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**SYSTEM AND METHOD OF nxSTS-1 BANDWIDTH SHARING AND
RING PROTECTION**

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SPECIFICATION

RELATED APPLICATIONS

This application is related to U.S. Provisional Application No. 60/228,008, filed on August 23, 2000, to U.S. Provisional Application No. 60/272,793, filed on March 1, 2001, to co-pending and commonly assigned U.S. Patent Application No. (Number to be assigned) with Attorney Docket Number 55369-014, filed on August 23, 2001, and to co-pending and commonly assigned U.S. Patent Application No. (Number to be assigned) with Attorney Docket Number 55369-015, filed on August 23, 2001. The contents of U.S. Provisional Application No. 60/228,008, filed on August 23, 2000, of U.S. Provisional Application No. 60/272,793, filed on March 1, 2001, of co-pending and commonly assigned U.S. Patent Application No. (Number to be assigned) with Attorney Docket Number 55369-014, filed on August 23, 2001, and of co-pending and commonly assigned U.S. Patent Application No. (Number to be assigned) with Attorney Docket Number 55369-015, filed on August 23, 2001, are hereby incorporated by reference. This application claims priority to U.S. Provisional Application No.

60/228,008, filed on August 23, 2000, and to U.S. Provisional Application No. 60/272,793, filed on March 1, 2001.

FIELD OF THE INVENTION

The present invention relates to optical networking. More particularly, the invention relates to a system and method of nxSTS-1 bandwidth sharing and ring protection.

BACKGROUND OF THE INVENTION

Both SONET (See Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria. GR-253-CORE, Issue 2, Revision 1. December, 1997.) and SDH (See International Telecommunication Union. Network Node Interface for the Synchronous Digital Hierarchy. Recommendation G.707. March, 1996.) enable the use of virtual concatenation to support both the dynamic resizing of transport trunks and the grooming of traffic. More recently, advances in the transport of routed datagram traffic leveraging the research and experience of ATM has resulted in the standardization of MPLS (See Internet Engineering Task Force. Multiprotocol Label Switching Architecture. IETF Draft Document. August, 1999 and <http://www.ietf.org/internet-drafts/draft-ietf-mpls-arch-06.txt>.) This work allows network devices to employ a standards-based method by which packet traffic can traverse a network, while receiving a previously agreed upon Quality of Service.

Referring to Figure 1, a prior art, standard SONET and SDH Unidirectional Path Switched Ring (UPSR) ring protection scheme 100 is shown. Nodes 110 and 112 are logically interconnected by fibers 120 and 122 to form ring 100, through which data traffic is being carried. Node 112 includes a selector 130. A source 140 is logically connected to node 110, while a destination 150 is logically connected to node 112. If fiber 120 is cut, then selector 130 selects data traffic from fiber 122. If fiber 122 is cut, then selector 130 selects data traffic from fiber 120.

SUMMARY OF THE INVENTION

The present invention provides a system and method of nxSTS-1 bandwidth sharing and ring protection. The system and method of nxSTS-1 bandwidth sharing by every node on a nxSTS-1 ring includes (1) placing nxSTS-1s in the nxSTS-1 ring, (2) creating a nxVT point-to-point or point-to-multipoint connection within a nxSTS-1 pipe, and (3) globally managing VT resources in the ring via a ring manager.

The system and method of method of bandwidth doubling includes (1) forming with fibers a primary ring to carry a primary nxSTS-1 ring and (2) forming with fibers a secondary ring to carry a secondary nxSTS-1 ring.

10 The system and method of protecting a nxSTS-1 ring includes (1) in a normal mode, only having one ring manager as an active ring manager and (2) if the active ring manager fails, making another ring manager a new active ring manager according to a election protocol, where every node on the ring can be a candidate ring manager.

15 **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 illustrates a prior art, standard SONET and SDH Uni-directional Path Switched Ring (UPSR) ring protection scheme.

Figure 2A illustrates a normal DBA Channel in a nxSTS-1 ring being protected by the present invention in accordance with an exemplary
20 embodiment of the present invention.

Figure 2B illustrates a DBA Channel in a nxSTS-1 ring with a fiber cut being protected by the present invention in accordance with an exemplary embodiment of the present invention.

