A Tree Based Routing Protocol for Mobile Sensor Networks (MSNs)

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***Abstract*: Wireless Sensor Networks (WSNs) has foreseen big changes in data gathering, processing and disseminating for monitoring specific applications such as emergency services, disaster management, and military applications etc. Wireless sensor networks (WSN's) are application dependent. Wireless sensor network can be classified into Static Sensor Network (SSN) & Mobile Sensor Network (MSN). In Static Sensor Network, the sensor nodes localize only first time during deployment. In case of Mobile Sensor Network, nodes collect the data by moving from one place to another place hence localization is needed. Mobile sensor networks are more energy efficient, better targeting and provide more data fidelity than Static Sensor Network (SSN). Mobile Sensor networks have gained great attention in recent years due to their ability to offer economical and effective solutions in a variety of fields. There are many routing protocols present for the static sensor network. In this paper we have present a Tree based Routing Protocols (TBRP) for mobile sensor network. TBRP was compared with LEACH and TEEN Protocol. Simulation results show that TBRP outperforms LEACH and TEEN in terms of mobility, energy efficiency & network life time.**

Keywords: Localization algorithms, Mobile sensor network, TBRP (Tree Based Routing Protocol) & SSN (Static Sensor Network).

I. Introduction

Wireless sensor network consists of a large number of such sensor nodes that are able to collect and disseminate data in areas where ordinary networks are unsuitable for environmental and/or strategic reasons. Each sensor node comprises sensing, processing, transmission, mobilize, position finding system (Such as GPS) and power units [19-27]. The system architecture of wireless sensor network is shown in Figure 1[1]. Each node has the capability to sense the data from the environment perform some computation and communicate with the other nodes in the network. Once a sensor node is deployed, the network can keep operating only until the battery power is sufficient.

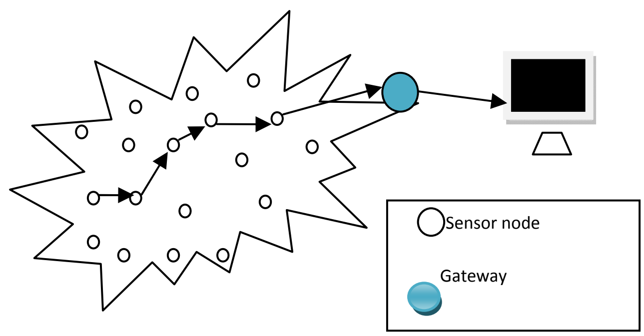

Figure 1 Architecture of Wireless Sensor Network

Wireless Sensor Networks (WSN) has a wide range of applications such as environmental monitoring, biomedical research, human imaging and tracking, and military applications [1]. Wireless sensor networks (WSNs) are mainly used in the emergency services. It can also be called Emergency Services Networks (ESNs). Micro Electro-Mechanical Systems technology, wireless communications, and digital electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes that are small in size and communicate undeterred in short distances. A wide range of applications utilizing low-end sensor nodes to collaborative work together is envisioned for sensor networks. Some of the application areas are health, military, and security.

The sensor nodes have the various limitations such as low battery power, minimum computation capability. A very important one, directly related with the application of WSN is energy. Optimization of energy consumption and other limited capabilities are still being investigated in different academic and industrial research groups.

In WSNs the participants are the sensor nodes, which according to the application are sinks, sources and intermediate sensor nodes. The sinks are identified as sensor nodes or external elements that interact with the network. Examples of sinks in the WSN are PDAs, Laptops or getaways to other networks. Mobile sensor networks are sensor networks in which nodes can move under their own control or under the control of the environment. Mobile networked systems combine the most advanced concepts in perception, communication, and control to create computational systems capable of interacting in meaningful ways with the physical environment, thus extending the individual capabilities of each network component and network user to encompass a much wider area and range of data. A key difference between a mobile sensor network and a static sensor network is how information is distributed over the network. Under static nodes, a new task or data can be flooded across the network in a very predictable way. Under mobility this kind of flooding is more complex. Under natural mobility this depends on the mobility model of the nodes in the system.

Wireless Sensor Networks (WSNs) are widely used network. These days, there are many researches running on in this field and many protocols have been designed for the Wireless Sensor Network. All these algorithms consider the Static Sensor Networks (SSNs). The Static Sensor Networks (SSNs) have various disadvantages such as first, less energy efficient, most of the gateway nodes loss their energy first means these nodes are die thus the whole network goes to die. Second, Static Sensor Networks (SSNs), the sensor nodes are static so its can not move to other places but in Mobile Sensor Networks (MSNs) the sensor node can move and reach the places where event is fired. Mostly the sensors are deployed randomly, as opposed to precisely, therefore there is often a requirement to move the sensor node for better sight or for close proximity. Also mobility helps in better quality of communication between sensor nodes.

