DETERMINING LOAD MEASURE FOR NETWORK ELEMENT USING A WEIGHTED METHOD

Priority and Cross-reference to Related Application

This application claims priority from U.S. Patent Application Serial No. 60/927,967, filed on May 7, 2007.

Technical Field

This invention generally relates to communications, e.g., wireless communications, and more specifically to determining a load measure for a network element (e.g., for Node B in downlink or uplink).

Background Art

In a new concept for a long term evolution (LTE) of 3GPP (3rd Generation Partnership Project), the assumption is to use extensive frequency domain packet scheduling (FDPS) to achieve a high spectral efficiency. As the LTE of 3GPP is targeted at being a cellular system providing handovers between the different evolved-Node Bs (eNBs), each of these eNBs needs knowledge of the traffic situation at the neighbouring eNBs for the network optimization. As there is no central entity in the network which will monitor the load situation for each eNB, exchanging the load information between the different neighbouring eNBs is needed.

In relation to the measurement of the load in a given cell, it is desirable to have a measurement, which will provide information to the other eNBs, which is useful for controlling the resulting performance of the network. The functions/entities, which can use this type of measurement may include (but are not limited to):

- Load based handover, such that a highly loaded cell can potentially hand off traffic/UEs to a less loaded neighbouring eNB;
- For deciding at which cell/carrier a UE (user equipment) should camp;
- Network performance monitoring and optimization.

In order to have effective utilization of these measurements, it is useful to know the current state of the cell load, which will describe the amount of information traffic that can be used/unused. Traditionally these types of load measurements are

performed using, for example, a total received power by a network element (e.g., a Node B) or in case of frequency division multiplexing (FDM) a number of occupied frequency designated channels, etc.

Disclosure of the Invention

According to a first aspect of the invention, a method, comprises: providing information traffic by a network element using all or selected blocks of a plurality of physical resource blocks available in the network element; and determining a load measure of the information traffic in a predetermined time interval using a predetermined algorithm: by weighing a number of the all or selected blocks with corresponding ratio of a number of digital bits used only for pre-selected information of the information traffic and a total number of digital bits both used for all user equipments participating in the information traffic, or by summing a number of one or more blocks of the all or selected blocks used by each user equipment of the all user equipments participating in the information traffic weighed with corresponding ratios of a number of digital bits used only for the pre-selected information and a total user number of digital bits both used for the each user equipment.

According further to the first aspect of the invention, the network element may be a Node B configured for wireless communications.

Further according to the first aspect of the invention, the predetermined time interval may be one millisecond.

Still further according to the first aspect of the invention, the information traffic may be in downlink.

According yet further to the first aspect of the invention, the information traffic may be in uplink.

Still yet further according to the first aspect of the invention, the method may comprise: providing the load measure to neighbouring network elements.

According still further to the first aspect of the invention, the substantial information may comprise at least one or all of: guaranteed bit rate bearers, radio resource control messages and medium access control MAC-c protocol data units.

According further still to the first aspect of the invention, each of the physical resource blocks may comprise twelve continuous sub-carriers of orthogonal frequency division multiplexing access.

According yet further still to the first aspect of the invention, the load measure may be in a range between zero and the plurality of physical resource blocks available in the network element.

According to a second aspect of the invention, a computer program product comprises: a computer readable storage structure embodying computer program code thereon for execution by a computer processor with the computer program code, wherein the computer program code comprises instructions for performing the first aspect of the invention, indicated as being performed by any component or a combination of components of a network element.

According to a third aspect of the invention, a network element, comprises: transmitters and receivers, configured to provide information traffic using all or selected blocks of a plurality of physical resource blocks available in the network element; and a load determining module, configured to determine a load measure of the information traffic in a predetermined time interval using a predetermined algorithm: by weighing a number of the all or selected blocks with corresponding ratio of a number of digital bits used only for pre-selected information of the information traffic and a total number of digital bits both used for all user equipments participating in the information traffic, or by summing a number of one or more blocks of the all or selected blocks used by each user equipment of the all user equipments participating in the information traffic weighed with corresponding ratios of a number of digital bits used only for the pre-selected information and a total user number of digital bits both used for the each user equipment.

