Sensitivity Analysis of EADARP Multicast Protocol

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Abstract

Energy Adaptable Distance Aware Routing Protocol (EADARP) designed for wireless mobile ad hoc networks. EADARP is on-demand mesh-based multicast protocol, depends on choosing the most efficient path in terms of distance and energy and makes some adjustments of nodes batteries power levels when required. It is convenient for networks having high channel capacity mobile hosts, frequent topology changes and constrained power. In this paper, we propose and apply a simulation methodology to perform sensitivity analysis for protocol performance due to changes in network parameters. Eighteen parameters are considered allowing to assess the impact of the changes in such parameters on the performance of the protocol. The results of application are analyzed and evaluated.

Keywords: *Wireless Ad hoc networks, EADARP protocol, Sensitivity analysis, Multicast Network Parameters.*

1. Introduction

Wireless communication use diverse communication techniques, and has two types; fixed or mobile, depending on the network structure. The fixed wireless communication is often called cellular networks, in which communication is achieved through a fixed number of base stations whose locations are known. Mobile wireless communication; also called mobile ad hoc networks[1 -3]; does not have a fixed infrastructure or centralized administration. Each host in the mobile ad hoc network communicates with the other hosts via packet radios to form a temporary network its infrastructure varies according to the hosts' mobility.

Wireless ad hoc networks have several different applications ranging from military applications such as: battlefield communications, law enforcement, disaster recovery, emergency search and rescue and lately to civilian applications such as; electronic classrooms, convention centers, construction sites, and special events.

The objectives of the applications is to determine if a communication session should be unicast (one-to-one), multicast (one-to-many), broadcast (one-to-all) or group communication (many-to-many). The rise in the number of mobile users has led to a wide variety of applications to become available. Some of these new applications depend on multicast communication to perform their operation. Multicasting has been implemented to the wireless ad hoc networks to make benefit from the dynamically reconfigurable nature of these wireless ad hoc networks and to adapt to topological changes in the network.

Multicast ad hoc networks [4 -10] are more complex than cellular wireless networks where all mobiles in a cell can be reached in a single hop, not like multicast mobile ad hoc networks where routes are "multihop". Multicast ad hoc networks are semantically identical to wired networks, but have a number of different characteristics and constraints such as: limited power, limited bandwidth, and high error rates. Multicast ad hoc networks is the focus in this paper. Multicast protocols are divided according to their network structure and formation to three main types; Tree-based multicast protocols, Mesh-based multicast protocols and Overlay multicast protocols.

In this paper, we gave a detailed analysis of the performance of the proposed ad hoc multicast EADARP[13,14] protocol, which is a mesh-based protocol employing the forwarding group concept, when the network parameters mentioned in the simulation environment section are varied, and the results obtained were analyzed.

The remainder of this paper is organized as follows. Section 2 gives a general description of the proposed technique (EADARP). Section 3 describes the simulation environment. In Section 4, the simulation experimental results are investigated and analyzed. Finally, Section 5 gives conclusions for this paper.

2. EADARP General Description

2.1 The EADARP protocol mesh creation

Group membership and multicast routes are established and updated by the source "on demand", a request phase and a reply phase comprise the protocol as shown in figure 1, while a multicast source has packets to send, it floods a member advertising packet with data payload piggybacked. This packet, called JOIN QUERY, is periodically broadcasted to the entire network to refresh the membership information and update the routes. Once, the JOIN QUERY packet reaches a multicast receiver, the receiver creates and broadcasts a JOIN REPLY to its neighbors. The JOIN REPLY is thus propagated by each forwarding group member until it reaches the multicast source via the route selection method.

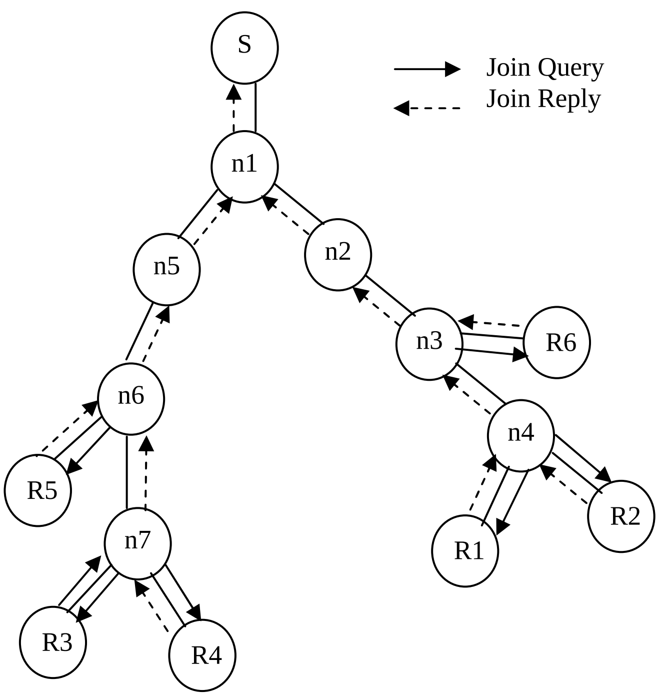


Fig. 1 On-demand procedure for membership and maintenance.

2.2 The EADARP protocol operation

In EADARP route selection, a multicast receiver selects the most stable route having the largest remaining energy, in other words, selecting the route with the highest lifetime. We find the route having the highest lifetime by measuring each route's nodes lifetimes, and choosing the node with the least lifetime in each route, and then selecting the route having the node with the highest lifetime among the least energy remaining nodes.

Then eliminate the nodes having energy below the level required (energy threshold level) in the selected route, for the purpose of avoiding route breakage if these nodes fail. But the eliminated nodes do not include neither the source node nor the destination node, to preserve the original route. After that, some nodes are eliminated between the source node and the destination node to make the selected route shorter, in other terms, reducing the path length leads to decreasing the power consumption during the transmission.

Then, EADARP performs adjustments of nodes batteries power levels when required, and also it increases the network bandwidth when there is a congestion in traffic and decreases it when there is no traffic. To select a route, a multicast receiver must wait for an appropriate amount of time after receiving the first JOIN QUERY so that all possible routes and their lifetimes will be known. The receiver then chooses the most stable route and broadcasts a JOIN REPLY.

3. Simulation Environment

We are going to describe the simulation environment in which we simulated the multicast protocols, and compared their results to conclude the properties of each protocol.

3.1 Simulation model Description

For evaluating EADARP and other multicast routing protocols, a simulation environment was implemented within the GloMoSim library [11]. The GloMoSim library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation capability provided by PARSEC [12]. The simulation is based on modeling a network of 30 mobile hosts placed uniformly within a 1000 m×1000 m area. Radio transmission power of 15 dBm was used for each node during experiments. The used channel capacity is 10 Mbps when comparing the protocols with each others. Each simulation between any 2 nodes is executed for 100 sec of simulation time. The network traffic load used was 1500 packets/sec.

3.2 Traffic pattern

To study the impact of data traffic load on multicast protocols, the traffic loads were used varied on the network. The network traffic load is

1500 packets/sec. A traffic generator was developed to simulate constant bit rate (CBR) sources. The size of the data payload (packet) was 2048 bytes when comparing the protocols with each others. We have 3 multicast source nodes, and each source node transmits to 3 receiver nodes, then, we have 9 receivers during the simulation.

3.3 Mobility Model

For simulation, the random-waypoint model was used for mobility, so there are some packets dropped due to nodes' mobility which stands at 10 m/sec in maximum, unlike the cases when no mobility is used, the packet drops are only caused by buffer overflow, collision and congestion. With mobility random-waypoint pause of 30 sec, and the mobility random-waypoint minimum speed stands at 0 m/sec; the nodes' placement during their mobility is uniform.

