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Evaluation of Energy Efficient Protocol for Object Tracking WSN using OMNet++

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Abstract: Wireless sensor networks are Ad-hoc networks which contain a set of nodes which have limited computational power and limited power resources. The usage of sensor networks is rapidly growing due to their small size and easily deployment. It means that we can easily expand and shrink such network, so sensor networks are more flexible as compare to the other wired networks. Due to this flexible nature, such networks have many applications in various fields. Object tracking is such one of the most important application of sensor network. As the energy resources are limited in the sensor node so full utilization of the resources with minimum energy remains main consideration when a wireless sensor network application is designed. Power is supplied with the help of batteries fitted with the sensor node and is not easily replaceable. In order to maximize the lifetime of sensor networks, the system needs aggressive energy optimization techniques, ensuring that energy awareness is incorporated not only into individual sensor nodes but also into groups of cooperating nodes and into an entire sensor network. In this paper we evaluate the performance of an energy saving routing protocol which tracks the object with minimum number of sensor nodes with the help of OMNet++. For this purpose Node-to-Node Activation Scheme(NNAS) is designed which works on the basis of protocol called, Node Base Routing protocol (NBR) in which next node is activated by the previous node until the object remain in the sensor network.

Keywords: ad-hoc network; object tracking; data aggregation; QoS; energy efficient; node activation;

I INTRODUCTION

The rapid development of wireless technologies has made it possible for people to monitor, control and interact with the physical world via sensor network. A wireless sensor network is a network in which a number of nodes are deployed in a region, connected to each other by means of wireless communication. This network has certain limitations such as:

- Limited energy supply.
- Limited storage.
- Wireless communication.
- Limited processing.

This network has certain advantages also over the traditional networks such as:

- Nearly Zero Configurability.
- Low Cost of Sensor Nodes as compared to GPRS Modems.
- Minimum Energy Consumption as compared to the traditional network.
- Easy Expansion and Reduction of coverage area.

Wireless sensor network though suffered from certain limitations even it has many applications such as:

- Environmental Monitoring to detect environmental changes in plains, forests etc.
- Industrial sensing and diagnostics.
- Infrastructure protection.
- Battlefield awareness to detect and gain as much information as possible about enemy movements, explosions and other phenomena of interest.
- Context-aware computing.
- Underwater cable monitoring.
- Biological and chemical attack detection.
- Tele-monitoring of human physiological data.
- Wireless traffic sensor networks to monitor vehicle traffic on highways or in congested parts of city.

The above list suggest that wireless ad-hoc sensor networks offer certain capabilities and enhancements in operational efficiency in civilian applications as well as assist in the national effort to increase alertness. Among the above mentioned applications object tracking is most typical application of the wireless sensor network (WSN), where tracking means to observe a moving object continuously without losing it and send report to the base station. Proactively waking up the neighboring node is a commonly used approach for keeping tracking [2, 3].

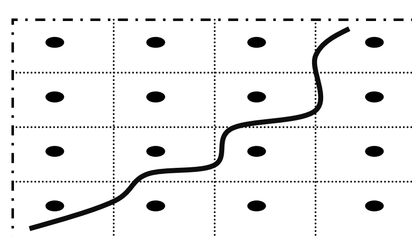


Figure 1. object Tracking in wireless sensor network field.

Figure 1 shows a field contains N number of sensor nodes which are ready to track an object. Each sensor has limited detection area, which is nearly a circle with radius *'R'*.

While designing a sensor network for object tracking, energy conservation is the most essential part under consideration because the sensor nodes are often supported by batteries which could be difficult to replace and if all the energy of a node is discharged then it will be consider as a dead node which can also disturb whole network. A lot of researches are focused on minimize the communication cost by inactivating radios as much as possible or by trading off computation for communication [4, 5, 7]. But these studies are not basically focused on the number of nodes involved in the tracking of object. In wireless sensor network some nodes are important for tracking purpose whereas other nodes are unnecessarily involved in the object tracking as they also sensed the required data, process it and send report to the base station where as same information is sent by other nodes at the same time and thus waste their energy as well their cluster head's energy also. So our main target, in this paper is to save this amount of energy to increase the life of wireless sensor network.

