Ad-hoc On Demand Distance Vector (AODV) Performance Enhancement with Active Route Time-Out parameter

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Abstract: - The routing protocols play an important role in the performance of the Ad-hoc mobile networks. The Ad-hoc On-Demand Distance Vector Routing Protocol (AODV) is a reactive routing protocol for mobile networks. The route discovery process in AODV is initiated only prior to link establishment for data communication. This research focuses on the effect of the Route states hold time parameter on the performance of the Ad-hoc mobile network which is indicated by the Packet Delivery Rate (PDR). Our aim is to identify the effect of varying Route states hold time parameters for Ad-hoc On Demand Distance Vector (AODV) and measure the degree at which the number of stations and their movement speeds affects the PDR. These factors are presented, discussed and simulated using OPNET simulation software.

Key-Words: - Aodv, Opnet, Olsr, Rreq, Rrep, Active route timeout (ART), Packet delivery rate (PDR)

1 Introduction

There are two categories of wireless networks. Wireless infrastructure networks are the first type; and consist of fixed and wired gateways.

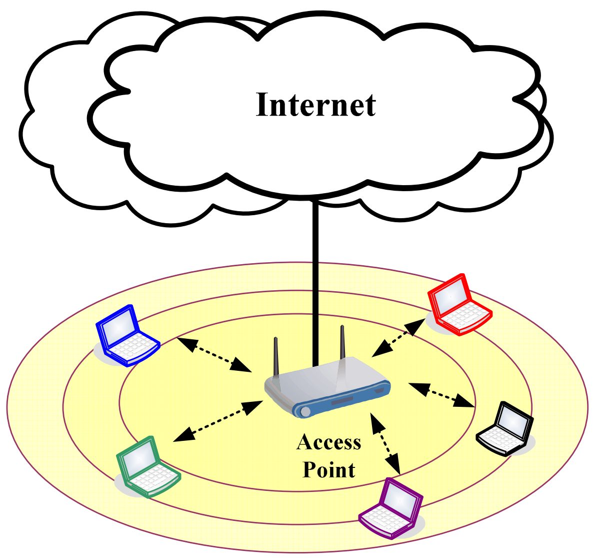

Fig.1 Infrastructure network

All stations communicate through and within the coverage range of an access points. Fig.1 illustrates an example of such a network and it is called wireless local area networks (WLAN) [7]. All stations cannot communicate directly with each others; instead all packets have to go through the access point before they can reach the destination. The stations can roam within the coverage area of a single access point (Basic Service Set (BBS)) or multiple access points (Extended Basic Service Set (EBSS)).

The second type is the Ad-hoc networks (infrastructureless) [12]. These types of networks have no fixed router or access points. The stations move around with more freedom and with ability to connect dynamically to other nodes. Moreover, the mobile stations can emulate a router by discovering and maintaining routes to others in the network [7] [15].Fig.2 presents an example of Ad-hoc networks. The red lines indicate the best possible route to a destination while the green dotted lines indicate the secondary possible route to an arbitrary destination.

