

**A Method, A Device and A Computer Program Product for
Determining a Data Transmission Characteristic**

5 The present application claims the benefit of the United States provisional application 61/019,681 (filed on 8 January 2008), the entire contents of which are incorporated herein by reference for all purposes.

10

Technical Field

Embodiments relate to the field of communication systems, such as wireless communication systems, for example. By way of example, embodiments relate to a method of determining a data transmission characteristic. In particular, the present
15 invention relates to WiMedia distributed MAC protocol as well as the future versions of IEEE 802.11 MAC, IEEE 802.15.3 MAC, IEEE 802.15.4 MAC and any other relevant MAC protocols.

Background

20 In the current version of the WiMedia standard, the existing link feedback mechanism allows for feedback from receiver to transmitter only every superframe (65 ms). In more detail, the current feedback mechanism allows the receiver to suggest the transmission rate and the differential increase or decrease of

transmit power. However, it should be noted that the coherence time of channels can be much less than 65 ms.

Hence, there is a need for a feedback strategy that allows for
5 more frequent link feedback between a transmitter and a receiver. Moreover, typically power control and rate control algorithms are preferred to be implemented at the transmitter side. The receiver typically does not have the knowledge of the transmit power. Hence, it is preferable to implement power
10 control algorithms at the transmitter. There are several rate and power control algorithms that have been proposed in the literature (see [5]-[8]) that can be implemented at the transmitter side.

15 The coherence time for UWB channels can be low ($\ll 65\text{ms}$) especially under mobile environments. The current WiMedia MAC allows for link feedback mechanism every Superframe ($\sim 65\text{ms}$). The current feedback mechanism allows the receiver to suggest the transmission rate and the differential increase or decrease of
20 transmit power.

However, a link feedback mechanism that can cater to channels with low coherence time ($\ll 65\text{ ms}$) is desirable.

A scheme that allows the implementers the flexibility to incorporate the rate and power control at the transmitter side is also desirable.

5 In [3], a scheme based on using reserved bits in Block Acknowledgement (B-ACK) frames [2] is suggested. The B-ACK frame acknowledges correct or incorrect receipt of the previous sequence of frames and provides information for the transmission of the next sequence of frames. However, it should be noted that
10 a transmitter may send frames using No-Acknowledgement (No ACK) policy. Even if acknowledgment frames are sent, the frequency with which acknowledgment frames may be sent to the transmitter may vary (independent of the coherence time of the channel). Moreover, it is desirable to have rate and power control at the
15 transmitter (transmit power is known only at the transmitter and several rate and power control algorithms that can be implemented at the transmitter have been proposed in the literature; see [5]-[8]).

20 In embodiments of the present invention, solutions are given for link feedback by using command/control frames between two WiMedia (ECMA specification [1] is based on the WiMedia standard [2]) specified devices. The solutions cater to low channel coherence times (that can be much less than 65 ms) and some of

them allow for power control and rate control to be incorporated at the transmitter node.

Summary

5 A method for determining a data transmission characteristic, wherein data are transmitted in at least one superframe, wherein each superframe is configured to transmit a plurality of frames, is provided, the method comprising: sending, in the superframe, a plurality of data transmission characteristic request messages to
10 a receiver for requesting data transmission characteristic information from the receiver, wherein the data transmission characteristic request messages are command/control messages; receiving, in the superframe, a plurality of data transmission characteristic response messages including data transmission
15 characteristic information from the receiver in response to the data transmission characteristic request messages wherein the data transmission characteristic response messages are command/control messages; determining, from the data transmission characteristic information, at least one data transmission
20 characteristic.

Brief Description of the Drawings

The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of

various embodiments. In the following description, various embodiments are described with reference to the following drawings, in which:

FIG. 1 shows the structure of a superframe;

5 FIG. 2 shows the illustration of a communication system;

FIG. 3 shows a command/control frame payload according to one embodiment;

FIG. 4 shows a command/control frame payload according to one embodiment;

10 FIG. 5 shows a command/control frame payload according to one embodiment;

FIG. 6 shows a command/control frame payload according to one embodiment;

15 FIG. 7 shows a command/control frame payload according to one embodiment;

FIG. 8 illustrates command/control frame payload formats according to one embodiment; and

FIG. 9 shows a communication device according to one embodiment.

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Description

As background information, under the ECMA standard, frame is defined as unit of data transmitted by a device, and a superframe is defined as periodic time interval used in the ECMA standard to

coordinate frame transmissions between devices, and is the basic timing structure for frame transmissions. A superframe is composed of 256 Medium Access Slots (MASs), and a superframe includes a Beacon Period (BP) followed by a data period. A BP comprises a number of beacon slots, and a beacon can be transmitted within a beacon slot. A MAS duration is of 256 μ s and a superframe duration is about 65 ms. Beacon Period (BP) may be defined as a period of time declared by a device during which it sends or listens for beacons according to the ECMA standard, and the term beacon may refer to information regarding such as the reservation of time slots in the further data period. Each superframe starts with a BP, which extends over one or more contiguous Medium Access Slots (MASs).

FIG. 1 illustrates the basic structure of superframe 110 according to the ECMA standard. The superframe 110 contains a beacon period 101 followed by a data period 102, wherein frame is defined as unit of data transmitted by a device. A superframe is composed of 256 MASs 103.

FIG. 2 shows an illustration of a communication system 200 including communication devices A to H (211-218). In one embodiment, the communication system may be an ad-hoc communication group (beacon group) 200 including ad-hoc

communication devices A to H (211 -218), wherein all the devices A to H (211-218) work in a particular frequency channel. An ad-hoc radio communication group generally consists of a plurality of ad-hoc radio communication devices, wherein the communication among these devices is self-organized. The plurality of devices are able to discover each other within a range to form the communication group, and within the communication group, they can communicate with each other without the need of a central control. The term frequency channel may refer to a combination of one or more frequency bands, and such a combination may be used for signal transmission. The term frequency band may refer to a predefined continuous frequency range, which may be used for signal transmission. For illustration, circle line 201 represents the transmission range of device B 212, meaning that device B is able to transmit data to other communication devices that are located within the circle line 201. In this illustration, device B 212 is able to transmit data to devices A 211, C 213, D 214, E 215, and H 218. Similarly, circle line 202 represents the transmission range of device C 213, meaning that device C is able to transmit data to other communication devices that are located within the circle line 202, and circle line 203 represents the transmission range of device D 214, meaning that device D is able to transmit data to other communication devices that are located within the circle line 203. In the ad hoc communication group,

any two communication devices may communicate with each other without a central control and may exchange information or data with each other.

