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ContikiMAC for Wireless Sensor Network Monitoring Application

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Abstract:*During the most recent decade there is a quickly developing interest in Wireless Sensor Networks (WSN). With the help of this technology, attempts are being made to apply it in various areas like medical and health care, wildlife monitoring, environment monitoring, military operations etc. WSNs in general consist of sensor nodes that are capable of computing, data processing, communication to other sensor nodes. In WSN some problems arise due to energy, coverage, maintenance etc. Medium Access Control (MAC) protocol is the most affected protocol. Accessing of wireless medium and deciding the transmission of data is done by MAC layer. MAC driver and the RDC driver are the two drivers which are focused in this work. Both detecting collisions and retransmissions are tasks of MAC driver. The RDC driver is answerable for the node's wakeup and sleep mechanism as it controls the radioactive state which extremely influences both the delay and the energy consumption of the node. The RDC drivers that are analysed in this project are ContikiMAC, CxMAC and NullRDC. Through simulations with ContikiOS, grid topology with various parameters is considered.*

Key Word*:WSN, MAC, ContikiOS, CSMA, NullMAC, ContikiMAC, CxMAC, NullRDC.*

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I. Introduction

WSN are the data networks comprise of sensor nodes [1]. Sensor nodes have restricted processing capability, battery power and channel bandwidth. Sensor network is useful for collecting data from sensor nodes and distributing measurements to destinations.

The MAC layer in wireless networking gives access to the wireless media. It is responsible for who and when the information has to be sent. This is extremely significant in wireless networking as all nodes share similar media. So, selecting of proper MAC protocol for a network is essential by considering how much it affects the lifetime and performance of the network.

This paper is organised in six sections. Section I introduces WSN, MAC layer and important in selection of proper MAC layer. Related works are discussed in Section II. Section III is about the MAC layers, Operating system and simulator used. Section IV explains about simulation settings whereas results are analysed in Section V. Conclusion is stated in Section VI.

II. Related Works

The author in [2], observed the performance of ContikiMAC with CxMAC and in particular, he questioned the efficiency of the transmission technique that depends on sending full data frames. The outcome of the fast-sleep optimization of ContikiMAC permits a node to decrease idle-listening to a minimum. The author proposed that, retransmissions are cost effective for ContikiMAC than CxMAC but explained that by decreasing the number of transmissions ContikiMAC was able to overcome the disadvantage.

In [3], the author presented an adaptive radio duty cycling layer which is an advancement of ContikiMAC i.e., ERA-ContikiMAC an autonomous mechanism which analyses battery capacity level and then checks channel radio activity. Finally, it decides about RDC frequency.

The author in [4] analysed the RPL behaviour under MAC protocol effect in terms of end-to-end delay, power consumption and packet delivery ratio where it shows that ContikiMAC is better in power consumption than other drivers.

In [5], the author presented the main challenges faced by the MAC layer and Routing protocol. In [6], the author explains the different issues associated with wireless sensor networks and implemented in some protocols to know the impact of them.

III. Background

In WSN protocol stack, Data link layer is also called as MAC layer as it performs the task of wireless-medium-sharing issue in 1-hop neighbours whereas data link layers handle the error detection and data framing [7]. The MAC layer design is separated into three primary parts (i) MAC layer, (ii) Framer and (iii) RDC layer. MAC layer takes care of collisions, retransmission and addressing. Framer is used to create and read the framers being sent and receive. RDC layer is responsible for wake-up and sleep mechanisms.

A. MAC Driver

ContikiOS supports two different MAC drivers there are

1. **CSMA (Carrier Sense Multiple Access)** which keeps the packet, if the packet has to be sent it will perform carrier sensing and sends the packet if the medium is free and
2. **NullMAC** is a minimalistic driver that simply forwards traffic to the appropriate part of the RDC.

B. RDC Driver

The RDC drivers available for ContikiOS are ContikiMAC, CxMAC and NullRDC. The RDC driver is the most significant driver in this work as it needs to choose when the radio should be turned off or on.

