NFC-based Smart Notification System for Hospital Discharge Process and Bed Management

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***Abstract*— An efficient discharge workflow with objective to minimize the turnaround time upon discharge of a patient in a typical hospital environment is proposed. The implemented workflow, which relies on a near-field-communication (NFC)-based patient discharge event, triggers a sequence of notifications and actions both by the nurses and housekeepers till the bed is cleared for occupancy by the next patient. The notifications are automated through Telegram Bot API. Android-based mobile applications are developed for both nurses and housekeepers. The mobile apps allow for follow-up actions and the status of the bed to be captured and sent to the cloud. Key functionalities of the system include immediate notification send to the housekeepers when a patient leaves the hospital, simple sending of cleaning requests and viewing of bed status. The system has been deployed in a hospital and evaluation is carried out in terms of improvement in the turnaround time of hospital beds.**

Keywords—NFC Tags, Hospital Discharge Process, Workflow Optimization, Mobile Applications

I. INTRODUCTION

With rising aging population throughout the world, shortage of beds in hospitals is a common problem. This leads to long waiting time for patients, queuing to be assigned a bed, which in some cases can be as long as two days. This problem is made worse during flu seasons where patients have to wait more than eight hours for a bed and were housed in tents or put in covered carpark areas [1, 2].

To free up more beds for patient admission, one of the area hospitals try to improve on is the patient discharge process. Previous study in [3] had found that the efficiency of the discharge process can have significant impact on the average length of stay (ALOS) for a patient.

Some of the factors concerned with the patient discharge process that leads to unnecessary delays in making beds available immediately upon discharge are a) family members being unable to accompany patients home promptly upon discharge; b) patients waiting for family members to collect their medications and documents; c) delays introduced in the communication to the housekeepers on the status of beds.

Many hospitals devise solutions to minimize this problem. These include setting up a patient discharge lounge which includes bed crunches to allow patients to rest while waiting for their medication, documents, and family members [4].

Radio Frequency Identification (RFID) technology has found applications in not just inventory managements systems [5] but across process control in many industries [6]. RFID have found extensive application in health care sector in the context of process and workflow managements [7, 8]. Bed management systems provide the capability to keep track of the patients and beds status by relying on RFID technology to provide real-time information on patient location, room status, and hospital bed occupancy.

Typically, active RFID tags are used and the discharge process would require patients to visit the nurse to remove the RFID tag. Upon removal of the tag, electronic notification (e.g. SMS or WhatsApp message) is sent to the housekeepers while concurrently updates are carried out to the patient's information system on the discharge. Once cleaning is done, the housekeepers will update the bed status by messaging the administrator at the bed management unit (BMU) instead of making multiple phone calls [9]. The BMU administrator will update bed status and this will automatically refresh the bed status dashboard, displaying the available beds [9].

In this paper, we describe a hospital discharge notification system that has been implemented in a local hospital. In the proposed implementation, the bed management system is decoupled and independent from the patient information system. Instead of adopting RFID-based solutions, a simple and cost-effective NFC-based solution is proposed and implemented.

The remaining of this paper is organized as follows. Section II will present the problem statement along with the existing workflow. Section III will describe the proposed NFC-based system and its integration with online messaging system to provide instant notifications to nurses and housekeepers through mobile apps. Section IV will present the evaluation of the system and the results for reduction in turnaround time of beds observed during the pilot study carried out in a hospital ward. Section V concludes the paper.

II. Discharge And Bed Management Workflow

A. *Existing Workflow*

Mount Alvernia Hospital (MAH) is the first private and only not-for-profit Catholic acute tertiary care hospital in Singapore. It is a 303-bed general acute care hospital with tertiary medical capabilities and two multi-disciplinary medical specialist centres. The hospital is supported by over 1,200 accredited doctors, with about 170 specialist doctors located on the campus [10].

MAH has been exploring ways to reduce the turnaround time of beds in the hospital. One of the solutions that they have looked into is to improve the patient discharge workflow. Unique to the patient discharge process adopted by MAH is that after patients completed the discharge process and have received the discharge slip, he may leave the ward only after an extended period of time. Because the discharge process has been completed, the existing patient discharge workflow does not require the patient to physically meet with the nurse or ward clerk when he leaves the ward.

Fig. 1 shows the current discharge workflow. When giving the discharge advice, the nurse will hand the patient a blank paper discharge slip. After receiving the discharge slip, the patient may continue to stay in his bed to wait for his family to pick him up and is not required to meet with the nurse when he leaves the ward.

