

# Performance Evaluation of WiMAX Networks with Mobility in Metropolitan Area Network (MAN)

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ENSC 894 : Communication Networks

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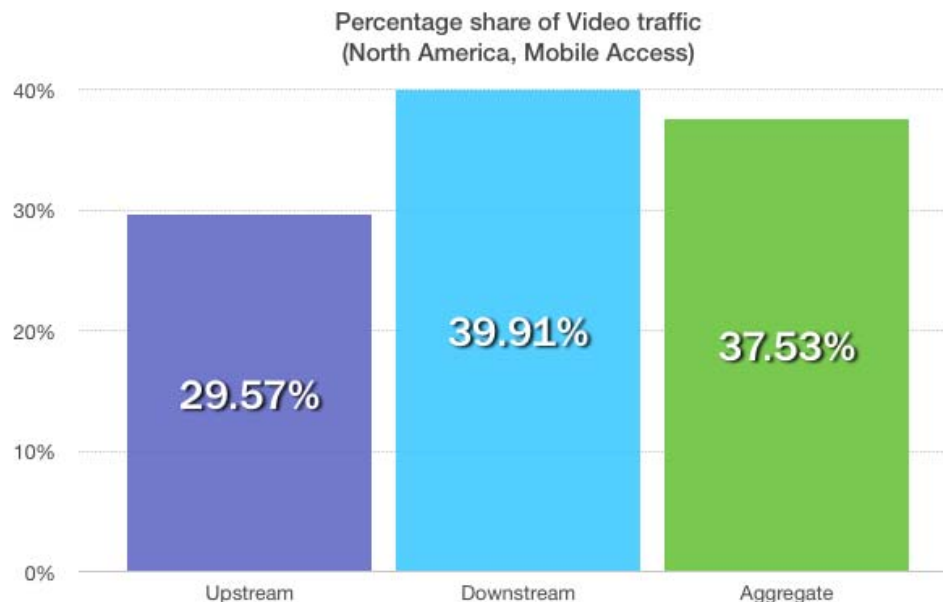
# Roadmap

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- Motivation
- Introduction
- Related Work
- Simulation Design
- OPNET model
- Simulation Results
- Conclusions
- Challenges and Future Work
- References

# Motivation

- Share of video streaming traffic – Increasing
- WiMAX – Wireless Broadband Standard
- Our Aim – To evaluate the performance of WiMAX Networks with Mobility





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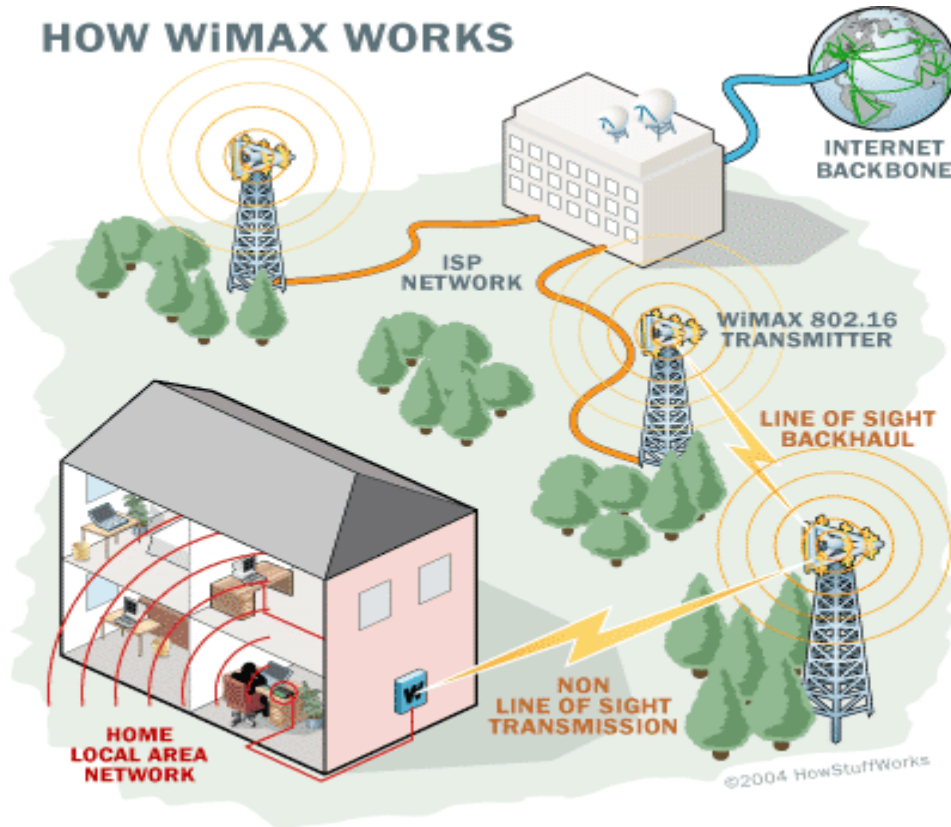
# WiMAX - Introduction

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- Worldwide Interoperability for Microwave Access
- Wireless Broadband Standard
- Based on IEEE 802.16 standard
- Started in 1999 : as an alternative to DSL
- 2005: Landmark Year
  - Standard 802.16e released
  - Mobility was introduced
- Evolved into 4G technology

# WiMAX System

## HOW WiMAX WORKS



- WiMAX tower
  - Range – 7 to 10 kms Radius
- WiMAX Backhaul
- WiMAX Receiver
  - Can be small box
  - In-built in the mobile device

Ref: M. Brain and E. Grabianowski. "How WiMAX works,"  
<http://computer.howstuffworks.com/wimax1.html> [Accessed: 22 Mar. 2014], December 2004

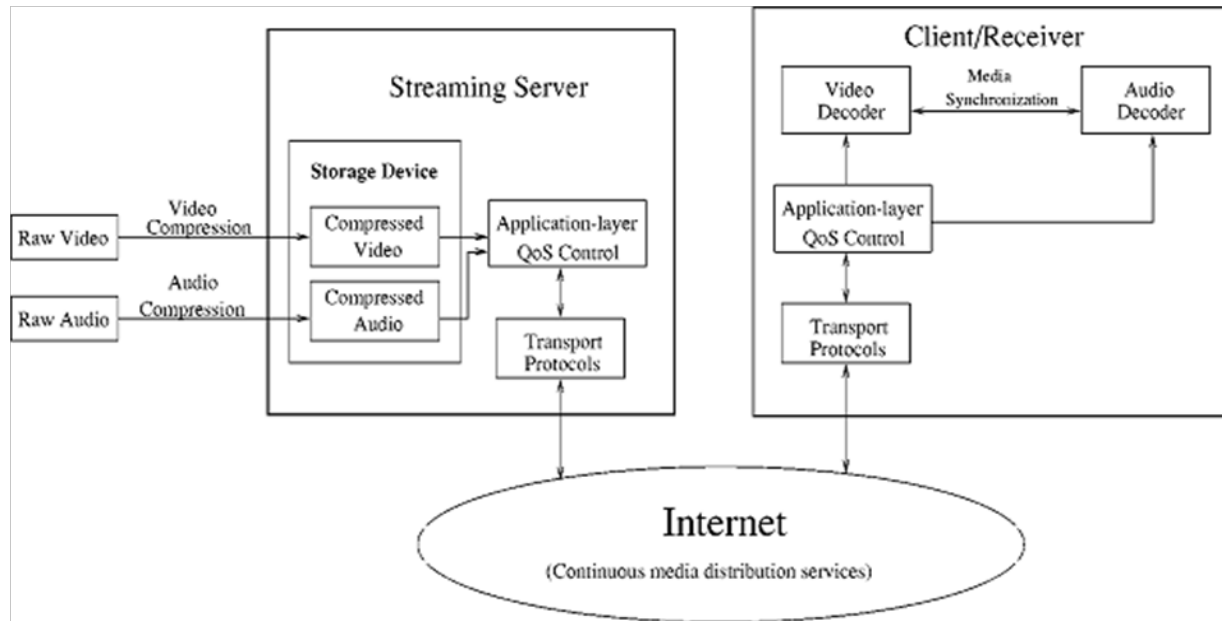


# WiMAX Features

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- Frequency : 2 – 66 GHz
  - Higher Frequencies
    - Affected by Rain
    - Lower data rates at higher mobility
    - Signal attenuation is higher
- High Data Rates : 75 Mbps
- Data Rates v/s Distance Trade-off
- Use of adaptive modulation
- Strong QOS Mechanism

# Video Streaming



- Client Request Video
- Server Responds
- Compression and corresponding Decompression techniques





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# Related Work

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- W. Hruday and Lj. Trajkovic, "Streaming video content over IEEE 802.16/WiMAX broadband access," *OPNETWORK*, Washington, DC, Aug. 2008. Higher Frequencies
  - Mobility not considered
- W. Hruday and Lj. Trajkovic, "Mobile WiMAX MAC and PHY layer optimization for IPTV," *Mathematical and Computer Modelling*, Elsevier, vol. 53, pp. 2119–2135, Mar. 2011
  - Concentrated on Mobile Hand-off among various BS
- R. Gill, T. Farah, and Lj. Trajkovic, "Comparison of WiMAX and ADSL performance when streaming audio and video content," *OPNETWORK 2011*, Washington, DC, Aug. 2011.
  - Mobility not considered



