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Modified Multi-Destination Restorations on ATM Multicast Tree

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ABSTRACT

Multimedia applications are forecast to benefit most multicast communication capabilities. The emerging high-bandwidth characteristic forces people to seek more high-speed technology than Internet Protocol (IP) multicasting. Recently, a connection-oriented nature of ATM network makes multicasting more powerful. In multimedia services, to support an ATM multicast tree (AMT) to connect all the conferencing members is a convenient and mordent method. The emergence of service and collaborative computing in distributed environments provides the AMT for system designers to include communication support incentive for the multimedia applications. In the high-speed nature in AMT, robust restoration becomes one of crucial and essential function since a network failure may cause a huge tangible and intangible loss for customers and service providers [17]. In this paper, based on survivability requirements, we investigate the restoration of an AMT. Two investigated dynamic restoration methods are developed to provide self-healing capability from a link or node failure: one is link-based and the other is tree-based restoration method. In the first mechanism, we apply a point-to-point restoration scheme on the AMT. In second, without changing the multicast services to the members, we allow reconfiguration of the AMT during the restoration phase. For each method, we also proposed two schemes to solve the AMT restoration problems: the three-phase Modified Multi-Destination Flooding (MMF) and the three-phase Tree-Type Flooding (TTF). By computer simulations, we verify the characteristics of the proposed schemes and the results show that the tree-based MMF and TTF outperform the link-based ones.

1. INTRODUCTION

Using multicasting, services offered by a group of nodes can be identified by a single IP address resulting in IP multicasting [16]. The IP multicasting transmits data that contains the destination of the group address to the group members in a connectionless and best-effort mode. Nowadays, multicasting approach enhances in an ATM (Asynchronous Transform Mode) backbone, which employ ATM switching. Many multicasting approaches [10-12] [14] based on ATM backbone provide reliable, scaleable and efficient ways of disseminating data from a sender to a group of receivers. The ATM multicasting support the multimedia services by forming an AMT (ATM Multicast Tree) to connect all the conferencing members in a connection-oriented mode. UNI (User Network Interface) 3.1 defined the signaling of point-to-multipoint connection services on ATM multicasting. Since of the vastly interest in grouping video-conferencing into AMT, point-to-multipoint multicasting has become widely used in broadband ATM network.

Two primary techniques on constructing AMT have been developed to support multicast services in ATM networks (see fig. 1). The first technique uses a centralized multicast server as a root for the AMT [1][13]. The server sets up a point-to-multipoint connection which includes all the members in the multicast group. For each member, the system sets up a point-to-point connection from its host node to the multicast server (see fig. 1). Any member can broadcast its information to other members by sending cells to the multicast server. The server, then, forwards the cells to the AMT. The advantage of this mechanism is that each node maintains only two connections. However, the centralized server may become a bottleneck [3]. The second technique is based on overlaid point-to-multipoint connections where each node forms a point to multipoint connections with all the other members in the group. Thus, *N* point-to-multipoint connections have to maintain multicasting at each node, where *N* is the number of nodes in the AMT. Nevertheless, this scheme does not work well when the *N* becomes large. The system also requires a registration process to manage the dynamic memberships in the tree. Contrast to IP multicasting, ATM multicasting requires to send setup signals to build a point-to-multipoint virtual circuit (VC) before data transmissions. Every member requires setting up a VC to all group members. In addition, the changing of the group membership requires a re-configuration of the point-to-multipoint VC. Due to the AMT point-to-multipoint constructing characteristics, In this paper, we investigate AMT restoration on the above two techniques.

