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Health Care and Internet of Things

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Abstract*: *Internet of Things (IoT), a term invented by Kevin Aston refers to a network of connected objects across the globe through some internet networks, software applications, electronic devices, and sensors which are capable of collecting and exchanging data among themselves. In the decade to come the impact of IoT will be seen in all possible verticals of human and societal development like transport, education, retail, health, finance etc. Health and medical progress is prime vertical of human development and symbol of a developed, strong and successful nation. This paper is an attempt to identify and discuss the possible roles of IoT with respect to solve certain important problems faced by health sector. This paper is an attempt to put together a survey of widely known health issues and their related IoT solutions with an aim to reduce them. This paper is written with a thought to serve as a source of information to researchers, student, and developers to implement solutions, frameworks, technologies and projects exploiting IoT for health sector.

Keywords* : *Internet of Things, Health, Wearable Devices, Hygiene Solutions

I. INTRODUCTION

Internet of Things (IoT), a term invented by Kevin Aston refers to a network of connected objects across the globe through some internet networks, software applications, electronic devices, and sensors which are capable of collecting and exchanging data among themselves[1][2][3][4]. [6] Internet and computers only have data and information the way as it is collected by people but what really matters is the things in the world. Data and information gathered manually is primarily prone to inaccuracy owing to natural limitations of humans. The better solution could be to have an integrated system or a network of machines, software, sensors, computers and internet that collectively captures the real time data from the things in world. The information and data collected in this way would be more accurate and lead to solving many problems that can possibly achieve the results with better precision. In [7] [8] researchers have cited things and the information communicated around them as sole and key aspects for any process implementation, business execution, social development, economic progress, growth etc. Technology evolvement in the last decade gives Internet of Things a new meaning to solve problems for the betterment of social and economic life. For an instance, think about an air conditioner or a refrigerator that may be capable of sensing the cooling effect with surrounding's temperature and informing about the time of repairing or replacement.

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A homemaker would be able to tirelessly manage the home with a smart system capable of reading the home status as guest arrival, travel planned etc. and consequently itself ordering the required items from the grocery store with a predefined automatic payment system.

IoT is now widely exploited as a prime possible role player in solving health sector issues as discussed among experts, researchers and policy makers [2][7]. Ioannis Daskalopoulos [8] while working on IoT and vaccine distribution mentioned about how continuous and substantial attempts are done to improve health in developing countries. In this paper, a wide survey is presented where the prime focus is on IoT and its impact on health sector. [7] [3] There is a great potential of designing and implementing IoT based solutions in health from basic applications as individuals information monitoring, critical patient remote monitoring, remote consulting to more sensitive ones as elderly person monitoring and their real time health status, immunization, vaccination, controlling malnutrition, controlling epidemics, wearables.

II. LITERATURE STUDY

This section elaborates a study on health sector problems and challenges conducted by various organizations and scientists. As quoted by Forbes [8] and keleno [11], India only spends 4-5% of its GDP on healthcare much lower than developed countries. The basic health issues like tuberculosis, heart attacks, diabetes, HIV, diarrhea, infant deaths, maternity care and child malnutrition needs immediate and effective attention. Diagnosis equipment, patient monitoring, treatment progress monitoring, drug integrity are some prime challenges. [9] The ratio of doctor assistance to individuals is very poor as with one doctor per 1700 people. A study of Marathe [9] discusses about how technology oriented health solutions like wearable devices, remote monitoring, connected elderly care, RFID enabled drug bottles etc. can be implemented to solve many above stated concerns. In [11] author discusses about exploiting technology and IoT in health area. It focuses on implementing solutions around IoT, cloud computing, big data for controlling infants deaths, automated in-patient care, big data disease tracking, counterfeit drug detection, secured video calling with patients, IoT sensor based health monitoring to save money. In context of India, other alarming medical impacting issues such as are female feticide causing skewed sex ratio, incomplete child immunization and deaths toll due to malnutrition etc. [12] [13] According to a study only 60% of candidate children are fully immunized while other 40% are either unimmunized or incomplete immunized. The reasons could be demographic related, parent illiteracy, lack of continuous monitoring or accessibility etc.

[14] UNICEF press release states about alarming decline in sex ratio in India last decade.

[15] Sex determination and sex selective abortion by unethical means has grown as an industry. The 2011 census indicates that in the age group of 0-6 years only 914.23 girls were born for every 1,000 boys. In urban areas pregnancy termination and in ruler areas female infanticide are the popular ways to survive sex based child. Another issue of counterfeit drugs manufacturing and selling is having threatening condition in India.

In this paper, the focus is to explore and discuss technological solution based around Internet of Things or related to control health concerns as discussed in previous section. Section III presents categorically organized details on IoT enabled solutions, researchers have proposed or worked upon in past in the domain of health and medical.

