Electrocardiagram Monitoring On OpenMTC Platform

Vera Suryani, Achmad Rizal,
Anton Herutomo, Maman Abdurohman
Unified Communication Laboratory
Telkom Institute of Technology
Bandung - Indonesia
{vra, arl, anton.herutomo, mma}@ittelkom.ac.id

Thomas Magedanz, Asma Elmangoush
Technical University Berlin
Berlin - Germany
thomas.magedanz@tu-berlin.de,
asma.a.elmangoush@campus.tu-berlin.de

***Abstract*— Information and Communication Technologies are playing major roles in creating Smart environments, and enhancing services in various sectors. The Machine-to-Machine (M2M) communication paradigm enables devices used in all live aspects to communicate and share information with limited human intervention. In this paper we present an M2M telemedicine service to monitor Electrocardiagram (ECG) signal remotely. ECG is a physiological signal produced by electrical activity of heart; it can be recorded using electrocardiograph device and used to detect many heart problems, such as heart attacks. Data generated by ECG's device are sent over M2M platform, that is OpenMTC for further processing in devices that are on the client side.**

***IndexTerms*—Electrocardiagram, Telemedicine, M2M.**

I. INTRODUCTION

Telemedicine refers to the use of telecommunication and information technologies in order to provide health services. The use of telecommunications and information technologies (IT) is to address distance problem between the patients and their medical personals. The main advantages of telemedicine are seen in providing better access to health services from regions that are geographically isolated, and lowering health care costs [3]. Additionally it allows people to monitor their health in comfort and independent ways without disturbing their daily work and life. In the remote monitoring systems, doctors or paramedics possible to monitor the health of patients with devices installed remotely. Patient or his/her family is responsible for placing the medical device into the patient's body and the device will sends patient's data through a telecommunications network. These kinds of systems are typically used to support health care for some chronic diseases such as heart disease, diabetes, or asthma [11].

A typical telemedicine system consists of four components: (1) hardware devices, workstations and peripherals that used to perform telemedicine activities, such as capturing medical information from patient's body. The advancement of semiconductor industry shrinking lithography continues to reduce chipset cost and power consumption, and embeds more sensors into devices used in different aspects in our daily life. (2) System's users who has different roles and means to use the system, i.e. clinicians and patients. (3) Telecommunications link to connect users of the system and allow the exchange of information. Many types of telecommunication links can be used to transmit medical information; however wireless technologies are more suitable to allow patient's mobility. (4) Policies and protocols: are also needed in telemedicine system, to specify users and operates roles and responsibilities, such as how patients pay the service provider and who will take a charge if technical problem exist.

The communication system architectures and protocols used to exchange information between users and connected devices are critical to the successful of the system deployment. Telemedicine information needs to be transported efficiently, reliably and securely. There are many activities in standardizing Machine-to-Machine (M2M) communications, which involves the automated exchange of data between devices without (or very little) human intervention. Popular M2M uses cases include home automation, telemedicine, smart metering, etc. M2M presumes the independent communication between a large number of devices, sensors and actuators – and service platforms, which in turn presumes the transmission of large amount of data of heterogeneous types and sizes over the network. Other network architectures (e.g., IP Multimedia Subsystem (IMS)) were built to be connection-oriented, suitable to support Human-to-Human (H2H) and Human-to-Machine (H2M) communications, and thus are not efficient to handle the requirements of M2M communications.

In this paper we present our work in utilizing the M2M communication trend in providing telemedicine services. The paper introduces an Electrocardiagram (ECG) monitoring system for acquisition, storage and visualization of heart electrical activity using a mobile phone, PDA or PC. The proposed system is implemented and evaluated by measuring the delay time conveyed by the data from the ECG device to OpenMTC platform.

