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A fault tolerance routing protocol considering defined reliability and energy consumption in wireless sensor networks

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Abstract - **In wireless sensor networks, optimal consumption of energy and having maximum life time are important factors. In this article attempt has been made to send the data packets with particular reliability from the beginning based on AODV protocol. In this way two new fields add to the routing packets and during routing and discovering of new routes, the lowest remained energy of nodes and route traffic based on the number of discarded packages, will store in this field as two variables. These two variables will be considered during choosing a suitable route for sending the data to that message which should be answered by sink. The efficiency of this protocol is based on the fact that, at the route request, it finds the routes with high energy and low traffic through which data are sent(information is sent).So data packets reach the destination with a higher probability and also the balance of energy consumption is considered in the network. From the energy point of view, not using weak nodes routes leads to not having off nodes at the end of the process. This fact affects balancing of energy consumption and reducing the variance of the energy remainder proportional to AODV model. Not using high traffic routes leads to reducing collision and sending fewer signaling packets; more data packets with lower delay reach the destination. In the case of high congestion, for meeting the desired reliability, which is among the main goals there may be more sending signaling packets, delay and collision. But this happens with sending more packets and a guaranteed reliability.**

Index Terms - **Wireless Sensor Networks, Ad hoc networks.**

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I. INTRODUCTION

Wireless sensor networks are bunches of sensor nodes which have been scattered in an environment. These nodes have the task of sensing the desired events and sending them to the sink via middle nodes. These nodes have limited resources such as batteries and processors. These limitation should be considered while routing, sending and receiving data in all protocols.

Wireless sensor network is different from wired sensor network in routing and energy consumption.

As a result of limitation in energy, bandwidth and doing various operations, routing protocols of wireless sensor networks are challenged. The conducted research, with the purpose of optimizing the efficiency of the current algorithm for proper energy consumption and avoiding a rise in routes traffic, are related to the following approaches.

1. Optimization of energy consumption (proposing methods for reducing energy consumption and increasing network lifetime)
2. Proposing various patterns for calculating the reliability (selecting various parameters for the reliability of a route)
3. K-coverage and K-connectivity (proposing methods for coverage and connectivity in a way that, every second each node at least with K is covered by the neighboring node).
4. Analyzing network fault tolerance
5. Examination of the network in high scales and also in the above mentioned states.

In other words, all the existing algorithm, focusing on one or some items mentioned above, either attempt to optimize their performance or try to propose different methods for examination of reliability and fault tolerance. Since none of them attempts to propose a precise amount to recognize a weaker or high traffic route and they recognize these routes proportionality. So in this article attempt has been made to focus on items 1 and 2 to appoint threshold quantity in order to recognize a route from the energy and traffic viewpoint. It means that if the energy field of a route is less than the threshold quantity, the route is a weak one and if the reliability of a route is less than the threshold quantity, it is a crowded route. The final purpose of this article is creating a better balance in energy consumption, increasing lifetime of the network, rising fault tolerance, and with exploiting the above mentioned items, data be sent to the destination with a definite reliability.

In the following section, the studies done before will be presented and also AODV algorithm will be explained. Then, the proposed algorithm will be analyzed and simulation and its result will be presented in the next part. Finally, the future plans will be discussed.

II. A REVIEW OF THE RELATED STUDIES

In designing all routing algorithm, having the maximum lifetime in this kind of network is one of the major subjects. Considering the remainder of energy of each node and the quality of connectivity can be good criteria in selecting the appropriate route and sending data. Multi-routing protocol seeks this purpose. [1] Efficiency in consumption is worthwhile when reliability in delivering the data packets is taken into account. Routing, with exploiting the energy and having reliability, seeks these issues [2,8,9]. For example, after a while , those nodes which have greater roles in sending data should be identified and special plan should be considered for them. Great care should be given to these nodes not to lose their energy soon. [3] Semi proactive AODV protocol attempts to meet this purpose.