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# Simulation Design

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- OPNET Modeler version 16.0 has been used
- Four metrics are used to measure the performance between the server and the client
- Packet Loss  
Avg:  $< 10^{-3}$       Ideal:  $< 10^{-5}$
- End-to-end Delay  
Avg:  $< 300$  ms      Ideal:  $< 10$  ms
- Jitter  
Avg:  $< 60$  ms      Ideal:  $< 20$  ms
- Throughput  
Satisfactory range: 10 kbps – 5 Mbps



# Network Design Parameters

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## WiMAX Deployment Parameters

Scheduling Algorithm	Best effort (BE)
Downlink / Uplink	3.0 Mbps / 0.640 Mbps
Transmission Power (BS/SS)	3.8W / 2W
PHY profile	Wireless OFDMA 20 MHz
Pathloss model	Flat terrain with light tree densities
Antenna Gain (BS/SS)	15 dBi / 14 dBi

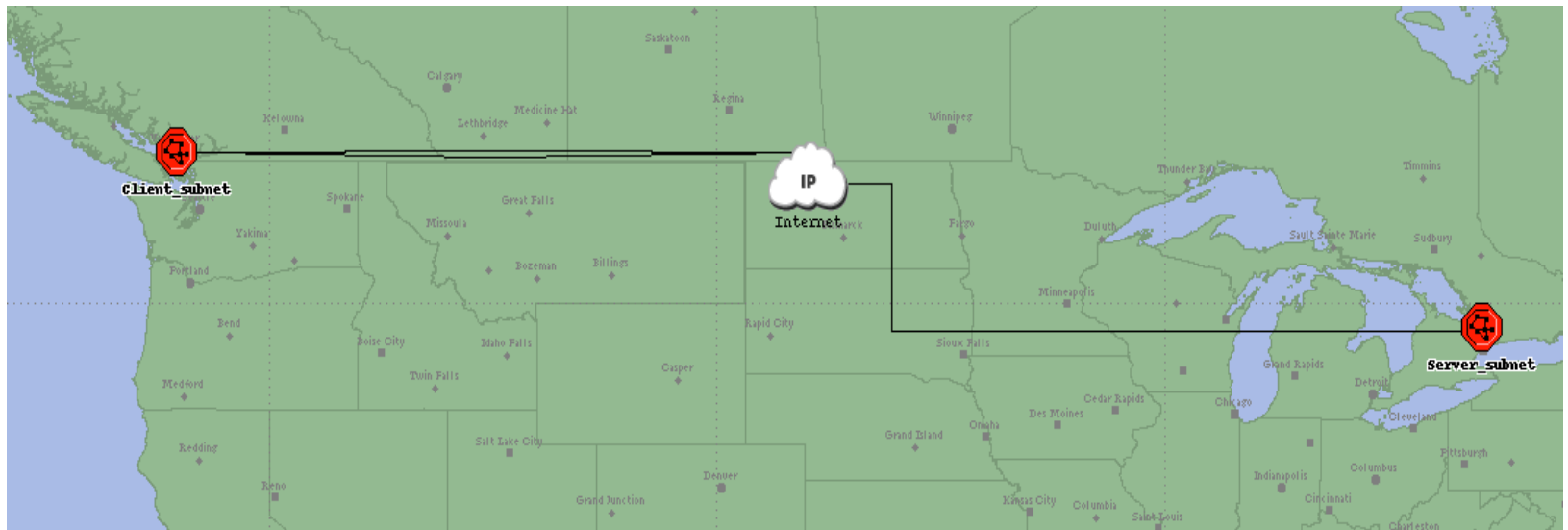


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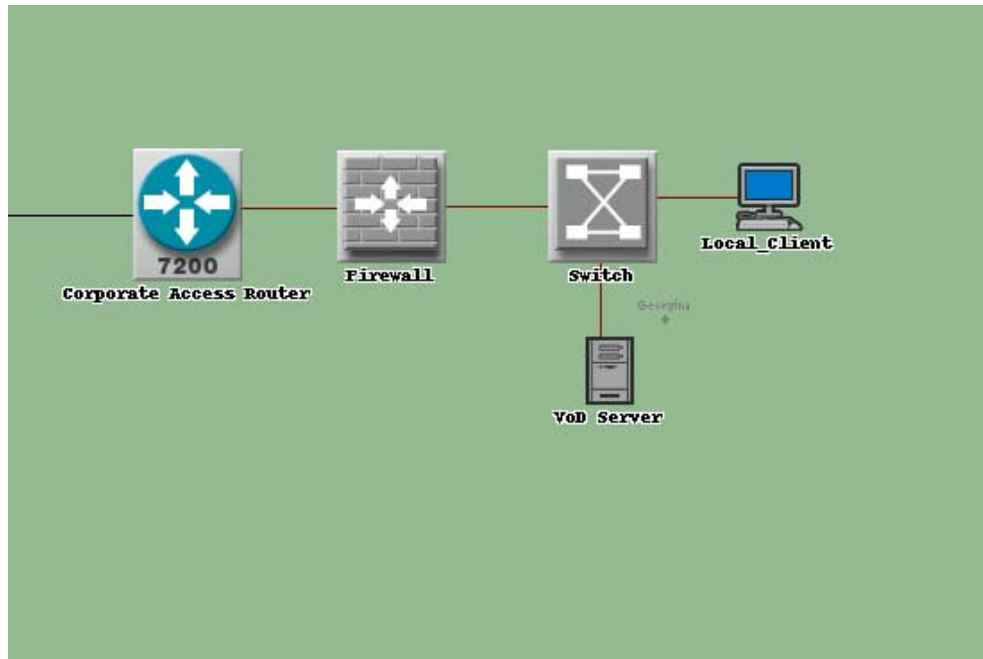
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# Network Topology



- Video Server in Toronto
- WiMAX Base station and clients in Vancouver
- Both subnets are about 3,340 km far

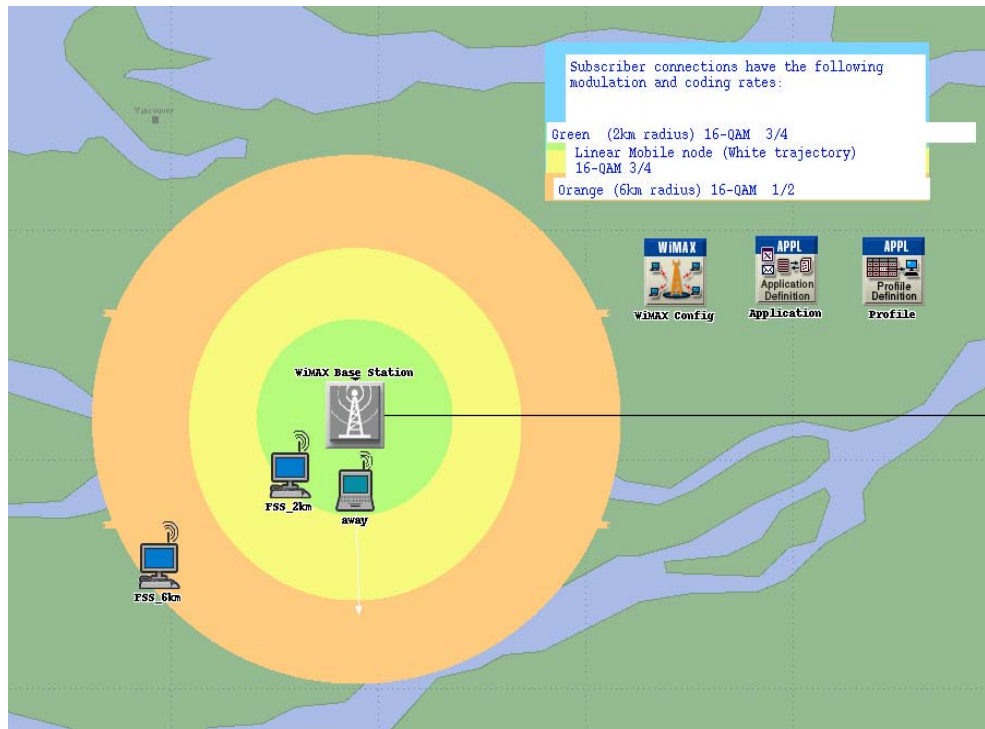
# Server Subnet Topology



- *Server streams audio and video content*
- *Server is protected by the firewall*
- *Access router connects the server to the Internet cloud via a 45 Mbps Digital Signal (DS3) wide area network (WAN) link*

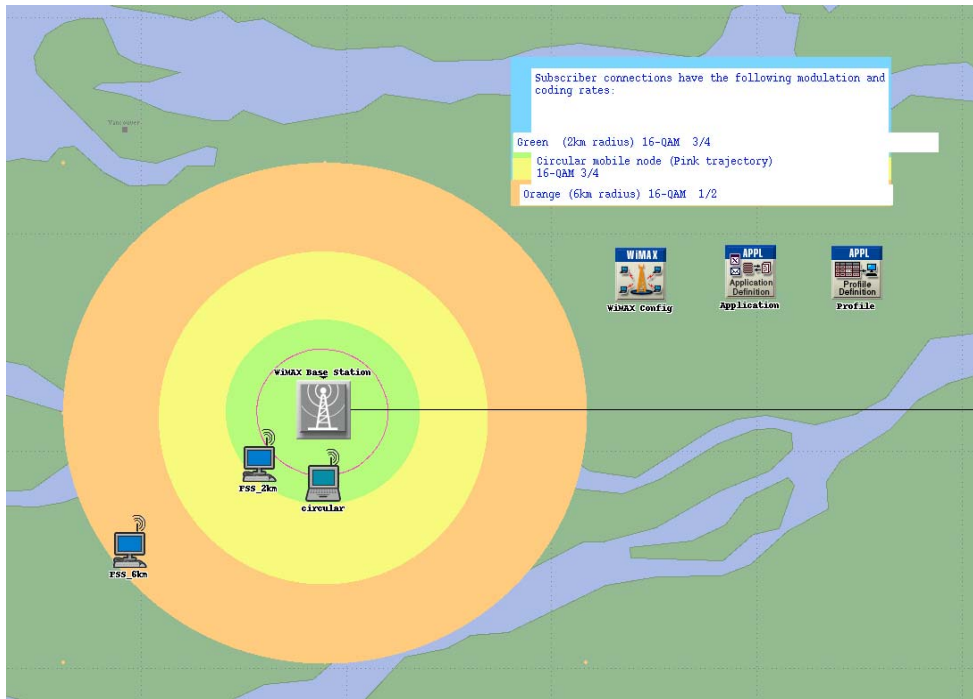


# Client Subnet Topology (Linear)



- *Two fixed WiMAX clients and one mobile client moving linearly away from the base station at a steady speed of 5 km/hr*
- *One WiMAX base station*
- *Fixed client stations located at 2km and 6km*
- *Mobile station moves from 2km to 6km.*

