Energy Efficient Object Tracking Technique using Mobile Data Collectors in Wireless Sensor Networks

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ABSTRACT
In wireless sensor networks (WSN), one of the important applications is object tracking. WSN is expected to provide the location of the detected object, and the real time location report. The sensors detecting the object need to transmit the sensing data and identification. In this paper, we propose to develop an energy efficient mobile data collector based technique which helps in tracking of an object. Within each cluster, the core sensors are selected based on the estimated signal strength since the nodes closer to the targets having larger measurements have a higher probability of becoming core sensors. The core sensors are used to compute the location of a target based on the locations of the neighboring nodes. These core sensors send this information to the corresponding cluster head, using which the target localization is processed. The position of moving object is detected by object moving algorithm and then collected by the visiting mobile data collectors from the respective cluster heads. By simulation results, we show that the proposed tracking technique is energy efficient with improved packet delivery ratio.

1. INTRODUCTION
The fast emerging wireless sensor networks (WSN) has bought great attention to the research community. These sensor networks include several small and low cost self-organizing ad hoc systems. On observing the physical environment the information is being collected and they are transmitted to the sink nodes. In the sensor network, the magnitude of the radio transmission range of the sensor nodes is smaller than the geographical extent of the entire network. Thus data needs to be transmitted to the sink node in a multi-hop manner. The energy of sensors depends upon the data to be transmitted, so that the energy consumption of the network can be reduced by reducing the size of data to be transmitted. [1] The sensor devices with sensing, computing and communication capabilities are included in large number in the wireless sensor networks. The sensory information such as temperature measurements are collected by these sensors in an extended geographic area [2].

1.1 Mobile Sink Based Data collection
Data collection is a standard use of a sensor network which deploys number of sensing nodes to measure the physical phenomena. Query dissemination and data retrieval are the two steps in data collection. One-to-many traffic patterns are characterized from the base station to the sensing nodes in the query dissemination. Many-to-one traffic patterns from the nodes to the base station are featured in the data retrieval. The nodes with the best channel to the base station have a heavier workload than their peers since they are used to relay traffic that they do not generate and this happens to be the main drawback of many-to-one traffic [3].

The system lifetime is increased by using mobile sinks in the sensor networks. Replacing or recharging of batteries is quite costly and impractical and thus the sustainable lifetime of the sensor networks are severely limited by the battery capacity of the sensor nodes. The number of transmitted packets is reduced when a mobile sink moves closer to the nodes which help in conserving energy since data is transmitted over fewer hops. The mobile sink is considered as external to the network factor and thus the there is no effect of extra energy spent for the operation and movement of the sink over the sensor network lifetime [4]. The data reports from the sensor nodes are lost due to the changing location of the sink and thus the existing path can become invalid when the sink moves. We need to thoroughly rebuild the communication paths or routing trees in order to overcome this situation. Energy consumption can be increased and significant delays can be provided for restarting communication by involving frequent updates of the routing tree. In order to save energy, protocol requires policies for sleeping and waking up the sensor nodes. This is due to that the sinks are collecting data only from the nodes inside a certain range [5]

1.2 Object Tracking and its Issues
The most important and accepted application of the WSNs is the object tracking. The location of the detected object should be known to the users in this application and it mostly consists of real time location report. Complete or partial historical movement information of the detected object is needed by some application of the object tracking. For example, for the protection of wild animals, we need information about the movement of animals.

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 and the energy is consumed in this approach. 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]

All the sensors which detect the object need to transmit their sensing data and identification because the detection and tracking of the continuous objects includes high communication overhead. When a continuous object spans a wide geographical area or travels with a high velocity, the problem gets intensified further. Only the boundary of the continuous objects need to detected in an efficient approach. There are two critical operations in the continuous object tracking.

1.2.1 Monitoring:
The movement of the mobile continuous object is being detected and their movement is being tracked by the sensors.

