CHAIN REACTIONS

THEMATIC BRIEF HEALTH 2

THE INTERNET OF THINGS IN HEALTH

ABOUT INNOVATION BRIEFS

CHAIN REACTIONS addresses the challenge for industrial regions to increase regional capacity to absorb new knowledge and turn it into competitiveness edge and business value. There is a strong need to help SMEs to overcome capacity shortages for innovation and integration into transnational value chains.

The project aims at empowering regional ecosystems with the knowledge and tools to help businesses overcome those barriers and generate sustained growth through value chain innovation. During the project lifetime CHAIN REACTIONS publish thematic briefs presenting the rationale behind specific innovation deployment within selected business areas.

The new paradigm known as the "Internet of Things (IoT)" has an extensive applicability in numerous areas, including healthcare. It is also the baseline for the deployment of Artificial Intelligence (AI) technologies in this area presented in previous CHAIN REACTIONS briefs. The full application of IoT in healthcare area is a mutual hope because it allows medical centers and professionals to function more competently and patients to obtain better treatment. In the present pandemic situation, all countries around the world are fighting with COVID-19 and are all still looking for a practical and cost-effective solution to face the related problems. Researchers and engineer in physical and computer sciences are attempting to take such challenges. This brief aims to provide awareness of IoT innovative market applied to healthcare and its significant applications for COVID-19 pandemic.

IoT in Health

Internet of Healthcare Things enabling full remote healthcare monitoring

Healthcare industry is among the fastest to embrace IoT-based solutions. It is being considered one of the key industry drivers and a special concept for it, considering the IoT application on e-Health. The Internet of Healthcare Things (IoHT) is a concept that describes uniquely identifiable devices connected to the Internet and able to communicate with each other, used in the medical and healthcare area. These solutions enable, for example, localization and real-time information about assets and also remote or automatic management of resources. These leads as a whole to higher quality care and time savings, while ensuring patient safety. Thanks to the IoHT, managing medical facilities is getting more efficient with uninterrupted access to equipment, data and patients' information.

From technical point of view, an IoHT based solution basically includes a network architecture that allows the connection between a patient and healthcare facilities as, for example, systems for electrocardiography, heart rate, diabetes, and other different kinds of monitoring of body (vital) signs based on biomedical sensors. These sensors include for instance pulse, oxygen in blood, airflow, body temperature, glucometer, galvanic skin response, blood pressure, electromyography and patient position (accelerometer).

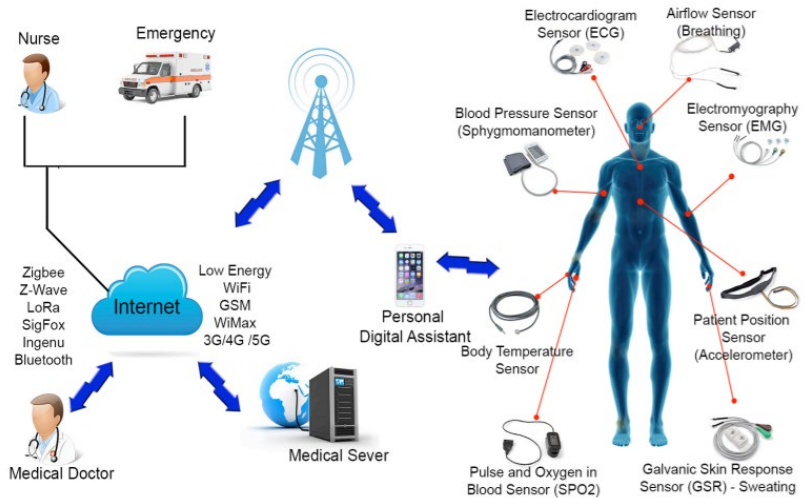

Figure 1. Illustration of an architecture for remote healthcare monitoring system. [1]

For the healthcare industry the rise of IoHT has many applications as, for instance:

- Reducing emergency room wait time
- Tracking patients, staff, and inventory
- Enhancing drug management
- Ensuring availability of critical hardware
- Introducing wearables and devices which make lives of patients more comfortable.

