Paper

Quality Management in 4G Wireless Networking Technology Allows to Attend High-Quality Users

Małgorzata Langer

Institute of Electronics, Lodz University of Technology, Lodz, Poland

Abstract—The 4G networks are all-IP based heterogeneous networks that allow users to use any system at anytime and anywhere, and support a variety of personalized, multimedia applications such as multimedia conferencing, video phones, video/movie-on-demand, education-on-demand, streaming media, multimedia messaging, etc. Personalized services should be supported by personal mobility capability, which concentrates on the movement of users instead of users' terminals. As the technology matures, traffic congestion increases, and competitive pressures mount, QoS and policy management will become more and more important. Also the users come with a number of new requirements on connectivity, and D2D networking technology must follow the idea of "Internet of things". Operators must make sure they are working with vendors that have a strong framework to supply end-to-end QoS and are capable of supporting evolving needs. The paper discusses qualitative and quantitative indicators of telecommunication services. Main challenges that need to be addressed by nowadays and future systems are shown, and within them the massive growth in traffic volume and in the number of connected devices seems to play the most key role.

Keywords—4G, device-to-device communication, LTE, policy management, QoS.

1. Introduction

With the introduction of the first generation (1G) mobile communication systems in the year 1980, "ordinary" people were able to communicate with others with voice while being on the move. Then with the second generation (2G) mobile communication systems, as CDMA (Code Division Multiple Access), GSM (Global Systems for Mobile Communications) in the early 90's, people were able to communicate not only with voice but also with text messaging. With the introduction of the third generation (3G) mobile communication systems, i.e., WCDMA (Wide-band Code Division Multiple Access), also known as UMTS, in the late 90's, people were able to communicate with more data-centric services and applications. 3G networks are based on wireless technology, which wins over its predecessors because of high speed transmission, advanced multimedia access and global roaming. This technology allows connecting the phone to the Internet, or other IP networks, to make a voice or video call or to transmit data. Although multimedia communication is possible with 3G systems, scalability and cost have been problems preventing wide deployment thus far. The 4G networks, i.e., LTE and WiMAX [1] support a variety of personalized, multimedia applications such as multimedia conferencing, video phones, video/movie-on-demand, education-on-demand, streaming media, multimedia messaging, etc. Personalized services should be supported by personal mobility capability, which concentrates on the movement of users instead of users' terminals (one will start watching a film on the 3" screen of his/her mobile, will continue from the exact point on 15" laptop screen and then will move to home TV set screen to see the final scenes), and which involves the provision of personal communications and personalized operating environments. D2D (Device-To-Device) communication forces to use LTE radio access not only for the access (network to terminal) link but also as a solution for wireless backhauling. The heterogeneous deployments of low power network nodes under the coverage of on overlaid layer of macro nodes will meet the idea of communicating machines in next several years.

In the 80's, five functional areas were identified, namely Fault management, Configuration management, Accounting management, Performance management, and Security management (FCAPS). These five functional areas were sufficient to cover most, if not all, of the issues related to the operations and management of the wired networks including the Internet and enterprise networks. With the introduction of wireless and mobile networks several additional areas, which could not be easily covered by FCAPS, had to be added. They are Mobility management, Customer management, and Terminal management.

The quality issues have stopped to be described as "best effort" only (though still it is "best effort" for low data rate in Internet). Supporting multimedia applications with different Quality of Service (QoS) requirements in the presence of diversified wireless access technologies (e.g., 3G cellular, IEEE 802.11 WLAN, Bluetooth) is one of the most challenging issues for fourth-generation (4G) wireless networks. In such network, depending on the bandwidth, mobility, and application requirements, users should be able to switch among the different access technologies in a seamless manner. Efficient radio resource management and CAC (Call Admission Control) strategies are key components in such a heterogeneous wireless system supporting multiple types of applications with different QoS requirements. 4G is a packet-based network. Since it should carry voice as well as Internet traffic it should be able to provide different level of QoS. Other network level issues include Mobility Management, Congestion control, and QoS Guarantees. 4G systems are expected to provide real-time services – so, e.g., pre-computed delay bound is required for the service.

