

A Modeling Approach for Mobile Monitoring and Supervisory Control Development based on Open-source Programming

Seno D. Panjaitan, Bomo W. Sanjaya, Aryanto Hartoyo, Rudi Kurnianto, and F. Trias P. Wigiyarianto

Abstract—This paper presents a modelling approach for monitoring and supervisory control the use of energy in buildings. The use of low-cost technology for monitoring and supervisory control of buildings especially the energy consumption is challenging and an open issue in current efforts to improve the efficiency and support the economic development. The low-cost system is very important if the technology is applied in developing countries due to limited funds to build supportive infrastructure and inadequate existing technology to be modified or reconfigured. Internet of Things technology is adopted in the implementation regarding the sensors and its connection to the network so the buildings energy use can be monitored from any location. There are similar technologies, but mostly they are not user-modifiable (open-source) and some of them use uncommon communication infrastructure. These can increase the inflexibility and the budget. The presented research is intended to provide a common modeling approach using Data Flow Diagram (DFD) and some model concept in Unified Modelling Language (UML) for a new alternative technology in monitoring and supervisory control. The approach was tested by using Android-based smart phones which is currently dominant used for connecting to internet. The test result in laboratory showed that the built system using Arduino Mega 2560 microcontroller equipped with sensor DHT22 had acceptable errors compared to the measurement using the standard digital measuring instruments, which are 0.27 °C for temperature and 2.67% for relative humidity.

Index Terms—Internet of Things (IoT), condition monitoring, telemetry, energy efficiency, energy conservation

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I. INTRODUCTION

THE telemetry technology in industry is indispensable to connect remote and separated devices and systems, used to send orders, programs and obtains data from an isolated area [1]. One of the common technologies used for telemetry is supervisory control and data acquisition (SCADA). It consists of computer equipment and programs that can provide information to users. For instance, it provides energy information so that users can measure, monitor and analyze their energy use and help identify energy saving opportunities.

The trend to use telemetry system for building is growing up to support the energy conservation due to the limitation of the sources. The current SCADA-like technologies have good capabilities, but due to the huge cost of application and limited access to the system, the telemetry technology development issue for building energy efficiency remains open.

A monitoring system for building used to apply a platform that feasible for its environment and budget. This system in some application can be integrated with the control system to reduce the energy use in the building. The monitoring normally used to implement demand response arrangements [2]-[3]. A management system of building presents centralized functions of monitoring, control and recording of the services [4]-[6].

Internet of Things (IoT) is becoming a new trend now that enters many applications including smart homes/buildings. There are many tutorials available online or in academic publication discussing development concept and requirement in applying IoT such as in [7]. However, IoT still have some issues to increase its utilization such as unavailability of standards, system security assurance, and a lack of completely developed top-down application [8]. In commercial buildings, there are a wide range of requirements in monitoring that can increase the energy consumption and access management [9] – [11]. Furthermore, the idea using power over ethernet for monitoring LED lighting are described in [12] and example how to control the lighting based on Fuzzy Logic to reduce the energy consumption can be seen in [13].

However, the network traffic is one of the considerations in developing monitoring system based IoT technology. It is recommended to anticipate network migration by IoT traffic carriers (e.g. from building to the cloud) to increase flexibility and resource optimization [14]-[17]. Furthermore, one of the challenges to endorse IoT technologies in the smart building is security assurance. For instance, in the market, IoT products designed with adequate IoT security is not more than 10%, as reported in [18]-[19].

Some examples of current monitoring system using mobile application are as follows: home automation system [20]-[21], biogas reactor for power plant [22]. The communication infrastructure is also very important to be considered in IoT system development. Monitoring system using non-android based smart phones is proposed in [23-24], however it might have obstacle for market in developing countries such as in Indonesia since Android-based devices are dominant. Therefore, to have an open-source system, a modelling approach is needed, which the system later can be modified or upgrade easily without having to spend significant budget for vendor or supplier for new system requirements. This paper proposes a modeling approach that can be reuse for simple monitoring and supervisory control of buildings. The model bases on Unified Modeling Language (UML), data flow diagram (DFD), Android-based system development which are available in many websites and can be installed without any cost.

