CHAPTER 1

INTRODUCTION

1.1 GENERAL

Multimedia Computing has transformed from a special interest research area into a pervasive aspect of everyday computing with new methods of programming and different ways of handling multimedia information evolving considerably. The tremendous growth in production and use of multimedia content is due to the availability of large storage space, decreasing hardware cost, rapid increase in computing power and bandwidth that have contributed numerous multimedia applications made available on-line which remained inaccessible in the past. Digital cameras, personal computers and Internet allow every individual to be a media content creator. As it becomes easier to produce the content, the amount of content grows faster and it becomes more complex to handle the issues related to media management and transmission. The increased availability and easy access to multimedia information brings new challenges in all areas involving media data specifically in terms of effective retrieval, reliable and congestion controlled transmission and digital rights management of the multimedia content.

As the complexity and programming burden of today's software system increases due to the expectancy of distributed capabilities and seamless networked operations, middleware computing is becoming an increasingly
popular way of providing helpful and useful software support abstractions in a coherent manner. Currently adequate support for multimedia computing within distributed environment remains to be provided. Successful implementation of a multimedia application in a distributed environment is itself a formidable task as distributed environment has combinatorial explosion problem. This problem is addressed by the encapsulation of communication mechanism between the client and server technologies such as RMI, CORBA and .NET Remoting. These technologies allow a collection of distributed components to interact with each other in such a way as if they are running in the same machine. Efforts to utilize distributed components are more concerned with functionality addition than with critically examining performance, enhancing reliability and security issues in transmission of data. Current middleware technologies for distributed programming impose quality and reliability constraints on top of the traditional requirements necessitating efficient management of resources with performance improvement.

This thesis proposes novel ideas for the development of media on demand applications in distributed environment using open standards, facilitates the performance evaluation of multimedia applications in distributed environment and provides support for adaptation and reconfiguration within middleware platform ensuring a higher level of availability and reliability for media applications. The enhancements are incorporated by way of dynamic re-routing, prefetching, distributed caching, multicasting and encrypting the media data in the distributed environment. It is also proposed to carry out effective content based media retrieval, end-to-end congestion control for media transmission and Digital Rights Management for media on demand.
1.2 STATE OF THE ART

Distributed object computing has emerged and gained acceptance for the development of a wide variety of applications. Networked computing has spawned the area of distributed computing, which has enabled the realistic investigation of component-oriented computing as a promising approach to distributed application development. However, there is little support for multimedia within either distributed computing platform or component systems addressing issues related to multimedia.

Many papers on the performance analysis of basic data types in distributed environment using benchmarking tools have been published but a standardized framework for the performance assessment of media on demand in distributed environment is not yet available. A considerable work on the performance analysis of distributed object middleware for basic data types was carried out and an optimized thread management in RMI-IIOP (Internet Inter ORB Protocol) that improves the performance by omitting unnecessary data copying and minimizing thread pool architecture context switching was suggested (Matjaz et al 1999, Matjaz et al 2000). CORBA latency and scalability over High speed Networks were measured using the Object Request Brokers (ORB) namely VisiBroker and Orbix and Gokhale suggested a method to improve scalability (Aniruddha and Douglas 1998).

Multimedia streaming has proved to be a very challenging goal to attain because of its one-way transmission nature, buffering at the client terminal and dynamic adjustment of streaming parameters. Despite some initial commercial success, streaming media still faces challenging technical issues such as quality of service, congestion, cost effectiveness, throughput, jitter and
security. The Internet has recently seen a steady rise in loss rates across the network and higher congestion at bottleneck routers due to the increase in large number of non-adaptive multimedia applications. As in Transmission Control Protocol (TCP), if the sending rate is halved in response to a single congestion indication in real-time streaming then the user perceived quality is reduced and affected considerably. Hence an end-to-end congestion control mechanism with active queue management at bottleneck routers is required to provide better quality of service for streaming media.

