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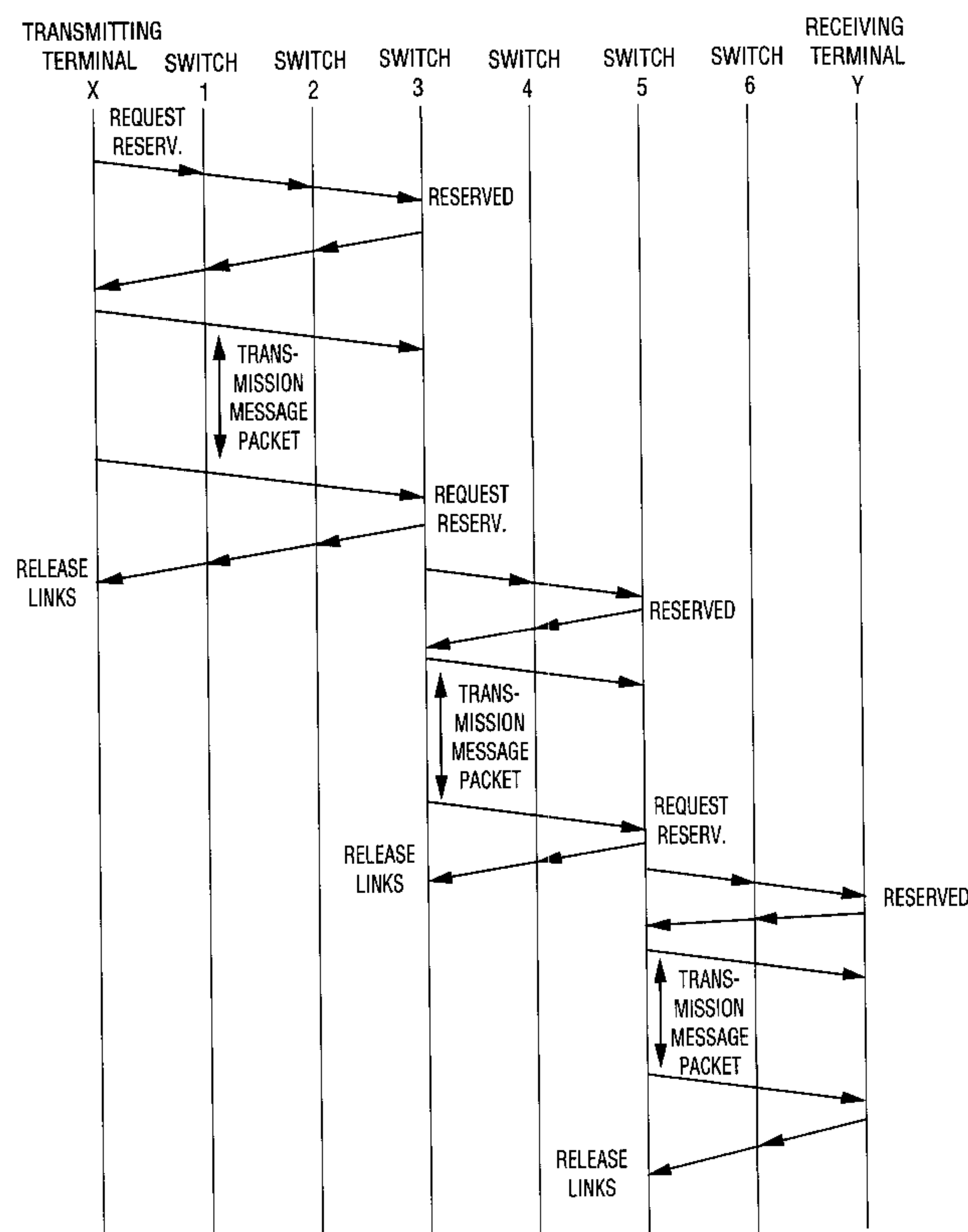
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(54) **SYSTEME DE COMMUTATION A SERVEURS DE SALVES ET
METHODE DE FONCTIONNEMENT DE CE SYSTEME**

(54) **BURST SERVER STORED SWITCHING SYSTEM AND ITS
METHOD**



(57) A packet transmission method and apparatus prevents the holding of unavailable links during packet transmission. An embodiment of the present invention assumes the case of a packet transmission between a transmitting terminal and a receiving terminal over a path which includes seven links and six switches. The third and fifth switches provide first and second intermediate burst servers which have a buffer for temporarily holding a message packet and a function of the packet transmission. The function comprises requesting a link reservation, transmitting a message packet, storing a received-message packet, and releasing reserved links upon completing the transmission of the message packet. When the transmitting terminal transmits a message packet, a first end burst server starts the packet transmission including the link reservation to the first intermediate burst server, and when the packet transmission is completed, reserved links between those burst servers are released. The same packet transmission is repeated consecutively to each burst server up to the receiving terminal, if the link reservations are not blocked. If a link reservation is blocked, the packet transmission is held at the latest burst server, and either another link reservation of the same bandwidth is used or the transmission is converted to use another available bandwidth.



ABSTRACT

A packet transmission method and apparatus prevents the holding of unavailable links during packet transmission. An embodiment of the present invention assumes the case of a packet transmission between a transmitting terminal and a receiving terminal over a path which includes seven links and six switches. The third and fifth switches provide first and second intermediate burst servers which have a buffer for temporarily holding a message packet and a function of the packet transmission. The function comprises requesting a link reservation, transmitting a message packet, storing a received-message packet, and releasing reserved links upon completing the transmission of the message packet. When the transmitting terminal transmits a message packet, a first end burst server starts the packet transmission including the link reservation to the first intermediate burst server, and when the packet transmission is completed, reserved links between those burst servers are released. The same packet transmission is repeated consecutively to each burst server up to the receiving terminal, if the link reservations are not blocked. If a link reservation is blocked, the packet transmission is held at the latest burst server, and either another link reservation of the same bandwidth is used or the transmission is converted to use another available bandwidth.

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BURST SERVER STORED SWITCHING SYSTEM AND ITS METHOD

This invention relates to a packet switching system, and in particular, to a packet switching system that includes an ATM (Asynchronous Transfer Mode).

A switching system (Fast Reservation Protocol (FRP)) in an ATM or a packet switching system in which a bandwidth necessary for information transfer, i.e. a transmission channel having an appropriate frequency, is reserved prior to information transfer, and information is then transferred on that bandwidth in order to avoid overcrowding of a network, is proposed as a FRP system in H. Suzuki et al., "Fast Bandwidth Reservation Scheme with Multilink & Multipath Routing in ATM Networks", IEEE INFOCOM 1991. The FRP system is described with reference to Figures 1 and 2. Link 0, link 1, link 2, link 3, link 4, link 5 and link 6 are connected in order from a transmitting terminal x to a receiving terminal y, as shown in Figure 1, and for $j = 0, 1, 2, 3, 4, 5$, switch $j+1$ is interposed between link j and link $j+1$. When information to be transmitted is produced, terminal x immediately sends out to link 0 a reservation-request packet for reserving a bandwidth B necessary for information transfer. Since link 0 may also possibly be used for information transfer between terminal x and a terminal other than terminal y, it may be that requested bandwidth B cannot be reserved (fails); link 0 then

returns a reservation-failure packet to terminal x. When bandwidth B can be reserved (succeeds), link 0 reserves bandwidth B and sends the reservation-request packet to link 1. Bandwidth reservation is also attempted by link 1, link 2, link 3, link 4, and link 5 in a similar procedure to that performed by link 0. It is assumed that link 6 is fixed exclusively to terminal 6 and does not require reservation. When the bandwidth reservation gets through at all of the links from link 0 to link 5 so that a bandwidth is reserved from terminal x to terminal y, terminal x sends information to terminal y. On the other hand, if reservation fails even at only one link, a reservation-failure packet is returned to terminal x from the particular link at which bandwidth reservation has failed. When reservation has failed, the bandwidth reservations from terminal x to the particular link are cancelled and the reserved bandwidths are released. The failure corresponds to a so-called loss in a telephone network, and the probability of failure indicates the quality of the network. This failure is called a block, and the probability of failure is called the block rate. Fig. 2 illustrates a possible transmission of control signals and information between transmitting terminal x and receiving terminal y when FRP communication is employed. Figure 2 shows that the first block occurs at link 1; the second block occurs at link 4; and the third block occurs at link 2; thereafter, bandwidth reservation

succeeds at all of the links from link 1 to link 5, and information is transmitted.

In this instance, in the FRP system described above, if bandwidth reservation fails even at only one of the links from link 1 to link 4, the information is blocked irrespective of success or failure of reservation at any other link as shown in Figure 2. Accordingly, the end-to-end block rate between transmitting and receiving terminals generally increases according to an increase in the number of links. For example, if it is assumed that the block probability at each link is independent of the block probability at any other links and is represented by g and the number of links to pass between the transmitting and receiving terminals is represented by K , the end-to-end block rate G is given by $G = 1 - (1 - g)^K$, because it is a complementary event of the probability $(1 - g)^K$ at which the reservation simultaneously succeeds at all of the links. For example, when g is 0.01 and K increases successively from 1, then G successively increases to approximately 0.01, 0.02 and 0.03. In a public telephone network scheme, since a value like 0.01 in the example mentioned above or 0.001 is used as g , G is approximated to $G = Kg$. Accordingly, when a large number of links must be passed, for example in long-distance communications, the block rate becomes high, resulting in a problem of low communication quality.

It is an object of the present invention to

provide a packet transmission method and apparatus which reduce the occupation time of a link, and which reduce the block rate and thereby improve the flow of traffic of the entire network.

5 In order to attain the object described above, according to a first aspect of the present invention there is provided a packet transmission method for a packet switching system. The method comprises a first step of providing at least one burst server interposed between a
10 transmitting terminal and a receiving terminal through at least one link, said burst server having ability to store a received message packet, to request reservation of a free link having a required bandwidth and a sufficient storage capacity at a receiving-side burst server, and to
15 release the link after transmission of the message packet has been completed. A second step involves performing reservation of the bandwidth and receiving-side storage capacity between the transmitting terminal and the closest burst server, between adjoining burst servers, and between
20 the receiving terminal and its adjoining burst server. A third step involves transmitting consecutively a message packet via interposed burst servers, and releasing consecutively the reserved links according to each completion of transmission of the message packet at the
25 corresponding burst servers.

Another object of the invention is to provide a second method for a packet switching system, comprising

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the initial step of providing at least one burst server interposed between a transmitting terminal and a receiving terminal through at least one link when the terminals are separated by at least two links, said burst server having the ability to store a received message packet, requesting reservation of free links having required bandwidth and sufficient storage capacity at the receiving side burst server, and releasing the links after the transmission of the message packet is completed. A second step involves performing a packet transmission which requires reservation of a necessary bandwidth through relevant links and reservation of receiving-side storage capacity for the message packet from the transmitting terminal to a first burst server closest to the transmitting terminal. In a next step, the received message packet is stored in the first burst server. The link between the transmitted terminal and the first burst server is released after the message packet is transmitted. A packet transmission is then performed to transmit the stored message packet from the first burst server to the next burst server. A received message packet is stored at each burst server when the message packet is received. The packet transmission is repeated to consecutively transmit the stored message packet to the next burst server until the message packet is received at the receiving terminal. A final step involves repeating the release of the link to the next burst server after the transmission of the

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message packet is completed at each burst server, the releasing being done consecutively until the message packet is received at the receiving terminal.

A third object of this invention is to provide a method of packet transmission in a packet switching system. The method provides at least one burst server interposed between any transmitting terminal and its corresponding receiving terminal through at least one link when said terminals are separated by at least two links. The burst server has the ability to store a received message packet, to request reservation of free links having the required bandwidth and sufficient storage capacity at the receiving-side burst server and to release the links after the transmission of the message packet is completed. Packet transmission is performed to reserve a necessary bandwidth through relevant links, and to reserve sufficient storage capacity for the message packet on the receiving side, from the transmitting terminal to a furthest-available burst server from the transmitting terminal, the transmission being repeated until the reservation is obtained. The received message packet is stored at said furthest-available burst server on the receiving-side. The link between the transmitting terminal and the furthest-available burst server is released after transmission of the message packet is completed. Packet transmission is performed to transmit the stored message packet from the furthest-available

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burst server to a second furthest-available burst server until the reservation is obtained. The received message packet is stored at each burst server as the message packet is received. The packet transmission for
5 transmitting the stored message packet to the furthest-available burst server until the reservation is obtained consecutively is repeated until the message packet is received at the receiving terminal. The release of the link used for transmitting the message packet after
10 completing transmission of the message packet at each concerned burst server is repeated consecutively until the message packet is received at the receiving terminal.