ECG is a physiological signal that is used to measure and diagnose abnormal rhythms of the heart. ECG is captured using device that is called electrocardiograph. For some special cases, it is required that patient's ECG should be monitored continuously. Usually in monitoring ECG, physician uses one or two electrodes attached in patient's body using typical configuration. In previous works, we have designed wireless LAN ECG for heart's patient telemonitoring [1]. Single channel ECG is connected with wireless data transmission module to transmit ECG signal to physician's computer or terminal devices. Some weaknesses exist in our previous works are: the used device was only able to communicate point-to-point and limited area to access the devices. M2M platform is a candidate for solving such problems, by enabling mobile devices/sensors to communicate through a central server environment. M2M platforms provide ubiquitous access to M2M data in a highly scalable manner. The aim of the proposed telemedicine system is enabling doctors to stay in contact with their patients in a wide scale regardless to their location.

The rest of the paper is organized as follows: Section II describes the proposed ECG monitoring system, Section III describes the M2M platform for telemedicine purpose, Section IV explains the ECG monitoring implementation on OpenMTC, and finally Section V concludes the implementation results.

II. Electrocardiagram Monitoring System

Electrocardiography is a transthoracic interpretation of the electrical activity of the heart over a period of time, detected by electrodes attached to the surface of the skin [2]. It's usually used to measure and diagnose abnormal rhythms of the heart such as cardiovascular diseases. The propose electrocardiagram monitoring system consists of an electrocardiograph device, data transmission module, the OpenMTC platform and an application for Android platform to connect with the M2M platform, as well as receive patient's data and display the ECG signal. The OpenMTC platform is used to store ECG measurements data that can be retrieved and displayed using a smart phone, see figure 1 for details of the monitoring system architecture. We used the Electrocardiograph device which is built in our previous work [1].

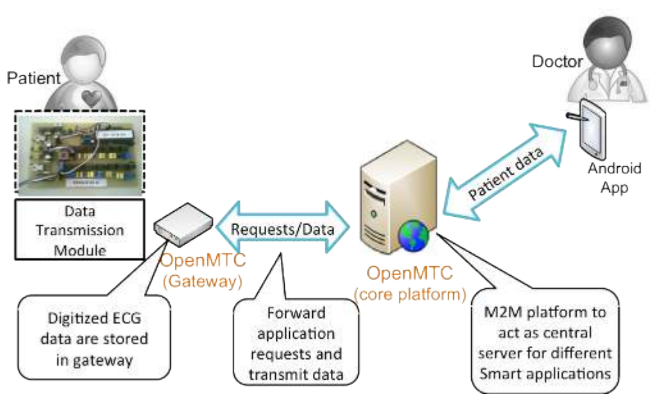

Fig 1. ECG Monitoring System Architecture

Figure 2 depicts the block diagram of the electrocardiagram device used in the system. The ECG signal is captured using biopotential electrode attached to patient's body. The signal is amplified using bio-potential amplifier which is implemented using AD620 integrated circuit. Amplified signal is filtered using band pass filter (BPF) to limit signal in range of 0.5-40 Hz. This BPF is used to remove low frequency noise and 50Hz power line interference. Low pass filter (LPF) in next stage will limit ECG signal less than 20Hz. The signal will be added by 1 Volt to make the signal level suitable as input for the analog digital converter (ADC). Analog process of ECG signal will produce signal within 0.5-20 Hz and 0-4 Volt. After digitizing the EGC signal input data by the digital block, the data will be sent to the OpenMTC server using Wifi connection.

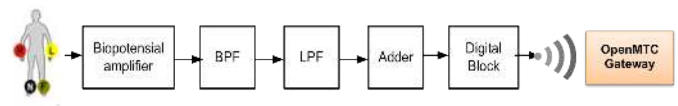

Fig. 2. Block diagram of electrocardiagram device

The data is stored in the gateway and forwarded to subscribe applications (via the core platform), whenever a suitable communication channel is available. This prevent patient's data from getting lost in case of connectivity shortage. The gateway can connect to the core via various access networks, including cellular networks, enabling mobile telemedicine in case of ambulance.

