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Quality of Heterogeneous Mobile Data Services: Capabilities and End-user Achievements

V. Batkauskas, A. Kajackas
Department of Telecommunication Engineering, Vilnius Gediminas Technical University, Naugarduko str. 41, LT-03227, Vilnius, Lithuania; e-mails: vaidasbatkauskas@delfi.lt, algimantas.kajackas@el.vgtu.lt

Introduction

Modern telecommunication systems are commonly used and they provide a lot of e-services to end-users. That stimulates development of new services and more powerful communication systems. The growing number of information sources and end-users requires higher capacity of last-mile data access systems as well as higher capacity of connections to the Internet. For higher comfortability of end-users wireless last-mile links are used more and more often.

Modern communication networks in terms of access network technologies are heterogeneous. Different high coverage technologies could be found at the same place: GPRS, EDGE, UMTS, HSPA and WiMax. In some high density areas of end-users additional WLAN hot-spots are also implemented. These access networks functions simultaneously, offering high efficiency for both high and low data rates, as well as for high and low traffic density configurations.

In order to receive e-services using any of these access networks end-users should use Multimode User Terminals. Usually mobile operators take care of Multimode User Terminals and they support all implemented technologies in the network: GSM, GPRS, EDGE, WCDMA and HSPA. Terminals, used for accessing WLAN (IEEE802.11), are usually implemented in laptops of end-users. WiMax (IEEE802.16) terminals are usually separate devices provided to the end-user by the provider of WiMax service. Multimode User terminals can choose any available wireless network for any communication session. They support intelligent techniques for switching between various available radio technologies at the particular moment.

Different technology networks together with Multimode User terminals offer variety of e-services to the end-user. Additionally they expand functionality of systems and the covered territory as well as increase overall reliability of the system.

The quality of the mobile data channel is characterised like of any other IP channel taking into account capacity, throughput, packet loss and delay. When presenting the technology to end-users the most commonly used network characteristic is the maximum data throughput.

Throughput is the average rate of successful message delivery through a communication channel. Throughput is usually measured in bits per second (b/s). The maximum theoretical throughput is closely related to the channel capacity. It is the maximum possible quantity of data that can be transmitted under ideal circumstances. In some cases the metrics, related to the end-user are used – user data throughput, user-perceived throughput and application-perceived throughput.

The goal of this paper is to investigate possibilities of end-users to receive service quality, defined by the network operator. Then using the received data throughput metrics, it is also important to analyse dependency of the achieved quality of mobile data services by the end-user upon the expected influencing factors. Investigation of a mobile system is a continuation of previous investigations [1], expanding them into the data transmission area.

Model of the radio access network for the end-user

Modern devices of end-users simultaneously support several mobile data technologies: GPRS, EDGE, UMTS and HSPA. Historically the GPRS technology was introduced in whole network territory as only upgrade of the software was necessary for GSM base stations. The EDGE technology also covers the territory that can be compared with the territory of the GPRS network. However UMTS and HSPA are only city/town technologies. UMTS is used for continuous 3G coverage in the city while HSPA is usually used for expansion of capacity in high traffic areas. That happens because of two main reasons. For implementation of 3G the rollout of hardware of new base stations was needed. It was very expensive to implement the new HW in all existing urban and rural sites. The second reason for lower 3G coverage is the used frequency that is more than two times higher (2,1GHz). It reduces the cell radius to 2 – 4 km while the radius of 2G cells (900MHz) is usually about 7 – 10 km if compared in the rural area.

The Communications Regulatory Authority of Lithuania announces the number of 2G and 3G base stations as well as coverage of each technology in the country. The GPRS coverage is about 99%, the EDGE coverage is near to 80% while UMTS/HSPA covers only about 14% of the territory of the country. However, UMTS/HSPA has coverage of up to 75% of population because its coverage is concentrated in cities and towns.

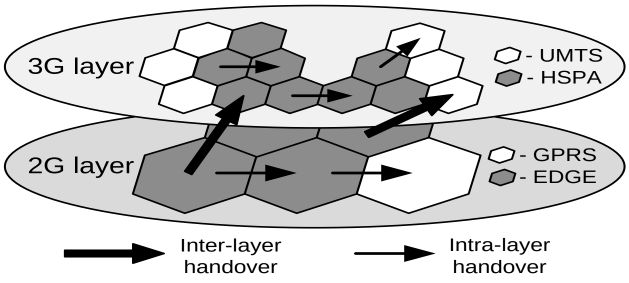

Fig. 1. Overlapping mobile data access networks

Technology specification – declared possibilities

Quality of data services, provided by different mobile data technologies, vary a lot. The research is oriented toward throughput of downlink data channels. Because of usage behaviour of end-users the downlink is more heavily used and downlink data channels are overloaded first.