Figure 2C illustrates a DBA Channel in a nxSTS-1 ring with a node
25 failure being protected by the present invention in accordance with an exemplary embodiment of the present invention.

Figure 2D illustrates a normal DBA Channel in a nxSTS-1 ring with primary or secondary DBA Channel support being protected by the present invention in accordance with an exemplary embodiment of the present
30 invention.

Figure 2E illustrates a DBA Channel in a nxSTS-1 ring 200 with primary or secondary DBA Channel support in BDM with a fiber cut being

protected by the present invention in accordance with an exemplary embodiment of the present invention.

Figure 3 illustrates a ring manager protection scheme in accordance with an exemplary embodiment of the present invention.

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DETAILED DESCRIPTION OF THE INVENTION

Introduction

The invention described in co-pending and commonly assigned U.S. Patent Application No. (Number to be assigned) with Attorney Docket
10 Number 55369-014 provides a system and method of virtually concatenating VT1.5s and STS-1s over SONET and SDH and WDM. The virtual concatenation invention allows users to setup connections or pipes with configurable bandwidth over either nxSTS-1/nxAU-3/nxAU-4 or nxVT1.5/nxTU-11/nxTU-12 within a nxSTS-1/nxAU-3/nxAU-4 pipe on an
15 existing SONET/SDH network. This provides a connection or pipe of adjustable bandwidth with a granularity of close to 1.5 Mbps to fit the needs of applications. The resulting connection can be treated as a TDM like connection.

By replacing "STS-1" with "AU-3" or "AU-4" and "VT" or "VT1.5"
20 with "TU-11" or "TU-12", the virtual concatenation invention applies to nxAU-3/nxAU-4 and nxTU-11/nxTU-12 for SDH networks. For simplicity, these connections are called "nxVT" for both SONET and SDH networks. By replacing "STS-1" with "VT" or "VT1.5", the virtual concatenation invention applies to nxSTS-1 and nxAU-3/nxAU-4.

25 On top of the virtual concatenation invention, a dynamic bandwidth allocation (DBA) protocol, which is described in co-pending and commonly assigned U.S. Patent Application No. (Number to be assigned) with Attorney Docket Number 55369-015, allows for dynamically changing the throughput of all nxVT connections, based on the real-time traffic loads of applications
30 using the nxVT connections. The DBA protocol allows for the efficient use of the SONET/SDH bandwidth through statistical multiplexing. The same dynamic bandwidth allocation protocol applies to nxSTS-1 and nxAU-3/nxAU-4.

The virtual concatenation invention provides for virtual concatenation, which includes creating a logical connection or pipe by combining multiple, n (where n is a positive integer), STS-1 or VT connections or pipes, which may be contiguous or non-contiguous, into a single connection or pipe, nxSTS-1 or nxVT, respectively, in order to support a connection or pipe with a higher throughput than the throughput of the original STS-1 or VT pipes.

The present invention provides a system and method of nxSTS-1 bandwidth sharing and ring protection.

UPSR Ring and DBA protection

The present invention provides for nxSTS-1s a modified UPSR ring architecture to realize both VT/STS path protection and DBA channel protection.

In an exemplary embodiment, the present invention protects two types of virtual ring topologies:

- (1) dedicated point-to-point channels; and
- (2) a nxSTS-1 ring.

Dedicated Point-to-Point Channels

The dedicated point-to-point channels are engineered as the same topology in Bellcore GR-1400. Path AIS is used for realizing ring path protection.

nxSTS-1 Ring

The present invention protects a nxSTS-1 ring in several ways. Referring to Figures 2A-2E, the protection ring (default is counter-clockwise) can be used to support unprotected secondary DBA channel (BDM, bandwidth doubling mode).

Normal DBA Channel

Figure 2A illustrates a normal DBA Channel in a nxSTS-1 ring being protected by the present invention. In Figure 2A, the present invention protects nxSTS-1 ring as follows:

- (1) one fiber 220 allows for SONET drop, add, and continue as a primary DBA channel; and

(2) another fiber 222 allows for either SONET bypass or SONET drop, add, and continue, as a secondary DBA channel.

Multiple nxVT connections can be created within nxSTS-1 ring 200. nxSTS-1 bandwidth can be shared by all nodes 210, 212, 214, and 216 on
5 ring 200. On ring 200, there are traffic paths 230, 232, 234, and 236. For traffic paths such as traffic path 230, traffic or data is either (a) continued in a SONET continue 231, (b) dropped in a SONET drop 233, or (c) added in a SONET add 235.

