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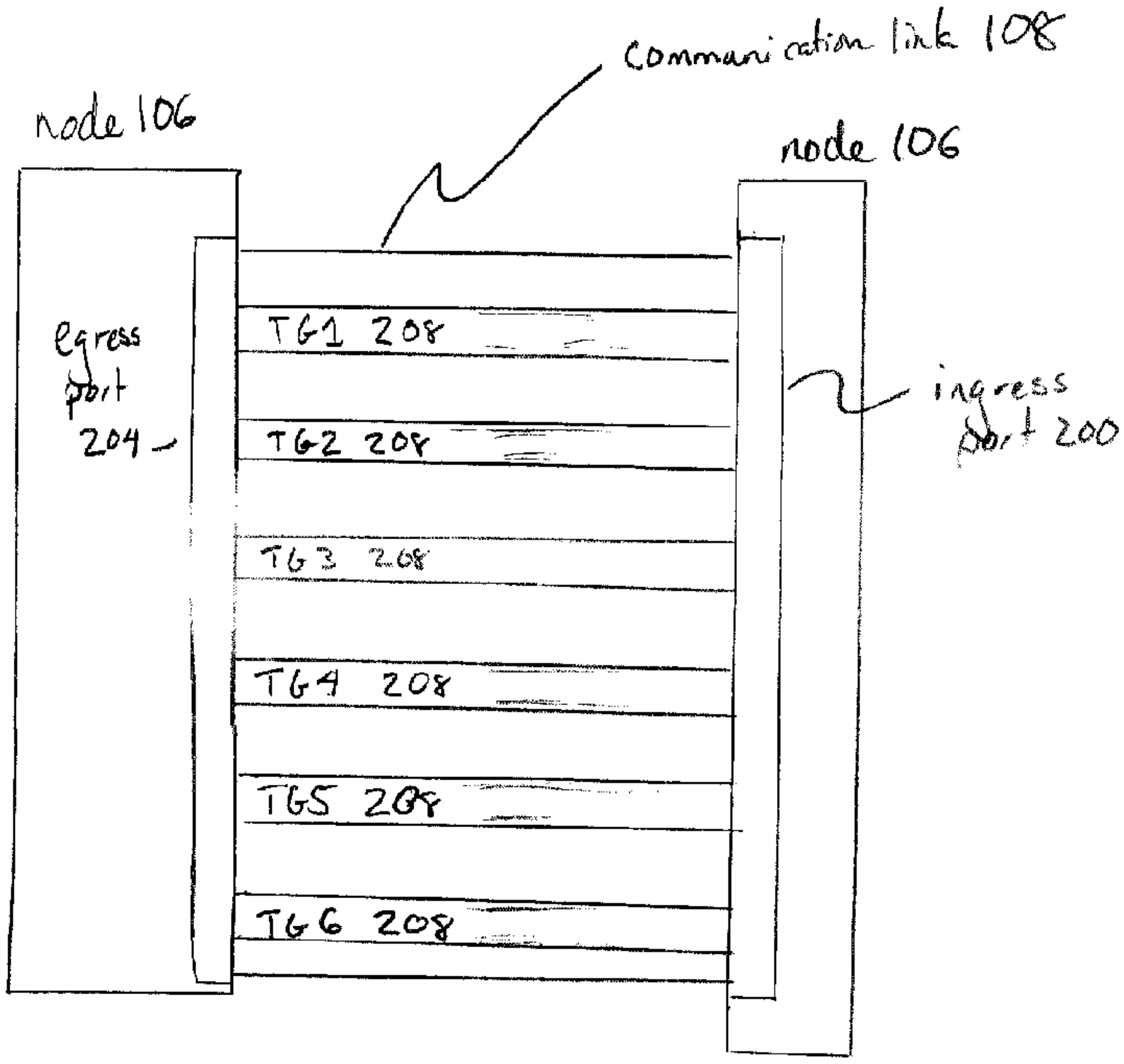


(57) Abrégé/Abstract:
The invention provides a system and method of a selecting an egress connection from egress connections at a node for a call being established in a network along a path being associated with the node. The invention determines which connections have sufficient bandwidth to carry the call and which connections have a service category being compatible with a service requirement for the call. For connections which are able to carry the call, the invention evaluates an administrative factor score for each connection, then if one score for a particular connection is superior to all other scores, the particular connection is selected as the egress connection. Otherwise, if at least two administrative factor scores are equally superior to all other administrative factor scores, then the egress connection is selected from the connections having the equally superior scores utilizing a bandwidth load balance value for those connections.

ABSTRACT

The invention provides a system and method of a selecting an egress connection from egress connections at a node for a call being established in a network along a path being associated with the node. The invention determines which connections have sufficient bandwidth to carry the call and which connections have a service category being compatible with a service requirement for the call. For connections which are able to carry the call, the invention evaluates an administrative factor score for each connection, then if one score for a particular connection is superior to all other scores, the particular connection is selected as the egress connection. Otherwise, if at least two administrative factor scores are equally superior to all other administrative factor scores, then the egress connection is selected from the connections having the equally superior scores utilizing a bandwidth load balance value for those connections.

TITLE: SYSTEM AND METHOD FOR PARALLEL CONNECTION SELECTION IN A COMMUNICATION NETWORK

FIELD OF THE INVENTION

The invention relates generally to a system and method for selecting a communication connection from a plurality of communication connections connecting a node to another node in a communication network. In particular, the invention relates to a system and method for selecting a trunk group from a number of trunk groups for a node when a connection, such as a Switched Virtual Connection (SVC), is being established.

BACKGROUND OF INVENTION

In a communication network where a series of nodes are interconnected via various communication links, calls are established in the network by routing a connection through the network from an ingress node to an egress node. The calls may be established by an operator at a network management terminal connected to the network.

In an ATM network, several types of calls may be established, with each call having distinctive characteristics. A permanent virtual circuit (PVC) establishes a permanent connection from an ingress node to an egress node. At each node in the connection, a permanent bearer channel cross-connection is established by the network management terminal, which decides the route and manually configures each cross-connection at each node in the connection. Meanwhile, a soft permanent virtual circuit (SPVC) comprises a series bearer channel paths that are interconnected through "switched" (i.e. on-demand) bearer channel cross-connections made across a series of nodes. Specifically, the ingress and egress nodes are typically provisioned at the network management terminal by a network operator, but the cross-connects for a node are commissioned via signalling through the network. Accordingly, a SPVC is signalled and routed across the network from the ingress node to the egress node. Next, a switched virtual connection (SVC) is a path that is signalled from user at the ingress node of the network to the egress node. The route of the SVC path is determined by the nodes as the path is signalled from the source node towards the destination node in the network. The individual cross-connects for the SVC path are configured and connected by call control software operating on each node along the path as the connection routes itself through the network. Routing tables for connected nodes resident on each node allow the call to be established by hop-by-hop routing. Alternatively, a predetermined route may be specified in the connection request to provide source-routing. It will be appreciated that the term "bearer channel" is synonymous with a communication channel.

For an ATM call, an ATM service category defines traffic contract parameters and quality of service (QoS) characteristics for the call, thereby enabling different calls to have different levels of priority and performance. QoS parameters include the cell loss ratio (CLR) and the cell delay variation (CDV) for a call. Defined service categories, known in the art, are:

Constant Bit Rate (CBR), which is suitable for real-time data transmission, e.g. video, requiring a fixed amount of bandwidth provided at regular intervals;

Real-time Variable Bit Rate (rt-VBR), which is suitable for for time-sensitive data traffic requiring a low CLR;

Non-real-time Variable Bit Rate (nrt-VBR), which is useful for data traffic having no constraints on CDV but having a variable transmission rate between the standard rate and the peak rate;

Available Bit Rate (ABR), which is useful for calls which require a low CLR but may tolerate a high CDV. Typically, minimal network resources are made available to an ABR connection. Calls in the ABR category are typically fulfilled by the network on a "best-effort" basis when higher priority calls do not supercede the ABR call; and

Unspecified Bit Rate (UBR), which is useful for calls which do not need low CLR nor CDV. As with ABR calls, UBR calls are typically serviced on a "best effort" basis.

