MOBILE CLOUD AND CLOUDLETS GAMING SYSTEM (MCCG) USING CLUSTERED DESTINATION-SEQUENCED DISTANCE VECTOR ROUTING PROTOCOL (c-DSDV)

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by

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TABLE OF CONTENTS

CHAPTER 2 LITERATURE REVIEW

CHAPTER 5 SIMULATION AND PERFORMANCE ANALYSIS

CHAPTER 6 CONCLUSION AND RECOMMENDATION FOR FUTURE WORK

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3G	Third Generation
4G	Fourth Generation
ABR	Associatively Based Routing
Ant	Antenna
AODV	Ad Hoc On-Demand Distance Vector Routing
APHIS	Adaptive HFR Video Streaming
CBRP	Cluster Based Routing Protocols
CCMG	Cloud Cloudlet Mobile Game
CD	Client Distance
c-DSDV	Clustered DSDV
CGSR	Cluster Head Gateway Switch Routing Protocol
CID	Client Identification
CS	Cloudlet Server
DSDV	Destination Sequenced Distance-Vector
DSR	Dynamic Source Routing
FPS	Frame Per Second
GMOS	Game Mean Opinion Score
GS	Cloudlet-Game Server
HFR	Providing High Frame Rate
ifq	Interface Queue
Ifqlen	Interface Queue Size
IMCA	Interactive Mobile Cloud Application
LAN	Local Area Network
ll	Link Layer

Mac	Mac Layer
MANET	Mobile A-Hoc Network
MCG	Mobile Cloud Gaming
MCS	Main Cloud Server
MGS	Main Gaming Server
MGUE	Mobile Game User Experience
MOCHA	Self-Extensible Database Middle wire
MP	Mobile Player
MRS	Main Rendering Server
ND	Network Delay
Netif	Network Interface
nn	Number of Nodes
NS-2	Network Simulator 2
OD	Playout Delay
OTCL	Extension of TCL
PD	Processing Delay
Prop	Propagation
QoE	Quality of Experience
RD	Response Delay
RREP	Route Reply Packet
RREQ	Route Request
RS	Cloudlet-Rendering Server
Seed	Random Seed Number
SSR	Signal Stability Routing
TCL	Transactional Control Language
TORA	Temporally Ordered Routing Algorithm
VM	Virtual Machines

WAN	Wide Area Network
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
ZHLS	Zone-based Hierarchical Link State Routing Protocol
ZRP	Zone Routing Protocol

SISTEM PERMAINAN AWAN BERGERAK DAN CLOUDLETS (MCCG) MENGGUNAKAN PROTOKOL PENGHALAAN PENGKELOMPOKAN DESTINASI BERJUJUK VEKTOR JARAK (c-DSDV)

ABSTRAK

Penyelidikan ini bertujuan untuk menyiasat keberkesanan kajian yang dicadangkan iaitu Sistem Awan Bergerak dan Cloudlets (MCCG) menggunakan protocol Penghalaan Pengkelompokan Destinasi Berjujuk Vektor Jarak *(c-DSDV).* Sistem Permainan Awan Bergerak (MCG) yang sedia ada telah dipertingkatkan dengan memperkenalkan rangkaian awan, Cloudlet dan rangkaian ad hoc mudah alih untuk mengurangkan kependaman dalam sistem MCG. Cloudlets diperkenalkan untuk mengurangkan jarak penghantaran data antara awan utama dan pengguna mudah alih. Sementara itu, rangkaian ad hoc mudah alih diperkenalkan untuk mengurangkan masa menunggu system MCCG. Peranti mudah alih kini boleh meminta video permainan dari peranti mudah alih lain yang berdekatan. Melalui cara ini, masa menunggu bagi peranti mudah alih boleh dikurangkan. Selain itu, protokol penghalaan yang digunakan dalam rangkaian ad hoc mudah alih juga telah dipertingkatkan dalam kajian yang dicadangkan. Protokol penghalaan Destinasi Berjujuk Vektor Jarak (DSDV) yang tipikal juga telah dipertingkatkan dengan mengehadkan kawasan perkhidmatan setiap peranti mudah alih yang mengambil bahagian dalam penghantaran paket video dalam rangkaian Ad Hoc. Protokol penghalaan DSDV yang dipertingkatkan yang dicadangkan dalam kajian ini dikenali sebagai protokol Penghalaan Pengkelompokan Destinasi Berjujuk Vektor Jarak (c-DSDV). Tujuan mengehadkan kawasan perkhidmatan setiap peranti mudah alih adalah untuk mengurangkan kesesakan rangkaian yang akan disebabkan oleh kekerapan kemas kini penghalaan oleh semua peranti mudah alih dalam rangkaian ad hoc. Keberkesanan kajian yang dicadangkan ini telah dianalisa dengan menggunakan keputusan yang diperolehi melalui simulasi. Simulasi yang digunakan dalam kajian ini adalah Network Simulator 2. Matriks yang digunakan untuk simulasi adalah lengahan titik hujung ke hujung, nisbah penghantaran paket, daya pemprosesan, kelewatan rangkaian, kelewatan tindak balas dan jalur lebar. Keputusan simulasi menunjukkan bahawa sistem MCCG yang menggunakan protokol penghalaan vektor c-DSDV dapat mengurangkan kependaman secara keseluruhan. Manakala berdasarkan keputusan simulasi untuk menentukan keberkesanan protokol ad hoc antara DSDV, AODV dan c-DSDV, ia menunjukkan bahawa protokol c-DSDV mampu mengurangkan lebih kependaman.

