Study on the Feasibility of NFC P2P Communication for Nursing Care Daily Work

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Abstract. Now, more and more hospitals manage patient's medical records by using PC support. However, Nurses and Doctors are complaining increasingly about the complications involved in using healthcare applications. These complexity procedures are waste of valuable time that could be better dedicated to patient care. In this paper, we propose a proposal which seeks to adapt NFC (Near Field Communication technology) for TPR (Temperature, Pulse, and Respire) records in daily nursing care. This consists of a combination of RFID, smart phones and NFC devices. We focus on NFC peer-to-peer communication in this research and find out that NFC P2P (peer-to-peer) communication is possible. Although there are some troubles in implement P2P transmission, we still saw the success rate of connection is 42% in Samsung.

Keywords: RFID, NFC, HIS, NIS, TPR, nursing care

1 Introduction

With the increasing requirements of CHIT (Comprehensive Hospital Information Technology), it is more in demand that HIS (Hospital Information System) for the collection of various clinical physiological information. However, the collection of the patient CIS (Clinical Information System) in HIS, it is only in ICU (Intensive Care Unit) or OR (Operation Room) that patients are connected to the medical equipment for monitoring physiological information and outputting vital signs data to CIS in the hospital.

It is because that the disease does not require and cost considerations, the hospital does not make every inpatient connected to VSM (Vital Sign Monitor). Therefore, the patient's vital signs data collection must rely on nurses who measured timed rounds according to doctor's orders, such as temperature, heartbeat, respire and blood pressure...and so on. Back to the nursing station, these data which are recorded and portrayed as vital signs data curve on the paper will be typed into NIS (Nursing Information System) and integrated into (HIS) manually. These will be used to provide to doctors as a reference for subsequent diagnosis and treatment plan.

Although there are some medical equipment with wireless and wired transmission function on the market such as Bluetooth and Wi-Fi, it sometimes spends more time in the set up and operation of these information devices for practical clinical applications. This is the reason why hospital operators and nursing staffs are deterred. The data collection of general inpatient physiological signs plays an important role in CHIT which is same as the role of the last mile in the implementation of a comprehensive network technology.

NFC builds upon RFID systems by allowing two-way communication between endpoints, where earlier systems such as contactless smart cards were one-way only. Since unpowered NFC "tags" can also be read by NFC devices, it is also capable of replacing earlier one-way applications. These no additional operating characteristics of NFC just suitable to solve the tedious steps such as cable wiring and operation of general inpatient care. This can save nurses' time to enhance the quality of care.

2 Literature Review

2.1 The Development of Hospital Information

The development of information technology in healthcare has been nearly 30 years in Taiwan. It develops from the early billing system, the development of computer hardware and software and clinical demands, to the re-

cently "patient-centered" medical information system. The record is no longer reporting the content of prescription, but also began to record the patient's all inspection records, such as PACS (Picture Archived Communication System), CIS (Clinical Information System) ... and so on. It will be integrated into EMR (Electronic Medical Record) and organized into Fig. 1.

To collect records is necessary to proceed from the device of diagnostic imaging systems, such as CT scanner (Computer Tomography), MRI scanner (Magnetic Resonant Image), X-ray machine, Ultrasonic Image scanner...and so on. These records which obtained by equipment angiography are based on a common protocol DICOM (Digital Image Communication) as an image exchange and collected manner.

For CIS aspects, the first to enter CIS is LIS (Laboratory Information System). It is firstly sent the patient's blood to the test center. And then the test results are transmitted to the computer by the device with RS232 interface. Finally, it is integrated into the doctor's examination screen and provide to the doctor on patient instructions. Recently, the concept of "patient-centered" improved and medical equipment hardware and technology increasingly sophisticated. Thus, to collect information is more complex than diagnostic imaging.

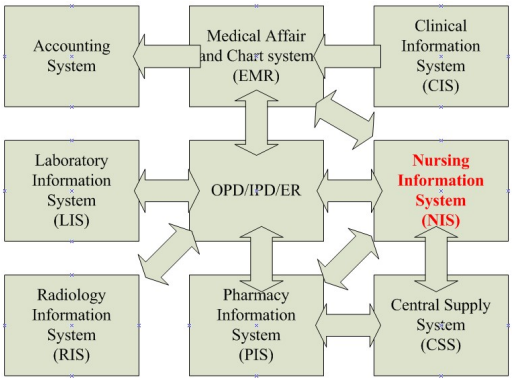

Fig. 1. Hospital Information System(HIS)

For ICU, CCU or OR aspects, due to illness needs the patient connected to the physiological monitoring equipment and concentrated to the nursing station as condition monitoring (Fig. 2).

