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(54) PROVIDING DUAL-HOMED, ACTIVE-ACTIVE DEVICES ON NETWORK FABRICS

(71) Applicant: **Cisco Technology, Inc.**, San Jose, CA (US)

(72) Inventors: **Raja Janardanan**, Milpitas, CA (US); **Sanjay Kumar Hooda**, Pleasanton, CA (US); **Prakash C. Jain**, Fremont, CA (US); **Ganesh Sankaranarayanan**, Cupertino, CA (US)

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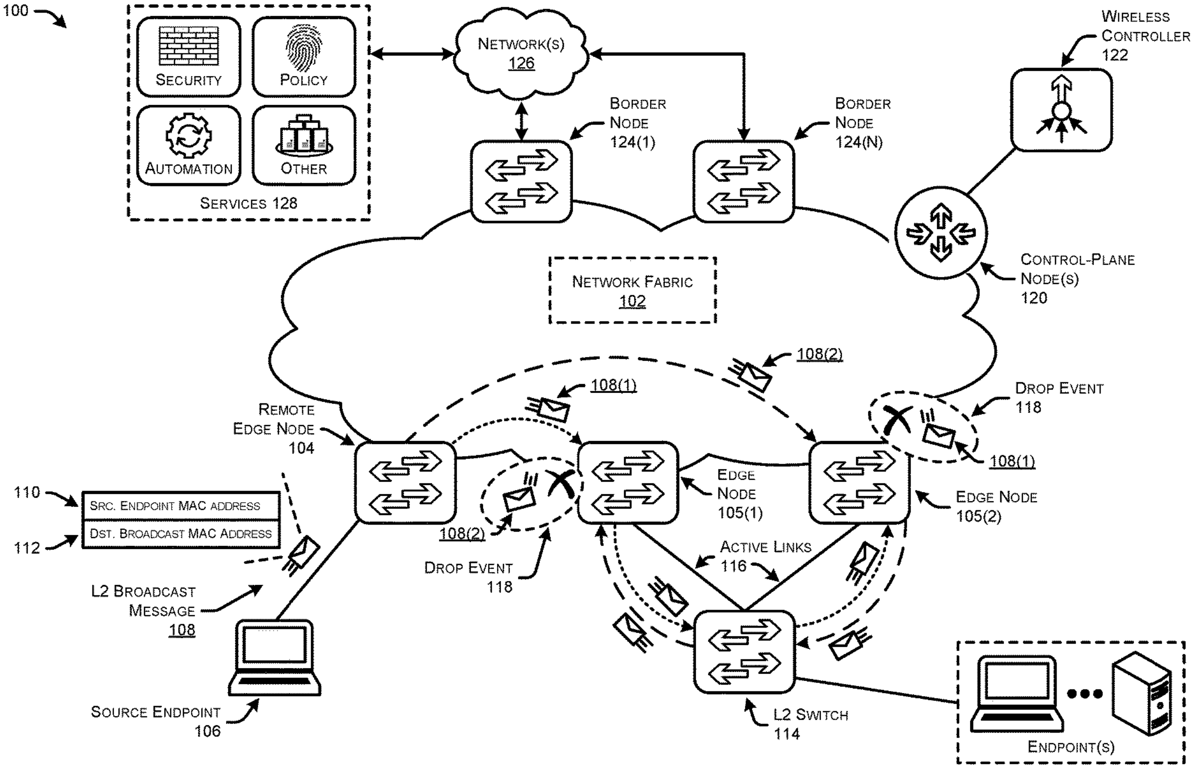
(57) ABSTRACT

Techniques for edge nodes of a network fabric to identify L2 broadcast messages that have been looped through connections with dual-homed, active-active endpoints. The edge nodes receive an L2 broadcast message from the network fabric, and store a source MAC address of the message in a local map-cache. The edge devices then forward the L2 broadcast message to the endpoint. The edge nodes may receive the messages that have been looped through the connections with the endpoint, and compare the source MAC address of the messages with the source MAC addresses stored in the locasl map-cache. If the source MAC address of the message matches to an address in the local map-cache, the edge nodes drop the message. However, if the source MAC address does not match to an address in the local map-cache, the edge nodes add the source MAC address to a source MAC address table.



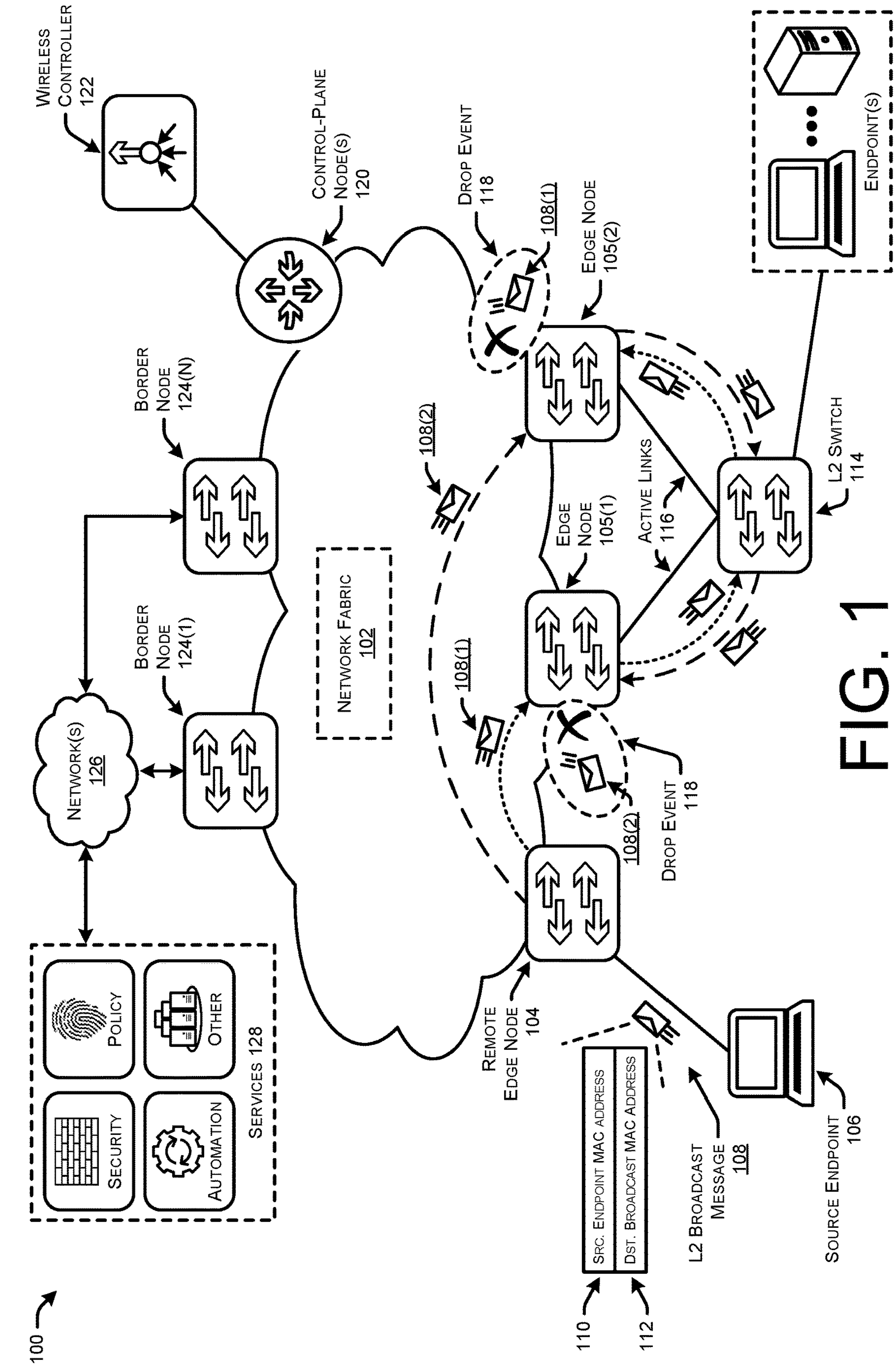

100
Services 128
Security
Policy
Automation
Other
Network(s)
126
Border
Node
124(1)
Border
Node
124(N)
Network Fabric
102
Control-Plane
Node(s)
120
Wireless
Controller
122
Drop Event
118
108(1)
Edge Node
105(2)
108(2)
Edge
Node
105(1)
Active Links
116
L2 Switch
114
Endpoint(s)
108(1)
Drop Event
118
108(2)
Remote
Edge Node
104
Src. Endpoint MAC Address
Dst. Broadcast MAC Address
110
112
L2 Broadcast
Message
108
Source Endpoint
106

FIG. 1

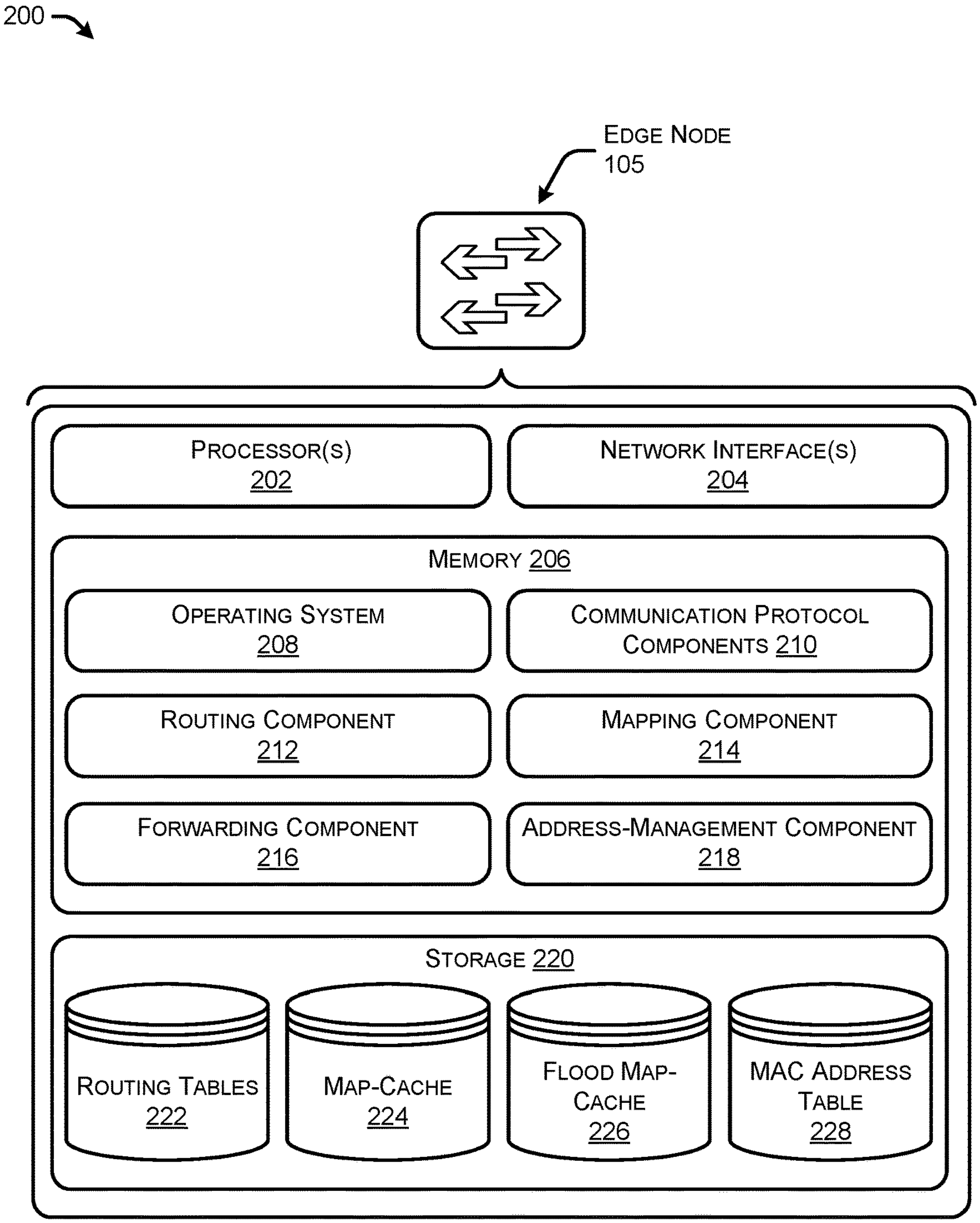

200
Edge Node
105
Processor(s)
202
Network Interface(s)
204
Memory 206
Operating System
208
Communication Protocol
Components 210
Routing Component
212
Mapping Component
214
Forwarding Component
216
Address-Management Component
218
Storage 220
Routing Tables
222
Map-Cache
224
Flood Map-
Cache
226
MAC Address
Table
228