III. M2M Platform For Telemedicine

M2M technologies can be beneficially applied to a broad range of use cases for smart grid, industry control, home automation and telemedicine. The European Telecommunications Standards Institute (ETSI) has started its work in M2M standardization by studying the service requirement for M2M in different use case, such as Smart Metering and e-Health. In [12] ETSI has documented the user service models for the identification of interoperable solutions for healthcare data collection, transmission, storage and interchange. Early 2012, The International Telecommunication Union (ITU) has established a group focusing on standards for the M2M service layer, to study and evaluate the M2M service layer landscape, with a view to identifying a common set of requirements of vertical markets, focusing initially on the health-care market and application programming interfaces (APIs) supporting e-health applications and services [13].

The communication requirements and traffic characteristics differ for each of these services [4]. Among others, telemedicine services have strong requirements on latency and transmission reliability. Although the aggregated information from biomedical sensors is sent as bulk messages, however in emergence cases real time communication is required. A reliable communication system is essential in order to transmit data of patient's biometrics, such as heart rate recorded by the ECG devices, to be delivered efficiently to the client side in an acceptable format.

Many solutions have been developed to provide telemedicine services using M2M technologies. Mainly all telemedicine applications can be grouped into following purposes [5]:

- Tracking of objects and people (staff and patients).
- Identification and authentication of people.
- Automatic data collection and sensing.

M2M platforms can be utilized for the purpose of decoupling sensors/devices (i.e. the ECG device in our system) and client devices (i.e. doctor's smart phone or patient's data record by health center). This enables the interoperability between various technologies in the sensors networks and the application domain. Additionally providing standard interfaces to the M2M platform allows reusability of services independently of vendor-supplied sensors.

The M2M platform which is chosen for the ECG monitoring system is OpenMTC, a middleware platform for M2M oriented applications and services. The OpenMTC platform [6][7] represents a horizontal layer enabling M2M communication, providing a prototype implementation of the ETSI M2M standards. Figure 3 depicts the OpenMTC architecture. ETSI M2M framework is an application agnostic standard which mainly focuses on the service middleware layer for M2M communications. The OpenMTC platform implemented features are aligned with ETSI M2M Rel.1 specifications [8-10]. An ETSI M2M system provides the required capabilities to store, retrieve, and discover entities, heterogeneous connected to the system, and the context information aggregated by these entities. The first release of OpenMTC platform consists of two main Service Capability Layers (SCL) at the gateway, and network core (GSCL, and NSCL), which are responsible of:

- Providing a set of M2M functions to applications in both network and device domains.
- Expose functions through specified open interfaces.
- Use Core Network functionalities.
- Simplify and optimize application development and deployment through hiding of network specificities.

ETSI specifications define three interfaces: mIa, dIa and mId, as depicted in Figure 3. These interfaces offer generic and extendable mechanism for interactions with the xSCL. OpenMTC supports a client/server based RESTful architecture, and communication over all interfaces is independent of the transport protocol. Commonly, HTTP is used as transport protocol with RESTful-based services, as CRUD operations (i.e. Create, Retrieve, Update and Delete) are mapped to HTTP methods POST, GET, PUT and DELETE.

