Traffic and Network Flow Model for Assessing Impact of 3D Applications on Internet

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Keynote Speech
ICWMC 2010, Polytechnic University of Valencia, Spain
24th September 2010

Keynote Outline

- Context and Scope
- Application Traffic Modelling
- Reference Network Modelling
- Conclusion

Context and Scope

Context

- 2006 Riga Ministerial Declaration on “e-Inclusion”:
  - Emphasis on participation of all individuals and communities in all aspects of the information society to improve economic performance, employment opportunities, quality of life, social participation and cohesion.
- Wireless network is moving on...
  - 3G communication network are delivering widespread mobile connectivity to high-speed data services.
  - 4G networks include 3G networks (LTE) and wireless broadband networks based on the IEEE 802.16 standard (WiMAX) are started in operation.
- Optical IP networks are fast being deployed (in the UK and by 2015 around two thirds of all homes will have been reached).
  - British Telecom pledges £1bn for fibre network. Virgin and Fibrecity are also investing heavily in fibre network. Intended capacity of 25Gbps for access optical network, and 40 to 100Gbps for Inter-regional optical networks.

Will caused a surge in the usage of internet-based application, thus the traffic loading on core and access network.

The impact on the advent of new network infrastructure to the home...

- Increase in diversity of internet-based applications and services.
- Increase in resolution and dimension of video media (2D to 3D, higher frame rate).
- Increase in media access duration
  - Society will become increasingly less reliant on travel and more reliant on communication networks to interact with each other, socially and at work, due to increasing cost of transport.

Scope of our study

- To examine the magnitude of traffic loading increases on the core and access network.
- To develop a flexible traffic and network flow model as a reference for the study.
- To define use case scenarios and modelling mixed heterogeneous internet-based traffic flows especially to include the future 3D applications/services.
- To investigate effect of peak hour and hourly traffic flows on the reference network model.

Motivation of our study

- Given the projected future Internet traffic mixes and use case scenarios:
  - the dimension of the Internet's contribution to core and access networks
  - the existing Internet's contribution to core and access network link capacities whether it is sufficient to support the increased traffic loads due to increased video resolutions and 3D video
- We want to develop a flow model, which is flexible and scalable that allows us to answer these questions for existing and future predicted traffic mixes, use case scenarios and reference network structures.

Application Traffic Modelling

Application Traffic

- The application traffic models for this study are built using a spreadsheet tool, which captures the model characteristics, and allows aggregate packet loads to be tallied, and resulting statistics to be derived.
- The following traffic parameters are considered:
  - Average Packet Call Object Size (Bytes)
  - Average Over-head (Bytes)
  - Inter-arrival (Sec)
  - Session Time (Sec)
  - Packet Calls / Session
  - Average Session Size (Kbytes)
  - Average Rate (kbps)

Application Traffic

- 8 applications of interest with up to total of 35 traffic variations have been defined:
  - 2D/3D Web Browser
  - Streaming Video/IPTV (2D/3D Web, SDTV, HDTV Quality - Clip/Programs)
  - Streaming Audio (MP3, Web, Home Theatre Quality)
  - Voice communication/VoIP (Toll, High Quality)
  - 2D/3D Video Communications (Web, SDTV, HDTV Quality)
  - P2P File Sharing (Small/Large)
  - Interactive Gaming (Large & Slow, Small & Fast)
  - Virtual Environment (Large & Slow, Small & Fast)

Application Traffic

- The application traffics are based on existing model and published statistical data:
  - Web browsing
    - Statistically modelled based on empirical measurements of top web sites.
    - Modelled as multiple downloads, interspaced by “read times”.
    - Draft IEEE 802.16m Evaluation Methodology Document" - IEEE 802.16 BWA WG - 6/18/2007.
    - "Application Traffic Model for WiMAX Simulation“ - Posdata - April 2007.
  - Streaming video
    - Statistical data based on MPEG4 video coding, the expected standard for future IPTV.
    - "Global IP Traffic Forecast and Methodology, 2006 - 2011" - Cisco Systems – 2007.
    - “MPEG-4 AVC to deliver greater bit-rate reduction in coming years,” Oct 24, 2006.
  - Streaming Audio
    - Statistical data based on MP3, which sends fixed-size audio frames at a constant rate (128 kbps typical for recorded music, while rates may be used for voice).

Application Traffic

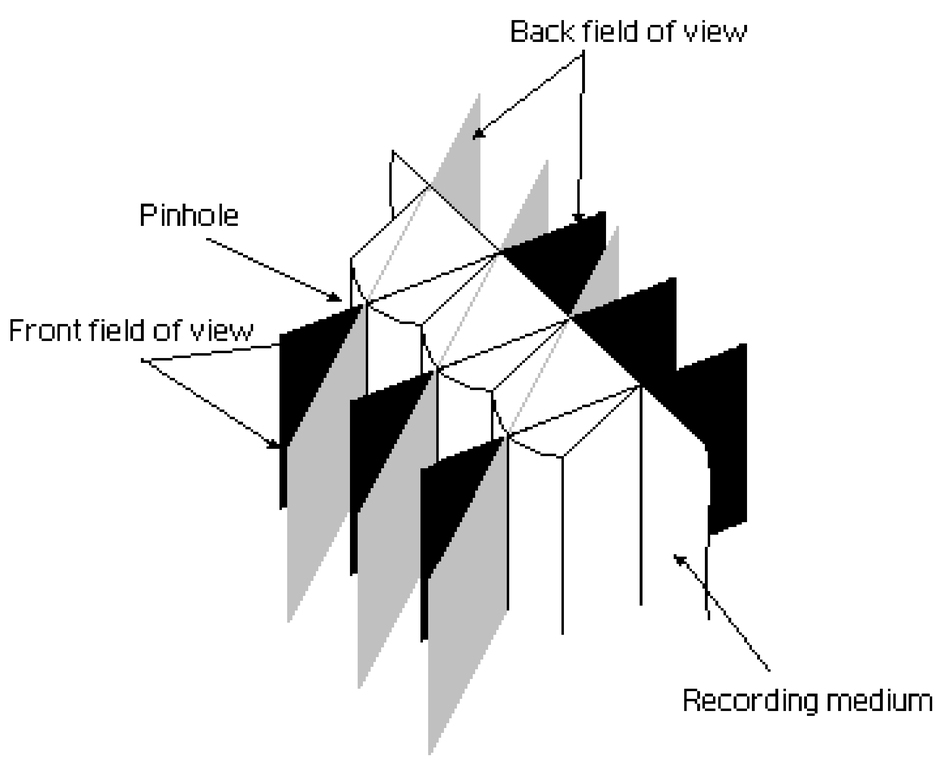
- Voice communication/VoIP
  - Statistical data based on G.711 64k codec used in VoIP and higher-quality codec e.g. Dolby 5.1 for immersive group communications.
  - “Networking Support for Immersive Collaborative Applications,” M. Needham, P. Maurer, IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, Orlando, FL, March 29, 2007.
- Video communication
  - An expected evolution of VoIP communication, hence important application to consider.
  - Statistical data based on video conference model derived from → F. Fitzek and M. Reisslein, “MPEG-4 and H.263 traces for network performance evaluation (extended version)”, Technical Report TKN-00-06, Technical University Berlin, Dept. of Electrical Eng., Germany, October 2000.
- P2P File Sharing
  - Traffic in each direction to/from a user is very much depends on the number of other peers sharing a file, as well as their connection bandwidth.
  - Mostly comprises of REQUEST messages sent by the client to uploading peers, and subsequent PIECE messages sent in return.
  - Statistical data derived from a comprehensive measurement study reported in "BitTorrent Traffic Measurements and Models" - David Erman Blekinge, Institute of Technology – October 2005.

Application Traffic

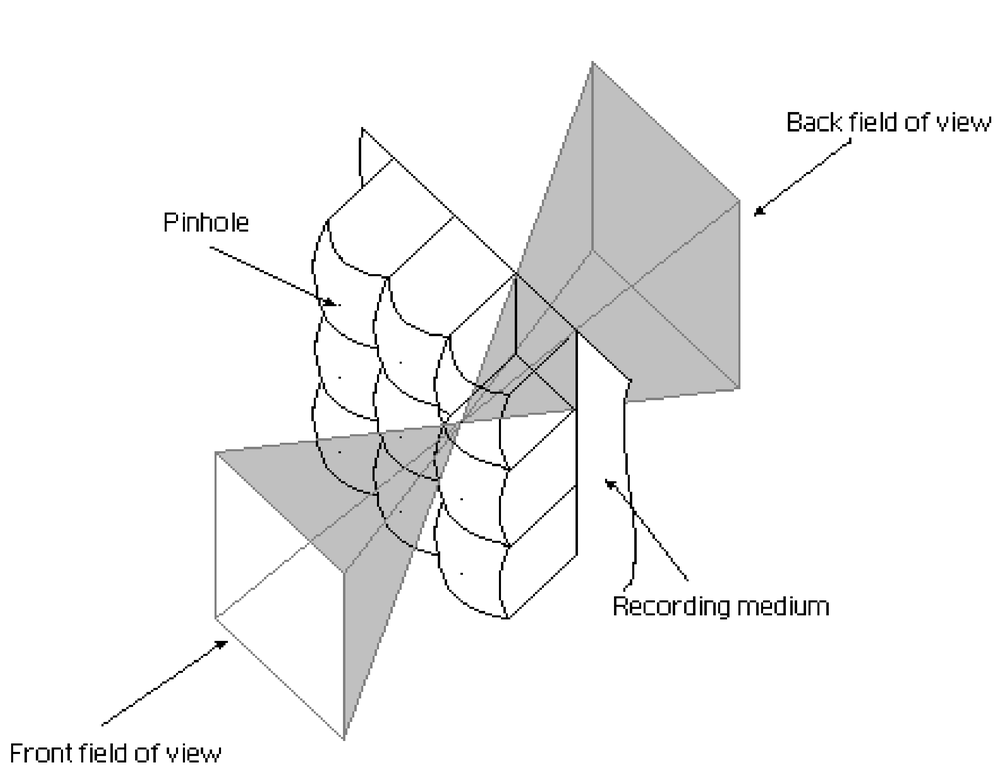
- Gaming
  - Traffic can broadly be divided into slow-pace role playing and adventure games.
  - Statistical data based on “Network Game Traffic Modelling,” Johannes Färber, NetGames2002, April 16-17, 2002, Braunschweig, Germany.
  - “Traffic Modelling for Fast Action Network Games”, Johannes Färber, Multimedia Tools and Applications, Vol. 23, Issue 1, pp. 31 - 46., May 2004.
- Virtual Environments
  - Increasing popular application related to gaming called virtual reality – “Second Life” (online 3D virtual world). The data must be transmitted across the network and rendered in real-time, hence the traffic is demanding in case of network loading.
  - Additionally, 3D environments will soon represent the Internet interface in near future, replacing current 2D web browsers.
  - "Traffic Analysis Beyond This World: the Case of Second Life" - Fernandes et al. – 2007.

New Application Traffic

- In addition, we modelled new and futuristic 3D video applications based on 3D holoscopic imaging technology for 3D video capturing with a single camera and playback.
  - Currently in development under the EU FP7 3D-Vivant project leading by Brunel University (http://www.3dvivant.eu/)

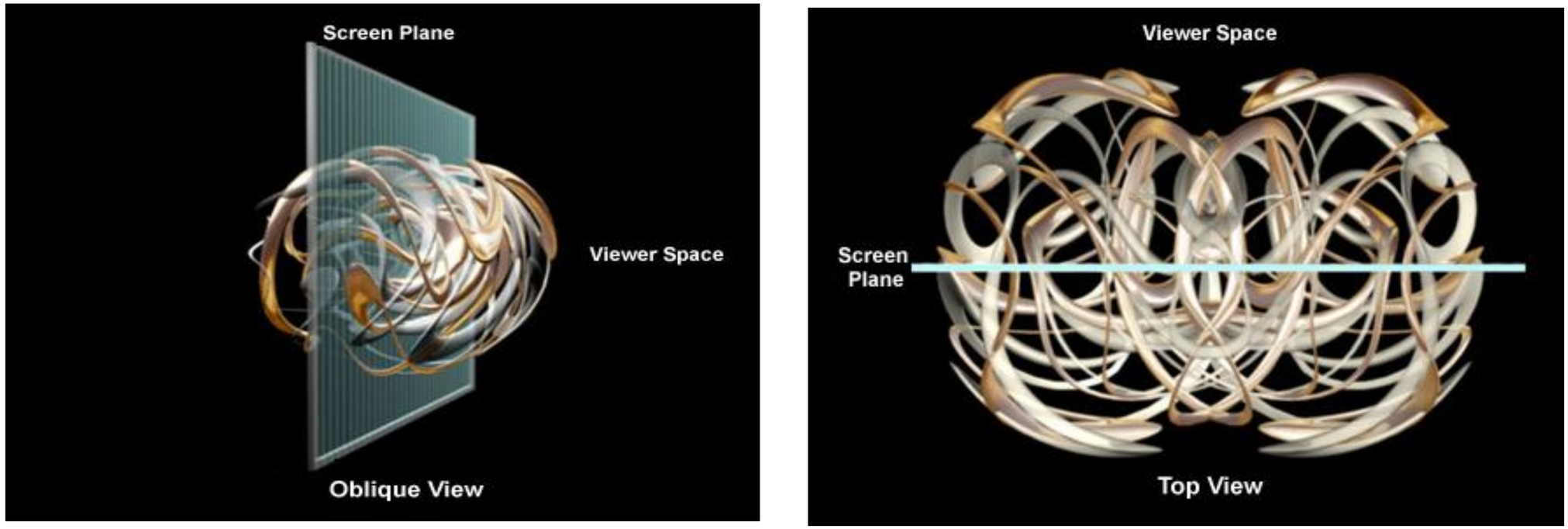


1D array (horizontal) of Cylindrical lenses to record Unidirectional Integral Images



2D array (horizontal & vertical) of microlenses to record Omnidirectional Integral Images

