ENSC-835 Communication Networks

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Streaming Video Content Over WiMAX Broadband Access


Motorola WAP400

Will Hrudey
www.sfu.ca/~whrudey
(whrudey@sfu.ca)

Bell RSU-2510

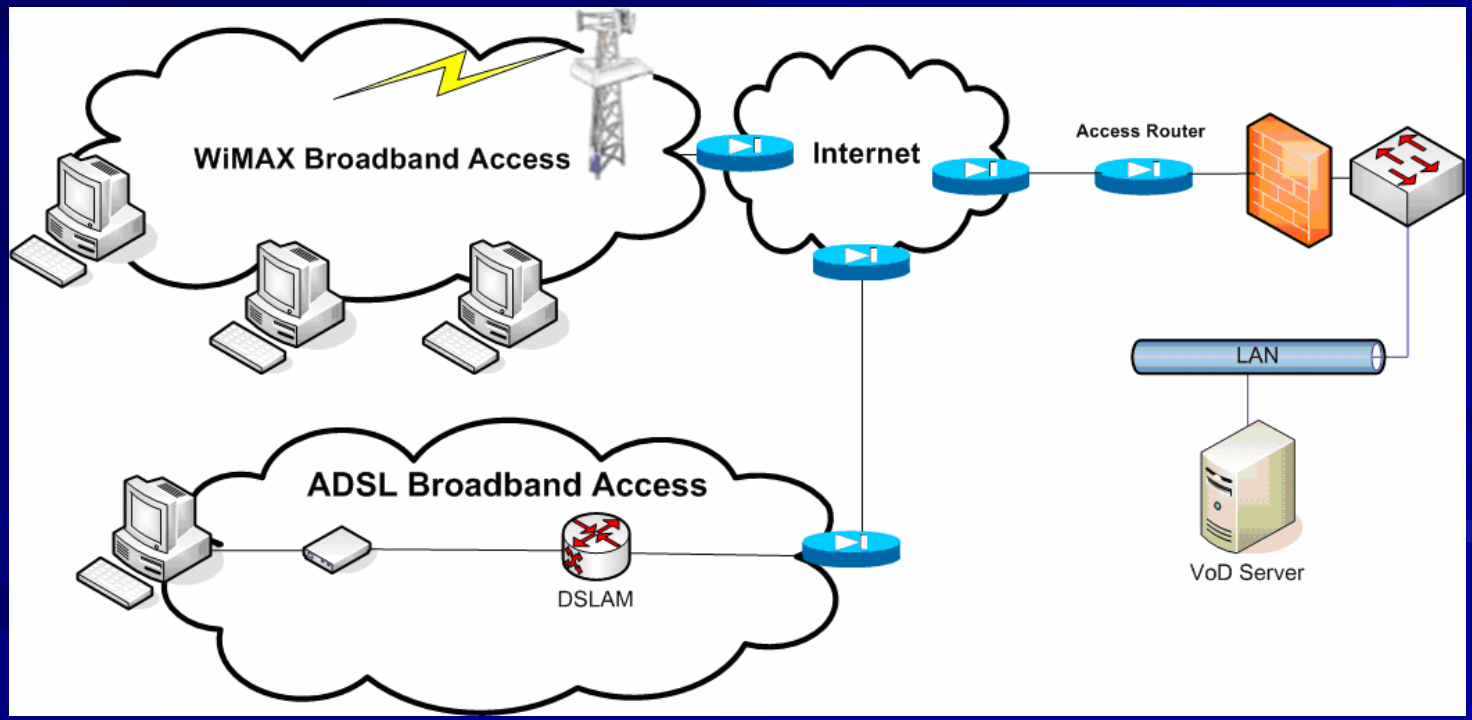
Roadmap

- ***Introduction***
- Design
- Validation
- Analysis
- Conclusions
- Challenges
- Future Work
- References

Introduction

- Focus of this study:

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



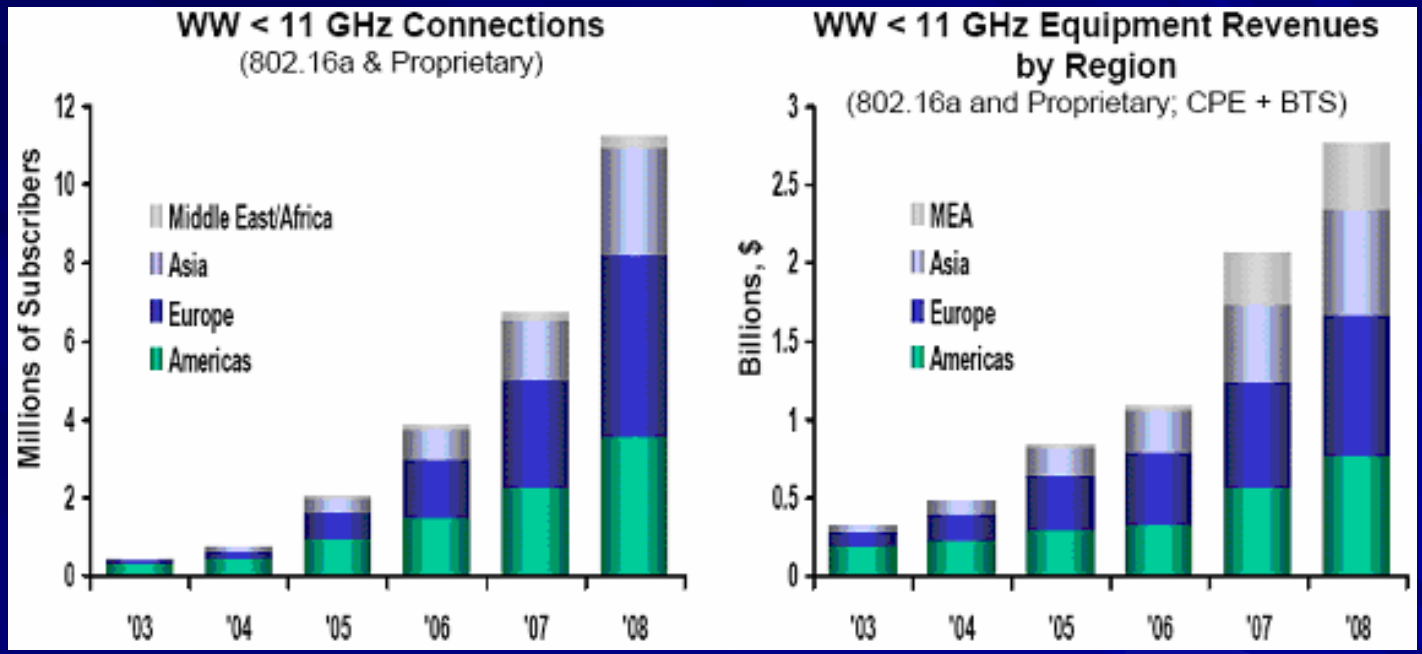
Simulation will stream an MPEG-4 2-hour movie to 4 video clients

Introduction

- What is WiMAX Broadband Access?
  - **W**orldwide **I**nteroperability for **M**icrowave **A**ccess
    - IEEE 802.16-2004 [12]
    - IEEE 802.16e-2005
  - All IP network architecture
  - Point-to-multipoint (PMP) mode
  - Connection oriented – bandwidth request / grant scheme
  - Flexible QoS supports voice & video
  - Optimum spectral efficiency
  - Channel bandwidths from 1.25 – 20 MHz
  - Typical cell size of 7 - 10 km
  - Optimized for outdoors
  - Scalable to 1000’s of users
  - Provides fixed, nomadic and mobile usage

Introduction

- Why WiMAX?