II. DESCRIPTION OF THE MONITORING SYSTEM

Fig. 1 shows informal or physical architecture of the monitoring system that have been modelled and built. The system involves control devices (microcontrollers, sensors, and monitoring equipment) and communication infrastructure. The idea of monitoring is to collect the data in buildings using IoT sensors, then processes the data through analog to digital converter and microcontroller that is working with a specific frequency. The controller employed Arduino Mega 2560 microcontroller. Microcontroller programming uses Bascom AVR. The program development is intended for data storage in SD Card with Serial Peripheral Interface (SPI) data communication type, microcontroller communication with modem serially using AT (ATtention) command, and communication with external input / output connected to sensor / actuator.

The data is recorded into secure digital memory (i.e., SD card) and sent to the internet networking to be available for user who read through mobile devices. The SD card has a flash memory inside for read, write, delete, and error control of data. It has main function to back-up data. Real Time Clock (RTC) with Inter Interface Circular (I²C) interface is used to get real time data. The main feature of RTC can calculate seconds, minutes, hours, date, year with correction leap year to year 2,100. Data can be saved with help of backup battery, and I²C interface.

In the sensor circuit, sensors for measuring temperature and relative humidity (RH) was used for energy systems in



Fig. 1. Networking architecture of the telemonitoring system

buildings. Temperature calculation is based on Celsius units, while RH uses a percent unit. To obtain a more accurate RH value over a wide temperature range, it has been compensated using the Automatic Temperature Compensation (ATC) function. Temperature and RH that are measured are then sent to an android-based data access device (e.g. smartphone), as shown in Fig. 1.

In the software development, the features used on android are the application framework in the form of menu / submenu (which allows the use and deletion of components available on the menu / submenu), virtual Dalvik engine (virtual machine optimized for mobile devices), graphics (2D and 3D graphics based on library OpenGL), SQLite (for storing data), image media, communication systems (GSM, 3G, WIFI, Bluetooth). The android application development in this research used Java Eclipse with Software Development Kit (SDK) installed in android-based access module as library of common class of program used and Abstract Data Type (ADT) for Java Eclipse program interface with android operating system.

III. MODELLING APPROACH

The modelling approach employ some diagrams from computer science namely DFD and UML that have main purpose to give a comprehensive model for the system in any level of system development. A related example of development process model for distributed system using UML can be seen in detail in [25]. Other formal modelling that can also be considered is Petri net, for instance the one that is described in [26]. By having a general model, the system can easily be modified and reconfigured.

A. Use Case Diagram (UML Model)

This Diagram is a graphical representation of actors, cases, and interactions among them such as introducing a system. Fig. 2 depicts the Use Case diagram for the monitoring system. It can be that there are two kinds of actor in the system, namely admin and user. Admin has more access than

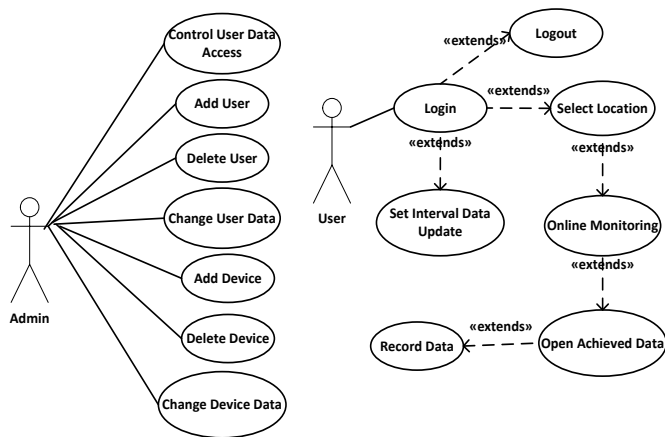


Fig. 2. Use case Diagram of the monitoring and supervisory control system

user, while user (one or more) needs a security code for login to the system. This security access is to secure all the information collected during the monitoring and to avoid spam that can affect the system performance.