Holoscopic 3D Video Display

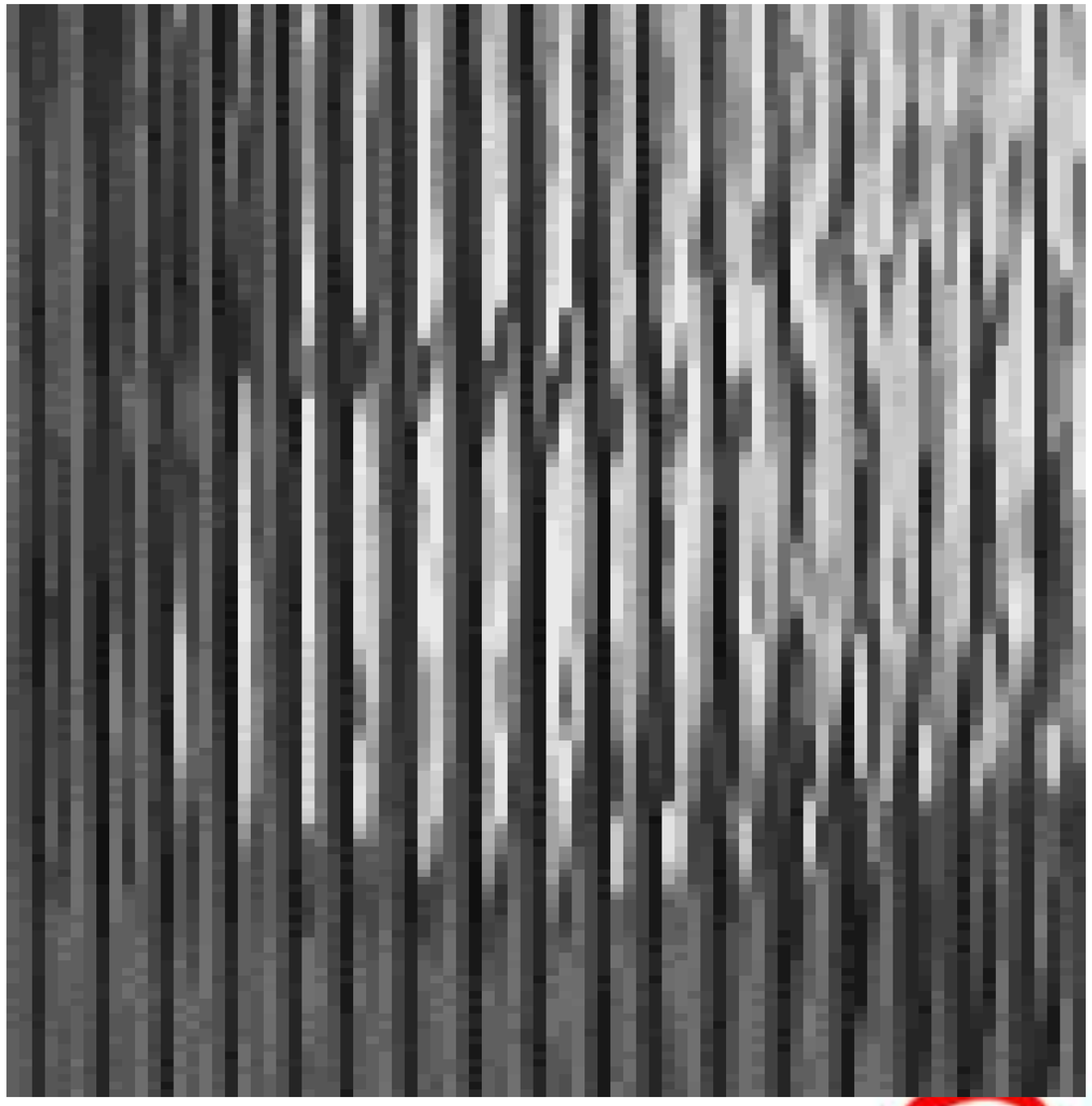


Horizontal Parallax 3D Integral Image

- This new technique allows more conventional single camera live capture and glasses-free display, for both horizontal and horizontal/vertical parallax, offers free viewing to more than one person independently of the viewer’s position.

- It allows the mixing of real and virtual video and it is now accepted as a strong candidate for next generation 3DTV.

Example of digitally captured unidirectional integral image



Holoscopic 3D video Traffic

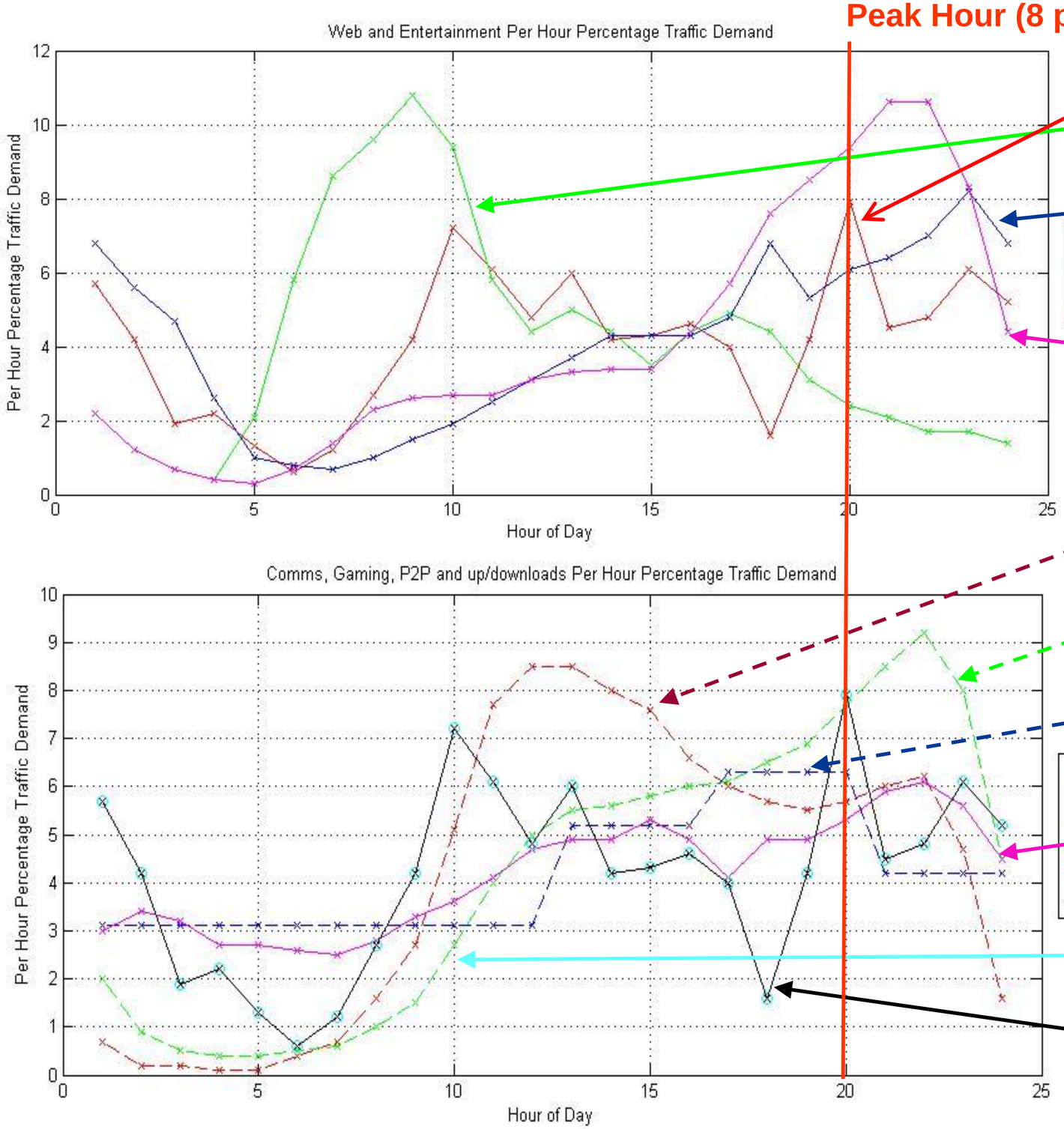
- Horizontal parallax images can be encoded at 0.075 bpp at a PSNR of 33.6 dB.
  - 2560 x 240 horizontal parallax video @ 25 fps with 3D wavelet encoded 8-bit holoscopic gives estimated rate of 1.735 Mbps
  - 57600 x 480 horizontal parallax video @ 25 fps with 3D wavelet encoded 8-bit holoscopic gives estimated rate of 7.816 Mbps
  - 10240 x 5760 horizontal and vertical parallax @ 25 fps with 3D wavelet encoded 64-bit holoscopic gives estimated rate of 16.61 Mbps.

Data provided by
Dr Amar Aggoun
Brunel University

Characterisation of Application Traffics

Application	Application Specifics	Packet Call Object (PCO)	Avg. PCO Size (Bytes)	Avg. Over-head (Bytes)	Inter-arrival (Sec)	Sess. Time (Sec)	Packet Calls / Session	Avg. Session (Kbytes)	Avg. Rate (bps)
2D Web Browser	2D graphics	Web Page	489350	40		300	17	8.320e+06	3.467e+03
3D Web Browser	3D graphics and Web pages	Web Page	665820	40		300	17	11.32e+06	4.717e+03
Streaming Audio (Web Quality)	MP3 (20k)	Audio Frame	65	40	0.026	300		1.212e+06	3.231e+04
Streaming Audio (MP3 Quality)	MP3 (128k)	Audio Frame	418	40	0.026	300		5.285e+06	1.410e+05
Streaming Audio (Home Theater)	AC3 Dolby 5.1 (448k)	Audio Frame	1792	88	0.032	300		1.763e+07	4.700e+05
Video/IPTV (2D Web Quality-Clip/Prog)	MPEG-4 320x240	Group of Pictures	20000	400	0.48	300/ 3600		1.275e+07 / 1.530+08	3.400e+05
Video/IPTV (3D Web Quality-Clip/Prog)	3D Wavelet 2560x240 (8-bit holoscopic, Horiz Parallax)	Group of Pictures	103680	400	0.48	300/ 3600		6.505e+07 / 7.806e+08	1.735e+06
Video/IPTV (2D SDTV Quality-Clip/Prog)	MPEG-4 720x480	Group of Pictures	90000	2400	0.48	300/ 3600		5.775e+07 / 6.930e+08	1.540e+06
Video/IPTV (3D SDTV Quality-Clip/Prog)	3D Wavelet 5760x480 (8-bit holoscopic, Horiz Parallax)	Group of Pictures	466560	2400	0.48	300/ 3600		2.931e+08 / 3.517e+09	7.816e+06
Video/IPTV (2D HDTV Quality-Clip/Prog	MPEG-4 1280x720	Group of Pictures	480000	12000	0.48	300/ 3600		3.075e+08 / 3.690e+09	8.200e+06
Video/IPTV (3D HDTV Quality-Clip/Prog	3D Wavelet 10240x5760 (64-bit holoscopic, Horiz/ Vert Parallax)	Group of Pictures	9953280	12000	0.48	300/ 3600		6.228e+09 / 7.474e+10	1.661+08
VoIP (Toll Quality)	G.711 (64k)	Speech Frame	160	40	0.02	210		2.100e+06	8.000e+04
VoIP (MP3 Quality)	MP3 (128k)	Frame	418	40	0.026	210		3.699e+06	1.409e+05
VoIP (Home Theater Quality)	AC3 Dolby 5.1 (448k)	Audio Frame	1792	88	0.032	210		1.234e+07	4.700e+05

Modelling of “Per Hour Percentage” Traffic Demand of Applications



Peak Hour (8 pm)

Web: Mid morning and evening peak

Audio: Morning peak

Video clip: High during day peaking at evenings

IPTV: High during evenings

VoIP: Peak in morning remaining high till late evening

AV Comms: High during day peaking in evening

Gaming: Peaks in synchronism with availability of other time zones

P2P: Higher during day and evening not varying much

Audio UDL: Mid morning and evening peak

Video UDL: Mid morning and evening peak

Use Case Scenarios

- 2D & 3D Residential Broadband
- 2D & 3D Increased Media Resolution
- 2D & 3D Max Media Resolution

