AN ENHANCED FIRST SEGMENT CACHING SCHEME (EFSCS) FOR MOBILE AD-HOC NETWORK BASED ON VIDEO ON DEMAND SYSTEM

Rami Dirar Malkawi, Mustafa Bani Khalaf, Belal Zaqaibah, Saleh Ali Alomari

Faculty of Sciences and Information Technology, Jadara University, Irbid 21110 (JORDAN)
E-mails: Malkawi@jadara.edu.jo, mbkhalaf@jadara.edu.jo, belal@jadara.edu.jo, omari08@jadara.edu.jo

ABSTRACT

Recently, videos are considered as a most efficient and effective way to share human knowledge around the world. This is due to advanced technologies such as high speed networks, fourth-generation wireless networks and existing smart video compression protocols. Nowadays, Video on Demand (VOD) system is used to making usage video services are easy, available and accessible everywhere. For example, VOD system allows students to select and watch educational videos of their interest online. It also enables tutors to record and save their lectures for later discussion and review. Although VOD system has been widely used in many real life applications, it suffers from a high latency streaming which makes end users experience difficulties to browse videos online. In this paper, a new Enhanced First Segment Caching Scheme (EFSCS) is developed to handle VOD system’s problem and to stream videos with a minimum end-to-end delay. Simulation results show that EFSCS achieves better performance in comparison with its counterparts such as All-Cache, Random-cache, Dominating-Set Cache and First Segment Caching Scheme. Experiment tests have carried out using OMNET++ simulator.

Key words: Video on Demand, MANET, EFSCS, FSCS, DSC, Random Cache, All Cache

1. INTRODUCTION

Nowadays, Mobile Ad hoc Network (MANET) is widely used in our daily life. It has been considered as a core stone of many important applications including but not limited to emergency applications, safety operations, public serves and browsing video online such as in Video on Demand (VOD) system [1-7]. Due to importance of VOD system application over other mentioned applications, this paper sheds light on optimizing its performance within MANET’s environment. MANET’s characteristics such as a high speed mobility, dynamic topology and multi-hop communication impose difficulties on operating MANET’s applications effectively. Hence, current research interests focus on handling such issues and achieving better utilization of MANET’s communication [8-9].

VOD system is an interactive multimedia system that enables clients to access videos from anywhere with access to the internet. It allows clients to view videos in real time or download and view them later. VOD system has further useful applications which are used extensively nowadays. This included, providing video films on demand, playing games online, weather forecasting and general local news.

The rise of social media such as Facebook, Twitter and YouTube has increased number of applications in which playing videos is an essential serves for end users. Furthermore, most of online educational systems use videos as a mean to distribute useful information to students. For instance, watching online lectures, distance learning, online group meeting and announcements. Therefore, existing MANET technology with conjunction of VOD system is vital to help clients to get video serves from a server. VOD system offers great advantages over MANET’s topology, as it provides subscribers with fully installed access to stored videos online. This can be established with assistance of a well-known protocol which is called Staggered Broadcast Protocol (SBP) [10-11]. However, SBP still suffers from high start-up delays when a new client requests a video from a server. This problem has been partially handled in [12-19].

The main contribution of this paper is to solve a long waiting time problem that is associated with the SBP, and to enhance the performance of FSCS [12] [13] [17]. Toward this ends, a new caching scheme which is so-called Enhanced First Segment Cashing Scheme (EFSCS), is developed to solve it and to leverage the performance of VOD system. The rest of paper is organized as follows: Section 2 describes the related background, which are Video on Demand Mobile Wireless, Wireless Mobile Network Approaches, Periodic Broadcasting Protocols and Caching schemes for VOD. The overall system architecture for the EFSCS is presented in section 3. The proposed Enhanced First Segment Caching Scheme (EFSCS) is described in Section 4. Section 5 describes the EFCS scenarios. The simulation preparations are presented in section 6. The simulation results and discussions are presented in section 7. Finally, the conclusion is presented in Section 8.

2. RELATED BACKGROUND

Current trends have severely affected by VOD system’s services due to the deployment of various types of networks’ infrastructures and the availability of different types of mobile devices. This type of applications which uses this technology are useful for many industries such as educational and entertainment industries. Furthermore, the current vogue and fashion industry is directing towards the digital media distribution through Internet. Wireless communications provide high level of independency for accessing these technologies without any constraints and boundaries. This paper proposes a new solution that demonstrates the system architecture of VOD over heterogeneous MANETs, which makes it suitable for supporting application over MANETs.

2.1. Video on Demand Mobile Wireless

VOD system is an interactive multimedia system that makes clients enjoy their time and make them select any suitable piece of video anywhere at anytime, this can be made due to the availability of large video database storage. The
current VOD can also be divided into three parts: Client/Server, Peer to peer (P2P) and the Periodic Broadcast. There are also many existing VOD techniques [6-12] that are based on the client/server approach, however this approach is not suitable for Mobile ad hoc network, simply because the wireless bandwidth cannot support a lot of clients who are using separate connection channels. The use of the P2P approach for the VOD techniques [20][21] has not been suggested or considered since time of transmitting long video from wireless node to another through more than one wireless hop, this was inefficient within the availability of the bandwidth and energy used. For this reason, using the broadcast approach to avoid the bottleneck problem in the client and server, and also within the fast service of the P2P approach is a main requirement. More details about the periodic broadcast subject area are discussed in this paper.

