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Performance Improvement in Wireless Sensor and Actor Networks

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ABSTRACT

Wireless sensor and actor network is a heterogeneous network in which actor nodes enjoy higher capabilities of sensing, transmitting, and processing. The collaboration of actor nodes with the sensor nodes has significant advantages compare to traditional sensing. Actor nodes take accurate decisions and appropriate actions based on the collected data by sensor nodes, and also reposition themselves to nearby event region. In Wireless Sensor and Actor Networks (WSAN), sensor nodes are larger in quantity with lesser capabilities and actor nodes are very few but have higher capabilities. Actor nodes are responsible for taking a localized decision which requires strong cooperation among neighboring actor nodes. Therefore, appropriate placement of actor nodes in WSAN is very important and it needs proper attention to cover larger region, reduce communication delay, and get better load balancing among actor nodes. However, in some applications this may not be possible as sensor networks are deployed on run time. Moreover, accurate deployment is difficult at the time of network establishment. After event detection sensor nodes inform the nearest actor node through multihop communication. To get better performances like low energy consumption by sensor nodes and better network life time, actor nodes must be repositioned near to the event region. In this paper we have introduced a novel mechanism for getting better network lifetime, low energy consumption, minimum delay, and high throughput through proper repositioning of actor nodes. In this paper an actor can find suitable coordinates for repositioning itself or some other actor based on Euclidean distance, energy of the region and number of nodes.
KEYWORDS: *Wireless Sensor and Actor Network, Actor repositioning and reallocation, Performance improvement in WSAN.*

1. INTRODUCTION

In wireless sensor networks, sensor nodes collaborate with each other based on energy level, region, type of sensing etc. After deployment sensor nodes communicate/broadcast with each other and make clusters in the network. Every cluster has one cluster head usually high power nodes are elected as cluster heads, and some member nodes. We have proposed a dual head clustering scheme in wireless sensor networks with two heads in each cluster[1]. After cluster formation member nodes send detected event information to the cluster head and cluster head further process this information. In many applications WSAN are using clustered approach despite of difficult management of clustered net-work. However, in some applications non-clustered approach is feasible compare to clustered approach [2]. Moreover, in clustered WSAN the actor becomes the cluster head due to their high processing and computation powers. In this paper we have proposed a mechanism that is suitable for both non-clustered and clustered approach, focusing on energy consumption and distance of sensor nodes. Our earlier work on WSAN can be studied in [3].

Wireless Sensor and Actor Networks consist of two types of nodes, i.e. a powerful actor nodes and resource limited sensor nodes connected via wireless links. In many applications both nodes are deployed randomly, and collaborate with each other to make inter-actor network [4], WSAN setup phase has been depicted in Figure 1. In WSAN sensor nodes collect data about the physical environment and actor nodes take decisions about the events. These actor nodes take suitable actions based on event detected, and let user to efficiently sense and act from a distance safely. To utilize characteristics of WSAN effectively, coordination is necessary between sensor and actor nodes. The deployed sensor nodes in a specific region are often few hundreds, whereas actor nodes do not need to be in such a great quantity due their high computational power.

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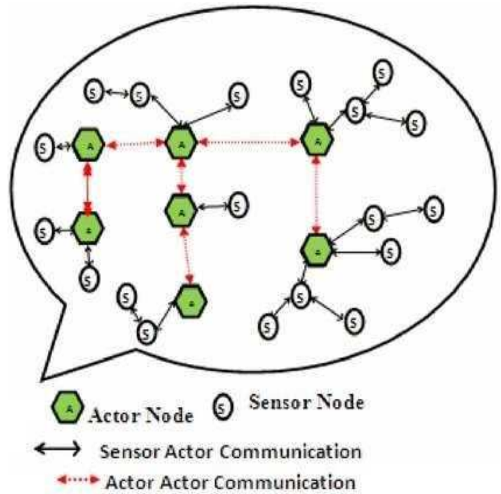

Fig. 1. A Wireless Sensor and Actor Network Setup

The main issue in WSAN is the repositioning of actor nodes in the sensing field for gaining larger region coverage , reducing delay at the time of data collection, producing high throughput, and good load balancing of actor nodes. Actor can be placed manually in areas where number of less sensor and actor nodes are deployed, for example, urban search and rescue [5]. On the other hand, area like forest and ocean monitoring consists of large number of sensor and actor nodes and these nodes are positioned in the distributed manner and their deployment is random, as sensor nodes are dropped from the aircraft.

