Every time new data from the first VoIP bearer arrives in the UE a buffer status report and a scheduling request is triggered as described above. Once the eNode B receives the buffer status report, it cannot know from which of the two configured VoIP bearers the data reported on in the buffer status report stems from. Hence, the eNode B needs to give a dynamic grant to the UE in order to assure a speedy and correct data delivery.

As can be seen in Fig. 9, if data from the second VoIP bearer arrives in the UE buffer, the buffer is once again empty and a new buffer status report and a scheduling request is triggered. Since the eNode B already received data of the first radio bearer on the dynamically allocated resources, it knows that the data reported in the new buffer status report must be from the second VoIP bearer. If the eNodeB received the buffer status well before the next TTI in which the UE has been assigned semi-persistently allocated resources, the eNode B could override the semi-persistently allocated resources with a dynamic uplink grant that fits the size of the data of the second VoIP bearer, which means that both the data of the first and the second VoIP bearer can be transmitted on the overwritten semi-persistently allocated uplink resources. However, if the buffer status report arrives too late in the eNode B, the eNode B needs to signal an additional dynamic uplink grant that will allocate dynamically allocated resources in a TTI after the TTI where the semi-persistently allocated uplink resources are configured. This can result in unnecessary segmentation and delay to the data of the VoIP bearers.

SUMMARY OF THE INVENTION

Embodiments of the invention propose a new buffer status reporting scheme that avoids unnecessary grants from the network. Advantageously, this new buffer status reporting scheme should be operable in configurations where one or more semi-persistently scheduled radio bearers are configured for a communication node.

Embodiments of the invention suggest a new handling of the resource usage in systems, where radio resources can be allocated according to different scheduling modes. Advantageously, the new resource usage scheme is co-operating with the new buffer status reporting scheme.

Embodiments of the invention suggest a new scheduling scheme that is taking advantage of the new buffer status reporting scheme and/or handling of the resource usage.

According to a first aspect of the present invention, there is provided an integrated circuit structured to control operation of a mobile terminal, the integrated circuit comprising one or more processing devices configured to: receive a semi-persistent scheduling activation transmitted from a base station to the mobile terminal via a physical downlink control channel signaling; when semi-persistent scheduling is not activated, cause the mobile terminal to transmit a scheduling request to the base station in order to request uplink resources for uplink transmission including transmission of a buffer status report; and when semi-persistent scheduling is activated, check a setup information element of a respective logical channel to determine whether to trigger a scheduling request or not, wherein, when a determination is made to trigger the scheduling request, the step of transmitting the scheduling request to the base station is performed by the mobile terminal for the logical channel, when a determination is made not to trigger the scheduling request, the step of transmitting the scheduling request to the base station is not performed by the mobile terminal, the physical downlink control channel signaling is received by the mobile terminal from the base station for activation of a scheduling mode, including a dynamic scheduling mode in which radio resources are dynamically allocated by dynamic grants and a semi-persistent scheduling mode in which radio resources are allocated on a semi-persistent basis by semi-persistent scheduling grants, and the setup information element is considered in the transmission of the buffer status report.

According to a second aspect of the present invention, there is provided a method for a mobile terminal comprising: receiving, by the mobile terminal, a semi-persistent scheduling activation from a base station via physical downlink control channel signaling; transmitting, by the mobile terminal, a scheduling request to the base station in order to request uplink resources for uplink transmission including transmission of a buffer status report when semi-persistent scheduling is not activated; when semi-persistent scheduling is activated, checking, by the mobile terminal, a setup information element of a respective logical channel to determine whether to trigger a scheduling request or not; when determining, by the mobile terminal, to trigger the scheduling request, transmitting, by the mobile terminal, the scheduling request to the base station for the logical channel; when determining, by the mobile terminal, not to trigger the scheduling request, not

transmitting, by the mobile terminal, the scheduling request to the base station; and considering, by the mobile terminal, the setup information element in the transmission of the buffer status report, wherein the physical downlink control channel signaling is received by the mobile terminal from the base station for activation of a scheduling mode, including a dynamic scheduling mode in which radio resources are dynamically allocated by dynamic grants and a semi-persistent scheduling mode in which radio resources are allocated on a semi-persistent basis by semi-persistent scheduling grants.