Thus, in case of Static Sensor Networks (SSNs), we have faced various problems. These problems can be overcome by using the Mobile Sensor Networks (MSNs). In this paper we have proposed a Tree Based Routing Protocol (TBRP) for Mobile Sensor Network (MSNs).

The rest of our paper is organized as: section II describes the related work. Section III contains the system architecture& proposed Tree Based Routing algorithm. Section IV shows the simulation results & discussion. Finally Section V concludes the whole paper.

II. PREVIOUS WORK

The routing protocols proposed for WSNs are classified considering several architectural factors [2, 3]. Routing protocols for Wireless Sensor Networks (WSNs) are mainly classified into two categories*: Network Structure Based protocols* and *Protocol Operation Based protocols*. The network structure based protocols depend on the system architecture of the network. These protocols are classified into three categories*: Data centric or flat routing protocols*, *Hierarchical routing protocols*, and *Location based routing protocols*. Protocol operation based protocols are classified into five categories: *Negotiation based routing protocol*; *Multi-path based routing protocol*, *Query-based routing protocol*, *Qos-based routing protocol*, and *Coherent-based routing protocol.*

Data centric protocols[2] are the first categories of protocol. In this protocol every node in the network has been assigned the same role. Whenever source node requires the data it fires a query in the whole network. It is not appropriate to use global identifiers for this huge number of randomly deployed nodes, in most of the WSN applications. However this introduces complexity to query data from a specific set of nodes. Therefore the data is collected from the deployed region. Since the collected data is correlated and mostly redundant; collected data is aggregated in some nodes resulting decrease in the amount of transmitted data so transmission power.

Hierarchical routing or *cluster based routing protocols* [2, 3] have been proposed in order to meet the energy efficiency and scalability requirement of the WSNs. The main issue is forming sub network clusters, encouraging multi hop transmission and enabling data fusion.

Routing Protocols for Mobile Sensor Network: It is a great challenge for routing in a WSN due to the following reasons. First, since it is not easy to grasp the whole network topology, it is hard to find a routing path. Secondly, sensor nodes are tightly constrained in terms of energy, processing, and storage capacities. Thus, they require effective resource management policies, especially efficient energy management, to increase the overall lifetime of a WSN.

A color theory based routing protocol by shee et. Al. presented in [1]. This protocol works in three phases. This protocol is based on the color of the geographical area. In this protocol a color theory based localization algorithm is used to find the position of the sensor node.

There are various localization algorithm is exist which is used for the localization of the sensor nodes. Monte Carlo localization algorithm [4, 5] and color-theory-based dynamic localization algorithm [1], MB-IPF (Mobile Beacons-Improved Particle Filter) localization algorithm [9]. Directional localization algorithm etc. is used for the localization purpose.

III. TBRP ALGORITHM

The system model Tree Based Routing Protocol (TRBP) as shown in figure 2 has the following property.

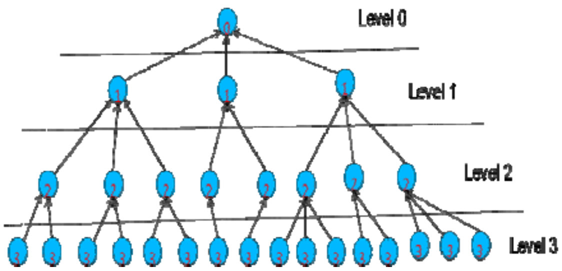

Figure 2 System architecture

- The entire nodes in the network form a tree with different level. And the node of the tree has some degree constrain which is depend on the level of the node
- The distance between the two levels is equal to the radio range of the sensor node (which is approximately equal to the maximum distance cover by the node in 1 second)

Tree-Based Routing algorithm with Degree Constraint for mobile sensor network has been proposed. This algorithm work in three phases: Tree formation phase, data collection and transmission phase, and finally Purification phase.

a. Tree formation phase:

The tree formation phase has the following steps:

Step 1: In tree formation phase, first base station broadcast an initial *init* message which contains the information about the position of the each base station and level distance, when any node gets this message it first calculates the Euclidian distance from the base station. And according to that distance assign a level to itself.