Fig. 2. The Medical Device in ICU

However, it is impossible to connect medical equipment to collect physiological parameters for each patient in general inpatient under the condition and cost considerations (Fig. 3). This requires nurses timed to go to the ward and measure the patient's basic physiological parameters, and then nurses record these data in the medical record or manual input to (NIS).

Fig. 3. The ordinary Ward

2.2 Daily Work of Nursing care in Hospital Wards

Daily clinical care activities divided into direct care, indirect care and Nurse station related care activities. Indirect care hour means that the time spent on preparing and recording of direct care activities. Direct care hour means that patients obtain directly the time of care from Nurses. Therefore, the higher the proportion of indirect care hour is, the more inadequate the direct care hour is. In the research of nursing human cost which studied by a medical center in Northern Taiwan in 1992 [1], Measuring body temperature, pulse and respiration is the first place in the top ten of daily care activities. The measurement of blood pressure and oral administration of a single dose ranked second and third respectively.

However, the first place in the top ten of the average time spent in care activities is ward rounds (12 minutes) and measuring body temperature, pulse and respiration (10.9 minutes) is the second. This shows the high frequency of the TPR care activities and the time-consuming of nursing work (Fig. 4).

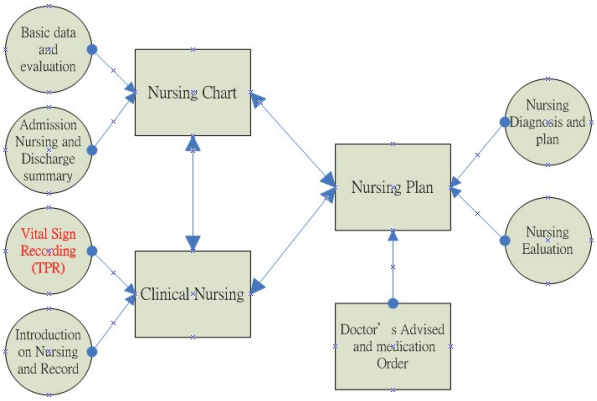

Fig. 4. The relation of Nursing planning and Nursing care

Traditional working flow for TPR recording shows in Fig. 5 [2]. TPR is very important to grasp and judge for inpatient illness and the medical staff can recall the condition changes as soon as possible. TPR records is the routine nursing care activities in wards and vital signs records such as body temperature, pulse, respire, blood pressure. Measurement results are recorded in the medical history form and nursing job record sheet and drawn the curve to show trend graph.

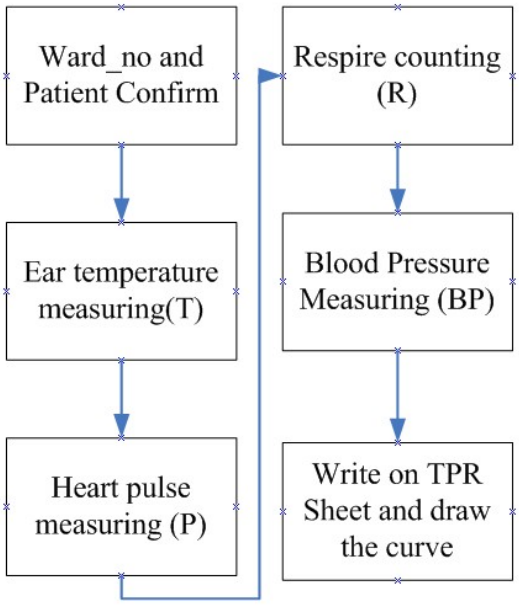

Fig. 5. Traditional working flow for TPR recording

Traditional TPR sheet (Fig. 6) is divided into two parts. The first part is to record the signs of life, and the second part is to fill other medical information. Its purpose makes the clinical disposal and efficacy clear after the patient's admission [3].