We define the problem and the requirements of object tracking applications and develop an energy saving scheme which reduce the number of sensor nodes needed for tracking the moving object. For this purpose we purpose a routing protocol called Node Base Routing protocol (NBR) which minimizes the number of nodes involved in tracking of moving object and also perform a node to node activation which means that current node will activate other node.

II BASIC SCHEME FOR ENERGY SAVING

Based on application requirements, we first introduce some existing basic energy saving schemes for object tracking sensor networks (OTSNs) [6]. These are:-

- Naive.
- Scheduled Monitoring (SM).
- Continuous Monitoring (CM).

Naive: It is the one of the simplest scheme used in object tracking in which all the nodes of sensor network stay active to monitor their detection area all the time. In this scheme object is tracked all the time and report is send to the base station after a regular interval by the nodes that the objects in their detection areas. This scheme is not suited for energy saving. This scheme is just discussed to compare with other schemes.

Scheduled Monitoring (SM): This scheme addresses the fact that the application does not request the network to report the sensed data all the time. Assuming that all the sensor nodes and base station are well synchronized, all the sensor nodes can turn to sleep and only wake up when object enter in to their detection area. In this scheme all the sensor nodes activate, track object and send report to the base station and go to sleep. The main advantage of this scheme is that the node spent minimum time in active mode and stay sleep for a long time. Hence a large amount of energy can be saved by using this scheme. The main disadvantage of this scheme is that it can be used only where frequent reporting is not required.

Continuous Monitoring (CM): This scheme exploits another aspect of energy saving in object tracking sensor networks. In this scheme only those sensor nodes will be activated where detection area has some object. If there will be only one node then it will be activated but if there is more than one node then all will be activated and participated in object tracking. In this way the network can save energy of wireless sensor network.

The ideal scheme shows that for each moving object in wireless sensor network, only one sensor node needs to be woken to monitor the movement of the object. However it may be noted that the required node should activate at the right time and right place. So the ideal scheme will be that which has least number of nodes participated in object tracking and the missing rate of the object should be 0% other wise to detect the missing object more energy will be consumed.

III CONSTRUCTING A NODE BASE ROUTING PROTOCOL (NBA)

The structure of the node base routing protocol is such that only node which has minimum distance from the object will remain in the active state and collect information about the object, send it to its cluster head for further processing and store it in the base station. The detail working of this technique is as under:

In figure 2 a network is designed with boundary nodes (B1, B2, B3, B4............BN) and other nodes (SN1, SN2, SN3.....................). This network also has cluster head and a path from starting location 'L1'. When an object will enter in the network the first node which is boundary node will activate which is 'B1' in this case. When object move further node 'SN1' and 'SN3' are in contact with 'B1', so at this point which node will be activated it will be decide by the cluster head and in this case 'SN1' is near to the object than 'SN3' so node 'SN1' will be selected by the cluster head not 'SN3' and 'B1' send message to the 'SN1' which activate it and it again send acknowledgement to the 'B1'. After receiving the acknowledgement 'B1' will go to sleep mode and 'SN1' start tracking object. Hence this process will continued until object will remain in the region of sensor network. In this way number of active nodes can be reduced and a lot of energy can be saved of the sensor network.

