(54) Title: COMMUNICATION SYSTEM, DEPENDENT STATION THEREOF AND DEPENDENT-STATION RELAY TRANSMISSION METHOD

F I G. 1
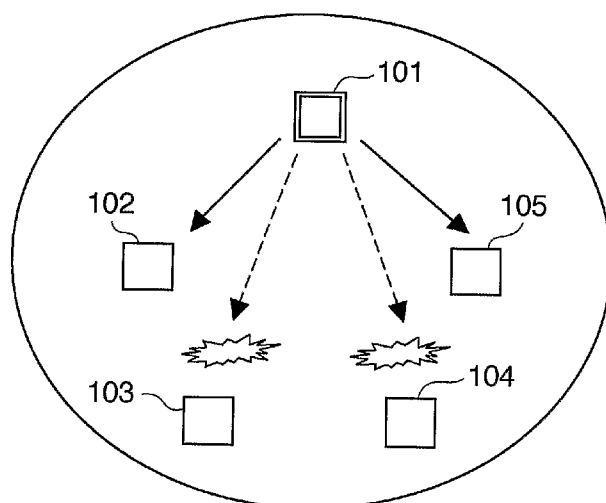
(57) Abstract: In a communication system comprising a control station (101) and a plurality of dependent stations (102,..., 105), the control station (101) broadcasts data intended for the plurality of dependent stations (102,..., 105) on a per-superf rame basis. The plurality of dependent stations relay the data, which has been received from the control station (101), among themselves. If a dependent station (102) has received the data transmitted from the control station (101), this dependent station (102) transmits an acknowledgement response. If a dependent station (102) does not receive an acknowledgement response from another dependent station (103), then this dependent station (102) relays the data intended for this other dependent station (103).

DESCRIPTION

COMMUNICATION SYSTEM, DEPENDENT STATION THEREOF AND

DEPENDENT-STATION RELAY TRANSMISSION METHOD

TECHNICAL FIELD

[0001]The present invention relates to a technique

whereby a control station broadcasts data, which is

intended for multiple dependent stations, on a per-

superframe basis.

BACKGROUND ART

[0002]Wireless communication systems are utilized as

network systems that excel in mobility and have

proliferated at a rapid pace due to improvements in

transmission speed over wireless communication zones,

the spread of mobile terminals and the appearance of

applications suited to mobile communication. In

particular, WLAN systems using radio waves in the 2.4-

GHz or 5-GHz band have come into widespread use as

schemes for wirelessly connecting computer equipment

over comparatively short distances indoors or on-

premises. Technical specifications for such schemes

have been defined, for example, by the IEEE 802.11

family of standards.

[0003]Further, there is growing demand for machine-to-

machine wireless communication for connecting not only

computer peripherals but also printers and mobile

telephones to consumer equipment such as digital still

cameras and digital video cameras. At present, such
equipment is generally connected by wire cables such as
those for use with USB or IEEE-1394, but wireless
connection methods are also under consideration as
methods by which users can connect these devices in
simple fashion.

[0004] Unlike WLAN, machine-to-machine wireless
communication over very short distances aims to provide
a wireless connection within a single person's
surrounding environment, considered to be ten meters at
most. Such a scheme is referred to as "WPAN" to
distinguish it from WLAN. In relation to WPAN,
physical and MAC layer specifications have been defined
in the ECMA-368 standard by ECMA International, an
organization that creates standards, with use being
made of UWB (Ultra-Wideband) communication. A wireless
USB standard has also been defined as a protocol that
operates under ECMA-368.

[0005] In order to prevent so-called "frame collision",
which is a state in which multiple wireless terminals
transmit wireless frames simultaneously in a WLAN or
WPAN system, the timing at which each wireless terminal
accesses the wireless media is controlled. What
determines the method of control is the MAC (Media
Access Control) protocol. Although various schemes
exist for the MAC protocol, they typically can be
classified into two schemes, namely asynchronous data

transfer and synchronous data transfer.

[0006]Generally, in asynchronous data transfer, a
terminal that has acquired the right to access the
media performs data transmission in accordance with the
CSMA/CA (Carrier Sense Multiple Access / Collision
Avoidance) protocol. If the terminal at the
destination of this data receives the data correctly,
the terminal generally sends back to the transmitting
terminal an acknowledgement response referred to as an
"acknowledge frame". If the data transmitting terminal
receives the acknowledgement response, it determines
that the data transfer is completed. Conversely, if
the transmitting terminal does not receive the
acknowledgement response, it determines that data
transfer failed and attempts to re-transmit its data
upon elapse of a fixed period of time.

[0007]Thus, in asynchronous data transfer, it is
possible to transfer data to a destination terminal
reliably. However, the amount of delay involved in the
data transfer varies depending upon failure to acquire
media-access privileges or re-transmission of data.
Such variation in the amount of data involved in data
transfer is referred to as "delay jitter".

[0008]It should be noted that since an application that
transfers voice or a moving image requires synchronism
or isochronism for a data transfer, asynchronous data
transfer, which cannot easily provide such latency

bounds on delay jitter, is not suitable for such an application.

[0009] With synchronous data transfer, on the other hand, each terminal performs the data transmission in a time slot allocated to the terminal as by a TDMA (Time Division Multiple Access) protocol. With such a protocol, each terminal is capable of acquiring the data transmission privilege at fixed periods and the delay jitter imposed upon the data transfer is small as a result. Accordingly, synchronous data transfer is well-suited for real-time data transmission having minimum delay requirements.

[0010] Further, with synchronous data transfer, it is required that delay jitter in a data transfer be kept within fixed limits. As a consequence, no acknowledgement response is exchanged between sending and receiving terminals and re-transmission processing is not executed when data fails. This means that with synchronous data transfer, there may be instances where data packets are lost, depending upon the state of communication.

[0011] However, in the transmission of voice or moving images, a characteristic of such communication is that the highest priority is always given to the maintenance of an average transmission speed and average delay. The application protocol therefore is designed so as to allow packet loss to some extent.

[0012] Thus, whereas synchronous data transfer is suitable for applications using that require delay bounds, as in the case of voice and moving images, application data can vanish due to packet loss. Such data loss is a drawback in that it can cause reproduced voice to be interrupted and degrade application quality.

[0013] In order to solve these problems encountered in synchronous data transfer, a repeater system in which identical data is transferred redundantly multiple times has been considered as a highly reliable communication system for suppressing the occurrence of data loss while maintaining synchronism. Such a repeater system will now be described.

[0014] FIG. 16 is a diagram illustrating an example of the configuration of a repeater system. This system comprises a control station 11 serving as a source that generates synchronous data such as voice or moving images, and four dependent stations 12 to 15 that are the destinations of synchronous data.

[0015] FIG. 17 is a diagram illustrating media access timing of the repeater system. This system employs TDMA as the access protocol, and the media access timing is managed in units of a fixed time period referred to as a superframe 21. The superframe 21 has been divided into time slots 31 to 35 in which the control station 11 and dependent stations 12 to 15, respectively, transmit data. In superframe 21, time

slot 31 is the time over which the control station 11 transmits data, and the time slots 32 to 35 are the times over which the dependent stations 12 to 15, respectively, transmit data successively.

[0016] FIG. 18 is a diagram illustrating a wireless frame transmitted in each time slot of the superframe. Initially, the control station 11 broadcasts a broadcast frame 41 to all dependent stations in time slot 31 of the superframe. The broadcast frame 41 holds synchronous data intended for each of the dependent stations.

[0017] FIG. 19 is a diagram illustrating the frame format of the broadcast frame transmitted by broadcast. The broadcast frame 41 includes a field 51 in which an ISO_DATA1 field is placed. The field 51 contains the body of the synchronous data intended for dependent station 12. Similarly, fields 52 to 54 contain synchronous data intended for dependent stations 13 to 15, respectively. A CHECKSUM_FRAME field is placed in a field 55. By examining the checksum, the station that has received the broadcast frame 41 detects any bit error that has occurred in the broadcast frame 41. It should be noted that each item of synchronous data is assumed to be of fixed length in this example.

[0018] FIGS. 20A to 20E are diagrams illustrating directions of data transfer in each of the time slots. FIG. 20A illustrates the manner in which the broadcast

frame 41 is transmitted from the control station 11 to each of the dependent stations 12 to 15 in the first time slot 31. Upon receiving the broadcast frame 41, each of the dependent stations 12 to 15 decides its own transmit timing by referring to a predetermined transmission sequence using the moment in time at which the broadcast frame 41 is received as a reference. From within the synchronous data contained in the broadcast frame 41 received, each of the dependent stations 12 to 15 utilizes the data intended for itself as application data. At the same time, the dependent stations 12 to 15 store the entirety of the broadcast frame 41 internally in order to relay it to another dependent station.

[0019] Upon receiving the broadcast frame 41 and deciding its own transmit timing, the dependent station 12 transmits a relay frame 42 in time slot 32 as a duplicate of the broadcast frame 41 received from the control station 11. This is illustrated in FIG. 20B. The other dependent stations 13 to 15 receive and store the relay frame 42. Similarly, in time slot 33, the dependent station 13 transmits a relay frame 43 as a duplicate of the broadcast frame 41 and the other dependent stations 12, 14 and 15 receive this relay frame 43.

[0020] Thus, the broadcast frame 41 transmitted from the control station 11 in time slot 31 is relayed from the

dependent stations 12 to 15 in the time slots 32 to 35, as illustrated in FIGS. 20B to 20E. Further, relay frames 42 to 45 that are relayed have a format identical with that of the broadcast frame 41. Accordingly, as far as each of the dependent stations is concerned, there is an opportunity to receive the same synchronous data a total of four times as the broadcast frame from the control station 11 and the relay frames from the other three dependent stations.

