Quality of Multimedia Streaming-oriented Handover Management Solution for Mobile Applications

Bogdan Ciubotaru, *Student Member, IEEE* and Gabriel–Miro Muntean, *Member, IEEE*

Abstract— **Mobility has become a mandatory feature of the future Internet as mobile computing gains increasing popularity among Internet users. The rapidly evolving heterogeneous wireless environment provides a variety of communication resources for the mobile host. In order to fully benefit of these wireless access networks an efficient and quality oriented mobility management system has to be employed. This paper presents an innovative solution for handover management based on an estimation of multimedia streaming quality which considers both quality of service and user quality of experience in the decision making process. The proposed solution aims at improving the user perceived quality in the context of mobile multimedia streaming by efficiently exploiting all the communication resources available to the mobile host. Simulation-based performance evaluation shows the performance improvement, both in Quality of Service and user perceived quality, when the proposed solution is used compared to other mobility solutions.**

Index Terms—**Handover management, Multimedia streaming, Wireless networks, QoS.**

I. Introduction

Wireless broadband technologies are increasingly popular among Internet users mostly because of the growing availability of various mobile devices with increased capabilities.

As the Internet was not initially designed to accommodate mobile users additional services including mobility management has to be developed and incorporated in the Internet's protocol stack. Mobility management includes among others services, handover management which allows a mobile device to change its point of attachment to the network while maintaining the current data sessions unaffected from the point of view of Quality of Service (QoS). Handover management is the most important component of a mobility management solution. It has the greatest impact on level of QoS received by the mobile host and consequently impacts the user perceived quality.

Different handover management solutions, developed at different network layers were proposed in the literature [1] including Mobile IP [2, 3], Mobile SCTP [4], Mobile DCCP [5], MOBIKE [6] and Mobile SIP [7]. They present various performances, some providing a seamless transition from one network to another. However the main drawback of these solutions is the lack of a quality oriented approach to mobility management especially in the presence of real-time, bandwidth hungry multimedia applications.

Consequently this paper presents the novel Smooth Adaptive Soft-Handover Algorithm (SASHA), a quality oriented approach to handover management which include QoS and user Quality of Experience (QoE) in the decision making algorithm. SASHA's goal is to improve user perceived quality while roaming through a heterogeneous wireless network environment.

The paper is organized as follows. Section II presents some of the current mobility solutions discussing their performance in terms of relevance for multimedia applications. Multimedia adaptation techniques are also presented. Section III details the proposed SASHA while section IV presents the simulation setup used to evaluate the performance of the proposed solution. Section V presents and analyses the simulation results. Conclusions and future work are outlined in section VI.

II. Related Work

A. Handover Management Solutions

Handover management allows a mobile node to change its point of attachment to the Internet while preserving its ongoing data sessions.

One of the most important mobility solutions for the Internet resides at the network layer and is represented by Mobile IP. Mobile IP was first developed as an extension of the IPv4 protocol (MIPv4) [2] and later standardized with the IPv6 protocol (MIPv6) [3]. Both solution provide location management through a Home Agent (HA) as well as handover management by tunneling the data traffic from the HA to the mobile node (MN) at its new location. The MN updates its point of attachment by sending binding updates to the HA which then intercepts the data traffic addressed to the MN's home address and tunnels the data packets to MN's current