# Client Subnet Topology (Circular)



- *Two fixed WiMAX clients and one mobile client moving in a circular fashion at a distance of 2km from base station*
- *One WiMAX base station*
- *Fixed client stations located at 2km and 6km*
- *Mobile station moves at 5km/hr*

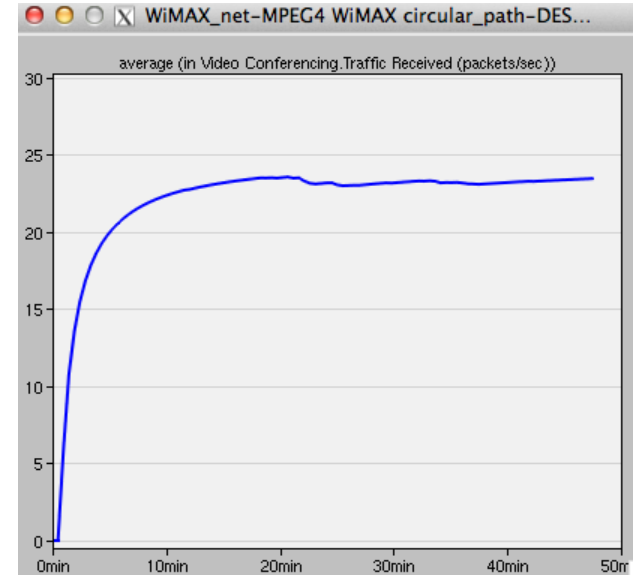
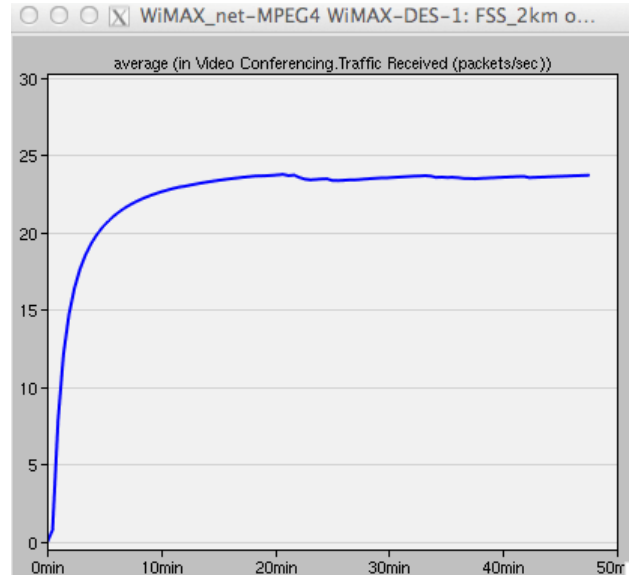
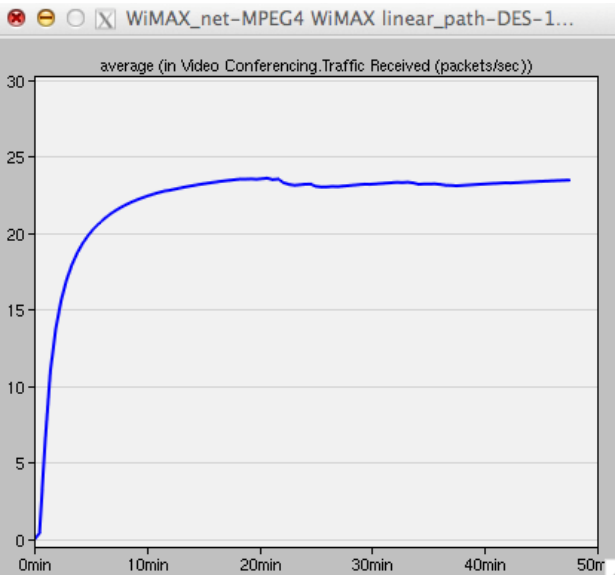


