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(54) **TRANSMITTING IP PACKETS ORIGINATING IN A WIRELESS STATION WHEN THE IP PACKETS ARE DESTINED FOR DELIVERY TO MULTIPLE DESTINATIONS VIA AN ACCESS POINT**

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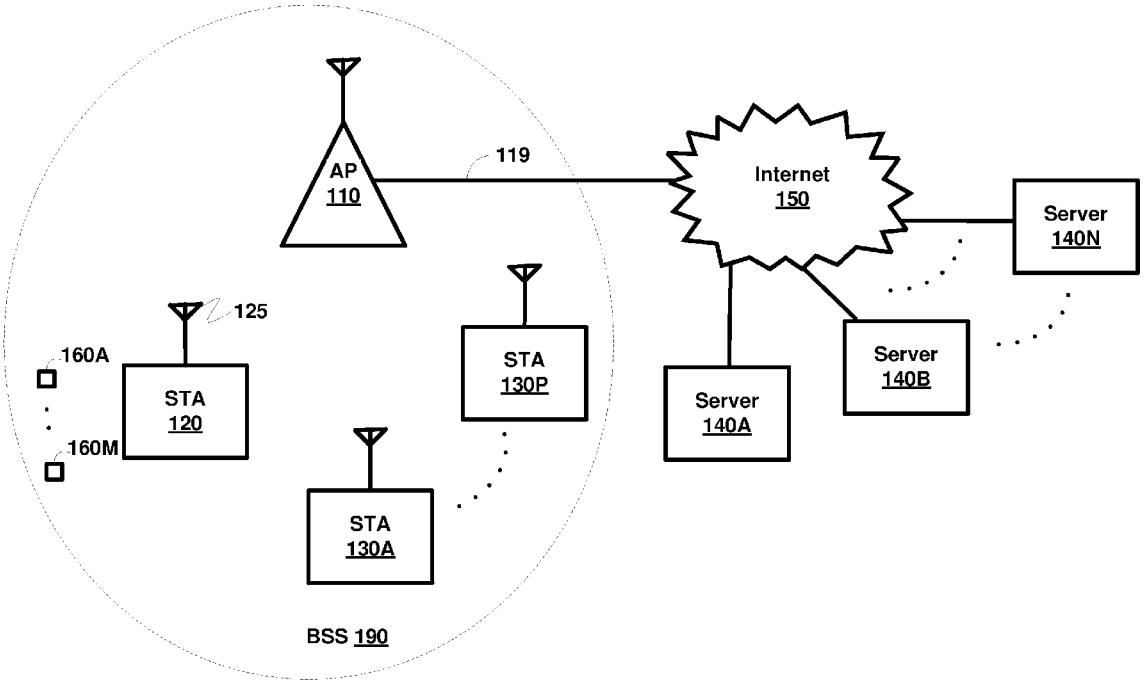
(57) **ABSTRACT**

A wireless station of a wireless network generates a single layer-2 frame containing multiple layer-3 packets in its payload. Each of the multiple layer-3 packets is destined to a corresponding different destination. The wireless station transmits the layer-2 frame to an access point (AP) of the wireless network. The AP receives the layer-2 frame, disassembles the payload into individual layer-3 packets, and transmits each of the individual layer-3 packets separately towards the corresponding destinations. In an embodiment, the wireless network is according to IEEE 802.11 standards, each layer-3 packet is an IP packet, and the layer-2 frame is a MAC frame.



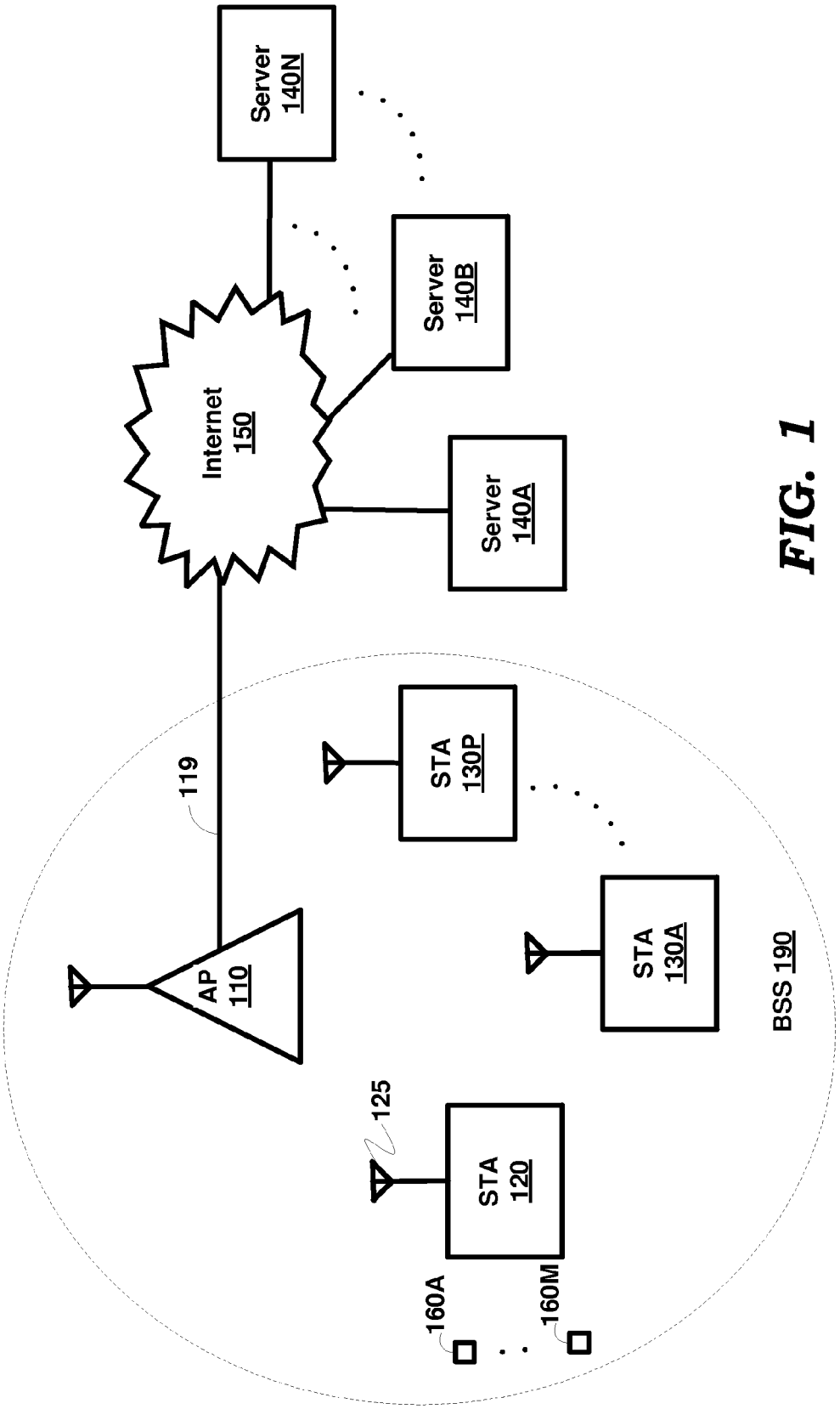

Server 140N
Server 140B
Server 140A
Internet 150
119
AP 110
STA 130P
STA 130A
BSS 190
125
STA 120
160A
160M

