ENHANCING HEALTHCARE SERVICE DELIVERY VIA PATIENT TRACKING SYSTEM USING MOBILE APPS TECHNOLOGY: A CASE STUDY

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Abstract

Overcrowding is one of the main issues for healthcare service delivery at an emergency department (ED) in a hospital. We conducted a case study at ED of Hospital Canselor Tuanku Mukhriz (HCTM), UKM. The study aimed at providing a useful patient tracking system (PTS) with Beacon Technology that can provide real time patients' information. Android mobile apps for PTS named TrackMe© was developed and tested for use by two groups of users: TrackMe© Kin for patients' next of kin and TrackMe© Nurse for hospital staff. Beacon devices were attached to patients (worn as bracelets) and Beacon readers read the information regarding Beacon chips and their whereabouts. Results analysis of user satisfaction study on 60 participants (30 patients' next of kin, 30 nurses) show that both groups found TrackMe© apps were beneficial. The apps provided real time remote monitoring of patients' locations, their health status and communications with patients' next of kin. All study participants agreed that TrackMe© has good user satisfaction, ease of use, ease of learning and has attractive system design. Indirectly, the use of PTS may improve healthcare services as satisfied TrackMe© users would have peace of mind and wait elsewhere to avoid overcrowding at the ED.

Keywords: Biomedical informatics, Computer science, Mobile technology, Patient tracking.

1. Introduction

The working and treatment environment in emergency departments (ED) includes dealing with patients who are unable to respond, switching rooms, physician's lab order and the stress level among workers as well as the patients and their next-of-kin [1]. On top of this, the patient's presentation, evaluation, registration, triage, bed placement and medical evaluation does not necessarily come immediately, nor in certain order [1, 2]. Working under these conditions and intensity, a good user satisfaction score is not easy to achieve. In addition, the ED worldwide also has been synonyms with three main problems that is overcrowding [3, 4], backlogged [4, 5] and absconded patients [6, 7].

Overcrowd in ED means that demand for emergency services exceeds the ability of physicians and nurses to provide quality care within a reasonable time while backlogged means that the build-ups of work that needs to be completed are increasing. While staff are busy with overcrowd patients and high amount of works, irresponsible patients took the chance to leave the ED secretly. Unrecorded leaving patient are known as absconded patients. These three issues and the good ED environment are illustrated in Fig. 1.
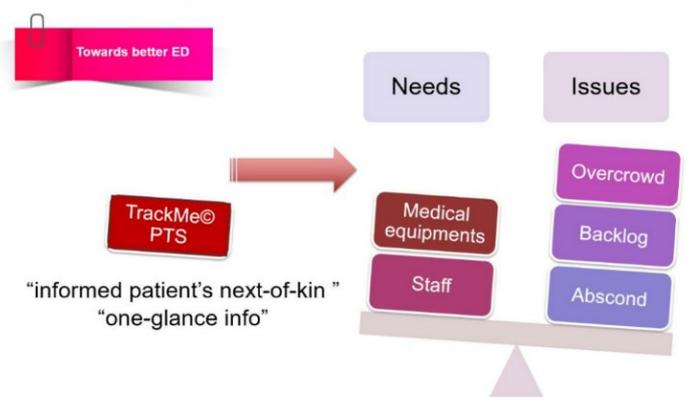
Fig. 1. Issues and needs for a better healthcare service delivery in ED.

Hospital Canselor Tuanku Muhriz (HCTM) is a public teaching hospital for Universiti Kebangsaan Malaysia (UKM), and it is categorized as a semi-public government hospital. The fees are slightly higher than that of a public government hospital operated by the Ministry of Health, Malaysia. The ED of HCTM received an average of 72,000 patients annually in 2011 [3]. Upon arrival at the ED, patients are assessed and dedicated to critical, semi-critical and non-critical zones [3]. The patient's trend in HCTM's ED is consistent with other patterns of ED visits at other hospitals' ED where non-critical patients are nearly doubled the amount of semi-critical patient [4]. When too many non-critical patients came in at a similar time, and the flow of semi and critical patients is disturbed, it will lead to backlogs and ED overcrowding [4]. Consequently, overcrowding leads to patients' absconding [5]. A study on asthma patients in ED of another Malaysian public government hospital reported a high proportion of absconded patients compared to that seen in ED HCTM [6]. Less absconded patients were observed in ED HTCM due to dedicated staff for asthma patients, shorter waiting time and higher registration fee. The quality measurement of

emergency care of a hospital is the patients' satisfaction. Saiboon et al. [8] reported that only 75% of ED patients were satisfied with the ED services in HCTM.

