C checks SL in the SRH. If $SL > 0$, a value of SL is subtracted by 1, and the destination address in the IPv6 header is updated to the address indicated by SL, that is, Segment List [0] corresponding to $SL=0$ which is an address of device E. Then device C looks up the routing table according to the destination address in the IPv6 header, and thus forwards the packet to device D.

Step 4: After receiving the packet, device D looks up the routing table according to the destination address in the IPv6 header and forwards the packet to device E.

Step 5: Device E, which is a tail node, receives the packet and checks the value of SL in the SRH. If $SL=0$, then device E decapsulates the packet, deletes the encapsulated IPv6 header and SRH, and forwards the packet according to the destination address of the original IPv6 packet.

In order to enhance the reliability of forwarding paths, the controller deploys multiple candidate paths on the source node in advance. The source node prioritizes forwarding traffic by the primary candidate paths with high preference, and when all the primary candidate paths with high preference are unavailable, the source node can switch traffic to the standby candidate paths with low preference.

The nodes in the forwarding path carry different services and have different forwarding capabilities. When the traffic is large, there may be traffic congestion on some nodes in the forwarding path, resulting in the actual maximum amount of traffic that can be forwarded by the forwarding path being less than the expected amount of traffic that can be forwarded by the forwarding path. When this happens, if the source node does not adjust the forwarding path in time, and still forwards the packet on the original forwarding path according to a preset bandwidth, the problem of packet loss due to insufficient bandwidth will be caused.

In order to solve this problem, it is necessary to obtain a minimum value among minimum available bandwidths of individual nodes in a current forwarding path, and

the minimum value can reflect the minimum available bandwidth of the current forwarding path. If the minimum available bandwidth of the current forwarding path is insufficient, the traffic can be switched to a forwarding path with sufficient bandwidth in time, to avoid packet loss.

5 However, at present, neither the controller nor the source node can obtain the minimum value among the minimum available bandwidths of individual nodes in the current forwarding path, and thus whether the minimum available bandwidth of the current forwarding path is insufficient can't be sensed, and further the paths can't be switched in time. Therefore, the problem of packet loss still exists.

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In order to solve the above problem, an example of the present disclosure provides a packet forwarding method applied to a first node, wherein the first node is a source node or an intermediate node in a SRv6 forwarding path. As shown in Fig. 2, the method includes:

15 S201. acquiring a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of nodes in the SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node.

20 Wherein, the SRv6 forwarding path is a forwarding path between the source node and the tail node in the SRv6 network, and the intermediate nodes in the SRv6 forwarding path can be transit nodes or endpoint nodes.

For example, in Fig. 1, the SRv6 forwarding path is a forwarding path composed of device A, device B, device C, device D and device E.

25 S202: sending the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

It can be understood that the minimum value among the minimum available

bandwidths of all the previous-hop nodes of the tail node (referred to as bandwidth A) is included in the first IPv6 option header of the packet received by the tail node. The tail node can compare the bandwidth A with a minimum available bandwidth of the tail node itself. If the minimum available bandwidth of the tail node itself is less than
5 the bandwidth A, the minimum available bandwidth of the tail node itself can be used as the minimum value among the minimum available bandwidths of all nodes in the SRv6 forwarding path; if the available bandwidth of the tail node itself is greater than or equal to the bandwidth A, the bandwidth A is still used as the minimum value among the minimum available bandwidths of all nodes in the SRv6 forwarding path.

10 With this method, the first packet acquired by the first node includes the first IPv6 option header and a second packet, wherein the first IPv6 option header includes the first bandwidth which is a bandwidth value among minimum available bandwidths of nodes in the SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node. Further, the first
15 packet is forwarded according to the SRv6 forwarding path, so that the tail node can know the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, and further can report the minimum value. In this way, the controller or the source node are allowed to acquire the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path in time. This
20 minimum value can reflect the minimum available bandwidth of the SRv6 forwarding path, and further the problem of packet loss caused by the inability to sense the minimum available bandwidth of the SRv6 forwarding path can be avoided.

It can be understood that, after the controller or the source node acquires the minimum value among minimum available bandwidths of all nodes in the SRv6
25 forwarding path, the minimum value can be used as the minimum available bandwidth of the SRv6 forwarding path. Further, when the minimum available bandwidth of the currently used SRv6 forwarding path is insufficient, path is switched in time, to avoid the problem of packet loss due to insufficient bandwidth.

In the path switching, besides the minimum available bandwidth, other factors,
30 such as transmission delay, etc., can be considered comprehensively to make the

decision, and the method for path switching is not limited in the example of the present disclosure.

In the example of the present disclosure, the first node may be a source node or an intermediate node, which are introduced respectively below.

