An Efficiency of Broadcast Mechanisms Based on Cluster Heads in Dependence on Clustering Algorithm Type

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Abstract— Efficiency of broadcast transmission based on Cluster Heads (CH) in clusterized wireless network in dependence on clustering algorithm type has been assessed in this paper. Broadcast Communications on the basis of Gateways (GW-BC) and on the basis of Cluster Heads (CH-MPR-BC) and three types of clustering algorithms (LNIDE, HDg and WCL) were implemented and tested. Tests have been done for static network assuming Free Space Path Loss propagation model with assumed reliability of information delivery in radio link. It was shown that for clustered network, CH-MPR-BC can be reliable and effective energetically.

1. INTRODUCTION

The broadcast communication as transmission from one point to all others is a very popular type of transmission used in wireless systems for route discovering, topology dissemination, alarm notification, location update, multicast tree building etc.Technical solution is dependent on a scenario and a network topology.

When clustered network is considered, one should decide whether broadcast communication is limited to one cluster or transmission to the whole network is needed. On the other hand, certain constraints can be associated with transmission time and different system layers are involved (usually the MAC (Medium Access Control) sub-layer and/or the Network Layer.

2. RELATED WORKS

There are many proposals of achieving Broadcast Communication (BC) in the literature. Our special interest is focused on solutions related to Ad-hoc and clustered networks [1, 2].

Many studies are focused on the problem of efficient broadcasts. A lot of proposed protocols are based on Connected Dominating Sets (CDS) such as [3], or multipoint relays (MPRs), e.g., [4].

The BC algorithms described in [5–8] utilize neighbourhood and/or previous routing information to reduce redundant packets.

When radio energy is discussed, the problem can be connected with electromagnetic compatibility of military equipment [9, 10].

Energy efficient and time constrained broadcast protocols are other groups of possibilities [1, 11, 12].

An efficiency of BC can be obviously different when different clustering algorithms are used. Different clustering algorithms can be applied in dependence of system type. For mobile Ad-Hoc networks following groups of algorithms with different characteristics can be identified [13]: DS-based clustering, Low-maintenance clustering, Energy-efficient clustering, Load-balancing clustering and Combined-metrics-based clustering.

A relatively wide set of clustering algorithms for Vehicular Ad-Hoc networks was presented in [14].

A reader can find various Cluster Head election algorithms for MANETs which can be divided generally on Identifier-based clustering group, Connectivity based group, Mobility-aware group, Power-aware group and Combined weight based group [15]. Other clustering schemes and classifications of can be find, e.g., in [16, 17].

3. BROADCAST MECHANISMS ON THE BASIS OF CLUSTERED NETWORK

We assumed a clustered network with 2-levels of hierarchy (Figure 1). The clustering procedure should assure the information about a system structure and the role of nodes.

We can distinguish 3 types of functional nodes: Cluster Head (CH), Gateway (GW) and Regular Node (RN).

The broadcast protocol can use a subset of nodes, called GW set to relay packets to all nodes in the network. In such a solution, a non-CH node relays the broadcast packet if it is selected as a GW, otherwise it does nothing. If there is at least one route among all the clusters (via GWs),

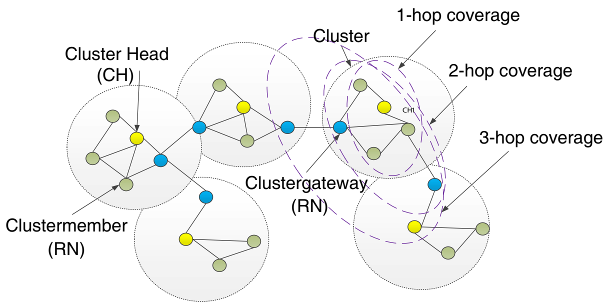

Figure 1: Clustered network.

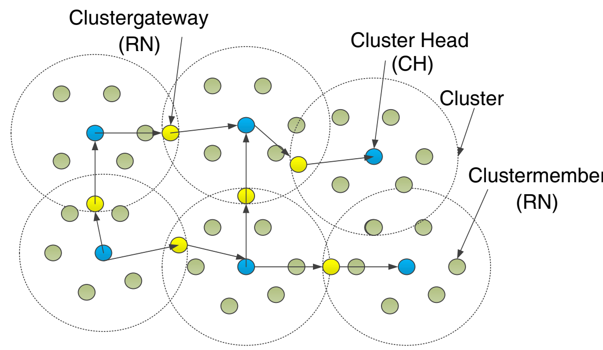

Figure 2: GW based BC (GW-BC).

a broadcast packet can be eventually delivered to the entire network. The broadcast process is limited only to the CHs and the GWs so that the broadcast redundancy is reduced.

