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(56) Documents Cited:
R2-1814365, 3GPP TSG-RAN WG2 Meeting #103b, Chengdu, P.R.China, 08th-12th October 2018, Ericsson, 'Uplink Scheduling in IAB Networks'.

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Other: **WPI, EPODOC, SEARCH-PATENT, SEARCH-NPL**

(54) Title of the Invention: **Improvements in and relating to scheduling latency in a telecommunication system**
Abstract Title: **Improvements in and relating to scheduling latency in a telecommunication system**

(57) A method performed by a network node (IAB Node B) in a wireless communication system wherein the network node detects at least one triggering event of a pre-emptive buffer status report (BSR), transmits the pre-emptive BSR S120 to a parent network node (IAB node C) in the case that the at least one triggering event is detected, wherein a format of the pre-emptive BSR is indicated by a logical channel identifier (LCID) value and wherein the pre-emptive BSR comprises information indicating an amount of data expected to arrive at the network node. The LCID value of the pre-emptive BSR is different from an LCID value indicating a format of a BSR that is different from the pre-emptive BSR and the information indicating the amount of data to be expected to arrive comprises expected data volume calculated across at least one logical channel of at least one logical channel group (LCG). A network node comprising a processor configured to perform the method is also claimed.

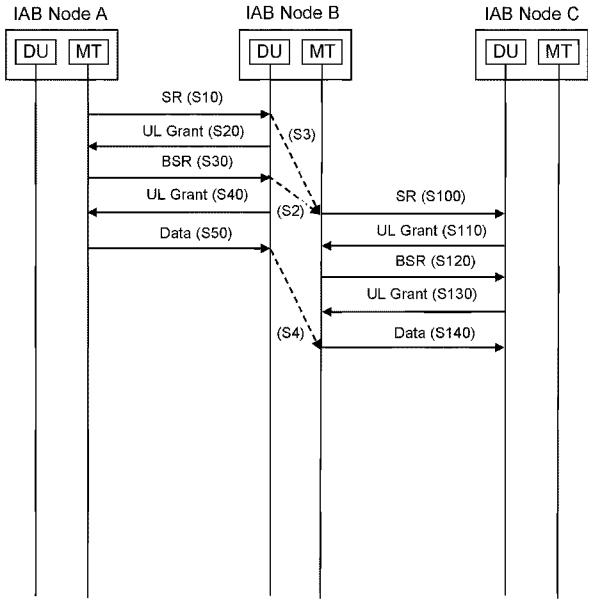

Fig. 2

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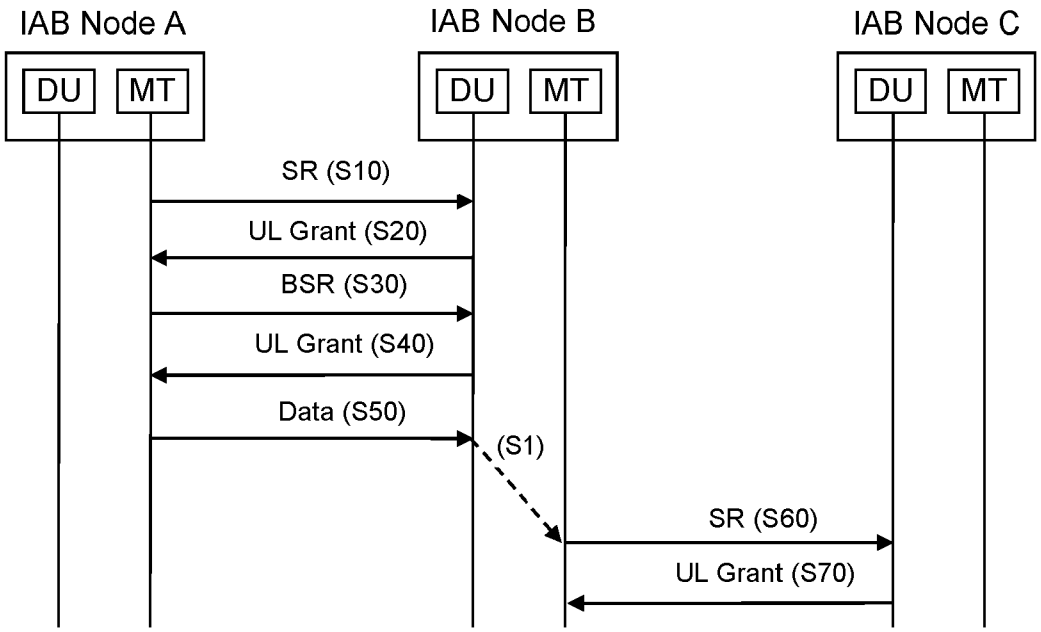
IAB Node A
IAB Node B
IAB Node C
DU
MT
DU
MT
DU
MT
SR (S10)
UL Grant (S20)
BSR (S30)
UL Grant (S40)
Data (S50)
(S1)
SR (S60)
UL Grant (S70)