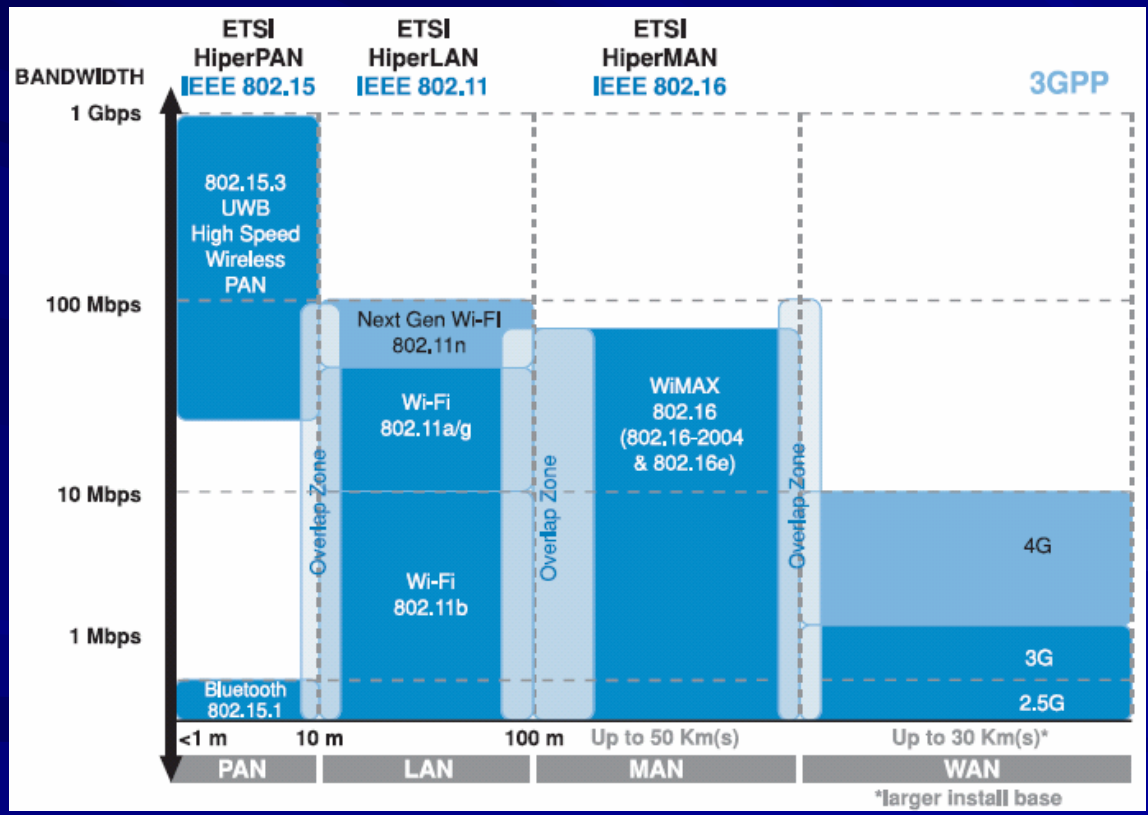


[10] Margaret LaBrecque, “WiMAX Introduction”, WiMAX Forum 2003

- WiMAX Forum March Press Release : 133 million users by 2012
- OPNETWORK 2007 Conference cited > 100 planned carrier trials

Introduction

- What is WiMAX Broadband Access?



[11] Intel, “Understanding Wi-Fi and WiMAX as Metro-Access Solutions”, 2007

Introduction

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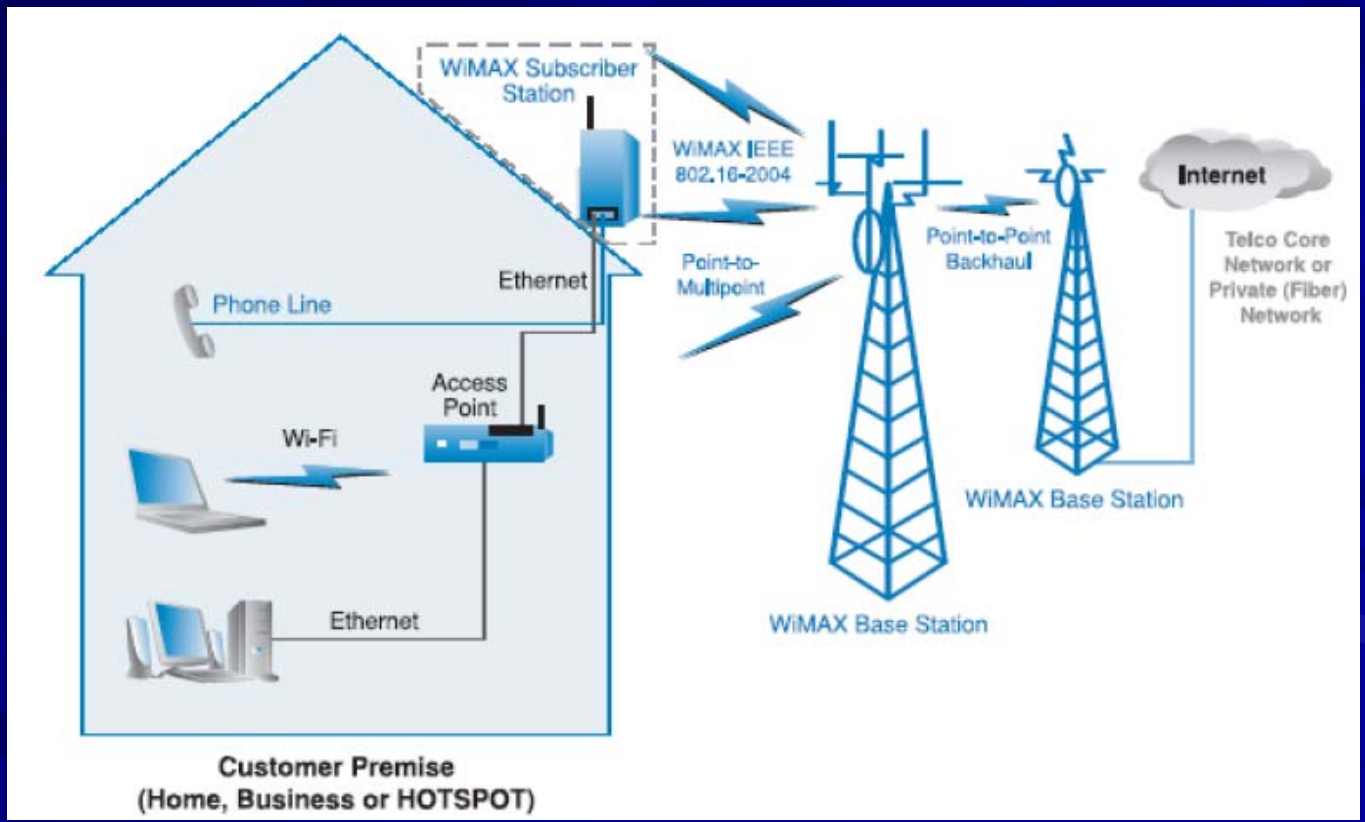


