VIDEO ON DEMAND SYSTEM FOR HETEROGENEOUS WIRELESS MOBILE NETWORKS

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by

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LIST OF ABBREVIATIONS

VOD	Video on Demand
VODHMN	Video on Demand System Architecture For Heterogeneous Mobile Network
OMNET++	Objective Modular Network Testbed in C++
NED	NEtwork Description
MANETs	Mobile Ad Hoc Networks
MN	Mobile Node
HD	High Definition
HDTV	High-definition digital television
MPEG	Motion Picture Experts Group
GMF	Global Media Forwarder
LMF	Local Media Forwarder
WIMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity, wireless local area network
APs	Access Points
ETSI	European Telecommunications Standardization Institute
BRAN	Broadband Radio Access Networks
DARPA	Defence Advanced Research Projects Agency
P2P	Peer to Peer
GPS	Global Positioning System
QoS	Quality of Service

VCEG	Video Coding Experts Group
VCL	Video Coding Layer
CDN	Content Delivery Network
SB	Staggered Broadcast
MOVi	Mobile Opportunistic Video-on-demand
T-VOD	True Video on Demand
N-VOD	Near video-on-demand
SkB	Skyscraper Broadcasting
PCSB	Popularity Cushion Staggered Broadcasting
CVSP	Central VOD Services Provider
PDAs	Personal Digital Assistants
RSSI	Received Signal Strength Indication
DNDS	Device and Network Discovery Services
RSSI	Received Signal Strength Indication
PrC	Primary Connectivity
SeC	Secondary Connectivity
WNIC	Wireless Network Interface Card
HeCHeN	Heterogeneous Clients with Heterogeneous Network
DSC	Dominating-Set Cache
OCS	Overlay Caching Scheme
CPU	Central Processing Unit
RAM	Random Access Memory

ABSTRAK

ABSTRACT

VIDEO ON DEMAND SYSTEM FOR HETEROGENEOUS MOBILE WIRELESS NETWORKS

ABSTRACT

In recent years, the services of the Video on Demand (VOD) system have taken place with the improvement of the high-speed networking and enhancement of the digital video technology. The VOD system allows users to select their desired videos from a remote server, so that they can watch them instantly anytime and anywhere through public communication networks. Currently the challenge of the VOD system is to provide a seamless video access to different type of devices with a small service delay in the existing heterogeneous network environments, such as WIMAX network. There are many issues need to be tackled in designing a VOD system including the system architectures, broadcasting techniques, caching techniques, transitions between different networks, and heterogeneous mobile devices. This thesis presents a new system architecture called Video on Demand system architecture for Heterogeneous Mobile Network (VODHMN) environment. This system architecture supports VOD services for heterogeneous devices with a different capability through different networks with a limited broadcasting bandwidth. The VODHMN system architecture introduces two new components that are consist of Local Media Forwarder (LMF) and Global Media Forwarder (GMF) components as compared to the existing architecture. Both of these components can cope with the wireless environment in term of connectivity. The LMF is responsible to provide VOD services within a limited transmission range with a primary connectivity and able to managing the indoor activities. The GMF, aims at providing wide area services coverage by deploying infrastructures with a secondary connectivity and able to managing the outdoor activities. Based on the support of the VODHMN system, three new schemes/operations have been proposed, such as the Popularity Cushion Staggered Broadcasting (PCSB) scheme that distributes videos to many users with smaller delays, the smoothing algorithm scheme that smoothes the transition (handover) of users when moving between different networks, and an adaptable codec scheme that can provide optimal quality (High-definition, Medium-resolution and Low-resolution video) for different type of devices depending on their capabilities and specifications. The performance of the proposed architecture was measured through the OMNET++ simulator. The results showed that the proposed system gave better performances in terms of service delay, caching storage requirement, bandwidth requirement, cache distance, start-up overhead, handover latency, buffer space, CPU usage and RAM usage as compared to the other existing systems.

SISTEM VIDEO ATAS PERMINTAAN UNTUK RANGKAIAN MUDAH ALIH HETEROGEN TANPA WAYAR

ABSTRAK

Sejak kebelakangan ini, perkhidmatan sistem video atas permintaan (VOD) telah mendapat perhatian dengan adanya penanambahbaikan dalam rangkaian berkelajuan tinggi dan peningkatan teknologi video berdigital. Sistem VOD membolehkan pengguna untuk memilih video yang dikehendaki mereka daripada pelayan-jauh (remote server) dan menontonnya pada bila-bila masa dan di mana sahaja melalui rangkaian komunikasi awam. Kini, cabaran bagi sistem VOD adalah menyalurkan capaian video yang lancar kepada peranti yang berlainan jenis dengan tempoh penangguhan perkhidmatan yang singkat dalam persekitaran rangkaian heterogen sedia ada, seperti WIMAX dan perkhidmatan 3G. Untuk merekabentuk sistem VOD, ia melibatkan banyak isu yang perlu ditangani termasuk seni bina sistem, teknik penyiaran, teknik caching, peralihan di antara rangkaian yang berbeza, dan peranti mudah alih heterogen. Sehubungan itu, tesis ini membentangkan suatu seni bina sistem baru yang dikenali sebagai persekitaran VODMHN (Video on Demand system architecture for Heterogeneous Mobile Network). Seni bina sistem ini menyokong perkhidmatan VOD untuk peranti heterogen dengan kebolehan yang berbeza melalui pelbagai jenis rangkaian dengan lebar jalur penyiaran yang terbatas. Senibina sistem VODHMN memperkenalkan dua komponen baru berbanding senibina sedia ada, yang dikenali sebagai komponen LMF (Local Media Forwarder) dan GMT (Global Media Forwarder). Kedua-dua komponen tersebut juga boleh berfungsi dalam persekitaran rangkaian tanpa wayar. Komponen LMT