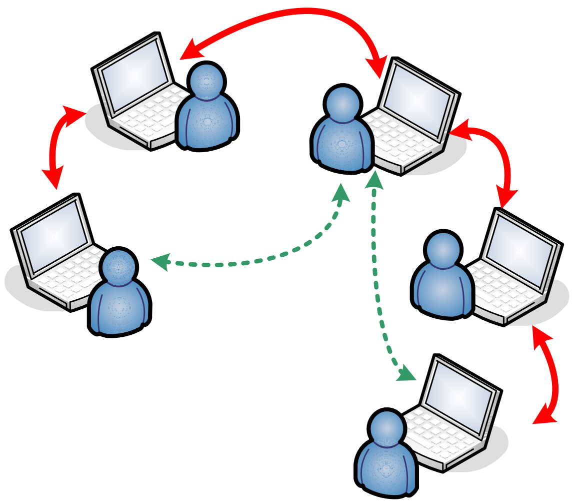

Fig.2 Ad-hoc network

With the significant increase in the popularity of wireless networks, more and more communication engineer showed their interest in implementing mobility in the wireless networks [7]. Mobile Ad-hoc networks consist of wireless nodes which communicate with each other without a centralized control or any kind of established infrastructure. Stations which are within each other's coverage range can communicate directly, while others (which are not within each other's coverage range) depend on their neighboring stations to forward their packets. Since the stations can act as a router or a host, it can easily join or leave the network freely. The self configuring advantage of Mobile Ad-hoc networks resulted in a highly dynamic network environments [9]. Such networks can be utilized in various fields such as, emergency cases like natural disaster (earthquakes, typhoons, tsunami, etc.), battlefields and emergency medical situations [10]. Other application includes the Wireless Community Networks to provide broadband Internet access to communities that previously didn't have such access due to terrain or cost restrictions [14].

This paper examines the effect of Active route timeout parameter in Ad-hoc On Demand Distance Vector (AODV) on the Packet Delivery Rate (PDR). Several factors which affect the PDR such as the Station mobility and speed are also evaluated. The first section presented a brief introduction and summery about the background of the wireless networks in general. The next section focuses on a comparison between proactive and reactive routing protocols. Section 4 and 5 explains how the mobility, number of stations and the ART parameter affect the Packet delivery rate and throughput. Section 6 focuses on the simulated model along with the results .The document ends with a conclusion and future work in the final section.

1.1 Related works

Mobility and number of users analysis in Ad-hoc mobile networks is presented in [7] and [8]. Our work differs in that it emphasizes the importance of the ART parameter in improving the PDR with various mobility speeds and number of users. Moreover, in our simulation, the mobility model utilized is very different from the popular random waypoint model and other random models utilized in [9].

2 Multi-hop

Multi-hop networks suffer from long transmission delays and frequent link breakages if conventional routing protocols such as AODV and DSR are used [13]. Generally, throughput degrades quickly as the number of hops increase. One of the reason for that is because the Ad-hoc networks utilizes only a small portion of the spectrum because only single radio is used to transmitting and receiving. And since that the 802.11 Mac is inherently unfair because of the collision avoidance, radio cannot be utilized for two operations at the same time. This may stall the flow of the packets over multi-hop wireless networks [14].

3 Proactive and Reactive Routing protocol

The routing protocols where developed to overcome limitations of the ad-hoc mobile networks such as high error rates, low bandwidth and high power consumption [7]. In case of mobile Ad-hoc networks, the limited resources (bandwidth, battery, etc), limited security and multi-hop nature create a lot of constrains on the routing protocols which makes it difficult to maintain a route path for a long time [10] [15]. Moreover, the Ad-hoc networks have lower capacity then in the wireless LANs which uses the same radio technology, channel reservation and data link protocols. The capacity is a function of number of nodes and the level of mobility due to control traffic required to maintain topology information of the network. The control information sent by stations in ad-hoc networks can limit the capacity of the network. These control information are required to maintain the routing information while allowing mobility to the stations in the network. Each node in the network is required to locate a route to the destination and announce this routing information to the neighboring stations. One of the challenges in large networks is the congestion due to the large amount of control massages which consume a major part of the available bandwidth [11]. Routing protocols can be categorized as reactive or proactive protocols. Proactive routing protocol such as OLSR maintains reliable routing information in the network by updating the topological information of the network continually. This is done through announcing (broadcasting) any changes in the route information to other nodes. This information is stored in the routing tables within the mobile nodes. On the other hand, the reactive routing protocol differs in that it defines the most suitable route from source to destination only when required. In this case, the route discovery is initiated when need by the source node. Once the route is established, it will be maintain by the route maintenance procedure until the route in no longer desired or the destination is no longer accusable from all routes[7][11].

3.1 AODV and OLSR

Table 1 compares between the two routing protocols AODV and OLSR. The two routing protocols are characterized with many parameters which define how the protocol will perform in different situation.

