Smart Health Care System for Underdeveloped Countries

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***Abstract*—Nowadays state of the art health care systems are either based on hospital or household environs and its scope is confined to urban areas of a country. Yet traditional healthcare systems are facing challenges such as lack of ubiquity, use of backdated techniques, inadequacies in tracking, observing and reporting status of patients and diseases as well as unaffordability. However, modern updates in IoT, cloud computing, mobile and web development and computer vision technology are offering us a wider scope in providing an effective health care system to everyone. The assistance includes automation in systematic monitoring of patients, transmission of medical data at real-time, saving those data in cloud servers, manipulate data for future use, presenting real time scenario to stake holders and many more. Here we suggest a wireless network infrastructure that will provide useful health and medical services to children and adults as well as assist in distributing vaccines, tablets and personnel to monitor endemic diseases. We have two components in our system, first one is the clinic booth accompanied by health workers. This system assists health workers in their work and acquire personalized data and sends them to an online server for future use. Second is the administration and presentation of the ground data to stake holders. In our preliminary network evaluation of the IoT powered clinic booth design we found average response time of 1.5 seconds with uptime of 98.16%.**

***Keywords*— Cloud computing, internet of things, tiny and affordable computers , health care system, sensors, mobile and web development.**

I. INTRODUCTION

Internet is everywhere, thanks to wide spread use of computers, cheap price of devices, heavy demand, new invention, optimization, miniaturization etc. Devices today became so small that a few years ago television sets dominated the living room. Now we can watch television in a handheld device and do much more than just watching soap operas or games. With these new devices and the internet connectivity comes the idea of Internet of Things (IoT). IoT is a novel idea in internet which targets to connect anything with anyone, at any given time, utilizing proper connection and services [1].

The IoT conglomerate is strengthened by connecting it to cloud servers. Application of IoT technologies have bright future in health care systems and it is already being used in different settings. Health related information of patients is very important and requires protection from manipulation and theft. It also requires efficient and secure distribution of devices and servers (application and database servers) to render good service to the end user.

Bulk of the IoT related work focuses mainly on devising a network of wireless human body sensors encompassing a hospital or home environment. These approaches don't cover the full spectrum of patients and their problems. For instance, what if a patient/child doesn't want to move or may have problems in moving from home to hospital. Thus in order to cover the full spectrum of patients; we need to employ both traditional and mobile systems which will be portable.

Apart from premature birth the leading causes of death of children under 5 are Pneumonia, Diarrhea, Malaria and Malnutrition. The consequences of malnutrition and illness in childhood are visible in subsequent periods of human growth. One of the key indexes of child health and wellbeing is child mortality rate, which continues to be an issue for majority of under developed countries. One of the 8 Millennium Development Goals (MDGs) was to reduce child mortality by two-thirds by 2015 [2].

Many developing countries are showing good results in preventing child mortality. For instance, in Bangladesh from 1990 to 2011, under age 5 mortality decreased from 151 to 53 per 1000 childbirths. Mortality wanes are connected to social awareness, preventive measurements, improvements in socioeconomic conditions, initiate programs to enlarge coverage area for vaccines, treatment of diarrhea, implementation of IMCI, etc. [3]. Most vaccines are given to children aged between 0 to 10.

However in many countries modern equipment's are confined to provincial health centers and is often very far away [4]. Health workers in developing countries setup clinics in rural areas use backdated techniques to determine and handle problems. Workers typically investigate fever by putting their hand on a child's brow. They measure heart rate using stop watch. height and weight were measured and feedback were given based on the weight chart e.g. normal, over weighted, underweighted or obese [5]. To provide improved health care services, updated and refined actions are required. As of 2015, UN's sustainable development goal number 3 is, to ensure "Good health and well-being" of the people [6].

Portable diagnostic tools and electronic health care services can play an important role in achieving this goal if utilized in an exact and timely manner. If clinical data is provided at actual time, it will be very effective in treating patients and allocate resource. Which can also detect outbreaks of diseases as well

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as find cases of drug-resistance. Thus we emphasize that further achievements in reducing child mortality can be realized if health workers are equipped with a detection system that is compact, portable and cheap.

These portable devices will also be useful in countries that are suffering from wars and catastrophic events like tsunami, earthquake, etc. In 2017 we often hear that in Yemen people are affected by Cholera, by consuming contaminated water. Children in Syria are suffering from malnutrition. Thus challenges in different parts of the world may vary. We can tailor our system for a particular area which will help prevent region specific challenges. We can take data from children at real time and store it to cloud-based storage facility for future processing.