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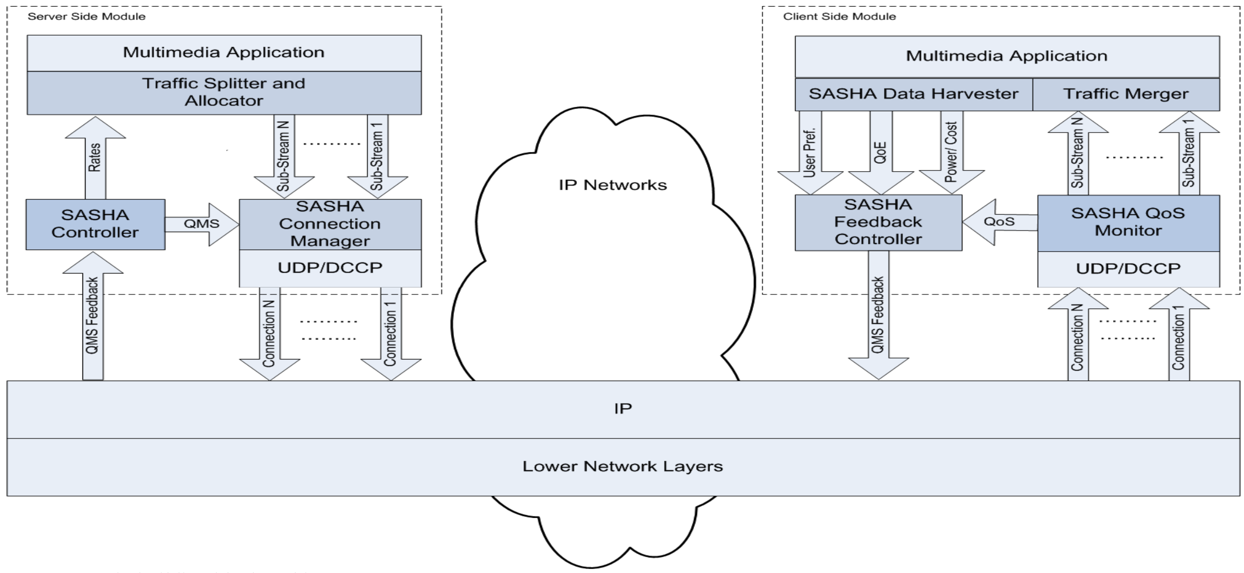

Fig. 1 SASHA main building block architecture

foreign network. To avoid the drawback of triangular routing, in MIPv6 the MN is allowed to inform also its correspondent nodes (CN) about its new location, performing in this way a route optimization. The CNs can send the data traffic directly to the MN's foreign network.

Mobility solutions were developed at the transport layer as well. One the of transport layer mobility solution is Mobile Stream Control Transmission Protocol (mSCTP) [4] which is based on the newly developed Stream Control Transmission Protocol (SCTP). mSCTP uses SCTP's ADDIP extension which allows each endpoint of an association to add and remove IP addresses and also to set the primary IP address without interrupting the current data session.

Another mobility solution for the transport layer is presented in [5] and is based on the Datagram Congestion Control Protocol (DCCP). Mobile DCCP uses a generalized connection which is formed of several normal DCCP connections. The handover is performed by adding a new connection to the generalized one and switching the traffic on the new connection while the old one is deleted.

The transport layer mobility solutions could provide seamless handover with good performance in terms of QoS but the mechanisms for determining the moment of traffic switching between the networks are not specified.

B. Adaptive Multimedia Streaming

The quality of the multimedia content as received by the user is dependent, among others, on the network conditions. In order to avoid network congestion which generates high levels of packet loss and consequently affects the quality of the delivered content, various multimedia adaptation algorithms were proposed. These adaptive solutions modify the bitrate of the streamed multimedia content in order to match the current network conditions.

Two of the existing multimedia adaptation schemes are TCP-Friendly Rate Control Protocol (TFRC) [8] and the enhanced Loss-Delay Adaptation Algorithm (LDA+) [9]. Although these two solutions offer good network-related quality in case of wired networks their main drawback is the lack of performance when streaming multimedia over wireless networks. Moreover TFRC and LDA+ do not include quality as perceived by the user in the adaptation process.

A better solution for adaptive multimedia streaming is the Quality-Oriented Adaptation Scheme (QOAS) [10], which considers user QoE in the adaptation process and performs better in wireless environments.

III. SASHA – Quality Oriented Handover Management

In the context of heterogeneous wireless networks the mobility management solution may exploit several communication resources (networks) simultaneously in order to maintain the required level of QoS for mobile roaming hosts.

