Guest Editorial Introduction to the Special Section: 4G Health—The Long-Term Evolution of m-Health

***Abstract*—In the last decade, the seminal term and concept of "m-health" were first defined and introduced in this transactions as "mobile computing, medical sensor, and communications technologies for healthcare." Since that special section, the m-health concept has become one of the key technological domains that reflected the key advances in remote healthcare and e-health systems. The m-health is currently bringing together major academic research and industry disciplines worldwide to achieve innovative solutions in the areas of healthcare delivery and technology sectors. From the wireless communications perspective, the current decade is expected to bring the introduction of new wireless standards and network systems with true mobile broadband and fast internet access healthcare services. These will be developed around what is currently called the fourth-generation (4G) mobile communication systems. In this editorial paper, we will introduce the new and novel concept of 4G health that represents the long-term evolution of m-health since the introduction of the concept in 2004. The special section also presents a snapshot of the recent advances in these areas and addresses some of the challenges and future implementation issues from the evolved m-health perspective. It will also present some of the concepts that can go beyond the traditional "m-health ecosystem" of the existing systems. The contributions presented in this special section represent some of these developments and illustrate the multidisciplinary nature of this important and emerging healthcare delivery concept.**

***Index Terms*—Body area network (BAN), e-health, m-health, Internet of Things (IOT), long term evolution (LTE), medical sensors, personal area network (PAN), telemedicine, WiMAX, 4G mobile technologies.**

I. Introduction

THE concept of m-health was first introduced and defined in this transactions as "mobile computing, medical sensor, and communications technologies for healthcare" [2]. Since then, it has become one of the key domains within the e-health and wireless telemedicine, bringing together major academic research and industry disciplines worldwide. This basic concept of the original definition of m-health is illustrated in Fig. 1.

The first editorial that highlighted the concept of m-health was published in the special section of this transactions, "Special Section on mobile telemedicine and telehealth systems," published in 2000 [1]. One of the key notes in the editorial introduction stated that the "convergence of information and telecommunications around telemedicine and mobile telecare systems is fostering a diversity of cost-effective and efficient mobile applications and will provide a new dimension to the original definition and concept of telemedicine as 'medicine practiced at distance' that will envisage new mobility directions in reshaping the structure of healthcare delivery globally into the next millennium." This potent prediction was the key to the massive successes of m-health systems that we witness today.

Furthermore, since then major advances in these m-health subdisciplines were introduced within the worldwide research community. In particular, major advances were introduced in the mobile broadband and wireless internet m-health systems [4]. Similar advances in wearable and body area sensor networks and challenges were also reported [3]. The relevant business models of m-health services were also introduced and reported in the recent literature [4]. This widespread and unprecedented evolution of m-health systems and services in recent years has been reflected in a 2010 study by McKinsey estimated that the opportunities in the global mobile healthcare market are worth between $50 billion and $60 billion in 2010 [5]. Further details of the review of existing m-health systems and advanced applications are beyond the scope of this editorial paper and can be cited in the recent literature in this area [6], [7].

However, one of the major breakthroughs and turning points in this evolution is the introduction of the fourth-generation (4G) mobile communication systems. The introduction of 4G technologies and networks in this decade will bring new services and consumer usage models that will be compatible with these emerging mobile network architectures.

It is timely that such major evolution is also reflected in corresponding m-health systems and services and introduced as 4G health. This new concept is defined as "*The evolution of m-health towards targeted personalized medical systems with adaptable functionalities and compatibility with the future 4G networks*." Fig. 2 shows the general concept of 4G.

II. 4G Health and the Long-Term Evolution of m-Health Systems

From the earlier definition of 4G health, it can be seen that this long-term evolution (LTE) of m-health reflects the recent advances in mobile and network technologies and sensor technologies in recent years. Furthermore, the realization of this evolution consists of several themes that constitute the evolution of the original building blocks of the earlier m-health concept shown in Fig. 1 with added new blocks that reflect the expected advances in the personalization of healthcare within the next decade.