In our work, we propose a bundled and generic system where sensors and devices are connected to one tiny and affordable computer either by cable or wireless technology. The proposed system contains a unit that can be transported through land, river, lakes and seas. We call it clinic booth. These booths are connected to 3rd party data server. We administer this data and present these data to stakeholders by creating mobile and web applications as shown in figure 1.

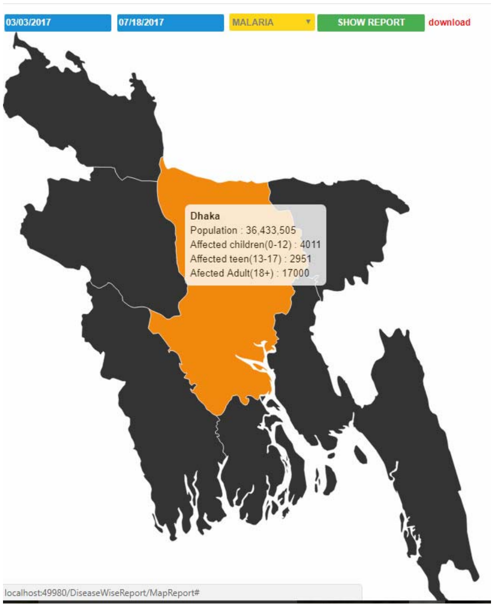

Fig. 1 Division wise demographic report on the number of people who are affected by Malaria in a selected period in Bangladesh.

II. OBJECTIVES

The role of modern technology is yet to be exploited fully in advancing health management in most parts of the world. Management of data relating to medical treatments and tests as well as execution of e-health continues to be a headache since paper-based systems are still used today, especially in hard-to reach rural areas. For instance, there had been some undertakings in countries like India, Malawi, Bangladesh to use SMS as a reporting tool for child health care monitoring. Maintaining processes like these are hard, requires double entry and are prone to human mistakes. Furthermore, the data is impersonal [5]. However, a system that is capable of automatically interpreting and transmitting personalized measurement data to cloud based servers at runtime would deal with these troubles.

We emphasize that our system be incorporated with other arms of a government. In most of the countries people have identification cards like National ID cards to identify themselves. Because our system is portable, we can move it across every corner of a country. Which will help us in relating children with their parents. We can take pictures of children, collect their ages and also store the number of vaccines they have taken over a period. We can also ensure whether a child is taking the same medicine twice. One problem arises in Bangladesh is often children die from taking medicines that have expired their service date. What occurs is the government buys more medicine than they actually need and tablets that were not distributed in one year were put in stock so that it can be used in the next year. Thus many children die when they consume those expired tablets. Health workers have an extended reach in every corner of a country. They know how much tablets or vaccines are required in a particular area. Thus policy makers can make decision about how much medicine they need to buy or import each season or year. Thus we can prevent child death and wastage of money. Our aim here is to monitor the growth, check crucial parameters, updating child vaccination chart, taking images, taking child and parent identification data, uploading data to the main server, present data to stake holders and give options for administrative tasks. Assessing body temperature and respiration rate is performed with sensor as it provides critical information about the child's well-being and guide the medical personnel about what to do next. Each child has a vaccination chart which maintains vaccination and dose report in the cloud server. Weight and height measurement is also performed to detect malnutrition.

Ambitions of our work are as follows:

1. Door to door delivery of simplified health services, enhancing accuracy and providing elegant quality of diagnostics through automatic review, record maintenance and spotting cases of malnutrition, fever, endemics, etc.

2. Improving existing health care systems by creating wireless network infrastructure and software as well as establishing storage structure in order to maintain personalized and customized clinical data to secure cloud-based storage systems.

3. Adjust child health care system with existing governmental systems of a country. like National ID Card number, child birth certificate number, social security number. Thus we can relate a child with their parents using their SSN or NID number. We can store locational information relating to pregnant women, suggest medication. Preserve information about vaccines and dosages, a child may have taken as well as prevent redundant usage of same medicine and vaccine. We can also store the level of medication and information relating to medicine brands.

4. Distribute and monitor the medicine flow to different areas in the country. Policy makers can see the medicine and vaccination distribution area at a particular moment. For instance, they can view demographic report of a particular country about how much area is vaccinated with polio vaccine. They can also view which of the areas are prone to which diseases and move assets like medicine and personnel to that area. In figure 1, we have shown a scenario about the number of people who were affected by Malaria disease with in the month of January in Bangladesh.

III. METHODOLOGY

For our health care system, these accompanying elements are suggested: portable clinic booth, Raspberry Pi, cloud platform, sensors, mobile application server, web server, image processing software and mobile and web based health monitoring software. Each clinic booth has internet access through wireless technologies, e.g. WiMAX, 3G or 4G.