The Random Early Detection (RED) for congestion avoidance in the packet switched networks was contributed, which detects incipient congestion by computing the average queue size in the router and drops the packet with certain probability (Floyd and Jacobson 1993). An equation based congestion control mechanism for unicast applications was suggested where the sender explicitly adjust its sending rate as a function of the measured rate of loss event, which consists of one or more packets dropped within a single round trip time (Floyd et al 2000). The negative impacts of increasing deployment of non-congestion controlled traffic on the Internet were analyzed and it was insisted that router mechanisms are needed to identify and restrict high bandwidth flows during congestion achieving end-to-end congestion control (Floyd and Fall 1999). (Ivan Bajic et al 2003) addressed the issue of efficient multimedia streaming by integrating an intelligent buffer management scheme with the congestion control at the source.

The explosive growth of multimedia data accessible to users poses a whole new set of challenges relating to its storage, indexing and retrieval. The current technology of text based indexing and retrieval implemented for
relational databases does not provide practical solutions for this problem of managing huge multimedia repositories. Most of the commercially available multimedia search systems index the media based on keyword annotations and use standard text based retrieval mechanism to retrieve media data. So it is essential to device new methodologies such as Content Based Video Retrieval (CBVR) for effective retrieval of media that proves to be the best solution.

Several groups of researchers have investigated the ways of video retrieval by adapting Content Based Image Retrieval (CBIR) methods to selected frames of video. Efficient transmission of media is achieved if it is retrieved effectively and quickly based on the motion activities and spatial contents such as color and shape. Motion activity, first stage of content filtering for content based querying in media applications uses automatic measurement of intensity of motion in video segments that helps in media retrieval was suggested by Divakaran and Sun (2000). An automatic identification and separation of scenes as opposed to individual shots for video retrieval was proposed by Yeo and Yeung (1997). Chang et al (1998) had implemented a fully automated content based video search engine that supports spatio-temporal queries.

Digital Rights Management (DRM) focusing on security and reliability aspects in media transmission is achieved through encryption and watermarking techniques. Qiong Liu et al (2003) reviewed the current state of DRM focusing on security technologies, underlying legal implications and main obstacles to DRM deployment. A digital rights management scheme for broadcast video with methods for copyright protection and copyright violation detection was proposed by Sabu Emmanuel and Kankanhalli (2003).
An in-depth overview of video watermarking techniques was described by Doerr and Dugelay (2003). Swanson et al (1998) presented a multi-resolution scene based video watermarking using perceptual models exploiting spatial and temporal properties to embed an invisible and robust watermark.

1.3 MOTIVATION AND OBJECTIVES

The emerging success of distributed object computing and the explosive growth of the Internet are followed by demands for multimedia applications in distributed environment. Unfortunately the requirements for continuous media handling and transmission are greater than the support offered by conventional client-server applications and the current distributed environments do not meet these demands due to the heterogeneity of client devices and their network connections. Hence in this thesis an analysis has been carried out to recognize the requirements for continuous media applications in distributed environment and to focus on distributed object computing support for media applications and its related issues that achieves better performance for media on demand and media streaming.

The main objective of this thesis is to investigate the provision of middleware to support various issues related to multimedia application in a distributed environment maintaining compliance with open distributed standards such as RMI, CORBA and .NET Remoting. This thesis investigates efficient retrieval of multimedia data from huge databases, reliable and secure transmission to the client addressing both distributors and subscribers concern for digital video demanded. It is proposed to improve quality of service in media streaming by incorporating an end-to-end congestion control mechanism by the way of active queue management. It is also proposed to provide a
support in the manner of a framework added as a part of the distributed platform. More specifically the approach advocated in this thesis has the following goals:

- to provide a middleware platform based on the current open distributed standards, which enables the realistic development of multimedia applications to examine and critically appraise the performance of the media transmission related issues in the distributed environments.

- to facilitate the evaluation of multimedia applications performance in the standard distributed environments and to provide an inherent support to adaptation and reconfiguration within middleware platform for performance enhancement ensuring a higher level of availability, reliability and security for media applications.

- to enhance multimedia streaming by incorporating an end-to-end congestion control mechanism by way of active queue management.

