Streaming Video Content Over WiMAX Broadband Access

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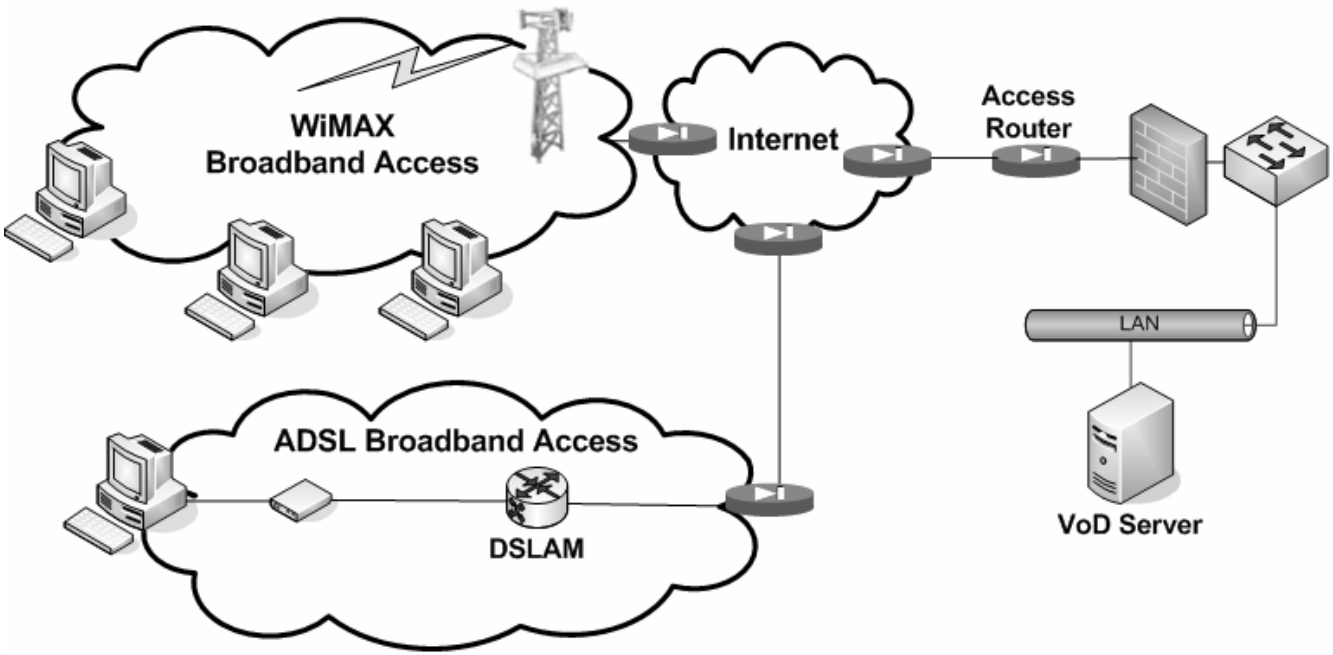
Roadmap

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

Introduction

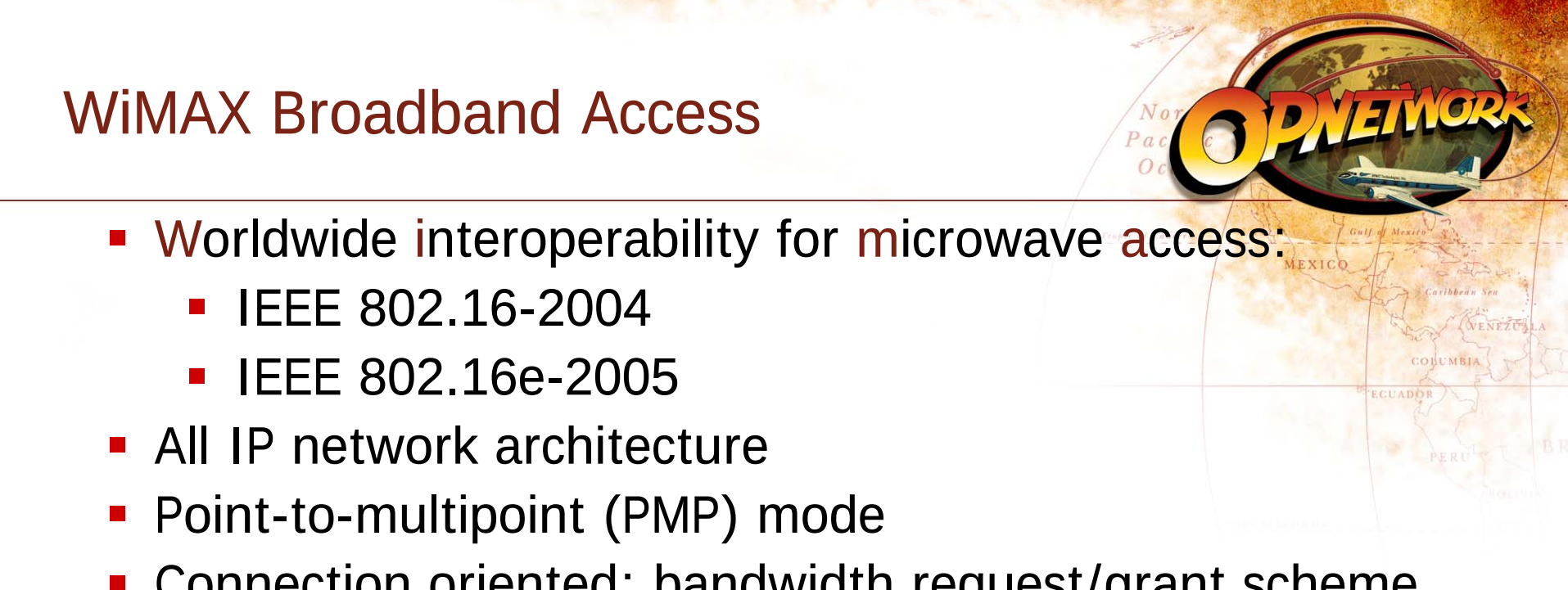
- Focus of this study:

