Energy Level and Link State Aware AODV Route Request Forwarding Mechanism Research

HAO JUTAO[1] ZHAO JINGJING[2] LI MINGLU[3]
[1]School of Computer and Electrical Engineering,
University of Shanghai for Science and Technology,
Shanghai 200093, China
[2]Department of Electrical Engineering,
Chongqing University，
Chongqing 400044, China
[3]Department of Computer Science& Engineering,
Shanghai Jiaotong University,
Shanghai 200240,China
Jt_hao@usst.edu.cn

Abstract: - Ad-hoc On-demand Distance Vector (AODV) provides scalable and effective solution for packet routing in *mobile* wireless ad hoc networks, however, the path generated by this protocol may derivate far from optimal because of inconsideration of node power ,load unbalance and link state，resulting in energy consumption of each nods is imbalanced and reduce the lifetime of whole networks. Based on the basic AODV protocols, an improved protocol is presented in this paper. When the protocol is selecting a route, node power, load status and link state between nodes are all considered. The proposed protocol can improve the network performance. Through the simulation on NS2, it is confirmed that the improved AODV protocol has higher package delivery ratio, lower end to end delay and lower routing overhead than basic AODV protocol.

Key-Words: - On demand distance vector routing，Mobile Ad hoc networks , Link state, Energy aware routing and so on

1. Introduction

A mobile ad-hoc network (MANET) is a kind of wireless ad-hoc network, and is a infrastructure-less network, dynamically formed by an autonomous system of mobile nodes that are connected by wireless links. Each mobile node in the networks functions as both a host and a router for other nodes. The communication between two mobile nodes can be either in a single hop transmission range where both nodes are within the transmission ranges of each other or in multi-hop transmission where the message is relayed by mediate mobile nodes. In recent years, MANET has been receiving significant attention due to its potential applications in these scenarios, including disaster and emergency relief, mobile conferencing, sensor dust, battle field communication, [1,2]. Among many interesting problems in ad hoc networks, routing is a fundamental and a challenging problem. Unlike its wired counterpart, continuously changing network topology, low transmission power, limited node power and available bandwidth are major challenges for routing. Several protocols have been proposed for MANET routing such as the DSDV (Destination-Sequenced Distance Vector) routing [3] , TORA (Temporally Ordered Routing Algorithm) [4] , DSR (Dynamic Source Routing) [5] , and AODV (Ad Hoc On Demand Distance Vector) routing protocol [6,7]. A MANET routing protocol could be a proactive protocol (table-driven), a reactive protocol (demand-driven), or a hybrid one. DSDV falls into the first category while AODV, TORA, and DSR fall in the second category.

Table-driven routing protocols that require periodic advertisement and global dissemination of connectivity information are not suitable for large networks. Demand-driven routing protocols are efficient for routing in large ad hoc networks because they maintain the routes that are currently needed, initiating a path discovery process whenever a route is needed for message transfer. In DSR, which is a source-based routing, identities of all the intermediate nodes are included in the packets header. For large ad hoc networks, the header length could become very long incurring extra overhead for the networks. While in AODV， the routing table the nodes cache the next hop router information for a destination and use it as long as the next hop router remains active.

Node power expired or node mobility can make link failures, as a result, the routing path will break down. Under such condition, an alternate route has to be discovered, incurring extra route discovery overhead and packet latency. The traffic is also interrupted at the transport layer, and proper traffic recovery schemes have to be applied. For some real-time applications such conditions are intolerable.

Since the mobile nodes in an ad hoc network need to relay their packets through the other mobile nodes toward the intended destinations, a decrease in the number of participating mobile nodes may lead to the network disconnected, thereby hurting the performance of the network. To prolong the lifetime of each mobile node in the network as well the entire network itself, an ad hoc routing should take into account both the energy consumption at each mobile node and the total energy consumption for each connection request carefully.

Though AODV provide scalable and effective solution for packet routing in mobile wireless ad hoc networks, the path generated by this protocol may derivate far from optimal because of inconsideration of node mobility, load unbalance and node power. In AODV, when network is stable, data is transmitted after choosing shortest path without any consideration of any particular node's traffic, and then traffic is concentrated on a particular node, which raises the problem of delay of transmission and huge energy consuming. The protocols do not proactively modify routes until they break. A node that lies on several routes will die prematurely and the network may get partitioned. It is imperative to study and design routing protocols which are able to conserve node energy to prevent such premature death.

