

[0001]

CHANNEL QUALITY MEASUREMENTS FOR DOWNLINK RESOURCE ALLOCATION

[0002]

BACKGROUND

[0003]

The present invention relates to wireless digital communication systems and, more particularly, to communication stations employing code-division multiple access (CDMA) technology utilizing measurement techniques to efficiently determine downlink resource allocation.

[0004]

In modern wireless communication systems, as the makeup of communication traffic has shifted from primarily voice traffic to an ever-increasing share of data traffic, such as for internet applications, the capacity requirements of such systems have increased. Thus, the provision of techniques to maximize the capacity of downlink (DL) transmissions is highly desirable.

[0005]

The propagation loss between a transmitter and a receiver is not fixed or constant. In addition to the dependence of propagation loss on distance, variations are caused by obstructions to the path, (or multiple paths), between the transmitter and receiver as well as the interaction between paths. These variations are referred to as fading. Additionally, the fading varies with time.

[0006]

In some communication systems, it is customary to transmit at each time instance to a particular user, or several users among multiple users, who enjoy the most favorable transmission conditions at that time. With these systems, it is necessary to define a channel quality that may be estimated for each user from time to time in order to transmit to each user at the most appropriate moment. Although selection of the most appropriate moment from the fading point of view is not mandatory, instantaneous path loss should be one of the considered factors in the selection.

[0007] One measure of channel quality is the instantaneous path loss. Channel quality improves as the instantaneous path loss is reduced, and channel quality is best when the instantaneous path loss is the smallest.

[0008] Another measure of channel quality is the interference seen by the user, since higher interference generally requires higher transmission power. As transmission power is limited, it results in reduction of system capacity. Channel quality (CQ) may therefore be defined as the ratio of the received power of a fixed-level base station transmission to the received interference. This ratio is inversely proportional to the required transmission power of the base station for user data. Maximization of this ratio, by continually selecting the users whose CQ is highest, (and therefore path loss and/or interference is lowest), at any instant in time, tends to increase system capacity as a whole over time.

[0009] The particular signal that is measured to determine the path loss and calculate the ratio is not critical. For example, the signal may be any pilot signal, beacon or even data-carrying signal that is transmitted at a constant or known power. In some systems the reception power is termed received signal code power (RSCP) and the received interference power is termed interference signal code power (ISCP). For example, in the Universal Mobile Telecommunication Systems (UMTS) frequency division duplex (FDD) standard, the common pilot channel (CPiCH) is measured, and the CQ is defined as $CPiCH_RSCP/ISCP$. In the UMTS time division duplex (TDD) standard, the beacon channel (PCCPCH) is measured and the CQ is defined as $PCCPCH_RSCP/ISCP$. Since channel conditions change rapidly, it is preferable to use a short time allocation, (i.e. a small timeslot), for each transmission. The measurement information used for the allocation must therefore also be timely.

[00010] In some communication systems it is customary to separate transmissions to users by time, or to separate one type of user-selective

transmission in time from other types of transmissions, such as normal voice services and data services. Such time separation can be obtained in different ways. For example, a repetitive frame may be divided into a plurality of timeslots. Each timeslot may each be allocated to one or more users at a time. In addition, several timeslots, adjacent or non-adjacent, may be allocated to one or more users. If a collection of one or more timeslots is allocated together, it may be referred to as a sub-channel.

[00011] In a time-separated transmission, it is likely that the interference in all of the timeslots or sub-channels is not equal. The reporting of a single value for all timeslots often results in a non-optimal allocation and the information in some of the timeslots may be lost. It is therefore desirable to report individual measurements for each timeslot.

[00012] SUMMARY OF THE INVENTION

[00013] The present invention provides for timely measurement of CQ and for signaling the information to the base station as appropriate. The present invention provides several embodiments to measure and signal the CQ per timeslot, or sub-channel, from the UE to the base station. Measurements may be performed at a high rate for all relevant timeslots or sub-channels, or may be made at a lower rate by selectively reducing the rate by which such measurements are performed.

