Effective Broadcasting and Caching Technique for Video on Demand over Wireless Network

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Abstract

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, which makes the VOD become an important technology for many applications. Numerous periodic VOD broadcasting protocols have been proposed to support a large number of receivers. Broadcasting is an efficient transmission scheme to provide on-demand service for very popular movies. This paper proposes a new broadcasting scheme called Popularity Cushion Staggered Broadcasting (PCSB). The proposed scheme improves the Periodic Broadcasting (PB) protocols in the latest mobile VOD system, which is called MobiVoD system. 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 in the Pool of RAM (PoR), and then transmitting them when the mobile nodes miss the 1st broadcasted segment. The results show that the PCSB is more efficient and better than the all types of broadcasting and caching techniques in the MobiVoD system. Furthermore, these results exhibits that system performance is stable under high dynamics of the system and the viewer's waiting time are less than the previous system.

Keywords: Video on Demand, Pool of RAM, periodic broadcast, MANET, SB, PCSB

The general components of the VOD system architecture have been presented in the ICCET, IJCSIS 2010 [34][35]. This work was supported in part by the School of Computer Science, Universiti Sains Malaysia, Pulau Penang, Malaysia. under Grants Number (1001/PKOMP/817066).

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1. Introduction

Nowadays, with the rapid deployment of the wireless networks, the people have this tendency to work outdoors, as a result, we can see a rapid increase in the number of mobile users. In these days after the extension of transmission media from wired to the wireless network became major advance in communication technology. Many of the wireless techniques, such as, Worldwide Interoperability for Microwave Access (802.16, WiMAX) [1][37] have been developed that can provide long distance communication even more than 10 kilometers. Additionally, the wireless technology, such as, IEEE 802.11 (WiFi) [2][3] is a good example for the small local wireless network and Bluetooth that is suitable for the short distance communication like Personal Digital Assistant (PDA), Cell Phones, Laptops etc.
The mobile wireless technologies allow users to enjoy watching what they want at anytime and anywhere within the coverage area. After the researcher has developed the VOD as an interactive multimedia system, a lot of practical applications, such as, Movies-on-Demand, Video conferencing, Distance learning, Interactive video games and etc, can be implemented due to the advancement of wireless technology [4][5][6][7][8]. Some of these applications are utilized to make the users enjoy ubiquities entertainment service, such as, play a game or view a video of their interest online at any place they are at. Universities could also install such a system on campus to allow students to watch video recorded earlier from lectures they were not able to attend. Airlines could provide VOD services in the airport lounges and in recorded video information on the previous activities in public carnival etc.

Current trends have drastically impact on video on demand services due to deployment of various types of network infrastructures and availability of different types of mobile devices. Furthermore, present vogue is directing towards the digital media distribution through the Internet. Wireless communications provide next level of freedom for accessing these technologies without any boundaries. This study provides a general overview of a proposed solution which will demonstrate the system architecture for VOD for heterogeneous Mobile Ad Hoc Networks (MANETs) that is more challenging than the traditional networks due to lack of proper infrastructure and different types of devices. MANET's consists of mobile hosts which are concerned with limited energy and unpredictable topology [36].

There are many Periodic Broadcasting (PB) protocols designed to provide efficient VOD services to a potentially large number of users without using too many resources from the clients, the server or the underlying network. Some of the main challenges in the broadcasting protocols is how to reduce viewer's waiting time maintaining a given bandwidth allocation and how to reduce a client's buffer requirement. In this paper, we propose a new broadcasting protocol called Popularity Cushion Staggered Broadcasting (PCSB).The proposed protocol improves the Periodic Broadcasting [9] protocols for mobile VOD system and the latest VOD system "MobiVoD" based on broadcasting techniques [10], which include different types of caching scheme to minimize the waiting time of the mobile clients.

We begin this paper with an overview of the segment based broadcasting schemes by discussing several broadcasting protocols and compares them to find the suitable one for the VOD. Section 3 explains the proposed system architecture for the broadcasting techniques, which include a brief explanation of the novel Popularity Cushion Staggered Broadcasting (PCSB) scheme. The Simulation results are presented in Section 4. Finally, we conclude the paper in Section 5.

2. Overview of the Segment Based Broadcasting Schemes

Assessing the performance of the broadcasting protocol is based on several metrics: client waiting time, server bandwidth, client bandwidth and client buffer space [11] The crucial trade-off indicates to the comparison between both; the client waiting time and the bandwidth usage [12]. Maintaining the worst client waiting time as small as possible was performed by several segment based broadcasting protocols. This is achieved by keeping the 1st segment small based on keeping 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 spaces will be needed in the client side. Accordingly, issues on decreasing buffer and bandwidth requirements are carried out by some of studies [13]. Moreover, several protocols that 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, 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) [14].

2.1 Client Waiting Time versus Server Bandwidth

In Staggered Broadcasting (SB) [15], K channels are allocated by the server to perform the transmission for a video program. In each channel, there is a fixed rate b, that is of the same rate of video playback. The maximum client waiting time in SB is L/K, where L indicates to the video program length. The Pyramid Broadcasting (PyB) protocol [16], a video program is divided into K geometric increasing-sizes of segments. Following that, these segments are transmitted on multiple channels with the same amount of bandwidth. A factor α is contained in the geometric series, such that $\alpha>1$. Ensuring an on-time delivery when the 1st segment is $1/\alpha$ of the size of the 2ed 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 $1/\alpha$ of the size of the 2ed segment. Therefore, the 1st segment must have a broadcasting time of $1/\alpha$ of its playback time. In additional, the 1st channel should have a bandwidth requirement 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 when a fixed server bandwidth takes place.

In Fast Broadcasting (FB) protocol[17], a video program is divided into 2_{K-1} segments, where K indicates to the number of available channels. On channel Ci , the broadcast segments 2_{i-1} to 2_{i-n} in order. $L/(2_{K-1})$ is considered as the maximum client waiting time. Smaller client waiting time is obtained by the FB protocol compared between SB and PyB protocols together. Based on the pagoda broadcasting scheme (PB) [18], the authors proposed a new pagoda broadcasting protocol (NPaB) [19] to divide a video program into fixed size segments and maps into equal bandwidth of data channels. The process is performing through the proper decreasing frequencies. As a result of this protocol, NPaB protocol obtained than smaller waiting time than FB protocol. Paris and Long at [20] 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 broadcasting protocol. A time slot is the duration of viewing a segment at the video playback rate. Moreover, main concept

behind RFS protocol is to broadcast a segment very close to its frequency based on this protocol. [21] has formalized 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 [22] a video is divided into many equal size segments as a 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 [20] that the least client waiting time is required by the HB protocol through the same server bandwidth. It was shown by [23], that this protocol cannot continuously have video data bring delivered on a specific requirement time. Unlike, the proposed cautious harmonic broadcasting (CHB) and quasi-harmonic broadcasting (QHB) protocols that solved the indicated problem [23].