In Table 1 the comparison of theoretical throughput and data throughput, achieved by the end-user, is presented. Theoretical data throughput is often used when describing, presenting or advertising a particular mobile data transmission technology. Data throughput achieved by the end-user was measured using commercial services provided by several mobile operators. In order to minimise degradation factors of data throughput, the maximum throughput was measured for more than two weeks monitoring two mobile data service providers. Measurements were performed using transmission of data packets using FTP. That was done under very good radio conditions (the received signal level was more than -70 dBm, the signal to interference ratio – from -7 dB to -5 dB) and avoiding recourse sharing among several simultaneous users in the cell.

Table 1. Theoretical downlink (DL) throughput and DL data throughput achieved by the end-user

Technology	Theoretical DL throughput, Mb/s	Achieved by the end-user DL throughput, Mb/s	Difference in percents
GPRS	0,17	0,08	47
EDGE	0,51	0,21	41
UMTS	2,0	0,32	16
HSPA 3,6	3,6	2,7	75
HSPA 7,2	7,2	5,2	72
HSPA 14,4	14,4	7,6	53

In different papers [2 - 5] lots of similar measurement results could be found. Throughputs, achieved by the end-user vary depending on measurement conditions.

The maximum theoretical data throughput includes all overheads of IP and upper layers and is calculated per radio transmitter of a base station (usually per one cell). In GPRS, EDGE and UMTS, throughput, achieved by the end-user, is hardly limited by capabilities of the end-user terminal. Therefore users are not able to achieve the maximum cell throughput. In HSPA modern end-user terminals have the same maximum capabilities as the cell. However, the maximum cell throughput is not achieved in the usual environment of end-users with real radio conditions. Higher throughput technologies use higher level modulations (16QAM) and coding of less protection that are not highly resistant to real interference in the usual environment of the end-user.

Factors influencing throughput perceived by the user

Data throughput in the GPRS/EDGE system depends on the number of Time Slots (TS) assigned to a particular user (the maximum for one end-user is four) and the coding scheme used for transmission of data in the TS. The number of assigned TS depends on the cell capacity and the number of users requiring resources of data and voice transmission. If the amount of voice users does not exceed the number of TS, dedicated to voice, the number of TS, assigned to one data user (N_T), can be estimated this way:

$$N_T = \frac{C_R + C_{SW}}{N_D}. \quad (1)$$

That is valid, if $N_{CS} \le C_{CS}$. Here: C_R – the amount of reserved packed data TS, C_{SW} – the amount of switchable TS, N_D – the number of data users, N_{CS} – the number of voice users, C_{CS} – the number of TS for voice users.

One of four in GPRS or one of nine in EDGE coding schemes could be used for transmission of data packed. Coding scheme depend on the received signal level, signal to interference ratio and bit error rate of previously received packets [2, 6].

In the UMTS cell, the number of Dedicated Traffic Channels (DTCH), which could be assigned to real time services, could be calculated using soft traffic capacity C of the cell

$$C = 1 + \frac{W/R}{E/I} \cdot \frac{\varphi_v \cdot \varphi_a}{1+f}, \quad (2)$$

here W – bandwidth of the system (5 MHz for UTRAN); R – data rate of the end-user; E/I – bit energy to interference ratio; φ_v and φ_a – voice/data activity gain and antenna gain respectively; f – the interference factor of the external cell (typically 0,6 – it depends on the load of neighbouring cells at a particular moment as well as on overlapping of cells that occurs due to imperfect cell planning).

UMTS Rel99 packet services are supported through dedicated radio channels. That limits the maximum number of users, that can be served simultaneously, especially at 384 kb/s (maximum 4 or 5 users). In addition, considering high burstiness of many Internet applications, the dedicated radio channels are often underutilized.

In release R7 HSPA the number of simultaneous HSPA users could be up to 32 or more depending on precision and speed of the scheduler. The amount of cell resources assigned to the end-user depends on the amount of data that the end-user would like to transmit.

Adaptive Modulation and Coding is a fundamental feature of HSPA. In good radio conditions more aggressive coding schemes and modulation of QAM16 are used. That results in high throughput of the channel. In worse radio conditions degradation of throughput is conditioned by usage of more data protection coding schemes and QPSK modulation [7].

