

DESCRIPTION

COMMUNICATION APPARATUS, COMMUNICATION METHOD, AND INTEGRATED CIRCUIT

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Technical Field

The present invention relates to a communication method for establishing communication among a plurality of communication apparatuses sharing a communication band and to a communication apparatus and an integrated circuit therefor.

Background Art

In a communication system that establish communication among a plurality of communication apparatuses sharing a communication band, such as power line communication, a wireless LAN (Local Area Network), and the like, the plurality of communication apparatuses perform communication by use of one transmission channel, and hence congestion among accesses from the plurality of communication apparatuses must be avoided.

One of the methods is a CSMA (Carrier Sense Multiple Access) scheme. Under the scheme, respective communication apparatuses monitor usage conditions of the transmission channel and perform transmission when another communication apparatus does not use the transmission channel (when the transmission channel is in an idle state). When it is detected that another communication apparatus does not use the transmission channel, transmission is commenced after elapse of a random wait time (a back-off time).

Fig. 10 shows an example of timing at which data are transmitted under the CSMA scheme. When the communication apparatus A transmits a packet PA1 at time T1, a communication apparatus B connected to the same transmission channel (a same network) detects the packet PA1 at time T2 achieved after a lapse of a carrier detection time C_t , thereby detecting that the transmission channel is in use. When the communication apparatus B attempts to perform transmission by way of the transmission channel, the communication apparatus B waits end of the packet PA1 from the communication apparatus A.

When end of transmission of the packet PA1 performed by the communication apparatus A is detected at time T3, the communication apparatus B remains on standby for a period of time (a random back-off time) that is a random multiple of a unit back-off time (a slot time) St . Specifically, when counting is performed each time a slot time St elapses and when the counted value reaches a random value generated at that time, a packet PB1 is transmitted. An example shown in Fig. 10 is a case where a random value assumes a value of 8, and the packet PB1 is transmitted at time T4 achieved after the communication apparatus B has remained on standby for $St \times 8$. The slot time St is set to a value that is equal to or greater than the carrier detection time C_t . Therefore, when another communication apparatus for which a small random value has arisen starts transmission, commencement of transmission of another communication apparatus can be detected without fail before counting of slots.

In the example shown in Fig. 10, a carrier is not detected until the random value 8 is counted; hence, the communication apparatus B can transmit

a packet PB1. However, when there is another communication apparatus for which a random value smaller than eight has arisen, a carrier is detected before time T4 is achieved, and counting is stopped. The communication apparatus B waits until a packet of the other communication apparatus is completed. A
5 method for generating a random value does not need to be constant, and the maximum value of the random value that arises in accordance with a priority level may also be changed. For instance, when the maximum value is increased at the time of re-transmission (the random value returns to the original maximum value when re-transmission is successful) or when counting
10 is stopped by detection of a carrier of another communication apparatus during standby, it is possible to avoid a continued state where one communication apparatus cannot perform communication, by means of decreasing the maximum value (the random value returns to the original maximum value when transmission is successful). A point at time T3 at which transmission of the
15 packet PA1 of the communication apparatus A is completed is taken as a point in time achieved when an IFS (an Inter-Frame Space) defined in IEEE802.11 standards elapses from when a carrier is not detected.

As mentioned above, as a result of the CSMA scheme being adopted, even when a plurality of communication apparatuses attempt to perform
20 transmission by way of a single transmission channel, commencement of transmission is made possible after elapse of a random back-off time that is a random wait time, so that the chance of a collision can be reduced. The random back-off time will often be hereinafter described as a "back-off time," a "back-off period," or a "BO."

25 In the meantime, in a communication system that establish

communication among a plurality of communication apparatuses sharing a communication band, such as power line communication and a wireless LAN (Local Area Network), assurance of QoS (Quality of Service) is required even when a variety of kinds of data are mixedly present in a transmission channel.

5 In particular, in the case of stream transfer of data that are to be transmitted and that are cyclic and subjected to limitations of delay conditions; for instance, VoIP (Voice on Internet Protocol) and a video, an interruption arises in data when fluctuations are present in a communication band; hence, it is required to perform transmission while a sufficient communication band is assured.

10 However, the CSMA scheme is basically a scheme for making an access after elapse of a random back-off time, the chance of a successful access will be reduced if the number of apparatuses that make an access (the number of communication apparatuses connected to a network) is increased, and it becomes difficult to assure the maximum delay for data, such as that
15 being subjected to limitations of delay conditions.

A priority control technique for ensuring QoS is; for instance, a wireless LAN technique (IEEE802.11e) described in US Patent No. 7,095,754. The technique described in the document is for inserting a gap time (hereinafter often described simply as "gap"), which is a fixed wait time, between frames
20 separately from the back-off time. Since the gap time changes according to a priority level of transmitting data (the time is short in the case of a high priority level but long in the case of a low priority level), high-priority data can be reliably transmitted by priority.

Figs. 11A and 11B show examples of timings for a case where data are
25 transmitted while a gap time whose length changes according to a priority level

of the data is added to the data. In an example shown in Figs. 11A and 11B, a priority level of transmitting data includes three stages: namely, a high priority, a normal priority, and a low priority, and a gap time for the case where the priority level is a high priority is zero. When the priority level is a "normal priority" and a "low priority," a gap time is set; however, the gap time is set such that a gap time for the case where the priority level is a low priority becomes longer than a gap time for the case where the priority level is a normal priority.

In the example shown in Fig. 11A, terminals 1 and 2 are about to transmit "high priority" data; a terminal 3 is about to transmit "normal priority" data; and terminals 4 and 5 are about to transmit "low priority" data. When an idle state of the transmission channel is detected at time t1 in Fig. 11A, the terminals 1 and 2 start clocking a back-off time, and the terminals 3, 4, and 5 start clocking the gap time. Since the back-off time of the terminal 1 first elapses, the terminal 1 initiates transmission of data. At a point in time when the back-off time of the terminal 2 has elapsed and when the gap times of the terminals 3 to 5 have elapsed, the transmission channel is already out of an idle state; hence, the terminal 2 does not transmit data, and the terminals 3 to 5 do not perform clocking of back-off times. In the drawings and drawings for describing subsequent timings, a clocking block and a data transmission block, which are surrounded by broken lines, show operation which is not actually performed. The idle state is a state where no data flow in the transmission channel.

The terminals 2 through 5, which hold transmitting data at time t2 that is achieved after elapse of the IFS since the terminal 1 completes transmission of data, start clocking a back-off time or a gap time as with the time t1. The

back-off time of the terminal 2 first elapses at this time, the second terminal starts transmitting data. Since the transmission channel is already out of an idle state at a point in time when the gap times of the terminals 3 through 5 have elapsed, the terminals 3 through 5 do not clock back-off times.

5 The terminals 3 through 5, which hold transmitting data at time t_3 that is achieved after elapse of the IFS since the terminal 2 completed transmission of data, start clocking a gap time and subsequently clocking a back-off time as with the time t_1 . The gap time and back-off time of the terminal 3 first elapse at this time, the third terminal starts transmitting data. Since the transmission
10 channel is already out of an idle state at a point in time when the gap times and back-off times of the terminals 4 and 5 have elapsed, the terminals 4 and 5 do not transmit data.

 The terminals 4 and 5, which hold transmitting data at time t_4 that is achieved after elapse of the IFS since the terminal 3 completed transmission of
15 data, start clocking a gap time and subsequently clocking a back-off time as with the time t_1 . The gap time and back-off time of the terminal 4 first elapse at this time, the terminal 4 starts transmitting data. Since the transmission channel is already out of an idle state at a point in time when the gap time and back-off time of the terminal 5 elapsed, the terminal 5 does not transmit data.

20 As mentioned above, the duration of the gap time is changed according to a priority level of transmitting data, whereby high-priority data are first transmitted when a plurality of terminals are about to transmit data.

