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Dynamic Virtual Topology for Congestion Control in high speed LANs

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***Abstract*—**Local Area Networks (LANs) have flourished over the past three decades to become an integral part of the office and information technology environments. Some of the more popular LAN technologies are ARC net, Ethernet, Token-ring, and AppleTalk. Fiber Distributed Data Interface (FDDI) is considered to be one of the newer Technologies LAN. ATM is a cell-based multiplexing and switching technology. It was designed to be a general purpose, connection-oriented transfer mode for a wide range of services like voice, data, still image or motion video. The organizational network is the combination of LANs interconnected using switches and hubs. This network intern is connected to the internet via router. Local Area Networks have evolved to very high speed networks. This paper develops a dynamic algorithm to find a virtual topology in high speed local area networks whenever there is a break in the link or there is congestion. The algorithm determines alternate paths where congestion is not appreciable and builds the dynamic virtual topology and routes the packets to the destination using these paths.
Keywords -: Topology, Virtual Path, Local Area Networks, Congestion.

I. Introduction

Interconnection of two or more computers for the purpose of sharing the data and services is known as computer network. The computer network connected within a limited area like a building or collection of buildings or university knows as Local Area Network (LAN). Computer Network Topology is the way of computer systems and associated devises are interconnected. Topologies can be viewed in two ways with respect to data communication networks Physical and Logical. Former emphasizes on the hardware associated with the system including workstations, remote terminals, servers, and the associated wiring. There are standard topologies for the physical LAN connections. Ethernet standard family using *IEEE802.3* is a regular topology used in LANs. Token Ring technology is still used by some companies. FDDI is sometimes used as a backbone LAN interconnecting Ethernet or Token Ring LANs. WLAN using IEEE 802.11 technologies is rapidly becoming the new leading LAN technology for its mobility and easy to use features. The Second is the logical Network Topology (also known as Signal Topology) emphasizes on the representation of the data flow among the nodes, not dissimilar from the Graph Theoretic representation. The logical topography of a network can be dynamically changing and recorded in network equipments such as switches and routers [12].

There are two basic issues [6] in local area networks. First, to provide reliable hardware and communication with minimum cost that will be taken care by the network equipments, second the protocols to be used for the operations of the network. Branch and broadcast communication system is used in Ethernet distributed packet switching for local computer networks that carries data packets. The packet transport has been used to build systems which can be viewed as either local computer networks or loosely coupled multiprocessors. Broadcasts are distributed among the contending transmitting stations using controlled statistical arbitration. Switching of packets to their destinations on the Ether is distributed among the receiving stations using packet address recognition. One can characterize distributed computing as a spectrum of activities varying in their degree of decentralization, with one extreme being remote computer networking and the other extreme being multiprocessing. Due to the interconnection of computers, the resource sharing of computers and the parallelism of multiprocessing are achieved. The separation between computers and the associated bit rate of their communication can be used to divide the distributed computing spectrum into broad activities.

Congestion is one of the prevailing challenges in computer networks. It is a state where a node or link carries data beyond the capacities that results in deterioration of network service quality, intern generating queuing delay, frame or data packet loss. In a congested network, response time and network throughput are reduced. The traffic in data network is self similar traffic. One of the key features of the congestion is the bursty traffic which requires a distributed solution.

II. Physical Topologies of LANs

The topology of the Ethernet is that of an unrooted tree and avoids multipath interference. It can be extended from any of its points in any direction. Any station wishing to join Ethernet taps into the Ether at the nearest convenient point [13]. The Ethernet has central interconnection through the

Ether and distributed control among its stations and supports many-to-many communication with a single broadcast multi-access channel. The major basic topologies used in the LANs are the ring, full mesh, star and bus.

