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Energy Efficient Cluster Based Routing Protocol for MANETs

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Abstract- Regarding to mobile ad hoc network characteristics which all mobile nodes of network connect to each other via wireless, one of the important aspects of this type of network is the limitation of amount of available energy in the network nodes that is the most critical factor in the operation of these networks. And the tremendous amount of using the mobile nodes in wireless communication medium makes Energy Efficiency (EE) a fundamental requirement for mobile ad hoc networks. On the other hand Cluster Based Routing Protocol (CBRP) is a robust/scalable routing protocol for Mobile Ad hoc Networks (MANETs) superior to the existing methods [1-3] (For example it's overhead of is less than while it's throughput of is more than of AODV which is a standard protocol for MANET [4]. We added the resource management protocol to the CBRP for service advertisement and service discovery [5]. Although this protocol does not have significant overhead on the network it needs more consideration about increasing the life time and especially decreasing the energy consumption. We propose the idea of putting the idle member nodes to sleep state. The experimental results show that proposed method causes decreasing energy consumption in CBRP which results to stability of the network.

Keywords*:* Energy Efficiency; CBRP; MANETs; Sleep and Idle State.

1 Introduction

A mobile ad hoc network (MANET) which is based on IEEE 802.11 has some mobile devices that we called network nodes. Nodes connect to each other via wireless connection to both exchange interest information as well as to maintain the network connectivity. These devices are free to movement arbitrarily. Therefore, this type of network called infrastructure less network and nodes should maintain its topology [6-10]. MANET technology is employing in some areas especially where not any infrastructure network is and need to communication between some nodes such as: (i) Conferencing; (ii) Emergency Services; (iii) Military Operations.

Regarding to MANETs characteristics and factors, one of important parameter which has a main rule in this type of network is energy efficiency which needs to seriously manage. Although, difference between devices, operational environments, energy management techniques and employing scenarios causes that can not introduce a comprehensive definition of energy consumption in mobile devices. This means we can not have a unique definition for all case and all devices. To control the energy consumption needs consider on the follow parameters[11]. (i) Design hardware with minimum energy consumption; (ii) Reduce complexity of calculation for reducing of using CPU and RAM and (iii) Employ some communication techniques to reduce send and receive information.

In this paper we consider only on communication techniques for reducing energy consumption. In communication techniques there are many states that have mane rule in energy consumption. These states are sending packet, receiving packet, discarding packet, idle time and sleep time [12]. Energy consumption for idle and sleep state are shown in Table 2 and for sending and receiving packet is calculated with the following formula [13].

$$\text{Energy Consumption} = M * \text{size (byte)} + D \quad (1)$$

M and D are two constants which are determined by hardware, using protocol and speed of sending and receiving information. Table 1 shows the energy consumption in various states[14-16].

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Since CBRP is a robust and scalable routing protocol for ad hoc, CBRP is used as a routing protocol in our simulations. In this routing protocol all nodes divide to some cluster. Any cluster node connects to other clusters by cluster head via inter-links between them. To reduce energy consumption in this type of network we put all idle member nodes except cluster Heads and gateways nodes to sleep mode. Our experiments show that the energy consumption is significant reduced but for have maximum saving energy we must pay its expenses by packet delivery latency.

This paper is organized as follows. Section II gives a brief summary of related works. In section III we explain CBRP. In section IV we explain our proposal. Section V discusses simulation result and analysis. We conclude this paper in Section VI.

2 Related Works

Network layer protocols are more efficient for saving power. Scheduling of the network interface is driven by network layer for put on sleep state, active or idle state. The first and easiest method is a synchronized power save mechanism. Nodes periodically go to sleep state, wake up to listen to announcements of pending traffics, and exchange it if necessary.