MOBILE CLOUD AND CLOUDLETS GAMING SYSTEM (MCCG) USING CLUSTERED DESTINATION-SEQUENCED DISTANCE VECTOR ROUTING PROTOCOL (c-DSDV)

ABSTRACT

This research work was designed to investigate the effectiveness of enhanced Cloud Mobile Gaming (CMG). The existing MCG system was enhanced by introducing cloudlets and mobile ad hoc network in the system in order to reduce the latency in MCG system. Cloudlets were introduced to reduce the transmission distance between main cloud and mobile users meanwhile mobile ad hoc network was introduced to reduce the service waiting time of the system. Mobile devices now can request video from nearby mobile nodes that has the same video. Besides that, the routing protocol used in the mobile ad hoc network also was enhanced. The typical Destination-Sequenced Distance Vector (DSDV) routing protocol was enhanced by limiting the service area of each mobile device that are participating in video packet transmission in the ad hoc network. The enhanced DSDV routing protocol proposed in this research work is Clustered DSDV (c-DSDV). The purpose of limiting the service area of each mobile device is to reduce the network congestion that will be caused by the frequent routing update by all the mobile nodes in ad hoc network. The effectiveness of the proposed work was analyzed by simulating the system using Network Simulator 2. The matrices used for simulation are end-to-end delay, packet delivery ratio, throughput, network delay, response delay and bandwidth. Based from the simulation results obtained, it shows that MCCG system applied with c-DSDV routing protocol could reduce more latency overall compared to the MCG system. Besides that, simulation was done to test the efficiency of ad hoc routing protocols

DSDV, AODV and c-DSDV. The result prove that c-DSDV could reduce more latency compared to the other two protocols.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Mobile game is a type of video game that is played on mobile devices such as smartphones, laptops, tablets and many more (Jacob & Issac, 2014; Shorrock et al., 2019). Mobile gaming such as Angry Bird, Candy Crush Saga, Word with Friends, Pokémon Go had become very popular not only among younger generation but also the older generation (Jiang & Shi, 2018; Warriar et al., 2019). The invention of smart devices, excellent and affordable internet connection, and the exploitation of cloud services brings a lot of changes in the gaming services. The latest trend of mobile gaming is the cloud gaming (Cai et al., 2015; Butt et al., 2019). Cloud gaming is a game where a user can request for their favorite game through an application in their mobile device at any time and at anywhere as long as they are connected to the internet and own a smart device. The video games are hosted in the game provider's cloud servers and the gaming video will be encoded and transmitted by the streaming server in the cloud to the game users (Chai et al., 2018).

Mobile Cloud gaming technology is totally the opposite compared to the legacy gaming technologies (Nag et al., 2017). It took four generations before Cloud Gaming were introduced. The first generation is where game files or data such as graphics, sound, input commands and processing of video output for particular games was exclusively installed on the computer it was being played on. The second generation is where mobile games were pre-installed in the mobile device itself such as an arcade version of game called Snake was preinstalled in Nokia mobile phone in 1997 (Mayra, 2015). Third generation is called as mobile based video gaming where users can install the mobile games application by downloading it in the mobile devices before can start playing (Prato et al., 2010). Finally, the fourth generation, Mobile Cloud Gaming or Games-on-Demand was introduced where it is a combination of two gaming concepts; cloud computing and online gaming. Game users do not need to download the whole game file to their system and install it in order to play a game. They can just send a game request to a Cloud and the gaming computation task (rendering and encoding) will be offloaded to the servers in the Cloud. Encoded game videos will be sent to the game user and by decoding the game video sent by the Cloud, the game user can immediately start playing the game on their device.

These changes bring advantages to the game developers, game operators and game users. Cloud gaming providers known as OnLive, NVIDIA (GeForce NOW), CiiNOW, Gaikai and more are becoming very popular and demanding providers for hosting millions of games in its Cloud (Kemppi, 2013). The game developer could develop a game in short period and with less cost because of cloud gaming's cross-platform nature. Meanwhile for game operators, the cloud gaming is maintenance free hence they do not need to invest for hardware and gaming software. As for game users, those who own low-end mobile devices could still play sophisticated games because of the offloading computational task approach in cloud gaming. Mobile Cloud gaming is the combination of Cloud Computing and Online Gaming concepts.

The number of game users playing cloud game has been increasing each year and more games applications are being developed by the game developers to fulfill the users demand on games from different genres (Cai et al., 2013; Barton & Stacks, 2019). The usage of high technology mobile devices such as Smart phones, I-pad, tabs, and notebooks as well as Internet are the main contributions for the increment of mobile games. According to the survey done by Alex Warwo from gamasutra.com (Alex ,2016), about 74% of North Americans people play cloud games to kill their time, 66% to relax, 57% to take a break from other activities and followed by other reasons such as to challenge themselves, peer pressures and more.

There are many cloud games were developed by game developer and mobile player can choose any games either by purchasing it or get for free from the game clouds (Mishra et al., 2014). Mobile Cloud gaming enables any devices to play any games available in the cloud; let it be low-end mobile devices, high-end mobile devices, any PCs, MAC, or SmartTV. Besides that, the library of the game titles and any games saved in the Cloud can be accesses at any time. Users are also able to play or continue playing the games from any devices and at any time. It is also not complicated because no new hardware is needed; there are no any complication setups, no game installations and no game patches (SlashGear,2016).

