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(54) **FORWARDING OF PACKETS IN A NETWORK BASED ON MULTIPLE COMPACT FORWARDING IDENTIFIERS REPRESENTED IN A SINGLE INTERNET PROTOCOL VERSION 6 (IPv6) ADDRESS**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

7,058,728 B1 * 6/2006 Eklund H04L 69/04 455/445
7,072,339 B2 * 7/2006 Tsuchiya H04L 61/2542 370/466
(Continued)

FOREIGN PATENT DOCUMENTS

WO 2020/226952 A1 11/2020

OTHER PUBLICATIONS

Jon Postel, "Internet Protocol," DARPA Internet Program Protocol Specification, RFC 791, Sep. 1981, Information Sciences Institute, University of Southern California, Marina del Rey, CA.

(Continued)

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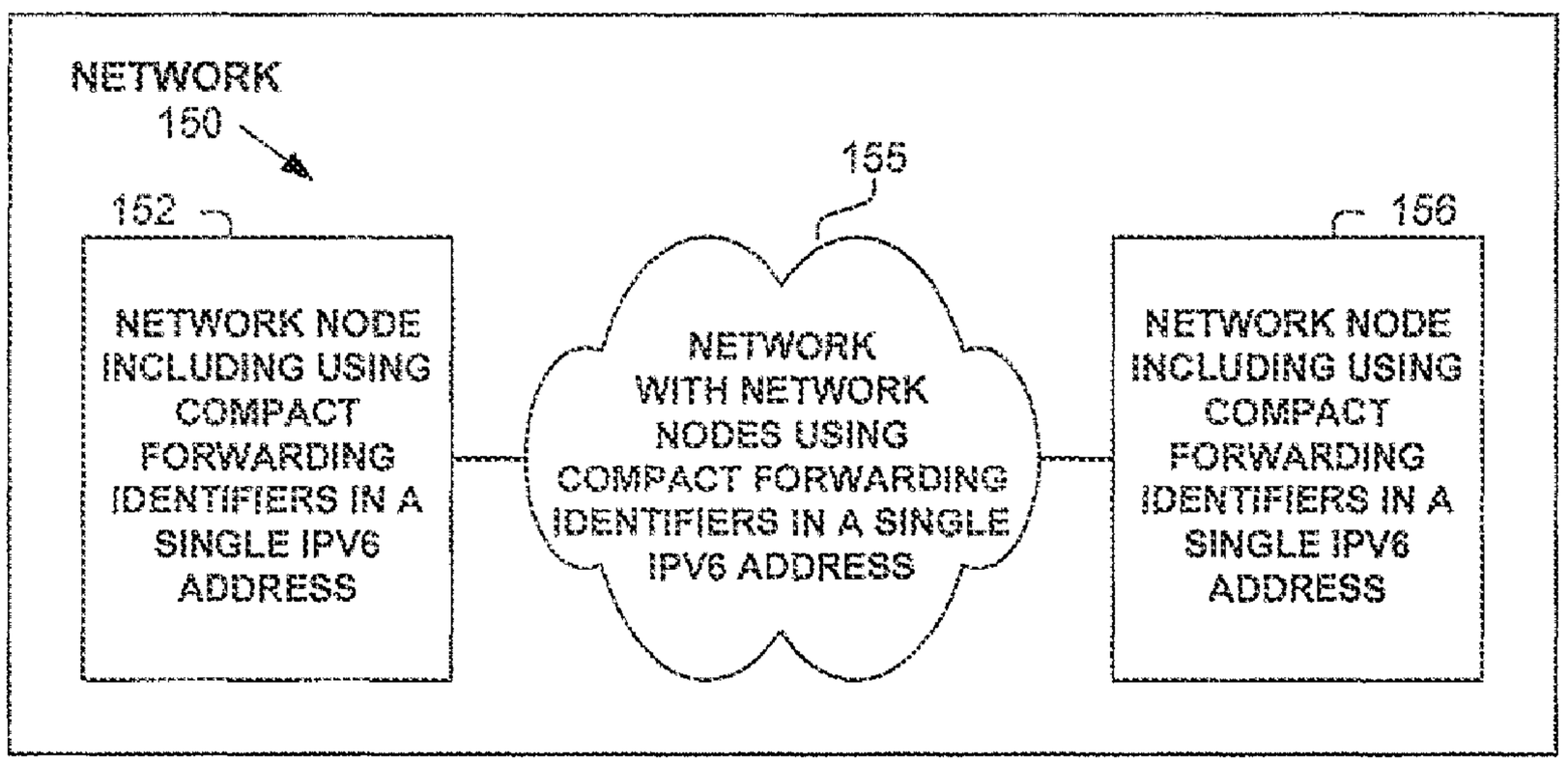
(57) **ABSTRACT**

In one embodiment, packets are forwarded in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., possibly in an extended IPv6 header). One embodiment follows the forwarding order of these multiple compact forwarding identifiers by respectively placing them in the single IPv6 address from high-order to lower-order bit positions. In one embodiment, a compact forwarding identifier prefix is part of the address represented by each compact forwarding identifier, typically with the compact forwarding identifier prefix stored in the highest-order bit positions. One embodiment uses a longest prefix matching operation to match the compact forwarding identifier to be used in determining how to next process the packet.

42 Claims, 7 Drawing Sheets



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(56) **References Cited**

U.S. PATENT DOCUMENTS

7,075,932	B2 *	7/2006	Matsuhira	H04L 45/00 709/239
7,088,726	B1 *	8/2006	Hamamoto	H04L 69/16 370/466
7,283,540	B2 *	10/2007	Hamamoto	H04L 69/16 370/466
7,539,202	B2 *	5/2009	Thubert	H04L 63/0407 370/466
8,300,631	B2 *	10/2012	Dai	H04W 60/00 370/328
9,537,769	B2	1/2017	Bryant et al.	
10,367,734	B2 *	7/2019	Bashandy	H04L 45/74
10,757,020	B2 *	8/2020	Morris	H04L 45/16
10,841,198	B1 *	11/2020	Morris	H04L 45/745
10,841,220	B1	11/2020	Filsfils et al.	
2009/0059866	A1 *	3/2009	Chen	H04W 36/0011 370/331
2010/0265869	A1 *	10/2010	Sarikaya	H04L 12/1836 370/312
2014/0269721	A1 *	9/2014	Bashandy	H04L 41/12 370/392
2019/0020583	A1	1/2019	Bashandy et al.	
2021/0029034	A1	1/2021	Filsfils et al.	
2023/0336478	A1 *	10/2023	Geng	H04L 45/34

OTHER PUBLICATIONS

Deering et al., "Internet Protocol, Version 6 (IPv6) Specification," RFC 2460, Dec. 1998, The Internet Society, Reston, VA, USA (thirty-nine pages).

Filsfils et al., Segment Routing Architecture draft-ietf-spring-segement-routing-12, Jun. 20, 2017 (from Applicant's IDS filed on Jul. 11, 2017) (Year: 2017).*

T. Bates et al., "Multiprotocol Extensions for BGP-4," RFC 4760, Jan. 2007, The Internet Society, Reston, VA, USA (twelve pages).

S. Deering and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," RFC 8200, Jul. 2017, The Internet Society, Reston, VA, USA (forty-two pages).

Filsfils et al., "SRv6 Network Programming," draft-filsfils-spring-srv6-network-programming-00, Mar. 9, 2017, The Internet Society, Reston, VA, USA (forty-one pages).

Filsfils et al., "SRv6 Network Programming," draft-filsfils-spring-srv6-network-programming-01, Jun. 28, 2017, The Internet Society, Reston, VA, USA (forty-two pages).

Filsfils et al., "Segment Routing Architecture," draft-ietf-spring-segment-routing-11, Feb. 16, 2017, The Internet Society, Reston, VA, USA (twenty-eight pages).

Filsfils et al., "Segment Routing Architecture," draft-ietf-spring-segment-routing-12, Jun. 20, 2017, The Internet Society, Reston, VA, USA (twenty-eight pages).

Previdi et al., "IPv6 Segment Routing Header (SRH)," draft-ietf-6man-segment-routing-header-06, Mar. 13, 2017, The Internet Society, Reston, VA, USA (thirty-five pages).

Rekhter et al., "A Border Gateway Protocol 4 (BGP-4)," RFC 4271, Jan. 2006, The Internet Society, Reston, VA, USA (104 pages).

Bates et al., "Multiprotocol Extensions for BGP-4," RFC 2283, Feb. 1998, The Internet Society, Reston, VA, USA (nine pages).

Deering et al., "Internet Protocol, Version 6 (IPv6) Specfication," RFC 2460, Dec. 1998, The Internet Society, Reston, VA, USA (thirty-nine pages).

Rosen et al., "Multiprotocol Label Switching Architecture," RFC 3031, Jan. 2001, The Internet Society, Reston, VA, USA (sixty-one pages).

"Information technology—Telecommunications and information exchange between systems—Intermediate System to Intermediate System intra-domain routeing information exchange protocol for use in conjunction with the protocol for providing the connectionless-mode network service (ISO 8473)," Second Edition, Nov. 15, 2002, ISO/IEC 2002, Switzerland (210 pages).