[0021] Data is thus transferred multiple times in this system. As a result, even if a dependent station cannot receive a broadcast frame from the control station correctly, it can acquire the synchronous data intended for its own station from the relay frame transmitted from another dependent station. With this system, therefore, even if an event such as an interruption in the communication path occurs, a data transmission is completed within one superframe. This makes it possible to maintain the synchronism of the data transfer.

[0022] It should be noted that a technique for transmitting broadcast data to a destination node reliably has been proposed in the specification of Japanese Patent Laid-Open No. 2007-266876.

[0023] In the repeater system described above, packet loss is suppressed and highly reliable synchronous data communication achieved by relayed transmission of the

same data between dependent stations. However, when this method is considered from the standpoint of efficient utilization of the frequency band, it is apparent that the same data is transmitted repeatedly and redundantly five times. Another aspect of this method, therefore, is that the communication band is utilized wastefully.

[0024]By way of example, if a certain dependent station is capable of receiving the broadcast data from the control station correctly, then repeated transmission in subsequent time slots is unnecessary communication and the communication band is consumed wastefully. In such a redundant repeater system, the communication band is essentially occupied by repeated transfer of data and it is not possible to transfer a greater amount of data.

[0025]As a result, a problem with the prior art is that it is difficult to optimize utilization of the communication band and increase the amount of data transferred in the system overall.

DISCLOSURE OF INVENTION

[0026]The present invention provides a wireless repeater system in which communication-band utilization efficiency is improved and the overall amount of transferred data, inclusive of synchronous data and asynchronous data, is increased.

[0027] In accordance with an aspect of the present invention, there is provided a communication system in which a control station broadcasts data, which is intended for a plurality of dependent stations, on a per-superframe basis, each of the plurality of dependent stations comprising:

means for receiving data broadcast from the control station in an Nth (where N is an integer) superframe;

means for transmitting an acknowledgement response, which indicates reception condition of the data, in a time slot that has been allocated to this dependent station in the Nth superframe; and

means which, in accordance with the acknowledgement response transmitted from another dependent station, is for relaying data intended for this another dependent station in a time slot that has been allocated to this dependent station in an (N+1)th superframe.

[0028] In accordance with another aspect of the present invention, there is provided a dependent station of a communication system in which a control station broadcasts data, which is intended for a plurality of dependent stations, on a per-superframe basis, the dependent station comprising:

means for receiving data broadcast from the control station in an Nth (where N is an integer)

superframe;

means for transmitting an acknowledgement
response, which indicates reception condition of the
data, in a time slot that has been allocated to this
dependent station in the Nth superframe; and

means which, in accordance with the
acknowledgement response transmitted from another
dependent station, is for relaying data intended for
this another dependent station in a time slot that has
been allocated to this dependent station in an (N+1)th
superframe.

[0029] In accordance with a further aspect of the
present invention, there is provided a method of relay
transmission by a dependent station in a communication
system in which a control station broadcasts data,
which is intended for a plurality of dependent stations,
on a per-superframe basis, the method comprising:

a step of receiving data broadcast from the
control station in an Nth (where N is an integer)
superframe;

a step of transmitting an acknowledgement
response, which indicates reception condition of the
data, in a time slot that has been allocated to this
dependent station in the Nth superframe; and

in accordance with the acknowledgement response
transmitted from another dependent station, a step of
relaying data intended for this another dependent

station in a time slot that has been allocated to this
dependent station in an (N+1)th superframe.

[0030] Further features of the present invention will
become apparent from the following description of
exemplary embodiments with reference to the attached
drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0031] FIG. 1 is a diagram illustrating an example of
the configuration of a wireless repeater system
according to a first embodiment of the present
invention;

[0032] FIG. 2 is a diagram illustrating an example of
the configuration of a control station in the first
embodiment;

[0033] FIG. 3 is a diagram illustrating an example of
the internal configuration of a dependent station in
the first embodiment;

[0034] FIG. 4 is a diagram illustrating the structure of
superframes in the first embodiment;

[0035] FIG. 5 is a diagram illustrating the structure of
a relay frame in the first embodiment;

[0036] FIG. 6 is a diagram illustrating the frame format
of a relay frame 407 transmitted by a dependent station
102 and a relay frame 410 transmitted by a dependent
station 105;

[0037] FIG. 7 is a diagram illustrating the frame format

of a relay frame 408 transmitted by a dependent station 103 and a relay frame 409 transmitted by a dependent station 104;

[0038] FIG. 8 is diagram illustrating superframes in a case where dependent stations 102 and 103 transmit asynchronous data as data other than synchronous data;

[0039] FIG. 9 is a diagram illustrating the frame format of a relay frame in which dependent station 102 transmits asynchronous data;

[0040] FIG. 10 is a diagram illustrating the frame format of a relay frame 808;

[0041] FIG. 11 is a diagram illustrating the structure of superframes in a case where a control station transmits an asynchronous frame;

[0042] FIG. 12 is a diagram illustrating an example of the structure of an asynchronous frame transmitted by a control station;

[0043] FIG. 13 is a diagram useful in describing a problem that arises in a third embodiment;

[0044] FIG. 14 is a diagram illustrating an example of the format of a broadcast frame transmitted by a dependent station;

[0045] FIG. 15 is a diagram illustrating the structure of superframes in the third embodiment;

[0046] FIG. 16 is a diagram illustrating an example of the configuration of a repeater system;

[0047] FIG. 17 is a diagram illustrating media access

timing of the repeater system;

[0048] FIG. 18 is a diagram illustrating a wireless frame transmitted in each time slot of a superframe;

[0049] FIG. 19 is a diagram illustrating the frame format of a broadcast frame transmitted by broadcast; and

[0050] FIGS. 20A to 20E are diagrams illustrating directions of data transfer in respective time slots.

BEST MODE FOR CARRYING OUT THE INVENTION

[0051] Preferred embodiments of the present invention will now be described in detail with reference to the drawings.

[0052] [First Embodiment]

The configuration and operation of a wireless repeater system according to a first embodiment will be described with reference to FIGS. 1 to 7. FIG. 1 is a diagram illustrating an example of the configuration of a wireless repeater system according to a first embodiment of the present invention. As shown in FIG. 1, the wireless repeater system comprises a control station 101 serving as a source that generates synchronous data such as voice or moving images, and dependent stations 102 to 105 that are the destinations of the synchronous data. In this example also use is made of TDMA and the media access timing is managed in units of the superframe 21 shown in FIG. 17. The

superframe 21 has been divided into a plurality of time slots 31 to 35 in which the control station 101 and dependent stations 102 to 105, respectively, transmit data.

[0053] FIG. 2 is a diagram illustrating an example of the configuration of the control station in the first embodiment. A superframe timing generator 206 in FIG. 2 generates the timing of a superframe, as described later. Timing information generated by the superframe timing generator 206 is sent to a transmit timing generator 207. In accordance with a command from the transmit timing generator 207, a transmit frame generator 204 generates a transmit frame using synchronous data, which is intended for each dependent station, accepted from an application processing unit 201 via an synchronous data generator 202. The transmit frame generator 204 further generates a transmit frame in similar fashion also in a case where asynchronous data is accepted via an asynchronous data generator 203. The asynchronous data will be described later.

[0054] A checksum for error detection is appended to the generated transmit frame in a checksum generator 205, the transmit frame is converted to a wireless signal by a modulator 250 and radio-frequency unit 252, and the resultant signal is then sent to the wireless media from an antenna 253.

[0055] On the other hand, a relay frame from each dependent station is received at the antenna 253 and is input to a checksum verifying unit 210 via the radio-frequency unit 252 and a demodulator 251. The checksum is verified and then the relay frame is sent to a frame-length determination unit 208 or asynchronous data receiver 209.

[0056] FIG. 3 is a diagram illustrating an example of the internal configuration of a dependent station in the first embodiment. In Fig. 3, an application processing unit 301, an asynchronous data generator 302, a transmit frame generator 303, a checksum generator 304, a transmit timing generator 305 and a superframe timing generator 308 are similar to those in the control station shown in FIG. 2. Further, a modulator 350, demodulator 351, radio-frequency unit 352 and antenna 353 have functions similar to those in the control station.

[0057] With reference to FIG. 3, a broadcast frame received by the antenna 353 is converted to receive data by the radio-frequency unit 352 and demodulator 351. The receive data is examined by checksum verifying unit 312 to determine whether it contains a bit error. If it is determined that the receive data does not contain a bit error, then the receive data is sent to a receive frame analyzer 309 and relay data storage unit 306. In order for all synchronous data

that has been received correctly by each dependent
station to be relayed to another dependent station, the
synchronous data is stored temporarily in the relay
data storage unit 306. The receive data is further
sent to a synchronous data receiver 310 or an
asynchronous data receiver 311 depending upon result of
analysis by the receive frame analyzer 309.

[0058] In a case where the receive data is a broadcast
frame from the control station 101, a synchronous
control signal is sent from the receive frame analyzer
309 to the superframe timing generator 308. Thus, the
dependent stations 102 to 105 are capable of
synchronously tracking a superframe managed by the
control station 101 and of transmitting relay frames in
the time slots that have been assigned to them.

[0059] Further, upon receiving the broadcast frame, each
of the dependent stations 102 to 105 decides its own
transmit timing and transmits a relay frame by
referring to a predetermined transmission sequence
using the moment in time at which the broadcast frame
is received as a reference.