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# Validation



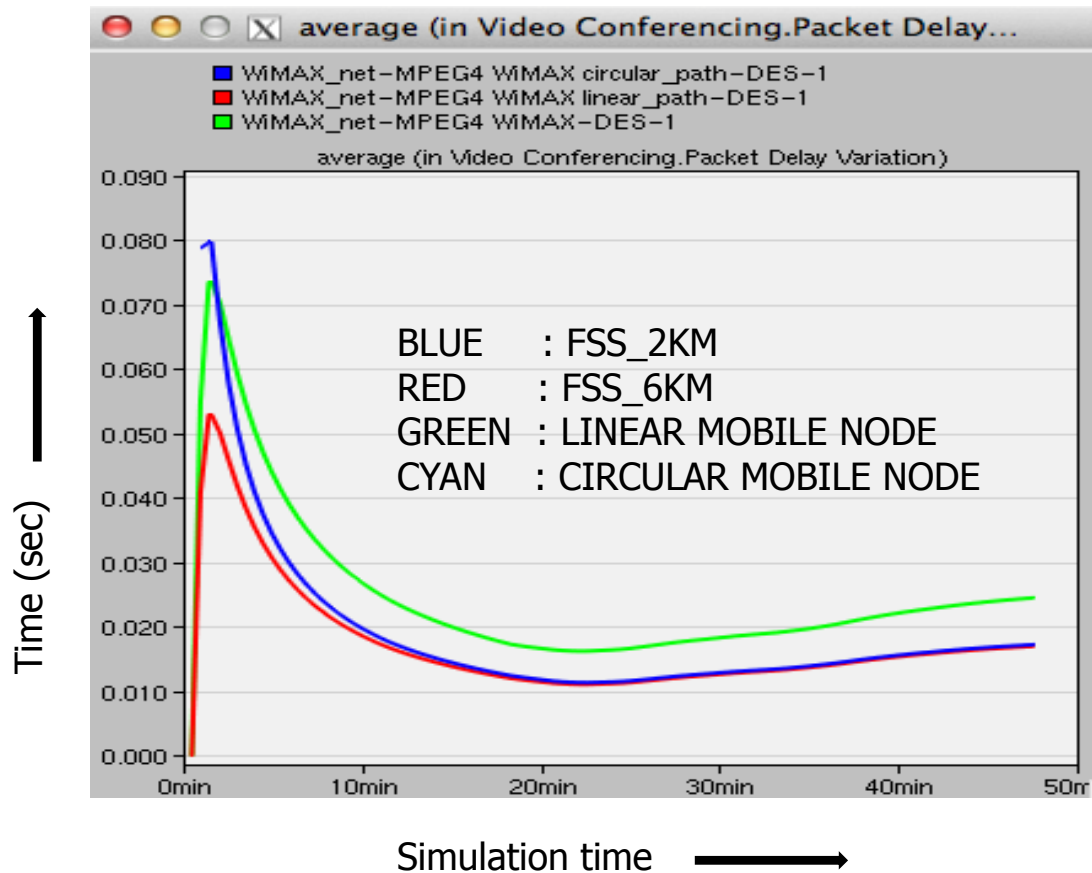
Linear Mobile  
Node Model

Reference  
Model

Circular Mobile  
Node Model

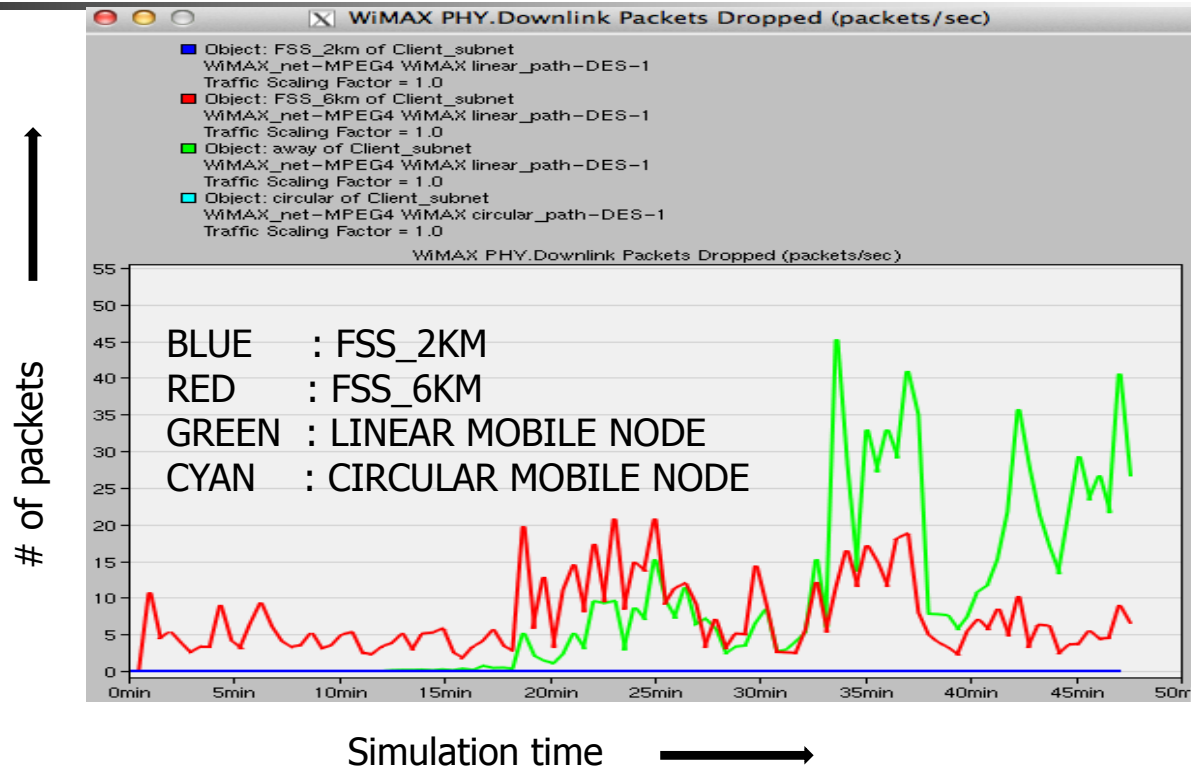
- *Comparing one of the global statistics (Traffic received) for all three cases shows that the model runs similar to the reference model.*

# Validation



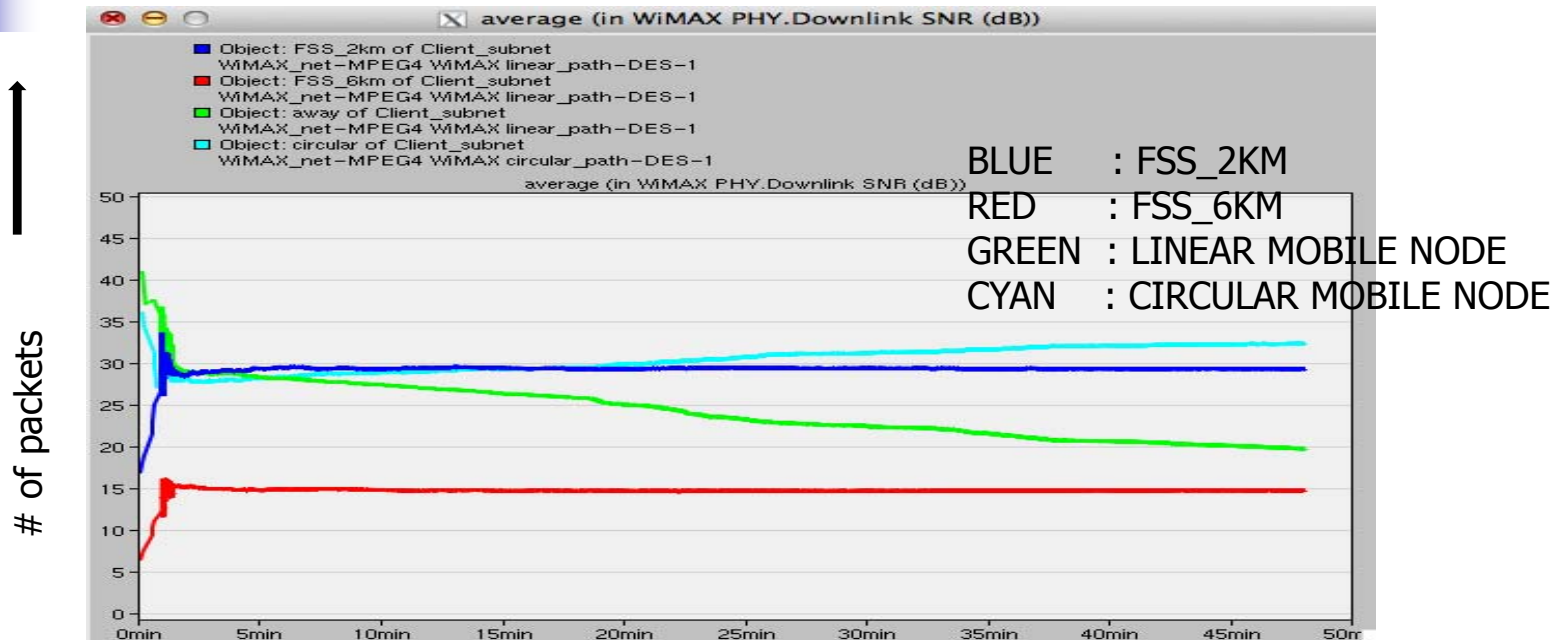
- *Average Jitter for all 4 nodes shows that they are similar and almost about the same value.*

# Packet Loss



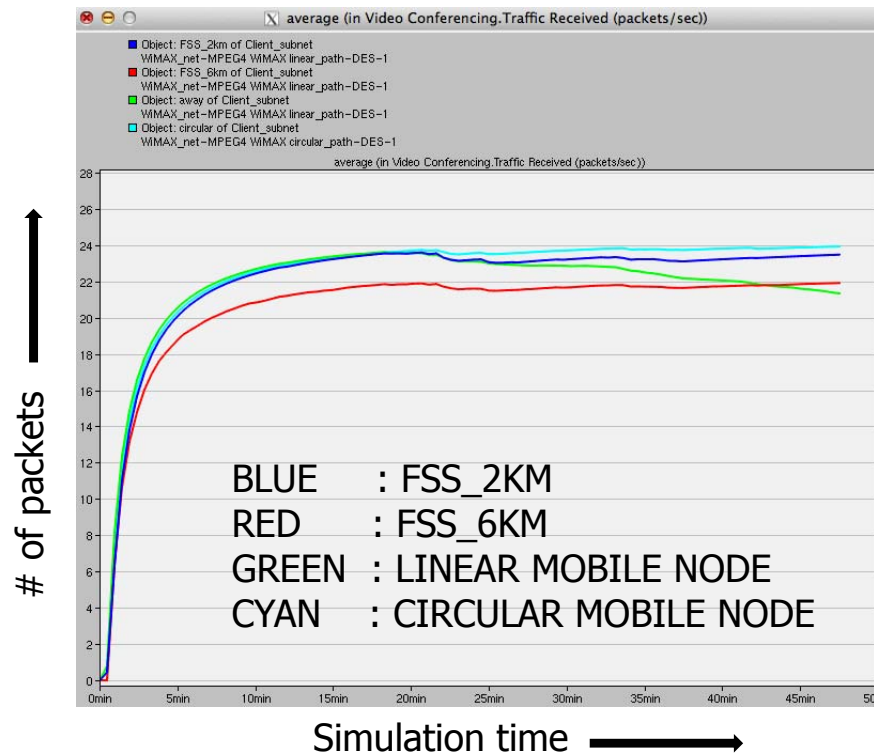
- *FSS-2KM and Circular Mobile Node : Negligible Packet Loss*
- *Linear Mobile Node : Packets Loss Increases as Distance Increases*
- *FSS\_6Km : Consistent Packet Loss Throughout Simulation*
- *Reason : Can be explained using SNR ( next slide)*

# Signal-to-Noise Ratio (Average)



- *FSS\_2KM and Circular Mobile Node have healthy SNR*
  - *Thus, packet Dropped is low.*
- *SNR of linear node decrease as distance increases*
- *SNR of FSS\_6KM is lower than required.*
  - *Thus, consistent packet loss throughout the simulation*