1.2.2 Reporting:
The location information about the sensors which detect and locate the objects boundary is gathered by the sink.

Along with the change in shape, the continuous object drifts under the influence of the wind, and so it is difficult to track the boundary movement in real-time. [7]

2. RELATED WORK
In-Sook Lee et al [8] have proposed our Efficient Dynamic Clustering Algorithm for Object Tracking in Wireless Sensor Networks. In proposed mechanism, it proposes a new cluster head election algorithm and helps to minimize the overlap area between clusters. This not only avoids redundant data but also reduce energy consumption based on prediction result of moving objects.

Jaebok Park et al [9] have proposed a tracking method that can track energy-efficiently in a mobile object in the sensor network. The proposed method can also improve the tracking accuracy using the dynamic clustering based on the movement prediction. Especially, the proposed PHP (Prospected Header Point) concept can reduce the communication overhead by the collaboration with other nodes in order to elect the next cluster header. As a result, it can decrease not only the missing-rate but also the energy consumption. It can eventually enhance the lifetime of the sensor network.

Jin Zheng et al [10] have proposed a link-segment storage and query protocol to track mobile object in wireless sensor network dynamically. The main idea of our protocol is to combine advantages of local storage with data centric storage methods to support the query of object movement information efficiently.

Zhou Sha, et al [11] have proposed a moving strategy for the mobile sink which prevents tracking or detecting on it by adversaries during its data collection phase around the sensor field. Their moving strategy aims to selecting a trajectory for mobile sink node, which minimizes the total number of message communication from all static sensor nodes to the mobile sink node and thereby reducing the possibility of being detected by the adversaries.

Liang Xue et al [12] have proposed a target tracking protocol–exponential distributed predictive tracking (EDPT) is proposed. To reduce energy waste and response time, an improved predictive algorithm–exponential smoothing predictive algorithm (ESPA) is presented. With the aid of an additive proportion and differential (PD) controller, ESPA decreases the system predictive delay effectively. As a recovery mechanism, an optimal searching radius (OSR) algorithm is applied to calculate the optimal radius of the recovery zone.

3. ENERGY EFFICIENT OBJECT TRACKING TECHNIQUE

3.1 Extension to Previous Work
In our previous work [13], we designed an Energy Efficient Reliable Data Gathering (EERDG) technique to determine maximum lifetime routing path construction in each cluster. First the nodes are grouped into clusters based on their buffer overflow time, so that the buffer overflow problem can be solved. Cluster heads are selected based on the minimum value of a combined cost metric. Then the cluster heads collect data from the cluster members and forward it to the MDC.

We considered the data gathering scenario where a mobile mule or mobile data collector (MDC) will start from any one node in the sub-network in which sink node is located, traverses any node of each isolated sub-network to gather sensing data. When the MDC is within the communication range of a landing port, the latter can collect all sensing data in its sub-network and forward to the MDC. When returning, the MDC will relay all sensing data to the sink via the starting sub-network. The traveling path of the MDC may reflect the data gathering latency and the energy consumption of the MDC.

As an extension to our previous paper, we propose a technique which helps in tracking of an object. In this information about the tracked object is collected from the sensors by the cluster head and is sent to the MDC. At the sink the exact location of the unknown object can be determined and we are able to track the object.

3.2 Target Detection
In this target detection algorithm, we find all sensors that can detect the presence of the targets. Nodes closer to the targets usually have higher measurements. Faulty sensors may report arbitrary values. The procedure of target region detection is described as follows.

Intuitively, an event sensor is a sensor that can detect the presence of the targets. We employ the robust operator median so that it effectively eliminates the effects of faulty sensors. Median is widely used to estimate the “center” of samples with outliers. 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.

Consider N as the bounded closed set containing a sensor S and additional n-1 sensors. The set N represents a closed neighborhood of the sensor S. An example of N is the closed disk centered at S with its radius equal to the radio range.