 In another example shown in Fig. 11B, the terminals 4 and 5 are about to transmit "low priority" data. When an idle state of the transmission channel
25 is detected at time t_{11} in Fig. 11B, the terminals 4 and 5 start clocking gap times

and subsequently clocking back-off times. Since both kinds of data that the terminals 4 and 5 are about to transmit have low priority levels, a gap time of the same duration is clocked, and a back-off time is subsequently clocked. Since the back-off time of the terminal 4 first elapses, the terminal 4 starts
5 transmitting data. Since the transmission channel is already out of an idle state at a point in time when the gap time and the back-off time of the terminal 5 have elapsed, the terminal 5 does not transmit data.

The terminals 4 and 5, which hold transmitting data at time t12 that is achieved after elapse of the IFS since the terminal 4 completed transmission of
10 data, start clocking a gap time and subsequently clocking a back-off time as with the time t11. The gap time and back-off time of the terminal 5 first elapse at this time, the terminal 5 starts transmitting data. Since the transmission channel is already out of an idle state at a point in time when the gap time and back-off time of the terminal 5 elapsed, the terminal 4 does not transmit data.

15 The terminal 4, which holds transmitting data at time t13 that is achieved after elapse of the IFS since the terminal 5 completed transmission of data, start clocking a gap time and subsequently clocking a back-off time as with the time t11. The terminal 4 starts transmitting data at a point in time when the gap time and back-off time of the terminal 4 have elapsed.

20 Thus, when contention arises at the time of transmission of data having the same priority level, any of the terminals transmit data in accordance with a random value of the back-off time.

As mentioned above, a gap time that is a fixed wait time is inserted between frames separately from a back-off time, the duration of the gap time is
25 changed according to transmitting data, whereby high priority data are

transmitted by priority in an environment (see Fig. 11A) where data having different priority levels are mixedly present. However, in an example where only data having low priority levels are present (see; for instance, Fig. 11B), a gap time is inserted before transmission of all kinds of data, the gap time becomes a waste time, which in turn deteriorates transmission efficiency.

Moreover, even when an attempt is made to transmit data having a high priority level in a prioritized manner by insertion of a gap time, a case where a requested delay time (a limit value of delay conditions) is not fulfilled arises depending on the data length (frame length) of transmitting data. Influence of a frame length will be described by reference to Fig. 12.

In the example shown in Fig. 12, the terminals 1 and 2 are about to transmit "high priority" data, and the terminal 5 is about to transmit "low priority" data. When an idle state of the transmission channel is detected at time t_1 in Fig. 12, the terminal 5 holding transmitting data starts clocking a gap time and a back-off time and starts transmitting data at time t_2 that is a point in time when the back-off time elapses.

Subsequently, even when transmitting data to the terminal 2 arises at time t_3 and when transmitting data to the terminal 1 arises at time t_4 , the transmission channel is in the middle of transmitting data from the terminal 5, and hence clocking of the back-off time by the terminals 1 and 2 is not started. Transmission of data from the terminal 5 ends at time t_5 ; the terminals 1 and 2 holding transmitting data start clocking back-off times at time t_6 achieved after elapse of the IFS; and the terminal 5 starts clocking a gap time. Since the back-off time of the terminal 1 first elapses, the terminal 1 starts transmitting data. At a point in time when the back-off time of the terminal 2 has elapsed

and when the gap time of the terminal 5 has elapsed, the transmission channel is already out of an idle state; hence, the terminal 2 does not transmit data, and the terminal 5 does not clock the back-off time.

Transmission of data from the terminal 1 ends at time t_7 , and the
5 terminal 2 holding transmitting data starts clocking a back-off time at time t_8 achieved after elapse of the IFS, and the terminal 5 starts clocking a gap time. Here, since the back-off time of the terminal 2 first elapses, the terminal 2 starts transmitting data. Since the transmission channel is already out of an idle state at a point in time when the gap time of the terminal 5 has elapsed, the
10 terminal 5 does not clock a back-off time.

As mentioned above, even in the middle of transmission of data having a low priority level, transmission of high-priority data is commenced after the transmission of data having the low priority level. However, there may arise a case where a requested delay time of high priority data is not fulfilled if no
15 limitations are imposed on the duration of transmitting data. In an example shown in Fig. 12, since the length (designated by a double-headed arrow of a solid line) of data from the terminal 5 is long, transmission of data from the terminal 1 and transmission of data from the terminal 2 do not satisfy a requested delay time of high priority data (designated by a double-headed
20 arrow of a dashed line). Specifically, the data delay time of the terminal 1 (a time from time t_4 when transmitting data arises until time t_7 when transmission of data ends is designated by a broken line) and the data delay time of the terminal 2 (a time from time t_3 when transmitting data arises until time t_9 when transmission of data ends is designated by a broken line) becomes longer than
25 the requested delay time.

Collision between data having the same priority level cannot be avoided in terms of a probability. When collision arises, a data delay time increases. Hence, it is necessary to prevent the data delay time from exceeding a requested delay time even when collision arises by increasing the number of
5 transmission operations performed within the requested delay time.

Disclosure of Invention

Embodiments of the present invention have been conceived in the circumstance. Embodiments of the invention provide a communication
10 apparatus, a communication method, and an integrated circuit that enable efficient transmission while fulfilling limitations on a delay appropriate to transmitting data.

In accordance with a first aspect of the present invention, there is provided a communication apparatus for connecting to a transmission channel
15 capable of transmitting a plurality of kinds of data, each kind of data having different priority levels, the apparatus comprising: acquiring means for acquiring each priority information of each kind of data on the transmission channel; and transmitting means for, when transmitting data having a predetermined priority are transmitted from the communication apparatus, controlling a time from a
20 predetermined transmission reference time to a transmission end time of the transmitting data in accordance with the priority information, wherein the transmitting means transmits the transmitting data after elapse of a predetermined wait time since the transmission reference time when the transmission channel enters an idle state; and wherein the transmitting means

controls the predetermined wait time in accordance with the priority information.

According to the above communication apparatus, a priority level of data transmitted through a transmission channel is acquired, and a time from a transmission reference time until a transmission end time of transmitting data is
5 controlled in accordance with priority information corresponding to the priority level; hence, data transmission with superior transmission efficiency can be

performed while delay conditions for transmitting data are fulfilled. A word
“data in the middle of transmission” used herein includes data transmitted
through a transmission channel during a predetermined period as well as data
that are in the middle of transmitting through the transmission channel at a
5 certain point in time. The predetermined period is determined, as appropriate,
by means of timing at which priority information is acquired, and the like.

According to the above communication apparatus, the transmission
controller controls a predetermined wait time in accordance with priority
10 information of data transmitted through a transmission channel, and hence a
useless wait time can be reduced by setting a time from the transmission
reference time until transmission of data to an optimum value for each data
transmission. Consequently, data transmission with superior transmission
efficiency can be performed while delay conditions for transmitting data are
15 fulfilled.

In an embodiment, the communication apparatus further includes a
communication frame generator which generates a communication frame which
has a predetermined length and stores the data, and the transmission controller
controls the length of the communication frame in accordance with the priority
20 information.

According to the above embodiment, the transmission

controller controls the length of a communication frame in accordance with priority information of data transmitted through a transmission channel; hence, data transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled. In particular, the apparatus
5 is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

In an embodiment, the transmission controller controls the predetermined wait time in accordance with the predetermined priority of the transmitting data.

10 According to the above embodiment, the transmission controller controls the predetermined wait time in accordance with a priority level of transmitting data; hence, data transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled.

In an embodiment, the transmission controller controls the length of the
15 communication frame in accordance with the predetermined priority of the transmitting data.

According to the above embodiment, the transmission controller controls the length of a communication frame in accordance with a priority level of transmitting data; hence, data transmission with superior transmission
20 efficiency can be performed while delay conditions for transmitting data are fulfilled. In particular, the apparatus is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

In an embodiment, the

predetermined wait time includes a random wait time randomly determined for each transmission and a fixed wait time determined at a constant value in accordance with the priority information and the predetermined priority of the transmitting data; and the transmission controller controls the fixed wait time in
5 accordance with at least one of the priority information and the predetermined priority.

