

BACKGROUND

[0001] The present disclosure relates generally to data transmission protocols in mobile communication systems and, more specifically, to systems and methods for controlling dynamic timeslot reduction (DTR) in a communication system during instances when data blocks may potentially be lost or incompletely transmitted.

[0002] As used herein, the terms "mobile station" (MS), "user agent," and "user equipment" (UE) can refer to electronic devices such as mobile telephones, personal digital assistants (PDAs), handheld or laptop computers, and similar devices that have network communications capabilities. In some configurations, MS may refer to a mobile, wireless device. The terms may also refer to devices that have similar capabilities but that are not readily transportable, such as desktop computers, set-top boxes, or network nodes.

[0003] An MS may operate in a wireless communication network that provides for data communications. For example, the MS may operate in accordance with Global System for Mobile Communications (GSM) and General Packet Radio Service (GPRS) technologies. Today, such an MS may further operate in accordance with Enhanced Data rates for GSM Evolution (EDGE), Enhanced GPRS (EGPRS), Enhanced GPRS Phase 2 (EGPRS2), or GSM EDGE Radio Access Network (GERAN).

[0004] To communicate with a network, an MS is configured to use a media access control (MAC) protocol to determine the uplink (UL) and/or downlink (DL) communication resources available for use by the MS. GPRS, for example, uses a timeslot structure similar to that of GSM, but where timeslots are dynamically allocated to MSs both for uplink and downlink transmissions. To communicate with a GPRS network, therefore, an MS may be configured to have a multi-slot capability that enables the MS to use between one (1) and eight (8) timeslots per carrier for data transfer between the MS and network. Because uplink and downlink channels are reserved separately, various multi-slot resource configurations may be assigned in different directions in different communications networks.

[0005] In some cases, an MS may be allocated timeslots on dual carriers. A dual carrier 'assignment' comprises a set of timeslots assigned on two carriers. In the case of an uplink dual carrier assignment, the assignment includes the total set of

timeslots on both carriers that may be used by the MS for uplink transmissions; in the case of a downlink dual carrier assignment, the assignment is the total set of timeslots on both carriers upon which the network may send data to the MS.

[0006] For any given radio block period, the network dynamically allocates resources and determines upon which downlink timeslots or uplink timeslots the MS may receive and/or transmit data. In basic transmission time intervals (BTI), a given radio block period can include 4 TDMA frames with each TDMA frame including 8 timeslots. The allocation algorithm may be implementation dependent, but may take account of the MS's multislot class (the maximum number of timeslots on which the MS can transmit or receive, and the time required to switch from transmit to receive and vice versa), and may take account of the amount of data the network (e.g., a base station controller (BSC)) expects the MS to receive or transmit.

[0007] In some cases, reduced transmission time intervals (RTTI) are used to communication with an MS. RTTI are a modification to the above structure where, instead of a radio block being transmitted as four bursts with each block being sent in a particular timeslot over four TDMA frames, a radio block (containing essentially the same amount of information) is transmitted using two timeslots in two TDMA frames. This reduces the transmission time for a block and reduces the overall latency of the system. Accordingly, a "reduced radio block period" can be 2 TDMA frames (approximately 10ms) compared with a basic radio block period, which can be 4 TDMA frames (approximately 20ms).

[0008] In EGPRS systems, a radio block containing RLC data comprises a header and one or more RLC data blocks. The header (which is relatively robustly encoded) may be successfully decoded independent of the failure or success of decoding the one or more RLC data blocks. The header indicates the sequence number(s) of the RLC data blocks and (for downlink blocks) indicates the identity of the intended recipient MS. Provided that the header was decoded correctly, each of the RLC data blocks may be either successfully or unsuccessfully decoded. For example, in attempting to decode a radio block containing 2 RLC data blocks, an MS may decode the header and one of the RLC data blocks successfully, but may fail to decode the other RLC data block.

[0009] In a network, uplink allocations can be signaled to an MS using an uplink state flag (USF), which is a number between 0 and 7 (inclusive) that is signaled in downlink radio blocks. As part of the MS's uplink assignment, the MS is informed of which USF(s) on which timeslot(s) indicate an uplink allocation for that MS. USFs are generally included in the headers of downlink blocks. In the case of RTTI, USFs

may be coded across radio blocks across four TDMA frames, for example, in the same manner as downlink BTTI radio blocks are sent (e.g., "BTTI USF mode") or (using two timeslots) across two TDMA frames (e.g., "RTTI USF mode").

[0010] In some communication standards, there are "m" timeslots assigned for reception and "n" timeslots assigned for transmission. Thus, for a multislot class type 1 MS, there may be $\text{Min}(m, n, 2)$ reception and transmission timeslots with the same timeslot number. For a multislot class type 2 MS, there may be $\text{Min}(m, n)$ reception and transmission timeslots with the same timeslot number. In the case of downlink dual carrier configurations, if timeslots with the same timeslot number are assigned on both channels, in calculating the value of m they may be counted as one timeslot. As a result, where both downlink and uplink timeslots are assigned, if assigned a single timeslot in one direction and one or more timeslots in the opposite direction, the timeslot number of the first timeslot may be the same as one of the timeslot(s) in the opposite direction. Similarly, if assigned two or more uplink timeslots and two or more downlink timeslots, at least two of the uplink and downlink timeslots may have a common timeslot number. As a result, in uplink+downlink assignments, the timeslots that may be monitored for USFs and downlink data blocks may be largely co-incident. In some networks, assignments and allocations are essentially under the control of the network (for example, the BSC).

[0011] During an ongoing packet data session, for example, an MS with an assigned downlink TBF (temporary block flow) can be required to monitor all downlink timeslots in the MS's assignment in case the network sends the MS data in any of the allocated downlink timeslots. Similarly, if an MS has an assigned uplink TBF, the MS may be required to monitor all timeslots on which the USF (uplink state flag) could be sent to dynamically allocate uplink resources. If an MS has both uplink and downlink TBFs, therefore, the MS must monitor as many relevant downlink timeslots as possible, taking into account any allocated uplink transmissions opportunities.

[0012] In the case that either the network or the MS has no data to send, and particularly when neither the network nor the MS has data to transmit, this monitoring activity results in significant wasted battery power in the MS. To minimize battery power consumption, the assigned resources (e.g., TBF) may be maintained, while the number of timeslots that the MS must monitor is reduced. This reduction in the number of timeslots being monitored can be referred to as DTR.

