MODELING THE SCALING PROPERTIES OF VIDEO ON DEMAND ACCESS NETWORKS: SIMULATED TRAFFIC AND WORKLOAD ANALYSIS

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ABSTRACT

Several different approaches –Pay per View, Near Video on Demand (NVOD) and Video on Demand (VOD) have been used to deliver video services to customers over cable networks, and a variety of network architectures have been proposed for VOD. This paper will model the performance characteristics of different VOD architectures and pay special attention to their scaling properties. To observe fundamental video stream traffic characteristics and the scalability of servers and the transmission infrastructure, we propose to perform simulation experiments for various VOD architectures to reveal which bottlenecks were the most serious. Different VOD architectures assume different locations or types of bottlenecks. Sensitivity analysis will be conducted by changing the values of various inputs (including technical ones such as headend locations, content distribution and streaming mechanisms). Simulation is done using different load balancing scenarios such as server load, round robin and the scalability issues are discussed by using server caching at the local hubs. Failure mode recovery analysis is also conducted as one of the scenarios to study the fault tolerance issues in VOD networks.

INTRODUCTION

Internet broadcasting and streaming contents has recently been attracting a great deal of attention, despite their inadequate content quality. The demand for such services is projected to continue to increase in the near future, and streaming contents are expected to play a major role among applications for the next-generation Internet. On the other hand, digital broadcasting and compressed audio/video such as DVD (MPEG2) and Video on demand are considered high-quality services and have become increasingly popular at home. Distribution of On-demand digital content is one of the major issues that need to be solved with a tradeoff between bandwidth and customer satisfaction. Cable operators have been constantly battling around to provide the best services to their subscribers by cost efficient, scalable and suitable technology to support these high bandwidth applications. This paper will discuss the scalability issues of various architectures by various simulation experiments considering load balancing on the head end and suitable server caching at the distribution end.

TECHNOLOGY OVERVIEW

Architecture Studies On Performance And Scalability

There are three main common architectures that are being used to locate the video servers and edge devices. They can be a fully distributed, fully centralized and partially centralized. One of the key issues that cable operators are still working through is where to locate the servers in their networks. They can choose to locate the bulk of their servers in the headed or in the hubs (which are closer to homes). The architecture must be capable of providing a good scalable, flexible model and it should also support high efficient bandwidth applications at a low operational cost per stream.

Fully distributed architecture involves installation of servers at the hub. This approach greatly helps to reduce the transportation cost, but since there is a duplication of content in the hubs, it increases the storage cost and it becomes difficult to manage the network thereby increasing the operational cost. Distributed architecture involves distribution of streaming transport in QAM/RF channels which is highly bandwidth demanding [1] and requires efficient use of bandwidth at HFC network .

Fully centralized architecture involves use of a one-server farm and other edge devices at the head-end. It overcomes the drawbacks of the distributed architecture by providing a low storage and operational cost, but it requires high bandwidth transportation between headend and the hubs. This architecture is not suitable for larger distances exceeding 25 kilometers [2].

Partially centralized architecture involves using the video servers at the headend and edge devices at the hubs. This architecture overcomes the drawback of both centralized and distributed architecture and it can be effectively utilized by using a Gigabit Ethernet backbone thereby providing long distance transport, increased carrying capacity and providing a flexible architecture.
Most cable operators have not yet decided on one scheme or the other, with many using different schemes in different markets.

Components Of Video On Demand

a.Vod Servers

VOD servers host large volumes of digital content supporting MPEG compression format. VOD servers encapsulate individual MPEG streams as single program transport mechanisms (SPTS) or into multiple program transport streams (MPTS). These SPTS or MPTS are mapped into ASI/ATM/Gbe/packet ring. IP-based servers are used as storage servers as IP takes advantage over other servers in using MPEG-2 over IP, thereby reducing the cost significantly in the system. Gigabit Ethernet interface helps in increasing the throughput per rack unit and the no of streams that can be encapsulated can be calculated as available bit rate to the total bit rate supported by Gigabit Ethernet. [3]

b.Edge Qam Nodes

QAM devices convert VOD server output (MPEG-2) to coax channels (6-8 MHz). It initally receives the MPEG-2 video and it re-stamps the packet that were delayed by the jitter and re-routes the packet to appropriate destinations. Its main role is in fixing up the jitter introduced due to the encapsulation in the network.[2]

c.Transport Network

The video content is distributed from headends to hubs. The transport architecture may be ranging from ATM or IP over Giga bit ethernet or IP cloud. The resilient packet can also be used to provide redundancy over the circuit in transmitting the video traffic incase of a ring failure or central /remote node headend failure.

d.Setup-Top Boxes

Set-top receivers at the customers premise acts as client nodes to VOD servers and terminate QAM signals to extract incoming VOD streams.