According to a third aspect of the present invention, there is provided a mobile terminal comprising: a receiver that receives a semi-persistent scheduling activation from a base station via physical downlink control channel signaling; and a transmitter that transmits a scheduling request to the base station in order to request uplink resources for uplink transmission including transmission of a buffer status report when semi-persistent scheduling is not activated, wherein when semi-persistent scheduling is activated, the mobile terminal checks a setup information element of a respective logical channel to determine whether to trigger a scheduling request or not, when the mobile terminal determines to trigger the scheduling request, the transmitter transmits the scheduling request to the base station for the logical channel, when the mobile terminal determines not to trigger the scheduling request, the transmitter does not transmit the scheduling request to the base station, the physical downlink control channel signaling is received by the mobile terminal from the base station for activation of a scheduling mode, including a dynamic scheduling mode in which radio resources are dynamically allocated by dynamic grants and a semi-persistent scheduling mode in which radio resources are allocated on a semi-persistent basis by semi-persistent scheduling grants, and the mobile terminal considers the setup information element in the transmission of the buffer status report.

Disclosed herein is a transmission scheme for buffer status reports in a mobile communication system. It is assumed that the scheduler of the radio resources of the mobile communication systems can utilize different scheduling modes for allocating radio resource. According to this aspect of the invention, the triggering and/or generation of the status buffer reports takes into account the scheduling mode of the respective radio bearer's data of which available for transmission in a communication node, e.g. a mobile terminal/user equipment. Given that data of a radio bearer is pending for transmission in a communication node, the decision on

whether or not to report on the data of the radio bearer in the status buffer report is depending on the radio bearer's scheduling mode and the status thereof. If no radio bearer of which data is available for transmission in a buffer of the communication node is fulfilling given criteria for inclusion to the buffer status report, an empty buffer status report may be sent (e.g. in case of a periodic buffer status report).

One embodiment thereof provides a method for transmitting a buffer status report by a communication node in a mobile communication system. The method comprises generating a buffer status report taking into account the scheduling mode of a respective radio bearer and the scheduling mode status of the respective radio bearer to decide whether data of a respective radio bearer is considered in the buffer status report, and transmitting the buffer status report, if there is any radio bearer's data to be considered in the buffer status report. As explained above, if there is no data of any radio bearer considered to fulfil the given set of criteria, the buffer status report is "empty" and is not sent.

Furthermore, also the triggering mechanism of buffer status reports as such (e.g. by some non-periodic event) may consider the scheduling mode. For example, the arrival of new data in a transmission buffer of a communication node may be triggering a buffer status report only, if certain criteria related to the scheduling mode of the radio bearer to which the data belong are fulfilled. For example, if the data arriving in the transmission buffer is data of a semi-persistently scheduled radio bearer and an activated semi-persistent resource allocation is taking into account this semi-persistently scheduled radio bearer, no buffer status report is triggered. In a further example, if a trigger event is depending on data already present in the transmission buffer upon the arrival of new data in the transmission buffer, already present data of semi-persistently scheduled radio

Disclosed herein is a new utilization of the allocated radio resources in a mobile communication system, where radio resources can be allocated by means of different scheduling modes. In this respect, a further embodiment of the invention provides a method for generating a transport block for transmission on an allocated radio resource. According to this method, data of at least one radio bearer is multiplexed to a transport block taking into account the scheduling mode of a respective radio bearer and the and scheduling mode status of the respective radio bearer. Furthermore, the multiplexing also takes into account whether the allocated radio resource is a semi-persistently allocated radio resource or a dynamically allocated radio resource. Upon having generated the transport block, same is transmitted on the allocated radio resource.

In one exemplary implementation, it is checked whether the allocated radio resource is a semi-persistently allocated radio resource or a dynamically allocated radio resource. If the allocated radio resource is a dynamically allocated radio resource, the following data of radio bearers are multiplexed to the transport block, as available for transmission:

- buffer status reports (e.g. respective MAC control elements comprising the buffer status reports),

- data of dynamically scheduled radio bearers,

- data of semi-persistently scheduled radio bearers, if semi-persistent resource allocation has not yet been activated, and

- data of semi-persistently scheduled radio bearers not considered in the current semi-persistent resource allocation, if semi-persistent resource allocation has been activated .

If the allocated radio resource is a semi-persistently allocated radio resource, data of those semi-persistently scheduled radio bearers are multiplexed to the transport block, as available for transmission, that are considered in the current semi-persistent resource allocation. As available for transmission means that only data of those radio bearers which have data in the transmission buffer may be multiplexed. If no data of a radio bearer is pending for transmission, no data of this can be multiplexed to the transport block.

Using the multiplexing rules as defined above, it can be assured that data of semi-persistently scheduled radio bearers is always transmitted on the semi-persistently

Accordingly, the communication node to transmit the transport block will code the transport block according to the modulation and coding scheme to obtain coded data and will modulate the coded data according the modulation and coding scheme to obtain at least one modulation symbol. The at least one modulation symbol is then transmitted on the allocated radio resource.