Upon leaving the ward, the patients are required to fill in the bed number and the time they left the ward in the discharge slip and deposit the slip into a discharge basket located at the nurse counter. As the nurses and ward clerk may not be at the nurse counter when the patient deposits the discharge slip, it may take some time before a staff returns to the nurse counter and processes the discharge slips. This involves manually sending WhatsApp messages to inform housekeepers which beds have been discharged and require cleaning.

After a housekeeper has completed cleaning the ward, he will notify the Admissions Office of the cleaned beds through WhatsApp messages. This allows the Admissions Office to send the waiting patient to the cleaned bed.

In the next section, we will propose an improved automated workflow as the existing patient discharge process has several unnecessary delays due to the manual sending of notifications between nurses, housekeepers and Admissions Office.

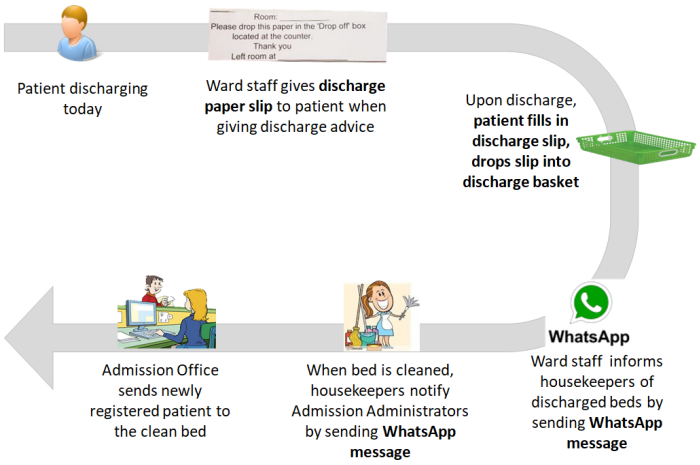


Fig. 1. Existing patient discharge workflow.

B. *Proposed Automated Workflow*

In the proposed workflow, the paper discharge slip is replaced by a NFC tag. The discharging patient will be assigned a NFC tag by the nurse during the discharge advice. The deposit basket at the nurse counter is replaced by a NFC reader that is hidden inside a deposit box. A NFC tag is adopted instead of RFID to keep the cost of the system low as a NFC tag costs much less and are easy to program and read than a RFID tag [11]. NFC cards can also be read with a smart phone equipped with NFC reader. Furthermore, in this application, the NFC reader reads only one tag at a time. RFID tags are effective and necessary only if there are requirements for multiple simultaneous reads of the tags.

The system uses a NFC tag reader which is connected to a Raspberry Pi with internet access. Once the discharged patient drops the NFC tag in the designated box that has the NFC reader, a read event is triggered. The Raspberry Pi automatically responds to the read event by sending a notification which contains the bed number to be cleaned to the housekeepers through the Telegram Bot API [12].

The housekeeper will receive the cleaning notification through a mobile app developed in this system for the housekeepers. Once the cleaning is completed, a housekeeper can update the bed status with a simple click of a button in the housekeeper's mobile app and the Admissions Office will be immediately notified by an automated Telegram notification of the beds that were cleaned. The automated workflow is show in Fig. 2.