- to propose a content based media retrieval system in a distributed environment and to further reduce the latency and bandwidth during transmission of multimedia by caching in a proxy server and multicast to a group of clients and

- to obtain a secured media transmission by digital rights management through authentication, encryption, watermarking and masking of media.
1.4 SCOPE OF THE THESIS

The thesis entitled "Enhanced distributed and streaming models for media transmission" delineates the development of media on demand applications in distributed environment, development of congestion control algorithms for media streaming applications, content based effective retrieval of media and digital rights management of media to enhance secured transmission. This thesis outlines new approaches to develop solutions for media on demand applications in distributed environment. This dissertation is divided into five chapters including the introduction.

In Chapter 2, the implementation of media on demand models using RMI, CORBA and .NET remoting technologies have been discussed. The proposed models adopt the concepts of platform, language and location independencies provided by the above core technologies and hence deployment of media on demand models have been achieved in a complete distributed environment. Runtime loading of proxy objects is achieved from a web server through code base that will make remote media objects to interact with each other. A location independent model that facilitates the media application integration through heterogeneous environment has been implemented which merges RMI with CORBA standardized Internet Inter-ORB Protocol. The media on demand model has also been implemented in .NET Remoting framework that provides common language runtime for deployment.

In .NET Remoting, when a media client calls a method on a remote media object, parameters and other details related to the call are bundled together in a packet and transported through the established channel to the
remote media object and the results for the call are returned in the same way. .NET Remoting does not overcome problems due to channel failure or interruption from unreliable sources or malicious attacks when a client invokes a method in a remote object. A dynamic re-routing model is proposed to overcome these issues, which improves the reliability of media transmission in the distributed environment. Standard protocols such as TCP and HTTP are used as channels to transport messages to and from remote media objects. A media client can select any of the routes on the media server to communicate with the remote media object, which must be registered before media objects can use it. The remoting framework ensures that the remote media object is connected through the correct route when a client attempts to connect to it or re-routes dynamically during execution.

Dynamic re-routing is achieved for the well-known remote object by eloquently identifying the metadata describing the media interface and the URL address of the remote media object. The interface is an abstract definition between media client and remote media object located in the shareable assembly installed in the General Assembly Cache (GAC), which allows easy building of distributed model. The URL address of the media object represents the physical description of the peer-to-peer connectivity, which is retrieved from the custom configuration file programmatically. The URL address gives significant information related to the location of the remote media object and the remoting channels used for media transmission. Along with URL address, Uniform Resource Identifier (URI), the remoting endpoint published by the media server is used to identify the exact remote media object.
Logical URL (LURL) address representing URL and URI integration is created and stored in the Url-knowledgebase (UrlKB). When media client makes a request, the router ensures the request format and the physical URL address required by the remoting infrastructure is obtained by mapping with the logical address. Client Router concept is proposed for mapping the physical URL address to a unique name, which represents the logical URL address on the client side and the mapping is done based on the Url-knowledgebase. The UrlKB located in the client sink is configured during the registration service from the configuration file.

Server router is proposed, which is responsible for transporting messages across channels in the network. The server router located in the media server channel processes the clients outgoing message and controls the workflow of the message based on the URL address. In this case, the message arriving at the server router is intercepted and dynamic re-routing is achieved which dispatches the messages to the remote object through the new route specified when reliability and security problems are encountered. A distributed model has been developed incorporating all these factors so that the request for media from a client is met with increased reliability.

The major factors that influence the performance of Media on Demand implementations in a distributed environment are Round Trip Time (RTT), Data Throughput, Scalability, Reliability and Security. Analysis on the performance of various implementations of media on demand models in a distributed environment using RMI (Remote Method Invocation), which provides platform independency, RMI-IIOP (RMI Over Internet Inter-ORB protocol) and CORBA-IDL (Interface Definition Language) that support
location independency and .NET Remoting that includes language independency has been carried out in single / multi-client scenario. The performance evaluation method reported in this work is independent of the underlying distributed object model, whose results are comparable and does not pose much overhead on the models. The performance analysis of these distributed models has been carried out for different media files of various sizes and the results are reported.

Component model for media on demand has been projected to afford portability, strong reusability and increased productivity without tormenting about the connection pooling and state management. It is intended to increase utilization of media by deploying it as a reusable component and increase the scalability of the media on demand system.

