How IoT Can Significantly Improve Healthcare in the Context of Smart City

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INTRODUCTION

Smart cities are parameterized based on several evaluation criteria(s), which differs across global agencies. ISO being one such global agency enacted ISO 37120 Smart City standard, which defines a common performance yardstick for cities. Healthcare is one key Smart City criteria, identified under this standard, with 7 healthcare indicators such as *Number of In-patient hospital beds, Physicians, Nursing personnel per 100,000 population, Average life expectancy, Under age 5 mortality per 1K births, Suicide rate per 100K population and Mental health practitioners per 100K population*[1]. For our discussion, we would focus on first three indicators.

Similarly, as per International Telecommunications Union (ITU), *Usage rate of electronic medical records* and *Sharing rate of resource and information among hospitals* are recognized as key criteria for Smart City health.

In the current landscape, majorly there are three major challenges in achieving Smart City healthcare targets:

1. Continuous year over year increases in healthcare cost,
2. The widening gap between required and available medical workforce, and
3. The lack of capabilities to share centrally available clinical data in real time.

The ultimate goal of Smart City healthcare is to increase quality and reach, while making it more affordable. The Internet of Things (IoT) powered by Digital 5 forces (i.e. Mobility, Big Data, Cloud, Social and Robotics & Artificial Intelligence (AI)), is transforming these challenges into opportunities. As per Frost & Sullivan, Smart City healthcare is anticipated to create business opportunities with a market value of $220 Billion by 2020[2].

This paper focuses on addressing these three challenges by leveraging digital technologies best suited for different scenarios, enabling a city's administration to increase their healthcare ratings and strengthen their bid to be acknowledged as a Smart City.

CHALLENGES

Below are some key challenges, which the healthcare industry is currently facing:

- *Year over Year increase in healthcare infrastructure cost* – In order to improve the healthcare services, Smart City administrations have been spending significantly in associated infrastructure (i.e., number of beds, medical equipment, etc.). For a developing nation like India, supporting a fifth of world population, the growth in average hospitalization costs annually is over

[1] http://smartcitiescouncil.com/article/dissecting-iso-37120-how-healthy-your-city-and-what-zip-codes-have-do-it

[2] http://www.egr.msu.edu/~aesc310-web/resources/SmartCities/Smart%20City%20Market%20Report%202.pdf

10%[3]. This burden is being passed on to patients and payers. A major chunk of hospital beds are occupied by patients for health monitoring purposes and not treatment, consuming a major share of available bandwidth[4].

- *Gap between required and available medical workforce* – With a growing aging population, the demand for physicians and nursing personnel has intensified around the world, which is already experiencing doctor shortages. A 2017 study conducted by IHS Inc., predicted that by the year 2030 the United States alone will face a shortage of at least 40 thousand physicians[5].

  Even the available medical personnel are wholly engaged in compliance related tasks, which limits value for the end consumer, i.e., patients. According to a research report published by the American College of Physicians, Doctors are wasting over two-thirds of their time doing paperwork and spent only 27% of their time in their offices seeing patients, which drastically impacts their effective utilization rates[6].

  Similarly, reading and recording patient data from a medical device manually (through paper and pen) by nursing staff, results in a wastage of around 100 nursing hours daily with up to 24 data errors for a typical hospital. Saving or eliminating this wasted time and expertise could improve the quality of patient care[7].

- *Lack of capabilities to capture and share centrally available clinical data in real time* – Most medical devices are supported by proprietary communications protocols and therefore cannot send clinical data over Internet protocols (IP) to a server on a healthcare network. Ensuring that all the devices speak the same language, so that data collected can be read and understood, is becoming increasingly difficult due to the growing number of network proprietary devices. As a result, many healthcare facilities have "islands" of data that cannot be shared and stored in a centralized location in an automated fashion.

  Apart from this, there is little electronic information sharing among clinicians and hospital as there are still major dependencies on traditional means like phone, fax, mail, etc. For those who use Electronic Health Record (EHR), around

[3] http://www.livemint.com/Opinion/DSH1OnDr2LG0zAcHhl29XJ/The-growing-burden-of-healthcare-costs.html

[4] http://www.corp.att.com/healthcare/docs/remote_patient_monitoring.pdf
http://www.techmahindra.com/sites/ResourceCenter/Infographics/IES/Remote_Patient_Monitoring_Solution.pdf

[5] https://news.aamc.org/for-the-media/article/gme-funding-doctor-shortage/

[6] https://www.forbes.com/sites/brucelee/2016/09/07/doctors-wasting-over-two-thirds-of-their-time-doing-paperwork/#57f6d3a05d7b

[7] https://www.buildingbetterhealthcare.co.uk/technical/article_page/Comment_Hospitals_and_the_Internet_of_Things/97292

40% are not satisfied with the EHR system due to the huge amount of time consumed in manual data entry needed to push the data to the servers. This situation results in dramatic unanticipated costs associated with the need to increase staff coupled with a loss in medical workforce productivity[8].