5 When the first node is the source node, S201 of acquiring the first packet can be implemented as follows:

receiving a second packet; acquiring a first bandwidth, carrying the first bandwidth into the first IPv6 option header, and encapsulating the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

10 The first bandwidth is a minimum available bandwidth of an outgoing interface of the first node, and the outgoing interface is an outgoing interface of the first node on the SRv6 forwarding path.

The second packet is a data packet or an active performance measurement packet. As an example, the active performance measurement packet can be of a simple
15 two-way active measurement protocol (STAMP), a two-way active measurement protocol (TWAMP), etc.

It can be understood that the source node needs to encapsulate the IPv6 header and SRH in the second packet before forwarding the second packet by using the SRv6 network. In an example of the present disclosure, the first IPv6 option header for
20 carrying the first bandwidth is additionally encapsulated. The first IPv6 option header is located between the IPv6 header and the SRH. Since the source node is a first node in the SRv6 forwarding path, the first bandwidth encapsulated by the source node is the minimum available bandwidth of the outgoing interface of the source node. The SRH includes a SID list which includes the SID of each endpoint node through which
25 the SRv6 forwarding path passes.

With this method, when the source node adds a SRv6 encapsulation to the second packet, the first IPv6 option header for carrying the minimum available bandwidth is additionally encapsulated, so that after receiving the first packet, a node in the SRv6 forwarding path can update the minimum available bandwidth carried by the first

IPv6 option header according to a minimum available bandwidth of the node itself, which enables the tail node to acquire the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path. Further, the following source node or controller can refer to the minimum value when switching paths, so as to
5 avoid packet loss due to insufficient bandwidth.

When the first node is an intermediate node, S201 of acquiring the first packet can be implemented as follows:

receiving a third packet, wherein the third packet includes a second IPv6 option header, and the second IPv6 option header includes a second bandwidth which is a
10 minimum value among minimum available bandwidths of all previous-hop nodes of the first node;

if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintaining the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the
15 first node, updating the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

It can be understood that, the first node can compare the second bandwidth with a minimum available bandwidth of the first node itself after receiving the third packet.

If the second bandwidth is less than or equal to the minimum available
20 bandwidth of the first node, it means that the minimum value among the minimum available bandwidths has not changed. Therefore, the second bandwidth is maintained, that is, the second bandwidth is used as the first bandwidth to obtain the first packet.

If the second bandwidth is greater than the minimum available bandwidth of the first node, it means that the minimum value among the minimum available
25 bandwidths has changed. Therefore, the second bandwidth is updated to the minimum available bandwidth of the first node, that is, the minimum available bandwidth of the first node is used as the first bandwidth to obtain the first packet.

It can be understood that when the first node is an endpoint node, after receiving

the third packet, the first node further needs to update the destination address in the IPv6 header and the SL in the SRH, to obtain the first packet, and then continues to forward the first packet along the SRv6 forwarding path.

5 With this method, after receiving the third packet, the intermediate node in the SRv6 forwarding path can compare the second bandwidth carried in the third packet with a minimum available bandwidth of the intermediate node itself. If the second bandwidth is smaller than the minimum available bandwidth of the intermediate node itself, the second bandwidth is maintained; if the minimum available bandwidth of the intermediate node itself is smaller than the second bandwidth, the second bandwidth
10 in the third packet is updated to the minimum available bandwidth of the intermediate node itself. By comparing and updating the minimum available bandwidth of each intermediate node, the tail node can obtain the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path. Further, the following source node or controller can refer to the minimum value when switching paths, so as
15 to avoid packet loss due to insufficient bandwidth.

In this example, the minimum value among minimum available bandwidths of individual nodes passed through by the SRv6 forwarding path is encapsulated in the first IPv6 option header as an IPv6 option, and the IPv6 option can be referred to as Minimum Available Bandwidth Option.

20 The encapsulation position of the minimum available bandwidth option depends on measurement requirements. If the minimum value among minimum available bandwidths of all IPv6 nodes (including transit nodes and endpoint nodes) in the SRv6 forwarding path needs to be measured, the minimum available bandwidth option is encapsulated in a Hop-by-Hop Options header. In this case, the first IPv6
25 option header is a Hop-by-Hop Options header, and the intermediate node in the above example is an endpoint node or a transit node. Accordingly, the all previous-hop nodes include endpoint nodes and/or transit nodes. For example, for device B in Fig. 1, all previous-hop nodes of device B include only device A which is an endpoint node, that is, all previous-hop nodes of device B are endpoint nodes. For
30 another example, for device C in Fig. 1, all previous-hop nodes of device C include

device A which is an endpoint node and device B which is a transit node, that is, all previous-hop nodes of device C include an endpoint node and a transit node.