A number of applications use such mobile actors which can move in the direction of the event region so that toreduce the transmission overhead and cover a larger area of event reporting. Mobile actors could be repositioned into the monitored region to avoid energy consumption of the sensor nodes in the network.

The rest of this paper is organized as follows. In next Section related work is reviewed, and Section III discuses system model, and system assumptions; detailed description of the proposed mechanism is provided in Section IV. Section V presents simulation results and Section VI concludes the paper.

II. RELATED WORK

In wireless sensor and actor networks communication is a hard area due to the limitations of wireless sensor nodes. Introducing high power mobile and static actor has been broadly considered as one the most impressive way for WSAN. The deployment of these nodes is random [4], therefore actor nodes must reposition themselves after network establishment. In [4] different approaches have been considered for inter-actor connectivity restoration in WSANs. The authors have focused on the inter-actor connectivity in critical applications where cooperative actions have to be taken by multiple actor nodes.

Multihop localization techniques for node mobility with locally available information have been studied for Wireless Sensor and Actor Networks with Meandering Mobility in [6]. The authors have proposed multihop actor affiliation according to network characteristics for low energy consumption. Similarly, [7] have studied WSAN from the perspective of unmanned aerial vehicles, where the actor has given the task of acting on environments and network establishment. The authors have proposed actor positioning strategy based on hybrid antenna, and a distributed algorithm for fast neighbor discovery. In [8] a detailed review of different node recovery algorithms, i.e. LeDir, RIM, DARA, have been performed and evaluated in terms of network overhead and path length validation metrics.

A distributed actor positioning and clustering algorithm has been studied in [9]. This work make use of actors as CHs and place them in their respective clusters in such manner that larger area should get covered, and take less time on data collection. This is achieved by determining the K-hop Independent Dominating Set (IDS) of the underlying sensor network. Prior to actor nodes placement, sensor nodes select CHs based on IDS, and the actor nodes are then placed at the coordinates of CHs with guaranteed inter-actor connectivity. In case inter-actor connectivity fails, the actor nodes adjust their coordinates with the help of established sensor and connectivity is achieved.

In [10] authors have proposed COLA & COCOLA for actor repositioning in WSANs. Like other mechanism, they work on minimizing data collection time, and maximizing area coverage. In this pair, the first mechanism is responsible for maximizing area coverage. Then actor nodes perform clustering and every actor node repositions itself for minimizing data collection time and energy in their respective clusters. The second mechanisms i.e. COCOLA is an extension of the first, and is responsible for inter-actor connectivity, minimum latency, and better area coverage. This is achieved through repositioning of actor nodes.

Another better approach have proposed a distributed actor deployment mechanism in [11], which provide maximum actor node coverage with better inter-actor connectivity. This approach works on spreading sensor nodes based repelling forces between neighboring actor nodes as well as from the sensor nodes which lie on boundaries. This spreading is performed using tree of actor nodes which allow the sensor nodes to freely move in the region but remain connected to the actor nodes. The authors have proposed two methods for the creation of actor nodes tree based on local pruning of actor node links and spanning tree of inter-actor node network.

In [12] the authors have modified the Gale-Shapely (GS) stable matching algorithm. This algorithm considers actor nodes as male and CHs as females. For concurrent and efficient execution of the algorithm, a cluster of actor node s and CHs is determined. Each cluster elects their CH for finding similar entries in the cluster based on GS algorithm. If non-elected/unmatched actor nodes are identified in this process, then another search is required to identify unmatched actor nodes or CHs share information about unmatched actor nodes to perform further matching. In [13-25], authors have performed different analysis and have proposed various performance improvements schemes for sensor networks, adhoc networks and their combination.

