Performance Measurement of Bandwidth Utilization for Video-on-Demand Streaming Across Networks

Rajesh Bhadada, Ph.D.[1], Birendra Rai[2]
[1]Head , [2]Principal
[1]Department of Electronics and Communication Engineering
M.B.M. Engineering College, J.N.V. University, Jodhpur
[2]Vyas College of Engineering & Technology, Jodhpur

ABSTRACT
During the last two decades, it has been observed the exponential growth in the number of users coupled with variety of wide area networks (WAN) at the global levels and provisions for bulky video data download through them. To achieve the goal of supporting such hundreds of interactive data streams simultaneously, optimization and various tradeoffs need be applied for the storage of data on huge secondary memory & high bandwidth for its transportation for retrieval and real time playback. Video on demand (VOD) streaming one such service where videos are delivered to asynchronous users with minimum delay and free interconnectivity. The VoD is costly due to the limited upload capacity of the video server and traditional centralized client/server & peer-to-peer mesh architectures. The VOD streaming through proposed hybrid cluster network architecture are an approach to simplify the limitation of existing system. This innovative approach combines the advantages of both client/server & mesh architectures. In this paper, firstly we provide a better understanding of the streaming media storage size & bandwidth requirement, storage architecture, brief concept of compression techniques and then present a hybrid cluster network for the performance measurement-based study for bandwidth utilization of VOD streaming. The results demonstrate the advantages of hybrid cluster network as an efficient video streaming with respect to centralized and mesh networks.

Index Terms
Centralized Networking, Mesh Networking, Hybrid Cluster Networking, Compression Techniques, Video on demand (VOD) Streaming, Wide Area Network (WAN), Bandwidth Utilization,

1. INTRODUCTION
The last two decades have seen interweave of computer, communication and multimedia technologies to support many new applications and developments. Current and future networks shall mainly provide broadband services for application like high speed person-to-person video communication, access to video information as well as broadcast of programs and multimedia data. In recent years, with the proliferation of high speed networks, there is an exclusive growth in internet data traffic especially video related traffic. A forecast by Cisco for year 2015 estimates more than 15 billion devices connected to the global internet[1,2]. The main aim of this paper is to understand the concept of video on demand streaming and study the benefits of transferring the video packets payload through proposed hybrid cluster network.

The rest of this paper is organized as follows. Section 2 explains the salient features of hardware/software making VOD streaming feasible across networks, Evolution of video services & distribution network, the requirement of streaming bandwidth and storage space. Section 3 presents network topologies for video distribution. The performance measurement-based study for bandwidth utilization is presented in Section 4, in which proposed hybrid cluster network observed as an efficient technique for VOD streaming. Finally Section 5 summarizes conclusions.

2. VIDEO ON DEMAND STREAMING
The video streaming services can be classified into two groups: Live streaming and on demand streaming. Live streaming allows video content to be transmitted in real time to all requesting users. One or more users have their playbacks synchronized to provide their stored content to other peers. On the other hand, on demand users have the flexibility to watch any video at any moment in time, meaning that they do not need to synchronize their playback times[3,4,5,6,7].

Compared to live streaming, in VOD systems the user has complete control over the media by making use of VCR operations such as pause, forward and backward functionalities (also known as jump operations), the same way as if the functionalities were used in a DVD player. VOD systems need to accommodate a large number of users watching the same video asynchronously, watching different parts of the same video at any given time[8,9].

2.1 Salient Feature of Hardware/ Software Making VOD Feasible
A number of advances in hardware and software have made video-on-demand (VOD) feasible. The salient ones are as follows:-

(i) Increase in Storage Capacity of Secondary Storage Device
Currently storage devices have become cheap and that too with capacity moving up. Digital Versatile Disk Read Only Memory (DVD ROM) are available at very low cost and can store upto 17 GB. Storage area networks, consisting of a large number of interconnected disks provide online storage of 1000s of Terabytes (Petabytes).