[0060] FIG. 4 is a diagram illustrating the structure of
superframes in the first embodiment. In this example,
an Nth superframe is illustrated above an (N+1)th
superframe for the sake of convenience in terms of the
drawing. However, the superframes are placed in such a
manner that the Nth superframe will precede the (N+1)th

superframe in terms of time.

[0061] First, in the initial time slot of the Nth superframe, the control station 101 broadcasts an Nth broadcast frame 401, which holds the synchronous data intended for the dependent stations, to all of the dependent stations. The frame format of the broadcast frame 401 is the same as that shown in FIG. 19.

[0062] Shown in FIG. 4 are a relay frame 402 transmitted by the dependent station 102, a relay frame 403 transmitted by the dependent station 103, a relay frame 404 transmitted by the dependent station 104 and a relay frame 405 transmitted by the dependent station 105.

[0063] Examples of frame formats of relay frames characterizing the present invention will be described with reference to FIGS. 5 to 7.

[0064] FIG. 5 is a diagram illustrating the structure of a relay frame in the first embodiment. Provided in the header of the relay frame are a LEN_FRAME field indicating the length of the overall frame, and an ACKNOWLEDGEMENT field indicating an acknowledgement response to the broadcast frame received by the same superframe. Depending upon the device packaging, a byte (eight bits) and a word (16 bits) can be mentioned as the unit of frame length indicated by the LEN_FRAME field. However, the present invention is applicable even if some other unit of length is adopted.

[0065] A station that has received these relay frames can ascertain the length of the relay frame by referring to the value of the LEN_FRAME field. At the same time, the station can calculate the length of the period of time over which the frame occupies the communication band.

[0066] Further, ACK, which indicates an acknowledgement response, and NACK, which indicates a negative-acknowledgement response, can be mentioned as examples of values stored in the ACKNOWLEDGEMENT field. In this example, a dependent station that has received the broadcast frame correctly sets ACK as the value in the ACKNOWLEDGEMENT field. On the other hand, a dependent station that has failed to receive the broadcast frame sets NACK as the value in the ACKNOWLEDGEMENT field.

[0067] A third field in the relay frame shown in FIG. 5 is a data payload. Synchronous data and other asynchronous data is stored in the data payload. Such data will be described in detail later.

[0068] A fourth and final field of the relay frame is a checksum for detecting whether the overall relay frame contains a bit error. Generally, a CRC (Cyclic Redundancy Code) or the like consisting of 16 bits, 32 bits, or the like, is utilized as the checksum. However, any code is applicable so long as bit error can be detected.

[0069] As illustrated in FIG. 1, consider a case where

the broadcast frame 401 transmitted from the control
station 101 could be received correctly by the
dependent stations 102 and 105 but not by the dependent
stations 103 and 104, where reception failed.

[0070]Each dependent station refers to the result of
error detection by the checksum verifying unit 312 and
decides the value set in the ACKNOWLEDGEMENT field
using an acknowledgement response generator 307. The
value ACK is stored in the ACKNOWLEDGEMENT field of the
relay frame 402 of dependent station 102 and in the
ACKNOWLEDGEMENT field of the relay frame 405 of
dependent station 105 since these dependent stations
received the Nth broadcast frame 401 correctly. The
value NACK is stored in the ACKNOWLEDGEMENT field of
the relay frame 403 of dependent station 103 and in the
ACKNOWLEDGEMENT field of the relay frame 404 of
dependent station 104 since these dependent stations
failed to receive the Nth broadcast frame 401.

[0071]As a result, due to the fact that an
acknowledgement response transmitted by each dependent
station using the ACKNOWLEDGEMENT field is received by
the other dependent stations, each dependent station is
capable of determining whether transfer of synchronous
data contained in the broadcast frame is necessary or
not. For example, the dependent station 102
comprehends that it itself received the Nth broadcast
frame 401 correctly, and further receives the

ACKNOWLEDGEMENT field holding the value ACK transmitted
by the dependent station 105 as the acknowledgement
response.

[0072]Accordingly, the dependent station 102 determines
that it will suffice if only the synchronous data
intended for the dependent stations 103 and 104 in the
Nth broadcast frame is relayed in the (N+1)th
superframe. Further, the dependent station 105
determines that it itself received the Nth broadcast
frame 401 correctly, and further receives the
ACKNOWLEDGEMENT field holding the value ACK transmitted
by the dependent station 102 as the acknowledgement
response.

[0073]Accordingly, the dependent station 105 similarly
judges that it will suffice if only the synchronous
data intended for the dependent stations 103 and 104 in
the Nth broadcast frame is relayed in the (N+1)th
superframe.

[0074]Described next will be the operation of each
station in the (N+1)th superframe in a case where the
Nth broadcast frame 401 has failed to be received by
the dependent stations 103 and 104. An (N+1)th
broadcast frame 406 that holds the synchronous data
intended for each of the dependent stations is also
broadcast in the (N+1)th superframe by the control
station 101 in the first time slot. Upon receiving the
broadcast frame 406, the dependent stations 102 to 105

decide their own transmit timings and transmit their
relay frames in the same manner as the Nth superframe.

[0075] Shown in FIG. 4 are a relay frame 407 transmitted
by the dependent station 102, a relay frame 408
transmitted by the dependent station 103, a relay frame
409 transmitted by the dependent station 104 and a
relay frame 410 transmitted by the dependent station
105.

[0076] FIG. 6 is a diagram illustrating the frame format
of relay frame 407 transmitted by dependent station 102
and the frame format of relay frame 410 transmitted by
dependent station 105. These relay frames also have a
header that includes the LEN_FRAME field and
ACKNOWLEDGEMENT field similar to the relay frame shown
in FIG. 5.

[0077] First, the LEN_FRAME field indicates the length
of the overall relay frame, and the ACKNOWLEDGEMENT
field is the acknowledgement response indicating
whether the broadcast frame in the same superframe was
received correctly or not. The relay frame further has
an synchronous data section in which synchronous data
that is to be relayed has been stored.

[0078] In FIG. 6, a DATA_TYPE field is indicated as a
third field. In order to indicate that this
synchronous data is data intended for the dependent
station 103, this field has been set to ISO2 as the
value thereof. The relay frame has an ISO_DATA field

as a fourth field. The body of the synchronous data
intended for the dependent station 103 has been stored
in this field.

[0079]Similarly, the relay frame has a DATA_TYPE field
as a fifth field. In order to indicate that the
ensuing synchronous data is data intended for the
dependent station 104, this field has been set to ISO3
as the value thereof. The relay frame has an ISO_DATA
field as a sixth field. The body of the synchronous
data intended for the dependent station 104 has been
stored in this field.

[0080]By transmitting relay data having this format,
only the synchronous data intended for the dependent
stations 103 and 104 is relayed from the dependent
stations 102 and 105.

[0081]FIG. 7 is a diagram illustrating the frame format
of the relay frame 408 transmitted by the dependent
station 103 and the relay frame 409 transmitted by the
dependent station 104. Since the dependent stations
103 and 104 have not correctly received the Nth
broadcast frame 401 transmitted from the control
station 101, synchronous data capable of being relayed
to another dependent station is not held in the (N+1)th
superframe.

[0082]Accordingly, the dependent stations 103 and 104
just transmit the acknowledgement response with respect
to the (N+1)th broadcast frame 406 and do not relay

synchronous data.

[0083]As described above, unnecessary relay

transmission of synchronous data is suppressed by using

the acknowledgement response. As illustrated in FIG. 4,

therefore, the relay frames 407 to 410 to which the

present invention has been applied have frame lengths

shorter than the frame length of the relay frames 42 to

45 in the conventional repeater system already

illustrated in FIG. 18.

[0084]As a result, as shown in FIG. 4, the time period

reserved for the purpose of relay transmission (the

latter-half portion of the time slot) is actually no

longer used for relay transmission and hence an

unoccupied time period can be provided in terms of the

communication media. Further, since synchronous data

transmitted from the control station to each dependent

station in the Nth superframe can be received by each

dependent station at least in the (N+1)th superframe, a

communication system having little delay jitter and

capable of utilizing the communication band efficiently

can be constructed.

[0085]In the description rendered thus far, it is

assumed that each dependent station does not possess

other data requiring transmission, such as asynchronous

data, and the formats shown in FIGS. 5 to 7 are

utilized as the relay frames. From this point onward,

a description will be provided for how unoccupied time

thus obtained is utilized in order that each dependent
station may transmit other data.

[0086] FIG. 8 is diagram illustrating superframes in a
case where the dependent stations 102 and 103 transmit
asynchronous data as data other than synchronous data.
Asynchronous data is data other than data transmitted
in synchronous fashion by relay transmission. It is
possible to transmit data having various formats and
characteristics as synchronous data.

[0087] In FIG. 8, reference numerals 801 to 806, 809 and
810 denote frames identical with the frames 401 to 406,
409 and 410, respectively, shown in FIG. 4. Indicated
at 807 is a relay frame transmitted by the dependent
station 102. FIG. 9 is a diagram illustrating the
frame format of a relay frame in which the dependent
station 102 transmits asynchronous data,

In FIG. 9, first to sixth fields are the same as those
shown in FIG. 6. Using these six fields, the dependent
station 102 makes an acknowledgement response to the
(N+1)th broadcast frame 806 and, at the same time,
relays synchronous data contained in the Nth broadcast
frame 801 to the dependent stations 103 and 104. In a
case where the dependent station 102 possesses
asynchronous data to be transmitted, seventh to ninth
fields are added as fields for transmission of
asynchronous data, as shown in the frame format of FIG.
9.