III. DETAILS

A. Hygiene

Hygiene means the surrounding conditions and personal habits that aid to maintain health and evade infection and spread of diseases. Different aspects of hygiene are - personal hygiene such as hand washing, menstrual hygiene; patient attendant hygiene; food hygiene [16]. Insufficient hand hygiene is an important reason of infection that may lead to further complications and delay the process recovering [43]. The hygiene factors become critical in case of infants. Exploiting IoT, multiple automatic solutions have been proposed and developed to automatically put check on the hygiene of patients to protect them from external infection, in public places, in food area etc. Few such popular technological solutions are discussed here.

- *HyGreen:* An application developed by University of Florida, helps the people to record all the hygiene events like handwashing and interaction with patient. It is based on wireless sensors and device feedback notifications. If sensor finds the alcohol on hands of workers involved in healthcare activities it immediately sends a notification to clean the hands as 'Hymarks' [28]. A workflow of HyGreen is present in figure 1.
- *Automated hand hygiene monitoring:* A wireless network architecture based system with each hygiene station considered as a node. This system consists of two main units – An infrared and RFID reader enabled soap dispenser scan the RFID name tag of the user and stored at server; A faucet not that process the data sent by dispenser node to record timestamps for the water flow start and end time. The timestamps are used to measure the hand hygiene duration pattern and achieve compliance [17].
- *Hagleitner Sense Management*: Based on Radio frequency, the intelligent dispensers record count of disinfectant release, fill level, battery status, number of entrances in washroom and send the data to a web based server for analysing the hygiene behaviour of visitors. The real time information collected can be used for analysing and improve compliance with hand disinfection regulations, forecast the demand, plan orders and plan cleaning schedules for larger events [29][39].

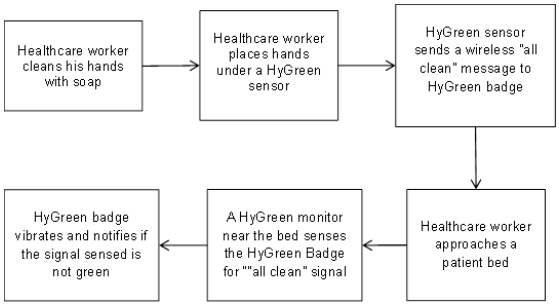

Fig. 1 Workflow of HyGreen

B. Infancy and Child Care

For effective child health compliance, passive surveillance of symptoms is important to control epidemics. Smart devices, can collect real time symptoms and provide the data to predict and prevent the contagious diseases [41].

- *Kinsa Smart Thermometer*: A combination of digital thermometer and app collects the symptoms and signs of infection, upload information on cloud for identification of symptoms or flu in the locality applying geocoding. Passively gathered information could help in preventing contagious diseases and mitigate epidemics [30] [40] [41].
- *Fever Smart:* Bluetooth based brain unit is attached to patient using a disposable patch to transmit the real time temperature data to a relay unit that is further put on cloud. Parents of the child can remotely anytime monitor the status and receive alerts [30] [44].
- *Mimo Baby Monitor:* A turtle shaped device is attached to baby's clothing. It continuously tracks sleeping patterns, breathing rates, temperature and transmits the data to sever with a Bluetooth based sensor installed in the room that can be easily accessed by parents in real time using a smart mobile phone app [30][45][46].
- *Sproutling:* A wearable around the ankle of infant is capable of recording movement, temperature and heart rate. Wirelessly charged (magnetic resonance) from a base station in the room, it has an optical sensor is used to monitor pulse, accelerometer to track position and motion, contactless sensor to measure temperature. Applying machine learning, the collected information is analysed to synthesize sleep patterns and schedule [30] [48] [49].
- *FiLip:* Wearable GPS enabled smartwatch act as a tracker for the toddlers and walkers with functions like parent massaging, emergency button. SafeZones can be setup by parents to monitor the entry and exit of child from safe zone [30].
- *Smart Phone based App:* An application for smart phones is capable to track the child and generate reminders related to polo vaccination dose based on child's age [50].
- *Platforms for vaccine/medicine supply chain:* Various implementations have used IoT for monitoring supply chain of drugs specifically vaccines.

1) A sensing application is proposed [52] to monitor vaccine supply-chain.

2) A conceptual model is applied to medicine or vaccine cold chain [51]. The RFID tags integrated with WSN network help in identification of counterfeited drugs and alarm its distribution to final consumer.

3) [64] Along a mathematical model to make vaccine supply efficient, an intelligent device with sensors and controllers connected to servers to record the real time vaccine transportation are beneficial in terms of temperature control, transportation route conjunction, inventory management, address the emergent demand or vehicle failure.