(ii) Increased bandwidth of communication channels
Presently bandwidths of a few Mbps through video cables or broadband are commonly available. Fiber optic cables being laid provide bandwidth of several Gbps.

(iii) Emergence of Compression Standards and Storage Techniques have been developed and more are developing, to compress the video information in lesser storage space.

2.2 Evolution of Video Services and Distribution Network

With the advent of the Web and the possibility to transmit multimedia content has become a major issue. CDNs are being developed to efficiently deliver content to end users. A number of CDNs already exist as part of different infrastructures[13,14]. Still, with constantly evolving networks, applications and user requirements, the developments in this area are very much on-going work. First generation CDNs have mainly focused on Web documents using caching and replication techniques (predominantly for the Web) to provide a better service. The second generation of CDNs has been mainly concerned with continuous media issues such as audio and video streaming, video on demand (VOD) schemes, scalable video support, etc. It is expected that the next generation of CDNs will focus on additional functionalities, e.g. to facilitate the creation, modification, active placement and management of content within the content infrastructure. This extends the functionality beyond traditional delivery and is therefore called content networking, which not only concerns distribution aspects but also with content management, retrieval, content creation and adaptation support.

2.3 Requirement of Streaming Bandwidth and Storage Space

The storage space for streaming media is calculated from the streaming bandwidth and length (in seconds) of the media by using the formula as given:

Number of MBytes transferred =

$$\frac{\text{Length (in seconds)} \times \text{Bit rate (in bit / seconds)}}{(8 \times 1024 \times 1024)}$$

Example: 1hour of video encoded at 500 Kbit/s requires

$$\frac{(3,600 \times 500,000)}{(8 \times 1024 \times 1024)}$$ i.e. approximately 215MBytes of storage.

If the file is stored on a server for on-demand streaming and this stream is viewed by 200 people at the same time, then the bandwidth requirement by using unicast, multicast and live streaming environments will be determined as follows:-

(i) Unicast Streaming

It requires multiple connections from the same streaming server even when it streams the same content as depicted in Figure 1. Unicast protocols send a separate copy of the media stream from the server to each recipient[10,11,12]. Unicast is the norm for most internet connections, but does not scale well when many users want to view the same program concurrently using a unicast protocol, the bandwidth requirement is:

500 Kbit/s × 200 = 100,000 Kbit/s = 100 Mbit/s of bandwidth. This is equivalent to around 45 GByte/ hour.

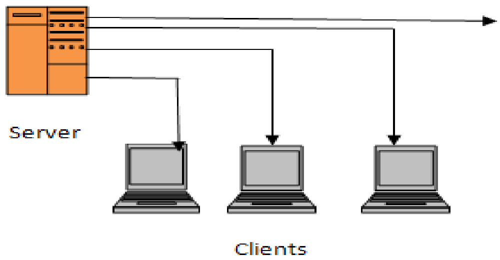

Figure1:Unicast Streaming

(ii) Multicast Streaming

Multicasting broadcasts the same copy of the multimedia over the entire network to a group of clients as depicted in Figure 2. Using a multicast protocol the server sends out only a single stream that is common to all users. Hence, such a stream would only use 500 Kbit/s of serving bandwidth. Multicast protocols are developed to reduce the data replication (and consequent server/network loads) that occurs when many recipients receive unicast content streams independently. These protocols send a single stream from the source to a group of recipients