* cited by examiner

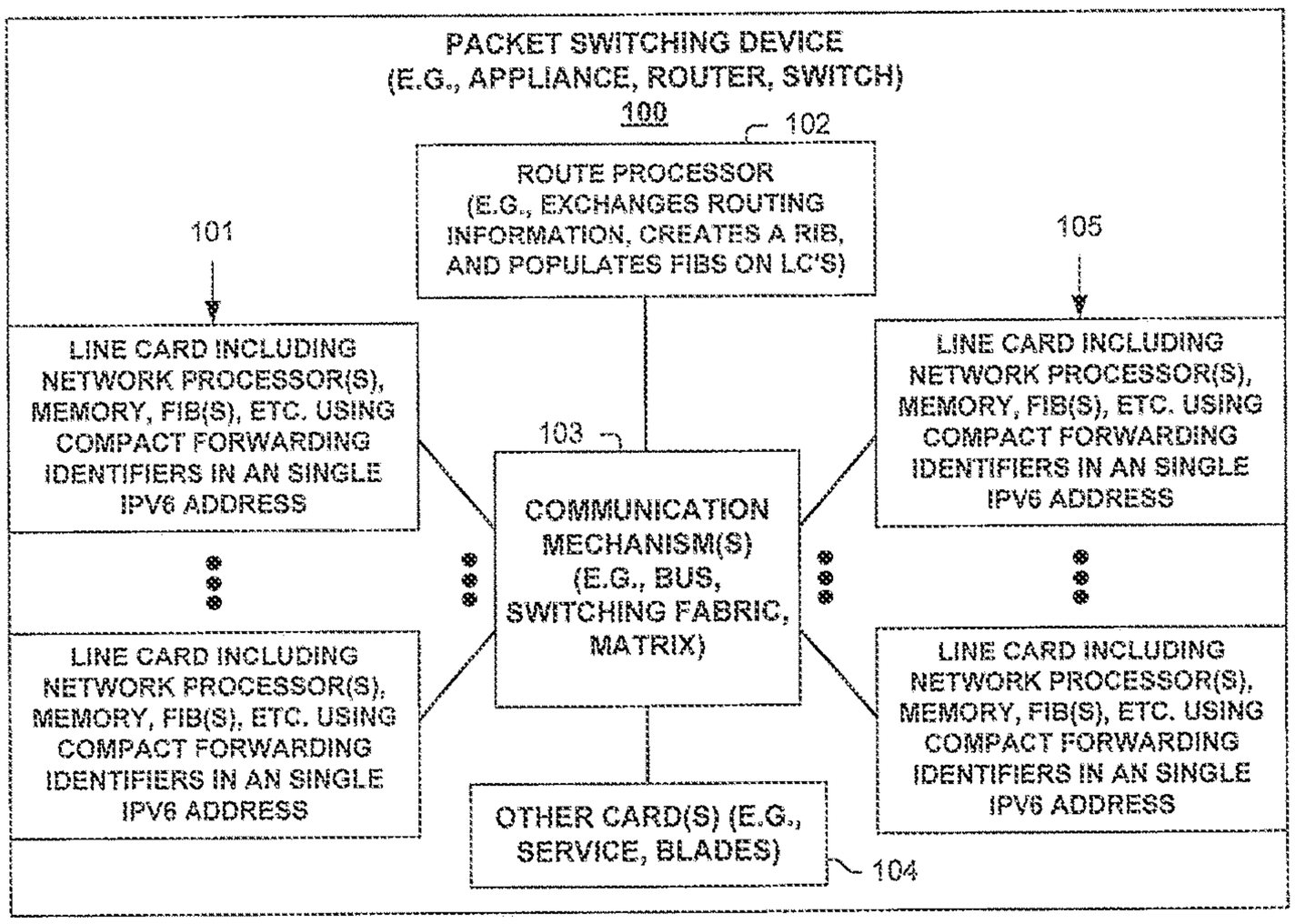

FIGURE 1A

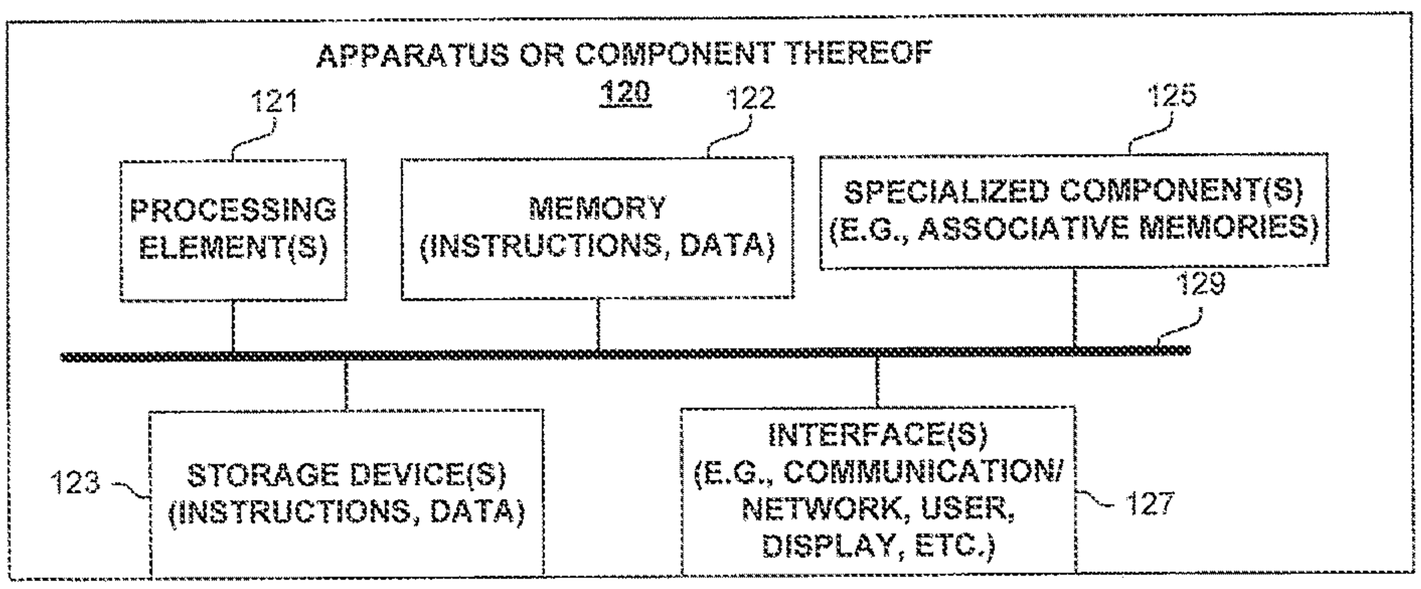

FIGURE 1B

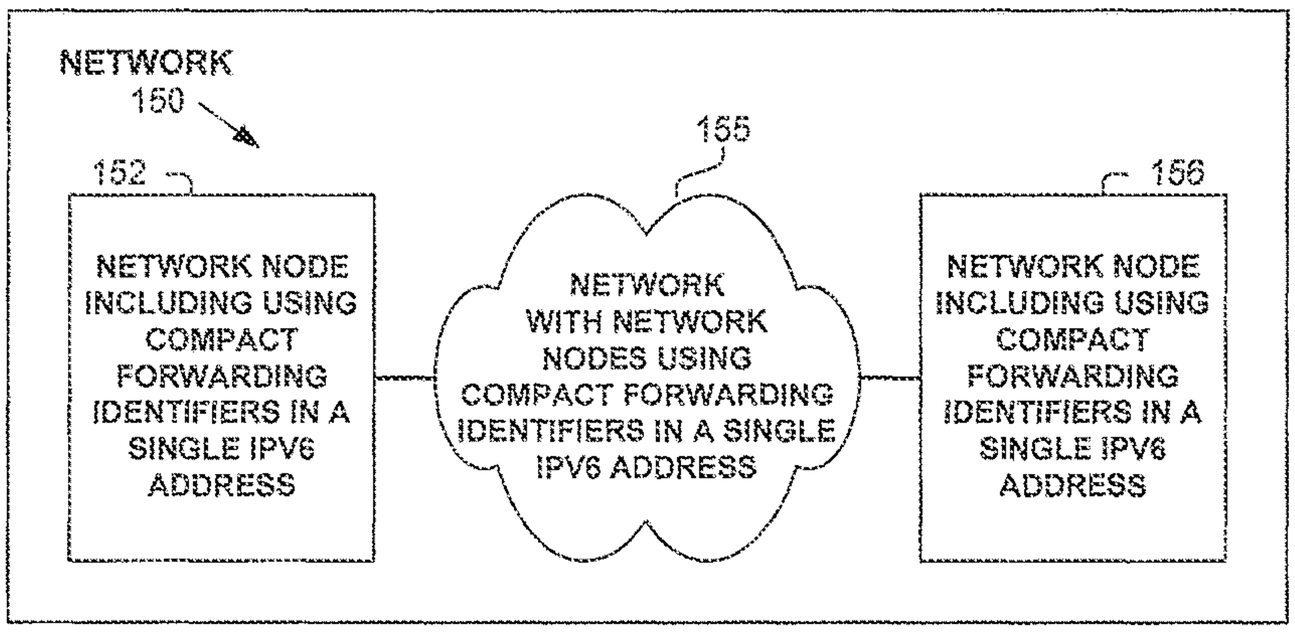

FIGURE 1C

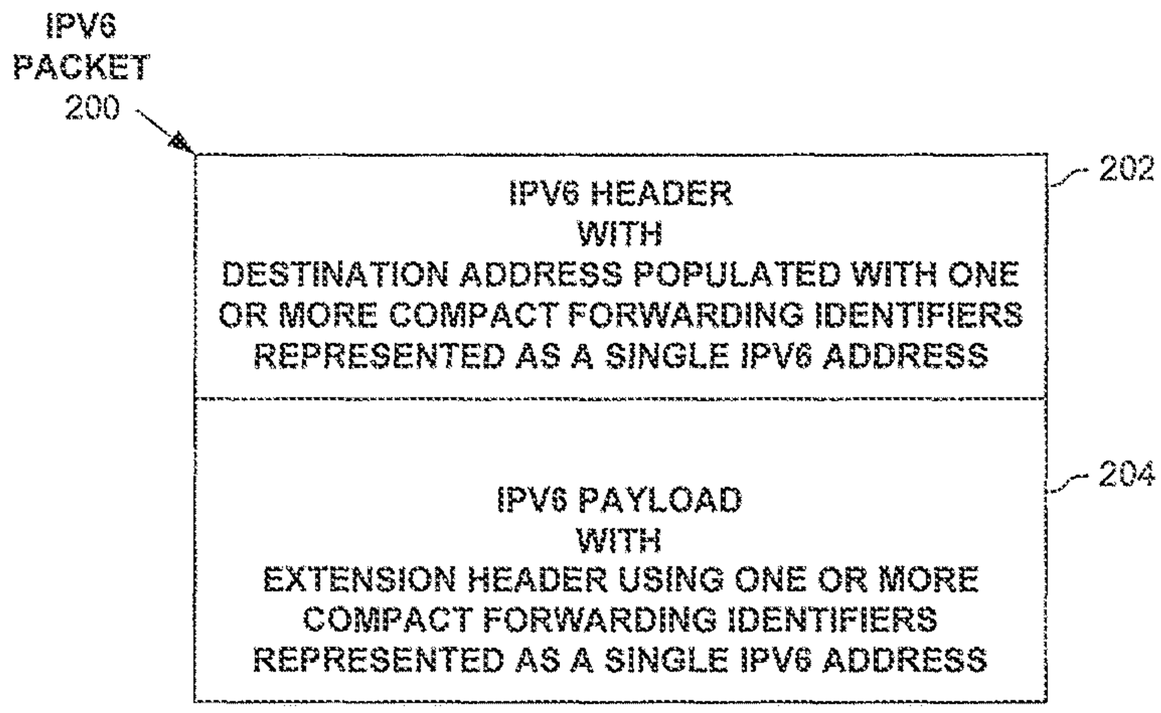

FIGURE 2A

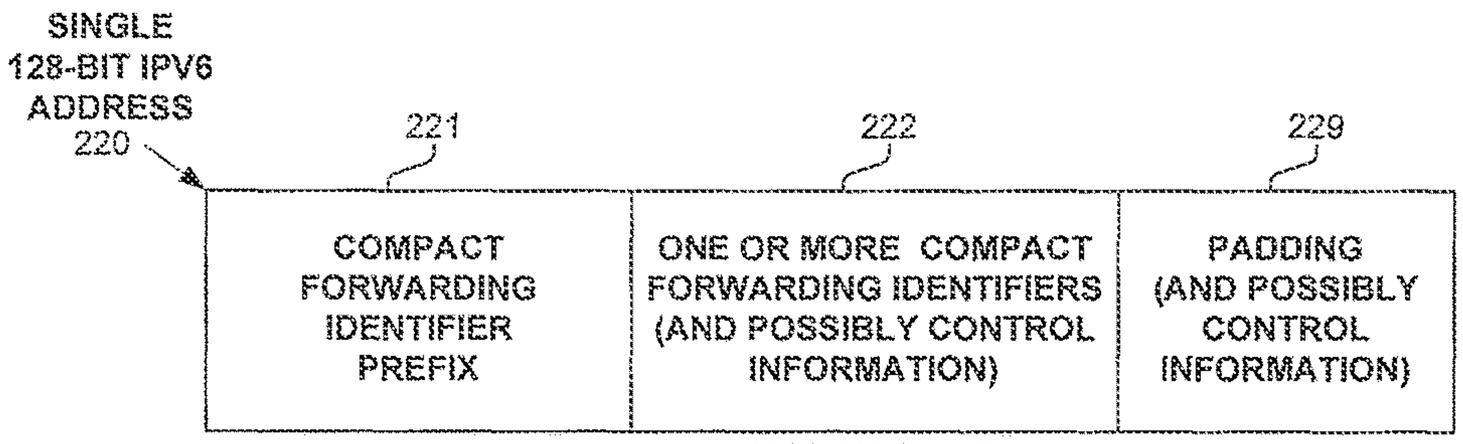

FIGURE 2B

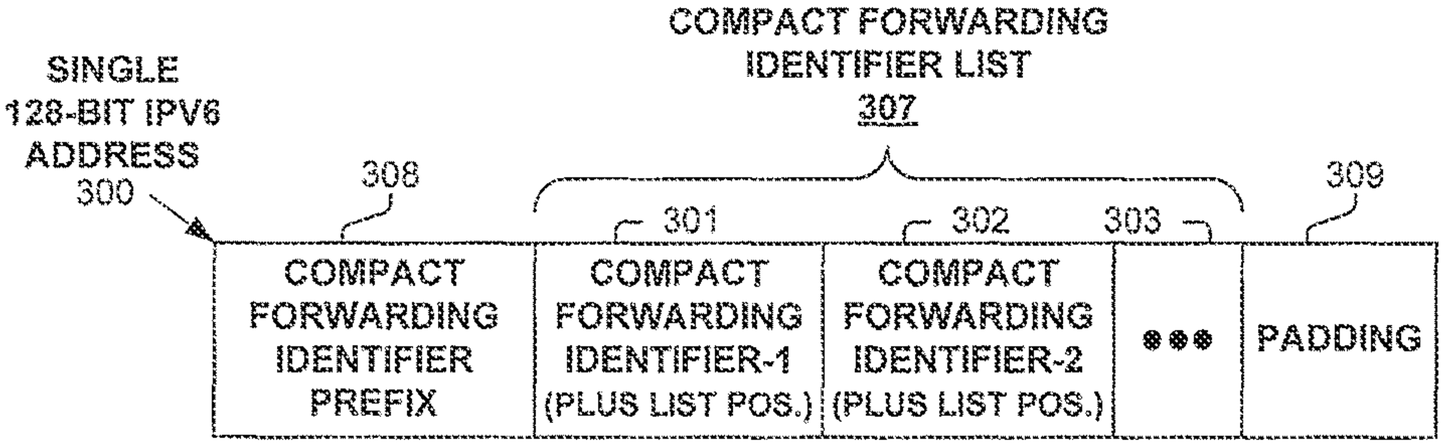

FIGURE 3A

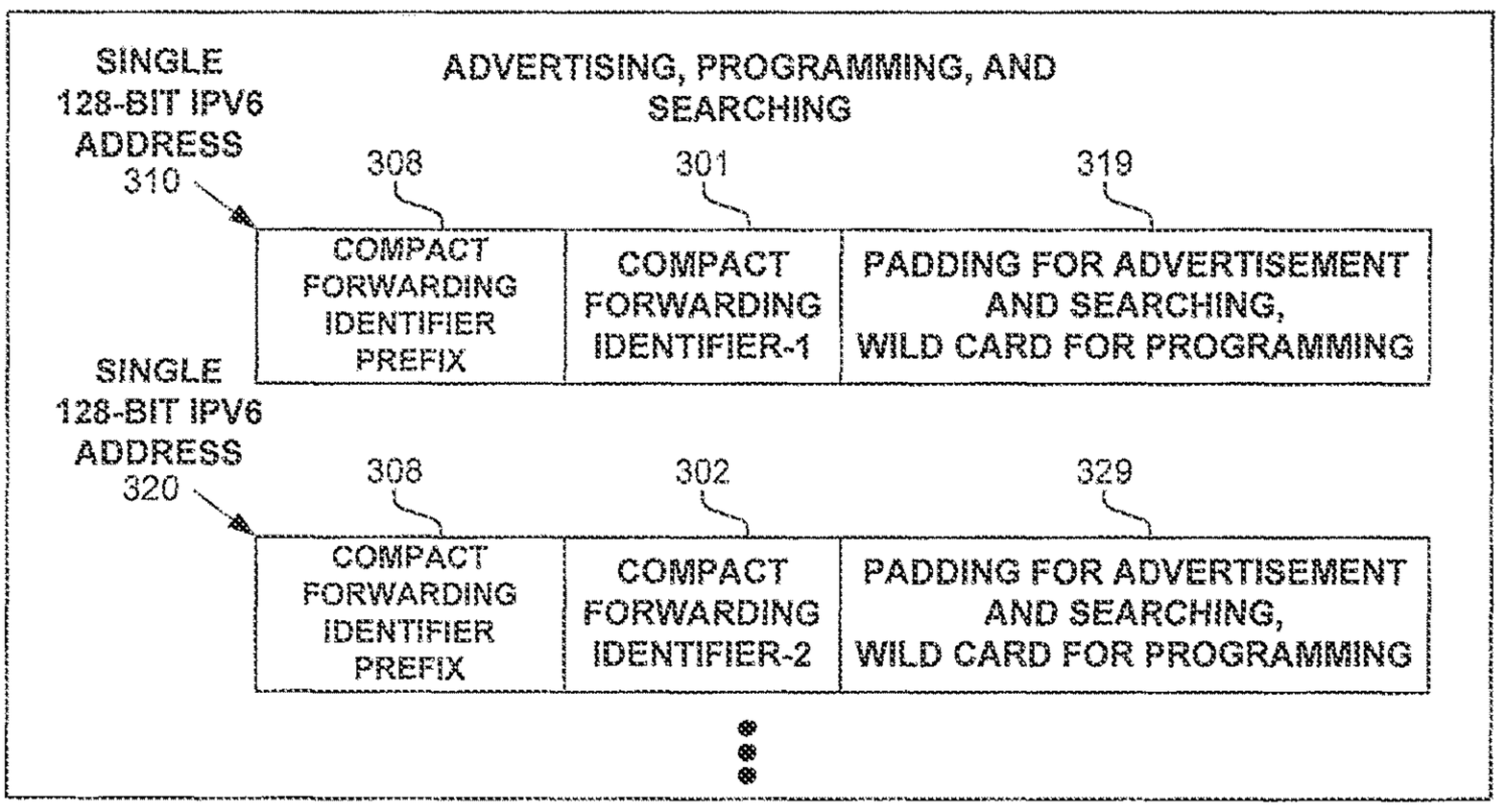

FIGURE 3B

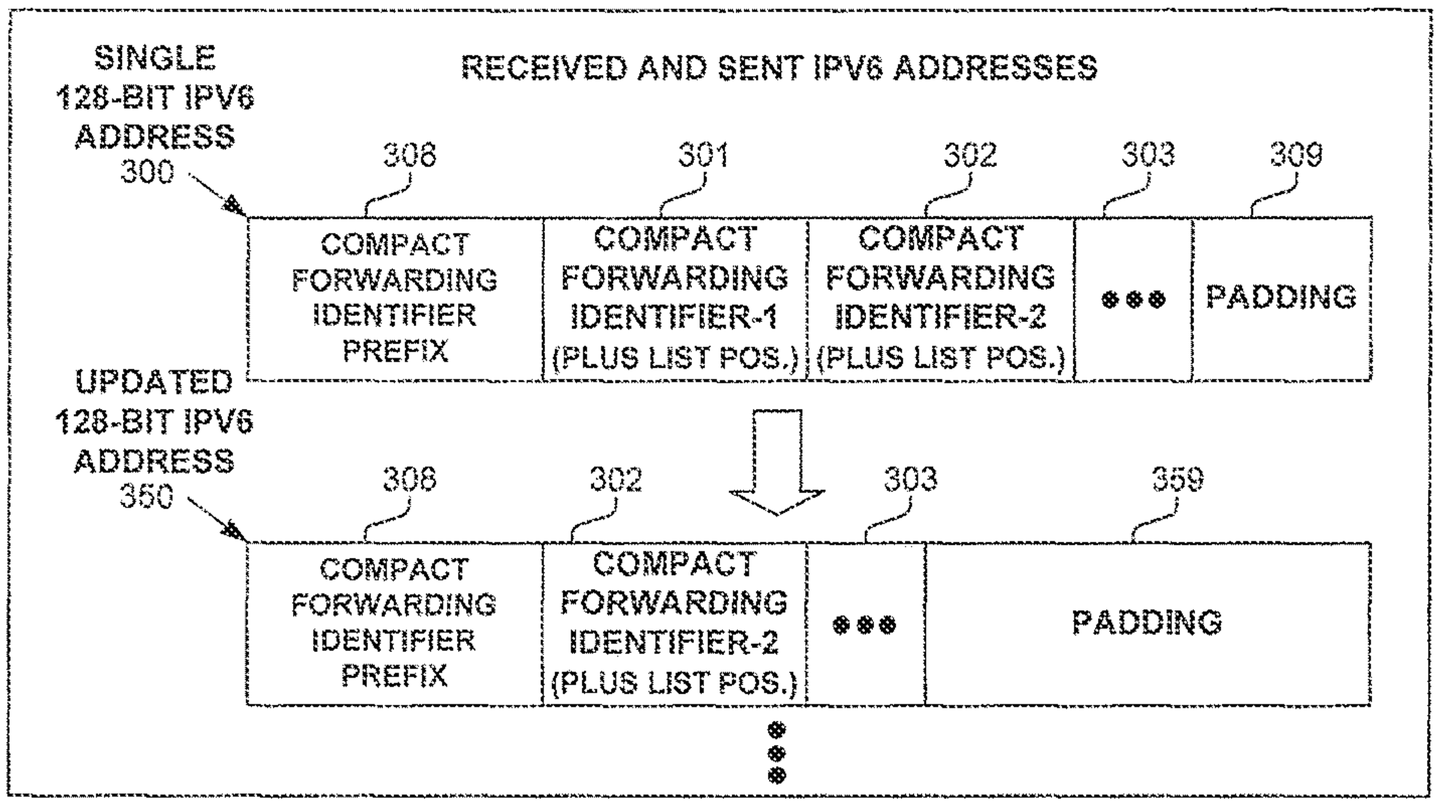

FIGURE 3C

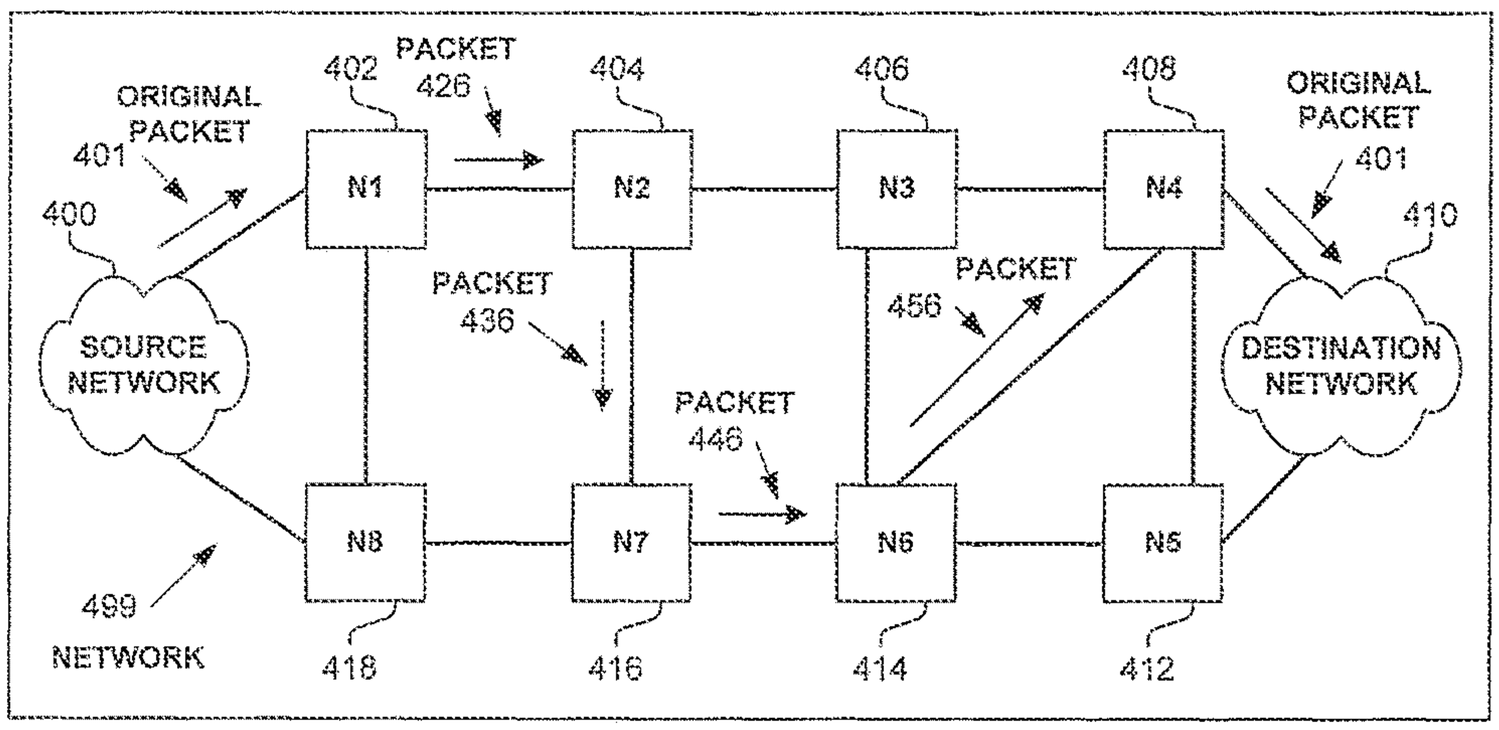

FIGURE 4A

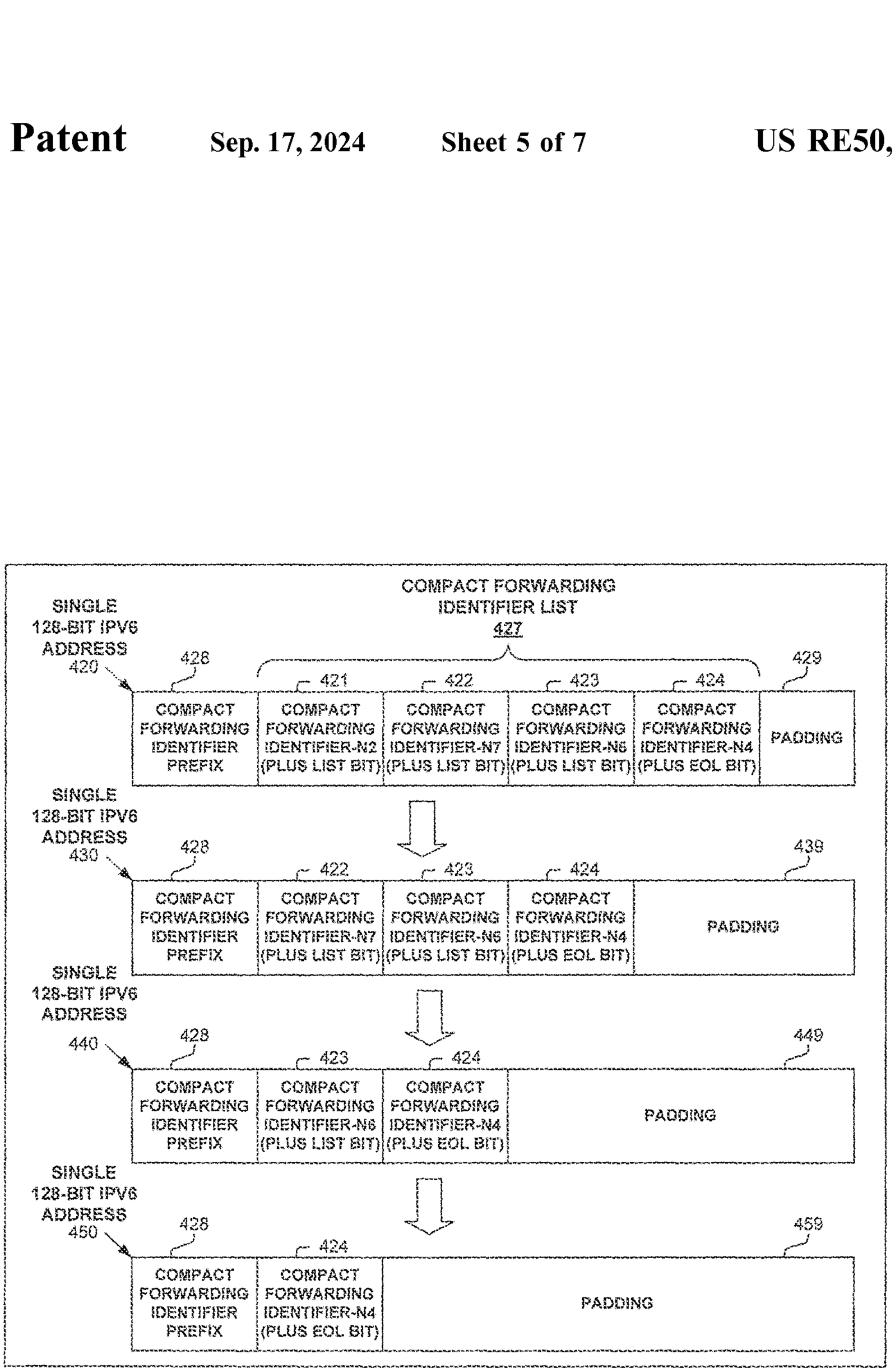
COMPACT FORWARDING IDENTIFIER LIST
427
SINGLE 128-BIT IPV6 ADDRESS
420
428