Example: Characterisation of Use Case Scenario

Predefined Traffic demand at Peak Hour

Calculated from predefined traffic parameters

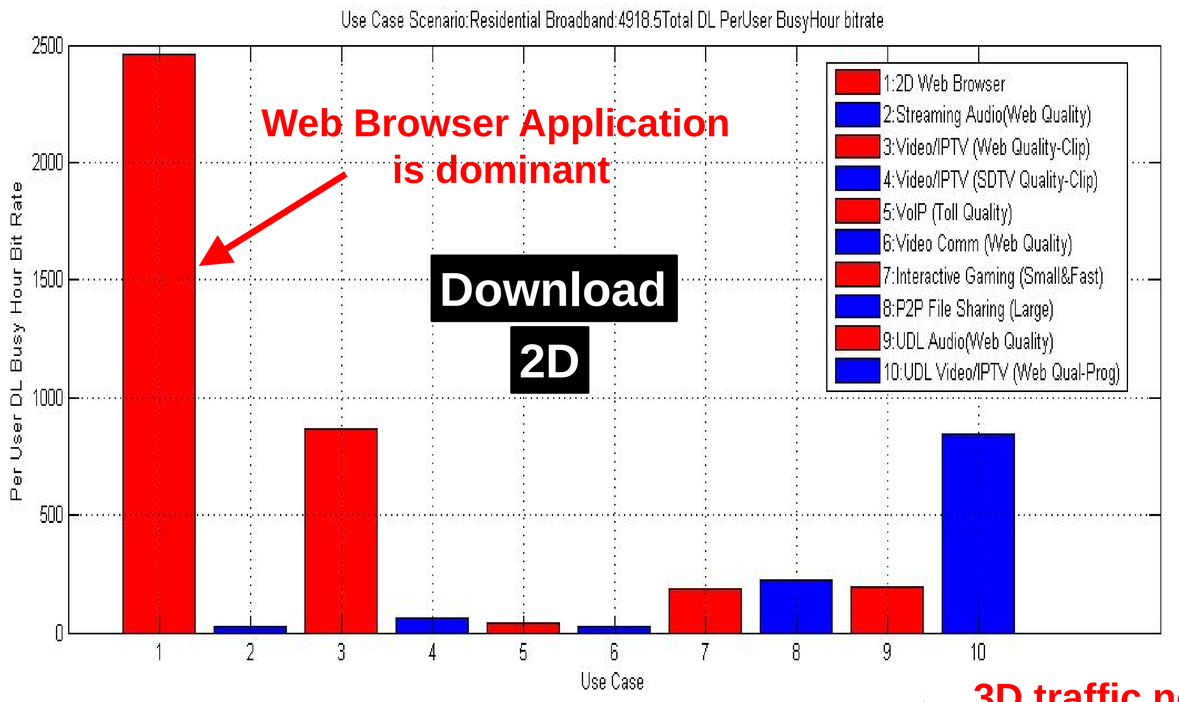
Residential Broadband

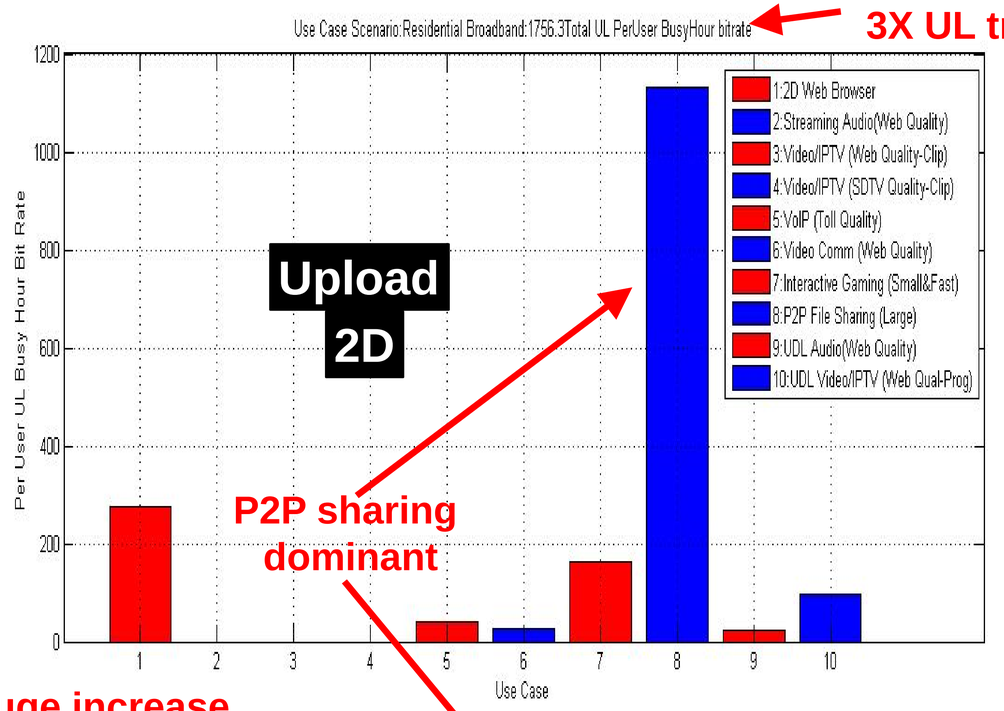
Application	Type Quality	Session per Day		Total Load User per Day (Mbytes)	Peak Hour %	Traffic Asymmetry (% uplink)	Equivalent per user Busy Hour bit rate Down/up link (bits/sec)
Web Browser	2D Web Browser	2.5		15.599	7.9	10.1	2462 / 277
Streaming Audio	Streaming Audio (Web Quality)	1.5		0.454	2.4	0	24 / 0
Streaming Video	Video/IPTV (Web Quality-Clip	1.0		6.375	6.1	0	864 / 0
IPTV – program	Video/IPTV (SDTV Quality-Clip)	1.0		2.888	9.4	0	60 / 0
VoIP Comms.	VoIP (Toll Quality)	2.0		0.630	5.7	50.0	40 / 40
Video Comms	Video Comm (Web Quality)	0.5		0.319	7.7	50.0	27 / 27
Interactive Gaming	Interactive Gaming (Small&Fast)	1.0		2.525	6.25	46.4	188 / 163
P2P File Sharing	P2P File Sharing (Large)	0.14		11.500	5.3	83.6	222 / 1132
Audio UD loading	UDL Audio(Web Quality)	2,0		1.211	7.9	10.4	191 / 22
Video UD loading	UDL Video/IPTV (Web Qual-Prog)	0.07		5.355	7.9	10.4	842 / 98
Total							4921 / 1759

3D Residential Broadband

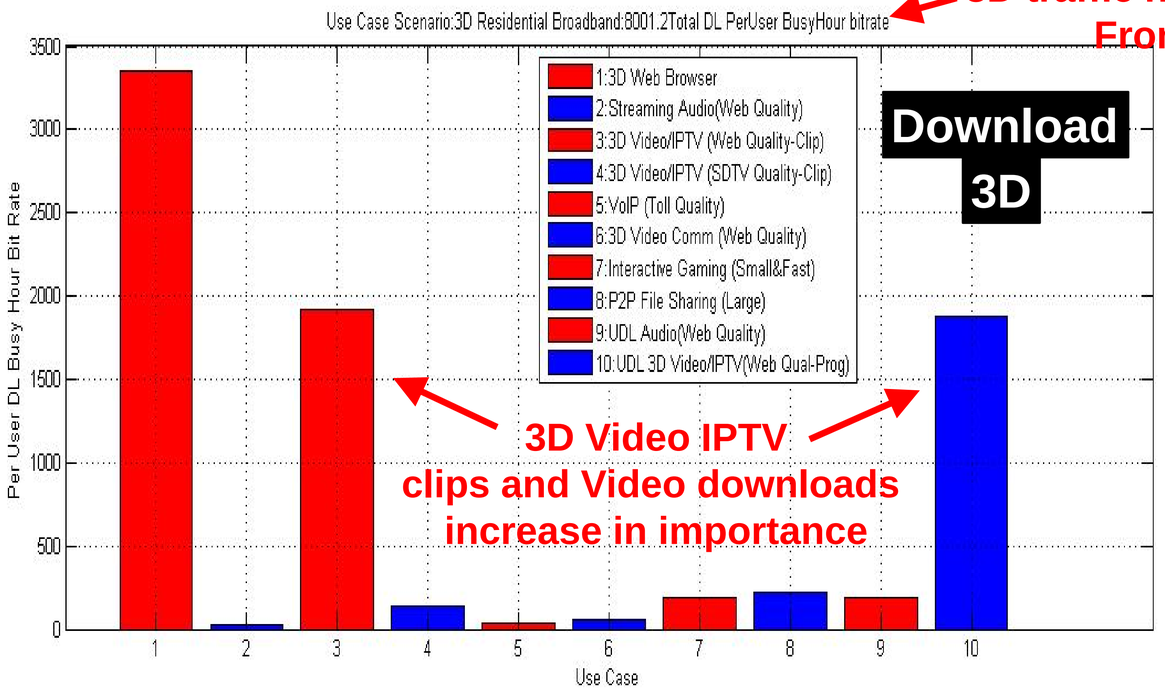
Application	Type Quality	Session per Day		Total Load User per Day (Mbytes)	Peak Hour %	Traffic Asymmetry (% uplink)	Equivalent per user Busy Hour bit rate Down/up link (bits/sec)
Web Browser	3D Web Browser	2.5		21.224	7.9	10.1	3350 / 376
Streaming Audio	Streaming Audio (Web Quality)	1.5		0.454	2.4	0	24 / 0
Streaming Video	3D Video/IPTV (Web Quality-Clip	1.0		32.525	6.1	0	4409 / 0
IPTV – program	3D Video/IPTV (SDTV Quality-Clip)	1.0		1.466	9.4	0	306 / 0
VoIP Comms.	VoIP (Toll Quality)	2.0		0.630	5.7	50.0	40 / 40
Video Comms	3D Video Comm (Web Quality)	0.5		1.626	7.7	50.0	139 / 139
Interactive Gaming	Interactive Gaming (Small&Fast)	1.0		2.525	6.25	46.4	188 / 163
P2P File Sharing	P2P File Sharing (Large)	0.14		11.500	5.3	83.6	222 / 1132
Audio UD loading	UDL Audio(Web Quality)	2,0		1.211	7.9	10.4	191 / 22
Video UD loading	UDL 3D Video/IPTV(Web Qual-Prog)	0.07		27.321	7.9	10.4	4298 / 499
Total							13166 / 2371

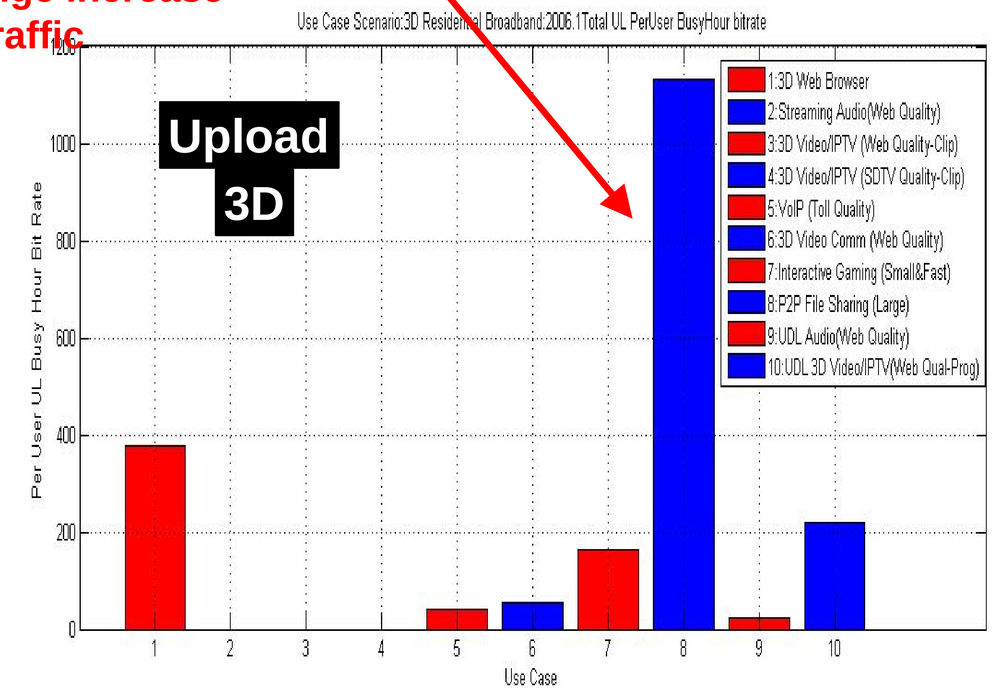
2D and 3D Residential Broadband:
Per User Up/Download Traffic Demand at Peak Hour



