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Analysis the Impacts of Transmission Range of AODV & DSDV Ad-Hoc Network Protocols Performance over Mobile WiMAX Networks

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Abstract

The IEEE 802.16 technology (WiMAX) facing great challenges due to owning high mobility of mobile nodes, limited radio coverage of wireless devices, time varying nature of wireless medium. The transmission range of base station (BS) has a vital influence and must achieve the most economic case of energy in wireless networks. This paper investigates the effects of transmission range of BSs for two prominent routing protocols- Destination Sequenced Distance Vector (DSDV) and Ad-hoc On-demand Distance Vector (AODV) respectively over WiMAX networks. The NIST WiMAX module is used to configure WiMAX environment and performance differentials are analyzed using NS-2. The QoS metrics used to evaluate the performance are packet delivery ratio (PDR), throughput, routing overhead (RO) and RTR packet loss. Simulation results reveal that performance increases with increasing the transmission range of the BSs. Although both protocols shows almost similar PDR and Throughput results, AODV is more sensitive to the transmission range that is correlated to transmission power of BS than DSDV. Unlike Ad hoc network here DSDV outperforms AODV in terms of RO and RTR routing packet loss probability.

Keywords: *WiMAX, Transmission Range, DSDV, AODV.*

1. Introduction

Recently, Broadband Wireless Access (BWA) has emerged as a promising solution for “last mile” access technology to provide high speed multimedia and Internet applications. Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard for BWA and its associated industry consortium, WiMAX forum have been working together to provide high data rate over large areas to a large number of users where broadband is unavailable [1]. This standard is intended to facilitate the users by low cost equipment, to ensure interoperability, and to reduce investment risk for operators. The IEEE 802.16 working group has developed and published a number of air interface standards for WMAN with focus on Medium Access Control (MAC) and physical layer (PHY). While the initial versions of 802.16a/d focused on fixed applications, the later version-802.16-2005 (16e) amendment includes features and functionalities needed to support enhanced QoS and mobility [2]. WiMAX network based on the IEEE 802.16e, also known as Mobile WiMAX, recently has gained tremendous momentum in the industrial and academic sectors [3]. A great challenge to the Mobile WiMAX providers is to provide the same quality access to both fixed and high speed mobile users. Because high speed nodes change their locations frequently and they may require frequent handovers as the probability of crossing the cell area is higher for them. That means, for proper routing of data packets, there is probability of high routing overhead and also a large number of packets may be lost. A solution of this problem may be the design of larger cells, that is, increasing the transmission range of WiMAX base stations in the areas where most of the users are highly mobile. This will require an adjustment in the subscriber receiver’s receiving threshold according to Eq. (1):

$$P_r(d) = {P_t G_t G_r h_t h_r} \Big/ {d^2 L} \tag{1}$$

Where,
d = distance between BS and subscriber
P_t = transmit-power
G_t = transmit-antenna-gain
G_r = receive-antenna-gain
L = system-loss
h_t = transmit-antenna-height
h_r = receive-antenna-height

This will cause the mobiles to spend more time within a particular cell and thus reducing the number of handovers. This in turn reduces the traffic load and successful packet delivery may increase. But, there is a negative impact on the capacity of the WiMAX network when larger cells are designed. The network must be carefully designed so that the improved performance neutralizes the reduced capacity that may result due to higher transmission range.

2. Effects of Transmission Power in WiMAX Network

In WiMAX, the transmission power of the BS significantly influences the network performance, especially in the highly mobile environment. In such areas, if the same transmission range as indicated by the WiMAX forum (1.4 km) [4] is used, this may result in frequent handovers of mobile nodes between BSs and a large number of packets may also be lost. Because high speed mobiles stay relatively short time within a cell and may cross the coverage area of several base BSs. Therefore it is clear that, higher transmission range of cells is necessary in such areas. This will reduce the probability of users getting out of range so frequently and hence reducing necessity of frequent handover. This will reduce the load on the BSs. This will also decrease the number of cells to cover a particular area and hence cost effective. But it is not efficient in term of capacity. Higher transmission range means less number of cells is required to cover an area now. This in result reduces the capacity that is achievable since frequency reuse is now also reduced. That means there is a tradeoff between the transmission range and overall network capacity. The designers must calculate an optimum solution that will fulfill both the requirements of avoiding unnecessary handover and of increasing capacity.

