ENERGY EFFICIENT MAC PROTOCOL DESIGN FOR REMOTE PATIENT MONITORING AND MEDICATION SYSTEM USING INTERNET OF THINGS (IoT)

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Abstract: *Internet of Things (IoT) becomes vibrant research field to satisfy the requirements of current trend in healthcare informatics.Time critical applications like patient monitoring in Critical Care Unit (CCU) and remote medication system are necessary to have minimum average end-to-end delay in communication in addition to reduced power consumption.Patient monitoring is a process of acquiring body parameters of a patient present at a remote location. This paper proposed the design, implementation and performance assessment of an enhanced Constrained Application Protocol (CoAP) which makes the patients being monitored by a central system and allowed the patients to move freely. This system was simulated in Cooja emulator environment and the results proved the energy efficiency of the system by comparing existing methods and improved implementation attempted more domestically.*

Key words: *Patient monitoring, CoAP, IoT, Sensor Networks, Contiki, Border router, 6LoWPAN , MSP 430F5438 SOC.*

1. Introduction

The internet is under continuous development, today we stand before a new revolution. As internet has shrunk the world in the current scenario, IoT going to play vital role in shrinking the universe in the coming era.The ubiquitous plug and play characteristics of commercially available open source hardware paved way for the development of smart IoT in reality. IoT is great enabling technology that can revolutionize information and communication technology, it has the potential to change the way we live and communicate. It has been over a decade since the term IoT was first coined [1]. IoT is a branch of embedded system enables a wide range of application scenarios with potentially critical actuating and sensing task. It is the combination of Internet-connected embedded devices and Web-based services which make the IoTa powerful paradigm[2],e.g., in e-healthcare, advanced home automation, industrial process monitoring and control, smart parking system etc.The Internet of Thingsisthe network of physical objectsaccessedthrough the internet enhances machine to machine communication using 6LoWPAN unique IPV6 addressing [3]. Analysts and visionaries predicted that in the year 2020 more than 50 billion devices will be connected through the internet. In Fig.1 machine to machine (M2M) connected devices increases exponentially predicted by Cisco has been presented.

These objectscontain embeddedtechnology to interact the internal states or tothe external environment. In other words, when objects can senseandcommunicate, it changes how and where decisions are made using unique IPV6 addressing. 6LoWPAN enables the use of IP in low power and lossy networks (LLN), such IP connected smart devices becoming part of the Internet hence forming the IoT[4].

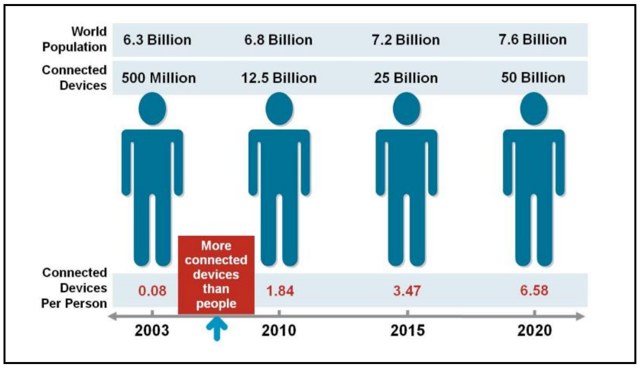


Fig. 1. Machine to machine connected devices predicted by CISCO

M2Mnetworks have become very useful in a wide range of applications such as ubiquitous healthcare (u-healthcare) monitoring. Such applications require providing Internet connectivity to wireless sensor networks for deployment and data collection. IPv6 over Low Power Wireless Personal Area Network (6LoWPAN) protocol specifications support the IoTthrough an adaptation layer that provides efficient header compression[5].

This paper presents the IoT based remote health care monitoring system that provides the patient's conditions through web browser. It is found by the analysis and experiment that the nodes in the existing system consumes the highest power as it continuously receives or transmits data from or to the neighboring nodes.

The power consumed by all the nodes are drastically decreased by altering Radio Duty Cycling (RDC) algorithm for different MAC protocol and the same thing is incorporated in application level by using the CoAP (Constrained Application Protocol) in application layer[6]. The energy saving MAC protocols such as ContikiMAC, CxMAC and NullMAC are compared with each other in terms of average power consumption to know the suitable MAC protocol. In addition, the different parameters of the ContikiMAC has been analysed by varying the default values of each to validate the energy efficiency of the proposed system.

Real time implementation of the proposed simulation work is attempted to address a problem in healthcare informatics by connected or implanted sensors with patient body to improve remote patient monitoring in Intensive Care Unit (ICU) of hospitals. In the OSI reference model, the MAC layer which is a part of Data Link Layer (DLL), determines which node can access the shared medium for transmission or reception of data at a particular time. MAC layer should be designed in such a way that each node in the network should get a fair access to the shared medium. It also decides the usage of battery power and the average End-to-End delay. This paper presents the average end-to-end delay and power consumption analysis for different MAC protocols supported by Contiki OS and analysed network parameters such as Channel Check Rate, Payload and Transmission range. To understand the proposed model,considera server-client model whereitconsists of oneclientand multiple servers. Theclientend serves asthe monitoring mode whereeach and everyserverhostsa patient data indigenously. The serverend hostsa page onthe webthat hasa two way communication with the server only. In our case the web page contains medical parameters, set of options and command buttons etc. This helps the doctors and attenders to provide remote medication by sending command signals through actuators connected in the patient's body.

The goal ofthe proposed workisto establisha webaddress for patient monitoring via Copper Web Browser.Usercanlog ontothe webaddressandenter his/her patient numberand required details via his/her mobile devices.Sensors inthepatient body give the information regarding the parameters ofthe medical science as required.

Accordingto the request oftheclient need, information is served. As perthe request by doctor,theinformation will be displayed in his/her mobile devices, thus reducingthetime spent for manual diagnosis. Here, a smart device, such as insulin, may be attached to the patient's body and periodically report the condition of the patient to a back-end service through some wireless means to the Internet as depicted in Fig.2.