To improve the patients' satisfaction at ED HCTM, a patient tracking system (PTS) was developed by adopting the PTS for nursing homes [9] and tailored for ED application. The advancement, robustness and secure wireless networking, sensors and cloud storage has enabled better wearable tracking devices and system for PTS. Wearable sensors not only records the patients whereabout, but also the vital signs as well as firing alarm when needed [10]. Thus, it is more suitable and robust to the different urgency and intensity in the ED. Latest PTS application published academically was for the Hospital of Navarre, a multi-building and tunnelled connected hospital using Long Range Wide-Area network [11]. A simulation of PTS in ED has also been carried out in Al-Zahra Hospital, Iran and showed that the radio frequency identification (RFID) based PTS has managed to cut-short the waiting time and bed management [12]. The technology used in commercial PTS products includes RFID, infrared (generation I and II) as well as ultrasound has proven to improve the patient flow in ED [5, 13, 14].

However, it is proven that the RFID technology used up more energy, prone to reader collisions, un-intended coupling with multiple devices and more suitable for the long-ranged area [15, 16]. A newer technology known as beacon can be a better option for the above short comings. Bluetooth Low Energy (BLE) beacon positioning has evolved over the past few years and today data from many beacons can be used to position a user in 2D space on indoor map [17]. Newly published articles on PTS using beacons in wards are quicker to locate patients [18] while in application in hospital building proves that beacons are more secure [19].

Therefore, in addition to the existing research on improving the ED flow and services, we proposed a patient tracking system (PTS) with a beacon technology. The use of Bluetooth beacon wristband and its gateway to detect patient's where-about is tested in the ED of HCTM. An apps pairing the TrackMe© for next-of-kin and medical staff were developed to put the captured data into a useful info for monitoring and tracking purposes. Thus, this paper presents the development of the beacon technology PTS and its TrackMe© apps and the evaluation of the system usability and satisfaction rate in the ED of HCTM. As illustrated in Fig. 1, the TrackMe© PTS is aimed to improve healthcare services while waiting for their family receiving emergency treatment by the medical team.

2. Methodology

A mobile PTS was developed and named as TrackMe©. The TrackMe© mobile apps with Beacon technology was designed and developed to enhance healthcare service delivery at the ED of HCTM. TrackMe© aims to facilitate reduction of congestion in the waiting area of the ED due to small space of ED and the presence of patients' next of kin who want to know their patient's whereabouts and condition. Also, TrackMe© was developed to reduce noise interference that cause by the announcements made from medical staff via public address system. Normally, the announcement was made to call patients' next of kin to acquire further information about the patient or to get the consent for certain medical procedure. Therefore, the primary function of TrackMe© mobile application consists of viewing the current location, medical status of the patient and chat panel for communication between medical staff with the patients' next of kin. The following subsection discusses the

mobile TrackMe© apps including its development, system architecture, the user interface and its usability study.

2.1. System architecture

Three-tier architecture has been utilized for the TrackMe© mobile application that contains stage of presentation, application, and data as shown in Fig. 2. Online databases were used to store the system's data and details, such as patient info, patient location, and chat information between a medical staff with the kin of the patient. A mobile application is used to display relevant data for users, which enables them to use TrackMe© mobile application efficiently.
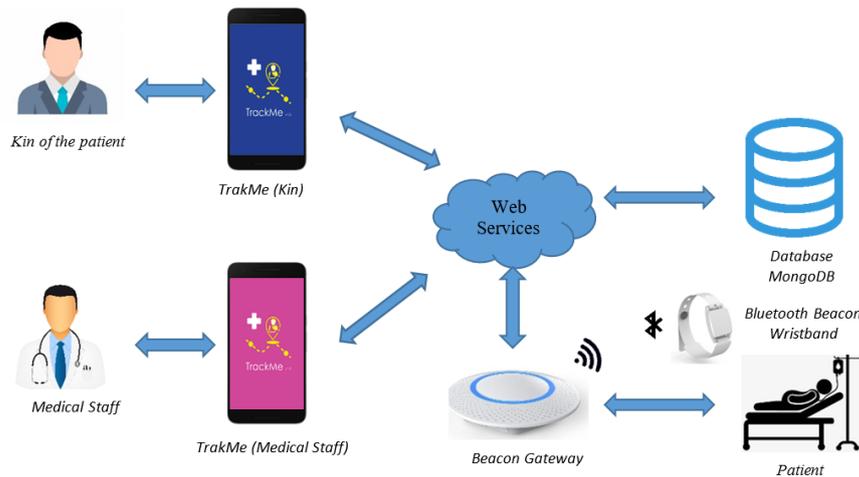
Fig. 2. The architecture of TrackMe© mobile application.