Fiber Cut

10 Figure 2B illustrates a DBA Channel in a nxSTS-1 ring 200 with a fiber cut being protected by the present invention. In Figure 2B, the present invention protects nxSTS-1 ring 200 if there is a fiber cut 240 as follows:

- (1) if the DBA channel receives an alarm indication signal (AIS) at its receive direction, switch receiver to the counter-direction;
- 15 (2) if the DBA channel receives AIS or AIS_L at its transmit direction, bridge transmitter to the counter-direction; and
- (3) switch boundary: nxVT, nxSTS-1, STS-nc, STS-nvc.

If there is a fiber cut 240, the present invention forms a new ring with and loops traffic via traffic paths 230 and 236 in order to protect the primary
20 DBA channel. Traffic paths 230 and 236 drop traffic from a healthy direction, add traffic to a healthy direction, and continue traffic in a healthy direction.

Node Failure

Figure 2C illustrates a DBA Channel in a nxSTS-1 ring 200 with a
25 node failure being protected by the present invention. In Figure 2C, the present invention protects nxSTS-1 ring 200 if there is a node failure 209 in node 210 similarly to the way the present invention protects nxSTS-1 ring 200 if there is a fiber cut in Figure 2B.

If there is a node failure 209, the present invention detects "cuts" in
30 the fiber 211 and 213 and forms a new ring with and loops traffic via traffic paths 232 and 236 in order to protect the primary DBA channel. Traffic paths 232 and 236 drop traffic from a healthy direction, add traffic to a healthy direction, and continue traffic in a healthy direction.

Another Normal DBA Channel

Figure 2D illustrates a normal DBA Channel in a nxSTS-1 ring 200 with primary or secondary DBA Channel support being protected by the present invention. In Figure 2D, ring 200 includes additional traffic paths 250, 252, 254, and 256, for the unprotected DBA channel. Traffic paths 230, 232, 234, and 236 still carry traffic for the protected DBA channel. The present invention protects ring 200 in Figure 2D similarly to how the present invention protects ring 200 in Figure 2A.

Another Fiber Cut

Figure 2E illustrates a DBA Channel in a nxSTS-1 ring 200 with primary or secondary DBA Channel support in BDM with a fiber cut being protected by the present invention. In Figure 2E, the present invention protects nxSTS-1 ring 200 if there is a fiber cut 240 similarly to the way the present invention protects nxSTS-1 ring 200 if there is a fiber cut in Figure 2B.

If there is a fiber cut 240, traffic paths 250, 252, 254, and 256 are eliminated, and the present invention forms a new ring with and loops traffic via traffic paths 230 and 232 in order to protect the primary DBA channel and discards the unprotected DBA channel. Traffic paths 230 and 232 drop traffic from a healthy direction, add traffic to a healthy direction, and continue traffic in a healthy direction.

Ring Manager Protection

The present invention provides ring manager protection as follows:

- (1) a newly elected primary ring manager (RM) takes a snapshot from ring 200:
 - (a) the primary RM recovers a RootVT from ring 200; and
 - (b) the primary RM forces all other VTs forced to an UNUSED stated; and
- (2) the newly elected primary RM examine all valid connection identifications (CID) and see if there is any CID without root_vt:

(a) for any CID without root_VT, the primary RM assigns an unused VT as the root_vt for the CID.

RM Election

5 In an exemplary embodiment, the RM protection scheme is illustrated in Figure 3. When a primary RM detects a heartbeat of another primary RM, only the RM with smaller node ID will remain as the primary RM. Whenever this happens, a CPU interrupt is generated. Either EMS or hardware will reset ring 200. The following then occurs:

- 10 (1) a secondary RM detects errors in a status message and starts RM election;
- (2) the elected RM starts taking VT table recovery procedure; and
- (3) the elected RM starts taking DBA commands.

15 A RM status message is sent on every STS1# POH from the current Active primary RM to all other nodes in a clockwise direction in ring 200.

A priority is determined according to the Node ID. A lower Node ID represents higher priority. The default RM is the one with Node ID = 0.