Fig. 1

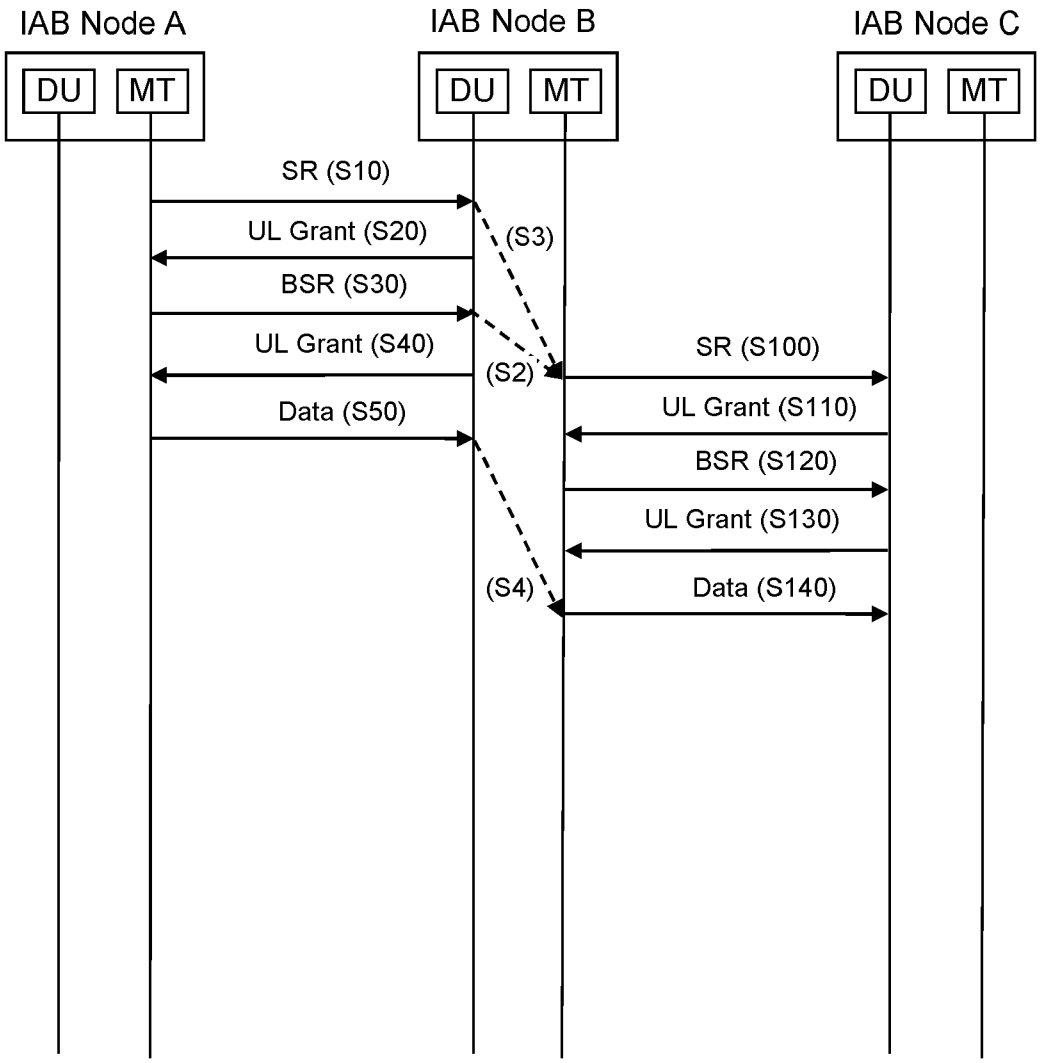
IAB Node A
IAB Node B
IAB Node C
DU
MT
DU
MT
DU
MT
SR (S10)
UL Grant (S20)
(S3)
BSR (S30)
UL Grant (S40)
SR (S100)
(S2)
UL Grant (S110)
Data (S50)
BSR (S120)
UL Grant (S130)
(S4)
Data (S140)

