Energy Efficient Face Tracking Scheme for Target Movement Detection in Wireless Sensor Networks

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***Abstract*—Wireless sensor networks have a lot of applications and among them target tracking is one of the most important application and it has gained a lot of attention. Due to various issues in WSN such as limited battery power, high mobility of nodes, sensor node failures, target tracking is challenging and difficult to achieve accurately. Existing schemes are mainly tree based or cluster based. This paper is based on a new target-tracking framework called Face tracking framework. Surrounding nodes of a target in its spatial region refer as a face. Edge detection algorithm is used to generate next face as target moves ahead. Optimal selection algorithm is used to determine which nodes should be active during target tracking. Face tracking framework is more energy efficient and achieves better tracking accuracy as compared to existing schemes for target tracking.**

Keywords- Edge detection, face tracking, sensor selection, target tracking, wireless sensor network

I. INTRODUCTION

WSNs provide accurate information about the environment in which the sensor nodes are deployed, mainly in the remote areas. Initially, WSNs were developed for surveillance in the battlefield. Now, WSN applications are extended for healthcare, industrial applications as well as traffic monitoring. Target tracking in WSN [10] is one of the recent research topics. In WSN, sensor nodes are deployed in a remote environment and collect information based on their functionality such as temperature monitoring, noise detection, etc. Sensor nodes collaborate with each other and send information to the sink.

Existing schemes for target tracking are mainly tree-based [4], cluster-based [10] and prediction-based schemes. Face tracking scheme [1] provides better tracking accuracy and minimum energy consumption as compared to previous schemes. In this scheme, polygons are constructed at initial step and the edge between two polygons is called as brink. Edge detection algorithm generates next polygon when target crossed the brink. Optimal selection algorithm decides which sensors should be kept active during target tracking.

Fig. 1 shows the detection of target movement through polygons. v1 and v10 nodes of polygon p1 detect the target initially, so they are called as couple nodes (CN) and are shown by black color, and all other nodes are shown by gray color.

The target is tracked step by step in the sequence p1-> p2-> p4-> p5-> as shown in fig 1.

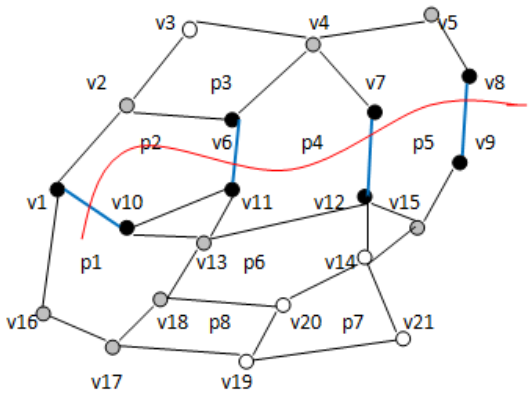

Fig. 1: Detection of target movements through polygons

II. RELATED WORK

Global Node Selection algorithm and Local Node selection algorithm are introduced by Kaplan [2][3] for target tracking. GNS scheme (Global Node Selection) [2] requires knowledge of all the neighbors of each sensor nodes for target tracking. ANS scheme (Autonomous Node Selection) [3] can be viewed as modification to GNS as it uses distributed strategy, which requires only local node information. GNS does not consider exceptions such as node failures. ANS is more desirable than GNS as, in ANS whole network need not to be reconstructed when nodes will be added or removed.

Dynamic Convoy Tree Based Collaboration (DCTC) [4] is a tree-based approach introduced by Zhang and Cao. Convoy tree is dynamically constructed, and when target enters the detection region, sensor nodes collaborate with each other and select a root. Root collects all information about the target and sends to the user. In DCTC technique, when target moves far from the root, more energy is consumed in the communication between the target and the root.

Kaltiokallio, Bocca, and Eriksson introduce RSSI scheme [5] for target movement detection using the signal strength of sensor nodes. In WSN, sensor nodes communicate with each other by continuously exchanging messages. When target enters into the network, signal strength of sensor nodes reduces and nodes come to know that target has entered in the network. However sometimes, signal strength of sensor nodes is purposely reduced for minimizing transmission power, but nodes misinterpret this reduction in signal

strength. In such cases, false detection of target takes place.