  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

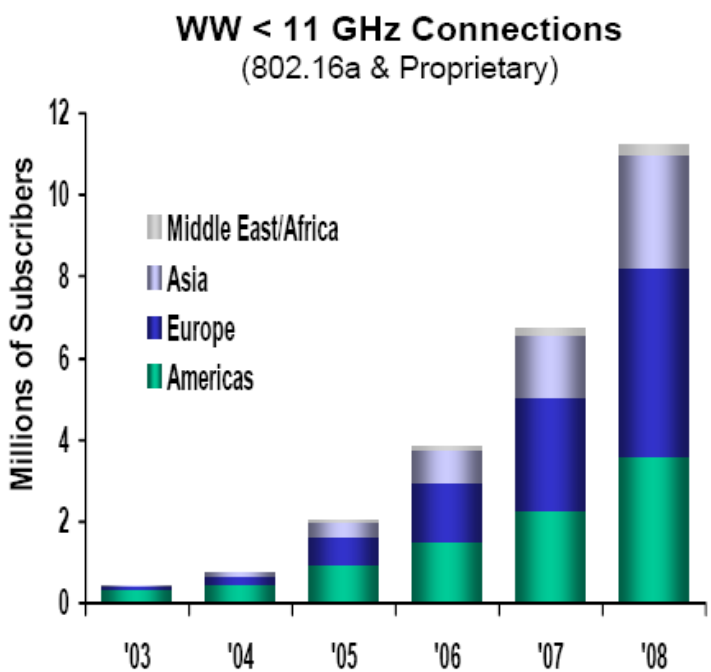
WiMAX Broadband Access

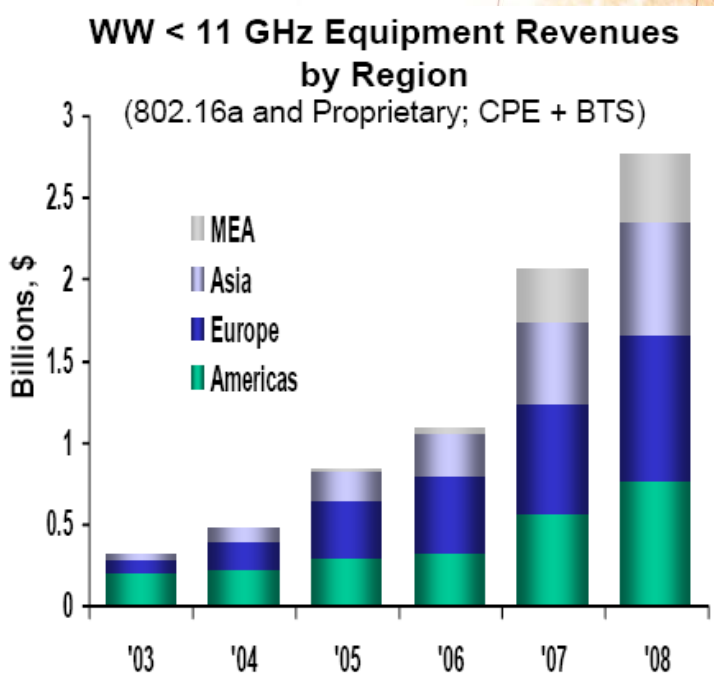


- Worldwide interoperability for microwave access:
  - IEEE 802.16-2004
  - IEEE 802.16e-2005
- All IP network architecture
- Point-to-multipoint (PMP) mode
- Connection oriented: bandwidth request/grant scheme
- Flexible QoS supports voice and video
- Optimum spectral efficiency
- Channel bandwidth: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

WiMAX Growth

- Why WiMAX?



