OPTIMAL ROUTING MULTI-AGENT SYSTEM APPROACH FOR CONGESTION CONTROL IN HIGH SPEED NETWORKS

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Abstract:

Traffic Management and Congestion Control are major issues in high speed networks. Congestion represents an overloaded condition in a network. In this paper, we described existing Multi-Agent architecture for management of ATM networks. We developed a software module using java, by using Optimal Routing for controlling congestion in high speed networks. We described the steps to be followed in developed software module and finally presented advantages over conventional approach.

Keywords: ATM Networks, Bandwidth Management, Multi-agent System, Optimal Routing, Virtual Paths.

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1. Introduction

Asynchronous Transfer Mode (ATM) [2] networks are high speed networks that support a variety of services with diverse characteristics, e.g. voice, video, data, etc. ATM is connection oriented packet switched data transport system, handling fixed size cells that are asynchronously multiplexed within the network and transmitted over a virtual circuit while preserving the cell sequence integrity. Asynchronous Transfer Mode provides the opportunity for both end users and communications carriers to transport virtually any type of information using a common format.

Congestion control [3][9][10][11], resource management and traffic management have become crucial role in protecting the network from becoming congested, in achieving the network performance objectives and optimizing the use of network resources. The key resource in network management is physical link bandwidth. When current traffic is more than available link bandwidth, congestion problem may arise in the network.

The multi-agent system architecture and Optimal Routing is described in this paper. A software module have been developed, to automate the activities of agents in multi-agent system to monitor the physical link bandwidth, Optimal routing between the two nodes and control congestion if any arise, in ATM network. This paper is organized as follows: Bandwidth management functions in High speed networks were described in section 2. The multi-agent system architecture for High speed networks is described in section 3. The Optimal routing multi-agent system for congestion control and for reducing number of messages between the NP agents is described in section 4. The Experiments and results conducted are described in section 5. The advantages of Optimal routing multi-agent approach over Multi-Agent System are discussed in section 6. Finally the paper is concluded in section 7.

2. Bandwidth Management in High Speed Networks

ATM networks have mainly three layers of hierarchy: Physical layer, ATM layer, and ATM Adoption layer. The physical layer deals with physical media. The ATM layer deals with cells and cells transport. Routing and congestion control is performed at this layer. The ATM Adoption Layer will split the message into cells at sender and reassemble to get back the original message at the receiver.

In the ATM layer, there are two levels of hierarchy: Virtual Path Connection (VPC) and Virtual Channel Connection (VCC) levels. A virtual path connection (VPC) is a labeled path which can be used to transport a bundle of virtual channel connections (VCCs) and to manage the resources used by these connections. The virtual network is organized as a collection of VPCs which form a VPC, or logical, overlay network. The highest is VC level: users can establish and release the connections i.e. virtual channels, through pre-established virtual paths (VPs). The Virtual path management [4][5][7] considered is the establishment and release of VPs between two nodes in a network. Initially bandwidth will be assigned to the established virtual paths in the network. Bandwidth management attempts to manage the capacities assigned to the different VPs that flow through the physical link. There are two actions normally taken by bandwidth management functions in Multi-Agent System architecture, namely bandwidth re-allocation and VP-rerouting.

If there are congested VPs and underused VPs in the same link, the bandwidth assigned to each VP can be reconfigured. This method is known as bandwidth re-allocation shown in Fig. 1

If almost all the VPs in the link are congested or near to congestion and there is an insufficient unutilized bandwidth capacity for swapping between VPs, routes as well as capacities are altered to minimize the traffic carried in the network. This means that a change in VP network topology is required. This is called VP re-routing.

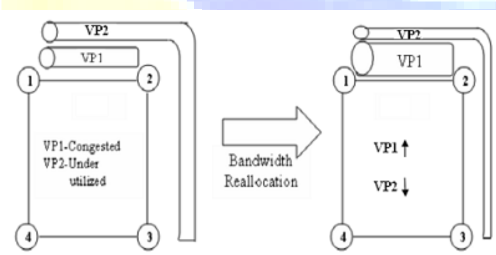

Fig. 1 Virtual path bandwidth reallocation.

S.No.	Node	NP-agent	Managing NM-agents and their corresponding virtual paths
1	a	P_a	$M_{a,b}$-1, $M_{a,c}$, -2 ,M $_{a,d}$ -3
2	b	P_b	$M_{b,a}$ -4, M $_{b,d}$ -5
3	c	P_c	$M_{c,a}$ -6, $M_{c,d}$ -7
4	d	P_d	M $_{d,a}$ -8,M $_{d,b}$ -9,M $_{d,c}$ -10

Table. 1 NP-agents and their managed NM-agents.

3. Multi-AgentSystem Architecture

Pere Vila et al, proposed Multi-agent system architecture [1][6][8] for management of ATM networks using intelligent agents. The main objectives of this architecture are the following.

- Maximize integration with conventional ATM management mechanisms.
- Robustness
- Scalability
- Simplicity of agents

Two types of agents are used in this architecture: Network Monitoring agents (NM-agents) and Network Planning agents (NP-agents).

