# **Information Technology – Next Generation:**

# **The Impact of 5G on the Evolution of Health and Care Services**

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## **Abstract**

*As more and more details of 5G technology specifications unveil and standards emerge it becomes clear that 5G will have an enabling effect on many different verticals including automotive, mobility and health. This paper gives an overview about technical, regulatory, business and bandwidth requirements of health care applications including e-connectivity in the pharmaceutical domain, medical device maintenance management, hospital at home, supply chain management, Precision and Personalized medicine, robotics and others based on latest research activity in the field.*

*Keywords: 5G, healthcare, LPWA, edge-clouds, algorithms*

## **Introduction**

Although concrete specifications are still lacking in some areas, 5G technology is approaching with giant footsteps. With vendors having announced trials with fixed mobile access as early as 2017 there can be no doubt that 5G technology has the potential to become a relevant enabler for the Internet of Things and the health vertical. There have been ongoing discussions about the specific requirements of the health sector to establish meaningful service offerings to health care providers, pharmaceutical industry and other relevant stakeholders such as patients, formal and informal carers and social care.

Health care is a relevant market as its overall share in national GDPs is significant with values ranging between 6% in China, 10% in Europe and 18.5% in the United States. eHealth has been going through a typical hype curve starting in the early 2000 fulling high hopes of quick enhancement of quality of care, quality of experience and a reduction in health care costs. However, the uptake of eHealth technology has been protracted and the reason for this protracted uptake is still unclear. The eHealth action plan published by the European Commission in 2012 [1] lists several barriers to deployment of eHealth that could be identified during public consultations and research on the topic:

* lack of awareness of, and confidence in eHealth solutions among patients, citizens and health care professionals
* lack of interoperability between eHealth solutions
* limited large-scale evidence of the cost-effectiveness of eHealth tools and services
* lack of legal clarity for health and wellbeing mobile applications and the lack of
* transparency regarding the utilisation of data collected by such applications
* inadequate or fragmented legal frameworks including the lack of reimbursement
* schemes for eHealth services
* high start-up costs involved in setting up eHealth systems
* regional differences in accessing ICT services, limited access in deprived areas

The World Health Organisation (WHO) concludes in their most recent report on eHealth that there *“is the need for stronger political commitment for eHealth, backed by sustainable funding and for effective implementation of policy”* [2].

Although there is some mentioning of high level issues with regards to interoperability and connectivity both reports say little about the technological readiness of network infrastructures, future applications and business models and the subsequent requirements. This paper will discuss details on the most relevant use case scenarios and estimate their technological requirements based on experimental tests and empiric evidence. Furthermore, the paper will discuss current 5G architecture and business models potentially suitable for the health domain.

This paper is seeking to contribute to the current discussion on 5G specifications in the health domain. In this paper we include a discussion of the empiric evidence for the rapid evolution of eHealth as a 5G application domain, the emergence of low wide area technology and its implication for health care, smart phones, 4G and mm Waves, advanced 5G functionalities, the role of mobile edge clouds, next generation network abilities, and 5G service examples and bandwidth requirements.

## **Empiric Evidence for the Rapid Evolution of eHealth as a 5G Application Domain**

Several white papers have been created in a bit to establish an outlook onto eHealth use cases and their potential requirements. Thus, in 2014 the European Commission published a “green paper” followed by a public consultation to obtain a better understanding of the strategic requirements for the use of mobile telephony in the health domain [3]; while contributors highlighted the need for regulatory certainty and made a case for more evidence synthesis through large scale implementations there was only limited input with regards to specific applications and concrete requirements [4].

With the emergence of 5G technology and the layout of an aligned international time table several white papers have been published to establish requirements for the application of 5G technologies in the health vertical [5, 6]. Several concrete applications have been highlighted, among them the use of smart pharmaceuticals connected directly to the network utilizing Low Power Wide Area technology, the use of millimetre-waves for quick audio and video connectivity with disease management portals, ultra-low latency to enable robotic assisted surgery and more. As the network capability grows there is strong evidence for the massive use of mobile health applications. The US Food and Drug Administration (FDA) estimated that 500 million smartphone users have been using health care applications by 2015 and that by 2018 50% of the more than 3.4 billion smartphone and tablet users will have downloaded mobile health applications [7]. This is supported by data from the European Commission estimating the value of the global m-Health market at 17.8 Billion Euro by 2017 [8]. In summary, with the growth in network capability and mobile health applications, several white papers have focused on the requirements for the application of 5G technologies in the health domain.

