A Routing Protocol for Internet of Things with High-speed Mobile Nodes

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Abstract

This paper presents an improved Reverse Energy AODV (REAODV) routing protocol for Internet of Things with high-speed mobile nodes, which is based on the traditional Ad hoc networks AODV routing protocol. The source node uses the same way as AODV to send RREQ packets but uses broadcast way to send RREP packets. So the source node moving at high speed can better receive RREP packets and effectively avoid the reroute discovery process in a high-speed mobile environment. Energy restriction policy is also added in the new agreement to make energy consumption more evenly. Simulation results show that, at the same energy consumption level, the new protocol outperforms AODV protocol in delay and throughput.

Keywords*: IOT, REAODV, Protocol, Energy Consumption*

1. Introduction

Internet of Things (IOT) is the third wave of the world's information industry following computers, the internet and mobile communication network. Since the concept was proposed in 1999, it has attracted widespread attention and achieved great progress. The leach protocol, the DSR and the AODV are some commonly used agreement for mobile communication networks. In [1], link breakage prediction algorithm was used for the routes selection which based on the signal power strength and backup routing mechanism was used. In [2], the source sensor node based on wireless channel SNR and routing control messages transmitted in the alternative path weights selected the current best path for the main path. In [3], the sum energy of all nodes in the network was calculated to get the average energy. Remaining energy module and local total remaining energy module were added in HELLO information and RREQ packets, respectively. And in the route maintenance process, the maintenance method is judged according to the number of hops from the destination to the source. [4] put forward the conditions of the intermediate node to selected the path. The energy consumption of data packets transmission between two nodes, which can be given as ((residual energy – sending energy) / initial energy), is compared with the minimum threshold θ. When the minimum energy consumption was met and θ was greater than 0.3, it can be selected as the path. [5] proposed an energy minimization protocol AODV-PP and the basic idea is: 1) Find the energy level of the route and update regularly. 2) Calculate the average route energy and the battery power of lowest charge node. 3) Check the priority of applications. 4) Select the high average energy route for data transmission. [6] put forward a new data structure local information table by which it can select maximum payoff to compute a transmit power. The local information table includes nearest node ID, distance between nodes and the interference power in neighbor node. By broadcasting hello message with interference power value, node can refresh its local information table and compute its payoff value. When a node wants to send message, it will search its local information table and select maximum payoff to compute a transmit power. [7] used both energy efficient and congestion control strategy to find an appropriate route. In energy strategy a distance threshold Q is given and unicast is used if the node's distance from the source node is less that Q or on the contrary multicast. In control strategy each node estimates its current traffic load and the arrival rate and set two thresholds. By comparing the number of packets in the queue with the two thresholds, multicast streams can be chosen to be released or be blocked. [8] gave an energy threshold to decide whether to flow or discard the RREQ. When node energy is larger than the threshold the RREQ is flowed. Or it will be discarded. [9] introduced three protocols, AODV, DSR and DSDV, and the average end-to-end packet delay is compared in detail. [10] created more than one RREP, to achieve the purpose of route optimization. The new protocol modifies the format of RREQ, RREP and RERR packets and makes the remaining energy as the route selection criteria rather than hops. [11] divided the node energy level into three states: less than 20% as dangerous state, greater than 20% and less than 50% as critical state, and greater than 50% as the active state. RREQ is sent as the traditional AODV and choose nodes in active state as the return path. Energy related function is used only in the route reply phase. [12] proposed an improved DSR protocol. When the node distance satisfies the minimum transmission energy consumption condition, data is directly transmitted. In addition, the biggest priority function is used. [13] put forward a new protocol AODV-UI by combining AODV with R-AODV. The node energy is divided into high and low levels. If the energy is high and the number of hops is 1, a reverse route is created; otherwise, the data packet is forwarded to a neighbor node. [14] created a reverse route discovery mechanism reverse-sends R-RREQ to better find the route. In addition the MAC feedback mechanism is used to detect the link connection and maintaining the route.