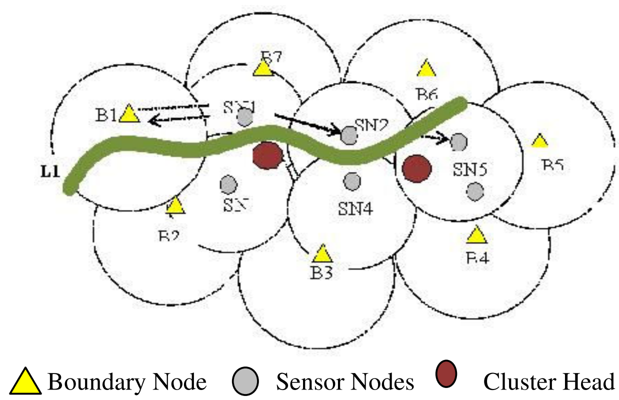


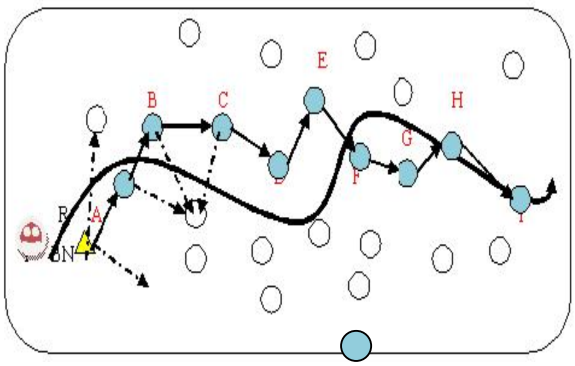
Figure2. Detail architecture of Object tracking sensor network

Another issue which cannot be avoided while discuss about object tracking in wireless sensor network is that missing of object. Missing of object cannot be avoided as there will be only one sensor node to monitor the object. If such situation arise, when object is missed by the current node then emergency tracking will be take place i.e.

If object moves with slow speed then the current node will activate the neighboring nodes for T seconds and will try to track the object. If any active nodes track the object then it will track the object by following the same procedure of NNAS and other active node will go to sleep state.

For the above mentioned Node-to-Node Activation Scheme (NNAS), we have proposed a routing protocol named Node Base Routing (NBR), which works as:

Let us consider a network of N nodes (where N represent the number of nodes being deployed in the required region) represented as SN1, SN2, SN3, SN4,…………SNi. Among these node one act as source denoted by SNsource and a node act as sink denoted by SNsink. This protocol will work as:



△ Boundary Node (BN) Active Node (AN)

◯ Nodes in Sleeping Mode (SN)

Figure3. Working of sensor network under the proposed scheme

Algorithm: Node Base Routing Algorithm

1. **input:** N nodes, an **object** P, **CN** current node
2. **if** object enter then
3. **BN** change its state from sleep mode to active mode
[Start tracking object]
BN ← Active
CN ← BN
Otherwise all nodes remain in sleeping mode
4. [as object move it will change its position and will go away from the range of current active node]
for X to Y (A, B, C, D…………) **do**
5. [activation of new node from N]
if r is min from CN then new node SN will be active
6. **SN ← Active**
7. **CN ← SN**
8. **BN ← Sleep Mode**
[after receiving acknowledgement from SN previous node will go to sleeping mode]
9. **end if**
10. **end for**
11. **else**
12. No tracking will be take place

In our proposed scheme whenever an object will try to enter in the network, a node on the boundary which will be self active node as per our assumption will detect the object and start tracking object. When object will move this active node will now activate other node SN from the network which will have small distance from this active node. All other nodes will remain in the sleeping mode.

STEP-I: Boundary nodes are self activated. This means that when an object will try to enter in the wireless sensor network, this object will be tracked by boundary node which is self activated node. If more than one node starts tracking the object then the one which is nearest to the object continue its task and others ones will go in sleep mode. Which node will be nearest to object, it will be decided by the cluster head as we have already assumed that the sensor nodes know their geographical location and cluster head has information about their locations.

STEP-II: This node will then activate other node in the network as per the direction of the moving object and will go to sleep mode, when it will receive acknowledgement from current active node.

STEP-III: This node then send the observed data to its cluster head and also will activate other node and go to sleep mode after receiving the acknowledgement from the current active node.

Step II and III are repeated until the object remains in the wireless sensor network.

