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A Prediction based Energy-Efficient Tracking Method in Sensor Networks

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***Abstract** - Energy is one of the most critical constraints for sensor network applications of tracking. Object tracking is an important feature of the ubiquitous society and also a killer application of wireless sensor networks. Object Tracking Sensor Network is mainly used to track certain objects in a monitored area and to report their location to the application's users. On the other hand, Object Tracking Sensor Network is familiar for their energy consumption when compared with other WSN applications. Based on the fact that the actions of the tracked objects are sometimes knowable, we propose a Prediction-based Energy Efficient tracking technique using sequential patterns deliberate to achieve considerable reductions in the energy degenerate by the Object Tracking Sensor Networks while maintaining tolerable missing rate levels. The intended method can not only decrease the missing-rate by predict future movements of moving objects, but can also reduce the energy consumption by sinking the number of nodes that join in tracking i.e., the majority of the sensor nodes stay in sleep mode and minimizing the communication disbursement.*

***Index Terms**- Object tracking, wireless sensor networks (WSNs), prediction based energy efficient technique, object tracking sensor network (OTSN).*

I. INTRODUCTION

Recently, an increasing interest in deploying wireless sensor networks (WSNs) for real-life applications. OTSN is mainly used to track certain objects in a monitored area and to report their position to the application's users.

Object tracking, which is also called target tracking, is a major field of research in WSNs and has many real-life applications such as wild life monitoring, security applications for buildings and compounds to avoid interference or trespassing, and international border monitoring for prohibited crossings. Additionally, object tracking is measured one of the most challenging applications in WSNs due to its application requirements, which place a heavy load on the network resources, mainly energy consumption. The main task of an object tracking sensor network (OTSN) is to track a moving object and to report its latest location in the monitored area to the application in an acceptable timely manner, and this dynamic process of sensing and reporting keeps the network's resources under heavy pressure. However, there has been a very limited focus on the energy lost by the computing components, which are referred to as microcontroller unit (MCU) and the sensing components [4]. Although the energy dissipated by the MCU and the sensing component is less than what is consumed by the radio component, it still represents a significant source of energy consumption in the sensor node. Therefore, our concern in this paper is to develop an energy-efficient OTSN that should make remarkable reductions in the energy consumed by both the MCU and the sensing components.

OTSN is considered as one of the most energy-consuming applications of WSNs. Due to this fact, there is a necessity to develop energy-efficient techniques that adhere to the application requirements of an object-tracking system, which reduce the total energy consumption of the OTSN while maintaining a tolerable missing rate level. [1].

In this paper, we map the prediction-based tracking technique using prediction model, which is an object tracking technique that gives ability to predict the objects' future movements to track it with the least number of sensor nodes while keeping the other sensor nodes in the network in sleep mode. This would accomplish our goals while notably reducing the network's energy consumption. The PTSP is based on the inherited patterns of the objects' movements in the network and the utilization of sequential patterns to predict to which sensor node that the moving object will be heading next. Since the PTSP totally depends on prediction, it is possible to have some missing objects during the tracking process.

The main contribution of this paper is the prediction technique that will be used to predict the future location of a moving object. The remaining section of this paper is organized as follows: Section II reviews the related work regarding the algorithms proposed for object tracking in WSNs. Section III gives our proposed tracking framework for moving objects. Section IV provides a performance study for our proposed schemes. Section V concludes this paper.

II. RELATED WORK

Dissimilar types of techniques have been proposed in the literature for object tracking in WSNs [3]. In their work, they classified object-tracking techniques into five main classes, which are naive, schedule monitoring, continues monitoring, dynamic clustering,

In the first technique all the sensor nodes stays in active mode and monitor their detection areas all the time and sends the detected data to the base station periodically. Therefore, the energy consumption is high [3],[4].

The scheduled monitoring scheme assumes that all the sensor nodes and base station are well synchronized, and all the sensor nodes can turn to sleep and only wake up when it comes to their time (turn) to monitor their detection areas and report sensed results. Thus, in this scheme, all the sensor nodes will be active for X second then go to sleep for (T − X) seconds.. However, actually the assumption that all sensor nodes and base station are well synchronized is very difficult to be realized and the number of sensor nodes involved in object tracking is more than necessary. Hence the energy consumption is high[3],[4].