2.2. Wireless Mobile Network Approaches
MANETs are dived into two types of networks [22-24]. Firstly, an infrastructure wireless network, which is also called Cellular, builds communication between nodes through a base station. Basically the cellular is supported by a wired fixed infrastructure and communication only occurs within the single hop. Secondly, an infrastructure wireless network that is known as MANETs. Unlike the cellular nodes, the ad hoc network dynamically forms a temporary network without any support of any network infrastructure based wireless LANs [25]. The communication between nodes within a network is formed in a P2P style. A source node directly forwards a packet of data to a destination node if both nodes are located within a same transmission range. Otherwise, an intermediate node is used to forward the message toward a destination node if a source node is unable to send the message directly. Due to mobility of nodes and a dynamic network topology, each node works as end host and as router.

2.3. Periodic Broadcasting Protocols
Broadcasting technique is the appropriate one for users to download broadcast video segments from the server. Hence, several approaches that use the Periodic Broadcasting schemes are proposed for this purpose [26-30]. Basically, a video is divided into several segments, each repeatedly broadcasts on a separate communication channel. The main reason of dividing video into small segments is to save a server’s channel bandwidth, minimize the latency and save a storage space in a mobile memory card. A client receives a video by tuning to one or more channels at a time and then downloads data. A broadcast schedule is existing at a server, while a playback synchronization protocol at a client. Although, several broadcast protocols have been proposed, the most popular one among Periodic Broadcasting schemes [31-36]. SBP is a simple periodic broadcast, which focuses on a single video. It just requires users to download the broadcast segments from one channel at a time, and using a buffer space. However, it causes high access latency to the length of video which is divided by the channel allocated to broadcast the video.

2.4. Caching schemes for VOD
Caching schemes are implemented with in order to assist VOD system to reduce a time delay, a bandwidth reduction, a request rejection and to save a caching space. This section lists most important caching schemes, that are used with VOD system.

- Partial Video Sequence (PVS) caching scheme [37], it decomposes video sequences into a number of parts by using a scalable video compression algorithm. Video parts are selected to be cached in local video servers based on the amount of bandwidth that would be demanded from the distribution network and central video server if it was only kept in the central video server. PVC caching improves the performance of caching, provides more reduction in the bandwidth requirement than the conventional caching scheme.
- Prefix Caching [38], it could reduce the request rejection ratio and client waiting time. The network bandwidth usage has also been reduced by the caching scheme through sharing the video data of the currently played video object with the other clients of the active chain.
- Dominating-Set Cache (DSC) [14] In DSC, when a new client X is in the transmission range of existing client Y and the client is not forwarding cache to any other client, client X can make use of the cache at Y and plays the video. But if client X is not in the transmission area of client Y, the client Y will find another client Z who shares the same transmission area with itself and client X, Y will download the broadcast portion that X misses from Z and forwards it to X.
- Random Cache [14], the simplest selective cache algorithm which contains a number of selected clients that are allowed to cache the first segment of a video. The advantage of this caching scheme is: the saving on caching space, while the disadvantage is that: it has the higher service delay.
- Client Caching Scheme for Interactive Video-on-Demand [39], it is used to reduce the traffic load on the network where a local client caches a video, and when the video once retrieved from the server it will be retained in a video cache on the client as a remainder of the session. If other clients want to watch the same video again, the video can be viewed from the cache and not from the server. If the local cache is full, an aging mechanism is used to decide which frame is to be overwritten by the most recently requested one.
- Neighbor Based Caching Scheme [39], Mobile client can download the first segment of the video from the initial buffer of the neighbor client to its own initial buffer. The mobile client must be within the coverage area of neighbor client. When the initial buffer of the mobile client is filled with the first segment downloaded from the neighbor client, it will act as the self based caching scheme and broadcast the segment like how the self based caching system does.
- All-Cache Scheme is one of the caching techniques, which has been proposed by [14] [15] in order to minimize the delay in the MobiVOD system. In this scheme, all clients who exist in the network coverage area have to cache the first segments of the video. This segment is used to serve the new arriving client who has missed out broadcasting the first segment from the local forwarder logical broadcasting channels. The new client who has missed out the first segment either by searching for a free neighbor client who has already the first segment or by waiting for the next first segment broadcasted to other logical channels. The first segment of the video is cached in the reusable client’s buffer, whereas other segments are cached in the pre-fetched client’s buffer. The reusable contents in the client’s buffer are shared with other clients in order to eliminate the time delay of the system. The
bandwidth limitation of the wireless network restricts clients from forwarding the first segment to more than one hop in the area.

- **First Segment Caching Scheme (FSCS)** is suggested to reduce the viewer’s waiting time when periodic broadcast protocols are used such as in SPB [14-16]. In FSCS, a memory card of mobile clients is divided space into three buffering types instead of two types as in [12] [13]. The new division is included the First buffer, the Initial Buffer, and the Pre-fetched buffer. When a new mobile client enters the network area, the Local Forwarder will detect it automatically. Once the client is detected, the first segment of a movie, which has not been sent to any other client’s first buffer, should be sent to it. The first segment is kept in the first buffer of mobile nodes. FSCS makes sure that all clients in MANET have the first segment of all movies that are stored in the Local Forwarder.