There are two modules of TrackMe© mobile applications, one for the patient kin where they can only view the information of their own relative, and another for medical staff in HCTM with an extra function to input the patient information. Patient requires to wear a Bluetooth Beacon wristband that will react to the Beacon Gateway, which it acts as a beacon reader and pre-allocated at a strategic location in the area of ED. The Beacon Gateway was integrated with the web series and communicates with the Bluetooth Beacon wristband via Bluetooth Low Energy (BLE), then web services will communicate with the database to update the current location for that patient. In such way, the location of patient can be detected automatically when patient passed by the detection area.

Other than the location information, the medical status information of the patient is available with the input from the medical staff. Therefore, the patients' next of kin can wait comfortably at other area and get the updated information from time to time without approaching physically to the medical staff. A chat panel was incorporated to enable medical staff to convey important or urgent message to the patients' next of kin. All that operation will happen through web services, and it needs internet connectivity to make sure that operation is working.

The location for Beacon gateway was made at the strategy location that will be pass through by patient when entering those area. There were five locations have been

installed the Beacon Gateway included yellow zone, observation ward, minor operating theatre, X-ray department area, and CT Scan department. Note that, yellow zone beacon reader able to cover the red zone patient. The Beacon gateway was setup and connect with the ethernet and power supply. Illustration of the installation location for Beacon Gateway can be referred in Fig. 3.
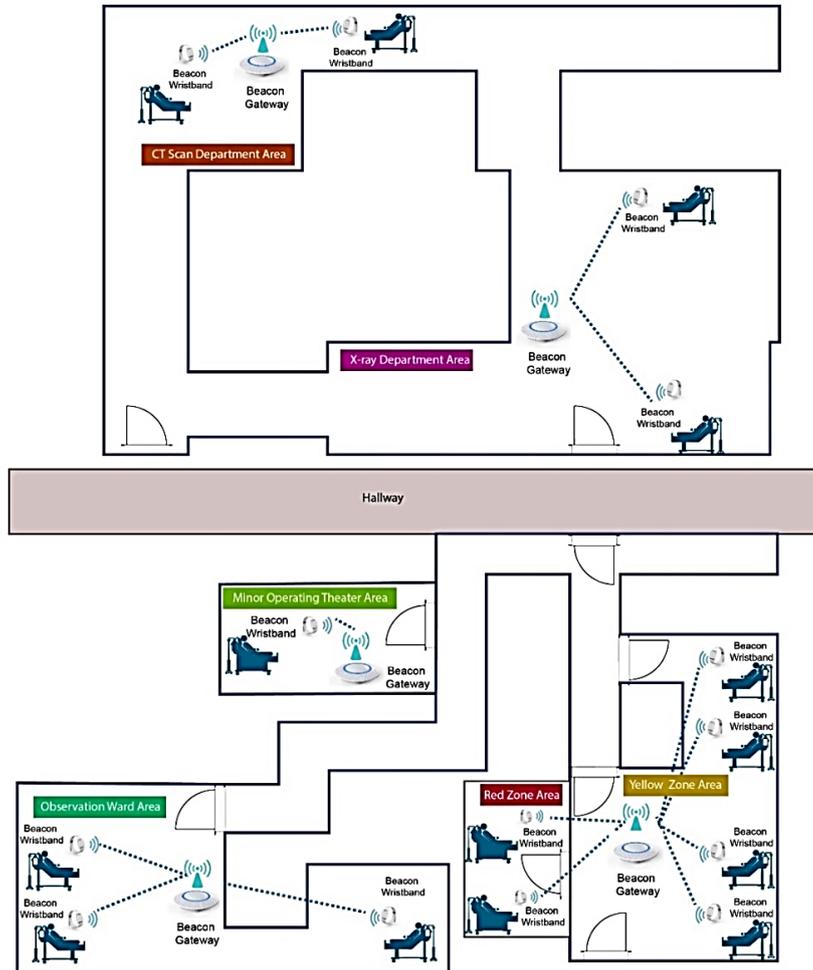