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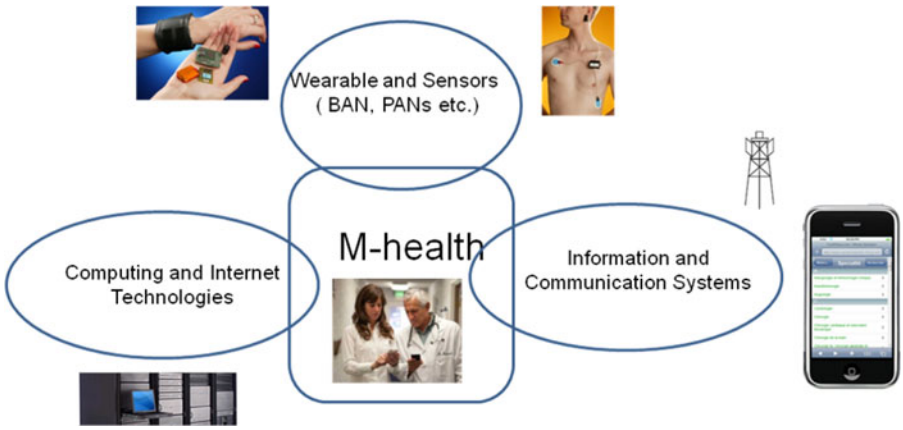

Fig. 1. General concept of m-health systems.

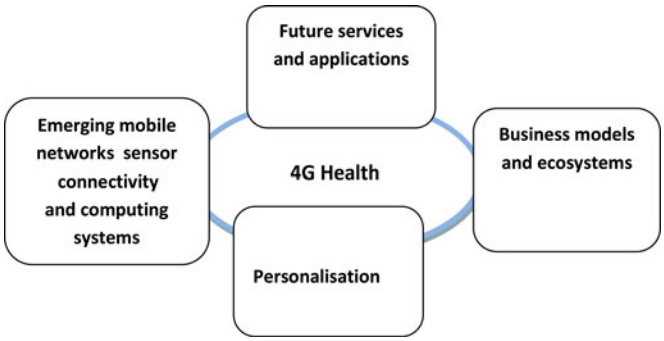

Fig. 2. General concept of 4G health.

In this section, we will discuss some of the major issues involved in this evolution as a snapshot of these advances. The four basic elements of 4G health systems and their evolution are as follows:

1) Future services and applications.
2) Emerging mobile access networks, sensor connectivity, and computing systems.
3) Business models, ecosystem development, and deployment issues.
4) Personalization.

A. Future m-Health Services and Applications

This is considered as the major element of 4G health systems and the key to their success and future evolution. In a recent WHO report on m-health [7] provided a comprehensive literature review and reporting on current m-health systems. Several listed of m-health services were categorized as follows:

1) Emergency response systems (road traffic accidents, emergency obstetric care, etc.).
2) Disease surveillance and control (Malaria, HIV/AIDS, TB, Avian Flu, chronic diseases—especially diabetes).
3) Human resources coordination, management, and supervision.
4) Synchronous and asynchronous mobile telemedicine diagnostic and decision support for clinicians at the point of care.
5) Remote patient monitoring and clinical care.
6) Health extension services, health promotion, and community mobilization.
7) Health services monitoring and reporting.
8) Health-related m-learning for the general public.
9) Training and continuing professional development for healthcare workers.

Another recent m-health reports that address similar key m-health services were identified and listed as [8], [9]:

1) *Education and awareness:* This category includes interventions designed to provide stakeholders with the information they need to support their decisions, at the right time, at the right place and in the right format.
2) *Data collection:* This includes tools that capture facts and statistics at the community level, enabling policy makers to judge and improve the effectiveness of healthcare programs, allocate resources more efficiently, and adjust programs and services accordingly.
3) *Remote monitoring:* This group refers to resources that allow one- or two-way communications to monitor the evolution of health conditions outside healthcare facilities, to maintain caregiver appointments, or to ensure adherence to medication regimens.
4) *Peer-to-peer communication among healthcare workers:* This category encompasses technologies that connect health professionals with each other, improving their sense of empowerment and their ability to make decisions effectively and self-sufficiently.
5) *Disease and epidemic outbreak tracking:* This group includes the use of devices to capture and transmit data on the incidence and geographic distribution of diseases, and to guide prevention and containment efforts.
6) *Diagnostic and treatment support:* This category includes efforts to use technology to the shift diagnostic and therapeutic efforts away from healthcare facilities to people's homes, workplaces, schools, and the community at large, while averting expensive or unfeasible face-to-face