[0013] Using DTR, an MS (for example an MS operating in packet transfer mode (i.e. with assigned packet resources)) can reduce its battery consumption by

reducing the set of timeslots that the MS monitors for downlink data and/or uplink allocations (as indicated by uplink state flags (USFs)). The MS may monitor only a single timeslot or, in RTTI, a single pair of timeslots per radio block period. As a result, the network may only transmit new data or USFs on timeslots that are actually monitored by the MS. Generally, for an MS in DTR, the transmission or reception of any new data (generally not retransmissions of previously transmitted data) causes the MS to leave DTR mode.

[0014] In various network configurations, there can be two particular mechanisms by which a network can cause an MS to enter DTR mode: option 1 - by transmitting a PACKET UPLINK ACK/NACK (PUAN) control message containing DTR information to the MS, or option 2 - by means of DTR information included within a Radio Link Control (RLC) data block transmitted to the MS.

[0015] In option 1, when a PUAN is used to instruct the MS to enter DTR, one of the conditions that should be met before the MS enters DTR is that no data block has been transmitted or received in the previous $(\max(\text{BS_CV_MAX}, 1) - 1)$ block periods. Here, BS_CV_MAX may be a value indicative of the round trip time for data packets (e.g., packets sent on a Physical Downlink Channel (PDCH) or Packet Associated Control Channel (PACCH)) between the network (or that part of the network that processes data packets) and the MS. The value is made available by the network for use by connected MSs and may be broadcast in system information (SI), for example. A typical value of BS_CV_MAX is 6, corresponding to 6 radio block periods, or approximately 120ms, for example.

[0016] BS_CV_MAX is a useful value as the MS can use the round trip time to determine whether Negative Acknowledgement (NACK) messages received from the network can safely be ignored. If, for example, a NACK that refers to a block that was very recently transmitted to the network by the MS is received from the network, the MS can use BS_CV_MAX to determine whether the NACK refers to the most recently transmitted block, or to a duplicate of the block that was transmitted earlier (such as when an MS retransmits a block to the network). If the most recent transmission of the block took place less than one round-trip time (i.e., BS_CV_MAX radio block periods) prior to reception of the NACK, then the NACK cannot refer to the most recently transmitted block because the network must have transmitted the NACK prior to receiving the most recent block (the NACK cannot be received in less time than BS_CV_MAX). Therefore, the NACK does not refer to the block that was most recently transmitted by the MS and the MS may choose to ignore the NACK

because the network could have safely received the most recent transmission, which would make the NACK moot.

[0017] Generally, in the first option for causing the MS to enter DTR, the condition that no data block has been transmitted or received in the previous $(\max(\text{BS_CV_MAX}, 1) - 1)$ block periods must be met at the time when the PUAN is received; if not, the DTR Information in the PUAN is ignored and the MS will not enter DTR.

[0018] In the second option, when using DTR information included within an RLC data block to cause the MS to enter DTR, the conditions for the MS entering DTR are 1) that any received poll has been responded to, 2) that $V(R) = V(Q)$, and 3) that the block with sequence number $V(R) - 1$ contain DTR information.

[0019] In this option, the parameters $V(R)$, $V(Q)$, $V(N)$ relate to the RLC receive window in the MS that is associated with RLC data blocks. $V(N)$ refers to an array of elements, each of which can take the value INVALID or RECEIVED. $V(R)$ identifies the block sequence number (BSN) of the next expected block (i.e. one more than the highest BSN that has been seen or, in some cases, one higher than the highest BSN whose corresponding data block has been received correctly). $V(Q)$ refers to the lowest BSN identifying a block that has not yet been received correctly. As such, when $V(R) = V(Q)$, the next expected block is also the only one that has not yet been received correctly, meaning that all blocks with lower BSNs have been received correctly. As an example, in a particular block sequence, if an MS has received blocks 1, 2, 3, 4, 5, 9, and 12 of the sequence correctly, $V(R) = 13$ (the next higher BSN after 12), and $V(Q) = 6$ (the lowest BSN of a block that was not received correctly). Alternatively, if an MS has received blocks 1, 2, 3, 4, and 5 correctly, but block 6 was received with errors, $V(R) = 7$ and $V(Q) = 6$. Finally, if an MS has received blocks 1, 2, 3, 4, 5, and 6 correctly, then $V(R) = V(Q) = 7$ (i.e., all blocks 1-6 have been received correctly).

[0020] When using DTR information included within a RLC data block to cause the MS to enter DTR, it may not be necessary that all three conditions be satisfied in any particular order. For example, an MS may first receive blocks 1, 2, 3, and 4, then receive block 7 containing DTR information, and then later receive blocks 5, and 6 (e.g. in response to a request for retransmission). At that end of that sequence, even though all blocks were not received in order and all conditions were not satisfied in order, the MS will enter DTR because $V(Q) = V(R) = 8$, and the block with $\text{BSN} = V(R) - 1$ (i.e. 7) contained DTR information (presuming the MS has responded to any pending polls).

[0021] Note that if the network should subsequently receive an acknowledgement of all blocks up to and including block 7 from the MS, the network can determine that the MS has entered DTR. To trigger such an acknowledgement, the network may poll the MS – polls are indicated by settings of bits (such as in the relative reserved block period (RRBP)/combined EGPRS supplementary polling (CESP) fields) in the header of radio blocks.

[0022] When using DTR information included within a RLC data block to cause the MS to enter DTR, Table 1 illustrates an example EGPRS downlink RLC data block for instructing an MS to enter DTR.

