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(54) **Title:** METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR PRIORITY ROUTING OF DIAMETER MESSAGES

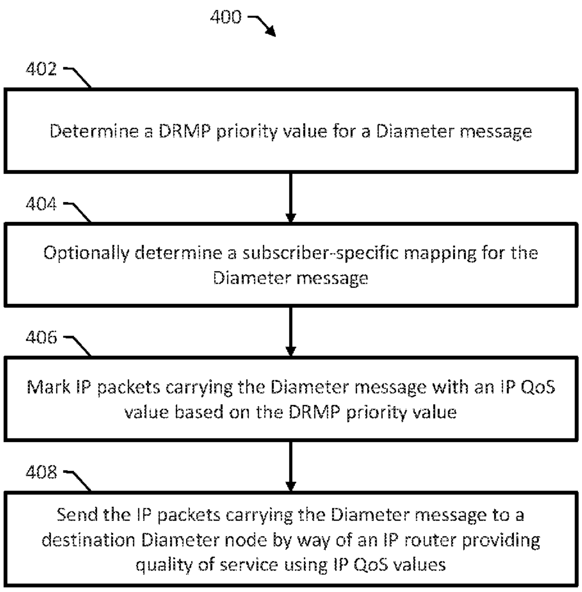

FIG. 4

(57) **Abstract:** Methods, systems, and computer readable media for priority routing of Diameter messages are disclosed. In some examples, a method includes determining a Diameter Routing Message Priority (DRMP) priority value for a Diameter message. The method includes marking each of one or more Internet protocol (IP) packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value. The method includes sending the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values.

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METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR PRIORITY ROUTING OF DIAMETER MESSAGES

PRIORITY CLAIM

This application claims the benefit of U.S. Patent Application Serial No. 15/382,057, filed December 16, 2016, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The subject matter described herein relates to methods and systems for routing Diameter messages. More particularly, the subject matter described herein relates to methods, systems, and computer readable media for routing Diameter messages using Diameter Routing Message Priority (DRMP) priority values.

BACKGROUND

The Diameter Overload Indication Conveyance (DOIC) solution for Diameter overload control introduces scenarios where Diameter routing decisions made by Diameter nodes can be influenced by the overload state of other Diameter nodes. This includes the scenarios where Diameter endpoints and Diameter Agents can throttle requests as a result of the target for the request being overloaded. In some systems, all requests have the same probability of being throttled, which can cause issues. For instance, a system operator may want to reduce the probability of transactions involving first responders being throttled during overload scenarios caused, for example, by a period of heavy signaling resulting from a natural disaster. Internet Engineering Task Force (IETF) Request for Comments (RFC) 7944 defines a mechanism, Diameter Routing Message Priority (DRMP), to allow Diameter endpoints to indicate the relative priority of Diameter transactions. With this information, Diameter nodes can factor that priority into routing, resource allocation, and overload abatement decisions.

Accordingly, there exists a need for methods, systems, and computer readable media for routing Diameter messages using Diameter Routing

Message Priority (DRMP) priority values and for extending DRMP usage to realize the possibilities enabled by DRMP.

SUMMARY

This specification describes methods, systems, and computer readable media for priority routing of Diameter messages. In some examples, a method includes determining a Diameter Routing Message Priority (DRMP) priority value for a Diameter message. The method includes marking each of one or more Internet protocol (IP) packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value. The method includes sending the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values.

In some examples, a system includes a Diameter node including at least one processor. The system includes a Diameter-to-IP priority mapper implemented on the Diameter node. The Diameter-to-IP priority mapper is configured for determining a Diameter Routing Message Priority (DRMP) priority value for a Diameter message; marking each of one or more Internet protocol (IP) packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value; and sending the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values.

In some examples, the IP router on the data communications network provides quality of service using differentiated services, and the method comprises determining the IP QoS value as a differentiated services code point (DSCP) value for the Diameter message based on the DRMP priority value and a mapping of DRMP priority values to DSCP code points. Marking each of the one or more IP packets carrying the Diameter message can include inserting the DSCP value into a differentiated services field in a header of each IP packet. In some other examples, the IP router on the data communications network provides quality of service using Integrated services,

and the method includes determining the IP QoS value as an Integrated services flow specification based on the DRMP priority value.

In some examples, the Diameter node is a Diameter Routing Agent (DRA), and determining the DRMP priority value for the Diameter message includes receiving the Diameter message and extracting the DRMP priority value from an attribute-value pair of the Diameter message reserved for DRMP priority values. In some other examples, the Diameter node is a Diameter client or Diameter server originating the Diameter message, and determining the DRMP priority value for the Diameter message comprises determining the DRMP priority value based on one or more other attribute-value pairs of the Diameter message.

In some examples, the Diameter node is configured for carrying signaling traffic for a telecommunications network including a long term evolution (LTE) and/or IP multimedia system (IMS) network. The method can include determining a subscriber identifier for the telecommunications network associated with the Diameter message and determining the IP QoS value for the Diameter message by mapping the DRMP priority value to the IP QoS value using a mapping, supplied by an operator of the LTE and/or IMS network, of DRMP priority values to IP QoS values for a service plan for the subscriber identifier.

The features described in this specification may be implemented using any appropriate combination of computing components, for example, hardware, software, and firmware. The terms “function” “node” or “module” refer to hardware, which may also include software and/or firmware components, for implementing the feature being described. In some examples, the features described in this specification may be implemented using a computer readable medium storing computer executable instructions that when executed by at least one processor of a computer control the computer to perform operations. Examples of appropriate computer readable media include non-transitory computer-readable media, such as disk memory devices, chip memory devices, programmable logic devices, and application specific integrated circuits. A computer readable medium may be located on a single device or computing platform or may be distributed across multiple devices or computing platforms.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A and 1B illustrate example networks where DRMP usage at Diameter nodes can be extended to IP routing of Diameter messages through an IP network;

Figure 2 is a block diagram of an example DRMP-configured Diameter node;

Figure 3 is a diagram of an example DSCP field layout;

Figure 4 is a flow diagram of an example method for priority routing of Diameter messages; and

Figure 5 is a flow diagram of an example method for priority routing of Diameter messages using DSCP.

DETAILED DESCRIPTION

This specification describes methods, systems, and computer readable media for extending DRMP usage at Diameter nodes to IP routing of Diameter messages through an IP network. IP networks can provide quality of service (QoS) using, for example, differentiated services (DiffServ) or integrated services (IntServ). Generally DiffServ is used to provide specific traffic routing treatment to IP packets in the IP network, which defines the per-hop behavior applied on packet during routing. The introduction of DRMP can aid in appropriately addressing Diameter message treatment behavior at Diameter nodes but still lacks a mechanism for addressing similar treatment over IP networks.

DiffServ specifies a DS field for IP headers (e.g., ToS Field in IPv4 header and Traffic Class field in IPv6 header). The DS field is used by DiffServ routers to determine the QoS forwarding requirements of the packets. For a packet to be receive consistent per-hop behavior treatment while traversing an IP network, Diameter nodes can be configured with a mapping between DRMP values to IP QoS values, so that IP routers in the IP network can prioritize routing decisions using the IP QoS values based on DRMP values.