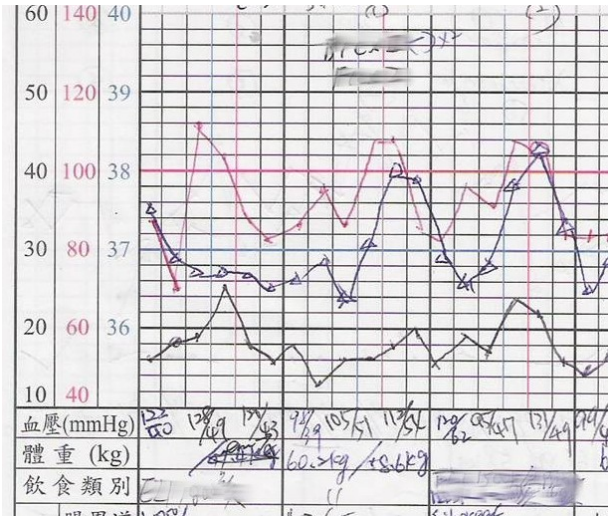

Fig. 6. Part of Traditional TPR Sheet

By this operation, we can see that the loading of paperwork is very heavy in the daily nursing care jobs. It accounts for about 22% of the working hours (1.8 hours), which do not contain the operating time of the information equipment. This also seriously affects the working hours of direct care and the quality of clinical care [4].

2.3 Link of Medical Device

With the advances in medical equipment technology and the development experience of imaging systems and network, the communications protocol has been transformed slowly from the traditional RS232 data output gradually into a standard RJ45 or USB socket. The overview of medical devices uploads function shown in 0.
The data format is also gradually developed from a free-form to HL7 (Healthy Level 7) protocol and can interoperate with the database of HIS (Table 1).

Table 2. The Comparison of Medical Device Link type

Link Type	Interface	Protocol	Extra operation
cable	RS232/RS485	Specific format	☑(Setting) Middleware
	USB	Specific format	☑ (Setting) Driver Middleware
	RJ45	HL7 or Specific format	☑ (Setting) Middleware
Wireless	Wi-Fi		☑ (Setting) Middleware
	Zigbee	Specific format	☑ (Setting) Driver Middleware
	Infrared ray(IR)	Specific format	☑ (Setting) Driver Middleware
	Bluetooth	Specific format	☑ (Pairing) Driver Middleware

Data transmission mode is developed from wire to wireless forms such as Wi-Fi, Bluetooth, infrared, ZigBee, and so on (Fig. 7).

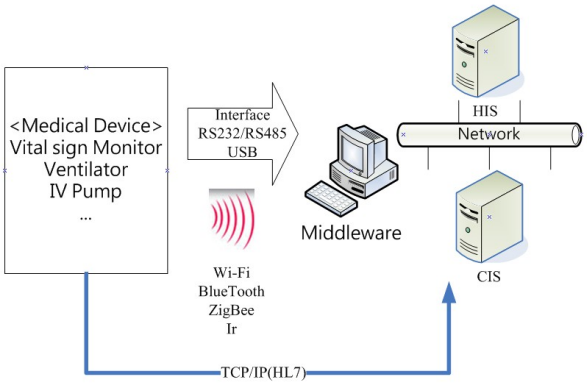

Fig. 7. The Overview of Medical Device upload function

There is no medical device connected for inpatients in ordinary Wards, so even the medical device (such as Non Invasive Blood Pressure device or Ear Temperature device) change with data upload function. It also needs the operation of inputting the patient ID, setting measuring parameter and wired to upload data when nurses back to the nurse station. The flow of TPR recording shows in Fig. 8.

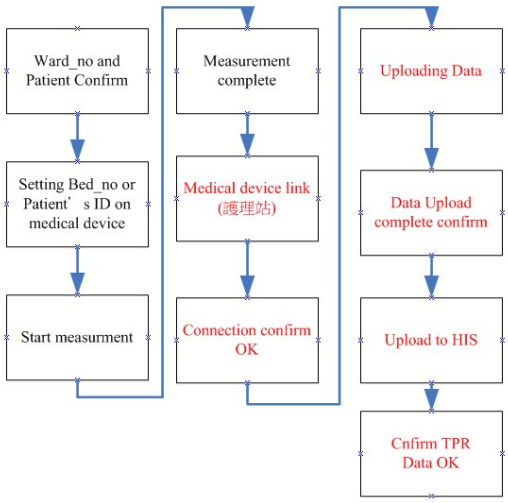

Fig. 8. The Flow of TPR recording with medical device upload

We compared Manual recording, PDA recording, Medical device measuring [5][6] and Nursing cart with PC about their paper work, link or not, Manual key in and inconvenient or risk[7], show in Table 2.

