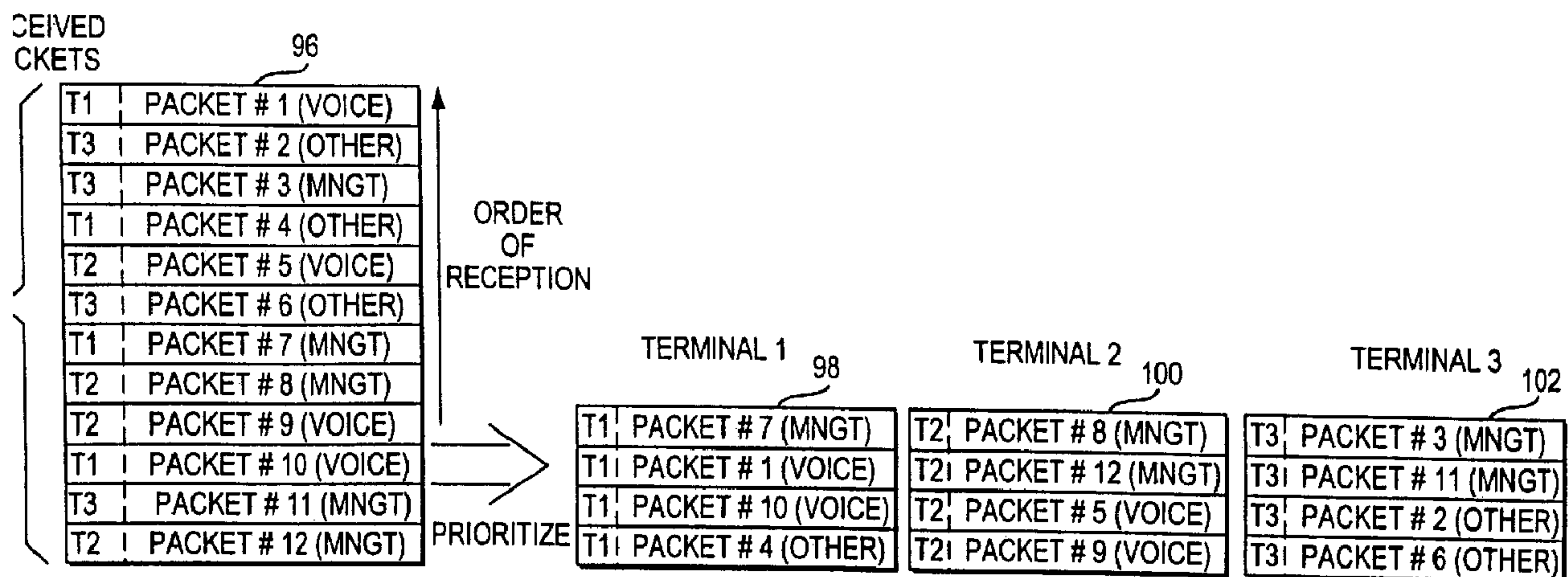




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(57) Abrégé/Abstract:

In a method and system, a priority level is determined for each of a plurality of packets, the packets are arranged from a highest priority level to a lowest priority level, and the packets are wirelessly transmitted over a communications medium. In these method and system, the packets having the highest priority level are transmitted prior to packets having the lowest priority level.

ABSTRACT

In a method and system, a priority level is determined for each of a plurality of packets, the packets are arranged from a highest priority level to a lowest priority level, and the packets are wirelessly transmitted over a communications medium. In these method and system, the packets having the highest priority level are transmitted prior to packets having the lowest priority level.

VOICE AND DATA WIRELESS  
COMMUNICATIONS NETWORK AND METHOD

Background of the Invention

This invention relates to wireless local area  
5 networks ("LANs"), and more particularly, to wireless  
local area networks that carry a mixed traffic of voice  
and data.

Wireless LANs are typically used in  
applications that involve mobile computers, in  
10 applications where wireline installation is not  
feasible, etc. Such applications include warehouse  
inventory tracking, portable point of sale, shipping  
and receiving, package tracking, etc.

The IEEE 802.11 communications standard has  
15 been used by some vendors to provide interoperability  
between wireless LAN equipment. The 802.11 standard  
specifies a protocol in which information is  
transmitted in packets. The standard specifies  
features such as packet size, packet content  
20 information, data rates, roaming, etc. The primary  
type of information that was initially transmitted in  
systems that were designed to the 802.11 standard as  
published was information such as barcode information,  
point of sale information, package tracking  
25 information, etc. In such known systems, several  
remote terminals may be in communications with a single

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access point to receive and transmit information such as bar code information, point of sale information, package tracking information, etc. The standard as published specifies a communications medium that is  
5 shared by transmitters (e.g., an access point and one or more remote terminals).

The standard further specifies that packet size may vary. A remote terminal that has a relatively large packet to transmit may need to occupy the shared  
10 communications medium for a longer period than a remote terminal that has a relatively short packet to transmit. Until recently, delays in communicating packets have typically been non-critical to providing communications at least partly because of the type of  
15 information that has been transmitted in such systems. Information such as bar code information, package tracking information, etc. typically remains valid until a next incremental event occurs (e.g., until bar code information has changed, until a package is  
20 tracked to a next point in route, etc.). In addition, such information does not generally effect system communications if delivered with some delay.

In some known systems, packets are simply transmitted in the order in which they have been  
25 received for transmission. In these known systems, a packet that is transmitted without being properly acknowledged by its intended recipient is repeated for a predetermined number of times while transmission of other remaining packets is delayed. After  
30 retransmitting a packet for a predetermined number of times without receiving a proper acknowledgment, the transmitter may proceed to transmit the remaining packets.



The demand for providing mixed voice and data traffic in wireless LAN systems has been increasing over recent years. Currently, the 802.11 standard does not provide specifications for providing voice communications. Information for providing voice communications is generally much more time critical than  
5 other information such as bar code information, package tracking information, etc. Communications for providing voice communications may require a greater volume of information to be carried by the system than when the system is providing communications for information that has typically been carried by wireless LANs. Moreover, the quality of voice communications is dependent on  
10 the rate in which information is exchanged. In data communications such as in communications for package tracking, the rate at which information is exchanged is non-critical because the quality of such communications is typically not a factor in evaluating the effectiveness of such communications.

15 Some known wireless LANs carry voice signals as part of the communications traffic but these systems are deficient in effectively meeting such complex communications demands as discussed above. Moreover, there may be a need to meet such demands with existing systems without substantially increasing system complexity, structure, design, cost, etc.

20

#### Summary of the Invention

In accordance with a first aspect of the present invention, there is provided a method, comprising: determining a priority level of each of a plurality of packets  
25 in periodic intervals based on a remote terminal to which each of the plurality of packets is directed; and wirelessly transmitting the packets in one-packet-per-terminal rounds over a communications medium with packets having higher priority levels being transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is  
30 transmitted in each round.

In accordance a second aspect of the present invention, there is provided a system, comprising: a plurality of remote terminals, each terminal including a

receiver to receive wirelessly transmitted packets; and an access point receiving the packets from a communication medium, each of the packets having a destination of one of the remote terminals, the access point further determining a priority level of each of the packets in periodic intervals based on a remote terminal to which each of the plurality of packets is directed and wirelessly transmitting each packet in one-packet-per-terminal rounds to the destination remote terminal with packets having higher priority levels being transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of the remote terminals is transmitted in each round.

10

In accordance with a third aspect of the present invention, there is provided an access point, comprising: a receiver to receive packets from a communication medium, each of the packets having a destination remote terminal, the receiver having a processor determining a priority level of each of the packets in periodic intervals based on the destination remote terminal to which each of the packets is directed; and a transmitter to wirelessly transmit each packet in one-packet-per-terminal rounds to the destination remote terminal, wherein packets having higher priority levels are transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

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In accordance with a fourth aspect of the present invention, there is provided a method, comprising: determining a priority level of each of a plurality of packets based on a terminal to which each of the plurality of packets is directed; and wirelessly transmitting the packets in one-packet-per terminal rounds over a communications medium, wherein the packets having higher priority levels are transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

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In accordance with a further aspect of the present invention, there is provided a mobile device, comprising: a processor to receive packets and determine a priority level of each of the packets in periodic intervals based on a



terminal to which each of the packets is directed; and a transmitter to wirelessly transmit each packet in one-packet-per-terminal rounds to a destination with packets having higher priority levels being transmitted prior to packets having lower priority levels.

5

In accordance with a sixth aspect of the present invention, there is provided a system, comprising: a plurality of receiving means for receiving wirelessly transmitted packets; and a transmitting means for receiving the packets from a communication medium, each of the packets having a destination  
10 remote terminal, the transmitting means for determining a priority level of each of the packets in periodic intervals based on the destination remote terminal to which each of the packets is directed and wirelessly transmitting each packet in one-packet-per-terminal rounds to the destination remote terminal with packets having higher priority levels being transmitted prior to packets having lower  
15 priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

In accordance with a still further aspect of the present invention, there is provided an access point, comprising: a receiver means for receiving  
20 packets from a communication medium, each of the packets having a destination remote terminal, the receiver means having a processor means for determining a priority level of each of the packets in periodic intervals based on the destination remote terminal to which each of the packets is directed; and a transmitter means for wirelessly transmitting each packet in one-packet-per-terminal rounds to the  
25 destination remote terminal, wherein packets having higher priority levels are transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

In accordance with an eighth aspect of the present invention, there is  
30 provided a mobile device, comprising: a processor means for receiving packets and determining a priority level of each of the packets in periodic intervals based on a terminal to which each of the packets is directed; and a transmitter means for wirelessly transmitting each packet in one-packet-per-terminal rounds to a

destination with packets having higher priority levels being transmitted prior to packets having lower priority levels.

5 The foregoing and other objects, advantages and features of the present invention will become more apparent upon reading of the following non-restrictive description of an illustrative embodiment thereof, given by way of example only, with reference to the accompanying drawings.

#### Brief Description of the Drawings

10

In the appended drawings:

FIG. 1 is a diagram of an illustrative communications network that includes an illustrative wireless local area network in accordance with the present  
15 invention;

FIG. 2a is a flow chart of illustrative steps involved in managing packet traffic for use in a transmitter in accordance with the present invention;

20 FIG. 2b is a diagram of illustrative queues that may be implemented based on the illustrative steps of FIG. 2a in accordance with the present invention;

FIG. 3a is a flow chart of illustrative steps involved in transmitting packets in accordance with the present invention;

25

FIG. 3b is a diagram of illustrative queues that may be implemented based on the illustrative steps of FIG. 3a in accordance with the present invention;

FIG. 4a is a flow chart of illustrative steps involved in managing packet  
30 traffic based on which packets are for voice in accordance with the present invention;



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FIG. 4b is a diagram of illustrative queues that may be implemented based on the illustrative steps of FIG. 4a in accordance with the present invention;

FIG. 5a is a flow chart of illustrative steps  
5 involved in managing packet traffic based on which packets are for network management in accordance with the present invention;

FIG. 5b is a diagram of illustrative queues that may be implemented based on the illustrative steps  
10 of FIG. 5a in accordance with the present invention;

FIG. 6a is a flow chart of illustrative steps involved in managing packet traffic with multiple levels of priority in accordance with the present invention;

15 FIG. 6b is a diagram of illustrative queues that may be implemented based on the illustrative steps of FIG. 6a in accordance with the present invention;

FIG. 7a is a flow chart of illustrative steps that are involved in managing packet traffic based on  
20 which terminals are voice capable in accordance with the present invention;

FIG. 7b is a diagram of illustrative queues that may be implemented based on the illustrative steps of FIG. 7a in accordance with the present invention;

25 FIG. 8a is a flow chart of illustrative steps involved in managing traffic based on determining which terminals are voice capable in accordance with the present invention;

FIG. 8b is a diagram of illustrative queues  
30 that may be implemented based on the illustrative steps of FIG. 8a in accordance with the present invention;

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FIG. 9a is a flow chart of illustrative steps involved in using variable contention windows in accordance with the present invention;

FIG. 9b is a diagram of illustrative  
5 durations for contention windows in accordance with the present invention;

FIG. 10a is a flow chart of illustrative steps involved in transmitting packets in accordance with the present invention;

10 FIG. 10b is a flow chart of illustrative packet-based communications that are based on the illustrative steps of FIG. 10a in accordance with the present invention;

FIG. 11a is a flow chart of illustrative  
15 steps involved in packet-based communications using frequency hopping in accordance with the present invention;

FIG. 11b is a flow chart of illustrative packet-based communications that are based on the  
20 illustrative steps of FIG. 11a in accordance with the present invention;

FIG. 12a is a flow chart of illustrative steps involved in incrementally transmitting packets in accordance with the present invention; and

25 FIG. 12b is a diagram of illustrative queues that may be implemented based on the illustrative steps of FIG. 12a in accordance with the present invention.

#### Detailed Description of the Invention

The present invention improves mixed traffic  
30 voice communications for wireless local area networks ("LANs") by substantially meeting the communications demands that have been mentioned above. Packets that



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are to be transmitted in a wireless LAN over a half-duplex communication medium are transmitted in order of priority. Priority may be determined based on at least whether a particular packet is for providing voice  
5 communications. One technique for determining whether a packet is for voice communications is to determine whether the intended recipient of the packet has been identified to be voice-capable and further determining whether the packet was received for transmission using  
10 a particular communications protocol (e.g., a protocol typically used to send voice communications). Other techniques for prioritizing packets for transmission and for determining which packets are for voice communications are discussed below.

15 Giving high priority to voice communications may block other non-voice communications packets from being transmitted. Blocking may be substantially prevented by providing for fair distribution of packets. Packets may be distributed fairly by  
20 transmitting packets in rounds where in each round one packet (e.g., the highest priority packet) is transmitted for every receiver (e.g., a remote terminal). In the case of a packet that is transmitted without being acknowledged by its intended recipient,  
25 the packet may be retransmitted in the next round of transmissions except for when another packet with a higher priority than the unacknowledged packet has been recently received for transmission to the same terminal. The recently received packet with a higher  
30 priority will be transmitted before the unacknowledged packet is transmitted again. The number of times a packet is retransmitted may be determined based on whether the packet is for providing voice



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communications. Priority may also be given to voice communications by using techniques that are discussed below that give greater access to the communications medium to transmitters that are about to transmit

5 packets that are for voice communications.

With reference to FIG. 1, wireless local area network ("LAN") 20 may include a plurality of cells 22. For brevity and clarity, wireless LAN 20 is illustrated and discussed primarily in the context of a LAN having  
10 one cell 22. Cell 22 may include an access point 24 (which is sometimes referred to as a wireless local bridge). Cell 22 may include remote terminals 26. Each terminal 26 may be a mobile, portable, or stationary terminal. Each terminal 26 may be a desktop  
15 workstation, laptop computer, palm top computer, handheld personal computer, pen-based computer, personal digital assistant, handheld scanner, data collector, handheld printer, etc. Each terminal 26 may include wireless- network-interface resources that are  
20 configured to provide two-way radio or infrared signal communications. Such resources may include an interface card (or an external modem), a software driver, and an antenna. Other suitable resources may also be used, but for clarity and brevity, the wireless  
25 network interface resources will be discussed primarily in the context of an interface card, a software driver, and an antenna. The interface card may have been configured to use a standard computer-bus interface (e.g., ISA, PCMCIA, etc.) or standard computer port  
30 (e.g., RS232, RS422, etc.) to provide convenient access to terminal equipment.

A network-operating-system may be implemented on each terminal 26. In each terminal 26, the

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interface card may be coupled to the network-  
operating-system application using the software driver.  
The interface card for each remote terminal 26 may be  
a network-communications interface. The network  
5 interface card for each terminal 26 are typically  
implemented to use a carrier sense access protocol and  
to modulate communications signals with a spreading  
sequence.

