

DATA COMMUNICATION METHOD AND DATA COMMUNICATION APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to a data communication method of an error control of an automatic repeat request system and a data communication apparatus therefor.

Description of the Related Art:

An error control method in a data communication includes an error control method of an automatic repeat request (ARQ) system suitable for application to a mobile data communication system in which a burst error occurs relatively frequently. According to this error control method of automatic repeat request system, if a data frame transmitted from a transmission side communication apparatus (data communication apparatus) to a reception side transmission apparatus (data communication apparatus) has an error, then the transmission side communication apparatus transmits the data frame to the reception side communication apparatus again based on a re-transmission request from the reception side communication apparatus to the transmission side communication apparatus.

Although there are various kinds of error control methods of automatic repeat request, an error control method of automatic repeat request system of a selective repeat (SR) system providing a high throughput will hereinafter be described by way of example. In theory, an apparatus employing the SR system requires a buffer memory of infinite size. Therefore,

usually such error control method of automatic repeat request system of SR system is not employed, but an improved method thereof is employed. For simplification of description, an error control method of automatic repeat request of an original SR system will be described.

An arrangement of an ARQ frame having the same format when it is a data frame and a feedback frame will be described with reference to FIG. 1A. This ARQ frame is formed of, for example, a 16-bit transmission data length indicating area a, an 8-bit transmission frame number area b, a 8-bit repeat request frame number area c, a 592-bit transmission data area d, and a 16-bit error detection code e for all the areas a to d. In this arrangement, one frame is formed of 640 bits.

The transmission data length indicating area a is an area for indicating a data amount of the transmission data area d. This data amount can be set within the range from 0 to 592 bits, and in this case the data amount of the transmission data area d is 592 bits. The transmission frame number area b indicates a number of a frame to be transmitted (e.g., frame numbers 0 or 1 to 255). The repeat request frame number area c is used in a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus and indicates a number of a frame required next time by the reception side communication apparatus (the smallest frame number among numbers of frames which the reception side communication apparatus has not received yet).

The error detection code e is a cyclic redundancy

check (CRC) code (16 bits) according to ITU-T recommendation³. This CRC code effects a 624-bit area from the transmission data length indicating area a to the transmission data area d.

An ARQ transmission chart according to the SR system presented when a transmission frame has an error will be described with reference to FIG. 1B. In FIG. 1B, numerals in rectangular frames of the data transmission side (transmission side communication apparatus) depict frame numbers of transmission frames. It is assumed that there are ten transmission frames 1 to 10 and the frame numbers 1 and 10 respectively depict the first transmission frame number and the last transmission frame number. An arrow pointing toward the lower right depicts a transmission frame transmitted from the transmission side communication apparatus to the reception side communication apparatus. An arrow pointing toward an upper right depicts a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus. A solid-line arrow depicts a frame having no transmission error. A broken-line arrow depicts a frame (transmission error) having a transmission error. A repeat request frame number of the feedback frame is depicted by a reference symbol R marked with a frame number. A reference symbol d depicts a round trip delay amount which indicates a time required for the transmission side communication apparatus to, after transmitting a transmission frame (data frame) therefrom to the reception side communication apparatus, receive a feedback frame from the reception side communication apparatus

indicating whether or not the reception side communication apparatus has received the transmission frame correctly. In this example shown in FIG. 1B, the round trip delay amount d corresponds to four frame periods required for the transmission side communication apparatus to transmit four transmission frames.

Operations of the transmission side communication apparatus and the reception side communication apparatus will hereinafter be described with reference to FIG. 1B.

[transmission side communication apparatus]

- (1) Transmit transmission frames 1, 2, 3 and 4 successively.
- (2) Receive a feedback frame including a response to the transmission frame 1 while transmitting the transmission frame 4. Since the repeat request frame number indicated by the feedback frame is 2, determine that the reception side communication apparatus has received the transmission frame 1 correctly.
- (3) Receive a feedback frame including a response to the transmission frame 2 while transmitting a transmission frame 5. Since the repeat request frame number indicated by the feedback frame is 3, determine that the reception side communication apparatus has received the transmission frame 2 correctly.
- (4) Receive a feedback frame including a response to the transmission frame 3 while transmitting a transmission frame 6. Since the repeat request frame number indicated by the feedback frame is 4, determine that the reception side communication

apparatus has received the transmission frame 3 correctly.

(5) Receive a feedback frame including a response to the transmission frame 4 while transmitting a transmission frame 7. Since the repeat request frame number indicated by the feedback frame is 4 again, determine that the reception side communication apparatus has not received the transmission frame 4 correctly.

(6) Transmit the transmission frame 4 again.

(7) Since it is determined after four frame periods whether or not the reception side communication apparatus correctly receives the transmission frame 4 transmitted again, transmit the succeeding frames 8, 9 and 10 successively.

(8) Receive the feedback frame including a response to the re-transmitted frame 4 while transmitting the last transmission frame 10. Since the repeat request frame number indicated by the feedback frame is 4, determine that the reception side communication apparatus has not received the transmission frame 4 correctly yet.

(9) Transmit the transmission frame 4 again.

(10) Since it is determined after four frame periods whether or not the reception side communication apparatus correctly receives the transmission frame 4 transmitted again, transmit the succeeding frames 5, 6 and 7 successively.

(11) Receive the feedback frame including a response to the re-transmitted frame 4 while transmitting the last transmission frame 7. Since the repeat request frame number indicated by the feedback frame is 9, determine that the

reception side communication apparatus has received the transmission frame 4 correctly and that the reception side communication apparatus has not received the transmission frame 9 correctly.

(12) Transmit the transmission frame 9 again.

(13) Since it is determined after four frame periods whether or not the reception side communication apparatus correctly receives the transmission frame 9 transmitted again, transmit the succeeding frames 10.

(14) Since there is no frame to be transmitted after transmission of the transmission frame 10, transmit again the transmission frame 9 which has been requested once.

(15) Transmit the transmission frame 10. Receive a feedback frame including a response to the transmission frame 9 while transmitting the transmission frame 10. Since the repeat request frame number indicated by the feedback frame is 10, determine that the reception side communication apparatus has received the transmission frame 9 correctly.

(16) Since there is no frame to be transmitted after transmission of the transmission frame 10, transmit again the transmission frame 9 which is requested at present.

(17) Receive a feedback frame including a response to the transmission frame 10 while transmitting the transmission frame 10. Since the repeat request frame number indicated by the feedback frame is 11, determine that the reception side communication apparatus has received the transmission frame 10 correctly. Thus, the transmission side communication apparatus

finishes its transmission of the transmission frames 1 to 10.

[reception side communication apparatus]

(1) Since having received the transmission frames 1, 2 and 3 correctly, transmit successively feedback frames having the frame numbers 2, 3 and 4.

(2) Since having not received the transmission frame 4 correctly, repeatedly transmit the feedback frame whose repeat request frame number is 4 until correct reception of the transmission frame 4.

(3) Since having received the transmission frame 4 correctly, repeatedly transmit a feedback frame including a repeat request frame number set to a frame number next to 8 which is a maximum number of frame numbers of the correctly received transmission frames, i.e., a frame number 9 which is a minimum number among frame numbers of frames that have not been received, until receiving the transmission frame 9 correctly.

(4) Since having received the transmission frame 9 correctly, transmit the feedback frame including a repeat request frame number set to a frame number 10 of the transmission frame requested to be transmitted next.

(5) Since having received the transmission frame 10 correctly, transmit the feedback frame including a repeat request frame number set to a frame number 11 of the transmission frame requested to be transmitted next.

In the ARQ error control method of SR system shown in FIG. 1B, since the transmission side communication apparatus transmits the transmission frames 1 to 10 to the reception side

communication apparatus, the number N_1 of the transmission frames practically transmitted is 16, while the number N_2 of the transmission frames transmitted until the transmission side communication apparatus receives all the feedback frames for confirming correct transmission of all the transmission frames 1 to 10 after transmitting the first transmission frame is 20.

A throughput S defined by a ratio N_0/N_1 (N_0 is the number of the transmission frames to be transmitted and N_1 is the number of all the transmission frames transmitted from the transmission side communication apparatus to the reception side communication apparatus) is $S = 10 \div 16 = 0.625$ in the example shown in FIG. 1B.