3. Techniques for Achieving Higher Transmission Range in WiMAX Network and Their Limitations

WiMAX networks can typically achieve coverage of about more than 1 km per BS. In order to achieve this, mobile WiMAX networks employ a number of techniques to achieve longer range, including high transmit power, sub-channelization and adaptive modulation.

3.1 High Transmission Power

Radio Frequency (RF) power translates directly into range. To achieve long range, WiMAX base stations transmit at power levels of approximately +43dBm (20W), while a WiMAX mobile station typically transmits at +23 dBm (200mW) [4]. In order to get higher transmission range, an easiest way is to increase the transmission power of both the BS and mobile nodes. But there are three important factors that limit the ability to transmit at higher power.

3.1.1 PA Efficiency

PAs, efficiency is the measure of the RF power out versus the DC power in [5]. The PA efficiency has a direct impact on the battery life of mobile devices. Poor efficiency means quicker discharging of battery. Therefore, to get higher transmission the PA efficiency must be as high as possible for longer battery life. Today's available WiMAX PAs, like SiGe Semiconductor's SE7262, operate with about 20 percent efficiency [5].

3.1.2 Available Supply Voltage

Mobile WiMAX devices get power directly from the mobile station's battery, and battery supply voltage is not stable. When freshly charged, the battery will operate at about 4.8V, but when the supply voltage discharges, the supply voltage also drops. The minimum practical supply voltage before the device shuts down is typically 2.7V. Most manufacturers want to use the battery for as much of this range as possible, and therefore specify that the power amplifier must deliver fully rated power at 3.3V (and occasionally 3.0 V) [5]. Delivering high power under these conditions imposes some significant challenges. A low supply voltage requires a high current, which implies very low output impedance. Consequently, matching the low impedance PA output to a 50 Ohm antenna is difficult to achieve. If higher output powers are required, the impedance becomes even lower, and it becomes increasingly difficult to achieve a good broadband match between the PA and the antenna.

3.1.3 Regulatory Requirements

There are some regulatory requirements that limit the amount of power that can be delivered by a PA. An ideal linear PA produces only the original frequency from the input signal. But, in real-world implementations, complete linearity cannot be achieved [5]. This PA non-linearity introduces new frequencies which interfere with users in adjacent channels and creates Inter-Modulation distortion (IMD). Regulatory bodies have placed some strict regulations to control the out of band power emission and to make the IMD tolerable. For example, for mobile devices in the 2.5GHz band, the Federal Communications Commission (FCC) specifies that the emissions must be below -25dBm/MHz, measured 5.5MHz outside the device's assigned band [5]. Hence, when output power is increased, more and more rejection of out-of-band emissions is required, which requires PAs that must be made more and more linear. For example, when transmitting at +23dBm with a 10 MHz channel bandwidth, achieving -25dBm/MHz requires a net rejection of 23 - 10 log (10) + 25=38 dB rejection.

Transmitting at 24.5dBm requires 39.5dB rejection. Therefore, with the increasing output power, the PA must operate more linearly to avoid extra IMD, which in result drops the PA efficiency significantly.

3.2 Sub Channelization and Adaptive Modulation

Like cellular networks, WiMAX networks are severely uplink limited. There is a large difference (approximately 20 dB) between downlink power (from the BS to the MS) and uplink power (from the MS to the BS). Therefore it is difficult for the BS to hear MSs. This becomes even more difficult when higher transmission ranges are used. To combat this mismatch, sub-channelization is used. In this technique, only a subset of the entire available sub channel is utilized for a particular MS. Each mobile concentrates its power over a smaller range of frequencies and as a result, a gain is achieved. The net gain can be expressed as

$$G = 10 \times \log(N_{total} / N_{used}) \quad (2)$$

Where, N_{used} and N_{total} are the number of sub carriers assigned to the user and the total number of available subcarriers respectively [5]. The other subcarriers are made available to other users, and they can use these simultaneously. Another technique to address the link imbalance is adaptive modulation. In this case, the mobile transmits using a lower order modulation compared to the BS [5]. For example, the mobile could transmit Quadrature Phase Shift Keying (QPSK) or 16QAM signals, while the BS transmits using 64QAM. Because the SNR required to receive QPSK or 16QAM is lower than 64QAM, using a lower order modulation allows the MS to communicate with the BS using less transmit power [5]. Thus, using sub-channelization and adaptive modulation collectively, a network operator can effectively balance the uplink and downlink budgets, and the network will operate bi-directionally [5]. The downside is that when these techniques are used, the uplink throughput will be lower than the downlink throughput; sub-channelization limits the number of subcarriers available for mobile transmission, and lower order modulation means that fewer bits are transmitted on each available sub-carrier. When higher transmission ranges are used, allocated subcarriers must be reduced to enhance the gain, which reduces the uplink throughput more. Again, increased transmission range increases the range of edge users and forces both the BS and MSs to use lower order modulations. The NIST WiMAX module that implements WiMAX PHY and MAC layers is used for simulation of WiMAX network. It supports only sub-channelization. It does not support adaptive modulation. To achieve an average result, 16QAM-1/2 is used.

