Video on Demand over IP

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During the past seven years, a number of advancements in hardware and software technology have led to novel applications of computers. The speed of processors has continued to increase. Gordon Moore, who predicted in the 70s that the speed of processors would double in every 18 months, has been proved right. In early 2005, Intel has announced a pentium processor with clock speed of 3.4 GHz. Simultaneously, the speed and capacity of random access main memories of computers has also been increasing. The capacity of computers has been doubling 18 months and today desktop PC has at least 2 GB memory. Hard disk drives are almost as amazing as microprocessors in terms of the technology they use and how much progress they have made in terms of capacity and speed in the last 20 years. The first PC hard disks had a capacity of 10 megabytes. Modern hard disks have capacities approaching 160 gigabytes. This represents an improvement of 1,000,000% in just under 20 years, or around 67% cumulative improvement per year. At the same time, the speed of the hard disk and its interfaces has increased dramatically as well.

The storage area network, consisting of a large number of interconnected disks, provide on-line storage of 100s of terabytes (10^{15} bytes). Better hardware and software have emerged to interconnect computers. The value of networking computers has been realized as it allows sharing of resources efficiently. It was observed by Metcalfe that the utility of individual computers increases as the square of the number of computers to which it is connected. In other words 10 computers are networked, the utility of computer increases by factor of 100. The advent of an infrastructure of a large number of interconnected computers led entrepreneurs to look for applications, which can use this infrastructure. One of the most exciting applications is *Video on Demand (VoD)*. It is concerned with providing video entertainment and education at home customers via the computer communication network.

As an IP network oriented to users, QoS is the basis for its operation. Unless the QoS problem is solved, everything that IP promises to be will become nothing more than a mirage and services like VoD and video conferencing will not be able to run on the IP network properly.

The current popular theory of broad bandwidth is not conducive to the development of the telecom industry, since the solution for broad bandwidth evades the following issues:

- Should broad bandwidth be provided to all people and for all services?
- Will there be continuous bandwidth available?
- Can bandwidth requirements of any and all persons be satisfied at the same time without discrimination?
- How can the carriers price their network services?

In the case of telecom services (voice/video/dedicated line) and the Internet services existing in

the same network, if the network cannot differentiate the services nor control the Internet flow, the QoS of network services cannot be in any way guaranteed whatsoever.

The problem now is that enabling real QoS functionality on a packet transmissions IP network backbone, network equipment largely compromises the forwarding capability of the equipment, while supporting QoS via hardware upgrade necessarily adds substantially to the investment.

Evolution of standards and protocols for high speed, integrated services networks, coupled with rapid advances in the storage and compression technology, has spurred interest in distributed multimedia systems. Of the many applications for distributed multimedia systems, video-on-demand (VoD) has much appeal because of its on-demand
nature.

VoD short for video-on-demand, VoD is an electronic video-rental services over a computer network. VOD provides a service to users to browse and to watch any videos at any time. Using a VoD system, client will be able to request a video from anywhere and at any time. In response to a client's request, VoD systems will deliver high quality digitized video directly to client set-top boxes or workstations for viewing on a television or computer screen. VoD can be used for entertainment (ordering movies transmitted digitally), education (viewing training videos), and videoconferencing (enhancing presentations with video clips). Although VoD is being used somewhat in all these areas, it is not yet widely implemented. *VoD's biggest obstacle is the lack of a network infrastructure that can handle the large amounts of data required by video*.

A VoD over IP system consists of hierarchies of servers and network elements connected to a large client base. The servers may transmit the multimedia data periodically over the network in response to a client's request. Because there can be no gaps in the presentation of the multimedia data on the client site, there must be a tight coordination among all components of a VoD system. Guarantees on server retrieval performance and network transfer conditions must be provided to maintain the stringent real-time performance and synchronization requirements of video applications. Current data management practices both at the server and the network levels must be modified to address real-time requirements of multimedia data.

At present, networks and service level technologies provide only best-effort service to conventional data transfer applications. In contrast, VoD applications require guaranteed throughput and bounded delays over a prolonged period of time. To provide these guarantees, it is essential to limit the number and nature of requests being served simultaneously in the VoD system. *For each request, we also need reservation processes to allocate resources along its routing path and maintain them for the length of time the request is being served.* All these requirements are different from the best-effort principle of present day servers and networks.