bertanggungjawab menyediakan perkhidmatan VOD dalam julat penghantaran yang terbatas seperti menguruskan aktiviti-aktiviti dalaman melalui keterhubungan utama, Sementara itu, komponen GMF pula bermatlamat menyediakan liputan kawasan perkhidmatan yang luas untuk tujuan menguruskan aktiviti-aktiviti luaran dengan menguruskan infrastruktur melalui keterhubungan kedua. Berasaskan sokongan sistem VODHMN, tiga skema/operasi baru telah dicadangkan, iaitu skema PCSB (Popularity Cushion Staggered Broadcasting) bertujuan mengedarkan video kepada pengguna dengan tempoh penangguhan yang amat singkat, skema algoritma pelicinan yang melancarkan peralihan (penyerahan) pengguna apabila beralih di antara rangkaian yang berbeza, dan skema codec boleh suai yang boleh memberikan kualiti yang optimum (Definisi tinggi, video beresolusi sederhana dan rendah) untuk pelbagai jenis peranti bergantung pada keupayaan dan spesifikasi mereka. Prestasi bagi senibina yang dicadangkan ini telah diuji dengan menggunakan alat simulator OMNET++. Hasil kajian menunjukkan bahawa sistem yang dicadangkan memberikan prestasi yang lebih baik dari segi tempoh penangguhan perkhidmatan, keperluan storan caching, keperluan lebar jalur, jarak cache, overhed permulaan, penyerahan kependaman, ruang penampan, penggunaan CPU dan RAM berbanding dengan sistem sedia ada.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Recently, with the emergence of the Internet, the availability of the high bandwidth, rapid development of wired and wireless network infrastructure, advanced video compressing algorithms and high processing power servers have allowed videos to be distributed around the world smoothly. People that are known as users now can enjoy watching videos comfortably anywhere (mobility) and at anytime with a small glitch. A system which provides users an online list of videos to be browsed and picked by anyone and watch them almost immediately is called Video on Demand (VOD) system. Some examples of the VOD application includes; YouTube, IPTV, and etc. The video content here (in a broader view) can be referred to as the animation, medical clips, course lectures, seminars, corporate training materials, product demonstrations and project demonstrations. The basic elements of the VOD system are servers, networks and user display equipment. The server is responsible for storing large number of videos and broadcasting them to users. Users may make requests of the videos and watch them by using users display equipments, such as smart phone, iPad, PDA's and etc.

The VOD system provides ubiquitous services to users (especially mobile users) in daily routines. For instance, VOD system allows university students to watch educational video of their interests online at anywhere and anytime. It also allows them to watch earlier recorded videos from lectures they were not able to attend. The VOD system allows people at the airport to instantly watch videos using their own PDAs while they are waiting for their flights'. There are many other VOD applications, such as IPTV (Shiroor, 2007), Facebook (Facebook, 2012), YouTube (YouTube, 2010), Educclip (Educclip, 2012), E-learning (digital video library) (Chawathe, 2000) (Williams and Camp, 2002), on-line shopping, medical information services and etc.

The VOD system is become a popular application nowadays and in the future as the trend of users who watch videos through the Internet are now increased. Based on the survey reported in (In-Stat, 2010) there are 144.5 million users out of 177 million overall Internet users now chose to view videos. Youtube is considered to be one of the VOD applications that contribute most to the survey with almost 100 million users have been daily accessing this application.YouTube services are considered to be the most successful VOD system and video sharing Web site on the Internet as reported in (WorldStat, 2011) that they provided with over 4 billion hours of videos that are being watched monthly. 72 hours of videos are uploaded every minute. It has hosted more than 45 terabytes of videos, and has attracted 1.73 billion viewers. More than 1 trillion views or around 140 views per person on earth were reported in the (WorldStat, 2011).

1.2 Video on Demand (VOD) Characteristics and Challenges

The Video on Demand (VOD) system is one of the most important applications for the future internet. It is a multimedia service that assists clients to watch various videos more freely. Wireless technology and mobile computing devices have given more flexibility and convenience to clients in order to enjoy viewing videos that are moving within the coverage area of the wireless network.

Presenting more videos to users anytime in mobile environment had to fulfill the system's characteristics, which can be summarized as follows:

- **Long-lived session:** long-lived sessions are supported by the VoD system, for example, in a typical movie-on-demand service, 90-120 minutes are spent.
- **High bandwidth requirements:** for instance, for a MPEG-I (MPEG-2) stream, the server storage I/O and network bandwidth requirements are 1.5 Mbps (3-10 Mbps).
- **QoS-sensitive service:** there are significant features included in this service, which are interactivity, defection rate, playback effects of the videos, and latency.

