Signal Strength-based Adaptive Multimedia Delivery Mechanism

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***Abstract*— The demand for multimedia services is increasing and users expect rich services at high quality levels, even while on the move and connected via different wireless networks. This paper proposes a novel Signal Strength-based Adaptive MultiMedia Delivery Mechanism (SAMMy) that makes use of the IEEE 802.11k standard when dynamically adjusting multimedia delivery based on estimated signal strength and actual loss rates, in order to increase user perceived quality for video streaming applications in WLAN. Location and time dimensions are used together with the receive signal strength estimations in order to predict the QoS characteristics along the user's path. The proposed mechanism is evaluated by simulation and compared with a non-adaptive multimedia delivery mechanism and with two other adaptive schemes, in terms of loss, throughput and Peak Signal to Noise Ratio (PSNR). The results show that the proposed signal strength-based adaptive multimedia delivery scheme outperforms the other schemes involved making more efficient use of the wireless network resources and increasing the user perceived quality.**

Keywords- wireless network, adaptive multimedia, IEEE 802.11k, IEEE 802.21

I. INTRODUCTION

Wireless networks have had an important impact in the area of mobile communications and their use has grown significantly in recent years. Delivering streaming video with QoS provisioning over wireless networks is more challenging than in wired networks due to the constraints of wireless links, and the user mobility. It is essential to provide QoS mechanisms to cater for multimedia throughput, delay, and jitter constraints, especially within the wireless environment where connections are prone to interference, high data loss rates, and/or disconnection. The aim of these mechanisms is to maintain an acceptable user perceived quality and make efficient use of the wireless network resources.

IEEE 802.11k is an extension of IEEE 802.11 wireless LAN standard [1]. This extension is defined for the provisioning of the radio resource measurement, in order to allow mobile stations to request and exchange information about the usage of the wireless medium. It defines basic structures for requesting and reporting measurement information for IEEE 802 protocols only.

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There are no interoperability methods between heterogeneous networks defined in IEEE 802.11k, and no inter - Radio Access Technology (RAT) measurement procedures. However, the Media Independent Handover Working Group IEEE 802.21 [2] has considered the interoperability aspect between heterogeneous networks and this new standard supports media-independent handover between IEEE 802 networks and cellular networks.

In this paper a novel **S**ignal Strength-based **A**daptive **M**ulti**M**edia Deliver**y** Mechanism (SAMMy) is proposed. SAMMy makes use of 802.11k radio measurements in order to collect information on the radio interface, and the location of the mobile node relative to the access point (AP). Mobile radio stations predict their receive power based on location and estimated current path, and based on that receive power and packet loss, the station can request the multimedia streaming source to adjust the transmission rate. In this way, SAMMy makes seamless multimedia adaptations, decreases the loss rate and consequently increases user perceived quality for video streaming applications in wireless networks.

The paper is structured as follows: in section II the related work is summarized, section III presents the proposed architecture, while section IV explains the principle of SAMMy. Section V details the simulation setup and test results, and finally concluding remarks and future work are described in section VI.

II. RELATED WORK

In terms of multimedia adaptive solutions, two of the best known schemes are: TCP Friendly Rate Control (TFRC) [3] and enhanced Loss-Delay Adaptation Algorithm (LDA+) [4]. These two solutions perform well in wired networks, but show serious performance degradation in the presence of random wireless loss. Real-time streaming requires uninterrupted services and adaptive video delivery according to the network conditions. For this reason the adaptive scheme should provide a better response to the dynamically varying available network resources and avoid possible congestion collapses. Also TFRC and LDA+ do not take into consideration user perceived quality. In [5], Muntean et al. proposed the Quality-Oriented Adaptation Scheme (QOAS), an adaptive multimedia streaming solution based on estimations of user quality, which maximizes end-user perceived quality.

