Performance of an Adaptive Multimedia Mechanism in a Wireless Multi-user Environment

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***Abstract* — With the increasing popularity of accessing multimedia services over different wireless networks, researchers have been trying to develop different adaptive multimedia mechanisms in order to mitigate the impact of fluctuating radio resources. This paper considers the case when multiple users stream video over the same IEEE 802.11b WLAN using a newly proposed Signal Strength-based Adaptive Multimedia Delivery Mechanism (SAMMy). SAMMy makes use of the IEEE 802.11k standard and uses estimated signal strength, location, and packet loss as part of its adaptive mechanism in order to increase user perceived quality for multimedia streaming applications in wireless networks. SAMMy is evaluated by modeling and simulations and compared with another adaptive multimedia delivery mechanism TFRC, in terms of aggregate throughput and fairness. The results show that the proposed signal strength-based adaptive multimedia delivery scheme outperforms the other scheme in terms of both throughput and fairness when performing video streaming in WLAN.**

***Index Terms* — dynamic content adaptation, multimedia, rate control, wireless networks**

I. Introduction

NOWADAYS wireless networks are used more and more to support an increasing demand in service delivery, especially for high-bitrate multimedia applications which require high Quality of Service (QoS) levels. These applications include video conferencing, video streaming, voice over IP (VoIP), and high definition television (HDTV).

Video streaming with QoS provisioning over wireless networks is challenging due to the constraints of the wireless links and 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.

The IEEE 802.11 Task Group “k” has developed an important extension of the IEEE 802.11 WLAN standard, which is referred to as IEEE 802.11k [1]. This extension is defined for the provisioning of radio resource measurements, in order to allow mobile stations to request and exchange information about the usage of the wireless medium. The IEEE 802.11k standard defines basic structures for requesting and reporting measurements information, butof IEEE 802 types only. There are no interoperability methods between heterogeneous networks and no inter-Radio Access Technology (RAT) measurements procedures. However, the Media Independent Handover Working Group IEEE 802.21 [2], has considered the interoperability aspect between heterogeneous networks, and developed a new standard referred to as IEEE 802.21. The new standard provides a media-independent framework which facilitates the handover between IEEE 802 networks and cellular networks.

We proposed a Signal Strength-based Adaptive Multimedia Delivery Mechanism (SAMMy) [3] which makes use of IEEE 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). We showed that SAMMy seamlessly adapts multimedia, decreases the loss rate and increases user perceived quality for video streaming applications in wireless networks.

In this paper we examine the performance of SAMMy in the presence of multiple simultaneous video streaming sessions in a multi-rate IEEE 802.11b network. Due to the characteristics of the WLAN there is an existing issue with the fairness of wireless resource distribution; users located near the AP transmitting at high data-rates are greatly impacted, in terms of throughput, by the introduction of a user at the cell border transmitting at a much lower rate [4]. In this context, the goal for SAMMy is to reduce the impact of the low rate users on nodes which are near the AP, maintaining a reasonable throughput for all users, relative to their locations in the network and their received signal strengths.

The rest of the paper is structured as follows: section II introduces a performance anomaly of IEEE 802.11b WLAN and section III summarizes the related works. Section IV presents the proposed architecture, while section V explains the principle behind SAMMy. Section VI details the simulation setup and scenarios and presents testing results. Finally, concluding remarks and future work details are included in section VII.

Manuscript received September 23, 2009. The support of Enterprise Ireland, Proof of Concept and Science Foundation Ireland Research Frontiers Programme is gratefully acknowledged.

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II. Performance Anomaly of IEEE 802.11b

With the increase in mobile devices that are capable of communicating at high data rates, IEEE 802.11 WLANs have become very popular access networks enabling connectivity to the Internet for hot-spot zones (airports, offices, hotel lounges, cafes, etc.) and also for university and enterprise campuses. In all these cases WLAN users expect access to rich services at higher quality levels from their devices.

