Mobility Support of Multi-User Services in Next Generation Wireless Systems

Luis Veloso
University of Coimbra
lmveloso@dei.uc.pt

Paulo Mendes
NTT DoCoMo Euro-Labs
mendes@docomolab-euro.com

Edmundo Monteiro
University of Coimbra
edmundo@dei.uc.pt

Abstract

The substantial advancement and proliferation of wireless technologies leads to the need to efficiently manage user mobility. Furthermore, the simultaneously emerging of services like video-conference, radio and TV has emphasized the importance to deliver content to several simultaneous receivers. This way, one of the key challenges to deploy multi-user services in the next generation wireless systems is the support of seamless mobility of multi-user services. In this paper the functioning of the Seamless Mobility of Users for Media Distribution Services (SEMUD) proposal is presented. This mobility management technique possesses two operation modes. To provide seamless mobility the standard mode resorts on the collaboration between caches (located in the base stations) and buffers (located in the mobile nodes). The enhanced mode introduces mobility prediction and messages for context transfer between access routers. A performance analysis is given to corroborate the merits of the proposal.

1. Introduction

Several wireless technologies have been developed to satisfy the different requirements and expectations of users. On the other hand, the size reduction, low cost affordability and increase in the autonomy of electronic devices have leaded for the development of portable devices. The wide spread utilization of these handheld devices and the astounding development of wireless technologies demands for the seamless mobility of users.

Furthermore, the simultaneously emergence of several applications like video-conference, radio and TV has emphasized the importance to deliver content to several simultaneous receivers. In this context, the multicast technique arises as the appropriate method to forward information simultaneously to several receivers (denominated multicast group). Its development leaded to the standardization of several multicast protocols by the IETF (Internet Engineering Task Force).

Nevertheless, the various multicast proposals were initially developed and optimized for fixed networks. That is, they were not aimed to support seamless mobility of users. Consequently, it is necessary to overcome this limitation of the IP multicast routing, and provide mobility support in the next generation wireless systems.

This way, one of the challenges in the next generation mobile networks and the objective of the present work is the development of a mobility management technique that provides seamless mobility of multicast data between different access technologies. This work presents the functioning of the Seamless Mobility of Users for Media Distribution Services (SEMUD) mechanism. This proposal aims to support the movement of users between different locations without packet losses and with reduced latency.

This mobility management technique possesses two operation modes. To provide seamless mobility the standard mode is based on the collaboration between caches (located in the base stations) and buffers (located in the mobile nodes). Additionally, the enhanced mode of the mechanism described in this paper includes mobility prediction and messages for context transfer between access routers. This proposal was developed under the QoS Architecture for Multi-user Mobile Multimedia (Q3M) project [1]. This project aims to develop a platform for publish-subscribe services over an IP-based mobile system and results from the collaboration between the University of Coimbra and the NTT DoCoMo Euro-Labs.

The remainder of this document is organized as follows. Section 2 gives a survey of the related work and section 3 presents the SEMUD mechanism with special emphasis to the enhanced functionality. Following, the simulation scenario and experimental results are presented in the section 4. Finally, the conclusions are presented in the section 5.

1-4244-1338-6/07/$25.00/©2007 IEEE

2. Related Work

Existing multicast proposals absorb several ideas from the unicast approaches but have different characteristics. In multicast routing the source sends just one copy of the information and the network duplicates the packets whenever necessary, instead of sending a number of copies equal to the number of receivers. This way, the network resources are used in an efficient way.

The proposal denominated Home Subscription or Bidireccional Tunneling is based on the Mobile IP architecture [2]. When the Mobile Node (MN) is in a Foreign Network (FN) and wants to subscribe a multicast group, it will establish a bidireccional tunnel with the Home Agent (HA). Through this tunnel the MN will send the membership report messages and receive the multicast data. Every time the MN moves to a new FN, it continues receiving the multicast data through the HA. In other words, the multicast tree does not need to be reconstructed every time the MN moves to a different network. Nevertheless, this proposal leads to an increase in the traffic of the Home Network (HN), and the routing of the multicast packets will not be optimal. Moreover, there will be packet duplication if several MNs have subscribed to the same multicast group in a FN.

In order to solve the problem of packet losses during handover, some micro-mobility protocols were designed to temporarily buffer packets. In some approaches, packets are buffered in the Previous Access Router (PAR). After handover, when the IP connectivity between the MN and New Access Router (NAR) is established, the buffered packets are sent from the PAR to the MN. This is used, for instance, in the pre-registration of the Low Latency Handoffs in Mobile IPv4 (LLH) [3]. Other schemes buffer the packets in the NAR. This is the case on Fast Handovers for Mobile IPv6 (FMIP) [4] and on post-registration of LLH [3]. However, none of these approaches avoids the starvation of the receiving application during handover and support the functioning of multi-user services.

On the other hand, caching has been used to surmount different kind of problems. Namely, to overcome lookup delays in web access or to replicate media. For instance, several media segmentation approaches to proxy caching of multimedia objects have been evaluated and compared with a whole media caching [5]. Instead of caching entire videos each one can be cached in several layers with respect to cached data sizes [6]. This progressive video caching policy enables cache of data based on the user access pattern and on proxy resources. Nonetheless, the above described approaches do not support multi-user multimedia services and do not support seamless mobility of users.

