iPAS: An User Perceived Quality-based Intelligent Prioritized Adaptive Scheme for IPTV in Wireless Home Networks

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***Abstract*—There are several real-time dynamic adaptation mechanisms that exist today for improving end user perceived quality for IPTV services in wireless local networks. However, an adaptation scheme based on stream priorities, combined with terminals characteristics and the expected service quality levels, has not been explicitly considered by the existing approaches. This paper proposes a novel solution – the intelligent Prioritized Adaptive Scheme (iPAS) for adapting the encoding and transmission bitrates of video traffic based on stream priority and current network bandwidth resources as estimated by the bandwidth estimation technique, *iBE*. Results show how iPAS outperforms an equal priority solution in terms of distribution of both bandwidth between streams with different requirements and associated user perceived quality.**

***Index Terms*—** IPTV, Stream Priority, End User Perceived Quality, iPAS

I. Introduction

NOWADAYS Wireless Home Networks (WHNs) have been the primary network infrastructure serving residential internet services due to their lower cost and convenience [1]. In fact, nearly one-fifth of American households and a large number in Europe and Asia now use Internet to watch TV, and user-generated video [2], with many of them opting for wireless in the last loop. However, there are several practical challenges when streaming multimedia wirelessly. Two of the most important challenges that affect the overall Quality of Experience (QoE) and thereby the end-user-perceived-quality are: limited radio resources, device and content characteristics. Many solutions were proposed to improve multimedia streaming quality, but they focus mainly on the network Quality of Service (QoS) as QoE is difficult to assess. Adaptive solutions such as RAP [3] and TFRCP [4] have achieved significant increase in QoS. Other solutions that dynamically adapt video to network conditions [5] have not been able to demonstrate a definite improvement in the resulting user perceived quality. Notably, none of them have proposed a prioritized scheme for wireless multimedia delivery.

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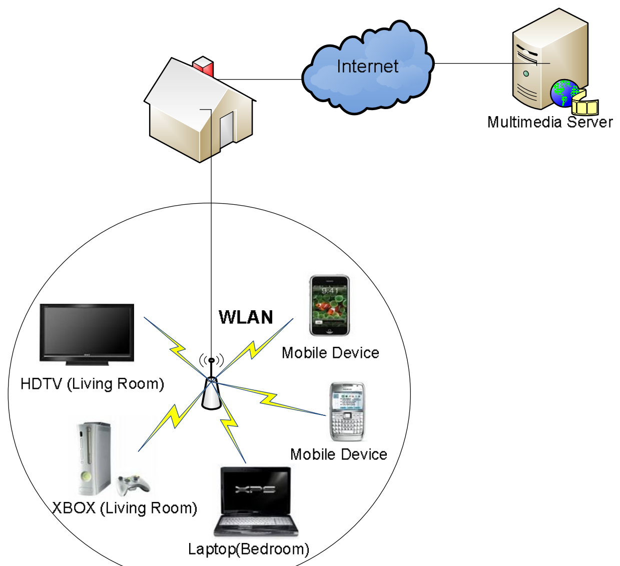

Fig.1Typical Wireless Home Network

There is a need for an innovative adaptive multimedia delivery scheme which will enable bandwidth distribution among different terminals based on their characteristics in order to fairly distribute the resulting perceived quality levels among the different users. Fig.1 shows a typical wireless home network which consists of heterogeneous terminals. Presently, the same priority is given to all wireless clients when accessing the medium. This results in an equal but unfair distribution of bandwidth among terminals with different characteristics.

Equal bandwidth distribution would result in poor EUPQ distribution, too. For instance, a smartphone may obtain higher bandwidth share while the a laptop is given not enough. A priority-based solution is providing higher bandwidth to those which require higher video bitrate. Furthermore, users might statically attribute priority to certain terminals according to their interests, for instance, a living room device (e.g. XBOX 360) could get higher priority, thus more bandwidth share than a bedroom device (e.g. laptop) during a party.

