How Can the Internet of Things Help to Overcome Current Healthcare Challenges

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Abstract: Healthcare systems are nowadays facing several challenges starting from an ageing population to a growing demand for more advanced and better healthcare outcomes. This leads to an increase of healthcare costs as well as a need for change in healthcare systems in terms of better and more efficient outcomes. Our paper aims to bring some preliminary evidence that the Internet of Things can improve the quality of healthcare and/or reduce the cost of it. In order to achieve our objective we have reviewed five recent Internet of Things solutions, from monitoring cardiac arrhythmia and congestion in heart failure, to management of diabetes and obesity prevention. Our findings show that the Internet of Things has a significant potential to contribute to the overall decrease of healthcare costs while increasing the health outcomes if it satisfies two conditions, namely if it enables the system management of a particular disease and the mindset and behavioural changes of the stakeholders in the system.

Key words: Internet, healthcare system, diabetes management, cardiac arrhythmia.

■ Internet of Things as a catalyst

Healthcare is nowadays one of the most popular topics on all political agendas (KAUFMAN, 2011). This can be explained by the increasing and ageing of the population, higher number of people living with long-term conditions and the growing demand for more advanced healthcare and more expensive new medical technologies (OMACHONU & EINSPRUCH, 2010).

The Internet of Things (IoT) is one of the recent technological and social trends that will have (it has actually already started) a significant impact in the delivery of healthcare. IoT represents a vision in which Internet extends to the real world (MATTERN & FLOERKERMEIER, 2005), connecting people with technology through various tools. By facilitating the flow of

information, IoT has a great impact over many domains from general and business relationships to management and economy.

According to SUNDMAEKER *et al*., (2010) and GUILLEMIN & FRIESS (2009) IoT can be defined as "a dynamic global network infrastructure with self configuring capabilities [...] where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network." These things will have the capability of directly interacting with each other, being able to exchange information (SUNDMAEKER *et al*., 2010, p. 41; RELLERMEYER *et al*., 2008).

Because any object can be connected to Internet, IoT can lead to major advances throughout different industries. However, the impact will not be the same in all sectors, healthcare being the one to play a leadership role (Accenture & Bankinter Foundation of Innovation, 2011). The current advances in technology will benefit firstly the prevention and easy monitoring areas and secondly cases of accidents and the need for ad hoc diagnosis (SUNDMAEKER *et al*., 2010; GUILLEMIN & FREISS, 2009).

In the IoT vision, things are becoming more and more integrated with the human body and communicate with treating physicians, emergency services, as well as other health providers (GUILLEMIN & FREISS, 2009). IoT will enable the patient to stay longer and safer at home since smart devices can alarm the hospital in case of critical situations. Furthermore due to constant monitorisation, the patient can be relieved from the hassle of routine checks when he feels better, replacing costly travel and reducing patient stress (European Commission, 2008). Using implantable wireless devices to store health records could save a patient's life in emergency situations. Adding smart labels on the drugs or smart biodegradable dust inside pills can inform consumers on dosage and expiration date, and in combination with a smart device that reads information transmitted by the drug labels, patients can be reminded to take their medicine at appropriate intervals, leading to higher compliance rates (SUNDMAEKER *et al*., 2010; European Commission, 2008).

Several studies have demonstrated that Internet is an enabler with the potential to greatly affect and improve the quality of healthcare (GULEC *et al*., 2011, CUCCIARE *et al*., 2009; GHAZALI *et al*., 2010). Connecting everything to the Internet, shifting "from anytime, anyplace connectivity for anyone" to "connectivity for anything" (ITU, 2005), in other words IoT, has

the potential to open entire new paths to generate benefits for the patients, health systems and society at large.

Given all the premises above, the objective of the paper is to bring some preliminary evidence to the core question of whether the IoT can improve the value generated by a healthcare system.

Based on previous literature reviews and the personal experience of the authors as participative observers in the healthcare industry we believe that there is a high "unlocked" value in the healthcare system, which is mainly hindered by two road blocks:

- Lack of systemic management of the healthcare system. During the medical pathway a patient interacts with many different stakeholders and systems, and normally he is the only integrator and vector of information. The patient acts therefore as the only hub of a very disconnected constellation while being the least adequate and efficient to cover such role. The formation of a proper network where every node has visibility on the whole is what we define as system management.

