NFC tag-based mHealth Patient Healthcare Tracking System

Abstract—**Patient misdiagnosis is quite a common occurrence in hospitals around the world. It is a mistake that can happen to anyone at any time, and especially during a pandemic crisis when hospital facilities are overwhelmed with increasing number of patients. This problem could stem from improper patient identification whereby patient files are mislabelled or placed in an incorrect patient dossier. It is the responsibility of a hospital and its employees to guarantee that such mistakes do not occur. With respect to this, near-field communication (NFC) technology, which is a short ranged wireless communication technology, has been identified to have great potential to help identify patients in hospitals.This paper demonstrates a solution by designing and developing a patient healthcare management information system that sees the seamless integration of the NFC technology along with and both web and mobile technologies,to provide a holistic solution to tackle the problem of patient misidentification in a hospital environment especially during pandemics such as COVID-19.The Technology Acceptance Model (TAM) was used as evaluation method in order to quantify the proposed systems's usability and acceptance using 5 constructs. Results showed acceptance of the system with a mean score of 4, indicating that the NFC tag-based mHealth Patient Healthcare Tracking System was found to be useful and easy to use.**

Index Terms—**authentication, prototyping, Healthcare, Medical information systems**

I. Introduction

The Institute of Medicine (IoM) indicates and estimates that errors pertaining to medication administration of hospitalized patients happens once every day. This medical administration stage accounts for 26% - 32% of medication errors for adult patients and 4% - 60% of medication errors in paediatric patients [1] These statistics show that proper care has to be taken when medications are administered to patients and even at times of their prescription. Proper identification of patients and their electronic health records where their medication information is stored, will greatly reduce these errors. Out-patients are also not left out as it is imperative that these patients have enough information about the medications that they have been prescribed by their doctors [2]. Information such as side-effects, wrongful ingestion or even effects of a possible overdose and emergency contact information [3], all have to be available for each and every bottle of medication. Technology has come a long way to make this possible with the aid NFC technology whereby these medication bottles or sachets, can be embedded with an NFC tag that are scanned with the patient's mobile device for more information [2]. Patients resident in hospital wards could be serviced better by medical personnel by firstly being properly identified after which they are serviced by doctors and nurses with appropriate tests and medication.

The unique identification of every patient in a hospital is a paramount requirement in any clinical workflow [4]. Patients need to be linked to their corresponding medical health records, blood tests, ECG charts, X-Rays etc., to help doctors and nurses provide adequate medical recommendations based on the data at hand. There are three major areas where patient identification is required in the hospital, at the emergency room (time of admission), while on admission (In the medical ward), and at various medical units such as urology, radiology, haematology, etc. Patients need to be properly identified in these medical departments on time in most cases. As the healthcare sector is a sensitive one, the safety of resident and out-patients' needs to be taken into consideration especially with the scorn of human error [5]. During the time of COVID-19 pandemic it is crucial to identify and direct the patient to the correct ventilator, for example.

Thus, this work set out to implement a proof-of-concept system to demonstrate NFC technology as an administrative tool when used alongside mobile and web applications that can directly extract patients' electronic health records. The paper is outlined as follows: Section II covers the background, Section III discusses the proposed model and its implementation, Section IV describes the evaluation method used, Section V elaborates on overall results obtained, and Section VI concludes the paper with a view towards future work.