FIG. 1

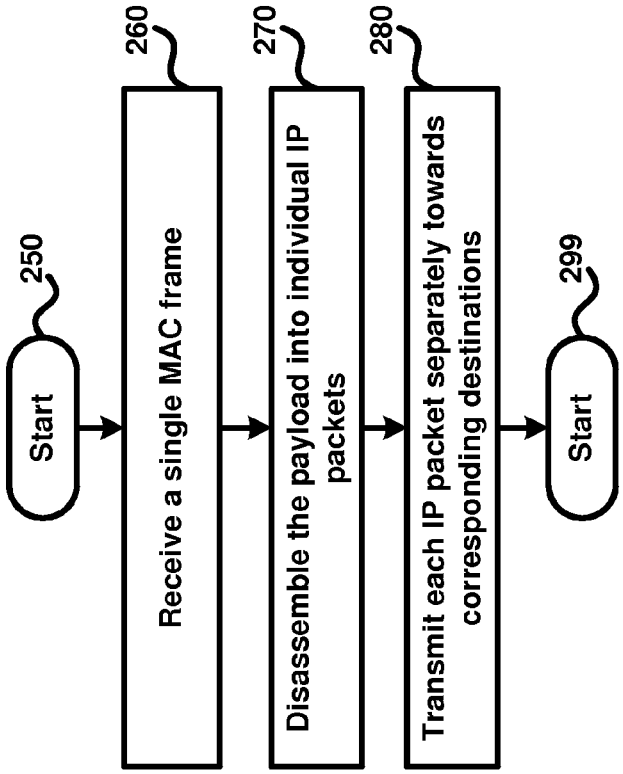

250
Start
260
Receive a single MAC frame
270
Disassemble the payload into individual IP packets
280
Transmit each IP packet separately towards corresponding destinations
299
Start

FIG. 2B

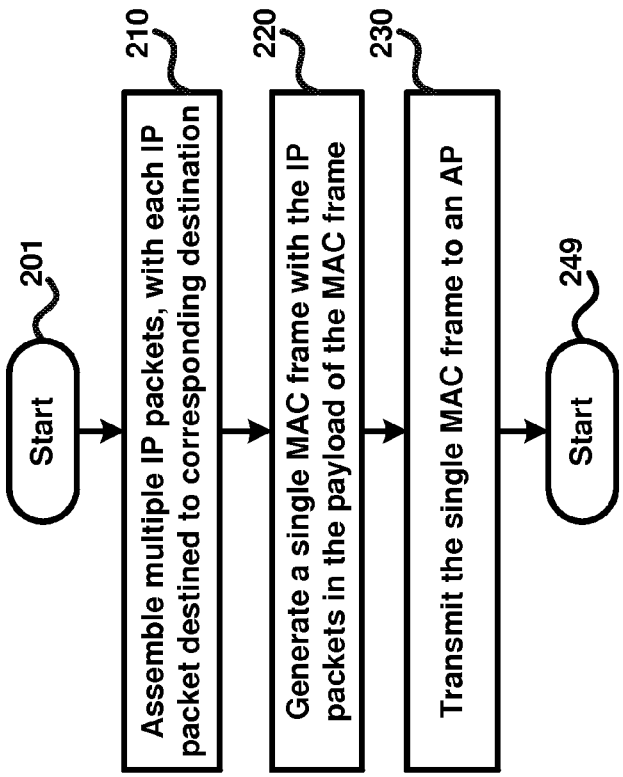

201
Start
210
Assemble multiple IP packets, with each IP packet destined to corresponding destination
220
Generate a single MAC frame with the IP packets in the payload of the MAC frame
230
Transmit the single MAC frame to an AP
249
Start

FIG. 2A

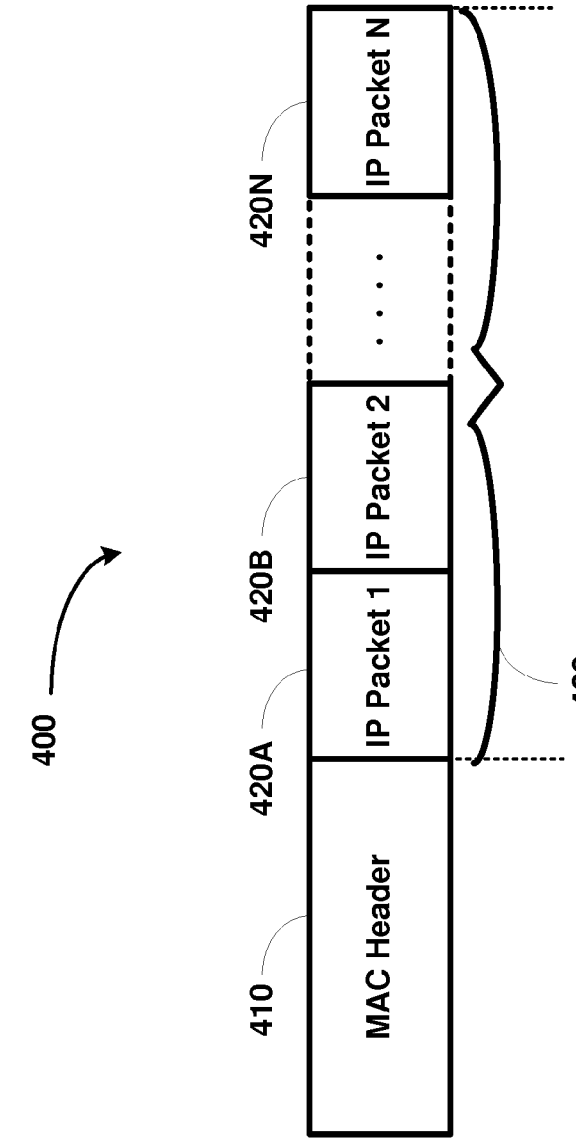

400
410
MAC Header
420A
IP Packet 1
420B
IP Packet 2
. . . .
420N
IP Packet N
420