Access point 24 may be an interface for  
10 communicating between wireless network 20 and a  
wireline network. Access point 24 may be configured to  
provide a communications gateway between terminals 26  
that are in cell 22 and between a wireline network and  
the terminals 26. Access point 24 may include a  
15 resource(s) (e.g., software, hardware, or a combination  
thereof) that is configured to connect the access point  
to a wireline network (e.g., on ethernet network, a  
token ring network, etc.). Access point 24 is  
typically configured to convert signals between  
20 wireline and wireless communications mediums. The  
conversion may allow the access point to pass  
communication information between the wireline network  
and wireless remote terminals 26.

Access points are typically provided with  
25 sufficient processing, hardware, software, etc. to  
operate in compliance with the IEEE 802.11 (e.g., to  
provide 802.11 roaming, standard 802.11 data rates,  
etc.) and to provide additional features that are  
developed by a vendor. Access point 24 may be  
30 implemented using a personal computer (e.g., a Power  
PC, an IBM compatible computer), server, workstation,  
etc., having an appropriate operating system, wireless-



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network-interface resources, wireline-network-interface resources, network-operating-system applications, etc.

Access point 24 and remote terminals 26 may be configured to communicate using spread spectrum modulation techniques (e.g., direct sequence spread spectrum modulation, frequency hopping spread spectrum modulation, etc.).

The IEEE 802.11 standard specifies the format and content of communications packets. Communications packets that may also be referred to as frames may be of variable size with the size of each packet being identified in packet header information. In some embodiments, the body of each packet may vary from 0 to 2312 octets.

15 In operation, initially when one of the terminals 26 is powered, that terminal 26 may seek to join cell 22 by associating with access point 24. Remote terminal 26 may become associated with access point 24 after a preliminary exchange of communications between access point 24 and terminal 26. A plurality of terminals 26 may be associated with each access point 24. Each terminal 26 may have different communications capabilities and requirements. Access point 24 may manage the communications traffic between terminals 26 and the wireline network. Access point 24 may manage the communications traffic by controlling when packets are transmitted to each remote terminal 26 in cell 22. The communications traffic in cell 22 may include data packets (e.g., signals that carry packets to provide data communications), voice packets (e.g., signals that carry packets to provide voice communications), real-time packets (e.g., signals that carry packets to provide real-time communications such



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as multimedia or voice communications), management packets (e.g., signals that carry packets to provide network management communications), etc.

The wireline network that is coupled to  
5 access point 24 may include equipment 23 that is configured to implement the wireline network. The wireline network may be coupled to an external network (e.g., PBX, PSTN, Internet, etc.).

Access point 24 may manage communications  
10 traffic by prioritizing packets that are to be transmitted to the remote terminals 26 that are associated with access point 24. Illustrative steps involved in managing communications traffic for use in an access point such as access point 24 of FIG. 1 are  
15 shown in FIG. 2a. At step 40, an access point may receive signals carrying packets that are to be transmitted to remote terminals (e.g., packets that are addressed to individual terminals 26 in cell 22 of FIG. 1). At step 42, the access point may prioritize the  
20 received packets for transmission. An access point may prioritize received packets to determine to which remote terminal to transmit a packet next and to determine which one of the packets that are to be transmitted to that remote terminal will be the packet  
25 to be transmitted next. Prioritization may be performed in intervals as packets are received by the access point. For example, prioritization may be performed at regular periodic intervals. Each packet may be prioritized based on time of reception, packet  
30 content, packet address information, message protocol, fairness to each terminal, etc.

For clarity, the management of packet communications traffic is primarily discussed in the

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context of queues. Techniques other than the use of queues may also be used for managing packet communications traffic. Illustrative queues 44, 46, 48, 50 and 52 of FIG. 2b may be provided based on the illustrative steps of FIG. 2a. Queue 44 includes illustrative packets in the order in which they were received by an access point. The packets in queue 44 may have been received from remote terminals that are associated with the access point or from a wireline network. The packets in queue 44 are packets that are directed to four terminals T1, T2, T3 and T4. Queues 46, 48, 50 and 52 may include packets from queue 44 when the packets have been prioritized by the access point. Each respective queue 46, 48, 50 and 52 is a queue that is associated with a respective terminal T1, T2, T3, and T4. Within each queue 46, 48, 50 and 52 packets may have been prioritized based on when the packets were received.

Each packet illustrated in queue 44 has a terminal address and a packet number. The packet number is used here for illustrative purposes to show the order in which packets were received by the access point. In queues 46, 48, 50 and 52, packets with lower packet numbers are higher in transmission priority because they were received first.

Packets may be transmitted based on priority. Illustrative steps involved in transmitting packets are shown in FIG. 3a. At step 54, an access point may prioritize packets for transmission. At step 56, the prioritized packets may be distributed by transmitting packets based on priority, based on fairness, based on fairness and priority, based on fairness per terminal, based on a one packet per terminal transmission



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sequence, etc. If desired, fairness may be determined as part of step 54 when the access point prioritizes packets.

Illustrative queues 58, 60, 62, 64 and 66 of FIG. 3b may be provided based on the illustrative steps of FIG. 3a. Queues 58, 60, 62 and 64 may each be associated with a respective terminal (T1, T2, T3, and T4). The packets may have been received by an access point for transmission to terminals (T1, T2, T3, and T4). In each queue, the packets may have been prioritized based on time of reception. To achieve fairness, the access point may transmit packets in rounds. In each round, the access point may transmit the same number of packets (e.g., one packet) to each terminal.

Queue 66 includes the packets from queues 58, 60, 62 and 64 in the sequence in which the packets are to be transmitted. The sequence may be divided into rounds with each round including one packet per terminal. As shown, the first and second rounds each have four packets, one for each terminal that is associated with the access point. The third round includes three packets because there are no more packets that are pending to be transmitted to T3 in queue 62 after the first two rounds were successfully transmitted.

An access point may select and transmit packets for each terminal in each round in the order in which that the packets for that terminal were received by the access point. With continued reference to FIG. 3b, in the first round, the access point transmits packets nos. 2, 3, 6 and 1 that are each the first packet in queues 58, 60, 62, and 64, respectively. In



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the second round, the access point transmits packets nos. 4, 8, 7 and 5 that are each the next packet that was received for each terminal T1, T2, T3 and T4, respectively. In each round, one packet from each  
5 queue is transmitted without having competition between the queues for a position in the round.

The illustrative packets in FIG. 3b (and in the other FIGS.) are variable size packets. The packets are illustrated as fixed length packets to  
10 simplify the figures.

The access point may prioritize packets based on which packets are for voice communications. Illustrative steps involved in prioritizing packets based on which packets are for voice communication are  
15 shown in FIG. 4a. At step 68, an access point may determine which of the packets that are to be transmitted are for voice communications.

Packets that are for voice communications may be packets that carry digitized voice communications.  
20 As discussed above, voice communications typically have stricter transmission requirements than other communications such as inventory data, point of sale information, etc. The access point may determine which packet is for voice based on a message flag in the  
25 packet, based on the packet being addressed to a voice-capable terminal, based on the messaging protocol (discussed further below), etc. At step 70, packets may be prioritized based on determining which packets are for voice. Packets for voice communications may be  
30 prioritized higher than other packets.

Illustrative queues 72, 74 and 76 of FIG. 4b may be provided based on the illustrative steps of FIG. 4a. Queue 72 may include packets that have been

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received by an access point for transmission to terminals T1 and T2. Queue 72 includes packets that are to be transmitted to provide voice communications (packets nos. 1, 4 and 6). Packets that are for voice  
5 communications are prioritized higher than other packets in queues 74 and 76 so that these voice packets are transmitted before other packets. Queue 74 for terminal T1 includes voice packet no. 6 that is prioritized higher than packets nos. 3 and 5 which were  
10 received before packet no. 6. Queue 76 for terminal T2 includes voice packets nos. 1 and 4 that are prioritized higher than packets nos. 2 and 7 that are for other communications. Within each queue, voice packets are prioritized to be transmitted before other  
15 packets. All packets in a queue are further prioritized for transmission based when each packet was received by the access point.

An access point may prioritize packets based on network management requirements. Illustrative steps  
20 involved in prioritizing packets based on network management requirements are shown in FIG. 5a. At step 78, the access point may determine which ones of the packets are to be transmitted to manage network operations. Packets are determined to be for network  
25 management based on a message flag, message length, etc. At step 80, packets may be prioritized based on which packets are for network management.

Illustrative queues 82, 84 and 86 of FIG. 5b may be provided based on the illustrative steps of  
30 FIG. 5a. Queue 82 of received packets may include packets nos. 1, 4 and 6 that are to be transmitted to provide network management. Management packets may be prioritized higher than other packets to protect the



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integrity of network operations. Queues 84 and 86 may be implemented for terminals T1 and T2, respectively. Management packets nos. 1 and 4 are prioritized higher (i.e., positioned at top of the queue) than the other  
5 packet in queue 84 for T1 and management packet no. 6 is prioritized higher than the other packets in queue 86 for T2. The higher priority packets in each queue are to be transmitted before the lower priority packets in the queue.

10 In a wireless local area network, packet traffic may be managed using different levels of priority. Illustrative steps involved in prioritizing packets with different levels of priority are shown in FIG. 6a. At step 88, an access point may determine  
15 which packets are for providing voice, network management, or other communications. At step 90, packets that are for managing network operations are prioritized highest. At step 92, packets that are for voice communications are prioritized second highest.  
20 At step 94, packets that are for other communications are prioritized third highest.

Illustrative queues 96, 98, 100 and 102 of FIG. 6b may be provided based on the illustrative steps of FIG. 6a. Queue 96 may include received packets that  
25 include voice, management and other communications packets that are to be transmitted for terminals T1, T2 and T3. Queues 98, 100 and 102 may be implemented for terminals T1, T2 and T3, respectively. In queues 98, 100 and 102, management packets are prioritized highest  
30 (i.e., higher than voice and other communications packets), voice packets are prioritized second highest, and other communications packets are prioritized third highest. Priority between packets that are for the



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same type of communications may be based on time of reception. Packets may be transmitted by the access point in the order of packet priority for each remote terminal.

5           Some wireless LANs use the seven-layer Open System Interconnect (OSI) reference model developed by the International Standard Organization (ISO). OSI specifies a complete set of network functions, grouped into seven layers. The seven layers are the physical  
10 layer (layer 1), data link layer (layer 2), network layer (layer 3), transport layer (layer 4), session layer (layer 5), presentation layer (layer 6) and application layer (layer 7). The network functions are structured so that each OSI layer is supported by the  
15 layers below it.

          The transport layer establishes and maintains communications between applications on different computers. Communications protocols such as Transmission Control Protocol (TCP) and User Datagram  
20 Protocol (UDP) operate at the transport layer. TCP provides full-duplex connection-oriented services (i.e., maintains a virtual communications connection between end users) while UDP provides connection-less-oriented services (i.e., provides communications  
25 between end users without maintaining an open connection). The communications protocol that is typically used for voice communications in the network layer is UDP.

          Illustrative steps involved in transmitting  
30 packets for use in a wireless local area network (e.g., wireless local area network 20 of FIG. 1) that is configured to implement the OSI transport layer are shown in FIG. 7a. At step 104, an access point may

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determine which terminals are voice capable. The access point may determine which terminals are voice capable based on a message flag in a packet, on pre-assigned addresses for voice-capable terminals, etc.

5 At step 106, the access point may receive packets for transmission to the terminals. Step 106 may be performed before, after, or during step 104.

At 108, the access point may prioritize packets. Prioritization may be based on a plurality of  
10 factors. Prioritization may be based on to which terminal a packet is directed, based on the communications protocol of the packet, based on whether the packet is for network management, and further based on time of reception. At step 110, packets may be  
15 transmitted. Packets may be transmitted based on how the packets were prioritized and based on fairness (e.g., maintains fairness by maintaining an equal distribution of packets among the remote terminals).

Illustrative queues 112, 114, 116, 118 and  
20 120 of FIG. 7b may be implemented based on the illustrative steps of FIG. 7a. Queue 112 may be a queue of received packets that are positioned in the queue 112 in the order in which they were received by an access point. Terminals T1, T2 and T3 may have  
25 already been associated with the access point when the packets were received by the access point. Queues 114, 116 and 118 may be implemented for terminals T1, T2 and T3, respectively, when the received packets are prioritized. The access point may have determined that  
30 terminal T1 is a voice-capable terminal before the packets in queue 112 were received.

Packets that are to be transmitted to manage the wireless network may have been prioritized highest.



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Queue 112 includes two management packets, packet no. 1 which is directed to terminal T1 (e.g., addressed to terminal T1) and packet no. 9 which is directed to terminal T3. Queue 114 for terminal T1 is implemented to have packet no. 1 have the highest priority in queue 114 and queue 119 for terminal T3 is implemented to have packet no. 9 have the highest priority in queue 119.

Packets that are to be transmitted to provide voice communications may have been prioritized second highest. The communications protocols of the OSI transport layer handle packets without determining whether the packets are for voice communications. Some networks that are implemented using the OSI transport layer use UDP for providing voice communications. An access point may determine which packets are for voice based on the communications protocol of the packets (e.g., UDP) and based on whether the packet is directed to a voice-capable terminal. Communications protocols operating in the transport layer (i.e., TCP and UDP) use Internet Protocol (IP) services in the network layer to deliver messages between source (e.g., an external network) and destination (e.g., wireless LAN of FIG. 1) systems. IP packets include a protocol field that indicates that the enclosed packets are for which protocol in the Transport Layer (e.g., UDP, TCP, etc.).

Packets may be received by an access point from a half-duplex communications medium (e.g., a radio frequency channel) that is shared between the access point and remote terminals on which remote terminals communicate with the access point and received from another communications medium on which a wireline



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network communicates with the access point. Packets may have been transmitted to the access point using Internet Protocol (e.g., using IP packet formats) for Network Layer communications and using UDP, TCP, etc. (e.g., using UDP packet formats) for Transport Layer communications. Accordingly, packets that are received by the access point from the remote terminals may already be in conformance with the communications requirements for IP and UDP, TCP, etc. When necessary, the access point may configure packets to conform to the 802.11 standard (e.g., when two remote terminals in the wireless LAN are communicating).

The access point may read the protocol field of received IP packets to determine the Transport Layer communications protocol of received packet. Packets which are to be handled using UDP and which are directed to a voice-capable terminal may be determined by the access point to contain voice communications. The access point may have determined earlier which terminals are voice-capable through an earlier exchange with the terminals. The earlier exchange may occur when a remote terminal initially seeks to establish communications with (e.g., be associated with) an access point. If desired, the access point may have been programmed with information related to the capabilities of each terminal.

With reference again to FIG. 7b, queue 114 for voice-capable terminal T1 includes packet no. 7 (UDP) and packet no. 10 (UDP) which are both prioritized higher than packet no. 3 that was received before them. In queues 116 and 118, UDP packets are not prioritized higher than TCP packets since the access point has not determined that T2 and T3 are

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voice-capable. In queues 116 and 118, management packets (if any) are prioritized highest with all other packets being prioritized second highest.

Queue 120 includes the packets in the order  
5 in which they are to be transmitted (i.e., the transmission sequence). Packets may be transmitted in one-packet-per-terminal rounds with the highest priority packet for each terminal being transmitted in each round. Such transmission techniques allow for the  
10 quick delivery of voice communications without substantially increasing the complexity, cost, structure, or design of network equipment.

Queues 114, 116 and 118 may have been configured to be of equal size. Queues of equal size  
15 may prevent the situation in which a large number of packets for one terminal occupies most of the storage space of the access point. Such a situation may block new packets that are received by the access point to be stored due to insufficient storage space. The size of  
20 such equal sized queues may be determined based on system limitations. For illustrative purposes, queues 114, 116 and 118 are each shown to be capable of storing only four packets.