II. Background

Over the years, the radio frequency identification (RFID) technology is used in hospitals for patient identification. RFID in health care is mostly applied to real-time location systems (RTLS), whereby, the identification and tracking of patients are done in real-time. Electronic means of ward round systems by medical personnel with RFID being one of the components involved often delivers a cumbersome system where by the RFID reader will be accompanied with a 'workstation-on-wheels', that will be dragged around to each patient's bedside [6]. NFC, on the other hand, is a specialized subset of the RFID technology, and has been developed to enable mobile applications using consumer smartphones and tablets, to identify and exchange information [7]. With the adoption of the NFC technology, the solution is more a seamless one, whereby NFC enabled consumer smartphones/tablets will be used to uniquely identify patients that have NFC tags in form of a simple silicone bracelet, where their e-Health records will be retrieved to an application running on the same smartphone/tablet that was used to uniquely identify the patient. Unlike RFID, NFC does not require dedicated devices as the technology is already present in phones and tablets. As a short-range wireless communication technology, near field communication (NFC) facilitates data exchange for consumers around the world by making it possible to perform transactions, exchange digital content and connect electronic devices with just a touch, as an individual performing payments, voting or ticketing functions [8], though the security aspects [9] of wearable health devices is something that gathers attention [10], their utility can aid in critical applications [11].

A. NFC In Medical Applications with Wireless Sensors

Owing to the tedious and rather time consuming means of patient data collation by medical personnel whereby patients vital signs are collected on an hourly basis all day long, a method was proposed by [12], whereby the NFC technology in collaboration with WSNs and an android application were employed to proffer a suitable solution. In-patients were outfitted with wearable wireless sensors (Pulse Oximeter: providing reliable access to a patient's heart rate and blood oxygen saturation; Electrocardiograph: accessing patients' electrical activity of the heart. These sensors persistently poll a patients vital signs over time. These data are then stored on a NFC enabled phone hooked up to the patient. In turn, medical personnel equally used NFC enabled smartphones to collect data from the patients' device by simply touching the both devices for data exchange to occur. As soon as this information exchange took place, all the patients data is uploaded to the hospitals central database under the electronic health record of that particular patient.

This indeed provided an easy way for medical personnel to collect patient data which saved time. As at the time this research work was carried out, the world had not seen such pervasiveness with respect to the NFC technology which is why discussed the lack of enough NFC enabled phones as the major drawback of their system. Also, there are challenges faced where this system is concerned regarding WSNs, where the mobility of patients and doctors can become a problem with frequent changes in the quality of wireless links; WSNs employ public and private key cryptography for the security of information carried across the network. This can be quite cumbersome as there is great complexity involved coupled with the expensive cost of implementation. It was stated that PIN codes were used for the security of the system.

B. NFC Based Patient Identification and Ward Round System

A ward-round application for medical personnel (doctor) was developed by [4], where patients are identified with the help of NFC technology, with NFC silicone bracelets/tags worn by every patient. The NFC technology here was used to identify patients in the midst of medical personnel during ward-round sessions. The unique identifier that associates a patient's EHR and NFC tag worn by the patient, is used by the system to fetch the appropriate EHR of a patient to the device of the medical personnel attending to the patient. The medical attendant can then proceed to view recent test results, can add or edit medical information such as a patient's treatment regiment. This method indeed saves time because the medical attendant need not manually search for a patient right in front of him/her from a lengthy log of in-patients present at the hospital at that point in time. The research was aimed at improving clinical workflows and technology usability. Patients are first identified at their first point of arrival where their full past medical history is taken by the doctor at the emergency room. They are issued with a NFC tags (silicone bracelet) to be worn at all times while on admission in the hospital. The patients EHR number or hospital numbers are written to the NFC tags. While the patient is on admission and when medical personnel are on their ward round session, the NFC tags play a huge role in identifying the patients, To identify a patient, all the medical attendant need do is tap his NFC enable smartphone/tablet with the patients NFC wristband for an activity to take place The medical attendants NFC enabled device proceeds to read the NFC tag that contains the patients EHR ID number and starts up the hospitals health mobile application, which connects to the hospitals backend central server, with the help of a backend plugin.

The backend plugin proceeds to search out the EHR ID matching that of the NF wristband worn by the patient. Once a match is found, all the vital information regarding the patient is pulled to the mobile application, where the medical attendant is free to create/update/delete health information. As soon as a save action is performed on the mobile application by the medical attendant, the central database storing patients EHR is updated.