A. System Architecture

SASHA performs handover management by exploiting all the communication resources available and balancing the load from one network to another based on the network's capacity to efficiently transport the multimedia content [11]. Each communication resource is represented by a separate connection established over a separate network. It is assumed the mobile host is capable of parallel communication over several networks. The transport capacity of each connection is evaluated based on a comprehensive Quality of Multimedia Streaming (QMS) metric. QMS is presented in equation (1) and its components include QoS, QoE, cost, power efficiency and user preferences.

$$QMS^i = w_1 * QoS^i{}_{grade} + w_2 * QoE^i{}_{grade} + w_3 * Cost^i{}_{grade} + w_4 * PEff^i{}_{grade} + w_5 * U\Pr ef^i{}_{grade} \quad (1)$$

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Fig. 1 presents the main building blocks of SASHA handover management service. Two main modules can be identified: the SASHA server module and SASHA client module.

SASHA server module includes the following sub-modules: SASHA Controller (SC), SASHA Connection Manager (SCM) and the Traffic Splitter and Allocator (TSA).

The SASHA Controller receives the QMS feedback from the SASHA client module and computes the QMS score for each connection separately. According to its QMS score each connection will transport a share of the main multimedia stream. The exact amount of traffic allocated to a certain connection is computed by the SC based on the bitrate of the main multimedia stream and the previously computed QMS scores.

The SCM module maintains the pool of active connections. In case a certain connection is not transporting any data a low bitrate sampling stream is generated by the SCM and sent over this connection to check its availability. SCM will close any dead connection and will open new connection when the client reports new networks available.

The TSA module receives the rates from the SC and splits the main data stream intro several sub-stream, each sub-stream having the corresponding bitrate.

In case the QMS scores of the available connections are too low, indicating a lack of communication resources capable of delivering the multimedia content at the current bitrate, the SASHA server module can inform the multimedia application to adapt the main stream's bitrate accordingly.

The SASHA client module is composed of four distinct modules. The SASHA Feedback Controller (SFC) is responsible for gathering the information required for QMS computation and for sending it as feedback to the SASHA server module. SASHA QoS Monitor (SQM) is responsible for evaluating the QoS parameters, including throughput, packet loss, packet delay and delay jitter for each active connection separately. SQM reports this statistics to the SFC module.

SASHA Data Harvester (SDA) gathers information related to the user and mobile host. This information includes user preferences, device power level and management, network traffic cost and the estimated QoE. SDA reports to SFC as well.

The Traffic Merger (TM) receives the data streams and merges them in a single application stream. The TM module is also responsible for packet reordering in case the used connections have present different delays.

B. Case Study

A particular mobility scenario is presented next as an example of the SASHA operation. Considering two WiFi access points AP1 and AP2 connected to the Internet via two distinct gateway routers. A mobile node (MN) equipped with two WiFi network cards is traveling from one router's coverage area towards the second one. While the MN resides entirely within the first router's coverage area the whole stream will be directed through the first router as its link is the only one available. When the MN enters the overlapping area of the two networks a new communication channel will be opened using this new router as relay. At first, this new communication channel will get only low bitrate sampling traffic. As the MN further moves towards the second router, and away from the first one, the first link starts to fade inducing packet loss which makes the QMS scores to drop for this communication channel. The QMS dropping for the first link determine the controller to increase the amount of traffic routed through AP2. As the first link continues to fade the traffic will be continuously increased on the new channel for which QMS scores are higher and decreased on the old channel until the whole traffic is route via AP2. At this point the handover process is complete.

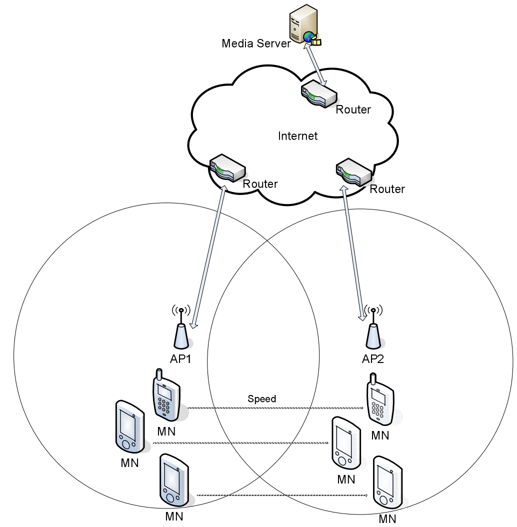

Fig. 2 Simulation Setup

IV. Simulation Environment and Scenario

The performance of SASHA was evaluated based on simulations using a typical multimedia broadcasting scenario. The performance of SASHA is compared with Mobile DCCP [5].

