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Individual Quality of Service Concept in Next Generations Telecommunications Networks

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Introduction

Nowadays widespread GSM/GPRS networks belong to 2-2.5 generation. Third generation (3G) networks were created only in the last decade. Currently 3G technologies are standardized. Equipment manufactures and network operators are in the process of deployment of 3G networks. Scientific institutions pay attention to 4G and generally to next-generation mobile telecommunication networks.

It is expected that 4G networks will be all-IP based heterogeneous networks. They will allow users to use any system at any time and anywhere. 4G systems provide not only conventional telecommunications services, but also data and multimedia services. Users carrying an integrated terminal can use a wide range of applications provided by multiple wireless networks. When 4G services will be launched, users in widely different locations, occupations, and economic classes will be able to use any type of the services. In order to meet the demands of these diverse users, service providers should design personal and customized services for them.

It is certain that next-generation networks will convey all information wrapped in packets. For example, voice is divided into length *T* time intervals (typically 10, 20, 30 ms) before transmitting. These intervals are encoded and transmitted. Transmitted block are named as frame. At the receiver end, it is possible that frame is damaged. Damaged frames are not normally decoded and decoder uses some substitution algorithm.

All generation mobile telecommunication systems pay attention to the service quality. ITU has standardized many quality measures. Quality of Service (QoS) is a concept, which first time emerged over 20 years ago. The basic meaning of QoS is defined in ITU's recommendation E.800, which defines QoS as: ”the collective effort of the service performance which determines the degree of satisfaction of the end-user“ [1]. The development of general QoS concept has determined many parameters. For example, for evaluation of voice quality parameter list is: subjective quality (noting age, sex, language, etc.), speaker recognition, naturality of voice, ease of conversation, perception of echo, interruption of service.

According to ITU – QoS is a conditional subject. However, the main criterion is “the satisfaction of the end user”. This formulation of QoS permits quality evaluation at the application level. The degree of satisfaction depends on the perceived service level, user expectations and cost. Service level is merely a reflection of the personal impression of the users, and consequently the best way to estimate it is testing conducted with a selected set of persons.

It is well known that service price is important factor for telecommunication service usage level regulation. Low tariffs determine high network load and vice versa. According to ITU QoS is related to pricing and tariffs.

New technologies are created on the top of old ones. They should bring to society not only new technological aspects but also they should meet new demands of society. One such demand is in finding means to evaluate QoS provided de facto to the individual user – iQoS [2-4].

In this paper we will investigate possibilities and means to create special purpose module for the evaluation of perceived service quality. Demand for such module can be justified because quality perceived by individual users varies greatly. Quality depends on user location, time, network load etc. When user moves changes his communication conditions as well as perceived quality level.

Attitude towards QoS from user perspective is relatively new. Traditionally quality related quantities are statistically processed. Averaging is usually done for the whole network.

Differentiation of QoS

Present telecommunication networks supplies differentiated services. Distinct services require particular quality levels or aspects. QoS models differ one from another in the way how they enable applications to send data and in which the network attempts to deliver that data. Basically, there are three kinds of service models: Best-Effort Service, Integrated Service, and Differentiated Service. Differentiated Service - a multiple service model that can satisfy different QoS requirements. For the best-effort service, the network delivers data if it is possible, without any assurance of reliability, delay bounds, or throughput.

Distinct service classes are well suited to supply needs of different users. Services of higher class require more network resources. It is necessary to reserve some network resources when supplying Differentiated Services. This reservation limits potential and partially quality of lower class services. From above it is obvious that higher level services are more heavily priced.

In the mobile telecommunication networks QoS as concept and a set of some parameters is used for network resource management. Telecommunication equipment of all generations constantly monitor communication conditions in mobile and base stations. Changes of communication conditions lead to change in system parameters. The power of transmitted signal is changed first. When increased power is not enough to hold good communication conditions then it is possible to change frequency channel, mobile station can be switched to another base station, etc. Third generation systems can also change voice codec parameters. Such means give to the mobile user some invariability limits. When mobile station moves in relatively small territory, quality level changes only slightly.