INTERNET OF THINGS REDEFINING HEALTHCARE INDUSTRY

IoT has been changing the Healthcare and health care providers (through real time patient data while the patient is in their natural habitat – remote ICU) and putting intelligence into action (predicting medical equipment failure, patient risk events and practicing precise medicine). Figure 1 below, illustrates how IoT is playing a role in addressing the key inhibitors and achieving the key criteria for Smart City health rankings.

IoT has become extremely valuable o this industry though the availability of low cost, small sized sensors, large sets of connectivity

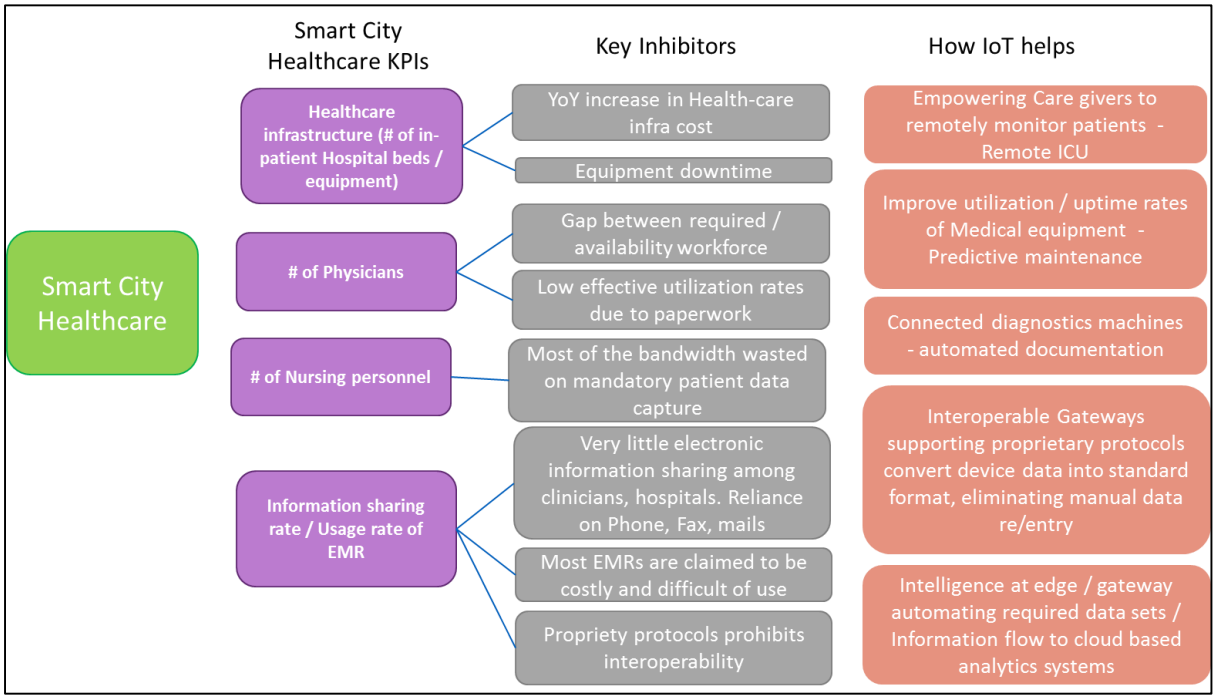

Figure 1 - Smart City Healthcare (KPIs – Inhibitors – IoT play)

Life Science industry outcomes, by introducing automation into associated processes (i.e., clinical documentation by doctors, capturing health data from wearable/medical equipment), empowering options to choose from and highly matured cloud services for data management and processing.

[8] http://medicaleconomics.modernmedicine.com/medical-economics/content/tags/ehr/physician-outcry-ehr-functionality-cost-will-shake-health-informa?page=full

USE CASES

Following are some key use cases, illustrated through real world deployment experiences and market ecosystem innovative activities.

1. Remote Patient Monitoring

Remotely monitoring patient health significantly cuts down on hospital stays and readmissions for health-related parameter monitoring, which would ultimately result in releasing the beds that can be used for actual treatment-related patient care. IoT enables remotely monitoring patients in their habitat and, in cases of any predicted risk events, enables proactive remedial action.

