Minimum GPRS Bandwidth for Acceptable H.261 Video QoS

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Key words: GPRS, H.261 video codec, Hurst parameter, multiplexing gain

Abstract: As part of a larger research on multimedia traffic performance over GPRS, we present a QoS study focusing on one parameter: *bandwidth*. GPRS is an evolutionary phase and a critical step towards the third generation (3G) of mobile systems providing a data rate of 2Mbps. In our study on GPRS, we investigate *multimedia video traffic*. The video codec used is H.261 with QCIF resolution. Many parameters are under research; however, in this paper we focus on one parameter: *minimum required bandwidth for acceptable QoS of QCIF H.261 video streams over the wireless and mobile medium, GPRS.* Some other parameters of interest like the Hurst parameter and multiplexing gain are tackled.

1. INTRODUCTION

The wireless and mobile telecommunication world is experiencing a very critical transitional stage, where new QoS parameters are to be defined. Within a more general study on mobile systems evolution, we analyse multimedia traffic over GPRS, a new phase of mobile communication media. GPRS represents an evolutionary step from the existing GSM system, where its purpose is to bring packet switched data services to the mobile system. With GPRS, the user can always be connected to the network since charging is not based on the connection time. The final billing scheme is not totally defined yet, but the main point is that the user should not care aboutconnection time.

J. Woźniak et al. (eds.), *Personal Wireless Communications*

One of the other goals of GPRS is to try to provide higher speeds than traditional GSM systems. The maximum theoretical speed over GPRS is supposed to be around 115Kbps. This bandwidth is achieved with very good radio conditions, and when the network is fully developed. In practice, the starting GPRS speed would, to a large probability, be somewhere between 20Kbps and 56Kbps. An enhanced GPRS system called EDGE is supposed to bring the speed up to 384Kbps. This very evolutionary phase of mobile systems is believed to be only one step towards the third mobile systems generation (3G), which is expected to give speeds up to 2Mbps.

The GSM system uses Time-Division Multiple Access (TDMA) with eight radio frequency time slots. A network operator can dedicate 0 to 8 of these time slots to GPRS. Each mobile terminal can send/receive in 1 to 8 time slots. It is believed that the first mobile terminals generation for GPRS will support 4 time slots downlink and 1 time slot uplink, which gives around 14Kbps uplink and 56Kbps downlink.

With this great shift that GPRS will introduce to the wireless and mobile world, we are interested in investigating the quality of service that GPRS can offer to multimedia applications, mainly video quality. Our research in this area is long term; however, in this paper we investigate few multimedia traffic parameters for one video standard. The format of the video streams we investigate over GPRS is H.261 with QCIF resolution. H.261 is chosen for its low bit rate [10]. The H.261 video streams in the experiments are variable bit rate streams, which makes them more suitable for the medium [4]. Quarter-CIF (QCIF) has 176 pixels per line, and 144 lines [9]. QCIF is chosen, because it is mainly used for desktop videophone applications i.e. the size will be suitable for a mobile unit. In addition, all codecs must be able to handle QCIF.

The parameter we focus on throughout the experiments is the minimum GPRS bandwidth required for acceptable QoS of H.261 video streams of QCIF resolution. We are also interested in self similarity since if we can define which type of videos show self similarity over GPRS, then GPRS vendors can learn more about how to deal with video over this medium [3, 6]. In this respect, the Hurst parameter is calculated. The Hurst parameter can be looked at as a self-similarity value; if near to 1, then this would be a sign of self-similarity. However, if it shows a value nearer to 0.5, then there is not much of self-similarity in the traffic.

In a study of multimedia over GPRS, it is very important to note that the standards with which the QoS is judged are subjective. Unfortunately, up till now, the judgements on acceptable QoS for multimedia streams are relative to the observer's personal standards [8]. Hence, we find it very important that, in our study, the minimum acceptable parameters investigated are defined by a representative number of people from different population backgrounds. Hence a common acceptable QoS is set to find the minimum bandwidth sought.