3.1 Network Monitoring Agents

The function of NM-agent is to monitor and control the bandwidth assigned to one virtual path. i.e. Each NM-agent is responsible for one resource, one virtual path or one physical link. If there are several unidirectional links or virtual paths commence from one node, several NM-agents exists at that node and each NM agent monitor the bandwidth of virtual path. NM-agents are supposed to be very simple reactive type of agents whose main task is, reacts fast when an event (connection release, bandwidth requests, faults, etc) occurs.

3.2 Network Planning Agents

There is one NP-agent per node and each one responsible for all logical paths or virtual paths that begin in its node. The planning agents are more deliberative and have the assignment of planning virtual path topology and bandwidth allocation to achieve good network performance. The mission of these agents is to monitor and control the network by monitoring NM-agents and contacting neighbour NP-agents. The NP-agents can manage NM-agents (creation, deletion, modify, consult, etc.). No NP-agent has a complete overall view of the network, but NP-agents maintains some kind of distributed view by means of co-operation between neighbors, by which each agent has limited domain view and possesses limited information. However, by polling their abilities, agents are able to solve the problems beyond the capacity of any one single agent.

3.3 Example Environment for Multi-Agent System Architecture

We consider a network configuration shown in Fig. 2. It consist of four nodes labeled with names a,b,c and d. There are a total number of 10 unidirectional logical paths in the network. Each path is labeled with numbers (i.e. 1 to 10) and each logical path is monitored by one NM-agent. There will be one NP-agent per node and one NM-agent per logical path. So there will be four NP-agents and ten NM-agents for the network shown in Fig. 2.

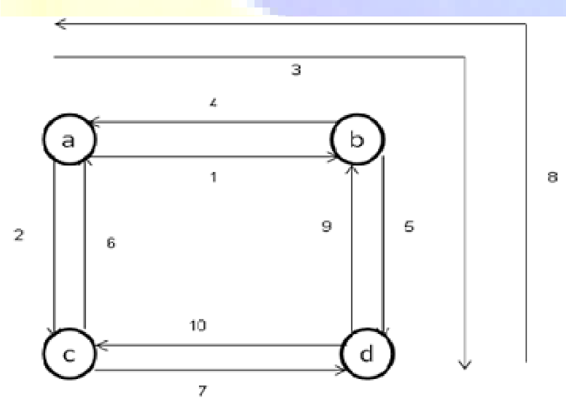

Fig. 2 Network configuration.

The NM-agents and NP-agents for the above network configuration are mentioned in Table1.

4. Optimal Routing for Multi-Agent System and Congestion Control

The steps used in the development of the software for optimized Multi-Agent System and to control congestion is as follows:

Step 1: Initially the network will be configured by specifying the number of nodes, number of logical paths, and maximum bandwidth capacity of each LP. NP-agents and NM-agents will be created based on number of nodes and LPs in the network respectively. For each LP a cost parameter is assigned based on the bandwidths given to them. The highest bandwidth LP in the entire network is assigned with least cost and the next higher bandwidth LP is assigned with the second least cost and so on. The example network topology along with bandwidth and cost assigned to LP's is shown in Fig. 3.

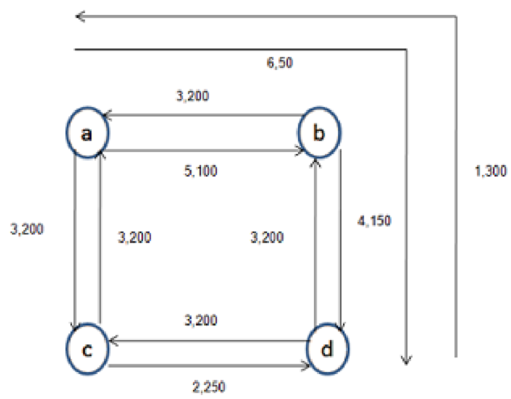

Fig. 3 Example Network Topology that represents bandwidth and cost of LP.

Step 2: When the source node wants to transmit data to destination node, the primary logical path (P_LP) is identified and invokes NM-agent process, monitoring that LP. The user specifies the bandwidth required for transmission of data from source to destination node. The NM-agent process of P_LP, checks to see if there is enough bandwidth available from the P_LP. If so, the user request will be granted and data will be transmitted over P_LP. The NM-agent records the available bandwidth of P_LP.If the user requests for some more bandwidth; NM-agent process of P_LP checks again the available bandwidth of LP. If no bandwidth is available, then it consults NP-agent process of that node.

Step 3: The NP-agent process checks to see if backup LP exists from that node. If any, NP-agent consults NM-agent which is currently monitoring backup LP. The NM-agent of backup LP, checks the available bandwidth capacity. If it finds the enough bandwidth capacity, NM-agent informs the NP-agent process and records the remaining available bandwidth. The NP-agent process informs the NM-agent process to utilize the backup LP bandwidth and this process is known as bandwidth re-allocation.