5 In another scenario, the communication system 200 may have a central control, for example, node B 212 as a Pico Net Coordinator (PNC) (see [4]). In this scenario, any device (such as device A 211, C 213, D 214, E 215, and H 218) that enters the transmission range of PNC B 212 may need to communicate with the
10 PNC B 212 to request information about the communication channel or to establish a communication with another communication device within the transmission range 201 of PNC B 212. The PNC B 212 may send information about other communication devices to each device that enters the PNC B 212's transmission range. In other words,
15 in this embodiment, any two devices that wish to communicate with each other need to first communicate with a central control, such as a PNC, and the central control will help the two devices to transmit and receive the messages among the two devices and establish communication between the two devices.

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In one embodiment, every device of the communication system 200 may be equipped with a transmitter and a receiver. In one embodiment, a communication device shown in FIG. 2 may send information or data or message to either another device or a PNC

by a transmitter. In one embodiment, a communication device shown in FIG. 2 may receive information or data or message from either another device or a PNC by a receiver.

5 The protocols and facilities of the WiMedia Standard are supported by the exchange of information between devices. For each type of information, an Information Element (IE) is defined. IEs can be included by a device in its beacon at any time and may optionally be requested or provided using the command frames. IEs
10 are contained in beacon and command frames. They convey certain control and management information.

According to the current WiMedia standard, the Link Feedback IE contains information on the recommended change to the data rate
15 and transmit power level recommended by a recipient device for one or more source devices. A device may include a Link Feedback IE in its beacon to provide feedback on a link with a specific neighbor.

20 A recipient device may use the Link Feedback IE to suggest the optimal data rate to be used by a source device, for example, to increase throughput and/or to reduce the frame error rate. The data rate in the Link Feedback IE should be interpreted as the maximum data rate that the source device should use for this

particular link, for an acceptable frame error rate. The source device is not required to follow the recommendation.

A recipient device may recommend a transmit power level change to be used by a source device by including a Link Feedback IE in its beacon. A device that receives a Link Feedback IE is not required to change its transmit power level. The recipient device might use the signal to noise ratio, received signal strength, frame error ratio or other parameters to determine the transmit power change to recommend to the source device.

According to the current WiMedia standard, Link Feedback IE is sent once every superframe. However, the coherence time of channels can be much less than the duration of a superframe, which is 65.536 ms. Thus, there is a need for a new link feedback strategy which can cater to lower coherence time.

In one embodiment, new link feedback strategies that use command/control frames for devices are proposed. The proposed strategies cater to lower channel coherence times (less than one superframe duration, i.e., 65.536ms) and some of them also allow for power and rate control at the transmitter side.

In one embodiment, a method for determining a data transmission characteristic, wherein data are transmitted in at least one superframe, wherein each superframe is configured to transmit a plurality of frames, is provided, the method comprising:

- 5 sending, in the superframe, a plurality of data transmission characteristic request messages to a receiver for requesting data transmission characteristic information from the receiver, wherein the data transmission characteristic request messages are command/control messages; receiving, in the superframe, a
- 10 plurality of data transmission characteristic response messages including data transmission characteristic information from the receiver in response to the data transmission characteristic request messages wherein the data transmission characteristic response messages are command/control messages; determining,
- 15 from the data transmission characteristic information, at least one data transmission characteristic.

In other words, in one embodiment, in order to determine at least one data transmission characteristic, a device A may send,

20 within a superframe, a data transmission characteristic request message to another device B every 'x' μ s or at least once every 'x' μ s. Since the duration of a superframe is about 65 ms, the transmitter of device A may send a plurality of data transmission characteristic request messages to the receiver of

device B within a superframe. In one embodiment, the receiver of device B may respond to each data transmission characteristic request message by sending a data transmission characteristic response message to device A, wherein the data transmission characteristic response message includes at least one data transmission characteristic. In one embodiment, device A determines the at least one data transmission characteristic based on the data transmission characteristic response message. In one embodiment, both the data transmission characteristic request message and the data transmission characteristic response message are command/control frames.

In one embodiment, the data transmission characteristic request message sent by device A may also include data transmission characteristic information or at least one data transmission characteristic. In one embodiment, both device A and device B may determine at least one data transmission characteristic based on at least one data transmission characteristic request message and/or at least one data transmission characteristic response message. In one embodiment, the data transmission characteristic may refer to information about transmission rate or transmission power of data transmission, but is not limited thereto. In one embodiment, the data transmission characteristic may refer to Link Quality Indicator (LQI) or Signal to Noise

Ratio (SNR). In one embodiment, the data transmission characteristic may refer to the number of correctly received packets. In one embodiment, the data transmission characteristic may refer to the number of lost packets. In one embodiment, the data transmission characteristic may refer to the number of packets received with Frame Check Sequence (FCS) error (with no Header Check Sequence or HCS error). In one embodiment, the data transmission characteristic may refer to the number of packets transmitted to intended recipient of the command frame. In one embodiment, the data transmission characteristic may refer to the size of measurement window in number of microseconds or milliseconds.

In one embodiment, the command/control messages are command/control frames. According to the WiMedia standard, command/control frames are for sending command/control information among communication devices within a communication devices' group.

In one embodiment, two or more frames (or sets of two or more frames) are transmitted in the superframe by a device, and at least one data transmission characteristic request message is sent by the device before (e.g. at the beginning of) the transmission of every set of two or more frames by the device.