According to the above embodiment, the transmission controller controls the fixed wait time in accordance with the priority information of transmitting data through a transmission channel or a priority level of
10 transmitting data. Hence, a useless wait time can be reduced by setting the fixed wait time to an optimum value for each data transmission. Consequently, data transmission with superior transmission efficiency becomes possible while delay conditions for transmitting data are fulfilled.

In an embodiment, when a priority level represented by the priority
15 information is lower than the predetermined priority of the transmitting data to be transmitted, the transmission controller sets the fixed wait time to zero.

According to the above embodiment, when a priority level represented by the priority level of data transmitted through the transmission channel is lower than by the predetermined priority of the transmitting data, the fixed wait
20 time is set to zero, so that efficient transmission of high priority data becomes possible. In particular, the device is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

In an embodiment, the

transmission controller sets the predetermined wait time, used when the transmitting data whose predetermined priority is not a high priority level are transmitted, to a value that is greater than a maximum value of the random wait time used at the time of transmission of the transmitting data having the high
5 priority level.

According to the above embodiment, since the transmission controller sets a predetermined wait time for transmitting data having a low priority level to a great value, efficient transmission of high priority data becomes possible. In particular, the device is suitable for data transmission requiring QoS (Quality of
10 Service) as in transmission of audio data and streaming data.

In an embodiment, when a priority level represented by the priority information is a high priority level, the transmission controller controls the length of the communication frame in accordance with delay information requested by the data having the high priority level.

15 According to the above embodiment, the transmission controller controls the length of a communication frame to be transmitted in accordance with delay information requested by data having a high priority level, and hence transmission of data having a high priority level can be early started, and delay conditions for the data can be fulfilled. In particular, the device is suitable for
20 data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

In an embodiment, a power line is used as the transmission channel.

In an embodiment, the acquisition section acquires the priority information by analysis of a header of data that are present on the transmission channel.

According to the above embodiment, a priority level of data that are in the middle of transmitting through a transmission channel can be briefly acquired. Timing for analysis of a header of a data frame is arbitrary; however, analysis is performed periodically; for instance, at a given time interval. A header of a data frame may also be analyzed by means of all communication apparatuses connected to the transmission channel or a specific communication apparatus.

In an embodiment, the acquisition section receives control information transmitted from another communication apparatus which is connected to the transmission channel and acquires the priority information contained in the control information.

According to the above embodiment, not all of the communication apparatus need to perform data processing for acquiring a priority level of data that are in the middle of transmitting through the transmission channel, and hence processing burden on an individual communication apparatus is lessened. The control signal is; for instance, a beacon signal. Moreover, a communication apparatus that perform data processing for acquiring a priority level of data that are in the middle of transmitting through the transmission channel is; for instance, a master unit.

In accordance with a second aspect of the present invention, there is provided a communication method for connecting to a transmission channel capable of transmitting a plurality of kinds of data, each kind of data having different priority levels, the method comprising the steps of: acquiring each
5 priority information of each kind of data on the transmission channel; and controlling a time from a predetermined transmission reference time until a transmission end time of a transmitting data in accordance with the priority information when the transmitting data having a predetermined priority are transmitted, wherein data are transmitted after elapse of a predetermined wait
10 time since the transmission reference time when the transmission channel enters an idle state; and wherein the predetermined wait time is controlled in accordance with the priority information.

According to the above method, a priority level of data transmitted through a transmission channel is acquired, and a time from a transmission
15 reference time until a transmission end time of transmitting data is controlled in accordance with priority information corresponding to the priority level; hence, data transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled. A word "data in the middle of transmission" used herein includes data transmitted through a transmission
20 channel during a predetermined period as well as data that are in the middle of transmitting through the transmission channel at a certain point in time. The predetermined period is determined, as appropriate, by means of timing at which priority information is acquired, and the like.

According to the above method, a predetermined wait time is controlled in accordance with priority information of data transmitted through a transmission channel, and hence a useless wait time can be reduced by setting a time from the transmission reference time until transmission of data to an optimum value for each data transmission. Consequently, data

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transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled.

In an embodiment communication method further comprises:
generating a communication frame that has a predetermined length and stores
5 the data; and controlling the length of the communication frame in accordance with the priority information.

According to the above embodiment, the length of a communication frame is controlled in accordance with priority information about data transmitted through a transmission channel; hence, data transmission with
10 superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled. In particular, the method is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

In an embodiment, the predetermined wait time is controlled in
15 accordance with the predetermined priority of the transmitting data.

According to the above embodiment, the predetermined wait time is controlled in accordance with the priority level of transmitting data; hence, data transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled.

20 In an embodiment, a length of the communication frame is controlled in accordance with the predetermined priority of the transmitting data.

According to the above embodiment, the length of a communication frame is controlled in accordance with the priority level of

transmitting data; hence, data transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled. In particular, the device is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

5 In an embodiment, the predetermined wait time includes a random wait time randomly determined for each transmission and a fixed wait time determined at a constant value in accordance with the priority information and the predetermined priority of the transmitting data; and the fixed wait time is controlled in accordance with at least one of the priority information and the
10 predetermined priority.

 According to the above embodiment, the fixed wait time is controlled in accordance with the priority information about transmitting data through a transmission channel or a priority level of transmitting data. Hence, a useless wait time can be reduced by setting the fixed wait time to an optimum value for
15 each data transmission. Consequently, data transmission with superior transmission efficiency becomes possible while delay conditions for transmitting data are fulfilled.

 In an embodiment, when a priority level represented by the priority information is lower than the predetermined priority of the transmitting data to
20 be transmitted, the fixed wait time is set to zero.

 According to the above embodiment, when a priority level represented by the priority level of the data transmitted through the transmission channel is lower than the predetermined priority of the transmitting data, the fixed wait time is set to zero, so that efficient transmission of high priority data

becomes possible. In particular, the method is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

5 In an embodiment, the predetermined wait time used when the transmitting data whose predetermined priority is not a high priority level are transmitted is set to a value that is greater than a maximum value of the random wait time used at the time of transmission of the transmitting data having the high priority level.

10 According to the above embodiment, since a predetermined wait time for transmitting data having a low priority level is set to a great value, efficient transmission of high priority data becomes possible. In particular, the device is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

15 In an embodiment, when a priority level represented by the priority information is a high priority level, the length of the communication frame is controlled in accordance with delay information requested by the data having the high priority level.

20 According to the above embodiment, the length of a communication frame to be transmitted is controlled in accordance with delay information requested by data having a high priority level, and hence transmission of data having a high priority level can be early started, and delay conditions for the data can be fulfilled. In particular, the device is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

25 In an embodiment, the

transmission channel is a power line.

In an embodiment, the priority information is acquired by analysis of a header of data that are present in the transmission channel.

According to the above embodiment, a priority level of data that are in
5 the middle of transmitting through a transmission channel can be briefly
acquired. Timing for analysis of a header of a data frame is arbitrary; however,
analysis is performed periodically; for instance, at a given time interval. A
header of a data frame may also be analyzed by means of all communication
apparatuses connected to the transmission channel or a specific
10 communication apparatus.

In an embodiment, control information transmitted from another
communication apparatus which is connected to the transmission channel is
received and the priority information contained in the control information is
acquired.

15 According to the above embodiment, not all of the communication
apparatus need to perform data processing for acquiring a priority level of data
that are in the middle of transmitting through the transmission channel, and
hence processing burden on an individual communication apparatus is
lessened. The control signal is; for instance, a beacon signal. Moreover, a
20 communication apparatus that perform data processing for acquiring a priority
level of data that are in the middle of transmitting through the transmission
channel is; for instance, a master unit.

In accordance with a third aspect of the present invention, there is provided an integrated circuit used in a communication apparatus for connecting to a transmission channel capable of transmitting a plurality of kinds of data, each kind of data having different priority levels, the circuit comprising:

5 acquiring means for acquiring each priority information of each kind of data on the transmission channel; and transmitting means for, when transmitting data having a predetermined priority are transmitted from the communication apparatus, controlling a time from a predetermined transmission reference time to a transmission end time of the transmitting data in accordance with the

10 priority information; wherein the transmitting means transmits the transmitting data after elapse of a predetermined wait time since the transmission reference time when the transmission channel enters an idle state; and wherein the transmitting means controls the predetermined wait time in accordance with the priority information.