Still yet further according to the first aspect of the invention, the network element may be a Node B configured for wireless communications.

Further according to the third aspect of the invention, the predetermined time interval may be one millisecond.

Still further according to the third aspect of the invention, theinformation traffic may be in downlink.

According yet further to the third aspect of the invention, the information traffic may be in uplink.

According still further to the third aspect of the invention, the network element may further comprise: a load transmitting module configured to transmit the load measure to neighbouring network elements.

According yet further still to the third aspect of the invention, the substantial information may comprise at least one or all of: guaranteed bit rate bearers, radio resource control messages and medium access control MAC-c protocol data units.

According further still to the third aspect of the invention, each of the physical resource blocks may comprise twelve continuous sub-carriers of orthogonal frequency division multiplexing access.

Yet still further according to the third aspect of the invention, the load measure may be in a range between zero and the plurality of physical resource blocks available in the network element.

Still yet further according to the third aspect of the invention, an integrated circuit may comprise the load determining module and the transmitter and receivers.

Brief Description of the Drawings

For a better understanding of the nature and objects of the present invention, reference is made to the following detailed description taken in conjunction with the following drawings, in which:

Figure 1 is a block diagram of a network element (e.g., a Node B) for determining (e.g., calculating) a load measure, according to an embodiment of the present invention; and

Figure 2 is a flow chart demonstrating determining a load measure for a network element (e.g., Node B), according to an embodiment of the present invention.

Modes for Carrying Out the Invention

A new method, system, apparatus and software product are presented for determining (e.g., calculating) a load measure by a network element (e.g., evolved-Node B, eNB, or a Node B in general, a Gateway or any other network elements) for optimizing information traffic in communication networks (e.g., wireless

communication systems). According to embodiments of the present invention, this load measure can represent the amount of available/excess traffic that a given network element can carry and is a relative measure, which would take into account the total amount of resources available in the system (e.g., depending on the system bandwidth) and the amount of resources that are free for carrying only "important" or "essential" traffic, using a weighted method described herein.

It is noted that in the frame of the present invention the load measure can be defined for a cell with a certain system bandwidth or information capacity which can map into a maximum number of simultaneously supported physical resource blocks (PRB) for transmission (for downlink or uplink). As an example among others, the PRB can be defined as a set of 12 continuous sub-carriers (using an orthogonal frequency division multiplexing access, OFDMA, as the access technique) for a period of 1 ms. The PRB then can be interpreted as the smallest allocation granularity that a UE (user equipment) can be allocated. Furthermore, within each cell, the traffic may be scheduled independently in uplink and downlink, therefore the load measure may be computed separately for the uplink and downlink. For example, for the load measure calculated at the eNB, it may be calculated at the transmitter for the downlink, while it may be calculated at the receiver for the uplink.

The obvious immediate load measure would be to define a measurement, which just take into account the average number of non-used or used PRBs over a given amount of time. The disadvantage of this is that it is not possible to distinguish "important" or "essential" information traffic from "best-effort" or "non-essential" information traffic which are equivalent to a real time (RT) and a non-real time (NRT) traffics, respectively, wherein RT and NRT terms are being traditionally used (e.g., see 3GPP TS 25.423). It is noted that QoS (quality of service) parameters: GBR (guaranteed bit rate)-bearer (e.g., defined in 3GPP TS 25.401, V8.1.0, section 4.7) is for RT and non-GBR bearer (e.g., defined in 3GPP TS 25.401 V8.1.0, section 4.7) is for NRT.