3.4 Network parameters used during the simulation

The constant network parameters used during the simulation are:

Simulation-Time: 150 seconds
Seed: 1
Terrain-Dimensions: 1000 x 1000 meters
Number-of-Nodes: 30
Node-Placement: Uniform
Mobility: RANDOM_WAYPOINT
Mobility-WP-Pause: 30 seconds
Mobility-WP-Min-Speed: 0 m/sec
Mobility-WP-Max-Speed: 10 m/sec
Mobility-Position-Granularity: 0.5
Propagation-Limit: -95 dBm
Propagation-Pathloss: FREE-SPACE
Noise-Figure: 10
Temperature: 290 Kelvin
Radio-Type: RADIO-ACCNOISE
Radio-Frequency: 2.4e9 hertz
Radio-Bandwidth: 10000000 bits per second
Radio-RX-Type: SNR-BOUNDED
Radio-RX-SNR-Threshold: 10 dB
Radio-TX-Power: 15 dBm
Radio-Antenna-Gain: 2.0 dB
Radio-RX-Sensitivity: -51 dBm
Radio-RX-Threshold: -81 dBm
Mac-Protocol: 802.11
Mac-Propagation-Delay: 1000 Nanoseconds
Promiscuous-Mode: NO
Network-Protocol: IP
Network-Output-Queue-Size-Per-Priority: 100
Red-Min-Queue-Threshold: 150
Red-Max-Queue-Threshold: 200
Red-Max-Marking-Probability: 0.1
Red-Queue-Weight: 0.0001
Red-Typical-Packet-Transmission-Time: 64000 Nanoseconds
App-Jitter: 100 milliseconds

The network parameters that were varied during consequent simulations are:

(1) Number of Nodes
(2) Terrain Dimensions
(3) Radio Transmission Power
(4) Radio Frequency
(5) Temperature
(6) MAC Protocols
(7) Mobility Models
(8) Propagation Models
(9) MAC Propagation Delay
(10) Node Placement
(11) Noise Figure
(12) Radio Antenna Gain
(13) Radio Receiver Type
(14) Radio Receiver SNR Threshold
(15) Radio Type
(16) Propagation Limit
(17) Radio Receiver Sensitivity
(18) Radio Receiver Threshold

3.5 Performance metrics

3.5.1 Error Loss Percentage

Is measured as the ratio between the data packets lost during transmission between the source node and the receiver node and the total number of data packets sent by the source node.

3.5.2 Average Number of Collisions

Is measured as the total number of collisions that occurred during the simulation over the total number of nodes.

3.5.3 Average Number of Control Packets

Is measured as the total number of routing control packets transmitted during the simulation time over the total number of nodes.

3.5.4 Average Power Consumption

Is the average power consumed by the system, and is measured as the sum of the power consumed at each node at the radio channel during the simulation time over the total number of nodes.

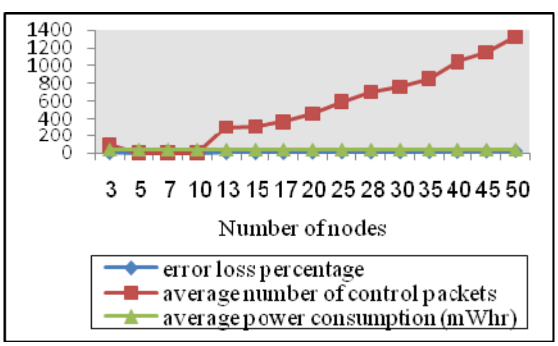
4. Simulation Experimental Results

We simulated the proposed mesh-based EADARP protocol, and the protocol was tested under some conditions, and the results obtained were compared and evaluated to see its performance.

4.1 Performance of EADARP protocol

4.1.1 Changing Number of Nodes

As it appears from figures 2, 3, the error loss percentage varies when changing the number of nodes. The error loss percentage increases when increasing the number of nodes using the EADARP protocol, when the number of nodes is 20 till 50, the error loss percentage of the EADARP protocol is higher in this range. And, when the number of nodes is 3 to 10, the EADARP has lower error loss percentage. Also, the average number of collisions varies when changing the number of nodes. The average number of collisions increases when the number of nodes increases for the EADARP protocol. And, the average number of collisions of the EADARP protocol is at its highest at 50 nodes.
Also, the average number of control packets varies when changing the number of nodes. The average number of control packets increases gradually, not in constant rate, when increasing the number of nodes using the EADARP protocol. Also, the average power consumption varies a little bit when changing the number of nodes. And the average power consumption of the EADARP protocol, measured in mWhr, is at its lowest between 5 and 10 nodes. And these results stem from the nature of the protocol, and that the number of nodes affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



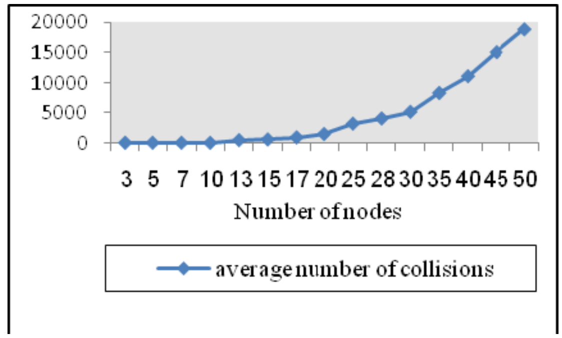
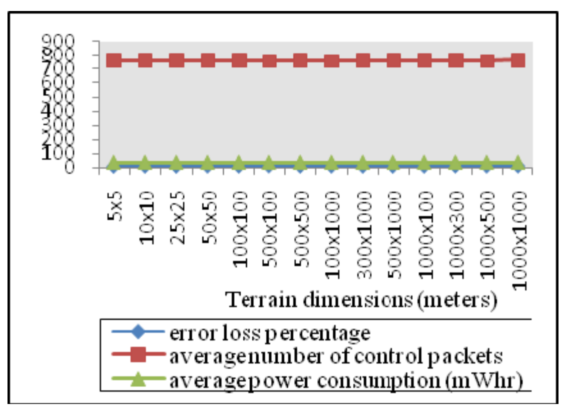


Fig. 2,3 Effect of number of nodes.

4.1.2 Changing Terrain Dimensions

As it appears from figures 4, 5, the error loss percentage does not vary too much when increasing the Terrain Dimensions from 5x5 meters to 1000x1000 meters. Also, the average number of collisions varies with a little margin of values when changing the Terrain Dimensions. Also, the average number of collisions increases gradually, not in constant rate, with a little margin of values, in the case of the EADARP protocol. Also, the average number of control packets does not vary when increasing the Terrain Dimensions from 5x5 meters to 1000x1000 meters. Also, the average power consumption does not vary when increasing the Terrain Dimensions from 5x5 meters to 1000x1000 meters. And these results stem from the nature of the protocol, and that the Terrain Dimensions affects a little bit the protocol operation, hence, has a little effect on the performance metrics; error loss performance, average number of collisions, average number of control packets, average power consumption.



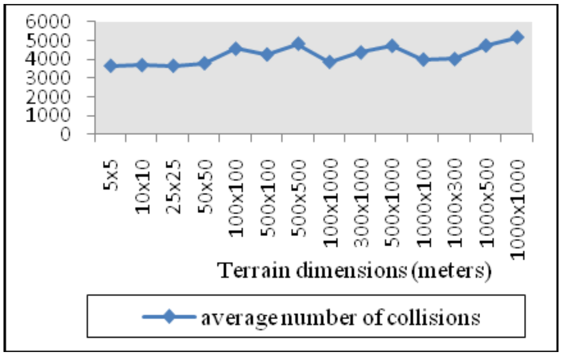


Fig. 4, 5 Effect of Terrain Dimensions.

