Perceptual Quality Measurement and Control: Definition, Application and Performance

A. R. Prasad, R. Esmailzadeh, S. Winkler, T. Ihara, B. Rohani, B. Pinguet and M. Capel

Genista Corporation
Tokyo, Japan
aprasad@genista.co.jp

Abstract

Quality of Service (QoS) is a key word today in the field of telecommunications but the meaning of QoS differs from person to person and system to system. The point that finally matters is the Perception of quality by the user.

In this paper we present definition of Perceptual QoS (PQoS) and objective methods to measure it. After which we discuss its application especially for quality control and management for systems like WLANs, Mobile Communications systems and Internet. Finally we give some simulation results.

1. Introduction

Currently all technologies are looking towards integration of services. Integration of service means providing voice, video, audio and data on a single system [1-6]. This brings forward several technical challenges the biggest being maintenance of service as per the requirement of the application and user i.e. fulfilling the Quality of Service (QoS) requirement.

In this paper we will focus on PQoS as provided by Wireless Local Area Networks (WLANs), Mobile Communications Systems (2G, 2.5G, 3G) and IP based networks.

WLANs available in market today work at 2.4 GHz ISM (Industry Scientific and Medical) band. As ISM band is unlicensed, several systems are working or are targeted to work in this band. Most of the systems are developed by separate standardization committees thus no co-existence study is done which means it is not possible to guarantee a minimum quality for a given service. Thus 5 Ghz is the target band for WLANs with QoS provision. In near future 5 GHz OFDM (Orthogonal Frequency Division Multiplexing) based WLANs will be available in the market. WLANs are usually wireless extension of IP networks providing best effort service although some work is going towards enhanced MAC (Medium Access Control) in IEEE 802.11 and hooks exist in HIPERLAN Type 2 (High Performance Local Area Network) [1-5]. Thus a study of PQoS measurement and control is a must for WLANs.

Mobile communications systems are also supposed to provide services besides voice [6]. Next generation mobile systems are envisaged to provide audio and video contents to user. In contrast to WLANs mobile communications systems define detail quality control mechanism. These systems are circuit switched while WLANs are packet switched. Even then the wireless medium being hazardous does not provide perfect communication. Here PQoS can help provide the QoS as the user perceive and help increase overall capacity.

IP networks like the Internet provide best effort services although lot of work has been done for QoS provision. IP based networks form the backbone network of most WLANs and will be used for next generation mobile communications systems also. Thus a good study of quality measurement and control is required for IP based networks.

QoS is mostly thought to be dependent on Bit Error Rate (BER), Packet Error Rate (PER) or Signal to Noise Ratio (SNR). PER, BER or SNR are usually used as parameters to control quality in above-mentioned systems. In reality it is the perception of user that defines the quality so it is important to perform PQoS measurement. PQoS measurement is conventional based on subjective measurements, e.g. 100 people giving score, but this cannot be used for quality measurement and control on-the-fly. Thus we need objective PQoS measurement with high correlation with subjective PQoS measurement and use this measurement for control.

In this paper we will first present definition of PQoS and PQoS measurement techniques in section 2. After which we will discuss the application of PQoS measurement and control in section 3. In section 4 the simulation model used for different systems are given. Finally some results are given in section 5. The paper is concluded with recommendations in section 6.

2. Definition

One can do subjective or objective quality measurement. Usually subjective measurements are performed to get PQoS measurement. Subjective method requires several people to listen or see a voice, video or audio clip in a given environment. This is obviously a very time consuming and expensive process. A faster method used by telecommunications systems is objective measurement. In current telecommunications systems these measurements are based on BER, PER or SNR [1-6] but as expected these are not accurate PQoS measures.

So as to provide better service to users and increase performance of systems and networks objective PQoS measurement is a must for telecommunications industry. The goal being to provide consistent perceived quality, Figure 1. This obviously will lead to higher customer satisfaction and increase in overall capacity.

There are standards which discuss PQoS measurement methods with reasonable correlation to the subjective measurements besides these there are also proprietary solutions [7-10].

In this section we discuss the definition of PQoS measurement method for voice, audio and video as described in standards. Besides this wherever possible we will propose novel methods for quality measurement. Due to lack of space we will not go in details of each technique.