Wearable/medical devices worn on the body (i.e., pulse, steps, ECG bands) read the relevant health parameters and pump the data to the Internet through a gateway (mostly a smartphone for outdoor scenarios). For home-based care, medical devices push the data to a gateway (home router) using proximity (short range) communication protocols such as Wi-Fi, BLE, RFID (BLE is used widely due to range and energy efficiency). Gateways near the edge are embedded with more intelligence (more than edge but less than cloud analytics layer), filter and apply rules, thereby saving network bandwidth and cost. Once the data reaches the cloud through the gateway, it is visible to the associated stakeholder for visualization and analyses with automated workflow. This architecture supports 2-way communication, with instructions being pushed from cloud to device for software updates, commissioning or de-commissioning, patch upgrades etc.

Further, such continuous monitoring enables physicians to make informed decisions as well as offer treatment that is evidence-based. This advocates precise medication, reducing adverse impact on patient health and unnecessary loads on payers. This concept is further being elaborated to cater to serious scenarios, such as remote ICUs, improving the last mile service to city patients.

Tata Consultancy Services (TCS) has implemented one such solution in Singapore, under the ambit of Smart City health: To help seniors age and live independently, with medical professionals remotely monitoring and supporting them. Singapore is under growing demographic pressures with citizens over 65 years of age expected to double by 2030 (known as the “silver tsunami”), steadily putting greater demands on social services and geriatric care. In order to address these challenges, TCS collaborated with Singapore Management University (SMU) to establish an innovation lab, backed by a grant from Government of Singapore, for research in several aspect of intelligent city, primarily monitoring the wellbeing of elderly.

The solution leverages Passive Infrared motion sensors (on doors) to detect the motion of the elderly in a particular part of the home, to derive real-time information relevant to caregivers when short-term anomalies arise (i.e., falls, fainting). The solution was deployed on TCS’s IoT platform, known as TCS Connected Universe Platform, and provides services such as sensor device management, data acquisition and storage, and analytics. Analytics included anomaly detection algorithms for understanding

elderly heath/mobility/sleep patterns and predicting any risk event, which is then averted by proactive remedial action.

For Singapore's administration, this meant less pressure on nursing homes, for which there is already high demand. This initiative is a benchmark for cities seeking to reform their healthcare infrastructure with respect to evolving citizens' needs[9].

According to a Veterans administrative study published by Marlis Meyer et al, by leveraging remote health monitoring solutions, there is a potential to reduce hospital admissions by 63%. This will significantly save on the infrastructure bandwidth (number of hospital beds, medical equipment, administrative overheads and documentation), which could be utilized for treatment-seeking patients, thereby enhancing a city's ranking on this criteria[10].

2. Medical Equipment Predictive Maintenance and Enhancing Utilization

Improving the uptime of medical equipment (diagnostic machines such as X-ray, MRI, Ultrasound; Anesthetic machines, incubators, etc.) in hospitals, can help improve utilization rates along with enhancing patient care, safety and experience. In-person manual maintenance visits at regular intervals incur high maintenance costs. Furthermore, certain medical equipment components are too expensive and are available only as sub-assemblies (not individual parts), making uniform wear and tear an ongoing objective. Also, the Food and Drug Administration (FDA) mandates reporting of all medical equipment failures, but due to non-digitized means of failure capture and repair, very low adherence rates were found by FDA-sponsored surveys[11].

Operational efficiencies and adherence to compliance requirements will be significantly enhanced by IoT-enabled sensing technologies. These technologies enable remote monitoring of medical equipment parameters/usage patterns and generates alerts on performance-sensitive issues.

For example, sensors embedded on existing medical equipment capture real time physical state data such as vibration/coolant levels, diagnostics machine lamp temperature thresholds, change in physical orientation, detection of nitrous oxide in anesthetic machines, thread cut depth, etc. These data sets are sent periodically (as per the business /operational requirement) over short-range radio (wireless) protocol to the gateway. Gateways filter data based on predefined rules and conditions (i.e., sending only the average vibration levels and not each reading). This filtered data is then sent to the cloud-based IoT platform, saving network bandwidth considerably. The IoT platform provides the capability to integrate this sensor data along with Enterprise Resource Planning data (number of

[9] https://icity.smu.edu.sg/sites/icity.smu.edu.sg/files/publications/WP_Technologies%20for%20Ageing-in-Place%20May%202016%20Webpress.pdf

[10] http://www.asklepios.de/upload/RSLT_A_0495_Clinical_Application_Note_Chronic_Disease_Overview_1606.pdf

[11] https://www.hindawi.com/journals/jhe/2016/7267983/

examinations done, mean time between examination, etc.) – to generate operational insights and alerts. Predictive analytical models (failure prediction, pattern finding, etc.) – will help ascertain whether standard operating procedures were followed during the equipment usage, further enhancing equipment life cycle, utilization and reducing depreciation rates.