By using this technique we can easily reduce the traffic congestion as well sampling rate which will definitely increase the life of wireless sensor network.

IV QoS FOR OBJECT TRACKING SENSOR NETWORK

Our aim is to design a scheme and not to find an optimal path to the gateway in terms of energy consumption and error rate while meeting the end-to-end delay requirements. End-to-end delay requirements are associated only with the real-time data. Hence our proposed scheme i.e. Node-to-Node activation scheme which is able to track the object efficiently with the few sensor nodes in the active state and maximum number of sensor nodes remain in sleep mode to save the overall energy of the object tracking sensor network and we have also tried to design this scheme so that it can met to the requirement of QoS within the same network. This Node-to-Node activation scheme is designed so smartly that at a given time 'T' there will be one node in the active state other than boundary nodes and it will sensed the data whenever object will remain in the detection region of sensor node and it will send this sensed data to the cluster head which further send it to the base station. As there is only one node in active state and it will continuously track the object as long as object remains in the detection area and send the sensed data to the cluster head, so this scheme save the energy of object tracking sensor network as well it meets the requirement of QoS in the following manner:

- Better Channel Utilization: In this scheme one node will be active and track the object so only this node will be detect the object and only this will send this piece of information in the form of packets to the cluster head. As the object move control will be shifted from current node to next node which will now track the object and previous one will go into sleep mode. So in this way overall channel utilization of the sensor network will be increased in this scheme as compare to other object tracking schemes.
- Low Packet Drop Rate: As one node detect the object and same node will transmit the sensed data to the cluster head hence there is no competition between the packets because at a given time one packet will be sent by this node as it exist in the various other object tracking schemes where more than one nodes

sensed the same piece of information and try to transmit it to the base station. In this case some packets reach the cluster head whereas other drop during the transmission and also consume more energy.

- Increase Network Throughput: Hence this scheme increases the overall throughput of the object tracking sensor network.
- Low Energy Consumption: Energy consumption in this scheme is also low as compared to the other existing schemes.

This is because most of the critical applications such as battlefield surveillance, fire detecting network, object tracking networks and many others which have to receive this piece of information regularly in order not to miss targets.

V SIMULATION AND RESULTS

The problem of tracking moving objects using a sensor network is related to not only detecting objects entering the boundary of the network, but also continuously gathering detailed information about the moving objects. A proposed solution to solve the problem must perform the required tasks while meeting the following requirements:

- Efficient overall energy dissipation.
- Optimal accuracy in detecting and tracking the objects.
- Reasonable longevity of the sensor network.

NNAS (Node-to-Node Activation Scheme) includes 4 phases: position collection, processing, tracking, and maintenance.

- In the position collection phase, the base-station collects positions of all reachable nodes in the network.
- Then, in the processing phase, it applies minimum distance techniques to clean up the redundant nodes, detect border nodes, and find the shortest path from each node to the base.
- In the tracking phase, the sensors in the network all work together to detect and track intrusion objects.
- The maintenance phase involves re-organizing the network when, for example, a change in the topology of the network occurs, or some of the sensor nodes die (i.e., running out of power).

The primary focus of this paper is development and evaluation of an algorithm for tracking moving objects inside a sensor network. The algorithm is called NBA, or Optimized Communication and Organization, which achieves the goals redundancy reduction, efficient energy dissipation, and low computation overhead on the sensor nodes, while ensures maximum accuracy of object tracking.

The simulation studies focus on the following factors:

- Number of Nodes involved in the tracking.
- Energy consume by the network as compare to the existing schemes.
- Concept of data aggregation implemented in the proposed network.
- Concept of QoS is applicable to this new designed network.

Wireless devices in ad hoc networks are normally powered by batteries. Batteries can only provide finite amount of energy. Therefore, it is important to design energy efficient protocols to reduce the unnecessary energy consumption in order to prolong the battery lifetime.

