Enhanced Passive Clustering Algorithm for Wireless Sensor Network

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ABSTRACT: *Wireless Sensor Networks (WSNs) is an emerging area belonging to the wireless technologies that has recently developed interest among the industry and academic researchers. It consists of small battery powered sensors, where failures of sensor nodes and disruption of connectivity are regular phenomena. Therefore, energy consumption and network lifetime are important issues. Clustering is one of the most efficient algorithms for selforganization. The most important point in this algorithm is cluster head selection because a good clustering guarantees stability, energy efficiency and load balancing in the network. In this paper we propose a new approach called EPC (Enhanced passive clustering algorithm), which evenly distributes the energy dissipation among the sensor nodes to maximize the network lifetime. This is achieved by using residual energy, number of neighbors and distance between nodes in the selection of nodes clusterheads and election of clusterhead backup. The simulation analysis of the EPC over the existing system shows the improvement in performance attained through the proposed passive clustering protocol. It reveals that the approach proposed algorithm improves significantly and particularly the network lifetime.*

Keywords: Wireless Sensor Networks, Self-organization, Clustering Passive, Clustering, Network Lifetime, Energy Efficiency, Fault Tolerance, Residual Energy

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1. Introduction

The WSNs have a large number of tiny sensor nodes that are deployed densely over the network and a base station. The base station can be placed either inside or outside the network. Wireless Sensor Networks (WSN) is emerging as a rich domain of active research involving hardware, networking, distributed algorithms and other disciplines. Sensor nodes which have the limited energy, are mostly set in the area where is dangerous or not easily accessible [1]. Accordingly, the reduction of energy consumption of nodes and increase the network lifetime is a challenge of these networks.

The sensor nodes are battery-operated, with low power and limited storage capacity, moreover non-rechargeable and not replaceable. Hence, efficient energy management plays a very critical role in increasing the lifetime of the network. Clustering techniques have been proposed among the best solutions. These techniques organize the nodes into clusters where some nodes work as clusterheads and collect the data from other nodes in the clusters. Then, the clusterheads can consolidate the data and send it to the base station as a single packet, thus reducing the number of packets exchanged in the network.

In a clustered network, the nodes are grouped into clusters. The energy efficiency of a clustered sensor network depends on the selection of the Clusterheads. In [2], they propose an energy-aware cluster formation protocol (GRIDS) which increase the lifespan of a sensor network by using an efficient selection mechanism of critical (or not) nodes. It promotes energy efficiency by reducing communication and effective sleep mode operation. By examining remaining power level, low powered sensor nodes can go to sleep for the next round of operation period. GRIDS inherits many advantages from Passive Clustering. Younis and Fahmy [3] propose a Hybrid Energy-Efficient Distributed clustering (HEED), which creates distributed clusters without the size and density of the sensor network being known. However, the cluster topology fails to achieve minimum energy consumption in intra-cluster communication. Heinzelman et al. [4] propose a low-energy adaptive clustering hierarchy (LEACH), which generates clusters based on the size of the sensor network. However, this approach needs a priori knowledge of the network topology.

This paper, provides a modified, yet improved version of this clustering protocol and the simulation results showing the performance analysis. The protocol proposes first identifies the nodes with highest residual energy and number of neighbors, takes them as a cluster Head and clusterhead backup, then forms a cluster associated to this CH by the proximity of the nodes to itself by sending the advertisement packets.

The rest of the paper is organized as follows. In Section 2, we present related works. Section 3 describes both the energy model and network model. Section 4 describes the proposed algorithm. Experimental results are reported in Section 5 and conclusions are drawn in Section 6.

2. Related Work

Clustering is an important research topic in the areas of wireless sensor network (WSN) because clustering improves the performance of many systems. In WSN, clustering can be used to improve the network performance through quality of service metrics such as throughput and delay, in the presence of both mobility and a large number of mobile nodes with minimal resources. Passive clustering can be described as on demand cluster formation protocol that does not use dedicated protocol-specific control packets or signals. The formation of cluster is dynamic and initiated by the first data message to be flooded. Which in turn reduces the duration of the initial set-up period, and the benefits of the reduction of the forwarding set can be felt by calculating the total energy consumed because the main function of the clusters is to optimize the exchange of flooded messages.