For the survivability of multicast services, most existing VP/VC-based schemes are only developed for the restoration of (link-based) point-to-point connections, without taking whole AMT into account. In this paper, we extend the dynamic restoration scheme of [4] to an ATM Multicast Tree (tree-base) restoration. Two methods, link-based and tree-based, are studied to provide restoration on AMT [17]. By a forward research, two link-based dynamic schemes are developed: Link-Base Modified Multi-Destination Flooding (MMF) and Link-Based Tree-Type Flooding (TTF). In these two schemes, the failure of a link on an AMT can be recovered by a point-to-point restoration scheme. For examples, in Fig. 2.a, connection B is restored for failed connection A. In this approach, the restoration scheme does not take the tree structure into account and the configuration of the tree is unchanged. With the idea that we may reconfigure the tree such that the multicast service can be preserved, two tree-based restoration schemes, Tree-Based MMF and Tree-Based TTF, are also proposed to specifically utilize AMT characteristics. For example, in Figure 2.b, connection B, C or D is used to restore failed connection A. Note that the structure of tree is changed, but the new tree can provide the same multicast service as the original tree. In the link-based scheme, only one Chooser in Sender-Chooser pairs performs the restoration process. However, the tree-based scheme allows multiple Choosers to exist. Thus, we may have multiple pairs of Sender-Chooser working together to restore the failed link. Therefore, a tree-based restoration can significantly improve tree restoration performance.

This paper is organized as follows: in Section 2, we propose two link-based AMT restoration schemes, Section 3, two tree-based schemes deployed. To compare the performance of the four proposed schemes, a simulation network is developed and an analysis of the simulation is presented in Section 4. Finally, conclusions are given in Section 5.

2. LINK-BASED RESTORATIONS

In a dynamic restoration scheme, when two adjacent nodes detect a link failure, one becomes Sender and the other becomes Chooser. The Sender begins to broadcast search messages to find alternative paths. When the Chooser receives search messages, it selects one of the alternative connections and informs the Sender to restore the failed connection. In order to compare the performance of dynamic VP-based restoration schemes, we use "phase" as one handshaking between Senders and Choosers. Thus, the Multi-Destination Flooding (MDF) [3] uses the four-phase mechanism. In the first phase, the Sender initiates a route-search message to discover alternative paths. In order to reserve the required bandwidth along the path, a Route-Reservation message is sent from the Chooser in the second phase. The Sender transmits a Cross-Connection message to set up the alternative VP connection in the third phase. Finally, in the fourth phase, the Chooser informs the Sender that the alternative VP is built and readies to receive the data. For simultaneously protect the link and node failure, a algorithm is modified the flooding on [17] applied a three-phase mechanism. As shown in [17], in the first phase, the Sender broadcasts a restoration message to find and reserve the spare capacity. The Chooser selects the first arrival restoration message and responses by sending connection message back in the second phase. The Sender informs the Chooser to re-start the multimedia service by a confirmation back Chooser in the third phase. In this paper, schemes use the three-phase handshaking to communicate the restoration information according to fast flooding requirement.

We consider an AMT consisting of N root nodes connected with directional logical connections as shown in Fig 1. Each tree is identified by a unique Tree ID, which is analogous to the global unique Root Call Identifier (RCID) [1]. In UNI 3.1[1], a multicast tree is identified by a unique tree ID, Global Tree Identified (GTID). When an AMT is set up, its GTID will be stored at the routing table along the path. The root node of a multicast tree distributes its GTID to all the nodes in its tree. Since a node may belong to multiple trees, a node may have multiple GTID. When an ATM is failed, Sender broadcasts search messages with its GTID, which can do the alternative path judgement discussed on below.

The behavior of the developed link-based restoration mechanism is composed of three phases, alternative route search, connection and confirmation phase, as follows.

A. Route-Search Phase

When AMTs are disrupted by a link or node failure, the node adjacent to the failed link detects failure from the system and become Sender. Sender will broadcast AIS signal to the downstream stream nodes of the AMT [17]. The Sender starts flooding search messages to all outgoing links to search alternative paths. The Chooser, in this scheme, is not involved in the search phase and waits for the arrival of a search message like [2]. When an intermediate node receives a search message, it calculates the available bandwidth like [2] and performs the flooding function by judging whether next flooding node overlaps the traversed path saved in the search message. When a search message arrives at the Chooser (by judging from same GTID and Server ID different from Sender ID), it means an alternative path has been found. This alternative route search phase was shown in Fig 5.