In this paper a new cashing scheme which is called Enhanced First Segment Caching Scheme (EFSCS), which is implemented in order to overcome problems of the recent suggested schemes [14-19], and in particular the limitations that are associated with the FSCS.

3. THE OVERALL SYSTEM ARCHITECTURE FOR THE EFSCS

The VOD system architecture over MANET is classified into six main categories based on [16] [17]. This classification included the Central VOD Services Provider (CVSP), the Local Forwarder, the wireless network infrastructure, the mobile clients, the broadcasting protocol and the caching technique. The overall system architecture is elaborated in Figure 1.

![Fig. 2. Video on Demand System architecture over Mobile Ad hoc Network (MANET)](image)

The CVSP is a server that is considered to be the main entity that can provide VOD services to end mobile clients. It has storage of VOD services, and it provides these services to end clients through Local Forwarders (LMF). Furthermore, the CVSP is responsible for monitoring all involved clients through different media forwarders. In particular, during the process, the CVSP is gathers information about relaying the media forwarders from the mobile node and it tracks the movement of mobile clients through different network infrastructures for the purpose of providing seamless services. In addition, the CVSP also prepares services for mobile clients by maintaining a dual connectivity between different LMFs.

The LMF is responsible for providing VOD services within a limited transmission range, such as, in indoor buildings, while using such standards as the WiFi (IEEE 802.11 a/b/g). On the matter of fact, the LMF is proposed to be used in indoor environments, such as, buildings. Furthermore, it is also proposed to make use of itself as a primary source that can provide VOD services to mobile clients due to the distributed resource sharing or the load balancing for the bandwidth.
Fig. 2. An example of multiple LMFs inside a building (indoor environment)

The general architecture of the multiple LMFs is illustrated as in Figure 2. It explains the procedure of the LMF that provides VOD services to different devices inside the building (indoor environment). In particular, this environment is physically located closer to its clients. The CVSP is considered as a main server that can provide VOD services to different Local Forwarders (LFs) (LF1, LF2, ..., LFn). Such LFs are installed inside a scatter and used to broadcast videos as segments through the wireless interface card to mobile clients. The server and the LFs are interconnected via an infrastructure-based wireless network. The LF is a stationary and a dedicated computer in which each LF has a limited bandwidth that can provide services to the mobile node within a limited area. This area is either called the transmission coverage area or a local service area.

Caching technique is considered one of the most important techniques that can be used effectively to minimize a delay. A cache is a storage buffer that is existed between any two devices. It is used as a temporary storage for frequently used data. The main reason for using this technique is to minimize the response time when requesting the data from a remote place. In addition, this technique is used to reduce the traffic in networks in order to save bandwidth. Furthermore, this technique has been widely used in the VOD system over the wireless network in order to minimize the waiting time. This in turn, will disseminate the video to clients, and reduce the consumption of the network bandwidth.

A broadcasting protocol is a method related to the scenario of handling clients who are watching different portions of the same video at any giving moment. The server has to have an efficient broadcasting mechanism, so that it can broadcast a video to many users as possible in a simultaneous fashion. In mobile nodes, when a mobile client wants to view a movie, the client has to request this video from the LF. Then, it broadcasts a video into segments to mobile clients through its Wireless Network Interface Card (WNIC) by making a use of the broadcasting protocol.

The Staggered Broadcasting (SB) Protocol [16] [17] is used, in this system, to disseminate a video data to the mobile clients. The server bandwidth will is divided into equally sized channels and the videos is segmented into $K$ equal size segments ($Seg_1$, $Seg_2$, $Seg_3$, ..., $Seg_K$). The duration of each segment is $D_i = V/K$, where $V$ is the total display duration of the whole video and $K$ is the number of the channels. And every Channel must be between $1 \leq i \leq K$, we decide the provider bandwidth is $Pb*K$ for the video two, and so on, where $Pb$ Mbps is the consumption rate or playback rate. This bandwidth is partitioned into physical channels ($Channel_i$) repeatedly broadcast the video ($Seg_1$, $Seg_2$, $Seg_3$, ..., $Seg_K$) with transmission rate ($Tr$) equal playback rate ($Pb$) as shown in Figure 3. Mobile clients which are in the LF's coverage area can join channels to receive the broadcasted segments of videos. The SB Protocol is used to broadcast movies from server to LF and from LF to mobile clients in MANET Based Video on Demand. Firstly, a client requests for a video from LF, and then the LF will broadcast the video after classifying it into several equal sized segments through WNIC of the mobile client. Furthermore, these segments will be re-broadcasted using the Staggered Broadcasting Protocol. This process is repeated for the subsequent segments until a last segment ($Seg_K$) is downloaded from $Channel_1$. Equation 1 follows directly the definition:

$$D_i = \frac{V}{K}$$

(1)

