Energy Saving Cache-based Routing Protocol in Wireless Ad hoc Networks

Yi-Chao Wu, Chiu-Ching Tuan †

Graduate Institute of Computer and Communication Engineering
National Taipei University of Technology
Taipei, Taiwan, 10608, R.O.C.
t5419001@ntut.edu.tw, cctuan@ntut.edu.tw

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Abstract

In wireless ad hoc networks, designing energy-efficient routing protocols is a major issue since mobile hosts are energy-limited. In this paper, we propose an energy saving cache-based routing protocol (ESCR) to address this issue. In the proposed routing protocol, when the energy of the grid header is not sufficient for data transmission, new grid header is elected directly by ESCR without the traditional grid header election. Moreover, each host could not wake up for registration in a period time. Therefore, the hosts could save more energy for data transmission and the routing lifetime could be prolonged. The simulation results show the routing lifetime, the host survival ratio, and the total energy consumption in comparison with existing grid-based routing protocols. Furthermore, when the host density is higher, the performance of ESCR is more outstanding.

1 Introduction

Wireless ad hoc networks had attracted a lot of attention recently. It is consisted of a set of mobile hosts which could communicate with one another at their will without infrastructure base stations. The packets sent by the source host are relayed by several intermediate hosts before reaching the destination host.

Due to the battery technology is not likely to progress as fast as computing and communication technologies, designing energy saving protocols to construct power-efficient routings becomes an important issue [1-4]. In [5], a protocol’s behavior does have significant impact on energy consumption. So a host should tune its wireless interface card into the doze mode whenever the host will not hurt its own and the network’s performance.

Among the existing routing protocols, grid-based routing is often used for energy saving by tuning the hosts into the doze mode [6-8]. In grid-based routing protocol, a host is elected as the header in its grid. Routing is conducted in a grid-by-grid manner through grid headers. Only the grid headers keep in the active mode. Other hosts could be tuned into the doze mode to save energy without hurting the network connectivity. However, when the energy of grid header is not sufficient for data transmission, each host is tuned into the active mode by the traditional grid header election to be elected as a new grid header. Moreover, each host is also tuned into the active mode in a period time for registration to update the status. In such situations, hosts consume the unnecessary energy without data transmission and the routing lifetime is decreased.

In this paper, we propose an energy saving cache-based routing protocol (ESCR) in wireless ad hoc networks. In ESCR, the cache-based grid header election, the power mode management mechanism, and the routing maintenance are proposed. So hosts could not be tuned to the active mode when the energy of the grid header is not sufficient for data transmission and each host does not wake up in a period time for registration. Therefore, ESCR could reduce more energy consumption and prolong the routing lifetime.

Simulation results are presented to demonstrate the efficiency of our proposed protocol. The rest of the paper is in the following sections. Section 2 presents the review of existing grid-based routing. Our scheme is stated in Section 3. Section 4 presents the simulation results. The conclusions are shown in Section 5.

2 Review of existing grid-based routings

Grid-based routing protocol is a geographic routing protocol based on grid architecture. It partitions the network area into square/hexagon grids by the location information such as global position system (GPS) [8]. Routing is performed in a grid-by-grid manner. One host is elected as the grid header in its grid. The responsibility of grid header includes: (i) forwarding routing discovery requests to neighbor grids, (ii) propagating data packets to neighbor grids, and (iii) maintaining routing which pass the grid. The other hosts which are not the grid headers are not responsible for these jobs unless they are destinations of (i) and (ii), and sources/destinations of (iii). To reduce unnecessary collisions, the communication is divided into intra-grid and inter-grid. The routing discovery and maintenance could be modified from any of following protocols: source routing and next-hop routing [6,9].

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However, most grid-based routing protocols focus on routing discovery and maintenance. To address the energy issue, FPALA is proposed [7,8]. FPALA is an energy-aware grid-based routing based on GRID [6]. It proposes a power mode management mechanism for grid header election to save energy. In FPALA, a host with the maximum battery energy is elected as grid header. The hosts which are not the grid headers could be tuned into the doze mode without hurting the connectivity of the network. So the hosts could save energy and the routing lifetime is prolonged. However, new grid header is elected by the traditional grid header election. Each host is tuned into the active mode in a period time for registration. Hence, hosts consume redundant energy without transmitting or receiving the data, and the routing lifetime is decreased. To solve the above issues, we propose an energy saving cache-based routing protocol in this paper.

