A Novel Analysis of T Mac and S Mac Protocol for Wireless Sensor Networks using Castalia

Smriti joshi, Anant Kr. Jaiswal, Pushpendra Kr. Tyagi

Abstract*-Wireless sensor networks have been kept evolving due to the advancements in various technologies like radio, battery and operating systems in sensor elements but mac protocols are still most important in wsn because the exact implementation of communication among sensors is derived by the mac protocols. Battery consumption, network lifetime, communication latency, packet collisions are some very important factors those depends on mac protocols used in a wireless sensor networks. T Mac and S Mac have been two landmark protocols in wireless sensor networks protocols because of their utility and ease of implementation along with simplicity.

Keywords—* *T Mac, protocol, S Mac, Castalia, Omnetpp, wsn.

I. INTRODUCTION

T Mac and S Mac have been studied thoroughly in the past. The study of these two protocols is important because these protocols are the parents of several newly designed Mac protocols and these two protocols are used as templates to design and implementation of such new contention based protocols. Our study of T Mac and S Mac is oriented towards the comparisons of these two protocols in some real world environments and conditions. Wireless sensor networks are applied in some very complicated conditions in actual life, so the comparisons of these two protocols demand these situations to be considered. For example a wireless sensor network applied on suspension bridge, a wireless sensor network in a battlefield where it is not possible to maintain a node or change the battery, in under water implementations of wireless sensor networks, wireless sensor networks in a metal foundry or situations like where the size of frame is very large, and several other such practical situations are possible in real world. T Mac is child protocol of S Mac and was introduced as an improvement over S Mac protocol. From the implementation perspective S Mac is much easier to implement and results are good. T Mac is little complex in comparison to S Mac as it uses a parameter called activation time out. It provides flexible duty cycle as the sensor node goes to sleep state if it hears nothing for activation time out period. This technique reduces the duty cycle if there is nothing to listen and the energy consumption is ke

For the study of T Mac and S Mac we have used Castalia. Castalia [1] uses Omnet‘s [2] features and is designed especially for wireless sensor networks. Omnet is a C++ based open source discrete simulation [3] tool and provides Eclipse [6] based GUI along with several promising features to simulate networking concepts. We can create different test beds for both these protocols by writing an initialization file in Castalia. About these initialization files we will discuss in detail later.

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Since physical layer is implemented according to the original papers for T Mac and S Mac in Castalia, we do not need to start everything from scratch. Operations, such as data rate, delay to carrier sense and physical overhead are three parameters related to physical layer and castalia have tackled these operations very well. Hence Castalia provides a perfect platform for such tests.

II. PRELIMINERIES

A. S Mac Protocol

S-MAC [5] protocol specifically designed for wireless sensor networks is a contention based protocol. It is inherited from CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance).It introduced a periodic “Listen and Sleep” method to avoid idle listening & to reduce the energy wastage. Each node follows a periodic sleep and listen schedule as shown in fig. In listen period, the node senses the network, if found idle, the node performs listening and communicate with other nodes. When sleep period comes, the node will try to sleep by turning off their radios. This significantly reduces the time spent on idle listening. In this protocol the nodes use the RTS (Ready to send), CTS (Clear to send) and Data Acknowledgement (ACK) to communicate. When a node finds a RTS or CTS packet destined for some other node, it goes to sleep mode. This is a periodic process. At the end of sleep mode the node wakes-up and look for some event, if not found it again go to sleep mode. S-MAC proposes a low-duty-cycle operation which reduces energy consumption.

Figure 1. Periodic listen and sleep

A complete cycle of listen and sleep period is called a frame. During sleep period, the node will turn off its radio if possible. In this way, a large amount of energy consumption caused by unnecessary idle listen can be avoided especially when traffic load is light. The nodes in the network make a virtual cluster with its neighbouring node and share a synchronization schedule for listen and sleep period. Thus there may exist more than one cluster in a network. In different clusters the nodes use periodic SYNC packet to find its neighbor. This process is called PND (Periodic Neighbor Discovery).

The S-MAC protocol uses the following to reduce or avoid the four major issues of energy wastage discussed above:

- The scheme of periodic listen and sleep reduces energy consumption by avoiding idle listening.