In other words, in one embodiment, a characteristic request message is transmitted by the device for each set of frames transmitted in the superframe by the device, such that the transmission of a characteristic request message by the device
5 is followed by the reception of a characteristic response message by the device followed by transmission of the respective set of frames by the device(i.e. no other frame is transmitted by the device between the characteristic request message and the respective set of frames).

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In one embodiment, the data transmission characteristic request messages are sent periodically. In one embodiment, a data transmission characteristic request message is sent at least once during each predetermined periodic time interval.

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In one embodiment, the transmitter and the receiver are communication devices according to WiMedia specification.

In one embodiment, the transmitter and the receiver are
20 communication devices according to IEEE 802.15.3b specification.

In one embodiment, the data transmission characteristic request messages are medium access control layer messages. In one

embodiment, the data transmission characteristic response messages are medium access control layer messages.

In one embodiment, data transmission comprises the transmission
5 of a plurality of data packets, and the data transmission characteristic information includes the number of data packets correctly received by the receiver or the number of data packets lost or the number of data packets received with FCS error (and not with HCS error) or the number of data packets transmitted by
10 the receiver in a measurement window time period. In one embodiment, the data transmission characteristic information includes information about the measurement window time period as well.

15 In one embodiment, data transmission is performed via a communication link between a transmitter and the receiver and the data transmission characteristic information is communication link feedback information or link quality information.

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In one embodiment, the data transmission characteristic information includes information about the signal to noise ratio at the receiver pertaining to the data transmission.

In one embodiment, the data transmission characteristic response message includes information for setting the transmit power level of the data transmission.

- 5 In one embodiment, the data transmission characteristic response message includes information for setting the transmit data rate of the data transmission.

In one embodiment, a data transmission characteristic request
10 message is sent aperiodically.

In one embodiment, the data transmission characteristic response messages include information for setting the data rate of the data transmission.

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In one embodiment, the data transmission characteristic information includes information about suggested data rate, information about suggest transmit power level change, information about number of packets received with error,
20 information about number of packets lost, information about number of packets transmitted to the recipient of the command frame, information about measurement window, information about number of packets correctly received, and information about SNR/LQI of communication link.

In one embodiment, the transmitter transmits a command/control frame or a data transmission characteristic request message every 'x' μ s or at least once in every 'x' μ s or aperiodically or at the beginning of frame transactions and the receiver
5 replies with a command/control frame or a data transmission characteristic response message upon reception of a command /control frame or a request message after a fixed period of time which may for example be Short Interframe Spacing (SIFS).

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In one embodiment, the time to send a data transmission characteristic response message by a device in response to a data transmission characteristic request message, after the receipt of the data transmission characteristic request message
15 is given by

$$pSIFS + pSlotTime + (\text{position value in a device list}) \times (\text{command frame duration of the data transmission characteristic response message} + pSIFS)$$

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wherein pSIFS and pSlotTime may have the values as defined by the ECMA standard.

In one embodiment, a data transmission characteristic response message transmitted in response to a data transmission characteristic request message comprises a duration field with a duration value that is given by

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a duration value included in the data transmission characteristic request message - (command frame body transmission time of the data transmission characteristic request message + pSIFS) - command frame transmission time of the data transmission characteristic response message + command frame body transmission time of the data transmission characteristic response message

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wherein pSIFS may have the value as defined by the ECMA standard.

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In one embodiment, a data transmission characteristic response message transmitted in response to a data transmission characteristic request message comprises a duration field with a duration value that is given by

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a duration value included in the data transmission characteristic request message - (command frame body transmission time of the data transmission characteristic request message +

pSIFS + pSlotTime + (position value in a list in the data transmission characteristic request message) × (command frame transmission time of the data transmission characteristic response message + pSIFS)) - command frame transmission time of the data transmission characteristic response message + command frame body transmission time of the data transmission characteristic response message

wherein pSIFS and pSlotTime may have the values as defined by the ECMA standard.

In the following, five different embodiments (five possible frame payload formats for command/control frames) are shown. In one embodiment, the transmitter may include a command/control frame (payload(s) as shown in various options; see Figs.2-6) every 'x' μs (or at least once every 'x' μs) and/or at the beginning of frame transactions or aperiodically, and the receiver reply with a command/control frame upon reception of a command/control frame after a fixed time period which for example may be Short Interframe Spacing (SIFS) [2].

In one embodiment, the command/control frame sent by the transmitter requesting data transmission characteristic is referred to "Link Feedback Request frame". In one embodiment,

the command/control frame sent by the receiver in response to a Link Feedback Request frame is referred to "Link Feedback Reply frame".

5; FIG. 3 illustrates the command/control frame payload formats 300 according to one embodiment.

Frame 310 shows the payload of a command/control frame (data transmission characteristic request message) sent by a
10; transmitter in one embodiment. In one embodiment, the payload of the command/control frame 310 sent by the transmitter comprises one octet 301. In one embodiment, the bit format of the octet 301 is shown as 330: bit1-bit7 305 of the octet 301 may be reserved, and bit0 306 may be set to be 0 when it is a Link
15; Feedback Request frame (data transmission characteristic request message).

In one embodiment, the transmitter may send the command/control frame 310 every 'x' μ s (or at least once in every 'x' μ s or
20; aperiodically) and/or at the start of frame transaction, and the receiver may reply with a command/control frame upon reception of the command/control frame from the transmitter after a fixed time period which for example may be SIFS.

Frame 320 shows the payload of command/control frame (data transmission characteristic response message) from a receiver in response to the Link Feedback Request frame (data transmission characteristic request message) according to one embodiment.

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In one embodiment, the data transmission characteristic response message 320 may comprise a link feedback control octet 302 indicating that the message is transmitted in response to a Link Feedback Request frame 310. In one embodiment, the data transmission characteristic response message 320 may comprise one or two octets 303 indicating the number of correctly received packets since last Link Feedback command/control frame exchange. In one embodiment, the data transmission characteristic response message 320 may comprise an octet 304 indicating LQI or the signal to noise ratio (SNR). In one embodiment, bit1-bit7 305 of the link feedback control octet 302 are reserved, and bit0 306 is set to be 1 to indicate that message 320 is a Link Feedback Reply frame (data transmission characteristic response message).