Fig. 3. Installation location for Beacon Gateway.

2.2. TrackMe© Mobile application

The mobile apps TrackMe© is developed on the Android platform with two different modules for the medical staff and patients' next of kin.

2.2.1. TrackMe© for medical staff

For medical staff module, the main functionality includes a) view all current location and medical status information of the patients, b) view patient detail

information, c) update the status of medical status information for the patient and, d) send message to the patients' next of kin. The medical status information consists of three type that is "In Treatment", "Discharge-Stay in Ward", and "Discharge-Return Home". The location of the patient will be updated automatically when the patient moved to the different location using the Bluetooth Beacon technology. For the chat panel, it is real-time chatting with function of push notification to help medical staff alert with the new chat coming in. Also, every patient will display info "Active" badge if the patients' next of kin of the patient is using TrackMe© mobile application. Figure 4 shows the user interface of TrackMe© mobile application for medical staff.
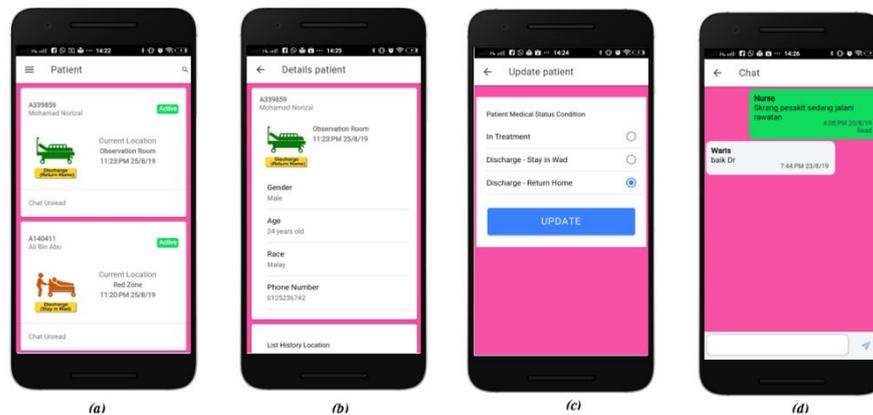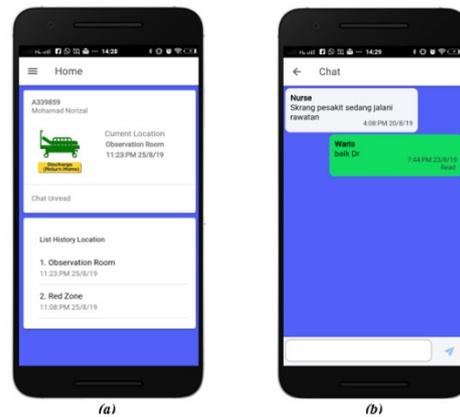

Fig. 4. TrackMe© for medical staff module: (a) Display current location and medical status information for all patient, (b) Details patient information, (c) Interface for update patient status, (d) Message panel for communication.

2.2.2. TrackMe© for patients' next of kin

TrackMe© mobile application for patients' next of kin is simple. The main functionality includes a) view current location and medical status information for the patient, b) send message to the medical staff. Location of the patient will be updated automatically when the patient moves to different location and also have real-time chatting with function of push notification to help the patients' next of kin alert with the new coming chat message. Figure 5 shows the user interface of TrackMe© mobile application for patients' next of kin.

