DEVELOPMENT OF MOBILE TELEMEDICINE SYSTEM WITH MULTI COMMUNICATION LINKS TO REDUCE MATERNAL MORTALITY RATE

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ABSTRACT
This paper describes the prototype of a mobile telemedicine system that has been developed for rural area. The system consists of a mobile telemedicine unit which is realized as a portable telemedicine unit. The unit may be placed in an ambulance or at community health centres. Conjunction with the mobile telemedicine unit is a base unit that can be located in a referral hospital. The developed prototype is focused to be applied for reducing Maternal Mortality Rate (MMR) in rural areas of Indonesia. Health services which can be operated on the system are patient’s data recording and reporting, teleconsultation, telediagnostic and tele-education.

To overcome transmission link stability problem in rural areas, multi communication links is employed to support data transmission. User can transmit data via GSM, CDMA, VHF radio, or internet. While the patient’s vital signs that can be monitored are ECG, BP, FHR, and temperature.

The system has been technically tested. The results are very promising. The next step is to set up a testbed that covers community health centres in Sukabumi areas, and to operate the system for emergency situation in an ambulance. Evaluation of the system will be focused on scenarios application, and clinical test.

KEY WORDS
Mobile telemedicine unit, base unit, multi communication links, MMR, rural area

1. Introduction

The number of Maternal Mortality Rate (MMR) in Indonesia is among the highest within Asian countries. Based on the data from the Health Department, the number of MMR in Indonesia is 365 per 100000 live births. When it is compared to other Asian countries, such as 50 for Thailand or 120 for Sri Lanka [1], this number is relatively very high. In order to handle this situation and to improve health care system, the Health Department has announced a vision is called Indonesia Sehat 2010. One of the most important program is management of high risk pregnancy which is aimed to reduce morbidity and mortality of both mother and infant.

The health service for pregnant women and infants in Indonesia, mostly is conducted by Community Health Centres (Puskesmas) as a part of primary health cares. Nationwide, there are more than 7600 Community Health Centres to serve more than half of 220 million population. As a typical developing country, most of Community Health Centres in Indonesia are located in rural areas which are difficult to be accessed due to limited communication and transportation infrastructure. In addition, because of shortage of resources and health care facilities, most of Community Health Centres operate on referral system [2]. That means a responsibility of a certain case of diseases may be referred to a referral hospital or a higher level hospital. Although the organization model of the health services network in Indonesia has been well managed, sometimes there is still a gap between a community health centre, the local hospital and a national hospital since the areas to covered is very wide. This is probably one of the reasons the MMR in Indonesia is still relatively high.

To alleviate this problem, in particular to reduce the number of MMR and in general to improve health services for people who live in rural areas, a mobile telemedicine system may become an answer. This research is dealing with the development of a mobile telemedicine system with multi communication links. Multi communication links is applied because one of the most critical aspect in designing a mobile telemedicine system is data transmission which depends on the bandwidth availability and transmission link stability.

Generally, in rural areas a transmission link stability becomes a serious problem to overcome. Although, competition in business cellular throughout the country is resulting in many cellular providers in most areas, but all connected phones may be dropping simultaneously when traveling through blank spot in network coverage. Therefore, the developed system should be able to cope with transferring from one network cell into another without any disconnection in communication lines. To alleviate this issue, a hybrid communications links with
overlapping network coverage is employed in the system [3][6].

The rest of the paper is organized as follow. Section 2 describes the architecture of a mobile telemmedicine system with multi communication links. While section 3 discuss the system applications and section 4 describes the system realization and operation. While, future works to be conducted in the research are presented in section 5 as a closing remarks.

2. System Architecture

The aim of this research is to design and to implement a working prototype of a mobile telemmedicine system with multi communication links to be used in rural areas. The architecture of the mobile telemmedicine system which has been developed is depicted in figure 1 [4][7]. The system consists of two main units, namely a Mobile Telemedicine unit that is placed in an ambulance, and a Base unit or Hospital unit. The Mobile Telemedicine unit is responsible for collecting medical information that includes biosignals and image from the patient and display the critical signals, e.g. ECG signal, blood pressure (BP), fetal heart rate (FHR) and temperature. The unit is provided with the ability to acquire vital sign from medical devices, write and record the data, and transmit the patient’s medical information to the base unit via variety of communication links. To support the functions, the mobile telemmedicine unit is equipped with a number of medical devices, a communication arbiter and a processing unit [5].