1. **ContikiMAC** is a radio-duty cycling protocol which uses periodic wake-ups for data transmission from neighbours. To achieve a long life time, the radio transceiver should be turned off for long time but then the node cannot send or receive any data. So, while receiving data it should be turned on and keeps off in between receiving and transmission of data. In ContikiMAC, nodes will be communicating by keeping their radio off. It uses precise time between data transmission, fast sleep optimization which let the receiver to go to sleep when the wake-up is due to some noise and phase-lock optimization which allows the node to know the wake-up period of a neighbour.
2. **CxMAC** is a MAC protocol that uses a technique called short preamble. Ordinary low-power listening (LPL) utilizes a long preamble, which is prone to create some waste of energy as the sender will send the whole preamble before the receiver may respond that it is awake[8]. Short preamble in contrast sends shorter preambles with a pause between, where the receiver may respond that it has woken up. Another problem with long preamble is that it wakes all the nodes until the preamble ends, and the sender says which node should receive the message. This problem is called as overhearing problem. With short preamble the preamble contains information about the receiver so that the other nodes may go to sleep earlier.
3. **NullRDC** is similar to NullMAC, a simplistic driver that is used to develop new drivers. NullRDC has two main tasks

- To create a header it uses framer functions, and
- It checks whether the packet was received or a collision has occurred. As it keeps the radio always on it does not consider about energy saving [9].

C. Operating System and Simulator

The operating system used in this project is ContikiOS which is an open source operating system. It is written in C language and supports multiple different platforms. Cooja is a network simulator for network running on ContikiOS. Each node can be individually programmed with its own code as Cooja supports simulation of several different types of nodes.

IV. Simulation Settings

TABLE 1: Simulation Settings

S. No	Parameters	Values
1	Operating System	Contiki 3.0
2	Simulator	Cooja
3	Node Type	Tmote Sky
4	Topology	Grid
5	MAC/RDC Drivers	CSMA,NULLMAC/ContikiMAC,CxMAC,NullMAC
6	Radio Environment	Unit Disk Graph Medium (UDGM)
7	Parameters Observed	Transmission Power, Reception Power
8	Channel Check Rate	8,16,32,64
9	Transmission Range	50,75,100
10	Simulation Duration	30 minutes per simulation

V. Results

Simulation is carried out for grid topology. Node 1 acts as sink and remaining are sender nodes. When the simulation gets started the packets will be transmitted from one node to another and the nodes which are not in range will transmit through multiple hop. Comparison of RDC drivers by changing channel check rate and transmission range to know the energy efficiency of the protocols supported by Cooja is observed.

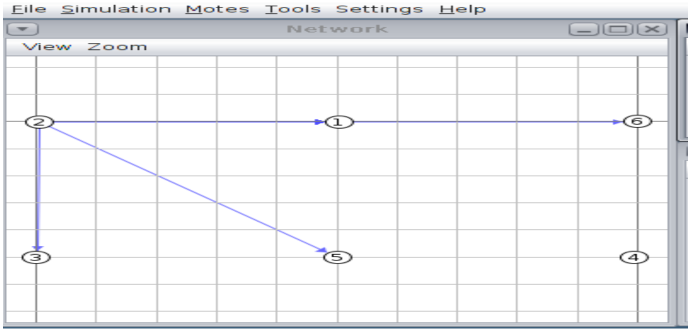

Figure 1: Grid Topology

Channel Check Rate is the number of times per second the node checks for the channel activity.

Transmission Range can be varied by adjusting the node range in the simulation window.
When the MAC driver is CSMA the following results are observed