In this paper, based on the basic AODV protocols, an improved protocol is presented in this paper. When the protocol is selecting a route, node power, load balance and link state between nods are all considered. The proposed protocol can improve the network performance.

The rest of the paper is organized as follows. In the next section, we briefly describe the AODV protocol and corresponding improvements in literatures. In section 3, we describe our energy level and link state incorporated forwarding mechanism as an extension of basic AODV. In section 4 we evaluate the performance of the improved protocol via simulations. We conclude in section 5.

2 AODV Protocol and Corresponding Improvements

AODV is an on demand protocol. Routes are established only on requests to transmit data from a source to destination. To create routes, AODV performs route discovery cycles in two stages: reverse route setup and forward path setup. When the discovery cycle is complete, the route will be stored in routing tables and be available for routing. The route discovery cycle uses two messages: Route Request (RREQ) and Route Reply (RREP). When a sender wants to send data to destination, and if there is not an already available route, a route should be established between the source and the destination (path discovery). First, the sender broadcasts a RREQ to its neighbors. Nodes within the transmission range of the sender node receive the RREQ. If the neighboring node has enough information (in route table) on how to reach the destination, it will notify back to the sender. Otherwise, it will rebroadcast the RREQ to its neighbors again.

The RREQ will be rebroadcast until it reaches either the destination or a node with up-to date information of a route to the destination. While the RREQ is propagated, each node records obtained data from the source on how to reach it in the reverse path. For that reason, this process is called reverse route setup.

The node with information to the destination (or the destination itself) will issue a RREP message that will propagate in the reverse path. While the RREP is being retransmitted in the back direction, nodes along the path update their route table entries to indicate the route information to the destination. This process is called forward path setup.

Periodically (by a specified interval), nodes announce their presence by issuing Hello messages. If a node doesn't hear from a prior neighbor for a period that is larger than the specified interval (hello_interval), it concludes link failure that may imply route invalidity. AODV uses a fixed hello_interval of one second. When link failures occur, route tables residing in other nodes should be repaired. A RRER is propagated in the MANET until it finds an alternative route. Please refer to [6] [7] for further details about AODV.

As discussed in above review, AODV does not respond quickly enough to link failure. And it usually suffers from the risk of flooding the whole network for new routing discovery. Many protocols have been proposed and studied to improve routing performance. Agarwal and Jain [8] proposed a modified AODV protocol in which a node records information of its two upstream nodes (instead of one with AODV) upon receiving a RREQ. When the same node receives Route Response (RREP) from the destination, it relays the RREP to the two nodes that it records earlier. After some evaluation, one of the upstream nodes will be included in the main route with the other being used for the backup route. Lee and Gerla [9] proposed a so called AODV-BR protocol in which a node (e.g., some node B that is one hop away from the main route) overhears a RREP packet sent from node Y to X will mark Y as its next hop. In case node X's upstream node (say, node A) finds its link to node X broken, it issues a FIND packet requesting a backup route. When node B receives such FIND packet, it responds and forms a new backup route (route changes from original A →X →Y to current A →B →Y). Chen and Lee [10] proposed a 2HBR protocol, which extends the idea of [9] further by including nodes that are two hops from the main route as the potential backup nodes. The Multiple Next Hops (MNH) routing protocol proposed by Jiang and Jan [11], applies the concepts of forward link and reverse link used in AODV. For each destination, each mobile node in MNH routing protocol maintains multiple next hops in its routing table. Hence the MNH may provide multiple routing paths for a source–destination pair. As link failure occurs, the upstream node will detect that and try to reconstruct a new route.

To reduce the frequency of costly route re-discovery procedures and to maintain continuous traffic flow for reliable transport layer protocols, Zhao and Wendi suggest discovering long lifetime routes (LLR)[12]. However, in many practical applications, the general interest to a given problem is not only to maximize the routes lifetime but also to maximize the lifetime at nodes due to the facts that the failure of a node may lead to the network partitioned and any further service will be interrupted. There are several studies that aim to prolong the network lifetime [13, 14, 15]. Chao and Prasant proposed an Energy Aware Load Balancing routing method to determine paths that result in low energy consumption or optimize the residual battery power [16].

