[0102]
This is illustrated in Fig. 16, which shows a power-limited situation where two uplink transmissions are scheduled for the UE, one to the MeNB and one to the SeNB. As apparent therefrom, the simultaneous uplink transmissions exceed to the total maximum UE transmit power, for which reasons power scaling is performed by the UE for the uplink transmissions so as to keep the total power used for the two transmissions below the total maximum UE transmit power. Power scaling in turn reduces the scheduling efficiency and performance.

Citation List

Non Patent Literature

[0103]

NPL 1 : 3GPP TS 36.211, "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation", version 8.9.0
NPL 2 : 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification", version 10.0.0
NPL 3 : 3GPP TS 36.213, "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures", version 8.8.0
NPL 4 : 3GPP TS 36.133, "Requirements for support of radio resource management", version 8.7.0
NPL 5 : 3GPP TS 36.101, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception", version 8.7.0

Summary

[0104]

One non-limiting and exemplary embodiment provides an improved method for power control in a mobile communication system with a mobile station in dual connectivity with a master and secondary base station, avoiding the problems of the prior art as identified above. Another exemplary embodiment provides the power headroom reporting so as to assist in the improved power control for dual connectivity scenarios.

[0105]

Additional benefits and advantages of the disclosed embodiments will be apparent from the specification and Figures. The benefits and/or advantages may be individually provided by the various embodiments and features of the specification and drawings disclosure, and need not all be provided in order to obtain one or more of the same.

[0106]
According to a first aspect of the present invention, there is provided a method for power headroom reporting in a mobile communication system, wherein a mobile station is connected via a first radio link to a master base station and at least to one secondary base station via a secondary radio link, the method comprising the steps of: calculating by the mobile station a first power headroom report for the first radio link between the mobile station and the master base station, transmitting the calculated first power headroom report together with information allowing the master base station to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, from the mobile station to the master base station, and calculating by the mobile station a secondary power headroom report for the secondary radio link between the mobile station and the secondary base station, and transmitting the calculated secondary power headroom report from the mobile station to the secondary base station.

[0106a]
According to a second aspect of the present invention, there is provided a mobile station for power headroom reporting in a mobile communication system, wherein the mobile station is connectable via a first radio link to a master base station and at least to one secondary base station via a secondary radio link, the mobile station comprising: a processor adapted to calculate a first power headroom report for the first radio link between the mobile station and the master base station, a transmitter adapted to transmit the calculated first power headroom report together with information allowing the master base station to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, to the master base station, the processor being further adapted to calculate a secondary power headroom report for the secondary radio link between the mobile station and the secondary base station, and the transmitter being further adapted to transmit the calculated secondary power headroom report to the secondary base station.

[0106b]
According to a third aspect of the present invention, there is provided a master base station for receiving power headroom reports from a mobile station in a mobile communication system, wherein the mobile station is connected via a first radio link to the master base station and at least to one secondary base station via a secondary radio link, the master base station comprising: a receiver adapted to receive from the mobile station a first power headroom report together with information allowing the master base station to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, and a processor adapted to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, based on the received information.

[0107]
The above aspects may be implemented using a system, a device, and a computer program, and any combination of systems, devices, and computer programs.

Brief Description of Drawings

[0108]

[fig. 1] Fig. 1 shows an exemplary architecture of a 3GPP LTE system.

[fig. 2] Fig. 2 shows an exemplary overview of the overall E-UTRAN architecture of 3GPP LTE.

[fig. 3] Fig. 3 shows exemplary subframe boundaries on a downlink component carrier as defined for 3GPP LTE (Release 8/9).

[fig. 4] Fig. 4 shows an exemplary downlink resource grid of a downlink slot as defined for 3GPP LTE (Release 8/9).

[fig. 5] Fig. 5 shows the 3GPP LTE-A (Release 10) Layer 2 structure with activated carrier aggregation for the downlink.

[fig. 6] Fig. 6 shows the 3GPP LTE-A (Release 10) Layer 2 structure with activated carrier aggregation for the uplink.

[fig. 7] Fig. 7 illustrates a DRX operation of a mobile terminal and in particular the DRX opportunity, on-duration, according to the short and long DRX cycle.