Alternatively, if the minimum available bandwidth of each segment (i.e., each endpoint node) in the SRv6 forwarding path needs to be measured, the minimum available bandwidth option is encapsulated in the Destination Options header. In this case, the first IPv6 option header is the Destination Options header, and the intermediate node in the above example is an endpoint node. Accordingly, all the previous-hop nodes are endpoint nodes. Since the Destination Options header is used to carry optional information that needs to be processed only by a node where the destination address of the packet is located, when the first packet is forwarded along the SRv6 forwarding path, the destination address in the IPv6 header can only be updated to the IP address of an endpoint node indicated in the SID list, and will not be updated to the IP address of a transit node. Therefore, only the endpoint node can identify the minimum available bandwidth option included in the Destination Options header, and compare and update the bandwidth value carried in the minimum available bandwidth option. In this case, the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path reported by the tail node refers to a minimum value among minimum available bandwidths of all endpoint nodes in the SRv6 forwarding path.

As shown in Fig. 3, the first IPv6 option header includes an Option Type field, an Option Data Length (Opt Data Len) field and a Minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

Each of the Option Type field and the option data length field occupies 1 byte, and the minimum available bandwidth field is an integer of 4 bytes.

Corresponding to the above method example, an example of the present disclosure further provides a packet forwarding method applied to a second node, wherein the second node may be a tail node in the SRv6 forwarding path. As shown in Fig. 4, and the method includes:

S401: receiving a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in the SRv6 forwarding
5 path.

The SRv6 forwarding path is a forwarding path between the source node and the tail node in the SRv6 network, and the tail node has received the first packet. Therefore, the first bandwidth is the minimum value among minimum available bandwidths of all nodes other than the tail node in the SRv6 forwarding path.

10 S402: reporting a third bandwidth, wherein the third bandwidth is a minimum available bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

When the minimum available bandwidth of the second node is less than or equal to the second bandwidth, the third bandwidth is the minimum available bandwidth of
15 the second node; when the minimum available bandwidth of the second node is greater than the first bandwidth, the third bandwidth is the first bandwidth.

It can be understood that the third bandwidth is the minimum value among minimum available bandwidths of all previous-hop nodes of the tail node. After receiving the first packet, the tail node acquires the first bandwidth from the first IPv6
20 option header before removing the SRv6 encapsulation, and then compares the first bandwidth with the minimum available bandwidth of the local link to determine the third bandwidth.

With this method, the first packet received by the second node includes the first IPv6 option header, and the first IPv6 option header includes the first bandwidth
25 which is the minimum value among minimum available bandwidths of all previous-hop nodes of the second node. Further, the second node takes the minimum bandwidth among the minimum available bandwidth of the second node itself and the first bandwidth as the third bandwidth, and reports the third bandwidth. In this way, the controller or the source node are allowed acquire the minimum value among

minimum available bandwidths of all nodes in the SRv6 forwarding path in time. This minimum value can reflect the minimum available bandwidth of the SRv6 forwarding path, and further the problem of packet loss caused by the inability to sense the minimum available bandwidth of the SRv6 forwarding path can be avoided.

5 It can be understood that, after the controller or the source node acquires the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, the minimum value can be used as the minimum available bandwidth of the SRv6 forwarding path. Further, when the minimum available bandwidth of the currently used SRv6 forwarding path is insufficient, the path is
10 switched in time, to avoid the problem of packet loss due to insufficient bandwidth.

In the example of the present disclosure, for the second node reporting the third bandwidth, specifically, there are the following three cases:

Case 1: if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third
15 bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, reporting the third bandwidth to the controller.

After the second node obtains the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, it will record the minimum
20 value locally. After the second node determines the third bandwidth, if the minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path has not been recorded locally at present, it can be determined that the third bandwidth is the firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path. In contrast, if the previously selected minimum
25 value among minimum available bandwidths of all nodes in the SRv6 forwarding path has been recorded locally, the third bandwidth is compared with the recorded minimum value. If the third bandwidth is different from the recorded minimum value, it means that the minimum value among the minimum available bandwidths has changed, and further the second node reports the third bandwidth. If the third
30 bandwidth is the same as the recorded minimum value, it means that the minimum

value among the minimum available bandwidths does not change, and the second node does not need to report the third bandwidth again, which can save transmission and processing overhead.

Case 2: if the third bandwidth is a firstly selected minimum value among
5 minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, sending an IP packet to a source node, wherein the IP packet includes the third bandwidth.

10 The IP packet is a packet with a user-defined format, and the format of the IP packet is not limited in the example of the present disclosure.

