A NOVEL SCHEME FOR RELIABLE MULTIPATH ROUTING THROUGH NODE-INDEPENDENT DIRECTED ACYCLIC GRAPHS

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Abstract

Multipath routing is essential in the wake of voice over IP, multimedia streaming for efficient data transmission. The growing usage of such network requirements also demands fast recovery from network failures. Multipath routing is one of the promising routing schemes to accommodate the diverse requirements of the network with provision such as load balancing and improved bandwidth. Cho et al. introduced a resilient multipath routing scheme known as directed acyclic graphs. These graphs enable multipath routing with all possible edges while ensuring guaranteed recovery from single point of failures. We also built a prototype application that demonstrates the efficiency of the scheme. The simulation results revealed that the scheme is useful and can be used in real world network applications.

***Index Terms** – Multipath routing, failure recovery, directed acyclic graphs*

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1. INTRODUCTION

As the cost of hardware devices decreased and there is steady increase in resource availability voice over IP and other multimedia data streaming is increased. In such applications high bandwidth is expected besides faster recovery from single point of failures. In order to achieve this modern networks are employing various strategies such as load balancing, recovery from node failures, and end-to-end bandwidth. Towards a good solution multipath routing can be used. This scheme along with techniques can achieve security [6], congestion reduction [5], aggregation of bandwidth [4], load balancing [3] and robustness. In existing networking applications where multipath routing is required use directed acyclic graphs [7]. When a data packet starts from source to destination, it has to carry routing table information in its header. When a node to be forwarded is not there, the packet is dropped. This behavior causes problems. This approach can't guarantee reliable packet delivery. However, the techniques for fast recovery need to recover link failures effectively. Based on the nature of techniques they are classified. As explored in [8] a default forwarding node is maintained. When a node fails to forward, the default forwarding node takes the responsibility of forwarding.

In [9] three solutions are provided for fast rerouting which were given considerable attention. There three solutions are known as tunneling using not via addressing [13], failure insensitive routing (FIR) [11], [12] and Multiple Routing Configurations (MRC) [10]. The common feature of these techniques is to use more than one routing tables. However, they are different in the way they solve problem. In [15] and [16] resiliency to a single like failure is explored using multipath routing. For each destination node two trees are construct red in this approach. These trees are used to solve such problem. It is similar to the approaches where multiple routing tables are involved. Only difference is that they employ only two routing tables. For this reason every packet has to carry in its header the routing table to be used to reach the destination. Colored trees concept is introduced in [17] which are also known as independent trees. Fig. 1 shows examples for node independent trees.

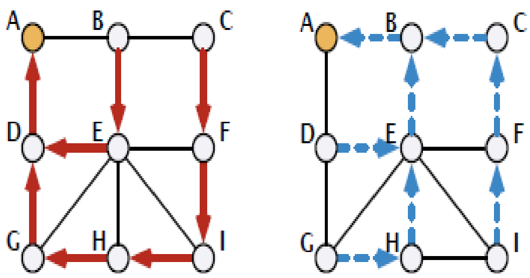

Fig. 1 – Illustrates node-independent trees (excerpts from [24])

In both the networks illustrated here the root node is A. The networks are constructed in such a way that they have capacity to recover from link failures. For instance when a packet forwarded from node F to root node encounters a failure, the packet will be sent through F-C-B-A. The networks work fine when a single link fails. When two links fail automatically, there might be problem. The goal of this paper is to overcome this drawback by using additional links from the network in order to make the multipath routing robust. The solution to this problem is the construction of independent directed acyclic graphs. The solution is illustrated in fig. 2.

As can be seen in fig. 2, node I has two edges for forwarding. This will enable the network to built possible paths for data forwarding.

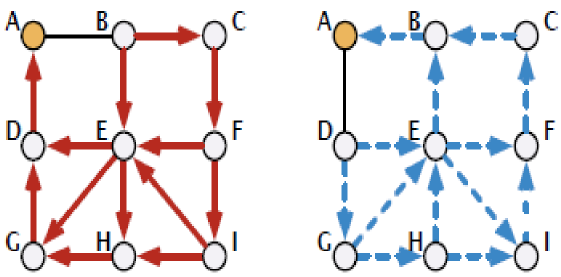

Fig. 2 – Node independent directed acyclic graphs (excerpts from [24])

However, there is no provision for backup forwarding in case of single link failure. Cho et al. [24] presented a solution for this which achieves multipath routing utilizing all possible edges; reduced overhead; recovery from single link failure is guaranteed. In this paper we implement the concept of [24] in Java platform. We built a prototype application that demonstrates the proof of concept.

The remainder of the paper is organized as follows. Section II provides details of the proposed work. Section III presents the details of prototype implementation. Section IV provides experimental results while section V concludes the paper.