2. Migration of Technology – Differences between 3G and 4G

Up to the 3G technology (UMTS) the transmission has been (and is) realized in time domain. The main difference in 4G technology is frequency domain for transmitting. Orthogonal Frequency Division Multiplexing (OFDM) is a combination of TDMA (Time Division Multiplexing Access) and FDMA (Frequency Division Multiplexing Access) and has been known since the 50–60's from military. Analog processing made it extremely expensive. In 80's its complexity reduced due to digital signal processing. It was already a technology proposal for UMTS, but only recently some challenges for mobile communication, particularly for uplink synchronization have been solved. The OFDM becomes today's dominating communication technology and WiMAX, LTE, Flash OFDMA are using it now. The main benefits are:

- high spectral efficiency with simple receiver design,
- bandwidth divided into many narrow tones – in theory fully orthogonal one to each other,

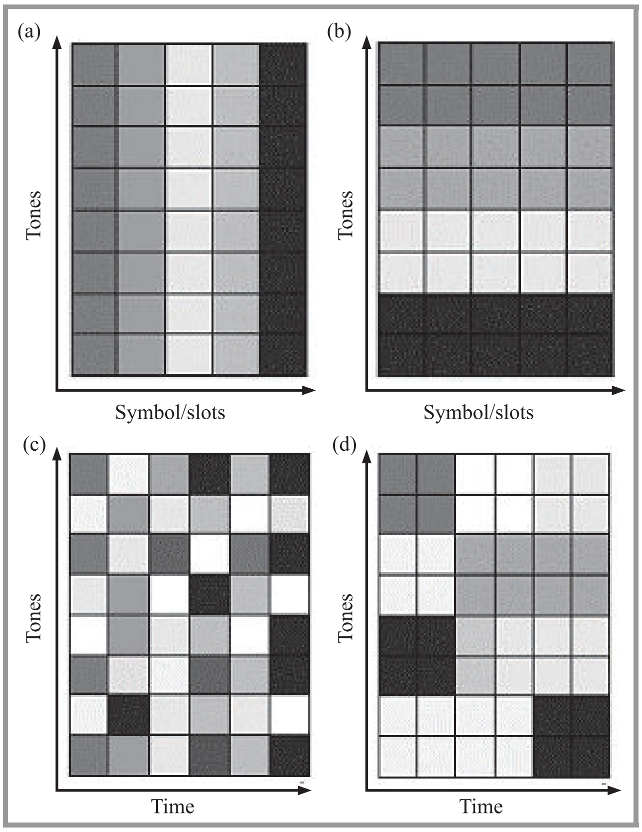

Fig. 1. Multiple access – resource allocation: (a) pure TDMA, (b) pure FDMA, (c) distributed OFDMA, (d) localized OFDMA.

- high-rate data distributed onto many low-rate channels,
- flexible bandwidth allocation.

Figure 1 shows the example of resource allocation in TDMA, FDMA and two types of OFDM: the distributed OFDMA (as in WiMAX), and the localized OFDMA (as in LTE). It helps in better understanding the issue of the technology basics. The deep technical description of them is not the task of this paper, and these considerations would be beyond its scope.

3. Key Services and QoS

The present and future mobile-communication systems differ and will differ with time and with country. They need to be adaptive to the changing service environment. The upper limit of the data rate demand and the lower limit of the delay requirement are difficult to provide in a cost-efficient manner. The services should be provided with the highest data rate, the lowest delay and the lowest jitter that the system can provide. This is unattainable in practice and contradictory to the operator goal of an efficient system – the more delay a service can handle the more efficient the system can be. There are several key services that span the technology space. Those are:

- **Voice**: The end-to-end delay requirement for circuit – switched voice is approximately 400 ms and it is not disturbing humans in voice communication. The sufficient today quality, as the end-to-end delay is not noticeable in older implemented technologies, slows the development of voice service in 4G.

  Voice packets in 4G should require small amounts of data, frequently, with no delay jitter. The problem is that IMS (IP Multimedia Subsystem) has not been developed as fast as it was expected and voice applications stay in the circuit switched domain, still.