421
422
423
424
429
COMPACT FORWARDING IDENTIFIER PREFIX
COMPACT FORWARDING IDENTIFIER-N2 (PLUS LIST BIT)
COMPACT FORWARDING IDENTIFIER-N7 (PLUS LIST BIT)
COMPACT FORWARDING IDENTIFIER-N6 (PLUS LIST BIT)
COMPACT FORWARDING IDENTIFIER-N4 (PLUS EOL BIT)
PADDING
SINGLE 128-BIT IPV6 ADDRESS
430
428
422
423
424
439
COMPACT FORWARDING IDENTIFIER PREFIX
COMPACT FORWARDING IDENTIFIER-N7 (PLUS LIST BIT)
COMPACT FORWARDING IDENTIFIER-N6 (PLUS LIST BIT)
COMPACT FORWARDING IDENTIFIER-N4 (PLUS EOL BIT)
PADDING
SINGLE 128-BIT IPV6 ADDRESS
440
428
423
424
449
COMPACT FORWARDING IDENTIFIER PREFIX
COMPACT FORWARDING IDENTIFIER-N6 (PLUS LIST BIT)
COMPACT FORWARDING IDENTIFIER-N4 (PLUS EOL BIT)
PADDING
SINGLE 128-BIT IPV6 ADDRESS
450
428
424
459
COMPACT FORWARDING IDENTIFIER PREFIX
COMPACT FORWARDING IDENTIFIER-N4 (PLUS EOL BIT)
PADDING

FIGURE 4B

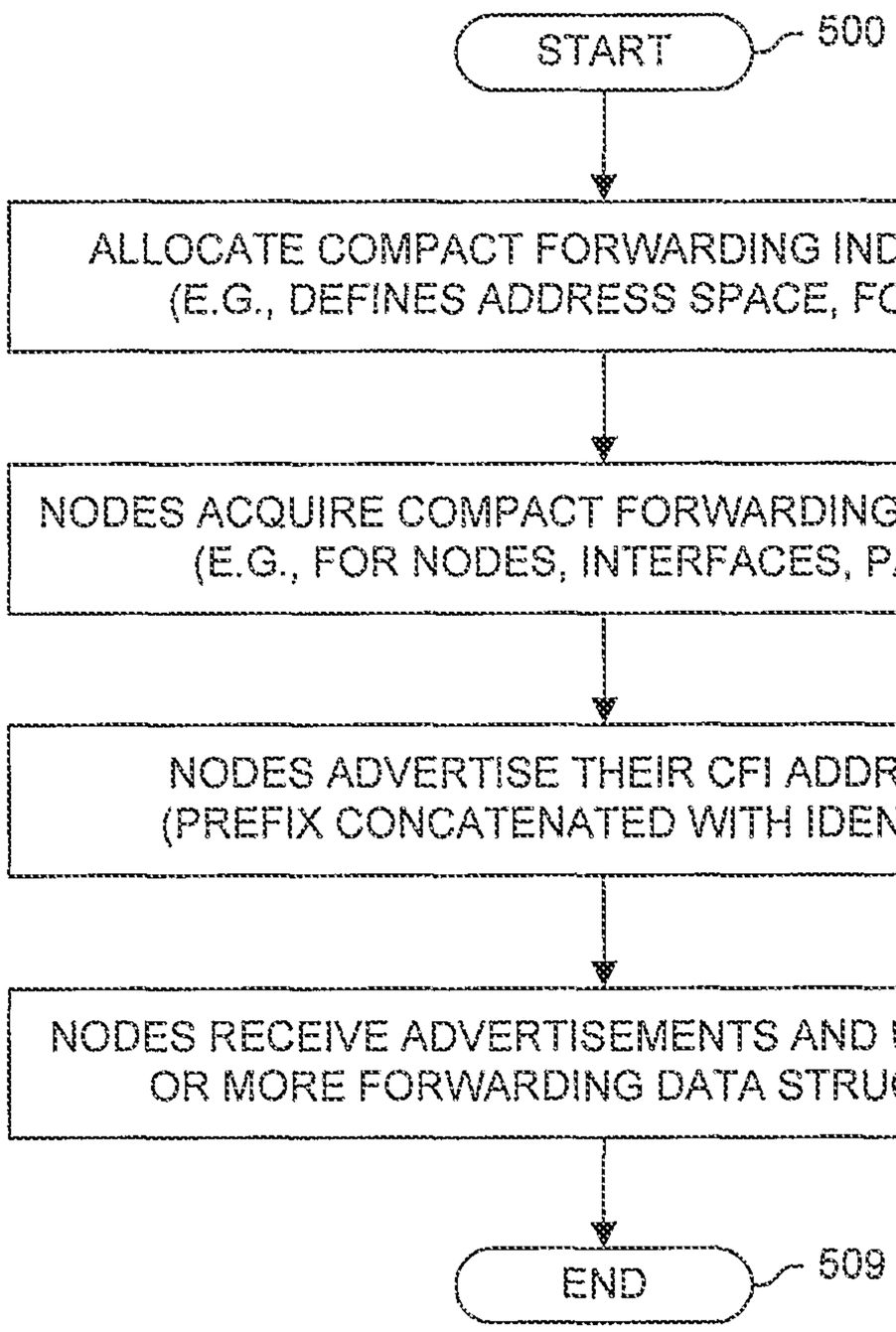
START
500
ALLOCATE COMPACT FORWARDING INDEX PREFIX (E.G., DEFINES ADDRESS SPACE, FORMAT)
502
NODES ACQUIRE COMPACT FORWARDING IDENTIFIERS (E.G., FOR NODES, INTERFACES, PATHS)
504
NODES ADVERTISE THEIR CFI ADDRESSES (PREFIX CONCATENATED WITH IDENTIFIER)
506
NODES RECEIVE ADVERTISEMENTS AND UPDATE ONE OR MORE FORWARDING DATA STRUCTURES
508
END
509