As indicated above, the method for transmitting a buffer status report according to any exemplary embodiment described herein may be readily combined with the method for generating a transport block for transmission on an allocated radio resource according to any exemplary embodiment described herein. By combining the methods, i.e. the multiplexing of data of radio bearers to a transport block depending on the type of radio resource allocation (dynamic or semi-persistent) in combination with the rules on data of which radio bearers is reported in the buffer status report provides the receiver of buffer status reports and transport blocks, commonly a base station (eNode B), with additional information on the status of the transmitter, commonly a mobile terminal (user equipment), which may be for example exploited in an optimized scheduling, as will be outlined below.

As indicated above, another embodiment of the invention is an optimized scheduling of mobile terminals by a base station, which may be *inter alia* optimized on the (additional) information implicit to the buffer status reports from the mobile terminals and their transmissions on the uplink. Accordingly, a further embodiment of the invention is related to a method for scheduling radio resources in a mobile communication system. The scheduler allocates radio resources to mobile terminal on a dynamic and semi-persistent basis. The scheduler determines the scheduling mode of radio bearers of which data is comprised in a transport block received from the mobile terminal on a dynamically allocated radio resource and reactivates a semi-persistent resource allocation of the mobile terminal (reactivates means that an already activated semi-persistent resource allocation is activated again), based on the scheduling mode of the respective radio bearers of which data is comprised in a transport block.

In more detail and exemplarily considering the multiplexing behaviour as discussed previously herein, if data of a semi-persistently scheduled radio bearer is comprised in the transport block transmitted on a dynamically allocated radio resource, this could be taken as an indication that the semi persistent resource allocation for the mobile terminal is not taking into account data of such radio bearer yet. Accordingly, the scheduler may decide to reactivate the semi-persistent resource allocation to account for the data of

semi-persistently scheduled radio bearer (i.e. to change the semi-persistent configuration of radio resources for semi-persistently scheduled radio bearers).

If considering the exemplary case of a semi-persistently scheduled radio bearer carrying an IP-based service employing IP header compression, such as for example VoIP, it may be advantageous if the reactivation of the semi-persistent resource allocation of the mobile terminal is performed upon the data rate of the data of the semi-persistently scheduled radio bearer is in a steady state. In this example, the data of the semi-persistently scheduled radio bearer may be for example transmitted on the dynamically allocated radio resource until the data rate, respectively size of the data packets reaches a steady state.

In a further embodiment of the invention the radio bearers of which data is comprised in a transport block received from the mobile terminal on semi-persistently scheduled radio resource is monitored a the semi-persistent resource allocation of the mobile terminal can be further reactivated or even deactivated based on whether or not a respective semi-persistently scheduled radio bearer configured for the mobile terminal is active or not, i.e. whether its service is generating data for transmission or not.

A further embodiment of the invention is the implementation of the different methods described herein in hardware and/or software. Accordingly, another embodiment of the invention relates to a mobile terminal for transmitting a buffer status report in a mobile communication system. The mobile terminal comprises a processing unit for generating a buffer status report taking into account the scheduling mode of a respective radio bearer and status of the scheduling mode to decide whether data of a respective radio bearer is considered in the buffer status report, and a transmitter for transmitting the buffer status report, if there is any radio bearer's data to be considered in the buffer status report.

Furthermore, in a more specific embodiment of the invention, when deciding on whether data of the respective radio bearer is considered in the buffer status report, the processing unit is adapted to take into account:

- the activation status of the semi-persistent resource allocation, and
- if the semi-persistent resource allocation is activated, whether or not a respective semi-persistently scheduled bearer is considered in the presently configured semi-persistent resource allocation.

CLAIMS:

1. An integrated circuit structured to control operation of a mobile terminal, the integrated circuit comprising one or more processing devices configured to:

receive a semi-persistent scheduling activation transmitted from a base station to the mobile terminal via a physical downlink control channel signaling;

when semi-persistent scheduling is not activated, cause the mobile terminal to transmit a scheduling request to the base station in order to request uplink resources for uplink transmission including transmission of a buffer status report; and

when semi-persistent scheduling is activated, check a setup information element of a respective logical channel to determine whether to trigger a scheduling request or not,

wherein, when a determination is made to trigger the scheduling request, the step of transmitting the scheduling request to the base station is performed by the mobile terminal for the logical channel,

when a determination is made not to trigger the scheduling request, the step of transmitting the scheduling request to the base station is not performed by the mobile terminal,

the physical downlink control channel signaling is received by the mobile terminal from the base station for activation of a scheduling mode, including a dynamic scheduling mode in which radio resources are dynamically allocated by dynamic grants and a semi-persistent scheduling mode in which radio resources are allocated on a semi-persistent basis by semi-persistent scheduling grants, and

the setup information element is considered in the transmission of the buffer status report.