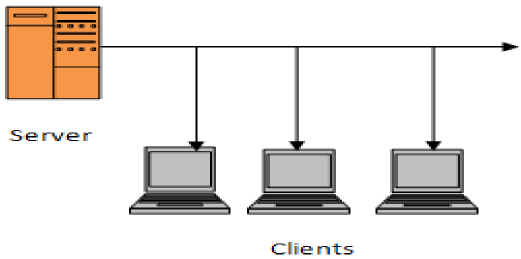

Figure2: Multicast Streaming

(iii) Live streaming: The calculation for live streaming is similar. Let us assume that the speed of the encoder be 1000 Kbit/s. If the show duration last for 3 hours, with 200 viewers then the bandwidth requirement is calculated as follows:

$$\frac{\text{Encoder speed (in Kbps)} \times \text{No. of seconds} \times \text{No. of viewers}}{(8 \times 1024)}$$

$$\frac{1000\ \text{(Kbps)} \times 3 \times 3600\ (= 3\ \text{hours}) \times 200\ \text{(No. of viewers)}}{(8 \times 1024)}$$

= 264 GBytes approximately.

3. NETWORK TOPOLOGIES FOR VIDEO DISTRIBUTION

The network topology considered for video distribution is as discussed below:-

(i) Centralized Topology

The figure 3 depicts the centralized topology which is based on the traditional client/server model.

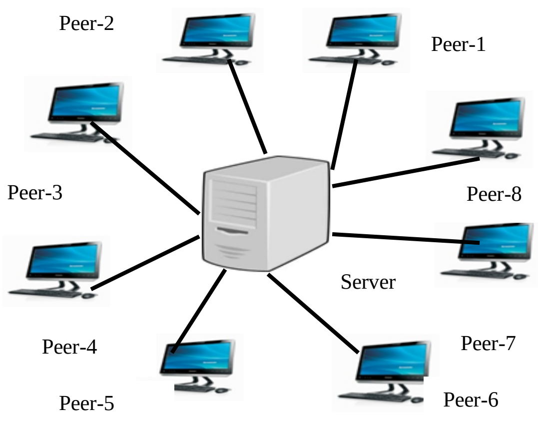

Figure 3: Concept of the Centralized Topology

The centralized server manages the files and user databases of multiple clients peers that log onto it. The client contacts the server to bring up to date of its current IP address and names of all the files that it is willing to share. It is done every time the application is launched. The information collected from the clients will then be used by the server to create a centralized database dynamically, that maps file names to sets of IP addresses. All search queries will be sent to the server, who will perform a search through its locally maintained database. If there is a match, a direct link to the peer sharing the file is established and the transfer executed

(ii) Mesh Topology

Mesh topology (fig.4), enables massive parallel content distribution among peers. They are based on self-organization of nodes in a directed mesh and do not have a static topology[16].

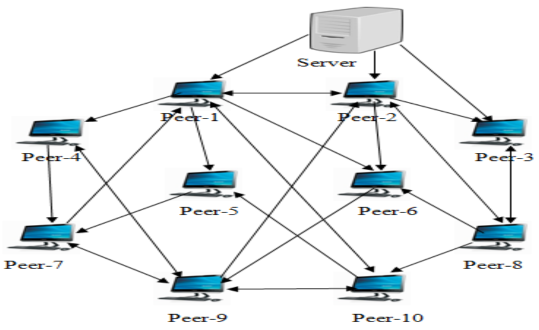

Figure 4: Mesh Topology

Connections are based on availability of content and bandwidth, while peers in a mesh have more links and thus better connectivity. To allow for mesh streaming, a video file is subdivided into many small pieces typically ranging from 32 KB to 512 KB. However, piece sizes of several megabytes have also been used especially for high definition content. Every peer would request the pieces about to be played out from other peers in its neighborhood. To find out which peer has which piece, "buffer maps" (bitmaps of available pieces) are periodically exchanged between the peers in the same neighborhood[15].

(iii) Proposed Hybrid Cluster Topology

By studying all above, under this paper a hybrid cluster network model (fig.5) has been investigated for efficient video distribution to overcome and simplify the limitation of existing topologies.