RELATED WORK ON DESIGN CONSIDERATION FOR SCALABILITY ISSUES

Scheduling Disk Issues

Real-time constraints make traditional disk scheduling algorithm, such as first come first serve, short seek time first, and scan, inappropriate for VOD. Studies on VOD networks [6] suggest that two scheduling algorithms can be used for real time scheduling.

The best-known algorithm for real-time scheduling of tasks with deadlines is the *earliest deadline first algorithm (EDF)*. The media block with the earliest deadline is fetched first. The disadvantage of this algorithm is excessive seeks and poor utilization of the server's resource. [6]

Under round-based algorithms, a server serves all streams in units of round. During each round, the server retrieves a certain number of blocks for each stream. Since MPEG-2 results in variable-bit-rate compressed streams, the number of blocks that must be retrieved for each client in each round will vary according to the compression ratio achieved for each block.

A simple scheme that retrieves the same number of blocks for each stream (generally referred to as a round robin algorithm) is inefficient since the maximum playback rate among all streams will dictate the number of blocks to read. This results in streams with smaller playback rates retrieving more data blocks than needed in each round. This may overflow some clients' buffer as well as decrease the capacity of the server. Consequently, more clients can be accommodated by reducing the number of data blocks retrieved per service round for streams with lower playback rate.

The Placement Scheme decides the cluster size and stores video files across all clusters and verifies that a proposed placement scheme meets the placement requirements. It is an important factor for load balancing on servers. David Du [7] suggested that the placement scheme has to satisfy the following two requirements.

It is necessary to include video data from each video file in a cluster. This is because that the types of video files requested by retrieval processes are unpredictable. Sub requests within a service cycle may read video data from any video files available in the server.

The continuity of data block for each video file should be maintained between clusters. All data blocks should be stored within one cluster and their corresponding next data blocks should also be stored in a cluster range. If this method is not followed, after serving current sub requests, the following requests in next service cycle will read data blocks not from a cluster range**.**

Load Balancing

Whenever a load balancer receives a packet from the client machine, it must choose an appropriate server to handle the request. Load balancer will use the policy to determine as which server is appropriate.

Popular load balancing methods include:

Random: The load balancer chooses one of the candidate servers at random.

Round-Robin: Round robin policy is a method of managing server congestion by distributing connection loads across multiple servers. The load balancer cycles through the list of candidate servers depending on the selection weight specified. It can be classified as

Server Load: The load balancer chooses the candidate server with the lowest CPU load among all the servers

No of connections: The load balancer checks the server for the number of connections. When a new request is made, the load balancer checks and makes the connection with the server with least number of connections.

SIMULATION MODEL AND ANALYSIS

This section explains the various simulation models and the assumptions done for conducting our study.

Requirement Assumptions

In order to model the VOD architecture properly,we use the following requirement assumptions in our study.

- High-speed connection exist betweent the headend and the hubs which helps to avoid delay thereby reducing the packet loss rate and minimum latency in the network

- Connection oriented transfer is necessary for the timely arrival of packets and to provide high level of QoS.
- The data stored in the servers must be efficiently managed. This aspect deals with disk scheduling, data placement schemes and cluster management. Servers with local buffers are necessary for transfer of data without delay and jitters.
- ATM backbone is used for simulation analysis between the headend and the edge devices. The other alternatives could be 10 Gigabit Ethernet or resilient packet ring [3]
- The end-to-end delay measured in the network must be minimum for efficient transport of high bandwidth streaming applications
- Jitter is one of the factors affecting the quality of service.A smaller jitter provides with a high quality picture to the customer
- The utilization in the network is proportional to the number of connection that the server supports.The utilization must be initally low in order to support multiple connections in the future therby increasing the scalability demands of the network.