4.1.3 Changing Radio-TX-Power

As it appears from figures 6, 7, the error loss percentage decreases when increasing the Radio-Tx-Power, measured in dBm. The protocol makes an error loss percentage around 100 % when the Radio-Tx-Power is between -30 dBm and 0 dBm, and, the error loss percentage continues to decrease until the Radio-Tx-Power reaches 30 dBm. The EADARP protocol has an error loss percentage standing between 97% to 11%, when the Radio-Tx-Power is in the range of 1 dBm to 30 dBm, during changing the values of the Radio-Tx-Power. Also, the average number of collisions increases gradually hen increasing the Radio-Tx-Power, then decreases again. The graph below shows that the protocol has a very little constant average number of collisions between -30 dBm and 0 dBm, the average number of collisions continues to increase from 1 dBm till 12 dBm, then, decreases from 12 dBm to 30 dBm. Also, the average number of control packets increases when increasing the Radio-Tx-Power, measured in dBm, using the EADARP protocol, when the range of a Radio-Tx-Power is from 1 dBm to 30 dBm. Also, the average power consumption, measured in mWhr, does not vary too much when increasing the Radio-Tx-Power, in other words, the average power consumption of the protocol, stays constant between -30 dBm and 20 dBm, standing around 38 mWhr, and increases a little bit between 20 dBm and 30 dBm. And these results stem from the nature of the protocol, and that the Radio-Tx-Power affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

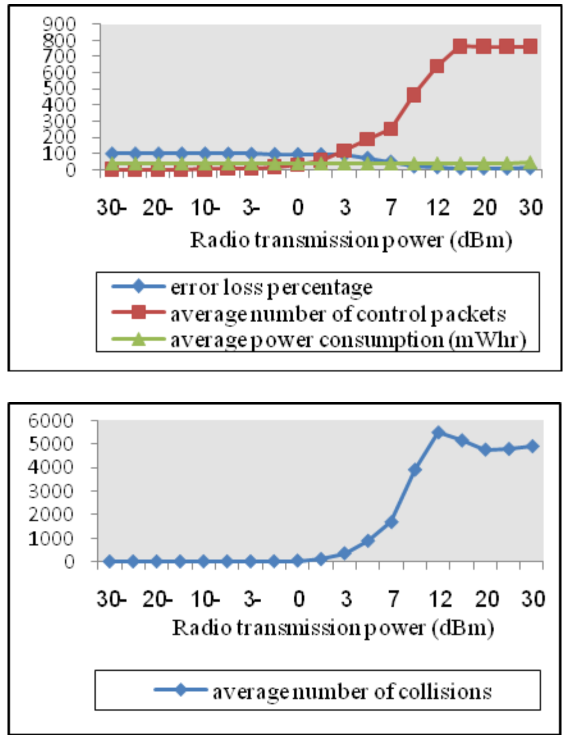
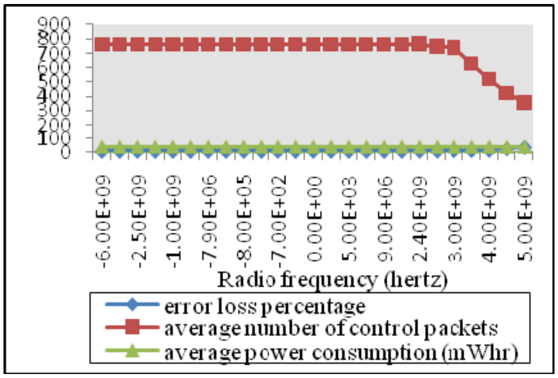


Fig. 6, 7 Effect of Radio-Tx-Power.

4.1.4 Changing Radio Frequency

As it appears from figures 8, 9, the error loss percentage does not vary too much when increasing the Radio Frequency, measured in hertz, in other words, the error loss percentage stays constant from radio frequency -6e9 hertz to radio frequency 9e6 hertz, and increases when the radio frequency becomes 2.4 e9 till the end of the graph. Also, the average number of collisions does not vary too much when increasing the Radio Frequency, measured in hertz, in other words, the average number of collisions stays constant from -6e9 hertz frequency till 5e3 hertz frequency, and then, begin to vary down then up gradually till the end of the graph, using the EADARP protocol. Also, the average number of control packets does not vary too much when increasing the Radio Frequency, measured in hertz. Since the Radio Frequency stays the same from the beginning of the graph till 3e9 hertz, then it decreases gradually till the end of the graph. Also, the average power consumption does not vary when increasing the Radio Frequency, measured in hertz, the Radio Frequency, in other words, when using the EADARP protocol, it stays constant from the beginning of the graph from -6e9 hertz radio frequency to 3e9 hertz, then, it decreases till reaching the end of the graph. And these results stem from the nature of the protocol, and that the Radio Frequency does not affect too much the protocol operation, hence, has a moderate effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



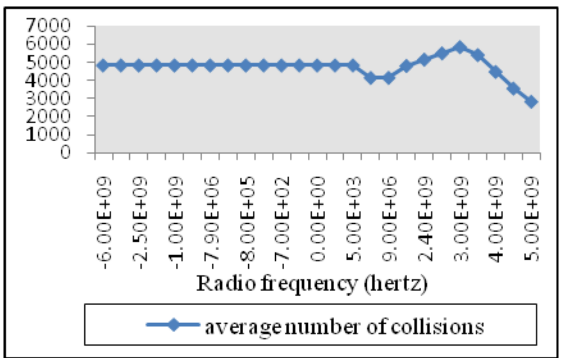
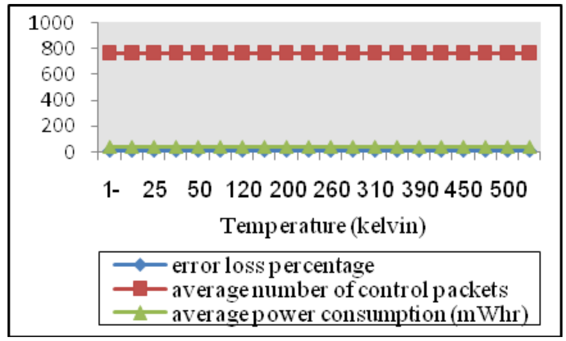


Fig. 8,9 Effect of Radio Frequency.

4.1.5 Changing Temperature

As it appears from figures 10, 11, the error loss percentage does not vary when increasing the values of the Temperature from 0 Kelvin to above 500 Kelvin. The error loss percentage of the EADARP protocol is standing around 11%. Also, the average number of collisions does not vary when increasing the values of the Temperature from 0 Kelvin to above 500 Kelvin. The average number of collisions of the EADARP protocol is standing at 5100. Also, the average number of control packets does not vary when increasing the values of the Temperature from 0 Kelvin to above 500 Kelvin. The average number of control packets of the EADARP protocol is standing at 790. Also, the average power consumption does not vary when increasing the values of the Temperature from 0 Kelvin to above 500 Kelvin. And these results stem from the nature of the protocol, and that the Temperature does not affect the protocol operation, hence, has no effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



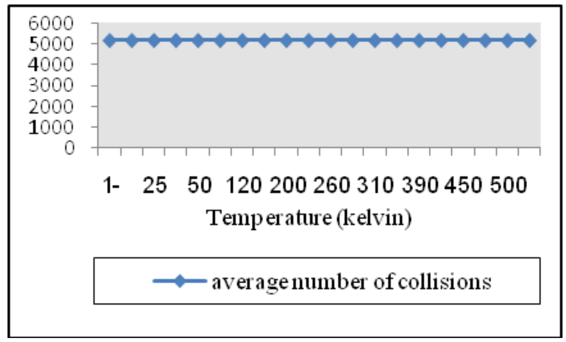


Fig. 10, 11 Effect of Temperature.

