Optimizing the Performance of MANET with an Enhanced Antenna Positioning System

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Summary

The most important feature of Mobile Ad-hoc Networks is their dynamic behavior. Increasing the number of antennas on a mobile node can result in complex antenna movement. This gives rise to a decrease in the system gain, causes more delay, and further the network throughput may decrease especially when the network load becomes heavy. Since an antenna on a mobile node can result in complex antenna movement, in this paper, Enhanced Antenna Positioning System (EAPS) was used to improve the performance gain. Performance gains were compared between the results obtained when using Isotropic antenna and when using the EAPS through simulations in OPNET. Through these comparisons it can be concluded that using EAPS improves the performance of mobile nodes in the proposed environment. The simulations indicate negligible effects for speeds up to 5 m/s.

Key words:

Mobile Ad Network, Enhanced Antenna Positioning System

1. Introduction

Necessities for high quality links and great requirement for high throughput in Wireless LAN especially Mobile Ad-hoc Network has motivated new enhancements and work in Wireless communications systems. MANET is a system of wireless mobile nodes that can freely and dynamically self-organize in arbitrary and temporary network topologies without the need of a centralized administration. MANET is comprised of mobile devices (e.g. laptop, palmtop, internet mobile phone etc.) that use wireless transmission for communication [1].Conventionally, ad-hoc networks have been known to use Omni-directional antennas for transmission as well as reception. The use of Omni-directional antennas may result in lower power efficiency due to interference caused by the transmission of packets in undesired directions. Use of Smart Antennas in Ad-hoc Networks is envisioned to take advantage of Space Division Multiple Accesses (SDMA) to increase network efficiency by directing the transmitted power in the desired direction [2]. However**,** it is difficult to find ways to set and control the direction of such antenna at each node in order to achieve the expected performance improvement in a Multi-hop communication environment of Mobile Ad-hoc Networks. This difficulty is mainly due to mobility and lack of centralized control. This may lead to hidden terminal problems, deafness and problem of determining a neighbor’s location, resulting in an expected collision, decrease in the system capacity (gain), causes more delay and further the network throughput may decrease significantly [3][4].

Increasing the number of antennas on a mobile node can result in complex antenna movement [5]. This as well decreases the system gain, causes more delay, and further the network throughput may decrease. In such a case the layers are designed to operate under these conditions by allowing nodes to adapt to the changing circumstances [6]. Since an antenna on a mobile node can result in complex antenna movement, in this work, EAPS was developed to improve the performance gain. With the development of EAPS, in this paper, i have proposed to incorporate the use of Isotropic Antenna to see the improvement of Enhanced Antenna Positioning System.

The use of EAPS directs the energy towards a desired direction, thus resulting in an increase in range of packet transmission, effectively decreasing the number of hops in a multi-hop route network.

The rest of the paper is organized as follows, in section 2. we describe the System model. Section 3 provides the simulation model, including Antenna and Network models. The network scenario is also described. Section 4. presents the performance analysis. Finally the paper is concluded in section 5.

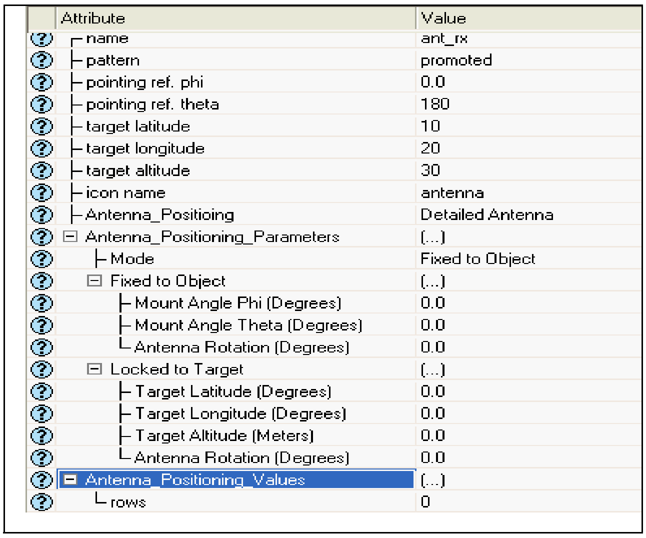
2. System Model

To develop the EAPS model, three-dimensional approach has been used. The information about the location of a node is provided in terms of latitude, longitude and altitude. The position and orientation of an antenna is determined by angle phi and theta. The pointing direction of the antenna was assumed to coincide with the positive z-axis of the antenna gain pattern used as in [5].