In wireless routing networks, nodes and connections have the potential of getting damaged. So something must be done to have alternative routes. Connectivity properties of large scale sensor networks algorithm seek providing alternative routes.[4] Coverage and connectivity are other subjects which help to define network fault tolerance. It means that, every second, it is possible to define precisely how many neighboring nodes cover each node. As connectivity is highly dependent upon the level of node coverage, always strong connectivity should be used. Measuring fault tolerance in wireless sensor network with large scales seeks to approximate this quantity.[5.6] Delay and scalability along with reliability and low energy consumption are important parameters in a system. So there should be a balance among energy consumption, fault tolerance, and delay. [7] Clustering is another method in satisfying the above mentioned aims. In other words, neighboring nodes are located in a cluster and a node, which may be the strongest one, can be defined as the cluster head. Clusters communicate with one another via cluster head and if the energy of cluster head is weakened, this task will be done by another node.[10] it shows a cluster-based wireless sensor system. In the following section, AODV protocol will be explained which is the basic and principal protocol in this paper and then the proposed protocol will be discussed and finally, simulation, result analysis, and future plans will be defined in the subsequent sections.

III. THE ANALYSIS OF AODV ALGORITHM

In this section AODV on-demand routing algorithm, which is one of the most important proposed protocols in Ad hoc networks, has been applied as a basic protocol for research in this article and it has been analyzed.

AODV algorithm provides the possibility of dynamic and multi-hop routing among nodes in a network. In this algorithm, nodes can find a route toward a destination fast and they do not save the unused routes.

In AODV algorithm, connectivity breakage, and network topology changes are controlled. Routing operation in AODV lacks a loop and it does not have the problem of "counting to infinity" of the Bellman-Ford algorithm at the time of network topology changes.

Using destination sequence number in each record of routing table is one of the characteristics of AODV algorithm.

Sequence number of destination is assigned by destination node. Using this field guarantee not creating a loop in routing and its planning is so simple. If there are two routes for a destination, the sender node select the route with the larger sequence number. Another characteristic of AODV is that a connectivity breakage is immediately informed to the affected node [11].

IV. EXPLANATION OF PROTOCOL

The existence of distinct traffic and sending data via repetitive routes are among the important problems in wireless sensor networks. These problems lead to high energy consumption of route nodes and also result in turning off and deletion of these nodes from the whole collection of nodes. If these nodes sense important information, in other words, if the events happen near them, their deletion can affect the whole network.

On the other hand traffic rise from specific routes lead to repletion of middle node buffer which can lead to another challenge in the network.

So there is enough energy in these nodes, but, as a result of buffer repletion, the received packets must be deleted; a huge amount of data will not reach the destination. Using on-demand routing and AODV protocol, this research attempts to prevent from transferring data through such routes. As the information of a route is defined when the route is discovered, the algorithm tries to be informed of the energy state and the traffic of the route. In AODV –based method, when the route request packets reach the destination node or when the middle nodes having a route towards the destination, route reply packets are sent to the origin which defines the route and the number of hops.

Having only this information cannot assure that the nodes of this route have a suitable condition regarding the energy and empty capacity of buffer. In this protocol, two other fields, called energy and reliability, are added to the route discovery packets (probability of sending the data through this route). During passing the route, these fields are quantified to be situated along other information which reach the destination node or sink in basic model. With considering all these data, an appropriate route will be declared in response to the route request.

In this protocol, for satisfying the desired reliability, if it is recognized that none of the routes has a suitable traffic state on its own(after passing time and reducing energy in each node and increasing the capacity of buffer), considering reliability formula, in parallel routes some routes can be offered to the origin. It is done to satisfy the desired reliability by sending multi-casting from the beginning.

The Manner of Quantifying the Energy Fields and Reliability in the Route Discovery Packet

The energy field is considered as a limiting parameter. In the beginning the quantity of this field equals the primary energy of each node (a primary energy is assumed for each node; with each sending or receiving, depending on the kind of contents, which can be signaling or data, a quantity of it is reduced) and during the process of route discovery, each node which has less energy of this field replace its energy. At the end of this procedure the energy field of route discovery packet will equal the least energy of that route node.

The second parameter, reliability, shows the traffic condition of the route and as it illustrates the sending probability, it will be a number between 0 and 1. At the beginning, quantity of this field would be 1 and when each node reach at the time of route discovery, this number is multiplied by the reliability. A new field or a damaged probability, called ρ , is added the information of nodes in time scale and it is quantified according to equation 1as follow:

ρ=(Dropped packets)/(Received packets) (1)

This fraction shows the ratio of drop packets to the whole received packets. For example, if it is 0.3, it means that the node has dropped 30 percent of the received packets.

Based on the quantity ofρ the reliability of the node will be according to the equation 2:

$$R = (1-\rho) \qquad (2)$$

For the above mentioned node, reliability will be 70 percent; the information will pass through it with 70 percent probability.