A. Simulation Environment

The simulations were performed using the NS-2 v2.29 network simulator [12]. The basic distribution was enhanced to support simultaneous communication on multiple channels. As the simulation scenarios involve multiple mobile nodes the NOAH (NO Ad-Hoc) routing agent was used to avoid communication between mobile nodes in an ad-hoc manner.

To have a simulation environment as similar as possible with a real testbed the Marco Fiore's realistic radio patch for ns-2.29 was also included [13].

B. Network Architecture

The network setup is presented in Fig. 2 and consists of two access points positioned close enough to each other to determine a sufficient coverage overlapping area. Each of the two access points is connected to a distinct router which acts as a gateway. The two gateway routers are further connected to a common router. The media server is connected to the common router. Several mobile nodes equipped with two

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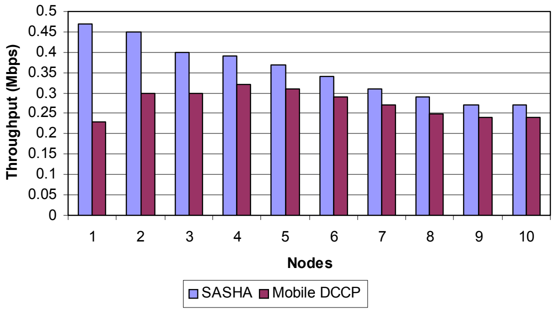

Fig. 3 Throughput for SASHA and Mobile DCCP

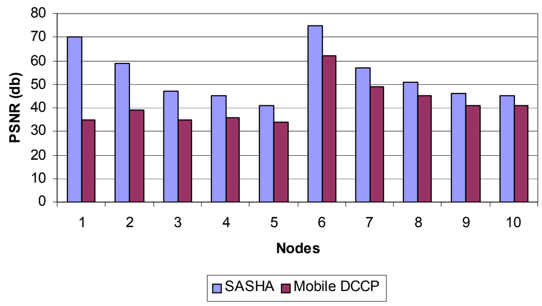

Fig. 4 PSNR for SASHA and Mobile DCCP

wireless interfaces are deployed. Each of the mobile nodes is capable of moving at various speeds within a certain area.

C. Simulation Scenarios

The goal of this simulation study is to determine the effect of the number of mobile nodes performing handover simultaneously on the QoS, measured by throughput and loss and the quality of multimedia content measured by PSNR. As a very important factor in wireless communication the impact of the mobile nodes' speed is also evaluated.

To evaluate the impact of the number of mobile nodes, mobility scenarios with one, up to ten mobile nodes passing the overlapping area were considered. To simulate a more realistic scenario a small difference in speed was induced for each mobile node.

For the impact of mobile node's speed a mobility scenarios with five mobile nodes traveling at constant speeds of 5, 20 and 50 km/h were considered.

D. Multimedia Adaptation

As the simulations were performed using various number of nodes, a multimedia adaptation scheme was used to overcome the impact on network congestion. The QOAS for wireless [10] adaptation scheme was used for its best performances in a wireless multimedia broadcasting environment. In these tests QOAS uses five levels of bitrate adaptation as follows 64 Kbps, 128 Kbps, 256Kbps, 384Kbps and 512Kbps.

Five different multimedia streams were selected, each encoded at a different bitrate evenly distributed between 64Kbps and 512Kbls as presented above. The adaptation scheme selects and transmits the appropriate stream based on the network conditions.