Some novel concepts of QoS and underlying network architectures have been now realized in design of 3G networks [5], providing means for distributing radio resources among different groups of users according to their individual preferences and QoS demands. Research of next generation networks treats QoS as part of network equipment. According to Nokia [6] in general QoS system it is necessary to separate the following subsystems: Network service QoS, Endpoint QoS, Network QoS control, QoS management.

The quality of service in telecommunication networks has been analyzed by many authors in various aspects. However, there is one aspect of QoS, which seems to be undervalued and insufficiently represented in literature and largely non-existent in telecommunications networks operated today. This missing part is the estimation of QoS provided *de facto* to individual end-users (referred as "individual QoS" or iQoS) [3]. That is namely this particular aspect of QoS that this paper discusses.

In the context of above discussion demand for QoS and de facto perceived quality analysis is obvious. Common network resources are always limited. If service provider (SP) declares many classes of services then supplying service of the higher class always conditions resource reallocation. In the same time services of the lower class may remain without resources. For example, in GSM/GPRS networks voice channels can occupy data channels.

Attention to iQoS can be based on the fact that, as indicates many investigations, in some places of the network real service quality may become low compared to usual conditions. An example which confirms this proposition is Ascom report [8]. This report provides the results of QVoice measurement data, recorded in Denmark. In these measurements speech quality in $\leq 5.3\%$ call attempts was found fair and in $\leq$ 2.3% call attempts was bad. Dropped calls were in $\leq$ 2.3% call attempts.

Ascom report also points out reasons of bad communication link: bad coverage, interference, etc. Percentage of bad quality links is not big but distribution of cases of bad communication quality is not uniform among users. Cases of bad communication quality fall to those users who are in some geographical location (usually between base stations) or use services when network load is high.

Currently there are millions of mobile telecommunication users. This fact, competition among operators and new services increases importance of next-generation QoS problem. Big complexity of QoS problem is mainly due to the following reasons:

- subscribers mobility,
- imprecise predictable demand for different services, variable network subsystems load,
- unpredictable radio propagation conditions. As a result increased interference level.

Diversity of technologies also makes QoS problem harder. For example, in speech services UMTS uses AMR–*n* [7] voice codec. Speech quality depends on *n* – coding rate.

Mobile telecommunication conditions and quality

In GSM/GPRS and UMTS systems radio frequency (RF) power control is employed to minimize the transmit power required by mobile station (MS) or base station (BS) while maintaining the quality of the radio links. By minimizing the transmit power levels, interference to co-channel users is reduced. RF power control is implemented in the mobile station on each uplink channel and optionally in the base station. The criteria for RF power control are based on radio channel quality or received signal quality. It is important to notice that power control criteria are not identical to those used in voice or video quality determination. Considering how many services there are it is not possible to apply power control criteria to quality determination unambiguously.

Radio channel quality Q is measured and power control is performed with the some measured/calculated parameters: received signal level (RxLev), carrier-to-interference ratio (CIR), bit-error rate (BER), frame erasure rate (FER) or received signal quality (RxQual) [9]. The power control mechanism in principle is quite simple. When i-th radio channel quality Q_i is better than required Q^{req}.

$$Q_i > Q^{\text{req}}, \qquad (1)$$

CIR shall be decreased. When radio channel quality is worse than required,

$$Q_i < Q^{\text{req}} \qquad (2)$$

CIR shall be increased.

The decision "CIR shall be increased" should be executed until

$$P_i \leq P_{\max}, \qquad (3)$$

here $P_{\max}$ - maximum allowed power of transmitter.

In these power control states, while $P_i < P_{\max}$, radio channel condition variations only slightly affect quality of service. But when power is increased and critical limit is reached

$$P_i = P_{\max}, \qquad (4)$$

it is not possible to increase power more. This modified power control algorithm is illustrated in Fig. 1. This model differs from conventional models because of it is impossible to increase transmitter power when P_{max} is reached.

