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Efficient Role-based self-organization Algorithm for Creation of Network in MANETs

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***Abstract*— This paper deals with a Role based Distributed Algorithm for creation and maintenance of MANET which includes diverse wireless devices controlled by multirole agents. This algorithm generates a backbone among the devices within an environment based on local interaction of the nodes. During the operation each agent may act as *leader, gateway, bridge, member or willingness showing node,* according to both its local interaction with neighbors and its residual energy for creation and maintenance of the connected network. The role switching allows backbone reconfiguration when the nodes are leaving or arriving network yields emergent behavior. After the network formation every agent varies in the time interval and power of transmission allowing energy saving. The algorithm is discussed in detail for creation of self organized MANET network.**

Keywords*— *ad-hoc networks, Self organising strategies, emergent behaviour, clustering,virtual-backbone.

I. INTRODUCTION

Several applications of ad-hoc networks, namely, sensor deployment in agricultural fields, devices deployment in battlefield to predict the movements of troops are studied in [8]. The aim of these networks is to keep the nodes connected during the arriving or leaving the networks, as well as to minimize the energy consumption.

Since configuring the MANETs is quite difficult due to dynamic emplacement of devices as the network topology is repeatedly changing. This motivates to design the effective algorithm for creation and maintenance of such critic mobile networks. Based on network topology structure, devices can be either source from where the data is generated or sink where whole networks data is collected.

In the work presented we propose a role-assignment algorithm for automatically creating and maintaining robust MANETs. Every node here can acquire its role based on two essential factors- Number of neighbors and Residual energy. The procedure allows the backbone reconfiguration when the nodes leave or arrive at the network yielding the properties such as scalability, robustness against segmentation and a complex behavior.

The above approach has some assumptions as follows [9]:

- Coordinating activities among nodes, i.e., the nodes must take all decision without any global reference.
- Links between such nodes are bidirectional, and they are unaware of their locations.
- All the nodes can change their transmission range.
- Each node has a unique ID, e.g., its IPv4 address.
- Each node should have its set of neighborhoods and its own residual energy; in other word its own scaling factor (SF).
- The nodes are not fixed. Hence, the network topology can change over time.

Literature survey based on self-organization strategy and role assignment is reviewed in successive section.

Remainder of the paper is organized as follows: In Section II important contributions in the wireless network are discussed in brief. Section III describes the algorithm, terminologies and assumptions for the algorithm, followed by mathematical model. Finally concluding remarks are drawn in Section IV.

II. RELATED WORK

Ad-hoc networks can easily be classified in three broad categories as Location based, Flat based and Hierarchical. Need of these network types is completely application specific and a detail survey of their strategies is discussed in [12].

Pure flooding, easy approach guarantees that each non-isolated node will receive the broadcast package. Main drawback of this technique is that it consumes a huge amount of bandwidth due to many unnecessary and redundant retransmissions [2].

Algorithms based on self-organization strategies proposed to optimize flooding that classified flooding into two main approaches: based on clustering, which is the approach mostly held, and based on connected dominating sets (CDS).

A Dominating Set (DS) plays an important role in energy saving of individual sensor in a graph G (V, E) which is a subset of nodes V' $\subseteq$ V such that each node in V' and their neighbors form V. On the other hand Connected DS (CDS) is a DS, induces connected sub-graph denoted as G (V'). Solution using DS have one major drawback of balanced energy distribution among the sensors because working sensors consume their energy rapidly while inactive sensors can save their energy [2][7].

There are many schemes available for identifying the control nodes that forms virtual backbone in the network.

In paper [4], a lightweight protocol for self-organization is presented; which creates a communication infrastructure that is collision, multi-hop and adaptive. In clustering, nodes wake ups randomly, the nodes that wake up earliest get selected as a cluster-head (CH). At each stage, node with highest Scaling Factor is chosen as CH; this will select next CH.

Subramanian and Katz proposed general architectural guidelines for designing self-organizing wireless sensor networks [1]. In particular, paper emphasizes the importance of implementing a hierarchical infrastructure in order to reduce routing complexity at every node. It also elaborates on the advantages of using multi-hop over single-hop communication.