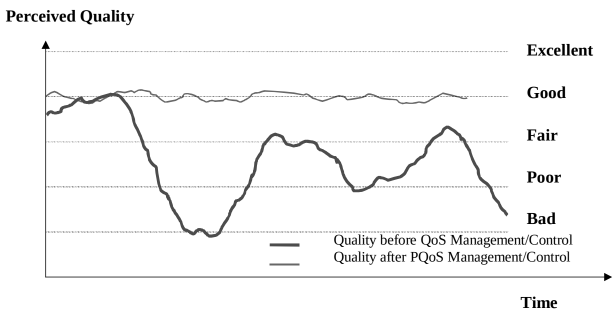

Figure 1 Quality before and after management/control.

2.1. Voice

Quality of voice is usually represented using a value called MOS (Mean Opinion Score) that lies between 1 - 5. ITU-T standard P.861 [7] defines method for objective measurement of voice quality. This is objective measurement is represented by Perceptual Speech Quality Measure (PSQM).

Within PSQM, the physical signals constituting the source and coded speech are mapped onto psychophysical representations that match the internal representations of the speech signals (the representations inside our heads) as closely as possible. These internal representations make use of the psychophysical equivalents of frequency (critical band rates) and intensity (Compressed Sone). Masking is modeled in a simple way: only when two time-frequency components coincide in both the time and frequency domains, masking is taken into account.

Within the PSQM approach, the quality of the coded speech is judged on the basis of differences in the internal representation. This difference is used for the calculation of the noise disturbance as a function of time and frequency. In PSQM, the average noise disturbance is directly related to the quality of coded speech.

The transformation from the physical (external) domain to the psychophysical (internal) domain is performed by three operations:

- time-frequency mapping;
- frequency warping;
- intensity warping (compression).

Besides perceptual modeling, the PSQM method also uses cognitive modeling in order to get high correlations between subjective and objective measurements.

PSQM values can be converted to MOS values by deriving transformation functions.

2.2. Audio

Usually audio, like voice, is also measured using MOS. ITU-R BS.1387 [10] defines Perceptual Audio Quality Measurement (PAQM) method. The basic idea of PAQM is very similar to PSQM although the internal algorithms are a bit different because of the inherent difference in audio and voice.

The analysis of results from subjective listening test in general is based on Subjective Difference Grade (SDG) defined as: $MOS_{SIgnal\ Under\ Test} - MOS_{Reference}$. The Objective Difference Grade (ODG) is the output of PAQM. ODG corresponds to SDG in subjective domain.

2.3. Video

Video quality is often measured using PSNR (Peak Signal to Noise Ratio). PSNR is defined as the ratio between peak signal and rms noise observed between the reference video and the processed video:

$$PSNR = 10 \log \left(\frac{255^2}{MSE \text{ between frames}} \right) \qquad (1)$$

However, PSNR does not take into account human vision and thus cannot be a reliable predictor of perceived visual quality. Human observers will perceive different kinds of distortions in digital video, e.g. jerkiness, blockiness, blurriness and noise. These cannot be measured by PSNR.

ANSI T1.801.03-1996 standard [9,11] defines a number of features and objective parameters related to the above-mentioned video distortions. These include:

- Spatial Information (SI) is computed from the image gradient. It is an indicator of the amount of edges in the image.

- Edge Energy is derived from Spatial Information. The difference in edge energy between reference and processed frames is an indicator of blurring (resulting in a loss of edge energy), blockiness or noise (resulting in an increase of edge energy).
- The difference in the ratios of Horizontal/Vertical (HV) Edge Energy to non-HV Edge Energy quantifies the amount of horizontal and vertical edges (especially blocks) in the frame.
- Temporal Information (TI) is computed from the pixel-wise difference between successive frames. It is an indicator of the amount of motion in the video. Repeated frames become apparent as zero TI, and their percentage can be determined for the sequence.
- Motion Energy is derived from Temporal Information. The difference in motion energy between reference and processed video is an indicator of jerkiness (resulting in a loss of motion energy), blockiness or noise (resulting in an increase of motion energy).

Motion Energy Difference, Percent Repeated Frames and other video parameters can then be combined to a measure of perceived jerkiness.