3 Energy saving cache-based routing protocol in wireless ad hoc networks

Energy saving cache-based routing protocol (ESCR) is a kind of power-aware and location-aware grid-based routing protocols in wireless ad hoc networks. It partitions the network into square grids by GPS. One host of the grid is elected as the grid header. In ESCR, we define \( d = (\sqrt{2}/3)r \), where \( d \) is the side length of grid and \( r \) is the transmission distance of a radio signal [6]. This represents the maximum of value \( d \) such that a grid header located at the center of a grid is capable of talking to any grid header of its 8 neighbor grids. The routing is performed in a grid-by-grid manner through grid headers, and divided into intra-grid and inter-grid communications.

3.1 Cache-based grid header election

In our proposed protocol, the grid header is responsible for routing, relaying packets, and maintaining the correct operation of grids. So an efficient grid header election is needed. In ESCR, we propose a cache-based grid header election (CGHE) in place of the traditional grid header election. In CGHE, each host is deployed a cache table. The cache table stores \( gid, id, \) and \( e \), where \( gid \) is the grid coordinate, \( id \) is the host identity, and \( e \) is the battery energy as shown in Table 1.

<table>
<thead>
<tr>
<th>( gid )</th>
<th>( id )</th>
<th>( e )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1020</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>0304</td>
<td>95</td>
</tr>
<tr>
<td>1</td>
<td>2013</td>
<td>85</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Table 1. Cache table of ESCR

CGHE is run in each grid to determine the header of its grid. The host with the maximum \( e \) is elected as the grid header. Once the grid header is elected, it maintains other hosts of its grid. The process of CGHE is the followings:

1. A host broadcasts a BID(\( gid, id, e \)) packet initially. When another host receives the BID packet, it compares its own \( e \) and the \( e \) of the BID packet. If its own \( e \) is larger than the \( e \) of the BID packet, it updates the \( e \) of the BID packet and broadcasts the BID packet to other hosts, otherwise it stops broadcasting it.

2. When the last host does not sense the BID packet for a predefined time, the host transfers itself into grid header and broadcasts its existence by sending a GATE(\( gid, id \)) packet to other hosts of its grid.

3. When a host receives the GATE packet, it sends a BID_E(\( gid, id, e \)) packet to its grid header.

4. The grid header sorts its cache table in a descending way by \( e \).

When the grid header wants to transmit the data to a host in its grid, it sends a WAKE(\( gid, id \)) packet to the host before sending the data. If a host would transmit data to other hosts, it sends a RENEW(\( gid, id, e \)) packet to its grid header after sending the data. Grid header updates the cache table and the status of the host when receiving a RENEW packet. So hosts could not wake up for registration in a period time.

3.2 Power mode management mechanism

In ESCR, a host is in one of three modes: active, monitor, and doze. The active mode implies that a host is transmitting or receiving the packets. The monitor mode means that a grid header receives a packet that is not destined to itself. In the doze mode, a host is idle without transmitting or receiving the data.

The host is tuned into the active mode after receiving a WAKE or GATE_E packet. After transmitting BID_E, RENEW, or GATE_E, the host is tuned into the doze mode. When a grid header does not transmit the data for a predefined time, it could be tuned into the monitor mode. The power state diagram is shown in Fig. 1.

![Power mode management mechanism](image)

3.3 Routing discovery

In our protocol, routing is conducted in two levels: inter-grid and intra-grid. The former is supported by the point coordination function (PCF) of IEEE 802.11 and the latter is supported by the distributed coordination function (DCF) of 802.11. The time axis is divided evenly into a sequence of
superframes for all hosts participating in the networks. In this paper, we add BID_E, GATE_E, WAKE, and RENEW packets to the modified superframe from FPALA [10]. The inter-grid and intra-grid routings are under the superframe as shown in Fig. 2.

Fig. 2. The structure of the superframe in ESCR

For intra-grid routing, if a packet is targeted at a host resident in the same grid, it is sent to that host directly by its grid header during the intra-grid phase. For inter-grid routing, a packet is forwarded in a grid-by-grid manner during the inter-grid phase. In inter-grid routing, a routing could be modified from any of the following protocols: source routing and next-hop routing. Because the route discovery could be done following the protocols in [8], we do not further elaborate. In our proposed protocol, we adopt the AODV protocol [9] as our routing discovery procedure.