FIG. 2

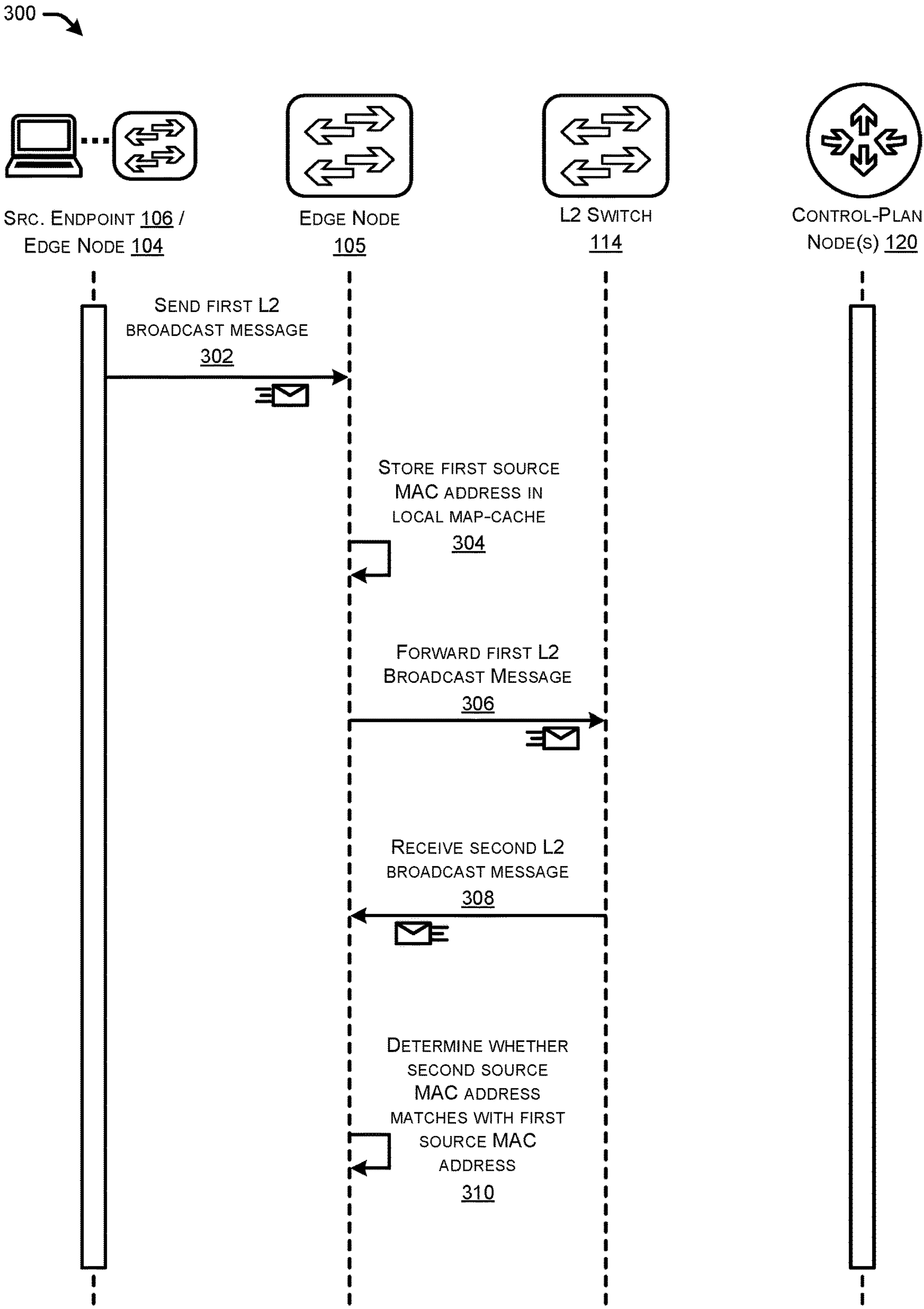

300
SRC. ENDPOINT 106 /
EDGE NODE 104
EDGE NODE
105
L2 SWITCH
114
CONTROL-PLANE
NODE(S) 120
SEND FIRST L2
BROADCAST MESSAGE
302
STORE FIRST SOURCE
MAC ADDRESS IN
LOCAL MAP-CACHE
304
FORWARD FIRST L2
BROADCAST MESSAGE
306
RECEIVE SECOND L2
BROADCAST MESSAGE
308
DETERMINE WHETHER
SECOND SOURCE
MAC ADDRESS
MATCHES WITH FIRST
SOURCE MAC
ADDRESS
310

FIG. 3A

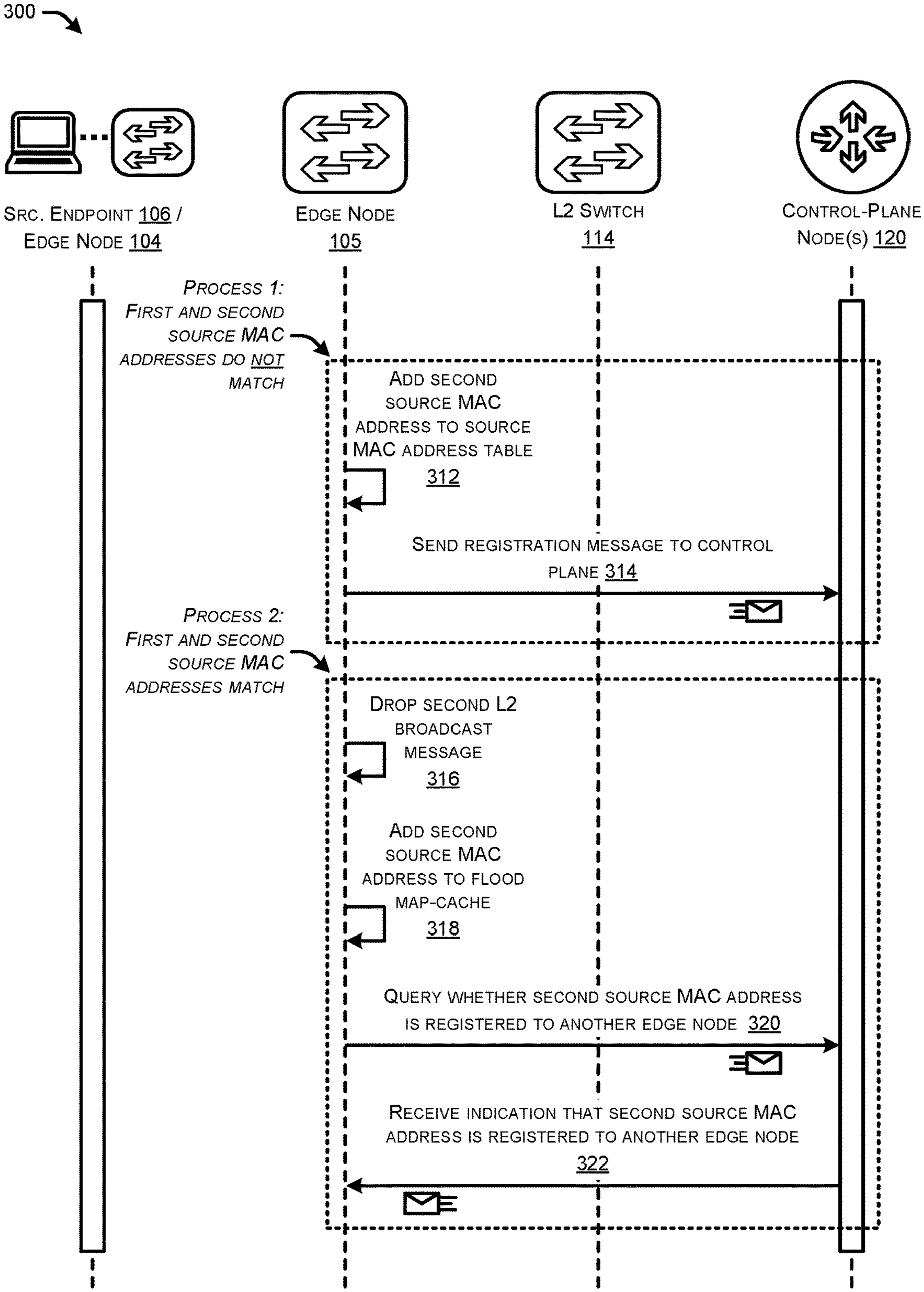

300
SRC. ENDPOINT 106 / EDGE NODE 104
EDGE NODE 105
L2 SWITCH 114
CONTROL-PLANE NODE(S) 120
PROCESS 1: FIRST AND SECOND SOURCE MAC ADDRESSES DO NOT MATCH
ADD SECOND SOURCE MAC ADDRESS TO SOURCE MAC ADDRESS TABLE 312
SEND REGISTRATION MESSAGE TO CONTROL PLANE 314
PROCESS 2: FIRST AND SECOND SOURCE MAC ADDRESSES MATCH
DROP SECOND L2 BROADCAST MESSAGE 316
ADD SECOND SOURCE MAC ADDRESS TO FLOOD MAP-CACHE 318
QUERY WHETHER SECOND SOURCE MAC ADDRESS IS REGISTERED TO ANOTHER EDGE NODE 320
RECEIVE INDICATION THAT SECOND SOURCE MAC ADDRESS IS REGISTERED TO ANOTHER EDGE NODE 322

FIG. 3B

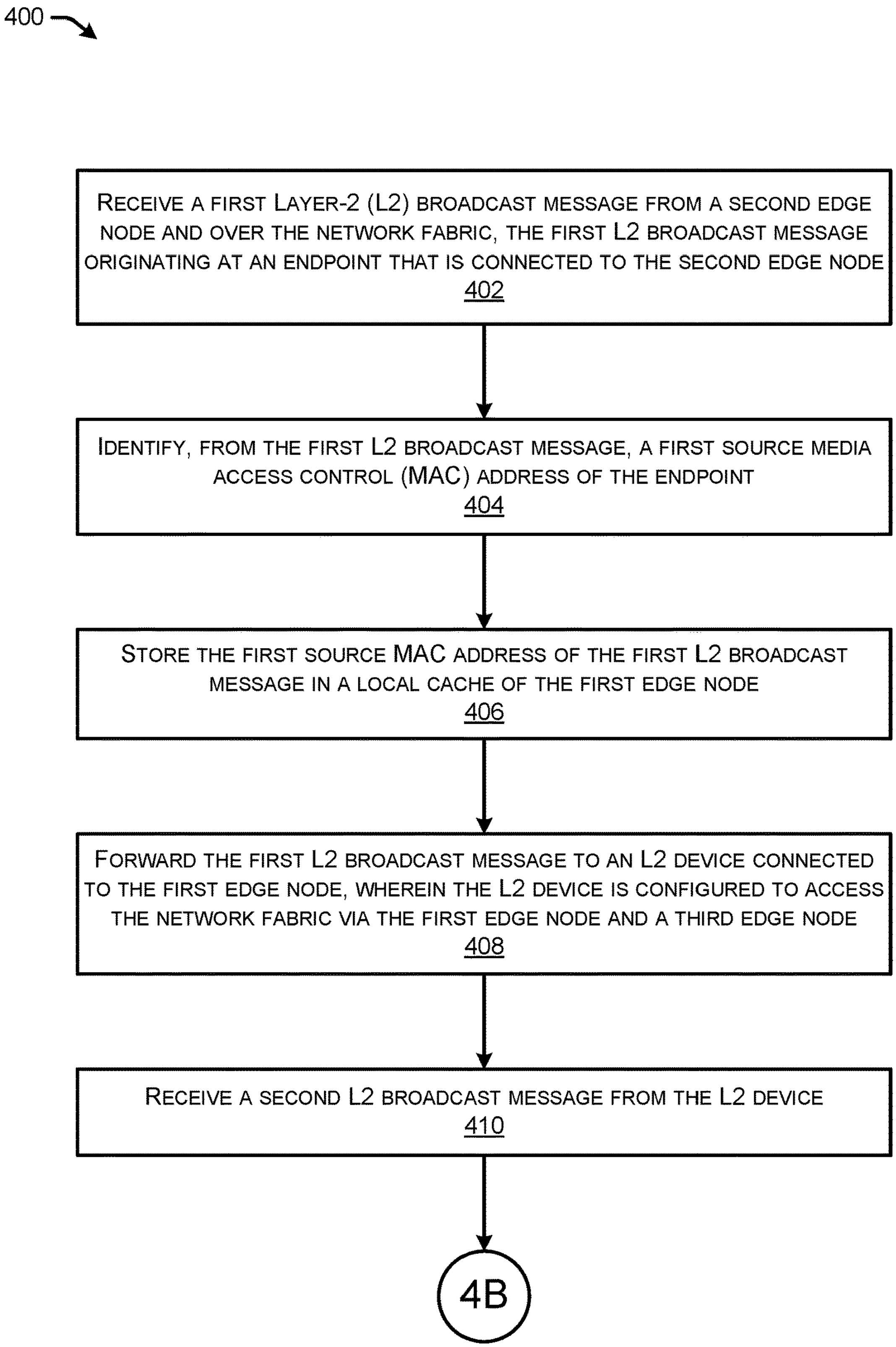

400
RECEIVE A FIRST LAYER-2 (L2) BROADCAST MESSAGE FROM A SECOND EDGE NODE AND OVER THE NETWORK FABRIC, THE FIRST L2 BROADCAST MESSAGE ORIGINATING AT AN ENDPOINT THAT IS CONNECTED TO THE SECOND EDGE NODE
402
IDENTIFY, FROM THE FIRST L2 BROADCAST MESSAGE, A FIRST SOURCE MEDIA ACCESS CONTROL (MAC) ADDRESS OF THE ENDPOINT
404
STORE THE FIRST SOURCE MAC ADDRESS OF THE FIRST L2 BROADCAST MESSAGE IN A LOCAL CACHE OF THE FIRST EDGE NODE
406
FORWARD THE FIRST L2 BROADCAST MESSAGE TO AN L2 DEVICE CONNECTED TO THE FIRST EDGE NODE, WHEREIN THE L2 DEVICE IS CONFIGURED TO ACCESS THE NETWORK FABRIC VIA THE FIRST EDGE NODE AND A THIRD EDGE NODE
408
RECEIVE A SECOND L2 BROADCAST MESSAGE FROM THE L2 DEVICE
410
4B

