



A Coordination and Communication Optimization of WSNs - using Clustering and Bandwidth

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Abstract— *Wireless Sensor and Actor Networks (WSANs) are designed to sense the environment with sensor node(s) and to take decision at actor node(s) after analysis of received data. WSAN has 1:n ratio in actor and sensor nodes and sensor nodes are responsible to extract information from their neighbourhood for which they are installed. Thus to transfer information from sensor to sensor/actor node we need connected network and some architecture to transmit information reliably and faster with less energy consumption to the receiver node so that appropriate decision can be taken accordingly. In this paper, a new framework based on bandwidth versus transmission length/coverage of network by actor and genetic algorithm (GA) to choose cluster head is discussed with actor level clustering technique. Actor node can increase the coverage area by decreasing bandwidth while keeping same transmission power; to transmit data to the sink node. Intermediate actor node(s) forwards data in segmented form to reduce retransmission of lost packets from initiator. The simulation results confirm the effectiveness of proposed framework over traditional approach.*

Keywords—WSANs, Sensor, Actor, Clustering, Genetic Algorithm

I. INTRODUCTION

WSANs are more powerful than WSN because of capability to process information and take decisions. Actor nodes communicate and coordinate with each other to process sensed information and the same is analysed to calculate the impact of changes in the area/environment. Actors are resourceful devices that can make decisions and can take actions too if required in the reported area. One of the examples of actors is robots. Robots/actors can move, communicate, coordinate with other actor(s) and can take decisions, and have capability to perform action(s). On the other side, sensor node(s) sense the environment and transmit the sensed data to the sink. Sensors are small in size; low cost with limited energy, computation capability and transmission powers. More precisely, sensor nodes are passive while actors are active in nature having more energy power, more computation capabilities and better transmission power. However, actors and actuators are used interchangeably in literature, but there is a minor difference in both. Actors are nodes which take decisions but could not physically perform the action(s) while actuators can do so. Moreover, actors have the capability to coordinate with each other and take decision collaboratively to assign task to one of the actor nodes. They can work as cluster head (CH), sink, data collector or gateway depending on the network architecture employed. Their architectures could be automated, semi-automated, single-actor or multi-actor architecture as per application requirement.

II. LITERATURE REVIEW

A WSAN has some actor nodes and large number of sensor nodes. The ratio between actor and sensor is always 1:n where n can vary even with every actor node depending on the network formation, requirement, and might also change after failure of one or more actor node(s). The major factors that affect the topology of network is a) energy, b) connectivity. A number of clustering techniques have been proposed in the literature. Clustering techniques form on the fly clustering while others have fixed number of clusters. The algorithms like FLOC, ACE, HEED, DWEHC, LCA, RCC, CLUBS, EEHC, LEACH, MOCA and GS3 generate variable cluster count while some algorithms have fixed cluster count.

The movement control algorithms in [17] move the disconnected blocks to restore the connectivity. While other approaches use the cascaded relocation of nodes on the time of connectivity restoration [18][19][20][21]. DARA, RIM, VCR, C2AM, PCR, PADRA works in a cascaded node replacement mode and are distributed. In cascaded mode one nearby node is selected on some predetermined parameters of the particular algorithm. Since this may disconnect the children/node(s) of the moved node. DARA and PADRA require each actor maintain 2-hop information of their neighbours. DARA, PADRA and C2AM require more network connectivity information but PADRA [18] and C2AM [21] also use Connected Dominating Set (CDS) and CAM approaches accordingly, to detect the cut-vertex (critical node) in the whole network [18]. However, the CDS based method to find the critical node is not accurate, so a depth-first search (DFS) is used by authors on each CDS node for the confirmation that node reported a cut-vertex is actually a cut vertex. Other algorithms like RIM, VCR, PCR use only 1-hop information of the network state at every node. So they reduce the communication overhead incurred in maintaining nearby neighbours information.

Whenever a node gets disconnected, the neighbours update information in their network state information table for the node if they don't receive heartbeat message even after waiting for a predefined period of time. Every node sends heartbeat messages to the directly connected nodes i.e. 1-hop nodes, to ensure them about its presence in the network. Where 2-hop information is maintained, nodes may communicate through their directly connected nodes. After detecting node failure the algorithm starts its restoration process is called reactive. Whereas, proactive algorithms designates a backup node to the critical (cut-vertex) node, and an alternate data path in the network is always available. The hybrid techniques identifies the critical actors in advance and proactively assigns one of the neighbour (preferably non-critical node) as a backup node and whenever in the future the critical actor node fails the backup node replaces that failed actor node to restore the connectivity.

