Advanced Passive Clustering

Mobility in wireless sensor networks

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***Abstract*—A wireless sensor network (WSN) is a set of nodes communicating through wireless links to observe a given phenomenon .Mobility of sensor nodes posed new challenge witch demands researchers' attention .Given the constraints of mobility and energy consumption, WSNs require the implementation of new algorithms. In this paper, we propose a new protocol designated for Mobile Nodes in Wireless Sensor Network that is based on the passive clustering. This is a strategy of balancing energy consumption between nodes to maintain the cluster architecture for long-term and reduces energy consumption.**

Keywords: wireless sensor network, self-organization, passive clustering, active clustering, mobility.

I. INTRODUCTION

Wireless sensor network consists of a large number of sensor nodes deployed over a geographical area to extract information in hostile environments. Each node in the network of wireless sensor can monitor its environment and communicate the information collected in one or more collection points.

Each sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission to a central collection point (sink node or base station)[1]

Wireless sensor networks can be used in a wide range of potential applications such as national security, surveillance, health care, biological detection, environmental monitoring, and many other applications where fixed infrastructure is not easily acquired.

A sensor network is composed of several nodes distributed geographically to form a network without established infrastructure. With the large number of sensor nodes deployed in remote environments, the ability of individual sensor nodes to self-organize is vital .The two main classes of self-organization protocols used today in wireless sensor networks are mainly based on clustering, and multi-hop routing[1].

In this paper, we present a new algorithm for clustering APC (Advanced Passive Clustering) suitable for sensor networks while introducing the dynamics of organizational constrained by the energy status of sensors and their mobility.

This paper is organized as follows. In the next section, we outline the methods clustrering. In the second section, we describe our clustering algorithm APC, its principle and its properties. The final section presents the perspectives.

II. SELF-ORGANIZATION IN SENSOR NETWORKS WIRELESS

Self-organization is a process by which a set of elements, interacting with each other, produce an organization that tends to be maintained over a certain period. It could for example create a hierarchy reflecting the network: the coordinators will be chosen from such nodes with the lowest mobile talk time with a high energy, large storage capacity and memory [2]. The challenge is to organize dynamically and spontaneously nodes to form a network with a maximum life while satisfying the constraints of quality of service.

The issue of self-organization is essential in sensor networks. It must take into account the structure of sensors: each sensor consists of three units: a unit of event detection, calculation and communication. All these components are powered by a battery, it is therefore necessary that the proposed self-organization algorithms limit the exchange of control packet for a minimum expenditure of energy. Thus, the sensor network will have a maximum longevity.

III. CLUSTERING METHODS

Clustering (or grouping) is to bring together geographically close nodes into groups called "clusters" and to establish patterns of different routing within the clusters (intraclusters) and between clusters (inter-cluster). It has been used for different objectives such as the collection of information in networks of sensors [3] and the sharing of bandwidth [4].

Each cluster is represented by a particular node called cluster-head is elected by a specific metric or combination of metrics it is responsible for coordination between the different members of the cluster, to aggregate their data collected and sent to the base station.

In a cluster, each node stores all the information of its cluster and some of the information of other clusters; This minimizes considerably the size of routing tables and the number of messages exchanged in the network. So clustering gives the best results from the multi-hop routing, the reason we have also adopted this approach.

Figure 1. Frame format in PC

A. *Active Clustering*

Active clustering uses a method of periodic exchange of Hello packets to collect information on the network topology. The first Active clustering algorithms were based on specific criteria for the selection of clusterhead Lowest-ID, for example [4] uses the identifiers of nodes and the number of neighbors, Mobic [6] uses the degree of mobility, for against LEACH (Low Energy Adaptive Clustering Hierarchy) randomly selects cluster-heads nodes and assigns this role to different nodes according to the policy management Round-Robin (it means tourniquet) to ensure a fair energy dissipation between the nodes [7].

These algorithms require two phases: neighbor discovery and cluster formation phase. However, nodes are assumed fixed over the steps and synchronization between them is necessary for the success of these algorithms. In addition, following each change of network topology these steps are repeated periodically which degrades the stability of clusters.

B. *Passive Clustering PC*

Passive Clustering (PC) is a protocol for formation of clusters, which does not use a specific protocol control packets or signals. It allows exploiting the data packets to transmit neighbor's information.

Passive Clustering uses the MAC frame (layer 2 of the TCP /IP) to encode the state of a network node; in particular, Passive Clustering introduces two bits to encode 4 states: ordinary, cluster_head, gateway, clutster_head_ready. Each data frame contains two additional bits (Figure 1) representing the state of the node has released the frame.