The system proposed by [4] does not go further to put in place a component for the unique identification of a patient. If there were to be a mix-match of patients NFC silicone bracelets, wrong medications will in fact be administered to patients which can prove fatal. This system does not involve Photo ID, to uniquely identify patients with their EHR IDs. This is what this study tries to accomplish with a proof-of-concept application system.

C. NFC Medicine Talk Application

A mobile application for primarily illiterate patients was developed by [13]. This involved a health care provider, NFC enabled prescription bottle caps, a mobile application and a remote server. Patients that are not well read, were to tap their NFC enabled mobile phones running the application on the caps of their medication bottles that had the NFC chip embedded, to get vocal instructions on how to take their medications. These instructions were to be pre-recorded by the health care provider at the time of dispensing. These audio files of prescription information are normally stored on the patient's mobile phone. In a case whereby the audio file was unavailable in the patient's phone at the time of request, the file was to be pulled from a remote server after the mobile application had establishes an internet connection. One of the strengths of this application lies in the simplicity of its presentation to the intended user where they were able to get access to the information they needed as at the time they needed it.

III. Proposed Model

Fig. 1 shows the prototype architecture that was developed. The system consists of a number of components, namely:

1) an NFC bracelet
2) Mobile Device
3) Electronic Health Record Management System

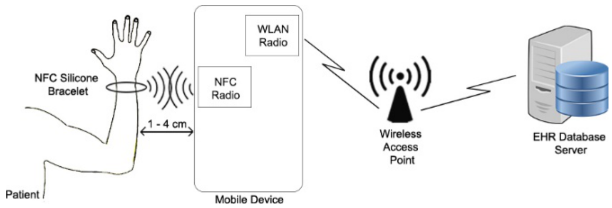

Fig. 1. System Architecture

In terms of workflow, the NFC silicone bracelet is scanned by a mobile device at a distance of about one to four centimetres, equipped with both the NFC and WLAN wireless communication radio antennas. Once the mobile device reads the NFC Tag ID assigned to a particular patient, it requests that particular ID number from the electronic health records database residing at the server where it is hosted. This request is performed over Wi-Fi communication, and the details matching the patient ID is returned to the application running on the mobile device, where the user can then lookup information while making desired changes that are seamlessly written back to the database hosted on the server.

A. The NFC tag

The MIFARE Ultralight NFC chip was chosen to be used for the proof-of-concept demonstration since the memory requirement of 48 bytes is sufficient in storing a patient's health identification number. This was enclosed in a silicone bracelet as in Fig. 2.

Fig. 2. Silicone Bracelet with NFC Scan screen

B. Mobile App

The Mobile App was developed in Android Studio using the Ionic framework with Apache Cordova which simplifies mobile development. NFC Data Exchange format (NDEF) APIs are used to interface NFC devices. Fig. 3 shows Patient View. A photograph is used to further identify the patient in question.

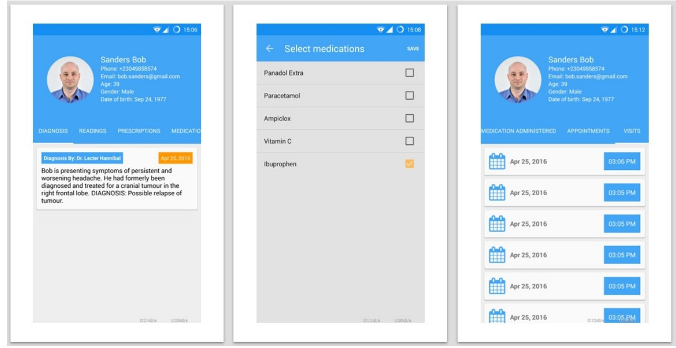

Fig. 3. Mobile app screens

C. Database Server

Details about patients, medications, tests amongst many other entities need to be stored in a database. For the purpose of this research, the MySQL database was used to hold all of such information. This database schema was developed to identify key relationships between these entities and how they affected one another. The entire database is made up of eleven tables (administrators, appointments, doctors, diagnosis, prescriptions, nurses, patients, medications, readings, visits and medication administered). A PHP based web application was developed to further maintain patient records (Fig. 4), and the server provided connectivity to mobile clients to allow authentication of NFC tags and collection of data. For the logic processing of the backend and mobile applications, the MVC model was used where models were created for each and every transaction, with certain controllers, that interact with the views which are basically what the user sees.