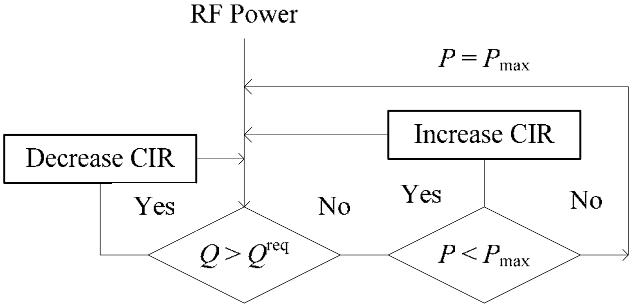

Fig. 1. Power control

When P_{max} is reached and in some location it is not possible to switch MS to another BS, quality of link may become poor.

When P_{max} is reached and in some location it is not possible to switch MS to another BTS quality of link may become poor. Examples measurements of the parameter's like RxLev and BER when mobile station moves in poor communication conditions area, are depicted in Fig. 2 and 3 [4].

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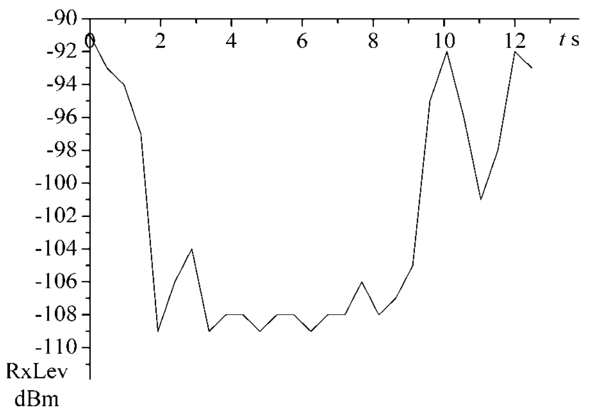

Fig. 2.·Received signal level as function of time (MS is moving)

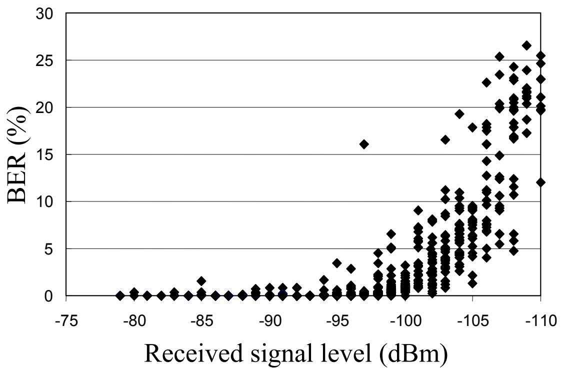

Fig. 3. BER as a function of received signal level

In Fig. 2 it can be seen 8 seconds time duration interval when signal level RxLev is near to sensitivity threshold of the receiver (–110 dBm). Fig. 3 shows that BER greatly rises when received signal level falls below –95 dBm.

The measurements [3] have shown that in cases of poor radio link quality (for $-110 < RxLev < -96$ dBm), the FER > 10% was observed for 17.9% of measurement points, and C/I<6 dB was observed at 38% of all points. The occurrence of both FER > 10% and C/I < 6 dB was observed for 17% measurement points. This confirms that in the areas with poor radio coverage (radio signal strength being near to the receiver sensitivity threshold) the obtainable voice quality will be significantly degraded.

When mobile station operates under critical radio link conditions quality degradation can be observed. In these cases user gets only best effort service. Voice quality impairments are due to lost radio frames. Consequence of this is lost speech frames. Single erased frames are heard as short disturbances. Long sequences of lost frames erase words or part of words.

Summarizing measurements of the link quality of mobile communication we can draw conclusions that are important for iQoS problem:

– Particular MS operates under distinct conditions. These conditions depends on MS localization, network load, etc.

– When MS is moving communication conditions changes randomly, there are time intervals when signal level approaches receiver sensitivity threshold;

– There are places in cells where elementary quality defects are observed and frames are lost;

– When MS operates under low signal level conditions series of lost frames are observed;

– Lost single frames and series of frames are the main reason of degraded speech and video quality.

Channel level defects, their modelling and simulation

Formulated propositions about particularity of mobile telecommunication conditions also are initial conditions for modelling. Variety of communication conditions in which mobile station operates forces us to choose random non-stationary process models for simulation. These models are capable to represent temporal variations in speech impairments. But this modelling sometimes is complicated.