Table 1 comparison between AODV and OLSR

Features	AODV	OLSR
Protocol type	Reactive	Proactive
Route discovery	Distance –victor routing	Link-state routing algorithm
Reliability	low	high
Complexity	low	high
Scalability	High	low
Latency	High	low
Network size limit	Up to 1000 station	Can handle more then 1000
Band width required	Low	High
Mobility	High	low

We focused on the parameters which affect the route discovery and route states hold times. For example in AODV, we concentrate on the effect of Active route timeout (ART) which is a static parameter that defines how long the route state is kept in the routing table after the last transmission of packet on this route. In the case of OLSR, the route state hold time is characterized by Hello Interval and Neighbor Hold Time parameter [4].

3.2 Route discovery in AODV

All active nodes in AODV broadcast Hello messages to detect links to any neighboring nodes. These Hello messages are also used to detect link break that occur when the node fails to receive any hello messages from a specific neighbor.

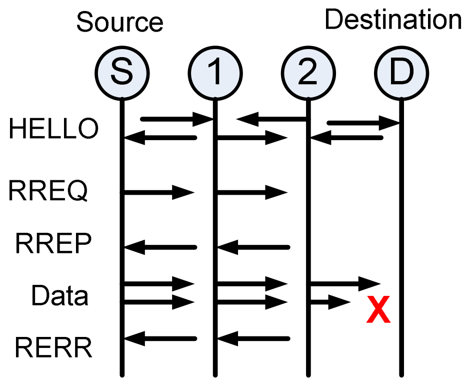

Fig. 3 Route discovery in AODV. Adopted from [6]

Fig.3 shows the process of sending data to unknown destination. Initially, the source station broadcasts a Route Request (RREQ) [15] in order to identify the best route to the destination. When an intermediate node receives the RREQ, it will create the route to the source. If this intermediate node is the destination or has a route to the destination, it will generate a Route Reply (RREP). The source station will record the route after it receives the RREP. If multiple RREP are received by the source station, the path with the least amount of hops will be chosen [3]. As the data flow from the source to the destination, the intermediate nodes will update their timer which is associated with maintaining the route. For the case of AODV, the routing table holds information about the destination address, next hop address, number of hops for the route, destination sequence number, and active neighbors for this route and the expiration time for this route table entry. Expiration time is reset after successful utilization of the route. The new time is found using the relation:

New Expiration time = Current time + Active route Timeout [3].

4 Active Route Timeout

When a route is not utilized for some time, the nodes will remove the route state from the routing table. The time until the node removes the route states is called Active Route Timeout (ART). ART is the time at which the route is considered invalid.

4.1 Mobility and ART value
The mobility model is specified by speed, direction and the pauses or stops in the movement. Mobility is an important performance affecting factor in wireless networks. It significantly impacts the packet delivery rate and the packet delay.
In Ad-hoc mobile networks, node's movement speed has an effect on the throughput. Fig.4 illustrates the effect of the mobility on the connectivity between the nodes. A Direct connection between nodes C and A can be established as a result of a high node mobility.

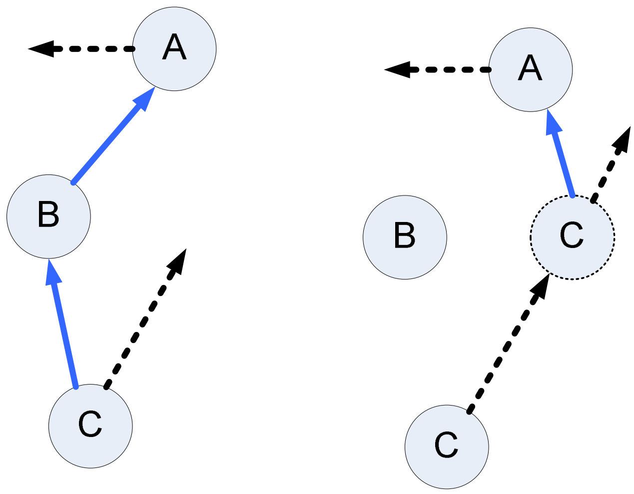

Fig. 4 Mobility affects connectivity. Adopted from [1]