## **The Emergence of Low Power Wide Area Technology and its Implications for Health Care**

One of the current challenges in 5G is the lack of crisp technology specifications. There is agreement that 5G will offer more than just a simple performance enhancement compared to previous network generations. Rather than being more of the same but faster and bigger, 5G will present as a set of services, especially addressing the need of the integration of M2M, audio and video and other services spread over a much larger spectrum range than any network generation before.

Low power wide area (LPWA) technology has become increasingly popular mainly through the introduction of smart meters. The roll out of LPWA in Europe is in full swing and mobile telecommunication operators are set to commence to fit their towers with LPWA modules in 2017 or 2018 depending on the geographical area. Gartner forecasts that in general “Low Power short range networks will dominate wireless connectivity through 2025” but predicts a significant role for LPWA devices [9] as an enabler for the Internet of Things (IoT). (See [10] for an overview over security and privacy implications of IoT.) This is emphasized by predictions of strong growth of LPWA by Cisco in their latest Visual Networking Index update [11].

In fact, with the 3GPP standardization of Narrow Band – Internet of Things (NB-IOT) radio access technology an alternative to Bluetooth for the connection of inhalers and Insulin Pens carrying advanced sensor technologies to remote disease management portal has gained serious momentum. While Bluetooth is dependent on smart phones or tablets as gateway with serious limitations to the number of devices that can be connected and also being affected by the physical limitations of high frequency radio communication (reduced indoor reach and penetration) LPWA modules have superior proprieties due to their operation on a lower frequency band. LPWA technologies seems also promising for indoor use in hospitals for supply chain management and monitoring and maintenance of medical devices such as infusion pumps, hospital beds, wheel chairs, ECGs, etc.

Onduo, a newly announced joint venture between Sanofi and Google, is aiming to provide services for 592 million diabetics globally by 2035 [12]. The number of patients suffering from asthma is on the rise. According to the Global Asthma Network there were 334 million people affected by asthma in 2014 [13]. These figures are likely to climb further. Due to the nature of the treatment of these conditions, which requires the regular use of insulin pens and inhalers it can be assumed that the use of directly connected devices might generate the need for more than 1 billion LPWA connections. There are concerns on the efficiency and cost effectiveness of e-connected devices. However, due to the high costs of hospitalization and the societal burden of inability to work based on the available evidence it must be assumed that devices directly connected to the network by LPWA technology will have a place in the management of chronic, non-communicable conditions. Given the demographic development in almost all industrialized countries and emerging economies it is also safe to say that 20th century hospital care is not a futureproof solution and that in the future more care will be delivered at home and over the Internet. LPWA will play a role in the monitoring of devices at home and in hospitals.

### **Smart phones, 4G and mm Waves**

Smart phones and tablets will continue to play an important role in health care as they hold audio and video capability. It will be crucial to provide sufficient bandwidth for audio and video interaction. This is not only relevant for the use of telemedicine and similar services but also for the virtualization of care. In many cases a personal visit from a carer might not be necessary but could be replaced by a video call. Visits to the doctor or the pharmacist to get advice on the use of medical devices might be replaced by video tutorials. They can be replayed at no extra costs. Smart algorithms and autonomous systems might advise people with chronic conditions on best practice beyond their prescriptions to cover non-pharmaceutical aspects of the disease management. Audio and video interfaces will play an important role in the virtualization of care. In this context, real time connectivity and the availability of suitable bandwidth might be required. Indoors this might soon be delivered by mm Waves (fixed mobile access).

1. **Advanced 5G Functionalities**

The integration of LPWA and mm Wave technology are important to the health vertical. However, more complex innovation is required in the access and core network to provide the ability to combine or re-combine data and services in order to add value. This will be achieved through multi domain orchestration and will play a particular huge role in the virtualization of care (Precision Medicine) where different services consumed by a patient need to be integrated in real time to conclude on for example the dose of a particular pharmaceutical required or in the external management of artificial organs such as insulin pumps in real time.

Multi-domain orchestration and multi-tenancy will play a key role in the use of the same physical network infrastructure by different stakeholders simultaneously. While patients will have an interest to combine several individual services other stakeholders using the same infrastructure might have different needs. Healthcare providers might want to see how the prevalence of a particular disease impact their budget. Pharmaceutical companies might want to know how a particular medication is utilized in a region. Self-help groups might want to implement peer to peer communication – all utilizing the same network at the same time.