Distributed Actor Detection Algorithm (DARA) proposed in [17] is distributed, localized in nature and reactive. The idea is to maintain the bi-connectivity by moving the blocks of nodes toward the cut-vertex. To compute a block tree BT a DFS is applied on an arbitrarily chosen node. The MAKEBICONNECTED(G) algorithm make the network bi-connected and try to remove the cut-vertices from the block tree [17]. Then to move the leaf nodes MOVE_LEAF_BLOCKS(G,BT) is applied to connect the individual blocks by moving them toward the parent cut-vertex of the parent block. Detailed study is given in [17]. So it is not a good approach to move all nodes in a block even if there is a connection and all operations can be carried out smoothly. Loss of heartbeat message assumed to be actor failure. If the actor failed was a cut-vertex then recovery process is started by all neighbouring actors.

The RIM approach is movement based, distributed, localized in scope algorithm for through inward motion and needs only 1-hop network state information to work [19]. Each node can independently start the restoration process and take movement decisions. One-hop Neighbour Table is maintained to store 1-hop neighbour's information in table. Each node broadcasts a HELLO message to its neighbours. Failure Detection and Initiating the Recovery is done with help of heartbeat messages. Missing heart-beat messages assumed as the failed node (Fa). The recovery process moves the 1-hop neighbours of Fa, until they are a distance $r/2$ from Fa, where r is the communication range of a sensor node.

PADRA [18], can determine possible partitioning in advance with the help of connected dominating set (CDS) and restore the connectivity in case of cut-vertex failures with a backup node (dominate). Each node in network will designate its dominatee. Thus the solution is to use cascaded movements, let on failure of A1, actor A2 moves to failed node location and results in cascaded movement of other nodes, from the closest dominatee to the failed node in order to maintain a maximum of r units of movement (i.e. MMI) for the individual actors where r is the actors' radio range and at the same time minimize the Total Movement distance of all the Actors (TMA) by decreasing the number of moving actors.

To handle the cycles in network graph an approach is used in PADRA. If node A wants to replace itself, node A has to pick a node B which has not moved before. If a node, let B here, already has travelled, it will not move anymore and will report to node A with a negative acknowledgement. It requires $O(n)$ messages to restore connectivity. PADRA outperforms DARA in terms of distance travelled that needs to know 2-hop network status information.

Volunteer-instigated Connectivity Restoration (VCR) Algorithm presented in [20] is a distributed, localized and reactive in nature. Each actor in VCR maintains 1-hop network connectivity information and monitors HEARTBEAT messages continuously. Recovery process works in two phases. First phase identify the volunteer actors in uncoordinated manner by utilizing their unused transmission power and actor diffusion. The neighbours of failed node F who participate in recovery are volunteers and others are horrid [20]. The neighbours within a certain distance from F only participate in recovery. The distance to include horrid can be increased if connectivity is not restored within predefined amount of time. The legibility factor (LF) of an actor captures the effect of the ratio of current range to maximum range. Actors with high LF are given preference and an actor can become a volunteer if its LF is more than a threshold value. Threshold value can be approximated based on the number of actors. When the volunteer actor starts moving it notifies to its children and increase its transmission power to stay connected as much possible to avoid or at least limit the cascaded relocations.

Partitioning detection and Connectivity Restoration (PCR) is a localized, distributed algorithm that proactively identifies the backup actor to handle the failure and reactively initiate localize recovery process for the failed actor node [22]. It is a hybrid recovery technique because it takes advantage of both proactive and reactive fault tolerant approach. PCR first identifies the cut-vertices with a simple localized cut-vertex detection method that can work on 1-hop network state information. After identification of critical actors, one of the neighbours is designated as backup node preferably non-critical actor with least degree and the less distant. Once each critical actor selects an appropriate backup, it informs in the HEARTBEAT messages. One actor may be selected as backup for more than one critical actor. If backup node moves, fails or relocates far away out of range then critical actor will select a new backup node. The backup actor continuously monitors the primary actor through HEARTBEAT messages. A number of lost HEARTBEAT messages indicate failure of critical actor. If the backup is non-critical actor then it will simply replace the failed node and designate a backup actor. Since each critical actor has to have a backup node to handle the disconnection in future. But if the backup node is critical actor then cascaded relocation will take place. In case, two critical actors both are serving to each other as backup.