The path overhead (POH) of every STS-1 in the STS-nvc group will
20 carry a RM status message. To get the RM status message, the present invention reads it from any STS-1. To send a status message, the present invention writes each STS-1 POH F2 [7:0] is used to carry these messages.

A board controller fills RM_Stsmg_STSnum register for the STS# to be used for reading status messages as an initialization process. A
25 RM_Node_ID register will be configured by the board controller. The board controller configures how many non-valid status messages are to be received for the secondary RM to start primary RM re-election by transmitting status messages with an Active bit de-asserted (CLAIM ON). A

RM_Stsmg_period register is configured by the board controller for this
30 function. The status message is not dropped by any RMs when the claim procedure is not on. In order to avoid a primary RM crash and a valid message still being on the bus, a toggling status message could be sent. One message is with its node id, and the next message is with FFF as its node ID.

Any time the primary RM crashes or goes down, the status message will not be as expected. There will be either a parity error, a wrong primary node id, a not toggling status, or an Active bit goes disabled. The secondary RMs see this and will start the CLAIM process. All RMs take part in the CLAIM process such that even if one node goes away, any other RM can be elected as the primary RM.

Once a RM enters into a CLAIM process, there are two rounds before the primary RM is identified. On the first round, RMs will always receive status messages with a claim bit on. Each RM will look at the receive node id and its own node id. If the receive node id is greater than its own node id, then this node transmits its own node id. If the receive node id is less than or equal to its own node id, then this node transmits the received node id. The RM with the lowest node id receives the status message with its own node id and will wait for one more status message to confirm. Afterwards, this RM will set itself as the primary RM and will start sending regular status messages with an Active bit asserted (CLAIM OFF). On the second round, RMs will receive the status messages with a claim bit off. RMs, except for the new elected Primary RM, will record the received id as the new primary RM id and will start monitoring status message as returning to normal operation. The primary RM will then start managing VTs.

DBA Command Protection

The present invention also protects DBA commands. Since the DBA protocol is not memoryless, the present invention protects the multiple distributed states in the DBA protocol such that they are in sync. This is difficult to achieve especially when there is a fiber cut or when redundancy protection switching is happening. The present invention provides several protection mechanism to ensure that the DBA protocol state machine does not go into a wrong state.

The present invention can detect errors in following two situations:

- (1) the present invention can detect errors in the VT POH with parity check error; and

(2) the present invention can detect errors in the CID command when the CID command is not consistent with the local database.

VT POH Errors

5 Whenever the VT POH has some error, the present invention performs the following:

(1) in demapping, the present invention ignores the incoming command and does not demap the data;

(2) in mapping, if there is a parity check error, the present invention issues a command/CID according to the original local database and maps the data accordingly; and

(3) the ring manager enforces the VT based on the original database, but collects back unused VTs.

VT POH CID Not Consistent

Whenever the VT POH CID is not consistent with the local database, the present invention performs the following:

(1) in mapping, the present invention changes the CID to an UNUSED state.

In addition, in the present invention, the mapper and RM perform the following whenever protection switching happens:

(1) monitor the Fiber AIS, the trunk card and XCC card status signal:

(a) if switching happens, the present invention blanks out the data for 3 consecutive frames before starting to use any commands in the VT POH bytes.

Conclusion

30 The present invention relates to optical networking. More particularly, the invention relates to a system and method of nxSTS-1 bandwidth sharing and ring protection.

Having fully described a preferred embodiment of the invention and various alternatives, those skilled in the art will recognize, given the teachings herein, that numerous alternatives and equivalents exist which do not depart from the invention. It is therefore intended that the invention not
5 be limited by the foregoing description, but only by the appended claims.

CLAIMS

We claim:

1. A method of nxSTS-1 bandwidth sharing by every node on a nxSTS-1 ring comprising:
 - 5 placing nxSTS-1s in the nxSTS-1 ring;
 - creating a nxVT point-to-point or point-to-multipoint connection within a nxSTS-1 pipe; and
 - globally managing VT resources in the ring via a ring manager.
- 10 2. The method of claim 1 wherein the managing comprises globally assigning VT resources to any node on the ring by the ring manager.
- 15 3. The method of claim 1 wherein the managing comprises globally assigning VT resources to any connection on the ring by the ring manager.
- 20 4. The method of claim 1 wherein the managing comprises globally removing VT resources from any node on the ring by the ring manager.
- 25 5. The method of claim 1 wherein the managing comprises globally removing VT resources from any connection on the ring by the ring manager.
6. A method of bandwidth doubling comprising;

forming with fibers a primary ring to carry a primary nxSTS-1 ring; and

forming with fibers a secondary ring to carry a secondary nxSTS-1 ring.