There are emerging requirements with regards to time synchronization. 5G will see an increased density of access points in the radio access network (RAT) due to the physical proprieties of the new wave formats. On top of this different technologies such as future satellite internet, device-to-device (D2D) communication and terrestrial Internet need to be coordinated. Time synchronization will also play a role in the progressive uptake of parallel processing where centralised public cloud intelligence will be progressively deployed into the network periphery.

### **The Role of Mobile Edge Clouds**

Especially from the perspective of the health domain the current technology trend towards everything as a service strategies (XaaS) is a difficult one. Patient information is on the one hand a desirable commodity for all kind of right and wrong reasons. On the other hand, health care providers have to obey the existing rules which make them liable for any data loss or data breach. At the same time, Big Data technology seems promising by opening the horizon for new research potentially leading to enhanced quality of care through new knowledge and technology.

The offerings of Google and IBM Watson with regards to smart algorithms are so far based on XaaS, meaning the data has to be delivered to the service provider for processing. This, however, seems incompatible with the duty of the health care provider to keep patient data private and safe. A proxy-server architecture, whereby the service provider positions a server on site is not a real remedy as the service provider is still in full control of the data. From a technological perspective edge clouds significantly reduce the latency, make the service more fluid but does not change the topology. In 2012 the European Commission published a report on the future of cloud computing, suggesting a shift in the existing cloud dogma by sending software to the data rather the other way around [14]. This idea has been developed further under FI-STAR a research project funded by the European Commission [15, 16, 17]. As such the edge-cloud could serve as a universal proxy-server in the user domain. This would prevent user lock-in and boost diversity.

### **Next Generation Network Abilities**

Although 5G will not be fully deployed until at least 2020 there are already speculations on 6G and the next generation network technology ongoing. It seems that 6G will be featured by satellite- and proxy internet. There is a proposal by Elon Musk under the working title Space X to launch 4425 satellites into low earth orbits [18]. While it is unlikely that this will remain the only proposal for space based internet services it needs to be anticipated that current networks, especially the “core network” will be expanded into space. Proxy-internet will be based on D2D capability and future technologies allowing to create dynamic mash-networks to enhance the reach at the cloud/service edge.

### **5G service examples and bandwidth requirements**

Current white papers are not specific about the potential future utilization of 5G technology yet. However, concrete and tangible applications have been discussed within the health care and pharmaceutical industry. Table 1 provides an overview about the current suggestions and the potentially required throughput.

We found that typically bandwidth requirements in the health domain are overestimated due a focus on telehealth services and remote diagnostics involving video-streaming. Not enough attention is being paid to M2M applications. Based on a recent study commissioned by Huawei we had an opportunity to study bandwidth requirement in an urban teaching hospital carefully and found that traffic scenarios are not challenging for the available infrastructure [19, 20]. However, the existing infrastructure does not allow for geographical flexibility. Many hospitals are fitted with Wi-Fi. However, many IT directors perceive Wi-Fi as risky and are not keen to allow devices to access their network.

## **Conclusions**

5G technology clearly has the potential to provide network capability and connectivity to boost the use of eHealth and mHealth in hospital and the community. Especially LPWA technology may lead to a break-through in the uptake of eHealth technology at home and in hospital. LPWA has the potential to massively grow the number of machine-to-machine (M2M) connections over the coming decade. Overall the need to connect 1000 times more devices via 5G is probably more relevant than providing for huge bandwidth for video streaming. There is the need to formulate new business models describing how different stakeholders can create win-win scenarios.