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- The overhearing problem is avoided by using the in-channel signalling to put each node to sleep when its neighbour is communicating to another node.
- A complete synchronization mechanism, including periodic SYNC packets broadcast is used to avoid collision.
- S-MAC uses only a pair of RTS/CTS for one message passing but requests an ACK for each fragment. This reduces the control packet overhead to a great extant.

The S-MAC protocol essentially trades used energy for throughput and latency. Throughput is reduced because only the active part of the frame is used for communication. Latency increases because a message-generating event may occur during sleep time.

B. TMAC(Timeout-MAC)

In T-MAC [7] all the messages are transmitted in a burst of variable length and there is gap between the bursts called sleep/sleep time. This is to reduce the idle listening. The node awakes periodically to communicate with neighbours and it uses RTS and CTS, Data Acknowledgement (ACK) scheme, which provides both collision avoidance and reliable trans-mission.

In this the messages are stored in a buffer and then a frame is made to transmit containing messages during the active time as shown in fig. The active time ends when there is no active event for a time period TA and the node goes to sleep mode. At the time of high load nodes communicates continuously without sleeping.

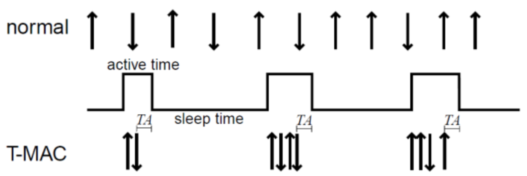

Figure 2

The major disadvantage with this technique is "The early sleep problem". i.e. the node goes to sleep mode even if it its neighbouring node have something to send to it.

It has been found from previous research papers that T-MAC is more efficient than the traditional protocols, Pendulum and Leach protocol.

C. MAJOR ISSUES OF ENERGY WASTAGE

a. Idle listening

When nodes have nothing to send or receive, the nodes still remain in active state and do idle listening to the network. This process consumes equal amount of energy as during transmitting or receiving process. Thus resulting into wastage of energy.

b. Collision or Corruption

Normally collision may occur when neighbouring nodes contend for free medium and lossy channel will result in corruption of transmitted packets. When either of two cases happens corrupted packets should be retransmitted, which increases energy consumption.

c. Overhearing

Which happens when a node receives some packets that are destined to other nodes.

d. Control Packet Overhead

Exchanging control packets between sender and receiver also consumes some energy.

III. CONFIGURATION FILE

According to Omnet's [8] nomenclature these files are named as omnet.ini generally. Castalia have a modular structure and all the modules are interconnected and communicate with each other. The behaviour of these modules can be controlled by modifying the value of parameters according the requirement. This is a property of Omnet to write initialization file and keep the value of most general parameters free from implementation, Castalia enhances this property by enabling users to pass parameter values at run time and user do not need to rewrite configuration file each and every time. Castalia enables to run more than one configuration at simultaneously or even the combination of more than one configuration simultaneously. Every configuration file in a Castalia implementation imports Castalia.ini.

IV. PARAMETERS

Table 1. Common parameters for both protocols

General Parameters	Value
Simulation Time	100 s
Radio used	Telos CC2420
Threshold RSSI(neighbour)	-89.3 Db
Transmission Power	-5 Db

Telos CC2420 is vary commonly used radio in sensor devices. We can vary transmission power and RSSI threshold if required in any simulation.

Table 2 . Various parameters used for both protocols

	S Mac	T Mac
Listen Timeout	61	Not applicable
Time Out Extension	Not required	Required
Collision resolution	Immediate retry	Immediate retry
Activation Timeout	Not Required	15 ms
Use FRTS	Not Required	Required
Ack Packet size	11bytes	11bytes
Sync Packet size	11bytes	11bytes
CTS/RTS Packet size	13bytes	13bytes
Frame time	610 ms	610 ms
Contention Period	10 ms	10 ms
Sync time	6 ms	6 ms
Frame size(case II)	2 KB	2 KB

Conservative activation timeout will always stay awake for at least 15 ms after any activity on the radio. Listen Timeout is generally 10% of Frame time.