This way, it would be interesting to investigate how the collaboration between caches in the access routers and buffers in the mobile devices can be used to reduce the packet losses during the handover and enhance the perceived quality by the user.

3. Seamless Mobility of Users for Media Distribution Services

The objective of SEMUD mechanism is to provide seamless mobility to multi-user services when they move between different access-routers. This is achieved through the combination of caches in the access routers and buffers in the mobile devices whose collaboration avoid packet losses during handover and reduce latency. To increase this capability, the proposal was enhanced with mobility prediction and messages for context transfer between access routers.

3.1 SEMUD Standard Mechanism

In the SEMUD standard mechanism the data packets received in the access router are stored in the cache (replacing the oldest ones) and forwarded to the interested receivers. When those packets are received by a MN they are stored into the buffer from where they are consumed by the application.

The functioning of the SEMUD mechanism is described in Figure 1. The scenario assumes an all-IP core network that supports the different access networks. When the handover occurs, the data in the buffer of the MN will continue to be read in order to keep the data flow (step 2).

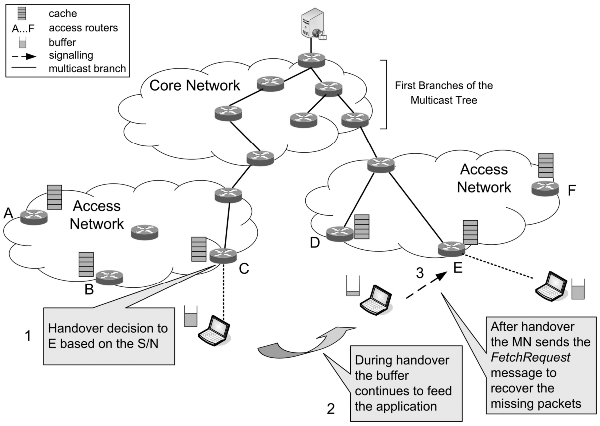

Figure 1 – Handover decision and sending of the *FetchRequest* message

When the handover finishes, the MN updates its buffer by fetching the missing packets from the cache. To fetch the packets not received during handover the MN sends the message *FetchRequest* towards the cache (step 3) requesting the packets that was not able to receive. In the message will be transported information concerning the available space in the buffer, the time stamp of the last packet received in the buffer before handover and the intended multicast session represented in the PIM-SSM (Source Specific Multicast) [7] protocol by <*Source, Group*> or <*S, G*>.

As depicted in Figure 2 if the packets are already present in the cache (e.g. other receiver is present in the cell or the enhanced SEMUD functionality is active), SEMUD can immediately recover the packets that were not received during handover (step 4). If not, it is necessary to take the necessary steps to subscribe the intended session. In this case, the seamless mobility will depend on the number of packets available on the buffer to feed the application while the session is not active.

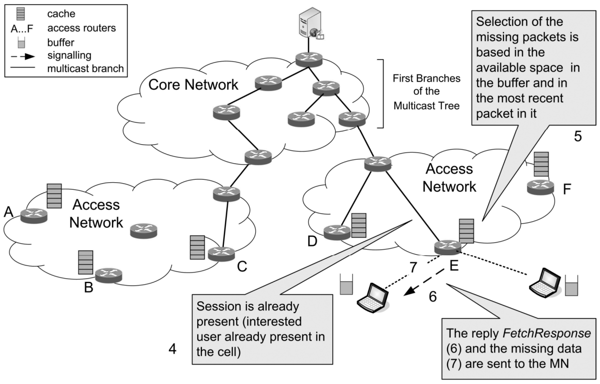

Figure 2 – Cache behavior and reception of the *FetchResponse* message

In this paper it is considered that the recovered packets are sent from the cache to the buffer via unicast. This way, the other MNs receiving the session are not going to receive this set of packets. With the information contained in the *FetchRequest* message, the NAR identifies the packets that must be sent to the MN (step 5), replies (*FetchResponse*) to the fetching request (step 6) and sends the fetched packets directly to MN (step 7). The MN gets the unicast fetched packets, de-encapsulates them and places the multicast packets in the buffer of the multicast session. After getting all the fetched packets, MN sends an MLDv2 report to subscribe the intended multicast channel. The NAR receives the MLDv2 report and configures the wireless interface to send the multicast packets (if the interface is not configured yet, due to a previous report from another MN). Finally, the MN starts to receive the multicast packets and places them in the multicast-channel buffer.

3.2 SEMUD Enhanced Mechanism

In the enhanced mechanism, the presence of the session in the next access router is guarantied through the use of mobility prediction. This is, the most probable cells to where the MN will move are predicted based on parameters like the moving direction, velocity, current position and historical records [8]. Based in this forecast, the necessary resources are reserved in advance in those cells.

In this case, a *ResourceQuery* message will be sent to the next most probable access routers in order to obtain information concerning the available resources and to reserve them in advance. The addresses of the predicted access routers could be obtained in a static way through agreements, where a machine in the current network exchanges this information with another one located in other network. Alternatively, the addresses discovery could be done in a dynamic way by querying a DNS-alike service.

