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A Survey on Energy Efficient Target Tracking Techniques in Wireless Sensor Networks

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Abstract— ***Wireless sensor networks (WSNs) find its application in areas such as target detection and tracking, environmental monitoring, industrial process monitoring, and tactical systems. Energy efficiency is one of the important research issues in WSNs, since it determines the lifetime of the sensor network deployed for the intended applications. Target tracking is one of the killer applications of wireless sensor networks and energy-efficient target tracking algorithms are used for accurate tracking. In this paper, the focus is mainly driven over the survey of the different energy-efficient target tracking techniques for Wireless Sensor Network.***

Index Terms—***Clustering, Prediction, target tracking, Wireless Sensor Networks.***

I. INTRODUCTION

Wireless Sensor Networks applications are attracting more and more research, especially in energy saving techniques which is the focal point of most researchers in this area [1]. One of the most interesting applications of Wireless Sensor Networks is the Object Tracking Sensor Networks (OTSNs) which are used mainly to track certain objects in a monitored area and to report their location to the application's users. This application is a major energy consumer among other Wireless Sensor Networks applications. There have been great advances in the last few years regarding wireless technologies that made them highly attractive for many applications especially military and commercial applications. Since wireless networks have great advantages over wired networks, being significantly more flexible towards changes in network topology, provides ad hoc networking, allows network users to become less restricted to be in certain locations and remarkably cost-effective construction with less hassle than creating a wired network. A strongly emerging name in the wireless technologies is the Wireless Sensor Networks which became one of the most researched subject in wireless networks [2].

A. Object Tracking

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 prevent intrusion or trespassing, and international's borders' monitoring for illegal crossings. Furthermore, object tracking is considered one of the most demanding applications in WSNs due to its application requirements which place a heavy burden on the network resources, especially 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 [2],[3]. Object Tracking Sensor Network (OTSN) is considered 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 [3].

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II. TECHNIQUES FOR OBJECT TRACKING

One of the major applications of WSN's is object tracking. In which energy efficiency is a major issue in WSN. There are different methods who try to address this issue. In this paper we focus on some of the methods.

A. Prediction-Based Tracking Technique using Sequential Pattern [PTSP]

Prediction-based tracking technique using sequential pattern is one of the object tracking technique that predict the future movements of the objects that track with the minimum number of sensor nodes. PTSP is based on two stages: Sequential pattern generation, Object tracking and monitoring [4],[5],[6]

(1) Sequential Patterns Generation

In this section, we highlight the main steps required for generating the Sequential Patterns.

1. Sequential-Tri-Sensor Patterns: In the proposed prediction model we are going to use a special form of Sequential Patterns, namely Tri-Sensor Patterns. Tri-Sensor Patterns can be represented as follows: Source Sensor, Current Sensor, and Destination Sensor. This represents the chronological ordering of the sensors detection of a certain moving object in the network. Furthermore, in order to evaluate the statistical significance of a certain Tri-Sensor Pattern, we have to calculate the confidence, in addition to its support, of each particular. Tri-Sensor Pattern. This can be viewed as the estimate of the probability P(Y |X), which is the probability of finding the right-hand-side (RHS) of the pattern in sequences while these sequences also contain the left-hand-side (LHS) of the pattern. Therefore, the confidence of tri-sensor pattern (*source sensor*, *current sensor*) =⇒ (*destination sensor*) is calculated as follows:

supp (source sensor, current sensor, destination sensor) / sup (source sensor, current sensor). "Movement Patterns Acquisition", our methodology describes the generation of Sequential Patterns in order to use them in our prediction model.

2. Movement Patterns Acquisition: The first major part of the proposed prediction technique is generating object movement patterns. As every object moves, its movement path and the sequence of sensors detecting it gets recorded into a database. Each tuple in the database will contain the object ID and the ID of the sensor that detects this object along with the time of

detection. The tri-sensor movement patterns can use sequential pattern generation. Pattern simply records the source sensor, the current sensor and the destination source. Each sequence of sensors will be transformed into tri-sensor patterns in the following form:

Source Sensor, Current Sensor, Destination Sensor. These patterns are generated in an overlapping manner where the *Current Sensor* becomes the *Source Sensor* and the *Destination Sensor* becomes the *Current Sensor*, whereas the *Destination Sensor* will be the next sensor in the sequence. Figure 1 demonstrates how the tri-sensor patterns are generated in an overlapping manner from the sequence of detections by the sensor nodes of the OTSN for a particular moving object.