We conclude that little work has been performed on the performance improvement with actor repositioning & relocation in WSAN. Related work shows that mostly WSAN follows clustering approach and using Euclidean distance to find the position of the sensor to actor nodes. This paper has presented a novel mechanism based on distance and energy, which can effectively work in clustered as well as non-clustered applications.

III. SYSTEM MODEL

In this section we explain networks assumptions and definitions. The network consists of sensor and actor nodes. All sensor nodes are static, whereas actor nodes are a set of static and mobile nodes. We assume that sensor nodes are position-aware, and actor nodes are deployed away from each other. Static actor nodes broadcast hello packet, the sensor and mobile actor nodes that receive this message connect themselves to the static actor node based on signal-strength. After cluster establishment in the region, grid formation is computed. Each grid size is 20 meters. Non-mobile actor nodes are responsible for keeping information about grid and location of sensor nodes. Static actor nodes hear sensor nodes and mobile actor nodes which are in their radio transmission range.

We assume a field size of 100 x 100 meters is filled with sensor nodes and a few static & mobile actor nodes. (as shown in Figure 1). When sensor nodes detect an event, they report it to the nearby actor nodes. Static actor nodes listen to the sensor nodes at an interval of 1 second. Event and grid information is computed from sensed data, whereas new positions of actor nodes are computed through the proposed mechanism (discussed in next section). Mobile actor nodes move to the desired positions that reduce number of transmissions from sensor nodes to actor nodes and save the overall energy of the network.

IV. PROPOSED MECHANISM

In this section the proposed mechanism has been introduced. Upon network initialization, the network area is divided into grid size of 20 meters. Every grid has unique identifier, which helps in finding sensor node position. Static actor nodes know position of sensor nodes, and actor nodes receive event information from sensor nodes. Based on location of sensor nodes and grid identifier the number of sensor nodes in a particular grid can be identified as well as the energy of sensor nodes reporting the event in the region.

Let x is a sensor node in a grid, n is the number of sensor nodes, and y is energy of the nodes reporting the event. Then the number of sensor reporting count is $C_i = \sum_{i=1}^{n} x$ and their average energy is given by $E_i = \sum_{i=1}^{n} y / n$, whereas Regional energy, R_i is the ratio between average energy and total number of sensor nodes reporting from a region. The value of R_i is calculated as $R_i = E_i/C_i$. The value of R_i shows the energy of a grid and number of sensor nodes reporting the event. If R_i value is larger, it means that the region has high energy and the smaller value of R_i shows that the number of sensor nodes reporting are larger. Critical region is the one having low R_i value because the number of sensor nodes reporting the event is high and their energy will be low. To increase network life time, critical region is must be focused. The mobile actor node must reposition itself to the critical region. Best positioning of mobile actor nodes (location coordinates for actor nodes) can be obtained based on certain scenarios.

A. Selection of Best Possible Location Coordinate

The theme of this algorithm is to find location coordinates for actor nodes, where it should cover maximum area. Static actor nodes finds the R_i value of a grid after data collection from that grid, then decide if a repositioning is necessary. Following are some possible scenarios where best location coordinates are calculated.

1) Case 1: One Grid Reporting Region: A grid with low

R_i value is detached from the region when neighboring grids do not have reporting nodes. In this case the center of the isolated grid is the new position of mobile actor node as depicted in Figure 2. The algorithm for one grid reporting region is depicted in Algorithm 2.