In the example shown in FIG. 1B, since the transmission side communication apparatus failed to correctly transmit the transmission frame 4 to the reception side communication apparatus twice and could correctly transmit the transmission frame 4 thereto once, it transmitted the transmission frame 4 thereto three times in total. Since the transmission side communication apparatus failed to correctly transmit the transmission frame 9 to the reception side communication apparatus once and could correctly transmit the transmission frame 9 thereto once, it transmitted the transmission frame 9 thereto twice times in total. Further, although the transmission frames 5, 6, 7 could correctly be transmitted from the transmission side communication apparatus to the reception side communication apparatus successively after transmission of the transmission frame 4, they were transmitted

again because of the round trip delay. The reason for this retransmission results from the fact that the repeat request frame numbers of the feedback frames are 4 until the transmission frame 7 is transmitted again. This means that some of the transmission frames are transmitted uselessly. Thus, in the example shown in FIG. 1B, the throughput is considerably lowered. In general, as the larger the round trip delay amount becomes, the more the throughput is lowered.

A general operation of the above ARQ transmission of SR system shown in FIG. 1B will be described. Initially, the transmission side communication apparatus transmits the frames from the first predetermined frame number to the last predetermined frame number to the reception side communication apparatus in ascending order (or descending order). The reception side communication apparatus transmits a feedback frame including a repeat request frame number $FB1(n)$ formed of a minimum frame number $FBM(n)$ among frames which has not been received and having the same format as that of a transmission frame, to the transmission side in response to the frame numbers of the received first to n th frames. The transmission side communication apparatus transmits a transmission frame which the reception side communication apparatus has not correctly received, to the reception side communication apparatus in response to the repeat request frame number $FB1(n)$ of the received feedback frame.

As described above, in a data communication method employing the ARQ transmission shown in FIGS. 1A and 1B, even

when the transmission side communication apparatus correctly transmits a data frame to the reception side communication apparatus, the transmission side communication apparatus sometimes disadvantageously transmit the data frame repeatedly.

In the data communication method employing the ARQ transmission shown in FIGS. 1A and 1B, if the reception side communication apparatus frequently fails to correctly receive a transmitted data frame of a certain number from the transmission side communication apparatus at the beginning of the successive transmission of the data frames, then the reception side communication apparatus continues transmitting the feedback frame including the same repeat request number to the transmission side communication apparatus until receiving the data frame of the requested frame number, which prevents the transmission side communication apparatus from determining whether or not the reception side communication apparatus could correctly receive all the data frames to be transmitted. Therefore, after the transmission side communication apparatus finishes all the data frames to be newly transmitted, the transmission side communication apparatus must repeatedly transmit the data frames once transmitted until it can confirm correct reception thereof.

SUMMARY OF THE INVENTION

In view of such aspects, it is an object of the present invention to provide a data communication method which makes it possible to transmit a feedback frame indicating a request frame number from a reception side data communication

apparatus to a transmission side data communication apparatus with an improved throughput of data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from the transmission side data communication apparatus to the reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame having a format including a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame.

It is another object of the present invention to provide a data communication method which can improve the throughput of the data frame from the transmission side data communication apparatus to the reception side data communication apparatus, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from the transmission side data

communication apparatus to the reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame.

It is further another object of the present invention to provide a data communication apparatus which makes it possible to transmit a feedback frame indicating a request frame number from a reception side data communication apparatus to a transmission side data communication apparatus with an improved throughput of data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus, in a data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from the transmission side data communication apparatus to the reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication

apparatus to the transmission side data communication apparatus a feedback frame having a format including a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame.

It is yet another object of the present invention to a data communication apparatus which can improve the throughput of the data frame transmitted from the transmission side data communication apparatus to the reception side data communication apparatus, in a data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from the transmission side data communication apparatus to the reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission

side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame.

According to an aspect of the present invention, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, the feedback frame also indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers

of first to nth data frames which the reception side data communication apparatus has received.

Moreover, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame and, the second to kth request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, the transmission side data communication apparatus transmits data frames having the indicated frame numbers which the reception side data communication apparatus has not received to the reception side data communication apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are a diagram showing an arrangement of an ARQ frame and a diagram showing a SR-ARQ transmission chart, respectively;

FIG. 2A is a diagram showing an arrangement of an ARQ frame according to a first embodiment of the present invention, by way of example;

FIG. 2B is a diagram showing the ARQ frame according to the first embodiment which has no transmission data when it is used as a feedback frame;

FIG. 3 is a diagram used to explain an ARQ transmission method of SR system according to the first embodiment when a transmission frame has an error;

FIG. 4 is an enlarged diagram of FIG. 3, used to explain an operation of data frame transmission based on a repeat request frame number;

FIG. 5 is a characteristic graph of round trip delay to throughput characteristics obtained in the first embodiment

and an example shown in FIG. 1A;

FIG. 6 is a characteristic graph of frame error rate to throughput characteristics obtained in the first embodiment and an example shown in FIG. 1A;

FIG. 7A and 7B are diagrams showing an arrangement of an ARQ frame according to a second embodiment of the present invention, by way of example;

FIG. 8 is a diagram showing an arrangement of an ARQ frame according to the second embodiment of the present invention, by way of example;

FIG. 9 is an enlarged diagram of FIG. 8 used to explain an ARQ transmission method of SR system according to the second embodiment when a transmission frame has an error

FIG. 10 is a characteristic graph of frame error rate to throughput characteristics obtained in the first and second embodiments; and

FIG. 11 is a diagram showing a communication system to which the embodiments of the present invention can be applied.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A data communication method according to a first embodiment of the present invention will hereinafter be described with reference to the accompanying drawings. The data communication method of the first embodiment employs an error control method of an automatic repeat request (ARQ) system of a selective repeat (SR) system. An arrangement of an ARQ frame having the same format when it is a data frame and a feedback

frame will be described with reference to FIG. 2A. This ARQ frame is formed of, for example, a 16-bit transmission data length indicating area a, an 8-bit transmission frame number area b, an 8-bit repeat request frame number area c, a 584-bit transmission data area d, an 8-bit next repeat request frame number area f and a 16-bit error detection code e for the areas a to d and f.

The 8-bit next repeat request frame number area f shown in FIG. 2A is provided in the 592-bit data area d of the ARQ frame shown in FIG. 1A. Therefore, the data area d of the ARQ frame shown in FIG. 2A is formed of $592 - 8 = 584$ bits.

The transmission data length indicating area a is an area for indicating a data amount of the transmission data area d. The data amount of the transmission data area d can be set within the range from 0 to 584 bits, and in the first embodiment the data amount thereof is 584 bits. The transmission frame number area b indicates a number of a frame to be transmitted (e.g., frame numbers 0 or 1 to 255). The repeat request frame number area c is used in a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus and indicates a number of a frame required next time by the reception side communication apparatus. The next repeat request frame number area f is used in a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus and indicates a number of a frame required at the time after the next by the reception side communication apparatus.

The error detection code *e* is a cyclic redundancy check (CRC) code (16 bits) according to ITU-T recommendation. This CRC code effects a 624-bit area from the transmission data length indicating area *a* to the transmission data area *d*.

FIG. 2B shows an arrangement of an ARQ frame transmitted as a feedback frame when the data length indicating area *a*, transmission number are *b* and the data area *d* have no transmission data. Since data of the data area *d* is replaced with a data having fixed values having no concern with a feedback information, i.e., with data in which all bits are set to 0 or 1, for example, it is possible to transmit the feedback frame from the reception side communication apparatus to the transmission side communication apparatus without any change of a frame format and without a reception rate being lowered. If the transmission side communication apparatus detects the data having all bits of the data area *d* set to 0 in the feedback frame transmitted from the reception side communication apparatus, then the transmission side communication apparatus can determine that the last 8 bits, i.e., 1 byte of the data area *d* indicates the next repeat request frame number. In this case, although the next repeat request frame number *f* is provided in the data area *d*, this does not lead to the lowering of the transmission data amount.

In the arrangement of the ARQ frame shown in FIG. 2A, the data frame transmitted from the transmission side communication apparatus to the reception side communication apparatus and the feedback frame transmitted from the reception

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side communication apparatus to the transmission side communication apparatus have the same format, i.e., a common format so that full-duplex communication can be realized. Most of practical communications other than a real time communication employ half-duplex communication. Therefore, the feedback frame of the ARQ frame according to the first embodiment constantly includes the repeat request frame number area c, while the feedback frame does not include the next repeat request frame number area f constantly and includes it only when it has no transmission data. As a result, it is possible to prevent the maximum transmission rate from being lowered.