The above mentioned solutions as well as others such as [6, 7, 8] adapt the transmission rate based on the current network conditions, such as loss rate, delay, jitter, and available bandwidth, but none of them take into consideration the receive signal strength at the mobile user's terminal.

When evaluating the performance of an IEEE 802.11 WLAN it is known that an important factor, that needs to be taken into consideration, is the propagation of Radio Frequency (RF) signals. Previous studies [9] have shown that it is not enough to consider only the signal strength when analyzing the performance of different wireless applications because of the RF dynamics. The RF environment is changing dynamically as people move through the coverage area. Also the presence of different objects or object movement can cause reflections which can lead to mobile device reading the same Receive Signal Strength Indication (RSSI) value twice or two different values. However, in the proposed mechanism we consider the RSSI and packet loss. Other parameters, such as wireless connection capacity, delay, and jitter will be considered for future improvements of the mechanism.

III. SAMMY'S ARCHITECTURE

SAMMy bases its adaptation decision on power prediction, user's location and packet loss. SAMMy is distributed and consists of server-side and client-side components, as shown in Figure 1.

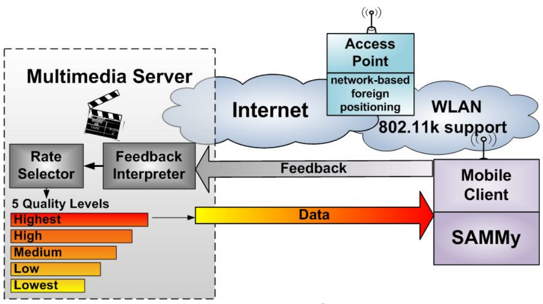

Figure 1. System architecture

On the Server side the content can be encoded at different quality levels, which correspond to different amounts of data to be delivered. Figure 1 illustrates five levels - from lowest (level 1) to highest (level 5). Based on the feedback received from the Client, client location and signal strength-related readings, the Server dynamically selects the most suitable quality level and consequently adjusts the multimedia delivery rate. The 802.11k standard features can be used in order to gather information at the mobile station side on the current user location through the location report, and information on the link quality from the beacon report [10].

The principle behind SAMMy is illustrated in Figure 2. The Mobility Model block predicts the future location of the mobile user. There are many proposed mobility models, which use different parameters and probability functions in order to predict the user's future location. However, the mobility model is not the focus of this paper and a simple straight line movement pattern, at a constant velocity without any stop-and-go behavior is assumed. More complex movements requiring path estimation may be considered in the future. On reception of a beacon report request, the Power Measurement block triggers instantaneous receive signal strength measurement. The Power Prediction block predicts the receive power for a future location of the mobile user. The Loss Monitoring block monitors the network traffic and triggers the Decision Module on detection of a packet loss. The Decision Module decides whether to increase or decrease the rate and sends feedback to the server. At the server side (see Figure 1), the Feedback Interpreter block receives the feedback from the client and sends the new rate level to the Rate Selector block which will change the rate and sends the data to the client.

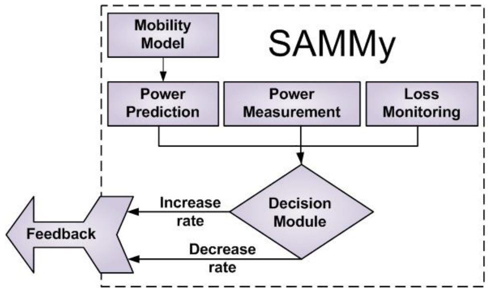

Figure 2. SAMMy architecture

IV. PRINCIPLE OF SAMMY

The IEEE 802.11b standard supports four data rates: 1Mbps, 2Mbps, 5.5Mbps, and 11Mbps and similarly IEEE 802.11g supports 13 different possible data rates from 1 to 54 Mbps. As the mobile user moves away from the AP, the signal attenuates until it drops below the threshold required to maintain a tolerable bit error rate.