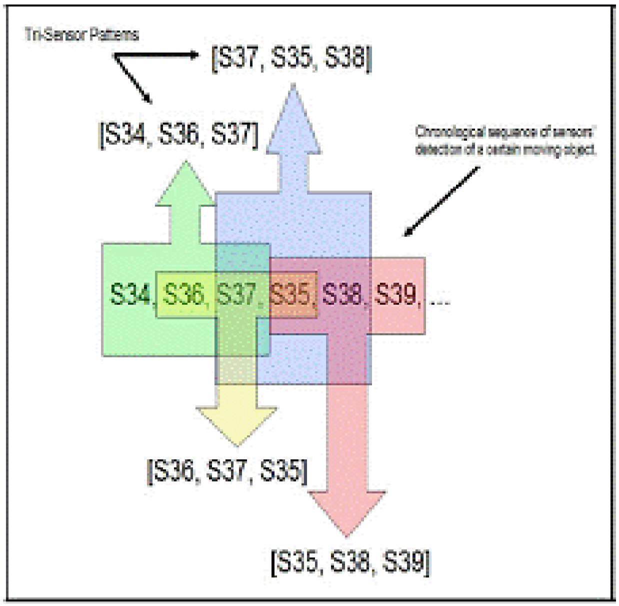

Fig. 1 Tri-Sensor Patterns Generated

As the patterns accumulate, we can find the most repeated patterns. For example, if we found that the pattern *S*3, *S*6, *S*8 occurs too frequently, we can tell that if an object is at *S*6 coming from *S*3 then most probably it will head to *S*8. We call this process, Sequential Patterns' generation. We can derive all sequential patterns along with their confidences. Therefore, prediction is achieved using these Sequential Patterns. The higher the confidence, the better the chance of predicting the next sensor right [7].

(2) Object Tracking and Monitoring

After the completion of the first stage of the PTSP, Sequential Patterns Generation, the second stage starts which is Object Tracking and Monitoring. The key objective of this stage is to keep in sleep mode for the longest possible period any sensor node that has no object moving in its detection area, and thus saving its energy. This stage has two parts: Activation Mechanism and Missing Object Recovery Mechanism. The use of the Activation Mechanism is to predict which node should be activated continually to keep track of the moving object. The missing object recovery mechanism is used to find the missing object in case of the activated node is not able to locate an object in its detection area. Sequential Pattern(s) on a particular sensor is based on the minimum confidence level required by the application would require from any Sequential Pattern before it could be used to predict the future movements of a moving object [2]. Therefore, if the application sets the minimum confidence level at 70%, then any Sequential Pattern with a confidence level lower than 70% will not be executed [7].

A. Multi-Target Tracking

In Multi-Target Tracking more than one sensor nodes tries to identify the objects which comes under the range of each sensor.

(1) Joint Sensing

In this, it is assume that each ultrasonic sensor installs the sound wave emitter and receiver and all the sensors in the network are homogeneous and time synchronized. Normally an ultrasonic sensor adopts the active sensing mechanism where the sensor emits sound wave and measures the reflected echo from the target. The Time Of Flight (TOF) is converted into range information towards the target. Sensors are adopt a simplified cone shape detection region model for a typical ultrasonic sensor, where one ultrasonic sensor „i" is characterized by its location (X_{si}, Y_{si}), orientation Θ_i, detection angle α , and detection range d. The TOF equals to the round trip time of the wave from the emitting sensor to the target and then back to the emitting sensor, which corresponds to the round trip distance of the sound wave that is bounded by 2d.

The target can be jointly sensed by two sensors, if the following joint sensing conditions are satisfied:

1. The target is within the detection angles of both sensors;
2. The sum of distances from the target to the sensors is less than 2d;
3. The two sensors are not within line of sight with each other (i.e., not within the detection angle of each other).