[00013a] According to the first aspect of the present invention, there is provided a user equipment (UE), comprising: a measurement device configured to take a plurality of measurements based on a downlink quality, wherein each of the plurality of measurements is taken on a respective downlink resource of a plurality of downlink resources; a channel quality determination device configured to: derive a first channel quality indication indicating a channel quality of the plurality of downlink resources;

and derive a plurality of difference indications, each difference indication being between the first channel quality indication and a channel quality indication for one of the plurality of downlink resources; and a transmitting device configured to transmit at least one report including the first channel quality indication and the plurality of difference indications.

[00013b] According to the second aspect of the present invention, there is provided a user equipment (UE), comprising: circuitry configured to: take a plurality of measurements based on a downlink quality, wherein each of the plurality of measurements is taken on a respective downlink resource of a plurality of downlink resources; derive a first channel quality indication indicating a channel quality of the plurality of downlink resources; derive a plurality of difference indications, each difference indication being between the first channel quality indication and a channel quality indication for one of the plurality of downlink resources; and transmit at least one report including the first channel quality indication and the plurality of difference indications to a network in a time interval including a plurality of time slots.

[00013c] According to the third aspect of the present invention, there is provided a network node, comprising: circuitry configured to: transmit a downlink transmission; receive at least one report including a first channel quality indication and a plurality of difference indications from a user equipment (UE) in response to the downlink transmission, wherein the first channel quality indication indicates a channel quality corresponding to a plurality of downlink resources and each of the plurality of difference indications indicates a difference between the first channel quality indication and a channel quality indication for each of a plurality of measurements, wherein each of the plurality of measurements is taken on a respective downlink resource of the plurality of downlink resources; and transmit at least one subsequent transmission having a formatting derived at least from the first channel quality indication and each of the plurality of difference indications.

[00013d] According to the fourth aspect of the present invention, there is provided a method, comprising: taking a plurality of measurements based on downlink quality by a user equipment (UE), wherein each of the plurality of measurements is taken on a respective downlink resource of a plurality of downlink resources; deriving a first channel quality indication by the UE, the first channel quality indication indicating a channel quality of the plurality of downlink resources; deriving a plurality of difference indications, each difference indication being between the first channel quality indication and a channel quality indication for one of the plurality of a downlink resources; and transmitting at least one report including the first channel quality indication and the plurality of difference indications by the UE.

[00014] BRIEF DESCRIPTION OF THE DRAWINGS

[00015] The objectives of the present invention will become apparent upon consideration of the accompanying detailed description and figures, in which:

[00016] Figure 1 is a simplified block diagram of the UMTS architecture.

[00017] Figure 2 is a simplified block diagram illustrating a UE and a

base station for implementing channel quality measurements for downlink resource allocation of the present invention.

[00018] Figure 3 is a flow diagram of one preferred method for performing channel quality measurements at the UE for downlink resource allocation of the present invention and reporting those measurements to the base station.

[00019] DETAILED DESCRIPTION OF
THE PREFERRED EMBODIMENTS

[00020] Presently preferred embodiments are described below with reference to the drawing figures wherein like numerals represent like elements throughout.

[00021] Referring to Figure 1, the UMTS network architecture includes a core network (CN), a UMTS Terrestrial Radio Access Network (UTRAN), and a User Equipment (UE). The two general interfaces are the Iu interface, between the UTRAN and the core network, as well as the radio interface Uu, between the UTRAN and the UE. The UTRAN consists of several Radio Network Subsystems (RNS) which can be interconnected by an Iur interface. This interconnection allows core network independent procedures between different RNSs. Therefore, radio access technology-specific functions can be kept outside of the core network. The RNS is further divided into the Radio Network Controller (RNC) and several base stations (Node Bs). The Node Bs are connected to the RNC by an Iub interface. One Node B can serve one or multiple cells, and typically serves a plurality of UEs. The UTRAN supports both FDD mode and TDD mode on the radio interface. For both modes, the same network architecture and the same protocols are used.