[fig. 8] Fig. 8 shows a Power Headroom Report, PHR, MAC control element as defined in 3GPP LTE (Release 8/9).

[fig. 9] Fig. 9 illustrates an extended Power Headroom Report, ePHR, MAC control element as defined in 3GPP LTE (Release 10).

[fig. 10] Fig. 10 illustrates a deployment scenario for small cell enhancement, where macro and small cells are on the same carrier frequency.

[fig. 11] Fig. 11 illustrates further deployment scenarios for small cell enhancement where macro and small cells are on different carrier frequencies, the small cell being outdoor.

[fig. 12] Fig. 12 illustrates further deployment scenarios for small cell enhancement where macro and small cells are on different carrier frequencies, the small cell being indoor.

[fig. 13] Fig. 13 illustrates a further deployment scenario for small cell enhancement with only small cells.

[fig. 14] Fig. 14 gives an overview of the communication system architecture for dual connectivity with macro and small eNBs connected to the core network, where the

CLAIMS

1. A method for power headroom reporting in a mobile communication system, wherein a mobile station is connected via a first radio link to a master base station and at least to one secondary base station via a secondary radio link, the method comprising the steps of:

calculating by the mobile station a first power headroom report for the first radio link between the mobile station and the master base station,

transmitting the calculated first power headroom report together with information allowing the master base station to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, from the mobile station to the master base station, and

calculating by the mobile station a secondary power headroom report for the secondary radio link between the mobile station and the secondary base station, and transmitting the calculated secondary power headroom report from the mobile station to the secondary base station.

2. The method according to claim 1, wherein the information, from which the master base station determines the information on the pathloss, is transmitted in form of a secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, the method further comprising the step of:

calculating by the mobile station, the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, based on a pre-configured virtual uplink resource assignment for said secondary radio link to the secondary base station.

3. The method according to claim 1 or 2, further comprising the steps of:

determining by the master base station an initial distribution of the available maximum transmit power of the mobile station between the master base station and the secondary base station, comprising determining a maximum output power of the mobile station for uplink transmissions to the master base station (PEMAX,MeNB) and a maximum output power of the mobile station for uplink transmissions to the secondary base station (PEMAX,SeNB), and

transmitting the determined maximum output power of the mobile station for uplink transmissions to the secondary base station (PEMAX,SeNB), from the master base station to the secondary base station, preferably in a signaling message transmitted on the interface between the master and secondary base station, and

transmitting the determined maximum output power of the mobile station for uplink transmissions to the master base station (PEMAX,MeNB) and the determined maximum output power of the mobile station for uplink transmissions to the secondary

base station (PEMAX,SeNB), from the master base station to the mobile station, preferably in a Radio Resource Control, RRC, message or in a Media Access Control, MAC, control element, or

transmitting the determined maximum output power of the mobile station for uplink transmissions to the master base station (PEMAX,MeNB), from the master base station to the mobile station, preferably in a Radio Resource Control, RRC, message or in a Media Access Control, MAC, control element, and transmitting the determined maximum output power of the mobile station for uplink transmissions to the secondary base station (PEMAX,SeNB), from the secondary base station to the mobile station.

4. The method according to one of claims 1 to 3, comprising the steps of:

when the mobile station determines that the secondary radio link between the mobile station and the secondary base station will become inactive for the uplink, the mobile station provides information to the master base station about the secondary radio link becoming inactive for the uplink,

preferably wherein the information, about the secondary radio link becoming inactive for the uplink, is provided to the master base station in the form of:

- a bit flag with a pre-determined value in the first power headroom report for the first radio link between the mobile station and the master base station, or
- a bit flag with a pre-determined value in the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, or
- a pre-determined power headroom value of the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station.

5. The method according to claim 4, further comprising the step of:

determining by the mobile station a length in time that the secondary radio link is expected to be inactive for the uplink, and wherein only in case the determined length in time exceeds a pre-determined length in time, the step of, the mobile station providing information to the master base station about the secondary radio link becoming inactive for the uplink, is performed.