These characteristics of the VOD system have made the design of the VOD system become a challenge. This is because of the nature of the video data. The video data are the real time data that has to satisfy certain QoS, as mentioned above. Besides, one of the important issues is how rapid a video can be watched, once requested. It is here referred to as the delay, which is the average period of time a client waits until being serviced. In other words, it determines an end-to-end time that is considered to be the difference between the times of requests for a packet travels from the source to the time of receiving at the user’s destination.

There are many elements influence the delay issue. The choice of the system architecture is one of the elements that influence the overall performance, especially, the location of the servers, the protocol of communication systems, and the availability of storage and other factors can contribute to the delay. The delay issue becomes apparent when mobility is mandatory in the system architecture. It can be witnessed that the alarming of mobility tends to be at today's wireless network technology (heterogeneous network), as well as the mobile devices production's tend. Heterogeneous network can be seen when Internet, WiFi and WiMAX technologies come together. Currently, the survey showed that these technologies are being installed everywhere. For instance, more than 223 million homes have WiFi connections worldwide, and there are over 127 million WiFi hotspots included in many restaurants, cafes and supermarkets as reported in (In-Stat, 2010). Mobile devices such as PDAs and hand phones with amazing processors are common in the market. The sales are also increasing where 10.8 million to 22.4 million sales have occurred between January 2008 and January 2009 as reported to the survey by (In-Stat, 2010). The Infonetics research forecasts that 397 million cellular video phones have created a market that is worth tens of billions of dollars that will be sold in the early 2013 as reported in (In-Stat, 2010). The overall system architecture for the VOD covering heterogeneous network has indeed influenced the performance, especially, the delay of delivering the VOD contents.

The broadcasting method at the server is another element in contributing to the delay, as well as, the number of concurrent users of which the VOD system can support. Broadcasting is related to the scenario of handling clients who are watching different portions of the same video at any given moment. In particular, the server has to have an efficient broadcasting mechanism so that it can broadcast the video to many users as possible in a simultaneous fashion with the stringent delay requirements. Another interesting issue is that connectivity in the transition between the heterogeneous networks is referred to as handover issue. The mobile client (MC) is provided with several Wireless Network Interface Card (WNIC) that have multiple network interfaces to allow the entire MC to connect to different wireless technologies. However, to extend the services by providing seamless access to these services when they move from a network to another or from a WNIC to another remains an issue. When the MC starts moving outside the coverage area, it starts losing the network connection and stops receiving data for several milliseconds/seconds. In this case, the MC will start to search for another available network in order to get connected with. This kind of process is called the handover issue. The handover must be smooth, as it requires a process that can maintain the channel connection and data transmission. The handover of the MCs among the network needs to consider: (1) A better service of the playback, and (2) a mechanism that is able to rapidly switch to the network connection (seamlessly) in order to reduce the handover latency.

The last element that could influence the delay is the different video codec problem. The video codec is a procedure that reduces the original size of a video so that it can be played directly on a computer or over a network. According to the existing server architecture, multiple video streams have different codec with different data rates, where these streams are stored in servers. Clients can only receive appropriate video streams according to the network restrictions and regulations.

1.3 Problem Statements

This thesis has identified some problems and limitations in the current VOD system over the mobile client, which comprises the followings:

1) The Architecture of the VOD system over the Heterogeneous Network

Nowadays, the transition between heterogeneous networks, such as WiFi and WiMAX was encountered through different locations. Accessing VOD services is highly possible for mobile clients, where a seamless and smooth delivery of the video from the server to its users. The heterogeneous network architecture should have a mechanism that could guarantee connectivity in different networks and coverage when handover occurs, VOD services can be possibly provided VOD services, so that they can allow seamless access to many heterogeneous networks. The current VOD system (Tran, 2011) either lack the support of mobility or still explore possible solutions for seamless switching networks. Furthermore, while switching between the networks, the server may not be able to provide suitable services since it restricts the services within a certain location. ***The first problem statement is how to design a new system architecture for VOD services in heterogeneous networks so that users can remain connected with a smooth handover.***

2) Broadcasting and Caching Techniques to Minimize the Waiting Time

Video is widely known as a real time data over the past years. At the same time, the bandwidth is limited when the video is large. For instance, if the duration of the video is 1 hour, and the wireless LAN of the video server has been enabled with (WiFi, 802.11g), therefore, will not be able to deliver more than (36 * 1.5Mbps) video streams simultaneously to its wireless clients. In addition, the situation in the 802.11b is worse, as compared with 802.11g, because it is only supported seven concurrent videos. This constraint increased the delay of users in order to watch the video. The delay is referred to the time that starts when clients choose the video until it is displayed on their devices. The MobiVoD system (Tran, 2011) used a periodic broadcasting that is known as the Staggered Broadcasting (SB) protocol in order to broadcast the video from the main server along to the local forwarder, and then, to the users. When the local forwarder broadcasts the segments, and the client misses out the current broadcast of the first segment, the client will then have to wait until the local forwarder broadcasts it again. The waiting time can be in minutes. This is one of the disadvantages of the MobiVoD system. ***The second problem statement is how to modify the existing broadcasting method and caching techniques in mobile client environments that can minimize the delay (in term of the users waiting time).***