Let Ti1 , Ti2 , . . . , Ti n denote the signal strengths measured by the nodes in N. A possible estimate of signal strength at location S is

$$MTi = med(Ti), \qquad \ldots\ldots\ldots (1)$$

Where med denotes the median of the set

{Ti1 , Ti2 , . . . , Ti n }.

After selecting the median sensors, we consider to delegate one sensor to communicate with the base station for each target and compute the position of the target locally.

The following algorithm is employed to locate the targets in the target region.

1. Initially we estimate the signal strength MT1, MT2,, MTk from k event sensors in N.
2. A sensor is selected as a core sensor if its estimated signal strength is maxima among event sensors in N. Nodes closer to the targets usually have larger measurements and thus have a higher probability to become core sensors.
3. After the determination of the core sensors, we estimate the location of the possible target by the geometric center of a subset of event sensors in N.

Let {ei1, ei2, ...eik} be the subset of event sensors in N such that MTj > MTi – z , for 1 < j > k where MTj is the estimated signal strength from eij , z is a threshold that mainly characterizes the target size. Consider two coordinates x and y of eij. Denote the x and y coordinates of ei j by x(eij) and y(eij) respectively, and set

Hi(x) = [x(ei1) + x(ei2) + ….. + x(eik)] / k

Hi(y)=[y(ei1)+y(ei2)+……+y(eik)]/k …. (3)

Furthermore, the number of core sensors is constrained by (2). A core sensor uses (3) to compute the location of a target based on the locations of some neighboring nodes. These core sensors send this information to the cluster heads. For each cluster, this procedure is repeated.

3.3 Boundary Detection

The target localization is processed and the nodes are located in the clusters. In order to track the objects in the boundary, we consider two scenarios one with a single cluster and then with two clusters.

We consider two IDs, object ID (Oid) and the cluster ID (Cid) for each target detected. We take two clusters C1 and C2. We determine the location of the target using the cluster ID.

3.3.1 Object within Single Static Cluster

- In figure 1, the object is located entirely within a single cluster (Cluster 1). In this case, after sensing the continuous object, the inner sensors within the object boundary, broadcast A(O1, C1) to notify CH1 that they have detected the object.
- The boundary sensors in C1 detect the object and they send query to the cluster C2. The object is detected in B(O1,C1), which also belongs to the same cluster. If the object is not detected in C2, no notification is sent. So, we determine that the object is not extended beyond the boundary of C1.

3.3.2 Object within Two Static Clusters

- In figure 2, the continuous object straddles two static clusters, i.e., C1 and C2. The boundary nodes in the cluster C1 transmits A(O1,C1) to the CH1 as long as they detect the continuous object. The boundary nodes A, B, and C in C1 query their neighboring boundary nodes X, Y, and Z in the cluster C2.
- In this case, these nodes report that the object has indeed spread to Cluster 2. Thus boundary nodes in the C1 send A(O1,C1), B(O1,C1), C(O1,C1) and that in the C2 send X(O1,C2), Y(O1,C2), Z(O1,C2) to the cluster heads.

When CH1 receives this message, it learns that the detected object is not confined solely within its own cluster, but has also spread to Cluster 2.

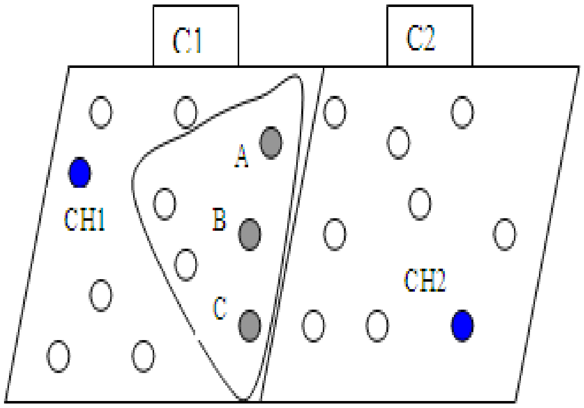

Fig 1: Object within a single static cluster

- The portion of the object boundary lying within its own cluster can be estimated using this method. Two boundary sensors which constitute the sensor pair with greatest separation distance are only considered and the other boundary sensors are eliminated