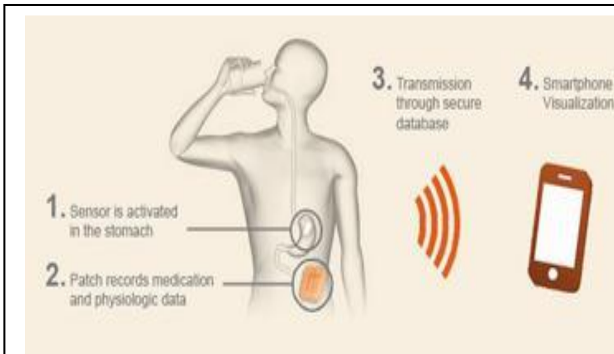


Fig.2. Remote Patient Monitoring System

In emergency cases, a physician may additionally be able to trigger instant injection of medication into the patient's body. Typical application scenario where IoT can be used is represented in Fig.3.

Thecontributions in this paper are: (1)a simulative evaluation ofthe proposedapproach in cooja simulator by comparing the performance of various MAC protocols. (2) Real time implementation of the proposed work was done with necessary healthcare sensors connected to TI ARM cortex M4 MSP 430F5438 core with system-on-chip (SOC).

The remainder of this paperis organizedas follows. Chapter II reviews the related work. Chapter

IIIdiscusses CoAP implementation in healthcare. Chapter IV explains the proposed system architecture and evaluation methodology based on the protocol to be used. Chapter V describes the simulation and the hardware implementation; the results are also presentedand discussed. Chapter VI concludes the paper with future enhancement. Chapter VII illustrated the references.

2. Related work

Internet of Things points out a vision of the machines of the future in the nineteenth century, machines learned to do in the twentieth century, they learned to think and becomes intelligent in the twenty-first century, they actually sense and respond and are learning to perceive[7]. Internet ofthings madecomplicated functions very simple,leading to formation of smart environmentand smart appliances makinga betterand safe placetolive in. The IETF is working on the connection-less lightweight Constrained Application Protocol (CoAP)[4], a new proposed standard for the IoT. CoAP is designed to meet specific requirements such as simplicity, low overhead and multicast support in resource-constrained environments. Security is particularly important for the Things as they are connected to the untrusted Internet. For instance, medical monitoring denotes a typical security-sensitive application scenario.

Some previous works was based on an easy web interface that provides information about temperature, humidity and led status of sensors [8]. Another work is done on various applications like car parking which was implemented through cooja simulator to offer parking facilities will get cars off the street and into parking spaces sooner thus contributing to congestion control in highly congested urban areas[9]–[12][13].

In order to develop a low power efficient CoAP system works have been carried out as implementation for Contiki that leverages a generic radio duty cycling mechanism to achieve a high energy efficiency [6].Authors done the Implementation of CoAP and its Application in Transport Logistics highlighting the use of the CoAP protocol for the retrieval of sensor data during land or sea transportation. Thus these early works are used for the betterment of environmental monitoring based application.

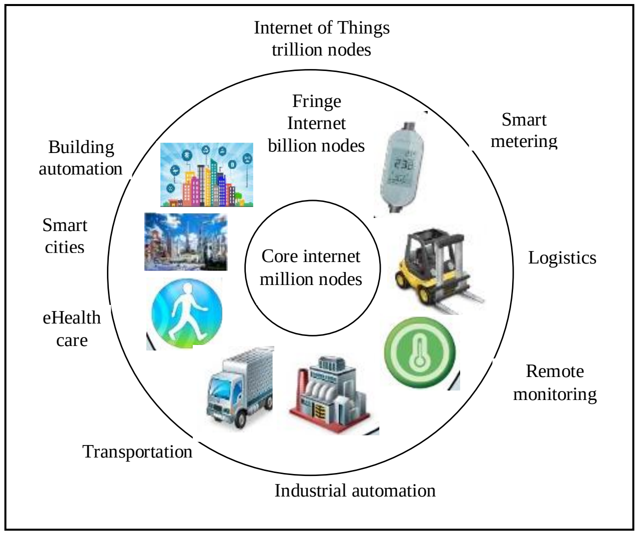


Fig. 3. Typical application scenario of IoT

The human body is equipped with sensors that are able to capture optical information from the environment (wireless sensor eyes), acoustic information such as sounds (wireless sensor ears), and smells (wireless sensor nose). These are examples of remote sensors, that is, they do not need to touch the monitored object to gather information [14], [15]. From a technical perspective, a sensor is a device that translates parameters or events in the physical world into signals that can be measured, analyzed and controlled.

Hasan Ali Khattak @el [16] surveys technologies and techniques for using CoAP-based WSN for connecting and monitoring medical sensors. The authors addressed application requirements for creating healthcare WSNs utilizing IPv6 and CoAP and real-time monitoring issues.

Matthias Kovatsch@el[17] presents an implementation of the IETF Constrained application Protocol (CoAP) for the Contiki operating system that leverages the ContikiMAC low-power duty cycling mechanism to provide power efficiency and also emphasized low-power mechanisms at the application layer, instead providing low-power operation only at the radio duty cycling layer. The authors analyzed the important role of WSN for IoT healthcare application, patient monitoring in real time, drug administration, helps in fast diagnosis, tracking system of patient inside the hospital. Remote monitoring of patients condition also helpful for doctors particularly if the patient is outside the hospital.

Chander@el[18]proposes a lightweight time synchronization algorithm for CoAP-based home automation system networks. The CoAP option field and a shim header are used to include time-stamps which can be applied to both IP-based and non-IP-based home automation systems.

Hardware features required for implementation

Patient monitoring system isan integral part of medical science that deals with remote medication andtreatment to inaccessibleareas. Thecurrent situation indicates the presence of biotelemetry wherethe hardwareinvolvedis complex andexpensive. The proposed methodis more domesticated whereas particular patientcan be monitored through mobile phone orcomputers byaconcerned person ora doctoraslongasall ofthem haveaccess tointernet andstayconnected. It indicatestheadvantage of implementing CoAP overexistingtechnical resources.