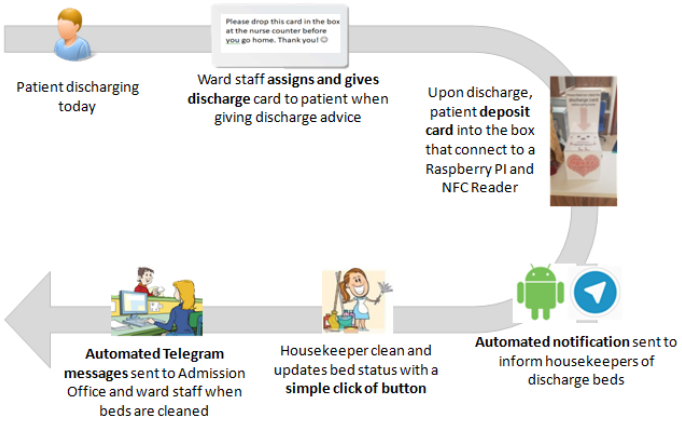


Fig. 2. Proposed automated discharge workflow

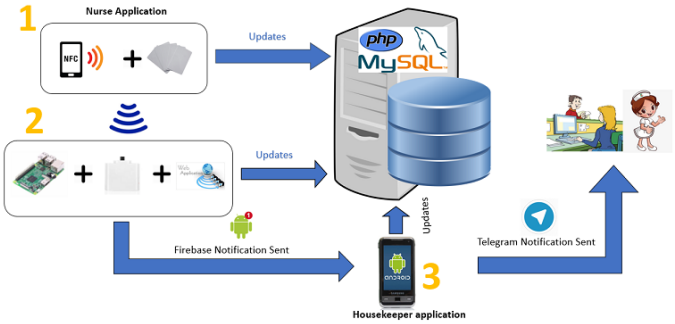


Fig. 3. Components in bed management system

III. BED MANAGEMENT SYSTEM

The various elements of the automated workflow is implemented and integrated into a single bed management system. The three key elements of the bed management system are: a) mobile application for the nurse; b) Raspberry Pi with NFC reader that connects to the internet; c) mobile application for the housekeeper; and d) other required software component used to integrate with the system.

A. Nurse's Mobile Application

The mobile application used by the nurse is built on Android. The main functionality is 1) to assign NFC cards to a patient's bed number to allow patient to drop the NFC card into the box embedded with the Raspberry Pi and NFC reader; 2) to view bed status, such as whether a room is to be cleaned, in the process of cleaning or have been cleaned; 3) to send manual cleaning requests that are non-discharge related requests, such as mopping the floor and cleaning of toilet when it is dirty.

The mobile application comprises of three major pages as shown in Fig. 5. The "Card Management" page allows a nurse to assign/reassign/unassigned NFC cards. This corresponds to the insert, update or delete operations on the online database hosted in a remote server. The NFC card chosen was a type A NFC which is also known as ISO14443-3A. Although type A NFC card has a lower memory size compared to other types, the objective of the NFC card is to get its unique serial number and store it in the database. Thus, the memory size is not a factor to be considered. Moreover, type A NFC card has a lower cost compared to the other types of NFC cards. The "SG Ward Room Status" page retrieves records from the database. The "Manual Cleaning Request" page inserts a record to the database and sends a Firebase automated notification to the housekeeper's application to inform the housekeepers of the bed number and the type of cleaning requests.

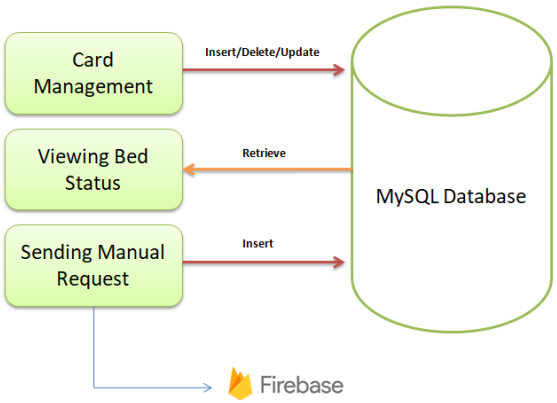
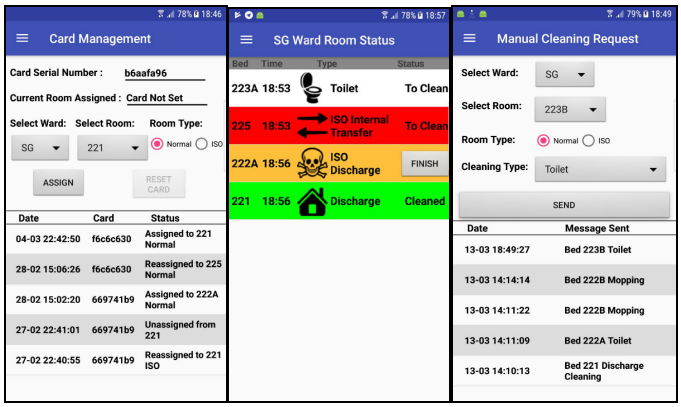


Fig. 4. Components of Nurse's mobile application



(a) (b) (c)

Fig. 5. Screenshots of Nurse's Mobile Application for (a) Assigning cards (b) Viewing bed status (c) Sending manual request