3.4 Routing maintenance

The purpose of routing maintenance is to keep the lifetime of a routing as long as possible. Under our proposed protocol, except the source and destination hosts, each intermediate host is the grid header. Therefore, how to maintain the grid header in each grid is an important issue for routing maintenance. Here, we define a threshold value of energy ($E_{th}$). When the $e$ of grid header is lower than $E_{th}$, the grid header maintenance is started. The process of grid header maintenance is the followings.

1. When the $e$ of grid header is lower than $E_{th}$, the grid header retrieves the $id$ of the first row in its cache table and sends a GATE_E($gid,id,RT,CT$) packet to new grid header which its $id$ is the same as the $id$ of GATE_E packet, where $RT$ is the former grid header’s routing table and $CT$ is the former grid header’s cache table. Then former grid header transfers itself into a host.
2. New grid header broadcasts its existence by sending a GATE packet, and then deletes the first row in its cache table.
3. While the data of cache table is empty, it is reestablished by CGHE.

In ESCR, new grid header is elected without the traditional grid header election. So the hosts could save more energy for data transmission and the routing lifetime is prolonged.

4 Simulation results

The simulation is conducted on $10 \times 10$ square grids within an area of $1000 \times 1000$ m$^2$. Set the side length of grid to be $d = 100$ m and the host’s maximum transmission distance to be $r = 150\sqrt{2}$ m. The data rate is 11 Mbits/s (IEEE 802.11b). The cache table is 128 kbytes. Each superframe length is 200 ms. The header phase occupies 1 ms and the maintenance phase occupies 4 ms. The length ratio of the intra-grid phase to the inter-grid phase is 1:4. The initial battery energy of the host is 40 J. $E_{th}$ is 10% of the initial battery energy. The active, monitor, and doze modes consume 280, 70, and 10 mW, respectively [7,8].

We evaluate the routing lifetime, the host survival ratio, and the total energy consumption under ESCR, FPALA, and GRID. The routing lifetime is defined as the time span from that the routing are living to that the routing are broken. The host survival ratio is defined to be the number of hosts with non-zero energy divided by the total number of hosts after the network is operating for a certain amount of time. The total energy consumption denotes the accumulative energy consumption by all hosts in the routing. Three tunable parameters are in our simulation.

1. Host density: we vary the total number of hosts in each grid. Since the network area is fixed, this number presents the host density.
2. Simulation time: it presents the lifetime of routing.
3. Number of routing maintenances: when the $e$ of grid header is lower than $E_{th}$, routing maintenance is started and the number of routing maintenance is increased by 1.

Fig. 3 shows the routing lifetime under ESCR, FPALA, and GRID. We found ESCR prolongs more routing lifetime than FPALA and GRID, when the number of hosts is increased. It means the routing lifetime of ESCR is better when the host density is higher. It improves more 20% than FPALA when the number of hosts is 30.

For host survival ratio, set the number of hosts to be 50. We found the survival ratio in ESCR is higher than in FPALA
and GRID when the simulation time is increased as shown in Fig. 4. When simulation time is around 2600 seconds, ESCR improves more 24% than FPALA.

For total energy consumption, set the number of hosts to be 50. We found the total energy consumption of ESCR is all lower than FPALA and GRID for each number of routing maintenances in Fig. 5. Moreover, the number of routing maintenances in ESCR is also more than FPALA and GRID.

In the simulation results, we could find the performance of ESCR is better than FPALA and GRID for the routing lifetime, the host survival ratio, and the total energy consumption. It is caused that the hosts which are not the grid headers could keep in the doze mode when routing maintenances is happened and do not be tuned into the active mode for registration in a period time. Therefore, the hosts could reduce energy consumption and the routing lifetime could be prolonged.

5 Conclusions

How to reduce the energy consumption is an important issue in wireless ad hoc networks. To address the issue, many energy-aware routing protocols are proposed. Among these protocols, grid-based routing is the general solution for energy saving. In grid-based routing, hosts could be tuned into the doze mode to save energy. However, the traditional grid-based routing protocols consume redundant energy on our paper survey. To solve the issue, we propose an energy saving cache-based routing protocol in wireless ad hoc networks. In our proposed protocol, grid header is elected without the traditional grid election and each host could not be tuned into the active mode when the routing maintenance is happened. Moreover, the host could not be tuned into the active mode in a period time for registration. Therefore, the host could save more energy for data transmission and the routing lifetime could be prolonged.

In this paper, we use AODV as our routing procedure and the host is not mobile. So we will make the hosts mobile and integrate other routing protocols with our proposal for more analysis and improvements in the future.

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References