However, a unified standard about IOT routing protocol has not yet appeared. So it is great significance to find a more appropriate routing protocol. Since most of the future IOT nodes have strong mobility, there is no fixed infrastructure and communication between nodes should be on demand. In this paper, we present an improved Reverse Energy AODV (REAODV) routing protocol based on the traditional Ad hoc networks AODV routing protocol. The source node sends RREQ packets in the same way as AODV, but sends RREP packets in a broadcast way. So it is possible for the source node to better receive RREP, thus effectively avoiding the reroute discovery process for a node in high-speed mobile environment. Meanwhile, the new agreement added energy restriction policy in reverse flooding RREP to make the average energy consumption more evenly. Simulation results show that the new protocol can achieve better delay and throughput performance than AODV protocol at the same energy consumption level. In high-speed environment, the new agreement also has smaller route discovery time and smaller energy consumption.

2. AODV Routing Protocol

Based on DSDV and DSR, AODV (Ad Hoc On-Demand Distance Vector Routing) uses both the route discovery and maintenance procedures of DSR and the periodic beaconing and sequence numbering procedure of DSDV. Its basic principal contains two components: route discovery and route maintenance.

2.1. Route discovery process

When the source node needs to send data, it first finds its own routing table. When there is an effective route to destination node in the routing table, then it immediately sends the data in accordance with the valid route. If there is no valid routing path exists, the route discovery request is initiated. The source node creates a routing request message RREQ and broadcasts to its neighbor. When the neighbor node receives the RREQ message it checks whether it is the originator or if such an RREQ has repeated. If it has repeated then the neighbor node will drop the RREQ message or otherwise it will broadcast it again until the message reaches the destination along an effective route. In this process, each node maintains and updates a routing table and checks whether corresponding reverse route exits in the table. If not then it creates an entry for the reverse route. When RREQ message reaches the destination node or the node which has effective route to destination, it produces a RREP message and sends it back along the reverse path to the source node. If there have many RREP messages to the source, it will check the one has bigger sequence number. If the sequence numbers are same, message with lesser hop count will be selected.

2.2. Route maintenance process

In AODV, each mobile node will periodically broadcast HELLO message in order that each node can find its neighbor nodes within one hop. If a node has not received any HELLO message from its neighbor nodes within a certain time, which means the node has been disconnected, the node will begin route discovery process again. If an effective routing is re-established in a given time, then the data will be sent. If the route creation process is unsuccessful, the node will send an error message to the nodes that are recorded in the corresponding precursors list in the routing table and remove the compromised route from their routing table.

3. Reverse Energy AODV (REAODV)

The REAODV sends RREQ packets in the same way as AODV and when a node can't find an effective route to a node, it will broadcast a RREQ packet.

(1) In a high-speed mobile environment, the source sends RREQ to the destination node and store intermediate node information to the routing table. When the destination node returns RREP, it will follow the shortest path to the source node. However, the reverse route which has been established may be destroyed during reverse transmission because the node moves very quickly and the source node may re-initiate route request. Fig 1. shows that the entire network overhead route, discovery time and node energy consumption will increase. In order to solve this problem, we send RREP packets into broadcast messages when they are transmitted. If a node receives the RREP and it is not the source node, it will store node information in the routing table. Fig. 1 illustrates an established REAODV route with high-speed mobile nodes, where S is the source node and D represents the destination node. Others represent intermediate nodes. Fig. 2 illustrates a destroyed REAODV route, where the path between the source node and node 2 does not exist.

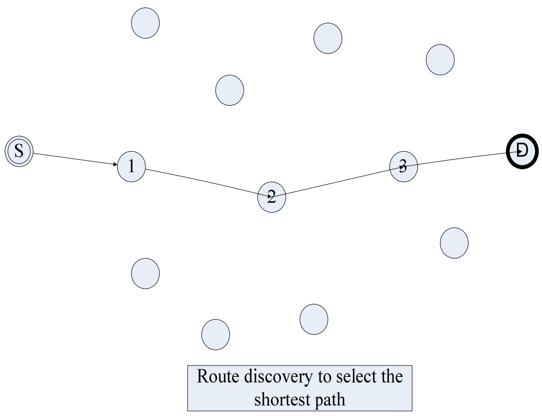

Figure 1. An effective route with high-speed mobile nodes

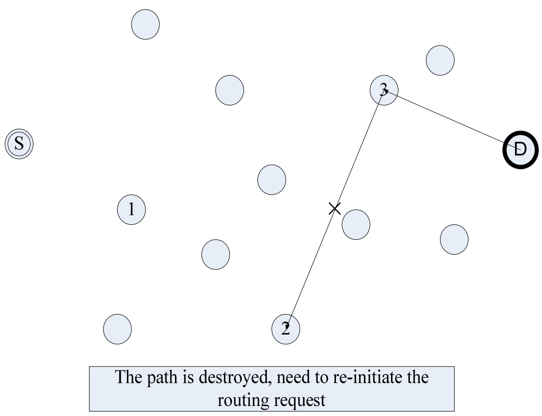

Figure 2. A destroyed route with high-speed mobile nodes

(2) The new protocol uses broadcast way to send messages and it will inevitably increase node energy consumption. In order to compensate the energy consumption, an energy balanced approach was introduced.