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7. The method of claim 6 further comprising forming a viable ring for data traffic with two fibers by looping back STS-1s from two nodes which are adjacent to a failure point to protect the primary ring or the secondary ring.

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8. The method of claim 6 further comprising only protecting the primary ring.

9. The method of claim 6 further comprising only protecting the
15 secondary ring if the secondary ring is viable.

10. A method of protecting a nxSTS-1 ring comprising:

in a normal mode, only having one ring manager as an active ring manager; and

20 if the active ring manager fails, making another ring manager a new active ring manager according to a election protocol, where every node on the ring can be a candidate ring manager.

11. The method of claim 10 further comprising:

25 taking a snapshot of the ring by the new active ring manager;
and

attempting to recover the connection for the ring by the new active ring manager via the snapshot.

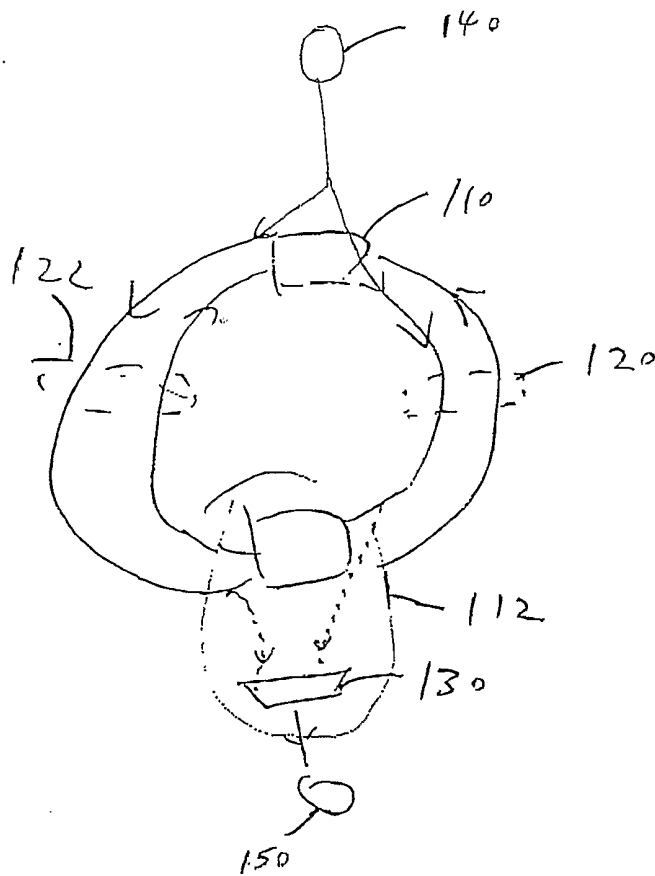
12. The method of claim 10 wherein the election protocol
5 comprises, when candidate ring managers can not detects a heartbeat of another active ring manager, making the candidate ring manager with the smaller node identification be the new active ring manager.

13. The method of claim 11 wherein taking the snapshot of the
10 ring comprises:

recovering from the ring only a root VT; and

enforcing all other VTs to an unused state.

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(PRIOR ART)

