Wireless Smart Monitoring of Patient Health Data in a Hospital Setup

Alexander Bødker Andersen and Albena Mihovska(✉)

BTECH, Aarhus University, Herning, Denmark
201407929@post.au.dk, amihovska@btech.au.dk

Abstract. Monitoring of patient health data is an important part of the medical treatment of a patient. This paper studies how wireless smart technology for patient monitoring can be used and implemented in a hospital setup. The research focuses on the patients and the clinical perspective on how wireless monitoring of health data in the hospital can be utilized for support of mobility of the patients and for cost-efficiency of the patient pathway during hospitalization. Furthermore, is it investigated which strategic considerations should be made before developing and implementing the technology. It is proposed to design the wireless monitoring system in the hospital as a LPWAN network system with the DASH7 network protocol for data transmission as it would have the advantages of low cost, long range and low-energy consumption. The results indicate that patients will benefit from the implementation of a wireless monitoring system in terms of increased mobility at the hospital. Moreover, the clinical personnel could potentially achieve a decrease in workload and an improvement of the quality of treatments.

Keywords: Wireless monitoring · Healthcare · IoT

1 Introduction

The Danish healthcare system faces several challenges in the near future, such as rising expenses, an increasing amount of patients with long term and chronic diseases and an increasing workload for clinical personnel in the hospitals. Several national strategies and technologies are emerging as potential solutions to some of the challenges. The Danish healthcare system has a large focus on new emerging solutions such as the digitalization of data and workflows, smart IT systems and the Internet of Things. One of the areas that are rapidly advancing in new technologies is monitoring of patient health data, which is an important part of the diagnosis and treatment of patients in the hospital.

The project of modernizing the Danish hospitals is a part of the big visions and goals set by the Danish government, Danish Regions and the Local Government Denmark. The three institutions, in a collaboration, have made a national quality program [1–3]. The quality program is a framework developed for ensuring that the Danish healthcare system has a high level of quality in the treatment of patients and a balanced focus on activities, quality, results and costs. The national quality program has three overall goals:

© ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2019
Published by Springer Nature Switzerland AG 2019. All Rights Reserved
V. Poulkov (Ed.): FABULOUS 2019, LNICST 283, pp. 37–48, 2019.
https://doi.org/10.1007/978-3-030-23976-3_4

- Improved state of health in the population;
- High patient experienced quality;
- Low costs per treated citizen.

An improved systematic use of health data with a focus on the management processes and the development of competencies is critical for an improved patient involvement [4]. Digitalization of data, procedures and workflows is part of the development and improvement of the Danish healthcare system. The digitalization of the healthcare system is underpinned by the implementation and use of information and communication technology (ICT). The use of ICT in the healthcare system is defined as e-health and has potential benefits for optimizing the processes and for improving the health data collection by, for example, tracking persons and objects in the hospital or smart monitoring of patients by wearable technology [5].

The monitoring is a continuous observation of a patient's vital signs, and it is necessary for a correct diagnosis. The traditional way of monitoring is manually using technology in form of devices that can monitor a specific vital sign of a patient. The device can, for example, be an electrocardiogram (ECG) for monitoring heart rhythms, a thermometer, for the measurement of a patient's temperature or inflatable pressure cuffs with a stethoscope to monitor the blood pressure. The monitored health data is assessed and analysed by clinical personnel such as medical doctors and nurses. The technology of patient monitoring has advanced in the recent years to include and obtain data from wearable sensors and devices, which can continuously and in real-time monitor and send the patient's data to the clinical personnel [6–8]. The remote monitoring has the advantage of providing vital health data related to a patient independently of a specific location [6].

Monitoring is a vital part of the treatment and diagnosis of patients and it is one of the areas that are in rapid development with new technologies emerging, such as the Internet of Things (IoT), smart technology and big data. The purpose of this research study was to identify key technical, ethical, and user aspects related to the successful acceptance and deployment of this technology on a wider scale.

This paper is further organized as follows. Section 2 describes the state-of-the-art in the area. Section 3 proposes the implementation model, which is based on DASH7 and LPWAN technologies. Section 4 analyzes the potential barriers for the implementation of the system. Section 5 concludes the paper.