2.2 Bandwidth Requirements and Buffer at Client End

All the aforementioned researches mainly focus on the decreasing of client waiting time. However, they require clients to be equipped with larger bandwidth and buffer to receive and store video data. To alleviate this shortcoming, some studies investigated the issues on decreasing buffer and bandwidth requirements at the client end. Skyscraper Broadcasting (SkB) protocol was proposed by [24], which allows the client to download video data via two channels. In Client Centric Approach (CCA) [25] a client is supported to downloading video data using a small number of channels. On the matter fact, this protocol is taken into account to be as a generalization of SkB protocol. The reason of 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 protocols reducing the waiting time of the client. [26] have proposed the GDB protocol to systematically analyzes the resource requirements (i.e. client buffer space, server bandwidth and client bandwidth). Furthermore, a tradeoff is encountered in the protocol among any two of the three resources. GDB protocol can have smaller client waiting time than the CCA protocol has. 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 [27] similarly obtains the same client waiting time of the previous protocol (FB protocol). It requires a client to buffer 25% of a playing video. This 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 compared to the StB protocol are supported by the Modified Staircase Broadcasting (MSB) protocol [28]. SB and HB protocols are combines by the Interleaving Staircase Harmonic Broadcasting (ISHB) protocol [29]. 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 higher waiting time than the ISHB has. In addition, it 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 [30], but only 25% of a playing video is buffered. Hybrid Broadcasting (HyB) protocol [31] combines both; the RFS and the RFB protocols. 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 [32] has 33%~50% smaller client buffer space than GDB protocol. Recently, a series of broadcasting protocol was proposed by [33] to combine SB protocol with PB, SB, FB, RHB and PFB protocols to decrease the client buffer space.

Table 1. A comparison of different segment based broadcasting schemes

	Broadcasting Schemes	Waiting Time (second)	Storage space (% of the Video)	Client 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
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	SyB	Adjustable, WT > FB	10%	2b
12	ISHB	ISHB HB < WT <FB	25%	(K-1)*b
13	Hybrid	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

Since mobile wireless clients are 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 better option considering of 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, non of broadcast techniques can provide True Video on demand (TVOD) due to their non-zero service delays. Comparing SB and SkB, the SkB provide less service delay, nonetheless, it is more complex and requires the client to be capable to download at a rate twice as large as the playback rate and have caching space enough for approximately 10% of the video length. As a conclusion, the SB is the a better choice for the current wireless architectures because of its simplicity and the storage space is (0%).

3. Proposed System Architecture for PCSP

The new broadcasting protocol called Popularity Cushion Staggered Broadcasting (PCSB) Protocol for mobile VOD system guarantee the viewer's waiting time is less than that of previous methods.

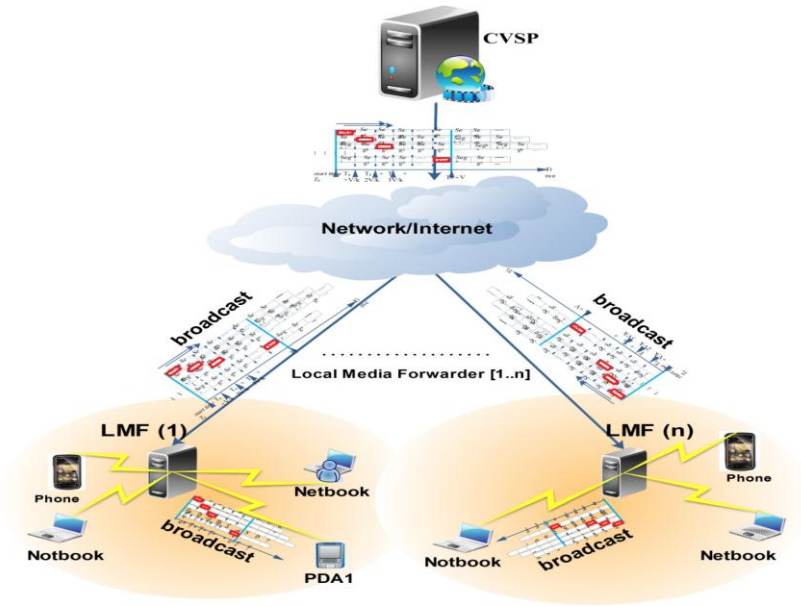


Fig. 1. Proposed system architecture for the broadcasting techniques [34]

As indicated in the **Fig. 1**, the main components of the proposed system architecture for the broadcasting techniques can be classified into five main categories: Central VOD Services Provider (CVSP), Local Media Forwarder (LMF), networks, mobile clients and broadcasting techniques. *CVSP* is a server or cluster of servers as a main entity for providing VOD services to the end mobile clients. It has storage of VOD services. It provides VOD service to the end client through media forwarders. CVSP is also responsible for monitoring all the clients through different media forwarders. It tracks moving of mobile clients through different infrastructure for providing services seamlessly. *LMF* are responsible to provide VOD services within a limited transmission range, such as, inside buildings while using standard like WiFi (IEEE 802.11 a/b/g). The previous papers briefly elaborated the components of the system [34] and [35], while this paper focuses on the broadcasting techniques and Cushion cashing mechanism. The main problem with broadcasting scheme is its service delay, when the clients miss the broadcasting of the 1st segment; they have to wait until the next broadcasting to join and playback the 1st segments of the video. The following section will discuss how the new Popularity Cushion Staggered Broadcasting (PCSB) scheme can be adapted to be fit for VOD systems in large-scale wireless networks to minimize the waiting time (delay).

3.1 Popularity Cushion Staggered Broadcasting (PCSB)

In the PCSB, the whole video is divided into K equal size segments (Seg^1, Seg^2, Seg^3, …, Seg^K). The duration of each segment is Di = V/K, where V is the total display duration of the whole video and K is the number of the channels. And every C_{hannel}^{i} 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 (C_{hannel}^{i}) repeatedly broadcast the video (Seg^1, Seg^2, Seg^3,…, Seg^K) with transmission rate (Tr) equal playback rate (Pb) as shown in **Fig. 2**. The Client_x can join C_{hannel}^{1} and waiting for the beginning of segment *Seg1* to download and playback it. After that, Client_x immediately switches to the *Seg2* for downloading. This process is repeated

for the subsequent segments until a last segment (Seg^K) is downloaded from $C_{hannel}{}^1$. Equation 1 follows directly the definition:

$$V = \sum_{i=1}^{k} \mathrm{D}i \qquad (1)$$

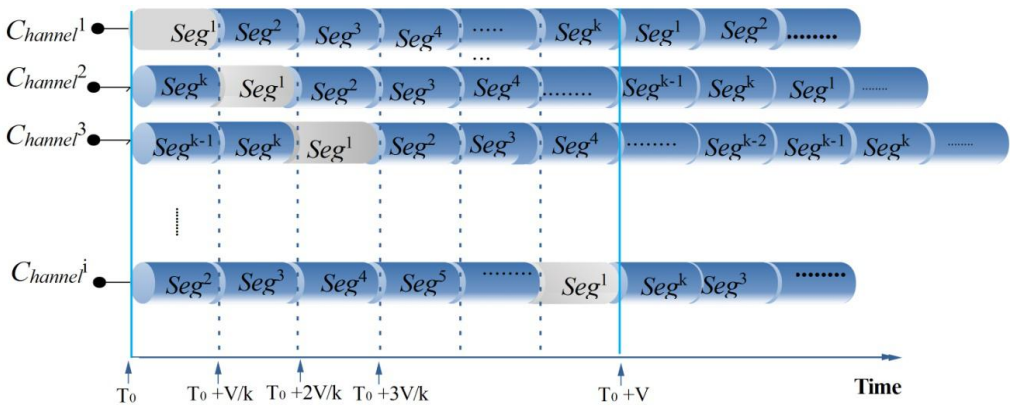


Fig. 2. Video division into segements by broadcasting protocol and segment Seg^i broadcasting at physical $C_{hannel}{}^i$