FIG. 4A

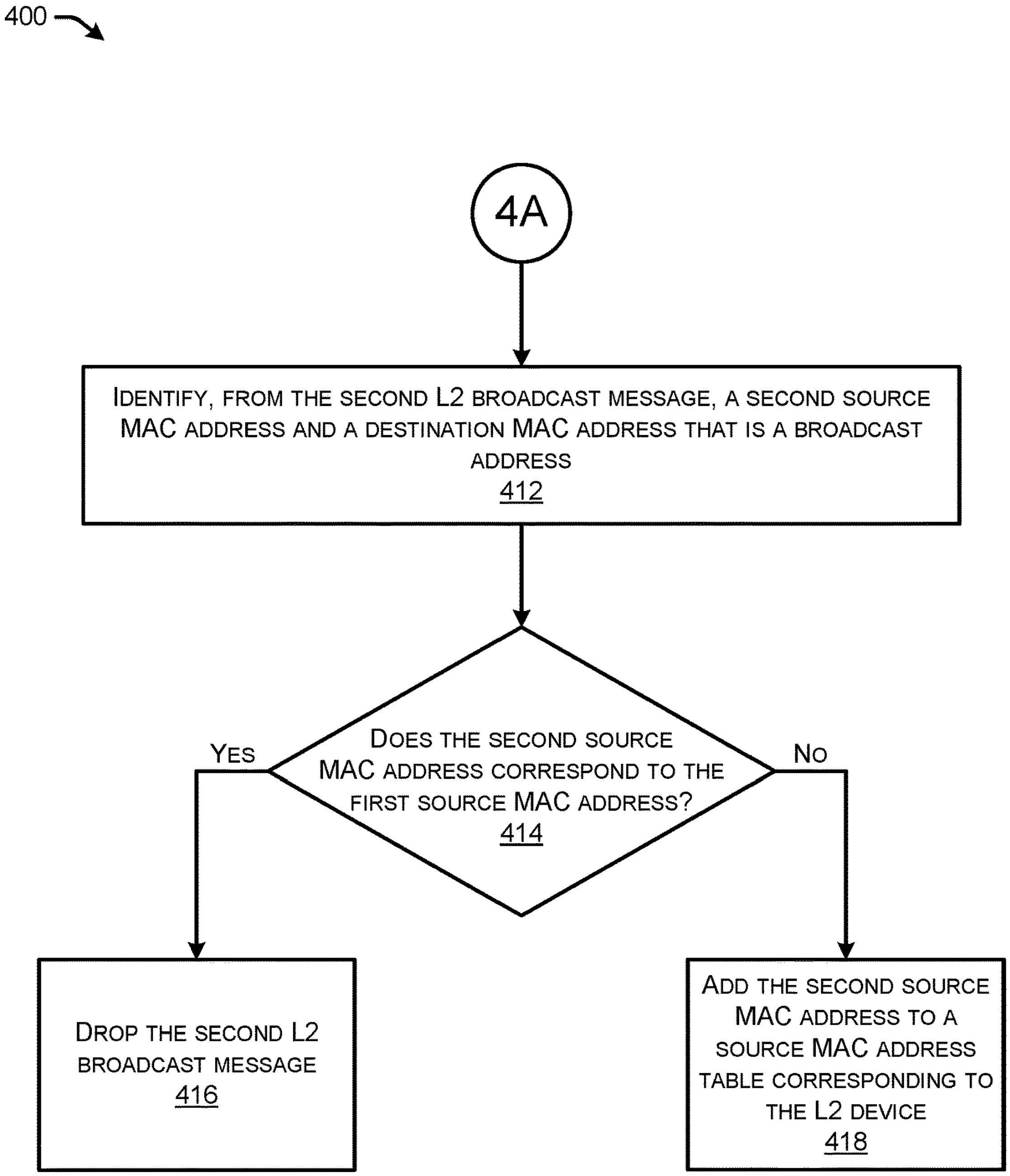

400
4A
IDENTIFY, FROM THE SECOND L2 BROADCAST MESSAGE, A SECOND SOURCE MAC ADDRESS AND A DESTINATION MAC ADDRESS THAT IS A BROADCAST ADDRESS
412
DOES THE SECOND SOURCE MAC ADDRESS CORRESPOND TO THE FIRST SOURCE MAC ADDRESS?
414
YES
NO
DROP THE SECOND L2 BROADCAST MESSAGE
416
ADD THE SECOND SOURCE MAC ADDRESS TO A SOURCE MAC ADDRESS TABLE CORRESPONDING TO THE L2 DEVICE
418

FIG. 4B

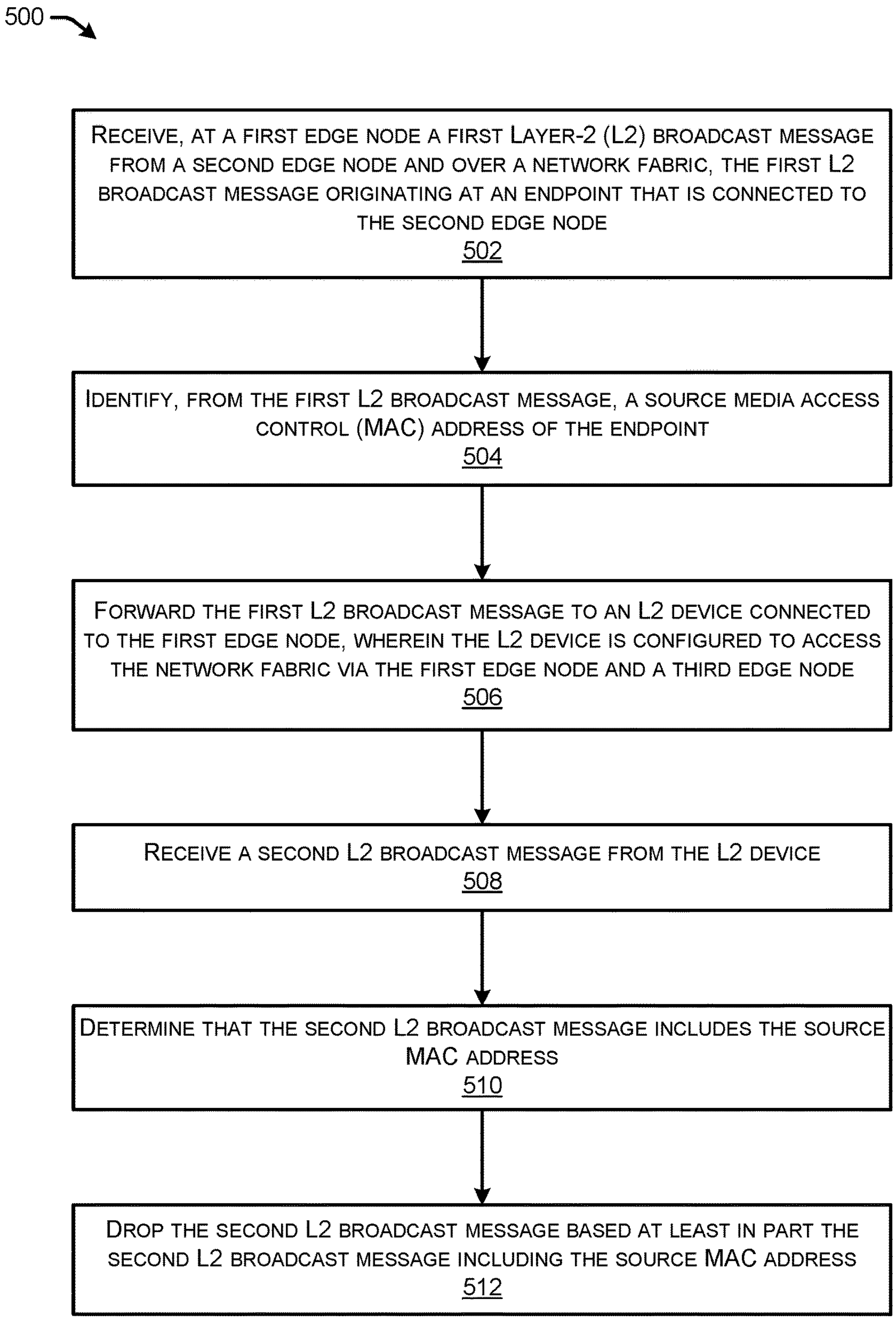

500
Receive, at a first edge node a first Layer-2 (L2) broadcast message from a second edge node and over a network fabric, the first L2 broadcast message originating at an endpoint that is connected to the second edge node
502
Identify, from the first L2 broadcast message, a source media access control (MAC) address of the endpoint
504
Forward the first L2 broadcast message to an L2 device connected to the first edge node, wherein the L2 device is configured to access the network fabric via the first edge node and a third edge node
506
Receive a second L2 broadcast message from the L2 device
508
Determine that the second L2 broadcast message includes the source MAC address
510
Drop the second L2 broadcast message based at least in part the second L2 broadcast message including the source MAC address
512

FIG. 6

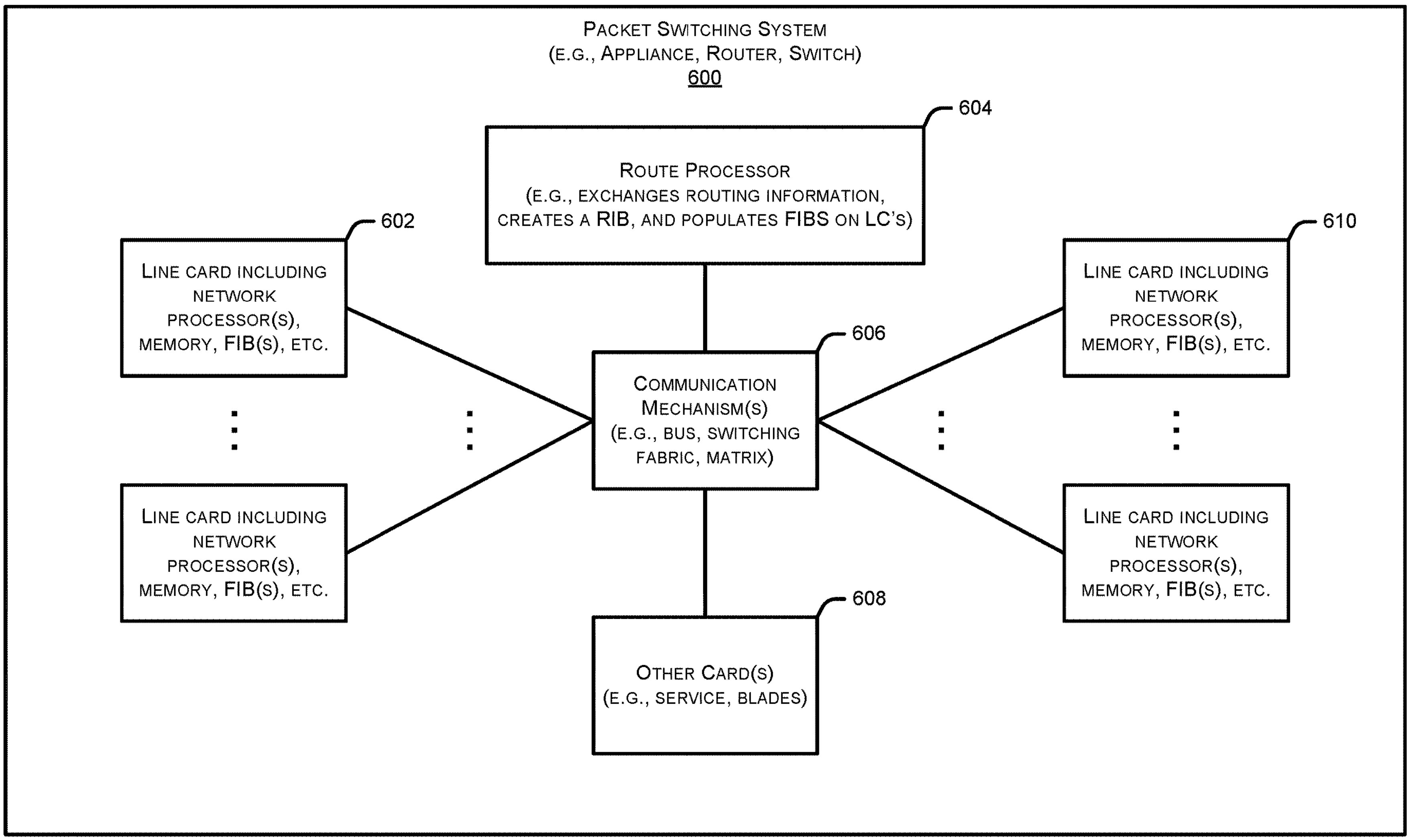

PACKET SWITCHING SYSTEM
(E.G., APPLIANCE, ROUTER, SWITCH)
600
ROUTE PROCESSOR
(E.G., EXCHANGES ROUTING INFORMATION,
CREATES A RIB, AND POPULATES FIBS ON LC'S)
604
602
LINE CARD INCLUDING NETWORK PROCESSOR(S), MEMORY, FIB(S), ETC.
LINE CARD INCLUDING NETWORK PROCESSOR(S), MEMORY, FIB(S), ETC.
606
COMMUNICATION MECHANISM(S)
(E.G., BUS, SWITCHING FABRIC, MATRIX)
610
LINE CARD INCLUDING NETWORK PROCESSOR(S), MEMORY, FIB(S), ETC.
LINE CARD INCLUDING NETWORK PROCESSOR(S), MEMORY, FIB(S), ETC.
608
OTHER CARD(S)
(E.G., SERVICE, BLADES)

