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- (54) **Title:** ACKNOWLEDGEMENT MESSAGE WITH PIGGY-BACKED BUFFER STATUS REPORT FOR WIRELESS NETWORK

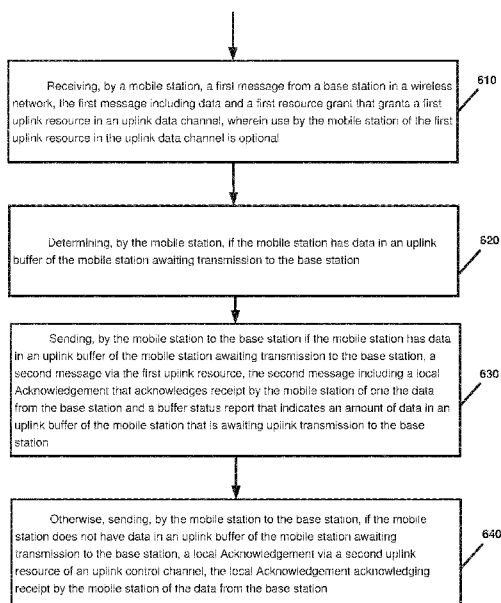


FIG. 6

- (57) **Abstract:** An example technique may include receiving, by a mobile station, one or more data packets from a base station in a wireless network; and sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

DESCRIPTION

TITLE

ACKNOWLEDGEMENT MESSAGE WITH PIGGY-BACKED BUFFER STATUS REPORT
FOR WIRELESS NETWORK

TECHNICAL FIELD

[0001] This description relates to wireless communications.

BACKGROUND

[0002] A communication system may be a facility that enables communication between two or more nodes or devices, such as fixed or mobile communication devices. Signals can be carried on wired or wireless carriers.

[0003] An example of a cellular communication system is an architecture that is being standardized by the 3rd Generation Partnership Project (3GPP). A recent development in this field is often referred to as the long-term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. E-UTRA (evolved UMTS Terrestrial Radio Access) is the air interface of 3GPP's Long Term Evolution (LTE) upgrade path for mobile networks. In LTE, base stations, which are referred to as enhanced Node Bs (eNBs), provide wireless access within a coverage area or cell. In LTE, mobile devices, or mobile stations are referred to as user equipments (UE). LTE has included a number of improvements or developments.

[0004] However, in some cases, wireless user devices (e.g., mobile stations) may experience significant latency in downloading data over a wireless network.

SUMMARY

[0005] According to an example implementation, a method may include receiving, by a mobile station, one or more data packets from a base station in a wireless network, and sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base

station.

[0006] According to an example implementation an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a mobile station, one or more data packets from a base station in a wireless network; and send, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0007] According to another example implementation, a computer program product includes a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: receiving, by a mobile station, one or more data packets from a base station in a wireless network; and sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0008] According to an example implementation, an apparatus may include means for receiving, by a mobile station, one or more data packets from a base station in a wireless network, and means for sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0009] According to an example implementation, a method may include sending, by a base station to a mobile station in a wireless network, one or more data packets, and receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0010] An apparatus may include at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: send, by a base station to a mobile station in a wireless network, one or more data packets; and receive, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0011] A computer program product, may include a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: sending, by a base station to a mobile station in a wireless network, one or more data packets; and receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0012] An apparatus may include means for sending, by a base station to a mobile station in a wireless network, one or more data packets; and means for receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0013] According to another example implementation, a method may include receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional, determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that

indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station, and otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0014] An apparatus may include means for receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional; means for determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station; means for sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and means for otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0015] An apparatus may include at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional; determine, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station; send, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the

base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and otherwise, send, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0016] A computer program product, the computer program product comprising a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional; determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station; sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0017] The details of one or more examples of implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 is a block diagram of a wireless network according to an example implementation.

[0019] FIG. 2 is a diagram illustrating transmission of signals in a wireless network according to an example technique.

[0020] FIG. 3 is a diagram illustrating transmission of signals in a wireless network according to an example implementation.

[0021] FIG. 4 is a flowchart illustrating operation of a mobile station according to an example implementation.

[0022] FIG. 5 is a flow chart illustrating operation of a base station according to an example implementation.

[0023] FIG. 6 is a flow chart illustrating operation of a mobile station according to another example implementation.

[0024] FIG. 7 is a block diagram of a wireless station (e.g., base station or mobile station/user device) according to an example implementation.

DETAILED DESCRIPTION

[0025] FIG. 1 is a block diagram of a wireless network 130 according to an example implementation. In the wireless network 130 of FIG. 1, mobile stations (MSs) 131, 132, 133 and 135, which may also be referred to as user equipments (UEs) or user devices, may be connected (and in communication) with a base station (BS) 134, which may also be referred to as an enhanced Node B (eNB). At least part of the functionalities of a base station or (e)Node B (eNB) may be also be carried out by any node, server or host which may be operably coupled to a transceiver, such as a remote radio head. BS 134 provides wireless coverage within a cell 136, including to mobile stations (MSs) 131, 132, 133 and 135. Although only four MSs are shown as being connected or attached to BS 134, any number of MSs may be provided. BS 134 is also connected to a core network 150 via a S1 interface 151. This is merely one simple example of a wireless network, and others may be used.

[0026] A mobile station (MS) (e.g., user terminal, user device, user equipment (UE)) may refer to a portable computing device that includes wireless mobile communication devices operating with or without a subscriber identification module (SIM), including, but not limited to, the following types of devices: a mobile station, a mobile phone, a cell phone, a smartphone, a personal digital assistant (PDA), a handset, a device using a wireless modem (alarm or measurement device, etc.), a laptop and/or touch screen computer, a tablet, a phablet, a game console, a notebook, and a multimedia device, as examples. It should be appreciated that a MS may also be a nearly exclusive uplink only device, of which an

example is a camera or video camera loading images or video clips to a network.

[0027] In LTE (as an example), core network 150 may be referred to as Evolved Packet Core (EPC), which may include a mobility management entity (MME) which may handle or assist with mobility/handover of MSs between BSs, one or more gateways that may forward data and control signals between the BSs and packet data networks or the Internet, and other control functions or blocks.

[0028] The various example implementations may be applied to a wide variety of wireless technologies or wireless networks, such as LTE, LTE-A, 5G, and/or any other wireless network. LTE and 5G networks are provided only as illustrative examples, and the various example implementations may be applied to any wireless technology/wireless network.

[0029] FIG. 2 is a diagram illustrating transmission of signals in a wireless network according to an example technique. As shown in FIG. 2, a BS 134 may exchange data and/or control signals with a MS 132. In FIG. 2, data signals may be generally indicated shown via solid lines and control signals are shown via dashed lines, although these lines are not limiting to such data or control in FIGs. 2 and 3. In response to a request for data, e.g., such as a request for a webpage, MS 132 may receive a burst of radio data packets 210 sent from BS 134 to MS 132 via a radio/wireless link. The data packets 210 are shown as data 1 (indicating a first radio data packet sent by BS 134 to MS), data 2, data 3, data 4, and data 5. These radio data packets 210 may include therein, for example, portions of the one or more Transport Control Protocol (TCP) segments, which may be provided as part of a webpage that may have been requested by the MS 132.

[0030] In this illustrative example shown in FIG. 2, approximately 40 ms after receipt of each radio data packet, BS 134 provides an uplink resource to allow MS 132 to send a local acknowledgment indicating receipt of each radio data packet such as data 1, data 2, data 3, data 4 and data 5. One uplink resource may be provided to acknowledge receipt of each radio data packet. In response to the receipt of data packets 210, MS 132 may send one or more local acknowledgments back to BS 134. Local acknowledgments may only provide a local acknowledgment between the MS 132 and BS 134 that a data packet or data envelope was received by MS 132, and such local acknowledgment is not typically forwarded on to a data server that may have sent the webpage or data. For example, the local acknowledgment may be a hybrid ARQ (HARQ) Acknowledgment (HARQ Ack). In this example, a HARQ Ack 1 (or local acknowledgement 1) may acknowledge receipt of data 1

(the first radio data packet sent over a wireless/radio link from BS 134 to MS 132). Similarly, HARQ Ack 2, HARQ Ack 3, HARQ Ack 4 and HARQ Ack 5 may acknowledge receipt of data 2, data 3, data 4 and data 5 (or the 2nd – 5th radio data packets received by the MS 132 from BS 134).

