

(51) International Patent Classification:  
*H04L 12/28* (2006.01) *H04L 29/02* (2006.01)(21) International Application Number:  
PCT/US2011/024625(22) International Filing Date:  
11 February 2011 (11.02.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
61/304,310 12 February 2010 (12.02.2010) US(71) Applicant (for all designated States except US): **TEK-ELEC** [US/US]; 5200 Paramount Parkway, Morrisville, NC 27560 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **WALLACE, Donald, E.** [US/US]; 3127 Buttercup Lane, Evergreen, CO 80439 (US). **KANODE, Mark, Edward** [US/US]; 3204 Colby Chase Drive, Apex, NC 27539 (US). **SPRAGUE, David, Michael** [US/US]; 14252 Wyndfield Circle, Raleigh, NC 27615 (US). **CRAIG, Jeffrey, Alan** [US/US]; 5 Summertime Court, Durham, NC 27707 (US). **MCCANN, Thomas, M.** [US/US]; 10560 Clubmont Lane, Raleigh, NC 27617 (US). **MARSICO, Peter, Joseph** [US/US]; 1415 Preston Spring Lane, Chapel Hill, NC 27516 (US).(74) Agent: **HUNT, Gregory, A.**; Jenkins, Wilson, Taylor & Hunt, P.A., Suite 1200, University Tower, 3100 Tower Boulevard, Durham, NC 27707 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: METHODS, SYSTEM, AND COMPUTER READABLE MEDIA FOR ANSWER-BASED ROUTING OF DIAMETER REQUEST MESSAGES

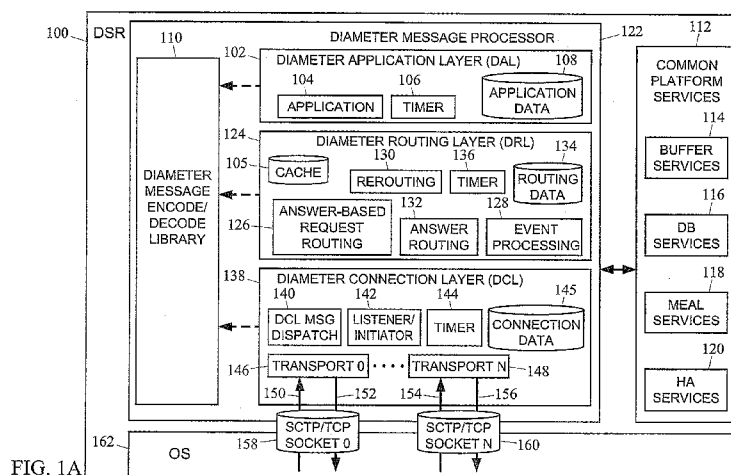


FIG. 1A

(57) Abstract: Methods, systems, and computer readable media for answer-based routing of Diameter request messages are disclosed. According to one method, a Diameter request message is received from a first Diameter node at a. A copy of at least a portion of the Diameter request message is cached at the DSR and the Diameter request message is routed to a second Diameter node. The DSR determines whether a predetermined condition associated with an answer to the first Diameter request message exists. In response to determining that the predetermined condition exists, the cached portion of the Diameter request message is retrieved, a Diameter request that includes the cached portion of the Diameter request message is generated, and the generated Diameter request message is routed.

## DESCRIPTION

METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR  
ANSWER-BASED ROUTING OF DIAMETER REQUEST MESSAGES

5

## PRIORITY CLAIM

This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/304,310, filed February 12, 2010; the disclosure of which is incorporated herein by reference in its entirety.

10

## STATEMENT OF INCORPORATION BY REFERENCE

The disclosures of each of the following commonly-owned, co-pending U.S. Patent Applications filed on February 11, 2011 are hereby incorporated herein by reference in their entireties:

“Methods, Systems, And Computer Readable Media For Inter-Diameter-Message Processor Routing,” Attorney Docket No. 1322/399/2 (Serial No. not yet assigned);

“Methods, Systems, And Computer Readable Media For Source Peer Capacity-Based Diameter Load Sharing” Attorney Docket No. 1322/399/3 (Serial No. not yet assigned);

20 “Methods, Systems, And Computer Readable Media For Inter-Message Processor Status Sharing,” Attorney Docket No. 1322/399/4 (Serial No. not yet assigned);

“Methods, Systems, And Computer Readable Media For Providing Priority Routing At A Diameter Node,” Attorney Docket No. 1322/399/5 (Serial No. not yet assigned);

25 “Methods, Systems, And Computer Readable Media For Providing Peer Routing At A Diameter Node,” Attorney Docket No. 1322/399/6/2 (Serial No. not yet assigned);

30 “Methods, Systems, And Computer Readable Media For Providing Origin Routing At A Diameter Node,” Attorney Docket No. 1322/399/7 (Serial No. not yet assigned);

“Methods, Systems, And Computer Readable Media For Providing Local Application Routing At A Diameter Node,” Attorney Docket No. 1322/399/8 (Serial No. not yet assigned);

5 “Methods, Systems, And Computer Readable Media For Performing Diameter Answer Message-Based Network Management At A Diameter Signaling Router (DSR),” Attorney Docket No. 1322/399/10 (Serial No. not yet assigned);

10 “Methods, Systems, And Computer Readable Media For Multi-Interface Monitoring And Correlation Of Diameter Signaling Information,” Attorney Docket No. 1322/399/11 (Serial No. not yet assigned);

“Methods, Systems, And Computer Readable Media For Diameter Protocol Harmonization,” Attorney Docket No. 1322/399/12 (Serial No. not yet assigned);

15 “Methods, Systems, And Computer Readable Media For Diameter Network Management,” Attorney Docket No. 1322/399/13 (Serial No. not yet assigned); and

“Methods, Systems, And Computer Readable Media For Diameter Application Loop Prevention,” Attorney Docket No. 1322/399/14 (Serial No. not yet assigned).

20

## TECHNICAL FIELD

The subject matter described herein relates to routing of Diameter messages. More specifically, the subject matter relates to methods, systems, and computer readable media for answer-based routing of  
25 Diameter request messages.

## BACKGROUND

Diameter is an authentication, authorization, and accounting (AAA) protocol for computer networks, and is a successor to RADIUS. The  
30 Diameter base protocol is defined in IETF RFC 3588, the disclosure of which is incorporated by reference herein in its entirety. Diameter communications may use a request-answer message exchange. Diameter routing involves routing of request messages in one direction and answer messages in the

reverse direction. However, Diameter routing does not use information learned from received Diameter answer messages or from non-receipt of expected Diameter answer messages to route request messages.

Accordingly, there exists a need for methods, systems, and computer readable media for answer-based routing of Diameter request messages.

## SUMMARY

Methods, systems, and computer readable media for answer-based routing of Diameter request messages are disclosed. According to one method, a Diameter request message is received from a first Diameter node at a. A copy of at least a portion of the Diameter request message is cached at the DSR and the Diameter request message is routed to a second Diameter node. The DSR determines whether a predetermined condition associated with an answer to the first Diameter request message exists. In response to determining that the predetermined condition exists, the cached portion of the Diameter request message is retrieved, a Diameter request that includes the cached portion of the Diameter request message is generated, and the generated Diameter request message is routed. Determining whether the predetermined condition exists may include determining whether a received Diameter answer message that correlates with the request message sent to the second Diameter node includes non-protocol 3xxx error indicator information. Determining whether a predetermined condition associated with an answer message exists may also include determining whether the answer message or the request message is lost. Determining whether the answer or request message is lost may include initiating a timer when the request message is sent to the second Diameter node. If an answer to the request message is not received before the timer reaches a predetermined value, then the answer or the request (or both) is determined to be lost. Determining whether a predetermined condition associated with an answer to the request message exists may also include receiving an answer message, and determining whether additional service information is required before responding to the request originator.

According to another aspect of the subject matter described herein, a system for answer-based routing of Diameter request messages is provided. The system includes a DSR. The DSR includes a Diameter message processor for receiving a Diameter request message from a first Diameter node. The DSR further includes a caching module that caches a copy of at least a portion of the Diameter answer message. The DSR further includes an answer message-based request routing module that is configured to route the Diameter request message to a second Diameter node, to determine whether an error condition associated with an answer to the first Diameter request message exists, and, response to determining that the error condition exists, the answer message-based routing module retrieves the cached portion of the Diameter request message, generates a Diameter request message that includes the cached portion of the Diameter request message, and routes the generated Diameter request message.