Table 2. The Compare of Various TPR recording method

	Paper work	Link	Manual Key in	inconvenient or Risk
Manual record-ing	V	X	V	mistake Writing
PDA recording	X	V	V	Connection setting Lack of PC
Medical device measuring	X	V	X	Too much time Connection setting Lack of PC
Nursing cart with PC	X	V	X	Unstable of wi-fi connection Lack of equipment High cost

2.4 Near Field Communication, NFC

NFC standards cover communications protocols and data exchange formats, and are based on existing RFID standards including ISO/IEC 14443 and FeliCa. The standards include ISO/IEC 18092 (Table 3) and those defined by the NFC Forum, which was founded in 2004 by Nokia, Philips and Sony. The Forum also promotes NFC and certifies device compliance.

NFC is a set of standards for smartphones and similar devices to establish radio communication with each other by touching them together or bringing them into close proximity, usually no more than a few centimeters. Present and anticipated applications include contactless transactions, data exchange, and simplified setup of more complex communications such as Wi-Fi. Communication is also possible between an NFC device and an unpowered NFC chip, called a "tag".

Table 3. The Comparison of NFC ISO

ECMA	ETS	ISO	Name and explanation
ECMA 34	ETS ITS 102 190 V1.1.1	ISO/IEC 18092	Near Field Communication Interface and Protocol (NFCIP-1)
ECMA 352	ETS ITS 102 312 V1.1.1	ISO/IEC 21481	Near Field Communication Interface and Protocol (NFCIP-2)
ECMA 356	ETS ITS 102 345 V1.1.1	ISO/IEC 22536	NFCIP-1-RF Interface Test Methods
ECA 362	None	ISO/IEC 23917	NFCIP-1-Protocol Test Methods

The specification of NFC we described as below:

(1) NFC operates at 13.56 MHz on ISO/IEC 18000-3 air interface and at rates ranging from 106k bit/s to 424k bit/s.

(2) NFC devices can be used in contactless payment systems, similar to those currently used in credit cards and electronic ticket smartcards, and allow mobile payment to replace or supplement these systems.

(3) NFC peer-to-peer communication is possible, provided both devices are powered.

(4) NFC always involves an initiator and a target; the initiator actively generates an RF field that can power a passive target. This enables NFC targets to take very simple form factors such as tags, stickers, key fobs, or cards that do not require batteries.

There are two modes for the communication:

(1) Passive communication mode: The initiator device provides a carrier field and the target device answers by modulating the existing field. In this mode, the target device may draw its operating power from the initiator-provided electromagnetic field, thus making the target device a transponder.

(2) Active communication mode: Both initiator and target device communicate by alternately generating their own fields. A device deactivates its RF field while it is waiting for data. In this mode, both devices typically have power supplies.

In Table 4, it shows the communication speeds and maximum working distance about the two modes.

Table 4. The Comparison of Speed of Active and Passive

	Speed(Kbps)	Range
Active Mode	106 / 212 / 424	20 cm
Passive Mode		10 cm

The air interface for NFCIP (Near-Field Communication Interface and Protocol) is standardized in ISO 18092 NFCIP-1 and ISO/IEC 21481 NFCIP-2. The transport protocol of ISO 18092 NFCIP-1can divides with three parts (Fig. 9) [11]:

(1) Starts attribute requirements and parameters select protocol.

(2) The data exchange protocol.

(3) Stop and release the connection protocol.

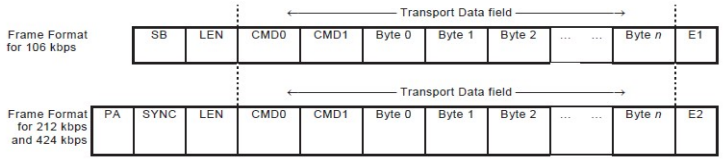

Fig. 9. ISO18092 Data Transmission Defined

The applications of NFC are essentially divided four types:

(1) Contact, Complete:

Such as entrance control or traffic / activity ticket checking, the user simply users simply put access

card near the reader to complete.

(2) Contact, Confirm:

Such as mobile payment, users must enter a password to confirm the transaction.

(3) Contact, Connect:

Such as download music and exchange images, users can conduct peer-to-peer network data transfer by two NFC-enabled device links.

(4) Contact, Explore:

Users can explore the equipment function to identify the potential features and services about NFC devices.

3 System Design

In order to solve the aforementioned problems, we compare related systems using in domestic and foreign (Table 5).