The reliability of a route, which will be available when route discovery packets reach the sink, equals the multiplication of reliability of each node and it is as follow:

$$R = (1-\rho_1)(1-\rho_2)(1-\rho_3)\cdots(1-\rho_n) \qquad (3)$$

In order to avoid sending the information through low energy and high traffic routes, which form the purpose of this article, we do as follow:

1. If the energy of the route is less than that of defined threshold, that route will be ignored (we should wait for new routes).
2. If the energy of the route is enough, its reliability will be examined and if it meets the desired quantity, response is given to this route.
3. If a route does not satisfy the reliability on its own, the response is given to some routes that generally satisfy the reliability.

Equation 4.the manner of calculation of parallel routes reliability

$$R_t = 1-(1-R_1)(1-R_2)(1-R_3)\cdots(1-R_n) \qquad (4)$$

We continue the number of selected routes (n) until Rt reach the desired level.

```
While (not end of  routes record  list) {
        If (current route has enough energy) {
        If (current route has enough reliability) {
                            RREP (current route);
                            Exit;  }
          Else
              (add current route to parallel routes)
        If (parallel routes had enough reliability)
                  { RREP (parallel routes);
                      Exit; }
                  }
           go to next record;
    }
```

V. SIMULATION AND THE RESULTS

In this article, by using Glomosim simulator software, attempt has been made to reconstruct and analyze the proposed hypothesis such as the existence of traffic in distinct routes. To this end, some nodes have been distributed in the whole simulation environment to discover routes and send information in a definite period and number. With having this number of sender nodes and data packets, we will certainly have heavy traffic and crossed routes. In this simulation, the aim is to show that AODV, by selecting repetitive routes, will encounter heavy drop of energy in specific nodes and finally their turning off. So, by expanding the operation in a more extended area of the network, the proposed protocol attempts to balance the energy consumption and increase the life time of the network. It also tries to provide the reliability.

First simulation:

TABLE 1
The primary information is as follow

Sender nodes	The size of data packets	The desired reliability	The quantity of energy threshold	The primary energy of nodes	Environment	The number of nodes
11	512B	99%	500	2000unit	1000× 1000 Meter	100 nodes

By taking a look at the above chart, it is understood that about 10 percent of the nodes start sending data. In the proposed protocol, regarding the quantity of the threshold with energy equal to 500, when the mentioned node reaches to the 25 percent of the primary energy, it will be renewed from the cycle of activity and it will not be used (with reducing the quantity of threshold, it can be used in the future).

On the other hand, by determining reliability of 90 percent, it is expected that the same percent of the data reach the destination.

The Results of simulation the important parameters of these networks are the criteria for evaluation of two protocols. These items include balance in energy consumption, existence or non-existence of off nodes, delay, the number of occurred collisions, and the number of signaling packets.

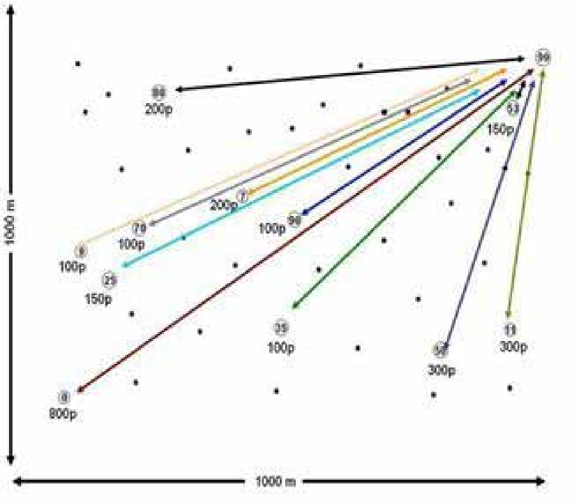


Fig.1 shows the topology of this simulation.

1. The Number of sent and arrival packets

TABLE 2
The number of sent and arrived packets in the destination

The counter of packet	The number of sent packets	The number of arrived packets	
		The proposed method	AODV
0	800	795	797
7	200	199	197
9	100	100	100
11	300	299	294
25	150	149	128
35	100	100	100
50	300	299	298
53	150	150	150
70	100	99	100
80	200	200	199
90	100	100	100
The sum of all packets		2490	2463
The number of dropped packets		10	37
The percent of arrived packets		99.6%	98.5%

As shown in table 2, in the proposed protocol, the percent of arrived data satisfies the desired reliability. The number of arrived packets in the destination in the proposed model is greater than that of AODV, and the data with high probability have arrived at the destination.