Waelchli, Scheidegger, and Braun introduce intensity Based Event Localization Scheme [6]. In this scheme, two algorithms are introduced for event detection and localization, distributed election winner algorithm (DENA) and intensity based localization algorithm (ILA). DENA determines which is the closest sensor node to an event (i.e. winner node) and sends a notification message to all sensor nodes about the winner node. ILA estimates position of the event and this takes place at the winner node determined by DENA. In this method, location estimation takes place in distributed manner, so there is no need to gather any information on a sink node.

TABLE 1: LITERATURE SURVEY

Sr. no.	Existing method	Advantages	Disadvantages
1.	DCTC	For power saving, most sensor nodes stay asleep before target arrives.	As the velocity of target increases, energy consumed by tree configuration also increases.
2.	GNS	-	The assumption that each node must know the location of all nodes can become overhead when network size grows.
3.	ANS	1) ANS is more desirable than GNS because the whole network does not need to reconfigure after addition or removal of extra nodes. 2) In the case of large network, memory requirements are not burdensome as that of GNS.	It cannot handle the scenario in which multiple targets are in detection range if the same nodes i.e. multi-target issues.
4.	1) DENA 2) ILA	Location of an event can be computed in a distributed manner without the need to gather any information on a sink node	1) ILA needs information of all neighboring nodes instead of considering subset of them. 2) DENA uses DDB that causes additional delay
5.	Distributed processing of RSSI	Minimizes power consumption, and reduces latency at the central base station.	False detection of target takes place in some cases.
6.	Maximum likelihood estimation with Kalman filtering	Improves tracking accuracy compared to commonly used extended Kalman filter approach.	-

Wang, Fu, and. Zhang proposes a target tracking approach by combining Kalman filtering(KF)and maximum likelihood estimation method (MLE) [7]. The maximum likelihood estimator is used for localization of target and measurement conversion is done to remove non-linearity in measurement. This target tracking approach has high tracking accuracy as compared to commonly used extended Kalman filtering approach.

III. PROPOSED WORK

In many existing schemes, a significant amount of energy is wasted because large numbers of nodes are kept active for long time though many of them are not participating in tracking process. Face tracking scheme overcomes drawbacks of previous schemes and provides better-tracking accuracy. In this scheme, the nodes, which are present in the active polygon i.e. the polygon in which the target is present, are only kept active, and rest nodes are kept in sleep mode. Therefore, energy consumption is minimum. This scheme handles exceptions such as node failure. In the case of node failure, polygon expansion takes place to maintain tracking accuracy. This method uses edge detection algorithm to construct further polygon in target's moving path and optimal selection algorithm to determine which sensor nodes should be kept active.

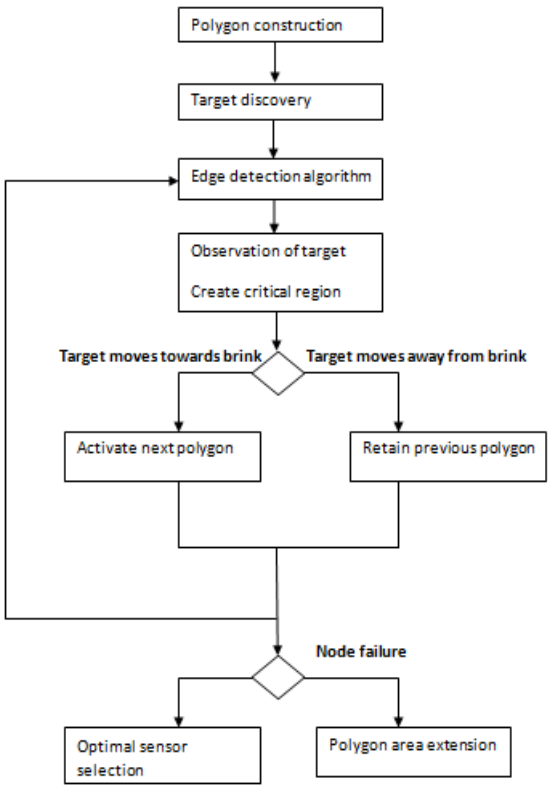

Fig.2: Framework of the proposed scheme

Proposed system framework is shown in Fig. 2. First step includes planarization that includes polygon construction in the network. Node has three states [11]: active (node participates in tracking), inactive (node is in sleep mode), awakening (node awakes for a short period). When target enters into the network, some