For the initial research, deterministic models look attractive, too. For example:

– Lost single frame in a word. Changes position of lost frame;

– Lost 2, 3, 4, *n* frames. Changes position of the beginning of lost sequence;

– Lost some frames. Lost pattern is known in advance.

This way of channel modelling is convenient for the analysis of concrete distortion influence on speech quality. For example in Fig 4 is depicted dependence of voice quality deterioration delta PESQ [10] on location of frame error. As delta PESQ we take value equal to difference of PESQ of not corrupted and corrupted speech. From graphs in Fig. 4 it is obvious that speech quality after the substitutions of lost packet substantially depends on position of packet loss. There are places in a word where packet can be lost without noticeable speech quality degradation.

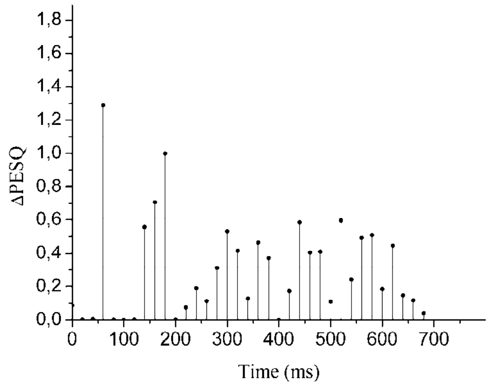

Fig. 4. ΔPESQ as function of time of lost frame (word "*cherry*")

Real communication conditions are better modelled with stochastic models. Some examples include Markov chains and Hidden Markov Models. In simulations we usually use Hilbert model (two state Markov chain).

Communications conditions effect on voice quality will be described in future works. The goal of this research is to measure impact of concrete lost frames on perceived speech quality.

iQoS module – part of network quality management

The purpose of iQoS module – constantly compute quality of supplied service in next-generation networks. iQoS should become the part of general quality management process. Proposed iQoS module for mobile communications is similar to RF power control mechanisms.

Integrated power control and quality system is depicted in Fig. 5. Radio channel characteristics used for the power control are passed to the quality evaluation system. In this system short time quality impairments are calculated. These calculated parameters are passed to Pricing block

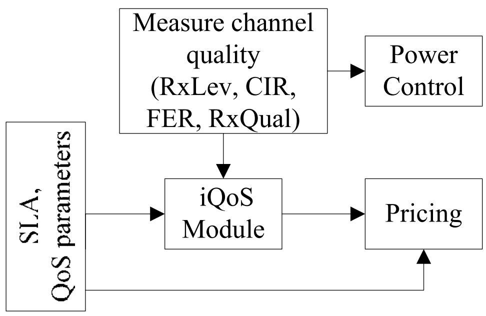

Fig. 5. Integrated power and quality control

iQoS measurements should be done in these network locations where power control related data are measured. Such iQoS modules placement scheme is shown in Fig. 6.

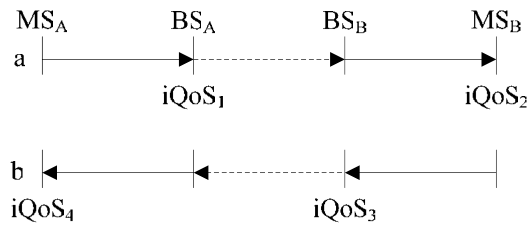

Fig. 6. Placement scheme of iQoS modules

Relations between SP and end-user

Relations between the Service Provider and the end-user, their inter-liability are regularized by means of contractual obligations. Currently wide spread rule is one that does not care about quality at all. Technical means of accounting calculates time (or amount of data) and knows nothing about quality. User also has not objective facts about perceived quality. Currently in practice user pays for service that assumed to be good and SP is not responsible if user is not satisfied with perceived service quality.

In next-generation networks SP and the end-user contractual obligations should include clause about quality level. For this purpose ITU formulated recommendation E.860 [8]. In this recommendation are stated general principles about Service Level Agreement (SLA). With the help of SLA it is possible to fully regulate relations between SP and the end-users. A SLA may include statements about performance, tariffing and billing, service delivery. A SLA may **include the compensations** for an unachieved level of quality as an economic issue of the contract.