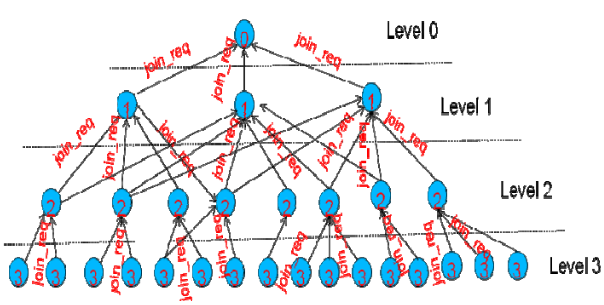

Figure 3 Join request is broadcasted

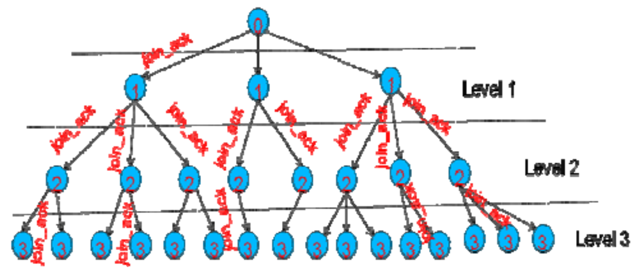

Figure 4 Join Acknowledgement by higher

Step 2: After assigning level, each node broadcast the join request (*join_req*) packet as shown in figure 3, which contains the node *id* and level of the node.

Step 3: When any node listen a join request, it first checks its parent and the level of the *join_req*. If the parent of the node is null or level is higher than or equal to the node itself then node discard this *join_req* packet, otherwise the node check its node degree if the node degree is greater than or equal to the degree constrain and also discard the request, otherwise response with a positive acknowledgement (*join_ack*) as shown in figure 4.

Step 4: The requested node join the node from which it get the first acknowledgement and as a child node to itself, then the parent node add this node to its child list and increase the node degree count by 1.

Step 5: Step 2-4 are repeated until whole tree has been form.

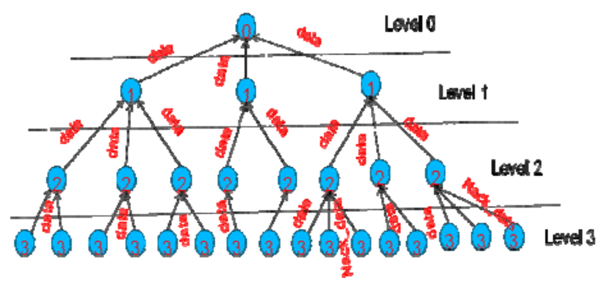

Figure 5 Child node sends its data to parent node

b. Data collection and data transmission phase

Step 6: After Tree formation phase, each node send its child list to its father node. According to the child list, the father node sends a TDMA schedule to its child node. In its schedule the child node can send its data to the father node.

Step 7: If the child node have the data then it forward its data to its parent node in its time slot (TDMA slot) otherwise it send a nack data to its parent node. CSMA/CA approach id used by the node to send the data as shown in figure 5.

Step 8: The parent node aggregate its data with children data and send it to its parent node. Finally the node near to the base station sends the collected data to the base station as shown in figure 5.

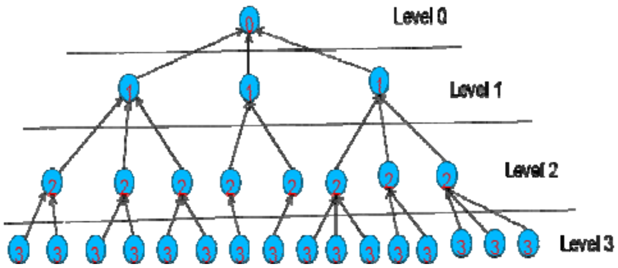

Figure 6 Movement of the node

c. Purification phase

This phase handle the several situations such as failure or movement of the parent or child node as shown in figure 6, figure 7, figure 8, and figure 9 and energy level of the nodes.

Step 9: When a node moves from one location to another location, its change its position. There are two possibilities regarding the movement of the node as shown in figure 6.

- The node either move within the same level or
- One level above or below

When the position of the node will get change it localizes

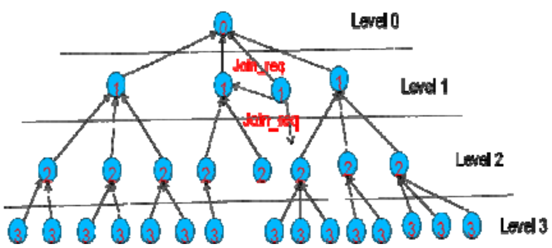

Figure 7 Node broadcast its join request

itself by localization algorithm. After calculating its position, node calculates its distance from the base station and re-calculates its level.