The numerous advantages of IoHT can be summarized as follow:

Advantages for patient	Advantages for medical staff	Advantages for managers
• Fast and easy notification of personnel about problems • Continuous monitoring of patients' conditions and saving their parameters • Increasing safety by providing remote medical care and detection of dangerous events • Faster and more effective access to medical care, and therefore to diagnosis and treatment • Comprehensive care outside medical facilities • Automatic transfer and analysis of data collected by devices • Remote medical consultations • Automatic reminders	• Constant access to patients' full medical history including latest data • Help of algorithms which can detect abnormalities • Easy location of patients with orientation difficulties (e.g. those suffering from dementia) • Quick and easy location of devices and other equipment • Constant access to essential information about the patients from mobile application • Patients' database available through a web browser	• Notifications when devices leave a defined area • Control of access to data and resources • Automatic or remote control of lighting systems, which can save energy and regulate patients' circadian rhythm • Analysis of resource consumption • Movement detection via sensors and alerts • Preventive/predictive maintenance • Quick data access and transfer in the event of emergency • Real-time fault and error detection • Maintenance automation

Table 1 - Advantages of IoHT [2]

Use of IoHT in modern clinical setup

When the data collected with IoHT devices are combined with electronic health record (EHR) systems, a new dimension is opened and many possibilities and uses are born. This technology can play there a pivotal role in transforming modern healthcare systems making them more efficient and robust [3].

IoT for hospitals enables real-time alerting, tracking, and monitoring, which permits hands-on treatments, better accuracy, apt intervention by doctors and improve complete patient care delivery results. Real-time monitoring via connected devices can save lives in event of a medical emergency like heart failure, diabetes, asthma attacks, etc. The IoT device collects and transfers health data (for instance blood pressure and oxygen) while dropping notifications to people about critical parts via other linked devices.

Apart from monitoring patients' health, IoHT devices tagged with sensors can also be used for tracking real time location of medical equipment like wheelchairs, defibrillators, nebulizers, oxygen pumps and other monitoring equipment. Deployment of medical staff at different locations can also be controlled and analysed real time.

As the spread of infections is a major concern for hospitals, IoHT-enabled hygiene monitoring devices can help in preventing patients from getting infected. IoHT devices also help in asset management like pharmacy inventory control, and environmental monitoring, for instance, checking refrigerator temperature, and humidity and temperature control.

Ambient Assisted Living (AAL)

The exact definitions given to the Ambient Assisted Living (AAL) sector and hence to the AAL market differ. Many of the definitions are overlapping but often overly restrictive or not covering all aspects of AAL. In this CHAIN REACTION brief, we will follow the definition of AAL directly only focusing on healthcare.

This way, Ambient Assisted Living (AAL) is an IoT-based service that supports care of lonely elderly or incapacitated patients. These solutions are aiming to extend the independent life of the individuals in their homes by providing more safety [4]. AAL is usually connecting users to smart objects and different types of sensors, such as blood pressure sensors. At a whole, AAL investigates the development of systems involving the use of different types of such sensors. These systems help to monitor activities and vital signs of lonely elderly or incapacitated people to detect emergency situations or deviations of desirable medical patterns. But AAL not only provides a safer environment: it also increases autonomy and stimulates the user to have a more active life [5].