The first packet transmission method of the packet switching system described above may include the
15 burst servers being fixedly provided. Each burst server may designate the next burst server to which received message packet is transmitted. One of the burst servers which is connected to a subscriber exchange in which the transmitting terminal is accommodated may designate the
20 burst server to use. Restarting the request for reservation may convert the required bandwidth to another available bandwidth when the reservation of a link is blocked. An enquiry may be made as to the storage capacity of the receiving-side burst server when the
25 reservation is requested, the enquiry being performed using a bandwidth reservation request packet. The current receiving storage capacity may be notified at least to the

adjoining burst servers, so that they can recognize the current receiving storage capacity without enquiry.

A further object of the invention is to provide a packet transmission apparatus of a packet switching
5 system providing at least one burst server interposed between a transmitting terminal and a receiving terminal through at least one link when the terminals are separated by at least two links. The burst server firstly comprises means for performing packet transmission which requires
10 reservation of a necessary bandwidth through relevant links and sufficient storage capacity for the message packet at the next burst server. It also comprises means for storing the received message packet, and means for releasing the links which are used for transmitting after
15 the completion of transmission of the message packet.

A second packet transmission apparatus of a packet switching system is to provide at least one burst server interposed between a transmitting terminal and a receiving terminal through at least one link when the
20 terminals are separated by at least two links. The burst server comprises means for performing packet transmission which requires the reservation of a necessary bandwidth through relevant links and sufficient storage capacity for the message packet at a receiving server between the
25 transmitting server and the furthest-available burst server which is first blocked. It also comprises means for storing the received message packet, and means for

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releasing the link used for transmitting the message packet when the transmission of the message packet is completed at the burst server.

The packet transmission apparatus described above
5 may include means for designating the next burst server based on the place of the switch in which the receiving terminal is accommodated. The burst server accommodating the transmitting terminal may have means for designating the burst server to be used based on the place of the
10 switch in which the receiving terminal is accommodated. The burst server may comprise means for converting the bandwidth to another available bandwidth, and for restarting to make the reservation on the converted bandwidth when the former reservation is blocked. The
15 link reservation may be requested by using a bandwidth reservation request packet. The burst server may further comprise means for notifying the current storage capacity to at least adjoining burst servers, so that they are aware of the current storage capacity without enquiry.

20 Figure 1 is a block diagram showing the construction of a packet transmission apparatus of a conventional packet switching system;

Figure 2 is a sequence chart of packet transmission in the conventional system shown in Figure 1;

25 Figure 3 is a block diagram showing an embodiment of the arrangement of a relay apparatus of a packet transmission apparatus, to which the packet

transfer method for a packet switching system of the present invention is applied;

Figure 4 is a sequence chart of packet transmission in the packet transmission apparatus shown in Figure 3;

Figure 5 is a sequence chart that includes restarting of transmission after a change in the packet bandwidth when a block has occurred with the packet transmission apparatus shown in Figure 3;

Figure 6 is a diagram showing a routing table;

Figure 7 is a diagram showing a control packet;

Figure 8 is a block diagram showing the construction of an exchange switch of each node;

Figure 9 is a block diagram showing the construction of a burst server;

Figure 10 is a block diagram showing the network construction in which a terminal and the network have a burst-server-selecting function;

Figure 11 is a block diagram showing the construction of a burst server with a bandwidth-changing apparatus;

Figure 12 is a diagram showing the sequence of transmission in the first embodiment in which the reservation request from a particular burst server to the next burst server is started before packet transmission to the particular burst server comes to an end; and,

Figure 13 is a diagram showing the sequence of

transmission in a second embodiment in which the reservation request from a particular burst server to the next burst server is started before packet transmission to the particular burst server comes to an end.

5 Embodiments of the present invention are described below with reference to the drawings.

Figure 3 is a block diagram showing the arrangement of intermediate apparatus for packet transmission with the packet switching system of the present invention. Any
10 intermediate apparatus in the present embodiment is called a burst server.

For the convenience of description, burst server 0 serves as transmitting terminal x, and burst server 3 serves as receiving terminal y. Link 0, switch 1, link 1,
15 switch 2, link 2, switch 3, link 3, switch 4, link 4, switch 5, link 5, switch 6 and link 6 are connected between transmitting terminal x and receiving terminal y, and burst server 0 is connected to switch 1; burst server 1 is connected to switch 3; burst server 2 is connected to
20 switch 5; and burst server 3 is connected to switch 6.

In the following description, it is assumed that the route of communication between the transmitting and receiving terminals is determined in advance for simplified description. However, the present invention can be
25 applied similarly to another routing mode wherein the route of communication is not determined in advance, but is determined by performing bandwidth reservation. It is

assumed that each burst server knows in advance the serial order of links and burst servers to be passed on the route. For example, each burst server may have a list of links and burst servers to be passed as a routing table.

5 Figure 6 shows an example of a table provided in burst server 1. It is possible to write the names of links and burst servers through which a reservation packet has passed upon bandwidth reservation into a routing region of a packet payload.

10 Figure 7 is a diagram showing an example of the contents of the routing region of a reservation packet described above when the packet is transmitted from link 3 toward link 4 from burst server 0. Referring to Figure 7, the destination of the packet, the transmitting terminal
15 of the packet and the type of packet are described in the header, and the routing region is included as one of the regions in the packet payload. In the routing region, the names of links, switches and burst servers through which the packet has passed are described according to the order
20 of passage. In the example of Figure 7, it is shown that the packet has passed through link 1, link 2, burst server 1 and link 3 sequentially.

Each switch includes, as shown in Figure 8, buffer switch 601 for a packet switching function similar
25 to that of a common ATM switch, and bandwidth control apparatus 602. A bandwidth-reservation packet is inputted from input line 603 to bandwidth control apparatus 602,

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and bandwidth control apparatus 602 has the functions of:
producing a control packet such as a bandwidth-reservation
packet, a bandwidth-reservation-failure packet, a band-
width-cancel packet and a bandwidth-release packet,
5 producing a packet header so that the control packet may
be sent to an adjacent burst server or an adjacent switch
through a link, and inputting the packet header to buffer
switch 601 through signal line 604. Buffer switch 601 has
the functions of: directing the packet to the destination
10 written in the header of the packet, and outputting the
message packet and the control packet to the relevant
destination through output line 605.

Each burst server comprises packet buffer 701
for storing information, buffer-use-state-control
15 apparatus 710, and bandwidth-reservation function 702 as
shown in Figure 9. Packet buffer 701 stores a message
packet supplied through input line 703 and sends out, when
an outputting instruction is received from bandwidth-
reservation function 702 through signal line 704, the
20 message packet through output line 705 in order to send
the message packet to the relevant destination. Buffer-
use-state-control apparatus 710 always supervises the use
state of the buffer and holds such use state as the free
capacity of the buffer, increasing the rate of the used
25 area of the buffer and the degree of exceeding a prede-
termined capacity. Buffer-use-state-control apparatus 710
determines, in the present embodiment, when a bandwidth-

reservation packet inquires whether the burst server is available or not, the possibility of allotting free buffer capacity necessary for message packet transfer requested by the reservation packet, and provides an answer to the
5 packet. However, it is otherwise possible to employ another control wherein, when the free capacity of the buffer is insufficient, buffer-use-state-control apparatus 710 sends a server-use-suspension packet to the other burst servers and terminals in the network, and then when
10 the free capacity of the buffer becomes sufficient, buffer-use-state-control apparatus 710 sends a server-restoration packet to the other burst servers and terminals in the network, whereby it becomes possible to respond to an incoming reservation-request packet. The
15 answer to a possibility-to-use request to the buffer is based on the determination whether the free capacity of the buffer is sufficient, and is judged in the present embodiment in terms of whether the free capacity of the buffer is greater than the maximum size of the message
20 packet to be transmitted. However, it is otherwise possible to employ another method wherein the size of the information to be transmitted is described in the bandwidth-reservation packet, and then compared with the free capacity of the buffer. Bandwidth-reservation function
25 702 receives a control packet such as a reservation packet, a reservation-failure packet, a bandwidth-cancel packet or a bandwidth-release packet through input line

703, performs corresponding processing which is herein-
after described, produces a control packet corresponding
to the inputted packet, and sends out the control packet
to an adjacent switch or burst server through output line
5 705. When information to be transmitted is stored in
packet buffer 701, the burst server works like a trans-
mitting terminal. In this instance, bandwidth-reservation
function 702 sends out the control packet through output
line 705 so that the bandwidth required for the message
10 packet is reserved up to the burst server which is accom-
modating the receiving terminal. Further, when a band-
width-reservation-success packet is received, bandwidth-
reservation function 702 controls packet buffer 701, so
that the information in packet buffer 701 is sent out to
15 the relevant destination.

The bandwidth of link f , where $f = 1, 2, 3, 4, 5$, is controlled by the bandwidth control apparatus of
switch f . Further, for simplified description, it is
assumed that link 0 and link 6 require no bandwidth
20 control and no bandwidth reservation because they are used
exclusively by burst server 0 and burst server 3, respec-
tively, so bandwidth reservation succeeds without fail at
link 0 and link 6.

The first embodiment is described with reference
25 to Figure 3. The first embodiment is a system wherein a
message packet is transmitted step-by-step between burst
servers.

Burst server 0 sends to link 1 a bandwidth-reservation packet which requests the reservation of a required bandwidth at all links on the route to burst server 1. Upon reception of the bandwidth-reservation request packet, switch 1 indicates to the reservation-requesting packet that, when the requested bandwidth is greater than the remaining bandwidth held in link 1, the reservation has failed at link 1. Switch 1 rewrites the packet header into another packet header of the type which indicates a reservation-failure packet, and then it sends the reservation-failure packet back to burst server 0. In this instance, since a block has occurred, burst server 0 performs another request for reservation.

On the other hand, if the requested bandwidth is equal to or smaller than the remaining bandwidth held in link 1, the bandwidth-control apparatus of switch 1 allocates the requested bandwidth and subtracts the requested bandwidth from the remaining bandwidth. Switch 1 then proceeds to send the packet to link 2. When the reservation-request packet is received by switch 2, the bandwidth-control apparatus of switch 2 indicates to the reservation-request that, if the requested bandwidth is greater than the remaining bandwidth of switch 2, that the reservation has failed at link 2. Switch 2 rewrites the packet header into another packet header of the type which indicates a reservation-failure packet, and then it sends the reservation-failure packet back to burst server 0.

When the reservation-failure packet is received, switch 1 releases the reserved bandwidth of link 1. In this instance, since a block has occurred, burst server 0 performs another request for reservation.

5 On the other hand, if the reservation-request bandwidth is equal to or smaller than the remaining bandwidth held in link 2, the bandwidth-control apparatus of switch 2 allocates the requested bandwidth and subtracts the requested bandwidth from the remaining bandwidth.

10 Switch 2 then sends the packet to burst server 1.

 Burst server 1 confirms from the arrival of the bandwidth-reservation packet that the reservation at link 1 and link 2 has succeeded. When buffer-use-state-control apparatus 710 of burst server 1 indicates permission for
15 use, burst server 1 sends a reservation-success packet back to burst server 0. Upon reception of the reservation-success packet, burst server 0 sends the message packet to burst server 1. After the message packet is sent out, burst server 0 sends a link-reservation-release
20 packet to all of the links up to burst server 1. The bandwidth-control apparatus of switch 1 and switch 2 returns the bandwidth, which had been used by the message packet, to the status of an available bandwidth. On the other hand, when buffer-use-state-control apparatus 710 of
25 burst server 1 indicates rejection of use, the bandwidth-control apparatus of burst server 1 indicates to the
A bandwidth-reservation request packet that the reservation

has failed at burst server 1, rewrites the packet header as a reservation-failure packet, and sends the reservation-failure packet back to burst server 0. Upon receiving the reservation-failure packet indicating that a
5 block has occurred, burst server 0 performs another request for reservation.