The repeat request frame number c and the next repeat request frame number f used in the feedback frame will be described with reference to FIG. 3 in case of the ARQ transmission chart according to the SR system when a transmission frame has an error. In FIG. 3, numerals in rectangular frames aligned in row on the data transmission side (transmission side communication apparatus) depict frame numbers of transmission frames. It is assumed that there are ten transmission frames 1 to 10 and the frame numbers 1 and 10 respectively depict the first transmission frame number and the last transmission frame number. An arrow pointing toward the lower right depicts a transmission frame transmitted from the transmission side communication apparatus to the reception side communication apparatus. An arrow pointing toward the upper right depicts a feedback frame transmitted from the reception side communication apparatus to the transmission side

communication apparatus. A solid-line arrow depicts a frame having no transmission error. A broken-line arrow depicts a frame (transmission error) having a transmission error. A repeat request frame number of the feedback frame is depicted by a reference symbol R marked with a frame number on the data reception side. A reference symbol d depicts a round trip delay amount which indicates a time required for the transmission side communication apparatus to, after transmitting a transmission frame (data frame) therefrom to the reception side communication apparatus, receive a feedback frame from the reception side communication apparatus indicating whether or not the reception side communication apparatus has received the transmission frame correctly. In this embodiment, the round trip delay amount d corresponds to four frame periods required for the transmission side communication apparatus to transmit four transmission frames.

Before describing operations shown in FIG. 3 in detail, how to determine the repeat request frame number and the next repeat request frame number will be described with reference to FIG. 4 which shows a part of FIG. 3 in an enlarged scale. In FIG. 4, like parts and portions corresponding to those in FIG. 3 are marked with the same reference numerals. Respective reference symbols in FIG. 4 are defined as follows.

FF(i) a frame number of an ith data frame transmitted from the transmission side communication apparatus to the reception side communication apparatus

FB(i) a repeat request frame number of a

feedback frame received during transmission of the i th data frame

$FB_{next}(i)$ a next repeat request frame number of a feedback frame received during transmission of the i th data frame

How the transmission side communication apparatus determines a frame number of a data frame when an $(i+1)$ th transmission frame is transmitted by using the next repeat request frame number of the feedback frame received upon transmission of the i th data frame will be described.

When all the following three conditions are satisfied, $FB_{next}(i)$ is set to the frame number of an $(i+1)$ th data frame.

condition 1: if the last data frame has already been transmitted; or if temporarily the data frame of the frame number $FF(i)+1$ cannot be transmitted when the data frame $FF(i+1)$ is to be transmitted

condition 2: $FF(i) = FB(i-1)$

condition 3: $FB_{next}(i) > FB(i)+1$

Operations of the transmission side communication apparatus and the reception side communication apparatus will hereinafter be described with reference to FIG. 3.

[transmission side communication apparatus]

The following steps (1) to (9) are similar to those described with reference to FIG. 1B.

(1) Transmit transmission frames 1, 2, 3 and 4 successively.

(2) Receive a feedback frame including a response to the transmission frame 1 while transmitting the transmission frame 4. Since the repeat request frame number indicated by the feedback frame is 2, determine that the reception side communication apparatus has received the transmission frame 1 correctly.

(3) Receive a feedback frame including a response to the transmission frame 2 while transmitting a transmission frame 5. Since the repeat request frame number indicated by the feedback frame is 3, determine that the reception side communication apparatus has received the transmission frame 2 correctly.

(4) Receive a feedback frame including a response to the transmission frame 3 while transmitting a transmission frame 6. Since the repeat request frame number indicated by the feedback frame is 4, determine that the reception side communication apparatus has received the transmission frame 3 correctly.

(5) Receive a feedback frame including a response to the transmission frame 4 while transmitting a transmission frame 7. Since the repeat request frame number indicated by the feedback frame is 4 again, determine that the reception side communication apparatus has not received the transmission frame 4 correctly.

(6) Transmit the transmission frame 4 again.

(7) Since it is determined after four frame periods whether or not the reception side communication apparatus correctly receives the transmission frame 4 transmitted again, transmit the succeeding frames 8, 9 and 10 successively.

(8) Receive the feedback frame including a response to the re-transmitted frame 4 while transmitting the last transmission frame 10. Since the repeat request frame number indicated by the feedback frame is 4, determine that the reception side communication apparatus has not received the transmission frame 4 correctly yet.

(9) Transmit the transmission frame 4 again (a portion indicated with $i = 12$ in FIG. 4).

(10) Since the above three conditions are satisfied when $i = 12$, transmit the transmission frame 9 indicated by a next repeat request frame number of a feedback frame received upon transmission of the twelfth data frame (a portion indicated with $i = 13$ in FIG. 4)

(11) Transmit the transmission frame 10 (a portion indicated with $i = 14$)

(12) Since there is no frame to be transmitted after transmission of the transmission frame 10, transmit the transmission frame 4 which is requested at present. Receive the feedback frame including a response to the re-transmitted frame 4 while transmitting the transmission frame 4. Since the repeat request frame number indicated by the feedback frame is 9, determine that the reception side communication apparatus has received the transmission frame 4 correctly (a portion indicated with $i = 15$ in FIG. 4).

(13) Transmit the transmission frame 9. Since receiving a feedback frame whose the repeat request frame number indicates 11 during transmission of the transmission frame 9, determine

that the reception side communication apparatus has received the transmission frame 10 correctly (a portion indicated with $i = 16$ in FIG. 4)

[reception side communication apparatus]

The reception side communication apparatus constantly sets as the repeat request frame number of the feedback frame a frame number of a data frame which it requests the transmission side communication apparatus to transmit next time, and also sets as a next repeat request frame number of the feedback frame a frame number of a data frame which it requests the transmission side communication apparatus to transmit at a time after the next. The reception side communication apparatus transmits the feedback frame to the transmission side communication apparatus.

(1) Since having received the transmission frames 1, 2 and 3 correctly, successively transmit feedback frames respectively including the repeat request frame numbers set to 2, 3 and 4 and the next repeat request frame numbers set to 3, 4 and 5 to the transmission side communication apparatus.

(2) Since having not received the transmission frame 4 correctly, repeatedly transmit the feedback frame whose repeat request frame number is 4 and whose next repeat request frame number is still 5 until correct reception of the transmission frame 4.

(3) Since having received the transmission frame 4 correctly, transmit a feedback frame including a repeat request frame number set to a frame number next to 8 which is a maximum

number of frame numbers of the correctly received transmission frames, i.e., a frame number 9 which is a minimum number among frame numbers of frames that have not been received, and including a next repeat request frame number set to 11.

(4) Since having received the transmission frame 9 correctly, transmit the feedback frame including a repeat request frame number set to a frame number 11 of the transmission frame requested to be transmitted next and including a next repeat request frame number set to a frame number 12.

Even if, when the feedback frame of the ARQ frame includes not only the repeat request frame number but also the next repeat request frame number, the reception side communication apparatus frequently fails to correctly receive the data frames transmitted from the transmission side communication apparatus thereto at the beginning of the transmission and hence repeatedly transmits the feedback frame indicating the repeat request, then it is possible for the transmission side communication apparatus to determine up to which data frame the reception side communication apparatus could correctly receive data frames after the reception side communication side communication apparatus had failed to correctly receive the data frame from the transmission side communication apparatus. Therefore, it can be avoid that the transmission side communication apparatus uselessly transmits again the data frames once transmitted therefrom to the reception side communication apparatus (e.g., re-transmission of

the data frames 5, 6, 7 in the example shown in FIG. 1B).²⁶

In the ARQ error control method of SR system according to the first embodiment shown in FIGS. 3 and 4, when the transmission side communication apparatus transmits the transmission frames 1 to 10 to the reception side communication apparatus, the number N1 of the transmission frames practically transmitted is 13, while the number N2 of the transmission frames transmitted until the transmission side communication apparatus receives all the feedback frames for confirming correct transmission of all the transmission frames 1 to 10 after transmitting the first transmission frame is 16.

A throughput S defined by a ratio $N0/N1$ ($N0$ is the number of the transmission frames to be transmitted and $N1$ is the number of all the transmission frames transmitted from the transmission side communication apparatus to the reception side communication apparatus) is $S = 10 \div 13 = 0.769$ in the first embodiment shown in FIGS. 3 and 4. Study of this result reveals that the throughput S obtained in the first embodiment is improved by 23% as compared with the throughput S of 0.625 obtained in the example shown in FIG. 1B.