# Packet Loss (Average)



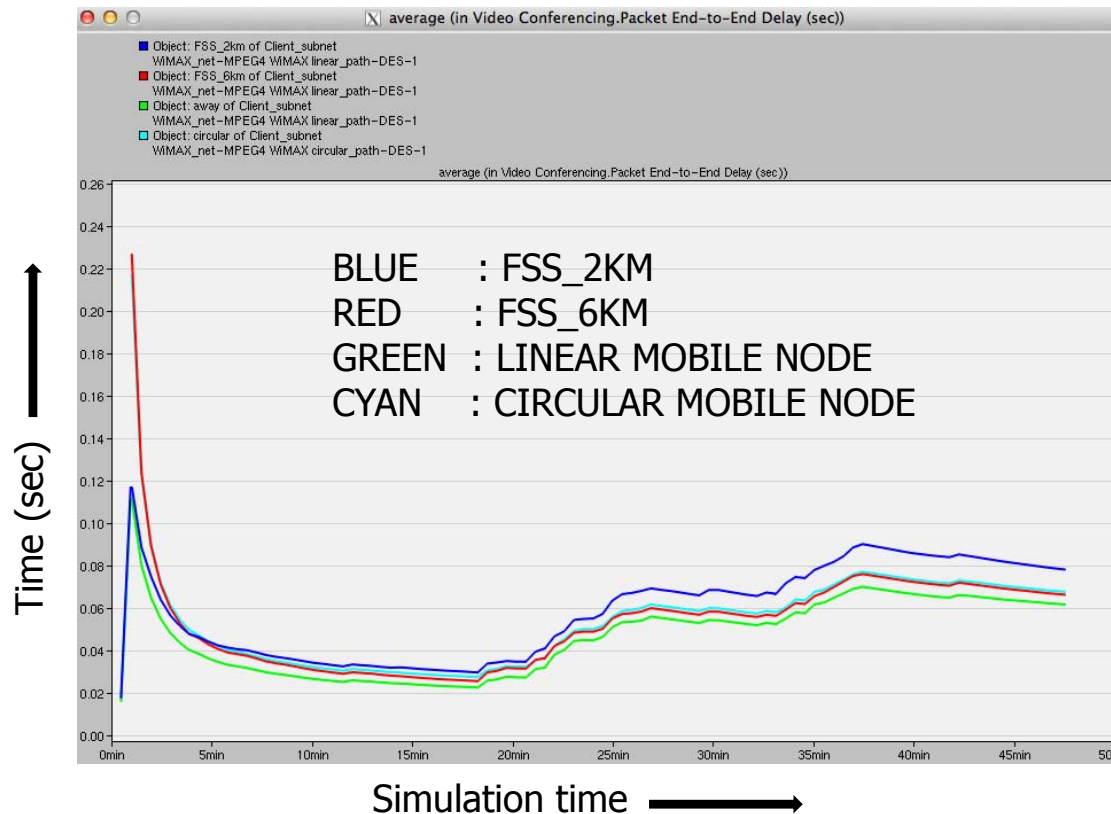
Avg:  $<10^{-3}$

Ideal:  $<10^{-5}$

- *Both mobile nodes meet the performance criteria*
- *Packet loss increases as linear mobile node moves away from the base station*



# End-to-End Packet Delay

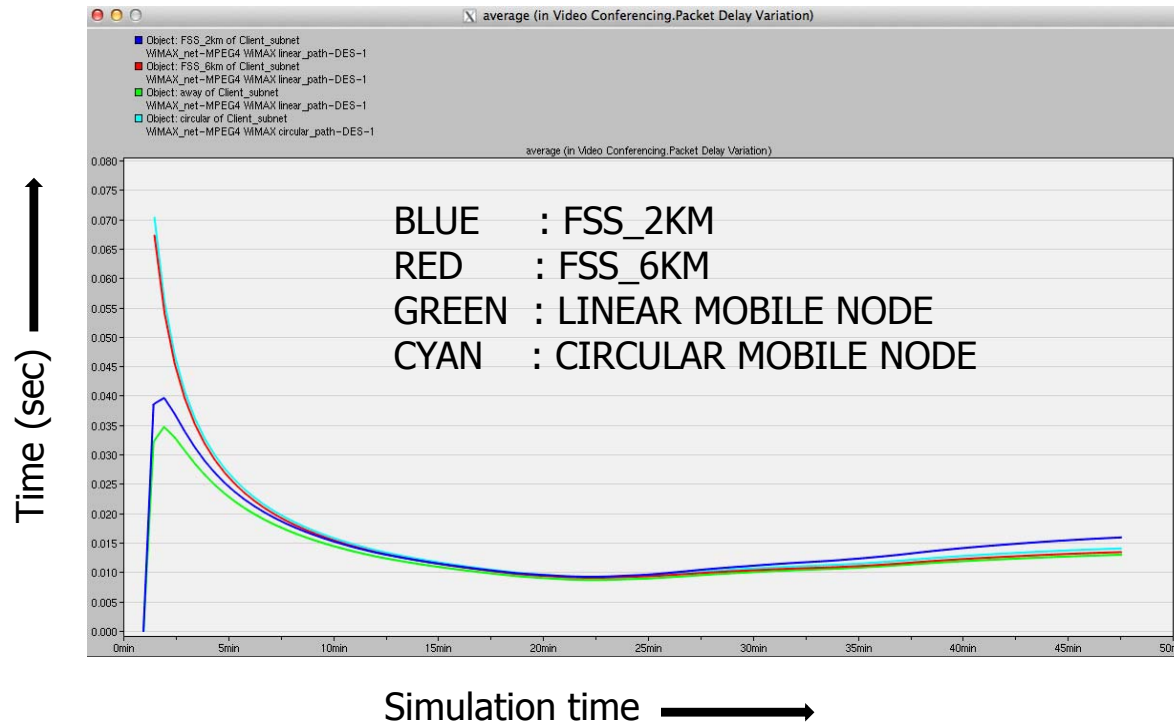


Avg: < 300 ms

Ideal: < 10 ms

- *End-to-end delay for all clients over the simulation of 48 minutes shows that mobile nodes are well within the acceptable range.*

# Delay Jitter

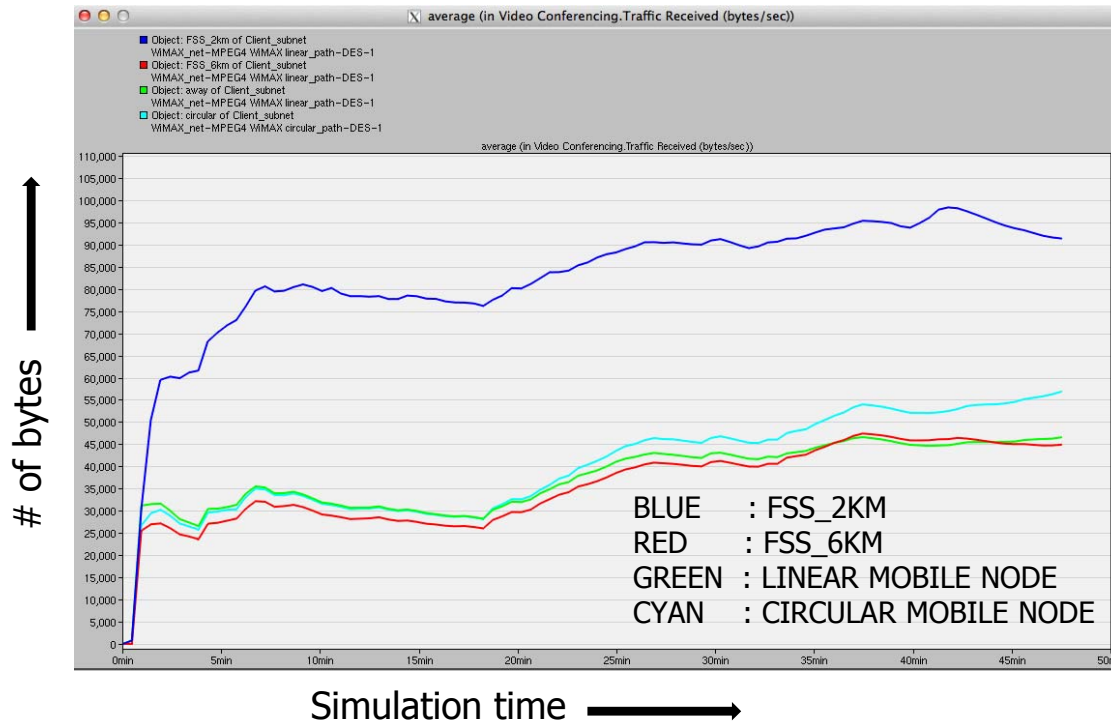


Avg: < 60 ms

Ideal: < 20 ms

- *There is no particular node that performs better. Hence, results are as expected and satisfactory.*



# Throughput



Acceptable range  
10 kbps – 5 Mbps

- *2 km station displays much better throughput than the rest*

# Overview of Analysis

	FIXED MOBILE NODE AT 2KM	FIXED MOBILE NODE AT 6KM	LINEAR MOBILE NODE MOVING FROM 2KM TO 6KM	CIRCULAR MOBILE NODE AT 2KM
PACKET LOSS	LEAST PACKET LOSS AND SIMILAR TO CIRCULAR	HIGHEST PACKET LOSS	VARIABLES AS BELOW 	LEAST PACKET LOSS AND SIMILAR TO FIXED MOBILE NODE AT 2KM
DELAY	$> 300 \text{ ms}$			
JITTER	$< 60 \text{ ms}$			
THROUGHPUT	HIGHEST THROUGHPUT	LEAST THROUGHPUT	VARIABLES AS BELOW 	2nd HIGHEST THROUGHPUT
	BLUE	RED	GREEN	CYAN



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# Conclusions

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- Extensive simulations of WiMAX wireless networks under different scenarios have been conducted and finally reached on the scenario discussed in this presentation
- Simulation time: 96 mins / Actual time: 30 mins
- WiMAX mobility passes the minimum acceptable range for various parameters
- Distance does play a role in performance output



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# Challenges and Future Work

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- Challenges:
  - Disk Quota Exceeded
  - Reference model working issue
  - Implementing mobile nodes in the current subnet
  - Defining circular trajectory
- Future Work:
  - Include random trajectories
  - Test the effect of speed on performance
  - Incorporate other applications like HTTP, email, etc
  - Test performance of mobile nodes for various buffer sizes





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# References

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- [1] Wimaxforum.org.(2001). "Mobile4G." [online] Retrieved from: <http://www.wimaxforum.org/mobile-4g> [Accessed: 22 Mar 2014].
- [2] Telegeography (2010) "Asia takes the lead in the 4G market." [Online], <http://www.telegeography.com/products/commsupdate/articles/2010/08/05/asia-takes-the-lead-in-the-4g-market/> [Accessed: 20 Mar. 2014].
- [3] M. Brain and E. Grabianowski. "How WiMAX works," <http://computer.howstuffworks.com/wimax1.html> [Accessed: 22 Mar. 2014], December 2004.
- [4] R. Prasad and V. J. Fernando, "WiMAX Networks." Springer 2010, p. 29.
- [5] J. H. Scott, "The how and why of COFDM." EBU technical Review, 1998, pp. 43-50.