Algorithm 1 One Grid Reporting Region

1: **procedure** REGION ONE CELL
2: *Reporting Region* ← Mobile Actor Node

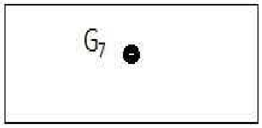

Fig. 2. Isolated Grid Reporting Region

2) Case 2: Two Adjacent Grid Reporting Regions: A grid having low R_i value and a neighboring grid has reporting nodes. In this case the common boundary line of both grids is considered a new position for mobile actor node as shown in Figure 3. In Figure 3, let grid identifier 6 (G_6) have low R_i value but C_i (total count) of G_6 and G_7 is greater than all other reporting regions. The best coverage location of a mobile actor node is the center of the G_6 and G_7/$G_1$0. The algorithm for two grid reporting region is depicted in Algorithm 3.

3) Case 3: Three Connected Grid Reporting Regions: In this case a grid with low R_i value has *two* reporting neighbor grids, where the best location for a mobile actor node is illustrated in Figure 4. A grid having lowest R_i value is used for selecting location of a mobile actor node. For example,

Algorithm 2 Two Grid Reporting Region

procedure REGION_TWO_CELL
  step-1:*search common boundary in the connected grids*
  step-2:*Common Boundary* ← Mobile Actor Node

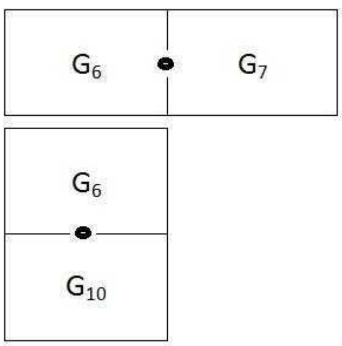

Fig. 3. Two Adjacent Grid Reporting Regions

grid identifier 6 (G_6) has minimum R_i value but total count (C_i) of G_6 with other neighbors is maximum. In Figure 4 i.e. (a),(b),(c), (d) and (e), maximum occurring corner is selected as best location for mobile actor nodes to cover maximum area. In (e) R_i value of G_6, G_7 and G_8 is compared, and gird identifier with lesser R_i value is selected as new position of mobile actor node. In this case G_6 R_i value is less than G_8, and hence selected as new position of mobile actor node. The algorithm for three grid reporting region is depicted in Algorithm 8.

Algorithm 3 Three Grid Reporting Region

procedure REGION_THREE_CELL
  if *Grid_Region = 3* **then**
    step-1:*search common vertex of grids*
    Common Vertex of Grids ← Mobile Actor Node
    if R_i *value of* $GRID_i$ ¡ R_i *value of* $GRID_{i+1}$ **then**
      Common Boundary of Reporting Grids ← Mobile Actor Node
    if R_i *value of* $GRID_{i+1}$ ¡ R_i *value of* $GRID_{i+2}$ **then**
      Common Boundary of Reporting Grids ←

Mobile Actor Node

4) Case 4: Four Connected Grid Reporting Regions:

When least R_i valued grid has *three* neighbor grids reporting the event, the proposed mechanism compare R_i of the three neighbor grids. The grid with lowest R_i value among three grids is considered a new position of the mobile actor node as depicted in Figure 5. The algorithm for four grid reporting region is depicted in Algorithm 7.

In Figure 5, six different scenarios for selection of new position of mobile actor node have been presented. In (a) common corner of all reporting grid has been selected, whereas in (b) corner of G_6 and G_9 is selected as G_6 has lower R_i compared to G_1. Similarly corner of the grid with lower R_i is selected in d (e). However, in (f) corner of G_6 & G_7 is the new location for mobile actor nodes because the combined R_i valu d G_7 is less than the combined R_i values of G_5 & G_6 and G_7 & G_8.