On the other hand, at high speed values, the mobility could affect the connectivity negatively. A sudden change in topology as a result of high speed values can affect the connectivity between nodes. In general, some routing protocols may perform better than others in a network with highly mobile nodes. For example, a reactive routing protocol such as AODV should perform better (in theory) than a proactive routing protocol such as Optimized Link State Routing protocol (OLSR). In such environments it is advised to have a routing protocol which can endure the frequent change in topology. The Route states hold time parameters play an important role in tolerating the fast change in topology. ART is the route state hold time in AODV. At low values of ART, the route state will not be held for a long time which is preferred in a highly mobile environment.

4.2 Number of stations in the network
The number of stations that exists in a network is also an important factor. The more station exists within the same area in a mobile Ad-hoc network, the higher connectivity achieved. That is because of the increase in number of interconnections between nodes. The example in Fig.5 demonstrates that for route 2 (from node A to node C), there is no need to establish a connection between nodes F and C which is already established from route 1. The probability of established connections is high when more stations exist in same area.

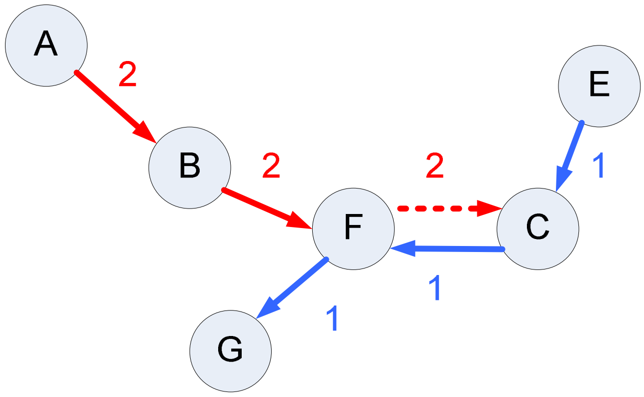

Fig. 5 Effect of number of stations. Adopted from [1]

On the negative side, the increased number of stations could result in a flood of Route request (RREQ) from the nodes which affect the throughput. One of the concerns in AODV route discovery is the large amount of the control messages sent with the increased number of stations. The experiments in [8] shows that the ratio of control messages per data message sent is linear to the number of users that participate in the network. This leads to a large protocol overhead in AODV, especially for large user populations.

5 Packet Delivery Rate
The PDR is the usual metric used to indicate the performance of A-hoc mobile networks protocol [2]. The PDR of a communication protocol is the ratio between the total number of messages send out and the number of messages that were successfully delivered to their destination [8].

$$PDR = \frac{Total \cdot messages \cdot sent}{Total \cdot messages \cdot delivered} \qquad (1)$$

The highest value of PDR is 1; which indicates a good performance since all the sent messages are successfully delivered.

6 Simulation

Two ad-hoc network arrangements were simulated in this work. The first setup was adopted to evaluate the effect of ART value, station's speed and number of stations in a mobile ad-hoc network. Packet Delivery Rate (PDR) was used as a metric for evaluation. The second arrangement evaluates the effect of number of hops on PDR and on the end-to-end delay in a wireless multi-hop Ad-hoc network. The main difference from the first arrangement is that the stations are not mobile; that is because of the difficulty to estimate the number-of hops effect in a mobile network. The results from these simulations are important for proposing solution to the throughput degradation problem in Ad-hoc mobile networks.

6.1 Convergence time

Convergence time is the minimum simulation time of the model so that the reference values achieved with fixed set of parameters such as throughput, delay and packet delivery, do not oscillate significantly in sequential runs. In other words, it's the minimum simulation time to achieve the expected value of the distribution. To achieve a reliable result, it's important to define a convergence time for the simulation. Some parameter's effect cannot be observed with a simulation time less then the convergence time [11]. Fig.6 indicates an example for the convergence time for the simulated model in this work. The figure shows the traffic sent by a station do not oscillate significantly around 2,000 bits/sec after 4 simulated minutes (convergence time).

