

Development of NFC and IoT-enabled measurement devices for improving health care delivery of Indonesian children

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Abstract. In this research, a prototype of NFC and IoT-enabled medical measurement device aimed for infants between 0-5 years old is designed. The device is aimed to record data and transmit them to NFC tags on a greater system containing electronic medical record of Indonesian children, which is normally recorded in a paper card named *Kartu Menuju Sehat* (KMS). The device can measure five parameters: height, weight, temperature, heart rate, and blood oxygen (SpO₂). The result is passed to a sensor fusion system to determine health status of the child, after which the data is transmitted to mobile KMS application owned by child's guardian and health personnel. The system is tested on 12 infants of 12 months and below in two Indonesia's community health centre *Posyandu* units. Based on the result, the system is able to measure five parameters at once and transmit it to the health personnel and child's guardian, making it feasible to develop the prototype further into a fully functional medical device for use with electronic KMS.

1. Introduction

Around 37% of Indonesian population consist children and adolescents. To ensure their well-being, health status of Indonesian children is recorded in a report card named *Kartu Menuju Sehat* (KMS), which contains records of a child's height and weight through certain periods and compared to a graph on the card to determine the child's health. The card may also contain other records such as immunization history. For children between 0-5 years old, a KMS subtype named *KMS Balita* (KMS-B) is used. KMS-B is filled and updated by the personnel of community health centre unit named *Pos Pelayanan Terpadu* (*Posyandu*), with the KMS itself is owned by the child's legal guardian.

KMS is paper-based; as such, KMS records also see limited use and cannot be fully utilized to improve the overall quality of the child's health care. Conventional KMS is not well-integrated within the system, which can result in access difficulty by relevant stakeholders (e.g. doctors from remote hospital). The manual process can slow down the health care delivery as a whole, such as during insurance handling and drug administration process.

To address the problem, in this research a system utilizing near-field communication (NFC) and Internet of Things (IoT) is proposed to allow better integration and management of the children's health records among the stakeholders. The research is comprised of several phases; however, this report gives is focused on development of NFC-enabled measurement device that is able to gather several data types at once while also transmitting the result to an NFC-enabled phone to speed up the examination process.



2. Literature study

2.1. NFC for health services

The near-field communication (NFC) is a communication protocol based on radio frequency identification (RFID) for data exchange of two devices within close range (< 10 cm). NFC communication is comprised of three types of data exchange process: read/write mode that involves an interrogator that reads information from NFC tag, card emulation mode that allows an NFC-enabled mobile phone to act as contactless smart card, and peer-to-peer mode where two NFC devices exchange information with each other [1]. NFC applications extend to various fields, including health care. Some examples of NFC application within medical and health care field include medication services [2], emergency medical data access using mobile phone [3], patient admission and mobile payment [4], health monitoring, and vaccination record [5]. In this research, NFC is utilized to instantly transmit examination result from NFC-enabled medical devices to the health personnel's smartphone and the e-KMS tag possessed by the child's legal guardian, thus eliminating manual recording and updating.

2.2. Sensor fusion for health services

Sensor fusion is a concept involving combination and management of different data from sensors that may result in more complex analysis that is otherwise impossible to do using separate or singular sensors, done to provide consistent and effective responses [6]. There have been several sensor fusion frameworks developed specifically for health care, such as for sports and biomedical applications [7], personalized health care [8, 9], and health monitoring with haptic feedback [10]. In this work, sensor fusion is applied for determining nutrition status of the child based on the measurements from the health device.

2.3. NFC-based health records

There have been several implementations of NFC-based health records those are intended to streamline the data recording and management processes within the health care system. In [11], Android-based NFC application is utilized to support health care delivery for elderly patients; since the elderly care involve multiple parties those tend to face difficulties for direct interaction, the proposed system is designed to work with multiple agents responsible for the elderly patient care. In [12], NFC is used to hasten diagnosis process by implanting NFC tag inside a patient's body, which will be scanned using Android application by the medical personnel to make data collection process faster. Meanwhile, in [13] NFC is used for managing discharge process and hospital bed management. While these examples show the wide range of applications of NFC for health care, none of these have been particularly focused on children health care. As such, in this work, NFC is utilized to support health care system for infants in Indonesia, specifically through the digitization of KMS health card.