2. The integrated circuit according to claim 1, which is further configured to trigger the scheduling request, in order to request uplink resources for transmitting the buffer status report, when semi-persistent scheduling is not activated, there are no uplink resources allocated for a transmission time interval, and the buffer status report has not been triggered.

3. The integrated circuit according to claim 1, wherein an activation status of a semi-persistent resource allocation is considered in the transmission of the buffer status report.

4. The integrated circuit according to claim 1, wherein a scheduling mode status is considered when deciding on which data of logical channels is reported in the buffer status report.

5. The integrated circuit according to claim 4, wherein the scheduling mode status is an activation of the semi-persistent scheduling or a deactivation of the semi-persistent scheduling.

6. A method for a mobile terminal comprising:

receiving, by the mobile terminal, a semi-persistent scheduling activation from a base station via physical downlink control channel signaling;

transmitting, by the mobile terminal, a scheduling request to the base station in order to request uplink resources for uplink transmission including transmission of a buffer status report when semi-persistent scheduling is not activated;

when semi-persistent scheduling is activated, checking, by the mobile terminal, a setup information element of a respective logical channel to determine whether to trigger a scheduling request or not;

when determining, by the mobile terminal, to trigger the scheduling request, transmitting, by the mobile terminal, the scheduling request to the base station for the logical channel;

when determining, by the mobile terminal, not to trigger the scheduling request, not transmitting, by the mobile terminal, the scheduling request to the base station; and

considering, by the mobile terminal, the setup information element in the transmission of the buffer status report,

wherein the physical downlink control channel signaling is received by the mobile terminal from the base station for activation of a scheduling mode, including a dynamic scheduling mode in which radio resources are dynamically allocated by dynamic grants and a semi-persistent scheduling mode in which radio resources are allocated on a semi-persistent basis by semi-persistent scheduling grants.

7. The method according to claim 6, further comprising:

transmitting, by the mobile terminal, the scheduling request in order to request uplink resources for transmitting the buffer status report, when semi-persistent scheduling is not activated, there are no uplink resources allocated for a transmission time interval, and the buffer status report has not been triggered.

8. The method according to claim 6, further comprising:

considering, by the mobile terminal, an activation status of a semi-persistent resource allocation in the transmission of the buffer status report.

9. The method according to claim 6, further comprising:

considering, by the mobile terminal, a scheduling mode status when deciding on which data of logical channels to report in the buffer status report.

10. The method according to claim 9, wherein the scheduling mode status is an activation of the semi-persistent scheduling or a deactivation of the semi-persistent scheduling.

11. A mobile terminal comprising:

a receiver that receives a semi-persistent scheduling activation from a base station via physical downlink control channel signaling; and

a transmitter that transmits a scheduling request to the base station in order to request uplink resources for uplink transmission including transmission of a buffer status report when semi-persistent scheduling is not activated,

wherein when semi-persistent scheduling is activated, the mobile terminal checks a setup information element of a respective logical channel to determine whether to trigger a scheduling request or not,

when the mobile terminal determines to trigger the scheduling request, the transmitter transmits the scheduling request to the base station for the logical channel,

when the mobile terminal determines not to trigger the scheduling request, the transmitter does not transmit the scheduling request to the base station,

the physical downlink control channel signaling is received by the mobile terminal from the base station for activation of a scheduling mode, including a dynamic scheduling mode in which radio resources are dynamically allocated by dynamic grants and a semi-persistent scheduling mode in which radio resources are allocated on a semi-persistent basis by semi-persistent scheduling grants, and

the mobile terminal considers the setup information element in the transmission of the buffer status report.

12. The mobile terminal according to claim 11, wherein

the transmitter transmits the scheduling request in order to request uplink resources for transmitting the buffer status report, when semi-persistent scheduling is not activated, there are no uplink resources allocated for a transmission time interval, and the buffer status report has not been triggered.

13. The mobile terminal according to claim 11, wherein

the mobile terminal considers an activation status of a semi-persistent resource allocation in the transmission of the buffer status report.

14. The mobile terminal according to claim 11, wherein

the mobile terminal considers a scheduling mode status when deciding on which data of logical channels to report in the buffer status report.

15. The mobile terminal according to claim 14, wherein the scheduling mode status is an activation of the semi-persistent scheduling or a deactivation of the semi-persistent scheduling.