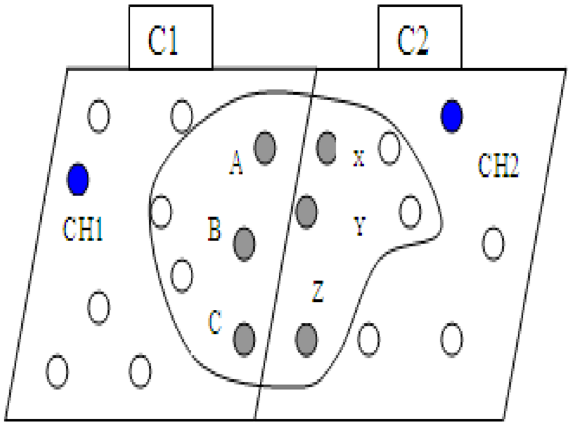

Fig 2: Object within two static clusters

3.4 Combined Algorithm

- Sensor nodes {Si} , i=1,2….n are partitioned according to their buffer overflow times.
- {Si} is then sub-partitioned into K clusters according to their locations
- Each cluster member CMj (j=1,….m) of cluster Ck (k=1,2..K) estimates the combined cost metric using (3).
- For each cluster Ck , k=1,2…K
- For each member CMj of Ck, j=1,2…m

If CMj receives a cluster head announcement from CMr, then If cost(CMr) = minimum, then Select CMr as CHk

Else Ignore the announcement

End if

End if

End For

- For each cluster k=1,2…K

Consider N set of closed neighborhood of sensors.The possible estimate of signal strength of an event sensor is

MTi = med(Ti),

where the signal strength measured by the nodes be Ti1 , Ti2 , . . Ti n. Select the core sensors (Rj} from the event sensors such that MTi > max {MT1, MT2,….. MTk}

{Rj} compute the location of the target based upon the location of the neighboring nodes. Cluster head CHk gets the target location information from the core sensors.

End For

- The objects in the boundary are tracked using the boundary detection technique. The notification of the object contains (Oid , Cid) and is broadcasted to the cluster head.
- If the notifications have same cluster ID

The object is confined within a single cluster.

Else

The object is confined with two clusters.

End if

- All the cluster heads get the information about the total boundary position of the continuous object and stores it in the format

<Oid, Cid, boundary location, time stamp > in its buffer.

- MDC starts its visit from sink Sn.
- MDC visits the cluster Cv such that OT(Cv) < OT(Cv+1)
- MDC collects the target boundary information from CHv of Cv
- let v=v+1
- MDC transmits all gathered target boundary information to sink Sn.
- Repeat from step 11 such that all clusters Ck are visited.

4. SIMULATION RESULTS

4.1 Simulation Model and Parameters

We evaluate our Energy Efficient Object Tracking (EEOT) technique through NS2 simulation [14]. We use a bounded region of 500 x 500 sqm, in which we place nodes using a uniform distribution. Assign the power levels of the nodes such that sensing range of the nodes are all 250 meters. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. The simulated traffic is Constant Bit Rate (CBR).

No. of Nodes	101
No. of objects	2
Area Size	500 X 500
Mac	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Speed of object and MDC	10,20,30,40 and 50 m/s
Transmit Power	0.660 w
Receiving Power	0.395 w
Idle Power	0.035 w
Initial Energy	7.1 J
Routing Protocol	AODV
Transmission Range	250,300,350,400 and 450 m.

The following table summarizes the simulation parameters used.

4.2 Performance Metrics

We compare the performance of the proposed Energy Efficient Object Tracking (EEOT) technique with the Continuous Object Detection and Tracking Algorithm (CODA) [7]. We evaluate mainly the performance according to the following metrics:

Delay: It is the average end-to-end between the sender and receiver. Average Packet Delivery Ratio: It is the ratio of the number of packets received successfully and the total number of packets sent.