3) Optimal Codec Quality in Heterogeneous Mobile Clients

In general, there can be different types of mobile devices, such as, notebooks, PDAs and cell phones, which are required to access VOD services over the network. Current systems provide VOD services to many devices by using a single coded video content without considering different device platforms and specifications, such as, H.264, MPEG-1, XVID, FLV, WMV9and 3GPP2 codec. This limitation makes the services available only to specific devices which are only capable of playing with some particular videos. Furthermore, other VOD systems store multiple video codec of the same video in the storage server. The issues of the bandwidth overhead emerge when creating video layers. The replication codec of the same video and the layered encoding need more bandwidth transmissions and storage. For example, in Youtube, the video is broadcasted in the server by reserving a High-quality video. In order to stream in the medium and Low-level video quality, the server should reduce the size and the frame-per-second of the designated video on-line in order to obtain the optimal broadcasting for different profiles to the mobile client. The system required to convert each video on-line for each requested mobile device profile, which will consume more CPU and RAM at the server side (Educlip, 2012 and YouTube, 2012). This is due to the fact that the mobile clients with a different capability and platforms is not taken into account by the MobiVoD system. ***The third problem statement is how to provide optimal video quality for different types of devices depending on their capabilities and specifications.***

1.4 Objectives of the Thesis

The main objectives of this research are:

1) To design a new system architecture that can provide VOD services to mobile clients smoothly.
2) To propose a new broadcasting protocol and caching techniques, in order to reduce the waiting time of the mobile client.
3) To propose a mechanism that can adapt an optimal video service according to mobile devices features and specification. Therefore, it can save CPU and RAM usage on the server side.
4) To propose a smooth transition mechanism for mobile users, in order to maintain the connectivity among heterogeneous networks with a smooth handover.

Furthermore, in order to evaluate and compare the effectiveness of the proposed VOD system in this research, a study and analysis the performance of this system is done based on a simulation work. This proposed system is compared with an existing system.

1.5 Research Motivation and Significance

The Video on Demand (VOD) system is a concept that takes place in our daily life, such as, involving cable televisions, and internet, where some concepts were unknown over the past years due to their general populations. However, they are concepts that belong to our daily routines. In the past, a video was rented out, and users were waiting for the news to be displayed in TVs. Thus, these were things that disappeared with the internet and the cable television. Over the past years, it was not imagined that movie would be downloaded and viewed from the Internet and would be displayed on live. This facility provided the possibility to choose any movie anytime and anywhere with an efficient quality. Therefore, this is considered to be one of the motivations to perform this work that is based on designing a new system which can provide clients with full access to their requested videos anytime and anywhere. Besides, clients can freely move away from the network at anytime while smoothly accessing VoD services.

In recent years, there has been a phenomenal growth in the wireless communications technology, where a rapid development of a number of protocols has been used in different environments, such as Wi-Fi and WiMAX technologies. This development led to increase the interest in several multimedia application systems in order to make users enjoy their video access anytime and anywhere. In addition, this has led to the increase of the demand to develop the communication and computational powers of many wireless mobile subscribers/mobile devices techniques, such as laptops, PDAs (Personal Digital Assistants), Smartphones and notebooks, as shown in Figure 1.1. Accordingly, the obtained results have provided clients with seamless services of these techniques in order to obtain VOD services that are accompanied with higher resolutions and qualities, especially, when they are moving from a place to another. The subscription and the download media storage revenue have reached 26.9% in the year 2008, which is approximately 3.3 billion USD. On the other hand, the forecast advancement has reached to 19% in the year 2009 according to the merchant services report that was published by the AccuStream Media Research.

Figure 1.1: Mobility devices

Nowadays, VOD services become crucial features in mobile wireless networks. These services are considered to be important examples of several multimedia application systems due to the high increase of such requested services. According to the In-stat/MDR1 report in 2002, the market of the VOD system would reach to 1.9 billion USD, where the number of online VOD users reached until 17-22.4 million in the years from 2006 to 2010. Since the VOD system has become an integrated part of the increasing number of applications and wireless networks that have emerged to dominate the communication environment of the future, it has been considered to be interesting and worthwhile to design a VOD system for mobile clients. Having such a system, many practical applications have taken place in our lives. In particular, some of these applications have become useful to make users enjoy ubiquitous entertainment services, such as, watching the videos of their interests online at any place they are located at and at anytime. In addition, these applications have become useful in education.

The TV Cable operators in the US are promptly increasing the accessibility of VOD services, and concurrently, testing various ways to attract users in public with the service. In the mid of 2003, it was shown that 40% of all US cable TV systems were offering VOD services, and surprisingly, about 4 million cable TV subscribers were currently using the service in order to watch movies and other events online. This report analyzed the connection between interactive VOD services. The types of VOD services, the packaging and economics of VOD services, business model, and challenges facing the VOD system provided a wide view at the current cable-based VOD operations. The report also presented the outcomes of the two VOD surveys. The first survey indicated that the US cable operators were related to the present and the prospect of the VOD services.

The second survey inquired over one thousand of North American households for their alertness and utilization of cable-based VOD services. Furthermore, the report provided North America and worldwide forecasts for VOD subscribers and service revenues through the year of 2007. In addition, all ad-supported VOD services experienced revenue growth. By 2013, the advertising value of online video services will be US$1.9 Billion, and the value of the Pay-TV services will be approximately US$2.9 Billion. These techniques have become integral parts of today's life, and have become necessary for everyday use anytime and anywhere. For this purpose, a new architecture with its components are proposed in this research in order to provide VOD services to different devices, while moving through heterogeneous networks.

