QMS-Quality of Multimedia Streaming Metric for Soft-Handover in Heterogeneous Wireless Environments

Bogdan Ciubotaru
PEL@DCU, School of Electronic Engineering
Dublin City University (DCU)
Dublin, Ireland
Email: bogdan@eeng.dcu.ie

Gabriel-Miro Muntean
PEL@DCU, School of Electronic Engineering
Dublin City University (DCU)
Dublin, Ireland
Email: munteang@eeng.dcu.ie

***Abstract*—Handover management becomes an increasingly important component of the emergent mobile Internet by maintaining mobile user's data sessions alive in the presence of user mobility. The great impact handover has on Quality of Service makes it a crucial factor in maintaining mobile user's Quality of Experience at a high level. This paper evaluates the Quality of Multimedia Streaming metric proposed by the authors in a previous paper. Quality of Multimedia Streaming is a comprehensive and flexible metric for estimating the amount of traffic each network can hold. Unlike the traditional handover algorithms which select the best network, the investigated solution estimates the capacity of each network and dynamically distributes the application traffic over the available networks accordingly. The simulation-based evaluation outlines the performance of the proposed metric and evaluates its parameters for best performance in term of user Quality of Experience.**

***Index Terms*—handover management, network selection, load balance, multimedia streaming.**

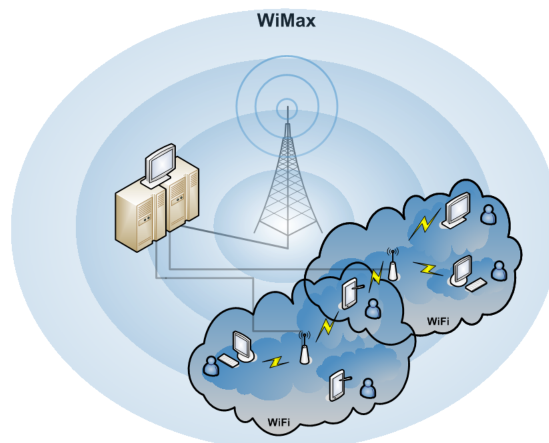

Fig. 1: Heterogeneous Wireless Environment

I. Introduction

Handover management maintains mobile user's data sessions active, while maintaining the required level of Quality of Service (QoS) and efficiently balancing the load between available network resources in the context of user mobility as illustrated in Fig. 1.

The handover management process in a heterogeneous wireless environment includes two main steps: network selection and the handover process (i.e. switching the data session from one network to another).

Most of the handover management solutions proposed in the literature switch the entire data traffic from one network to another and usually rely on the Always Best Connected (ABC) principle for deciding when and to which network the handover has to be performed.

These approaches have two major drawbacks. First is, by relying only on one network to convey the whole application traffic, in certain circumstances, none of the available networks may provide the required QoS level and communication resources may be left unused leading to quality degradation and reduced efficiency. Second is, the ABC principle becomes increasingly complex as the number of decision parameters (i.e. cost, energy, user preferences, QoE) increases leading to high processing power requirements and increased delay in making the decision.

Unlike traditional handover management approaches, SASHA the handover mechanism proposed in [1] (Smooth Adaptive Soft-Handover Algorithm) exploits multiple wireless networks in parallel and performs handover by splitting the main application traffic and distributing it over the available networks in the context of an All-IP network architecture [2]. The traffic rate allocation is performed based on the novel Quality of Multimedia Streaming (QMS) metric [1].

In this paper the impact of the most important QMS parameters on the overall performance of SASHA handover algorithm is assessed using both QoS measurements and QoE estimations. Optimum weights for these parameters (i.e. QoS, Energy consumption and Monetary cost) are determined for use in possible application implementations.

II. Related Work

Three aspects of wireless data communications are tightly related to the scheme investigated in this paper: handover management, network selection and traffic rate allocation.

Various handover mechanisms were proposed in the literature at almost all the layers of the network protocol stack. The most popular are Mobile IP [3], at the network layer, Mobile SCTP [4] and DCCP [5], at the transport layer and Mobile SIP [6] at session layer.

For network capacity estimations and network selection several solutions were proposed in the literature.

