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Full Length Research Paper

A Novel Optimized Design of Popularity Cushion Staggered Broadcast over Video on Demand System

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Video on Demand (VOD) system is an electronic video rental system where the clients have the ability to request and view the video at any time, which makes the VOD to become an important technology with many applications. Numerous periodic VOD broadcasting protocols have been proposed to support a large number of receivers. Broadcasting is an efficient transmission scheme which provides on-demand service for very popular movies. This paper proposed a new broadcasting protocol called Popularity Cushion Staggered Broadcasting (PCSB) protocol. This proposed protocol improved the Periodic Broadcasting (PB) protocol for the latest mobile VOD system (MobiVoD). It also reduces the maximum waiting time of the mobile node, by partitioning the 1st segment of the whole video and storing it in the Local Media Forwarder (LMF) exactly as it is in the Pool of RAM (PoR) and then transmitting them when the mobile nodes missed the already broadcasted 1st segment. The results show that the PCSB is more efficient and better than all other types of broadcasting and caching techniques in the MobiVoD system. Furthermore, these results exhibited that system performance is stable under high dynamics of the system and the viewer's waiting time are less than 3.61374 s in most scenarios when compared with that in the previous system.

Key words: Video on Demand, Pool of RAM (PoR), Periodic Broadcast, Mobile Ad Hoc Networks (MANETs), Local Media Forwarder (LMF), Popularity Cushion Staggered Broadcasting (PCSB).

INTRODUCTION

Video on Demand (VOD) is a multimedia service which allows a remote user to select and then view video at his convenience at any time he wants (Alomari and Sumari, 2010). This system can be implemented under several approaches according to the technique that has been used to design the VOD systems. The designs of VOD systems are categorized rized into three main approaches; such as, Client/Server, Peer to Peer (P2P) and Periodic Broadcast (PB) (Tran et al., 2003; Tran and Nguyen, 2008; Chen et al., 2007). Each one of these approaches have such limitations (Tran et al., 2004). First of all, the Client/Server approach does not simply fit for MANETs. On the matter of facts this was due to the limitation of wireless bandwidth. Besides, this limitation of wireless bandwidth creates problems when the number of requests increases.

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The second approach stated the P2P approach which is not suggested to transmit the long video through more than one wireless hope, because of inefficient bandwidth and energy being used. Finaly, PB used to avoids the bottleneck problem in the client and server and in the same time service vulnerability of the P2P approach.

Nowadays, with the rapid deployment of wireless networks, people have this tendency to work outdoors and as a result we can see a rapid increase in the number of mobile users. This days also, the extension of transmission media from wired to wireless network has began a major advance in communication technology. Many of the wireless techniques such as Worldwide Interoperability for Microwave Access (802.16 WiMAX) (Andrews et al., 2007) have been developed which can provide long distance communication even more than 10 kilometers. Additionally, the wireless technology such as IEEE 802.11 (WiFi) (Cali et al., 1998; Huang and Lai, 2002) is a good example of the small local wireless network and bluetooth that is suitable for portable electronic consumer gadgets.

The mobile wireless technologies allow users to enjoy watching what they want at anytime and anywhere within the coverage area. After the researcher developed the video on demand (VOD) as an interactive multimedia system, a lot of practical application such as movies-on-demand, video conferencing, distance learning, interactive video games, etc, can be implemented due to the advancement of wireless technology. Some of these applications are utilized to make the users to enjoy ubiquities and provide entertainment service such as playing a game or watching a video of their interest online wherever they are. Universities could also install such a system on campus to allow students to watch video earlier recorded from lectures they were not able to attend. Airlines could provide VOD services in the airport lounges to record video information on the previous activities in public carnival.

Current trends have drastically made impact on VOD services due to deployment of various types of network infrastructures and availability of different types of mobile devices. Furthermore, the present VOD service in vogue is directed towards the digital media distribution through the Internet. Wireless communications provide the next level of freedom for accessing these technologies without any boundaries. This study provides a general overview of proposed solution that will demonstrate the system architecture of VOD for heterogeneous Mobile Ad Hoc Networks (MANETs) which is more challenging than the traditional networks, due to lack of proper infrastructure and different type of devices. As indicated in Figure 1, MANET consists of mobile hosts which are concerned with limited energy and unpredictable topology.

There are many Periodic Broadcasting (PB) protocols designed to provide efficient VOD services to potential large number of users without using too many resources from the clients, the server or the underlying network. Some of the major challenges in these broadcasting protocols is on how to reduce viewer's waiting time while maintaining a given bandwidth allocation and how to reduce a client's buffer requirement. In this paper, we proposed a new broadcasting protocol called Popularity Cushion Staggered Broadcasting (PCSB) protocol.This proposed protocol improves the PB (Tran and Nguyen, 2008) protocol for mobile VOD system (MobiVoD), based on broadcasting techniques(Tran et al., 2004), which includes different types of caching scheme to minimize the waiting time of the mobile clients.

In this paper, an overview of several broadcasting protocols, the proposed system called PCSB protocol and the simulation results were discussed.

BROADCASTING PROTOCOLS IN THE VOD SYSTEM

Assessing the performance of the broadcasting protocol is based on several metrics: client waiting time, server bandwidth, client bandwidth and client buffer space (Eager et al., 2001). The crucial trade-off indicates the comparison between the client waiting time and the bandwidth usage (Lakshman et al., 1998). Maintaining the worst client waiting time as small as possible was performed by several segment based broadcasting protocol. This is achieved by keeping the 1st segment based small while guaranteeing a jitter-free playback at the client end. Video segments are sent to the clients from all channels as a requirement of these protocols. Therefore, several client bandwidths are needed, besides, more buffer space will be needed in the client side. Accordingly, issues on decreasing buffer and bandwidth requirements are carried out by some recent studies (Yu et al., 2009). Moreover, several protocols concentrates on the following issues: variable bit rate (VBR), encoded video program support, video cassette recorder (VCR) functionality support, live video program support, seamless channel transition support and heterogeneous receivers support. For instance, VOD is a multimedia service allowing remote clients to connect and then view a video of his/her choice. With a True VOD service, the user feels free to interact with the media without restrictions. In fact, he/she can perform VCR operations such as Fast Forward (FF), Pause/Resume and Jump Forward/Backward (JF/JB) (Kwon and Yeom, 2002).

Figure 1. Wireless ad hoc network (K.Al-Omari and Sumari, 2010).

Client waiting time versus server bandwidth

In Staggered Broadcasting (SB) (Almeroth and Ammar, 1996) protocol, K (which indicates the number of available channels) channels are allocated by the server to perform the transmission of a video program. In each channel, there is a fixed rate b, that is of the same rate as video playback. The maximum client waiting time in SB is L/K, where L indicates the video program length. The Pyramid Broadcasting (PyB) protocol (Viswanathan and Imielinski, 1995), a video program that is divided into K geometric increasing-sizes of segments. These segments are transmitted on multiple channels with the same amount of bandwidth. A factor α is contained in the geometric series, such that α >1. Ensuring an on-time delivery where the 1st segment is 1/α of the size of the 2nd segment is important as the playback time of the 1st segment must be at least equal to the broadcasting time of the second segment. It would be significant to guarantee on-time delivery where the 1st segment is 1/α of the size of the 2nd segment. Therefore, the 1st segment must have a broadcasting time of 1/α of its playback time. In addition, the 1st channel should have a bandwidth requirement of at least α time of the video playback rate. Small client waiting time is needed to be less than the time of the SB protocol. This is required by the PyB protocol where a fixed server bandwidth takes place.

In Fast Broadcasting (FB) protocol (Juhn and Tseng, 1998), a video program is divided into 2*K*-1 segments. On channel C_i, the broadcasting segments, 2i-1 to 2i-*n* is in order. L/(2K-1) is considered as the maximum client waiting time. Smaller client waiting time is obtained by the FB protocol when compared with SB and PyB protocols. Paris and Long (1999) proposed a new pagoda broadcasting protocol (NPaB) to divide a video program into fixed size segments and mapping it into equal bandwidth of data channels. The process is performed through proper decreased frequencies. As a result of this protocol, NPaB protocol obtained smaller waiting time than FB protocol. Tseng et al. (2002) has improved the NPaB protocol by proposing the Recursive Frequency Splitting (RFS) protocol. This improvement was based on client waiting time. In every continuous time slots, each segment (Si) should appear at least once in the segment based on broadcasting protocol. A time slot is the duration of viewing a segment at the video playback rate. Moreover, the main concept behind RFS protocol is to broadcast a segment very close to its frequency based on this protocol. Bar-Noy and Ladner (2003) formalize the segment to channel mapping as the windows scheduling problem, and proposed the greedy broadcasting protocol that is exactly similar to RFS protocol. Nonetheless, computational complexity of O (N log N) affects the RFS protocol, where the number of segments of the video refers to N. In Harmonic Broadcasting (HB) protocol (Juhn and Tseng, 1997a), a video is divided into many equal size segments in the first step, then these segments are horizontally divided into equal size sub-segments. This later division is based on the harmonic series. On the same channel, the sub-segments of the same segment Si are broadcasted with bandwidth (b/i). It was proven by Tseng et al. (2002) that the least client waiting time is required by the HB protocol through the same server bandwidth. It was shown by Paris et al. (2001) that this protocol cannot continuously have video data being delivered at a specific requirement time, unlike the proposed cautious harmonic broadcasting (CHB) and quasi-harmonic broadcasting (QHB) protocols that solved the indicated problem (Paris et al., 2001).