6. The method according to claim 4 or 5, wherein the information, about the secondary radio link becoming inactive for the uplink, is provided to the master base station in the form of a pre-determined power headroom value of the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, and

wherein the pre-determined power headroom value is a pre-determined negative value, preferably encoding time information about a length in time that the secondary radio link is expected by the mobile station to be inactive for the uplink.

7. The method according to one of claims claim 4 to 6, further comprising the steps of:

determining by the master base station an updated distribution of the available maximum transmit power of the mobile station between the master base station and the secondary base station, based on the received information about the secondary radio link becoming inactive for the uplink, comprising at least determining an updated value for the maximum output power of the mobile station for uplink transmissions to the master base station (PEMAX,MeNB), and

transmitting by the master base station, the updated maximum output power of the mobile station for uplink transmissions to the master base station (PEMAX,MeNB), to the mobile station.

8. The method according to one of claims 1 to 7, comprising the steps of:

when the mobile station determines that the first radio link between the mobile station and the master base station will become inactive for the uplink, the mobile station provides information to the secondary base station about the first radio link becoming inactive for the uplink,

preferably wherein the information, about the first radio link becoming inactive for the uplink, is provided to the secondary base station in the form of:

- a bit flag with a pre-determined value in the secondary power headroom report for the secondary radio link between the mobile station and the secondary base station, or
- a bit flag with a pre-determined value in the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, or
- a pre-determined power headroom value of the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station.

9. The method according to claim 8, further comprising the step of:

determining by the mobile station a length in time that the first radio link is expected to be inactive for the uplink, and wherein only in case the determined length in time exceeds a pre-determined length in time, the step of, the mobile station providing information to the secondary base station about the first radio link becoming inactive for the uplink, is performed.

10. The method according to claim 8 or 9, wherein the information, about the first radio link becoming inactive for the uplink, is provided to the secondary base station in the form of a pre-determined power headroom value of the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, and

wherein the pre-determined power headroom value is a pre-determined negative value, preferably encoding time information about a length in time that the first radio link is expected by the mobile station to be inactive for the uplink.

11. A mobile station for power headroom reporting in a mobile communication system, wherein the mobile station is connectable via a first radio link to a master base station and at least to one secondary base station via a secondary radio link, the mobile station comprising:

a processor adapted to calculate a first power headroom report for the first radio link between the mobile station and the master base station,

a transmitter adapted to transmit the calculated first power headroom report together with information allowing the master base station to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, to the master base station,

the processor being further adapted to calculate a secondary power headroom report for the secondary radio link between the mobile station and the secondary base station, and

the transmitter being further adapted to transmit the calculated secondary power headroom report to the secondary base station.

12. The mobile station according to claim 11, wherein the information, from which the master base station determines the information on the pathloss, is transmitted in form of a secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station,

wherein the processor is adapted to calculate the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, based on a pre-configured virtual uplink resource assignment for said secondary radio link to the secondary base station.

13. The mobile station according to claim 11 or 12, wherein when the processor determines that the secondary radio link between the mobile station and the secondary base station will become inactive for the uplink, the transmitter is adapted to provide information to the master base station about the secondary radio link becoming inactive for the uplink, preferably in the form of:

- a bit flag with a pre-determined value in the first power headroom report for the first radio link between the mobile station and the master base station, or

- a bit flag with a pre-determined value in the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, or
- a pre-determined power headroom value of the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station.

14. The mobile station according to claim 13, wherein the information, about the secondary radio link becoming inactive for the uplink, is provided to the master base station in the form of a pre-determined power headroom value of the secondary virtual power headroom report for the secondary radio link between the mobile station and the secondary base station, and

the processor is adapted to set the pre-determined power headroom value to a pre-determined negative value, preferably encoding time information about a length in time that the secondary radio link is expected by the mobile station to be inactive for the uplink.

15. A master base station for receiving power headroom reports from a mobile station in a mobile communication system, wherein the mobile station is connected via a first radio link to the master base station and at least to one secondary base station via a secondary radio link, the master base station comprising:

a receiver adapted to receive from the mobile station a first power headroom report together with information allowing the master base station to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, and

a processor adapted to determine information on the pathloss of the secondary radio link between the mobile station and the secondary base station, based on the received information.