Configuring Diameter nodes to map DRMP values to IP QoS values can provide one or more of the following advantages: 1) DRMP priority values are extended beyond the Diameter protocol and Diameter node scope, which can facilitate improved IP routing experience to telecommunications signaling traffic; and 2) telecommunications service operators have configuration flexibility to map DRMP priority values to IP QoS values, which can enhance the Diameter messages in-flight experience over the IP network.

Figures 1A and 1B illustrate example networks where DRMP usage at Diameter nodes can be extended to IP routing of Diameter messages through an IP network. Figure 1A shows a first network **100** including an upstream Diameter node **102** communicating with a downstream Diameter node **104** by way of a Diameter router **106**. Upstream Diameter node **102** is coupled to Diameter router **106** by an IP router **108** of an IP network, and downstream Diameter node **104** is coupled to Diameter router **106** by another IP router **110**.

In operation, upstream and downstream Diameter nodes **102** and **104** exchange Diameter messages **112** by sending IP packets **114** that traverse IP routers **108** and **110** and Diameter router **106**. Figure 1B shows a second network **150**, similar to first network **100**, where upstream and downstream Diameter nodes **102** and **104** exchange Diameter messages by way of IP router **108** and Diameter router **106**. Diameter router **106** receives IP packets carrying Diameter messages from IP router **108** and can return those IP packets back to IP router **108** for appropriate routing. First and second networks **100** and **150** are example networks that can be used, for example, in a telecommunications network for carrying signaling information using the Diameter protocol.

Diameter is a networking protocol that evolved from RADIUS for authentication, authorization, and accounting. Diameter applications extend the base protocol by adding new commands and attributes, e.g., commands and attributes for use in policy and charging control. A typical Diameter message includes a Diameter header and a variable number of attribute-value pairs (AVPs) for encapsulating information relevant to the Diameter message.

Diameter router **106** can be implemented as a system of one or more computers executing software for routing Diameter messages. For example, Diameter router **106** may be implemented on a computing platform that includes one or more processor blades, each implementing a routing agent or other function. Diameter router **106** may be implemented in a distributed computing system, e.g., executing on a virtual machine, or any appropriate system of one or more computers.

Similarly, Diameter nodes **102** and **104** can each be implemented as a computer system programmed for originating and processing received Diameter messages. For example, Diameter nodes **102** and **104** may be Diameter clients or servers, or Diameter Edge Agents, executing on virtual machines of a distributed computing system, for long term evolution (LTE) and IP multimedia system (IMS) networks. Examples of Diameter messages carrying signaling traffic for a telecommunications network include Diameter messages related to policy, subscriber data, a network resource utilization.

Each of upstream Diameter node **102**, downstream Diameter node **104**, and Diameter router **106** is configured for using DRMP. For purposes of illustration, consider an example where downstream Diameter node **104** originates a Diameter message addressed to upstream Diameter node **102**. Downstream Diameter node **104** assigns a DRMP priority value to that Diameter message. The DRMP priority value can be in a range from PRIORITY_0 (lowest priority) to PRIORITY_15 (highest priority). The method of determining the DRMP priority value is application-specific.

For example, higher DRMP priority values can be assigned to Diameter messages for first-responder-related signaling after natural disasters or to emergency-call-related signaling. In another example, a network operator may desire to differentiate network-based services by providing a service level agreement (SLA) that includes preferential Diameter routing behavior, e.g., by offering platinum, gold, and silver levels of service. DRMP priority values can be assigned based on the selected service level of a subscriber.

Downstream Diameter node **104** inserts the DRMP priority value into the Diameter message as an AVP in an appropriate location. The DRMP (AVP code 301) is of type Enumerated. Downstream Diameter node **104** inserts other AVP pairs into the Diameter message as appropriate for the application.

Downstream Diameter node **104** sends the Diameter message to upstream Diameter node **102** by way of Diameter router **106**, which is configured for compliance with DRMP and will process the Diameter message according to the DRMP priority value. IP routers **108** and **110**, however, will route the IP packets carrying the Diameter messages without regard to the DRMP priority value. To extend DRMP usage to IP routing of the Diameter message, downstream Diameter node **104** marks the IP packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value.

For example, suppose that IP routers **108** and **110** provide quality of service using DiffServ. Downstream Diameter node **104** can determine the IP QoS value as a DSCP value based on the DRMP priority value and a mapping of DRMP priority values to DSCP code points. Downstream Diameter node **104** marks the IP packets carrying the Diameter message comprises inserting the DSCP value into a differentiated services field in a header of each IP packet.

In another example, IP routers **108** and **110** provide quality of service using Integrated Services, and downstream Diameter node **104** determines the IP QoS value as an Integrated Services flow specification based on the DRMP priority value. Downstream Diameter node **104** can use any appropriate IP QoS for the IP network.

Downstream Diameter node **104** sends the IP packets carrying the Diameter message to Diameter router **106** by way of IP router **108**. IP router **108** uses the IP QoS value inserted into the IP packets to appropriate prioritize the routing of the IP packets. Diameter router **106** receives the Diameter message and extracts the DRMP priority value from the AVP of the Diameter message reserved for DRMP priority values. Diameter router **106** then uses the DRMP priority value to appropriately prioritize the routing of the Diameter message.

Diameter router **106** marks the outgoing IP packets carrying the Diameter message to IP router **110** with the IP QoS value. For example, Diameter router **106** can determine the IP QoS value using a local mapping between DRMP values and IP QoS values. In another example, Diameter router **106** can determine the IP QoS value by copying the IP QoS value of the IP packets received from IP router **108**.

Diameter router **106** sends the outgoing IP packets either to IP router **110** (in first example network **100**, as shown in Figure 1A) or back to IP router **108** (in second example network **150**, as shown in Figure 1B). The outgoing IP packets are appropriately prioritized during IP routing. Upstream Diameter node **102** receives the Diameter message. Depending on the application, upstream Diameter node **102** may use the DRMP priority value in processing the Diameter message.

Figure 2 is a block diagram of an example DRMP-configured Diameter node **200**. Diameter node **200** is implemented as a computer system comprising one or more processors **202** and memory **204** storing executable instructions for processors **202**. Diameter node **200** may be a Diameter Routing Agent (DRA), or a Diameter client or Diameter server, for example.

Diameter node **200** includes a Diameter-to-IP priority mapper **206** implemented on processors **202** and memory **204**, e.g. as one or more computer programs. Diameter-to-IP priority mapper **206** includes a DRMP priority determiner **208** and an IP packet marker **210** for determining DRMP priority values and marking IP packets with IP QoS values. Diameter-to-IP priority mapper can include an optional subscriber handler **212** for performing subscriber-specific mappings between DRMP priority values and IP QoS values.

Diameter-to-IP priority mapper **206** includes a mapping **214** between DRMP priority values and IP QoS values. Mapping **214** may be populated, e.g., by a network operator, or may store default values for specific IP QoS systems such as DiffServ. Mapping **214** can be implemented, for example, as a table indexed by DRMP priority values, where each entry in the table for a DRMP priority value specifies a corresponding IP QoS value. Table 1, below, is an example of a table indexed by DRMP priority values that maps the DRMP priority values to DSCP values.