A. Variation in Channel Check Rate

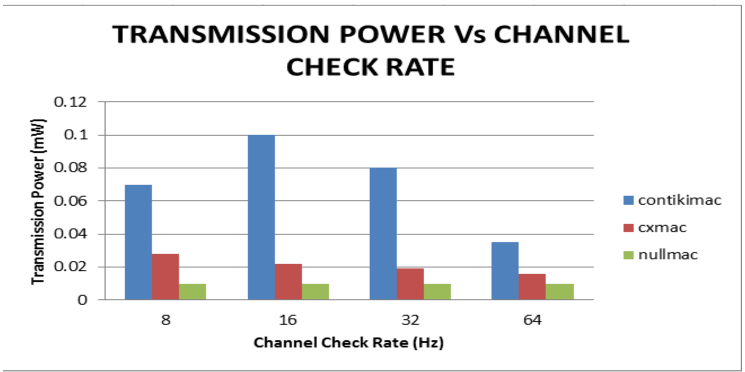

Figure 2: Transmission Power vs. Channel Check Rate in CSMA

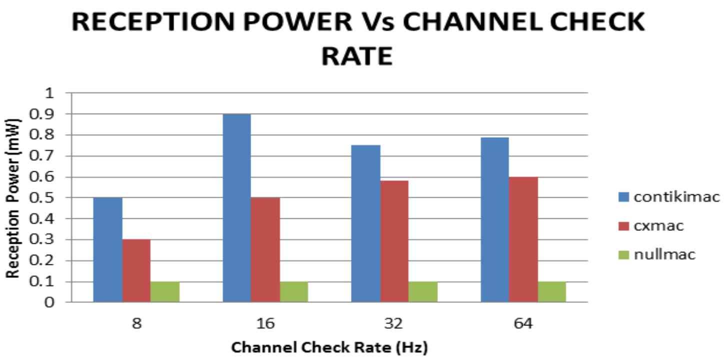

Figure 3: Reception Power vs. Channel Check Rate in CSMA

As number of times checking of channel activity increases, the transmission power of ContikiMAC decreases since the transmitter will know about the activity state of receiver more accurately and reception power increases as it will be receiving the whole data. In CxMAC, the transmission power decreases as the preamble contains the target address. So, when channel check rate increases it checks the activity state of that particular receiver. Transmission and reception power of NullRDC remains constant as it only consider about whether the packet is transmitted or collision occurred and does not care about energy utilization.

B. Variation in Transmission Range

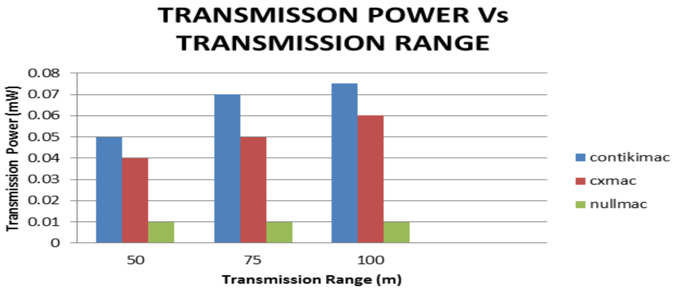

Figure 4: Transmission Power vs. Transmission Range in CSMA

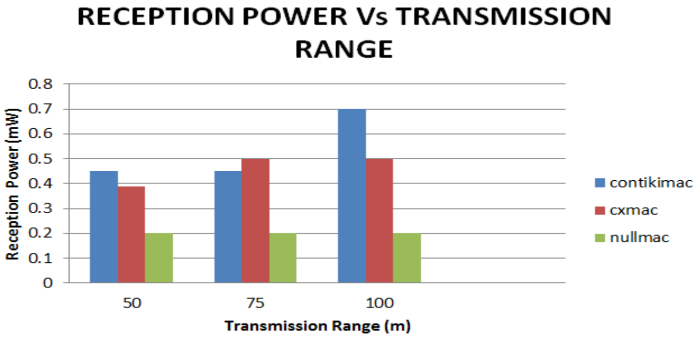

Figure 5: Reception Power vs. Transmission Range in CSMA

Here in grid topology we cannot measure for 25meters range as the sink node with that radius cannot receive data as sender nodes will be out of range. As the transmission range increases, the sender nodes will be able to be in range of sink. So, the to and fro communication will be better for data transmission. Therefore, the transmitting and receiving power will be more in ContikiMAC and CxMAC whereas NullRDC remains constant.

