



# Streaming Video Content Over WiMAX Broadband Access

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# Roadmap

- Introduction
- Related work
- OPNET model
- Simulation results:
  - packet loss, delay, and jitter
  - traffic throughput
- Conclusions and future work
- References

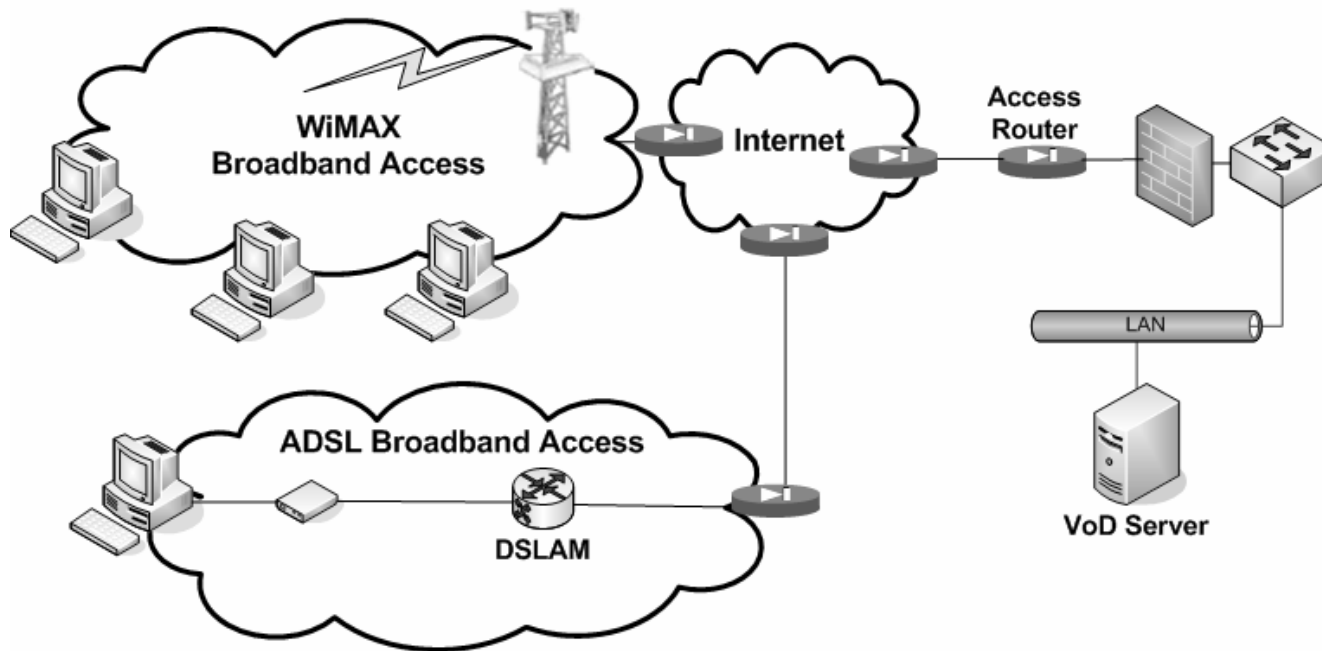


# Introduction



- Focus of this study:

Can WiMAX deliver comparable network performance to ADSL broadband access for streaming video applications?



Simulation streaming an MPEG-4 two-hour movie to four video clients

# WiMAX Broadband Access

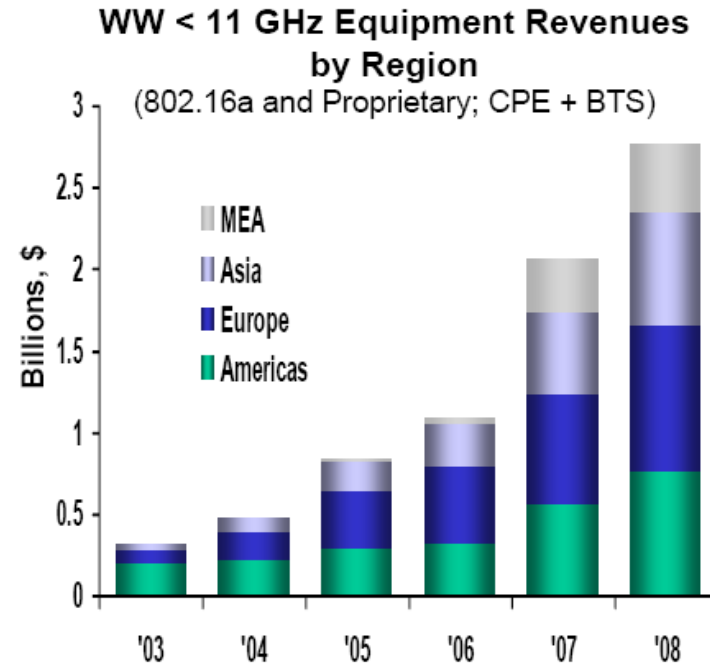
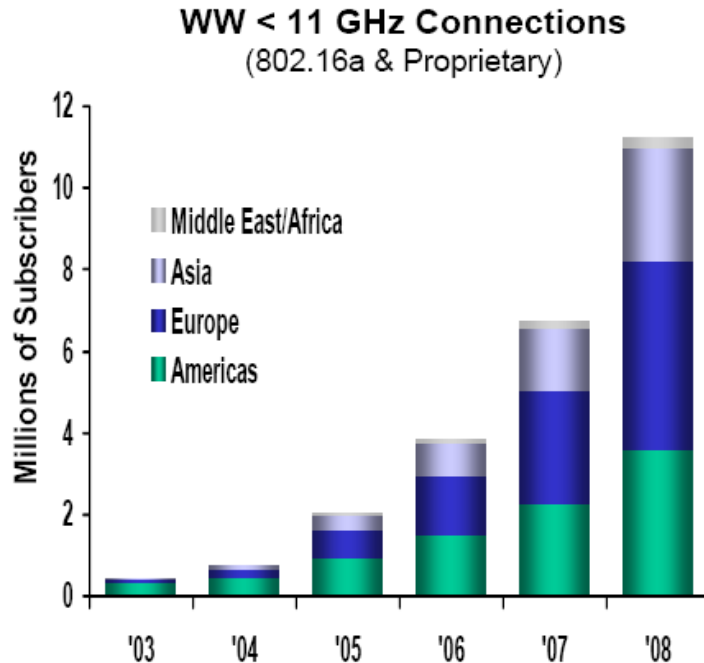