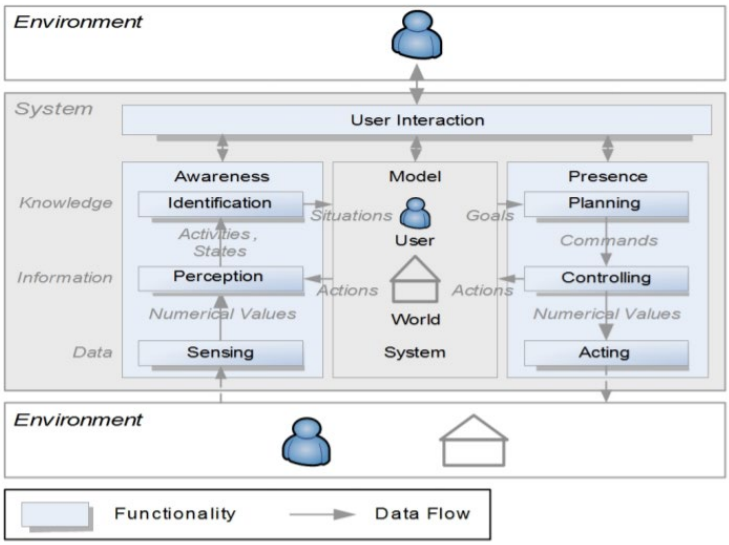

Figure 2 - Ambient Assisted Living Reference Architecture [5].

Ambient assisted living solutions are providing innovative products and services being key to market growth. A recent Market Research Future (MRFR) market study reveals that AAL

market is expected to grow by 19% CAGR by forecast 2027, thus escalating from USD 2 Billion to USD 13 Billion by 2027 [6]. Occupancy sensors, temperature sensors, medical assistance systems, and communication systems are among the major growth areas of the market.

According to a recent Statista's Digital Market Outlook, the size of the EU AAL market in 2017 was €186m and it would grow to €1,384m by 2021. The largest AAL markets in the EU are there forecasted to be Germany (€383m or 31% of the AAL market in the EU), the UK (€232m, 21%), France (€180m, 13%), and Italy (€139m, 6%) in 2021. Yet, in 2017, the AAL household penetration in these countries was rather limited, ranging just from 0.2% in Italy to 0.5% in Germany, but expected to increase to 3.1% on average by 2021. [7]

Healthcare solutions using smartphones

Many IoHT solutions use smartphones. Nowadays, healthcare and in particular ambient assisted living solutions cannot be proposed and designed without considering mobile health support and smartphone use. These applications usually support diagnosis, clinical communication, provide drug references or medical education. It aims to create a connection between sensors, smartphones, and the healthcare team. Because of the current pandemic situation, this type of IoHT solution has been quickly deployed, in different forms, all around the world.

COVID Track Quarantine

A current critical need in stopping the spread of COVID-19 is the effective quarantine of infected people. Many governments have taken mandatory home quarantine actions to contain the spread of the disease. An app, developed by South Korea and launched in March 2020, allows those who have been ordered not to leave home to stay in contact with case workers and report on their progress. This app also uses GPS to keep track of their location to make sure they are not breaking their quarantine. With this type of app, it becomes easier for health care professionals and the concerned bodies to keep a track on the quarantine. The mechanism behind this IoHT solution is creating a virtual perimeter using GPS, RFID, Wi-fi, BlueTooth signal, as well as cellular network.

COVID-19 tracing apps

The "COVID-19 apps" are mobile software applications for digital contact tracing during the COVID-19 pandemic, i.e. the process of identifying persons who may have been in contact with an infected individual. This specific type of smartphone applications is since months front-page news. Since March 2020, numerous applications were developed or proposed all around the world, with official government support in some territories and jurisdictions. Nevertheless, privacy concerns have been raised, especially about systems that are based on tracking the geographical location of app users. Less intrusive alternatives include the use of Bluetooth signals to log a user's proximity to other cell phones.

However, many questions remain unanswered about the technology, effectiveness, functionality and arguably most importantly, the ethics of such apps. Germany's "Corona-Warn-App" had seemed to be making decent headway. This app had been downloaded 18.2 million times in Germany— accounting for an impressive 20% of the population [8]. The downloads results are much less satisfying in other countries so far. While number of downloads relative to a population size is obviously a key metric, it becomes less so if the app has functionality issues or is seen to be unreliable. Thus, it's not yet clear how to measure success in the COVID-19 app business.

Connected Thermometers against the pandemic

Digital "smart" thermometers are getting very popular. Such a thermometer connects via

Bluetooth to an app on the user's phone and collects temperature data in real-time and can reports back to the health station over the Internet. Hospitals themselves use connected thermometers to screen patients and staff.

