Intelligent Packaging and Intelligent Medicine Box for Medication Management towards the Internet-of-Things

Zhibo Pang*, Junzhe Tian**, Qiang Chen**

**Corporate Research, ABB AB, Västerås, Sweden*

*** ICT School, Royal Institute of Technology (KTH), Stockholm, Sweden*

pang.zhibo@se.abb.com, {junzhe, qiangch}@kth.se

***Abstract*—The medication noncompliance problem has caused serious threat to public health as well as huge financial waste would wide. The emerging pervasive healthcare enabled by the Internet-of-Things offers promising solutions. In addition, an in-home healthcare station (IHHS) is needed to meet the rapidly increasing demands for daily monitoring and on-site diagnosis and prognosis. In this paper, a pervasive and preventive medication management solution is proposed based on intelligent and interactive packaging (I2Pack) and intelligent medicine box (iMedBox). The intelligent pharmaceutical packaging is sealed by the Controlled Delamination Material (CDM) and controlled by wireless communication. Various vital parameters can also be collected by wearable biomedical sensors through the wireless link. On-site diagnosis and prognosis of these vital parameters are supported by the high performance architecture. Additionally, friendly user interface is emphasized to ease the operation for the elderly, disabled, and patients. A prototyping system of the I2Pack and iMedBox is implemented and verified by field trials.**

***Index Terms*—Medication Management; Internet-of-Things (IoT); In-Home Healthcare Station (IHHS); Wireless Sensor Network (WSN); Controlled Delamination Material (CDM); Radio Frequency Identification (RFID);**

I. INTRODUCTION

PERVASIVE healthcare has been recognized to be the next generation form of healthcare, and distributed, patient-centric and self-managed care is emphasized as an alternative to the traditional hospitalized, staff-centric and professional-managed care [1]. Pervasive healthcare based on the emerging technologies of the Internet-of-Things (IoT), as so-called Health-IoT, is highlighted as one of the killer applications of the IoT [18, 21]. Many projects and initiatives have been devoted in this promising area. Unfortunately, the concern to prescription medication noncompliance, a basic type of self-managed care, is insufficient in the existing research [2]. A frequently cited fact is: medication noncompliance costs the United States healthcare system up to $100 billion per year, and it is the cause of approximately 11% of US annual hospitalizations [3]. It has been proven that, for the 4 most drug-spending chronic conditions (diabetes, hypertension, hypercholesterolemia, and congestive heart failure), hospitalization rates are significantly lower for patients with higher medication compliance [4]. More startling figures are listed in a report from the National Council on Patient Information and Education (NCPIE) in 2007 [5]: only about 50% of American patients take their medicines as prescribed, resulting in approximately $177 billion direct and indirect costs to the U.S. economy annually.

To address the medication noncompliance problem, one solution from traditional packaging industry is the One Dose Packaging [6] which packetizes the tablets or capsules of one dosage into one small box of bag. It just makes medication more convenient for patients, but neither improves the compliance nor prevents from noncompliance. Noncompliance detecting and recording capability is offered by the Smart Medical Refrigerator in [7], the microchip powered tablet package in [8] and the Smart Dose Reminder in [9]. But these are mainly afterward checking measure instead of preventive measure, and the operations of these solutions are so complicated that they are only usable for trained caregivers instead of the elderly, disabled, and patients.

At the same time, the increasing demands of daily monitoring prompt the Health-IoT solution to integrate more sensing and data processing capacities especially for on-site diagnosis and prognosis. For example, tri-axis accelerometer, electrocardiogram (ECG), blood pressure, blood oxygen saturation (SpO2), respiration oxygen saturation, blood sugar concentration, body temperature can be monitored on 24/7 basis [10-14]. So a powerful in-home terminal is needed not only to address the medication noncompliance but also to be used as a generic in-home healthcare station (IHHS) in everyone's home.

In this paper, extending our previous works in [16-21], an in-home medication management and healthcare system is

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Zhibo Pang is with ABB AB, Corporate Research, Forskargränd 7, 72178, Västerås, Västmanland, Sweden (phone: +46-21 325104; fax: +46-21 323212; e-mail: pang.zhibo@se.abb.com).

Junzhe Tian and Qiang Chen are with Royal Institute of Technology, Department of Electronic Systems, Isafjordsgatan 39, 16440, Kista, Sweden. (e-mail: {junzhe, qiangch}@kth.se).

proposed based on intelligent and interactive packaging (I2Pack) and intelligent medicine box (iMedBox). Preventive medication management is enabled by the intelligent pharmaceutical packaging which is sealed by Controlled Delamination Material (CDM) and controlled by wireless communication. Various vital parameters can also be collected by wearable biomedical sensors through the wireless link. On-site diagnosis and prognosis of these vital signals are supported by the powerful architecture. Additionally, friendly user interface is emphasized to ease the operations especially for the elderly, disabled and patients. A prototyping system is implemented and verified by field trials.

The rest of this paper is organized as follows. The vision of Health-IoT and related concepts are introduced in section II. The system functionality and architecture are given in section III. Implementation and experimental results of the I2Pack and iMedBox are presented in section IV and V respectively. Section V concludes the paper and discusses open issues.

II. The Vision

A. *The Health-IoT*

The in-home healthcare (IHH) service enabled by the IoT technology (the so-called Health-IoT) is promising for both traditional healthcare industry and the ICT industry. The Health-IoT service is ubiquitous and personalized and will speed up the transformation of healthcare from career-centric to patient-centric. Typically, a Health-IoT solution includes the following functions:

Tracking and monitoring. Powered by the ubiquitous identification, sensing, and communication capacity, all the objects (people, equipment, medicine, etc.) can be tracked and monitored by wearable WSN devices on a 24/7 basis.