FIG. 4

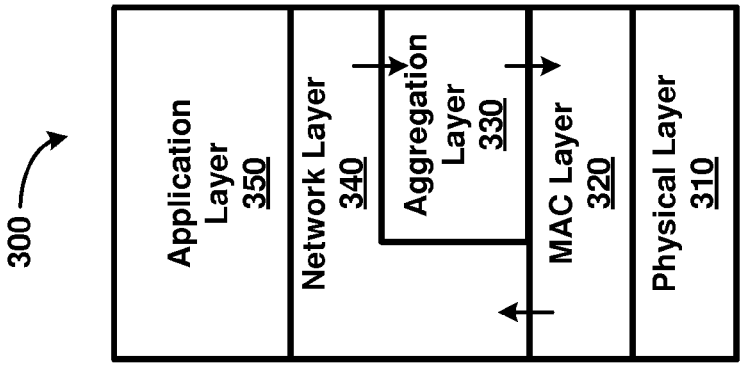

300
Application Layer 350
Network Layer 340
Aggregation Layer 330
MAC Layer 320
Physical Layer 310

FIG. 3

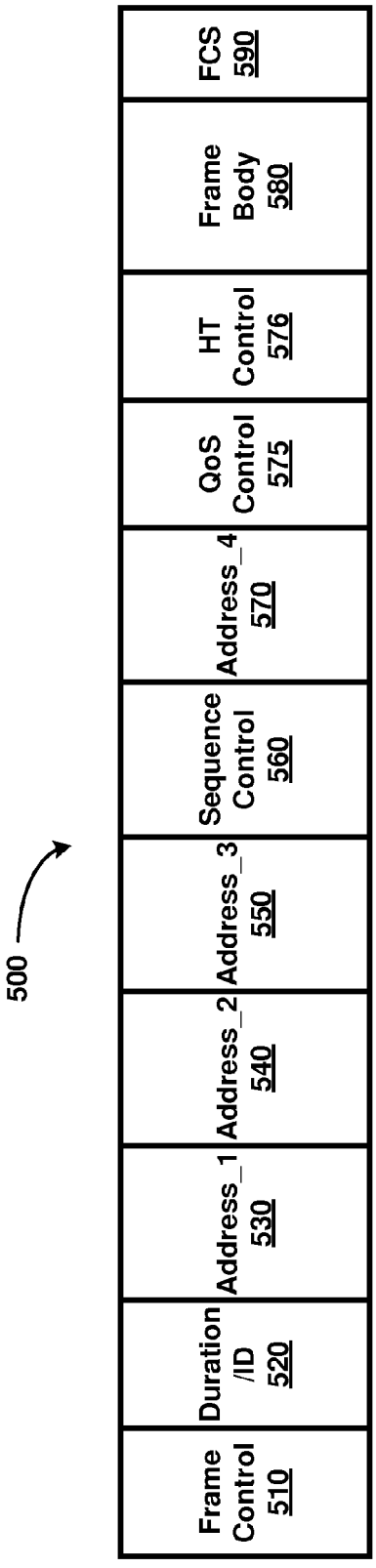

500
Frame Control 510
Duration /ID 520
Address_1 530
Address_2 540
Address_3 550
Sequence Control 560
Address_4 570
QoS Control 575
HT Control 576
Frame Body 580
FCS 590

FIG. 5

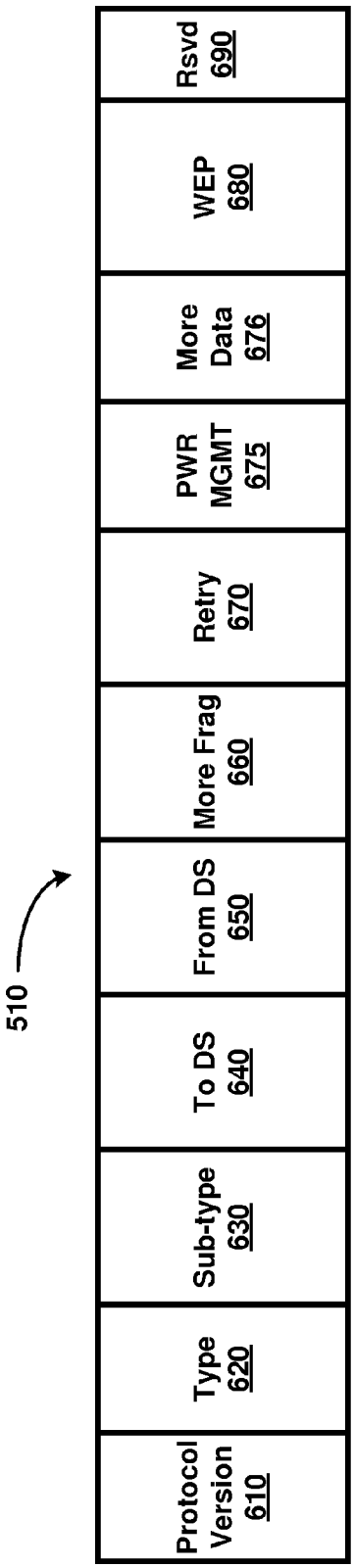

510
Protocol Version 610
Type 620
Sub-type 630
To DS 640
From DS 650
More Frag 660
Retry 670
PWR MGMT 675
More Data 676
WEP 680
Rsvd 690