Wearable devices

Another sort of IoHT solution are „wearables devices". These are smart devices that can be attached, for example, to the body, such as watches, shoes, or body sensors. Those devices should be able to connect to physiological transducers to display patient's signals, such as body temperature, heart rate, blood pressure, and others.

Wearable technology is the most ubiquitous of IoT implementations to date. Wearable IoT devices can let the care teams collect numerous data points about the patient (e.g. heart rate, temperature). These wearables offer real-time information to caregivers and patients. The efficiency of the data processing by these smart wears ranging from rings to clothes is demonstrating how IoHT technology will add value in our daily life. Wearables devices becoming the new age technology for vital tracking of movement, IoT companies are concentrating on developing the related apps.

Insulin pens

A smart device currently improving the lives of diabetes patients is the smart insulin pen. Smart insulin pens have the ability to automatically record the time, amount and type of insulin injected in a dose, and recommend the correct type of insulin injection at the right time. The devices interact with a smartphone app that can store long-term data, help patients calculate their insulin dose, and even allow them to record their meals and blood sugar levels.

Ingestible sensors from Proteus Digital Health

Proteus Digital Health and its ingestible sensors are another example of how far the IoHT approach can go. Proteus, founded in 2001, developed ingestible sensors and a wearable sensor patch to track medication-taking behaviour. The company has created pills that dissolve in the stomach and produce a small signal that is picked up by a sensor worn on the body. The data is then relayed to a smartphone app, confirming that the patient has taken their medication as directed.

The "smart pill" maker's sensor was one of the first of its kind to receive clearance from the U.S. Food and Drug Administration (FDA). But, apart from the innovative approach, it has also to be noticed that the Proteus Digital Health company struggled to find a market for its digital pill and the company recently filed for bankruptcy protection in June 2020.

Corona Data Donation App in Germany

At the beginning of the pandemic in Europe, the Robert Koch Institute (RKI) launched the official Corona Data Donation App [9]. This app collects data from fitness watches worn by users. Collected data includes level of activity (e.g., sleep, sport, etc.) and health data (e.g., heartrate, temperature and blood pressure). Since then, more than 500.000 German inhabitants have decided to donate their data. The app works by collecting activity and heart rate data, along with postal codes, and analysing the information for potential COVID-19 symptoms. The app is voluntary, and the collected information is currently being analysed. In addition, RKI analyses the aggregated and anonymized data of mobile phones to identify changes in the mobility of citizens.

The data is used to create a "fever map" for Germany. The goal of this map is to detect regions in which the number of residents exhibiting fever symptoms is higher than average. By updating the map on a daily and municipality-level basis, RKI aims to identify so-called "hot spots" of COVID-19 as they emerge.

IoHT to fight against COVID-19 pandemic

The current global challenge of COVID-19 pandemic has surpassed all boundaries and solutions are needed from all industrial areas.

IoHT is obviously very useful for proper monitoring of COVID-19 patients, by employing an interconnected network, and can also fulfil significant challenges during lockdown situations.

Following is an overview of major applications of IoHT for COVID-19 pandemic.

Applications	Benefits from IoHT
Connected hospital	IoHT is a part of a complete integrated network within hospital premises
Information of medical staff during emergency	Inform the staffs to respond more quickly and effectively whenever needed
Automated treatment process	IoHT facilitate the selection of treatment methods and helps the appropriate handling of the cases
Telemedecine consultation	This especially makes the treatment available for the needy ones in the remote locations via employing the well-connected teleservices
Identification of COVID-19 patients	Applications installed into smartphones, which can make the identification procedure smoother and more fruitful through wireless healthcare network
Tracing of infected patients	Tracing of patients ultimately strengthened the service providers to handle the cases more smartly
Real-time information during the spread of this infection	As the devices, locations, channels, etc. are well informed and connected, the on-time information sharing can be done, and cases can be handled accurately
Quick COVID-19 screening	IoHT allows for proper and quick diagnosis through smart connected treatment devices.
Medical tools and devices connection through the internet	During COVID-19 treatment, IoHT connected all medical tools and devices through internet that can convey the real-time information during treatment
Forecasting of COVID-19	Based on the data report available, Artificial Intelligence (AI) technologies and statistical method, IoHT contributes to predict the situation in the coming times and help the government, doctors, academicians, etc. to plan for a better working environment.