Illustrative steps involved in prioritizing  
25 packets based on a terminal having a voice-capable status are shown in FIG. 8a. At step 122, a terminal may transmit a packet that includes a voice flag to an access point. The voice flag may be set to indicate that the terminal is voice-capable. At step 123, the  
30 access point may determine the status of the terminal by receiving the packet and reading the voice flag of the packet. At step 124, the access point may store information indicating the voice-capable status of the



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terminal. At step 126, the access point may prioritize packets based on the terminal having a voice-capable status.

Queue 128 and packet flow chart 130 of FIG. 8b may be implemented based on the illustrative steps of FIG. 8a. Chart 130 indicates that terminal T transmitted to an access point a packet having a voice flag that was set to indicate the voice-capable status of terminal T. The terminal may have transmitted the packet in an initial communications exchange between the terminal and access point. Terminal T may be a terminal that is one of a plurality of terminals that are associated with the access point.

The packets in queue 128 may have been received after the initial exchange between the access point and terminal T. The packets in queue 128 were prioritized based on the voice-capable status of terminal T (e.g., UDP packets are prioritized higher than TCP packets). Within the access point, an application may assign a priority to each packet in queue 128. The packets are then transmitted based on the assigned priorities and an acknowledgment packet is transmitted by terminal T and for each packet that is properly received by terminal T. Received packets in queue 128 are prioritized and transmitted in the following sequence: packet no. 4 (MNGT), packet no. 1 (UDP), packet no. 3 (UDP), and packet no. 2 (TCP).

In wireless LANs that use carrier-sense multiple access with collision avoidance (CSMA/CA) greater access to the communications bandwidth may be provided for transmitting voice communications than for transmitting other communications. Illustrative steps involved in transmitting voice packets in a CSMA/CA



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system are shown in FIG. 9a. At step 132, a transmitter (such as an access point or a terminal) may determine whether a packet that is to be transmitted is for providing voice communications. At step 136, the  
5 transmitter may determine whether the carrier channel is idle for a predetermined duration  $T_0$  (i.e., the carrier channel is available). The determination may be made using carrier sensing equipment that is implemented in the transmitter. At step 134, the  
10 transmitter may determine whether the carrier channel is idle for a duration  $T_r$  that is less than duration  $T_0$  (e.g., what is the duration that is actually used) when the transmitter determines that the packet that is to be transmitted is for voice communications. At step  
15 138, the transmitter may transmit the packet when the transmitter determines that the carrier channel has been idle for an appropriate duration of time (i.e.,  $T_0$  or  $T_r$ ). A contention window may specify the duration which a transmitter is to sense for a carrier channel  
20 frequency to determine whether the channel is idle (e.g., available for carrying transmissions). FIG. 9b shows a graph that illustrates different contention windows for voice and other data.

Transmitted packets may be acknowledged by  
25 each recipient by the recipient transmitting an acknowledgment packet in response to the intended recipient receiving the transmitted packet. The transmitter may then discard the transmitted packet that has been acknowledged and/or commence transmitting  
30 packets which have not yet been transmitted. Packets that have not yet been acknowledged may be retransmitted (e.g., the packets remain in queue for transmission). Illustrative steps involved in

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retransmitting packets for use in a wireless LAN (e.g., wireless LAN 20 of FIG. 1) are shown in FIG. 10a. At step 140, a packet that is directed to a particular terminal may be transmitted. At step 142, the

5 transmitter may determine whether an acknowledge packet has been received. At step 144, the transmitter may transmit the next packet (e.g., the next highest priority packet) for that terminal after an acknowledgment has been received for the transmitted

10 packet. At step 146, when an acknowledgment has not been received for the transmitted packet, the transmitter may continue to retransmit the packet until the packet is acknowledged or until the number of times the packet is transmitted reaches a retry threshold.

15 Step 146 may include the step of determining the retry threshold based on whether the packet is for voice communications. The retry threshold for voice packets may be preset to be lower than the retry threshold for other packets.

20 Illustrative packet transmission rounds 148, 150, 152 and 162 of FIG. 10b may be implemented based on the illustrative steps of FIG. 10a. In round 148 (the first round), packet A is transmitted by access point 154 to terminal T2 and an acknowledgment is not

25 transmitted in reply by terminal T2. In round 150 (the second round), packet A is retransmitted and an acknowledgment is again not received from terminal T2. Packet A continues to be transmitted in the subsequent rounds for a total of n rounds where in each round an

30 acknowledgment for packet A has not received. The value of n may be a retry threshold and the value may be different for voice and data packets. After the nth round 152, retransmissions of packet A may be



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discontinued and a different packet (e.g., the next highest priority packet for terminal T2) may be transmitted in the subsequent round, round 162.

Illustrative steps for retransmitting  
5 unacknowledged packets for use in a wireless LAN (e.g., wireless LAN 20 of FIG. 1) that is configured to use frequency hopping spread spectrum modulation are shown in FIG. 11a. At step 104, a transmitter may transmit a packet for a particular terminal. At step 166, the  
10 transmitter may determine whether an acknowledgment has been received in reply to the transmitted packet. At step 168, the transmitter may transmit the next packet for that terminal when the transmitter has determined that an acknowledgment for the transmitted packet has  
15 been received. At step 170, when it is determined that an acknowledgment has not been received, the packet is retransmitted until it is acknowledged or until an initial retry threshold has been reached (e.g., the packet has been transmitted k times). If desired, step  
20 170 may include determining how many times to retry transmission (step 170a) (e.g., based on whether the packet is for voice communications). When the initial retry threshold is reached, further retry transmissions are halted until after a frequency hop in modulation  
25 (step 172). At 174, the packet may be further retransmitted until it is acknowledged or until a total retry threshold has been reached. If desired, step 174 may include determining how many total times to retry the transmission of the packet (e.g., based on whether  
30 the packet is for voice communications).

Illustrative transmission rounds 176, 178, 180 and 182 of FIG. 11b may be implemented based on the illustrative steps of FIG. 11a. In round 176, access

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point 184 may transmit packet A to terminal T2. In round 178, access point 184 may again transmit packet A to terminal T2 when an acknowledgment packet was not received for packet A in the previous round. In the following rounds, access point 184 continues to retransmit packet A while a responsive acknowledgment has not been received and until packet A has been transmitted a particular number of times k. When packet A has been transmitted k times, any further retransmissions are halted until a hop in the frequency that is being used for spread spectrum communications. In round 182 after a frequency hop, access point 182 resumes transmitting packets to terminal T2.

Retransmission of an unacknowledged packet may be preempted by the reception of a packet that has a higher priority than the unacknowledged packet. Illustrative steps involved in transmitting a highest priority packet for each terminal in a wireless local area network (e.g., wireless LAN of FIG. 1) are shown in FIG. 12a. At step 190, received packets may be prioritized. At step 192, the highest priority packet for each terminal may be selected. At step 194, one round of packets (e.g., the selected packets) are transmitted. At step 196, the transmitter determines whether an acknowledgment has been received for each transmitted packet. At step 198, new packets are received for transmission. At step 200, the packets that are to be transmitted (i.e., the received packets and the unacknowledged packets) are prioritized. At step 202, the highest priority packet for each terminal is selected. At step 204, another round of packets is transmitted.



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Illustrative queues 206, 208, 210, 212 and 214 of FIG. 12b may be implemented based on the illustrative steps of FIG. 12a. Queue 206 and 208 may be queues that include prioritized packets that access point 216 is to transmit to terminals T1 and T2, respectively. In a first round, when a half-duplex communications channel (e.g., a predetermined frequency band on which multiple devices communicate using CSMA and spread spectrum modulation) is determined to be idle, the access point may transmit packets nos. 1 and 6 which are the highest priority packets for T1 and T2, respectively. In the first round, packet no. 6 (UDP) that is transmitted to a voice-capable terminal T2 is unacknowledged by terminal T2. For the next round, packet no. 6 is reinserted into queue 208 for terminal T2. Additional packets 210 may be received by the access point 216 for transmission to terminals T1 and T2 before the next round of packets are to be transmitted. Queues 206a and 206b may be implemented when the additional packets are prioritized. Queues 206a and 206b include prioritized packets that are to be transmitted to terminals T1 and T2, respectively. In the previous round, packet no. 6 for terminal T2 was unacknowledged and reinserted into queue 208a. New management packet 13 for terminal T2 has been received after the first round and has been prioritized to have a higher priority than packet no. 6. When access point 216 transmits the highest priority packet for terminal T2, packet no. 13 is transmitted over unacknowledged packet no. 6. Thus, retransmission of packet no. 6 is preempted by transmission of higher priority packet no. 13. Retransmission may commence in a future round when

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packet no. 6 is the highest priority packet that is pending to be transmitted for terminal T2.

Thus it is seen that a wireless LAN system and methods are provided that effectively carry mixed traffic communications. Greater priority is given to the transmission of packets for voice communications than for data communications while preventing transmission of data communications from being substantially blocked. Moreover, the system and methods, while meeting the complex demands of a mixed communications traffic environment, may still be implemented without substantial increases in structure, complexity, cost, processing delay, etc. over known wireless LAN systems and methods.

The foregoing is merely illustrative of the principles of this invention and various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention.



THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method, comprising:  
determining a priority level of each of a plurality of packets in periodic intervals based on a remote terminal to which each of the plurality of packets is directed; and  
wirelessly transmitting the packets in one-packet-per-terminal rounds over a communications medium with packets having higher priority levels being transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.
2. The method of claim 1, wherein the priority level of each packet is determined based on priority information in each packet.
3. The method of claim 2, wherein the priority information includes a type of each packet.
4. The method of claim 3, wherein the type of each packet includes one of a data packet, a voice packet and a management packet.
5. The method of claim 2, wherein the priority level of each packet is determined based on an assigned priority level of each packet.
6. The method of claim 2, wherein the priority level of each packet is determined based on a reference to other data indicating the priority level.
7. The method of claim 6, wherein the other data is a protocol of the packet.
8. The method of claim 6, wherein the other data is a destination of the packet.
9. The method of claim 2, wherein the priority information includes one of a length of each packet and a flag in each packet.

10. The method of claim 1, further comprising:  
placing the packets in a transmission queue based on the priority level.
11. The method of claim 10, wherein the transmission queue is a plurality of transmission queues, each transmission queue corresponding to one of the priority levels for the packets.
12. The method of claim 10, wherein the transmission queue is a plurality of transmission queues, each transmission queue corresponding to a destination of the packets.
13. The method of claim 1, wherein the determining the priority level of each of the packets includes determining a time of receipt of each packet.
14. A system, comprising:  
a plurality of remote terminals, each terminal including a receiver to receive wirelessly transmitted packets; and  
an access point receiving the packets from a communication medium, each of the packets having a destination of one of the remote terminals, the access point further determining a priority level of each of the packets in periodic intervals based on a remote terminal to which each of the plurality of packets is directed and wirelessly transmitting each packet in one-packet-per-terminal rounds to the destination remote terminal with packets having higher priority levels being transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of the remote terminals is transmitted in each round.
15. The system of claim 14, wherein the access point determines the priority level of each packet based on priority information in each packet.
16. The system of claim 15, wherein the priority information includes a type of each packet.
17. The system of claim 16, wherein the type of each packet includes one of a data packet, a voice packet and a management packet.



18. The system of claim 14, wherein the access point determines the priority level of each packet based on an assigned priority level of each packet.

19. The system of claim 14, wherein the access point determines the priority level of each packet based on a reference to other data indicating the priority level.

20. The system of claim 19, wherein the other data is a protocol of the packet.

21. The system of claim 19, wherein the other data is a destination of the packet.

22. The system of claim 15, wherein the priority information includes one of a length of each packet and a flag in each packet.

23. The system of claim 14, wherein the access point includes a memory implementing a transmission queue and the packets are arranged in the transmission queue based on the priority level.

24. The system of claim 23, wherein the transmission queue is a plurality of transmission queues, each transmission queue corresponding to one of the remote terminals, the packets being arranged based on the priority level in the transmission queue corresponding to the destination remote terminal of each packet.

25. The system of claim 14, wherein the access point determines the priority level of each packet based on at least a time of receipt of each packet by the access point.

26. The system of claim 14, wherein the access point receives further packets, determines the priority level of each of the further packets and wirelessly transmits each further packet to the destination remote terminal with further packets having higher priority levels having the higher probability of being transmitted prior to un-transmitted packets having lower priority levels.

27. The system of claim 14, wherein at least one of the remote terminals wirelessly transmits additional packets to the access point, with the additional packets having

higher priority levels having a higher probability of being transmitted prior to the additional packets having lower priority levels.

28. An access point, comprising:

a receiver to receive packets from a communication medium, each of the packets having a destination remote terminal, the receiver having a processor determining a priority level of each of the packets in periodic intervals based on the destination remote terminal to which each of the packets is directed; and

a transmitter to wirelessly transmit each packet in one-packet-per-terminal rounds to the destination remote terminal, wherein packets having higher priority levels are transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

29. The access point of claim 28, wherein the processor determines the priority level of each packet based on priority information in each packet.

30. The access point of claim 29, wherein the priority information includes a type of each packet.

31. The access point of claim 30, wherein the type of each packet includes one of a data packet, a voice packet and a management packet.

32. The access point of claim 28, wherein the processor determines the priority level of each packet based on an assigned priority level of each packet.

33. The access point of claim 28, wherein the processor determines the priority level of each packet based on a reference to other data indicating the priority level.

34. The access point of claim 33, wherein the other data is a protocol of the packet.

35. The access point of claim 33, wherein the other data is a destination of the packet.

36. The access point of claim 29, wherein the priority information includes one of a



length of each packet and a flag in each packet.

37. The access point of claim 28, further comprising:  
a memory implementing a transmission queue to store the packets in an order based on the determined priority level.
38. The access point of claim 37, wherein the transmission queue is a plurality of transmission queues, each transmission queue corresponding to a destination for the packets.
39. The access point of claim 37, wherein the transmission queue is a plurality of transmission queues, each transmission queue corresponding to one of the priority levels of the packets.
40. The access point of claim 28, wherein the processor determines the priority level of the packets based on at least a time of receipt of each packet by the access point.
41. The access point of claim 28, wherein the processor receives further packets, determines the priority level of each of the further packets and the transmitter wirelessly transmits each further packet to the destination remote terminal, wherein further packets having higher priority levels have a higher probability of being transmitted prior to un-transmitted packets having lower priority levels.
42. The access point of claim 28, wherein the transmitter is a transceiver.
43. A method, comprising:  
determining a priority level of each of a plurality of packets based on a terminal to which each of the plurality of packets is directed; and  
wirelessly transmitting the packets in one-packet-per terminal rounds over a communications medium, wherein the packets having higher priority levels are transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.
44. A mobile device, comprising:

a processor to receive packets and determine a priority level of each of the packets in periodic intervals based on a terminal to which each of the packets is directed; and

a transmitter to wirelessly transmit each packet in one-packet-per-terminal rounds to a destination with packets having higher priority levels being transmitted prior to packets having lower priority levels.

45. A system, comprising:

a plurality of receiving means for receiving wirelessly transmitted packets; and  
a transmitting means for receiving the packets from a communication medium, each of the packets having a destination remote terminal, the transmitting means for determining a priority level of each of the packets in periodic intervals based on the destination remote terminal to which each of the packets is directed and wirelessly transmitting each packet in one-packet-per-terminal rounds to the destination remote terminal with packets having higher priority levels being transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

46. An access point, comprising:

a receiver means for receiving packets from a communication medium, each of the packets having a destination remote terminal, the receiver means having a processor means for determining a priority level of each of the packets in periodic intervals based on the destination remote terminal to which each of the packets is directed; and

a transmitter means for wirelessly transmitting each packet in one-packet-per-terminal rounds to the destination remote terminal, wherein packets having higher priority levels are transmitted prior to packets having lower priority levels, wherein a highest priority packet for each of a plurality of remote terminals is transmitted in each round.