Fig. 2

Improvements in and relating to scheduling latency in a telecommunication system

The present invention relates to the reduction of scheduling latency in a telecommunication system. In particular, it relates to a problem with latency in a system implementing Integrated Access and Backhaul (IAB). This is known and used in at least Fifth Generation (5G) or New Radio (NR) systems.

An IAB node features, at least conceptually, a base station part or Distributed Unit (DU) and a Mobile Telephone (MT) part. The MT part can currently only request uplink (UL) resources for the UL data transmission after it actually receives the data to be transmitted from its child node, despite already having knowledge of incoming data. In a multi-hop network, any such latency delays are likely to accumulate due to the number of hops and aggregated volume of data at IAB nodes. This is illustrated in Figure 1, which shows the worst-case scenario where neither of the IAB nodes A or B have any UL resource currently allocated to them.

In Figure 1, there is a typical telecommunication network shown, which uses several IAB nodes in a multi-hop configuration. Data is passed from Node A to Node B to Node C and onward. In the prior art, when Node A (the child) needs to transmit data to Node B (the parent), it transmits a message (S10) comprising a Scheduling Request (SR). Node B responds with a UL grant message (S20) allocating some capacity to Node A. Node A then transmits a Buffer Status Report (BSR) message (S30). This indicates to Node B the quantity of data which it needs to transmit. Node B responds with a further UL grant message (S40) allocating a suitable capacity to Node A to transmit its data, which it does in message S50.

If there is capacity already available for Node A to signal to Node B that a substantial amount of data needs transmitting, then steps S10 and S20 may be omitted and Node A may be able to transmit its BSR message (S30) directly.

Once Node B receives the data at its DU, its MT sends a new scheduling request message (S60) to Node C. Node C responds with a UL grant message (S70) and the same pattern of steps as already set out (i.e. identical to S30 to S50) is repeated between Nodes B and C.

Importantly, in this arrangement, Node B is not able to request resources from Node C until it has received the data (S50). This dependence is indicated by dashed arrow S1.

It is an aim of embodiments of the present invention to address issues in the prior art, such as that set out above.

According to the present invention there is provided an apparatus and method as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

According to an aspect of the present invention, there is provided a method of requesting resources from a node in a multi-node telecommunication system, wherein a first node transmits data to a second node and the second node transmits the data to a third node, comprising the steps of: the first node indicating to the second node that it has data intended for the second node; the second node, in response, determining whether to request resources from the third node; and the third node providing resources to the second node based, in part, on the request from the second node; and the second node transmitting the data received from the first node to the third node.

In an embodiment, the step of the first node indicating to the second node that it has data intended for the second node comprises the first node transmitting either a Scheduling Request, SR, message or a Buffer Status Report, BSR, message.

In an embodiment, the step of the second node, in response, requesting resources from the third node occurs before the second node receives the data transmitted from the first node.

In an embodiment, the step of the second node, in response, requesting resources from the third node further comprises the step of only requesting resources if one or more additional criteria are met.

In an embodiment, the one or more additional criteria includes information from the first node indicating:

- the presence of data in the first node of a specific type or pertaining to a specific service; or
- the presence of data of high priority; or
- the presence of data of a certain priority relative to priority of existing data in the node's own buffers; or
- the total buffer occupancy at the first node is above a certain threshold; or
- that the amount of data of a specific type or pertaining to a specific service or of high priority, is above a certain threshold; or

- the presence of data which will require a certain number of hops above a defined threshold to reach its destination; or
- the presence of data, the transmission of which will require a type of resource which is not already configured.