Drop: It is the average number of packets dropped.

Average Energy Consumption: The average energy consumed by the nodes in receiving and sending the packets.

4.3 Results

4.3.1 Based on Varying Range

In the first experiment, we vary the transmission range as 250, 300,350,400 and 450m, keeping the speed as 20m/s.

Fig.3 presents the average end-to-end delay when we increased the range. It is clear that EEOT has low delay than the existing CODA..

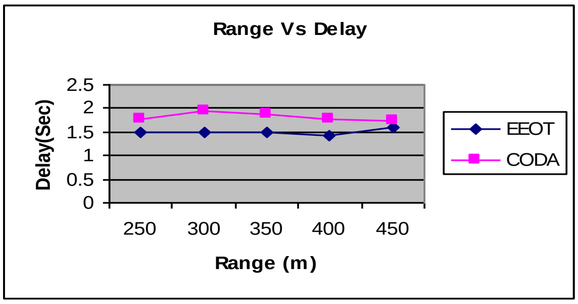

Fig 3: Range Vs Delay

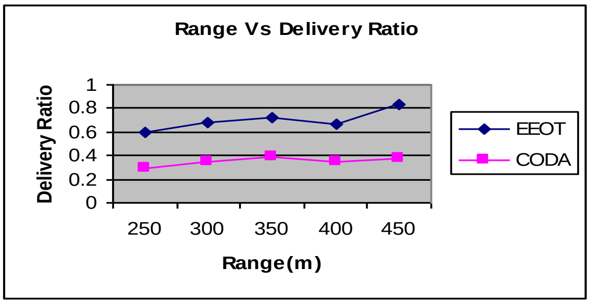

Fig 4: Range Vs Delivery Ratio

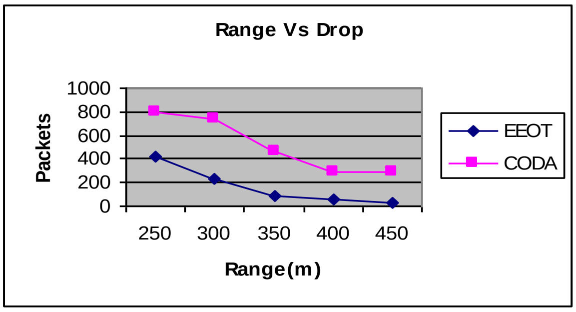

Fig 5: Range Vs Drop

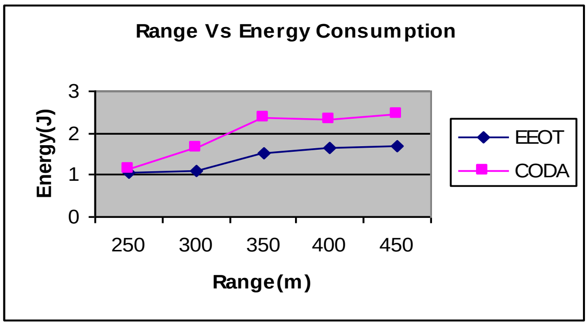

Fig 6: Range Vs Energy Consumption

Fig. 4 presents the packet delivery ratio when the transmission range is increased. It is clear that EEOT achieves good delivery ratio when compared with the CODA scheme. Fig. 5 gives the packet drop when the transmission range is increased. We can see that EEOT has less packet drop when compared with the CODA scheme.Fig. 6 shows the average energy consumed by the nodes in receiving and sending the data. The values are considerably less in EEOT when compared with CODA scheme.

4.3.2 Based on Varying Speed

In the second experiment, we vary the nodes speed as 10, 20, 30, 40 and 50m/s keeping the range as 250m.