Fig. 3. Video division into segments by broadcasting protocol and segment $Seg_i$ broadcasting at physical $Channel_i$
Each channel is repeatedly broadcast segments of a video with a transmission rate equals to playback rate. To broadcast the segments to mobile nodes, this is conducted according to the schedule that is fixed in the SBP as shown in Figure 3. Any mobile client can join the channel which will broadcast the first segment as soon as possible. In the SBP, a client can only join a single channel at all time, a mobile client can join the channel 1 at t0 to download and playback the 1st segment of a video that is requested by - mobile clients and can continue download and playback the rest of the segments from the same channel. The playback of the video starts when a mobile client starts to watch the first segment and if the mobile client enters the network at time t0+δ (0<δ<s), the client here has missed the 1st segment of the video and should wait until the channel 2 broadcasts the same segment again at time t0+s, s=V/K where V is the length of the video and K is the number of channel. Thus the client has to wait about s-δ which is the worst case. When size of the video is 60 minutes and (V=60) and number of the channel is 5, the result will be in a worse case with delay of 12 minutes (s= 60/5 = 12minutes). The disadvantage of SBP is its high service delay. This is because when a client missed the first segment of a video that is broadcasted by the local forwarder, the client has to wait until the Local Forwarder broadcasts the segment again.

4. EFSCS: MOTIVATION AND CONTRIBUTION

This section discusses the Enhanced First Segment Caching Scheme (EFSCS), and describes how it can elevate the side effect of using the traditional schemes such as, All-Cache, the Random-cache and the Dominating-Set Cache (DSC). The first section illustrates the basic division of a mobile client’s memory card, and how it is divided based on EFSCS' strategy. The second section explains the main idea behind proposing the EFSCS.

4.1 The Traditional Memory Card of Mobile Clients

Mobile clients’ memory card that are involved in this research use 3G and/or 4G technology, as it enables mobile clients to download and playback videos on their phones. In the traditional systems such as in [14-19], a memory card of mobile clients is divided into two main types of buffers, the Initial Buffer and the Pre-fetched buffer. The Initial buffer is used to cash a first segment of a movie either from the LF or from neighbor clients. On the other hand, the Pre-fetched buffer cashes the rest of the movie’s segments. Although this sort of division reduces the total waiting time for all existing clients, it still suffers from imposing a long waiting for new clients. This happens when the SBP broadcasts a movie’s first segment to available clients at time t1. Hence, a new client which just joins the network at time t2 misses it (a movie’s first segment). Therefore, the new client should wait another broadcast period to receive that first segment. This waiting time is not desirable in a high mobility network such as MANETs.

4.2. First Segment Caching Scheme (FSCS)

The aforementioned problem is handled in the (FSCS) through adding a new buffer to the memory card of mobile clients. This buffer is called a First Buffer. It is used to store random first sub-segments from different movies on the memory card of all available mobile clients. A new client, which has joined a network recently, requests a movie’s first segment from its surrounding neighbors in case it has missed it. This enables new clients to playback a requested video immediately, rather than waiting a next transmission period. Although The FCS is achieved a best performance in terms of the total delay time compared to the All-Cache, the Random-cache and the Dominating-Set Cache (DSC) schemes, it suffers from several disadvantages. Firstly, memory consumption, as it forces a client to reserve memory space equal to size of a movie’s first segment. Secondly, a probability of client to find a first segment of a requested video within its transmission range is too low.

4.3. Enhanced First Segment Caching Scheme (EFSCS)

The EFSCS is proposed in this paper to overcome the aforementioned shortcoming of FSCS and other related schemes. It optimizes usage of the First Buffer through reducing size of the first segment, and increasing its number inside the First Buffer. The EFSCS divides size of the First Buffer into two equal spaces. This enables mobile clients to store in its First Buffer two different first sub-segments from two different movies. Therefore, size of each space should be equal to size of the first sub-segment. The main idea behind dividing the First Buffer into two parts is to force mobile client to store a small size of a first sub-segment from two different movies, instead of storing a one large first segment as shown in Figure 4. This increases a probability of most mobile clients to have all first sub-segments from all movies that are stored in a server. So, when a new client has joined a network recently, it requests a movie from its neighbors rather than waiting the LF to broadcast it.

![Fig. 4. The feature of mobile client with 3 buffers.](image)

5. EFSCS SCENARIOS

This section introduces brief explanations based on the ways of providing optimal VOD services to mobile clients by presenting EFSCS. Figure 5(a) shows a scenario of the LF sends a message to the mobile client A to acknowledge it, to
receive the two 1st sub-segments of two different movies j,g to its First-Buffer, when it detects the arrival of the client to the network area.

Figure 5(b) shows the Local Forwarder sending the 1st sub-segment of movie 1 and movie 4 to the client's first buffer after sending the message. Figure 6(a) shows the Mobile client A sending a message to Local Forwarder to acknowledge that it already receive Movie 1 and 4 two sub segment.

Figure 6(b) shows Mobile Client A caching the 1st segment of movie 2 to its initial buffer by tuning to channel 1 followed by caching the remaining segments to its pre-fetched buffer. The time delay occurs when the mobile client missed the first segment of a movie that was broadcasted by the SPB. If the mobile client wants to download and playback the first segment, the client has to wait until the broadcast protocol broadcast the same segment again. Thus, to decrease the waiting time, for the previous purpose then the present First Segment Caching Scheme (FSCS) will be a solution to reduce the viewer’s waiting time, nevertheless, it has some disadvantages. For the above purpose, EFSCS is the solution to minimize these disadvantages. In FSCS, when a new mobile client enters the network area, the Local Forwarder automatically detects a client. Once the client is detected, the two 1st sub-segment of a movies that has not been sent to any other client's first buffer will be sent to the new client. The two sub-segments will be kept in the 1st buffer of the mobile. By sending the two sub-segments of a movie to the 1st buffer of the new client, it ensures that all the clients in the MANET environment will have the 1st sub-segment of all the movies that are stored in the Local Forwarder. The architecture of the Enhancement First Cache Scheme is shown in Figure 7 and Figure 8.
Below is the step of detecting the arrival of mobile clients to the local area network used in this caching scheme which is shown below, where U1 is the new mobile client, LF1 is the Local Forwarder: The first step to detect the arrival of mobile clients to the local area network used in this caching scheme can be seen below, where U1 is the new mobile client, LF1 is the Local Forwarder:

Detection Procedure for mobile client arrival:
1. U1 enters the network.
2. LF1 detects U1 in the network area.
3. LF1 checks which movie’s two 1st sub segment is not in other client’s first buffer.
4. If all the movie’s 1st sub segment is in all the other client’s 1st buffer.
5. LF1 will not send any 1st segment to U1.
6. Else if any movie’s 1st segment is still not sent.
7. LF1 will chose that two 1st sub segment to be sent to U1.
8. LF1 sends a message to the U1 to accept the two 1st sub segment.
9. LF1 sends the sub segment to U1’s 1st buffer.
10. U1 accepts the sub segment.

Figure 9 shows that mobile client E which arrives the network at time t0+1, according to SBP schedule, it broadcasts the 1st sub segment of movie 2 at time t0. Mobile E wants to watch movie 2 but could not cache the 1st sub segment to its initial buffer because it already missed the first segment. Thus in order to watch the movie, the client has to wait until the SBP broadcasts the same segment again at the same channel or can switch to another channel that broadcasts the same 1st subsegment the soonest. Waiting for the broadcasting protocol to broadcast, the 1st sub-segment will again consume more time for the client, thus the client can simply request from its neighbors. Since the Local Forwarder already sent the 1st subsegment of movie 2 to Mobile Client B’s first buffer, mobile client E can immediately request for the 1st sub segment of movie 2 from client B. Mobile client B can send the sub 1st sub-segment of movie B to client E as long as it is still in the LF transmission area and is not transmitting any segment of video to any other client.
Fig. 9. Mobile client E requesting 1st sub-segment of Movie 2 from mobile client B and caching the rest of 1st to initial buffer and 2nd segment and the following segments to its pre-fetched buffer

Figure 10 shows that the mobile client E arrives the network at time $t_0+1$ and according to the Staggered Broadcasting Protocol schedule, it broadcasted the 1st sub-segment of movie 2 at time $t_0$. Mobile E wants to watch movie 2 but could not cache the 1st sub-segment to its initial buffer because it has already missed the first segment, and the neighbor's client in safe distance does not have the 1st sub-segment or not enough of bandwidth or not enough battery. Thus, in order to watch the movie, the client has to wait until the Staggered Broadcasting Protocol broadcast the same segment again at the same channel or switch to another channel that broadcasts the same 1st sub-segment the soonest. Waiting for the broadcasting protocol to broadcast the 1st sub-segment will again consume more time for the client, thus the client can simply request from its different. Local Forwarder has already sent the 1st sub-segment of movie 2 to Mobile Client D's first buffer, mobile client E can immediately request for the 1st sub-segment of movie 2 by infrastructure. Mobile client D can send the 1st sub-segment of movie 2 by infrastructure using socket to client E as long as it is not transmitting any segment of video to any other client, enough bandwidth and battery can be sent by socket with infrastructure.

In the same service, the client B has this 1st sub-segment but cannot be transmitted because the battery is almost weak. In this case, the Local Forwarder sends a unicast message for server media with info for client E to find a client in other service area to send 1st sub-segment, server media sends a broadcast message to all Local Forwarders to ask the 1st sub-segment, which is found in, the Local Forwarder responses a unicast message with info for client and asks info for client B. Server media-sends the info for client to both Local Forwarders. Now, the client D begins sending a 1st sub-segment to client E with infrastructure using socket. Figure10 shows that:
Fig. 10. When the 1st sub-segment is not available of client's in the same service area of his request from a client at another service area.

The scenarios of the Playback procedure shown below, explains how the Enhancement First Caching Scheme works:

First scenario of the Play Back Procedure:

1. Detect local forwarder
2. Find the channel from local forwarder which is going to broadcast the S1 soonest
3. Wait and join that channel
4. Download the S1 in its initial_play buffer and cache remaining segments into pre-fetched buffer.
5. Play S1 in initial_play buffer and switch to pre-fetched buffer to play remaining segments.
6. Quit the channel.

If mobile client missed the first segment (S1) of the video, second scenario of the Play Back Procedure will be played.

Second scenario of the Play Back Procedure:

1. U1 send request for 1st sub-segment from neighbors who in the same area network of U1
2. U2 within the network area
3. U2 currently are not forwarding 1st sub-segment to other mobile user
4. If such U2 exist
5. Download 1st sub-segment from U2 into U1’s initial_play buffer
6. The U1 join the broadcasting channel and save the remaining segments of the video.
7. If download is complete
8. U1 play data in its initial_play buffer
9. After play the S1, U1 switch to pre-fetched buffer to play remaining segments of the video.
10. Else If such U2 does not exist
11. Detect a local forwarder
12. Find the channel from local forwarder which is going to broadcast the S1 soonest
13. If wait to join that channel
14. Then local forwarder send request to server with info for U1
15. Server send broadcast to all local forwarder to find client can be sent
16. U1 receive in the 1st sub-segment using socket
17. At the same time U1 join the broadcast channel in local forwarder.
18. Download the rest S1 in its initial_play buffer and watch remaining segments from pre-fetched Buffer.
19. Quit the channel.

