Original Article

Smart Healthcare Applications using Contiki and Cooja

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Abstract

The Internet of Things (IoT) is the most trending technology to influence the internet and communication technologies. Among several applications IoT, healthcare application plays a major role. Several emerging technologies related to IoT such as body sensor networks, advanced healthcare systems, cloud-based platforms for wireless transfer of data, storage and display of clinical data, etc. have contributed to the wide utilization of the technology in the field of medicines. A body sensor network scenario will be created with various body sensor nodes using 6LoWPAN and Rime protocol. Rime is a data collection protocol implemented using Contiki operating system.Contiki OS, a free open-source simulation tool, helps in analyzing the performance parameters of Wireless Personal Area Networks (WPAN). The Cooja simulator in Contiki OS simulates the network scenario and provides the means and tools to observe network behavior across many platforms and contexts. This paper presents work done on the analysis of the Rime protocol stack of the Wireless Sensor Networks(WSN). Various performance parameters of sensor nodes like light, temperature and blood glucose levels of body are measured using sensor nodes and also the position of neighboring nodes is measured and analyzed which helps to set up a more efficient Wireless Sensor Network. The proposed work focuses on the study of protocol standards in wireless mesh networks and the Performance are measured in case of mobility as well. Then by using Dijkstra's algorithm, the shortest path to reach the record maintainer is measured. The proposed work focuses on the analysis of protocol standards used to monitor patient information in the healthcare management system.

Keywords: Wireless Body Area Networks, IoT, Wireless Mesh Networks, Contiki Operating System, Cooja Simulator, Wireless Sensor Networks, Rime Communication Stack, Wireless Personal Area Networks.

1. INTRODUCTION

Internet of Things (IoT) is the most advanced technology in which objects, animals, or people are given unique identifiers and the data is transferred over a network without any human-to-human interaction which reduces the workload on human. It has emerged from the combination of wireless technology, mechanical systems and the internet. Traditionally in the object-oriented model, everything in the world is considered as an object, whereas in the IoT model everything in the world is considered as a smart object, and communication between them can be done physically or virtually via internet technologies. IoT enables connection between things and people at any time with anything in any place using any network or path in any service. The Internet of Things, in short, IoT permit objects of the physical world to be united into an imaginary world[13], where the interaction of actuators, sensors, human users and software agents takes place among themselves on the Internet. IoT data can be made available to users via Web service technologies, which can directly combine the functionalities of data within IoT and the Web via the Internet.

IoT has a wide application. Some of them include using wireless sensor networks, IoT in agriculture and air pollution control systems, waste management systems, smart parking systems, water distribution systems, etc. The Healthcare domain of IoT is considered to be the most promising application domain. All the IoT characteristics have a significant impact on the field of healthcare[10]. Tele-homecare, telehealth and telemedicine services are the applications of E-healthcare[11] information systems. Wireless Sensor Networks play a major role in the allowance of healthcare systems distributing sources of information in a prevalent manner in order to make better tracking resolution and ability[12]. Evidently, various views were owned to be considered in this form of applications, where translucent and discreet terminology involvement is forcibly required. There are many applications of IoT in healthcare like mobile-medical applications or wearable devices that allow patients to monitor their health data[9].

Wireless Mesh Networks:

Wireless Mesh Network is a communications network created through the connection of radio nodes arranged in a mesh topology. It is also a kind of wireless Adhoc network. Recently, wireless networks have become progressively important in the field of computer networking and they are already categorized into different types of networks.

Categorizing networks:
These wireless networks can be divided into numerous categories. In accordance with distance is a common method. This results in categories such as Wireless Personal Area Networks (a couple of meters, e.g. Bluetooth), Wireless Local Area Networks (up to 100m, e.g. Wi-Fi) and Wireless Wide Area Networks (several kilometers, e.g. WiMax)[23]. Wireless networks can also be categorized according to the number of wireless links each end device is separated from a base station or target device.

Wireless Sensor Networks:
A large number of sensor nodes form Wireless Sensor Networks. Wireless Sensor Networks come under IEEE 802.15.4 protocol. A device that senses the data, stores it and sends it to a sink node for collection and analysis is known as a sensor node. Due to their flexibility sensors can be placed anywhere, randomly. There are many applications of wireless sensor networks. Temperature, pressure, motion, humidity, etc. are the sensors that can be placed in these networks. The sensor nodes sense the environment around them and obtain the data. In order to find suitable action, these data are analyzed and operations are performed on them. Home appliances and environment control in buildings and medical are a few other applications of Wireless Sensor Networks.