The GW-BC process can be described as follows. A source node initiates a broadcast process, than:

1. If the source is not a CH, it sends the packet to its CH.
2. When a CH receives the packet for the first time, it chooses its GW set to forward the packet to all its neighboring CHs. If the received packet is a duplicated one, the CH does nothing.
3. When GW node receives the broadcast packet for the first time, it relays the packet (Figure 2).

The CH-MPR-BC is based on an assumption (used usually with GW-BC as well) that in one cluster (controlled by one CH) each radio can communicate with any other radio directly (peer to peer, they are in radio distance). Therefore, according to typical clustering algorithm and assumed max power of radios within the network, each CH can communicate with at least one adjacent CH [18] (Figure 3). A source node initiates a broadcast process, than:

1. If the source of BC information is not a CH, it sends the packet to its CH.
2. When a CH receives the packet for the first time, it chooses its CH-MPR set to forward the packet to all its neighboring clusters; if the received packet is a duplicated one, the CH does nothing.

4. CLUSTERS FORMATION

The main objective of clustering is to identify suitable node representatives, i.e., Cluster Heads (CHs), to store routing and topology information and maximize clusters stability. The comparison of BC efficiency in dependence of three clustering algorithms were assessed:

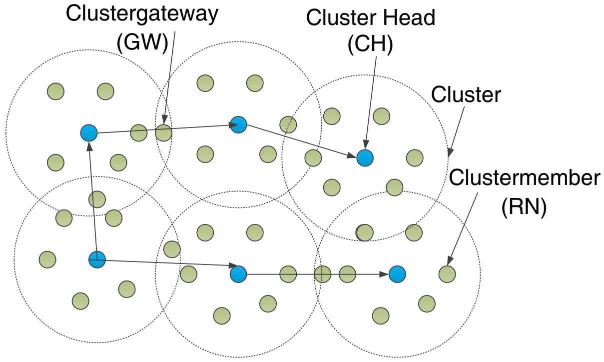

Figure 3: CH-MPR based BC (CH-MPR-BC).

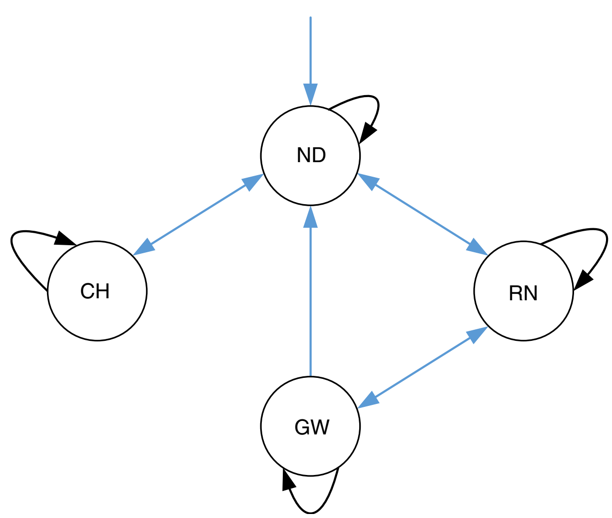

Figure 4: Node state transition diagram.

- LNIDE — own algorithm with CH election on the basis of Lowest ID concept.
- HDg — an algorithm with CH election on the basis of Highest Degree concept.
- WCL — an algorithm with CH election on the basis of weighted fitness measure concept.

As we assumed static network, only cluster formation phase was needed and cluster maintenance procedures were not implemented. Omitting details about each node state changing conditions, CHs are elected based on following criteria:

- For LNIDE (based on LID [19]) — the node can be a CH when it has the lowest MAC address among uncovered ND nodes (a node is uncovered for others when they received assumed number of Hello messages from this node).
- For HDg (based on [15]) — the node can be a CH when in comparison to other uncovered ND nodes it noticed the maximum number of uncovered nodes its vicinity.
- For WCL (based on [15]) — the node can be a CH when in comparison to other uncovered ND nodes it noticed the maximum fitness function value.

For proper deciding about its state, nodes periodically send Hello messages with following information: MAC address, Node State, List of Neighbors (MAC, State, Power), Fitness Value, My CH. In result each node can have all information about all other nodes in 2-hop distance (Figure 1). The node state transition diagram is shown in Figure 4.

5. PERFORMANCE EVALUATION

In order to determine efficiency of BC we used the OMNeT++ [20] simulation environment.