DRMP Priority Value	DSCP Value
PRIORITY_0	DSCP_0
PRIORITY_1	DSCP_1
PRIORITY_2	DSCP_2
PRIORITY_3	DSCP_3
PRIORITY_4	DSCP_4
PRIORITY_5	DSCP_5
PRIORITY_6	DSCP_6
PRIORITY_7	DSCP_7
PRIORITY_8	DSCP_8
PRIORITY_9	DSCP_9
PRIORITY_10	DSCP_10
PRIORITY_11	DSCP_11
PRIORITY_12	DSCP_12
PRIORITY_13	DSCP_13
PRIORITY_14	DSCP_14
PRIORITY_15	DSCP_15

Table 1: Mappings from DRMP Priority Values to DSCP Priority Values

For instance, Diameter-to-IP priority mapper **206** using the mapping illustrated in Table 1 would map a Diameter message having a DRMP priority value of PRIORITY_5 to a DSCP value of DSCP_5. Mapping **214** can alternatively be implemented in any appropriate manner, e.g., by a formula or series of operations to transform a DRMP priority value to an IP QoS value.

In operation, Diameter-to-IP priority mapper **206** takes a DRMP priority value, applies the DRMP priority value to mapping **214** as appropriate for mapping **214**, and retrieves the corresponding IP QoS value for the DRMP priority value. For example, suppose that mapping **214** is implemented as a table indexed by DRMP priority values. Diameter-to-IP priority mapper **206** performs a look-up in the table using a DRMP priority value and then retrieves the IP QoS value of the entry returned by the look-up.

When Diameter node **200** processes a Diameter message, DRMP priority determiner **208** determines a DRMP priority value for the Diameter message. For example, if Diameter node **200** is originating the Diameter message, DRMP priority determiner **208** assigns the Diameter message an application-specific DRMP priority value. In another example, if Diameter node **200** is receiving the Diameter message, DRMP priority determiner **208** extracts the DRMP priority value from an AVP of the Diameter message reserved for DRMP priority values.

To illustrate assigning an application-specific DRMP priority value, consider the following examples. Natural disasters can result in a considerable increase in usage of network resources and, in some cases, loss of network capacity, e.g., where network equipment is damaged. The combination of added load and reduced capacity can lead to Diameter node **200** becoming overloaded.

In this case, signaling associated with first responders can be given a higher priority to help ensure they can most effectively do their jobs. The United States wireless priority services (WPS) and government emergency telecommunications service (GETS) are examples of systems designed to address the command and control aspects of these first responder needs. By assigning higher DRMP priority values to Diameter messages for first-responder-related signaling after natural disasters, first responders and other individuals responsible for handling the after effects of the disaster can have a better chance of gaining access to the network resources in order to communicate both between themselves and with other network resources.

In another example, consider the signaling associated with emergency calls. Although these calls may not tax the network with the same level of severity as natural disasters, emergency calls are still critical to safety. By assigning higher DRMP priority values to Diameter messages for emergency calls, DRMP priority determiner **208** can improve the chances of the emergency calls being successfully completed.

IP packet marker **210** marks outgoing IP packets carrying an outgoing Diameter message with an IP QoS value for the outgoing Diameter message based on the DRMP priority value for the outgoing Diameter message. The DRMP priority value is determined by DRMP priority determiner **208**. Typically, IP packet marker **210** inserts the IP QoS value into a header of each outgoing IP packet. For example, if the IP QoS value is DSCP value, IP packet marker **210** can insert the DSCP value into a DiffServ field in a header of each IP packet.

Subscriber handler **212** is configured for performing subscriber-specific mappings between DRMP priority values and IP QoS values. For example, suppose that Diameter node **200** is configured for carrying signaling traffic for a telecommunications network, e.g., a long term evolution (LTE) and/or IP multimedia system (IMS) network. Subscriber handler **212** can determine a subscriber identifier for the telecommunications network associated with a Diameter message.

For example, subscriber handler **212** can determine the subscriber identifier by extracting the subscriber identifier from an appropriate AVP of the Diameter message. Then, subscriber handler **212** can determine the IP QoS value using a mapping, supplied by an operator of the LTE and/or IMS network, of DRMP priority values to IP QoS values for the subscriber. For example, the operator can supply mappings for various service plans, and subscriber handler **212** can using the mapping for the service plan for the subscriber identifier.

To illustrate an example of different mappings, consider the example of three different mappings illustrating in Table 2.

DRMP Priority Value	**DSCP Value – Silver**	**DSCP Value – Gold**	**DSCP Value - Platinum**
PRIORITY_0	DSCP_2	DSCP_1	DSCP_0
PRIORITY_1	DSCP_2	DSCP_1	DSCP_0
PRIORITY_2	DSCP_2	DSCP_1	DSCP_0
PRIORITY_3	DSCP_2	DSCP_1	DSCP_0
PRIORITY_4	DSCP_3	DSCP_2	DSCP_1
PRIORITY_5	DSCP_3	DSCP_2	DSCP_1
PRIORITY_6	DSCP_3	DSCP_2	DSCP_1
PRIORITY_7	DSCP_3	DSCP_2	DSCP_1
PRIORITY_8	DSCP_4	DSCP_3	DSCP_2
PRIORITY_9	DSCP_4	DSCP_3	DSCP_2

PRIORITY_10	DSCP_4	DSCP_3	DSCP_2
PRIORITY_11	DSCP_4	DSCP_3	DSCP_2
PRIORITY_12	DSCP_5	DSCP_4	DSCP_3
PRIORITY_13	DSCP_5	DSCP_4	DSCP_3
PRIORITY_14	DSCP_5	DSCP_4	DSCP_3
PRIORITY_15	DSCP_5	DSCP_4	DSCP_3

Table 2: Subscriber-specific mappings

As shown in Table 2, a network operator provides three subscriber-specific mappings for three levels of service: silver, gold, and platinum. The IP networks support six different DSCP values: DSCP_0 – DSCP_5. Diameter messages for subscribers of the platinum service agreement are given DSCP values from DSCP_0 – DSCP_3, Diameter messages for subscribers of the gold service agreement are given DSCP values from DSCP_1 – DSCP_4, and Diameter message for subscribers of the silver service agreement are given DSCP values from DSCP_2 to DSCP_5.

For example, suppose that Diameter node **200** receives a Diameter message and that DRMP priority determiner **208** determines that the Diameter message has a DRMP priority value of PRIORITY_8. Subscriber handler **212** can determine the subscriber identifier for the Diameter message and then determine, e.g., by accessing a local or remote database storing service level agreements for subscribers, the service level agreement associated with the subscriber identifier.

If the service level agreement is platinum, then Diameter-to-IP priority mapper **206** maps the DRMP priority value of PRIORITY_8 to DSCP value DSCP_2. If the service level agreement is gold, then Diameter-to-IP priority mapper **206** maps the DRMP priority value of PRIORITY_8 to DSCP value DSCP_3. If the service level agreement is silver, then Diameter-to-IP priority mapper **206** maps the DRMP priority value of PRIORITY_8 to DSCP value DSCP_4.

