Performance Analysis of WiMAX under Single and Multi-Carrier Jamming

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Summary
WiMAX is at the peak of communication technology as it is gaining a great position in the next generation of wireless networks. With the development of various wireless networks rapidly, they have turn into necessary infrastructure in our networking atmosphere. The main challenge for WiMAX is the problems associated with various jamming attacks that make them unavailable. Jamming attack is easy to be launched with very little efforts while its damage is severe since it effects the communication of all the nodes in the jamming range. This paper examines the threats at physical layer of the WiMAX and the performance analysis of WiMAX under physical layer is discussed. Issues related to single carrier jamming and multi carrier jamming has been covered. Various antenna patterns like Omni directional antenna isotropic antenna and sector antenna has been discussed with their effect on the WiMAX system has been discussed.

Key words
WiMAX, Jamming, Network Security, Wireless Communication, Single Carrier Jamming, Multi-Carrier Jamming

1. Introduction

Wi-MAX which stands for Worldwide Interoperability for Microwave Access is a telecommunications technology that provides wireless transmission of data using a variety of broadcast modes, from point-to-point links to portable Internet access technology providing up to 75 Mb/s symmetric broadband speeds without the need for cables like DSL. The technology is based on the IEEE 802.16 standard also called Broadband Wireless Access.
The unique idea of WiMAX is to offer users in rural areas with high speed communications as an alternative to comparatively costly wired connections. WiMAX standard includes utilization of adaptive modulation and coding, which makes it possible to provide users with high connection speeds close to the BS (Base Station) and lower speeds when the radio channel is not as good. It is also designed to enable LANs to communicate with each other through a WMAN .The WiMAX technology is capable of providing a platform to deliver the applications for the convergence of data, voice, and video services [4]. WiMAX works in the same way as Wi-Fi but at higher speeds over greater distances and with increased numbers of users. Mainly WiMAX consists of two parts [8]:

1. A WiMAX tower or Base Station
2. A WiMAX receiver

A WiMAX tower station as shown in figure 1 can connect directly to the Internet using a high bandwidth, wired connection and it can also connect to another WiMAX tower using a LOS microwave link which is also called backhaul.

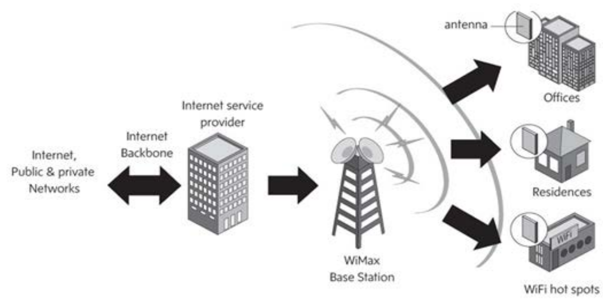

Figure 1: WiMAX Network

This paper is divided into total of seven sections. Section II describes physical layer threats under which duplex scheme has been discussed. In Section III related work has been examined. Section IV consists of Simulation setup. Section V gives simulation results of our proposed Opnet model. Section VI concludes with the conclusion

2. Physical Layer Attacks

There are two basic types of attacks that can affect the physical layer of WiMAX. One is jamming and the other is packet scrambling. The first is comparatively simple, and it sometimes results in interference rather than an attack. Jamming is a disruption of the frequency such as strong noise. It can either be intentional or accidental. Increasing the power of the signal can be achieved easily by means of using a more powerful transmitter or a high gain transmission antenna and a high gain receiving antenna. At various points most WiMAX service providers will face some type of interference or jamming problem. Jamming consists of a stronger signal than the WiMAX network

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crushing network data feeds either in discontinuous bursts or with constant carrier waves.

2.1 Duplexing scheme in WiMAX: TDD or FDD

Duplexing is a two way wireless transmission that refers to the way downlink and uplink data is arranged in the system. The downlink carries information from a Base Station (BS) to Subscriber Stations (SSs). Downlink is also known as forward link. The uplink carries information from a Subscriber Station to a Base Station. It is also known as reverse link. Duplexing techniques are of two types: FDD and TDD.