The subject matter described herein can be implemented in software in combination with hardware and/or firmware. For example, the subject matter described herein can be implemented in software executed by a processor. In one exemplary implementation, the subject matter described herein can be implemented using a non-transitory computer readable medium having stored thereon executable instructions that when executed by the processor of a computer control the processor to perform steps. Exemplary non-transitory computer readable media suitable for implementing the subject matter described herein include chip memory devices or disk memory devices accessible by a processor, programmable logic devices, and application specific integrated circuits. In addition, a computer readable medium that implements the subject matter described herein may be located on a single computing platform or may be distributed across plural computing platforms.

## BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter described herein will now be explained with reference to the accompanying drawings of which:

Figure 1A is a block diagram of an exemplary Diameter signaling router for performing answer-based routing of Diameter request messages according to an embodiment of the subject matter described herein;

5 Figure 1B illustrates an exemplary Diameter signaling router with a distributed internal architecture and that performs answer-based routing of diameter signaling messages according to an embodiment of the subject matter described herein;

Figure 2 is a flow chart illustrating exemplary steps for answer-based routing of Diameter request messages according to an embodiment of the  
10 subject matter described herein;

Figure 3 is a message sequence diagram illustrating an exemplary conditional-on-response "error" condition scenario as part of performing answer-based routing of Diameter request messages according to an embodiment of the subject matter described herein;

15 Figure 4 is a flow chart illustrating exemplary steps for answer-based routing of Diameter request messages according to an embodiment of the subject matter described herein;

Figure 5 is a message sequence diagram illustrating an exemplary conditional-on-response "non-error" condition scenario as part of answer-based routing of Diameter request messages according to an embodiment of  
20 the subject matter described herein; and

Figure 6 is a message sequence diagram illustrating an exemplary conditional-on-response "non-error" condition scenario as part of answer-based routing of Diameter request messages according to an embodiment of  
25 the subject matter described herein.

#### DETAILED DESCRIPTION

Figure 1A is a block diagram of an exemplary Diameter signaling router (DSR) for performing Diameter answer message-based routing of  
30 Diameter request messages according to embodiments of the subject matter described herein. DSR 100 may perform a variety of Diameter message routing functions and, therefore, may include functionality including a Diameter routing agent, Diameter translation agent, Diameter proxy agent,

Diameter relay agent, and/or Diameter redirect agent. However, for the sake of simplicity, the term DSR will be used throughout the description of the subject matter disclosed herein to refer to an entity that performs these functions. Referring to Figure 1A, DSR **100** may include a Diameter connection layer (DCL), Diameter routing layer (DRL), one or more applications, and one or more routing tables. Exemplary DRL capabilities may include: routing request messages to peers or local applications based on message content, discarding or rejecting Diameter request messages based on message content rules, peer congestion control, allowing an operator to access only the features and capacities that are purchased, and easier configuration. DSR **100** may support Relay Agent Diameter message routing and a variety of value-add services/applications. In order to support both application processing and core Diameter routing functions, DSR **100** may support two message routing tables: an application routing table (ART) and a peer routing table (PRT). Additionally, the subject matter described herein for performing Diameter answer-based routing of Diameter request messages may be designed with the assumption that answer messages or routed request messages will be lost and, therefore, effectively handle lost answer or request messages in order to avoid wasting memory or other resources to maintain pending transaction records for transactions that are no longer pending.

Diameter application layer (DAL) **102** may include applications **104**. Exemplary applications **104** may include, but are not limited to, a Diameter client, Diameter server, translation agent, proxy agent, redirect agent, integrated monitoring application, Diameter message screening and filtering application, Diameter firewall application, and a load generator. Diameter application layer **102** may also include timer **106** and application data **108**. DAL **102** may interface with Diameter message encode/decode library **110** for encoding and decoding Diameter messages.

Common platform services **112** may include buffer services **114**, database services **116**, measurements events alarms and logs (MEAL) services **118**, and high availability (HA) services **120**.

Diameter message processor (MP) **122** may further include Diameter routing layer (DRL) **124**. DRL **124** may be responsible for the following functions. DRL **124** may perform ingress and egress message looping detection and prevention. DRL **124** may route ingress message to one or  
5 more local DSR applications based upon user-defined rules. DRL **124** may reroute messages upon failures. DRL **124** may perform message routing based upon route priorities and weights. DRL **124** may perform message routing based upon user-defined message content. DRL **124** may perform message routing to peers with multiple transport connections. DRL **124** may  
10 manage peer transport connections (TPS). DRL **124** may throttle ingress messages based upon local DSR congestion. DRL **124** may detect and avoid peer congestion. DRL **124** may load balance peer connection load to meet transaction per second (TPS) constraints of Diameter message processor **122**.

15 DRL **124** may include answer-based request routing module **126**, event processing module **128**, DRL rerouting module **130**, answer routing module **132**, routing data **134**, and DRL timer task **136**. Answer-based request routing module **126** may perform the operations described herein for answer-based routing of Diameter request messages.

20 DRL **124** may communicate with DAL **102** via message-based APIs. For example, DRL **124** may use application indication and application request APIs to communicate with DAL **102**.

Diameter connection layer (DCL) **138** may perform the following functions. DCL **138** may implement Diameter connection state machine **140**  
25 for each Diameter peer. DCL **138** may establish transport connections with Diameter peers and process Diameter peer-to-peer messages and related functionality. This may include capabilities exchange request/answer (CER/CEA), Diameter Watchdog request/answer (DWR/DWA), and Disconnect Peer request/answer (DPR/DPA). DCL **138** may interface with  
30 the DRL **124** by sending Diameter messages received from peers to DRL **124** using one or more message-based APIs. DCL **138** may send Diameter messages received from DRL **124** to the appropriate peer. DCL **138** may notify DRL of peer transport connection and congestion status changes.



DCL **138** may process configuration and maintenance requests from DSR OAM for transport configuration objects. DCL **138** may update MEAL data for transport configuration objects. DCL **138** may perform transport layer capacity control.

5 DCL **138** may include Diameter message dispatch module **140**, DCL listener/initiator module **142**, DCL timer task **144**, and connection data **145**.

DCL **138** may also include one or more IP transport tasks. For example, DCL **138** may include IP transport task **146** and **148**, where each IP transport task includes a receiving thread and a transmitting thread. For  
10 example, IP transport task **146** includes Rx thread **150** and Tx thread **152** and IP transport task **148** includes Rx thread **154** and Tx thread **156**. IP transport tasks **146** and **148** may each communicate with SCTP/TCP sockets for interfacing with an operating system. For example, IP transport task **146** may communicate with SCTP/TCP socket **158** and IP transport  
15 task **148** may communicate with SCTP/TCP socket **160**. SCTP/TCP sockets **158** and **160** may be associated with OS **162**.

For simplicity, DSR **100** illustrated in Figure 1A includes a single message processor **122**. This is one possible configuration of DSR **100**, where a single message processor routes all Diameter signaling messages.  
20 However, DSR **100** may include plural message processors, each configured as message processor **122** illustrated in Figure 1A. Figure 1B illustrates such an embodiment. In Figure 1B, DSR **100** includes a plurality of message processors **122A-D**, each of which sends Diameter signaling messages to and receives Diameter signaling messages from a Diameter  
25 network. Message processors **122A-D** may be connected through an internal network **162**. Although each message processor **122A-D** may include all of the components of message processor **122** illustrated in Figure 1A, for simplicity, only answer-based message routing module **126** and message cache **105** are shown.

30 In operation, when a Diameter message arrives at one of message processors **122A-D**, the message is routed based on Diameter signaling information in the message from the ingress message processor to the egress message processor, and from the egress message processor to the

Diameter network. As will be described in detail below, each Diameter message processor **122A-D** may perform the steps described herein for answer-based routing of Diameter request messages, which may in some instances over-ride or supplement the routing of Diameter messages based on Diameter signaling information.