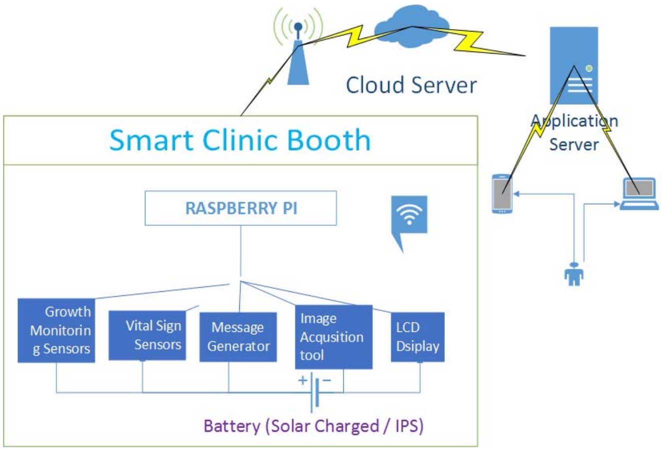

Fig. 2 Configuration of different components used in the proposed health care system.

A configuration of the suggested system is shown in figure 2. We use IPS and solar panels to power the electronic materials accompanied with the health workers.

A. Architecture of the Clinic Booth

Fig. 3 Portable Smart clinic booth with accompanying components.

A construct of the booth is picturized in figure 3. It comprises of a collapsible, small, handy booth that is transportable through car, motorcycle, canoes or by hand. The length, breadth and height of the booth is 70 by 70 by 130 cm respectively, as this device will only be used for babies. Inner height of the booth is 120cm allowing us to measure babies aged from 0-7 in standing position. The parts that comprises our clinic booth are: Raspberry Pi, camera, mobile phone and laptops to use the software, temperature sensor, weight-height measurement device, display device, audible message generator. some sensors and devices are handled by Raspberry Pi which has its own Wi-Fi ports and software. Child growth is audited through a scaling device that can measure weight, water percentage, muscle mass and bone mass. Measurement of sleeping child is also possible with health worker's assistance. We avoided using traditional technologies instead we used sensors to measure individuals pulse rate, respiration rate and temperature. Measurements are displayed on the software and health workers can overwrite the data if need. Findings from the derived data can be narrated to guardians or users.

IV. TECHNICAL DETAILS

Several ideas and elements were consolidated for effective service delivery of our system such as skilled design, technology alternatives, stability, scalability, security, integration, accessibility, pricing of elements, response time, accuracy, evaluation result, communication bandwidth, etc. Here, we describe about the underlying technology for clinic booth; Software associated with its operation, connectivity of the booth to the cloud platform, administration of data and servers and presentation of data to stakeholders.

A. Underlying hardware and software modules

There have been encouraging developments in every sectors of ICT. From our strength point of view, we have preferred to use mini-computer instead of microcontrollers which ensure us fast prototyping, greater software control, reliability on the hardware, good community support, scalability and many more. Our system is constructed using Raspberry Pi, a tiny and affordable computer, with a processor speed of 700Mhz to 1200 MHz, RAM size of 512 MB or 1 GB with built in USB, Ethernet, Wireless and Bluetooth capabilities depending on the model. The price of this device varies from $5 -$35 depending on the model [7].

We have used "Windows 10 IoT Core" operating system for our Raspberry Pi devices. It is an operating system that is built for IoT. It is not the same operating system that we use in our desktop computers. Windows 10 IoT Core is the environment that will allow us to deploy our applications to Raspberry Pi. We used a compatible SD card in order to setup the "Windows 10 IoT Core Dashboard". Resources like documentation, Software, compatibility issues, source codes and IEDs related to Windows 10 IoT Core are available online [8].

Computer vision is a field that aims to gain remarkable understanding from videos or images. We used image recognition software in order to match images of our patients. A number of open source software(OSS) in computer vision are available online for example [9], GitHub [https://github.com/ageitgey/face_recognition], etc. These open source software aims to motivate people and collaborate with other scientists.

B. Data storage, manipulation and security

The application is developed using Firebase which offers a complete backend solution. It has supports for authentication [10] (supports OAuth 2.0) [11] , analytics, remote configuration, cloud messaging, crash reporting, REST API, NoSQL and many more. NoSQL database is more applicable compared to relational database in regards to real-time web application development and is known for its simplicity of design and control. Applications store data as JSON objects and interact with the database using a JavaScript API. Developers can add Firebase to their Android or iOS project very easily. Thus providing us future scaling and optimization option. The data store is designed to scale with application demand, so there is no need to add additional servers, partition data or perform other database administration tasks that were required to preserve database back end.