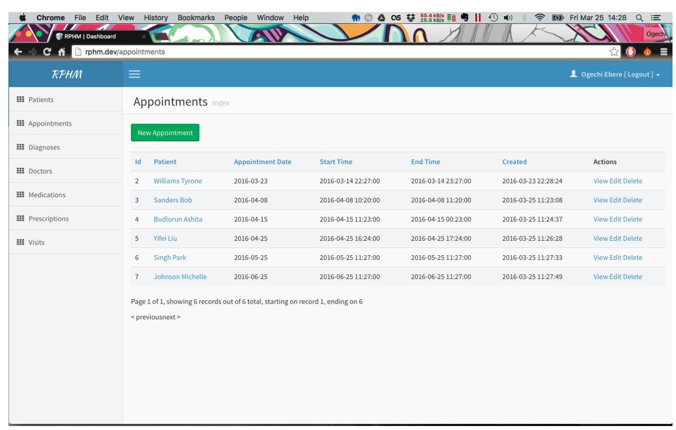

Fig. 4. Appointment Screen

IV. Evaluation Method

For evaluating the acceptance of NFC tag-based mHealth Patient Healthcare Tracking System, the Technology Acceptance Model (TAM) was chosen as it is a very popular evaluation model used by numerous researchers around the world [14]. The aim was to develop a comprehensive adoption model that studies several aspects of the TAM and assesses the degree of user acceptability of the features provided by Patient Healthcare Tracking System [15]. The TAM constructs that were investigated were as follows: perceived convenience (PC), perceived ease of use (PEOU), perceived usefulness (PU), attitude towards use (ATU) and continuance intention to use (CIU), which were adopted from previous studies [16]. Thus, a TAM questionnaire using the abovementioned constructs was designed as data collection instrument so as to achieve an accurate measure for the technology acceptance level of the project whilst ensuring quality with statistically sound results. The constructs used as part of the TAM questionnaire are defined in Table I.

TABLE I
DEFINITION OF TAM ATTRIBUTES

Attribute	Definition
Perceived Convenience (PC)	Convenience level perceived by users with respect to time, place and execution while carrying out an action on the app
Perceived Ease of Use (PEOU)	The degree to which users feel that using the technology will be effortless
Perceived Usefulness (PU)	The level to which users feel that utilisation of a certain technology will help in enhancing their work
Attitude Towards Using (ATU)	Attitude that one feels, usually positive, towards the application.
Continuance Intention to Use (CIU)	The degree of willingness displayed by users to continue using the application in the future.

Prior to conducting the actual study, a pilot test was carried out so as to finalise the evaluation process and procedures.

A. Participant Recruitment

Medical doctors working in five major local private medical institutions were contacted and invited to participate in the testing and evaluation phase. Participants were contacted individually for the study via email or WhatsApp. A brief on the study was also sent to them prior to requesting for their informed consent using an online form. 45 participants agreed to take part in the study, which satisfied the minimum number of users required for the TAM survey to give reliable results.

B. System Interaction

Participants were given a series of five simple tasks to do, which included scanning a patient NFC tag, verifying patient information and vitals signs data, writing a diagnosis, writing a prescription, and setting up a future appointment. Without any prior training with the system, the participants were asked to navigate and comprehend the solution. As they interacted with the system, their interaction was captured through screen-record for post-interaction analysis. This form of observational evaluation helps identify any usability problems, which in turn can be used for improving the user interface. Moreover, any possible technical issues/glitches/bugs were also noted.