B. Reservation Phase

The Chooser selects some failed AMT, which total bandwidth less or equal to the searched available bandwidth, to be recovered. For each recovered AMT, Chooser sends back reservation message which reserves required bandwidth. If the bandwidth reservation failed (or reservation blocked) , a canceling message will be send back Chooser. Since Chooser may receive many copies of a search message, Chooser selects the alternative AMT in first-come-first-served manner. Later arriving search messages but no failed ATM to be recovered will be saved in a reservation pool to wait for probability re-selection on canceling message back. An example is shown in Fig. 6.

C. Connection Phase

If reservation message gets to Sender, the Sender enters into the Connection Phase. The Sender selects suitable failed AMT and sends a connection message according the reserved alternative route. As mapped Chooser receives the connection message, it means the alternative route is successfully found. An example is shown in Fig. 7.

2.1 Scheme 1 : Link-Based Modified Multi-Destination Flooding

The link-based Multi-Destination Flooding is directly applied the MDF on the link-based AMT restoration. It is benefit to use the link-based MDF to search alternative routes. Conveniently, the applied MDF scheme is modified to a three-phase MMF restoration scheme followed above three-phase algorithm. On best-effort flooding scenario, the found alternative routes are not optimized solution. The algorithm maybe meets the problem on blocking reservation, which is mentioned before. The blocking condition is caused by the reservation or bandwidth contention failure on the Reservation Phase. Since There are some alternative routes which can not complete the bandwidth reservation from Sender to Chooser, it causes the reserved alternative route have to be released and make system restart a restoration process on Sender. On the part of restart, we need a pool to save the found alternative routes. If some blocking messages backward, the system can do a new selection from the pool.

As failure occurred, search messages will be broadcast to find alternative routes. A search message contains the following information: (1) Tree ID (GTID) (2) Bandwidth (3) Priority (4) Hop count (5) Traversed Path (6) Sender node ID. A Chooser can clearly decide if an alternative node is found by comparing GTID of search message with its GTID. The bandwidth is the available bandwidth for the restoring AMT [2], and priority indicates the restoration priority. The hop count is used to limit the flooding area. When a search message traverses a hop, the hop count is decreased by one. The search message will be discarded if the hop count is equal to zero. The traversed path denotes the nodes which the search message had traversed. By this traversed path, a Chooser can trace back along the alternative path to the Sender, or vice versa. The Sender node ID is used to distinguish the search message broadcast from different Senders but with same GTID. As node failure, the search messages with different Sender node ID will content bandwidth reservation. The total size of a search message is 32 octets plus 3 bits and can be filled in the Function Specific fields of one F4 or F5 OAM (Operation Administration and Maintenance) cell.

2.2 Scheme 2 : Link-based Tree-Type Flooding

In scheme 1, MDF exhaustively search the alternative routes and make a good performance on searching; however, it sends huge search messages that make the network system congested on restoration process. In order to solve this problem, a new link-based tree-type flooding method is proposed in this paper. The main idea is to let the intermediate nodes save the routing information [17] and judge to stop flooding whether the same-source search message has arrived. It is different from scheme 1, which judges overlap on the traversed path in the information of search message (see fig. 3). In order to increase the search rate as overlap occurred, the search algorithm on TTF is enhanced and modified to let the intermediate node not to stop searching but generate "overlapped search messages" forwarding the traversed route (see fig. 4), which found by first coming search message, to the Chooser. As forward the overlapping traversed route, the intermediate node just continues to generate overlapped search messages to follow the traversed route.

A search message contains the following information: (1) Tree ID (GTID) (2) Bandwidth (3) Priority (4) Hop count (5) Incoming node ID (6) Sender node ID. Link scheme 1, GTID is for searching judgement. The bandwidth is the required bandwidth for the restoring AMT, and priority indicates the restoration priority. The hop count is used to limit the flooding area. When a search message traverses a hop, the hop count is decreased by one. The search message will be discarded if the hop count is equal to zero. The incoming node ID denotes the ID of the node, which forwards the search message. By this ID, a Chooser can trace back along the alternative path to the Sender. The Sender node ID is used to distinguish the search message broadcast from different Senders but with same GTID. Note that the total size of a search message is 18 octets plus 3 bits and can be filled in the Function Specific fields of one F4 or F5 OAM (Operation Administration and Maintenance) cell. Thus a single OAM cell can be used to carry one control message. Obviously, it is easier to implement the restoration process when a control message consists of a single cell.