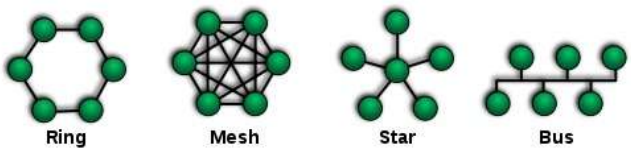

Fig1. Physical Topologies

Other topologies are tree, line partial mesh. Myrinet is a new type of local area network based on the technology used for packet communication and switching within massively parallel processors, that provide flow control, packet framing, and error control, low-latency, cut-through switches. Myrinet's host interfaces map the network, select routes and translate network addresses to routes also handle packet traffic. Its streamlined software allows direct communication between user processes and the network [4][15].

III. Logical Virtual Topology

Virtual Topology is the way data paths are connected. Like the set of semi-permanent light paths in Wavelength-division multiplexing (WDM) is a method of combining multiple signals on laser beams at various infrared (IR) wavelengths for transmission along fiber optic media. Each laser is modulated by an independent set of signals. These paths may be viewed as a virtual topology by higher layers such as SONET. Reconfiguration is to change in virtual topology to meet traffic pattern in high layers. Design the logical topology and routing Algorithm on physical topology, so as to minimize the network congestion constraining the average delay seen by source destination pair and the amount of processing required at the nodes.

Creating a virtual topology different from the physical topology of the underlying network is the ability of wavelength routing in WDM. Advances in optical technology have made it possible to develop systems that are capable of providing a large bandwidth. Optical fiber links typically form a mesh topology. The WDM divides the tremendous bandwidth of a fiber into many non- overlapping wavelengths called WDM channels. The major role of WDM optical network is to interconnect client networks like IP, ATM and serves as a national or international backbone to transport client traffic.

The traffic grooming is applied to groom low speed traffic to high speed light paths to share the resources in optical layer there by utilizing the network resources and reducing the overall cost of network. The process of finding paths to consolidated client calls over logical topology is called traffic grooming. Efficiently grooming low-speed connections onto high capacity light paths will improve the network throughput and reduce the network cost [1].

High-speed LAN, static reconfiguration techniques are used when there is change in their topology due to switches being turned on/off, hot expansion, link remapping, and component failures. In most cases, user traffic is stopped during the reconfiguration process to avoid deadlock. This technique is valid for any topology, including regular as well as irregular topologies. It is also valid for packet switching as well as for cut-through switching techniques and does not rely on the existing virtual channels to work. Dynamic reconfiguration protocols are significantly better than the protocols based on user traffic [5][11].

Distributed multimedia applications have quality of service (QoS) requirements. Therefore, in order to support hard real-time and distributed multimedia applications over a high-speed LAN, we need to avoid stopping user traffic and discarding packets when the topology changes. [10].

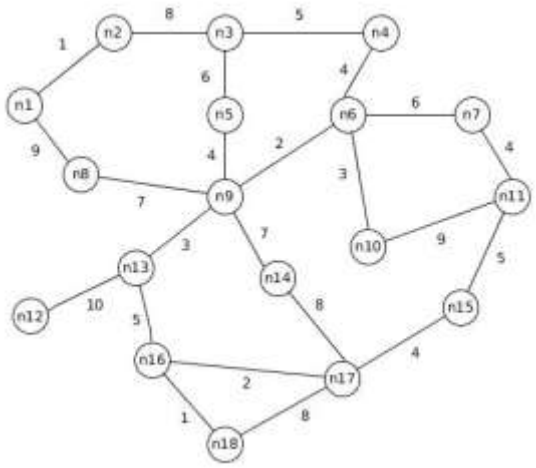

Fig2. Extended LAN (only interconnected switches are shown)

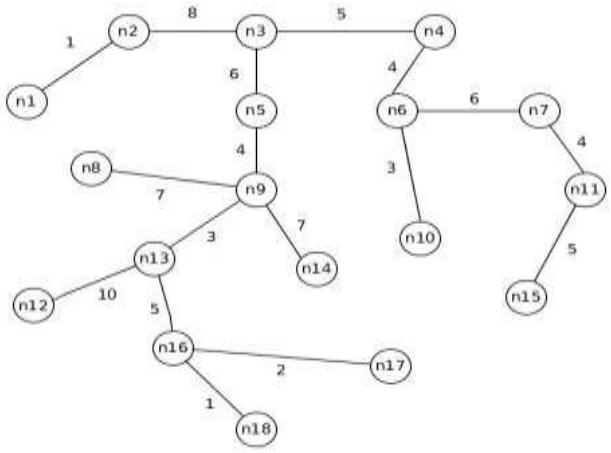

Fig3. Virtual Topology of Fig2.