Hybrid Energy-Efficient Distributed Clustering (HEED) [3] is a distributed clustering. WSN has some actor nodes and large number of sensor nodes. The ratio between actor and sensor is always 1:n where n can vary even with every actor node depending on the network formation, requirement, and might also changes after failure of one or more actor node(s). The major factors that affects the topology of network is a) energy, b) connectivity. A number of clustering techniques have been proposed in the literature. Clustering techniques form on the fly clustering while others have fixed

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Hybrid Energy-Efficient Distributed Clustering (HEED) [3] is a distributed clustering scheme in which CH nodes are picked from the deployed sensors based on their residual energy and communication cost when selecting CHs.

Energy Efficient Hierarchical Clustering (EEHC) maximizes the network lifetime. It is a randomized distributed clustering algorithm for WSNs. CHs collect information from sensor nodes and perform aggregation before transmitting this to the base-station. Two stage cluster formation i.e. initial and extended is used in this algorithm. Every sensor node broadcast message claiming itself as a CH to 1-hop neighbouring nodes. The nodes that are within k-hops range of a CH receive this announcement either by direct communication or by forwarding. The sensor nodes, those are not CH and are not even competing to become CH, joins a cluster as a volunteer.

Linked Cluster Algorithm (LCA) [5] emphasizes on forming an efficient network topology that can handle nodes mobility too. Adaptive clustering [6] is to minimize the transmission delay in the network and distinct code is assigned to the cluster to reduce interference between clusters. The algorithm controls the cluster size by having more number of clusters but small size.

CLUBS [7] forms clusters with the conditions that none of the nodes should be out of cluster. Each cluster must have same size diameter and nodes should be able to talk with other cluster nodes. Each node in the network takes part in the cluster formation and clusters are formed including nodes with a maximum of two hop distance. Random competition based clustering (RCC) [8] is designed for mobile ad hoc networks and also usable to WSNs. RCC mainly strives for the cluster stability and it is based on the first come first serve strategy. Hierarchical control clustering [9-11] form a multi-tier hierarchical clustering where cluster size and the degree of overlap-ping are taken into consideration. Any of the nodes in the network can start clustering process. It is a two phase process: (1) Tree discovery and (2) Cluster formation.

Wang et al. [12] favours the idea of clustering that resembles the data-centric design model of WSNs that is based on the well-known leader election algorithm. Based on their energy level a node is selected to be cluster head. The sensor node that with more remaining energy level wait longer.

Distributed Weight-Based Energy-Efficient Hierarchical Clustering (DWEHC) [13] for generating balanced cluster size and optimizing the intra-cluster topology. Each sensor node is responsible to calculate its weight, based on its energy level with respect to the neighbouring nodes. The node having largest weight would be elected as a CH and the remaining nodes become members.

Youssef et al. [14] in Multi-hop Overlapping Clustering Algorithm (MOCA), argued that guaranteeing some degree of overlap among clusters can facilitate many applications like inter-cluster routing, topology discovery and node localization and recovery from cluster head failure, etc. They proposed a randomized, distributed algorithm that organizes the sensors into overlapping clusters. Overlapping helps in inter cluster routing, recovery from CH failure and topology discovery. It also ensures that each node should be either a CH or within k hops from at least one CH, where k is a pre-set cluster radius.

In [15], Zhang et al. presented an algorithm called GS3, for self-configuring a wire-less network into a cellular hexagon structure and control the geographical boundary of clusters. The frequency re-use technique is used to minimize energy consumption.

In cellular hexagon structure, the area is divided into cells of equal radius R. There are two kinds of nodes i.e. big and small in this framework. One of the big nodes starts the clustering process and selects the CH in neighbouring cells and this selected CH selects their neighbours and so on. GS3 can be used in both environments i.e. static network as well as in highly dynamic network where nodes are mobile and change their location frequently scheme in which CH nodes are picked from the deployed sensors based on their residual energy and communication cost when selecting CHs.