In this area (reducing energy consumption), we reviewed some research papers as follows:
L.Tan et al. in [11] Introduced an Error-aware Candidate Set Routing Protocol (ECSRP) that avoids overusing certain route. If there are more routes in the candidate set, ECSRP employ a metric achieving the trade off between energy efficiency and load balancing the optimal routes. The condition of the channel will be considered by examining the probable packet loss in the computation of energy consumption**.** C.K. Toh et al. in [17] Proposed Conditional Max-Min Battery Capacity Routing (CMMBCR). This paper chooses a shortest path if all nodes in all possible route, have sufficient battery, when the battery capacity for some nodes goes below based predefine threshold, route going through these nodes will be avoided. Therefore this algorithm was extended the life time of routing. S. Y. Wang et al. in [18] Proposed a manner for avoiding flooding in a large scale network. This paper introduced two propose as bellow: (i) Merging some small flooding message to a large one and (ii) Limiting the scope of flooding. It is shown that with using this method the flooding message reduced without delivering failure rate. Thus reducing the flooding causes reduces the energy consumption. G.Schiele et al. in [19] Proposed a middle ware named SANDMAN. In this protocol any node has two state, sleep or aware. Any node after α sec in idle state can go to sleep state for β sec. After β sec it waked up via an inside timer. Zhenxin et al. in [20] used the idle and listening state and promote saving energy. The wireless card starts the work every 5 sec if there is not any information to communicate it go to sleep again. Vijay et al. in [21] shows that in the ad hoc network there are the below fact: 1- energy consumption is significant low if the size of packet is grater than 100 byte and the bandwidth (transmission rate) is also high.2- energy consumption is significant high for sending the small packet(the size of packet is less than 100 byte)3- RF power level does not have more side effect on energy consumption if the packet size is grater than 500 byte. M. Cardei et al. in [22] by dividing network's nodes into some adjoined sets proposed a manner to maximize network lifetime. All sets of the network nodes satisfy the network function. They prove that the node participation in several sets may improve network lifetime.

3 CBRP

CBRP is a robust/scalable routing protocol for MANETs and superior to the existing methods [1-3](e.g. the overhead of it is less than and throughput of it is more than of AODV [4]. CBRP is a routing protocol designed for medium to large mobile ad hoc networks. The protocol divides the nodes of the ad hoc network into a number of

TABLE 1: Power consumption measurements (send & receive parameter) for LUCENT IEEE 802.11 2 MBPS WAVELAN PC CARD 2.4 GHZ

Parameter	M (µW.sec)	D (µW.sec)
Broadcast Send	1.9	266
Point to point Send	1.9	454
Broadcast Receive	0.50	56
Point to point Receive	0.50	356
Idle	843 (mW)	
Sleep	66 (mW)	

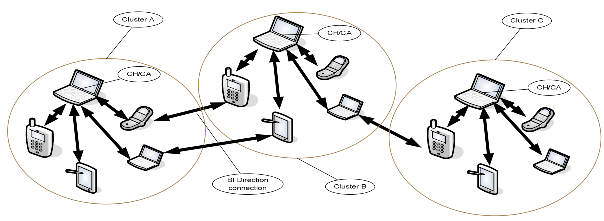

Figure 1: A cluster based ad hoc network

Overlapping or disjoint 2-hop diameter clusters in a distributed manner. Each cluster chooses a head to retain cluster membership information. The algorithm is a variation of the "lowest ID" cluster algorithm. The node with a lowest ID among its neighbors is elected as the Cluster Head (CH). Each node maintains a

Neighbor Table and a Cluster Adjacency Table. Neighbor Table is a conceptual data structure that it employs for link status sensing and cluster formation. Cluster Adjacency Table keeps information about adjacent clusters for Adjacent Cluster Discovery. These tables are updated by the periodic Hello Messages (HM).

In CBRP, routing is based on source routing. Cluster structure is exploited to minimize the flooding traffic during route discovery phase. Furthermore, certain uni-directional links are discovered and used, thus it is increasing the network connectivity. Based on cluster membership, information kept at each cluster head, Inter-cluster routes are dynamically discovered. Essentially, in Route Discovery, only cluster heads are flooded with Route Request Packets (RREQ) in search for a source route. Each cluster head node forwards an RREQ packet only once and it never forwards it to a node that has already appeared in the recorded route. It proactively acquires its intra cluster topology information through the exchange of HELLO messages and reactively acquires the route information inter cluster. An example of an ad hoc network is shown in Figure 1. Nodes are organized to three clusters, each of which has a CH.