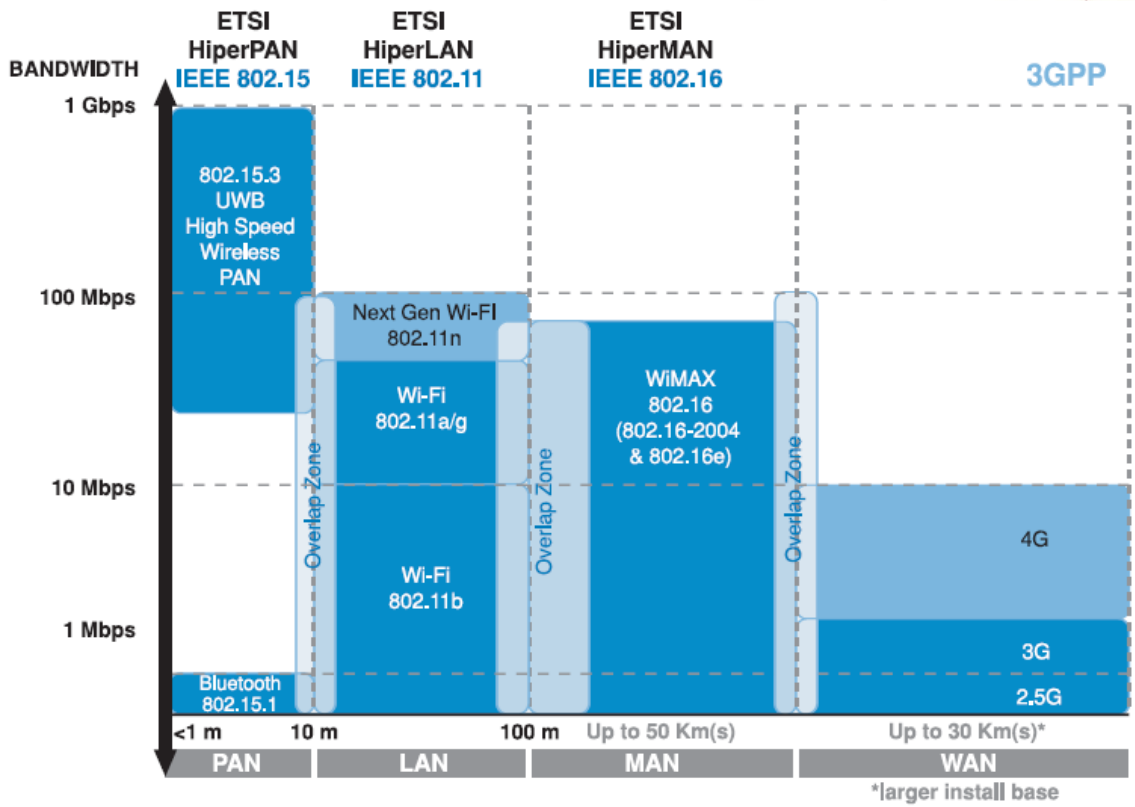


M. LaBrecque, WiMAX introduction [Online]. Available: http://www.wimaxforum.org/technology/downloads (February 2008).

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

Wireless Technologies

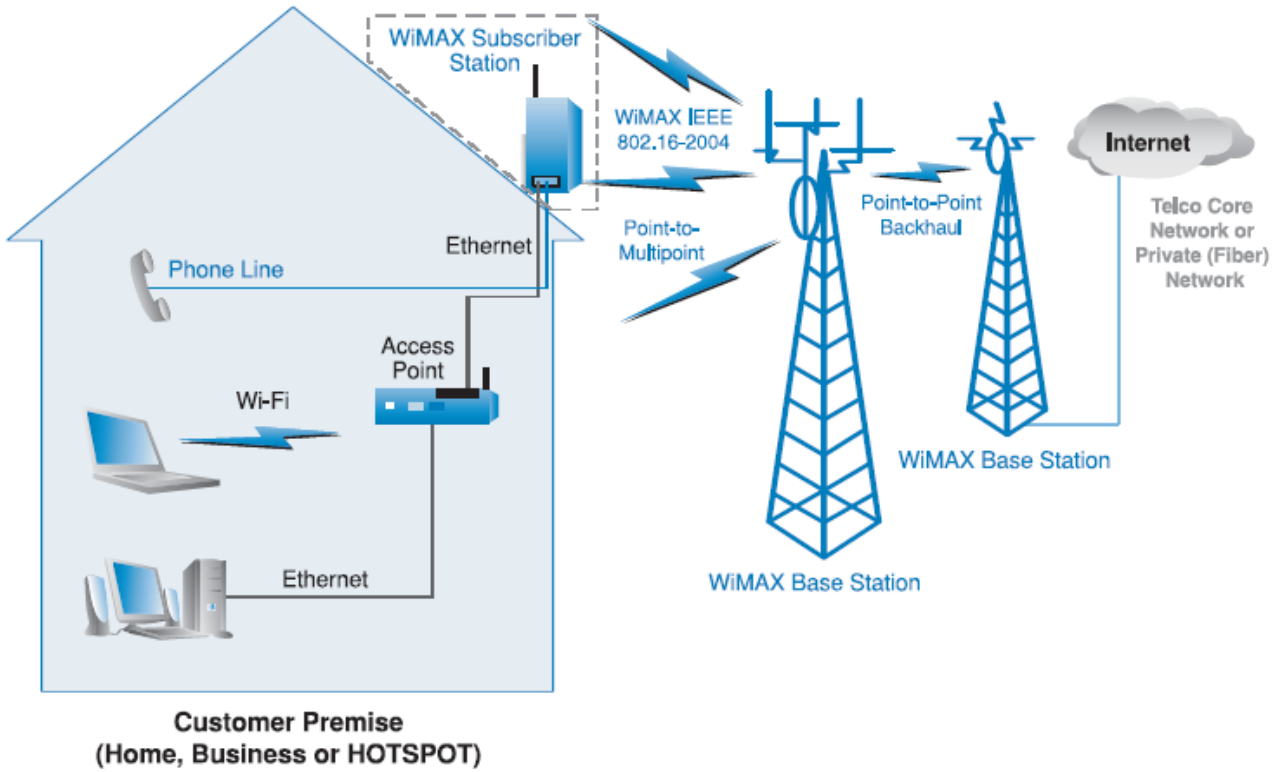
- WiMAX Broadband Access



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



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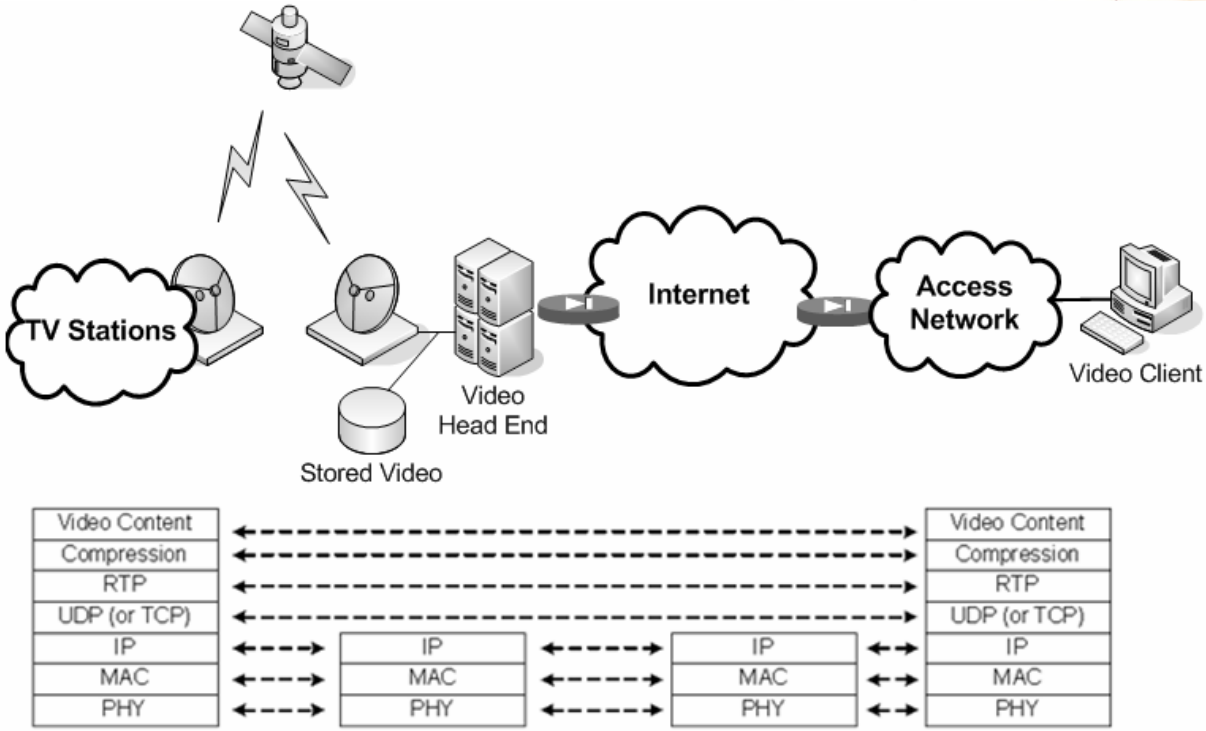
Video Services