Continuous monitoring scheme, instead of having all the sensor nodes in the sensor network wake up periodically to sense the whole area, only one node which has the object in its detection area will be activated. Whenever a node wakes up, it will keep on monitoring the object until it enters a neighboring cell. In order to reduce the missing rate, the active sensor has to stay awake as long as the object is in its detection area. This causes the unbalanced energy consumption among the sensor nodes and thus reduces the network lifetime [2],[3].

The another scheme is Dynamic Clustering which the network is formed with powerful CH nodes and low-end SN nodes. The CH node which has the strongest sensed signal of target becomes the cluster head and organizes nearby SN nodes to form a cluster. The SN nodes in the cluster transmit the sensed data to the cluster head, and then the cluster head sends digested data to base station after data aggregation After cluster formation there is no rotation in cluster head, object travels at high speed so cluster head would consume high energy [2],[3].

These techniques use energy level as high, which is used to track the object and also cannot predict the position movement of the object. A number of works have been proposed in the literature for using sequential patterns, in WSNs. Most of these works aim to generate hidden patterns in the area of phenomena under monitoring such as temperature and medical data[13],[14]. However, there are some works that have been proposed to generate patterns about the sensors' behavior. In [10], the authors proposed sensor association rules in an attempt to capture the temporal correlations between the sensor nodes in a particular WSN[6]. Sensor association rules generate patterns concerning the sensor nodes; thus, these patterns can be used to develop the quality of service (QoS) of the network, predicting the source of missed objects or estimating the value of a missed reading.

III. PREDICTION-BASED TRACKING TECHNIQUE USINGSEQUENTIAL PATTERN

Object-tracking sensor network (OTSN) is a widely used technique to track certain objects in a monitored area and to report their location to the application's users. On the other hand OTSNs are well known for their energy consumption when compared with other WSN applications. Due to this fact, there is a necessity to develop energy-efficient techniques that adhere to the application requirements of an object-tracking system, which reduce the total energy consumption of the OTSN while maintaining a tolerable missing rate level[4].

The prediction-based tracking technique using sequential pattern (PTSP), which is an object tracking technique that revolves around the ability to predict the objects' future movements to track it with the minimum number of sensor nodes while keeping the other sensor nodes in the network in sleep mode. This would achieve our goals while significantly reducing the network's energy consumption. The proposed PTSP is based on two stages:

a. Sequential Pattern Generation

b. Object Tracking and Monitoring

These stages use three mechanisms for tracking to reduce energy usage asshown in Figure1.

If the object entered into the monitoring area, it reads the object and predicts future movement by mechanisms [1].

1. Operation of PTSP

MECHANISMS

The PTSP consists of three parts. These are

1. A prediction model which anticipates the future movement of an object so only the sensor nodes expected to discover the object will be activated;
2. Awake up mechanism that, based on some heuristics taking both energy and performance into accounts, sets up which nodes and when they should be activated;
3. A recovery mechanism initiated only when the network loses the track of an object.

Prediction algorithm at sensor nodes

Incoming Message: HistMsg(*Hist*)

Local Variables: *Sen Read, Pred*

System Functions: *Predictor*()

Procedure:

{Once the object enters the detection area, the sensor predictsobject's movement from history}
Pred ← Predictor(Hist)
while** object is inside the detection area **do
monitor the object, record the sensor readings to Sen Read
end while
if** (Sen Read _= Pred) **then
Send Update Msg(Sen Read) to cluster head
end if
{Calculate object's movement history from the previoushistory and movement in its detection area}
Hist ← (SenRead,Hist)
send HistMsg(Hist) to destination node

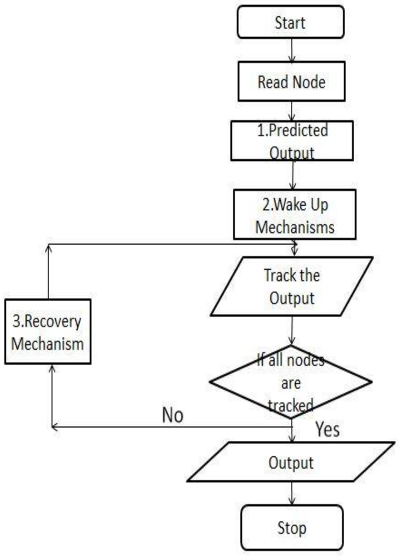


Figure:1 Flow chart for PTSP

Wake up Mechanism

No matter what kind of heuristics we use, we do not expect the prediction to achieve 100% accuracy. In this case, prediction errors means object missing, which causes excessive energy overhead for re-locating the object. To accommodate the prediction errors, a set of target nodes are woken up to help capturing the object, instead of only one destination node[9].