- **Real-time applications** (games, mainly): Experts say that players look for game servers with a ping time of less than 50 ms [2]. So these applications require small amounts of data, as game update information, but with a low delay, a limited delay jitter and relatively frequent.

- **Interactive file applications** (download and upload): They require high data rates and low delays.

- **Background file download and upload**: The example is e-mail. This service accepts lower bit rates and longer delays.

- **Television**: This is the streaming downlink to many users at the same time requiring moderate data rates (higher with HD). The very low delay jitter, though delays may be tolerated (but approximately the same delay for all users in the neighborhood.

Table 1
Selected indicators and assessed parameters of telecommunications services

Service	Indicator	Parameters
Audio	Availability	Rate of server accessibility; listening break-up ratio; listening break-up frequency; successful one minute listening ratio
	Fidelity/ accuracy	Audio quality
	Speed	Access time; starting delay
	Capability	Throughput achieved
	Reliability	Rate of overall technical reliability; levels of customers complaints
	Flexibility	Provider capacity to adjust to the user connection and equipment features
	Usability	User friendless of the interface
	Security	Protection against user identity theft; protection against intrusion and breach of customer's privacy
Directory enquiry services	Availability	Rate of accessability to the service; outage frequency; served call rate
	Fidelity/ accuracy	Rate of correctness in answering the customer questions
	Speed	Response time for directory enquiry services; replay time
	Capability	Adequacy of the number of operators to the number of call
	Flexibility	Range of availability means to access the service
	Usability	User friendless of the interface; ability of the operator to cope with the caller language
	Security	Compliance to the customer security specifications as given in the contract, in particular: protection of the customer's private data or related to the person concerned by the enquiry
E-mail	Availability	Rate of SMTP failures; rate of POP3 failures; outages rate; outages frequency; rate of message loss
	Fidelity/ accuracy	Rate of undue deletions of email by the security mechanisms
	Speed	Average time to check an empty mailbox; average delivery time
	Capability	Server throughput; speed to upload to mail server; speed of download from mail server
	Reliability	Rate of overall technical reliability; level of customers complaints
	Flexibility	Ease to change the contractual specifications
	Usability	User friendless if the interface
	Security	Protection against intrusion, spam and any king of viruses
Fax	Availability	Refers to availability of connection
	Fidelity/ accuracy	Transmission fidelity test
	Reliability	Ratio of sent and received fax; rate of overall technical reliability; level of customer complaints
	Security	Protection against identity, theft and content violation
Internet access	Availability for Internet access	Successful login ratio; outage rate, outage frequency; rate of successful authentication; rate of successful access to generic name translation
	Availability for web of browsing	Outage rate to a set of designed sites; availability of web pages hosted by ISP; frequency of untimely breakup; rate accessibility to the input ports, rate of accessibility to the output ports
	Availability for web page hosting	Rate of accessibility to the allocated space
	Fidelity/ accuracy for web browsing	Error rate in data transmissions
	Speed for Internet access	Delay; radio channel access delay; authentication time; generic domain name translation time
	Speed for web browsing	Web response time
	Speed for web page hosting	Time to upload a test web page
	Capability for Internet access	Throughput achieved; throughput of dialup access to the Internet
	Capability for web Browsing	Occupation rate of ISP links, occupation rate of ISP input ports
	Reliability for the overall service	Rate of overall technical reliability; level of customer complaints; fault report rate per fixed access lines
	Flexibility for the overall service	Ease to change the contractual specifications
	Usability for easier the overall service	User friendless of the interface; adaptability to make use to people with disabilities
	Security for the overall service	Protection against user identity theft, intrusion and breach of customer's privacy
Multimedia Message Service (MMS)	Availability	Successful MMS Ratio
	Fidelity/ accuracy	Completion Rate for MMS
	Speed	End to end delivery time
	Reliability	Rate of overall technical reliability; level of customer complaints
	Flexibility	Ease to change the contractual specification; range of available means to send and receive MMS
	Usability	User Friendless of the interface
	Security	Protection against intrusion, spam and any kind of viruses
Operator services	Availability	Rate of accessibility to the service; outage frequency; served call rate
	Fidelity/ accuracy	Rate of correctness in fulfilling the customer request
	Speed	Response time for operator services; call setup time
	Capability	Adequacy of the number of operators to the number of call
	Reliability	Rate of overall technical reliability; level of customer complaints
	Flexibility	Range of available means to access the service
	Usability	User friendless of the interface; ability of the operator to cope with the caller language
	Security	Protection of the customer's private data
Short Message Service (SMS)	Availability	Successful SMS Ratio
	Fidelity/ accuracy	Completion rate for SMS
	Speed	End to end delivery time for SMS
	Reliability	Rate of overall technical reliability; level of customer complaints
	Flexibility	Range of available means to send and receive SMS
	Usability	User friendless of the interface
	Security	Protection against intrusion, spam and any kind of viruses
Telephony	Availability	Unsuccessful call ratio; dropped call ratio; retain ability rate; outage rate
	Fidelity/ accuracy	Audio quality, video quality
	Speed	Access time, starting time
	Capability	Throughput achieved
	Reliability	Rate of overall technical reliability; level of customer complaints
	Flexibility	Ease to change the contractual specifications
	Usability	User friendliness of the interface, adaptability to make use easier to disable people
	Security	Protection against user identity theft, fraudulent
Video broadcast	Availability	Rate of server accessibility; display breakup ratio; display breakup frequency; successful one minute watching ratio
	Fidelity/ accuracy	Audio quality; video quality
	Speed	Access time; starting time
	Capability	Throughput achieved
	Reliability	Rate of overall technical reliability; level od customer complaints
	Flexibility	Ease to change the contractual specifications
	Usability	User friendliness of the interface
	Security	Protection against user identity theft
Voice mail	Availability	Rate of success ful access to the recording server; rate of successful access to the message listening server; outage frequency of the message recording server; rate of message loss
	Fidelity/ accuracy	Rate of message spoiling failure of the information to the voice mailbox owner
	Speed	Response time of the voice guide after the reply time out; message recording server response time; time to receive the notification of a message record in the voice mailbox; listening message server response time
	Reliability	Rate of overall technical reliability; level of customer complaints
	Flexibility	Ease to change the contractual specifications; range of available means to record and receive
	Usability	User friendliness of the interface
	Security	Protection against fraudulent message listening and change of the welcome recorded message