C. Data Collection

Following the interacting with the system, the participants were asked to fill in the questionnaire. The questionnaire was made up of two main sections, one for capturing the demographic details and one for capturing TAM constructs. All 5 constructs were graded on a Likert-5 scale. The scale was labelled as follows: 1 - Strongly Disagree, 2 - Disagree, 3 – Neither Agree Nor Disagree, 4 - Agree, 5 - Strongly Agree. A suggestions area was also provided for additional feedback.

D. Data Analysis

Upon successfully data collection, the data was checked thoroughly for reliability and integrity. IBM SPSS software package was used to perform statistical analysis [17], and key statistics and graphs were generated for enhanced visual representation of the results.

V. RESULTS & DISCUSSIONS

The results collected represented a demographic of 20 females and 25 males, which is respectively 44.4% and 55.6%. As shown in Fig. 5., the age distribution was as follows: 6.7% of participants were within the age group 25-29 years, 24.4% of participants were in the age group 30-39 years, 22.2% were in the group 40-49 years, 20% were in the group 50-59 years, and 26.7% were 60 years plus. All participants had at least an undergraduate medical degree. The participants owned a smartphone and had access to internet. They also used both as part of their daily lives.

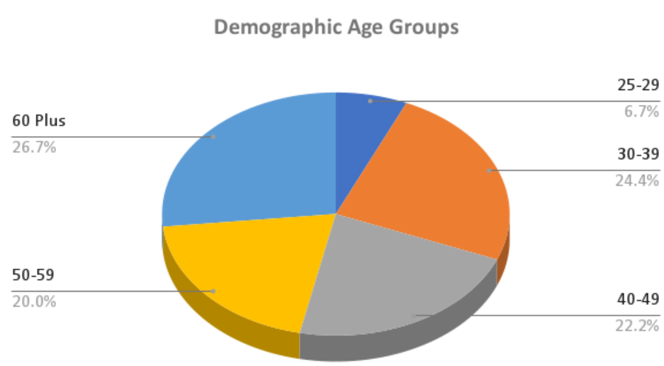

Fig. 5. Demographic Age Groups

After carrying out the statistical analysis, an overall TAM score of 4.0, as shown in Table II, suggests that developing this system provided the medical staff with a useful system. Additionally, the NFC tag-based mHealth Patient Healthcare Tracking System also introduced a novel experience with its architecture. Overall, a positive impact was noticed amongst the participants towards the system. The participants found the system convenient to use with an average score of 4.23 for PC, this being the highest score among the constructs, representing high level of engagement and satisfaction. For PEOU, users faced no major issues since the system was built using proper UI and UX principles. With a lower score 3.94 for PU the system can be considered useful. However future versions can