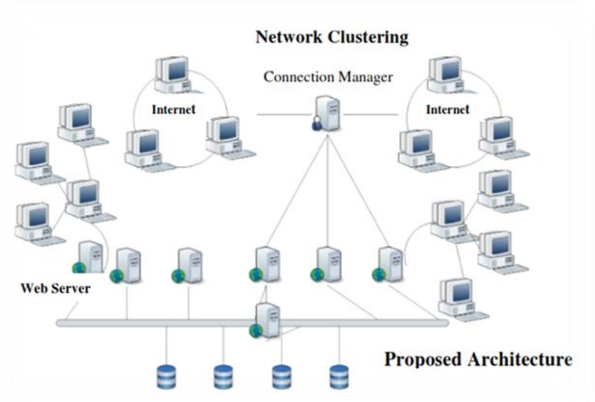

Figure 5: Proposed Hybrid Cluster Network Model

The proposed hybrid network model shall be compared with existing topologies to find the differences in performance as well as their applicability to real applications. For performance measurement to adjudge proposed model the Bandwidth utilization need investigation in this paper. The inherent properties of hybrid cluster networking represents a fundamental measurement of content delivery supply in directly proportional to demand and/or inversely proportional to cost.

4. INVESTIGATION OF BANDWIDTH UTILIZATION

The bandwidth utilized by centralized, mesh and proposed hybrid cluster video streaming network architectures against the variation of streaming bit rate and busy hour traffic were investigated. The investigation was aimed to explore whether the proposed model offer better response, effective to increase the scalability and can it reduce the overall cost under the following parameters:-

Table 1(a): Network Parameters

Parameters	Default Value	Description
LANBandwidth	80 Mb/s	Bandwidth of LAN connection in Mb/s
WANBandwidth	8 Mb/s	Bandwidth of WAN connection in Mb/s
CPUSpeed	800 MHz	Speed of processor in MHz
Number of Servers	5	Number of servers in the system.
User-Server Network	WAN	Type of network connection between users & servers
Server-Server Network	LAN	The type of network connection between servers

The bandwidth is the viewer's connection speed that controls viewer's ability to retrieve and play video smoothly over the Internet. Higher delivery bandwidths allow to stream higher quality video to the viewer.

The bit rate is the most important factor in streaming video quality, i.e. lower the data rate, the lower the quality of the compressed file and vice versa. The bandwidth for the centralized, mesh as well as the proposed cluster network was measured against the variation of streaming bit rate by using the Packet Tracer Network Simulator and the Bandwidth Calculator software tool/platform.

Simulation Configuration over Network

Open bandwidth calculator to find out available bandwidth for centralized, mesh and proposed hybrid cluster architecture. Add the devices which are used in network topology and add them simultaneously with the respect of bit rate in Kbps for the MPEG 2 video format resolution.

Simulation Run

Table 1(b): Measured Parameters for Bandwidth Utilization against

Bit Rate *(Perform-1)*

Video Streaming Bit Rate (Kbps)	Bandwidth Utilization (Kbps)		
	Centralized	Mesh	Proposed Hybrid Cluster
185	258	272	286
200	279	293	308
215	300	322	329
230	315	343	350
245	336	358	365

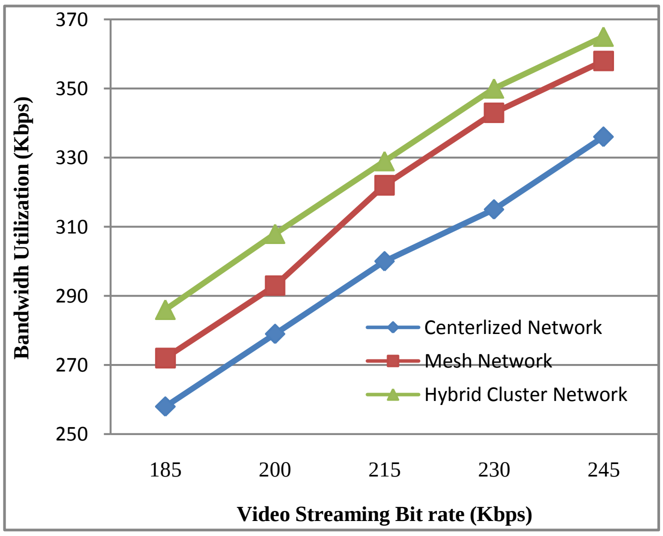

Figure 6: Impact Analysis of Bandwidth Utilization for Centralized, Peer to Peer Mesh and Hybrid Cluster against bit rate variation