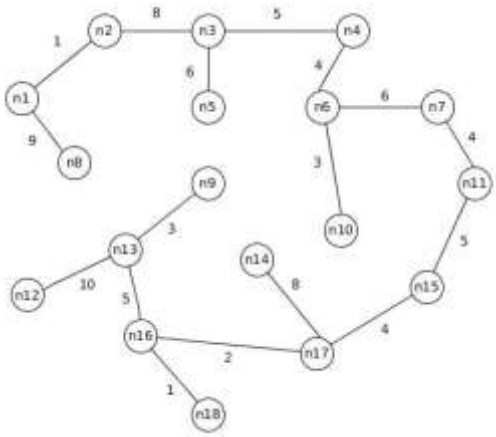

Fig4. Virtual Topology when congestion occurs at n9 in Fig1.

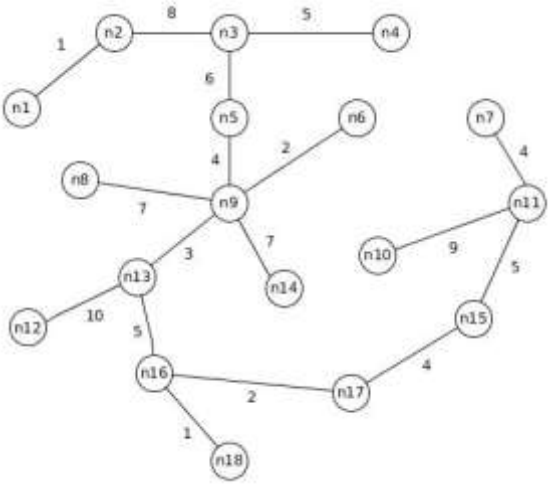

Fig5. Virtual Topology when congestion occurs at n6 in Fig1.

IV. Dynamic Reconfiguration

There exist three basic approaches to implement dynamic reconfiguration:

1. Avoiding cyclic dependencies between network resources at all times.
2. Allowing cyclic dependencies between network resources while avoiding permanent deadlocks.
3. Splitting network resources into two sets and statically reconfiguring those sets in sequence.

Approach 1 can be used in all the networks, including networks with source routing and/or networks without virtual channels. The reason is that, avoiding cyclic dependencies between network resources will always avoid deadlock. Approach 2 requires distributed routing. It is not possible to implement this strategy in networks with source routing because the whole path is specified before injecting the messages into the network. Therefore, even if new routing tables specify a new path for a given source destination pair, messages already in the network has no choice and may remain blocked forever.

Finally, approach 3 can only be implemented in networks with distributed routing and extra routing resources (e.g., virtual channels). Otherwise, it is not possible to empty one set of resources while the other set is used for routing.

Basically, there exist three *solutions* for this problem:

1. Discard unroutable messages.
2. Buffer unroutable messages until they become routable.
3. Allow especial routing options for unroutable messages.

Solution 1 obviously solves the problem at the cost of having to retransmit messages. This section describes the approach followed in our protocol for dynamic reconfiguration in an informal way. The first step in network reconfiguration is detecting the addition and removal (or failure) of network components (links and/or switches). This issue has been addressed in [14].

Myrinet is a new type of local area network based on the technology used for packet communication and switching within massively parallel processors (MPP). Its streamlined software allows direct communication between user processes and the network. It supports significantly benefit in distributed computing, image transport, and other communication-intensive applications. In realizing this distributed MPP network, specialized communication channels, cut-through switches, host interfaces, and software are developed. Myrinet demonstrates the highest performance per unit cost of any current LAN [4][9].