2 Digitalization and Health Data

2.1 Digitalization in the Danish Healthcare System

Digitalization and digitization have become extensive and they are topics with a large focus in the Danish healthcare system. The Danish healthcare system is, in general, a front-runner in the use of digital health and the system is characterized by its large use of electronic communication and IT systems in hospitals. A new national strategy was launched by the Danish government, Danish Regions and Local Government Denmark in January 2018 and the strategy has the goals of high use of digital health data in a combination for both primary- and secondary user purposes. The primary user purpose

is using digital data for direct care and treatment of patients and citizens, while the latter is using digital data for research, quality assurance and management in the healthcare sector [3].

Health data is systematically collected throughout the Danish healthcare system including in the hospitals and by the general practitioners. The large amount of data is an important part of the monitoring and treatment of patients and the data are saved in electronic health records, the national patient register and medication databases among others. The health data is transported across, both, the primary and the secondary sector as well across several departments and institutions such as hospitals, general practitioners, local authorities and home care services.

The Danish healthcare system has a large focus on the prevalence of IT standards for facilitating such data transportation through electronic communication [9]. The Danish healthcare system's high use of ICT, digital workflows and e-health, in general, secures a fully integrated use of digital health data. However, the Danish healthcare system seeks to improve the quality and efficiency of the offered healthcare services with a coherent collaboration across sectors and departments, while having a high focus on continuously improving the use of digital health [9].

2.2 Wireless Technologies for Smart Monitoring

A key requirement for a smart monitoring technology is that it is energy-efficient because most of the elements of such a network would be battery-driven devices. Narrowband technologies, such as Low Power Wide Area Networks (LPWAN) have been gaining a lot of attention for use in the above scenario because of their capability to provide a high energy-efficient transmission of small data packages with a high coverage at low costs [10]. The use and implementation of LPWAN in the Danish infrastructure and industries are in the early stage of progress. However, the technologies are emerging and it is predicted to have a high influence on the societies in the near future. There exists a broad range of different LPWAN technologies and operators - each with their individual advantages, features and limitations.

Some of the most well-known and important technologies for LPWAN are the following:

- Sigfox;
- NarrowBand-IoT;
- LoRaWAN;
- DASH7.

DASH7 technology has been explored by researchers to develop a radio-frequency identification (RFID) tracking system that places tags on beds, materials and equipment and makes it possible to locate either inventory or patients in a hospital environment. Such system has currently been implemented at Aarhus University Hospital (AUH) and is the largest RFID installation of this kind in the world, with 1.000 hospital beds and 300.000 pieces of material to be part of the tracking system with the availability of locating them wirelessly [11, 12].

DASH7 is based on the ISO/IEC 18000-7 international standard, which provides technical specifications on RFID devices and can be used in item management applications. It is suitable to describe the use and specifications on RFID devices operating at the 433-MHz frequency band. The low frequency enables a high propagation with penetration ability on multi-floored buildings and it operates with a low energy consumption. The DASH7 uses asynchronous communication and the network consists of gateways and endpoints. The gateways have the functionality of receiving data and processing it, whereas the endpoints are simpler devices, containing sensors that monitor the needed data and information. The endpoint is designed to be in a sleep mode, which enables the low energy consumption and allows for periodically receiving and sending data to the gateways.

DASH7 can be used as a wireless technology for facilitating and enabling of data transmissions to support effective patient care. DASH7 has a high reliability potential in a medical environment compared to Wi-Fi, Bluetooth and ZigBee as it is not suffering from interference problems while having the advantages of low power, long range and low cost [16].

2.3 Smart Monitoring of Patients Using the Internet of Things

Using a wearable monitoring technology, which can remotely monitor patients is a part of the term called 'smart technology'. The environment of using smart technology consists of objects that can exchange, store and process data and information applying the concept of IoT [16]. The possibilities of IoT in the healthcare industry fits the emerging challenge of an increasing number of patients with chronic and long-term diseases due to the fact that it can create value by providing different monitoring functions and application possibilities [7, 8, 16]. This is also supported by a rapid evolvement of wearable technology, such as computerized watches, sensors integrated in textiles and smart glasses. The trend is towards technology with minimized sizes and a higher possibility of monitoring biomedical data, including the vital signs of patients [17]. The use of wearable devices for monitoring is potentially making the treatment process more patient-centric hence making the individual patient possible of managing their own health data monitoring and giving the possibility of continuous ambulatory monitoring of vital signs with the advantages of enabling mobility and minimising interference with other activities [18].