3. Simulation Model

OPNET V11.5 was used to build the simulation model. Changes were made on the standard OPNET pipeline stages. There is no interface as all operations are performed using OPNET KPs (Kernel Procedures), this process is called Baseline Simulation. The Transmitter Antenna Gain and the Receiver Antenna Gain pipeline stages were modified. The role of the pipeline stage is to compute the antenna gain, throughput and BER, for each transmission given some position and orientation information about the transmitter and receiver. This information is used to find out a point on an antenna pattern model which is in the direction of the transmitter or receiver. Φ and θ are angular measurements determined from the position and orientation of the transmitter and receiver as well as the position and orientation of the antenna mounted to either or both objects.

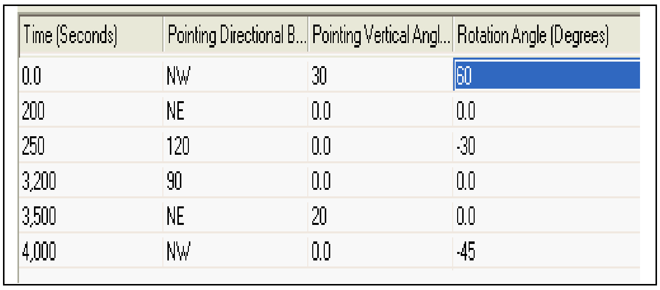
To make use of this antenna model enhancement, new attributes like Antenna_Positioning, Antenna_Positioning _Parameters and Antenna_Positioning_Values were added in the antenna model attribute as shown in Fig. 1.



Attribute	Value
name	ant_rx
pattern	promoted
pointing ref. phi	0.0
pointing ref. theta	180
target latitude	10
target longitude	20
target altitude	30
icon name	antenna
Antenna_Positioing	Detailed Antenna
⊟ Antenna_Positioning_Parameters	(...)
Mode	Fixed to Object
⊟ Fixed to Object	(...)
Mount Angle Phi (Degrees)	0.0
Mount Angle Theta (Degrees)	0.0
Antenna Rotation (Degrees)	0.0
⊟ Locked to Target	(...)
Target Latitude (Degrees)	0.0
Target Longitude (Degrees)	0.0
Target Altitude (Meters)	0.0
Antenna Rotation (Degrees)	0.0
⊟ Antenna_Positioning_Values	(...)
rows	0

Fig.1: Enhanced Antenna Positioning System Attributes

The EAPS when enabled works in two modes: Fixed to Object and Locked to Target. When not enabled, the antenna positioning parameters and values are all ignored resulting in the original standard antenna parameters and default pipeline stages being used. The Fixed to Object mode is intended for describing the movement of an antenna mounted to the mobile node and moves with the node. The Locked to Target mode is intended for describing an antenna which repositions itself so as to always points at a specific target. Both modes allow the use of a rotation angle parameter which causes rotation of the antenna about its pointing axis. When the mode is Fixed to Object more information is needed to describe the trajectory than what exists in the current models [5]. The values of phi and theta were varied. Fig. 2 depicts the Antenna Positioning Values, where we have time in seconds, the Pointing Directional Bearing (degrees), the Pointing Vertical Angle (degrees) and the Rotation Angle (degrees). These three variables as a function of time describe the orientation of a node.



Time (Seconds)	Pointing Directional B...	Pointing Vertical Angl...	Rotation Angle (Degrees)
0.0	NW	30	60
200	NE	0.0	0.0
250	120	0.0	-30
3,200	90	0.0	0.0
3,500	NE	20	0.0
4,000	NW	0.0	-45

Fig. 2: Antenna Positioning Values

3.1Scenario Description

The system consists of a fixed transmitter and a mobile receiver with a mobile jammer moving in a trajectory, as shown in Fig. 3, all in an area of 200x200 meters. The receiver is model by using random waypoint mobility i.e. it moves randomly. The purpose of the jammer node is to create radio noise. The jammer's trajectory takes it in and out of the radio range of the receiver node, increasing and decreasing interference at the receiver. To enhance simulation flexibility, the transmitter and receiver nodes' power attribute are promoted so that it can be set at run-time by the user.

The transmitter and the receiver modules use different frequency bands in order to provide different logical channels for exchange of control and data packets. The jammer follows changes to a new position every minute completing its path around the receiver. Simulation time is 600 seconds during which the jammer moves around the receiver, moving at a rate of approximately 4 m/s. Three scenarios were built. In the first scenario both the transmitter and receiver were using Isotropic antenna. The tx and the rx nodes were implemented for the second scenario with the Isotropic antenna and Enhanced Antenna Positioning System respectively. For the third scenario both the transmitter and the receiver were implemented using EAPS.