15 According to the above integrated circuit of the present invention, a priority level of data transmitted through a transmission channel is acquired, and a time from a transmission reference time until a transmission end time of transmitting data is controlled in accordance with priority information corresponding to the priority level; hence, data transmission with superior

20 transmission efficiency can be performed while delay conditions for transmitting data are fulfilled. A word "data in the middle of transmission" used herein includes data transmitted through a transmission channel during a predetermined period as well as data that are in the middle of transmitting through the transmission channel at a certain point in time. The predetermined

period is determined, as appropriate, by means of timing at which priority information is acquired, and the like.

As is apparent from the description provided above, embodiments of the present invention enable provision of a communication apparatus, a
5 communication method, and an integrated circuit that enable efficient transmission of data while fulfilling delay conditions conforming to the transmitting data.

Brief Description of Drawings

Fig. 1 is a view showing an example general configuration of a power line communication system.

Figs. 2A to 2C are views showing appearances of a PLC modem.

Fig. 3 is a block diagram showing an example hardware of the PLC
5 modem.

Fig. 4 is a view for explaining an example digital signal processing performed in the PLC modem.

Fig. 5 is a functional block diagram for describing control a transmission timing of the PLC modem or the length of transmitting data.

10 Fig. 6 is a view showing an example configuration of a data frame employed in the power line communication system.

Figs. 7A to 7C are views each showing a specific example of frame priority level information acquired in the power line communication system.

15 Figs. 8A to 8C are views each showing example transmission timing based on control of a gap time in the power line communication system.

Figs. 9A and 9B are views each showing example transmission timing based on control of a data length of communication data performed in the power line communication system.

20 Fig. 10 is a view showing example timing achieved when data are transmitted by means of a CSMA scheme.

Figs. 11A and 11 B are views each showing example timing achieved when transmission is performed while a gap time whose length varies according to a priority level of data is added to data.

25 Fig. 12 is a view for describing the effect of the length of communication data on a requested delay time.

Best Mode for Carrying Out the Invention

An embodiment of the present invention will be described hereunder by reference to the drawings. A power line communication apparatus and a power line communication system are taken as examples in the following description, but another communication apparatus and another communication system using a scheme such as a wireless LAN, may also be adopted.

A power line communication system shown in Fig. 1 has a plurality of PLC (Power Line Communication) modems 100M, 100T1, 100T2, 100T3, and 100T4 connected to a power line 900. Fig. 1 shows five PLC modems, but the number of modems to be connected is arbitrary. The PLC modem 100M serves as a master unit and manages connection statuses (link statuses) of the other PLC modems 100T1, ..., 100T4 serving as slave units. However, the PLC modem serving as a master unit is not indispensable.

In the following descriptions, when mention is made of the master unit and a specific slave unit, the units are described as the PLC modems 100M, 100T1, 100T2, 100T3, and 100T4. When mention is generally made of a slave unit, the slave unit is described as the PLC modem 100T. Further, when mention is made of a PLC modem which is not confined to a master unit or a slave unit, the modem is described simply as a PLC modem 100.

Although the power line 900 is depicted by one line in Fig. 1, the power line actually consists of two or more lead wires, and the PLC modem 100 is connected to two of the lead wires.

As described in detail later, the PLC modem 100 has a LAN (Local Area Network) modular jack, such as RJ45, and the modular jack is connected to a

television (TV) set 51, a personal computer (PC) 52, an IP phone 53, a recorder 54, and a broadband router 55. The broadband router 55 is connected to the Internet. The power line communication system is an example communication system that implements the communication method of the present invention and
5 may also be another communication system, such as wireless LAN.

The PLC modem 100 shown in Figs. 2A to 2C has a housing 101, and an indicator 105 consisting of LEDs (Light-Emitting Diodes) 105A, 105B, and 105C as shown in Figs. 2A and 2B is provided on the front of the housing 101. A power supply connector 102, a LAN (Local Area Network) modular jack 103,
10 such as RJ45, and a changeover switch 104 for switching an operation mode, and the like, are provided on the back of the housing 101, as shown in Fig. 2C. A power supply cable (not shown in Figs. 2A to 2C) is connected to the power supply connector 102, and a LAN cable (not shown in Figs. 2A to 2C) is connected to the modular jack 103. The PLC modem 100 may also be
15 additionally provided with a Dsub (D-subminiature) connector, and a Dsub cable may also be connected to the connector.

As shown in Fig. 3, the PLC modem 100 has a circuit module 200 and a switching power supply 300. The switching power supply 300 is for supplying the circuit module 200 with various voltages (e.g., +1.2V, +3.3V, and +12V) and
20 includes, for instance, a switching transformer and a DC-DC converter (both of which are not illustrated).

The circuit module 200 is provided with a main IC (Integrated Circuit) 210, an AFE IC (Analog Front END Integrated Circuit) 220, an Ethernet PHY IC (Physic layer Integrated Circuit) 230, memory 240, a low-pass filter (LPF) 251, a
25 driver IC 252, a bandpass filter (BPF) 260, and a coupler 270. The switching

power supply 300 and the coupler 270 are connected to the power connector 102 and further to the power line 900 by way of a power cable 600, a power plug 400, and an electric outlet 500. The main IC 210 functions are a control circuit that performs power line communication.

5 The main IC 210 consists of a CPU (Central Processing Unit) 211, a PLC MAC (Power Line Communication Media Access Control layer) block 212, and a PLC PHY (Power Line Communication Physical layer) block 213. The CPU 211 is equipped with a 32-bit RISC (Reduced Instruction Set Computer) processor. The PLC MAC block 212 manages a MAC (Media Access Control)
10 layer of a PLC transmit/receive signal, as well as managing a MAC layer for controlling Ethernet communication. The PLC PHY block 213 manages a PHY (Physical layer) of a transmit/receive signal. The AFE IC 220 consists of a DA converter (DAC: D-A converter) 221, an AD converter (ADC: A-D converter) 222, and a variable amplifier (VGA: Variable Gain Amplifier) 223. The coupler 270
15 consists of a coil transformer 271 and coupling capacitors 272a and 272b. The CPU 211 controls operation of the PLC MAC block 212 and operation of the PLC PHY block 213 by utilization of data stored in the memory 211, as well as controlling the entirety of the PLC modem 100.

 Communication established by the PLC modem 100 is generally
20 performed as follows. Data input from the modular jack 103 are sent to the main IC 210 by way of the Ethernet PHY IC 230 and subjected to digital signal processing, whereby a digital transmission signal is generated. The thus-generated digital transmission signal is converted into an analogue signal by means of the DA converter (DAC) 221 of the AFE IC 220 and output to the
25 power line 900 by way of the low-pass filter 251, the driver IC 252, the coupler

270, the power connector 102, the power cable 600, the power plug 400, and the power outlet 500.

The signal received from the power line 900 is transmitted to the bandpass filter 260 by way of the coupler 270 and converted into a digital signal by means of the AD converter (ADC) 222 after a gain of the signal has been adjusted by the variable power amplifier (VGA) 223 of the AFE IC 220. The thus-converted digital signal is sent to the main IC 210 and subjected to digital signal processing, to thus be converted into digital data. The thus-converted digital data are output from the modular jack 103 by way of the Ethernet PHY IC 230.

Example digital signal processing realized by the main IC 210 will now be described. The PLC modem 100 is for performing multicarrier communication using a plurality of sub-carriers of an OFDM (Orthogonal Frequency Division Multiplexing) scheme, and the like. Transmitting data are converted into an OFDM transmission signal, and digital processing for converting an OFDM received signal into received data is principally performed by the PLC PHY block 213.