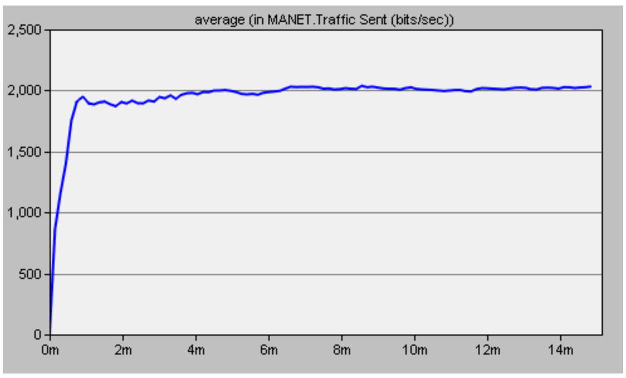

Fig.6 example of convergence time for the simulation

6.2 The first simulated model

OPNET modeler 11.0 is used for simulating the Ad-hoc mobile network [5]. This simulation is based on the previous work done by the Disaster Management and Mitigation Group in the National Institute of Information and Communications Technology (NICT). The previous work simulated a disaster stricken area of 500x500 meters as shown in Fig.7. The work focused on the multimedia information gathering at disaster and movement behavior in an emergency case. Fig 7 represents the simulated map area. This map area is utilized to represent an actual floor in a building (which consists of rooms and corridors). Each mobile station will start moving from a certain point and will keep moving throughout the simulation until it reaches its predefined destination. The station will move randomly within the corridors of the building and will not cross the wall of the building. At each turning point, the available directions (e.g., Front, Back, Right and Left) will have equal probability. That is to create randomness to the motion while following predefined paths. The mobility model is an important part in performance evaluation on Mobile ad-hoc wireless networks because it represents the moving behavior of each mobile not in the wireless network [9]. This movement model symbolizes an actual human movement pattern than other models such as, the Random Waypoint Model. In comparison, the mobile nodes in Random Waypoint Model move in one direction with certain speed then pause for some time, the next direction and speed are chosen randomly from a fixed set. This could lead to rapid change in direction and speed which doesn't exactly simulate the actual human movement. The stations in this work follow straight lines (which represent corridors) with less variation in speed.

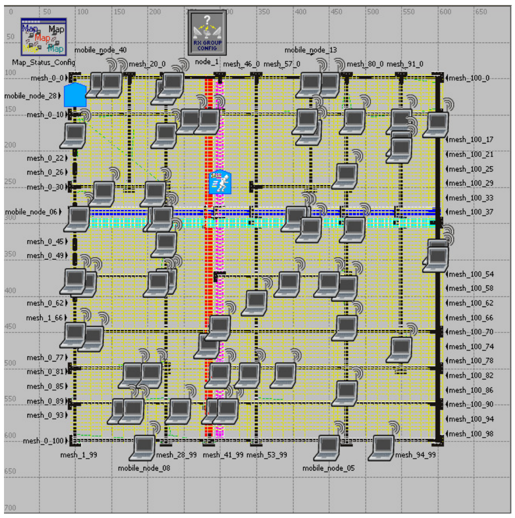

Fig. 7 Simulated Ad-hoc mobile network

The main focus in this work is the communication between two stations which represents the disaster stricken point and the headquarters (which are represented by the two blue nodes in Fig.7).

6.2.1 Simulation parameters

The default values of the route state hold time parameters ART is set to 3 sec. Table 2 summarizes the parameters used in the simulation for the stations in the network.

Table 2 Simulation parameters

Parameter	Value
Active Route Timeout	3 sec (Defualt)
Simulated time	900 seconds
WLAN protocol	802.11g
Bit rate	11 Mbps
Station coverage distance	100 meter
Station transmission power	0.05 mW
Station movement speed	0m/s, 4m/s, 10m/s
Encoding type	Constant Bit Rate (CBR)
Packet Inter-Arrival time	0.25 seconds
Packet size	64 byte (512 bits)
Traffic generation start time	[0,10] with uniform distribution

To achieve a coverage distance of 100 m for each station, equation (2) was utilized.

$$P = \left[\frac{4\pi D}{0.12476}\right]^2 \times 10^{-12.5} \qquad (2)$$

Where P is the transmission power and D is the coverage distance.