The requested information is sent back to the requesting access router through a *ResourceResponse* message. After collecting this information the current access router selects the next access router. For example, access routers that give guaranties of QoS (Quality of Service) should be preferred to those that do not give those guaranties or cannot built the branch to the multicast tree. The current access router sends the information regarding the future access router to the MN. This is accomplished by the *HandoverBearer* message that contains the IP address of the future access router and the correspondent multicast channels.

This way, after the handover the session will be already present at the new access router and the MN will only need to fetch the packets that were not received during the handover.

Following, a scenario where the SEMUD mechanism uses a mobility prediction mechanism to reserve the necessary resources in the most probable cells to where the MN could move is described. Figure 3 shows a scenario of operation of the SEMUD mechanism when the MN is the receiver of a multi-user session. The current access router predicts that handover will be performed to base stations located outside the current access network (step 1). Therefore, it needs to reserve resources in advance in the future locations, and consequently, to discover the addresses of the predicted access routers (using one of the approaches mentioned before). Then, *ResourceQuery* messages will be sent to the access router candidates (step 2). In each access router candidate, an existing session control management protocol will be triggered in order to handle the resource reservation to the session (step 3). After reservation of the necessary resources (step 4), the session control management protocol notifies SEMUD regarding the possibility or not to reserve the requested resources.

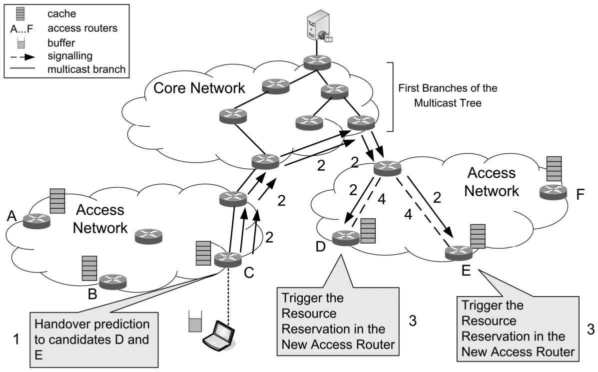

Figure 3 - Handover prediction and resources request in the predicted access routers

As depicted in Figure 4, after obtaining this information, the predicted access router will reply with a *ResourceResponse* message (step 5) towards the requesting access router.

Based on the S/N ratio and the response from the access router candidates, the current access router decides to handover to access router E (step 6) and sends the information regarding the future access router to the MN through the message *HandoverBearer* (step 7). During handover packets continue to arrive into the caches. When the MN arrives into the new base station, it needs to recover from the cache (located in the access router) the packets not received during the handover.

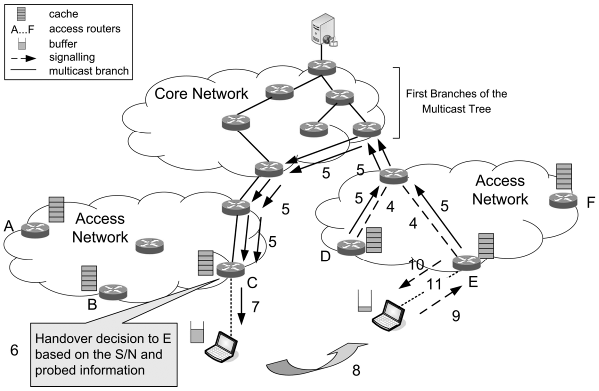

Figure 4 - Request responses and handover decision in based in the S/N and probed information

It sends the message *FetchRequest* towards the cache (step 9) requesting the packets that was not able to receive. With the information contained in the *FetchRequest* message, the cache identifies the packets that must be sent to the MN, replies (*FetchResponse*) to the fetching request (step 10) and sends the fetched packets (step 11). Meanwhile, due to a soft release mechanism the unused resources associated with the other base station are released.

This way, the use of caching and buffering by the SEMUD mechanism can keep the data flow during handover and contributes to a solution of seamless mobility by reducing the latency and constraining packet losses with higher assurance.

3.3 Interfaces and Components

The SEMUD mechanism described above contains the following interfaces needed for the seamless mobility of the MN.

- The *prediction interface* for the interaction with the movement prediction module. It is used to predict the next most probable base station based on the location of the base stations and on the properties of the mobile node such as location, moving direction and velocity.
- The *mobility interface* that gives support to mobility operations. It interacts with other access routers that are SEMUD aware. This allows to transfer the context of multi-user sessions from the previous to the new predicted access router, and to collect information concerning the capability and connectivity provided by the latter.
- The *resource reservation interface* that interacts with session control mechanisms. This interaction allows for the reservation of network resources in the predicted access routers, for the release of the resources reserved on the old path, and for the release of the resources reserved on the new paths that the mobile node is not going to use.

Furthermore, the SEMUD mechanism is composed by the following components:

- The *cache component* is used to store packets that can be recovered afterwards. When a packet is retrieved from the cache, a copy will remain for further requests. A packet is only permanently removed from the cache when the replacement policy is applied.
- The *cache management component* is responsible for the identification, selection and delivering of the packets that are missing in the buffer.
- The *buffer component* is used to store packets before they are delivered to the application. When the data is retrieved no copy will remain in the buffer. That is, contrarily to what happens in the cache, the data can be read from the buffer only once.
- The *buffer management component* is responsible to supervise the amount and identification of the packets present in the buffer. This is necessary to know

the available space in the buffer and the last received packet.