- 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
    - IPTV (live & VoD)
    - Video conferencing
  - Unmanaged services
    - IPTV (live & VoD)
    - 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

Roadmap

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- OPNET model
- Simulation results:
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- Conclusions and future work
- References

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

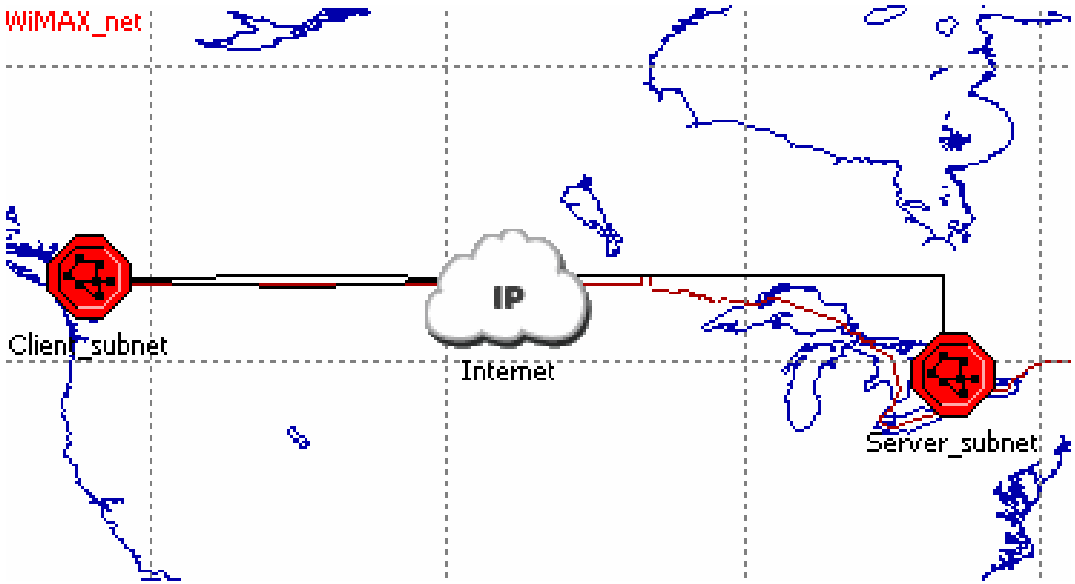
- Loss: Number of packets dropped
  - 1 - (# of received packets) / (# of expected packets)
  - Avg: $< 10^{-3}$ Ideal: $< 10^{-5}$
- Delay: Average time of transit
  - Processing delay + propagation delay + queuing delay
  - Avg: < 300 ms Ideal: < 10 ms
- Jitter: Variation in packet arrival time
  - Actual reception time – expected reception time
  - Avg: < 60 ms Ideal: < 20 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

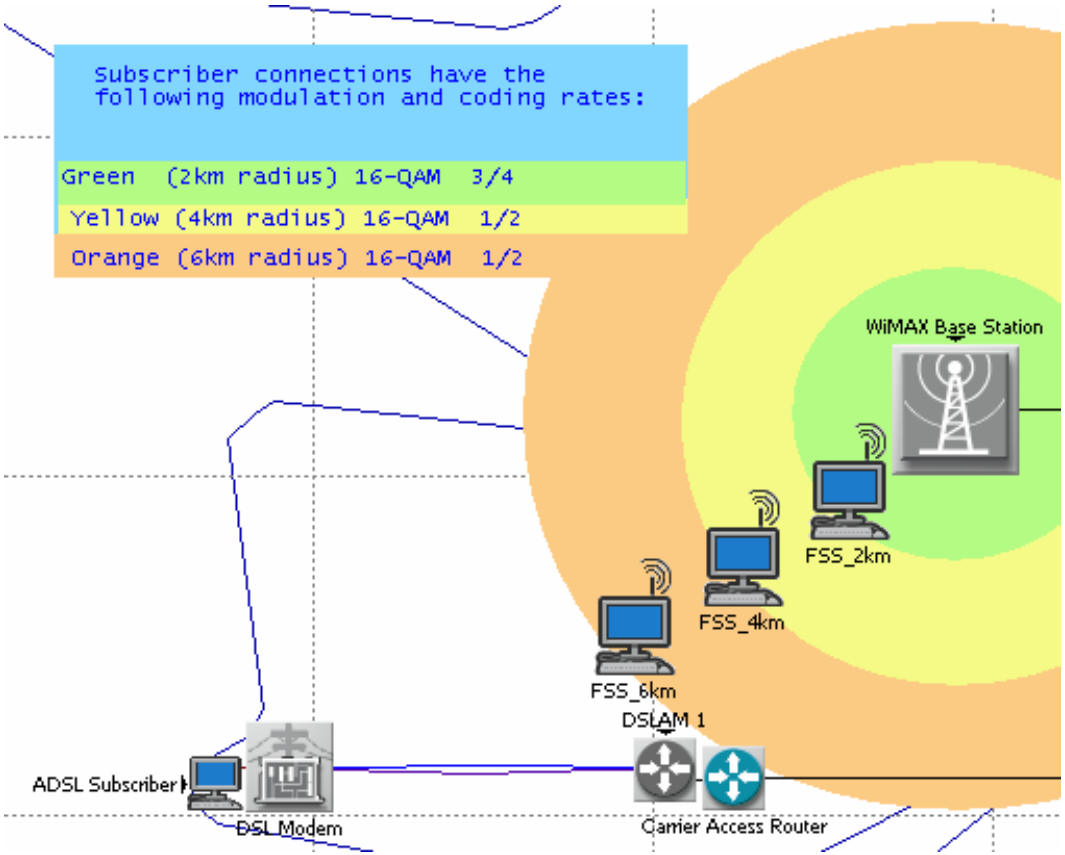
- Network:
  - video services subnet located in Toronto
  - video clients subnet located in Vancouver (distance: 3,342 km)