Remote service. Healthcare and assist living services e.g. emergency detection and first aid, stroke habitation and training, dietary and medication management, telemedicine and remote diagnosis, health social networking etc. can be delivered remotely through the internet and field devices.

Information management. Enabled by the global connectivity of the IoT, all the healthcare information (logistics, diagnosis, therapy, recovery, medication, management, finance, and even daily activity) can be collected, managed, and utilized throughout the entire value chain.

Cross-organization integration. The hospital information systems (HISs).are extended to patient' home, and can be integrated into larger scale healthcare system that may cover a community, city or even state.

B. *Application Scenario*

A typical application scenario of the Health-IoT system is illustrated in Figure 1. The center of the system is a powerful intelligent medicine box (iMedBox), which works not only as a traditional in-home medicine container (such as a drawer of cabinet, a thermostat or an icebox), but also as a "*medication inspector*", and an "*on-site examiner*" in daily monitoring. On one side, it is linked to public area (e.g. the hospital, the medicine supply chain and the emergency help center) through wireless internet. On the other side, it controls a suit of intelligent pharmaceutical packages (iPackage) and a suit of wearable biomedical sensor tags (iTag) through radio frequency identification (RFID) links and wireless biomedical sensor network (WBSN) respectively. More information is available in our previous work [16-21].

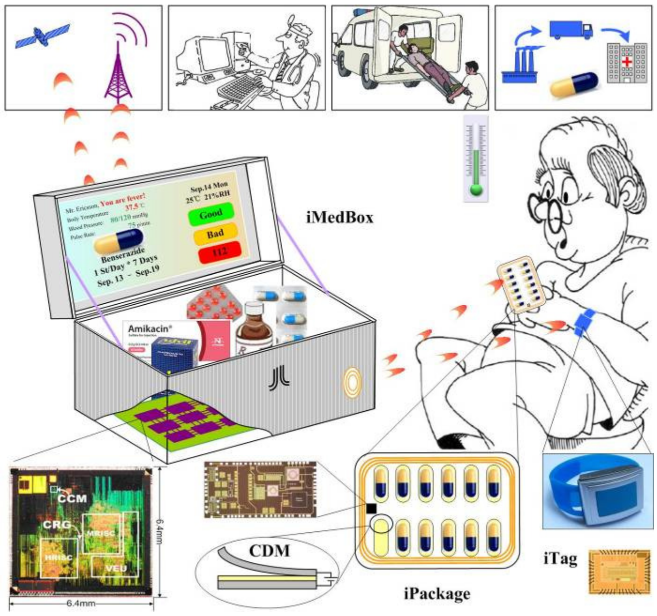


Figure 1 Application Scenario

C. *Intelligent and Interactive Packaging*

"Ubiquitous" is the distinct feature of IoT technologies. Ideally, it should be able to reach every item of the objects. The Health-IoT system should be able to track every package of medicine, record the medication activity of every tablet of capsule, and present all prescription information related to the patient. To realize this feature, a suitable format of a smart device is demanded. It should be able to carry the capacities and benefits of IoT with affordable cost and in a natural manner. According to the vision of iPack VINN Excellence Center [22], the Intelligent and Interactive Packaging (I2Pack) is a suitable format of smart device for this purpose.

As shown in Figure 2 [22], the I2Pack is the next generation of packaging which can interact with customers by integrating RFID, sensing, energy harvesting, communication, display, acting and other functions onto traditional packaging. When paper-based actuators and display are integrated, the packaging can not only be aware of the presence of customers, but also be able to inform the customer what's on.

The vision of I2Pack may make big transformations to the business world. The information carried by the packaging will transform from static to dynamic, the flow of information will transform from single-directional (product-to-consumer only) to dual-directional (both product-to-consumer and consumer-to-product), and the role of packaging will transform from "passive" (only controlled by consumer) to "active" (self-controlled or remotely controlled). So the I2Pack can be assigned more responsibilities in addition to the containing and protecting of goods. The role of packing becomes "communication medium" between suppliers and consumers. It is expected to be a seller on-site, an information presenter, an information collector, and even an executor of particular operations. For example, in the retailing application scenario, the I2Pack with a touch sensor knows who has touched it, and if integrated with a price tag, it can inform the customer "today's special offer". In the Food-IoT application scenario, it can inform customer the quality and freshness of the food automatically. In the Health-IoT application scenario, an intelligent pharmaceutical packaging glued can be electrically opened through finger touch. [22]

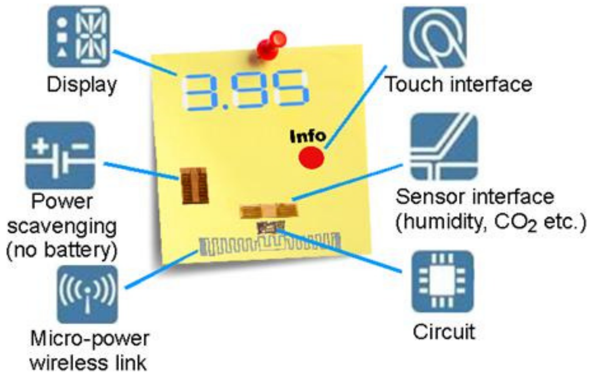


Figure 2 The vision of the intelligent and interactive packaging [22]

Intelligent pharmaceutical packaging is one of the typical implementations of the vision of I2Pack (see section III). It has offered a technical solution to achieve the so-called preventive medication management.

D. Intelligent and Preventive Medication Management

Comparing to the existing solutions, preventive medication management has been suggested to be more effective to address medication noncompliance problem [5]. Preventive medication management requires real-time reminding, recording, preventing of the medication activity, on-site diagnosis and prognosis of vital parameters, and emergency supporting to the users. in particular, it includes the following functionalities.

