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(54) **METHOD FOR PRIORITY BASED QUEUING AND ASSEMBLING OF PACKETS**

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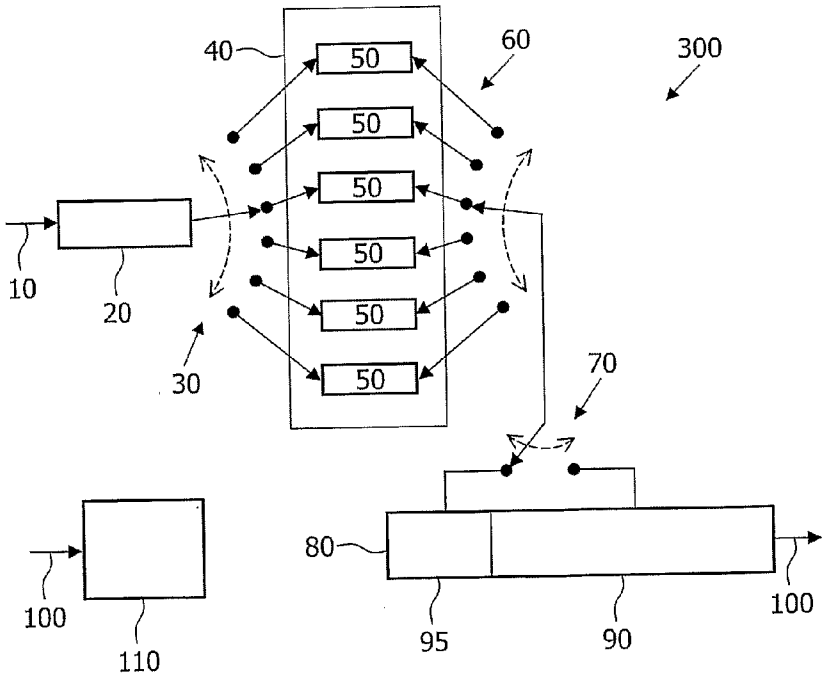
(57) **ABSTRACT**

Data packets having different assigned priorities are multiplexed by operating a queue for each different priority of data packet and assembling groups (**80**) of the data packets for transmission. Each group has two portions. A first portion (**90**) of the group is populated with data packets selected from one or more of the queues according to a first rule and a second portion (**95**) of the group is populated with data packets selected from one or more of the queues according to a second rule. Preferably the first portion contains data packets having the highest priority, and the second portion contains a selection of the data packets having a lower a priority. Selection of data packets for the second portion may depend on criteria such as delay experienced and queue length. The size of the first and second portions may be adapted according to delay experienced and queue length.



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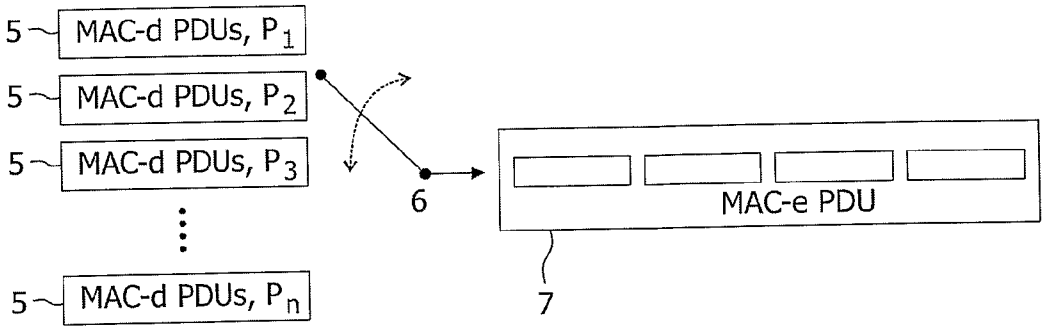