The latest status and the location of patient information showing on the patients' next of kin module was trying to tackle the overcrowding issue at the emergency department. Patients' next of kin could wait at the location other than emergency department such as canteen, lobby, library etc which have a more comfortable environment to check the patient information via mobile app. The messaging module also allow nurse to contact the next of kin to come over the emergency department to do any necessary discussion, document signing or any required procedure. It will reduce the noisy announcement from using the public address (PA) system to call out for patients' next of kin. In additional, the location of patient was updated automatically using Bluetooth Beacon technology which reduce the input effort from nurse or admin. An evaluation has been performed to confirm the usability of it as discussed in the next section.

Fig. 5. TrackMe© for patient's next of kin module: (a) Display patient's current location and medical status, (b) Message panel for communication.

2.3. The evaluation of TrackMe© Apps

Evaluation of user satisfaction using TrackMe© apps among the sample subjects at ED of HCTM was done using statistical analysis. All users of the apps comprising the medical staff (nurses or doctors) and patients' next of kin that participated in the study were asked to answer a set of questionnaires at the end of their participation. The answers & responses to the questionnaires represent the users' satisfaction were evaluated by the Likert scales. These Likert scale answers are the representation of someone's attitude which measure the extent to which they agree or disagree with a particular question or statement [20]. The use of Likert scale responses is an attempt to quantify qualitative data. Thus, the results and analysis of the questionnaires will indicate the usability of implementing the proposed mobile apps for patient tracking. Table 1 summarizes the sample questions and the Likert scale answers for the user satisfaction questionnaires were improvised from [21, 22].

3. Result and Discussion

The user satisfaction study and testing using the proposed TrackMe© apps prototype has included participants of 30 patients' next of kin and 30 medical staff working at the emergency room. Figure 6 shows the age distribution of the participants.
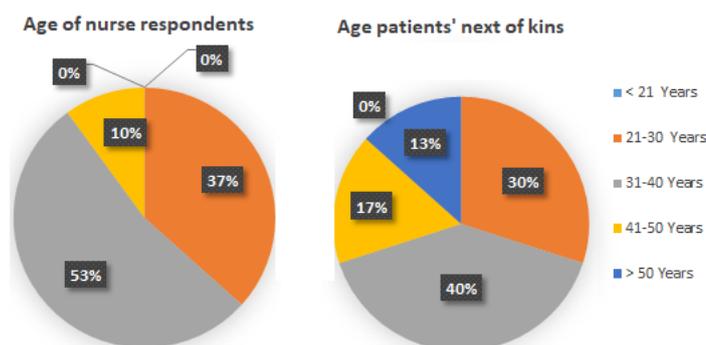
Users from medical staff are nurses age between 21-50 years: 21-30 years (37%, n=11), 31-40 years (53%, n= 16), 41-50 years (10%, n=3), none less than 21 years (0%, n=0) and above 50 years (0%, n=0). However, the users from patients' kin are of broader age range from 21years to above 50 years: 21-30 years (30%, n= 9), 31-40 years (40%, n= 12), 41-50 years (17%, n=5), above 50 years (13%, n=4) and none less than 21 years (0%, n=0). For both nurses and patients' next of kin, the users age between 31-40 years out numbered other age ranges. Prior to using the TrackMe© apps, majority of the user respondents have had experience of difficulties tracking the patients (90%) and getting their status (83%) while in the ED.

The overall user evaluation responses from the patients' next of kin and the nurses are summarized in Table 2. The mean score received from the user's evaluation by the nurses for the usability is 4.1±0.6 and by the patients' next of kin users is 4.0±1.2. The mean score for ease of use including satisfaction and TrackMe© apps design

rated by the nurses and patients' next of kins are 4.1±0.6 and 4.4±1.0, respectively. The Cronbach's alpha, which is a statistical parameter used to measure and assess the reliability or internal consistency of a set of scale or test items, for all test items are more than 0.93 while the suggested benchmark is 0.7 [23]. Therefore, all the evaluation responses received in this study are considered reliable.

Table 1. Summary and content of user satisfaction questionnaires.