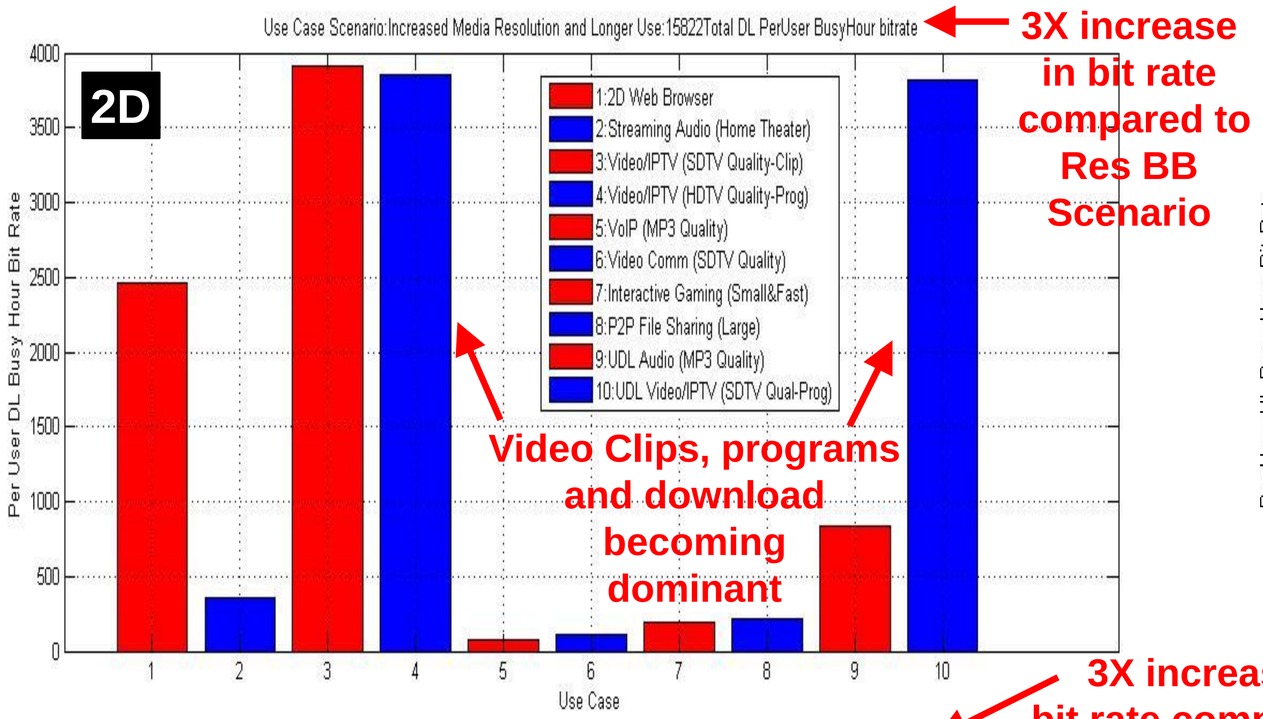


3D traffic not a huge increase From 2D traffic



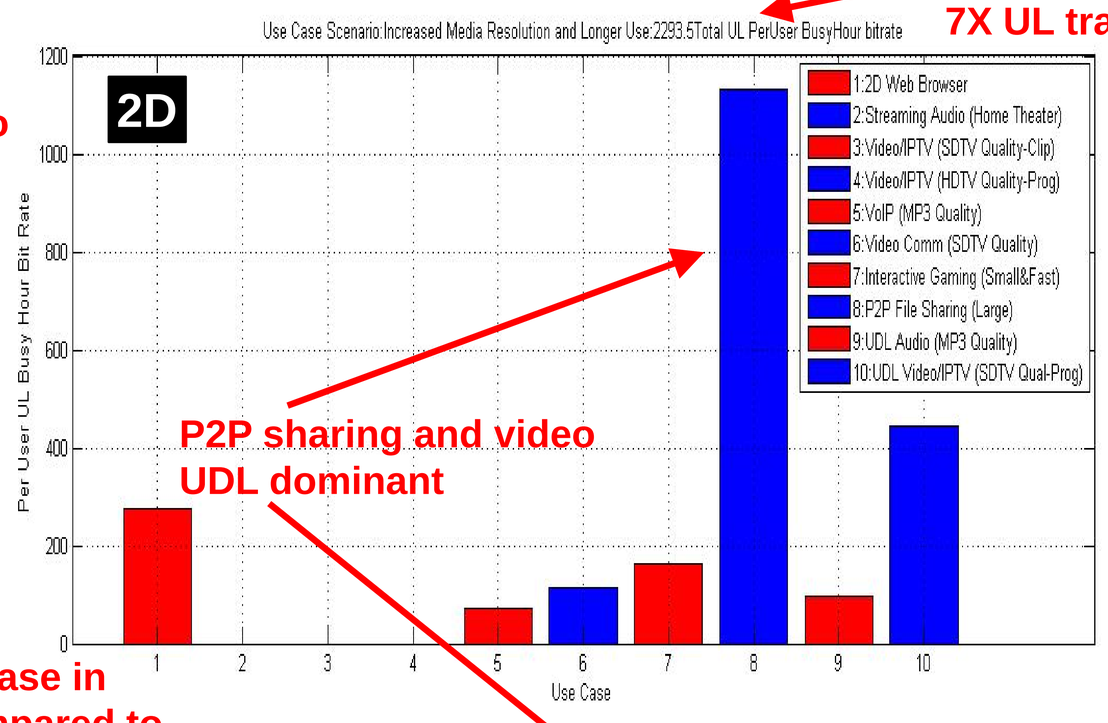


2D and 3D Increased Media Resolution:
Per User Up/Download Traffic Demand at Peak Hour



3X increase in bit rate compared to Res BB Scenario

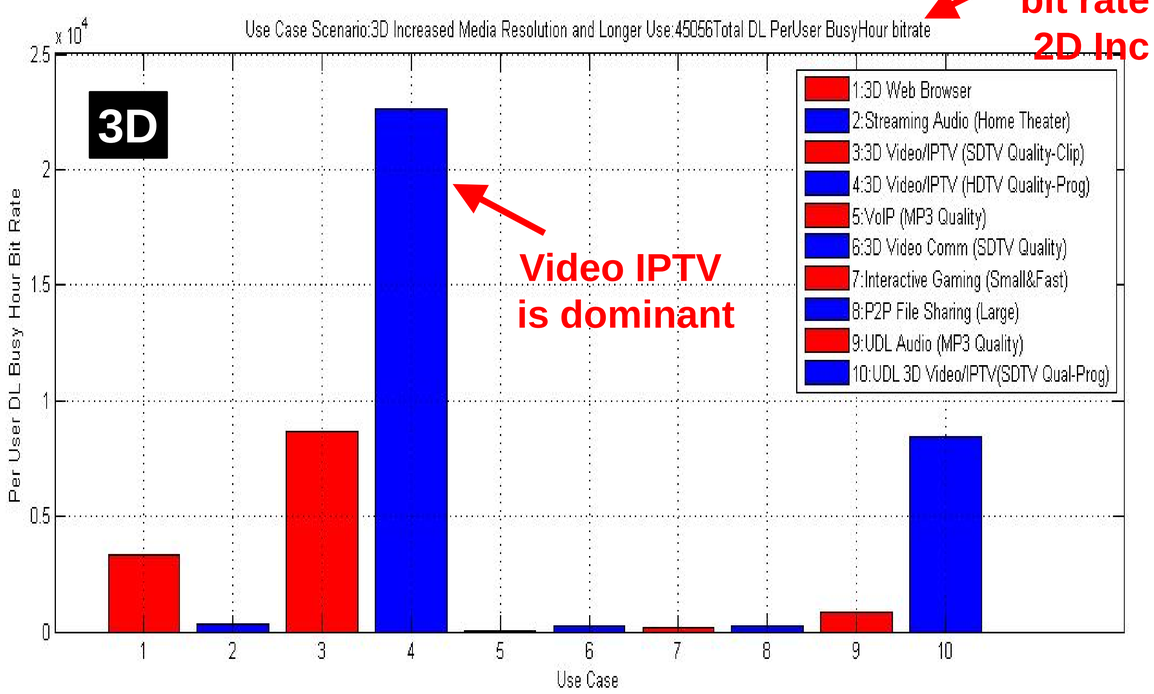
Video Clips, programs and download becoming dominant



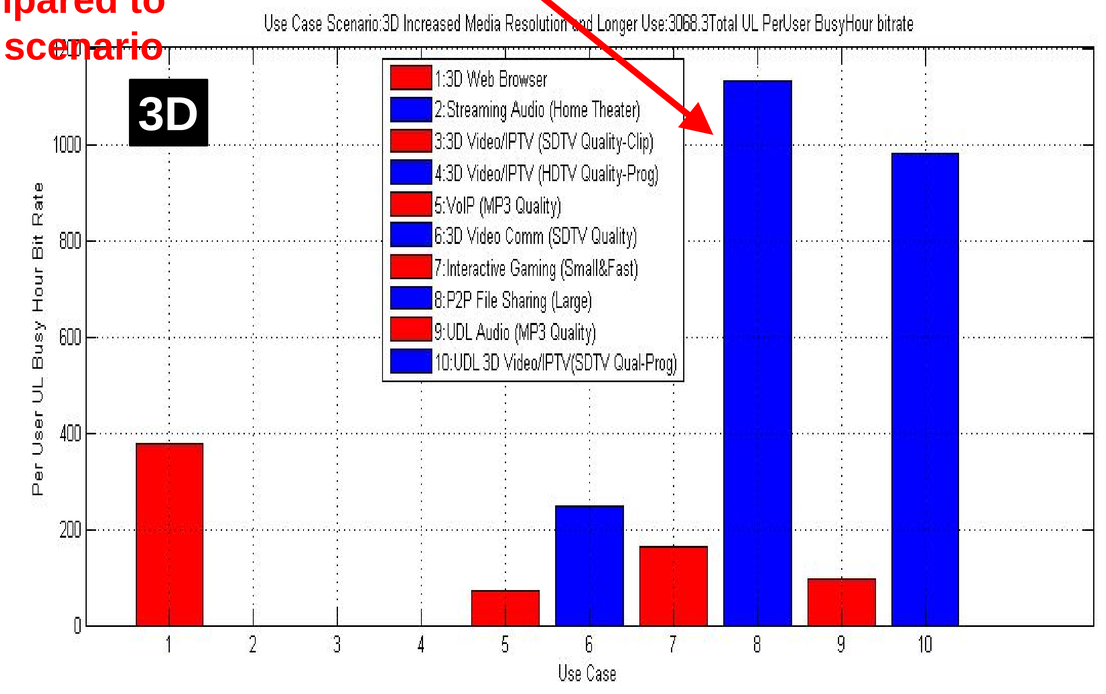
DL traffic bit rate 7X UL traffic

P2P sharing and video UDL dominant

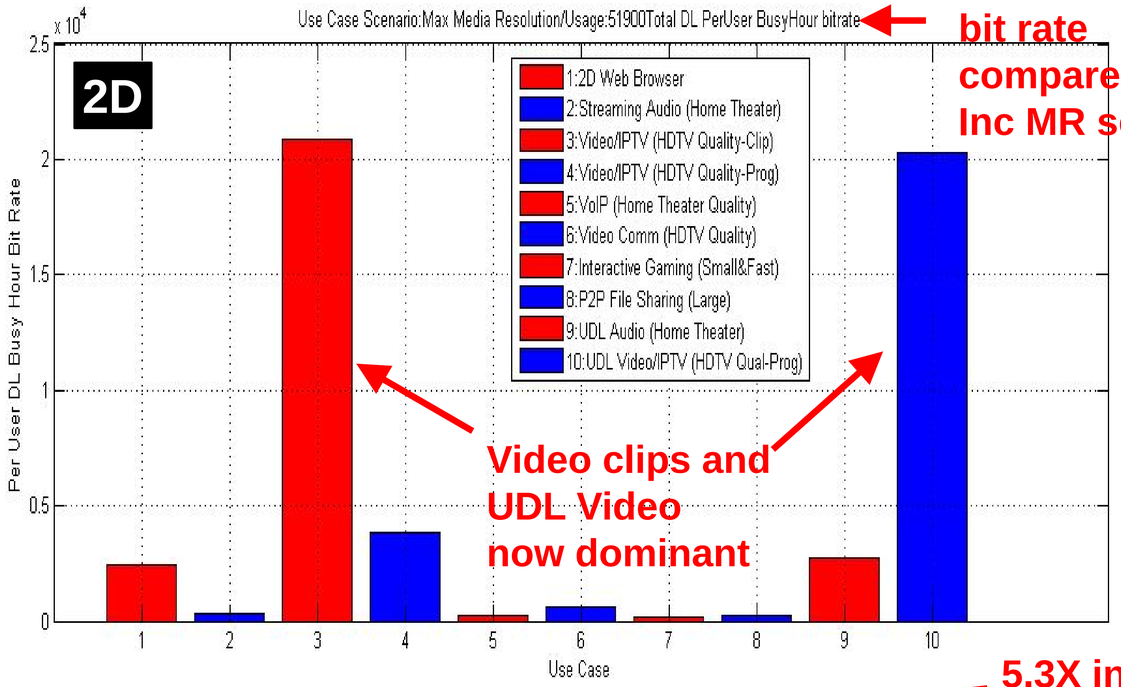
3X increase in bit rate compared to 2D Inc MR scenario