In an ATM network, nodes are connected to each other through a series of physical communication links. As calls are routed through the network, a virtual path (VP) for the call is established through the nodes and their associated communication links. Within the virtual path, a series of virtual circuits (VCs) are typically provided, thereby ensuring that a given VP may be associated with several VCs, i.e. SVC, PVC and SPVCs. At each node, each VP/VC set is identified by a VPI/VCI address identifier.

Between a source node and a destination node, several connection types (SVC, PVC, SPVC etc.) may exist. The connection types are asssociated with particular ports on the source and destination nodes. Ports may be partitioned into sections, referred to as trunk groups. Accordingly, a trunk group may have several partitions each of which define a separate service category and connection type.

When a connection is routed from the source node to the destination node, a trunk group must be selected to carry the data traffic of the connection. In the prior art, when a SVC or a SPVC is being routed from a source node to a destination node, at the source node, the trunk group having a partition which meets the call requirements would be selected. When two or more trunk groups meet the call requirements, a prior art solution utilizes a round-robin algorithm to select the trunk group, to distribute traffic amongst the trunk groups. However, the round-robin algorithm does not consider the bandwidth allocation of each trunk group. Consequently, a trunk group with lower bandwidth allocation than its peer trunk groups may become unnecessarily overloaded, which may lead to undesirable congestion and cell loss.

Thus, there is a need for a system and method for selecting a trunk group in a communication link which upon the prior art systems.

SUMMARY OF INVENTION

In an aspect of the invention, a method of a selecting an egress connection from many egress connections at a node for a call being established in a network along a path being associated with the node is provided. Each egress connection of the many connections has sufficient bandwidth to carry the call and has a service category being compatible with a service requirement for the call. The method comprises evaluating an administrative factor score for each connection. If one administrative factor score for a particular connection from all administrative factor scores of the connections is superior to all other administrative factor scores, then the egress connection associated with that one score is selected as the particular connection. If two or more scores are comparably superior to all other scores, then the particular connection is selected from a set of connections having the comparably superior score. The particular connection is selected by utilizing a bandwidth load balance value which is calculated for each connection of the set.

The method may have the administrative factor score for each connection comprising a cost value for each connection.

The method may have for each connection, the bandwidth load balance value comprising a ratio of a numerator and a denominator. The numerator is selected from the bandwidth used on each connection and the bandwidth available on each connection. The denominator is selected from the bandwidth configured for each connection and the bandwidth configured for the connections.

The method may have the call having a guaranteed bandwidth associated therewith.

The method may have the call following a transmission protocol selected from ATM, MPLS and IP.

The method may have the call having a service requirement selected from one of: constant bit rate (CBR), real-time variable bit rate (rt-VBR), non-real-time variable bit rate (nrt-VBR), available bit rate (ABR) and undefined bit rate (UBR) services.

Alternatively, the method may have the call having no minimum bandwidth guarantee. Further, for each connection, the bandwidth load balance value may comprise a ratio of a first value representing a number of calls associated with each connection, each of call of the number of calls having no minimum bandwidth guarantee, and a second value selected from one of a maximum bandwidth configured for the each connection and a number of calls for the node having no minimum bandwidth guarantee.

The method may have the call following a transmission protocol selected from ATM, MPLS and IP.

The method may have the call having a service requirement selected from one of: constant bit rate (CBR), real-time variable bit rate (rt-VBR), non-real-time variable bit rate (nrt-VBR), available bit rate (ABR) and undefined bit rate (UBR) services.

The method may have each connection comprising a trunk group.

In a second aspect, a system for selecting an egress connection from a number of egress connections at a node in a network along a path being associated with the node is provided. The system comprises connection data, a connection evaluation module and a connection selection module. The connection data is associated with each connection and comprises a bandwidth limit, a set of compatible service categories and a cost value. The connection evaluation module evaluates the connection data for each connection against the call and selects a set of connections from the connections which can process the call. The connection selection module selects one connection from the set to carry the call, utilizing the cost value from connection data of each connection in the set. The selection module further utilizes a bandwidth load balance value for each connection to select the egress connection when the cost values of the connections in the set do not identify a single connection of the set as the best connection.

In the system, when the call has a guaranteed bandwidth associated with it, the bandwidth load balance value may comprise a ratio of a numerator and a denominator. The numerator is selected from one of bandwidth used on each connection and bandwidth available on each connection. The denominator is selected from one of bandwidth configured for each connection and bandwidth configured for the connections. Alternatively, when the call has no minimum bandwidth guarantee, said bandwidth load balance value may comprise a ratio of a first value and a second value. The first value represents a number of calls having no minimum bandwidth guarantee associated with each connection. The second value is selected from one of a bandwidth configured for each connection and the number of calls having no minimum bandwidth guarantee for the node.

The system may be used when the call follows a transmission protocol selected from ATM, MPLS and IP.

In a third aspect, a method of selecting a trunk group for routing a call in a connection-based network is provided. The method comprises (a) identifying a set of trunk groups that are capable of meeting requirements of the call, with each trunk group of the set having the same destination node; (b) accessing a predetermined administrative factor for each trunk group of the set; (c) selecting, responsive to only one trunk group of the set having the lowest administrative factor, a trunk group with the lowest administrative factor for routing the call; and (d) calculating, responsive to two or more trunk groups of the set having the lowest administrative factor, a bandwidth parameter for each trunk group therein, and selecting a particular trunk group therein for routing the call utilizing the bandwidth parameter.

The method may have a requirement of the call having a guaranteed bandwidth. Further, step (d) may calculate, for each trunk group providing the guaranteed bandwidth, the bandwidth parameter as a ratio of available bandwidth of each trunk group to maximum bandwidth configured for the each trunk group. Further still, the method may select, as the particular trunk group, a trunk group with the lowest bandwidth parameter.

The method may have the call having no guaranteed bandwidth. Further still, the step (d) may comprise calculating, for each trunk group supporting the call, the bandwidth parameter as a ratio of a number of unspecified bandwidth services calls carried by the each trunk group to a maximum bandwidth configured for the each trunk group. Further still, the method may select, as the particular trunk group, a trunk group with the lowest bandwidth parameter.

In other aspects of the invention, various combinations and subsets of the above aspects are provided.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects of the invention will become more apparent from the following description of specific embodiments thereof and the accompanying drawings which illustrate, by way of example only, the principles of the invention. In the drawings, where like elements feature like reference numerals (and wherein individual elements bear unique alphabetical suffixes):

Fig. 1 is a block diagram of a communication network having a node connected to another node with a communication link, the node embodying the invention;

Fig. 2A is a diagram of ingress ports, a switching core and egress ports connected to a communication link of the node of Fig. 1;

Fig. 2B is a diagram of a partitioning of bandwidth of a communication link of an egress port of the node of Fig. 2A; and

Fig. 3 is a block diagram of the node and the communication link of Fig. 2A connected to another node.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The description which follows, and the embodiments described therein, are provided by way of illustration of an example, or examples, of particular embodiments of the principles of the present invention. These examples are provided for the purposes of explanation, and not limitation, of those principles and of the invention. In the description, which follows, like parts are marked throughout the specification and the drawings with the same respective reference numerals.