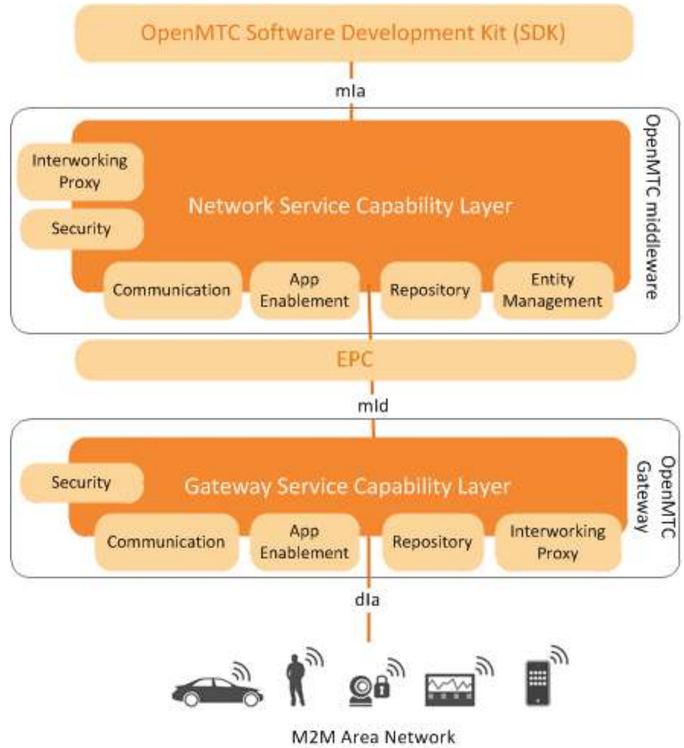

Fig.3 OpenMTC architecture

Message flow between components in a system that use OpenMTC platform can be seen in the figure 4 [14]. Device, sensor, and application have to register to xSCL first as part of OpenMTC platform. Once registration process is done will enable devices to send messages to each other without human interference.

Similar message flow mechanism is also used in this monitoring system, as seen in figure 5. The only difference is that device and sensor in this system are combined in one device.

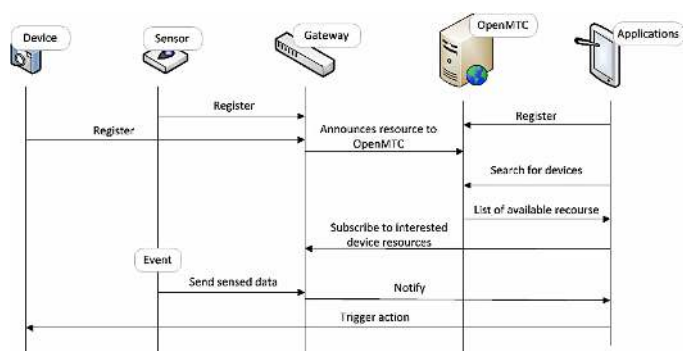

Fig. 4. Message flow on OpenMTC platform

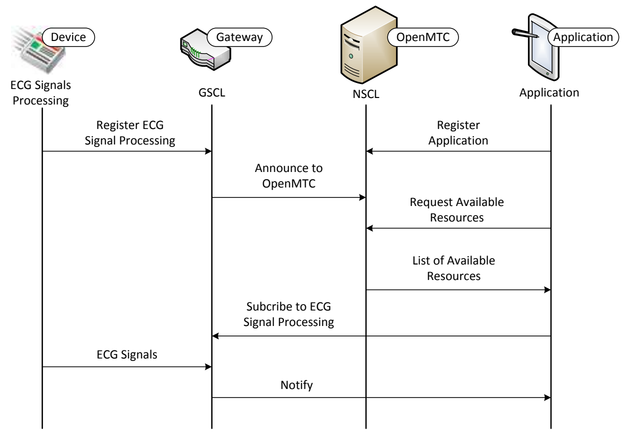

Fig. 5. Message flow on ECG monitoring system

IV. IMPLEMENTATION AND ANALYSIS

In this section we describe the implemented testbed and analyze the obtained results. The ECG monitoring system architecture as presented in figure 1 is implemented using one ECG device, one IBM PC server type X650M3 which acts as OpenMTC server, and some Android Smart phones.

The ECG signal produced from ECG device has two signals from two leads. Example of these data is shown in figure 6 and figure 7.