Following, the simulation scenario and the obtained results concerning the evaluation of the fetching process are presented. Particularly, the packet losses and quality of a video sequence will be evaluated regarding the variation of the cache size.

4. Experimental Results

A video sequence denominated Akiyo [9], composed of 300 frames with YUV format, sampling 4:2:0 and dimension CIF (352x288) was used in the simulation. Through a MPEG4 encoder those frames were compressed into a sequence with a Group of Pictures (GOP) comprised of 30 frames, and subsequently, transmitted with a 30 frame/s rate. Each frame was fragmented in blocks with 1024 bytes length and transported through IP packets. Considering a UDP header with 8 bytes and an IP header with 20 bytes, the final length to the IP packet is 1052 bytes. Those packets were sent using a Variable Bit Rate (VBR) with an average rate of 86 KB/s.

The components that constitute the simulation model can be classified in three groups. The first one is responsible to support and evaluate the multimedia content. That is, it copes with the conversion between the frame formats by resorting in tools from the Evalvid platform [10, 11]. The second group is responsible for the implementation of the SEMUD mechanism and to support the transmission of content through the same. This means that it is responsible to implement the cache, the buffer and the process of recovering packets from the cache to the buffer. This implementation was accomplished through the use of the Network Simulator (NS) [12]. Finally, the Matlab tool was used to evaluate the obtained results and produce the figures that are present in the next sub-sections.

4.1 Totality of Lost Packets

The totality of packet losses at the end of the simulations was obtained by varying the cache size and buffer size between 1 and 105.2 KB and by considering a constant handover duration (500 ms). The simulations were performed with and without the activation of the SEMUD mechanism to verify the improvements introduced by the proposal.

The Cumulative Density Function (CDF) for the total number of lost packets with and without the activation of the SEMUD mechanism is depicted in Figure 5.

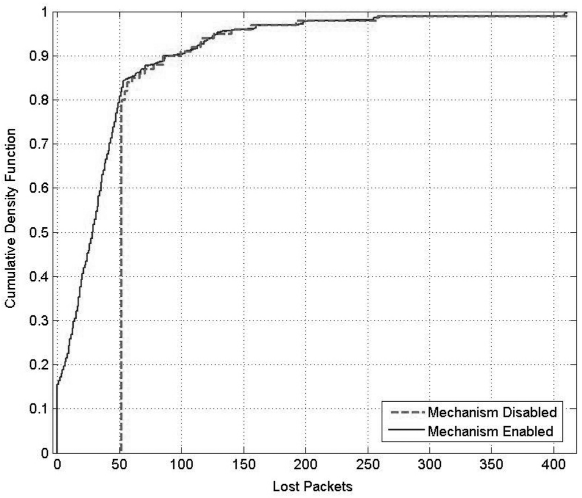

Figure 5 - Cumulative Density Function (CDF) for the total number of lost packets

The CDF corroborates the expected improvement introduced by the SEMUD mechanism. The amount of packets recovered by the SEMUD mechanism is present in Figure 6.

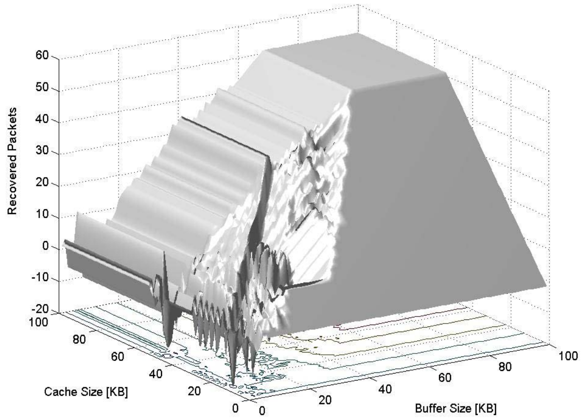

Figure 6 - Number of recovered packets when the SEMUD mechanism is enabled

These results were obtained by comparing the total number of lost packets that occur with and without the activation of the mechanism. Again, this figure confirms the enhancement introduced by the SEMUD proposal. Namely, the number of recovered packets increases as the buffer size or the cache size augments. On the one hand the augment in the buffer size allows for the recovery of a greater number of packets from the cache. On the other hand, an augment in the cache size leads to an increase in the probability that the missing packets can be found in it. As expected, the packets recovery is not effective when the buffer or cache size is too small.

4.2 Temporal Variation of the Buffer Occupation

In the previous section, the number of recovered packets versus the cache size and the buffer size was presented. In this section, the temporal variation of the buffer occupation versus the cache size will be described. The results were obtained for a cache variation between 1 and 105.2 KB, a constant handover duration of 500 ms (beginning at 4.984s) and a 50 ms sampling period.

The results concerning the buffer occupation with the SEMUD mechanism disabled are presented in Figure 7. The observed oscillations are explained by the fragmentation of each frame into several IP packets. The number of these packets depends on the frame size (e.g. I, P, B) and on the maximum IP packet size (1052 bytes in this scenario).