The following is a description of a network element in a network associated with an embodiment. Referring to Fig. 1, a communication network 100 is shown. Network 100 enables data traffic to be communicated between customer premises equipment (CPE) 102A and a CPE 102B through network cloud 104. Network 100 also enables data traffic to be communicated to other CPEs 102 through network cloud 104.

Network cloud 104 comprises a plurality of nodes 106. Each node 106 is a communication switch which receives data traffic from another node 106 or CPE 102 and selectively transmits the data traffic to another node 106. In the embodiment, nodes 106 utilize ATM protocols to govern data traffic flow. In other embodiments, other nodes may utilize other protocols, such as, for example, Multiprotocol Label Switching (MPLS) or IP.

Data traffic is carried between nodes 106 and CPEs 102 via individual communication links 108. Communication links 108 may comprise standard physical interfaces such as OC-3, OC-12 or DS3. As shown, CPE 102 is to node 106A via communication link 108A.

When CPE 102A transmits data traffic to CPE 102B through network cloud 104, a data path must be established in network cloud 104 to link CPE 102A to CPE 102B through selected nodes 106 to carry the data traffic. As shown, a data path 110 may comprise the path traversing nodes 106A, 106B, 106C and 106D. It will be appreciated that a data path is a logical connection and may be referred to as a routing path, connection, or a circuit. Accordingly, a data path 110 is a logical connection through nodes 106 which is carried over a physical link, namely communication link 108.

In establishing and maintaining a data path 110, a node 106 needs to communicate status information to other nodes 106. In the embodiment, a node 106 communicates with another node 106 using the Private Network-to-Network Interface (P-NNI) protocol which is described in the reference "Private Network-Network Interface Specification Version 1.0 (P-NNI 1.0)", doc. no. af-p-nni-0055.00, March 1996, published by the ATM Forum, and which is incorporated herein by reference in its entirety.

Further detail on aspects of the node 106 are now provided. Referring to Fig. 2A, features of a given node 106 in network 100 are shown. Node 106 is connected to ingress communication links 108, which are each connected to separate ingress ports 200. The data traffic received from the ingress communication links 108 are processed by node 106 and are routed to be switched through the switching fabric 202 towards a selected egress port 204. At an egress port 204, an egress communication link 108 is connected thereto to enable transmission of the data traffic to the node connected to the egress communication link 204. As shown, data paths 110B and 110C may be provided between ingress ports 200 and egress ports 204.

Referring to Fig. 2B, relationships amongst an egress port 204 for a node 106 and the associated egress communication link 108 are shown. As described earlier, an egress port 204 provides the physical connection point for egress communication link 108 to node 106. Through communication link 108, the egress port 204 can carry a plurality of connections 206. Again, the connections 206 may provide any of a SVC, PVC, SPVC and others. Each connection 206 can be configured to provide a particular QoS, e.g. CBR, VBR, rtVBR, nrtVBR, ABR and UBR. A set of connections may be grouped into a trunk group 208. A trunk group may also have an associated a P-NNI signalling link 210 and a P-NNI routing link 212. For example, trunk group 208A comprises SVC 206A, PVC 206B, SVC 206C, SPVC 206D, PVC 206E, signalling link 210 and routing link 212. Sets of trunk groups may be established within ports to reach the same destination node.

In establishing a connection, e.g. an SVC connection, through network 100, at a given node 106 the following procedure is used to negotiate a cross-connection through its switching core 204 for an egress path from the node for an ingress path to the node. It will be appreciated that for data path 110, the negotiations are conducted on a node-by-node basis in building a data path from CPE 102A to CPE 102B through network 100. The procedure involves processing on the ingress side of the node and the egress side of the node.

On the ingress side of the node 106, a connection is not routed, per se, as the node has already been selected to be routed there by the upstream node. However, support for connection endpoint for the requested connection with the ingress trunk group must still be verified against the service and path parameters of the trunk group in order to determine whether the selected route can support the connection. The parameters include the type of service supported by the trunk group and the assigned path cost, described later, for the trunk group. Next, a bandwidth partition relating to the requested connection type (e.g. SVC, SPVC) that supports the requested service category and that has sufficient bandwidth for the requested connection must be selected from the available egress connections. Finally, an appropriate VPI/VCI or VPI must be selected for the egress connection if the connection is being assigned.

Next, on the egress side of node 106, the appropriate outgoing route must be selected. There may be several egress trunk groups associated with the outgoing route for the node 106. Each trunk group will have the same destination node; however each trunk group may have differing service and connection characteristics. Again, the selected route must be able to support the connection. For a route, values for data path parameters which are required to have the route reach a specific ATM address are maintained for the route. Examples of data path parameters include administrative factors relating to "costs" for using a trunk group, destination addresses, lists of trunk groups, and status of routes. For each route, a list of trunk groups which can carry the connection is maintained. The outgoing trunk group 208 must be selected from the list.

Next, the bandwidth partition relating to the requested connection type (e.g. SVC, SPVC) that supports the requested service category and that has sufficient bandwidth for the requested connection must be selected from the available egress connections in the selected trunk group. Finally, an appropriate VPI/VCI or VPI must be selected for the egress connection if the connection is being assigned.

Further detail is provided on the selection of a trunk group on the egress side of node 106. When selecting the appropriate route, the call defined by the network operator is examined by the node against the ATM addresses known to the node 106. These ATM addresses are stored in a routing table. The ATM address entry in the routing table having the most complete contiguous match with the called party number is the best match. If a match or a suitable substitute is not found in the routing table, the call is rejected. For each ATM address entry in the routing table, a trunk group list is provided. The trunk group list provides a list of possible physical connections that can forward calls to that ATM address.

In the embodiment, the routing table provides a primary route and an alternate route in a route list. The primary route is the first route selected when attempting to route a call. The alternate route is selected only if either the call cannot be routed on any trunk group within the primary route or after the primary route is selected and the call is forwarded out the primary route, the call is cranked back to the node. The alternate route may contain a longer path for the call which goes through more nodes to reach the destination node. In the node 106, each route may be associated with a series of trunk groups and each trunk group may be associated with more than one route.

Once the primary or alternate route has been selected, a trunk group from the selected route must be identified. When selecting a trunk group, it must be operational and the signalling link controlling it must be operational. The connection admission control (CAC) must also be able to admit the call to the trunk group. If a series of trunk groups meet the noted minimum characteristics, then the bandwidth load characteristics of each trunk group is examined to determine the trunk group which provides a desired bandwidth distribution for the call in view of the other calls carried by the node.

First, when assessing bandwidth load characteristics of the trunk groups, each trunk group is assessed for its administrative compatibility with the call. Administrative factors for a trunk group include: its routability; the "cost" associated with the trunk group; the operational status of its signalling link; whether it is different than the ingress trunk group; whether it has a partition which supports the service category of the call (CBR, rt-VBR, nrt-VBR, ABR, UBR) and the type (SVC, SPVC). The routability of the call relates to operational status of higher signalling links (e.g. P-NNI signalling links) and the operational status of its associated links for a trunk group. The cost associated with the trunk group is a cost figure, which is typically assigned by a network administrator, associated with data traffic using that trunk group. For example, a high-capacity trunk group may have a higher cost figure than a low-capacity trunk group. Alternatively, a longer distance connection may have a higher cost than a shorter distance connection. Cost factors are known parameters which can be assigned to trunk groups according to P-NNI standards. It will be appreciated that costs and weights may be customized for different parameters and structures, which may be determined by the network administrator. Also, in the embodiment, complete routing of a call is not permitted in the same trunk group. Accordingly, a call from an ingress trunk group is not allowed to be routed out onto the same trunk group.