This paper proposes a novel innovative *Prioritized Adaptive Scheme (iPAS)* for IPTV service which enables differentiation among traffic streams with various priorities when sharing local wireless network bandwidth resources. The goal of iPAS

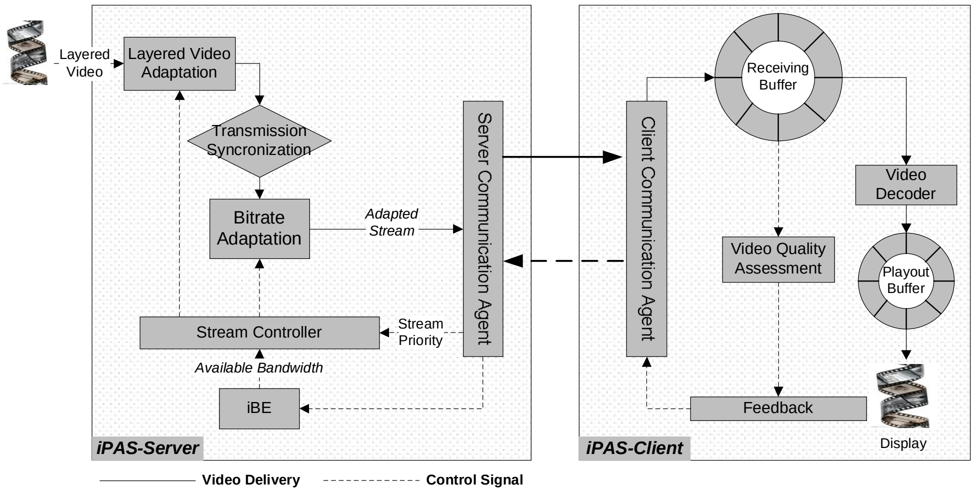

Fig. 2 iPAS System Architecture

is to fairly distribute user QoE when availing from IPTV services via heterogeneous terminals over a WHN.

Section II describes related techniques in current IPTV applications. Section III describes the iPAS, and section IV shows testing setup and analyses the experimental results. Section V concludes the paper and presents future works.

II.RELATED WORK

A. Prioritization of Video Delivery Services

Typical MPEG encoded video utilizes a GOP structure which specifies the arrangement of intra- and inter-frames of three types, I, P and B. Each I frame is encoded independently, B and P frames are encoded based on the previous or following I or/and P frames. Size-wise I frames typically occupy 40% of the bandwidth share with remaining 60% being used by the P and B frames [6]. As their number is also lower, it can be concluded that an I frame uses approximately ten times the number of transport units (RTP or MPEG) or IP packets used by a B or P frame. However their importance is very high. Current solutions such as [7] proposed packet drop priority schemes for MPEG video streams. This scheme introduced multiple levels of drop precedence for packets that belong to different frame types. Thus, packets from B-frames are more likely to be dropped when congestion occurs than packets belonging to P-frames. Similarly, packets from P-frames would be discarded first when comparing to I-frame packets.

B. Bandwidth Estimation

The number of services over IEEE 802.11-based wireless networks has increased dramatically. This has resulted in an exponential increase in the bandwidth requirements, especially for high-quality multimedia services. Traditional bandwidth estimation techniques like [8] have been based on the packet-pair principle. However, such techniques did not consider the problem of cross-traffic interference. In order to alleviate this problem, various refinements have been proposed, that include - sending trains of packets of various sizes (e.g., bprobe [9]) and better filtering techniques to discard incorrect samples: for example, nettimer [10]. Many of the recently proposed techniques fall into two categories: packet rate method (PRM) and packet gap method (PGM). PRM-based solutions, such as PTR [11], pathchirp [12], and TOPP [13], are based on the observation that a train of probe packets is sent at a rate lower than the available bandwidth. PGM solutions such as Spruce [14] and IGI [15] assume that the network capacity is known, and that bandwidth estimation with certain accuracy is available fast.

III.INTELLIGENT PRIORITIZED ADAPTIVE SCHEME

iPAS is a rate-based adaptive scheme for multimedia streaming which fairly distributes user QoE among different streams based on their priorities. iPAS utilizes the *intelligent Bandwidth Estimation* (*iBE*) scheme [16], which estimates the current available bandwidth of the WLAN. Fig. 2 illustrates the architecture of the iPAS-based system. *Server and Client Communication Agents* are in charge of exchanging IPTV traffic and control information.

A. iPAS-Server

iPAS Server monitors the overall available bandwidth using the *Stream Controller*, and manages the resource allocation among video streams using the *Bit-rate Adaptation* module. Whenever the *iPAS Server* detects a decrease of bandwidth, the transmission bitrate allocated to the video streams is decreased as well. Otherwise, when the overall estimated bandwidth increases, only streams requiring higher bandwidth get extra bandwidth share. Whether a stream requires more bandwidth is determined according to the estimation made by *iPAS Client's Video Quality Assessment*. In both cases, video encoding is adapted using the *Layered Video Adaptation* and *Bitrate Adaptation* modules. The three modules mentioned above are further explained in details next.