Based on this concept, an adaptive multimedia delivery scheme that takes the signal strength into account in the rate adaptation decision module is proposed. Given that as a mobile node moves away from the AP its receive signal strength drops, the coverage area of an AP was divided in different areas. These areas are mapped and each of them is associated with a maximum multimedia quality level, as defined at the server. This level is determined by the maximum bit rate a mobile user can get in that area. For the five quality level case and IEEE 802.11b, four thresholds are defined to delimit the five different rate zones. Each threshold was computed based on the estimated maximum receive power and the wireless card receiver sensitivity. The maximum power is considered as the power received by the user's terminal if its location will be within one meter of the AP. As the mobile user moves away from the AP, the device will pass from one area to another and its corresponding maximum quality level will drop by 1 at each bound. In a wireless network, loss can happen for a number of reasons, mainly congestion based losses, where packets are lost due to collisions and signal strength losses, where packets are lost due to drop in signal strength. SAMMy considers both.

Positive feedback was used to indicate that no loss has been detected since the last received feedback, and negative feedback indicates that loss has been detected since the last received feedback. If two consecutive negative feedback reports are received, the rate is decreased by one. The rate will be increased again only if ten consecutive positive feedback reports are received. The maximum achieved rate depends on the area the mobile user is located in. The two values were set based on the Auto Rate Fallback (ARF) mechanism [11] for IEEE 802.11. ARF is a rate adaptation scheme which was first proposed for Lucent Technologies WaveLAN-II networking devices and designed to switch rates between 1Mbps and

2Mbps. If a number of consecutive acknowledgment (ACK) frames are not received (e.g. two), the transmitter decreases the rate and starts a timer. The rate is increased only if another number of consecutive ACK frames are received (e.g. ten) or the timer's timeout occurs.

V. SIMULATION SETUP AND RESULTS

In this section the simulation setup and scenarios used to evaluate the proposed SAMMy in comparison with two other adaptive multimedia delivery schemes (MmApp and TFRC) and a non-adaptive solution (Non-Ad) are described. Three scenarios are considered, as illustrated in Figure 3. In the first scenario, the mobile user moves in a path towards and then away from the AP at a constant speed of 1m/s. In this case, the losses are mainly due to reduced receive power with increased distance from the AP. In the second scenario, two additional nodes generate background traffic in order to load the wireless network: one receives FTP traffic over TCP, with a packet size of 1480 bytes, and the second one receives CBR traffic over UDP with a data rate of 1Mbps and packet size of 1000 bytes. Both background traffic users are located near the AP, and do not move. The mobile user is in a fixed position (5 different positions are tested), so losses are mainly due to congestion. In the third scenario, the background traffic from scenario two is used together with the mobility included in scenario one (5 different paths are tested) such that losses may be due to both reduced receive power and congestion.

The user is watching a video stream on a mobile device. The video data is streamed from a multimedia server on the wired network to the user's mobile device through an AP. The multimedia server stores five five-minute long multimedia clips encoded at five different rates 0.5Mbps, 0.75Mbps, 1Mbps, 1.5Mbps, and 2Mbps respectively.

For the simulations the Network Simulator NS-2 version 2.33 [12] was used. The wireless update patch from [13] was added in order to improve the support for wireless networks by adding realistic channel propagation, multi-rate transmission support, and adaptive auto rate fallback (AARF) [14]. AARF is based on the same principle as ARF. It decreases the rate when two consecutive ACK frames are not received, but it handles the increase differently. For the first attempted increase the consecutive ACK frames threshold is set as for ARF, but if this fails each subsequent attempted increase is spaced further and further apart by multiples of this threshold. The NOAH (No Ad-Hoc) patch [15] was also added, which allows infrastructure mode communication between nodes through the AP. The loss-based adaptive multimedia solution MmApp (from the NS-2 tutorial) was also deployed. With MmApp, if congestion is detected, the receiver reduces the data rate to half and notifies the sender. If no packet loss is detected, the receiver increases the value by one and notifies the sender. The TCP-Friendly Rate Control protocol (TFRC) [3] model included in this version of NS-2 was used in the simulations. The protocol adjusts the transmission rate to match the expected throughput of a TCP stream in similar conditions, being therefore TCP friendly to elastic traffic. A non-adaptive (Non-Ad) solution was also considered. Non-Ad streams multimedia content at the encoding rate without taking the network conditions into consideration. In this case the encoding rate used was 2Mbps, the highest quality level considered by SAMMy.