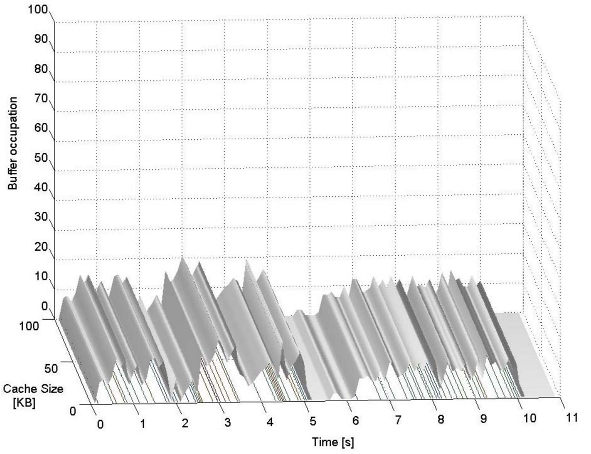

Figure 7 - Buffer occupation versus the simulation time and the cache size (SEMUD mechanism disabled)

In other words, the retrieving or arriving of a frame to the buffer corresponds to the retrieving or arriving of the packets that convey it. As expected, during the handover period [4.984, 5.484]s the buffer occupation is reduced. After the handover completion the buffer reinitiates the reception of packets with the same fluctuating behavior as in the beginning of the simulation.

When the SEMUD mechanism is enabled the buffer occupation will be significantly different. This occupation is presented in Figure 8. In this case, the buffer occupation rises abruptly when the handover finishes due to the recovering process of the packets not received during handover.

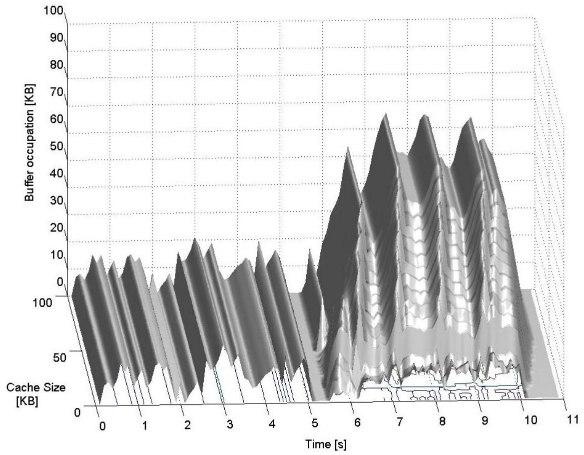

Figure 8 - Buffer occupation versus the simulation time and cache size (SEMUD mechanism enabled)

This is, when the handover finishes, the MN requests the packets that were not received from the cache. To accomplish this, it sends a message that contains the identification of the last packet received in the buffer and the available space in it. Based on this information, the cache selects and sends the available packets to the MN. This way, the bigger the cache size the higher the probability to find the missing packets in it. For this reason, the buffer occupation after handover increases as the cache size augments.

However, the buffer occupation ceases to increase when the cache size reaches a certain value. This happens when the cache reaches a value that encloses all the missing packets. This way, an increase in the cache size above this value is not translated into a higher buffer occupation. This value for the cache size depends on the handover duration and on the transmission rate.

4.3 Temporal Variation of the Lost Packets

In the previous section, the buffer occupation versus the simulation time and the cache size was presented. In this section, the number of lost packets will be presented versus the simulation time and cache size considering the same values for the cache size variation, handover duration and sampling period. Moreover, a buffer size with 105.2 KB was used.

The obtained results when the mechanism is disabled are presented in Figure 9, where it is observed that the variation of the packet losses during the simulation time is independent from the cache size. In this case the cache has no active role in recovering packets. Due to this passive behavior, its size variation will not affect the results.

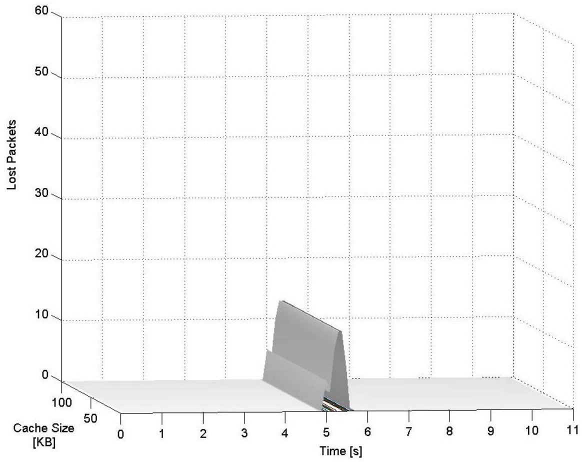

Figure 9 - Packet losses versus the simulation time and cache size (SEMUD mechanism disabled)

The results obtained when the mechanism is enabled are present in Figure 10. In this case, a reduction in the number of lost packets is observed when the cache size increases. Since the SEMUD mechanism is now enabled, the cache possesses a preponderant role in recovering packets, and consequently, in reducing packet losses.