Medicine Inventory: The iMedBox can register, record, query and statistic all medicine utilities automatically by reading the RFID tags on them.

Medication Reminding: The iMedBox can download and parse the prescription automatically and remind the patient to take the medicine on time e.g. by flashing on the screen, playing music via the speakers, flashing the lights, etc.

Noncompliance Recording: All of the patient's medication activities (e.g. opening the box, taking a dose, forgetting to take a dose, destroying some medicines by mistake, throwing some medicines away, etc.) are detected and recorded.

Noncompliance Preventing: Without an "OPEN" command from the iMedBox according to the prescription, the user/patient cannot by hand open the iPackage which is sealed tightly by the CDM films. Thus early or excessive medication can be completely prevented.

III. System Architecture

A. System Architecture Diagram

As shown in Figure 3, multiple wireless links are integrated in the iMedBox. User friendly user interfaces are provided including a LCD displayer, a touch screen, a camera, speakers, a microphone, shining LED lamps, and vibrators.

Wireless internet link: includes WiFi and/or GPRS/3G communication stacks, system security, data base access, web server for data shearing.

Global Positioning System (GPS) link: is useful to deliver emergency supporting to the right location at the first moment.

WBSN link: includes stacks for star-topology networking and data collection.

RFID link: includes medicine inventory management, CDM controlling and medication compliance detection.

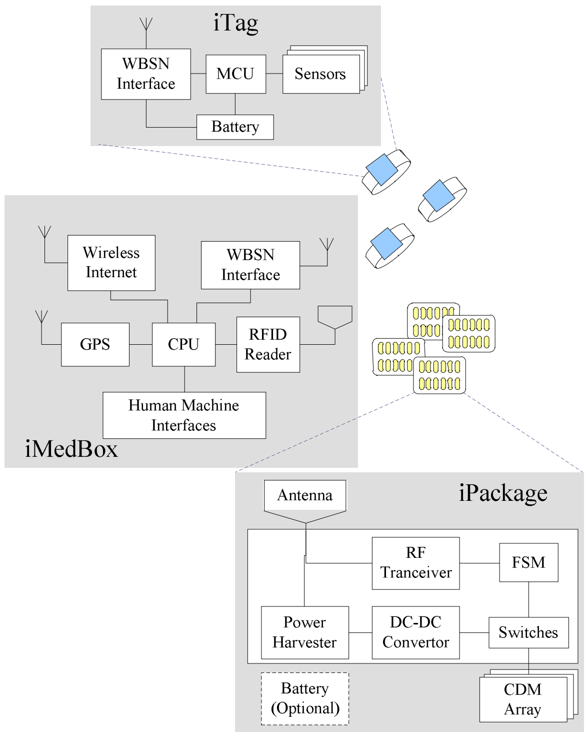


Figure 3 System Architecture

In the iPackage, a significant difference comparing to traditional RFID-enabled packages is, an array of CDM films and corresponding control circuits are added. The CDM film is a 3-layer foil composed of an aluminum bottom layer, an aluminum top layer and an adhesive middle layer made of electrochemical epoxy. When the voltage subjected between the bottom layer and top layer is higher than a particular threshold called Delamination Voltage (V_d), the electrochemical reaction is triggered in the middle layer. If the voltage maintains longer than a particular time called Delamination Time (T_d), the epoxy layer is destroyed and thus the top layer bottom layer are separated. V_d and T_d are both distinct parameters determined by the formula and processing when the material is manufactured [15].

The distinct characteristics of the CDM are used to perform noncompliance preventing function of the intelligent pharmaceutical packaging. The iPackage which is sealed with a CDM film can be opened by the iMedBox by sending an OPEN command to the microchip in the iPackage. And it cannot be opened by the patient without the OPEN command since the adhesive glue of CDM is too tight to human's hands. For each tablet or capsule, there is one dedicated piece of CDM which is controlled separately. In other words, each tablet or capsule can be controlled by the iMedBox. So the compliance of prescription is achieved at tablet level.

The energy needed to open the CDM can be transmitted by wirelessly by near field magnetic resonance, so the intelligent pharmaceutical is still battery-less. Or as an alternative, a printed battery could be manufactured along with the package to make a self-powered packaging solution. This has been proven by experimental results in the next sections. Both the battery-less and battery-power solutions will have similar out-looking to the traditional ones

The iTag has a typical architecture of WBSN. It comprises a WBSN interface, a low power MCU, a suit of biomedical sensors and a battery. The battery-powered WBSN device has significant advantages in communication distance and sensing capacity comparing to the battery-less and self-powered ones.

B. *On-site Diagnosis Framework*

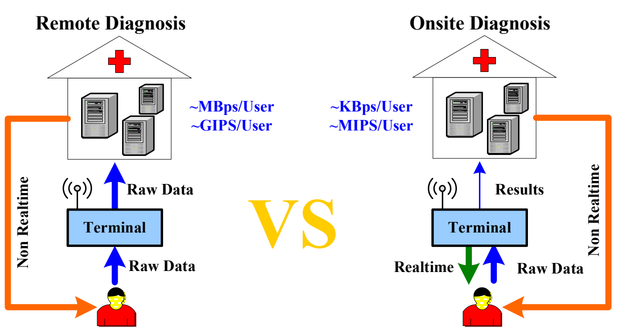


Figure 4 On-site diagnosis vs. remote diagnosis

There are mainly two kinds of frameworks in pervasive healthcare systems (Figure 4). In Remote Diagnosis Framework, the raw data collected by on-site terminal is transmitted directly to the server and a non-real-time and long term feedback is given to the user according to analysis results. Contrary, in On-site Diagnosis Framework, preprocessing is performed in the on-site terminal and only results (instead of raw data) are transmitted to the server. In this way, both the traffic load between terminal and server and the computation load in the server are reduced significantly. This makes the latter solution more effective and efficient, because the data transmission and processing in Remote Diagnosis Framework would overwhelm the communication system and resources in server when it is widely adopted. Furthermore, the on-site terminal could give users feedback at first time and first place, which is very important for some urgent situations such as acute myocardial infarction.