Thereafter, the procedure described above is repeated in which burst server 1 acts as burst server 0; link 3 acts as link 1; link 4 acts as link 2; switch 3
10 acts as switch 1; and switch 4 acts as switch 2. In particular, burst server 1 sends to link 3 a bandwidth-reservation-request packet which requests reservations of a required bandwidth at all of the links on the route up to burst server 2. The bandwidth-control apparatus of
15 switch 3 having received the bandwidth-reservation-request packet indicates to the bandwidth-reservation-requesting packet that, when the requested bandwidth is greater than the remaining bandwidth of link 3, the reservation has failed at link 3, rewrites the packet header as a
20 reservation-failure packet, and sends the reservation-failure packet back to burst server 1. Upon receiving the reservation failure indicating that a block has occurred, burst server 1 performs another request for reservation.

On the other hand, when the requested bandwidth
25 is equal to or smaller than the remaining bandwidth of link 3, the bandwidth-control apparatus of switch 3 allocates the requested bandwidth and subtracts the

requested bandwidth from the remaining bandwidth. Further, switch 3 sends the packet to link 4. The bandwidth-control apparatus of switch 4 having received the reservation packet indicates to the requesting packet
5 that, when the requested bandwidth is greater than the remaining bandwidth of link 4, the reservation has failed at link 4, rewrites the packet header as a reservation-failure packet, and sends the reservation-failure packet back to burst server 1. When the reservation-failure
10 packet is received, switch 3 releases the reserved bandwidth of link 3. In this instance, since a block has occurred, burst server 1 performs another request for reservation.

On the other hand, when the requested bandwidth
15 is equal to or smaller than the remaining bandwidth of link 4, the bandwidth-control apparatus of switch 4 allocates the requested bandwidth and subtracts the requested bandwidth from the remaining bandwidth. Switch 4 then sends the packet to burst server 2.

20 Burst server 2 confirms from the arrival of the bandwidth-reservation packet that the reservation at link 3 and link 4 has succeeded. Further, when buffer-use-state-control apparatus 710 of burst buffer 2 indicates permission for use, burst server 2 sends a reservation-
25 success packet back to burst server 1. Upon receiving the reservation-success packet, burst server 1 sends the message packet to burst server 2. After the message packet

is sent out, burst server 1 sends a link-reservation-release packet to all of the links up to burst server 2. The bandwidth-control apparatus of switch 3 and switch 4 returns the bandwidth, which had been used by the message information, as a free bandwidth to the remaining bandwidths of link 3 and link 4, respectively. On the other hand, when buffer-use-state-control apparatus 710 of burst server 2 indicates rejection of use, burst server 2 indicates to the requesting packet that the reservation has failed at burst server 2, rewrites the packet header as a reservation-failure packet, and sends the reservation-failure packet back to burst server 1. Upon receiving the reservation-failure packet indicating that a block has occurred, burst server 1 performs another request for reservation.

Thereafter, burst server 2 sends to link 5 a bandwidth-reservation-request packet which requests reservation of a required bandwidth at all of the links on the route up to burst server 3. When switch 5 receives the bandwidth-reservation packet, if the requested bandwidth is greater than the remaining bandwidth of link 5, the bandwidth-control apparatus of switch 5 indicates to the bandwidth-reservation-requesting packet that the reservation has failed at link 5, rewrites the packet header as a reservation-failure packet, and sends the reservation-failure packet back to burst server 2. Upon receiving the reservation-failure packet, since a block

has occurred, burst server 2 performs another request for reservation.

On the other hand, when the requested bandwidth is equal to or smaller than the remaining bandwidth of link 5, the bandwidth-control apparatus of switch 5 allocates the requested bandwidth and subtracts the requested bandwidth from the remaining bandwidth. Further, switch 5 sends the packet to burst server 3.

Burst server 3 confirms from the arrival of the bandwidth-reservation packet that the reservation at link 5 has succeeded. Further, when buffer-use-state-control apparatus 710 of burst buffer 3 indicates permission for use, burst server 3 sends a reservation-success packet back to burst server 2. Upon reception of the reservation-success packet, burst server 2 sends the message packet to burst server 3. After the message packet is sent out, burst sever 2 sends a link-reservation-release packet to all of the links up to burst server 3. The bandwidth-control apparatus of switch 5 returns the bandwidth, which has been used for the message packet, as a free bandwidth to the remaining bandwidth of link 5. On the other hand, when buffer-use-state-control apparatus 710 of burst server 3 indicates a rejection for use, burst server 3 indicates to the bandwidth-reservation-request packet that the reservation has failed at burst server 3, rewrites the packet header as a reservation-failure packet, and sends the reservation-failure packet back to

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burst server 2. Upon receiving the reservation-failure packet, since a block has occurred, burst server 2 performs another request for reservation.

Figure 4 is a signal sequence chart illustrating that burst server 3 receives information from burst server 0 as a result of the sequence of operations described above.

A second embodiment according to the present invention is described with reference to Figure 3. The second embodiment is a system wherein attempts are made to complete reservations up to the furthest-available burst server until reservation of a link succeeds. If the reservation fails, a message packet is sent to the burst server positioned just before the link at which the reservation has failed, and the procedure is repeated by the burst server.

A burst server which has received message information to be transmitted is called a transmitting server. Initially, burst server 0 is the transmitting server. On the other hand, a burst server at a destination where a message information is sent is called a receiving server. The receiving server is fixed to burst server 3 in this embodiment.

The following procedure is recursively repeated to transmit a message packet to the receiving server.

The transmitting server sends to the receiving server a bandwidth-reservation-request packet, which

requests reservation of a required bandwidth at all of the links on the route from the transmitting server to the receiving server.

In switch j ($j = 1, 2, 3, 4$), which has received
5 the bandwidth-reservation-request packet, the bandwidth-control apparatus allocates the requested bandwidth and subtracts the requested bandwidth from the remaining bandwidth of link j if the requested bandwidth is equal to or smaller than the remaining bandwidth. Further, switch
10 j sends the packet to link $j+1$.

In switch 5, which has received the bandwidth-reservation-request packet, the bandwidth-control apparatus allocates the requested bandwidth and subtracts the requested bandwidth from the remaining bandwidth of switch
15 5 if the requested bandwidth is equal to or smaller than the remaining bandwidth of link 5. Burst server 3 indicates to the bandwidth-reservation-request packet that the reservation has succeeded at the links up to the receiving server, and sends a reservation-success packet to the
20 transmitting server. The transmitting server which has received the reservation-success packet sends a message packet to the receiving server from which the reservation-success packet has been transmitted. After the message packet is sent out, the transmitting server sends a link-reservation-release packet to all of the links up to the
25 receiving server. The bandwidth-control apparatus in each switch j ($j = 1, 2, 3, 4, 5$) returns to the remaining

bandwidth of link j the bandwidth which has been used for the transmission of the message packet.

After switch j ($j = 1, 2, 3, 4, 5$) has received the bandwidth-reservation-request packet, when the requested bandwidth is greater than the remaining bandwidth of link j , the bandwidth-control apparatus indicates to the bandwidth-reservation-request packet that the reservation has failed at link j , rewrites the packet header as a reservation-failure packet, and sends the reservation-failure packet back to the burst server (hereinafter referred to as a tentative-receiving server) positioned just before the link at which the reservation has failed. For instance, when link 1 or link 2 is the reservation-failure link, the reservation-failure packet is sent to burst server 0; when link 3 or link 4 is the reservation-failure link, the reservation-failure packet is sent to burst server 1; and when link 5 is the reservation-failure link, the reservation-failure packet is sent to burst server 2.

When switch k receives a reservation-failure packet, the bandwidth-control apparatus of switch k which controls link k returns the bandwidth which is reserved for the bandwidth-reservation-request packet to the remaining bandwidth of link k , and cancels the reservation.

When the tentative-receiving server which received the reservation-failure packet is the transmit-

ting server, since a reservation block has occurred, the transmitting server repeats the procedure described above after waiting a predetermined time.

By contrast, when the tentative-receiving server
5 which receives the reservation-failure packet is not the transmitting server, the tentative-receiving receiver having received the reservation-failure packet indicates to the reservation-failure packet that, when buffer-use-state-control apparatus 710 of the tentative-receiving
10 server indicates permission for use, the reservation has succeeded at the links up to the tentative receiving server, rewrites the packet header of the reservation-failure packet as a reservation-success packet, and sends the reservation-success packet to the transmitting server.
15 On the other hand, when buffer-use-state-control apparatus 710 of the tentative-receiving server indicates rejection for use, the tentative-receiving buffer sends the reservation-failure packet back to the transmitting server. Upon receiving the reservation-failure packet indicating
20 that a block has occurred, the transmitting server again repeats the procedure described above.

The transmitting server, having received the reservation-success packet, sends a message packet to the tentative-receiver server. After the message packet is
25 sent out, the transmitting server sends a link-reservation-release packet to all of the links up to the tentative-receiving server. The bandwidth-control apparatus of

each switch j ($j = 1, 2, 3, 4, 5$) returns the bandwidth which has been used for the transmission of a message packet as a free bandwidth to the remaining bandwidth of link j . Further, in this instance, since the message
5 packet is received by the tentative-receiving server, the procedure described above is repeated by the tentative-receiving server because the tentative-receiving server now acts as a transmitting server.

For example, if each of links 1, 2, 3 and 5 has
10 sufficient remaining bandwidth for reserving a requested bandwidth but only link 4 temporarily has insufficient remaining bandwidth, the procedure is modified as follows. Burst server 0 first attempts and succeeds to make a reservation for link 1 using a bandwidth-reservation packet
15 and then attempts and succeeds to make a reservation for link 2, whereafter it attempts and succeeds to make a reservation for link 3 and then attempts to make a reservation for link 4. The reservation unfortunately fails to be made at link 4, and a reservation-failure packet is
20 sent to burst server 1 and the reservation at link 3 is also cancelled. Burst server 1 now serves as a tentative-receiving server, and burst server 0 and burst server 1 transmit a message packet using the reserved bandwidths of links 1 and 2. Thereafter, burst server 1 attempts to
25 reserve a link using a bandwidth-reservation-request packet. If the reservation for link 4 succeeds, burst server 1 then attempts and succeeds to make a reservation

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for link 5. In this instance, the bandwidth-reservation-request packet arrives at burst server 3, and a reservation-success packet is sent from burst server 3 to burst server 1. Consequently, burst server 1 and burst server 3
5 transmit a message packet using the reserved bandwidths of links 1 and 2. A sequence chart of communication for the example described above is shown in Figure 5.

Further, in the first and second embodiments described above, if the buffers have sufficient capacity,
10 it is possible to modify the construction of the switches and burst servers, eliminating buffer-use-condition-control apparatus 710 and the procedure of inquiring as to availability of the buffers of the burst servers. The modified construction operates similarly to the construc-
15 tions of the first and second embodiments when each buffer in the first and second embodiments is always in an enabled condition so that it can be used at any time.

Further, in the first and second embodiments described above, all of the burst servers on the route
20 need not necessarily be used, and it is otherwise possible to employ a construction wherein only a limited numbers of burst servers are used in accordance with the determination of a terminal or the network.

It is also possible to employ a construction
25 wherein a transmitting source additionally has a selecting function for selecting a burst server or servers to be limited as described above. Further, it is also possible

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to employ a construction wherein the selecting function for selecting a burst server is provided in the network. The selecting function determines a burst server using variable information, such as the load condition of the network and structural information such as the number of links between the transmitting and receiving terminals. Figure 10 shows an example of a construction wherein selecting function 801 is added to the transmitting terminal and selecting function 802 is provided in the network. In the examples shown in Figure 10, selecting function 801 placed in the transmitting terminal has the procedures for selecting burst servers to be used from the number of links between the transmitting and receiving terminals, and for selecting a number of burst servers equal to or smaller than one third the number of links at random from all of the burst servers on the route between the transmitting and receiving terminals.

It is to be noted that, while a burst server operating as a part of the network functions like a switch or a link in the embodiments described above, constructions are also possible in which a burst server operates independently of the network and in which some burst servers act as part of the network functions and other burst servers act independently from the network in a mixed condition.