Model Description

The goal of this simulation is to evaluate the end-to end delays of a VOD network using load balancing and server caching techniques.We use a ATM cloud as the backbone for the network and high speed 1000 basex links are used to connect the headend servers to the headend gateway.These are the links that carry the high speed streaming MPEG-2 streams from the headend to the headend gateway. OC3 links are used to connect the headend and edge devices gateway. Three IP based servers were used. TheMPEG-2 streams can be encapsulated as SPTS so that each stream can be used to transport audio,video and sent to any desired IP destination at the lowest cost.GBE is used as a single GBE can provide a througput of 1000mbps.

CISCO 12016 Gigabit switch router is used as the gateway and some of the key features of this model are

- An IP forwarding rate of 60,000,000 packets/sec

- The router model implements a "store and forward" type of switching methodology.

Multiple GBE server outputs are aggregated into one GBE output and a payload of 900Mbps is recognized out of the GbE switch. The atm32_cloud node model represents a cloud through which ATM traffic can be modeled using 32 input/output physical links. Bandwidth management is highly critical in ATM networks as a delay of few milli seconds in a highly congested network can cause the cells to be dropped and lost. This results in retransmission of packets and it might compound congestion [6]. (Although voice and video are not retransmitted,this may cause a degradation in the performance of the enitre network.)

Some of the other parameters that are being used for the network are:

- Frame interarrival time information is assumed as 15 frames/sec.
- Frame size information is assumed as 128*240 pixels.

Type of service is assumed as high quality streaming multimedia. Simulataneous traffic generation is there in network until the end of the profile.Traffic is generated exponentially using a mean factor of 30.

Simulation Scenarios

Various simulation experiments were conducted and the performance of the VOD network under different test conditions were observed.There was a comparison of the different VOD architectures and the end-to end-delay, traffic of the network were analysed under two different scenarios namely load balancing and Server caching.There was a failure mode analysis of the network and the effects of the load balancer on the failure mode recovery are discussed below.

Scenario 1: Comparison of traffic in the network

Two different architectures namely the centralized and distributed architectures were simulated for heavy traffic conditions . Distributed architecture is preferred over centralized architecture in terms of all reduced congestion and delay, as the servers are located near the hubs, but management of media storage is a problem. This is the only disadvantage as the servers are located internally at different places unlike centralized architecture where servers are located at a single point.

Figure 2 shows the voice traffic sent for both the architectures. It is shown that voice traffic sent for distributed architecture increases linearly with time and voice traffic sent for centralized architecture remains steady after reaching certain time period. This shows that the distributed architecture has high throughput relatively compared to centralized architecture, which is evident from Figure 2.

Scenario 2: Load Balancing and Server Caching

a. No Load Balancing

In this scenario,no load balancing is applied on the servers and performance analysis of the network is done and the end-to end delays are measured. The end to-to-end delays are found to be relaitvely high when compared to other scenarios.The end-to end delay for this network using no loadbalancing is around 0.2 secs on an average and it is considered to be higher compared to load balanced and server cached scenario.

b.Load Balancing

In this scenario,a load balancer is used to control the load acting on the three servers.There are three policies that are being used .

The are classified as Round Robin,Server Load and the no of connections.The first server is loaded with a selection weigth of 10 and the other two servers are chosen with a selection weight of 5.The first server is loaded twice as that of other two servers and the end –to end-delay was found to be greatly reduced to 0.009 secs from 0.12 secs in a scenario that doesnot use load balancing.

c.<u>Server Caching</u>

In this scenario,an additional server is duplicated with contents of one of the head-end servers and is installed at the hub,and the end-to-end delays were analysed for this scenario.The end-to-end delay was found to increase,but the traffic in the network was decreased considerably as there was data duplication in the hubs.

d.<u>Failure Recovery</u>

Failure recovery analysis was conducted in VOD networks.One of the servers was set to fail while the servers are handling the high traffic in the network.The load balancer helps to isolate the server and it distributes the load among the other two servers in the networks.Towards the end of the simulation,the server recovers and it again couples with the other two servers to handle the load.The end-to end delays and the traffic of the network were analyzed and the graphs were obtained in Figure 6 .

When the server three fails,the end-to end delay increases and its 24.9 secs at the point of failure and it gradually decreases towards the end of the simulation as the server three recovers.Thetraffic in the network can be seen as decrease during the period of failure and gradually increase towards the end of simulation.The traffic dropped was analyzed in this scenario and it was found that there was no packet loss in the network.