[0031] In this example, in order for the MS 132 to provide or send data acknowledgments back to the server that provided the Web page (e.g., TCP segments), MS 132 must typically wait for the next periodic uplink resource for MS 132 to request resources. For example a periodic resource may be provided to each MS, such as to MS 132, every 40 MS, e.g. to allow MS 132 to send a scheduling request (SR) 212 over a physical uplink control channel (PUCCH), which is a technique to allow MS 132 to request uplink resources on an uplink data channel. However, the scheduling request 212 only indicates whether or not an uplink resource is requested, and does not indicate an amount of data that has been stored for transmission nor an amount of resources that is requested. Later, in response to the SR 212, BS 134 sends an uplink grant 214 to MS 132 which grants uplink resources on an uplink data channel, e.g., on a physical uplink shared channel (PUSCH). The MS 132 may then transmit one or more data acknowledgments 216 via the uplink resource that was allocated by uplink grant 214.

[0032] The data acknowledgments 216 may be sent via a physical uplink shared data channel (PUSCH). The uplink resources provided by uplink grant to 214 may be a very small amount of resources (e.g., 1 bit, or very few bits), and, therefore, MS 132 may typically be unable to send all of its data or data acknowledgments (e.g., TCP Acknowledgements) 216 during the allocated uplink resource. Therefore, in order for the MS 132 to request additional uplink resources, the data acknowledgments 216 may also include a buffer status report (BSR) which may indicate an amount of data to be sent to the BS 134. In response to the BS 134 receiving the BSR at 216, BS 134 may send an uplink grant 218 to grant additional uplink resources. MS 132 may then use the additional uplink resources to transmit additional data or data acknowledgments 220 such as a remaining group of TCP acknowledgments.

[0033] Therefore, as can be seen in the exchange of packets or messages within FIG. 2, a substantial delay may occur from the time the initial burst of data radio packets 210 is first received by MS 132 (at data 1 as part of data radio packet 210), until data acknowledgments (e.g. TCP acknowledgments) may be finally sent to BS 134 at 216, to be delivered to a Web server that delivered the web data or TCP segments. In some cases, a delay of several hundred milliseconds or more may result, e.g., at least in part because of a

minimum time period between SR resources allocated to MS 132 of every 40 ms or other time period. In this example, an uplink resource may be periodically scheduled to MS 132 only every 40 ms to allow MS 132 to send a scheduling request (SR) via a physical uplink control channel (PUCCH) to request resources. Furthermore, in this example, the resources allocated every 40 ms to MS 132 are typically a very small amount of uplink resources to allow a one bit signal that such as a scheduling request (SR) to be sent to indicate only that resources are being requested. Such resources that are periodically scheduled for a scheduling request are typically not enough to send data acknowledgments or other data, for example. Thus, significant delays may be introduced in this example due to the delay after the uplink grant 214 until the MS 132 is finally able to transmit its data (e.g., TCP) acknowledgments to BS 134 at 216.

[0034] FIG. 3 is a diagram illustrating transmission of signals in a wireless network according to an example implementation. The example techniques illustrated in FIG. 3 may reduce the latency or delays that may occur in the example shown in FIG. 2. As shown in FIG. 3, a BS 134 may exchange data and/or control signals with a MS 132. In FIG. 3, data signals may be generally shown via solid lines and control signals are shown via dashed lines, although in some cases control or data signals may be sent via any of the signals depending on the situation.

[0035] In response to a request for data, e.g., such as a webpage, MS 132 may receive a burst of radio data packets 310 sent from BS 134 to MS 132 via a radio/wireless link. The data packets 310 are shown as data 1 (indicating a first radio data packet sent by BS 134 to MS), data 2, and data 3. While only three radio data packets (data 1, data 2 and data 3) are included within the burst of radio data packets 310, any number of radio data packets may be included within the burst of radio data packets. In an illustrative example implementation, these radio data packets 310 may include portions of the one or more Transport Control Protocol (TCP) segments, which may be provided as part of a webpage that may have been requested by the MS 132 from a web server, for example.

[0036] Referring to FIG. 3, after MS 132 receives one or more of the radio data packets, MS 132 may send a local acknowledgment (e.g., HARQ Ack) back to BS 134. For example, BS 134 may automatically reserve and uplink resource to allow MS 132 to provide a local acknowledgment or HARQ Ack to BS 134 to acknowledge receipt of each radio data packet. For example, BS 134 may reserve an uplink resource on an uplink control channel 40 ms after sending a radio data packet to allow the MS 132 to send a local acknowledgment

(e.g., HARQ Acknowledgement) confirming receipt of such radio data packet. According to the example implementation shown in FIG. 3, HARQ Ack 1, HARQ Ack 2 and HARQ Ack 3 (local Acknowledgements 1-3) sent by MS 132 may acknowledge receipt by MS 132 of radio data packets data 1, data 2 and data 3, respectively from BS 134. In order to reduce the common delays associated with transmitting data and providing acknowledgments (e.g., see example of FIG. 2), it may be desirable to reduce the delay from the time the data is transmitted from BS 134 to MS 132 until data acknowledgments (e.g., TCP acknowledgments) can be sent by the MS 132 to the BS 134.

[0037] Therefore, according to an example implementation, rather than waiting for a next scheduled resource (e.g., see SR 212, FIG. 2) for MS 132 to send a scheduling request (SR), MS 132 may piggyback a buffer status report (BSR) onto one or more of the local acknowledgments (e.g., Piggyback the BSR onto one or more of the HARQ Acks). In this manner, a control message may be sent by MS 132 to BS 134 that includes both the local acknowledgement (e.g., HARQ Ack) and a buffer status report (BSR). According to an example implementation, the buffer status report (BSR) that is piggybacked on a HARQ Ack may include a BSR index that may indicate an amount of data in an uplink buffer(s) of the MS 132 that is awaiting uplink transmission to the BS 134. As shown in FIG. 3, one or more buffer status reports (BSRs) may be sent with a local Acknowledgement (e.g., HARQ Ack), including, for example one or more of the following: a BSR1 (a first buffer status report) may be sent with or piggybacked onto HARQ Ack 1 (e.g., a first control message that includes both HARQ Ack 1 and BSR1), a BSR2 (a second buffer status report) may be sent with or piggybacked onto HARQ Ack 2 (e.g., a second control message that includes both HARQ Ack 2 and BSR2), and a BSR3 (a third buffer status report) may be sent with or piggybacked onto HARQ Ack 3 (e.g., a third control message that includes both HARQ Ack 3 and BSR3). In an example implementation, BS 134 may allocate uplink resources on a data channel to the MS 132 in response to each received BSR.

[0038] For example, prior to sending a buffer status report (BSR) (or prior to including the BSR with a HARQ Ack), MS 132 may first determine an amount of data that MS 132 has in one or more uplink buffers that is awaiting uplink transmission to the BS 134. A BSR index may then be determined based upon the amount of data in the one or more uplink buffers where the BSR index may indicate the amount of data in the one or more uplink buffers awaiting transmission. For example, the following BSR indices, by way of illustrative example, may be used to indicate an amount of data and one or more uplink buffers awaiting

transmission, by way of example, as shown in Table 1:

<u>BSR Index</u>	<u>Buffer size (BS) value (bytes)</u>
1	$0 < BS \leq 10$
2	$10 < BS \leq 12$
...	...
20	$171 < BS \leq 200$
...	...
63	$BS > 150,000$

Table 1 – Example BSR index values

[0039] As shown in FIG 3, in response to the control message that included both the HARQ Ack 1 (or local Acknowledgement 1) and the BSR1, BS 134 may send or provide an uplink grant 312 which grants uplink resources to the MS 132 to send data to BS 134. For example, BS 134 may attempt to allocate or grant to MS 132 an amount of uplink resources that may meet or satisfy the amount of data for uplink transmission that is indicated by the BSR index. Therefore, in response to the uplink grant 312, MS 132 may send one or more data acknowledgments (such as TCP Acks that may acknowledge receiving one or more TCP segments, for example) via data message 314. Data message 314 may also include a buffer status report (BSR), e.g., in the event that additional uplink resources are required by the MS 132 to send additional data acknowledgements. For example, if the resources allocated to MS 132 via uplink grant 312 are insufficient to transmit all the data, including all the TCP or data acknowledgements, that the MS 132 has in one or more uplink buffers for uplink transmission, then additional uplink resources may be requested by MS 132 via a piggybacked BSR provided within the message 314.