So we adopt the On-site Diagnosis Framework to design the proposed system. In iMedBox, a suit of basic diagnosis and prognosis examinations can be performed in the software. Feasible algorithms are becoming available during the efforts in many research activities, e.g. human movement classification and detection based on tri-axial acceleration, ECG signal compression based on discrete wavelet transformation, heart premature detection based on ECG signal classification [11-14].

IV. Implemetnation of the Intelligent Packaging

A. *Prototype of the CDM*

To analyze and evaluate the CDM material for iPackage, we made a dedicated demonstration board including a near-field resonance coil, a resonance driver chip, an MCU, two button batteries, a DC-DC converter, a power switch and a piece of CDM film (Figure 5). In this step, the main power source is the button batteries and the near-field resonance coil is just for control commands. The DC-DC converter multiplies 3V battery voltage to 30V to the CDM if an OPEN command is received from the coil. More information is available in our previous work [17].

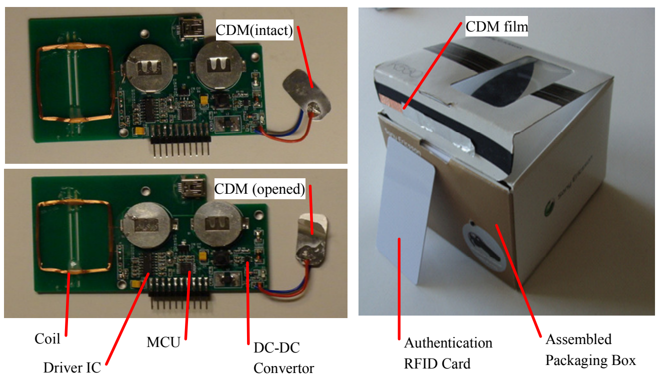


Figure 5 Prototypes of CDM (left) and assembled intelligent package (right)

B. *Setup of experiments for CDM charactorization*

The main task of CDM characterization is to evaluate the energy and power needed to open a unit area of CDM film, where the Delamination Voltage (V_d), Delamination Maximum Current (I_d), Delamination Time (T_d), Delamination Power (P_d) and Energy expense (E_d) are measured and calculated.

As mentioned in the previous study [15], CDM will quickly open if it is added a voltage in 10-50V range, and if some environment conditions affect CDM electrochemical characteristics. The following tests are performed at a temperature round 22°-25° and a relative humidity of 30%-37%, within the safety range of 36V for human. To formalize the test results, the size of test CDM pieces is set to 1cm^2 because the size of film is almost unrelated with opening time [15]. During the whole delamination period, current through the CDM film is measured by a 180 Ohm serial resister.

C. *Delamination Behavior*

To monitor the delamination behavior of CDM, we apply a 30V DC power source to a 1cm^2 CDM film. As shown in Figure 10, in the beginning, the current reaches its maximum value 0.95 mA/cm2 (I_d) in a few seconds. When holding power source voltage for about ten seconds, the current drops down significantly. After 90 seconds, the current is reduced by over 90%, and the diminution turns to slow. At this moment, the CDM film is so weak that just a slight tough can make it peel off. But as we can see in the last 60 seconds, without any external force, the current through the material is very small which is infinitely close to zero but never equal to zero.

In order to standardize the delamination behavior, a static shear force is added to one surface of the CDM film by hanging a mall weight. When the adhesive strength cannot afford the weight, the CDM film is disbanded immediately. The current at that moment is called Turnoff Current which signifies the material is delaminated. And T_d is defined as the interval from power supply is applied on the surface till the current reaches the Turnoff Current in a current curve.

D. *Impact of Power Source Dutycycle*

Four duty cycles of a 100 KHz and 30V power source are applied to a 1cm^2 CDM film respectively. When duty cycle of power source increases from 20% to 100%, the T_d decreases disproportionately (Figure 6).

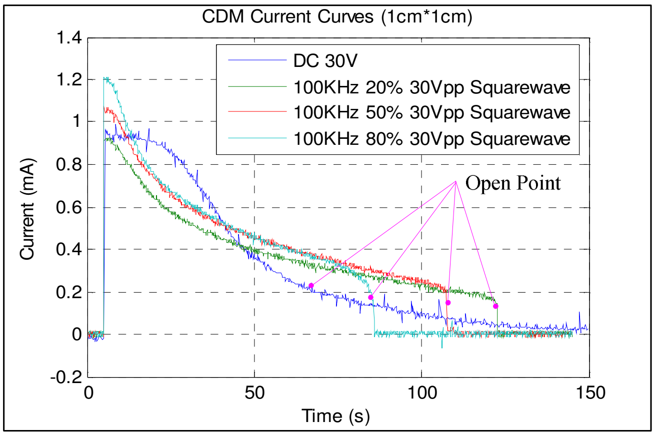


Figure 6 Impact of Power Source Duty Cycle

E. *Impact of Power Source Voltage*

The current through the material under different power source voltages from 5V DC up to 30V DC are plotted in Figure 6. When the power supply is lower than 5V, the CDM will not open within 2 minutes without any large external shear force. When the voltage increases from 5V to 30V, the T_d decreases significantly and disproportionately.