Other important metrics such as SNR could also help to achieve a better understanding of the simulated model discussed earlier. At this stage of this work the PDR was the main focus because it gives an indication of how successfully the data has been transmitted.

6.2.2 Simulation scenarios and results

Two scenarios were simulated:

1. Active Rout Timeout (ART) vs. the PDR for different station movement speed.
2. Station movement speeds vs. PDR for different number of stations.

6.2.3 Scenario 1

In this scenario, the ART parameter was changed from 0 to 5 seconds for different movement speeds in a 50 nodes network.

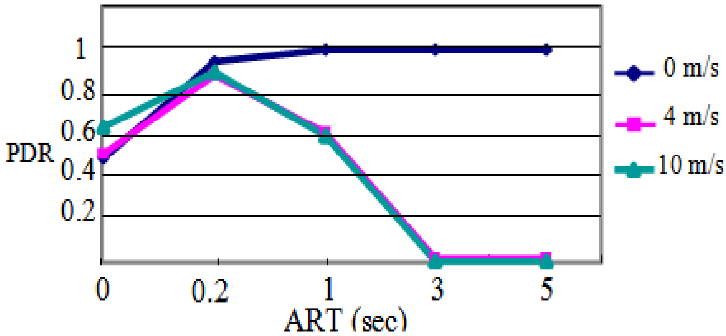

Fig. 8 Active Route timeout vs PDR

Fig. 8 shows that for low values of ART, the PDR will have higher values. At ART 0 sec, the nodes will not keep the route states after it has been used, which will cause the node to repeat the route discovery process after each use of the route. This caused the 10m/s speed to have a slightly higher PDR. Fig. 8 also shows that at 0m/s speed, the throughput was higher than other speeds and nearly unchanged for other values of ART. This result was expected since the stations are stationary and changing the ART value will not affect the PDR. At higher speeds of 4m/s and 10m/s, the values of PDR decreased with the increase of ART. This results from the continuous change in the position of the nodes which makes it difficult to establish connection between the stations.

In general, the figure shows that we could achieve a higher PDR values for lower values of ART then the default OPNET value 3 sec. It is also noticeable that ART value of 0.25 sec gave the highest ART.

From the ART simulation in [11], it was proven that the ART value has a negligible effect on the throughput of the Ad-hoc network in case of 0m/s (stationary) which is consistent with our results in Fig.8.

6.2.4 Scenario 2

In this scenario, the PDR is compared against the station speed for different number of stations at the default value of ART. The number of station was increase to 60 stations then to 70 stations for the same network size. Fig. 9 shows the result obtained from this scenario's simulation.

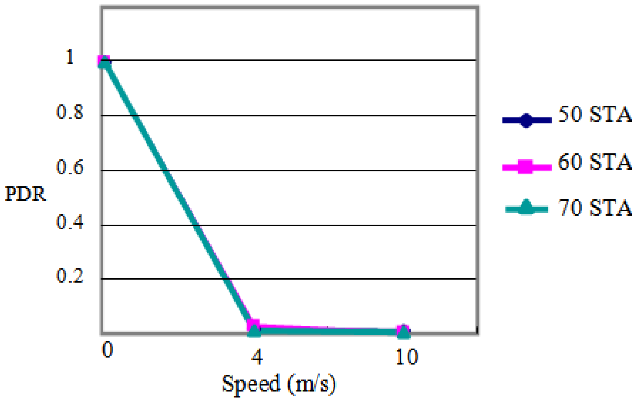

Fig. 9 Speed vs PDR for 50, 60 and 70 stations at default value of ART (3sec)

For the default value of ART, the PDR value dropped sharply with the increase in movement speed. This was expected since the stations will react slowly to the rapid change in the topology which is represented by the 4m/s and 10m/s speeds. Moreover, there was no obvious difference in the performance between the different numbers of user. From [8], it was proved that the number of users has a significant impact on the performance of AODV especially on the delivery rate. However, the PDR increases very rapidly with the increase of number of users until 45 stations. with further increment in number of users, no improvement was observed. The results from [8] agree with the simulated results in Fig.9.