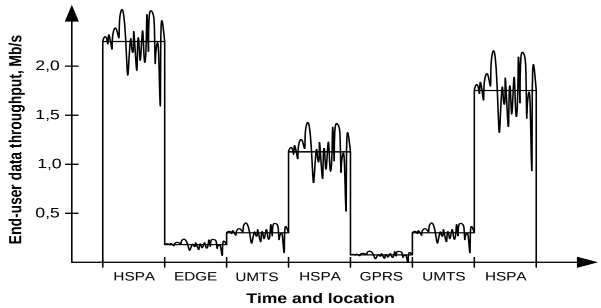

Fig. 2. Dependency of data throughput of the end-user on the technology of data transmission, time and location

Finally, the QoS, received by the end-user depends:

- on the serving technology. UMTS, HSPA, WiMax and WLAN usually have higher capacity but lower coverage area if compared to GPRS or EDGE;
- on the position of the user in the covered territory. It could be described by the distance to the base station and physical radio conditions (strength and fluctuation of the radio signal, signal to noise ratio and etc.);
- on the number of concurrent end-users in the cell (the radio segment of the wireless network). All cell recourses will be divided to all end-users, concurrently accessing the network recourses in that cell. The scheduler of cell recourses, that takes in to account QoS of the end-user, could be implemented.

All these factors influence QoS of the end-user, that could be unstable (fig. 2.) and sometimes even unacceptable.

Measurements of QoS received by the end-user

In order to investigate the received data throughput of an individual end-user, downlink transmission of data files using Ericsson TEMS equipment was performed. Several cells in the suburban area were analysed measuring dependency of throughput received by the end-user on the user location (drive tests) and on the time in the fixed position.

Measurement results presented in figures 3 and 4, were summarised taking into consideration the distance between the measurement point and the base station.

The average data throughput of the end-user in the cell coverage area (Fig. 3.) is about 1Mb/s. However end-users, located more than 2,3 km from the base station, obtain unstable data throughput, that often drops below an acceptable level (sometimes it drops to the zero).

Depending on the relief of the territory more than 2.3 km away from the base station the signal level, received by the end-user, (Fig. 4) drops below -90 dBm and the signal to interference ratio drops below -11 dB. In such low signal and relatively high interference areas a neighbouring cell should be selected. However due to lower coverage area of the HSPA cell only the radio signal of the EDGE cell is at the acceptable level. In this situation the multi-mode terminal of the end-user initiate selection of a different radio technology.

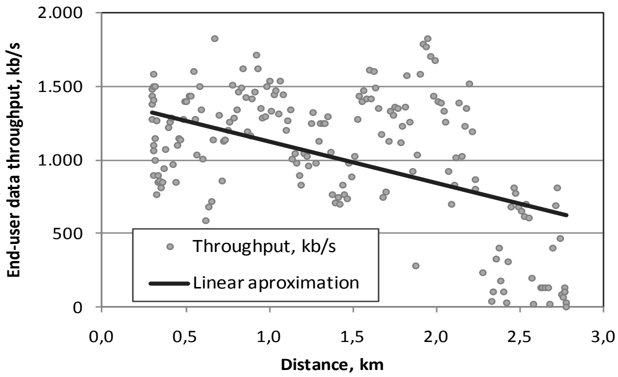

Fig. 3. Dependency of the data throughput, received by the end-user on the distance to the base station

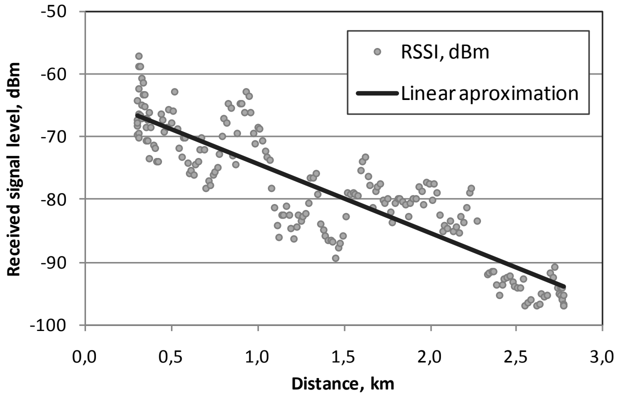

Fig. 4. Dependency of the received signal level (RSSI) on the distance to the base station

In the fixed position (signal level about -70 dBm) downlink data throughput, received by the end-user, depends on the number of simultaneous users sharing recourses of the same cell.