- 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

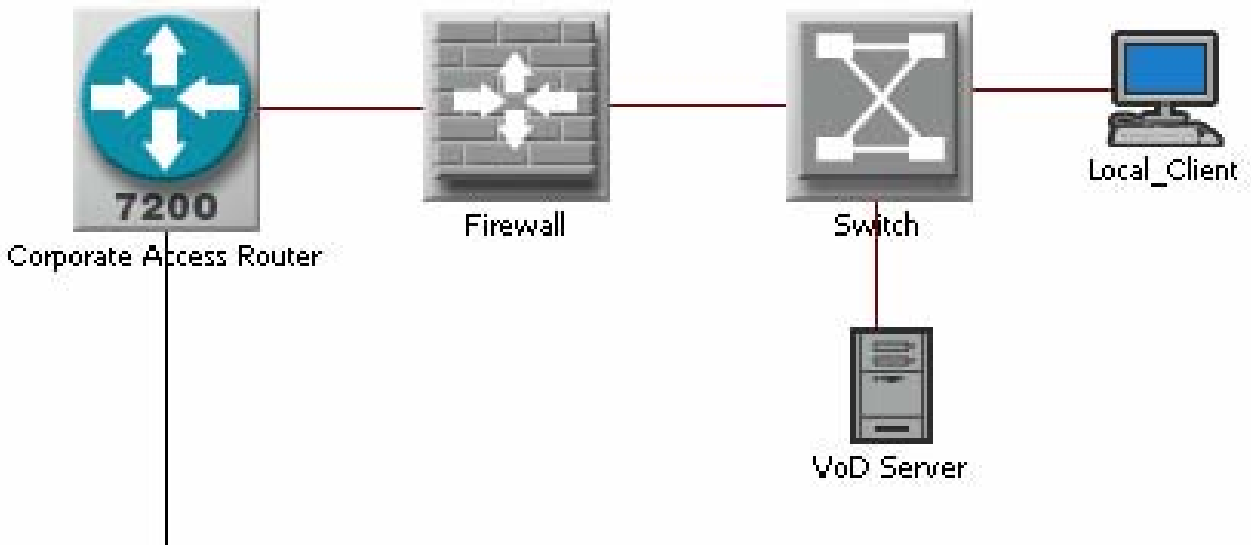
Modulation	Coding	Information Bits/symbol/Hz	Required SNR (dB)
QPSK	1/2	1	9.4
	3/4	1.5	11.2
16-QAM	1/2	2	16.4
	3/4	3	18.2
64-QAM	2/3	4	22.7
	3/4	4.5	24.4

- 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



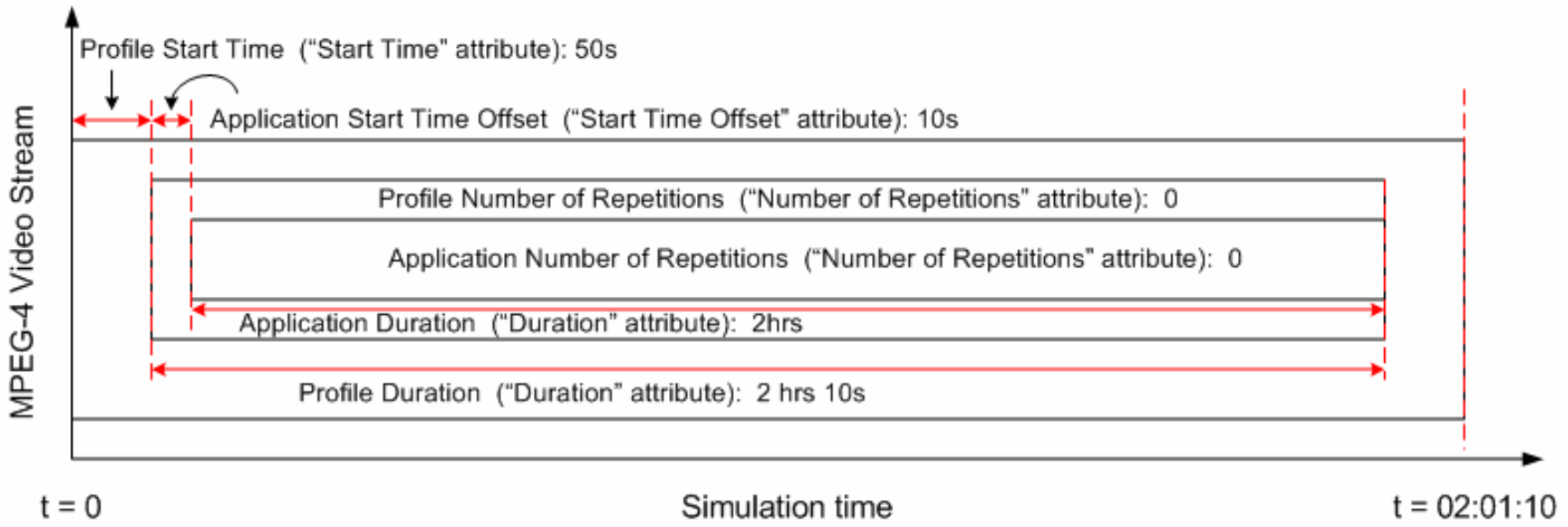
- Server provides video on demand (VoD) services
- Local client used only for initial troubleshooting and validation