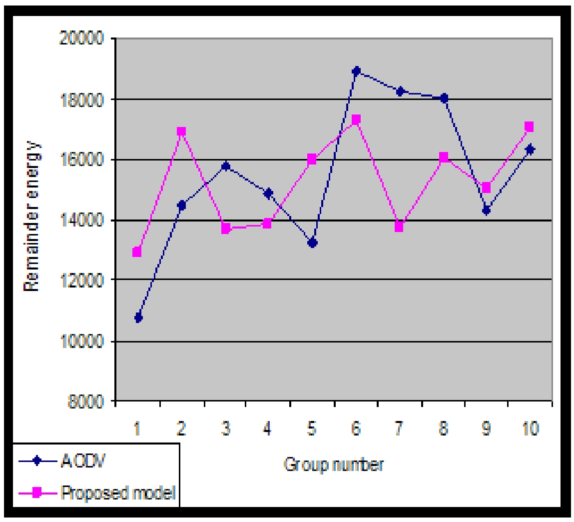
2. The condition of energy remainder

TABLE 3
The sum of energy remainder

AODV	The proposed method	Difference
155229	152447	2782
	Energy variance	
2527	1616	911

Based on the information in table 3, sending more data packets, it refers to sending data through low traffic routes which do not need retransmission. Lesser variance points to a better balance in the energy remainder. It means that the energy of nodes has reduced in a balanced proportion and unlike the AODV, there are neither a number of nodes with energy equal the primary energy or a number of off nodes in another part. All nodes are on and active.

As the number of nodes is 100 and their locations are random, the nodes from 0 to 99 have been classified into 10 groups for both. This has been done to simplify the explanation and comparison of algorithm performance. Now each group is analyzed.



Graph .1 the amount of energy remainder of each group

As predicted, the balance in energy consumption in the proposed model is better than that of AODV algorithm and the variance (table3) shows this issue.

In the proposed model, all nodes are on at the end of the simulation and their minimum energy equals the threshold, while, by performing AODV (figure2) it can be observed that 3 nodes are off. Among these nodes, two of them are near the sink and are located in an important place.

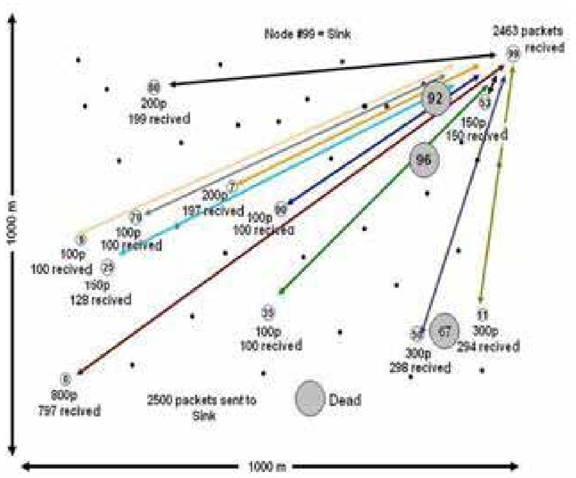


Fig .2 turned off nodes

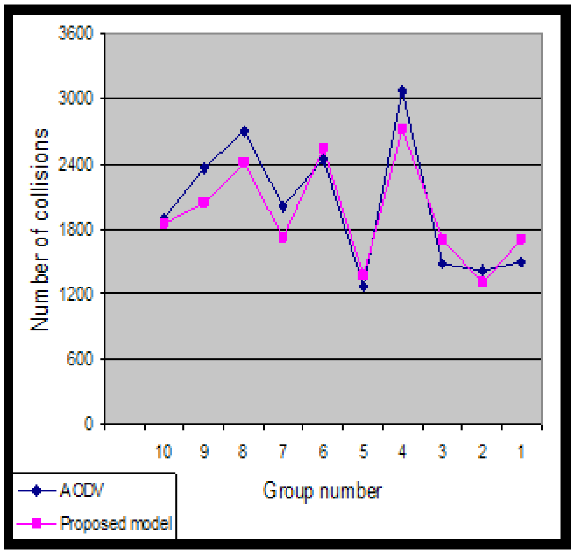
analyzing the energy of nodes more precisely after the simulation in AODV model, it is found out that about 25 percent of them have lost a bit energy; it shows that they had no roles in sending and receiving data. In the proposed model, more consumption of energy is the result of selecting different routes which are possibly farther to the destination. It should be mentioned that more consumption of energy has been along sending more data.