1) iBE

A novel *intelligent Bandwidth Estimation* (*iBE*) algorithm was proposed in [16], making use of the information related to multimedia packets delivery only at the application layer. iBE recognizes the dynamic fluctuations of the wireless channel quickly, enabling it to be used for real-time services.

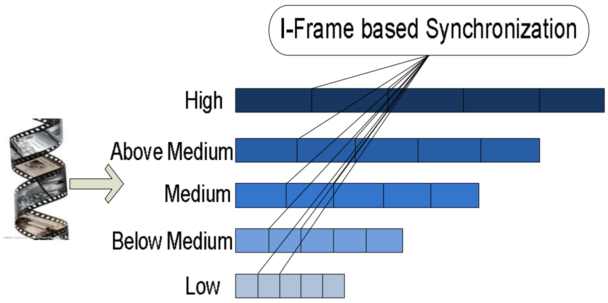

Fig.3. I-Frame based Video Traffic Adaptation

TABLE I.
PSNR-MOS MAPPING WITH THE EQUIVALENT ITU-T R. P.910 QUALITY AND IMPAIRMENT SCALE

MOS	Impairment	PSNR(db)
5(Excellent)	Imperceptible	>37
4(Good)	Perceptible, not Annoying	31-37
3(Fair)	Slightly Annoying	25-31
2(Poor)	Annoying	20-25
1(Bad)	Very Annoying	<20

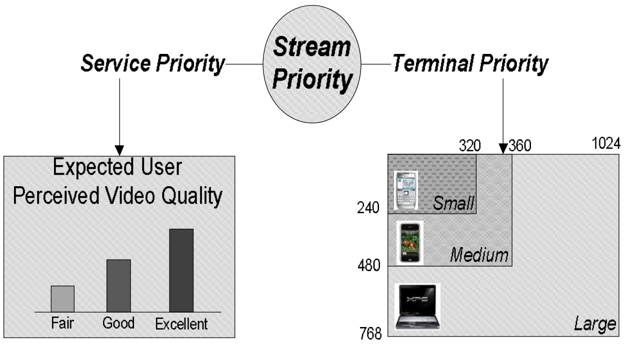

Fig. 4 . Stream Priority Introduced in iPAS

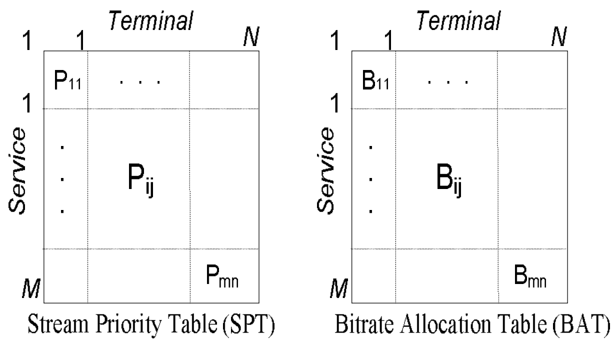

Fig.5-.Stream Priority Table and Bit-rate Allocation Table

The experimental results demonstrate that the accuracy of the bandwidth estimated by iBE is significantly superior to other state-of-the-art methods. Additionally, even in high traffic conditions, the bandwidth estimated by iBE is very close to the actual measured bandwidth.

2) Layered Video Adaptation

Layered Video Adaptation enables the adjustment of the bitrate of the delivered stream according to the bandwidth share it was allocated by the iPAS mechanism. For pre-recorded video, the same content is encoded using different quantization factors, but same GOP length, IBBPBB structure and framerate, generating multiple stream versions. Any bitrate adaptation would require real-time switching among these different versions. In order to maintain high user perceived quality and hide the effect of the switch, I-Frame-based synchronization is employed, as illustrated in Fig 3. For real-time video content delivery, transcoding performs the bitrate adaptation and there is no need for the interference of the *Layered Video Adaptation* module. For instance, *Microsoft IIS Media Services 3.0* [17] performs real-time adaptation to current available bandwidth with very good results, too.