The RREQ message in original AODV protocol contains the following information: message type, hop count, broadcast ID, destination address, destination sequence number, source address, source sequence number and request time. In the new protocol two new fields, residual energy and energy sum are added in the original RREQ packets, which can be seen in Table 1. The RREQ is then transmitted and the node residual energy is stored in the RREQ until the destination node or intermediate node contains an effective routing to destination.

The RREP message in AODV protocol contains the following information: message type, hop count, broadcast ID, destination address, destination sequence number, source address, source sequence number and replay time. From Table 2 we can see that two new fields, average energy and residual energy message are incorporated in the new RREP packets. The average energy is calculated according to the following formula: energy_ave = energy_sum / hopCount. In the broadcast RREP, if it is first received, then the RREP is sent according to the formula T=D*energy_ave/energy and write down the information to the routing table. Or the RREP will be thrown away.

Table 1. RREQ Message Format

Type	Reserved	Hop Count	Residual Energy	Energy Sum
Broadcast ID				
Destination IP address				
Destination Sequence Number				
Source IP address				
Request Time				

Table 2. RREP Message Format

Type	Reserved	Hop Count	Residual Energy	Energy Ave
Broadcast ID				
Destination IP address				
Destination Sequence Number				
Source IP address				
Reply Time				

(3) When the source node received the RREP packets, it chooses the best path to update routing table. The node first compares the sequence number and higher sequence number means the very recent route. If packets have the same sequence numbers, source compares number of hops up to destination and fewer hops along routing path is selected. Then it will update its information in the routing table for data transmission. Each mobile node will periodically broadcast HELLO message and it can find its neighbor nodes within one hop. If the source moves, it can start a new route discovery procedure to find the destination and if one of the intermediate nodes moves, its neighbors can realize and send an error message (RERR) notification to its upstream neighbors till it reaches the source. If needed, the source node can rebuild new route.

The Pseudo-code of the improved protocol is as follows:

a) Start.
b) If source want to send data to destination, check up routing table.
c) If it has effective route to the destination, then begin transmitting data.
d) Else start route discovery process and send RREQ.
e) If the source or intermediate node have heard the RREQ, then Drop.
f) Else create reverse route in the routing table.
g) If I am intermediate node and
h) If I have fresh enough route, then broadcast RREP
i) Else write residual energy E_i and energy sum which RREQ pass in RREQ, then broadcast
j) If I am destination and receive the first RREQ, then calculate the node average energy $\overline{E_{ave}}$ which RREQ through pass, write it in RREP and broadcast.
k) Else Drop RREQ.
l) If I am the destination or intermediate node have heard the RREP, then Drop.
m) Else create route in the route table.
n) If I am intermediate node and receive the first RREP, then delay $T = D * (\overline{E}_{ave} / E_i)$ and broadcast
o) Else Drop.
p) If I am source and received the first RREP, then Drop RREP and Begin transmit Data
q) Else Drop.
r) If one RREP packet has higher sequence number, source considers it as recent routes.
s) Else if some packers have the same sequence number, then routing path with fewer hops is selected.
t) Begin to transmit Data along the chosen path.
u) If the source and some intermediate nodes have been moved, check the route or the source rebuild new route when needed.

The flow chart of the new improved agreement is shown in Fig. 3.