1.2 Mobile Cloud Gaming System Architecture

Figure 1.1 and Figure 1.2 shows examples of Cloud gaming architecture proposed by Onlive Cloud Gaming provider and author Wei Chai (2008).

Figure 1.1. Onlive Game Service Architecture (Image Source: OnLive)

Figure 1.1 shows that OnLive Cloud Gaming enables any mobile devices to stream down games from the OnLive servers which are situated miles away from the clients. The games are hosted in the The OnLive high-performance game servers that are placed in the Cloud. OnLive being the first Cloud Gaming made public through the 2009 Game Developers Conference. More research on Cloud Gaming started after the introduction made by OnLive (Huang et al., 2013; Manzano et al., 2014; Cai et al., 2016; Li et al., 2019).

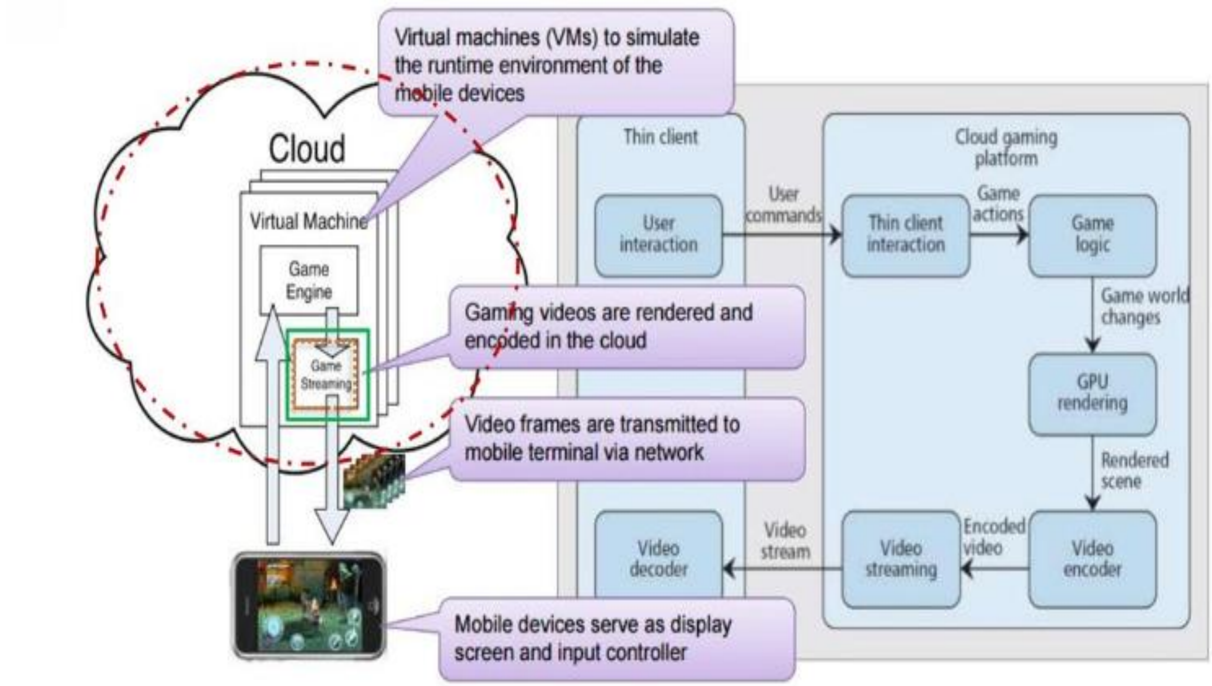

Figure 1.2. Cloud Gaming Architecture (Cai,2008)

Based on the Figure 1.2, it shows that there are two main components involved in Cloud Gaming, a thin client and cloud based rendering devices. Game players view the games available in the Cloud through an application in a thin client. Once the game player has requested for the game, the game will be rendered in the Cloud. The scenes of the game will be encoded as video sequences and streamed down back to the game player over the internet. Game player then decode the video sequences, start playing the game and send back the player's commands back to the cloud. Based on the above figures, it explains the components and processes involved in Mobile Cloud Gaming. Cloud gaming brings a huge development to the digital entertainment system by exploiting the computing resources in the cloud. When a request was sent, the dedicated server in the cloud start to render the game raw files and is encoded

Cloudlet is the next improvement of Cloud which was introduced by Satyanarayanan, 2014. The author defines Cloudlet as a new element based on the combination of Mobile Computing and Cloud Computing. In the 3-tier hierarchy among mobile device, Cloudlet and Cloud, Cloudlet is represented in the middle between mobile device and cloud (Satyanarayanan, 2014). Cloudlet brings the Cloud closer to its users hence decreasing the distance between the mobile user and the Cloud. Figure 1.3 shows the Cloud and Cloudlet usage in streaming a video by mobile clients from the Cloud with the help of Cloudlet.