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III. MOTIVATION

The energy consumed by antenna depends on the transmission length and bandwidth both. We can increase transmission length by reducing bandwidth while keeping energy consumption unchanged. Actor nodes can communicate over a long range and short range both while sensor nodes communicate with each other on a short range channel. Whenever actors communicate with each other, they use long range channel, but if an actor need to communicate with sensor, it switches to short range communication channel. The reason is that the number of actor nodes is very less as compared to the sensor nodes and actor network is prone to get partitioned whenever any or some of the actor nodes fails. Thus, to utilize actor and sensor nodes in better way, we can use the communication power of both i.e. short and long range, to transmit data over the network. Actor network can be used to transmit data whenever path between actor-actor does not exists by moving nodes or using sensor nodes as bridge to restore connectivity. Actor nodes may use fragmentation on data and get selective acknowledgement from the next actor in path to the sink/target actor. The actor node on the path keeps the segmented data until it receives selective/segmented acknowledgement from the next actor in path. After getting acknowledgment it can flush the segment from the buffer data.

Therefore, our proposed approach transmits data to the target but leaving the bridging sensor node(s) about to dead, because data may be forwarded through the same sensor node. Sensor nodes drain their energy very fast if same sensor nodes are used as a gateway again and again. And if nodes are moved to restore connectivity, it will drain the network energy. To avoid the energy drainage of the few of the nodes that may be working as a gateway or cascaded movement, the clustering can be formed on the actor nodes and transmission length of actor is in-creased by reducing bandwidth while keeping power consumption as it was. In our proposal, we use genetic algorithm (GA) to select cluster head (CH) at actor level.

IV. CONTRIBUTION OF OUR PROPOSAL

The objective of the proposed approach is to maintain a connectivity in network. We reduce the transceiver bandwidth but increases coverage length without changing power requirement. Thus network could be connectivity could be extended up to some level affecting the network transmission speed. In normal working of network (without adjustment of bandwidth) the actor nodes forwards data faster and reliably. More specifically, the main contributions of the proposed approach are:

- In our work, the network is silent until a connection is needed.
- Setup initial attributes of devices depend upon user defined scenario.
- Create a cluster network of these devices, and divide a bunch of devices into number of clusters based on sensor distribution. In each cluster, there is a cluster head (CH), all devices (sensors) transmit there data to cluster head (actor) and then cluster head route the data to the other cluster head (actor) in normal band-width or reduced bandwidth in order to transmit data to the destination.
- Model a selection procedure which is based upon genetic algorithm for the proper selection of node head devices in the network arrangement.
- Calculate distance vector between devices, and update look up matrix with respect to distance matrix.
- Calculate path and cost with respect to source device, destination device and lookup values between them.
- Devices start sending packets to cluster heads according to distance vector.
- The cluster head (actor) route the data gathered from devices (sensor) to other actor depends upon the distance vector between nodes in network (One can simply say it as cluster based distance vector routing scheme).

- We also use a transport wrapper [16], in order to increase the network efficiency. The wrapper interacts with the routing protocol and obtains route information from it. Based on the route information, it establishes multiple transport sessions between consecutive actor network partitions.

A. Genetic algorithm

The genetic algorithm chooses the best candidate node that can become the cluster head. The inputs supplied to the genetic algorithm are the energy parameters i.e. 1) initial energy of the node, 2) residual energy of the node and 3) average energy of the network. The wireless radio model plays a major role in energy consumption and therefore in the network lifetime too. The node is selected as cluster head based on the probability calculated by the genetic algorithm (GA). The genetic algorithm loops for a number of generations to produce the optimum result. Every iteration is consists of the following steps: 1) selection, 2) reproduction, 3) evaluation and 4) replacement. The fitness function checks for the solution produced in every new generation each time for optimal value.

B. Bandwidth versus coverage adjustment

The coverage capability of transceiver depends on the power requirement with re-spect to bandwidth. If we design the low power transceiver obviously it will have less coverage with same data transmission bandwidth. In our work we maintained the power consumption and reduced the data transmission bandwidth to increase the coverage length. Thus we will have connectivity with more distant devices. However it will affect network speed badly but will save network energy to restore connectivity in cascaded node movement. Node movement requires physical repositioning which requires a lot of energy and may result in cascaded movement in network leaving some nodes dead while repositioning.