47. A mobile device, comprising:

a processor means for receiving packets and determining a priority level of each of the packets in periodic intervals based on a terminal to which each of the packets is directed; and



a transmitter means for wirelessly transmitting each packet in one-packet-per-terminal rounds to a destination with packets having higher priority levels being transmitted prior to packets having lower priority levels.

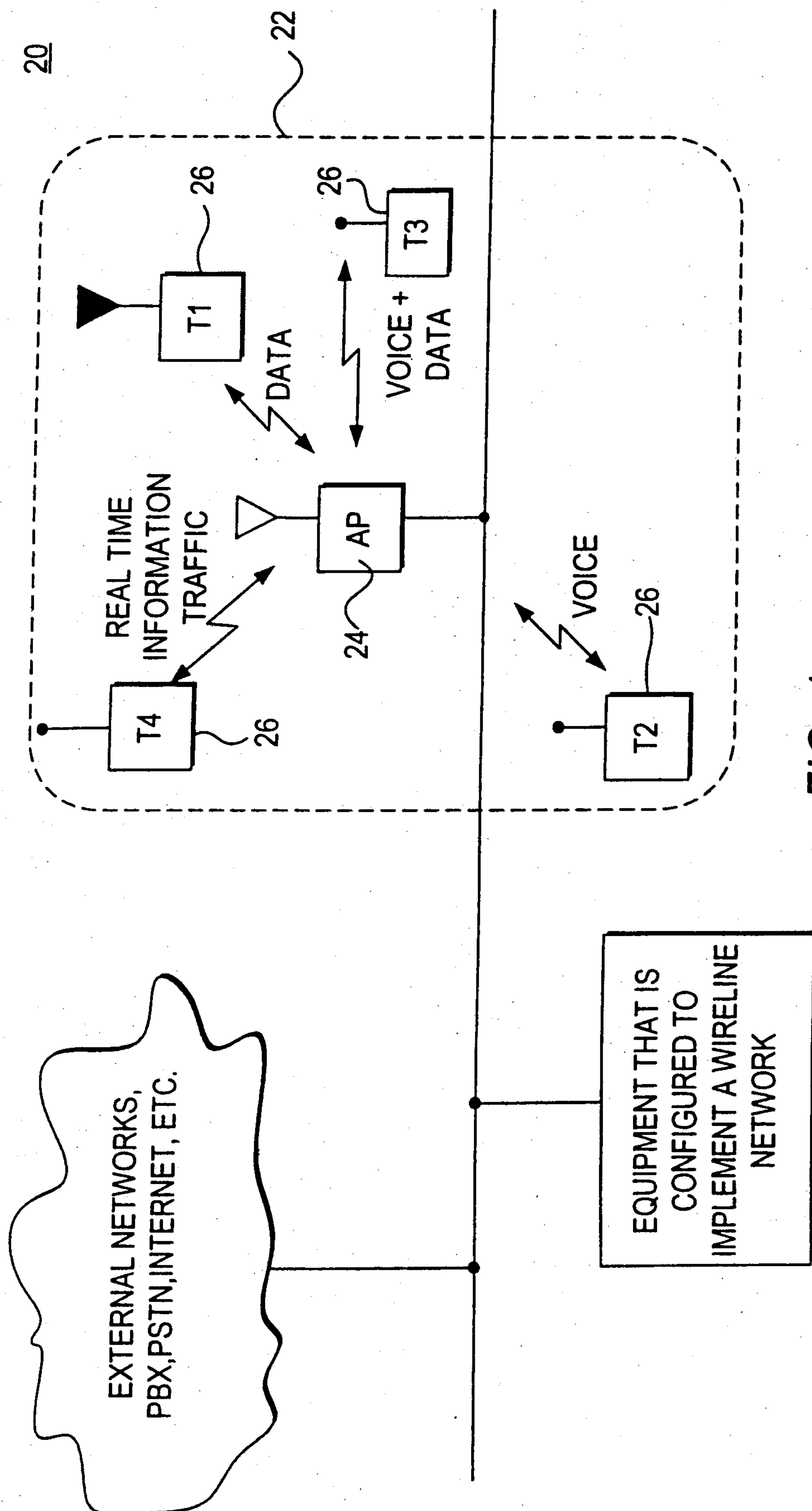


FIG. 1



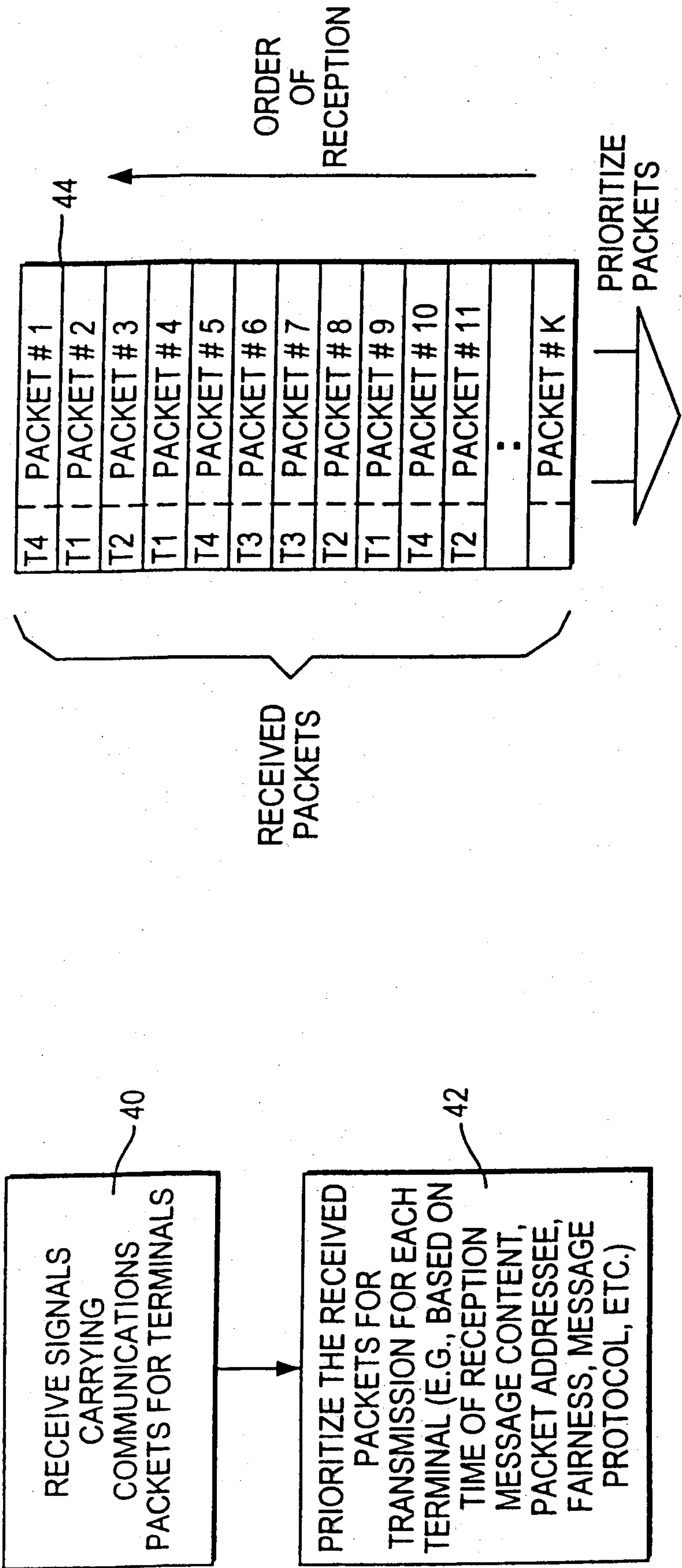


FIG. 2a

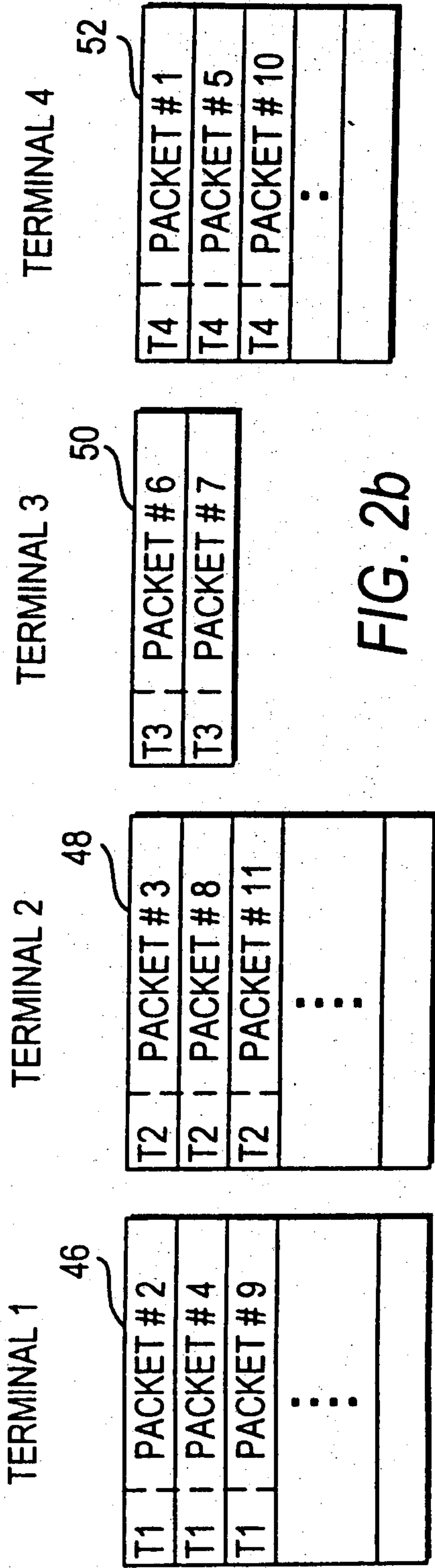


FIG. 2b

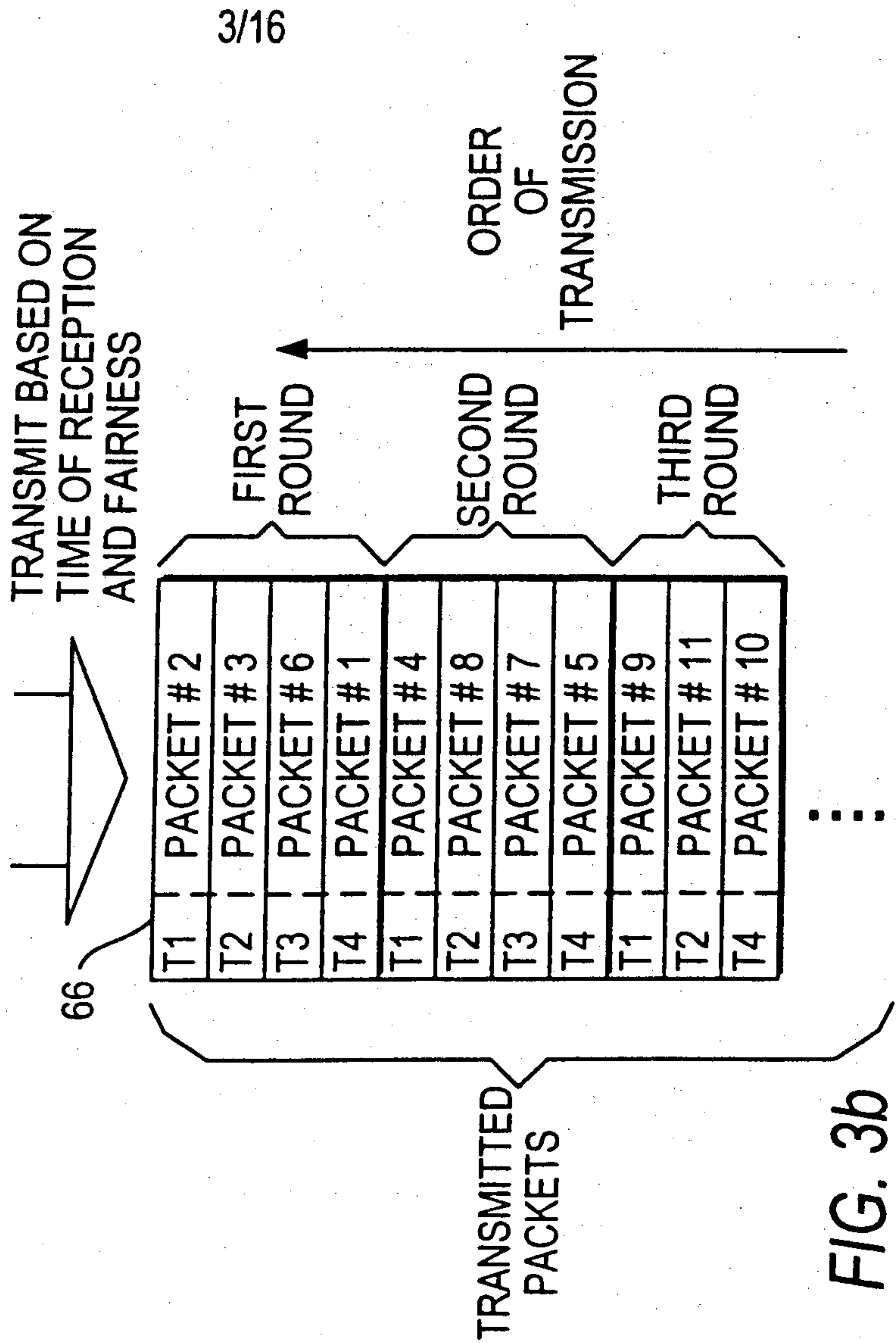
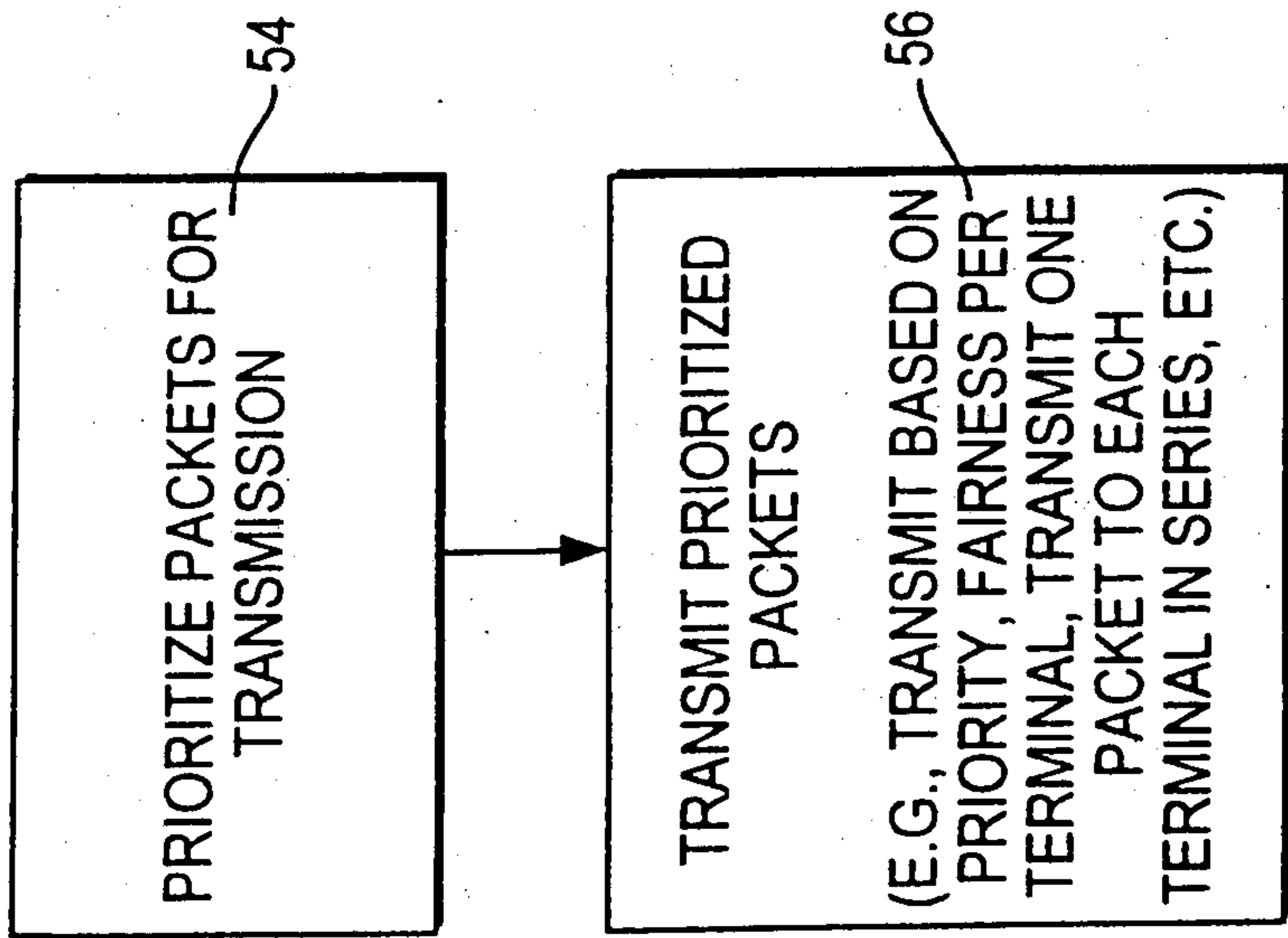
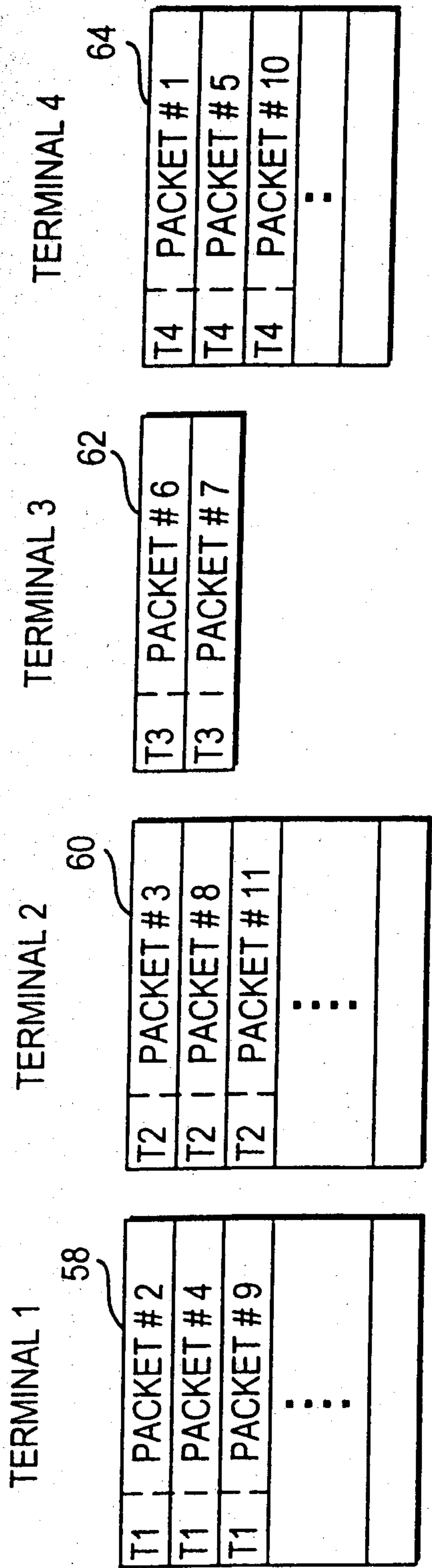
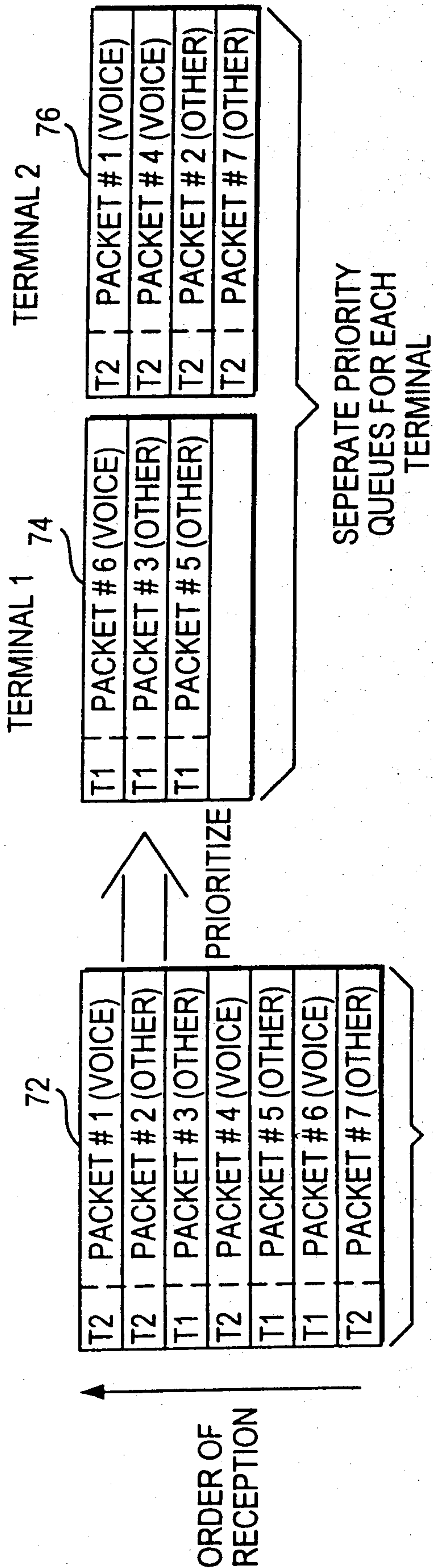
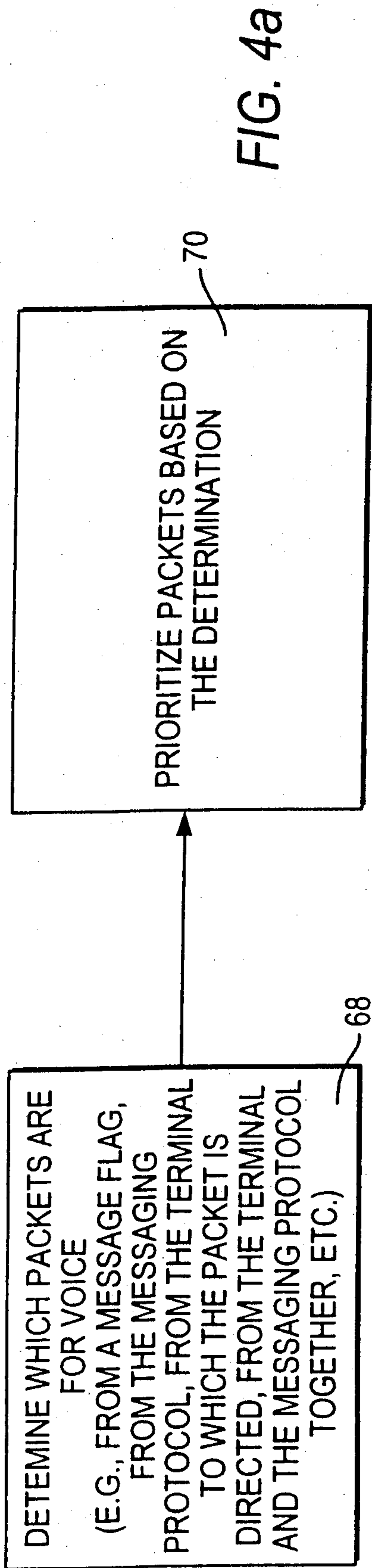