3. Application

The perceptual QoS measurement methods that we have discussed in previous section require the availability of reference and test signals. One of the basic things for communications systems is that the reference signal will not be available at the receiver. Thus a non-reference measurement must be done with high degree of accuracy. Solution for this is to find a practical relation between channel conditions and the perceptive quality value.

In this section we will discuss few applications of PQoS for different communication systems.

3.1. Monitoring

This application can be used by WLANs, Mobile Communications and IP based systems. By monitoring a service provider can get the perceptive quality value for different services this can be used in optimizing the network. This information can be stored for all connections or test signals can be used to perform the network optimization work. Using test signals will also mean that reference signal is available.

3.2. Quality Control and Management

A non-reference PQoS measurement solution can be used for quality control and management. Once PQoS measurement is available one can make accurate quality control system as shown in Figure 2. This can be used for WLAN, mobile communications and IP based networks. Using perceptual value for quality measurement we can be sure that the customer gets the agreed and consistent quality.

The control will be dependent on communication system being used. For example, for WLAN systems transmit power and data rate can be used to control the quality for HIPERLAN Type 2 but for IEEE 802.11 packet size can also be used.

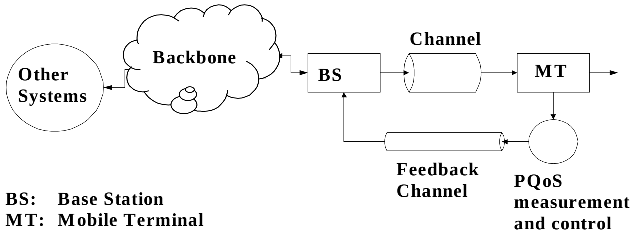

Figure 2 PQoS based control and management.

3.3. Resource Management and Call Admission Control

Resource Management (RM) and Call (or connection) Admission Control (CAC) are very important for any communications system. PQoS based RM and CAC will guarantee that all the users in the network get the quality based on their service level agreement. Besides quality guarantee the overall capacity of the network can be increased by using PQoS instead of PER, BER or SNR.

3.4. Quality Billing

Quality billing can be used to charge customers based on the PQoS. It can also be used to provide different levels of services. A generic way to express different types of services would be gold, silver and bronze service. The user will be charged on the type of service requested with a guarantee that the PQoS will be as agreed upon. Providing different level of services will also mean increasing the capacity of the network.

3.5. Quality based Deployment

PQoS information can be used in deployment tools to provide a quality based deployment. Current deployment tools do not provide quality values let alone PQoS.

3.6. End-to-End & Top-to-Bottom QoS

The most important thing in the network is to provide end-to-end QoS but with IP based backbone network coming up it is also important to have top-to-bottom QoS. Top-to-bottom means all protocol layers understand and speak the same QoS language.

PQoS measurement and control can be used at different levels in network and protocol stack to guarantee end-to-end or top-to-bottom quality.

3.7. Terminal Quality

PQoS solution can also be used for benchmarking terminal quality during research, development, test and production.

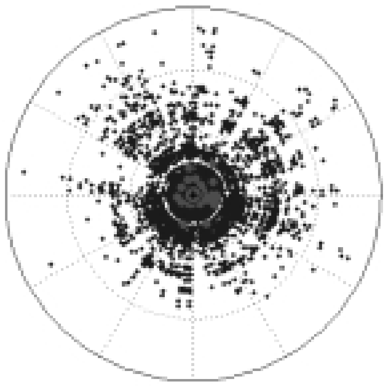

Figure 3 Variance of subjective results (black) and objective result from DualVQ (gray).

4. Simulation

For the purpose of simulation we use a number of tools for quality measurement and link level simulation. In this section first the tools are explained after which the simulation model used is explained. We will limit the simulations to WLANs and IP networks.

4.1. Quality Measurement and Control Tools

We use two tools for quality measurement in this paper.

The first tool we used is called DualVQ which gives the MOS results with reference signal. The tool is very accurate. The accuracy of the tool is proved by Figure 3. This result gives the subjective test results by 150 people and the objective result by DualVQ. A system is accurate if the results are close to the center as can be seen by gray results of DualVQ.