We propose a wake up mechanism [4], that decides the membership of the target nodes based on the different levels of conservativeness shown in Figure:2.

SEQUENTIAL PATTERN GENERATION

The huge log of data collected from the sensor network and aggregated at the sink in a database, producing the inherited behavioral patterns of object movement in the monitored area. Based on these data, the sink will be able to generate the sequential patterns that will be deployed by the sink to the sensor nodes in the network. This will allow the sensor nodes to predict the future movements of a moving object in their detection area[10].

OBJECT TRACKING AND MONITORING

In the second stage, the actual tracking of moving objects starts. Object tracking consists of two stages: sensor node activation occurs when the next sensor that should wake up is decided, whereas missing object recovery, which is the second stage, involves the location of missing objects. This stage works based on two mechanisms:

1. Sensor Node Activation mechanism, which entails the use of the sequential patterns to predict which node(s) should be activated to continually keep tracking of the moving object.
2. Missing object recovery mechanism, which will be used to find missing objects in case the activated node is not able to locate an object in its detection area.

IV. PERFORMANCE EVALUATION

To evaluate this technique, different scenarios and settings have been implemented using a GloMoSim simulator. The simulation experiments carried out in an OTSN of 55 logical sensor nodes in a $1000 \times 1000m^2$ monitored region. It is assumed that each sensor node will have a coverage range of 15 m. The network is based on a hexagon topology, i.e., sensor nodes are evenly placed in the area such that each sensor node has a hexagon-shaped detection area. The default speed of the tracking the object = 5m/s.E_{wake}=0.5mw, E_{sleep}=0.05mw, TS=100seconds, X=180seconds, T=210seconds.

We have assumed that an object may choose a random path. The ratio of the key paths to the random paths is 3:1. The sampling duration will be 210ms (X), and the OTSN will send a report regarding the location of the moving object every 2100 ms (T) to the application. Each simulation experiment will last for 280s which will include more than one object.

As for the energy consumption, we have adopted the WINS energy consumption for sensor nodes used in PES [5] (see Table I). We have only included the MCU and the sensing components' energy consumption since our proposed tracking technique focuses on reducing the energy consumption on those two components. The energy consumption for the radio component will be the subject of our future research. We will show different charts depicting performance under variations of the preceding parameters, and we will thoroughly analyze their effect on the results.

Two metrics have been used in the performance analysis.

1) Total energy consumed:the amount of energy consumed by the whole network to monitor moving objects, which include the active and sleep modes during the simulation.

2) Missing rate:The missing reports' percentage to the total number of reports that should have been received by the application. Since there is no 100% prediction, it is necessary to have this metric as a basic for comparison.

Energy Consumption Analysis

In this, we have tested and compared PTSP to the other basic tracking schemes, i.e., SM and CM, in the context of network workload. The experiments were conducted by increasing the number of moving objectsfrom one to ten objects. The naïve technique is participation of all nodes, consumes energy 2.75w

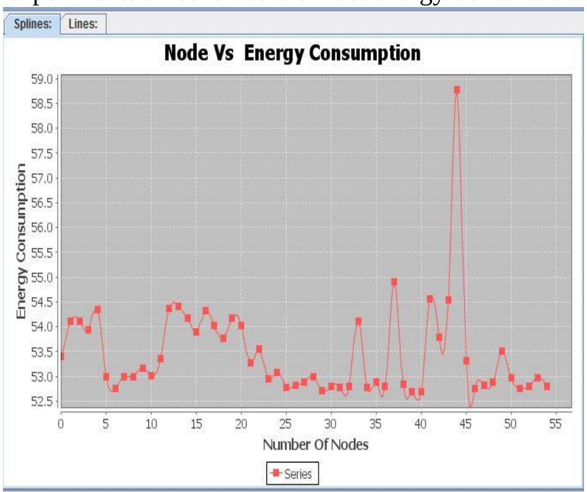
The continuous monitoring is participation of all nodes not continuously, consumes energy 0.39w.The scheduled monitoring consumes energy 0.32w. The planned PTSP technique consumes 0.2709mw energy for tracking the object which reduces energy consumption of 15.5%