V. DATA TRANSPORT PROTOCOL

We assume that the WSAAN consists of a number of clusters of actor nodes and we have to transmit data to next nearby actor in path. Actor nodes are resource rich and have large memory to store received packets and forward at a later point of time. Therefore, reliable transport between actor nodes belonging to different partitions can be obtained by setting up multiple inter-partition reliable transport sessions, one between each pair of consecutive partitions along the routes. The data wrapper is used to transmit the data in segmented form i.e. data is divided into segments and the actor node seeks acknowledgement for segment as well as packets transmitted [16]. After receiving selective acknowledgment for the segment from the next actor node in the route, the actor flushes the segment from its buffer. The wrapper interacts with the routing protocol and obtains route information from it. Based on the route information, it establishes multiple transport sessions between consecutive actor network partitions. The first actor node of every partition along the route acts as the transport cache and stores the packets in the memory before it is reliably transferred to the next actor’s cache along the route. The transport cache removes the packets from memory only after it receives acknowledgments from the transport cache of the next actor network partition. At the same time, there is an end-to-end wrapper session active between the source actor node and the destination actor node. The source node maintains a “master-copy” of the packets and flushes them out only when it receives an end-to-end acknowledgment from the destination node. The routing protocol informs the wrapper in case of path breaks, and the wrapper sets up a new wrapper session along the new path. Thus, the transport wrapper with sufficient cross-layer collaboration from the routing protocol achieves end-to-end reliable transport.

Actor node have more transmission power and can cover large area, so more than one cluster head (CH) may be connected to the one actor node. Whenever an event is detected by any of the sensor node, it immediately report to the CHi. The CHi can perform different aggregation function as per application’s requirement(s). The CHi after receiving sensor data from the region, it looks for the nearby actor node to forward it. Data is forwarded to the nearest actor node. Thus communication takes place in between sensor nodes and the sink node through actor node(s) to speed up the transmission. Because CH may be in direct range of sensor node so CHi don’t need to forward information through other sensor nodes but directly to the actor node. This will reduce the energy consumption and time delay. Even if the cluster head is not directly connected to other actor node(s) then the CHi will transmit in reduced bandwidth to the next actor/cluster head CHi-1 toward the sink. Thus the end-to-end transmission reliability is achieved in both the cases. Thus the communication takes place in between sensor nodes and the sink node through actor node(s) to speed up the transmission. This will also reduce the energy consumption and time delay.

VI. PERFORMANCE EVALUATION

Here is the performance evaluation of our proposed framework using simulation experiments. Table 1 shows simulation parameters for evaluation. We consider the end-to-end delay, packet delivery ratio, network lifetime, packet loss and throughput to evaluate the performance of proposed framework. All metrics are evaluated based on the traffic generated from sensor node to the sink node, through actor nodes and cluster head(s). We used the caching capability of actor nodes that increases throughput and consequently minimizing end-to-end delay.

Parameters	Value
Simulation area	100 x 100
Number of sensor nodes	200
Number of actor nodes	30
Initial energy (E0)	0.5 J/node

Transmitter Electronics (Eelec)	50 n J/bit
Receiver Electronics (Eelec)	50 n J/bit
Data Packet size (l)	2000 bits
Transmitter Amplifier (fs)	100 pJ/bit/m ²

The network lifetime is increased as the cluster head is changed periodically on the basis of energy parameters. Every time an actor node that have more energy level and higher probability, assigned by genetic algorithm, is selected. The clustering at actor level decreased the end-to-end packet delay because the packets travel through the actor and actor to the sink. The cluster head collects the packets and transmit to the nearby actor directly without using sensor node as a bridge.

The simulation results show the enhanced performance over the traditional WSANs sensor nodes are used to forward the packets toward the sink. Where data transmission in between sensor nodes takes more time and prone to sensor node's death. In traditional WSANs where data retransmission and selection of the wrong cluster head also degrades the network performance.

A. End-to-End Delay

The transport protocol proposed here uses the buffers of the intermediate actor nodes while transmission. Therefore, the original sender node transmits the segment to the next actor node in path to the receiver.

The end-to-end delay is decreased as the number of rounds increases, because the numbers of the intermediate nodes which are used to forward the data store stores the packets received from the previous actor/sender node until delivered to next actor in path This reduces end-to-end delay in our proposed approach as confirmed in Fig. 1.