3) Stream Controller

A key component on iPAS server side is the *Stream Controller* which receives estimated bandwidth from *iBE*, and sends control information to both *Layered Video Adaptation* and *Bitrate Adaptation* modules. It uses the iPAS *Stream Priority* consisting of (*Service Priority*, *Terminal Priority*) pair, as illustrated in Fig. 4. *Terminal Priority* is mainly dependent on screen resolution and N levels are defined. The *Service Priority* is one of the M service classes the clients expect to obtain.

4) Bit-rate Adaptation

The *Bit-rate Adaptation* unit works in conjunction with the *Layered Video Adaptation* module and performs the actual bitrate adjustment. It makes use of a *Stream Priority Table (SPT)* and a *Bitrate Allocation Table (BAT)* as indicated in Fig. 5. SPT is initialized with values according to equation (1) and is updated when terminal or service priorities are modified by the users. Equation (2) indicates how each stream is allocated a bandwidth share of the total estimated bandwidth based on their stream priorities from SPT. It considers the estimated bandwidth (by *iBE*) B_e, a safety coefficient μ to support bursty traffic, streaming service class I and terminal class j and stream priority P_{ij}. Bandwidth share B_{ij} will be determined such as equation (3) remains true.

$$P_{ij} / P_{11} = i + j - 1 \qquad (1)$$

$$B_{ij} = P_{ij} * \mu * B_e / \sum P_{ij} \qquad (2)$$

$$\sum B_{ij} = \mu * B_e \quad (0<\mu<1) \qquad (3)$$

B. iPAS-Client

iPAS Client evaluates the video quality received by each client, and sends feedback to the *iPAS Server*. There are two important parameters to be considered at the client level. The first is the buffer size (both receive and playout buffers) and the second is video quality. This paper focuses on video quality and its assessment only.

TABLE II.
VIDEO CLIPS AND THEIR PROPERTIES

Clip	Compression Ratio(YUV:MP4)	Mean Bit-rate (Mbps)	Peak Bit-rate (Mbps)	Frame Rate (fps)
1	5.84	1.3	8.8	25fps
2	17.91	0.42	4.4	25fps
3	32.66	0.23	4.0	25fps

1) Video Quality Assessment

Peak Signal-to-Noise Ratio (*PSNR*) [18], one of the most commonly used objective video quality metric and *Mean Opinion Score (MOS)*, one of the most important subjective video quality metric are used in conjunction. ITU-T R. P.910 five level perceptual quality scale is also considered.

In order to be able to compute PSNR online, iPAS estimates PSNR based on maximum expected bitrate and loss [19].

For video quality assessment, the heuristic mapping PSNR, MOS [20] and the ITU-T five-level quality scale illustrated in Table I, was used.

2) Feedback Mechanism

Feedback is generated and sent by the *iPAS Client* to the *iPAS Server* after monitoring the delivery process. Feedback information includes stream priority and quality of streamed video. Unlike the wired network case, the available bandwidth in wireless local network is dynamically changing due to various reasons such as, interference, contention among streams, average size of transmitted packets, client movement, transmission power fluctuation, environmental obstacles, etc. As iPAS relies on an accurate information, iPAS employs very high inter-feedback intervals (100 ms) and makes use of small feedback control packets (40 bytes).

IV. EXPERIMENTAL TESTING AND RESULTS

A. Simulation Setup

1) Testing Environment

iPAS has been tested using modeling and simulations, making use of the Network Simulator NS-2.33 [21] and an IEEE 802.11b WLAN testbed. Two additional wireless update patches were deployed: No Ad-Hoc (NOAH) [22] and Marco Fiero [23]. NOAH was used for simulating the infrastructure WLAN environment whereas Marco Fiero's patch provided a more realistic wireless network environment.

2) Video Traffic

A video sequence was selected from the *Simpsons* series and was encoded at different quality levels. The three resulting video clips were MPEG-4 encoded in the QCIF (176×144) format, with different quantization parameters and Table II presents their characteristics. Traces were extracted from these video clips and used as input for the NS-2 simulations.

The video traffic trace format includes the IBBPBB GOP structure and frame sizes. During simulations, the frames are transmitted and all data exceeding 1000 bytes (UDP packet size) was segmented at the sender, and reassembled at the receiver.

