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Energy Efficient Cluster Based Routing Protocol for MANETs

Giao thức định tuyến theo cụm hiệu quả về mặt năng lượng cho các MANET

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

1. Giới thiệu

Mạng tùy biến di động (MANET) dựa trên chuẩn IEEE 802.11 có một số thiết bị di động có thể gọi các nút mạng. Các nút kết nối với nhau qua kết nối không dây để trao đổi thông tin quan trọng cũng như duy trì kết nối mạng. Những thiết bị này có thể tự do di chuyển. Do đó, loại mạng này được gọi là mạng không có cơ sở hạ tầng và các nút duy trì topology của nó [6–10]. Kỹ thuật MANET đang được sử dụng trong một khu vực không cần dịch vụ hạ tầng mạng để giao tiếp giữa các nút chẳng hạn như: (i) Hội nghị truyền hình; (ii) Dịch vụ cấp cứu; (iii) các hoạt động quân sự.

Về các đặc điểm và yếu tố của MANET, một trong những tham số quan trọng có quy tắc chính trong loại mạng này là hiệu suất năng lượng cần được quản lý nghiêm ngặt. Mặc dù sự khác biệt giữa các thiết bị, môi trường hoạt động, kỹ thuật quản lý năng lượng và các ngữ cảnh sử dụng khác nhau làm cho chúng ta không thể đưa ra định nghĩa toàn diện về tiêu thụ năng lượng trong các thiết bị di động. Điều này có nghĩa là chúng ta không thể đưa ra một định nghĩa duy nhất cho tất cả các trường hợp và tất cả các thiết bị. Để kiểm soát quá trình tiêu thụ năng lượng cần xét đến các tham số sau đây [11]. (a) Thiết kế phần cứng có mức tiêu thụ năng lượng thấp nhất; (ii) Giảm độ phức tạp tính toán để hạn chế dùng CPU và RAM và (iii) Sử dụng một số kỹ thuật truyền thông để giảm thiểu việc gửi và nhận thông tin.

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].

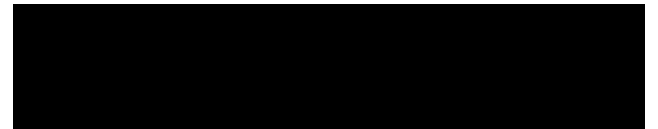
$$\text{Energy Consumption} = M * \text{size (byte)} + D \quad (1)$$

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].

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

Trong bài báo này, chúng ta chỉ xét những kỹ thuật truyền thông để giảm sự tiêu thụ năng lượng. Trong những kỹ thuật truyền thông, có nhiều trạng thái có các kiểu tiêu thụ năng lượng khác nhau. Những trạng thái này là gửi gói tin, nhận gói tin, loại bỏ gói tin, thời gian nhàn rỗi và thời gian ngủ [12]. Quá trình tiêu thụ năng lượng đối với trạng thái nhàn rỗi và trạng thái ngủ được biểu diễn trong Bảng 2 và đối với quá trình gửi và nhận gói tin được tính bằng công thức sau đây [13].



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 (ECSR) that avoids overusing certain route. If there are more routes in the candidate set, ECSR 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 a sec in idle state can go to sleep state for p sec. After p 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

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 go 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

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 1 and 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

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.

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.