It should be noted that in cases 1 and 2, a data packet is encapsulated in the inner layer of the first packet, that is, the source node encapsulates the first IPv6 option header in the outer layer of the ordinary data packet, so that the tail node can obtain the minimum value among minimum available bandwidths of all nodes in the SRv6
15 forwarding path, and further report the third bandwidth to the controller or the source node according to the configuration.

Case 3: the active performance measurement packet0 is encapsulated in the inner layer of the first packet. In this case, the second node sends a response packet for the active performance measurement packet to the source node, and the response packet
20 includes a TLV structure which is used to carry the third bandwidth.

In one implementation, the active performance measurement packet is a STAMP packet. Accordingly, as shown in Fig. 5, the TLV structure includes STAMP TLV Flags, a Type field, a Length field and a Minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the
25 STAMP TLV Flags include a U flag with a value of 1. The U flag of 1 indicates that the TLV is an extended TLV that needs to be recognized by the counterpart.

The STAMP TLV Flags occupy 1 byte;

the Type field occupies 1 byte;

the Length field is used to indicate the length of content carried by the TLV structure, occupies 2 bytes, and has a value of 4;

the minimum available bandwidth field is an integer of 4 bytes.

5 In this example of the present disclosure, the tail node is used as a STAMP session reflector. Under the condition that the tail node supports a bandwidth measurement function, after the tail node obtains the minimum available bandwidth (i.e. the third bandwidth) of the SRv6 forwarding path, the minimum available bandwidth needs to be encapsulated in the TLV of the response packet, so that the minimum available bandwidth can be transmitted to the source node as reflected data.

10 In this way, the STAMP protocol can be used to measure the minimum available bandwidth of the SRv6 forwarding path. The tail node, as the session reflector, makes the STAMP TLV of the response packet carry the minimum available bandwidth by extending the STAMP TLV, such that the session sender (that is, the source node) obtains the minimum available bandwidth of the SRv6 forwarding path, so as to
15 switch paths in time when the minimum available bandwidth is insufficient and avoid packet loss due to insufficient bandwidth.

The following description is illustrated with specific examples. As shown in Fig. 6 which shows a SRv6 policy multipath scenario, for the service traffic from Node A to Node E, the controller issues two Candidate Paths (CPs) to the source node A,
20 namely CP1 and CP2.

CP1 is the primary candidate path, CP2 is the backup candidate path, and the preset bandwidths of segment list paths of CP1 and CP2 are both 100Mbps.

The SRv6 forwarding path on the source node A is configured as follows:

SRv6 policy POL1 (policy 1)

25 Candidate Path CP1 (candidate path 1)

Preference 200

Segment List 11 <SID-A,SID-B,SID-E>, Weight 1, 100Mbps

Segment List 12 <SID-A,SID-B,SID-D,SID-E>, Weight 1, 100Mbps

Candidate Path CP2

Preference 100

Segment List 21 <SID-A,SID-C,SID-F,SID-E>, Weight 1, 100Mbps

5 Segment List 22 <SID-A,SID-F,SID-E>, Weight 1, 100Mbps

That is, the preference of the candidate path 1 is 200, and the candidate path 1 includes two segment list paths. A weight of a path consisting of Node A, Node B and Node E is 1, and a bandwidth of the path is 100Mbps. A weight of a path consisting of Node A, Node B, Node D and Node E is 2 and a bandwidth of the path is 100Mbps.

10 The preference of the candidate path 2 is 100, and the candidate path 2 includes two segment list paths. A weight of a path consisting of Node A, Node C, Node F and Node E is 1, and a bandwidth of the path is 100Mbps. A weight of a path consisting of Node A, Node F and Node E is 1 and a bandwidth of the path is 100Mbps.

15 Under normal circumstances, the primary candidate path CP1 can forward traffic of 200 Mbps. When there is traffic congestion on CP1 and CP1 no longer meets the forwarding requirement, the source node A needs to switch the traffic to the standby candidate path CP2 in time. As an example, the forwarding requirement is that the bandwidth of the candidate path should be greater than 150Mbps.

20 For the switching requirement, the function of measuring the minimum available bandwidth can be enabled on the SRv6 forwarding path according to the method of the example of the present disclosure. If there is traffic congestion on node D, the bandwidth (that is, the minimum available bandwidth) that can be actually used by Node D to forward traffic drops below 50Mbps, for example, 43Mbps, and the minimum available bandwidths of other nodes are still 100Mbps. When receiving the
25 SRv6 packet, Node D will encapsulate a minimum available bandwidth of Node D itself in the IPv6 option header and forward the SRv6 packet to Node E. Node E can determine that the minimum value among minimum available bandwidths in a path consisting of Node A, Node B, Node D and Node E is 43Mbps, and feed back the

minimum value among the minimum available bandwidths to the source node A. The source node A can calculate that the minimum available bandwidth of the two segment list paths of CP1 at this time is 143Mbps, which is already less than 150Mbps specified in the forwarding requirement, and then can quickly switch the candidate path and switch the traffic flow to CP2 without congestion.