- Worldwide interoperability for microwave access:
  - IEEE 802.16-2004
  - IEEE 802.16e-2005
- All IP network architecture
- Point-to-multipoint (PMP) mode
- Connection oriented: bandwidth request/grant scheme
- Flexible QoS supports voice and video
- Optimum spectral efficiency
- Channel bandwidth: 1.25 – 20 MHz
- Typical cell size: 7 – 10 km
- Optimized for outdoors
- Provides fixed, nomadic, and mobile usage

# WiMAX Growth



## ■ Why WiMAX?



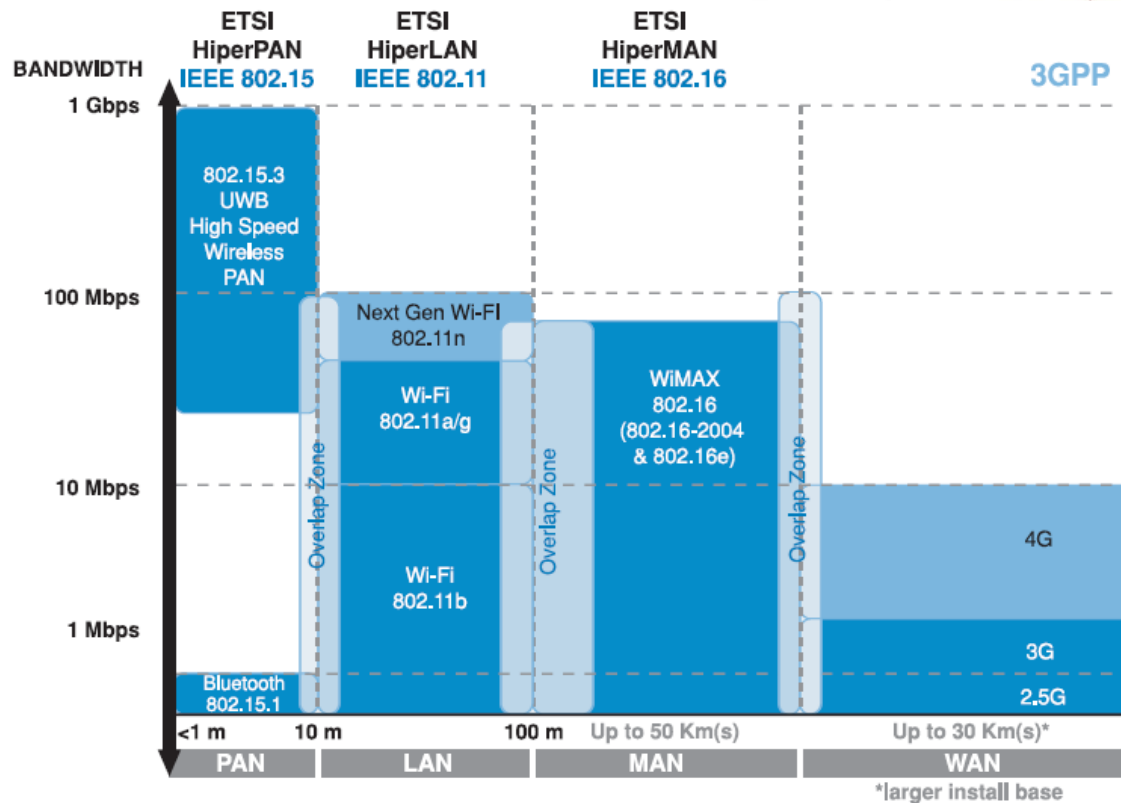
M. LaBrecque, WiMAX introduction [Online]. Available:  
<http://www.wimaxforum.org/technology/downloads> (February 2008).

- WiMAX Forum March press release: 133 million users by 2012
- OPNETWORK 2007 conference cited > 100 planned carrier trials

# Wireless Technologies



- WiMAX Broadband Access

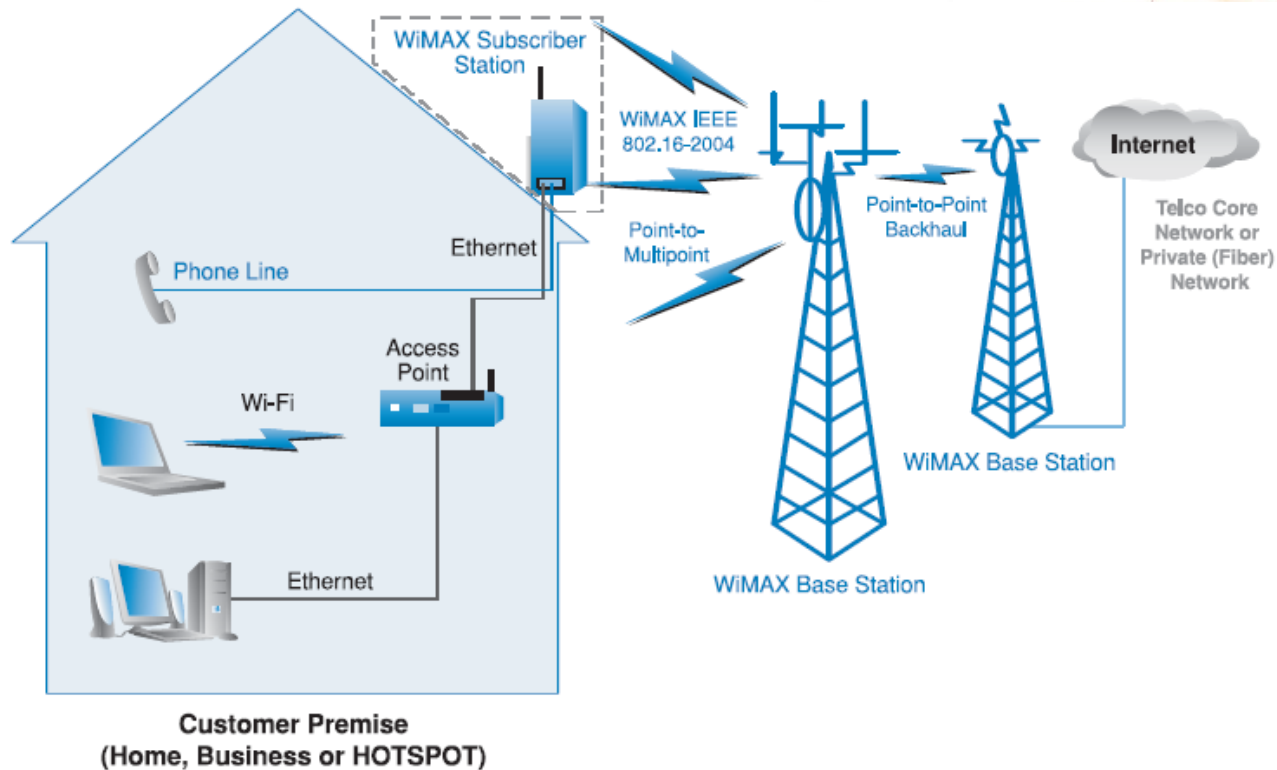


Intel, Understanding Wi-Fi and WiMAX as metro-access solutions [Online]. Available: <http://www.rclient.com/PDFs/IntelPaper.pdf> (February 2008).