Unlike the other on-demand routing protocols, In CBRP the nodes are organized in a hierarchy. As almost in all hierarchical protocols, CH coordinates the data transmission between clusters. The advantage of CBRP is that only CHs exchange routing information, therefore the number of control overhead transmitted through the network is far less than the traditional flooding methods. However, as in any other hierarchical routing protocol, there are overheads associated with cluster formation and maintenance. This is because some nodes may carry inconsistent topology information due to long propagation delay [3]. A neighbor table in every node of CBRP keeps the information about link states (uni-directional or bi-directional) and the state of its neighbors. A CH keeps information of its neighboring clusters, in addition to the information of all members in its cluster. The information includes the CHs of neighboring clusters and gateway nodes connecting it to the neighboring clusters [2].

4 Energy Efficient Method (EEM)

One manner for saving energy in cluster based ad hoc network is all of member node except gateways node can goes to sleep mode when they are in idle mode. In this method only CHs and gateway nodes are active for any communication in other words the backbone of the network every time is active to any communication. If a node be idle for t_1 sec send a packet to CH for goes to sleep. If this node received an ACK form the CH, it goes to sleep state for t_2 second. Every node has an internal clock which reset with putting to sleep state. After t_2 sec the node wakes up automatically.

Since, clusters heads and gateway nodes are alive during the network life; delay time is not very high in our implementation.

In our module we define idle timer which shows the time that node was in idle state and sleep timer which shows the time that node was sleep. We implement the algorithm in routing layer and considered only on member nodes except gateway and cluster head nodes. State diagram for inter-links is shown in Figure 2.

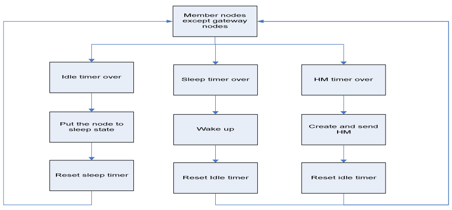

Figure 2: State diagram for nodes with concern to energy

$$\text{Average of idle mode time} = \left(\sum_{j=1}^{g}\left(\left(\sum_{i=1}^{n}(idle\_time)_i\right)/n\right)_j\right)/g$$

$$\text{Average of sleep mode time} = \left(\sum_{j=1}^{g}\left(\left(\sum_{i=1}^{n}(sleep\_time)_i\right)/n\right)_j\right)/g$$

$$\text{Average of communication consumption} = \left(\sum_{j=1}^{g} EC\right)/g$$

Figure 3: Formulas to calculate the average energy consumption

We have done some experiment about average of energy consumption based on idle, sleep, sending and receiving state. Figure 3 shows the average of energy consumption and saving energy. This average is calculated based on formulas in Figure 3.In Figure 3 g is number of groups that we have done our experiments. Group number one has 15 nodes, group number two has 20 nodes and group number 8 has 90 nodes. The n is number of member nodes in a group. The idle_time and sleep_time are total times that a node passed in idle and sleep mode. EC is energy consumption for sending and receiving packet which is calculated based on formula 1and information of Table 1.

5 Simulation and Evaluation Result

In order to evaluate our proposal, we use simulation. Our experiments were conducted in the Network Simulator 2 (NS2)[23]. We consider energy consumption in the sending, receiving, idle and sleep modes of operation. The scenario files are created by the SetDest tool of the NS2 and the traffic files are created by cbrgen.tcl. The simulation setting and parameter are shown in Table 2. We ran our simulation for different network population. Our goal is minimizing the energy consumption in CBRP. We use same traffic pattern and same mobility for all simulation experiment. We employ CBR for background traffic in the network with 16 links. In any link it sends 4 packets in 1 second.

TABLE 2: Simulation setting

Background Traffic	CBR	Simulation duration	900 sec
CBR Maxpkts	1100	Broadcast interval	2 sec
Max connection	16	Pause time	2 sec
Sending rate	0.25	Maximum Speed of the node	10 m/s
Seed	1.0	Simulation duration	900 sec
Number of nodes	15,20,30,40,50,60,70,80,90	Area	Max x = 500 m max y= 500 m

Figure 4 shows the energy consumption with and without energy consumption on idle state in various population nodes. This graph obviously shows that network nodes long times during simulation are idled. Since the node consumption in idle mode is significant value (843 mw per second) then total of consumption in idle mode is more significant against consumption without idle. Thus, anywhere, the power is a critical issue it fines that we forestalling of energy consumption in this way. Based on mentioned mechanism, the simulation results show for maximize saving the energy we put the nodes in sleep state instead idle state because the value of consumption in sleep mode is very low (56 mw per second). Figure 5 shows value of the energy consumption in sleep state in various population nodes. Figure 6 shows the energy consumption on idle and sleep state in various population nodes. It shows that there is a significant difference between them.