FIGURE 5A

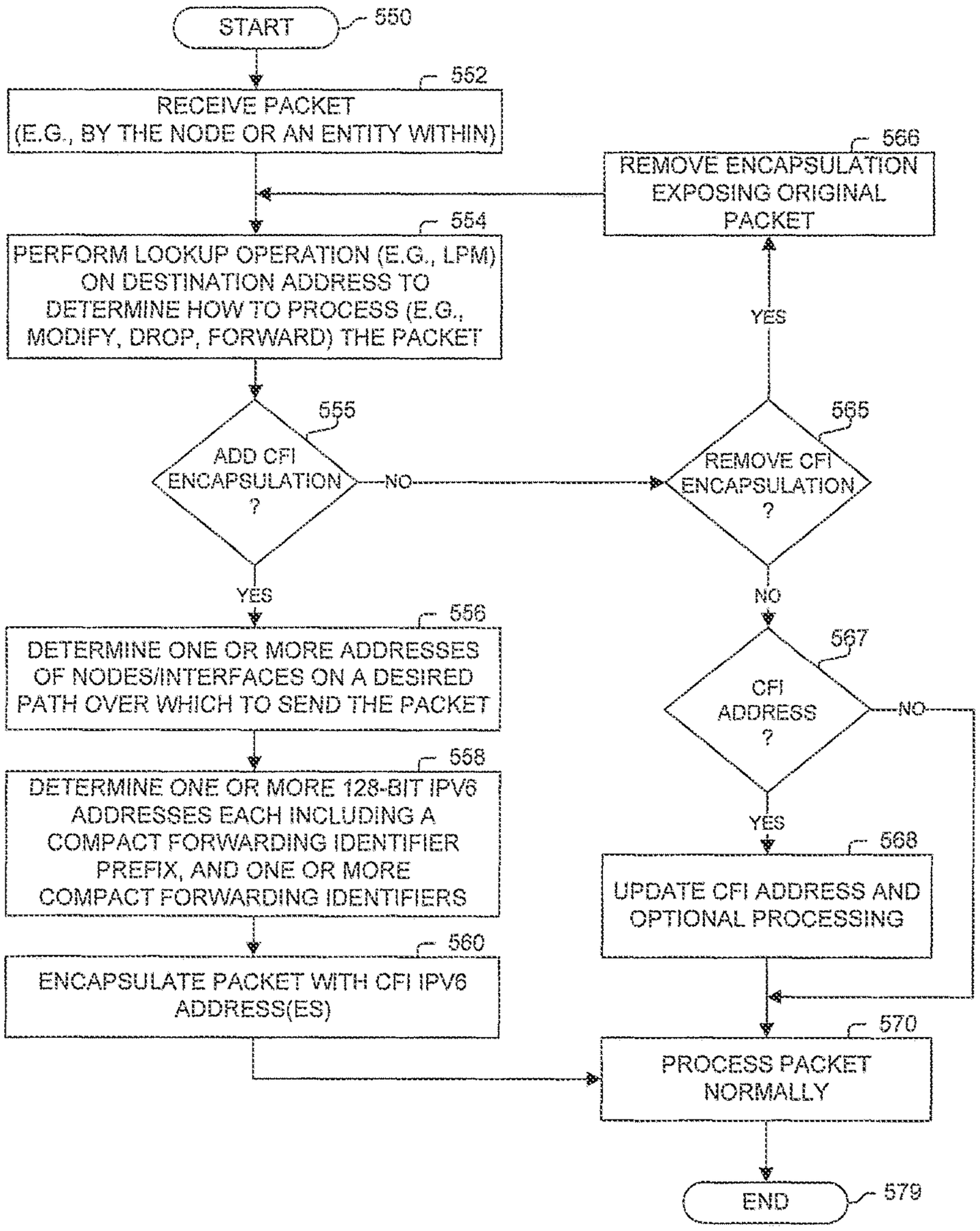
START
550
RECEIVE PACKET (E.G., BY THE NODE OR AN ENTITY WITHIN)
552
PERFORM LOOKUP OPERATION (E.G., LPM) ON DESTINATION ADDRESS TO DETERMINE HOW TO PROCESS (E.G., MODIFY, DROP, FORWARD) THE PACKET
554
ADD CFI ENCAPSULATION ?
555
YES
NO
DETERMINE ONE OR MORE ADDRESSES OF NODES/INTERFACES ON A DESIRED PATH OVER WHICH TO SEND THE PACKET
556
DETERMINE ONE OR MORE 128-BIT IPV6 ADDRESSES EACH INCLUDING A COMPACT FORWARDING IDENTIFIER PREFIX, AND ONE OR MORE COMPACT FORWARDING IDENTIFIERS
558
ENCAPSULATE PACKET WITH CFI IPV6 ADDRESS(ES)
560
REMOVE CFI ENCAPSULATION ?
565
YES
NO
REMOVE ENCAPSULATION EXPOSING ORIGINAL PACKET
566
CFI ADDRESS ?
567
YES
NO
UPDATE CFI ADDRESS AND OPTIONAL PROCESSING
568
PROCESS PACKET NORMALLY
570
END
579

FIGURE 5B

FORWARDING OF PACKETS IN A NETWORK BASED ON MULTIPLE COMPACT FORWARDING IDENTIFIERS REPRESENTED IN A SINGLE INTERNET PROTOCOL VERSION 6 (IPv6) ADDRESS

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

TECHNICAL FIELD

The present disclosure relates generally to sending of packets in a packet network, including in packets with multiple forwarding addresses represented in a single Internet Protocol Version 6 (IPv6) 128-bit address.

BACKGROUND

The communications industry is rapidly changing to adjust to emerging technologies and ever increasing customer demand. This customer demand for new applications and increased performance of existing applications is driving communications network and system providers to employ networks and systems having greater speed and capacity (e.g., greater bandwidth). In trying to achieve these goals, a common approach taken by many communications providers is to use packet switching technology. Packets are typically forwarded in a network forwarded based one or more values representing network nodes or paths.

BRIEF DESCRIPTION OF THE DRAWINGS

The appended claims set forth the features of one or more embodiments with particularity. The embodiment(s), together with its advantages, may be understood from the following detailed description taken in conjunction with the accompanying drawings of which:

FIG. **1**A illustrates a packet switching device according to one embodiment;

FIG. **1**B illustrates an apparatus according to one embodiment;

FIG. **1**C illustrates a network operating according to one embodiment;

FIG. **2**A illustrates a IPv6 packet to one embodiment;

FIG. **2**B illustrates one or more compact forwarding identifiers represented in a single 128-bit IPv6 address according to one embodiment;

FIG. **3**A illustrates one or more compact forwarding identifiers represented in a single 128-bit IPv6 address according to one embodiment;

FIG. **3**B illustrates advertisement and forwarding information programming according to one embodiment;

FIG. **3**C illustrates changing of one or more compact forwarding identifiers represented in a single 128-bit IPv6 address during packet forwarding according to one embodiment;

FIG. **4**A illustrates a network operating according to one embodiment;

FIG. **4**B illustrates changing of one or more compact forwarding identifiers represented in a single 128-bit IPv6 address during packet forwarding according to one embodiment;

FIG. **5**A illustrates a process according to one embodiment; and

FIG. **5**B illustrates a process according to one embodiment.

DESCRIPTION OF EXAMPLE EMBODIMENTS

1. Overview

Disclosed are, inter alia, methods, apparatus, computer-storage media, mechanisms, and means associated with forwarding of packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header). One embodiment follows the forwarding order of these multiple compact forwarding identifiers by respectively placing them in the single IPv6 address from high-order to lower-order bit positions. In one embodiment, a compact forwarding identifier prefix is part of the address represented by each compact forwarding identifier, typically with the compact forwarding identifier prefix stored in the highest-order bit positions. One embodiment uses a longest prefix matching operation to match the compact forwarding identifier to be used in determining how to next process the packet.

In one embodiment, a first network node receives an Internet Protocol version 6 (IPv6) packet with the IPv6 header including a particular destination address of length 128 bits in the destination address field of the IPv6 header. This particular destination address includes encoded therein a first destination address and a second destination address, with the first destination address corresponding to the first network node and the second destination address corresponding to a second network node. The first network node changes the particular destination address to an updated particular destination address of length 128 bits, with the updated particular destination address including encoded therein the second destination address. The first network node sends the IPv6 packet with the destination address field in the destination address field of the IPv6 header including the updated particular destination address.

In one embodiment, the particular destination address includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier.

In one embodiment, a first network node receives an IPv6 packet with a particular address, with the particular address including encoded therein a first destination address and a second destination address, with the particular address being 128 bits in length and located in a 128-bit address field of the IPv6 packet, and with the first destination address corresponding to the first network node and the second destination address corresponding to a second network node. The first network node determines a forwarding result based on performing a lookup operation in at least one of one or more forwarding data structures based on the second destination address or search key including the second destination address encoded therein. Based on the forwarding result, the first network node sends the IPv6 packet from the first network node.

In one embodiment, the particular address in the received IPv6 packet includes a compact forwarding identifier prefix,

a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier.

One embodiment includes a packet switching device, comprising a plurality of hardware interfaces sending and receiving packets, and one or more network processors with memory associated therewith. The packet switching device performs packet processing operations, with said packet processing operations in one embodiment including: receiving via one of the plurality of hardware interfaces a packet with a first particular value, with the first particular value including encoded therein a first destination address and a second destination address, with the first particular value being 128 bits in length and located in a 128-bit Internet Protocol Version 6 (IPv6) address field of the packet, and with the first destination address corresponding to the first network node and the second destination address corresponding to a second network node; modifying the particular value to become a second particular value of length 128 bits, with the second particular destination address including encoded therein the second destination address; performing a lookup operation in one or more data structures based on the second particular value or the second destination address resulting in the determination of a lookup result; and responsive to the lookup result, sending the packet with the second particular value from the packet switching device via one or more of the plurality of hardware interfaces.

In one embodiment, the first particular value includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier but not the first compact forwarding identifier.

In one embodiment, the first particular value in said received packet includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier; wherein the highest-order bits of the first particular value in said received packet are the compact forwarding identifier prefix followed by the first compact forwarding identifier; and wherein the highest-order bits of the second particular value in said sent packet are the compact forwarding identifier prefix followed by the second compact forwarding identifier.

2. Description

Disclosed are, inter alia, methods, apparatus, computer-storage media, mechanisms, and means associated with forwarding of packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header). In one embodiment, such forwarding of the packet includes modifying the contents of the single IPv6 address to a new value to represent the next address. In one embodiment, a compact forwarding identifier represents a segment identifier, a forwarding label or index (e.g., an MPLS label, an index value in an MPLS label space), a forwarding address (e.g., an IPv4 or IPv6 address), and/or another value used in making forwarding decisions of packets in a network. A common definition of compact is occupying little space compared with others. Thus, the adjective "compact" is used to suggest a typically, but not required, property of such a forwarding identifier (e.g., a 128-bit IPv6 address representing multiple addresses or values, not just a single address).

Embodiments described herein include various elements and limitations, with no one element or limitation contemplated as being a critical element or limitation. Each of the claims individually recites an aspect of the embodiment in its entirety. Moreover, some embodiments described may include, but are not limited to, inter alia, systems, networks, integrated circuit chips, embedded processors, ASICs, methods, and computer-readable media containing instructions. One or multiple systems, devices, components, etc., may comprise one or more embodiments, which may include some elements or limitations of a claim being performed by the same or different systems, devices, components, etc. A processing element may be a general processor, task-specific processor, a core of one or more processors, or other co-located, resource-sharing implementation for performing the corresponding processing. The embodiments described hereinafter embody various aspects and configurations, with the figures illustrating exemplary and non-limiting configurations. Computer-readable media and means for performing methods and processing block operations (e.g., a processor and memory or other apparatus configured to perform such operations) are disclosed and are in keeping with the extensible scope of the embodiments. The term "apparatus" is used consistently herein with its common definition of an appliance or device.