Video IPTV is dominant

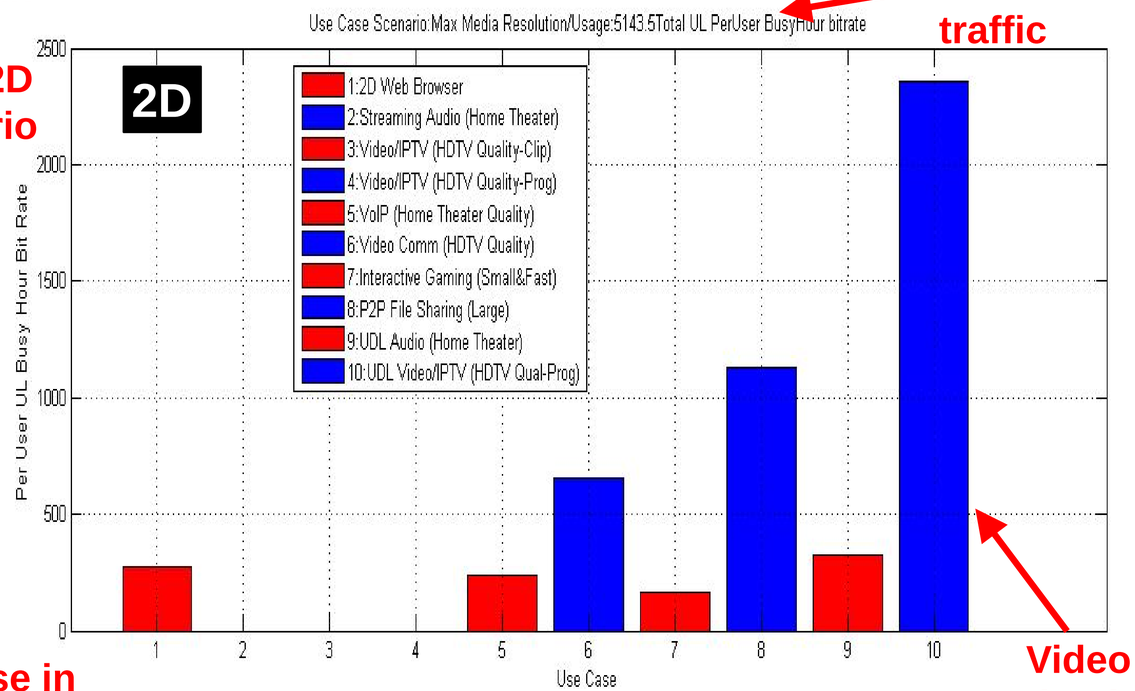


2D and 3D Max Media Resolution:
Per User Up/Download Traffic Demand at Peak Hour



3.3X increase in bit rate compared to 2D Inc MR scenario

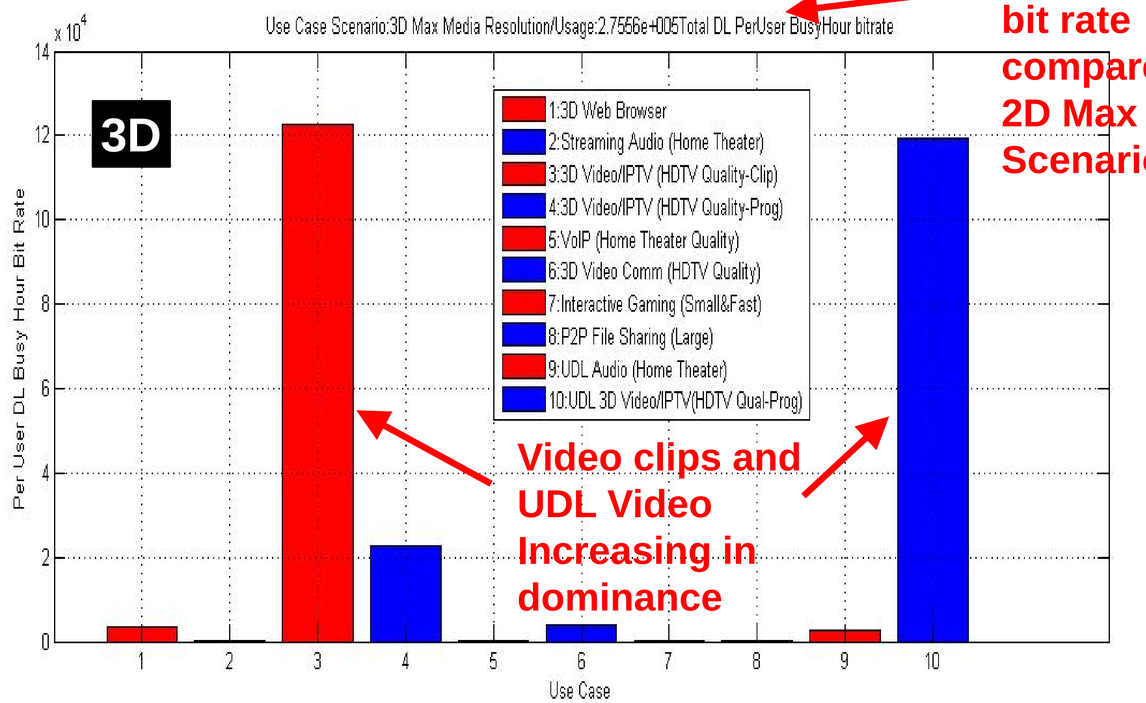
Video clips and UDL Video now dominant



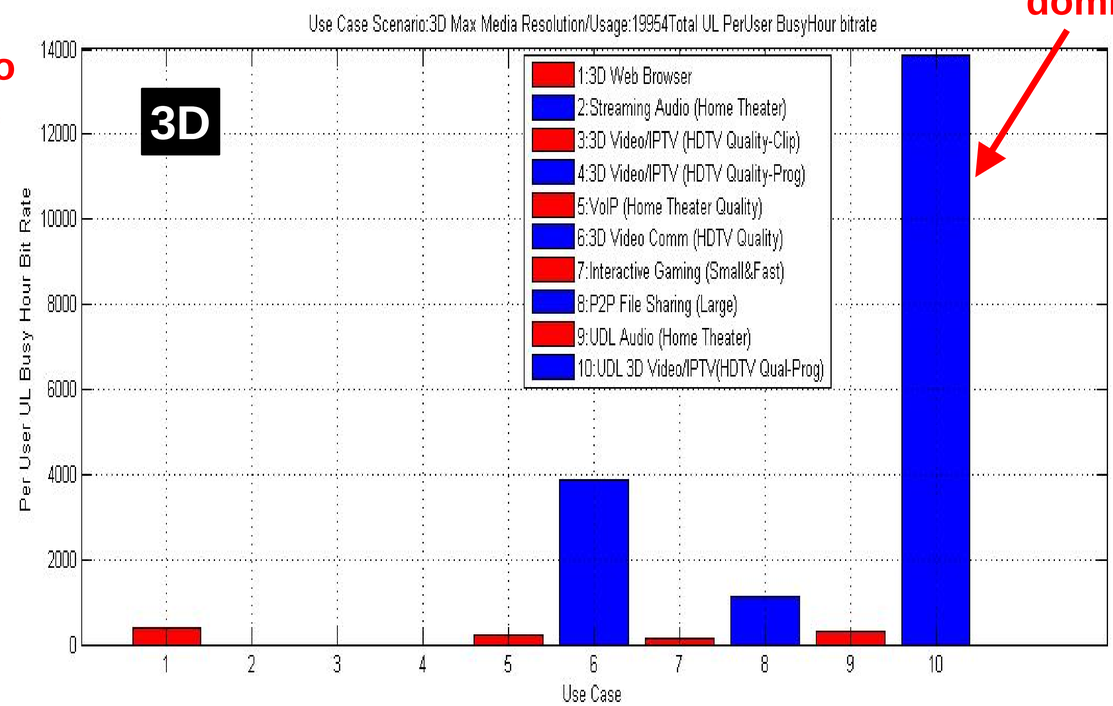
DL traffic bit rate 10X UL traffic

Video UDL dominant

5.3X increase in bit rate compared to 2D Max Res Scenario

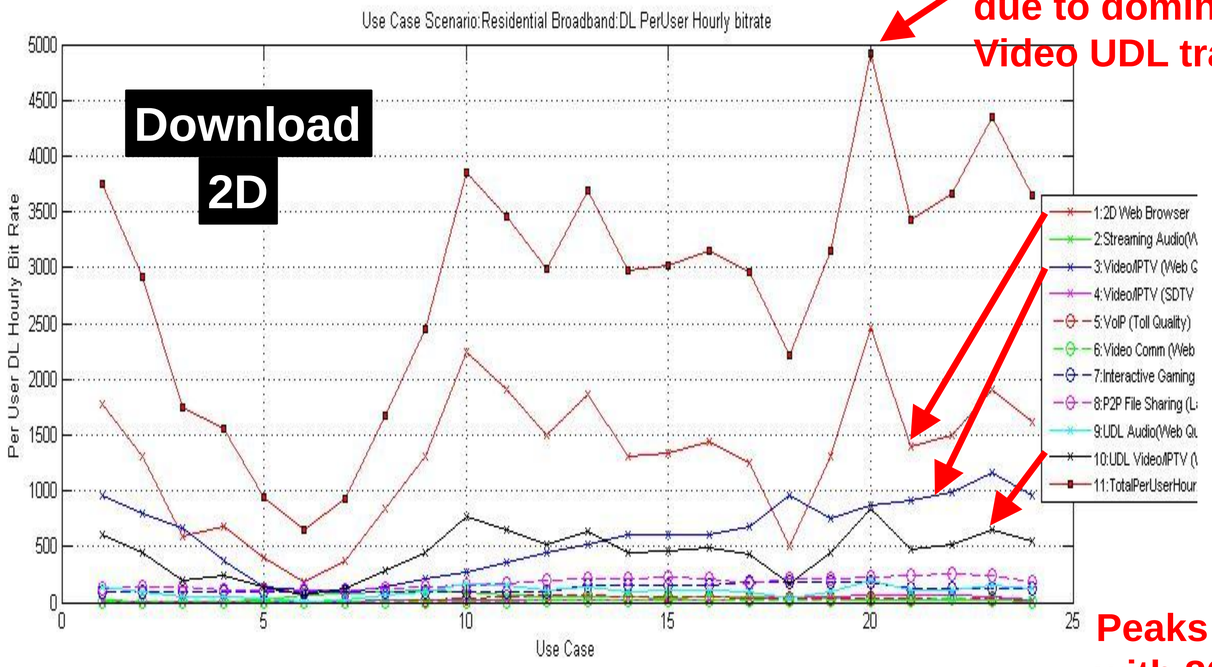


Video clips and UDL Video Increasing in dominance

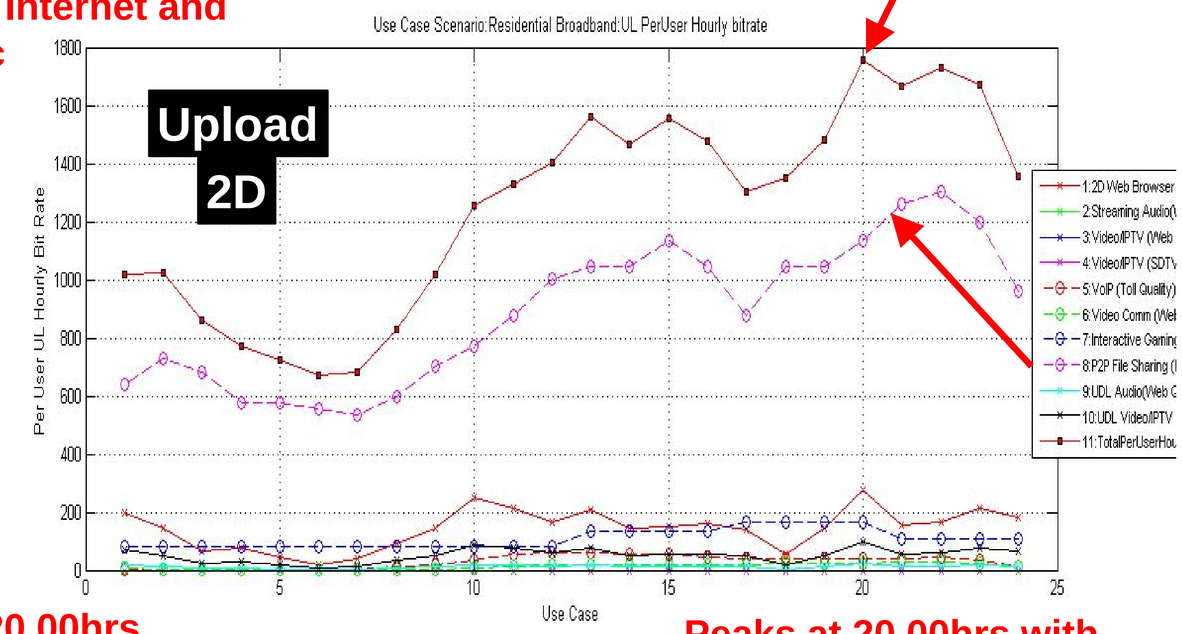


2D and 3D Residential Broadband:
Per User Up/Download Link Demand over 24 hours

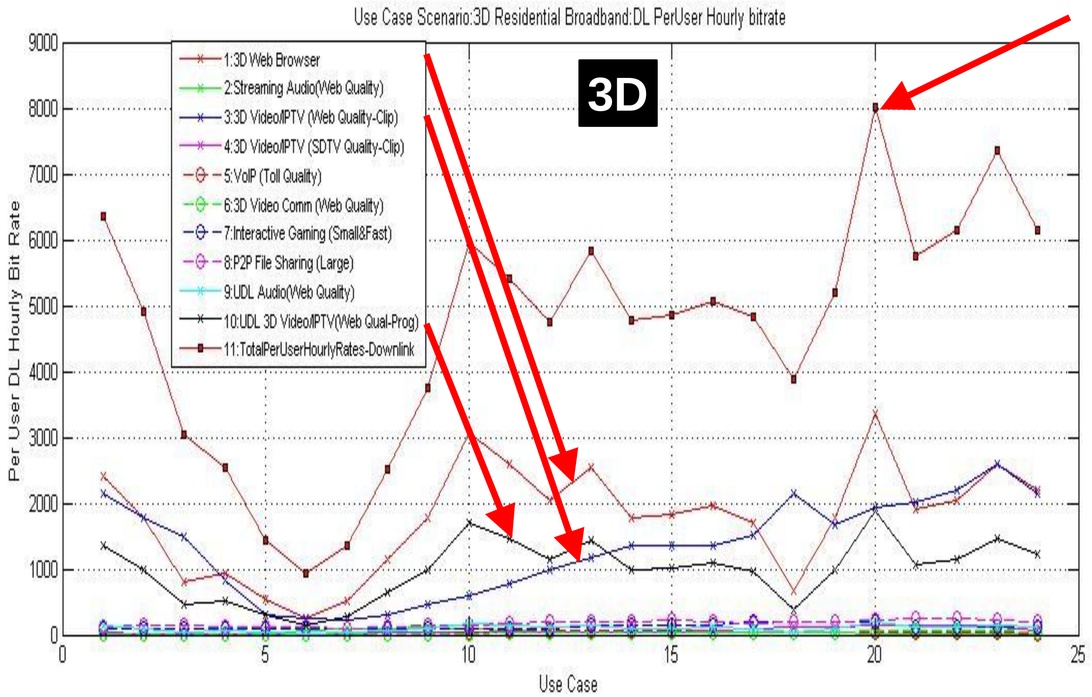
Peaks at 20.00hrs with 4919 bps due to dominant Internet and Video UDL traffic



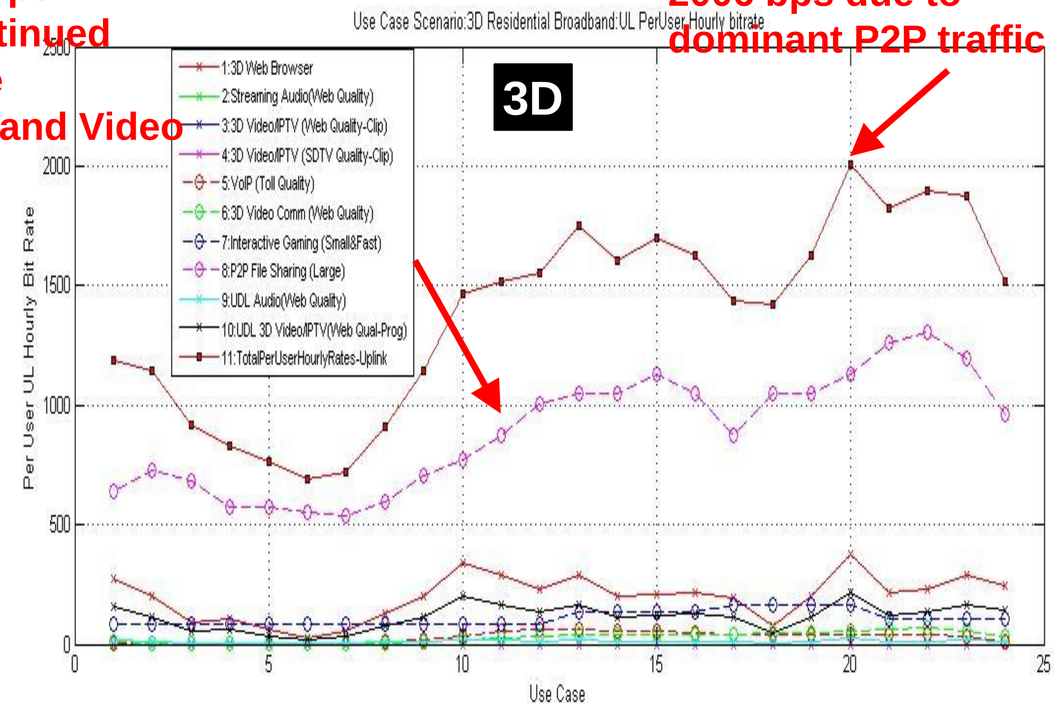
Peaks at 20.00hrs with 1756 bps due to dominant P2P traffic