From simulation, the result shows the restoration rate will be decreased a little bit compared with MDF (see fig.17). The reason is the number of searched routes is decreased. It causes the new flooding dislike the MDF broadcasting messages (see fig 4). Nevertheless, the simulation shows the number of the search message can be decreased tremendously discussed in section 4. This makes the system congestion burden reduced.

3. TREE-BASED RESTORATIONS

First, we investigate how to select appropriate nodes as Choosers such that multicast service is more preserved. As a link fails, its adjacent downstream node becomes the Sender, which activates the restoration process. (Note that a failure maybe causes many disrupted AMTs. Let us focus on a particular AMT.) From the Sender, an AIS OAM message is then sent down to its descendents in the AMT. When a node receives this AIS message, it sets its AMT mode to be a failure mode, and then forwards this AIS message to its child nodes in the AMT. Besides, the nodes are not affected by this failure if they are not the descendents of the Sender. That is its AMT mode is still in a normal mode. Conceptually, we define the subtree rooted at the Sender as a C-subtree, which consists of nodes with failure mode. P-subtree is rooted at the original root [17] as shown in Fig. 8.

Now, we can extend the link-based scheme to the proposed tree-based restoration in link failure as follows. To preserve the multicast service, we can simply join two sub-trees by merging C-subtree under any node in the P-subtree as shown in Fig. 8. P-subtree is referred to be the subtree with the original root while the downstream node of the failed link becomes the root of the C-subtree. Therefore, any node of the P-subtree can be a Chooser. To preserve the multicast service, we can simply join two sub-trees by merging C-subtree under any node in the P-subtree as shown in Fig. 8. Consequently, any node of the P-subtree can be a Chooser. Especially, in a node failure scenario, restoration becomes more complicated than in link failure. As one node fails, some nodes detect failure and become Senders like in the link failure scenario. However, the AIS maybe is delayed on broadcasting. If a Chooser node receives an AIS, it then initiates failure mode behavior, aborting Chooser behavior. That is, if a node initiates Chooser behavior and subsequently receives an AIS, the node then aborts Chooser behavior, at the same time releasing all selected alternative routes by sending canceling messages. The Chooser will also send a release message to the relative Sender. The Sender can then restart the restoration process.

A search message will be constructed at the Sender when network detects failure. The message uses the same format as in the link-based scheme, except that the message needs only contain the GTID of the Sender; it does not need the GTID of the Chooser. The process at the intermediate nodes is similar to link-based restoration. When a node receives a search message, first, it needs to check if it is the Chooser of this message by the following rules: As link failure occurred, the first node under the failed link will be the Sender and must send AIS to their descendent nodes. The AIS will take the failure tree ID and broadcast down to all branches related to the Sender. Note that one node may receive multiple AIS with different GTID. In restoration process, the AIS will broadcast to the descendant nodes of Senders and trigger the failure mode. One can distinguish a node is in C-subtree or P-subtree of a failed AMT by judging whether it is in failure mode or not. If the node contains the GTID of the failed AMT and is in failure mode, it is in C-subtree of the failed AMT. Otherwise, if the node contains the GTID of the failed AMT but not in failure mode, it is in P-subtree. For avoiding inefficient NACK retransmission [11], all the branches under a failed link must trigger themselves into failure mode. Note that each such node cannot become a Chooser. The failure mode of such nodes aborts both Chooser selection and NACK transmission. In each Sender, any descendant node cannot be the Chooser. Therefore, the C-subtree contains the nodes in failure mode including Sender. Only the node in P-subtree has the opportunity to be the Chooser (see Fig. 8). As a search message arriving one Chooser, the Chooser forms a setup message and sends it back to the Sender to set up an alternative connection. As a Sender receives a reservation message, it sends a connection message back to the Chooser and broadcasts the setup message to change the GTID of its ascendant nodes. After the relative Chooser receives a connection message, the tree is restored and data can be retransmitted into the alternative route.