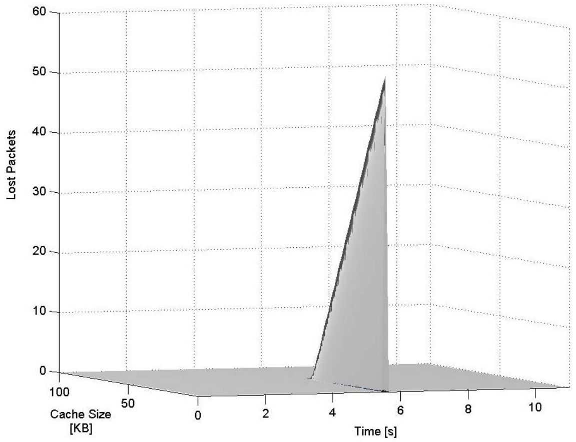

Figure 10 - Packet losses versus the simulation time and cache size (SEMUD mechanism enabled)

An increase in the cache size leads to a higher amount of packets that can be stored in it, and consequently, to a higher probability to find there the packets not received during the handover. However, when the mechanism is enabled the accounting of the lost packets is done when the handover finishes. For this reason, it is apparent in Figure 10 (for cache sizes lower than 52.6 KB) greater packet losses comparatively with Figure 9. Nevertheless, the amount of packet losses accounted at the end of the handover when the SEMUD mechanism is enabled is always inferior to the summation of the partial losses that occur during the handover when the mechanism is disabled.

An increase in the cache size above the value 56.8 KB will not be translated into an improvement. In other words, above this threshold the cache possesses enough space to contain all the packets that were not received during the handover by the MN. The threshold value depends on the handover duration (number of lost packets) and on the transmission rate.

4.4 Video Quality Assessment

After the presentation of the temporal variation of the number of lost packets versus the cache size, it is now described the variation of the received video sequence quality versus the cache size. The video sequence quality was obtained considering a handover duration of 500 ms (beginning at 4.984s), a buffer size of 105.2 KB and a cache size varying between 1 and 105.2 KB.

The Peak Signal to Noise Ratio (PSNR) was the metric used to evaluate the quality of the video transmission. Considering frames with MxN pixels and 8 bits/sample this metric is defined through the expression:

$$PSNR = 20\log_{10}\left(\frac{255}{\sqrt{\frac{1}{MxN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left\|Ys(i,j)-Yd(i,j)\right\|^2}}\right)$$

In this expression, *Ys(i,j)* designates the pixel in the position *(i, j)* of the original frame and the *Yd(i,j)* denominates the pixel located in the position *(i, j)* of the reconstructed frame.

The obtained results when the SEMUD mechanism is disabled are present in Figure 11. It is observed that the cache size has no effect in the quality of the received sequence when the mechanism is disabled. This observation is in accordance with the fact that in this case the cache is passive, and consequently, its size is irrelevant. Moreover, the frames affected by the packet losses during the handover suffer high quality degradation.

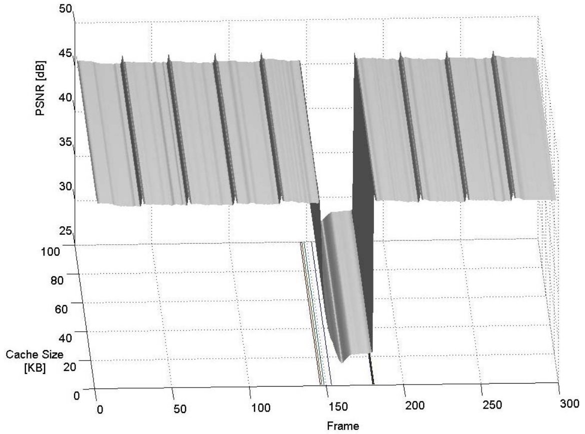

Figure 11 - PSNR of the video sequence versus the cache size (SEMUD mechanism disabled)

As exhibit in Figure 12, when the mechanism is enabled a significant improvement is observed in the quality of the received frames when the cache size augments. The increase in the cache size leads to the augment in the number of packets that are possible to recover, and consequently, to an augment in the quality of the corresponding frame.

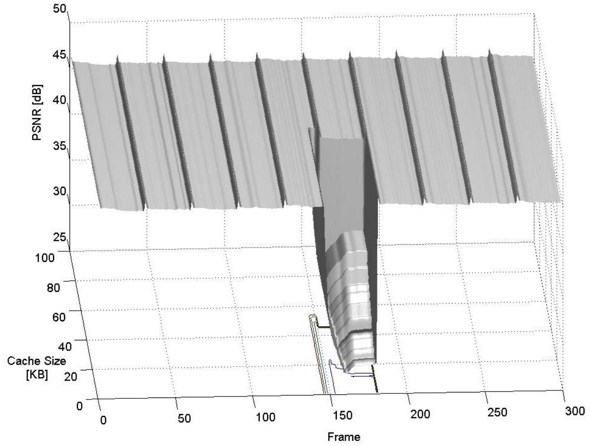

Figure 12 - PSNR of the video sequence versus the cache size (SEMUD mechanism enabled)

This improvement could be more expressive for lower cache sizes. However, despite the recovery process there are packets that are irrecoverable. Among those are packets pertaining to an I frame. Recall that a GOP is formed by an I frame and all subsequent frames until the next I frame. When a I frame is lost it is impossible to correctly decode the subsequently frames pertaining to the GOP. In this scenario it was considered a GOP with 30 frames, and consequently, when an I frame is lost it is impossible to correctly decode the other 29 frames belonging to the GOP. This way, the I frame that is lost in the irrecoverable packets leads to the lost of the remaining 29 frames pertaining to the GOP, even if they are correctly received.

4.5 Example

In this section a concrete example with a cache size of 105.2 KB, a buffer size of 105.2 KB and a handover duration of 500 ms (beginning at 4.984s) is presented. The Akiyo video sequence with YUV format and CIF (352x288) size is used. This sequence was compressed into the MPEG4 format with a GOP of 30 frames. The buffer occupation and packet losses during the simulation time and the quality of the received frames were analyzed.