The PLC PHY block 213 performs digital signal processing for effecting OFDM transmission utilizing wavelet transformation. As shown in Fig. 4, the PLC PHY block 213 has functions equivalent of a conversion controller 10, a symbol mapper 11, a serial-parallel converter (an S-P converter) 12, an inverse wavelet converter 13, a wavelet converter 14, a parallel-serial converter (a P-S converter) 15, and a demapper 16.

The symbol mapper 11 converts bit transmitting data into symbol data and perform symbol mapping (e.g., PAM modulation) in accordance with the

symbol data. The S-P converter 12 converts mapped serial data into parallel data. The inverse wavelet converter 16 subjects the parallel data to inverse wavelet conversion, to thus generate data pertaining to a time axis and a sampled value sequence representing a transmission symbol. The data are
5 sent to the DA converter (DAC) 221 of the AFE IC 220.

The wavelet converter 14 converts received digital data (a sampled value sequence sampled at the same sampling rate as that used for transmission) received from the AD converter (ADC) 222 of the AFE IC 220 into data pertaining to a frequency axis through discrete wavelet conversion. The
10 P-S converter 15 converts the parallel data pertaining to the frequency axis into serial data. The demapper 16 computes amplitude values of the respective sub-carriers and determines a received signal, thereby determining received data.

Even in the power line communication system shown in Fig. 1,
15 transmission timing for a case where data transmission is performed is basically timing for a CSMA (Carrier Sense Multiple Access) scheme. Specifically, each of the communication apparatuses monitors the usage condition of the transmission channel and performs transmission when another communication apparatus is not using the transmission channel (i.e., when the transmission
20 channel is in idle). When it is detected that another communication apparatus is not using the transmission channel, transmission is started after elapse of a random wait time (a back-off) time. The power line communication system differs from a related-art power line communication system in that transmission channel priority level information showing a priority level of data that are in the
25 middle of transmitting through the transmission channel is acquired and that a

wait time or the length of transmitting data is controlled on the basis of the acquired transmission channel priority level information and the priority level information of the transmitting data. The word "idle state" means a state where no data are present in the transmission channel and where data communication
5 is possible; specifically, where carrier sensing is not carried out.

When a wait time is controlled, the wait time is determined by including a random wait time (a back-off time) randomly determined at each transmission timing and a fixed wait time (a gap time) set to a given value in accordance with transmission channel priority level information and priority level information of
10 transmitting data, and the fixed wait time is changed in accordance with the transmission channel priority level information and the priority level information of the transmitting data. For instance, when a priority level indicated by the transmission channel priority level information is not higher than the priority level of the transmitting data, a fixed wait time for the transmitting data is altered
15 to zero.

When the length of transmitting data is controlled and when the priority level indicated by the transmission channel priority level information shows a high priority level, the length of transmitting data is set to a length based on delay information requested by the data having the high priority level.
20 Specifically, the length is set to a data length which enables performance of transmission satisfying a delay request after completion of communication even when data having a lower priority level is in the middle of transmitting at the time of an attempt being made to transmit the data having the high priority level.

Fig. 5 is a functional block diagram for describing control of a
25 transmission timing or the length of transmitting data on the basis of the

transmission channel priority level information showing a priority level of data that are in the middle of transmitting through the transmission channel. The PLC modem 100 has a receive processor 21, a receive controller 22, a priority level information storage 23, a transmission controller 24, a transmission processor 25. The PLC modem 100 also has a high priority queue 26A, a normal priority queue 26B, and a low priority queue 26C which store transmitting data in accordance with a priority level.

The receive processor 21 processes a receive signal from the transmission channel, thereby generating receive data, and corresponds to the driver IC 252, the LPF 251, the AFEIC 220, the PLC PHY block 213, and the like, of the main IC shown in Fig. 3. The receive controller 22 generates, from received data, transmission channel priority level information showing a priority level of data that are in the middle of transmitting through a transmission channel and corresponds to the PLC MAC block 212, the CPU 211, the memory 240, and the like, of the main IC shown in Fig. 3. Generation of the transmission channel priority level information will be described later. The priority level information storage 23 stores transmission channel priority level information generated by the receive controller 22 and corresponds to an unillustrated storage device or the memory 240 in the PLC PHY block 213 of the main IC.

The transmission controller 24 controls transmission of data stored in the high priority queue 26A, the normal priority queue 26B, and the low priority queue 26C and corresponds to the PLC MAC block 212 of the main IC, the CPU 211, the memory 240, and the like, shown in Fig. 3. Specifically, at least one of the priority level information acquired from the priority level information

storage 23 or a gap time and a data length (the length of a transmission frame) for transmitting data stored in each queue is controlled, and transmission timing is further controlled by means of back-off operation. Details of transmission control will be described later. The transmission processor 25 generates a
5 transmission signal from transmitting data supplied from the transmission controller 24 and corresponds to the PLC PHY block 213, the AFEIC 220, the filter block 260, and the like of the main IC shown in Fig. 3. The high priority queue 26A, the normal priority queue 26B, and the low priority queue 26C may also be divided into a plurality of queues in respective terminals and managed
10 on a per-terminal basis. Queues having the same priority level are assumed to be subjected to transmission control by use of the same parameters.

Generation of transmission channel priority level information performed by the receive controller 22 will now be described. Transmission channel priority level information is generated by analysis of a header of a data frame
15 that is present in the transmission channel; specifically, the information is generated by means of determining frame priority level information contained in the header of the transmitting data frame through the transmission channel within a predetermined period. Fig. 6 shows an example configuration of a data frame. Since a header of the data frame can be demodulated by all
20 terminals (the PLC modems 100), each of the terminals can perform individual generation processing. For instance, eight data frames are received for a predetermined period, and transmission channel priority level information is generated from the frame priority level information contained in the header.

Figs. 7A to 7C show specific examples of the thus-acquired
25 transmission channel priority level information. The frame priority level

information is assumed to have eight levels (from level 0 to level 7, and the level 7 is a high priority level). Frame priority level information to be acquired is labeled as assigned when data frames with respective priority levels are received and labeled as none when the data frames are not received. Fig. 7A shows transmission channel priority level information acquired when data frames with priority levels 7, 6, and 3 are received and when data frames with the other priority levels are not received. Fig. 7B shows transmission channel priority level information acquired when data frames with priority levels 6 and 3 are received and when data frames with the other priority levels are not received. Fig. 7C shows transmission channel priority level information acquired when only the data frame with a priority level 3 is received and when data frames with the other priority levels are not received. Although omitted from the drawings, a control frame, such as a response frame responsive to a data frame and a beacon, may also be transmitted while a high priority level value of priority level information of data belonging to a terminal that transmits the frame or all priority level values are described in the control frame, and the information may also be acquired and reflected as with the data frame.

The priority level is determined in accordance with the type of data. For instance, from the viewpoint of assurance of QoS, audio data, such as VoIP data, and video data, such as streaming data, are set to a higher priority level (priority levels 7, 6 in the case of the above embodiment). Priority levels may also be fixedly set in advance in each of the PLC modems 100.

Not all of the PLC modems must carry out generation of transmission channel priority level information to be performed by the receive controller 22.

For instance, only the master PLC modem 100M in the power line

communication system shown in Fig. 1 may also perform generation of transmission channel priority level information. In that case, the master PLC 100M transmits the transmission channel priority level information to the slave PLC modems 100T by means of a beacon, and the like. The slave PLC modems 100T store the thus-received transmission channel priority level information into the priority level information storage 23.

When the respective PLC modems 100 carry out generation of transmission channel priority level information performed by the receive controller 22, generation may also be performed at individual timings or in a synchronous manner in accordance with a system time, and the like.