Peaks at 20.00hrs with 8001 bps due to continued dominance of Internet and Video UDL traffic

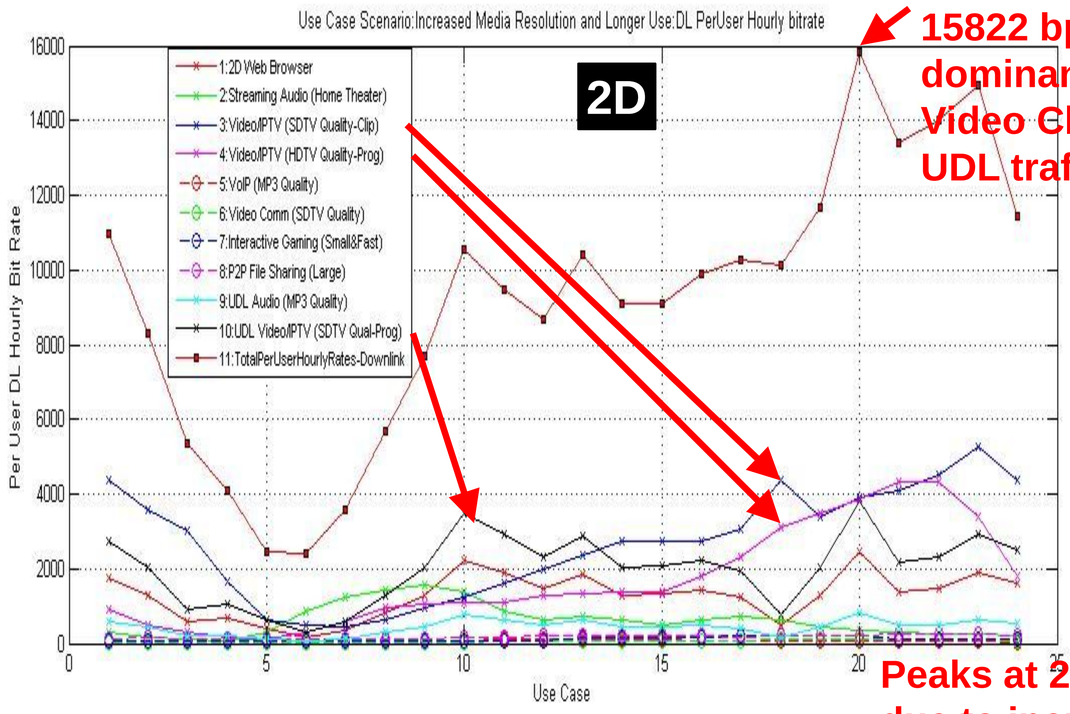


Peaks at 20.00hrs with 2006 bps due to dominant P2P traffic

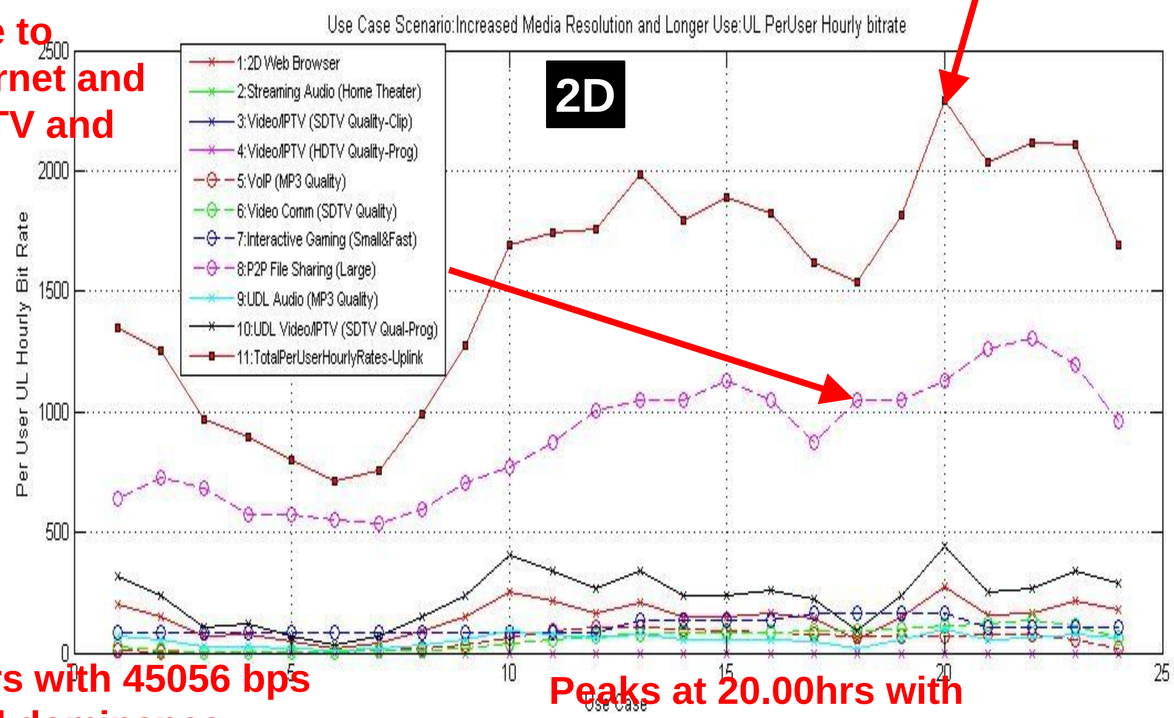


2D and 3D Increased Media Resolution:
Per User Up/Download Link Demand over 24 hours

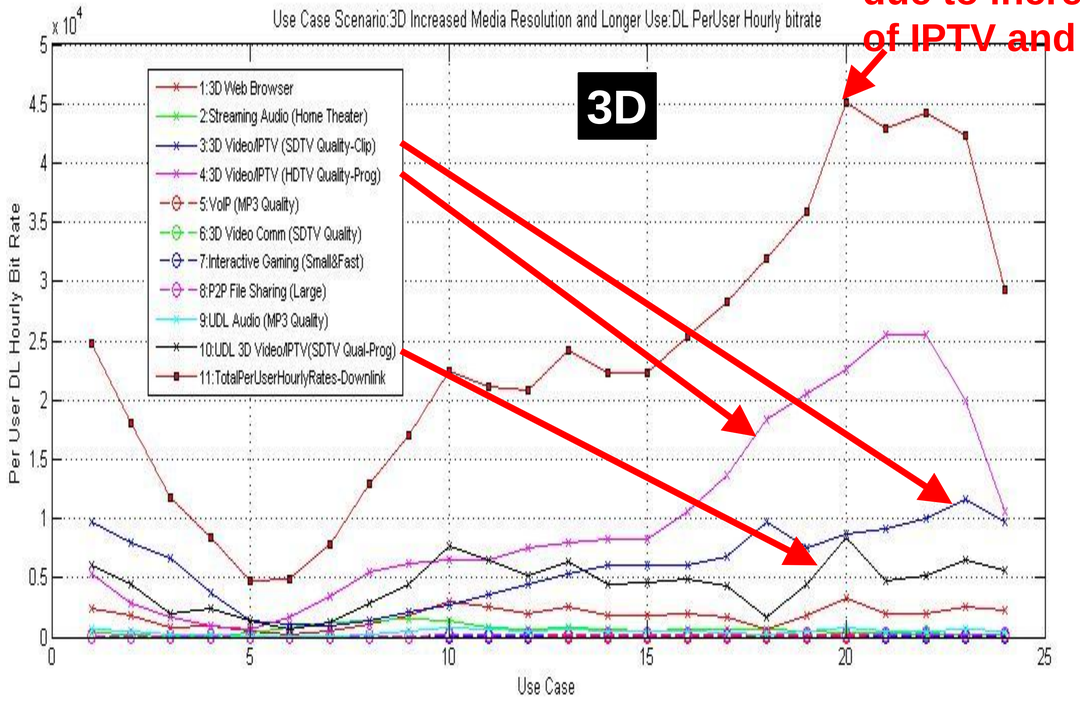
Peaks at 20.00hrs with 15822 bps due to dominant Internet and Video Clip, IPTV and UDL traffic



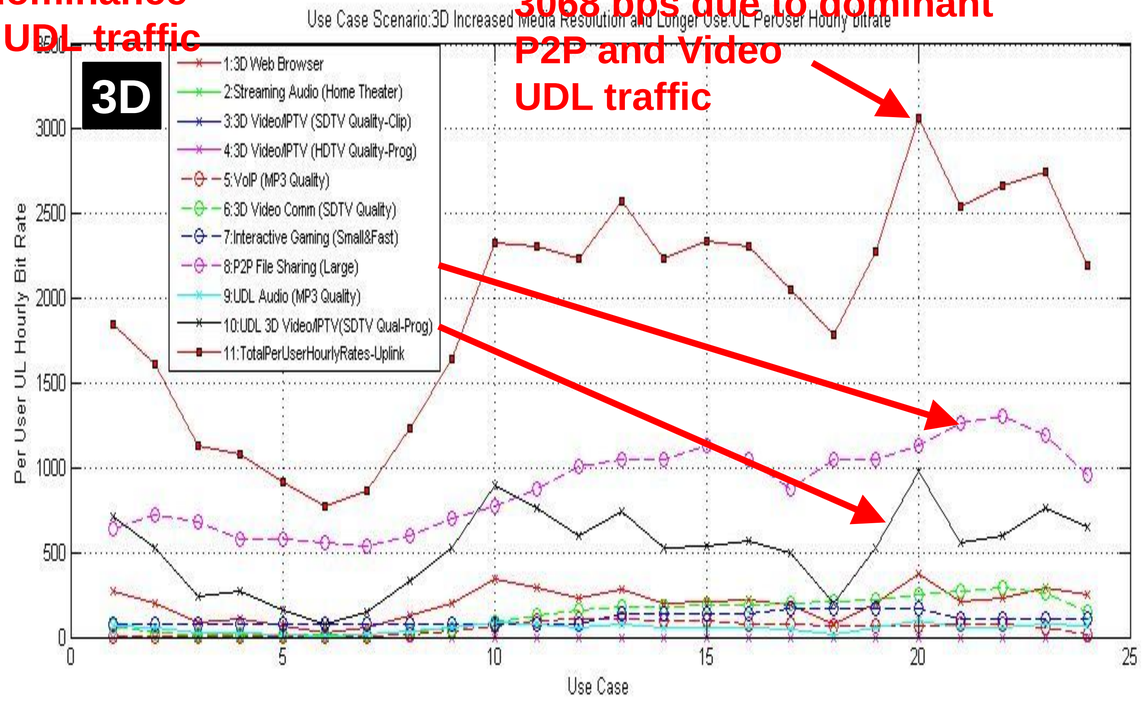
Peaks at 20.00hrs with 2294 b/s due to dominant P2P traffic



Peaks at 20.00hrs with 45056 bps due to increased dominance of IPTV and Video UDL traffic



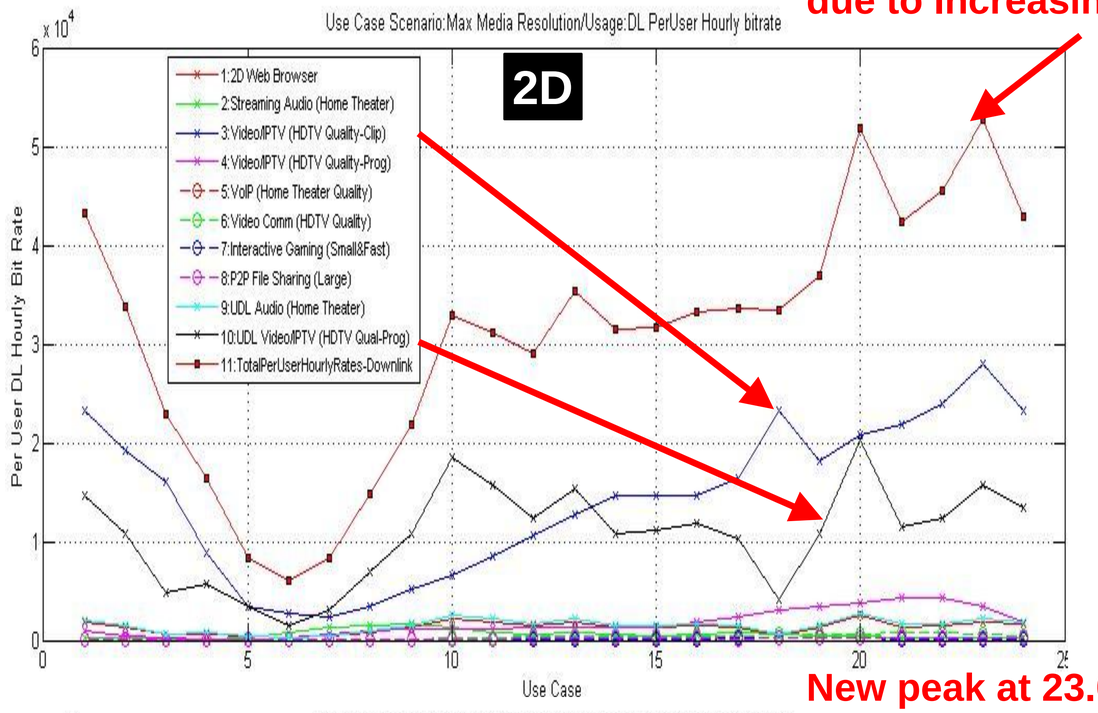
Peaks at 20.00hrs with 3068 bps due to dominant P2P and Video UDL traffic