4.1.6 Changing MAC Protocols

As it appears from 12, 13, the error loss percentage varies a little bit when changing the MAC protocols. Also, the average number of collisions varies down and up consecutively when changing the MAC protocols. Also, the average number of control packets varies down and up consecutively when changing the MAC protocols. Also, the average power consumption does not vary too much when changing the MAC protocols.

From the graphs, we notice that the MACA protocol with or without promiscuous mode provides the lowest average number of collisions and the lowest average number of control packets, but keeps at the same time, the same error loss percentage and the same average power consumption, compared to other protocols; 802.11 and CSMA protocols. And these results stem from the nature of the protocol, and that the MAC protocol affects the protocol operation, hence, has a moderate effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

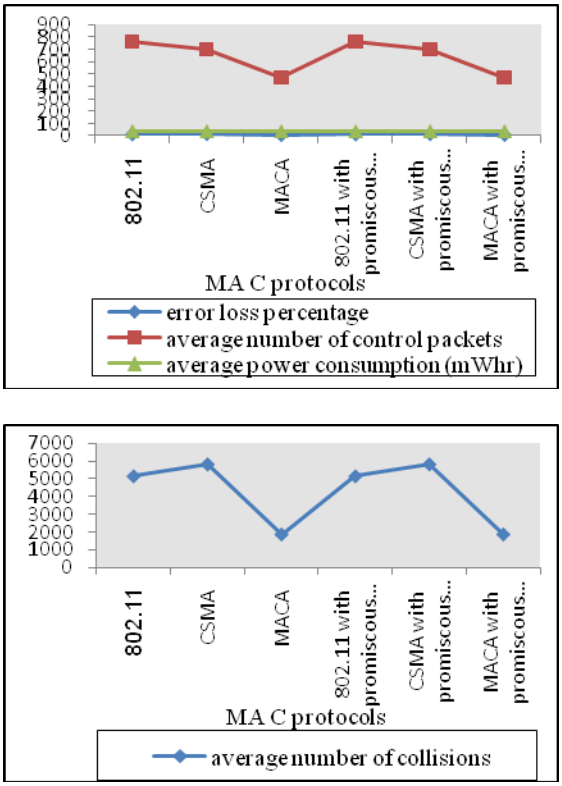


Fig. 12, 13 Effect of MAC Protocols.

4.1.7 Changing Mobility Models

As it appears from figures 14, 15, the error loss percentage does not vary too much when changing mobility models from NONE to RANDOM_WAYPOINT, and stays at 11% for both mobility models. Also, the average number of collisions decreases from 5800 to 5100 when changing the mobility model from NONE to RANDOM_WAYPOINT. Also, the average number of control packets increases from 650 to 800 when changing the mobility model from NONE to RANDOM_WAYPOINT. Also, the average power consumption, measured in mWhr, does not vary too much when changing the mobility model from NONE to RANDOM_WAYPOINT, except with a very small parts of fractions. And these results stem from the nature of the protocol, and that the mobility model does not affect too much the protocol operation, hence, has no big effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

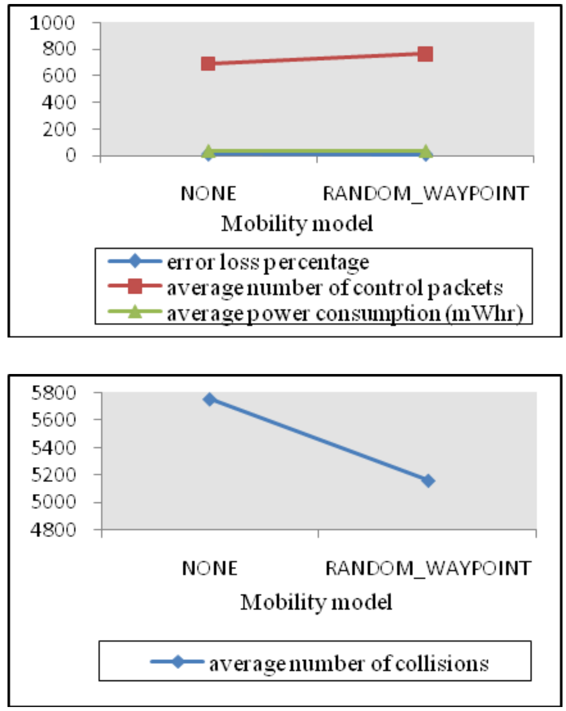


Fig. 14, 15 Effect of Mobility Models.

4.1.8 Changing Propagation Models

As it appears from figures 16,17, the error loss percentage varies a little bit when changing the propagation model from FREE_SPACE to TWO_RAY. Also, the average number of collisions decreases from 5100 to 2200 when changing the propagation model from FREE_SPACE to TWO_RAY. Also, the average number of control packets decreases from 790 to 400 when changing the propagation model from FREE_SPACE to TWO_RAY. Also, the average power consumption, measured in mWhr, does not vary too much when changing the propagation model from FREE_SPACE to TWO_RAY. And these results stem from the nature of the protocol, and that the propagation model affects the protocols operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

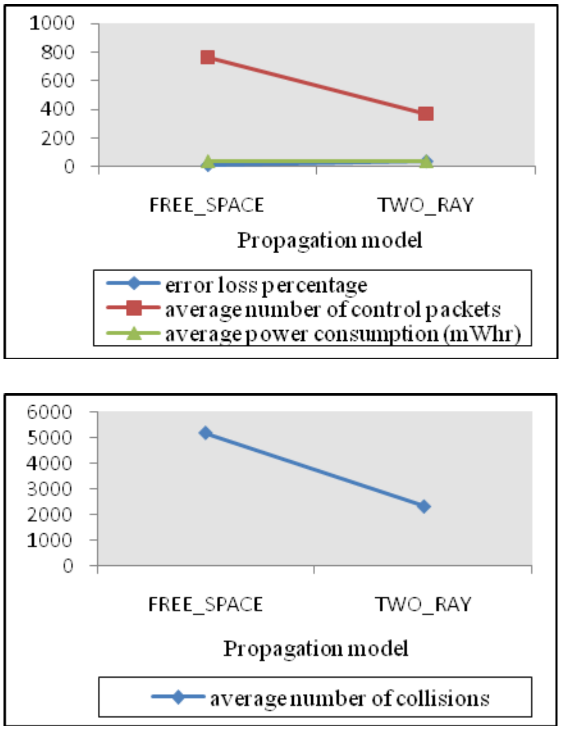


Fig. 16, 17 Effect of Propagation Models.