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The embodiment as illustrated in FIG. 3 allows for power and rate control to be done at the transmitter. The feedback information includes SNR or LQI and number of packets correctly received.

FIG. 4 illustrates the command/control frame payload formats 400 according to one embodiment.

- 5 Frame 410 shows the payload of command/control frame (data transmission characteristic request message) from a transmitter in one embodiment. In one embodiment, the payload of the command/control frame 410 from a transmitter may comprise one
10 octet 401. In one embodiment, the octet 401 may have the bit format as shown in format 430: bit1-bit7 406 of octet 401 may be reserved, and bit0 407 may be set to be 0 when it is a Link Feedback Request frame (data transmission characteristic request message) from the transmitter.
- 15 Frame 420 shows the payload of command/control frame (data transmission characteristic response message) from a receiver in response to the data transmission characteristic request message 410 according to one embodiment.
- 20 In one embodiment, the command/control frame 420 comprises a link feedback control octet 402 indicating that the message is in response of the Link Feedback Request frame 410. In one embodiment, the command/control frame 420 may comprise one octet 403 indicating the data rate and the change of transmit power

level. In one embodiment, bit3/bit4-bit7 404 of the octet 403 may be used to indicate data rate. In one embodiment, bit0-bit2/bit3 405 of the octet 403 may be used to indicate the change of transmit power level.

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In one embodiment, the octet 402 may have the bit format as shown in format 430: bit1-bit7 406 of octet 402 may be reserved, and bit0 407 may be set to be 1 when it is a Link Feedback Reply frame (data transmission characteristic response message) from
10 the receiver.

In one embodiment, the transmitter includes a command/control frame (payload as shown in 410) every 'x' μ s (or at least once in every 'x' μ s or aperiodically) and/or at the start of frame
15 transaction and the receiver replies with a command/control frame upon reception of a command/control frame after a fixed time period which for example may be SIFS.

The embodiment as illustrated in FIG. 4 allows for rate control
20 to be done at the receiver and information pertaining to incremental/decremental change in power to be fed back to the transmitter. The feedback information from the receiver to the transmitter includes data rate and incremental/decremental power increase/decrease.

FIG. 5 illustrates the command/control frame payload formats 500 according to one embodiment.

5 In one embodiment, the command/control frame (Link Feedback Request frame, namely the data transmission characteristic request message) sent by the transmitter and the command/control frame (Link Feedback Reply frame, namely the data transmission characteristic response message) sent by the receiver in
10 response to the Link Feedback Request frame may have the same format as shown in frame 510.

In one embodiment, the command/control frame 510 may comprise a Link Feedback Control Octet 501. In one embodiment, the
15 command/control frame 510 may comprise one or two octets 502 to indicate the number of correctly received packets (i.e. since last Link Feedback command/control frame exchange). In one embodiment, the command/control frame 510 may comprise an octet 503 to indicate the LQI or SNR.

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In one embodiment, bit format of the Link Feedback Control octet 501 is shown in frame 520. In one embodiment, bit2-bit7 504 of the Link Feedback Control Octet 501 may be reserved. In one embodiment, bit1 505 of the Link Feedback Control Octet 501 may

be used to indicate whether there is additional two or three octets (502 and/or 503) following the Link Feedback Control Octet 501 included in the command/control frame 510. In one embodiment, bit1 505 may be set to be 0 to indicate there is no additional two or three octets (502 and/or 503) following the Link Feedback Control Octet 501 included in the command/control frame 510. In one embodiment, bit1 505 may be set to be 1 to indicate there is additional two or three octets (502 and/or 503) following the Link Feedback Control Octet 501 included in the command/control frame 510. In one embodiment, bit0 506 of the Link Feedback Control Octet 501 may be used to indicate that the command/control frame is a link feedback request frame, namely a data transmission characteristic request message. In one embodiment, bit0 506 is set to 0 to indicate that the command/control frame is a link feedback request frame, namely a data transmission characteristic request message. In one embodiment, bit0 506 of the Link Feedback Control Octet may be used to indicate that the command/control frame is a link feedback reply frame, namely a data transmission characteristic response message. In one embodiment, bit0 506 is set to 1 to indicate that the command/control frame 510 is a Link Feedback Reply frame, namely a data transmission characteristic response message.

In one embodiment, the transmitter includes a command/control frame (payload as shown in format 510) every 'x' μ s (or at least once in every 'x' μ s or aperiodically) and/or at the start of frame transaction, and the receiver replies with a

5 command/control frame upon reception of a command/control frame after a fixed time period which for example may be SIFS (Transmitter is also able to give feedback to the receiver).

The embodiment as illustrated in FIG. 5 allows for exchange of
10 link feedback information between transmitter and receiver. The feedback information includes SNR/LQI and number of packets correctly received. Rate and power control can be done simultaneously at the transmitter and receiver nodes during frame exchange with this embodiment.

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FIG. 6 illustrates the command/control frame payload formats 600 according to one embodiment.

In one embodiment, the command/control frame (Link Feedback
20 Request frame, namely the data transmission characteristic request message) sent by the transmitter and the command/control frame (Link Feedback Reply frame, namely the data transmission characteristic response message) sent by the receiver in

response to the Link Feedback Request frame may have the same format as shown in frame 610.

In one embodiment, the command/control frame 610 may comprise a
5 Link Feedback Control octet 601 and a Link Feedback octet 602.

In one embodiment, bit format of the Link Feedback octet 602 is shown in 620. In one embodiment, bit3/4-bit7 603 of the Link Feedback octet 602 may be used to indicate the data rate. In one
10 embodiment, bit0-bit2/bit3 604 may be used to indicate the change of transmit power level.