C. Environment

Many models and frameworks are proposed exploiting the technology of IoT for various problems and challenges related to environment. Various types of sensors used are humidity sensors, Non dispersive Infrared (NDIR) CO2 Sensors RFID, Temperature sensors. Three main types of environment related IoT solutions are explored in this study such as waste management, intelligent recycle systems, and environment monitoring systems.

- *Waste Management:* Unhandled waste is prime and common cause of disease spread specially in children. The technological solutions equipped with smart alert system, smart dustbin, overflow sensors can ensure a timely waste clearance.

1) Smart garbage alert system based on RFID tags, ultrasonic sensor with interface as Arduino UNO, message is sent to web server about garbage level for timely clearance and post verification [36].

2) A similar smart dustbin [60] of technovation makes use of ultrasonic sensors, microcontroller that alerts a real time garbage level of the dustbin beyond a defined tolerance system.

3) A waste management prototype using HCSR04 ultrasonic sensors to send real time waste bin level are used with Arduino UNO to calculate percentage. Accordingly is capable of routing the collection vehicles in the decreasing order of filled percentage [61].

- *Recycling and Municipal Solid Waste Management System (MSWMS):* Recover and recycle important components from the waste are of prime attention especially in industrialized countries and cities [62]. A sound 3R system is major concern for MSWMS in developed countries.

1) A RFID based technology for recycling purposes [62] focuses on smart labelling the products to move towards self-product management.

2) A three module IoT enabled based intelligent cycle will enable passive to active management [63]. Three modules included in intelligent cycle system are intelligence collection module, Intelligence transportation module, Intelligence processing module. A case study of Wuhan city with the digital management strategy shows the improvements achieved in recycle economy, real time monitoring, emergency handling of MSW, real time report to authority.

3) A Decision Support System [64] with real time data sharing among truck drivers and optimized routing is efficient for smart cities waste collection. This model provides –SaaS products to customer companies involved in MSW; a cloud based DSS to enable a beneficial information exchange among stake holders. The sensors in waste trucks and bins generate data about waste capacity, location, fuel; on-line navigation transform real time traffic information for effective routing.

- *Environment Monitoring System:* Such systems are capable to monitor various environment parameters like humidity, temperature, air quality, carbon mono oxide (CO) concentration.

1) A Raspberry-Pi based IoT enabled monitoring system [66] for remote areas can measure temperature, humidity, light level, CO pollutants concentration and a seismic sensor can detect earthquake. The real time data is automatically uploaded and is used to predict bad weather.

2) RainTrak Model RT-ICE [67] is rainfall detection and reporting model by HyQuest.

3) HailSens [68] is capable of recording hail events in real time, transfer the data to services for statistical analysis, showing tabulated and graphical results and using web technology to provide timely warnings.

D. Personal Care Wearable Devices

The study reveals that trend of self-monitoring towards health is increasing with an intention to take necessary actions for preventive measures and consequently avoid major health risks [32].

- *Motion Tracker:* Veltink and Boom introduced the concept of motion tracking with accelerometers was introduced in 1996 [33]. These applications include fall risk assessment; measuring personal habits, sports exercise. Multiple commercial motion trackers in form of wrist wearable are available for use like Fitbit, Withings, Misfit with capability to record movement statistics like distance travelled, step counting, calories burnt etc [32].
- *Body-worn smart clothing:* Smart cloths differ from wearable devices in deployment of sensors. Vital signs measuring sensors are integrated into textile clothing. Placement of sensors is critical to these solutions. Like sensors measuring pulse, body temperature, ECG and blood oxygen are placed at wrist, under arm seam, chest and ribs and Triceps muscles respectively. Crucial factors to intelligent clothing are wireless communication using low power, sensors quality, layout of flexible electricity cable, weak signal acquisition and user comfort [32].

E. Remote Patient Monitoring

Elderly care is sensitive and critical. Mandatory precautions and vigilance is utmost required for handling any medical emergency, along with providing an independent lifestyle to them for their happy well-being. Smart objects and systems based on IoT and related technologies in homes tracking the various parameters periodically and alarming the emergency to caretakers are proving helpful [55].