FIG. 6

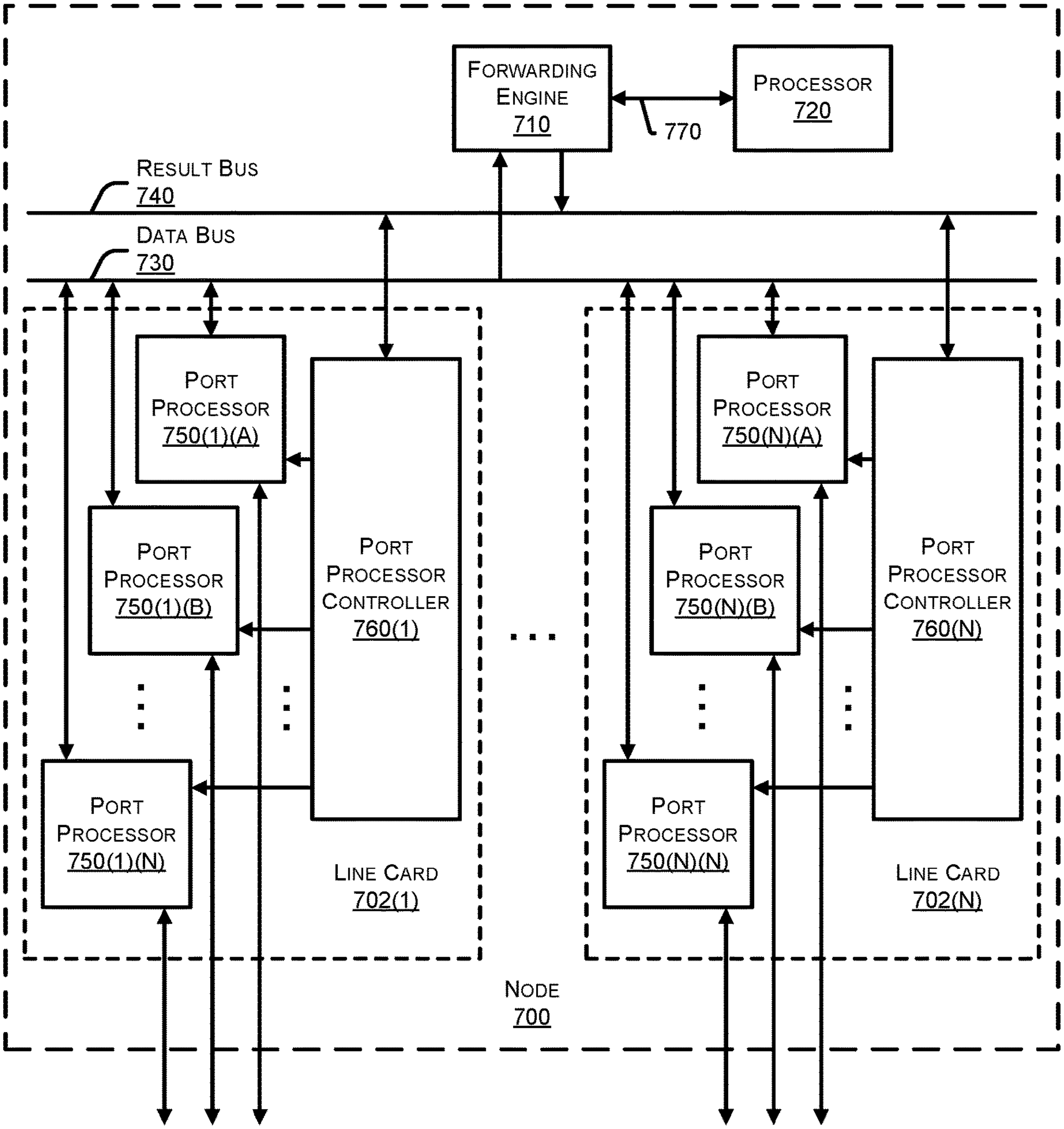

FORWARDING ENGINE 710
770
PROCESSOR 720
RESULT BUS 740
DATA BUS 730
PORT PROCESSOR 750(1)(A)
PORT PROCESSOR 750(1)(B)
PORT PROCESSOR CONTROLLER 760(1)
PORT PROCESSOR 750(1)(N)
LINE CARD 702(1)
PORT PROCESSOR 750(N)(A)
PORT PROCESSOR 750(N)(B)
PORT PROCESSOR CONTROLLER 760(N)
PORT PROCESSOR 750(N)(N)
LINE CARD 702(N)
NODE 700

FIG. 7

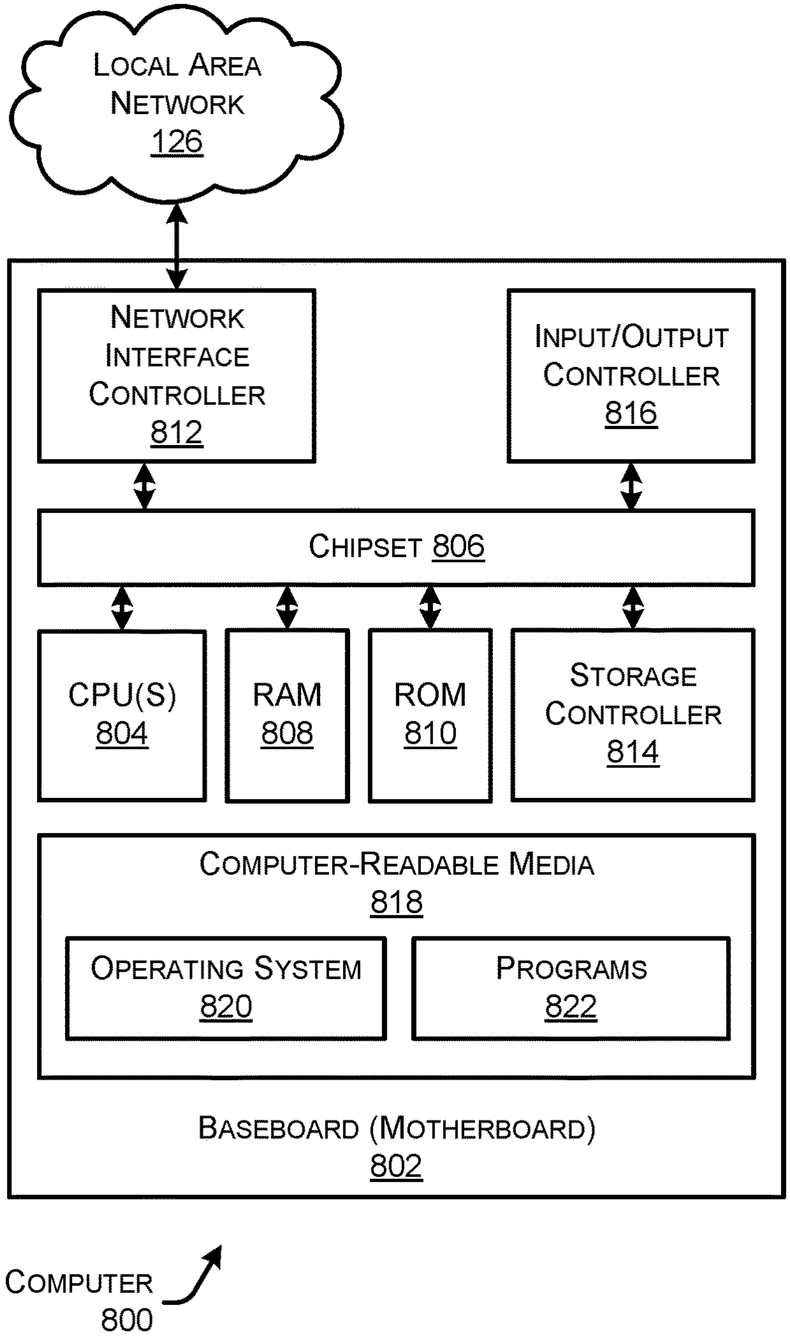

LOCAL AREA NETWORK 126
NETWORK INTERFACE CONTROLLER 812
INPUT/OUTPUT CONTROLLER 816
CHIPSET 806
CPU(S) 804
RAM 808
ROM 810
STORAGE CONTROLLER 814
COMPUTER-READABLE MEDIA 818
OPERATING SYSTEM 820
PROGRAMS 822
BASEBOARD (MOTHERBOARD) 802
COMPUTER 800

FIG. 8

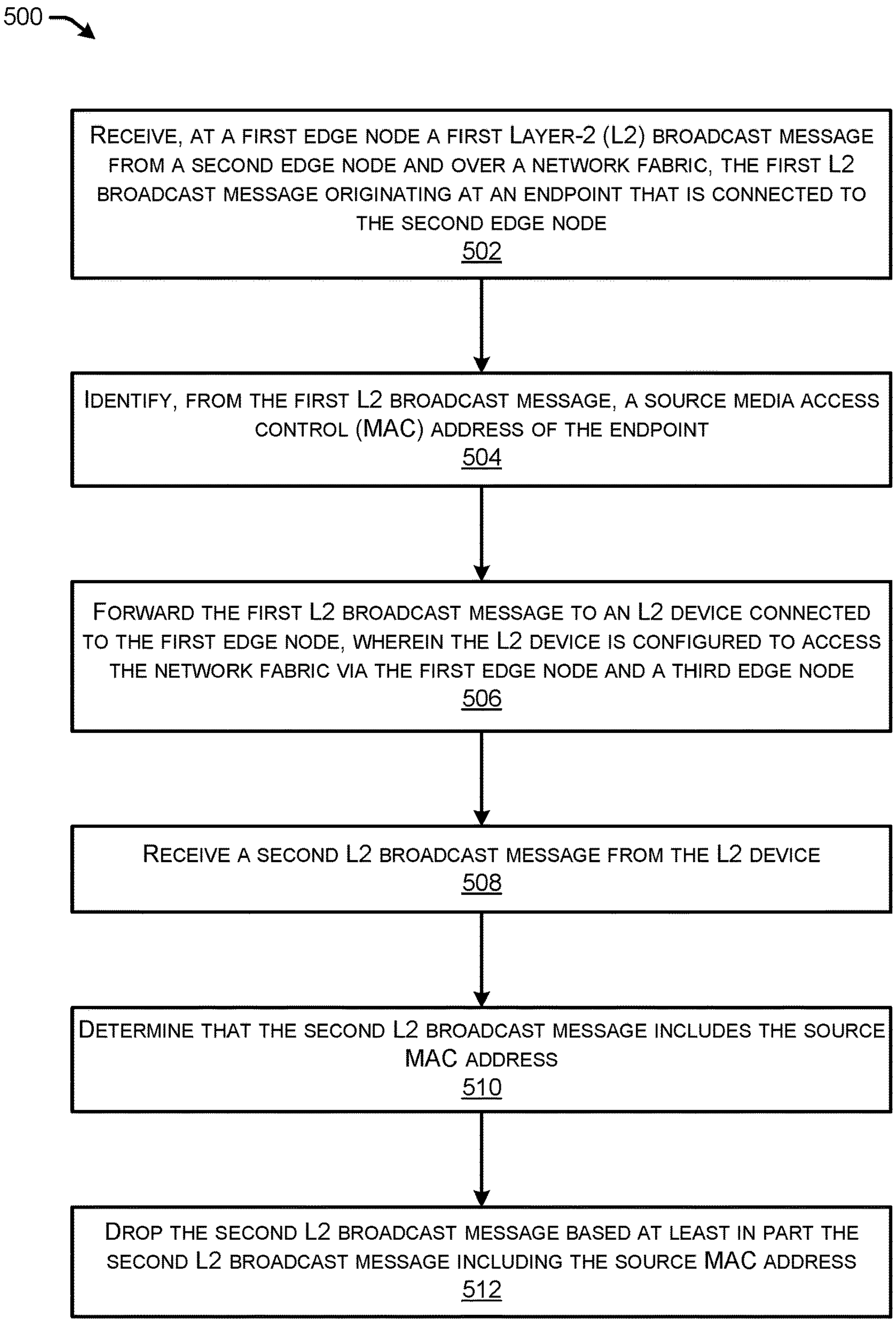

500
RECEIVE, AT A FIRST EDGE NODE A FIRST LAYER-2 (L2) BROADCAST MESSAGE FROM A SECOND EDGE NODE AND OVER A NETWORK FABRIC, THE FIRST L2 BROADCAST MESSAGE ORIGINATING AT AN ENDPOINT THAT IS CONNECTED TO THE SECOND EDGE NODE
502
IDENTIFY, FROM THE FIRST L2 BROADCAST MESSAGE, A SOURCE MEDIA ACCESS CONTROL (MAC) ADDRESS OF THE ENDPOINT
504
FORWARD THE FIRST L2 BROADCAST MESSAGE TO AN L2 DEVICE CONNECTED TO THE FIRST EDGE NODE, WHEREIN THE L2 DEVICE IS CONFIGURED TO ACCESS THE NETWORK FABRIC VIA THE FIRST EDGE NODE AND A THIRD EDGE NODE
506
RECEIVE A SECOND L2 BROADCAST MESSAGE FROM THE L2 DEVICE
508
DETERMINE THAT THE SECOND L2 BROADCAST MESSAGE INCLUDES THE SOURCE MAC ADDRESS
510
DROP THE SECOND L2 BROADCAST MESSAGE BASED AT LEAST IN PART THE SECOND L2 BROADCAST MESSAGE INCLUDING THE SOURCE MAC ADDRESS
512

FIG. 5

PROVIDING DUAL-HOMED, ACTIVE-ACTIVE DEVICES ON NETWORK FABRICS

TECHNICAL FIELD

[0001] The present disclosure relates generally to techniques performed by edge nodes of a network fabric that forward and receive Layer-2 (L2) messages with dual-homed endpoints connected to the network fabric an active-active fashion.