Figure 2 is a flow chart illustrating exemplary steps for answer-based routing of Diameter request according to an embodiment of the subject matter described herein. It may be appreciated that the exemplary scenario described in Figure 2 includes a determination as to whether Diameter answer messages contain non-protocol 3xxx error information. However, routing of Diameter request messages by DSR **100** is not intended to be limited to only a non-protocol 3xxx error determination and may include determining whether Diameter messages include any error indicator information (e.g., Diameter transient failure 4xxx, Diameter permanent failure 5xxx) without departing from the scope of the subject matter described herein. Referring to Figure 2, in step **200**, a Diameter request message may be received at a DSR from a first Diameter node. For example, a request message associated with service A may be received by DSR **100** from a source Diameter peer node.

In step **202**, a copy of at least a portion of the Diameter request message is cached at the DSR. For example, a portion of (or the entirety of) a Diameter request message may be stored in routing data **134** on DSR **100**.

In step **204**, Diameter request message is routed to a second Diameter node. For example, the request message may be forwarded, by DSR **100**, to Diameter node 1 for performing service A.

In step **206**, a Diameter answer message associated with the Diameter request message from the second node is received at the DSR. For example, DSR **100** may receive a Diameter answer message corresponding to the Diameter request message for service A.

In addition, one embodiment of DSR **100** may include DCL **138** and DRL **124** being hosted on different computers and/or multiple interacting instances of DCL **138** and DRL **124** (i.e., scalable DSR). As such, an additional step (not shown) may be performed between steps **206** and **208**

during which DCL **138** may determine the location of the DRL **124** having the cached copy of the corresponding request message and forward the answer message to that instance of DRL **124**. However, for simplicity of illustration and description, unless otherwise noted, embodiments described herein  
5 assumed a single instance of DRL **124** co-located with DCL **138**.

In step **208**, it is determined whether the received Diameter answer message contains non-protocol 3xxx error information. A non-protocol error is one that occurs at the base protocol level and may require per hop attention. Exemplary 3xxx error codes and their corresponding descriptions  
10 are listed below.

DIAMETER\_COMMAND\_UNSUPPORTED 3001

The request contained a Command-Code that the receiver did not recognize or support. This is used when a Diameter node receives an experimental command that it does not understand.

15 DIAMETER\_UNABLE\_TO\_DELIVER 3002

This error is given when Diameter cannot deliver the message to the destination, either because no host within the realm supporting the required application was available to process the request, or because Destination-Host AVP was given without the associated Destination-Realm AVP.

20 DIAMETER\_REALM\_NOT\_SERVED 3003

The intended realm of the request is not recognized.

DIAMETER\_TOO\_BUSY 3004

This error must be used when a specific server is requested and it cannot provide the requested service.

25 DIAMETER\_LOOP\_DETECTED 3005

An agent detected a loop while trying to get the message to the intended recipient.

DIAMETER\_REDIRECT\_INDICATION 3006

A redirect agent has determined that the request could not be  
30 satisfied locally.

DIAMETER\_APPLICATION\_UNSUPPORTED 3007

A request was sent for an application that is not supported.

DIAMETER\_INVALID\_HDR\_BITS 3008

A request was received whose bits in the Diameter header were either set to an invalid combination, or to a value that is inconsistent with the command code's definition.

DIAMETER\_INVALID\_AVP\_BITS 3009

- 5 A request was received that included an AVP whose flag bits are set to an unrecognized value, or that is inconsistent with the AVP's definition.

DIAMETER\_UNKNOWN\_PEER 3010

A CER was received from an unknown peer.

- Returning to Figure 2, if the received Diameter answer message does
- 10 not contain non-protocol 3xxx error information, control proceeds to step **210** where the answer message may be processed normally. For example, if DSR **100** receives an answer message with error cause 'Diameter\_Too\_Busy' and the Origin-Host of the answer message equals the Destination-Host of the original request, DSR **100** may process the answer
- 15 message normally. Alternatively, if DSR **100** receives an answer message with error cause 'Diameter\_Too\_Busy' and the Origin-Host of the answer message does not equal the Destination-Host of the original request, then DSR **100** may discard the answer message and attempt to re-route the request message according to the routeset used to route the original
- 20 message. Additionally, in the event that a peer node transport failure or timeout is detected, DSR **100** may apply alternate routing of any pending transactions (for which DSR **100** had sent a request, but not received an answer message yet) according to the routeset used to route the original message. If an alternate route is not available when re-routing is attempted,
- 25 DSR **100** may process the answer message normally.

If the received Diameter answer message contains non-protocol 3xxx error information, then control proceeds to step **212** where the Diameter request message's copy associated with the Diameter answer message is retrieved from the cache.

- 30 In step **214**, the Diameter message copy is routed. The Diameter message may be routed to the second Diameter node and after a configurable number of failed delivery attempts, to a third Diameter node. Alternatively, the Diameter message copy may be sent to a third Diameter

node after detecting the error condition associated with the answer message. For example, the request message for service A may be forwarded to Diameter node 2 for performing service A. DSR **100** may allow the user to define a set of cause values which, when received, may result in  
5 alternate routing being attempted. The set of cause values may be found, for example, in the result-code attribute value pair (AVP) of the message.

In one embodiment, upon receiving an answer message responsive to a message sent by DSR **100**, DSR **100** may add the original Hop-by-Hop ID from the request message to an answer message, forward the answer  
10 message to the original peer from which DSR **100** received the corresponding request message, and purge the corresponding request message. It may be appreciated that the user/operator may specify whether to make a copy of an answer message and route it to a specified Diameter destination.

15 In another embodiment, upon receiving an answer message for which DSR **100** has no pending transaction, DSR **100** may discard the message and, according to one possible embodiment, generate a UIM.

Figure 3 is a message sequence diagram illustrating an exemplary conditional-on-response "error" condition scenario as part of performing  
20 answer-based routing of Diameter request messages according to an embodiment of the subject matter described herein. Referring to Figure 3, DSR **100** and associated answer-based request routing module **126** may communicate with client Diameter node **300**, server Diameter node **302A** and server Diameter node **304A**. For example, client Diameter node **300**  
25 may send Diameter request message **306** for service A to DSR **100**. DSR **100** may cache a copy of at least a portion of the Diameter request message and route Diameter request message **308** for service A to server Diameter node **302A**. Server Diameter node **302A** may return Diameter answer message **310** that includes error information. At step **312**, DSR **100** may  
30 analyze Diameter answer message **310** to determine whether Diameter answer message **310** includes non-protocol 3xxx error information. In the scenario shown, Diameter answer message **310** may be determined to include non-protocol 3xxx error information and, therefore, DSR **100** may

retrieve the Diameter request message copy from the cache **105** and route Diameter request message **314** to server Diameter node **304A**. In response, server Diameter node **304A** may return Diameter answer message **316** (e.g., Answer message (non-error to client Diameter node **300**). At step **318**, DSR  
5 **100** may analyze the answer message and, in step **320**, DSR **100** may forward Diameter answer message (non-error) **316** to client Diameter node **300**.

Figure 4 is a flow chart illustrating exemplary steps for performing Diameter answer-based routing of request messages according to an  
10 embodiment of the subject matter described herein. In the example illustrated in Figure 4, information from a first answer message is cached and used to generate and route a new request message, as described above. However, the first answer message may not indicate an error condition, but may indicate that further or additional service information is  
15 required before sending an answer to the request originator. Referring to Figure 4, in step **400**, a first Diameter request message is received from a first Diameter node at a DSR. For example, DSR **100** may receive a Diameter request message for service A from a client Diameter node.

In step **402**, the first Diameter request message is routed to a second  
20 Diameter node. For example, the Diameter request message for service A may be forwarded, by DSR **100**, to Diameter node 1, which may be a server.

In step **404**, a first Diameter answer message associated with the first Diameter request message from the second Diameter node is received at the DSR. For example, DSR **100** may receive a Diameter answer message  
25 from the Diameter server corresponding to the request message for service A.

In step **406**, information contained in the first Diameter answer message is analyzed to determine whether additional service information is needed before answering the request originator. For example, the first  
30 Diameter request message may be a request for subscriber information from an HSS, and the first answer message may be an indication that the subscriber is not provisioned in the HSS. Accordingly, step **406** may include

analyzing the first answer message to determine that a second Diameter request message to a second HSS is needed.