The behavior of the proposed tree-based restoration mechanism is composed of three phases, alternative route search, reservation, and connection phase, as follows.

A. Alternative Path Search Phase

When AMTs are disrupted by link or node failures, the node adjacent to a failed link broadcasts AIS to the downstream nodes. It starts the restoration algorithm and enters the alternative route search phase like the link-based scenario, as shown in Fig 9. Note that there are multiple Choosers for one Sender.

B. Reservation Phase

The Choosers may select the alternative AMT and send reservation messages backward to Senders like in the link-based scenario, as shown in Fig. 10. Note that, in Reservation Phase, when a link has insufficient bandwidth to accommodate the required bandwidth, a canceling message is sent back along the traversed links back Chooser to release the reserved bandwidth. The chooser must do re-selection process as previously mentioned.

C. Connection Phase

When a Sender receives a reservation message, an alternative route has been successfully discovered. The Sender must send connection messages back Chooser to setup the selected routes as shown in fig. 11. Note that there may be multiple alternative routes selected by different Choosers. The connection messages from different Choosers must also contend each other. If failed contention, the failed route will be released by a canceling message sent by the Sender when it receives a later connection message (see fig.11).

3.1 Scheme 3 : Tree-Based Modified Multi-Destination Flooding

Since we can use the tree-ID to do multi-chooser restoration on AMT, a tree-Based Multi-Destination Flooding is directly applied on the tree-based AMT restoration. Conveniently, the applied MDF scheme is modified in a three-phase cell-based restoration scheme. It is different from the scheme 1 by using MDF flooding algorithm to search all possible alternative routes on each failed AMT. The search message can convey search information in only one cell [17]. However, it has also the problem on blocking reservation. It will cause the reserved alternative route be released and need restart new restoration process. On the part of re-selection, the restoration pool is also applied to save the found alternative routes since the system can re-select new alternative candidate from the pool (if any blocking message backward). By the advantage of tree-based restoration scheme, the flooded path is shorten (see fig.13). It means the restoration time can be reduced. Besides, the multiple-chooser scenario, the restoration rate is enhanced. The simulation improved the number of search message; besides, the restoration rate is increased since more alternative routes are found (see fig.16).

3.2 Scheme 4 : Tree-Based Tree-Type Flooding

Since MDF exhaustively search the alternative routes and make huge search messages, we applied the tree-type flooding on cell-based AMT restoration, which makes the network system avoid network congestion. By the advantage of Tree-Based TTF, the number of search message is reduced. The restoration rate is also enhanced into a good performance since of more Chooser candidates mapped to one Sender (see fig. 17-18).

4. SIMULATION AND DISCUSSION

To verify the characteristics of the proposed scheme and evaluate restoration performance, we developed a simulation network. The simulation network topology, which is also used in [2], is shown in Fig. 12. The network consists of 25 nodes and 28 links. All connection links are directional. The total working and spare capacity is 403 and 230 DS3 capacity, respectively. The processing time is estimated to be 5 ms at each node. The hop count limit is set to 9. Each AMT has the same bandwidth and is equal to the capacity of DS-3. 214 AMTs were generated randomly with this topology. On the average, each link was used in 18.43 trees. Thus, when a link fails, multiple trees need to be restored. The restoration rate is defined as the ratio of the number of restored trees to the number of tree failures caused by the initial link failure.