nodes detect the target and communicate with the surrounding nodes. Active polygon is the one in which target is present, and all the nodes in this polygon are kept active. The edge between couple nodes is called as brink. When target approaches towards the brink, and it is about to cross the brink then edge detection algorithm is invoked. In this step, the nodes in the future polygon are notified that the target is approaching, and they change their state from inactive to awakening. When the target crosses the brink, nodes of the previous polygon receive the message to change their state to inactive (except couple nodes).

Target can be present in following three phases:

- Square detection phase: this phase shows that target has been detected by any two couple nodes but it does not guarantee that target will cross the brink.
- Rectangular detection phase: this phase shows that target may cross the brink between two polygons.
- Crossing phase: this phase shows that target is about to cross the brink between two polygons.

In this scheme, the information provided by all the nodes may not be useful. So, optimal selection algorithm is used to determine which nodes should be kept active during target tracking in order to minimize the energy consumption. Due to certain situations like node failure or battery depletion, initially constructed polygons may not be preserved. In such cases, polygon area is expanded.

When the target moves far from the sink, the energy consumption for communication and transmission of data is more. This energy consumption can be minimized by adjusting transmission power levels. Sensor nodes communicate with each other and adjust their transmission power in order to minimize the energy consumption.

Algorithm for the proposed scheme:

Step 1: Consider a WSN $G = (V, E)$ where V is set of nodes and E is set of edges.
Construct the polygons in the plane using planarization.

Step 2: Target emits the signal and closest sensor detects the signal.
Send notification to neighboring nodes and the sink.

Step 3: Target can be detected in square phase or rectangular phase or crossing phase.

Step 4: Identify the critical region and observe the target.

Step 5: If the target crosses the brink then invoke edge detection algorithm,
Send message to the nodes of future polygon and their state is changed to active state.
Nodes of previous polygons change their state to inactive.
Else, go to Step 4

Step 6: Use optimal selection algorithm to minimize energy consumption. Energy efficient cost percentage (EECP) is used to measure energy efficiency of WSN. Higher the EECP ratio, energy efficiency is higher.

$$\text{EECP} = \frac{\text{E nodes that can detect the target}}{\text{E nodes that are in the active state}}$$

Where 'E nodes that can detect the target is the energy' is energy used by the nodes that can detect the target.
'E nodes that are in the active state' is the energy used by all the nodes that are in the active state.

Step 7: If any node failure occurs then expand polygon region.

IV. MATHEMATICAL MODEL

Set Theory

1. Identify the nodes

- Let N be the set of sensor nodes
- N= {CN, NN}
- CN= Couple nodes
- NN= Neighboring nodes

2. Calculate the energy measurement by sensor nodes for target detection

- Let E_s be the set of energy measurement.
- E_s= {e_s (t1), e_s (t2), e_s (t3)….)}
- Where $e_s(t)$ is the time-dependent average signal energy measurements over time t.
- $e_s(t)=S_i(t) + n_i(t)$
  S_i (t) is the signal and n_i (t) is the noise energy.

3. Invoke the edge detection algorithm

- Let p be the set of detection probabilities of target.
  p= {p1, p2, p3}
- p1 is the detection probability for square phase.
- $\rho 1 = \frac{1}{A} \int_{D/2}^{D/2} es\,(CN, j)dx \int_{D/2}^{D/2} dy$,
- D=distance between couple nodes
- where A= area of the square phase= D^2
- CN= couple nodes
- p2 is the detection probability for the rectangular phase.
- $\rho 2 = \frac{1}{A} \int_{D/2}^{D/2} es\,(CN, j)dx \int_{D/4}^{D/4} dy$
  where, A= area of the rectangular phase= D* D/2
- p3 is the detection probability for the crossing phase.
- $\rho 3 = \frac{1}{A} \int_{D/2}^{D/2} es(CN, j)dx \int_{D/8}^{D/8} dy$
  where, A=area of the crossing phase

4. Select optimal nodes using optimal selection algorithm for reducing energy consumption

- Apply selection function ϕ as:
- $\phi(\delta(\bar{x} \mid NN,CN))=\alpha*\lambda use((\delta(\bar{x} \mid NN, CN)) - (1-\alpha) * \gamma cost(NN, CN))$ …….. (1)
  Where,
- NN= neighboring nodes
- CN= couple nodes
- $\delta(\bar{x} \mid NN,CN)$ = estimate of the target, formed by each node and NNs.
- α =relative weight of the usefulness and cost.