In this simulation, while varying the transmission range, the BS and mobile station transmit power is set to 43dBm and 23dBm respectively, which is defined by the WiMAX forum. The transmission range of a cell is varied from 100 to 2000m to analyze the effects. Higher ranges were not used since that will require higher transmission power. As mentioned in this section, this results in higher IMD and battery consumption. The aim was to retain the power same, and to get the highest performance with this power.

4. Routing Protocols

4.1 Destination Sequenced Distance Vector (DSDV) Routing Protocol

DSDV is a table-driven routing scheme for ad hoc networks based on the Bellman-Ford algorithm [6], [7]. The main contribution of the algorithm was to solve the Routing Loop problem. In DSDV, each node periodically broadcast its routing updates to its immediate neighbors. A node also transmits its routing table if a significant change has occurred in its table from the last update sent. So, the update is both time-driven and event-driven. The routing table updates can be sent in two ways: - a “full dump” or an incremental update [6]-[9]. A full dump sends the full routing table to the neighbors and could span many packets whereas in an incremental update only those entries from the routing table are sent that has a change since the last update and it must fit in a packet. When the network is relatively stable, incremental update method is applied to avoid extra traffic and full dump method is used infrequently. In a fast changing network, incremental packets can grow big so full dump is more frequent [6]-[9].

4.2 Ad-hoc On-demand Distance Vector (AODV) Routing Protocol

The AODV routing algorithm is a routing protocol designed for ad hoc mobile networks. It is a reactive protocol and is capable of both unicast and multicast routing [6], [10]. AODV shows on-demand characteristics hence discovers routes whenever it is needed via a route discovery process. It maintains these routes as long as they are needed by the sources. AODV adopts traditional routing tables; one entry per destination. It doesn’t require global periodic routing advertisements [1]. AODV uses sequence numbers to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes [6]. AODV discovers and builds routes using a route request / route reply query cycle [6], [10]-[11]. In this cycle, route request (RREQ) messages are broadcasted across the network and when the destination is found, route reply (RREP) messages are sent by the destination in a unicast fashion [9], [10]. In AODV, each node locally broadcasts its routing tables and thus gets neighborhood information. These broadcasts are done periodically and are called “Hello Messages” [11]. Although AODV is a reactive protocol it uses these periodic Hello Messages to inform the neighbors that the link is still alive.

5. Simulation Model

5.1 Simulation Environment

The result of this study is based on simulations using the network simulator (NS-2) from Lawrence Berkeley National Laboratory (LBNL) in Red hat 5.0 platform. For the simulation of WiMAX network; a patch “WiMAX Module” from National Institute of Standards and Technology (NIST) is used, which implements the MAC layer (IEEE 802.16) and PHY (OFDMPHY) layer for creating WiMAX environment. As QoS specification, only Best Effort (BE) service class is used. In BE services, the QoS requirements in terms of channel access latency are the loosest of all the five services the bandwidth is not guaranteed [12]. Best effort services are appropriate for applications such as web browsing and file transfers since these can tolerate intermittent interruptions and reduced throughput without serious consequence. To evaluate simulation result we consider the simulation scenario has an area of 2200 X 2200 square meters where the length of each simulation is 210 seconds. The traffic starts at 100 second to provide time for initial ranging and other synchronization and authentication. In the simulation area 10 mobile nodes can move randomly. DSDV and AODV are used as the routing protocols and both of them have an Interface Queue (IFQ) of 50 packets. The IFQ is a (First in First out) FIFO priority queue where routing packets gets higher priority than data packets. All MAC and Network layer operations of the wireless network interfaces are logged in trace files. Post simulation analyses are performed to each of the trace file by using Perl language.