Step 10: If the level of the node does not change then node checks that it is in the range of its father or not, if it is within the range of its parent node then no need to re-join the tree, otherwise, node change its level according to the distance from the base station and broadcast a join request as shown in figure 7 and add the new node in its father node list from which it will get the join_ack and remove the old.

Step 11: Handling the node Invalidation

(a). Child node invalidation: when the data transmission take place if the parent node does not get any response from any of its child it add this node in the invalid list and wait for the next time slot. In the next time slot the node not getting any response this node will infer as an invalid child

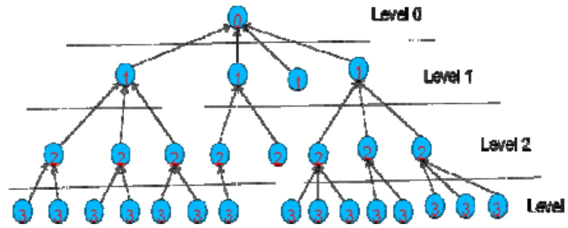

Figure 8 New tree formations

and remove this node from its child list as shown in figure 9.

b). Parent node invalidation: Each node transmits the data after receiving the data request packet to from its parent node. If any node does not receive the data request from the long time (approximately 2 time slot), it delete the father node from its list as shown in figure 10. And send the join request packet. And Re-join the tree.

Step 12: Handling the energy constrains: There are two possible value of the energy level of the node.

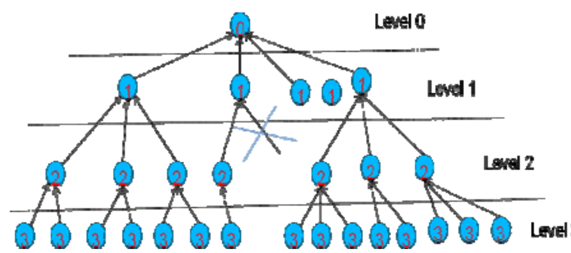

Figure 9 Child Node invalidation

- A node with an energy level higher than half of the original battery capacity.
- A node with an energy level lower than half of the original battery capacity but higher than the average energy level.

a. If the node energy level is lower than half of the original battery capacity but higher than the average energy level (Threshold value) then move the node one level lower and increase the level

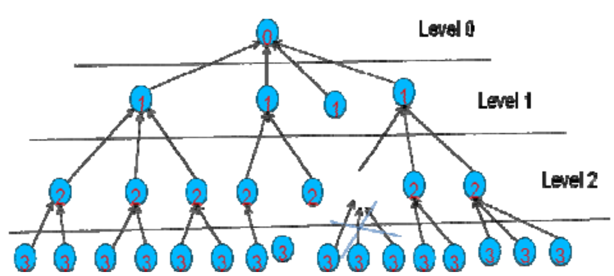

Figure 10 Parent Node invalidation

count by 1. Otherwise if the node energy level is lower than the threshold value then move this node to the lowest level.

b. If the leaf node has the energy higher than the battery capacity then move this node one level above and decrease the level count by 1.

IV. SIMULATION RESULTS & DISCUSSION

Figure 11 shows that the first node of TBRP protocol dies first when 20 nodes were taken for simulation. But as the number of nodes increases the performance of the TBRP protocol improves. This is because when less nodes are deployed, nodes were scattered very far from each other, so in order to form a tree structure more control messages were required and node had to move in order to be a part of a tree. Because of the mobility and more control messages transmitted by node, more energy was consumed hence the first node in the network with less number of nodes die early in case of TBRP. But as the number of nodes are increases then in tree formation phase the control message energy is consume and energy in mobilty is less hence the performance of TBRP protocol improve.