Table 5. Domestic and Foreign Related Systems Comparison

	Hardware	Pt Identify	Private and security	TPR	Transmit type
Domestic	PDA	By Nurses	Low Data security	Replace paper	cablewastetime
Foreign	Cell phone	V		X	NFC
Our Design	Closed recorder	V	Close System	V	NFC

Therefore, we propose a system for this study using the "Tagging" characteristic of NFC. This system used to replace the connection action for data upload (Fig. 10).

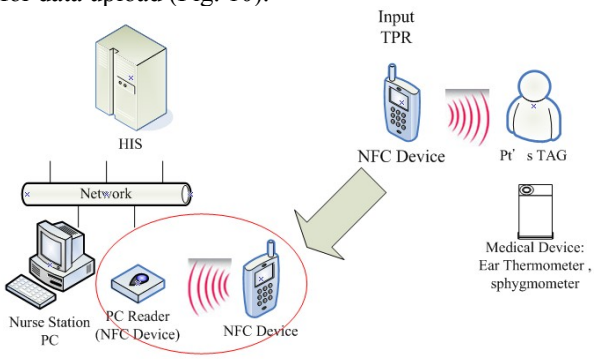

Fig. 10. System Overview

And this design could solve the time-consuming wiring operation and simplified the TPR Recording Flow as Input and tag to upload data. No more setting operation needed on medical device (Fig. 11).

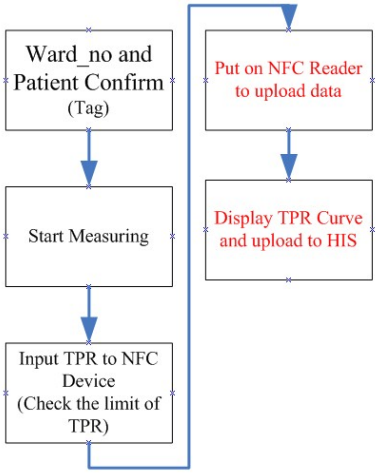

Fig. 11. TPR Measuring Flow with NFC device

Our design is based on NFC-enabled mobile phone and NFC device with the input software of TPR record developed by J2ME. The mode of operation is: when the nurse goes to the ward for TPR rounds, she just uses the NFC device to tag the Tags which dressed on the patient. The purpose of this action is to confirm the identity of the patient and whether the nurse is responsible for or not [9][10]. Then she can start measuring TPR of patient and input the value into NFC device, after input the value into NFC device she can tag the TAG again for completes the TPR records.

Back to the nursing station, the nurse as long as places NFC Device on NFC reader of the PC. And it will automatically upload and download information to update these data by the "Tagging" characteristic of NFC.

The working flow of NFC device is shown in 0, and its data structure is shown in Fig. 12. When the primary care nurse do TPR daily work for the patients, she can tag the tag on the patient and determine whether the primary care nurse responsible for the patients. If the agency nurse helps to record TPR, she can set the agency confirmation code in the NIS and send to NFC Device. This is for nurses who are busy as elastic support each other.

After the confirmation of patients, nurses measure patients' blood pressure and TPR. And the measurement is recorded in NFC Device, nurses tag patient's tag as a complete confirmation. The action of TPR records completed.

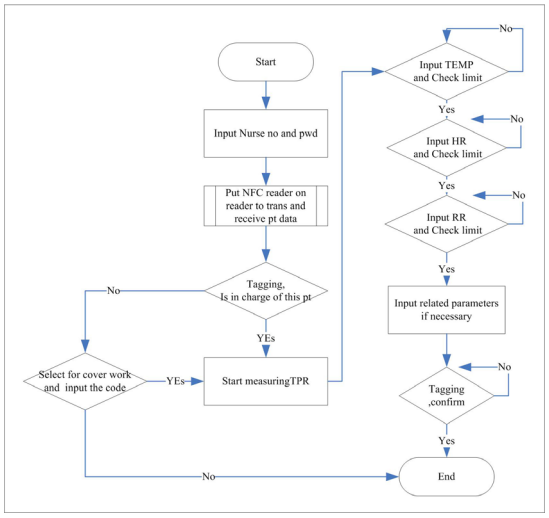

Fig. 12. The System Flow of NFC Device

We use Windows C# to be development tools and cooperate with MySQL for passing messages. In Fig. 10 with time as the horizontal axis shows the variation curve of the TPR values. We setup a NFC Device on PC Reader and we named it to be PC Reader in here. It can let us distinguish PC Reader from NFC Device in Fig. 10 (red circle).