2. PROPOSED MULTIPATH ROUTING APPROACH:

The goal of this paper is to construct as many directed acyclic graphs as possible for ensuring reliable multipath routing. The sample DAGs are presented in fig. 2. The link independent DAG construction is made using the procedure suggested by Cho et al. [24].

Procedure for LI-DAGs Construction

1) Divide the network into two vertex connected (2V) Components.
2) In each 2V component, select the unique articulation node through which every path from any node in that component must traverse to reach d. We refer to this articulation node as the root node of the component. In the component that contains node d , we assume that the root node of the component is node d itself.
3) In each 2V component, construct two node independent DAG to the root node of that component.
4) Merge all node independent DAG to obtain the Link independent DAGs.

The above procedure is given to construct multiple link independent DAGS. These DAGs provide reliable communication in multipath routing fashion. The algorithm is implemented on different network topologies as shown in fig. 3 and 4.

In Fig. 3 and Fig. 4 four real time topologies are presented. They have different nodes and links.

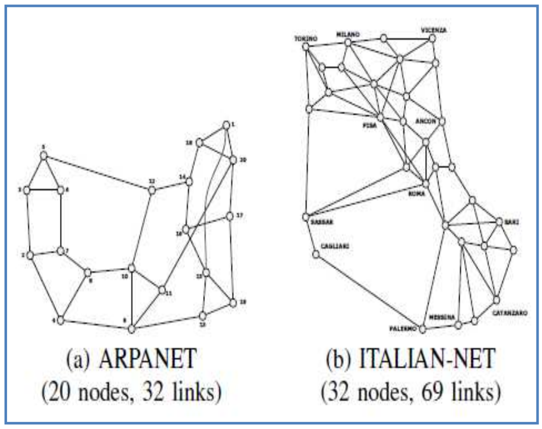

Fig. 3 – Illustrate real world topologies such as ARPANET and ITALIAN-NET (excerpts from [24])

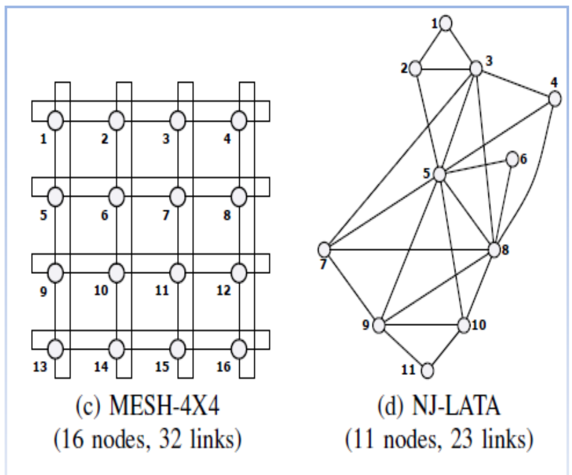

Fig. 4 – Illustrate real world topologies such as MESH-4X4 and NJ-LATA (excerpts from [24])

These topologies are used in the practical experiments of this paper.

3. PROTOTYPE IMPLEMNETATION

A prototype application is built using Java platform which simulates the concept of reliable multipath routing scheme presented by Cho et al. [24]. The environment used for the implementation is Java platform, a PC with 4 GB RAM, Core 2 Dual processor running Windows 7 operating system. The Java custom simulator application is used to generate number of nodes and make experiments on different topologies. The simulator supports four topologies such as MESH-AX4, NJ-LATA, ARPANET and ITALIAN-NET. After generating nodes, the main UI of the application is as shown in fig. 5.

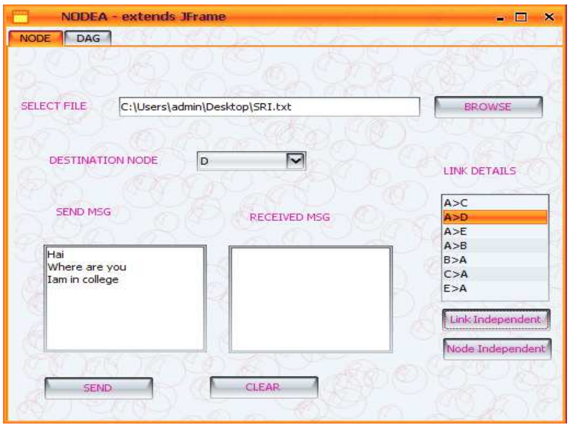

Fig. 5 – Main UI of the prototype

The prototype application facilitates shown in Fig.5 is to send data from source to destination. There are many links from node A to node D. The details are as shown in Fig. 5. The application also has provision to generated IDAGs based on the approaches like link independent and node independent. Sample DAG between given source and destination is given in fig. 6.