Policy management allows operators to control granularly the availability and QoE of different services. First, policies are used to dynamically allocate network resources – for example, a particular bandwidth can be reserved in the radio base station and core network to support a live video conversation. Next, policy rules control the priority, packet delay, and the acceptable loss of video packets in order for the network to treat the video call in a particular manner. The quality of service is characterized by the combined aspects of service support performance, service operability performance, service ability performance, service security performance and other factors specific to each service [3].

TL 9000 [4] is the first unified set of quality system requirements and metrics designed specifically for the telecommunications industry. TL 9000 encompasses the ISO 9001 standard, plus additional industry-specific telecom requirements and covers industry performance based measurements including reliability, delivery, and service quality. The TL 9000 management system is applied by telecom manufacturers and suppliers engaged in the design, development, production, delivery, installation and maintenance of telecommunications products and services.

Table 1 presents QoS indicators, gathered on the base of the ETSI Guide – Quality of Telecom Services [5]. The introduced set of parameters gives the review of technical, economical and functional issues those have to be considered and indicators those should be measured and tested objectively. Some technical measurements may not be directly perceptible by customers or can vary from a particular user feeling but still the indicator value or the feature affects the quality and assurance of service. The indicators presented in ETSI Guide can be divided into two parts. The first one is related with technical, functional aspect and the second one is related to other aspects such as: sales, repair, provision, charging, billing, upgrade, complaint management, commercial and technical support. Nowadays, there are several standards describing QoS measurements, for example [4], [6], [7]. Measurements of the parameters can be made using different methods: technical measurements performed by an independent organization or by the supplier, a survey performed among users, or a mixture of user's opinion and technical measurements. Some results are obtained in terms of degrees of satisfaction and not in technical terms. For example the condition of "Seamless mobility" is kept until a user doesn't notice that the hand-over happens.