FIG. 1

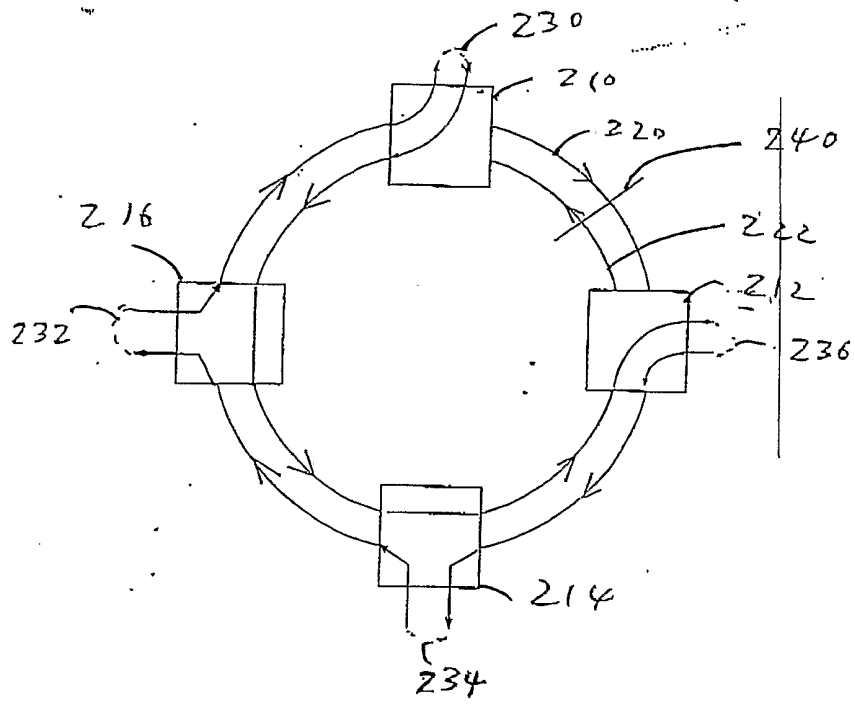


FIG. 2B

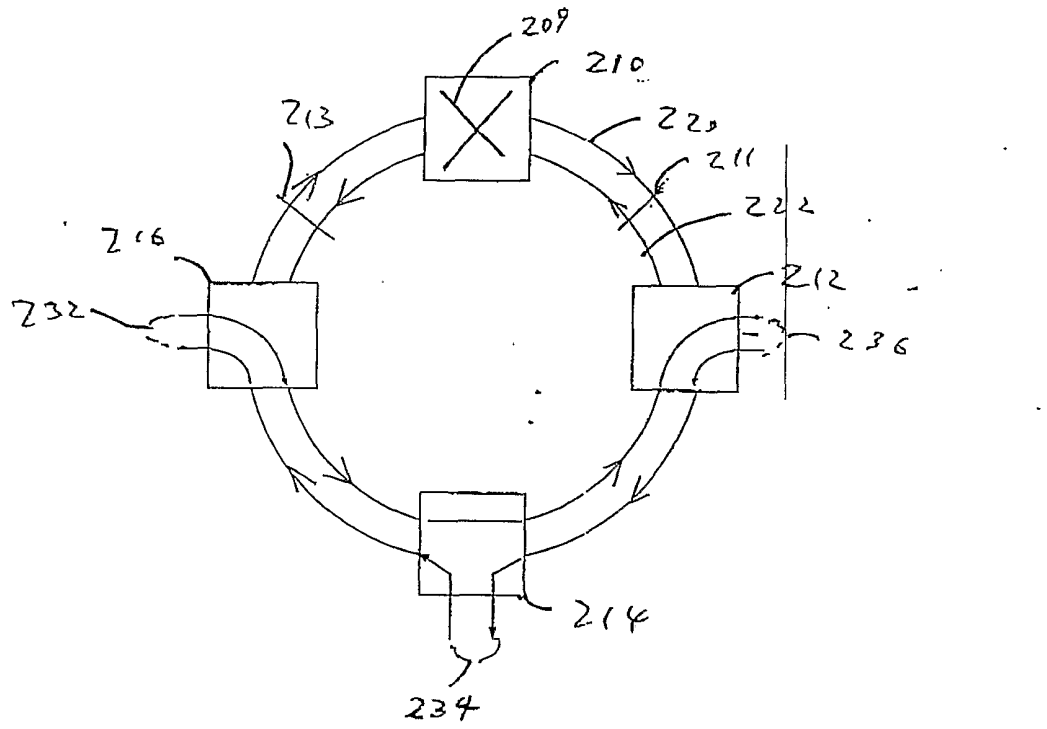