We focus on the NFC peer-to-peer communication in this paper and take advantage of ISO18092 transfer instructions which describe as follow:

D4 00：Attribute Request (sent by Initiator)

D5 01：Attribute Response (sent by Target)

D4 06：Data Exchange Protocol Request (sent by Initiator)

D5 07：Data Exchange Protocol Response (sent by Target)

D4 0A：Release Request (sent by Initiator)

D5 0B：Release Response (sent by Target)

The Command Bytes shall consist of 2 bytes. The first byte shall be CMD0 and the second byte shall be CMD1 (Fig. 9). It implies that D4 for request and D5 for Response.

The mode of operation can be also divided into active and passive ways: (Fig. 13)

(1) Active way: (go to synchronize the NFC Device in Fig. 13)

By the NFC Device placed on PC Reader, the software will automatically interpret the internal data in NFC Device and comparison with the last upload content. And it updates the database of the patient whom the nurse is responsible for.

(2) Passive way: (go to NFC-server System in Fig. 13)

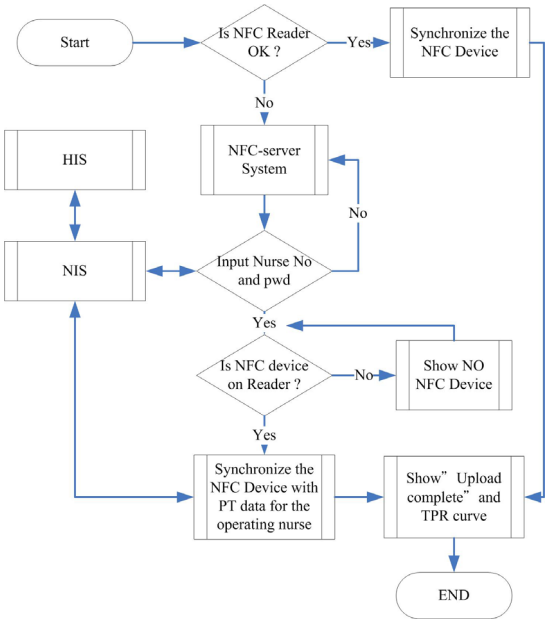

Fig. 13. PC Reader flow chart

After the nurse selects the desired function of NFC-Server software on the PC, she follows the prompts to place NFC Device on PC Reader. And then it will upload and download to update the information in NFC Device. According to the TPR data which uploaded by nurses, TPR curve will be drawn by different color on the screen. Here we draw one curve with color for simulation shown in Fig. 14.

Our development devices and test environment are:

(1) PC ASUS A55V (CPU: i7,Ram:8G HDD:750G) Win7 (X64) with ACS ACR122U

(2) Development Platform: Eclipse indigo (X64), Jre6, Android SDK

(3) NFC Device:

- SONY SOLA (MT27i) (NFC Chip: Felica)
- Samsung Galaxy Nexus (NFC Chip: NXP PN544)
- ASUS Nexus 7 (NFC Chip: Felica)
- ANDROID ICS 4.04

PC Reader: ACS ACR122U (NFC Chip: NXP PN532) firmware 210

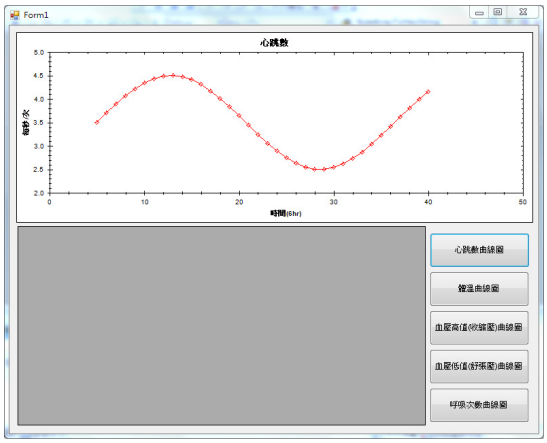

Fig. 14. The simulation TPR curve on NFC-Server Screen

4 Implement Results and Performance Comparison

We focus on NFC peer-to-peer communication in this research, and we use the SDK of ACR122U [12] to do the connection test and recheck the NFC Chips type using for the three kinds of devices, SONY mt27i, Samsung Galaxy Nexus and ASUS Nexus 7. Respectively, we do the connection test for 30 and 100 times and record the connection status and the phenomenon of the occurrence (Table 7, Table 8).