In one embodiment, bit format of the Link Feedback Control octet 601 is shown in 630. In one embodiment, bit2-bit7 605 of the
15 Link Feedback Control octet 601 may be reserved. In one embodiment, bit1 606 of the Link Feedback Control octet 601 may be used to indicate whether there is an Link Feedback octet 602 included in the command/control frame 610 following the Link Feedback Control octet 601. In one embodiment, bit0 607 of the
20 Link Feedback Control octet 601 may be used to indicate whether the command/control frame 610 is a Link Feedback Request message (data transmission characteristic request message) or a Link Feedback Reply message (data transmission characteristic response message). In one embodiment, bit0 607 is set to be 0 to

indicate that the command/control frame is a Link Feedback Request message. In one embodiment, bit0 607 is set to be 1 to indicate that the command/control frame is a Link Feedback Response message.

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In one embodiment, the transmitter includes a command/control frame (payload as shown in 610) every 'x' μ s (or at least once in every 'x' μ s or aperiodically) and/or at the start of frame transaction, and the receiver replies with a command/control frame upon reception of a command/control frame after a fixed time period which may for example be SIFS (Transmitter node is also able to give feedback to the receiver node).

The embodiment as illustrated in FIG. 6 is based on link feedback information as in the current WiMedia standard (data rate and incremental/decremental power increase/decrease). In this embodiment, rate control can be done simultaneously at the transmitter and receiver during frame exchange.

FIG. 7 illustrates the command/control frame payload formats according to one embodiment.

In one embodiment, the command/control frame (Link Feedback Request frame, namely the data transmission characteristic

request message) sent by the transmitter and the command/control frame (Link Feedback Reply frame, namely the data transmission characteristic response message) sent by the receiver in response to the Link Feedback Request frame may have the same
5: format as shown in frame 710.

In one embodiment, the command/control frame 710 may comprise a Link Feedback Control octet 701.

10: In one embodiment, the command/control frame 710 may comprise one or two octets 702 in addition to the Link Feedback Control octet 701 in the command/control frame 710 to indicate the number of correctly received packets.

15: In one embodiment, the command/control frame 710 may comprise one or two octets 703 in addition to the Link Feedback Control octet 701 in the command/control frame 710 to indicate the number of packets lost.

20: In one embodiment, the command/control frame 710 may comprise two octets 704 in addition to the Link Feedback Control octet 701 in the command/control frame 710 to indicate the number of packets received with FCS error and with no HCS error.

In one embodiment, the command/control frame 710 may comprise two octets 705 in addition to the Link Feedback Control octet 701 in the command/control frame 710 to indicate the number of packets transmitted to intended recipient of the command frame.

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In one embodiment, the command/control frame 710 may comprise one or two octets 706 in addition to the Link Feedback Control octet 701 in the command/control frame 710 to indicate the size of measurement window in number of microseconds or milliseconds.

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In one embodiment, the command/control frame 710 may comprise one octet 707 in addition to the Link Feedback Control octet 701 in the command/control frame 710 to indicate the LQI or SNR.

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In one embodiment, Link Feedback Control octet 701 may have the format as shown in 720. In one embodiment, bit2-bit7 708 of the Link Feedback Control octet 701 may be reserved. In one embodiment, bit1 709 may be used to indicate whether there is/are other octets, such as octets 702 and/or octets 703 and/or octets 704, and/or octets 705, and/or octet(s) 706, and/or octet 20 707, included in the command/control frame 710 following the Link Feedback Control octet 701. In one embodiment, bit0 711 may be used to indicate whether the command/control frame 710 is a Link Feedback Request frame (data transmission characteristic

request message) sent by the transmitter or a Link Feedback Reply frame (data transmission characteristic response message) sent by the receiver. In one embodiment, bit0 711 may be set to be 0 to indicate that the command/control frame is a Link
5; Feedback Request frame. In one embodiment, bit0 711 may be set to be 1 to indicate that the command/control frame is a Link Feedback Reply frame.

In one embodiment, Link Feedback Control octet 701 may have the
10; format as shown in 730. In one embodiment, bit3-bit7 712 of the Link Feedback Control octet 701 may be reserved. In one embodiment, bit2 713 may be used to indicate whether there is/are other octets, such as octets 702 and/or octets 703 and/or octets 704, and/or octets 705, and/or octet(s) 706, included in
15 the command/control frame 710 following the Link Feedback Control octet 701. In one embodiment, bit1 714 may be used to indicate whether octet 707 is included in the command/control frame 710. In one embodiment, bit0 715 may be used to indicate whether the command/control frame is a Link Feedback Request
20 frame (data transmission characteristic request message) or a Link Feedback Reply frame (data transmission characteristic response message). In one embodiment, bit0 715 may be set to be 0 to indicate that the command/control frame is a Link Feedback Request frame. In one embodiment, bit0 715 may be set to be 1 to

indicate that the command/control frame is a Link Feedback Reply frame.

In one embodiment, each bit of bit3-bit7 712 of the Link

5 Feedback Control octet 701 may indicate individually if one of the octets 702, octets 703, octets 704, octets 705, and octet(s) 706 is included in the command/control frame 710 following the Link Feedback Control octet 701.

10 In one embodiment, the transmitter may include a command/control frame (payload as shown in format 710) once in every 'x' microseconds or aperiodically and the receiver reply with a command/control frame upon reception of a command/control frame after a fixed time period, say for example SIFS (or later;
15 transmitter node is also able to give feedback to the receiver node).

The embodiment as illustrated in FIG. 7 is similar to the embodiment as illustrated in FIG. 5, but in addition allows
20 feedback information to include number of packets received with error, number of packets lost (determined using sequence numbers and/or fragment numbers), number of packets transmitted to the recipient of the command frame, and measurement window (number of microseconds/ milliseconds where measurements were taken).

FIG. 8 illustrates the command/control frame payload formats 800 according to one embodiment.

5 In one embodiment, the command/control frame (Link Feedback Request frame, namely the data transmission characteristic request message) sent by the transmitter may have the format as shown in frame 810. In one embodiment, the command/control frame (Link Feedback Reply frame, namely the data transmission
10 characteristic response message) sent by the receiver in response to the Link Feedback Request frame may have the format as shown in frame 710 without the octets 802.