Wireless Personal Area Networks:
Wireless Personal Area Network (WPAN) as the name says the connection is for the user's personal use. It is a network of a computer suitable for transmission of data between devices like tablets, computers, personal digital assistants and telephones. According to the IEEE definition, Wireless Personal Area Networks (WPANs) are used to transmit data across short distances among a private, intimate group of participant devices. A connection established by a WPAN needs a minimal infrastructure or direct contact to the outside world, in contrast to a wireless local area network (WLAN). This enables the implementation of compact, affordable, and cost-effective solutions for a variety of devices. Typically, as the name suggests, in WPAN communication is wireless and within the range of about 10 meters. Bluetooth is such kind of technology, being used as the basis for a new standard, IEEE 802.15.1. Other popular WPAN standards are Zigbee IEEE 802.15.4, UWB (Ultra Wide Band) IEEE 802.15.3a and Proprietary standards based on Embedded Wireless Chips.

Wireless Body Area Networks:

A Wireless Body Area Network (WBAN) which interconnects several distinct nodes (Eg. Actuators and sensors) are placed in the clothes, under the skin of a person or on the body. Typically, the network here spreads over the entire human body and the connection between nodes are done via a communication channel that is wireless. WBANs are mainly used in healthcare applications where the patient has to be monitored.

2. CONTIKI OPERATING SYSTEM AND COOJA SIMULATOR

Contiki is an open-source, lightweight operating system evolved by the Swedish Institute of Computer Science (SICS) [7]. Contiki is implemented in C language and it gives a platform to develop applications for different hardware. The replacement of individual programs and dynamic loading is supported by Contiki. Due to its low power, it is very helpful in situations where energy consumption is not expensive, as in WBANs. Contiki also defines a set of instructions that are useful in communication with low-power networks [29]. Cooja is the network simulator in Contiki designed specifically for Wireless Sensor Networks (WSNs). Contiki supports Cooja, which also allows real hardware platforms to be emulated, unlike other simulators. The behavior of the application can be tested in a faster and easier way through the Cooja simulator. The testing of programs or applications with different platforms can be done in advance with the Cooja simulator. The discrete event simulator also known as Cooja defines a variety of radio mediums such as MRM (Multi-path Ray-tracer Medium) and UDGM (Unit Disk GraphMedium). The representation of Cooja Simulator Window is shown in Figure 1.

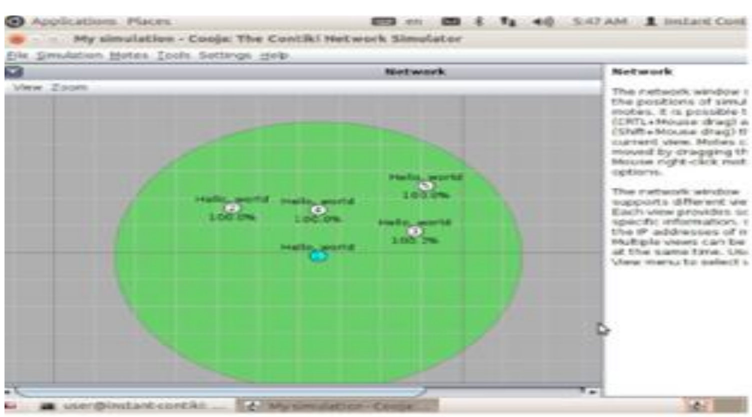

Figure 1. Representation of Cooja Simulator Window.

3. THE RIME COMMUNICATION STACK

The lightweight layered communication stack known as Rime is designed for sensor networks and low-power radios. It is implemented in Contiki and research proposes that it can rationalize the implementation of the protocol with a slight increase in resource requirements. A wide range of communication primitives, from reliable multi-hop bulk data flooding to best-effort local area broadcast is defined by the Rime stack. It has been designed for plotting on to typical sensor network protocols: data collection, mesh routing and data dissemination. Rime enables the reuse of code and simplifies the sensor network protocols implementation. The major components of the Rime protocol stack are shown in Figure 2.