The IEEE 802.11b standard uses the Distributed Coordination Function (DCF) based on the Carrier Sense Multiple Access Collision Avoidance (CSMA/CA) access method in order to provide similar medium access priority to all the users. Previous studies have analyzed the performance of the IEEE 802.11b multi-rate WLANs and have shown the existence of a performance anomaly [4]. This anomaly occurs when multiple users share the radio channel of an IEEE 802.11b network. If there is at least one mobile node transmitting at a lower rate, the throughput of all the mobile nodes transmitting at a higher rate will be degraded below the level of the lower transmission rate.

It seems unfair that the mobile nodes located near the AP are penalized in terms of throughput because there are other mobile nodes badly located near the network edge. To overcome this problem many solutions have been proposed [5, 6, 7]. The main disadvantage of these solutions is that they require changes to the existing standards at MAC or network layers.

If we consider an IEEE 802.11b network with multiple users sharing the radio channel for video streaming applications, all of whom are using the same adaptive delivery mechanism, it would be most important to reduce the impact users have on each other, while also maintaining fairness among them. From the service provider point of view, it is essential to give the assurance of consistent QoS and high throughput to users in order to avoid the degradation of performance which will lead to users perceiving unsatisfactory quality. The proposed rate-control adaptive mechanism, SAMMy was designed to use the received signal strength and node location as controlling parameters to mitigate the fairness problem, and also improve the aggregate throughput of the IEEE 802.11b network. By improved fairness we mean that all mobile nodes will be capable of achieving and maintaining a reasonable throughput according to their received signal strengths and locations.

III. Related Works

In terms of multimedia adaptive solutions, two of the best known schemes are TCP Friendly Rate Control (TFRC) [8] and enhanced Loss-Delay Adaptation Algorithm (LDA+) [9]. These two solutions perform well in wired networks, but show serious performance degradations in the presence of random wireless loss. Real-time streaming requires uninterrupted service 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 [10], Muntean et al. proposed the Quality-Oriented Adaptation Scheme (QOAS), an adaptive multimedia solution based on estimations of user quality, which optimizes end-user perceived quality and shows good results in wireless networks.

All the solutions presented above as well others such as [11, 12, 13] adapt the transmission rate based on the network conditions, such as loss rate, delay, jitter, available bandwidth, but none of them takes into consideration the received signal strength at the mobile user terminal combined with the user location relative to AP.

In terms of rate adaptation mechanisms for IEEE 802.11 WLANs there are a number of proposed solutions, of which the most popular are Auto Rate Fallback (ARF), Adaptive Auto Rate Fallback (AARF), Receiver Based Auto Rate (RBAR) and Closed Loop Adaptive Rate Allocation (CLARA) [14].

ARF is a rate adaptation scheme which was first proposed for Lucent Technologies WaveLAN-II networking devices and designed to switch rates between 1 Mbps and 2 Mbps. 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 times out.

The AARF mechanism uses the same principle as ARF, decreasing 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. In this way AARF takes better account of the wireless channel conditions, obtaining similar performance as RBAR when in stationary and non-fading wireless channels [14].

RBAR makes use of the Request to Send / Clear to Send (RTS/CTS) handshake mechanism in order to send feedback to the source. The mechanism requires the calculation of Signal to Noise Ratio (SNR), and assumes that the value is available at the receiver.

CLARA is a combination of attributes from ARF and RBAR with additional features such as adaptive fragmentation. It senses the multipath fading in wireless channels.

IV. SAMMy's Architecture

SAMMy is an adaptive delivery mechanism which bases its adaptation decision on received signal power prediction, user location and packet loss. SAMMy is distributed and consists of server-side and client-side components, as shown in Figure 1. On the server side the content can be encoded at different quality levels from lowest (level 1) to highest (level N), which correspond to different amounts of data to be delivered. 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 IEEE 802.11k standard can be used for gathering information at the mobile station side on the current location, and information on the link quality. The location report includes a Location Configuration Information (LCI) element which indicates information on latitude, longitude and altitude [15].