It can be seen that, with the example of the present disclosure, the actual minimum available bandwidth of the SRv6 forwarding path can be measured, and when the actual minimum available bandwidth of the SRv6 forwarding path does not meet the forwarding requirement, the controller or the source node can quickly sense that the actual minimum available bandwidth of the SRv6 forwarding path does not meet the forwarding requirement and select a new forwarding path for the traffic flow in time.

It should be noted that the above method for switching path is only an example. In actual implementation, the path can be switched by comprehensively considering the minimum available bandwidth of the SRv6 forwarding path and other factors, which is not limited by the example of the present disclosure.

Corresponding to the above method example, an example of the present disclosure also provides an packet forwarding apparatus applied to a first node. As shown in Fig. 7, the apparatus includes:

an acquiring module 701, to acquire a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node; and

a sending module 702, to send the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

Optionally, when the first node is a source node, the acquiring module 701 is

specifically to:

receive a second packet;

acquire a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

- 5 carry the first bandwidth into the first IPv6 option header, and encapsulate the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

Optionally, when the first node is an intermediate node, the acquiring module 701 is specifically to:

- 10 receive a third packet, wherein the third packet includes a second IPv6 option header, and the second IPv6 option header includes a second bandwidth which is a minimum value among minimum available bandwidths of all the previous-hop nodes of the first node;

- 15 if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintain the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, update the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

- 20 Optionally, the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes include the endpoint nodes and/or the transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

- 25 Optionally, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

Optionally, the second packet is a data packet or an active performance

measurement packet.

Corresponding to the above method example, an example of the present disclosure also provides a packet forwarding apparatus applied to a second node. As shown in Fig. 8, the apparatus includes:

5 a receiving module 801, to receive a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6 forwarding path; and

10 a reporting module 802, to report a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

Optionally, a data packet is encapsulated in an inner layer of the first packet; the reporting module 802 is specifically to:

15 if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, report the third bandwidth to a controller; or,

20 if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, send an IP packet including the third bandwidth to a source node.

25 Optionally, an active performance measurement packet is encapsulated in an inner layer of the first packet; the reporting module 802 is specifically to:

send a response packet for the active performance measurement packet to a source node, wherein the response packet includes a TLV structure which is used to

carry the third bandwidth.

Optionally, the active performance measurement packet is a STAMP packet, and the TLV structure includes STAMP TLV Flags, a Type field, a Length field and a minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags include a U flag with a value of 1.

Optionally, the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

Optionally, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

Corresponding to the above method example, an example of the present disclosure also provides a network device, which should be the first node. As shown in Fig. 9, the network device includes:

a processor 901;

a transceiver 904;

a machine-readable storage medium 902 having stored therein machine-executable instructions that can be executed by the processor 901; the machine-executable instructions cause the processor 901 to:

acquire a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path include the first node and all previous-hop nodes of the first node;

send the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6

forwarding path.

Optionally, when the first node is a source node, the machine-executable instructions further cause the processor 901 to:

receive a second packet;

5 acquire a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

carry the first bandwidth into the first IPv6 option header, and encapsulate the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

10 Optionally, when the first node is an intermediate node, the machine-executable instructions further cause the processor 901 to:

receive a third packet, wherein the third packet includes a second IPv6 option header, and the second IPv6 option header includes a second bandwidth which is a minimum value among minimum available bandwidths of all the previous-hop nodes
15 of the first node;

if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintain the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, update the second bandwidth to the minimum available bandwidth of the
20 first node to obtain the first packet.

Optionally, the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate
25 node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

Optionally, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum

available bandwidth field is used to carry the first bandwidth.

Optionally, the second packet is a data packet or an active performance measurement packet.

As shown in Fig. 9, a communication bus 903 may also be included in the network device. The processor 901, the machine-readable storage medium 902 and the transceiver 904 communicate with each other via the communication bus 903, which can be a Peripheral Component Interconnect (PCI) bus or an Extended Industry Standard Architecture (EISA) bus and the like. The communication bus 903 can be divided into an address bus, a data bus, a control bus and the like.

The transceiver 904 can be a wireless communication module. Under the control of the processor 901, the transceiver 904 performs data interaction with other devices.

The machine-readable storage medium 902 may include Random Access Memory (RAM), and may also include Non-Volatile Memory (NVM), such as at least one disk memory. In addition, the machine-readable storage medium 902 can also be at least one storage device located far away from the aforementioned processor.