For SLA attitude implementation it is necessary to supply next-generation mobile telecommunication equipment with iQoS modules.

iQoS modules should not only perform supplied quality evaluation, but also relate these evaluations with an amount of supplied service. For this reason quality modules should be integrated with pricing tools (Fig. 7). iQoS modules are necessary for SLA attitudes implementation between SP and the end-user. Gathered data could help users to protect their rights.

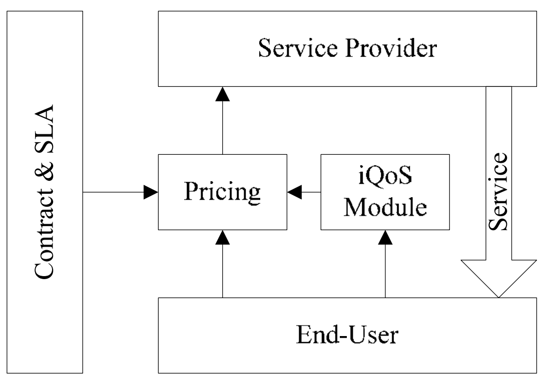

Fig. 7. Support of SP and the end-user contract agreement

iQoS module collects all information required to evaluate the actual service received by a user, which can include poor service reception due to wireless channel impairment or unavailability as well as network congestion. This information then will be used to adjust any charge to a user.

In Fig. 7 iQoS module is presented as a mean for controlling Service Level Agreement. For the purpose to implement SLA attitudes and relate them with tariffs it is necessary to solve many questions. The first group of questions is how to describe relations between the end-user and the service provider.

When talking about tariffs, pricing – the first thing that is necessary to solve – to choose basic pricing unit - u_0. In conventional telephony basic pricing unit is duration of conversation expressed in seconds. Current and next-generation systems convey information in packets. So it is reasonable to take as a basis the pricing unit packet of some form. This unit- u_0, obviously has and quantitative aspect – number of bytes N_u. Kind of service (voice, video, e-mail) can be marked with some kind of index. In this case index could be just number in list of services. Much complex situation is with quality indicators. Development of any current telecommunication technology considers quality requirements. When communication conditions are good and meets technological requirements, supplied quality level should be named nominal or required quality level - Q_{os}^{req}. This Q_{os}^{req} quality level could be named reference quality level for iQoS evaluations. When SLA is constructed, required quality level Q_{os}^{req} should be given as well as methods and algorithms for quality level calculation. For example, when voice is coded with AMR-n codec, quality of each codec differs [11]. Under real conditions perceived service level is equal or less than Q_{os}^{req}. The purpose of research is to find a set of quality degradation levels. ITU describes voice quality degradation levels in Opinion scale for Degradation Category Rating: inaudible, audible but not annoying, slightly annoying, annoying, very annoying. Non-stationary mobile communication conditions imply new category – bad voice quality – when parts of words or whole words are erased.

In order to specify quality levels, it is necessary to consider many factors: what quality impairments users will notice, if it is possible to evaluate these impairments precisely.

In order to solve some of the above mentioned problems revision of some well-established concepts should be performed. For example, according to ITU recommendations for subjective voice quality testing speech samples must be longer then 2 seconds. It is not obvious that such a long time interval is valid for iQoS measurements because average person can recognize intense impairment even when sample length is about 0.5s long.

Questions about compensation for unachieved quality level are even more complex.

Here we have mentioned only part of questions related to SLA and iQoS modules.

Conclusion and future Work

In this paper presented information shows that conditions of mobile communication are not the same for individual users. Sometimes these conditions become poor or even bad. From the point of view of individual user conditions of mobile communication should be considered non-stationary. After proofing that conditions of mobile communication differs greatly it is proposed to make the next step – to create individual quality of service modules and their deployment system. Relations between the service provider and the end-user should be based on SLA. Currently the idea about de facto perceived service quality is only concept. Deployment of this concept is far ahead. This paper tries to form technological aspects of de facto perceived service quality evaluation. List of near future tasks for iQoS development is formulated. After implementation of iQoS modules that computes perceived service quality, actually given discount can be small or negligible in average over all network. Operators of well developed networks will not have substantial loss of income. Moreover, the proposed scheme does not try to improve QoS in mobile networks but to increase the level of the end-user satisfaction about QoS. However iQoS subsystem will increase user confidence in SP.