Monitoring of Vital Biosignals. Monitoring of patients consists of several different monitoring technologies and devices since the human body is producing multiple various measurable vital biosignals. The signals can be bioelectrical or biochemical signs and the signals are monitored, analyzed and assessed for diagnosis and treatment of patients. Some of the most important vital biosignals are summarized in Table 1.

Table 1. Monitoring of vital biosignals (based on [12])

Vital biosignals	Description	Monitoring technology
ECG	Information of the cardiac electrical cycle shown as an ECG waveform. Used to analyse the cardiac rhythm, ischemic changes and to predict and treat acute myocardinal infarctions and coronary events	Electrodes used for transduce ionic current from the heart into electron current
Heart rate	Information about the physiologic status by indicating changes in the heart cycle	Data extraction from ECG or use of inertial sensors
Blood pressure	Indicating the pressure exerted by blood against the arterial wall. Provides information about the blood flow including systole and diastole. Can monitor hypertension and hypotension	Use of inflatable pressure cuffs with a stethoscope or sensors on the wrist
Blood oxygen saturation	Monitor oxygen level in the patient's blood. Used for detecting hypoxia	Photoplethysmography technology and pulse oximetry principles on a patient's finger
Body temperature	Balance between heat production and heat loss. Detection of too high or too low body temperature	Measurement of core and skin temperature by sensors

3 Impact of the Wireless Monitoring Technology Implementation in a Hospital Environment

The impact was evaluated for the case study of an implementation at AUH, Aarhus, Denmark, and relates to both types of potential users, namely, the patients and the medical personnel. The RFID tracking system at AUH uses small tags, which are attached to the materials or the staff's name badge.

3.1 Requirements for the Wireless Monitoring System

The users had a key role in identifying the technical requirements for the proposed architecture. For this purpose, questionnaires were carried out with both, patients and medical personnel. Additional interviews were carried out with selected medical personnel.

Patients Requirements. Changes in the vital biosignals of patients carry important information used for their treatment and diagnosis in the hospitals. The human body is producing multiple biosignals, which are used when clinical personnel assess the health condition of a given patient. In order to find out how using smart technology in wireless monitoring could affect the treatment of patients in the hospital, a questionnaire was conducted at AUH for the purpose of getting data on patients', and their relatives', the

view on using wireless technology in the hospital and monitoring equipment in general. The questionnaire got a total of 10 respondents where the one half are women and the other half are men. The ages of the respondents are distributed in the ages from 18 to 75, where most of them are in the age categories 46–55 and 56–65. Three of the respondents have been hospitalized in the past two years and the remaining are either relatives or ambulant patients. The respondents were asked about their experience on using monitoring technology including a question whether they have felt inconvenience by the way they have been monitored and a question addressed to the potential limitation of their freedom of movement in the hospital.

The results from the questionnaire show that 100% of the respondents either strongly disagree or disagree on the statement of feeling inconvenience in the way they have been monitored.

Concerning the potentially limited freedom of movement because of monitoring equipment, 80% either strongly disagree or disagree and 20% agree on the statement. The answers regarding the current monitoring procedures and technologies at AUH indicates that the patients are satisfied with the monitoring as it is. Hence, the current technology is well-functioning and does not disturb or unsettle the patients.

However, when the respondents were asked if they would prefer higher freedom of movement when hospitalized, they answered with a higher distribution among the answers with 20% 'strongly disagree', 10% 'disagree', 40% were neutral and 30% agreed on the statement. This could indicate that some patients and their relatives would like to have an increased amount of freedom of movement in the hospital but it is not valid for all of them. The respondents were moreover asked about the idea of having the exact location of the patients visible continuously for the clinical personnel. The respondents were predominantly positive about the idea as 80% either agreed or strongly agreed on the statement of being fine with continuously being tracked and 20% were neutral. These results indicate that patients have no problem with the monitoring technology being able to inform the clinical personnel about the location at the hospital.