Based on **Fig. 1** and **Fig. 2**, each Local Media Forward (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 in the main server to broadcast the packet to the services area. In this case, all the clients in the service area (LMFs area) will receive the broadcast packets. In the video on demand broadcasting, the starting times for the video program evenly across K server channels. **Fig. 3**, depicted the number server channels and the process of the broadcasting over them. As illustrated in the figure, if the first channel starts broadcasting video at the playback rate Pb 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 is started every phase offset, it is the duration that each client needs to wait for this video to playback.

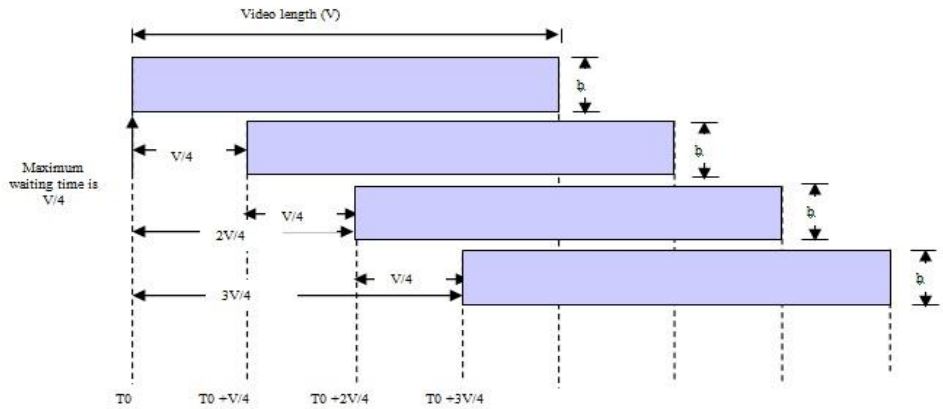


Fig. 3. broadcasting scheme starting times for video across each physical channel

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*.

$$\mathrm{T}r \times K \times \mathrm{N}vi \leq b \qquad where\ i = \{1,2..N\} \qquad (2)$$

Given that each video has a transmission rate Tr = 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 * K * 5 ≤ 54), the result the K must be less than 7 as elaborated in **Fig. 3**. Equation 3 follows the definition:

$$b = \sum_{j=1}^{K} \mathrm{b}j \qquad (3)$$

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

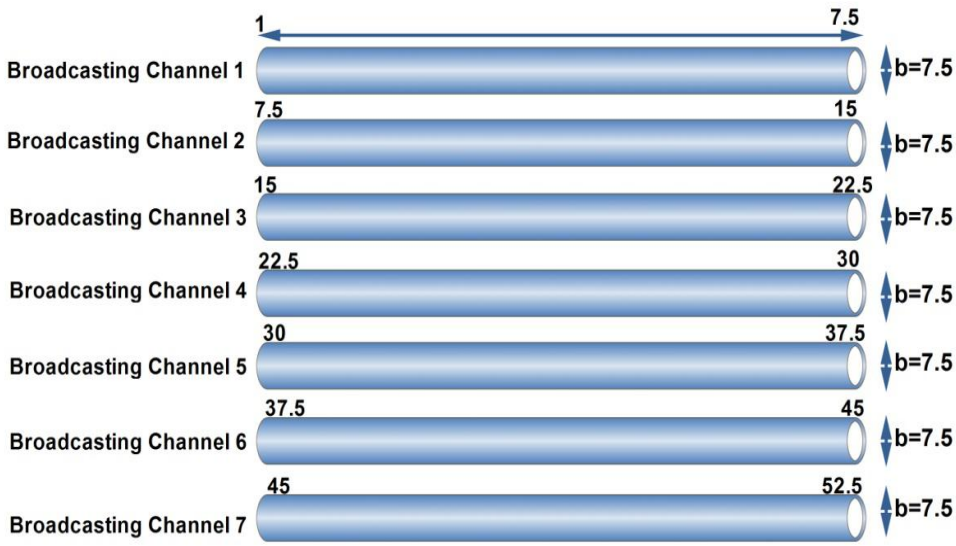


Fig. 4. Maximum number of the broadcasting physical channel K when Nv=5

The server bandwidth is T*r* × *K* for the second video, and so on. This bandwidth allocation is divided into K logical channels; each repeatedly broadcasts the video with a transmission rate equal to the consumption rate. The scheduling of these broadcasts is illustrated in **Fig. 4**. The bandwidth of each video is (T*r* × K) ⇔ (1.5 * 5 = 7.5 Mbps). For example, when K=5, this implies that each video has 7.5 Mbps from 54Mbps. Where T*r* is transmission rate (Mbps), K is numbered of the channels. The number of the segment will be equal the number of the logical channels, where the size of the segment will be 12 minutes, so the video will be divided into five equal size segments and will broadcast it into five logical channels. The scheduling of these broadcasts is illustrated in **Fig. 5**.

- Transmission rate(r) =1.5
- Bandwidth of the broadcast channel / number of the segments = 7.5/5 = 1.5, this implies that each logical channel has bandwidth 1.5 Mbps from 7.5 Mbps to repeatedly broadcast the video segments *(Seg^1, Seg^2, Seg^3,…, Seg^K)*.