Further, it is also possible to modify the constructions of the first and second embodiments so as to

reserve, when a bandwidth-reservation-request packet is to be sent from an arbitrary burst server j (j is not equal to 0) in order to send a message packet, a bandwidth the same size as or another bandwidth different from that of the bandwidth reserved by burst server h ($h < j$). Figure 11 shows an example of a construction wherein the second embodiment is modified so that a bandwidth-changing function 909 for changing the bandwidth as described above is additionally provided for burst server 1. For example, when burst server 0 requests reservation of bandwidth B , if each of links 1, 2, 3 and 5 has a remaining bandwidth sufficient to reserve requested bandwidth B but only link 4 temporarily has an insufficient remaining bandwidth, the following communication can be performed using the bandwidth changing function. Burst server 0 first attempts and succeeds in reserving link 1 using a bandwidth-reservation-request packet, and then attempts and succeeds in reserving link 2. It then attempts and succeeds in reserving link 3, and then attempts to reserve link 4. The reservation fails at link 4, and a reservation-failure packet is sent to burst server 1; the reservation for link 3 is also cancelled. Burst server 1 now serves as a tentative-receiving server, and burst server 0 and burst server 1 transfer a message packet in bandwidth B using the reserved bandwidths of links 1 and 2. Thereafter, burst server 1 sets requested reserved bandwidth B' to $B' < B$, that is, reduces requested reserved bandwidth B' , and

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attempts to reserve link 4 using a bandwidth-reservation-request packet. Since the requested bandwidth is smaller, the reservation for link 4 succeeds. Consequently, burst server 1 then attempts and succeeds in reserving link 5.

5 In this instance, the bandwidth reservation packet arrives at burst server 3, and a reservation-success packet is sent from burst server 3 to burst server 1. Consequently, burst server 1 and burst server 3 transmit a message packet in bandwidth B' using the reserved bandwidths of
10 links 1 and 2.

Also in the first embodiment, a construction is possible wherein a bandwidth-changing function for changing the bandwidth is additionally provided in a similar manner for burst server 1.

15 In the first and second embodiments described above with reference to Figures 4 and 5, after a transmission of a message packet to a burst server comes to an end, another reservation request is started for another burst server. However, another reservation
20 request may be started for another burst server after the lapse of an arbitrary time, immediately after a transmission of a message packet is started and without waiting until the message packet transmission comes to an end. Figures 12 and 13 illustrate possible transmission
25 sequences for constructions of the first and second embodiments, respectively, modified so that another reservation request is started for another burst server

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after the lapse of an arbitrary time immediately after reception of the message packet described above.

In this manner, according to the present invention, since a burst server is employed, a message packet can be sent without the necessity that bandwidth reservation succeeds simultaneously at all of the links up to a receiving terminal. In other words, it is possible to reduce K in the equation $G = Kg$ which defines an end-to-end block rate G described above under the related art. Accordingly, since block rate g of each link is fixed, a remarkable reduction of the end-to-end block rate can be anticipated. Further, since a message packet is actually sent to any link at which the reservation has succeeded, the utilization efficiency or throughput of the links of the entire network can be enhanced. Further, where the buffer capacity of a server for storing the message packet is small, loss of message packet by an overflow of the buffer can be eliminated in transmission of a message packet by taking advantage of the utilization condition of the buffer. Consequently, the situation can be prevented in which resending resulting from loss brings about an unnecessary increase of traffic on the network and causes congestion of the network, and in which an increased delay by resending degrades the quality of communication.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A packet transmission method for a packet
switching system, the method comprising the steps of:

(a) interposing a series of burst servers between a
transmitting terminal and a receiving terminal through a
5 series of links, each burst server having the ability to
store a message packet that is received, to request reser-
vation of a link that is free and has a required bandwidth
for transmitting the message packet, to request reserva-
tion of a sufficient receiving-side storage capacity for
10 the message packet to be sent on the link, and to release
the link immediately after transmission of the message
packet is completed;

(b) reserving, for each of the following pairs, a
link that is free between the pair and sufficient storage
15 capacity at a receiving one of the pair:

(i) the transmitting terminal and a first
interposed burst server closest to the transmitting
terminal; and,

(ii) pairs of interposed burst servers, ex-
20 tending from the first interposed burst server to a
first furthest-available burst server;

(c) transmitting a message packet from the transmit-
ting terminal to the first furthest-available burst server
via interposed burst servers extending therebetween;

25 (d) releasing, immediately after the message packet has reached the first furthest-available burst server, the links that were reserved between the transmitting terminal and the first furthest-available burst server via the interposed burst servers extending therebetween;

30 (e) performing additional steps, corresponding to steps (b) to (d), for transmission of the message packet from the first furthest-available burst server to a second furthest-available burst server, the additional steps being repeated to move the message packet sequentially
35 between subsequent furthest-available burst servers until the message packet is received at the receiving terminal.

2. A packet transmission method for a packet switching system, the method comprising the steps of:

(a) interposing at least one burst server between a transmitting terminal and a receiving terminal through at
5 least one link, said at least one burst server having the ability to store a message packet that is received, to request reservation of a link that is free and has a required bandwidth for transmitting the message packet, to request reservation of a sufficient receiving-side storage
10 capacity for the message packet to be sent on the link, and to release the link immediately after transmission of the message packet is completed;

(b) reserving a link that is free between the transmitting terminal and a first burst server, closest to the

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15 transmitting terminal, and reserving sufficient storage capacity on the first burst server;

(c) transmitting a message packet from the transmitting terminal to the first burst server;

(d) storing the message packet at the first burst
20 server;

(e) releasing the link between the transmitting terminal and the first burst terminal;

(f) performing additional steps, corresponding to steps (b) to (e), for transmission of the message packet
25 between burst servers, if there is more than one burst server, the additional steps being repeated until the message packet is stored on a burst server closest to the receiving terminal;

(g) performing further steps, corresponding to steps
30 (b) to (e), for transmission of the message packet to the receiving terminal from the burst server closest to the receiving terminal; and,

(h) notifying at least adjoining burst servers of a current receiving storage capacity so that the adjoining
35 burst servers can recognize the current receiving storage capacity without inquiry.

3. The packet transmission method for a packet switching system as in claim 1, wherein the burst servers are fixedly provided.

4. The packet transmission method for a packet switching system as in claim 1, wherein each of the burst servers designates a next burst server to which a received message packet is transmitted.

5. The packet transmission method for a packet switching system as in claim 1, wherein one of the burst servers, which is connected to a subscriber exchange in which the transmitting terminal is accommodated, has the step of designating which burst servers are to be used.

6. The packet transmission method for a packet switching system as in claim 1, wherein said method further comprises the step of restarting a link-reservation request by converting the bandwidth to another available bandwidth when the link-reservation request is blocked.

7. The packet transmission method for a packet switching system as in claim 1, wherein an enquiry of the storage capacity of a receiving-side burst server when a request is made for a reservation is performed using a bandwidth-reservation-request packet.

8. The packet transmission method for a packet switching system as in claim 1, wherein the method comprises the further step of notifying a current receiving

storage capacity to at least adjoining burst servers so that the adjoining burst servers can recognize the current receiving storage capacity without inquiry.

9. A packet transmission apparatus for a packet switching system, the apparatus comprising:

at least one burst server interposed between a transmitting terminal and a receiving terminal through at least
5 one link when the terminals are separated by at least two links, each burst server having means for performing packet transmission and including:

message-packet storage means for storing a message packet that is received;

10 reservation-request means to request (i) reservation of links that are free to a furthest-available burst server, and that have a required bandwidth for transmitting the message packet to the furthest-
available burst server, and (ii) reservation of a
15 sufficient receiving-side storage capacity for the message packet at the furthest-available burst server, the furthest-available burst server being, in a path of burst servers, a last burst server in the path that allows the reservations;

20 link release means to immediately release the links after the message packet has been transmitted on the links to the furthest-available burst server.

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10. The packet transmission apparatus for a packet switching system as in claim 9, wherein said burst server further comprises means for designating the next burst server based on a placement of a switch in which the receiving terminal is accommodated.

11. The packet transmission apparatus for a packet switching system as in claim 9, wherein a burst server which accommodates the transmitting terminal comprises means for designating the burst server to be used based on the position of the switch in which the receiving terminal is accommodated.

12. The packet transmission apparatus for a packet switching system as in claim 9, wherein said burst server comprises means for converting the bandwidth to another available bandwidth and for restarting the reservation request for the converted bandwidth when the former reservation is blocked.

13. The packet transmission apparatus for a packet switching system as in claim 9, wherein said link reservation is requested by using a bandwidth-reservation-request packet.

14. The packet transmission apparatus for a packet switching system as in claim 9, wherein said burst server

further comprises means for notifying the current storage capacity to at least adjoining burst servers so that they can recognize the current storage capacity without enquiry.

15. A packet transmission method for a packet switching system, said packet switching system having at least one burst server interposed in a path extending between any transmitting terminal and a corresponding receiving terminal, message packets being transmitted through at least one link when said terminals are separated by at least two links, said burst server having a storage capacity adequate to store a received message packet, said system including means for requesting a reservation of free links on a basis of a required bandwidth and a sufficient storage capacity at the receiving burst server, and means for releasing the links after transmission of the message packet is completed, said method comprising:
- 15 performing a packet transmission on a basis of a reservation of a link having a necessary bandwidth through selected links and to a receiving burst server having a sufficient capacity for storing the message packet at the receiving end of said link, the message packet being sent
- 20 from the transmitting terminal over reserved links to a furthest-available burst server;

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storing the receiving message packet at said
furthest-available burst server;

releasing the link between the transmitting terminal
25 and the furthest-available burst server immediately after
completing a transmission of the message packet;

performing a second packet transmission for transmit-
ting the stored message packet from the furthest-available
burst server to a next-furthest-available burst server
30 until the reservation is obtained;

storing the received message packet at each burst
server when the message packet is received;

repeating said packet transmission for transmitting
the stored message packet to the next-furthest-burst ser-
35 ver until the consecutive reservation of free links is
obtained and until the message packet is received at the
receiving terminal; and,

repeating the release of the link used for transmit-
ting the message packet immediately after completing the
40 transmission of the message packet at each concerned burst
server consecutively until the message packet is received
at the receiving terminal.

16. The packet transmission method for a packet
switching system as in claim 15, wherein the burst servers
are provided on a fixed basis.

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17. The packet transmission method for a packet switching system as in claim 15, wherein each of the burst servers designates the next burst server in turn as to which a received message packet is transmitted.

18. The packet transmission method for a packet switching system as in claim 15, wherein one of the burst servers which is connected to a subscriber exchange in which the transmitting terminal is accommodated provides the added step of designating the burst servers that are used.

19. The packet transmission method for a packet switching system as in claim 15, wherein said method further comprises the step of restarting the link reservation request by converting the requested bandwidth to another available bandwidth when the request link reservation request is blocked.

20. The packet transmission method for a packet switching system as in claim 15, wherein an enquiry of the storage capacity of the receiving-side burst server at the request of said reservation is performed using a requested bandwidth reservation request packet.

21. The packet transmission method for a packet switching system as in claim 15, wherein the method com-

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prises the further step of notifying the current receiving storage capacity to at least adjoining burst servers so that they can recognize the current receiving storage capacity without inquiry.

22. A packet transmission apparatus for a packet switching system having at least one burst server interposed between a transmitting terminal and a receiving terminal, transmission being through at least one link
5 when the terminals are separated by at least two links, said burst server comprising:

means for performing packet transmission which requires a reservation of a necessary bandwidth through relevant links and a sufficient storage capacity for
10 storing the message packet at the furthest-available burst server which is a first-blocked burst server in a path including a plurality of burst servers;

means for storing a message packet as it is being received; and,

15 means for releasing the link used for transmitting the message packet responsive to a complete transmission and storage of the message packet at the burst server.