BACKGROUND

[0002] Computer networks are collections of interconnected computers and other devices that communicate over connections to share information and resources among the connected devices. These networks include various types of network devices to communicate data and provide resources and services, such as routers, switches, firewalls, servers, endpoint devices, wireless controllers, and so forth. The physical and logical arrangement of a network through which the devices pass data to each other is often referred to as a "network fabric." There are various types of network fabrics, such as Local Area Networks (LANs) of endpoints or user devices, and Wide Area Networks (WANs) that provide between remote LANs and over large geographic areas.

[0003] Access networks are another type of network fabric that provide connectivity between end-users and core networks (or service providers), such as connecting endpoints and users to the Internet or service platforms (e.g., cloud-based platforms, software-as-a-service (SaaS) platforms, etc.). Examples of access networks may include campus area networks, enterprise networks, home networks, and mobile networks. Generally, access networks have edge nodes (or "edge routers") that facilitate the communication between the endpoints and the core network, as well as endpoint-to-endpoint communications. These edge nodes utilize various types of routing protocols in order to exchange information between the LANs or other autonomous networks, such as exchanging routes to endpoints located behind the edge routers and determining optimal network routes for data transmission across the access network.

[0004] Traditionally, the edge nodes have been connected to "single-homed" endpoints, which are endpoints that are connected to the access network through a single edge node. However, there are now "dual-homed" endpoints that are connected to multiple edge nodes for various reasons, such as failover mechanisms, load balancing, and high-availability. Additionally, these dual-homed endpoints can be operating in an active-active fashion where both network connections or interfaces on the dual-homed endpoints are available and actively transmitting and receiving data in order to improve performance, enable load balancing, and provide redundancy. However, various issues may arise when dual-homed devices are connected to an access network in an active-active fashion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The detailed description is set forth below with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items. The systems depicted in the accompanying figures are not to scale and components within the figures may be depicted not to scale with each other.

[0006] FIG. **1** illustrates a system-architecture diagram of an example network fabric having edge nodes that identify L2 broadcast messages that have already been communicated with dual-homed endpoints connected to the network fabric.

[0007] FIG. **2** illustrates a component diagram of an example edge node configured to perform techniques described herein.

[0008] FIGS. **3**A and **3**B collectively illustrate a flow diagram of an example method for edge nodes in a network fabric to identify L2 broadcast messages that have already been communicated with dual-homed endpoints connected to the network fabric.

[0009] FIG. **4**A and **4**B collectively illustrate a flow diagram of an example method for edge nodes in a network fabric to determine whether L2 broadcast messages have already been communicated with dual-homed endpoints connected to the network fabric.

[0010] FIG. **5** illustrates a flow diagram of an example method for an edge node in a network fabric to determine that a L2 broadcast message has already been communicated with dual-homed endpoints connected to the network fabric, and dropping the L2 broadcast message.

[0011] FIG. **6** illustrates a block diagram illustrating an example packet switching system that can be utilized to implement various aspects of the technologies disclosed herein.

[0012] FIG. **7** illustrates a block diagram illustrating certain components of an example node that can be utilized to implement various aspects of the technologies disclosed herein.

[0013] FIG. **8** is a computer architecture diagram showing an illustrative computer hardware architecture for implementing a computing device that can be utilized to implement aspects of the various technologies presented herein.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

[0014] This disclosure describes techniques performed by edge nodes of a network fabric to identify L2 broadcast messages that have already been communicated with dual-homed endpoints connected to the network fabric an active-active fashion. A first method to perform techniques described herein includes receiving a first L2 broadcast message from a second edge node and over the network fabric, where the first L2 broadcast message originated at an endpoint that is connected to the second edge node. Further, the first method may include identifying, from the first L2 broadcast message, a first source media access control (MAC) address of the endpoint, and storing the first source MAC address of the first L2 broadcast message in a local cache of the first edge node. Additionally, the first method may include forwarding the first L2 broadcast message to an L2 device connected to the first edge node, where the L2 device is configured to access the network fabric via the first edge node and a third edge node. Even further, the first method may include receiving a second L2 broadcast message from the L2 device, and identifying, from the second L2 broadcast message, a second source MAC address and a destination MAC address that is a broadcast address. The first method may further include determining whether the second source MAC address corresponds to the first source MAC address stored in the local cache. In some instances, the first method may include, in response to determining that the second source MAC address corresponds to the first source MAC address, dropping the second L2 broadcast message. In other instances, the first method may include, in response to determining that the second source MAC address does not correspond the first source MAC address, adding the second source MAC address to a source MAC address table corresponding to the L2 device.

[0015] A second method to perform techniques described herein includes receiving a first L2 broadcast message from a second edge node and over the network fabric, where the first L2 broadcast message originated at an endpoint that is connected to the second edge node. Additionally, the second method may include identifying, from the first L2 broadcast message, a source media access control (MAC) address of the endpoint, and forwarding the first L2 broadcast message to an L2 device connected to the first edge node, wherein the L2 device is configured to access the network fabric via the first edge node and a third edge node. Further, the second method may include receiving a second L2 broadcast message from the L2 device, and determining that the second L2 broadcast message includes the source MAC address. The second method may additionally include, based at least in part the second L2 broadcast message including the source MAC address, dropping the second L2 broadcast message.

[0016] Additionally, the techniques described herein may be performed by a system and/or device having non-transitory computer-readable media storing computer-executable instructions that, when executed by one or more processors, performs the first and second methods described above.

Example Embodiments

[0017] When edge nodes receive Layer 2 (L2) broadcast messages, the default behavior is to examine the destination MAC address, and if the destination MAC address is a broadcast address, the edge node will forward the L2 broadcast messages to all devices that are within the broadcast domain. This mechanism is helpful for tasks such as Address Resolution Protocol (ARP) resolution, where devices need to discover the MAC address associated with particular IP addresses within network segments. However, edge nodes may be connected to dual-homed endpoints, or endpoints that that are connected to multiple edge nodes for various reasons, such as failover mechanisms, load balancing, and high-availability. These dual-homed endpoints can be operating in an active-active fashion where both network connections or interfaces on the dual-homed endpoints are available and actively transmitting and receiving data in order to improve performance, enable load balancing, and provide redundancy.

[0018] However, dual-homed, active-active endpoints may cause various issues with L2 broadcast messages because the endpoints will receive L2 broadcast messages from one edge node, and forward those L2 broadcast messages to the other edge node. Consider an instance where each edge node receives an L2 broadcast message advertised across the network fabric, and each edge node forwards the L2 broadcast message to a dual-homed, active-active endpoint. The dual-homed, active-active endpoint will receive L2 broadcast messages from each edge node, and forward them back towards the different edge nodes. Thus, dual-homed, active-active endpoints can cause loops in L2 broadcast messages being forwarded between the connected edge nodes. The edge nodes will not know if the L2 broadcast message was originated at the endpoint, or if the L2 broadcast message is being looped back by the endpoint and the edge nodes have already processed the L2 broadcast message. This can result in various issues, such as endpoint identifiers (EIDs) being assigned to the wrong endpoints, and EID flap between different endpoints.

[0019] This disclosure describes techniques performed by edge nodes of a network fabric to identify L2 broadcast messages that have already been communicated with dual-homed endpoints connected to the network fabric an active-active fashion. The edge nodes that are connected to a dual-homed, active-active endpoint may receive an L2 broadcast message that has been sent over the network fabric, and identify the source MAC address of a remote endpoint that sent the L2 broadcast message. The edge nodes may then store the source MAC address in a local map-cache and forward the L2 broadcast message to the dual-homed, active-active endpoint via their active links. The edge nodes may then again receive the L2 broadcast message from the dual-homed, active-active endpoint due to the looping caused by the active-active links. When the edge nodes receive these L2 broadcast messages, the edge nodes may compare the source MAC address of the L2 broadcast messages with the source MAC addresses stored in the local map-cache. In response to determining that the source MAC address of the L2 broadcast message matches or corresponds to a source MAC address stored in the local map-cache, the edge nodes may drop the L2 broadcast message and refrain from forwarding the message because it has been looped by the endpoint. However, in response to determining that the source MAC address of the L2 broadcast message does not match or correspond to a source MAC address stored in the local map-cache, the edge nodes may add the source MAC address to a source MAC address table because the L2 broadcast message originated at an endpoint located behind the edge nodes.

[0020] Thus, using the local map-cache, the edge nodes are able to determine whether an L2 broadcast message has originated at an endpoint located behind the edge nodes and that are connected to the access fabric via the edge nodes, or if the L2 broadcast message is being looped through a dual-homed, active-active endpoint. Traditionally, edge nodes are configured to add a source MAC address to a source MAC address table for endpoints that are located behind the edge nodes, and further configured to send a registration message to a control-plane of the network fabric to register the endpoint with the edge nodes. However, in examples where the L2 broadcast message has a source MAC address that matches to a source MAC address in the local map-cache, the edge nodes may be configured to refrain from adding the source MAC address to the source MAC address table, and refrain from sending the registration message to the control-plane of the network fabric. Further, the edge nodes may be configured to add the source MAC address to flood map-cache tables stored in the edge nodes, where the flood map-cache tables stores source MAC addresses received in L2 broadcast messages that belong to endpoints which are registered to other edge nodes of the network fabric.

[0021] Additionally, in instances where the L2 broadcast message has a source MAC address that matches to a source

MAC address in the local map-cache (e.g., looped L2 broadcast message), the edge nodes may query the control-plane to determine whether the endpoint is registered to another edge node of the network fabric. If the control-plane returns a reply that states that the MAC address is already registered by another edge node in the network fabric, the edge node may keep the MAC address in the flood map-cache table. However, if the control-plane returns a reply that states that the MAC address is not registered by another edge node in the network fabric, the edge node may remove the entry created in the flood map-cache table and clear the local map-cache as well for that entry. This ensures that a scenario where an endpoint legitimately moved from a remote edge node to a new edge node is handled appropriately and the MAC address of the endpoint is registered to the new edge node.

[0022] Although the techniques described herein are primarily with respect to a Locator/ID Separation Protocol (LISP), the techniques are applicable to other routing protocols, such as Border Gateway Protocol (BGP), Intermediate System to Intermediate System (IS-IS), ARP, Routing Protocols for Low-Power and Lossy Networks (RPL), and/or other protocols. Further, while the techniques are described with reference to a L2 broadcast message, the techniques may be applicable for a multicast message as well.

[0023] Certain implementations and embodiments of the disclosure will now be described more fully below with reference to the accompanying figures, in which various aspects are shown. However, the various aspects may be implemented in many different forms and should not be construed as limited to the implementations set forth herein. The disclosure encompasses variations of the embodiments, as described herein. Like numbers refer to like elements throughout.

[0024] FIG. **1** illustrates a system-architecture diagram **100** of an example network fabric **102** having edge nodes **104** that identify L2 broadcast messages **108** that have already been communicated with dual-homed endpoints connected to the network fabric **102**. The network fabric **102** includes a mesh of connections between network devices such as access points, switches, and routers that transports data to its destination. The term "fabric" can mean the physical wirings that make up these connections, but may refer to a virtualized, automated lattice of overlay connections on top of the physical topology. The network fabric **102** may, include any combination of Personal Area Networks (PANs), Local Area Networks (LANs), Campus Area Networks (CANs), Metropolitan Area Networks (MANs), extranets, intranets, the Internet, short-range wireless communication networks (e.g., ZigBee, Bluetooth, etc.) Wide Area Networks (WANs)—both centralized and/or distributed—and/or any combination, permutation, and/or aggregation thereof.

[0025] In some instances, the network fabric **102** may be an access fabric, and include the underlying network infrastructure within an organization that facilitates connectivity for endpoints **106** (e.g., end-user devices), enabling them to access various network services and resources. The access fabric may be primarily situated in the access layer of a hierarchical network architecture and serves as the entry point for devices connecting to a core network. In the context of software-defined access (SDA) fabrics, the fabric may refer to a network architecture where all the devices, including switches and routers, are interconnected and work together seamlessly. The fabric is "software-defined" because the control plane is abstracted from the physical infrastructure and is managed centrally through software. Thus, SDA fabrics include a network architecture that leverages software-defined networking (SDN) principles to simplify and automate network management, enhance security, and provide better visibility and control over network resources. SD-Access focuses on the access layer of the network, which is responsible for connecting end-user devices, such as computers, smartphones, and IoT devices, to the network.