GRIDS [2] is an energy-aware cluster formation protocol which increase the lifespan of a sensor network by using an efficient selection mechanism of critical (or not) nodes. This mechanism allows balanced energy consumption among thesensor nodes without requiring additional overheads including additional signaling, time synchronization and global information. GRIDS is based on an energy model which delivers node’s residual/remaining energy level in real time. This information is piggybacked in the nodes packet header. Each sensor determines being insomnious or not based on its residual energy and the number of neighbouring insomnious nodes and their energy level. An efficient flooding during each wake up period determines insomnious nodes in the network. GRIDS selects insomnious nodes well distributed in the sensor deployed area. GRIDS inherits PC for constructing and maintaining clusters. The main differentiator is that a set of nodes in a cluster with higher energy levels have higher probability to become critical nodes, i.e., CH or GW. In PC, CHs keep their cluster status until there is a CH collision, i.e. the hop distance between two CHs becomes 1, and one of them resigns from CH. In GRIDS, an energy abundant node can challenge CH and usurps the role. Even if there is a CH declaration, nodes can challenge when their energy levels are higher than the one of CH. These nodes keep their cluster status even if they receive packets from the current CH.

LEACH [4] is one of the first hierarchical routing Protocols used for wireless sensor networks to increase the life time of network. LEACH distributes energy consumption all along its network, the network being divided into clusters and CHs which are purely distributed in manner and the randomly elected CHs, collect the information from the nodes which are coming under its cluster. Only cluster-head can directly communicate to sink and member nodes use cluster-head asintermediate router in case of communication to sink. LEACH routing protocol operations based on rounds, where each round normally consists of four phases: Advertisement phase, cluster set-up phase, schedule creation and data transmission. Once all the nodes are organized into clusters, the CH is responsible for collecting data from the cluster members and fusing it. Finally each clusterhead has all the data from the nodes in its cluster, the cluster-head node aggregates the data and then transmits the compressed data to the base station.

Passive Clustering [5] is a cluster formation protocol that does not use dedicated protocol-specific control packets or signals.

Each node collects neighbor information when there are on-going data packets and can construct clusters even without collecting the complete neighbor list. This is an innovative approach to clustering which virtually eliminates major cluster overheads - the time latency for initial clustering construction as well as the communication overhead for neighbor information exchanges. Instead of using protocol specific signals or packets, cluster status information (2 bits forfour states: Initial, Clusterhead, Gateway, and Ordinary-node states) of a sender is stamped in a reserved field in the packet header. Sender ID (another key piece of information for clustering) is carried by all the existing MAC protocols and can be retrieved from the MAC header. Since in flooding the MAC packets are transmitted in broadcast (instead of unicast) mode, every node receives and reads the packets (in a promiscuous way), and thus participates in passive clustering.

3. Energy and Network Model

In this section, we present the model of energy that will be used in the performance evaluations section.

3.1 Energy model

The energy model used is same with that in [6]. Equation (1) represents the amount of energy consumed for transmitting l bits of data to d distance. Equation (2) represents the amount of energy consumed for receiving l bits of data which is caused only by circuit loss.

$$E_{TX}(l,d) = \begin{cases} l * E_{elec} + l * \varepsilon_{fs} * d^2, d \prec do \\ l * E_{elec} + l * \varepsilon_{mp} * d^4, d \geq do \end{cases}$$

$$E_{RX}(l,d) = l * E_{elec}$$

In which:

- the energy consumption per bit in the transmitter and receiver circuitry;
- ε_{fs}: Free space model's amplifier energy consumption;
- ε_{amp}: Multiple attenuation model's amplifier energy consumption;
- d_0: a constant which relies on the application environment.

3.2 Network model

We consider a sensor field consisting of a set of sensors deployed randomly in a rectangular space. The algorithm assumes the following characteristics:

- Sensor nodes are mobile.
- Sensor nodes are densely deployed.
- Sensor nodes have similar capabilities for sensing, processing and communication.
- Sensor nodes transmit data to its immediate cluster head in the allotted time slots or to the backup.
- All nodes are energy constrained and perform similar task.