In addition, medical doctors were also interviewed, with regard to mobility of the patients at the Pediatric ward. An increased mobility based on use of wireless monitoring would be desired for the case of newborn babies during their transfer from to their parents and back again. Another potential hurdle with the current cable-based monitoring technology at the hospital is about patients in intensive care where the high amount of cables for monitoring technologies can trouble and disturb the treatment of patients. Further, patients would be more likely to be physically active when they are not inhibited by many wires around their body.

Medical Personnel. Interviews were carried out with medical doctors (MDs). The MDs could see potentials gains of the technology if, however, the monitoring will satisfy the requirements of being reliable, user-friendly and highly dependable for successfully using it in the treatment of patients. The interviews indicate that using wireless monitoring technology with a tracking function of hospitalized patients could improve the treatments in the hospital. Being able to continuously having the exact location of patients could potentially ease the tasks of the clinical personnel in terms of locating the patients in an easier way.

A tracking function could potentially make resource savings for the clinical personnel in the hospital, which is advantageous due to the challenges of rising expenses and the shortage of clinical personnel in the healthcare system.

Technical Requirements. The technical requirements can subdivided into functional and non-functional.

Functional Requirements

- The monitoring device shall monitor vital biosignals by sensors. The vital biosignals can be: blood pressure, heart rate, ECG, blood oxygen saturation or body temperature.
- The system shall include an alarm system. The alarm system notifies the clinical personnel if the measured values from the biosignals surpasses preset thresholds.
- The system shall send continuously the monitored data to the clinical personnel's equipment.
- The system shall have a tracking function where patients' location can be shown in case of the alarm system notifies the clinical personnel.

Non-Functional Requirements

- The monitoring technology shall be user-friendly and dependable.
- The data transfer from the monitoring system shall be reliable.
- The data transfer from the monitoring system shall be wireless.
- The monitoring system shall be designed according to the LPWAN protocol DASH7 and ISO 18000-7. The monitoring devices shall be operating at 433-MHz frequency band.

3.2 Proposed Wireless Monitoring Architecture

The proposed wireless monitoring architecture is shown in Fig. 1. It consists of the overall monitoring system and three entities, namely, Patient, Clinical personnel and Data storage.

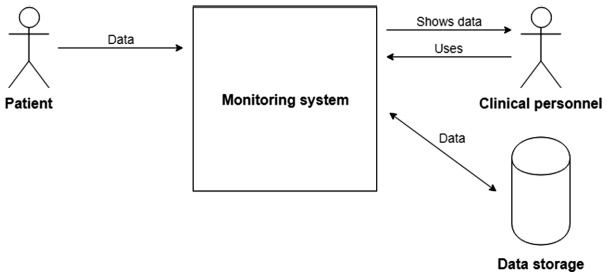

Fig. 1. Wireless monitoring architecture for hospital environment.

The Monitoring system shall be seen as a black box system consisting of all the sensors, connections, algorithms etc., which are part of the system. The entities are described below.

The Patient is a primary entity that interacts with the wireless monitoring system. The patient shall be interpreted as a human, in any age, being treated at the hospital.

The treatment of the patient can be acute, ambulant or regarding a hospitalization of the patient. The patient interacts with the monitoring system in terms of a monitoring or measurement of a vital biosignal, such as blood pressure, ECG, blood oxygen saturation or localisation of the patient. The monitoring enabled by sensors attached to the patient's skin.

The Clinical Personnel are the other primary entity of the monitoring system. The clinical personnel shall be interpreted as a human employed at the hospital and can have the function of a nurse, medical doctor or another clinical function. The clinical personnel interacts with the system in a double way. The first is when the personnel uses the monitoring system to measure and monitor the patients, which is an important part of their tasks and functions at the hospital. The interacting is double sided, because the system sends and shows the monitored data to the clinical personnel's equipment which is used for diagnosis and treatment of the patient.