Media blocks in a VoD application need to be retrieved at the server and transmitted over the network to the client within strict timing constraints. Unlike traditional data blocks, media blocks are not independent entities but are synchronized with other media blocks and served as a stream of blocks. This is also the situation in the network, where data is viewed as a stream of packets, sometimes termed a flow. Setting up a flow identifies the set of packets that must receive special guarantees. These continuity requirements over a period of time lead to complex resource management requirements at the heart of which is the concept of admission control. End-to-end admission control strategies determine whether adequate resources are available along the path of the new request so that it can be admitted without violating the continuity requirements of the requests already in service.

Tight coordination among subsystems and end-to-end admission control are key to

providing real-time performance in VoD systems. If we ignore the coordination and admission control requirements and operate a VoD system on best-effort delivery, much like the current practices on servers and networks, every client is admitted into the system and gets a fair share of the system even under heavy load. This indiscriminate, though fair, distribution of limited resources leads to degraded quality in service under high load. In this scenario, analysis and design of isolated subsystems is sufficient because we would be primarily interested in learning how a certain subsystem performs under various workload conditions.

For VoD clients, however, the resulting degraded quality in service under high load conditions in a best-effort delivery will not be acceptable, because degraded service means dropped packets resulting in visual artifacts or gaps in display. VoD clients need firm guarantees on throughput and bounded delays. Because of this requirement, if there are not enough resources to provide these guarantees, the client is denied service through admission control. In this mode of operation, the objective is to maximize the number of clients being served in the VoD system or minimize the number of requests getting blocked or rejected. This requires careful examination of resource usage on all subsystems taken together. *Therefore, there is a strong need for end-to-end analysis and a global policy for request handling and admission control in a VoD system.*

Clients of a VoD system use a device generally known as the set-top box (STB) to interact with the video servers over an integrated services network. Most of the proposed architecture for STBs assume that cable TV networks will coexist with some kind of packet switched integrated services network. In (Kohiyama, Shirai,Ogawa, Manakata, Koga, and Ishizaki 1996), an architecture of a 64QAM MPEG-2 digital set-top box for VoD applications is described. The architecture integrates high resolution (720X480), color (256 colors our of 17.6 million) graphics, MPEG-2 video and analog NTSC television signals. If current television technology is kept as an output medium for VoD services, a digital video signal has to be converted to an analog NTSC signal before it is displayed on a conventional TV (Furht, Kalra, Rodriguez, and Wall 1995). Furht (Furht, Kalra, Rodriguez, and Wall 1995) proposes a hardware architecture of an STB as consisting of a processing subsystem which runs a real-time operating system, a video subsystem which decompresses encoded video streams such as MPEG-2 streams, possibly using MPEG-2 decoding chipsets, and an audio subsystem which decodes the audio corresponding to the video stream.

The buffer management is the issue we are most concerned with for the client subsystem. Gollapudi and Zhang (Gollapudi and Zhang 1998) examine buffering requirements necessary to maintain continuity and synchrony of presentation of multimedia objects. This is done by taking into account the network and server delays while matching pre-loading and consumption times of media objects. The Medic algorithm will direct the data either to the decoder if there is enough memory or to the disk. Downloading an entire video and providing interactive playout at a client station is possible (Chen and Kandlur 1995). *Therefore, downloading an entire video required more buffer space at client subsystem.*

Research on video server design has shown several ways of maximizing retrieval effectiveness. But its implication on the network or the client subsystem is missing. On the other hand, several network service disciplines have been proposed. *But the impact of a server transmission pattern coupled with a known network service discipline on the display requirements of a client has not received much attention*.

While there is merit in discussing issues related to individual subsystems, a complex VoD architecture needs to be evaluated as an end-to-end system for the following reason.

Because of the limited resources and guaranteed service requirement for each request, the number of simultaneous requests being served at a resource needs to be limited. Therefore, some of the arriving requests will have to be turned away when there are no adequate resources to provide

guaranteed services to those requests. Based on this mode of request handling, we have to maximize the resources so as to minimize rejection of service to incoming requests. This requires a careful design of all the subsystems involved in the VoD architecture. Contrast this logic with the other mode of request handling similar to best effort paradigm, namely, accept all incoming requests. In this mode of operation, if the system gets overloaded the service will get degraded. Therefore, the design and analysis can be limited to isolated subsystems to verify the level of performance obtained in each subsystem at various workloads.

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