# References

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- [6] C. Eklund, R. B. Marks, K. L. Stanwood, and S. Wang. "IEEE standard 802.16: a technical overview of the WirelessMAN™ air interface for broadband wireless access," IEEE Communications Magazine, vol. 40, no. 6, 2002, pp. 98-107.
  
- [7] J. Kurose and K. Ross, Computer Networking: A Top-Down Approach, 6/e. Boston, MA: Pearson/Addison-Wesley, 2010, p. 589 and p. 592.
  
- [8] W. Hruday and Lj. Trajkovic, "Streaming video content over IEEE 802.16/WiMAX broadband access," OPNETWORK, Washington, DC, Aug. 2008.
  
- [9] W. Hruday and Lj. Trajkovic, "Mobile WiMAX MAC and PHY layer optimization for IPTV," Mathematical and Computer Modelling, Elsevier, vol. 53, pp. 2119–2135, Mar. 2011.
  
- [10] R. Gill, T. Farah, and Lj. Trajkovic, "Comparison of WiMAX and ADSL performance when streaming audio and video content," OPNETWORK 2011, Washington, DC, Aug. 2011.

# Questions



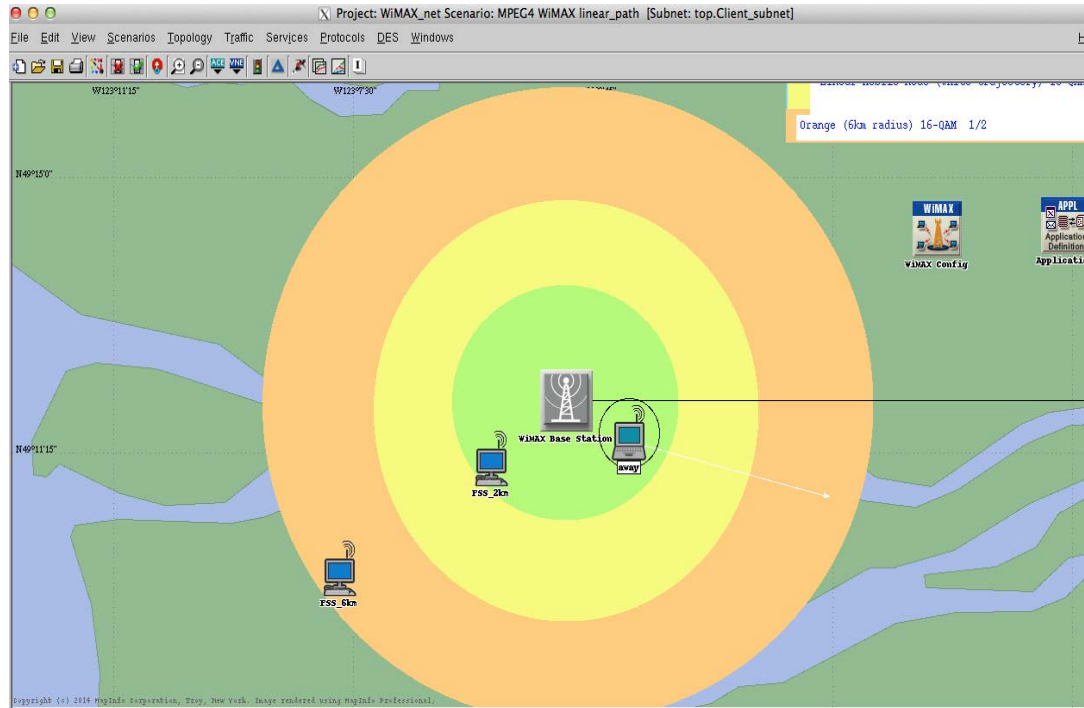


# APPENDIX

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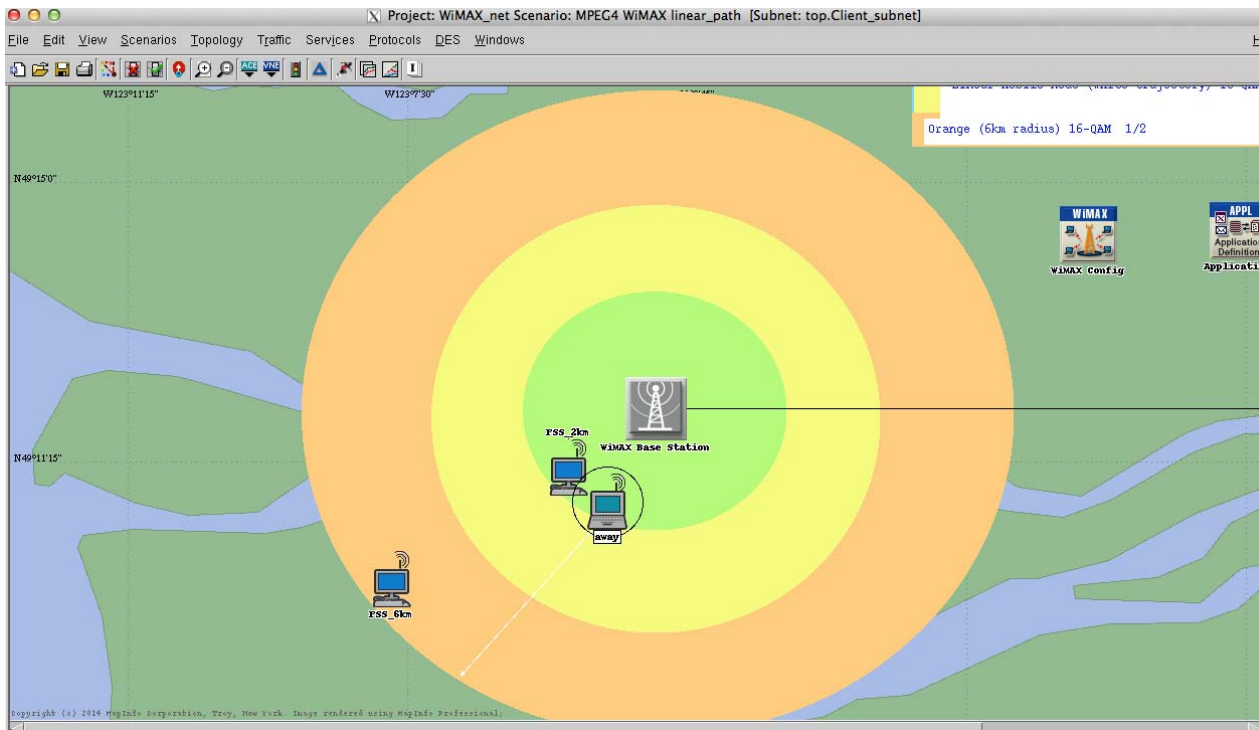
- Different trajectories tested
- Original Reference Model
- Reference Model working issue
- Reference Model fix

# Different trajectories tested (1)



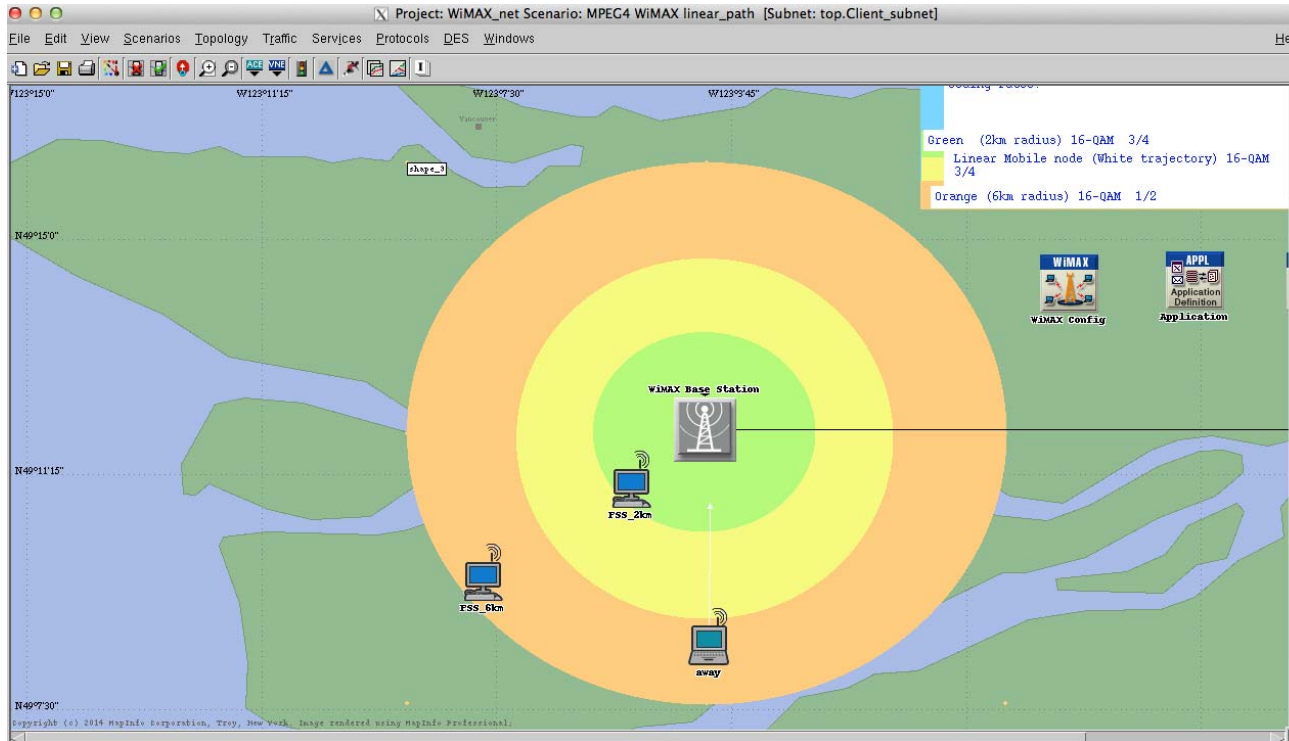
- *To test if the results are the same if a different trajectory with the same attributes as of the linear scenario are implemented.*