Thus, according to an embodiment of the present invention, the load measure can be generated by taking into account the fact that the "best-effort" (or "non-essential") information traffic is the traffic which is carried in the network without any guarantees for the UE requesting the traffic. For the purpose of the present

invention, the "important" or "essential" traffic, is considered to be a traffic, which is either guaranteed for the UE or needed for the network operation. This "essential" information traffic can be pre-selected for determining the load measure according to embodiments of the present invention as described herein. For instance, the traffic needed for the network ("essential" traffic) may include (but is not limited to): SAE (system architectural evolution) GBR (guaranteed bit rate), RRC (radio resource control) messages, and medium access control (MAC-c) protocol data units (PDUs). It is noted that the SAE bearer is called EPS (evolved packet system) bearer in the latest 3GPP documents (e.g., see 3GPP TS 25.401 V8.1.0, section 4.7). The latter two are control messages, which may be needed, for example, to inform the UEs on the configuration and assignments in the network and are crucial for the network operation.

Thus, according to one embodiment of the present invention, the load measure of the "essential" (equivalent to RT) information traffic can be determined (calculated) in a predetermined time interval (e.g., per transmission timing interval TTI) as a weighted sum of the used PRBs for the scheduled users using pre-selected essential information of the traffic as follows:

$$PRB_{load,TTI,e} = \sum_{n} PRB_{used}(n) \cdot \frac{TBS_{SAE_GBR}(n) + TBS_{RRC}(n) + TBS_{Mac-C}(n)}{TBS_{total}(n)} \qquad (1),$$

wherein index n is referring to the n-th scheduled user equipment (or user) in the predetermined time interval (e.g., TTI). Hence, the number of used PRBs per user, $PRB_{used}(n)$, are weighted with the ratio of number of bits used for GBR bearers + RRC messages + MAC C-PDUs, $(TBS_{SAE_GBR}(n) + TBS_{RRC}(n) + TBS_{Mac-C}(n))$, for individual users (in the numerator) versus the total number of transmitted bits, ($TBS_{total}(n)$), for the corresponding individual users (in the denominator). By applying a division of the total carried payload, we here have a measure for the effective PRBs that are used for "essential" traffic, and therefore it is possible then to calculate the available traffic by subtracting this number from the total number of available PRBs in a cell which is typically supported by one Node B. The Equation 1

can be applied for downlink traffic, uplink traffic or a combination of uplink and downlink traffic.

Alternatively, according to another embodiment of the present invention, Equation 1 can be modified to apply to all users simultaneously without summation, as follows:

$$PRB_{load,TTI,e}{}^{all} = PRB_{used}(n)^{all} \cdot \frac{TBS_{SAE_GBR}(n)^{all} + TBS_{RRC}(n)^{all} + TBS_{Mac-C}(n)^{all}}{TBS_{total}(n)^{all}} \quad (2).$$

The load measured in the Equations 1 and 2 can be in the range between 0 and N (e.g., rounded to an integer), wherein N is the maximum number of PRBs in the cell (depends on the system bandwidth). Hence, if the cell is fully loaded with transmission on all PRBs with SAE GBR traffic, then the load will equal N. The determined load measure can be reported to one or more neighbouring network elements (e.g., Node Bs) for effective control of the information traffic in the network. The load measure in the Equations 1 and 2 can be averaged over several time intervals (e.g., several TTIs) before being reported to the one or more neighbouring network elements (cells). The predetermined time interval (TTI) can be, e.g., one millisecond.

It is further noted that from an implementation perspective, it does not matter, whether to report the used load in the cell (determined from Equations 1 or 2) or the complementary unused load, i.e. N minus the average used load determined from Equations 1 or 2.

Given the same approach as described above, the equivalent per a TTI-load measure of "non-essential" (equivalent to NRT) traffic can be expressed as follows:

$$PRB_{load,TTI,ne} = \sum_{n} PRB_{used}(n) \cdot \frac{TBS_{total}(n) - \left(TBS_{SAE_GBR}(n) + TBS_{RRC}(n) + TBS_{Mac-C}(n)\right)}{TBS_{total}(n)} \quad (3), \text{ and}$$

$$PRB_{load,TTI,ne}{}^{all} = PRB_{used}(n)^{all}\left(1 - \frac{TBS_{SAE_GBR}(n)^{all} + TBS_{RRC}(n)^{all} + TBS_{Mac-C}(n)^{all}}{TBS_{total}(n)^{all}}\right) \quad (4),$$

respectively (similar to Equations 1 and 2).