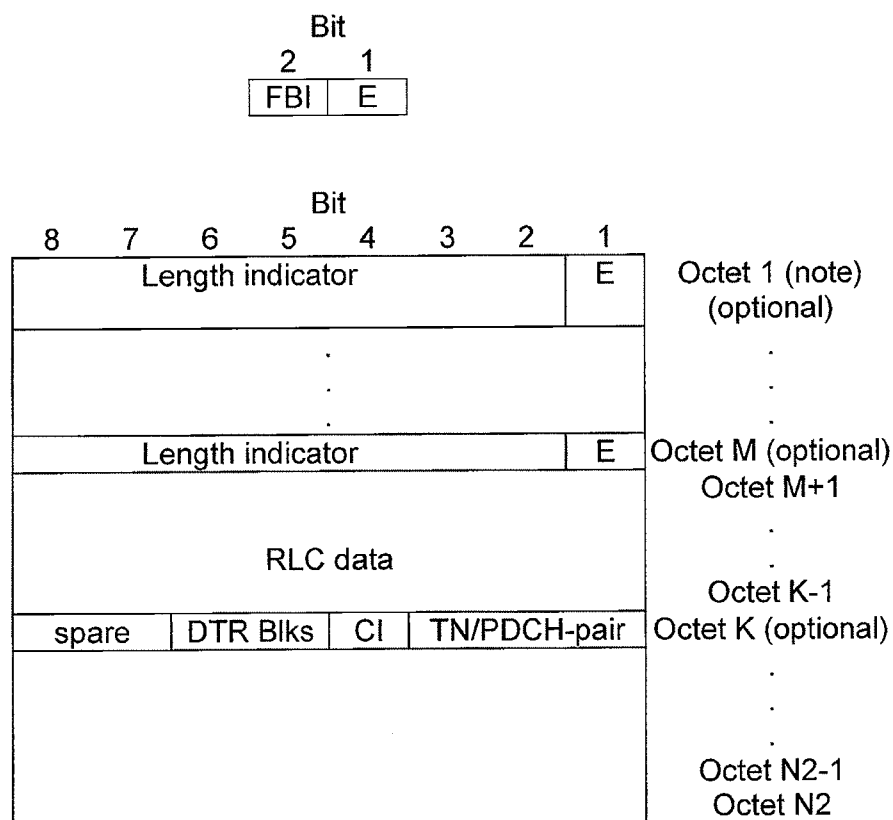


Table 1

[0023] Referring to Table 1, the carrier ID (CI) field contains a identification of the carrier that may be encoded as DTR_CI IE. The CI field can be used to indicate the carrier that the MS monitors when DTR is used. In that case, the timeslot or PDCH-pair to monitor on that carrier can be indicated with the TN/PDCH-pair field. The TN/PDCH-pair field may contain the timeslot number (BTTI configuration) or the PDCH-pair number (RTTI configuration) the MS monitors on the indicated carrier (CI field) when DTR is implemented. Finally, the DTR Blks field may indicate a subset of downlink radio blocks during which the MS monitors for USFs and/or downlink RLC data blocks when in DTR mode. In some cases, when causing an MS to enter DTR,

in both options 1 and 2 described above, there may be a maximum reaction period permitted between the conditions for an MS to enter DTR being satisfied and the MS actually entering DTR. Also, there may be some situations where, though inefficient, the MS may be required to leave DTR only to, soon thereafter, reenter DTR when instructed by the network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] For a more complete understanding of this disclosure, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts.

[0025] Fig. 1 is a diagram illustrating communications between a mobile station and an associated network that result in the mobile station leaving DTR due to the identification of the content of an RLC data block not being received correctly.

[0026] Fig. 2 is a diagram illustrating communications between a mobile station and an associated network operating in accordance with the present disclosure.

[0027] Fig. 3 is a diagram of a wireless communications system including a mobile station operable for some of the various embodiments of the disclosure.

[0028] Fig. 4 is a block diagram of a mobile station operable for some of the various embodiments of the disclosure.

[0029] Fig. 5 is a diagram of a software environment that may be implemented on a mobile station operable for some of the various embodiments of the disclosure.

[0030] Fig. 6 is an illustrative general purpose computer system suitable for some of the various embodiments of the disclosure.

DETAILED DESCRIPTION

[0031] The present disclosure provides a system and method for controlling Dynamic Timeslot Reduction (DTR) in a communications network by allowing the MS to remain in DTR mode if it receives "new data" meeting certain criteria. These criteria are designed so that, with high probability, the MS can distinguish between a block being sent to keep the MS in DTR and any other type of transmission where the network's intention is that the MS leave DTR mode, such as when transmitting large amounts of real "new data," for example, noting that if the amount of new data to be sent is very small, the consequences of mis-detection are limited.

[0032] The method may include a method for operating a mobile station in communication with an associated network. The method includes receiving an assignment of a number of timeslots from the network, monitoring a first set of timeslots in accordance with the assignment, and reducing a number of timeslots monitored to less than the first set of timeslots and monitoring less than the first set of timeslots. The method includes, while monitoring less than the first set of timeslots, receiving a data block within a radio block, and, when the mobile station does not successfully decode the data block and when the mobile station does not successfully decode from the radio block an indication to continue to monitor less than the first set of timeslots, continuing to monitor less than the first set of timeslots.

[0033] Another embodiment includes a method for operating a network to communicate with an associated mobile station. The method includes transmitting an assignment of a number of timeslots to the mobile station, determining that the mobile station has reduced a number of timeslots monitored to a reduced set of timeslots that is less than a first set of timeslots monitored in accordance with the assignment, and, after determining that the mobile station is monitoring the reduced set of timeslots, transmitting a first data block within a radio block. The first data block includes an indication that the mobile station monitor less than the first set of timeslots. The method includes receiving a negative acknowledgment for the first data block, and, before retransmitting the first data block, transmitting a second data block on the reduced set of timeslots. The second data block is substantially free of an indication that the mobile station monitor less than the first set of timeslots.

[0034] Another embodiment includes a mobile station comprising a processor configured to receive an assignment of a number of timeslots from a network, monitor a first set of timeslots in accordance with the assignment, and reduce a number of timeslots monitored to less than the first set of timeslots and monitoring less than the first set of timeslots. The processor is configured to, while monitoring less than the first set of timeslots, receive a data block within a radio block, and, when the mobile station does not successfully decode the data block and when the mobile station does not successfully decode from the radio block an indication to continue to monitor less than the first set of timeslots, continue to monitor less than the first set of timeslots.

[0035] Another embodiment includes a network component comprising a processor configured to transmit an assignment of a number of timeslots to a mobile station, determine that the mobile station has reduced a number of timeslots monitored to a reduced set of timeslots that is less than a first set of timeslots

monitored in accordance with the assignment, and after determining that the mobile station is monitoring the reduced set of timeslots, transmit a first data block within a radio block. The first data block includes an indication that the mobile station monitor less than the first set of timeslots. The processor is configured to receive a negative acknowledgment for the first data block, and before retransmitting the first data block, transmit a second data block on the reduced set of timeslots. The second data block is substantially free of an indication that the mobile station monitor less than the first set of timeslots.