Table 1(c): Measured Parameters for Bandwidth Evaluation with respect to Busy Hour Traffic (Perform-2)

Busy Hours Traffic (Erl.)	Bandwidth (Kbps)		
	Centralized	Mesh	Proposed Hybrid Cluster
10	1248	1480	1595
15	1390	16415	1725
20	1484	1660	1790
25	1610	1750	1880
30	1630	1800	1915
35	1745	1890	1967
40	1820	1936	2052
45	1925	2085	2195

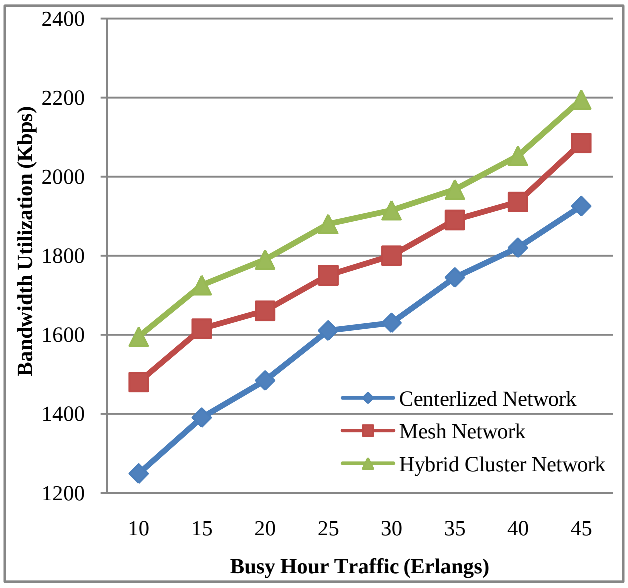

Figure 7: Impact Analysis of Bandwidth Utilization with respect to variation in Busy Hour Traffic (Erlang)

5. CONCLUSION

The evaluation of the storage space and bandwidth requirement of unicast/multicast/live streaming environment and the topologies for distributing video streaming across these networks are surveyed. The performance has been evaluated under various system configurations. The effectiveness and appropriateness of the proposed hybrid cluster network is measured with respect to centralized and mesh network, by observing the network parameters and transferred of video samples across these networks.

The simulation observation and results are summarized in the tables and the impact analysis of examined parameters depicted via graphical figures in the previous section. The bandwidth evaluation was undertaken for network parameters as per Table 1(a) against varying video streaming bit rates as per Table 1 (b, c) for centralized, mesh and proposed hybrid cluster networks. Figure 6 illustrates the impact on bandwidth utilization for centralized, mesh and proposed hybrid cluster network topology respectively at varying streaming bit rates of 185, 200, 215, 230 and 245 Kbps. Figure 7 illustrates the impact on bandwidth utilization for centralized, mesh and proposed hybrid cluster network topology respectively at varying busy hour traffic of 10, 15, 20, 25, 30,35, 40 and 45Erlangs.

It is observed that for the specified video streaming bit rate and busy hour traffic, the proposed network offered the maximum bandwidth as compared to centralized and mesh networks. It affirms that proposed model can serve larger number of users. This analysis also implies that the proposed model offers better response and more effective i.e. increase in scalability at same cost. These results highly recommend hybrid cluster model more efficient solution for delivering good quality video services to customers in local broadband IP-networks, even in variable traffic conditions.

The future internet initiatives should be taken to take into considerations these techniques while designing new architectures and protocols to enable future personalized applications and services, operating under high heterogeneous and dynamic environments for maximizing the QoS of the users.

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