If no additional service information is determined to be needed, control proceeds to step **407** where the DSR sends an answer message to the request originator. If, in step **406**, it is determined that additional service information is needed, control proceeds to step **408** where a copy of at least a portion of the first Diameter answer message is cached at the DSR. For example, DSR **100** may cache the answer message in message cache **105**. In an embodiment in which the DCL and DRL layers are implemented on different computers, the DCL may determine the location of the DRL having the cached copy of the corresponding request message and may forward the answer message to that instance of the DRL. The DRL may then cache the answer message along with the corresponding request in its message cache **105**.

In step **410**, a second Diameter request message is generated, and, in step **412**, the second Diameter request message is routed to a third Diameter node. For example, Diameter message B may be generated and forwarded to Diameter node 2, which in this example may be a new HSS.

In step **414**, a second Diameter answer message associated with the second Diameter request message is received from the third Diameter node. For example, DSR **100** may receive Diameter answer message B. Continuing with the example, answer message B may be an update location answer message from the new HSS and may include the requested subscriber information.

In step **416**, information from the first Diameter answer message copy and the second Diameter answer message are combined. For example, information from the first Diameter answer message that indicates that the subscriber is not provisioned in the first queried HSS and information from the second answer message indicating that the subscriber is provisioned in the second queried HSS along with the requested subscription information may be combined.

In step **418**, a Diameter answer message containing the combined information is sent to the first Diameter node. For example, a Diameter

answer message containing the non-serving HSS, serving HSS, and subscription information may be forwarded to the source Diameter peer node that sent the original Diameter request message.

Figure 5 is a message sequence diagram illustrating an exemplary conditional-on-response “non-error” condition scenario as part of performing answer-based routing of Diameter request messages according to an embodiment of the subject matter described herein. The message flow in Figure 5 provides an example of the processing described above with respect to Figure 4. Referring to Figure 5, DSR **100** may include message cache **105** and answer-based Diameter request routing module **126** as described above. In Figure 5, client Diameter node **300** may send Diameter request message **500** for service A to DSR **100**. DSR **100** may cache a copy of at least a portion of the Diameter request message and forward Diameter request message **502** for service A to server Diameter node **302A**. Server Diameter node **302A** may return Diameter answer message **504**.

At step **506**, DSR **100** may analyze the information contained in Diameter answer message **504** and trigger a new request B message. For example, DSR **100** may determine that additional service is required before answering client Diameter node **300**. Examples of additional processing include the above-described HSS example or an example where multiple different service nodes providing the same or different services are required to be queried before responding to a Diameter request originator.

In the scenario shown, DSR **100** may generate Diameter request message **508** for service B, which may be the same or a different service from service A. In response, server Diameter node **304B** may return Diameter answer message (e.g., answer message (non-error)) **510** for service B. At step **512**, DSR **100** may analyze Diameter answer message **510** and combine information from Diameter answer messages **504** and **510**. DSR **100** may then send Diameter answer message **514** containing the combined information from Diameter answer messages **504** and **510** to client Diameter node **300**.

Figure 6 is a message sequence diagram illustrating an exemplary conditional-on-response “non-error” condition scenario as part of performing



Diameter answer message-based routing at a DSR according to an embodiment of the subject matter described herein. Referring to Figure 6, client Diameter node **300** may send Diameter request message **600** for service A to DSR **100**.

5           At step **602**, DSR **100** may store a copy of Diameter request message **600**. At step **604**, request A message may be routed and a response timer may be started. DSR **100** may then send Diameter request message **606** for service A to server Diameter node **302A**.

          At step **608**, it may be determined whether the timer has expired  
10       without receiving a Diameter answer message for Diameter request message **606**. If the timer has expired, at step **610**, DSR **100** may retrieve a copy of Diameter request message **606** and select an alternate route to server Diameter node **302A** to which Diameter request message **606** should be sent and record an indication that delivery to server Diameter node **302A**  
15       was attempted and failed to limit redelivery attempts to server node **302A**. DSR **100** may then send Diameter request message **612** to server Diameter node **304A**. In response, server Diameter node **304A** may return Diameter answer (e.g., answer A message (non-error)) message **614** to DSR **100**. At step **616**, DSR **100** may analyze answer B message and, at step **618**, DSR  
20       **100** may forward Diameter answer A+B message (non-error) to client Diameter node **300**.

          In addition to the scenario described above, it may be appreciated that the loss of a request message sent by DSR **100** may be indistinguishable (e.g., treated the same) from the loss of an answer  
25       message sent to DSR **100** by a peer node. In the event of a lost request message, it may be appreciated that the peer node would never send an answer message.

#### Lost Answer Messages

          When answer messages are lost prior to their receipt by DSR **100**, the  
30       “pending transactions” associated with the lost answer messages may either be aborted (answer message sent to peer) or re-routed. Since DSR **100** cannot “detect” a lost answer message, nor can it query the remote status of

a forwarded request message, it may predict with high probability that one has been lost.

One method may be time-based. If an answer has not been received in "X" seconds, then the answer message may be assumed to most likely be lost. The larger the value of "X", the higher the probability of loss. In one embodiment, a DRL "Lost answer Timer" may be supported and operator-configurable. An exemplary default value for X may be 30 seconds. It may be appreciated that the value of X may also be application dependent. For example, if the "Lost answer Timer" is application specific and DSR 100 supports multiple applications, the value may be per-application specific. It may also be appreciated that when the "Lost answer Timer" expires, DRL 124 may abort the transaction (default) and send an answer message to an originator of the request indicating an error condition. In another embodiment, DRL 124 may re-route the transaction. Additionally, it may be appreciated that if a connection fails at DSR 100, and it is the only connection between DSR 100 and a peer node, then all pending answer messages for that connection may be deemed, by DSR 100, to be lost.

#### Processing Answer Messages From Redirect Agents

As discussed previously, a forwarded request message may be routed to a Redirect Agent which sends an answer message containing an ordered list of hosts for routing the message. The base Diameter specification states that the recipient of a redirect response may re-route a pending request message using Redirect-Host AVPs, but does not require the recipient to do so. Therefore, in one embodiment, rather than re-routing the original request message using the redirect routing information received, DSR 100 may be configured to backwards-route the redirect response. However, because backwards routing may not be supported by a downstream peer in all customer networks, in another possible embodiment, the answer message may be re-routed using Redirect-Host AVPs. It may be appreciated that the process for redirecting an answer message may be a DRL-configurable option. As such, an operator may configure DRL 124 to use backward propagation as the default option.

### Routing Answer Messages to Unavailable/Congested Peers

When DRL **124** receives an answer message and the message cannot be immediately delivered because the transport layer queue for the peer is full or the peer is congested, then DRL **124** has two options: delay  
5 delivery of the message within DRL **124** or immediately discard the answer message.

Delaying delivery of the message within DRL **124** may include buffering answer messages for a configurable time-period X1. If the peer's status changes before the timer expires, then the buffered answer messages  
10 may be forwarded. If the timer expires and the peer is available, then an attempt may be made to forward the buffered answer message until the buffer is flushed or another blocking condition occurs (e.g., transport queue full). In order to prevent an answer message from being queued indefinitely, a "maximum answer message queue delay" may be supported (i.e.,  
15 message aging) where the answer message may be discarded when the above mentioned maximum delay is exceeded. It may be appreciated that if the transport connection is blocked for an inordinate period of time, preventing any answer messages from being sent, the transport layer may be disconnected in order to clear the condition and trigger the peer to re-  
20 forward the messages in the pending transaction queue(s).

It will be appreciated that in some or all of the embodiments described above, the DSR may be adapted to record or log each occurrence of a Diameter answer message error-driven routing event. The DSR may include in such log entries information associated with the related routing action  
25 taken by the DSR. The DSR may provide this information Diameter answer-based routing event log information to a network operations center or other network administration system.