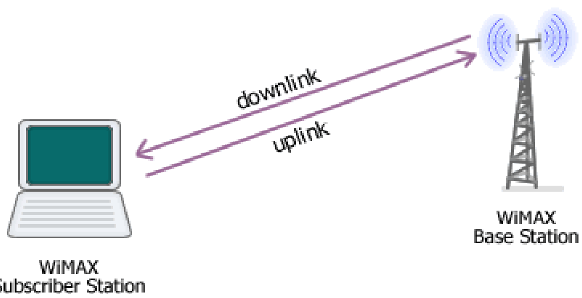

Figure 2: Downlink and uplink traffic in a 2-way communication.

FDD (Frequency Division Duplex) requires two different channels for transmitting downlink sub-frame and uplink sub-frame at the identical time slot. Bi-directional voice service is suitable for FDD since it occupies a symmetric downlink and uplink channel pair. WiMAX supports full-duplex FDD and half-duplex FDD. The difference is in full-duplex FDD a user device can broadcast and receive simultaneously, while in half-duplex FDD a user device can only broadcast or receive at any given instant.

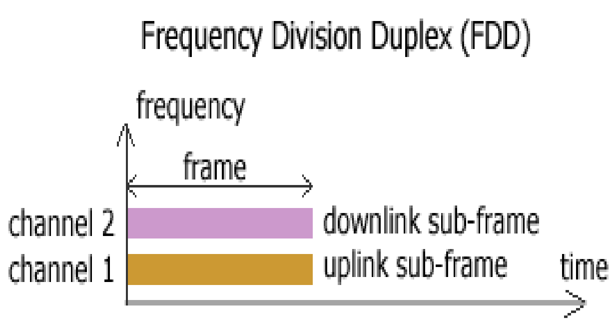

Figure 3: Frequency Division Duplex (FDD) - full duplex mode

FDD is ineffective for handling asymmetric data services since data traffic occupy a small part of a channel bandwidth at any given time. TDD (Time Division Duplex) is another duplexing scheme that requires only one channel for transmitting downlink and uplink sub-frames at two distinct time slots Moreover, using TDD downlink to uplink (DL/UL) ratio can be adjusted dynamically. TDD can flexibly handle both symmetric and asymmetric broadband traffic. Figure 2.3 shows that Downlink and uplink sub-frames are transmitted at different time slots in one channel.

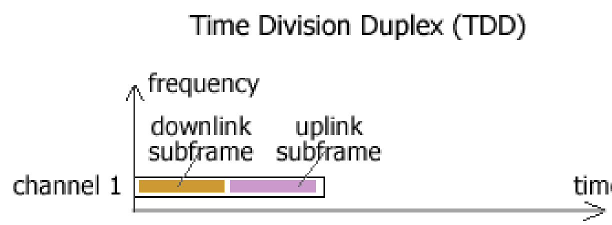

Figure 4: Time Division Duplex (TDD)

Most WiMAX implementations either on licensed or license-exempt bands will most likely use TDD. One advantage of using is that TDD uses half of FDD spectrum thus saving the bandwidth, other can be TDD system is less composite and thus cheaper, and WiMAX traffic will be conquered by asymmetric data .Fixed WiMAX profiles support both TDD and FDD, while Mobile WiMAX profiles only comprise TDD. In the next section of the paper, physical layer features and framing of TDD is discussed.

3. Related Work

Syed Ahson [10] analyzed that there are two principal threats to the WiMAX PHY are jamming and scrambling. Resilience to jamming can be augmented by increasing the power of signals or increasing the bandwidth of signals via spreading techniques such as:

- Frequency hopping
- Direct sequence spread spectrum

The practical options include a more powerful WiMAX transmitter, a high gain WiMAX transmission antenna, or a high gain WiMAX receiving antenna. It is easy to detect jamming in WiMAX communications as it can be heard by the receiving equipment. Law enforcement can also be involved to stop jammers. In this paper, the performance of an IEEE802.16-2004 based system in jamming environment is evaluated by computer simulations. Two categories of jamming, multi carrier pilot jamming and partial-band jamming, are investigated. The results reveal that, the system exposed to multi carrier pilot jamming suffers greater throughput loss than the system exposed to partial-band jamming, when the same total jamming power is applied.