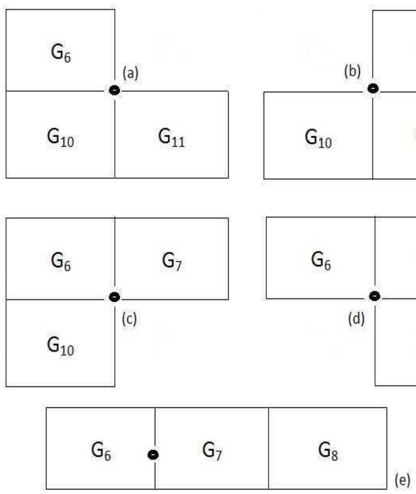

Fig. 4. Three Connected Grid Reporting Regions

Algorithm 4 Four Grid Reporting Region

procedure REGION_FOUR_CELL

if *Grid_Region* = *4* **AND** *all are connected with same Vertex* **then**

Common Vertex of Grids ← Mobile Actor Node

Common Vertex of R_{i+1} ***AND*** R_{i+2} ← $\mathrm{MIN}(R_i + RI + 1, R_{i+1} + RI + 2)$

search all three connected vertex of grids **AND** *compare their average* R_i *value*

Region with lowest R_i *value* ← Mobile Actor Node

5) Case 5: Five Connected Grid Reporting Region:

Similar to the above cases, a grid with lowest R_i value have four neighbors with reporting node. Selection of mobile actor node has to be made exactly the same way as in case four. The five connected grid reporting region is shown in figure 6.

The algorithm for five grid reporting region is depicted in Algorithm 5.

Algorithm 5 Five Grid Reporting Region

procedure REGION_FIVE_CELL

if *Grid_Region* = *5* **then**

search all three connected vertex of grids **AND** *compare their average* R_i *value*

Region with lowest R_i *value* ← Mobile Actor Node

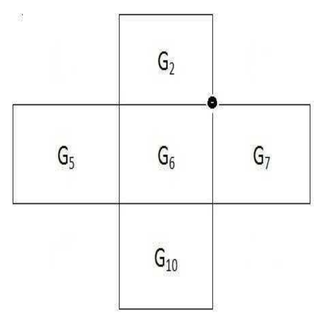

Fig. 5. Four Connected Grid

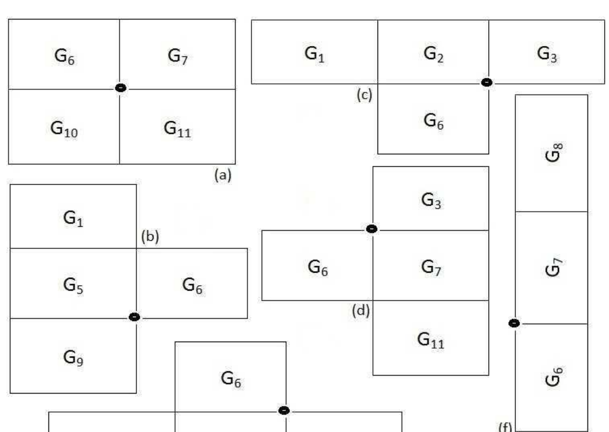

Fig. 6. Five Connected Grid Reporting Regions

B. Mobile Actor Node Repositioning

Let *P1* be the location of a static actor node and *P2* be the newly selected position for a mobile actor node by static actor node. After creation of desired location a static actor node request a mobile actor node to move to that location iff *P1* 6= *P2*, otherwise the position is discarded. The desired location is based on application specific tolerance factor, which is an acceptable range for the selection of new position and we assume it as 5 meters. Further if static actor node is in the tolerance factor of a desired location, it will perform according to the application, otherwise it will send message to the mobile actor node for moving to the desired location. The mobile actor node will broadcast a joining beacon and sensor nodes will send their data to the newly joined actor node. This new connection helps in better utilization of the network energy by avoiding re-transmission (in case of low signal-strength) as well as long-distance transmissions. As number of hops are reduced and the energy of sensor nodes (gateway/router) used for forwarding event information is saved.

V. EVALUATION OF THE PROPOSED MECHANISM

In this section the evaluation of the proposed mechanism is presented, and we assume error-free communication. This paper has simulated the proposed mechanism and has wide range of experiments on it and the results have shown in the paper are the average of all experiments. The proposed mechanism runs at the application layer. and has been evaluated in terms of *throughput*, *delay*, *Packet Delivery Ratio*, and *Residual Energy*. Simulation conditions are shown in Table I.