Table 2 covers standardized QCIs (QoS Class Identifiers) for LTE, where GBR stands for Ground Based Radio here [8].

Guaranteed Bit Rates (GBRs) are not part of them since as traffic handling attributes cannot be preconfigured for a QoS class. They must therefore be dynamically signaled within the service, instead. A QCI is simply a "pointer" to a TFP (Traffic Forwarding Policy) and can be associated with a TFP defined within each user plane edge/node. Within a specific node multiple QCIs may be associated with the same TFP. Within up to the 4G technologies either "best effort" policy prevails or, in the 3G (i.e. UMTS) four traffic classes with defined QoS attributes may be pointed: conversational, streaming, interactive, background.

Table 2
Standardized QCI for LTE

QCI	Resource type	Priority	Packet delay budget [ms]	Packet error loss rate	Example services
1	GBR	2	100	10^{-2}	Conversational voice
2	GBR	4	150	10^{-3}	Conversational video (live streaming)
3	GBR	5	300	10^{-6}	Non-conversational video (buffered streaming)
4	GBR	3	50	10^{-3}	Real gaming
5	Non-GBR	1	100	10^{-6}	IMS signaling
6	Non-GBR	7	100	10^{-3}	Voice, video (live streaming), interactive gaming
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP-based (i.e. WWW, e-mail), chat, FTP, P2P file sharing, progressive video, etc.

Performance-enhancing features can improve perceived quality of service (end-user's point of view) or system performance (operator's point of view). Though LTE and its evolution can yield better data rates and shorter delay, so it can greatly improve as the service experience (for an end-user) as the system capacity (for an operator).

4. Network Architecture

In up to 3G technologies, i.e., for example in majority of today implemented cellular networks, based on circuit-switching, they consist of base stations, base station controllers, switching centers, gateways, and so on. The base station (BS) plays the role of physical transmission with fast power control and wireless scheduling. The base station controller (BSC) performs the largest part of the radio resource management. Whenever a mobile terminal (MT)

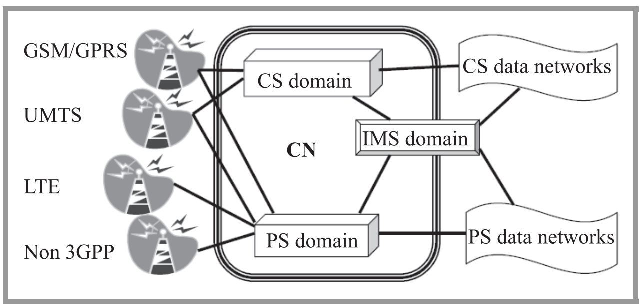

Fig. 2. Idea of coexisting technologies.

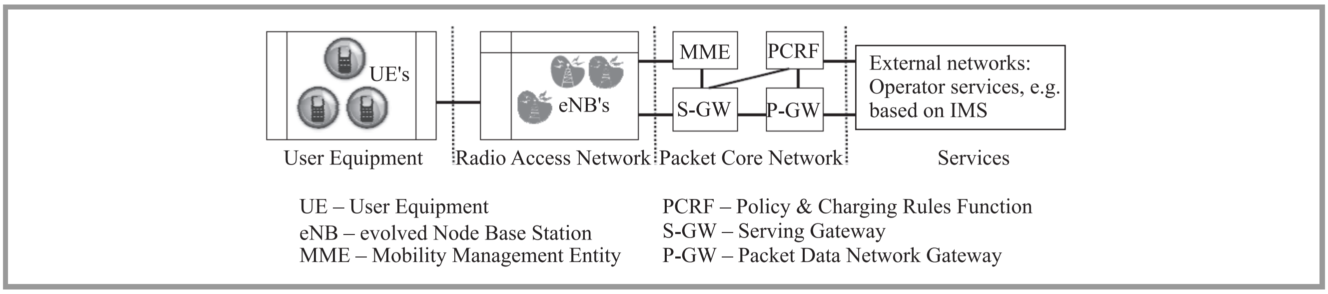

Fig. 3. LTE architecture – separated domains.

moves into another cell, it requires handoff to another base station. In 4G network the base station must function intelligently to perform radio resource management as well as physical transmission, more as a smart access router. Figure 2 introduces the idea of coexisting technologies. LTE is only connected to the packet core, while circuit core will not continued to be developed. 3GPP packet core can connect to non 3GPP technologies. IMS (IP Multimedia System) is (it should be) the integral part of the evolved packet core.