4. Proposal- Enhanced Passive Clustering

In this section, we present the details of the new algorithm which provides several advantages . It uses balanced energy consumption among network nodes, minimizes the number of clusters (Clusterhead) and provides effective coverage of the network, thus it keeps longer the structure of clusters and minimize the consumed energy. As a result, the network stability is preserved and the lifetime of the network is significantly increased.

4.1 EPC mechanism

EPC (Enhanced Passive Clustering) defines a protocol for cluster formation and election of clusterheads based on the following principles:

a) There are six possible states: dead, initial, ordinary, clusterhead_ready, custerhead, gateway and clusterhead- Backup.

b) Initially, all nodes are in the 'initial' state. This state does not change as long as a node does not receive a packet from another node.

c) When a node receives a packet and if the state of a sender is ClusterHead the node switches to state ordinary or gateway. Otherwise, the receiver's state switches to ClusterHead_ready,

d) A node in ClusterHead_ready state will switches to ClusterHead, when its coefficient $K(i)$ *is best.*

e) The node ClusterHead_ready switches to state gateway when the number of ClusterHeads is greater or equal to the number of Gateways. Otherwise, the node becomes an Ordinary Node or an alternate node.

f) The node ClusterHead_ready switches to clusterhead-backup status when the number of clusterheads is greater than or equal to the number of gateways and the number of clusterheads is greater than the number of backups and the coefficient $K(i)$ *is the second best. Otherwise, the node becomes an Ordinary Node.*

g) The cluster head node selects the second best $K(i)$ *node as clusterhead-backup in case of failure of the previous one. The cluster head checks periodically the presence of his backup. In case of failure of the backup, the cluster head replays the selection process of a new backup.*

h) Similarly, if the clusterhead-backup discovers the leaving of the cluterhead it switches to state ClusterHead and launch the procedure to select a backup(see Figure 1).

i) An ordinary node switches to clusterhead-backup if its $K(i)$ *is higher. The clusterhead-backup node switches to state ordinary.*

EPC uses the same principles as PC for the construction and maintenance of clusters in wireless sensor networks. It also inherits the characteristics of the algorithm GRIDS by giving nodes with the highest level of energy to become a critical node, i.e., ClusterHead, Clusterhead-backup or GateWay.

$$\mathbf{K(i) = (E_n(i) * NN_n) \div D_n}$$

$$\mathbf{E_n(i) = E_{remaining}(i) \div E_{Initial}(i)}$$

$$\mathbf{D_n(i) = (\text{The average distance between the node i with all other nodes in the same cluster}) \div (\text{The maximum range of a node})}$$

$$\mathbf{NN_n(i) = (\text{the number of neighbors}) \div (\text{The maximum number of neighbors supported})}$$

Where k (i) is the threshold of elect CH.

4.2 State diagram EPC

5. Simulations

In this section, we present comparison between proposed algorithms and two most important clustering protocols, PC and GRIDS. The simulation models used for the performance evaluation were implemented in the GloMoSim library [7]. The GloMoSim library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation language called PARSEC [8]. We begin first by specifying the metrics that we considered interesting to evaluate this algorithm and results obtained.

The simulation para meters used are as follows:

- the roaming space is 600 × 600 m square,
- The radio propagation of each node reaches up to 250 meters
- The channel capacity is 2 Mbits/second.
- The battery capacity is equal to 500 mW
- Nodes are mobiles.
- Simulations use a variable number of nodes ; distributed randomly in the roaming area;
- The random-way point model is used for node mobility
- AODV [9] is chosen as the routing protocol;