Diameter node **200** is a DRMP-configured Diameter node in that Diameter node **200** is configured for processing Diameter messages containing DRMP AVPs. In general, Diameter node **200** includes DRMP priority values in the DRMP AVP in all Diameter request messages, and when available, Diameter node **200** uses DRMP priority values the DRMP AVP when making Diameter overload throttling decisions.

Diameter node **200** is configured with a default priority to apply to Diameter message of transactions that do not have a pre-configured DRMP priority value. For example, Diameter node **200** can be configured to use the PRIORITY_10 priority as the default value. Diameter node **200** can support the ability for the default priority to be modified through local configuration interfaces.

In some examples, Diameter node **200** is DRMP-configured in that Diameter node **200** is programmed to use DRMP priority values when relaying request and answer messages. For example, Diameter node **200** can use DRMP priority values in the selection of routes and the ordering of messages relayed.

For Diameter node **200** to effectively carry out DRMP operations, the priorities defined for messages across different applications used in the Diameter administrative domain for Diameter node **200** should be defined in a consistent and coordinated fashion in view of the default priorities. Otherwise, it may be possible for messages for one application to gain unwarranted preferential treatment for other applications.

Moreover, with the Diameter administrative domain, the Diameter nodes capable of modifying DRMP AVPs will normally be trusted nodes. Misbehaving nodes would have the ability to use the DRMP mechanism to gain unwarranted preferential treatment.

When Diameter node **200** sends Diameter messages that cross Diameter administrative boundaries, Diameter node **200** can be configured to strip or modify the DRMP priority values in those messages. This can avoid a problem where the priority definitions vary between the two Diameter administrative domains, which could allow Diameter messages to gain unwarranted preferential treatment.

In some examples, where Diameter node **200** is a Diameter endpoint, Diameter node **200** can be programmed to use DRMP priority values to make resource allocation decisions. For instance, suppose that Diameter node **200** is a Diameter server. Diameter node **200** can be programmed to use DRMP priority values to treat higher-priority requests ahead of lower-priority requests. In another example, Diameter node **200** can be programmed to use DRMP priority values to fail a Diameter request as a result of insufficient resources.

Figure 3 is a diagram of an example DSCP field layout **300**. DSCP is an example of an IP QoS system that can be used for extending DRMP usage at Diameter nodes to IP routing of Diameter messages through an IP network. One or more IP packets carrying a Diameter message can be marked with DSCP values in the headers of the IP packets. For example, the IP packets can be marked in the ToS Byte field of the headers of the IP packets.

DiffServ is a computer networking architecture that specifies a mechanism for classifying and managing network traffic. In particular, DiffServ provides a scalable mechanism for providing QoS on various types of IP networks. For instance, a computer network can be configured to use DiffServ to provide low-latency to critical network traffic such as voice or video streaming. The same computer network can be configured, using DiffServ, to provide best-effort service to non-critical services such as web traffic or file transfers.

DiffServ typically uses a six bit DSCP value in the eight bit differentiated services (DS) field in the IP header for the purpose of classifying IP packets. The DS field and explicit congestion notification (ECN) replace the IPv4 TOS field, although that field may still be used in some networks. DSCP field layout **300** shows the DSCP bits of the ToS Byte field. Bits B5-B7 **302** represent the DSCP categories. Bits B3-B4 **304** represent the drop probability. B2 **306** is set to zero and the remaining bits **308**, B0-B1, are reserved.

DiffServ relies on a mechanism to classify and mark packets as belonging to a specific class. For example, DRMP-enabled Diameter nodes can classify and mark IP packets carrying Diameter messages based on the DRMP priority values of those Diameter messages. DiffServ-enabled routers implement per-hop behaviors (PHBs), which define the packet-forwarding properties associated with a class of traffic. Different PHBs may be defined to offer, for example, low-loss or low-latency.

In a network implementing DiffServ, routers on the network can be configured to differentiate IP packets based on the marked DSCP bits for those packets. Each traffic class can be managed on a class-specific basis, e.g., so that priority treatment can be given to higher-priority traffic on the network. In some examples, the high overhead functions of packet classification and policing can be implemented at the edge of the network by edge routers, e.g., so that the edge routers mark the packets with DSCP bits and core routers can be relieved of the marking.

The DiffServ RFCs recommend certain encodings. Since the encodings are recommended and not required, this gives a network operator flexibility in defining traffic classes. In some example, networks can use the following commonly defined Per-Hop Behaviors:

- *Default* PHB— best-effort traffic
- *Expedited Forwarding* (EF) PHB—a class above default for low-loss, low-latency traffic
- *Assured Forwarding* (AF) PHB—to assure delivery under certain conditions
- *Class Selector* PHBs—for backward compatibility with the IP precedence field, which is used in IPv4 networks in the TOS byte of the IPv4 header to mark priority traffic.

The core routers can implement PHB treatment using any technique or appropriate combination of techniques. For example, the core routers can use a combination of scheduling policy and queue management policy.

DSCP bits can be set using any appropriate method. For example, DSCP bits can be set at interface, port, or per packet level using Linux utilities. Linux utilities such as socket application programming interfaces (APIs) or iptables can configure a DSCP codepoint for a desired target, e.g., a desired interface or port. iptables is a flexible firewall utility built for Linux operating systems. iptables is a user-space application program that allows a system administrator to configure port and interface tables provided by the Linux kernel firewall, and other applications.

Using the utilities, however, fixes the DSCP value to the interface or port, so that traffic routed through that interface or port gets marked, which may not be useful in addressing the flexibility needed to DSCP marking on a per-packet basis.

Providing DSCP marking on a per-packet basis may be useful in reducing the need of reserving dedicated system resources. For example, implementing DSCP marking using the Linux utilities described above would normally requiring reserving a port, interface, or IP address, just to facilitate the DSCP marking. Providing DSCP marking on a per-packet basis (e.g., in the IP packet marker **210** of Figure 2) avoids this need to reserve a port, interface, or IP address.

Although DSCP is described in detail with reference to Figure 3, the methods, systems, and computer readable media described in this specification for extending DRMP usage to IP routing of Diameter messages can use any appropriate IP QoS system. For example, IntServ is another IP QoS system. DiffServ is a coarse-grained, class-based mechanism for traffic management, whereas IntServ is a fine-grained, flow-based mechanism.

In a network implementing IntServ, every router in the system implements IntServ, and every application that requires some kind of guarantees has to make an individual reservation. Flow specifications describe how the reservation will be used, and RSVP provides the mechanism for signaling the reservation across the network. Extending DRMP to networks using IntServ may require more computing resources than extending DRMP to networks using DiffServ since the Diameter nodes mapping DRMP priority values to IP QoS values would need to be programmed to make the appropriate reservations.

Figure 4 is a flow diagram of an example method **400** for priority routing of Diameter messages. Method **400** can be performed by the Diameter node **200** of Figure 2 or any appropriate computer system.

Method **400** includes determining a DRMP priority value for a Diameter message (**402**). For example, suppose that the Diameter node is a DRA. Determining the DRMP priority value for the Diameter message can include receiving the Diameter message and extracting the DRMP priority value from an attribute-value pair of the Diameter message reserved for DRMP priority values.