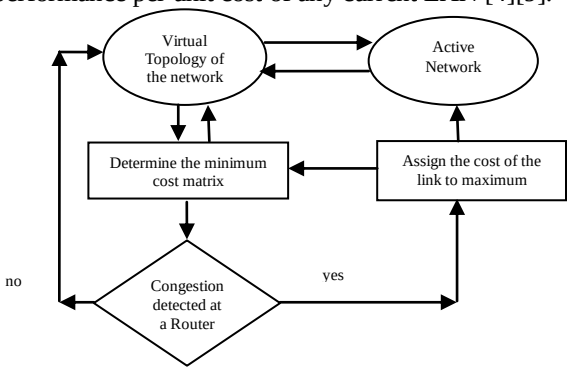

Fig6. Schematic diagram of the network Scenario

The reconfiguration of high capacity WDM optical Network has been reviewed in [1] [8]. A set of temporary light paths are set up in the network that can be viewed as a virtual topology by higher layers such as ATM, SONET and IP. Reconfiguration is to charge in virtual topology to meet traffic pattern in higher layers to minimize the net work congestion. The average delay seen by source destination pair and the amount of processing required at the nodes is improved. High-performance distributed computing

communications networks are possible using current technology. An arbitrary topology point-to-point network with link speeds of up to 1 Gbps is developed that deals with fixed-length ATM-style cells. It provides high bandwidth and low latency for datagram traffic. Parallel iterative matching can fill unused slots with datagram traffic [2].

High-speed local and system area networks may change their topology due to switching one of the routers and hosts or due to component failures. In such cases, a reconfiguration algorithm must be executed to restore the network connectivity and thus achieve high system reliability. However, most of the solutions are based either on redundant network paths or on regular network topologies. An algorithm for dynamically reconfiguring an arbitrary network topology when a permanent fault occurs is compatible with all modern routing techniques, including wormhole-based system area networks. It restores the network connectivity by building a tree that spans all immediate neighbors of the faulty node that are still connected to the network [3].

Algorithms are developed to allocate virtual channels where a packet has performed to eliminate cycles in resource dependency graphs. The dynamic algorithm improves virtual channel utilization by permitting dependency cycles and instead eliminating cycles in the packet wait-for graph. These algorithms are proved to be deadlock-free and for non-uniform traffic patterns, the network throughput is improved at moderate traffic rates [7].

V. Congestion in Local Area Networks

Effect of congestion is buildup of packets in buffers leading to increased delay, packet loss, inefficient use of network resources, bandwidth, buffer space, processing power and need for retransmissions. Generally congestion in LANs is short-term in nature, capacity is over-provisioned and long term congestion is dealt with by higher layers. Sources of LAN Congestion are burst in traffic and demand exceeds available resources at some point in the network like traffic merging and rate mismatch.

VI. Dynamic Virtual Topology building Algorithm

The procedure for determining the virtual topology for the data routing in a given network N can be viewed as two phases. First is to identify the congestion nodes in the network. Congestion Detection algorithm determines all the possible congested links and updates in the switch handling the traffic. Here the average queue sizes are monitored for each link and if it crosses the threshold value which is preset, congestion is notified.

```
ALGORITHM CongestionDetection (N(D,L))
// This algorithm identifies the congestion node in network N
// Input: The network N (D, L) with D devices with L links
//Output: Identifies the nodes with congestion
    read the network N as the weighted graph matrix
    cong = false
    for i 0 to n – 1  do
        for j  0 to n – 1 do
            if (averageQueueSize>threshold)
                N[i,j] = 9999
                cong = true
            else
                cong = false
```

Second is to determine the tree graph with efficient resource utilization of the network resources to send the data across the network directing to the destination. The following algorithm identifies the nodes with congestion.

```
ALGORITHM VTopology (N (D, L))
// This algorithm determines the dynamic virtual topology
    for effective data routing.
// Input: Network N(D,L) with current congestion status.
// Output: Virtual Topology for efficient data routing.
    read the network N as the weighted graph matrix
        for i 0 to n – 1  do
            for j  0 to n – 1  do
                if (CongestionDetection(N(D,L)= TRUE)
                    //Determine Minimum Spanning Tree
                        VT = MST (N(D,L))
        return VT
```

VII. Simulation Results

Extended Local Area Network with eighteen switches interconnected is built and simulated. The throughput versus load is to be studied. As the load increases the throughput also increases, later it starts going down and after some time there is going to be catastrophic fall in the throughput resulting in congestion collapse. In this paper a closed loop control mechanism is use to address the congestion.