The modelling approach can be more transparent using this model. Deleting or adding of system function or actors can be done by keeping the general idea still understandable and reconfigurable.

B. DFD model

DFD is a model that graphically represents the data flow in the system and its process modelling feature. It is commonly applied to model an initial stage to create a system overview by reduce the technical details, which can be elaborated afterwards. It can also be employed for data processing picturing. The DFD can show physical or logical model of data in the system. The proposed DFD model can guide the developer to build and to modify a simple monitoring system easily in various open sources and programming code since the idea is mainly similar.

Fig. 3 shows DFD for the monitoring system. The rectangle box is for data input/output, the circle shape is for function and the arrow shows the data flow, usually from input/output to a function, or vice versa. The activities described in the DFD is the following: USER can login to the system to get the monitored data from the system, DEVICE sends monitored

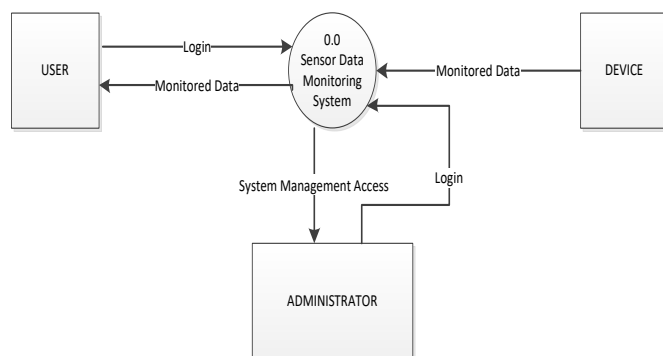


Fig. 3. DFD model of the system

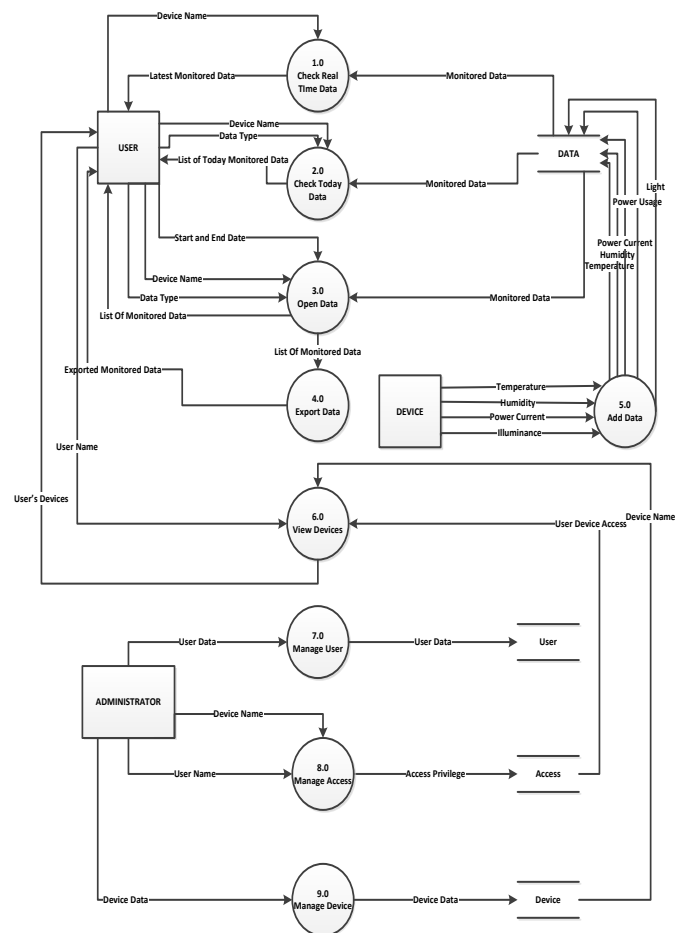


Fig. 4. DFD of the overall system

data to the system, ADMINISTRATOR can login to the system to get privilege for system management activity. It is quite different with the use case diagram (cf. Fig. 2) which more focuses on the actor and its function, the DFD describes the data managed by each actor and main device in the developed system.