In the embodiment, an administrative factor score is assigned to each trunk group for its cost factor. The score of the administrative factors of each trunk group are tallied and the trunk group having the best score, i.e. lowest cost, is the "cheapest" trunk group in the route for the call. It will be appreciated that other tallying regimes may be used wherein other administrative factors for each trunk group are evaluated in some other fashion against each other. In other embodiments, the administrative factors may not be evaluated for each trunk group.

In addition to evaluating the administrative factor score for each trunk group, the embodiment evaluates the connection and service parameters of each trunk group against the requirements of the call. Accordingly, each trunk group is also evaluated for its available bandwidth and its associated service categories (e.g. CBR, rt-VBR, nrt-VBR, ABR and UBR) and its connection types (e.g. SVC, PVC, SPVC). Trunk groups meeting all minimum requirements for the call may are capable of processing the call. However, the embodiment further analyzes the properties and bandwidth loading levels of the capable trunk groups in order to select a superior trunk group for the call.

In many cases, several trunk groups may each be capable of handling the connection and may each have the same, or sufficiently comparable, best cost value for its administrative factor scores. Accordingly, in order to select one trunk group from those several trunk groups, a bandwidth load balance value is calculated for each trunk group. The load balance value indicates what percentage of the total available bandwidth in that trunk group would be consumed by the bandwidth of the current calls plus the proposed call. Briefly, for a given trunk group "i" (TGi), its load balance value is calculated as:

$$\text{Load balance (TGi)} = \frac{\text{Bandwidth used on TGi}}{\text{Max. Bandwidth configured for TGi}}$$

$$= \frac{\text{Bandwidth used for current calls + Bandwidth of proposed call}}{\text{Max. Bandwidth configured for TGi}}$$

(Equation 1)

It will be appreciated that as the number of current calls changes dynamically, the value of the "Bandwidth used by the current calls" in Equation 1 will change. Accordingly, the load balance value in Equation 1 is not static.

After each trunk group has had its load balance value calculated, the node will select the trunk group having the lowest load balance value. The trunk group with the lowest load balance value has, as a percentage, more capacity to handle the call. As the load balance value introduces a percentage into the evaluation of the capacities of the trunk group, with Equation 1 the absolute capacity values of each trunk group are not used. Accordingly, use of the defined load balance values provides a mechanism which ensures that a trunk group is not necessarily always selected merely because it has the larger capacity, regardless of its current loading state.

It will be appreciated that in other embodiments, it may be desireable to select a trunk group on the basis of the total absolute available bandwidth therein. In such other embodiments, the following load balance equation may be used:

$$\text{Load balance (TGi)} = \frac{\text{Bandwidth available for TGi}}{\text{Max. Bandwidth configured for TGi}} \qquad \text{(Equation 2)}$$

Using Equation 2, the trunk group which has the most available bandwidth would be selected.

It will be appreciated in balancing the bandwidth load amongst trunk groups, other algorithms may be used. One alternative algorithm would select the trunk group having the largest bandwidth first, until the available bandwidth in that trunk group drops to the value of the available bandwidth for the next larger trunk group. At that point, the algorithm distributes the load between the two trunk groups in an even fashion. In an alternative embodiment, an algorithm would evenly distribute loads between two trunk groups until one trunk group is operating at capacity, and then the algorithm would distribute the remaining load to the other trunk group.

It is noted that both Equations 1 and 2 may be used when the proposed call has a defined, non-zero bandwidth allocation. Guaranteed bandwidth allocations are provided with calls having services in the following service categories: CBR, rtVBR, nrtVBR, ABR with a non-zero minimum cell rate (MCR) and UBR with a non-zero MCR.

However, as noted in the background, some service categories are provided on a "best effort" basis. Accordingly, calls having such service categories essentially have a bandwidth allocation of 0. Examples of these zero bandwidth service categories include ABR with zero MCR and UBR with zero MCR. Accordingly, if Equation 1 was used for calls with zero bandwidth service categories, the value of the "Bandwidth of the current call" would be 0 and Equation 1 would produce a result which did not account for the bandwidth used by all the calls having zero bandwidth service categories.

To ensure that calls having zero bandwidth (ZBW) service categories are accounted for in some manner when selecting a trunk group, the following equation is used for ZBW calls:

$$\text{Load balance (TGi)} = \frac{\text{Number of current calls with ZBW + 1}}{\text{Max. Bandwidth configured for TGi}} \qquad \text{(Equation 3)}$$

Equation 3 provides a ratio of the total number of calls having a zero bandwidth service category in the trunk group (which is the number of current calls with ZBW in the trunk group + 1, for the proposed call with ZBW) against the total available bandwidth for the trunk group. Again, the load balance value is calculated for each trunk group and, the trunk group having the lowest loading value is selected.

It will be appreciated that in other embodiments, for a zero bandwidth call, it may be desirable to evaluate the percentage of zero bandwidth calls handled by each trunk group. In such other embodiments, the following load balance equation may be used:

$$\text{Load balance (TGi)} = \frac{\text{Number of current calls with ZBW in TGi + 1}}{\text{Total number of ZBW calls in node + 1}} \qquad \text{(Equation 4)}$$

In Equation 4, the denominator essentially tracks the number all calls with the proposed call (which is represented by the "+ 1" factor) having a zero bandwidth service category rating which are currently being processed in all trunk groups in the node. If Equation 4 were used, the trunk group having the lowest load balance value would be selected. It will be appreciated that results from Equation 4 does not distinguish between capacities of trunk groups being compared (e.g. OC-3 vs. OC-12), but it does provide a measure of allocation of calls per trunk group.

It will be appreciated that for the Equations, for the bandwidth values, while they are described as being the maximum values, other values may be substituted therefor. Other values include predefined bandwidth values which may not be at the absolute maximum bandwidth capacity for the trunk groups.

It will be appreciated that in other embodiments, combinations and variations on the above noted algorithms and Equations may be used to distribute loads for both calls having a defined bandwidth and calls with ZBW.

It will further be appreciated that in another embodiment, a source node may be embodied as a logical source node, which is a group of nodes and a destination node may be embodied as a logical destination node. Trunk groups connecting the two logical nodes may comprise links where one source node in the logical source node is connected to one destination node in the logical destination node. Logical source and destination nodes are provided in P-NNI hierarchies. Accordingly, an embodiment may be used to select a trunk group between two logical nodes utilizing bandwidth load balance values, such as those described above.

After node 106 selects a trunk group, node 106 may proceed in a known conventional manner to establish or commission a signalling link cross-connection between an incoming communication link 108 and an outgoing communication link 108.

Following is an example of the use of Equations 1 and 3 in an embodiment. Referring to Fig. 3, two nodes (node 106A and node 106B) are shown with communication link 108 connecting each node to each other. In communication link 108, there are six trunk groups 206, identified as TG1, TG2...TG6. The following Table A identifies the supported connection types, the supported service categories, the predetermined cost scores for administrative factors and bandwidth capacities for each trunk group.

Table A

Trunk Group 208	Supported Connection Types	Supported Service Categories	Admin. Factor Score	Maximum Bandwidth (Mbps)
TG1	SVC, SPVC	CBR, rtVBR	10	5
TG2	SVC, SPVC	CBR, rtVBR, ABR	20	10
TG3	SVC, SPVC	CBR, rtVBR	40	10
TG4	SVC, SPVC	CBR, ABR	40	5
TG5	SVC, SPVC	ABR, UBR	60	5
TG6	SVC, SPVC	ABR, UBR	60	10

It is assumed that all calls (SVC and SPVC) are received on node 106A and destined to node 106B.