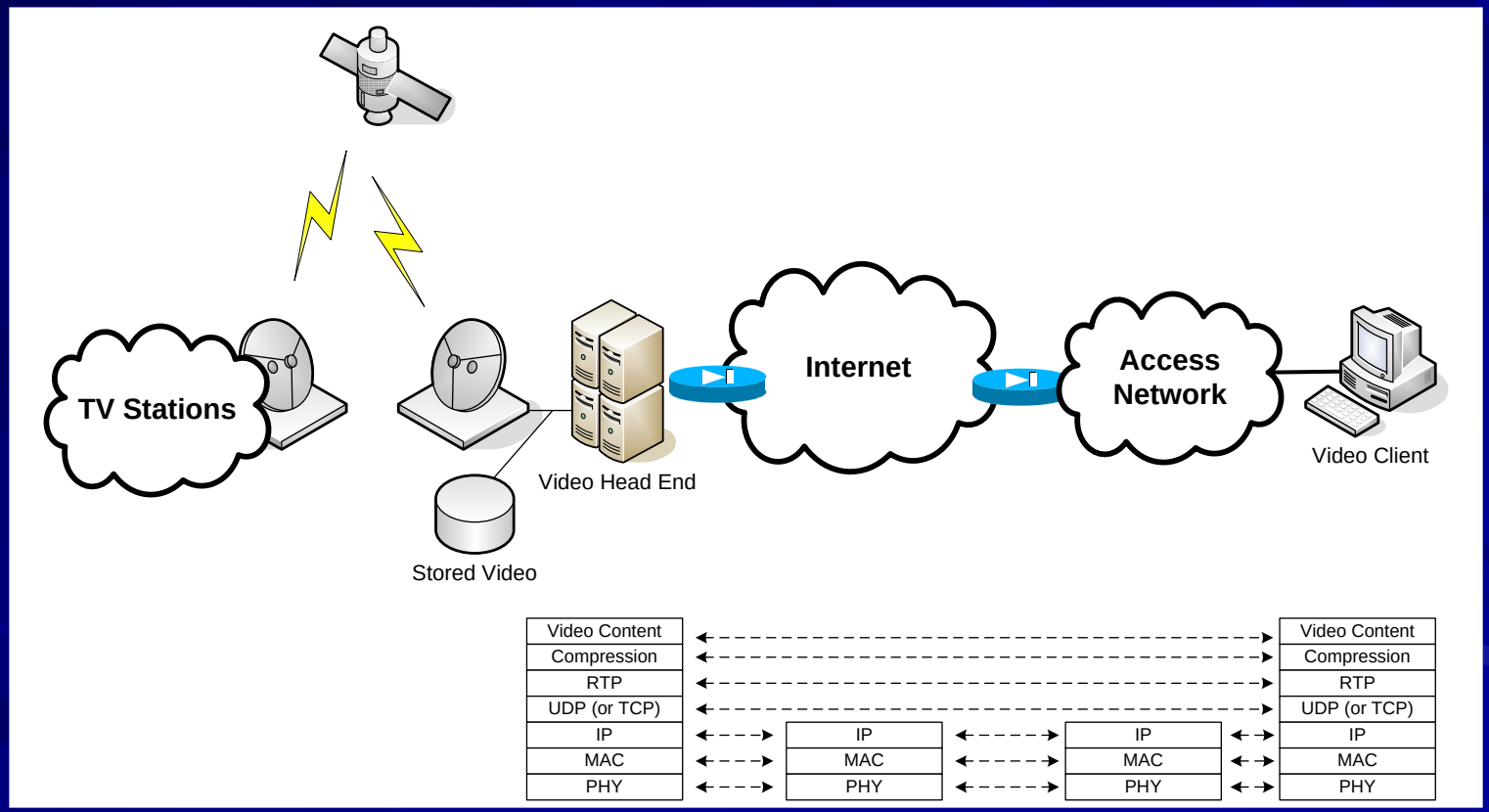
[11] Intel, “Understanding Wi-Fi and WiMAX as Metro-Access Solutions”, 2007

Introduction

- What Is Video 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

Introduction

- What Is Video Streaming?



[7] “Framework for Delivering IPTV Services Over WiMAX Wireless Services”, IEEE EIT 2007

Introduction

- Video Coding Schemes
  - Exploit temporal and spatial characteristics
  - Various standards and codecs
    - ITU (H.26x) & 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

Introduction

- Related Work
  - Imaging/Voice/Video For E-Health Applications over WiMAX [2]
    - Simulation performed in Matlab
  - IPTV over WiMAX Considerations and Transceiver Design [4]
    - No simulations
  - Evaluation of WiMAX With Various Generic TCP and UDP loads [5]
    - Utilized testbed instead of simulations
  - IPTV over WiMAX Proposed Framework and Challenges [7]
    - No simulations

Roadmap

- Introduction
- ***Design***
- Validation
- Analysis
- Conclusions
- Challenges
- Future Work
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Design

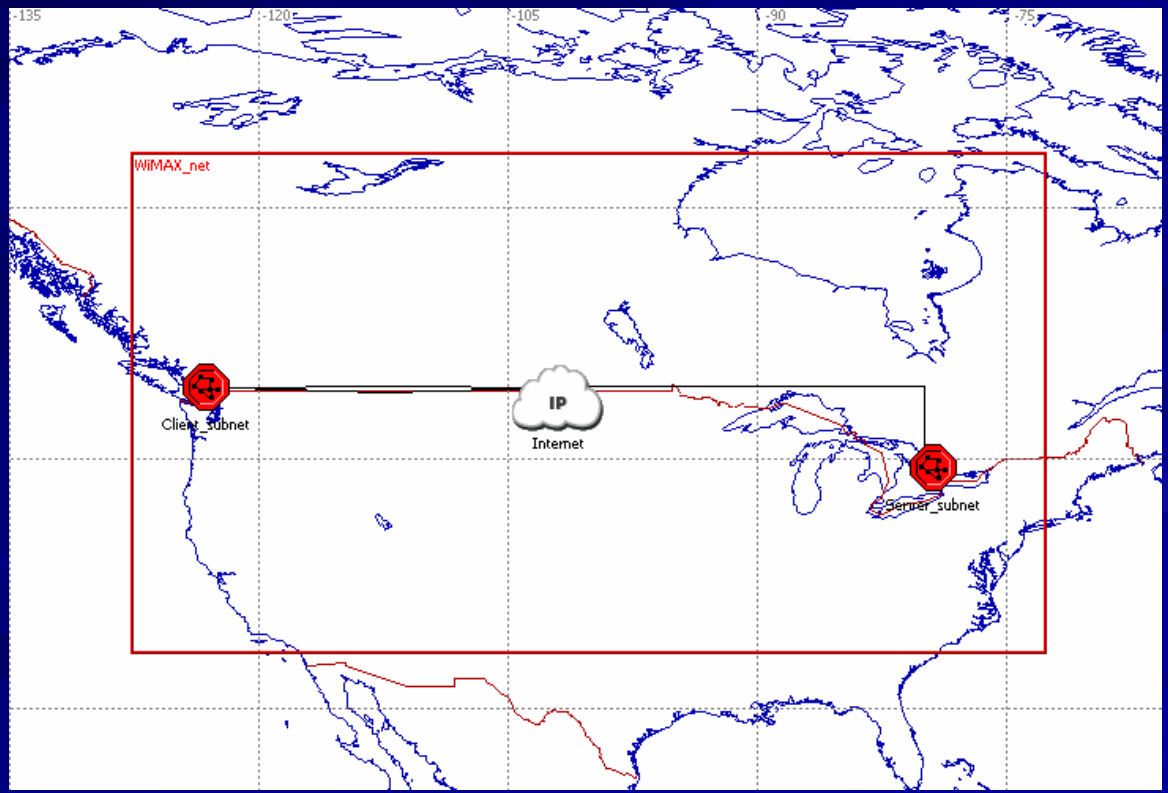
- Loss – Number of Packets Dropped
  - 1 - (# of received packets) / (# of expected packets)
  - Avg: $< 10^{-3}$ Ideal: $< 10^{-5}$
- Delay – Average Time of Transit
  - Processing delay + propagation delay + queuing delay
  - Avg: < 300 ms Ideal: < 10 ms [9]
- Jitter – Variation in Packet Arrival Time
  - Actual reception time – expected reception time
  - Avg: < 60 ms Ideal: < 20 ms
- Throughput – Minimum End-to-End Transmission Rate
  - Measured in bytes / sec (or bps)
  - 10kbps – 5Mbps [14]