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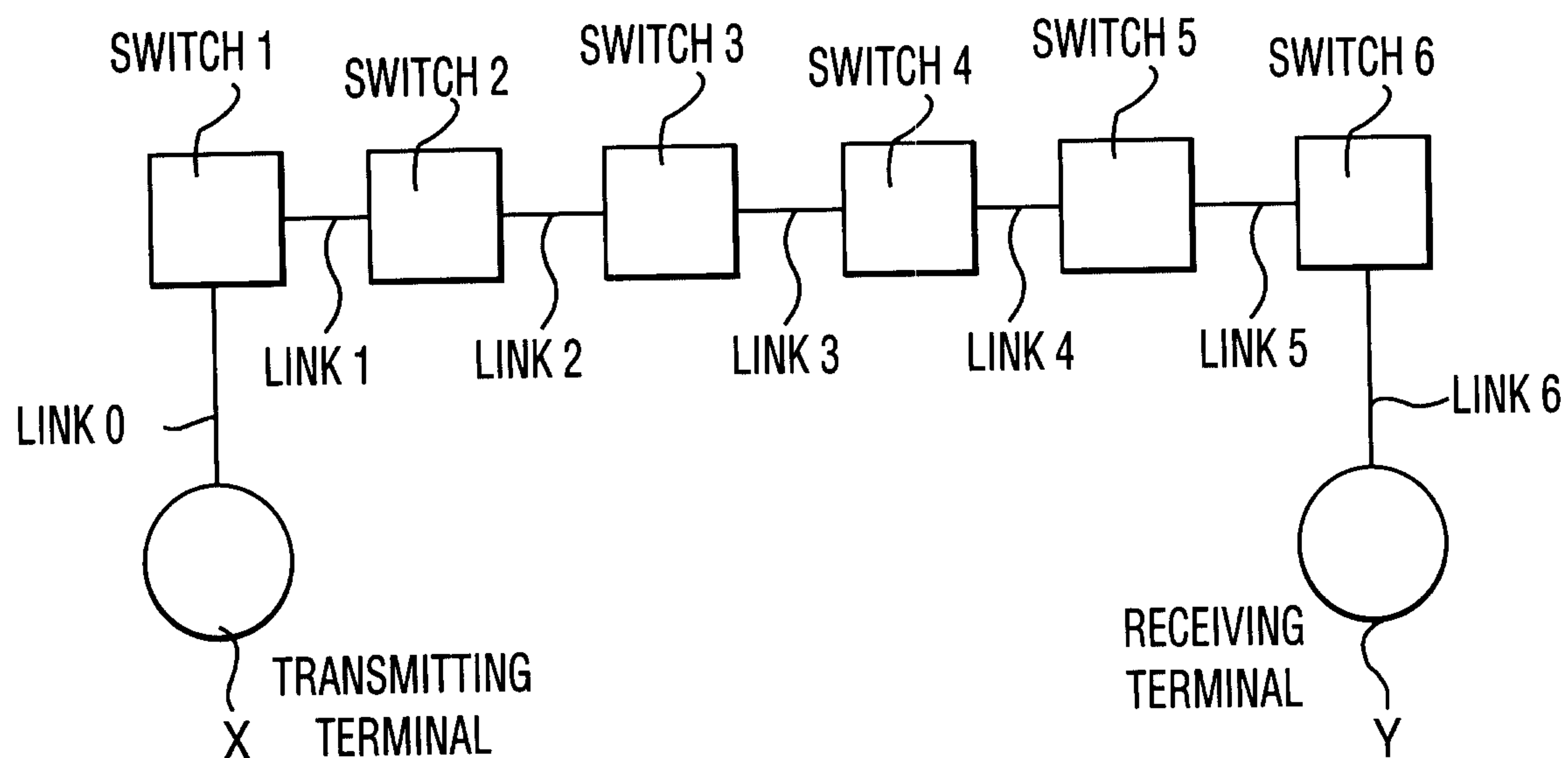


FIG.1 (Prior Art)

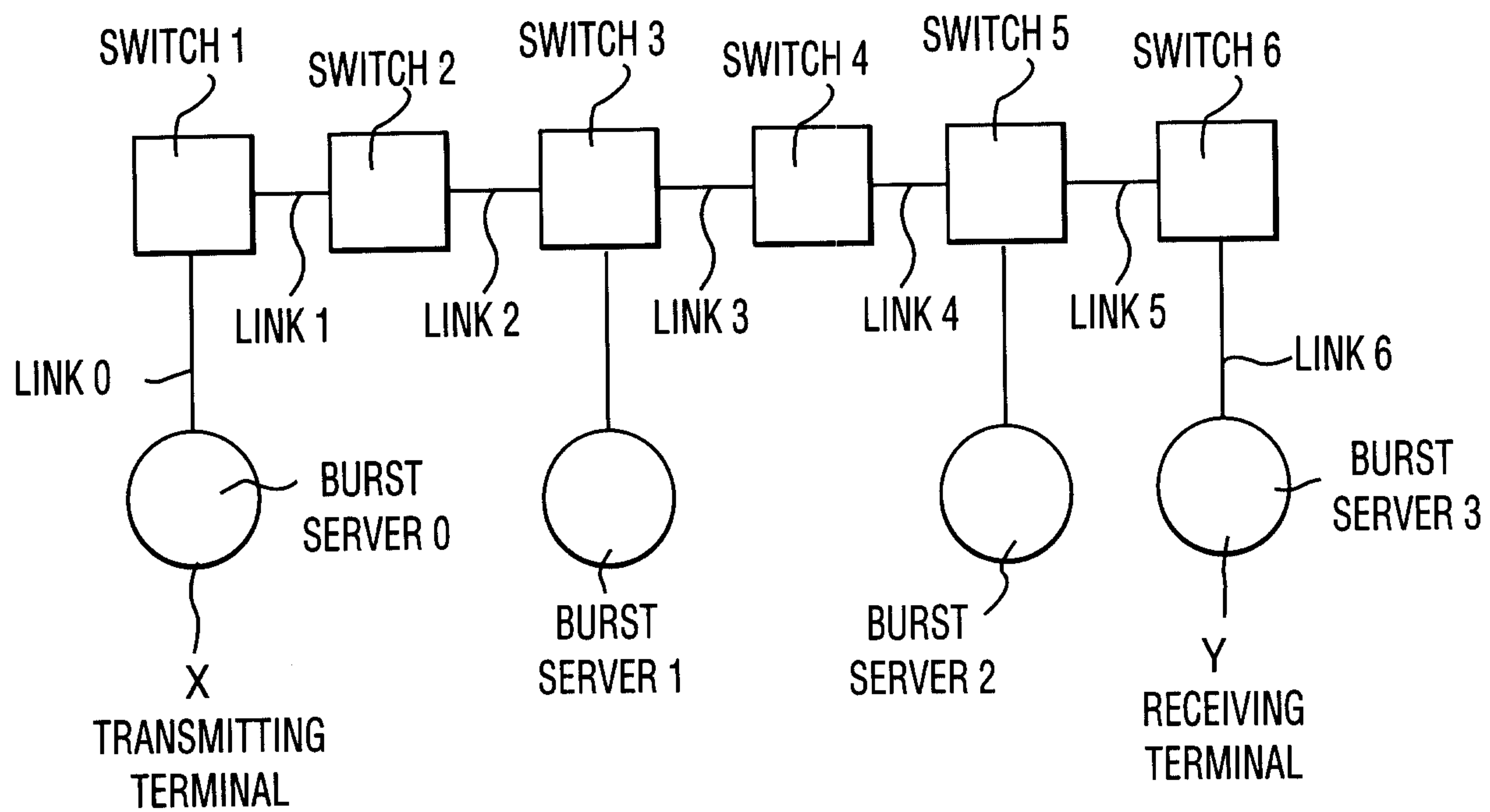


FIG.3

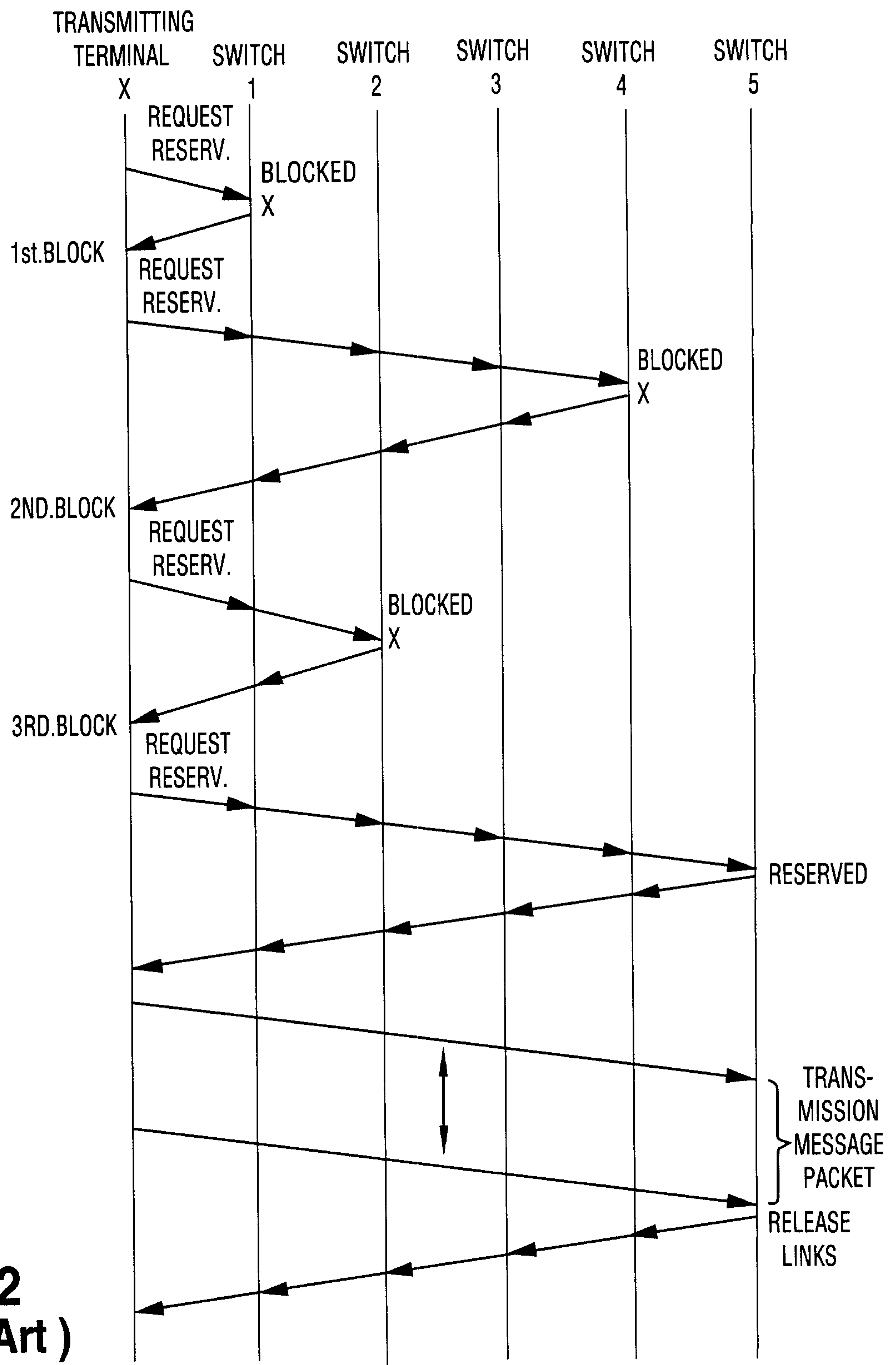


FIG.2
(Prior Art)