The processor 901 may be a general-purpose processor, including a Central Processing Unit (CPU) and a Network Processor (NP) etc., and may also be a Digital Signal Processing (DSP), an Application Specific Integrated Circuit (ASIC), a Field-Programmable Gate Array (FPGA) or other programmable logic devices, discrete gate or transistor logic devices, and discrete hardware components.

Corresponding to the above method example, an example of the present disclosure also provides a network device, which is a second node. As shown in Fig. 10, the network device includes:

a processor 1001;

a transceiver 1004;

a machine-readable storage medium 1002 having stored therein machine-executable instructions that can be executed by the processor 1001; wherein

the machine-executable instructions cause the processor 1001 to:

receive a first packet, wherein the first packet includes a first IPv6 option header, and the first IPv6 option header includes a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node,
5 and all the previous-hop nodes are located in a SRv6 forwarding path; and

report a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

Optionally, a data packet is encapsulated in an inner layer of the first packet; the
10 machine-executable instructions further cause the processor 1001 to:

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path selected, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, report the third
15 bandwidth to a controller; or,

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, send an IP packet including the
20 third bandwidth to a source node.

Optionally, an active performance measurement packet is encapsulated in an inner layer of the first packet; the machine-executable instructions further cause the processor 1001 to:

send a response packet for the active performance measurement packet to a
25 source node, wherein the response packet includes a TLV structure which is used to carry the third bandwidth.

Optionally, the active performance measurement packet is a STAMP packet, and the TLV structure includes STAMP TLV Flags, a Type field, a Length field and a

minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags include a U flag with a value of 1.

Optionally, the first IPv6 option header is a Hop-by-Hop Options header, and all
5 the previous-hop nodes include endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

Optionally, the first IPv6 option header includes an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum
10 available bandwidth field is used to carry the first bandwidth.

In Fig. 10, a communication bus 1003 may also be included in the network device. The processor 1001, the machine-readable storage medium 1002 and the transceiver 1004 communicate with each other via the communication bus 1003, which can be a Peripheral Component Interconnect (PCI) bus or an Extended Industry
15 Standard Architecture (EISA) bus or the like. The communication bus 1003 can be divided into an address bus, a data bus, a control bus and the like.

The transceiver 1004 can be a wireless communication module, and the transceiver 1004 performs data interaction with other devices under the control of the processor 1001.

20 The machine-readable storage medium 1002 may include a Random Access Memory (RAM), and may also include a Non-Volatile Memory (NVM), such as at least one disk memory. In addition, the machine-readable storage medium 1002 can also be at least one storage device located away from the aforementioned processor.

The processor 1001 may be a general-purpose processor, including a Central
25 Processing Unit (CPU) and a Network Processor (NP), and may also be a Digital Signal Processing (DSP), an Application Specific Integrated Circuit (ASIC), a Field-Programmable Gate Array (FPGA) or other programmable logic devices, discrete gate or transistor logic devices, and discrete hardware components.

Based on the same inventive concept, according to the packet forwarding methods provided by the above examples of the present disclosure, an example of the present disclosure also provides a machine-readable storage medium having stored therein machine-executable instructions that can be executed by the processor. The processor is caused by machine-executable instructions to carry out the operations of any of the above packet forwarding methods.

In yet another example provided by the present disclosure, a computer program product containing instructions is also provided, which, when run on a computer, causes the computer to carry out operations of any packet forwarding method in the above examples.

It should be noted that in the present disclosure, relational terms such as first and second are only used to distinguish one entity or operation from another entity or operation, and do not necessarily require or imply that there is any such actual relationship or order between these entities or operations. Moreover, the terms “including”, “comprising” or any other variation thereof are intended to cover non-exclusive inclusion, so that a process, method, article or device including a series of elements includes not only those elements, but also other elements not explicitly listed or elements inherent to such process, method, article or device. Without further restrictions, an element defined by the phrase “including one” does not exclude the existence of other identical elements in the process, method, article or device including the element.

The above descriptions are only the preferred examples of the present disclosure, and are not used to limit the present disclosure. Any modification, equivalent replacement, improvement, etc. made within the spirit and principle of the present disclosure should be included within the scope of protection of the present disclosure.