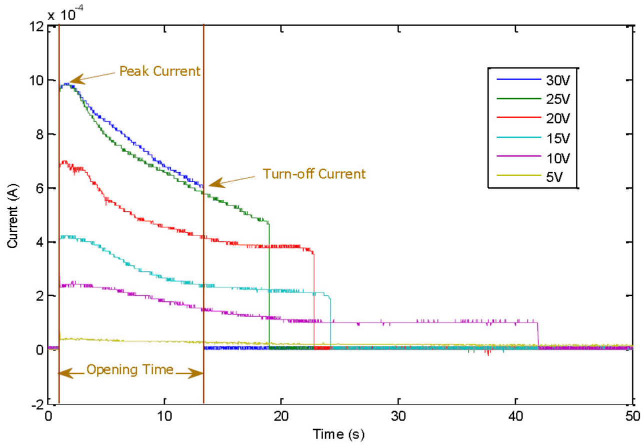


Figure 7 Impact of Power Source Voltage

F. *Impact of Material Process Variety*

For CDM pieces at different position from the same reel, the difference of T_d is neglidgible. But the difference between pieces from different reels is larger according to measurement results of 4 pieces from 4 different reels in Figure 7. The main reason is that the difference in the material process and quality from reel to reel is larger than that from region to region in one reel.

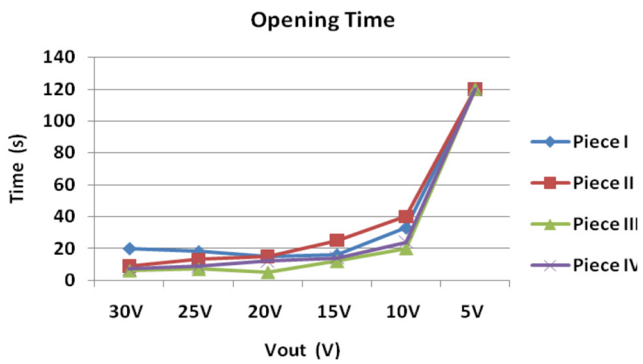


Figure 8 Impact of Material Process Variety

G. *Summary of the CDM Characterization*

From the results described above, we can make the following conclusions:

1) I_d is at the order of 1mA/cm2
2) V_d is at the order of 30V
3) T_d is at the order of 100s
4) P_d is at the order of 30mW/cm2 (=1mA/cm2*30V)
5) E_d is at the order of 3J/cm2 (=30mW/cm2*100s)

This implies that a printed thin-film battery with 3.3mAh capacitance is sufficient to open up to 12 tablets sealed with 1cm^2 CDM film for each. This is a typical application case in practical tablet packages. But one important factor should be taken into considerations: most of printed batteries have a large internal resistance which will decrease the peak current and prolong the T_d. So, it is feasible to use the CDM material to realize the proposed intelligent package.

H. *Battery-less Intelligent Pharmaceutical Packaging*

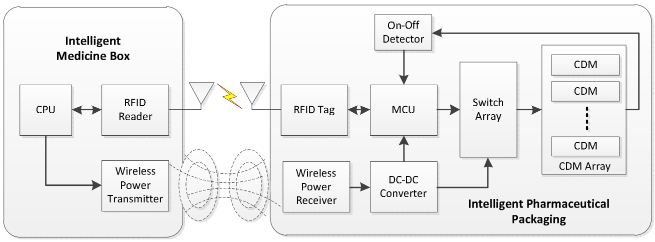


Figure 9 Battery-less intelligent pharmaceutical packaging based on wireless power transmission

Currently the prototype is power by two icon batteries which is not environment friendly. A battery-less solution is more suitable for the intelligent pharmaceutical packaging. As shown in Figure 9, a battery less intelligent pharmaceutical packaging is proposed based on the wireless power transmission technology (WPT). The WPT is already in mass-production in consumer electronic products, e.g. Nokia Lumia 920 mobile phone, with affordable cost and sufficient maturity. According to the results of CDM characterization, today's wireless power transmission technology is sufficient to provide this energy. For example, the single chip wireless power receiver IDTP9020 from Integrated Device Technology, Inc. can output up to 5W@5V conforming to the Wireless Power Consortium (WPC) "Qi" specification. It is sufficient to drive a CDM array in the pharmaceutical packaging.

V. Implementation of Intelligent Medicine Box

A. *iMedBox Prototype*

As shown in Figure 10, the 3nd generation of the iMedBox prototyping system is implemented based on Samsung Galaxy Tab10.1 tablet PC. The processor is Tegra 2 dual-core ARM Cortex-A9 at the speed of 1GHz and manufactured by NVIDIA. It has 16GB internal flash memory and could be extended by MicroSD card up to 32GB. It also has internal 2.0MP front-camera, Wi-Fi/Bluetooch/3G access module, 6860mAh battery, and USB connection. To support different port types of WSN, a connection bridge based on FTDI Vinculum II programmable USB Host/Slave controller is also implemented. The connection bridge support UART, SPI Master, SPI Slave, and USB Host/Slave connection.

The tablet is embedded in the lid of the medicine box. And the connection bridge together with plug-in modules is placed in the bottom of the box. In the prototype, the connection bridge is implemented with four adapter nodes. Each adapter node is implemented with a VNC2 from Future Technology Devices International Limited development module (Vinculum II), and can provide one USB host port, one USB slave port, one SPI master port, one SPI slave port, and one high speed UART port. Four nodes are connected with SPI port as a chain. The first node is connected to the tablet via USB port with the table in slave mode. The Android Open Accessory Protocol of Android OS ensures the Vinculum II can be recognized and accessed by the tablet without extra driver.