5.2 Radio Propagation and Mobility Model

The propagation model that is used in this research paper is TwoRayGround propagation model. This model is more realistic than free space path loss propagation model as it considers both the Line of Sight (LOS) and ground reflected signals [13]. As the mobility model, Random Waypoint Mobility (RWM) Model is used. In this model, each of the mobile nodes starts their movement from a randomly selected initial position within the simulation area and moves to a random destination with a randomly chosen speed. The maximum possible speed can be selected by the user. Once the destination is reached, the node chooses another one after a pause time and this process continues until the simulation ends. In RWM model, the Pause Time, which affects the relative speeds of the mobiles, can also be varied by the user. Pause Time and Maximum Speed of a mobile are the two key parameters that determine the mobility behavior of nodes [14]. If the nodes move slowly and the pause time is long, the topology of the network is relatively stable. But when nodes move fast with a small pause time, the network topology becomes highly dynamic. In this research, we have chosen the pause time as zero and that means the WiMAX network that is considered in the simulation is chosen to be highly dynamic.

5.3 Simulation Parameters

The simulation parameters which have been considered for performance evaluation are provided in Table 1.

Table 1: Parameters used in simulation

Number of nodes	10
Minimum speed of nodes (m/s)	1
Maximum speed of nodes (m/s)	20
Pause time (s)	0
BS Height (m)	32
Mobile Station Height (m)	1.5
BS Transmission Power (dB)	43 (20 W)
BS Transmission Range (m)	100, 300, 500, 700, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000
Operating Bandwidth (GHz)	2.412
RXThreshold	1.95929e-07, 2.17699e-08, 7.83715e-09, 3.99855e-09, 2.41887e-09, 1.95929e-09, 1.61925e-09, 1.36062e-09, 1.15934e-09, 9.99636e-10, 8.70794e-10, 7.65347e-10, 6.77954e-10, 6.04718e-10, 5.42739e-10, 4.89822e-10 respectively.
Packet size (Byte)	1520

6. Performances Metrics

To investigate the impact of transmission range on QoS metrics for two MANET routing protocols over WiMAX network, both qualitative and quantitative metrics are needed. Most of the routing protocols ensure the qualitative metrics [1]. For this reason, we use four different quantitative metrics to compare the performance. They are:

Packet Delivery Ratio: The ratio between the number of packets originated by the application layer CBR sources and the number of packets received by the CBR sink at the final destination.[15], [16].

$$PDR = \sum_{1}^{N} CBR_{recv} \Big/ \sum_{1}^{N} CBR_{Send} \times 100 \quad (3)$$

Throughput: The ratio of the total data received by the end user and the connection time [15]. A higher throughput will directly impact the user's perception of the QoS.

$$Throughput = \sum_{1}^{N} rec\_pkt \Big/ \sum_{1}^{N} Simulation\_time \,(\text{bps}) \quad (4)$$

Routing Overhead: The routing overhead describes how many routing packets for route discovery and route maintenance need to be sent in order to propagate the data packets [1].

$$RO = \sum_{1}^{N} send\_pkt \Big/ \sum_{1}^{N} rec\_pkt \quad (5)$$

Number of RTR Packets Loss: It indicates the number of routing packets that have been lost.

7. Simulation Results Analysis and Discussion

The effects of transmission range of the BS are investigated for node velocity of 20 m/s. The graphs given below (Fig 1 to Fig 4) show the effect of transmission range on QoS metrics (PDR, Throughput, Routing overhead and RTR Packets loss) for both routing protocols.

7.1 Results Analysis- Transmission Range vs.PDR

From fig. 1, it is observed that PDR increases with increasing transmission range of the BS and both protocols offer almost similar PDR result. This similarity in result can be explained by investigating the working procedures of the protocols in WiMAX networks.

In WiMAX networks, time driven and event driven updates are transferred only between mobile nodes and BS, not from one mobile to another. This centralized routing of packets reduces the overhead tremendously. That means DSDV offers wider channel bandwidth for data traffic in WiMAX network.