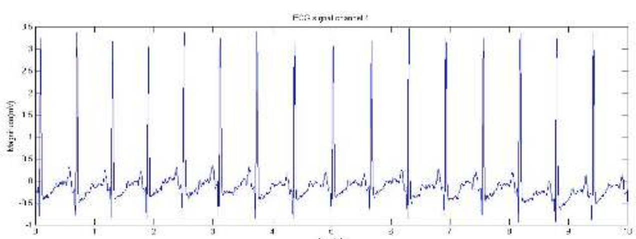

Fig.6 First Lead ECG Data Signal

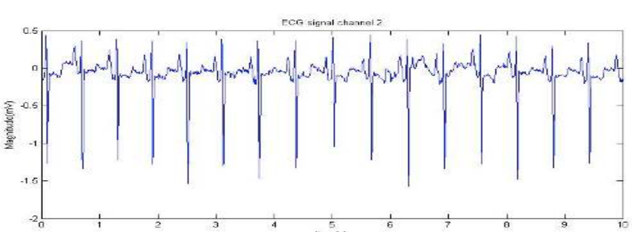

Fig.7 Second Lead ECG Data Signal

The transmission module digitizes the obtained signal and sends data to OpenMTC gateway in JavaScript Object Notation (JSON) format, which is a lightweight data-interchange format easy to parse and generate be machines. The data are stored in OpenMTC gateway to allow access by client applications via standards interfaces. The system showed an acceptable performance in term of the presented signal retrieved by the end user, and the response time. The mean delay measured through the testing of the system was at 1.206 seconds, measured from the time the ECG device starts transmitting data until processing the data in OpenMTC gateway.

The OpenMTC platform provides a subscription/notification mechanism for applications to expresses their interested in specific data to get notified whenever it's available or updated in the platform. An application for Android smart phone has been devolved to be used by health care provider to view the EGC signals in the client side. The application registered to the OpenMTC platform and sends subscriptions requests to the platform for desired data, aggregated from sensors attached to the patient. Once the data are available, the platform sends notification to the clients, and data can be displayed in graph format, as shown in figure 9 and 10.

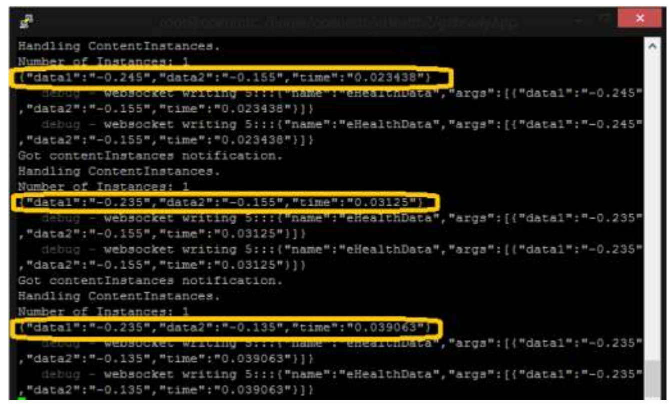

Fig.8 Data stored in OpenMTC using JSON format

Fig.9 Signal output for 1st lead on smart phone

Fig.10 Signal output for 2nd lead on smart phone

V. Conclusion and Future Work

Telemedicine industry is foreseen as an important sector to benefits from the potential growth in Smart City implementation. Exchanging health information supports the remote assistance and medical surveillance for disabled and elderly people. In this study, an ECG monitoring system has been deployed using the OpenMTC platform for M2M communication. The use of M2M platform in this system has enabled point to multipoint ECG data transmission using smart phones to display the ECG signal. The experiments that have been carried out indicated that ECG data has been successfully sent to the client's devices via OpenMTC platform and displayed in accepted form. Further developments can be done by adding more sensors to the system, which can be activated or deactivated at specific situations, such as detecting any suspicious measurements. The additional sensors shall be controlled from the client application to allow the doctor to request more examination, or from an analysis software in order to response automatically to any critical situation. E.g. in case of detecting some suspicious measurements such as, heart beat less or greater than normal value, notifications will be sent to the doctor, who can activate more sensors or directly contact the patient.

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