# Client Connection



## ■ WiMAX Broadband Access



Intel, Understanding Wi-Fi and WiMAX as metro-access solutions [Online]. Available: <http://www.rclient.com/PDFs/IntelPaper.pdf> (February 2008).

# Video Services



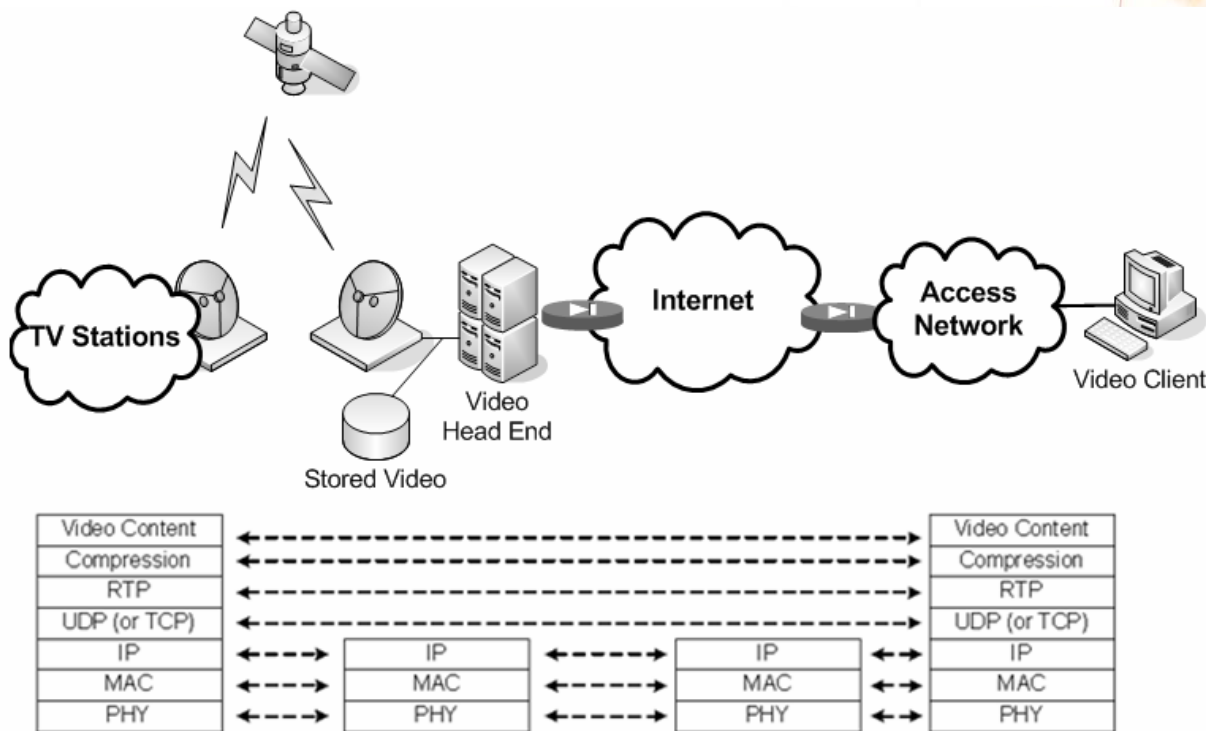
- Video Content Streaming
  - Digital video source delivered to video clients over an IP network infrastructure:
    - digital video information is organized as frames
    - frames are compressed using a video codec
    - compressed frames are encapsulated in protocol headers
    - video frame packets are transmitted at a constant rate
  - Video packets may be IP multicast or IP unicast
  - Managed services                      Unmanaged services
    - IPTV (live & VoD)                      ■ IPTV (live & VoD)
    - Video conferencing                      ■ YouTube, Google Video



# Video Streaming



## ■ Architecture



I. Uilecan, C. Zhou, and G. Atkin, "Framework for delivering IPTV services over WiMAX wireless networks," *Proc IEEE EIT 2007*, Chicago, IL, May 2007, pp. 470-475.

# Video Coding Schemes



- Exploit temporal and spatial characteristics
- Various standards and codecs
  - ITU (H.26x) and ISO (MPEG-x)

Codec	Raw data rate	Compressed rate
MPEG-1	30 Mbps	1.5 Mbps
MPEG-2	128 Mbps	3 – 10 Mbps
MPEG-4		< 1.024 Mbps

Based on QCIF and/or CIF video formats

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# Related work



- D. Niyato, E. Hossain, and J. Diamond, "IEEE802.16/WiMAX-Based broadband wireless access and its application for telemedicine / e-health services," *IEEE Wireless Communications Magazine*, vol. 14, no.1, pp. 72-83, Feb. 2007.
  - simulation performed in Matlab
- F. Retnasothie, M. Ozdemir, T. Yucek, H. Celebi, J. Zhang, and R. Muththaiah, "Wireless IPTV over WiMAX: challenges and applications," *Proc. IEEE WAMICON 2006*, Clearwater, FL, Dec. 2006, pp. 1-5.
  - no simulations
- F. Yousaf, K. Daniel, and C. Wietfeld, "Performance evaluation of IEEE 802.16 WiMAX link with respect to higher layer protocols," *Proc. IEEE ISWCS 2007*, Trondheim, Norway, Oct. 2007, pp. 180-184.
  - utilized testbed instead of simulations
- I. Uilecan, C. Zhou, and G. Atkin, "Framework for delivering IPTV services over WiMAX wireless networks," *Proc IEEE EIT 2007*, Chicago, IL, May 2007, pp. 470-475.
  - no simulations

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# Performance Metrics



- Loss: Number of packets dropped
  - $1 - (\# \text{ of received packets}) / (\# \text{ of expected packets})$
  - Avg:  $< 10^{-3}$       Ideal:  $< 10^{-5}$
  
- Delay: Average time of transit
  - Processing delay + propagation delay + queuing delay
  - Avg:  $< 300 \text{ ms}$       Ideal:  $< 10 \text{ ms}$
  
- Jitter: Variation in packet arrival time
  - Actual reception time – expected reception time
  - Avg:  $< 60 \text{ ms}$       Ideal:  $< 20 \text{ ms}$
  
- Throughput: Minimum end-to-end transmission rate
  - Measured in bytes/sec (bps)
  - 10 kbps – 5 Mbps