Same paper, also suggests an approach for clustering in which an initiator sends a *hello* message, and all the sensors that hear the initiator node respond to it. At the end of each round, the initiator increments its power and the clustering process continues until the number of nodes that respond are between a certain bound on the cluster size.

An energy-aware self-organized routing algorithm [6] for networking of simple battery powered micro-sensors (e.g., in security or environmental monitoring systems) is developed where battery life of individual sensor is typically limited by the power required to transmit their data to sink. Thus algorithm [6] [5] allows reducing transmission power and extending both lifetime and span of the mobile (sensor devices) network as whole.

CDS and MPR has been proven to be NP-Hard in most of the previous works. Also several studies stated that clustering strategies increases network lifetime [3] [5] and can aid in reducing energy consumption. This paper uses role-based approach for creation and reconfiguration of clusters. This algorithm introduces new role called willing bridge, which enhances the backup mechanism on basis of virtual backbone.

III. NEW ROLE-BASED ALGORITHM

A. Overview of NewRole-based Algorithm

The proposed algorithm is based on self-organization principle which assures a low number of packet exchanges. All the nodes in the network are with same configurations and can have any one role out of the following roles at each instance.

1) *Any*
2) *Member*
3) *Leader*
4) *Gateway*
5) *Bridge*
6) *Willing Leader*
7) *Willing Gateway*
8) *Willing Bridge*

At the start of algorithm when nodes are arriving randomly, Election algorithm is used to select a “leader” out of group of nodes. Many such clusters are created in the network forming a hierarchical structure. In this creation, a virtual backbone is created among all Leaders for network communication. All the member nodes of a cluster can communicate only with its leader for any communication and all Leaders are communicating with each other to work as member of virtual backbone in the communication [11](Fig 1a).

At the time of formation of this network some leaders are in direct visibility of each other and some are not. The leaders which are in direct visibility of each other can communicate with each other as a member of backbone but Leaders which are not in the direct visibility need some intermediate node. A node which is sensing two different leaders and if these two Leaders are not visible to each other, this node works as “Gateway” among two Leaders to create virtual backbone (Fig.1b). If two Leaders are not in visibility of each other and there is no common node which is sensing both Leaders, here occurs segmentation in the network. At this situation two member nodes which are sensing each other and they are members of cluster which are lead by these Leaders form a “Bridge” as a part of virtual backbone to avoid segmentation in the network (Fig.1d).

After successful assignment of roles like Leader, Gateway and Bridge remaining nodes are assigned with the role of “Member”. Once this network is created the topology is not permanent as all the nodes are mobile in nature and they are moving inside the network as well as in and out of network. As new nodes are arriving in the cluster and leaving cluster at any time some maximum and minimum limit on number of node members is maintained to avoid bottleneck in the communication.

Under every cluster there can be one agent playing a role of leader. It makes possible the communication among members. If more than one leader exists; conflict gets solved by deploying role-assignment algorithm. In cluster, there can be a zero or more agents playing role of gateway which is responsible for connecting members of different clusters through leaders or bridge that connects different segments of network. Finally, one or more agents playing role of member are connected to single leader. All nodes communicate with each other with a fixed message format as below.

Nodes usage following message format:

Id	Type	Role	Score	P_{tx}

Where:

Id= node identifier.
Type= Message type.
Role= Current played role of node.
Score= Evaluation factor for role assigning.
P_{tx}= Message transmission power (residual energy).

B. New Role-based Algorithm

Algorithm 1: Role Assign ()

```
Role= ANY;
No_of_neigh= NoofNeigh ();
Residual_Energy= ResEnergy ();
Score= no_of_neigh * Residual_Energy;

if  no_of_neigh > 0
        Role = Leader;
end if
nol = Searchleader ();
if nol > 0
        for i = 0 to nol
                pop stack;
                push stack1;

                 if sc < threshold
                    nolpointer = current leader in stack;
                    break;
                end if
        end for

        if nolpointer ! = 0
                Role = Leader;
                copy_database ();
                OL = Member;     //OL = old Leader
                send_packet ();
        end if

        else
                Role = Member;
                if nol > 1
                  Role = Send_packet1 (pop);

                    for i=0 to nol-1
                        send_packet2 (pop);
                     end for
                end if

                else if nol==1 and Role!=Gateway/WG
                    if RP = Receive_packet(B2)
                        Role = Bridge;
                        send_packet (pop);
                   end if
                else
                  for i = 0 to no_of_neigh
                     if Leader ! = Leader_id
                        Role = send_packet3 (pop);
                                if Role == Bridge
/                                   send_packet4 (node
(i));
                                end if
                     end if
                  end for
                end else
        else if WLF==false and node! = gateway
                WLF=True;
                role = Send_Packet5 (pop);
        end else
end if
```