In one embodiment, the command/control frame 810 may comprise a
15 Link Feedback Control field 801.

In one embodiment, the command/control frame 810 transmitted by a transmitter may comprise two or more octets 802 in addition to the Link Feedback Control field 801 in the command/control frame
20 810 to indicate the device addresses of the receivers that should respond to this command/control frame transmitted by the transmitter. The order in which the device addresses of the receivers are mentioned in the list 802 is the order in which they shall respond with a response Link feedback command frame.

The Device List field 802 shall not be included in a transmitted Link feedback command frame 810 addressed to a single receiver (unicast address). The Device List field 802 shall be included in a transmitted Link feedback command frame 810 if that Link feedback command frame is sent to multiple receivers or more than one receiver (multicast address).

In one embodiment, Link Feedback Control field 801 may have the format as shown in 820. In one embodiment, bit11-bit15 805 of the Link Feedback Control field 801 may be reserved.

In one embodiment, bit7-bit10 806 of the Link Feedback Control field 801 may be used to indicate the suggested data rate. In one embodiment, bit3-bit6 807 may be used to indicate the suggested change of transmit power level.

The Link Information Field Request/Inclusion bit 808 shall be set to ONE by the sender of the Link feedback command frame 810 which has its Link Feedback Request bit 811 set to ONE if the sender is requesting the Link Information field 803 to be included in any Link feedback command frame in response to the transmitted Link feedback command frame 810. The Link Information Field Request/Inclusion bit 808 shall be set to ONE by the sender of the Link feedback command frame 810 which has its Link Feedback Request bit 811 set to ZERO if the Link

Information field 803 is included in the transmitted Link feedback command frame 810. In all other cases, the sender of the Link feedback command frame 810 shall set the Link Information Field Request/Inclusion bit 808 to ZERO.

5

The LQI Field Request/Inclusion bit 809 shall be set to ONE by the sender of the Link feedback command frame 810 which has its Link Feedback Request bit 811 set to ONE if the sender is requesting LQI field 804 to be included in any Link feedback

10 command frame in response to the transmitted Link feedback command frame 810. The LQI Field Request/Inclusion bit 809 shall be set to ONE by the sender of the Link feedback command frame 810 which has its Link Feedback Request bit 811 set to ZERO if the LQI field 804 is included in the transmitted Link feedback
15 command frame 810. In all other cases, the sender of the Link feedback command frame shall set the LQI Field Request/Inclusion bit 809 to ZERO.

The Link Feedback Request bit 811 shall be set to ONE by the
20 sender of the Link feedback command frame 810 if the sender is requesting a Link feedback command frame in response to the transmitted Link feedback command frame 810. The Link Feedback Request bit 811 shall be set to ZERO in the Link feedback

command frame 810 that is transmitted in response to a Link feedback command frame received.

In one embodiment, the command/control frame 810 may comprise
5 two octets 804 in addition to the Link Feedback Control field
801 in the command/control frame 810 to indicate the LQI or SNR.

The octets 804 shall not be included as part of the transmitted
Link feedback command frame 810 if its Link Feedback Request bit
10 811 is set to ONE.

The octets 803 shall not be included in a transmitted Link
feedback command frame 810 if the Link Feedback Request bit 811
in that Link feedback command frame 810 is set to ONE.

15

In one embodiment, the command/control frame 810 may comprise a
Link Information field 803. In one embodiment, Link Information
field 803 may have the format as shown in 830. In one
embodiment, the octets 812 indicate the number of packets lost.
20 In one embodiment, the octets 813 indicate the number of packets
received with FCS error and with no HCS error.

In one embodiment, the octets 814 indicate the number of
correctly received packets.

In one embodiment, the octets 815 indicate the number of packets transmitted to intended recipient of the command frame.

In one embodiment, the octets 816 indicate the size of
5 measurement window in number of microseconds or milliseconds.

A device that receives a Link feedback command frame 810 addressed to a unicast address (single receiver) and to the device with its Link Feedback Request bit 811 set to ONE shall
10 respond with a Link feedback command frame 810 SIFS or any fixed time period after the reception of the received Link feedback command frame. The device shall include suggested transmit power level change 807 and data rate 806 in the Link feedback command frame 810 it transmits in response to a received Link feedback
15 command frame. The device shall include LQI field 804 in the Link feedback command frame 810 it transmits in response to a received Link feedback command frame if the LQI Field Request/Inclusion bit 809 was set to ONE in the received Link feedback command frame. The device shall include Link
20 Information field 803 in the Link feedback command frame 810 it transmits in response to a received Link feedback command frame if the Link Information Field Request/Inclusion bit 808 was set to ONE in the received Link feedback command frame.

On reception of a Link feedback command frame 810 sent to a multicast address (multiple receivers), that includes its device address in the Device List 802, a device shall respond with a response Link feedback command frame 810. The device shall
5; include suggested transmit power level change 807 and data rate 806 in the Link feedback command frame 810 it transmits in response to a received Link feedback command frame. The device shall include LQI field 804 in the response Link feedback command frame 810 it transmits in response to a received Link
10; feedback command frame if the LQI Field Request/Inclusion bit 809 was set to ONE in the received Link feedback command frame. The device shall include Link Information field 803 in the response Link feedback command frame 810 it transmits in response to a received Link feedback command frame if the Link
15; Information Field Request/Inclusion bit 808 was set to ONE in the received Link feedback command frame. The device shall transmit the response Link feedback command frame after a delay given by:

*Time to send Response = pSIFS + pSlotTime + (Position in
20; Device List) × (response Link feedback command frame duration + pSIFS)*

Time to send Response is calculated from the end of reception of the received Link feedback command frame. Possible values of Position in Device List in Link feedback command frame are in the range [0, N-1], inclusive.

5

The Duration value in a transmitted Link feedback command frame shall cover the Link feedback command frame as well as all the expected Link feedback command frames in response to the transmitted Link feedback command frame. For a response Link
 10 feedback command frame that is transmitted in response to a received unicast Link feedback command frame, the Duration field is given by the following equation.