Table 2 - Major applications of IoHT for COVID-19 pandemic

IoHT Challenges and Threats

Integration: facing multiple devices & protocols

IoHT enables machine-to-machine communication, information exchange, and data movement that makes healthcare service delivery effective. Used connectivity protocols could therefore help healthcare personnel to change the way they spot illness and ailments in patients. IoHT already brings down the cost, by cutting down unnecessary visits, utilizing better quality resources, and improving the allocation and planning. But the integration of multiple devices is still an important challenge in the implementation of IoHT. There is still today no consensus from device manufacturers in this area regarding communication protocols and standard. Even if the variety of devices can be connected, the communication protocol differences complicates or even hinders the process of data aggregation. This non-uniformity of the connected device's protocols slows down the whole process and reduces the scope of scalability of IoHT.

Data security

As IoHT devices capture and transmit health related data in real-time, one of the most significant threats that IoT poses is of data security. This issue is particularly difficult to address as, as mentioned below, most of the IoT devices lack data protocols and standard. Standard security tools are anyway not adapted for IoHT: IoHT devices have unique communications patterns. Without considering the medical context, standard firewall and security policies could disrupt the normal function of critical devices. All these factors make data from IoHT systems highly susceptible to cybercriminals who can hack into the system and compromise information of both patients as well as doctors.

There are billions of IoHT devices connected to the global clinical ecosystem today. The majority are connected without security checks, and thousands are moved between wards and off-campus sites completely unchecked. Keeping track of them all without an automated IoHT asset management solution is pretty much impossible. This is the reason why healthcare organisations, like hospitals and medical research institutions, have been hit hard by the COVID pandemic. Cyber criminals have tried to take advantage of the situation. Thus, attacks have risen quickly since the COVID pandemic started. If a lesson can be taken from the COVID first wave, it's that the healthcare industry should take preventative measures to fortify clinical networks and preserve medical services.

Data privacy and General Data Protection Regulation (GDPR)

The European GDPR has created a host of challenges for healthcare organizations and IoHT providers around the world. IoHT providers must now be prepared for the serious legal and reputational hazards that comes with security breaches involving European Citizens data. Indeed, the GDPR insists that privacy protection should be built into IoT devices by design and by default. This includes mechanisms to ensure that data-sharing is limited to the specific purposes that have been presented to the individual concerned.

The GDPR is inducing that other purposes for using data collected through clinical IoT should not be permitted. The providers has now to design devices or procedures that provide sufficient transparency to individuals and ensure that they can control how the IoT device works. According to the GDPR, users should also be able to take their data over to a rival service provider if they want, in a commonly used format that makes this possible. Thus, IoHT manufacturers will have to design systems in a way that the data can be portable.

Conclusion

The COVID-19 is pushing the top IoT healthcare companies to scale up and meet the changing needs of the healthcare segment while taking care of data security and system integration. IoHT changes now quickly with virtual assistants, medical sensors and smart medical wearables, the way to ensure the safety of the population.

The future of IoHT is therefore very promising. All around the globe medical sector and health related services are adopting IoHT. Both the hardware and the software aspects of the technology are contributing towards this shift. On the hardware side, new technologies and enhanced capabilities of devices on reduced costs are making them affordable and widespread. Innovative wearable devices and their utility continues to attract the users to adopt them too. On the software side, innovative ways of utilizing existing hardware and facilitation of end user is making them more attracted to IoHT based medical care.

Countries around the globe are making laws and policies for including IoT in medical care practices. Along with these, there are many challenges faced by IoHT infrastructure, architectures, devices and services.

Literature

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