3. Methodology

In order to strengthen the research scope, this research is conducted with several limitations. As the system is designed based on KMS-B (for children between 0-5 years old), devices in this research is designed to work for health care of children between 0-5 years old. In addition, only text data is used.

3.1. System architecture

The overall system architecture proposed in this research is depicted in Figure 1. The system is comprised of four types of components: NFC-enabled measurement devices, local computer containing measurement database, an IoT network, and NFC-enabled user devices such as the e-KMS card and NFC-enabled smartphone. The system works as follows: first, the infant's data is authorized by scanning the NFC tag containing the health data of the infant. Then, the infant will be measured for the health parameters, after which the data are stored in local storage. In the local storage, the data is processed to determine the health status of the infant, after which the data and result are transmitted to the stakeholders through the NFC and IoT network.

3.2. NFC-enabled measurement device

Children, particularly infants (0-5 years old), represent a vulnerable group, and therefore the design of medical devices aimed for children tend to have more specific requirements to ensure their safety. Based on the recommendation published by FDA, there are several things those need to be taken into design consideration. However, the device in this research only take height and weight factors into consideration to prove the feasibility of the concept. Based on the average physical condition of the children of the aforementioned age group, the device is designed with following specifications:

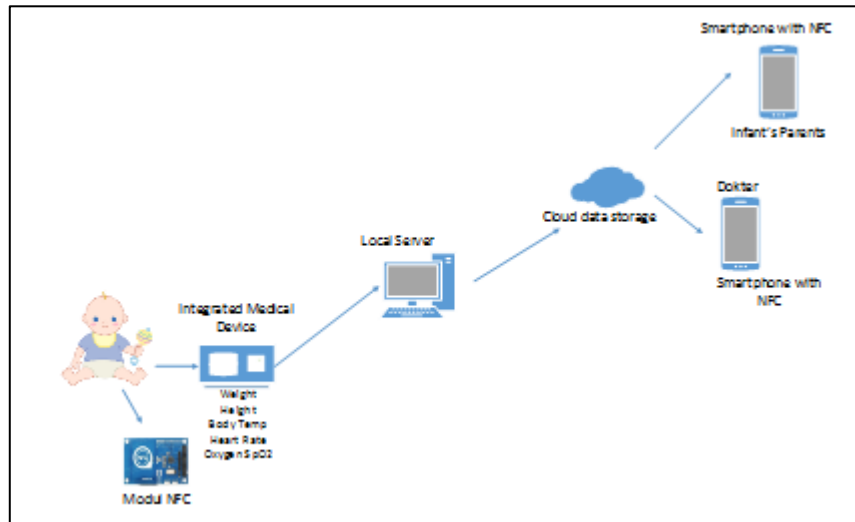


Figure 1. System architecture for the e-KMS-B health management system.

- Input voltage: 220 V (AC)
- Dimension: 90 cm x 45 cm x 31 cm
- Maximum weight: 50 kg
- Data storage: NFC tag (card/bracelet)
- Measurement duration: 20 seconds

The block diagram of the measurement device is depicted in Figure 2. The device takes five parameters to be measured: height, weight, blood oxygen (SpO_2), heart rate, and temperature. The measurement results are then processed through sensor fusion in order to determine health level of the infant, after which the result is transmitted to the database and NFC tag with the help of a microcontroller unit. The result of the measurement will also be shown in an LCD embedded on the measurement device.

