e-Health Applications

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ABSTRACT:

e-Health services comprise a broad range of healthcare services delivered by using information and communication technology. In order to support existing as well as emerging e-Health services over converged *next generation network (NGN)* architectures, there is a need for network *quality of service (QoS)* control mechanisms that meet the often stringent requirements of such services.

In this paper, we evaluate the QoS support for e - Health services in the context of the *Evolved Packet System (EPS),* specified by the *Third Generation Partnership Project (3GPP)* as a multi-access all-IP NGN. We classify heterogeneous e-Health services based on context and network QoS requirements and propose a mapping to existing 3GPP *QoS Class Identifiers (QCIs)* that serve as a basis for the class-based QoS concept of the EPS. The proposed mapping aims to provide network operators with guidelines for meeting heterogeneous e-Health service requirements. As an example, we present the QoS requirements for a prototype e-Health service supporting tele-consultation between a patient and a doctor and illustrate the use of the proposed mapping to QCIs in standardized QoS control procedures.

Keywords:

NGN, QoS mechanism, EPS, 3GPP , Tele-consultation

1. INTRODUCTION

With recent trends and technology advancement in the development of converged broadband next generation networks (NGNs) and advanced multimedia services, the potential has Increased for delivering various e-Health services to end users “anywhere, anytime”. The term e-Health has been used to refer to the use of information and communication technology (ICT) in delivering healthcare services [1]. A wide variety of e-Health services exist, including health information networks, electronic health record (EHR), telemedicine services, wearable and portable systems which communicate, health portals, and many other ICT based tools assisting disease prevention, diagnosis, treatment, health monitoring, and lifestyle management.

A related term is m-Health, referring to “mobile computing, medical sensor, and communications technologies for health care” [2]. M-Health services refer to e- Health services in mobile environments, characterized by limited resource availability and changing network conditions. In general, a wide variety of services may be built on top of tools and applications that provide the necessary communications and computer-aided support (for example, multimedia conferencing/streaming enablers, image analysis and visualization tools, immersive and collaborative virtual environments, etc.) as shown in (Figure 1)

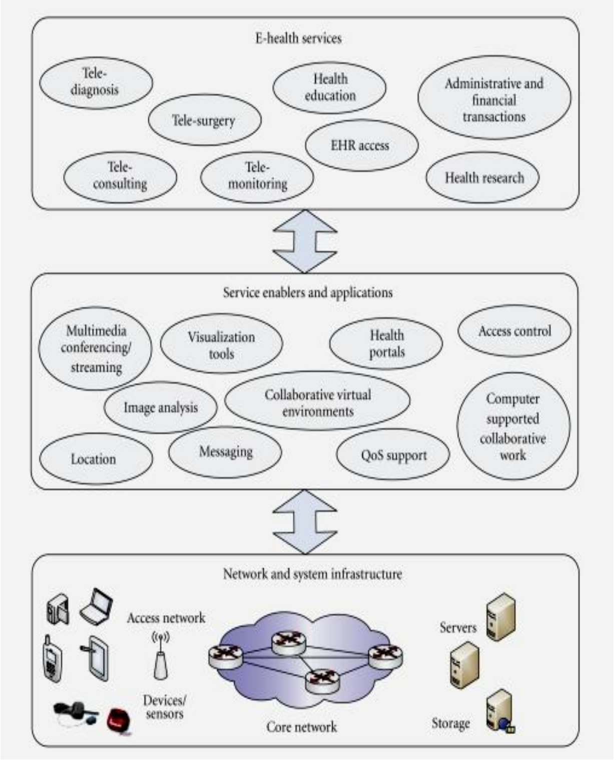


Figure 1:
Layered service environment for e-services (Source - journals/ijta/2010/628086/fig1/)

Converged NGNs are being designed to deliver different types of traffic across heterogeneous end environments. In order to meet the requirements of e-Health service traffic delivered over networks in conjunction with other commercial traffic (e.g., voice calls, streaming multimedia, and Internet traffic), QoS mechanisms such as class based traffic prioritization are necessary. The wide variety of e-Health services impose different Quality of Service (QoS) requirements on underlying networks. One aspect is delay tolerance, with service requirements ranging from strict real and delay-intolerant data transmission (e.g., tele-consultation services involving transmission of patient physiological parameters in emergency situations) to delay-tolerant services (e.g., access to a patient's EHR; home tele-monitoring). Another aspect is application data elaborative e-Health end-user, class based real-time, sensitivity to loss, with conversational voice-based applications often tolerating a certain packet loss, while data transmission (e.g., transfer of medical images)

In (Section 2), we are discussing requirements of e-Health services and propose a service classification. 3)gives a short overview of the 3GPP QoS control architecture. A mapping of e-Health service requirements to standardized QCIs is given in (Section 4 and Section 5) presents an example involving a tele-consultation service between a patient and a doctor used to illustrate EPS QoS control procedures and use of the proposed mapping to QCIs.