TABLE I. SIMULATION CONDITIONS

Parameters	Conditions
Field Size	[100 x 100] m
Grid Region	[20 x 20] m
Number of Grid Region	25 Cells
Antenna type	Omni directional
Channel Data Rate	1Kbps
Radio Propagation	Two-ray ground
Transmission range	20[m]
Carrier transmission range	40[m]
Connection type	UDP/CBR
Packet Size	40 [bytes]
Initial energy	3 Joule
BS location	[85, 45] m
Number of nodes	150
Event Reporting Sensors	10
Static Actor Listening Interval	15 sec
Protocol Used	AODV
Simulation Time	210 sec

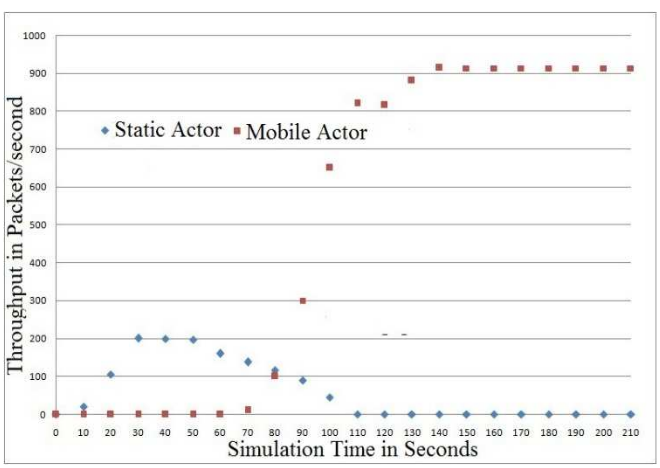

Fig. 7. Throughput of 10 sensor nodes with Packet Size of 150[bytes]

A. Throughput

Throughput is the amount of bits transferred in one second.

The throughput of 10 sensor nodes is shown in Figure 7, the static actor node receive packets after 15 seconds. Around 45 seconds the static actor nodes continuously receive fewer packets and therefore it directs the mobile actor node to a new position. At 75 seconds the throughput of static actor node approaches to zero, whereas the throughput of mobile node increases due short distance between sensor nodes and mobile actor node. The throughput gradually increases and reaches to the upper limit at around 190 second.

A throughput with reduced packet size, i.e. 100[bytes] is depicted in Figure 8, where static actor node receives packets at 15 seconds and around 45 seconds decides new location of mobile actor node. At 60 seconds mobile actor nodes receive data from the sensor nodes, and due to shorter distance to the sensor nodes and a better throughput is achieved.
Similarly, the throughput with high Data Rate, i.e. 1.6Kbps and packet size of 150[bytes] has been demonstrated in Figure 9. In this Figure at around 100 seconds a new position for mobile actor node is made and it starts receiving packets at 105 seconds. Due to high date rate a better throughput is achieved. This better achievement of throughput in all three cases shows that the new selected position for mobile actor node is the best possible coverage location where it can get maximum packets from different sensors in the region.

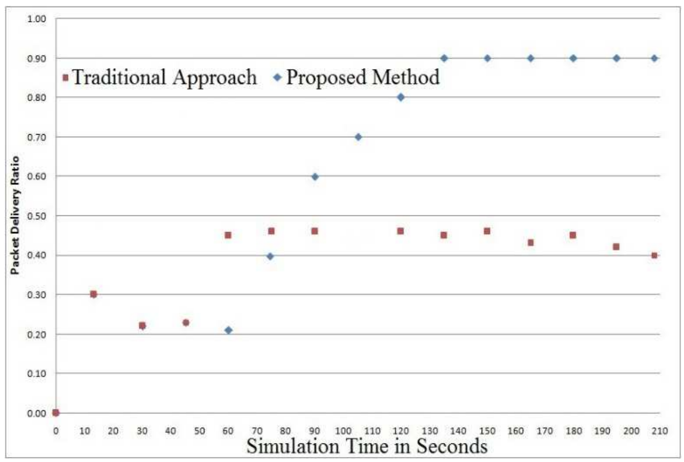

Fig. 8. Throughput of 10 sensor nodes with Packet size 100[bytes]