When the MAC driver is NullMAC the following results are observed

C. Variation in Channel Check Rate

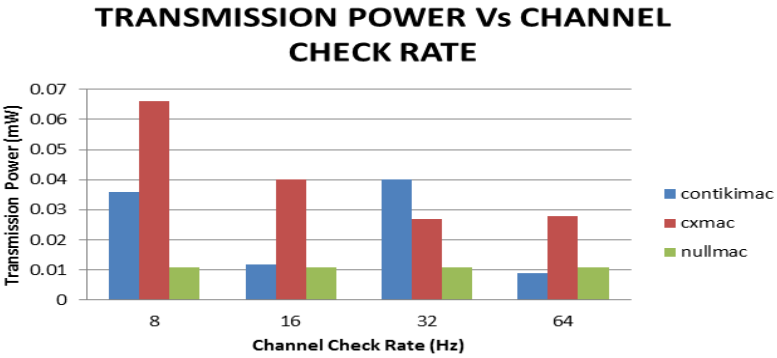

Figure 6: Transmission Power vs. Channel Check Rate in NullMAC

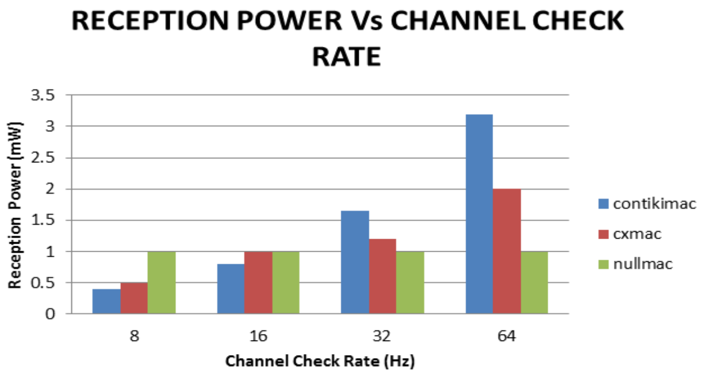

Figure 7: Reception Power vs. Channel Check Rate in NullMAC

When the MAC driver is NullMAC, the reception power of ContikiMAC and CxMAC increases as this NullMAC sends the traffic to the appropriate RDC driver. Transmission power of ContikiMAC alters and CxMAC decreased gradually as the channel check rate increases. NullMAC remains constant.

D. Variation in Transmission Range

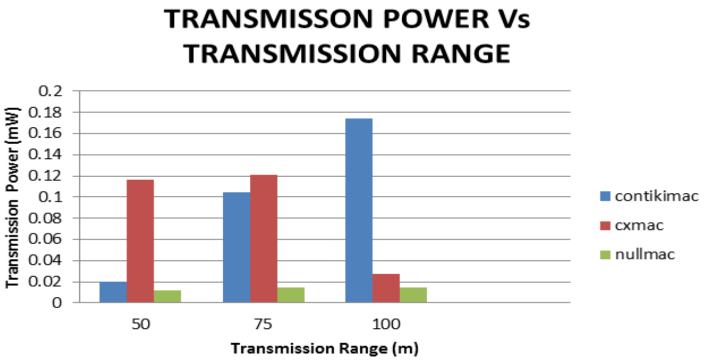

Figure 8: Transmission Power vs. Transmission Range in NullMAC

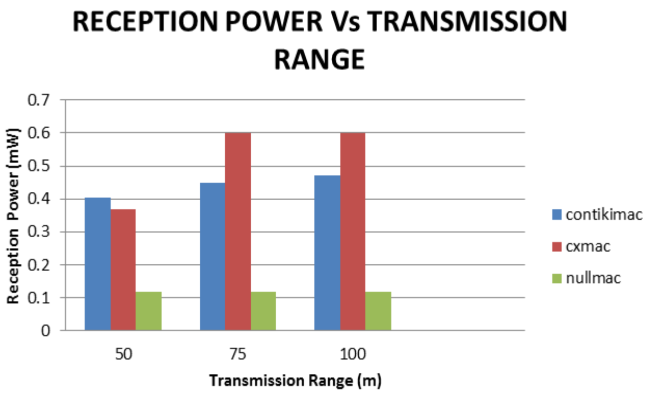

Figure 9: Reception Power vs. Transmission Range in NullMAC

Both transmission power and reception power increases with increase in transmission range for ContikiMAC as the nodes will be in communicative range, CxMAC is reciprocal in power as the nodes transmit the data through multiple hops and NullRDC remains constant.

VI. Conclusion

The results indicate that if the amount of traffic is more concerned then, CSMA should be used as it avoids the collisions in the network and if delay is more important then, NullMAC is preferred. In case of successful transmission of data, ContikiMAC is the better RDC driver. CxMAC does not provide any good transmission rate as it is not doing any retransmissions like ContikiMAC. Only if the link is free from collisions and interference, then NullRDC is better but of course it is not realistic in the real world network as there will be always some interference.

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