FIG. 3a

FIG. 3b





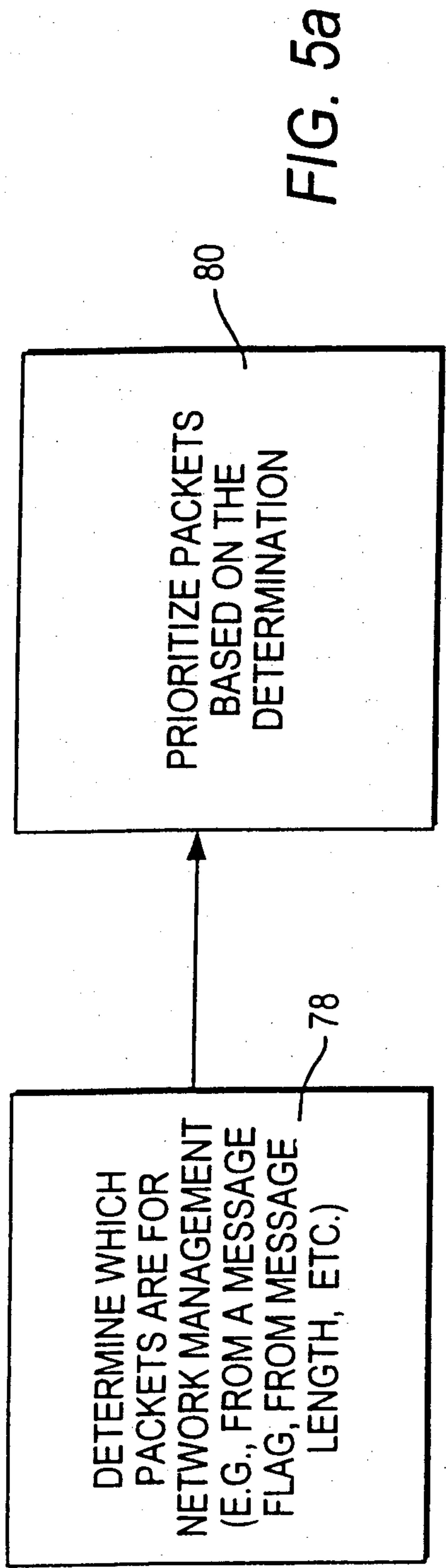


FIG. 5a

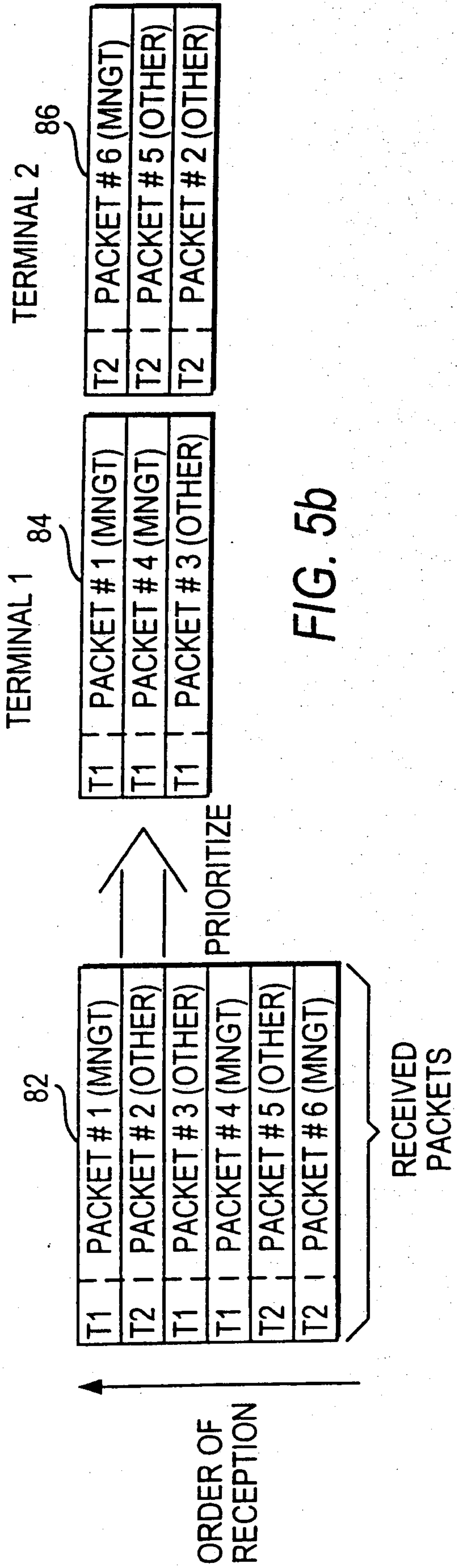


FIG. 5b

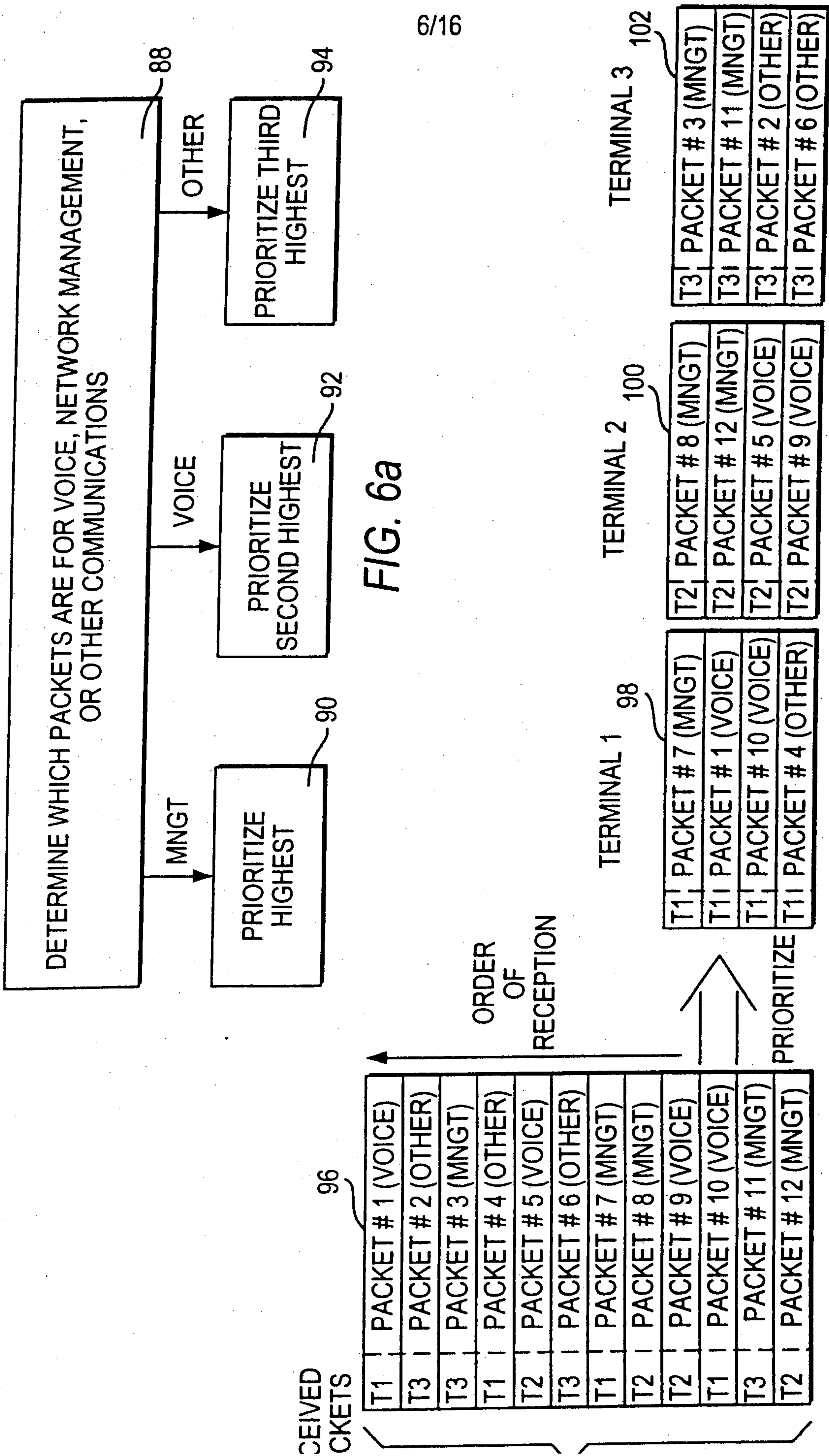


FIG. 6a

FIG. 6b