FIG. 5 is a graph showing characteristic curves of a round trip delay amount d (number of frame) to a throughput S obtained in the first embodiment and in the example shown in FIG. 1B. In FIG. 5, the characteristic curves are obtained by calculating values of the throughput S respectively obtained when the round trip delay amount d is changed to 5, 10, 15, 20, 25, 30. In this calculation, it is assumed that a frame error

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rate is 0.1 and a total frame number is 40. Study of the characteristic graph of FIG. 5 reveals that the larger the round trip delay amount d becomes, the more the throughput S obtained in the first embodiment is improved as compared with that obtained in the example shown in FIG. 1B. For example, when the round trip delay amount d is 20, the throughput S obtained in the first embodiment is improved by 6.2 % as compared with that in the example shown in FIG. 1B. If the data communication method according to the first embodiment is applied to a personal handy-phone system (PHS), a transmission rate therein is improved by about 1.8 kb/sec on the assumption that the maximum transmission rate obtained when an ARQ error control method is employed is 30 kb/sec. Contrary, the smaller the round trip delay amount d becomes the hardly the throughput S obtained in the first embodiment is improved as compared with that obtained in the example shown in FIG. 1B.

FIG. 6 is a graph showing characteristic curves of the frame error rate to the throughput S in the first embodiment and in the example shown in FIG. 1B. In FIG. 6, the characteristic curves are obtained by calculating values of the throughput S respectively obtained when the frame error rate is changed from 0 to 0.2 by a unit of 0.02. In this calculation, it is assumed that a round trip delay amount d is 20 and a total transmission frame number is 40. Study of the characteristic graph of FIG. 6 reveals that the larger the frame error rate becomes, the more the throughput S obtained in the first embodiment is improved as compared with that obtained in the

example shown in FIG. 1B.

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A general data communication method will subsequently be described. This general data communication method is as follows. The transmission side data communication apparatus transmits to the reception side data communication apparatus data frames from the first predetermined frame number to the last predetermined frame number in an ascending order (or in a descending order). The reception side data communication apparatus transmits to the transmission side data communication apparatus the feedback frame including the first repeat request frame number $FB1(n)$ formed of the minimum (or maximum) frame number $FBM(n)$ among the frame numbers of the data frames which it has not received yet, in response to the frame numbers of the first to n th data frames which it has already received. The transmission side data communication transmits to the reception side data communication apparatus again the data frame of the frame number which the reception side data communication apparatus has not correctly received, in response to the first repeat request frame number $FB1(n)$ indicated by the received feedback frame.

In response to the frame numbers of the first to n th data frames received by the reception side data communication apparatus, the reception side data communication apparatus sets in the feedback frame the second repeat request frame number $FB2(n)$ formed of the frame numbers $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] of the data frames which have not been received to the k th repeat request frame number $FBk(n)$ (where k is an integer exceeding 1)

formed of the frame numbers $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] of the data frames which have not been received.

In response to the first repeat request frame number $FB1(n)$ of the received feedback frame and the second repeat request frame number $FB2(n)$ to the k th repeat request frame number $FBk(n)$, the transmission side data apparatus transmits the data frame of the frame numbers which the reception side data communication apparatus has not correctly received, to the reception side data communication apparatus

Assuming that the frame number of the first data frame transmitted from the transmission side data communication apparatus to the reception side data communication apparatus in response to the first repeat request frame number $FB1(n)$ of the received feedback frame and the second repeat request frame number $FB2(n)$ to the k th repeat request frame number $FBk(n)$ thereof is $FF(i)$ and that the first repeat request frame number and the second to k th repeat request frame number indicated by the feedback frame received during transmission of the data frame of the frame number $FF(i)$ are respectively $FB1(n)$ and $FB2(n)$ to $FBk(n)$ in response thereto, the frame number of the data frame to be transmitted at a $(i+1)$ th frame is set to $FBk(i)$ subjected to satisfaction of all the following conditions.

the k th condition

(1): if the data frame of the last predetermined frame number has already been transmitted; or if the data frame $\{FF(i)+1\}$ [or $\{FF(i)-1\}$] cannot temporarily be transmitted as the data frame of the frame number $FF(i+1)$ to be transmitted at

the (i+1)th frame.

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(2): $\{FF(i) = FB(k-1)(i-1)\}$ [or $\{FF(i) = FB(k-1)(i+1)\}$]

(3): $\{FB_k(i) > FB(k-1)(i)+1\}$ [or $\{FB_k(i) < FB(k-1)(i)-1\}$]

The frame number of the data frame to be transmitted at a (i+1)th frame is set to $FB(k-1)(i)$ when the above kth conditions are not satisfied but the following (k-1)th conditions are satisfied.

the kth condition

(1): if the data frame of the last predetermined frame number has already been transmitted; or if the data frame $\{FF(i)+1\}$ [or $\{FF(i)-1\}$] cannot temporarily be transmitted as the data frame of the frame number $FF(i+1)$ to be transmitted at the (i+1)th frame.

(2): $\{FF(i) = FB(k-2)(i-1)\}$ [or $\{FF(i)+1 = FB(k-2)(i+1)\}$]

(3): $\{FB(k-1)(i) > FB(k-2)(i)+1\}$
[or $\{FB(k-1)(i) < FB(k-2)(i)-1\}$]

The frame number of the data frame to be transmitted at a (i+1)th frame is set to $FB_2(i)$ when the above kth, (k-1)th, ..., third conditions and the second conditions are not satisfied.

(1): if the data frame of the last predetermined frame number has already been transmitted; or if the data frame $\{FF(i)+1\}$ [or $\{FF(i)-1\}$] cannot temporarily be transmitted as the data frame of the frame number $FF(i+1)$ to be transmitted at the (i+1)th frame.

(2): $\{FF(i) = FB_1(i-1)\}$ [or $\{FF(i)+1 = FB_1(i+1)\}$]

(3): $\{FB_2(i) > FB_1(i)+1\}$ [or $\{FB_2(i) < FB_1(i)-1\}$]

The frame number of the ³¹data frame to be transmitted at a (i+1)th frame is set to FB2(i) when the above kth, (k-1)th, ..., third conditions are not satisfied but the following second conditions are satisfied.

According to the first embodiment, since in the error control method of the automatic repeat request system of the selective request system the feedback frame supplied from the reception side communication apparatus to the transmission side communication apparatus includes not only the repeat request frame number but also the next repeat request frame number, even if the reception side communication apparatus frequently fails to correctly receive the data frames at the beginning of the data frames transmitted from the transmission side communication apparatus thereto and hence repeatedly requests the transmission side communication apparatus to transmit again a data frame which it failed to correctly receive, then it is possible for the transmission side communication apparatus to determine up to which data frame the reception side communication apparatus has correctly received the data frames. Therefore, it is possible to prevent the transmission side communication apparatus from uselessly re-transmitting the data frames once transmitted therefrom to the reception side communication apparatus on the basis of a prospect of the transmission side communication apparatus. Especially, while, when such data communication is carried out via a satellite circuit, the round trip delay amount reaches a considerable amount of thirty five frames, which is a considerably long delay amount (assuming that one frame is

formed of 640 bits and a transmission rate is 32 kb/sec, then the delay amount of thirty five frames is equivalent to 700 msec), employment of the data communication method according to the present invention remarkably improves the throughput. While the method with the numbers of the repeat request frame number area set to $k=2$ has been generally described in the first embodiment, when the total number of the transmission frames is large, the effect of the present invention can be more achieved by setting the value of k to 3 or larger.

When the feedback frame does not include any transmission data, even if the next repeat request frame number area is provided in the data area, it does not lower the maximum transmission rate but it improves the throughput. When this method according to the first embodiment of the present invention is employed, it is unnecessary to considerably add/change a software/hardware to be added to the data communication apparatus used in the example shown in FIG. 1B in order for the reception side communication apparatus to add the next repeat request frame number area to the feedback frame transmitted to the transmission side communication apparatus and in order for the transmission side communication apparatus to determine the frame number of the data frame based on the next repeat request frame number.

A data communication method according to a second embodiment of the present invention hereinafter be described with reference to the accompanying drawings. The data communication method according to the second embodiment employs

the error control method of automatic repeat request system of selective repeat system providing a high throughput similar to those presented by the method shown in FIG. 1B and the first embodiment. An arrangement of an ARQ frame having the same format when it is a data frame and a feedback frame will be described with reference to FIGS. 7A and 7B. This ARQ frame is formed of, for example, a 16-bit transmission data length indicating area a, an 8-bit transmission frame number area b, an 8-bit repeat request frame number area c (shown in FIG. 7A) or 8-bit next repeat request frame number area f (shown in FIG. 7B), a 591-bit transmission data area d, a 1-bit repeat request identifier area g and a 16-bit error detection code e for the areas a, b, c (or f), d and g.