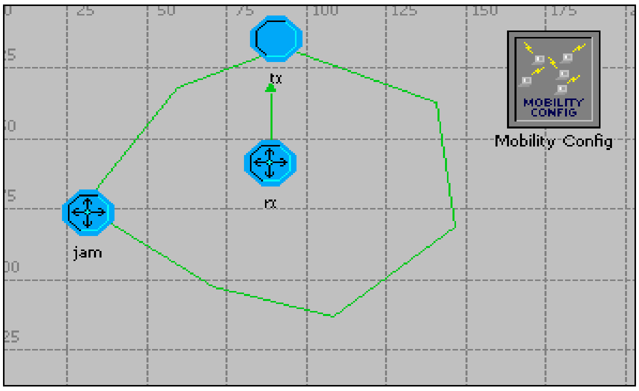


Fig. 3: Baseline Simulation Scenario

In order to run the baseline simulation, the *jac_dra_ragain* pipeline stage is selected and the *pattern* parameter in the rx_ant antenna module is set to,

a. Isotropic_antenna
b. Full_cone_antenna

The closure model was set to *dra_closure_all* to ensure link closure irrespective of earth curvature.

3.2 Node Model

A. Transmitter

The transmitter node model, as shown in Fig. 4, consists of a simple source module that generates packets and is generally treated as a desired node, transmitter and an antenna. The probability distribution functions of the packet size and packet inter-arrival time used within the simple source may be set as desired from those available within OPNET, and are set as constant in this case. The second module is the antenna_target_tracker module, which is use to track the antenna location or positions of the antenna. After generation, packets move through a packet stream to the radio transmitter module that transmits the packets on a radio channel. The transmitter node's power attribute is promoted so it can be set at run time by the user.

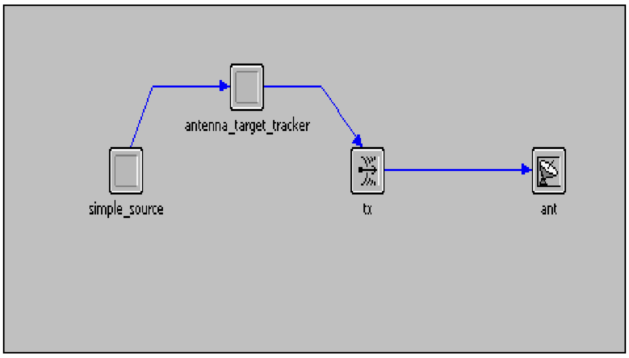


Fig. 4: Transmitter Node Model

B. Jammer

The network jammer node, whose node model is shown in Figure 5, introduces interference into the network. Like the transmitter node, it consists of a simple source packet generator module and a radio transmitter module. Its behavior is similar to the transmitter node, but its signal modulation is set to jammer modulation (jammod). The jammer node's power attribute is also promoted so it can be set at run time by the user.

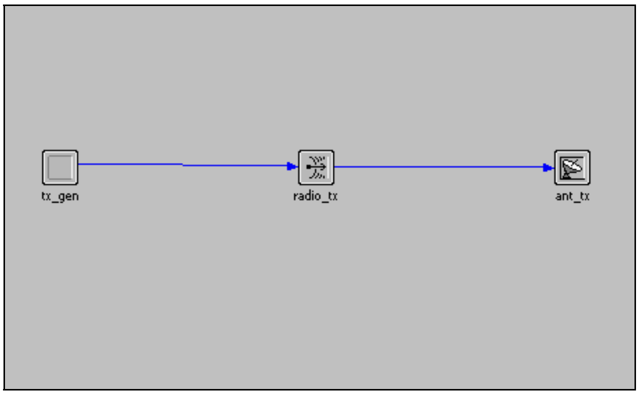


Fig. 5: Jammer Node Model

C. Receiver

The receiver node, as shown in Fig. 6, consists of an antenna module, radio receiver module, and a sink processor module. The radio receiver (rx) contains the receiver gain ragain pipeline which is changed in order to run the scenario as specified for the system. The function of the sink module is to sink data packets received.