To calculate the theoretical values for the minimum acceptable bandwidth, we use the Multiplexing Gain formula [5]:

$$G_n = nR_p/C_n \qquad \dots (1)$$

where R_p is peak rate for the video stream; n is the number of independent streams combined for transmission; and C_n is the link-bandwidth required for the desired QoS for the multiplexed stream of n sources (C_1 being the link bandwidth for a single source).

$$(1) \Rightarrow G_n = nR_p/C_n = [nC_1/C_n][R_p/C_1] = [nC_1/C_n]G_1 \qquad \dots (2)$$

where G_1 is the multiplexing gain for one source.

$$(2) \Leftrightarrow C_n = n[G_1/G_n]C_1 \qquad \dots (3)$$

Here we think of the multiplexing gain as a parameter to use in order to achieve the minimum link-bandwidth for n streams where $n \in N^*$, the set of natural numbers - *{0}*. The multiplexing gain G_n for n number of independent streams is given by,

$$\frac{1}{G_n} = \frac{1}{b} + \left(\frac{1}{G_1} - \frac{1}{b}\right) n^{\frac{1-2H}{2H}} \qquad \dots (4)$$

where b is the peak-to-average and H is the Hurst parameter. Many methods can be used to calculate the Hurst parameter, like time variance plot, R/S analysis [2], and periodogram method.

2. EXPERIMENTS AND RESULTS

Figure 1 shows the testbed, which consists of two video senders, a GPRS emulator, a receiver, and a traffic measurement and analysis tool, NIKSUN NetVCR™. All the experiments, except the last one, use one sender only, for they are dedicated to studying the bandwidth required for one video stream. On the other hand, the last experiment concentrates on the performance when multiple streams are sent over GPRS. Table 1 shows the video streams, where "Comm" is the stream used in experiments 1 to 5. The packet time slots on the GPRS medium are set to 8 time slots throughout all the experiments since using less for video transmission will not lead to acceptable QoS. First, we look into whether there is any difference between the behavior of two media: GPRS with no restricting limits, and 10-BT. The associated results for the H.261 video stream are presented in table 2, where one would conclude that when the GPRS is dedicated to one video stream, with no background users, it will most likely behave like Ethernet. However, when running the first experiment on 10 Mbps Ethernet, we got no missing frames at the receiver end, while in running the experiment over GPRS, with 12dB, we had 2,670 video frames missing out of 6,306 video frames of the same stream (see table 4, Exp. 1 and 2). Figures 1-8 show the number of bytes (vertical axis) versus the packet size categories (horizontal axis).

Table 1. Video sequences used in the experiments. "Comm" is used in experiments 1 to 5.

Type of video	Length (mm:ss)	Total bytes	Total packets	Average bandwidth (bps)	Hurst param.
Music 1	05:18	1,769,912	7,941	44,387	0.81
Music 2	03:39	3,027,270	4,745	109,584	0.78
Music 3	03:25	2,633,906	4,582	101,793	0.88
News	13:55	10,657,756	18,313	101,623	0.74
Talking head	12:51	11,682,038	13,682	120,901	0.61
Commercial "Comm"	05:06	3,631,412	6,942	94,322	0.79
Total	*44:14*	*33,402,294*	*56,205*		