Figs. 8A to 8C show example transmission timings conforming to gap time control performed in the power line communication system of the embodiment of the present invention. Fig. 8A shows a case where transmission channel priority level information data shown in Fig. 7A is acquired; namely, where a priority level 7 is labeled as a "high priority level," a priority level 6 is labeled as a "normal priority level," and a priority level 3 is labeled as a "low priority level." Fig. 8A shows timings acquired when the transmission channel priority level information includes a "high priority level" and when data having a plurality of priority levels are mixedly present. In the embodiment shown in Fig. 8A, a terminal 1 and a terminal 2 are about to transmit "high priority" data; a terminal 3 is about to transmit "normal priority" data; and a terminal 4 and a terminal 5 are about to transmit "low priority" data. When it is detected, at time t1 shown in Fig. 8A, that the transmission channel is in idle, the terminals 1 and 2 start clocking back-off times, and the terminals 3, 4, and 5 start clocking gap times. Since the back-off time of the terminal 1 first

elapses, the terminal 1 starts transmission of data. At a point in time when the back-off time of the terminal 2 elapses and points in time when the gap times of the terminals 3 to 5 elapse, the transmission channel is already out of an idle state. Hence, the terminal 2 does not transmit data, and the terminals 3 to 5 do not clock back-off times. An IFS (Inter Frame Spacing) is defined as the minimum time in consideration of an internal processing time of a terminal, and the like, and the same also applies to any counterparts in the following descriptions. Further, the IFS can also be defined as zero. In the following descriptions, there may also be a case where the terminal is used in the sense of the PLC modem 100.

Fig. 8B shows timings achieved in a case where the priority level information data shown in Fig. 7B are acquired; where the priority level 6 is labeled as a "normal priority level" and the priority level 3 is labeled as a "low priority level"; and where the terminal 3 is about to transmit "normal priority" data and the terminal 5 is about to transmit "low priority" data. In this case, the "high priority" data are not present in the transmission channel, and the transmission channel priority level is "normal priority level" and is not higher than the priority level of the data that the terminal 3 is about to transmit. Hence, a gap time for transmitting data of the terminal 3 is set to zero.

When it is detected, at time t_{21} shown in Fig. 8B, that the transmission channel is in idle, the terminal 3 starts clocking a back-off time, and the terminal 5 starts clocking a gap time and subsequently clocking a back-off time. Since the back-off time of the terminal 3 first elapses, the terminal 3 starts transmitting data. At points in time when the gap time and back-off time of the terminal 5 elapse, the transmission channel is already out of an idle state. Hence, the

terminal 5 does not transmit data.

There is a case where a time (e.g., time t1, t2, ..., or t34 in Figs. 8A to 8C) at which clocking of the back-off time or the gap time is started is defined as a transmission reference time. Further, there is also a case where a time when
5 transmission of transmitting data is completed is defined as a transmission end time.

The terminal 3 holding transmitting data, as at time t21, at time t22 achieved after elapse of the IFS since the terminal 3 completed data transmission starts clocking of a back-off time, and the terminal 5 starts clocking
10 a gap time and subsequently clocking a back-off time. Even in this case, the back-off time of the terminal 3 first elapses, and hence the terminal 5 starts transmitting data. At points in time when the gap time and the back-off time of the terminal 5 elapse, the transmission channel is already out of an idle state, and hence the terminal 5 does not transmit data.

15 At time t23 achieved after elapse of the IFS since the terminal 3 completed data transmission, only the terminal 5 holding transmitting data performs clocking of a wait time for data transmission; namely, starts clocking a gap time and subsequently clocking a back-off time. At a point in time when the gap time and back-off time of the terminal 5 elapsed, data are transmitted.

20 As mentioned above, at the time of transmission of data from the terminal 3, transmission timing is controlled while the gap time is taken as zero. Hence, a useless gap time is not inserted, and deterioration of transmission efficiency is avoided. Moreover, the gap time of the terminal 5 that transmits "low priority" data is also shortened, whereby transmission efficiency can be
25 enhanced further.

Fig. 8C shows a case where priority level information data shown in Fig. 7C are acquired and where the priority level 3 is labeled as a "low priority level" and timings achieved when the terminals 4 and 5 are about to transmit "low priority" data. In this case, the "high priority" and "normal priority" data are not present in the transmission channel, and the transmission channel priority level becomes a low priority level and are not higher than the priority level of the data that the terminals 4 and 5 are about to transmit; hence, the gap time of transmitting data from the terminals 4 and 5 is also taken as zero.

When it is detected, as time t_{31} in Fig. 8C, that the transmission channel is in idle, the terminals 4 and 5 start clocking gap times and subsequently clocking back-off times. Since the back-off time of the terminal 4 first elapses, the terminal 4 starts transmitting data. At a point in time when the back-off time of the terminal 5 has elapsed, the transmission channel is already out of an idle state, and hence the terminal 5 does not transmit data.

At time t_{32} achieved after elapse of the IFS since the terminal 4 completed data transmission, the terminal 5 holding transmitting data starts clocking a back-off time as at time t_{31} . Since transmitting data to the terminal 4 arise in the course of clocking operation of the terminal 5, the terminal 4 also starts clocking a back-off time. Since the back-off time of the terminal 5 first elapses, the terminal 5 starts data transmission. At a point in time when the back-off time of the terminal 4 has elapsed, the transmission channel is already out of an idle state, and hence the terminal 4 does not transmit data.

At time t_{33} achieved after elapse of the IFS since the terminal 5 completed data transmission, the terminals 4 and 5 holding transmitting data start clocking back-off times as at time t_{31} . Since the back-off time of the

terminal 4 first elapses, the terminal 4 starts data transmission. At a point in time when the back-off time of the terminal 5 has elapsed, the transmission channel is already out of an idle state, and hence the terminal 5 does not transmit data.

5 At time t_{34} achieved after elapse of the IFS since the terminal 4 completed data transmission, the terminals 4 and 5 holding transmitting data start clocking back-off times as at time t_{31} . Since the back-off time of the terminal 5 first elapses, the terminal 5 starts data transmission. At a point in time when the back-off time of the terminal 4 has elapsed, the transmission
10 channel is already out of an idle state, and hence the terminal 4 does not transmit data.

Even when the priority levels of all of kinds of data that the terminals attempt to transmit are low priority levels, transmission timing is controlled at the time of transmission of data transmitted from the terminals while the gap time is
15 taken as zero. Hence, a useless gap time is not inserted, and deterioration of transmission efficiency is avoided. A contention window of a back-off time (the maximum length of the back-off time) is made smaller than a contention window shown in Fig. 8A, so that transmission efficiency can be enhanced to a much greater extent.

20 When the priority level of data in the transmission channel is higher than the priority level of data that the terminal attempts to transmit, control is performed such that a gap time becomes longer.

An example setting of a gap time in accordance with the transmission channel priority level information will now be described. Basically, setting is
25 performed while a gap time for the highest priority level that is present in the

transmission channel is taken as zero and while a CW (Contention Window) assigned value conforming to the priority level is taken as a reference. When transmission channel priority level information shown in Fig. 7A is acquired, gap times, for instance, are set as follows:

5 (Example setting 1)

- Gap for priority level 7 = 0
- Gap for priority level 6 = CW of priority level 7
- Gap for priority level 3 = CW of priority level 7 + CW of priority level 6

Transmission sequence for respective priority levels is assured by
10 means of such settings (this is limited to a case where data are still present after the channel is busy).

(Example setting 2)

- Gap for priority level 7 = 0
- Gap for priority level 6 = CW of priority level 7
- 15 • Gap for priority level 3 = CW of priority level 7 and value which is smaller than CW of priority level 6

Since there is a case where the priority level 3 is given higher priority than that given to the priority level 6 as a result of making of such settings, transmission of data having the priority level 3 becomes faster, so that a
20 transmission rate of low priority data is enhanced.

Further, the gap time for priority level 3 may be set as follows:

- Gap for priority level 3 = value smaller than sum of (CW of priority level 7 and CW of priority level 6)

When the transmission channel priority level information shown in Fig.
25 7B is acquired, gap times, for instance, are set as follows:

(Example setting 3)

- Gap for priority level 6 = 0
- Gap for priority level 3 = CW of priority level 6

When the transmission channel priority level information shown in Fig.