## **References**

1. European Commission.: eHealth Action Plan 2012-2020 - Innovative Health care for the 21st Century. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0736&from=EN. (2012)
2. WHO, ed.: From Innovation to Implementation: eHealth in the WHO European Region. Copenhagen: WHO Regional Office for Europe. (2016)
3. European Commission.: Green Paper on Mobile Health (“mHealth”). https://ec.europa.eu/digital-single-market/en/news/green-paper-mobile-health-mhealth. (2014)
4. European Commission.: Public Consultation on the Green Paper on Mobile Health. https://ec.europa.eu/digital-single-market/en/public-consultation-green-paper-mobile-health. (2014)
5. 5G PPP.: 5G and E-Health. https://5g-ppp.eu/wp-content/uploads/2016/02/5G-PPP-White-Paper-on-eHealth-Vertical-Sector.pdf. (2015)
6. WWRF.: A New Generation of E-Health Systems Powered by 5G. Wireless World Research Forum. http://www.wwrf.ch/files/wwrf/content/files/publications/outlook/Outlook17.pdf. (2016)
7. US FDA.: Mobile Medical Applications. U.S. Food and Drug Administration. http://www.fda.gov/medicaldevices/digitalhealth/mobilemedicalapplications/. (2015)
8. European Commission.: mHealth, What Is It? - Infographic. https://ec.europa.eu/digital-single-market/en/news/mhealth-what-it-infographic. (2014)
9. Gartner.: Gartner Identifies the Top 10 Internet of Things Technologies for 2017 and 2018. http://www.gartner.com/newsroom/id/3221818. (2016)
10. BITAG.: Internet of Things (IoT) Security and Privacy Recommendations’. Broadband Internet Technical Advisory Group. http://www.bitag.org/documents/BITAG\_Report\_-\_Internet\_of\_Things\_(IoT)\_Security\_and\_Privacy\_Recommendations.pdf. (2016)
11. Cisco.: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2015–2020 White Paper. http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html. (2016)
12. Roland, D., Lantauro, I.: Google Parent and Sanofi Name Diabetes Joint Venture Onduo. The Wall Street Journal, September 12. http://www.wsj.com/articles/google-parent-and-sanofi-name-diabetes-joint-venture-onduo-1473659627. (2016)
13. Global Asthma Network.: The Global Asthma Report 2014. http://www.globalasthmareport.org/. (2014)
14. Schubert, L.: The Future of Cloud Computing. Edited by Keith Jeffery and Burkhard Neidecker-Lutz. http://cordis.europa.eu/fp7/ict/ssai/docs/cloud-report-final.pdf. (2010)
15. fistar.eu.: FI-STAR. Accessed February 11. https://www.fi-star.eu/fi-star.html. (2016)
16. Thuemmler, C., Mueller J., Covaci, S., Magedanz, T., de Panfilis, S., Jell, T., Gavras, A.: Applying the Software-to-Data Paradigm in Next Generation E-Health Hybrid Clouds. In Proceedings of the 2013 10th International Conference on Information Technology: New Generations, 459–463. ITNG ’13. Washington, DC, USA: IEEE Computer Society. doi:10.1109/ITNG.2013.77. (2013)
17. Paulin, A., Thuemmler, C.: Dynamic Fine-Grained Access Control in E-Health Using: The Secure SQL Server System as an Enabler of the Future Internet’. In Proceedings of the 2016 HealthCom, 1–4. IEEE. doi:10.1109/HealthCom.2016.7749462. (2016)
18. Caole Villa, A.: Elon Musk to Launch Super Fast Internet from Space. Nature World News, November 19. http://www.natureworldnews.com/articles/32332/20161119/elon-musk-launch-super-fast-internet-space.htm. (2016)
19. Paulin, A., Thuemmler, C., Lim, A. K., Schneider, A., Feussner, H.: E-Health Traffic Analysis and 2035 Future Network Requirements - Part I: State of the Art Service Description. (2016)
20. Paulin, A., Thuemmler, C., Lim, A. K., Schneider, A., Feussner, H.: E-Health Traffic Analysis and 2035 Future Network Requirements - Part II: Future Ecosystem Conditions and Constraints. (2016)
21. Sanofi, Sanofi fights against counterfeit medicines, http://en.sanofi.com/Images/33151\_DP\_Counterfeit.pdf

Table 1. 5G Health Vertical Use Case Scenarios, Technological, Regulatory and Business Case Specifications