[0088] First, a DATA_TYPE field serving as the seventh field holds ASYNC as its value. Each station that has received the relay frame 807 can, by referring to this field, identify the fact that asynchronous data has been transmitted. Next, a LEN_ASYNC field serving as the eighth field indicates the data length of the asynchronous data. Unlike synchronous data, often the data length of asynchronous data is variable. Each station that has received the relay frame 807 can, by referring to this field, ascertain the data length of the asynchronous data. Finally, an ASYNC_DATA field serving as the ninth field is the field in which the asynchronous data is stored.

[0089] Here the manner in which a dependent station transmits asynchronous data using unoccupied time is described. No particular description of the details of the internal format of the ASYNC_DATA field will be provided. However, it is assumed that the content of the ASYNC_DATA field includes an address of a station that is the destination of the asynchronous data, and various tags, and the like, for identifying data type, in accordance with the communication protocol of the asynchronous data.

[0090] Further, it is possible for the ASYNC_DATA field to be divided into a plurality of subfields in order to transmit asynchronous data to a plurality of destination terminals. It goes without saying that the

present invention is applicable regardless of what
method of use is employed with regard to the content of
the ASYNC_DATA field.

[0091] The operation of the dependent station 103 will
be described next. The dependent station 103 transmits
the relay frame 808 in the (N+1)th superframe, as
illustrated in FIG. 8. The frame format of the relay
frame 808 is illustrated in FIG. 10. The first and
second fields in this frame format are identical with
those shown in FIG. 7, and the dependent station 103
transmits an acknowledgement response with respect to
the (N+1)th broadcast frame 806.

[0092] In a case where the dependent station 103
possesses asynchronous data to be transmitted, the
third to fifth fields are added as fields for
transmission of asynchronous data, as shown in FIG. 10.
These fields correspond to the seventh to ninth fields
in the relay frame 807 transmitted by the dependent
station 102 shown in FIG. 9.

[0093] The dependent station 103 does not perform a
relay transmission in the (N+1)th superframe. However,
by utilizing the third to fifth fields, the dependent
station 103 can transmit asynchronous data utilizing
the unoccupied time in a manner similar to that of the
dependent station 102.

[0094] As described above, the communication band is
provided with unoccupied time owing to transmission of

an acknowledgement response by a dependent station, and
the dependent station can transmit asynchronous data by
utilizing this unoccupied time. As a result, it is
possible to transfer asynchronous data anew and to
increase the overall amount of transfer of data
inclusive of both synchronous data and asynchronous
data.

[0095] It should be noted that since synchronous data
often is handled as fixed-length data, the invention
has been described using fixed-length synchronous data.
However, the present invention is applicable even to
synchronous data of variable length. Furthermore,
formats for carrying out transmission of the
acknowledgement response, relay transmission of
synchronous data and transmission of asynchronous data
using a single frame have been exemplified. However,
it is possible for these to be transmitted from
dependent stations as separate frames.

[0096] [Second Embodiment]

A second embodiment according to the present invention
will now be described in detail with reference to the
drawings. In the first embodiment, it is described
that dependent stations can transmit asynchronous data
in the wireless repeater system to which the present
invention is applied. In the second embodiment, a
method in which the control station 101 transmits
asynchronous data in a manner similar to that of the

dependent stations 102 and 103 will be described.

[0097]The configuration of the wireless repeater system according to the second embodiment is similar to that of the first embodiment described with reference to FIG. 1 and need not be described again. Further, the internal configuration of the control station 101 and the internal configuration of the dependent stations 102 to 105 also are similar to those of the first embodiment described with reference to FIGS. 2 and 3 and need not be described again.

[0098]A case where the frames shown in FIG. 8 described in the first embodiment are transmitted will be described as an example of operation of the repeater system according to the second embodiment. As described in the first embodiment, the dependent stations 102 to 105 execute relay transmission and transmission of asynchronous data simultaneously by transmitting the relay frames 807 to 810 in the (N+1)th superframe.

[0099]In the (N+1)th superframe illustrated in FIG. 8, the dependent station 103 transmits the relay frame 808 but unoccupied time still remains from the end point of the relay frame 808 to the next time slot. In the second embodiment, an asynchronous frame holding asynchronous data is transmitted by the control station 101 in this unoccupied period of time.

[0100]The control station 101 receives the relay frames

shown in FIG. 8. Since each of these relay frames includes the LEN_FRAME field, as mentioned earlier, the control station 101 can ascertain the length of this relay frame by using the frame-length determination unit 208 to refer to the value in the LEN_FRAME field. Furthermore, since the control station 101 controls the TDMA protocol, the starting time of each time slot is already known.

[0101] Accordingly, it is possible for the control station 101 to accurately detect unoccupied time in which the communication media are not being utilized from end time of relay data transmitted by each slot until the next time slot.

[0102] In FIG. 2, the transmit timing generator 207 obtains information relating to end time of a receive frame from the frame-length determination unit 208 and starting time of the next time slot from the superframe timing generator 206. On the basis of such information, the transmit timing generator 207 instructs the transmit frame generator 204 to perform frame transmission. Thus, by transmitting an asynchronous frame in an unoccupied time period, the control station 101 can transmit asynchronous data without causing frame collision with another dependent station.

[0103] FIG. 11 is a diagram illustrating the structure of superframes in a case where the control station transmits an asynchronous frame. Numerals 1101 to 1110

in FIG. 11 denote frames identical with those frames
801 to 810 shown in FIG. 8.

[0104] In the (N+1)th superframe, the control station
101 that has received the relay frame 1108 of dependent
station 103 senses the end of the relay frame 1108 and
immediately starts transmitting an asynchronous frame
1111.

[0105] FIG. 12 is a diagram illustrating an example of
the structure of an asynchronous frame transmitted by
the control station. The first field is a LEN_FRAME
field indicating the overall length of the asynchronous
frame 1111. Depending upon the device packaging, a
byte (eight bits) and a word (16 bits) can be mentioned
as the unit of frame length indicated by the LEN_FRAME
field. However, the present invention is applicable
even if some other unit of length is adopted.

[0106] The control station 101 decides the length of the
asynchronous frame 1111 and sets the LEN_FRAME field in
such a manner that the asynchronous frame 1111 will end
before the moment at which the next time slot begins.

[0107] The second field shown in FIG. 12 is an
ASYNC_DATA frame in which asynchronous data transmitted
from the control station 101 is stored. In the second
embodiment, it is described how the control station 101
transmits asynchronous data using unoccupied time. No
particular description of the details of the internal
format of the ASYNC_DATA field are provided. However,

it goes without saying that it is possible to apply the
present invention regardless of what method of use is
employed with regard to the content of the ASYNC_DATA
field.

[0108]As described above, in a case where the dependent
stations 102 to 105 transmit asynchronous data
utilizing unoccupied time, the control station 101 can
also transmit asynchronous data in similar fashion.
Applying the present invention makes it possible for
the control station and dependent stations to transmit
both synchronous data and asynchronous data.

[0109]Furthermore, the number of times relay
transmission is required is optimized in accordance
with the state of communication, and nearly all of the
unoccupied time can be utilized to transmit
asynchronous data. This makes it possible to increase
the amount of data transferred in the overall system.

[0110][Third Embodiment]
Next, a third embodiment according to the present
invention will be described in detail with reference to
the drawings. In the third embodiment, relay
transmission is optimized.

[0111]The configuration of the wireless repeater system
according to the third embodiment is similar to that of
the first embodiment described with reference to FIG. 1
and need not be described again. Further, the internal
configuration of the control station 101 and the

internal configuration of the dependent stations 102 to
105 also are similar to those of the first embodiment
described with reference to FIGS. 2 and 3 and need not
be described again.

[0112] In the third embodiment as well, a case where the
Nth broadcast frame 401 has failed to be received by
the dependent stations 103 and 104 is assumed. As
illustrated in FIG. 13, the occurrence of a bit error
is possible only in an ISO_DATA3 field, which is
synchronous data intended for the dependent station 104
contained in the third field of the received broadcast
frame 401.

[0113] Even if the entire broadcast frame 401 cannot be
received correctly, as long as the dependent station
103 can acquire its own synchronous data contained in
an ISO_DATA2 field, a subsequent relay transmission
from another dependent station will be unnecessary.
Despite this fact, in the first embodiment under these
conditions, the dependent stations 102 and 105 relay
the synchronous data intended for the dependent station
103 and waste communication bandwidth by needless
communication.

[0114] In view of these circumstances, the third
embodiment uses the format shown in FIG. 14 as an
example of the format of a broadcast frame transmitted
by the control station 101. In FIG. 14, the
synchronous data intended for the dependent stations

has been stored in the respective fields ISO_DATA1 to
ISO_DATA4. Furthermore, the fields CHECKSUM1 to
CHECKSUM4 are provided immediately after the ISO_DATA1
to ISO_DATA4 fields, as checksums based upon an error-
detection code for every item of synchronous data.

[0115] FIG. 15 is a diagram illustrating the structure
of superframes in the third embodiment. First, in the
Nth superframe, the control station 101 broadcasts a
broadcast frame 1501. The broadcast frame 1501 has the
frame format shown in FIG. 14. Upon receiving the
broadcast frame 1501, the dependent station 103
investigates CHECKSUM-ISO1 to CHECKSUM-ISO4, which are
checksums regarding each item of synchronous data.
Thereafter, in its own time slot, the dependent station
103 transmits a relay frame 1503. The relay frame 1503
contains an ACKNOWLEDGEMENT field just as in the first
embodiment.