The Data Storage is a secondary entity used for storage of the monitored data from the patients. The data storage is connected to the monitoring system and the monitored data gets transferred back and forth from the system.

The overall system architecture is shown in Fig. 2 and its different components are found and analyzed based on information from [13, 19]. The sensors are attached to the patients with specific on-body placements all dependent of, which biosignal being monitored and the condition of the patient. The sensor module can be measuring vital biosignals such as ECG, blood pressure, heart rate, body temperature, blood oxygen saturation or the sensor can provide the localisation of the patient. The sensors are endpoints in the DASH7 network that transmits the data asynchronously to the gateways.

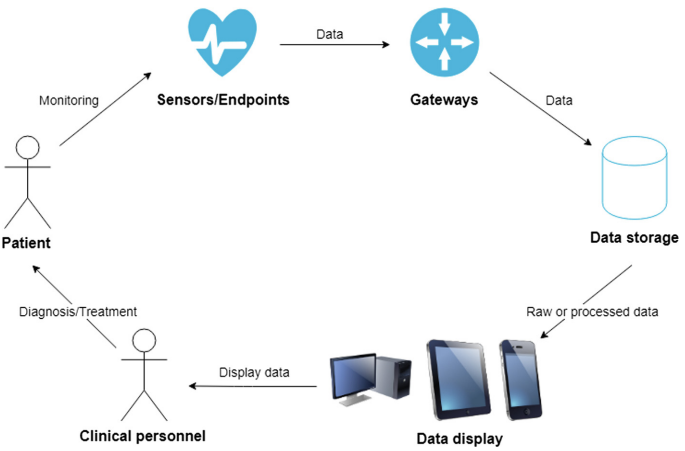

Fig. 2. Overall system architecture.

The gateway is a device, which continuously is listening for packets of data from the endpoints. The gateway receives the monitored data from the patients at transmit further in the hospital's network. The gateway can be installed as several devices throughout the hospital.

The data display component of the system architecture consist of the technology displaying the monitored and processed data from the patients. The data display can be designed in several ways dependent on the user and the setup in the hospital. The technology can be handheld, such as smartphones or tablets, and it can be stationary, such as computer screens or other screens. The data is transmitted by the data storage component and is either raw or processed dependent on which biosignal is being measured and what the purpose of the signal is.

4 Barriers to Real-Hospital Implementation and Deployment

4.1 Technical Barriers

The monitoring system has an extensive amount of components and different technical connections and the system faces several barriers that can potentially limit the clinical implementation of the monitoring system. The technological setup is in an early stage of the design and development process, that is why specifications of the wireless monitoring have to be carefully defined further for a successful implementation of the system.

One of the potential technical barriers is the design of the sensor module in the wireless monitoring system. The type of sensor used in the system depends on several aspects, including what kind of biosignal is being monitored as each signal can be measured with different kinds of electrodes and sensors. The sensors have to be resistant to motion artefacts, because one of the benefits of wireless monitoring is to have an increased patient mobility. The wireless sensor module moreover have to incorporate solutions to electromagnetic interference for getting reliable data. It is recommended to design the data storage and processing components with modern technologies and techniques such as machine learning, artificial intelligence or a clinical decision support system for a more successful use and implementation of the monitoring system. In that way, will the monitored data provide an even more informative information to the clinical personnel, which could potentially decrease the workload for the staff.

4.2 Compliance

Compliance is defined as "the ability of an individual or organisation to implement, manage and follow law, regulations, standards, guidelines, norms and similar normative directives" [20]. When a product is in compliance with the existing regulations and standards, it would have the advantage of fulfilling the requirements, which facilitates the deployment implementation. The healthcare sector has a large number of regulations and requirements for any technology aimed for medical use.