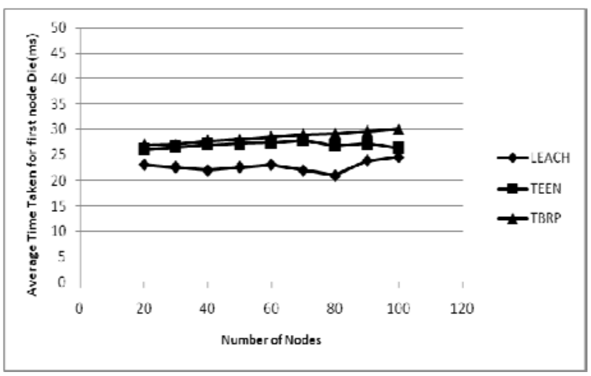

Figure 11 Average Time for first node to die vs. Number of nodes

The figure 12, initially, the energy consume in the TBRP protocol is little high than the LEACH & TEEN protocols because of the mobility of the nodes and numbers of control messages required are more. Initially, each node broadcasts the join request and receives several join request from other

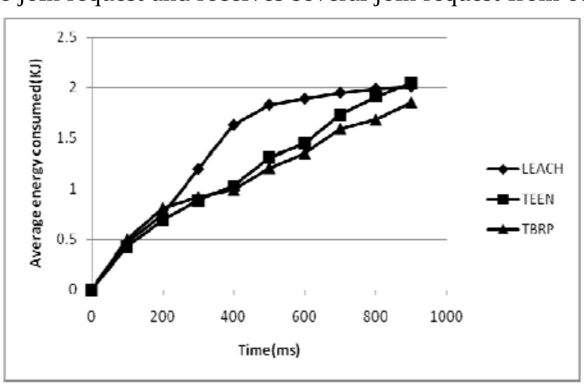

Figure 12 Average Energy Consumed vs. Time

nodes to form a tree structure, so initial energy consumption of the node is little high due to number of control messages but once the tree is form the energy consumption decreases. Thus the performance of the TBRP protocol increases as the time increases than LEACH & TEEN. Thus the TBRP protocol is energy efficient protocol for the Mobile Sensor Networks (MSNs).

Figure 13 shows the graph between average delays vs. number of nodes for different levels for TBRP protocol. When we simulate TBRP Protocol on 20 nodes, the average delay is high for the level 2 nodes and less for the level 0 nodes (Nodes near to the Base Station). The figure 13 shows that as average delay at the various levels is not increasing proportionally to the increase in the numbers of nodes. As the numbers of nodes have increased there is very small change in the delay. This shows that delay will not be much for large number of nodes hence this protocol can be used for more number of nodes and is scalable.

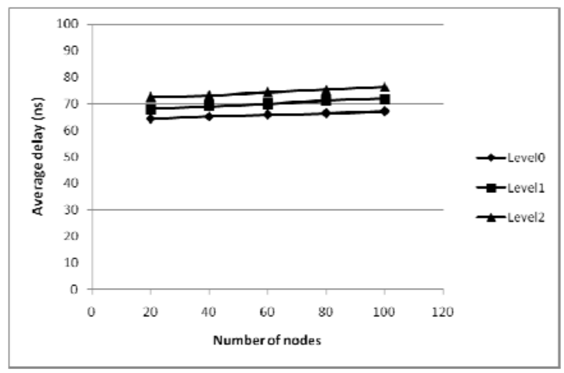

Figure 13 Average delays vs. Number of nodes for TBBRP

V. CONCLUSION AND FUTURE WORK

Mobile Sensor Networks (MNSs) have enhanced performance over static wireless sensor networks because of the mobility of the nodes. In static WSNs, the nodes closer to the sink always lose their energy first, thus causing the overall network to "die". In this work TBRP has been proposed to build an optimum mobility pattern for maximum energy efficiency. The other advantage of TBRP is that it is better targeting because sensor nodes are deployed randomly, therefore there is often a requirement to move the sensor nodes for better sight or for close proximity to the physical activity. Mobility in TBRP helps in better quality of communication between sensor nodes. TBRP is a Mobile Wireless Sensor Network Protocol. TBRP protocol improves nodes and network life time by moving the node to the next higher level. Simulation results show that the nodes in level 0 consume more energy than at higher level. When these nodes at lower level reach a critical level of energy, they move to next higher level, where energy consumption is less thus improving the life time of the nodes and network.

Simulation results show that because of mobility in TBRP energy dissipation is more efficient. Simulation results also show that the TBRP protocol for Mobile Sensor Networks (MSNs) performs better than the Static Networks (SSNs) Protocols such as LEACH and TEEN. The TBRP protocol is energy efficient than LEACH and TEEN.

There are various possible applications scenarios for traditional wireless sensor networks, which are envisaged at the moment. These applications include environmental monitoring, military surveillance, digitally equipped homes, and health monitoring, manufacturing monitoring, conference, vehicle tracking and detection and monitoring inventory control. Since, Mobile Sensor Networks (MNSs) is relatively a new concept; its specific, unique application areas are yet to be clearly defined. Most of its application scenarios are the same as that of traditional wireless sensor networks, with the only difference of mobility of the nodes.

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