Several categories of network selection algorithms can be identified [7] including function based strategies [8], [9], user-centric strategies, multiple attribute and context aware decision strategies, as well as strategies based on fuzzy logic and neural network.

All the above presented solutions are designed for single network selection and not for traffic distribution over multiple simultaneous networks.

Rate control is widely investigated and implemented at various layers of the network protocol stack. Among the most popular are Transmission Control Protocol's (TCP) congestion control mechanisms [10] and the TCP-Friendly Rate Control (TFRC) [11] as well as the application layer adaptive multimedia streaming techniques such as QOAS [12].

Traffic distribution over multiple networks has also been widely investigated in the literature such as the one proposed by Zhu et al. [13] (denoted throughout this paper as DRA) and the technique proposed by Luo et al. [14].

Although there are similarities between SASHA and the various schemes presented above none of them combines traffic distribution with mobility features in a dynamic and efficient manner.

III. Quality of Multimedia Streaming

A. Architecture

Smooth Adaptive Soft-Handover Algorithm (SASHA) is an application level handover management solution for delivering high quality multimedia content to mobile clients in the context of a dynamic heterogeneous network environment.

As presented in Fig. 2 SASHA exploits several communication channels (links) in parallel, each channel using a different wireless network and presenting its own dynamics in terms of QoS. SASHA is splitting and efficiently distributing the application's data traffic over these channels relying on the novel QMS metric to quantify the capacity of each network to transport a certain amount of high quality multimedia content. Details about the architecture and functionality of SASHA are described in [1].

B. Quality of Multimedia Streaming Metric

Quality of Multimedia Streaming (QMS) estimates the efficiency with which a certain network connection can transport multimedia data.

QMS is described in equation (1) and is related to the characteristics of network i.

$$\begin{aligned} QMS^i = w_{QoS} * QoS^i_{grade} + w_{QoE} * QoE^i_{grade} \\ + w_C * Cost^i_{grade} + w_P * PEff^i_{grade} \\ + w_U * UPref^i_{grade} \end{aligned} \quad (1)$$

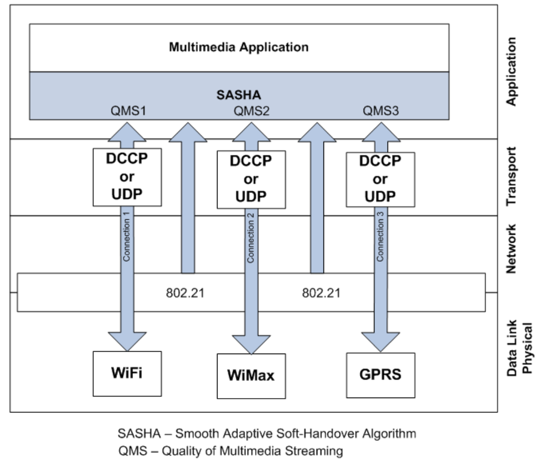

Fig. 2: SASHA architecture

For maximum efficiency and flexibility weights are associated with each component; weight normalization is required. QMS and all its components are expressed on a 100 point scale from 0 to 100, with maximum grade 100.

The detailed algorithm for distributing the traffic using the QMS metric as well as the detailed mathematical model of QMS are presented in [1].

IV. Simulation Results and Analysis

The QMS metric used by SASHA is evaluated based on simulations in order to fine tune some of its most important parameters.

A. Simulation Environment

The simulation environment and models used for QMS evaluation is built in the NS-2 Network Simulator (v2.34) [15] enhanced with the realistic radio patch developed by Marco Fiore [16]. The standard architecture of the mobile node specific to NS-2 was also improved in order to support multiple simultaneous connections.

The simulation topology is presented in Fig. 3. Four different wireless (IEEE 802.11) networks with overlapping coverage areas are considered. The SASHA enabled mobile terminal is positioned within the overlapping area of the four networks. Each network uses a separate non interfering channel.

As the topology is symmetric the impact of delay and delay jitter is minimized by setting their weights to 0.

B. Simulation Scenarios

The server streams 2 Mbps MPEG2 encoded video content which is distributed to the mobile host through multiple simultaneous links. The traffic distribution is performed using the SASHA algorithm based on the QMS metric assessed for each network separately.