In another example, the Diameter node is a Diameter client or server originating the Diameter message, and determining the DRMP priority value for the Diameter message includes determining the DRMP priority value based on one or more other attribute-value pairs of the Diameter message, i.e., so that the DRMP priority value is application-specific.

Method **400** includes optionally determining a subscriber-specific mapping between DRMP priority values and IP QoS values for the Diameter message (**404**). For example, suppose that the Diameter node is configured for carrying signaling traffic for a telecommunications network comprising a long term evolution (LTE) and/or IP multimedia system (IMS) network.

Method **400** can include determining a subscriber identifier for the telecommunications network associated with the Diameter message and determining the IP QoS value for the Diameter message by mapping the DRMP priority value to the IP QoS value using a mapping, supplied by an operator of the LTE and/or IMS network, of DRMP priority values to IP QoS values for a service plan for the subscriber identifier.

Method **400** includes marking each of one or more IP packets carrying the Diameter message with an IP QoS value for the Diameter message based on the DRMP priority value (**406**). For example, suppose that an IP router on the route provides quality of service using DiffServ. Method **400** can include determining the IP QoS value as a DSCP value for the Diameter message based on the DRMP priority value and a mapping of DRMP priority values to DSCP code points, and marking each of the one or more IP packets carrying the Diameter message comprises inserting the DSCP value into a differentiated services field in a header of each IP packet.

In another example, the IP router provides quality of service using integrated services, and method **400** includes determining the IP QoS value as an Integrated services flow specification based on the DRMP priority value.

Method **400** includes sending the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values (**408**). As a result, DRMP usage at Diameter nodes is extended to IP routing of Diameter messages through an IP network.

Figure 5 is a flow diagram of an example method **500** for priority routing of Diameter messages using DSCP. Method **500** can be performed by a Diameter Routing Agent (DRA) any appropriate computer system.

Method **500** includes receiving a Diameter message (**502**). In some Diameter networks, some Diameter nodes may be configured to use DRMP and some other Diameter nodes may not be configured to use DRMP. For example, some Diameter networks may include Diameter nodes that are awaiting an upgrade or that purposefully lack DRMP capability for purposes of, e.g., reduction of cost or complexity.

So method **500** includes determining whether or not the Diameter message has a DRMP AVP value (**504**). For example, determining whether or not the Diameter message has a DRMP AVP value can include searching the AVP values of the Diameter message for the AVP reserved for DRMP priority values. If the Diameter message does not include a DRMP AVP value, then method 500 includes processing the Diameter message as if it were a legacy message (proceed to **510**), i.e., without marking IP packets carrying the Diameter message with DSCP values. The Diameter message may lack a DRMP AVP value if the originating Diameter node is not configured to use DRMP.

If the Diameter message does include a DRMP AVP value, the method **500** includes determining a DSCP value for the Diameter message (proceed to **506).** Method **500** includes determining whether there is a DSCP value in one or more headers of the incoming IP packets carrying the Diameter message (**506**). If the incoming IP packets include a DSCP value in the headers of the incoming IP packets, then method **500** includes using the DSCP value of the incoming IP packets for the outgoing IP packets (proceed to **510**).

If the incoming IP packets carrying the Diameter message lack a DSCP value in the headers of the incoming IP packets, then method **500** includes determining a DSCP value for the Diameter message using the DRMP priority value from the DRMP AVP (**508**). The incoming IP packets may lack DSCP values, for example, if the originating Diameter node is configured for using DRMP but is not configured for extending DRMP to IP networks, e.g., as described above with reference to Figures 1A-4.

In that case, even though the originating Diameter node is not configured for extending DRMP to IP networks, method **500** can extend DRMP to IP networks for that Diameter message since method **500** includes routing that Diameter message. For example, determining the DSCP value for the Diameter message based on the DRMP priority value can include looking up the DRMP priority value in a mapping of DRMP priority values to DSCP values and retrieving a corresponding DSCP value for the DRMP priority value as specified in the mapping.

In that case, the mapping may not be application-specific, i.e., determining the DSCP value may include using a generic or default mapping. Alternatively, the mapping may be application-specific, and determining the DSCP value includes checking other AVPs of the Diameter message to determine the application and selecting an appropriate mapping for the application. In some examples, the mapping may be subscriber-specific, and determining the DSCP value includes determining a subscriber identifier for the Diameter message and selecting an appropriate mapping for the subscriber.

Method **500** includes sending the Diameter message to the destination Diameter node (**510**). If the Diameter message has a DRMP AVP, then sending the message includes prioritizing the routing of the message using the DRMP priority value and marking the outgoing IP packets carrying the Diameter message using the DSCP value based on the DRMP priority value. If the Diameter message lacks a DRMP AVP, then method **500** includes processing the Diameter message without marking IP packets carrying the Diameter message with DSCP values.

A DRA executing method **500** is thus able to route Diameter message from Diameter nodes lacking DRMP capability, DRMP-configured Diameter nodes, and DRMP-configured Diameter nodes that are also configured to extend DRMP to IP networks, for example, the DRMP-configured Diameter node **200** of Figure 2. In a Diameter network that includes DRMP-configured nodes that are not configured to extend DRMP to IP networks, the DRA can still extend DRMP to IP networks as it routes Diameter messages that include DRMP AVPs but lack DSCP values.

Accordingly, while methods, systems, and computer readable media have been described in reference to specific examples and features, the utility of the subject matter is not thus limited, but rather extends to and encompasses numerous other variations, modifications and alternatives, as will suggest themselves to those of ordinary skill in the field of the present subject matter, based on this specification.

Various combinations and sub-combinations of the structures and features described in this specification are contemplated and will be apparent to a skilled person having knowledge of this disclosure. Any of the various features and elements disclosed may be combined with one or more other disclosed features and elements unless indicated to the contrary. Correspondingly, the subject matter as claimed is intended to be broadly construed and interpreted, as including all such variations, modifications and alternatives, within its scope and including equivalents of the claims.

It will be understood that various details of the subject matter described herein may be changed without departing from the scope of the subject matter described herein. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation.

CLAIMS

What is claimed is:

1. A method for routing Diameter messages, the method comprising:

determining, by a Diameter node comprising at least one processor, a Diameter Routing Message Priority (DRMP) priority value for a Diameter message;

marking, by the Diameter node, each of one or more Internet protocol (IP) packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value; and

sending, by the Diameter node, the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values.

2. The method of claim 1, wherein the IP router on the data communications network provides quality of service using differentiated services, and wherein the method comprises determining the IP QoS value as a differentiated services code point (DSCP) value for the Diameter message based on the DRMP priority value and a mapping of DRMP priority values to DSCP code points.

3. The method of claim 2, wherein marking each of the one or more IP packets carrying the Diameter message comprises inserting the DSCP value into a differentiated services field in a header of each IP packet.

4. The method of any of the preceding claims, wherein the IP router on the data communications network provides quality of service using Integrated services, and wherein the method comprises determining the IP QoS value as an integrated services flow specification based on the DRMP priority value.

5. The method of any of the preceding claims, wherein the Diameter node comprises a Diameter Routing Agent (DRA), and wherein determining

the DRMP priority value for the Diameter message comprises receiving the Diameter message and extracting the DRMP priority value from an attribute-value pair of the Diameter message reserved for DRMP priority values.