Figure 3 shows the overall LTE architecture, where one can see the clear separation and defined interfaces between different domains. In such a layout any evolution is independent of access, core, transport and services. The main principle of SAE (System Architecture Evolution) is that control and user's panels are separated one from the other (Fig. 4). Nevertheless it is only a "logical" architecture by now, though it assures the flexible deployment for various scenarios.

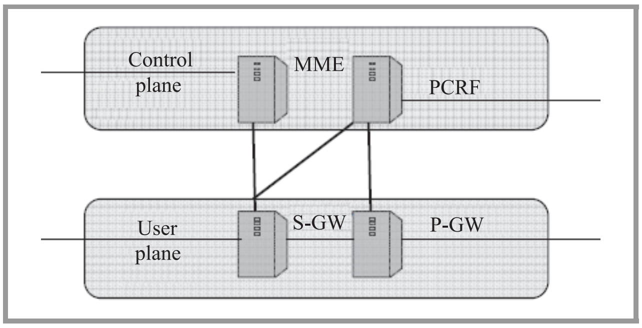

Fig. 4. Separation of control and user planes.

The separation of control and user planes gives the highly optimized implementation and scalability (number of users versus data traffic/services). The control plane covers MME, which is a powerful server and is placed at a secure location. It contains NAS (Non Access Stratum) protocol, covers such functions as security control, managing subscriber profile and service connectivity, packet core bearer control. The other server PCRF is a part of the operator's switching centre and deals with policy and charging control, with decisions on how to handle QoS in the network.

The bearer uniquely identifies packet flows that receive a common QoS treatment between the terminal and the gateway. Independent of a service type, a bearer is defined through the network to which it connects the UE (User Equipment), referred to as Access Point Name in 3GPP and the QoS Class Identifier (QCI). The bearer is the basic enabler for traffic separation, that is, it provides differential treatment for traffic with differing QoS requirements. So one UE can have several bearers at the same time, if a call is on, files are transferred, etc. The concept of the bearer and the associated signaling procedures further enable the system to reserve system resources before packet flows those are mapped to that bearer into the system. Data to be transmitted enters the processing chain in the form of IP packets on one of the SAE bearers.

Prior to transmission over the radio interface, incoming packets are passed through multiple protocol entities.

With regard to quality and quality management the most important protocol entities are:

- PDCP (Packet Data Convergence Protocol) – there is one PDCP entity per SAE bearer and it is responsible for ciphering and integrity protection of the transmitted data;
- RLC (Radio Link Control) – located in the eNodeB, which offers services to the PDCP in the form of RBs (Radio Bearers) – there is one RLC entity per radio bearer configured for a terminal; it is responsible for segmentation/concatenation, retransmission handling and in-sequence delivery to higher layers;
- MAC (Medium Access Control) – which handles scheduling (as uplink as downlink); the scheduling functionality is located in eNodeB, which has one MAC per cell;
- PHY (Physical Layer) – it offers services to the MAC layer in the form of transport channels; the PHY handles coding/decoding, modulation/demodulation, multi-antenna mapping and other typical physical layer functions; it offers services to the MAC layer in transport channels.

4.1. Logical Channels and Transport Channels

The logical channels' set (the MAC offers services to the RLC in the form of logical channels) covers control channels, used for transmitting control and configuration information necessary for LTE, and a traffic channel, used for the user data (Dedicated Traffic Channel – DTCH).

The MAC uses services in the form of transport channels, and a transport channel is defined by how and with what parameters the information is transmitted over the radio interface. Data in a transport channel is organized into transport blocks. Each transport block is related to a Transport Format (TF). The TF includes information about size, modulation scheme etc., but also the MAC layer can control different data rates by varying the transport format.