2. QOS REQUIREMENTS FOR E-HEALTH SERVICES

2.1. E-Health Service Classification

Among the numerous classifications of e-Health services that may be found in literature, services are often broken down based on specific objectives into the following [4] tele-diagnosis, tele consultation, tele-monitoring, tele management, tele-education, and value added services. Tele-diagnosis have been described as generally characterized by asynchronous point-to- point communication (e.g., specialists at a remote site review transmitted patient data and return a diagnosis report), while consultation has been described as generally based on synchronous viewing and manipulation of medical multimedia data. Tele-monitoring in most cases refers to transmission of a patient's vital bio-signals and other related data, as in the case of home care telemedicine services [6]. Such services are often targeted at treating patients with chronic diseases or for post-hospital home care, and may involve multiparametric monitoring including patient vital signs (e.g., electrocardiogram (ECG), blood pressure, saturation of peripheral oxygen (SpO2), glucose level, etc.), physical sensors (monitoring patient activity), and environmental sensors (e.g., air temperature, humidity, and air pressure).

The European Commission funded MobiHealth project has focused on mobile tele-monitoring. Tele-monitoring may also involve an expert interacting with a remote examination site using audio/visual communication. For the purposes of this paper, we use the term tele-education as referring to any health-related education performed at a distance and in nonemergency situations. In [1], Perakis and Koutsouris use the term tele-management to refer to a combination of advanced telemonitoring and tele-consultation services, such as those involving computer assisted medical interventions and automatic surgical tools (tele-surgery).

2.2. Multimedia Conferencing

Multimedia conferencing applications are often a key part of e-Health services, as they may be used for various communication scenarios including patient-doctor, doctor-doctor (e.g., hospital specialists and general practitioners), and patient-patient scenarios (e.g., virtual support groups). Furthermore, they may involve preorchestrated, as well as live conferencing. The Third Generation Partnership Project (3GPP) specifies the requirements for conversational audio/video applications in UMTS networks as being highly delay and jitter sensitive, with one-way end-to-end (E2E) delay bounds being 150–400ms. With regards to loss, acceptable frame erasure rates (FERs) are specified as <3% (voice) and <1% (video).

Furthermore, it is the International Telecommunications Union (ITU) which specifies objective values for IP packet transfer performance in IP networks, with bounds of 100–400ms for E2E delay and 1×10^{-3} packet loss ratio for real-time conversational services [6]. The ITU also specifies the model for end-user QoS categories with respect to tolerance to information loss and delay tolerance, and provides indicative performance targets for audio and video applications as well as for data applications [3]. The 3GPP has specified the quality of experience and related metrics of the end-to-end multimedia service performance in 3G networks [2]. In [7], there is mentioned that it is important to distinguish between the requirements for:

(a) real-time video transmission.

(b) offline video transmission.

(c) medical video and audio for diagnostic applications.

(d) non-diagnostic video and audio.

Real-time video transmission for diagnostic applications is stated as being the most demanding. Real-time diagnostic audio applications include the transmission of stethoscope audio, or the transmission of the audio stream that accompanies the diagnostic video.

2.2.1. Still and Streaming Medical Images

The transmission of high definition still images is often a part of a tele-consultation service. Examples of images include: dermatological images, X-Rays, Magnetic Resonance Images (MRIs), ultrasound images, and computed tomography (CT). With regards to bandwidth, there are no specific requirements other than the fact that low bandwidth leads to longer transmission times. An overview of image sizes and data rates corresponding to typical devices is given in Table 1. In general, an important issue in the transfer of medical data is reliable data delivery, with packet losses having potentially disastrous consequences in terms of patient diagnosis.