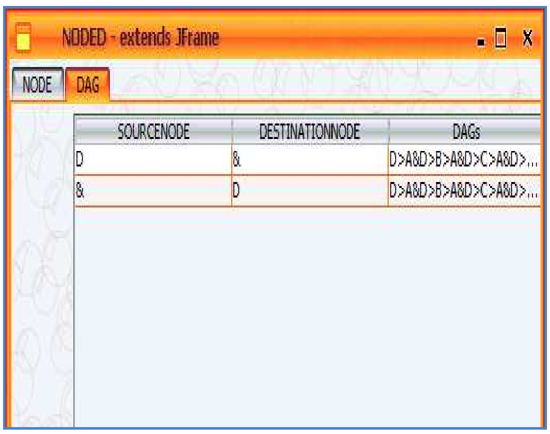

Fig. 6 – UI highlighting DAG between the given source and designation.

As can be seen in Fig. 6, it is evident that the DAG is formed between the given source and destination. There are multiple DAGs possible as shown in fig. 6.

4. RESULTS:

Number of experiments is made to know the number of paths between the source and destination nodes on various topologies. The number of paths from source to destination is considered to be the degree of the node. It is obvious that when number of links is increased in the network, the number of paths increase automatically. The experimental results are shown as a series of graphs.

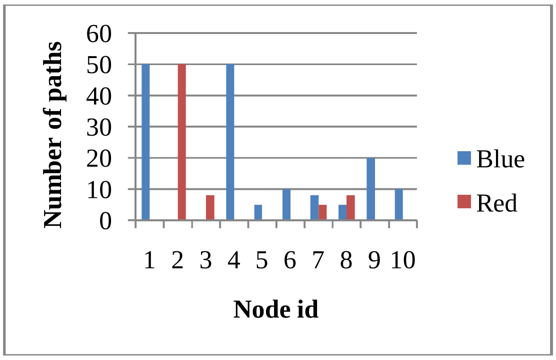

Fig. 7 – Number of paths from source to destination on ITALIAN-NET topology

As can be seen in Fig. 7, it is evident that the node ids which are participated in experiments are presented in horizontal axis while the vertical axis represents the number of paths in given topology. The results revealed that number of paths is more when number of links is increased.

As can be seen in Fig. 8, it is evident that the node ids which are participated in experiments are presented in horizontal axis while the vertical axis represents the number of paths in given topology.

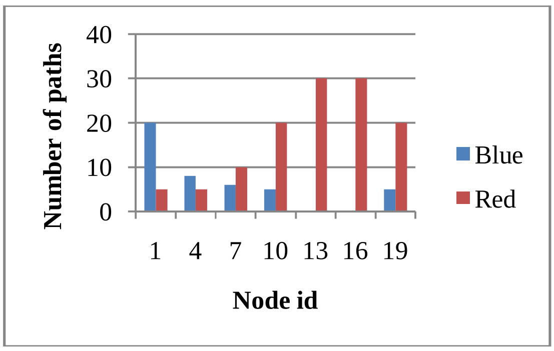

Fig. 8 – Number of paths from source to destination on ARPANET topology

The results revealed that number of paths is more when number of links is increased.

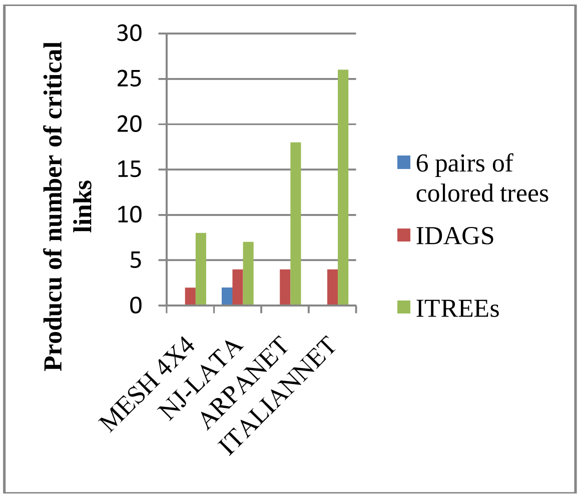

Fig. 9 – Product of number of critical links with given approaches and topologies

As seen in Fig. 9, the horizontal axis represents topologies while the vertical axis presents the product of number of critical links. The approaches followed are 6 pairs of colored trees, IDAGs and ITREEs on four topologies namely MESH-AX4, NJ-LATA, ARPANET and ITALIAN-NET.