In scheme 1, the simulation shows there are 65137 search messages, 2185 cancel messages, 1715 reserve messages, and 3411 connect messages on flooding. However, the blocking number is 671. For enhancing the MDF performance, the MMF simulation makes a restoration pool to save the found routes. We count the restoration rate approached to 96.9%. The number of failed AMT is 806 and the number of restored AMT is 781 on link failure. In scheme2, the simulation shows there are 1920 search messages,. 1302 cancel messages, 1301 reserve messages, and 3411 connect messages on flooding. In addition, there are 23977 overlapped search messages forward the overlapped route the choosers. The blocking number is decreased to 405. We count the restoration rate approached to 90.4%. The number of failed AMT is 806 and the number of restored AMT is 729 on link failure. In scheme 3, the simulation shows there are 44351 search messages, 116 cancel messages, 1267 reserve messages, and 1886 connect messages on flooding 204 generated AMT. The blocking number is 88. We count the restoration rate approached to 99.9%. The number of failed AMT is 806 and the number of restored AMT is 805 on link failure. In scheme 4, the simulation shows there are 7334 search messages, 141 cancel messages, 1346 reserve messages, and 1975 connect messages on flooding. In addition, there are 18316 overlapped search messages forward the overlapped route the choosers. The blocking number is decreased to 78. We count the restoration rate approached to 99.6%. The number of failed AMT is 806 and the number of restored AMT is 803 on link failure. The link-failure restoration performance of the four schemes are shown in fig. 17 and 18.

Average length of alternative route, average restoration time, average restoration number, and restoration rate for single link failure is depicted in fig. 13, 14 15, and 16. As we expected, the tree-based scheme can significantly improve restoration performance than link-based scheme (see fig.17-18). This is because the tree-based scheme uses multiple Choosers to restore the failed connection. In fact, the Choosers of tree-based scheme always include the single Chooser of the link-based scheme. Therefore, more alternative paths can be found. Another factor that can improve performance is that less overhead traffic is generated for the tree-based scheme. The reason is that the tree-based scheme is likely to use a shorter alternative path than the link-based scheme (see average length fig. 13). Importantly, the number of search messages is the most affect point on dynamic restoration.

The TTF reduces the flooding cells and make a better performance in tree-base one. Besides, recall the link-based restoration scheme. Search messages will be broadcast at all intermediate nodes until the Chooser receives the message. The broadcast cost is quite high and may result in severe network congestion. Therefore, more Choosers imply fewer overheads.

5. CONCLUSION

For robust transmission on multimedia applications, ATM Multicast Tree (AMT) is more and more required restoration in the future. In this paper, link-based MDF and TTF mechanism , without taking the characteristics of a tree into account, is proposed to support link protection on AMT. Especially, TTF makes the flooding search messages reduced fewer than MDF. In order to improve restoration performance, we extend the two link-based schemes to tree-based schemes. In the tree-based configuration, more Chooser candidates can be considerable and enhance the AMT restoration better performance. Basically, the Tree-Based schemes are cell-based restoration and Link-Based schemes are group-based restoration. Simulations verify the characteristics of the proposed schemes and the results show that tree-based TTF and MDF restoration schemes outperforms the link-based schemes.

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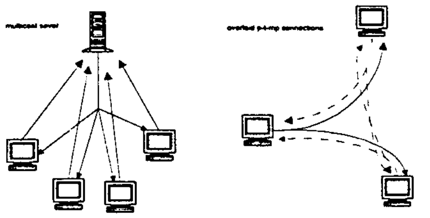
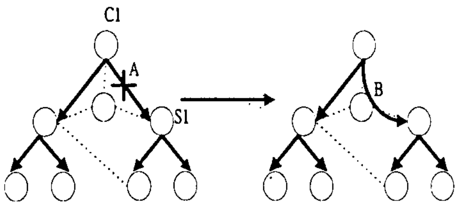


Fig. 1 Centralized Multicast Server and Overlaid Point-To-Multipoint Connections



Si : Sender i
Ci : Chooser i
Fig. 2.a Link-Based Restoration on a AMT in Link Failure

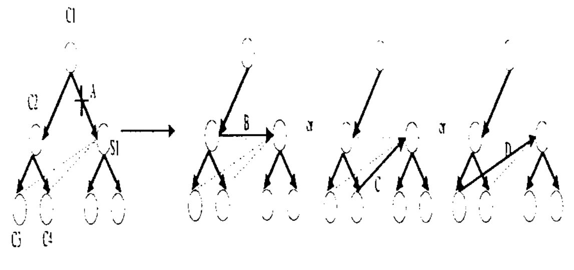
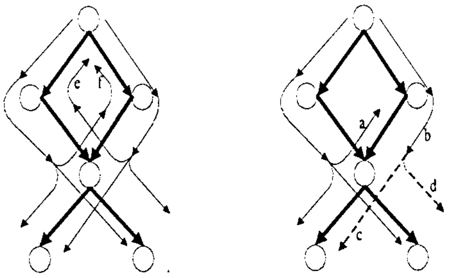


Fig.2.b Tree-Based Restoration on a AMT in Link Failure

Fig. 2 Two Restoration Approaches for Multicast Tree



(1) (left figure: Multi-Destination Flooding) Message "e" and Message "f" stop flooding as detection overlap in traversed route.