[0036] The various aspects of the disclosure are now described with reference to the annexed drawings, wherein like numerals refer to like or corresponding elements throughout. It should be understood, however, that the drawings and detailed description relating thereto are not intended to limit the claimed subject matter to the particular form disclosed. Rather, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the claimed subject matter.

[0037] As used herein, the terms “component,” “system,” and the like are intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a computer and the computer can be a component. One or more components may reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers.

[0038] The word “exemplary” is used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0039] Furthermore, the disclosed subject matter may be implemented as a system, method, apparatus, or article of manufacture using standard programming and/or engineering techniques to produce software, firmware, hardware, or any combination thereof to control a computer or processor based device to implement aspects detailed herein. The term “article of manufacture” (or alternatively, “computer program product”) as used herein is intended to encompass a computer program accessible from any computer-readable device, channel, or media. For example, computer readable media can include but are not limited to magnetic

storage devices (for example, hard disk, floppy disk, magnetic strips, and the like), optical disks (for example, compact disk (CD), digital versatile disk (DVD), and the like), smart cards, and flash memory devices (for example, card, stick, and the like). Additionally, it should be appreciated that a carrier wave can be employed to carry computer-readable electronic data such as those used in transmitting and receiving electronic mail or in accessing a network such as the Internet or a local area network (LAN). Of course, those skilled in the art will recognize many modifications may be made to this configuration without departing from the scope or spirit of the claimed subject matter.

[0040] Referring to Fig. 1, a diagram illustrating communications between an MS 10 and an associated network 12 is illustrated. Network 12 may include any appropriate network component, such as a component of a wireless communications network configured to communicate with an MS. As illustrated, the MS 10 is in DTR and has previously and correctly received block 5, 6, and 7. Beyond the above examples, one of the motivations for including DTR information in RLC data blocks is to allow for the case where an RLC data block must be sent in order to prevent a "T3190" timer from expiring. In the illustrated example, the MS 10 is subject to a "T3190" timer, which refers to a "Wait for Valid Downlink Data Received from the Network" timer. This T3190 timer is used by the MS 10 to determine when to stop waiting for the valid data to be received from the network 12, either following the initial Packet Downlink Assignment/MBMS Assignment or after some previous downlink RLC data block. Hence, the MS 10 has a V(R) and a V(Q) of 8 and is, thus, expecting block 8 as DTR continues. However, in this situation, as illustrated, there is a risk that the header of a subsequent RLC data block containing block 8 may be received correctly, but the contents, which includes the DTR information, may not be received correctly. This situation would, according to the current specifications, cause the mobile to leave DTR (at least temporarily) as indicated. That is, current implementations require that on receipt of any new data, the MS 10 shall leave DTR. However, in the case where the "new data" is sent where the intention is to keep the MS 10 in DTR (including the case where the "new data" is sent specifically for this purpose) but is incorrectly received, this is counter-productive. For example, as illustrated, the MS 10 leaves DTR and, since the RLC data block containing block 8 (and the DTR information) was not correctly received, sends a PDAN indicating a NACK for block 8, which causes the network 12 to retransmit block 8 and the DTR information. Though inefficient, the MS 10 finally re-enters DTR.

[0041] In such cases, there is therefore a risk of ambiguity as to whether the contents of a data block is to keep the MS in DTR (for example, where the data block is sent to avoid expiration of a timer associated with the reception of such data, such as the T3190 timer) or not (such as when new data is transmitted and the network determines that the MS should leave DTR), in which case the MS should exit DTR). The present disclosure is designed to specify that the MS 10 remains in DTR under certain conditions to efficiently resolve this ambiguity.

[0042] Referring now to Fig. 2, as illustrated, the MS 10 is in DTR already and has received blocks 5, 6, and 7 or otherwise received a block with $BSN = V(R) - 1$. In this case, $V(R) = V(Q)$, or has otherwise met any applicable conditions for entering and remaining in DTR. However, when block 8 is not received correctly $V(R)$ becomes $BSN+1$ and the condition $V(R) = V(Q)$ is no longer met. In this situation, the MS 10 remains in DTR. Additionally or alternatively, in some embodiments, the MS 10 may remain in DTR only if the received block contains a poll, which is quite likely for a DTR block, but less likely if there is further data to come. Additionally or alternatively, in some embodiments, the MS 10 may remain in DTR only if the block was sent using the lowest modulation and coding scheme (MCS) possible (such as, the lowest MCS which can be used for data transmission in accordance with the mode of operation of the assigned resources), which may be a block sent purely for a T3190 refresh (or, more generally, to meet a condition associated with a maximum period between successive transmissions to the MS e.g. to confirm to the MS that assigned resources are still active) and may not contain any other useful information (such as data from higher layers) and therefore could be robustly encoded, since the total quantity of data to be included is low. An example where the MS may remain in DTR independently of the value or presence of a BSN in a received data block (but based on one or more other conditions described above) is where the identity of the addressed MS can be reliably determined after decoding the radio block but no BSN associated with the transmission can be reliably determined (for example, because the radio block did not contain any BSN, or because the BSN is not encoded robustly, or is encoded independently of the identity of the addressed MS). Other criteria that must be met in some embodiments for the MS to remain in DTR are: i) the value of a timer (such as T3190) being close to (e.g. within some pre-determined time from) its expiry; and/or ii) the number of data blocks within the radio block being equal to 1.

[0043] It should be noted that if the network 12 intends that the MS 10 does leave DTR, for example because it has a large amount of new data to transmit, it may send

one or more higher sequence number blocks initially (e.g. BSN = 9 in the example) so that the above condition are guaranteed not to be fully met and the MS will leave DTR. In the illustrated case, the network 12, could, for example, send a block with BSN = 9 before 8. In another example, the network could send block 8 concurrently with a higher-numbered block, for example in the same radio block. Also, if the network 12 only has one block to send and, so, cannot send what the MS 10 considers to be $V(R) + 1$, then having the MS 10 remain in DTR will not degrade performance significantly. This is because only one (1) timeslot is required to retransmit (pre-emptively, or in response to PDAN) the block. In fact, in this case, the network 12 is likely to include DTR information in this single block to keep the MS in DTR mode, so this case could be considered as being a subset of the "remain in DTR mode" case.

