Object-Tracking in Wireless Sensor Networks with A novel Energy Efficient Algorithm

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Abstract— **In this paper we propose and simulate an energy efficient protocol for object-tracking over Wireless Sensor Networks. The proposed algorithm aims to use virtual clustering among the observation region to initiate duty-cycle across the border nodes and the nodes in the inside region. The mean idea is to keep the outer nodes active and the interior nodes sleep for energy saving until an object is detected by the outer nodes. Castalia 3.2 wireless sensor network simulator is used to simulate the proposed protocol. Results indicate that an improvement of 42% is achieved in terms of energy consumption. Furthermore, it is demonstrated that S-MAC protocol is a better choice in high load traffic applications in terms of energy consumption.**

I. Introduction

In 1999, The BusinessWeek expected that the Wireless Sensor networks (WSNs) to be one of most important technologies [1]. The applications of wireless sensor networks are unlimited; it includes all fields where monitoring of a physical quantity is difficult to be performed by humans due to location, time or environmental conflicts. Surveillance systems and continues monitoring, forest fire detection, and chemical plant observation system are few examples of such applications[2-4].

This paper aims to propose and simulate an application specific energy-efficient protocol for object tracking wireless sensor network systems. In this type of applications it is very important to tradeoff between power consumption and other performance metrics because of the life-time requirements of these systems. The simulation is used for extensive testing because the nature of the WSN makes it impractical to use testbeds for hundreds or thousands of nodes [5-7].

In object-tracking sensor networks, the nodes remain awake to sense any target, although, this is the main goal, but it is unpractical to keep all the nodes awake from the energy consumption point of view. Virtual clustering and Regional clustering are not the best solutions when considering the unpredicted object entering the field. Trigged wakeup techniques allowing the nodes to wake up as required, made it possible to put nodes on sleep for longer time till tracking event occur. The need to propose object-tracking specific protocols to benefit from these new techniques has been established and proposed [8-15].

Energy consumption is very important constraint because the node is used once and the life-time of the node must be long enough to support the application. The radio unit of the sensor consumes most of the energy compared to the energy consumed by central processing unit or the sensing device [16]. The idle listening mode in wireless nodes consumes most of the energy likewise transmission or receiving modes. Thus, efficient MAC protocol designs are essential to reduce energy consumption. Scheduled-sleep active/sleep MAC Protocols were introduced in literature to reduce the wasted power in idle listening. S-MAC and T-MAC are the most commonly used to achieve this purpose [17, 18].

II. Problem Identification

One of the most important applications in WSN is tracking of mobile objects [19]. Tracking of enemy, animals, humans and cars in highways are few examples of object tracking. The energy saving techniques may vary according the application requirements. For example, the latency constraint in observing animals is much less compared to observing enemy targets in battlefield. Thus, there are application specific techniques and protocols which can be applied to save energy depending on the nature of the application [20].

In object-tracking, sensor nodes are deployed in different regions. The target may not navigate through all of them. Therefore, there is a need to reduce the energy consumption in those inactive regions where tracking the system is unnecessarily active at all times. Some researchers have proposed Wake up and Sleep mechanics such as clustering and filtering. Clustering leads sometimes to black hole issue while filtering involves very complicated calculations not well suitable to sensor nodes from energy point of view [21].

This paper proposes an improvement on the target tracking algorithm proposed by Wang Duoqiang *et al.* [21]. The original algorithm of Wang Duoqiang *et al*. proposes an approach in which all the boundary nodes are active at all times, and if an intruder is detected, the inside nodes cluster is activated by using a triggered-wake up technique. This allows the inter nodes to sleep when no object is available to track to save energy. The authors assumed that localization protocol and wake up technique are both available. Although the authors tried to reduce the energy consumption of the wireless sensor network by switching on only the nodes around the field, the technique is not saving any energy for the boundary nodes. Also there is no contingency plan if any of the boundary nodes is dying. The proposed changes in this paper make the algorithm more reliable and make the life-time of the boundary nodes longer.

III. Proposed Solution

In [21], the authors save energy based on the idea of a sleep schedule for the nodes. All the nodes inside the monitoring region will remain sleep until they receive a signal from the boundary/head nodes which will be active all the time for object detection. When an object enter the region through boundary nodes, then the major node, which is the nearest node to the object will send a message to the nodes in its area of detection to wake up for some period of time then they go to sleep mode again after the object has left their sensing area.