(2) (right figure: Tree-Type Flooding)Message "a" stops flooding overlap Message "b". Message "b" broadcast overlapped messages "c" and "d" following traversed routes.

Fig. 3 Flooding on MDF and **Fig. 4** Flooding on TTF

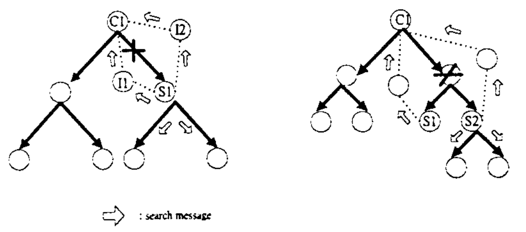


Fig.5 Link-Based Search Phase

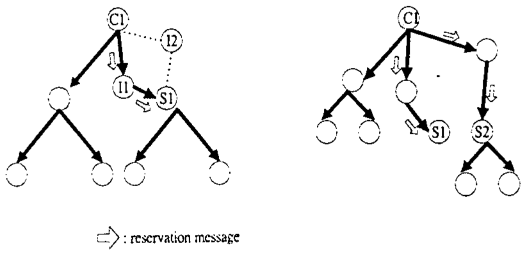


Fig. 6 Link-Based Reservation Phase

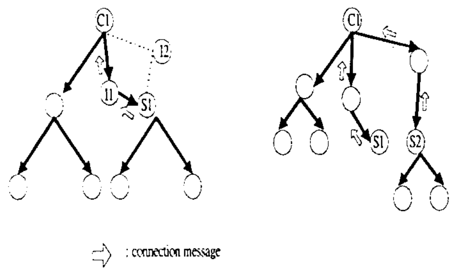


Fig. 7 Link-Based Connection Phase

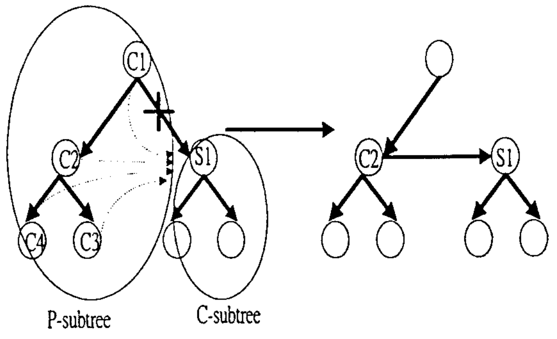


Fig. 8 Tree-Based Restoration

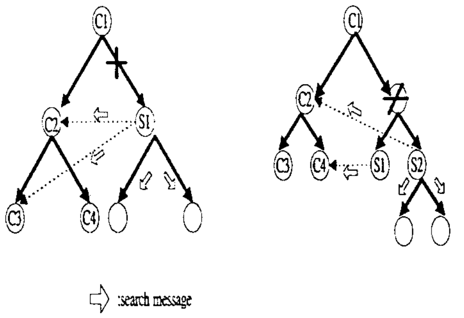


Fig. 9 Tree-Based Search Phase

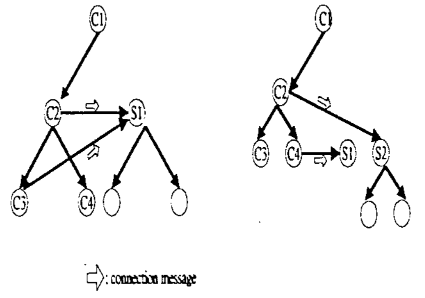