V. ANALYSIS AND RESULTS

Following two cases covers all most all the situations of these two protocols because first case analyses a situation when we have several sensor nodes in our network and we want to have look on overall network behaviour, second case analyses individual sensor node in a wide area with general problems like near/far terminals, hidden exposed terminal, collision of packets and application level latency.

A. Case I

In our first consideration there are 100 sensor nodes (Figure 3) those are arranged in uniform fashion in a square field which is 200 m×200 m size. Sensor density is high in wireless sensor network. Parameters are detailed in table 1 and table 2.The study of these two protocols gets more significant because almost all the parameters of both these protocols are same except few, so we can get even clearer picture independent of variable parameters. In this example all the nodes are static as generally happens in real world.

A.Case I

B.

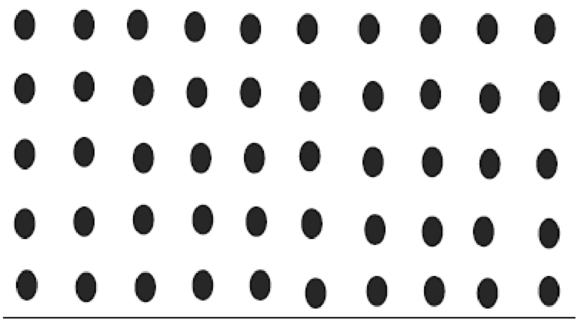

Figure 3. 10×10 nodes wireless sensor network

The energy consumption in S Mac is higher as shown in figure 3. All the nodes from node 0 to node 99 are shown in figure 3.Energy consumption patterns are same for all the nodes respectively which actually depends on the position of sensor node in the experiment field. The nodes on the boundary consume comparatively less energy. This experiment shows better energy Efficiency of T Mac protocol. Energy efficiency was the main design issue for the development of T Mac protocol.