[0044] When implementing this solution, if the network wishes the MS 10 to exit DTR, but sends the block with BSN = $V(R)$, there is a risk that the MS 10 will not decode the block correctly and, hence, remain in DTR, as described above. In this case, at least some, subsequent blocks transmitted on non-DTR timeslots would, not be received, resulting in a delay in downlink data transmissions while the MS 10 determines that conditions for leaving DTR have been met, and re-configures itself to receive on the full set of downlink timeslots according to its assignment. However, the exact sequence of events and consequences depend on the subsequent network scheduling of data and polls, and the reaction time allowed for leaving DTR mode. With this said, the above solution for ordering an MS 10 to enter or stay in DTR by means of an RLC data block advantageously handles issues surrounding the existing T3190 timer requirement. However, there is a risk of ambiguity as to the intended DTR status that can arise when the RLC data block is incorrectly decoded and this solution addresses that problem and reduces the risk that the MS 10 leaves DTR when there is actually no further downlink data to be transmitted.

[0045] Therefore, in light of the foregoing, the present disclosure provides a system and method for controlling DTR in a communications network by allowing an MS to remain in DTR mode if it receives a transmission meeting certain criteria. Conversely, in addition, the present disclosure provides a system and method for controlling DTR in a communications network by allowing an MS to leave DTR mode if these criteria are not met. These criteria are designed so that, with high probability, the MS can distinguish between a block being sent to keep the MS in DTR and a block which is intended to cause the MS to leave DTR such as the start

of the transmission of a large amount of data, for example, noting that if the amount of new data to be sent is very small, the consequences of mis-detection are limited.

[0046] During a downlink TBF, the network may transmit the DTR information within downlink RLC data blocks of the TBF. Upon reception of an RLC data block resulting in an empty RLC receive window (i.e. $V(R) = V(Q)$), if the RLC data block with BSN equal to $V(Q) - 1$ modulo SNS contained valid DTR information: i) a mobile station not already in DTR mode shall start monitoring only the indicated PDCH or PDCH-pair (and if applicable, carrier) within the reaction time specified for control messages, and shall enter DTR mode and ii) a mobile station in DTR mode shall assume the DTR information is unchanged and shall therefore remain in DTR mode without attempting to confirm the status of DTR information (i.e. the network shall ensure the DTR information is kept unchanged for this MS while it remains in DTR mode).

[0047] A mobile station in DTR mode may, upon reception of an RLC data block with $BSN = V(R)$ whose contents were not correctly decoded resulting in an RLC receive window such that $V(R) = V(Q) + 1$, assume the RLC data block contained valid DTR information which is unchanged and remain in DTR mode. In some cases, however, the MS is configured to require that additional criteria be met before the MS will remain in DTR. Example criteria include any combination of the following: i) the RLC data block was encoded using the most robust MCS applicable for the TBF, and/or ii) the RLC data block includes a valid poll request (e.g. by means of an RRBP or CES/P field). In the case where the network has new data to send to the MS, to ensure a mobile station leaves DTR mode, the network may be configured to transmit first a block with BSN greater than the MS's $V(R)$.

[0048] Referring now to Fig. 3, a wireless communications system including an embodiment of an exemplary MS 10 is illustrated. The MS is operable for implementing aspects of the disclosure, but the disclosure should not be limited to these embodiments. Though illustrated as a mobile phone, the MS may take various forms including a wireless handset, a pager, a personal digital assistant (PDA), a portable computer, a tablet computer, a laptop computer, smart phones, printers, fax machines, televisions, set top boxes, and other video display devices, home audio equipment and other home entertainment systems, home monitoring and control systems (e.g., home monitoring, alarm systems and climate control systems), and enhanced home appliances such as computerized refrigerators. Many suitable devices combine some or all of these functions. In some embodiments of the disclosure, the MS 10 is not a general purpose computing device like a portable,

laptop or tablet computer, but rather is a special-purpose communications device such as a mobile phone, a wireless handset, a pager, a PDA, or a telecommunications device installed in a vehicle. The MS 10 may also be a device, include a device, or be included in a device that has similar capabilities but that is not transportable, such as a desktop computer, a set-top box, or a network node. The MS 10 may support specialized activities such as gaming, inventory control, job control, and/or task management functions, and so on.

[0049] The MS 10 includes a display 702. The MS 10 also includes a touch-sensitive surface, a keyboard or other input keys generally referred as 704 for input by a user. The keyboard may be a full or reduced alphanumeric keyboard such as QWERTY, Dvorak, AZERTY, and sequential types, or a traditional numeric keypad with alphabet letters associated with a telephone keypad. The input keys may include a track wheel, an exit or escape key, a trackball, and other navigational or functional keys, which may be inwardly depressed to provide further input function. The MS 10 may present options for the user to select, controls for the user to actuate, and/or cursors or other indicators for the user to direct.

[0050] The MS 10 may further accept data entry from the user, including numbers to dial or various parameter values for configuring the operation of the MS 10. The MS 10 may further execute one or more software or firmware applications in response to user commands. These applications may configure the MS 10 to perform various customized functions in response to user interaction. Additionally, the MS 10 may be programmed and/or configured over-the-air, for example from a wireless base station, a wireless access point, or a peer MS 10.

[0051] Among the various applications executable by the MS 10 is a web browser, which enables the display 702 to show a web page. The web page may be obtained via wireless communications with a wireless network access node, a cell tower, a peer MS 10, or any other wireless communication network or system 700. The network 700 is coupled to a wired network 708, such as the Internet. Via the wireless link and the wired network, the MS 10 has access to information on various servers, such as a server 710. The server 710 may provide content that may be shown on the display 702. Alternately, the MS 10 may access the network 700 through a peer MS 10 acting as an intermediary, in a relay type or hop type of connection.

[0052] Fig. 4 shows a block diagram of the MS 10. While a variety of known components of UAs 10 are depicted, in an embodiment a subset of the listed components and/or additional components not listed may be included in the MS 10.