In an embodiment, the information from the first node is included in a Buffer Status Report, BSR.

In an embodiment, the one or more additional criteria includes the second node determining that its time to grant for the first node and/or the time until resources referenced in the grant are available is above a defined threshold.

In an embodiment, the one or more additional criteria includes the second node determining that it cannot provide resources to the first node within a defined period.

In an embodiment, the one or more additional criteria includes the use by the first node of a particular configuration on which to send the resource request, which indicates that the resource request is originated at least in part by:

- a logical channel of high priority; or
- a logical channel of a certain priority relative to priority of existing data in the node's own buffers; or
- a logical channel dedicated to a specific service or with data of high priority, is above a defined threshold; or
- a logical channel with data which will require a defined number of hops above a defined threshold to reach its destination; or
- a logical channel with data which will require a type of resource which is not already configured.

In an embodiment, the information from the first node is included in a Scheduling Request, SR.

In an embodiment, the step of the second node, in response, requesting resources from the third node comprises forwarding, to the third node, a buffer status of the first node.

In an embodiment, the step of the second node, in response, requesting resources from the third node comprises transmitting information to the third node relating to full or partial buffer status of the first node, converted to the status of the second node buffers.

In an embodiment, the full or partial buffer status of the first node, converted to the status of the second node buffers comprises matching priorities of logical channels and/or services provided by logical channels to obtain a cumulative value comprising actual buffer status of the second node and expected change of the buffer status of the second node.

In an embodiment, the information transmitted to the third node is either:
(a) indicative of an expected increase of the buffer status of the second node after data from the first node is received; or
(b) indicative of a combination with existing data in the second node buffers.

In an embodiment, in the case of option (a), the information comprises an indication that it relates to the expected increase.

In an embodiment, in the case of option (b), the information comprises an indication that it relates to the total amount of data.

In an embodiment, the information transmitted to the third node includes a deduction in expected buffer status occupancy based on UL resource already granted to the second node.

In an embodiment, the expected increase in buffer status or the combination with existing data in the second node buffers is included when resources allocated to the second node have padding, a size of which is equal to or larger than the size of expected buffer status or the combination with existing data in the second node buffers plus any associated subheader or control element.

In an embodiment, a padding size is smaller than the total size of actual buffer status and the expected increase or the combination with existing data in the second node buffers, whereby a determination, based on prioritization, is made as to which information is transmitted.

In an embodiment, the determination, based on prioritization, is made on the basis of how recently information on existing buffer status has been transmitted.

According to a second aspect of the present invention, there is provided apparatus arranged to perform the method of the first aspect.

According to a third aspect of the present invention, there is provided a telecommunication network comprising a plurality of base stations, each operable to perform the method of the first aspect.

Although a few preferred embodiments of the present invention have been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention, as defined in the appended claims.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example only, to the accompanying diagrammatic drawings in which:

Figure 1 shows a prior art message exchange involving three nodes in a multi-hop IAB network arrangement; and

Figure 2 shows a message exchange according to at least one embodiment of the present invention.

Figure 2 illustrates more than one embodiment of the present invention by means of a message exchange involving Nodes A, B and C.

In a first embodiment, Node A sends an SR message (S10), as in the prior art, and Node B responds with a UL Grant message (S20). Node A then sends a BSR message (S30). At this point, the embodiment of the invention differs from the prior art. Upon receipt of the BSR message (S30), Node B is aware of the quality and quantity of data which is destined for onward transmission to Node C and so transmits an SR message (S100) to Node C. Node C responds with a UL grant message (S110). Meanwhile, Node A, in response to a UL grant message (S40) from Node B, transmits is data (S50) to Node B.

Once Node B receives the UL grant message (S110) from Node C, it transmits a new BSR message (S120) to Node C, based on the information it has received from Node A in its BSR message (S30). Node C responds with a UL Grant (S130) and Node B transmits the data (S140) to Node C. Note that in certain circumstances, Node C may not comply with the request from Node B if, for instance, it supplies resources of its own accord or if it is otherwise unable to comply due to capacity or other operational reasons. However, in the case where Node B requests resources, Node C will consider the request and decide whether to provide the requested resources.