[0040] According to an example implementation, as shown in FIG. 3, in the event that a buffer status report (BSR) is included or piggybacked on the data message 314, BS 134 may send an uplink grant 318 allocating additional uplink resources to the MS 132, e.g., to allow MS 132 send additional data and/or additional data acknowledgments to BS 134. The uplink grant 318 may allocate resources, for example, to allow the MS 132 to send a data message 320 that may include one or more data acknowledgments (e.g., TCP Acks) and/or other data, such as a Get request that may request additional data from a Web server for example.

[0041] According to an example implementation, one or both of: the uplink grant 312 and/or the data message 314 sent via the allocated uplink resources granted to the MS 132

(via uplink grant 312) on the uplink data channel may be provided or may occur before a next scheduled resource 316 for the MS 132 to send a scheduling request (SR), for example. In this manner, for example, the uplink grant 312 and its associated data message 314 may be provided much earlier in the communication process, e.g. much closer to the end of the data burst 310, without the additional delay shown in FIG. 2. In this manner, the data acknowledgements (e.g., TCP Acks) may be sent via data message 314 much earlier in the process, by avoiding the additional delays or waiting periods shown in FIG. 2. This is because, for example, the buffer status report, such as BSR1, is sent within a control message with the HARQ Ack, such as within HARQ Ack 1, which may allow the request for additional resources to be sent much earlier, without waiting for a next scheduled resource for the MS 132 to send a scheduling request (SR). Furthermore, the resources allocated by BS 134 via the uplink grant 312 may be significantly larger than what would be initially allocated in response to BS 134 receiving a scheduling request (SR), which may further decrease the delay or latency of the communication of data (e.g., the web page in this example) by providing significant resources (e.g., typically more than 1 bit) for MS 132 to send the data acknowledgments (e.g., TCP Acknowledgments) and/or other data to the BS 134 much earlier than shown in the technique shown in FIG. 2, for example.

[0042] Although not shown in FIG. 3, an uplink grant may be provided by BS 134 to MS 132 in response to each piggybacked BSR that is sent with an associated HARQ Ack, such as for BSR 2 and BSR 3, for example.

[0043] In an example implementation, BS 134 may send a control message to MS 132, where the control information may indicate how frequently the mobile station (MS) 132 may send control messages that include both a local acknowledgment (e.g., HARQ Ack) and a buffer status report (BSR). In other words, for example, this control information may indicate how frequently the MS 132 may piggyback or attach a buffer status report (BSR) to a local acknowledgment (e.g., HARQ Ack) that is sent to the BS 134. For example, in order to limit the amount of resources that may be used to send a piggybacked buffer status reports (piggybacked or attached to the HARQ Ack), a control message or other control information may be sent or provided to the MS 132 that may, for example, indicate a minimum period of time between the MS 132 sending of control messages that include both a local acknowledgment (e.g., HARQ Ack) and a buffer status report. For example, the control message or control information may indicate that a BSR may be provided or piggybacked on a local Acknowledgement or HARQ Ack only every 20 ms (no more than every 20 ms), or

only for every other HARQ Ack that is sent to the BS 134, as an example. These are merely some illustrative examples of how the BS 134 or other control entity may place limitations how frequently MS 132 may transmit or piggyback a buffer status report (BSR) on a local acknowledgment or HARQ Ack, for example.

[0044] While the above examples described with respect to FIG. 3 illustrate techniques that allow a buffer status report to be piggy-backed on a local Acknowledgement (or HARQ Ack) that is sent from a MS 132 to BS 134, these techniques may be more broadly used to allow a MS to provide a quick reply or response, or a quick request for additional information, or other information (via either uplink control channel or uplink data channel) in response to receiving downlink data, for example. Thus, MS 132 may receive data from BS 134, such as via data 1 (first data packet). The MS 132 may send a quick reply to BS 134 via an uplink resource allocated for a local Ack/HARQ Ack (or other allocated uplink resource, via uplink control channel or uplink data channel), where the reply may then be forwarded from the BS 134 to a data server or web server connected to core network 150, for example.

[0045] As an illustrative example, MS 132 may receive downlink data via data 1, e.g., providing a status of another network device, and the MS 132 may then quickly reply to BS 134 by sending a reply message (e.g., a command sent to the network device, or a request for information from such network device) sent via uplink resources (e.g., PUCCH resources) that may have been allocated by BS 134 to MS 132 to allow MS 132 to provide a reply (e.g., HARQ Ack, or other reply, a request for additional information, a BSR or request for additional uplink resources, a TCP Ack(s), or other information). Thus, in this manner, the MS 132 may use the uplink control channel resources that maybe have been allocated by the BS 134 to MS 132 (e.g., to provide HARQ Acks) to provide various other types of information to the BS 134. As noted, this additional information that may be provided in the HARQ Ack uplink control channel, e.g., PUCCH resources (or allocated uplink data channel, e.g., PUSCH resources) may include, for example, a request for additional resources (e.g., BSR), a request for additional web page (e.g., HTTP Get request), a command to be forwarded to a network device connected to the internet, or other request or information, or reply, as examples. These are merely some examples of the types of information that may be sent via the uplink resource that may be allocated by BS 134 to MS 132. This uplink resource may be allocated by BS 134 to MS 132 at a predetermined location/time, e.g., 4 subframes after transmission of the downlink data. Alternatively, an uplink resource grant for the control channel (e.g., PUCCH) or for a data channel (e.g., PUSCH) may be included with a message sent by the

BS 134 to MS 132 when sending the data (e.g., data 1) to the MS 132.

[0046] In other example implementations, there may be other limitations on when or under what circumstances a MS may send a BSR to a BS. According to an example implementation, a MS may send a buffer status report (BSR) in/with (e.g., piggy-backed on) a HARQ Ack only when the MS is not reporting CQI (Channel quality indication) with the Ack, and/or only when uplink data channel resources (e.g., in the physical uplink shared data channel/PUSCH) are not available to the MS to send the BSR to the BS.

[0047] FIG. 4 is a flow chart illustrating operation of a mobile station according to an example implementation. Operation 410 may include receiving, by a mobile station, one or more data packets from a base station in a wireless network. Operation 420 may include sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0048] According to an example implementation of the method of FIG. 4, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

[0049] According to an example implementation of the method of FIG. 4, the method may further include receiving, by the mobile station from the base station in response to the buffer status report, a resource grant that grants a resource in a uplink data channel; and sending, by the mobile station to the base station via the resource, a data acknowledgement that acknowledges receipt of one or more application data packets.

[0050] According to an example implementation of the method of FIG. 4, the data acknowledgement may include a TCP (Transport Control Protocol) acknowledgement that acknowledges receipt by the mobile station of one or more TCP segments.

[0051] According to an example implementation of the method of FIG. 4, the buffer status report is provided as a buffer status report index that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission.

[0052] According to an example implementation of the method of FIG. 4, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement; and wherein the sending may include sending a control message that includes the HARQ Acknowledgement that is provided in a field of the control message instead of a channel quality indication (CQI) in the field.

[0053] According to an example implementation of the method of FIG. 4, the method may further include receiving, by the mobile station from the base station, control information that indicates how frequently the mobile station may send control messages that include both a local Acknowledgement and a buffer status report.

[0054] According to an example implementation of the method of FIG. 4, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement, the method further including: receiving, by the mobile station from the base station, control information that indicates a minimum period of time between the mobile station sending of control messages that include both a HARQ Acknowledgement and a buffer status report.

[0055] According to an example implementation of the method of FIG. 4, the resource in the uplink data channel occurs before a next scheduled resource that is allocated to the mobile station for transmitting a scheduling request to the base station.

[0056] According to an example implementation an apparatus includes at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a mobile station, one or more data packets from a base station in a wireless network; and send, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0057] According to another example implementation, a computer program product includes a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method comprising: receiving, by a mobile station, one or more data packets from a base station in a wireless network; and sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0058] According to an example implementation, an apparatus may include means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by a mobile station, one or more data packets from a base station in a wireless network, means (e.g., 702A/702B, and/or 704, FIG.

7) for sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0059] According to an example implementation of the apparatus, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

[0060] According to an example implementation of the apparatus, the apparatus may further include means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by the mobile station from the base station in response to the buffer status report, a resource grant that grants a resource in a uplink data channel; and means (e.g., 702A/702B, and/or 704, FIG. 7) for sending, by the mobile station to the base station via the resource, a data acknowledgement that acknowledges receipt of one or more application data packets.