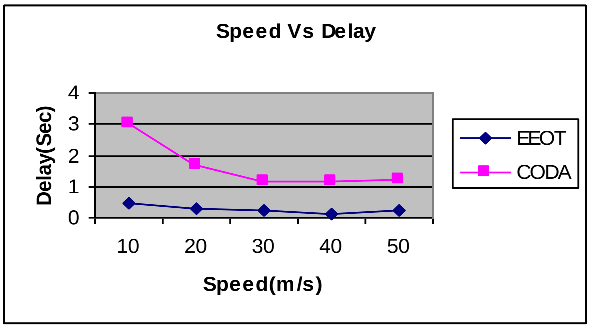

Fig 7: Speed Vs Delay

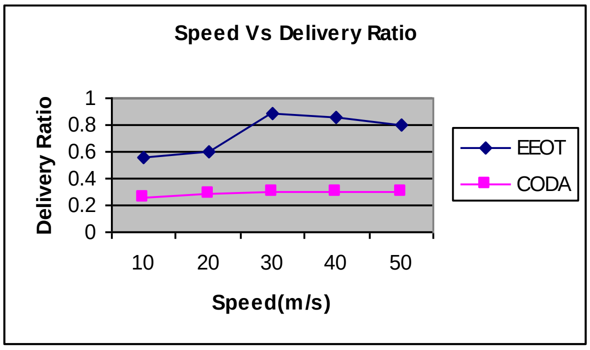

Fig 8: Speed Vs Delivery Ratio

Fig.7 presents the average end-to-end delay when we increased the speed. It is clear that EEOT has low delay than the existing CODA technique.Fig. 8 presents the packet delivery ratio when the speed is increased. It is clear that EEOT achieves good delivery ratio when compared with the CODA scheme.Fig. 9 gives the packet drop when the speed increased. We can see that EEOT has less packet drop when compared with the CODA scheme.

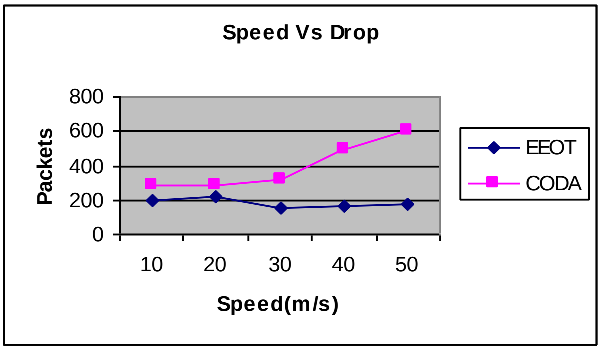

Fig 9: Speed Vs Drop

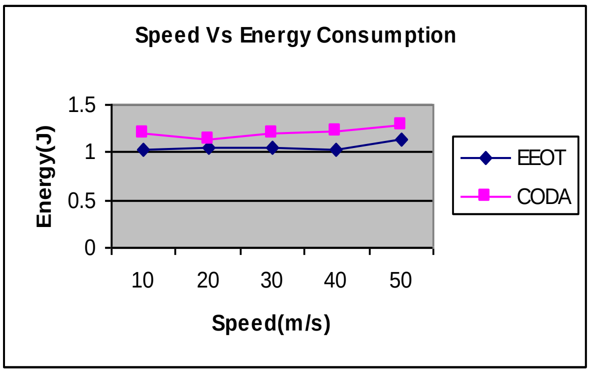

Fig 10: Speed Vs Energy Consumption

Fig. 10 shows the average energy consumed by the nodes in receiving and sending the data. The values are considerably less in EEOT when compared with CODA scheme.

5. CONCLUSION

In this paper, we propose an Energy efficient mobile sink based technique which helps in tracking of an object. 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. . Faulty sensors may have extreme values, representing outliers in the sample set. Faulty readings have little influence on medi 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 using wh

ich the target localization is processed. 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 WSNs. By simulation results, we have shown that the proposed tracking technique is energy efficient with improved packet delivery ratio.

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