[0026] As shown, the network fabric **102** may include a remote edge node **104** and edge nodes **105**(**1**)-**105**(**2**), where the edge node **104** and edge nodes **105** may comprise any type of edge node, such as routers, switches, wireless access points (APs), customer premises equipment (CPE), gateway devices, and/or security appliances. The edge node **104** and edge nodes **105** ensure that connected devices, such as endpoints **106**, L2 switches **114**, etc., can connect to the network fabric **102**, access services, and communicate with other devices in local and wider network infrastructures. As illustrated, the edge node **104** may be connected to a source endpoint **106** that generates a L2 broadcast message **108** to be sent over the network fabric. As shown, the L2 broadcast message may include a source endpoint MAC address that is a MAC address of the source endpoint **106**, and also a destination broadcast MAC address (e.g., FF-FF-FF-FF-FF-FF) that is configured to reach every device on a network segment. The L2 broadcast message may be used to indicate a mapping between an Internet Protocol (IP) address and the source endpoint MAC address of the source endpoint **106**.

[0027] In some instances, the network fabric and associated devices may use the LISP protocol rather than the IP protocol, where LISP generally separates the location and identity of a device through Routing Locators (RLOCs) and Endpoints Identifiers (EIDs). The RLOC represents the IP address of the egress tunnel router (ETR) (e.g., edge node the host is attached to, and the EID represents the IP address assigned to the host.

[0028] For network fabrics that use LISP, the Layer 2 broadcast message **108** may be sent over the network fabric to advertise the source endpoint MAC address as belonging to or mapping to an EID of the source endpoint **106**. The L2 broadcast message **108** will be forwarded by devices of the network fabric **102** until the L2 broadcast message **108** reaches edge node **105**(**1**) and edge node **105**(**2**). As shown, edge node **105**(**1**) and edge node **105**(**2**) are each connected to an L2 switch **114** using active links **116**. Thus, the L2 switch **114** may be a dual-homed, active-active endpoint. Although illustrated as an L2 switch **114**, any type of device may be operating as the dual-homed, active-active device, such as user devices (e.g., desktop computers, laptop computers, phones, tablets, wearable devices, entertainment devices such as televisions, etc.), network devices (e.g., servers, routers, switches, access points, etc.), and/or any other type of computing device.

[0029] According to the techniques of this disclosure, edge node **105**(**1**) and edge node **105**(**2**) perform to identify L2 broadcast messages that have already been communicated with dual-homed endpoints connected to the network fabric an active-active fashion. The edge nodes **105** that are connected to a dual-homed, active-active endpoint may receive respective versions of the L2 broadcast message

108(1) and **108(2)** that have been sent over the network fabric **102**, and identify the source endpoint MAC address **110** of the source endpoint **106** that sent the L2 broadcast message **108**. The edge nodes **105** may then store the source endpoint MAC address **110** in a local map-cache and forward the L2 broadcast message **108** to the L2switch **114** via their active links **116**.

[0030] Generally, the edge nodes **105** will forward the L2 broadcast message **108** to devices with active links **116**, such as the L2 switch **114**. As shown, the edge node **105(1)** and edge node **105(2)** both have active links **116** with the L2 switch **114**, and each of the edge node **105(1)** and edge node **105(2)** will forward the L2 broadcast message **108** to the L2 switch **114**. The L2 switch **114** is configured to forward the L2 broadcast message **108** on its active, egress active links **116**. Thus, the L2 broadcast message **108(2)** that is sent from the edge node **105(2)** is forwarded by the L2 switch **114** to the edge node **105(1)**, and the L2 broadcast message **108(1)** that is sent from the edge node **105(1)** is forwarded to the edge node **105(2)** from the L2 switch **114**.

[0031] Thus, edge nodes **105** may then again receive the L2 broadcast message **108** from the L2 switch **114** due to the looping caused by the active links **116**. When the edge nodes **105** receive these L2 broadcast messages **108**, the edge nodes **105** may compare the source MAC addresses of the L2 broadcast messages **108** with the source endpoint MAC addresses stored in the local map-caches. In response to determining that the source MAC addresses of the L2 broadcast message **108** match or correspond to a source MAC address stored in the local map-caches, the edge nodes **105** may drop the L2 broadcast messages **108** (drop events **118**) and refrain from forwarding the messages **108** because they have been looped by the L2 switch **114**. However, in response to determining that the source MAC addresses of the L2 broadcast messages **108** do not match or correspond to a source MAC address stored in the local map-caches, the edge nodes **105** may add the source MAC addresses to source MAC address tables of the edge nodes **105** because the L2 broadcast message originated at an endpoint located behind the edge nodes **105**. Generally, the edge nodes **105** uses this source MAC addresses to update the source MAC address tables, and the source MAC address tables are a database that associates MAC addresses with the specific ports on the switch to which devices are connected.

[0032] Thus, using the local map-cache, the edge nodes **105** are able to determine whether an L2 broadcast message **108** has originated at an endpoint located behind the edge nodes **105** (e.g., L2 switch **114**) and that are connected to the network fabric **102** via the edge nodes **105**, or if the L2 broadcast message **108** is being looped through a dual-homed, active-active endpoint (e.g., L2 switch **114**). Traditionally, edge nodes **105** are configured to add a source MAC address to a source MAC address table for endpoints that are located behind the edge nodes **105**, and further configured to send a registration message to a control-plane node **120** of the network fabric **102** to register the endpoint with the edge nodes **105**. However, in examples where the L2 broadcast message **108** has a source MAC address that matches to a source MAC address in the local map-cache, the edge nodes **105** may be configured to refrain from adding the source MAC address to the source MAC address table, and refrain from sending the registration message to the control-plane nodes **120** of the network fabric **102**. Further, the edge nodes **105** may be configured to add the source MAC address to flood map-cache tables stored in the edge nodes, where the flood map-cache tables stores source MAC addresses received in L2 broadcast messages **108** that belong to endpoints which are registered to other edge nodes (e.g., remote edge node **104**) of the network fabric **102**.

[0033] Additionally, in instances where the L2 broadcast message has a source MAC address that matches to a source MAC address in the local map-cache (e.g., looped L2 broadcast message), the edge nodes **105** may query the control-plane nodes **120** to determine whether the endpoint is registered to another edge node of the network fabric **102**. If the control-plane nodes **120** return a reply that states that the MAC address is already registered by another edge node in the network fabric **102**, the edge node **105** may keep the MAC address in the flood map-cache table. However, if the control-plane nodes **120** returns a reply that states that the MAC address is not registered by another edge node in the network fabric **102**, the edge node **105** may remove the entry created in the flood map-cache table and clear the local map-cache as well for that entry. This ensures that a scenario where, for example, the source endpoint **106** legitimately moved from the remote edge node **104** to the edge node **105(1)** is handled appropriately and the MAC address of the endpoint is registered to the edge node **105(1)**.

[0034] In examples where the network fabric uses a LISP routing framework, the control-plane nodes may be or include one or more Mapping System (MS)/Mapping Request (MS/MR) servers. The mapping system may be responsible for maintaining the mappings between EIDs and RLOCs, and stores information about how EIDs are currently mapped to specific RLOCs in the network fabric **102**. The mapping system may be queried by LISP routers (e.g., edge nodes), specifically the Ingress Tunnel Router (ITR), to obtain the RLOC information associated with a particular EID when a data packet needs to be sent. The mapping request may be a message sent by an ITR (Ingress Tunnel Router) to the mapping system to query for the current mapping information of a specific EID. However, the control-plane nodes **120** may be other types of nodes depending on the protocol being used, such as route reflectors when the edge nodes utilize BGP or other protocols. The control-plane nodes **120** may be in communication with a wireless controller **122** that performs techniques for orchestrating wireless networking within the network fabric **102**.

[0035] In some instances, the endpoints may utilize the edge nodes to communicate over the network fabric **102** to access one or more networks **126**, which may be core networks. The network(s) **126** may, include any combination of Personal Area Networks (PANs), Local Area Networks (LANs), Campus Area Networks (CANs), Metropolitan Area Networks (MANs), extranets, intranets, the Internet, short-range wireless communication networks (e.g., ZigBee, Bluetooth, etc.) Wide Area Networks (WANs)—both centralized and/or distributed—and/or any combination, permutation, and/or aggregation thereof. The network(s) **126** may provide access to the endpoints to various services **128**, such as security services, policy services, automation services, and/or other types of services.

[0036] FIG. **2** illustrates a component diagram **200** of an example edge node **105** configured to perform techniques described herein.

[0037] As illustrated, the edge node **105** may include one or more hardware processors **202** (processors), one or more devices, configured to execute one or more stored instructions. The processor(s) **202** may comprise one or more cores. Further, the edge node **105** may include one or more network interfaces **204** configured to provide communications between the edge node **105** and other devices, such as the L2 switch **114**, remote edge node **104**, and/or other network devices. The network interfaces **204** may include devices configured to couple to personal area networks (PANs), wired and wireless local area networks (LANs), wired and wireless wide area networks (WANs), and so forth. For example, the network interfaces **204** may include devices compatible with Ethernet, Wi-Fi™, cellular or mobile protocols, and so forth.

[0038] The edge node **105** may also include memory **206** (e.g., computer-readable memory) that stores various executable components (e.g., software-based components, firmware-based components, etc.). In addition to various components discussed in FIG. **1**, the memory **206** may further store components to implement functionality described herein. The memory **206** may store one or more operating systems **208** utilized to control the operation of the one or more devices that comprise the edge node **105**. According to one embodiment, the operating system comprises the LINUX operating system. According to another embodiment, the operating system(s) comprise the WINDOWS® SERVER operating system from MICROSOFT Corporation of Redmond, Washington. According to further embodiments, the operating system(s) can comprise the UNIX operating system or one of its variants. It should be appreciated that other operating systems can also be utilized.

[0039] Additionally, the edge node **105** may include storage **220** which may comprise one, or multiple, repositories or other storage locations for persistently storing and managing collections of data such as databases, simple files, binary, and/or any other data. The storage **220** may include one or more storage locations that may be managed by one or more database management systems.

[0040] The memory **206** may store one or more communication protocol components **210** that enable the edge node **105** to communicate using various communication protocols. The communication protocol components **210** enable effective communication between the edge node **105** and devices using communication stacks. This communication protocol components **210** facilitate the exchange of information by defining a set of rules and conventions that devices must follow during communication. Communication protocols specify how data is formatted, transmitted, received, and interpreted, and the communication protocol components **210** help the edge node **105** utilize communication stacks, which are layered structures of protocols, to establish reliable and standardized communication. Examples of communication protocols include LISP, BGP, TCP/IP (Transmission Control Protocol/Internet Protocol) for the Internet, Bluetooth for short-range wireless communication, and MQTT (Message Queuing Telemetry Transport) for lightweight messaging in IoT applications.

[0041] The memory **206** may store a routing component **212** that makes decisions on how to route data packets between different networks using the routing tables **222**. The routing component **212** may determine the optimal path or route for data to travel from the source to the destination. Some of the key functions performed by the routing component **212** include: (i) maintaining routing tables **222**, which are databases containing information about available routes and their associated metrics (such as cost, distance, or bandwidth), (ii) using the routing tables to determine the best path for forwarding the packet based on various factors, such as the destination IP address, network topology, and routing metrics, to select the optimal route, (iii) forwarding data packets to next hops along routes, and (iv) implementing routing protocols (e.g., RIP, LISP, OSPF, BGP) to exchange routing information with neighboring routers such as information about network topology changes and help build and update the routing tables.

[0042] The memory **206** may further store a mapping component **214** configured to store various mappings in caches of the storage **220**, such as a map-cache **224**. The mapping component **214** may store mappings between MAC addresses, Endpoint Identifiers (EIDs), and their associated Routing Locators (RLOCs). An EID represents the identity of a device, while the RLOC indicates the device's current location in the network.

[0043] The memory **206** may further store a forwarding component **216** that determines whether to forward L2 broadcast messages **108** using the techniques described herein and information in the map-cache **224**. When the edge node **105** receives an L2 broadcast message **108**, the forwarding component **216** may compare the source MAC addresses of the L2 broadcast messages **108** with the source endpoint MAC addresses stored in the local map-cache **224**. In response to determining that the source MAC address of the L2 broadcast message **108** matches or corresponds to a source MAC address stored in the local map-cache **224**, the forwarding component **216** may drop the L2 broadcast messages **108** (drop events **118**) and refrain from forwarding the messages **108** because they have been looped by the L2 switch **114**. However, in response to determining that the source MAC addresses of the L2 broadcast message **108** does not match or correspond to a source MAC address stored in the local map-cache **224**, an address-management component **218** may add the source MAC addresses to a MAC address table **228** of the edge node **105** because the L2 broadcast message **108** originated at an endpoint located behind the edge node **105**. Generally, the edge node **105** uses the source MAC addresses to update the MAC address table **228**, and the source MAC address table **228** is a database that associates MAC addresses with the specific ports on the edge node **105** to which devices are connected.