1.6 Research Methodology

In order to investigate the stability, robustness and performance of the VOD system and accomplish the research objectives, the involved steps in this research are shown in Figure 1.2.

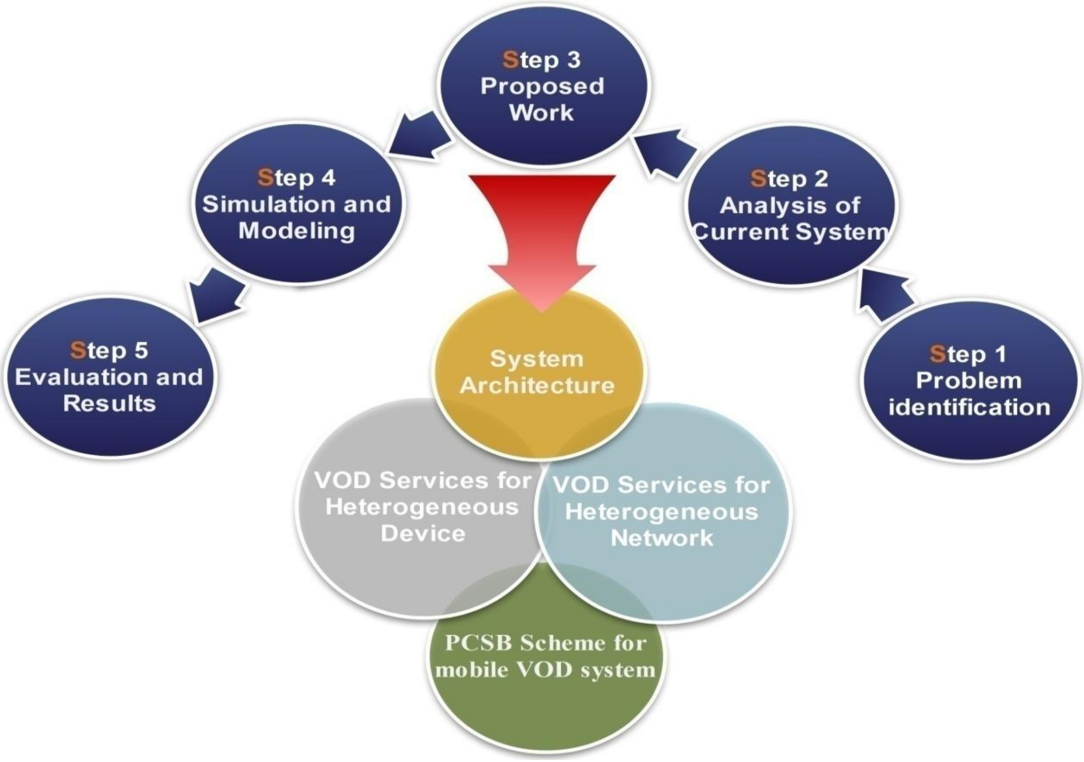

Figure 1.2: The research methodology

1.6.1 Problem Identification

In this step, the problems that are related to the VOD system are relatively new, which allowed researchers to explore some possible solutions of the current systems for mobility in mobile client environments. In addition, they proposed various VOD solutions for mobile clients. These systems have built the basis for VOD services for mobile clients. However, they still lack essential components in the practical deployment of VOD systems. For these purposes, this research has deeply explored more components in order to provide feasible solutions for current systems by providing a new VOD system architecture that can allow heterogeneous mobile users to seamlessly access VOD services through a heterogeneous network at anytime and anywhere.

1.6.2 Analysis of the Current Systems

This step focuses on the current VOD systems, including broadcasting and caching techniques. In particular, this research proposed a new system that is called the Video on Demand System for Heterogeneous Mobile Network (VODHMN) to provide VOD services for a different networks and infrastructures. In addition, it provides VOD services to different types of devices, such as, notebooks, PDAs, mobile phones, and so on. Furthermore, new broadcasting techniques minimized the waiting time. Such a common technique is called the popularity cushion staggered broadcasting technique. This technique is based on the VOD system that is spread over various wireless networks, such as, current MobiVoD system, and several types of periodic broadcasts.

1.6.3 The Proposed Work

This step is concerned with the proposed system to improve the problems that have been identified from the existing system and techniques in order to achieve the objectives of this research. Therefore, in this research, the proposed system has extended and improved the existing VOD system (Tran et al., 2004) by designing a new VOD architecture for heterogeneous networks and heterogeneous devices. The problems in the current system are involved in homogeneous networks and homogeneous devices, where the system can only serve one kind of devices within limited transmission ranges (IEEE 802.11), where the waiting time to provide the VOD in the system is extremely long. Furthermore, the broadcasting technique and caching techniques are not efficient enough to provide services with less waiting time.

The new system architecture is called the Video on Demand System for Heterogeneous Mobile Network (VODHMN) will provide seamless VOD services to different types of devices, such as notebooks, PDAs and mobile phones, accessing through different network infrastructures, such as, WI-Fi and WiMAX. Such systems allow clients to access video information anytime and anywhere. The new system architecture classified into six main components, which are: the Central VOD Services Provider (CVSP), Local Media Forwarder (LMF), Global Media Forwarder (GMF), wireless networks, mobile clients and broadcasting and caching technique as shown in Figure 1.3.