Simulators are useful tools for studying many aspects of sensor networking but without validating the simulator the results are of uncertain quality. In this simulation, we design network for three existing techniques to track the object as well new proposed one. We design sensor network for all techniques with various number of sensor nodes.

- Sensor network with 10 sensor nodes.
- Sensor network with 17 sensor nodes.
- Sensor network with 25 sensor nodes.
- Sensor network with 50 sensor nodes.

Assumptions: The following assumptions are used during the simulation:

- As the main approach of this theses is to track an object inside the wireless sensor network but for simulation purpose we assume that the object in the network is stable.
- We assume that there are two types of nodes (a) boundary nodes which have more energy (b) normal nodes which will be deployed inside the network.

Parameters: In this subsection, we list and explain all the other parameters used in the simulation study in this paper. The parameters are shown in Table 1. The various parameters that are used in this paper are:

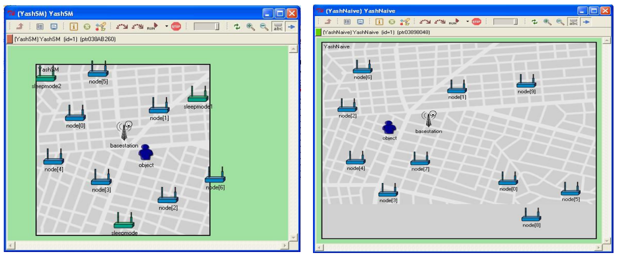
- *Sensor Nodes:* It shows the total number of sensor nodes involved in the network and this number varies as network change. In our simulation, we design four networks by changing the total numbers of sensor nodes.
- *Area observed:* This parameter shows the area covered by the sensor nodes deployed in the given reason.
- *Sensing Range:* Sensing range is the most important factor to be considered in the sensor network and as we have two different type of nodes and both have different sensing range.
- *Transmission Range (Radio):* It is the range for which a node can send data to the cluster head or the base station.
- *Power in Active Mode:* It is the amount of energy which is consumed by the sensor node when the node remains in the active state i.e. energy consume during the sending and receiving of the data.
- *Power in Sleep Mode:* When any sensor node remains in sleep mode even it will consume some amount of energy but for our simulation purpose we consider it to be zero.
- *Packet Size:* It represents the size of packet which is to be transmitted during the simulation by one node to another. For implementation simplicity, we assume that all data packets have the same size.
- *Speed of Moving Object:* This parameter tells us about the speed of the moving object but, in our simulation model we assume that object is stable and did not change its location.
- *Simulation Time:* This is the time for which the simulation runs.

Table 1: Parameters used in simulations.

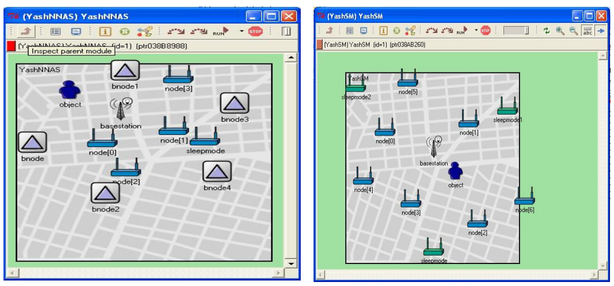
Parameters	Values
Number of Nodes used in the network	Can Vary
Area observed by the sensor nodes	Can Vary
Sensing Range of the sensor node	6m (assumed)
Transmission Range (Radio)	5.2 Kbps (assumed)

Power in Active Mode	1.2 Jps (assumed)
Power in Sleep Mode	0.0067 Jps (assumed)
Packet Size	450 bytes (assumed)
Speed of Moving Object	Object is Stable (assumed)
Simulation Time	As per requirement.

A small Wireless Sensor Network of 10 nodes is organized in a regular grid with a single sink node called base station and all the nodes are directly in contact with this node or we can say that it is the cluster head of the network and is the destination of all packets; a snapshot of this is shown in Fig. 4.