We propose an automated sleep and wake-up schedule for the boundary nodes itself to make their life-time longer, which can be achieved using T-MAC protocol. Also we propose an out-of-energy algorithm to be automatically triggered whenever a boundary node battery is less-than or equal-to 5% of its full energy level. The algorithm main function is to replace a dying boundary node with the nearest inter node.

A. Proposed Algorithm

This paper focuses on an automated sleep schedule for boundary nodes. T-MAC protocol is used so that the boundary nodes will automatically start a scheduled sleep based on their location as boundary node, while the interior nodes will remain sleep till they receive a wakeup call from one of the outer nodes in case of object detection as shown in Figure 1. The red circles indicate the active nodes, while the green circles are the sleep nodes.

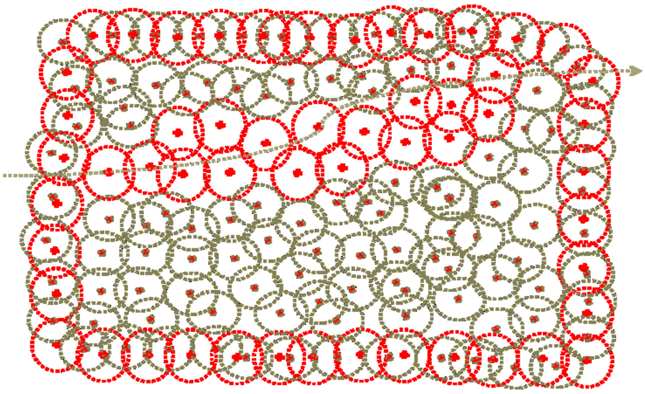

Fig 1 Virtual- Clustering Automated sleep schedule for boundary nodes

We also propose an algorithm that acts as a contingency plan for any boundary node that is dying. Hence we are protecting the whole system from being destroyed when losing boundary nodes. For this purpose an algorithm was developed to transfer the responsibility of the dying node to the adjacent node in its sensing area while it passes on the information to the nodes in that area. The algorithm works as follows:

```
If (E ≥ 0.05*Ef AND i is a boundary node)
  {
  Send WM to Ni nodes
  localize Ni , and calculate di
  loop (K=1 to k= n , where n is Number of Ni nodes)
  If (Jn ≠ a boundary node & di= Min(dk, dk=1, dk=2..dn)
     { send, New ID = ID , Tw, die };
        Else { ignore , k=k+1}
   }
```

where, Battery level can be measured

~ *Ef* is max level

~ *Ni* is the nodes in sensing area of node (i)

~ *di* 1 ,2 ,3…K is the distance between node *i* and it's sensing radius neighbors *i(n)*

The minimum number of nodes in the boundary coverage is given by [21]:

$$Nmin = L/R$$

Where, L is the length of the boundary of the monitoring region and R is the sensing radius. In this paper when using the T-MAC model at any instant of time, the minimum number of active nodes in the boundary will be approximated:

$$Nmin= L/2R$$

This means that the number of active boundary nodes at any instant of time is 50% less. According to [21], the proportion of boundary nodes to all nodes is:

$$P = Nmin/ N= (4L/R)/(pL^2) = 4/LpR$$

According to our proposed improvement this will be:

$\boldsymbol{P=2/(LpR)}$, where p the node density

Based on this mathematical model, we expect to save more energy in the boundary nodes and make their life-time longer with 40% more.

IV. SIMULATION

Castalia WSNs simulator has been selected to demonstrate the performance of the proposed algorithms. 136 nodes were deployed on field of 10x10 meters according to the configuration given in Table 1.

TABLE I NODE DEPLOYMENT CONFIGURATIONS TABLE

Node ID	Deployment type	Code used
0 to 99	Gird	*SN.deployment = "[0..99]->10x10"*
100 to 135	Manually located around the field	*SN.deployment = "[100..135]->" SN.node[ID].xCoor = X SN.node[ID].yCoor = Y*

The configuration in Table 1 creates a deployment that is shown in Figure 2. The outer nodes are manually allocated by using Cartesian coordinates to simulate the assumption that automatic allocation algorithm is implemented in the nodes. By grouping the nodes according to their ID to two groups; Outer and Interior nodes; a virtual clustering is created within these two groups. The main goal of this simulation is to compare the power consumption when no energy saving protocol is used and the case when an approximate configuration to the proposed protocol is used.