The implement results of the connection test with ACR122U TOOL show that:

(1) In the GET STATUS of Modulation and card Type, it aims to confirm the NFC chips type. SONY and ASUS are using Felica and Samsung using the different chip.
(2) In GETUID of ACR122U Tool, it will request the response NFC ID data of the NFC device, success rate of Samsung Galaxy Nexus is 100%, SONY mt27i is 33% and ASUS Nexus 7 is 46.7%.

In GETATR of ACR122U Tool, it will request the NFC device response the command from ACR122U (response the current setting of the contactless interface), success rate of Samsung Galaxy Nexus is 100%, SONY mt27i is 10% and ASUS Nexus 7 is 10%.

Our implementation for NFC Device linked with PC Reader, We using in two ways:

(1) Only NFC: Android Beam enabled and extra program running on NFC Device, and PC Reader running JAVA Program [13]. We test the NFC function between different brands Android Device. The result we got show in 0, for stage 1 linked with ACR122U for SONY is 8%, and Samsung is 28% and ASUS is 0%; the stages 2 linked and data received by Android Beam for SONY is 0%,and Samsung is 0% and ASUS is 0%.
(2) By program: Android Beam enabled and running specific program on NFC Device [13]. We test the NFC upload function between different brands Android Device. The result we got show in 0, for stage 1 linked with ACR122U for SONY is 28%, and Samsung is 42% and ASUS is 0%; the stage 2 linked and data received by program for SONY is 0%, and Samsung is 2% and ASUS is 0%.

In these results, we found that the same NFC chip (Felica chip) using for SONY and ASUS got same situation for keep beeping when linked with ACR122U but Samsung doesn't. In test processing, Sony will hanging on for almost 6 seconds for reset NFC function, it may be caused by different NFC Chip.

Table 7. The statistic of ACR122U TOOL Link

	SONY mt27i	Samsung Galaxy Nexus	ASUS Nexus 7
Modulation Type ACR122U Tool GET STATUS	01(FeliCa)	00(ISO14443 or Mifare)	01(FeliCa)
Card Type ACR122U Tool GET STATUS	ISO 14443A, Part3 (Felica 212K)	ISO 14443A, Part3	ISO 14443A, Part3 (Felica 212K)
GETUID of ACR122U Tool	33% (10/30)	100% (30/30)	46.7% (14/30)
GETATR of ACR122U Tool	10% (3/30)	100% (30/30)	10% (3/30)
Description	ACR122U Keep beeping and flashing	ACR122U Connected but sometimes Keep beeping and flashing (3/30, 10%)	ACR122U Keep beeping and flashing

In ACR122U with PN532 control chip can provide three modes:

- Card mode(T=1),
- Reader Mode (T=CL)
- P2P Mode(T=0)

Our steps of the connection test are:

(1) Open port to confirm that ACR122U has successfully connected.
(2) Coupled with PN532 chip control codes [14] and ISO18092 transfer protocol, it transfers the initial code of the initial device to initialize the target.

```
SendBuff[0] = (byte)0xFF; //PSDO Prefix
SendBuff[1] = (byte)0x00; //PSDO Prefix
SendBuff[2] = (byte)0x00; //PSDO Prefix
SendBuff[3] = (byte)0x00; //PSDO Prefix
SendBuff[4] = (byte)0x0A; // command length
SendBuff[5] = (byte)0xD4; //CMD0
SendBuff[6] = (byte)0x56; //CMD1:InJumpForDEP
SendBuff[7] = (byte)0x01; //active mode
SendBuff[8] = (byte)0x02; //424kbps
SendBuff[9]=(byte)0x01;// NFCID3i Instruction
SendBuff[10] = (byte)0x00;
SendBuff[11] = (byte)0xFF;
SendBuff[12] = (byte)0xFF;
SendBuff[13] = (byte)0x00;
SendBuff[14] = (byte)0x00;
```

From Table 8, we can see that there are some troubles in implement P2P transmission because the chip is not the same in the NFC embedded smartphones. It is not very stable to maintain a fixed connection status to transfer data between PC Reader and NFC Device. The Success rate of connection is less than 50%.