The communication arbiter is a functional unit that consists of a medical information concentrator module and a communication manager module [6]. The arbiter is responsible for polling biosignals which is done by a concentrator module. Basically the concentrator is an interface to be connected to each medical devices. To manage data interchange within the system is implemented by a communication manager module. This module is a modem array that comprises of mixture a number of GSM, CDMA, radio, GPRS, and satellite (optional) modems. The specification of the module is independent zone, and able to select a most suitable communication link to transmit the data.

In conjunction with the Mobile Telemedicine unit, is the Base unit which can be located at a hospital or CHC (Community Health Centres). This unit is equipped with a personal computer (PC) to display incoming signals from the Mobile unit, and a communication manager module that functions as a transceiver. This module will implement a continuous scanning to monitor incoming information and responds to them as soon as possible. In addition, a hospital data base that contains of patient information record will be integrated to the unit. All information relating to the case handled must be recorded into the data base. The information includes the patient history such as past illness, present illness, treatment details, etc. and patient demographics, i.e. patient identity. Data may be transmitted to a base unit within a reference hospital or CHC which enables the doctor or medical staffs to diagnose or monitor the patient’s condition in real time.

The data interchange is conducted using TCP/IP network protocol. It is expected that the system will be bandwidth independent. To achieve this objective, the system will be provided with options of variety communication links from ordinary telephone lines, both GSM and CDMA mobile phones, GPRS, and VHF radio. Depending on the geographic location, a user can determine the mode of communication that suits her or his requirement.

A special purpose software is developed as a protocol for data interchange by applying TCP/IP network protocol, that allows operation over several communication means. The telemmedicine software is able to acquire information concerning to the patient, store and display data of the patient, maintain and control connection between the Mobile Telemedicine unit and the Base unit, schedule doctor appointments, and capture image/other data from the output of the medical equipments. Furthermore, the software can also support Patient Information Record (PIR) as a part of acquisition data process.

3. System Applications

In general, the mobile telemmedicine system which has been designed can be operated for many health care services, such as patient’s data recording and reporting, telediagnostic, teleconsultation, outbreak management, tele-education etc. Since the system is aimed to reduce the number of MMR in rural areas, so in this research the application of the system is focused on patient’s data recording and reporting, telediagnostic, teleconsultation, and tele-education [2][4].

Patient’s data recording and reporting are basic activities for monitoring pregnancy. It depends on the patient’s condition, patient monitoring scenario can be divided into two types, i.e. continuous patient monitoring and temporary patient monitoring. The first is applied for patients who suffer some chronic diseases, or a patient with a certain condition so that she needs to be monitored continuously. Hence, recording and reporting the patient vital signs have to be done as much as possible. In temporary patient monitoring, recording and reporting patient vital signs are implemented according to request from doctors. By using this way, a doctor is possible to monitor the patient’s health, and it can be repeated periodically. Vital signals which can be monitored from the system are ECG, FHR, BP and temperature.

As mentioned earlier, that primary health care in Indonesia is conducted by Community Health Centres. Since most of them are still not able to detect high risk woman pregnancy earlier, hence the developed mobile telemedicine system is provided with facilities for teleconsultation and limited telediagnosics as well.
Teleconsultation takes place between separated individuals e.g. healthcare professionals and their patients, or healthcare professionals engaged in diagnostics, mentoring, or other clinical decision making activities related to the delivery of healthcare services. In this case, teleconsultation is only conducted between healthcare professionals and other clinical decision making, e.g. between a general practitioner and a medical specialist. While telediagnosis occurs in a real time, and there is an interactive dialogue between the expert and the doctor at the remote side with observe the diagnosis of patient’s disease. When the expert is not available at the time the patient’s information is transmitted, telediagnosis might be implemented in an indirect mode (store and forward).

In order to reduce the number of MMR in Indonesia, one of the solutions is by giving education for women in rural areas. Education about at-risk pregnancies and prenatal can help women to recognize pre-term labor or other problems with pregnancy as early as possible and increase the chance for intervention early. This application can be also facilitated by the system through tele-education menu.

For each of services, we have developed the usage scenario as a basic for designing the application software. An example of the use case diagram is depicted in Figure 2.

### 4. System Realization and Operation

Currently, the working prototype of a mobile telemedicine system with multi communication links has been designed and realized. As the core of the system is the mobile telemedicine unit and the base unit. In this research, the mobile telemedicine unit is realized in a form of a portable mobile telemedicine unit. Primarily the unit is intended to be used in a moving vehicle, such as an ambulance. However because of its portability, it can be employed in Community Health Centers as well. The unit consists of a PC instrument that processes a dedicated mobile telemedicine software. Moreover, a number of medical devices, namely blood pressure instrument, thermometer, and fetal heart rate monitor are also included in this unit. While a camera, and an ECG device are placed outside the unit. All components are arranged in a durable plastic case that weighs less than 5 kilograms. The system is supported by a battery of 12 Volts 24AH 10 Ampere. Figure 3 shows the prototype of the portable mobile telemedicine kit and the ECG portable monitor.