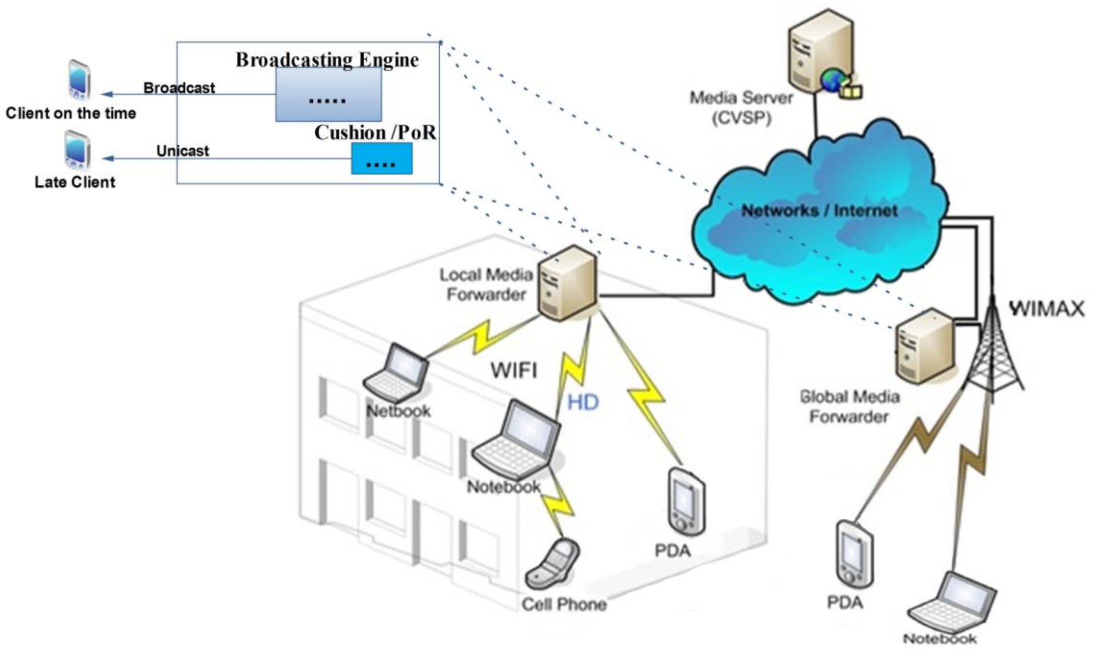

Figure 1.3: The proposed VODHMN system architecture

1.6.4 Simulation Environment

The OMNET++ simulation is a cross platform simulator that supports Windows, Linux, UNIX and the MAC environment. From this step, the proposed system and technique will be implemented based using OMNeT++ Version 4.1. The experiments have been performed on a Core (TM) i7 CPU with a 10 GB Random access Memory (RAM) and 1 Tera Byte (TB) hard-drives that are used to sufficiently accommodate the simulation. This can be performed by running the Ubuntu operating system. The new system improves the stability, robustness and performance that are implemented in order to achieve the objective of this research.

1.6.5 Evaluation and Results

This step is concerned on examining the performance efficiency of the proposed system by evaluating the results of the proposed system architecture for the VOD system with respect to few metrics, such as, the service delay, caching storage requirement, bandwidth requirement, cache distance and start-up overhead. Furthermore, the system is formed for investigation as a function of dynamics in client request rates {2, 4, 6, 8, 10}, failure rates {0%, 10%, 20%, 30%, 40%}, moving probability {0, 0.1, 0.2, 0.3, 0.4}, video length {3, 60, 90} and the number of broadcasting channels {3, 4, 5, 6, 7}. The experiment showed that each case represents an input parameter that varies, while other parameters are fixed. The results of the proposed schemes (PCSB and P2P scheme) were much better than other cache schemes, such as All-cache, Random-Cache, and Dominating-Set Cache. The performances of the IP mobility and link handover have been expressed in terms of the “Handover latency” and “Buffer space” in order to provide a seamless VOD service to mobile clients through heterogeneous networks. The results showed a suitable delay time for different mobile client speeds. In addition, they showed how to perform a real-time application in a suitable manner. Moreover, the packet buffer is reasonable. This implies that the proposed system can deliver packets with fewer impediments, where there is no much effect when the handover occurred. The proposed system can run smoothly when a handover occurs through different speeds due to the ability of this system in providing a seamless connection while the mobile node is moving from a single network to another. In addition, the performances of the heterogeneous devices are measured depending on the number of the clients' requests of the designated video at a period of time. The designated video is stored with a standard format in three levels of size and frame-per-second. This would provide each device with three different video qualities (low quality, mid quality and high quality) based on different profiles. The simulation of the proposed system and Educclip.com are applied several times in order to test the CPU and RAM usage of the server for several clients {1, 2, 3, ...10}. The result shows that for the proposed server, there is a lower overload because the server CPU and RAM are not required to convert each on-line video for each requested device profile. It rather chooses the most suitable video from the created profiles, and directly provides it to the requested devices according to their capabilities.

The new system architecture and technique have improved the stability, robustness and performance that are implemented in order to achieve the objectives of this research. In addition, the simulation is run several times for each scenario. Accordingly, it has been found that the collected results for those runs have slightly varied, and have been at most unnoticeable. Therefore, a single set of the results has been selected and presented for each case. In the proposed work, the chapters have presented the entire results in detail.