FIG. 1 PRIOR ART

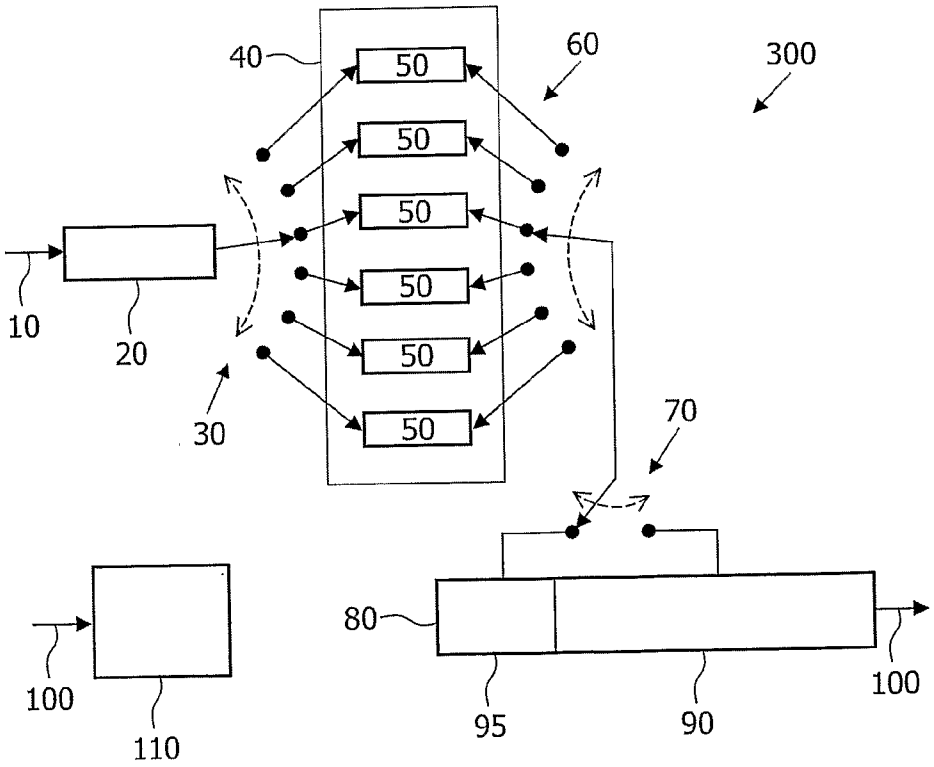

FIG. 2

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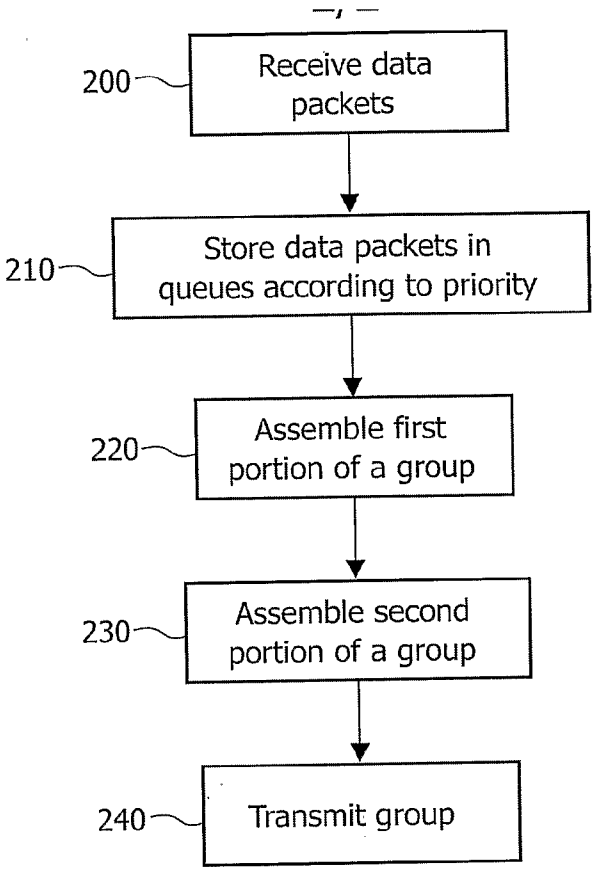