# Development Platform

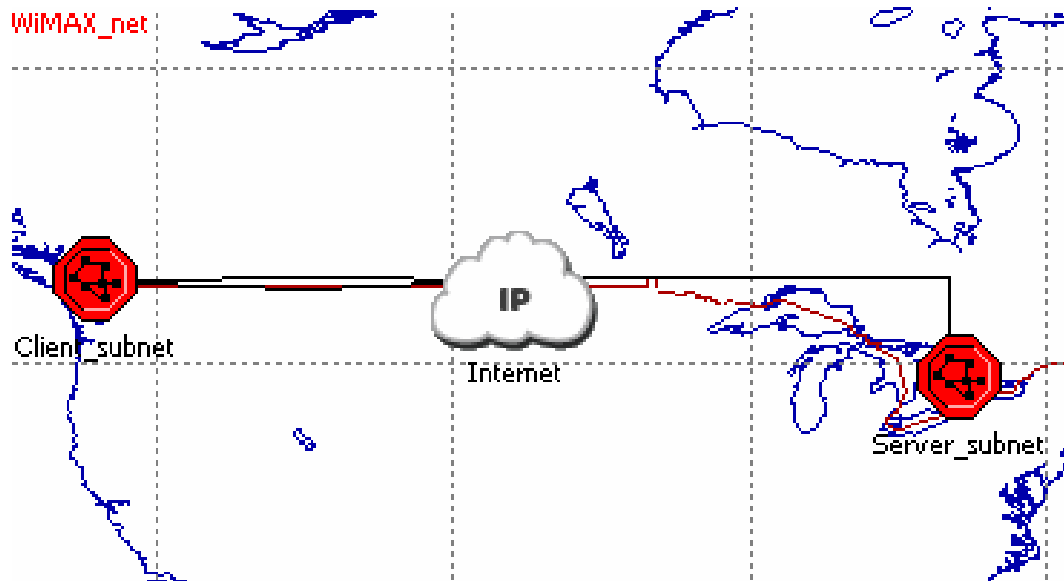
- Toshiba Tecra S2 laptop:
  - Intel Pentium M Processor / 1GB RAM
  - Windows XP Service Pack 2
- OPNET 12.0.A PL3 + WiMAX Module:
  - integrated WiMAX and ADSL nodes
  - generic video conferencing application
- Visual Studio .NET 2003 development environment:
  - required to compile models



# Simulated Network Topology



- Network:
  - video services subnet located in Toronto
  - video clients subnet located in Vancouver (distance: 3,342 km)



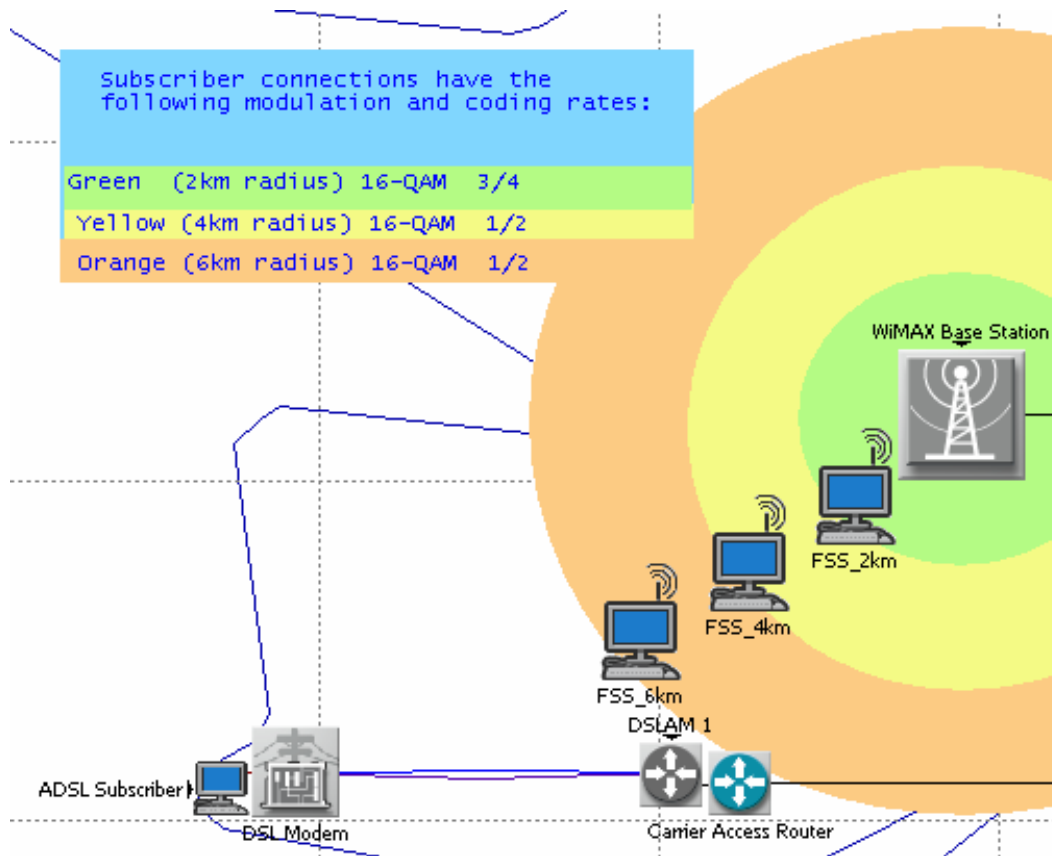
- Client WAN link  
1,547 km  
6.1 ms  $d_{prop}$
- Server WAN link  
1,795 km  
7.2 ms  $d_{prop}$



# Video Clients Topology



- Subnet



- three WiMAX stations  
2, 4, and 6 km from  
base station
- one ADSL station  
1 km from central  
office

# Network Design Parameters



- Network:
  - ADSL configuration:
    - downlink: 3.0 Mbps / uplink: 0.640 Mbps
    - subscriber to central office: 5 km delay based link
  - Adopted latitude / longitude coordinate system to model pathloss and propagation delay
  - WiMAX clients are located 2/4/6 km from base station:
    - manually configured robust burst profiles as a function of distance
  - Reviewed Motorola datasheets for current generation WiMAX hardware

# Network Design Parameters



- WiMAX deployment parameters (not disclosed without NDA):
  - Scheduling algorithm: best effort (BE)
  - Min sustainable data rate:  
downlink: 3.0 Mbps / uplink: 0.640 Mbps
  - Frequency band/channel bandwidth: 2.5 GHz / 5 MHz
    - derived 5 MHz channel definition
  - PHY layer access scheme: OFDM 512
  - Transmit power levels (BS/SS): 5W/2W
  - Pathloss model: suburban with mostly flat terrain with light tree densities