CE Marking. When developing technology to be used in the hospitals and in the healthcare sector in general it is required to investigate if the technology has to be classified as a medical device. By spring 2020, the classification of medical devices would follow the regulation "Medical Device Regulation 2017/745" (MDR) made by the European Parliament [21]. This classification process is key to the successful market implementation. According to Article 2 in MDR, the wireless monitoring technology can be defined as a medical device with the specific purpose of monitoring patients for treatment and diagnosis. Depending on the intended use of the technology and its inherent risks, it will be classified and divided in one out of four risk classes: I, IIa, IIb and III. The classification will be carried out according to Annex VIII in MDR. The Annex contains a set of classification rules, and by the intended use of the monitoring technology, it can be concluded that for our case, rule 10 applies. The technology consists of active devices intended for diagnosis and the monitoring of vital physiological parameters, and the nature of variations in the parameters could immediately result in danger to the patients (class IIb).

The classification as a medical device in class IIb means that AUH, or another manufacturer of the product, will have to demonstrate that the technology meets the requirements in the MDR by conducting a conformity assessment before CE marking the product and using it in the hospital.

The requirements in MDR consist of general safety and performance requirements such as clinical evidence and investigation, physical properties and performance characteristics. The manufacturer, furthermore, has to formulate technical documentation with specifications and models for the technology. For completing the process and satisfying the requirements of MDR, it is recommended to follow the harmonized standard [22]. The road to being in compliance with MDR and the harmonized standards can be a complex and expensive process, why it is recommended to make a collaboration with companies or consultants who are experts within the field of market medical devices in the healthcare sector.

Technical Compliance. Besides the harmonised standards and requirements of the MDR, due to the classification as a medical device, it is advisable to be in compliance with ISO/IEC 18000-7 and the DASH7 Alliance Protocol. The ISO/IEC 18000-7 standard describes the specifications and detailed technical description of air interface communication at 433 MHz, and the standard will be applicable in the development of the wireless monitoring system [23]. Using the DASH7 Alliance Protocol will be helpful in the development as it contains specifications and open source data. Being in compliance with ISO/IEC 18000-7 and the DASH7 protocol is advisable and can potentially ease the development of the technology and make of the technical requirements in the development specific.

The General Data Protection Regulation (GDPR) was introduced in May 2018 and it is a European regulation for data protection and privacy. The GDPR contains a set of requirements that each organization must comply with. Especially, healthcare organizations, such as the hospital, have a unique set of requirements since they are having a high use of health data and personal data collected from the patients. The wireless monitoring technology provides several kinds of data from the patients including personal genetic data and biometric data. Therefore, the manufacturer of the monitoring

technology required to facilitate cybersecurity capabilities and satisfy other requirements. It is largely recommended to incorporate and satisfy the requirements of GDPR for a successful implementation of the technology. A large hospital, normally would have a strong experience with handling health data and the relevant requirements in the legislation.

5 Conclusion

This paper investigated how wireless monitoring technology could be used and implemented in a large hospital in Denmark. A system concept based on the DASH7 protocol was proposed. The problem statement and research questions have been focused on the patient and the clinical perspective of how the proposed system for wireless monitoring of health data in the hospital could improve the patients' well-being and treatment, while allowing for more cost-efficiency of the hospital operations. The research was performed with a general deductive approach by a research design consisting of a case study including the used data collection techniques, state-of-the art analysis, interviews and a questionnaire. Several strategic considerations have to be included in the development and implementation of the wireless monitoring system for a successful process. Compliance with MDR, GDPR and other essential standards is a critical requirement. It can be overall concluded that the use and implementation of a wireless monitoring system could improve the monitoring of health data in the hospital. There are several potential benefits with a clinical perspective, but the technology is in a very early stage of the process and the topics have to be investigated further for a more clear conclusion can be made.