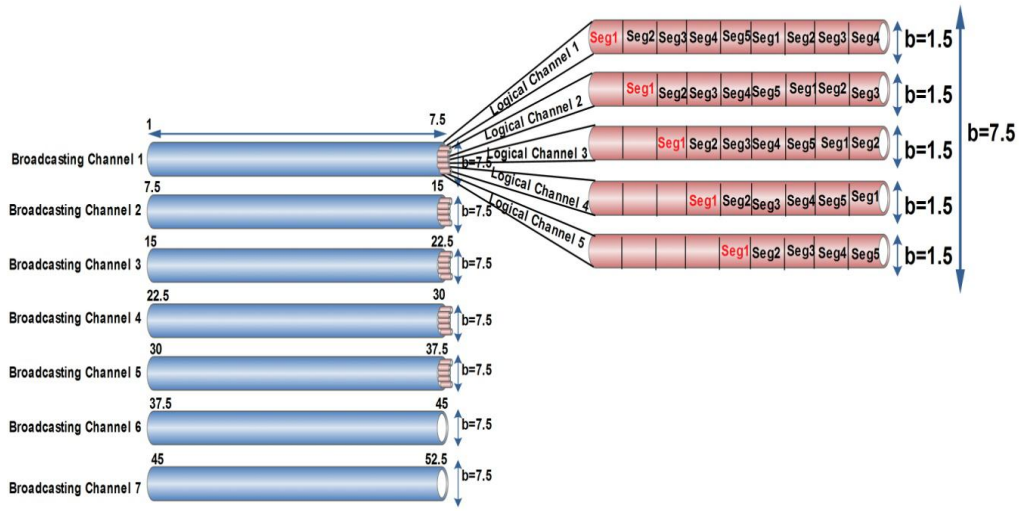


Fig. 5. Channel broadcasting the video into logical channel when V=60 minutes, D=12 and K=5

The service latency of each video when the number of the channels K=7 is (Tr × K) ⇔ (1.5 *7 = 10.5 Mbps), Its means each video have 10.5 Mbps from 54Mbps. Where Tr is transmission rate (Mbps), K is numbered of the channels. This bandwidth allocation is dividing into five logical channels, each repeatedly broadcasting the video with a transmission rate equal to the consumption rate. The scheduling of these broadcasts is illustrated in **Fig. 6**.

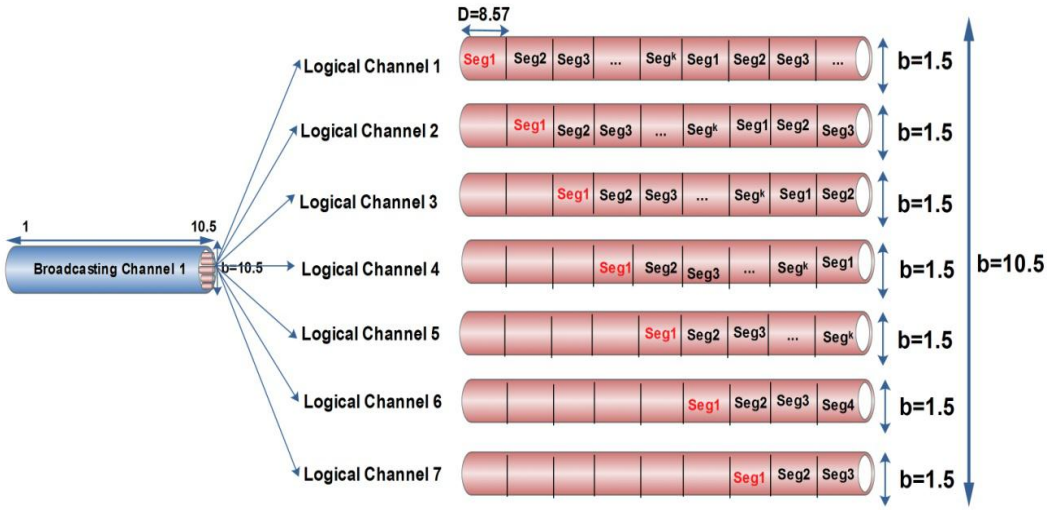


Fig. 6. Channel broadcasting the video into logical channel when V=60 minutes, D=8.57 and K=7

3.2 Simulation Model of the PCSB

The characteristics of the broadcasting technique is shown in Table 2, if the video starts broadcasting at C_{hannel}^{1} at the system setup time T_0, in the same time the Client_X request to join the C_{hannel}^{1} to get the 1st segment, in this case the Client_X will get the services without any service's latency. 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 Seg^1, and therefore, the Client_Y must be waiting until the next broadcast of the 1st segments. Assuming that the number of the channels is 5, which is suitable with 802.11g = 54Mbps and MPEG-1 = 1.5, and the size of the video is 60 minutes, so the duration of each segment is D*i*= V/K = 60/4 = 12. In the worst 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 7 the services latency would be 60/7= 8.75142.

Table 2. Characteristics of the broadcasting technique

Parameter	**Notation**
Segment	$\{Seg^1, Seg^2, Seg^3, \ldots, Seg^K\}$
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 C_{hannel}^{i}	$1 <= i <= K$
Probability of watching a video at T_0	$P_{arrival}$
Waiting time for the client (Delay)	D = Maximum waiting time is V/K
Services bandwidth	*b*K*
Number of the Video	$N_{Vi \quad i=\{1,2,3....N\}}$
Total number of the users	T*n*

3.3 Popularity Cushion Cashing Mechanism

The main problem is still having a waiting time in the broadcasting technique once the clients miss the 1st segment of the current broadcasting. Based on the well-known mechanism call, popularity cushion caching mechanism the waiting time must be eliminated. To minimize the services latency, it is assumed to install a scatter of Local Media Forwarders (LMF). LMF install indoor environment such as buildings {*LMF1, LMF2 LMF3,..., LMFk* }, the Local Media Forward LMFn is a stationary and dedicated computer, used to relay on the service to LMFn transmission coverage area, Local Services Area (LSA) network. In the proposed mechanism, LMF is acting as a node, which 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 arrives in the LSA1. The Client_x starts searching to find the closest LMFs, and then request to view 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 broadcast channel to get the 1st segment. For instance, as shown in **Fig. 7,** the client getting the services from C_{hannel}^{1} at times zeros (T_0).

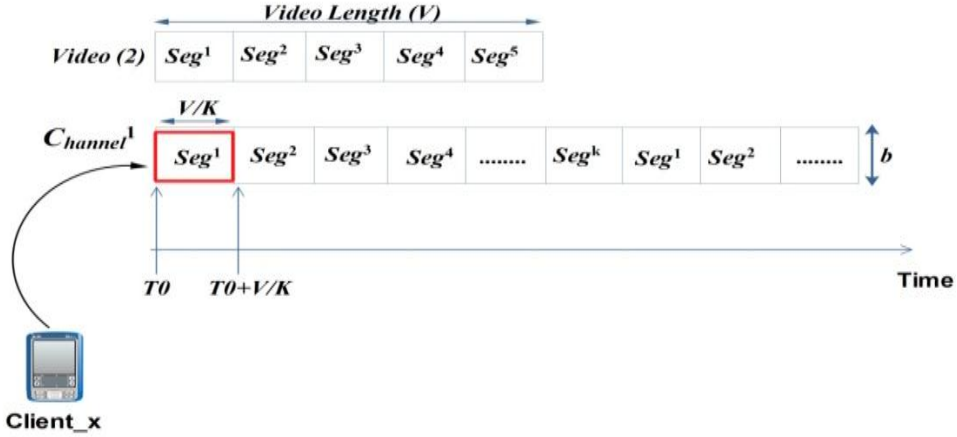


Fig. 7. Client _x join the channel (C_{hannel}^{1}) at times zero (T_0)

Assume the size of the video is 60 minutes and the number if the channel 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 minutes or 720 second**.** If the Client_x join the channel at T_0 ($T_{request} = T_0$), the Client_x will download and playback the 1st segment without any delay, at the same time, the 1st segments will be stored in the Prefix-Buffer. Once Client_x finishes downloading the 1st segment (Seg^1), the client immediately switches to the second segment (Seg^2) to download it on the same channel, and so on, until all the segments have been downloaded. The probability of the client to watch a video at times zero (T_0) determined as follows:

$$P_K = \binom{n}{k} p_{arrival}^{k} (1 - P_{arrival})^{n-k} \qquad (4)$$

Where, $P_{arrival}$ is the probability of the client to 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 connection channels with the forwarder.