Bandwidth requirements and buffer at client end

Skyscraper Broadcasting (SkB) protocol was proposed by Hua and Sheu (1998), which allows the client to download video data via two channels. In Client centric approach (CCA) (Juhn and Tseng, 1997b), a client is expected to download video data using a small number of channels. As a matter of fact, this protocol is taken into account to be a generalization of SkB protocol. The reason for this is that more than two channels can be provided to each transmission group. However, extra client bandwidth could be leveraged by the CCA protocol in contrast to the SkB protocol. Thus, the CCA protocol reduce the waiting time of the client. Cai et al. (2001) proposed the GDB protocol to systematically analyse the resource requirements (that is, client buffer space, server bandwidth and client bandwidth). Furthermore, a tradeoff is encountered in the protocol among any two of the three resources. GDB (greedy disk-conserving broadcasting) protocol can have smaller client waiting time than the CCA protocol. This happens when constraints of client bandwidth and client buffer space are given. However, these protocols obtain higher client waiting time than the FB protocol. Staircase Broadcasting (StB) protocol (Gao, 2002) similarly obtains the same client waiting time of the previous protocol (FB protocol). It requires a client to buffer 25% of a playing video which is ½ of what FB protocol requires. Besides, a client bandwidth is required by the StB protocol as twice as the video playback rate. Smaller waiting time, higher client bandwidth and client buffer space when compared to the StB protocol is supported by the Modified Staircase Broadcasting (MSB) protocol (Chand and Om, 2002). SB and HB protocols are combined by the Interleaving Staircase Harmonic Broadcasting (ISHB) protocol (Yang et al., 2005). The aim of this protocol is to acquire a good tradeoff among the client waiting time and client buffer space. The HB protocol is slightly lower than client waiting time, where it provides a theoretical lower bound. SB protocol has a higher waiting time than the ISHB protocol. In addition, it also has the same client buffer space as SB protocol. Besides, the video quality degradation caused by packet loss could be eliminated by the ISHB protocol. FB protocol has the same client waiting time as the Reverse Fast Broadcasting (RFB) protocol (Yu et al., 2007), but only 25% of a playing video is buffered. Hybrid Broadcasting (HyB) protocol (Yu, 2008) combines both, the RFS and the RFB protocol. The RFS protocol is slightly higher than client waiting time and the RFB protocol is as the same as the client buffer space. Extending the GDB protocol by applying the reverse segment transmission and lazy segment downloading, reverse greedy disk-conserving broadcasting (RGDB) protocol (Yu et al., 2008) has 33-50% smaller client buffer space than GDB protocol. Recently, a series of broadcasting protocol was proposed by Jeong et al. (2008) to combine SB protocol with PB, SB, FB, RHB and

Table 1. A comparison of different segment based broadcasting protocols.

S/N	Broadcasting protocols	Waiting time (second)	Storage space (% of the video)	Client bandwidth
		Client waiting time vs. server bandwidth		
1	SB	L/K	0	B
2	FB	L/(2K-1)	50	K*b
3	HB	HB L/eK-0.57722	37	K*b
4	NPaB	HB < WT < FB	45	K*b
5	CHB	HB < WT < FB	37	K*b
6	QHB	HB < WT < FB	37	K*b
7	RFS	HB < WT < FB	37	K*b
		Bandwidth requirements and buffer at client end		
8	StB	L/(2K-1)	25	2b
9	MSB	HB < WT < FB	37	(K-1)*b
10	RFB	L/(2K-1)	25	K*b
11	SkB	Adjustable, WT > FB	10	2b
12	ISHB	ISHB HB < WT <FB	25	(K-1)*b
13	HyB	HB < WT < FB	25	K*b
14	GDB	Adjustable, WT > FB	Adjustable	Adjustable
15	RGDB)	Adjustable, WT > FB	Adjustable	Adjustable
16	CCA	Adjustable, WT > FB	Adjustable	Adjustable

PFB protocols so as to decrease the client buffer space. Since mobile wireless clients usually have limited resources including bandwidth and cache space, some of these techniques such as (HB, FB, and PB) are not well suitable. PyB seems a better option considering the client bandwidth but its client caching requirement remains very high. The two potential techniques for efficient deployment in a large-scale wireless environment are SB and SkB.

We have summarized the whole characteristics and the client resource requirement of different broadcasting techniques that have been discussed earlier in Table 1. Nevertheless, none of these broadcasting techniques can provide true video on demand (TVOD) due to their non-zero service delay. Comparing SB and SkB, the SkB provides less service delay, but it is more complex and requires that the client be capable of downloading at a rate twice as large as the playback rate and should have a caching space enough for approximately 10% of the video length. By way of conclusion, the SB is the better choice for the current wireless architecture because of its simplicity and the storage space is 0%.

THE SYSTEM ARCHITECTURE FOR PCSB

The new broadcasting protocol called Popularity Cushion Staggered Broadcasting (PCSB) Protocol for mobiVOD system guarantees the viewer's waiting time to be less than that of previous methods.

As indicated in Figure 2, the main components of the PCSB can be classified into five main categories: 1) central VOD services provider (CVSP), 2) local media forwarder, 3) networks, 4) mobile clients and 5) broadcasting protocols. The previous papers explained briefly the component of the system (Alomari and Sumari, 2010; Alomari et al., 2010). The main problem with this broadcasting protocol is its service delay, particularly, when the clients miss the broadcasting of the 1st segment, they have to wait to join the next broadcasting channel and playback the 1st segments of the video. The following section will discuss how the new PCSB protocol can be adapted to VOD systems in large-scale wireless networks in order to minimize the delay.

Analysis of CVSP and LMF

Let us define video k with Qth quality, it is denoted as (VkQ) which is encoded at a rate S_{kQ}^{rate}, which are denoted as follows $S_{k1}^{rate}, S_{k2}^{rate}, S_{k3}^{rate}, \ldots S_{kQL_k}^{rate}$. We first considered how to determine whether the video is stored in the LMF or not. It is assumed that $P_{rob}R_j$ is the probability of the users requesting VkQ ∀k where, $\sum_{Q=1}^{QL_k} P_{rob}R_j = 1$. In the proposed system, the LMF simply stores the most popular videos to maximize the cache hits, we define the media forwarder map as MF_{kQ}, which is used to describe the subsets of video replicas in its cache. The MF_{kQ} is set to 1 if the VkQ is in the media forwarder. Otherwise, it is set to 0. Therefore,

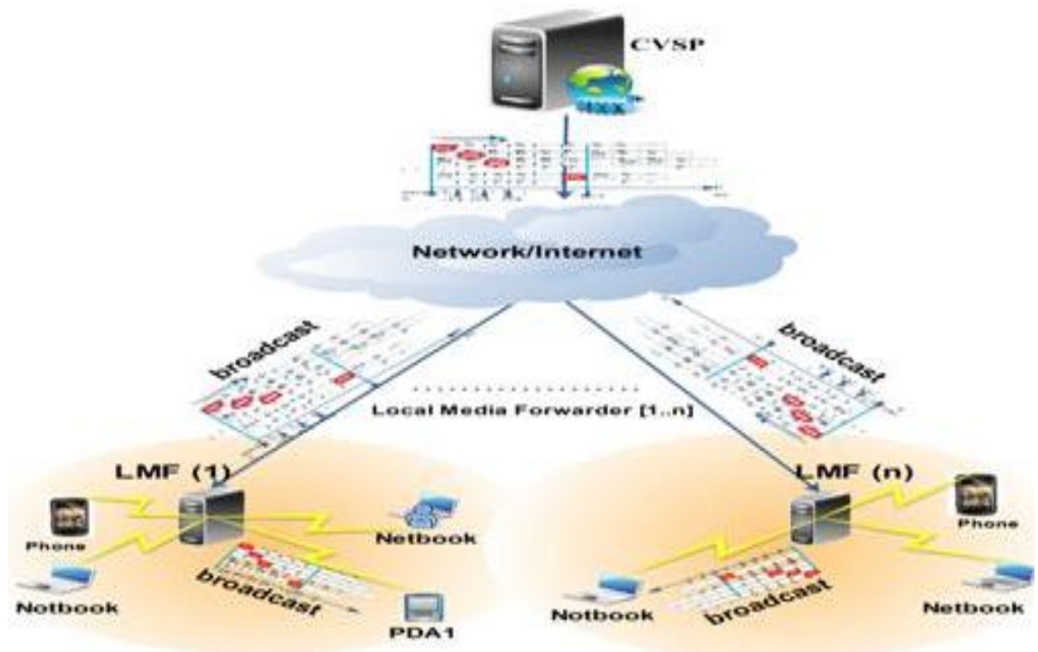

Figure 2. The system architecture for the PCSB.

the cache hits the optimization problem that can be expressed as:-

$$\sum_{k=1}^{K} \sum_{Q=1}^{QL_k} P_{rob}K * P_{rob}R_j * \mathrm{MF}_{kQ} \quad (1)$$

Where, the $P_{rob}K$ is the probability of the video and $P_{rob}R_j$ is the probability of the users request.

$$\sum_{k=1}^{K} \sum_{Q=1}^{QL_k} S_{kQ} * \mathrm{MF}_{kQ} \leq S_{\mathrm{MF}} \quad (2)$$

Where, the S_{kQ} is the size of the video k encoded in Qth quality (bits) and S_{MF} is the size of the media forwarder.

Based on Figure 3, VkQ is broadcasted from the CVSP to the LMFs. After that, the VkQ is sorted by the LMFs in the ascending order into the stack based on the popularity $P_{rob}K * P_{rob}R_j$. In the stack, each value contains (VkQ, $P_{rob}K * P_{rob}R_j$) pair. From the top of the stack, one value is selected by each loop. If inside the LMF the cache is high to accommodate the related video content, then the VkQ for this video will be set to value “1”. Otherwise, the process continues and the next value will be selected by this process from the stack until the entire cache space is allocated. Once VkQ has been found by maximizing the efficiency of the cache, the fraction of requests can be identified. This fraction rises to the CVSP for the dedicated streams. Since the LMF is already saturated by the number of the requests, the remains of the request will get through the PoR, where Equation 3 can compute the arrival rate of these requests. Since the delivery of the multiple qualities of the video streams are at different data rates from CVSP, LMF and PoR to the mobile clients, then Equation 4 can calculate the average streaming rate.

$$\lambda_{stram}^{rate} = \lambda \,(1 - \sum_{k=1}^{K} \sum_{Q=1}^{QL_k} P_{rob}K * P_{rob}R_j * \mathrm{V}_{kQ}) \quad (3)$$

Where, the λ_{stram}^{rate} is the arrival rate of dedicated stream (request/second) of the broadcasting.

$$AS^{rate} = \frac{\lambda}{\lambda_{stram}^{rate}} \sum_{k=1}^{K} \sum_{Q=1}^{QL_k} P_{rob}K * P_{rob}R_j * S_{kQ}^{rate} * \overline{\mathrm{MF}}_{kQ}) \quad (4)$$

Where, the AS^{rate} is the average stream rate of the detected stream (bit/ second) of the broadcasting, S_{kQ}^{rate} is the streaming rate of the video k having Qth quality level (bits/ second) and $\overline{\mathrm{MF}}_{kQ}$ is the complement of the MF_{kQ}.

According the discussions in Chapters 5 and 6, the scalability issues can be raised by CVSP. The reason of this is that it is considered to be the bottleneck of the system itself when numerous numbers of video streams are being served. Therefore, we specifically concentrate on the performance of both; LMF/PoR and CVSP to provide video on demand services.