- Difficulty of permanently changing people mindset and behaviours (doctors, patients, etc). While resistance to change can be found as a general human trait, a healthcare systems acts onto two social groups which are particularly resilient to change. Both patients and doctors have developed, at least in the Western medicine, a mindset based on reductionism: identify the cause of the disease and develop a pill, or a procedure, to treat it, while diseases and conditions have many facets. The human body is a very complex system and research has shown that often a mono approach is not the most effective and diets, counselling and other life-style changes are indeed major boosters of the efficacy of treatments. The system management described before would not be useful unless both patients and doctors develop a more holistic approach and start looking at the whole rather than at the parts.

The core thesis of the paper is that the value generated by the IoT is greater than the intrinsic value of any specific IoT solution, as it will trigger a systemic effect either enhancing the outcome or reducing the cost (or both) of one or many of the components which build the total value of a healthcare system (value delivered by the pharmaceutical industry such as drug efficacy, value of the medical care itself, value of the patient productivity, e.g. patients who are not prevented from working and producing, and value delivered by the healthcare infrastructure such as hospitals, clinics and logistics).

We believe that such statement will prove true if two main propositions are verified:

P1= IoT solutions enable the system management (disease pathway) of a particular disease bringing transparency of responsibilities and visibility of impact and effort of each activity involved in the disease management.

P2= IoT solutions enable mindset and behavioural changes of the stakeholders in the system.

The remainder of the paper is dedicated to bringing preliminary evidence to the stated thesis under the given conditions via the examination of a number of IoT solutions implemented across the world.

■ Methodology

We have conducted a thorough analysis of the innovative health solutions that have been developed in the last five years by pharmaceutical companies, technology developers, and healthcare providers. We have reviewed in total 71 solutions developed for 10 therapeutic areas.

We then selected those solutions that were Internet based: 47 in total. As a next step, we screened those that represent, in our view, an IoT solution for better managing and monitoring chronic diseases as well as the prevention of them. We chose to focus on chronic diseases since they represent one of the highest challenges to the health systems. In the end, we have reviewed in more detail 5 IoT solutions, which can enable the system management of a particular disease and drive mindset and behavioural changes of the stakeholders. In order to understand the impact of each solution on the healthcare system and to demonstrate how they validate our two conditions, we followed a structured three-phased approach to analyse them.

- We first looked at the disease the specific IoT solution is addressing, explaining what it is, what the causes are, what key therapies are available and what the implications are for patients;
- We then reviewed how the IoT solutions address some of the main problems for the specific disease including some of the barriers and challenges in their implementation;

- We then looked at their impact towards the overall assumption that IoT solutions can either enhance the value of the outcome or reduce the costs of its components and try to establish if this was derived from the stated propositions.

■ Findings: 4 cases of how Internet of Things addresses healthcare system challenges

Cardiac arrhythmia monitoring services

Cardiac Arrhythmia

Arrhythmias represent deviations of the heart from the norm, an abnormality of the heart's rhythm, which may lead to too fast, too slow or irregular heartbeats (Mayo Clinic, 2012). If not treated immediately, atrial and ventricular fibrillations are the most hazardous arrhythmias, leading to loss of consciousness and death (NHS Choices, 2012).

The most common causes of arrhythmias are the scarring of heart tissue, changes to the heart's structure, high blood pressure, diabetes, overactive thyroid gland, smoking, drinking too much alcohol or caffeine, drug abuse, stress, medications, dietary supplements and herbal treatments, electrical shock.

There are several ways to treat an arrhythmia, but there are few methods to help prevent one (Mayo Clinic, 2012). The treatments may include implantable devices such as the pacemaker and cardioverter-defibrillator or surgical procedures such as maze procedure, ventricular aneurysm surgery and coronary bypass surgery.

Many people suffer from recurrent arrhythmia. However it is not always an alarming situation when people feel that their heart is beating very fast and in some cases, it is normal to develop tachycardia. In order to evaluate what are the normal or abnormal deviations for a patient, it is essential to measure and monitor patient's possible/actual heart problems in daily activities that may cause stress or a lot of effort, activities that cannot be recreated in a hospital environment.

Internet of Things solutions

We found two solutions for monitoring and diagnosing cardiac arrhythmia. The first one, the Mobile Cardiac Outpatient Telemetry (MCOT) is a portfolio of cardiac arrhythmia monitoring services for diagnosing patients and monitoring the efficacy of treatment. The mechanism monitors patients 24 hours a day via a small sensor as they continue with their normal daily routine. As events occur, patient activity is automatically transmitted to the company's monitoring centre for analysis and response (CardioNet, 2012). Physicians can receive the data via fax or the Internet.

The second solution consists in a sensor attached to a patient's chest like a large band-aid that adheres to the skin. This object automatically detects, records, and transmits physiological information via wireless connection to a central server for analysis and review by doctor and patient (Corventis, 2012). Then, a cardiologist technician reviews it and provides a response to the physicians in the form of notifications of urgent events as well as actionable information (Corventis, 2012).