Moreover, the same conditions were simulated with the ART value of 0.25 sec instead of the default values as shown in Fig.10. The PDR values exhibit a significant improvement at 4m/s and 10m/s speeds. In general, the PDR values were between 1 and 0.8 for all number of stations which is considered to be high. The result was as expected because with smaller ART values, the network will be capable of adapting to the topology change as a result of station movement.

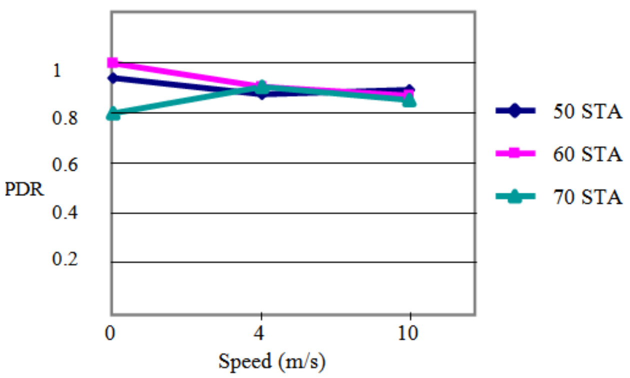

Fig. 10 Speed vs PDR for 50, 60 and 70 at 0.25 sec ART

Again, the increased number of station did not impact the PDR values as explained in the pervious case. Generally it is difficult to realize and measure the number of connections for a selected section in the network. In order to measure the effect of increasing number of station, we have to examine different sections in the network to monitor the change in the interconnection as a result of increasing number of stations.

6.3 The second simulated model

This simulation focuses on the relation between the number of hops with PDR and the end-to-end delay in a wireless multi-hop Ad-hoc network. The network is composed of 6 stations arranged in a way to achieve maximum of 5 hops. The number of hops will be reduced after each simulation and the stat of delay and packet delivery rate is collected. The parameters used in this simulation are summarized in Table 3.

Table 3 Simulation parameters

Parameter	Value
Active Route Timeout	3 sec (Defualt), 0.25 sec
Simulated time	900 seconds
WLAN protocol	802.11g
Bit rate	11 Mbps
Station coverage distance	20 meter
Station transmission power	0.00128 mW
Station movement speed	0m/s
Encoding type	Constant Bit Rate (CBR)
Packet Inter-Arrival time	0.25 seconds
Packet size	64 byte (512 bits)
Traffic generation start time	[0,10] with uniform distribution

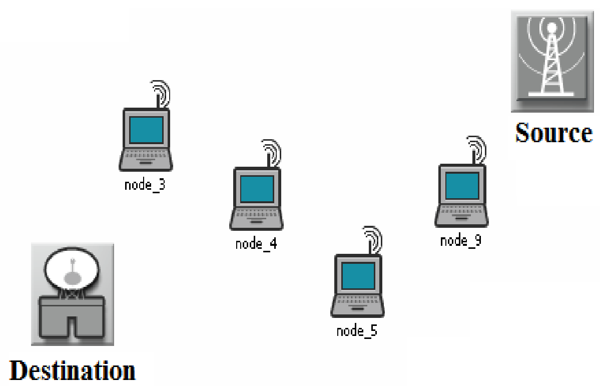

Fig. 11 Simulated Ad-hoc mobile network

6.3.1 Scenario 1

The focus of this Simulation is to measure the effect of number of hops on the end-to-end delay in the wireless ad-hoc network. Two values of ART (0.25 sec and 3 sec) were used in the simulation for comparison purposes.