Design

- Development Platform
  - Toshiba Tecra S2 laptop
    - Intel Pentium M Processor / 1GB RAM
    - Windows XP Service Pack 2
  - OPNET 12.0.A PL3 + WiMAX Module [13,17]
    - Integrated WiMAX and ADSL nodes
    - Generic Video Conferencing Application
  - Visual Studio .NET 2003 Dev. Environment
    - Required to compile models

Design

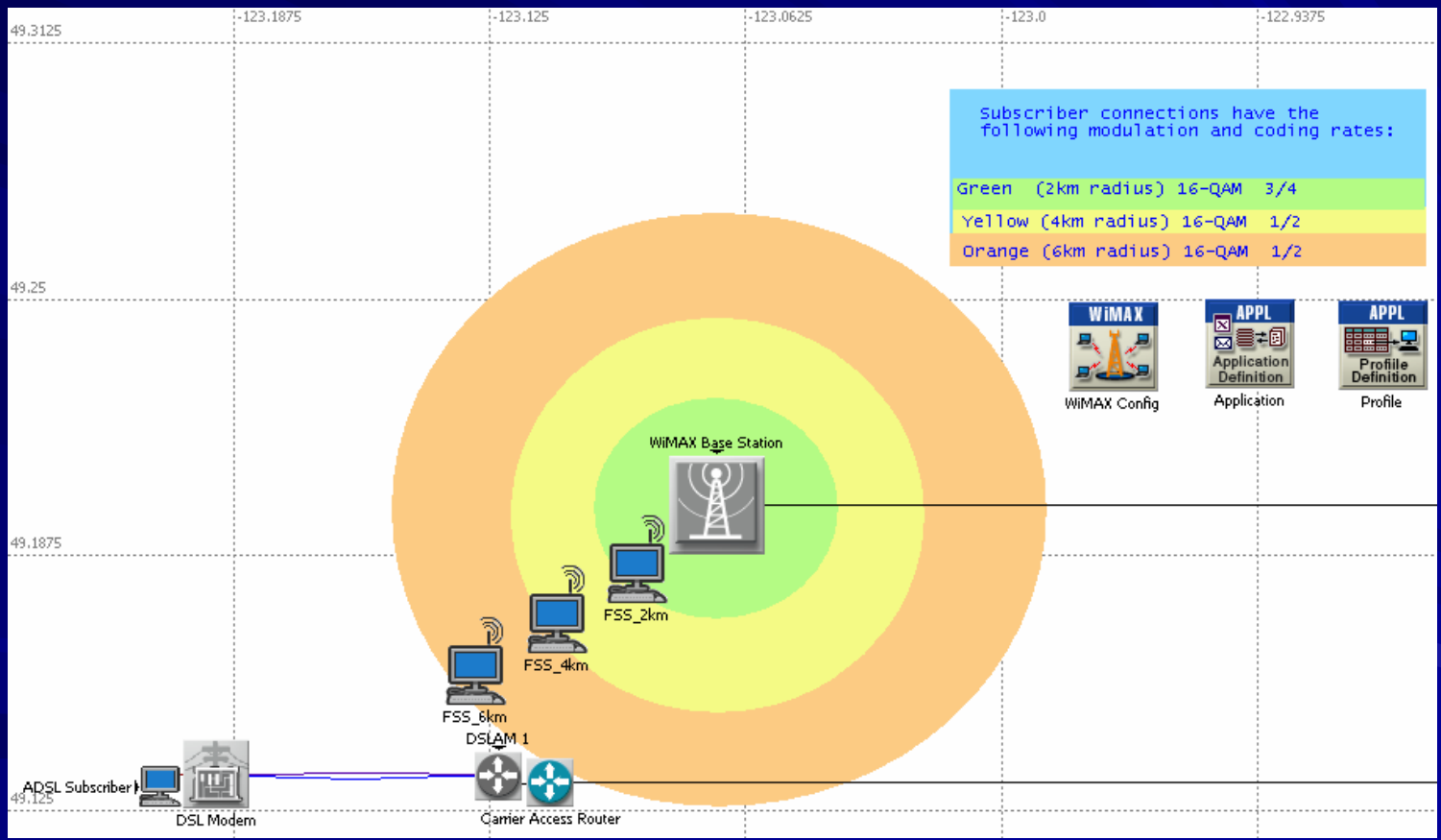
- Overall Network Topology
  - Video services subnet located in Toronto
  - Video clients subnet located in Vancouver (3342 km away)



- **Client WAN link**
  1547 km
  6.1ms d_{prop}
- **Server WAN link**
  1795 km
  7.2ms d_{prop}

Design

- Video Clients Subnet Topology



Design

- Network Parameters
  - Adopted latitude / longitude coordinate system to model pathloss & propagation delay
  - WiMAX deployment parameters (not disclosed without NDA)
    - Scheduling algorithm: best effort
    - Min sustainable data rate (DL): 3.0 Mbps
    - Min sustainable data rate (UL): 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
      - Reviewed Motorola datasheets for current generation WiMAX hardware
    - WiMAX clients are located 2 / 4 / 6 km from base station
      - Manually configured robust burst profiles as a function of distance
    - Pathloss model : suburban with mostly flat terrain with light tree densities
  - ADSL Configuration
    - Downlink: 3.0 Mbps
    - Uplink: 0.640 Mbps
    - Subscriber to Central Office is 5km delay based link

Design

- Network Parameters
  - Modulation / coding and required SNR [2]