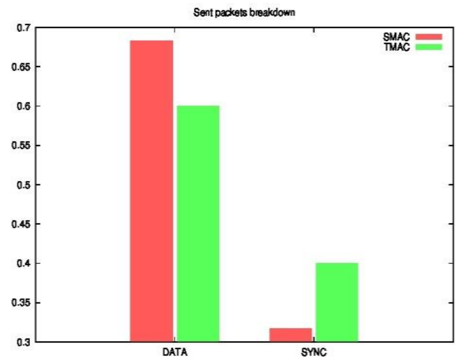

Figure 4. Average Sent packet breakdown for each node

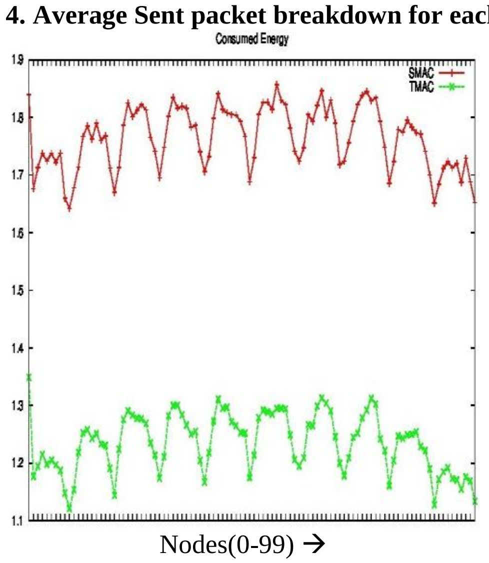

Figure 5. Energy consumption for each node

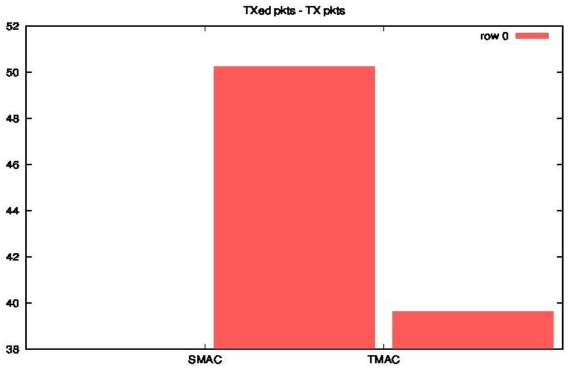

Figure 6. Packets transmitted during transmission mode

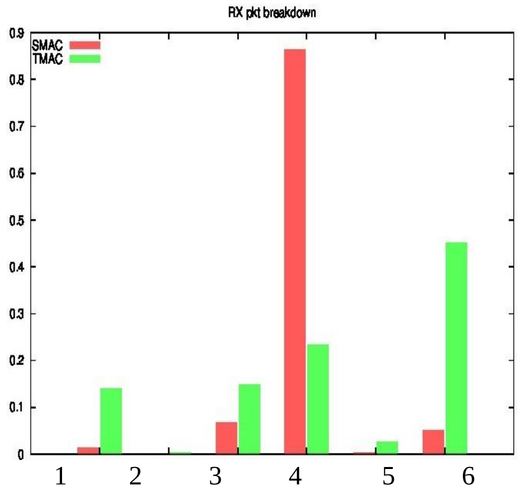

Figure 7. Details of packets during reception mode

1. Failed with No interference
2. Failed with interference
3. Failed below sensitivity
4. Failed, non RX State
5. Received despite interference
6. Received without interference

The difference in these two protocols with respect to energy consumption per node, average number of packets sent by each node, average number of packets during transmission and average number of packets during reception can be illustrated with figure 3, 4, 5 and 6 respectively

T Mac Protocol is more energy efficient due to the introduction to activation time out. FRTS (Future request to send) is also be added to T Mac Protocol which is responsible for large number of control packets in T Mac Protocol. S Mac lesser uses number of control packets. In conditions where large amount of data transfer takes place among sensor nodes then S Mac may perform better because of its simpler implementation. Figure 5 illustrates that in normal conditions S Mac Protocol send more Data packets and less number of Sync Packets than T Mac. S Mac performs better than T Mac in this reference. Figure 6 shows the number of packets during transmission mode in T Mac and S Mac Protocols. Figure 7 is more self explanatory and tells about the sent packets failure and reception.

B. Case II

In our second scenario there are 5 nodes arranged in a linear order. This consideration is useful to cover the

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- Hidden/exposed terminal problem
- Near/far terminal problem
- The effect of collisions
- The mobility nodes
- Latency

Five nodes arranged in linear order are enough to cover all the problems associated with hidden, exposed, near and far terminal problems. To bring collisions to higher effect among the packets transmitted among the nodes we are using large size frames (2 KB). As the length of frame increase the probability of collision increases propositionally. The arrangement can be better understood with figure 8.

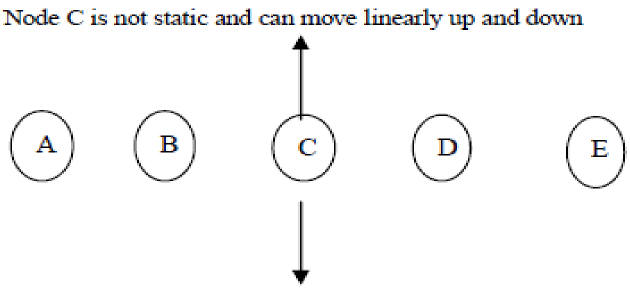
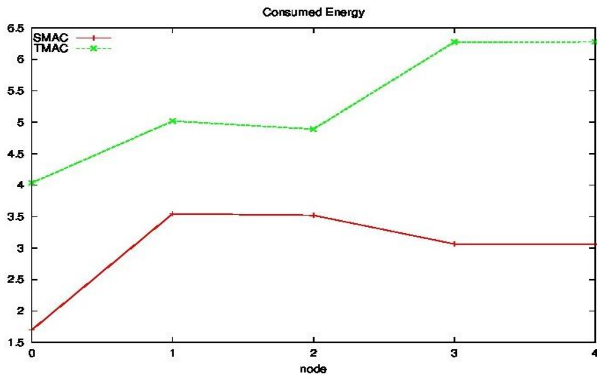


Figure 8. Case II Graphical representation (200×200) m2 area and sensors situated on its diagonal