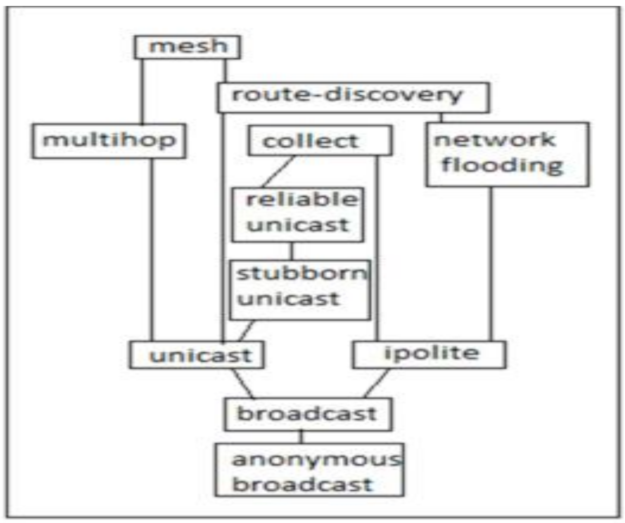

Figure 2. The communication primitives in the Rime stack

4. EXISTING SYSTEM

Lipman et.al.[1], explains the role of the Internet of Things on e-Health communication and most importantly how the devices with low power and low cost can improve the condition of life of human beings during emergencies and bearing chronic diseases. Electronic healthcare solutions are also explored mostly in terms of Health Care Record (HCR) databases and designs that contain healthcare information about particular patients as well as wearable scaled-down sensors have been described by the authors.

Alok K et. al.[2] illustrate a joined-up sensor system for monitoring the long-time cardiorespiratory signal and devoted packages of signal processing in physiological data in order to discover the absence of breathing or shallow breathing. The movement of the body surface proportionate to heartbeats has been detected using a PVDF (PolyVinyliDene Fluoride) sensor with piezoelectric properties are used. The traditional system for polysomnography (PSG), sleep study and specific hardware respiratory signals and ECG using cardiorespiratory belt sensor has been developed. The process for integration of remotely sensed patient-centered data collected using compact wireless devices with patient-reported data placed in their homes and on patients has been explained. Self-monitoring has been taught to patients using handheld devices. The control over the monitoring system could be given to the patients via their mobile phones, or other handheld devices. Medical monitoring using sensor networks and self-monitoring of bipolar disorder via Hand-held devices have been proposed.

Jiang et. al. explains a Mobicare body sensor network involving a rearrangeable, programmable service model for patient care was developed. The five key technologies involved in Personal Ambient Monitoring Infrastructure (PAMI) are the environmental wireless sensors, body sensing platform, involved in home and other monitoring environments of patients, an Adhoc communications network, the gateway of the network, and the query stations integrates data of body sensor, environment and patient-report. In order to identify sensors situated within the individual personal area, technology has emerged as a body sensor network. The patients can wear the sensing nodes and keep track of physiological metrics such as blood oxygen levels and heart rate as well as information related to the environment such as user motion and light levels are kept in track via accelerometers[3].

Blum J et. al. [4] used the concept of Ultrasound-based technology, in order to locate and keep track of senior residents' activity and detect movement. For hospitalized patients, IoT-driven, non-invasive monitoring systems were used with close attention to physiological status. To analyze the data and then share it through wireless connecting, different types of sensors and complex algorithms are used.

Dunkels et. al. [5], known as the creators of the Contiki operating system have initiated the Contiki operating system for lightweight sensing devices.

Bui et. al.[6], the authors established the concept of WBAN and IEEE protocol 802.15.6. Then they discuss the applications of WBAN in different fields, characteristics of WBAN, types of nodes, number of nodes and topology. Then the discussion continues on the architecture of WBAN which are divided into tiers and explains about the layers in WBAN, their functions, responsibilities and challenges in WBAN.

Adam Dunkles et. al.[6][7] gives the fundamental course on programming in Contiki and Cooja simulator.