For the communication between the mobile user and the AP the support of 802.11k can be used. The standard provides beacon request/report in order to obtain the instantaneous receive power. Also an AP that has support for network-based foreign positioning can be used, together with the IEEE 802.11k location request/report in order to obtain information about the mobile user's location in the network. For the purpose of the simulations, we assumed that all this data is already available at the mobile node side. Additionally the simulation makes use of the knowledge that user moves in a straight line, at a constant speed in order to enable next location estimation and computation of the predicted power strength 1m ahead in the user's path.

The simulation results for all three scenarios are presented in Table I. One of the most widespread objective methods used to measure user perceived quality is the calculation of the Peak Signal to Noise Ratio (PSNR). PSNR to Mean Opinion Score (MOS) conversion [16] and also subjective testing can be considered in future work for more realistic results. The PSNR was calculated based on the loss and throughput rates using the equation presented in [17].

The results show that in all three cases SAMMy performs very well in comparison with all the other schemes involved. When located in a loaded network, where the losses are due to congestion (Scenario 2) and the mobile user is located at 100m (Position 5) away from the AP, SAMMy performs better than TFRC recording 48% decrease in loss and 75% increase in throughput, leading to 22.13% increase in PSNR.

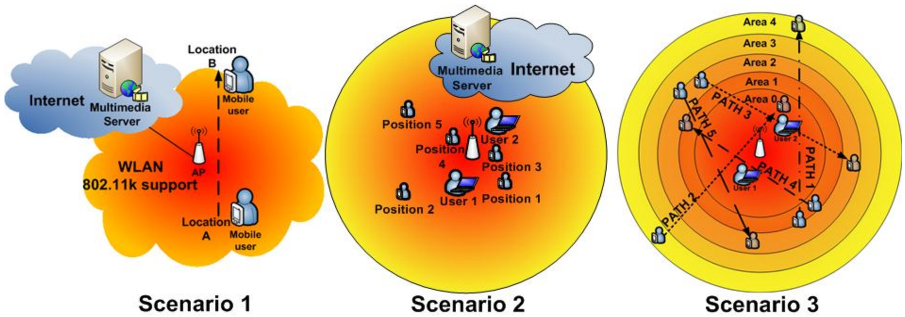

Figure 3. Simulated network topologies

TABLE I. PERFORMANCE RESULTS WHEN STREAMING OVER WLAN

Scenario 1		MmApp	TFRC	Non-Ad	SAMMy
Loss(%)		0.94%	0.54%	3.82%	0%
Average Throughput		1.90Mbps	1.90Mbps	1.91Mbps	1.62Mbps
Average PSNR		92dB	98dB	82dB	100dB
Scenario 2		MmApp	TFRC	Non-Ad	SAMMy
Position 1	Loss	1.93%	2.64%	21.01%	0.90%
	Avg. Throughput	1.56Mbps	0.64Mbps	1.55Mbps	1.40Mbps
	Avg. PSNR	76.2dB	59.03dB	51.14dB	81.30dB
Position 2	Loss	6.10%	3.30%	22.98%	2.98%
	Avg. Throughput	0.97Mbps	0.43Mbps	1.51Mbps	0.85Mbps
	Avg. PSNR	49.52dB	59.73dB	47.22dB	66.42dB
Position 3	Loss	2.45%	1.48%	3.56%	1.42%
	Avg. Throughput	1.5Mbps	0.90Mbps	1.90Mbps	1.07Mbps
	Avg. PSNR	61.67dB	66.38dB	51.08dB	72.42dB
Position 4	Loss	4.37%	2.39%	4.37%	1.76%
	Avg. Throughput	1.04Mbps	0.71Mbps	1.54Mbps	1.15Mbps
	Avg. PSNR	50.44dB	60.35dB	48.48dB	74.43dB
Position 5	Loss	13.04%	3.79%	29.37%	1.97%
	Avg. Throughput	0.64Mbps	0.37Mbps	1.38Mbps	0.65Mbps
	Avg. PSNR	35.65dB	53.5dB	19.69dB	71.45dB
Scenario 3		MmApp	TFRC	Non-Ad	SAMMy
PATH 1	Loss	4.68%	1.80%	8.52%	1.28%
	Avg. Throughput	1.21Mbps	0.84Mbps	1.81Mbps	0.97Mbps