It depends upon a rule which will be described later on whether the repeat request frame number area c or the next repeat request frame number area f is set in an 8-bit area between the transmission frame number b and the data area d. When the repeat request frame number area c is set therein, a value of the 1-bit repeat request identifier area g is set to $g=0$ (or $g=1$). When the next repeat request frame number area f is set therein, the value of the 1-bit repeat request identifier area g is set to $g=1$ (or $g=0$). Thus, it is possible to discriminate whether the repeat request frame number area c or the next repeat request frame number area f is set in the 8-bit area between the transmission frame number b and the data area d.

The 1-bit next repeat request identifier area g shown

in FIGS. 7A and 7B is provided in the 592-bit data area d of the ARQ frame shown in FIG. 1A. Therefore, the data area d of the ARQ frame shown in FIGS. 7A and 7B is formed of $592 - 1 = 591$ bits. Since the data amount of the data area d according to this second embodiment is only slightly smaller as compared with that according to the first embodiment shown in FIG. 2A, this area format according to this second embodiment is more advantageous in full-duplex communication with data in the data area d of the feedback frame as compared with that of the first embodiment.

The transmission data length indicating area a is an area for indicating a data amount of the transmission data area d. The data amount of the transmission data area d can be set within the range from 0 to 591 bits at a bit unit, and in the second embodiment the data amount thereof is 591 bits. The transmission frame number area b indicates a number of a frame to be transmitted (e.g., frame numbers 0 or 1 to 255). The repeat request frame number area c is used in a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus and indicates a number of a frame required next time by the reception side communication apparatus. The next repeat request frame number area f is used in a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus and indicates a number of a frame required at the time after the next by the reception side communication apparatus.

The error detection code *e* is a cyclic redundancy check (CRC) code (16 bits) according to ITU-T recommendation. This CRC code effects in total a 624-bit area formed of the areas *a*, *b*, *c* (or *f*), *d* and *g*.

The repeat request frame number *c* and the next repeat request frame number *f* used in the feedback frame will be described with reference to FIG. 8 in case of the ARQ transmission chart according to the SR system when a transmission frame has an error. In FIG. 8, numerals in rectangular frames aligned in row on the data transmission side (transmission side communication apparatus) depict frame numbers of transmission frames. It is assumed that there are ten transmission frames 1 to 10 and the frame numbers 1 and 10 respectively depict the first transmission frame number and the last transmission frame number. An arrow pointing toward the lower right depicts a transmission frame transmitted from the transmission side communication apparatus to the reception side communication apparatus. An arrow pointing toward the upper right depicts a feedback frame transmitted from the reception side communication apparatus to the transmission side communication apparatus. A solid-line arrow depicts a frame having no transmission error. A broken-line arrow depicts a frame (transmission error) having a transmission error. A repeat request frame number of the feedback frame is depicted by a reference symbol *R* marked with a frame number on the data reception side. A reference symbol *R* marked with a frame number and in parenthesis is a frame number which the reception side

communication apparatus has not transmitted to the transmission side communication apparatus. A reference symbol d depicts a round trip delay amount which indicates a time required for the transmission side communication apparatus to, after transmitting a transmission frame (data frame) therefrom to the reception side communication apparatus, receive a feedback frame from the reception side communication apparatus indicating whether or not the reception side communication apparatus has received the transmission frame correctly. In the second embodiment, the round trip delay amount d corresponds to four frame periods required for the transmission side communication apparatus to transmit four transmission frames.

Before describing operations shown in FIG. 8 in detail, how to determine the repeat request frame number and the next repeat request frame number will be described with reference to FIG. 9 which shows a part of FIG. 8 in an enlarged scale. In FIG. 9, like parts and portions corresponding to those in FIG. 8 are marked with the same reference numerals. Respective reference symbols in FIG. 9 are defined as follows.

$FF(i)$ a frame number of an i th data frame transmitted from the transmission side communication apparatus to the reception side communication apparatus

$FB(i)$ a repeat request frame number of a feedback frame received during transmission of the i th data frame

$FB_{next}(i)$ a next repeat request frame number of a latest repeat request frame number $FB(i)$ requested by the

reception side communication apparatus received during
transmission of the i th data frame

There will be described how to determine whether the
feed back frame including the repeat request frame number area
or the next repeat request frame number area is to be
transmitted from the reception side communication apparatus to
the transmission side communication side apparatus. Usually,
the feedback frame including the repeat request frame number area
is transmitted. However, only when the following two conditions
are satisfied, the feedback frame including the next repeat
request frame number area is transmitted.

condition (1): $j \bmod \alpha = 0$

(the feedback frame including the next repeat
request frame number area is transmitted once in α transmission
times. $\alpha > 1$ is established and j depicts the number of an order
in which the reception side communication apparatus transmits
frames)

condition (2): next repeat request frame number $>$
repeat request frame number + 1

Operations of the transmission side communication
apparatus and the reception side communication apparatus will
hereinafter be described with reference to FIG. 8.

[transmission side communication apparatus]

Since the transmission side communication apparatus
is prevented from receiving the feedback frame including both of
the repeat request frame number area and the next repeat request

frame number in the second embodiment, the transmission side communication apparatus is provided with memories for respectively storing therein the repeat request frame number and the next repeat request frame number which are constantly replaced with new frame numbers.

(1) Transmit transmission frames 1, 2, 3 and 4 successively.

(2) Receive a feedback frame including a response to the transmission frame 1 while transmitting the transmission frame 4. Since the repeat request frame number indicated by the feedback frame is 2, determine that the reception side communication apparatus has received the transmission frame 1 correctly.

(3) Receive a feedback frame including a response to the transmission frame 2 while transmitting a transmission frame 5. Since the repeat request frame number indicated by the feedback frame is 3, determine that the reception side communication apparatus has received the transmission frame 2 correctly.

(4) Receive a feedback frame including a response to the transmission frame 3 while transmitting a transmission frame 6. Since the repeat request frame number indicated by the feedback frame is 4, determine that the reception side communication apparatus has received the transmission frame 3 correctly.

(5) Receive a feedback frame including a response to the transmission frame 4 while transmitting a transmission frame 7. Since the repeat request frame number indicated by the feedback frame is 4 again, determine that the reception side

communication apparatus has not received the transmission frame 4 correctly.

(6) Transmit the transmission frame 4 again.

(7) Since it is determined after four frame periods whether or not the reception side communication apparatus correctly receives the transmission frame 4 transmitted again, transmit the succeeding frames 8, 9 and 10 successively.

(8) Receive the feedback frame including a repeat request frame number 4 while transmitting the last transmission frame 10. The next repeat request frame number indicated by the feedback frame is 8.

(9) Since there is no transmission frame whose frame number exceeds 10 and the latest repeat request frame number stored in the memory is 4, transmit the transmission frame 4 again (a portion indicated with $i = 12$ in FIG. 9).

(10) Since the above two conditions of re-transmission based on the next repeat request frame number are satisfied, transmit the transmission frame 8 again (a portion indicated with $i = 13$ in FIG. 9)

(11) Transmit the transmission frames 9 and 10 (portions indicated with $i = 14$ and $i = 15$ shown in FIG. 9)

(12) Since there is no transmission frame whose frame number exceeds 10 and the latest repeat request frame number stored in the memory is 4, transmit the transmission frame 4 again. Receive the feedback frame including the repeat request frame number area while transmitting the transmission frame 4. The repeat request frame number indicated by the feedback frame

is 9 (a portion indicated with $i = 16$ in FIG. 9).

(13) Transmit the transmission frame 9. Receive a feedback frame whose the repeat request frame number area during transmission of the transmission frame 9. Since the repeat request frame number indicated by the feedback frame is 11, determine that the reception side communication apparatus has received the transmission frame 10 correctly, and finish the transmission of the data frames.

[reception side communication apparatus]

The reception side communication apparatus transmits the feedback frame including the next repeat request frame number area instead of that including the repeat request frame number area in every fourth time only when the next repeat request frame number is larger than a value obtained by adding the repeat request frame number with 1.

(1) Since having received the transmission frames 1, 2 and 3 correctly, successively transmit feedback frames respectively including the repeat request frame numbers set to 2, 3 and 4 to the transmission side communication apparatus (when $j=1$ to 3).

(2) The reception side communication apparatus has not received the transmission frame 4 correctly. At this time, instead of the timing of $j=4$ at which the feedback frame including the next repeat request frame number to be transmitted, the next repeat request frame number does not exceed the value obtained by adding the repeat request frame number with 1, and hence the reception side communication

apparatus transmit the feedback frame whose repeat request frame number is 4.