FIG. 6

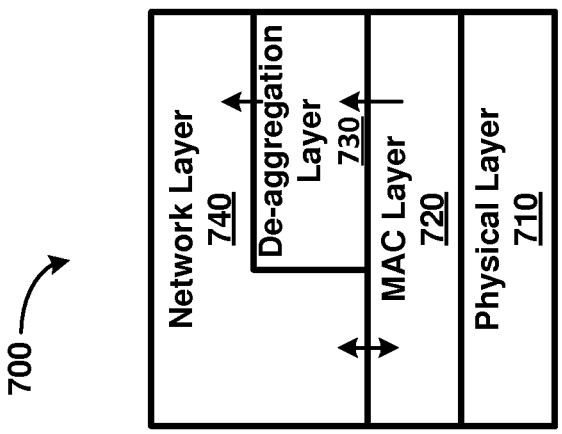

700
Network Layer
740
De-aggregation
Layer
730
MAC Layer
720
Physical Layer
710

FIG. 7

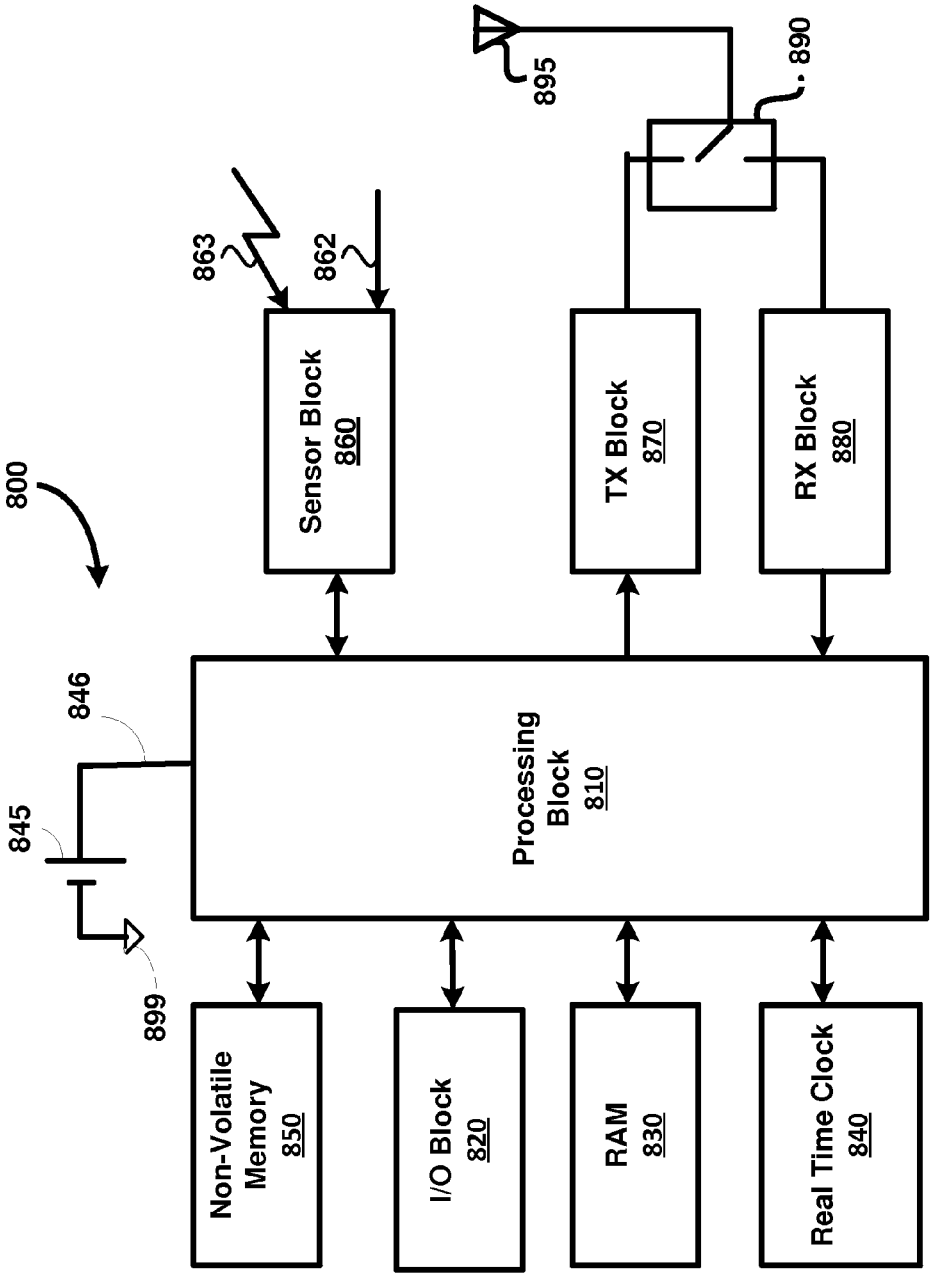

800
Sensor Block
860
863
862
TX Block
870
RX Block
880
895
890
Processing
Block
810
846
845
899
Non-Volatile
Memory
850
I/O Block
820
RAM
830
Real Time Clock
840

FIG. 8

TRANSMITTING IP PACKETS ORIGINATING IN A WIRELESS STATION WHEN THE IP PACKETS ARE DESTINED FOR DELIVERY TO MULTIPLE DESTINATIONS VIA AN ACCESS POINT

BACKGROUND

[0001] Technical Field

[0002] Embodiments of the present disclosure relate generally to wireless networks, and more specifically to delivering of IP (Internet Protocol) packets originating in a wireless station when the IP packets are destined for delivery to multiple destinations via an access point.

[0003] Related Art

[0004] A wireless network may be viewed as having wireless stations communicatively coupled on wireless path to each other via an access point (AP). The wireless stations are either the source machines or (target) destination machines for the data packets (from the viewpoint of the wireless network), with the AP operating as a switching device which receives each data packet from a source station and forwarding the packet to the destination station. Wireless networks are implemented using standards such as IEEE 802.11, as is well known in the relevant arts.

[0005] Wireless stations often encode data packets in the form of Internet Protocol (IP) packets. An IP packet is characterized by a destination IP address, which specifies the destination machine. IP is commonly used when the data may need to be communicated to systems outside of the wireless network. In a known configuration, an AP is coupled with a wired path to a router-type device, which extends the connectivity of the wireless stations to devices on the Internet, in a known way.

[0006] A wireless station may need to transmit multiple IP packets, with each packet destined to a different destination. For example, a wireless station may take multiple measurements corresponding to different parameters, and the measured value for each parameter may need to be sent to a different target. Assuming such different parameters are temperature, pressure, water level, etc., temperature measurements may be sent to one target, pressure measurements may be sent to another target, and water level measurements may be sent to another target.

[0007] It is generally desirable that access points send such multiple IP packets efficiently, as suited in the corresponding environments.

BRIEF DESCRIPTION OF THE VIEWS OF DRAWINGS

[0008] Example embodiments of the present invention will be described with reference to the accompanying drawings briefly described below.

[0009] FIG. **1** is a block diagram of an example environment in which several aspects of the present disclosure may be implemented.

[0010] FIG. **2**A is a flow chart illustrating the manner in which a wireless station (STA) of a wireless network transmits IP packets, in an embodiment of the present disclosure.

[0011] FIG. **2**B is a flow chart illustrating the manner in which an access point (AP) of a wireless network processes a layer-2 frame containing multiple IP packets, in an embodiment of the present disclosure.

[0012] FIG. **3** is a block diagram showing the details of a communication protocol stack in a STA of a wireless network, in an embodiment of the present disclosure.

[0013] FIG. **4** is a diagram illustrating the contents of a layer-2 frame transmitted by a STA of a wireless network, in an embodiment of the present disclosure.

[0014] FIG. **5** is a diagram illustrating the contents of a layer-2 frame transmitted by a STA of a wireless network according to IEEE 802.11 standards, in an embodiment of the present disclosure.

[0015] FIG. **6** is a diagram illustrating the sub-fields of a 'frame control field' of an IEEE 802.11 MAC frame transmitted by a STA, in an embodiment of the present disclosure.

[0016] FIG. **7** is a block diagram showing the details of a communication protocol stack in an AP of a wireless network, in an embodiment of the present disclosure.

[0017] FIG. **8** is a block diagram illustrating the implementation details of a wireless device in an embodiment of the present disclosure.

[0018] In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The drawing in which an element first appears is indicated by the leftmost digit(s) in the corresponding reference number.

DETAILED DESCRIPTION

1. Overview

[0019] A wireless station of a wireless network generates a single layer-2 frame containing multiple layer-3 packets in its payload. Each of the multiple layer-3 packets is destined to a corresponding different destination. The wireless station transmits the layer-2 frame to an access point (AP) of the wireless network. The AP receives the layer-2 frame, disassembles the payload into individual layer-3 packets, and transmits each of the individual layer-3 packets separately towards the corresponding destinations. In an embodiment, the wireless network is according to IEEE 802.11 standards, each layer-3 packet is an IP packet, and the layer-2 frame is a MAC frame.

[0020] Several aspects of the invention are described below with reference to examples for illustration. It should be understood that numerous specific details, relationships, and methods are set forth to provide a full understanding of the invention. One skilled in the relevant arts, however, will readily recognize that the invention can be practiced without one or more of the specific details, or with other methods, etc. In other instances, well-known structures or operations are not shown in detail to avoid obscuring the features of the invention.

2. Example Environment

[0021] FIG. **1** is a block diagram representing an example environment in which several aspects of the present disclosure can be implemented. The example environment is shown containing only representative devices and systems for illustration. However, real-world environments may contain more or fewer systems/devices. FIG. **1** is shown containing access point (AP) **110**, wireless stations (STA) **120**, STAs **130**A-**130**P, servers **140**A-**140**N, internet **150**, and sensors **160**A-**160**M. The wireless network (WLAN) con-

taining AP **110**, STA **120** and STAs **130**A-**130**P may be referred to as an infrastructure basic service set (BSS) **190**.