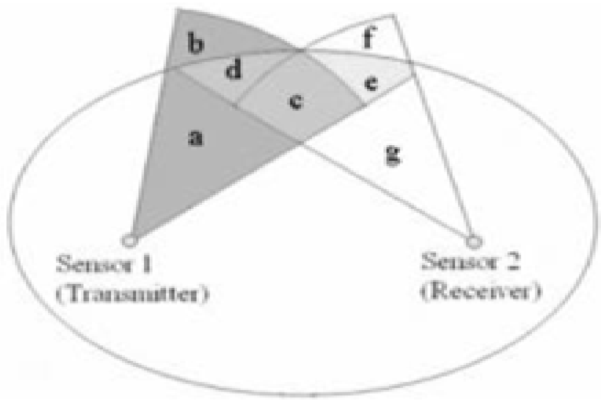

Figure 2 Joint Sensing Region

As an example, Fig. 2 shows the joint sensing region of sensors 1 and 2, when sensor 1 is the emitting sensor and sensor 2 is the receiving sensor. The ellipse consists of all points where the sum of its distances to sensor 1 and sensor 2 are 2d. The target must be inside this ellipse if sensor 1 and sensor 2 can jointly sense the target. In above Figure areas a and b can only be sensed by sensor1 individually, as any point in area a is not in the detection angle of sensor 2 (i.e., not satisfy joint sensing condition 1) and the sum of the distances from any point in area b to sensor 1 and sensor2 is larger than 2d (i.e., not satisfy joint sensing condition 2). Areas c, d, and e can be jointly sensed by sensor1 and sensor2 as any point in them satisfies the three joint sensing conditions. The target located in area e can also be jointly sensed, which indicates that joint sensing can increase the detection region of

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individual sensors. In addition, if the target is located in area c or d, it can be obtain two sensor measurements, one is the distance from sensor 1 to the target, and the other one is the sum of the distances from sensor 1 to the target and from the target to sensor 2.

(2) Adaptive Scheduling

A serious problem in WSN of active sensors is the inter-sensor interference (lSI) when nearby ultrasonic sensors emit sound wave simultaneously [7]. In Adaptive Scheduling each sensor is assigned with some Active sensing time. In that duration the particular sensor senses the data which avoids the inter-sensor interference.

(3) Collaborating Sensing

Collaborative sensing is used to stand for joint sensing and the joint sensing enabled adaptive sensor scheduling [7]. Here one sensor senses the object and that sensed information will be transferred to remaining other sensor nodes. And, this information will be transferred to the fusion node which acts as a central node from which the base node collects the data each time. Among all nodes any nodes can be turned to fusion model. When fusion node receives the data it acknowledges to the sender sensor node by mentioning the next active time for that sensor node. Then that sensor node will move to sleep mode. So every other node within the region performs the same operation. Every node will have the information regarding the all objects which are sensed by individual nodes within its range.

B. Mobile Data Collector (MDC)

In this technique, we propose an Energy efficient mobile sink based technique which helps in tracking of an object [8]. Cluster based and non-cluster based protocols are the two classifications of the object tracking protocols in WSNs. The information is forwarded to the cluster head on detecting the object by a non-cluster head sensor node. The information is collected by the cluster head and propagated to the sink. The required communication bandwidth is reduced. No node serves as the cluster head in non-cluster based protocols in WSNs. The information about the moving object is recorded in sensor's local memory when a sensor detects an object. The location of the tracked object can be known by the user by issuing a request. The information is replied to the user when the sensor contains the information of the tracked object [6]. The detection and tracking of continues object in a wide geographical area [8] the problem gets intensified further, so only boundary of the continuous object need to be detected in an efficient approach. There are two critical operations in the continuous object tracking: Monitoring, Reporting. Within each cluster, we select the root sensors based upon the estimated signal strength since the nodes closer to the targets having larger measurements has a higher probability of becoming root sensors.

(1) Target Detection

In this target detection, we find all sensors that can detect the presence of the targets. Nodes closer to the targets usually have higher measurements. Faulty sensors may have extreme values, representing outliers in the sample set. Faulty readings have little influence on median as long as most sensors behave properly. Thus target is detected initially by considering the median sensors alone. The root sensors are used to compute the location of a target based on the locations of the neighboring nodes. These root sensors send this information to the corresponding cluster head. For each cluster, the procedure is repeated [9],[10].