(3) Successively transmit feedback frames including repeat request frame numbers set to 4 at the timings of $j=5$ to 7. Since having received the transmission frames up to the transmission frame 7, the next repeat request frame number at that time is 8.

(4) Since the transmission timing is a timing of $j=8$ at which the feedback frame including the next repeat request frame number area is to be transmitted and since the next repeat request frame number is larger than the value obtained by adding the repeat request frame number with 1, transmit the feedback frame including the next repeat request frame number 8 instead of that including the repeat request frame number.

(5) Receive the transmission frames 8, 10 at the timings of 9 to 11. During these timings, transmit the feedback frame including the repeat request frame number area indicating the repeat request frame number 4. The next repeat request frame number at this time is 11.

(6) Correctly receive the transmission frame 4 at the timing of $j=12$. Since the timing of $j=12$ is a timing of transmission of the feedback frame including the next repeat request frame number and the next repeat request frame number is larger than the value obtained by adding the repeat request frame number with 1, transmit the feedback frame including the next repeat request frame number area indicating the repeat request frame number of 11.

(7) Since having received the transmission frame s 8, 9 at the timings of $j=13, 14$, transmit the feedback frames respectively including the repeat request frame number areas indicating the repeat request frame numbers 9, 11.

FIG. 10 is a graph showing characteristic curves of a frame error rate to a throughput respectively obtained in the first embodiment shown in FIG. 2A and the second embodiment shown in FIG. 7A for comparison. In FIG. 10, the characteristic curves are obtained by calculating values of the throughput S respectively obtained when the frame error rate is changed from 0 to 0.2 by a unit of 0.02. In this calculation, it is assumed that a round trip delay amount d is 20 and a total frame number is 40. Study of the characteristic graph of FIG. 10 reveals that, if the throughputs obtained at the same error rate in the first and second embodiments are compared, the throughput obtained in the second embodiment is lower as compared with that obtained in the first embodiment and that, however, the difference therebetween is very small and hence hardly influences practical data transmission. Therefore, since the data amount of the data area of the feedback frame is lowered only slightly in the second embodiment, the second embodiment is superior to the first embodiment shown in FIG. 2A in this point.

In the ARQ error control method of SR system according to the second embodiment (whose data format is shown in FIG. 7A) shown in FIGS. 8 and 9, when the transmission side communication apparatus transmits the transmission frames 1 to 10 to the reception side communication apparatus, the number $N1$

of the transmission frames practically transmitted is 14, while the number N_2 of the transmission frames transmitted until the transmission side communication apparatus receives all the feedback frames for confirming correct transmission of all the transmission frames 1 to 10 after transmitting the first transmission frame is 17.

A throughput S defined by a ratio N_0/N_1 (N_0 is the number of the transmission frames to be transmitted and N_1 is the number of all the transmission frames transmitted from the transmission side communication apparatus to the reception side communication apparatus) is $S = 10 \div 14 = 0.714$ in the second embodiment shown in FIGS. 8 and 9. Study of this result reveals that the throughput S obtained in the second embodiment is improved by about 8.9% as compared with the throughput S of 0.625 obtained in the example shown in FIG. 1B.

According to the second embodiment shown in FIG. 7A, similarly to the first embodiment shown in FIG. 2A, even if the reception side communication apparatus frequently fails to correctly receive the data frames transmitted from the transmission side communication apparatus thereto at the beginning of the transmission and hence repeatedly transmits the feedback frame indicating the repeat request, then it is possible for the transmission side communication apparatus to determine up to which data frame the reception side communication apparatus could correctly receive data frames after the reception side communication side communication apparatus had failed to correctly receive the data frame from

the transmission side communication apparatus. Therefore, it can be avoided that the transmission side communication apparatus uselessly transmits again the data frames once transmitted therefrom to the reception side communication apparatus.

While the repeat request identifier area requires only 1 bit as described above when there are two kinds of the repeat request frame number areas, even if the number of the repeat request frame number areas is increased, reduction of a data capacity of the data area can be suppressed even in the full-duplex transmission of transmitting the feedback frame including the data area containing data as compared with the first embodiment shown in FIG. 2A (e.g., the repeat request identifier area requires 2 bit when the number of the repeat request frame number areas is three or four, 3 bits when the number of the repeat request frame number areas is five or six,).

A communication system including a data communication apparatus to which the present invention can be applied will be described with reference to FIG. 11. A data communication apparatus 1A is a telephone in a personal handy-phone system (PHS), for example, which can communicate with various data communication apparatus 1B, 1C, 1D, 1E, by wireless or through wireless communication network NW. The data communication apparatus 1B, 1C, 1D, 1E, are a PHS telephone similar to the data communication apparatus 1A, a wireless telephone such as a cellular system telephone or the like, a wire telephone, a relay station, a base station, or the like.

The data communication apparatus 1A has a transmission/reception unit 2, a transmission/reception antenna 3, a modulator 4 and a demodulator 5 connected to the transmission/reception unit 2, a signal processing unit 6 connected to the modulator 4 and the demodulator 5, a speaker 7 connected to the signal processing unit 6, a microphone 8 connected to the signal processing unit 6, a display device 9 connected to the signal processing unit 6 for displaying a text, a numeric, a symbol, a figure, an image and so on (formed of a liquid-crystal display or the like). An input/output terminal 10 for an external digital data is derived from the signal processing unit 6. The above-mentioned data frame transmitted from the transmission side communication apparatus to the reception side communication apparatus and the feedback frame transmitted from the above-mentioned reception side communication apparatus to the transmission side communication apparatus are respectively generated by the transmission side communication apparatus and the reception side communication apparatus which are a certain data communication apparatus, of the data communication apparatus 1B, 1C, 1D, 1E,, for communicating the other data communication apparatus thereof and the other data communication apparatus.

According to a first aspect of the present invention, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending

order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, the feedback frame also indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which the reception side data communication apparatus has received. Therefore, it is possible to obtain a data communication method which makes it possible to transmit the feedback frame indicating a request frame number from the reception side data communication apparatus to the transmission side data communication side apparatus with an improved throughput of the data frame transmitted from the transmission side data communication apparatus to the reception side data communication apparatus.

According to a second aspect of the present

invention, in a data communication method according to claim 1, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame and, the second to k th request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, the transmission side data communication apparatus transmits data frames having the indicated frame numbers which the reception side data communication apparatus has not received to the reception side data communication apparatus. Therefore, in addition to the above effect, it is possible to obtain a data communication method which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus.

According to a third aspect of the present invention, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame having the same format as that of the data frame and indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data

communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, if there is no transmission data to be included in the feedback frame, the feedback frame includes a data area which indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which the reception side data communication apparatus has received. Therefore, it is possible to obtain a data communication method which makes it possible to transmit the feedback frame indicating a request frame number from the reception side data communication apparatus to the transmission side data communication side apparatus with an improved throughput of the data frame transmitted from the transmission side data communication apparatus to the reception side data communication apparatus, and which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus without lowering a maximum transmission rate.

According to a fourth aspect of the present invention, in a data communication method according to claim 3, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame and, the second to k th request

frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, the transmission side data communication apparatus transmits data frames having the indicated frame numbers which the reception side data communication apparatus has not received correctly to the reception side data communication apparatus. Therefore, in addition to the above effect, it is possible to obtain a data communication method which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus without lowering the maximum transmission rate.

According to a fifth aspect of the present invention, in a data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, the feedback

frame also indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which the reception side data communication apparatus has received. Therefore, it is possible to obtain a data communication apparatus which makes it possible to transmit the feedback frame indicating a request frame number from the reception side data communication apparatus to the transmission side data communication side apparatus with an improved throughput of the data frame transmitted from the transmission side data communication apparatus to the reception side data communication apparatus.

According to a sixth aspect of the present invention, in a data communication apparatus according to the fifth aspect of the present invention, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame and, the second to k th request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, the transmission side data communication apparatus transmits data frames having the indicated frame numbers which the reception side data communication apparatus has not received correctly to the reception side data communication apparatus. Therefore, in addition to the above effect, it is possible to obtain a data communication apparatus which can improve the throughput of the data frames transmitted from the transmission

side data communication apparatus to the reception side data communication apparatus.

According to a seventh aspect of the present invention, in a data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame having the same format as that of the data frame and indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, if there is no transmission data to be included in the feedback frame, the feedback frame includes a data area which indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response

to frame numbers of first to n th data frames which the reception side data communication apparatus has received. Therefore, it is possible to obtain a data communication apparatus which makes it possible to transmit the feedback frame indicating a request frame number from the reception side data communication apparatus to the transmission side data communication side apparatus with an improved throughput of the data frame transmitted from the transmission side data communication apparatus to the reception side data communication apparatus, and which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus without lowering a maximum transmission rate.