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

## CLAIMS

What is claimed is:

1. A method for answer-based routing of Diameter request messages, the method comprising:
  - 5 at a Diameter signaling router (DSR):
    - receiving a Diameter request message from a first Diameter node;
    - caching, at the DSR, a copy of at least a portion of the Diameter request message;
    - 10 routing the Diameter request message to a second Diameter node;
    - determining whether a predetermined condition associated with an answer to the first Diameter request message exists; and
    - in response to determining that the predetermined condition exists:
      - 15 retrieving the cached portion of the Diameter request message;
      - generating a Diameter request message that includes the cached portion of the Diameter request message; and
      - 20 routing the generated Diameter request.
2. The method of claim 1 wherein routing the generated Diameter request message includes at least one of: attempting to deliver the generated Diameter request to the second Diameter node and sending the generated Diameter request message to a third Diameter node.
- 25 3. The method of claim 1 wherein determining whether the predetermined condition exists includes receiving a Diameter answer message, correlating the answer message with the received Diameter request message, and determining whether the Diameter answer message includes one of non-protocol 3xxx error indicator information, transient 4xxx error indicator information, and permanent 30 5xxx error indicator information.

4. The method of claim 1 wherein determining whether the predetermined condition exists includes initiating a timer with the Diameter request message is routed and detecting that the timer has reached a predetermined value without receipt of an answer message that correlates with the routed Diameter request message.
5. The method of claim 1 wherein determining whether the predetermined condition exists includes determining whether an operational connection exists between the DSR and the second Diameter node.
- 10 6. The method of claim 1 comprising receiving a Diameter answer message and discarding the received Diameter answer message in response to determining that no pending transaction exists at the DSR corresponding to the Diameter answer message.
7. The method of claim 1 comprising storing, at the DSR, Diameter answer message-based routing event log information that includes information associated with at least one occurrence of a detected Diameter answer message-based error condition.
- 15 8. The method of claim 7 comprising storing, with the Diameter answer message-based routing event log information at the DSR, routing action information that includes information associated with a routing action taken by the DSR.
- 20 9. The method of claim 8 comprising providing, by the DSR, the Diameter answer-based routing event log information to one of a network operations center or network administration system.
- 25 10. The method of claim 1 wherein determining predetermined condition exists includes receiving, at the DSR, a first Diameter answer message associated with the first Diameter request message from the second Diameter node, analyzing information contained in the first Diameter answer message, to determine whether additional service information is required before answering the first Diameter node, and, in response to determining that additional service information is required:
- 30

- caching at least a portion of the information contained in  
the first Diameter answer message:  
    generating a second Diameter request message; and  
    routing the second Diameter request message to a third  
5     Diameter node;  
    receiving, at the DSR, a second Diameter answer  
message associated with the second Diameter request  
message from the third Diameter node;  
    combining the cached information from the first  
10     Diameter answer message copy with information from the  
second Diameter answer message; and  
    sending a Diameter answer message containing the  
combined information to the first Diameter node.
11.   A system for answer-based routing of Diameter request messages,  
15     the system comprising:  
    a Diameter signaling router (DSR) including:  
    a Diameter message processor for receiving a Diameter  
request message from a first Diameter node;  
    a caching module for caching a copy of at least a portion of the  
20     Diameter request message; and  
    an answer message-based request routing module for:  
    routing the Diameter request message to a second  
Diameter node;  
    determining whether a predetermined condition  
25     associated with an answer to the first Diameter request  
message exists; and  
    in response to determining that the predetermined  
condition exists:  
    retrieving the cached portion of the Diameter  
30     request message;  
    generating a Diameter request message that  
includes the cached portion of the Diameter request  
message; and

routing the generated Diameter request message.

12. The system of claim 11 wherein the answer-based request routing module is configured to attempt to route the generated Diameter request message to one of: the second Diameter node and a third Diameter node.
13. The system of claim 11 wherein the answer-based request routing module is configured to receive a Diameter answer message, correlate the answer message with the received Diameter request message, and determine whether the received Diameter answer message includes one of non-protocol 3xxx error indicator information, transient 4xxx error indicator information, and permanent 5xxx error indicator information.
14. The system of claim 11 wherein the answer-based request routing module is configured to determine whether the predetermined condition exists by initiating a timer when the Diameter request message is routed and detecting that the timer has reached a predetermined value without receipt of an answer message that correlates with the routed Diameter request message.
15. The system of claim 11 wherein the answer-based request routing module is configured to determine whether an operational connection exists between the DSR and the second Diameter node.
16. The system of claim 11 wherein the Diameter message processor is configured to determine whether no Diameter answer message responsive to the Diameter request message has been received by the DSR.
17. The system of claim 11 wherein the answer—based request routing module is configured to receive a Diameter answer message and discard the received Diameter answer message in response to determining that no pending transaction exists at the DSR corresponding to the Diameter answer message.
18. The system of claim 11 wherein the caching module is configured to store Diameter answer message-based routing event log information

that includes information associated with at least one occurrence of a detected Diameter answer message-based error condition.

19. The system of claim 18 wherein the caching module is configured to store, with the Diameter answer message-based routing event log information at the DSR, routing action information that includes information associated with a routing action taken by the DSR.
20. The system of claim 18 wherein the answer-based request routing module is configured to provide the Diameter answer-based routing event log information to one of a network operations center or network administration system.
21. The system of claim 11 wherein, in determining whether the predetermined condition exists, the answer-based request routing module is configured to:
- analyze information contained in the first Diameter answer message to determine whether additional service information is required before answering the first Diameter node;
  - in response to Determining that additional service information is required:
    - caching at least a portion of the information contained in the first Diameter answer message;
    - generate a second Diameter request message;
    - route the second Diameter request message to a third Diameter node; and
  - receiving a second Diameter answer message;
  - combining the cached information from the first Diameter answer message with information from the second Diameter answer message; and
  - generating and routing to the first Diameter node, a third Diameter message including the combined information.
22. A non-transitory computer readable medium comprising computer executable instructions embodied in a non-transitory computer



readable medium and when executed by a processor of a computer performs steps comprising:

at a Diameter signaling router (DSR)

5 receiving a Diameter request message from a first Diameter node;

        caching, at the DSR, a copy of at least a portion of the Diameter request message;

        routing the Diameter request message to a second Diameter node;

10 determining whether a predetermined condition associated with an answer to the first Diameter request message exists; and

        in response to determining that the predetermined condition exists:

15 retrieving the cached portion of the Diameter request message; and

        generating a Diameter request message that includes the cached portion of the Diameter request message; and

        routing the generated Diameter request message.