[0116] In a case where a bit error has occurred only in
ISO_DATA3 and the dependent station 103 has received
ISO_DATA2, which is the synchronous data intended for
this dependent station, without any bit error, the
dependent station 103 sets the value ACK in the
ACKNOWLEDGEMENT field of the relay frame 1503. Another
dependent station that has received the ACKNOWLEDGEMENT
field recognizes that there is no need to relay the
broadcast frame 1501 to the dependent station 103.

[0117] Relay transmission with respect to the Nth

broadcast frame 1501 is performed by the (N+1)th
superframe, the dependent station 102 transmits a relay
frame 1507 and the dependent station 105 transmits a
relay frame 1510. Since the dependent stations 102 and
105 are already aware that it is unnecessary to make a
relay transmission to the dependent station 103 due to
the relay frame 1503, the relay frames 1507 and 1510 do
not contain synchronous data intended for the dependent
station 103.

[0118] Accordingly, the length of the relay frame 1507
transmitted from the dependent station 102 becomes
shorter than that of the relay frame 407 shown in FIG.
4. Similarly, the length of the relay frame 1510
transmitted from the dependent station 105 becomes
shorter than that of relay frame 410 shown in FIG. 4.
This means that unoccupied time in the (N+1)th
superframe is longer than that of the case shown in FIG.
4.

[0119] By thus improving the checksum and
acknowledgement response system, it is possible to
optimize relay transmission and a longer period of
unoccupied time can be provided.

[0120] Further, the control station and dependent
stations transmit asynchronous data by utilizing this
unoccupied time through a method similar to that of the
first and second embodiments. As a result, it is
possible to further increase the amount of overall

synchronous data and asynchronous data transferred in a
repeater system.

[0121] In accordance with the embodiments described
above, it is possible to reduce the number of
unnecessary relay transmissions in a case where a
receiving station has received a data frame correctly
in a wireless repeater system. Accordingly,
communication time that is no longer utilized in relay
transmission can be used to transfer other data such as
asynchronous data. This has the effect of increasing
the amount of data transferred in the overall network.

[0122] Aspects of the present invention can also be
realized by a computer of a system or apparatus (or
devices such as a CPU or MPU) that reads out and
executes a program recorded on a memory device to
perform the functions of the above-described
embodiment(s), and by a method, the steps of which are
performed by a computer of a system or apparatus by,
for example, reading out and executing a program
recorded on a memory device to perform the functions of
the above-described embodiment(s). For this purpose,
the program is provided to the computer for example via
a network or from a recording medium of various types
serving as the memory device (e.g., computer-readable
medium).

[0123] While the present invention has been described
with reference to exemplary embodiments, it is to be

understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0124] This application claims the benefit of Japanese Patent Application No. 2008-220501, filed August 28, 2008, which is hereby incorporated by reference herein in its entirety.

CLAIMS

1. A communication system in which a control station broadcasts data, which is intended for a plurality of dependent stations, on a per-superframe basis, each of said plurality of dependent stations comprising:

   means for receiving data broadcast from the control station in an Nth (where N is an integer) superframe;

   means for transmitting an acknowledgement response, which indicates reception condition of the data, in a time slot that has been allocated to this dependent station in the Nth superframe; and

   means which, in accordance with the acknowledgement response transmitted from another dependent station, is for relaying data intended for this another dependent station in a time slot that has been allocated to this dependent station in an (N+1)th superframe.

2. The system according to claim 1, wherein in a case where an acknowledgement response indicating that data from the control station was received correctly is not received from another dependent station, data intended for this another dependent station is relayed.

3. The system according to claim 1, wherein in a case where an acknowledgement response indicating that data from the control station was not received correctly was received from another dependent station, data intended

for this another dependent station is relayed.

4. The system according to claim 1, wherein in a case where each of the plurality of dependent stations does not relay data intended for another dependent station, the dependent station transmits other data in a time period that has been reserved for the relay in a time slot that has been allocated to this dependent station.

5. The system according to claim 1, the control station comprising means for detecting a time period which is not being used in a time period that has been reserved in order that each dependent station may relay data intended for the other dependent station;

wherein other data is transmitted in the detected time period.

6. The system according to claim 1, wherein the plurality of dependent stations transmits the acknowledgement response and the relayed data in one frame.

7. The system according to claim 1, wherein data broadcast from the control station and relayed among the plurality of dependent stations is synchronous data.

8. A dependent station of a communication system in which a control station broadcasts data, which is intended for a plurality of dependent stations, on a per-superframe basis, said dependent station comprising:

means for receiving data broadcast from the

control station in an Nth (where N is an integer)

superframe;

        means for transmitting an acknowledgement

response, which indicates reception condition of the

data, in a time slot that has been allocated to this

dependent station in the Nth superframe; and

        means which, in accordance with the

acknowledgement response transmitted from another

dependent station, is for relaying data intended for

this another dependent station in a time slot that has

been allocated to this dependent station in an (N+1)th

superframe.

9. A method of relay transmission by a dependent

station in a communication system in which a control

station broadcasts data, which is intended for a

plurality of dependent stations, on a per-superframe

basis, said method comprising:

        a step of receiving data broadcast from the

control station in an Nth (where N is an integer)

superframe;

        a step of transmitting an acknowledgement

response, which indicates reception condition of the

data, in a time slot that has been allocated to this

dependent station in the Nth superframe; and

        in accordance with the acknowledgement response

transmitted from another dependent station, a step of

relaying data intended for this another dependent

station in a time slot that has been allocated to this dependent station in an (N+1)th superframe.