The term "route" is used to refer to a fully or partially expanded prefix (e.g., 10.0.0.1 or 10.0.*.*), which is different than a "path" through the network which refers to a nexthop (e.g., next router) or complete path (e.g., traverse router A then router B, and so on). Also, the use of the term "prefix" without a qualifier herein refers to a fully or partially expanded prefix.

The steps, connections, and processing of signals and information illustrated in the figures, including, but not limited to, any block and flow diagrams and message sequence charts, may typically be performed in the same or in a different serial or parallel ordering and/or by different components and/or processes, threads, etc., and/or over different connections and be combined with other functions in other embodiments, unless this disables the embodiment or a sequence is explicitly or implicitly required (e.g., for a sequence of read the value, process said read value—the value must be obtained prior to processing it, although some of the associated processing may be performed prior to, concurrently with, and/or after the read operation). Also, nothing described or referenced in this document is admitted as prior art to this application unless explicitly so stated. The term "one embodiment" is used herein to reference a particular embodiment, wherein each reference to "one embodiment" may refer to a different embodiment, and the use of the term repeatedly herein in describing associated features, elements and/or limitations does not establish a cumulative set of associated features, elements and/or limitations that each and every embodiment must include, although an embodiment typically may include all these features, elements and/or limitations. In addition, the terms "first," "second," etc., as well as "particular" and "specific" are

typically used herein to denote different units (e.g., a first widget or operation, a second widget or operation, a particular widget or operation, a specific widget or operation). The use of these terms herein does not necessarily connote an ordering such as one unit, operation or event occurring or coming before another or another characterization, but rather provides a mechanism to distinguish between elements units. Moreover, the phrases "based on x" and "in response to x" are used to indicate a minimum set of items "x" from which something is derived or caused, wherein "x" is extensible and does not necessarily describe a complete list of items on which the operation is performed, etc. Additionally, the phrase "coupled to" is used to indicate some level of direct or indirect connection between two elements or devices, with the coupling device or devices modifying or not modifying the coupled signal or communicated information. Moreover, the term "or" is used herein to identify a selection of one or more, including all, of the conjunctive items. Additionally, the transitional term "comprising," which is synonymous with "including," "containing," or "characterized by," is inclusive or open-ended and does not exclude additional, unrecited elements or method steps. Finally, the term "particular machine," when recited in a method claim for performing steps, refers to a particular machine within the 35 USC § 101 machine statutory class.

FIGS. **1**A-B and their discussion herein are intended to provide a description of various exemplary packet switching systems used in forwarding packets according to one embodiment. One embodiment forwards packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header).

One embodiment of a packet switching device **100** is illustrated in FIG. **1**A. As shown, packet switching device **100** includes multiple line cards **101** and **105**, each with one or more network interfaces for sending and receiving packets over communications links (e.g., possibly part of a link aggregation group), and with one or more processing elements that are used in one embodiment associated with forwarding of packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header). Packet switching device **100** also has a control plane with one or more processing elements **102** for managing the control plane and/or control plane processing of packets associated with forwarding of packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header). Packet switching device **100** also includes other cards **104** (e.g., service cards, blades) which include processing elements that are used in one embodiment 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 based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header), and some hardware-based communication mechanism **103** (e.g., bus, switching fabric, and/or matrix, etc.) for allowing its different entities **101**, **102**, **104** and **105** to communicate.

Line cards **101** and **105** typically perform the actions of being both an ingress and egress line card, in regards to multiple other particular packets and/or packet streams being received by, or sent from, packet switching device **100**. In one embodiment, network processors on line cards **101** and/or **105** forwards packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header).

FIG. **1**B is a block diagram of an apparatus **120** used in one embodiment associated with forwarding of packets in a network based on multiple compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header). In one embodiment, apparatus **120** performs one or more processes, or portions thereof, corresponding to one of the flow diagrams illustrated or otherwise described herein, and/or illustrated in another diagram or otherwise described herein.

In one embodiment, apparatus **120** includes one or more processor(s) **121** (typically with on-chip memory), memory **122**, storage device(s) **123**, specialized component(s) **125** (e.g. optimized hardware such as for performing lookup and/or packet processing operations, associative memory, binary and/or ternary content-addressable memory, etc.), and interface(s) **127** for communicating information (e.g., sending and receiving packets, user-interfaces, displaying information, etc.), which are typically communicatively coupled via one or more communications mechanisms **129** (e.g., bus, links, switching fabric, matrix), with the communications paths typically tailored to meet the needs of a particular application.

Various embodiments of apparatus **120** may include more or fewer elements. The operation of apparatus **120** is typically controlled by processor(s) **121** using memory **122** and storage device(s) **123** to perform one or more tasks or processes. Memory **122** is one type of computer-readable/computer-storage medium, and typically comprises random access memory (RAM), read only memory (ROM), flash memory, integrated circuits, and/or other memory components. Memory **122** typically stores computer-executable instructions to be executed by processor(s) **121** and/or data which is manipulated by processor(s) **121** for implementing functionality in accordance with an embodiment. Storage device(s) **123** are another type of computer-readable medium, and typically comprise solid state storage media, disk drives, diskettes, networked services, tape drives, and other storage devices. Storage device(s) **123** typically store computer-executable instructions to be executed by processor(s) **121** and/or data which is manipulated by processor(s) **121** for implementing functionality in accordance with an embodiment.

FIG. **1**C illustrates a network **150** operating according to one embodiment. As shown, network **150** includes multiple network nodes **152**, **156** and network **155** including network nodes, each of which send and receive packets from other nodes in network **155** and/or other communicatively coupled nodes. In one embodiment, at least one of multiple network nodes **152**, **156** and in network **155** forwards packets based on one or more compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address, such as, but not limited to being in the destination address field of the IPv6 header (e.g., in an extended IPv6 header).

FIG. **2**A illustrates a IPv6 packet **200** according to one embodiment forwarding packets in a network based on one or more compact forwarding identifiers represented in a single 128-bit Internet Protocol Version 6 (IPv6) address. As show, IPv6 packet inherently includes the IPv6 header **202** and IPv6 payload **204**. Thus, a reference to "the IPv6 header" refers to this header, not an extension header in the IPV6 payload discussed in the next paragraph.

In one embodiment, the destination address field of the IPv6 header **202** is populated with one or more compact forwarding identifiers represented as a 128-bit IPv6 address. In one embodiment, a forwarding value field (e.g., for a label, segment identifier, IPv6 address, other value) in an extension header (or other forwarding information storage) of IPv6 payload **204** is populated with one or more compact forwarding identifiers represented as a 128-bit IPv6 address.

FIG. **2**B illustrates one or more compact forwarding identifiers **222** represented in a single 128-bit IPv6 address **220** according to one embodiment. In one embodiment, the single IPv6 address **220** includes a compact forwarding identifier prefix **221**, one or more compact forwarding identifiers **222**, and padding 229 (as needed to fill out the 128 bits). In one embodiment, compact forwarding identifier prefix **221** is placed in the highest-order bits of IPv6 address **220** and identifies an address space and possibly encoding format for the compact forwarding identifier(s) **222**. In one embodiment, compact forwarding identifier prefix **221** is forty-eight bits, with the remaining eighty bits used in storing one or more compact forwarding identifiers **222** and padding 229. In one embodiment, compact forwarding identifiers field **222** and/or padding 229 include control information (e.g., an offset value, counter, list position indication), such as for, but not limited to identifying an actual compact forwarding identifier stored in field **222** to currently use and/or to use in the future. In one embodiment, a node searches and locates the position of its corresponding compact forwarding identifier in compact forwarding identifiers field **222** and then uses the next identifier in the sequence if any remain or processes the packet accordingly if there is no other identifier.

Further in illustration, FIG. **3**A illustrates one or more compact forwarding identifiers **301-303** stored in a list format **307** and represented in a single 128-bit IPv6 address **300** according to one embodiment. As shown, the single IPv6 address **300** includes a compact forwarding identifier prefix **308**, a list **307** of one or more compact forwarding identifiers **301-303** each with a list position indication, and padding 309 (as needed to fill out the 128 bits). In one embodiment, a list position indication (e.g., one or more bits) is a value of zero to indicate that the compact forwarding identifier is not the last one in list **307**, and a value of one to indicate that it is the last one in list **307**. In one embodiment, a list position indication is a value of one to indicate that the compact forwarding identifier is not the last one in list **307**, and a value of zero to indicate that it is the last one in list **307**. In one embodiment, the value of compact forwarding identifier prefix **308** has associated with it a predetermined length of itself as well as each compact forwarding identifier **301-303** providing information for decoding of the single 128-bit IPv6 address. In one embodiment, an encoded IPv6 address or value (e.g., segment identifier, label or other value to be represented as an IPv6 address) encoded in IPv6 address **300** is the compact forwarding identifier prefix **308** concatenated with a compact forwarding identifier **301-303**.

In one embodiment, an encoded IPv6 address or value encoded in IPv6 address **300** is compact forwarding identifier prefix **308** concatenated with compact forwarding identifier **301** (at the top of list **307**), which conveniently occupies the highest order bits of address **300**, with other bits within the encoded IPv6 address being zero or more compact forwarding identifiers **302-303** and/or padding 309 (filling in zero or more bit positions)—depending on the context of packet forwarding, route advertisement, forwarding information base programming, etc., such as, but not limited to that described and/or illustrated herein. FIG. **3**B illustrates such advertising and programming, and FIGS. **3**C-**3**E illustrate such modification of IPv6 address **300** in forwarding of a packet, with an example further illustrated in FIGS. **4**A-**4**B.

FIG. **3**B illustrates advertising, programming, and searching of decoded IPv6 addresses **310** and **320** derived from IPv6 address **300** (of FIG. **3**A). As shown, single 128-bit IPv6 address **310** includes compact forwarding prefix **308** and compact forwarding identifier-**1** (**301**); and single 128-bit IPv6 address **320** includes compact forwarding prefix **308** and compact forwarding identifier-**2** (**302**). Remaining bits **319**, **329** are padded when used for route advertising and as a search key (e.g., for longest prefix matching), and are wildcard or don't care for programming of a data structure to be searched (e.g., a forwarding information base).

FIG. **3**C illustrates the updating of IPv6 address **300** as packets are sent to a next destination encoded in IPv6 address **300**. Initially, IPv6 address **300** is as described in relation to FIG. **3**A. In one embodiment, an IPv6 packet is sent to a first network node identified by an IPv6 address with its high-order bits of compact forwarding identifier prefix **308** concatenated with compact forwarding identifier **301** (without the list position indication) followed by padding 309, with the IPv6 destination address field in its IPv6 header being populated with IPv6 address **300**. First network node receives and processes the IPv6 packet including changing of IPv6 address **300** to that of IPv6 address **350** by removing compact forwarding identifier-**1** (**301**) typically by shifting the remaining portions **302**, **303** and **359** to the left such that the highest-order bits of IPv6 address **350** are those of compact forwarding identifier prefix **308** concatenated with compact forwarding identifier **302** (representing a network address of a second network node). The IPv6 packet is sent from the first network node towards the second network node, with this IPv6 packet including the updated IPv6 address **350** in the IPv6 destination address field in its IPv6 header.