Third Scenario of the Play Back Procedure:
The following is the scenario of the Playback procedure, when the mobile clients (U1) already have the 1st subsegment of a movie A.

1. LF detect mobile client U1
2. LF send message followed by S1 to U1 First Buffer
3. U1 request 1st sub-segment of movie 1
   a. If First Buffer have the same 1st sub-segment of movie 1
4. U1 will playback the 1st sub-segment from the First Buffer.
5. At the same time U1 join the broadcasting channel to receive the rest of segments in the pre-fetched buffer.
6. After U1 finish viewing the 1st segment will switch to the pre-fetched buffer.
7. Quit the channel.
8. Else use the Second scenario of the Play Back Procedure.

6. SIMULATION PREPARATIONS

To evaluate the performance of EFSCS, extensive simulation experiments are conducted to get results by using OMNET++ simulator. This section discusses and presents the results of the implementation study, as the main objective of the implementation seeks to test the validity and the functionality for the proposed protocols’ mechanisms.

6.1. The Specification of Hardware
The hardware specifications used during the implementation of the EFSCS Scheme are shown in Table 1. Furthermore, the software specifications used during the implementation of the EFSCS Scheme are shown in Table 2.

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<th>Table 1. Hardware specification</th>
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<td><strong>CPU</strong></td>
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<td><strong>RAM</strong></td>
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<td><strong>Hard Disk</strong></td>
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<th>Table 2. Software Specification</th>
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<td><strong>OS</strong></td>
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<td><strong>Microsoft Visual Studio 2008</strong></td>
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<td><strong>Library used</strong></td>
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6.2. Simulation Model
Figure 11 and 12 show the simulation visualization of the Enhancement First Caching Scheme on MANET Based Video on Demand System.
There are few stages a new client should go through to receive the two sub 1st segment of a movie. Firstly, the LF should detect arrival of a new client and sends a message to accept the two sub of 1st segment's to be sent to the client and send the two sub of 1st segment's to the client's first buffer.

Then the client sends a message to the LF to acknowledge it, that it has already received the two sub of 1st segment's. At the same time, the new client can request for 1st segment of its favorite movie to the LF and can tune in to the
broadcasting channel that is broadcasting the 1st segment the soonest. But if the 1st segment which is sent to the first buffer of the new client is the same as the movie that the new client wants to watch, the client can immediately start watching the 1st segment. If the 1st segment is not the same, then the client request time will be:

\[ t_{\text{req}} = t_{\text{send}} + t_{\text{buffer}} + t_{\text{wait}} + t_{\text{delay}} + t_{\text{trans}} + t_{\text{play}} \]

New mobile client can tune to either channel 1, channel 2, channel 3, channel 4 or channel 5.

\[ t_{\text{req}} = t_{\text{send}} + t_{\text{buffer}} + t_{\text{wait}} + t_{\text{delay}} + t_{\text{trans}} + t_{\text{play}} \]

So, the client now can request the 1st sub-segment from the neighbors. At this stage, the LF sends a message to the new client to inform it that the client has missed the broadcasting time of the 1st sub-segment and information about neighbors who have the 1st sub-segment, and the position of the neighbors with the time delay for the broadcasting protocol to broadcast the same segment again. The new client can now send message to their neighbor who has the 1st sub-segment when the distance of the neighbor is near as shown in Figure 11.

Figure 12 shows the new client that does not get any reply from its neighbors hence when the time reached until the time for the broadcasting protocol to broadcast the 1st sub-segment again, the new client can immediately tune in to the channel that is going to broadcast the 1st sub-segment. If the waiting time, \( t_{\text{wait}} = t_{\text{delay}} \) then search in another service area that is going to broadcast the 1st sub-segment. The new client can now start to watch the movie by playing the 1st subsegment from its initial buffer and can immediately switch to the pre-fetch buffer to continue watching the movie.

6.3. Simulation Parameters

The simulation tool has been used for the simulation, a video of 60 minutes is divided into \( K \) equally sized segments and the \( K \) value depends on the LF’s bandwidth limit. The formula for Bandwidth is:

\[ T \times N \leq h = \{1,2, \ldots \} \]

(2)

Additionally, the bandwidth limit of the LMF is determined by the value \( K \). The bandwidth capacity of a LMF knows as \( b \) (Mbps), and the number of the videos broadcasted from the server is known as \( N_v \). We utilize the following relationship to determine the value \( K \). Given that each video has a transmission rate \( T_r = 1.5 \) according to MPEG-1, where the number of the video \( N_v = 5 \) and the providers bandwidth \( b = 54 \) according to 802.11g, depending of the equation 1, \( (1.5 \times K \times 5 \leq 54) \), the result the \( K \) must be less than 7 as elaborated in Figure. 3. Equation 3 follows the definition:

\[ b = b_j \]

(3)