5 7C is acquired, gap times, for instance, are set as follows:

(Example setting 4)

- Gap for priority level 3 = 0

Control of a frame length based on transmission channel priority level information will now be described. Figs. 9A and 9B show example
10 transmission timings conforming to control of the length of communication data in the power line communication system of the present embodiment of the present invention. Fig. 9A shows timings achieved when the transmission channel priority level information includes a high priority level and where data having a plurality of priority levels are mixedly present.

15 In the embodiment shown in Fig. 9A, the terminals 1 and 2 are about to transmit "high priority" data, and the terminal 5 is about to transmit "low priority" data. Although unillustrated in Fig. 9A, the terminal 5 has already acquired transmission channel priority level information pertaining to the "high priority" data transmitted by the terminals 1 and 2 before time t1, and control of a length
20 of communication data to be described later is performed by use of the transmission channel priority level information acquired before t1. When an idle state of the transmission channel is detected at t1 in Fig. 9A, the terminal 5 holding transmitting data starts clocking a gap time and a back-off time and starts transmitting data at time t2 achieved after elapse of the back-off time.

25 Subsequently, even when transmitting data to the terminal 2 arise at

time t_3 and when transmitting data to the terminal 1 arise at time t_4 , data from the terminal 5 are still in the middle of transmitting through the transmission channel; hence, clocking of the back-off time is not started. Transmission of the data from the terminal 5 ends at time t_5 ; the terminals 1 and 2 holding
5 transmitting data start clocking back-off times at time t_6 achieved after elapse of the IFS; and the terminal 5 starts clocking a gap time. Since the back-off time of the terminal 1 first elapses, the terminal 1 starts transmitting data. At a point in time when the back-off time of the terminal 2 has elapsed and a point in time when the gap time of the terminal 5 has elapsed, the transmission channel is
10 already out of an idle state. Hence, the terminal 2 does not transmit data, and the terminal 5 does not clock a back-off time.

Transmission of data from the terminal 1 ends at time t_7 ; the terminal 2 holding transmitting data starts clocking a back-off time at time t_8 achieved after elapse of the IFS; and the terminal 5 starts clocking a gap time. Since the
15 back-off time of the terminal 2 first elapses, the terminal 2 starts transmitting data. Since the transmission channel is already out of an idle state at a point in time achieved after elapse of the gap time of the terminal 5, the terminal 5 does not clock a back-off time.

As is apparent from Fig. 9A, the length of the data from the terminal 5
20 (designated by a double-headed arrow of a solid line) becomes shorter than its counterpart achieved at a timing shown in Fig. 12. Consequently, a data delay time achieved at the terminal 1 (a time duration from time t_4 when transmitting data arises until time t_7 when transmission of data ends is denoted by a broken line) and a data delay time achieved at the terminal 2 (a time duration from time
25 t_3 when transmitting data arise until time t_9 when transmission of data ends is

denoted by a broken line) are shorter than a requested delay time (designated by a double-headed arrow of a one-dotted chain line).

In the embodiment shown in Fig. 9B, the terminal 5 is about to transmit "low priority" data. In this case, since data having the other priority levels are not in the transmission channel, transmitting data are transmitted at a requested data length without undergoing limitations on a data length. Consequently, overhead attributable to the gap time and the back-off time can be reduced, and deterioration of transmission efficiency can be prevented. As shown in Fig. 9B, when the priority level represented by the data in the transmission channel is lower than the priority level information of the data that the terminal is about to transmit, setting the length of transmitting data to a longer length is also preferable. Even in this case, overhead attributable to the gap time and the back-off time can be reduced, and deterioration of transmission efficiency can be reduced.

Example setting of the length of communication data in accordance with transmission channel priority level information will now be described. Basically, settings are made on the basis of a delay condition required for the highest priority level in the transmission channel. The length of a low priority frame achieved at that time is preferably set to a value that fulfills a relationship of (a transmission time of a low priority frame + a gap time + CW + a transmission time of a high priority frame) < (a requested delay time for a high priority frame).

Provided that a requested delay time of the priority level 7 is 5 ms; a requested delay time of the priority level 6 is 300 ms; and a requested delay time of the priority level 3 is none, settings, for instance, are made as follows when the transmission channel priority level information shown in Fig. 7A is

acquired.

(Example setting 1)

- The maximum frame length for the priority level 7 = a limiting value

unique to a system

- 5
- The maximum frame length for the priority level 6 = 2 ms

- The maximum frame length of the priority level 3 = 2 ms

When the transmission channel priority level information shown in Fig. 7B is acquired, settings are made; for instance, in a manner provided below.

(Example setting 2)

- 10
- The maximum frame length for the priority level 6 = a limiting value

unique to a system

- The maximum frame length for the priority level 3 = 10 ms

As in the example settings 1 and 2, the maximum frame length of the data frame not having a high priority level is changed in accordance with the high priority level of the transmission channel, thereby enabling enhancement of transmission efficiency.

15

When a payload section shown in Fig. 6 is a union of plurality of packets (Ethernet frames, and the like), a method for limiting a frame length can be realized by a method for making a limitation by changing the number of packets that can be transmitted within a specified time, a method for making a limitation by dividing one packet into sizes that enable transmission of the packets within the specified time, and a combination thereof.

20

It is desirable to simultaneously set a gap time conforming to the transmission channel priority level information and control a frame length. In this case, a synergistic effect can be expected in terms of enhancement of

25

transmission efficiency.

The foregoing communication method may be for transmitting data after elapse of a predetermined wait time from a reference transmission time since the transmission channel changed to an idle state and controlling the predetermined wait time in accordance with the priority level information of transmitting data through the transmission channel.

According to the communication method, the predetermined wait time is controlled in accordance with the priority level information of the transmitting data through the transmission channel, and hence a time duration from the reference transmission time to the time when data are transmitted is set to an optimum value for each data transmission, thereby enabling a reduction in useless wait time. Consequently, data transmission with superior transmission efficiency can be performed while delay conditions for transmitting data are fulfilled.

Moreover, under the foregoing communication method, a communication frame that has a predetermined length and that stores the data may be generated, and the length of the communication frame may be controlled on the basis of the priority level information of the transmitting data through the transmission channel.

According to the communication method, the length of the communication frame is controlled in accordance with the priority level information of transmitting data through the transmission channel. Hence, it becomes possible to perform data transmission with superior transmission efficiency while delay conditions for transmitting data are fulfilled. In particular, the method is suitable for data transmission requiring QoS (Quality of Service)

as in transmission of audio data and streaming data.

The foregoing communication method may include controlling a predetermined wait time in accordance with a priority level of transmitting data.

According to the communication method, a predetermined wait time is
5 controlled in accordance with a priority level of transmitting data. Hence, it becomes possible to perform data transmission with superior transmission efficiency while delay conditions for transmitting data are fulfilled.

The communication method may include controlling the length of a communication frame in accordance with the priority level of transmitting data.

10 According to the communication method, the length of a communications frame is controlled in accordance with a priority level of transmitting data. Hence, data transmission with superior transmission efficiency becomes possible while delay conditions for transmitting data are fulfilled. In particular, the method is suitable for data transmission requiring
15 QoS (Quality of Service) as in transmission of audio data and streaming data.

Under the communication method, a predetermined wait time may include a random wait time randomly determined at each transmission timing and a fixed wait time set to a given value in accordance with priority level information of transmitting data through a transmission channel and a priority
20 level of transmitting data. The method may include controlling the fixed wait time in accordance with at least one of the priority level information and a predetermined priority.

According to the communication method, the fixed wait time is controlled in accordance with the priority level information about transmitting
25 data through a transmission channel or a priority level of transmitting data.

Hence, a useless wait time can be reduced by setting the fixed wait time to an optimum value for each data transmission. Consequently, data transmission with superior transmission efficiency becomes possible while delay conditions for transmitting data are fulfilled.

5 The communication method may include setting a fixed wait time to zero when a priority level represented by priority level information of transmitting data through a transmission channel is lower than the priority level of transmitting data.