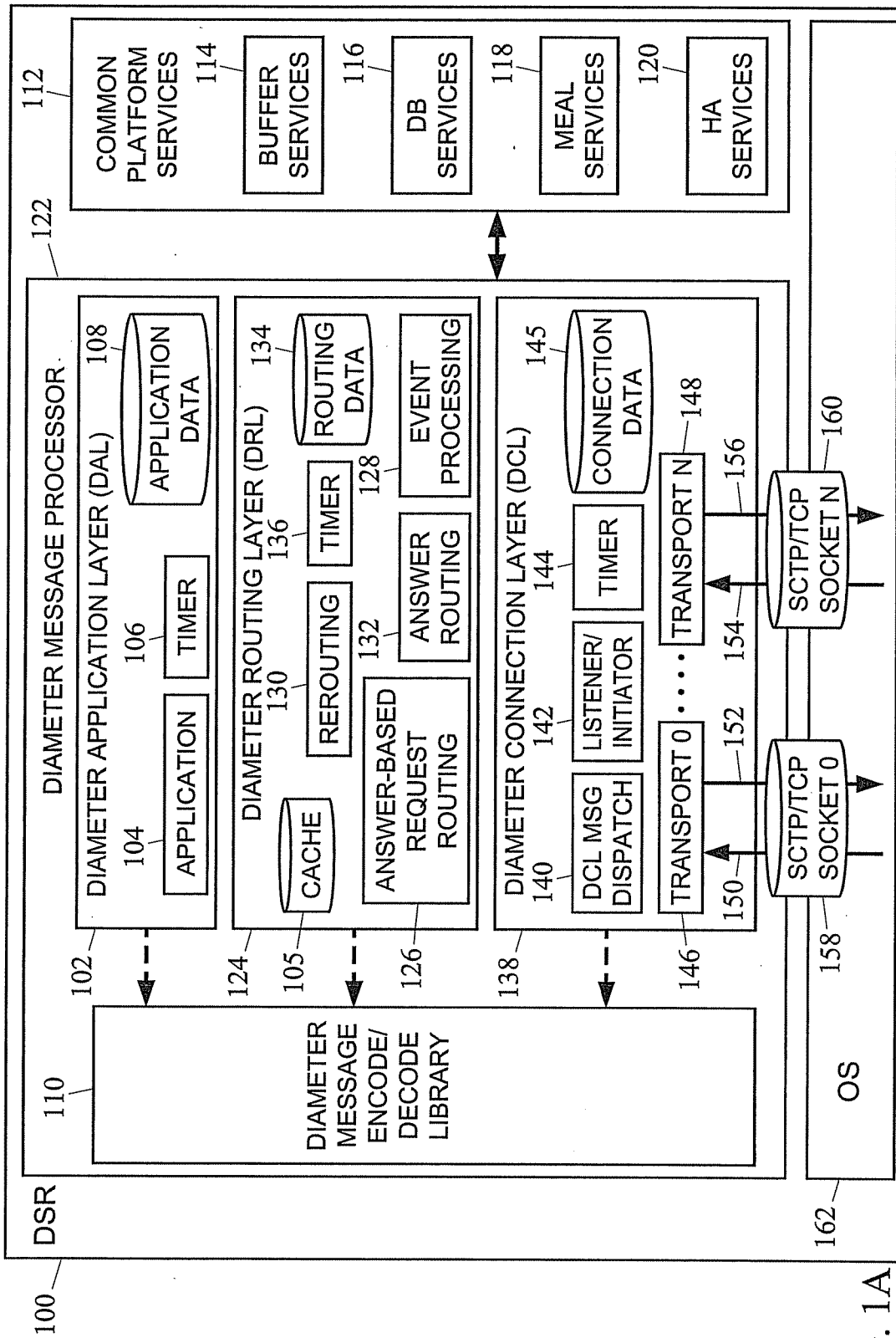


FIG. 1A

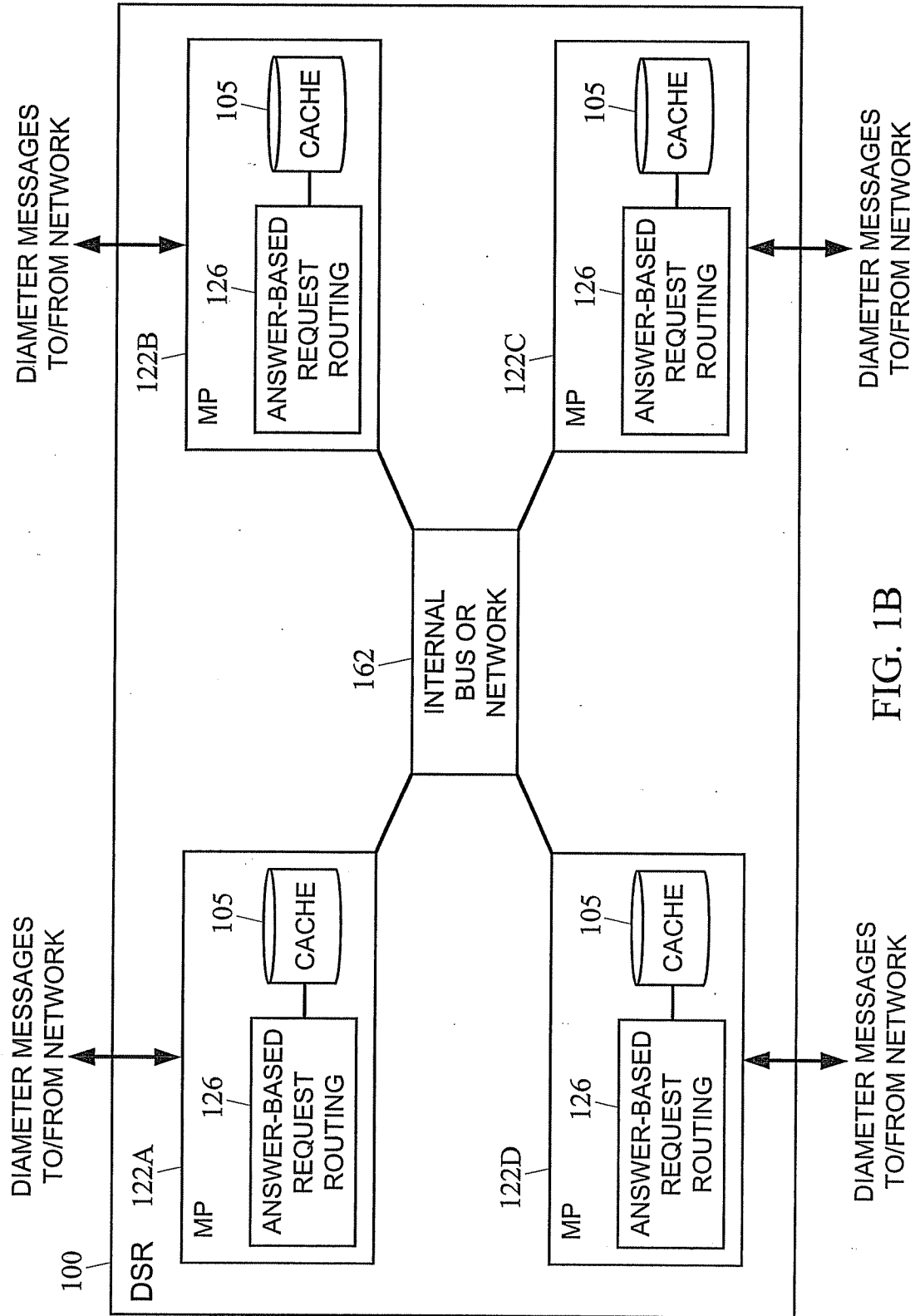