Figure 1.3. Cloud and Cloudlet Based Architecture (Satyanarayan et al., 2009)

1.3 Destination-Sequenced Distance Vector (DSDV) Routing Protocol

One important section in cloud gaming system is the routing protocol. Routing protocol will be used by the mobile devices in a network to transmit packets of data from source mobile device to another mobile device until it reaches its destination mobile device by choosing the best path/route available in the network (Sharma et al., 2013; Uttarwar et al., 2019). Routing protocols are responsible to find the shortest possible route from a source to a destination for the data transmission. DSDV routing protocol is a proactive Ad hoc networking protocol which is also known as table driven protocol because the routes to every node in a network is recorded in every node routing table as shown in Figure 1.4 (Ramya, 2015). The figure shows that each node has routing table that stores the details of other nodes available in the system.

During streaming and request between mobile player and Cloudlet, DSDV routing protocol will choose the best path based on each nodes routing table. A routing table stores information that helps to route data from one destination to another destination. Each routing table needs frequent update and each table will be broadcasted frequently. It contains the list of all available destination/neighbors, the next hop for destination/neighbor, metric/distance hop and a sequence number. Each node will broadcast its routing table periodically or when there is a network topology changes to inform neighbors about any changes that happens in the network such as additional nodes or loss of any node.

There are two ways a DSDV's updated packets can be sent to the nodes in the network; Periodic Update and Triggered Update (Narra et al., 2011; Alabdullah et al., 2019). The involved node will broadcast entire routing table during the 15 seconds default periodic update. Meanwhile Triggered Updates are the updates that will be sent out when a node receives a DSDV packet that causes a change in its routing table (Mantoro et al, 2016). Table 1.1 shows a design of a routing table of a node. Figure 1.4 shows the updated routing tables of nodes in the cloudlet. Based on the routing table of each node, a data will be transferred from a node to another node. If node N4 in the figure would want to send data packets to node N1, it will check on its routing table to find the available paths to reach N1. Based on Table 1.1, node N4 has to forward the data packets to N3 before reaching the destination, which is N1.

Table 1.1: The Routing Table of Node 4

Destination	**Next Hop**	**Metric/(Distance hop)**	**Sequence Number**
N1	N3	3	S123_N1
N2	N3	2	S124_N2
N3	N3	1	S213_N3
N4	N4	0	201_N4

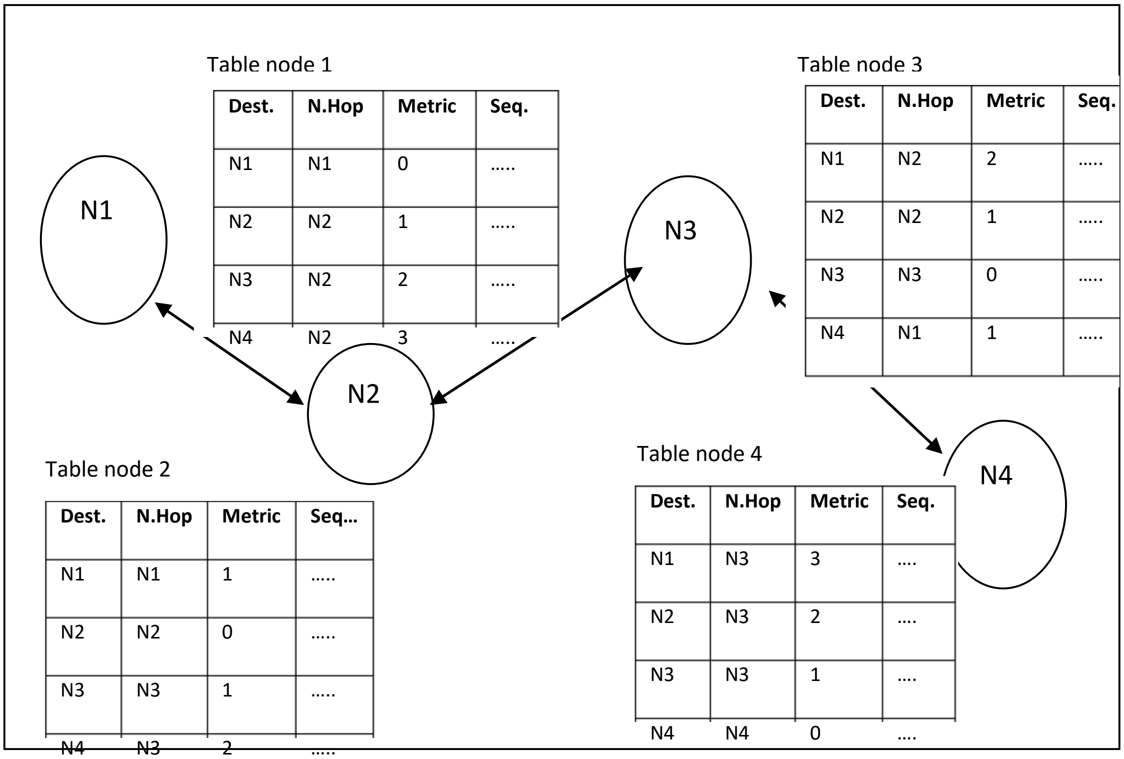

Figure 1.4. An Example of Nodes in the Cloudlet

1.4 Problem Statements

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

The main reason that makes some clients to opt out from joining the MCG system is because of latency due to distance differences, network congestion and limited bandwidths. Even though 3G and 4G networks helps to provide higher coverage and bandwidth range but this fundamental challenge still remains (Wang et al., 2009; Wu et al.,2017).