The MS 10 includes a digital signal processor (DSP) 802 and a memory 804. As shown, the MS 10 may further include an antenna and front end unit 806, a radio frequency (RF) transceiver 808, an analog baseband processing unit 810, a microphone 812, an earpiece speaker 814, a headset port 816, an input/output interface 818, a removable memory card 820, a universal serial bus (USB) port 822, a short range wireless communication sub-system 824, an alert 826, a keypad 828, a liquid crystal display (LCD), which may include a touch sensitive surface 830, an LCD controller 832, a charge-coupled device (CCD) camera 834, a camera controller 836, and a global positioning system (GPS) sensor 838. In an embodiment, the MS 10 may include another kind of display that does not provide a touch sensitive screen. In an embodiment, the DSP 802 may communicate directly with the memory 804 without passing through the input/output interface 818.

[0053] The DSP 802 or some other form of controller or central processing unit operates to control the various components of the MS 10 in accordance with embedded software or firmware stored in memory 804 or stored in memory contained within the DSP 802 itself. In addition to the embedded software or firmware, the DSP 802 may execute other applications stored in the memory 804 or made available via information carrier media such as portable data storage media like the removable memory card 820 or via wired or wireless network communications. The application software may comprise a compiled set of machine-readable instructions that configure the DSP 802 to provide the desired functionality, or the application software may be high-level software instructions to be processed by an interpreter or compiler to indirectly configure the DSP 802.

[0054] The antenna and front end unit 806 may be provided to convert between wireless signals and electrical signals, enabling the MS 10 to send and receive information from a cellular network or some other available wireless communications network or from a peer MS 10. In an embodiment, the antenna and front end unit 806 may include multiple antennas to support beam forming and/or multiple input multiple output (MIMO) operations. As is known to those skilled in the art, MIMO operations may provide spatial diversity which can be used to overcome difficult channel conditions and/or increase channel throughput. The antenna and front end unit 806 may include antenna tuning and/or impedance matching components, RF power amplifiers, and/or low noise amplifiers.

[0055] The RF transceiver 808 provides frequency shifting, converting received RF signals to baseband and converting baseband transmit signals to RF. In some descriptions a radio transceiver or RF transceiver may be understood to include

other signal processing functionality such as modulation/demodulation, coding/decoding, interleaving/deinterleaving, spreading/despreading, inverse fast Fourier transforming (IFFT)/fast Fourier transforming (FFT), cyclic prefix appending/removal, and other signal processing functions. For the purposes of clarity, the description here separates the description of this signal processing from the RF and/or radio stage and conceptually allocates that signal processing to the analog baseband processing unit 810 and/or the DSP 802 or other central processing unit. In some embodiments, the RF transceiver 808, portions of the antenna and front end 806, and the analog baseband processing unit 810 may be combined in one or more processing units and/or application specific integrated circuits (ASICs).

[0056] The analog baseband processing unit 810 may provide various analog processing of inputs and outputs, for example analog processing of inputs from the microphone 812 and the headset 816 and outputs to the earpiece 814 and the headset 816. To that end, the analog baseband processing unit 810 may have ports for connecting to the built-in microphone 812 and the earpiece speaker 814 that enable the MS 10 to be used as a cell phone. The analog baseband processing unit 810 may further include a port for connecting to a headset or other hands-free microphone and speaker configuration. The analog baseband processing unit 810 may provide digital-to-analog conversion in one signal direction and analog-to-digital conversion in the opposing signal direction. In some embodiments, at least some of the functionality of the analog baseband processing unit 810 may be provided by digital processing components, for example by the DSP 802 or by other central processing units.

[0057] The DSP 802 may perform modulation/demodulation, coding/decoding, interleaving/deinterleaving, spreading/despreading, inverse fast Fourier transforming (IFFT)/fast Fourier transforming (FFT), cyclic prefix appending/removal, and other signal processing functions associated with wireless communications. In an embodiment, for example in a code division multiple access (CDMA) technology application, for a transmitter function the DSP 802 may perform modulation, coding, interleaving, and spreading, and for a receiver function the DSP 802 may perform despreading, deinterleaving, decoding, and demodulation. In another embodiment, for example in an orthogonal frequency division multiplex access (OFDMA) technology application, for the transmitter function the DSP 802 may perform modulation, coding, interleaving, inverse fast Fourier transforming, and cyclic prefix appending, and for a receiver function the DSP 802 may perform cyclic prefix

removal, fast Fourier transforming, deinterleaving, decoding, and demodulation. In other wireless technology applications, yet other signal processing functions and combinations of signal processing functions may be performed by the DSP 802.

[0058] The DSP 802 may communicate with a wireless network via the analog baseband processing unit 810. In some embodiments, the communication may provide Internet connectivity, enabling a user to gain access to content on the Internet and to send and receive e-mail or text messages. The input/output interface 818 interconnects the DSP 802 and various memories and interfaces. The memory 804 and the removable memory card 820 may provide software and data to configure the operation of the DSP 802. Among the interfaces may be the USB interface 822 and the short range wireless communication sub-system 824. The USB interface 822 may be used to charge the MS 10 and may also enable the MS 10 to function as a peripheral device to exchange information with a personal computer or other computer system. The short range wireless communication sub-system 824 may include an infrared port, a Bluetooth interface, an IEEE 802.11 compliant wireless interface, or any other short range wireless communication sub-system, which may enable the MS 10 to communicate wirelessly with other nearby mobile devices and/or wireless base stations.

[0059] The input/output interface 818 may further connect the DSP 802 to the alert 826 that, when triggered, causes the MS 10 to provide a notice to the user, for example, by ringing, playing a melody, or vibrating. The alert 826 may serve as a mechanism for alerting the user to any of various events such as an incoming call, a new text message, and an appointment reminder by silently vibrating, or by playing a specific pre-assigned melody for a particular caller.

[0060] The keypad 828 couples to the DSP 802 via the interface 818 to provide one mechanism for the user to make selections, enter information, and otherwise provide input to the MS 10. The keyboard 828 may be a full or reduced alphanumeric keyboard such as QWERTY, Dvorak, AZERTY and sequential types, or a traditional numeric keypad with alphabet letters associated with a telephone keypad. The input keys may include a track wheel, an exit or escape key, a trackball, and other navigational or functional keys, which may be inwardly depressed to provide further input function. Another input mechanism may be the LCD 830, which may include touch screen capability and also display text and/or graphics to the user. The LCD controller 832 couples the DSP 802 to the LCD 830.