FIG. 1B

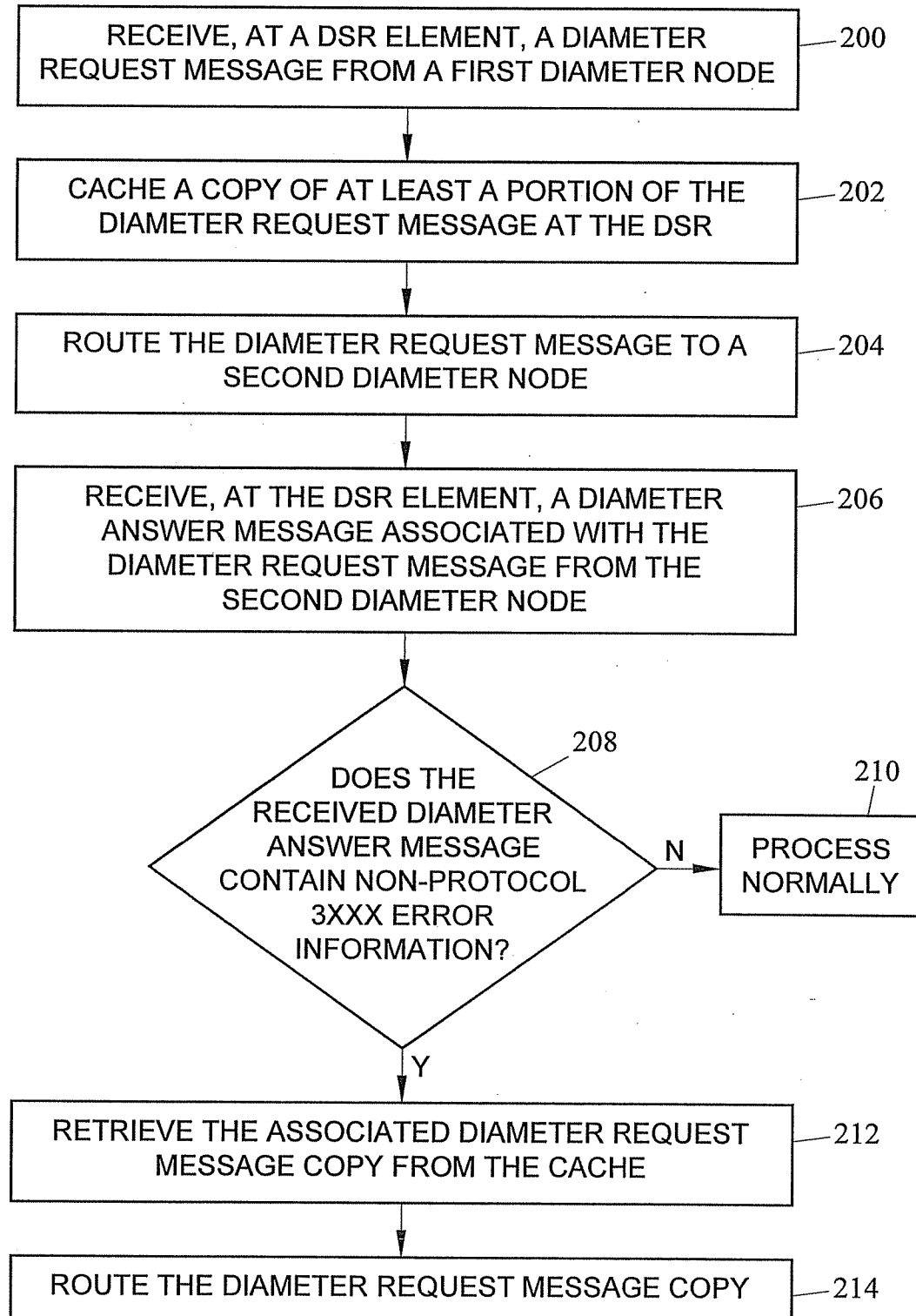
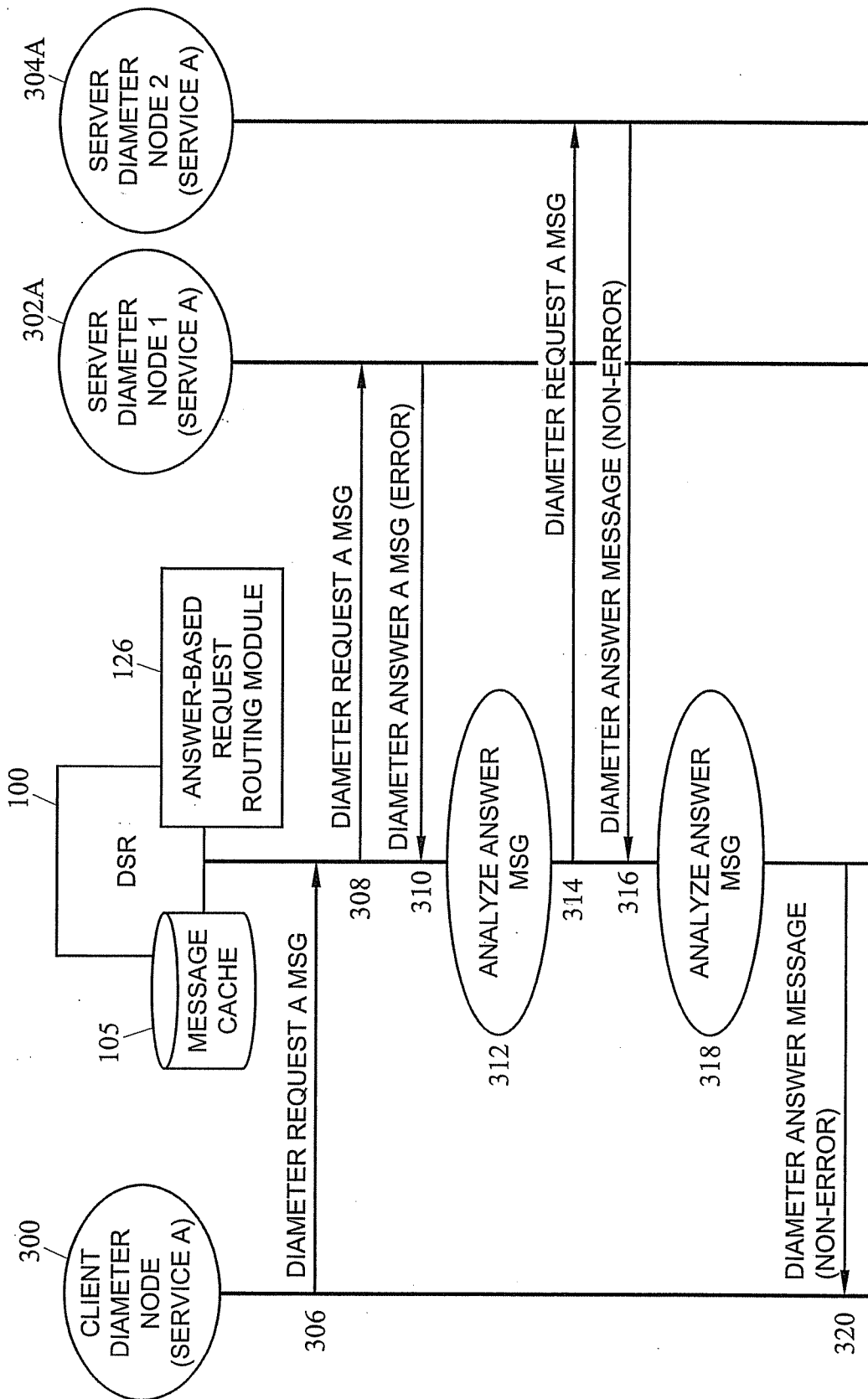