To propose a method that can effectively reduce the above obstacles in MCG system, the following questions need to be answered.

i. Latency in Mobile Cloud Gaming (MCG) is caused by the distance between users and cloud data centers?

MCG provides its services to a large number of mobile users who are situated near and miles away from Cloud data centers. Mobile users who are far from the Cloud servers require more time to receive/send video game files and are prone to experience latency especially in Response Delay which directly affect the gaming Quality of Experience (QoE) and MCG Quality of Service (QoS). Response delay is defined as the time taken for a mobile user to send request to the cloud, cloud takes the time to process the corresponding video frame in its server and stream down the video back to the mobile user finally displaying the video on the mobile device before the user can start playing the game or can be defined as time difference between receiving a user input at the client side and the game scene updated on the user's screen (Chambers et al., 2010). Lower response delay is very important for real time games such as fighting games because it requires ultra-twitch movements and responses (Andrew, 2014). The further distance between Cloud and mobile users does not favor the main requirement of MCG services.

ii. How can user request for game video when the Cloudlet service is not available?

Although cloudlet become as one of the solution for the above problems, it is actually a constrained computer resources and it could provide services for a limited number of nodes in limited transmission range. There are high possibilities for the cloudlet to be busy and not available when the number of mobile clients joined the system increases. If there are no any alternative ways to be there to enable the mobile users to choose to download their favorite game, it will only increase the delay. Mobile users have to wait to request for video until the cloudlet become available again.

iii. How to reduce latency, network congestion and higher bandwidth consumption during video transmission between nodes?

Routing protocol is one of the most important factors that have to mind when providing MCG service to Ad Hoc nodes that are connected to Cloudlet. Routing protocol ensures the packets delivered securely and fast between nodes that are in the range of Cloudlet. Choosing the wrong protocol for transmission causes delay and incomplete transmission. Cloudlet transmission range is within WLAN connection hence its range is smaller compared to coverage area of Cloud that is connected via WAN connection. Choosing an appropriate routing protocol that transmits video data to particular nodes even when the network is inconsistent and has limited bandwidth is necessary for this proposed work to tackle these issues.

1.5 Objectives of the Thesis

The aim of this research is to overcome the latency, inconsistent network, and limited bandwidth issues in MCG system. The primary objectives of this research are as follows:

- To propose a new MCG architecture aimed to reduce latency and the distance between Main Cloud and mobile nodes.

- To propose the formation of Ad Hoc mobile network within the transmission range of a Cloudlet.
- To propose of the improvised c-DSDV routing protocol in reducing transmission delays.

1.6 Scope

The scope of this thesis is limited to certain constraints, which are defined as follows:

i. There are three types of MCG game formats have been developed so far which are video-based, file-based, and component-based. Video-based MCG is the most famous category in MCG; hence this study is limited to study on video streaming.

ii. The ad hoc mobile network is formed in the existence of stationary Cloudlets places near Wi-Fi Access Point.

iii. Routing protocol used in this thesis is an enhanced ad hoc mobile routing protocol (c-DSDV) and compared with other ad hoc routing protocols such as AODV and the original DSDV.

1.7 Research Motivation and Significance

The main significance of this research is the latency in the MCG that has been a great challenge. Limited bandwidth, inconsistent network and the higher distance between the cloud and mobile users contributes to the latency in the existing MCG system.

1.8 Research Methodology

In order to investigate the stability, robustness and performance of the MCCG system and accomplish the research objectives, the involved steps in this research are shown in Figure 1.5.