10. A program for causing a computer to execute the method of relay transmission by a dependent station set forth in claim 9.
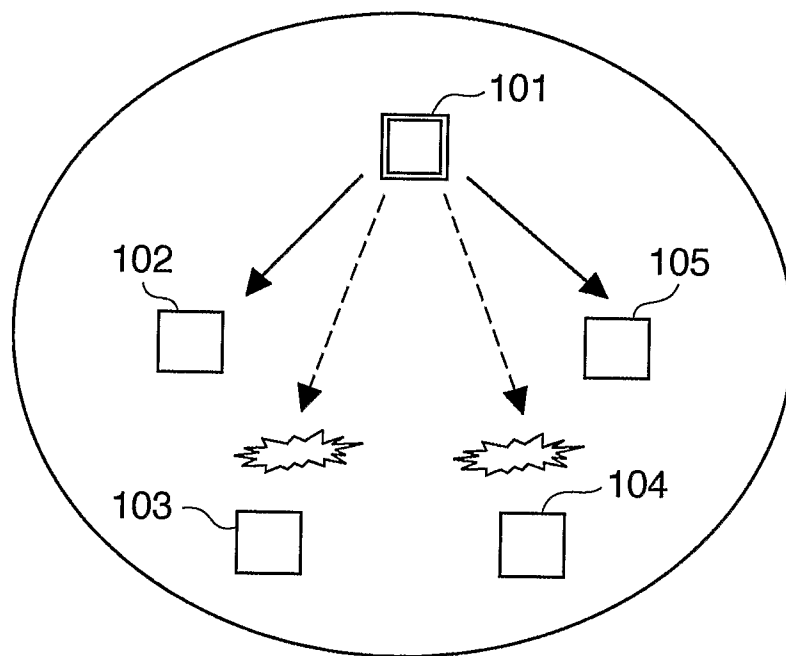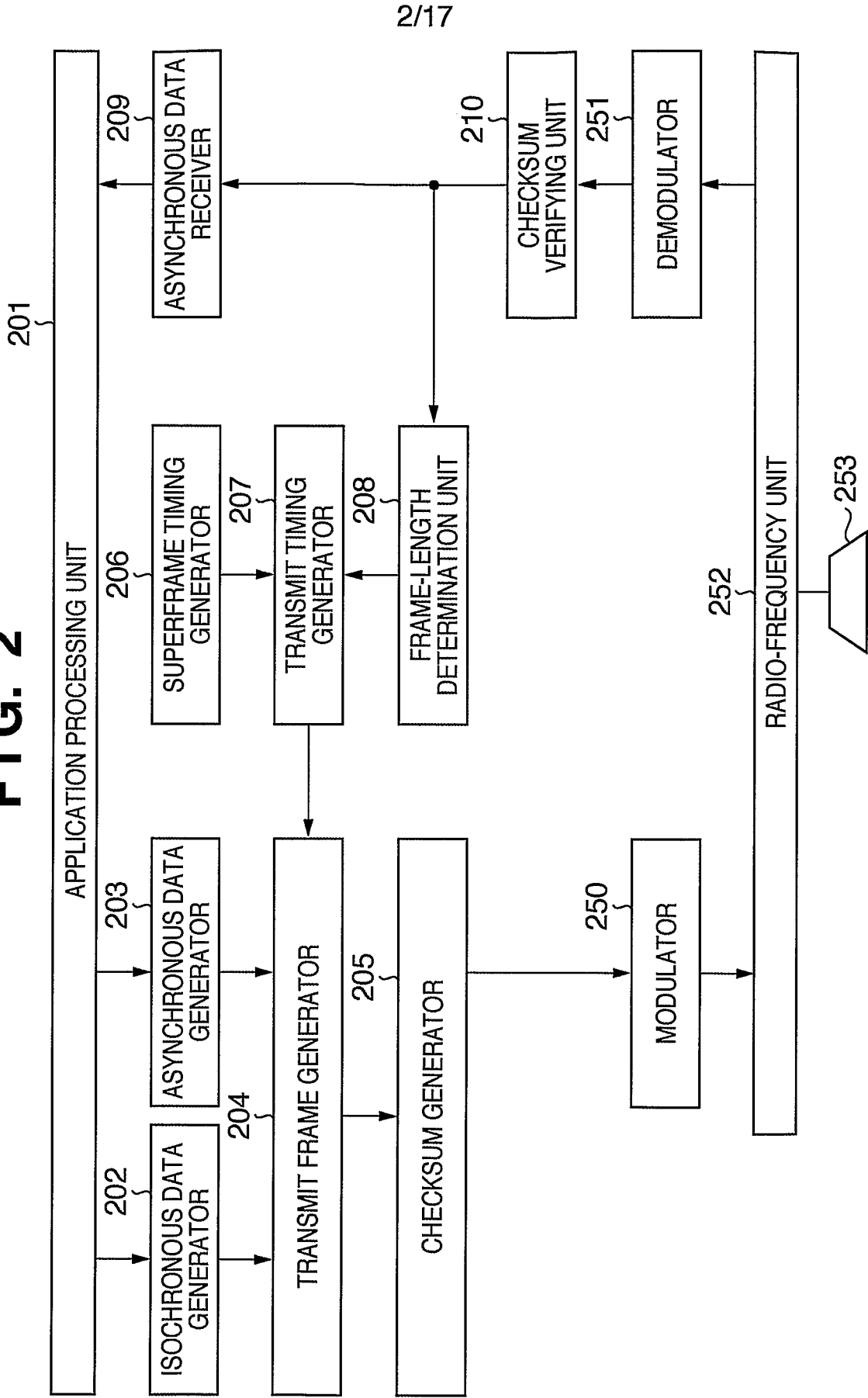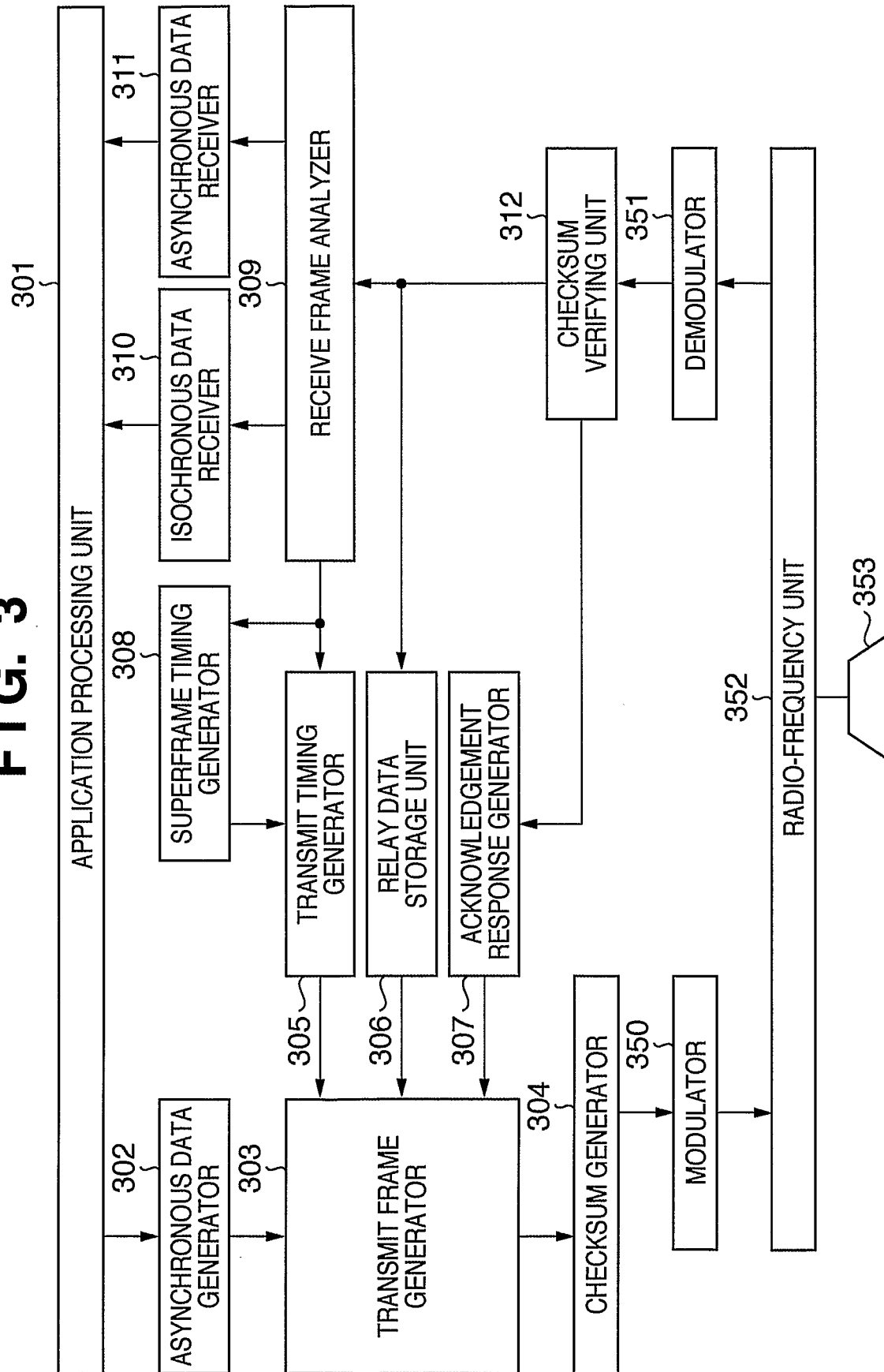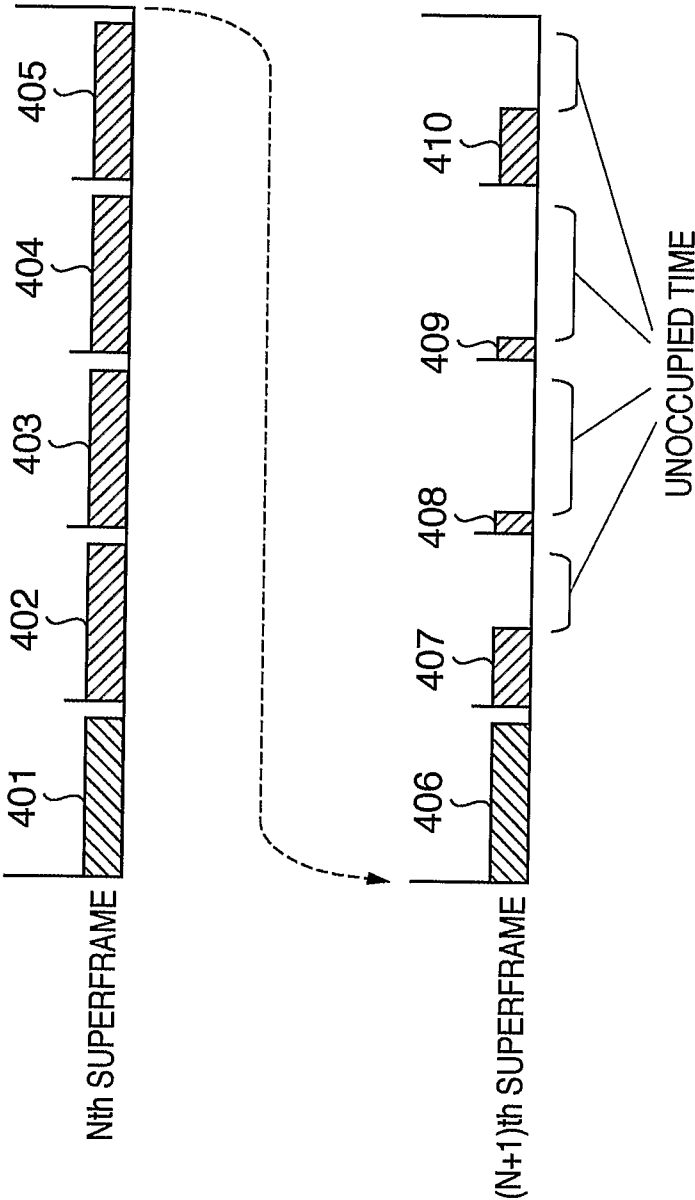
FIG. 1

FIG. 2

FIG. 3

F I G. 4

F I G. 5

#1	LEN_FRAME	---- OVERALL FRAME LENGTH
#2	ACKNOWLEDGE	---- ACK/NACK
#3	DATA PAYLOAD	
#4	CHECKSUM_FRAME	---- ERROR-DETECTION CHECKSUM FOR OVERALL FRAME

FIG. 6

#1	LEN_FRAME	---- OVERALL FRAME LENGTH
#2	ACKNOWLEDGE	---- ACK/NACK
#3	DATA_TYPE(ISO2)	---- ISO1/ISO2/ISO3/ISO4/ASYNC
#4	ISO_DATA(ISO2)	---- ISOCHRONOUS DATA INTENDED FOR SECOND SLAVE STATION
#5	DATA_TYPE(ISO3)	---- ISO1/ISO2/ISO3/ISO4/ASYNC
#6	ISO_DATA(ISO3)	---- ISOCHRONOUS DATA INTENDED FOR THIRD SLAVE STATION
#7	CHECKSUM_FRAME	---- ERROR-DETECTION CHECKSUM FOR OVERALL FRAME

FIG. 7

#1	LEN_FRAME	---- OVERALL FRAME LENGTH
#2	ACKNOWLEDGE	---- ACK/NACK
#3	CHECKSUM_FRAME	---- ERROR-DETECTION CHECKSUM FOR OVERALL FRAME