Table 1: Data rates for typical telemedicine devices [7]**.**

Digital device	Temporal/Spatial (no. of samples/sec)	Contrast/Resolution (Bits per sample)	Required data rate
Digital blood pressure	1	× 16	< 10 kbps
Digital audio stethoscope	10000	× 12	appx. 120 kbps
Electrocardiogram (ECG)	1250	× 12	appx. 15 kbps
Ultrasound, Cardiology, Radiology	512 × 512	× 8	256 KB (image size)
Scanned X-ray	1024 × 1250	× 12	1.8 MB (image size)
Mammogram	4096 × 4096	× 12	24 MB (image size)
Compressed & full motion video	----	----	384 kbps to 1.54

2.2.2. Tele-Robotic Systems

Tele-robotic systems, such as those used for tele-surgery and tele-ultrasonography may involve the transmission of both still and streaming images. QoS requirements. (taken ultrasonography, are generally very strict in terms of delay and loss intolerance, with invasive robotic services (tele-surgery) being patient critical and thus having more stringent requirements than non-invasive services (e.g., tele-ultrasonography).

In the case of robotic tele-surgery, a key requirement is a minimal delay time from when a surgeon's hand movement is initiated, the remote manipulator actually moves, and images are shown on the surgeon's monitor. Studies have shown that the limit of the acceptable time delay in terms of a surgeon's perception of safety was roughly 330ms [1]. Mechanisms for compensating delay include slowing surgeon hand movement and a remote surgeon performing tasks that require less precision, while a local surgeon performs precision-dependent tasks.

Furthermore, it has been noted that two conferencing among members of the healthcare team greatly enhances robotic tele-surgery. With regards to reliability and error rate, relatively low data rates for transmission of robotic control data (<20 kbps) allow for error-protection coding and the possibility for transmitting equipment to send commands more than once to the receiving end [3].

2.2.3. Transmission of Patient Vital Signs

The amount and frequency of information related to monitored patient vital signs that needs to be transmitted depends on patient needs. While for some patients it may be sufficient to transmit vital signs every few minutes, other patients (e.g., those considered high-risk) may require transmission every few seconds. Here the authors discuss the requirements of tele robotic system, two-way video telemonitoring systems for cardiac patients which consist of wearable and light wireless biomedical sensors (for measuring 3 lead ECG, SpO2, heartbeat, and blood pressure). Sensors communicate with a signal processing module which further transmits physiological measurements (based on patient-specific thresholds, timing and frequency as specified by a healthcare provider) via various network interfaces to, for example, hospital servers, emergency stations, local physician clinic, and so forth. Transmission requirements are mapped to the following categories based on the severity of the patient's health condition (as specified by a health provider):

i) Class 0: highest priority requiring real-time monitoring (patients in emergency situations, or, with severe medical conditions).
ii) Class 1: requiring near real monitoring within a few hours.
iii) Class 2: requiring periodic monitoring such as twice daily.
iv) Class 3: requiring monitoring from time to time.

2.2.4. Research and Education

A wide variety of applications support health related education, such as distance learning for health professionals located in rural and remote areas. Examples of applications include interactive collaborative tools and tele conferencing, streaming audio/video, virtual classrooms, and interactive surgical simulations. Such applications are generally not considered to be as time-critical as those involving patient care, and may tolerate low delay, data loss, and unavailability. However, highly interactive surgical simulations would greatly suffer from long delays [4]. Furthermore, biomedical research may involve the transmission of high resolution images from remote databases. In the case of remote instrument manipulation for research purposes, low-delay requirements may result from the need to position samples or adjust instrument settings [4].

2.2.5. Summary

A summary of findings related to the QoS requirements for e-Health services is given in Table 2. We group together services based on delivery requirements (real time or non-real time) and transmission type (two-way conversational communication system, unidirectional streaming, interactive request-response, and background data retrieval).

For certain services, delay requirements are indicated as “not available” since no specific requirements have been found. For example, in the case of image transfer, delay will depend on image size and available bandwidth. It is clear that for emergency services, such transfer should be completed within a few seconds.