Three different scenarios were considered as follows. In the first scenario the wired link's bandwidth is limited, simulating congestion at the core network level. The bottleneck

TABLE I: QoS Evaluation For the Three Congestion Scenarios

W_T	W_L	Scenario 1			Scenario 2			Scenario 3		
		PSNR (dB)	Throughput (Mbps)	Loss (Mbps)	PSNR (dB)	Throughput (Mbps)	Loss (Mbps)	PSNR (dB)	Throughput (Mbps)	Loss (Mbps)
0	1	0.88	0.0851	1.9149	4.00	0.1523	1.8477	3.58	0.1284	1.8716
0.1	0.9	1.17	0.1045	1.8955	4.06	0.1456	1.8544	4.63	0.1295	1.8705
0.2	0.8	1.19	0.1059	1.8941	4.60	0.1494	1.8506	4.11	0.1295	1.8705
0.3	0.7	2.96	0.2071	1.7929	5.36	0.1519	1.8481	4.00	0.1536	1.8464
0.4	0.6	3.21	0.2176	1.7824	4.14	0.1566	1.8434	4.03	0.1603	1.8401
0.5	0.5	3.63	0.2450	1.7550	3.99	0.1478	1.8522	4.08	0.1572	1.8428
0.6	0.4	9.20	0.7071	1.2929	12.78	0.7705	1.2295	16.36	1.0208	0.9792
0.7	0.3	24.78	1.4208	0.5792	12.14	0.7934	1.2066	16.42	1.0201	0.9802
0.8	0.2	24.78	1.4206	0.5794	22.60	1.2830	0.7170	34.74	1.6053	0.3947
0.9	0.1	46.24	1.8007	0.1993	19.70	1.1375	0.8625	23.81	1.3219	0.6781
1	0	36.45	1.6764	0.3236	20.64	0.4364	1.5636	10.94	0.6287	1.3713

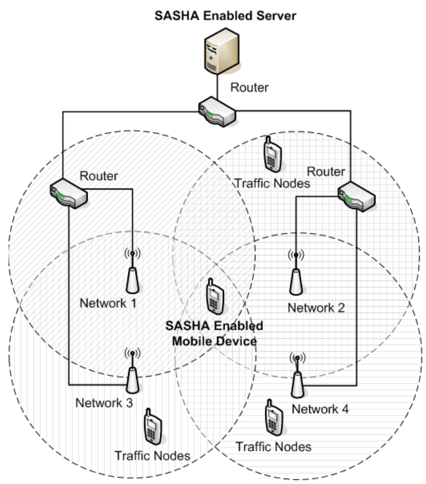

Fig. 3: Simulation topology

bandwidths are 0.2Mbps, 0.4Mbps, 0.6Mbps and 0.8Mbps respectively.

In the second scenario the core wired network does not present any congestion however the wireless links are highly congested by separate wireless traffic nodes. Each node generates heavy constant bit rate (CBR) multimedia traffic to each wireless router separately (one node per router).

In the last scenario the traffic is generated at the wireless networks level by multiple wireless nodes in each cell aiming to evaluate the performance of the proposed metric in the context of higher collision rates.

Each simulation runs for 600s, with the main data traffic initially equally distributed over the four networks.

C. QoS Component Assessment

The performance analysis is made in terms of user QoE estimated based on video quality assessment using Peak Signal-to-Noise Ratio (PSNR) and Video Quality Metric (VQM) (lower scores denotes better video quality).

Table I presents the average PSNR, throughput and loss measured at the mobile device when various combinations of throughput and loss weights are used for QoS_{grade} assessment in the context of the three scenarios considered.

As outlined in Table I QMS presents a good performance

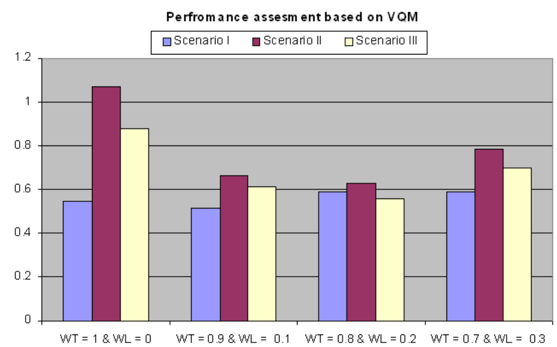

Fig. 4: Video quality assessed using VQM

for throughput and loss weights ranging from 1 to 0.7 and 0 to 0.3 respectively.