This paper mostly considers mobile telecommunication systems. It is relatively easy to justify that similar methods of quality evaluation are necessary in VoiP and analogous systems.

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Atlikus skelbtų darbų apžvalgą ir pasitelkiant matavimų duomenis, parodoma, kad mobiliojo ryšio sąlygos ne visiems vartotojams yra vienodai geros. Kai kuriems jos būna net blogos. Todėl žvelgiant iš individualaus vartotojo pozicijų, mobiliojo ryšio sąlygas galima imituoti pritaikius atsitiktinių nestacionariųjų procesų modelius. Įrodžius, kad mobiliojo ryšio sąlygos tikrai nėra ir negali būti vienodos, siūloma sukurti individualios kokybės vertinimo modulius bei jų įdiegimo sistemą ir SLA pagrindu sureguliuoti SP ir vartotojo santykius, įskaitant kompensacijas už blogą kokybę. Šiuo metu faktiškai gautos paslaugos individuali kokybė yra tik tam tikra koncepcija. Iki jos įgyvendinimo dar toli. Darbe pradėti formuoti technologiniai de facto suteiktos paslaugos kokybės vertinimo pagrindai. Aptariami galimi iQoS modulių sudarymo būdai, jų išdėstymas tinkluose, pradinės informacijos, reikalingos kokybei vertinti, gavimo būdai. Suformuluotas tam tikras su iQoS įgyvendinimu susijusių uždavinių sąrašas ir aptariami jų sprendimo būdai. Il. 7, bibl. 11 (anglų kalba; santraukos lietuvių, anglų ir rusų k.).

A. Kajackas, A. Anskaitis, D. Guršnys. Individual Quality of Service concept in Next Generations Telecommunications networks // Electronics and Electrical Engineering. – Kaunas: Technologija, 2005. – No. 4(60). – P. 11–16.

After the review of published articles and with the help of measurement data this paper shows that mobile communication conditions are not equal for different users. For some of them it can be even bad. From the point of view of individual user communication conditions can be modelled with the help of non-stationary random processes. After proof that mobile telecommunication conditions can not be equal it is proposed to develop individual quality evaluation modules and their deployment system. Relations between SP and the end-user should be based on SLA. This regulation includes compensations for unachieved level of quality. Currently conception of de facto perceived quality level is only hypothesis. This conception is far from deployment. This work tries to form technological methods for evaluation of de facto perceived quality. Presented work discusses means for iQoS modules construction and their placement in network infrastructure. Methods of initial information for quality evaluation gathering are reviewed, too. This paper forms a list of problems which should be solved in order to deploy iQoS concept. Also there are given some solution methods of these problems. Ill. 7, bibl. 11 (in English, summaries in Lithuanian, English, Russian).

А. Каяцкас, А. Анскайтис, Д. Гуршнис. Принципы индивидуального качества услуг в телекоммуникационных сетях нового поколения // Электроника и электротехника. – Каунас: Технология, 2005. – № 4(60). – С. 11–16.

На основе анализа опубликованных работ и проведенных измерений показано, что условия мобильной связи не для всех пользователей достаточно качественны. Для некоторых эти условия бывают просто плохими. Поэтому с точки зрения пользователя, условия мобильной связи можно имитировать создавая модели на базе нестационарных случайных процессов. Для учета реальных условий мобильной связи, предлагается создавать и внедрять модули индивидуальной оценки качества (iQoS). Такие модули совместно с договором по качеству представляют техническую основу по нормальному урегулированию отношений (учитывая и компенсации за плохое качество) между поставщиком услуг и пользователем. Индивидуальная оценка качества фактически полученной услуги в настоящее время является новой концепцией. Эта концепция пока не реализована. В данной работе формулируются технические основы оценки качества фактически полученного качества услуг. Рассматриваются варианты модулей iQoS, их размещение в сети, возможности получения начальной информации. Сформулирован список задач, решение которых необходимо в процессе разработки модулей iQoS. Ил. 7, библ. 11 (на английском языке; рефераты на литовском, английском и русском яз.).