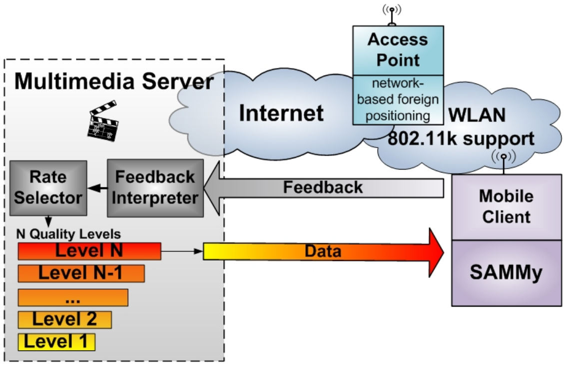

Figure 1. System architecture

The beacon report includes a Received Channel Power Indicator (RCPI) field which indicates the received channel power of the Beacon, Measurement Pilot or Probe Response frame expressed in dBm. It also includes a Received Signal to Noise Indicator (RSNI) field which indicates the received signal to noise indication for the Beacon, Measurement Pilot or Probe Response frame, also expressed in dBm [16].

Figure 2 illustrates the principle behind SAMMy. The Mobility Model block is used to predict the future location of the mobile user. When a beacon report request is received, the Power Measurement block is triggered to measure the instantaneous received signal strength. The Power Prediction block predicts the received power for a future location of the mobile user.

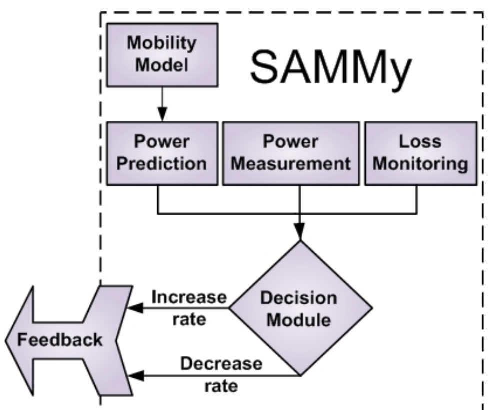

Figure 2. SAMMy architecture

The role of the Loss Monitoring block is to monitor the network traffic and to trigger the Decision Module on detection of a packet loss or change in Received Signal Strength (RSS) band. The Decision Module takes a decision to increase or decrease the rate and sends feedback to the server. At the server side 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 multimedia data to the client.

V. PRINCIPLE OF SAMMY

The proposed mechanism was tested over a multi-rate IEEE 802.11b network which supports four data rates: 1 Mbps, 2 Mbps, 5.5 Mbps and 11 Mbps. Each rate corresponds to a different modulation scheme. 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.

We consider two cases in which two mobile users are watching a video stream on their mobile devices. In the first case both are located near the AP, in the 11 Mbps zone and in the second case user 1 is located near the AP while user 2 is located far away from the AP, in the 1 Mbps zone. Table I illustrates the average throughput achieved by each user when the two cases are simulated using NS-2 [17].

TABLE I. PERFORMANCE ANOMALY

	Average Throughput [Mbps]	
	User 1	**User 2**
Case 1	2.79 Mbps	2.58 Mbps
Case 2	0.87Mbps	0.84Mbps

The results in the first case are natural. However, the results in the second case show how user 1 achieves almost the same low throughput as user 2, which is located at the edge of the network, in the 1 Mbps zone.

SAMMy is designed to take into account the received signal strength, packet loss and node location in the rate adaptation decision module. Knowing that as a mobile node moves away from the AP its received signal strength drops, the coverage area of the AP was divided in M different zones. Figure 3 illustrates the case with five such zones (M=5).

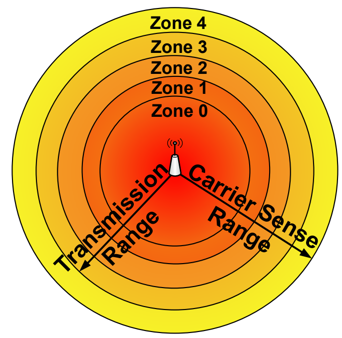

Figure 3. Access point coverage area divided in five zones

Each zone is associated with one quality level, which is the maximum level that can be obtained by a mobile user in that zone. In order to delimit each zone, we defined M-1 thresholds. Each threshold was computed based on the estimated maximum received power and wireless card receiver sensitivity. We consider the maximum power as the power received by the user's terminal if his location will be within one meter of the AP. As the mobile user moves away from the AP, passing from one zone to another his corresponding maximum quality level will drop by 1 at each bound.