3 An Improved AODV Route Request Forwarding Mechanism

In the basic AODV protocol, to avoid "broadcast storm" problem, a route request forwarding scheme is designed. When any intermediate node receives a RREQ, it rebroadcasts after a random delay.

Obviously, in the route request forwarding scheme of basic AODV, the differences between nods are not considered, such as node residual energy, link state between nodes and node load. Thus, routes founded under this condition are prone to broken due to limited power. Meanwhile, some busy nodes which lie on several routes will die prematurely and the network may get partitioned.

In the improved AODV protocol, whenever a node receives a route request, the forwarding mechanism can decide the length of the delay according to the node residual power, link state and node load. And then rebroadcasts the route request.

Firstly, in the energy limited ad ho networks, node residual power is an important factor to be considered in selecting a route, and have become a research focus. When a node receives a route request, node can calculate the time of delay according to residual power. The introduction of this energy constraint can balance the energy consumption and prevent premature death.

The energy model adopted in this paper is:

$$Energy = Power \times Time \tag{1}$$

namely, energy consumption of sending or receiving a packet is decided by transmission power or receiving power and the time needed for processing the packet. The time needed for processing a packet is defined as:

$$Time = 8 \times Packetsize / Bandwidth \tag{2}$$

Therefore,

$$E_{tx} = P_{tx} \times 8 \times Packetsize / Bandwidth \tag{3}$$

$$E_{rx} = P_{rx} \times 8 \times Packetsize / Bandwidth \tag{4}$$

where P_{tx} and P_{rx} represent transmission power and receiving power respectively.

The total energy consumption of forwarding a packet is defined as:

$$E_f = E_{tx} + E_{rx} \tag{5}$$

Let E_{i0} and E_{i1} denote initial energy and residual energy of node i, T_{iE} represents time delay affected by energy factor of node i. r_{iE} is defined as the ratio of residual energy to initial energy.

$$r_{iE} = {E_{i0}} \big/ {E_{i1}} \tag{6}$$

In order to maintain connectivity of the networks and reduce latency, in this paper, the energy constraint take effect only if the ratio of residual energy to initial energy is less than 20 percent. The delay associated with residual energy is defined as:

$$T_{iE} = 1 \big/ (1 + r_{iE}) \tag{7}$$

Secondly, in the basic AODV protocol, the length of buffer queue is not considered. In fact, the conditions of buffer queen reflect the capabilities of node to process packets and communication and the load status of the node. So, the introductions of the length of buffered packets into AODV can efficiently relief the effects of nodes load unbalance, for example, premature death and packet latencies.

Let Q_{iLen} represents the maximal length of buffer queen in node i and Q_{iL} denotes the number of buffered packets. So, the delay caused by the current length of buffer queen is defined as:

$$T_{iQ} = {Q_{iL}} \big/ {Q_{iLen}} \tag{8}$$

Thirdly, in mobile ad hoc networks, the movement of the node is continuous. Namely, ad hoc topology changes slightly with time as the nodes move. The basic AODV protocol always selects the shortest path, but because of the limited transmission range, the shortest path is the easiest broken one. Routes failure is almost caused by the break of the most fragile path. Thus, to deal with this problem, the most efficient way is to find most stable link as much as possible. Link state introduced into AODV protocol can prevent link break, reduce times of route request and increase system packet delivery ratio.

In present, there are three main radio propagation models: free space model, two-ray ground reflection model and shadowing model. In this paper, two-ray ground model is adopted. This model considers both the direct path and a ground reflection path. The model gives more accurate prediction at a long distance than the free space model. The received power is predicted by

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \tag{9}$$

where P_t is the transmitted signal power. G_t and G_r are the antenna gains of the transmitter and the receiver respectively. L is the system loss, and

d is the distance between transmitter and receiver. h_t and h_r are the heights of the transmit and receive antennas respectively.

In this paper, we suppose that the transmit power of each node is equivalent and the signal power loss is completely caused by the increment of distance between nodes. According to Equ. (9), link state can be approximately presented by the distance between nodes. In link state considered AODV protocol, when link state is stable, namely, the distance is relatively short; the route request will be rebroadcast after a short delay.

Let T_{iSig} denote the delay caused by link state, the definition is as :

$$T_{iSig} = D_{ij} / D_{Max} \quad (10)$$

where D_{ij} is the distance between transmitter j and the receiver i. D_{Max} represents the transmit range.