According to an eighth aspect of the present invention, in a data communication apparatus according to the seventh aspect of the present invention, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame and, the second to k th request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, the transmission side data communication apparatus transmits data frames having the indicated frame numbers which the reception side data communication apparatus has not received correctly to the reception side data communication apparatus. Therefore, in addition to the above effect, it is possible to provide a data communication apparatus which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication

apparatus without lowering the maximum transmission rate.

According to a ninth aspect of the present invention, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, the data communication method includes a process of generating a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which the reception side data communication apparatus has received, processes of replacing the request frame number $FB1(n)$ with the second request frame number $FB2(n)$ at every β_1 transmission times (β_1

is a natural number satisfying $0 < \beta_1 < \alpha_1$) during every α_1 transmission times (where α_1 is a natural number satisfying $\alpha_1 > 1$) of a feedback frame indicating the first request frame number $FB1(n)$, $\dots$, and replacing the request frame number $FB(k-1)(n)$ with the second request frame number $FBk(n)$ at every $\beta_{(k-1)}$ transmission times ($\beta_{(k-1)}$ is a natural number satisfying $0 < \beta_{(k-1)} < \alpha_{(k-1)}$) during every $\alpha_{(k-1)}$ transmission times (where α_1 is a natural number satisfying $\alpha_{(k-1)} > 1$) of a feedback frame indicating the first request frame number $FB(k-1)(n)$, and a process of including in the feedback frame a request identifier indicating either of the first to kth request frame numbers $FB1(n)$ to $FBk(n)$. Therefore, an effect substantially similar to that achieved by a first aspect of the present invention can be achieved. Moreover, it is possible to obtain a data communication method which can suppress a reduced amount of data capacity to only a very slight amount even in a full-duplex communication in which data is transmitted from the reception side data communication apparatus to the transmission side data communication apparatus.

According to a tenth aspect of the present invention, in a data communication method according to the ninth aspect of the present invention, the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ based on the request frame number and the request identifier indicated by the received feedback frame are obtained and stored in a storage means, and a data frame of a

frame number which the reception side data communication apparatus has not confirmed is transmitted from the transmission side data communication apparatus to the reception side data communication apparatus in response to respective latest request frame numbers of the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ stored in the storage means. Therefore, in addition to the above effect, it is possible to obtain a data communication method which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus.

According to an eleventh aspect of the present invention, in a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to nth data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number

FB1(n) indicated by the received feedback frame, the data communication method includes a process of generating a second repeat frame number FB2(n) formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a kth request frame number FBk(n) formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to nth data frames which the reception side data communication apparatus has received, processes of replacing the first request frame number FB1(n) included in the feedback frame with the second request frame number FB2(n) when a first predetermined condition is satisfied, ..., and replacing the (k-1)th request frame number FB(k-1)(n) included in the feedback frame with the kth request frame number FBk(n) when a (k-1)th predetermined condition is satisfied, and a process of including in the feedback frame a request identifier indicating either of the first to kth request frame numbers FB1(n) to FBk(n). Therefore, it is possible to obtain a data communication method which can achieve an effect substantially similar to that achieved by the ninth aspect of the present invention.

According to a twelfth aspect of the present invention, in a data communication method according to the eleventh aspect of the present invention, the first to kth request frame numbers FB1(n) to FBk(n) based on the request frame number and the request identifier indicated by the received feedback frame to be obtained and stored in a storage means, and a data frame of a frame number which the reception

side data communication apparatus has not confirmed is transmitted from the transmission side data communication apparatus to the reception side data communication apparatus in response to respective latest request frame numbers of the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ stored in the storage means. Therefore, it is possible to a data communication method which can achieve an effect substantially similar to that achieved by the tenth aspect of the present invention.

According to a thirteenth aspect of the present invention, in a data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to nth data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, a second repeat frame number $FB2(n)$ formed of a

frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FB_k(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) are generated in response to frame numbers of first to n th data frames which the reception side data communication apparatus has received. The first request frame number $FB_1(n)$ is replaced with the second request frame number $FB_2(n)$ at every β_1 transmission times (β_1 is a natural number satisfying $0 < \beta_1 < \alpha_1$) during every α_1 transmission times (where α_1 is a natural number satisfying $\alpha_1 > 1$) of a feedback frame indicating the first request frame number $FB_1(n)$, $\dots$, and the $(k-1)$ th request frame number $FB_{(k-1)}(n)$ is replaced with the k th request frame number $FB_k(n)$ at every $\beta_{(k-1)}$ transmission times (where $\beta_{(k-1)}$ is a natural number satisfying $0 < \beta_{(k-1)} < \alpha_{(k-1)}$) during every $\alpha_{(k-1)}$ transmission times (where α_1 is a natural number satisfying $\alpha_{(k-1)} > 1$) of a feedback frame indicating the $(k-1)$ th request frame number $FB_{(k-1)}(n)$. The request identifier indicating either of the first to k th request frame numbers $FB_1(n)$ to $FB_k(n)$ are included in the feedback frame a . Therefore, an effect substantially similar to that achieved by a first aspect of the present invention can be achieved. Moreover, it is possible to obtain a data communication method which can suppress a reduced amount of data capacity to only a very slight amount even in a

full-duplex communication in which data is transmitted from the reception side data communication apparatus to the transmission side data communication apparatus.

According to a fourteenth aspect of the present invention, in a data communication apparatus according to the thirteenth aspect of the present invention, the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ are obtained based on the request frame number and the request identifier indicated by the received feedback frame to be stored in a storage means, and a data frame of a frame number which the reception side data communication apparatus has not confirmed is transmitted from the transmission side data communication apparatus to the reception side data communication apparatus in response to respective latest request frame numbers of the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ stored in the storage means. Therefore, in addition to the above effect, it is possible to obtain a data communication apparatus which can improve the throughput of the data frames transmitted from the transmission side data communication apparatus to the reception side data communication apparatus.

According to a fifteenth aspect of the present invention, in a data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from the reception

side data communication apparatus to the transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from the transmission side data communication apparatus to the reception side data communication apparatus a data frame which the reception side data communication apparatus has not confirmed, in response to the first request frame number $FB1(n)$ indicated by the received feedback frame, a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) are generated in response to frame numbers of first to n th data frames which the reception side data communication apparatus has received. The request frame number $FB1(n)$ included in the feedback frame is replaced with the second request frame number $FB2(n)$ when a first predetermined condition is satisfied, ..., and the $(k-1)$ th request frame number $FB(k-1)(n)$ is replaced with the k th request frame number $FBk(n)$ when a $(k-1)$ th condition is satisfied. A request identifier indicating either of the first to k th request frame numbers $FB1(n)$ to $FBk(n)$ is included in the feedback frame a. Therefore, it is possible to obtain a data communication apparatus which can achieve an effect substantially similar to that achieved by the thirteenth aspect

of the present invention.

According to a sixteenth aspect of the present invention, in a data communication apparatus according to the fifteenth aspect of the present invention, the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ are obtained based on the request frame number and the request identifier indicated by the received feedback frame to be stored in a storage means, and a data frame of a frame number which the reception side data communication apparatus has not confirmed is transmitted from the transmission side data communication apparatus to the reception side data communication apparatus in response to respective latest request frame numbers of the first to kth request frame numbers $FB1(n)$ to $FBk(n)$ stored in the storage means. Therefore, it is possible to obtain a data communication apparatus which can achieve an effect substantially similar to that achieved by the fourteenth aspect of the present invention.

Having described preferred embodiments of the present invention with reference to the accompanying drawings, it is to be understood that the present invention is not limited to the above-mentioned embodiments and that various changes and modifications can be effected therein by one skilled in the art without departing from the spirit or scope of the present invention as defined in the appended claims.

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What is claimed is:

1. A data communication method comprising the steps of:

transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order);

transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received; and

transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, wherein said feedback frame also indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to



frame numbers of first to nth data⁶³ frames which said reception side data communication apparatus has received.

2. A data communication method according to claim 1, wherein, in response to said first request frame number FB1(n) indicated by said received feedback frame and, said second to kth request frame numbers FB2(n) to FBk(n) indicated thereby, said transmission side data communication apparatus transmits data frames having the indicated frame numbers which said reception side data communication apparatus has not received to said reception side data communication apparatus.