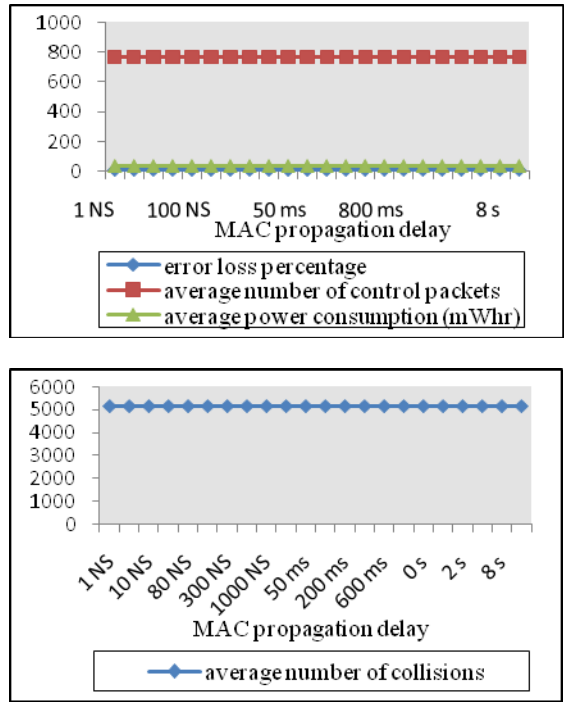


Fig. 18, 19 Effect of MAC Propagation Delay.

4.1.9 Changing MAC Propagation Delay

As it appears from figures 18, 19, the error loss percentage does not vary when changing the MAC propagation delay from 1 Nanoseconds to 8 seconds. The EADARP protocol error loss percentage is at 11% along the graph. Also, the average number of collisions does not vary when changing the MAC propagation delay. The average number of collisions of the EADARP protocol is at 5100 along the graph. Also, the average number of control packets does not vary when changing the MAC propagation delay from 1 Nanoseconds to 8 seconds. The average number of control packets of the EADARP protocol is 790 along the graph. Also, the average power consumption, measured in mWhr, does not vary when changing the MAC propagation delay from 1 Nanoseconds to 8 seconds. The average power consumption of the EADARP protocol is 37.7 mWhr along the graph.
And these results stem from the nature of the protocol, and that the MAC propagation delay does not affect the protocol operation, hence, has no effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

4.1.10 Changing Node Placement

As it appears from figures 20, 21, the error loss percentage does not vary when changing the Node placement method from: Random with NONE Mobility, Random with RANDOM_WAYPOINT, Uniform with NONE Mobility, Uniform with RANDOM_WAYPOINT. Also, the average number of collisions varies when changing the Node placement method from: Random with NONE Mobility, Random with RANDOM_WAYPOINT, Uniform with NONE Mobility, Uniform with RANDOM_WAYPOINT. The EADARP protocol shows higher average number of collisions at node placement methods: Random with NONE Mobility and Uniform with NONE Mobility. Also, the average number of control packets varies when changing the Node placement method from: Random with NONE Mobility, Random with RANDOM_WAYPOINT, Uniform with NONE Mobility, Uniform with RANDOM_WAYPOINT. The average power consumption of the EADARP protocol is a little lower using the Random with NONE Mobility and the Uniform with NONE Mobility node placement methods. Also, the average power consumption, measured in mWhr, does not vary when changing the Node placement method from: Random with NONE Mobility, Random with RANDOM_WAYPOINT, Uniform with NONE

Mobility, Uniform with RANDOM_WAYPOINT. The average power consumed of the EADARP protocol is standing at 37.7 mWhr. And these results stem from the nature of the protocol, and that the Node placement method does not affect too much the protocol operation, hence, has a moderate effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

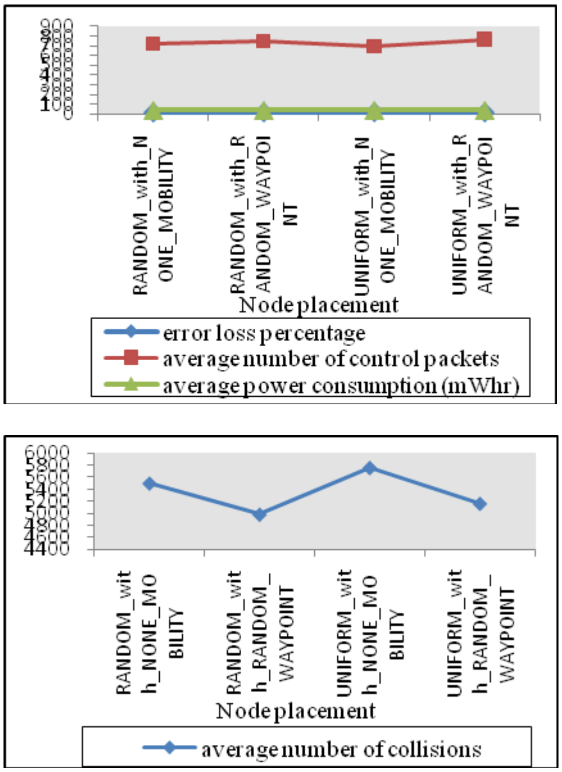


Fig. 20, 21 Effect of Node Placement.

-200 to 20. The number of control packets of the EADARP protocol is 790 along the graph. Also, the average power consumption does not vary when increasing the Noise Figure from -200 to 20. The average power consumed of the EADARP protocol is at 37.7 mWhr. And these results stem from the nature of the protocol, and that the Noise Figure does not affect too much the protocol operation, hence, has a small effect in general on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

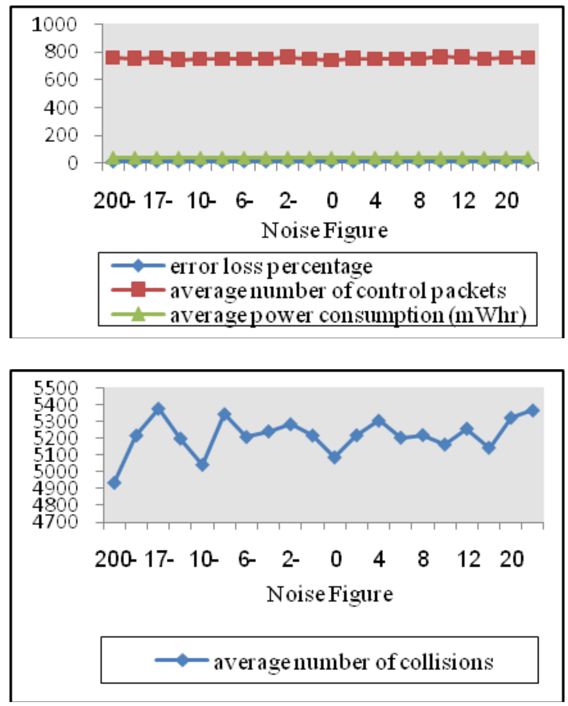


Fig. 22, 23 Effect of Noise Figure.