FIG. **4**A illustrates a network **499** operating according to one embodiment, with various IPv6 addresses correspondingly used as illustrated in FIG. **4**B. The following description will refer to entities from both FIGS. **4**A and **4**B.

Network **499** includes a source network **400** (of one or more network nodes) communicatively coupled to a destination network **410** (of one or more network nodes), communicatively coupled by network nodes **402-408** and **412-418** as shown by the illustrated links.

In one embodiment, an original packet **401** is being sent from source network **400** to destination network **410**. Initially, network node N**1** (**402**) receives original packet **402**, and determines (typically based on a lookup operation of its destination address) to route packet **401** over a particular path via the order of network nodes **404**, **416**, **414**, **408**. In response, network node N**1** (**402**) determines single 128-bit IPv6 address **420** with a compact forwarding identifier prefix **428**, compact forwarding identifier list **427**, and padding 429. Compact forwarding identifier list **427** includes compact forwarding identifiers **421-424** corresponding to the order of network nodes **404**, **416**, **414**, **408**. Network node

N1 (402) encapsulates original packet 401 and sends the resultant IPv6 packet with IPv6 address 420 in the IPv6 destination address of its IPv6 header.

Network node N2 (404) receives IPv6 packet 426, and performs a longest prefix matching operation on its destination address IPv6 address 420 to determine how to process IPv6 packet 426. Responsive to the lookup result, IPv6 address 420 is changed to IPv6 address 430 (removing field 421 and shifting fields 422-424, with longer padding 439). Responsive to a result of a longest prefix matching operation performed on IPv6 address 430, the resultant IPv6 packet 436 with IPv6 address 430 in the IPv6 destination address of its IPv6 header is sent from network node N2 (404).

Network node N7 (416) receives IPv6 packet 436, and performs a longest prefix matching operation on its destination address IPv6 address 430 to determine how to process IPv6 packet 436. Responsive to the lookup result, IPv6 address 430 is changed to IPv6 address 440 (removing field 422 and shifting fields 423-424, with longer padding 449). Responsive to a result of a longest prefix matching operation performed on IPv6 address 440, the resultant IPv6 packet 446 with IPv6 address 440 in the IPv6 destination address of its IPv6 header is sent from network node N7 (416).

Network node N6 (414) receives IPv6 packet 446, and performs a longest prefix matching operation on its destination address IPv6 address 440 to determine how to process IPv6 packet 446. Responsive to the lookup result, IPv6 address 440 is changed to IPv6 address 450 (removing field 423 and shifting field 424, with longer padding 459). Responsive to a result of a longest prefix matching operation performed on IPv6 address 450, the resultant IPv6 packet 456 with IPv6 address 450 in the IPv6 destination address of its IPv6 header is sent from network node N6 (414).

Network node N4 (408) receives IPv6 packet 456, and performs a longest prefix matching operation on its destination address IPv6 address 450 to determine how to process IPv6 packet 456. Responsive to the lookup result and the End of List indication for compact forwarding identifier list 427, network node N4 (408) decapsulate received packet 456 revealing original packet 401. Responsive to the result of a lookup operation on the destination address of original packet 401, original packet 401 is sent from network node N4 (408) to destination network 410.

FIG. 5A illustrates a process according to one embodiment. Processing begins with process block 500. In process block 502, a compact forwarding identifier prefix is allocated. In one embodiment, identified therewith is a corresponding format of the encoding within the IPv6 address (e.g., the length of the prefix, the length a compact forwarding identifier, control information). In one embodiment, the format is the same for all compact forwarding identifier prefixes. In process block 504, each participating network node acquires one or more compact forwarding identifiers, such as, but not limited to, corresponding to the network node itself, interfaces of the network node, egress paths or processing associated with the network node. In process block 506, the network nodes advertise their respective compact forwarding identifier addresses (e.g., each combination of compact forwarding identifier prefix concatenated with one of its compact forwarding identifiers). In one embodiment, a standard routing protocol (e.g., BGP-4, IS-IS) or a label distribution protocol is used. In process block 508, participating network nodes receive these advertisements and update their routing and forwarding data structures accordingly. In one embodiment, non-participating network nodes (e.g., network nodes that do not modify the IPv6 address with compact forwarding identifier encoded therein) will exchange these advertisements, update their routing and forwarding data structures accordingly, and forward packets properly as these advertisements are simply advertisements of routes which they can process normally. Processing of the flow diagram of FIG. 5A is complete as indicated by process block 509.

FIG. 5B illustrates a process according to one embodiment. Processing begins with process block 550. In process block 552, a packet is received. In process block 554, a lookup operation is performed on the IPv6 destination address of the received packet to determine how to process the packet. In one embodiment, this lookup operation is a longest matching prefix operation. In one embodiment, this lookup operation is performed on a value corresponding to a compact forwarding identifier prefix concatenated with a first compact forwarding identifier in the IPv6 destination address.

As determined in process block 555, if the node is to encapsulate the packet and add an IPv6 destination address with multiple addresses encoded therein, processing proceeds to process block 556; else processing proceeds to process block 565.

Proceeding from process block 555 to process block 556, a path over which to send the IPv6 packet encapsulating the original packet is determined in process block 556. In process block 558, the compact forwarding identifier prefix and corresponding one or more compact forwarding identifiers to encode in an IPv6 address are determined resulting in a 128-bit IPv6 destination address. In process block 560, the encapsulating IPv6 packet is created including placing the 128-bit IPv6 destination address in the IPv6 destination address field of with the IPv6 header. In process block 570, the encapsulating IPv6 is processed normally (e.g., lookup and forwarding operations performed thereon). Processing of the flow diagram of FIG. 5B is complete as indicated by process block 579.

Proceeding from process block 555 to process block 565. As determined in process block 565, if an IPv6 encapsulating packet using compact forwarding identifiers is received with no more compact forwarding identifiers to use (e.g., at the end of the list), then processing proceeds to process block 566; else processing proceeds to process block 567.

Proceeding from process block 565 to process block 566. In process block 566, the original packet is decapsulated, with processing proceeding to process block 554 to process the original packet.

Proceeding from process block 565 to process block 567. As determined in process block 567, if the IPv6 destination address has a compact forwarding identifier prefix, then processing proceeds to process block 568; else processing proceeds directly to process block 570.

Proceeding from process block 567 to process block 568. In process block 568, the IPv6 destination address is updated for the next compact forwarding identifier (and possibly some additional processing). Processing proceeds to process block 570 to process the IPv6 packet with the updated IPv6 destination address. Processing of the flow diagram of FIG. 5B is complete as indicated by process block 579.

Proceeding from process block 567 directly to process block 570. In process block 570, the packet is processed normally. Processing of the flow diagram of FIG. 5B is complete as indicated by process block 579.

In view of the many possible embodiments to which the principles of the disclosure may be applied, it will be appreciated that the embodiments and aspects thereof described herein with respect to the drawings/figures are only illustrative and should not be taken as limiting the

scope of the disclosure. For example, and as would be apparent to one skilled in the art, many of the process block operations can be re-ordered to be performed before, after, or substantially concurrent with other operations. Also, many different forms of data structures could be used in various embodiments. The disclosure as described herein contemplates all such embodiments as may come within the scope of the following claims and equivalents thereof.

What is claimed is:

1. A method, comprising:

receiving, by a first network node, an Internet Protocol version 6 (IPv6) packet **[**with**]** *an* IPv6 header including a **[**particular**]** destination address of length 128 bits in **[**the**]** *a* destination address field of the IPv6 header, with the **[**particular**]** destination address including encoded therein a first destination address and a second destination address, with the first destination address corresponding to the first network node and the second destination address corresponding to a second network node;

changing, by the first network node, the **[**particular**]** destination address to an updated **[**particular**]** destination address of length 128 bits, with the updated **[**particular**]** destination address including encoded therein the second destination address; and

sending, from the first network node, the IPv6 packet with the destination address field in the destination address field of the IPv6 header including the updated **[**particular**]** destination address.

2. The method of claim **1**, wherein the **[**particular**]** destination address includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier.

3. The method of claim **2**, wherein the **[**particular**]** destination address includes the compact forwarding identifier prefix concatenated with the first compact forwarding identifier; and the updated **[**particular**]** destination address includes the compact forwarding identifier prefix concatenated with the second compact forwarding identifier.

4. The method of claim **3**, wherein the **[**particular**]** destination address includes, in the following order: the compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier.

5. The method of claim **2**, wherein the compact forwarding identifier prefix identifies an encoding format for the **[**particular**]** destination address and the updated **[**particular**]** destination address.

6. The method of claim **2**, further comprising the limitations of:

programming, by the first network node, one or more forwarding data structures with a first entry including the compact forwarding identifier prefix and the first compact forwarding identifier, and with a second entry including the compact forwarding identifier prefix and the second compact forwarding identifier;

processing, by the first network node, the IPv6 packet in response to a first lookup operation performed in at least one of said forwarding data structures based on the **[**particular**]** destination address resulting in a match of the first entry; and

performing a second lookup operation in at least one of said forwarding data structures based on the updated **[**particular**]** destination address resulting in a match of the second entry based on which the first network node determines to perform said sending the IPv6 packet;

wherein said processing includes said changing the **[**particular**]** destination address, said performing the second lookup operation, and said sending the IPv6 packet.

7. The method of claim **6**, further comprising the limitations of:

the first network node advertising that it is associated with a first 128-bit IPv6 address including the compact forwarding identifier prefix and the first compact forwarding identifier; and

the first network node performing said programming of the second entry responsive to a received advertisement that the second network node is associated with a second 128-bit IPv6 address including the compact forwarding identifier prefix and the second compact forwarding identifier.

8. The method of claim **7**, wherein **[**the**]** *a* highest-order bits of the first 128-bit IPv6 address are the compact forwarding identifier prefix followed by the first compact forwarding identifier; wherein the highest-order bits of the second 128-bit IPv6 address are the compact forwarding identifier prefix followed by the second compact forwarding identifier; and wherein each of the first and second lookup operations is a longest prefix matching operation.

9. The method of claim **2**, further comprising the limitations of:

programming, by the first network node, one or more forwarding data structures with a first entry including the compact forwarding identifier prefix and the first compact forwarding identifier, and with a second entry including the compact forwarding identifier prefix and the second compact forwarding identifier;

processing, by the first network node, the IPv6 packet in response to a first lookup operation performed in at least one of said forwarding data structures based on the first destination address resulting in a match of the first entry; and

performing a second lookup operation in at least one of said forwarding data structures based on the second destination address resulting in a match of the second entry based on which the first network node determines to perform said sending the IPv6 packet;

wherein said processing includes said changing the **[**particular**]** destination address, said performing the second lookup operation, and said sending the IPv6 packet.

10. The method of claim **2**, further comprising the limitations of:

programming, by the first network node, one or more forwarding data structures with an entry including the compact forwarding identifier prefix and the second compact forwarding identifier; and

determining, by the first network node, to **[**said**]** send the IPv6 packet based on a lookup operation in at least one of said forwarding data structures based on the updated **[**particular**]** destination address resulting in a match of the entry.

11. The method of claim **10**, wherein the first network node performs said programming of the entry responsive to a received advertisement that the second network node is associated with a 128-bit IPv6 address including the compact forwarding identifier prefix and the second compact forwarding identifier.

12. The method of claim **11**, wherein **[**the**]** *a* highest-order bits of the 128-bit IPv6 address are the compact forwarding

identifier prefix followed by the second compact forwarding identifier; and wherein the lookup operation is a longest prefix matching operation.