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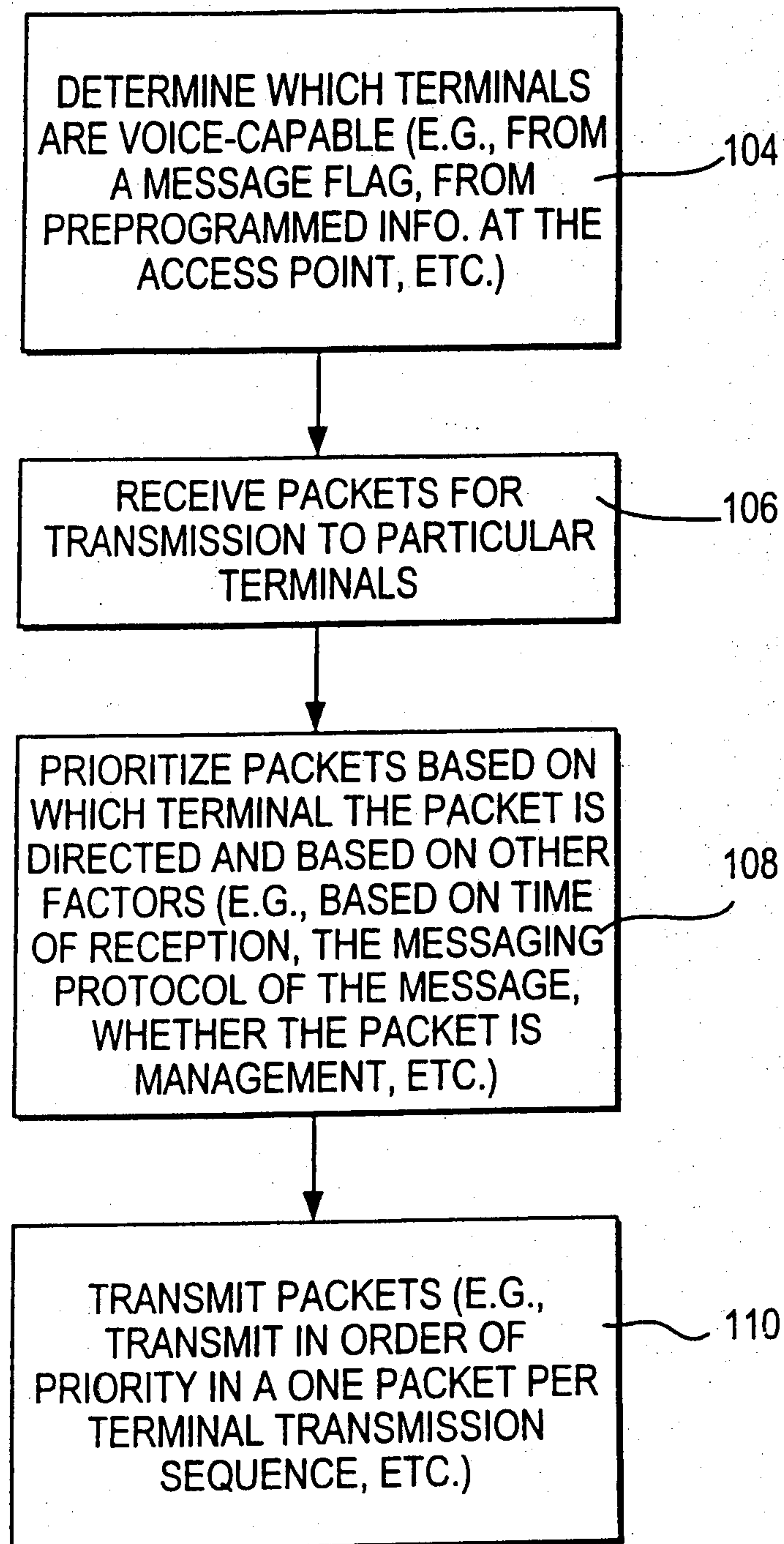


FIG. 7a

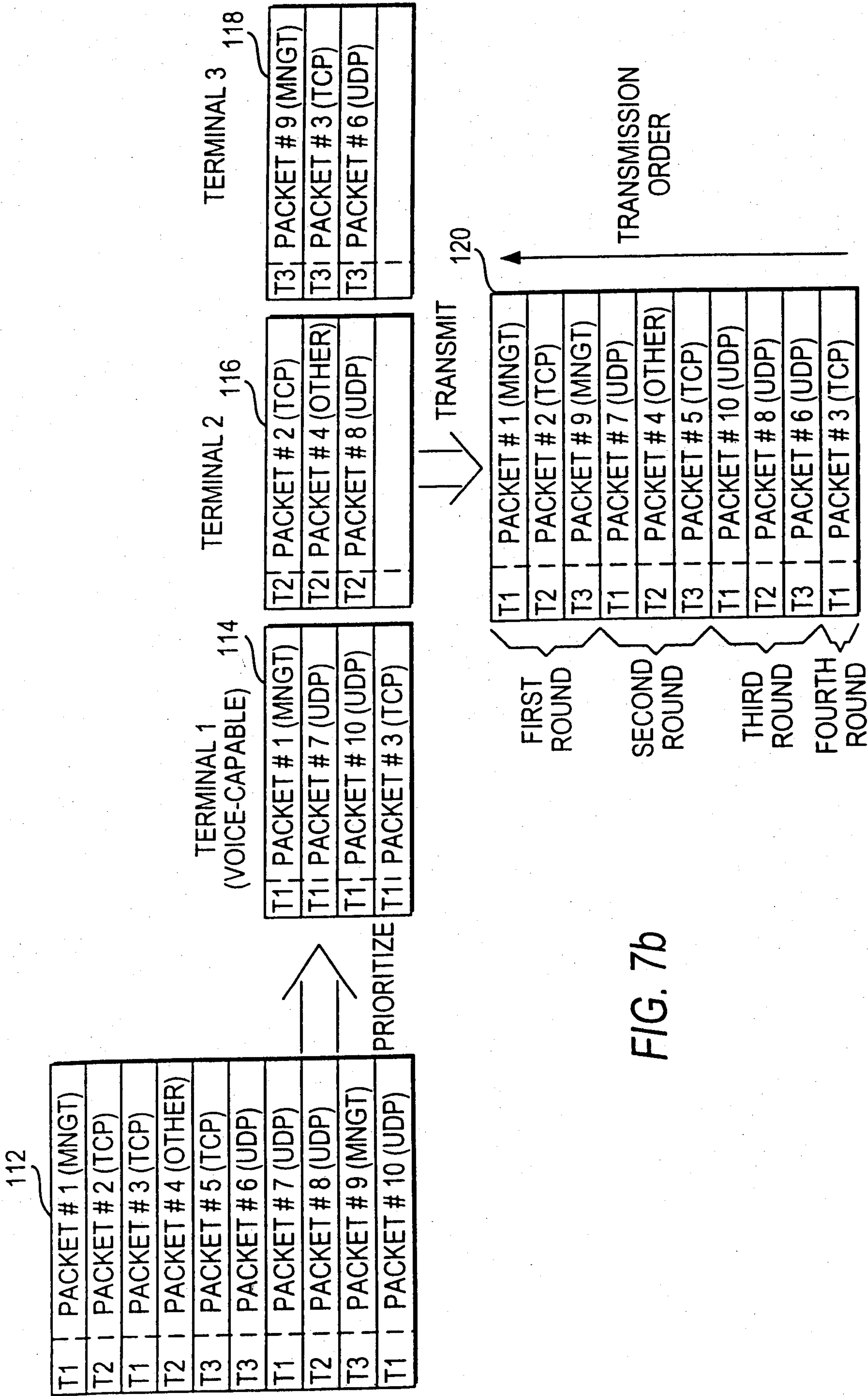


FIG. 7b

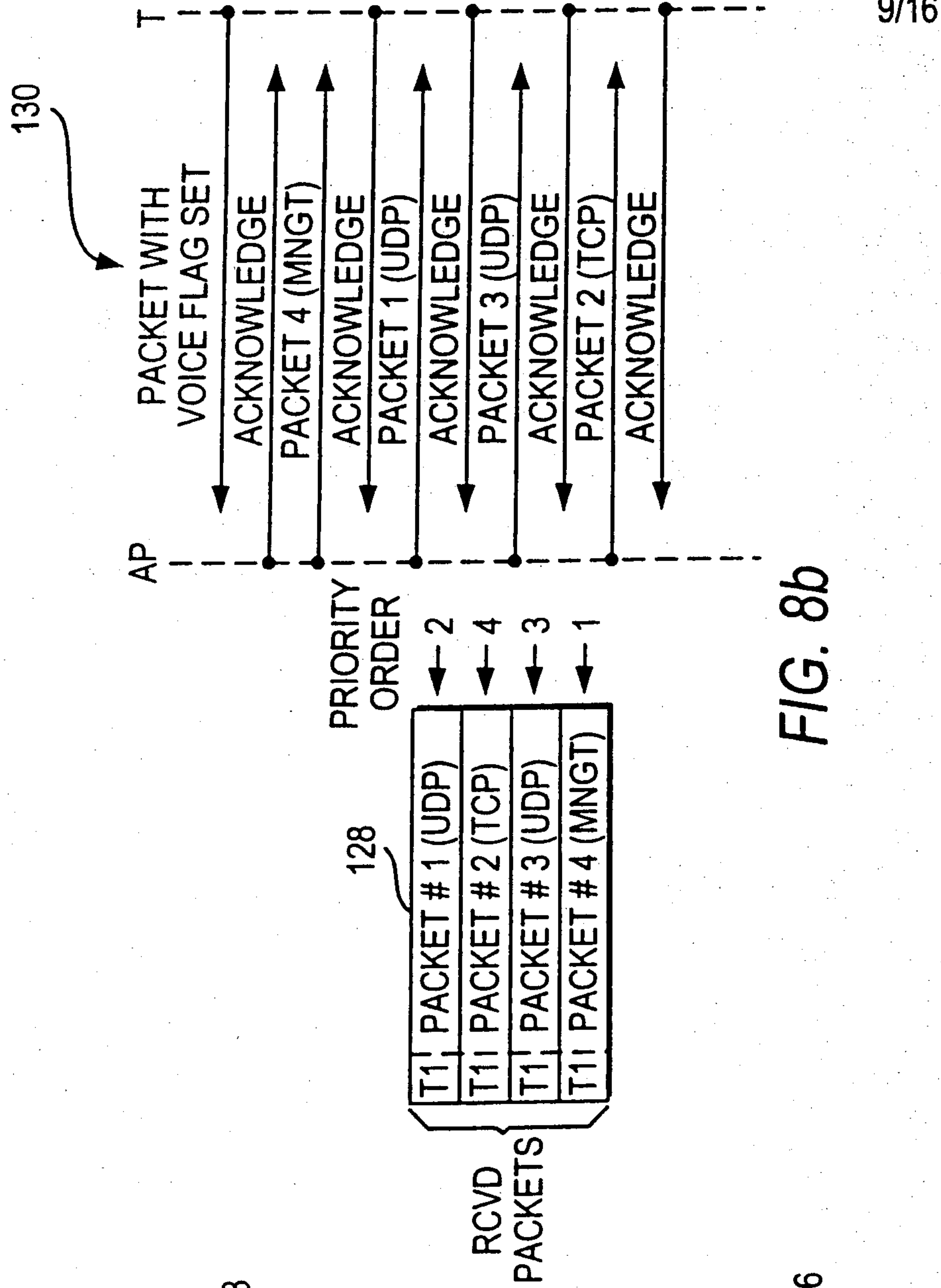
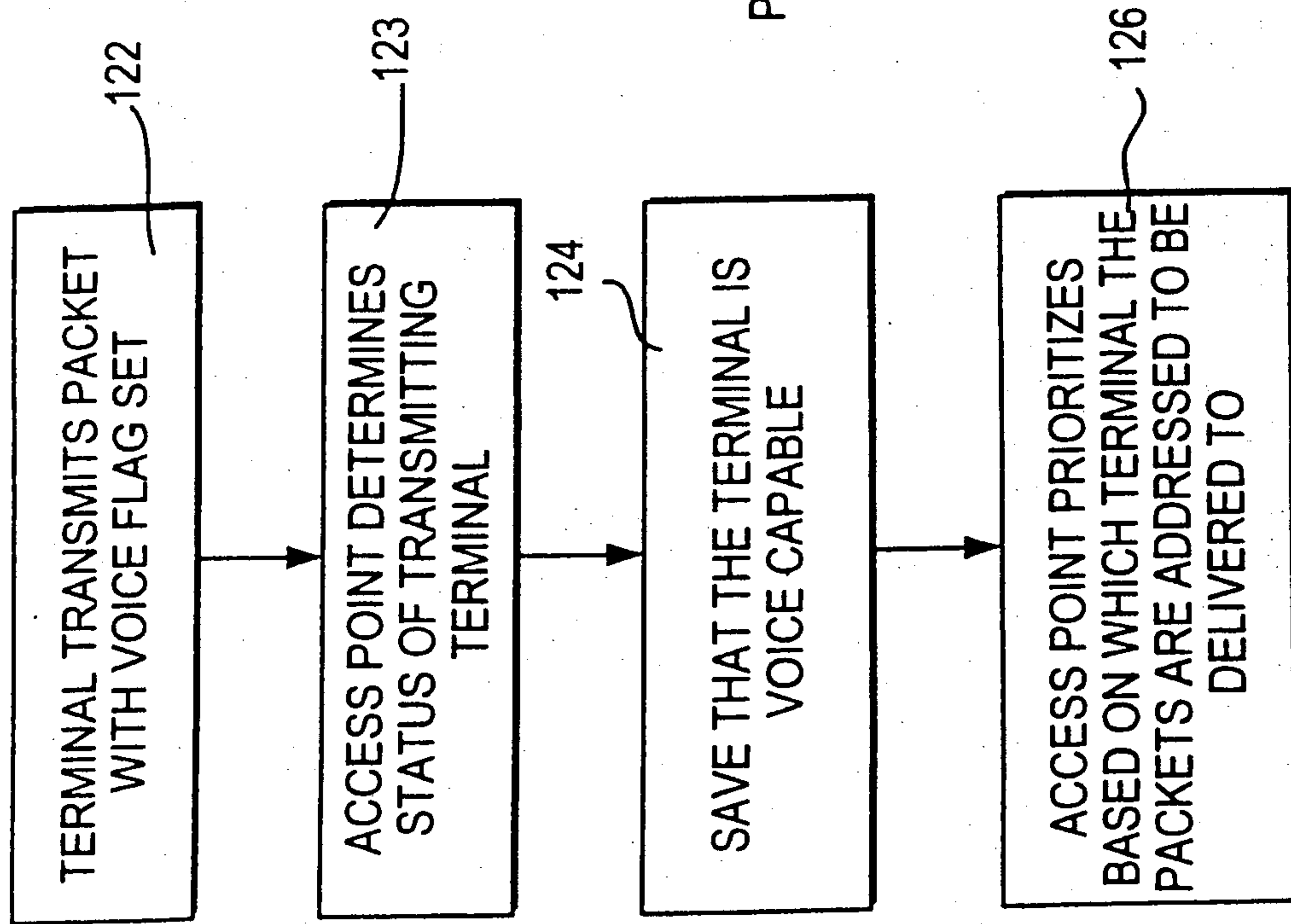