00	01	09	14	15	18	24	09	16	21	28	29	19	23	30	24	26	25
01	00	08	13	14	17	23	08	15	20	27	28	18	22	29	23	25	24
09	08	00	05	06	09	15	17	10	12	21	23	13	17	24	18	20	19
14	13	05	00	10	04	10	13	06	07	14	19	09	13	19	14	16	15
15	14	06	10	00	06	12	11	04	09	18	17	07	11	23	12	14	13
18	17	09	04	06	00	06	09	02	03	10	15	05	09	15	10	12	11
24	23	15	10	12	06	00	15	08	09	04	21	11	15	09	15	13	16
09	08	17	13	11	09	15	00	07	12	19	20	10	14	19	15	17	16
16	15	10	06	04	02	08	07	00	05	12	13	03	07	1	08	10	09
21	20	12	07	09	03	09	12	05	00	09	18	08	12	14	13	15	13
28	27	21	14	18	10	04	19	12	09	00	25	15	17	05	11	09	12
29	28	23	19	17	15	21	20	13	18	25	00	10	20	21	15	17	16
19	18	13	09	07	05	11	10	03	08	15	10	00	10	11	05	07	06
23	22	17	13	11	09	15	14	07	12	17	20	10	00	12	10	08	11
30	29	24	19	23	15	09	19	14	14	05	21	11	12	00	06	04	07
24	23	18	14	12	10	15	15	08	13	11	15	05	10	06	00	02	01
26	25	20	16	14	12	13	17	10	15	09	17	07	08	04	02	00	03
25	24	19	15	13	11	16	16	09	13	12	16	06	11	07	01	03	00

Cost Matrix1

Matrix1 shows the cost matrix of the network (Fig2) constructed. Matrix2 is the minimum spanning tree (Fig3) of the network before congestion. When congestion occurs at node n9 due to the flooding of inputs from different sources, the weight of each congestion link becomes infinite. Hence the dynamic virtual topology is determined for effective routing without much loss in packets at the congestion node (Fig4). Matrix3 shows the resultant cost matrix for this scenario. Similarly matrix4 shows for the situation when congestion occurs at node n6 (Fig5).

00	01	09	14	15	18	24	09	47	21	28	54	44	45	33	39	37	40
01	00	08	13	14	17	23	10	46	20	27	53	43	44	32	38	36	39
09	08	00	05	06	09	15	18	38	12	21	45	35	36	24	30	28	31
14	13	05	00	11	04	10	23	33	07	14	40	30	31	19	25	23	26
15	14	06	11	00	15	21	24	44	18	27	51	41	42	30	36	34	37
18	17	09	04	15	00	06	27	29	03	10	36	26	27	15	21	19	22
24	23	15	10	21	06	00	33	23	09	04	30	20	21	09	15	13	16
09	10	18	23	24	27	33	00	56	30	37	63	53	54	42	48	46	49
47	46	38	33	44	29	23	56	00	32	19	13	03	18	14	08	10	09
21	20	12	07	18	03	09	30	32	00	13	39	29	30	18	24	22	25
28	27	21	14	27	10	04	37	19	13	00	26	16	17	05	11	09	12
54	53	45	40	51	36	30	63	13	39	26	00	10	25	21	15	17	16
44	43	35	30	41	26	20	53	03	29	16	10	00	15	11	05	07	06
45	44	36	31	42	27	21	54	18	30	17	25	15	00	12	10	08	11
33	32	24	19	30	15	09	42	14	18	05	21	11	12	00	06	04	07
39	38	30	25	36	21	15	48	08	24	11	15	05	10	06	00	02	01
37	36	28	23	34	19	13	46	10	22	09	17	07	08	04	02	00	03
40	39	31	26	37	22	16	49	09	25	12	16	06	11	07	01	03	00