10 According to the communication method, when a priority level represented by the priority level of the transmitting data through a transmission channel is lower than the priority level of transmitting data, a fixed wait time is set to zero; hence, efficient transmission of high priority data becomes possible. In particular, the method is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

15 The communication method may include setting a predetermined wait time achieved when transmitting data having not a high priority level are transmitted to a value that is greater than the maximum random wait time achieved when transmitting data having a high priority level are transmitted.

20 According to the communication method, since a predetermined wait time for transmitting data having a low priority level is set to a great value, efficient transmission of high priority data becomes possible. In particular, the method is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

25 The communication method may include controlling the length of a communication frame in accordance with delay information requested by data

having a high priority level when a priority level represented by priority level information about transmitting data through a transmission channel is high.

According to the communication method, the length of a communication frame to be transmitted is controlled in accordance with delay information requested by data having a high priority level, and hence transmission of data having a high priority level can be early started, and delay conditions for the data can be fulfilled. In particular, the method is suitable for data transmission requiring QoS (Quality of Service) as in transmission of audio data and streaming data.

10 The communication method may include a method using a power line as a transmission channel.

The communication method may include acquiring priority level information about data transmitted through a transmission channel by analysis of a header of data that are present in the transmission channel.

15 According to the communication method, a priority level of data that are in the middle of transmitting through a transmission channel can be briefly acquired. Timing for analysis of a header of a data frame is arbitrary; however, analysis is performed periodically, for instance, at a given time interval. A header of a data frame may also be analyzed by means of all communication
20 apparatuses connected to the transmission channel or a specific communication apparatus.

The communication method may include receiving control information transmitted from another communication apparatus connected to a transmission channel and acquiring priority level information about data transmitted through a
25 transmission channel contained in the control information.

According to the communication method, not all of the communication apparatus need to perform data processing for acquiring a priority level of data that are in the middle of transmitting through the transmission channel, and hence processing burden on an individual communication apparatus is
5 alleviated. The control signal is; for instance, a beacon signal. Moreover, a communication apparatus that perform data processing for acquiring a priority level of data that are in the middle of transmitting through the transmission channel is; for instance, a master unit.

This application is based upon and claims the benefit of priority of
10 Japanese Patent Application No. 2007-295684 filed on November 14, 2007, the contents of which are incorporated herein by reference in its entirety.

Industrial Applicability

The present invention is useful as a communication method, a
15 communication system, a communication apparatus and an integrated circuit therefor that enable efficient transmission while a delay limitation appropriate to transmitting data is fulfilled.

CLAIMS

1. A communication apparatus for connecting to a transmission channel capable of transmitting a plurality of kinds of data, each kind of data having

5 different priority levels, the apparatus comprising:

acquiring means for acquiring each priority information of each kind of data on the transmission channel; and

transmitting means for, when transmitting data having a predetermined priority are transmitted from the communication apparatus, controlling a time
10 from a predetermined transmission reference time to a transmission end time of the transmitting data in accordance with the priority information,

wherein the transmitting means transmits the transmitting data after elapse of a predetermined wait time since the transmission reference time when the transmission channel enters an idle state; and

15 wherein the transmitting means controls the predetermined wait time in accordance with the priority information.

2. The communication apparatus according to claim 1, further comprising:

communication frame generating means for generating a communication frame which has a predetermined length and stores the data,

20 wherein the transmitting means controls the length of the communication frame in accordance with the priority information.

3. The communication apparatus according to claim 1 or 2, wherein the transmitting means controls the predetermined wait time in accordance with the predetermined priority of the transmitting data.

4. The communication apparatus according to claim 2 or 3, wherein the transmitting means controls the length of the communication frame in accordance with the predetermined priority of the transmitting data.

5. The communication apparatus according to any one of claims 1 to 4, wherein the predetermined wait time includes a random wait time randomly determined for each transmission and a fixed wait time determined at a constant value in accordance with the priority information and the predetermined priority of the transmitting data; and

wherein the transmitting means controls the fixed wait time in accordance with at least one of the priority information and the predetermined priority.

6. The communication apparatus according to any one of claims 1 to 5, wherein, when a priority level represented by the priority information is lower than the predetermined priority of the transmitting data to be transmitted, the transmitting means sets the fixed wait time to zero.

7. The communication apparatus according to any one of claims 1 to 6, wherein the transmitting means sets the predetermined wait time, used when

the transmitting data whose predetermined priority is not a high priority level are transmitted, to a value that is greater than a maximum value of the random wait time used at the time of transmission of the transmitting data having the high
5 priority level.

8. The communication apparatus according to any one of claims 2 to 7, wherein, when a priority level represented by the priority information is a high priority level, the transmitting means controls the length of the communication
10 frame in accordance with delay information requested by the data having the high priority level.

9. The communication apparatus according to any one of claims 1 to 8, wherein the transmission channel is a power line.
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10. The communication apparatus according to any one of claims 1 to 9, wherein the acquiring means acquires the priority information by analysis of a header of data that are present on the transmission channel.

20 11. The communication apparatus according to any one of claims 1 to 10, wherein the acquiring means receives control information transmitted from another communication apparatus which is connected to the transmission channel and acquires the priority information contained in the control information.

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12. A communication method for connecting to a transmission channel

capable of transmitting a plurality of kinds of data, each kind of data having different priority levels, the method comprising the steps of:

acquiring each priority information of each kind of data on the transmission channel; and

5 controlling a time from a predetermined transmission reference time until a transmission end time of a transmitting data in accordance with the priority information when the transmitting data having a predetermined priority are transmitted,

10 wherein data are transmitted after elapse of a predetermined wait time since the transmission reference time when the transmission channel enters an idle state; and

wherein the predetermined wait time is controlled in accordance with the priority information.

15 13. The communication method according to claim 12, further comprising the steps of:

generating a communication frame that has a predetermined length and stores the data; and

20 controlling the length of the communication frame in accordance with the priority information.

14. The communication method according to claim 12 or 13, wherein the predetermined wait time is controlled in accordance with the predetermined

priority of the transmitting data.

15. The communication method according to claim 13 or 14, wherein a
5 length of the communication frame is controlled in accordance with the
predetermined priority of the transmitting data.

16. The communication method according to any one of claims 12 to 15,
wherein the predetermined wait time includes a random wait time
10 randomly determined for each transmission and a fixed wait time determined at
a constant value in accordance with the priority information and the
predetermined priority of the transmitting data; and

wherein the fixed wait time is controlled in accordance with at least one
of the priority information and the predetermined priority.

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17. The communication method according to any one of claims 12 to 16,
wherein, when a priority level represented by the priority information is lower
than the predetermined priority of the transmitting data to be transmitted, the
fixed wait time is set to zero.

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18. The communication method according to any one of claims 12 to 17,
wherein the predetermined wait time used when the transmitting data whose
predetermined priority is not a high priority level are transmitted is set to a value
that is greater than a maximum value of the random wait time used at the time
25 of transmission of the transmitting data having the high priority level.

19. The communication method according to any one of claims 13 to 18, wherein, when a priority level represented by the priority information is a high priority level, the length of the communication frame is controlled in accordance with delay information requested by the data having the high priority level.

20. The communication method according to any one of claims 12 to 19, wherein the transmission channel is a power line.

21. The communication method according to any one of claims 12 to 20, wherein the priority information is acquired by analysis of a header of data that are present in the transmission channel.

22. The communication method according to any one of claims 12 to 21, wherein control information transmitted from another communication apparatus which is connected to the transmission channel is received and the priority information contained in the control information is acquired.

23. An integrated circuit used in a communication apparatus for connecting to a transmission channel capable of transmitting a plurality of kinds of data, each kind of data having different priority levels, the circuit comprising:

acquiring means for acquiring each priority information of each kind of data on the transmission channel; and

transmitting means for, when transmitting data having a predetermined priority are transmitted from the communication apparatus, controlling a time from a predetermined transmission reference time to a transmission end time of

the transmitting data in accordance with the priority information,

wherein the transmitting means transmits the transmitting data after elapse of a predetermined wait time since the transmission reference time when

5 the transmission channel enters an idle state; and

wherein the transmitting means controls the predetermined wait time in accordance with the priority information.