The RESTful API includes query operations but not SQL operations. The query API is tailored to work with channels of data. There are also query operators with SQL-equivalents, such as orderByKey, orderByValue and orderByPriority. For instance, limit, limitToLast and limitToFirst query operations can restrict the number of JSON documents returned by the query [12].

Firebase will validate domain ownership, provision of SSL certificate and deploy it across the Firebase content delivery network. Once users or in the case of IoT, when the devices are authenticated, security rules control the operations they can execute and the data they can access.

At last we will access Firebase data through REST API. There are not many C# REST libraries to access Firebase. We use NuGet package manager to install the desired library(FirebaseDatabase.net). We give the opportunity to our admin of this system to view demographic reports, bar charts, create and send emails to stakeholders, view stock, ship medicine, tablets and personnel depending on the situation.

V. DEVELOPMENTS

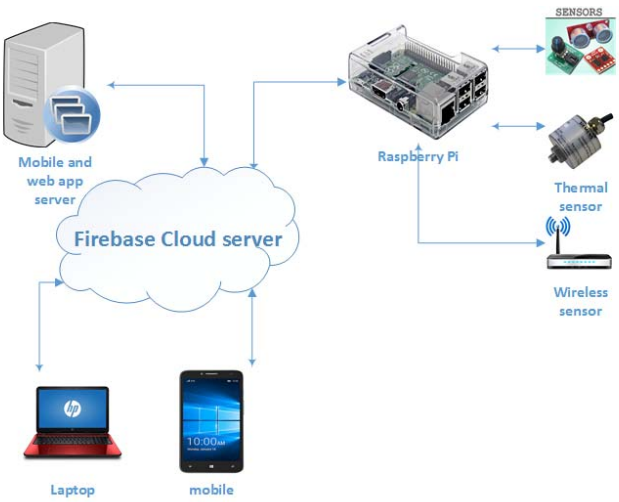

Fig. 4 Development phase (communication between hardware and software).

Our primary task was to establish connection between the cloud infrastructure and the booth. Then we focused on controlling the devices and sensors from Raspberry Pi. Take automated readings and save them to cloud servers. Give input and view output on application window and finally administer and present data as well as provide administrative options to stakeholders. In our work we have check our system in terms of responsiveness, dependability, accessibility and security.

As illustrated in figure 4, our device is built with Raspberry Pi that communicates with sensors. Controlling the devices and sensors from Windows 10 IoT operating system is done through dedicated USB, Wi-Fi ports and pins. There is admin for each booth who have a unique user name and password. Apart from helping the patient admin of the booth can also input and update data in the storage system. Personalized data of a patient are saved to the cloud storage at run time. Health workers communicate with the storage system and the Raspberry Pi device through our dedicated android and web apps. They can perform create, edit, update and delete operations on the cloud data. Log information about access to the storage are saved to the system automatically. Our Web app was created with Asp.net MVC technology. Stake holders having unique username and password can view demographic report, bar report (shown in figure 5), current distribution of personnel, stock and endemics in a particular area as well as create and send emails from this site. We have stored detailed patient data in our system in order to build trust in our system. Furthermore, we designed our system in such a way so that any human error would come to light very easily.

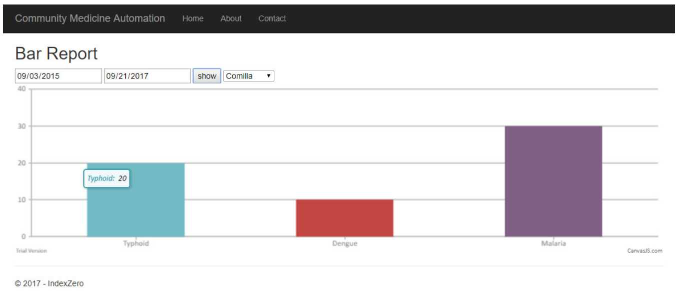

Fig. 5 Disease and district wise endemics bar report based on some selected date ranges in 2017.

VI. RESULTS

A. *Performance*

We measure performance in terms of latency. Latency is the time from when a user sends an instruction from the mobile or web application to the time when a response is received by the application. Latency is measured by deducting the transmitted message (TX) date-time stamp from the Received message (RX) date-time stamp. We measured time in terms of milliseconds by using different analytical tools.

B. *System Availability*

Availability is the quality of being at hand when needed is a proof of a systems reliability. For our system, system availability is measured in terms of the reachability of the main component of clinic booth (Raspberry Pi) and its corresponding data store on Firebase from our software platforms. During the period 13th to 18th June 2017, the clinic booth was connected to its data store, representing a total duration of 432000s. The activity was monitored from the Google analytics, our mobile and web app servers as well as using 3rd party analytical tools. Our hardware and software components performance were extremely satisfactory.