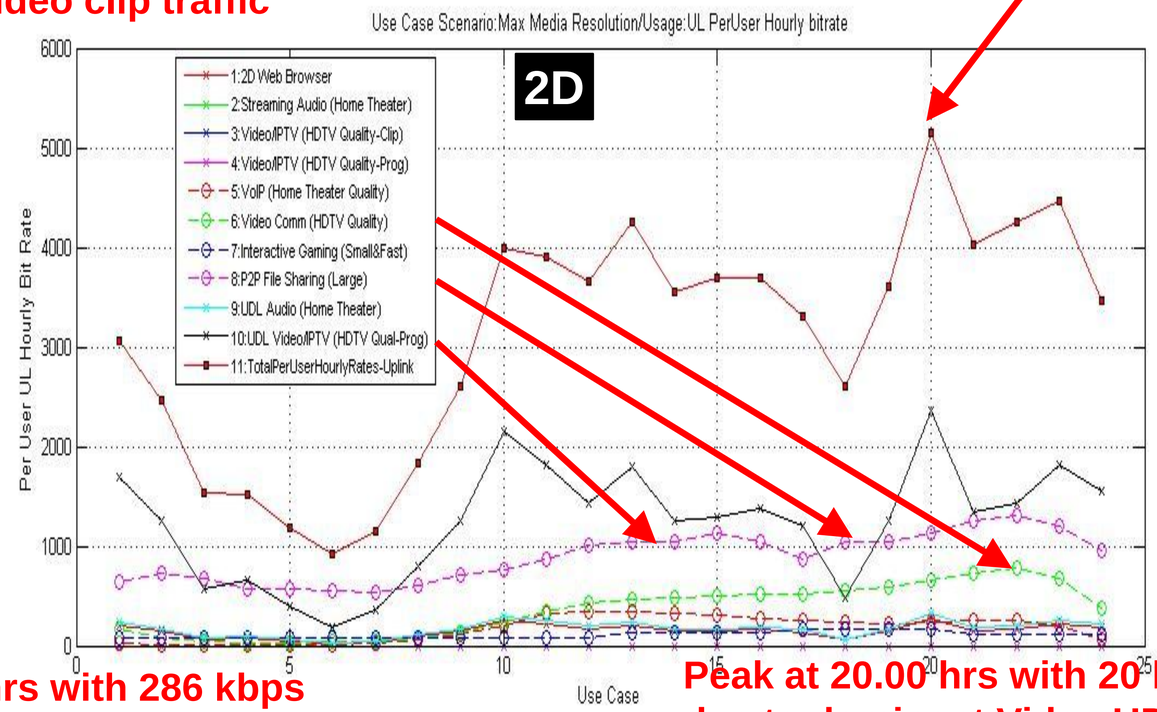


2D and 3D Max Media Resolution:
Per User Up/Download Link Demand over 24 hours

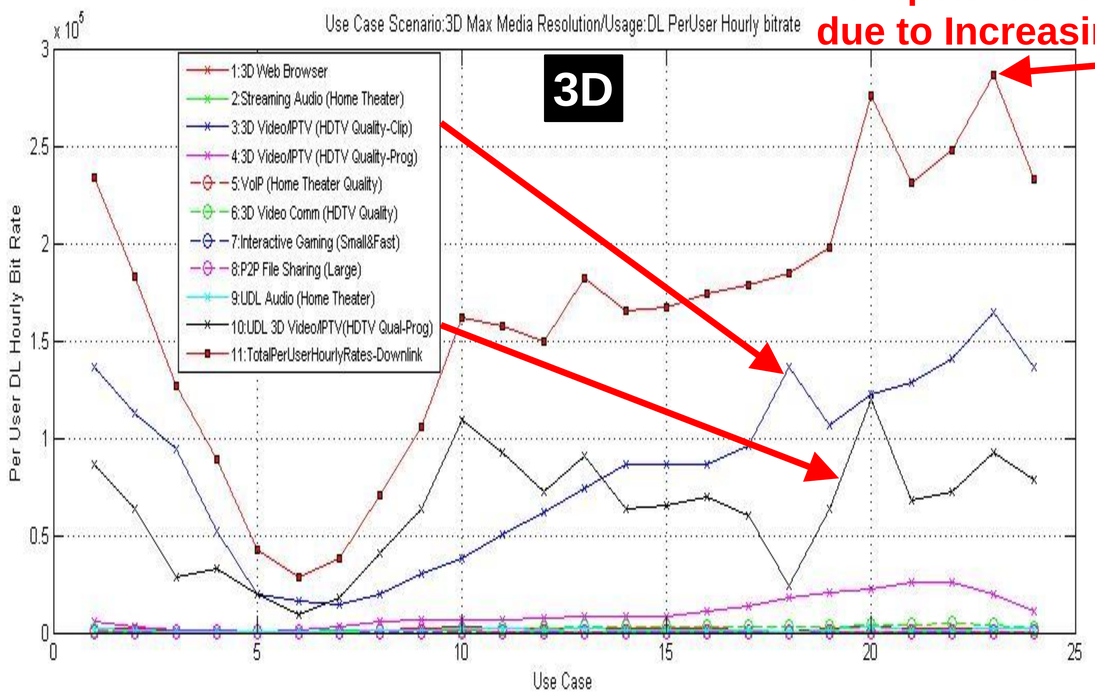
New peak at 23.00 hrs with 53 kbps due to Increasing Video clip traffic