When the Loss Monitoring block detects packet loss, it triggers the Decision Module. In a wireless network, loss can happen for a number of reasons, the main ones considered in SAMMy are congestion based losses, where packets are lost due to collisions, and signal strength losses, where packets are lost due to drop in signal strength. Positive feedback is 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 zone the mobile user is located in. The two values (2 and 10) were set based on the ARF mechanism for IEEE 802.11.

VI. Simulation Setup and Results

A. Simulation Setup

In this section we describe the simulation setup and evaluate SAMMy in comparison with TFRC, another adaptive multimedia delivery scheme, for multiple users delivering video in the wireless environment.

The Network Simulator NS-2 [17], version 2.33 was used for modeling and simulations. In order to improve the support for wireless networks realistic channel propagation, multi-rate transmission support and adaptive auto rate fallback (AARF) [18] were added as part of the wireless update patch [19]. Also the NOAH (No Ad-Hoc) patch [20], which allows communications between nodes through the AP, for infra-structure based WLAN setup, was added.

The TCP-Friendly Rate Control protocol (TFRC) [8] model included in this version of NS-2 was used in the simulations. The protocol adjusts the transmission to match the expected throughput of a TCP stream in similar conditions, being therefore TCP friendly to elastic traffic.

The support of 802.11k standard can be used for communication between the mobile user and the AP in order to obtain the instantaneous received power and information about the mobile user's location in the network. For the purpose of the simulation, we assumed that all this data is already available at the mobile node side.

B. Simulation Scenarios

1) Scenario 1

In the first scenario five mobile users share the radio channel of a multi-rate IEEE 802.11b network. Four users are located near the AP in the 11 Mbps zone, while one user is located at the edge, in the 1 Mbps zone, as showed in Figure 4.

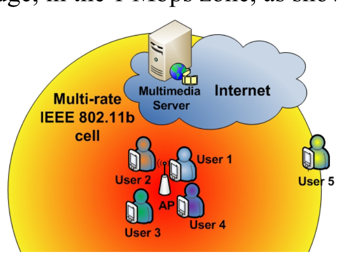

Figure 4. Simulated network topology for scenario 1

All mobile users start to watch a video stream on their mobile devices with a 2 seconds delay interval between them. They all use the same adaptive multimedia mechanism.

The video data is streamed from a multimedia server on the wired network to the users' mobile devices through an AP. The multimedia server stores three-minute long multimedia clips encoded at N=5 different rates corresponding to five quality levels such as:

- rate1 – 0.2 Mbps (Lowest);
- rate2 – 0.4 Mbps (Low);
- rate3 – 0.6 Mbps (Medium);
- rate4 – 0.8 Mbps (High);
- rate5 – 1.0 Mbps (Highest).

The average throughput achieved by each user is illustrated in Figure 5. Looking at the results, it can be seen that when using TFRC, all the users located in the 11 Mbps zone, near the AP, are impacted by user 5, which is located at the edge of the cell and achieves almost the same throughput.

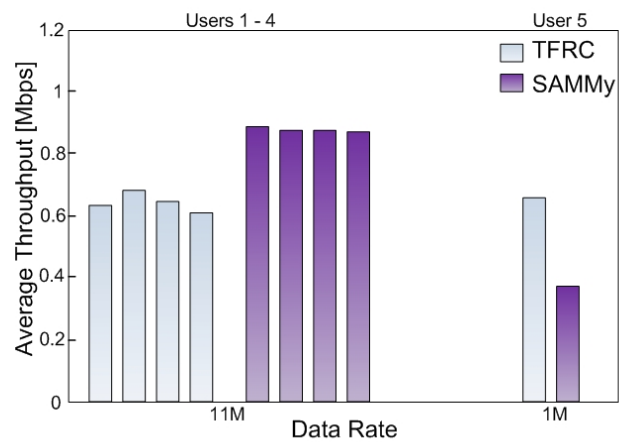

Figure 5. Throughput achieved by each mobile node in Scenario 1

On the other hand, SAMMy is fair to the users near the AP, while maintaining a reasonable throughput to user 5. SAMMy achieves an 18% increase in the total throughput of the IEEE 802.11b network.