[00022] Referring to the block diagram in Figure 2, a preferred communication system 10 for performing the process of obtaining CQ measurements for downlink resource allocation in accordance with the

principles of the present invention is shown. The communication system 10 comprises a UE 12 and a base station/node-B 30, (hereinafter referred to as base station 30) which are coupled together via a wireless radio interface 14.

[00023] UE 12 includes an antenna 16, an isolator or switch 18, a matched filter 20, a reference channel code generator 21, a power measurement device 22, a timeslot interference measurement device 24, a CQ transmitter 26 and a CQ determination device 28. The antenna 16 is coupled through the isolator/switch 18 to the matched filter 20, which receives the downlink signal and provides an output to the power measurement device 22. The reference channel code generator 21 generates a reference channel code, which is applied to the matched filter 20. The power measurement device 22 analyzes the output of the matched filter 20 to determine the power level of the downlink signal and outputs this power level to the CQ determination device 28.

[00024] The output of isolator/switch 18 is further coupled to the timeslot interference measurement device 24, which measures the downlink channel and provides an output to a second input of the CQ determination device 28. The CQ determination device 28 analyzes the power level output from the power measurement device 22 and the interference level from the timeslot interference measurement device 24 and provides a CQ measurement to the transmitter 26. The transmitter 26 is coupled to the antenna 16 through the isolator/switch 18 for wireless RF transmission to the base station 30 through wireless radio interface 14.

[00025] Base station 30 comprises a reference channel transmitter 36, an isolator or switch 34, an antenna 32, a CQ receiver 38 and a CQ storage device 40. The antenna 32 receives the wireless RF transmission from the UE, including the CQ measurement through the wireless radio interface 14, and couples via the isolator/switch 34 to the received signal to the channel quality receiver 38. The received CQ measurement is then stored at the CQ storage device 40. The reference channel transmitter 36 provides a reference signal,

which is transmitted in the downlink to UE 12 through the isolator/switch 34 and the antenna 32. The reference downlink signal from the transmitter 36 is utilized by the UE 12 to create the downlink CQ measurement.

[00026] It should be noted that the foregoing preferred method 50 in accordance with the present invention shown in Figure 3 may be performed by communication systems other than the types shown in Figures 1 and 2, and the present invention is not intended to be so limited.

[00027] Referring to Figure 3, the method 50 may be implemented by a digital communication system 10 as explained with reference to Figures 1 and 2, comprising a UE 12 which is in communication with a base station 30.

[00028] A fast quality estimate per timeslot or sub-channel is one preferred technique for CQ measurement employed by the present invention to provide the best performance for the downlink (DL) allocation since the base station 30 will have all of the information needed to choose the modulation and coding, select the best user or users and to allocate to them the best timeslots or sub-channels. Although the present invention is applicable to both the UMTS frequency division duplexing (FDD) and time division duplex (TDD) standards, only one example will be set forth herein. In the FDD standard, for example, the common pilot channel (CPICH) may be measured and divided by a per-timeslot or sub-channel interference signal code power (ISCP) measurement, which is performed in all relevant timeslots. In the TDD standard the physical common pilot channel (PCCPCH) is an example of a channel that may be measured.

[00029] The base station 30 transmits a fixed-level transmission (step 52), such as a pilot beacon or a data-carrying signal, over the PCCPCH, hereafter referred to as the reference channel. It should be understood that the reference channel may be any type of fixed-level, (or known), base station transmission, whether or not it is a control channel or a data channel. It is only necessary that the reference channel power be known by the UE 12 at the time of

measurement. The UE 12 measures received signal code power (RSCP) (step 54). The UE 12 then measures the ISCP (step 56). The RSCP and/or the ISCP may be measured continuously, (i.e. for every frame and timeslot), or on a less frequent basis as discussed below.