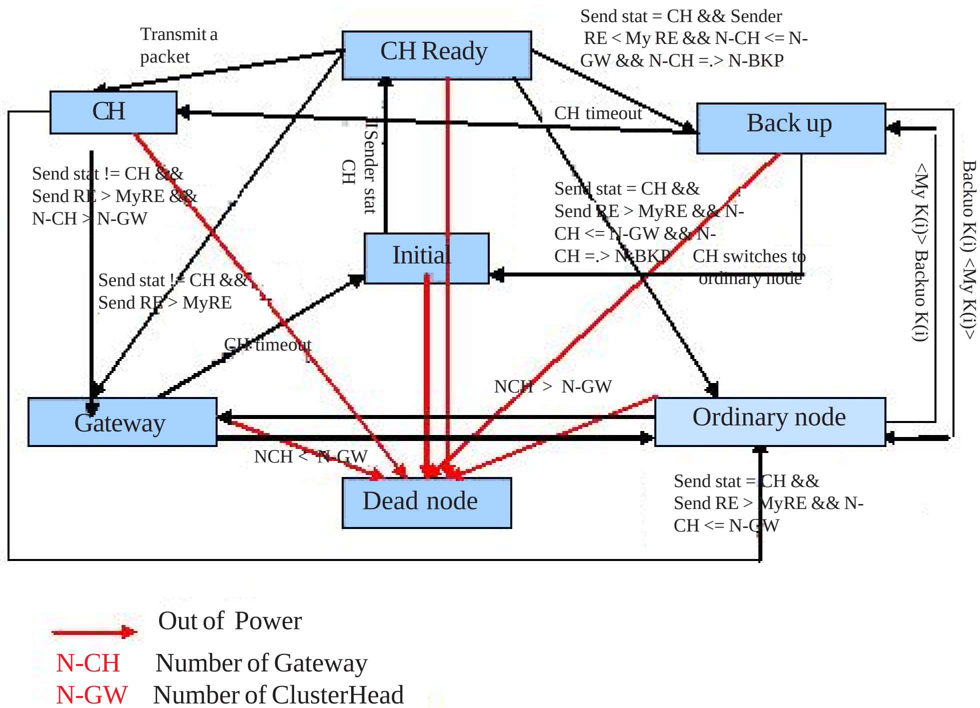

Figure 1. State diagramme of EPC

We use three metrics for analyze and compare the simulation results: network lifetime, energy wasting and delivery ratio at base station.

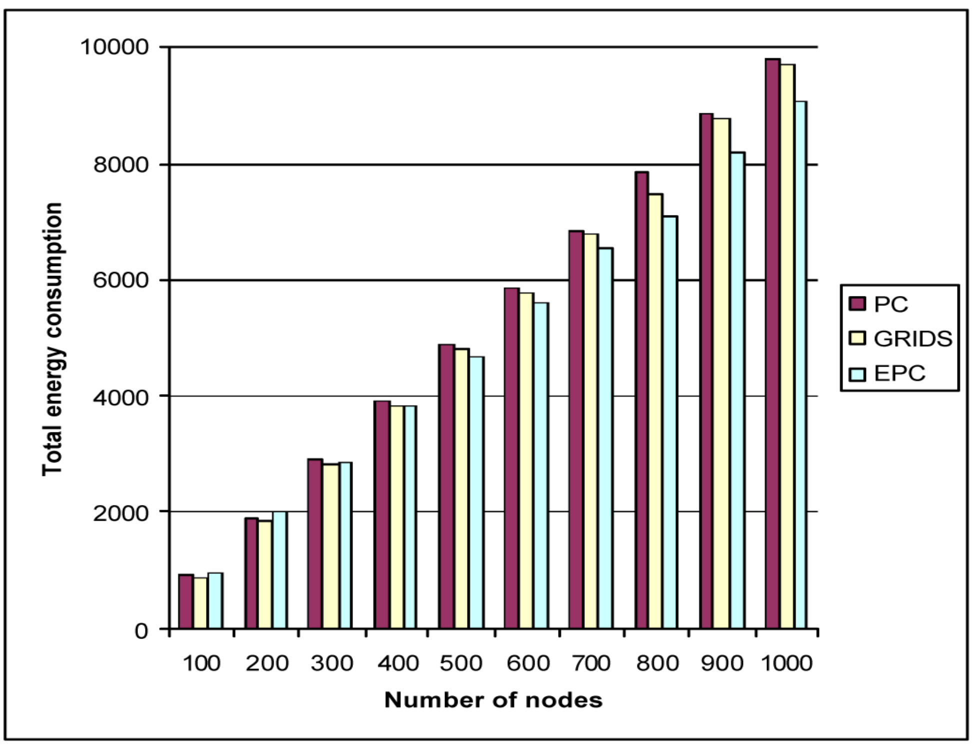

Figure 2. Total energy consumed during a simulation of 30 seconds

Figure 2 show that the proposed algorithm consumes more energy for a number of nodes less than 400 nodes. By against, it consumes less energy for a greater number of nodes. Thus, we conclude that this algorithm is more suitable for large scale networks.