We suggest the Client_x join the C_{hannel}^{1} and start watching the first 7 minutes of the 1st segment of the video2 as shown in **Fig. 8**, at the same time Client_Y request the same video from the LMF at T_0+ Di + δ (0 < δ < Di). The Client_Y after checking the broadcasting channels realizes that already misses the current broadcasting of the 1st segment from video2 as shown in **Fig. 9**.

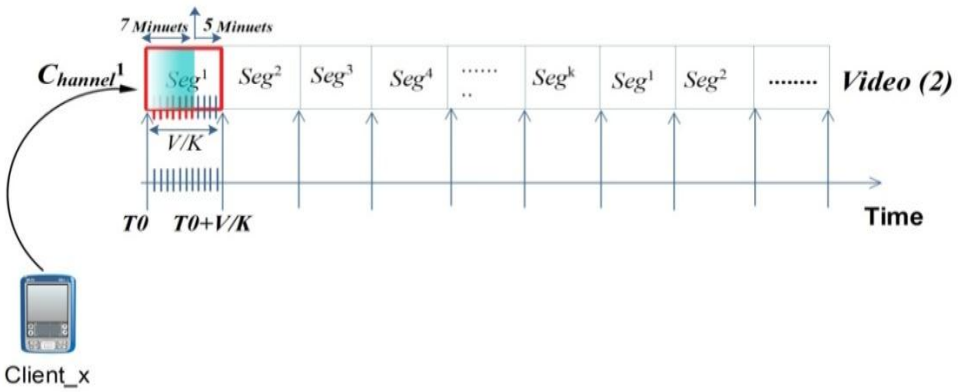


Fig. 8. Client_x streaming the (7 minutes from the 1st segment) without delay from C_{hannel}^{1}

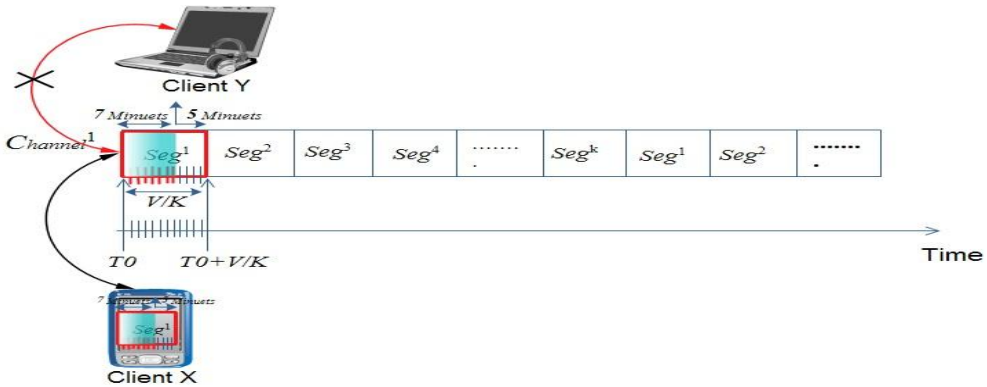


Fig. 9. Client_Y misses the current broadcasting of the 1st segment from C_{hannel}^{1}

In this case, the Client_Y has already missed the 1st segment (the first 7 minute of the 1st segment). Now Client_Y can not join the C_{hannel}^{1} and he must wait for the next broadcast of the 1st segment (T_0+2VK). To solve this problem and make the client obtain the video packet without waiting for the next broadcast of the 1st segment. The client directly requests the 1st segment from the existing LMF in its transmission range. The LMFs have stored the 1st segment of the whole videos in a Pool of RAM (PoR) as shown in **Fig. 10**.

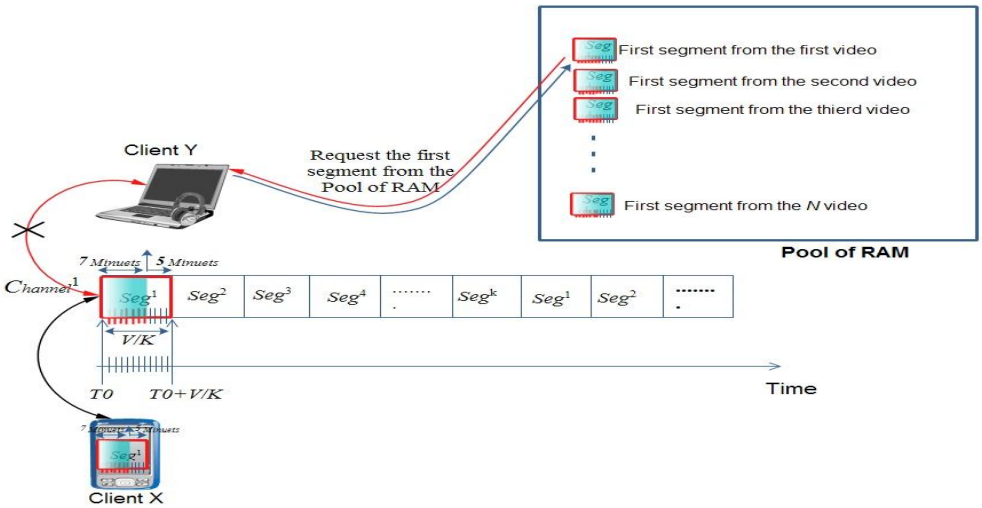


Fig. 10. Client_Y gets the service (1st segment from the PoR)

3.4 Simulation Model of the Pool of RAM (PoR)

Table 3 shows the characteristics of Pool of RAM (PoR).