The available bandwidth between the CVSP and LMF refers to b. On the matter of fact, the number of video streams (Nvi) can be supported by both of them at the same time based on the Equation 5. Moreover, we assume that the service time (T) of each video stream is exponentially distributed with service rate $\mu = \frac{1}{T}$ by considering the varying length of different videos.

$$N_{vi} = \frac{b}{AS^{rate}} \qquad \textit{Where, } v_i = \{1, 2, 3...K\} \qquad (5)$$

As shown in the Equation 6, the blocking probability is formulized. If the bandwidth from the media forwarder to the clients is large enough and no requests will be blocked, the overall of the blocking probability of the system will be given by Equation 7.

$$P_{rob}\ b^{r} = \frac{\left(\frac{\left(\lambda^{rate}_{stram}/(\frac{1}{T})\right)^{N_{vi}}}{N_{vi}}\right)}{\sum_{z=0}^{N_{vi}}\left(\frac{\left(\lambda^{rate}_{stram}/(\frac{1}{T})\right)^{z}}{z}\right)} \qquad (6)$$

$$P_{rob}\ OA^{rate} = \frac{\lambda^{rate}_{stram} * P_{rob}\ b^{r}}{\lambda}$$

Where, $P_{rob}\,OA^{rate}$ is the overall blocking probability of the system and λ is the system arrival rate (request/second).

Analysis with Broadcasting Protocol

By employing the caching and broadcasting techniques, the enhancement in the performance can be gained. Apart from storing the popular videos in the LMF, some popular videos will also be broadcasted to the clients over the backbone network as well as over the PoR. For example, a low quality video can be delivered over the broadcasting channels while the higher encoded version of the same video is transmitted to the clients through the dedicated streams. Then, it is necessary to determine which video can be delivered over the broadcast channels. Since our goal is to improve the overall performance of the system, as well as the broadcasting and caching techniques. Generally, any efficient protocols, such as (Hua and Sheu, 1998) (Liu and Jack, 2003), can be applied to the framework, as the broadcasting bandwidth and caching requirement is based on the transmission schedule and user bandwidth constraints. In chapter 6 is denoted KPCSB (KPCSB= {C_{hannel}^{1}, C_{hannel}^{2},…C_{hannel}^{k}}), as the number of channels required for the protocol PCSB to broadcast a video such that the start-up delay is insensitive to the clients. It is also assumed that each receiver is equipped with enough buffers to implement the efficient broadcasting protocol. To determine which popular video should be sent over the broadcasting channels, we use XkQ to check whether the VkQ is already broadcasted or not yet. The consumption bandwidth for broadcasting can be calculated as follow Equation 8.

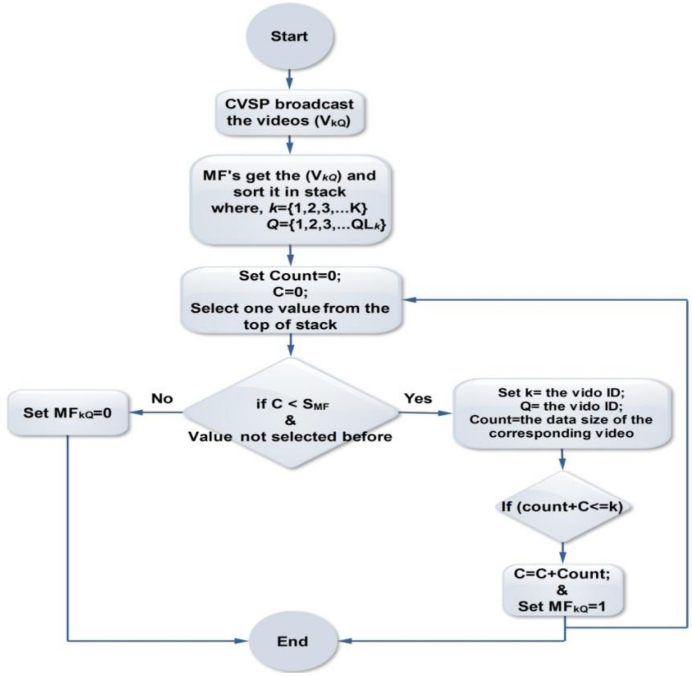

Figure 3. The procedure to determine which video should be cashed in the LMF.

$$b^{brod} = \sum_{k=1}^{K}\sum_{Q=1}^{QL_k} S^{rate}_{kQ} * K^{PCSB} * \overline{MF}_{kQ} * X_{kQ} \qquad (8)$$

Where, b^{brod} is the bandwidth required for broadcasting, K^{PCSB} is the number of the channels, $\overline{MF}_{kQ}$ is the complement of the streaming rate if the required video k have Qth quality lever per-bits (MF_{kQ}).

Similarly, in the LMF caching, XkQ is selected for the broadcasting channels according to their popularity. For example, based on the previous explanation, the videos will be sorted depend on their popularity, where the most popular video "first video in the stack" will be broadcasted. Assume that the broadcasting bandwidth is (preserved), in one case it will found that the video XkQ with the broadcasting bandwidth doesn't exceed the capacity of the existing bandwidth. That means the required broadcasting bandwidth need to be is less or equal the reserved broadcasting bandwidth (b<= preserved). This occurred due to some replicated videos are being broadcasted. Equation 9, demonstrates the arrival rate for the dedicated channels. This rate is equal to the arrival rate to the system minus the arrival rate to the LMF as well as the arrival rate to the broadcast channels itself. The average streaming rate of the dedicated channels can thus be found by Equation 10.

$$\lambda_{stram}^{brod} = \lambda\,(1 - \sum_{k=1}^{K} \sum_{Q=1}^{QL_k} P_{rob}K * P_{rob}R_j * \mathrm{MF}_{kQ} \qquad - \sum_{k=1}^{K} \sum_{Q=1}^{QL_k} P_{rob}K * P_{rob}R_j * \overline{\mathrm{MF}}_{kQ} * \mathrm{X}_{kQ}) \tag{9}$$

$$AS^{broad} = \frac{\lambda}{\lambda_{stram}^{brod}} \sum_{k=1}^{K} \sum_{Q=1}^{QL_k} P_{rob}K * P_{rob}R_j * S_{kQ}^{rate} * \overline{\mathrm{X}}_{kQ}\ ) \tag{10}$$

Where, λ_{stram}^{brod} is the arrival rate to the broadcast channels, AS^{broad} is the average streaming rate of the dedicated channels and $\overline{\mathrm{X}}_{kQ}$ is the complete of the $\mathrm{X}_{\mathbf{kQ}}$.

Furthermore, as b is the available bandwidth, the number of streams that can be concurrently supported by the CVSP is calculated as follow: $N^{brod} = \frac{b-b^{brod}}{AS^{broad}}$, and the to the Equations 6 and 7, the overall blocking probability can be found accordingly (Prabhu, 1997).

PCSB architecture

In the PCSB, the whole video is divided into K equal size segments (*Seg1*, *Seg2*, *Seg3*, …, 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. Every physical channels (C_{hannel}^{1}) must be between 1 ≤ i ≤ *k*. We decide the provider bandwidth as Pb*K for the 2nd video and so on, where Pb Mbps is the consumption rate or playback rate. This bandwidth is partitioned into C_{hannel}^{1} repeatedly broadcasting the video segments (*Seg1*, *Seg2*, *Seg3*, …, Seg^K) with transmission rate (*Tr)* equal to playback rate (*Pb)* as shown in Figure 4. The client x can join C_{hannel}^{1} and wait for the beginning of segment (*Seg1)* to download and playback. After that, the client x switches to the next segment (*Seg2*) for downloading. This process is repeated for subsequent segments until the last segment (*SegK*) is downloaded from C_{hannel}^{1}. Equation 1 follows the definition.

$$V = \sum_{i=1}^{k} \mathrm{D}i \tag{11}$$

Based on Figures 2 and 4, each Local Media Forwarder (LMF) joins all the broadcasting channels and therefore receives the entire packet broadcast from the main server. The broadcast technique is exactly the same as that in the main server and it is used to broadcast the packet to the service area. In this case, all the clients in the LMFs area will receive the broadcast packets. In the VOD broadcasting, the starting time for the video program varies based on each K channel. Figure 5 illustrates the number of channels and the process of broadcasting through them. As shown, if the first channel starts broadcasting video at the Pb Mbps at the time T_0, the second channel starts broadcasting the same video at the time T_0 + V/K, the third channel at the time T_0 + *2V/K*, and so on. The difference in the starting times, *V/K*, is known as the phase offset shifts. Since a new stream of a video program starts every phase offset, it is the duration that each client needs to wait for this video to playback that counts.

Additionally, the bandwidth limit of the LMF determined by the value K. the bandwidth capacity of a LMF knows as *b* (Mbps) and the number of the video broadcast from the server knows as N_V are utilized in the following relationship to determine the value *K*.

$$\mathrm{Tr} \times K \times \mathrm{N}vi \leq b \quad where\ i = \{1,2..N\} \tag{12}$$

Given that each video has a transmission rate, Tr = 1.5 according to MPEG -1(also known as MP 3), where the number of the video, N_V =5 and the providers bandwidth *b* = 54 according to 802.11 g. Depending on equation 2, (1.5 * K * 5 < = 54), the result of K must be less than 7 as elaborated in Figure 5. Equation 13 follows the definition:

$$b = \sum_{j=1}^{K} \mathrm{b}j \tag{13}$$

Where, *b*j is a bandwidth of logical broadcasting channel as a ratio over b, j=1, 2,…K.

The server bandwidth is Tr × *K* for the 2nd video and so on. This bandwidth allocation is divided into K logical channels, each repeatedly broadcasting the video with Tr= 1.5 Mbps which is equal to the Consumption Rate (1.5 Mbps). The scheduling of these broadcasts is

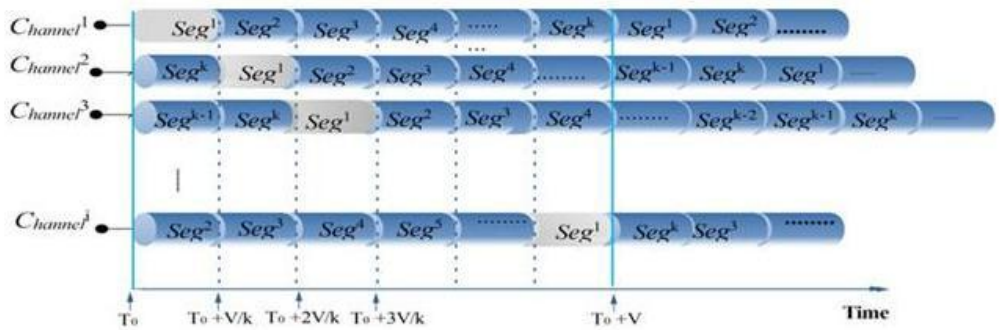

Figure 4. Video division into segements by broadcasting protocol and segment Seg^i broadcasting at physical channel C_{hannel}^{i}.