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

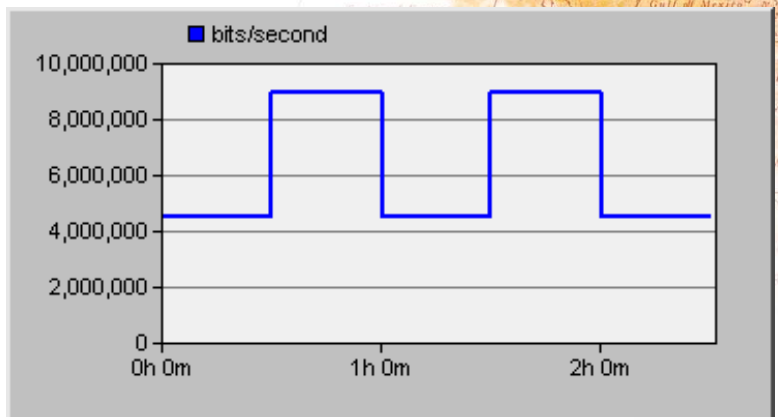
- Traffic profile

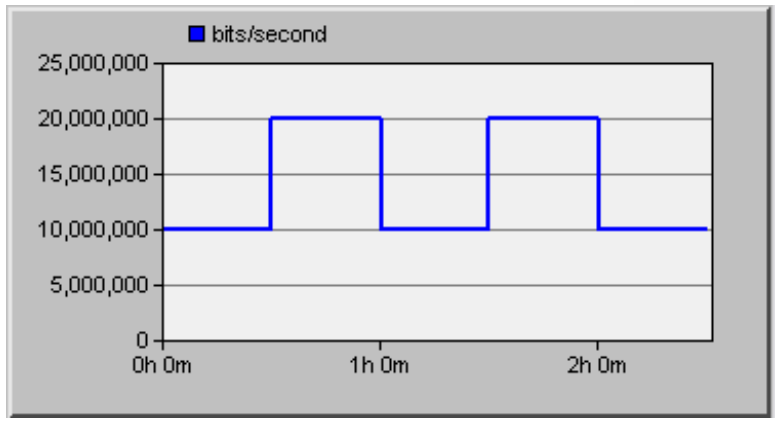


- MPEG-2 performed poorly: simulation employed an MPEG-4 stream

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
Frame Rate (frames/sec)	**1**	**30**	**25**
Number of Frames	7,200	324,000	180,000
Peak Rate (Mbps)	0.138	30.488	7.290
Mean Rate (Mbps)	**0.138**	**5.720**	**0.637**

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

Simulation Model

- Limitations:
  - video traffic only*
  - no RTP encapsulation
  - WiMAX AMC not available**
  - WiMAX power management not available**

* 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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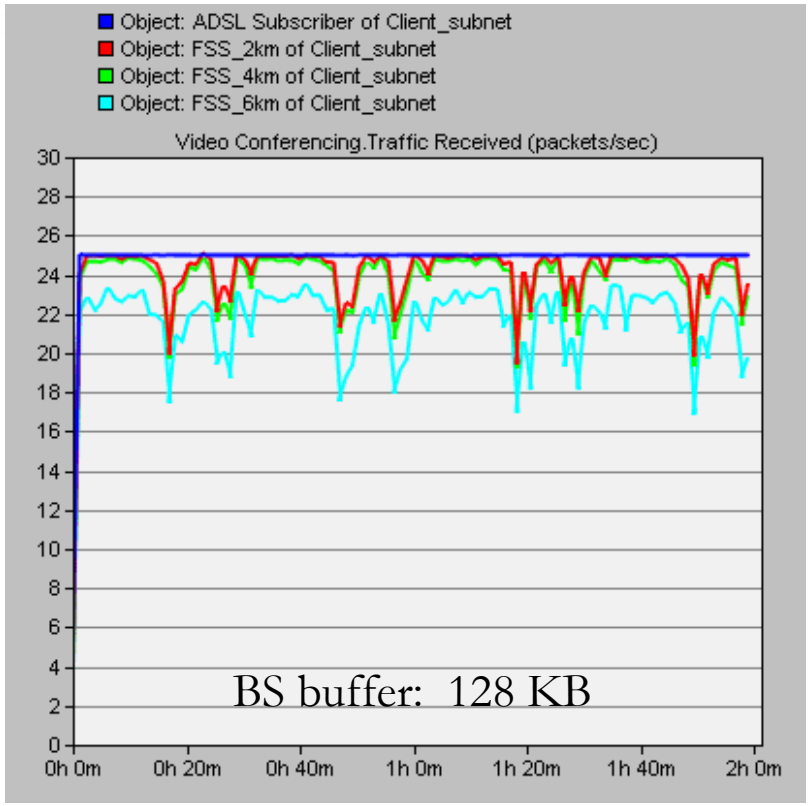
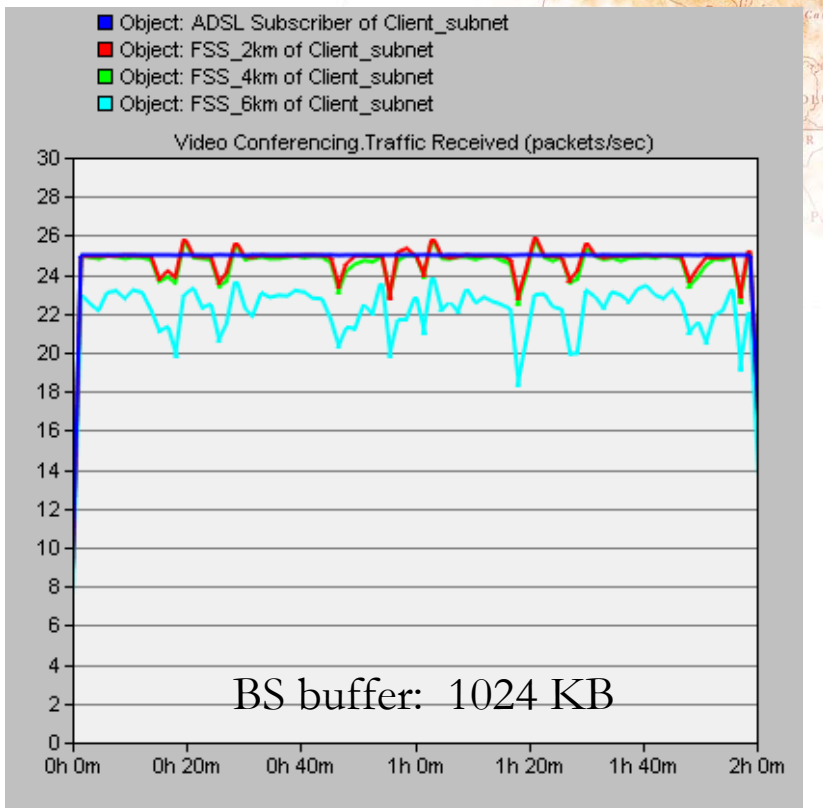
Video Packet Loss