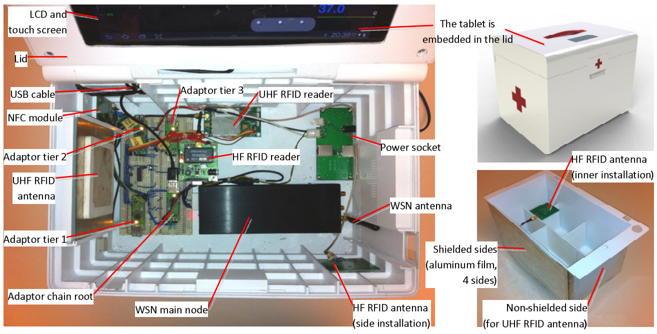


Figure 10 Hardware of the 3rd generation of iMedBox prototype

With the Vinculum II chips, the USB port of the tablet is remapped to four UART ports. One of the ports is connected to a main node receiving wireless sensor signals. One is connected to a RFID reader which monitors the status of the tags on the medicine package. The prototyping system also has a built-in NFC reader. Take the advantage of the pear to pear communication capability of NFC, the NFC reader can be another interface for the iMedBox to communicate with biomedical devices and authentication cards. One extra UART is left for future extension.

B. *Software and User Interface*

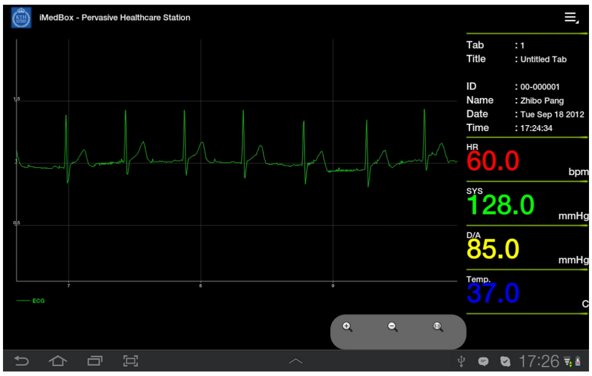
The tablet is running Android 3.1 Honeycomb open source mobile operating system released by Google under Apache license. It is also capable to upgrade the system to Android 4.0 Ice Cream Sandwich or higher.

The demonstration software is called *iMedBox – Pervasive Healthcare Station*. The software contains seven modules: core activity, screen subsystem, database, USB controller, net controller, alarm service and setting & configure subsystem. The basic unit of the user interface of this iMedBox application is tab. Users can add or remove tabs to customize the user interface, and switch between each tab by swapping on the screen. The screen subsystem support for displaying tab pages of two basic types: the Chart Tab and Table Tab. The Chart Tab content is rendered by a third party engine called AChartEngine. The Table Tab is rendered by the build-in List View element. Both the Chart tab and the Table Tab are designed to be customized easily for a specified application. One customized tab is called medicine tab.

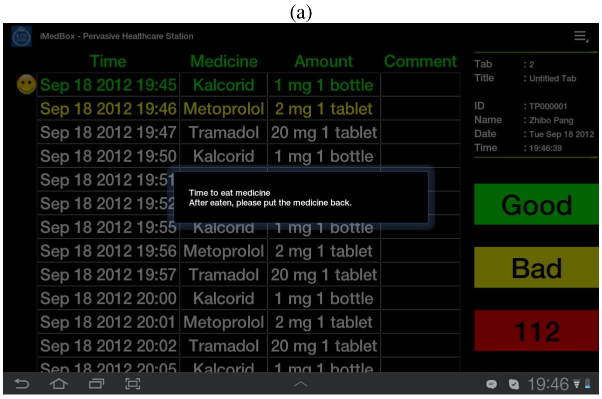
There are two predefined tabs, a Chart Tab called "Signal View" (Figure 11a) for real-time monitoring of biomedical signals (e.g. ECG, body temperature, blood pressure, etc.), and a Table Tab called "Medication View" (Figure 11b) for medication management application.

The Signal View shows the waveforms of signals e.g. ECG. The chart can live update with the input ECG data packets. It can also show some extra summarized results like the heart beat rate and body temperature. The Medication View shows the medicine taken schedule for the user, contains the history and the following plan. User can enable the alarming service of this tab. Then if the next time is up to take a dose of medicine, the tablet will wake up automatically, play a piece of alarm music, and show the medicine information for user to take.

When the alarm is triggered, the connected RFID reader starts to detect the status of a specified tag. The tag ID has mapped to the medicine which needs to be taken at the moment. When the user picks up the right medicine, the alarm will stop automatically and the alarm for the next medicine is set, but the screen keeps showing a warning message. When the user finishes taking the medicine and puts the bottle back, the warning message will go away. Each successful medication procedure will be marked with a happy face.



(a)



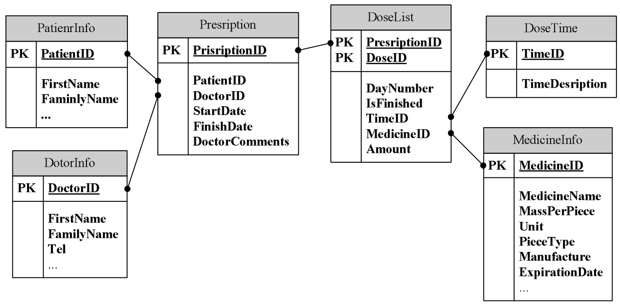
(b)

Figure 11 User interfaces of the iMedBox software for (a) Signal View, and (b) Medication View.