In this case, the dashed arrow S2 represents the link between Node B learning from Node A the details of the data to be forwarded to Node C and Node B consequently taking action.

The dotted arrow S4 indicates the data flowing from Node B to Node C. Note that this is earlier than in the case of the prior art (Figure 1) where the data from Node A must be received at Node B before any request is even made to forward it to Node C. In this embodiment, Node B is able to pre-empt the need to request capacity and so certain activities are conducted in parallel, as shown.

By use of the embodiments set out above, latency can be reduced an overall increase in system performance is experienced. However, it is possible to further improve performance by means of other trigger mechanisms to pre-empt the need to request capacity.

However, it may not be desirable to for Node B to request UL resources from Node C in every situation when it is aware of data arriving from Node A. To do so could be wasteful in terms of the finite resources which are available. As such, in embodiments of the invention, the request of resources from node C by means of SR (S100) is not automatic and is triggered if one or more of the following conditions is met:

- BSR (S30) from node A indicates the presence of data in child node (node A) of a specific type / pertaining to a specific service;
- BSR (S30) from node A indicates the presence of data of high priority;
- BSR (S30) from node A indicates the presence of data of a certain priority relative to priority of existing data in the node's own buffers; or
- BSR (S30) from node A indicates that the total buffer occupancy at the child node is above a certain threshold (which can be configurable);
- BSR (S30) from node A indicates that the amount of data of a specific type / pertaining to a specific service / of high priority is above a certain threshold;
- BSR (S30) from node A indicates the presence of data which will require a certain number of hops above a certain (configurable) threshold to reach its destination;
- BSR (S30) from node A indicates the presence of data, the transmission of which will require a type of resource that is not already configured (e.g. a different type of carrier / bandwidth part / numerology).

In a further embodiment, the new BSR (S120) from node B to node C is triggered only if node B determines that the time-to-grant for its child node and/or the time until resources referenced in the grant are available is above a certain threshold.

In a still further embodiment, the new BSR (S120) from node B to node C is not triggered if node B determines that it cannot give resources to its child node within a reasonable (configurable) time window.

The embodiments described so far relate to new BSR triggers based on reception of BSR (S30) from the child node (node A). Embodiments of the invention also relate to new BSR triggers based on reception of SR (S10) from the child node. In this way, an even earlier request can be made. This is represented by dashed arrow S3 in Figure 2. Many of the examples cited above apply equally here.

However, as mentioned previously, it may not be desirable for Node B to request UL resources from Node C in every situation when it is aware of data arriving from Node A. To do so could be wasteful in terms of the finite resources which are available. As such, in another embodiment, the new BSR (S120) is only triggered if, as well as reception of SR (S10) from the child node (node A), one or more of the following conditions is met:

- SR configuration (used for transmission of the SR) is configured for a logical channel of high priority;
- SR configuration is configured for a logical channel of a certain priority relative to priority of existing data in the node's own buffers; or
- SR configuration is configured for logical channel dedicated to a specific service / with data of high priority is above a certain threshold;
- SR configuration is configured for logical channel with data which will require a certain number of hops above a certain (configurable) threshold to reach its destination;
- SR configuration is configured for a logical channel with data which will require a type of resource that is not already configured (e.g. a different type of carrier / bandwidth part / numerology)..

In this context, SR configuration refers to a collection of resources where a node/terminal is allowed to send the SR, more specifically a set of PUCCH resources. In NR there are multiple such sets (called configurations), and which one is used indicates certain properties of the channel that triggered the SR.

In an embodiment, the new BSR (S120) is generated and transmitted when UL resources are allocated to node B and the number of padding bits is equal to or larger than the size of the BSR (S120) according to its subheader. When examining the padding size, the existing BSR (S30) can be prioritized over the new BSR (S120). Alternatively, the new BSR (S120) can be prioritized over the existing BSR (S30). This decision may be made based on how recently the existing BSR (S30) has been sent. It will also depend on whether the new BSR (S120) comprises the existing BSR, for which, see below.

Embodiments of the invention additionally relate to the format of the new BSR (S120), and its content.