# Network Design Parameters



- Required SNR for modulation / coding

Modulation	Coding	Information Bits/symbol/Hz	Required SNR (dB)
QPSK	1/2	1	9.4
	3/4	1.5	11.2
16-QAM	1/2	2	16.4
	3/4	3	18.2
64-QAM	2/3	4	22.7
	3/4	4.5	24.4

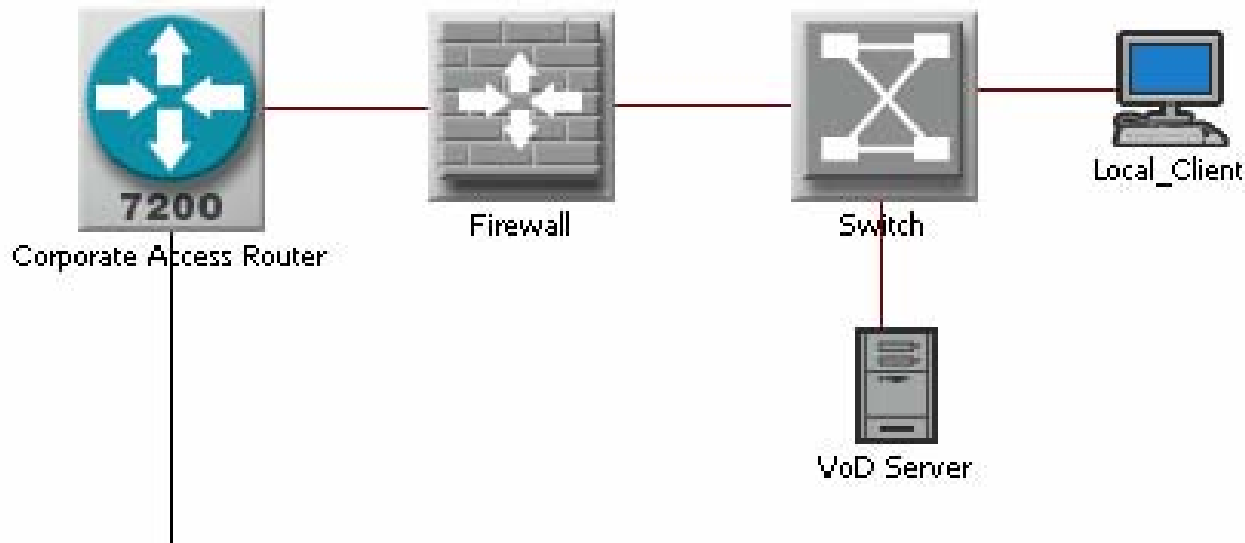
- OFDM 512 subcarriers

Frequency Division		
	DL Zone	UL Zone
Number of Null Subcarriers - Lower Edge	46	52
Number of Null Subcarriers - Upper Edge	45	51
Number of Data Subcarriers	360	272
Number of Subchannels	15	17

# Video Services Topology



- Subnet



- Server provides video on demand (VoD) services
- Local client used only for initial troubleshooting and validation

# Video Design Configuration

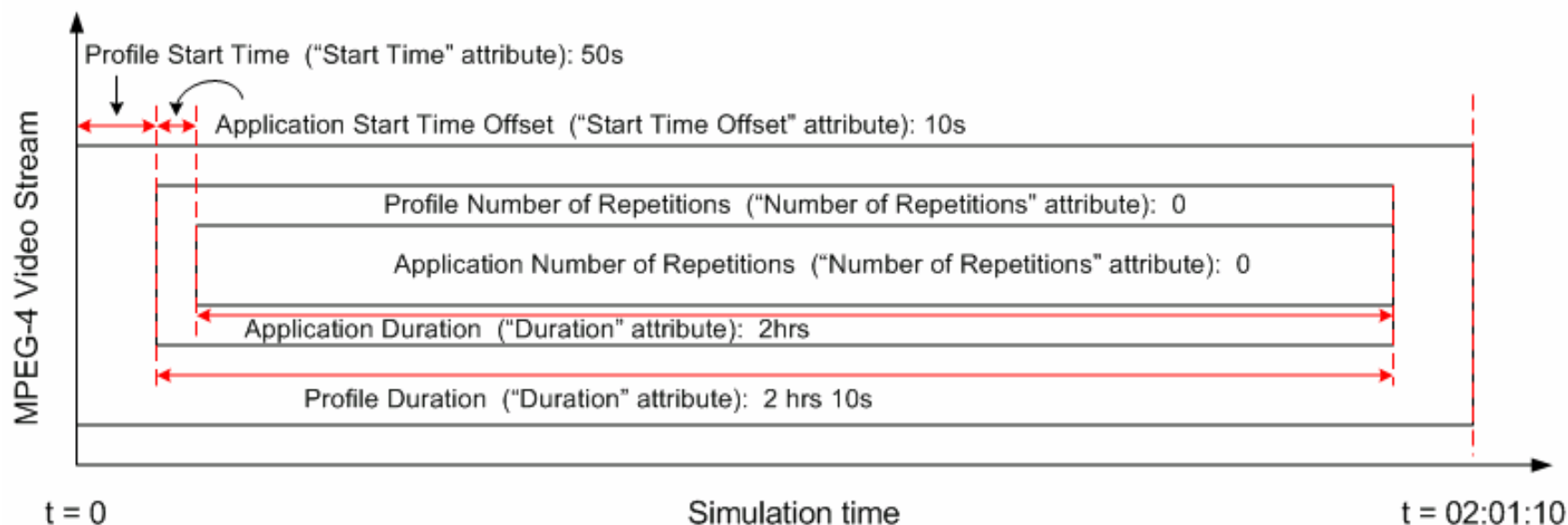


- Video traffic is loss tolerant but delay sensitive
- Simulation model is trace driven
- Configured 2 video streams:
  - MPEG-2 1280x720 at 30 fps (performed poorly)
  - MPEG-4 352x288 at 25 fps (primary stream)
- Video trace pre-processing:
  - sorted into codec sequence (versus display sequence)
  - converted frame sizes to bytes
  - imported into OPNET as a distribution
- Configured Application and Profiles Nodes
- Promoted necessary statistics