Necessary components required for data acquisition and actuation task is shown in Fig.4. A system which has direct or indirect contact with the parameter to be measured often referred to as a sensor device[15], [19]. The resulting electrical signals are often not ready for immediate processing, therefore they pass through a signal conditioning stage where variety of operations can be applied to the sensed signal to prepare it for making compatible to the succeeding stage. Signals often require amplification or attenuation to change the signal magnitude to better match the range of the following analog-to-digital conversion. Further, signal conditioning often applies filters to the signal to remove unwanted noise within certain frequency ranges high pass filters can be used to remove 50 or 60 Hz noise picked up by surrounding power lines. After conditioning, the analog signal is transformed into a digital signal using an analog-to-digital converter (ADC). The signal is now available in a digital form and ready for further processing, by a programmable digital hardware like microprocessor or microcontroller.

Commercially available hardware for WSN is very costly as it has integrated all the necessary inbuilt functionalities in single silicon chip, many wireless sensor networks also include actuators which allow them to directly control the physical world[20]. An actuator can be a valve controlling the flow of hot water, a motor that opens or closes a door or window, or a pump that controls the amount of fuel injected into an engine.

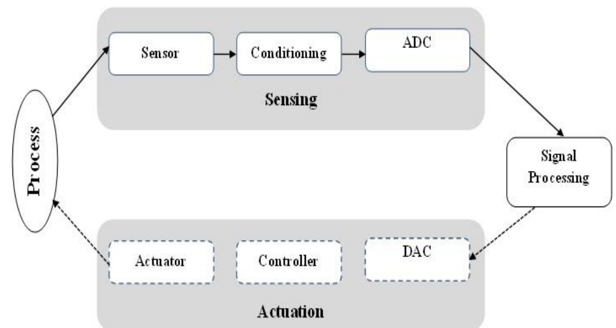


Fig. 4.Components available in a mote for data acquisition and actuation task

Such a wireless sensor and actuator network (WSAN) takes commands from the processing device or controller and transforms these commands into control signals for the actuator, which then interact with a physical process, thereby forming closed loop control functionalities. One hardware mote consists of: sensing module, processing module, communication module and power module[21]. Typical sensor mote architecture for health monitoring with connected sensors is represented in block diagram form in Fig.5. A simulator is a software tool that imitates selected parts of the behavior of the real hardware and is normally used as a tool for research and development.

Sensors have limited energy resources and their functionality continues until their energy is drained. Sensor networks are typically expected to last for several years, and since the sensor nodes are battery powered, another challenge is to develop power efficient communication protocols [22], [23].

Most sensor networks and sensing applications rely on radio transmissions in the unlicensed Industrial Scientific Medical band, which may result in communications significantly affected by noise and interferences.

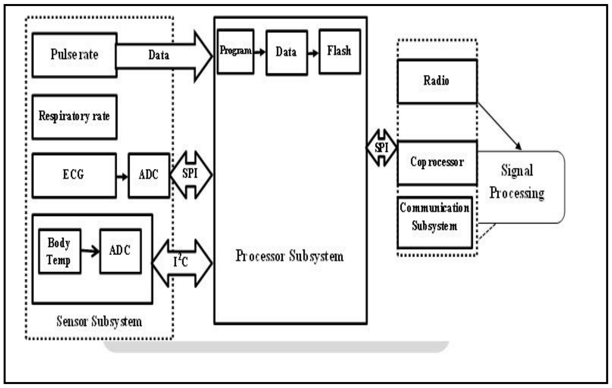


Fig. 5. Mote Architecture connected with vital sensors

3. Overview of CoAP

Contiki is an open source operating system that runs on tiny low-power microcontrollers and makes it possible to develop applications that make efficient use of the hardware while providing standardized low-power wireless communication for a range of hardware platforms.

Constrained Application Protocol (CoAP)[24]–[26] isa software protocol intendedto be usedin very simple electronics devices thatallows themtocommunicate interactively over the Internet. Itis particularlytargeted for smalllow power sensors, switches, valves and similar components that needto becontrolled or supervised remotely, through standard Internet networks. Therefore, energy efficiency is very much important. CoAPcan run on most devices that supportUDP ora UDPanalogue.

Message types involvedare Confirmable,Non confirmable, Acknowledgement, Reset messages. Confirmable requires Acknowledgement whereas Non Confirmable doesn't require Acknowledgment. Reset messageindicates missing of fewcontexts.

- GET-TheGET method helps in retrieving information from that of server.
- POST-The POST method requeststhe serverto provide data forthe user.
- PUT-The PUT method helps in updating orcreatingthe information in thecorresponding URI.
- DELETE- the DELETE method helps increasing the information stored.

The usage of CoAPin patient monitoringapplication is to formaclient-server relationship, whereasDoctors usethe browser asclientand the server program runsin theGUI for updating the browser dynamically. Thus theMethod definitions are used efficiently for remote monitoring application.

IPv6 addressing

Version 6 of the IP protocol introduced in 1990 as an update for IPV4[27]. The most noticeable change is an expansion of the address space from 32 bits to 128 bits. The 32 bits in IPV4 can support around 4.3 billion unique addresses, while the 128 bits in IPV6 can support around 3.4*1038 unique addresses. An IPv6 address consists of 128 bits and depending on type it can be used to represent one or several interfaces. The three different types of addresses used are:

Unicast - Specific address

Anycast - reference to a group of interfaces where the messages delivered to the nearest group member based on the routing protocols distance measure.

Multicast- reference to a group of interfaces where the message is delivered to each member.Protocol stack for CoAP and HTTP comparison is represented in Fig.6.

The addresses are written on the form x:x:x:x:x:x:x:x where each x represents a 16 bit hexadecimal number. Leading zeros do not have to be written out and subsequent zeros can be truncated with a double colon notation that is original and simplification representation is shown below for a particular smart sensor ID Original FE80:0:0:0:0:1234:5678:9ABC Simplification FE80::1234:5678:9ABC

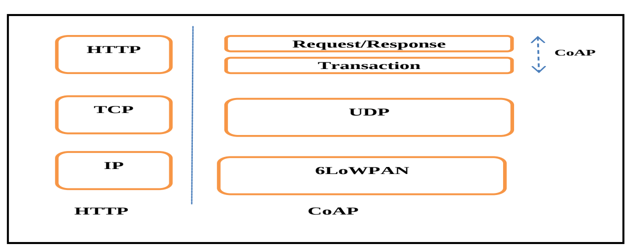


Fig. 6. HTTP and CoAP stack comparison

4. System Architecture

If doctors request server for data, the CoAP protocol helps to connect server with client to verify any variation of sensor values. As shown in Fig.7patientis monitored by the sensors placed insidethem.Servers will be percolated inside patient for CoAPconnection totake place[28]. This server contains sensors for datacollection. Onthe other side,Doctors are acting as clients. Ifthere isany variation, then doctorscan give medication indicating emergency situation forthe patient. This medication is done in browser using CoAP protocol. The sensed parameters from patient is either uploaded to cloud or storedin some data storage device for future purposes and diagnostic valuestocomputeanaction[5]. Thena particular ora group of parameterscan be modifiedto stimulate anaction in order to bring the patient conditionto normal or to the required state.

