An Improved MAC Model for Critical Applications in Wireless Sensor Networks

Gayatri Sakya  
JSSATE, Noida

Vidushi Sharma  
GBU, Greater Noida

Trisha Sawhney  
JSSATE, Noida

ABSTRACT

The wireless sensor networks consists of auto configured large number of nodes, deployed in Adhoc fashion in specific area to gather information and send it to base station for further actions. Energy is the main constraint, when they are deployed in some unattended area for years. Also if the applications are mission critical, then apart from energy the throughput and packet delivery performance also becomes important. In this scenario, according to the distribution of nodes and the network traffic, the protocol must be intelligent enough to adapt changes for saving energy as well as provide efficient transmission of data. This paper studies the popular SMAC protocol and suggests the improvement based on node selection and duty cycle management, to make it suitable for mission critical scenarios. The simulation experiments are done in ns-2.35 in grid and ring scenarios and accordingly the improved protocol model is suggested.

Keywords

Dynamic sleep listen mechanism, wireless sensor networks, mission critical applications

1. INTRODUCTION

Wireless sensor networks [1] are low power devices consisting of sensors, a processor, memory, a power supply, and a transceiver. Since the sensor nodes have limited memory and are typically deployed in unattended locations, a radio is implemented for wireless communication to transfer the data to a base station. [2] Battery is the main source of power in a sensor node. Wireless sensor networks are used in range of applications such as monitoring, tracking and surveillance of borders, in industry for factory instrumentation, in metro cities to monitor traffic and road conditions, in engineering to monitor buildings structures, in environment to monitor forest, oceans etc. To serve these different applications of wireless sensor networks, the protocol stack has not been standardized yet, and the research is continued on each layer to design energy efficient protocols suitable for specific applications.

The MAC protocol has been the research area since past few years because by designing a good MAC protocol, the energy efficiency of the nodes may be increased which is the prime concern in case of wireless sensor networks [1]. The MAC protocols are categorized as i) contention based ii) contention free iii) Hybrid and nowadays according to specific mission critical requirement, they can be categorized as event based, network topology based and mission critical application based. In the second section of the paper, the contention based MAC protocol is studied with the perspective of mission critical scenarios. In the third section the simulation experiments are discussed. In the fourth section the observations and results are discussed and in fourth section a new protocol model is proposed based on dynamic sleep/awake mechanism is discussed. The fifth section of the paper discusses the future aspects of the model suggested.

2. SMAC PROTOCOL REVIEW

In MAC protocols such as IEEE 802.11 designed for wireless LANs, the nodes transceiver must be in active state all the time to receive traffic when there is no traffic. So half energy of nodes get wasted in idle listening. But [3] S-MAC tries to reduce the energy waste from idle listening by making the nodes to go in sleep state in certain interval of time. SMAC design is based on periodic listen and sleep, collision and overhearing avoidance, and message passing. Each node goes to sleep for some time, and then wakes up and listens to see if any other node wants to talk to it. During sleep, the node turns off its radio, and sets a timer to awake it later.
S-MAC gives a controllable parameter called duty cycle, defined by the ratio of the listen period to the frame length which is fixed in SMAC protocol.

So irrespective of the scenarios or the traffic rate, the periodic sleep/awake mechanism follow the same schedule.

Each node follows a fixed sleep/listen schedule throughout the network.

This protocol is implemented by the researchers in ns-2 and also implemented in Mica2 MOTEs platform.

In ns-2, we have tested SMAC in different scenarios and concluded how it can be improved according to our specific requirements like forest fire fighting, smart agriculture system, industrial monitoring applications etc.

\[ T_{\text{frame}} = T(\text{listen}) + T(\text{sleep}) \]

Energy saved in SMAC with periodic sleep is given by \( E_s \),

\[ E_s = \frac{\text{Time (listen)}}{\text{Time (sleep)}} = 1 - \text{duty cycle} \]

So duty cycle = 1 - \( E_s \), Here we are able to observe at low duty cycle, SMAC saves energy.

To increase the energy efficiency, at lower traffic rate we can choose the low duty cycle, but in some applications it affects the throughput, latency and packet delivery ratio of the protocol. So some scenarios are studied here for deciding the duty cycle in specific cases. The purpose is to make an intelligent protocol for such applications.

3. SIMULATION EXPERIMENTS:

The simulation experiments are performed in NS-2.35. The TCL script is written for the different topologies. The .tr file generated is used to extract the information about the residual energy.