The IoT solutions mentioned in this case benefit all parties involved, transmitting data when it becomes available, reducing the time of diagnosis and setting a corresponding treatment. In this way it can reduce hospitalization costs and readmissions. By constantly monitoring the patient's heartbeat, it will provide the evidence of the impact and effort of all activities involved in the disease management, for example of the efficacy of a specific treatment or diet adjustment. This information can be then used by the health system to make the whole clinical pathway for the specific disease more efficient.

The challenges that could be faced when implementing the above solutions are connected to the anxiety which could be experienced when these devices go out of range of networks. In this case patients would receive phone calls from the companies' staff to check if everything is in order (Mayo Clinic, 2012). Furthermore, the information sent to the physician may not be always accurate because patients might lose the device or quit using it due to the anxieties mentioned above (Mayo Clinic, 2012). Therefore the behaviour of the patient is a key driver in the adoption of these solutions.

Another challenge is that these devices, even though beneficial to patients, can be very costly and not everyone can afford them. So far, insurance companies do not cover the costs of using these devices, due to

insufficient evidence in the clinical literature to conclude major improvement in clinical outcomes.

Monitoring congestion in heart failure

Heart failure

Heart failure is a condition in which the heart can no longer pump enough blood to the rest of the body. When this happens, blood may back up in other areas of the body. Fluid builds up in the lungs, liver, gastrointestinal tract, and the arms and legs. This is called congestive heart failure. (PubMedHealth, 2011)

The causes of heart failure are coronary artery disease, weakness of the heart muscles due to infections, congenital heart disease, heart attack, heart valve disease and some types of abnormal heart rhythms (arrhythmias) (PubMedHealth, 2011) For most people, the treatment of heart failure involves a balance of right medication, and in some cases, right devices that help the heart beat and contract properly.

Assessing heart failure congestion is challenging, several studies showing that a significant proportion of patients with heart failure are not receiving treatment with guideline-recommended, evidence-based therapies (FONAROW, 2006). Traditional methods of patient assessment have a low sensitivity for detecting pulmonary congestion and heart failure decompensation (YAMOKOSKI *et al*., 2007). Therefore fluid volume overload (congestion) is a major complication for patients, many of them ending up frequently hospitalized for fluid overload (SACKNER-BERNSTEIN, 2004).

Internet of Things solution

The fluid status monitoring device is implanted in the patient's heart, helping him and his physician to detect any fluid build-up in the thoracic cavity. The device is connected to the patient's physician through the company's network system, facilitating the interpretation of the heart monitor. Therefore, patients at risk for worsening heart failure can be identified quickly and the doctor can recommend diet adjustments or alter medications in real time (Medtronic, 2012).

The fluid status monitoring device helps doctors identify patients at greater risk of worsening heart failure, so they can better manage the disease. When a patient crosses the (fluid) threshold, diet and medication are immediately adjusted to get him back on track. Furthermore the device helps patients comply with their treatment management routine, which often includes diet adjustments and evolved medication. This is made possible as a result of establishing a link between the fluid increase and a specific event in their routine, e.g. forgetting to take their pills.

The major challenge for wide implementation of this solution regards the need for more evidence of efficacy to conclude to major improvement in clinical outcomes. While the solution has been approved to be financially covered in the US, it is still under review in Europe.

Diabetes management systems

Diabetes

Diabetes is a chronic disease that affects how the body uses the glucose, the amount of sugar in the body, its source of energy. This amount of sugar is controlled by the insulin, a hormone produced by the pancreas. This hormone is the one responsible with transforming the glucose into energy (NHS Choices, 2012). If there are problems in achieving this process it is a sign of diabetes.

There are two types of diabetes: type 1 diabetes is a chronic condition in which the pancreas produces little or no insulin, a hormone needed to allow sugar (glucose) to enter cells to produce energy. Type 2 diabetes, which is far more common, occurs when the body becomes resistant to the effects of insulin or doesn't make enough insulin (Mayo Clinic, 2012; NHS Choices, 2012).

For type 1 diabetes, but also in most cases of type 2 diabetes, the treatment involves taking insulin injections for life. Furthermore, for both types it is important to monitor the blood sugar by checking and recording the level of blood sugar several times a week or day. Oral or other medications can be administered in order to stimulate the pancreas to produce and release more insulin. In some situations, a pancreas transplant or bariatric surgery can be recommended.