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Use Case | 5G Technology | Regulatory | Business | Bandwidth / data volume |
| Smart Pharma | * LPWA
* mm Waves
* Network slicing
* Multi domain orchestration
* 100 x connections
* Intelligent networks
* Terminal with network control capacity
* 1/10 of energy consumption
 | * Medical Product Legislation
* International standardization
* National and EU privacy rules
* Safe Harbouring (EU)
* National eHealth legislation (for example Germany, Austria (ELGA), Denmark (Sundhed)
 | * Transition of business models of pharmaceutical industry from manufacturing to service
* Massive enhancement of adherence
* Prevention of serious episodes, sick days, hospitalization and death
* Combination of pharmaceutical and non-pharmaceutical therapy
* Patient feedback
* Use of authorized data for research purposes
* Pharma – Telco joint ventures
* Medication incompatibility
* GS1 compliance
* QoS management
* Governance
 | < 1Mb per unit per day |
| Precision Medicine /Personalized Medicine | * LPWA
* 4G
* mm Waves
* Multi domain orchestration
* Mobility support at speed
 | * Medical Product Legislation
* International standardization
* National and EU privacy rules
* ISO 27000
* ISO 80001
 | * Tagging and tracking of personalized medicines
* Time management and synchronization
* Telemedicine
* VOIP
* GS1 compliance
 | 5 Mbps or  |
| Hospital at Home | * mm Waves
* 4G
* LPWA
* Multi domain orchestration
* Real-time
 | * Universal health and care budgets
* National “Social Legislation”
* National eHealth legislation (for example Germany, Austria, Denmark)
* Mandatory conformity marking, such as for example CE
* National and EU privacy rules
* ISO 27000
* ISO 80001
 | * Transition of health care delivery to distributed patient centric care
* Speed up transition from hospital to home
* Improved mental health management
* Home diagnostics (for example ultrasound scanner, echocardiogram, Doppler)
* Empowering patients to make decisions on care priorities
* Releasing “Social Capital” equity
* Peer-to-peer
* Self-help groups
* Monitoring (for example blood glucose, heart rate, blood pressure, regular infusions, feeding pumps, etc)
* GS1 compliance
* Governance
* Billing
 | 5 Mbps |
| Surgical Robotics | * mm Waves
* Low latency
 | * Medical device regulations
* Mandatory conformity marking, such as for example CE
* BEREC rules on Net Neutrality
 | * Specialists to support generalists in peripheral locations
* Improvement of quality of care through availability of expert input in real time
* Enhancing patient safety
* High resolution 3D video imaging (4k plus)
* Augmented reality
 | >50 Mbps  |
| Social Robotics | * mm Waves
* Low latency
* Mobility support at speed
* Multi-tenancy
 | * Mandatory conformity marking, such as for example CE
* BEREC rules on Net Neutrality
 | * Wide-spread manual support in activity of daily living (ADL) which might not require a human
* HD video
* Augmented reality
 | < 25 Mbps |
| Antibioticsresistance prophylaxis | * 4G
* mm Waves
 | * Medical product legislation
* Mandatory conformity marking, such as for example CE
 | * Automated screening of samples (swaps, urine, blood)
 | 200 Kb per sample |
| Medical device management (in hospital and at home) | * LPWA
* mm Waves
* 4G
* Multi-tenancy
* Multi-domain orchestration
 | * Medical product legislation
* Warranty
* Mandatory conformity marking, such as for example CE
* ISO 80001
* ISO 27000
 | * Obligatory maintenance as defined by medical product legislation
* Prevention of nosocomial infections by contamination detection
* Malfunction alert
* QoS monitoring for vendors and service providers
 | 200 Kb per unit per day |
| Smart Packaging | * LPWA
* Multi domain orchestration
* 100 x connections
* 1/10 energy consumption
 | * Medical product legislation
* ISO 80001
* ISO 27000
 | * Counterfeiting: 1 in 10 drugs sold globally is fake. For 1,000 dollars invested, a criminal can garner 20,000 dollars in profits with trafficking heroin and 400,000 dollars by dealing in counterfeit drugs [21]
* Supply chain management of value drugs
* Storage and transport conditions (cooling chain, humidity, temperature, etc)
* Block-chain technology to establish audit-trail
* GS1-compliance
 | 300 Kb per unit per week |
| Artificial organsEndo-prostheticsArtificial limbsBody Area Networks | * mm Waves
* 4G
* LPWA
* Multi-tenancy
* Mobility support at speed
* 1/10 energy consumption
 | * IEEE 802.15.6
* ISO 80001
* ISO 27000
* BEREC rules on Net Neutrality
 | * Pacemaker
* Insulin pumps
* Brain pacemakers
* In vivo sensors
* Sensors in endo-prosthetic devices
* etc
 | 200 kb per unit per day |
| Emergency services | * 4G
* mm Waves
* LPWA
* Terminal with network control capacity
* Multi domain orchestration
* Multi-tenancy
 | * BEREC rules on Net Neutrality
* Emergency regulations
* Mandatory conformity marking, such as for example CE
* Medical product legislation
 | * Tagging and tracking
* Telemedicine
* Documentation
* Modularity
* Remote diagnostics (ultrasound)
 | 5 Mbps per unit |
| Wound-management | * LPWA
* 1/10 energy consumption
 | * Medical product legislation
 | * Smart wound dressings
* Decubitus monitoring
 | 100 kb per unit per day |
| Wellness and Fitness | * LPWA
* 4G
* mm Waves
* 1/10 energy consumption
 | * Mandatory conformity marking, such as for example CE
* Potentially medical product legislation
 | * Health insurance discount
* Non-pharmaceutical therapy (for example diabetes, high blood pressure and hypercholesterolemia)
 | <1Mbps |