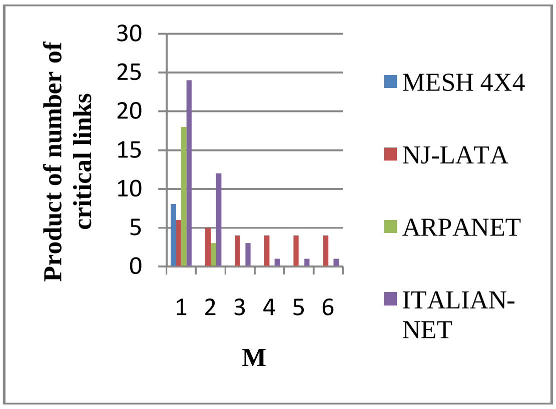

Fig. 10 – Product of number of critical links with given approaches and topologies

As seen in Fig. 10, the horizontal axis represents number of pairs of colored trees while the vertical axis presents the product of number of critical links. The experiments are done using topologies like MESH-AX4, NJ-LATA, ARPANET and ITALIAN-NET.

As seen in Fig. 11, the horizontal axis represents topologies like MESH-AX4, NJ-LATA, ARPANET and ITALIAN-NET while the vertical axis represents average path length ratio.

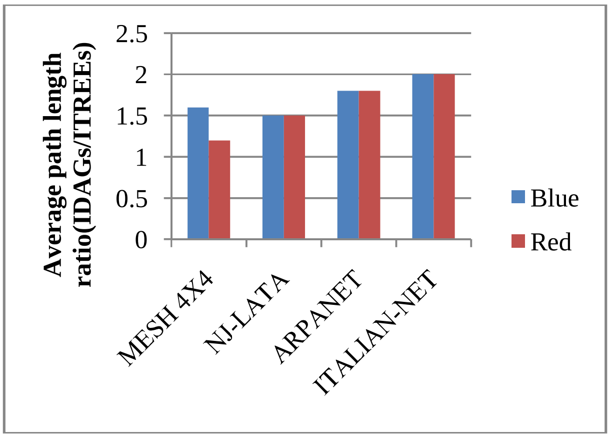

Fig. 11 – Average ratio of path lengths of IDAGs and I Trees

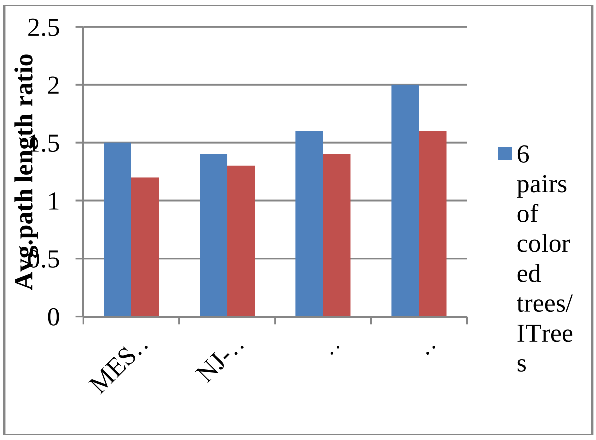

Fig. 12 – Ratio of average six pairs of colored trees and IDAGS path lengths

As seen in Fig. 12, the horizontal axis represents topologies like MESH-AX4, NJ-LATA, ARPANET and ITALIAN-NET while the vertical axis represents average path length ratio.

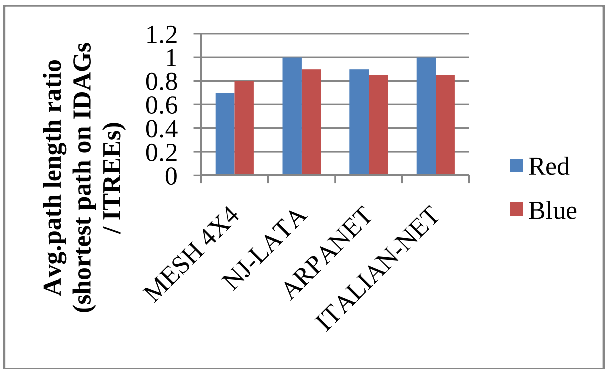

Fig. 13 – Ratio of average six pairs of colored trees and IDAGS path lengths

As seen in Fig. 13, the horizontal axis represents topologies like MESH-AX4, NJ-LATA, ARPANET and ITALIAN-NET while the vertical axis represents average path length ratio.

CONCLUSIONS

Multipath routing is important for reliable data transfer in modern networks. When independent directed acyclic graphs are constructed, it is possible to achieve reliable communication with multiple IDAGS that ensure fast recovery in case of link failures. The solution presented by Cho et al. [24] and the polynomial time algorithms are implemented in this paper in order to ensure reliable multipath routing. We implemented the IDAGs using a custom simulator. The simulation results revealed that the node independent IDAGs are practically reliable and can recover faster from link failures.

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