<u>CONCLUSION</u>

This paper provides a good insight into the scalability isssues on VOD networks.We discuss the scalability issues in different perspectives as how disk scheduling and data placement can affect the performance of VOD networks. Three alogorithms namely EDF, round-based algorithm and QMPS are discussed under the scheduling disk issues. Data placement decides about the admission scheduling schemes and discusses the cluster placement issues. Our simulation study shows the overall packet-end-to-end delay in the VOD network under different scenarios. This shows that load balancing with server load policy can definitely be a good suggestion for high performance in the network. Delay is one of the major factors in high speed network and this shows that load balancing can certainly help in reducing the end-to-end delay of the network and it can also help with fault tolerance capabilities, if there is a problem of server failure during operation in the network. Server caching can be one of the possible solutions to reduce the traffic in the network, if streaming media is sent to longer distances,but it always has a drawback on the management and storage associated with the duplication of data.

<u>Future work</u>

Resilient Packet Ring (RPR) is a new transport standard and can be used for more efficient multiprotocol transport. This standard combines the best attributes of SONET,WDM,and GbE to provide with high quality of streaming content with redundant links. However this standard is at the initial stages of development and it could be expected to be more expensive than the other options that were discussed.

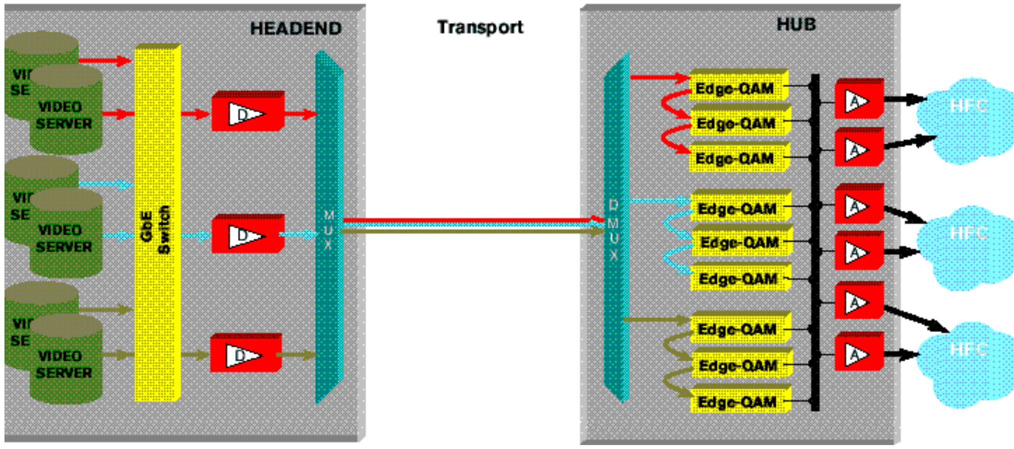

Figure 1.Components of VOD network [1]