TABLE II
TAM CONSTRUCTS RESULTS

Construct Statement	1	2	3	4	5	Avg. Score	Construct Avr.
Perceived Convenience (PC)							
PC1: Using PHTS app is comparable to other apps in my experience.	0	0.11	0.22	0.4	0.27	3.82	4.23
PC2: I find using PHTS very engaging.	0	0.02	0.11	0.31	0.56	4.4	
PC3: Using PHTS fits my profession.	0.04	0	0.16	0.29	0.51	4.22	
PC4: Using PHTS is convenient and reduces misdiagnosis.	0	0	0.09	0.33	0.58	4.49	
Perceived Ease of Use (PEOU)							
PEOU1: I think learning to use PHTS was easy.	0.04	0.02	0.22	0.31	0.4	4	4.08
PEOU2: I think learning to operate PHTS would be easy.	0	0.04	0.09	0.44	0.42	4.24	
PEOU3: My interaction with PHTS would be clear and understandable.	0	0.02	0.18	0.49	0.31	4.09	
PEOU4: I think navigating for what I want through PHTS app was easy and flexible.	0.02	0	0.18	0.58	0.22	3.98	
Perceived Usefulness (PU)							
PU1: Using PHTS would better assist me in patient identification.	0	0.04	0.09	0.6	0.27	4.09	3.94
PU2: Using PHTS app would improve my effectiveness on the job.	0.02	0.04	0.33	0.22	0.38	3.89	
PU3: Using PHTS is very helpful for my profession.	0	0.02	0.22	0.38	0.38	4.11	
PU4: Using PHTS would significantly reduce patient misdiagnosis.	0	0.11	0.11	0.44	0.33	4	
PU5: Using PHTS helps me focus on more critical part of my job.	0.11	0.16	0.07	0.33	0.33	3.62	
Attitude Towards Using (ATU)							
ATU1: Using PHTS is a positive influence for me.	0.02	0.07	0.16	0.42	0.33	3.98	3.87
ATU2: Developing PHTS was a wise idea.	0.09	0.16	0.07	0.33	0.36	3.71	
ATU3: Using PHTS positively contributes in solving the problem of patient misidentification.	0.04	0.09	0.04	0.31	0.51	4.16	
ATU4: I look forward to use this technology at my workplace.	0.04	0.22	0.13	0.27	0.33	3.62	
Continuance Intention to Use (CIU)							
CIU1: Provided access to PHTS I indend to use it.	0.02	0.22	0.09	0.33	0.33	3.73	3.88
CIU2: Assuming I had access to PHTS, I predict that I would use it.	0.09	0.16	0.07	0.44	0.24	3.6	
CIU3: I intend to continue using PHTS.	0.04	0.07	0.16	0.27	0.47	4.04	
CIU4: I intend to gain more knowledge about mHealth and NFC technology in the coming future.	0	0.04	0.18	0.38	0.4	4.13	
						TAM Average	4

still be improved. Attitude towards using the system was noted to be positive, and users were optimistic about the idea of using the system in the future. In terms of sample size, a larger group of medical personnel would have better represented the user-base. An improved formulation of hypothesis would have been possible with their respective relationship.

VI. CONCLUSION & FUTURE WORK

This paper has showcased the possibility of integrating a short range wireless communication technology with a client-server based application system, in the form of a health management information system, whereby patients resident in a hospital ward, can be uniquely identified by means of near-field communication. It has been shown that the NFC technology and NFC tags more specifically, could be used to properly and uniquely identify patients in a hospital or clinics, even where hospital patients knowingly or unknowingly get their tags mixed up, where patient A will be wearing patient B's NFC tag, and vice versa. This hurdle was mitigated by the prototype application having the functionality and capability of adding and displaying photographs of the patient, which is the key contribution as compared to previous works.Thus in cases whereby NFC tags are mismatched, the medical personnel attending to a patient at any given point in time, always has a photograph image using their mobile device to verify that this is indeed the patient who owns the personal details and medical history. It has proved that the solution, if adopted in a live scenario, has the potential to be a game changer in how medical personnel carry out their duties towards patients, with the reduction and hopeful, complete mitigation of the pervasive paper-charting system used in hospitals and clinics today. This paper emphasised on the possibility of using the near-field communication technology to uniquely identify patients in hospital wards via a client-server application system, where the patients' personal and medical information are swiftly and easily accessible to the medical personnel attending to patients. For this to happen, the NFC technology had to be investigated to see what benefits it brought to medical applications. Various types of NFC tags were analysed, while their operational modes, communication modes, their forum standards and technical information were individually examined.

The backend server can be worked on further to make it a fully-fledged hospital information management system, where the provisions for granular-level patient and staff information can exist. The user interface and user experience of the backend server can be improved upon, to deliver a professional look. As for where the mobile application is concerned, efforts can be made to make it more sophisticated with additional functionalities that can be seamlessly integrated to the backend solution. The design and user interface can also be improved upon to deliver better overall perceived enjoyment levels from its users.

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