[0061] According to an example implementation of the apparatus, the data acknowledgement may include a TCP (Transport Control Protocol) acknowledgement that acknowledges receipt by the mobile station of one or more TCP segments.

[0062] According to an example implementation of the apparatus, the buffer status report is provided as a buffer status report index that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission.

[0063] According to an example implementation of the apparatus, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement; and wherein the means for sending may include means (e.g., 702A/702B, and/or 704, FIG. 7) for sending a control message that includes the HARQ Acknowledgement that is provided in a field of the control message instead of a channel quality indication (CQI) in the field.

[0064] According to an example implementation of the apparatus, the apparatus may further include means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by the mobile station from the base station, control information that indicates how frequently the mobile station may send control messages that include both a local Acknowledgement and a buffer status report.

[0065] According to an example implementation of the method of FIG. 4, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement, the apparatus further including: means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by the mobile station from the base station, control information that indicates a minimum period of time

between the mobile station sending of control messages that include both a HARQ Acknowledgement and a buffer status report.

[0066] According to an example implementation of the apparatus, the resource in the uplink data channel occurs before a next scheduled resource that is allocated to the mobile station for transmitting a scheduling request to the base station.

[0067] FIG. 5 is a flow chart illustrating operation of a base station according to an example implementation. Operation 510 may include sending, by a base station to a mobile station in a wireless network, one or more data packets. Operation 520 may include receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0068] According to an example implementation of the method of FIG. 5, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

[0069] According to an example implementation of the method of FIG. 5, the method may further include sending, by the base station to the mobile station in response to the buffer status report, a resource grant that grants a resource in a uplink data channel; and receiving, by the base station from the mobile station via the resource, a data acknowledgement that acknowledges receipt of one or more application data packets.

[0070] According to an example implementation of the method of FIG. 5, the method may further include sending, by the base station to the mobile station, control information that indicates how frequently the mobile station may send control messages that include both a local Acknowledgement and a buffer status report.

[0071] An apparatus may include at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: send, by a base station to a mobile station in a wireless network, one or more data packets; and receive, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0072] A computer program product, may include a non-transitory computer-readable

storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: sending, by a base station to a mobile station in a wireless network, one or more data packets; and receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0073] An apparatus may include means (e.g., 702A/702B, and/or 704, FIG. 7) for sending, by a base station to a mobile station in a wireless network, one or more data packets; and means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

[0074] The apparatus wherein the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

[0075] The apparatus may further include means (e.g., 702A/702B, and/or 704, FIG. 7) for sending, by the base station to the mobile station in response to the buffer status report, a resource grant that grants a resource in a uplink data channel; and means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by the base station from the mobile station via the resource, a data acknowledgement that acknowledges receipt of one or more application data packets.

[0076] The apparatus may further include means (e.g., 702A/702B, and/or 704, FIG. 7) for sending, by the base station to the mobile station, control information that indicates how frequently the mobile station may send control messages that include both a local Acknowledgement and a buffer status report.

[0077] A further example implementation will now be described. According to another example implementation, BS 134 may automatically allocate a first uplink resource in an uplink data channel (e.g., in PUSCH) that may allow the MS 132 to send both a local Acknowledgement or HARQ Ack and data, e.g., if the MS 132 has data for transmission to the BS 134. For example, the BS 134 may send a message at data 1 in FIG. 3 that may include both data and a first resource grant that grants a first uplink resource in an uplink data

channel, where it may be optional for the MS 132 to use this first uplink resource in the uplink data channel, for example. Thus, in this case the data (at data 1 in FIG. 3) and an uplink resource grant on the uplink data channel may be combined by BS 134 and sent via one message that includes the data and first uplink resource grant that allocates an uplink resource in an uplink data channel, e.g., in PUSCH. Thus, the MS 132 may then use this first uplink resource (e.g., at 314 in FIG. 3) in the uplink data channel (e.g., PUSCH) to send both a local Acknowledgement (or HARQ Ack) and data (where the data may include various types of information, commands, TCP Acks, a BSR, etc.). However, according to an example implementation, use of this first uplink resource in the uplink data channel is not required, but may be optional.

[0078] BS 134 may also allocate a second uplink resource in an uplink control channel (e.g., PUCCH) based upon the transmission of data, e.g., data 1, to MS 132, e.g., to allow the MS 132 to send a local Acknowledgement (or HARQ Ack) and/or other information such as a BSR). In this illustrative example implementation, MS 132 may use the first uplink resource in the uplink data channel (e.g., PUSCH) to send both the local Acknowledgement/HARQ Ack for the data 1 and a BSR (or other information/data) if the MS 132 has data in an uplink data buffer for transmission to the BS 134. Otherwise, if the MS 132 does not have data in an uplink buffer awaiting transmission to BS 134, then the MS 132 may simply send only a local Ack/HARQ Ack via the second uplink resource of the uplink control channel (e.g., PUCCH).

[0079] FIG. 6 is a flow chart illustrating operation of a mobile station according to another example implementation. Operation 610 may include receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional. Operation 620 may include determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station. Operation 630 may include sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station. And, operation 640

may include otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0080] According to an example implementation of the method illustrated in FIG. 6, the local Acknowledgement may include a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

[0081] According to an example implementation of the method illustrated in FIG. 6, the method may further include receiving, by the mobile station from the base station in response to the buffer status report, a resource grant that grants a third uplink resource in the uplink data channel; and sending, by the mobile station to the base station via the third uplink resource, data or other information.

[0082] An apparatus may include means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional; means (e.g., 702A/702B, and/or 704, FIG. 7) for determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station; means (e.g., 702A/702B, and/or 704, FIG. 7) for sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and means (e.g., 702A/702B, and/or 704, FIG. 7) for otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0083] The apparatus wherein the local Acknowledgement comprises a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

[0084] The apparatus may further include means (e.g., 702A/702B, and/or 704, FIG. 7) for receiving, by the mobile station from the base station in response to the buffer status report, a resource grant that grants a third uplink resource in the uplink data channel; and means (e.g., 702A/702B, and/or 704, FIG. 7) for sending, by the mobile station to the base station via the third uplink resource, data or other information.

[0085] An apparatus may include at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to: receive, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional; determine, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station; send, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and otherwise, send, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0086] A computer program product, the computer program product comprising a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method including: receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional; determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station; sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting

transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

[0087] FIG. 7 is a block diagram of a wireless station (e.g., BS or user device) 700 according to an example implementation. The wireless station 700 may include, for example, two RF (radio frequency) or wireless transceivers 702A, 702B, where each wireless transceiver includes a transmitter to transmit signals and a receiver to receive signals. The wireless station also includes a processor or control unit/entity (controller) 704 to execute instructions or software and control transmission and receptions of signals, and a memory 706 to store data and/or instructions.

[0088] Processor 704 may also make decisions or determinations, generate frames, packets or messages for transmission, decode received frames or messages for further processing, and other tasks or functions described herein. Processor 704, which may be a baseband processor, for example, may generate messages, packets, frames or other signals for transmission via wireless transceiver 702 (702A or 702B). Processor 704 may control transmission of signals or messages over a wireless network, and may control the reception of signals or messages, etc., via a wireless network (e.g., after being down-converted by wireless transceiver 702, for example). Processor 704 may be programmable and capable of executing software or other instructions stored in memory or on other computer media to perform the various tasks and functions described above, such as one or more of the tasks or methods described above. Processor 704 may be (or may include), for example, hardware, programmable logic, a programmable processor that executes software or firmware, and/or any combination of these. Using other terminology, processor 704 and transceiver 702 together may be considered as a wireless transmitter/receiver system, for example.

[0089] In addition, referring to FIG. 7, a controller (or processor) 708 may execute software and instructions, and may provide overall control for the station 700, and may provide control for other systems not shown in FIG. 7, such as controlling input/output devices

(e.g., display, keypad), and/or may execute software for one or more applications that may be provided on wireless station 700, such as, for example, an email program, audio/video applications, a word processor, a Voice over IP application, or other application or software.

[0090] In addition, a storage medium may be provided that includes stored instructions, which when executed by a controller or processor may result in the processor 704, or other controller or processor, performing one or more of the functions or tasks described above.

[0091] According to another example implementation, RF or wireless transceiver(s) 702A/702B may receive signals or data and/or transmit or send signals or data. Processor 704 (and possibly transceivers 702A/702B) may control the RF or wireless transceiver 702A or 702B to receive, send, broadcast or transmit signals or data.