Table 2: QoS requirements for different types of e-Health services

Application type	Required through put	Small delay	Small jitter	Sensitivity to context
Tele-diagnosis	High	Yes	No	Yes
Tele-consultation	High	Yes	Yes	Yes
Tele-monitoring	Low	No	No	Yes
Tele-education	High	No	No	No
Access to EHR	Low/High	No	No	Yes

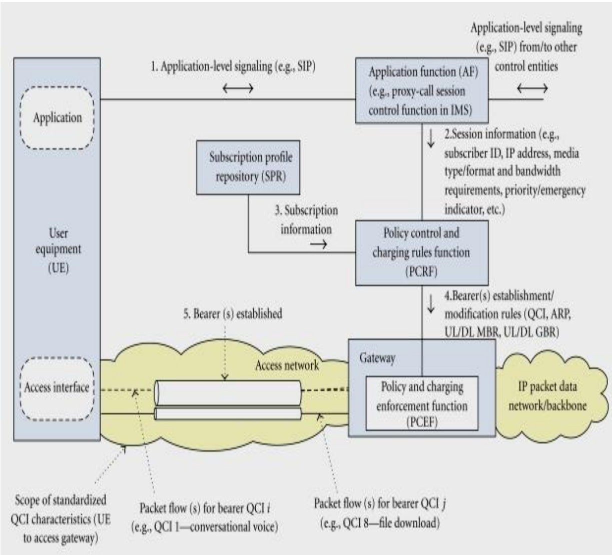
met, in particular for emergency and patient critical services. In the following sections, we describe the QoS control architecture specified by 3GPP and map e-Health services to standardized QoS classes.

3. QOS CONTROL IN THE 3GPP EPS

In order to provide support for IP multimedia services in converged NGNs, the 3GPP has specified the EPS [4], comprised of both an Evolved Packet Core (formerly known as Service Architecture Evolution (SAE), together with an evolved radio access network (E and E-UTRAN, commonly associated with the Long Term Evolution (LTE) work item). The EPS also supports non access, wireline (e.g., xDSL, cable), as well as fixed and mobile wireless (e.g., WLAN, WiMAX).

The EPS specifies class-based QoS provisioning, allowing operators to differentiate the treatment received by different subscribers and services. Functional network entities and interfaces responsible for providing service QoS control have been specified as a part of the overall 3GPP Policy and Control (PCC) architecture [6], which is to be illustrated in (Figure 2), and briefly summarized in the later part. In general, the PCC architecture extends the architecture of an IP-CAN (IP Connectivity Access Network), where the Policy and Charging Enforcement E-UTRA non-3GPP, service-aware Charging], , Function (PCEF) is a functional entity in the gateway node implementing the IP access to a packet data network (PDN).

An Application Function (AF) located along the application signalling path interacts with end user applications, situated in the User Equipment (UE), and extracts session information from signalling example of an AF is the Proxy Session Control Function (PIP Multimedia Subsystem (IMS). The IMS has been specified by the 3GPP (and further adopted by other standardization bodies) as a multimedia session control subsystem comprised of core network elements for the provision of multimedia services [7]. Session Initiation Protocol (SIP) in combination with the Session Description Protocol (SDP) enhancement involving negotiable QoS based on advanced QoS parameter matching and optimization functionality to be included along the signalling IMS has been proposed in the following figure.



Function (PCRF) (2), which is the policy engine of the PCC architecture. Each established bearer is assigned one and only one QoS Class Identifier (QCI).

A QCI is defined as a scalar value which represents a standardized reference specific packet forwarding behaviour provided to a service data flow on the path between a user equipment and access gateway. (The parameters that control the forwarding behaviour are preconfigured by the operator owning the node.) The goal of standardizing QCI characteristics is to ensure that applications and services mapped to that particular QCI receive the same minimum level of QoS across multivendor networks, in multioperator environment, and in case of roaming. The 3GPP specifications include nine QCIs with corresponding to the standardized characteristics in terms of bearer type (also referred to as "resource type"), priority, packet delay budget, and packet rate (given in Table 3). A primary difference between QCI 1–4 and QCI 5 is the bearer type (GBR versus non The specified packet delay budget defines an upper bound for the time that a packet may be delayed between a user equipment and the access gateway, with actual packet delays. The packet error loss rate defines an AF (1), and value that to be packet-error-loss) 5–9 non-GBR). Upper bound for a rate of noncongestion related packet losses.