[0061] The CCD camera 834, if equipped, enables the MS 10 to take digital pictures. The DSP 802 communicates with the CCD camera 834 via the camera

controller 836. In another embodiment, a camera operating according to a technology other than Charge Coupled Device cameras may be employed. The GPS sensor 838 is coupled to the DSP 802 to decode global positioning system signals, thereby enabling the MS 10 to determine its position. Various other peripherals may also be included to provide additional functions, e.g., radio and television reception.

[0062] Fig. 5 illustrates a software environment 902 that may be implemented by the DSP 802. The DSP 802 executes operating system drivers 904 that provide a platform from which the rest of the software operates. The operating system drivers 904 provide drivers for the UA hardware with standardized interfaces that are accessible to application software. The operating system drivers 904 include application management services ("AMS") 906 that transfer control between applications running on the MS 10. Also shown in the figure are a web browser application 908, a media player application 910, and Java applets 912. The web browser application 908 configures the MS 10 to operate as a web browser, allowing a user to enter information into forms and select links to retrieve and view web pages. The media player application 910 configures the MS 10 to retrieve and play audio or audiovisual media. The Java applets 912 configure the MS 10 to provide games, utilities, and other functionality. A component 914 might provide functionality described herein.

[0063] The MS 10, access device 120, and other components described above might include a processing component that is capable of executing instructions related to the actions described above. Fig. 6 illustrates an example of a system 1000 that includes a processing component 1010 suitable for implementing one or more embodiments disclosed herein. In addition to the processor 1010 (which may be referred to as a central processor unit (CPU or DSP), the system 1000 might include network connectivity devices 1020, random access memory (RAM) 1030, read only memory (ROM) 1040, secondary storage 1050, and input/output (I/O) devices 1060. In some embodiments, a program for implementing the determination of a minimum number of HARQ process IDs may be stored in ROM 1040. In some cases, some of these components may not be present or may be combined in various combinations with one another or with other components not shown. These components might be located in a single physical entity or in more than one physical entity. Any actions described herein as being taken by the processor 1010 might be taken by the processor 1010 alone or by the processor 1010 in conjunction with one or more components shown or not shown in the drawing.

[0064] The processor 1010 executes instructions, codes, computer programs, or scripts that it might access from the network connectivity devices 1020, RAM 1030, ROM 1040, or secondary storage 1050 (which might include various disk-based systems such as hard disk, floppy disk, or optical disk). While only one processor 1010 is shown, multiple processors may be present. Thus, while instructions may be discussed as being executed by a processor, the instructions may be executed simultaneously, serially, or otherwise by one or multiple processors. The processor 1010 may be implemented as one or more CPU chips.

[0065] The network connectivity devices 1020 may take the form of modems, modem banks, Ethernet devices, universal serial bus (USB) interface devices, serial interfaces, token ring devices, fiber distributed data interface (FDDI) devices, wireless local area network (WLAN) devices, radio transceiver devices such as code division multiple access (CDMA) devices, global system for mobile communications (GSM) radio transceiver devices, worldwide interoperability for microwave access (WiMAX) devices, and/or other well-known devices for connecting to networks. These network connectivity devices 1020 may enable the processor 1010 to communicate with the Internet or one or more telecommunications networks or other networks from which the processor 1010 might receive information or to which the processor 1010 might output information.

[0066] The network connectivity devices 1020 might also include one or more transceiver components 1025 capable of transmitting and/or receiving data wirelessly in the form of electromagnetic waves, such as radio frequency signals or microwave frequency signals. Alternatively, the data may propagate in or on the surface of electrical conductors, in coaxial cables, in waveguides, in optical media such as optical fiber, or in other media. The transceiver component 1025 might include separate receiving and transmitting units or a single transceiver. Information transmitted or received by the transceiver 1025 may include data that has been processed by the processor 1010 or instructions that are to be executed by processor 1010. Such information may be received from and outputted to a network in the form, for example, of a computer data baseband signal or signal embodied in a carrier wave. The data may be ordered according to different sequences as may be desirable for either processing or generating the data or transmitting or receiving the data. The baseband signal, the signal embedded in the carrier wave, or other types of signals currently used or hereafter developed may be referred to as the transmission medium and may be generated according to several methods well known to one skilled in the art.

[0067] The RAM 1030 might be used to store volatile data and perhaps to store instructions that are executed by the processor 1010. The ROM 1040 is a non-volatile memory device that typically has a smaller memory capacity than the memory capacity of the secondary storage 1050. ROM 1040 might be used to store instructions and perhaps data that are read during execution of the instructions. Access to both RAM 1030 and ROM 1040 is typically faster than to secondary storage 1050. The secondary storage 1050 is typically comprised of one or more disk drives or tape drives and might be used for non-volatile storage of data or as an over-flow data storage device if RAM 1030 is not large enough to hold all working data. Secondary storage 1050 may be used to store programs that are loaded into RAM 1030 when such programs are selected for execution.

[0068] The I/O devices 1060 may include liquid crystal displays (LCDs), touch screen displays, keyboards, keypads, switches, dials, mice, track balls, voice recognizers, card readers, paper tape readers, printers, video monitors, or other well-known input devices. Also, the transceiver 1025 might be considered to be a component of the I/O devices 1060 instead of or in addition to being a component of the network connectivity devices 1020. Some or all of the I/O devices 1060 may be substantially similar to various components depicted in the previously described drawing of the MS 10, such as the display 702 and the input 704.

[0069] While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods may be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted, or not implemented.