1.7 Research Contributions

The contributions of this research can be summarized as follows:

1. A new system architecture that can provide seamless VOD services to heterogeneous mobile devices that transmits videos through heterogeneous network environments.

2. A new broadcasting protocol and caching techniques that are called the Popularity Cushion Staggered Broadcasting (PCSB) scheme for a mobile VOD system that can reduce the waiting time of mobile devices.

3. A new self-adaptable VOD system architecture for mobile devices that can provide optimal video quality services for different types of devices, accompanied with different platforms, different video qualities, different capabilities and different specifications.

4. A new smoothing transition mechanism for mobile users that can maintain the connectivity among heterogeneous networks with a smooth handover.

1.8 Organization of the Thesis

This thesis is organized into seven chapters including this chapter. The following paragraphs provide brief descriptions of the remaining chapters of this thesis.

Chapter Two respresents a literature review of the VOD system that presents a brief description, and discusses the main concepts of the VOD system's characteristics and the VOD system over heterogeneous networks. The current VOD system architecture has also been surveyed. In particular, this system has been classified into several types of architectures depending on the domains they operate in. It also elaborates the concept of broadcasting techniques for heterogeneous mobile networks techniques that are used to disseminate the video to clients and compare it with existing protocols in order to find out the suitable broadcast for the VOD system. In addition, several caching techniques were used in different VOD system architectures that have been proposed. The handover in heterogeneous network environments with the metrics and algorithms have been proposed. Moreover, a brief explanation was given for the main concepts of the client heterogeneity. Finally, comprehensive studies have highlighted relevant systems to the VOD system.

Chapter Three presents the main components of the new architecture that is called the Video on Demand System Architecture for Heterogeneous Mobile Network (VODHMN). It is designed to provide VOD services to different types of mobile devices through different types of networks and infrastructures. Furthermore, VODHMN used a new broadcasting and caching protocol, which is called the Popularity Cushion Staggered Broadcasting (PCSB) scheme in order to minimize the service latency, and other metrics that can be suitable with the research’s objective.

Chapter Four presents the methodology of the new Popularity Cushion Staggered Broadcasting (PCSB) for the proposed VOD system that is well-known as the (VODHMN), in order to provide VOD services over homogeneous and heterogeneous mobile networks. The purpose of the PCSB scheme is to minimize the waiting time of mobile clients. The chapter showed an overview of the PCSB scheme. Furthermore, the broadcasting engine component and cushion component of the PCSB scheme are presented. In particular, this proposed work came out in order to solve the problem of the late clients who missed out the 1st segment from the current broadcasting channel. Furthermore, it presented the scenarios of the playback procedure in the PCSB scheme. A brief explanation of the analytical calculations for the CVSP, MF's and broadcasting for the PCSB was provided. Furthermore, a brief explanation of the scenario of the P2P scheme which made up the proposed work more robust was given. The research methodology in this chapter comprised several metrics, such as, service delay, caching storage occupancy, bandwidth requirement, cache distance and startup overhead. Finally, it described the simulation results and discussions.

Chapter Five, this chapter presents the adaptive policy in order to provide VOD services for heterogeneous mobile devices. The Device and Network Discovery Services (DNDS) protocol showed that there is a need of a mechanism by which information needs to be gathered for providing optimal VOD services to mobile clients. This protocol was designed to run in the entire new architecture. It was implemented and executed among the main server, media forwarders and mobile clients as well. In this chapter, a new policy was achieved in order to smoothly provide VOD services to different types of devices. Accordingly, the result showed that for the proposed server, a lower overload was obtained since the CPU and RAM of the server were not required to convert each on-line video for each requested device profile.

Chapter Six, this chapter presents an adaptive policy for the proposed system architecture in order to provide VOD services to mobile nodes, which are moving through different networks and infrastructures, such as wifi and wimax. This can be achieved by a mobility component in the proposed system architecture, whereas it will provide a smoothing playback mechanism for the sake of accessing VOD services in heterogeneous network environments, such as WiFi and WiMAX. The main components include the Local Media Forward (LMF) and the Global Media Forward (GMF). The LMF which is responsible to provide VOD services within a limited transmission range, such as indoor environments, is equipped with WiFi that is used as primary source connectivity. The GMF provides wide area service coverage through deploying infrastructures, such as, outdoor environments that are equipped with WiMAX services. The GMF is used as a secondary connectivity that can provide VOD services to mobile clients, which are physically located closer to their clients. The performance of the simulation is investigated based on two factors; the movement of the clients from a network to another, with different speeds, and the size of the buffer in the storage. The simulation results indicated that the system still provides seamless VOD services and connections. This implies that the system is able to smoothly deliver video segments when the mobile node is moving out from a single network to another without any notable effects.

Chapter Seven, provides a summary of the entire thesis, including the research contributions, and gives suggestions for the direction of possible future works with regards to this research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature review of the VOD system and its related technologies. Section 2.2 explains the fundamental video on demand system and its characteristics. Section 2.3 reviews the VOD system over the heterogeneous network. Section 2.4 reviews the existing architecture of the VOD system. Section 2.5 reviews the broadcasting techniques of the VOD system. Section 2.6 reviews the caching scheme for the VOD systems. Section 2.7 reviews the handover method over the network. Section 2.8 reviews the heterogeneous mobile devices. Section 2.9 reviews the existing VOD systems. Finally, a summary of this chapter is given in Section 2.10.