	Avg. PSNR	51.3dB	59.7dB	45.9dB	75.6dB
PATH 2	Loss	4.09%	1.81%	16.53%	1.65%
	Avg. Throughput	1.33Mbps	0.84Mbps	1.65Mbps	0.92Mbps
	Avg. PSNR	56.53dB	59.73dB	37.55dB	75.19dB
PATH 3	Loss	6.71%	1.83%	9.41%	1.45%
	Avg. Throughput	1.10Mbps	0.81Mbps	1.79Mbps	1.04Mbps
	Avg. PSNR	42.97dB	58.55dB	47.12dB	75.68dB
PATH 4	Loss	4.08%	1.39%	4.62%	0.57%
	Avg. Throughput	1.35Mbps	0.99Mbps	1.89Mbps	1.40Mbps
	Avg. PSNR	51.98dB	58.31dB	58.48dB	84.25dB
PATH 5	Loss	5.85%	1.68%	28.8%	1.42%
	Avg. Throughput	1.09Mbps	0.82Mbps	1.41Mbps	1.15Mbps
	Avg. PSNR	46.33dB	61.42dB	18.00dB	78.42dB

When located at 10m (Position 4) away from the AP, there is 26.35% decrease in loss and 61.97% increase in throughput, reflecting a 23.33% increase in PSNR. In the third scenario in case of PATH 1, there is a 28.8% decrease in loss and 15.47% increase in throughput, resulting in a 26.6% increase in PSNR in comparison with TFRC. With respect to the Non-Adaptive Solution, SAMMy achieves 84.9% decrease in loss and 64.7% increase in PSNR. If an average for all five paths presented in the simulation is computed SAMMy performs better than TFRC and Non-Ad, achieving 25% and 90% decrease in loss, respectively, with an impact of 30.7% and 87.94% increase in PSNR.

VI. CONCLUSIONS

In this paper a novel Signal Strength-based Adaptive Multimedia Delivery Mechanism (SAMMy) which makes use of the receive signal strength and loss rate, in order to seamlessly adapt multimedia delivery and increase user perceived quality is proposed. The proposed scheme was compared with three other solutions: TFRC, MmApp and a non-adaptive (Non-Ad) solution.

The simulation results show that SAMMy outperforms the other schemes involved in terms of throughput, loss, and estimated PSNR. Unlike other schemes such as TFRC which cannot distinguish losses due to congestion from losses caused by the wireless channel, SAMMy bases its mechanism on the differentiation between packet loss due to collision and packet loss due to drop in signal strength, making it more suitable for wireless network delivery.

SAMMy performance-related results have shown that by combining the signal strength and loss rate in the adaptive mechanism, the user perceived quality can be greatly improved.

As demand for multimedia services over wireless networks increases, it is important to have a well-designed rate adaptation scheme. In the future, we plan to improve this scheme, by adding other parameters into the decision module, such as delay and jitter. We also plan to adapt the scheme for a handover process, in which we will combine the functionalities of the two standards: IEEE 802.11k and IEEE 802.21.

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