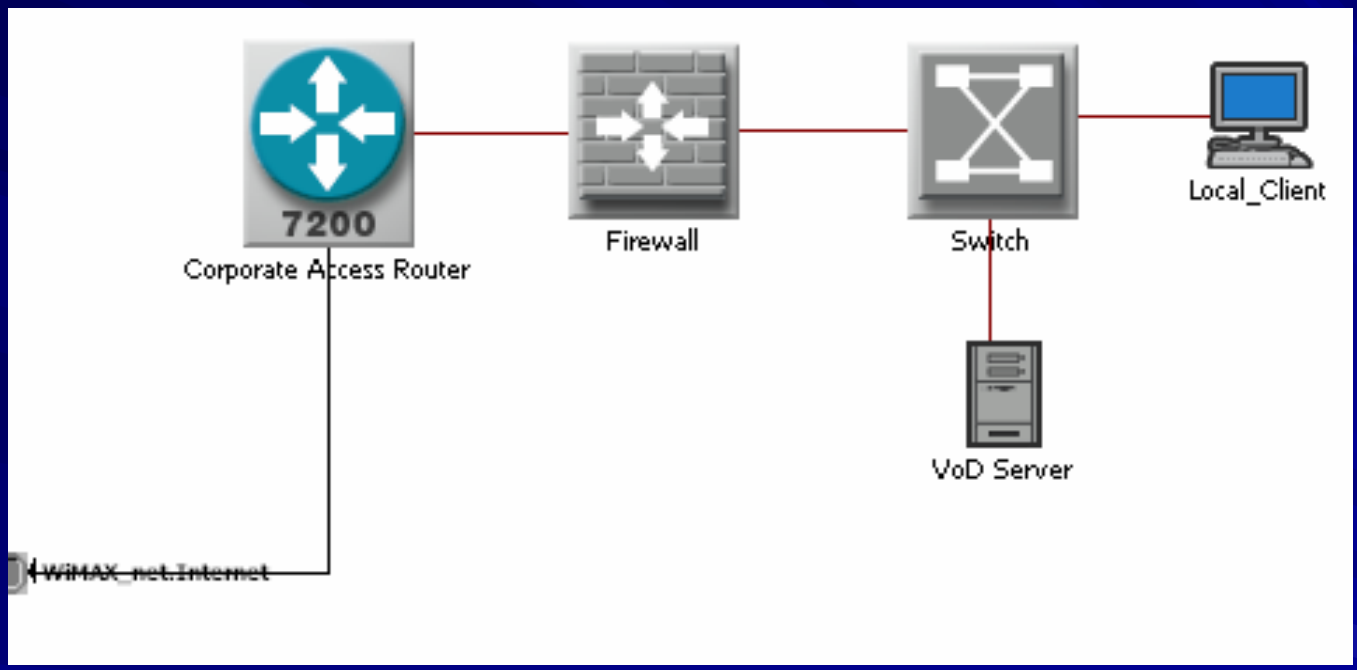
Modulation	Coding	Information Bits/symbol/Hz	Required SNR (dB)
QPSK	1/2	1	9.4
	3/4	1.5	11.2
16-QAM	**1/2**	**2**	**16.4**
	3/4	**3**	**18.2**
64-QAM	2/3	4	22.7
	3/4	4.5	24.4

  - 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

Design

- Video Services Subnet Topology



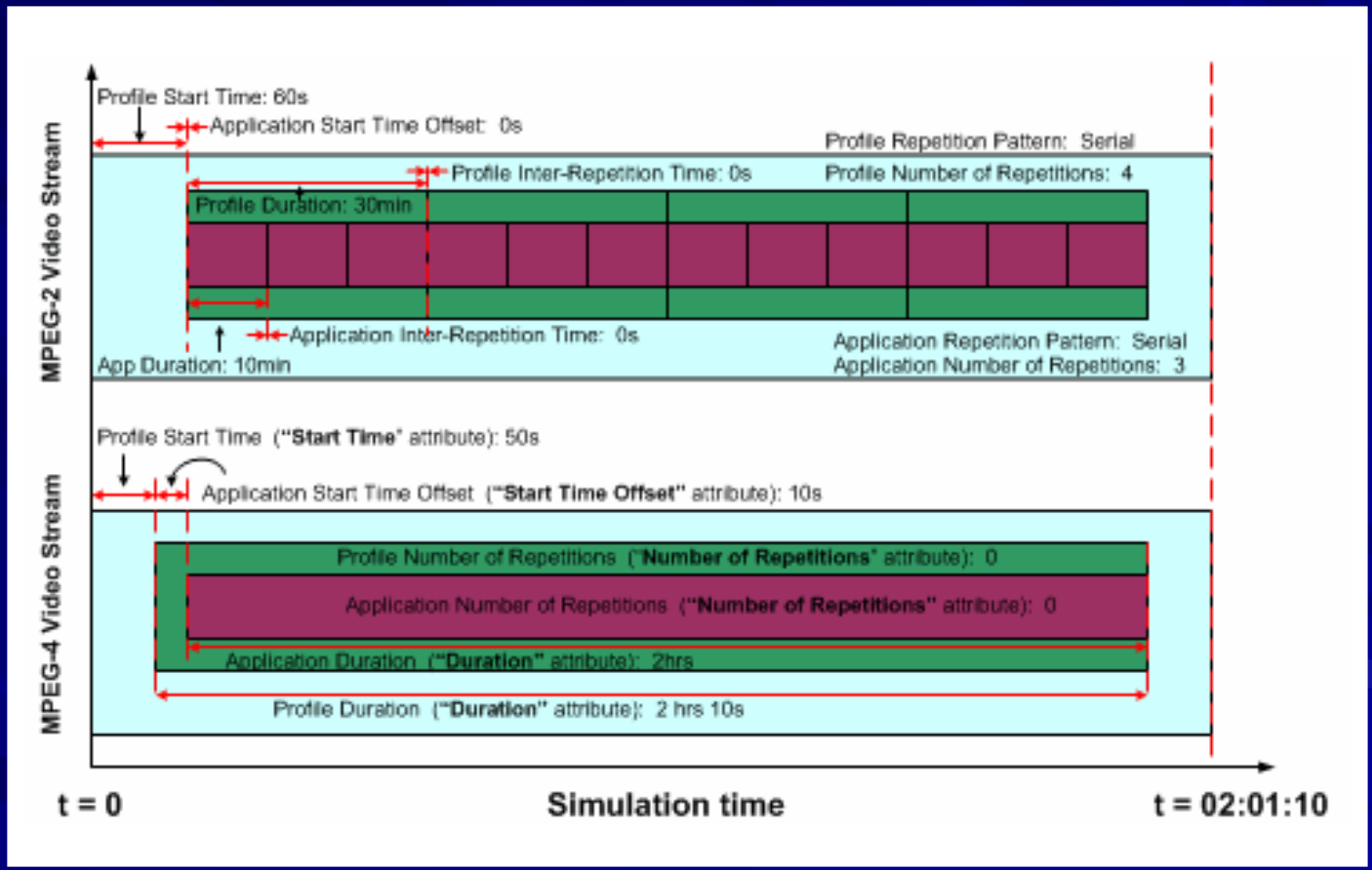
  - Server provides Video on Demand (VoD) services
  - Local client used only for initial troubleshooting and validation