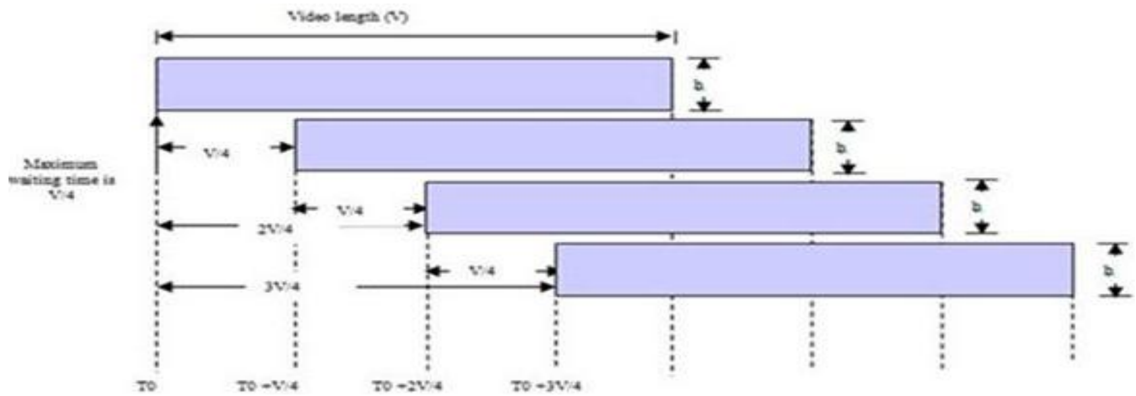

Figure 5. Broadcasting protocol starting times for video across each physical channel.

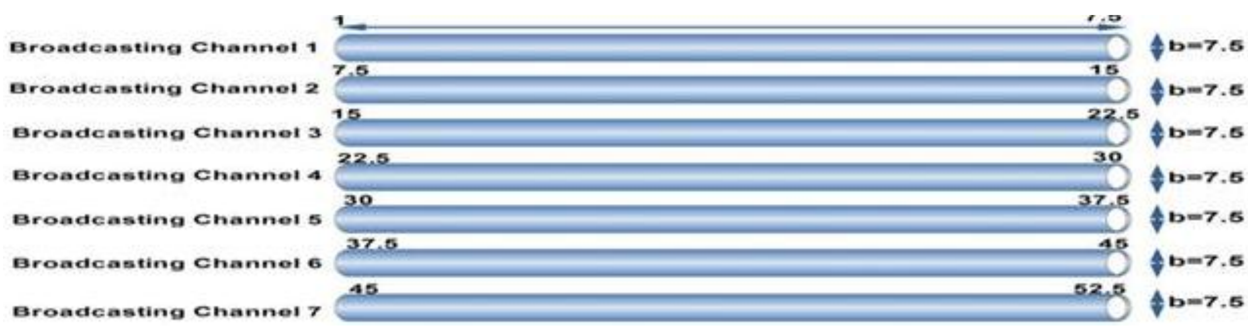

Figure 6. Maximum number of the broadcasting physical channel K when Nv =5.

illustrated in Figure 6. The bandwidth of each video is: $(Tr * K) \Leftrightarrow (1.5 * 5 = 7.5 \text{ Mbps})$. For example, when K=5, its means each video has 7.5 Mbps from 54 Mbps. The number of the segments will be equal to the number of the logical channels, where the size of the segment will be 12 min. So the video will be divided into five equal size segments and broadcasted in five logical channels. The scheduling of these broadcasts is illustrated in Figure 7.

Transmission Rate(r) =1.5

Bandwidth of the broadcast channel / number of the segments = 7.5/5 = 1.5. It means that each logical channel has bandwidth 1.5 Mbps from 7.5 Mbps to repeatedly broadcast the video segments *(Seg1, Seg2, Seg3, …, SegK).*

The service latency of each video when the number of the channels, *K*=7 is $(Tr * K) \Leftrightarrow (1.5 * 7 = 10.5 \text{ Mbps})$. It means that each video have 10.5 Mbps from 54 Mbps. This bandwidth allocation is divided into five logical channels, each repeatedly broadcasting the video with a

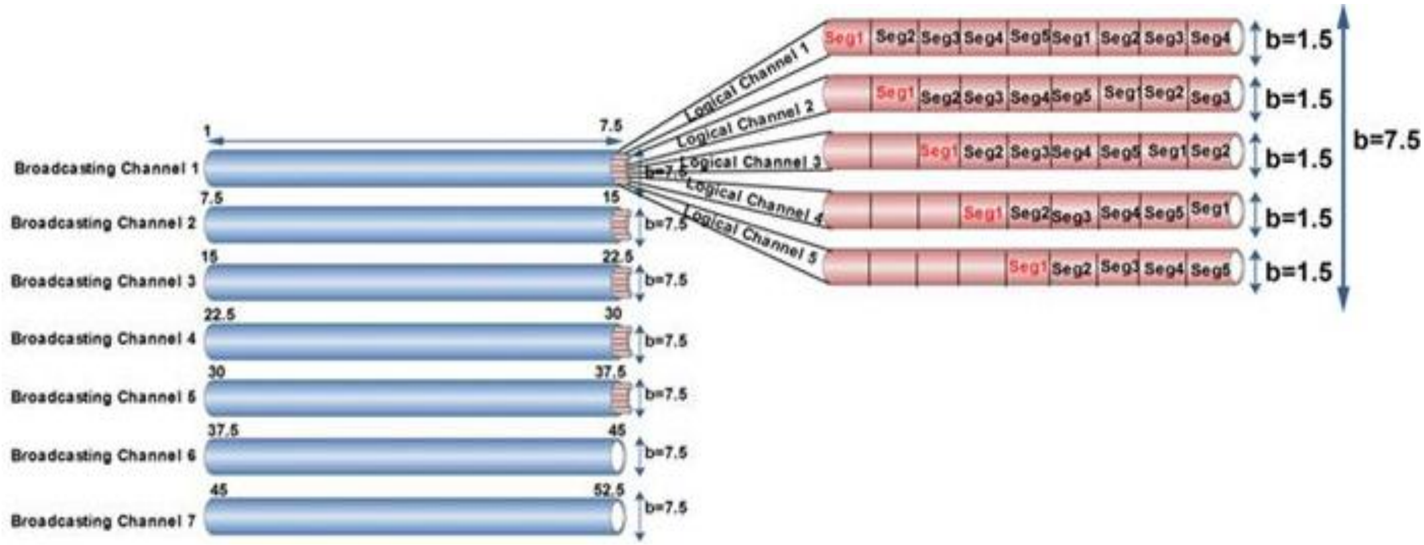

Figure 7. Channel broadcasting the video into logical channel when V=60 min, D=12 and K=5.

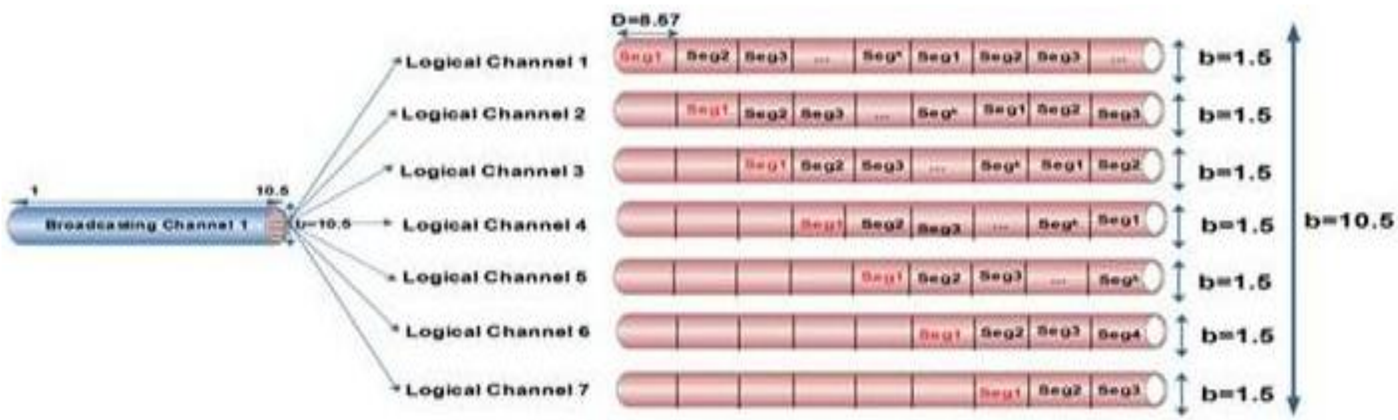

Figure 8. Channel broadcasting the video into logical channel when V=60 min, D=8.57 and K=7.

Transmission rate equal to the consumption rate. The scheduling of these broadcasts is illustrated in Figure 8.

PCSB SIMULATION MODEL

The characteristic of the broadcasting technique is shown on Table 2. The broadcast of the video starts at Channel1 at the system setup time of T_0, at the same time, Client x request to join the Channel1 to get the 1st segment, and in this case Client x will get the services without delay. However, if Client Y needs to join the same channel (C_{hannel}^{1}) to get the 1st segment, Client Y already misses the broadcast packet of the Seg1 and therefore Client Y must wait until the next broadcast of the 1st segments begins. Assuming the number of the channels is 5, which is suitable with 802.11 g = 54 Mbps and MPEG-1 = 1.5, and the size of the video is 60 min, so the duration of each segment is D*i*= V/K = 60/5 = 12. In the worse case, the delay is the duration of the 1st segment, D*i*=12 and in the best case, when the number of the channel is equal to 7, the services latency would be 60/7= 8.75142.

Popularity cushion caching mechanism

Based on the well-known mechanism called popularity cushion caching mechanism, the waiting time must be eliminated. To minimize the services latency, we assume we install a scatter of LMF, LMF install indoor environment such as buildings {*LMF1, LMF2 LMF3, ..., LMFk*}. The LMFn is a stationary and dedicated computer, used to relay the service to LMFn transmission coverage area and Local Services Area (LSA) network. In the proposed mechanism, LMF is acting as a node, which is equipped with a wireless network interface card (WNIC), and then they are able to form a Mobile Ad Hoc Network (MANET). The main server transmits the video packets to the LMF and then broadcast it to the mobile nodes within the transmission ring of the local services area network through the WNIC.