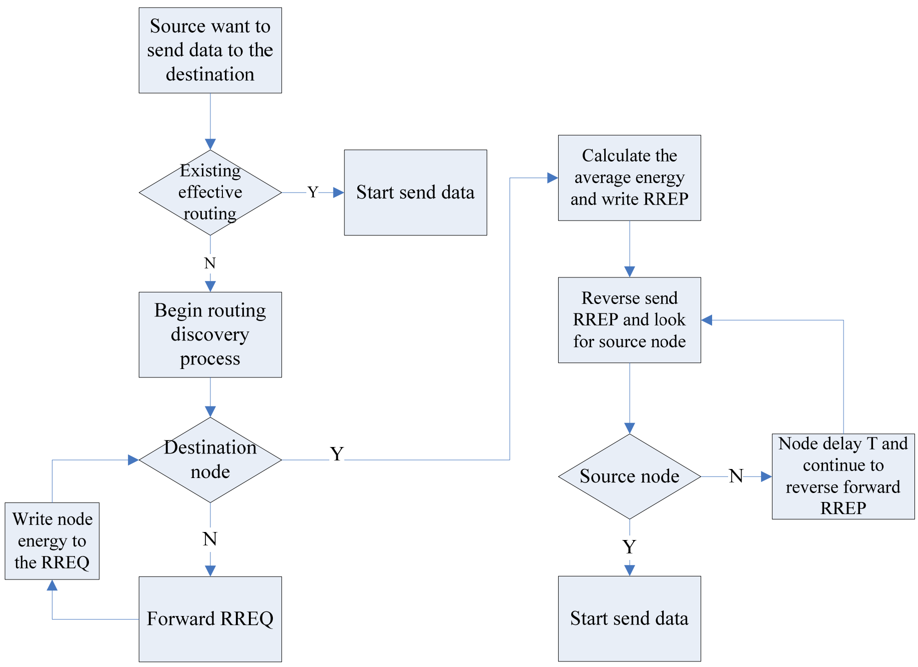

Figure 3. The Flow Chart of the New Improved Agreement

4. Simulation Results and Performance Analysis

The transmission range, the maximum possible distance between two communication mobile nodes is set to be150m. The simulation scenario consists of 50 nodes in network. The data type is Constant Bit Rate(CBR). The topology dimension of this simulation is a square area of 1000*1000 meter. The entire simulation time is 500 seconds.

In this paper, the routing discovery delay, the entire throughput and the percentage of the remaining total network energy are calculated and analyzed:

Routing discovery delay is defined as the time between the points in time the source wants to send a packet and the time the packet reaches its destination, which can be given by

$$\frac{\sum(\text{Time Dest Receive Packet-Time Source Sent Packet})}{\text{Total Number of Connection Pairs}} \quad (1)$$

Throughput is the successfully transmitted data in the unit time and can be given by

$$\frac{\text{The Successfully Transmitted Data}}{\text{The Simulation Time}} \quad (2)$$

The percentage of the remaining total network energy is the ratio between the sum of all nodes' residual energy and the total initial energy and can be calculated by

$$\frac{\sum(\text{Residual Energy of Every Node})}{\sum(\text{Initial Energy of Every Node})} \quad (3)$$

4.1. Simulation Conditions

The simulation parameters are as follows:

a) Number of nodes: 10, 20, 30, 40, 50, respectively.
b) Testing area: 1000m*1000m.
c) Mobile speed: 75m/s.
d) Mobility model: Random way point model.
e) Traffic load: Constant Bit Rate (CBR).
f) Radio transmission range: 150m.
g) MAC layer: IEEE 802.11.
h) Packer size: 512bit.
i) Node initial energy: 5J.

4.2. Simulation results and analysis

In this paper, the routing discovery delay, the entire throughput and the entire energy consumption are calculated and analyzed.

Fig. 4 shows the time delay comparison of AODV and REAODV with the same simulation time, movement speed (75m/s) and the same number of nodes. We can see that our new agreement has a smaller time delay.