4.1.11 Changing Noise Figure

As it appears from figures 22, 23, the error loss percentage does not vary too much when increasing the Noise Figure from -200 to 20, in other words, the EADARP protocol has a changeable error loss percentage with a little margin of values. The error loss percentage of the EADARP protocol is varying between 10.5% and 12%. Also, the average number of collisions varies when increasing the Noise Figure from -200 to 20 along the graph. The average number of collisions of the EADARP protocol increases and decreases consecutively till reaching the end of the graph. Also, the average number of control packets does not vary when increasing the Noise Figure from

4.1.12 Changing Radio Antenna Gain

As it appears from figures 24,25, the error loss percentage of the EADARP protocol decreases from 100% to below 12% when increasing the Radio Antenna Gain from -20 db to 0.1 db and stays constant at 11% till reaching the end of the graph. Also, the average number of collisions increases at a Radio Antenna Gain of -4 db, then decreases at a Radio Antenna Gain of 1.8 db before reaching the end of the graph when increasing the Radio Antenna Gain from -20 db to 15 db. Also, the average number of control packets varies when increasing the Radio Antenna Gain from -20 db to 15 db, in other words, the Radio Antenna Gain of the EADARP protocol increases from a Radio Antenna Gain of -4 db to 1.8 db, and stays constant from a Radio Antenna Gain of 2.5 db till the end of the graph. Also, the average power consumption, measured in mWhr, does not vary when increasing the Radio Antenna Gain from -20 db to 15 db. And these results stem from the nature of the protocol, and that the Radio Antenna Gain affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

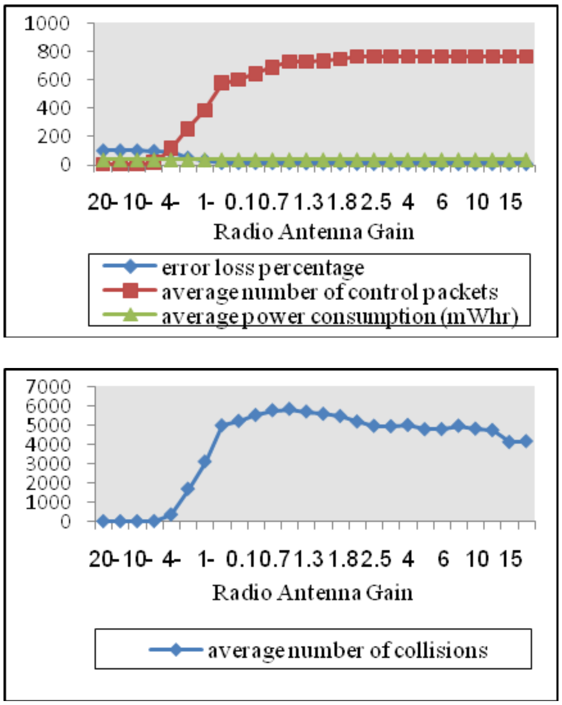


Fig. 24, 25 Effect of Radio Antenna Gain.

4.1.13 Changing Radio-RX-Type

As it appears from figures 26, 27, the error loss percentage decreases a little bit when changing the Radio-RX-Type from BER_BASED to SNR_BOUND using the EADARP protocol. The error loss percentage of the EADARP protocol is ranging from 14% to 11% consecutively. Also, the average number of collisions increases when changing the Radio-RX-Type from BER_BASED to SNR_BOUND using the EADARP protocol. When using the BER_BASED Radio-RX-Type, the EADARP protocol has an average number of collisions equal to zero. When using the SNR_BOUND Radio-RX-Type, the average number of collisions of the EADARP protocol is 5300. Also, the average number of control packets does not vary when changing the Radio-RX-Type from BER_BASED to SNR_BOUND. The average number of control packets of the EADARP protocol stands at 800 for both cases. Also, the average power consumption, measured in mWhr, does not vary when changing the Radio-RX-Type from BER_BASED to SNR_BOUND. The average power consumed of the EADARP protocol is standing at 37.7 mWhr. And these results stem from the nature of the protocol, and that the Radio-RX-Type affects a little the protocol operation, hence, has a small effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.

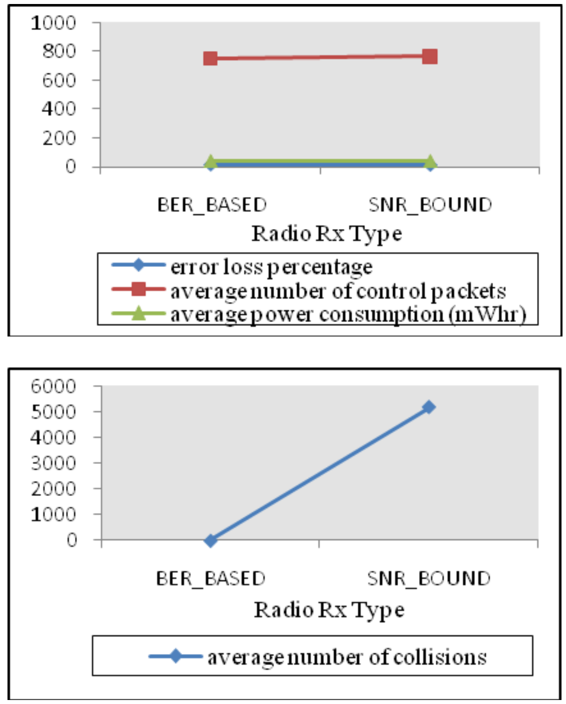
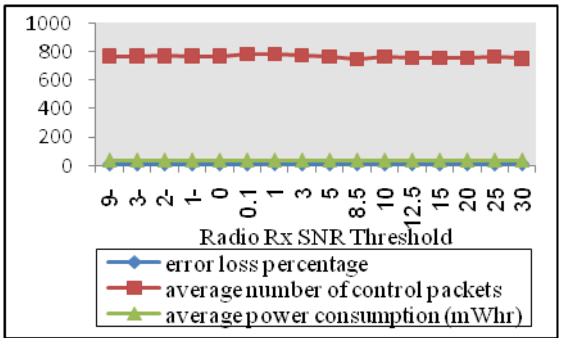


Fig. 26, 27 Effect of Radio-RX-Type.

4.1.14 Changing Radio-RX-SNR-Threshold

As it appears from figures 28, 29, the error loss percentage varies with small fractions when increasing the Radio-RX-SNR-Threshold from -9 dB to 30 dB. Also, the average number of collisions increases when increasing the Radio-RX-SNR-Threshold from -9 dB to 30 dB. When the Radio-RX-SNR-Threshold is from -9 dB to 0.1 dB, the average number of collisions is equal to 1000. When the Radio-RX-SNR-Threshold is from 0.1 dB till 30 dB, the average number of collisions increases gradually till the end of the graph. Also, the average number of control packets does not vary when increasing the Radio-RX-SNR-Threshold from -9 dB to 30 dB, and is staying at

790. Also, the average power consumption, measured in mWhr, does not vary when increasing the Radio-RX-SNR-Threshold from -9 dB to 30 dB. And these results stem from the nature of the protocol, and that the Radio-RX-SNR-Threshold affects a little the protocol operation, hence, has a small effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



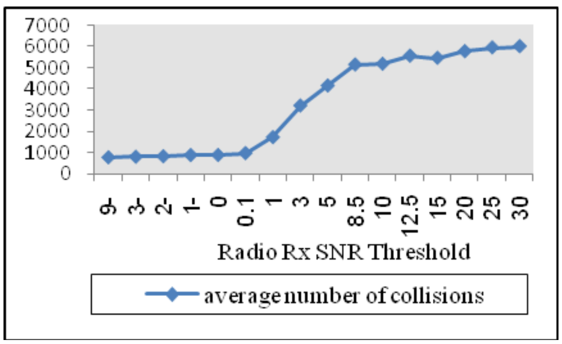
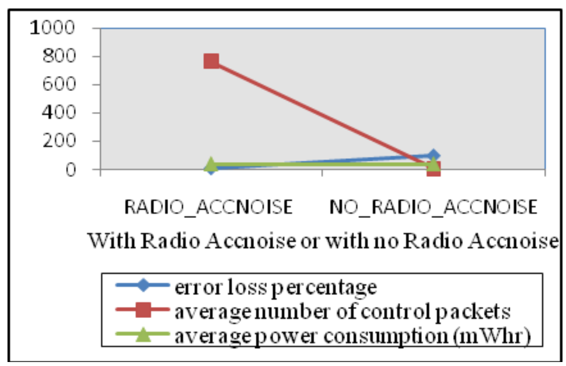


Figure 28, 29: Effect of Radio-RX-SNR-Threshold.