Video QoS tool was used to get video quality result. This tool measures the difference between reference and processed video streams for various ANSI and perceptual parameters. For this paper we have considered only few of the parameters.

4.2. Link Level Simulation Tools

Link level simulation is performed by using Ortholink tools for 5GHz systems (HIPERLAN Type 2 or IEEE 802.11a). These tools are implemented as per the standard for receiver and transmitter. The channel used is Rayleigh fading and AWGN channel defined as per the standard requirement for different test conditions. For IP network Network Simulator is used.

4.3. Simulation Model

In Figure 4 the simulation model used for study is given. For all systems (WLAN, and IP network) we have transmitter, realistic channel and receiver. The input data can be voice, audio or video this is encoded before transmitting using the required codec at the receiver decoding takes place after which the transmitted and received signals are compared. This gives the PQoS value which is used to perform control. In this simulation we only control the transmitter not the encoder.

Simulation is not performed for control given as dotted line in Figure 4.

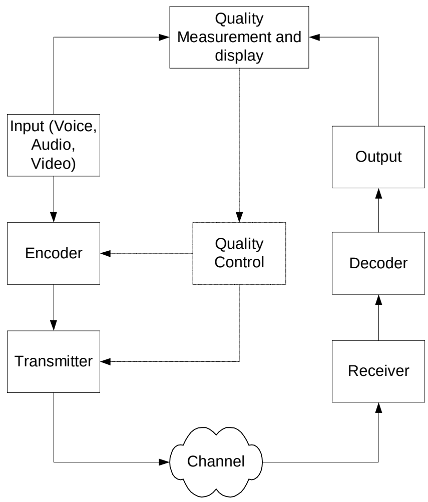

Figure 4 Simulation model.

5. Results

In this section some results for voice over IP and video over WLANs are presented.

5.1. Voice over IP

The first result shown is for voice over IP, Figure 5. The network considered was a simple duplex link i.e. transmitter connected to one router and receiver to another router. There was only one user and no other load in the network. The voice traffic, of 60s, was generated using a P50 ITU artificial voice generator. The artificial voice was PCM 16 bits per sample at 16 kHz. 10ms of voice was transmitted per UDP packet. We can see interesting result for MOS against packet loss. Results can be generated by adding load interns of voice traffic and data traffic. These information will give the accurate range for CAC and RM for a given level of quality requested by a user. Partial or non-reference solution can be used for control of quality.

5.2. Video over HIPERLAN Type 2

Video quality over HIPERLAN/2 was measured using Video QoS tool. The results are shown in Figure 6 For this simulation only one user was considered with indoor office 16 path Rayleigh fading channel as defined by the standard. The video used was MPEG 2, 300 frames of 10 seconds length, in studio environment. The results were generated for 12 Mbps and 18 Mbps with 20 LCH, f_d (Doppler Frequency) of 1Hz and SNR of 14dB. Result for 12Mbps is far better than that at 18Mbps.

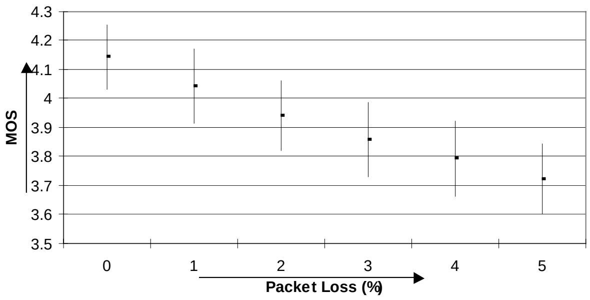

Figure 5 MOS versus packet loss for voice over IP.

6. Conclusions

In this paper we presented the PQoS definition for video, audio and voice. These solutions make use of reference (original) and output signal to give PQoS result. Non reference solution can be designed based on channel conditions. One such solution, MultiVQ, is also discussed in this paper.

Results are generated for voice over IP giving MOS for percentage of packet loss. For WLAN result is given for video over HIPERLAN Type 2. The above mentioned results give PQoS measurement. PQoS can also be used for quality measurement and control.

Although we haven't shown here, PQoS will increase the capacity of system. As discussed in the paper there are several practical applications envisaged for PQoS.