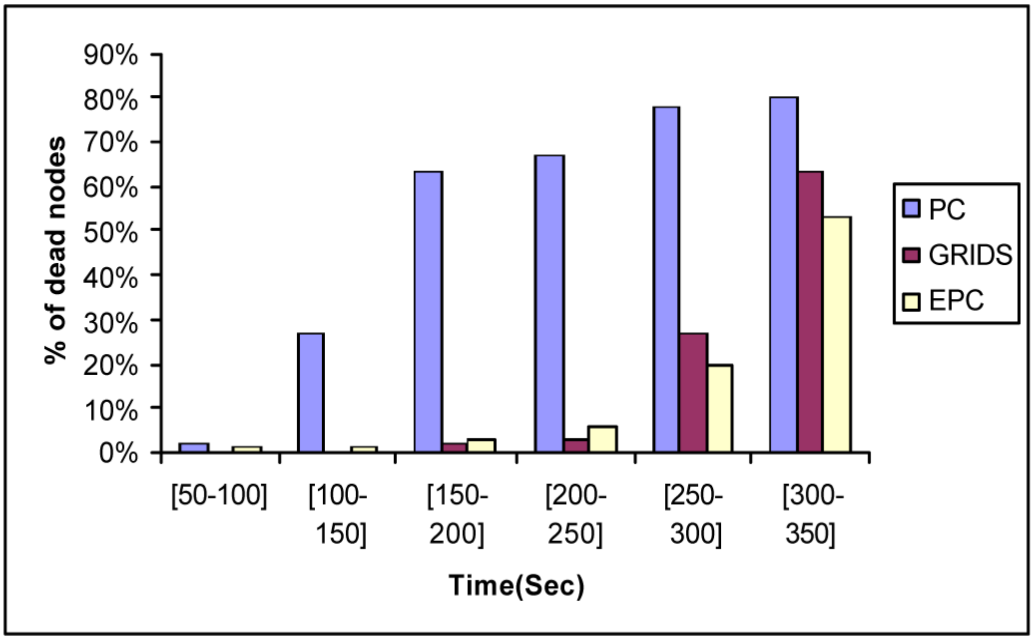

Figure 3. Percentage of dead nodes in a simulation of 300 nodes

Figure 3 shows a comparison of dead nodes between the three algorithms PC, GRIDS and proposed EPC algorithm. The results show that the proposed algorithm retains more the energy of each node. Thus, it achieves better results in optimizing the energy consumption.