5. RESULTS AND DISCUSSION

The simulation is done considering five nodes using the Radio medium called Unit Disk Graph Medium (UDGM). A number of fundamental communication primitives are used in the Rime stack, including best-effort network flooding, hop-by-hop reliable multi-hop unicast, best-effort single-hop broadcast, and best-effort single-hop unicast. Simulations were carried out for the purpose of analysing node performance. The Simulation of the Collect protocol is shown in Figure 3. Among the various Rime primitives, collect primitive is given importance. It provides for a data collection protocol by building upon the reliable unicast primitive.

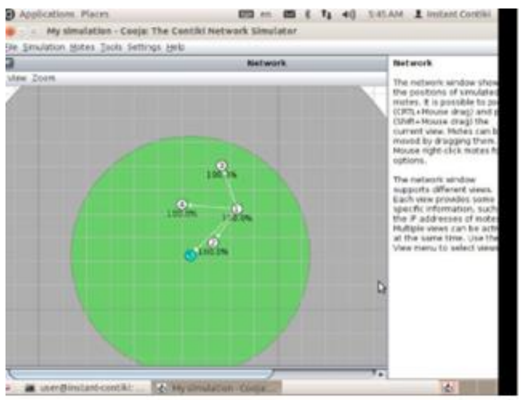

Figure 3. Simulation of Collect protocol

Mote Output window shows the execution of the programs, and any events occurring with a mark for different motes such as source node from which the message is being sent, sequence number, number of hops and length of the message with respect to time as illustrated in Figure 4.

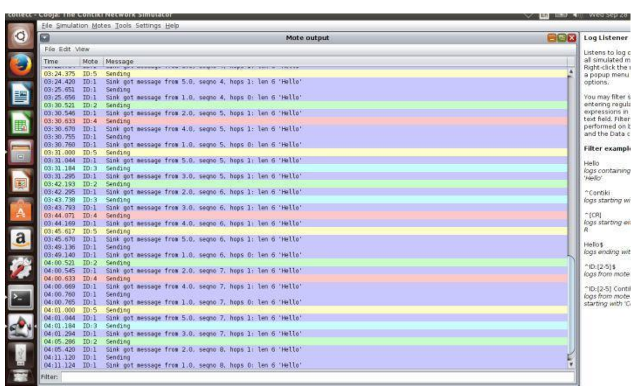

Figure 4. Mote Output

The network window shows the positions of simulated motes, communication between the various nodes and overall node configuration as shown in Figure 5.

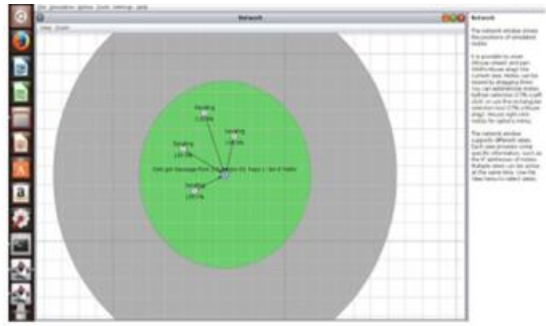

Figure 5. Network Window

Initially deploy all the motes in the simulation window. Select any one mote as a record maintainer or admin and all the remaining motes will act as a patient as shown in the Figure 6.