Design

- Video traffic is loss tolerant but delay sensitive
- Simulation model is trace driven
- Configured 2 video streams
  - MPEG-2 1280x720 @ 30 fps [15,16]
  - MPEG-4 352x288 @ 25 fps [15,16]
- 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

Design

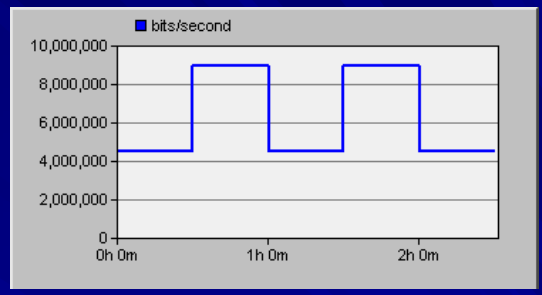
- Video Traffic Profiles

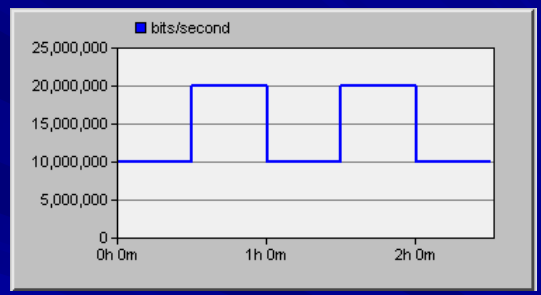


MPEG-2 stream resulted in poor performance so used MPEG-4 stream

Design

- WAN links
  - 10-20% background traffic
- LAN links
  - 10-20% background traffic
- Internet
  - Packet Discard Ratio: 0.001%
  - Packet Latency: 0.001s
- Background Traffic Growth: 10% every 30 min





Design

- Video Traffic Details

Parameters	Validation Traffic	Terminator 2	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	15	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**
		[15,16]	[15,16]

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

Design

- Model Limitations
  - Video traffic only [15,16]
  - No RTP encapsulation
  - WiMAX AMC not available [13]
  - WiMAX power management not available [13]

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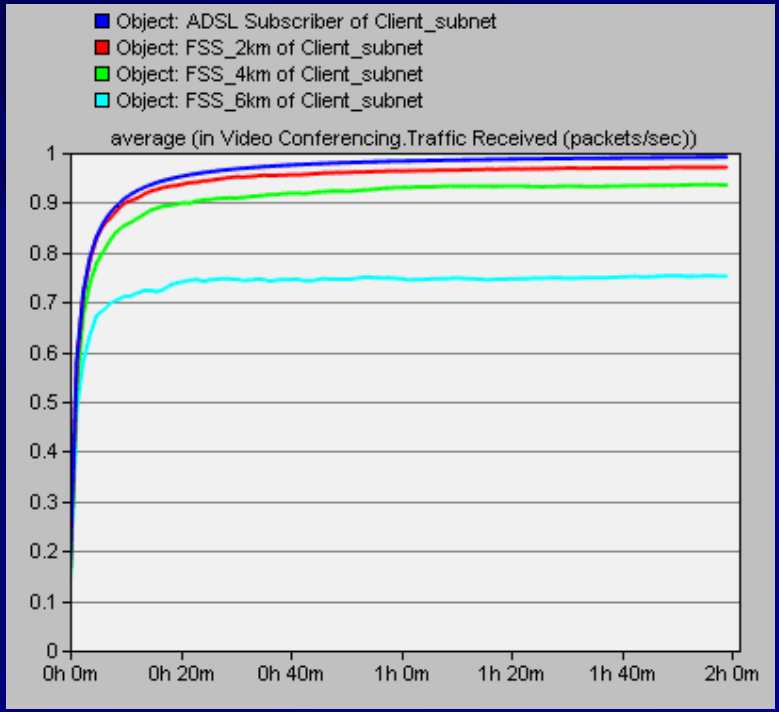
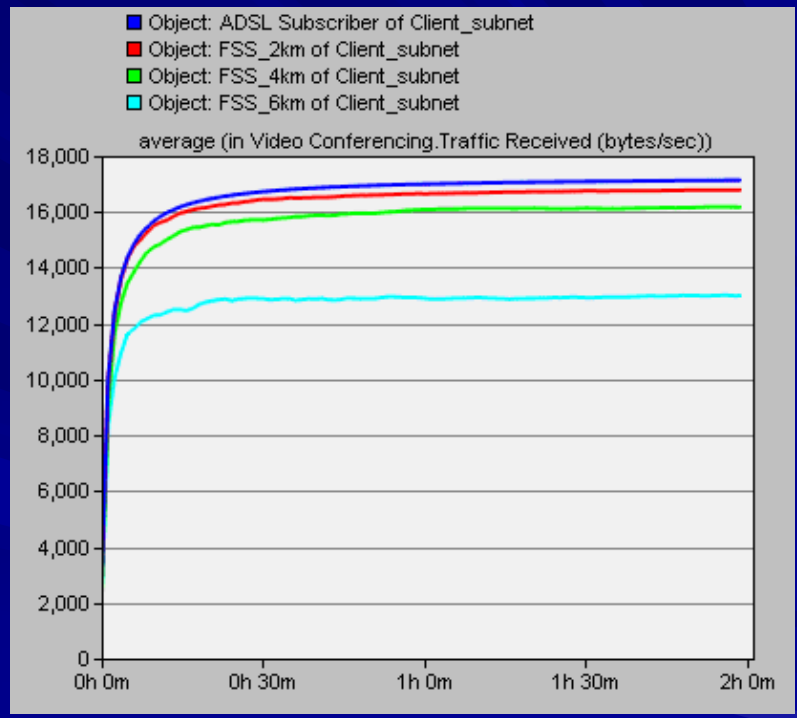
Validation

- CBR Video Traffic Using 1 fps (17280 bytes/sec)





- DES Log
- Observe WAN and LAN background traffic

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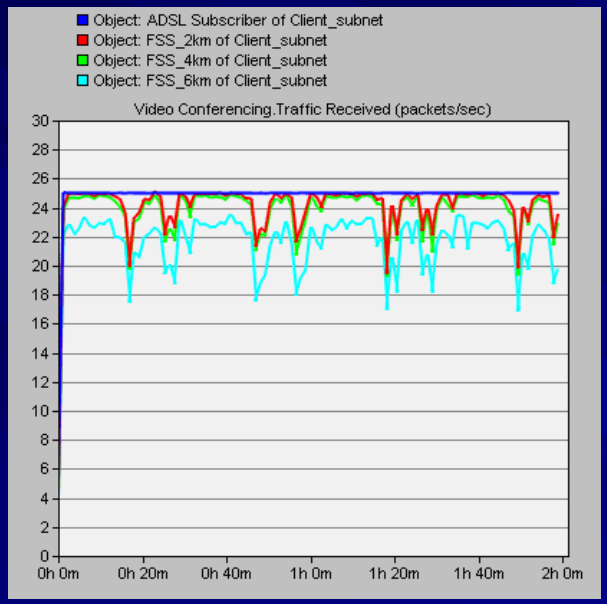
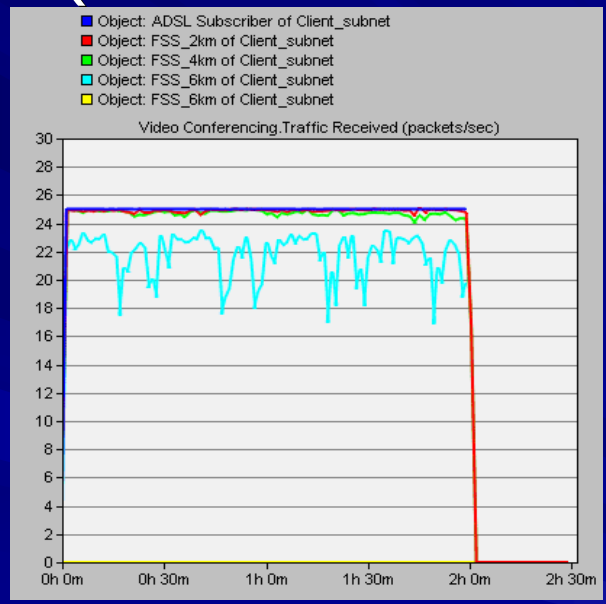
Analysis