Integrated three factors as is mentioned above, we get the final calculation formula of rebroadcast delay

$$T = T_C \times (\alpha_1 T_{iE} + \alpha_2 T_{iQ} + \alpha_3 T_{iSig}) \quad (11)$$

where α_1 , α_2 and α_3 are the weights, and satisfied $\alpha_1 + \alpha_2 + \alpha_3 = 1$. T_C is a constant, which is used to control the magnitude of delay.

4 Protocol simulation and performance evaluation

To evaluate the performance of the proposed AODV protocol, the protocol was tested on NS2 and the simulation results was compared with basic AODV protocol.

4.1Simulation Environment

In our simulations, fifty nodes were initially placed randomly within a fixed size 1200mx1200m square area. We used IEEE 802.11 MAC protocol for nodes in the simulation. Transport layer protocol is UDP, A 30 Constant Bit Rate (CBR) data flows each one generating 4 packets/seconds with a packet size of 512 bytes are generated. Two-ray ground reflection model was adopted and the radio range of each node was set at 250m.Nodes position and speeds were generated randomly. When nodes arrive at a destination, they do not stay and continue to move toward the next random destination with a random speed. In our simulations, the maximum speeds were set at 0m/s、5m/s、10m/s、15m/s and 20m/s respectively. Initial energy level for all nodes is 60J, transmit power and receive power are 200mW and 600mW respectively. Each simulation lasted for 600s of simulated real time.

In our simulations, the parameters in Equ. (11) are set as follows: $\alpha_1 = \alpha_3 = 0.4$, $\alpha_2 = 0.2$ $T_C = 0.08$.

4.2Performance metrics

The performance of each routing protocol is compared using the following performance metrics:

(1). *packet delivery ratio (PDR):*

The PDR is the ratio of the number of number of packets received by the destination to the number of packets sent by the source.

(2). *end-to-end delay:*

The end-to-end delay represents the average delay experienced by each packet when traveling from the source to the destination.

(3). *the average number of hops:*

The average number of hops is that a packet travels through until it reaches the destination.

(4). *routing overhead*

The routing overhead measures the algorithm's internal efficiency and is calculated as the total number of control packets sent divided by the number of data packets delivered successfully.

4.3 Performance evaluation

Fig.1 gives comparisons between basic AODV protocol and improved AODV in performance. Fig.1 (a) illustrates the comparison result of two protocols in average number of hops, and the result shows that the average number of hops in improved AODV is less than basic AODV protocol. In Fig.1 (b), routing overhead is compared, and the result shows that the improved AODV can reduce routing overhead notably. This achievement mainly owes to the introduction of link state into the route request forwarding mechanism which increase the resistibility to node movement and reduce the times of link break. From Fig.1(c) we can see that the improved AODV protocol has great advantage over basic AODV protocol in packet delivery ratio. While Fig.1.(d) illustrates that two protocol each has advantages in average delay.

Fig.2 (a) shows the energy consumption of each mobile node using basic AODV protocol. In Fig.2(b), the energy change of each node are illustrated. Comparing two figures, with the lapse of time, the energy level of each node is decreasing. Because of the consideration of energy level in the improved AODV protocol, the protocol avoids selecting nodes with too lower energy level and prevents the nodes to the premature deaths. Therefore, in the improved protocol, energy consumption of each node is more balanced.

5 Conclusions

Ad-hoc On-demand Distance Vector (AODV) provides scalable and effective solution for packet routing in mobile wireless ad hoc networks, however, the path generated by this protocol may derivate far from optimal because of inconsideration of node power ,load unbalance and link state，resulting in energy consumption of each nods is imbalanced and reduce the lifetime of whole networks. Based on the basic AODV protocols, an improved protocol is presented in this paper. When the protocol is selecting a route, node power, load status and link state between nodes are all considered. The proposed protocol can improve the network performance. Through the simulation on NS2, it is confirmed that the improved AODV protocol is more energy-efficient than AODV and has higher data package delivery rate, lower end to end delay and lower routing overhead.