[00030] There are a number of different alternatives that can be implemented for steps 56 and 54. In a first alternative, the UE 12 measures the ISCP and/or the RSCP in specifically-identified timeslots and in a specifically-identified order. In a second alternative, the UE 12 measures the ISCP and/or the RSCP in all of the timeslots in a predetermined order or a random order. In a third alternative, the UE 12 measures the ISCP and/or the RSCP in a randomly identified number of timeslots in a random order. In a fourth alternative, the UE 12 rotates the measurement of the timeslots. For example, ISCP and/or RSCP in timeslots 1-4 of the first frame are measured, then timeslots 5-8 of the subsequent frame are measured and timeslots 9-12 of the subsequent frame, etc. By having this inherent flexibility, the method 50 in accordance with the present invention may be adapted to the particular needs of the system operator and the specific application.

[00031] As discussed above, it is not necessary to have both path loss and interference measured using the same timing scheme at the same rate. Thus, ISCP may be measured much less frequently than RSCP. For example, ISCP may be measured in accordance with the fourth alternative of Table 1 and RSCP may be measured in accordance with the second alternative of Table 1.

[00032] Table 1 summarizes the different embodiments for UE measurement. However, it should be noted that any combination of predetermined or dynamic selection of timeslots and/or timeslot order may be used without departing from the spirit and scope of the present invention.

ALTERNATIVE	UE MEASUREMENT
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First	Measure in specific timeslots and in a specific order
Second	Measure in all timeslots in a predetermined or random order
Third	Measure in randomly identified timeslots and in a random order
Fourth	Rotate measurement in different timeslots

TABLE 1

[00033] Returning to Figure 3, regardless of the timeslots or timeslot order that was selected and measured, the UE 12 at step 58 determines the downlink CQ from the measurements taken and reports downlink CQ to the base station 30. The CQ measurement may comprise transmitting ISCP (from step 56) and RSCP (from step 54) individually, transmitting the ISCP/RSCP ratio calculated by the UE 12, or may comprise one of many other alternatives which will be explained in further detail hereinafter.

[00034] The downlink CQ measurement report generated and transmitted by the UE 12 at step 58 is received by the base station 30 at step 60, and is analyzed at step 62 to determine the activity necessary for subsequent transmissions to the UE 12, taking into account the downlink CQ measurements.

[00035] The manner in which the UE 12 collects the measurements and transmits the measurement data is typically a trade-off between the amount of data provided, and the overhead necessary to transmit the measurement data back to the base station 30. For example, measurement and transmission of all data for both ISCP and RSCP for every selected timeslot provides the most information. However, the drawback is the large amount of data required to be transmitted and the overhead required to transmit it.

[00036] The goal of the present invention is to return timely and accurate CQ information and to determine the proper modulation and coding to use for the downlink channels. As such, there are many different alternatives that the

UE 12 can use to measure and transmit this information to the base station 30.

Table 2 shows the different alternatives for transmitting RSCP and ISCP to the base station 30.

ALTERNATIVE	UE TRANSMITTED INFORMATION
1	RSCP and ISCP for every timeslot
2	RSCP once per frame and ISCP for every specified timeslot
3	RSCP/ISCP ratio for every specified timeslot
4	A "coded" RSCP/ISCP ratio for every specified timeslot
5	Soft symbol errors for every specified timeslot
6	An indication of one of the available sets or levels of the modulation coding set (MCS) for each timeslot
7	A combined coding of all timeslots
8	A mean of the CQ for all timeslots (i.e., 4-5 bits) and the difference from the mean (i.e., 1 or 2 bits) for each timeslot
9	The actual measured value of one predetermined or identified timeslot or sub-channel as a reference, and then transmit the difference of the remaining timeslots from the reference timeslot.