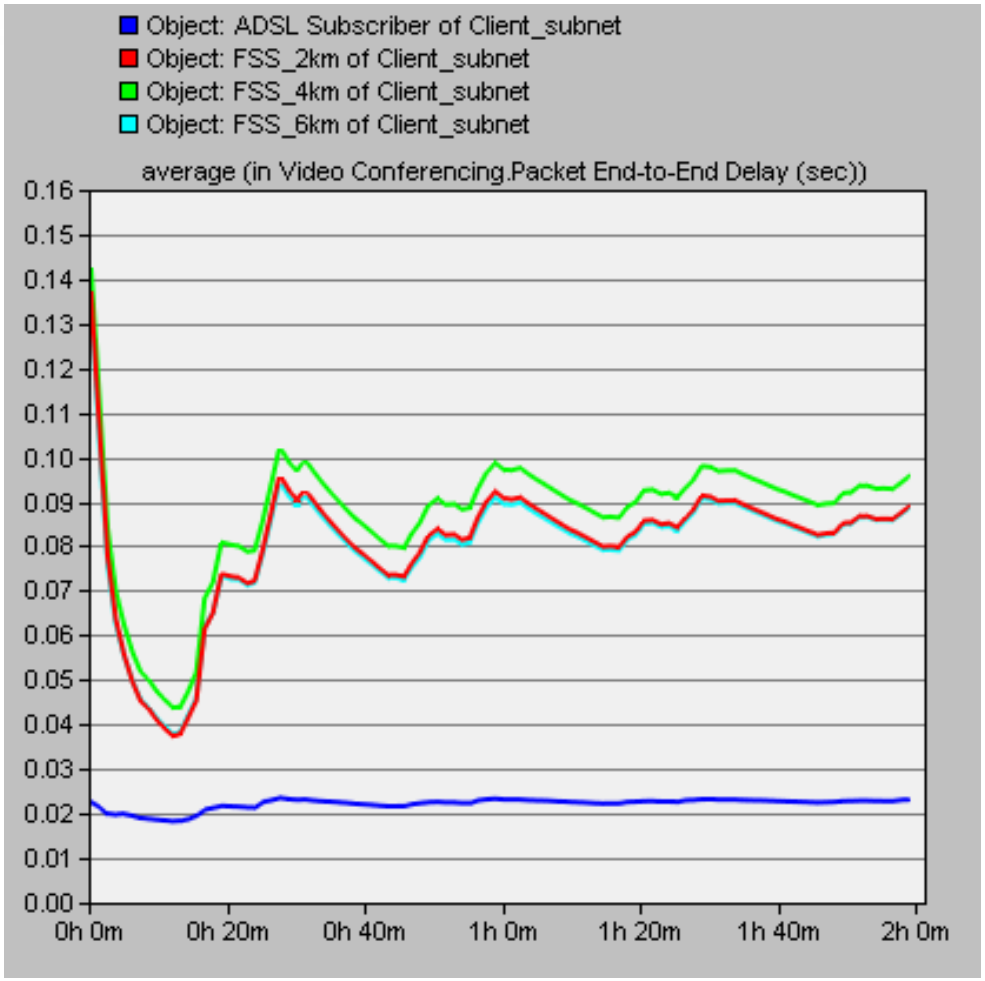
- Instantaneous values





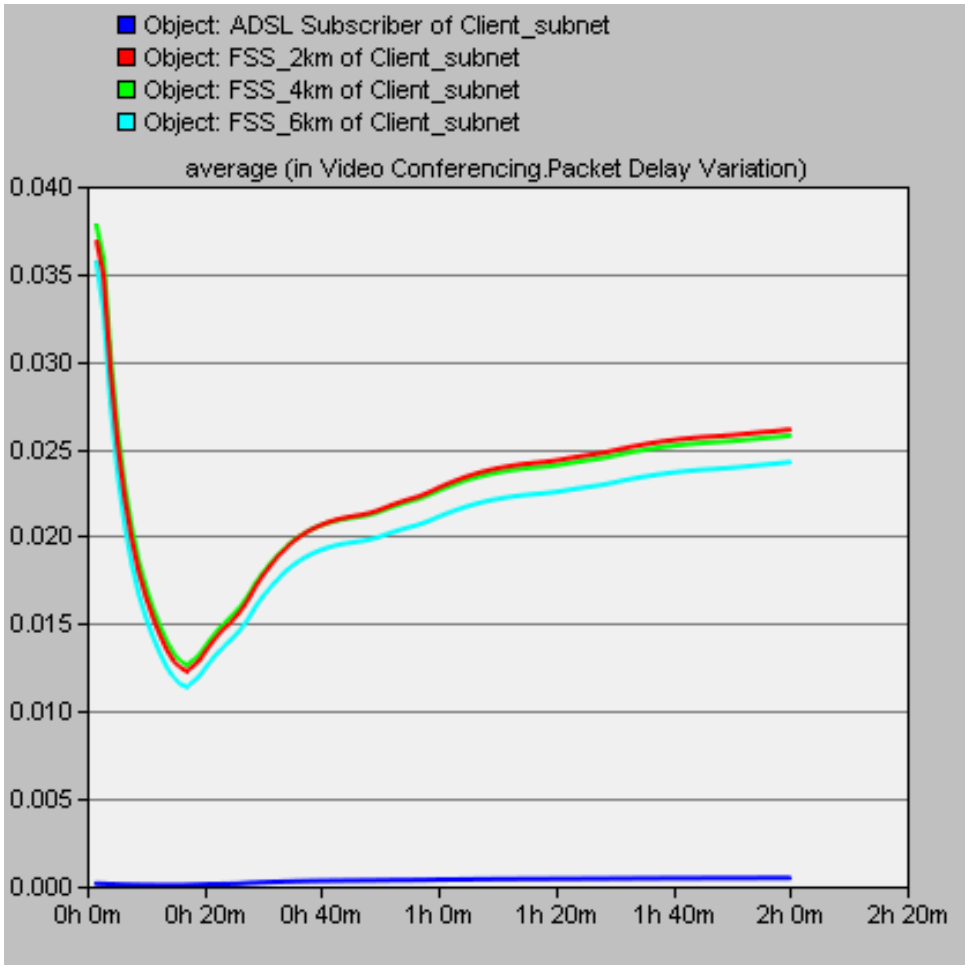
- Loss is depicted as deviation from the blue line representing 25 pkts/sec
- 1024 KB is large enough to prevent dropped downlink packets at BS
- 6 km WiMAX station loss because SNR is < min level for modulation/coding