The pre-selected "essential" information of the traffic represented by a sum of 3 terms, $TBS_{SAE_GBR}(n) + TBS_{RRC}(n) + TBS_{Mac-C}(n)$, used in Equations 1 and 3 (similar 3 terms are used in Equations 2 and 4 as well) represent only one possible scenario and other definitions of the pre-selected "essential" information are possible.

It is further noted that according to an embodiment of the present invention, both "essential" and "non-essential" load measures can be calculated, e.g., in the Node-B at Layer-2 (the network layer).

Figure 1 is an example among others of a block diagram of a network element **10** (e.g., Node B, a base transceiver station BTS, etc.) in a wireless network **11** for determining (e.g., calculating) a load measure for the network element **10**, according to an embodiment of the present invention.

In the example of Figure 1, the network element **10** comprises transmitters **12**, receivers **18**, an allocation and scheduling module **14**, a load determining module **15** and a load transmitting module **17**.

The load determining module **15** is used to determine (calculate) the load measure according to embodiments of the present invention described herein (e.g., see Equations 1-4) using an input signal **20** from the allocation and scheduling module **14** regarding the downlink information traffic (the signal **20** is transmitted as a signal **20a** to corresponding UEs). It is noted that the signal **20** can comprise information about uplink traffic as well if the module **14** is used for scheduling the uplink traffic as well. The module **15** can also get input signal **22a** from receivers **18** regarding received uplink signals **22** from the UEs, as shown in Figure 1, for determining the uplink load measure, according to embodiments of the present invention described herein (e.g., see Equations 1-4). After the load measure is determined (calculated) by the module **15**, it can be transmitted using, for example, the load transmitting module **17** to neighbouring elements (e.g., to Node Bs and possibly to other network elements, for example, to Gateways, etc.) for optimizing the network performance as described herein.

According to an embodiment of the present invention, the module **15, 17** or **14** can be implemented as a software or a hardware module or a combination thereof. Furthermore, the module **15, 17** or **14** can be implemented as a separate block or can be combined with any other standard block or it can be split into several blocks according to their functionality. The transmitters **12** and receivers **18** can be implemented as

transceivers as well known in the art. All or selected modules of the network element **10** can be implemented using an integrated circuit.

Figures 2 shows an example of a flow chart demonstrating determining a load measure for a network element (e.g., Node B), according to an embodiment of the present invention.

The flow chart of Figure 2 only represents one possible scenario among others. The order of steps shown in Figure2 is not absolutely required, so generally, the various steps can be performed out of order. In a method according to an embodiment of the present invention, in a first step **32** the network element such as Node B can provide information traffic (downlink or/and uplink) using all or selected blocks of a plurality of physical resource blocks (PSBs) available in the network element (e.g., a PSB can comprise of 12 sub-carriers, or equivalently to a frequency chunk of 180 kHz, and being the same for uplink and downlink). In a next step **34**, the network element can determine (calculate) a load measure of the information traffic in a predetermined time interval (e.g., TTI) using the weighted method, according to embodiments of the present invention described herein. In a next step **36**, the network element can provide the load measure to the one or more neighbouring network elements for effective control of the information traffic in the network.

As explained above, the invention provides both a method and corresponding equipment consisting of various modules providing the functionality for performing the steps of the method. The modules may be implemented as hardware, or may be implemented as software or firmware for execution by a computer processor. In particular, in the case of firmware or software, the invention can be provided as a computer program product including a computer readable storage structure embodying computer program code (i.e., the software or firmware) thereon for execution by the computer processor.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the scope of the present invention, and the appended claims are intended to cover such modifications and arrangements.