CLAIMS

What is claimed is:

1. A packet forwarding method applied to a first node, comprising:

5 acquiring a first packet, wherein the first packet comprises a first IPv6 option header, and the first IPv6 option header comprises a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path comprise the first node and all previous-hop nodes of the first node;

10 sending the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

2. The method according to claim 1, wherein when the first node is a source node, acquiring the first packet comprises:

receiving a second packet;

15 acquiring a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

carrying the first bandwidth into the first IPv6 option header, and encapsulating the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

20 3. The method according to claim 1, wherein when the first node is an intermediate node, acquiring the first packet comprises:

receiving a third packet, wherein the third packet comprises a second IPv6 option header, and the second IPv6 option header comprises a second bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of
25 the first node;

if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintaining the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, updating the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

4. The method according to claim 3, wherein,

5 the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes comprise endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

10 5. The method according to any one of claims 1 to 4, wherein the first IPv6 option header comprises an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

15 6. The method according to claim 2, wherein the second packet is a data packet or an active performance measurement packet.

7. A packet forwarding method applied to a second node, comprising:

receiving a first packet, wherein the first packet comprises a first IPv6 option header, and the first IPv6 option header comprises a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6 forwarding path;

reporting a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

25 8. The method according to claim 7, wherein a data packet is encapsulated in an inner layer of the first packet; reporting the third bandwidth comprises:

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth

is different from a previously selected minimum value among the minimum available bandwidths of all nodes in the SRv6 forwarding path, reporting the third bandwidth to a controller; or,

5 if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, sending an IP packet comprising the third bandwidth to a source node.

10 9. The method according to claim 7, wherein an active performance measurement packet is encapsulated in an inner layer of the first packet; reporting the third bandwidth comprises:

sending a response packet for the active performance measurement packet to a source node, wherein the response packet comprises a TLV structure which is used to carry the third bandwidth.

15 10. The method according to claim 9, wherein the active performance measurement packet is a STAMP packet, and the TLV structure comprises STAMP TLV Flags, a Type field, a Length field and a minimum available bandwidth field, wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags comprise a U flag with a value of 1.

20 11. The method according to any one of claims 7-10, wherein,

the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes comprise endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

25 12. The method according to claim 11, wherein the first IPv6 option header comprises an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

13. An packet forwarding apparatus applied to a first node, comprising:

an acquiring module, to acquire a first packet, wherein the first packet comprises a first IPv6 option header, and the first IPv6 option header comprises a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path comprise the first node and all previous-hop nodes of the first node;

a sending module, to send the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

10 14. The apparatus according to claim 13, wherein when the first node is a source node, the acquiring module is specifically to:

receive a second packet;

acquire a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

15 carry the first bandwidth into the first IPv6 option header, and encapsulate the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

15. The apparatus according to claim 13, wherein when the first node is an intermediate node, the acquiring module is specifically to:

20 receive a third packet, wherein the third packet comprises a second IPv6 option header, and the second IPv6 option header comprises a second bandwidth which is a minimum value among minimum available bandwidths of all the previous-hop nodes of the first node;

25 if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintain the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, update the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

16. The apparatus according to claim 15, wherein,

the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes comprise endpoint nodes and/or transit nodes; or,

5 the first IPv6 option header is a Destination Options header, the intermediate node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

17. The apparatus according to any one of claims 13 to 16, wherein the first IPv6 option header comprises an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is
10 used to carry the first bandwidth.

18. The apparatus according to claim 14, wherein the second packet is a data packet or an active performance measurement packet.

19. An packet forwarding apparatus applied to a second node, comprising:

15 a receiving module, to receive a first packet, wherein the first packet comprises a first IPv6 option header, and the first IPv6 option header comprises a first bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6 forwarding path;

20 a reporting module, to report a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

20. The apparatus according to claim 19, wherein a data packet is encapsulated in an inner layer of the first packet; the reporting module is specifically to:

25 if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, report the third bandwidth to a controller; or,

if the third bandwidth is a firstly selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth is different from a previously selected minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path, send an IP packet comprising
5 the third bandwidth to a source node.

21. The apparatus according to claim 19, wherein an active performance measurement packet is encapsulated in an inner layer of the first packet; the reporting module is specifically to:

send a response packet for the active performance measurement packet to a
10 source node, wherein the response packet comprises a TLV structure which is used to carry the third bandwidth.

22. The apparatus according to claim 21, wherein the active performance measurement packet is a STAMP packet, and the TLV structure comprises STAMP TLV Flags, a Type field, a Length field and a minimum available bandwidth field,
15 wherein the minimum available bandwidth field is used to carry the third bandwidth, and the STAMP TLV Flags comprise a U flag with a value of 1.

23. The apparatus according to any one of claims 19-22, wherein,

the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes comprise endpoint nodes and/or transit nodes; or,

20 the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

24. The apparatus according to claim 23, wherein the first IPv6 option header comprises an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first
25 bandwidth.