2.2 Video on Demand (VOD) System and its Characteristics

The Video on Demand (VOD) service is a system that allows remote users to playback any of the large collection of videos at anytime through public communication networks. Typically, these video files are stored in a set of central video servers, and are distributed through high-speed communication networks to geographically-dispersed clients. In this scenario, when a video is being viewed by a user, a request is made by this user based on a list of available videos (by picking up any list of these videos). This request is sent to the server, and then, the server delivers the video to the client, where the video is ready to perform a playback within a short time. A sequence of Video Cassette Recorders (VCRs) commands may as well generated by the user during the video entertainment in order to control the playback‟s flow. Furthermore, VOD interactivity is an essential feature of the VOD service. In the VOD system, clients will be able to use the VCR control operation in order to perform the video, where they can have the following types of interactions: Play/Resume, Stop/Pause/Abort, Fast Forward/Rewind, Fast Search/Reverse Search, and Slow Motion as illustrated in Table 2.1. There are two types of interactivity: continuous or discontinuous interaction as referred to (He et al, 2007). Continuous interactive functions allow a customer to fully control the duration of all actions to support True Video-on-Demand (T-VOD) service, whereas discontinuous interactive functions allow actions to be specified only for durations that are integer multiples of predetermined time increment. Note that the size of the discontinuity is a measure of the QoS experienced by the customers. In addition, this research categorizes interactions, such as interactions with a picture or interaction without a picture. Other interactive features include the ability to avoid or select advertisements that can investigate additional details regarding the news events, for example, through hypermedia, and to browse, select, and purchase goods.

Table 2.1: The operation of the VCR control

Play/Resume	Start a presentation from the beginning or resume it after a Stop.
Stop	Stop the presentation, without picture and sound.
Pause	Hold the presentation with picture.
Jump Forward	Jump to a target time of the presentation in the forward direction without picture and sound.
Jump backward	Jump to a target time of the presentation in the backward direction without picture and sound.
Fast Forward	Browse the presentation in the forward direction with picture and sound.
Slow Down	Present forward with a lower playback rate with picture and sound.
Reverse	Play the presentation in the reversed direction with picture and sound.
Fast Reverse(REW)	Browse the presentation in the backward direction with picture and sound.
Slow Reverse	Present backward with a lower rate with picture and sound.

The VOD system has many applications in different areas that can provide services to users, such as, the movie on demand, news on demand, distance learning, home entertainment, medical information service, and different interactive training programs and etc. Based on the level of interactivity, the VOD video can be categorized into 5 categories (Little and Venkatesh 1996; Ma and Shin 2008): Pay-Per-View (PPV), Broadcast (No-VOD), Near Video-on-Demand (N-VOD), Quasi Video-on-Demand (Q-VOD), True Video-on-Demand (T-VOD) as listed in Table 2.2. The significant VOD system, which is known as the T-VOD system, is that with a large amount of the video data, the VOD system needs to obtain a great network bandwidth to transmit large amounts of data. Before adding each user, it is significant also to ensure adequate bandwidth for new users, when the number of users increase, users will require more bandwidth in order to obtain their services, when the bandwidth is low, this VOD system will be unable to provide services to new users. In order to solve the above problem into a serious shortage of bandwidth, there are a variety of experts who have proposed alternative methods that can be broadly distinguished by batching, stream tapping, or patching, and broadcasting and by other mechanisms of the VOD service strategy (Nikolaus, 2008). In the T-VOD system, dedicated transmission channels must be reserved from server resources for each client. Clients can receive video data without any delay via dedicated transmission channels as if they are using their own Video Cassette Recorders (VCRs). Such systems, however, may simply run out of channels because the channels can never remain with the growth in the number of clients. Therefore, many researchers have investigated many ways of reducing the channels that have concurrently been used. In the N-VOD system, clients have to wait for some delay time, since a video program is broadcasted over several channels within a periodical cycle. The number of broadcasting channels has taken place due to the allowable viewer‟s waiting time, and not because of the number of requests. Thus, it is more suitable for distributing hot video programs (Chien et al., 2005 and Liu et al., 2005).

Table 2.2: The classification of the VOD system (Nikolaus, 2008)

Classification	Features
No-VoD	It is a technique in which a user is passive, and has no control on what this user views. In addition, this technique is similar to the broadcasting TV.
PPV	It is a service in which a viewer signs up and pays to view a specific program starting at a different time, similar to existing CATV PPV services.
Q-VoD	It is a technique that groups users based on a given threshold upon their interests, where the user can then successfully control a set of time depending on the group that switches (control activity by switching to a different group).
N-VoD	It is a service that makes users wait in order to view the video of their interests. This service does not provide a full control. Functions like forward and reverse are simulated by transitions in discrete time intervals.
T-VoD	It is a service that allows clients to have full control over the session presentation, with full VCR control operation including programme selection, forward / reverse play at different speeds, freeze and random positioning.

The VOD service has the following characteristics:

- **Guaranteeing long-lived session:** long-lived sessions have to be supported by the VoD system, for example, in a typical movie-on-demand service, 90-120 minutes is spent.

- **Serving high numbers of simultaneous users***:* the server component must be able to serve large numbers of simultaneous users. The number of users can reach