TABLE 1 AVERAGE THROUGHPUT, LOSS AND PSNR FOR SASHA

No. Nodes	Throughput (Mbps)	Loss (%)	PSNR (db)
1	0.47	2.0	70
2	0.45	2.1	59
3	0.40	4.7	47
4	0.39	4.8	45
5	0.37	5.1	41
6	0.34	5.5	75
7	0.31	6.0	57
8	0.29	6.4	51
9	0.27	6.8	46
10	0.27	6.8	45

TABLE 2 AVERAGE THROUGHPUT, LOSS AND PSNR FOR MDCCP

No. Nodes	Throughput (Mbps)	Loss (%)	PSNR (db)
1	0.23	52.0	35
2	0.30	34.7	39
3	0.30	28.5	35
4	0.32	21.9	36
5	0.31	20.5	34
6	0.29	19.4	62
7	0.27	18.1	49
8	0.25	19.3	45
9	0.24	17.2	41
10	0.24	17.2	41

TABLE 3 THROUGHPUT, PSNR AND LOSS FOR 5 NODES WITH VARIABLE SPEEDS

Handover Algorithm	Speed (km/h)	Throughput (Mbps)	PSNR (db)	Loss (%)
SASHA	5	0.37	41	5.1
	20	0.34	39	12.8
	50	0.28	34	25.6
MDCCP	5	0.31	34	20.5
	20	0.32	36	17.9
	50	0.32	35	17.9

V. SIMULATION RESULTS AND ANALYSIS

The performance of SASHA is evaluated mainly regarding its scalability with the number of mobile nodes performing handover simultaneously. As mobile node speed has a significant impact on wireless network's QoS, especially when mobility is involved, the performance of SASHA was also evaluated regarding resilience to different mobile node speeds.

The metrics used to evaluate performance are throughput and packet loss as network QoS metrics and peak signal-to-noise ratio (PSNR) as a user quality of experience metric. The measurements were made during the handover including 50s before and after the handover operation.

Fig. 3 presents the average throughput received by the mobile devices while performing handover using SASHA and Mobile DCCP. As adaptive multimedia streaming application was used, the data traffic bitrate sent by the media server to each mobile node decreased as the number of mobile nodes

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increases. As it can be seen in Fig. 3, SASHA presents a good scalability with the number of nodes obtaining a 12.5% improvement for 10 mobile nodes compared to Mobile DCCP. The throughput improvement is 19% for 5 mobile nodes and 33% in case of 3 mobile nodes simultaneously performing handover. The same performance increase can be observer in Fig. 4 where the user quality of experience is presented in relation with the number of mobile nodes. The PSNR improvement is 37% for 3 mobile nodes, 20% for 5 mobile nodes and 10% for 10 mobile nodes.

Table 1 and Table 2 present the average throughput, loss and PSNR for handover performed with SASHA and Mobile DCCP respectively for one to ten mobile nodes passing from one network to another simultaneously. The packet loss percentage shows a constant evolution especially when more then six nodes perform handover which is determined by the use of QOAS multimedia adaptation scheme. The loss rates presented in Table 1 and 2 also denotes SASHA's better scalability with the number of mobile nodes which can also be observed by analyzing throughput and PSNR. Table 3 presents the evolution of the average throughput, PSNR and loss with mobile node speed. The scenario when 5 nodes are switching networks simultaneously traveling at different speeds was chosen for this analysis. SASHA presents good performance for nodes travelling at 5km/s and 20km/h with improvements of 20% and 8% for PSNR and 19% and 6% for throughput. The performance decreases when the speed of 50km/h is reached which may be overcome by a correlation between the sensitivity and reaction speed of SASHA handover algorithm and the traveling speed of the mobile node.

VI. Conclusion

Accessing multimedia content over the Internet using wireless mobile devices has became increasingly popular making mobility a mandatory feature for the future Internet. This paper evaluates the performance of SASHA, a novel multimedia handover management solution for the Internet which provides quality oriented handover management. SASHA exploits the diversity of communication channels available to a mobile device in a heterogeneous wireless environment performing handover by gradually transferring the load from one network to another.

Simulation-based evaluation of the proposed solution showed SASHA performing better then Mobile DCCP in terms of scalability to the number of mobile nodes performing handover simultaneously. SASHA performs well for different mobile node speed although the performance can be improved for high speed mobile nodes by correlating the reaction speed and sensitivity of the algorithm with the device traveling speed.

Future work will consider assessing the performance of SASHA in different scenarios including different patterns of background traffic. The correlation between the sensitivity and reaction speed of the handover algorithm will also be considered for improving the performance of SASHA in high speed mobility scenarios.

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