# Different trajectories tested (2)



- *Testing linear trajectory from tip of green circle to tip of orange circle. Realized later on that 2km from the base station is not at tip of circle instead a little inside.*

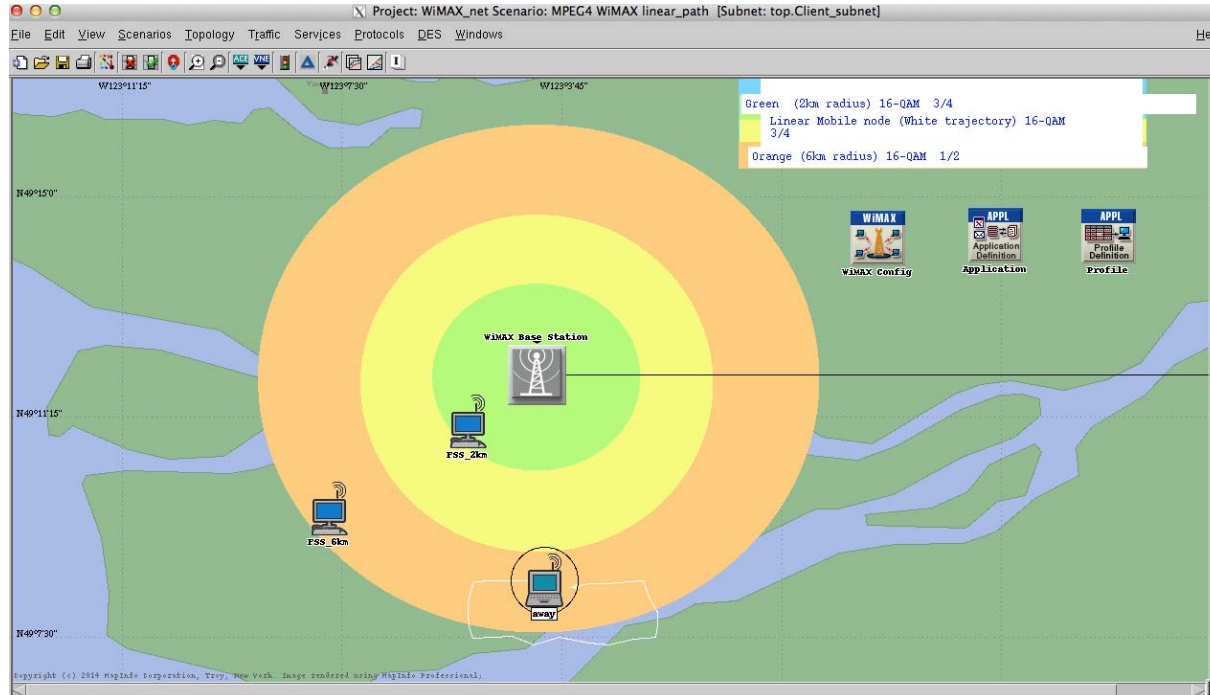
# Different trajectories tested (3)



- *We also tried to test the node moving from 6km to 2km i.e moving towards the base station. However, this scenario did not provide meaning to our project goal.*

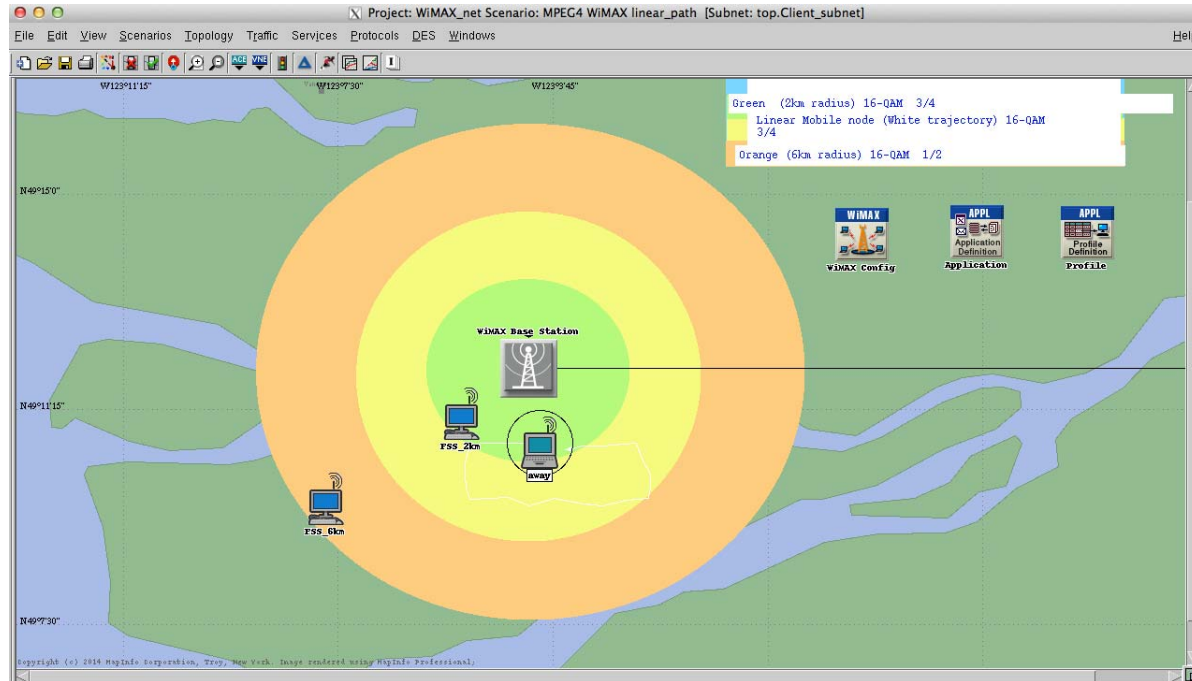


# Different trajectories tested (4)



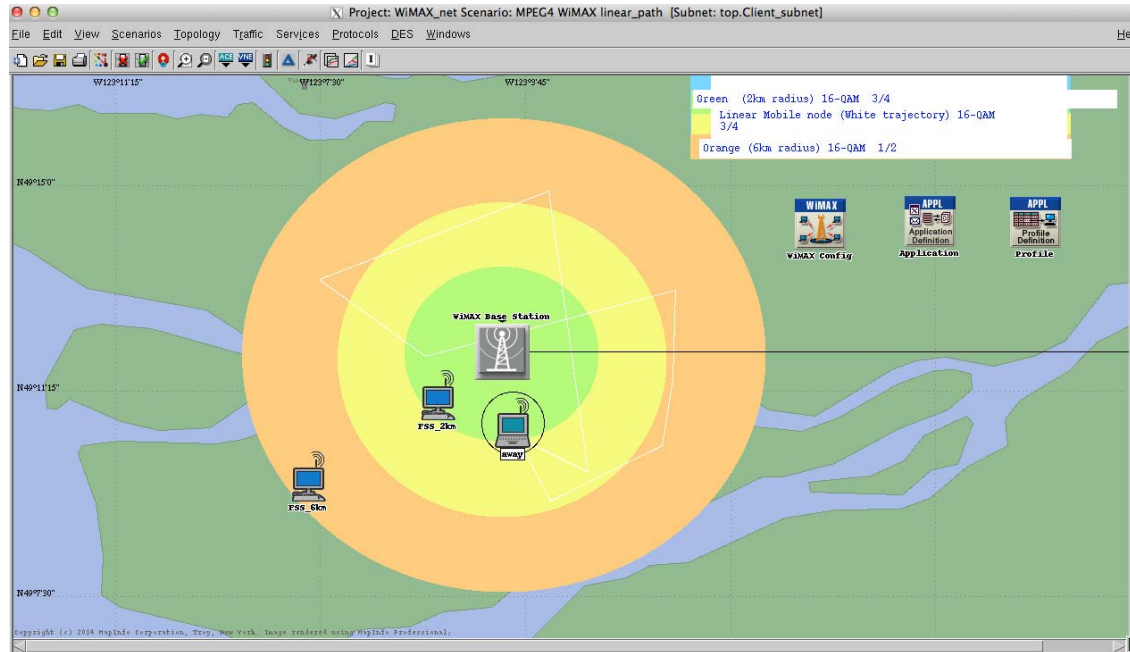
- *Implementing random trajectory using built-in tools where the node moves out of the circle for some time and comes back in. Again this scenario had no purpose in our final goal although it was meaningful at the start of the project.*