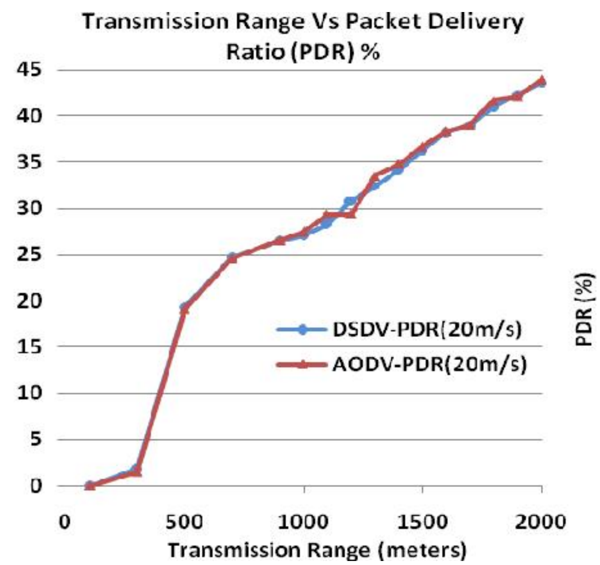

Fig. 1 PDR as function of the Transmission Range.

But due to its inefficient periodical update scheme, DSDV losses a large amount of data packets between two consecutive updates in a dynamic network. During this time, most of the routes become invalid due to the movement of the mobiles, and following these routes result in packet losses. Hence, DSDV cannot utilize the available bandwidth effectively and provides almost similar PDR values as AODV.

When transmission range increases, the frequency of cell crossing by mobiles decreases and which decreases the number of event driven updates in case of DSDV and unnecessary route discovery processes for reconnecting out of range mobiles in case of AODV. As, a result, more bandwidth is available for data transmission and hence PDR improves with increasing transmission range for both the protocols as shown in the figure.

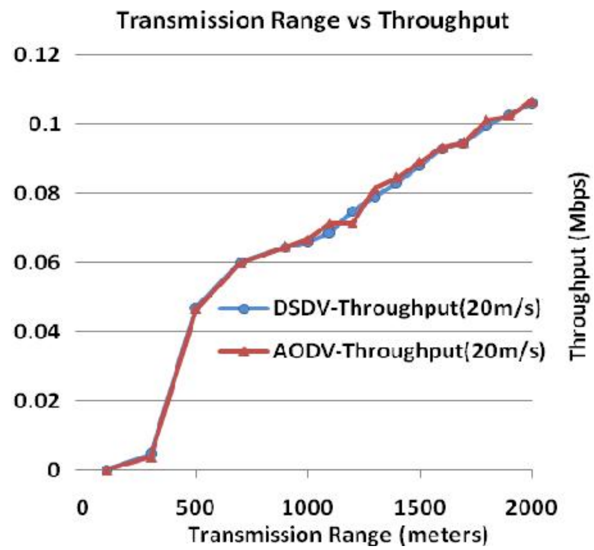

Fig. 2 Throughput as function of the Transmission Range.

7.2 Result Analysis- Transmission Range vs. Throughput

Fig. 2 illustrates that, the throughput of both DSDV and AODV is increased with increasing transmission ranges of the BS. As discussed in the previous subsection, this is due to the reduction in overhead with the increasing range which provides relatively wider bandwidth for data transmission for both the protocols. Although DSDV offers much lower overhead for each of the range, due to its proactive nature DSDV losses a large number of data packets in a highly dynamic network. In a dynamic network, entries into the routing table of the BS become invalid frequently as mobile changes their positions regularly. When these invalid paths are used before next table update, packet could not find their destination and eventually are lost. As a result, in spite of having better bandwidth DSDV cannot have better throughput values when comparing with AODV.

7.3 Result Analysis- Transmission Range vs. Routing Overhead

Fig. 3 shows the simulation result for Routing overhead for both the routing protocols. From the figure, it can be observed that AODV offers much higher routing overhead than DSDV. This is due to the on demand route discovery algorithm that is followed by AODV. In a highly dynamic network as like as the one we have considered in this simulation (Pause time 0), because of the movement of the nodes, links break regularly. As a result, almost each time the nodes and BS requires to communicate, they need to run route discovery procedure.