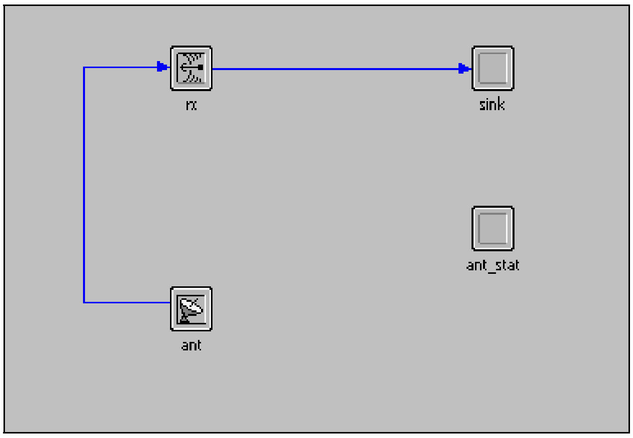


Fig. 6: Receiver Node Model

Table 1: Transmitter//Receiver Attributes

Parameters	Type/value
Modulation	BPSK
Power	Promoted to be set by user at run time
Data rate	100 kbps
Bandwidth	100KHz
Min frequency (tx_tx)	1.5GHz
Min frequency (tx_rx)	1.8GHz

Table1 shows the parameters used for the Baseline simulation. Note that the selection of the transmission rate is determined by a link adaptation scheme, *i.e.*, a process of selecting the best coding rate and modulation schemes based on channel conditions.

4. Performance Analysis

This section list the results obtained for the Simulation methods done. Specifically, Bit Error Rate (BER) and throughput in packets/sec presuming packet rejection when any error occurs in the packet were measured in the above mentioned scenarios. The received power was also measured. Note as the jammer and the transmitter actually generate packets asynchronously and independently, the BER and throughput are artificially improved due to transmit packets arriving when no jammer packet is present. This yields packets with no interference and thus exceedingly high SINR. To provide a more realistic interpretation of the operation of the EAPS, throughput is plotted on a packet-by-packet basis instead of a bit-by-bit basis as shown in figures below.

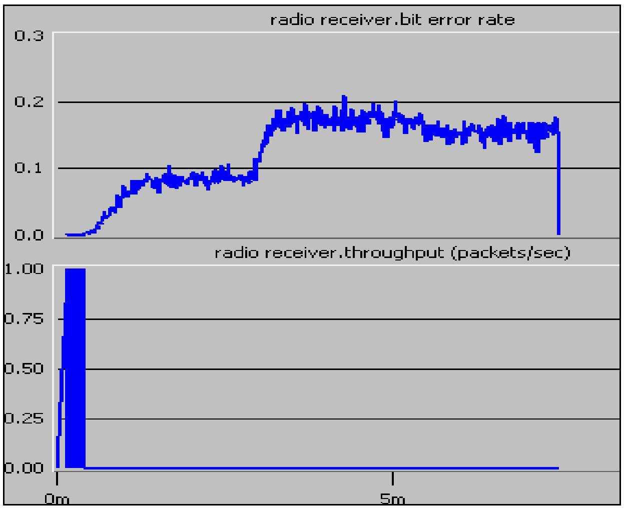


Fig. 7: BER and Throughput of the Isotropic Antenna

Fig.7 shows the BER and Throughput for Isotropic Antenna. The graph for the isotropic antenna pattern shows that the bit error rate at the receiver node gradually increases as the distance between the jammer and receiver nodes decreases. The BER reaches a maximum of about 0.2 errors/bit when the distance between the jammer and the receiver is smallest. The isotropic receiver antenna receives jammer interference during the entire simulation as such the throughput was zero.

Fig. 8 shows the BER and throughput for the Receiver when using EAPS at the Receiver only. The bit error rate reveals that the bit error rate at the receiver node was zero initially as the distance between the jammer node and receiver node is large. However, after about 5 minutes, the direction vector between the jammer antenna and the receiver antenna was in line with the direction of greatest gain for the receiver antenna. Therefore, the receiver node started to receive interference from the jammer node and the BER at the receiver approached 0.15 errors/bits. This increase radically decreased the number of packets received from the stationary transmitter node. It can also be seen that after the jammer passed the transmitter the BER dropped to 0. This drop drastically increased the receiver throughput.