The consequences of diabetes are numerous, especially on blood vessels and nerves. Being a long-term disease it can lead to a large number of complications over the long run: cardiovascular, heart attack, stroke and narrowing of arteries; nerve damage; kidney damage; eye damage; foot damage; skin and mouth conditions as well as brain problems (Diabetes.co.uk, 2012).

When managed effectively, diabetes is a disease which people can live normal lives with. Among the selfcare behaviours recommended by physicians, self-monitoring of blood glucose is a key component of the treatment regimen (American Association of Diabetes Educators, 2010). In these conditions compliance becomes an issue, since it relies upon user lifestyle changes, upon regular sampling and measuring of blood glucose levels. Many people find that it is difficult to make blood glucose monitoring a routine part of their lives.

Internet of Things solution

The IoT solution for diabetes management is a monitoring device which uses a blood pressure and glucose monitor to give accurate test results and better manage diabetes. The monitor communicates via Bluetooth to a smart screen, PC or cellular / or land line phone, transmitting the data to a web-enabled server. Here, the data is stored, reviewed and interpreted by the patient's doctor, helping in providing a proper treatment (LifeWatch, 2012).

This solution facilitates the improvement of patients' lives and of their clinical outcomes due to better monitoring. The solution is easy to implement and facilitates the transmission of the data regardless of the location, enabling the immediate contact with the medical staff (LifeWatch, 2012). Furthermore it has an immediate impact on the patient's behaviour since it will not only help them constantly monitor their blood sugar, but will also enhance the consistent maintenance of glucose control.

The benefits for health providers are also considerable. Using the IoT solution strengthens their relationship with the patient, provides immediate access to data, which improves treatment and allows them to focus more on the patient and less on collecting information (LifeWatch, 2012). Furthermore the health system will have direct feedback on the efficacy of the treatment based on the data provided by the devices. This can be then used to improve the efficacy of the overall clinical pathway.

Reimbursement is one of the barriers to widespread adoption of this solution, as so far, there are no mechanisms to reimburse physicians for non-face-to-face services. Medical legal issues related to timeliness of provider response and privacy are other barriers to the wide implementation of this solution (AZAR & GABBAY, 2009).

At the patient level, one of the challenges in monitoring diabetes is related to wearing the device daily, which can be stressful sometimes and can give them a sense of losing their privacy. Furthermore, some of the solutions can be expensive. All these factors may lead patients into quitting using the devices and mislead the physicians by sending wrong information. This, in turn, will lead to inappropriate treatment.

Obesity prevention

Obesity

Obesity refers to excessive body fat that a person is carrying for their height and gender. It is considered that an obese person has a body mass index (BMI) of 30 or greater (NHS Choices, 2012; WHO, 2012).

The problems that obesity may cause are numerous and can have a negative aspect over the course of a person's life: high cholesterol and triglycerides, type 2 diabetes, high blood pressure, metabolic syndrome, heart diseases, stroke, cancer, sleep apnea, gynaecologic problems, such as infertility and irregular periods, erectile dysfunction and sexual health issues, osteoarthritis and skin problems, such as poor wound healing (Mayo Clinic, 2012). Obesity can be treated by reaching and staying at a healthy weight. A diet and exercising plans need to be formulated together with health professionals in order to accomplish the necessary changes in the lifestyle (NHS Choices, 2012). Medication and surgical treatment could also be prescribed by a specialised doctor, if the other methods are not successful (Mayo Clinic, 2012).

Recent studies have shown that a healthy lifestyle may prevent a large proportion of mortality from chronic diseases (SASSI & HURST, 2008). Active lifestyle change may bring important benefits, PUSKA *et al*., (1998) showing a 68% decline in cardiovascular disease mortality, 73% in coronary heart disease, 44% in cancer, 71% in lung cancer, and to a 49% decline in deaths from all causes.

Internet of Things solution

The IoT solution is a wireless-enabled wearable fitness tracker, containing a 3D motion sensor that accurately tracks calories burned, steps taken, distances travelled and sleep quality. All the data collected by the device will be automatically uploaded on Internet every time the tracker is within about 15 feet of a base station. The data can be analysed by the patient or if necessary, by the personal doctor who, in return, can prescribe a diet, medication or other advice that can improve the patient's life (FITBIT, 2012). The fitness tracker helps people monitor their lifestyle and understand in real time what they should change/continue in their everyday lives to prevent the appearing of obesity, that may lead to chronic issues such as diabetes or heart diseases. By providing a large amount of information on people's activity levels, the device has a great potential to change their lifestyle.