Table 3: Standardized QCI characteristics

QCI	Resource type	Priority	Packet delay budget	Packet error loss rate	Example services
1		2	100 rms	10-2	Conversational voice
2	GBR	4	150 rms	10-3	Conversational video
3		3	50 rms	10-3	Real time gaming
4		5	300 rms	10-6	Non-conversational video
5		1	100 rms	10-6	IMS Signalling
6		6	300 rms	10-6	Video - TCP based
7	Non- GBR	7	100 rms	10-3	Voice, Video, Interactive gaming
8		8	300 rms	10-6	Video - TCP based

between service data flow aggregates of the same UE and also to differentiate between flow aggregates from different UEs (i.e., a scheduler shall meet the packet delay budget requirements of flows on priority level *N* in preference to meeting the packet delay budget of flows on priority level *N* + 1). The rules for this mapping with regards to the QCI parameter are specified in Table 4.

Table 4: Maximum authorised UMTS traffic class and handling priority

QCI		Max authorised UMTS traffic class and traffic handling priority
1 or 2	-	Conversational
3 or 4	-	Streaming
5 or 6	-	Interactive, Traffic handling priority = '1'
7	-	Interactive, Traffic handling priority = '2'
8	-	Interactive, Traffic handling priority = '3'
9	-	Background

While a QCI specifies user-plane treatment for associated bearers, the QoS parameter Allocation and Retention Priority (ARP) (also signalled by the PCRF to the access gateway) specifies control plane-treatment for bearers, that is, it may be used to decide whether a bearer establishment or modification request should be accepted or rejected due to resource limitations. The ARP parameter contains information about the priority level, the pre-emption capability and the pre-emption vulnerability of a resource request. The priority level defines the relative importance of a bearer request. The range of the ARP priority level is 1 to 15, with 1 as the highest level of priority.

Values reserved for intra-operator use (priority levels 1–8) may be used to prioritize IMS emergency calls [8]. The pre-emption capability information defines whether a service data flow can get resources that were already assigned to another service data flow with a lower priority level. The pre emption vulnerability information defines whether a service data flow can lose the resources assigned to it in order to admit a service data flow with a higher priority level. Both values are flags which can be set to either "yes" or "no". In situations when the system is overloaded, or, when resources must be freed up for other purposes (e.g., an incoming emergency call), bearers associated with a low ARP are released. For example, for video telephony, the operator may map video to a bearer with a lower ARP and voice to a bearer with a higher ARP, and thus have the option to drop only the video bearer if needed, while keeping the voice bearer unaffected. In normal circumstances, ARP has no impact on packet forwarding treatment for successfully established bearers.

Each EPS bearer QoS profile comprises the parameters QCI and ARP; and for GBR bearers also GBR and MBR. For aggregate (set of) EPS non-GBR bearers, AMBR values may be defined. A mapping of authorized IP QoS parameters received from the PCRF to authorized UMTS QoS parameters is performed by the translation/mapping function in the packet gateway. The rules for this mapping with regards to the QCI parameter are specified in [9] and summarized in Table 4. For the purposes of this paper, we assume that the EPS as such can provide the performance as specified and we use these values as a basis for our mapping.

4. MAPPING OF E-HEALTH SERVICE REQUIREMENTS TO STANDARDIZED QCIS

In the context of delivering e-Health services over an NGN architecture based on the EPS, a key issue for operators will be the accurate mapping of service requirements at the session establishment/modification time to standardized QCIs. A particular service may comprise multiple media types and traffic flows that may need to be mapped to different QCIs. (An example of such a situation is shown in an illustrative example later in this paper.)

Using as a basis the analysis of referenced work which has addressed the QoS requirements of heterogeneous e-Health services (summarized in Table 4), we explored the idea of mapping the previously defined types of e-Health services to QCIs. While for some types of e-Health services this mapping turned out to be rather straightforward, the question of context, as well as “relative importance” between flows belonging to different services within the same QCI, proved to be more difficult, as will be explained in more detail shortly.

In order to address the requirements of e-Health in different contexts, we find it necessary to break down existing classifications as proposed in [7, 10] by considering service delivery requirements (real time or non-real time) and the transmission type i.e. (two-way conversational communication, unidirectional streaming, interactive request-response, and background data retrieval).

5. Example

In order to illustrate EPS QoS control procedures and the proposed mapping of e-Health service requirements to standardized QCIs, we present a use case involving a tele-consultation service. For the purposes of this paper, the service is referred to as *E-consult* and it involves real-time video conferencing and streaming of ECG signals between a patient and a doctor. The service enables a patient or doctor to initiate an E-consult session using an early research prototype client application.