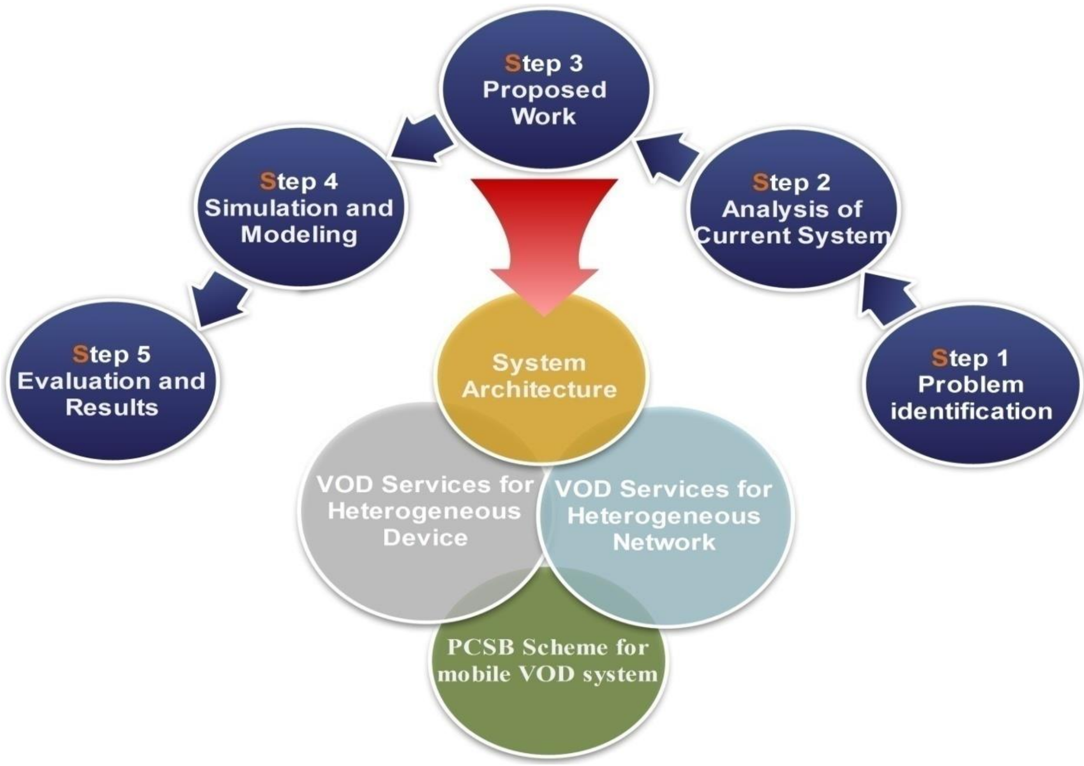

Figure 1.5. Research Methodology

1.8.1 Problem Identification

The first step in research methodology is problem identification. A lot of research study are done to identify the root problem in the chosen research topic, Mobile Cloud Gaming (MCG).

1.8.2 Analysis of the Current Systems

Analyzing the current system is very crucial for this research work because it helps to identify the shortcoming and issues with the current system. Besides that, it helps to provide comprehensive understanding in identifying the inputs, outputs and processes involved in mobile cloud gaming system.

1.8.3 The Proposed Work

Once problems are identified and analysis are done on current systems, the main idea on proposed work is established.

1.8.4 Simulation Environment

The simulation work begins after concluded the research work architecture. Simulation is used to conduct performance and evaluation tests on the proposed MCCG architecture.

1.8.5 Evaluation and Results

Evaluation is done based on the results obtained in simulation. Evaluation is important in identifying area for improvement and to demonstrate the proposed worked has fulfilled the objectives of the work. As in this thesis, the results is finalized after running simulation for each scenario for 10 times.

1.9 Research Contributions

This thesis has led to three contributions which are detailed as follows:

1) Establishing remodeled MCG architecture by introducing pre-stored Cloudlet (servers) in the MCG system. The established architecture provides an alternative way of constructing the existing MCG system architecture which could solve many challenging problems. Experimental results show that the established architecture is able to provide better Quality of Service to the mobile game users.

2) The formation of ad hoc mobile cloud in the Cloudlet environment to decrease the waiting delay when the Cloudlet is busy or far compared to the distance of nearby nodes.

3) Proposed c-DSDV routing protocols to reduce the packet loss and packet demolish before reaching its destination in the ad hoc mobile cloud.

1.10 Organization of the Thesis

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

Chapter Two, presents a literature review of the fundamental concepts relevant to the work in this thesis. This chapter serves as a foundation for cloud computing, mobile cloud gaming, cloudlets, and mobile games.

Chapter Three, discusses about the system overall including the architecture, the algorithm involved, calculations.

Chapter Four, discusses about the improved Clustered Destination-sequenced Distance Vector (DSDV) routing algorithm and the algorithm involved.

Chapter Five, discusses about the parameters and formulas involved in the thesis work and discusses about the simulation results obtained. Also 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 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses briefly about mobile cloud computing, mobile cloud gaming, cloudlets, mobile devices, mobile users, and mobile games. This chapter explains how from the invention of mobile cloud computing, it can contribute to the beginning of mobile cloud gaming, how the users, devices and the games will be related in the formation of the proposed cloud cloudlet gaming and the importance of ad hoc routing protocol in game video transmissions in cloudlet.

2.2 Mobile Cloud Computing

Cloud Computing technology has been very useful for many fields including education, gaming, share markets, business and many more (Velte & Velte, 2019). It is becoming very demanding and developing rapidly because of its ability to enable ubiquitous, convenient, on-demand network access, share computing resources such as networks, servers, storages, applications and services (Wei, 2012). According to the National Institute of Standards and Technology (NIST), the cloud model is composed of five essentials, three service models, and four deployment models. The five essentials are on-demand self-service, broad network access, resource pooling, rapid and measured service (Zhang et al., 2019). Meanwhile the three service models are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). The four deployment models are Private Cloud, Community Cloud, Public Cloud, and Hybrid Cloud (Peter et al., 2011).

Based on all this qualities, Mobile Cloud Computing has been introduced and became very demanding especially for Cloud based Mobile Gaming (Abolfazli el at., 2016 & Noor el at., 2018). Cloud offloading has become the important aspect in Mobile Cloud Computing (MCC) (Kulkarni et al., 2019). Mobile devices are known to have limited primary storage, limited capacity, limited battery life, and lower processing power compared to desktop computer (Akherfi et al., 2018). People are more engaged to mobile devices nowadays compared to desktop computer due to convenience but they could not handle resource intensive applications such as augmented reality, 3D mobile games or artificial intelligence on their mobile devices because of its limitations as mentioned above. MCC comes in handy as a solution for these limitations because mobile users now can offload their work to the cloud servers of MCC.

MCC has a dedicated server placed in the cloud where it would execute the computation task that was offloaded by the mobile device users and the computation results are sent back to mobile device. MCC is made up of the relationships between infrastructure providers, Application/Services providers, End-User, and Developers (Roth, 2016). Infrastructure providers are those who provide the hardware and software infrastructure, provides services or applications in the Cloud. Application/Service providers are the first level user of MCC. They provide applications and/or services in the Cloud for the End-users to utilize. They are also known as business consumers. Developers are the second level user of MCC where they create/develop applications and services that is being hosted in the cloud and finally the third level and the most important user of MCC, the End-User. They use the applications or services that are provided in the Cloud to process their task and get the processed result back to the End-User device (Kitanov, 2014).