Table 3. Characteristics Pool of RAM (PoR)

Number of the Video	N_{Vi} ,where vi is video {1,2,3..N}
Length of a video(minutes)	Vi
Segment	K ={Seg^{1} }
Duration of the segment	Di ={Seg^{1} }
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}

Let N_{Vi} be a stochastic variable representing the number of videos, and it may take the different values (videos) for N_{Vi} (i=1,2,3,…N). D_i is the size of the video (duration for each video/minutes) of ith video (i=1,2,3,…N), with arrival rates λ_i (i=λ_1, λ_2, .. . λ_N), respectively, that are being streamed to the users using Local Media Forwarder (LMF). LMF has a large enough space to storage a number of prefixes segments in the PoR, T_{zPoR}/minutes of T_{nvPoR} number of segments at PoR**.**

Section 3.1 briefly explained how the video is staggered into several segments equal sizes and broadcast it to the mobile clients. Furthermore, 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 as *(pref)i*, for example {(V_1, Seg^1), (V_2, $^{Seg1)}$, (V_3, Seg^1)…. (Vn, Seg^k)}. The remaining portion of the video segments is referred as a suffix of the rest of *Vi*.

$$T_{zPoR} = \sum_{i=1}^{T_{NvPoR}} (Pref)i\,, \quad where\ T_{zPoR}\,(Pref)i\ > 0 \qquad (5)$$

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

$$\mathrm{S_{zPref}}\,(pref)i = \mathrm{P_{rob}} \times \mathrm{D}_i \qquad \text{where } 0 < Prob < 1 \qquad (6)$$

Where D*i* is the size of the 1st segments (Seg^1) of the ith video (*i*=1,2,3,…N), and P_{rob} is the probability of occurrence of mobile clients requests with frequency for segment *i* from last *t* minutes. This arrangement enables the 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 of (BW^{PoR}) in the local media forwarder. Moreover, the request rejection 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 will request it directly from the PoR. The request rejection ratio (R_{reject}) as the ratio of the number of requests is rejected (N_{reject}) to a total number of requests arrived (N_{ra}) at the system, which is inversely proportional to the system throughput $S_{efficient.}$ We can estimate the system efficiency according to the following relationship:

$$\mathrm{S_{efficient}} = \frac{\text{Total number of requests served}}{\text{Total number of requests arrived}} \qquad (7)$$

Where the N_{rs} is the ratio of 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:

$$S_{efficient} = \frac{N_{rs}}{N_{ra}} \tag{8}$$

$$BW^{PoR} = \sum_{i=1}^{N_{rs}} BW\,(D_i - (pref))_i^{PoR} \tag{9}$$

$$RS_{delay} = \frac{1}{N_{rs}} \sum_{i=1}^{N_{rs}} (RS_{delay}) \tag{10}$$

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

$$R_{reject} = \frac{N_{reject}}{N_{ra}} \tag{11}$$

3.5 Playback Procedure of Popularity Cushion Cashing

We have shown the Popularity Cushion Staggered Broadcasting (PCSB) scheme in the **Fig. 12**. Here in this section the PCSB scheme is simply explained within four steps. Firstly, as **Fig. 11** shows, once the Client_x detects the LMF and then finds 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 of the 1st segment, and then, the Client_x keeps stays connected to the same channel to get the rest of the segments until the end of the movie.

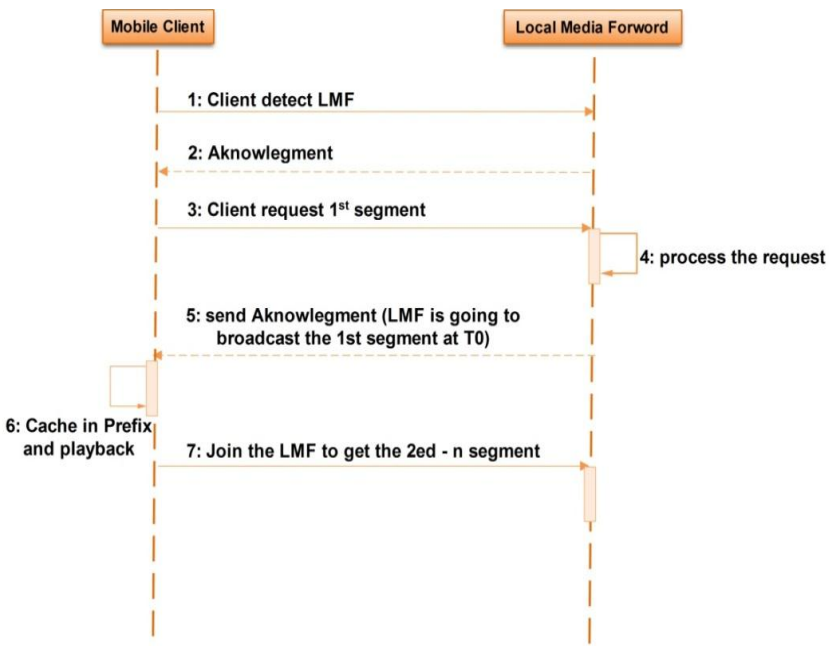


Fig. 11. Flow charts of Client_x get the 1st segment without waiting time

Secondly, when new arriving Client_Y detects the LMF and then founds the Channel from LMF is already broadcast the 1st segment, it realizes that it missed the current broadcasting. As shown in **Fig 9,** the PCSB scheme the Client_x downloads and playbacks the first 7 minutes of the 1st segment and the Client_Y joins at the time $T_0 + \delta$. So, Client_Y already misses 7 minutes of the 1st segment and the remaining of the 1st segment is 5 minutes. 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 that downloads and playbacks the 1st segment and caches it in its Prefix-Buffer. As mentioned before, the client needs the Prefix-Buffer if it is selected to cache the 1st segment.

Finally, at the same time Client_Y joins the channel and wait to start broadcasting the second segment (Seg^2) from the same C_{hanne}^1 at the time $T_0 + V/K$, the packets will be stored from the LMF into the Suffix_Buffer. After that, the Client_Y keeps joined to the same channel until the last segment. When Client_Y finishes 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 Client_Y still can manage to watch the video immediately.