FIG. 2



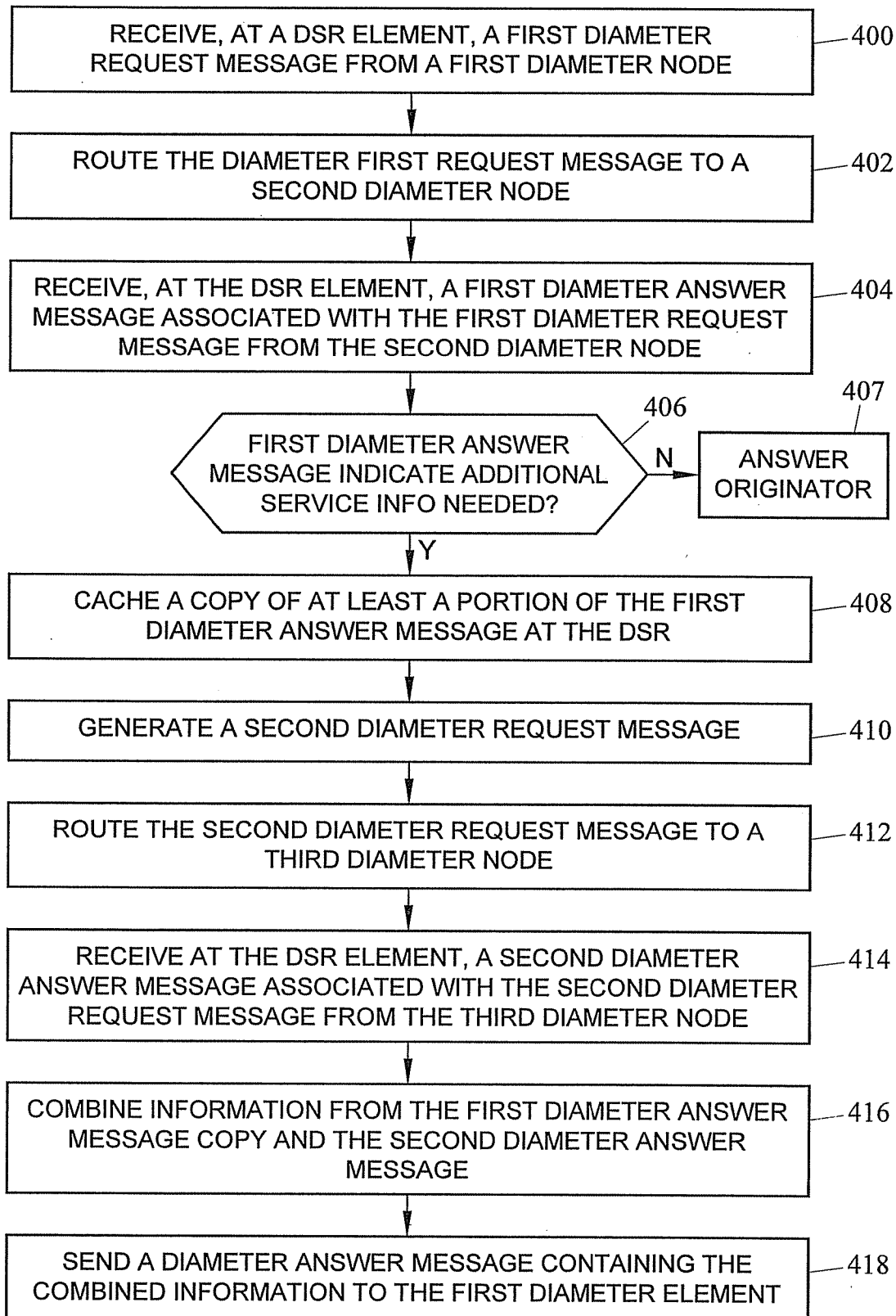


FIG. 4

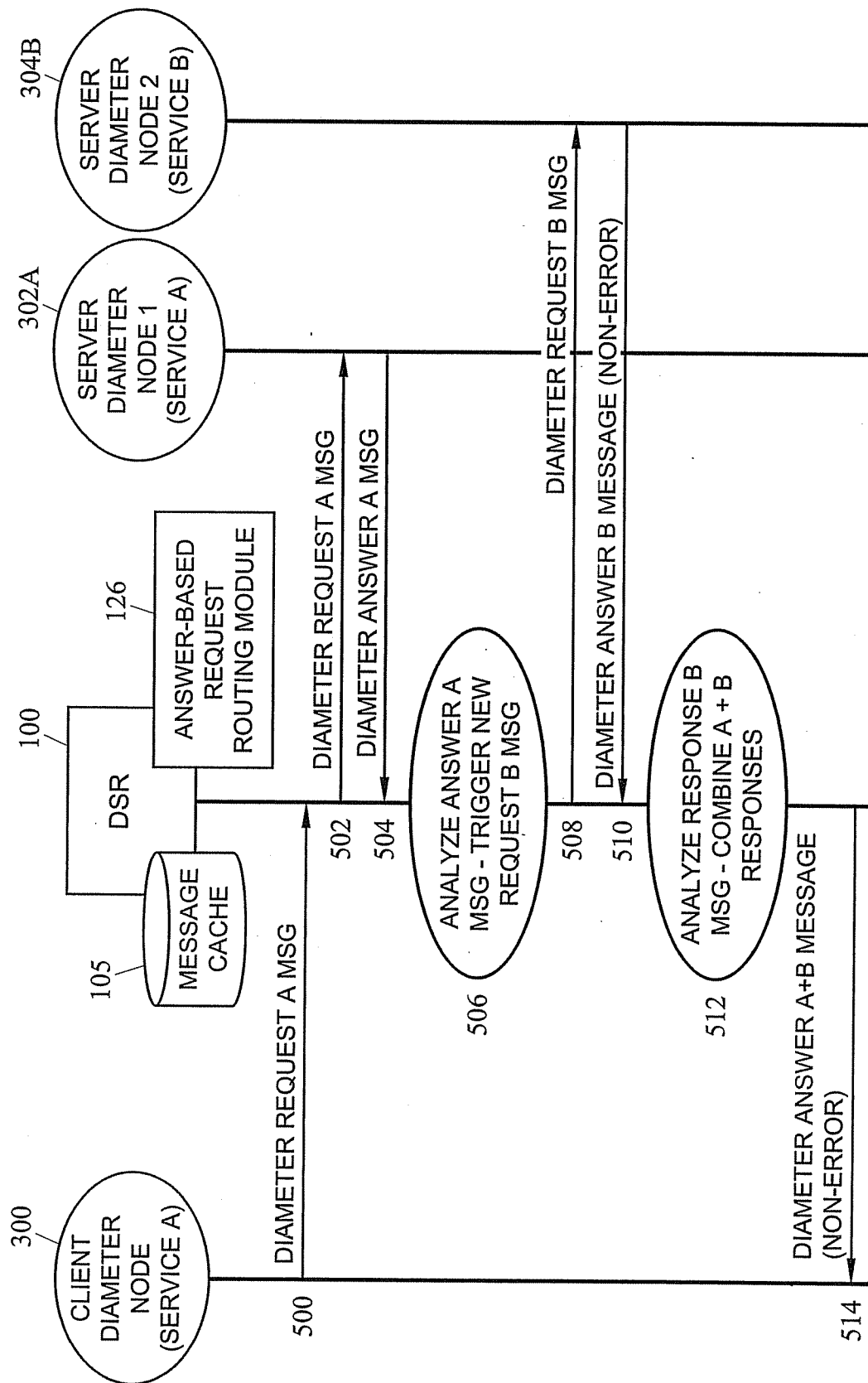


FIG. 5

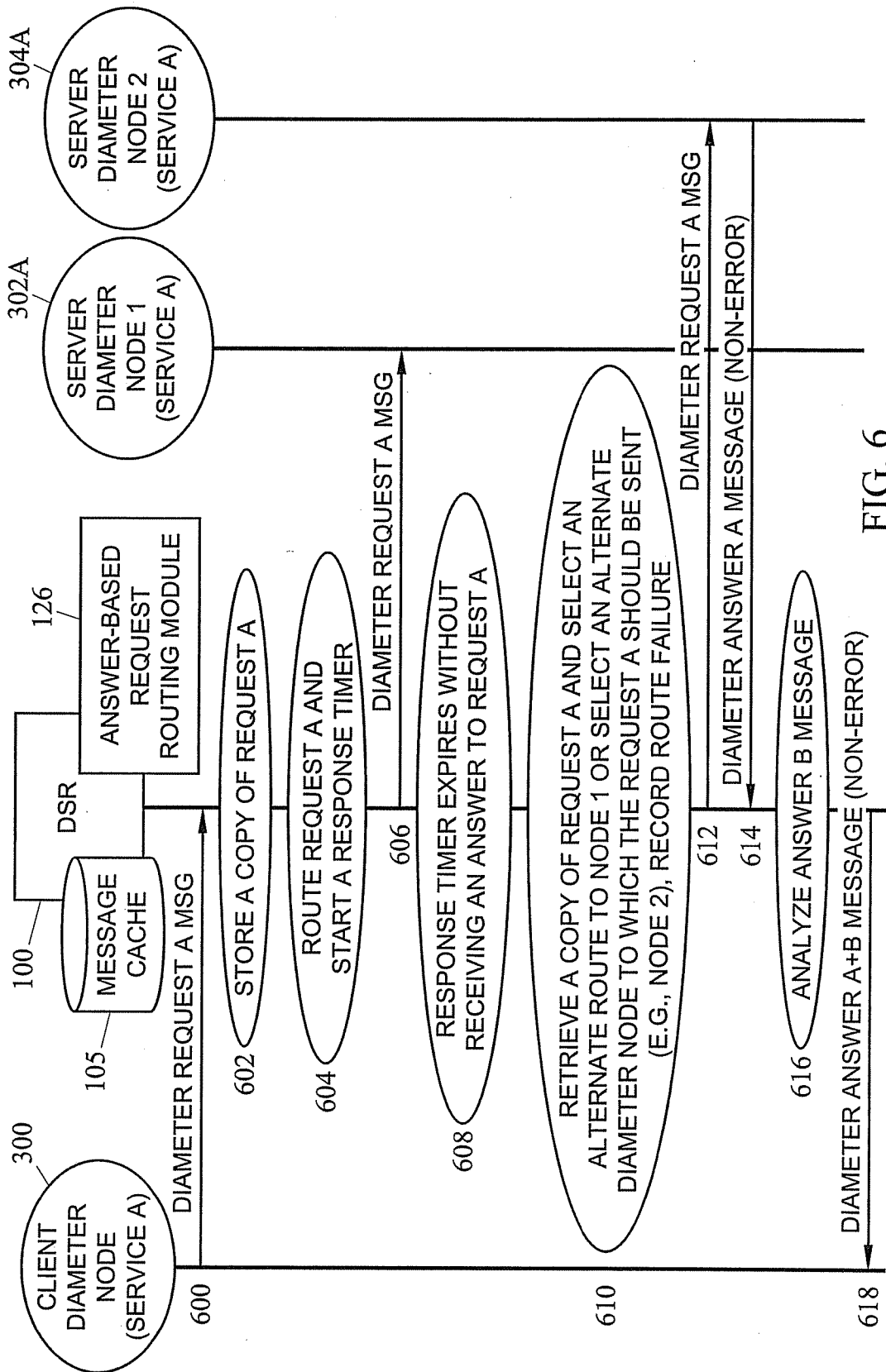


FIG. 6