*Duration = Duration value in received Link feedback command
 15 frame - (received Link feedback command frame body transmission time + pSIFS) - response Link feedback command frame transmission time + response Link feedback command frame body transmission time*

20 For a response Link feedback command frame that is transmitted in response to a received multicast Link feedback command frame, the Duration field is given by the following equation.

$$\begin{aligned} \text{Duration} = & \text{Duration value in received Link feedback command} \\ & \text{frame} - (\text{received Link feedback command frame body transmission} \\ & \text{time} + pSIFS + pSlotTime + (\text{Position in list in received Link} \\ & \text{feedback command frame}) \times (\text{response Link feedback command frame} \\ 5; & \text{transmission time} + pSIFS)) - \text{response Link feedback command} \\ & \text{frame transmission time} + \text{response Link feedback command frame} \\ & \text{body transmission time} \end{aligned}$$

In general, embodiments as illustrated in FIGs. 3, 5, 7 and 8
 10) are based on command/control frames and allow for rate and power
 control to be done at the transmitter side. The proposed schemes
 (FIGs. 3-8) cater to channels with low coherence time. The
 variable 'x' may be left to the implementers. Typically 'x' may
 be decided at the transmitter side based on the past measures in
 15) terms of SNR or packet error rate as fed back from the receiver.
 The size of the payload of the proposed frames may be as low as
 1 or 2 octets from the transmitter side and up to 3 or 4 octets
 (for embodiments shown in FIGs. 3-6) or up to 2 to 14 octets
 (for embodiments shown in FIG. 7 and FIG. 8) from the receiver
 20) side. Actual rate and power control strategy at the transmitter
 may be left to implementers (Several rate and power control
 schemes based on SNR/LQI are available in the literature). The
 proposed schemes can apply to the future versions of IEEE 802.11

MAC, IEEE 802.15.3b MAC, IEEE 802.15.3c MAC, IEEE 802.15.4 MAC and other relevant MAC protocols.

FIG. 9 shows a communication device 900 according to one
5 embodiment.

In one embodiment, the communication device 900 comprises a sending circuit 901, a receiving circuit 902, and a determining circuit 903.

10

In one embodiment, the sending circuit 901 is configured to send, in a superframe, a plurality of frames and a plurality of data transmission characteristic request messages to a receiver for requesting data transmission characteristic information from
15 the receiver, wherein the data transmission characteristic request messages are command/control messages.

20

In one embodiment, the receiving circuit 902 is configured to receive, in the superframe, a plurality of data transmission characteristic response messages including data transmission characteristic information from the receiver in response to the data transmission characteristic request messages wherein the data transmission characteristic response messages are command/control messages.

In one embodiment, the determining circuit 903 is configured to determine, from the data transmission characteristic information, at least one data transmission characteristic.

5

In one embodiment, a computer program product is provided, wherein, when the computer program product is executed by a computer, the computer program product makes the computer perform a method for determining a data transmission

10 characteristic, wherein data are transmitted in at least one superframe, wherein each superframe is configured to transmit a plurality of frames, the method comprising: sending, in the superframe, a plurality of data transmission characteristic request messages to a receiver for requesting data transmission
15 characteristic information from the receiver, wherein the data transmission characteristic request messages are command/control messages; receiving, in the superframe, a plurality of data transmission characteristic response messages including data transmission characteristic information from the receiver in
20 response to the data transmission characteristic request messages wherein the data transmission characteristic response messages are command/control messages; determining, from the data transmission characteristic information, at least one data transmission characteristic.

In one embodiment, a method of allowing link feedback using command/control frames between two devices is provided, the method comprising: allowing the transmitter to include a
5 command/control frame every 'x' μ s (or at least once in every 'x' μ s or aperiodically) and/or at the beginning of frame transactions; allowing the receiver to reply with a command/control frame upon reception of a command /control frame after a fixed period of time which may for example be SIFS.

10

In one embodiment, the method of allowing link feedback further comprises allowing the transmitter to include the payload of link feedback control octet; and allowing the receiver to reply with the payload of link feedback control octet, information
15; about number of correctly received packets and information about LQI/SNR.

In one embodiment, the method of allowing link feedback further comprises allowing the transmitter to include the payload of
20) link feedback control octet; and allowing the receiver to reply with the payload of link feedback control octet, information about data rate and information about transmit power level change.

In one embodiment, the method of allowing link feedback further comprises allowing the exchange of link feedback between the transmitter and the receiver; allowing the transmitter to include the payload of link feedback control octet, information
5 about number of correctly received packets and information about LQI/SNR; and allowing the receiver to reply with the payload of link feedback control octet, information about number of correctly received packets and information about LQI/SNR.

10 In one embodiment, the method of allowing link feedback further comprises allowing the exchange of link feedback between the transmitter and the receiver; allowing the transmitter to include the payload of link feedback control octet, information about data rate and information about transmit power level
15 change; and allowing the receiver to reply with the payload of link feedback control octet, information about data rate and information about transmit power level change.

In one embodiment, a method of allowing link feedback using
20 command/control frames between two devices is provided, the method comprising: allowing the transmitter to transmit a command/control frame every 'x' microseconds or aperiodically; allowing the receiver to reply with a command/control frame upon reception of a command/control frame after a fixed time period

which may be for example SIFS; allowing the exchange of link feedback between the transmitter and the receiver; allowing the transmitter to include the payload of link feedback control octet, information about number of packets received with error, 5; information about number of packets lost, information about number of packets transmitted to the recipient of the command frame, information about measurement window, information about number of packets correctly received, and information about SNR/LQI; and allowing the receiver to reply with the payload of 10; link feedback control octet, information about number of packets received with error, information about number of packets lost, information about number of packets transmitted to the recipient of the command frame, information about measurement window, information about number of packets correctly received, and 15; information about SNR/LQI.