FIG. 8

FIG. 9

| #1	LEN_FRAME	---- OVERALL FRAME LENGTH
#2	ACKNOWLEDGE	---- ACK/NACK
#3	DATA_TYPE(ISO2)	---- ISO1/ISO2/ISO3/ISO4/ASYNC
#4	ISO_DATA(ISO2)	---- ISOCHRONOUS DATA INTENDED FOR SECOND SLAVE STATION
#5	DATA_TYPE(ISO3)	---- ISO1/ISO2/ISO3/ISO4/ASYNC
#6	ISO_DATA(ISO3)	---- ISOCHRONOUS DATA INTENDED FOR THIRD SLAVE STATION
#7	DATA_TYPE(ASYNC)	---- ISO1/ISO2/ISO3/ISO4/ASYNC
#8	LEN_ASYNC	---- LENGTH OF ASYNCHRONOUS DATA
#9	ASYNC_DATA	---- ASYNCHRONOUS DATA
#10	CHECKSUM_FRAME	---- ERROR-DETECTION CHECKSUM FOR OVERALL FRAME

F I G. 10

#1	LEN_FRAME	---- OVERALL FRAME LENGTH
#2	ACKNOWLEDGE	---- ACK/NACK
#3	DATA_TYPE(ASYNC)	---- ISO1/ISO2/ISO3/ISO4/ASYNC
#4	LEN_ASYNC	---- LENGTH OF ASYNCHRONOUS DATA
#5	ASYNC_DATA	---- ASYNCHRONOUS DATA
#6	CHECKSUM_FRAME	---- ERROR-DETECTION CHECKSUM FOR OVERALL FRAME

FIG. 11

F I G. 12

#1	LEN_FRAME	---- OVERALL FRAME LENGTH
#2	ASYNC_DATA	---- ASYNCHRONOUS DATA
#3	CHECKSUM_FRAME	---- ERROR-DETECTION CHECKSUM FOR OVERALL FRAME

F I G. 13

#1	ISO_DATA1
#2	ISO_DATA2
#3	ISO_DATA3
#4	ISO_DATA4
#5	CHECKSUM_FRAME

BIT ERRORS
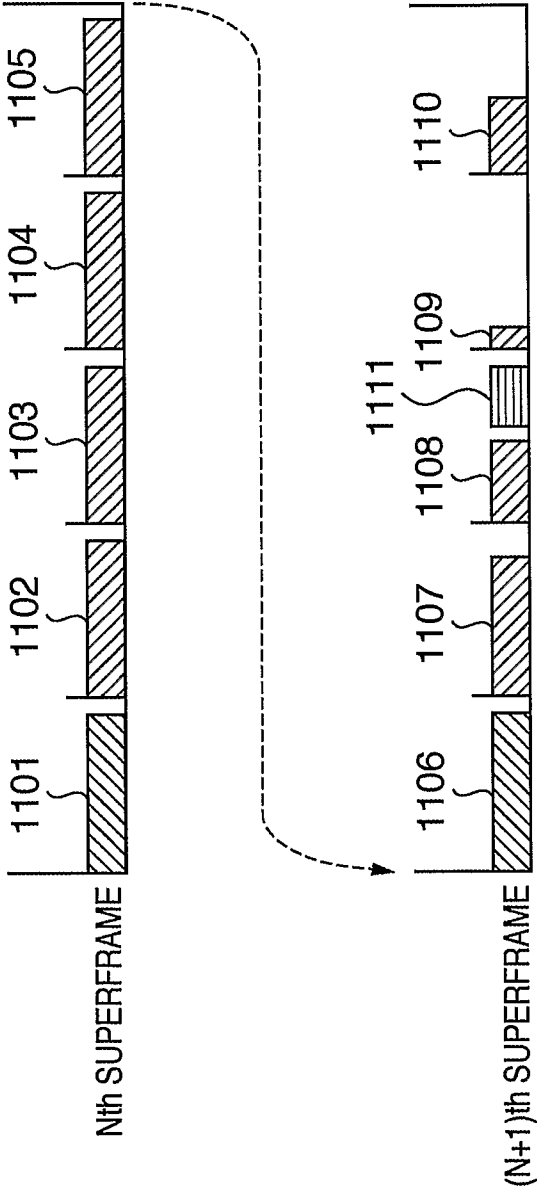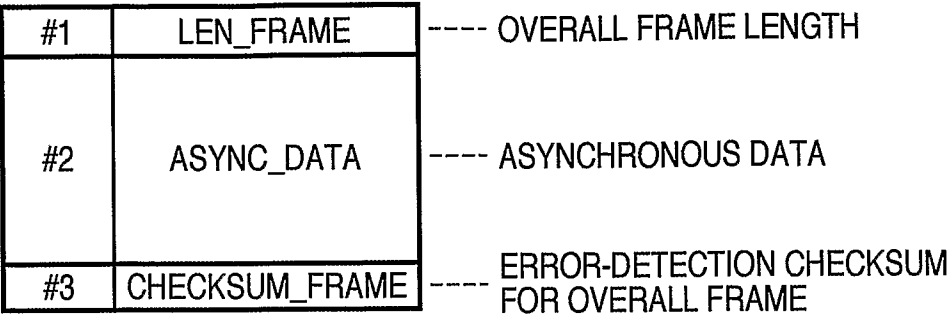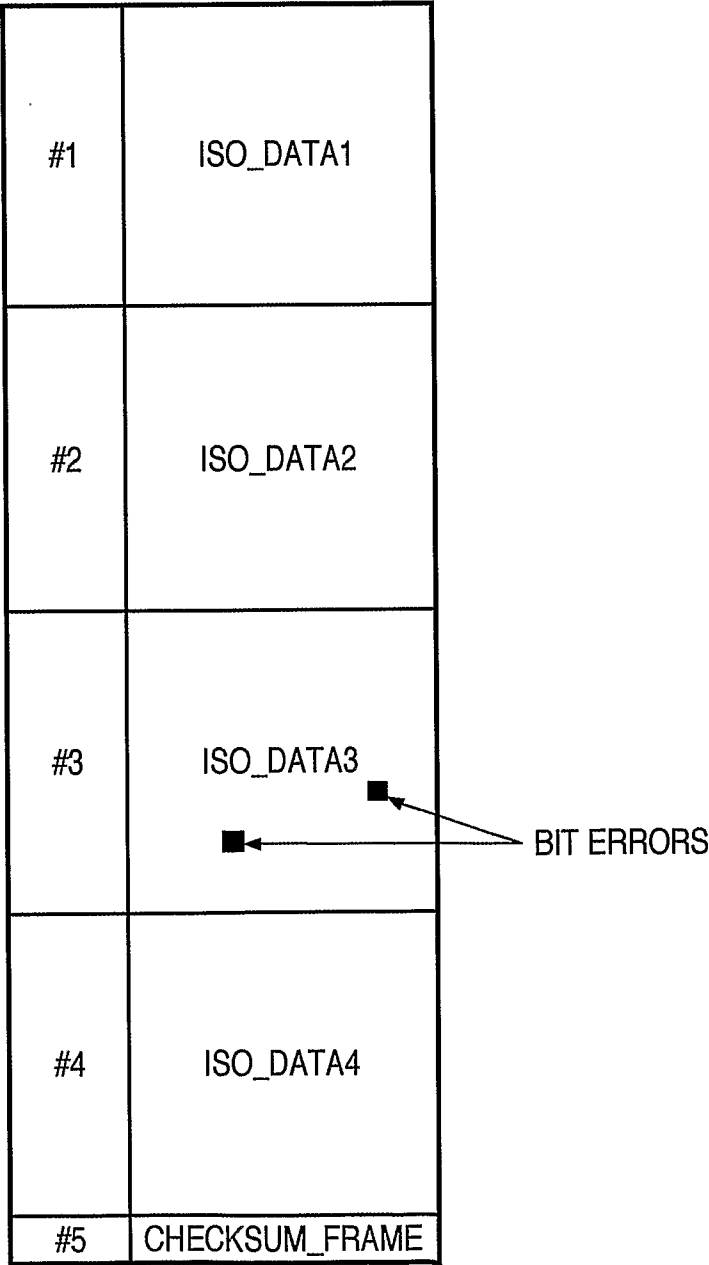
F I G. 14