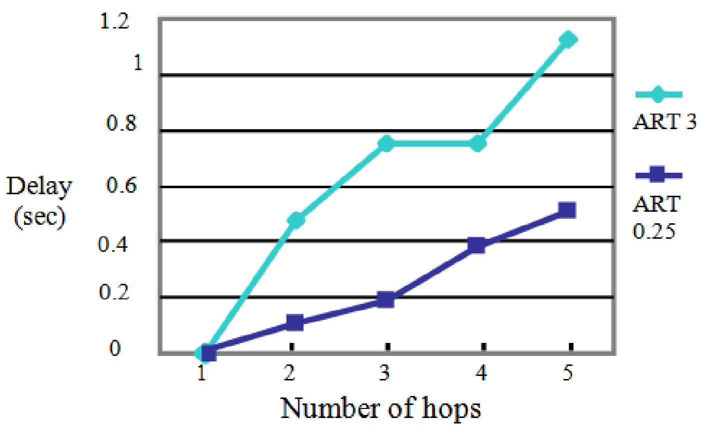

Fig. 12 Number of hops vs Delay

From the Fig.12, it was shown that as the number of hops increase, the delay will also increase. The delay introduced with each hop is due to inability of the station to receive and transmit simultaneously. This delay especially affects communications with have delay restrictions such as voice communications. In general, the delay does not have effect on transmissions which require a large bandwidth or high throughput. Also it can be noted that, even without mobility, the delay was lower for the small values of ART. This indicates that indeed the ART values have an effect on the end-to-end Delay.

6.3.2 Scenario 2

For the second scenario, the PDR is measured against the number of hops. The arrangement is basically the same as the previous scenario with the same parameters from Table 3.

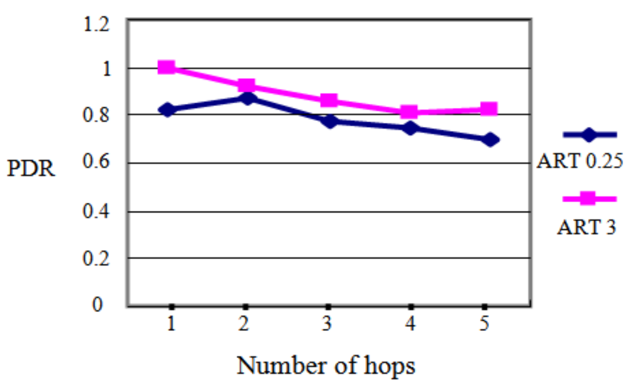

Fig. 13 Number of hops vs PDR

Fig.13 indicates that with the increase in number of hopes, the PDR is slightly decreased. We can also conclude that for stationary stations, it is advice to use high values of ART to achieve a better performance then the lower values of ART. With low values of ART, the stations have to rediscover the route more frequent in a given time which causes a delay (Fig.12) that has a small but obvious effect on PDR.

From both simulations we can summarize that the ART values in AODV could help in reducing the end-to-end delay but not the PDR in case of non mobility.

7 Conclusion and future work

At the default value of ART parameters, the PDR values were very low especially at high station movement speeds. That is because of slow adaptation to the new station's positions as a result of the rapid movement. The effect of changing ART parameters for AODV was very apparent from the simulated results. The speed increase affected the PDR for all the simulation scenarios. Reducing the ART values resulted in a better network performance especially for higher speed values. The increased number of stations didn't achieve the expected results. That is because it is difficult to realize and measure the number of connections for a selected section in the network.

The second simulated model illustrated the delay increment with the increase in number of hops. ART values affected the end-to-end Delay. On the other hand, this delay didn't seam to affect the PDR values significantly as observed from the second scenario. As a conclusion for the second simulated model, for time-sensitive applications, it is recommended to use low ART values in a multi-hop wireless network to reduce the end-to-end delay. For high throughput requirement applications, high ART values is preferred to perform better in case of non mobile nodes.

As for future work, other metrics such as SNR will be investigated with the change in ART parameter. The effect of increasing number of stations will also be examined with greater details. Other routing protocols will be simulated such as the Optimized Link State Routing protocol (OLSR) OLSR.

8 Acknowledgment

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