A survey was made by Mahmoud Nasreldin [7] on carrier-to-interference-noise ratio (CINR) based link adaptation algorithm is also proposed to enhance the system resistance to jamming. According to the simulations, the system performance is improved by applying the algorithm. This paper presents a jamming resistant architecture for military applications of WiMAX (802.16) mesh network. The main idea is to use multiple base stations (BS), access points to the fixed core network. This will facilitate network survivability both in case of BS destruction and in case of jamming. When the nodes are affected by jamming they can reroute to another base station if possible.

According to Juan Li [5] the multiple base station architecture requires distributed scheduling as there is no single point of control that can execute centralized scheduling. A distributed scheduling algorithm, performing well in both jammed and non-jammed environment, is a key issue in implementation of the architecture. Several scheduling algorithms are considered in the paper: a static algorithm using the number of traffic flows in the node, dynamic load-dependent algorithms using two and three-hop neighbor information. Finally, an algorithm based on finite field initial slot assignment is proposed. This algorithm uses two-hop information and is also load-dependent. Performance of different algorithms is evaluated with and without jamming. The finite field algorithm shows the best performance in both cases.

LUO Cuilan [6] has provided us two goals to achieve the efficient security of WiMAX, one is to provide privacy across the wireless network and the other is to provide access control to the network. Privacy is accomplished by encrypting connections between the subscriber station and the base station. The base station protects against unauthorized access by enforcing encryption of service flows across the network.

Rakesh Kumar Jha [8] has described the performance of the system was found out to greatly differ with the use of different jamming signals, allowing central areas to be identified, where system development should be focused on. There are several techniques to reduce the jamming. BEAMFORMING, It is the technique to improve the directionality of the antenna. This technique is useful in the base station which uses sector pattern instead of the Omni directional antenna. Let's consider three sector of base station antenna. If jamming antenna is in sector one then the other two sectors are less affected by the jammer. Jamming resistant architecture, this jamming resistant architecture is also used to reduce the jamming effects. In this architecture more than one base station is used in one cell. All subscriber stations are connected in mesh topology including base stations which is serving in particular cell. Multi-tone pilot jamming affects the system more severely than partial-band jamming under the same Jamming power. In multi-tone pilot jamming, the number of jammed pilots decides the jamming severity and jamming 8 (full) pilots degrades the system to the most. In partial band jamming, system performance is degraded by either increased power of sub jammer or increased number of sub jammer, depending on the level of jamming power.

4. Simulation Methodology

In this paper, we use the OPNET Modeler 14.5 Simulator tool for simulation. We have built a jammer with transmitter and receiver while in the multicarrier jamming we have mobile nodes and wimax config with http application configuration and http_prof profile configuration and a mobile jammer is used.

4.1 Node Model of Jammer

Jammer is achieved by changing the modulation to jam mod.

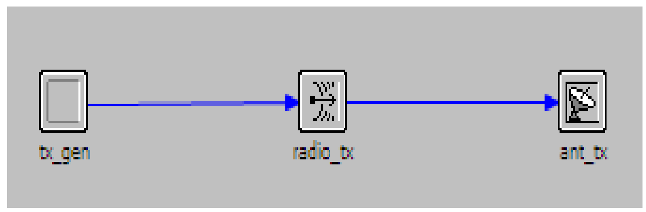

Figure 5: Node Model of Jammer

Design of jammer is given in this paper using Opnet modeler but it is not feasible to include each step by step procedure. The plan has been discussed in the paper for the design of jammer.