Where, \( b_j \) is a bandwidth of logical broadcasting channel as a ration over \( b, j = 1,2, \ldots K \)
Hence the value of K< less than 7, thus for this simulation the value for K =5 and the bandwidth allocation is also divided into K channels where each channel will repeatedly broadcast the video with a transmission rate equal to the consumption rate. The radio transmission radius, D of the service area surrounding of the LF is fixed as 100m therefore the service area of a local forwarder is 2-D with the location of the Local Forwarder is at the center of the area (0, 0). The mobile clients can only stream or download movie when they join this service area and the arrival time of the mobile client is following a Poisson distribution with a rate r arrival (client/minute). Mobile clients can contact each other at 20m of distance because of bandwidth constraint and at each second, it is assumed that a client is moving with a probability of pmove to a random location within a distance of dmove € (0, MoveMax). The maximum moving distance of a mobile client is 1m which means every time when the mobile client moves, the maximum distance that can move is 1m. The default value for the client arrival rate is set to 6 clients per minute but the value range that will be simulated is also 2 clients per minute, 4 clients per minute, 8 clients per minute and 10 clients per minute. The moving probability’s default value is fixed to 0.2 but also tested at the range of 0.1, 0.3, and 0.4. Each simulation runs for T = 24 hours when the mobile clients join the service area with arrival times. Table 3 shows the simulation parameter that is used to run the simulation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Default Value</th>
<th>Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service area radius</td>
<td>D_plan</td>
<td>100m</td>
<td>N/A</td>
</tr>
<tr>
<td>Client Transmission</td>
<td>C_plan</td>
<td>20m</td>
<td>N/A</td>
</tr>
<tr>
<td>Simulation period</td>
<td>T_simulation</td>
<td>24 hours</td>
<td>N/A</td>
</tr>
<tr>
<td>Client arrival rate</td>
<td>s_arr</td>
<td>6 client/min</td>
<td>(2,4,6,8,10)</td>
</tr>
<tr>
<td>Moving probability</td>
<td>p_move</td>
<td>0.2</td>
<td>(0.0,0.1,0.2,0.3,0.4)</td>
</tr>
<tr>
<td>Maximum moving distance</td>
<td>MoveMax</td>
<td>1m</td>
<td>N/A</td>
</tr>
<tr>
<td>Video length</td>
<td>L</td>
<td>60 minutes</td>
<td>(30,60,90)</td>
</tr>
<tr>
<td>Number of broadcast channels</td>
<td>N</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Video Consumption Rate</td>
<td>R</td>
<td>1.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of Video</td>
<td>N</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>B</td>
<td>54Mbps</td>
<td>N/A</td>
</tr>
</tbody>
</table>

7. SIMULATION RESULTS AND DISCUSSIONS

In the results, the performance of the proposed scheme is investigated from the several metrics, such as number of mobile clients, moving probability, client distance and then compare with other schemes known as All-Cache scheme, Dominating-Set Cache (DSC) scheme, Random-Cache scheme and First Segment Cache scheme.

7.1 The Effect of the Service Delay Depending on Number of Mobile Clients.

The Table 4 shows the result obtained for service delay directly proportional to the number of clients in the Local Forwarder’s service area tested on 3 caching schemes.

| Request Arrival Rate (Client/minute) | | |
|--------------------------------------|-----------------|-----------------|-----------------|
|                                      | Enhancement FSCS Avg.delay (seconds) | First Segment Cache Avg.delay (seconds) | All Cache Avg.delay (seconds) |
| 2                                    | 2.82            | 4.02            | 5.84            |
| 4                                    | 2.87            | 4.02            | 5.76            |
| 6                                    | 2.89            | 4.05            | 5.79            |
| 8                                    | 3.30            | 4.62            | 6.60            |
| 10                                   | 3.86            | 5.60            | 7.72            |

From the result obtained, it shows that the service delay decreases when the mobile client arrival rate increases. The more clients, the less time consumed to receive the 1st sub-segment from the neighbor. When there are 2 clients per minute, the average service delay for Enhancement First Segment Cache is 2.9 seconds compared with 4.09 seconds and 5.8 seconds by First Segment Cache and All Cache but when there are 10 clients per minute, First Segment Cache’s delay is only 3 seconds meanwhile First Segment Cache is 5 seconds and all cache will be the most late that is 7 seconds. The service delay is very less when there are more clients because there is a higher probability that almost all the movie’s 1st sub-segment in the client’s first buffer. So in this situation, the client can immediately request and receive the 1st sub-segment from its neighbor and other service area rather than waiting for the Local Forwarder to broadcast the segment again. Enhancement First Segment Cache’s delay is very less compared with the other two caches because there is also another possibility that the 1st sub-segment of a movie sent to the new client’s first buffer by the Local Forwarder, the same segment that the new client wants to request. Since the client has already the 1st sub-segment in its first buffer, it does not need to wait for the broadcast of the 1st segment or request from the neighbors but it can immediately start watching the 1st sub-segment while...
caching the remaining segments to its pre-fetched buffer. This situation directly reduces more time delay for the clients, and this is why the time delay for the Enhancement First Segment Cache is farther more when compared with the other caches.