# Different trajectories tested (5)



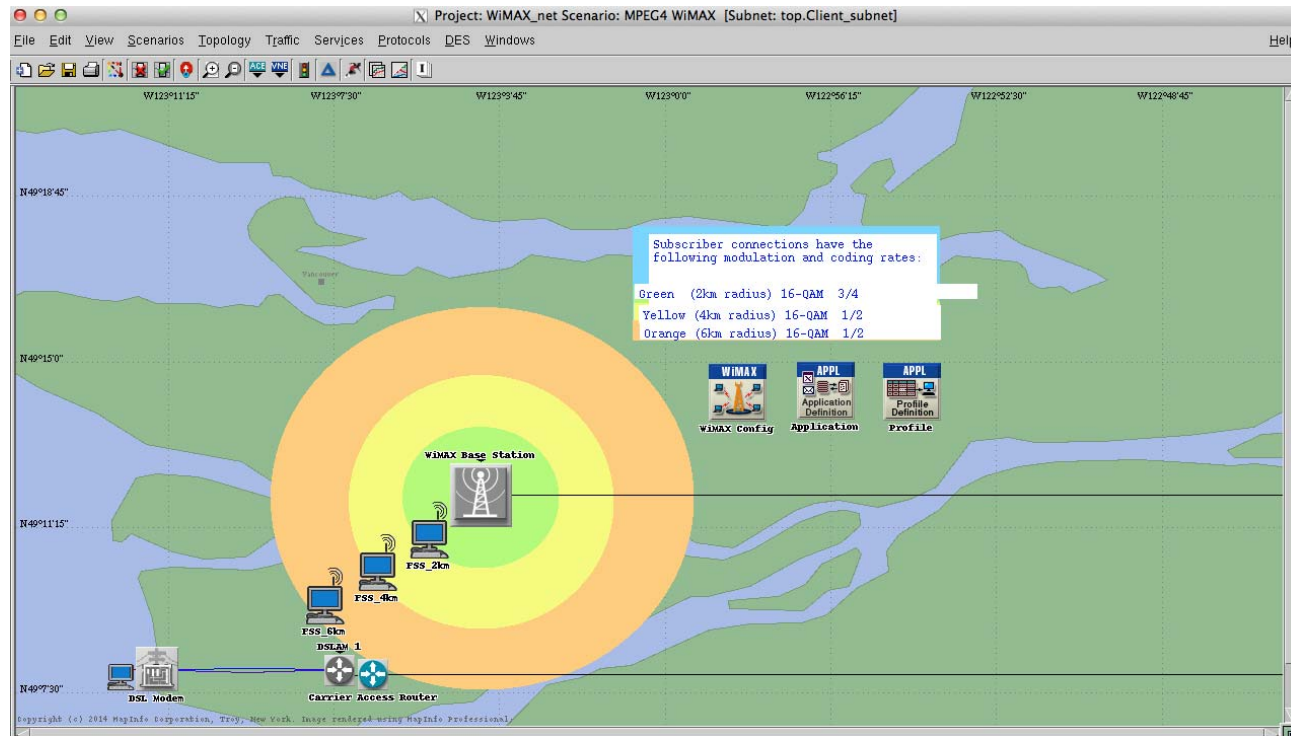
- *Using the same random trajectory again but this time the node is at 2km.*

# Different trajectories tested (6)



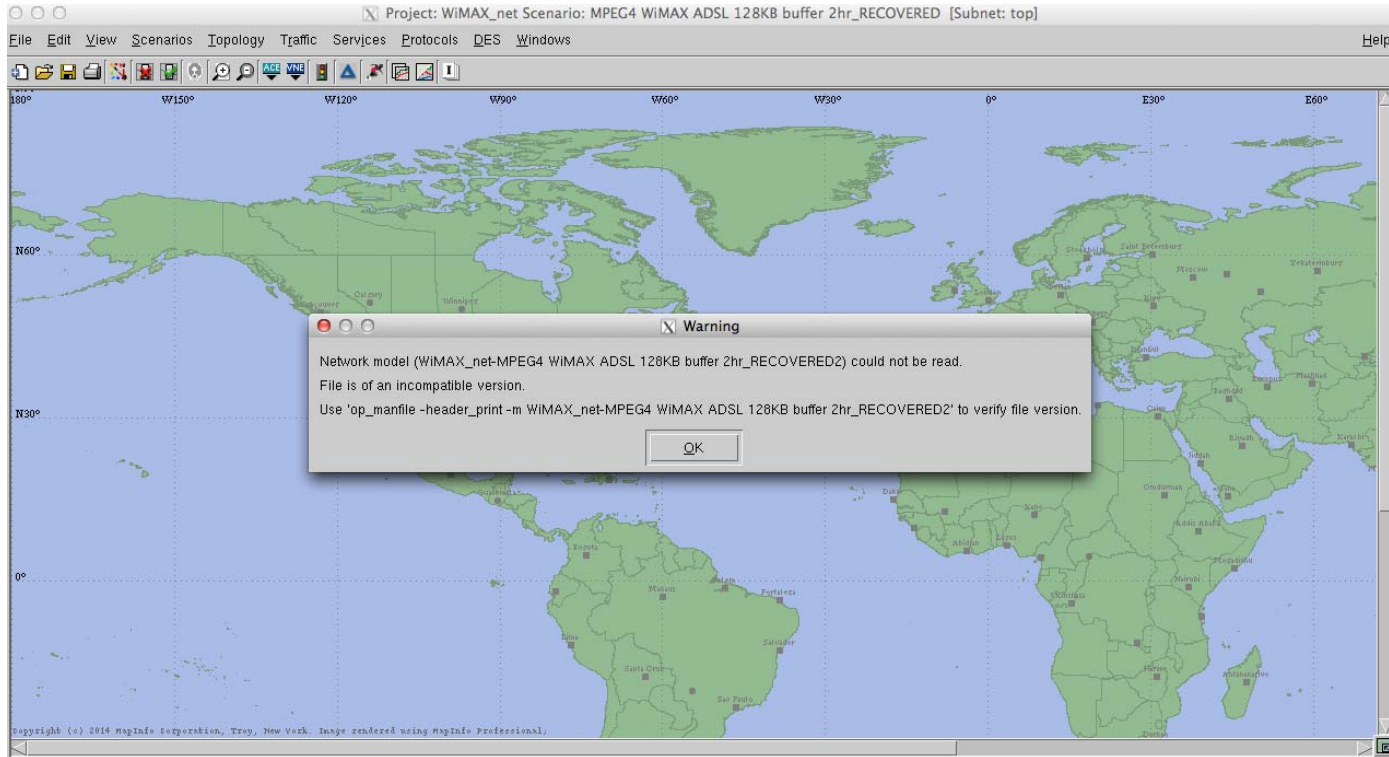
- *Implementing a random trajectory which would be much more realistic for a user that moves around in the range of the current base station.*

# Original Reference Model



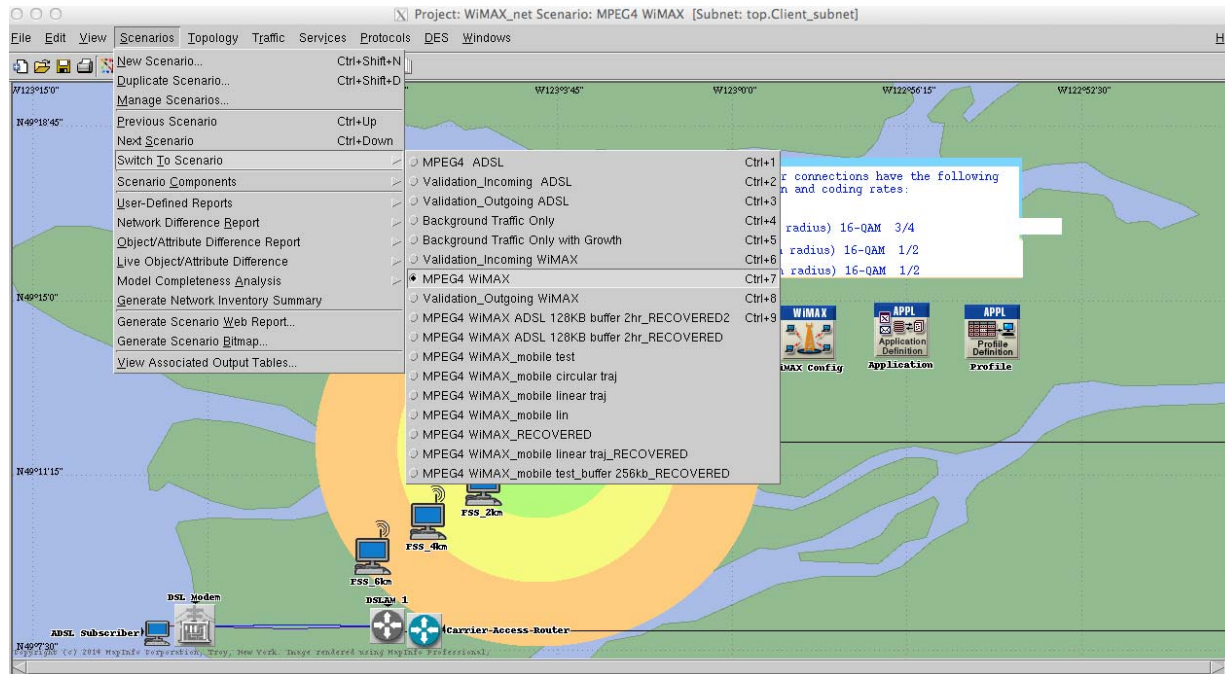
- *We removed the ADSL network completely and also the 4km node as it was not giving any meaning to our project goal.*

# Reference Model working issue



- *As soon as you try to open the reference model in OPNET, you will get the above error and after clicking OK, it will show you an empty map.*

# Reference Model working fix



- *The trick is, only a few scenarios work in the model. For our purpose, we switched scenario to MPEG4 WiMAX and built our model from there after duplicating the scenario.*