(a) (b)



(c) (d)

Figure 4: Deployment of sensor nodes in case of various schemes

In these snapshots, the deployment of sensor nodes is shown for various schemes and in figure 4 c boundary nodes are clearly shown as in that case we use two types of nodes boundary nodes and normal nodes. The triangle shapes represent the boundary nodes and as the sensor nodes are connected wirelessly so links between the nodes are not visible. There is a base station which acts as cluster head and each node send the sensed data to the cluster head which further forward this data to the server.

When these schemes are run using OMNet++ for a fixed time period than it is found that in case of our proposed scheme the total number of nodes involved in the tacking scenario is less hence consume less energy as shown in Figure 5. When number of nodes is less so total number of frames generated will be less and fewer will be collision between the frames as shown in the figure 6. All it happens due to the architecture of the tracking scheme in which a try is made to keep more and more sensor nodes in sleep mode without losing the object. Hence in this paper all characteristics of QoS like energy consumption, data redundancy, dropping of data packets etc. is consider and minimize these factors.

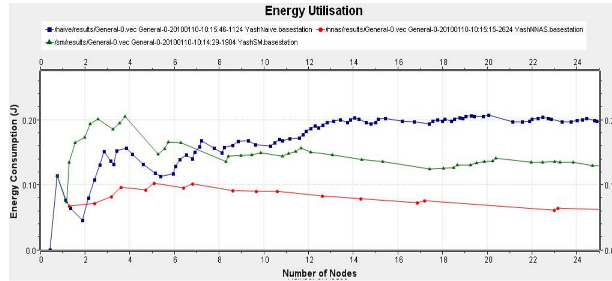
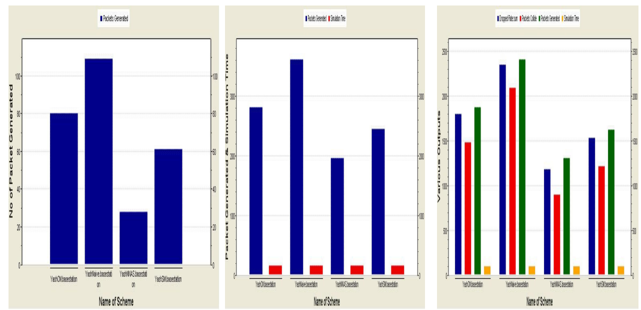


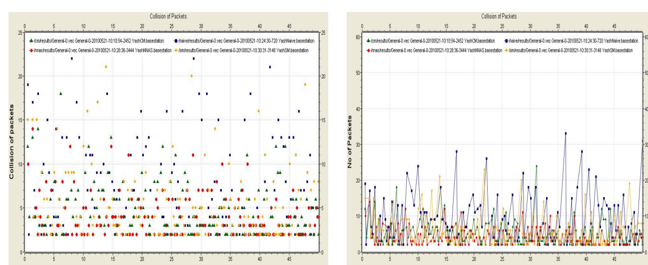
Figure 5. Comparisons of Various Schemes



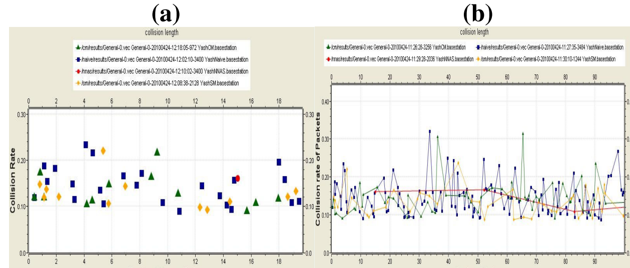
(a) (b) (c)

Figure 6. Number of Packets Generated, Collided Frames with Simulation Time.

It is clear from the figure 6 that in NNAS number of packet generated is less as compare to other schemes when all are ran for the same amount of time. It means that few nodes participated in the tracking of object and helps in the saving of energy of a wireless sensor network. As number of packets generated is low, hence dropping of packets and collision of packets is also low in case of NNAS as compare to other existing schemes which is clear from the figure.