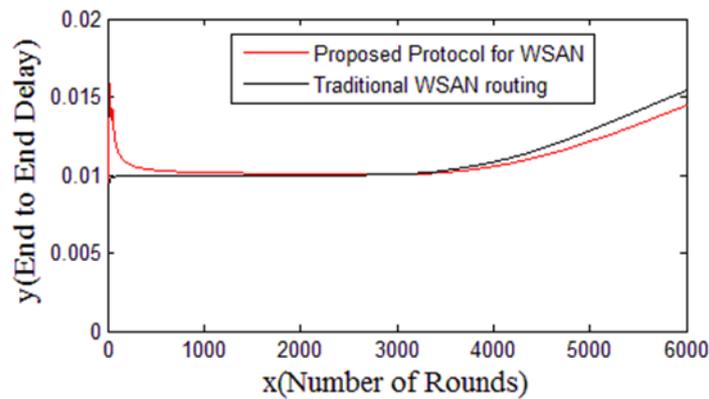


Figure 1 End-to-End Delay

The intermediate actor stores the packets received from the previous actor/sender node until delivered to next actor in path or the original receiver. When acknowledgement for the segment is received the intermediate actor node deletes the segment. Therefore, the packet delivery performance will remain high in our proposed approach as shown in Fig. 2.

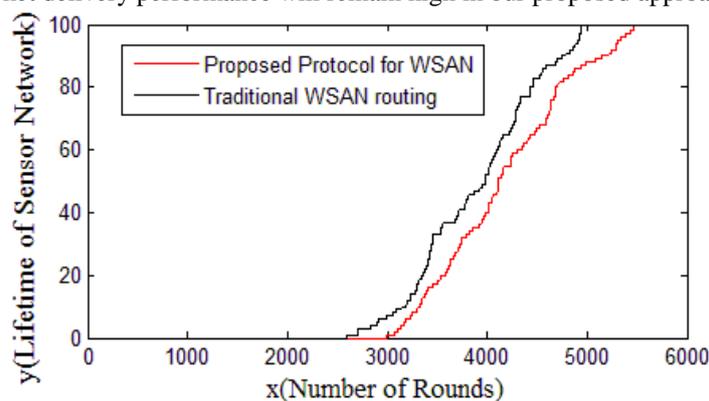


Figure 2 Network Lifetime

B. Network lifetime

A node can be dead due to some physical damage or might be out of battery power due to battery exhaustion. A network is reliable if the node death rate is low i.e. number of alive nodes are more. A reliable network will have a better data gathering rate i.e. data received at base station will also be high. Fig. 3 illustrates the number of rounds for last node death as function of number of nodes in the network. Proposed approach outperforms due to use of stable nodes as cluster heads (CHs) to transmit data through multi-hop paths instead of direct transmission to BS. Moreover, as the network size increases, the probability to find eligible stable nodes is more which is confirmed in Fig. 3. The genetic algorithm also helps in choosing the best cluster head on the basis of residual energy of the node.

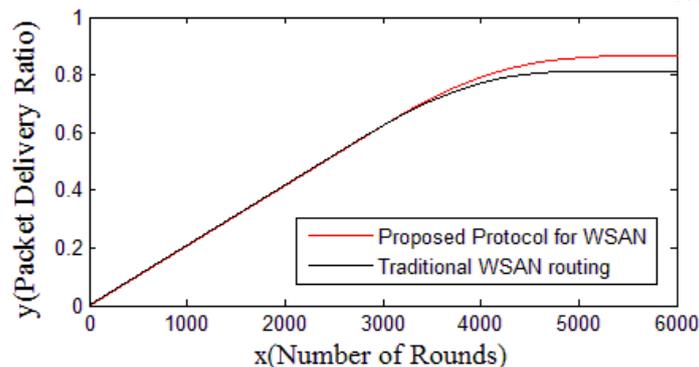


Figure 3 Packet Loss

C. Packet loss

Proposed approach outperforms traditional approach, because proposed approach uses intermediate acknowledgement packets during data transmission without using flooding mechanism. Segmented data transmission improves the performance with retransmission of packets, if required from previous actor node only not from original sender.