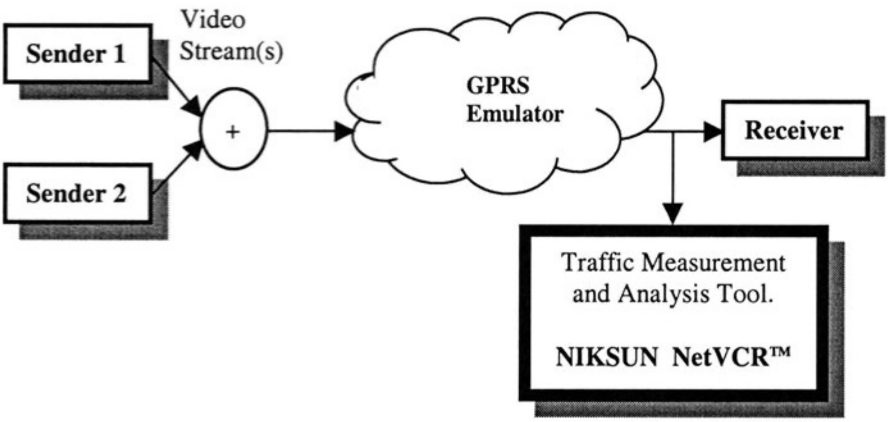

Figure 1. Testbed of bandwidth investigation for H.261 video quality over GPRS.

Hence in figure 1, the peak (bytes) is for the packets that are 512-1024 bytes in size, excluding 1024 byte packets. The second level peaks are for packets of 1024-2048 bytes (excluding 2048 byte packets) and 216-512 bytes (excluding 512 byte packets) respectively. Figures 2 through 8 can be read in a similar way for the associated experiments.

Table 2. Differences between GPRS with no restrictions and 10BT for "Comm". S/N=12 dB.

	No limits on GPRS	10 Mbps Ethernet
Total no. of bytes received	1.7284e+003	1.7289e+003
Median	3848	3788
Peak-to-Average ratio	5.3804	4.7394

We use the parameters in tables 3 and 4 to do some calculations for comparisons with the values received by the application. In this respect, we would like to note that the video is observed in real time and then the number of missing video frames is calculated. We believe that these numbers are very important to relate to acceptable QoS of the H.261 streams over GPRS. The fact that no frame is missing in experiment 1 can also be seen while watching the video stream live. Experiment 1 is also used as a comparison basis for acceptable QoS.

Table 3. Number of packets vs packet size for "Comm" video stream.

Packet Size Categories (Bytes)	Count (Packets)				
	10 BT	*GPRS*			
	Exp.1,fig.1	**Exp.2**,*fig.2* 12dB 0 BGU	**Exp. 3**,*fig.3* 15dB 0 BGU	**Exp. 4**,*fig.4* 12dB 20 BGU	**Exp.5**,*fig.5* 12dB 40 BGU
0 to 128	507	305	271	282	275
128 to 256	1089	651	594	585	623
256 to 512	2332	1332	1365	1302	1367
512 to 1024	2152	1312	1303	1232	1302
1024 to 2048	862	658	672	606	641
2048	0	14	19	12	21

Table 4. Statistics for "Comm" Video Stream over 10 Base-T and GPRS.

	10 BT	GPRS			
	Exp. 1	**Exp .2** 12dB 0 BGU	**Exp. 3** 15dB 0 BGU	**Exp. 4** 12dB 20 BGU	**Exp. 5** 12dB 40 BGU
Total Number of Bytes	7262824	4639074	4674424	4366946	4614556
Average Rate (bps)	48418.83	77317.90	103876.09	72782.43	102545.69
Number of Packets	13884	8544	8448	8038	8458
Average Rate (pps)	11.57	17.80	23.47	16.75	23.49
Minimum Packet Size	67	69	68	67	69
Maximum Packet Size	1066	1066	1066	1066	1066
Mean Packet Size	523.11	542.96	553.32	543.29	545.58
Packet Size Variance, B^2	93519.15	101585.97	100581.10	99668.34	99399.37
Variance/Mean	178.78	187.10	181.78	183.45	182.19
Missing Video Frames	0	2670	2719	2811	2788

In the second experiment GPRS is used. The S/N is 12dB i.e. worst case. However the main concern of this experiment is to measure the same parameters as in experiment 1 but over GPRS, hence we have no BackGround Users (BGU) i.e. the "Comm" video has all the bandwidth. The results are presented in figure 2. Collecting these parameters, we can also find a great similarity in the QoS delivered as well as the shapes of the graphs in figures 1 and 2. Around 41% of the frames are missing, but still the QoS is acceptable. The receiver end shows a rate ranging between 48Kbps and 62Kbps, which is a very good rate in our point of view for a video transmission with a QCIF resolution.