An uninterruptible media on demand service is proposed by using mobile agents on a network of workstations, which is envisioned to be a powerful paradigm for building distributed media applications. Mobile agents have the unique ability to transport themselves from one system in a network to another and operate asynchronously and independently of the process that created them. Mobile agent based video caching is proposed for a server-proxy-multiclient architecture which contributes to the reduction in transmission delay and also enables the clients to access the media server at any time.

Efficient prefetching of media at proxies and multicasting the media to clients can lead to significant bandwidth savings, server load balancing, network latency reduction and higher content availability thereby enhancing efficiency and performance of media on demand model. It has been proposed
to enhance the media on demand model by encrypting the media for a secured transmission. It has been aimed to achieve security by XMLising the media data and encrypting it with Advanced Encryption Standard (AES).

In Chapter 3, an end-to-end congestion control for unicast real-time multimedia traffic by way of active queue management in routers is proposed to enhance the quality of service in media streaming. A new congestion avoidance scheme namely Application Priority Based Random Early Detection (APRED) that extends RED by adding priorities at the application level depending on the video frame type is proposed so that the drop probability of higher priority multimedia packets is reduced considerably.

APRED uses a linear drop function to calculate the drop probability of a packet and uses parameters such as maximum buffer size or queue limit, the minimum threshold and the maximum threshold of the RED region, the maximum drop probability and the weight factor to calculate the average queue size. APRED drops packets of lesser priority and shows a better performance than RED. It is aimed at achieving end-to-end congestion control by the design and implementation of an adaptive multimedia transmitter that adjusts its rate of sending that depends on the feedback from the multimedia receiver pertaining to the level of congestion in the network, preserving fairness and TCP friendliness.

Video is an expressive and exuberant form of medium, whose retrieval should be effective and secure. Chapter 4 proposes a content based video retrieval model that retrieves video by combining the motion activities with colour descriptors that are standardized by MPEG-7 for indexing and
retrieval of media. The motion activity descriptor captures the intuitive notion of intensity of action in a video segment to separate high and low motion parts of video sequence and then use color descriptors for refined retrieval. The standard deviation of the motion vector magnitude is used to compute the intensity of motion activity and Dominant Color Descriptors (DCD) are used to provide compact description of region, which improves the performance of the video retrieval system.

Effective retrieval of multimedia information allows faster transactions, but its digital nature allows individuals to manipulate or duplicate media information beyond the terms and conditions agreed upon. Legitimate service is to be provided for all parties such as content creators, providers and receivers for a large-scale acceptance of digital media. A digital rights management scheme has been proposed to address these issues for media on demand that achieves copyright protection, violation detection and secured transmission.

The proposed digital rights management architecture takes into consideration the concern of distributors and customers by masking the raw video or compressed video to prohibit the viewing for non-subscriber, to maintain proper relationship between the distributor who broadcasts video and the subscriber who pays for receiving the video and to embed watermarks for copyright protection. The masking is carried out for entire video on a frame-by-frame basis. The content distributor and subscriber maintain their mutual understanding by duly authenticating each other by an interactive protocol using public key crypto system.
The interactive communication involves the transfer of digital certificate and a signed message. Digital certificate contains the identity of the customer or distributor, the public key to verify the signed portion and the period of validity. The signed message supports in authentication, authorization and non-repudiation and provides a means for the customer or distributor to bind the identity to the piece of message sent. The signed message has the timestamp component containing a generation time and an expiration time and nonce to prevent replay attack, which is unique within expiration time and other relevant components such as request for proof of distributorship, order information and payment information. Thus at the end of the protocol both the subscriber and distributor would know each other, complete the payment transaction and issue the unmasking frame.

Two invisible watermarks are embedded in the digital content for copyright protection and violation detection and for addressing subscribers concern of false implication. The watermarks are acquired from a Watermark Generating Authority (WGA) and are embedded bit-by-bit in a set of $n_1$ 8 X 8 DCT blocks taken from I-frame of MPEG compressed video stream using the Differential Energy Watermarking (DEW) algorithm. An opaque frame masks the watermarked video to achieve confidentiality against non-subscribers. An integrated solution to DRM is thus achieved.

In Chapter 5, a review of work reported, major conclusions reached and contributions made are dealt with. Recommendations for further research are stated.