TABLE 2

[00037] The nine alternatives are generally in the order from requiring the most number of bits to requiring the least number of bits to transmit the downlink CQ information from the UE 12 to the base station 30. It should be understood that this list is not an all-inclusive and the present invention should not be limited to the specific enumerated alternatives shown in Table 1.

[00038] In alternative 1, the UE 12 transmits RSCP and ISCP for every timeslot to the base station 30.

[00039] In alternative 2, the UE 12 transmits RSCP once per frame and transmits ISCP for every specified timeslot to the base station 30.

[00040] In alternative 3, the UE 12 transmits an RSCP/ISCP ratio for every specified timeslot to the base station 30.

[00041] In alternative 4, the UE 12 codes and transmits the RSCP/ISCP ratio for every specified timeslot to the base station 30. Coding of the ratio

reduces the number of bits required to transmit the information.

[00042] In alternative 5, the UE 12 transmits the number soft symbol errors, detected by the UE 12, to the base station 30. Soft symbol errors are well known by those of skill in the art as an indication of downlink CQ.

[00043] In alternative 6, the UE 12 selects the available modulation coding sets (MCS) from the RSCP and ISCP measurements, and transmits this selection to the base station which the base station 30 uses for transmission. There are typically a predefined number of MCSs available to a UE, for example eight (8) such sets. Once the UE performs the RSCP and ISCP measurements, it calculates which MSCs would be supportable give the current CQ.

[00044] In alternative 7, the UE 12 combines coding of CQ information for all timeslots. Separately coding the common and differential quality of all timeslots or sub-channels results in a saving of transmitted bits.

[00045] In alternative 8, the UE 12 measures and transmits the mean of the CQs for all timeslots, which is coded using a larger number of bits, and then transmits the difference of each remaining timeslot to the mean value using coded values having a smaller number of bits. As one example, four (4) or five (5) bits may be used to identify the mean value of the timeslots, while the difference of each timeslot or sub-channel to the mean value requires only one (1) or two (2) bits.

[00046] In alternative 9, one of the timeslots or sub-channels is designated as a reference point. The CQ measurement for this timeslot is transmitted, and then for the remaining timeslots it is only necessary to transmit the differential information as referred to the reference point. In a manner similar to the alternative 8, the reference timeslot may be four (4) or five (5) bits and the difference from the reference for the remaining timeslots may be one (1) or two (2) bits.

[00047] In order to reduce power requirements as well as the complexity of the implementation necessary for measurement and processing, it is desirable to minimize the number of measurements and the amount of processing. For systems in which the UE 12 must perform measurements at all times pending information requests from the base station 30, this can impose a heavy measurement burden on the UE 12 if the number of timeslots or sub-channels are large. In situations where the interference does not change at the same rate that the fading does, timeslot measurements may be rotated in such a way that a recent interference measurement is available for some timeslots while older information is used for other slots.

[00048] By reducing the number of timeslots measured, complexity can be substantially reduced. Large numbers of timeslots to be measured results in frequent measurement reports and high complexity. A smaller number of timeslot measurements result in lower complexity but less frequent measurement reports, which leads to some degradation in performance. A compromise can be adopted according to the needs and/or preferences of the particular application.

[00049] Although the invention has been described in part by making detailed reference to the preferred embodiment, such detail is intended to be instructive rather than restrictive. It will be appreciated by those skilled in the art that many variations may be made in the structure and mode of operation without departing from the spirit and scope of the invention as disclosed in the teachings herein.

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Claims

1. A user equipment (UE), comprising:

a measurement device configured to take a plurality of measurements based on a downlink quality, wherein each of the plurality of measurements is taken on a respective downlink resource of a plurality of downlink resources;

a channel quality determination device configured to:

derive a first channel quality indication indicating a channel quality of the plurality of downlink resources; and

derive a plurality of difference indications, each difference indication being between the first channel quality indication and a channel quality indication for one of the plurality of downlink resources; and

a transmitting device configured to transmit at least one report including the first channel quality indication and the plurality of difference indications.