# Video Traffic Profile Parameters



- Traffic profile

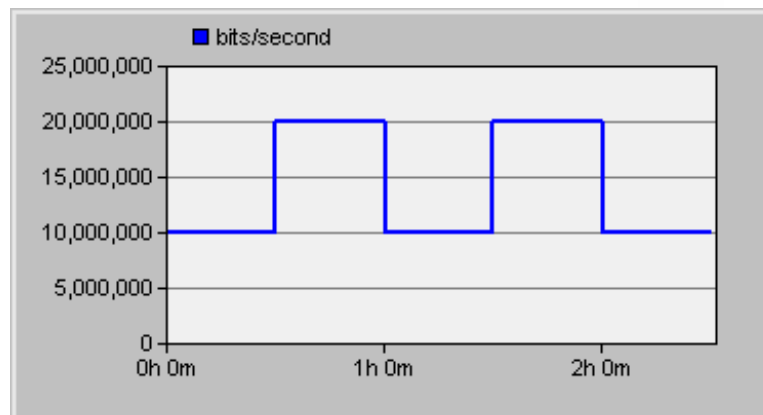
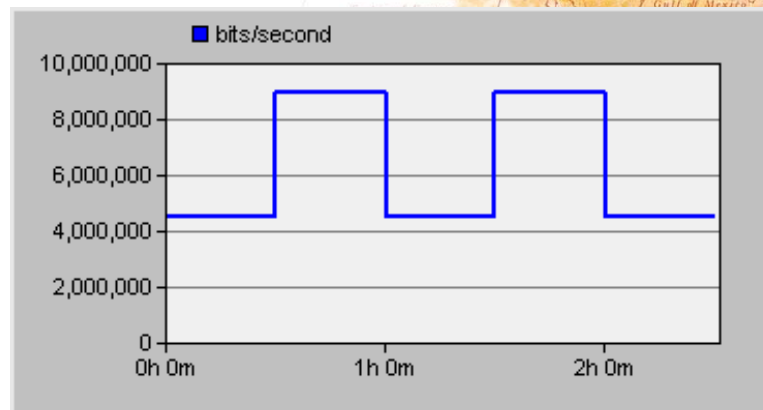


- MPEG-2 performed poorly: simulation employed an MPEG-4 stream

# Network Background Traffic



- WAN Links:
  - 10-20% background traffic
- LAN Links:
  - 10-20% background traffic
- Internet:
  - packet discard ratio: 0.001 %
  - packet latency: 0.001 s



- Background traffic growth: 10% every 30 min



# Video Traces



- Traffic Details

Parameters	Validation	T2	Matrix III
Resolution	128x120	1280x720	352x288
Codec	<none>	MPEG-2	MPEG-4 Part 2
Frame Compression Ratio	1	58.001	47.682
Min Frame Size (Bytes)	17280	627	8
Max Frame Size (Bytes)	17280	127036	36450
Mean Frame Size (Bytes)	17280	23833.792	3189.068
Display Pattern	N/A	IBBPBBPBBPBB	IBBPBBPBBPBB
Transmission Pattern	N/A	IPBBPBBPBBIB	IPBBPBBPBBIB
Group of Picture Size	N/A	12	12
<b>Frame Rate (frames/sec)</b>	<b>1</b>	<b>30</b>	<b>25</b>
Number of Frames	7,200	324,000	180,000
Peak Rate (Mbps)	0.138	30.488	7.290
<b>Mean Rate (Mbps)</b>	<b>0.138</b>	<b>5.720</b>	<b>0.637</b>

- Note peak and mean rates for MPEG-2 and MPEG-4 traffic

# Simulation Model



- Limitations:
  - video traffic only<sup>\*</sup>
  - no RTP encapsulation
  - WiMAX AMC not available<sup>\*\*</sup>
  - WiMAX power management not available<sup>\*\*</sup>

- \* G. Auwera, P. David, and M. Reisslein, "Traffic characteristics of H.264/AVC variable bit rate video," [Online]. Available: <http://trace.eas.asu.edu/h264/index.html> (March 2008).
- \* G. Auwera, P. David, and M. Reisslein, "Traffic and quality characterization of single-layer video streams encoded with the H.264/MPEG-4 advanced video coding standard and scalable video coding extension" [Online]. Available: <http://trace.eas.asu.edu/h264/index.html> (March 2008).
- \*\* OPNET WiMAX (802.16e) model user guide [Online]. Available via OPNET WiMAX registration.

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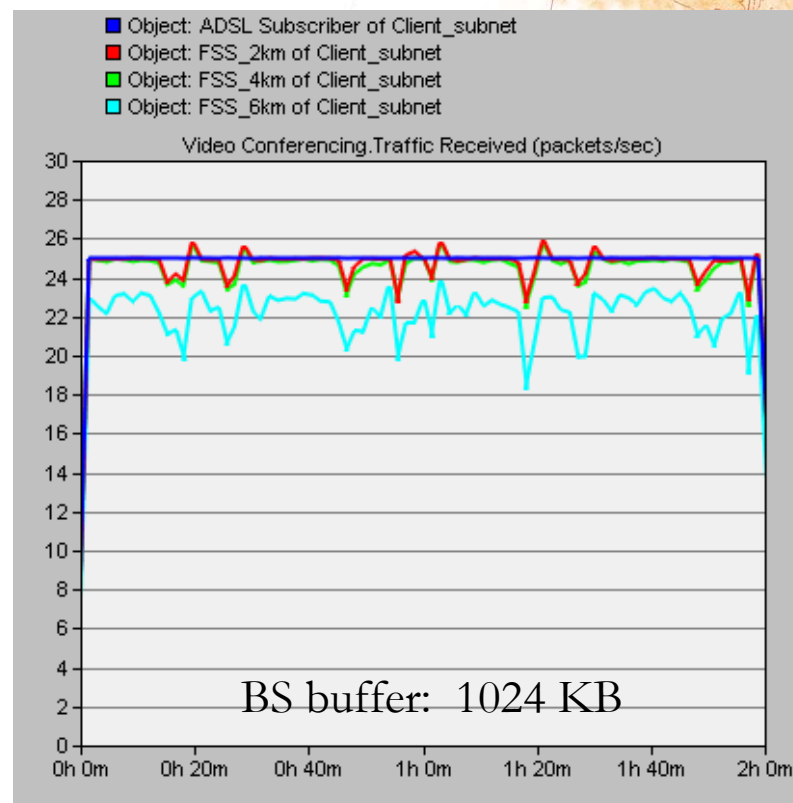
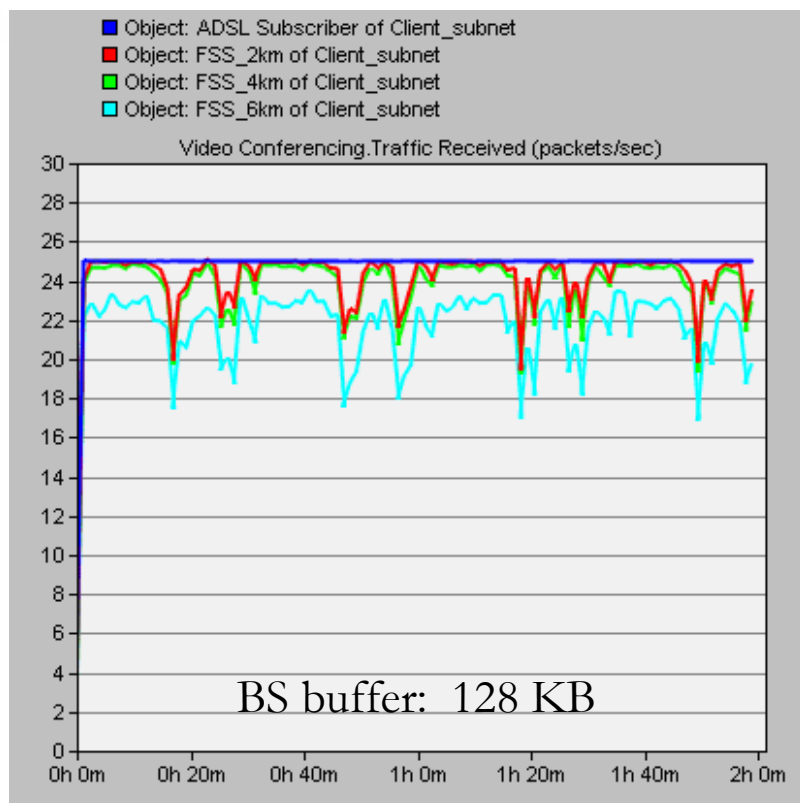
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# Video Packet Loss