[0022] Servers **140**A-**140**N represent computing devices that provide desired user applications. In an embodiment, each of servers **140**A-**140**N is designed to process a corresponding set of measurements (e.g., temperature, pressure, etc.) received from STA **120** based on respective user applications. Each of servers **140**A-**140**N is connected to internet **150**, and can communicate using IP (Internet Protocol) with other devices/systems in internet **150**, as well as with STA **120** and STAs **130**A-**130**P. The servers may process IP packets received from other devices in a desired manner and present the results of the processing to a user/administrator.

[0023] Internet **150** extends the connectivity of devices (STA **120** and STAs **130**A-**130**P) in BSS **190** to various devices/systems (e.g., servers **140**A-**140**N) connected to, or part of, internet **150**. Internet **150** is shown connected to AP **110** (which may be viewed as operating as a border router as well) through a wired path **119**. Internet **150** may be implemented using protocols such as IP (Internet Protocol). In general, in IP environments, an IP packet is used as a basic unit of transport, with the source address being set to the IP address assigned to the source system from which the packet originates and the destination address set to the IP address of the destination system to which the packet is to be eventually delivered. The IP packet is encapsulated in the payload of layer-2 packets when being transported across WLANs.

[0024] An IP packet is said to be directed to a destination system when the destination IP address of the packet is set to the IP address of the destination system, such that the packet is eventually delivered to the destination system. When the packet contains content such as port numbers, which specifies the destination application, the packet may be said to be directed to such application as well. The destination system may be required to keep the corresponding port numbers available/open, and process the packets with the corresponding destination ports.

[0025] Each of STAs **120** and STAs **130**A-**130**P represents an end device that is a source or destination of data elements, when viewed from the perspective of the wireless network of FIG. **1**. The data elements are transmitted to (and received from) AP **110** in layer-2 (medium access control (MAC)) frames in accordance with 802.11 family of standards. While the data elements are described as being destined only to servers **140**A-**140**N in the description below, such servers can be placed in conjunction with some of the STAs in BSS **190** in alternative embodiments.

[0026] The STAs **130**A-**130**P may communicate with each other via AP **110** using IP, with IP addressing being used for communications with servers **140**A-**140**N as well. Thus, each of STA **120** and STAs **130**A-**130**P is assigned a unique IP address using DHCP type protocols well known in the relevant arts. AP **110**, in addition to performing operations consistent with the corresponding wireless standard, operates as an IP router to forward packets received from the other devices of FIG. **1** to the appropriate destination or next-hop device.

[0027] In an embodiment, AP **110**, STA **120** and STAs **130**A-**130**P form a basic service set (BSS) **190** consistent with IEEE 802.11 family of standards (including amendments such as 802.11a, 802.11b, 802.11i, 802.11n, etc.). However, in other embodiments, AP **110**, STA **120** and STAs **130**A-**130**P may be designed to operate according to other wireless standards, such as for example, IEEE 802.15.4. The antenna of STA **120** is shown numbered as **125**. Antennas of other wireless devices of FIG. **1** are indicated by the corresponding symbol, but not numbered.

[0028] Each of sensors **160**A-**160**M generates measurements (data values) representing a parameter of interest, such as for example, temperature, pressure, etc., of/in corresponding objects. Each of sensors **160**A-**160**M forwards the respective data values to STA **120** on a wired or wireless path (not shown). STA **120** is designed to forward the data values to one or more of desired destinations STA **130**A-**130**P and/or servers **140**A-**140**N in the form of IP packets.

[0029] According to a prior technique, STA **120** may use a separate MAC frame for transmitting data values as IP packets to different servers **140**A to **140**N. In other words, a single MAC frame would contain only a single IP packet (containing data values) destined to only a single server in such an approach. Assuming the temperature reading is to be transmitted to server **140**A, STA **120** forms an IP packet containing the temperature measurement in its payload, and the destination IP address of server **140**A in the destination IP address field of the IP packet (with the other fields of the IP packet containing corresponding entries). STA **120** then encapsulates the IP packet thus formed in a layer-2 frame, and transmits the layer-2 frame to AP **110**.

[0030] AP **110** extracts the IP packet from the layer-2 frame, and forwards the IP packet to a next-hop device in the route to server **140**A. For another data value to another server, STA **120** would similarly form another layer-2 frame with encapsulated IP packet, and transmit the layer-2 frame to AP **110**, which then forwards the encapsulated IP packet along the path to the corresponding destination.

[0031] The prior approach may have a drawback in that STA **120** would have to contend for the wireless transmission medium prior to transmitting each IP packet, and the prior approach may therefore be inefficient in terms of power consumption and/or time required for overall data transfer.

[0032] Aspects of the present disclosure overcome the drawback noted above, as described next with respect to a flowchart.

3. IP Packet Aggregation

[0033] FIG. **2**A is a flow chart illustrating the manner in which a STA of a wireless network transmits multiple IP packets efficiently, in an embodiment of the present disclosure. Merely for illustration, the flowchart is described below as being performed in STA **120**. However, the features can be implemented in other STAs also, as well as in other environments, without departing from the scope and spirit of various aspects of the present invention, as will be apparent to one skilled in the relevant arts by reading the disclosure provided herein.

[0034] In addition, some of the steps may be performed in a different sequence than that depicted below, as suited to the specific environment, as will be apparent to one skilled in the relevant arts. Many of such implementations are contemplated to be covered by several aspects of the present disclosure. The flow chart begins in step **201**, in which control immediately passes to step **210**.

[0035] In step **210**, STA **120** assembles multiple IP packets, with each IP packet destined to a corresponding IP destination. The payloads of each of the IP packets may contain one or more measurement values (data values) received from one or more of sensors **160**A-**160**M. It should

be appreciated that the IP packets themselves can be formed within STA **120** or received from corresponding sensors (in which case each IP packet contains measured values only from that sensor). Irrespective of where each IP packet is formed, the IP packets are assumed to be available for further processing, as described below. Control then passes to step **220**.

[0036] In step **220**, STA **120** generates a single layer-2 (i.e., MAC) frame with the assembled IP packets in the payload of the MAC frame. In other words, a single MAC frame contains multiple IP packets, with each IP packet being destined to potentially different destination (server **140**A-**140**N). Control then passes to step **230**.

[0037] In step **230**, STA **120** transmits the single MAC frame to AP **110**. Control then passes to step **249**, in which the flowchart ends.

[0038] Although in the flowchart of FIG. **2**A, multiple IP packets are described as being placed in the payload of a single MAC packet, the technique can be extended in general to place multiple layer-3 packets in the payload of a layer-2 packet, which is then transmitted on a wireless medium. As is well known in the relevant arts, a layer-2 packet is a packet that is destined to a next-hop device (with respect to the transmitter of the layer-2 packet) within a network, while a layer-3 packet is a packet that is designed to be routed to a destination device one or more networks away from the transmitter in the network.