2. The UE of claim 1, further comprising:

a receiver configured to receive at least one subsequent downlink transmission associated with at least one modulation and coding set in response to the transmitted first channel quality indication and the plurality of difference indications.

3. The UE of claim 1, wherein each of the plurality of measurements is derived at least from a received power of a reference signal.

4. A user equipment (UE), comprising:

circuitry configured to:

take a plurality of measurements based on a downlink quality, wherein each of the plurality of measurements is taken on a respective downlink resource of a plurality of downlink resources;

derive a first channel quality indication indicating a channel quality of the plurality of downlink resources;

derive a plurality of difference indications, each difference indication being between the first channel quality indication and a channel quality indication for one of the plurality of downlink resources; and

transmit at least one report including the first channel quality indication and the plurality of difference indications to a network in a time interval including a plurality of time slots.

5. The UE of claim 4, wherein the circuitry is further configured to receive at least one subsequent downlink transmission associated with at least one modulation and coding set in response to the transmitted first channel quality indication and the plurality of difference indications.

6. The UE of claim 4, wherein each of the plurality of measurements is derived at least from a received power of a reference signal.

7. A network node, comprising:

circuitry configured to:

transmit a downlink transmission;

receive at least one report including a first channel quality indication and a plurality of difference indications from a user equipment (UE) in response to the downlink transmission, wherein the first channel quality indication indicates a channel quality corresponding to a plurality of downlink resources and each of the plurality of difference indications indicates a difference between the first channel quality indication and a channel quality indication for each of a plurality of measurements, wherein each of the plurality of measurements is taken on a respective downlink resource of the plurality of downlink resources; and

transmit at least one subsequent transmission having a formatting derived at least from the first channel quality indication and each of the plurality of difference indications.

8. A method, comprising:

taking a plurality of measurements based on downlink quality by a user equipment (UE), wherein each of the plurality of measurements is taken on a respective downlink resource of a plurality of downlink resources;

deriving a first channel quality indication by the UE, the first channel quality indication indicating a channel quality of the plurality of downlink resources;

deriving a plurality of difference indications, each difference indication being between the first channel quality indication and a channel quality indication for one of the plurality of downlink resources; and

transmitting at least one report including the first channel quality indication and the plurality of difference indications by the UE.

9. The method of claim 8, further comprising:

receiving at least one subsequent downlink transmission associated with at least one modulation and coding set in response to the transmitted first channel quality indication and the plurality of difference indications.

10. The method of claim 8, wherein each of the plurality of measurements is derived at least from a received power of a reference signal.

11. The UE of claim 1, wherein in the at least one report, a number of bits used for each of the plurality of difference indications is less than a number of bits used for the first channel quality indication.

12. The UE of claim 11, wherein in the at least one report, the number of bits for each of the plurality of difference indications is two and the number of bits of the first channel quality indication is four.

13. The UE of claim 4 wherein in the at least one report, a number of bits used for each of the plurality of difference indications is less than a number of bits used for the first channel quality indication.

14. The UE of claim 13, wherein in the at least one report, the number of bits for each of the plurality of difference indications is two and the number of bits of the first channel quality indication is four.

15. The network node of claim 7, wherein in the at least one report, a number of bits used for each of the plurality of difference indications is less than a number of bits used for the first channel quality indication.

16. The network node of claim 15, wherein in the at least one report, the number of bits for each of the plurality of difference indications is two and the number of bits of the first channel quality indication is four.

17. The method of claim 8, wherein in the at least one report, a number of bits used for each of the plurality of difference indications is less than a number of bits used for the first channel quality indication.

18. The method of claim 17, wherein in the at least one report, the number of bits for each of the plurality of difference indications is two and the number of bits of the first channel quality indication is four.