Client -A CoAP client cycles through 4 resources on event detection such as GET, PUT, PUSH, and DELETE. It gets connected to the server via multi-hoptopology. The communication between server and clients are of multi hop fashion. The data from the motes are sent to that of Copper Web Browser which can be viewed by the user[4], [29].

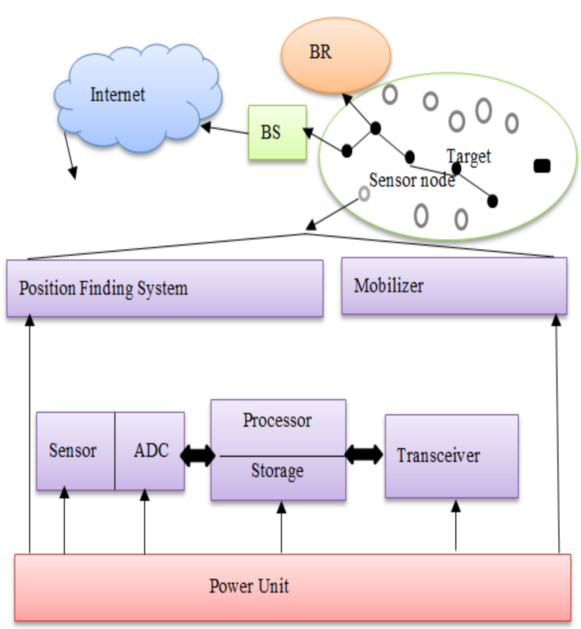


Fig. 7.Sensing processing communication system architecture

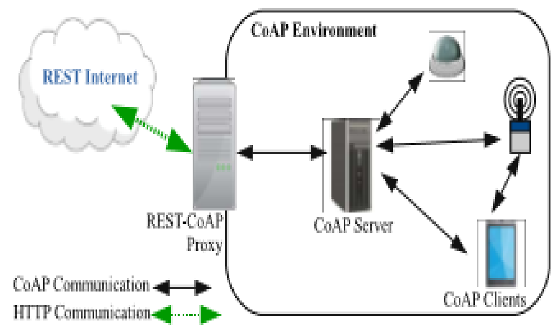


Fig. 8.CoAP Functionality with REST architecture

The flowchart in fig 9 explains the methodology to carry out this particular application. If the unique address of the server is typed in the URL using a copper plugin which runs on top of the HTTP. The hosted servers responds to the requests only after access is granted. The hosted webpage displays the status of the patient connected with the sensor values that has been under operation. The obtained values can also be stored on the cloud or offline for future references. The collected values are compared with the standard or normal values to provide essential information to patients.

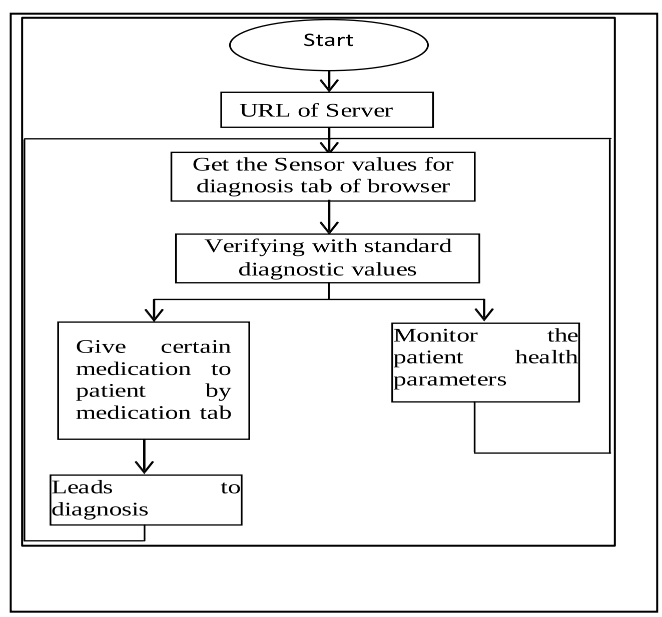


Fig.9. Flow chart of client operation for server in browser

5. Classification of MAC protocols

Contention based MAC protocols

Contention based MAC protocols are the simple protocols while considering setup and implementation process. In this protocol design the nodes will contented for the channel in many ways to utilize the channel for data transmission and reception. Earlier the protocols like such as ALOHA and slotted-ALOHA have higher collision data which will limit the throughput [30].
Carrier Sense Multiple Access (CSMA) based protocols reduce the collision but does not completely eliminate the collision and it may lead to throughput degradation [15], [22], [31]–[33]. If the node density increases the performance will be greatly affected due to increased collision in Machine-to-Machine (M2M) communication. So it makes the contention-based MAC protocols and suitable for Machine-to-Machine communication.

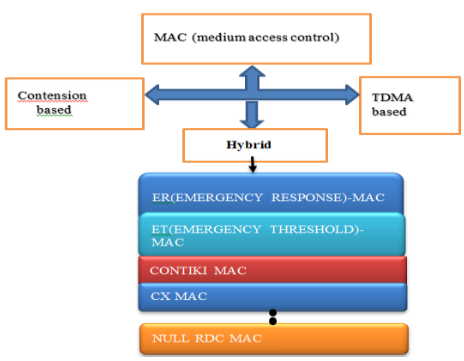


Fig. 10.Classification of MAC protocols

Contention-free MAC protocols

Contention-free protocols remove the problems caused by collision by pre-allocating transmission resources to the nodes in the network. TDMA type protocols have poor time synchronization requirements that are difficult to implement and result in more power consumption. Code Division Multiple Access (CDMA) protocols have poor flexibility and are not very efficient at low loads. This makes them unsuitable for low cost M2M communication.FDMA requires additional complicated band pass filters that lead to high cost. FDMA is less suitable for low-cost devices when compared to TDMA and CDMA [15], [31], [34]–[39].