(2) Boundary Detection

The target localization is processed and the nodes are located in the clusters. In order to track the objects in the boundary. The target boundary information is then collected by the visiting mobile data collectors from the respective cluster heads. The target boundary information consists of the object ID, cluster ID, boundary location and the time stamp. The mobile data collector collects this information starting from the sink and gathers all the information. Thus using this technique we can effectively track the objects in WSN [11].

C. Adaptive Clustering

Adaptive clustering [9] uses external feedback to improve cluster quality; past experience serves to speed up execution time. Adaptive clustering supports the reuse of clustering's by memorizing what worked well in the past. It has the capability of exploring multiple paths in parallel when searching for good clusters. A distance function adaptation scheme that uses external feedback is proposed and compared with other distance function learning approaches. Clustering and prediction techniques, which exploit spatial and temporal correlation among the sensor data, provide opportunities for reducing the energy consumption of continuous sensor data collection. An energy-efficient framework for clustering-based data collection in wireless sensor networks is done by integrating adaptively enabling/disabling prediction scheme. Here the framework is clustering based. A cluster head represents all sensor nodes in the cluster and collects data values from them. Adaptive scheme is used to control prediction used in our framework, analyze the performance tradeoff between reducing communication cost and limiting prediction cost, and design algorithms to exploit the benefit of adaptive scheme to enable/disable prediction operations. Increase the network energy efficiency and stability in cluster based network and improve the network lifetime. Uses cluster-to-cluster propagation rather than node-to-node propagation [12].

(1) Adaptive Clustering Algorithm (ACA)

ADAPTIVE CLUSTERING ALGORITHM (ACA)

ACTION 1:

Broadcast a beacon signal to all its neighbor nodes in the transmission range;

Process the beacon signals received from the neighbor nodes in the network and form the connection matrix, A;

ACTION 2:

Calculate Weight of node V, as Wv;

ACTION 3:

Broadcast weight value Wv to all its neighbor nodes;

Process the signals received from the neighbor nodes in the network and identify the weights of the neighbors;

ACTION 4:

Find the node with minimum weight in the neighborhood;

If (Wv is the least weight)

Declare itself as the Cluster-head;

Else

Send request to join the Cluster formed by the neighbor with least weight;

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CLUSTER-HEAD

ACTION:
Verify the threshold on the Cluster Head's Battery Power;

If (Battery power < Threshold)
Cluster-Head sends a LIFE_DOWN message to all its Neighbors;
All the Member nodes participate in the Re-Election Procedure using Modified Weighted Clustering Algorithm and the Node with least weight is selected as the New Cluster-Head;
Else
Re-election is not needed

The Cluster-Heads Power decreases more rapidly when compared to the Cluster Members. When the Cluster-Heads Battery Power falls below a threshold then the node is no longer able to perform its activates and a New Head from the members available need to be chosen. By using Adaptive Clustering Algorithm energy consumption is reduced and network life time is increased. Weighted Clustering Algorithm is best suited for cluster maintenance [11].

III. CONCLUSION

Wireless sensor networks have attracted significant attention over the past few years. A growing list of civil and military applications can employ WSNs for increased effectiveness; especially in hostile and remote areas. The massive researches in these areas have inspired us to present the literature survey on tracking. In this paper, we have explored different Energy Efficient Tracking Techniques: Prediction-Based Tracking Technique using Sequential Pattern (PTSP), Multi-Target Tracking, Mobile Data Collector and Adaptive Clustering.Due to the scarce energy resources of sensor nodes, energy efficiency is becoming one of the main challenges in the design of target tracking protocols for WSNs. The ultimate objective behind the protocol design is to keep the sensors operating for as long as possible, thus prolonging the network lifetime. In this paper, we have surveyed and summarized recent research works focused mainly on the energy-efficient target tracking routing protocols for WSNs. As this is a broad area, this paper has covered only a few samples of tracking routing protocols. The protocols discussed in this paper have individual advantages and pitfalls. For realization of sensor networks, it is needed to satisfy the constraints introduced by factors such as fault tolerance, coverage, scalability, network cost, environmental, and power consumption. Since these constraints are highly stringent and specific for sensor networks, new wireless sensor networking techniques are required to be explored more. Though the performance of the protocols discussed in this paper is promising in terms of energy efficiency, further research would be needed to address issues related to tracking accuracy and Quality of Service (QoS).

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