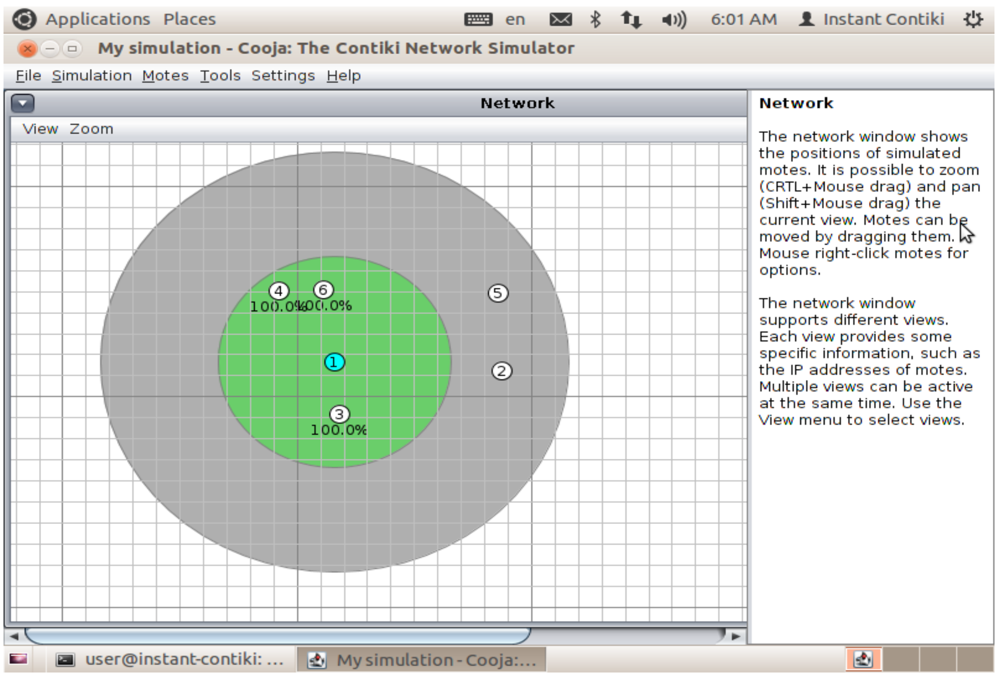

Figure 6: Record Maintainer and patients

To differentiate the patients and the admin each mote has been given a unique identity. This unique identifier helps us to create IPV6 addresses as shown in Figure 7.

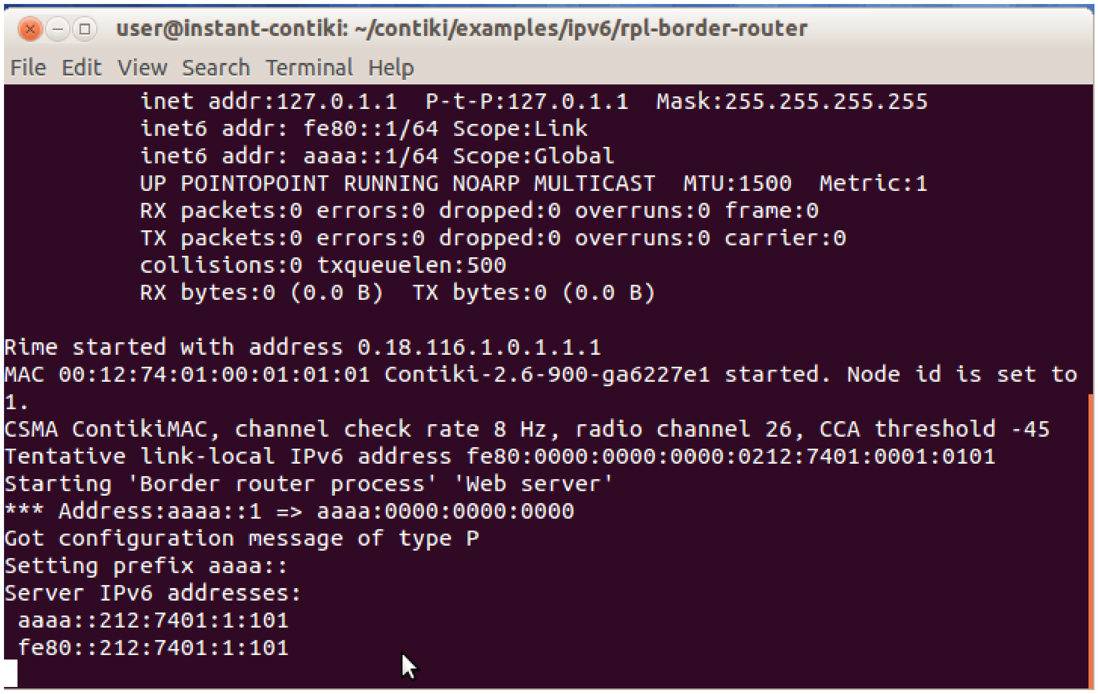

Figure 7: Creation of IPV6 addresses

The IPV6 address helps the admin, to find out all the neighboring patients and the paths to be followed to reach all the neighboring patients as shown in Figure 8.