[0039] FIG. **2**B is a flow chart illustrating the manner in which an AP of a wireless network processes a MAC frame containing multiple IP packets, in an embodiment of the present disclosure. Merely for illustration, the flowchart is described below as being performed in AP **110**. However, the features can be implemented in other environments, without departing from the scope and spirit of various aspects of the present invention, as will be apparent to one skilled in the relevant arts by reading the disclosure provided herein. In addition, some of the steps may be performed in a different sequence than that depicted below, as suited to the specific environment, as will be apparent to one skilled in the relevant arts. Many of such implementations are contemplated to be covered by several aspects of the present disclosure. The flow chart begins in step **250**, in which control immediately passes to step **260**.

[0040] In step **260**, AP **110** receives a single MAC frame containing multiple IP packets in the payload of the MAC frame. As an example, the MAC frame could be the MAC frame transmitted by STA **120** in step **230** of the flowchart of FIG. **2**A. Control then passes to step **270**.

[0041] In step **270**, AP **110** disassembles the payload of the received MAC frame into individual IP packets. In an embodiment, each individual IP packet requires no modifications to any headers, etc., and therefore AP **110** can retransmit IP packets without requiring modifications to IP headers. AP may merely need to encapsulate each IP packet with any header as suitable for transmission on wired path **119**. Control then passes to step **280**.

[0042] In step **280**, AP **110** transmits each IP packet separately to the corresponding destination. The destination addresses are contained in the destination IP address fields of the IP packets. Control then passes to step **299**, in which the flowchart ends.

[0043] Again, although the flowchart of FIG. **2**B describes disassembly of the payload of a MAC frame to obtain multiple IP packets which is are then individually (sequentially) forwarded to the corresponding destinations, the technique can be extended in general to disassembly of the payload of a layer-2 packet to obtain multiple layer-3 packets, which are then individually transmitted to the corresponding destinations.

[0044] It may be appreciated that since multiple layer-3 packets are assembled into the payload portion of a single layer-2 frame, STA **120** needs to contend for the wireless medium only once, rather than for each layer-3 packet as in the prior approach noted above. As a result, the transmission of layer-3 packets at least in BSS **190** is rendered efficient.

[0045] The operations of the steps of the flowcharts of FIGS. **2**A and **2**B are illustrated next with examples.

4. EXAMPLES

[0046] FIG. **3** is a diagram illustrating the various layers of a communication protocol stack in STA **120**. Communication protocol stack **300** is shown containing physical layer **310**, data-link layer (or MAC) layer **320**, aggregation layer **330**, network layer **340** and application layer **350**.

[0047] Application layer **350** represents a communications component that allows software applications executing in STA **120** to communicate with software applications in other nodes, such as for example, servers **140**A-**140**N. Application layer executes user applications, and receives data values generated by one or more of sensors **160**A-**160**M. Application layer **350** may process the data values suitably, and forwards each received data value to network layer **340**, along with the destination IP address to which the data value is to be to be transmitted. Application layer **350** may forward each packet as the packet is received (or with a slight delay). In an embodiment, each type of data value is destined for a specific destination. As an example, all temperature measurements may be destined for server **140**A, pressure measurements may be destined to server **140**B, etc.

[0048] Network layer **340** receives a data value, and forms an IP packet, with the data value placed in the payload portion of the IP packet. Network layer **340** stores the destination address to which the data value is to be sent in the destination IP address field of the header of the IP packet. Other fields of the header (e.g., total length of the IP packet) may suitably be programmed by network layer **340**. As specified in RFC **731**, bits **16**-**31** of an IP packet are used to specify the total length of the IP packet, and network layer **340** places the corresponding length of the IP packet in this field, to enable AP **110** to identify IP packet boundaries and correctly disassemble an aggregated payload, as described below.

[0049] Network layer **340** similarly forms other IP packets, each containing a corresponding data value as its payload and a corresponding destination IP address in the destination IP address field of its header. While the IP packets are described as being formed within STA **120**, it should be appreciated that IP packets may be received from the sensors generating the data values as well. Irrespective, network layer **340** assembles (gathers) multiple IP packets. Network layer **340** may also store multiple data values in the payload of a same IP packet if all such multiple data values are destined to a same destination. Network layer **340** forwards each IP packet thus formed to aggregation layer **330**. It is assumed that each IP packet is encoded as a UDP packet, and accordingly the transport layer is not shown between layers **340** and **350**. However, alternative embodiments may employ TCP for reliable delivery of each packet.

[0050] Aggregation layer **330** receives IP packets from network layer **330**, and concatenates multiple of such received IP packets to form a single (aggregated) payload. Aggregation layer **330** forwards the aggregated payload to MAC layer **320**. In an embodiment, the size of the aggregated payload is limited to the maximum allowed size, i.e., maximum transmission unit (MTU) specified by the IEEE 802.11 family of standards. It should be appreciated that MTU size may be easily obtained since packets destined to multiple destinations are being aggregated, and accordingly the wireless medium is efficiently used.

[0051] In addition, or in an alternative embodiment, aggregation layer **330** aggregates only as many IP packets into a single payload as can be done before the expiry of an MTU timer. The timer may be started upon the availability of the first IP packet to be incorporated into the frame, and if the maximum MTU size (noted above) is not reached before the expiry of the MTU timer, the MAC frame is transmitted with as many packets as are then available/assembled (at the expiration of the timer).

[0052] MAC layer **320** receives an aggregated payload from aggregation layer **330**, and forms a single MAC frame with the aggregated payload placed in the payload of the single MAC frame. MAC layer **320** places the MAC address of AP **110** in the destination address field of the MAC frame. An example of a MAC frame formed by MAC layer **330** is shown in FIG. **4**. Field **410** of MAC frame **400** is the MAC frame header, and field **420** is the payload portion of MAC frame **400**. IP packets **420**A, **420**B through **420**N represent the multiple IP packets placed in the payload portion **420**. In an embodiment, each of packets **420**A, **420**B through **420**N is destined to a different destination. For example, packets **420**A, **420**B through **420**N may respectively be destined to servers **140**A, **140**B through **140**N. As another example, packets **420**A through **420**N may be destined respectively for STAs **130**A through **130**P (P assumed to equal N in this example).

[0053] When frame **400** corresponds to an IEEE 802.11 (WLAN) frame, frame **400** has the detailed structure shown in FIG. **5**A. Frame **500** of FIG. **5**A is shown containing fields Frame Control **510**, Duration/ID **520**, Address_1 **530**, Address_2 **540**, Address_3 **550**, Sequence Control **560**, Address_4 **570**, QoS Control **575**, HT control **576**, Frame Body **580** and FCS **590**.

[0054] Frame Body **580** corresponds to payload **420** of FIG. **4**. The rest of the fields together represent MAC header **410** of FIG. **4**. A detailed description of the fields of packet **500** is provided in Section 8 of the IEEE Std 802.11-2012 document available with the International Telecommunications Union (ITU). Only those fields as relevant to this disclosure are described herein. It is also noted that, in practice, frame **500** may contain more or fewer fields or proprietary modifications depending on the specific deployment environment.