With PC, each time a packet arrives at any node, the node needs only the state that is bonded to the received packet to the treatments for the selection of gateway, clusterhead or ordinary node. Only clusterhead and gateways that broadcast data packets and control; ordinary nodes receive the packet but do not participate in their broadcasts, Reducing collisions and reduces the amount of packets exchanged; therefore, there is a considerable decrease in energy consumption by the ordinary nodes which can increase the lifespan of WSN.

C. *Comparison between active and passive clustering*

In Active clustering, aggregation of data is centralized and carried out periodically. However, in some cases, the periodic transmission of data may not be necessary, which rapidly depletes the limited energy of sensors. Passive clustering was defined to overcome/eliminate the limitations of active clustering in terms of overhead and energy consumption (more traffic means more energy consumption). So PC has many advantages compared at active clustering.

- It reduces the latency of the establishment of clusters and the additional traffic control by exploitation of data packets.
- It uses a very effective heuristic that reduces the number of gateway during the delivery of packet.
- It reduces energy consumption by eliminating the periodic sending of control information.
- It is easy to implement and fully distributed.

IV. NEW ADVANCED PASSIVE CLUSTERING PROTOCOL (APC)

APC (Advanced Passive Clustering) is a protocol for the formation of cluster, like the Passive Clustering - PC, that does not require an initialization phase before routing cluster.

Since the information is embedded in data packets, the traffic generated by the transmission of these packets is used to build the infrastructure of the Cluster regardless of the routing protocol. APC also takes into account the energy level of nodes in operations and many decisions are made based on the energy level of nodes. So APC predicts changes in the topology of sensor networks in environments with high mobility.

A. *Principle*

Our clustering algorithm based on the APC following principles: the designation of the clusterhead, the formation of clusters, election clusterhead_backup and maintenance of clusters formed.

B. *Operating mode*

The state diagram describes the APC functions (figure2).

APC has the same operating mode as PC. In this new protocol were defined six states: CLUSTERHEAD (C_H), CLUSTERHEAD_READY(C_H_R), GATEWAY(G), ORDINARY, INITIAL(I) and the state added to passive clustering is CLUSTERHEAD_BACKUP (C_H_B).

We summarize the algorithm of APC as follows:

- At startup, all nodes are in the initial state, a node that joins the network, also starts with the initial state. A node changes its state only when it receives a packet from its neighbors. If the sender is not clusterhead, its status is clusterHead_Ready.
- The clusterhead will clusterhead-ready, if he can transmit packets before receiving of another clusterhead. If the packet comes from another clusterhead, the node records its id, the time of receipt, and adds this node to the list of clusterhead, and then it switches to Ordinary.
- The clusterhead selects from its neighbors list a ClusterHead_Bakup, this is the node that has the highest energy among all its neighbors.

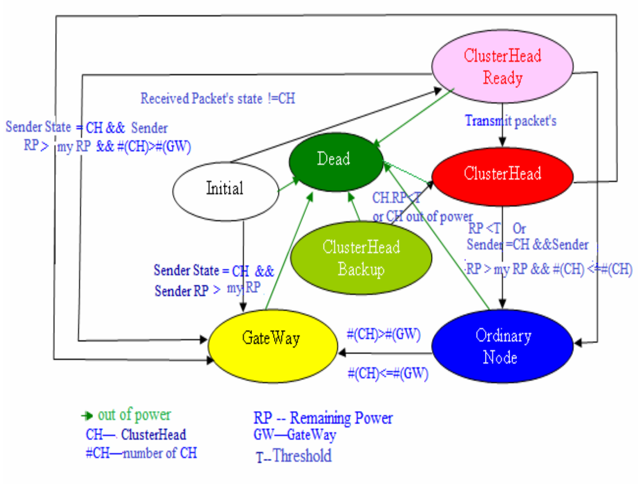

Figure 2. State diagram of APC

- Once the clusterhead leaves the cluster, or its energy is below a given threshold T, ClusterHead_Backup replaces the clusterhead and chooses its ClusterHead_Backup from its neighbors list.
- All non-clusterhead nodes maintain a neighbors list of clusterhead. When a node receives a packet from a clusterhead, it updates the list of clusterhead at the same time it checks the number of active clusterhead. If it is greater than or equal to two node becomes Gateway. In general, in mobile ad hoc networks and wireless sensors, the number of gateways is significant and can exceed the number of Ordinary nodes, so we must reduce the number of gateways for effective flood.
- Several heuristics are used to elect a clusterhead in each cluster following a weight calculated that distinguishes it from other network nodes. As an example algorithm "Distributed and Mobility Adaptive Clustering" in [8] and [9] introduced the notion of generic weights for the selection of clusterhead. A clusterhead, which does not receive a packet from gateway during a preset time, change its status to normal. This node broadcasts all packets that it receives.
- Each node collects information about the neighbors. It stores id, status and idle time - if the idle time beyond the timeout threshold, the entry is deleted.