We also investigate the behavior and the used-bandwidth results for the 15dB S/N. We run exactly the same experiment as in experiment 2, but with 15dB instead of 12dB. The result is shown in figure 3. This experiment shows just a slight difference where there are more of large packets i.e. the traffic concentration is more in the middle (512-1024B) than in experiment 2. The rate ranges between 48Kbps and 63Kbps i.e. acceptable.

To get more practical results, we force background users over the GPRS network. The number of background users we have in experiment 3 counts to 20, with 12dB. The result can be seen in figure 4. The behavior still shows a graph similar to the previous experiments. The rate at the receiver's end still shows a range between 40Kbps and 60Kbps.

In the fifth experiment we force 40 users with 12dB over GPRS. The behavior is similar to the previous experiments in terms of graphical shape (figure 5), but the video quality drops down. In fact it is not acceptable at all. However, the rate at the receiver's end still shows a range between 48Kbps and 60Kbps.

In the sixth experiment our concentration is on the bandwidth when multiple streams are injected over GPRS, 12dB and 40 BGU. The results are predictable as shown in figures 6, 7 and 8. Filtering the traffic of each stream alone is important to study the bandwidth from the multiplexing gain point of view. Figure 6 shows the result for the traffic of both H.261 video streams at the same time. Since both streams, when injected together, have their first level peaks at (512-1024B), as well as their second level peaks at the same points (figures 7 and 8), then adding the two would lead to a graph with peaks at the same relative points (figure 6). For the first stream, the rate at the receiver's end still shows a range between 21Kbps and 37Kbps. For the second stream, the rate at the receiver's end still shows a range between 30Kbps and 50Kbps. The rates show that the bandwidth is divided, and this is a normal behavior. Around 60% of the frames are lost in each video stream. The visual effects on the QoS can be observed, and the delay between the frames is not within the acceptable range when there are transitions in the video stream. We also run multiple streams over GPRS to investigate more on the multiplexing gain and suitable bandwidth for the set QoS. Results are shown in table 7.

Referring to equation 3, if we know G_1 and C_1, then knowing C_n will be just a matter of knowing G_n, which can be calculated using equation 4. For an acceptable QoS, we will use equation 1 to get to a $C_1 = R_p$, where R_p is investigated in the experiments to be around 70Kbps. This makes $G_1 = 1$ for acceptable QoS. Hence (3) becomes: $C_n = n(1/G_n)(70) = 70n(1/G_n)$.

Table 5. Number of packets vs packet size; 2 video streams; GPRS, 12dB, 40 BGU.

Packet Size Categories (Bytes)	**Count (Packets)**		
	GPRS, 12 dB, 40 BGU		
	Total of Two video streams	First video stream **filtered**	Second video stream **filtered**
0 to 64	355	-	-
64 to 128	307	162	144
128 to 256	824	366	313
256 to 512	1433	747	699
512 to 1024	1452	730	728
1024 to 2048	624	304	305
2048	13	0	8

Table 6. Two video streams over GPRS, 12dB, 40 BGU.

	GPRS, 12dB, 40 BGU		
	Total of Two video streams	First video stream **filtered**	Second video stream **filtered**
Total number of Bytes	4949190	2456798	2401096
Average Rate (bps)	94270.27	16378.65	45735.16
Number of Packets	10016	4618	4394
Average Rate (pps)	23.85	3.85	10.46
Minimum Packet Size	60	72	68
Maximum packet size	1066	1066	1066
Mean Packet size	494.13	532.00	546.45
Packet Size Variance, B^2	10533.95	96162.32	97318.30
Variance/Mean	213.17	180.75	178.09
Missing video frames		4499	4399

Table 7. Multiplexing gain and min. bandwidth for a increasing number of video streams.