[0055] MAC layer **320** places the BSSID of BSS **190**, MAC address of STA **120** and the MAC address of AP **110** respectively in address fields **530**, **540** and **550**. Address field **570** is a "don't care". Frame control field **510** is shown in greater detail in FIG. **6**, which shows sub-fields Protocol Version **610**, Type **620**, Sub-type **630**, To DS **640**, From DS **650**, More Frag **660**, Retry **670**, Power Management **675**, More Data **676**, WEP **680** and Reserved (Rsvd) **690**. A detailed description of the fields of packet **500** is provided in Section 8.2.4 of the IEEE Std 802.11-2012 document available with the International Telecommunications Union (ITU). Only those fields as relevant to this disclosure are described herein. MAC layer **320** programs fields 'To DS' **640** and 'From DS' **650** to 1 and 0 respectively.

[0056] In an embodiment, MAC layer **320** programs the 'type' field **620** and 'sub-type' field **630** to indicate that frame **500**/**400** contains multiple IP packets in its payload, to enable AP **110** to disassemble packet **500**/**400** correctly. The specific values of the 'type' and 'sub-type' fields can be any that are not currently specified for use by the IEEE 802.11 standard. As an example, the value of the 'type' field can be 10 (binary), and the value of the 'sub-type' field can be 1101 (binary). In an alternative embodiment, MAC layer **320** programs fields **620** and **630** with a 'regular' value (for example 'type' field as 10 (binary), and 'subtype' field as any value that has data/QoS data combination, for example 0000 (binary)), and indication that frame **500**/**400** contains multiple IP packets is provided in an information element (IE) field of an association request packet sent by STA **120** to AP **110** prior to joining BSS **190**.

[0057] MAC layer **320** also performs medium access operation (e.g., CSMA/CA) specified by the corresponding wireless standard, and forwards frame **500**/**400** to physical layer **310**. Physical layer **310** transmits frame **500**/**400** on the wireless medium via antenna **125**.

[0058] The respective layers of the communication protocol stack **700** implemented in AP **110** are shown in FIG. **7**. Communication protocol stack **700** is shown containing physical layer **710**, data-link layer (or MAC) layer **720**, de-aggregation layer **730**, and network layer **740**. The operations at the respective layers of stack **700** upon receiving frame **500**/**400** are noted next.

[0059] Physical layer **710** receives, via the antenna of AP **110**, MAC frame **500**/**400**, and forwards the frame to MAC layer **720**. MAC layer **720** inspects fields **620** and **630** of the MAC header of frame **500**/**400** to determine if multiple IP packets are present in the payload of the MAC frame. If fields **620** and **630** indicate that the payload of the MAC frame contains multiple IP packets, MAC layer **720** strips the MAC header off frame **500**/**400**, and forwards the aggregated payload portion of the MAC frame to de-aggregation layer **730**. Alternatively, MAC layer **720** may rely on indication received during association (in an IE field of the association request frame) of STA **120** with AP **110**, as well as the source address field (**540** of FIG. **5**) to determine whether the MAC frame **500**/**400** contains multiple IP packets or not. If MAC layer **720** determines that frame **500**/**400** is a 'normal' frame (i.e., does not contain multiple packets in its payload), MAC layer **720** forwards the payload directly to network layer **740**.

[0060] De-aggregation layer **730** disassembles the aggregated payload containing multiple IP packets into individual IP packets, and forwards each of the individual IP packets to network layer **740**.

[0061] For each of the individual IP packets received from de-aggregation layer **730**, network layer **740** determines, based on the destination IP address in the corresponding IP packet and a routing table (not shown), the next-hop device (or specifically, the interface coupling to such next hop device) to which the IP packet is to be transmitted. Network layer **740** instructs MAC layer **720** to transmit each packet (and directly, i.e., without sending them to de-aggregation layer) to the determined next-hop device in case the packet is being transmitted on the wireless medium.

[0062] MAC layer **720** adds appropriate layer-2 headers to each of the IP packets received from network layer **740**, and forwards each of the resulting layer-2 frames to physical layer **710**. For example, if a received IP packet is destined for a STA in BSS **190**, then MAC layer **720** adds an IEEE 802.11 header. On the other hand, if the next-hop device for a received IP packet is a device in internet **150**, then MAC layer **720** adds an IEEE 802.3 header.

[0063] Physical layer **710** forwards each of the layer-2 frames along the path (coupled to the determined interface) to the destination.

[0064] As an example, when IP packets **420**A through **420**N are respectively destined for servers **140**A through **140**N, each of IP packets **420**A through **420**N would respectively be forwarded on the corresponding route (path **119**) to servers **140**A through **140**N.

[0065] The description is continued with an illustration of the implementation details of a wireless device in an embodiment.

5. Wireless Device

[0066] FIG. **8** is a block diagram showing the implementation details of a wireless device in an embodiment of the present disclosure. STA **120** as well as AP **110** of FIG. **1** can be implemented as wireless device **800**. Wireless Device **800** is shown containing processing block **810**, input/output (I/O) block **820**, random access memory (RAM) **830**, real-time clock (RTC) **840**, battery **845**, non-volatile memory **850**, sensor block **860**, transmit (TX) block **870**, receive (RX) block **880**, switch **890**, and antenna **895**. The whole of wireless device **800** may be implemented as a system-on-chip (SoC), except for battery **845** and antenna **895**. Alternatively, the blocks of FIG. **8** may be implemented on separate integrated circuits (IC). Terminals **846** and **899** respectively represent a power and a ground terminal.

[0067] Battery **845** provides power for operation of wireless device **800**, and may be connected to the various blocks shown in FIG. **8**. While wireless device **800** is shown as being battery-powered, in another embodiment, wireless device **800** is mains-powered and contains corresponding components such as transformers, regulators, power filters, etc. RTC **840** operates as a clock, and provides the 'current' time to processing block **810**.

[0068] I/O block **820** provides interfaces for user interaction with wireless device **800**, and includes input devices and output devices. Sensor block **860** may contain one or more sensors (e.g., sensors **160**A-**160**M of FIG. **1**), as well as corresponding signal conditioning circuitry, and provides to processing block **810**, measurements/values of physical quantities such as temperature, pressure, etc., sensed via wired path **862** or wireless path **863**. Sensor block **860** may perform analog-to-digital conversion of the measurement/values prior to forwarding the measurements/values to processing block **810**. When AP **110** is implemented as wireless device **800**, sensor block **860** may not be included.

[0069] Antenna **895** (corresponds to the antennas of AP **110** or STA **120**), and operates to receive from, and transmit to, a wireless medium, corresponding wireless signals (e.g., according to IEEE 802.11 (WLAN) standards). Switch **890** may be controlled by processing block **810** (connection not shown) to connect antenna **895** to one of blocks **870** and **880** as desired, depending on whether transmission or reception of wireless signals is required. Switch **890**, antenna **895** and the corresponding connections of FIG. **8** are shown merely by way of illustration. Instead of a single antenna **895**, separate antennas, one for transmission and another for reception of wireless signals, can also be used. Various other techniques, well known in the relevant arts, can also be used instead.