	For Patients' Next of Kin	**For the Nurses/ Doctors**
Part A	**Respondent Demography** ●Age of respondent ●Had experience being in the emergency room ●Had experience difficulties tracking patient ●Had experience difficulties getting patient status	**Respondent Demography** ●Age of respondent ●Had experience difficulties tracking patient ●Had experience difficulties tracking patient's next of kin
Part B	**The usability of using TrackMe©** ●It is easy to identify patient location ●It is easy to get info on patient status ●It helps minimize worries on patient ●Getting info on patient location is useful ●Getting info on patient status is useful ●The short message received ease up communication with the hospital staff **Easiness of using TrackMe©** ●TrackMe© is easy to use **Satisfaction using TrackMe©** ●I'm satisfied using TrackMe© ●TrackMe© functions as I want **Design of TrackMe© apps** ●The apps design looks attractive ●The text content is easy to understand ●The text sizes are easy to read ●I agree TrackMe© to be used in the emergency room ●By using TrackMe©, I don't have to be in the waiting room	**The usability of using TrackMe©** ●It helps me complete my task faster ●It improves my work performance ●It elevates my work efficiency ●It makes my work easier ●It is useful for my work ●It is easy to learn using TrackMe© ●Instructions are easy to understand ●I feel comfortable using TrackMe© ●TrackMe© is user friendly
Part C	**Open Questions** ● State the strength of TrackMe© ● State the weakness of TrackMe© ● State any suggestion for improvement	**Open Questions** ● State the strength of TrackMe© ● State the weakness of TrackMe© ● State any suggestion for improvement

The answers for Part A are nominal values for age and Yes or No for others
The answers for Part B are Likert Scale:
1=Very Disagree 2=Partly Disagree 3=Agree 4=Partly Agree   5=Very Agree

Fig. 6. Respondents age distributions for the nurses and patients' next of kin.

Although the mean scores for all areas of the questionnaires for TrackMe© apps users are more than 4.0, the distribution of Likert scale rating responses from the patients' next of kin group have more scores of 5 compared to the Likert scale rating responses from medical staff which have more scores of 4. A slightly different of age distributions for the two user groups participated in the TrackMe© apps testing may have influenced this difference for the overall user satisfaction responses. The nurses, who are in majority younger than the patients' next of kin, are more exposed to mobile technology and have higher expectations of IoT technology than older generation representing the patients' next of kin group. Many patients'next of kin are of the X-generation (age 41-70 years) may have more trust on IoT gadget compared to the Y-generation (age 21-40 years) in which many of the nurses belongs to. A group of researchers conducted a survey on generation gaps preference in adoption of new technology revealed that majority of respondents from the X-generation had plan to invest on wearable technology, but less than half of the respondents from the Y-generation showed an interest in the devices [24].

Table 2. Evaluation of user responses and feedback.

Patients' Next of Kin feedback	Mean ± SD	Cronbach's alpha	Nurses/Doctor's feedback	Mean ± SD	Cronbach's alpha
The usefulness of using TrackMe© apps	*4.0 ± 1.2*		**The usefulness of using TrackMe© apps**	*4.1 ± 0.6*	
It is easy to identify patient location	3.0 ± 0.0		It helps me complete my task faster	4.0 ± 0.7	
It is easy to get info on patient status	3.9 ± 1.3	0.939	It improves my work performance	4.1 ± 0.7	0.953
It helps minimize worries on patient	4.2 ± 1.2		It elevates my work efficiency	4.1 ± 0.7	
Getting info on patient location is useful	4.4 ± 1.1		It makes my work easier	4.2 ± 0.6	
Getting info on patient status is useful	4.2 ± 1.2		It is useful for my work	4.1 ± 0.7	

Item	Value	Reliability	Item	Value
The short message received ease up communication	4.2 ± 1.2		It is easy to learn using TrackMe©	4.2 ± 0.6
Ease of use & satisfaction	**4.0 ± 1.2**		Instructions are easy to understand	4.2 ± 0.6
TrackMe© is easy to use	4.0 ± 1.2	0.990	I feel comfortable using TrackMe©	4.1 ± 0.7
I'm satisfied using TrackMe©	3.9 ± 1.2		TrackMe© is user friendly	4.2 ± 0.6
TrackMe functions as I want	3.9 ± 1.3			
Design of TrackMe© apps	**4.4 ± 1.0**			
The apps design looks attractive	3.8 ± 1.2			
The text content is easy to understand	4.1 ± 1.1			
The text sizes are easy to read	4.2 ± 1.2	0.959		
I agree TrackMe© to be used in the emergency room	5.0 ± 0.0			
By using TrackMe©, I don't have to be in the waiting room	5.0 ± 0.0			

Another study on behavioural intention to use internet of things (IoT) technology in healthcare settings revealed no correlation between gender and behavioural intention [25].