4.2 Simulation Model for Single Jamming

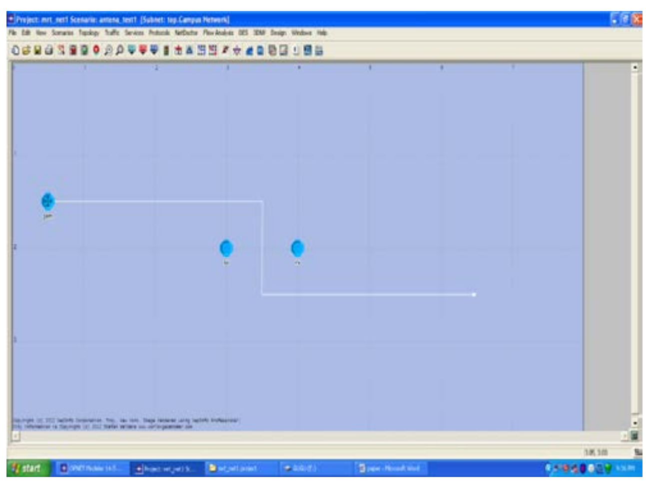

Figure 6: Simulation Model of Single Carrier Jamming

C Simulation Model for Multicarrier Jamming

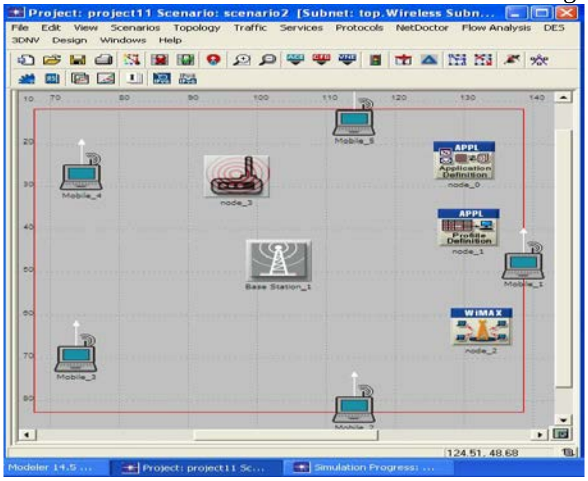

Figure 7: Simulation Model for Multicarrier Jamming

5. Result

Bit error rate difference in single carrier jamming with isotropic and sector antenna

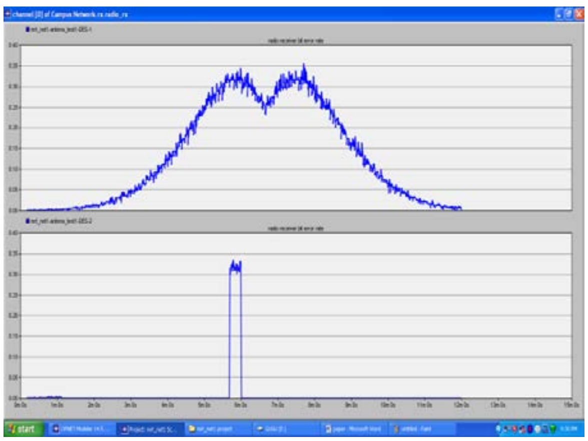

Figure 8: BER vs. Simulation time

The graph for the isotropic antenna pattern shows that the bit error rate at the receiver node steadily increased as the distance between the jammer and receiver nodes decreases. The isotropic receiver antenna receives jammer interference during the entire simulation.

The graph for the directional shows that bit error rate at the receiver node is non-zero at the start as the distance between the jammer node and receiver node decreases.

After approximately 6 minutes, the bit error rate increases and the number of packets received first drops then increases again when the jammer leaves the antenna's sector and the bit error rate drops back to 0.