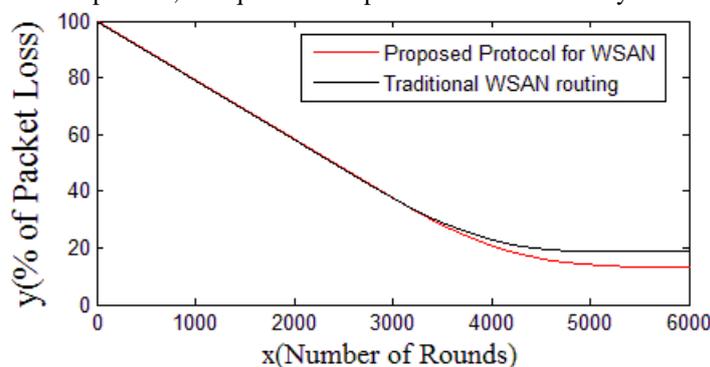


Figure 4 Packet Loss

D. Throughput

Due to the storage capability of the actor nodes the throughput increases and the direct communication between sensors and actor nodes also makes it faster. The sensors have limited storage capability and they can forward data to the actor at fast speed and actor is capable to handle more data in its memory. Fig. 5 shows that ad-vantage of our proposed approach over traditional routing protocol.

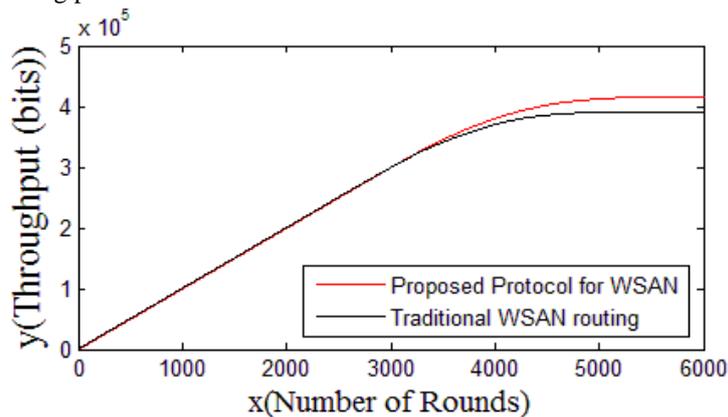


Figure 5 Throughput

VII. CONCLUSION AND FUTURE SCOPE

The network connectivity is most important factor for transportation of data and also it is most energy consuming process when number of packet failure increases in the wireless sensor network. To maintain connectivity we proposed adjustable bandwidth and transmission length/coverage capability of actor node. Thus we can have connected network always. To minimize packet failure, we have used reliable transport protocol that transmits the data in segmented form to the nearest actor node. This intermediate actor node saves the segment until next node does not send acknowledgement for the complete segment. It avoids end-to-end retransmission, but intermediate node i.e. immediate packet forwarder that has stored the segment, provide the lost message immediately. The framework presented in this paper improves not only end to end transmission delay but also improves throughput and packet delivery ratio with the help of the multi-tier clustering. In the future, our plan is to include intermediate node(s) failure to further improve network reliability.