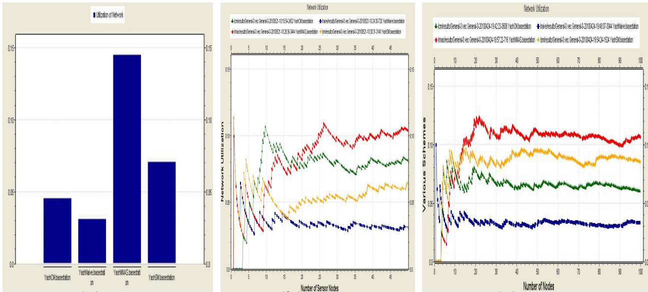
(a) **(b)**



(c) **(d)**

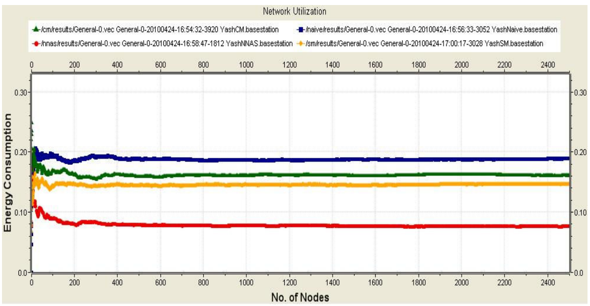
Figure 7. Different Outputs during the Simulation between Various Schemes.

As per the above discussion it is clear that in case of NNAS number of packet generated is low, also dropping rate and collision of packets is also low which show that the concept of data aggregation is fitted to this scheme also and it also fulfill the requirements of QoS as overall network utilization is increased by using this proposed scheme as shown in figure 8.

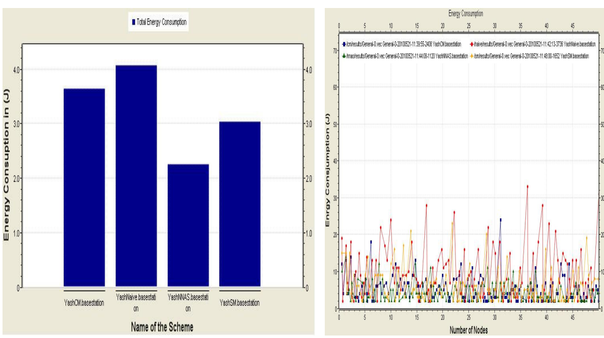


(a) (b) (c)

Figure 8. Network Utilization under various Schemes.



(a)



(b) (c)

Figure 9. Energy Consumption under Various schemes

Last but important theme of this paper is to increase the lifetime of object tracking sensor network. So the main question at this point is that 'is NNAS consume low energy as compare to other existing schemes which we have considered in this paper.

When simulation is run for various schemes for fixed time period it is found that the proposed scheme NNAS which works according to the routing protocol known as NBR (Node Base Routing protocol) consumes less energy during the tracking of object as compare to other schemes. The comparison of energy consumed by various schemes is shown in figure 9.

In this paper, we provided detailed simulation results and analysis of NBR protocol which is proposed in [9]. Simulation results show that NNAS can achieve energy savings of about approximately 45% and17% respectively as compared to the Naïve and Control Monitoring, Scheduled Monitoring.

VI CONCLUSION AND FUTURE WORK

Wireless Sensor Networks typically consist of a number of small, inexpensive, locally powered sensor nodes that communicate detected events wirelessly via multi-hop routing. WSNs are continuing to receive increasing research interest, largely due to the wide range of applications to which they are suited. A key research area is concerned with extending the limited network lifetime, inherent to the sensor nodes, which is being attempted from all areas of WSN development. This paper has addressed the issue of energy-efficient operation by considering energy-management techniques by reducing the number of nodes involved in the tracking of the object, and for this purpose an algorithm have been developed and simulated using OMNeT++ simulator which is very user friendly.