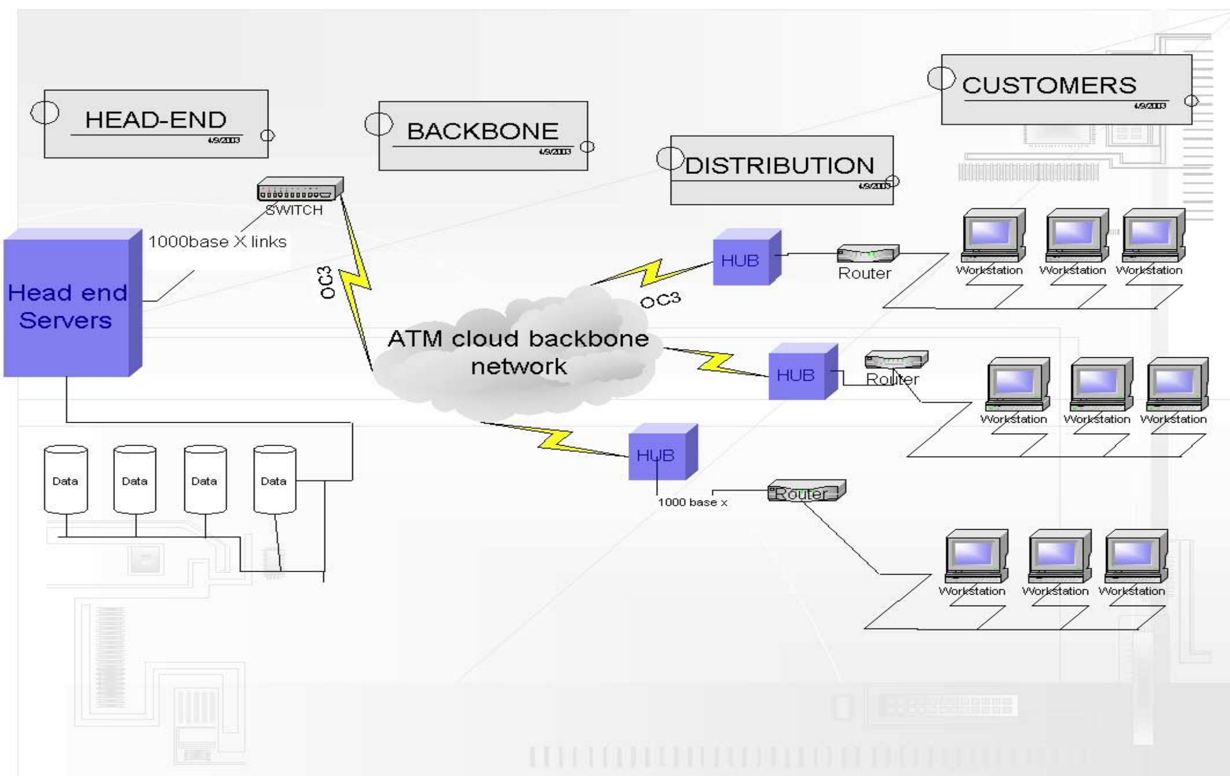

Figure 2 : Video on demand network - Topology

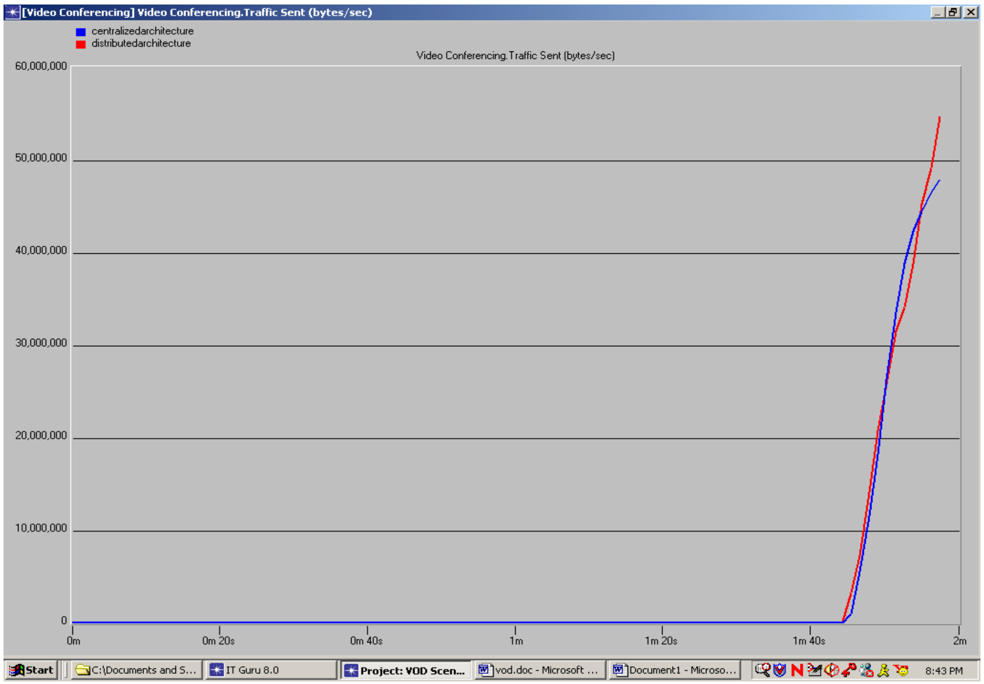