What is claimed is:

1. A method, comprising:

providing an information traffic by a network element (10) using all or selected blocks of a plurality of physical resource blocks available in said network element; and

determining a load measure of said information traffic by a weighted method using pre-selected information of said information traffic provided by said all or selected blocks participating in said information traffic.

2. The method of claim 1, wherein said weighted method comprises: weighting a number of said all or selected blocks with corresponding ratio of a number of digital bits used only for pre-selected information of said information traffic and a total number of digital bits both used for all user equipments participating in said information traffic.

3. The method of claim 1, wherein said weighted method comprises: summing a number of one or more blocks of said all or selected blocks used by each user equipment of said all user equipments participating in said information traffic weighed with corresponding ratios of a number of digital bits used only for said pre-selected information and a total user number of digital bits both used for said each user equipment.

4. The method of claim 1, wherein said load measure is determined in a predetermined time interval.

5. The method of claim 4, wherein said predetermined time interval is one millisecond.

6. The method of claim 1, wherein said network element (10) is a Node B configured for wireless communications

7. The method of claim 1, wherein said information traffic is in downlink.

8. The method of claim 1, wherein said information traffic is in uplink.

9. The method of claim 1, further comprising:
providing said load measure to one or more neighbouring network elements.

10. The method of claim 1, wherein said pre-selected information is for an essential information traffic and comprises at least one or all of:
guaranteed bit rate bearers,
radio resource control messages and
medium access control MAC-c protocol data units.

11. The method of claim 1, wherein each of said physical resource blocks comprises twelve continuous sub-carriers of orthogonal frequency division multiplexing access.

12. The method of claim 1, wherein said load measure is in a range between zero and said plurality of physical resource blocks available in said network element.

13. A computer program product comprising: a computer readable storage structure embodying computer program code thereon for execution by a computer processor with said computer program code, wherein said computer program code comprises instructions for performing the method of claim 1.

14. A network element (10) , comprising:
transmitters (12) and receivers (18) , configured to provide an information traffic using all or selected blocks of a plurality of physical resource blocks available in said network element; and
a load determining module (15) , configured to determine a load measure of said information traffic in a predetermined time interval by a weighted method using

pre-selected information of said information traffic provided by said all or selected blocks participating in said information traffic.

15. The network element of claim 14, wherein said weighted method comprises: weighting a number of said all or selected blocks with corresponding ratio of a number of digital bits used only for pre-selected information of said information traffic and a total number of digital bits both used for all user equipments participating in said information traffic.

16. The network element of claim 14, wherein said weighted method comprises: summing a number of one or more blocks of said all or selected blocks used by each user equipment of said all user equipments participating in said information traffic weighed with corresponding ratios of a number of digital bits used only for said pre-selected information and a total user number of digital bits both used for said each user equipment.

17. The method of claim 14, wherein said load measure is determined in a predetermined time interval.

18. The network element of claim 17, wherein said predetermined time interval is one millisecond.

19. The network element of claim 14, wherein said information traffic is in downlink.

20. The network element of claim 14, wherein said network element is a Node B configured for wireless communications.

21. The network element of claim 14, wherein said information traffic is in uplink.

22. The network element of claim 14, further comprising:

a load transmitting module configured to transmit said load measure to one or more neighbouring network elements.

23. The network element of claim 14, wherein said pre-selected information is for an essential information traffic and comprises at least one or all of:

guaranteed bit rate bearers,

radio resource control messages and

medium access control MAC-c protocol data units.

24. The network element of claim 14, wherein each of said physical resource blocks comprises twelve continuous sub-carriers of orthogonal frequency division multiplexing access.

25. The network element of claim 14, wherein said load measure is in a range between zero and said plurality of physical resource blocks available in said network element.

26. The network element of claim 14, wherein an integrated circuit comprises the load determining module and said transmitter and receivers.