FIG. 3

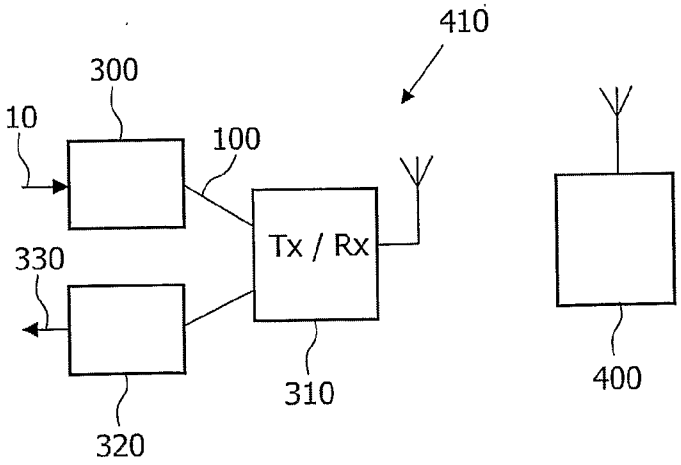

FIG. 4

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METHOD FOR PRIORITY BASED QUEUING AND ASSEMBLING OF PACKETS

[0001] The invention relates to a method of multiplexing data packets, to a multiplexing apparatus for multiplexing data packets, to a communication terminal comprising the multiplexing apparatus, and to a communication system comprising the communication terminal. The invention has application in, for example but not exclusively, mobile communication systems such as the Universal Mobile Telecommunication System (UMTS).

[0002] There is a requirement in communication systems to multiplex data packets having different priorities. For example, in UMTS for an Enhanced Uplink Data Channel (E-DCH), at the Medium Access Control (MAC) layer data packets, referred to as MAC-d Protocol Data Units or MAC-d PDUs, are grouped together for transmission to form larger, enhanced PDUs termed MAC-e PDUs. When there is a continuous supply of MAC-d PDUs having the highest priority, the MAC-e PDUs can be filled with these high priority MAC-d PDUs, but when there are fewer high priority MAC-d PDUs to be transmitted, any spare capacity in the MAC-e PDUs can be used to transmit waiting MAC-d PDUs having a lower priority. In this way, a MAC-e PDU can accommodate a combination of different priorities of MAC-d PDU.

[0003] In UMTS, the process of multiplexing of MAC-d PDUs into MAC-e PDUs is responsible for ensuring that MAC-d flow priorities are taken into account in an appropriate way. In the simplest case, this multiplexing could simply follow the priorities directly. An example illustrated in FIG. **1** shows queues **5** of MAC-d PDUs having different priorities $P_1 \ldots P_n$, with the priorities decreasing from P_1 through to P_n, being multiplexed by a selector switch **6** onto a MAC-e PDU **7**. The MAC-e PDU can accommodate four MAC-d PDUs, and is populated with the MAC-d PDUs having the highest priority available. In this simple scheme if we have continuous high-priority MAC-d PDUs arriving for transmission, then the transmission of simultaneously-arriving lower-priority MAC-d PDUs will be delayed. Strictly priority-based multiplexing of MAC-d PDUs into the MAC-e PDUs will not always lead to the optimal filling of the MAC-e PDUs and would be too inflexible to satisfy all QoS (Quality of Service) requirements for PDUs, such as delay requirements and bit rate requirements. For example, queues containing low priority PDUs may experience starvation, being starved of opportunities to transmit their PDUs.

[0004] An object of the invention is to enable flexible and efficient multiplexing of data packets.