5.1. Experimental setup

The prepared network model consists of fixed number of static radio nodes, ranged from 150 to 300 and located randomly in the square area of 50 km side length. All nodes can send and receive the radio frames with path loss and transmission delay proportional to a mutual distance. The node is able to use the GW-BC or the CH-MPR-BC. The selected node periodically sends a new broadcast message. Other phenomena of transmission has been neglected, in particular, we assumed that there is no interferences nor collisions between signals from nodes. We used the following metrics to assess the efficiency of one BC process:

- *Delivery Time* — a time from first transmission (BC message from an originator node) till the moment when the last node is notified (assuming that all nodes are notified).
- *Consumed Energy* — the total energy used by a network during one completed broadcast process; this energy is calculated as the sum of energy consumed by nodes involved in this broadcast process.
- *Number Of Nodes* — the number of nodes in each state in clusterization period (CH, RN, GW, ND).
- *Nervous Measure* — the number of nodes which are changing their states during assumed period of time (a result is calculated periodically while a clusterization process lasts).

5.2. Experimental Results

Simulation results are shown in Figures 5–8. Clustering algorithms are stable and work properly (Figure 5, Figure 6).

We found that Delivery Time as well as Consumed Energy are generally dependent on clusters size and a type of BC (Figure 7, Figure 8). Assuming the same Signal to Noise power ratio constraints, CH-MPR-BC is always better than classical GW-BC. The CH election criterion can have significant influence on probability of message delivery as it decides on CH location in relation to other nodes but we didn't collect these data assuming that each node has at least one connection with the rest of network. When interference level is discussed, it is known that the level of intersystem interference is proportional to a cluster size, frequency, and the sum of transmitted power. Concluding from differences in energy observed in Figure 7, CH-MPR-BC has definitely the best potential in this area.

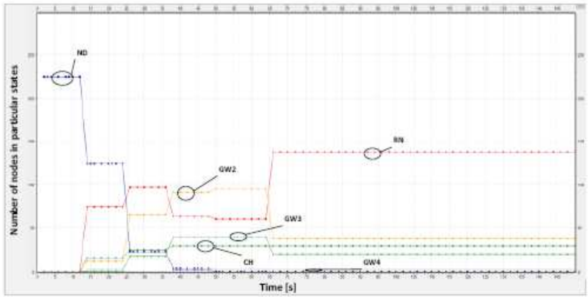

Figure 5: Number of nodes in particular state in function of time.

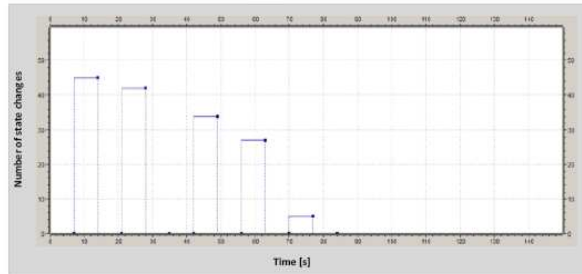

Figure 6: Number of state changes in function of time.

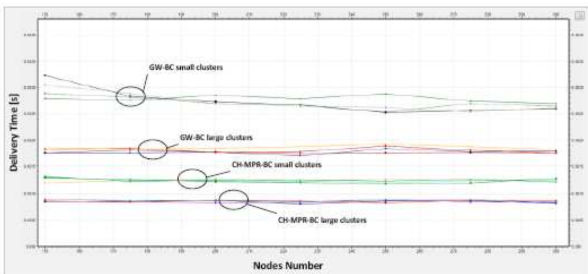

Figure 7: Delivery time in function of nodes number.

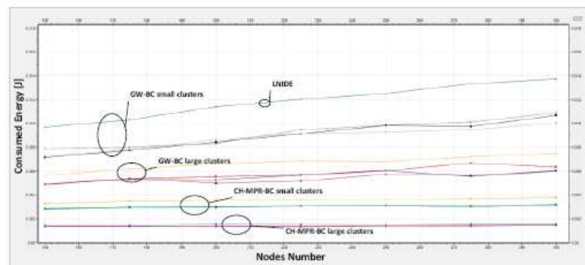

Figure 8: Consumed energy in function of nodes number.

6. CONCLUSION

According to simulation results, CH-MPR-BC is energy and time efficient. Assuming high probability of receive, influence of clustering type on BC process can be neglected. This influence is expected to be important when a signal to noise power ratio is low causing transmission errors and wrong network formation (e.g., disconnected parts of the network). Our studies will be continued for node movement with different propagation conditions.

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