3. Collision condition

In graph 2, the amount of collision in 10 selected groups has been shown. As expected, identification of high and low traffic routes and sending data through different and uncrowded routes has led to lesser intermixture.

As illustrated in the graph, except two groups, intermixture in each group either equals or is less than that of AODV model.

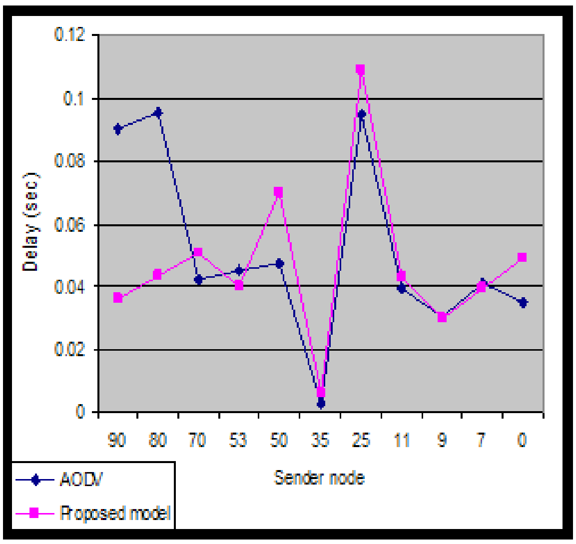
It has also been shown in energy consumption because intermixture rise in data packets can have high energy consumption.



Graph .2 the amount of collision

4. End- to- End Delay Condition

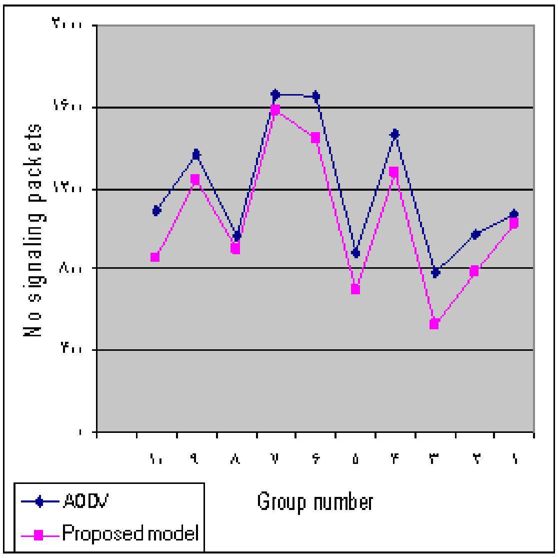
Regarding sending data through different or farther routes, and expending the activity to a more extended area of the network, it seems that there should be more delay. So intermixture decrease in data packets, and not requiring retransmit have led to less delay generally. In graph 3, transfer delay rate of each node to the destination by second has been defined



Graph .3 delay rate of all data transfer from each node

5. The Number of Signaling Packets

Data transfer through low traffic routes, result in better arrival of data packets. So there is no need to discover new routes to transfer data; regarding this approach, the number of signaling packets in all groups in algorithm is fewer than that of AODV.



Graph .4 number of signaling packets

Second simulation: (more extensive)

TABLE 4
The primary information is as follow

Sender nodes	The size of data packets	The desired reliability	The quantity of energy threshold	The primary energy of nodes	Environment	The number of nodes
11	2KB	90%	500	2000unit	1000× 1000 Meter	100 nodes

1. The Number of sent and arrival packets

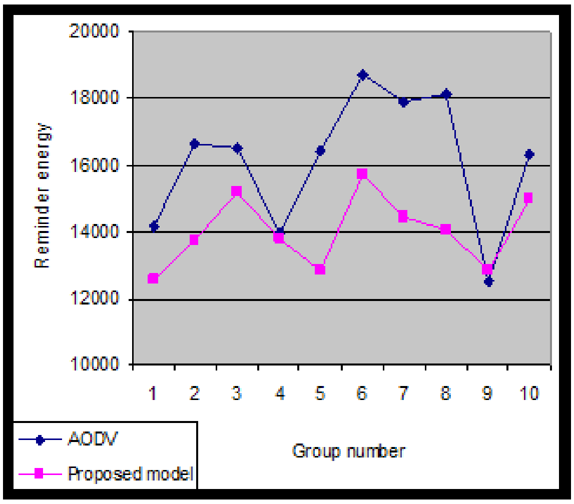
TABLE 5
The number of sent and arrived packets in the destination