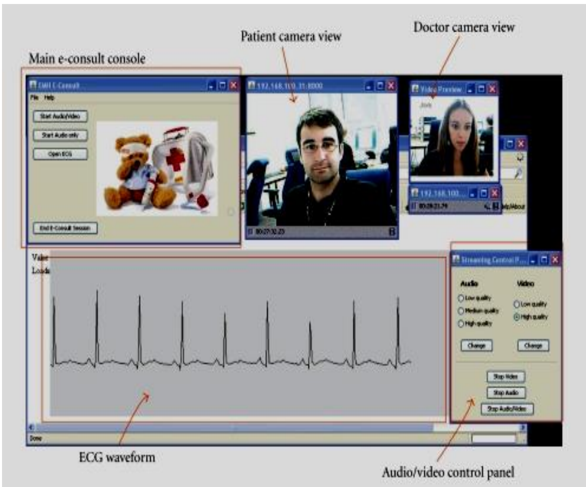


Figure 3: Early research prototype tele-consultation service—doctor desktop view
(Source - journals/ijta/2010/628086/fig4/)

(Figure 3 shows the makeshift GUI). The main E-consult console offers the choice of media components to include in the session (audio/video, audio only, and ECG). In case audio/video is selected, two windows with camera views of the “patient” and the “doctor”, respectively, are shown. There is also a user-friendly streaming control panel for selecting audio/video quality and starting and stopping the media flows. The ECG window shows the patient's ECG waveform. Early research prototype tele-consultation service—doctor desktop view.

In the prototype application, audio and video streaming corresponds to bidirectional conversational streaming, and it has been implemented using the Java Media Framework (JMF) API [11], which enables the capture, streaming, and transcoding of multiple media formats. We simulate a scenario whereby the patient has access to a remote ECG sensor unit and may choose to transmit ECG signal data to the doctor during the active session. In order to simulate streaming ECG data, we used data available from PhysioBank, a freely available archive of digital recordings of physiological signals to be used for research purposes [12]. The recorded ECG files in PhysioBank used 2-, 3-, and 12-lead ECG records sampled at 500 Hz with 16-bit resolution over a 32 mV amplitude range. For the purpose of our ECG visualization, a small sample of data extracted from ECG recording was stored in a text file in a numerical format. The network requirements for audio/video correspond to standard requirements for audio and video streaming, with exact values for network parameters depending on the specific type of codec. A streaming control panel included in the E-consult application enables end users to configure preferences with regards to audio and video quality (different chosen quality levels will results in different codec). Audio quality levels correspond to the following JMF codec settings: (1) low-quality—GSM, (2) medium-quality—ULAW, and (3) high quality—MPEG AUDIO. Video quality levels and JMF settings were specified as follows: (1) low-quality—H.263, and (2) high-quality—motion JPEG.

In the case of E-consult, the different media flows established as part of the session are mapped to different QCIs due to different QoS requirements. We assume the following mappings: (1) audio stream to QCI 1, (2) video stream to QCI 2, and (3) ECG signal stream to QCI 4. Considering that the example service is not of an emergency nature, there is no need to assign ARP values corresponding to emergency services. On the other hand, if this were to be treated as an emergency situation, then the ECG signal stream would be mapped to QCI 3, and operator policies would determine what ARP values to assign. Since QCI characteristics are specified for the access network (UE to access gateway/PCEF), in the case of two access networks along the end-to-end path, delay values should be summed, and a value for delay in the core network (likely to be much lower) added to it. Based on the findings described earlier, and considering that delay values specified for QCIs represent upper bounds, it may be concluded that the required end-to-end values could be met. Further research and concrete case studies would be needed to validate these conclusions in practice.

6. CONCLUSIONS AND FUTURE SCOPE

Due to a possibly high impact on human life and well-being, e-Health services represent a category of services for which the research on QoS requirements has moved beyond the well-known properties of individual media flows. It has been shown that the context in which the service is invoked may determine the actual classification and prioritization of flows.

Our work provides some general guidelines and proposes a mapping of e-Health service types to standardized QCIs in EPS as a next - generation communication technology. A use case of the E-consult service illustrates how the mapping can be applied. Future work will focus on validation of the proposed mapping for selected services.

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