[0044] In the context of the Locator/ID Separation Protocol (LISP), the local map-cache **224** plays a crucial role in facilitating efficient and optimized routing within a LISP-enabled network. The map-cache 2 is a data structure maintained by LISP devices, and the local map-cache **224** specifically refers to the mapping information stored locally on an individual edge node **105**. The local map-cache **224** stores mappings between Endpoint Identifiers (EIDs) and their associated Routing Locators (RLOCs). An EID represents the identity of a device, while the RLOC indicates the device's current location in the network. When an edge node **105** receives a packet destined for an EID, it consults its local map-cache **224** to determine the corresponding RLOC for that EID. This information is crucial for making forwarding decisions. If the mapping is found in the local map-cache **224**, the edge node **105** can quickly and efficiently forward the packet based on the stored RLOC. The local map-cache **224** is queried during the process of forwarding packets. The edge node **105** checks whether it has a valid and up-to-date mapping for the destination EID. If the mapping is present, it avoids the need to query a

Map-Resolver or Map-Server (e.g., control-plane nodes **120**) for mapping information, reducing latency and improving packet forwarding efficiency. Each entry in the local map-cache **224** has a Time-to-Live (TTL) associated with it. The TTL indicates how long the mapping information is considered valid. The local map-cache **224** is responsible for managing and updating TTL values to ensure that mappings are refreshed and kept current. In dynamic networking environments, device mobility, network changes, or updates in mapping information may occur. The local map-cache **224** is designed to handle dynamic updates, refreshing mappings based on TTL values and adapting to changes in the network.

[0045] FIGS. **3**A and **3**B collectively illustrate a flow diagram of an example method **300** for edge nodes **105** in a network fabric **102** to identify L2 broadcast messages **108** that have already been communicated with dual-homed endpoints connected to the network fabric **102**.

[0046] At **302**, the edge node **104** may send a first L2 broadcast message **108** to an edge node **105**. The first L2 broadcast message **108** may have been generated by the source endpoint **106** and include a source endpoint MAC address **110** of the source endpoint **106**.

[0047] At **304**, the edge node **105** may receive the first L2 broadcast message **108** and store the first source endpoint MAC address **110** in a local map-cache **224** based on the local map-cache **224** not having an existing entry for the first source endpoint MAC address **110**. At **306**, the edge node **105** may forward the first L2 broadcast message **108** to the L2 switch **114** (or another endpoint), and receive a second L2 broadcast message **108** at **308** from the L2 switch **114**.

[0048] At **310**, the edge node **105** may determine whether the second source MAC address matches with any MAC addresses stored in the local map-cache **224**. At **312**, in response to determining that the second MAC address does not match with an MAC addresses stored in the local map-cache **224**, the edge node **105** may add the second source MAC address to the MAC address table **228**. Further, at **314**, the edge node **105** may send a registration message to the control-plane nodes **120** to register the source endpoint **10**.

[0049] However, in response to determining that the second MAC address does match with a MAC address stored in the local map-cache **224**, the edge node **105** may drop the second L2 broadcast message **108** at **316**. Further, the edge node **105** may, at **318**, add the second source MAC address to a flood map-cache **226**, and at **320**, query the control-plane nodes **120** as to whether the second source MAC address is registered to another edge node for confirmation. At **322**, the edge node **105** may receive an indicating that the second source MAC address is registered to another edge node and verify the determination that the second L2 broadcast message **108** was a looped message. However, the control-plane nodes **120** may in some instances indicate that the second source MAC address is not registered to another edge node, and in such an example, the edge node may clear the map-cache **224** and flood map-cache **226** entries for that MAC address and add the MAC address to the MAC address table **228**.

[0050] FIGS. **4**A, **4**B, and **5** illustrate flow diagrams of example methods **400** and **500** that illustrate aspects of the functions performed at least partly by the devices in the distributed application architecture as described in FIGS. **1**-**3**B. The logical operations described herein with respect to FIGS. **4**A, **4**B, and **5** may be implemented (1) as a sequence of computer-implemented acts or program modules running on a computing system and/or (2) as interconnected machine logic circuits or circuit modules within the computing system.

[0051] The implementation of the various components described herein is a matter of choice dependent on the performance and other requirements of the computing system. Accordingly, the logical operations described herein are referred to variously as operations, structural devices, acts, or modules. These operations, structural devices, acts, and modules can be implemented in software, in firmware, in special purpose digital logic, and any combination thereof. It should also be appreciated that more or fewer operations might be performed than shown in the FIGS. **4**A, **4**B, and **5** and described herein. These operations can also be performed in parallel, or in a different order than those described herein. Some or all of these operations can also be performed by components other than those specifically identified. Although the techniques described in this disclosure is with reference to specific components, in other examples, the techniques may be implemented by less components, more components, or different arrangements of components.

[0052] FIG. **4**A and **4**B collectively illustrate a flow diagram of an example method **400** for edge nodes **105** in a network fabric **102** to determine whether L2 broadcast messages **108** have already been communicated with dual-homed endpoints connected to the network fabric **102**.

[0053] At **402**, the first edge node **105** may receive a first Layer-2 (L2) broadcast message **108** from a second edge node (e.g., remote edge node **104**) and over the network fabric **102**. In some examples, the first L2 broadcast message **108** originates at an endpoint (e.g., source endpoint **106**) that is connected to the second edge node.

[0054] At **404**, the first edge node **105** may identify, from the first L2 broadcast message **108**, a first source media access control (MAC) address **110** of the endpoint. At **406**, the edge node **105** may store the first source MAC address **110** of the first L2 broadcast message **108** in a local cache (e.g., map-cache **224**) of the first edge node **105**.

[0055] At **408**, the first edge node **105** may forward the first L2 broadcast message **108** to an L2 device (e.g., L2 switch **114**) connected to the first edge node **105**, where the L2 switch **114** (or other device) is configured to access the network fabric **102** via the first edge node **105**(**1**) and a third edge node **105**(**2**).

[0056] At **410**, the first edge node **105** may receive a second L2 broadcast message from the L2 device. At **412**, the first edge node **105** may identify, from the second L2 broadcast message, a second source MAC address and a destination MAC address **112** that is a broadcast address (e.g., FF-FF-FF-FF-FF-FF). At **414**, the first edge node **105** may determine whether the second source MAC address corresponds to the first source MAC address stored in the local cache (e.g., comparison with entries in the MAC address table **228**).

[0057] At **416**, the first edge node **105** may, in response to determining that the second source MAC address corresponds to the first source MAC address, drop the second L2 broadcast message.

[0058] In some instances, the method **400** may further comprise, in response to determining that the second source MAC address corresponds to the first source MAC address, refraining from adding the second source MAC address to the source MAC address table.

[0059] In some instances, the method **400** may further comprise, in response to determining that the second source MAC address corresponds to the first source MAC address, refraining from sending a registration message to a control-plane of the network fabric to register the endpoint with the first edge node.

[0060] In some instances, the method **400** may further comprise, in response to determining that the second source MAC address corresponds to the first source MAC address, querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric, and receiving, from the control-plane, an indication that the endpoint is registered to the second edge node of the network fabric.

[0061] In some instances, the method **400** may further comprise, in response to determining that the second source MAC address corresponds to the first source MAC address, adding the second source MAC address to a flood map-cache table stored in the first edge node, wherein the flood map-cache table stores source MAC addresses received in L2 broadcast messages that belong to endpoints which are registered to other edge nodes of the network fabric.

[0062] In some instances, the method **400** may further comprise, in response to determining that the second source MAC address corresponds to the first source MAC address, querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric, receiving, from the control-plane, an indication that the endpoint is not registered to another edge node of the network fabric, and in response to receiving the indication that the second source MAC is not registered to another edge node of the network fabric, removing the second source MAC address from the flood map-cache table.

[0063] In some instances, the method **400** may further comprise, in response to determining that the second source MAC address corresponds to the first source MAC address, querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric, receiving, from the control-plane, an indication that the endpoint is not registered to another edge node of the network fabric, and in response to receiving the indication that the second source MAC is not registered to another edge node of the network fabric, adding the second source MAC address to a source MAC address table corresponding to the L2 device.

[0064] At **418**, the first edge node **105** may in response to determining that the second source MAC address does not correspond the first source MAC address, add the second source MAC address to a source MAC address table corresponding to the L2 device.

[0065] FIG. **5** illustrates a flow diagram of an example method **500** for an edge node **105** in a network fabric **102** to determine that a L2 broadcast message **108** has already been communicated with dual-homed endpoints connected to the network fabric **102**, and dropping the L2 broadcast message.

[0066] At **502**, the first edge node **105** may receive a first Layer-2 (L2) broadcast message **108** from a second edge node (e.g., remote edge node **104**) and over the network fabric **102**, where the first L2 broadcast message **108** originates at an endpoint (e.g., source endpoint **106**) that is connected to the second edge node.

[0067] At **504**, the first edge node **105** may identify, from the first L2 broadcast message, a source media access control (MAC) address of the endpoint. At **506**, the first edge node **105** may forward the first L2 broadcast message to an L2 device connected to the first edge node, wherein the L2 device is configured to access the network fabric via the first edge node and a third edge node.

[0068] At **508**, the first edge node **105** may receive a second L2 broadcast message from the L2 device. At **510**, the first edge node **105** may determine that the second L2 broadcast message includes the source MAC address. At **512**, the first edge node **105** may, based at least in part the second L2 broadcast message including the source MAC address, drop the second L2 broadcast message.

[0069] FIG. **6** illustrates a block diagram illustrating an example packet switching device (or system) **600** that can be utilized to implement various aspects of the technologies disclosed herein. In some examples, packet switching device (s) **600** may be employed in various networks, such as, as an edge node **104** connected to network fabric **102** as described with respect to FIG. **1**.

[0070] In some examples, a packet switching device **600** may comprise multiple line card(s) **602**, **610**, each with one or more network interfaces for sending and receiving packets over communications links (e.g., possibly part of a link aggregation group). The packet switching device **600** may also have a control plane with one or more processing elements **605** for managing the control plane and/or control plane processing of packets associated with forwarding of packets in a network. The packet switching device **600** may also include other cards **608** (e.g., service cards, blades) which include processing elements that are used to process (e.g., forward/send, drop, manipulate, change, modify, receive, create, duplicate, apply a service) packets associated with forwarding of packets in a network. The packet switching device **600** may comprise hardware-based communication mechanism **606** (e.g., bus, switching fabric, and/or matrix, etc.) for allowing its different entities **602**, **604**, **608** and **610** to communicate. Line card(s) **602**, **610** may typically perform the actions of being both an ingress and/or an egress line card **602**, **610**, in regard to multiple other particular packets and/or packet streams being received by, or sent from, packet switching device **600**.

[0071] FIG. **7** illustrates a block diagram illustrating certain components of an example node **700** that can be utilized to implement various aspects of the technologies disclosed herein. In some examples, node(s) **700** may be employed in various networks, such as, as an edge node **104** connected to network fabric **102** as described with respect to FIG. **1**.

[0072] In some examples, node **700** may include any number of line cards **702** (e.g., line cards **702**(**1**)-(N), where N may be any integer greater than **1**) that are communicatively coupled to a forwarding engine **710** (also referred to as a packet forwarder) and/or a processor **720** via a data bus **730** and/or a result bus **740**. Line cards **702**(**1**)-(N) may include any number of port processors **750**(**1**)(A)-(N)(N) which are controlled by port processor controllers **760**(**1**)-(N), where N may be any integer greater than **1**. Additionally, or alternatively, forwarding engine **710** and/or processor **720** are not only coupled to one another via the data bus **730** and the result bus **740**, but may also communicatively coupled to one another by a communications link **770**.

[0073] The processors (e.g., the port processor(s) **750** and/or the port processor controller(s) **760**) of each line card

702 may be mounted on a single printed circuit board. When a packet or packet and header are received, the packet or packet and header may be identified and analyzed by node **700** (also referred to herein as a router) in the following manner. Upon receipt, a packet (or some or all of its control information) or packet and header may be sent from one of port processor(s) **750**(**1**)(A)-(N)(N) at which the packet or packet and header was received and to one or more of those devices coupled to the data bus **830** (e.g., others of the port processor(s) **750**(**1**)(A)-(N)(N), the forwarding engine **710** and/or the processor **720**). Handling of the packet or packet and header may be determined, for example, by the forwarding engine **710**. For example, the forwarding engine **710** may determine that the packet or packet and header should be forwarded to one or more of port processors **750**(**1**)(A)-(N)(N). This may be accomplished by indicating to corresponding one(s) of port processor controllers **760** (**1**)-(N) that the copy of the packet or packet and header held in the given one(s) of port processor(s) **750**(**1**)(A)-(N)(N) should be forwarded to the appropriate one of port processor (s) **750**(**1**)(A)-(N)(N). Additionally, or alternatively, once a packet or packet and header has been identified for processing, the forwarding engine **710**, the processor **720**, and/or the like may be used to process the packet or packet and header in some manner and/or maty add packet security information in order to secure the packet. On a node **700** sourcing such a packet or packet and header, this processing may include, for example, encryption of some or all of the packets or packet and header's information, the addition of a digital signature, and/or some other information and/or processing capable of securing the packet or packet and header. On a node **700** receiving such a processed packet or packet and header, the corresponding process may be performed to recover or validate the packet's or packet and header's information that has been secured.

[0074] FIG. **8** is a computer architecture diagram showing an illustrative computer hardware architecture for implementing a computing device that can be utilized to implement aspects of the various technologies presented herein.

[0075] The computer architecture shown in FIG. **8** illustrates a conventional server computer, workstation, desktop computer, laptop, tablet, network appliance, e-reader, smartphone, or other computing device, and can be utilized to execute any of the software components presented herein. The computer **800** may, in some examples, correspond to a physical server described herein, and may comprise networked devices such as servers, switches, routers, hubs, bridges, gateways, modems, repeaters, access points, etc.

[0076] The computer **800** includes a baseboard **802**, or "motherboard," which is a printed circuit board to which a multitude of components or devices can be connected by way of a system bus or other electrical communication paths. In one illustrative configuration, one or more central processing units ("CPUs") **804** operate in conjunction with a chipset **806**. The CPUs **804** can be standard programmable processors that perform arithmetic and logical operations necessary for the operation of the computer **800**.