Consider there is a client x which arrives in the LSA1. The client x starts searching to find the closest LMFs and then request to watch the video 2. This client then tries to find the channel from the LMF*n* that is going to broadcast the 1st segment of the video 2 soonest, and directly joins the broadcasting channel to get the 1st

Table 2. Characteristics of the broadcasting technique.

Parameter	Notation
Segment	*{Seg1, Seg2, Seg3, …, SegK }*
Length of a video	V
Duration of the segment	D*i*
Channels	C_{hannel}^{i}
Playback rate	*Pb*
Starting Time	T_0
Probability of the channel C_{hannel}^{i}	1 <= *i* <= *K*
Probability of watching a video at T0	$P_{arrival}$
Waiting time for the client (Delay)	D = Maximum waiting time is V/K
Services bandwidth	*b*K*
Number of the Video	N_{Vi} $_{i=\{1,2,3….N\}}$
Total number of the users	T*n*

Figure 9. Client x join the channel (Channel 1) at times zero (T_0).

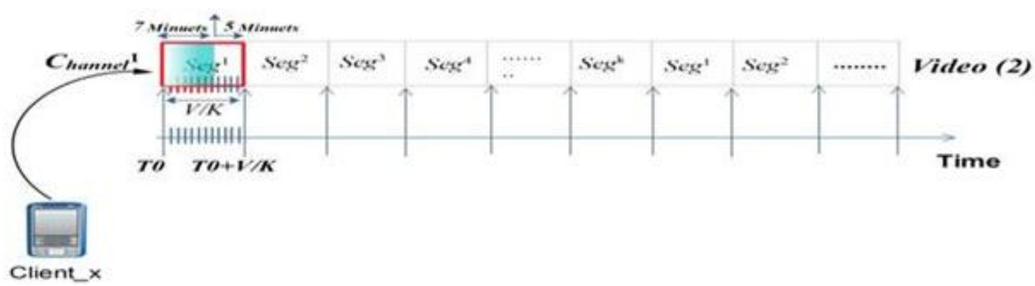

Figure 10. Client x streaming the (first 7 min from the 1st segment) without delay from Channel1.

segment. For instance, as shown in Figure 9, getting the services from C_{hannel}^{1} at time zero (T_0).

Assume the size of the video is 60 min and *K* is 5. So *V/K* = 60/5= 12. Then the number of segments will be 5 and the size of each segment will be 12 min or 720 s. If the Client x joins the channel at T_0 ($T_{request} = T_0$), the Client x will download and playback the 1st segment without any delay and at the same time the 1st segments will be stored in the Prefix-Buffer. Once Client x finishes downloading the 1st segment (*Seg1*), the client immediately switches to the second segment (*Seg2*) to download it on the same channel and so on until all the segments have been downloaded. The probability of the client watching a video at times zero (T_0) is determined as follows:

$$P_k = \binom{n}{k} P_{arrival}^{k} \left(1-P_{arrival}\right)^{n-k} \quad (14)$$

Where $P_{arrival}$ is the probability of is watching the video at times zero (T_0), n is the number of the clients in the area and k is the number of the channels connected with the forwarder.

We suggest that the Client x joins the C_{hannel}^{1} and starts watching the first 7 min of the 1st segment of the video 2 as shown in Figure 10 at the same time Client Y requested the same video from the LMF at T_0+ D*i* + δ (0 < δ < D*i*). After checking the broadcasting channels, Client Y will realize that he or she has already missed the current broadcast of the 1st segment from video 2 as shown in Figure 11. In this case, Client Y has already missed the 1st segment (the first 7 minute of the 1st segment). Now Client Y cannot join the C_{hannel}^{1} and must wait for the next broadcast of the 1st segment (T_0+2V/K). To solve this problem and make the client get the video packet without waiting for the next broadcast of the 1st segment, the client directly requests the 1st segment from the

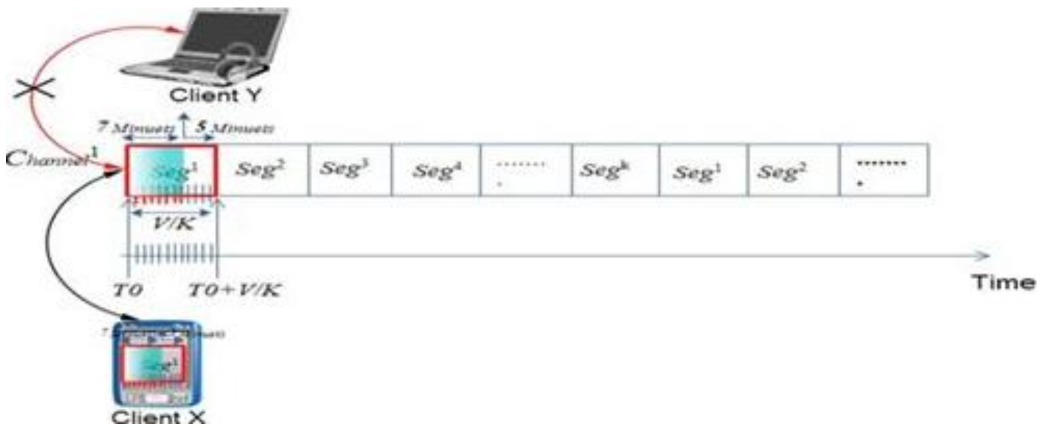

Figure 11. Client Y misses the current broadcasting of the 1st segment from C_{hannel}^{1}.

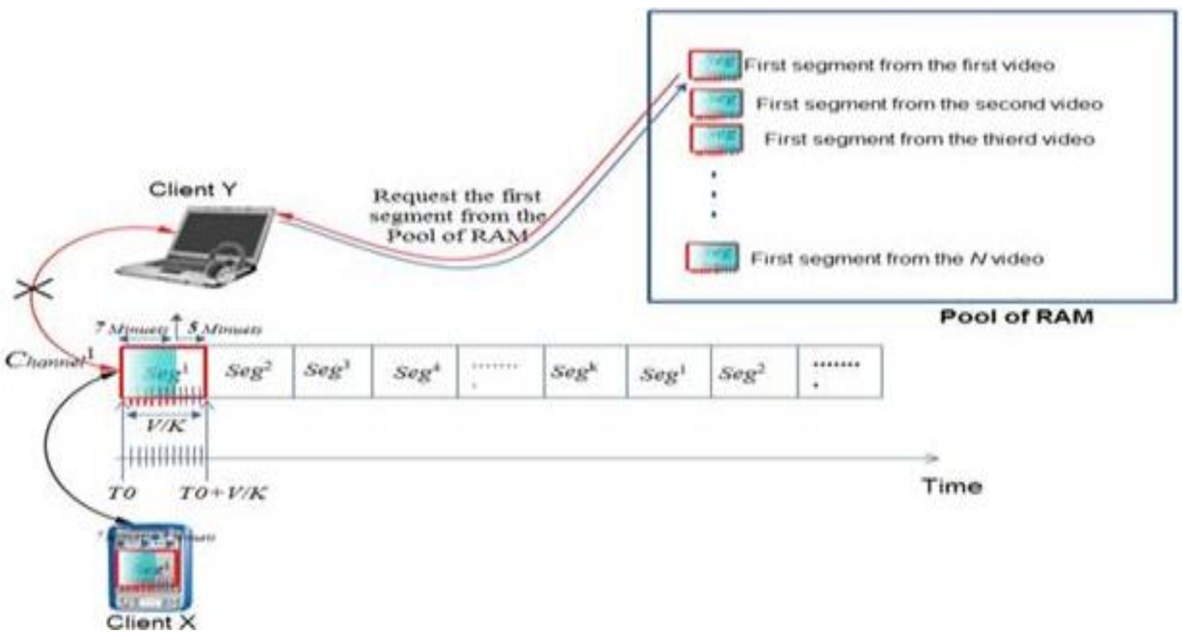

Figure 12. Client Y gets the service (1st segment from the PoR).

existing LMF in its transmission range. The LMFs have stored the 1st segment of the whole video in a Pool of RAM (PoR) as shown in Figure 12.

Simulation model of the pool of RAM (PoR)

Table 3 shows the characteristics of the Pool of RAM (PoR). Let N_{Vi} be a stochastic variable representing the number of videos, and it may take the different values of N_{Vi} (i=1, 2, 3,…N). D_i is the size of i^{th} video (duration of each video/minutes) where i^{th} could be =1, 2, 3,…N, with arrival rates $\lambda_{i.}$ ($i=\lambda_1, \lambda_2, .. . \lambda_N$) respectively that are being sent to the users using LMF. LMF has enough space to store a number of prefix segments in the Pool of Ram (PoR), T_{zPoR}/minutes of T_{nvPoR} number of segments at PoR.

It has been previously explained how the video is staggered into several segments of equal sizes and broadcast to the mobile clients. There are two-factors that determine the duration of the segments: the size of the video and the number of the broadcast channel. However, when the LMF broadcast the *Vi,* the LMF will store the 1st segment in the PoR, where the T_{zPoR} minute of each segment is referred to as *(pref)i*, for example {(V_1, *Seg1*), (V_2, *Seg1*), (V_3, *Seg1*)…. (*Vn, Segk*)}. The remaining portion of the video segments is referred to as a suffix of the rest *Vi.*

$$T_{zPoR} = \sum_{i=1}^{T_{NvPoR}} (Pref)i\,, \quad where\ T_{zPoR}\,(Pref)i > 0 \tag{15}$$

However, the frequency of mobile clients requests to any segments determines the popularity (P_{rob}) of the segments and size of the prefix to be cached in the PoR. The S_{zPref} of *(pref)i* for a number of videos can be calculated as follows.

Table 3. Characteristics pool of RAM (PoR).