Step 4: When NP-agent process finds no backup LP exists or backup LP bandwidth have completely utilized, then it checks for alternate path which exists from source to destination node. Here the NP-agent can find many alternative paths between source and destination nodes. But among the many alternative paths the NP-agent chooses the least cost alternative path.

Step 5: The NP-agent chooses the least cost alternative path with the help of the cost parameter assigned to the LP.For that the total cost of each alternative path that exists between source and destination nodes is calculated by the summation of the costs of LP's that exists in the path. Then a comparison is made between the total costs of the alternative paths, among them the path having less total cost is chosen by the NP-agent.

Step 6: The NP-agent consults the NM-agent and NP-agents of the other nodes in the alternative paths, the NM-agent checks the status for the availability of bandwidth and if enough bandwidth is available, the same thing is informed to the NP-agent and records the remaining available bandwidth and giving permission to utilize the requested bandwidth. The NP-agent informs the original NM-agent to utilize the alternative LP bandwidth. This is called Re-routing. If the first minimum cost alternative path does not exists, i.e., bandwidth in that path is completely utilized then the NP-agent chooses the second minimum cost alternative path and so on.

Step 7: Since the least cost alternative path selection concept is used, the cost required for the transmission of data will be less and the data is transmitted fastly. The number of messages between NP-agent and NP-agent of the nodes will be reduced because transmission of data is done through the less cost paths; automatically the data is transmitted with the highest bandwidth. Even though the user requests high bandwidth, transmission is done through highest bandwidth, so there is no need to communicate with the other NP-agents. So the number of messages will be reduced when compared with the normal multi-agent system. Since the number of messages between NP-agent and NM- agent does not have any influence on the network traffics, that case is not considered here. Thus we can control congestion, reduce the cost required for the transmission of data and can reduce the number of messages between NP-agent and NP-agent of the nodes.

5. Experiments and Results conducted for Optimal Routing Multi-Agent System

The experiment have been conducted for the network configuration shown in Fig.3 by taking 'a' as source node and'd' as destination node. An observation is made to know, the number of messages between NP and NM agents of same node, and between NP and NP agents of different nodes as the bandwidth capacity is increased. Initially source node 'a' requests bandwidth of 50 MBPS, later with incremental bandwidth of 50 MBPS over time. From the graph shown in Fig.4 the no. of messages exchanged between NM agents and NP agents in the same node is found to be 2,6,6,6,6 for the bandwidths 50,100,150,200,250 respectively. These messages are not being transmitted in the network, so there is no impact on network traffic.

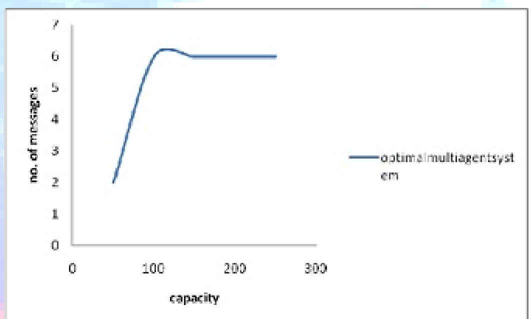

Fig. 4 Bandwidth vs no. of messages between NM and NP agents.

From the graph shown in Fig.5, the number of messages exchanged between NP-agents among different nodes is found to be 0,2,2,2,2 for the bandwidths 50,100,150,200,250 respectively. There is minimal impact on the network traffic, since the number of messages are found to be very less. Hence logical path's bandwidth management and congestion can be effectively controlled by using optimal routing methodology.

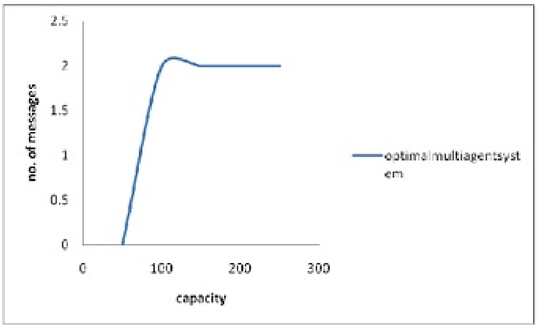

Fig. 5 Bandwidth vs no. of messages

between NP-agents.

6. Advantages of Optimal Routing Multi-Agent System Approach

6.1 Advantages

In multi-agent system, that supports agent's approach, if the number of nodes in the network grows the messages that are communicated between the planning agents of different nodes increases in addition to the actual data, when the optimal route is not used for the transmission of the data between the nodes. This will lead to the traffic overhead and to congestion. But with the proposed system as the data is being send with highest bandwidth first, the number of messages for communication between the planning agents of different nodes are less. And since optimal routing algorithm is being used, the data is send through the optimal path.

Another advantage of multi agent approach is the system can be scalable. The performance of the system does not degrade as network grows.

7. Conclusion

We described Optimal routing methodology for bandwidth management and congestion control in high speed networks, using multi-agent approach. The functionalities of NM agents and NP-agents were described. The developed methodology effectively manages logical paths bandwidth and controls congestion with minimum number of control messages exchanged between NP agents among different nodes in the network.

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