No. of Streams	Average (bits/interval)	Peak (bits)	Peak-to-Average	Hurst Param.	Mux Gain	=>	**Minimum Bandwidth**
2	198,307	278,528	1.40	0.87	1.82	=>	76.9Kbps
3	297,458	455,384	1.53	0.79	1.83	=>	114.8Kbps
5	487,719	628,664	1.29	0.82	1.60	=>	218.8Kbps
10	970,794	1,246,264	1.28	0.83	1.50	=>	466.7Kbps
15	1,455,795	2,002,776	1.38	0.84	1.54	=>	681.8Kbps

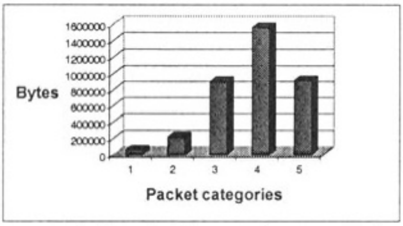

Figure 1. Exp. 1, "Comm" bytes vs packet categories over 10-BT.

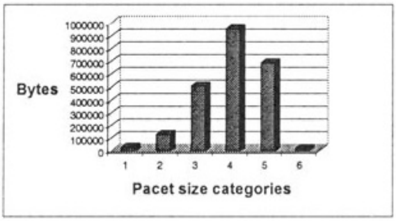

Figure 2. Exp. 2, "Comm" bytes vs packet size categories; GPRS, 12dB, 0 BGU.

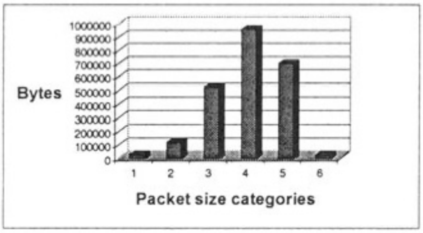

Figure 3. Exp. 3, "Comm" bytes vs packet size categories; GPRS, 15dB, 0 BGU.

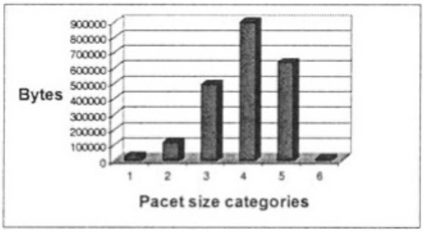

Figure 4. Exp. 4, "Comm" bytes vs packet size categories; GPRS, 12dB, 20 BGU.

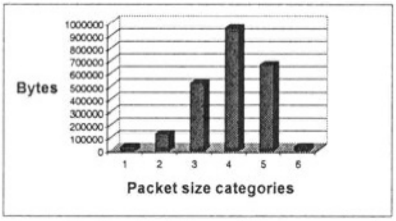

Figure 5. Exp. 5, "Comm" bytes vs packet size categories; GPRS, 12dB, 40 BGU.

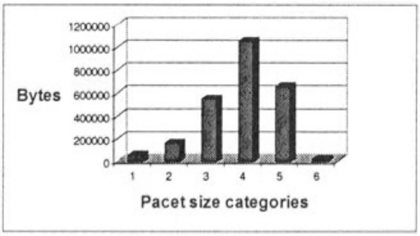

Figure 6. Exp. 6, two video streams traffic over GPRS, 12dB, 40 BGU.

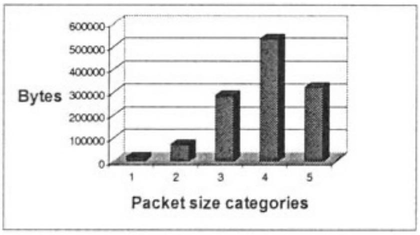

Figure 7. Exp. 6, first video stream over GPRS, 12dB, 40 BGU.