Parameter	Notation
Number of the Video	N_{Vi} ,where vi is video {1,2,3..N}
Length of a video (minutes)	Vi
Segment	K ={*Seg1* }
Duration of the segment	Di ={*Seg1* }
Arrival rate	λi
Pool of RAM	PoR
Local Media Forward	LMF
SzPref minutes of video Vi	pref-1
Size of pref-1	S_{zPref}
Total number of videos/segments at PoR	T_{nvPoR}
Total size of Pool of RAM (minutes)	T_{zPoR}
probability of occurrence of user requests	P_{rob}

$$S_{zPref}\,(pref)i = P_{rob} \times D_i \quad ,where\ 0 < P < 1 \tag{16}$$

Where D*i* is the size of the 1st segments (*Seg1*) of the *ith* video (*i*=1, 2, 3,…N), and P_{rob} is the probability of occurrence of mobile clients requests with frequency of segment *i* from last *t* minutes. This arrangement enables the Pool of RAM (PoR) to cache maximum portion of most frequently requested video segments. Hence, in this case, most of the mobile client's requests can be served immediately from PoR, which significantly minimizes the Request Service Delay (RS_{dealy}) for the mobile clients and the network Bandwidth Requirement (BW^{PoR}) in the local media forwarder. Furthermore, the rejection request from the PoR is very low in the system because the LMF will store the 1st segment of each video broadcast in the PoR and when the mobile clients miss the 1st segment from the current broadcast, it will request it directly from the PoR. The rejection request ratio (R_{reject}) is defined as the ratio of the number of requests rejected (N_{reject}) to the total number of requests arrived (N_{ra}) at the system, which is inversely proportional to the system throughput.

The system efficiency ($S_{efficient.}$) is estimated according to the following equation:

$$S_{efficient} = \frac{\text{Total number of requests served}}{\text{Total number of requests arrived}} \tag{17}$$

Where the N_{rs} is the ratio of the number of requests served to the total number of requests arrived (N_{ra}) at the system. So in this case the maximum system efficiency, the average bandwidth usage and average Request Service Delay (RS_{delay}) are according to the following equations:

$$S_{efficient} = \frac{N_{rs}}{N_{ra}} \tag{18}$$

$$BW^{PoR} = \sum_{i=1}^{N_{rs}} BW\,(D_i - (pref))_i^{PoR} \tag{19}$$

$$RS_{delay} = \frac{1}{N_{rs}} \sum_{i=1}^{N_{rs}} (RS_{delay}) \tag{20}$$

The average rejection request ratio (R_{reject}) in the system is shown in the following equation:

$$R_{reject} = \frac{N_{reject}}{N_{ra}} \tag{21}$$

Playback procedure of PCSB

Figure 13 shows the playback procedure of PCSB protocol. The PCSB protocol is simply explained within four steps. Firstly, as shown by Figure 14, once the clients x detects the LMF and then finds that the Channel from LMF is going to broadcast the 1st Segment at the time T_0, the client downloads and playbacks the 1st segment and caches it in the Prefix-Buffer, where the size of the Prefix-Buffer is the same size as the 1st segment, and then the clients x stays connected to the same channel to get the rest of the segments until the end of the movie.

Secondly, when new arriving client (say client Y) detects the LMF and then found that the Channel from LMF has already broadcast the 1st segment, he realizes that he has missed the current broadcast. As shown in Figure 11 by the PCSB protocol, the Client x downloads and playbacks the first 7 min of the 1st segment and the Client Y joins at the time $T_0 + \delta$. So, Client Y has already missed 7 min of the 1st segment and the remainder of the 1st segment is 5 min. The Client Y also misses the broadcasting channel of the requesting video. Thirdly, client Y directly requests the missing part (1st segment) from the LMF (the PoR). The PoR provides the 1st segment directly to the client Y which downloads and playbacks the 1st segment and caches it in its Prefix-Buffer. As mentioned previously, the client needs the Prefix-Buffer if it is selected to cache the 1st segment. Finally, at the same time, clients Y joins the channel and wait to start broadcasting the second segment (Seg2) from the same channel at time $T_0 + V/K$. The packets will be stored from the local forwarder into the Suffix Buffer. After that, the client Y maintains joining the same channel until the last segment. When client Y ends playing the missing part (1st segment from the PoR), it switches to play the video packets from the Suffix Buffer. The size of the Suffix is equal to the already broadcasted segments that the client misses. A client Y needs Suffix Buffer to store the rest of the packets from broadcasting channel. Hence, the clients Y can still manage to watch the video immediately.

Since the bandwidth of the clients is limited and the clients in MANET can not forward the video packets to the other clients at the same time, the Pool of RAM in the local media forwards the clients request to join in watching the video and receiving the missing

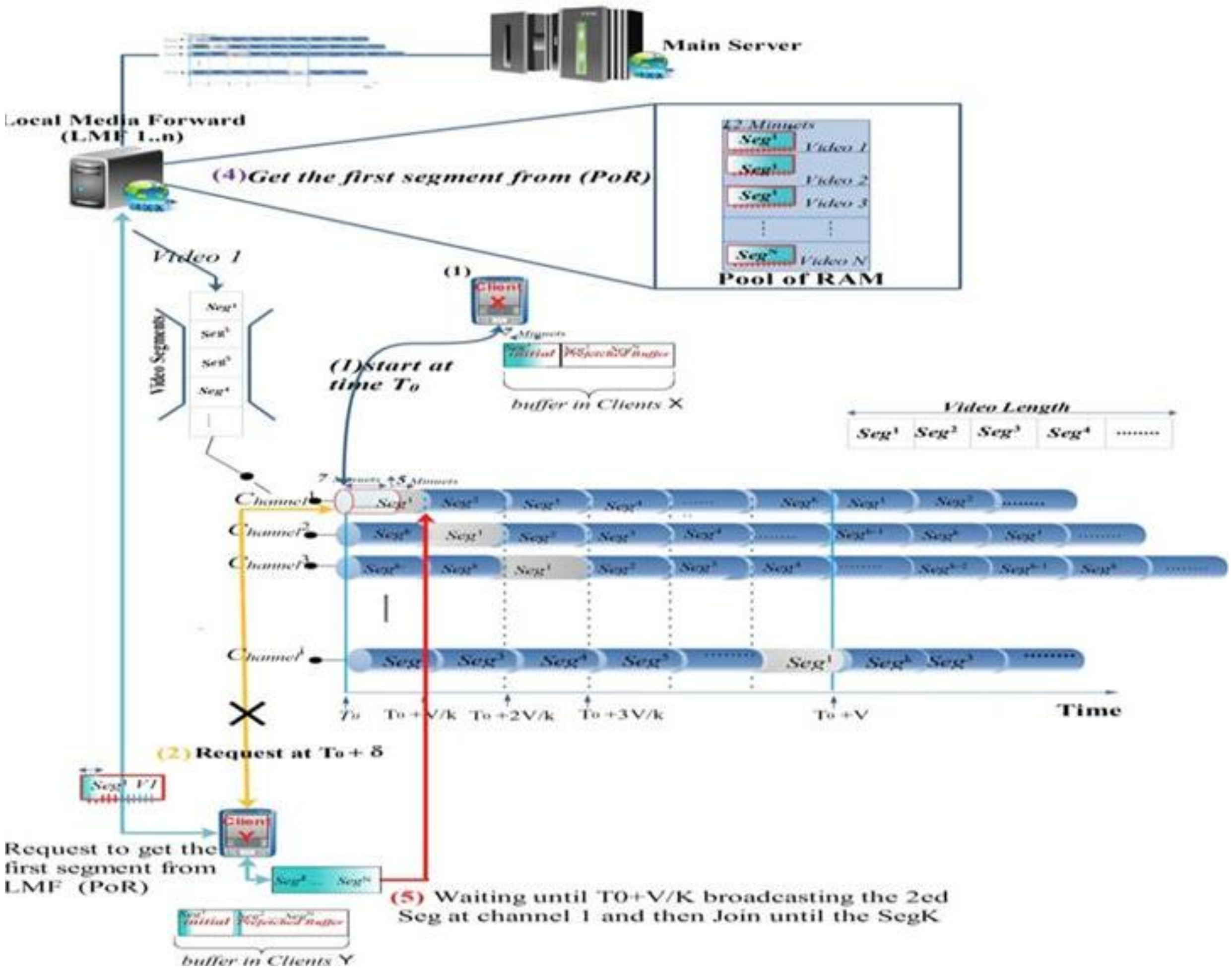

Figure 13. PCSB schemes.

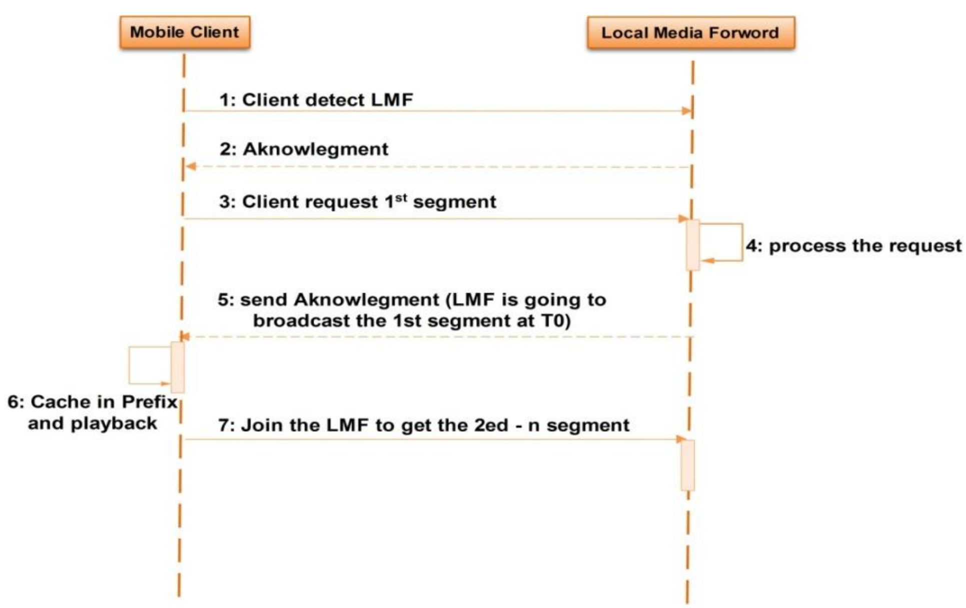

Figure 14. Flow charts of clients x get the 1st segment without waiting time.