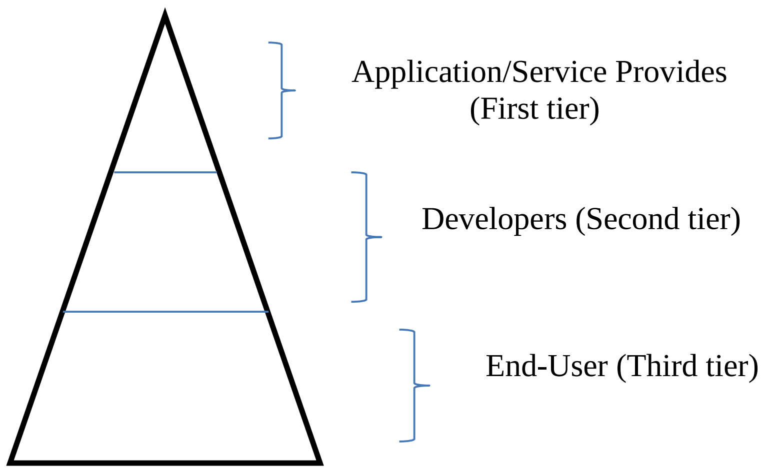

Figure 2.1. Relationship Between First, Second, and Third Tiers (Kitanov, 2014)

2.2.1 Mobile Cloud Computing Architecture

According to Mobile Cloud Computing Forum, mobile cloud computing is defined as follows:

"*Mobile Cloud Computing at its simplest refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and mobile computing to not just Smartphone users but a much broader range of mobile subscribers*" (Warhekar et al., 2013).

Figure 2.2 shows an example of MCC architecture which is consists of five components. The components are mobile users, connection operators, wireless connection devices, internet providers and cloud providers.

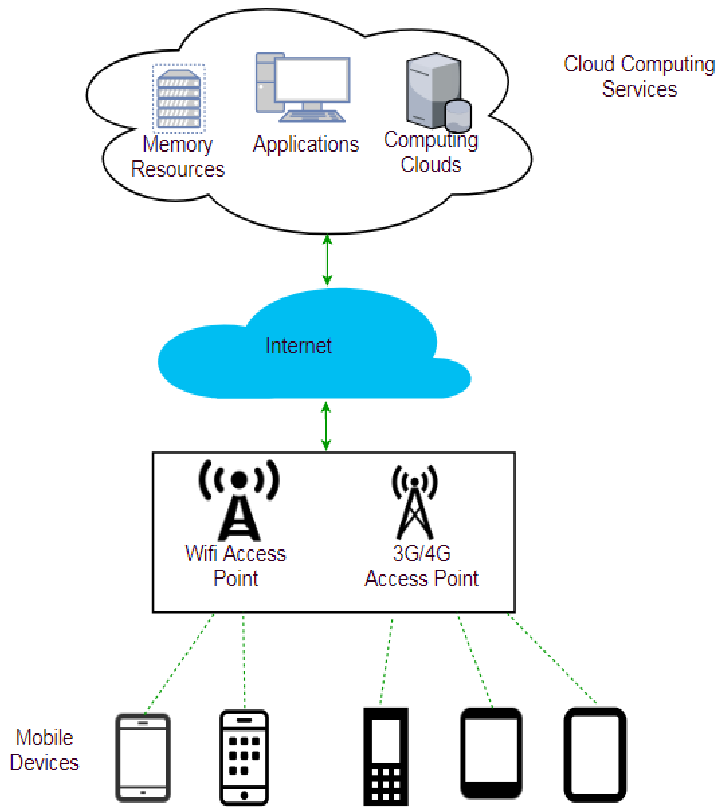

Figure 2.2. Mobile Cloud Computing Architecture (Alakbarov et al, 2017)

Based on the Figure 2.2, it shows that the mobile devices are first connected to the available or nearest access point which enables them to connect to the internet. Through the internet connection, the mobile devices now can immediately connect to the Cloud Computing services in the Cloud either to offload computation work, to utilize the database or to utilize other services provided by the Cloud.

2.3 Cloud Gaming

The emergence and popularity of Mobile Cloud Computing (MCC), has helped and contributed in new cloud inventions especially in gaming field (Butt et al., 2019). The first mobile games, *Snake* are an embedded game that was launched on 1997 on Nokia 6610 (Chris, 2016). The game was installed in the mobile and user has no other choice except to play the game that was provided in the mobile. When the technology has enhanced, normal mobile phones started to replace smart phones, laptop, iPad, and other smart mobile devices.

Mobile users can now download their favorite mobile games to their mobile devices, install the game and start playing. Only the owner of the high-end mobile devices could play high-end mobile games because the installation of the games files to the mobile devices requires high storage, high capacity and high processing power. Although they could play high-end games, they are still limited from playing the games with full speed and with better Quality of Service (QoS) compared to playing through the desktop computers.