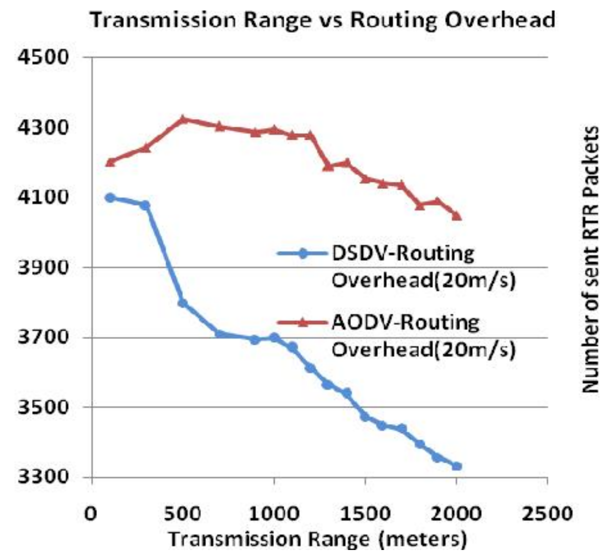

Fig. 3 Routing Overhead as function of the Transmission Range.

Besides, periodical Hello Messages are also broadcasted by the network nodes to detect active or valid routes and to remove broken or invalid routes. All these result in a large amount of routing overhead in AODV. Since unlike AODV, DSDV does not discover routes on demand, it offers much lower overhead. With the increase in transmission range of BS routing overhead of AODV decreases along with DSDV, but total overhead is always higher than DSDV for a particular range.

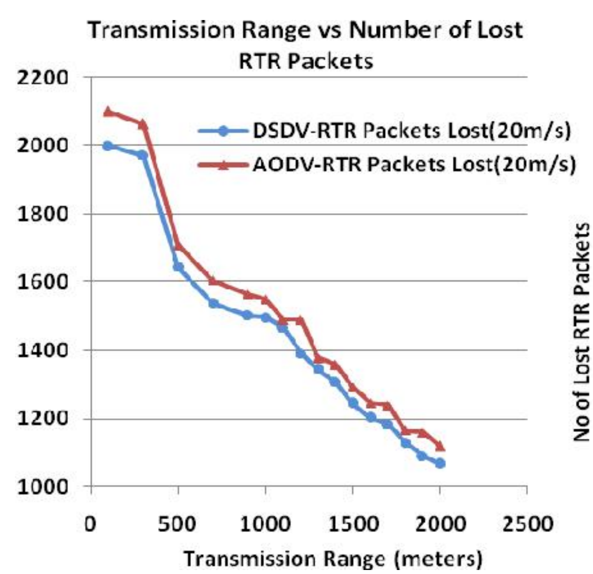

Fig. 4 No of Lost RTR Packets as function of the Transmission Range.

7.4 Result Analysis- Transmission Range vs. No of RTR Packets Loss:

Fig. 4 shows the result for the number of RTR packets loss as a function of the transmission range of the BS. The figure indicates that, the probability of RTR packets loss decreases as the transmission range increases. Because the higher transmission range means the nodes spend more time within the cell and hence fewer packets are lost due to the nodes that go outside the range of the cell and the packets cannot reach them. Fig. 4 also illustrates that, proactive DSDV performs better than on demand AODV in this case. The reason behind this is the on demand route discovery process applied by AODV. In AODV, when any node goes out of range of the BS, the BS tries to reconnect the node and initiates route discovery process. Since the node is not within the transmission range of the BS, those RTR packets sent or route discovery are eventually lost. More the nodes cross the cell boundary, more the RTR packets are lost due to this unnecessary and unsuccessful route discovery process. As DSDV does not apply this route discovery process, it losses relatively lower RTR packets which is for the movement of the nodes. Fig 4 shows that the number of lost of routing packets is least for the highest transmission range (2000m) for both the protocols since then the probability of crossing the cell boundary by the mobile nodes is lowest and vice versa.

8. Conclusion

Transmission range of the BS largely influences the capacity of the WiMAX network. Higher transmission range means lower capacity, which is not desirable. But in dynamic environment where most of the mobiles move fast, there must be a compromise with the capacity to provide desired services. The simulation addressed in this paper illustrates that, performance upgrades explicitly while increasing the transmission range of a cell with high speed mobile users. It is observed that the higher transmission range compensate for the instability that is caused by the high speed mobile nodes. The performance comparison of the two Ad hoc routing protocols, DSDV and AODV over WiMAX environment, shows that both the protocols provide almost similar PDR and Throughput values. But DSDV performs better than AODV in case of routing overhead and the probability of lost of RTR packets. AODV offers much greater overhead due to its on demand routing algorithm for discovering new routes which may leads to poor PDR and throughput values when the number of subscribers is large in a WiMAX network. it can be concluded that to get the optimum performance in a highly dynamic WiMAX network, transmission range should be increased carefully to select the well-matched coverage for the network .

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