DL-SCH (Downlink Shared Channel) is the main transport channel used to transmit downlink data in LTE. It supports the dynamic rate adaptation, channel-dependent scheduling in time and frequency domains, hybrid ARQ (Automatic Repeat Request) with soft combining, controls mobile-terminal power consumption through DRX (discontinuous reception). The similar features relate to UL-SCH (Uplink Shared Channel).

4.2. Schedulling

The main principle of the LTE radio access is shared transmission, it means that the time – frequency resources are dynamically shared between users. The dynamic scheduler is a part of the MAC layer. It controls the assignment of uplink and downlink resources.

The scheduler takes advantage of the channel variations and schedules transmissions to a mobile terminal on resources with better channel conditions. But the decision is taken per mobile terminal and not per radio bearer (RB). So the terminal is the only one that handles logical-channel multiplexing and is responsible for the choice from which RB the data is taken. Each RB is assigned a priority and a prioritized data rate. Remaining resources, if any, are given to the radio bearers in priority order.

For the downlink the terminal transmits channel-status reports and for the uplink a sounding reference signal those make the base to take the proper decision. The scheduler also controls the inter-cell interference. The scheduling strategy is vendor specific and may vary for different cases.

5. Policy Management

In term of global connectivity, LTE solutions can deliver a data rate of at least 100 Mbit/s between any two points in the world, with smooth handoff across heterogeneous networks, so they result in seamless connectivity and global roaming across multiple networks. They provide a high quality of service for next-generation multimedia support including real-time audio, high-speed data, Internet protocol television (IPTV), video content and mobile TV. On top of that, carriers must provide for interoperability with existing wireless standards, and an all IP, packet switched network that can bridge the great difference of latency between networks. Quality of service provision in 4G networks present several challenges including: the specification of QoS requirements, the translation of QoS parameters among heterogeneous access networks, the renegotiation of QoS, and the management of QoS requirement within roaming agreements and mobile users profiles. Traditionally, the handover process has been considered among wireless networks using the same access technology (e.g., among cells of a cellular network). This kind of handover process is the horizontal handover (HHO). The new handover process among networks using various technologies is the vertical handover (VHO). The vertical handover in 4G networks and WiMAX networks has been developed to provide QoS routing, specification and management of QoS contracts, and handover control through the establishment of transparent procedure.

Policy management plays a fundamental role in implementing QoS in mobile broadband. It is the process of applying operator-defined rules for resource allocation and network usage. Dynamic policy management sets rules for allocating network resources, and includes policy enforcement processes. Policy enforcement involves service data flow detection and applies QoS rules to individual service data flows.

Manufacturers, vendors, mobile operators do not have unlimited resources and capital and the radio spectrum is finite. Three areas relate to the policy management:

- limiting network congestion,
- monetizing services,
- enhancing service quality.

Providing high service quality by over-provisioning network capacity would leave an operator at a competitive disadvantage to providers that offer the same or better quality service at a lower cost. Policy management starts with differentiating services and subscriber types, and controlling the QoE (Quality Of Experience) of each type.

6. Key Challenges for the Nearest Future

Company Ericsson estimates that the human-centric communication devices that are currently dominant will be surpassed tenfold by "communication machines" in the future [9] and predicts that overall traffic demands will increase in the order of a thousand times within the next 10 years. In addition to straightforward densification of a macro deployment, network densification can be achieved by the deployment of complementary low-power nodes under the coverage of an existing macro-node layer. In such a heterogeneous deployment, the low-power nodes provide very high traffic capacity and very high user throughput locally, for example in indoor and outdoor hotspot positions. Highly efficient macro base stations will ensure QoE over the entire coverage area and at the same time will have to serve as backhaul for more local access (so called: "dual connectivity"). Energy efficient load balancing, per link optimization, enhanced support for mobility are some examples of benefits in such a solution.

Complementing a cellular system with the option of Wi-Fi access can be used to further boost the overall traffic capacity and service level.

LTE is already capable of handling a wide range of D2D scenarios, though some revolutionary development is requested, i.e., mass, low cost D2D device types; allowing for very low device energy consumption; handling a very large number of devices per cell. Signaling for every connected device can result in a very high control-plane load. For that reason, lightweight signaling procedures are desired to reduce the signaling load per device that is caused to the network. A key feature of LTE D2D communication, including proximity detection, is its integration into the overall wireless access network. Whether communication occurs directly between devices or via the infrastructure should be transparent to the user, and the network should be involved and assist in the D2D communication.