This paper has highlighted the importance of data aggregation as well QoS in the case of object tracking wireless sensor network. This paper has also considered the effect and highlighted the importance that various environmental and physical aspects of WSNs, including energy components (stores, sources and consumers), sensing devices, timing and wireless communication, can have on the operation of sensor nodes and networks. The developed algorithms have been evaluated through simulation, and the obtained results demonstrate that significant energy-savings and beneficial energy-management can be obtained by considering the value of information.

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Fifteen years from now, wireless sensors will be a "behind-the-scenes" technology that has grown to impact every aspect of our lives. All factory and machine command and control systems will have switched over to relying on wireless sensing and control points. The millions of miles of cumbersome wiring you hear about in building control and automation systems will be replaced by an invisible wireless mesh. The devices themselves will become as common place as light switches and thermostats are today. They will be tiny, cheap, commodity pieces of silicon that interact with the physical world. Today we give little thought to the modern electrical grid and what our lives would be like without it. Tomorrow we will give little thought to wireless sensor network technology and the systems that have grown to impact every aspect of our lives.

VII REFRENCES

[1]Feng Zhao, Leonidas J. Guibas, "Wireless Sensor Networks: An information processing approach ," Morgan Kaufmann Publishers an imprint of elsevier.

[2] J. Fuemmeler and V. Veeravalli. Smart sleeping policies for energy efficient tracking in sensor networks. IEEE Transactions on Signal Processing, 2007.

[3] X. Wang, J.J. Ma, S. Wang, and D.-W.Bi. Prediction-based dynamic energy management in wireless sensor networks, 2007.

[4] S. Goel and T. Imielinski. Prediction-based monitoring in sensor networks: taking lessons from MPEG. ACM Computer Communication Review, 31(5), October 2001.

[5] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan. Energy-efficient communication protocol for wireless microsensor networks. In IEEE Proceedings of the Hawaii International Confrence on system Sciences (HICSS), January 2000.

[6] Y. Xu, J. Winter, W.C. Lee. Prediction-based strategy for energy saving in object tracking sensor networks. IEEEroceedings of the International Confrence on Mobile Data Management, 2007.

[7] D. Estrin, R. Govindan, J. Heidemann, and S. Kumar. Next century challenges: Scalable coordination in sensor networks. In Proceeding of the ACM/ IEEE International Confrence on Mobile Computing and Networking, pages 263-270, seattle, Washington, USA, August 1999.

[8] M. Ditzel, C. Lageweg, J. Janssen, A. Theil, "Multitarget data aggregation and tracking in wireless sensor networks", Journal of Networks, vol. 3, no. 1, January, 2008.

[9] Y. Pal, L. K. Awasthi, A. J. Singh, "Maximize the lifetime of object tracking sensor network with node-to-node activation scheme", IEEE international Advance Computing Conference, Patiala, India, March, 2009.

[10]K. Vaidyanathan, S. Sur, S. Narravula, P Sinha, "Data aggregation Techniques in sensor networks",A Technical Report OSU-CISRC-11/04-TR60.

[11]C. Lageweg, J. Janssen, and M. Ditzel, "Data aggregation for target tracking in wireless sensor networks," in European Conference on Smart Sensing and Context, ser. Lecture Notes in Computer Science, vol. 4272. Springer, 2006, pp. 15–24.

[12] B. Jiang, K. Han, B. Ravindran, H. Cho. Energy efficient sleep scheduling based on moving directions in target tracking sensor network. IEEE Proceeding, 2008

[13] S. Aeron, V. Saligrama, D. A. Castanon. Efficient sensor management policies for distributed target tracking in multihop sensor networks. IEEE Transactions on Signal Processing, Vol.-56, No. 6, 2008.

[14] Y. Xu and W.C. Lee. On localized prediction for power efficient object tracking in sensor networks. In Proc. 1st International Workshop on Mobile Distributed Computing (MDC), pages 434-439, Providence, Rhode Island, May 2003.