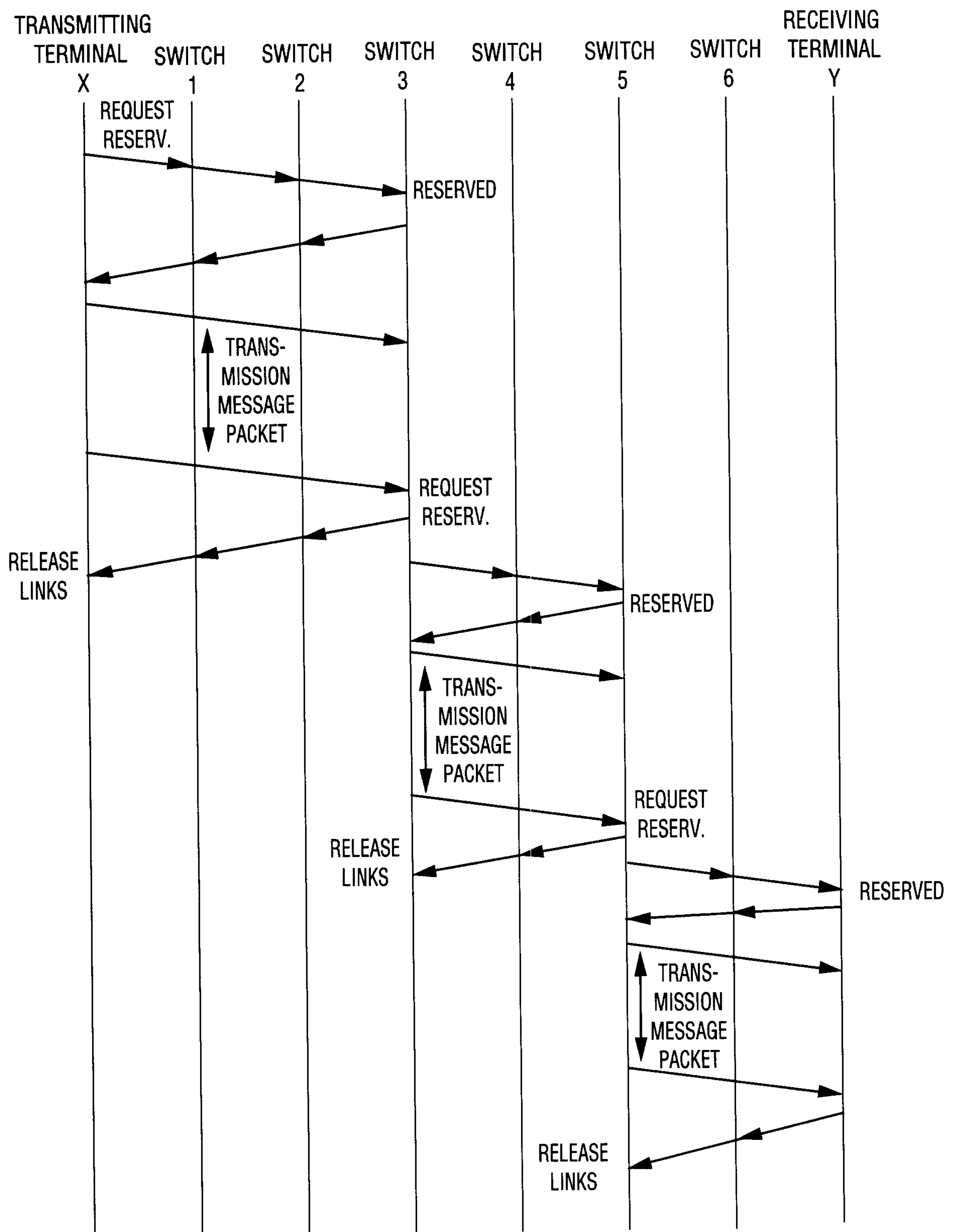


FIG.4

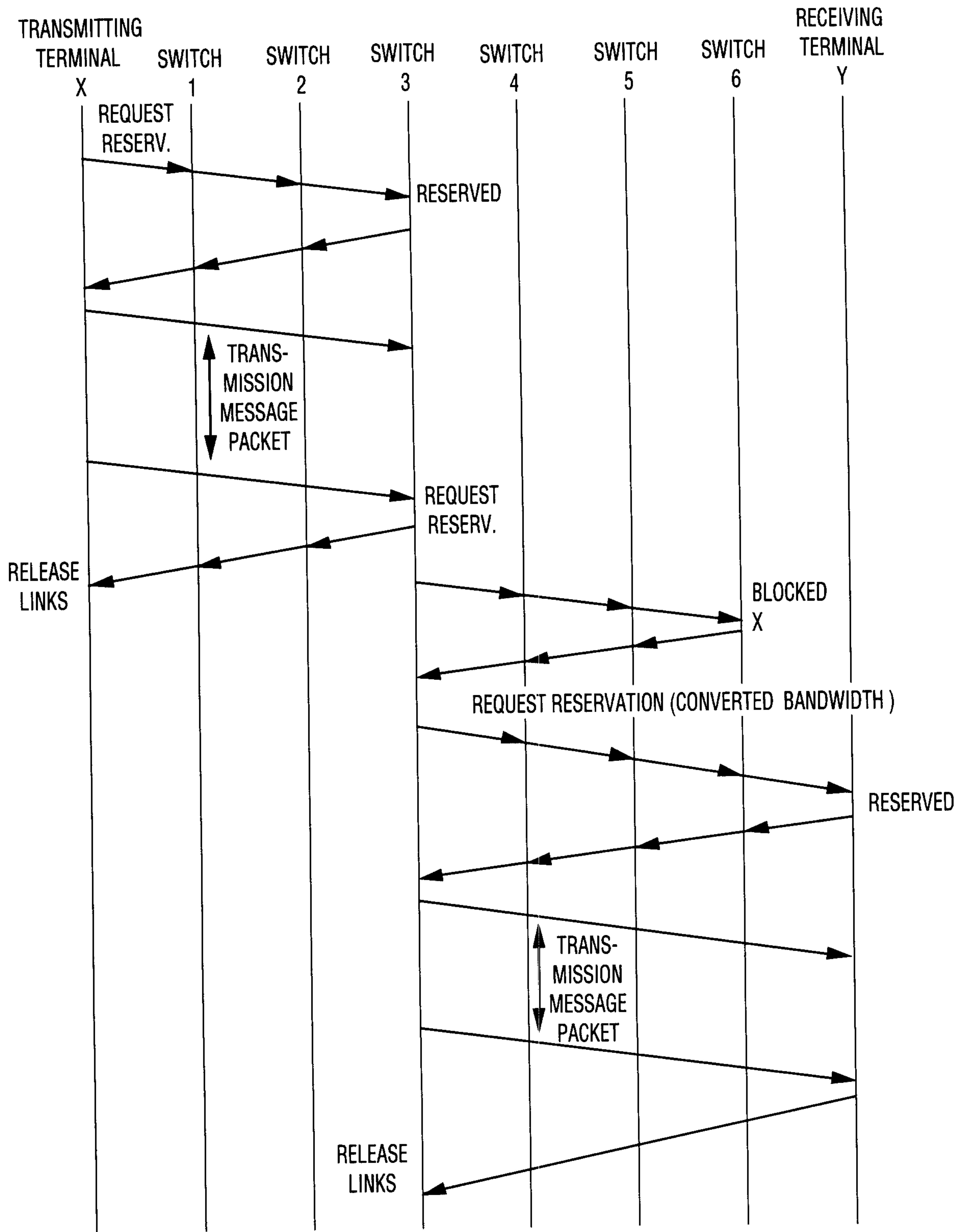


FIG.5

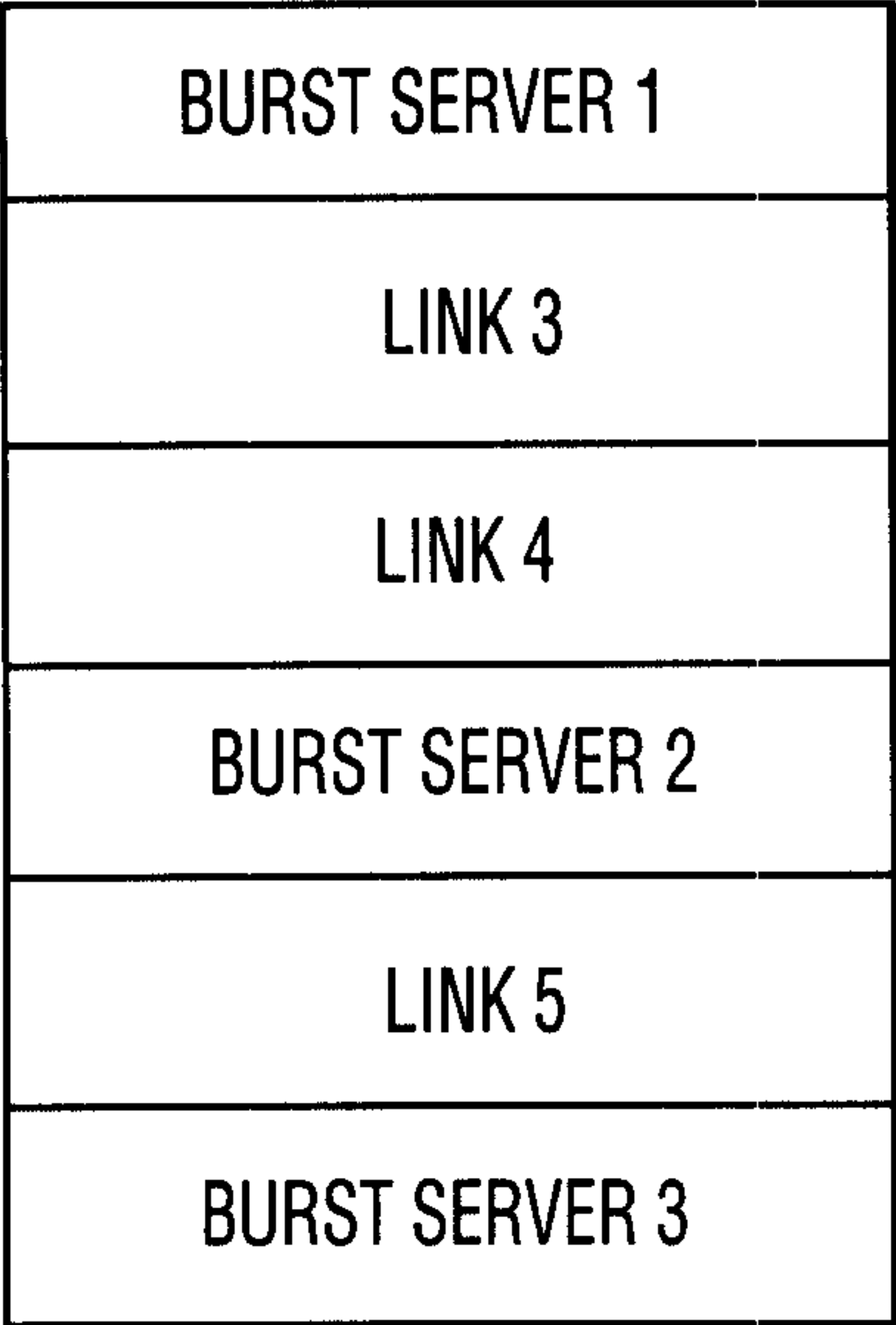


FIG.6