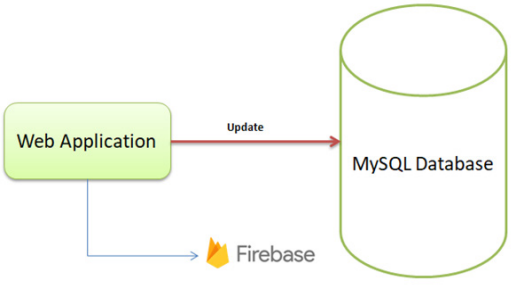


Fig. 6. Components of application running on the Rasberry-Pi

B. *Rasberry-Pi*

Raspberry Pi3 model B was used because of its faster processor and built-in Wi-Fi modules which can communicate with the remote server without the need of an additional USB wireless dongle. The NFC card reader is connected to the Raspberry Pi through a USB. The Raspberry Pi is setup to run a web-based application having the main functionality of 1) reading the NFC cards; and 2) send automated notification to the housekeepers when the NFC card is detected. The web application hosted by the Raspberry Pi only consists of a single textbox to read assigned NFC cards deposited by the patients. The status of the bed in the database will be updated once the web application reads the serial number of the NFC cards. Besides that, the system also sends an automated Firebase notification to the housekeeper's mobile application with the bed number of the discharge patient. The components in the application are shown in Fig. 6. Lastly, the round-trip time of the remote server to update the database when the NFC card detected is less than two seconds. Thus, it is unlikely that the reader fails to read a subsequent NFC card deposit by the next patient.

C. *Housekeeper's Mobile Application*

The housekeeper mobile application is also built on Android. The main functionality is 1) to obtain notification automatically when NFC cards are detected; 2) update bed status easily by pressing the "start" and "end" button; 3) send automated notification to the Admissions Office and nurses when cleaning request was completed. The components of the application are shown in Fig. 7. When viewing bed status, the records from the database are retrieved. When updating bed status, the bed status of the database record is updated. Besides that, when the bed status has been updated to "cleaned", an automated Telegram message is sent to the nurse's and Admissions Office's Telegram chat group through the Telegram Bot API. The housekeeper mobile application consists of two pages: 1) list of beds to be cleaned; and 2) status of all the beds. The screenshots of the housekeeper mobile application are shown in Fig. 8. The status is color-coded for easy visual identification.

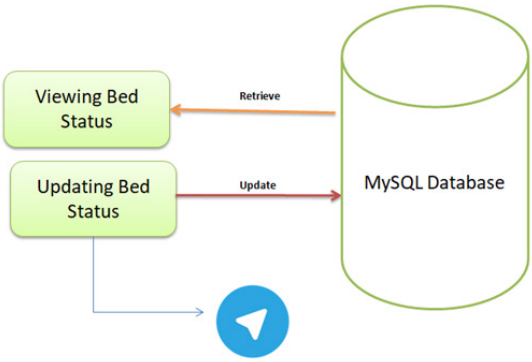
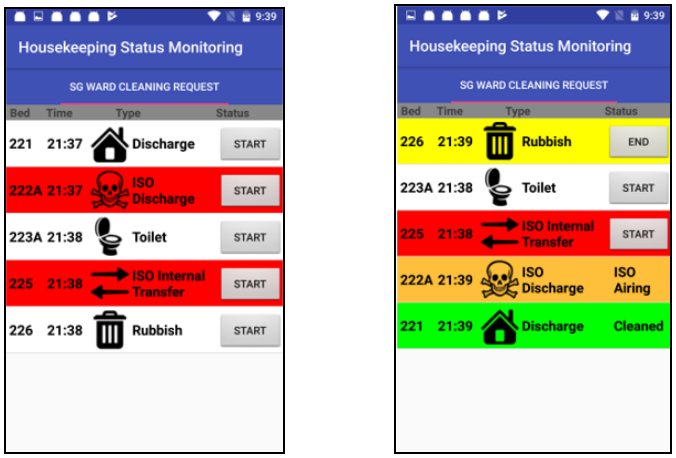


Fig. 7. Components of housekeepers mobile application



(a) (b)

Fig. 8. Screenshots of housekeeper Mobile Application for (a) viewing beds to be cleaned (b) Viewing status of all the beds.

D. *Other Required Software Component*

The automated notification sent to the housekeeper's mobile application and Admissions Office Telegram chat group uses Firebase Cloud Messaging and Telegram Bot API respectively. Both components have a HTTP-based interface. Thus, upon NFC card detection or completed cleaning, the remote server will send an HTTP request to the respective users. The automated notification sent to the housekeeper's mobile application and Admissions Office Telegram chat group uses Firebase Cloud Messaging and Telegram Bot API respectively. Both components have a HTTP-based interface. Thus, upon NFC card detection or completed cleaning, the remote server will send an HTTP request to the respective users.

Fig. 9 shows the database schema design. It consists of a "card" table and a "bed" table. The card table stores the unique serial number of the NFC card and a "bedid", foreign key reference to the bed table "id". When a NFC card was assigned with a specified bed, a record will be added both tables. However, once a NFC card has been deposited by the patient, the "status" field in the bed table will updated while the card table record will be deleted. This allows the NFC card to be reusable immediately.