4.1.15 Changing Radio Type

As it appears from figures 30, 31, the error loss percentages of the EADARP protocol increases from below 12% to 100%, when changing the Radio Type from RADIO_ACCNOISE to NO_RADIO_ACCNOISE. Using the NO_RADIO_ACCNOISE Radio Type, the EADARP protocol has an error loss percentage of 100%. When using the RADIO_ACCNOISE Radio Type, the error loss percentage of the EADARP protocol, is standing at 11%. Also, the average number of collisions of the EADARP protocol decreases to 0 when changing the Radio Type from RADIO_ACCNOISE to NO_RADIO_ACCNOISE. Using the NO_RADIO_ACCNOISE Radio Type, the EADARP protocol has an average number of collisions of 0. When using the RADIO_ACCNOISE Radio Type, the average number of collisions of the EADARP protocol is 5000. Also, the average number of control packets of the EADARP protocol varies when changing the Radio Type from NO_RADIO_ACCNOISE to RADIO_ACCNOISE. Using the NO_RADIO_ACCNOISE Radio Type, the EADARP protocol has an average number of control packets equal to 0. Using the RADIO_ACCNOISE Radio Type, the average number of control packets of the EADARP protocol is 800. Also, the average power consumption of the EADARP protocol does not vary when changing the Radio Type from RADIO_ACCNOISE to NO_RADIO_ACCNOISE. Using the NO_RADIO_ACCNOISE Radio Type, the EADARP protocol has an average power consumption, equal to 37.5 mWhr. When the RADIO_ACCNOISE Radio Type is used, the average power consumption of the EADARP protocol is the same. And these results stem from the nature of the protocol, and that the Radio Type affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



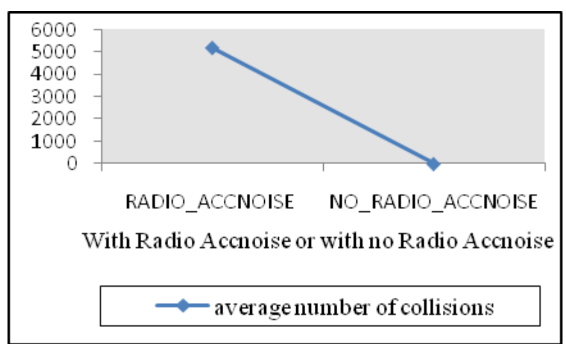
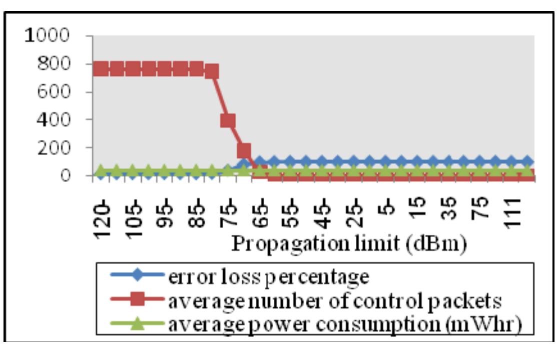


Fig. 30, 31 Effect of Radio Type.

4.1.16 Changing the Propagation Limit

As it appears from figures 32, 33, the error loss percentage increases when increasing the Propagation Limit from -120 dBm to 111 dBm. When the Propagation Limit is between -120 dBm and -80 dBm, the error loss percentage of the EADARP protocol is standing at 11%. When the Propagation Limit is between -80 dBm to -65 dBm, the EADARP protocol increases its error loss percentages to 100%, and from -65 dBm till reaching the end of the graph, the protocol keeps its error loss percentages at 100%. Also, the average number of collisions decreases when increasing the Propagation Limit from -120 dBm to 111 dBm. When the Propagation Limit is between -120 dBm to -80 dBm, the average number of collisions of the EADARP protocol is around 5000. When the Propagation Limit is between -80 dBm and -65 dBm, the average number of collisions decreases from around 5000 to 0. The EADARP protocol has an average number of collisions equal to 0, when the Propagation Limit is -65 dBm till the end of the graph. Also, the average number of control packets of the EADARP protocol is constant and equal to 0, when increasing the Propagation Limit from -65 dBm to 111 dBm. Taking the range when the Propagation Limit is between -120 dBm to -80 dBm, the EADARP protocol has an average number of control packets equal to 800. When the Propagation Limit is between -80 dBm and -65 dBm, the average number of control packets decreases from 800 to 0. Also, the average power consumption, measured in mWhr, of the EADARP protocol decreases from a higher power to a power of 37.5 mWhr between a Propagation Limit of -65 dBm till reaching the end of the graph, when increasing the Propagation Limit from -120 dBm to 111 dBm. And these results stem from the nature of the protocol, and that the Propagation Limit affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



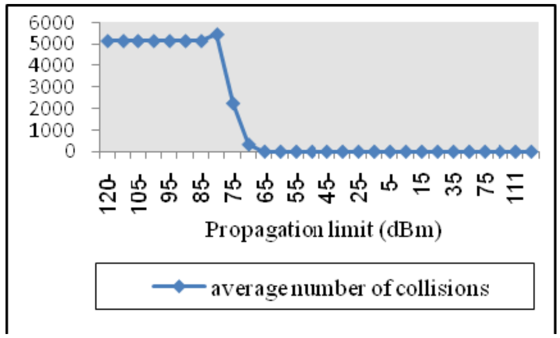
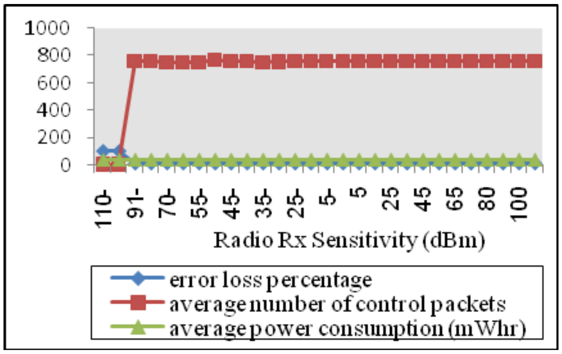


Fig. 32, 33 Effect of Propagation Limit.

4.1.17 Changing the Radio-RX-Sensitivity

As it appears from figures 34, 35, the error loss percentage varies when increasing the Radio-RX-Sensitivity from -110 dBm to 100 dBm. When the Radio-RX-Sensitivity is between -110 dBm to -91 dBm, the EADARP protocol decreases its error loss percentages from 100% to below 12%. But when the Radio-RX-Sensitivity is between -91 dBm till reaching 100 dBm, the error loss percentage of the EADARP protocol is 11%. Also, the average numbers of collisions of the EADARP protocol increases when increasing the Radio-RX-Sensitivity from -110 dBm to 100 dBm. When the Radio-RX-Sensitivity is between -110 dBm to -100 dBm, the EADARP protocol has an average number of collisions of 0. But when the Radio-RX-Sensitivity is between -100 dBm to -70 dBm, the average number of collisions of the EADARP protocol increases from 0 to 5300. When the Radio-RX-Sensitivity is between -70 dBm till 100 dBm, the EADARP protocol keeps its average number of collisions at 5300. Also, the average number of control packets of the EADARP protocol varies along the graph. When the Radio-RX-Sensitivity is between -110 dBm to -100 dBm, the EADARP protocol has an average number of control packets equal to 0. When the Radio-RX-Sensitivity is between -100 dBm to -91 dBm, the EADARP protocol increases its average number of control packets from 0 to 800. When the Radio-RX-Sensitivity is from -91 dBm till 100 dBm, the average number of control packets of the EADARP protocol is equal to 800. Also, the average power consumption of the EADARP protocol increases at -100 dBm from a power of 37.5 mWhr to a higher power when increasing the Radio-RX-Sensitivity from -110 dBm to 100 dBm. And these results stem from the nature of the protocol, and that the Radio-RX-Sensitivity affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