![Graph of the Effect on Service Delay Depending on Number of Mobile Clients](image)

**Fig. 13.** Graph of the Effect on Service Delay Depending on Number of Mobile Clients

### 7.2. The Effect on Service Delay Depending on Moving Probability

**Table 5.** Effect on Average Delay Depending on Moving Probability

<table>
<thead>
<tr>
<th>Moving Probability</th>
<th>EFSCS Avg. delay (seconds)</th>
<th>FSCS Avg. delay (seconds)</th>
<th>DSC Avg. delay (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.68</td>
<td>3.76</td>
<td>20.37</td>
</tr>
<tr>
<td>0.1</td>
<td>2.84</td>
<td>3.98</td>
<td>24.71</td>
</tr>
<tr>
<td>0.2</td>
<td>3.33</td>
<td>4.86</td>
<td>28.69</td>
</tr>
<tr>
<td>0.3</td>
<td>3.38</td>
<td>4.73</td>
<td>31.93</td>
</tr>
</tbody>
</table>

The above result shows that the lesser the moving probability, the lower the average delays. This is because when the clients are prone to move from 1 place to another with the maximum distance of 1m each time, the furthest client needs more time to get the service either from the Local Forwarder or the neighbors or other service area. If the client did not move anywhere, there will be no any disturbance while transmitting the 1st sub-segment thus less time required getting the service from the system. When comparing the results of the three caches, the average delay of Enactment First Segment cache more reasonable compared with the other two caching schemes. When the moving probability is 0.0, the average service delay for Enhancement First Segment Cache is 2.86 seconds which is equal to First Segment Cache, but it takes 20.37 seconds for DSC Cache. There are no changes in average delay for the Enhancement First Segment cache from 0.1 until 0.4 that is the delay is 5 seconds meanwhile when the moving probability is 0.1 the average delay for First Segment cache is 5 and the following reading from 0.2 until 0.4 is the same which is 4.6 seconds. DSC cache’s delay is very high compared with both First Segment cache and First Segment cache because its service delay when the moving probability 0.1 is 24 seconds, 0.2 is 28 seconds, 0.3 is 31 seconds, and when it is 0.4 the value is 32 seconds.
7.3. The Effect of Client Fail Probability Depends on Number of Clients

In Table 6 shows the average time taken for the Local Forwarder to send the 1st sub-segment of a video to mobile client who joined the network according to the distance range from the Local Forwarder.

Table 6. Effect of Service Delay depending on Client Distance

<table>
<thead>
<tr>
<th>Number of Clients</th>
<th>EFSCS Avg.delay(seconds)</th>
<th>FSCS Avg.delay(seconds)</th>
<th>Random Cache Avg.delay(seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.49</td>
<td>0.68</td>
<td>1.08</td>
</tr>
<tr>
<td>10</td>
<td>0.49</td>
<td>0.68</td>
<td>1.06</td>
</tr>
<tr>
<td>20</td>
<td>0.49</td>
<td>0.68</td>
<td>1.07</td>
</tr>
<tr>
<td>30</td>
<td>0.49</td>
<td>0.68</td>
<td>1.06</td>
</tr>
<tr>
<td>40</td>
<td>0.48</td>
<td>0.68</td>
<td>1.06</td>
</tr>
</tbody>
</table>

The table and graph above shows the result obtained for the Effect of Client Fail that depends on Number of Clients. From the result above, it can be concluded that the probability of client has failed to receive the 1st sub-segment from the neighbors decreases when the number of clients increases. There are many factors that can cause failure for the client to cache the 1st sub-segment from the neighbors such as the neighbor is busy forwarding segment to another neighbor, the neighbor is disconnected from the network, or the neighbor stopped the service. The result shows that when the number of clients is 10, the probability of client fails and the First Base Caching Scheme is only 0.49 meanwhile for the First Segment Cache is 0.68 and for Random Cache it is 1. This is because when the number of client increases, almost all the clients will have the 1st sub-segment of movies in their First Buffer and even more than 1 client can have the same 1st segment of a movie in their First buffer. Hence the new client has more than 1 option to request for the 1st sub-segment of the movie that wants to watch. When there are only 10 clients, the probability of client fail is very high, it will be 0.4 of the Enhancement First Segment Cache Scheme, and 0.6 of the First Segment Cache, and 1.20 of the Random Cache. This situation is the worst case for Enhancement First Segment Cache Scheme because for this caching the number of clients must be more than the number of movies. The less the number of neighbors, the less chances for the new client to request for 1st sub-segment from its neighbors because there will be a situation where none of the clients have the 1st sub-segment requested by the new client. Finally after comparing the result with the caching schemes, it shows that the probability of client failure for First Segment Cache Scheme is very less.

Fig. 14. Graph of the Effect on Service Delay Depending on Moving Probability
8. CONCLUSION

As a conclusion, the simulation result shows that the proposed Enhanced First Segment Caching Scheme reduces the service delay in MANET Based Video on Demand System more than the other two existing caching schemes that are All Cache, Random Cache, and FSCS. EFSCS produces better results as its caching scheme ascertains that all the mobile clients that enter the MANET network assigned with a sub of first segment of a movie by the Local Forwarder to the client’s first buffer. When any clients would like to watch any movie, they can always request it from its neighbors immediately. Hence the delay time can be reduced when the number of clients per minute increases and the moving probability decreases, or when there are no moves. The probability of client failure is also reduced when the number of clients increases by the proposed Enhancement First Segment Caching Scheme.

REFERENCES