Initially, it is presumed that all calls have a CBR service category and that all trunk groups have sufficient bandwidth available to process the calls. Accordingly, in assessing the trunk groups, TG5 and TG6, which do not support CBR traffic, are not considered. Of the remaining trunk groups, TG1...TG4, node 106A forwards calls through TG1 because it has the lowest administrative factor score ("10"). The value of the available bandwidth for TG1 is updated to reflect the consumed bandwidth of the CBR call.

As calls are added, each trunk group in the selected route is re-evaluated to determine whether it meets the minimum characteristics for the call. Again, for the example, it is presumed that CBR calls are received. Accordingly, only trunk groups TG1...TG4 are considered. The bandwidth available for trunk groups TG1...TG4 is checked and it is presumed each trunk group has sufficient bandwidth. As TG1 still has the lowest administrative factor score factor ("10") of the considered trunk groups, CBR calls are provided to it. The value of the available bandwidth for TG1 is updated to reflect the consumed bandwidth of the CBR call.

As calls are added to TG1, TG1 becomes exhausted and cannot admit more calls. After such time, for the next call when the available bandwidth is checked, it will be recognized that the TG1 does not have sufficient bandwidth for the call. Accordingly, TG1 it is not included in the set of available of trunk groups for the call.

Thereafter, node 106A receives more CBR calls. Again, each trunk group in the selected route is re-evaluated to determine whether it meets the minimum characteristics for the call. Again, for the example, trunk groups TG2...TG4 have available bandwidth for the call. After the administrative factor scores of the trunk groups are evaluated, new calls are forwarded to TG2, as it has the lowest administrative factor score ("20").

Again, as calls are added to TG2, it is presumed that TG2 becomes exhausted and cannot admit more calls. At such time, TG2 does not meet the minimum requirements for new calls and TG2 is not included in the set of available trunk groups for new calls. It is presumed that for TG2, no calls are dropped.

Thereafter it is presumed that node 106A processes a CBR call. As only TG3 and TG4 are both capable of handling CBR traffic and have available bandwidth, their administrative factor scores are compared to determine the better trunk group. As their scores are equal, node 106A utilizes Equation 1 to determine which of TG3 and TG4 has the lower bandwidth load balance value. Note that as TG3 has a higher maximum bandwidth capacity than TG4, 10 Mbps vs. 5 Mbps, the load balance value of each trunk group will reflect, as a ratio, which trunk group is more fully loaded. The trunk group having the lower load balance value is selected by node 106A to carry the call. For subsequent CBR calls, node 106A recalculates the load balance values for TG3 and TG4 and again selects the trunk group having the lower load balance value. It can be seen that as subsequent CBR calls are provided to TG3 and TG4, the calls will be provided to the trunk group which is, as a percentage, less full than the other trunk group. Accordingly, load balance providing one type of fair allocation of bandwidth is achieved between the trunk groups.

Thereafter it is presumed that node 106A processes an ABR (with no MCR) call. The trunk groups which have ABR connections are TG2, TG4, TG5 and TG6. Assuming that TG4, TG5 and TG6 have sufficient bandwidth for the call, node 106A selects the trunk groups having the lowest administrative factor score which can process the call. Accordingly TG4 is selected. For the next ABR call, it is assumed that only TG5 and TG6 have sufficient bandwidth for the call. Accordingly, node 106A examines the administrative factor scores for each TG5 and TG6. As the factor scores for TG5 and TG6 are the same, node 106A utilizes Equation 3 to determine which trunk group should be selected. The trunk group having the lower load balance value determined from Equation 3 is selected. On the arrival of subsequent ABR calls, node 106A re-examines the trunk groups to see whether they have the bandwidth to handle the call and recalculates the load balance values for TG5 and TG6 using Equation 3. Again, the trunk group having the lower load balance value will be provided with the call.

It will be appreciated that in other embodiments other load balance value equations may be used for both calls having minimum bandwidth guarantees and calls without minimum bandwidth guarantees.

It will be appreciated that the embodiment may be implemented in software modules operating on a node 106. The software modules will have the ability to determine the connection type and service type for a call, using techniques known in the art. Also, a data structure containing relevant administrative factor scores for the connections must be maintained and be accessible by the software modules. The load balance equations would be processed by the software modules to select the appropriate connection. Alternatively, the calculations and processing may be done in software operating centrally at a control node for the network.

While the above description presents a load balance system for use in a node in an ATM network, it will be appreciated that in other embodiments, a load balance system using comparable algorithms and equations, and combinations thereof, as described above may be used in other networks where a selection is required between two communication paths. Accordingly, an embodiment may be implemented in an MPLS network where an MPLS node has the ability to select a tunnel between two tunnels connected to the same next node. Further still, an embodiment may be implemented in a connection-less network, such as an IP network, where an IP node must select forwarding a packet between two paths going to the same destination.

It is noted that those skilled in the art will appreciate that various modifications of detail may be made to the present embodiment, all of which would come within the scope of the invention.

WE CLAIM

1. A method of a selecting an egress connection from a plurality of egress connections at a node for a call being established in a network along a path being associated with the node, each connection of said plurality of egress connections having sufficient bandwidth to carry said call, said method comprising:

evaluating an administrative factor score for said each connection;

if one administrative factor score for a particular connection from all administrative factor scores of said plurality of egress connections is superior to all other administrative factor scores of said all administrative factor scores, selecting said egress connection as said particular connection; and

if at least two administrative factor scores from said all administrative factor scores are comparably superior to all other administrative factor scores of said all administrative factor scores, selecting said egress connection from a subset of said plurality of egress connections, each egress connection of said subset having one score of said at least two administrative factor scores, by utilizing a bandwidth load balance value for said each connection of said subset.

2. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 1, wherein said administrative factor score for said each connection comprises a cost value for said each connection.

3. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 2, wherein for said each connection, said bandwidth load balance value comprises a ratio of

a numerator selected from one of bandwidth used on said each connection and bandwidth available on said each connection; and

a denominator selected from one of bandwidth configured for said each connection and bandwidth configured for said plurality of egress connections.

4. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 3, wherein said call has a guaranteed bandwidth associated therewith.

5. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 3, wherein said call follows a transmission protocol selected from ATM, MPLS and IP.

6. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 4, wherein said call has a service requirement selected from one of: constant bit rate (CBR), real-time variable bit rate (rt-VBR), non-real-time variable bit rate (nrt-VBR), available bit rate (ABR) and undefined bit rate (UBR) services.

7. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 2, wherein

said call has no minimum bandwidth guarantee; and

for said each connection, said bandwidth load balance value comprises a ratio of a first value representing a number of calls associated with said each connection, each of call of said number of calls having no minimum bandwidth guarantee; and

a second value selected from one of a bandwidth configured for said each connection and a number of calls for said node having no minimum bandwidth guarantee.

8. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 7, wherein said call follows a transmission protocol selected from ATM, MPLS and IP.

9. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 7, wherein said call has a service requirement selected from one of: constant bit rate (CBR), real-time variable bit rate (rt-VBR), non-real-time variable bit rate (nrt-VBR), available bit rate (ABR) and undefined bit rate (UBR) services.

10. A method of a selecting an egress connection from a plurality of egress connections at a node as claimed in claim 9, wherein said each connection comprises a trunk group.

11. A system for selecting an egress connection from a plurality of egress connections at a node in a network along a path being associated with the node, said system comprising:

connection data for each connection of said plurality of connections, said connection data comprising a bandwidth limit, a set of compatible service categories and a cost value;

a connection evaluation module adapted to evaluate said connection data for each of said plurality of connections against said call and to select a set of connections from the plurality of connections which can process said call;

a connection selection module adapted to select one connection from said set of connections to carry said call, utilizing said cost value from connection data of each connection in said set of connections and utilizing a bandwidth load balance value for each connection in said set of connections when a single connection of said set of connections is not identifiable as a best connection utilizing said cost value from said connection data.