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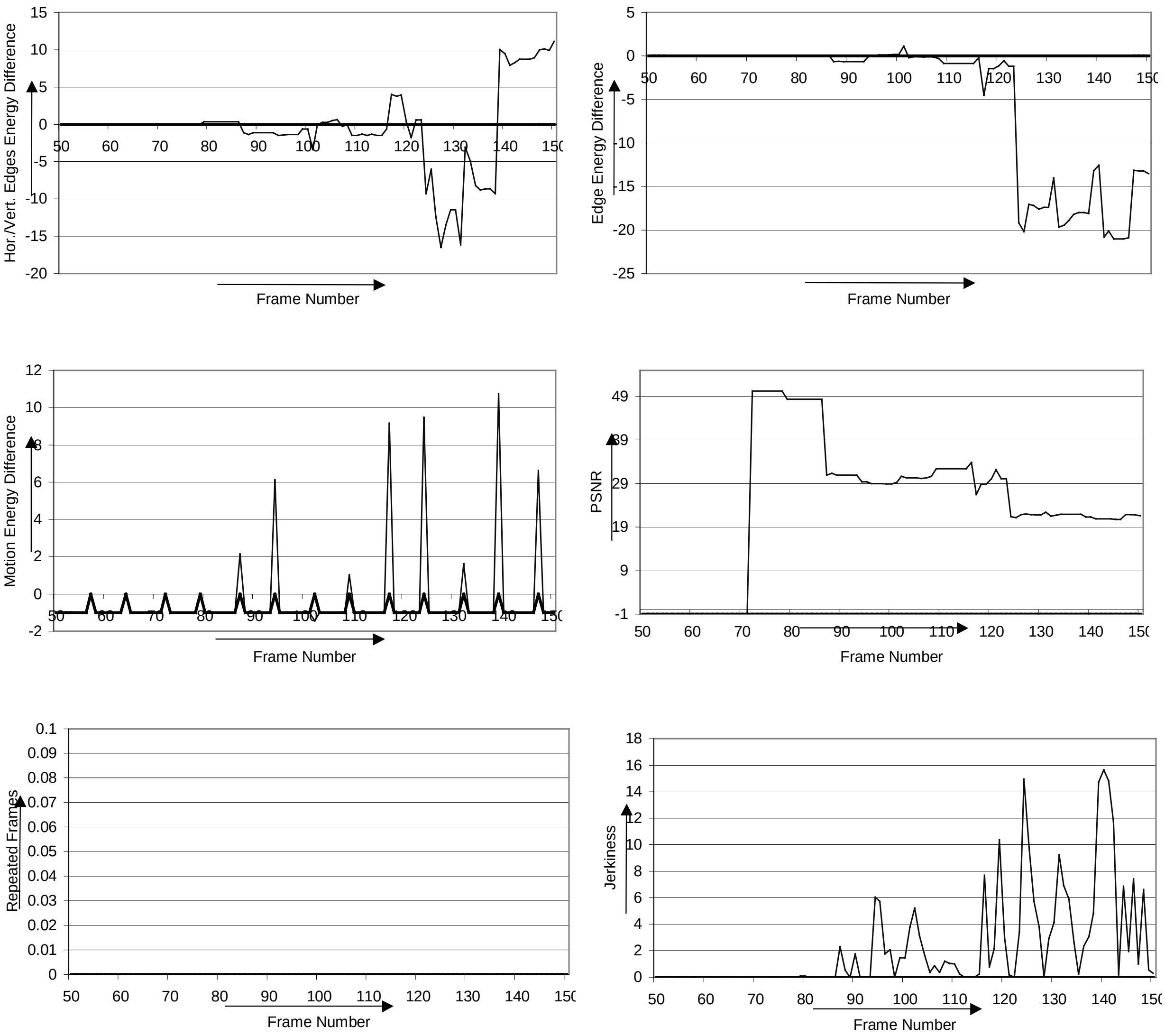

Figure 6 Video QoS results for video over HIPERLAN Type 2. With HIPERLAN Type 2 parameters: LCH = 20, f_d = 1Hz, SNR = 14dB, thin line: 18 Mbps, thick line: 12Mbps.