Fifigure 8. Consumed energy by each node

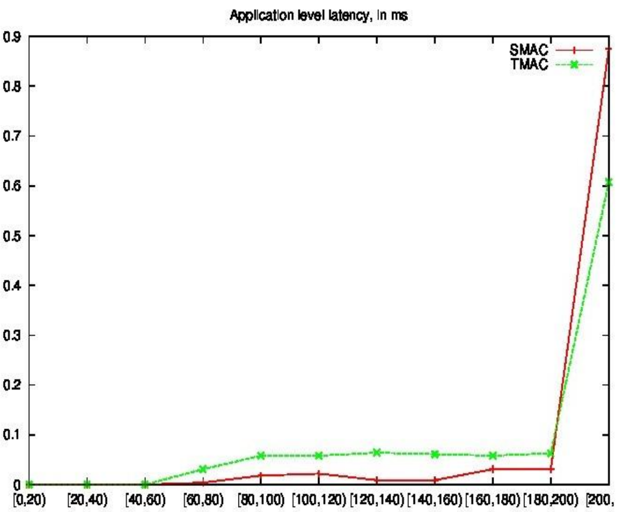


Figure 9. Latency per node in ms

get insignificant..Figure 9 shows the application level latency for all the five nodes in wireless sensor network. S Mac protocol faces severe packet failure in non reception mode. The effect of interference is minor in both the protocols because the sensor nodes in this arrangement are kept far from each other.

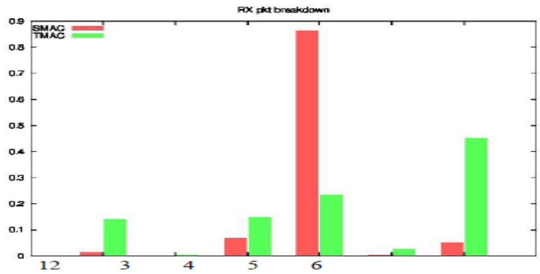


Figure 10. Packets during reception mode

1. Failed with No interference
2. Failed with interference
3. Failed below sensitivity
4. Failed, non RX State
5. Received despite interference
6. Received without interference

VI. CONCLUSION

Previous studies have shown that T Mac is better mac protocol than S Mac protocol because the major criteria of performance in wireless sensor networks is energy consumption and network lifetime. This study gives a more detailed view of these protocols. The S Mac protocol is better in certain aspects like latency and number of control packets sent, still T Mac performs better in low load condition with higher energy efficiency and higher network lifetime. Interference and varying data rate affect both of these but the effects are quite similar. The most important thing about these protocols that can be concluded with this study is that, as we can see clearly by making very few amendments in S Mac, a better protocol is devised; hence these protocols provide perfect templates to design new high performance, contention based wireless sensor network mac layer protocols. By introducing some simple but well thought out mechanisms these protocols can produce tremendous results.

REFERENCES

1. www.omnet.org
2. A. Varga, The OMNeT++ discrete event simulation system, in: *European Simulation Multiconference (ESM'2001)* (Prague, Czech Republic,
3. http://castalia.npc.nicta.com.au/
4. Yuri Tselishchev, Athanassios Boulis, Lavy Libman, "Experiences and Lessons from Implementing a Wireless Sensor Network MAC Protocol in the Castalia Simulator," submitted to IEEE Wireless Communications & Networking Conference 2010 (WCNC 2010), Sydney, Australia.
5. Wei Ye, John Heidemann, Deborah Estrin "An Energy-Efficient MAC Protocol for Wireless Sensor Networks", INFOCOM 2002. Twenty-First Annual Joint Conferences of the IEEE Computer and Communications Societies. Proceedings. IEEE.
6. www.ecilipse.org
7. T. van Dam and K. Langendoen, An adaptive energy-efficient MAC protocol for wireless sensor networks, in: *1st ACM Conf. on Embedded Networked Sensor Systems (SenSys 2003)*, (Los Angeles, CA,November 2003)
8. A. Varga. The OMNeT++ discrete event simulation system. In European Simulation Multiconference (ESM'2001), Prague, Czech Republic, June 2001.

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