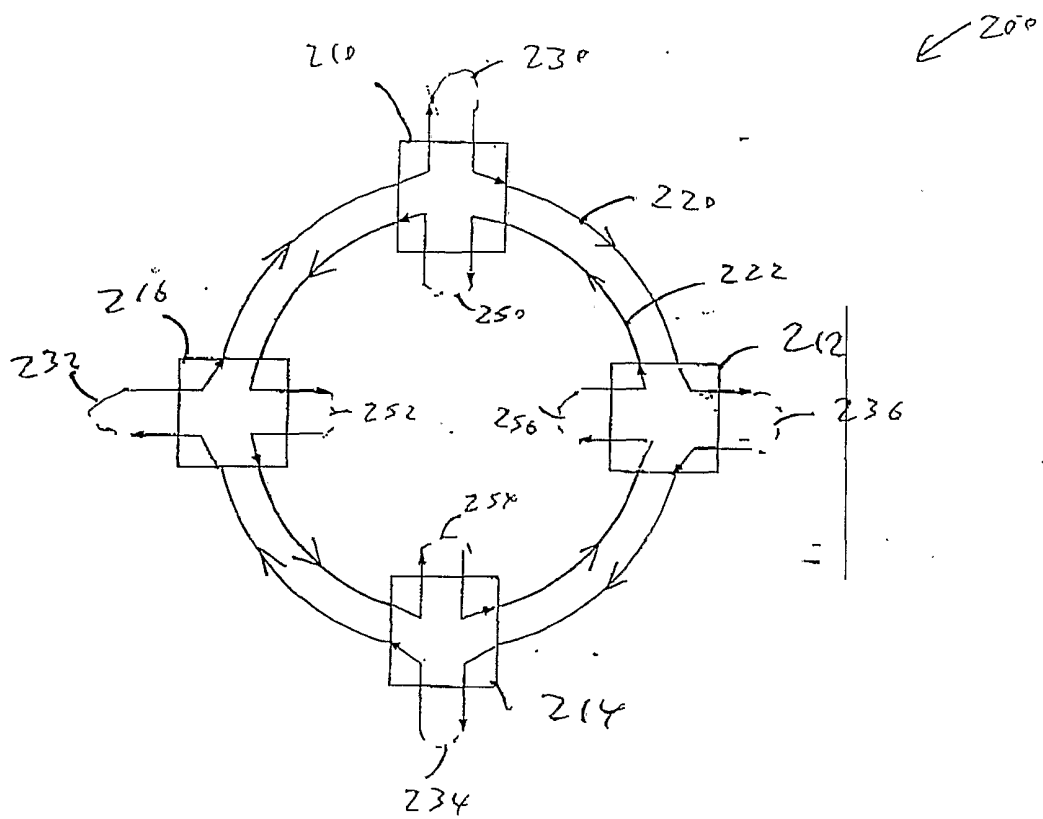
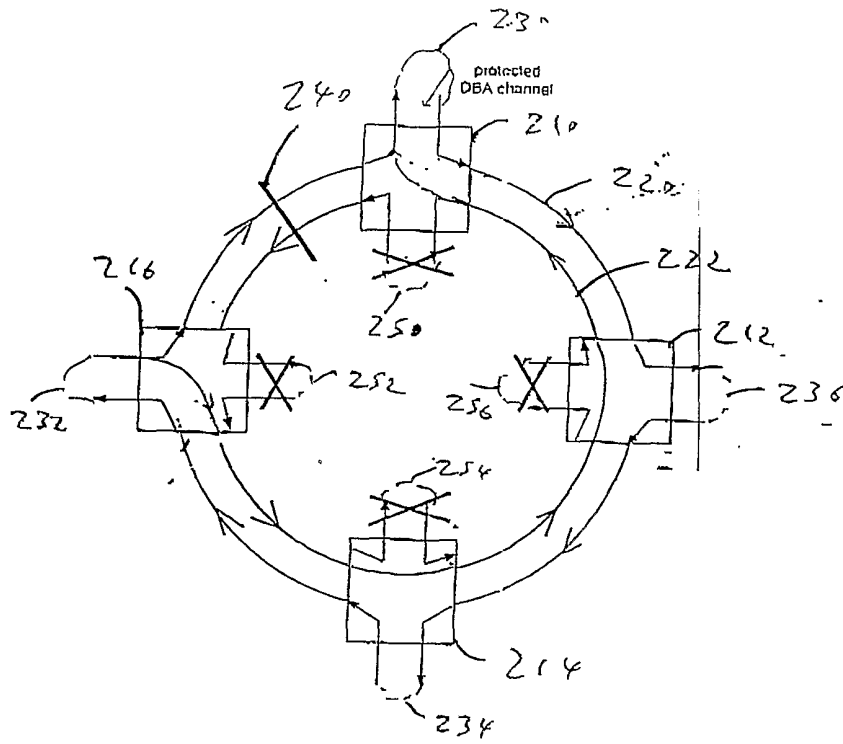