Table 8. The statistic of P2P(ISO18092) Link and data Exchange

		SONY mt27i	Samsung Galaxy Nexus	ASUS Nexus 7
ACR122U connected	Only NFC	8% (8/100)	28% (28/100)	0% (0/30)
	By program	8% (8/100)	42% (42/100)	0% (0/30)
Data transmitted	Only NFC	0% (0/30)	0% (0/100)	0% (0/30)
	By program	0% (0/30)	2% (2/100)	0% (0/30)
Description	Only NFC	ACR122U hanging (1)，ACR122 respond after 6 sec	ACR122U hanging (5)，need re-plugging	ACR122U Keep beeping and flashing
	By program	ACR122U hanging (1)，ACR122 respond after 6 sec	Cell phone hanging(3) ACR122U hanging (6)，Keep Waiting And Retransmitting(3)	ACR122U Keep beeping and flashing

Where, the PN532 chips which used by ACR122U and the Felica chips which used by SONY and ASUS are produced by SONY, their success rate of connection is only 8%. In the case of PN 544 chips which used by Samsung, their success rate of connection is 42%. For Now the Card mode functions of NFC in Android still not available, only Reader mode function available. We use the Library get from ISMB[13] to test for the Feasibility of NFC P2P Communication, So, maybe success rate of connection can improved when the Card mode function is available in the future.

The connection stability which is between PC Reader and NFC Device was under our expected, because the chips brands are different. In this paper, we use the NFC Device for Nursing Care to improve time-consuming record-keeping, we estimate the time of link operation and data upload.

Therefore, we propose a system for this study using the "Tagging" characteristic of NFC. This system used to replace the connection action for data upload (Fig. 10). The authors may express their acknowledgement and the financial support project number here.

The time of upload data included 6 commands:

(InJumpForDEP+ACK)+(InDataExchange+ACK)+ (DEP_REQ+ DEP_RES).

The average length of commands is 6bytes，

$$6\times 8\times 6 \Big/ 424000 = 0.68ms .$$

The upload time of 6 commands are 0.68ms for 424k bps, it is too short to take in calculation. Thus we neglect this part in our research.

We can control the length of data under 52-60 bytes and send one TPR data with single data frame for the stable 424kbps transmitting speed.

In general, a nurse is responsible for 15 patients and records 30 data for a patient (including 1 TPR record and medication time records in SQL database). The estimated upload time will be

$$30\times 52\times 8 \Big/ 424000 = 0.29\sec .$$

Except the time of upload data, the nurse also need extra operation of “Touch Screen” to confirm upload data, it will take 0.5~1sec. The total time of link and upload all patients data will be take 1~2 sec (**Table 9.**). After data was written into the database, it could draw the TPR trend curve by the application function in PC Reader (**Fig. 10.**). The results compare with PDA that already used in Hospital and it will take 30 seconds only for exchange data [6].

The frequencies of TPR records are from 0.5~4 times per hour that depends on the situation of patients and ordered by Doctor. We use one time per hour for estimation and 8 hours for the regular working hours. So it will need 8 times for TPR rounds. The nurse will spend 48 minutes on it for using PDA, so we can save this time by using our design. It shows in Table 9.

Table 9. Compare of Time for Upload data

Time for	This Study	PDA
before operate	Automatic transmitted when NFC detected X	Depend on UI design 180~300 Sec
Connect cable	Put on Reader X	USB/RS232/base 5~10 Sec
Confirm when connected	tagging <1 Sec	Select item on screen and confirm 5~10 Sec
Transmitting	0.29 sec	30 Sec
Dissemble cable	Take from reader X	USB/RS232/base 5~10 Sec
total	1.29 Sec	360 Sec
factor	Chip type of Embedded NFC	The software environment of PC

5 Conclusion

In this paper, we take the advantage of the NFC features and implement the connection test of P2P transmission. We found that NFC peer-to-peer communication is possible. Although there are some troubles in implement P2P transmission, we still saw the success rate of connection is 42% in Samsung. The success rate of Samsung Galaxy Nexus is 100%, SONY mt27i is 33% and ASUS Nexus 7 is 46.7% in GETUID of ACR122U Tool. The success rate of Samsung Galaxy Nexus is 100%, SONY mt27i is 10% and ASUS Nexus 7 is 10% in GETATR of ACR122U Tool.

We also expect at least each nurse can save the time of the connection operating twice to eighth per day and the time of instruments and equipment operator 47.8 minutes per day. This will enhance the working efficiency and the quality of care.

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