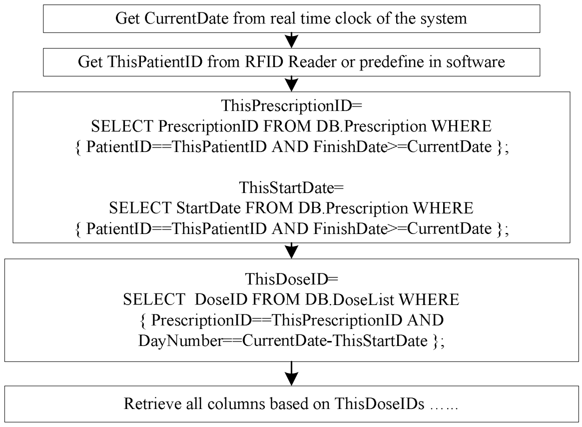
Additionally, there is one reserved tab called "Home Tab" which is a welcome page showing some general information like current time, a tab list, an icon for switching to chatting application (e.g. Skype), and a note area for displaying customized messages.

C. Medication Database

The primary entities (tables) of the Medication Database (MDB) and relations among them are shown in Figure 12a where all prescription and medication information is well organized. Correctly handling of the DoseList table in MDB is the core of the database system. Firstly, when a new prescription is issued in hospital, corresponding records are added in by dispatching one prescription into multiple dose lists. Secondly, when user opens the iMedBox, a timely dose list that should be taken today is retrieved. Thirdly, medications records will be updated to the MDB no matter if the doses are taken correctly or not. Example procedure and codes in Structured Query Language (SQL) are shown in Figure 12b.



(a)



(b)

Figure 12 The Medication Database (a) tables and keys, and (b) procedure of query

D. Service Backend

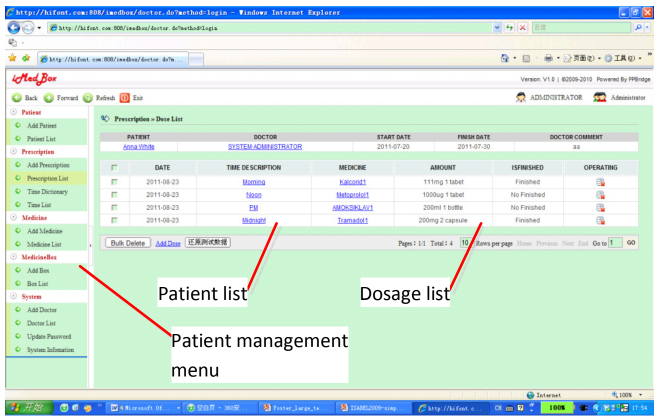


Figure 13 Web interface for doctors to manage the medication information

A demonstrative backend system has been implemented. A web-based server as well as databases are implemented by Java and deployed on an Apache Tomcat web server. Professional management interfaces are implemented as web page (Figure 13), such as prescription management, case history management, and remote diagnosis. The iMedBox can connect to the backend system via either 3G modem or WiFi.