[0092] The embodiments are not, however, restricted to the system that is given as an example, but a person skilled in the art may apply the solution to other communication systems. Another example of a suitable communications system is the 5G concept. It is assumed that network architecture in 5G will be quite similar to that of the LTE-advanced. 5G is likely to use multiple input – multiple output (MIMO) antennas, many more base stations or nodes than the LTE (a so-called small cell concept), including macro sites operating in co-operation with smaller stations and perhaps also employing a variety of radio technologies for better coverage and enhanced data rates.

[0093] It should be appreciated that future networks will most probably utilise network functions virtualization (NFV) which is a network architecture concept that proposes virtualizing network node functions into “building blocks” or entities that may be operationally connected or linked together to provide services. A virtualized network function (VNF) may comprise one or more virtual machines running computer program codes using standard or general type servers instead of customized hardware. Cloud computing or data storage may also be utilized. In radio communications this may mean node operations may be carried out, at least partly, in a server, host or node operationally coupled to a remote radio head. It is also possible that node operations will be distributed among a plurality of servers, nodes or hosts. It should also be understood that the distribution of labour between core network operations and base station operations may differ from that of the LTE or even be non-existent.

[0094] Implementations of the various techniques described herein may be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in

combinations of them. Implementations may be implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device or in a propagated signal, for execution by, or to control the operation of, a data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. Implementations may also be provided on a computer readable medium or computer readable storage medium, which may be a non-transitory medium. Implementations of the various techniques may also include implementations provided via transitory signals or media, and/or programs and/or software implementations that are downloadable via the Internet or other network(s), either wired networks and/or wireless networks. In addition, implementations may be provided via machine type communications (MTC), and also via an Internet of Things (IOT).

[0095] The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers.

[0096] Furthermore, implementations of the various techniques described herein may use a cyber-physical system (CPS) (a system of collaborating computational elements controlling physical entities). CPS may enable the implementation and exploitation of massive amounts of interconnected ICT devices (sensors, actuators, processors/microcontrollers,...) embedded in physical objects at different locations. Mobile cyber physical systems, in which the physical system in question has inherent mobility, are a subcategory of cyber-physical systems. Examples of mobile physical systems include mobile robotics and electronics transported by humans or animals. The rise in popularity of smartphones has increased interest in the area of mobile cyber-physical systems. Therefore, various implementations of techniques described herein may be provided via one or more of these technologies.

[0097] A computer program, such as the computer program(s) described above, can be written in any form of programming language, including compiled or interpreted languages, and can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit or part of it suitable for use in a computing environment.

A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

[0098] Method steps may be performed by one or more programmable processors executing a computer program or computer program portions to perform functions by operating on input data and generating output. Method steps also may be performed by, and an apparatus may be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

[0099] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer, chip or chipset. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. Elements of a computer may include at least one processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer also may include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory may be supplemented by, or incorporated in, special purpose logic circuitry.

[00100] To provide for interaction with a user, implementations may be implemented on a computer having a display device, e.g., a cathode ray tube (CRT) or liquid crystal display (LCD) monitor, for displaying information to the user and a user interface, such as a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input.

[00101] Implementations may be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a

graphical user interface or a Web browser through which a user can interact with an implementation, or any combination of such back-end, middleware, or front-end components. Components may be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network (LAN) and a wide area network (WAN), e.g., the Internet.

[00102] While certain features of the described implementations have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the various embodiments.

WHAT IS CLAIMED IS:

1. A method comprising:
receiving, by a mobile station, one or more data packets from a base station in a wireless network; and
sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.
2. The method of claim 1 wherein the local Acknowledgement comprises a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).
3. The method of claim 1 and further comprising:
receiving, by the mobile station from the base station in response to the buffer status report, a resource grant that grants a resource in a uplink data channel; and
sending, by the mobile station to the base station via the resource, a data acknowledgement that acknowledges receipt of one or more application data packets.
4. The method of claim 3 wherein the data acknowledgement comprises a TCP (Transport Control Protocol) acknowledgement that acknowledges receipt by the mobile station of one or more TCP segments.
5. The method of claim 1 wherein the buffer status report is provided as a buffer status report index that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission.
6. The method of claim 1:
wherein the local Acknowledgement comprises a Hybrid-ARQ (HARQ) Acknowledgement; and
wherein the sending comprises sending a control message that includes the HARQ Acknowledgement that is provided in a field of the control message instead of a channel quality indication (CQI) in the field.

7. The method of claim 1, and further comprising:
receiving, by the mobile station from the base station, control information that indicates how frequently the mobile station may send control messages that include both a local Acknowledgement and a buffer status report.

8. The method of claim 1, wherein the local Acknowledgement comprises a Hybrid-ARQ (HARQ) Acknowledgement, the method further comprising:
receiving, by the mobile station from the base station, control information that indicates a minimum period of time between the mobile station sending of control messages that include both a HARQ Acknowledgement and a buffer status report.

9. The method of claim 1:
wherein the resource in the uplink data channel occurs before a next scheduled resource that is allocated to the mobile station for transmitting a scheduling request to the base station.

10. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to:
receive, by a mobile station, one or more data packets from a base station in a wireless network; and
send, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

11. A computer program product, the computer program product comprising a non-transitory computer-readable storage medium and storing executable code that, when executed by at least one data processing apparatus, is configured to cause the at least one data processing apparatus to perform a method comprising:
receiving, by a mobile station, one or more data packets from a base station in a wireless network; and

sending, by the mobile station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

12. A method comprising:

sending, by a base station to a mobile station in a wireless network, one or more data packets; and

receiving, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

13. The method of claim 12 wherein the local Acknowledgement comprises a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

14. The method of claim 12 and further comprising:

sending, by the base station to the mobile station in response to the buffer status report, a resource grant that grants a resource in a uplink data channel; and

receiving, by the base station from the mobile station via the resource, a data acknowledgement that acknowledges receipt of one or more application data packets.

15. The method of claim 12, and further comprising:

sending, by the base station to the mobile station, control information that indicates how frequently the mobile station may send control messages that include both a local Acknowledgement and a buffer status report.

16. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to:

send, by a base station to a mobile station in a wireless network, one or more data packets; and

receive, by the base station, a control message that includes a local Acknowledgement that acknowledges receipt by the mobile station of one or more of the data packets from the base station, the control message also including a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station.

17. A method comprising:

receiving, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional;

determining, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station;

sending, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and

otherwise, sending, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

18. The method of claim 17 wherein the local Acknowledgement comprises a Hybrid-ARQ (HARQ) Acknowledgement (HARQ ACK).

19. The method of claim 17 and further comprising:

receiving, by the mobile station from the base station in response to the buffer status report, a resource grant that grants a third uplink resource in the uplink data channel; and

sending, by the mobile station to the base station via the third uplink resource, data or other information.

20. An apparatus comprising at least one processor and at least one memory including computer instructions, when executed by the at least one processor, cause the apparatus to:

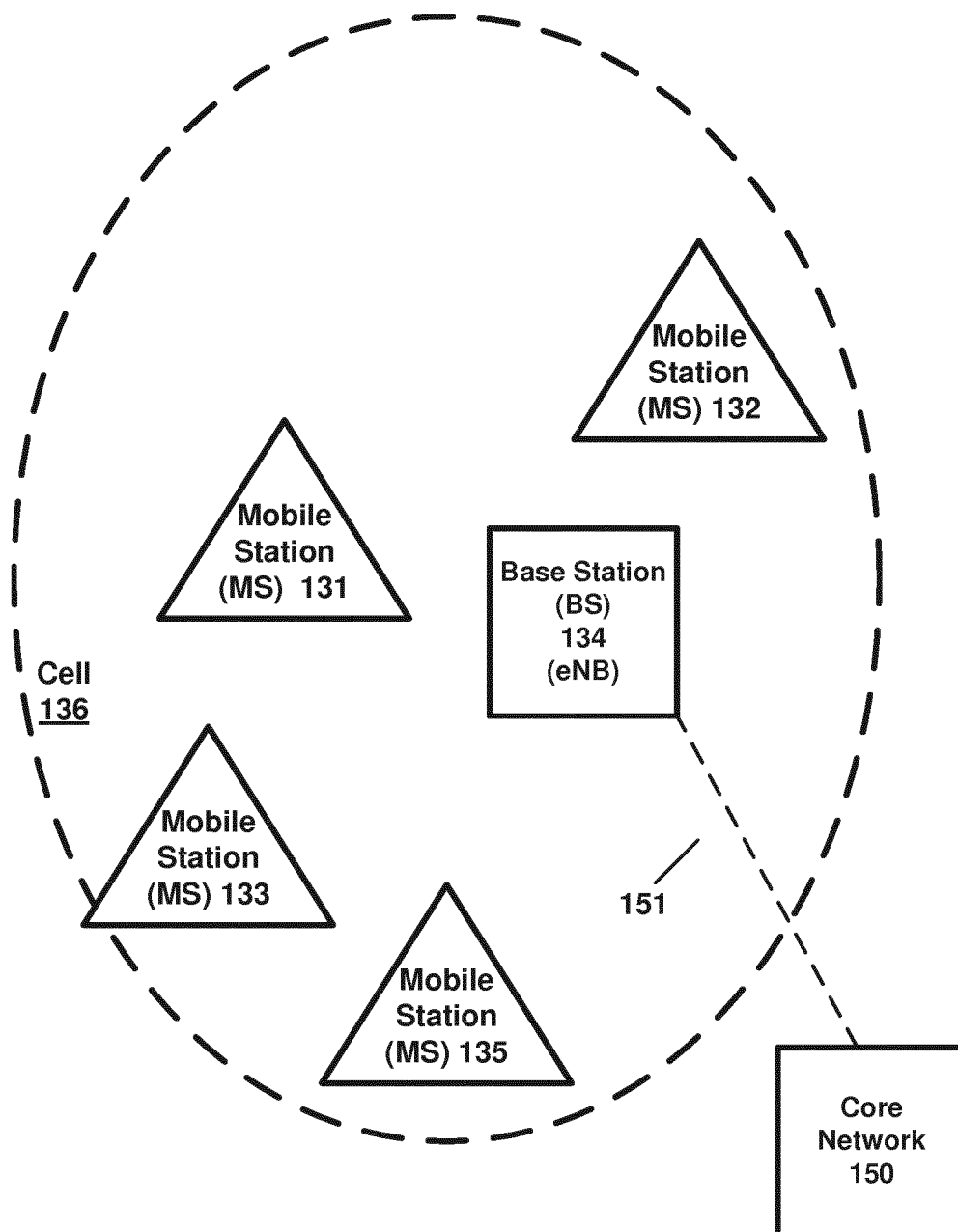
receive, by a mobile station, a first message from a base station in a wireless network, the first message including data and a first resource grant that grants a first uplink resource in an uplink data channel, wherein use by the mobile station of the first uplink resource in the uplink data channel is optional;

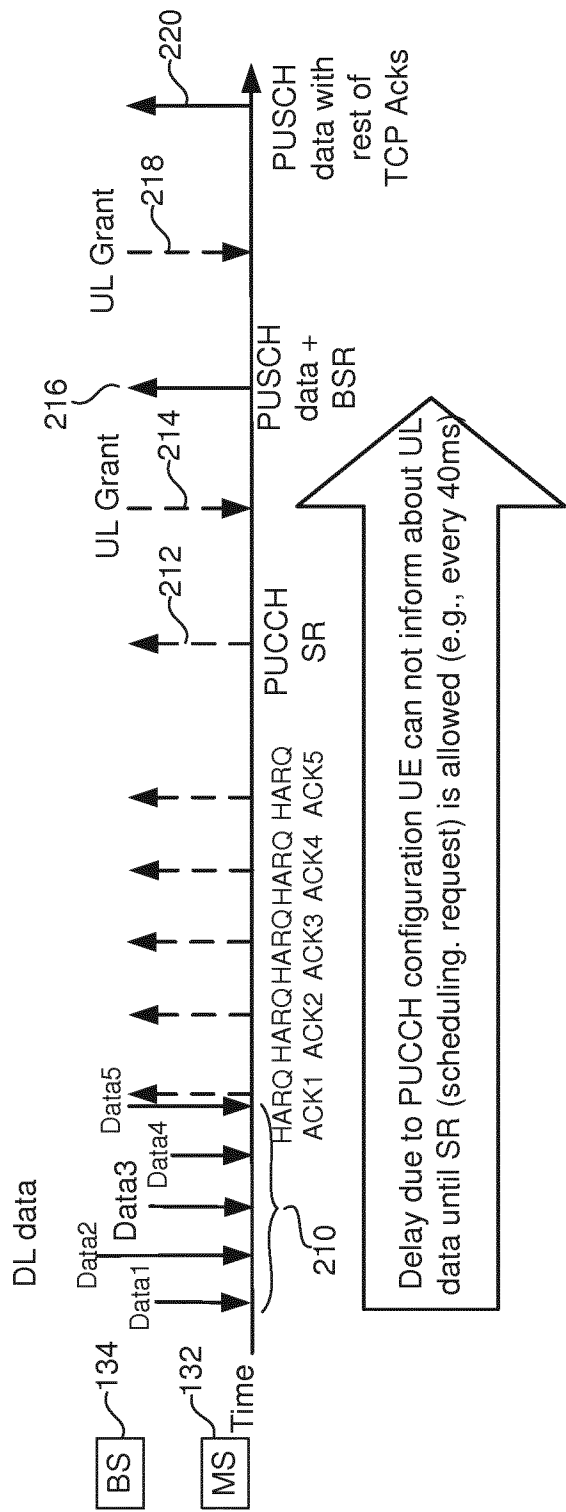
determine, by the mobile station, if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station;

send, by the mobile station to the base station if the mobile station has data in an uplink buffer of the mobile station awaiting transmission to the base station, a second message via the first uplink resource, the second message including a local Acknowledgement that acknowledges receipt by the mobile station of one the data from the base station and a buffer status report that indicates an amount of data in an uplink buffer of the mobile station that is awaiting uplink transmission to the base station; and

otherwise, send, by the mobile station to the base station, if the mobile station does not have data in an uplink buffer of the mobile station awaiting transmission to the base station, a local Acknowledgement via a second uplink resource of an uplink control channel, the local Acknowledgement acknowledging receipt by the mobile station of the data from the base station.