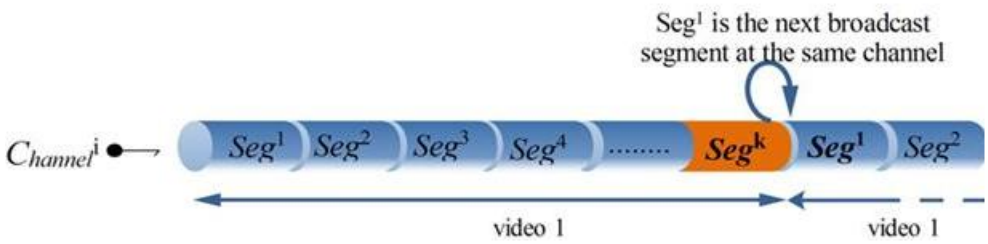

Figure 15. Clients join the 1st segments of the next broadcast at the same $C_{hannel}{}^{i}$.

portion with less services delay. When the client misses the 1st segment, he or she will go to the PoR and get the 1st segment directly without waiting any longer for the next broadcasting channel. The playback procedure for the new client is summarized below:

1. Check the PoR in the LMF.
LMF is in client's transmission range.
LMF holds 1st segment of the videos in PoR.
LMF currently is able to forward the 1st segment to other clients who missed the broadcast.
2. If such PoR does not exist.
3. Run Client Playback.
4. Else.
5. Run the two following tasks in parallel.
6. Task 1.
7. Detect the LMF.
8. Find the channel from LMF that is broadcasting the 1st segment of the request video soonest.
10. Join the broadcast channel.
11. Download/Playback and cache packets of the 1st segment into Prefix-Buffer.
12. Quit this channel.
13. Task 2.
14. Detect the LMF.
13. Download/Play the missing portion from the LMF/PoR and store the packets from PoR into the Prefix –Buffer.
14. Find the channel from LMF that is broadcasting the 1st segment of the same video soonest.
15. Join the broadcast channel.
16. Download/Playback 2nd seg - seg k and save in Suffix-Buffer.
17. Quit this channel.
18. Note: Segment 1 is stored in reusable buffer during the previous two steps.

Furthermore, since the broadcasting of the video is repeatedly on the same channel, it is possible that the clients N reaches the last segment of the video (segk) as explained in Figure 15.

Let us consider a client N who tunes in a random $C_{hannel}{}^{i}$, where this channel is currently broadcasting Seg_z. if the Seg_z = K, make the $C_{hannel}{}^{i}$ equal to $C_{hannel}{}^{j}$ and wait until the $C_{hannel}{}^{j}$ starts broadcasting Seg^1. Join this channel and then playback the video received from this channel and quit when the video has finished playing. In this case we can present the playback procedure for the client N as follows:

$$Channel = \begin{cases} Channeli + Segz - K, & \text{if } Channeli + Segz - K > 0 \\ Channeli + Segz, & \text{otherwise} \end{cases} \quad (22)$$

Where, K is the last segment in the currently broadcasting channel and *Channelj* must be currently broadcasting segment K (SegK) so that it will be able to get the 1st segment from same broadcast of the *Channeli*.

SIMULATION RESULTS AND DISCUSSION

The new system architecture and technique that improve the robustness and imperceptibility was implemented in order to achieve the objective of the research.

We investigated the system as a function of the dynamics in client request rate, failure rate, moving probability, video length and number of the channel. For each case, we assume that an input parameter varies while the others remain constant, as we run the simulation several times. We have found that the results collected for those runs varied slightly and almost unnoticeable. Therefore, we chose one set of the results for each case and presented them in Figure 16, Figure 17 and Figure 18.

The average services delay without caching would be a half of the duration of the 1st segment (V/K/2 = 60/5/2=6 minutes for 60-minutes video lengths). As shown in the results, the caching helps to reduce the waiting time of the mobile clients substantially. In all four caching techniques, the client population is spared ($P_{arrival=}$ 2), the duration is less than 90 s and when we test it ($P_{arrival=}$ 6), it was less than 40 s, which is 4 times better than without caching. These improvements are even more notable as the request rate increases. This is because as the client population becomes denser, a client has a better chance to find a cache, thus reducing the service delay. PoR almost provides true on-demand services, as its offered delay is less than 5 s in most scenarios above. The All-cache was almost 10 s in the previous system. Furthermore, DSC (distributed selfish caching) always outperforms Random-cache by about 10 s. When the arrival rate increase or decrease, the mobile clients can find the 1st segment smoothly in the local media forwarder (PoR) and when the $P_{arrival=}$ 2, the services delay is less than 5.03173 s. The average delay of the arrival rate is less than 3.61374. The failure rate and moving probability are more prone to the system. The service delay increased slowly, for instance, DSC's delay is 17.384553 s and All-Cache is 4.106974 when no client moves, while PoR is only 1.106974 s and only 2.1117 s when 40% of the clients move every second. The average delay of video length is almost 0.252535, because whatever the size of the videos {30, 60 and 90}, the client can join the broadcast channel and get the

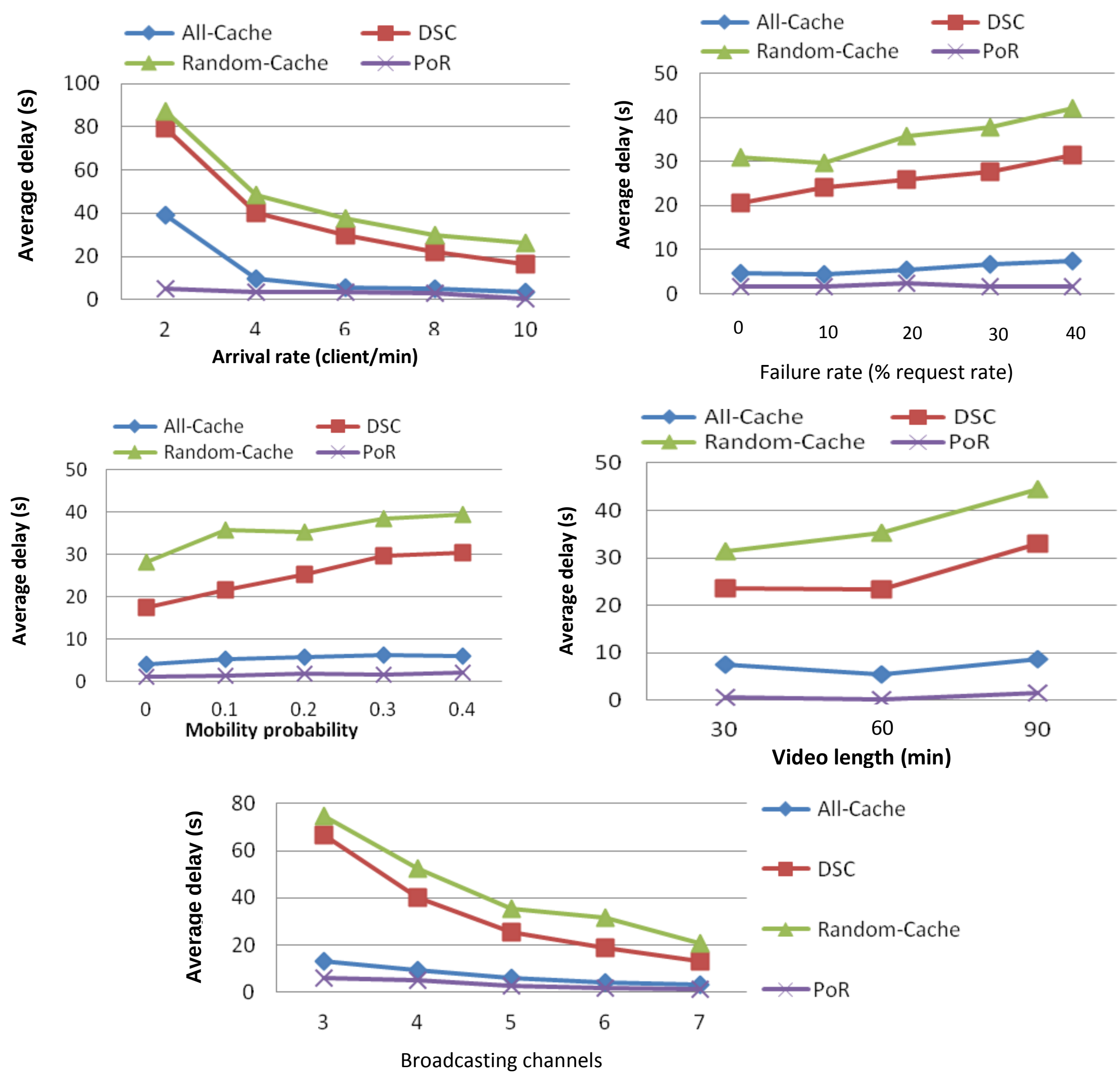

Figure 16. Effect on service delay.

missing 1st segment from the PoR. The average failure rate is 3 times less than All-cache (1.515274). We test the system with a different parameter and different number of the channel {3, 4, 5, 6, 7} so that the results shown by increasing the number of the channels in the service delay would decrease. When the number of the channel is three times the average delay, it is 6.177176 and when it is 7 times the channel, the average delay is 1.205303 (that is 3 times less than All-caching). These results exhibits that system performance is stable under high dynamics of the system variables.

The bandwidth requirement becomes significant as the system experiences different request rate, failure rate, moving probability rate, video length and broadcasting channel. In any case, the average bandwidth required by a client is less than 1.3 times the playback rate in all the scenarios. It means almost providing a true video on demand to the mobile clients. In contrast, as shown in Table 1, convention VOD broadcasting techniques require bandwidths of at least 2 times the playback rate. Therefore, the proposed technique is more feasible formobile clients equipped by current wireless technologies and will even be more powerful by developing the wireless technology. According to the results in request rate, failure rate, moving probability rate and video length which increased slowly, the average arrival rate of PoR is almost 1.12491 when the $P_{arrival} = 2$ and it is almost similar to the All-cache, and when $P_{arrival} =$ 6, it is almost 1.138805 less than All-cache. All-cache, DSC and Random-cache require more client bandwidth than PoR. However, the difference is tiny between them. For instance, when all the input parameters are set by