- Loss Measurement (instantaneous)



BS buffer: 128 KB

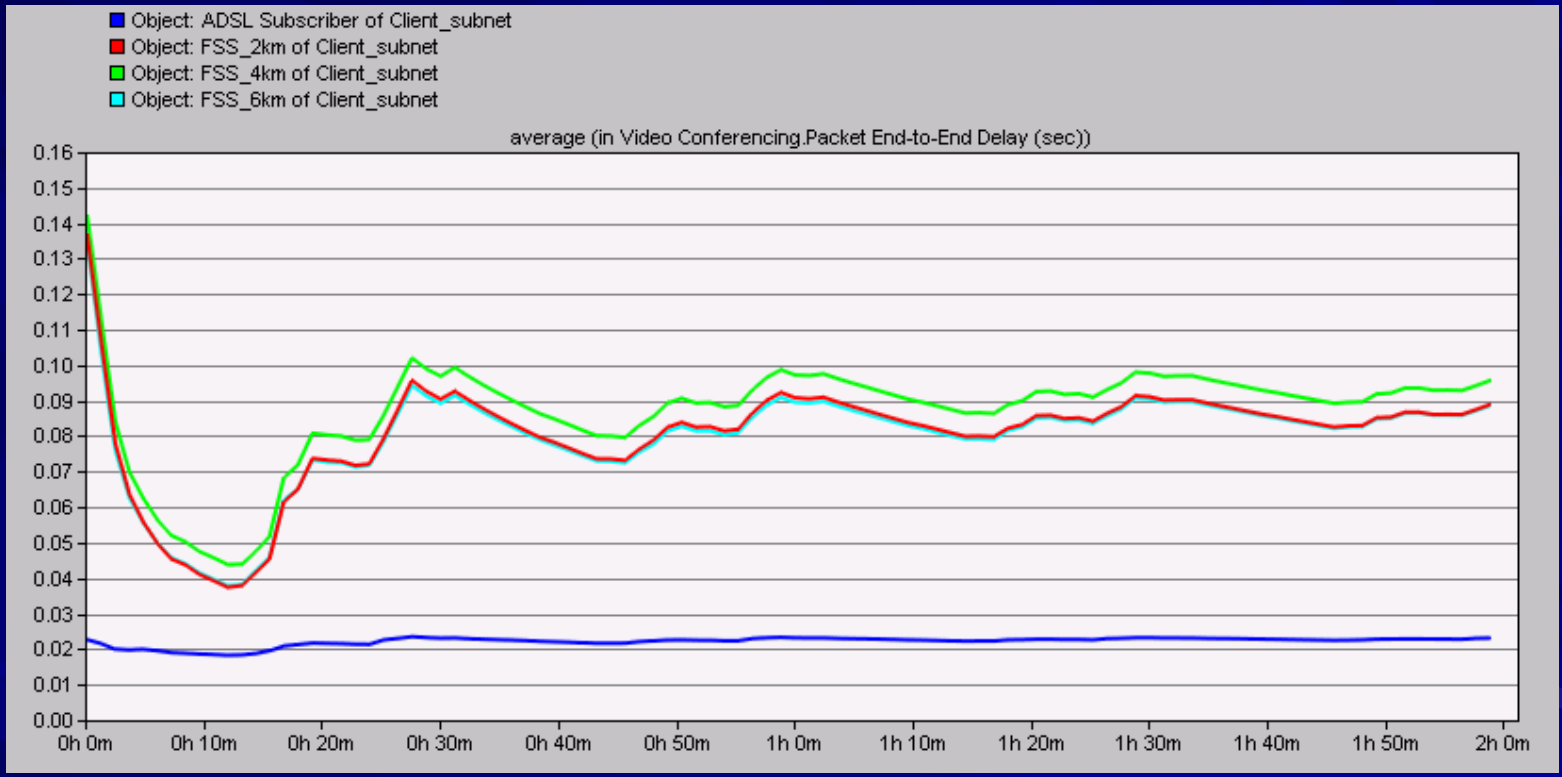


BS buffer: 1024 KB

- 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
- 6km WiMAX station loss still significant because SNR is below minimum level modulation/coding [2]