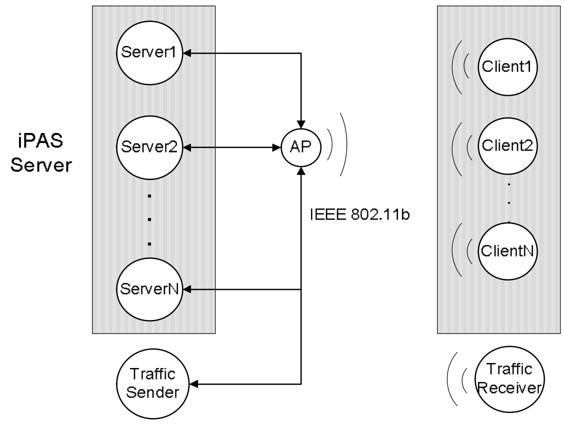

Fig.6. NS-2Simulation Topology for iPAS Testing

3) Service and Terminal Priority Classification

During these simulations there was no differentiation between service and terminal priorities. Consequently, the following stream priority pairs were used: (3,3), (2,2) and (1,1) (as described when the *Stream Controller* was introduced). They define three priority levels: *High-Priority (HP)*, *Medium-Priority (MP)* and *Low-Priority (LP)*.

4) Simulation Topology

Fig. 6 presents the network simulation topology used for evaluating iPAS. Six video streams (*N* = 6) were exchanged between six server-client pairs. A 200 kbps CBR/UDP stream was also transmitted as background traffic in order to additionally load the network between the Access Point and wireless clients. During the experiment, it was assumed that the IEEE 802.11b WLAN was the bottleneck link on the end-to-end path.

5) Simulation Scenarios

The simulation was designed to last 100 seconds and was divided into three transmission periods. The first period from 0 to 40 seconds, the second period from 40 to 70 seconds and the third - from 70 to 100 seconds. Two separate tests were conducted. In the first test iPAS was deployed and three different scenarios were considered: (1) six *High-Priority* streams are transmitted during the first period; (2) three *High-Priority* and three *Medium-Priority* streams are active in the second period; (3) two *High-Priority*, two *Medium-Priority* and two *Low-Priority* streams are delivered in last period. The second test utilized the same approach as the first one, but without any priority mechanism (equal priority applies to all steams).

B. Results and Analysis

Fig. 7 and Fig. 8 present the performance comparison results when iPAS and the equal priority scheme are used, respectively. Fig.-7 (a) indicates the stream bit-rate variation as a function of time. The *estimated bandwidth* (*iBE*) signifies the maximum end-to-end throughput which could be achieved in the presence of background traffic. Current *available bandwidth* is calculated considering the difference between the instantly estimated bandwidth and the throughput of multimedia streams. Note that at times t=40s and t=70s, when new streams started,

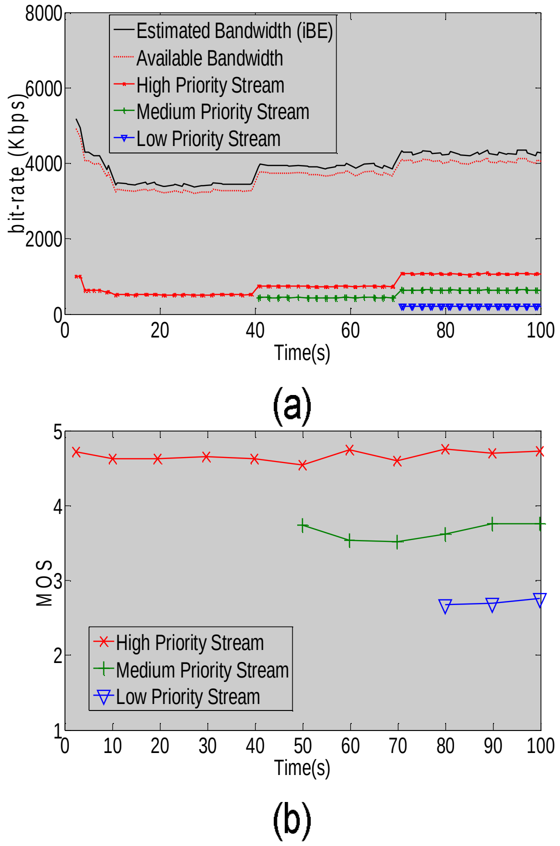

Fig.7. a) Bit-rate variation of iPAS scheme as a function of time b) Variation of the estimated user perceived quality expressed in terms of MOS.