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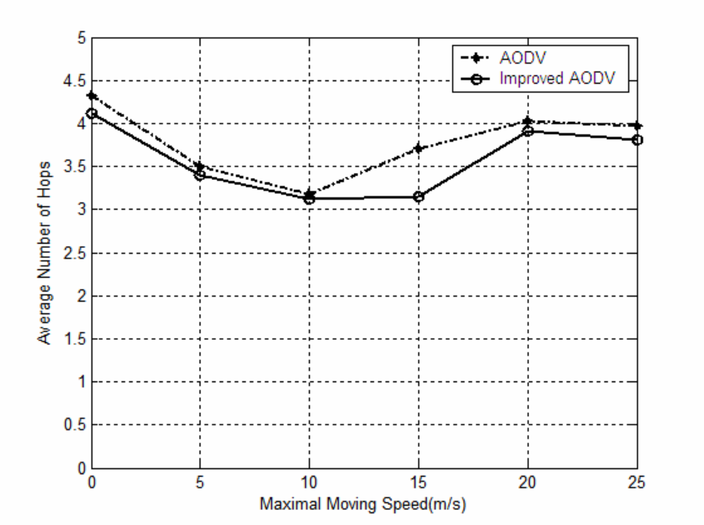
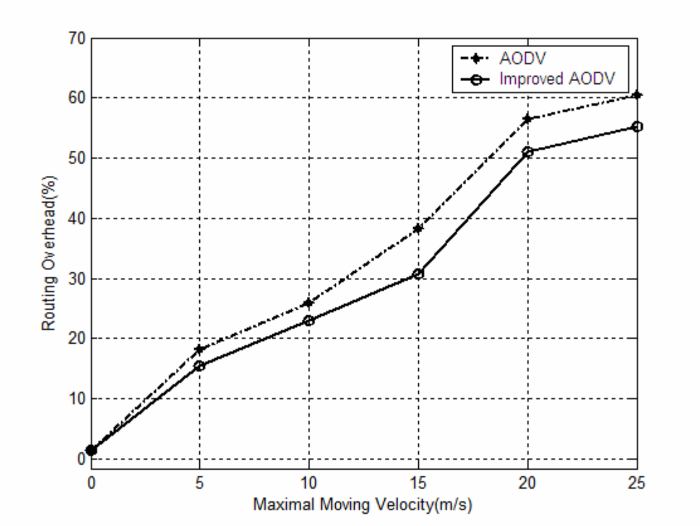
Hao Ju-tao received his PhD in computer science and engineering from Shanghai Jiaotong University in 2007 and now is a lecturer of School of Computer and Electrical Engineering, University of Shanghai for Science and Technology, His research interests are Mobile Ad hoc networks, image processing and pattern recognition.

Zhao Jing-jing is a Ph.D. candidate of Electrical Engineering Department, Chongqing University. Her research interests are Mobile Ad hoc networks, power sources, and electrical system.

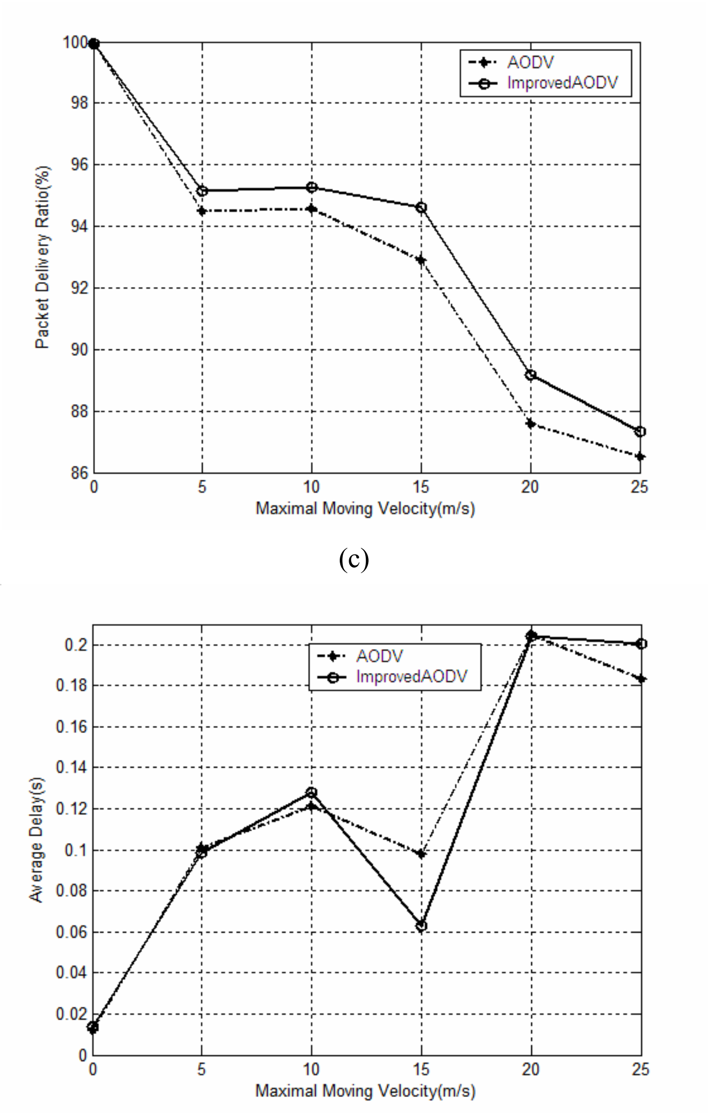
Li Ming-Lu is a full professor and deputy director of Department of Computer Science and Engineering, Shanghai Jiaotong University, China. He also is a director of Grid Computing Center of Shanghai Jiaotong University, Grid expert of Ministry of Education, P.R. China, and expert-in-chief of Shanghai Grid, an influential Grid project in China. His research interests mainly include Grid computing, Web services, service computing and sensor network.