For any of the above embodiments, the BSR in question (S120) only reports the total amount of data in the buffers of its child node (node A). In a further embodiment, the BSR (S120) reports the full (or partial) buffer status of the child node (node A) buffers but converted to the status of its own (node B) buffers, meaning that, in other words, node B will calculate the expected change in the occupancy of its own Logical Channel Groups (LCGs) or a subset thereof, if e.g. a padding BSR is sent if the data was to be received as reported in a BSR by node A.

In a further embodiment, this calculation takes into account any existing grants already given to node B by node C and deducts any reductions in buffer status occupancy expected based on available UL resource. Further, the new BSR (S120) uses a different format (indicated e.g. by a flag/reserved bit/LCID) making it clear that this is the “expected data BSR”. In cases where this new BSR indicates cumulative occupancy (current + expected data), this may be sent as two separate BSRs.

In an embodiment, according to the foregoing detail, three different types of buffer status are defined:

1. Current data only (existing BSR, as known in the prior art)
2. Current data + expected data (new BSR Type A)
3. Expected data only (new BSR Type B)

Embodiments of the invention operate with a mix of option 1 and at least one of options 2 and 3.

In another embodiment, the new BSR (S120) includes additional data on top of buffer occupancy data, including one or more of:

- Time when the child node BSR (S30) was received;
- Time when the reception of data (S50) from child node is expected;
- Time when the child node SR (S10) was received;
- Time when node B expects to give UL grant (S40) to node A.

In another embodiment, node C can configure reporting of the new BSR (S120) with certain periodicity, and/or on occasions when node B is polled. Node C can also prohibit reporting of the new BSR (S120) over a certain period of time.

The embodiments described so far have focused on node B having only one parent node (node C). Embodiments also relate to situations where node B has multiple parent nodes. This includes, but is not limited to, the case of dual connectivity. In this case, embodiments of the invention also relate to:

- New BSR (S120) is only sent to one of the parent nodes node (e.g. Master node, or node where bulk of grants are expected to come from based on past history, or node where bulk of grants are expected to come from based on known destination addresses of past packets from this child node, or node where bulk of grants are expected to come from based on known IDs of configured DRBs from this child node, or node which node B would prefer to get a grant from);
- New BSR (S120) is sent to a subset or all of the parent nodes in identical copies;
- New BSR (S120) is sent to a subset or all of the parent nodes but the reported expected data occupancy is split across the multiple reports according to some configurable threshold.

As can be seen from the foregoing, embodiments of the present invention permit the earlier provision of resources in a network comprising a plurality of IAB nodes, such that latency is decreased. Furthermore, by use of secondary triggers, as defined in the foregoing, it is possible to optimise the use of finite resources by not allocating capacity in the network unless certain criteria are satisfied.

At least some of the example embodiments described herein may be constructed, partially or wholly, using dedicated special-purpose hardware. Terms such as ‘component’, ‘module’ or ‘unit’ used herein may include, but are not limited to, a hardware device, such as circuitry in the form of discrete or integrated components, a Field Programmable Gate Array (FPGA) or Application Specific Integrated Circuit (ASIC), which performs certain tasks or provides the associated functionality. In some embodiments, the described elements may be configured to reside on a tangible, persistent, addressable storage medium and may be configured to execute on one or more processors. These functional elements may in some embodiments include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables. Although the example embodiments have been described with reference to the components, modules and units discussed herein, such functional elements may be combined into fewer elements or separated into additional elements. Various combinations of optional features have been described herein, and it will be appreciated that described features may be combined in any

suitable combination. In particular, the features of any one example embodiment may be combined with features of any other embodiment, as appropriate, except where such combinations are mutually exclusive. Throughout this specification, the term “comprising” or “comprises” means including the component(s) specified but not to the exclusion of the presence of others.

Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A method performed by a network node in a wireless communication system, the method comprising:

detecting at least one triggering event of a pre-emptive buffer status report (BSR); and

transmitting the pre-emptive BSR to a parent network node of the network node in case that the at least one triggering event is detected,

wherein a format of the pre-emptive BSR is indicated by a logical channel identifier (LCID) value,

wherein the pre-emptive BSR comprises information indicating an amount of data expected to arrive at the network node from a user equipment (UE) or a child network node of the network node,

wherein the LCID value indicating the format of the pre-emptive BSR is different from an LCID value indicating a format of a BSR that is different from the pre-emptive BSR, and

wherein the information indicating the amount of the data expected to arrive comprises expected data volume calculated across at least one logical channel of at least one logical channel group (LCG).