[0070] TX block **870** receives, from processing block **810**, packets (such as those of the parallel data streams described above) to be transmitted on a wireless signal (e.g., according to a wireless standard such as IEEE 802.11), generates a modulated radio frequency (RF) signal (according to the standard), and transmits the RF signal via switch **890** and antenna **895**. TX block **870** may contain RF and baseband circuitry for generating and transmitting wireless signals, as well as for medium access operations. Alternatively, TX block **870** may contain only the RF circuitry, with processing block **810** performing the baseband and medium access operations (in conjunction with the RF circuitry).

[0071] RX block **880** represents a receiver that receives a wireless (RF) signal (e.g., according to IEEE 802.11) bearing data and/or control information via switch **890**, and antenna **895**, demodulates the RF signal, and provides the extracted data or control information to processing block **810**. RX block **880** may contain RF as well as baseband processing circuitry for processing a WLAN signal. Alternatively, RX block **880** may contain only the RF circuitry, with processing block **810** performing the baseband operations in conjunction with the RF circuitry.

[0072] Non-volatile memory **850** is a non-transitory machine readable medium, and stores instructions, which when executed by processing block **810**, causes wireless device **800** to operate as STA **120** when STA **120** is implemented as wireless device **800**, and as AP **110** when AP **110** is implemented as wireless device **800**. In particular, the instructions enable STA **120** and AP **110** to operate respectively as described with respect to the flowcharts of FIG. **2**A and **2**B.

[0073] RAM **830** is a volatile random access memory, and may be used for storing instructions and data. RAM **830** and non-volatile memory **850** (which may be implemented in the form of read-only memory/ROM/Flash) constitute computer program products or machine (or computer) readable medium, which are means for providing instructions to processing block **810**. Processing block **810** may retrieve the instructions, and execute the instructions to provide several features of the present disclosure.

[0074] Processing block **810** (or processor in general) may contain multiple processing units internally, with each processing unit potentially being designed for a specific task. Alternatively, processing block **810** may contain only a single general-purpose processing unit. Processing block **810** may execute instructions stored in non-volatile memory **850** or RAM **830** to enable wireless device **800** to operate according to several aspects of the present disclosure (as corresponding to wireless station or AP), described above in detail.

6. CONCLUSION

[0075] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A method performed in a wireless station of a wireless network, said method comprising:

generating a single layer-2 frame containing a plurality of layer-3 packets, with each layer-3 packet of said plurality of layer-3 packets being destined to a corresponding destination of a plurality of destinations; and

transmitting said single layer-2 frame to an access point (AP) of said wireless network.

2. The method of claim **1**, wherein said wireless network is according to IEEE 802.11 standards, each layer-3 packet is an IP packet and said single layer-2 frame is a medium access control (MAC) frame.

3. The method of claim **2**, wherein each of said IP packets contains an IP destination address of the corresponding destination.

4. The method of claim **3**, wherein said generating generates a sequence of layer-3 packets at respective times instances of a sequence of time instances, and includes only some of said sequence of IP packets as said plurality of layer-3 packets without violating a maximum transmission unit (MTU) specified by said wireless network.

5. The method of claim **4**, wherein said generating includes only those of said sequence of IP packets which are formed before expiration of a timer.

6. The method of claim **5**, wherein said AP upon receiving said MAC frame containing said header, disassembles said payload into individual IP packets, and transmits each IP packet towards a corresponding destination.

7. The method of claim **6**, wherein said wireless station associates with said AP to join said wireless network by exchanging a sequence of messages,

wherein a first message of said sequence of messages sent by said wireless station to said AP contains a field for said wireless station to indicate that multiple IP packets would be contained in subsequent MAC frames, wherein said disassembling and transmitting of each IP packet are performed by said AP in response to said first message.

8. The method of claim **6**, wherein said MAC frame contains a header and a payload, said header indicating that said payload contains multiple IP packets, wherein said disassembling and transmitting of each IP packet are performed by said AP in response to said header indicating that said payload contains multiple IP packets.

9. A non-transitory machine readable medium storing one or more sequences of instructions in a wireless station, wherein execution of said one or more instructions by one or more processors contained in said wireless station enables said wireless station to perform the actions of:

generating a single layer-2 frame containing a plurality of layer-3 packets, with each layer-3 packet of said plurality of layer-3 packets being destined to a corresponding destination of a plurality of destinations; and

transmitting said single layer-2 frame to an access point of said wireless network.

10. The non-transitory machine readable medium of claim **9**, wherein said wireless network is according to IEEE 802.11 standards, each layer-3 packet is an IP packet and said single layer-2 frame is a medium access control (MAC) frame.

11. The non-transitory machine readable medium of claim **10**, wherein each of said IP packets contains an IP destination address of the corresponding destination.

12. The non-transitory machine readable medium of claim **11**, wherein said generating generates a sequence of layer-3 packets at respective times instances of a sequence of time instances, and includes only some of said sequence of IP packets as said plurality of layer-3 packets without violating a maximum transmission unit (MTU) specified by said wireless network.

13. The non-transitory machine readable medium of claim **12**, wherein said generating includes only those of said sequence of IP packets which are formed before expiration of a timer.

14. The non-transitory machine readable medium of claim **13**, wherein said AP upon receiving said MAC frame containing said header, disassembles said payload into individual IP packets, and transmits each IP packet towards a corresponding destination.

15. The non-transitory machine readable medium of claim **14**, wherein said wireless station associates with said AP to join said wireless network by exchanging a sequence of messages,

wherein a first message of said sequence of messages sent by said wireless station to said AP contains a field for said wireless station to indicate that multiple IP packets would be contained in subsequent MAC frames, wherein said disassembling and transmitting of each IP packet are performed by said AP in response to said first message.

16. The non-transitory machine readable medium of claim **14**, wherein said MAC frame contains a header and a payload, said header indicating that said payload contains multiple IP packets, wherein said disassembling and transmitting of each IP packet are performed by said AP in response to said header indicating that said payload contains multiple IP packets.

17. An access point (AP) of a wireless network, said AP comprising:

a processing block, a memory, and a transmitter circuit,

said memory to store instructions which when retrieved and executed by said processing block causes said STA to perform the actions of:

receiving a single layer-2 frame containing multiple layer-3 packets in a payload of said single layer-2 frame, wherein each of said multiple layer-3 packets is destined to a different destination;

disassembling said payload into individual layer-3 packets; and

transmitting each of said individual layer-3 packets separately towards a corresponding destination.

18. The AP of claim **17**, wherein said wireless network is according to IEEE 802.11 standards, each layer-3 packet is an IP packet and said single layer-2 frame is a medium access control (MAC) frame.

19. The AP of claim **18**, wherein said single layer-2 frame is transmitted by a wireless station, wherein said wireless station associates with said AP to join said wireless network by exchanging a sequence of messages,

wherein a first message of said sequence of messages sent by said wireless station to said AP contains a field for said wireless station to indicate that multiple IP packets would be contained in subsequent MAC frames, wherein said disassembling and transmitting of each IP packet are performed by said AP in response to said first message.

20. The AP of claim **18**, wherein said MAC frame contains a header and a payload, said header indicating that said payload contains multiple IP packets, wherein said disassembling and transmitting of each IP packet are performed by said AP in response to said header indicating that said payload contains multiple IP packets.

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