Fig. 10 Tree-Based Reservation Phase

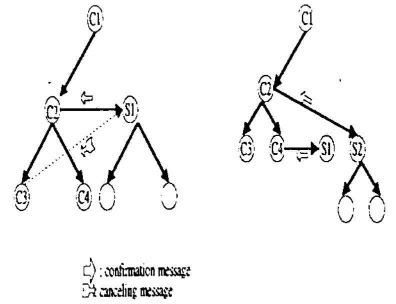


Fig. 11 Tree-Based Connection Phase

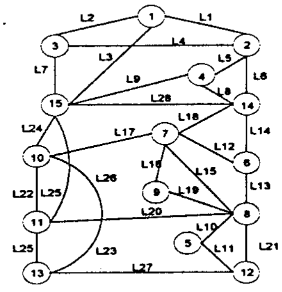


Fig. 12 Simulation LATA Network

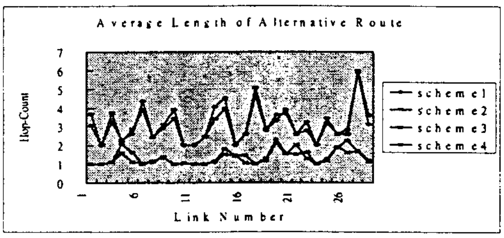


Fig. 13 Average Length of alternative Route

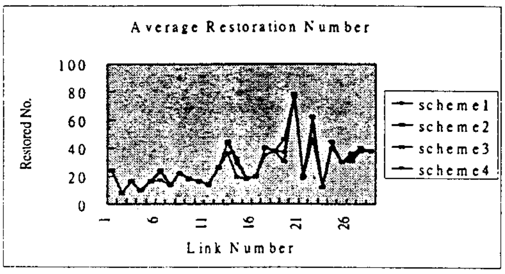


Fig. 14 Average Restoration Number

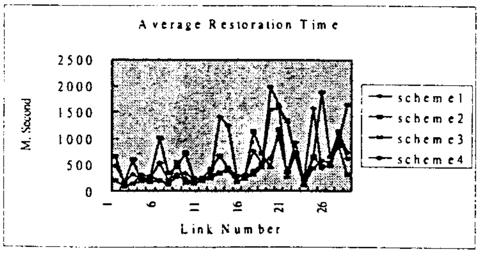


Fig. 15 Average Restoration Time

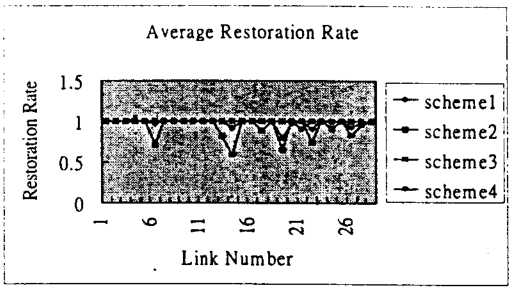


Fig. 16 Average Restoration Rate

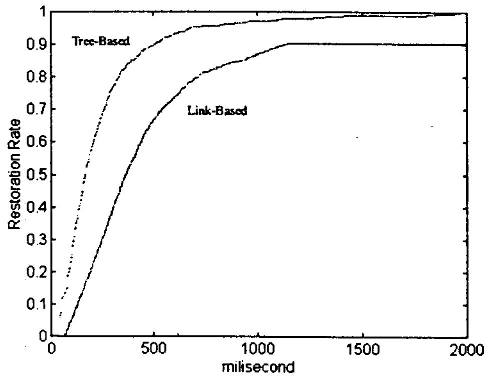


Fig. 17 Comparison of Restoration on MMF

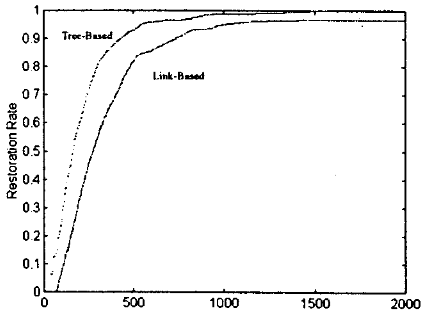


Fig. 18 Comparison of Restoration on TTF