On a topology level (Fig. 1), when new node arrives to network it gets selected as leader depending upon its weight which corresponds to several aspects like residual energy, its memory availability, number of neighbors, processing capabilities, etc.

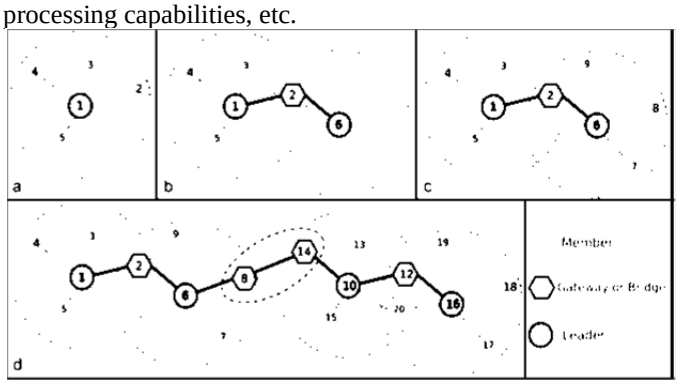

Fig.1. Represents the Working phase of new role-based algorithm

During formation of cluster due to mobility of node, case may occur where it can sense more than one neighbor playing role of leader; it takes the role of gateway. On other hand to avoid segmentation problem, a bridge agent role was designed for node when it senses a member node of another cluster.

As all nodes are mobile in nature, it is possible that nodes which are playing some role in the network may move out of current cluster destructing the current cluster structure. At this situation instead of re executing any leader selection algorithm here a backup mechanism is provided with willingness role. At the time of creation of cluster a node other than Leader with proper energy, visibility to other nodes in the cluster is selected as Node with "willingness to work as Leader". This node holds entire tables maintained by the Leader as backup but works as normal member of the cluster. These tables are updated by Leader to "willing to work as Leader" at regular interval. At any failure condition of Leader or movement of Leader outside cluster, this "willing to work as Leader" becomes Leader of the cluster with same information as that of previous Leader. This mechanism avoids unnecessary destruction and recreation of cluster minimizing packet broadcast in the network.

In the same way "willing to work as Gateway " and "willing to work as Bridge" are also created as a backup to these roles. Throughout the network infrastructure, if any of the main role mentioned above fails, leaves the network or crashes, its corresponding willing role will takes its place. Selection of such willing role always refers to SF aspect.

C. Mathematics

Let S be the set of nodes such as,

$S = \{N\,1\ ,\ N\,2\ ,\ N\,3\ \ldots\ N\,a \mid set\ of\ nodes\}$

where 'a' represents number of nodes deployed in network.

Set of Role decides a role of node at each instant where,

$R = \{L, WL, G, WG, B, WB, M \mid set\ of\ different\ roles\ and\ L \cap WL \cap G \cap WG \cap B \cap WB \cap M = \phi\}$

where,
L = Leader; WL = willing to act as Leader;
G = Gateway; WG = willing to act as Gateway;
B = Bridge; WB = willing to act as Bridge
M = Member;
A node will act as a leader when it is elected as Leader with Leader_Election_Algorithm at the time of formation of network. Cluster head of each cluster will play a role of Leader. and
L = {L 1 , L 2 , L 3 … L i | set of leaders}
where 'i' represents cluster head for each cluster formed in network.

A node play willing to act as leader role when all its configuration matches with current leader present in cluster and back up in case of leader failure is to be maintained.
WL = {WL 1 , WL 2 , WL 3 … WL j | set of willing to act as leaders}
where 'j' represents number of willing to act as leaders formed in network.