References

1. Central Denmark Region: Inauguration of the new super-hospital in aarhus (2017). http://www.en.auh.dk/press-room/news-archive/2017/inauguration-of-the-new-superhospital-in-aarhus/. Accessed 02 Jan 2019
2. Danske Regioner: Pres på sundhedsvæsenet, Technical report, Danske Regioner (2015)
3. Healthcare Denmark: Danish digital health strategy 2018–2022 now available in English (2018). https://www.healthcaredenmark.dk/news/listnews/danish-digital-health-strategy-2018-2022-now-available-in-english/. Accessed 29 Dec 2018
4. Ministry of Health: Nationalt kvalitetsprogram for sundhedsområdet 2015–2018, Technical report, Ministry of Health, Denmark (2015)
5. The National eHealth Authority [2013], Making ehealth work, Technical report, The Danish Government, Local Government Denmark and Danish Regions
6. Omoogun, M., Ramsurrun, V., Guness, S., Seeam, P., Bellekens, X., Seeam, A.: Critical patient ehealth monitoring system using wearable sensors. In: 2017 1st International Conference on 'Next Generation Computing Applications (NextComp), pp. 169–174. IEEE (2017)
7. Kyriazakos, S., et al.: "eWALL: an open-source cloud-based eHealth platform for creating home caring environments for older adults living with chronic diseases or frailty. Wireless Pers. Commun. **97**, 1835 (2017). https://doi.org/10.1007/s11277-017-4656-7

8. Mihovska, A., et al.: Integration of sensing devices and the cloud for innovative e-Health applications. In: Velez, F.J., Derogarian Miyandoab, F. (eds.) Wearable Technologies and Wireless Body Sensor Networks for Healthcare, Chapter 11,, IET Publications (2019). expected April 2019
9. Ministry of Health: "Healthcare in Denmark - an Overview", Technical report, Ministry of Health, Denmark (2017)
10. Herlich, M., von Tüllenburg, F.: Introduction to narrowband communication (2018)
11. P 360 [n.d.]: Mere tid til patienterne: 300.000 enheder rfid-tagges på skejby. http://p360.dk/mere-tid-patienterne-300000-enheder-rfid-tagges-pa-skejby. Accessed 02 Jan 2019
12. Lyngsoe Systems [n.d.], 'World's largest rfid-based tracking installation of its kind'. https://www.lyngsoesystems.com/en/case-stories/auh-aarhus-university-hospital/. Accessed 02 Jan 2019
13. Weyn, M., Ergeerts, G., Berkvens, R., Wojciechowski, B., Tabakov, Y.: Dash7 alliance protocol 1.0: Low-power, mid-range sensor and actuator communication. In: 2015 IEEE Conference on 'Standards for Communications and Networking (CSCN), pp. 54–59. IEEE (2015)
14. Weyn, M., Ergeerts, G., Wante, L., Vercauteren, C., Hellinckx, P.: Survey of the dash7 alliance protocol for 433 mhz wireless sensor communication. Int. J. Distrib. Sens. Netw. **9** (12), 870430 (2013)
15. Park, A., Chang, H., Lee, K.J.: How to sustain smart connected hospital services: an experience from a pilot project on IoT-based healthcare services. Healthcare Inf. Res. **24**(4), 387–393 (2018)
16. Yearp, A., Newell, D., Davies, P.,Wade, R., Sahandi, R.: Wireless remote patient monitoring system: Effects of interference. In: 2016 10th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), pp. 367–370. IEEE (2016)
17. Haghi, M., Thurow, K., Stoll, R.: Wearable devices in medical internet of things: scientific research and commercially available devices. Healthcare Inf. Res. **23**(1), 4–15 (2017)
18. Dias, D., Paulo Silva Cunha, J.: Wearable health devices—vital sign monitoring, systems and technologies. Sensors **18**(8), 2414 (2018)
19. Baig, M.M., GholamHosseini, H., Moqeem, A.A., Mirza, F., Lindén, M.: A systematic review of wearable patient monitoring systems–current challenges and opportu nities for clinical adoption. J. Med. Syst. **41**(7), 115 (2017)
20. Tambo, T.: Compliance management, in 'Lecture, Aarhus University - BTECH' (2018)
21. European Commission [n.d.]: The new regulations on medical devices. https://ec.europa.eu/growth/sectors/medical-devices/regulatory-frameworkda. Accessed 06 Jan 2019
22. MHRA [n.d.]: An introductory guide to the medical device regulation (mdr) and the in vitro diagnostic medical device regulation (ivdr), Technical report, MHRA
23. International Organization for Standardization: ISO/IEC 18000-7: Information technology—radiofrequency identification for item management – parameters for active air interface communications at 433 mhz, Standard, International Organization for Standardization, Geneva, CH (2014)