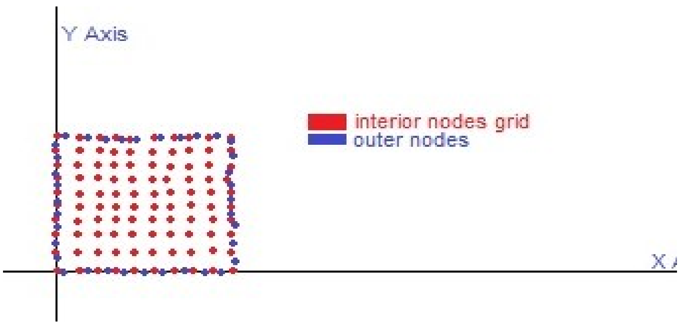

Fig 2 Node Deployment Setup

In the first scenario we simulate the case when no energy saving protocol is used. This means that all the nodes in the field are active all the time. The assumptions used in this case are:

- All nodes are active.
- No energy saving MAC is used.
- CC2420 Radio parameters will be used.
- Throughput Test application is used.

In the second scenario we simulate the case using our proposed protocol. The assumptions used in this case are:

- The interior nodes are sleep until an object is detected after sometime then they start to be active.
- Throughput Test is used.
- The outer nodes are active at the beginning of the simulation.
- TMAC protocol is enabled for the outer nodes to simulate the duty cycle sleep schedule within the outer nodes.
- CC2420 Radio parameters are used.

A. Simulation Results

Figure 3 shows the improvement in energy consumption using OTP (Object-Tracking Proposed Protocol) compared with no energy saving protocol.

Figure 4 shows the effect of using different MAC protocols on energy consumption, with high traffic application throughput test. Figure 5 shows the effect on energy consumption of using different power transition levels for each MAC protocol used in conjunction with the proposed protocol.

Figure 6 shows that TMAC has better performance over SMAC for 1000 maximum MAC layer packet size, while keeping the payload at 2000. Also, it demonstrates that changing the payload and the packet rate has significant effect on the type of MAC used in terms of energy saving.

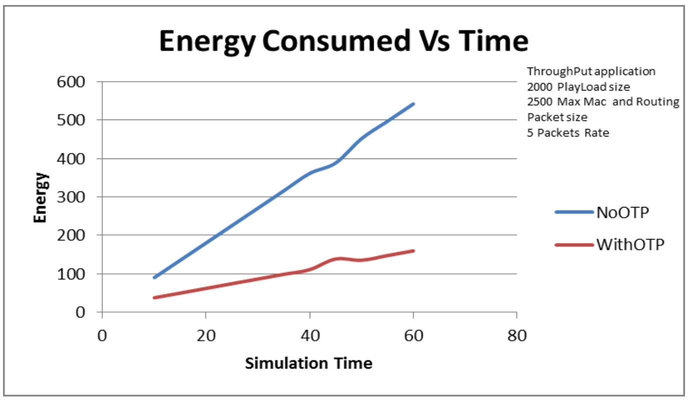

Fig 3 Power Consumption VS Time with and without using the proposed

protocol

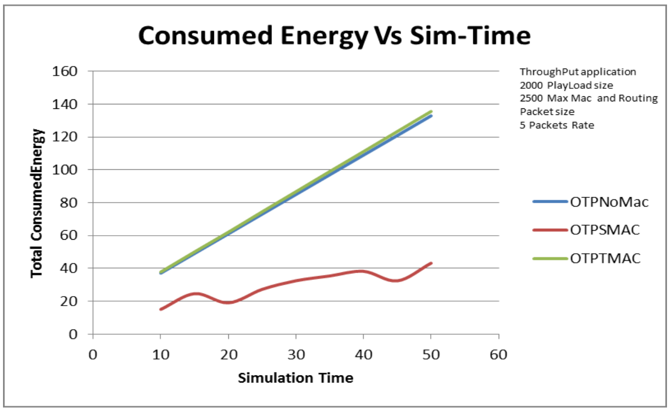

Fig 4 Energy Consumption VS Time with use of different MAC Protocols

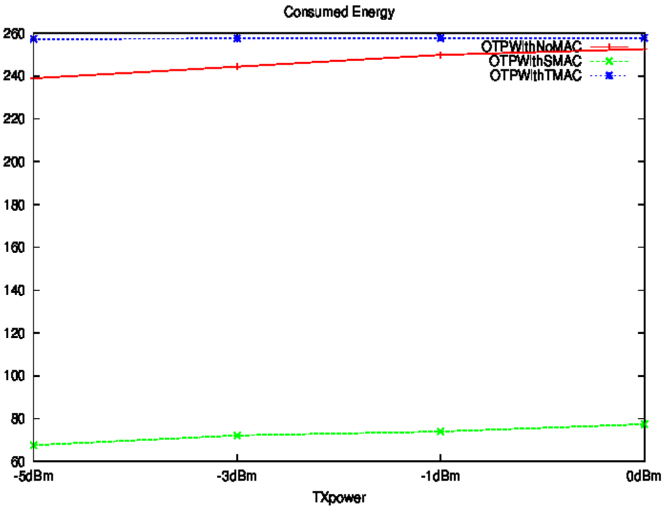

Fig 5 Energy consumption VS TX Power for of different MAC protocols, 2500 Max packet size