Gateway is a node which can sense more than one leader at a time and will be the part of backbone network. Then
G = {G 1 , G 2 , G 3 … G k | set of gateways}
where 'k' represents number of gateways formed in network.

Willingness Gateway provides the backup mechanism in case of failure of current gateway on same path. Configurations of this node is such that its configuration are same as current Gateway and can handle all traffic generated on same path.
WG = {WG 1 , WG 2 , WG 3 … WG l | set of willing to act as gateways}
where 'l' represents number of willing to act as gateways formed in network.

When two member nodes from different cluster who can sense each other and communication between two cluster can happen with the help of these two member nodes .These two nodes forms a "Bridge".
B = {B 1 , B 2 , B 3 … B m | set of bridges}
where 'm' represents number of bridges formed in network.
WB = {WB 1 , WB 2 , WB 3 … WB n | set of willing to act as bridges}
where 'n' represents number of willing to act as bridges formed in network.

M = {M1, M2, M3 … Mp | set of Members}
Where 'p' represents number of members formed in network.
Considering,
SF(Scaling Factor) = {λ | it represents threshold value formed by NON and RE}
where ,
'NON' represents number of neighbors
'RE' represents Residual Energy

T = {T1 , T2 , T3 …To | set of time instances}

At any instance if we are considering that all roles assignment is done and network formed then
{L}∩{WL}∩{G}∩{WG}∩{B}∩{WB}∩{M}=Ø.
This is success condition for successful network creation with proper role assignment.
Now backbone network will be
NB= {LUGUB | Set of control nodes*}*

Failure condition in this network creation will be
FC={WL U WG U WB U M} ≠ M-{L U G U B}

D. Network Maintainance

The proposed algorithm besides adjusting energy consumption with the willing roles played by nodes; indirectly increases lifetime of the overall network. Cluster based control topology allow more efficient use of energy resources. Due to grouping strategy nodes consumes only required amount of power and enhances energy level.

Specifically this article focuses on energy-awareness which means nodes RE when reach to threshold value it switches its role to member. This allows every node in network to utilize its power optimistically. Mainly intrusion of new role willing bridge, avoids segmentation problem, when bridge fails to perform its task. This strategy allows obtaining significant energy saving because of nodes proper usage of power as per their role:

- Member node needs energy just to communicate with their leader [Fig. 2]
- Energy required by Leader only for executing its tasks, keeping its routing table updated and communicating with their member's agents and their gateway agents.
- Gateway and Bridge need energy for executing their tasks and communicating with leader agents.

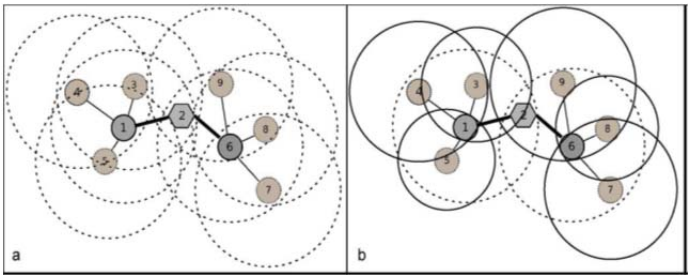

Fig.2 Represents reduced transmission power.

Best advantage of our approach according to energy efficiency is due to intrusions of willingness roles that manages inter and intra-cluster communication, further reducing unnecessary packet forwarding.

IV. CONCLUSION

An efficient use of energy is very important issue in ad-hoc networks, since most of the wireless devices are affected by this constraint. In this paper, it has been urged that self-organization strategies improve energy saving during efficient network creation and maintenance.

The proposed algorithm manages variations on both transmission power and periods which allows increase in the lifetime of the network. Further, willing role nodes avoid random network failures and provide backup mechanism for crashed nodes. Energy-aware reconfiguration of backbone, scalability is additional characteristics proposed by algorithm.

In all, the algorithm enhances network working periods by undertaking Self-Organization strategy and newly introduced willingness role which supports backup mechanism. Implementation of network creation , maintenance algorithm and comparision of new energy efficient algorithm with already existing self oraganisation algorithm is going on.

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