4.5.1 Evaluation with the SEMUD Mechanism Disabled

Initially the simulation was carried out with the SEMUD mechanism disabled. The results concerning the buffer occupation during the simulation time are presented in Figure 13. During the handover period the buffer becomes empty and continues that way until the handover finishes.

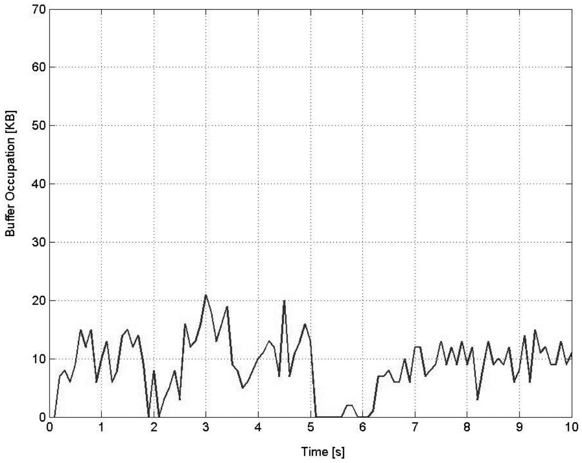

Figure 13 - Buffer occupation when the SEMUD mechanism is disabled

Figure 14 shows how the packet losses vary during the simulation time. The packet losses only occur in the interval [4.984, 5.484]s, which corresponds to the handover time.

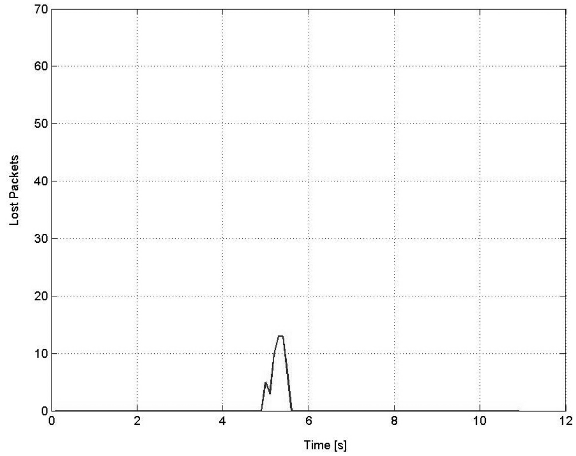

Figure 14 - Number of lost packets when the SEMUD mechanism is disabled

A direct consequence of the packet losses will be quality degradation in the received frames. This degradation can be observed in Figure 15, in which the PSNR values for each frame that constitutes the sequence are exhibit.

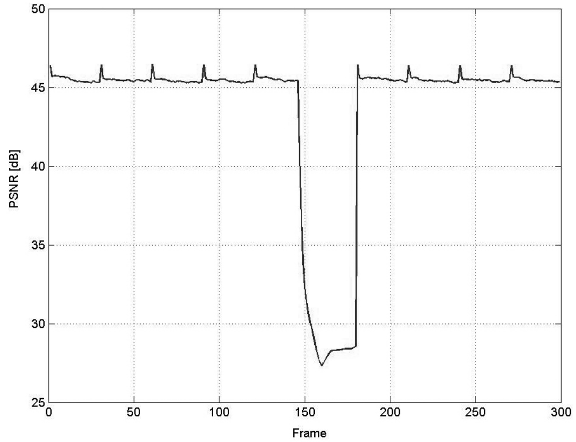

Figure 15 - PSNR values when the SEMUD mechanism is disabled

This quality degradation can be observed in the frames presented in Figure 16. The decoder tries to recover the lost/degraded frames by resorting in the last frame that was correctly decoded. The quality degradation is visible, particularly in the announcer face.

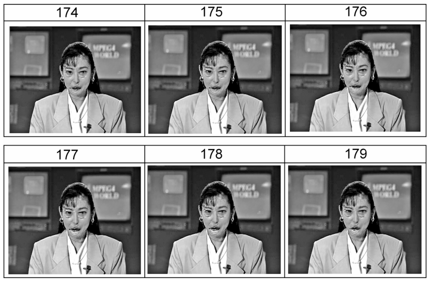

Figure 16 - Some of the frames affected by the quality degradation when the SEMUD mechanism is disabled

4.5.2 Evaluation with the SEMUD Mechanism Enabled

In this section the simulation was carry out with the SEMUD mechanism enabled. In this case the packet losses were null during the simulation time. For this reason the figure concerning the packet losses is not presented. On the other hand, the variation of the buffer occupation is described in Figure 17.