The open questions are divided into positive and negative responses. For the positive open questions there were 22 responses from the nurses. These responses were grouped into three main categories where the nurses feel that via the use of TrackMe© it eases patient monitoring (68.2%), the system is useful and user friendly (18.2%) and it is easy to access patients where about (13.6%).

From the patients' next of kin users, there were 18 responses that can be grouped into four main categories of responses. Patients' next of kin feel that it is easy to handle TrackMe© apps (38.9%) as it is easier and useful to locate patients (33.3%), it can avoid missing patients (16.7%) and it helps to prevent over-crowding at the nurse counter (11.1%). The negative responses from the nurses (14 responses) can be listed as three categories of difficulties, lack of time to update patient status in TrackMe© apps (57.1%), the apps require feature updates such as 2-way communication with patients' next of kin (28.6%) and the nurses are afraid of missing the Beacon bracelet or mobile device (14.3%).

The negative responses from patients' next of kin (7 responses) indicate that TrackMe© apps is limited for use in ED only (71.4%), they are unaware of the availability of the apps (14.3%), and they are not familiar with its use (14.3%). As

an overall final remark for TrackMe© apps testing, all of the patients' next of kin (100%) agree that the apps are to be recommended for used by all patients' next of kin in the future and its use be extended in areas other than the emergency department in the hospital. However, the nurses do not recommend such thing and their overall comment is the apps has added additional work to their daily chores which is to update the patients' status in TrackMe©.

The overall results of considerable user satisfaction scores after using the TrackMe© apps obtained from the study subjects, who are representing the actual intended users especially patients' next of kins, indicate the customer needs are mostly fulfilled. The TrackMe© apps can locate patients, update patients' status and minimize patients' next of kin worries. This would provide peace of mind to patients' next of kin while they are waiting for their dependent relatives. Thus, they will have better faith and trust that the patients under their responsibility are being attended to by the medical team in the ED. As such, the patients' next of kins will have more confident to be at a distance from the ED, yet they will be contactable and be alert for nurse calls via the apps. Consequently, the objective of using a mobile apps for PTS and monitoring to avoid overcrowding in the ED can be achieved such that all patients' next of kin be given the TrackMe© apps.

4. Conclusion

A prototype of mobile application systems named TrackMe© for patient tracking has been developed and undergone the device usability and user satisfaction test at the emergency department of Hospital Canselor Tuanku Muhriz (HCTM).

The mobile apps are targeted for use by patients' caretakers from two different types of users: patients' next of kin (TrackMe© Kin) and hospital staff (nurses and doctors: TrackMe© Nurse). The apps developed on the Android OS system functions on wireless communication via the use of Beacon technology to locate real time patient locations in the hospital environment.

A field study on application of the TrackMe© apps has been carried out at the emergency department of HCTM mainly to obtain the parameters for user satisfaction of the system prototype. The findings from the study show that the prototype TrackMe© received positive feedbacks based on the survey questionnaires completed by the study participants.

The majority of the TrackMe© users are satisfied with the system where both groups of the nurses and patients' next of kin provided encouraging responses in all aspects of the user satisfactions tests. Above all, the usability questionnaires received an above-average rating score of more than 4 of 5 Likert scales indicating the users have good experience handling the apps.

Furthermore, patients' next of kins agreed that the mobile application will be recommended for use beyond the ED and extended to other areas in the hospital. The nurses also feel that despite additional task to update patients' status in the apps, they commented that TrackMe© is helpful for them in executing their routine tasks in the emergency department.

Therefore, indirectly, the use of PTS may improve healthcare services as satisfied TrackMe© users would have peace of mind and wait elsewhere to avoid overcrowding at the ED.

Acknowledgement

Abbreviations	
BLE	Bluetooth Low Energy
ED	Emergency department
HCTM	Hospital Canselor Tuanku Mukhriz
PA	Public access
PTS	Patient tracking system
RFID	radio frequency identification
UKM	Universiti Kebangsaan Malaysia

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