3. A data communication method comprising the steps of:

transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order);

transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame having the same format as that of said data frame and indicating a first request frame number FB1(n) formed of a minimum (or maximum) frame number FBM(n) among the frame numbers of data frames which have not been received in response to frame numbers of first to nth data frames received; and



transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, wherein, if there is no transmission data to be included in said feedback frame, said feedback frame includes a data area which indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which said reception side data communication apparatus has received.

4. A data communication method according to claim 3, wherein, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame and, said second to k th request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, said transmission side data communication apparatus transmits data frames having the indicated frame numbers which said reception side data communication apparatus has not received correctly to said reception side data communication apparatus.

5. A data communication apparatus employing a data communication method of transmitting data frames from a first



predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, comprising:

a signal processing unit for processing a transmission frame when said apparatus serves as said transmission side data communication apparatus and for processing a feedback frame when said apparatus serves as said reception side data communication apparatus, wherein said feedback frame also indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which said reception side data communication apparatus



has received.

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6. A data communication apparatus according to claim 5, wherein, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame and, said second to k th request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, said transmission side data communication apparatus transmits data frames having the indicated frame numbers which said reception side data communication apparatus has not received correctly to said reception side data communication apparatus.

7. A data communication apparatus employing a data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame having the same format as that of said data frame and indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side



data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, comprising:

a signal processing unit for processing a transmission frame when said apparatus serves as said transmission side data communication apparatus and for processing a feedback frame when said apparatus serves as said reception side data communication apparatus, wherein, if there is no transmission data to be included in said feedback frame, said feedback frame includes a data area which indicates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which said reception side data communication apparatus has received.

8. A data communication apparatus according to claim 7, wherein, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame and, said second to k th request frame numbers $FB2(n)$ to $FBk(n)$ indicated thereby, said transmission side data communication apparatus transmits data frames having the indicated frame numbers which said reception side data communication apparatus has not received to correctly said reception side data communication apparatus.



9. A data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, comprising the steps of:

generating a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which said reception side data communication apparatus has received;

replacing said request frame number $FB1(n)$ with said second request frame number $FB2(n)$ at every β_1 transmission



times (β_1 is a natural number satisfying $0 < \beta_1 < \alpha_1$) during

every α_1 transmission times (where α_1 is a natural number

satisfying $\alpha_1 > 1$) of a feedback frame indicating said first

request frame number $FB1(n)$, ..., and replacing said request

frame number $FB(k-1)(n)$ with said second request frame number

$FBk(n)$ at every $\beta_{(k-1)}$ transmission times ($\beta_{(k-1)}$ is a natural

number satisfying $0 < \beta_{(k-1)} < \alpha_{(k-1)}$) during every $\alpha_{(k-1)}$

transmission times (where α_1 is a natural number satisfying $\alpha_{(k-1)}$

$\alpha_{(k-1)} > 1$) of a feedback frame indicating said first request frame

number $FB(k-1)(n)$; and,

including in said feedback frame a request identifier indicating either of said first to kth request frame numbers $FB1(n)$ to $FBk(n)$.

10. A data communication method according to claim 9, wherein further comprising the steps of:

obtaining said first to kth request frame numbers $FB1(n)$ to $FBk(n)$ based on said request frame number and said request identifier indicated by said received feedback frame to store them in a storage means; and

transmitting a data frame of a frame number, which said reception side data communication apparatus has not confirmed, from said transmission side data communication apparatus to said reception side data communication apparatus in response to respective latest request frame numbers of said



first to kth request frame numbers $FB1(n)$ to $FBk(n)$ stored in said storage means.

11. A data communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to nth data frames received, and transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, comprising the steps of:

generating a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a kth request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to nth data frames which said reception side data communication apparatus has received;



replacing said first ⁷¹request frame number FB1(n) included in said feedback frame with said second request frame number FB2(n) when a first predetermined condition is satisfied, ..., and replacing said (k-1)th request frame number FB(k-1)(n) included in said feedback frame with said second request frame number FBk(n) when a (k-1)th predetermined condition is satisfied; and

including in said feedback frame a request identifier indicating either of said first to kth request frame numbers FB1(n) to FBk(n).

12. A data communication method according to claim 11, wherein further comprising the steps of:

obtaining said first to kth request frame numbers FB1(n) to FBk(n) based on said request frame number and said request identifier indicated by said received feedback frame to store them in a storage means; and

transmitting a data frame of a frame number, which said reception side data communication apparatus has not confirmed, from said transmission side data communication apparatus to said reception side data communication apparatus in response to respective latest request frame numbers of said first to kth request frame numbers FB1(n) to FBk(n) stored in said storage means.

13. A data communication apparatus employing a data communication method of transmitting data frames from a first



predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, comprising:

a signal processing unit, wherein said signal processing unit generates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which said reception side data communication apparatus has received, wherein said signal processing unit replaces said first request frame number $FB1(n)$ with said second request frame number $FB2(n)$ at every β_1 transmission times (β_1 is a natural number satisfying $0 < \beta_1 < \alpha_1$) during every α_1 transmission times



(where α_1 is a natural number satisfying $\alpha_1 > 1$) of a feedback frame indicating said first request frame number $FB1(n)$, $\dots$, and replaces said $(k-1)$ th request frame number $FB(k-1)(n)$ with said k th request frame number $FBk(n)$ at every $\beta_{(k-1)}$ transmission times (where $\beta_{(k-1)}$ is a natural number satisfying $0 < \beta_{(k-1)} < \alpha_{(k-1)}$) during every $\alpha_{(k-1)}$ transmission times (where α_1 is a natural number satisfying $\alpha_{(k-1)} > 1$) of a feedback frame indicating said $(k-1)$ th request frame number $FB(k-1)(n)$, and wherein said signal processing unit includes in said feedback frame a request identifier indicating either of said first to k th request frame numbers $FB1(n)$ to $FBk(n)$.

14. A data communication apparatus according to claim 13, wherein said first to k th request frame numbers $FB1(n)$ to $FBk(n)$ are obtained based on said request frame number and said request identifier indicated by said received feedback frame to be stored in a storage means, and a data frame of a frame number which said reception side data communication apparatus has not confirmed is transmitted from said transmission side data communication apparatus to said reception side data communication apparatus in response to respective latest request frame numbers of said first to k th request frame numbers $FB1(n)$ to $FBk(n)$ stored in said storage means.

15. A data communication apparatus employing a data



communication method of transmitting data frames from a first predetermined frame number to a last predetermined frame number from a transmission side data communication apparatus to a reception side data communication apparatus in an ascending order (or a descending order), transmitting from said reception side data communication apparatus to said transmission side data communication apparatus a feedback frame indicating a first request frame number $FB1(n)$ formed of a minimum (or maximum) frame number $FBM(n)$ among the frame numbers of data frames which have not been received in response to frame numbers of first to n th data frames received, and transmitting from said transmission side data communication apparatus to said reception side data communication apparatus a data frame which said reception side data communication apparatus has not confirmed, in response to said first request frame number $FB1(n)$ indicated by said received feedback frame, comprising:

a signal processing unit, wherein said signal processing unit generates a second repeat frame number $FB2(n)$ formed of a frame number $\{FBM(n)+1\}$ [or $\{FBM(n)-1\}$] among the frame numbers of data frames which have not been received to a k th request frame number $FBk(n)$ formed of a frame number $\{FBM(n)+(k-1)\}$ [or $\{FBM(n)-(k-1)\}$] (where k is an integer exceeding 2) in response to frame numbers of first to n th data frames which said reception side data communication apparatus has received, wherein said signal processing unit replaces said request frame number $FB1(n)$ included in said feedback frame with said second request frame number $FB2(n)$ when a first predetermined condition



is satisfied, , and replaces said (k-1)th request frame number $FB(k-1)(n)$ with said kth request frame number $FBk(n)$ when a (k-1)th condition is satisfied, and wherein said signal processing unit includes in said feedback frame a request identifier indicating either of said first to kth request frame numbers $FB1(n)$ to $FBk(n)$.

16. A data communication apparatus according to claim 15, wherein said first to kth request frame numbers $FB1(n)$ to $FBk(n)$ are obtained based on said request frame number and said request identifier indicated by said received feedback frame to be stored in a storage means, and a data frame of a frame number which said reception side data communication apparatus has not confirmed is transmitted from said transmission side data communication apparatus to said reception side data communication apparatus in response to respective latest request frame numbers of said first to kth request frame numbers $FB1(n)$ to $FBk(n)$ stored in said storage means.