6. The method of any of claims 1 to 4, wherein the Diameter node comprises a Diameter client or Diameter server originating the Diameter message, and wherein determining the DRMP priority value for the Diameter message comprises determining the DRMP priority value based on one or more other attribute-value pairs of the Diameter message.

7. The method of any of the preceding claims, wherein the Diameter node is configured for carrying signaling traffic for a telecommunications network comprising a long term evolution (LTE) and/or IP multimedia system (IMS) network.

8. The method of claim 7, comprising determining a subscriber identifier for the telecommunications network associated with the Diameter message and determining the IP QoS value for the Diameter message by mapping the DRMP priority value to the IP QoS value using a mapping, supplied by an operator of the LTE and/or IMS network, for a service plan for the subscriber identifier.

9. A system for routing Diameter messages, the system comprising:

a Diameter node comprising at least one processor; and

a Diameter-to-IP priority mapper implemented on the Diameter node and configured for:

determining a Diameter Routing Message Priority (DRMP) priority value for a Diameter message;

marking each of one or more Internet protocol (IP) packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value; and sending the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values.

10. The system of claim 9, wherein the Diameter-to-IP priority mapper is configured for determining the IP QoS value as a differentiated services code point (DSCP) value for the Diameter message based on the DRMP priority value and a mapping of DRMP priority values to DSCP code points.

11. The system of claim 10, wherein marking each of the one or more IP packets carrying the Diameter message comprises inserting the DSCP value into a differentiated services field in a header of each IP packet.

12. The system of any of claims 9 to 11, wherein the Diameter-to-IP priority mapper is configured for determining the IP QoS value as an integrated services flow specification based on the DRMP priority value.

13. The system of any of claims 9 to 12, wherein the Diameter node comprises a Diameter Routing Agent (DRA), and wherein determining the DRMP priority value for the Diameter message comprises receiving the Diameter message and extracting the DRMP priority value from an attribute-value pair of the Diameter message reserved for DRMP priority values.

14. The system of any of claims 9 to 12, wherein the Diameter node comprises a Diameter client or Diameter server originating the Diameter message, and wherein determining the DRMP priority value for the Diameter message comprises determining the DRMP priority value based on one or more other attribute-value pairs of the Diameter message.

15. The system of any of claims 9 to 14, wherein the Diameter node is configured for carrying signaling traffic for a telecommunications network comprising a long term evolution (LTE) and/or IP multimedia system (IMS) network.

16. The system of claim 15, wherein the Diameter-to-IP priority mapper is configured for determining a subscriber identifier for the telecommunications network associated with the Diameter message and determining the IP QoS value for the Diameter message by mapping the DRMP priority value to the IP QoS value using a mapping, supplied by an operator of the LTE and/or IMS network, for a service plan for the subscriber identifier.

17. A non-transitory computer readable medium storing executable instructions that when executed by at least one processor of a Diameter node cause the Diameter node to perform operations comprising:

determining a Diameter Routing Message Priority (DRMP) priority value for a Diameter message;

marking each of one or more Internet protocol (IP) packets carrying the Diameter message with an IP quality of service (QoS) value for the Diameter message based on the DRMP priority value; and

sending the one or more IP packets carrying the Diameter message to a destination Diameter node by way of an IP router on a data communications network providing quality of service using IP QoS values.

18. The non-transitory computer readable medium of claim 17, wherein the operations comprise determining the IP QoS value as a differentiated services code point (DSCP) value for the Diameter message based on the DRMP priority value and a mapping of DRMP priority values to DSCP code points.

19. The non-transitory computer readable medium of claim 18, wherein marking each of the one or more IP packets carrying the Diameter message comprises inserting the DSCP value into a differentiated services field in a header of each IP packet.

20. The non-transitory computer readable medium of any of claims 17 to 19, wherein the Diameter node is configured for carrying signaling traffic for a telecommunications network comprising a long term evolution (LTE) and/or IP Multimedia Subsystem (IMS) network.

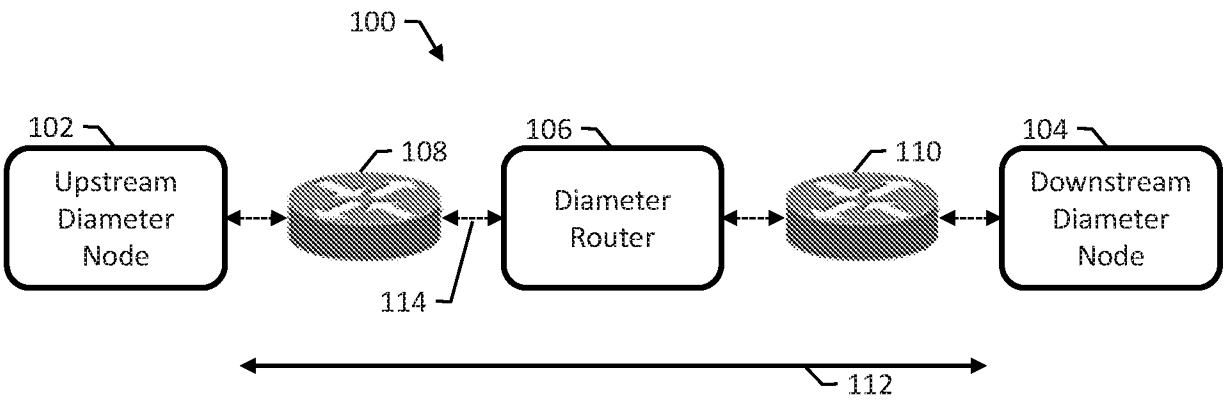
100
102
Upstream
Diameter
Node
108
106
Diameter
Router
110
104
Downstream
Diameter
Node
114
112

FIG. 1A

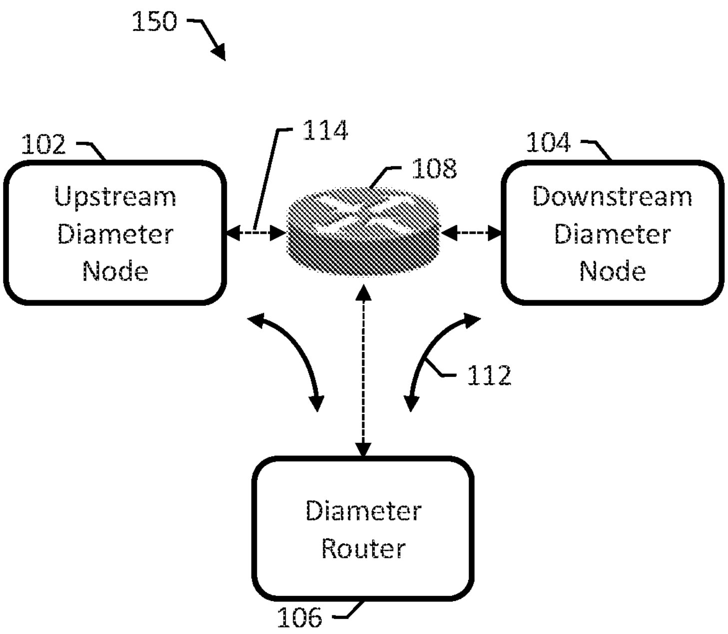
150
102
Upstream
Diameter
Node
114
108
104
Downstream
Diameter
Node
112
Diameter
Router
106