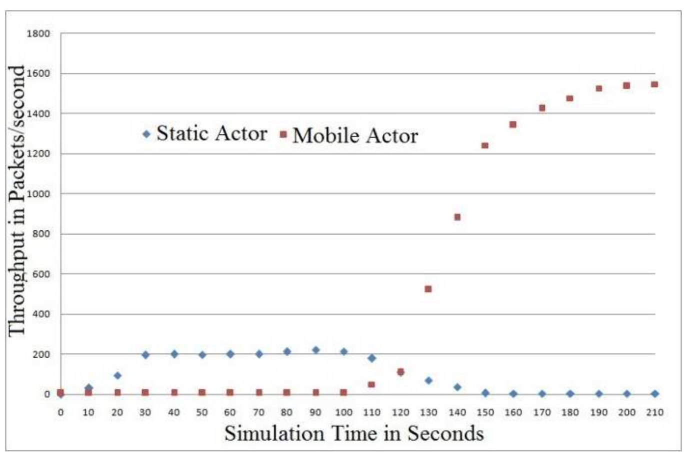

Fig. 9. Throughput of 10 sensor nodes with Data Rate of 1.6Kbps

B. Residual Energy of the Network

As sensor nodes have limited energy and we must utilize it efficiently. In the proposed mechanism the main theme of mobile actor node is to reduce energy consumption. The energy consumption is reduces when mobile actor node (have high resources) moves to the location of event and collect data from the nearby reporting sensor nodes by reducing distance & number of transmissions.

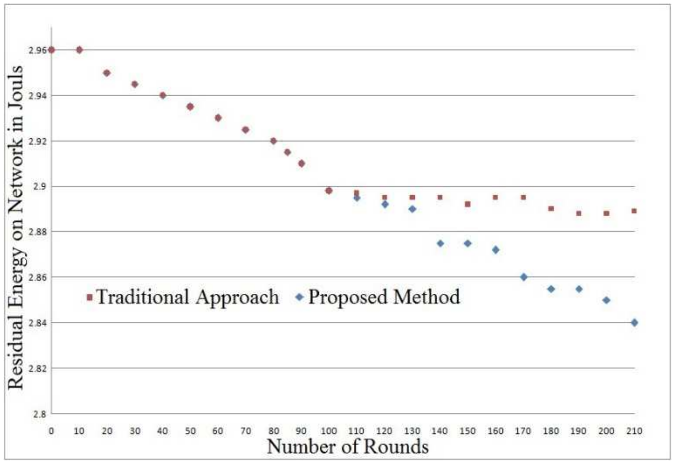

Fig. 10. Residual energy of the network

The residual energy of the network is shown in Figure 10. The communication between static actor node and sensor nodes is multihop, which uses more power of the sensor nodes. It is observed that due mobile actor node energy consumption is reduced by a greater factor compare to static actor nodes. Figure 10 demonstrates that repositioning of mobile actor node near to the event region reduces energy. At 70 second the mobile actor node start receiving packets, the network energy consumption is reduced. The efficient utilization of the network energy is possible due to reduced number of transmissions, less number of hops, and shorter distance between source & destination nodes.

C. Packet Delay

Delay is the difference between information reception time of an actor node and information transmission time of sensor nodes. In other words, let T be the transmission time of a packet and R be the reception time of that packet, then delay $d = t - r$. Figure 11 depicts average packet delay, we define average delay as $E_i = \sum^{p}_{i=1} d / p$, where p is the number of packets.