Figure 2 : Comparison of voice traffic received

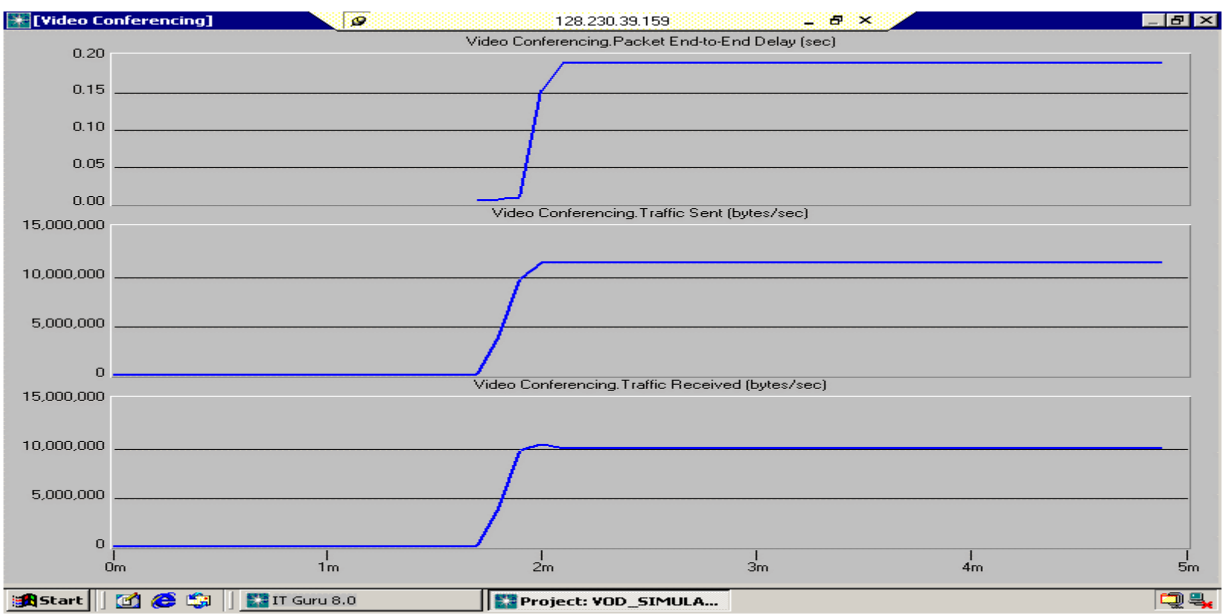

Figure 3: No Load Balancing Scenario

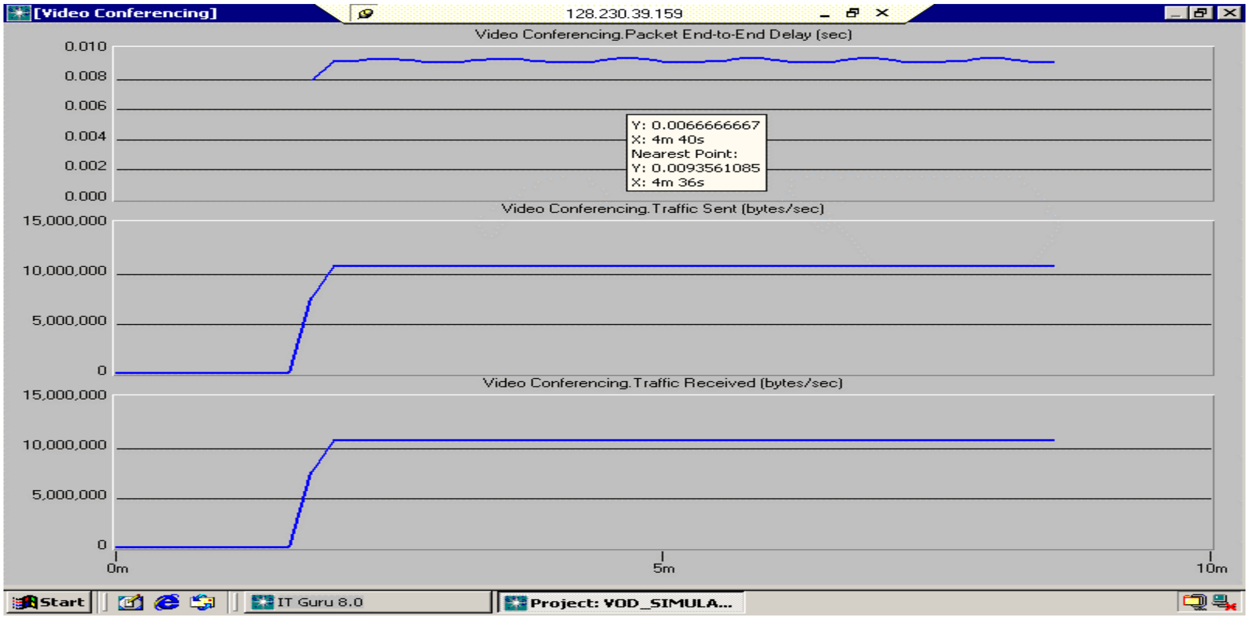