12. A system for selecting an egress connection from a plurality of egress connections at a node as claimed in claim 11, wherein:

when said call has a guaranteed bandwidth associated, said bandwidth load balance value comprises a ratio of

a numerator selected from one of bandwidth used on said each connection and bandwidth available on said each connection; and

a denominator selected from one of bandwidth configured for said each connection and bandwidth configured for said plurality of egress connections;

and

when said call has no minimum bandwidth guarantee, said bandwidth load balance value comprises a ratio of a first value representing a number of calls associated with said each connection, each call of said number of calls having no minimum bandwidth guarantee; and

a second value selected from one of a bandwidth configured for said each connection and a number of calls for said node having no minimum bandwidth guarantee.

13. A system for selecting an egress connection from a plurality of egress connections at a node, as claimed in claim 12 wherein said call follows a transmission protocol selected from ATM, MPLS and IP.

14. A method of selecting a trunk group for routing a call in a connection-based network, said method comprising the steps of:

(a) identifying a set of trunk groups that are capable of meeting requirements of said call, each trunk group of said set having a same destination node;

(b) accessing a predetermined administrative factor for each trunk group of said set;

(c) selecting, responsive to only one trunk group of said set having the lowest administrative factor, a trunk group with the lowest administrative factor for routing said call; and

(d) calculating, responsive to a plurality of trunk groups of said set having the lowest administrative factor, a bandwidth parameter for each trunk group of said plurality, and selecting a particular trunk group of said plurality for routing said call utilizing said bandwidth parameter.

15. The method of claim 14, wherein

a requirement of said call comprises a guaranteed bandwidth; and

said step d) comprises:

calculating, for each trunk group providing said guaranteed bandwidth, said bandwidth parameter as a ratio of available bandwidth of said each trunk group to maximum bandwidth configured for said each trunk group; and

selecting, as the particular trunk group, a trunk group with the lowest bandwidth parameter.

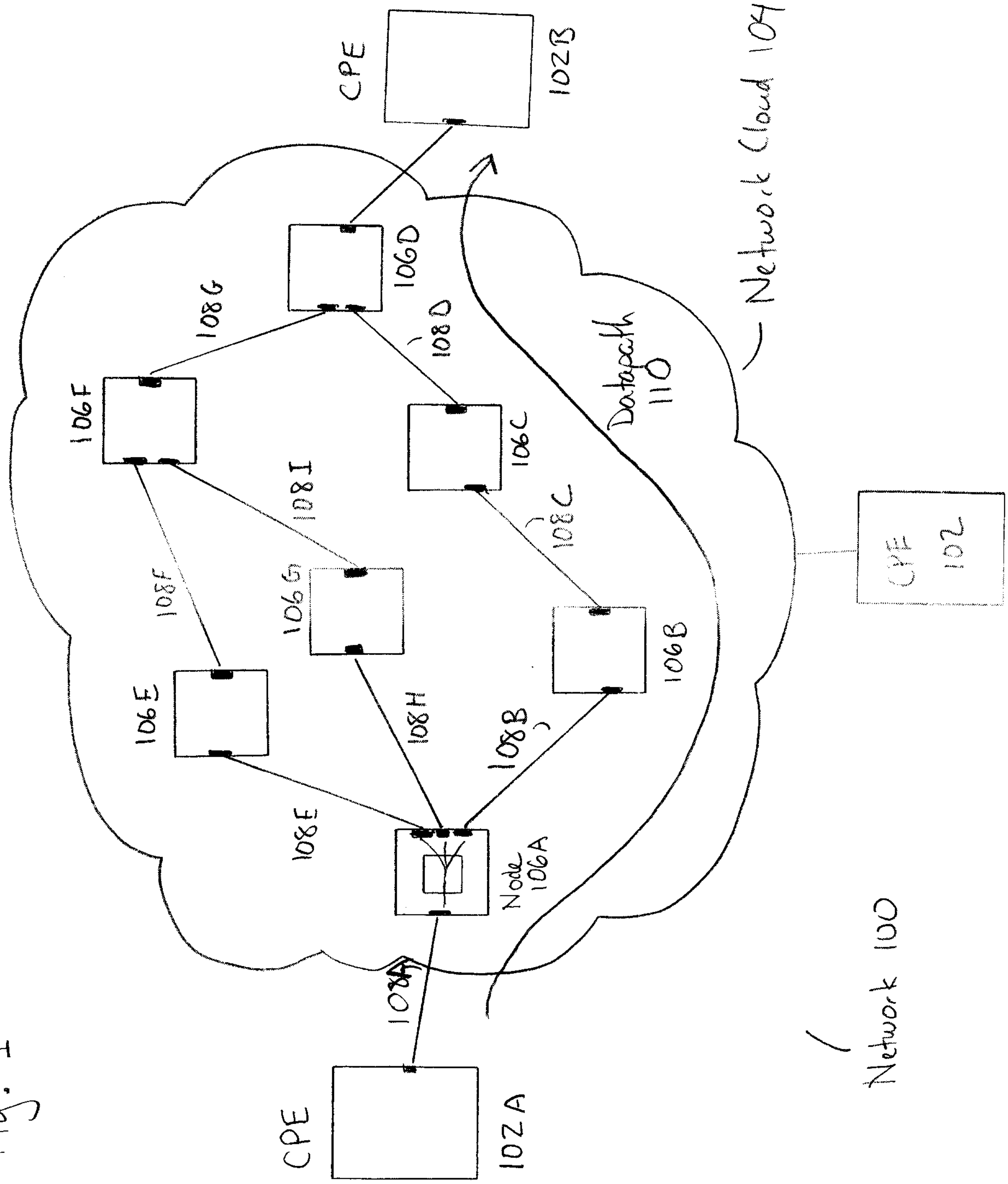
16. The method of claim 14, wherein

said call has no guaranteed bandwidth; and

said step d) comprises:

calculating, for each trunk group supporting said call, said bandwidth parameter as a ratio of a number of unspecified bandwidth services calls carried by said each trunk group to a maximum bandwidth configured for said each trunk group; and

selecting, as said particular trunk group, a trunk group with the lowest bandwidth parameter.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Network Cloud 104
106D
108G
108D
106F
106C
Datapath 110
108I
108C
CPE
102
106G
108F
106B
106E
108H
108B
108E
Node 106A
108A
Network 100
CPE
102A