Hybrid MAC protocols

Hybrid Mac protocols is a combination of Contention based and Contention-free approach of MAC protocols. TDMA (Time Division Multiple Access) is a schedule based MAC protocol which has been reviewed to be best during high traffic condition avoiding much of colliding problems whereas it suffers certain disadvantages as it needs global synchronization, does not easily adapt to changes in network topology and it is difficult to ascertain interference among neighborhood nodes (interference irregularity). CSMA (Carrier Sensing Multiple Access) is a contention based MAC Protocol, which provided fine results during less traffic levels whereas experienced hidden terminal problems and hence chance of packet collision is more[31]. To make use of the advantages of both approaches and to compensate for their disadvantages, hybrid MAC protocols are being used[15], [22], [23], [28], [31], [33]–[44]. The Hybrid MAC protocols used in this work are ContikiMAC, CxMAC and NullRDCMAC[45].

ContikiMAC

ContikiMac is a Radio Duty Cycling Protocol that employs periodic wake-ups for packet transmission for neighbors. During the awake up state, if the packet is detected, the receiver will be in ON state for packet reception. Then it acknowledges the sender. It uses precise timings between the data transmissions. In addition it makes use of fast sleep optimization which quickly detect false positive awake ups and a transmission face-lock optimization for energy efficient operation [11].

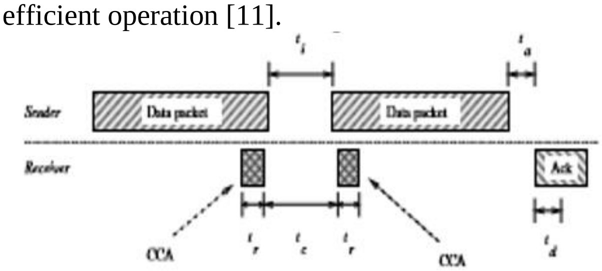


Fig . 11. ContikiMAC transmission and CCA timing.

The mechanism used for ContikiMAC wake-ups is the Clear Channel Assessment (CCA) mechanism. It uses the Received Signal Strength Indicator (RSSI) of the radio transceiver to give an indication of radio activity on the channel. If the RSSI is below a given threshold, the CCA returns positive, indicating that the channel is clear. If the RSSI is above the threshold, the CCA returns negative, indicating that the channel is in use.

CxMAC

CxMAC was introduced to overcome the problems faced in low power listening. In LPL, long preamble is used which leads to more energy consumptions at both the sender and receiver. The target receiver has to wait for the full preamble before the data reception. But in CxMAC, the address information of the target is embedded in the preamble itself so that the non-target receivers can quickly go back to sleep state. To reduce the waiting time of sender CxMAC allows the receivers to inform about their availability, even in the middle of the preamble transmission. This short strobed preamble technique increases the energy wastage in waiting for the whole preamble to complete. Non target receivers which overhear the strobed preamble can go back to sleep immediately.

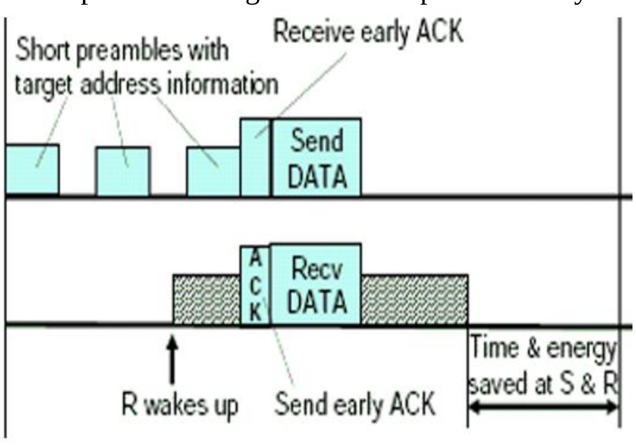


Fig. 12.CxMAC transmission mechanism

NullRDC MAC

NullRDC MAC uses framer functions for header functions/parsing. It works as a pass through layer that only transmit a packet and retains the results of such transmission (success or collision).
NullRDC has two main tasks; (i) it uses framer functions to create a header, and (ii) it simply checks if the packet was received or a collision has occurred. It does not take any consideration to energy saving at all as it keeps the radio always on [15]

6. Simulation output

The objective of this proposed work is to reduce overall energy consumption of mote and average end-to-end delay in communication for various topologies, channel check rate, payload and transmission range. The results shows how the different protocols are related to each other and performance of the network evaluated with respect to different topologies, channel check rate, payload and transmission range.

The end-to-end delay is measured as the average end-to-end transmission time that is the time needed by a sender to transmit a packet to a destination in multiple hops. The latency includes the retransmissions needed in case of collision or lack of acknowledgement.

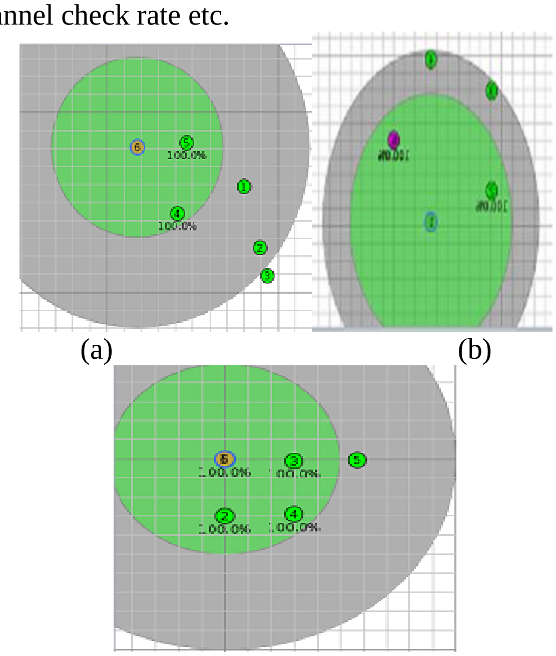
RDC drivers keep the radio off as much as possible and periodically check the radio medium for activity. When activity is detected, the radio is kept on to receive the packet. The number of channel checks per second to detect the activity in radio medium is called as channel check rate. Channel check rates are given in powers of two in Contiki and typical settings are 2, 4, 8, 16, 32 and 64 Hz. Payload is the number of bytes in the message transferred from client to server or vice versa. Power consumption is important for wireless sensor nodes to achieve a long network lifetime. To achieve this, low-power radio hardware is not enough. Existing low-power radio transceivers use too much power to provide long node lifetimes on batteries. To achieve a long lifetime, the radio transceiver must be switched off as much as possible. However, when the radio is switched off, the node is not able to send or receive any messages. Thus the radio must managed in a way that allows nodes to receive messages but keep the radio turned off in between the reception and transmission of messages.