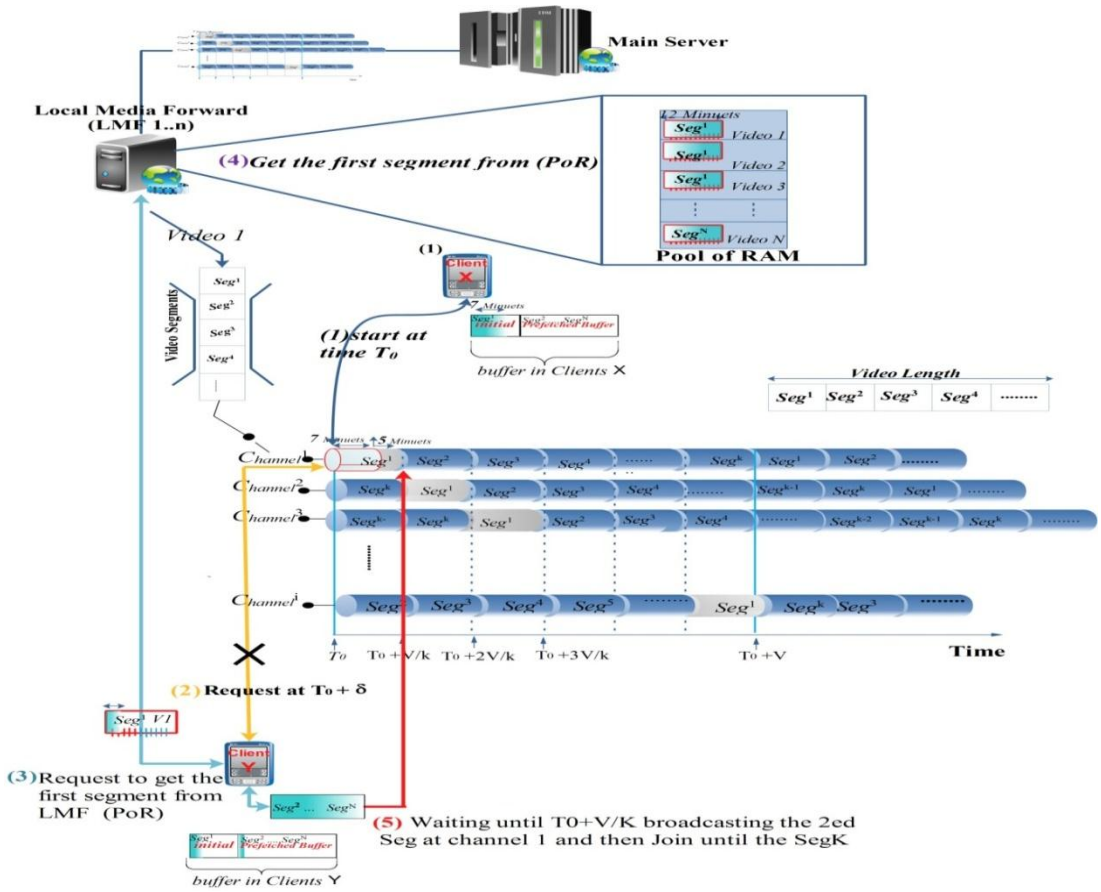


Fig. 12. Popularity Cushion Staggered Broadcasting (PCSB) schemes

Since the bandwidth of the clients is limited and the clients in mobile ad hoc network cant forward the video packets to the other clients at the same time. Therefore, with choosing the PoR in the LMF the clients request to join to view the video and receives the missing portion with less services delay. Because the clients miss up the 1st segment, he/she will go to the PoR and get the 1st segment directly without waiting longer to the next broadcast 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 forwarding the 1st segment to other clients missing the broadcast.
2. If such PoR does not exists
3. Run ClientPlayback()
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 2st segment of the same video soonest
1.5 Join the broadcast channel
1.6 Download / Playback 2nd seg - seg k and save in Suffix-Buffer
17. Quit this channel
18. Note: Segment 1 is store into reusable buffer during the previous two steps.

Furthermore, since the broadcasting of the video repeatedly on the same channel, it is possible that the Client_N reaches at the last segment of the video (Seg^k) as explained in **Fig. 13**.

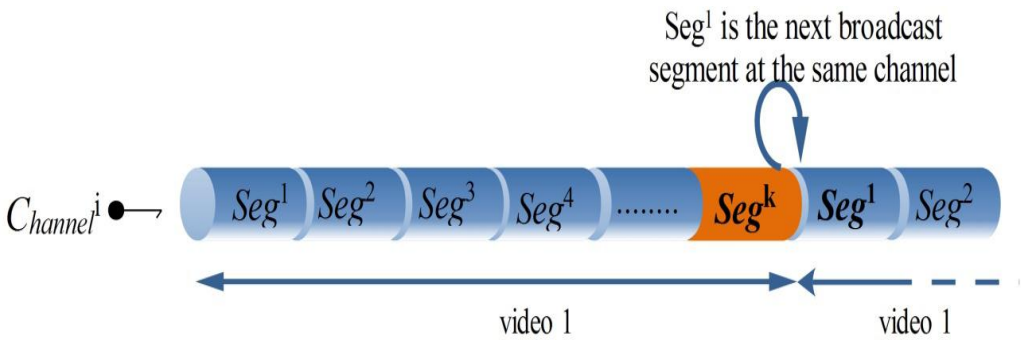


Fig. 13. Clients join the 1st segments of the next broadcast at the same C_{hannel}^{i}

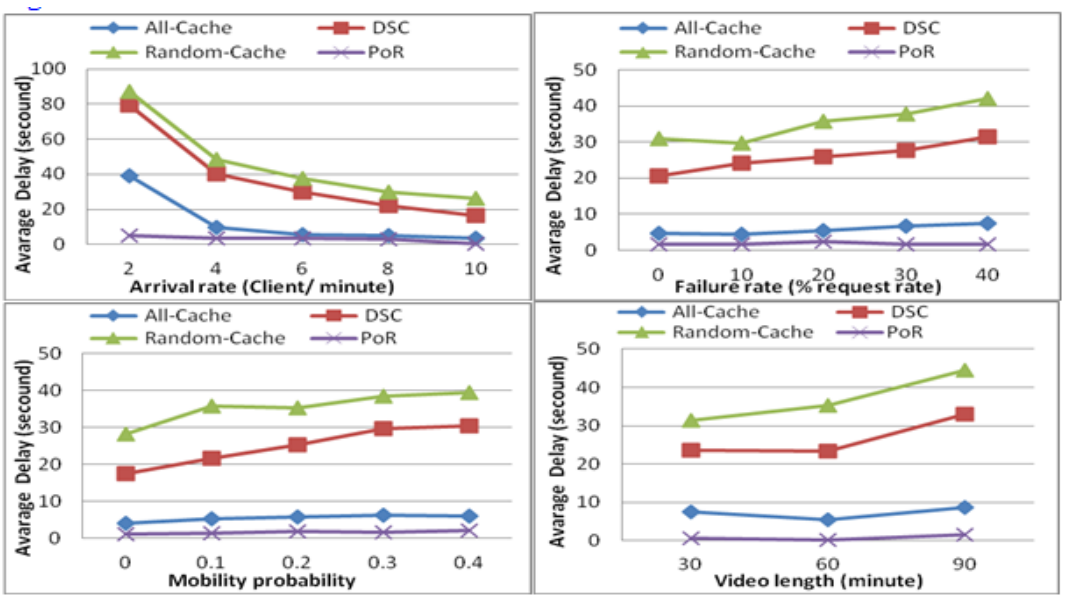
Let us consider a Client_N tunes in a random C_{hannel}^{i}, where this channel is currently broadcasting segment Seg_z, if the Seg_z= K, make the C_{hannel}^{i} equal to the C_{hannel}^{j} and wait the C_{hannel}^{j} starts broadcasting segment Seg^1 and join this channel and then playback the video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

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

Where, K is the last segment in the currently broadcasting and Channelj must be currently broadcasting segment Seg^K to be able to get the 1st segment from same broadcast of the C_{hannel}^{i}.

4. Simulation Results

The system architecture and PCSB implemented using OMNeT++ version 4.1, and the experiments have been performed on a Core (TM) i7 CPU, running Ubuntu 6.0.1 operating system. The new system architecture and technique improves the robustness and imperceptibility implemented in order to achieve the objective of the research.We investigate 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 stay fixed, as well 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 present them in the **Fig. 14** and **Fig. 15**.