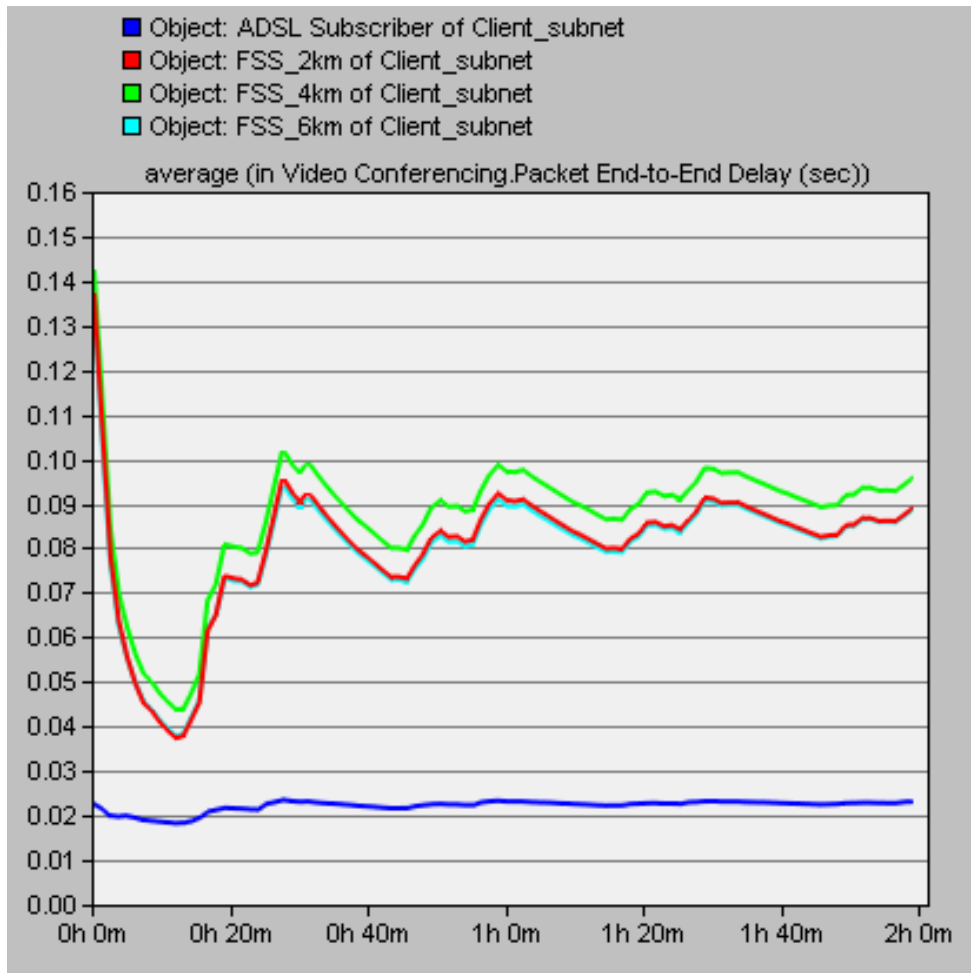


## ■ Instantaneous values



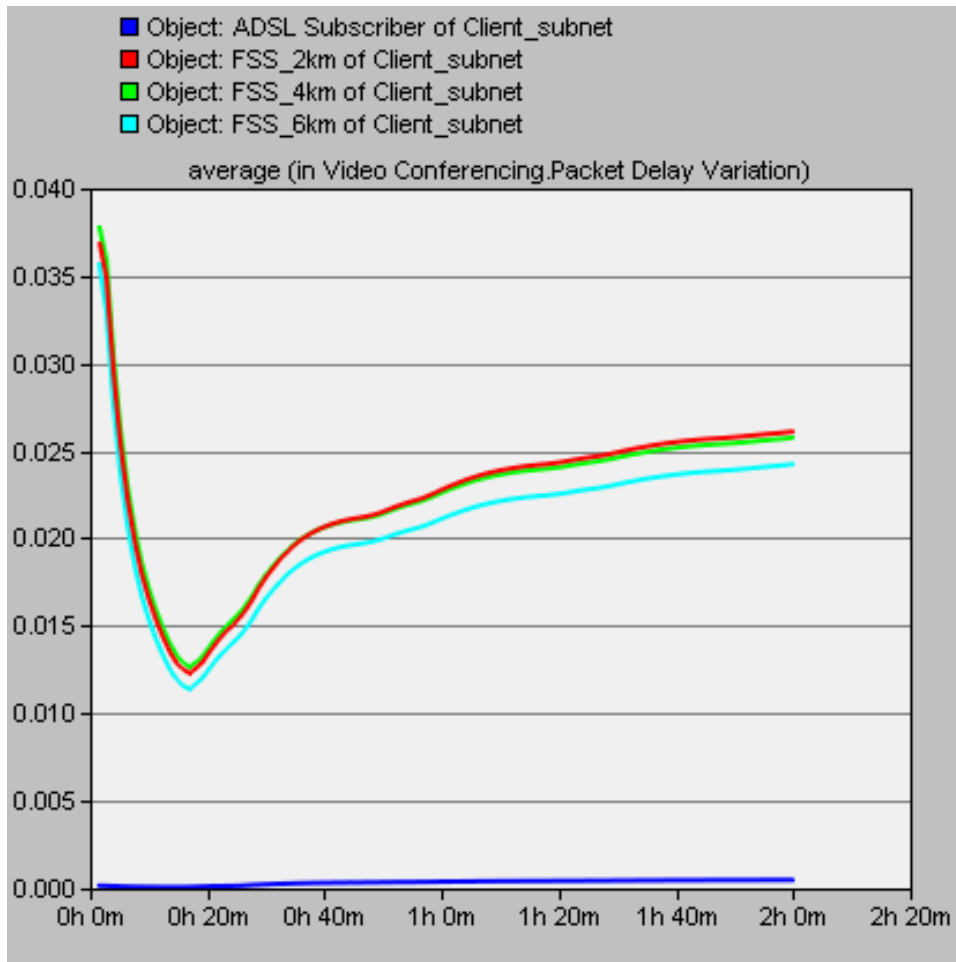
- Loss is depicted as deviation from the blue line representing 25 pkts/sec
- 1024 KB is large enough to prevent dropped downlink packets at BS
- 6 km WiMAX station loss because SNR is  $<$  min level for modulation/coding