The MAC layer takes care of addressing and retransmission of lost packets. Here the MAC driver used is CSMA/CA. RDC layer takes care of optimization of sleep and wakeup period of nodes. This is the most important layer, because it is the one responsible for deciding exactly, when the packets transmitted and making sure that the node is awake, when packets received. The RDC drivers analysed in this research are ContikiMAC, CxMAC and NullMAC.

The use of ContikiMAC reduces the power consumption significantly and allows the controller to run even on 2-AA batteries for more than a couple of years.

Variation in Topology

Contiki supports three topologies namely linear, random and ellipse as seen in Fig.13. Experiments have been conducted to identify the preferred topology based on power consumption, transmission range, channel check rate etc.



(a) (b)

(c)

Fig. 13.Motes deployed in various topologies (a) Linear (b) Random (c) Ellipse

The required number of sky motes deployed in various topologies and its power consumption is analyzed and reported in Fig 13. Periodically allowed the motes to exchange information among them at report interval of 60 seconds using collect view shell program.

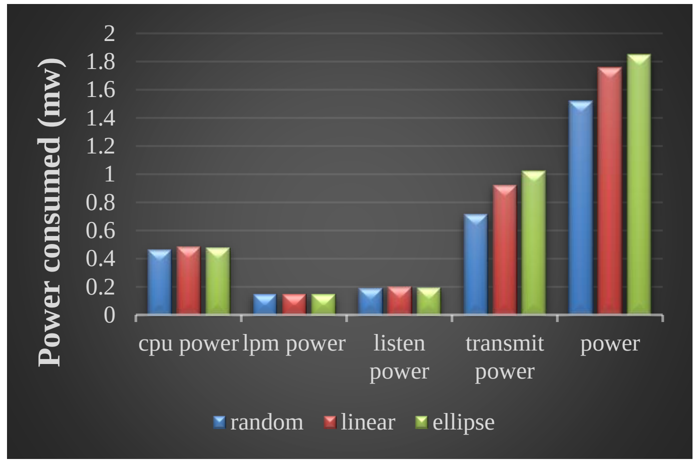
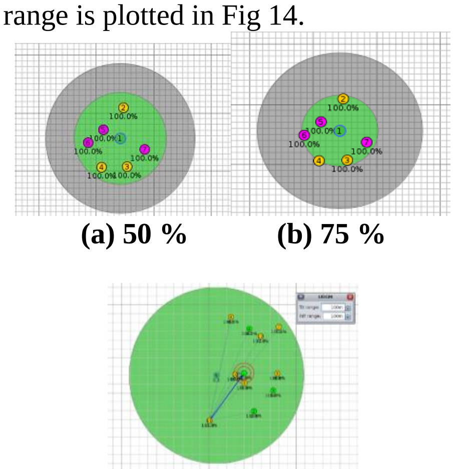


Fig. 14.Power consumed by various modules of motes for various topologies

It is observed from the Fig 13, that the power consumed by motes varies for every topology and the power consumed in random topology is less compared to other topologies. Hence, by using random topology with less number of transmissions, overall power consumption can be reduced.

Variation in Transmission Range

To evaluate the performance of network for various transmission ranges and various topologies, power consumed by motes observed. Transmission range of motes reduced from 100m to 50m in steps of 10m and the corresponding power consumed by motes in various range is plotted in Fig 14.



(a) 50 % **(b) 75 %**

(c) 100%

Fig. 15.Transmission Range

To evaluate the power consumed by various modules of motes, the targeted motes are deployed in various topologies given in Fig 15. The transmission range is reduced from 100m to 50m in steps of 10m and the corresponding power consumed by various modules observed.

Variation in Channel Check Rate

To evaluate the performance of ContikiMAC, CxMAC and NullMAC , the targeted motes deployed in random topology. Channel check rate of motes varied from 8 to 64 in multiples of 2^n and corresponding average end-to-end delay, transmission power and reception power consumed by motes in communication is observed. Average end-to-end delay for various channel check rate is plotted in Figure.5.14. Transmission power for various channel check rate is plotted in Fig 15. Reception power for various channel check rate is plotted in Fig 16.

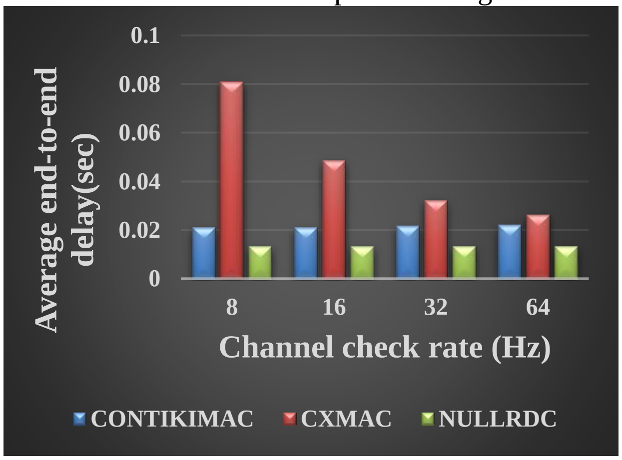


Fig. 17.Average end-to-end delay offered by ContikiMAC, CxMAC and NullMAC with varying Channel check rate.