Video Packet Delay



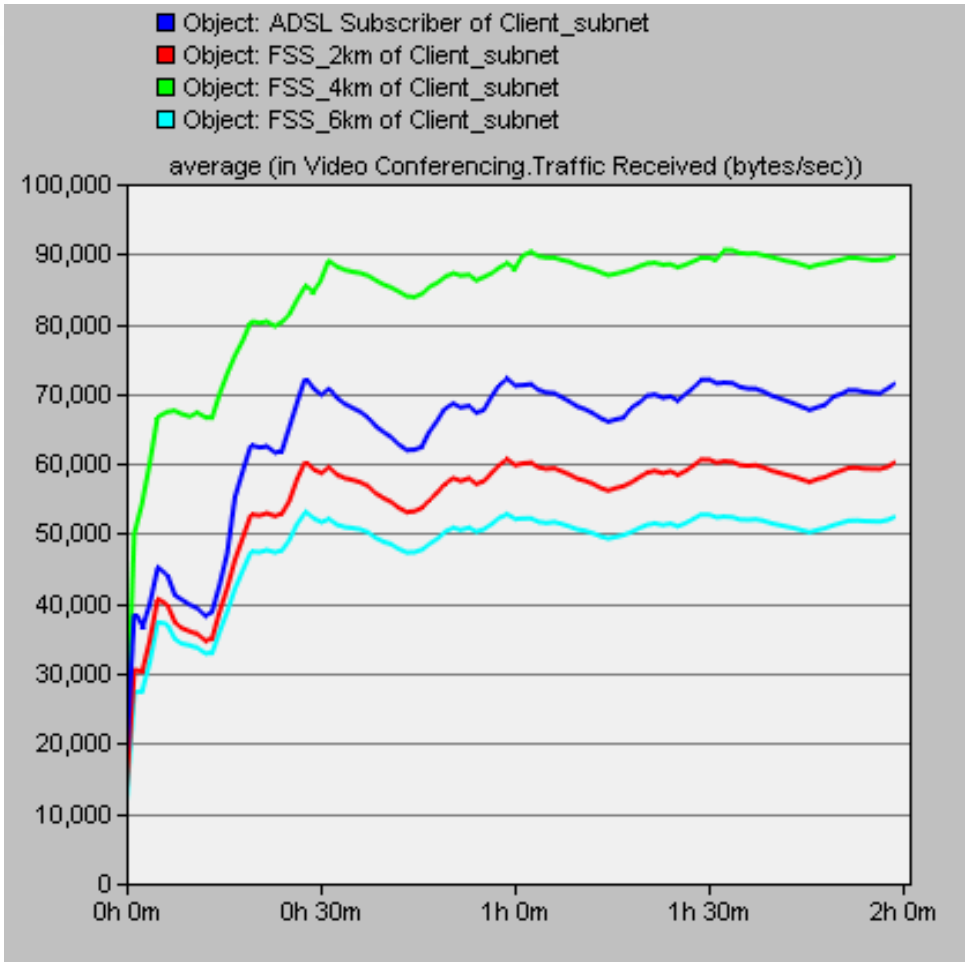
- Values are averaged over the two-hour movie duration
- Metric:
  average: < 300 ms
  ideal: < 10 ms

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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