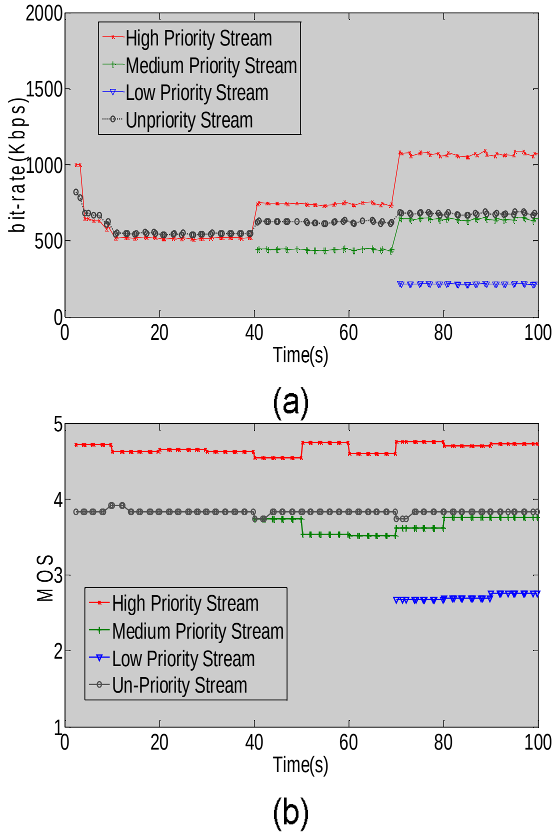

Fig.8. a) Bit-rate variation of equal priority scheme as a function of time b) Variation of the estimated user perceived quality expressed in terms of MOS when considering the GOP structure of traffic traces

the estimated bandwidth increased since the overall priority of the six streams decreased.

Fig. 7 (b) presents the average user perceived quality for each transmitted video stream. We introduce *Exp_Q* as the expected perceived quality, and *Q* as the actual perceived quality expressed in terms of MOS. For *High-Priority* streams which require excellent perceived quality (*Exp_Q* =5), the average *Q* obtained during the three periods were 4.62, 4.65 and 4.73, providing 92.4%, 93% and 94.6% degree of satisfaction respectively. *Medium-Priority* streams, which require good perceived quality (*Exp_Q* =4), obtained on average *Q*=3.68 and 3.76 in the second and third period, respectively. Hence, the degree of satisfaction was 92% and 94%. For the *Low-Priority* streams which required fair perceived quality (*Exp_Q* = 3), the degree of satisfaction was 92.7% in the third period.

Table III presents the iPAS simulation results in terms of time, transmission bit-rate, video encoding rate adopted and the average Q. Note that the first period was 10 seconds longer than other two periods. As shown in Fig 7.(a), video stream bit-rate varies significantly during the first transitory 10 seconds, when *iBE* has not accurately estimated bandwidth. Therefore statistics from t=10s to t=40s were gathered only.

The performance of the equal priority scheme is presented in Fig. 8. Since all the video streams transmitted have the same priority, they fairly share the overall bandwidth resource. Fig. 8 (a) indicates that the average bit-rate was 0.61Mbps from 0 to 100s, and the perceived quality for each transmitted stream was the same as shown in Fig. 8 (b), regardless of their requirements. It could be concluded that the overall end user perceived quality was attributed unfairly in the equal priority case.

V. CONCLUSIONS AND FUTURE WORKS

This paper proposes an innovative prioritized adaptive scheme (iPAS) for IPTV service delivery over wireless home networks. iPAS defines two types of stream-related priorities: terminal priority and service priority and performs the adaptation based on them. The major benefit of iPAS is that it fairly distributes user QoE among different streams by allocating bandwidth resources based on the stream priority. Experiment tests have shown that iPAS performs better than an equal priority scheme in terms of average user perceived quality. In future, comparisons with other QoS oriented prioritized schemes like IEEE 802.11e [24] will be verified. In addition, assessment of iPAS performance in real network environments will also be performed.

TABLE III
STATISTICS OF PRIORITIZED VIDEO STREAMS DURING THE THREE TIME PERIODS

Time	**10s-40s**				**40s-70s**				**70s-100s**			
Estimated Bandwidth	3.41Mbps				3.72Mbps				4.15Mbps			
Available Bandwidth	3.25Mbps				3.61Mbps				3.82Mbps			
	N	Rate	Encoding	Q	N	Rate	Encoding	Q	N	Rate	Encoding	Q
HP	6	0.55	0.42	4.62	3	0.74	0.42	4.65	2	1.07	1.3	4.73
MP					3	0.44	0.42	3.68	2	0.64	0.42	3.76
LP									2	0.22	0.23	2.78

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