#1	ISO_DATA1
#2	CHECKSUM_ISO1
#3	ISO_DATA2
#4	CHECKSUM_ISO2
#5	ISO_DATA3
#6	CHECKSUM_ISO3
#7	ISO_DATA4
#8	CHECKSUM_ISO4

F I G. 15
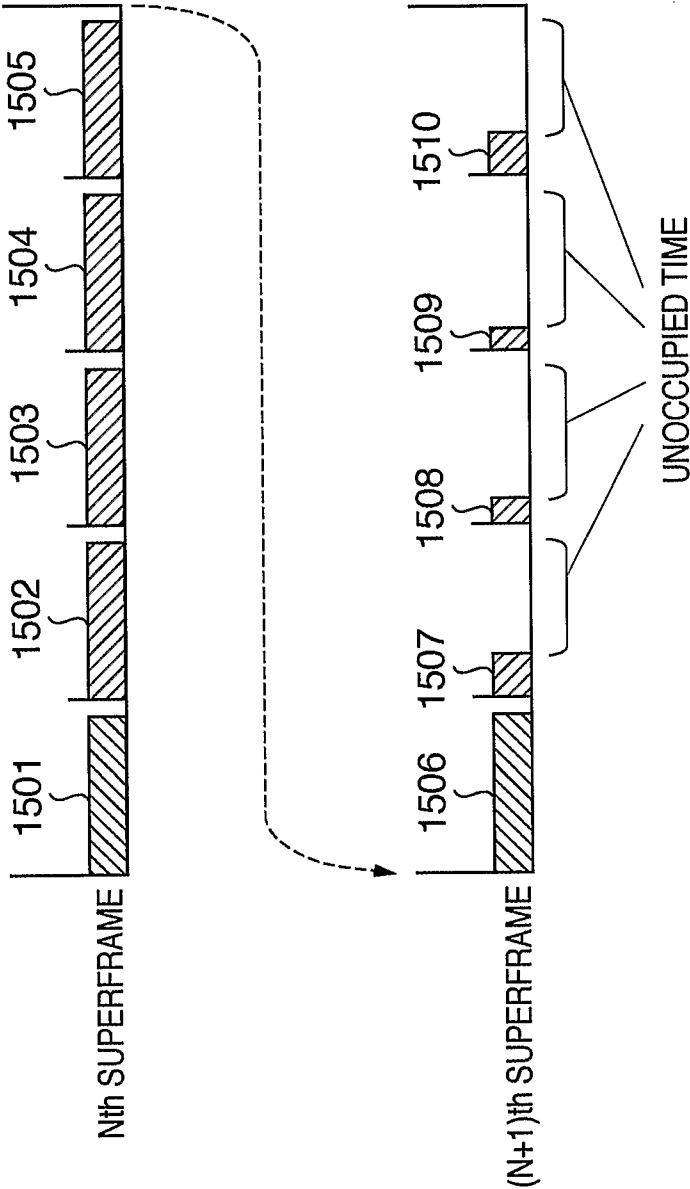
F I G. 16
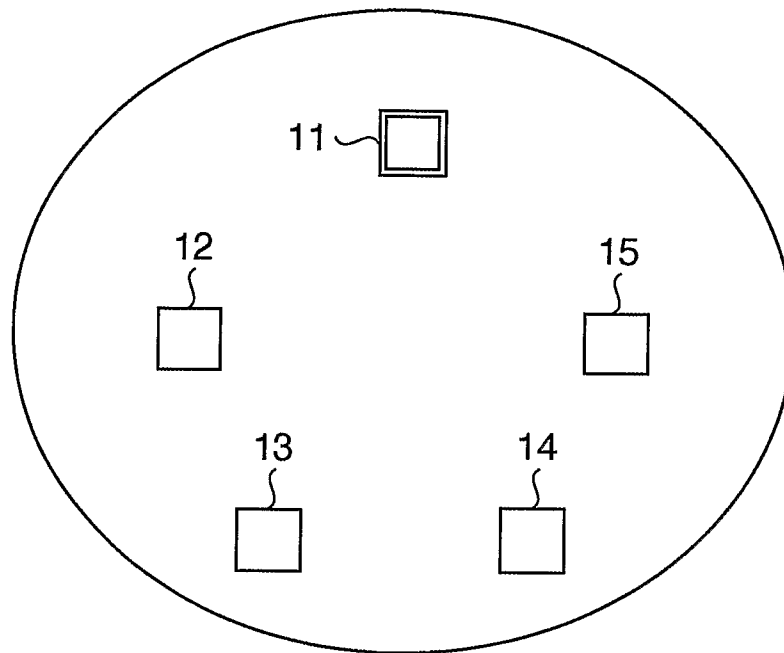
F I G. 17
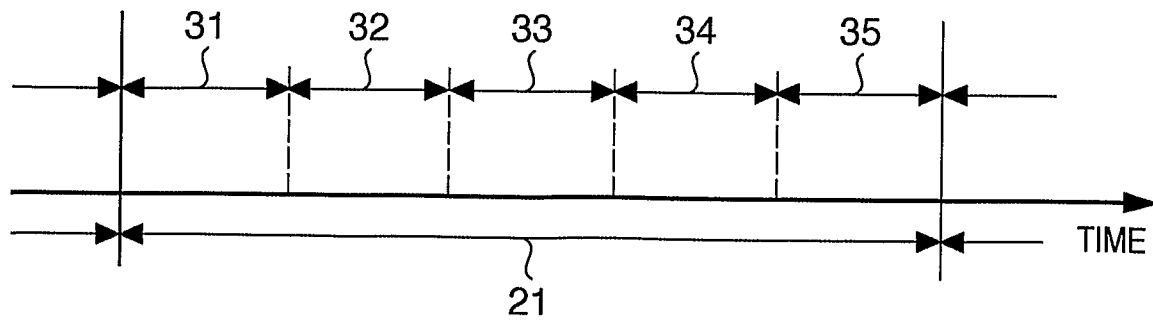
FIG. 18
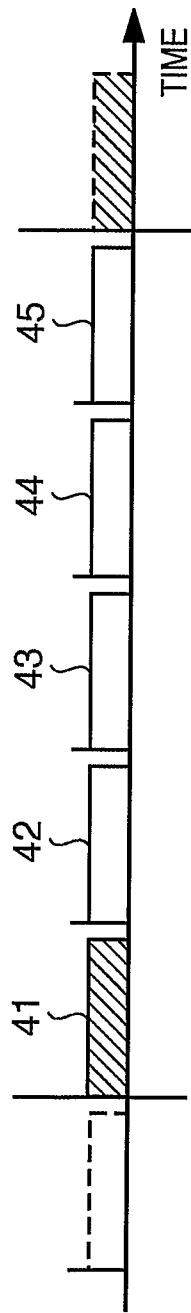
F I G. 19

51	#1	ISO_DATA1
52	#2	ISO_DATA2
53	#3	ISO_DATA3
54	#4	ISO_DATA4
55	#5	CHECKSUM_FRAME
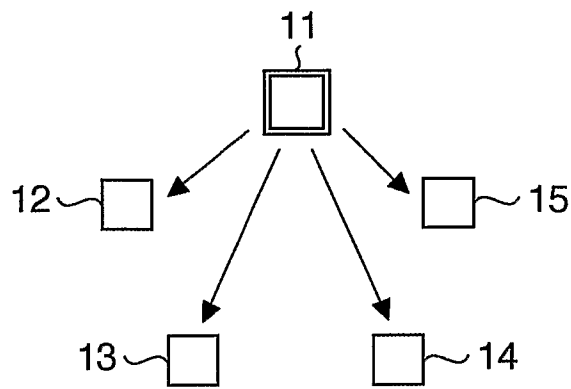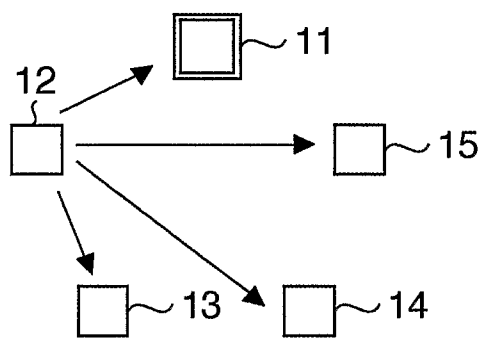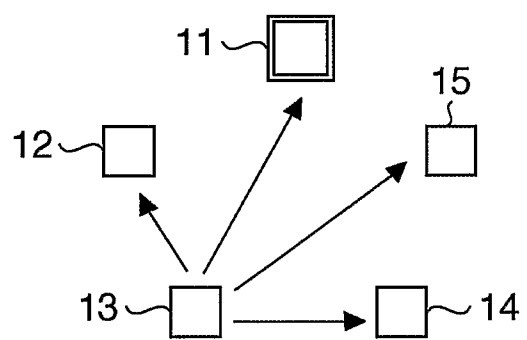
F I G. 20A

F I G. 20B

F I G. 20C
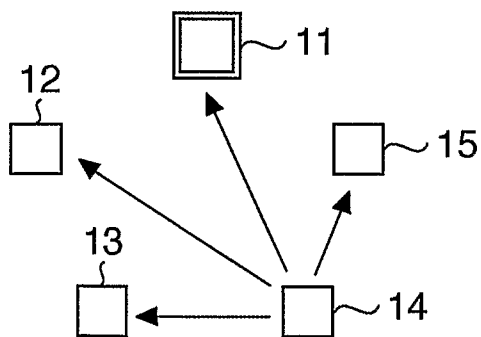
F I G. 20D
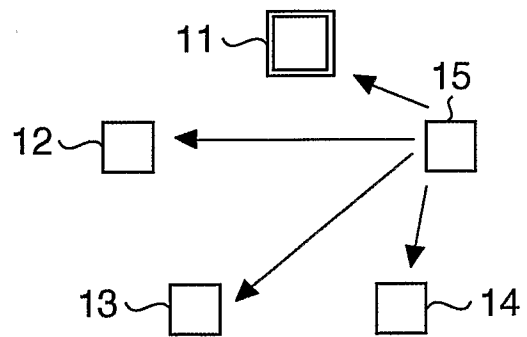
F I G. 20E

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/18   H04L1/00   H04L12/56   H04H20/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/256741 A1 (NOZAKI MASANORI [JP]) 16 November 2006 (2006-11-16) paragraphs [0004], [0006], [0008] – [0010], [0012], [0037], [0039], [0045], [0047], [0048], [0052], [0060], [0061], [0066], [0067], [0070], [0074] paragraphs [0076], [0080]; figures 2,4A,5A,9A	1-10
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| X | Further documents are listed in the continuation of Box C. | | X | See patent family annex. |

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 November 2009	04/12/2009

| Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016 | Authorized officer Keller, Matthias |

INTERNATIONAL SEARCH REPORT

C(Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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