3.1. Scenario 1: Two Hop network Topology shown in figure 1

We have simulated a network comprising of 5 nodes in a ring form. Node 0 is taken to be the source and node 2 as the sink node.

\[ \begin{align*} 
0 & \quad 1 \\
3 & \quad 2 \\
\end{align*} \]

Fig. 1 Two hop network topology

i. Network Topology: Now we consider a network of five nodes with following coordinates:

Node 0= (0,0); Node 1=(300,0); Node 2=(300,150); Node 3=(0,150); Node 4=(150,75). Node 0 is taken to be the source and node 2 as the sink. The distance between nodes is taken keeping in mind the maximum transmission range of 250m.

ii. Traffic Pattern: Source keeps sending the 80 byte data packets to sink with varied message inter-arrival time from 0.01 seconds (highest traffic rate) to 50 seconds (lowest traffic rate).

iii. Energy Model: All nodes in the topology have a finite energy of 1000 Joules.

iv. Routing Protocol: The DSR routing protocol has been used in the simulation.

v. Propagation Model: Two ray ground propagation models is employed here.
vi. Energy and Radio Model are set on because we have to perform residual energy computations.

vii. SYNC Flag is set 1, which implies a periodic traffic. The Duty Cycle is then varied in a given range. If SYNC Flag is set 0, change in Duty cycle is meaningless.

The detailed list of all other parameters is shown in the table 1 given below:

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulator</td>
<td>NS2.35</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>10000s</td>
</tr>
<tr>
<td>No. of Nodes</td>
<td>5</td>
</tr>
<tr>
<td>Topology</td>
<td>Mesh</td>
</tr>
<tr>
<td>Routing Protocol</td>
<td>DSR</td>
</tr>
<tr>
<td>Application</td>
<td>CBR</td>
</tr>
<tr>
<td>Transport Agent</td>
<td>UDP</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>10% to 50%</td>
</tr>
<tr>
<td>Traffic Rate</td>
<td>0.0001s to 50s</td>
</tr>
</tbody>
</table>

Table 1 Simulation Parameters

Fig 2 Graph depicting residual energy vs. CBR interval at different duty cycle

The multihop scenario is studied in the above case. It is observed that the residual energy is better in high traffic scenarios duty cycle is 30%. Since the listen time is fixed in SMAC protocol. So sleep time should be adaptive to make duty cycle 30%. The residual energy is minimum at 20% duty cycle and at 40% duty cycle, the network is failed.

3.3 Scenario 2: Grid Topology

We have simulated a network comprising of 9 nodes in a grid form in figure 3. Node 0 is taken to be the source node generating the CBR traffic and node 8 as the sink node.

Fig 3 Grid Topology
Network Topology: Now we consider a grid of 9 nodes with following coordinates:
Node 0=(0,0); Node 1=(150,0); Node 2=(300,0); Node 3=(300,100); Node 4=(150,100); Node 5=(0,100); Node 6=(0,200); Node 7=(150,200); Node 8=(300,200). The distance between nodes is taken keeping in mind the maximum transmission range of 250m. Rest all other things are same as above.

The network is not able to handle the traffic in the grid scenario at any CBR interval when the duty cycles are 10%, 40% and 50%, which implies that the transmission link failed in these cases. Also for duty cycle 20%, the network collapsed for CBR intervals other than 0.1s and 1s.

![Graph showing residual energy vs. CBR interval at different duty cycles]

Fig. 4 Rresidual energy vs. CBR interval at different duty cycles

4. ALGORITHM FOR PROPOSED MODEL

Previous work analyzed various network topologies [4][5] and observed that in [4]linear topology, it was successfully implemented for all values of duty cycles and CBR intervals. However for non-linear topologies like grid and ring, since
1. All neighbouring nodes awake at a time in specific area
2. All neighbouring nodes in a specific area send information to all other nodes.

Hence residual energy and network lifetime of network decreases. Also at high traffic rate and low duty cycle, the network will not be able to handle the traffic in nonlinear scenarios like ring and grid.

So SMAC protocol can be improve in the following manner.
1. All neighbouring nodes should not be awakening at the same time. Only selected nodes in a specific group must be awaken which can complete the path till base station.
2. According to the traffic rate scenario and topology in specific area, the sleep time should be adaptive to optimize the duty cycle.

5. CONCLUSION AND FUTURE SCOPE

In critical[6][7][8][9] applications, like fire fighting, gas leakage and other surveillance applications, the nodes of specific area suddenly become active, so the SMAC protocol which is the bases of MAC protocol design in wireless sensor network can be further improved for the specific applications. The work has already been done to improve it, but this paper suggests a new approach by which improved SMAC can be used in today’s wireless sensor network applications in critical scenarios.

REFERENCES

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