Figure 4: Load Balancing Scenario

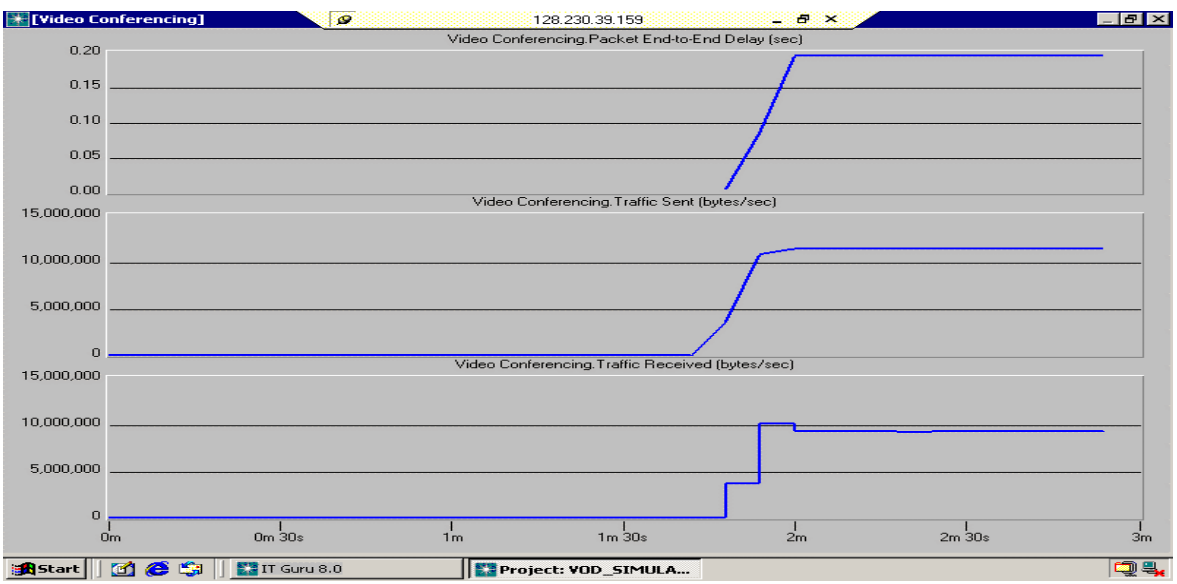

Figure 5: Server Caching

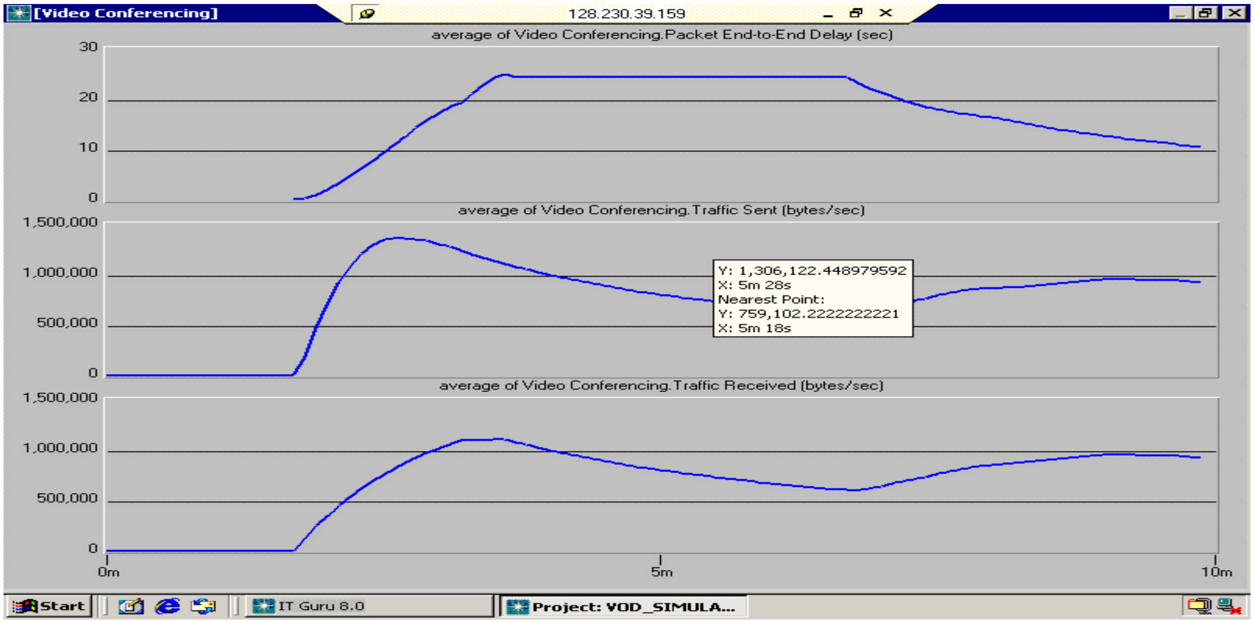