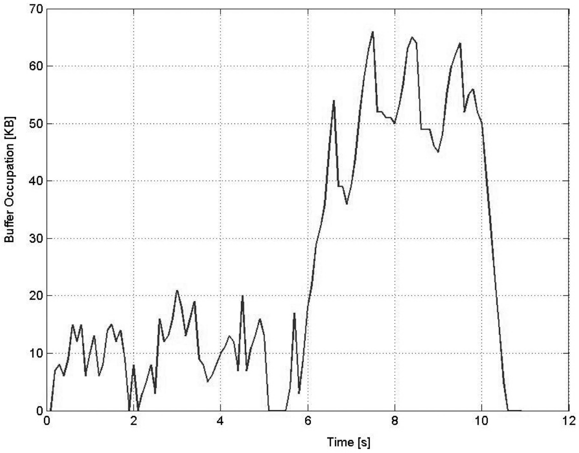

Figure 17 - Buffer occupation when the SEMUD mechanism is enabled

During the handover period the buffer becomes empty, and afterwards, its occupation raises to values higher than observed previously. This augment results from the recovery process of packets from the cache to the buffer. Through this process it is possible to recover the packets that were not received during handover. Since none of the packets is lost it is expected that the received frames possess a good quality, as observed in Figure 18.

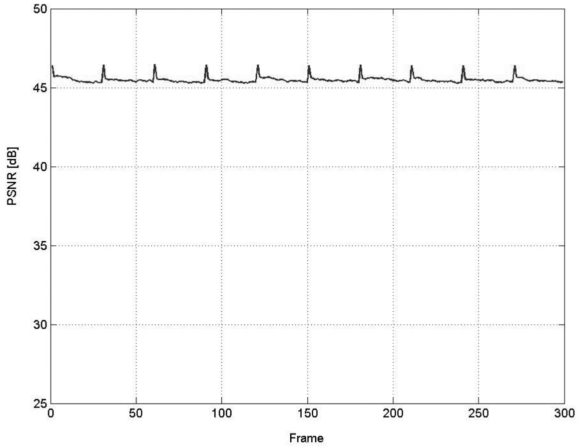

Figure 18 - PSNR values when the SEMUD mechanism is enabled

This way, the frames that previously suffered from degradation when the mechanism was inactive present now a good quality, as show in Figure 19.

Figure 19 - Obtained frames when the SEMUD mechanism is enabled

Notice that in Figure 16 the face position is different than the one in Figure 19. As mentioned before, in the former situation the decoder tries to compensate the lost frames by resorting in the last frame decoded correctly.

5. Conclusion

The performance evaluation of the fetching process justifies the benefits of the proposed mechanism in constraining the packet losses, and consequently, in improving the quality of a video sequence perceived by the user. To absorb rate variations and to efficiently recover the missing packets, the buffer and the cache should be correctly dimensioned. For example, for an average rate of 86 KB/s, a handover duration of 500 ms and a buffer size of 105.2 KB the losses will be reduced 72.5% when the cache size has 42 KB. Furthermore, for the mentioned bit rate and handover duration the losses will be totally eliminated when combining cache sizes above 56.8 KB with buffer sizes above 71.5 KB.

In the future, to take the improvement of the video sequence even further, the packets should be recovered from the cache taking in account their type. In other words, the packets pertaining to frames I should be recovered with higher priority comparatively to the packets belonging to frames P or B.

6. Acknowledgments

Other authors from the University of Coimbra (UC) contributed for this paper, namely Eduardo Cerqueira, Augusto Neto and Marilia Curado. This project is supported by the NTT DoCoMo Euro-labs, by the Portuguese Ministry of Science, Technology and High Education (MCTES), and by European Union FEDER – program POSC (projects Q3M and SAPRA).

REFERENCES

[1] E. Cerqueira, L. Veloso, A. Neto, M. Curado, E. Monteiro, and P. Mendes, "A Unifying Architecture for Publish-Subscribe Services in the Next Generation IP Networks," Globecom 2006, San Francisco, California, 2006.

[2] C. Perkins, "IP Mobility Support for IPv4," IETF RFC 3344, August 2004.

[3] K. E. Malki, "Low Latency Handoffs in Mobile IPv4," IETF Internet Draft, 2005.

[4] R. Koodli, "Fast Handovers for Mobile IPv6," IETF RFC 4068, July 2005.

[5] K. Wu, P. Yu, and J. Wolf, "Segmentation of Multimedia Streams for Proxy Caching," in *IEEE Transactions on Multimedia*, vol. 6, 2004.

[6] W. Ma and D. Du, "Design a Progressive Video Caching Policy for Video Proxy Servers," in *IEEE Transactions on Multimedia*, vol. 6, 2004.

[7] H. Holbrook and B. Cain, "Source-Specific Multicast for IP," IETF RFC 4607, August 2006.

[8] I. F. Alkyildiz and W. Wang, "The Predictive User Mobility Profile Framework for Wireless Multimedia Networks," in *IEEE/ACM Transactions on Networking*, vol. 12, 2004.

[9] Video Traces Research Group, "YUV 4:2:0 Video Sequences," (http://trace.eas.asu.edu/yuv/qcif.html), Arizona State University.

[10] C. Ke, C. Lin, C. Shieh, and W. Hwang, "A Novel Realistic Simulation Tool for Video Transmission over Wireless Network," IEEE SUTC, Taiwan, 2006.

[11] J. Klaue, B. Rathke, and A. Wolisz, "EvalVid - A Framework for Video Transmission and Quality Evaluation," *13th Int. Conference on Modeling Techniques and Tools for Computer Performance Evaluation,* Urbana, Illinois, USA, 2003.

[12] K. Fall and K. Varadhan, "The ns Manual (formerly ns Notes and Documentation)," (http://www.isi.edu/nsnam/ns/ns-documentation.html) The VINT Project, 2007.