Fig. 4 describes the DFD model of overall data flow in the monitoring system. It has nine functions related to the data management: check real-time data, check today data, open data, export data, add data, view devices, manage user, manage access, and manage devices.

The data management in DFD furthermore can be explained as follows:

- 1) The USER can check real time data by providing the device name. The DATA in database also provide the monitored data to complete the process.
- 2) The USER can also check today data by providing device name and data type. The DATA in database also provide the monitored data to complete the process.
- 3) The USER can open data by providing start date and end date, data type, and device name. The DATA in database also provide the monitored data to complete the process.
- 4) The USER can export the opened data after open the data. The process will give the exported version of data to the USER.

- 5) The DEVICE can add the data to the database. The DEVICE provides four types of data (temperature, humidity, power current, illumination/light data). The process will add five types of data to the DATA database (temperature, humidity, power current, power usage, illumination/light data).
- 6) The USER can view devices by providing user name. The DEVICE database provide the device name data and the ACCESS database provide the User Device Access data to complete the process.
- 7) The ADMINISTRATOR can manage user data by providing user data. The process will change user data in the USER database.
- 8) The ADMINISTRATOR can manage user access to device by providing device name and user name. The process will change Access privilege data in the ACCESS database.
- 9) The ADMINISTRATOR can manage device by providing device data. The process will change device data in the DEVICE database.

C. Sequence Diagram (UML Model)

Sequence diagram are used to provide a detailed overview of each use case diagram created earlier and shows interactions between objects. Each object involved in a use case is represented by a vertical dashed line, then the message sent by the object is described horizontally in chronological order from top to bottom.

In this case, there 14 sequence diagrams built for each case. Due to the limitation of space in this paper, only sequence diagram for online monitoring is presented, as shown in Fig. 5. In this diagram, there are five objects that have interactions each other in the described sequence: Main, interface (i.e., *Antarmuka*), WebServiceMonitoring, Database connection (i.e., *KoneksiDatabase*), and Data. This sequence runs once a user wants to monitor the measured data (i.e., device identity, time, temperature, RH, and power consumed through the measured current).

D. Class Diagram (UML Model)

Class diagram is one of the main diagrams of UML to describe a class or blueprint object in a system. This diagram is related to the programming based on object-oriented concept. Fig. 6 shows the class diagram for the monitoring system.

IV. MOBILE MONITORING INTERFACE

Fig. 7 shows the snapshot of the mobile application for monitoring system and the hardware for data measuring and communication. The mobile application works as designed in the models. User must input username and password for login. If the login is succeeded, the system will get the device list data from the server and display it to user mobile's screen. The login information must be exact the same with the one that was recorded to avoid the failure. After user success login to the system, user can do logout process or go to the Home

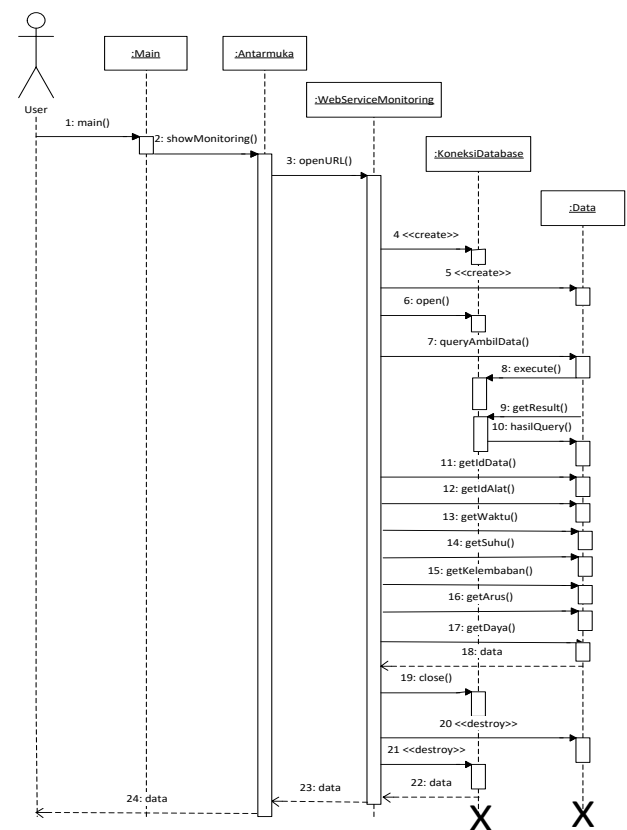


Fig. 5. Sequence diagram of one case in the system: online monitoring

layout. If user choose to go to Home, the system will get latest data from the server and display it to the user's screen.