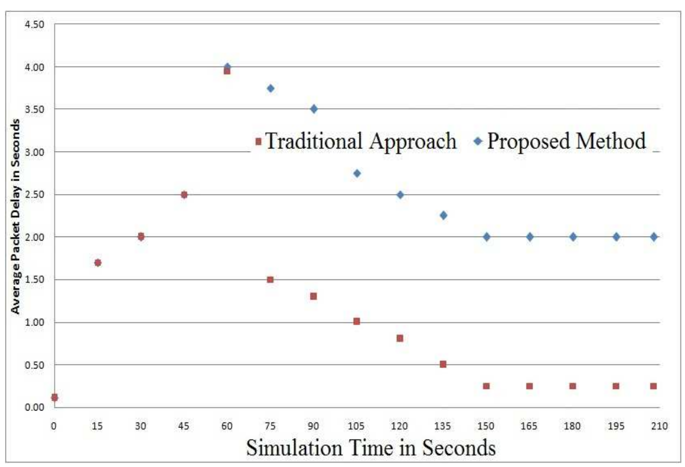

Fig. 11. Average Packet delay

The average delay in data transmission from sensor to actor node is depicted in Figure 11. Initially delay is high because all sensor nodes start transmission and congestion occurred but around 50 seconds due to the repositioning of mobile actor node (proposed mechanism) delay is better than the traditional approach (static actor nodes). When the time passes the delay is reduced because mobile actor node moved to a better position.

D. Packet Delivery Ratio

Packet Delivery Ratio is the number of packets received to the number of packets sent, and is shown in Figure 12.

Initially packet delivery ratio is low because all sensor nodes start transmission and congestion is experienced, and packets get dropped. After some time again packets are dropped and then mobile actor node is in a better position and better packet delivery ratio becomes stable. However, in case of the traditional approach (without repositioning) packets are dropped and packet deliver ratio is low.

VI. CONCLUSION

A number of applications employ mobile actor nodes be repositioned near to the event region, and that is why wireless sensor and actor networks have attracted a lot of attention in recent years due to their potential relevance in many applications. Due to mobile actor nodes, the number of transmissions is minimized and a maximum area is covered by event reporting sensor and actor nodes. Mobile actors could be repositioned to the event region for achieving high throughput, low latency, sensor nodes energy, and better packet delivery ratio. As sensors are low power devices, the proposed mechanism has focused on efficient energy consumption by reducing transmission distance and power of the sensor nodes in reporting events to actor nodes over multiple hop network. Due to the constrained resources of wireless sensor network, the movement of mobile actor nodes to the event region makes it possible to reduce distance and number of transmission. Thus better performances are achieved like reduced delay, high throughput, better residual energy of the network, and packet delivery ratio. Simulation results have shown that the proposed mechanism has reduced the energy consumption; minimize latency with high through-put and packet delivery ratio by introducing mobile actor nodes. The high throughput achievement and low latency, minimum number of packet transmissions and better network lifetime achievement makes the proposed mechanism suitable candidate to be used extensively in applications that require repositioning of actor nodes in the field.

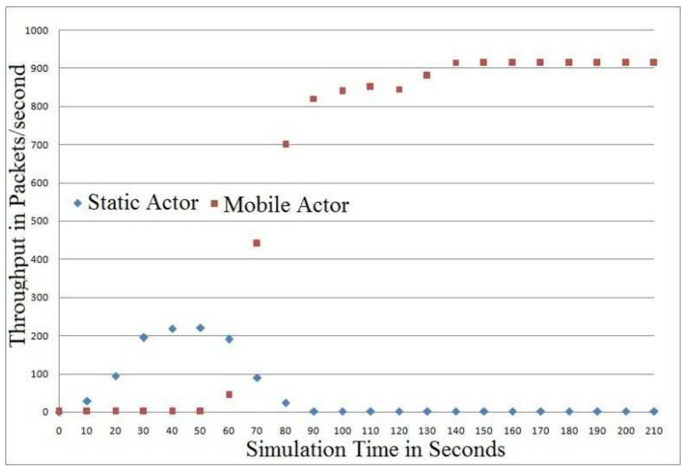

Fig. 12. Packet Delivery Ratio

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