7. Conclusions

The world is at the beginning of an era marked by tremendous growth in mobile data subscribers and mobile data traffic. Infonetics Research predicts that mobile data subscribers will grow from 548.9 million in 2010 to 1.8 billion in 2014 [10]. Today's mobile broadband networks carry multiple services that share access (radio) and core network resources. Each service has different QoS requirements in terms of packet delay tolerance, acceptable packet loss rates, and required minimum bit rates. Additionally one should consider two perspectives of performance: end user's one and operator's one. Given that system resources are limited, there will thus be a trade-off between a number of active users and the perceived quality of service in terms of user throughput. The 4G mobile systems focus on seamlessly integrating the existing wireless technologies including GSM, wireless LAN, and Bluetooth. The 4G networks are all-IP based heterogeneous networks that allow users to use any system at anytime and anywhere. Users carrying an integrated terminal can use a wide range of applications provided by multiple wireless networks. The 4G systems provide not only telecommunications services, but also data and multimedia services. The evolution of LTE is the most important step to ensure a high-quality wireless network for the future.

As the technology matures, traffic congestion increases, and competitive pressures mount, QoS and policy management will become more and more important. In preparation, operators must make sure they are working with vendors that have a strong framework to supply end-to-end QoS and are capable of supporting evolving needs.

A bearer has two or four QoS parameters, depending whether it is real-time or best effort service:

- QoS Class Indicator (QCI),
- Allocation and Retention Priority (ARP),
- Guaranteed Bit Rate (GBR)– real real-time services only,
- Maximum Bit Rate (MBR) – real-time services only.

Data applications are typically best effort services, characterized by variable bit rates, and are tolerant to some loss and latency before the user perceives poor quality.

The standards and recommendations provide mechanisms to drop or downgrade lower-priority bearers in situations where the network become congested.

The eNodeB is the radio base station in LTE and it plays a critical role in end-to-end QoS and policy enforcement. The eNodeB performs uplink and downlink rate policing, as well as RF radio resource scheduling. It uses ARP when allocating bearer resources. The effectiveness of radio resource scheduling algorithms in eNodeB's has a tremendous impact on service quality and overall network performance. Quality of Experience is a measure of the overall level of customer satisfaction with a service. Quantitatively measuring QoE requires an understanding of the Key Performance Indicators (KPI) that impact users' perception of quality. KPIs are unique by service type. Soon the radio base stations at the same time will have to serve as backhaul for dual connectivity. Each service type such as conversational video, voice, and internet browsing, have unique performance indicators that must be independently measured.

The evolved LTE architecture is able to provide QoS per user and per service, implementing the notion of a user profile associated with control element functions. An integrated management approach to service and network management in the case of heterogeneous and mobile network access is a key to quality management. LTE employs intelligent scheduling methods to optimize performance, from both end-user and operator standpoints of view.

Next steps on developing the technology should extent LTE (or LTE-A) to new use cases (machine type communications for D2D mainly), and probably to better possibilities for the close integration of LTE and Wi-Fi deployments.

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Małgorzata Langer graduated in Analogues and Digital Circuits of Automatics, at the Lodz University of Technology and got her Ph.D. degree in electronics. After several years in international marketing she joined the TUL in 1988, first in the Institute of Materials Science and then the Institute of Electronics (since 2004 as Associate Director on Science). She works as Associate Professor in Telecommunications Team and delivers lectures and laboratories for students of various courses in Polish and English. Her main science and research interests are in non-deterministic object simulation, telecommunications, QoS, some aspects of new nonconventional technologies in microelectronics, reliability, theory of experiments, etc. She is the author and the co-author of over 60 publications, also quoted, and has been involved in several international, home, and university research and didactics programs.

E-mail: Malgorzata.langer@p.lodz.pl
Institute of Electronics
Lodz University of Technology
Wolczanska st 223
90-924 Lodz, Poland