FIG. 8a



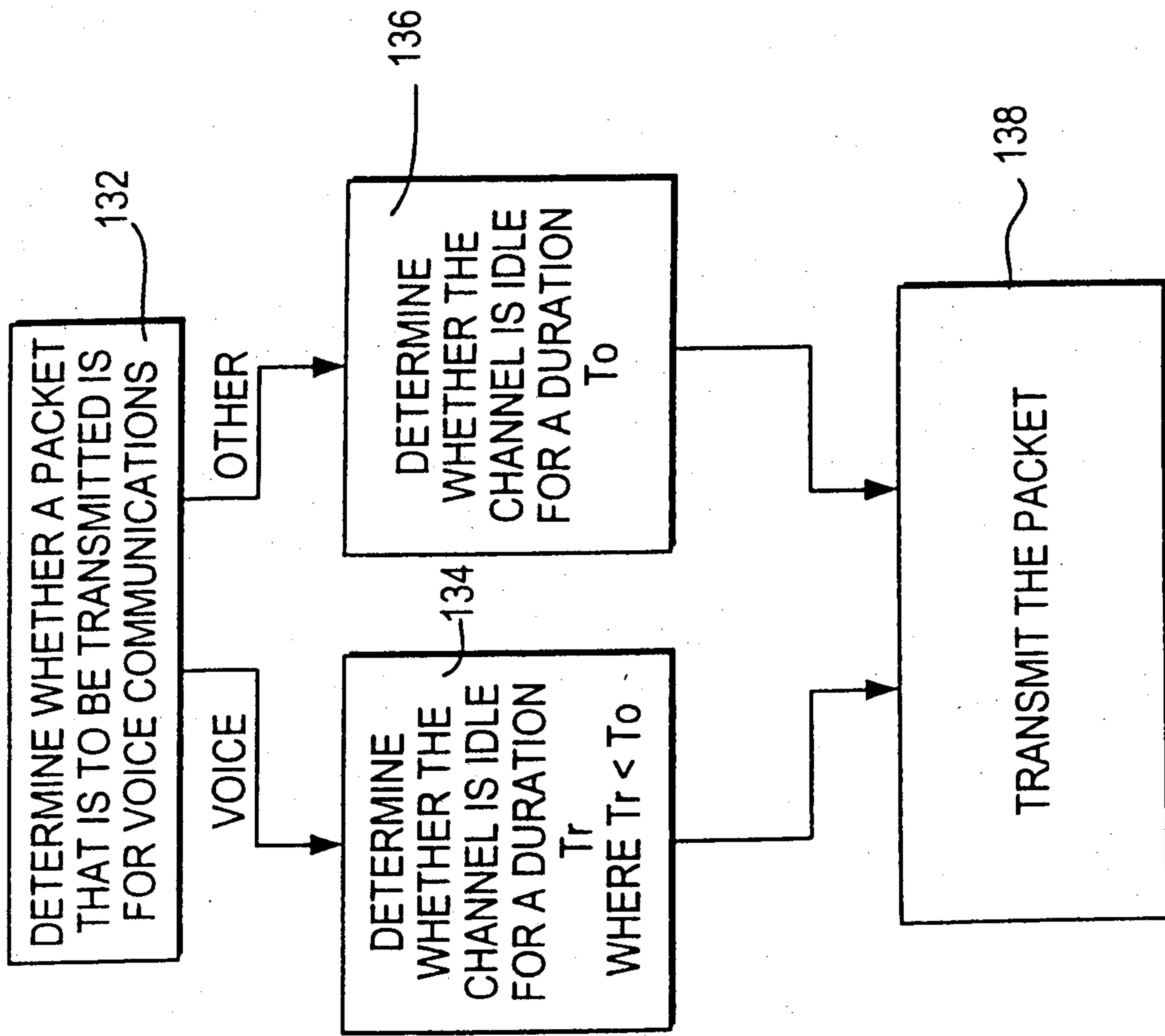


FIG. 9a

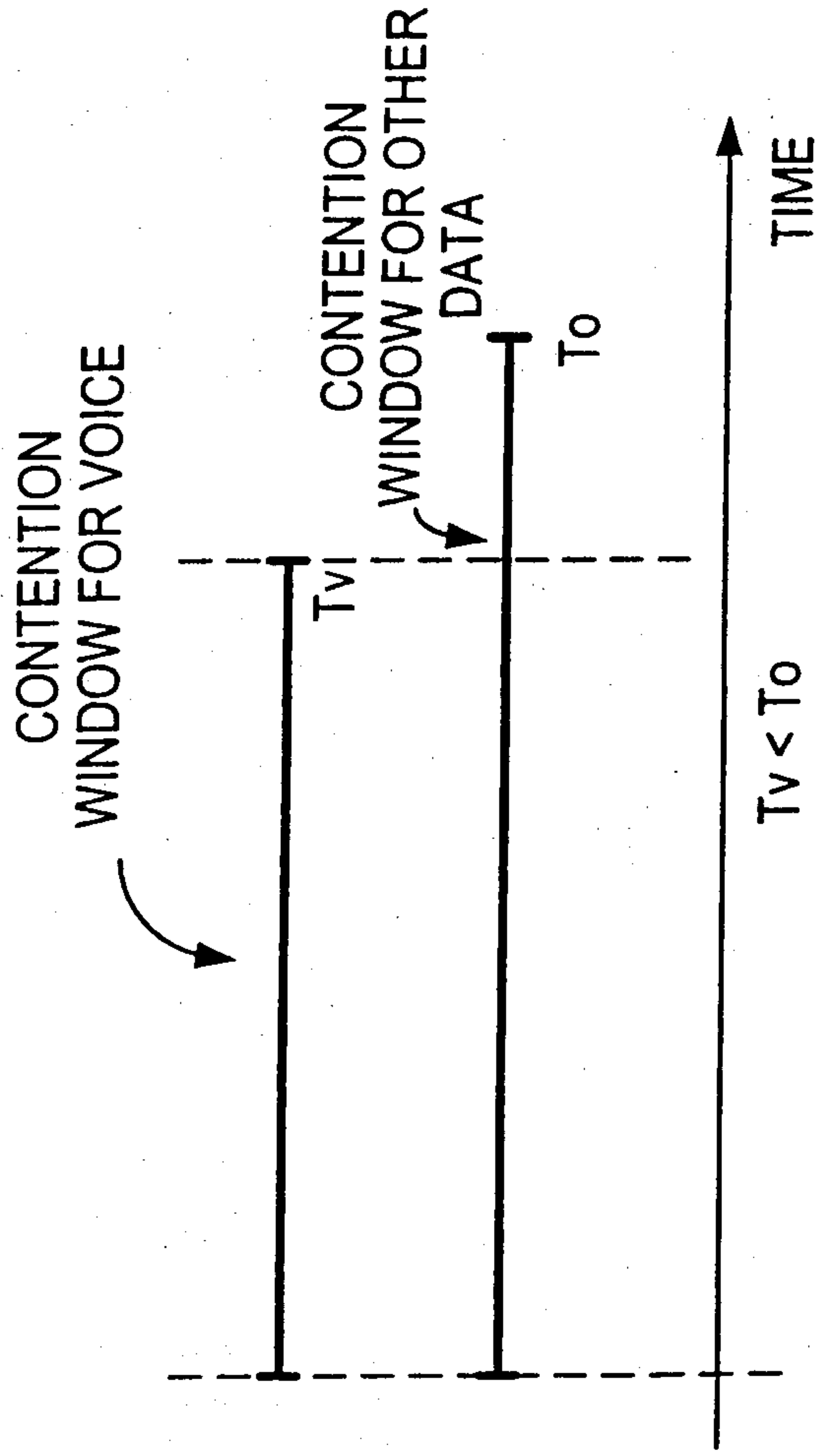


FIG. 9b

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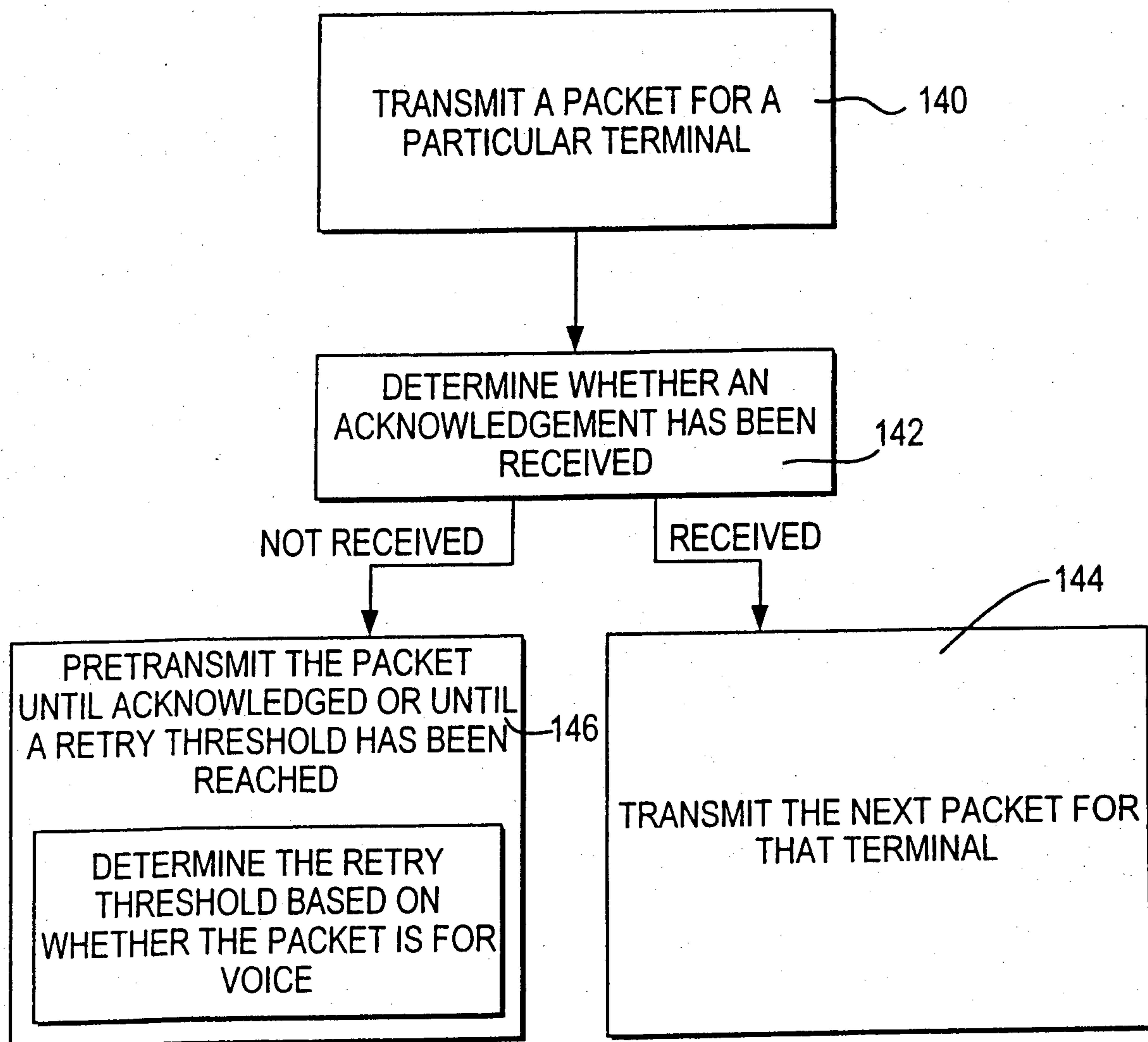