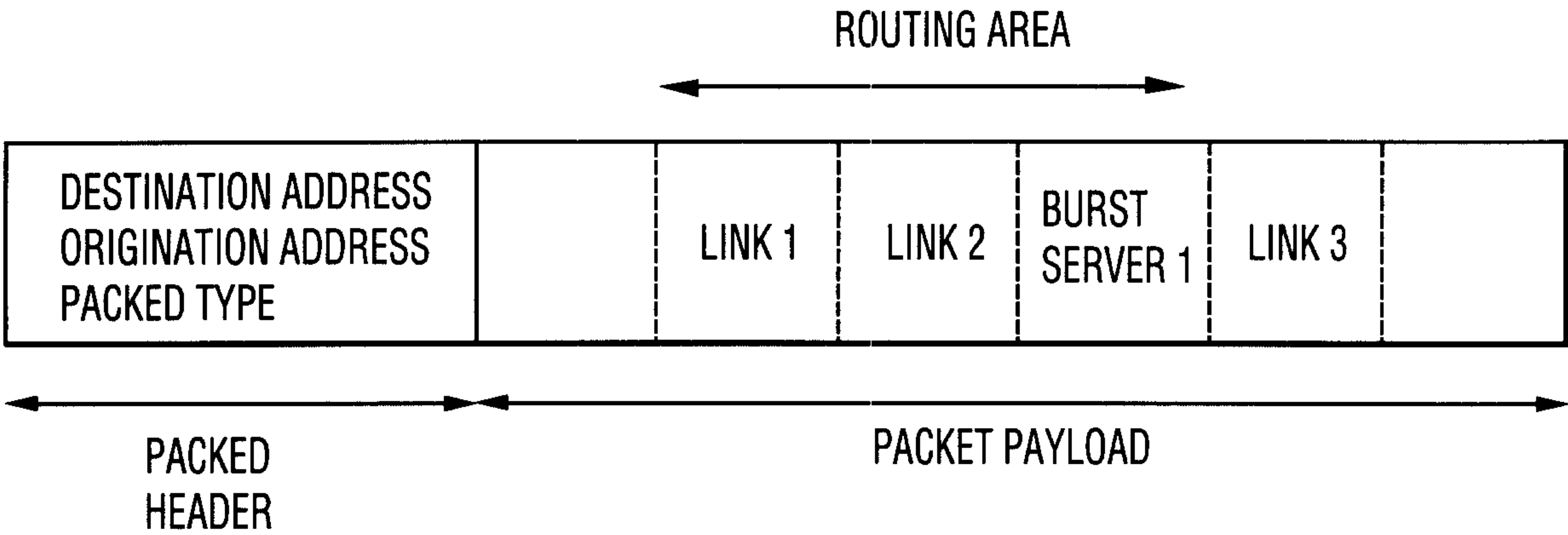


FIG.7

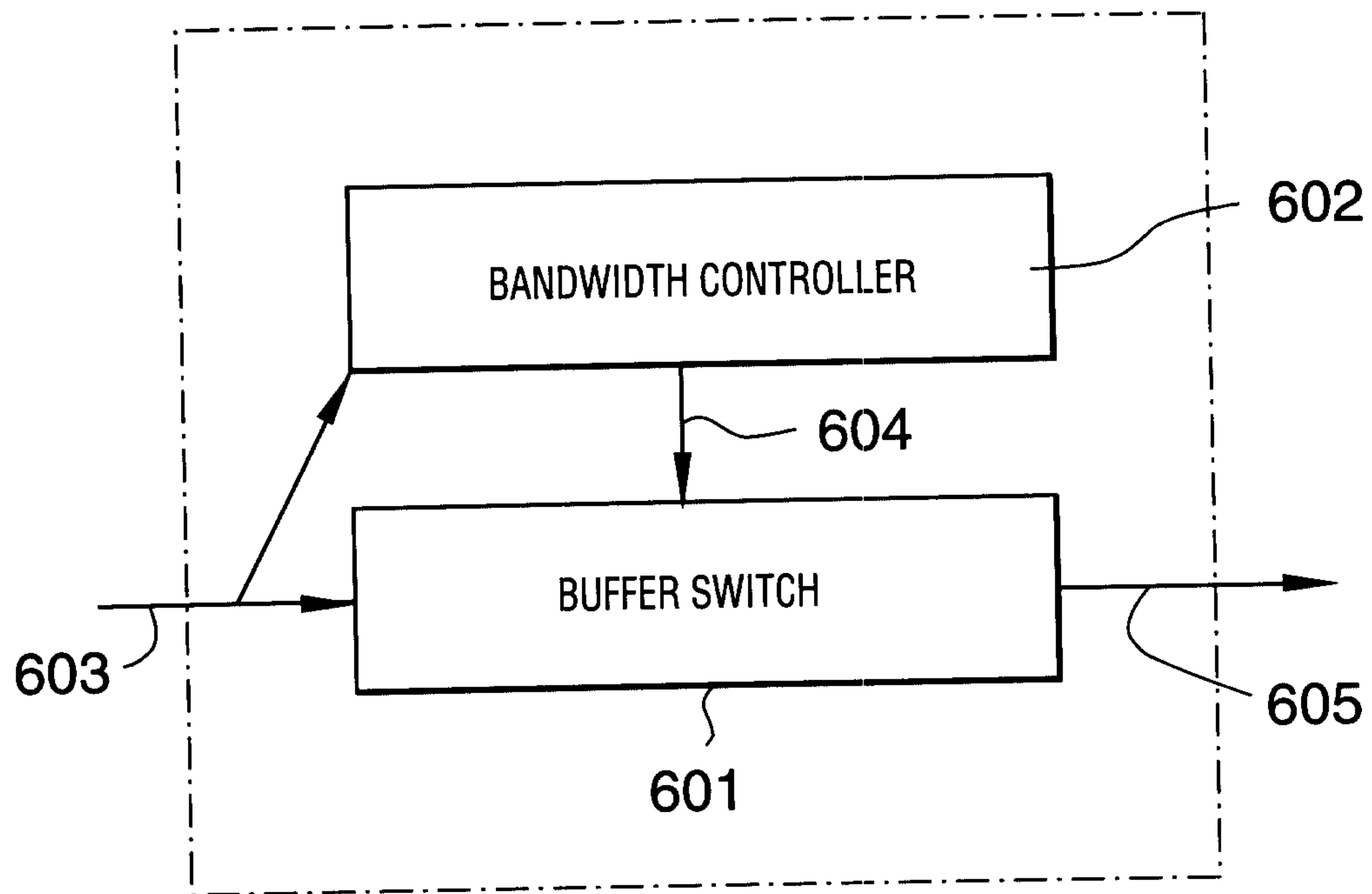


FIG. 8

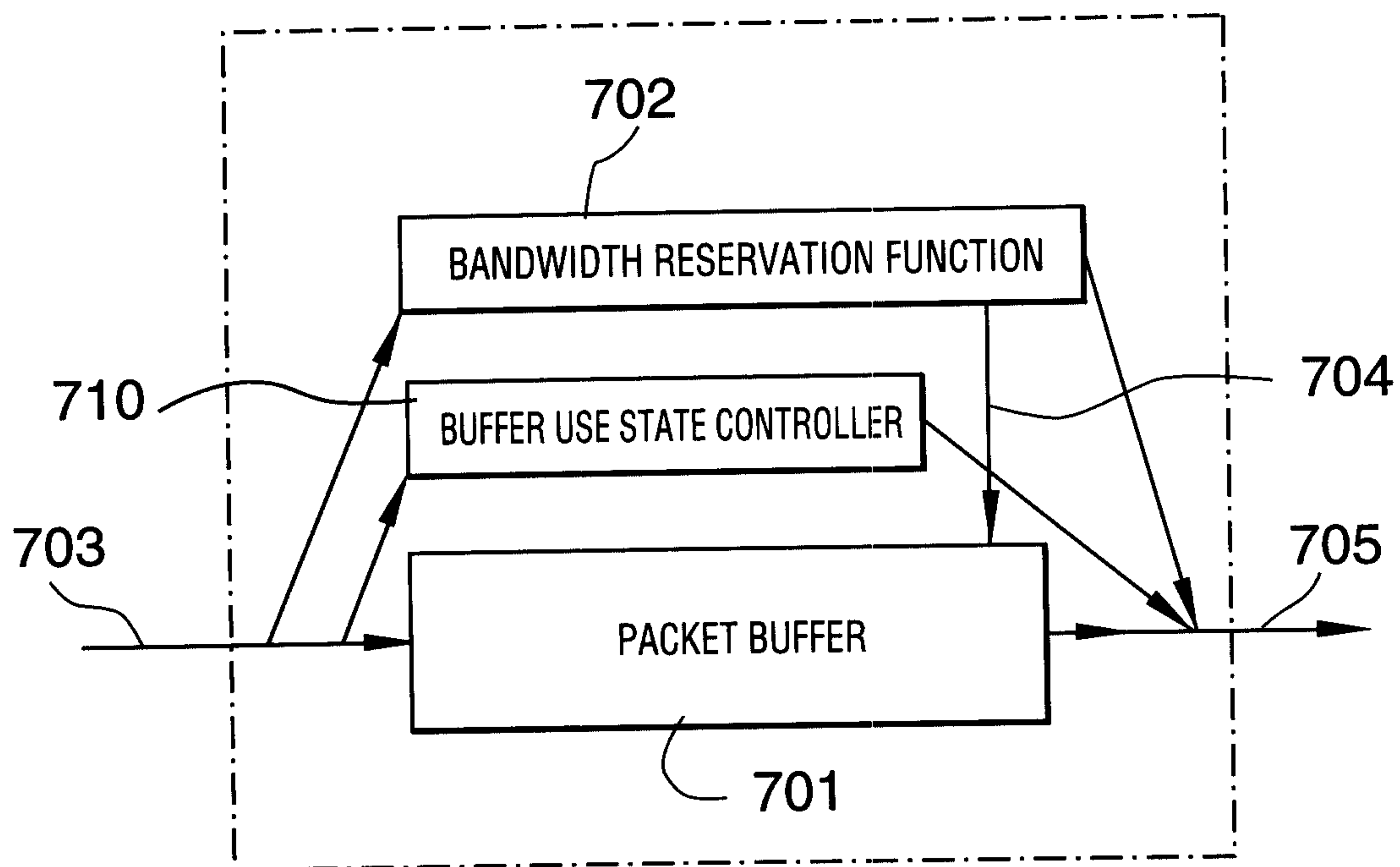


FIG. 9

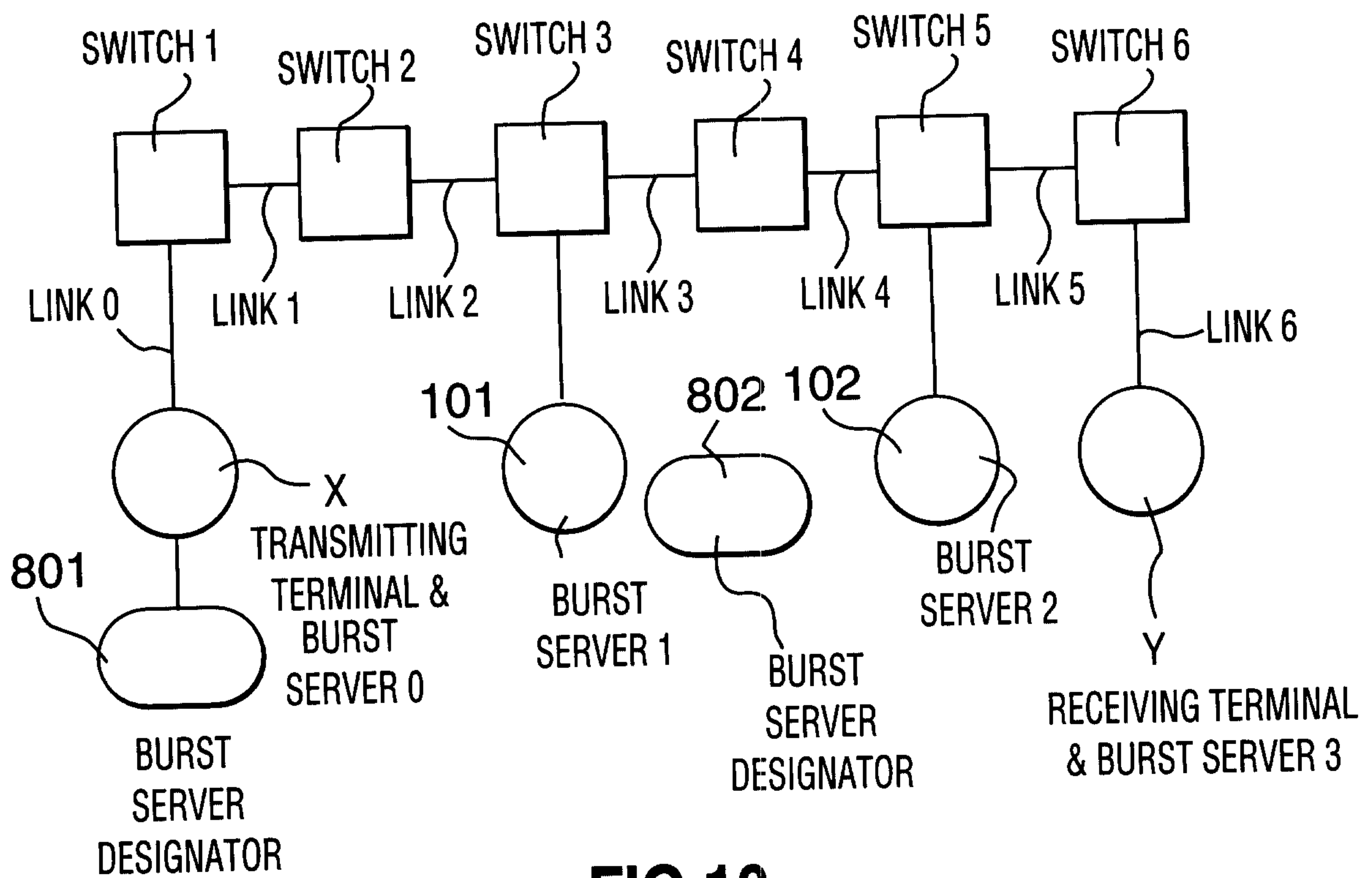