The counter of packet	The number of sent packets	The number of arrived packets	
		The proposed method	AODV
0	800	770	790
7	200	37	22
9	100	89	95
11	300	294	195
25	350	322	33
35	100	92	94
50	300	291	294
53	150	150	150
70	100	97	98
80	200	188	197
90	100	70	96
	The sum of all packets	2400	2064
	The number of dropped packets	300	636
	The percent of arrived packets	%89	%76

2. The condition of energy remainder

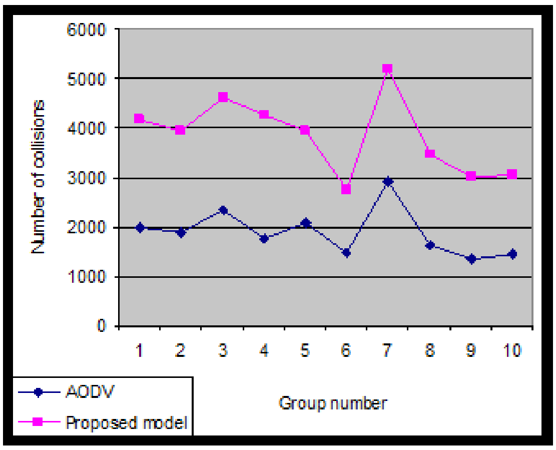
TABLE 6
The sum of energy remainder

AODV	The proposed method	Difference
161220	140194	21026
	Energy variance	
1994	1047	947



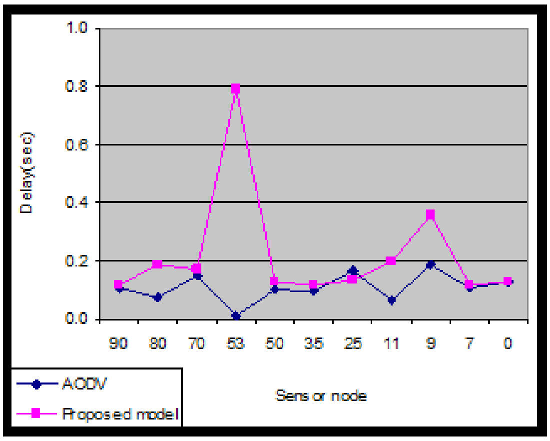
Graph .5 the amount of energy remainder of each group

3. Collision condition



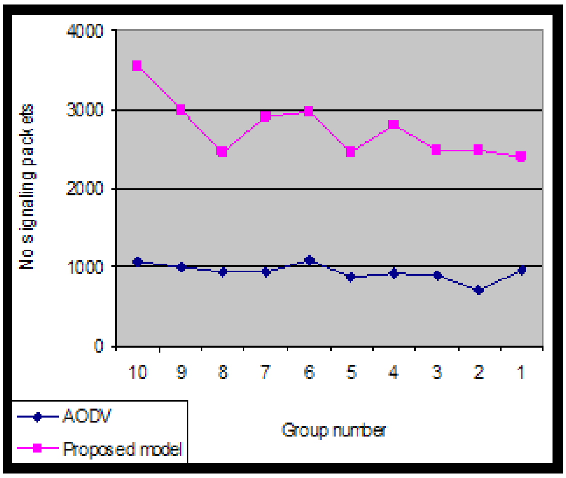
Graph .6 the amount of collision

4. End- to- End Delay Condition



Graph .7 delay rate of all data transfer from each node

5. *The Number of Signaling Packets*



Graph .8 number of signaling packets

VI. FUTURE PLANS

Great attention must be given to an important case in the future and it can be precise selection of the quantity of threshold energy and reliability. Sometimes, the static of this quantity can lead to more energy consumption and greater number of controlling messages. By selecting a precise and intelligent algorithm and implementing it in a sink which has no limitation, these quantities can be changed dynamically and be transferred to all nodes.

If a node is not used for a long time, its reliability do not change (according to the ρ formula, if no datum is given to it for transfer, the denominator remains constant) and despite transferring the current data in the memory, this node is presumed as a high traffic node which is not used. So it is essential that, in specific time intervals, this node correct the reliability by considering the buffer capacity.

VII. CONCLUSION

As expected, two important aims have been met: creating balance in energy consumption in the network and providing the desired reliability for transferring data. It can be seen that for more parameters the proposed method has been better than AODV.

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