Table 2 presents a pseudo-code that shows the operation details of APC.

```
Input
Packet; /*packet received by the node*/
Node; /* node receiving the packet */
Batery = 300; /*maximum capacity of the battery*/
T = 150;/* Threshold energy*/
```

```
Begin
Node.state = initial;
While (true)
If (Node.energyLevel == 0)
   Node.state = dead;
Else If (Node receives Packet)
      Switch (Node.state)
          Case Initial:
            If (Received Packet's state != CH)
               Node.state = CH_ready;
            Else If (Sender.state = CH && Sender.RP>My.RP)
               /*RP represents the remaining/residual energy*/
                Node.state = Gateway;
                 Endif
          Endif
       Case CH_ready:
          If (Node Transmit a packet)
              Node.state = CH;
              Check_clusterhead_backup;
         Else If (Sender.state = CH && Sender.RP>My.RP
                    && #(CH) <= #(GW))
                   Node.state = ON;
         Else If (Sender.state = CH && Sender.RP> My.RP
              &&  #(CH) > #(GW)
                 Node.state = GW;
              Endif
        Endif
        Endif

     Case CH:
        If (Sender.state = CH && Sender.RP > My.RP &&
              #(CH)  <= #(GW))
              Node.state = ON;
              CHBtoOrdinary;
              Check_clusterhead_backup(sender);
       Else If (Sender.state = CH && Sender.RP> My.RP &&
              #(CH) > #(GW))
              Node.state = GW;
             CHBtoOrdinary;
             Check_clusterhead_backup(sender);
             Endif
             Endif

     Case CH_backup:
            If (CH_timeout or CH.RP <T)
              Node.state = CH;
              Check_clusterhead_backup;
              CHtoOrdinary;

      Case GW:
             If (#(CH) <= #(GW)
              Node.state = ON;
             Endif
      Case ON:
            If (#(CH) > #(GW)
```

```
            Node.state = GW;
       Endif
      EndSwitch
    Endif
  Endif
Endwhile
End
```

C. Comparison between APC and other algorithms of PC

Most clustering protocols require reconstruction of the cluster at the time of departure of the clusterhead (Figure 3).

As against APC maintains the structure the cluster by replacing the clusterhead by its clusterhead_backup (Figure 4) which allows it to reduce the control traffic between nodes, and increase the life without losing the performance of sensor networks.

On the other hand, APC deals and makes available in real time the current energy level and the amount of energy consumed by each node that is not the case for most algorithms of PC; and it reduces energy consumption based on the predictions of motion of the nodes.