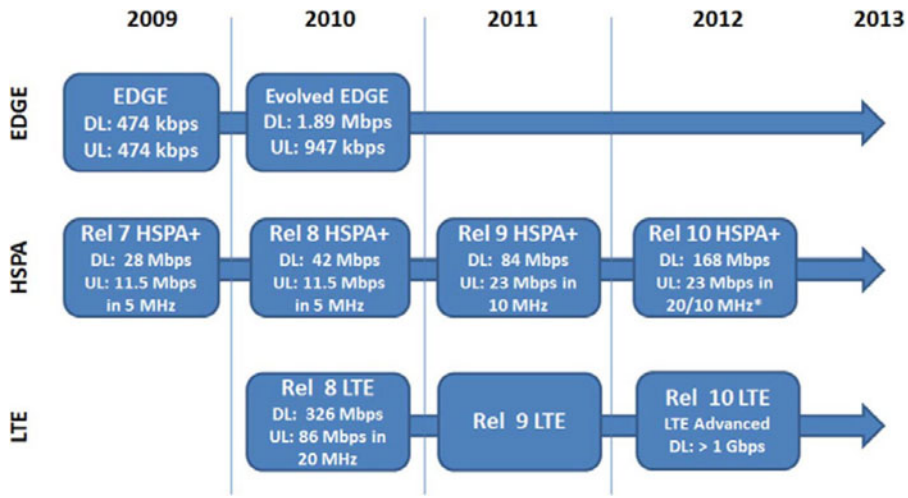

Fig. 3. LTE technology evolution [13].

in-person consultations with health professionals or visits to hospitals or clinics.

From these studies, three innovation example areas were cited as potential and successful examples of m-health applications and services especially for the developing world.

1) SMS services and alerts that remind patients to take their prescription drugs at the appropriate time.
2) Remote diagnosis and appropriate treatment for patients who do not have easy access to a physician.
3) Remote health monitoring devices that track and report patients' conditions.

In conclusion, it can be seen from these reports that the major applications of "long-term evolution of m-health" services could be classified in the following categories.

1) 4G wellness, prevention, and long-term chronic diseases management systems.
2) 4G mobile emergency care and response systems.
3) 4G medical multimedia services and diagnostic systems.
4) 4G personalization.
5) Social robotics and social medicine systems.

B. Emerging Mobile Access Networks, Sensor Connectivity, and Computing Systems

This building block constitutes several subblocks that include the evolutions of the wireless networks and cellular systems, the developments of short-range communication with medical sensors, and Internet-of-Things (IoT) connectivity in addition to the future computing systems such as cloud computing.

1) Background on 4G Mobile Technologies: In recent years, there have been major advances in mobile communication systems, in particular, the 4G mobile technologies with LTE network that are currently being deployed worldwide and are expected to be in commercial use by 2013–2014. LTE basically is the next generation of cellular networks standardized by the 3rd Generation Partnership Project (3GPP). Furthermore, the IMT-Advanced 4G standards that include LTE-Advanced will provide a global platform on which the next generations of interactive mobile services that will provide faster data access, enhanced roaming capabilities, unified messaging, and broadband multimedia services will be built. In addition, the coexistence of the LTE with high-speed packet access, enhanced data rates for global evolution will provide more service choices for mobile healthcare services and applications. Fig. 3 shows the summary of 3GPP technology evolution map and the perspective data rates of each of these technologies [13].

The other key mobile network technology that constitutes part of the 4G evolution is the World Wide Interoperability for Microwave Access (WiMAX) networks. WiMAX aims, in general, to provide wireless broadband services on the scale of the metropolitan area network and is the commercialization of the IEEE 802.16 standard.

In recent years, several standards have been ratified including the IEEE 802.16e (mobile WiMAX) and the IEEE 802.16j multihop WiMAX systems [10].

The competitive and effective usage of these two key 4G constituent technologies for m-health applications will be one of the key research challenges in the future.

2) Future Sensor Connectivity and Internet of m-Health Things (m-IOT): IoT is another key networking advances that links the internet with everyday sensors and working devices for an all IPV6 based architecture [11]. Internet of Things (IoT) and Internet of Services (IoS) will have major impact on future implementation issues of 4G health systems. To reflect on this, a new concept that matches the functionalities of m-health and IoT for new and innovative future (4G health) applications has been recently proposed [12]. These together with other low-power short-range communication systems will be the perfect enabling connectivity platforms that will link future personalized and wearable sensors to the different 4G access networks. The concept of m-health based on Internet of Services (m-IOS) will also be a major research direction within this framework.

3) Business Models, Ecosystem Development, and Deployment Issues: The potential of 4G health as one of the key vertical markets for 4G communication systems will be key to the success for these applications. However, the design of successful

ecosystem models that reflect the expected growth in the market in this area will be an important building block of this implementation process. These models need to include not only the different elements that have been addressed in current m-health ecosystems such as interoperability standards, but also future demand of 4G radio systems such as green communications and low power consumption that will be an important part of future 4G health systems.

4) Personalization: The other key development within the 4G health concept will be the personalization of the future m-health services toward new tailored medication protocols and mechanisms that will combine the specific delivery of the disease medicines and drugs of the individual patient based on his/her specific "genetic push" and "habitual pull." The new 4G health technologies will be able to achieve this critical balance in the next few years provided that the advances in both "genomic signal processing' and medical and wearable sensor technologies will be able to provide a workable balance within this vision.