[0070] Also, techniques, systems, subsystems and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as coupled or directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device, or intermediate component, whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

What is claimed is:

1. A method for operating a mobile station in communication with a network, comprising:
 - receiving an assignment of first timeslots for uplink communications;
 - receiving an instruction to enter a dynamic timeslot reduction (DTR) mode, the DTR mode causing the mobile station to reduce monitoring to a set of timeslots, the set of timeslots having a number of timeslots less than a number of timeslots to be monitored in accordance with the assignment;
 - while the mobile station is in DTR mode and monitoring the set of timeslots, receiving a data block within a radio block; and
 - when the mobile station does not successfully decode the data block and when the mobile station does not successfully decode from the radio block an indication to continue to monitor the set of timeslots:
 - continuing to operate the mobile station in the DTR mode, and continuing to monitor the set of timeslots having a number of timeslots less than a number of timeslots to be monitored in accordance with the assignment.
2. The method of claim 1 wherein the data block has an associated block sequence number (BSN) greater than a previously received BSN.
3. The method of claim 2 wherein the associated BSN is one greater than a highest BSN previously received by the mobile station.
4. The method of claim 3 wherein BSNs of previously received data blocks were successfully decoded.
5. The method of claim 1, further comprising receiving and successfully decoding a poll request within the radio block, wherein the poll request is associated with the radio block.

6. The method of claim 1 wherein the radio block has a predetermined modulation and coding scheme (MCS).
7. The method of claim 1, wherein the portion of the data block that was not coded correctly includes a part that may contain an order for the mobile station to continue to monitor less than the assigned number of timeslots.
8. The method of claim 1 further comprising:
 - receiving another data block after receiving the data block and continuing to monitor less than the first set of timeslots;
 - determining a BSN associated with the another data block; and
 - when the BSN associated with the another data block is greater than a BSN associated with the data block, resuming monitoring the first set of timeslots in accordance with the assignment.
9. The method of claim 1 wherein the step of continuing to monitor less than the first set of timeslots is additionally conditioned upon at least one of:
 - when the data block includes a data block having an associated block sequence number (BSN) greater than a previously received BSN;
 - when the data block includes a data block having an associated block sequence number (BSN) that is one greater than a previously received BSN;
 - when previously received data blocks with lower BSNs than the BSN associated with the data block were successfully decoded by the mobile station;
 - when the radio block is free of a data block other than the received data block; or
 - when the mobile station successfully decodes from the radio block a poll request.
10. The method of claim 9 wherein a data block associated with the previously received BSN contained an indication instructing the MS to enter the DTR mode.

11. The method of claim 1 wherein the radio block comprises the received data block and a second data block.

12. A method for operating a network to communicate with an associated mobile station, comprising:

transmitting an assignment of a number of timeslots to the mobile station;

determining that the mobile station is operating in a dynamic timeslot reduction (DTR) mode and has reduced a number of timeslots monitored to a reduced set of timeslots that is less than a first set of timeslots monitored in accordance with the assignment;

after determining that the mobile station is operating in the DTR mode, transmitting a first data block within a radio block, the first data block including an indication that the mobile station monitor less than the first set of timeslots;

receiving a negative acknowledgment for the first data block;

determining that the mobile station is continuing to operate in the DTR mode and is monitoring the reduced set of timeslots; and

before retransmitting the first data block, transmitting a second data block on the reduced set of timeslots, wherein the second data block is free of an indication that the mobile station monitor less than the first set of timeslots.

13. The method of claim 12 wherein the first data block includes a poll request associated with the first data block.

14. The method of claim 12 wherein the first data block has a predetermined modulation and coding scheme (MCS).

15. A mobile station, comprising:

a processor, the processor being configured to:

receive an assignment of a number of timeslots from a network;

monitor a first set of timeslots in accordance with the assignment;

reduce a number of timeslots monitored to less than the first set of timeslots and monitoring less than the first set of timeslots;

while monitoring less than the first set of timeslots, receive a data block within a radio block; and

when the mobile station does not successfully decode the data block and when the mobile station does not successfully decode from the radio block an indication to continue to monitor less than the first set of timeslots, continue to monitor the set of timeslots having a number of timeslots less than a number of time slots to be monitored in accordance with the assignment.

16. The mobile station of claim 15 wherein the data block has an associated block sequence number (BSN) greater than a previously received BSN.

17. The mobile station of claim 16 wherein the associated BSN is one greater than a highest BSN previously received by the mobile station.

18. The mobile station of claim 17 wherein BSNs of previously received data blocks were successfully decoded.

19. The mobile station of claim 15 wherein the processor is configured to receive and successfully decoding a poll request within the radio block, wherein the poll request is associated with the data block.

20. The mobile station of claim 15 wherein the radio block has a predetermined modulation and coding scheme (MCS).

21. The mobile station of claim 15 wherein the portion of the data block that was not decoded correctly includes a part that may contain an order for the mobile station to continue to monitor less than the assigned number of timeslots.

22. The mobile station of claim 15 wherein the processor is configured to:
receive another data block after receiving the data block and continuing to monitor less than the first set of timeslots;
determine a BSN associated with the another data block; and

when the BSN associated with the another data block is greater than a BSN associated with the data block, resume monitoring the first set of timeslots in accordance with the assignment.

23. The mobile station of claim 15 wherein continuing to monitor less than the first set of timeslots is additionally conditioned upon at least one of:

when the data block includes a data block having an associated block sequence number (BSN) greater than a previously received BSN;

when the data block includes a data block having an associated block sequence number (BSN) that is one greater than a previously received BSN;

when previously received data blocks with lower BSNs than the BSN associated with the data block were successfully decoded by the mobile station;

when the radio block is free of a data block other than the received data block; or

when the mobile station successfully decodes from the radio block a poll request.

24. The mobile station of claim 23 wherein a data block associated with the previously received BSN contained an indication instructing the MS to enter DTR mode.

25. The mobile station of claim 15 wherein the radio block comprises the received data block and a second data block.

26. A network component, comprising:

a processor, the processor being configured to:

transmit an assignment of a number of timeslots to a mobile station;

determine that the mobile station has reduced a number of timeslots monitored to a reduced set of timeslots that is less than a first set of timeslots monitored in accordance with the assignment;

after determining that the mobile station is monitoring the reduced set of timeslots, transmit a first data block within a radio block, the first data block

including an indication that the mobile station monitor less than the first set of timeslots;

receive a negative acknowledgment for the first data block;

determine that the mobile station is continuing to monitor the reduced set of timeslots; and

before retransmitting the first data block, transmit a second data block on the reduced set of timeslots, wherein the second data block is free of an indication that the mobile station monitor less than the first set of timeslots.

27. The network component of claim 26 wherein the first data block includes a poll request associated with the first data block.

28. The network component of claim 26 wherein the first data block has a predetermined modulation and coding scheme (MCS).