[0077] The CPUs **804** perform operations by transitioning from one discrete, physical state to the next through the manipulation of switching elements that differentiate between and change these states. Switching elements generally include electronic circuits that maintain one of two binary states, such as flip-flops, and electronic circuits that provide an output state based on the logical combination of the states of one or more other switching elements, such as logic gates. These basic switching elements can be combined to create more complex logic circuits, including registers, adders-subtractors, arithmetic logic units, floating-point units, and the like.

[0078] The chipset **806** provides an interface between the CPUs **804** and the remainder of the components and devices on the baseboard **802**. The chipset **806** can provide an interface to a RAM **808**, used as the main memory in the computer **800**. The chipset **806** can further provide an interface to a computer-readable storage medium such as a read-only memory ("ROM") **810** or non-volatile RAM ("NVRAM") for storing basic routines that help to startup the computer **800** and to transfer information between the various components and devices. The ROM **810** or NVRAM can also store other software components necessary for the operation of the computer **800** in accordance with the configurations described herein.

[0079] The computer **800** can operate in a networked environment using logical connections to remote computing devices and computer systems through a network, such as the network **126**. The chipset **806** can include functionality for providing network connectivity through a NIC **812**, such as a gigabit Ethernet adapter. The NIC **812** is capable of connecting the computer **800** to other computing devices over the network **126**. It should be appreciated that multiple NICs **812** can be present in the computer **800**, connecting the computer to other types of networks and remote computer systems.

[0080] The computer **800** can be connected to a storage device **818** that provides non-volatile storage for the computer. The storage device **818** can store an operating system **820**, programs **822**, and data, which have been described in greater detail herein. The storage device **818** can be connected to the computer **800** through a storage controller **814** connected to the chipset **806**. The storage device **818** can consist of one or more physical storage units. The storage controller **814** can interface with the physical storage units through a serial attached SCSI ("SAS") interface, a serial advanced technology attachment ("SATA") interface, a fiber channel ("FC") interface, or other type of interface for physically connecting and transferring data between computers and physical storage units.

[0081] The computer **800** can store data on the storage device **818** by transforming the physical state of the physical storage units to reflect the information being stored. The specific transformation of physical state can depend on various factors, in different embodiments of this description. Examples of such factors can include, but are not limited to, the technology used to implement the physical storage units, whether the storage device **818** is characterized as primary or secondary storage, and the like.

[0082] For example, the computer **800** can store information to the storage device **818** by issuing instructions through the storage controller **814** to alter the magnetic characteristics of a particular location within a magnetic disk drive unit, the reflective or refractive characteristics of a particular location in an optical storage unit, or the electrical characteristics of a particular capacitor, transistor, or other discrete component in a solid-state storage unit. Other transformations of physical media are possible without departing from the scope and spirit of the present description, with the foregoing examples provided only to facilitate this description. The computer **800** can further read information from the storage device **818** by detecting the physical states or characteristics of one or more particular locations within the physical storage units.

[0083] In addition to the mass storage device **818** described above, the computer **800** can have access to other computer-readable storage media to store and retrieve information, such as program modules, data structures, or other data. It should be appreciated by those skilled in the art that computer-readable storage media is any available media that provides for the non-transitory storage of data and that can be accessed by the computer **800**. In some examples, the operations performed by devices in the network fabric, such as the edge nodes **105**, and or any components included therein, may be supported by one or more devices similar to computer **800**. Stated otherwise, some or all of the operations performed by the devices in the network fabric **102**, and or any components included therein, may be performed by one or more computers **800** operating in any arrangement.

[0084] By way of example, and not limitation, computer-readable storage media can include volatile and non-volatile, removable and non-removable media implemented in any method or technology. Computer-readable storage media includes, but is not limited to, RAM, ROM, erasable programmable ROM ("EPROM"), electrically-erasable programmable ROM ("EEPROM"), flash memory or other solid-state memory technology, compact disc ROM ("CD-ROM"), digital versatile disk ("DVD"), high definition DVD ("HD-DVD"), BLU-RAY, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store the desired information in a non-transitory fashion.

[0085] As mentioned briefly above, the storage device **818** can store an operating system **820** utilized to control the operation of the computer **800**. According to one embodiment, the operating system comprises the LINUX operating system. According to another embodiment, the operating system comprises the WINDOWS® SERVER operating system from MICROSOFT Corporation of Redmond, Washington. According to further embodiments, the operating system can comprise the UNIX operating system or one of its variants. It should be appreciated that other operating systems can also be utilized. The storage device **818** can store other system or application programs and data utilized by the computer **800**.

[0086] In one embodiment, the storage device **818** or other computer-readable storage media is encoded with computer-executable instructions which, when loaded into the computer **800**, transform the computer from a general-purpose computing system into a special-purpose computer capable of implementing the embodiments described herein. These computer-executable instructions transform the computer **800** by specifying how the CPUs **804** transition between states, as described above. According to one embodiment, the computer **800** has access to computer-readable storage media storing computer-executable instructions which, when executed by the computer **800**, perform the various processes described above with regard to FIGS. **1-7**. The computer **800** can also include computer-readable storage media having instructions stored thereupon for performing any of the other computer-implemented operations described herein.

[0087] The computer **800** can also include one or more input/output controllers **816** for receiving and processing input from a number of input devices, such as a keyboard, a mouse, a touchpad, a touch screen, an electronic stylus, or other type of input device. Similarly, an input/output controller **816** can provide output to a display, such as a computer monitor, a flat-panel display, a digital projector, a printer, or other type of output device. It will be appreciated that the computer **800** might not include all of the components shown in FIG. **8**, can include other components that are not explicitly shown in FIG. **8**, or might utilize an architecture completely different than that shown in FIG. **8**.

[0088] As described herein, the computer **800** may comprise one or more of a router, load balancer, switch, gateway, and/or another network device. The computer **800** may include one or more hardware processors **804** (processors) configured to execute one or more stored instructions. The processor(s) **804** may comprise one or more cores. Further, the computer **800** may include one or more network interfaces configured to provide communications between the computer **800** and other devices, such as the communications described herein as being performed by the devices described herein. The network interfaces may include devices configured to couple to personal area networks (PANs), wired and wireless local area networks (LANs), wired and wireless wide area networks (WANs), and so forth. For example, the network interfaces may include devices compatible with Ethernet, Wi-Fi™, and so forth.

[0089] The programs **822** may comprise any type of programs or processes to perform the techniques described in this disclosure for providing an edge node **105** that is capable of performing the techniques described herein. The programs **822** may comprise any type of program that cause the computer **800** to perform techniques for communicating with other devices using any type of protocol or standard usable for determining connectivity.

[0090] While the invention is described with respect to the specific examples, it is to be understood that the scope of the invention is not limited to these specific examples. Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

[0091] Although the application describes embodiments having specific structural features and/or methodological acts, it is to be understood that the claims are not necessarily limited to the specific features or acts described. Rather, the specific features and acts are merely illustrative some embodiments that fall within the scope of the claims of the application.

What is claimed is:

1. A first edge node of a network fabric, the first edge node comprising:

one or more processors; and

one or more non-transitory computer-readable media storing computer-executable instructions that, when executed by the one or more processors, cause the one or more processors to perform operations comprising:

receiving a first Layer-2 (L2) broadcast message from a second edge node and over the network fabric, the first L2 broadcast message originating at an endpoint that is connected to the second edge node;

identifying, from the first L2 broadcast message, a first source media access control (MAC) address of the endpoint;

storing the first source MAC address of the first L2 broadcast message in a local cache of the first edge node;

forwarding the first L2 broadcast message to an L2 device connected to the first edge node, wherein the L2 device is configured to access the network fabric via the first edge node and a third edge node;

receiving a second L2 broadcast message from the L2 device;

identifying, from the second L2 broadcast message, a second source MAC address and a destination MAC address that is a broadcast address;

determining whether the second source MAC address corresponds to the first source MAC address stored in the local cache;

in response to determining that the second source MAC address corresponds to the first source MAC address, dropping the second L2 broadcast message; or in response to determining that the second source MAC address does not correspond the first source MAC address, adding the second source MAC address to a source MAC address table corresponding to the L2 device.

2. The first edge node of claim **1**, the operations further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address, refraining from adding the second source MAC address to the source MAC address table.

3. The first edge node of claim **1**, the operations further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address, refraining from sending a registration message to a control-plane of the network fabric to register the endpoint with the first edge node.

4. The first edge node of claim **1**, the operations further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric; and

receiving, from the control-plane, an indication that the endpoint is registered to the second edge node of the network fabric.

5. The first edge node of claim **1**, the operations further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

adding the second source MAC address to a flood map-cache table stored in the first edge node, wherein the flood map-cache table stores source MAC addresses received in L2 broadcast messages that belong to endpoints which are registered to other edge nodes of the network fabric.

6. The first edge node of claim **5**, the operations further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric;

receiving, from the control-plane, an indication that the endpoint is not registered to another edge node of the network fabric; and

in response to receiving the indication that the second source MAC is not registered to another edge node of the network fabric, removing the second source MAC address from the flood map-cache table.

7. The first edge node of claim **1**, the operations further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric;

receiving, from the control-plane, an indication that the endpoint is not registered to another edge node of the network fabric; and

in response to receiving the indication that the second source MAC is not registered to another edge node of the network fabric, adding the second source MAC address to a source MAC address table corresponding to the L2 device.

8. The first edge node of claim **1**, wherein:

the network fabric is a software-defined access (SDA) fabric; and

the SDA fabric is associated with a Locator/Identifier Separation Protocol (LISP) control plane.

9. The first edge node of claim **1**, wherein:

the network fabric includes an Ethernet Virtual Private Network (EVPN) fabric; and

the EVPN fabric is associated with a Border Gateway Protocol (BGP) control plane that includes a route reflector.

10. A computer-implemented method performed by a first edge node of a network fabric, the method comprising:

receiving a first Layer-2 (L2) broadcast message from a second edge node and over the network fabric, the first L2 broadcast message originating at an endpoint that is connected to the second edge node;

identifying, from the first L2 broadcast message, a first source media access control (MAC) address of the endpoint;

storing the first source MAC address of the first L2 broadcast message in a local cache of the first edge node;

forwarding the first L2 broadcast message to an L2 device connected to the first edge node, wherein the L2 device is configured to access the network fabric via the first edge node and a third edge node;

receiving a second L2 broadcast message from the L2 device;

identifying, from the second L2 broadcast message, a second source MAC address and a destination MAC address that is a broadcast address;

determining whether the second source MAC address corresponds to the first source MAC address stored in the local cache;

in response to determining that the second source MAC address corresponds to the first source MAC address, dropping the second L2 broadcast message; or in response to determining that the second source MAC address does not correspond the first source MAC address, adding the second source MAC address to a source MAC address table corresponding to the L2 device.

11. The computer-implemented method of claim **10**, further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address, refraining from adding the second source MAC address to the source MAC address table.

12. The computer-implemented method of claim **10**, further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address, refraining from sending a registration message to a control-plane of the network fabric to register the endpoint with the first edge node.

13. The computer-implemented method of claim **10**, further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric; and

receiving, from the control-plane, an indication that the endpoint is registered to the second edge node of the network fabric.

14. The computer-implemented method of claim **10**, further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

adding the second source MAC address to a flood map-cache table stored in the first edge node, wherein the flood map-cache table stores source MAC addresses received in L2 broadcast messages that belong to endpoints which are registered to other edge nodes of the network fabric.

15. The computer-implemented method of claim **14**, further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric;

receiving, from the control-plane, an indication that the endpoint is not registered to another edge node of the network fabric; and

in response to receiving the indication that the second source MAC is not registered to another edge node of the network fabric, removing the second source MAC address from the flood map-cache table.

16. The computer-implemented method of claim **10**, further comprising, in response to determining that the second source MAC address corresponds to the first source MAC address:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric;

receiving, from the control-plane, an indication that the endpoint is not registered to another edge node of the network fabric; and

in response to receiving the indication that the second source MAC is not registered to another edge node of the network fabric, adding the second source MAC address to a source MAC address table corresponding to the L2 device.

17. A computer-implemented method performed by a first edge node of a network fabric, the method comprising:

receiving a first Layer-2 (L2) broadcast message from a second edge node and over the network fabric, the first L2 broadcast message originating at an endpoint that is connected to the second edge node;

identifying, from the first L2 broadcast message, a source media access control (MAC) address of the endpoint;

forwarding the first L2 broadcast message to an L2 device connected to the first edge node, wherein the L2 device is configured to access the network fabric via the first edge node and a third edge node;

receiving a second L2 broadcast message from the L2 device;

determining that the second L2 broadcast message includes the source MAC address; and

based at least in part the second L2 broadcast message including the source MAC address, dropping the second L2 broadcast message.

18. The computer-implemented method of claim **17**, further comprising refraining from adding the source MAC address to a source MAC address table corresponding to the L2 device.

19. The computer-implemented method of claim **17**, further comprising refraining from sending a registration message to a control-plane of the network fabric to register the endpoint with the first edge node.

20. The computer-implemented method of claim **17**, further comprising:

querying a control-plane of the network fabric to determine whether the endpoint is registered to another edge node of the network fabric; and

receiving, from the control-plane, an indication that the endpoint is registered to the second edge node of the network fabric.

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