2. The method of claim 1, wherein the at least one triggering event comprises an event that an uplink grant is provided to the UE or the child network node.

3. The method of claim 1, wherein the at least one triggering event comprises an event that a BSR is received from the UE or the child network node.

4. The method of claim 1, wherein the format of the pre-emptive BSR is different from the format of the BSR that is different from the pre-emptive BSR.

5. The method of claim 1, further comprising receiving a scheduling request (SR) from the UE or the child network node, wherein the transmitting of the pre-emptive BSR to the parent network node comprises transmitting the pre-emptive BSR based on configuration of the SR.

6. The method of claim 1, wherein the transmitting of the pre-emptive BSR to the parent network node comprises transmitting the pre-emptive BSR based on a priority of the data expected to arrive.

7. The method of claim 6, wherein the transmitting of the pre-emptive BSR based on the priority of the data expected to arrive comprises transmitting the pre-emptive BSR in case that the priority of the data expected to arrive is higher than a priority of data present in a buffer of the network node.

8. The method of claim 1, wherein the transmitting of the pre-emptive BSR to the parent network node comprises transmitting the pre-emptive BSR based on number of hops required for the data to reach destination of the data.

9. A network node in a wireless communication system, the network node comprising:

a transceiver; and

at least one processor configured to:

detect at least one triggering event of a pre-emptive buffer status report (BSR), and control the transceiver to transmit the pre-emptive BSR to a parent network node of the network node in the case that the at least one triggering event is detected,

wherein a format of the pre-emptive BSR is indicated by a logical channel identifier (LCID) value,

wherein the pre-emptive BSR comprises information indicating an amount of data expected to arrive at the network node from a user equipment (UE) or a child network node of the network node,

wherein the LCID value indicating the format of the pre-emptive BSR is different from an LCID value indicating a format of a BSR that is different from the pre-emptive BSR, and

wherein the information indicating the amount of the data expected to arrive comprises expected data volume calculated across at least one logical channel of at least one logical channel group (LCG).

10. The network node of claim 9, wherein the at least one triggering event comprises an event that an uplink grant is provided to the UE or the child network node.

11. The network node of claim 9, wherein the at least one triggering event comprises an event that a BSR is received from the UE or the child network node.

12. The network node of claim 9, wherein the format of the pre-emptive BSR is different from the format of the BSR that is different from the pre-emptive BSR.

13. The network node of claim 9, wherein the at least one processor is further configured to:

control the transceiver to receive a scheduling request (SR) from the UE or the child network node, and

control the transceiver to transmit the pre-emptive BSR to the parent network node based on configuration of the SR.

14. The network node of claim 9, wherein the at least one processor is further configured to control the transceiver to transmit the pre-emptive BSR to the parent network node based on a priority of the data expected to arrive.

15. The network node of claim 14, wherein the at least one processor is further configured to control the transceiver to transmit the pre-emptive BSR to the parent network node in case that the priority of the data expected to arrive is higher than a priority of data present in a buffer of the network node.

16. The network node of claim 9, wherein the at least one processor is further configured to control the transceiver to transmit the pre-emptive BSR to the parent network node based on number of hops required for the data to reach destination of the data.

Intellectual Property Office

Application No:	GB2310767.5	**Examiner:**	Mr James Richards
Claims searched:	1-16	**Date of search:**	17 August 2023

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	R2-1814365, 3GPP TSG-RAN WG2 Meeting #103b, Chengdu, P.R.China, 08th-12th October 2018, Ericsson, 'Uplink Scheduling in IAB Networks'.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

H04B; H04W

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, SEARCH-PATENT, SEARCH-NPL

International Classification:

Subclass	Subgroup	Valid From
H04W	0088/04	01/01/2009
H04B	0007/15	01/01/2006
H04W	0028/02	01/01/2009
H04W	0028/18	01/01/2009
H04W	0072/12	01/01/2023
H04W	0084/04	01/01/2009