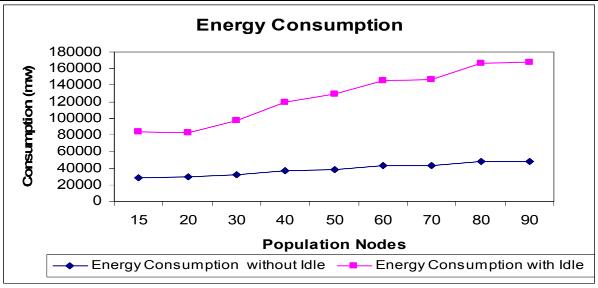

Figure 5: Total energy consumption for several of population nodes

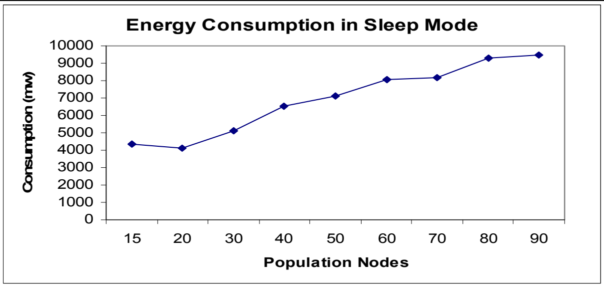

Figure 6: energy consumption in sleep state

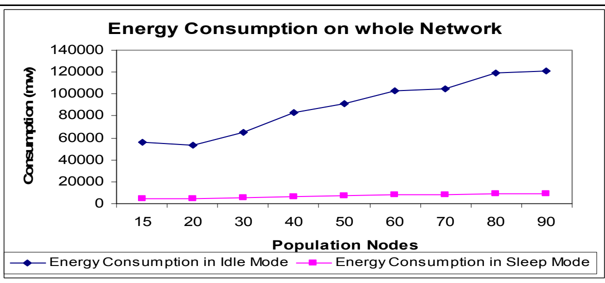

Figure 7: energy consumption in sleep and idle state

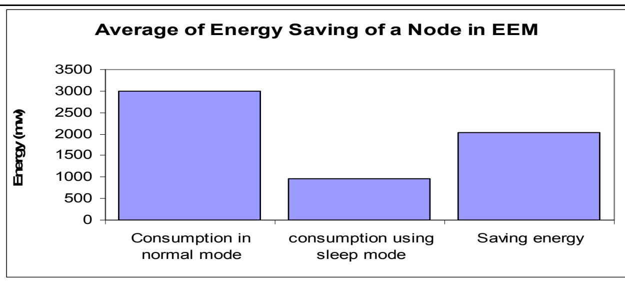

Figure 8: Average of energy consumption and saved energy per node in all experiments during 900 second in 9 experiments with various population.

Average of energy consumption in idle and sleep modes of member nodes and the value of saved energy are shown in figure 4. The value of saved energy is more than 2000 mw during 900 second simulation which is significant value.

6 Conclusion

CBRP is a powerful and scalable routing protocol for ad hoc network. In comparison to AODV which is a standard protocol, the overhead of CBRP is less and throughput of it is more than of AODV. For minimizing the consumption in whole network we employ sleep mechanism for all member nodes except gateway nodes that are in idle mode. Our experiment shows that the average of energy saving in the whole network during of simulation time (900 s) with several of population nodes is about 2000mw that is a significant saving energy. This strategy helps to maximize the lifetime of them, stability, connectivity and saving battery in ad hoc networks.

7 References

[1]. M. Abolhasan, T. Wysocki, E. Dutkiewicz, C. Liu, and J. Kaiser, "A review of routing protocols for mobile ad hoc

networks," Ad hoc networks, vol. 2, pp. 1-22, 2004.

[2]. M. Jiang, J. Li, and Y. C. Tay, "Cluster Based Routing Protocol(CBRP) (INTERNET-DRAFT draft-ietf-manet-cbrp-spec-01.txt)," in National University of Singapore, I. E. T. F. (IETF), Ed., 1999, pp. 1-27.