Cost Matrix2

00	01	09	14	15	18	24	26	19	21	28	32	22	26	33	27	29	28
01	00	08	13	14	17	23	25	18	20	27	31	21	25	32	26	28	27
09	08	00	05	06	09	15	17	10	12	19	23	13	17	24	18	20	19
14	13	05	00	11	04	10	22	15	07	14	28	18	22	19	23	25	24
15	14	06	11	00	15	21	11	04	18	25	17	07	11	30	12	14	13
18	17	09	04	15	00	06	26	19	03	10	32	22	26	15	27	29	28
24	23	15	10	21	06	00	32	25	09	04	38	28	32	09	33	35	34
26	25	17	22	11	26	32	00	07	29	36	20	10	14	41	15	17	16
19	18	10	15	04	19	25	07	00	22	29	13	03	07	34	08	10	09
21	20	12	07	18	03	09	29	32	00	13	35	25	29	18	30	32	31`
28	27	19	14	25	10	04	36	29	13	00	42	32	36	05	37	39	38
32	31	23	28	17	32	38	20	13	35	42	00	10	20	47	15	17	16
22	21	13	18	07	22	28	10	03	25	32	10	00	10	37	05	07	06
26	25	17	22	11	26	32	14	07	29	36	20	10	00	41	15	17	16
33	32	24	19	30	15	09	41	34	18	05	47	37	41	00	42	44	43
27	26	18	23	12	27	33	15	08	30	37	15	05	15	42	00	02	01
29	28	20	25	14	29	35	17	10	32	39	17	07	17	44	02	00	03
28	27	19	24	13	28	34	16	09	31	38	16	06	16	43	01	03	00

Cost Matrix3

VIII. Future work

This paper concentrates on the congestion in high speed extended LANs. The algorithm used can be extended to attend to issues like link failures, bursts in WANs. This work can give some insights in developing a new protocol for improving the network performance.

00	01	09	14	15	21	42	16	19	47	38	32	22	26	33	27	29	28
01	00	08	13	14	21	41	15	18	46	37	31	21	25	32	26	28	27
09	08	00	05	06	12	33	07	10	38	29	23	13	17	24	18	20	19
14	13	05	00	11	17	38	12	15	43	34	27	18	22	29	23	25	24
15	14	06	11	00	06	27	11	04	32	23	17	07	11	18	12	14	13
21	21	13	17	06	00	25	09	02	30	21	15	05	09	17	10	12	11
42	41	33	38	27	25	00	14	23	13	04	30	20	30	09	15	13	16
16	15	07	12	11	09	14	00	07	35	26	20	10	14	21	15	17	16
19	18	10	15	04	02	23	07	00	28	19	13	03	07	14	08	10	09
47	46	38	43	32	30	13	35	28	00	09	35	25	35	14	20	18	21
38	37	29	34	23	21	04	26	19	09	00	26	16	26	05	11	09	12
32	31	23	28	17	15	30	20	13	35	26	00	10	20	21	15	17	16
22	21	13	18	07	05	20	10	03	25	16	10	00	10	11	05	07	06
26	25	17	23	11	09	30	14	07	35	26	20	10	00	21	15	17	16
33	31	24	29	18	17	09	21	14	14	05	21	11	21	00	06	04	07
27	26	18	23	12	10	15	15	08	20	11	15	05	15	06	00	02	01
29	28	20	25	14	12	13	17	10	18	09	17	07	17	04	02	00	03
28	27	19	24	13	11	16	16	09	21	12	16	06	16	07	01	03	00

Cost Matrix4

IX. CONCLUSION

The size of the local area network grows as the number of organization grows. It is convenient and comfortable to divide the big LAN into small ones across the departments. These LANs interconnected forms the extended LAN. Content sharing across the organization's departments is crucial. When the content is of the mixed type, the need for faster access and low latency is increased. In this paper algorithms are developed to handle large data on high speed local area networks. Whenever congestion or link failure occur the topology of the data path is changed dynamically to facilitate the minimum data loss. Such algorithms can be developed for the data communication in wide area networks and the Internet.

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