FIG. 10a

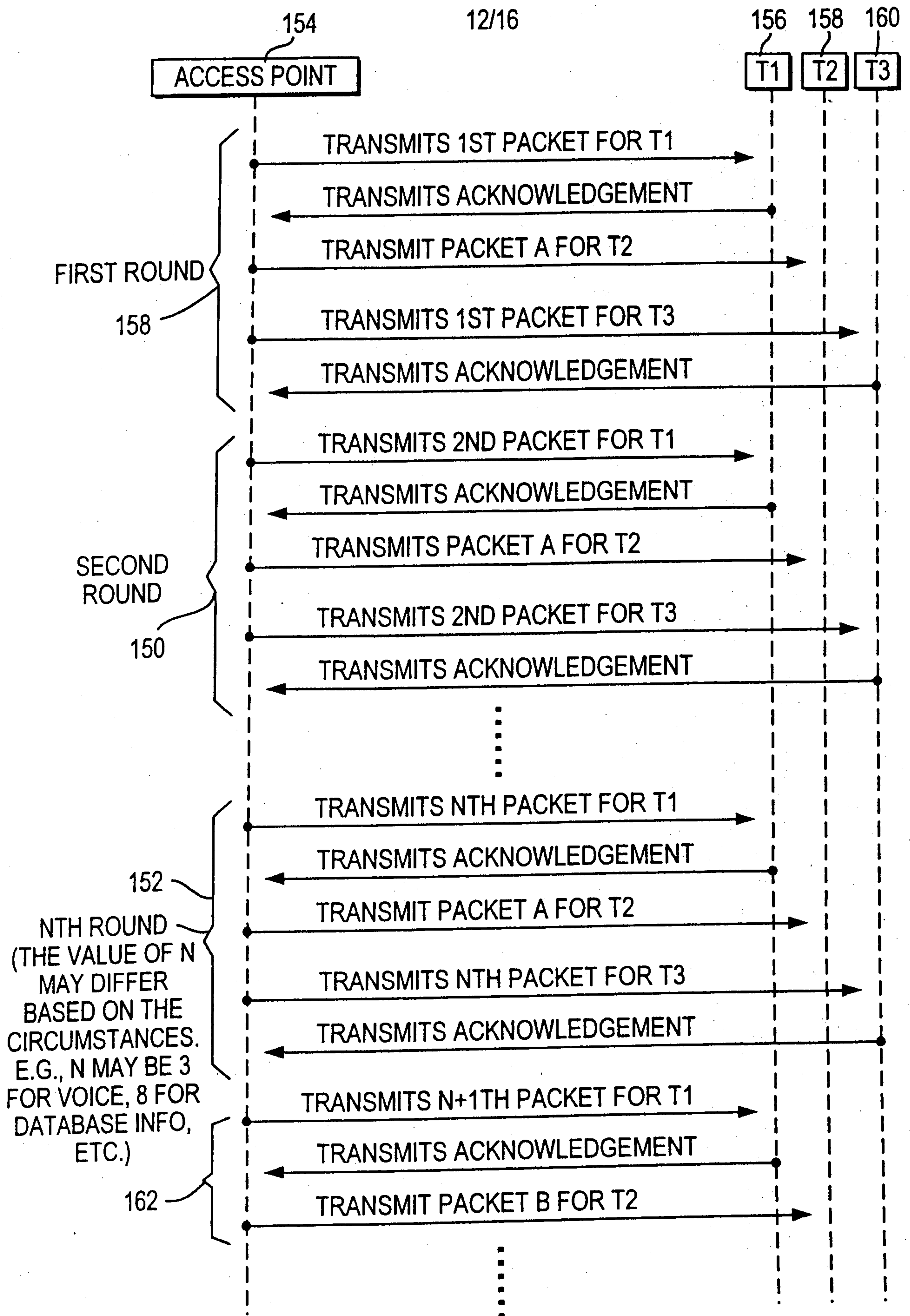


FIG. 10b



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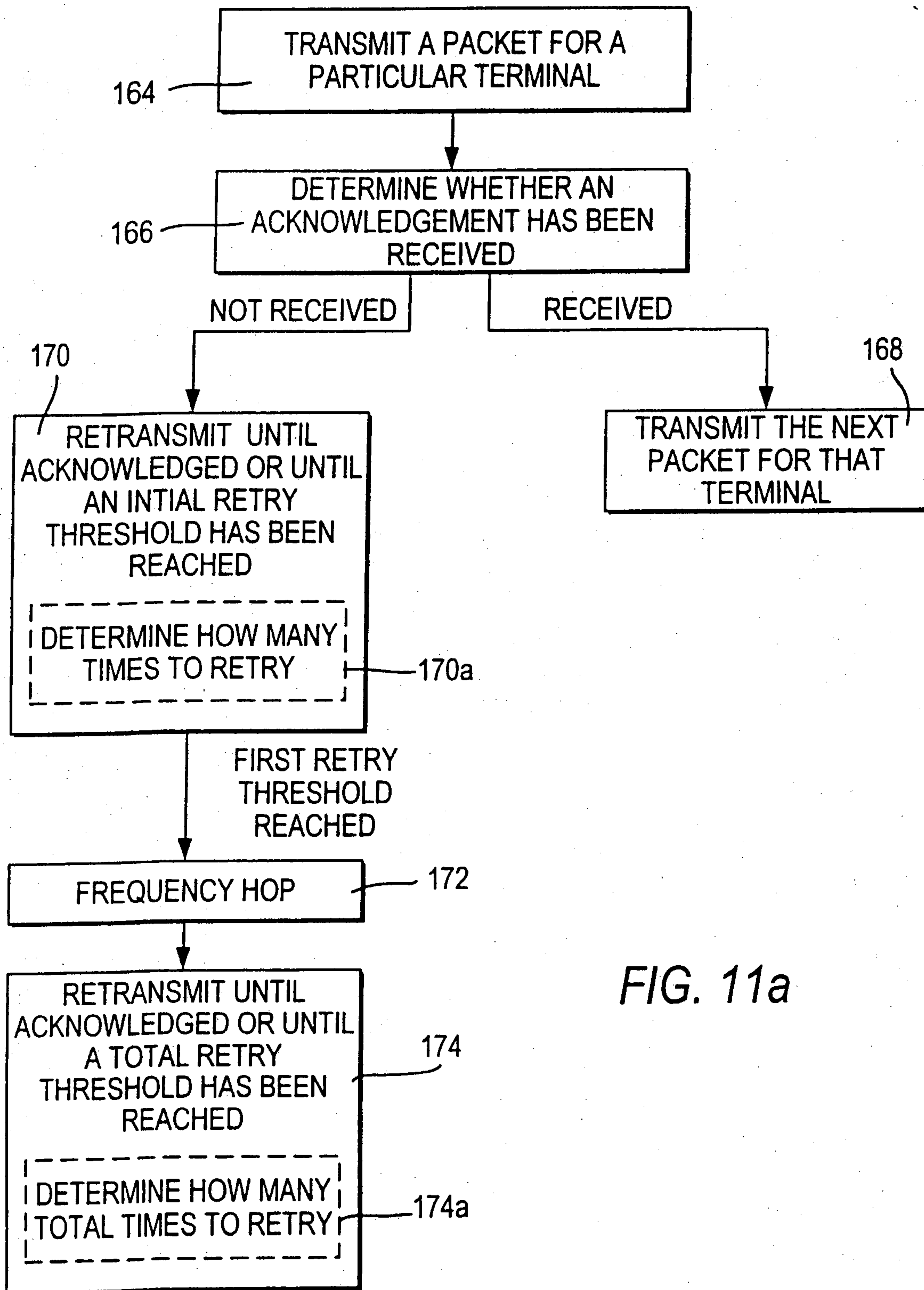


FIG. 11a

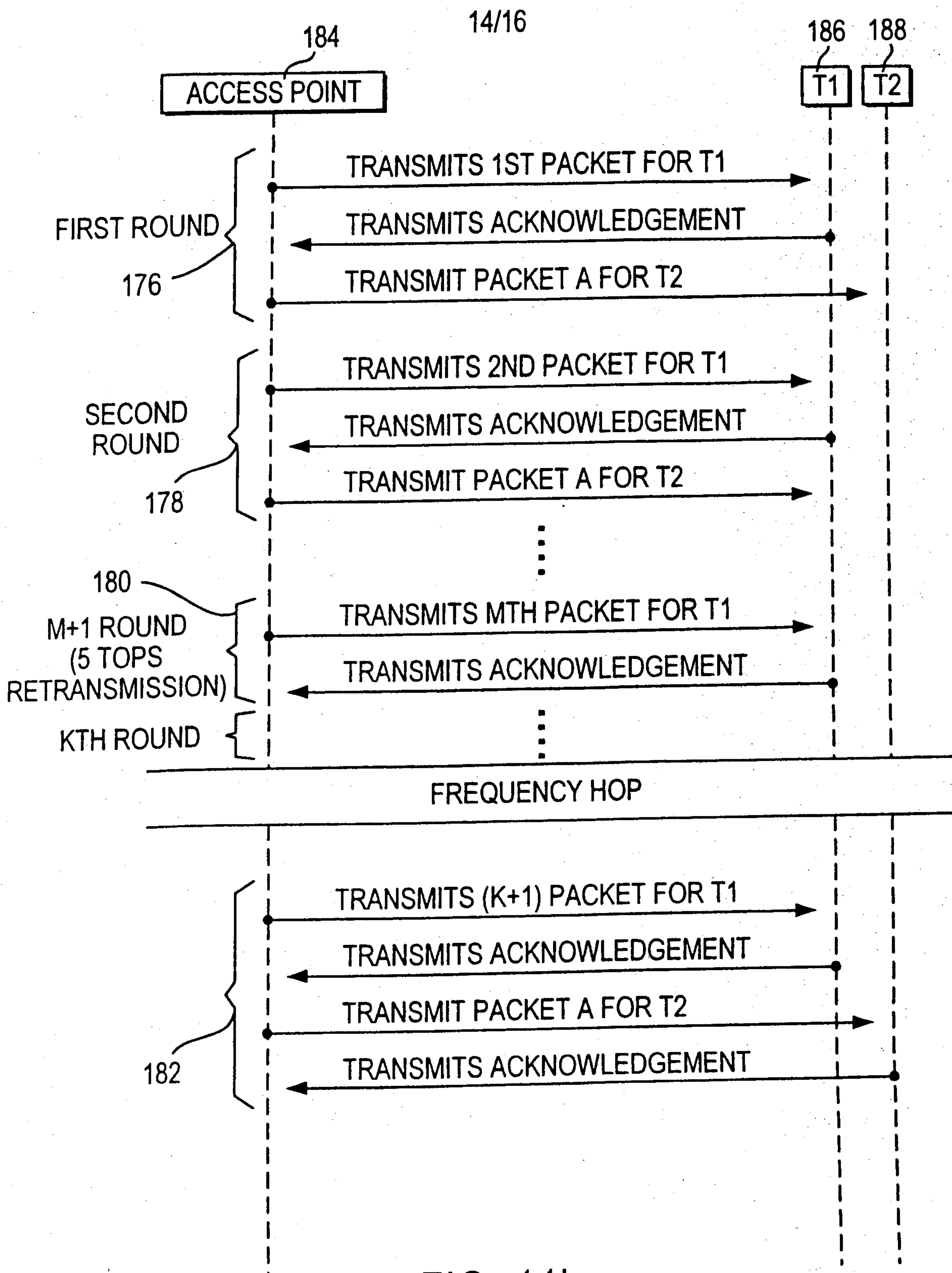


FIG. 11b

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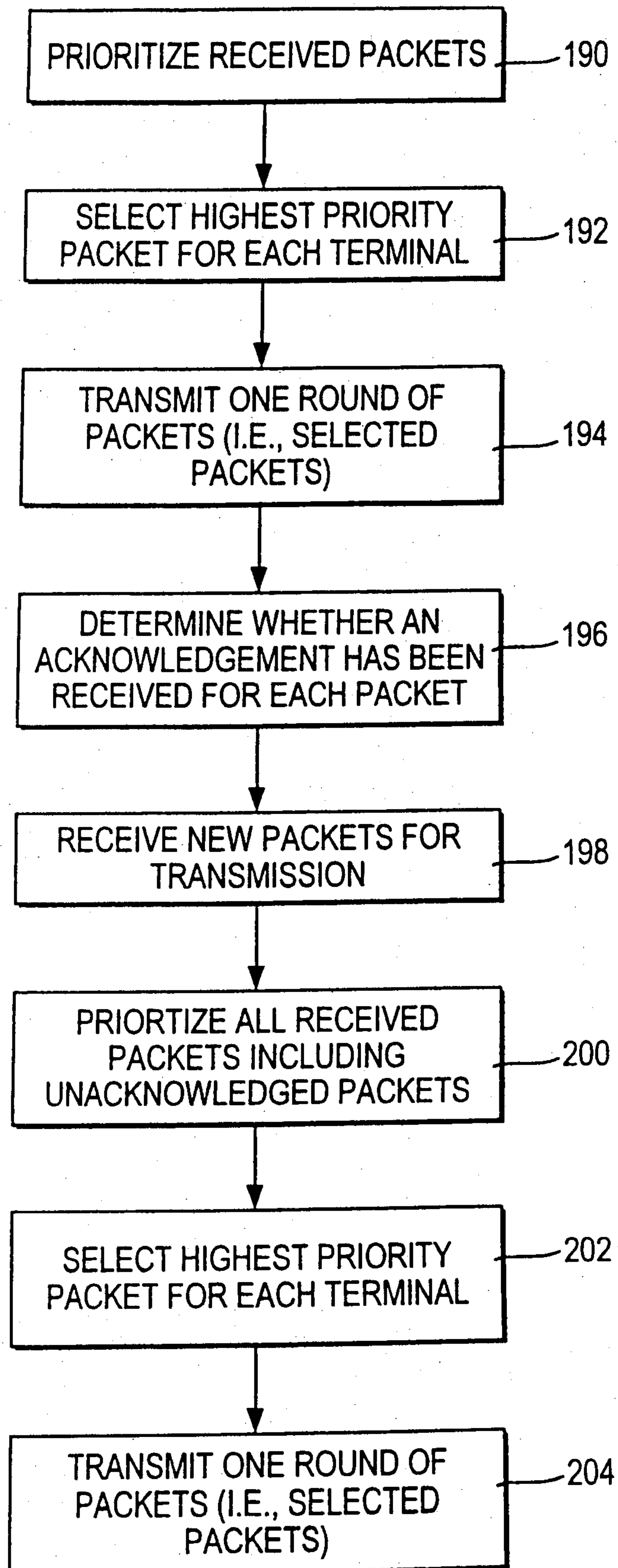


FIG. 12a



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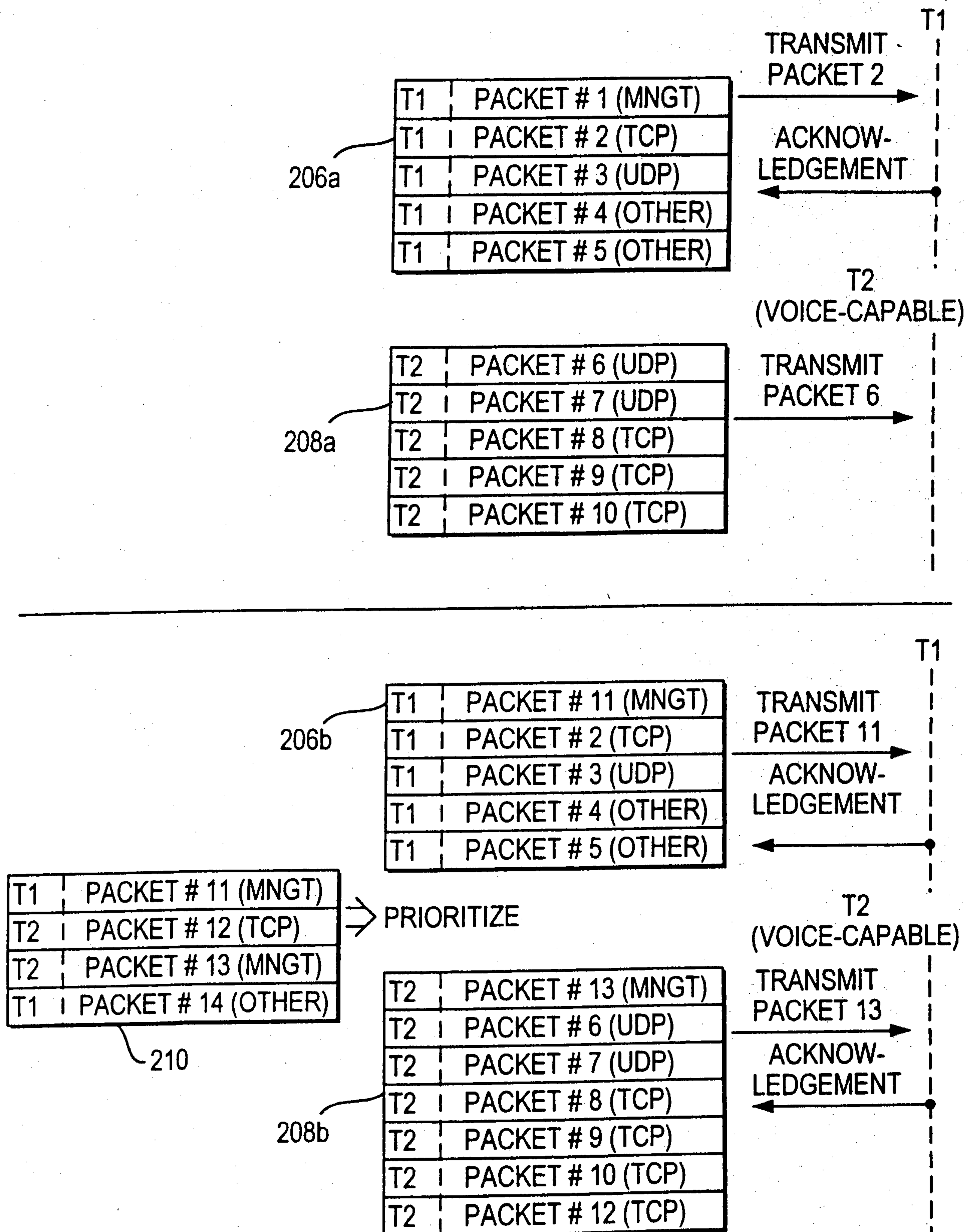


FIG. 12b

CEIVED  
CKETS

96

T1	PACKET # 1 (VOICE)
T3	PACKET # 2 (OTHER)
T3	PACKET # 3 (MNGT)
T1	PACKET # 4 (OTHER)
T2	PACKET # 5 (VOICE)
T3	PACKET # 6 (OTHER)
T1	PACKET # 7 (MNGT)
T2	PACKET # 8 (MNGT)
T2	PACKET # 9 (VOICE)
T1	PACKET # 10 (VOICE)
T3	PACKET # 11 (MNGT)
T2	PACKET # 12 (MNGT)

ORDER  
OF  
RECEPTION

PRIORITIZE

TERMINAL 1  
98

T1	PACKET # 7 (MNGT)
T1	PACKET # 1 (VOICE)
T1	PACKET # 10 (VOICE)
T1	PACKET # 4 (OTHER)

TERMINAL 2  
100

T2	PACKET # 8 (MNGT)
T2	PACKET # 12 (MNGT)
T2	PACKET # 5 (VOICE)
T2	PACKET # 9 (VOICE)

TERMINAL 3  
102

T3	PACKET # 3 (MNGT)
T3	PACKET # 11 (MNGT)
T3	PACKET # 2 (OTHER)
T3	PACKET # 6 (OTHER)