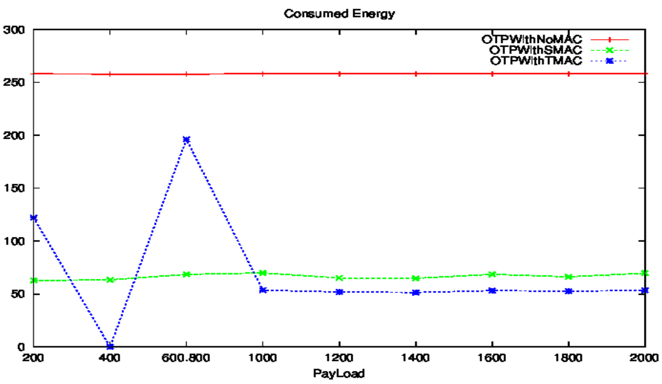

Fig 6: Energy consumption VS TX Power for of different MAC protocols, 1000 Max packet size

Figure 7 shows the effect of using different payload on energy consumption for each MAC. Figure 8 shows that there almost no effect on energy consumption while changing the data packet rate in the application we used, because all the nodes are sending to the sink node in this application. Although there is low packet rate for each node, the overall channel will be busy.

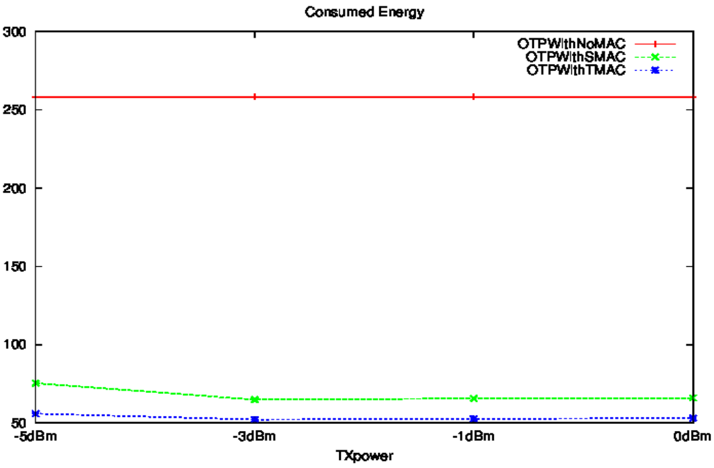

Fig 7 Energy consumption VS payload for each MAC used with OTP.

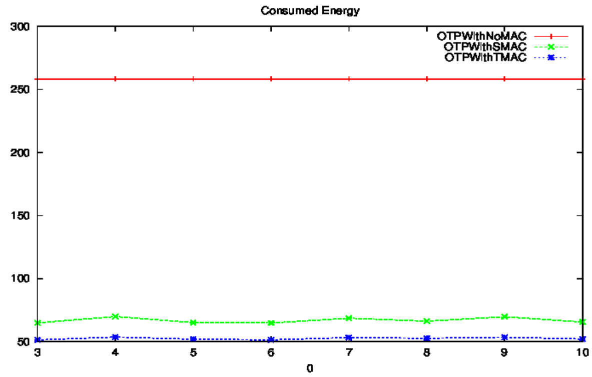

Fig 8 Energy Consumption vs Data Packet Rate per second, with 1000 payload, 2000 Max MAC Packet size

V. CONCLUSION

This paper proposes an application specific protocol to be used for object-tracking systems. The protocol is based on virtual clustering by dividing the nodes into two groups; interior and boundary nodes. The results demonstrate an improvement of performance in terms of energy consumption. The simulation establishes the following results:

- the proposed protocol improves energy consumption,
- SMAC has better performance over TMAC,
- changing the payload size affects only TMAC's performance and it is better to use TMAC with larger payload, and
- changing the data rate has no effect on the energy performance in case of using an object tracking application.

These results emphasize that an application oriented energy efficient protocol is better solution for the energy problem in object-tracking systems.

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