5. Reduce selection function and represent in the form of target locations

- $\lambda use((\delta(\bar{x} \mid NN, CN))$ is the information usefulness measurement function given as:
  $\lambda use((\delta(\bar{x} \mid NN, CN)) = \lambda use(xi, \bar{x})=(xi-\bar{x})^T * C_V$ …….....(2)
  Where,
- xi= location vector of the i th sensor node
- $\bar{x}$= location vector of the target that is estimated by the i th sensor node and one of the CNs.
- γ_{cost} is a function that refers to the energy cost of communications between NNs and previous CNs.
  $\gamma cost(NN,CN))=(x_i-x_c)^T(x_i-x_c)$……...……..(3)
  where,
- $x_{c=}$ location of a CN
- $(x_i - x_c)$= distance between the neighbors and one of the CNs.
- Finally, the selection function, (1), can be reduced by substituting (2) and (3) as follows:
  $\phi(\delta(x_c, x_i, \bar{x})) = \alpha * (xi - \bar{x})^T C_V - (1 - \alpha) * (x_i - x_c)^T (x_i - x_c)$ ……..……(4)
- Using selection function, usefulness of the sensor node is decided and when it is more than threshold value (which is greater than zero and selected randomly) then node is chosen as optimal node.

V. EXPECTED RESULTS

TABLE 2: ENERGY CONSUMPTION BETWEEN EXISTING AND PROPOSED SYSTEM

Target Speed (in m/s)	Energy consumption (in terms of power consumed by sensor nodes in Watt)	
	Existing System	Proposed System
3	0.085	0.06
6	0.100	0.07
9	0.115	0.08
12	0.130	0.088
15	0.145	0.095

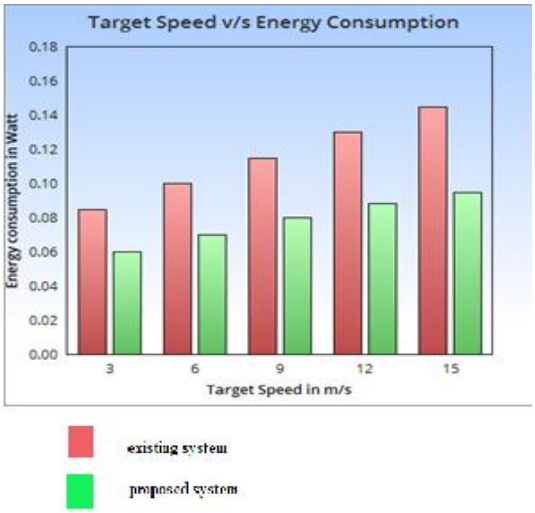

Fig.3: Energy consumption of existing system and proposed system

Above graph is the target speed vs. energy consumption graph for the existing system and proposed system. This graph shows that, in proposed system, energy consumption is minimized than existing system. Optimal selection algorithm and adjustable transmission power level algorithm is used in proposed system for minimizing transmission power consumption of sensor nodes.

VI. CONCLUSION

One of the main applications of WSN is to track the unauthorized target in the surveillance field. WSNs have energy constraint due to limited battery power of sensor nodes. Therefore, it is necessary to propose a target-tracking framework that is more energy efficient.

This paper proposes a polygon based target-tracking framework with higher tracking accuracy and minimum energy consumption. Proposed scheme is more energy efficient, as in this scheme, only some nodes, which provide useful information for target tracking, are kept active and rest of the nodes are kept in sleep mode. In addition, energy consumption is minimized by adjusting transmission power of sensor nodes.

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