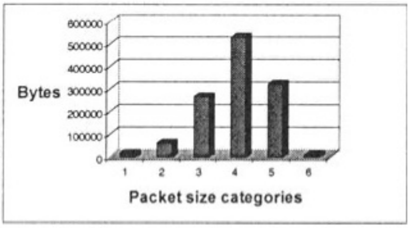

Figure 8. Exp. 6, second video stream over GPRS, 12dB, 40 BGU.

Figures 1-8. Horizontal axes show packet size categories of size X bytes, where labels 1, 2, 3, 4, 5, and 6 represent categories with $1 \leq X < 128$ bytes, $128 \leq X < 256$ bytes, $256 \leq X < 512$ bytes, $512 \leq X < 1024$ bytes, $1024 \leq X < 2048$ bytes, and $X = 2048$ bytes respectively.

3. EVALUATION OF RESULTS

As we increase the number of users and limitations on the GPRS, our calculations lead to a final value that we would like to present. The minimum acceptable bandwidth for H.261 video streams QoS over GPRS is found - after many iterations and trials - to be around 70-80Kbps for one QCIF H.261 video stream. This number is not very satisfactory since the practical limit that GPRS can deliver now is around 50Kbps. However, work is going on to reach higher practical limits, and if 70Kbps is reached, then sending video streams with QCIF resolution will be possible for the defined QoS. When a bandwidth of less than 70Kbps over GPRS is reached, the video quality and the missing frames number are not acceptable. In this respect, and regarding the transmission of multiple streams to one receiver to two different application port numbers, the sharing of the bandwidth will surely happen. However, the results in table 7 clearly show that the bandwidth needed over GPRS for the H.261 video for (n) streams will be less than the sum of the peak rates of the two streams. In other words, multiplexing gain will occur and will be a value greater than 1;

$$C_n = nR_p/G_n < nR_p = nC_1 ; \qquad G_n > 1, n \in N^*.$$

The quality with multiple streams will always be less than for one video sent as shown in experiment 6.

One parameter that seems promising for more research is the Hurst parameter shown in figure 9 with a *Log variance* vs *Log lag* plot. Since the self similarity is an interesting parameter to look at when all the presented data is available [7], we look at the Hurst parameter for two streams. The two H.261 video streams over GPRS show a Hurst parameter of around 0.97, with 12dB, 40 BGU. This means that the self-similarity is highly probable to occur [1]. This still needs more study to be conducted, but it is a very interesting start.

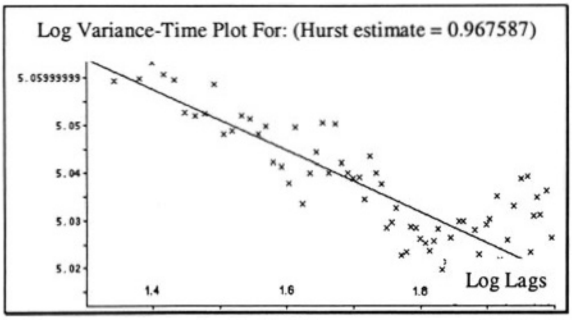

Figure 9. Hurst parameter plot for 2 video streams over GPRS, 12dB and 40 BGU.

4. CONCLUSION

We investigate some multimedia traffic parameters over GPRS, the third generation of mobile systems. The video streams investigated are encoded in H.261 codec. QCIF resolution is chosen for investigation since it can be deployed on mobile units. The minimum bandwidth required for acceptable QoS of QCIF H.261 video is dependent on the peak rate of the video, the number of streams, and how much the medium can have of multiplexing gain. For one video stream, the minimum bandwidth is around 70Kbps, which is still not easy to achieve over GPRS. However future GPRS generations will be able to supply this bandwidth and more. The encouraging part is that when two or more video streams are injected, they need less bandwidth than the sum of the peak rates of each. We hope that our study triggers more investigation in the filed of multimedia over GPRS from the traffic analysis point of view. The Hurst parameter is also presented briefly.

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