13. The method of claim **2**, wherein the first compact forwarding identifier is associated with a first list position indication included in the **[**particular**]** destination address; and wherein the second compact forwarding identifier is associated with a second list position indication included in the particular destination address and in the updated **[**particular**]** destination address.

14. The method of claim **1**, wherein the **[**particular**]** destination address includes encoded therein the first destination address, the second destination address, and a third destination address corresponding to a third network node; and wherein the updated **[**particular**]** destination address includes encoded therein the second destination address and the third destination address.

15. A method, comprising:

receiving, by a first network node, an Internet Protocol version 6 (IPv6) packet with a **[**particular**]** address, with the **[**particular**]** address including encoded therein a first destination address and a second destination address, with the **[**particular**]** address being 128 bits in length and located in a 128-bit address field of the IPv6 packet, and with the first destination address corresponding to the first network node and the second destination address corresponding to a second network node;

determining a forwarding result based on performing a lookup operation in at least one of one or more forwarding data structures based on the second destination address or search key including the second destination address encoded therein; and

based on the forwarding result, sending the IPv6 packet from the first network node.

16. The method of claim **15**, wherein the**[**particular**]** address in the received IPv6 packet includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier.

17. The method of claim **[15]** *16*, wherein **[**the**]** *a* highest-order bits of the **[**particular**]** address in said received IPv6 packet are the compact forwarding identifier prefix followed by the first compact forwarding identifier; wherein the highest-order bits of the **[**particular**]** address in said sent IPv6 packet are the compact forwarding identifier prefix followed by the second compact forwarding identifier; wherein the search key is the **[**particular**]** address in said sent IPv6 packet; wherein the lookup operation is a longest prefix matching operation; and wherein the method includes modifying the **[**particular**]** address in said received IPv6 packet to the **[**particular**]** address in said sent IPv6 packet.

18. A packet switching device, comprising:

a plurality of hardware interfaces sending and receiving packets; and

one or more network processors with memory associated therewith;

wherein the packet switching device performs packet processing operations, with said packet processing operations including:

receiving via one of the plurality of hardware interfaces a packet with a first **[**particular**]** value, with the first **[**particular**]** value including encoded therein a first destination address and a second destination address, with the first **[**particular**]** value being 128 bits in length and located in a 128-bit Internet Protocol Version 6 (IPv6) address field of the packet, and with the first destination address corresponding to **[**the**]** *0* first network node and the second destination address corresponding to a second network node;

modifying the **[**particular**]** value to become a second **[**particular**]** value of length 128 bits, with the second **[**particular**]** destination address including encoded therein the second destination address;

performing a lookup operation in one or more data structures based on the second **[**particular**]** value or the second destination address resulting in the determination of a lookup result; and

responsive to the lookup result, sending the packet with the second **[**particular**]** value from the packet switching device via one or more of the plurality of hardware interfaces.

19. The packet switching device of claim **18**, wherein the first **[**particular**]** value includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier but not the first compact forwarding identifier.

20. The packet switching device of claim **18**, wherein the first **[**particular**]** value in said received packet includes a compact forwarding identifier prefix, a first compact forwarding identifier, and a second compact forwarding identifier; wherein the first destination address includes the compact forwarding identifier prefix and the first compact forwarding identifier, and the second destination address includes the compact forwarding identifier prefix and the second compact forwarding identifier; wherein **[**the**]** *a* highest-order bits of the first **[**particular**]** value in said received packet are the compact forwarding identifier prefix followed by the first compact forwarding identifier; and wherein the highest-order bits of the second **[**particular**]** value in said sent packet are the compact forwarding identifier prefix followed by the second compact forwarding identifier.

21. A packet switching device, comprising:

a plurality of hardware interfaces operative to send and receive packets; and

one or more network processors with memory associated therewith;

wherein the packet switching device performs packet processing operations including:

receiving, via one of the plurality of hardware interfaces, an Internet Protocol version 6 (IPv6) packet with an IPv6 header including a 128-bit destination address in a destination address field of the IPv6 header, the 128-bit destination address comprising a compact forwarding identifier prefix, and a plurality of compact forwarding identifiers including a first compact forwarding identifier, a second compact forwarding identifier and zero or more additional compact forwarding identifiers; wherein the 128-bit destination address comprises a first destination address encoded therein, wherein the first destination address includes the compact forwarding identifier prefix concatenated with the first compact forwarding identifier;

changing the 128-bit destination address to an updated 128-bit destination address, with the updated 128-bit destination address including encoded therein a second

destination address comprising the compact forwarding identifier prefix and the second compact forwarding identifier, with said changing including removing the first compact forwarding identifier such that a highest-order bits of the updated 128-bit destination address are the compact forwarding identifier prefix concatenated with the second compact forwarding identifier followed by said zero or more additional compact forwarding identifiers;

adding padding bits to the updated 128-bit destination address after the second compact forwarding identifier and said zero or more additional compact forwarding identifiers;

performing a lookup operation in one or more data structures based on the updated 128-bit destination address resulting in a lookup result and

forwarding, based on the lookup result, the IPv6 packet with the updated 128-bit destination address in the destination address field of the IPv6 header.

22. The packet switching device of claim 21, wherein the first compact forwarding identifier is said removed by shifting the compact forwarding identifiers of the plurality of compact forwarding identifiers after the first compact identifier, with said shifted compact forwarding identifiers including the second compact forwarding identifier.

23. The packet switching device of claim 21, wherein the 128-bit destination address of the received IPv6 packet includes, in the following order: the compact forwarding identifier prefix, the first compact forwarding identifier, and the second compact forwarding identifier.

24. The packet switching device of claim 21, wherein the compact forwarding identifier prefix identifies an encoding format for the 128-bit destination address and the updated 128-bit destination address.

25. The packet switching device of claim 21, wherein the packet processing operations further include programming at least one of the one or more data structures with an entry including the compact forwarding identifier prefix and the second compact forwarding identifier.

26. The packet switching device of claim 25, wherein the programming of the entry is responsive to a received advertisement from a remote network node that is associated with an Internet Protocol (IP) route including the compact forwarding identifier prefix and the second compact forwarding identifier.

27. The packet switching device of claim 21, wherein the highest-order bits of the updated 128-bit destination address are the compact forwarding identifier prefix followed by the second compact forwarding identifier; and wherein the lookup operation is a longest prefix matching operation.

28. The packet switching device of claim 21, wherein said zero or more additional compact forwarding identifiers includes a third compact forwarding identifier; and

wherein a third destination address includes the compact forwarding identifier prefix and the third compact forwarding identifier;

wherein the destination address of the received IPv6 packet includes encoded therein the first destination address, the second destination address, and a third destination address; and

wherein the updated destination address includes encoded therein the second destination address and the third destination address.

29. The packet switching device of claim 21, wherein the compact forwarding identifier prefix identifies an address space.

30. The packet switching device of claim 21, wherein the packet processing operations further include transmitting one or more messages advertising that the packet switching device is associated with an an Internet Protocol (IP) route including the compact forwarding identifier prefix and the first compact forwarding identifier.

31. The packet switching device of claim 21, wherein the packet processing operations further include:

programming at least one of the one or more data structures with a first entry including the compact forwarding identifier prefix and the first compact forwarding identifier, and with a second entry including the compact forwarding identifier prefix and the second compact forwarding identifier;

processing the received IPv6 packet in response to a first lookup operation performed in at least one of said forwarding data structures based on the destination address resulting in a match of the first entry;

wherein the second lookup operation matched the second entry in identifying the lookup result:

wherein the lookup operation in one or more data structures based on the updated 128-bit destination address results in a match of the second entry, with the lookup result determined based on the match of the second entry; and

wherein said processing the received IPv6 packet includes said changing the destination address, said performing the lookup operation in one or more data structures based on the updated 128-bit destination address resulting in the lookup result, and said forwarding the IPv6 packet.

32. A method, comprising:

receiving, via a network interface, an Internet Protocol version 6 (IPv6) packet with an IPv6 header including a 128-bit destination address in a destination address field of the IPv6 header, the 128-bit destination address comprising a compact forwarding identifier prefix, and a plurality of compact forwarding identifiers including a first compact forwarding identifier, a second compact forwarding identifier and zero or more additional compact forwarding identifiers; wherein the 128-bit destination address comprises a first destination address encoded therein, wherein the first destination address includes the compact forwarding identifier prefix concatenated with the first compact forwarding identifier;

changing the 128-bit destination address to an updated 128-bit destination address, with the updated 128-bit destination address including encoded therein a second destination address comprising the compact forwarding identifier prefix and the second compact forwarding identifier, with said changing including removing the first compact forwarding identifier such that a highest-order bits of the updated 128-bit destination address are the compact forwarding identifier prefix concatenated with the second compact forwarding identifier followed by said zero or more additional compact forwarding identifiers;

adding padding bits to the updated 128-bit destination address after the second compact forwarding identifier and said zero or more additional compact forwarding identifiers;

performing a lookup operation in one or more data structures based on the updated 128- bit destination address resulting in a lookup result and

forwarding, based on the lookup result, the IPv6 packet with the updated 128-bit destination address in the destination address field of the IPv6 header.

33. The method of claim 32, wherein the first compact forwarding identifier is said removed by shifting the compact forwarding identifiers of the plurality of compact forwarding identifiers after the first compact identifier, with said shifted compact forwarding identifiers including the second compact forwarding identifier.

34. The method of claim 32, wherein the 128-bit destination address of the received IPv6 packet includes, in the following order: the compact forwarding identifier prefix, the first compact forwarding identifier, and the second compact forwarding identifier.

35. The method of claim 32, wherein the compact forwarding identifier prefix identifies an encoding format for the 128-bit destination address and the updated 128-bit destination address.

36. The method of claim 32, further comprising programming at least one of the one or more data structures with an entry including the compact forwarding identifier prefix and the second compact forwarding identifier.

37. The method of claim 36, wherein the programming of the entry is responsive to a received advertisement from a remote network node that is associated with an Internet Protocol (IP) route including the compact forwarding identifier prefix and the second compact forwarding identifier.

38. The method of claim 32, wherein the highest-order bits of the updated 128-bit destination address are the compact forwarding identifier prefix followed by the second compact forwarding identifier; and wherein the lookup operation is a longest prefix matching operation.

39. The method of claim 32, wherein said zero or more additional compact forwarding identifiers includes a third compact forwarding identifier; and

wherein a third destination address includes the compact forwarding identifier prefix and the third compact forwarding identifier;

wherein the destination address of the received IPv6 packet includes encoded therein the first destination address, the second destination address, and a third destination address; and

wherein the updated destination address includes encoded therein the second destination address and the third destination address.

40. The method of claim 32, wherein the compact forwarding identifier prefix identifies an address space.

41. The method of claim 32, further comprising transmitting one or more messages advertising that a packet switching device including the network interface is associated with an an Internet Protocol (IP) route including the compact forwarding identifier prefix and the first compact forwarding identifier.

42. The method of claim 32, further comprising:

programming at least one of the one or more data structures with a first entry including the compact forwarding identifier prefix and the first compact forwarding identifier, and with a second entry including the compact forwarding identifier prefix and the second compact forwarding identifier;

processing the received IPv6 packet in response to a first lookup operation performed in at least one of said forwarding data structures based on the destination address resulting in a match of the first entry;

wherein the second lookup operation matched the second entry in identifying the lookup result:

wherein the lookup operation in one or more data structures based on the updated 128-bit destination address results in a match of the second entry, with the lookup result determined based on the match of the second entry; and

wherein said processing the received IPv6 packet includes said changing the destination address, said performing the lookup operation in one or more data structures based on the updated 128-bit destination address resulting in the lookup result, and said forwarding the IPv6 packet.

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