MCC was introduced to support mobile devices to process high capacity tasks by offloading the selected task to the cloud (Biswas & Whaiduzzaman, 2019). Using the same concept, cloud gaming was introduced. The main advantage of cloud gaming is that the users are not required to install the game in their mobile devices but can offload the game rendering process to the cloud.

2.4 Mobile Cloud Gaming (MCG)

MCG has its advantages and disadvantages and it is considered as the best replacement of PlayStations and Xboxes. The diversity of end-user devices and the frequent changes in network stability reduces the efficiency of Quality of Experience (QoE) for game players (Laghari et al., 2019). A component-based gaming platform that supports click-and-play, intelligent resource allocation and partial offline execution is designed and implemented by an author to provide cognitive capabilities across the cloud gaming system and to improve the QoE (Wei, 2013).

MCG is defined as interactive gaming utilizing mobile devices that access the cloud as an external resource for processing of game scenarios and interactions, and to enable advanced features such as cross-platform operations, battery conservation, and computational capacity improvement (Wei, 2013; Kim & Kim, 2019). MCG has unlimited resources, the cloud renders game engines, has high storage to store games and other computational resources. MCG also offers Data Security and Seamless Gaming, all the gaming data are stored in the Cloud server and there are no possibilities of losing data if the mobile phone corrupted or lost and the mobile users gaming contents with status will sustain in the cloud which directly provides seamless gaming experience across multiple networks and devices for the mobile game players.

The main drawbacks of MCG are that it is strongly dependent on network, consumes high bandwidth and latency (Butt et al., 2019). The Cloud gaming services highly dependent on bandwidth requirement and latency (Di, 2014). The gaming platform should provide very short latency for real-time gaming and to give feedback for user inputs immediately. There are many ways have been found by researchers to reduce the delay in

MCG including introducing a new basic architecture of mobile digital games based on Cloud Computing (Zamith, 2011).

MCG architecture is explained by Shaoxuan Wang and SujitDey (Wang et al., 2009). It is understood that the mobile user uses their mobile device to access the game server and is connected to the cloud server after the connection is confirmed by Game Content Server (GCS). The GCS is extended by two other supportive servers known as Game Engine Server (GES) and Game Streaming Server (GSS). Once the connection is confirmed, GCS initializes GES and GSS. Client data and game data is collected by GES from GCS and processes the client data and game logic to render the raw game. The rendered files then sent to GSS to encode the file before streaming it to mobile device through wireless connection.

The mobile device decodes the file and can start play the game. The input by the user is translated by the mobile device and sent to the GCS to process the input. GCS sent the input to GES to render it and sent to GSS to encode the feedback and stream it to mobile device. This process proceeds until the mobile user exit the game. Figure 2.3 shows the architecture of MCG and the data/flow control.

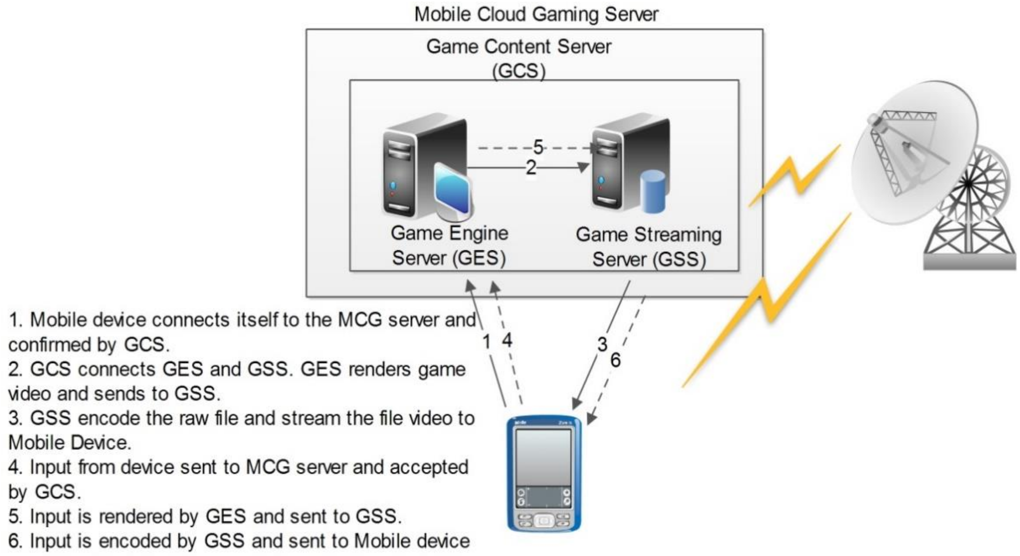

Figure 2.3. The Architecture of MCG and The Data/Flow Control (Wang et al, 2009).

There are three categories of MCG architecture has been developed so far which are video-based, file-based and component-based. Video-based MCG being the most famous category compared to the other two categories. This research project focuses on Video-based MCG and how with the help of Cloudlets, and enhanced routing protocol, it could help to overcome the most serious issues in MCG that is latency, inconsistent network/bandwidth, and Quality of Service.

2.4.1 Video Based Mobile Cloud Gaming

The most popular Mobile Cloud Gaming (MCG) is based on video streaming (Wu et al., 2017). It is the most typical and widely used MCG and it is similar to video on demand type of services. In video based cloud gaming, most of the game computation such as game rendering and game encoding will be done in the Cloud (Kennedy et al., 2019). The encoded video will be streamed down to mobile devices. The mobile devices