# Video Packet Delay



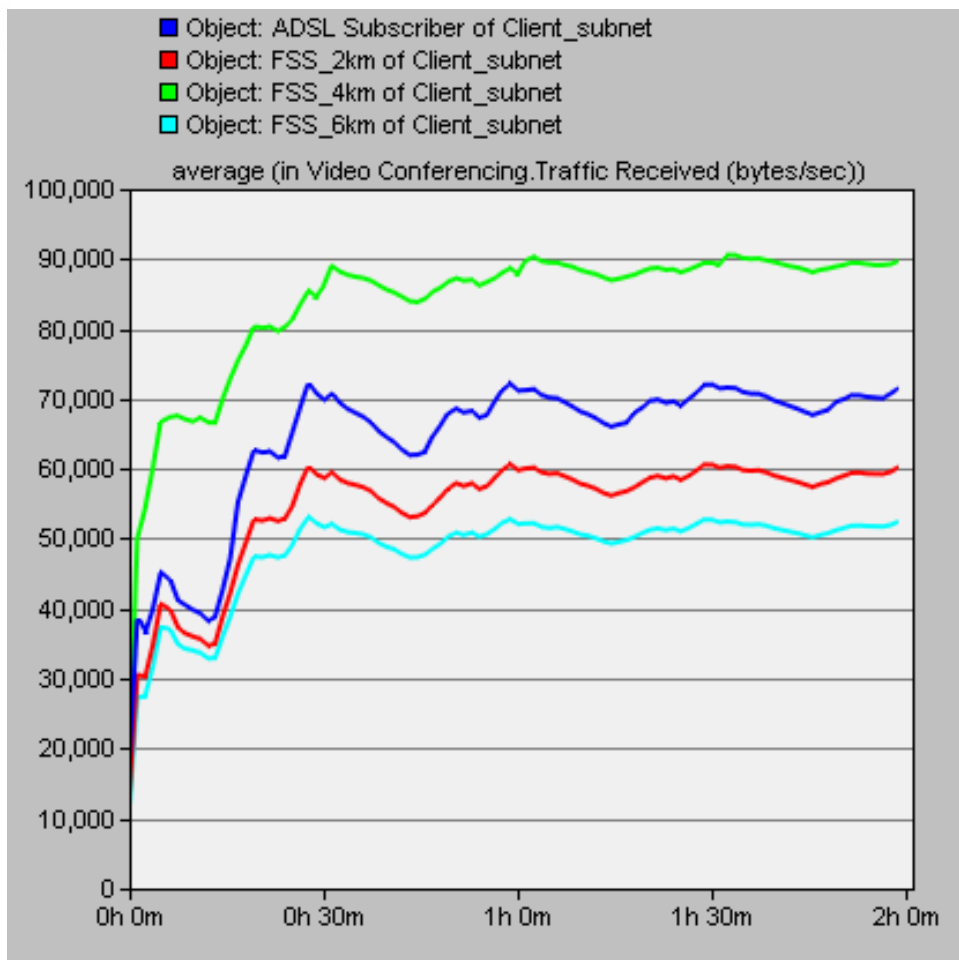
- Values are averaged over the two-hour movie duration
- Metric:  
average: < 300 ms  
ideal: < 10 ms

# Video Packet Jitter



- Values are averaged over the two-hour movie duration
- Metric:  
average: < 60 ms  
ideal: < 20 ms

# Video Traffic Throughput



- Values are averaged over the two-hour movie duration
- Metric: 10 kbps - 5 Mbps

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# Conclusions



- Simulation time: 2.0 hrs / Actual time: > 8 hrs
- WiMAX satisfied the video performance metrics:
  - WiMAX packet loss reduced by increasing BS buffering
  - results are understated (model used worst case BE scheduler)
- Promising overall results in comparison to ADSL:
  - dependant on specific carrier deployment parameters
    - WiMAX has capacity to deliver higher throughput rates and QoS than ADSL
  - With further refinement, WiMAX can provide comparable performance to ADSL for video streaming services
- Simulations do not replace real world equivalence:
  - should be considered when interpreting results

# Future work



- Develop more comprehensive simulations:
  - experimentally characterize specific WiMAX parameters: scheduling, transmit power, antenna gain, channel bandwidths
- Conduct comprehensive analysis on data
- Research and refine video performance metrics
- Encapsulate video traffic in RTP
- Incorporate audio streams
- WiMAX mobility and shadowing

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- M. LaBrecque, WiMAX introduction [Online]. Available: <http://www.wimaxforum.org/technology/downloads> (Feb. 2008).
- WiMAX forum [Online]. Available: <http://www.wimaxforum.org/news/pr/> (Apr. 2008).
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- M. Chatterjee, S. Sengupta, and S. Ganguly, "Feedback-based real-time streaming over WiMax," *IEEE Wireless Communications Magazine*, vol. 14, no. 1, pp. 64–71, Feb. 2007.
- Intel, Understanding Wi-Fi and WiMAX as metro-access solutions [Online]. Available: <http://www.rclient.com/PDFs/IntelPaper.pdf> (Feb. 2008).

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- H. Juan, H. Huang, C. Huang, and T. Chiang, "Scalable video streaming over mobile WiMAX," *Proc. ISCAS 2007*, New Orleans, Louisiana, May 2007, pp. 3463–3466.
- F. Yousaf, K. Daniel, and C. Wietfeld, "Performance evaluation of IEEE 802.16 WiMAX link with respect to higher layer protocols," *Proc. IEEE ISWCS 2007*, Trondheim, Norway, Oct. 2007, pp. 180–184.