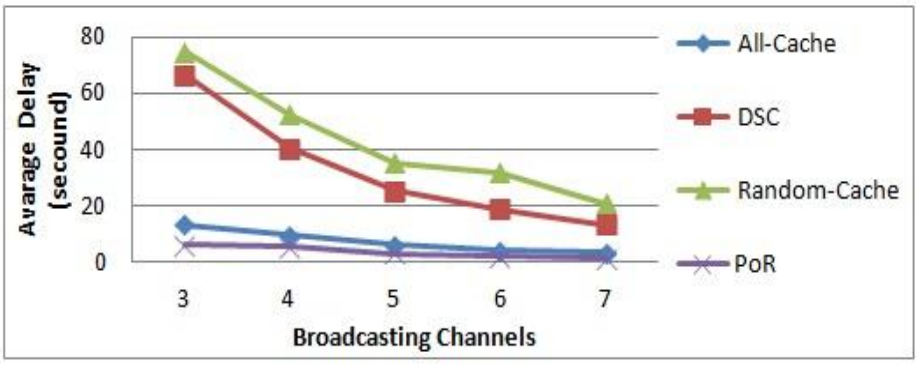
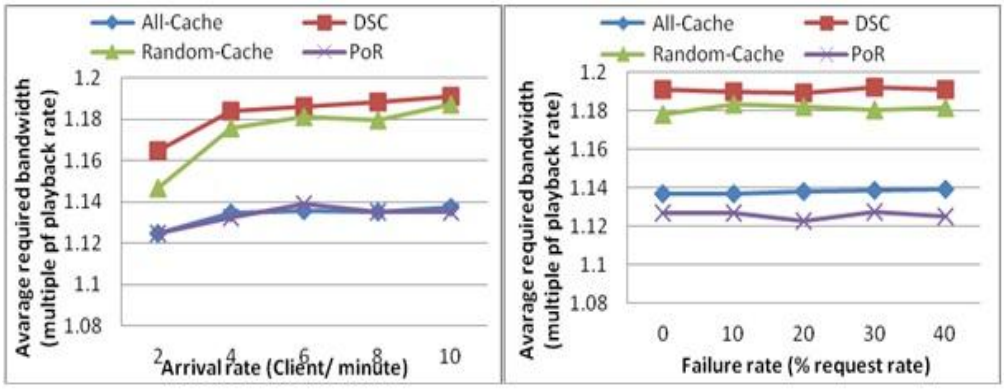


Fig.14. Effect on Service Delay

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 helped to reduce the waiting time of the mobile clients substantially. In all four caching techniques the client population is spares ($P_{arrival=}2$), the dealy is less than 90 seconds and when we test it in the ($P_{arrival=}6$), it was less than 40 seconds, which is 4 times better than that 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 it offered a delay that is less than 5 seconds in most scenarios above. The All-cache was almost 10 seconds in the previous system. Furthermore, DSC always outperforms Random-cache by about 10 seconds. When the arrival rate increase or decrease the mobile clients can find the 1st segment smoothly in the local media forwarder (PoR), when the $P_{arrival=}2$ the services delay is less than 5.03173 seconds. The average delay of the arrival rate is less than 3.61374. The failure rate and moving probability are more prone in the system, almost the service delay increases slowly. For instance, DSC's delay is 17.384553 seconds and All-Cache is 4.106974 when no client moves, while PoR is only 1.106974 seconds and only 2.1117 seconds 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 missing (1st segment) from the PoR. The average failure rate is 3 times less than All-cache (1.515274).We test the system with different parameters and different numbers of the channel {3,4,5,6,7}. The results showed that by increasing the number of the channels, the services delay would be decreased. When the number of the channel is three the average delay is 6.177176 and when its 7 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.



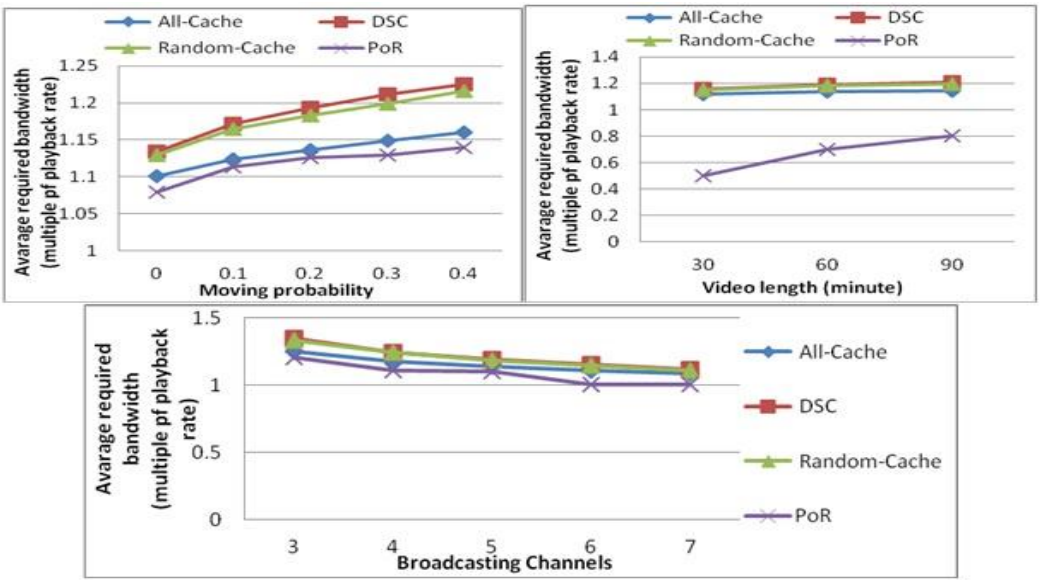


Fig. 15. Effect of bandwidth requirement

The bandwidth requirement is became 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 the all scenarios, its 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 for mobile clients equipped by current wireless technologies and will be even more powerful by developing the wireless technologies. According to the results in request rate, failure rate, moving probability rate and video length are increases slowly. The average arrival rate of PoR is almost 1.12491 when the $P_{arrival} = 2$ and it's almost similar to the All-cache, and when $P_{arrival} = 6$ its almost 1.138805 was less than All-cache. As well as we, All-cache, DSC and Random-cache are require more client bandwidth than PoR. However, the difference is tiny between them. For instance, when all the input parameters are set by 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 to the results, the PoR is much better than the all other caching techniques. Furthermore, the DSC and Random-cache offer service delays much better than 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.

5. Conclusion

This study discusses the video on demand broadcast techniques for homogeneous and heterogeneous mobile networks and proposes an improved broadcasting scheme. At first the paper provides an overview on Segment Based Broadcasting Schemes by mentioning several broadcasting protocols and comparing the existing broadcast protocol to find the suitable broadcast for the VOD. As well as, we 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 any broadcast technique can provide true video on demand because their service delay is non-zero. However, in SB and SkB provides better service delay. On the other hand, SkB is more complex and requires that the client be capable of download 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 the better choice for the current wireless architectures because of 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 a system architecture in Section 3 including the main contents of proposed system architecture for the broadcasting techniques and explained the channels design of the PCSB and Characteristics of the PoR. Finally, the simulation results of the whole system shows how is the playback procedure of popularity cushion cashing 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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