Possible challenges which can be encountered when using this IoT solution can appear due to people's lack of diet and lifestyle adherence. Determining people to adhere to a treatment and, more recently, to a healthy lifestyle is a major challenge for any healthcare system. Therefore, it is difficult to say if they will comply with what the doctor or a specific website application will advise them to do. Furthermore, even though the data carried by the device is automatically and wirelessly uploaded on the website, people will still have to permanently wear the device with them, which could be difficult to achieve.

The four cases previously described show how the IoT can address important challenges, improving healthcare outcomes and helping better manage costs. We also see that IoT can enable the system management (pathway) of the four diseases described, bringing the right data at the right time, therefore improving visibility of impact and effort of each activity involved in the disease management. In the case of Cardiac Arrhythmia, Monitoring Congestion in Heart Failure and Diabetes Management Systems, the devices monitoring the patient's heartbeat, fluid threshold and blood glucose level will provide direct feedback on the efficacy of the different treatments or procedures which are part of the patient's clinical pathway. The fitness tracker will contribute to obesity prevention by providing valuable data on people's everyday activities. This will lead to a better understanding of how each of these activities influences health outcomes and consequently the demand for health services.

Table 1 - Synthesis of findings
Impact of the IoT solutions and their fulfilment of the propositions

IoT Solution	*Impact on Value*	*Proposition 1*	*Proposition 2*
Mobile cardiac outpatient telemetry Cardiac arrhythmia monitoring patch Fluid status monitoring device Blood pressure and glucose monitor Fitness tracker	Enhanced outcome of medical care by enabling real-time transmission of time sensitive data Enhanced outcome of drug/treatment efficacy by increasing compliance Reduced cost of medical care and healthcare infrastructure and by limiting unnecessary hospitalisation and readmissions Reduced cost of medical care by decreasing demand on medical staff	The solutions enhance system management in at least two ways: - Generating new information that contributes to improved health outcomes - Interconnecting patients, doctors and technicians for timely adjustment on medication	The first 4 IoT solutions give an immediate feedback to both patients and doctors, therefore showing real time evidence of efficacy of treatment and life-style changes Feedback loops drive behavioural change of various stakeholders, e.g. through: - Close monitoring of patient's lifestyle and permanent link to doctors - Better management of treatment compliance - Patients taking control of their health (e.g. monitoring lifestyle in last IoT solution)

The four cases also exemplify that IoT solutions can enable mindset and behavioural changes of the stakeholders in the system, creating the context for doctors, nurses and patients to work together, encouraging patients to take control of their disease, also making stakeholders accountable for the return on investment (IoT solutions do not come for free). The device monitoring blood sugar level transmits data regardless of the location, facilitating immediate contact with the medical staff and instant impact on the patient's behaviour, by pointing him to take a specific course of action. Another example is the one of cardiac arrhythmia monitoring services and monitoring fluid congestion device, which transmit physiological information to both doctor and patient, allowing them to adjust diet or alter medications in real time. In the case of obesity prevention, the device presented has a significant potential of changing the lifestyle of its users, providing them with a large amount of information on their activity levels which in turn can be used to check behavioural patterns and results with a health provider.

■ Conclusion

The purpose of this work was to shed some preliminary light on the potential contribution of the IoT to the value generated by a healthcare system, reviewing a cluster of IoT solutions already implemented in practice.

For such solutions we have investigated two core propositions, that IoT solutions enable the system management (disease pathway) of a particular disease bringing transparency of responsibilities and visibility of impact and effort of each activity involved in the disease management; and that IoT solutions enable mindset and behavioural changes of the stakeholders in the system.

Our early findings show a relation between the enhancement of the several components which make the value of a healthcare system and our two propositions, as illustrated in Table 1. From such early evidence it emerges how the IoT can address important challenges, improving healthcare outcomes and helping better manage costs.

In order to drive a widespread diffusion of IoT there are some challenges/barriers that need to be overcome. One of them is to provide a right balance between the benefits and gains in efficiency on one side, and human contact on the other side, since solitude and isolation may be also dangerous. Another one is the large dependency on intelligent objects and sensors, which in the case of statistical error probabilities could have fatal consequences (European Commission, 2008). Security and privacy represent another barrier that needs to be overcome in order to have people embrace IoT solutions. And last but not least, providing the necessary clinical evidence for the effectiveness and efficiency of the solutions would be another challenge that needs to be solved. This will, in the end, ensure that these solutions will be reimbursed by the public and private health systems.

■ Limitation and further research

The major limitation of this work is the absence of quantitative evidence on the effect of the IoT solutions under review, given the very early adoption stage for all of them.

The authors will continue the research effort by investigating, in due time, those IoT solutions gathering both quantitative evidence and performing in-depth cases studies in the healthcare units were they have been implemented.

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