[0005] According to a first aspect of the invention there is provided a method of multiplexing data packets having different assigned priorities, comprising: receiving data packets; operating a queue for each different priority of data packet; assembling a group of the data packets wherein a first portion of the group is populated with data packets selected from one or more of the queues according to a first rule and a second portion of the group is populated with data packets selected from one or more of the queues according to a second rule; and transmitting the group.

[0006] The invention provides flexibility for supporting scenarios by dividing a data packet, such as a MAC-e PDU, that is large enough to accommodate a plurality of smaller data packets, such as MAC-d PDUs, into at least two portions and enabling different multiplexing rules to be used for the different portions. In this way, a combination of data packets having different priorities may be transmitted.

[0007] Preferably, according to the first rule, data packets are selected from the queue containing the highest priority of the data packets. This ensures that the highest priority data packets are assigned a regular portion of the capacity.

[0008] Preferably, according to the second rule, data packets are selected from one or more of the queues containing data packets having a lower priority than the highest priority. This ensures that the lower priority data packets are assigned some capacity.

[0009] In one embodiment, according to the second rule, data packets are selected from any queue, except at least the highest priority queue, for which the data packets have experienced a delay longer than a threshold delay. The threshold delay may be the same or different for the queues. This approach can assist compliance with a QoS delay requirement.

[0010] In one embodiment, according to the second rule, data packets are selected from any queue which has more data awaiting transmission than a threshold amount of data, except at least the highest priority queue. This approach can reduce the likelihood of buffer overrun in which a queue length exceeds the available buffer size.

[0011] In one embodiment, the sizes of the first and second portions of the group of data packets transmitted is adapted according to the prevailing mix of priorities of the data packets, or according to the amount of data in the queues, or according to the delay experienced by data in each queue relative to a delay criterion for the respective queue. This approach can enable efficient use of transmission capacity and can assist compliance with a QoS requirement.

[0012] According to a second aspect of the invention there is provided a multiplexing apparatus for multiplexing data packets having different assigned priorities, comprising means for receiving data packets, means for operating a queue for each different priority of data packet, means for assembling a group of the data packets wherein a first portion of the group is populated with data packets by selecting data packets from one or more of the queues according to a first rule and a second portion of the group is populated with data packets by selecting data packets from one or more of the queues according to a second rule, and means for transmitting the group.

[0013] According to a third aspect of the invention there is provided a communication terminal comprising the multiplexing apparatus in accordance with the second aspect of the invention.

[0014] According to a fourth aspect of the invention there is provided a communication system comprising, for transmitting data packets, a first communication terminal in accordance with the second aspect of the invention, and a second communication terminal for receiving the data packets.

[0015] The invention will now be described, by way of

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[0016] FIG. **1** is a schematic diagram illustrating a prior art method of MAC-d multiplexing;

[0017] FIG. **2** is a multiplexing apparatus in accordance with the invention;

[0018] FIG. **3** is a flow chart illustrating a further method of multiplexing in accordance with the invention; and

[0019] FIG. **4** is a communication system in accordance with the invention.

[0020] Referring to FIG. **2**, there is illustrated an apparatus for multiplexing **300**, hereafter referred to as a multiplexing apparatus **300**. There is an input **10** for receiving data packets. Coupled to the input **10** is an input buffer **20**, such as a random access memory, for storing the received data packets. There is a bank **40** of a plurality of queue stores **50** for containing queues and which may comprise a storage medium such as random access memory. The input buffer **20** is coupled to the bank **40** by means of a first routing means **30**, such as a switch or a functional equivalent, for routing each data packet from the input buffer **20** to one of the queue stores **50** according to a priority assigned to each data packet. The priority may be assigned to each data packet prior to reception of the data packet, or may be assigned by a control means **110**. Alternatively, the packets may be routed to the queue stores **50** according to their respective MAC-d flows, with each flow having an associated priority; this approach may be used if for example the flow priorities are changed dynamically. There is an output buffer **80**, such as a random access memory, for storing the data packets prior to transmission on an output **100**. The output buffer **80** comprises a first portion **90** and a second portion **95**. The first portion **90** and the second portion can each accommodate at least one data packet. Data packets are selected for transfer from the queue stores **50** to the output buffer **80** by means of a second routing means **60**, such as a switch or a functional equivalent, and are transferred into the first portion **90** or the second portion **95** by means of a switch **70**. The first and second routing switches **30**, **60** and the switch **70** are controlled by a control means **110**, such as a microprocessor. The control means **110** controls the routing of the data packets to the output buffer **80** according to a predetermined criterion. The control means **110** may also control the sizes of the first and second portions **90**, **95**.