Example Wireless Network 130

**FIG. 1**



200

FIG.2

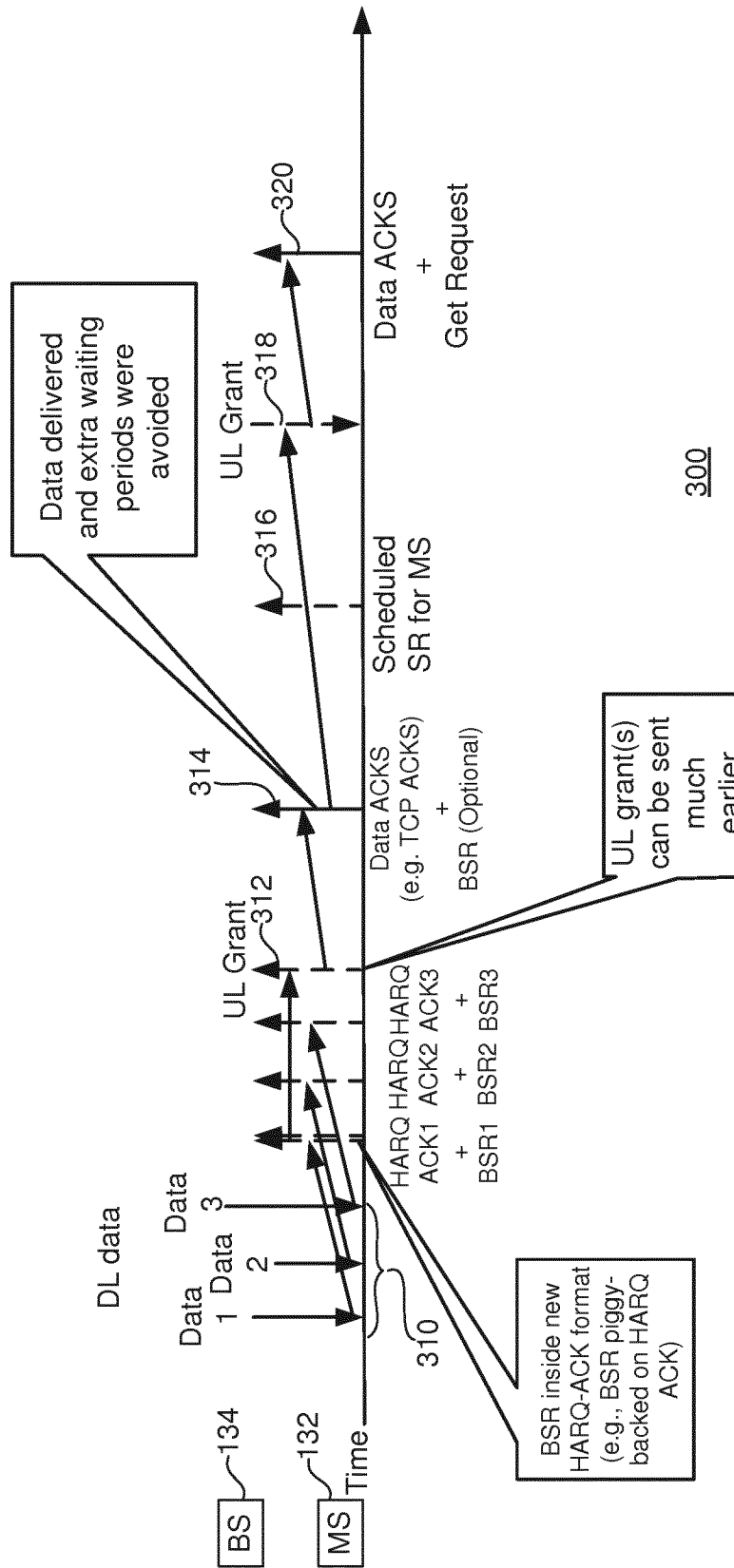
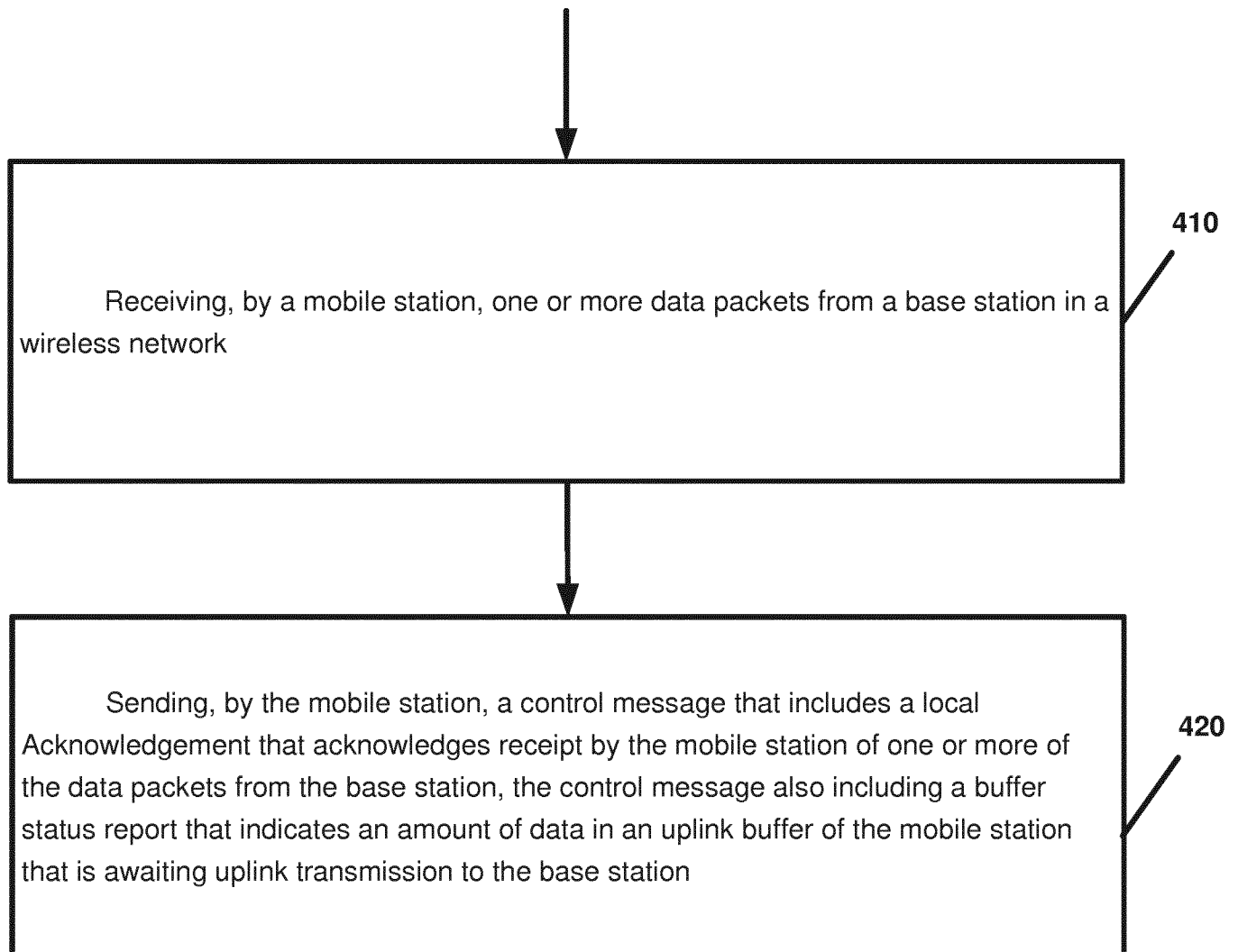
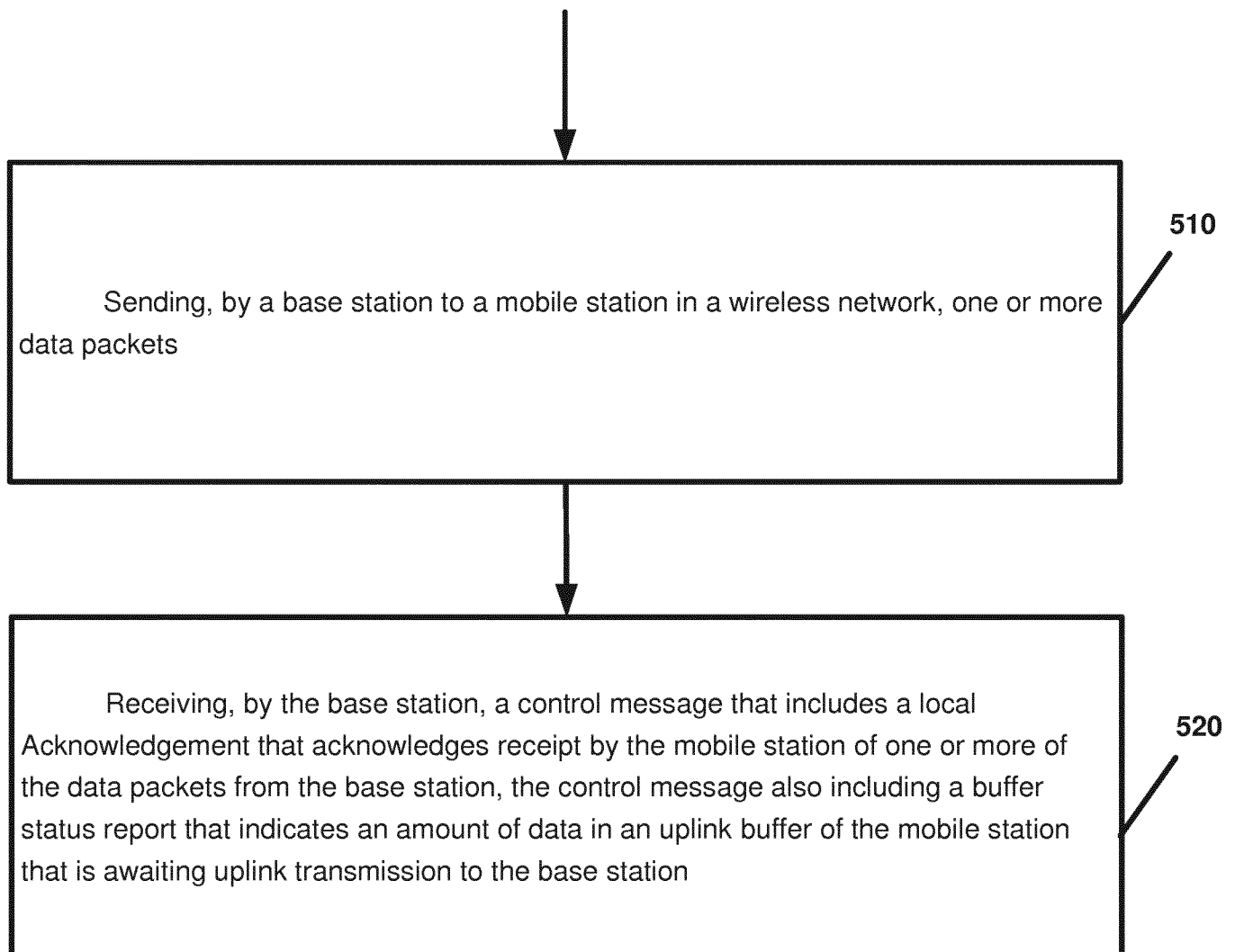
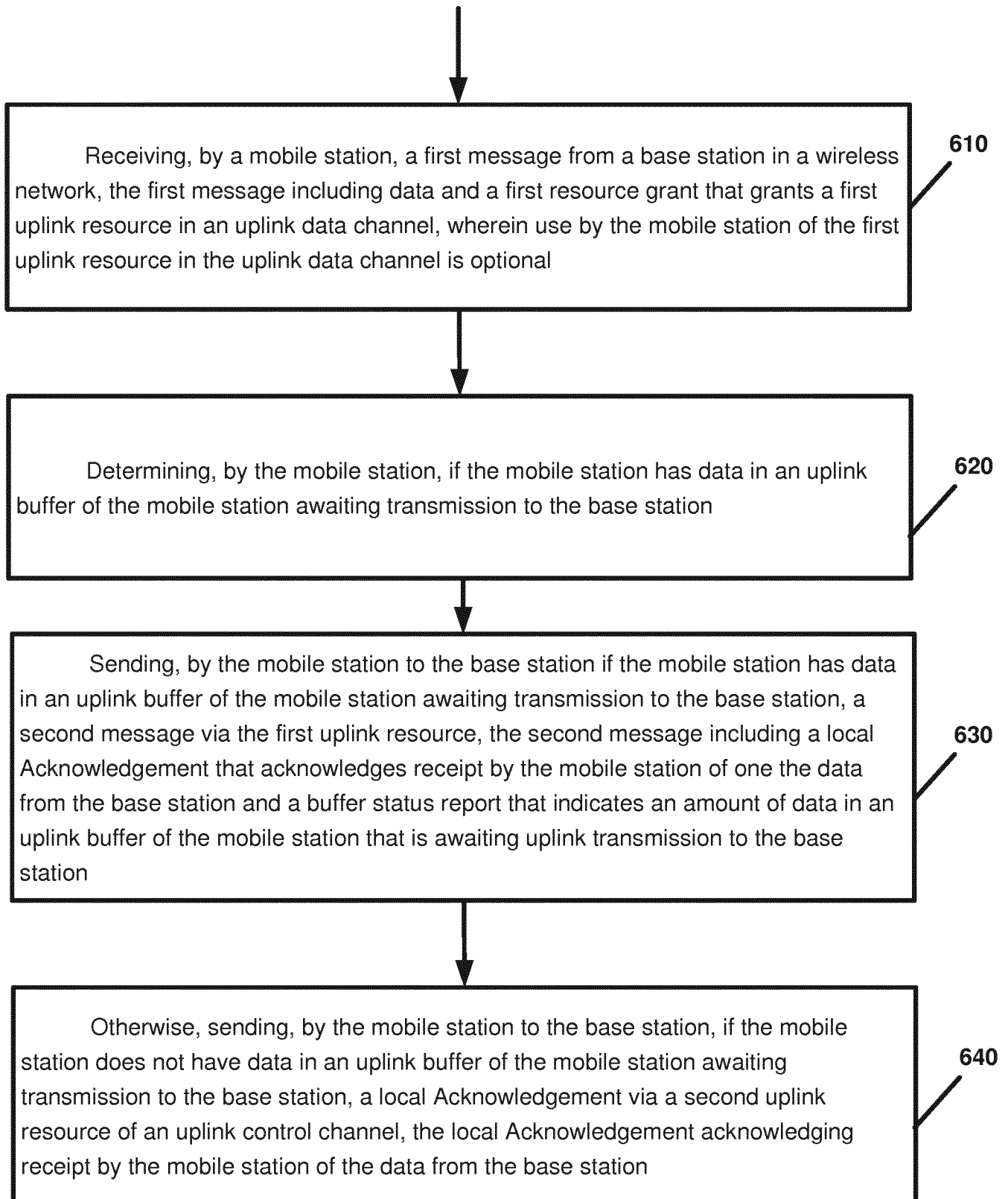