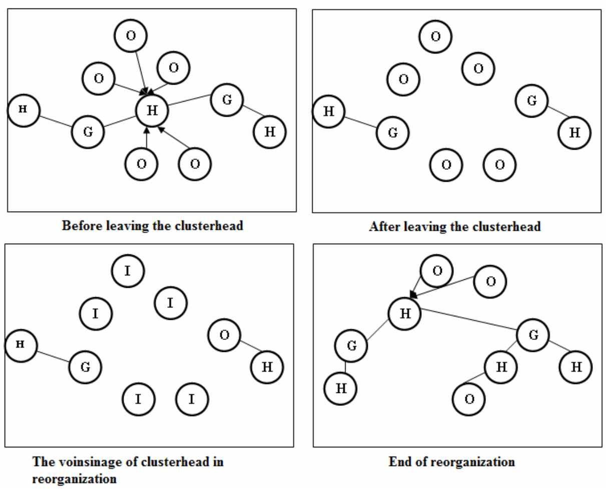

Figure 3. Depart of clusterhead in PC

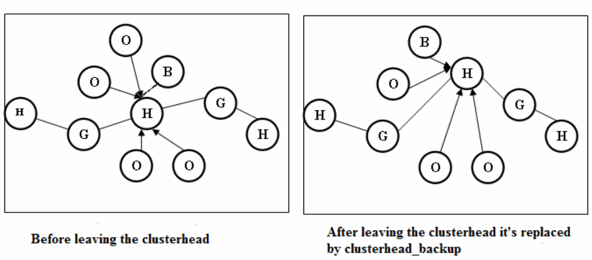

Figure 4. Depart of clusterhead in APC

V. SIMULATIONS AND RESULTS

We conducted a series of simulations to assess the performance of the proposed clustering mechanism. and compare it to other protocols such as PC and GRIDS. The simulation models used were implemented in the GloMoSim library[9], which is a scalable simulation environment for wireless networks based on the Parsec language[10]. The radio propagation range for each node is 150 meters and channel capacity is 2 Mbits/sec. The roaming space is 600x600 meters square. The size of the network is 300 nodes; randomly in the roaming area. The node's maximum speed is 4m/s.The distributed coordination function (DCF) of IEEE 802.11 [11] is used as the MAC layer. Each simulation is executed for 6 minutes. Traffic sources are CBR. The source-destination pairs are totally randomized. Data packets are all 512 bytes long. Control packet length is 32 bytes. The random waypoint model [12] was used for node mobility. Each node sends 100 packets with inter-arrival time of 0.5 second. We use AODV (Ad hoc On-demand Distance Vector routing) [13] because AODV is one of the most flooding-dependent routing protocols.

The objective of the simulations is to show that APC maintains the structure of the cluster even at the leaving of clusterhead and thus increases the lifetime of the network and reduces energy consumption.

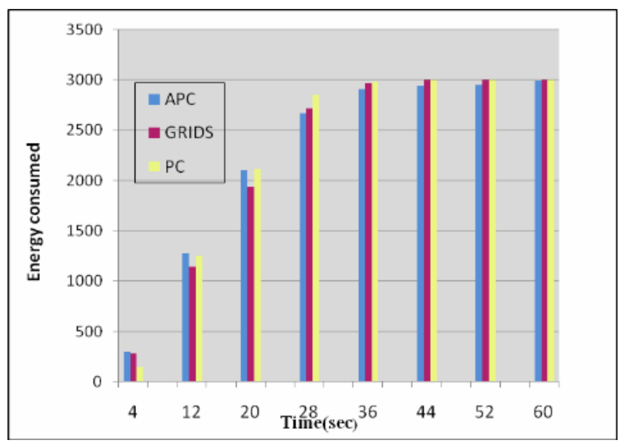

Figure 5. comparison of energy consumption

Statistics Figure 5 shows that our algorithm uses more power than the other algorithms at the beginning of the simulation because there's an additional load due to the election of clusterhead_backups. But after it consumes less energy than others. Thus APC allows balanced energy consumption among the network nodes and it maintains the cluster structure for longer than in the case of original PC or GRIDS.

Figure 6 shows the number of dead nodes, over time, in the Network using APC, PC and GRIDS; let us note that until time 28s, no node is dead using APC. We record less than 10% death during [28s, 34s [. During this time period, 40% of nodes are dead using PC and 15% are dead using

GRIDS. In 44s all nodes are dead using PC and GRIDS against 10% are alive in APC. This means that during this time period, APC keeps most of nodes alive. Thus APC increases the lifespan of the network.

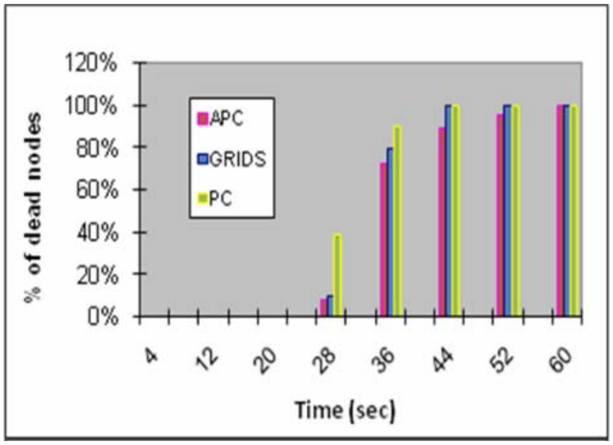

Figure 6. Percentage of dead nodes

VI. CONCLUSION AND PERSPECTIVES

In this article, we defined a curative solution for mobility in wireless sensor networks. The basic idea was to replace the clusterhead once it leaves the cluster to maintain cluster structure for a long time. Thus this approach generally increases the lifetime of sensor networks and reduce energy consumption based on the predictions of motion of the nodes. The originality of the algorithm lies in the management of reaffiliation nodes between clusters.

In perspective, we plan to further study detailed performance of our algorithm by introducing an energy threshold from which there will be a change of state between the clusterhead and clusterhead_backup and comparing the influence of this parameter with existing results.

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