Fig. 1

Fig. 2A

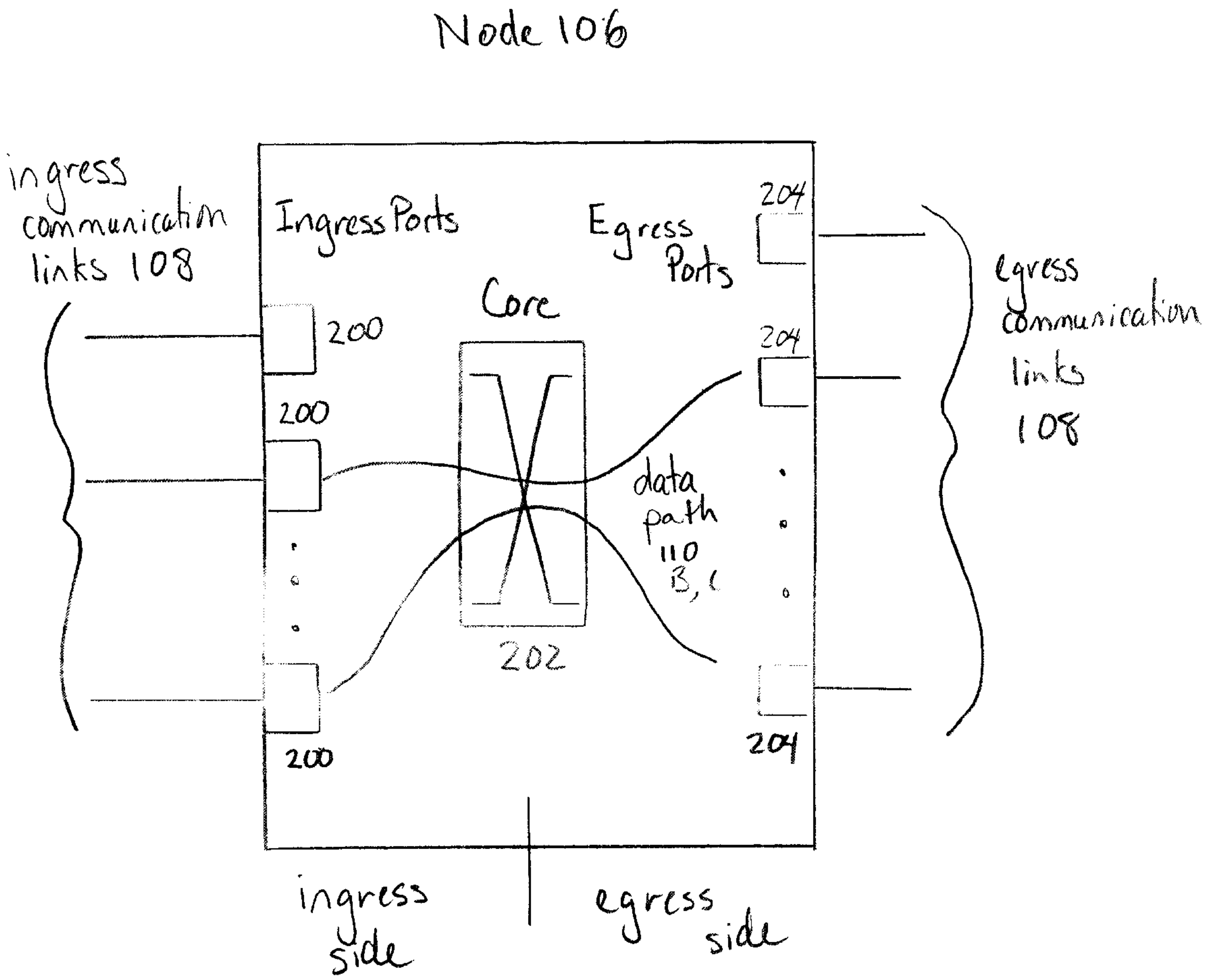

Node 106
ingress communication links 108
Ingress Ports
Egress Ports
Core
204
200
204
200
data path 110 B, C
202
200
204
egress communication links 108
ingress side
egress side

Fig 2B

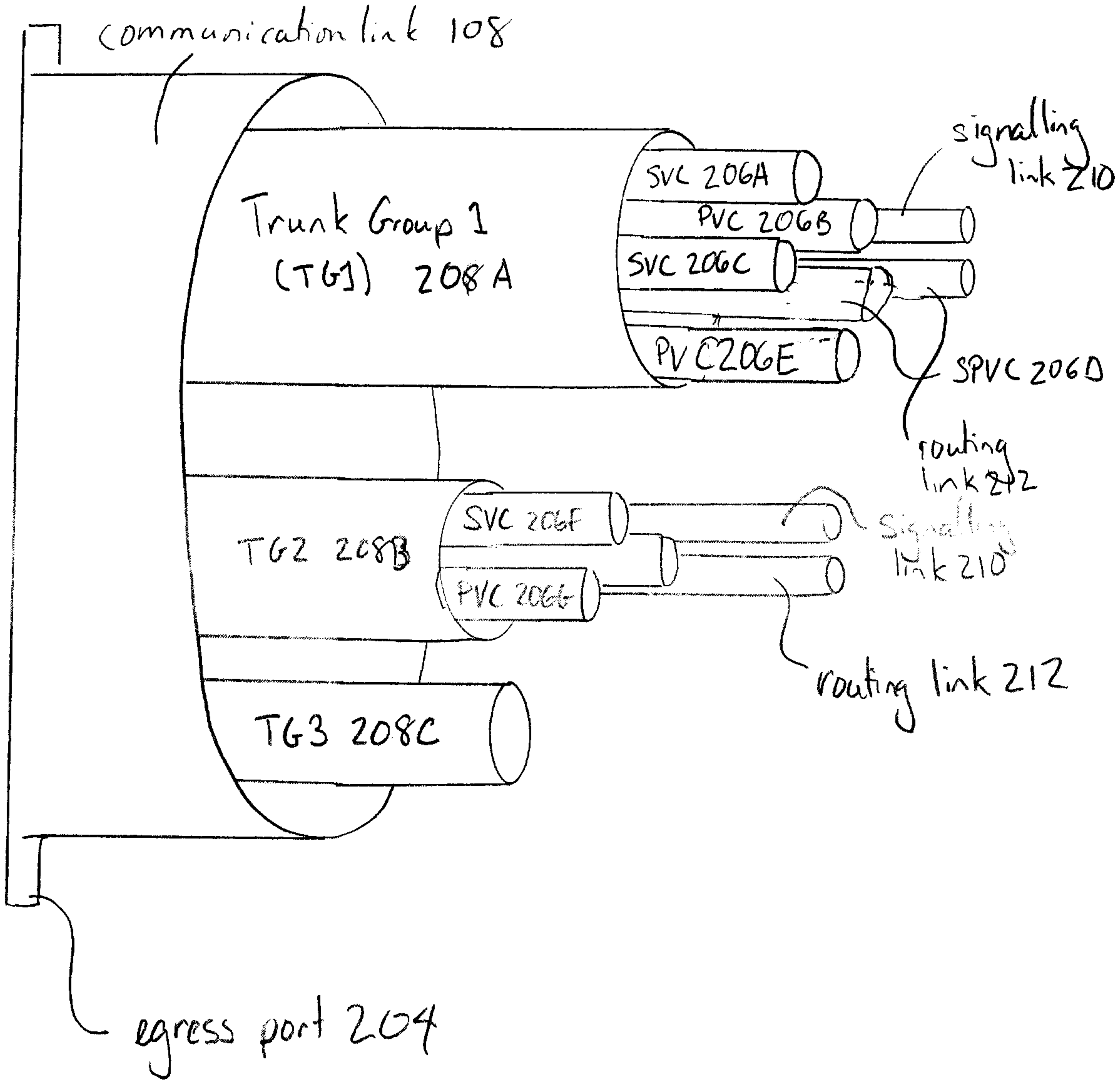
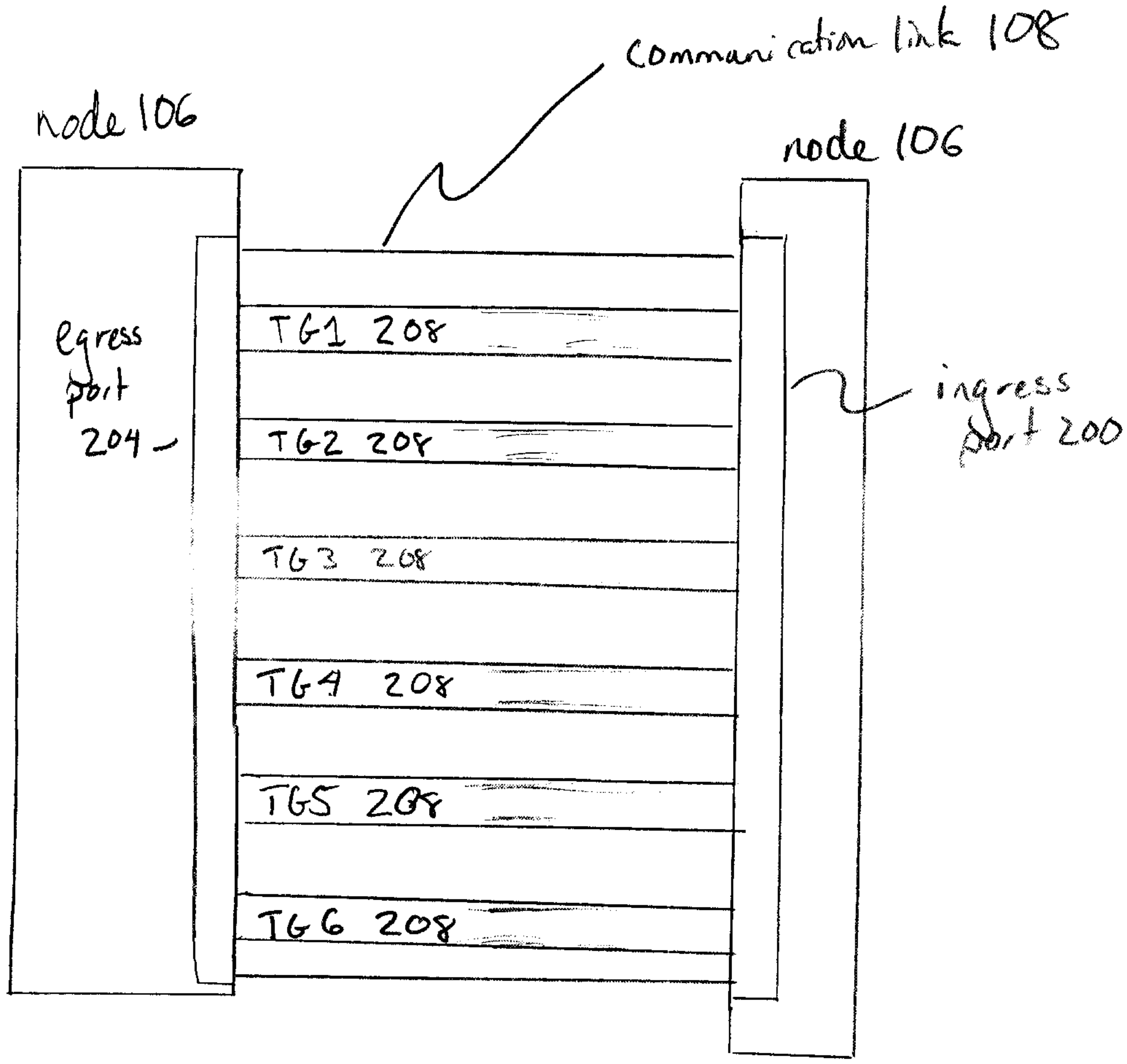