FIG.10

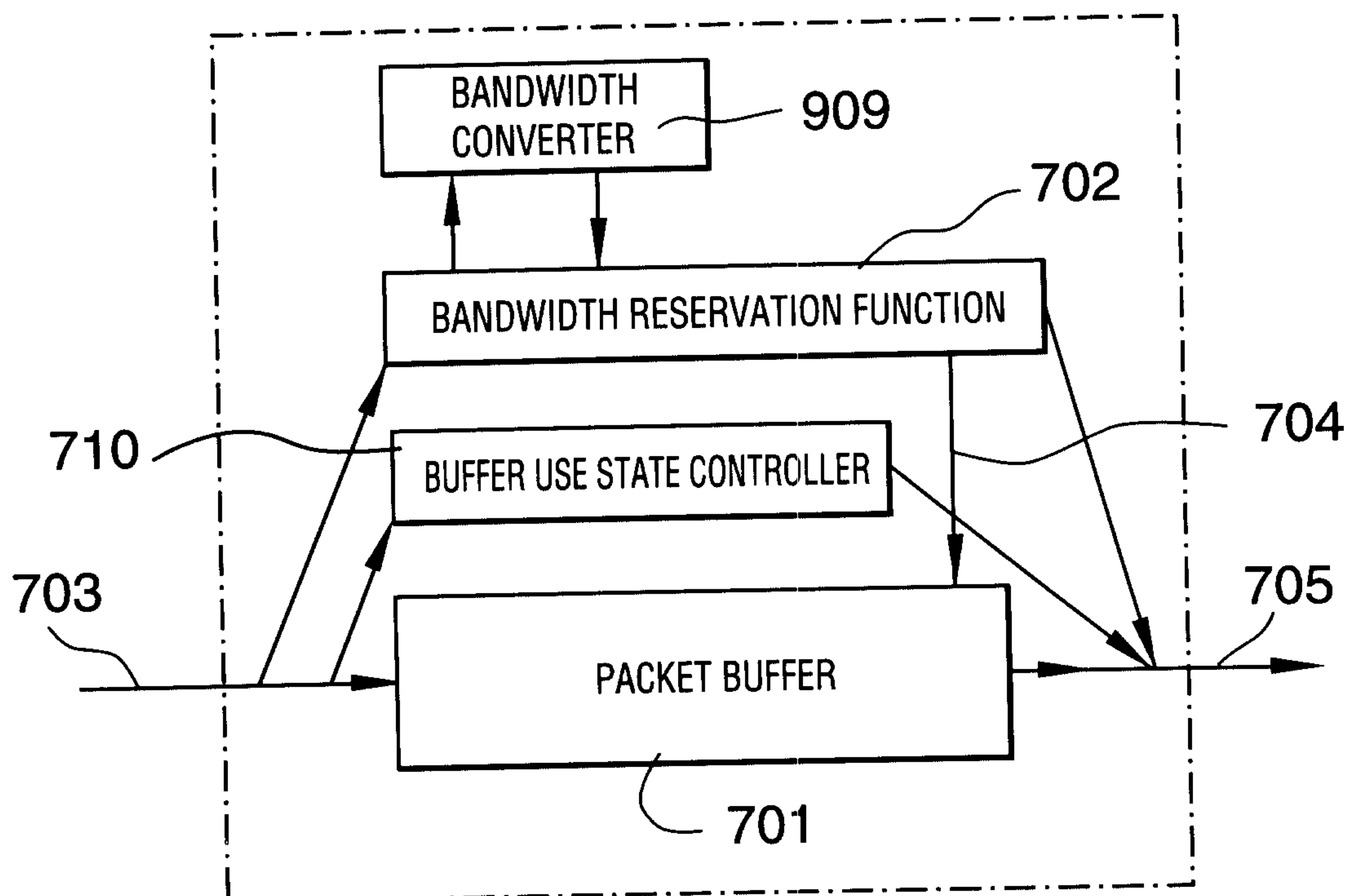


FIG.11

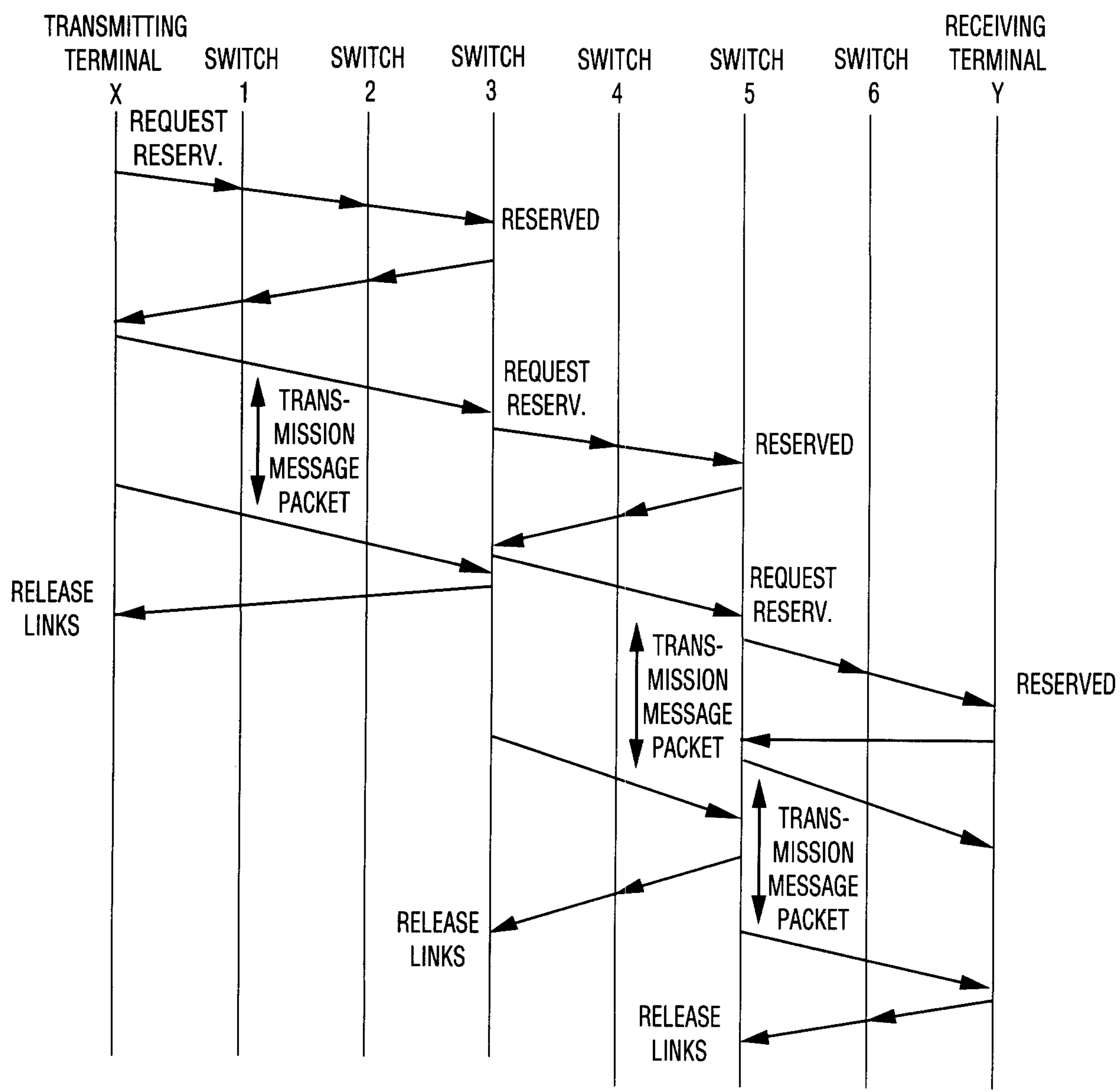


FIG.12

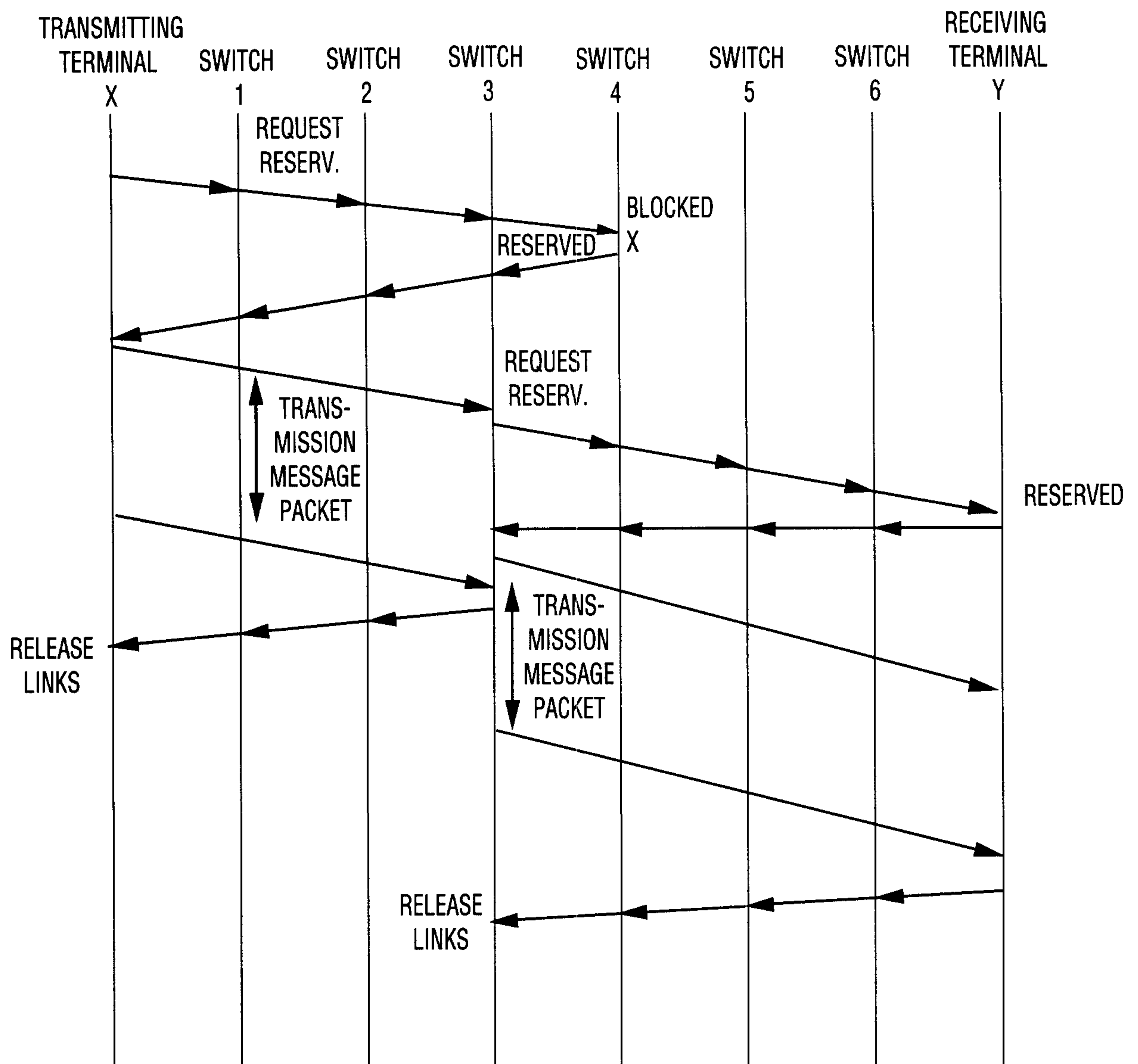


FIG.13