ContikiMAC has the average end-to-end delay by a good margin. On increasing the channel check rate ContikiMAC, consistently provides same delay. CxMAC offers slightly higher delay due to collision and retransmission. Even though NullMAC offers least delay, it is not power efficient. The above observations are depicted from Fig 14.

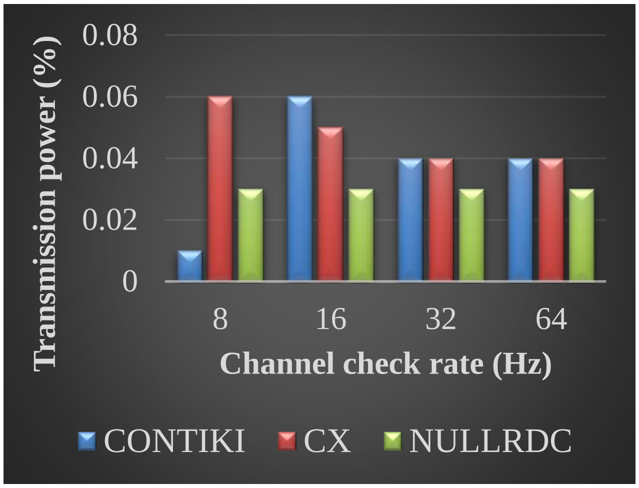


Fig. 18.Transmission power consumed by motes with varying channel check rate for three different MAC protocols

Contiki MAC is having the lowest transmission power consumption with channel check rate 8 Hz and thus, it is the default channel check rate in Contiki simulation environment. On increasing the channel check rate up to 16 Hz for ContikiMAC, the power consumption increases due to collision and retransmissions. ContikiMAC and CxMAC gradually decreases transmission power, when the channel check rate increases as seen in Fig 15 and for NullRDC it remains unchanged.

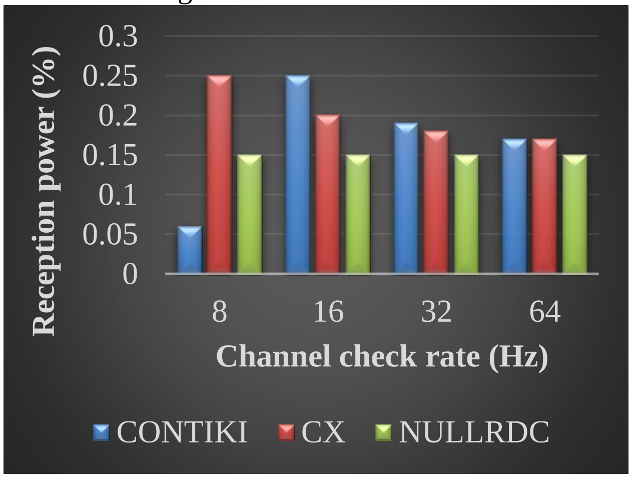


Fig. 19.Reception power consumed by motes with varying channel check rate for three different MAC protocols

Fig 16.Shows that ContikiMAC has the reception power in a good margin for 8 Hz. On increasing the channel check rate up to 16 Hz for the ContikiMAC, the power consumption increases due to collision and retransmissions. ContikiMAC and CxMAC gradually decreases reception power, when the channel check rate increases and NullRDC stays unchanged, since the radio is always in on condition.

Variation in Payload

Data payload varied from 10 to 50 bytes and the corresponding average end-to-end delay in communication is observed for various MAC protocols. Average end-to-end delay for variouspayload is plotted in Fig 17. Transmission power offered by motes is given in Fig 18. Reception power due to variation in payload is plotted in Fig 19.

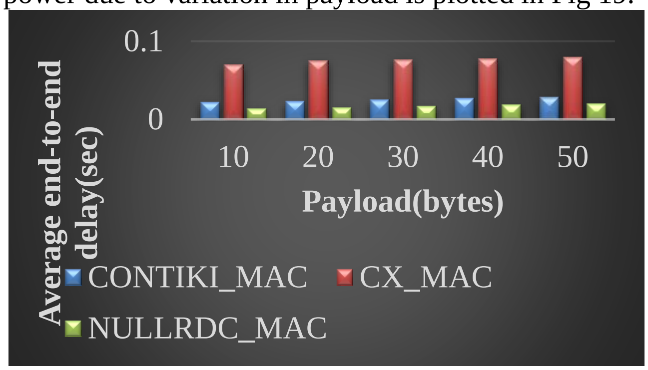


Fig. 20.Average end-to-end delay offered by motes for three different MACs with payload varied from 10 to 50 bytes

On increasing the payload, ContikiMAC gives slight increase in average end-to-end delay. Even though NullMAC offers least delay, it is not energy efficient.

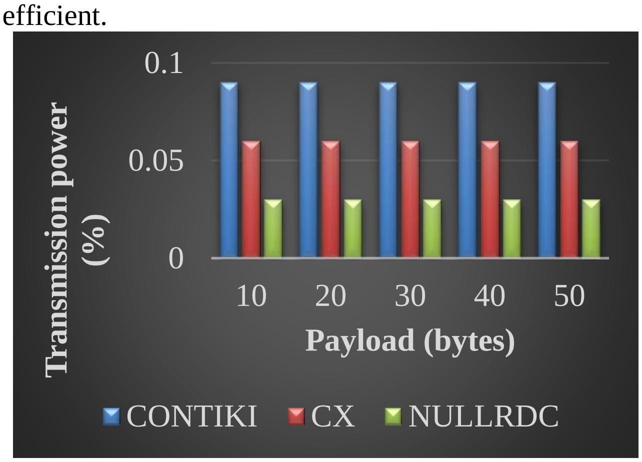


Fig. 21.Transmission power offered by motes for three different MACs with payload varied from 10 to 50 bytes.

On increasing the payload, all the three MAC protocols maintains same transmission power because remaining bytes are padded as all zeros in IEEE 802.15.4.standard are plotted in Fig 20. Even though NullMAC offers least transmission power, its radio must be in ON state always, which in not desirable for energy constraint.