In [55] presents AAL, a three tier technical system for elderly patients focusing on health, safety, mobility exploiting IoT with Keep In touch (KIT) and Closed Loop Healthcare Services. Based on NFC, RFID and mobile phone, KIT collect and forwards the

S No	Areas	IoT Application / Solution
1.	Hygiene	*HyGreen* , a sensor based solution to record all hygiene events like handwashing, patient interaction etc. and generates notifications toc lean hands on violation. [26]
		Automated hand hygiene monitoring with use of RFID reader at soap dispenser and records the user tag information at server. Timestamps to measure hand hygiene pattern and enforce compliance. [17]
		Hagleitner Sense Management is a system with radio frequency based intelligent dispenser to analyze hygiene behavior of visitors. Real time usage information helps in forecasting schedule, inventory requisition. [29]
2	Infancy and Child care	Kinsa Smart Thermometer is a digital thermometer with intelligent capability to capture symptoms and signs of infection or flu in a locality to passively prevent contagious disease. [29] [40] [41]
		Mimo Baby Monitor, a device based on Blue tooth technology and mobile app that helps in monitoring the child from remote by parents
		Sproutling a wirelessly charging device to monitor pulse, accelerometer to track position and motion, contactless sensor to measure temperature of infant wearing it.
		FiLip, a GPS enabled tracker for toddlers with inbuilt messaging and emergency button with ability to set safe zones to monitor entry/exit from safer zones.
3	Environment	Waste Management oriented smart application with microcontrollers and ultrasonic sensors, to send real time garbage level of remotely located bins [36][60][61]
		MSWMS solutions with smart labelling the products [62] for self-product management [62], three module based intelligent cycle based, a decision support system [64]
		Environment Monitoring Systems such as Raspberry-Pi enabled monitoring for temperature [66]; RainTrak model for rainfall detection [60_67]; HailSens with capability to record hail events for statistical analysis to take necessary measures [68].
4	Personal Care Wearable devices	Motion Tackers devices include risk assessment, measure personal habits, physical activity statistics like Fitbit, Withings, Misfit.
		Body-worn smart clothing application has sensors integrated to measure vital signs. Key factor are sensor placement, sensor quality and user comfort [32]
5	Remote patient Monitoring	UroSense provides real time CBT and urine data for proper diagnosis and treatment in catheterized patients which can be monitored remotely by family members or medical staff to prevent emergency situation.
		Medication dispensing service can monitor medication schedule, reminders, alerts of missed doses [35] [48]
		Alert System as GoSafe2 is GPS enabled and is capable to generate help call on fall detection [35] [55]

health parameter information on a service center. CLHS ensures closed loop health care with access of physicians; rule based algorithmic analysis of thresholds and identifying the patients with severe conditions in near future.

In [56] also author discusses an IoT technology driven architecture to achieve AAL for patients keeping the privacy of patient. [57] Ray proposes a five layered architecture H3IoT- Physiological Sensing Layer (PSL) equipped with biosensors read the biological data of the patient, Local Communication Layer (LCL) transfers the data to upper layers, Information Processing Layer (IPL) using open source technology Arduino, Raspberry Pi, process data to information, Internet Application Layer (IAL) puts information for Android, IOS, cloud etc. , UAL a top most layer for various stakeholder users to get real time information. Few commercially IoT based tools are discussed below.

- *UroSense:* It is a device capable of providing the real time accurate data on CBT and urine output enabling the proper diagnosis and treatment of critical problem in the catheterized patients. Based on fluid sensor with the help of software and Wi-Fi, the vital signs can be monitored accurately and remotely by caregivers, medical staff or family member to avoid medical emergency [35] [59].
- *Medication Dispensing Service:* Alert devices are useful for elderly care for timely and correct medicine intake. Philips automated medication dispensing service is capable to monitor medication schedule, prefilled dosage, reminder alerts, alerts to caretakers about missed doses. An accurate and timely intake of medicine dose can avoid unplanned hospitalization and complications [35] [54].
- Alert System: GoSafe2 medical alert system is capable to make help possible around the clock using GPS, generate a help call on fall detection [35] [55].

IV. RESULT AND DISCUSSIONS

Health related applications make use and implementation of IoT in multiple domains. A domain wise application of IoT is depicted in Table 1. For improvement of personal hygiene, multiple systems are implemented those primarily focus of hand washing of patient, monitoring staff and visitors. Wearable devices are much common and widely used. These primarily record statistics related to physical activities and habits of the user. Some are also capable to analyze physiological attributes which are sent to concerned persons or system on real time basis to avoid any emergency or issue prior warnings. Similarly, remote patient monitoring applications are real time and capable of collecting sensitive data and alert medical staff or caretakers in case of any emergency signs. Two major areas where IoT can be very effective is vaccine status monitoring of individual child and vaccine distribution supply-chain. The analysis reveals that IoT must be exploited to apply technologies like RFID or Bluetooth to collect community level information to avoid any pandemic situations.

V. CONCLUSION

Health is important for any country to progress and is vital to human lives. Scientists exploit technology to solve problems to have a better life for human being. IoT is a stage further to Internet, which focuses on passive collection of data, process it and act. In this paper we try to summarize the various works done around IoT technology in the domain of health and provide solutions to improve it.

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