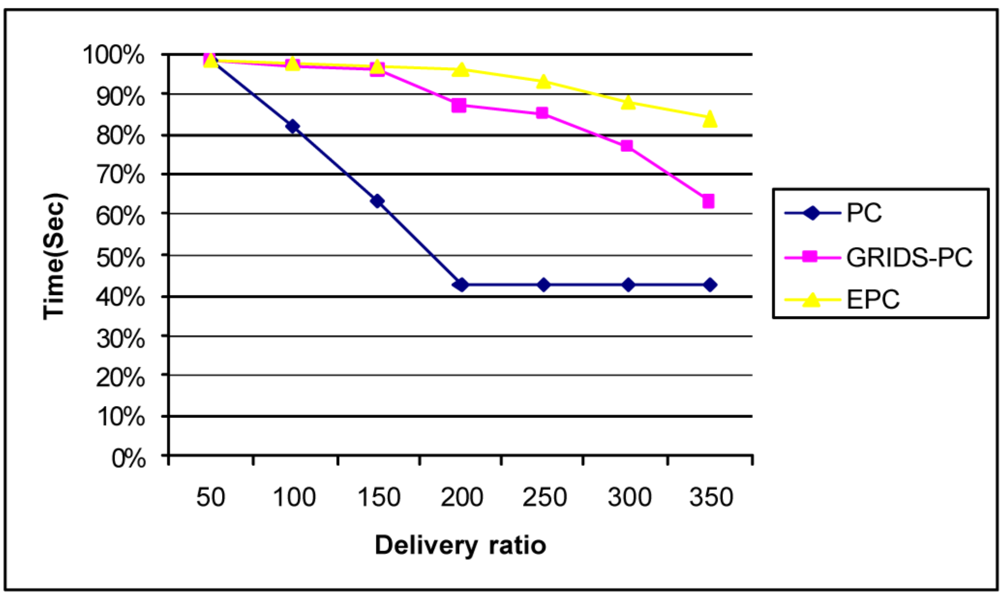

Figure 4. Delivery ratio in a simulation of 300 nodes

Similarly, Figure 4 shows that also the Delivery ratio is much better with EPC, because EPC decreases the number of dead nodes, minimize and retains more the cluster structure. Thus, the simulation results show that the Enhanced Passive Clustering for Wireless Sensor Network scheme not only provides an efficient forwarding and balances the energy consumption but also improves network performance.

6. Conclusion and Future Work

Due to the limitations of wireless sensor networks in terms of energy, many algorithms for self-organization have been proposed to increase the lifetime of the network. This paper includes several contributions; first, it has considered the critical nodes (clusterhead) and these nodes select backup nodes with more energy and less distance. The second, Nodes clusterhead and nodes backup shall periodically to share information and verify the presence of each other. The third, the clusterhead and the backup clusterhead are selected according to the average distance between the nodes of the cluster and the remaining energy. Simulation results show the effectiveness of the approach in reducing the amount of energy consumed by the network in comparison with two well-known protocols, passive clustering and GRIDS PC.

In the future, we plan to study different failure scenarios in sensor networks and introduce run-time fault-tolerance in the system.

References

[1] Ian F. Akyildiz, Weilian Su, Yogesh SanKarasubramaniam, Erdal Cayirci. (2002). A survey on Sensor Networks, *IEEE Communications Magazine*, 40 (8) 102-114, August.

[2] El-Ghanami, D., Kwon, T. J., Hafid, A. (2008). GRIDS: Geographically Repulsive Insomnious Distributed Sensors An efficient node selection mechanism using Passive Clustering, IEEE WIMOB'08, France.

[3] Younis, O., Fahmy, S. (2004). HEED: A Hybrid, Energyefficient, Distributed Clustering Approach for Ad Hoc Sensor Networks, *IEEE Transactions on Mobile Computing*, 3 (4) 366-379.

[4] Heinzelman, W., Chandrakasan, A., Balakrishnan, H. (2000). Energy-Efficient Communication Protocol for Wireless Micro-sensor Networks, *In*: Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00)

[5] Kwon, T. J., Gerla, M. (2002). Efficient flooding with passive clustering in ad hoc networks, *ACM SIGCOMM Computer Communication Review*, 32 (1) 44–56.

[6] Heinzelman, W., Chandrakasan, A., Balakrishnan, H. (2000). Energyefficient Communication Protocol for Wireless Sensor Networks[C], *In*: Proceeding of the Hawaii International Conference System Sciences, Hawaii, January.

[7] Gerla, M., Bajai, L., Takai, M., Ahuja, R. (1999). GloMoSim: A Scalable Network Simulation Environment, Technical Report 990027, University of California at Berkley.

[8] Bagrodia, R., Meyer, R., Takai, M., Chen, Y., Zeng, X., Martin, J., Park, B., Song, H. (1998). Parsec: A parallel simulation environment for complex systems, *Computer*, 31 (10) 77-85, October.

[9] Perkins, C. E. et al., Ad hoc on-demand distance vector (AODV) routing, [Online] Available: http://www.ietf.org/internet-drafts/draft-ietf-manet-aodv- 13.TX