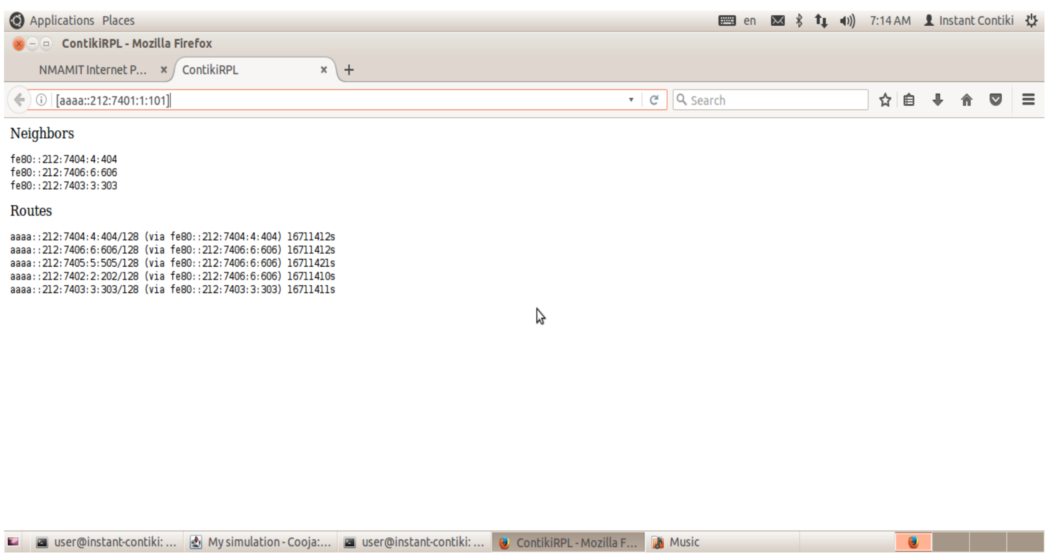

Figure 8: Neighboring Patient Information

On the same time, the light, temperature and blood glucose levels of a particular patient can be measured by deploying the sensor nodes in a mote as shown in the Figure 9.

Figure 9: Patient data

The main aim of the research work to find the nearest path between the record maintainer and a patient. Therefore, Dijkstra's algorithm is used to find the shortest path for the patient to reach the record maintainer measured is as shown in Fig 10.

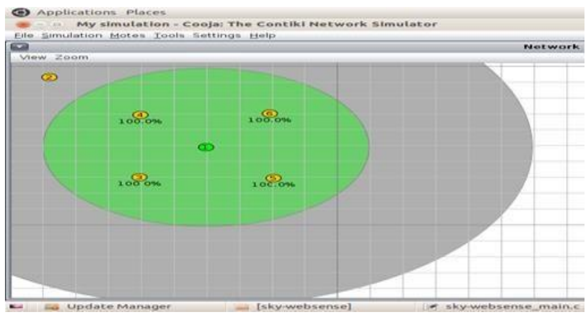

Figure 10: Shortest path using Dijkstra's algorithm

It is evident from the Figure 11, the optimum shortest path from the patient to reach the admin is obtained.

Figure 11: Shortest path between patient and the admin

6. CONCLUSION

Wireless Body Area Networks guarantee low cost, great versatility and also require minimum hardware and thus resulting in low power consumption. Several network topologies are supported and multi-hop transmission permits flexibility for constructing dynamic networks. The proposed work demonstrates the performance of the Rime communication stack and its primitives. For the simulation of Rime in WSNs, Cooja happens to be the ultimate tool. At the hardware level, slower motes can be reproduced but allow strict examination behavior of the system, or at a level which is less elaborated is faster and allows simulation of larger networks. The Contiki OS becomes more suitable for the Internet of Things with the abilities and features of the Cooja simulator. Since Contiki is an open-source Operating System, the codes can be further modified and various performance statistics can be obtained. Thereby, achieving a better performance.

The proposed Rime communication stack can then be used to measure various performance parameters like temperature, relative humidity, instantaneous power consumption, and radio duty cycle. Also, a summary of all the nodes and their statistics can be obtained. Plotting of topological graphs like sensor map and network graphs are also possible. Further, sensor, network metrics and power-related plots can be obtained. Here motes are referred as the body sensor nodes. The different types of sensors like the light, temperature and blood glucose levels of each of the nodes are measured. These parameters are also measured in case of mobility as well. On the same time, the best optimal shortest path is measured for the patients to reach the Admin.

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