FIG. 2C



↖ 200



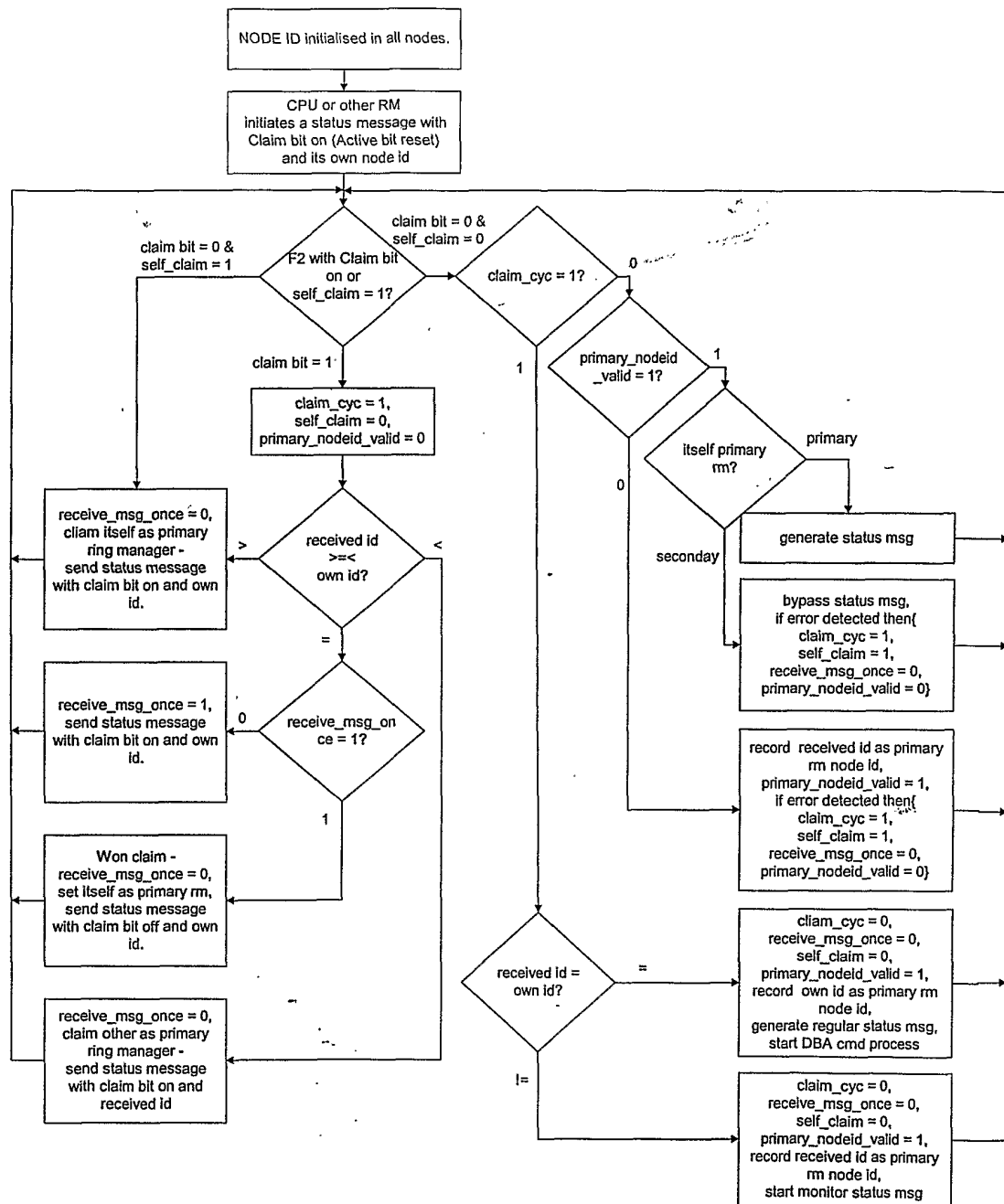


FIG. 3