25. A network device which is applied to a first node, the network device comprising:

a processor;

a transceiver;

a machine-readable storage medium having stored therein machine-executable instructions that can be executed by the processor, wherein the machine-executable instructions cause the processor to:

5 acquire a first packet, wherein the first packet comprises a first IPv6 option header, and the first IPv6 option header comprises a first bandwidth which is a minimum value among minimum available bandwidths of nodes in an SRv6 forwarding path, and the nodes in the SRv6 forwarding path comprise the first node and all previous-hop nodes of the first node;

10 send the first packet on the SRv6 forwarding path, so that a tail node reports a minimum value among minimum available bandwidths of all nodes in the SRv6 forwarding path.

26. The network device according to claim 25, wherein when the first node is a source node, the machine-executable instructions further cause the processor to:

15 receive a second packet;

acquire a first bandwidth, wherein the first bandwidth is a minimum available bandwidth of an outgoing interface of the first node;

20 carry the first bandwidth into the first IPv6 option header, and encapsulate the first IPv6 option header in an outer layer of the second packet to obtain the first packet.

27. The network device according to claim 25, wherein when the first node is an intermediate node, the machine-executable instructions further cause the processor to:

25 receive a third packet, wherein the third packet comprises a second IPv6 option header, and the second IPv6 option header comprises a second bandwidth which is a minimum value among minimum available bandwidths of all previous-hop nodes of the first node;

if the second bandwidth is less than or equal to a minimum available bandwidth of the first node, maintain the second bandwidth to obtain the first packet;

if the second bandwidth is greater than the minimum available bandwidth of the first node, update the second bandwidth to the minimum available bandwidth of the first node to obtain the first packet.

28. The network device according to claim 27, wherein,

5 the first IPv6 option header is a Hop-by-Hop Options header, the intermediate node is an endpoint node or a transit node, and all the previous-hop nodes comprise endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, the intermediate node is an endpoint node, and all the previous-hop nodes are endpoint nodes.

10 29. The network device according to any one of claims 25 to 28, wherein the first IPv6 option header comprises an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

15 30. The network device according to claim 26, wherein the second packet is a data packet or an active performance measurement packet.

31. A network device which is applied to a second node, the network device comprising:

a processor;

a transceiver;

20 a machine-readable storage medium having stored therein machine-executable instructions that can be executed by the processor, wherein the machine-executable instructions cause the processor to:

receive a first packet, wherein the first packet comprises a first IPv6 option header, and the first IPv6 option header comprises a first bandwidth which is a
25 minimum value among minimum available bandwidths of all previous-hop nodes of the second node, and all the previous-hop nodes are located in a SRv6 forwarding path;

report a third bandwidth, wherein the third bandwidth is a minimum bandwidth among the first bandwidth and a second bandwidth, and the second bandwidth is a minimum available bandwidth of the second node.

32. The network device according to claim 31, wherein a data packet is
5 encapsulated in an inner layer of the first packet; the machine-executable instructions further cause the processor to:

if the third bandwidth is a firstly selected minimum value among minimum
available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth
is different from a previously selected minimum value among minimum available
10 bandwidths of all nodes in the SRv6 forwarding path, report the third bandwidth to a
controller; or,

if the third bandwidth is a firstly selected minimum value among minimum
available bandwidths of all nodes in the SRv6 forwarding path, or the third bandwidth
is different from a previously selected minimum value among minimum available
15 bandwidths of all nodes in the SRv6 forwarding path, send an IP packet comprising
the third bandwidth to a source node.

33. The network device according to claim 31, wherein an active performance
measurement packet is encapsulated in an inner layer of the first packet; the
machine-executable instructions further cause the processor to:

20 send a response packet for the active performance measurement packet to a
source node, wherein the response packet comprises a TLV structure which is used to
carry the third bandwidth.

34. The network device according to claim 33, wherein the active performance
measurement packet is a STAMP packet, and the TLV structure comprises STAMP
25 TLV Flags, a Type field, a Length field and a minimum available bandwidth field,
wherein the minimum available bandwidth field is used to carry the third bandwidth,
and the STAMP TLV Flags comprise a U flag with a value of 1.

35. The network device according to any one of claims 31-34, wherein,

the first IPv6 option header is a Hop-by-Hop Options header, and all the previous-hop nodes comprise endpoint nodes and/or transit nodes; or,

the first IPv6 option header is a Destination Options header, and all the previous-hop nodes are endpoint nodes.

5 36. The network device according to claim 35, wherein the first IPv6 option header comprises an Option Type field, an option data length field and a minimum available bandwidth field, and the minimum available bandwidth field is used to carry the first bandwidth.

10 37. A machine-readable storage medium having stored therein machine-executable instructions which, when called and executed by a processor, cause the processor to carry out the method of any one of claims 1 to 12.

38. A computer program product, which causes a processor to carry out the method of any one of claims 1 to 12.