Similarly, evaluating component-level wear and tear patterns (for instance, only one bush of motorized platform getting exhausted in an MRI machine rather than both, requires part swapping) will help control costs and mean time between repairs (MTBR). Evaluating medical diagnostic equipment handling and usage patterns (average exam time per patient and body region, MTB patient exams, average study prep time), comparing against standard operating procedures and providing guidance to operators/users, will help additionally cut non-usage time and improve utilization for hospitals. For the equipment provider, it will enhance product life cycle and hence profitability

According to a leading research agency, the global medical equipment maintenance market (remote monitoring & maintenance) is expected to reach USD 2.24 billion by 2020 from USD 1 billion in 2015, at a CAGR of 16.7%. [12] These services can create significant savings for hospitals by preventing equipment downtime and hence improving utilization rates. Some vendors like Olympus Medical and Siemens Healthcare have been offering related service (i.e., remote failure diagnosis, Over the Air updates services). They are further maturing with introduction of deep analytical models and easing out on cloud specific restrictions.

3. Automated Documentation/Connected medical devices

As mentioned above, there is a tremendous shortage of medical professional (physicians and nursing personal) across the globe. Even for the ones available, efficiency goes down due to complex compliance related to patient health data documentation.

In the last decade, the data capture process has maturated from paper-based patient reported outcome (PRO) to electronic PRO (ePRO). But the process still involves manual activities such as data entry by patient into the ePRO. Further downstream, medical professionals have to scan it and then enter it into the electronic medical record (EMR) system. This is still a complex and time-consuming process from the perspective of physicians.

In a clinical trials scenario, integration between ePRO and cloud-based EMR systems enables automatic and secure import of clinical data from the ePRO directly into the electronic data capture system. For other scenarios, connected medical devices at investigational sites record patient clinical data directly into an electronic application,

[12] http://www.marketsandmarkets.com/Market-Reports/medical-equipment-maintenance-market-69695102.html

removing paper from the current standard electronic data capture model and making the process user friendly and highly automated. This will enable better adoption rates for EMR systems among care givers universally, improving the score on the Smart City health care parameter. [13] Realizing the benefits of this ecosystem, players including EMR vendors (i.e., Veeva Vault eSource, etc.) and chip makers such as Intel have launched or are planning to launch such innovation to their products in the next 3-4 quarters. This will enable devices to push data directly to EMR systems hosted on the cloud[14].

Enhancing medical devices and equipment interoperability will enable the safe, secure and effective exchange of information among one or more medical devices through standard communication protocols. This will potentially improve efficiencies by eliminating manual data entries at various milestones, patient safety and control manual data capture errors, with the same level of inputs. The Food and Drug Administration (FDA) has been collaborating with hospitals, health care providers, manufacturers and standards development organizations to promote medical device interoperability through synchronization of measurement parameter unit and time, alignment of data transmission protocols, categorization and labelling of equipment based on interoperable standards followed, etc. This can significantly boost the usage of EMR and information sharing rates among hospitals, which can improve the Smart City score[15].

TCS, for example, is working on a SaaS platform for improving clinical trial cycles. The platform ensures verification of individual medication intake via sensor-enabled and Near Field Communication (NFC) smart medication packages. This platform can interoperate with medical kits from different makers. Medical devices can be registered, verified and generate alerts of missed dosage intake and push data to the EMR systems. This automates the documentation process, removing paper-based or manual data entry. During the pilot of this platform, the patient medication compliance rate reached a very high 92%[16].

To summarize, automation of the patient health data capture process will save significant physician and nursing personal time bandwidth, which could be delivered proactively among larger patient/deprived groups, thereby enhancing the reach of patient care.

[13] **http://medicaleconomics.modernmedicine.com/medical-economics/content/tags/ehr/physician-outcry-ehr-functionality-cost-will-shake-health-informa?page=full**

[14] http://www.sascommunity.org/planet/blog/category/eclinical-systems/
https://en.wikipedia.org/wiki/Electronic_patient-reported_outcome
http://www.intel.in/content/dam/www/program/embedded/internet-of-things/blueprints/nexcom-intel-medical-blueprint.pdf

[15] https://www.fda.gov/MedicalDevices/DigitalHealth/ucm512245.htm

[16] http://www.appliedclinicaltrialsonline.com/digitally-enhanced-janssen-drives-effort-bring-suite-smart-clinical-trials-practice-2017?pageID=1

CONCLUSION

The Internet of Things has tremendous potential to automate processes, empower stakeholders with real time actionable information exchanges and not only raw data. The industry is embracing digital in the form of digitization, but that is just the tip of the iceberg. A shift to a highly matured state such as digital transformation by automating associated business processes will mark the onset of truly smart healthcare systems. Further, IoT-led innovations will drive a shift towards highly mature, value-based care indicators for Smart City health, improving operational efficiency, collaboration and better quality of life.

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