[0021] The control means **110** may be adapted to populate the first portion **90** with data packets from the queue store **50** containing the highest priority data packets.

[0022] The control means **110** may be adapted to populate the second portion **95** with data packets from one or more of the queue stores **50** containing data packets of a lower priority than the highest priority. The lower priority data packets selected to populate the second portion **95** may be those which have experienced a delay longer than a predetermined delay threshold, or those that have experienced the longest delay. The predetermined delay threshold may be different or the same for each of the queue stores **50**. The lower priority data packets selected to populate the second portion **95** may be those in a queue store **50** which contains a number of data packets above a predetermined occupancy threshold. The predetermined occupancy threshold may be different or the same for each of the queue stores **50**. The

[0023] The control means **110** may adapt the size of the first portion **90** and the second portion **95** according to the prevailing mix of priorities of the data packets stored in the bank **40**, or according to the amount of data packets stored in the queue stores **50**, or according to the delay experienced by data packets in each queue store **50** relative to a delay criterion for the respective queue, or according to a received signal indicative of a mix of first and second portions. In the latter case, the mix may comprise, for example, an indication of relative proportions or absolute sizes.

[0024] Referring to FIG. **3**, the illustrated method of multiplexing commences at step **200** where some data packets are received by the multiplexing apparatus **300**. They may be received with priorities already assigned to them, or priorities may be assigned after receipt. At step **210** the data packets are stored into the set of queue stores **50**, one queue store for each priority level $P_1 \ldots P_n$. One way of identifying which queue store **50** a data packet is stored in is by a label signifying the packet's priority level. At step **220** a first portion **90** of a group of data packets is assembled from data packets having the highest priority of the stored data packets. At step **230** a second portion **95** of a group of data packets is assembled from data packets having a lower priority, or lower priorities. At step **240** the assembled group comprising the first portion **90** and second portion **95** is transmitted. The process is repeated for further data packets.

[0025] Some examples are given below of how the data packets may be selected from the queues in the queue stores **50** to populate the group of data packets assembled in the first portion **90** and second portion **95** of the output buffer **80**. In general we can assume that the resources available for the first portion **90** and the second portion **95** are both known before the multiplexing operation is carried out, for example in terms of the number of PDU's which can be transmitted. In the case that the resources are not known exactly in advance, for example if the total available resource depends in any way on the outcome of the multiplexing, it may be necessary to consider the outcome of the multiplexing for a number of possible resource allocations and then select one of them.

[0026] 1) Strict priority based selection: In this case each MAC-d flow is assigned a priority. Then for the first selection, data packets are taken from the queue having the highest priority until the resource available for the first portion **90** is filled. If this queue becomes empty, data packets are taken from the queue with the next highest priority and so on. For the second portion **95** the same procedure is carried out, but for a subset of the queues. Suitable selection of the subset can enable the multiplexing apparatus **300** to avoid starvation of particular queues, for example to enable a delay criterion to be met.

[0027] 2) Fair selection for the second portion: In this case the second portion **95** is populated by taking one data packet in turn from each of the subset of queues, excluding the highest priority queue. To maximise fairness, especially when a large number of queues are present, the last selected queue may be remembered for use in subsequent multiplexing operations.

3) As a variation on 2), if the resource available for the first

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