Analysis

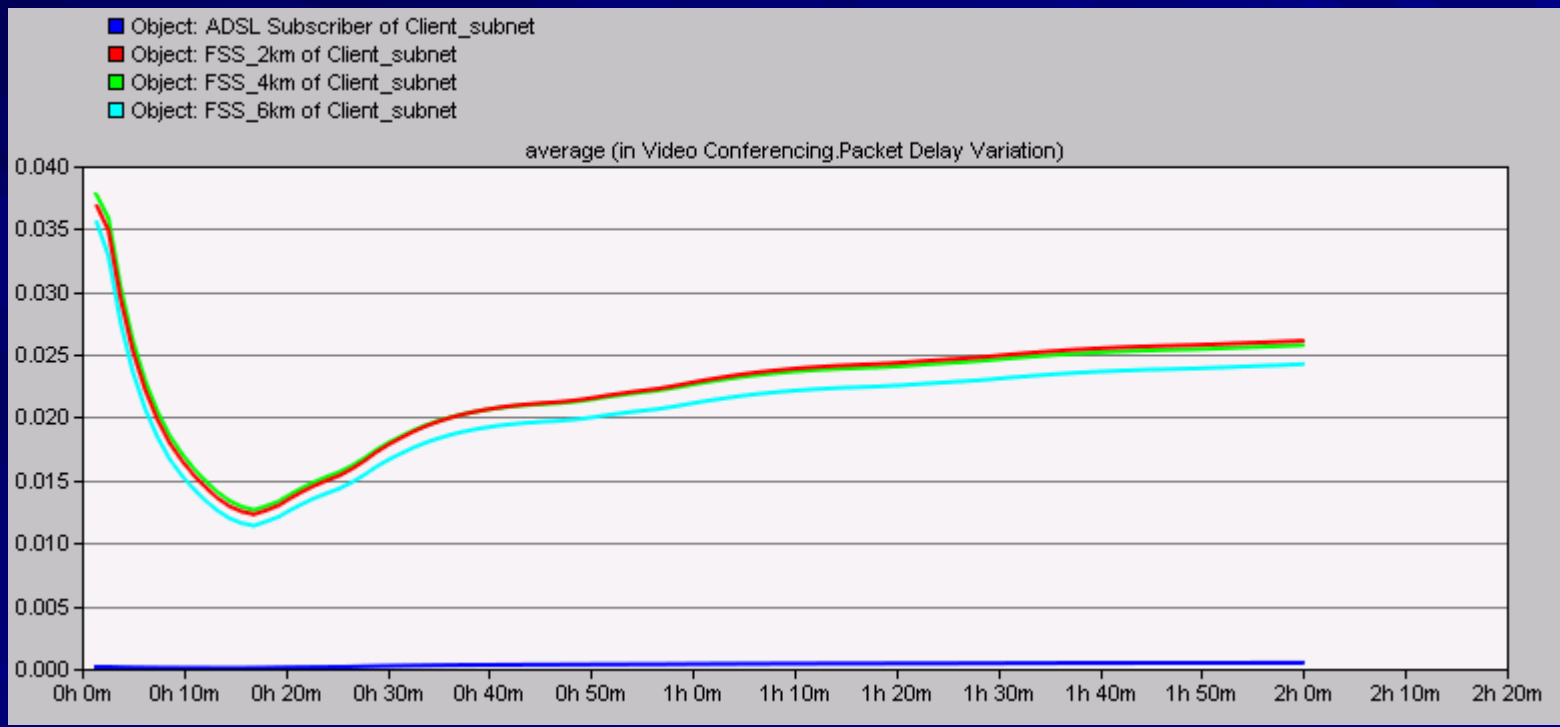
- Delay Measurement



  - Curves are averaged across the 2-hour movie duration
  - Metric Avg: < 300 ms Ideal: < 10 ms [9]

Analysis

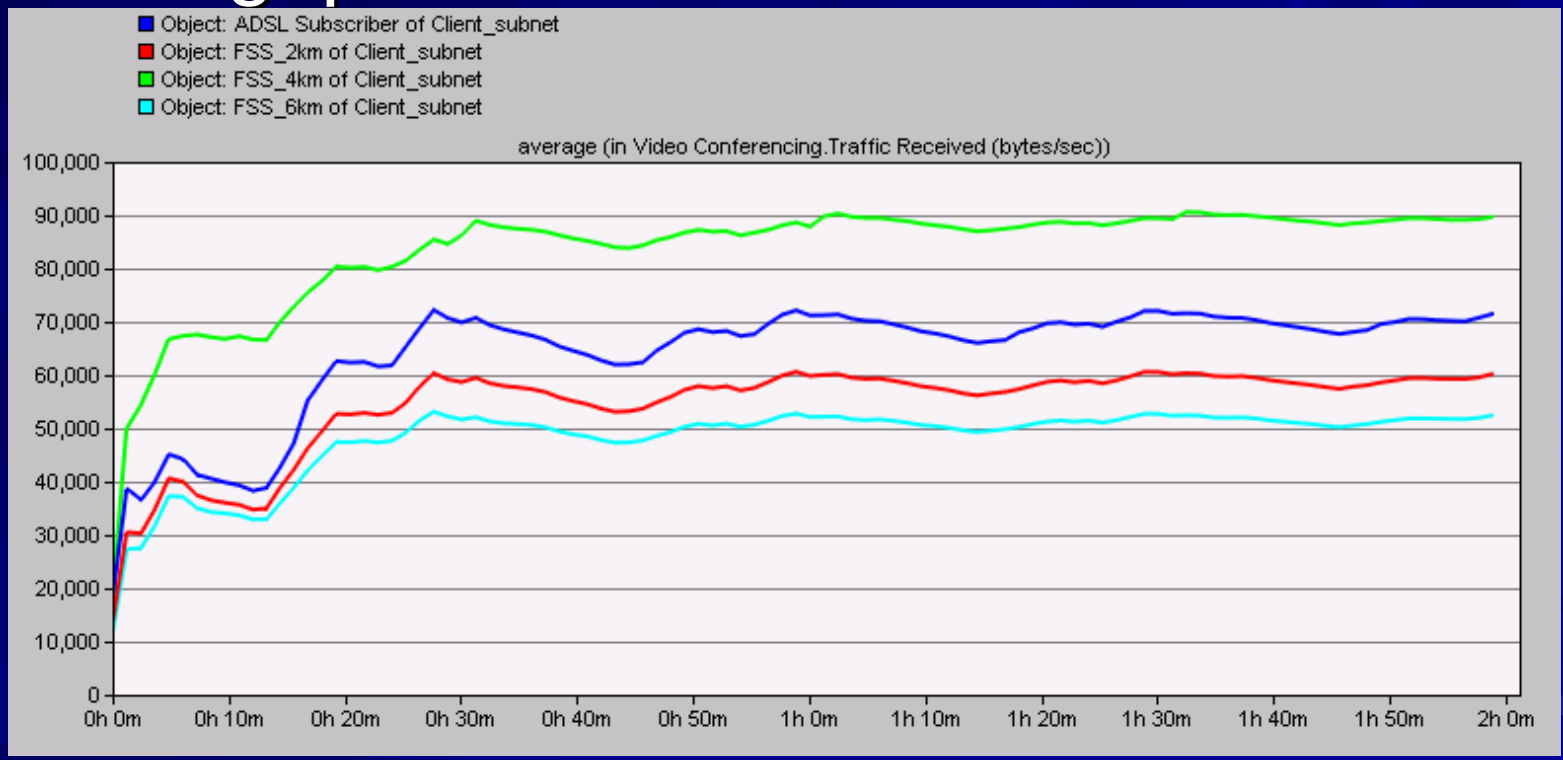
- Jitter Measurement



  - Curves are averaged across the 2-hour movie duration
  - Metric Avg: < 60 ms Ideal: < 20 ms

Analysis

- Throughput



  - Curves are averaged across the 2-hour movie duration
  - Metric 10kbps – 5Mbps [14]

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Conclusions

- Simulation Time: 2.0 hrs Actual time: > 8 hours primary scenario
- WiMAX satisfied the video performance metrics
  - WiMAX packet loss significantly reduced by increasing BS buffering
  - Results are understated since the model used worst case BE scheduler
- Overall results in comparison to ADSL are promising
  - Dependant on specific carrier deployment parameters
    - WiMAX has capacity to deliver higher throughput rates & QoS than ADSL
  - While further refinement is required, WiMAX can provide comparable network performance to ADSL for video streaming services
- Model stability may improve with OPNET 14
  - WiMAX model results were unreasonable at times
- Simulations do not guarantee real world equivalence
  - Must be considered when interpreting results

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Project Challenges

- Environment (licensing, access, VS integration)
- No OPNET newsgroups, gurus, or user-uploaded models
- Steep learning curve for OPNET configurations and video
  - Insufficient documentation
  - Importing video traces, detailed profile configuration, routing
  - WiMAX implementation
  - Extended troubleshooting (confirmed bugs: SPR-113276 / SPR-82429)
  - Learning video traffic details (formats, codecs, GOP details)
- WiMAX rtPS scheduling difficult to configure
  - Could not achieve working configuration
- Learning WiMAX fundamentals within project duration

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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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