[3]. C. Liu and J. Kaiser, "A Survey of Mobile Ad Hoc network Routing Protocols," Tech.Report Series,Nr.2003-08 2003.

[4]. N. Moghim, F. Hendessi, N. Movehhedinia, and T. A. Gulliver, "Ad-Hoc Wireless Network Routing Protocols and Improved AODV," in The Arabian Journal for Science and Engineering. vol. 28, 2003, pp. 99-114.

[5]. S. A. Hosseini-Seno, B. Pahlevanzadeh, T. C. Wan, R. Budiarto, and S. Ramadass, "Routing Layer Service Advertisement Approach for MANETs," in International Conference on Future Networks (ICFN 2009) Bangkok-Thiland: IEEE, 2009, pp. 249-254.

[6]. S. Kapp, "802.11: Leaving the wire behind," IEEE Internet Computing, January-February 2002, p. 4, 2002.

[7]. S. Kapp, "802.11a: More Bandwidth without the Wire," IEEE Internet Computing, p. 5, 2002.

[8]. E. Danielyan, "IEEE 802.11," The Intrnet Protocol Journal, vol. 5, p. 11, 2002.

[9]. IEEE802, "IEEE 802.11 Working group website,http://www.ieee802.org/11," in EEE 802.11. vol. 2009: IEEE, 2009.

[10]. S. V. Saliga, "An introduction to IEEE 802.11 wireless LANs," in Radio Frequency Integrated Circuits (RFIC) Symposium, 6 June 2000. IEEE Boston, USA: IEEE, 2002, pp. 11-14.

[11]. L. Tan, P. Yang, and S. Chan, "An Error-aware and Energy Efficient Routing Protocol in MANETs," in ICCCN 2007, 2007, pp. 724-729.

[12]. G. Smit and P. Havinga, "A Survey of energy saving techniques for mobile computers,Internal Technical Report," University of Twente, , Enschede, Netherlands, 1997 1997.

[13]. C. Campo, C. García-Rubi, A. M. López, and F. A. Mendoza, "PDP: A lightweight discovery protocol for local-scope interactions in wireless ad hoc networks," Computer Networks, pp. 3264-3283, 2006.

[14]. L. M. Feeney and M. Nilsson, "Investigating the Energy Consumption of a Wireless Network Interface in an Ad Hoc Networking Environment," in INFOCOM 2001. Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies, 2001, pp. 1548-1557.

[15]. J. Aslam, Q. Li, and D. Rus, "Three power-aware routing algorithms for sensor networks," WIRELESS COMMUNICATIONS AND MOBILE COMPUTING, vol. 3, p. 22, 2003.

[16]. L. M. Feeney, "Energy Effcient Communication in Ad HocWireless Networks," in Mobile Ad Hoc Networking., M. C. Stefano Basagni, Silvia Giordano, and Ivan Stojmenovic, editors,, Ed. Kista, Sweden: Wiley, 2004, pp. 1-32.

[17]. C.-K. Toh, "Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks," IEEE Communications Magazine, pp. 1-11, 2001.

[18]. S. Y. Wang, "Reducing the energy consumption caused by flooding messages in mobile ad hoc networks," Computer Networks, vol. 42, pp. 101-118, 2003.

[19]. G. Schiele and C. Becker, "SANDMAN: an Energy-Efficient Middleware for Pervasive Computing," Report 2007.

[20]. F. Zhenxin and L. Layuan, "Advanced Save-Energy Mechanism of Ad hoc Networks," in Sixth Annual IEEE International Conference on Pervasive Computing and Communications. vol. 00 Washington, DC, USA: IEEE Computer Society 2008, pp. 657-662

[21]. S. Vijay, S. C. Sharma, and S. C. Sharma, "An Analysis of Energy Efficient Communication in Ad-hoc Wireless Local Area Network," in First International Conference on Emerging Trends in Engineering and Technology: IEEE Computer Soeiety, 2008, pp. 140-144.

[22]. M. Cardei, Y. L. M. Thai, and W. Wu, "Energy-efficient target coverage in wireless sensor networks," in INFOCOM 2005. 24th Annual Joint Conference of the IEEE Computer and Communications Societies. vol. 3 Miami, Florida: IEEE, 2005, pp. 1976- 1984.

[23]. NS-2, "Network simulator 2 (NS2), http://www.isi.edu/nsnam/ns/," in NS, 2008.