AODV
Improved AODV
Average Number of Hops
Maximal Moving Speed(m/s)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
5
10
15
20
25

(a)


AODV
Improved AODV
Routing Overhead(%)
Maximal Moving Velocity(m/s)
0
10
20
30
40
50
60
70
0
5
10
15
20
25

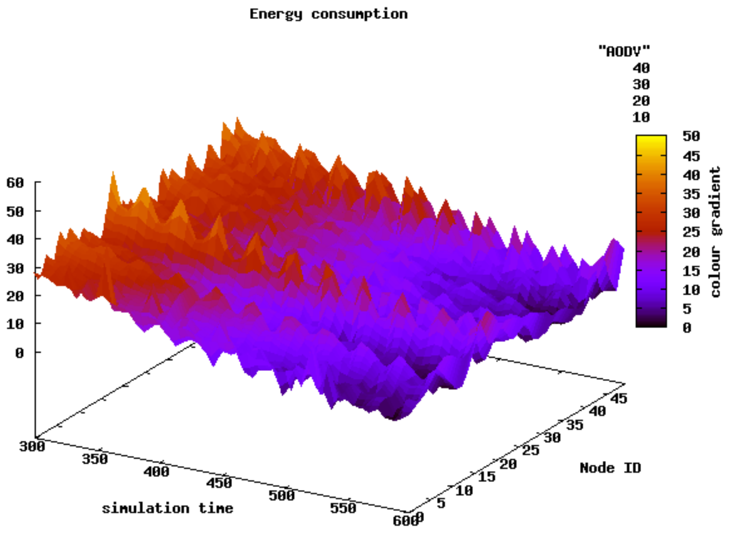
(b)



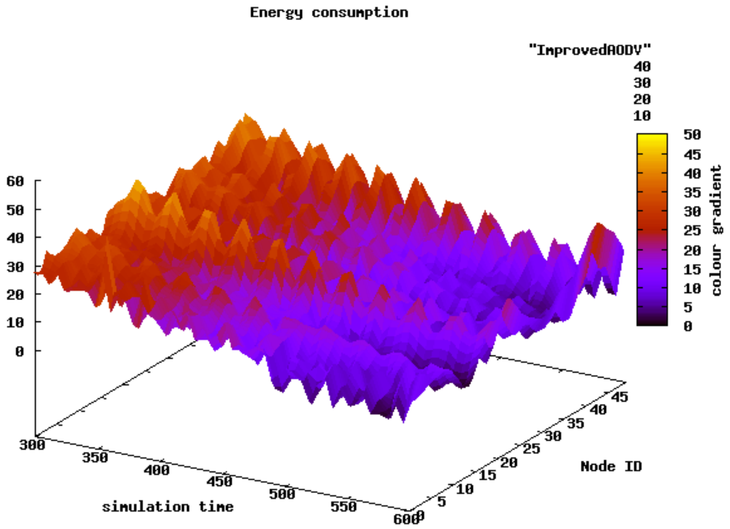
(c)

(d)

Fig.1. A comparison of basic AODV with improved AODV in performance



(a)



(b)

Fig.2. A comparison of basic AODV comparison with improved AODV in nodes residual energy