Figure 6 :Failure Recovery Scenario

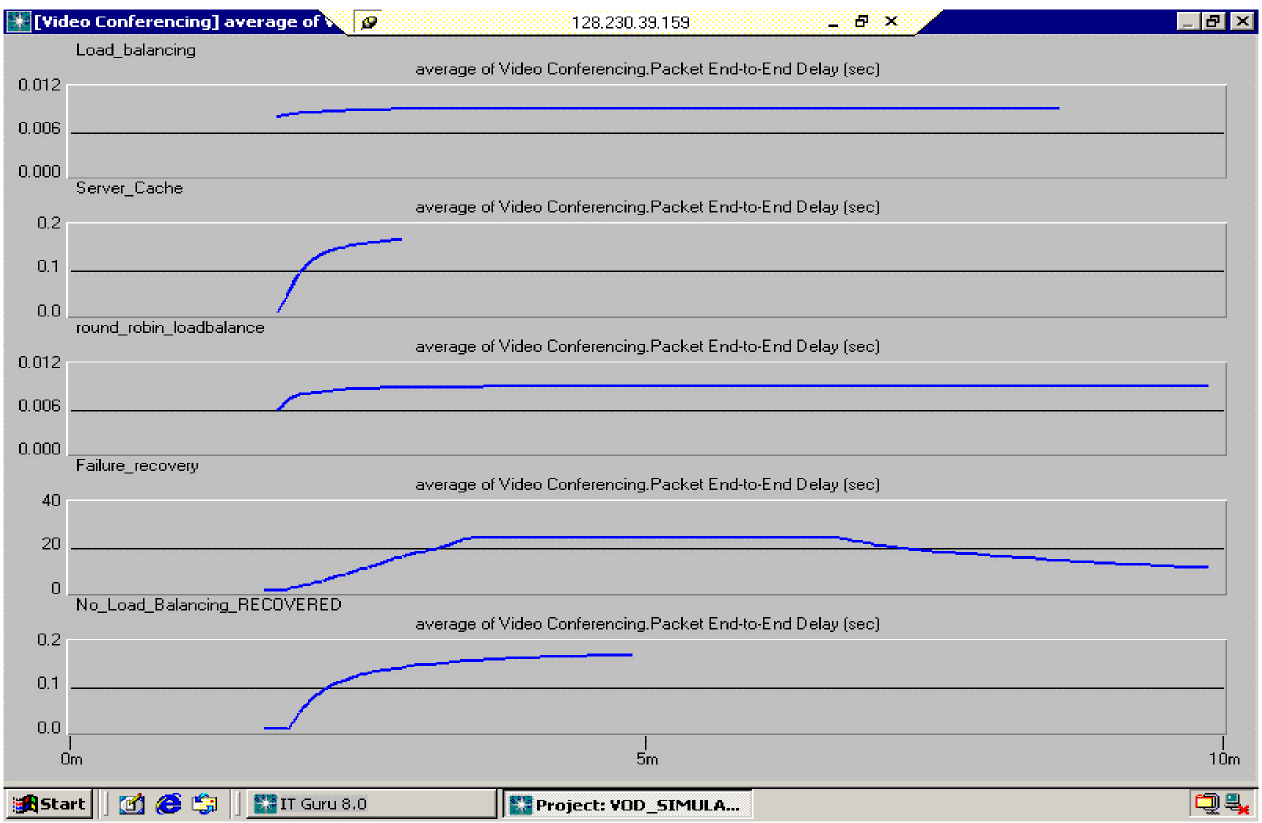

Figure 7 :Overall Scenario Summary

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