The video quality was further objectively assessed based on the VQM metric using the MSU Video Quality Assessment Tool [17].

The VQM assessment for the three scenarios is presented in Fig. 4. T-tests performed on pairs of results involving throughput and loss weights varying between (0.7, 0.3) and (1.0, 0.0) has confirmed that there is a statistical difference between these results with a significance level of $\alpha = 0.1$ in favor of: (0.9, 0.1) and (0.8, 0.2).

Consequently (0.85, 0.15) was chosen for the two weight parameters: throughput and loss respectively.

D. Cost Component Assessment

Similar test settings were applied and the Scenario 1 was simulated only as the monetary cost does not vary across scenarios. The relationship between the monetary cost and video quality (VQM) when various combinations of weights were used for the QoS_{grade} and $Cost_{grade}$ is graphically presented in Fig. 5.

There is a direct proportional relationship between the monetary cost and the received throughput and the consequent video quality (as estimated by VQM). The relationship between the two quality parameters and the weight given to $Cost_{grade}$ is inverse proportional.

The variation in cost for various weight configurations is relatively small. However if a large number of streams

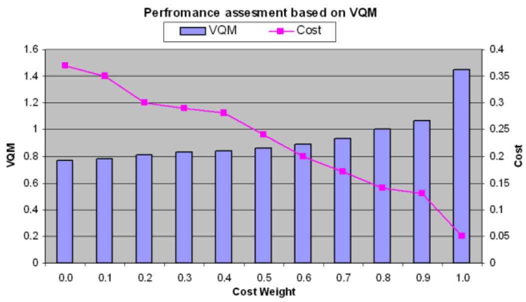

Fig. 5: Cost vs. Quality assessment

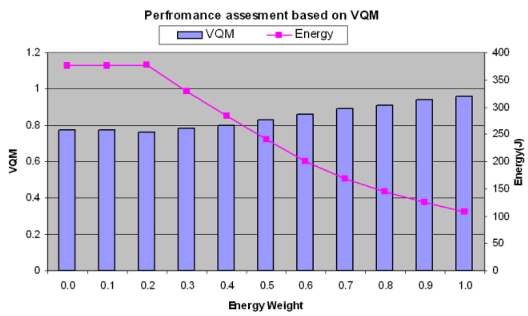

Fig. 6: Energy vs. Quality assessment

and longer play time is considered these will determine a significant cost benefit.

E. Energy Component Assessment

Fig. 6 presents the relationship between energy consumption and video quality (estimated by VQM) when various combinations of weights were used for the QoS_{grade} and $PEff_{grade}$ in the same scenario. A similar inverse proportional relationship between energy consumption and VQM scores can be observed.

However when using QOAS a slight degradation in video quality can be observed while a high improvement in terms of energy is achieved. More exactly a 71% improvement in energy consumption is achieved with only 24% decrease in video quality as estimated by VQM.

F. Benefit

As already outlined in the previous sections by using the QMS metric, SASHA achieves high benefits providing both high levels of QoS and consequent QoE, and monetary cost and power efficiency. SASHA is compared theoretically with a simplified model of DRA [13] which uses a minimum distortion stream bitrate set to 2 Mbps.

As it can be seen in Table II that an insignificant decrease in video quality resulted in a 30% less data transfer cost and 32% less consumed energy when using SASHA.

V. Conclusion

Efficiently distributing the traffic over multiple wireless networks improves the user perceived quality in highly loaded network conditions. Including the monetary cost and energy consumption components improves the performance of SASHA while maintaining the QoS and QoE at high levels. For future development the QMS metric will be evaluated in several other scenarios covering different networks conditions. Perceptual tests will further evaluate the effect of QMS parameters on SASHA performance.

TABLE II: Benefit Evaluation

Energy (J)	32 (%)	SASHA	187 (J)
		DRA	276 (J)
Cost (Euro)	30 (%)	SASHA	0.19 (Euro)
		DRA	0.27 (Euro)

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