As a result, if the network has a large number of moving objects, then the most ideal scheme would be SM shown in Figure:5. In the case of CM and PTSP, the increase in the number of objects means an increase in the number of active sensor nodes and, thus, higher energy consumption levels shown in Figure:3 and Figure:4.

Schemes	Nodes Involved	Continuous	Energy Consumption
Naïve	All(=*S*)	Yes	Ewake × TS × S
SM	All(=*S*)	No	((Ewake × X + Esleep × (T − X)) ×(TS/T) × S
CM	One for each object	Yes	Ewake × TS + Esleep × TS × (S − 1)
PTSP	One for each object	No	Ewake × (TS/T)+ Esleep × (TS × S – (TS/T)× X)

Recovery Mechanism Analysis

In this experiment, we have evaluated the three previously explained recovery mechanisms (source recovery, destination recovery, and all neighbors recovery) in terms of energy consumption. Therefore, we have chosen the first recovery mechanism (source recovery) as our recovery mechanism of choice in all the previous experiments since it was the most energy-conservative recovery mechanism.



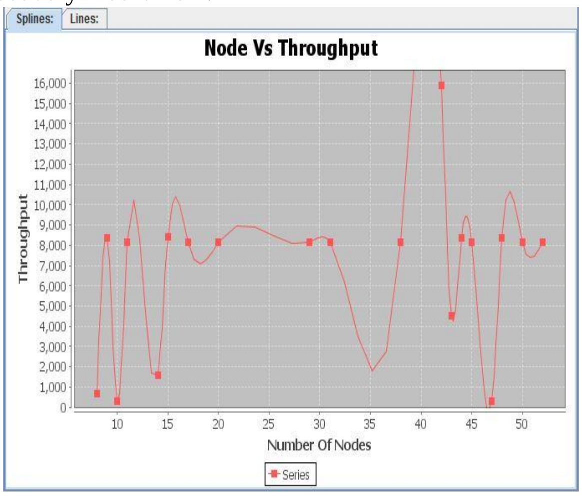


Figure:4.Illustration of Energy Throughput

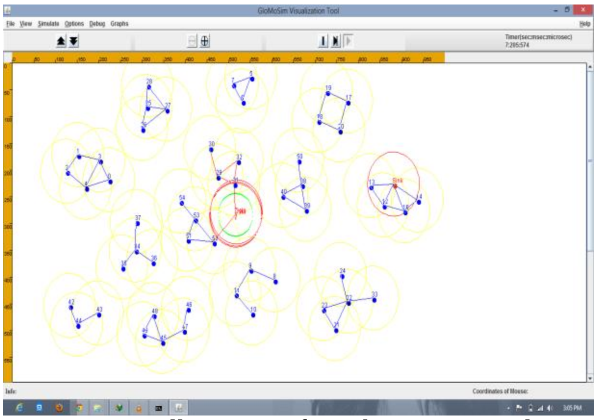


Figure:5.Illustration of Tracking sensor nodes

V. CONCLUSION

A Prediction based Energy Efficient Technique is proposed for tracking the object in wireless sensor networks, by reducing energy consumption, which minimizes nodes participation, has been achieved. PTSP utilizes the sensor sequential patterns to produce accurate predictions of the future movements of a certain object. These sequential patterns are continuously evaluated and updated to provide the prediction mechanism with the late stand most accurate predictions. We have simulated our proposed tracking scheme (PTSP), along with two basic tracking schemes for comparison purposes. The results generated by the experiments were mainly through testing the performance of PTSP and the other tracking schemes such that the total energy consumed by the network during the simulation period, including the active and sleep mode energy consumption for each sensor node in the network, and missing rate, which represents a ratio of the missing reports to the total number of reports received by the application. Moreover, it has been verified by the simulation results that PTSP outperformed all the other tracking schemes by observance allow energy consumption level while maintaining an adequate level of missing rate.

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