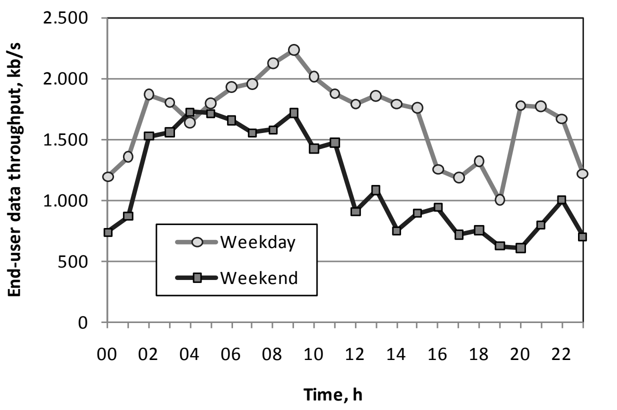

Fig. 5. Dependency of the data throughput, achieved by the end-user, on time in the fixed position

The end-user achieves the highest data throughput at night and in the morning, because the load of the mobile network and the number of active simultaneous users is the lowest then. The lowest data throughput is during the usage peak. The peak distribution differs during the week.

Conclusions

Estimation of the quality of services for cellular data networks is a multidimensional process, that requires special attention when designing the test. Because of many different technologies functioning in the same mobile data network the real throughput, achieved by the end-user, can vary in wide range and it depends on many factors.

The measurements have indicated major differences in QoS delivered to the same end-user in different locations or in the same location during the time. It was proved theoretically and practically that the downlink throughput, achieved by the end-user, depends on the user location in the coverage area.

Different data services have different requirements for QoS of the data channel. The measurement results have indicated that in some places the quality for some services like video streaming or online gaming can be unacceptable.

The growing number of end-users, information sources, e-services and service delivery channels requires verification of service quality delivered to the end-user.

The existing flat-rate price of the service is not dependant on the quality of services received by the end-user. Introduction of differentiation system of price of data services can be based on the number of situations when the end-user requests, but does not receive a specific service (or the received service quality is unacceptable). The acceptance criteria of the service quality should be predefined.

Due to the fact that service quality is not stable, the end-user should have a possibility to choose to receive or not to receive a service of a particular quality at the selected price. This functionality should be implemented in devices of the end-users.

Acknowledgement

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Then analyzing quality characteristics of different segments of the telecommunication network it was noticed that bandwidth, delay of packets and reliability of the last-mile of the end-users are worse and less stable than in the core network of the system. It means that the bottleneck of QoS of end-users is in the radio access of the last-mile therefore different users receive different QoS. The goal of this paper is to investigate possibilities of end-users to receive service quality, defined by the network operator. It is also important to analyze dependency of the received data throughput of the end-user on the distance to the base station and time in the fixed position. It was proved theoretically and practically that the downlink throughput, achieved by the end-user depends very much on the location of the user in the coverage area and time. Ill. 5, bibl. 7, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

В. Баткаускас, А. Каяцкас. Качество гетерогенных услуг передачи данных мобильной связи: возможности и реальность пользователя // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – С. 43–46.

Анализ качественных характеристик передачи данных мобильной связи показал, что пропускная способность, задержка пакетов, надежность связи и качество услуг в целом для разных пользователей различна. Цель данной работы – обратить внимание на существующую проблему, пояснить причины и представить примеры того, в каких пределах может меняться качество услуги передачи данных по мобильной связи. Показано, что реальная скорость передачи данных зависит от места нахождения пользователя в зоне действия сети, от нагрузки и времени суток. Ил. 5, библ. 7, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

V. Batkauskas, A. Kajackas. Heterogeninių mobilių duomenų paslaugų kokybė: galimybės ir vartotojo patirtis // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 43–46.

Analizuojant mobiliojo ryšio tinklų kokybės charakteristikas pastebėta, kad vartotojo linijos pralaidumas ir bendras patikimumas nėra vienodi ir keičiasi priklausomai nuo vartotojo buvimo vietos ir laiko. Vartotojams realiai teikiamos skirtingos kokybės paslaugos. Šio darbo tikslas – atkreipti dėmesį į esamą problemą, atskleisti jos priežastis ir pateikti pavyzdžių, kaip kinta galutiniam vartotojui teikiamų paslaugų kokybė. Parodyta, kad galutinio vartotojo pasiekiama duomenų perdavimo sparta priklauso nuo vartotojo vietos bazinės stoties aprėpties zonoje, nuo tinklo apkrovos ir nuo laiko. Il. 5, bibl. 7, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).