If user is going to look for detailed data, user can choose the specific type of data, and the system will get the specific type's today data from the server and display it to the user's screen. If not user can go back to the home layout. If user is going to open monitored data, user input the start and end date first, then the system will get(open) data from the server and display it to the user screen's. If not user can go back to the Specific Data Type layout. If user choose to export data, the system will export the opened data, and save it to the user's storage, otherwise user can go back to the open data layout. If user choose to logout, system process is ended. The result of measurement of for several rooms in Table I shows that the developed system has overall average error 0.27 °C for temperature and 2.67 % for RH.

V. CONCLUSION

This paper has elucidated a modelling approach using DFD and UML to pave away a comprehensive process on mobile monitoring system development. Some aspects are covered in these various modeling concept: use case diagram (relationship of the system's actors), DFD (model for data management system), sequence diagram (show the logical sequence in each case in use case diagram), and class diagram (model for coding based on object-oriented programming). This modeling approach can help designer of monitoring

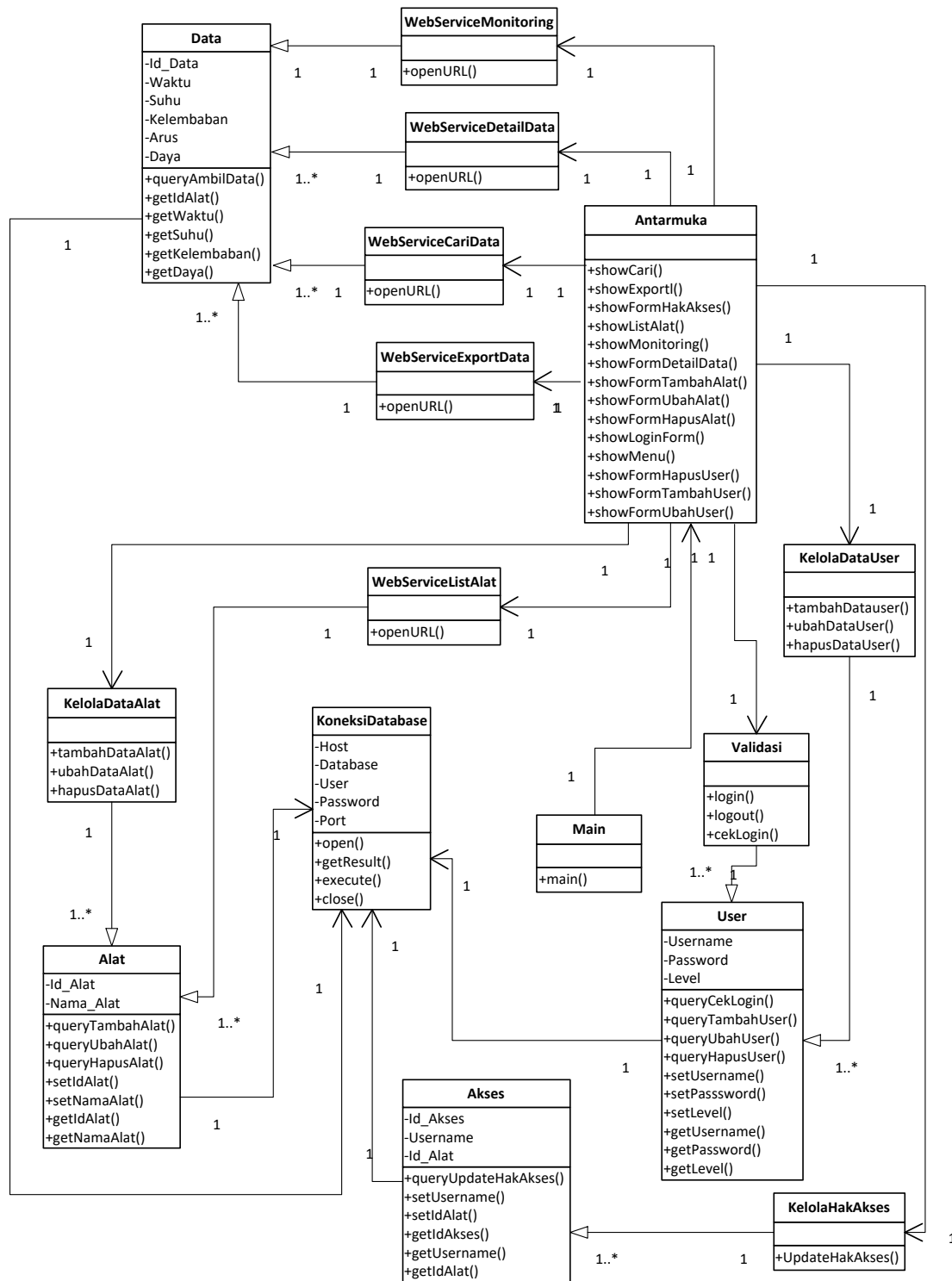


Fig. 6. Class Diagram for the Monitoring Systems

system to reuse and reconfigure the model for similar purpose by maintaining the main idea of the system, in other word, this model gains the system development understanding.

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TABLE I
COMPARISON MEASURED TEMPERATURE AND RH: STANDAR VS MOBILE
MONITORING VALUES

No.	Location	Averaged Temperature (°C)		Averaged RH (%)	
		Standar	Mobile Monitoring	Standar	Mobile Monitoring
1	Digital Workshop	28.5	28.3	54	47.2
3	Lab assistance room 1	25	26.4	42	41.4
4	Lab assistance room 1	24.4	23.6	42	41.4
Overall Average		25.97	25.70	46	43.33

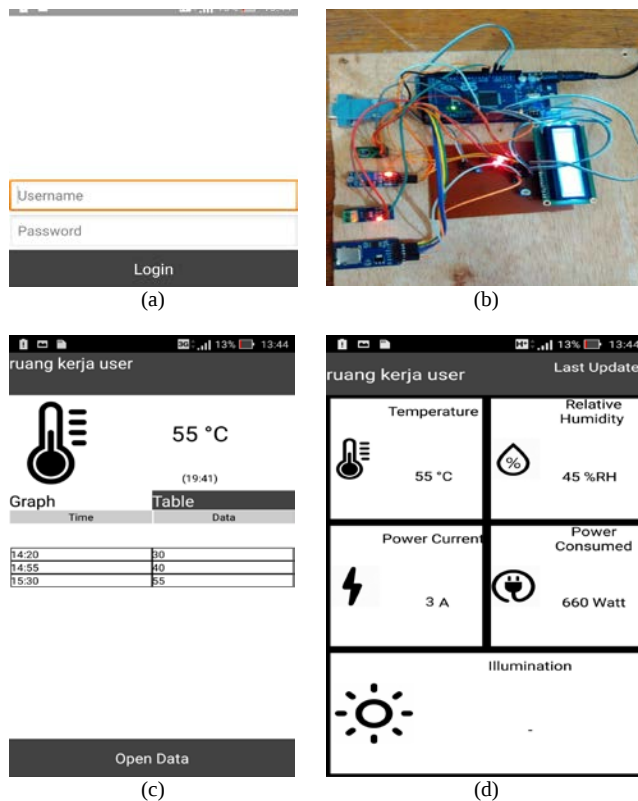


Fig. 7. User Interface in Smart-phone for monitoring system: (a) Login to the system, (b) System's hardware (c) Display the temperature as table (can also displayed as graph), (d) Some energy monitoring parameters

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