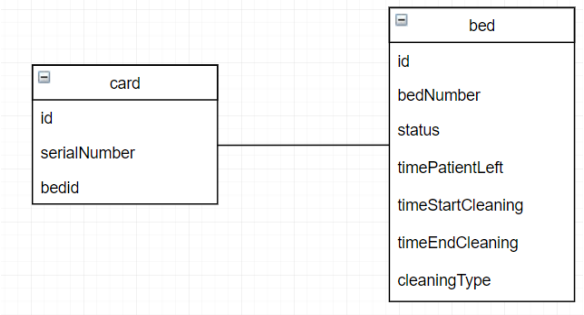
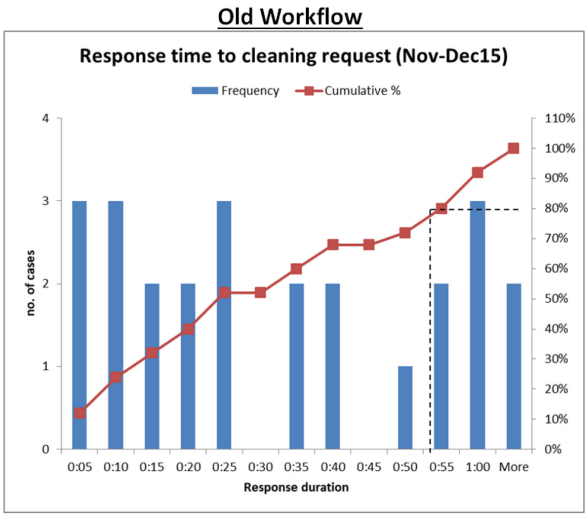
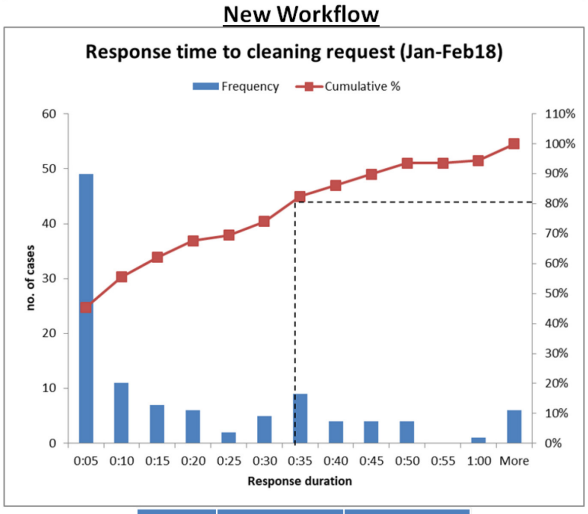


Fig. 9. Database schema design





	Before (n = 25)	After (n = 108)
Average	32 mins	20 mins
Median	30 mins	10 mins
80%ile	55 mins	35 mins

Fig. 10. Results of pilot run indicating the reduction in turnaround time.

IV. EVALUATION

The system has been deployed in one of the MAH ward and the user acceptance test (UAT) was carried out with MAH after 3 weeks of pilot testing. One of the main objectives of the system is to reduce the bed turnaround time which will in turn reduce the waiting time for patients to be warded. Fig. 10 shows the preliminary results of response time to cleaning request after 3 weeks of pilot testing in one of the MAH's ward as compared to the old paper-based workflow.

For the period of the pilot study, there were a total of 25 cleaning requests for the old workflow, and 108 cleaning requests for the new workflow. From the graph of the old workflow, only 3/25 (12%) of the cleaning requests were started within 5 minutes (at 0.05). For the new workflow, 50/108 (46%) of the cleaning requests were started within 5 minutes.

Overall, after doing a t-test, the p-value achieved was 0.000012 and the result was significant at $p < 0.05$. This means that the new system did greatly improve the response time to cleaning request. In summary, we can conclude that the bed's turnaround delays of the old workflow were due to the housekeepers not knowing when the patients have left the ward. Thus, by reducing the response time for bed cleaning requests, the overall bed's turnaround delays will be reduced.

V. CONCLUSIONS

The paper described a NFC-based patient discharge process that automatically informs housekeepers which bed to clean and also inform the Admissions Office which beds have been cleaned. This leads to a reduction of the turnaround time of hospital beds, and hence the shortening of the waiting time for patients to be admitted. The system is low cost and easy to deploy. It simplifies the patient discharge process through automated notifications and messages, which leads to improvement in the productivity of both the nurses and the housekeepers.

ACKNOWLEDGMENT

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