3.3. Sensor fusion design

Sensor fusion is used to determine infant's health status based on the measured data. In this research, five parameters are used to determine health status: nutrition, weight status (e.g. overweight), body temperature, heart rate, and blood oxygen. The five status are used to determine final health status of the infant: healthy, slightly unhealthy, and unhealthy or sick. The nutrition and weight status of the infant are determined based on anthropometry standard published in Indonesian Ministry of Health Decision no. 1995/MENKES/SK/XII/2010. Figure 3 describes the sensor fusion design.

The sensor fusion consists of 3 parts: sensor, fusion operator, and control application. There are 4 sensors viz. load cell sensor to measure weight, ultrasonic sensor to the measure height, temperature sensor to measure the body temperature, heart rate sensor, and oxygen in the blood (SpO_2) sensor. The sensor readings are processed through fusion operator, producing new data such as nutritional status, body weight status, heart rate status, and oxygen status in the blood. Afterwards, the final decision based on the five status is delivered to control application and determined the infant's health into one of three

results: healthy with information, less healthy with information, and not healthy. If the infant is unhealthy, there will be information that the baby should be checked by a doctor immediately.

3.4. Database design

The measurement result is stored in database of a local storage. The database is comprised of two tables: identity of the infant patient (name, sex, address, etc.) and patient measurement results (date, ID, height, weight, heart rate, body temperature, and SpO₂). As of now, the database is located in the mobile phone of the health personnel, which is implemented using TinyDB.

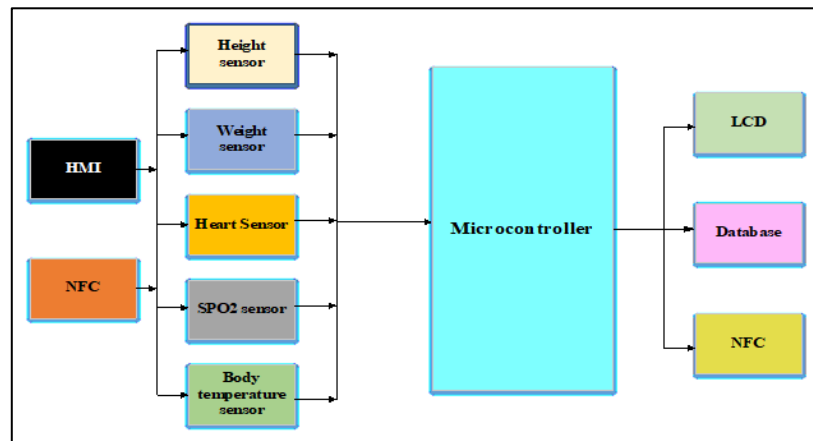


Figure 2. Block diagram of NFC-enabled measurement device.

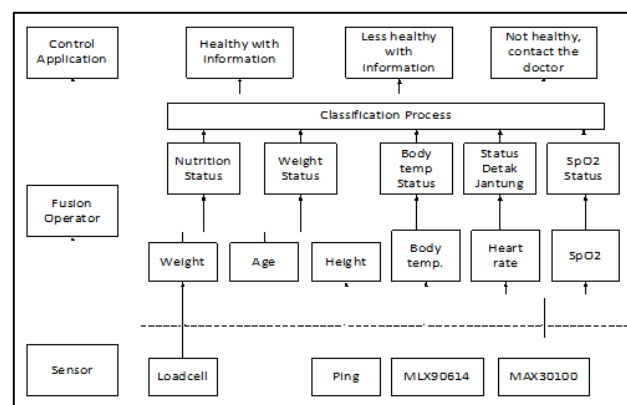


Figure 3. Sensor fusion design.

3.5. Mobile phone application

Two prototypes of mobile phone applications are designed using MIT AppInventor: one application serves as the e-KMS installed in the infant's legal guardian's phone, while another is installed in the mobile phone maintained by the health personnel of *Posyandu* for measurement and management. In order to be able to use the e-KMS, the infant's legal guardian must perform registration aided by *Posyandu* personnel first, after which health information of the infant can be exchanged through NFC.