FIG. 1B

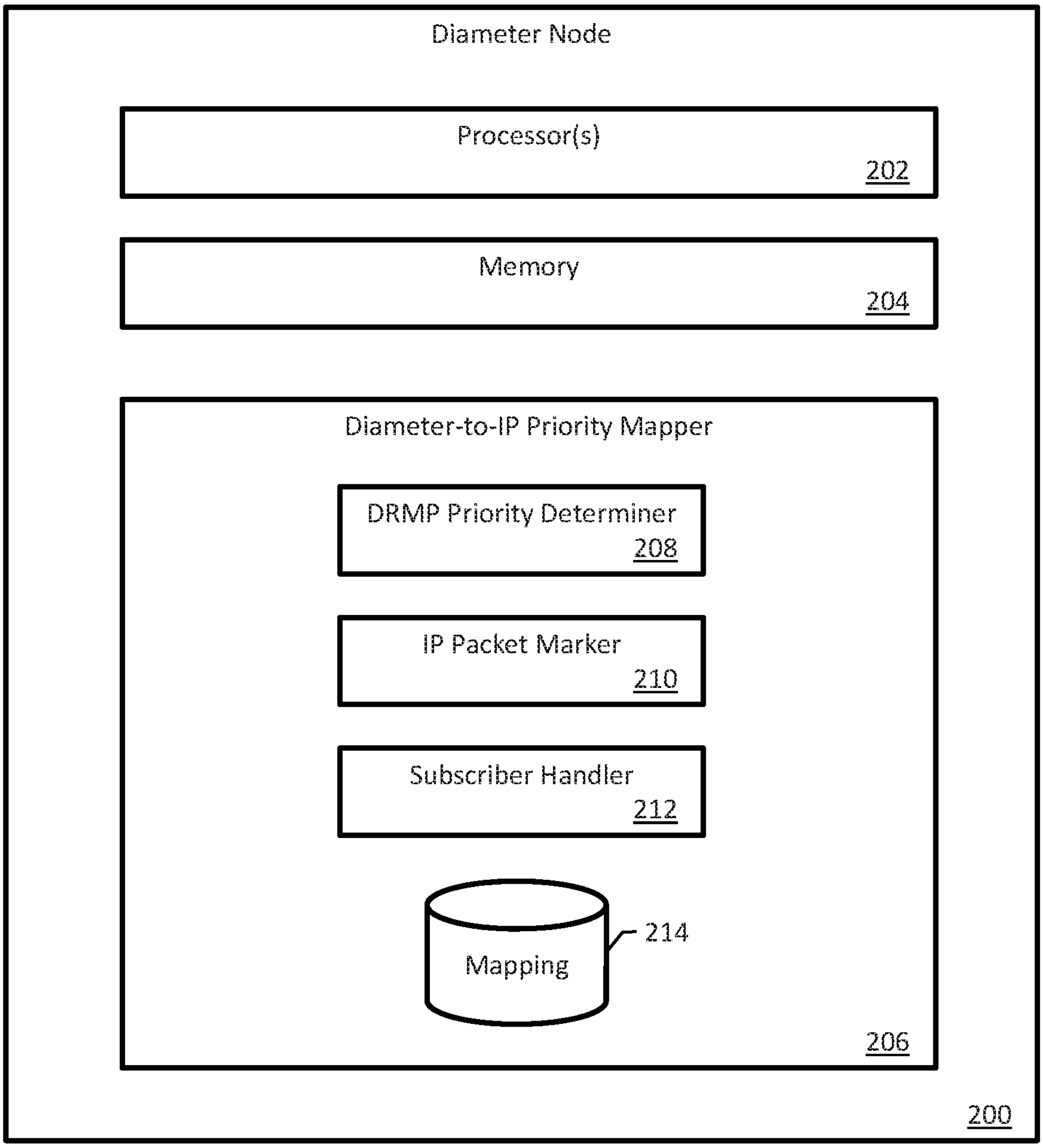
Diameter Node
Processor(s)
202
Memory
204
Diameter-to-IP Priority Mapper
DRMP Priority Determiner
208
IP Packet Marker
210
Subscriber Handler
212
Mapping
214
206
200

FIG. 2

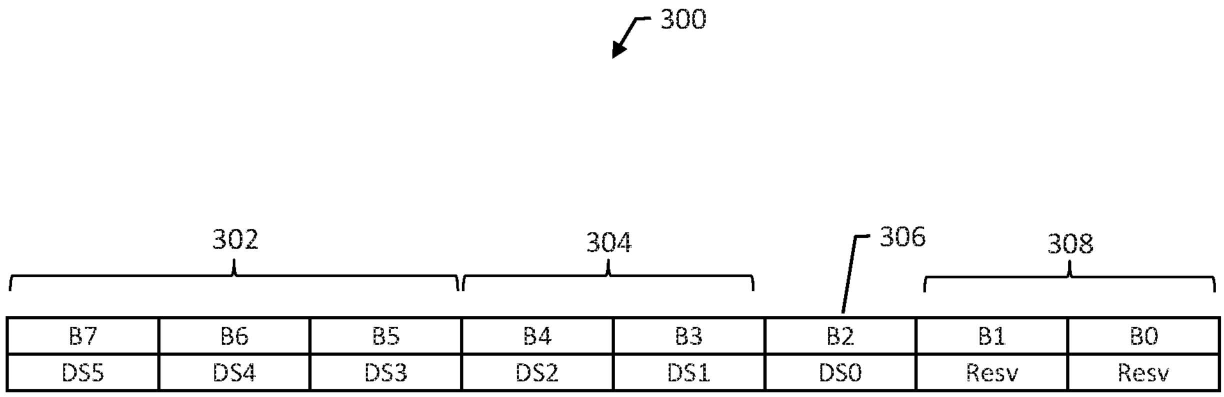
300
302
304
306
308
B7
B6
B5
B4
B3
B2
B1
B0
DS5
DS4
DS3
DS2
DS1
DS0
Resv
Resv