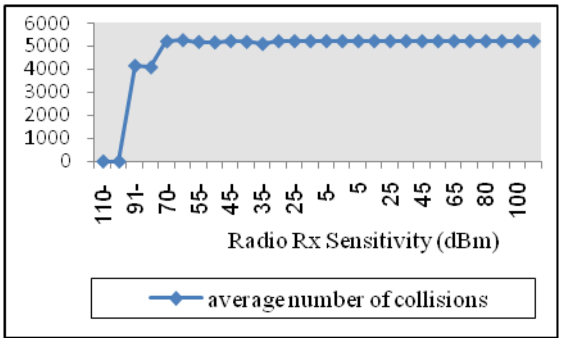
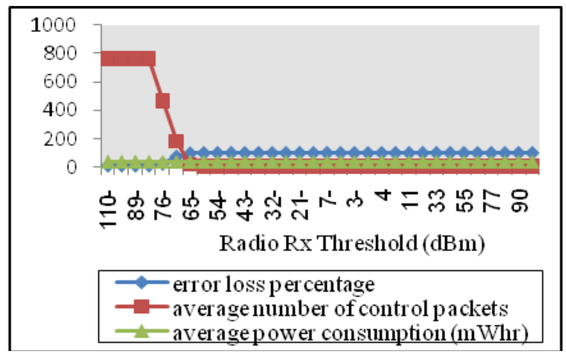


Fig. 34, 35 Effect of Radio-Rx-Sensitivity.

4.1.18 Changing the Radio-RX-Threshold

As it appears from figures 36, 37, the error loss percentage of the EADARP protocol increases from below 12% to 100% when increasing the Radio-RX-Threshold from -110 dBm to 90 dBm. When the Radio-RX-Threshold is between -110 dBm to -76 dBm, the error loss percentage of the EADARP protocol is standing at 11%. When the Radio-RX-Threshold is between -76 dBm to -65 dBm, the EADARP protocol increases its error loss percentage to 100% and this error loss percentage stays constant till the end of the graph. Also, the average number of collisions of the EADARP protocol decreases from higher average number of collisions to 0 at a Radio-RX-Threshold of -65 dBm, when increasing the Radio-RX-Threshold from -110 dBm to 90 dBm. When the Radio-RX-Threshold is between -65 dBm to 90 dBm, the EADARP protocol has an average number of collisions equal to 0. Also, the average number of control packets of the EADARP protocol stays equal to 0, when increasing the Radio-RX-Threshold from -65 dBm to 90 dBm. When the Radio-RX-Threshold is between -65 dBm to -89 dBm, the average number of control packets of the EADARP protocol increases from 0 to 800. When the Radio-RX-Threshold is between -89 dBm to -110 dBm, the EADARP protocol has an average number of control packets equal to 800. Also, the average power consumption, measured in mWhr, of the EADARP protocol decreases from a higher power to a power of 37.5 mWhr at a Radio-RX-Threshold of -60 dBm, when increasing the Radio-RX-Threshold from -110 dBm to -60 dBm. When the Radio-RX-Threshold is between -60 dBm to 90 dBm, the EADARP protocol keeps the same average power consumption, standing at 37.5 mWhr. And these results stem from the nature of the protocol, and that the Radio-RX-Threshold affects the protocol operation, hence, has an effect on the performance metrics; error loss percentage, average number of collisions, average number of control packets, average power consumption.



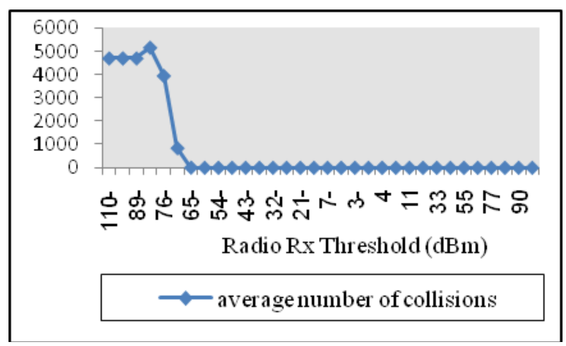


Fig. 36, 37 Effect of Radio-Rx-Threshold.

5. Conclusions

In [13,14], the EADARP protocol for multicast wireless ad hoc networks was proposed. EADARP provides multiple paths by the formation of mesh configuration making the protocol robust to mobility. Alternate routes secure data delivery when there is mobility and link breaks while the primary route is being reconstructed. The key properties of EADARP are; simplicity, low channel and storage overhead, usage of up-to-date shortest routes, reliable construction of routes and forwarding group, robustness to host mobility, maintenance and utilization of multiple paths.

In this paper, we continued to investigate and study sensitivity of the performance of the protocol due the effect of changing the network parameters, Eighteen parameters are considered allowing to assess the impact of the changes in such parameters on the performance of the protocol and analyzing the results obtained from the simulation, to give conclusions.

From the results obtained, the parameters that does not affect the EADARP protocol operation are the following: Temperature, MAC propagation delay.
The parameters that have a very limited effect in some cases on the performance of the EADARP protocol performance, are: Terrain Dimensions, MAC Propagation Delay, Noise Figure.

The performance of the EADARP protocol enhances in general when increasing the following parameters: RADIO_TX_POWER, Using MACA MAC protocol with or without promiscuous mode is best for the protocol, Using the RANDOM_WAYPOINT is best for the protocol, the FREE_SPACE propagation model is best, the RANDOM_with_NONE_MOBILITY is the best node placement method, Radio Antenna Gain, the BER_BASED Radio_RX_TYPE is better, the RADIO_ACCNOISE is better, Radio-RX-Sensitivity.

The performance of the EADARP protocol deteriorates in general when increasing the following parameters: number of nodes, Radio Frequency, Radio-RX-SNR-Threshold, the Propagation Limit, Radio-RX-Threshold.

There are other remarks that are concluded from the simulation results as follows:

- Using MACA MAC protocol with or without promiscuous mode is better for the protocol.
- UNIFORM_WITH_NONE_MOBILITY is the worst node placement for the protocol.
- Using a RADIO_TX_POWER below 0 dBm, makes the error loss percentage of the protocol, equal to 100%, the average number of collisions equal to 0, and the average number of control packets equal to 0.
- Increasing the Radio Frequency above 2.4e9 hertz, makes the error loss percentage of the protocol increase.
- Increasing the Radio Antenna Gain leads to decreasing the error loss percentage of the protocol.
- Using a NO_ACCNOISE_RADIO leads to an 100% error loss percentage, a zero average number of collisions, a zero average number of control packets, and an average power consumption equal to 37.5 mWhr for the protocol.
- Increasing the Propagation Limit above -65 dBm leads to an 100% error loss percentage, a zero average number of collisions, a zero average number of control packets, and an average power consumption equal to 37.5 mWhr for the protocol.
- Decreasing the Radio-RX-Sensitivity below the -91 dBm makes an 100% error loss percentage, a zero average number of collisions, a zero average number of control packets, and an average power consumption equal to 37.5 mWhr for the protocol.
- Increasing the Radio-RX-Threshold to -65 dBm and above makes an 100% error loss percentage, a zero average number of collisions, a zero average number of control packets, and an average power consumption equal to 37.5 mWhr for the protocol.

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