This portable mobile telemedicine unit supports communication via variety of communication means, namely ordinary telephone lines (PSTN), GSM, CDMA, VHF radio, and internet. The PSTN is included in the system as an option for deployment flexibility whenever the system is used in CHC (Community Health Centre). Data transmission via internet is also preferred, in view of the fact that internet application in Indonesia is growing up.

To provide overlapping coverage, the system uses a number of modems which covers GSM modem, CDMA modem, fixed phones, and VHF radio modem. All the modems are configured as a communication manager module integrated in a function unit called a communication arbiter [6]. Users may select the type of communication links to be used based on the existing communication technologies at the user location and the health service to be run. Further discussions on multi communication links have been described in the reference [3].

![Figure 1: The architecture of mobile telemedicine system with multi communication links](image-url)
Especially for wireless communication, the selection of communication links is based on the signal strength which is monitored continuously. In designing the mobile telemedicine system, we define that if the signal strength is less than three bars, the system has to find an alternative link. Additionally, if the signal strength is less than two bars, the connection will be interrupted.

The test of the system results an average time of 15 seconds is required to establish the connection between the mobile telemedicine unit and the base unit. For the moment the wireless technology that satisfies for mobile telemedicine in rural areas in Indonesia, mostly is GSM.

The portable telemedicine unit is operated together with the base unit which is placed in a hospital site. A three-tiered client-server architecture is applied on the system as shown in Figure 4. There are two types of clients, i.e. thin client is clients in a hospital which are connected to the server via intranet network (WAN/LAN), and web-based for clients outside a hospital. Hence, the portable telemedicine unit is a client which is linked to the server through the internet network.

The functions of the server are:

1. To Control communication between the mobile unit and the base unit via available communication links
2. To Transmit data or information from the mobile unit to a doctor or paramedics via intranet network within the hospital
3. As a database to store patient’s information, user’s data, teleconsultation or telediagnostic data, and emergency report
4. To manage user’s data, portable telemedicine unit’s data, and PIR.

Figure 4 A three-tiered client-server architecture of the system

There three types of user which are allowed to operate the system, viz.:

1. Doctor: as an expert to give teleconsultation or telediagnostic services. The doctor will need PIR that may consists of patient’s personal data, medical record, and patient’s medical history
2. Paramedics: as a user to entry data, manage PIR, take and implement vital signs measurement, etc.
3. Administrator: as a user to maintain the system, configure the system, and manage user’s data and access to the system.

To start with the system, a user has to login by entry the user name and a password. Then the user may decide an application according to her or his requirements.

For application of patient’s data recording and reporting, user can select the type of vital signs to be measured, such as EGG or FHR signals. Figure 5 depicts measured ECG signals which are displayed on the portable telemedicine unit.
In addition to vital signs information, the system provides patient information record to be filled by user, as shown in Figure 6.

Generally, the applications of the system which have been tested are grouped into three categories, viz.:

1. Sub-system at the mobile unit
2. Sub-system server at the base unit
3. Sub-system client at the base unit.

The services which can be implemented successfully at the mobile unit are:

- Initialisation teleconsultation
- Vital signs measurement: EGG, BP, and FHR
- Teleconsultation reporting
- Transfer patient’s data files.

While application of a thin client at the base unit that has been tested successfully are:

- Login to the system
- View list of Request
- View list of Teleconsultation
- Give Respons
- View list of Patients
- Search for Teleconsultation’s data.

For other system applications, i.e. telediagnostic and tele-education, we are still improving the software and preparing the material courses to be uploaded into the system.

5. Conclusion

The first version of the prototype of a mobile telemedicine system with multi communication links has been realized. A number of technical tests, such as data transmission, and system application i.e. patient’s data recording and reporting, and teleconsultation has been implemented. The test results are encouraging and may satisfy the requirements.

Before the system can be deployed all over the country, the presented prototype should be well received by professional healthcare. To gain the recognition, a testbed is prepared in Sukabumi areas. The testbed covers five Community Health Centres, RSUD Syamsudin as a hospital unit, and a mobile ambulance for emergency situation. Evaluation of the system is going to be focused on scenarios application, technical verification, clinical test and user survey.

Currently, the mobile telemedicine system is under continuous progress. An improvement version of the portable telemedicine unit is being designed and developed. A number of features, which are required to monitor high risk pregnancy, such as SpO2 measurement and pre-term labor monitoring will be included in the system. In addition, a more compact system is also expected.

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