VII. MERITS

Our campaign mainly focused on targeting 3 kind of people: citizens with less privileged health access, health workers and policy makers. We expect our system will ensure better service delivery to people in rural areas of underdeveloped countries. It can even more effectively provide services in disaster hit areas and can be accompanied by field workers working for NGOs or health workers of a state. With this system the tasks of health workers will be automated by our system; all collected and log data are automatically stored at our cloud servers; data can be processed/updated for any future use and presented to policy makers at any given time. This benefits ensures that our system will supported by policymakers as well as other stakeholders. Furthermore, it will give an exact scenario about current distribution of health agents, vaccinators, vaccines and medicines to a certain region. If medicine shortage or disease outbreak is reported in an area, this system will assist people in the government to take decisions in order to remedy the situation. Moreover, avoiding the use of paper-based systems would help us to protect the environment, reduce human errors and hardships as well as protect us from corruption. This system also awards us market spaces in cloud platform, data mining, data analysis, sensor technology, mini-computer and IC production technology.

VIII. CONCLUSIONS

In the aforementioned work, we propose a health care system consisting of IoT, cloud computing, Raspberry Pi, sensors, software, web and mobile app servers. All test experiment results involving sensors and measurement devices, transmission of readings to Firebase backend server and presentation of data to stakeholders were remarkable.

We recorded an average delay of 1.5 seconds in our experiment of sending a command from the application software and receiving a response in the same application window. System availability of 98.16% was recorded. Thus, the network operation of our system reasserts the suitability of the IoT system in underdeveloped rural areas.

Although many tasks performed here are automatic but health workers can intervene when taking images or inputting NID/ SSN/ birth certificate numbers to the system. We have plans to develop a more sophisticated image recognition tools and integrate the system with our existing system. We have also plans to develop a customized mini-computer like Raspberry Pi, to minimize the production cost. There are not many REST API libraries available in dot net for accessing Firebase. Developing a web server with Python or Ruby seemed to be more preferable.

REFERENCES

[1] S. M. R. Islam, D. Kwak, H. Kabir, M. Hossain, and K.-S. Kwak, "The Internet of Things for Health Care : A Comprehensive Survey," *Access, IEEE*, vol. 3, pp. 678–708, 2015.

[2] Statistics Division of United Nations, "The Millennium Development Goals Report 2015," UN Statistics Division, New York, 2015.

[3] B. Ministry of Health and Family Welfare, *Success factors for women's and children's health: Bangladesh I.World Health Organization.* Geneva, 2015.

[4] O. Vermesan and Peter Friess, *Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems*. 2013.

[5] T. Nyasulu, "Smart under-five health care system," in *2016 IST-Africa Conference, IST-Africa 2016*, 2016.

[6] U. N. UN Web Services Section, Department of Public Information, "Sustainable Development Goals launch in 2016." [Online]. Available: http://www.un.org/sustainabledevelopment/blog/2015/12/sustainable-development-goals-kick-off-with-start-of-new-year/. [Accessed: 17-Aug-2017].

[7] R. P. FOUNDATION and U. R. C. 1129409, "Raspberry Pi FAQs - Frequently Asked Questions." [Online]. Available: https://www.raspberrypi.org/help/faqs/. [Accessed: 10-Aug-2017].

[8] Microsoft, "Windows 10 IoT Core Official Website | Developer Resource | Windows IoT." [Online]. Available: https://developer.microsoft.com/en-us/windows/iot. [Accessed: 17-Aug-2017].

[9] U. of S. CVSSP Webpages, "University of Surrey - Centre for Vision, Speech and Signal Processing - Home." [Online]. Available: https://www.surrey.ac.uk/centre-vision-speech-signal-processing. [Accessed: 17-Aug-2017].

[10] L. A. R. R. Copyright © 2006-2017 How-To Geek, "What Is OAuth? How Those Facebook, Twitter, and Google Sign-in Buttons Work." [Online]. Available: https://www.howtogeek.com/53275/exchanging-data-safely-with-oauth/. [Accessed: 17-Aug-2017].

[11] D. Hardt, "The OAuth 2.0 Authorization Framework [RFC 6749]," *RFC 6749*, pp. 1–76, 2012.

[12] S. M. Sohan, C. Anslow, and F. Maurer, "SpyREST in action: An automated RESTful API documentation tool," in *Proceedings - 2015 30th IEEE/ACM International Conference on Automated Software Engineering, ASE 2015*, 2016, pp. 813–818.