REFERENCES

- [1] Loscri, V. Morabito, G. Marano, S., "A Two-Level Hierarchy for Low-Energy Adaptive Clustering Hierarchy (TL-LEACH)," Vehicular Technology Conference, 2005, vol. 3, pp. 1809-1813, September 2005.
- [2] S. Lindsey, C.S. Raghavendra, "PEGASIS: Power-Efficient Gathering in Sensor Information Systems", IEEE Aerospace Conference Proceedings, vol. 3, pp. 1125-1130, 2002.
- [3] O. Younis and S. Fahmy, "HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks," IEEE Trans. Mobile Computing, Vol. 3, No. 4, pp. 366-379, Oct.-Dec. 2004.
- [4] S. Bandyopadhyay, E. Coyle, An energy efficient hierarchical clustering algorithm for wireless sensor networks, in: Proceedings of the 22nd Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2003), San Francisco, California, April 2003.
- [5] D.J. Baker, A. Ephremides, The architectural organization of a mobile radio network via a distributed algorithm, IEEE Transactions on Communications, COM-29, vol. 11, pp. 1694-1701, 1981.
- [6] C.R. Lin, M. Gerla, Adaptive clustering for mobile wireless networks, IEEE Journal on Selected Areas Communications, vol. 15, no.7, pp. 1265-1272, 1997.
- [7] R. Nagpal, D. Coore, An algorithm for group formation in an amorphous computer, in: Proceedings of the 10th International Conference on Parallel and Distributed Systems (PDCS'98), Las Vegas, NV, October 1998.
- [8] K. Xu, M. Gerla, A heterogeneous routing protocol based on a new stable clustering scheme, in: Proceeding of IEEE Military Communications Conference (MILCOM 2002), Anaheim, CA, October 2002.
- [9] S. Banerjee, S. Khuller, A clustering scheme for hierarchical control in multi-hop wireless networks, in: Proceedings of 20th Joint Conference of the IEEE Computer and Communications Societies (INFO-COM'01), Anchorage, AK, April 2001.
- [10] M. Demirbas, A. Arora, V. Mittal, FLOC: a fast local clustering service for wireless sensor networks, in: Proceedings of Workshop on Dependability Issues in Wireless Ad Hoc Networks and Sensor Networks (DIWANS'04), Palazzo dei Congressi, Florence, Italy, June
- [11] H. Chan, A. Perrig, ACE: an emergent algorithm for highly uniform cluster formation, in: Proceedings of the 1st European Workshop on Sensor Networks (EWSN), Berlin, Germany, January 2004.
- [12] K. Wang, S. Abu Ayyash, T.D.C. Little, P. Basu, Attribute-based clustering for information dissemination in wireless sensor networks, in: Proceeding of 2nd Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks (SECON'05), Santa Clara, CA, September 2005.
- [13] P. Ding, J. Holliday, A. Celik, Distributed energy efficient hierarchical clustering for wireless sensor networks, in: Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS'05), Marina Del Rey, CA, June 2005.
- [14] A. Youssef, M. Younis, M. Youssef, A. Agrawala, Distributed formation of overlapping multi-hop clusters in wireless sensor networks, in: Proceedings of the 49th Annual IEEE Global Communication Conference (Globecom'06), San Francisco, CA, November 2006.
- [15] H. Zhang, A. Arora, GS3: scalable self-configuration and self-healing in wireless networks", in: Proceedings of the 21st ACM Symposium on Principles of Distributed Computing (PODC 2002), Monterey, CA, July 2002.
- [16] Handigol N, Selvaradjou, K, Murthy, C.S.R., "A reliable data transport protocol for partitioned actors in Wireless Sensor and Actor Networks," High Performance Computing (HiPC), 2010 International Conference on , vol., no., pp.1,8, 19-22 Dec. 2010.
- [17] P. Basu and J. Redi, "Movement Control Algorithms for Realization of Fault-Tolerant Ad Hoc Robot Networks," IEEE Networks, Vol. 18, No. 4, pp. 36-44, August 2004.
- [18] K. Akkaya, A. Thimmapuram, F. Senel, S. Uludag, "Distributed Recovery of Actor Failures in Wireless Sensor and Actor Networks", Proceedings of Wireless Communications and Networking Conf., Los Vegas, USA 2008, pp. 2480-2485.
- [19] M. Younis, S. Lee, S. Gupta, K. Fisher, "A Localized Self-healing Algorithm for Networks of Moveable Sensor Nodes," Proc. of the IEEE Global Telecommunications Conf. (Globecom'08), New Orleans, LA, Nov 2008.
- [20] M. Imran, M. Younis, A. M. Said, H. Hasbullah, "Volunteer-instigated Connectivity Restoration Algorithm for Wireless Sensor and Actor Networks", Proc. the 2010 IEEE International Conference on Wireless Communication, Networking and Information Security (WCNIS '10), Beijing, China, June 2010.
- [21] A. Abbasi, U. Baroudi, M. Younis, and K. Akkaya, "C2AM: An algorithm for application-aware movement-assisted recovery in wireless sensor and actor networks," in International Conference on Wireless Communications and Mobile Computing, 2009, pp. 655-659.
- [22] Imran, M., Younis, M., Said, A.M., Hasbullah, H., "Partitioning Detection and Connectivity Restoration Algorithm for Wireless Sensor and Actor Networks," Embedded and Ubiquitous Computing (EUC), 2010 IEEE/IFIP 8th International Conference on, vol., no., pp.200-207, 11-13 Dec. 2010.