III. Future Challenges of 4G Health and the LTE of m-Health

The concept of 4G health as defined in this special editorial will be one of the key focus areas for future m-health research and enterprise activities in the coming years. This evolution of m-health requires a clear global plan and framework on how these systems will work and function in different countries and healthcare systems globally. These will ensure the successful and large-scale adoption of 4G health systems globally. However, there are several challenges and issues that need to be addressed further on this matter. Some of these are summarized as follows:

1) *Globalization and the potential options of decreasing healthcare disparities and inequality levels*. It is expected that smart 4G mobile technologies will be able to decrease healthcare disparities provided they are designed, applied and deployed correctly. However some of these technologies if not designed properly with the patient and user at the heart of this process, these can then have inherent disparities in their functionality from the healthcare perspective.
2) *The development of the best applicable 4G health ecosystem*. In recent years, there have been numerous discussions on the proper model of m-health ecosystem. However, to date there is no acceptable and validated model, as most of the proposed models are market-driven models or disease focused. However, there is fairly good opportunity for a global 4G health ecosystem to be proposed and validated and applied for major healthcare services and problems. This can be implemented provided that all the global stakeholders agree on such a process with economically valid and clinically acceptable models. There are currently several ongoing initiatives underway to address these critical issues within the different international m-health stakeholders and interested organizations such as the WHO's m-health alliance and the GSMA and also within the European Commission research activities.
3) *Social medicine challenges*. The 4G technologies will perhaps move some of the m-health services to a personalized level, combined with social interaction and collective responsibility approach using evolving web2.0 platforms that can shift the doctor–patient knowledge process further toward the patient–patient process in some healthcare delivery services. However, clear governmental regulations and reforms need to be discussed within this process.
4) *Privacy and security challenges*. The expected advances in future 4G smart terminals and devices and their expected multifunctional 4G health services imply that further privacy and security challenges will be required for these terminals. The relevant wireless privacy and security challenges need to be further addressed, with more research to be carried out in this specific area. This will be more urgent in ethically sensitive 4G health applications such as multimedia personal access of patient records, 4G-based electronic health record systems, etc.
5) *Future mobile technologies beyond 4G and future networks*. The research is already underway to propose the next generation beyond the 4G mobile technologies and future mobile networks (5G). It is also imperative that this process need to include the healthcare sector as an integral part in the design and development of such systems and networks considering the expected economical and fiscal benefits to be obtained from this vertical market. Future research issues include multidisciplinary areas such as design, social, policy, and psychology in addition to the technological and clinical areas. In general, it is envisaged that by pooling the resources of the telecom industry, the interested stakeholders and medical companies will promote the delivery and application of health data content through different vertical markets such automotive, future TV and home entertainment system. Furthermore, new emerging concepts such as "medical quality of service - m-QoS" and "medical quality of experience - m-QoE" will be a hot field of research within the coming years especially from the future communications and network technologies perspective [14].

IV. Special Section

The goal of this special section is to provide a sample collection of papers that will reflect the spectrum of the recent advances in m-health technologies and the role of the emerging mobile and network technologies in m-health systems and applications. We received more than 20 papers in response to the call, and six papers were accepted for this special section that reflect some of these advances and developments.

The first paper by Wang *et al*. addresses some of the advances in the protocol design of ZigBee-based wireless patient monitoring and provides some insight into the potential use of this technology for future m-health monitoring systems. The second paper by Morak *et al*. also addresses the concept of short-range monitoring with the focus on the potential of near field com-

munication and radio frequency identification technologies for m-health monitoring and particularly for future personal area network and body area network systems.

The third paper by Markarian *et al*. addresses some of the key challenges in the video distribution techniques over WiMAX networks for m-health applications with specific focus on the scheduling and content-aware video-streaming applications. The fourth paper by Alinejad *et al*. addresses an important challenge within the medical video streaming and mobile health multimedia applications that will be one of the major 4G health services. This paper addresses the cross-layer design of this application using two network platforms, mobile WiMAX and high-speed uplink packet access (HSUPA). The results of this work provide a prelude for the future application of these concepts for LTE-based m-health networks. The fifth and final papers by Constantinescu *et al*. and Depursinge *et al*. address the concept of m-health-based multimedia medical data retrieval and medical video information retrieval systems. The mobile access of multimedia medical data information will also be one of the key research works within the 4G health systems and these two papers present some of the new concepts and future framework issues within this area.

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