communication link 108
Trunk Group 1
(TG1) 208A
SVC 206A
PVC 206B
SVC 206C
PVC 206E
signalling
link 210
SPVC 206D
routing
link 212
TG2 208B
SVC 206F
PVC 206G
signalling
link 210
routing link 212
TG3 208C
egress port 204

Fig. 3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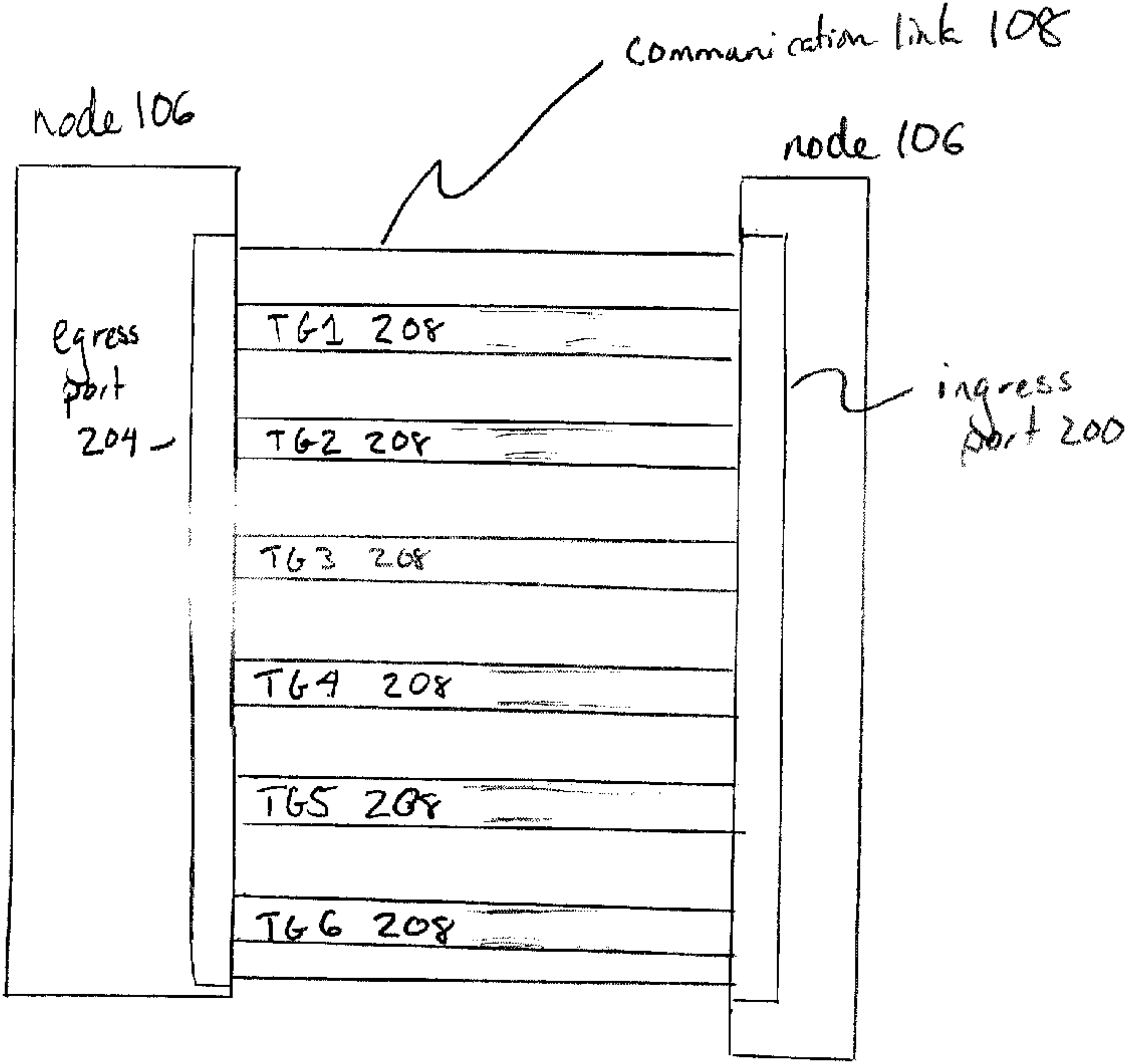
node 106
egress port 204
ingress port 200
TG1 208
TG2 208
TG3 208
TG4 208
TG5 208
TG6 208


communication link 108
node 106
node 106
egress port 204
ingress port 200
TG1 208
TG2 208
TG3 208
TG4 208
TG5 208
TG6 208