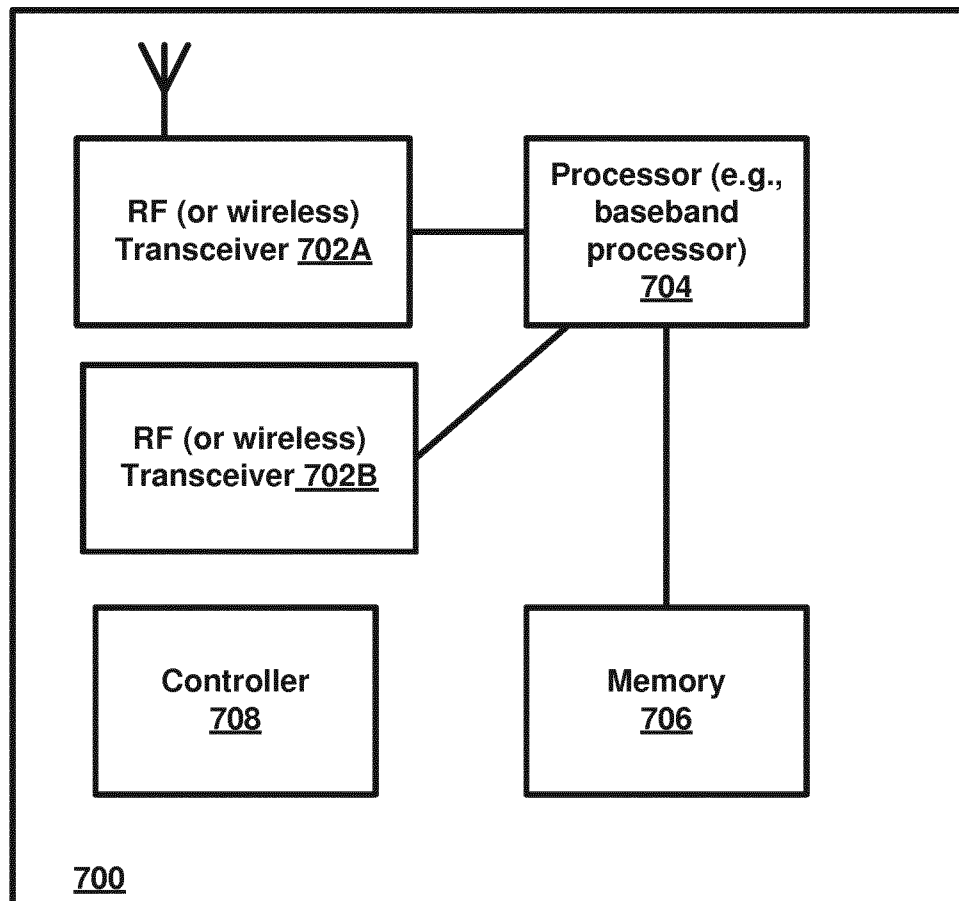
FIG. 3

**FIG. 4**

**FIG. 5**

6/7

**FIG. 6**

**FIG. 7**

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/067508

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/16 H04L1/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, COMPENDEX, INSPEC, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/056266 A1 (MONTJOJO JUAN [DE] ET AL) 27 February 2014 (2014-02-27) page 5, paragraph 67 -----	1-16
X	US 2011/026478 A1 (LEE DAE WON [KR] ET AL) 3 February 2011 (2011-02-03) page 3, paragraph 50 - page 4, paragraph 53 -----	1-16
Y		17-20
Y	AU 2015 203 574 A1 (INTERDIGITAL PATENT HOLDINGS) 23 July 2015 (2015-07-23) page 3, paragraph 11a ----- -/-	17-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

18 March 2016

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01/04/2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/067508

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	QUALCOMM INCORPORATED: "UCI Transmission for CA", 3GPP DRAFT; R1-102746 UCI TRANSMISSION FOR CA, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. Montreal, Canada; 20100510, 4 May 2010 (2010-05-04), XP050419940, [retrieved on 2010-05-04] the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/067508

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