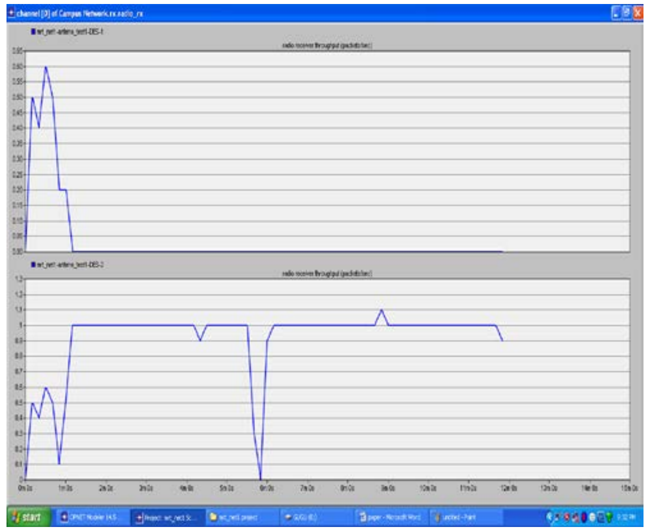

Figure 9: Throughput vs Simulation time

The graph of throughput in case of isotropic antenna is .60 then after 1 minute it almost drops to zero because of maximum error rate.

Throughput in case of directional antenna is high than that of isotropic antenna. As a result this shows us that the performance with the use of directional antenna increases. When the bit error rate is high it almost drops and afterwards it again increases.

Figure 10: Throughput of 512 sub carrier

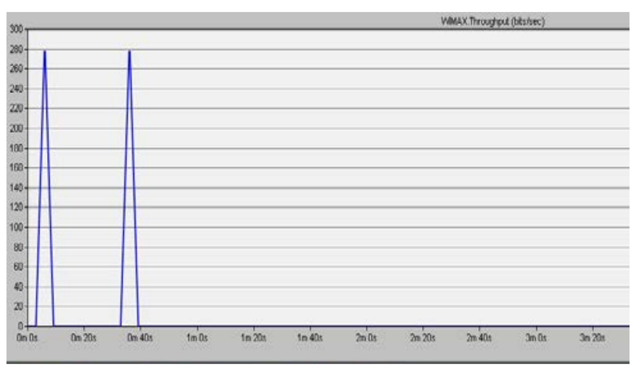

Figure 11: Throughput of 1024 sub carrier

With the increase in sub carrier in multi carrier jamming there is increase in throughput which results in increase in performance. Thus the 1024 sub carrier is less affected to jamming then that of the 512 sub carrier.

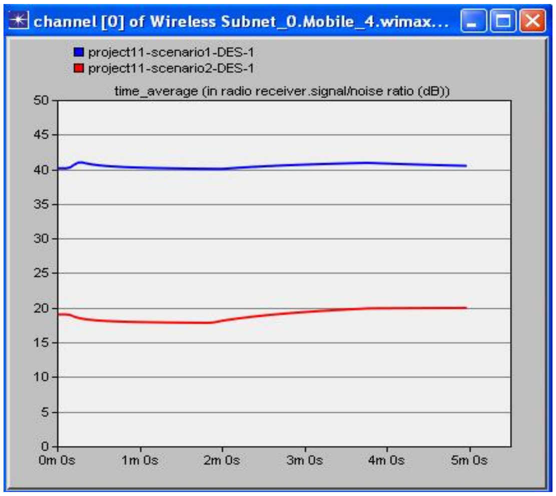

Figure 12: Comparison of SNR (blue-no jammer deploy) and (red- jammer deployed)

From the Figure 12 we came to know that when the jammer is deployed, the noise or interference increases which results in low SNR. Thus when the jammer is used the SNR becomes half of the original.

6. Conclusion

As the attractiveness of WiMAX increases, so will the threats to it. Jamming attack is one of the dangerous attacks which deliberately uses radio noise or signals in an attempt to disrupt communications. Jamming is the attack that has resulted in the decrease the performance of the WiMAX network. In this paper, the result shows that with isotropic antenna the effect of jamming is more rather than using sector antenna. Another result reveals us that higher the sub carrier higher is the throughput. When the jammer is installed noise increases, its SNR (signal to noise ratio) decreases thus it is affected by jamming.

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