While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and 20; detail may be made therein without departing from the scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

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Claims

What is claimed is:

1. A method for determining a data transmission characteristic, wherein data are transmitted in at least one
50 superframe, wherein each superframe is configured to transmit a plurality of frames, the method comprising
sending, in the superframe, a plurality of data transmission characteristic request messages to a receiver for requesting
data transmission characteristic information from the receiver,
100 wherein the data transmission characteristic request messages are command/control messages;
receiving, in the superframe, a plurality of data transmission characteristic response messages including data transmission
characteristic information from the receiver in response to the
150 data transmission characteristic request messages wherein the data transmission characteristic response messages are
command/control messages;
determining, from the data transmission characteristic information, at least one data transmission characteristic.
200
2. The method according to claim 1, wherein each data transmission characteristic request message includes data
transmission characteristic information of a transmitter or from
a transmitter.

3. The method according to claim 1, wherein sets of two or more frames are transmitted in the superframe, and wherein at least one data transmission characteristic request message is sent before the transmission of each set of the two or more frames.

4. The method according to any one of the claims 1 to 3, wherein the data transmission characteristic request messages are sent periodically.

5. The method according to any one of the claims 1 to 4, wherein a data transmission characteristic request message is sent at least once during each predetermined periodic time interval.

6. The method according to any one of the claims 1 to 5, carried out by a transmitter, the transmitter and the receiver being communication devices according to WiMedia specification.

7. The method according to any one of the claims 1 to 6, wherein the data transmission characteristic request messages are medium access control layer messages.

8. The method according to any one of the claims 1 to 7,
wherein the data transmission characteristic response messages
are medium access control layer messages.

5 9. The method according to any one of the claims 1 to 8,
wherein data transmission comprises the transmission of a
plurality of data packets and wherein the data transmission
characteristic information includes the number of data packets
correctly received by the receiver or the sender of the data
10 transmission characteristic information.

10. The method according to any one of the claims 1 to 9,
wherein data transmission is performed via a communication link
between a transmitter and the receiver and the data transmission
15 characteristic information is communication link quality
information.

11. The method according to any one of the claims 1 to 10,
wherein the data transmission characteristic information
20 includes information about the signal to noise ratio of the
communication link.

12. The method according to any one of the claims 1 to 11,
wherein the data transmission characteristic response messages

includes information for setting the power level of the data transmission.

5 13. The method according to any one of the claims 1 to 4, wherein a data transmission characteristic request message is sent aperiodically.

14. The method according to any one of the claims 1 to 12,
10 wherein the data transmission characteristic response messages include information for setting the data rate of the data transmission.

15. The method according to any one of the claims 1 to 12 and
15 14, wherein the data transmission characteristic information includes information about suggested data rate, information about suggest transmit power level change, information about number of packets received with error, information about number of packets lost, information about number of packets transmitted
20 to the recipient of the command frame, information about measurement window, information about number of packets correctly received, and information about SNR/LQI of communication link.

16. The method according to any one of the claims 1 to 12 and 14 to 15, wherein the transmitter transmits a command/control frame or a data transmission characteristic request message every 'x' μ s or at least once in every 'x' μ s or aperiodically or at the beginning of frame transactions and the receiver replies with a command/control frame or a data transmission characteristic response message upon reception of a command /control frame or a request message after a fixed period of time which may for example be Short Interframe Spacing (SIFS).

17. The method according to any one of the claims 1 to 16, wherein the time to send a data transmission characteristic response message by a device in response to a data transmission characteristic request message after the receipt of the data transmission characteristic request message is given by

$$pSIFS + pSlotTime + (\text{position value in a device list}) \times (\text{command frame duration of the data transmission characteristic response message} + pSIFS)$$

wherein pSIFS and pSlotTime may have the values as defined by the ECMA standard.

18. The method according to any one of the claims 1 to 17,
wherein a data transmission characteristic response message
transmitted in response to a data transmission characteristic
request message comprises a duration field with a duration value
5 that is given by

a duration value included in the data transmission
characteristic request message - (command frame body
transmission time of the data transmission characteristic
10 request message + pSIFS) - command frame transmission time of
the data transmission characteristic response message + command
frame body transmission time of the data transmission
characteristic response message

15 wherein pSIFS may have the value as defined by the ECMA
standard.

19. The method according to any one of the claims 1 to 17,
wherein a data transmission characteristic response message
20 transmitted in response to a data transmission characteristic
request message comprises a duration field with a duration value
that is given by

a duration value included in the data transmission
 characteristic request message -(command frame body transmission
 time of the data transmission characteristic request message +
 pSIFS + pSlotTime + (position value in a list in the data
 5 transmission characteristic request message) × (command frame
 transmission time of the data transmission characteristic
 response message + pSIFS)) -command frame transmission time of
 the data transmission characteristic response message + command
 frame body transmission time of the data transmission
 10 characteristic response message

wherein pSIFS and pSlotTime may have the values as defined by
 the ECMA standard.

15 20. A communication device comprising
 a sending circuit configured to send, in at least a superframe,
 each superframe being configured to transmit a plurality of
 frames, a plurality of data transmission characteristic request
 messages to a receiver for requesting data transmission
 20 characteristic information from the receiver, wherein the data
 transmission characteristic request messages are command/control
 messages;
 a receiving circuit configured to receive, in the superframe, a
 plurality of data transmission characteristic response messages

including data transmission characteristic information from the receiver in response to the data transmission characteristic request messages wherein the data transmission characteristic response messages are command/control messages;

- 5) a determining circuit, configured to determine, from the data transmission characteristic information, at least one data transmission characteristic.

21. A computer program product, which, when executed by a

- 10) computer, makes the computer perform a method for determining a data transmission characteristic, wherein data are transmitted in at least one superframe, each superframe being configured to transmit a plurality of frames, the method comprising sending, in the superframe, a plurality of data transmission
- 15) characteristic request messages to a receiver for requesting data transmission characteristic information from the receiver, wherein the data transmission characteristic request messages are command/control messages;
- receiving, in the superframe, a plurality of data transmission
- 20) characteristic response messages including data transmission characteristic information from the receiver in response to the data transmission characteristic request messages wherein the data transmission characteristic response messages are command/control messages;

determining, from the data transmission characteristic information, at least one data transmission characteristic.