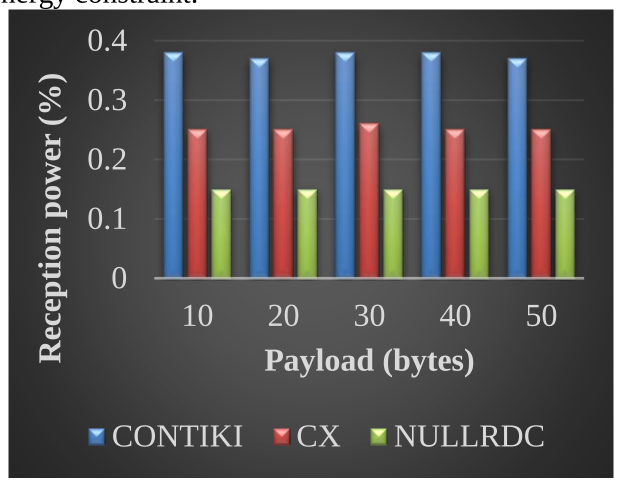


Fig. 22.Reception power consumed by motes for variations in payload

The power consumption for all protocols does not vary much for various payloads, which can be understood from Fig 21and Fig 22. It can be inferred that change in payload does not affect the transmission and reception power.

The transmission power of ContikiMAC remains constant whereas the reception power increases for increase in transmission range. In CxMAC transmission power decreases, whereas the reception power increases for various transmission range. For NullMAC transmission power remains constant whereas the reception power increase for increase in transmission range. In conclusion considering all constraints ContikiMAC performance is better.

7. Real Time implementation

Constrained Application Protocolis simulated viacooja simulator. Cooja simulatorisa java based simulator andit is alsocalledas “crosslevel simulator”.

Fig 7, gives theidea of connection exhibiting between different patients with doctor. Where border router node acts like a gateway to connect to the internet.

Fig 11, gives the overview of output which can be viewed in browser with a Mozilla Firefox add-on called Copper. Patientisa resourceaddedtotheleft side window of the browserin the address, CoAP://[aaaa::212:7402:2:202]/ connectsclient to the particular server.
Discovery – calls the resources included in the server.
Ping– which helpsto view theconnectivity of the serverandclient.
GET, POST, PUT, DELETE are the method definitions which gets in to effect only after Pinging.
Fig 10,shows motes connection and different topology of server and client connected, time line of radio messages, motes output window, collect view etc.Fig 11shows the CoAP interface through copper browser indicates change in patient's body by the actuator signal. The sub-resources include diagnosis and medication options to perform suitable operations during emergency situations. Diagnosis used to collect sensor data from server end and check with standard values to perform medication operations. Medication- information can be used to indicate the patient to go to nearest hospital by actuator[46]–[49]. Fig.23. shows the cooja simulation windows indicating emergency medication.

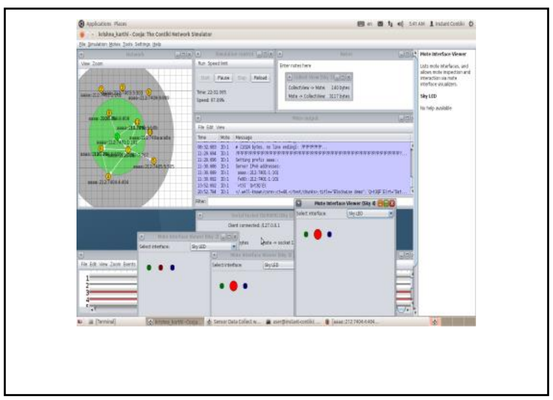


Fig. 23 .Shows various windows motes arranged in random topology, radio messages, remote medication

Fig. 24. Photographical view of sensors connected to the MSP 430F5438 development board.

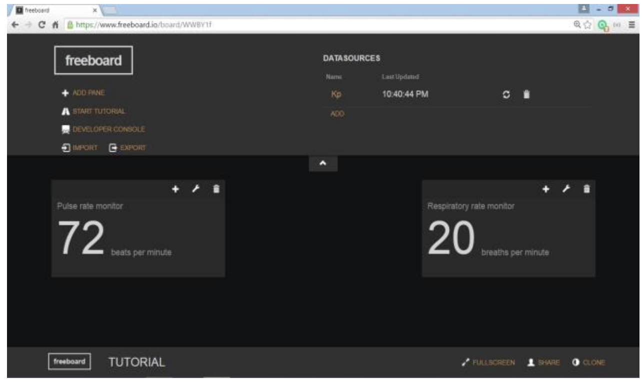


Fig. 25. Data sensed through pulse rate, respiratory rate sensors uploaded to cloud through web browser

Fig.24. shows the Photographical view of sensors connected to the MSP 430F5438 development board and real time values sensed by various sensors uploaded to the freeboard cloud, which can be used for remote medication as well as further analysis. Fig.16. shows the sub dialogue box which represents sensors sensed normal condition of the patient. Fig.25. Data sensed through pulse rate, respiratory rate sensor and uploaded to cloud through web browser.

From these above simulation results, it can be ensured that the healthcare situations will go to its pinnacle point. It also ensures that certain modification in these factors will make the CoAP protocol to work in various other applications.

8. Conclusion and future enhancements

The results indicate that no single MAC protocol is suitable for all situations, and it is highly dependent on the scenario and application requirements. The amount of nodes, position of the nodes, amount of traffic and wireless environment greatly affect the performance of the drivers. It is to be noted that, conclusions in this work are derived based on various topology assumed for experiments.
NullRDC is a driver that performs well, but with the expense of consuming more power as the radio is supposed to be always on. This is an important issue as energy efficiency in many sensor network applications is one of the major requirements. Also NULLRDC is not suitable for the network where nodes need to run on battery power.
Contiki MAC also offers a reasonable delay with reduced power consumption, high delivery rate and low overhead.
For time critical applications like patient monitoring in ICU and remote medication system, it is necessary to have minimum average end-to-end delay along with reduced power consumption.

The proposed work presented low-power CoAP implementation for ContikiOS that leverages a generic radio duty cycling mechanism to achieve a high-energy efficiency on a cooja simulator. It is experimentally evaluated both in simulation and in real time using MSP 430F5438 development boards. The results showed that the use of optimized duty cycle results in a low power consumption and low end-to-end delay.

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