E. Demonstration and field trials

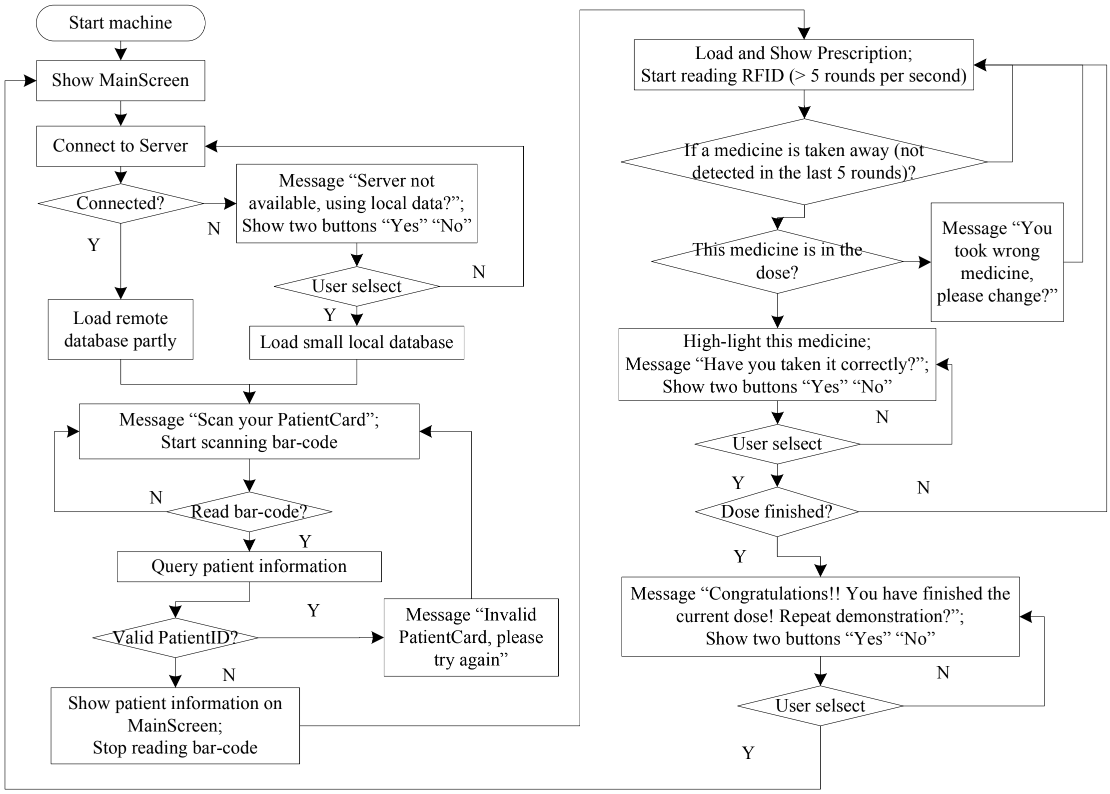


Figure 14 Flow chart of the demonstration

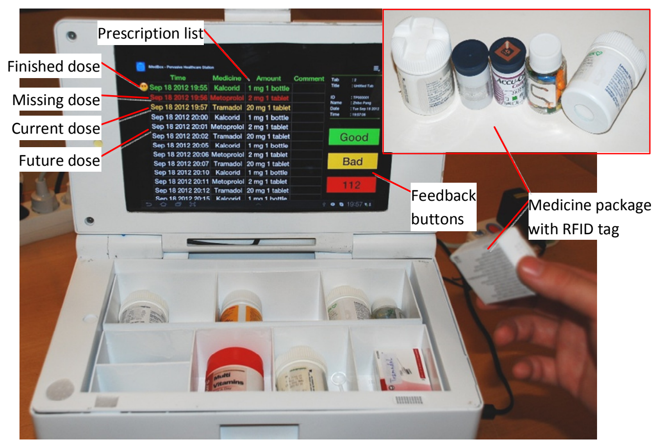


Figure 15 Demonstration of the iMedBox for medication management application

Field trials for the medication management services have been carried out with Blekinge Center of Competence (BCC), County Council of Blekinge, Sweden [18]. The scenario is shown in Figure 14 and the flow chart in Figure 15. The iMedBox prototype were demonstrated to patients, relatives that take care of patients, elder people, and healthcare personal. Three different groups have been chosen:

(1) A sheltered housing “Vidablicks” in the city of Ronneby. We demonstrated to a group of nurses that have meeting every second months to share their experiences in the field of dementia care.

(2) Healthcare staffs at Valjeviken’s rehabilitation center. We met the healthcare staffs including medicine doctors, nurses, undersköterskor, arbetsterapeuter, sjukgymnaster and kuratorer to get the detailed information about the benefits and consequences of using iMedBox.

(3) Staff and caretakers at an elderly living in Karlskrona “Fregatten”. We discussed the acceptances of different kind of assisting equipment to remind medicine time or to make it easier to take the right amount.

The concepts and ideas proposed in this paper have been confirmed by positive feedback. All audience agree that the medication reminding and recording functions can significantly improve the compliance especially for elderly, and even more necessary for the elderly with light dementia symptoms. It is necessary to integrate it to the hospital’s prescription system to reduce the workload.

At the same time, the comments from the audience have indicated directions of improvement in the future. For example,

(1) To add pictures of the drugs and drug packages on the screen.

(2) The iMedBox should be secured with a locking system, making it accessible only by specified user rather than unsuitable person such as the patient with dementia symptom.

(3) To simplify the user interface further and make the texts and colors clearer.

VI. Conclusion

In this paper, a pervasive and preventive medication management solution addressing the medication noncompliance problem is proposed. A prototype system is implemented which confirms the feasibility of the presented intelligent pharmaceutical packaging and intelligent medicine box.

As future work, on-site algorithms will be implemented as well as data collection through WBSN devices. Integrating the CDM film with wireless power transmission and RFID tag onto one flexible substrate is another task. User interfaces and experience will be further improved too.

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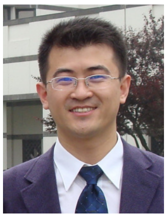
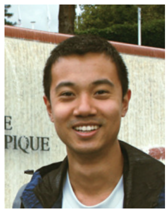


Zhibo Pang received B.Eng. degree in Electronic Engineering from Zhejiang University, Hangzhou, China, in 2002, MBA in Innovation and Growth from University of Turku, Turku, Finland, in 2012, and PhD in Electronic and Computer Systems from the Royal Institute of Technology (KTH), Stockholm, Sweden, in 2013.

He is a research scientist at ABB Corporate Research, Västerås, Sweden. Before joined ABB, he worked as technical manager in semiconductor industry, designing baseband and application processors and turn-key solutions for mobile smart devices. He has 15 patents and over 30 peer-reviewed papers in international journals and conferences. He was awarded the National Great Invention Award by the Ministry of Information Industry of China in 2005, won the First Place Prize of the RFID Nordic EXPO in 2008 and Outstanding Paper Awards in ICACT2013. His current research interests include the Internet-of-Things, wireless sensor network, industrial communication, real time embedded system, enterprise information systems, automation networks, and multicore system-on-chip and network-on-chip. He also works on the business-technology joint research such as business model design, value chain formulation, strategy, and entrepreneurship & intrapreneurship.



Junzhe Tian received B.Eng. degree in Communication Engineering from Beijing University of Posts and Telecommunications (BUPT), Beijing, China, in 2010, M.Sc. degree in System-on-Chip Design from Royal Institute of Technology (KTH), Stockholm, Sweden, in 2013. After graduate, he became a Software developer at Excosoft AB Stockholm, Sweden. Currently he is working on design and implementation of Graphical Editing Framework (GEF) and Document Type Definition (DTD) in publishing industry.

Qiang Chen received the Ph.D. degree in electronics from Linköping University, Linköping, Sweden, in 1993.

He was with Ericsson Microelectronics, Stockholm, Sweden, from 1994 to 2002 and became an Ericsson Expert in 2001. He joined Infineon Technology Sweden, Stockholm, in 2003 as a Principal. He has been at Royal Institute of Technology, Stockholm, as a Senior Research Fellow and Project Leader with the Department of Electronic Systems since 2008. He is a Senior Research Scientist with the Department of Electronic Systems and iPack VINN Excellence Center, School of Information and Communication Technology, Royal Institute of Technology. He has published more than 40 international reviewed scientific papers. His current research interests include electronic devices and circuits, wireless sensor network and sensor technology, and printed electronics.