4. Preliminary results and discussion

4.1. Device testing

Twelve subjects aged 1-12 months participated in the testing. The test is conducted in two *Posyandu* units by performing measurements using the designed device and conventional measurement tools (e.g. meter roll and weight scale), after which the results are compared. The testing process is as follows:

first, the mobile phone owned by the infant's guardian is installed with a blank e-KMS application. Next, the guardian registers for e-KMS aided by *Posyandu* personnel, after which medical examination can be performed on the infant. The guardian gave the infant's data to *Posyandu* personnel through NFC, after which the *Posyandu* personnel use their mobile phone to authorize the measurement process. The infant's health status is then measured using the device, after which the result is transferred to the *Posyandu* personnel's mobile phone through NFC and stored in a TinyDB database. Finally, The *Posyandu* personnel send the measurement result to e-KMS owned by the infant's legal guardian through NFC.

4.2. Results

The result of the device testing on twelve subjects is depicted in Table 1. Five parameters are measured using the device: height, weight, body temperature, blood oxygen (SpO_2), and heart rate. Based on the result, it can be inferred that the device can be used to measure several parameters at once thus saving time required to examine each patient.

Table 1. Measurement result using designed device.

No	Age (months)	Sex	Height (cm)	Weight (kg)	Temperature (°C)	SpO_2 (%)	Heart rate (bpm)
1	9	Female	59.97	7.00	37.21	97	132.68
2	1.5	Male	58.00	4.80	36.25	97	140.44
3	4	Female	62.80	6.20	36.85	96	130.30
4	12	Female	72.79	9.50	37.27	97	98.20
5	1	Male	58.72	4.40	37.00	97	180.49
6	9	Female	66.70	8.80	37.75	96	172.64
7	8	Male	62.98	6.60	37.44	96	140.36
8	9	Female	65.40	7.30	37.35	96	147.55
9	8	Female	62.21	7.20	36.00	97	125.20
10	11	Female	72.00	9.10	36.05	98	112.40
11	4	Female	61.03	6.10	37.25	96	162.13
12	7	Male	65.34	6.60	37.44	96	145.20

Testing of the health status classification of the sensor fusion is conducted on the data of first five subjects. Classification parameters are elaborated in Table 2, while the result is reported in Table 3.

Table 2. Sensor fusion classification parameters.

Parameter	Health Status		
	Healthy	Slightly unhealthy	Unhealthy – advised to see doctor
Nutrition status	Good	Undernutrition, overnutrition	Malnutrition
Weight status	Normal	Underweight, overweight	Very underweight
Temperature	Normal (36-37.5 °C)	Fever (37.7-38 °C)	Hypothermia (< 35 °C) Hyperpyrexia (> 38 °C)
Heart rate	Normal (89-189 bpm)	-	Above normal (> 189 bpm) Below normal (< 89 bpm)
Blood oxygen	Normal (96-100%)	-	Low (< 96%)

Table 3. Sensor fusion classification result

No	Age (months)	Sex	Nutrition level	Weight status	Body temperature	SpO ₂ status	Heart rate status	Final result
1	9	Female	Good	Normal	Normal	Normal	Normal	Healthy
2	1.5	Male	Good	Overweight	Normal	Normal	Normal	Slightly unhealthy (overweight)
3	4	Female	Good	Normal	Normal	Normal	Normal	Healthy
4	12	Female	Good	Normal	Normal	Normal	Normal	Healthy
5	1	Male	Good	Normal	Normal	Normal	Normal	Healthy

5. Conclusions

In this research, a prototype of medical measurement device based on NFC and IoT is designed, which is able to measure five health parameters at once. Based on the result, it is feasible to develop the prototype further into a fully-functional medical device to speed up examination process. However, the measurement data is still limited to text data. As such, in the future, the system will be developed further. Device safety and data privacy will also be addressed further, with security protocol will be implemented on the NFC communication to secure the data exchange of the infant health record.

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