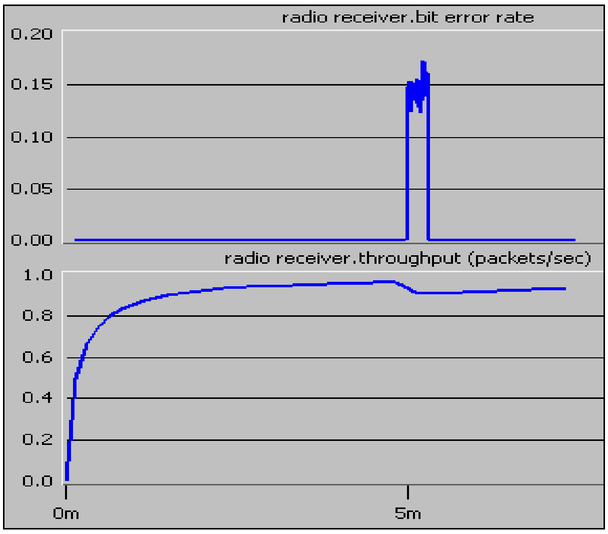


Fig. 8: BER and Throughput of the receiver when using the proposed system at the receiver only

Fig. 9 depicts the BER and Throughput of the proposed System. As the jammer moves along the prescribed path, it can be seen from the figure that the throughput of the receiver increases. This is because whenever the distance between the jammer and receiver or transmitter is decreasing the transmitter and receiver antennas using the Enhanced Antenna Positioning System can place their antennas in the specified direction ignoring the interference (jammer) signal.

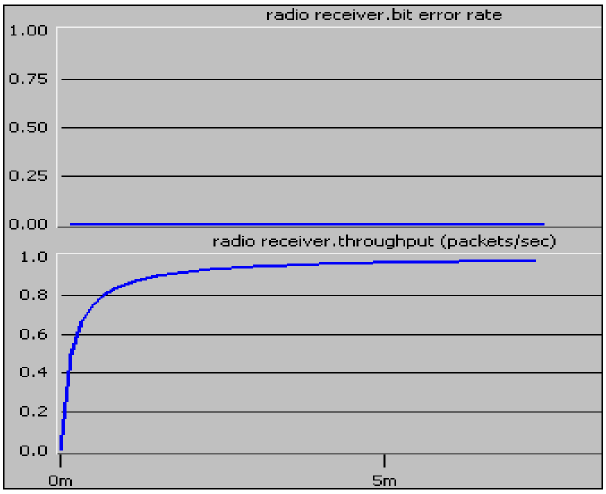


Fig. 9: BER and Throughput of Enhanced Antenna Positioning System when using at both Transmitter and Receiver

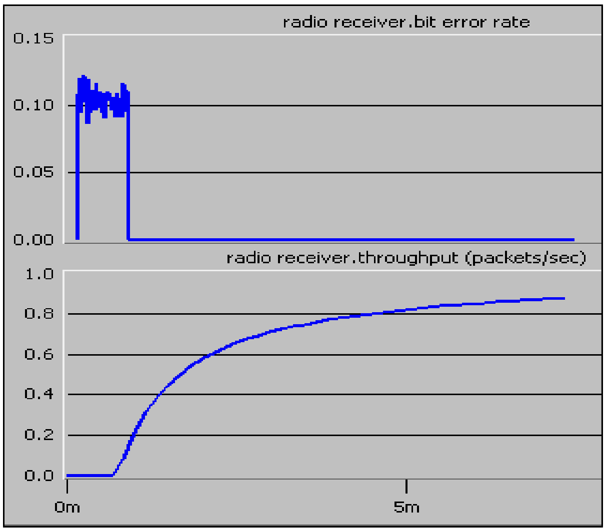


Fig.10: BER and Throughput of Enhanced Antenna Positioning System when using at both Transmitter and Receiver when the speed is more than 5m/s.

In fig. 10 when the speed was increased i observed that the throughout was 0 initially. In this case we concluded that the simulations indicate negligible effects for speeds up to 5m/s.

We observed that, for the Isotropic antenna pattern, the average number of received packets declined during the entire simulation. When using EAPS at the receiver side only, receiver throughput drops whenever the direction vector connecting the jammer and receiver antennas was in line with the receiver antenna's direction of greatest gain. However, after about 5 minutes—when the jammer was no longer in the direction of greatest gain for the receiver—the number of received packets began to increase. When using EAPS at both the transmitter and receiver sides, packet throughput was Excellent.

5. Conclusion

Increasing the number of antennas on a mobile object can result in complex antenna movement. In this paper, EAPS model was used to allow users to describe antenna positioning in more detail. Simulation comparisons were done for three different scenarios, one using Isotropic antenna, another using EAPS at receiver side only and the last one using EAPS at both the receiver and transmitter sides. From these three, it can be concluded that using EAPS at both Receiver and Transmitter gives better result as compared to the performance of Isotropic Antenna and when using EAPS at the Receiver only for MANET. The performance of the mobile nodes using the EAPS was expected to degrade with increase node mobility. However, the simulations indicate negligible effects for speeds up to 5 m/s. Results for higher node speeds may be more accurately captured using experimental setup.

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