2) Scenarios 2 and 3

Table II presents the results obtained for two other simulations using different locations for users. In Scenario 2, 6 users compete between each other, with every two users located in each of the following zones expressed in theoretical throughput zones: 11 Mbps, 5.5 Mbps and 1 Mbps. In scenario 3 only one user is located in the 11 Mbps zone and 4 users are located in the 1 Mbps zone.

TABLE II. Results when streaming over WLAN in scenarios 2 & 3

	User	User 1	User 2	User 3	User 4	User 5	User 6	Total avg. Thr. [Mbps]
Scenario 2	Zone	11M	11M	5.5 M	5.5 M	1M	1M	
		Average Throughput [Mbps]						
	SAMMy	0.67	0.63	0.49	0.42	0.29	0.32	2.82
	TFRC	0.40	0.38	0.36	0.42	0.41	0.42	2.39
Scenario 3	User	User 1	User 2	User 3	User 4	User 5	User 6	Total avg. Thr. [Mbps]
	Zone	11M	1M	1M	1M	1M	-	
		Average Throughput [Mbps]						
	SAMMy	0.64	0.34	0.36	0.29	0.27	-	1.9
	TFRC	0.33	0.32	0.32	0.33	0.34	-	1.64

The results confirm the observations stated above. In Scenario 3, when using SAMMy the throughput of the user located near the AP is almost 50% better in comparison with TFRC, while the users located far away from the AP achieve an acceptable throughput similar to the rates TFRC users receive.

3) Scenario 4

Scenario 4 uses the same settings as in Scenario 1, but one user is located in each zone as presented in Figure 6.

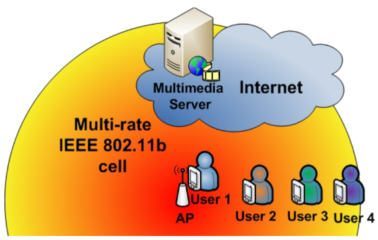

Figure 6. Simulated network topology for scenario 4

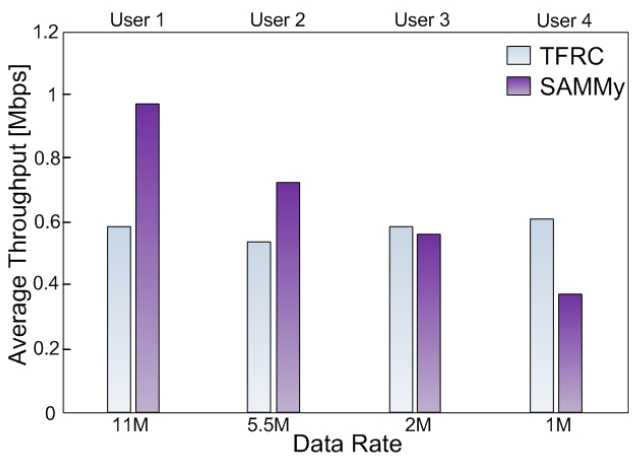

Figure 7. Throughput achieved by each mobile node in scenario 4

Figure 7 illustrates the average throughput for each user. In comparison with TFRC, SAMMy provides a fairer share of bandwidth based on the location and received signal strength. It can be seen that in SAMMy's case the users located near the AP have higher priority and achieve higher throughput, while the users located far away from the AP have low priority. In this way the user located near the AP is not severely affected by the user located in the 1 Mbps zone.

VII. Conclusions

In this paper we looked at the scenario when there are multiple video streaming sessions within the same IEEE 802.11b WLAN. We studied the performance of SAMMy in comparison with TFRC in terms of aggregate throughput and fairness. Fairness referred to mobile users' capability of achieving and maintaining throughputs according to their received signal strengths and locations.

The results show that when using TFRC the throughput experienced by users located near the AP decreases in the presence of users located at the edge of the network. SAMMy reduces the impact of the low rate users on users located near the AP, while maintaining a reasonable throughput for all users relative to their proximity to the AP. In comparison with TFRC, SAMMy achieves an average of 18% increase in overall throughput of a multi-rate IEEE 802.11b network.

As the 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 the adaptive scheme, by adding other parameters into the decision module, such as delay or jitter, which also have an impact on the user perceived quality

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