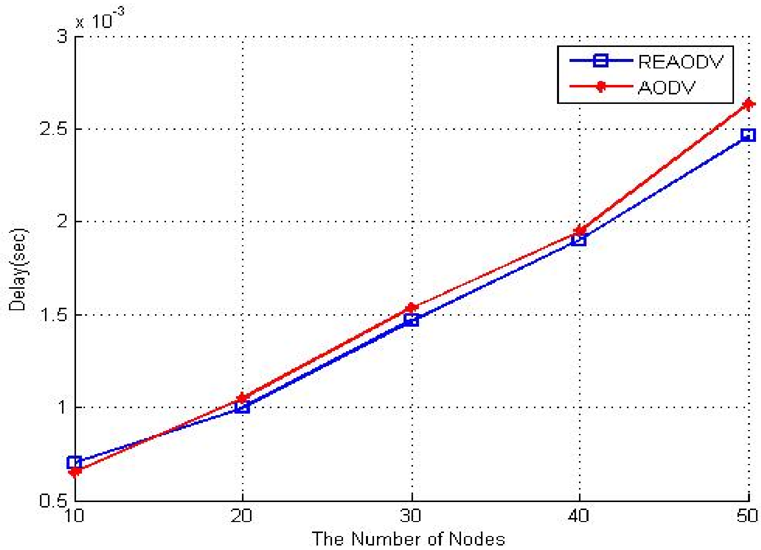

Figure 4. Time delay comparison

Fig. 5 shows the network throughput comparison of AODV and REAODV with the same simulation time, movement speed (75m/s) and the same number of nodes. From the figure we can see that with the increase of the number of node, our new protocol can get higher throughput than the original AODV protocol and can achieve better network performance.

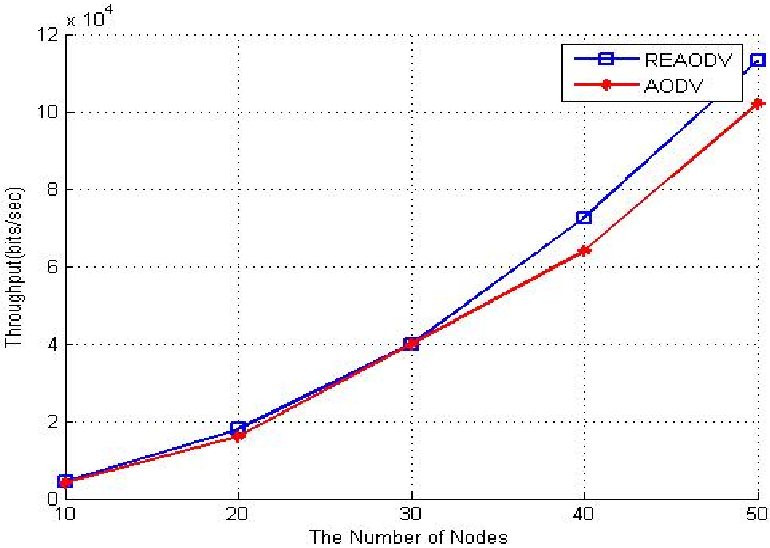

Figure 5. Network throughput comparison

Fig. 6 shows the percentage of the remaining total network energy after the simulation. It can be seen that the energy consumption in our new agreement is slightly larger than the original agreement when the number of nodes in the network is small and within an allowable range. When the number of nodes in the network increases, our new agreement has less energy consumption and the remaining energy of our new agreement is larger than that in AODV.

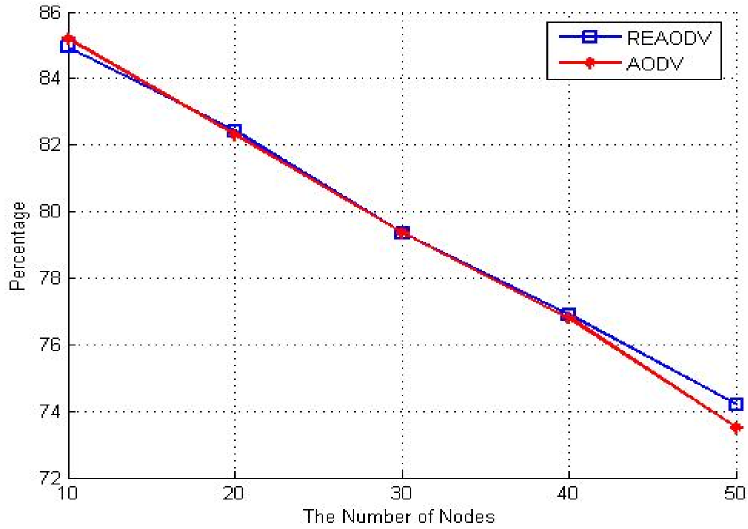

Figure 6. The percentage of the remaining total network energy

5. Conclusion

In this paper, we proposed an REAODV protocol for the scenario with high-speed mobile nodes. We use the reverse broadcast RREP and add energy restriction to achieve less network delay, higher throughput and energy consumption overweight improvement in fast-changing network. Simulation results show that the improved agreement can effectively improve the network performance.

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