FIG. 3

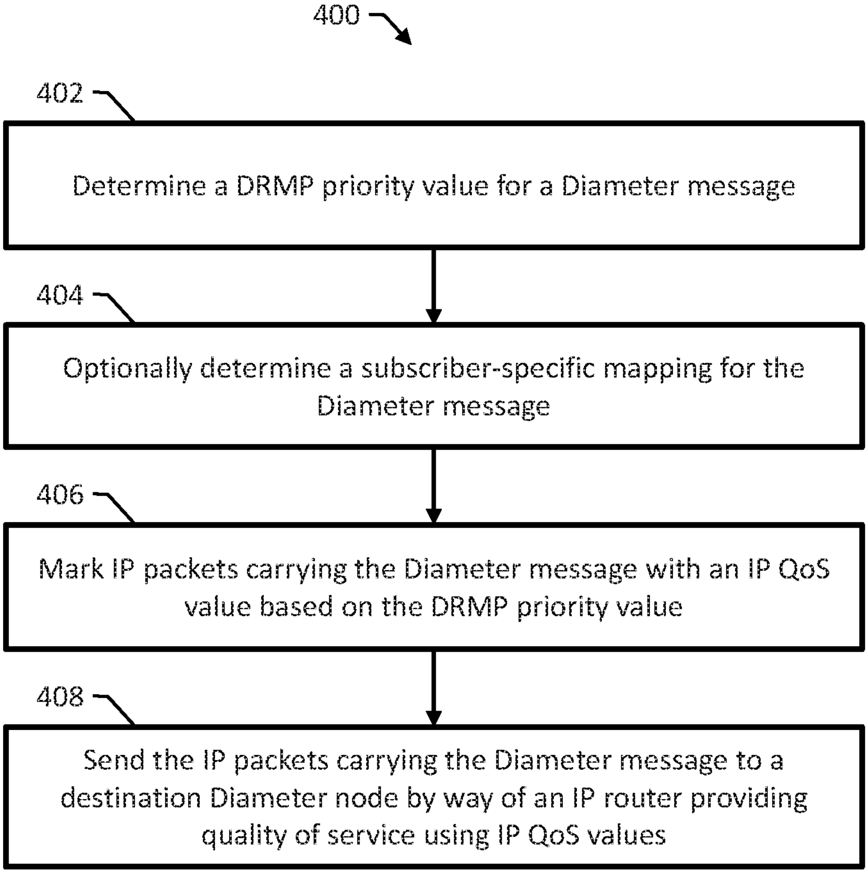
400
402
Determine a DRMP priority value for a Diameter message
404
Optionally determine a subscriber-specific mapping for the Diameter message
406
Mark IP packets carrying the Diameter message with an IP QoS value based on the DRMP priority value
408
Send the IP packets carrying the Diameter message to a destination Diameter node by way of an IP router providing quality of service using IP QoS values

FIG. 4

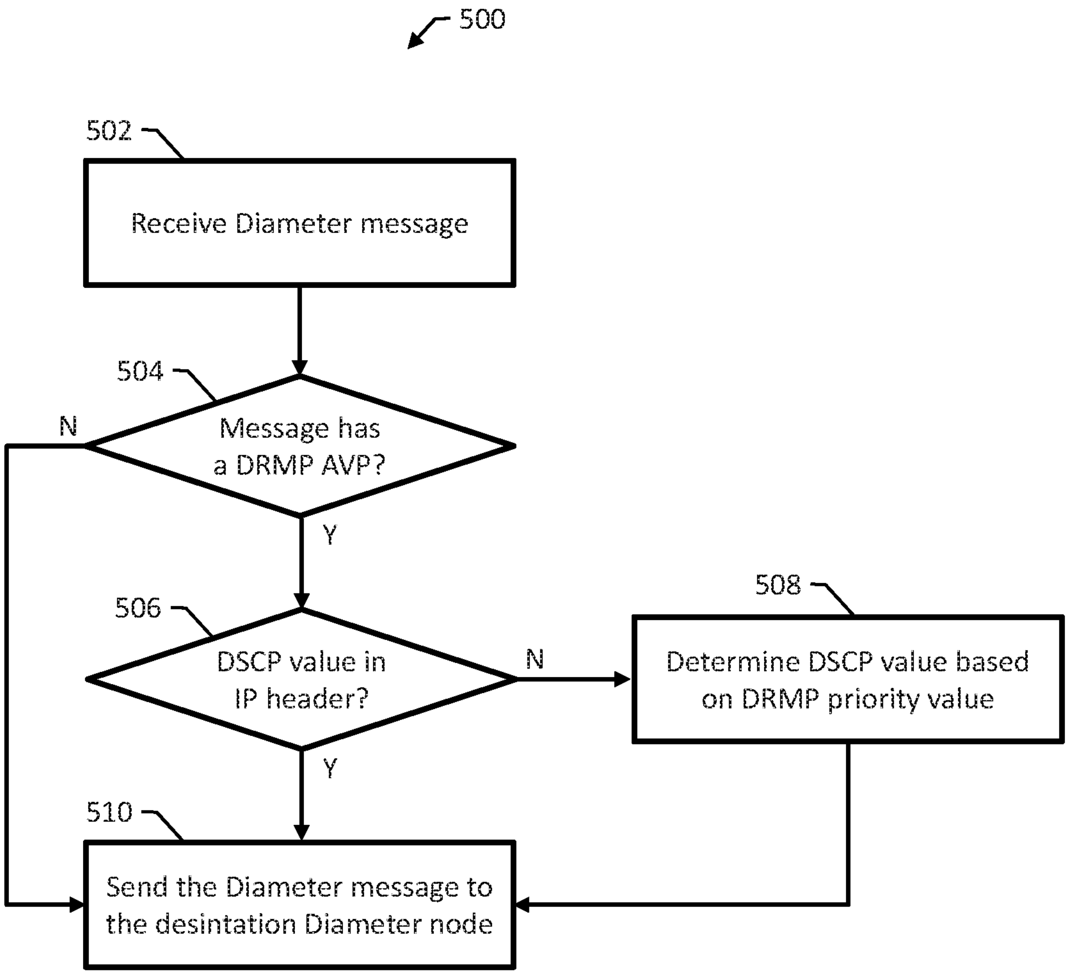
500
502
Receive Diameter message
504
Message has a DRMP AVP?
N
Y
506
DSCP value in IP header?
N
Y
508
Determine DSCP value based on DRMP priority value
510
Send the Diameter message to the desintation Diameter node

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/066331

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/801 H04L12/857
ADD. H04L12/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DONOVAN ORACLE S: "Diameter Routing Message Priority; rfc7944.txt", DIAMETER ROUTING MESSAGE PRIORITY; RFC7944.TXT, INTERNET ENGINEERING TASK FORCE, IETF; STANDARD, INTERNET SOCIETY (ISOC) 4, RUE DES FALAISES CH- 1205 GENEVA, SWITZERLAND, 5 August 2016 (2016-08-05), pages 1-18, XP015114683, [retrieved on 2016-08-05] section 1; page 2 - page 3 section 4; page 5 section 5.3; page 7 section 6; page 8 - page 9 -----	1-20

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 March 2018	08/03/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cortés Gómez, F

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/066331

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7 827 256 B2 (CISCO TECH INC [US]) 2 November 2010 (2010-11-02) column 41, line 18 - column 42, line 49; figure 26	1-20
X,P	VENCORE LABS ET AL: "Support for signaling transport level packet marking", 3GPP DRAFT; C4-173152 SUPPORT FOR DSCP MARKING 29.283 REL14, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. CT WG4, no. Zhangjiajie, China; 20170515 - 20170519 15 May 2017 (2017-05-15), XP051271271, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/CT4/Docs/ [retrieved on 2017-05-15] the whole document	1-20

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/066331

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 7827256 B2	02-11-2010	US 7606867 B1	20-10-2009
		US 2006288208 A1	21-12-2006
		US 2006288404 A1	21-12-2006
		US 2007005786 A1	04-01-2007
		US 2007011332 A1	11-01-2007
		US 2007028001 A1	01-02-2007
		US 2007156919 A1	05-07-2007
		US 2013132518 A1	23-05-2013
		WO 2007002334 A1	04-01-2007