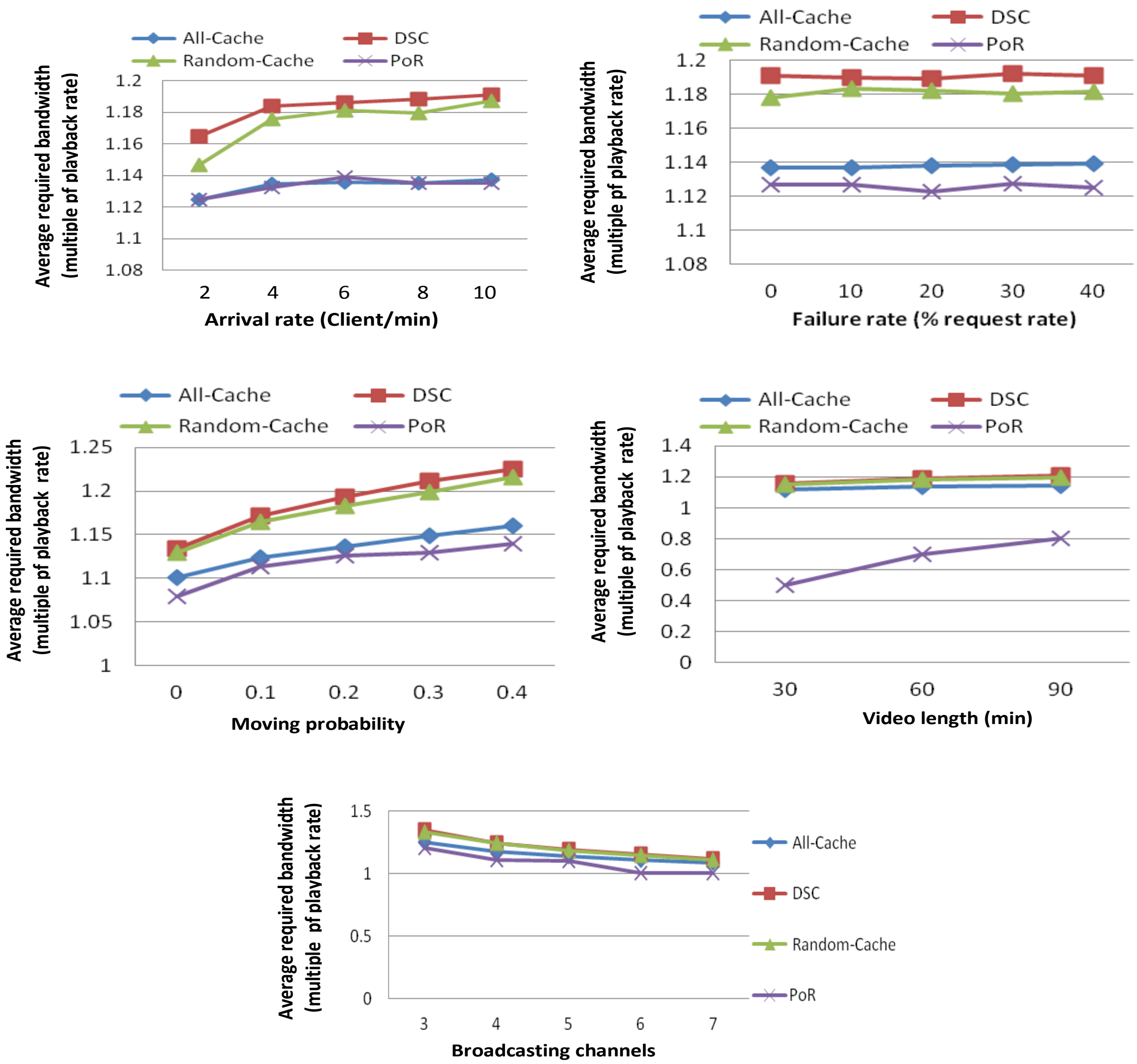

Figure 17. Effect of bandwidth requirement

default, an average DSC client needs a bandwidth of 1.185881 times the playback rate while an average Random-cache client needs 1.183912 times the playback rate. The bandwidth difference here is almost 0.002 times the playback rate. Regarding the results, the PoR is much better than all other caching techniques. Furthermore, the DSC and Random-cache offer service delays much better than that without caching. Indeed, in most scenarios, they are 9 times better than without caching. Between DSC and Random-cache, DSC is preferable as its service delay is shorter than the latter.

As shown in Figure 18, the PoR cache distance is the shortest since a mobile client never gets a cache more than one hop away , because the LMF is stationary in the location (0,0), which allowed any client to request the missing 1st segment through the PoR and avoid any caching from the other client. As the clients move, point to point link maybe dropped due to terrain interference or simply, because they move beyond range of other nodes.

In this paper proposed an efficient way to provide the VOD services smoothly with less waiting time. In the other techniques a client may get a cache from two hops away or more. It is also understandable that Random-cache's cache distance is less than that of DSC. This is because DSC is more effective in using cache than Random-cache, which is already substantiated in Figure 5. However, according to results the PoR more efficient than others, especially in request arrival rate, failure rate and moving probability, but it had almost the same performance in video length and broadcasting channel. The average arrival rate of PoR when the $P_{arrival}$=2 is almost 0.11131 client/minute and when the $P_{arrival}$=6, its almost 0.24431 was more effect comparing with the All-Cashe (0.984694). As well as, the PoR failure rate is less

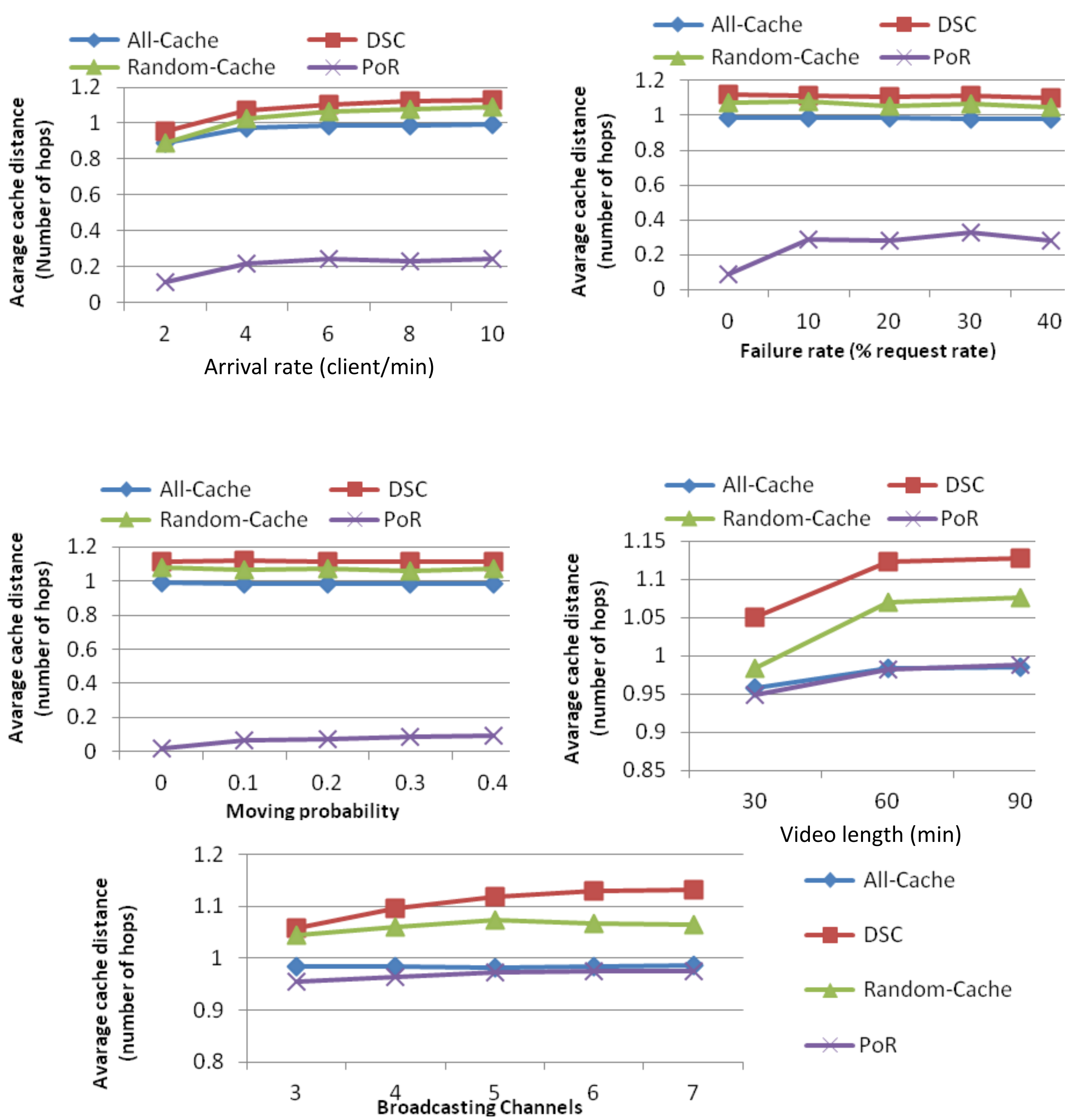

Figure 18. Effect on cache distance.

than the all types of caching, because the client does not need to download and cache from more than one hope away, and the LMF is stationary and available for to any client, which shown the results with less failure rate, when 20% of the request rate, the failure rate is 0.284438 comparing with All-Caching, which equal 0.98821. Furthermore, the average cache distance of failure rate and moving probability are not prone like others. For instance, when the moving probability 0.2%, the DSC cache distance is 1.111354, the All-Cache is 0.984092 and the Random cache is 1.072507, but in the PoR is 0.072093, which mean the PoR is able to provide the services without disconnected, especially when the client move with different speed. Moreover, the average cache distance of video length of PoR is almost similar to the All-Cache, with 0.982212 of request rate.

Conclusion

This study discusses the video on demand broadcast techniques for homogeneous and heterogeneous mobile networks and proposes an improved broadcasting protocol. At first the paper provides an overview on segment based broadcasting protocol by mentioning several broadcasting protocols and comparing the existing broadcasting protocols in order to find the most suitable broadcast for the VOD. We also classified the broadcasting assessment techniques into two types, firstly, the client waiting time versus server bandwidth. Secondly, bandwidth requirements and buffer at client end. The comparison shows that no other broadcasting technique can provide true video on demand because their service delay is non-zero. However, SB and SkB provide better service delay. On the other hand, SkB is more complex and requires that the client be capable of downloading at a rate twice as large as the playback rate and have caching space enough for approximately 10% of the video length. In this case, the SB is a better choice for the current wireless architectures because the storage space is 0, but the disadvantage with SB is its service delay. To solve this problem and provide the VOD services to the mobile devices within less waiting time, we proposed system architecture as earlier treated including the main contents of proposed system architecture for the broadcasting techniques , explained the channels design of the PCSB and characteristics of the PoR. Finally, the simulation results of the whole system shows how the playback procedure of popularity cushion caching reduces the waiting time of the mobile devices, and proves that the PoR is more efficient and better than the other caching techniques in the latest VOD system (MobiVoD). Furthermore, these results exhibits that system performance is stable under high dynamics of the system.

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