Peak at 20.00 hrs with 5.1 kbps due to Increasing Video UDL traffic

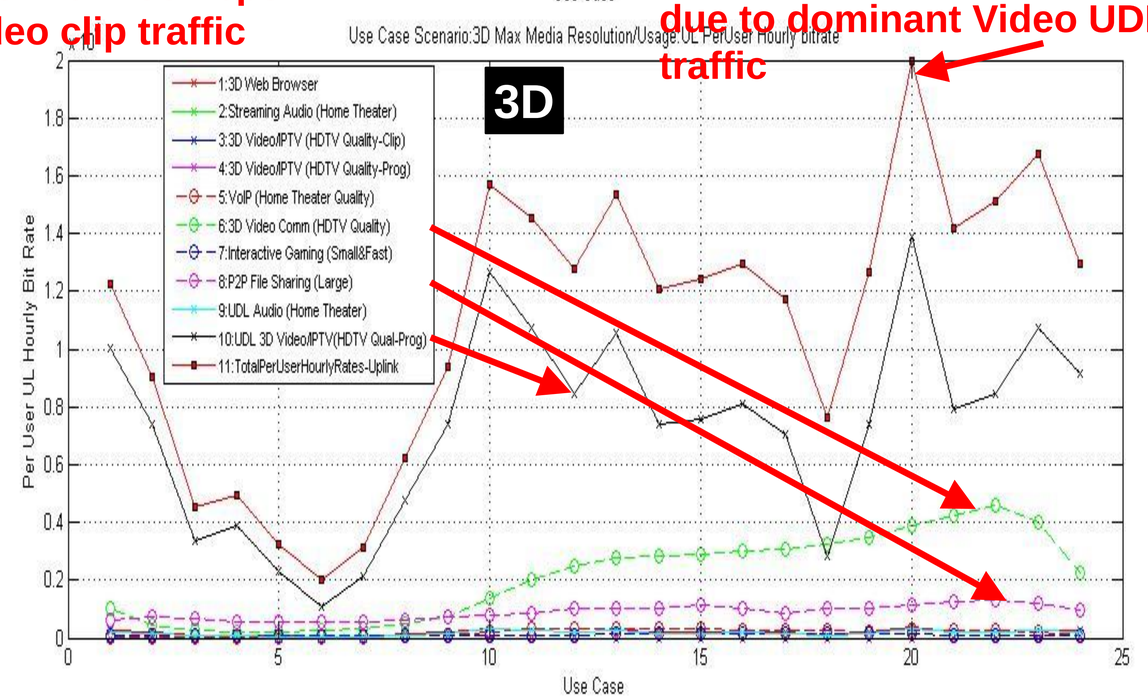




New peak at 23.00 hrs with 286 kbps due to Increasing Video clip traffic

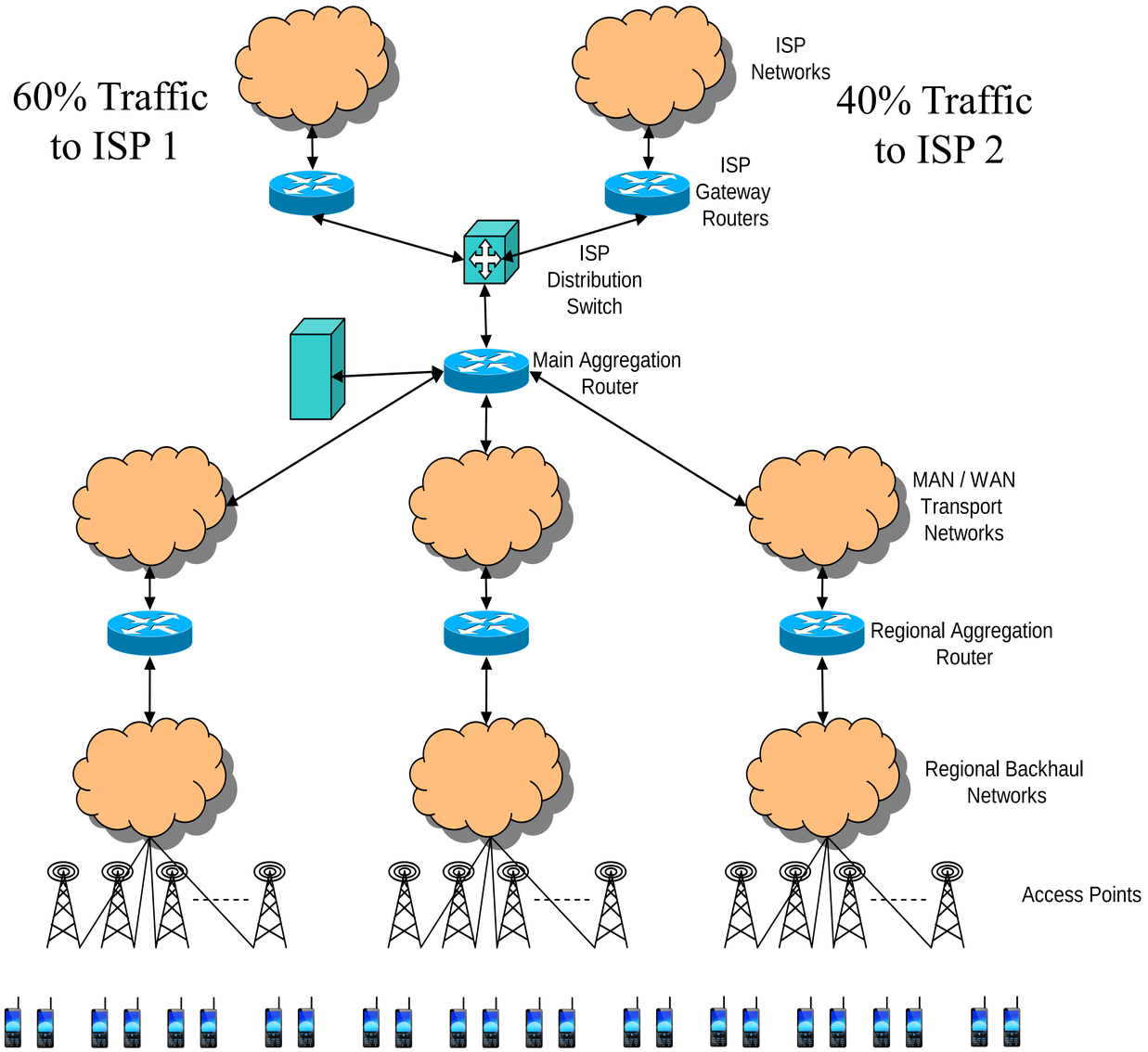


Peak at 20.00 hrs with 20 kbps due to dominant Video UDL traffic

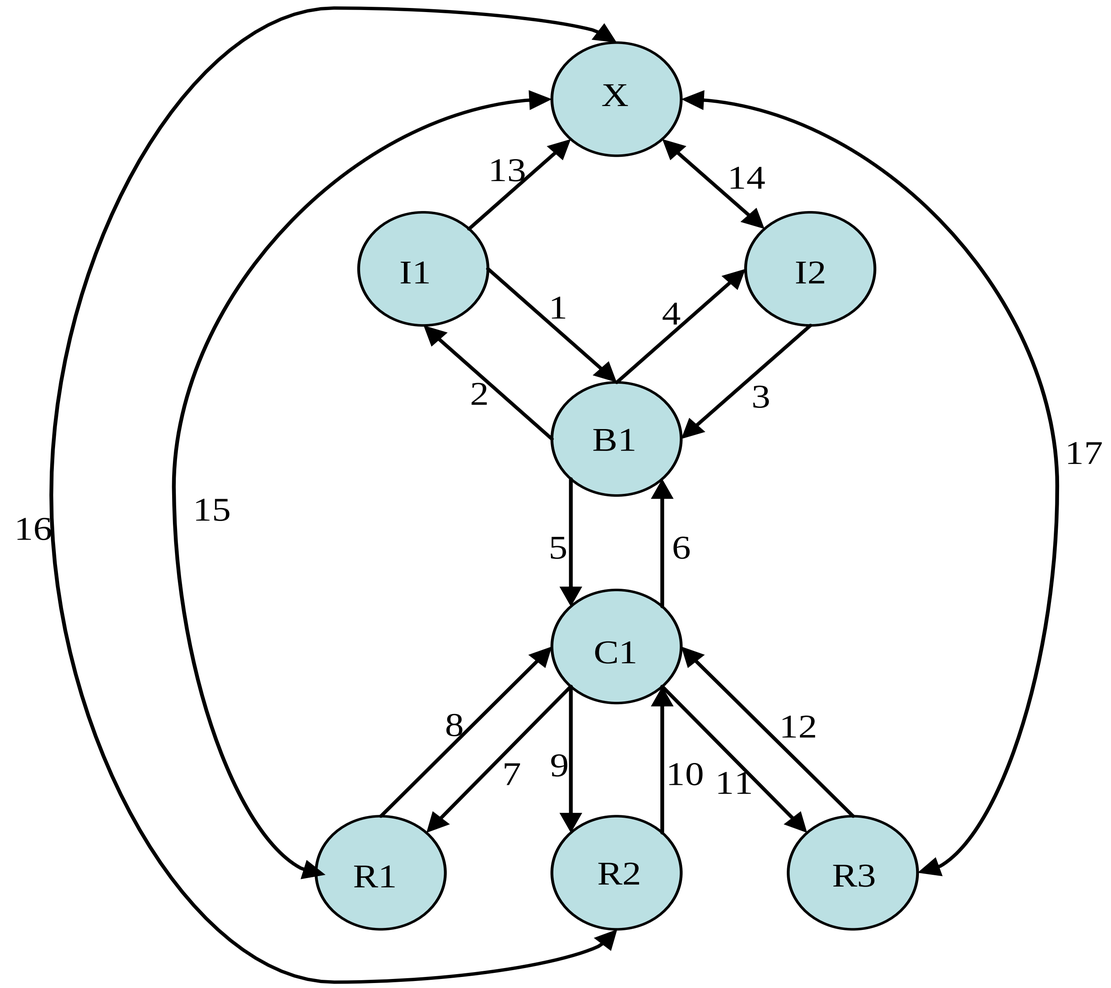


Reference Network Modelling

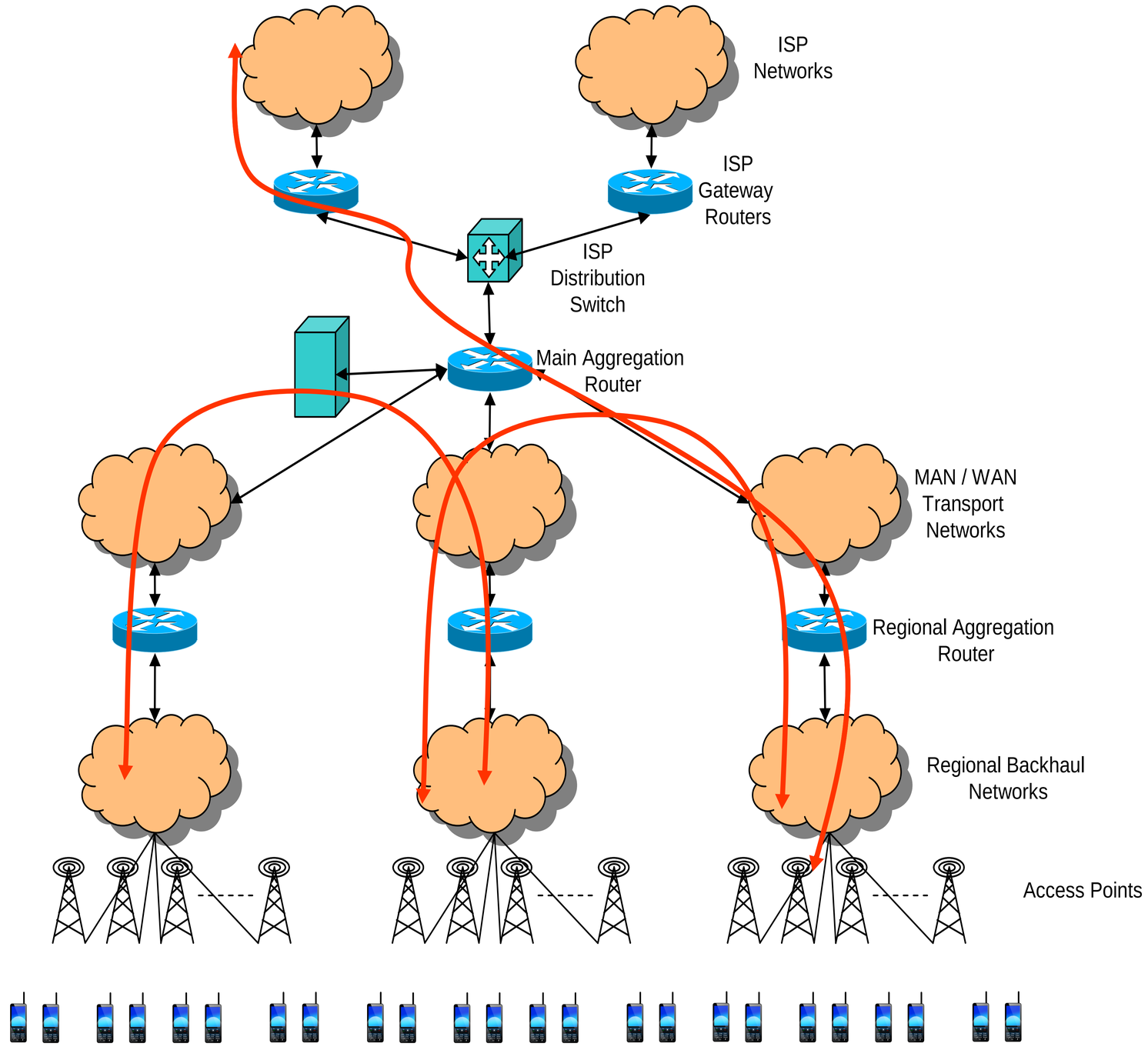
Motorola's Reference Network and Network Flow Model



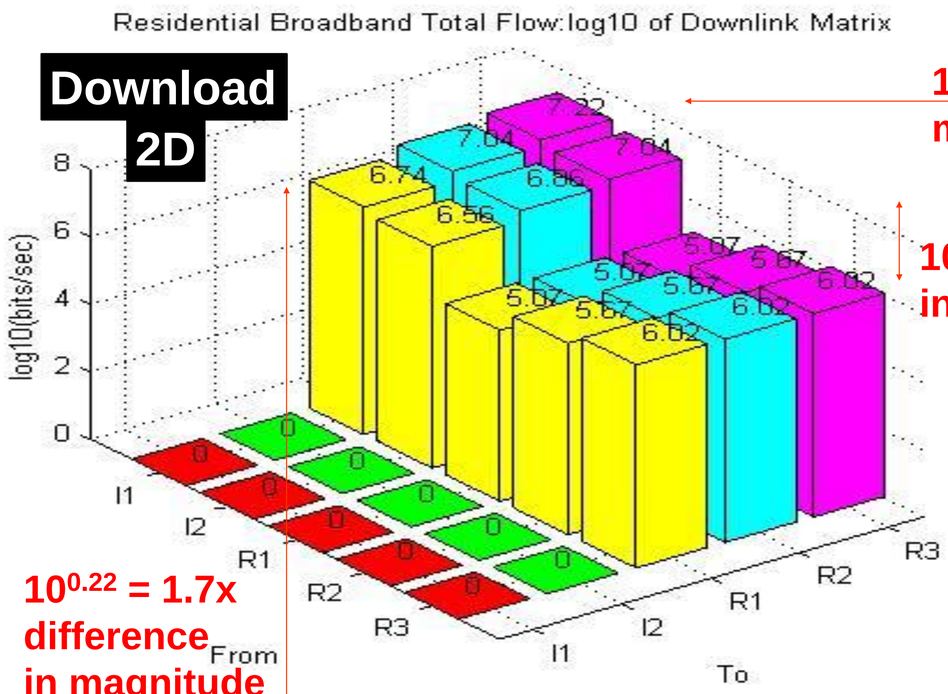
No of RAN Sites per MAN	10	20	30
No of Users per MAN	200	200	200



End to End Flows Considered in our Reference Network



End to End Flows at Peak Hour:
2D and 3D Residential Broadband

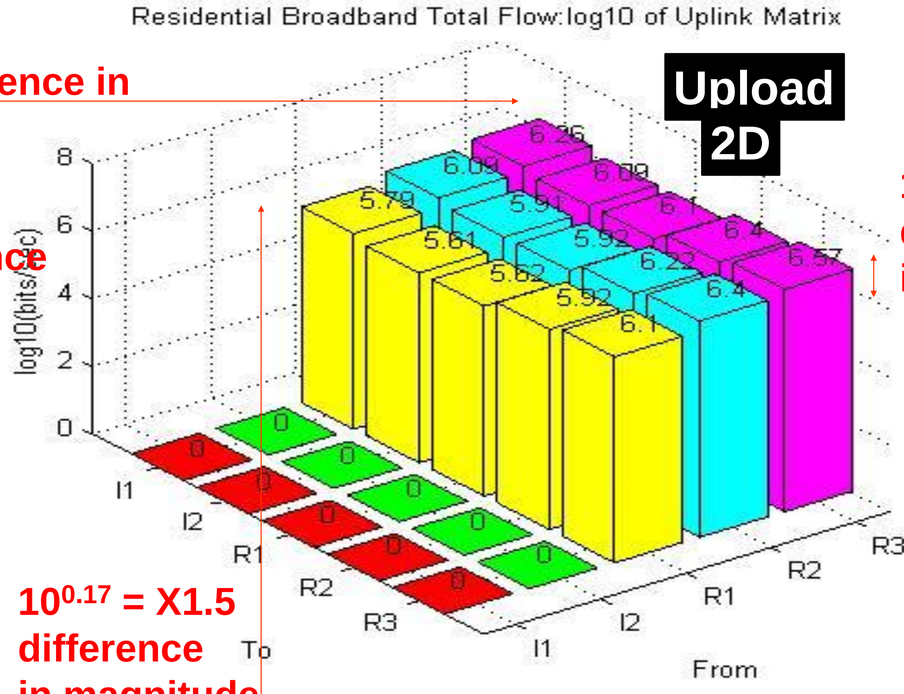


Download 2D

$10^{0.96}$ = 9.1x difference in magnitude

$10^{1.2}$ = 15x difference in magnitude

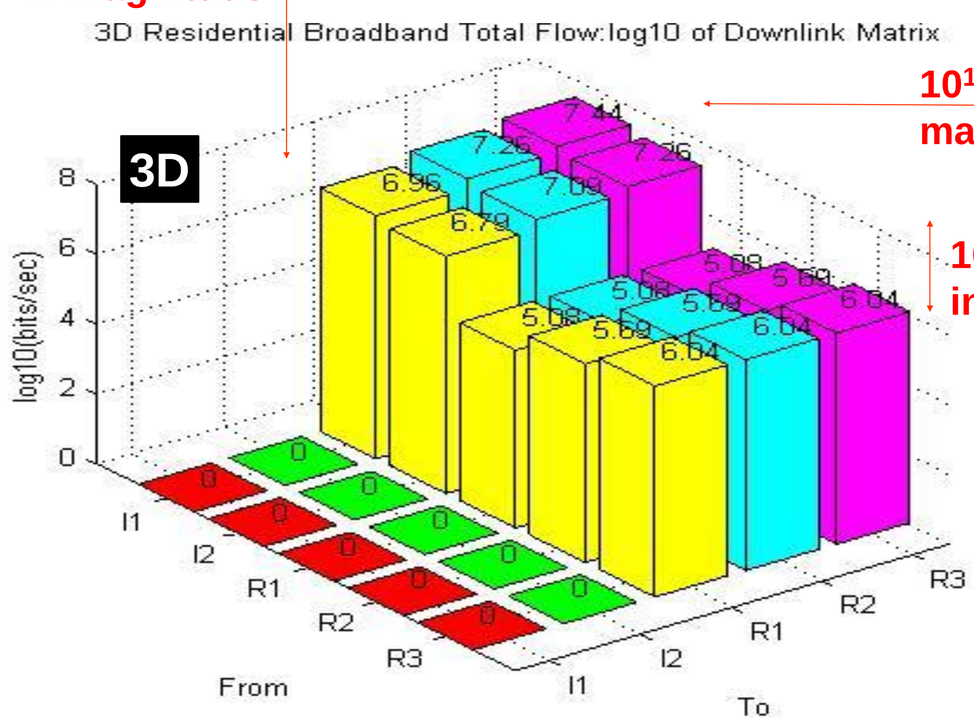
$10^{0.22}$ = 1.7x difference in magnitude



Upload 2D

$10^{0.31}$ = 2x difference in magnitude

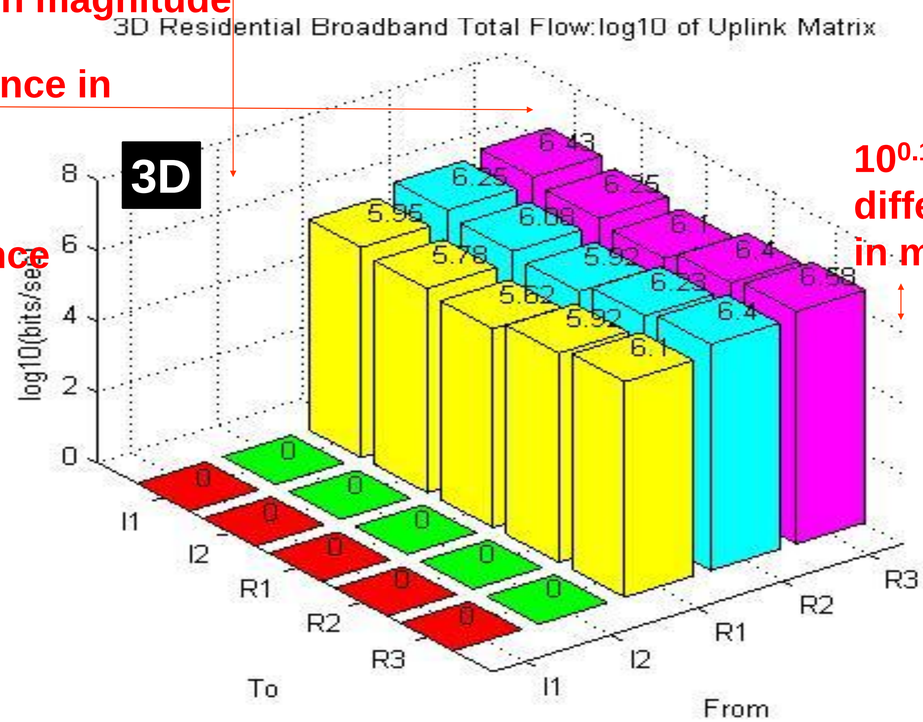
$10^{0.17}$ = X1.5 difference in magnitude



3D

$10^{1.01}$ = 10.2x difference in magnitude

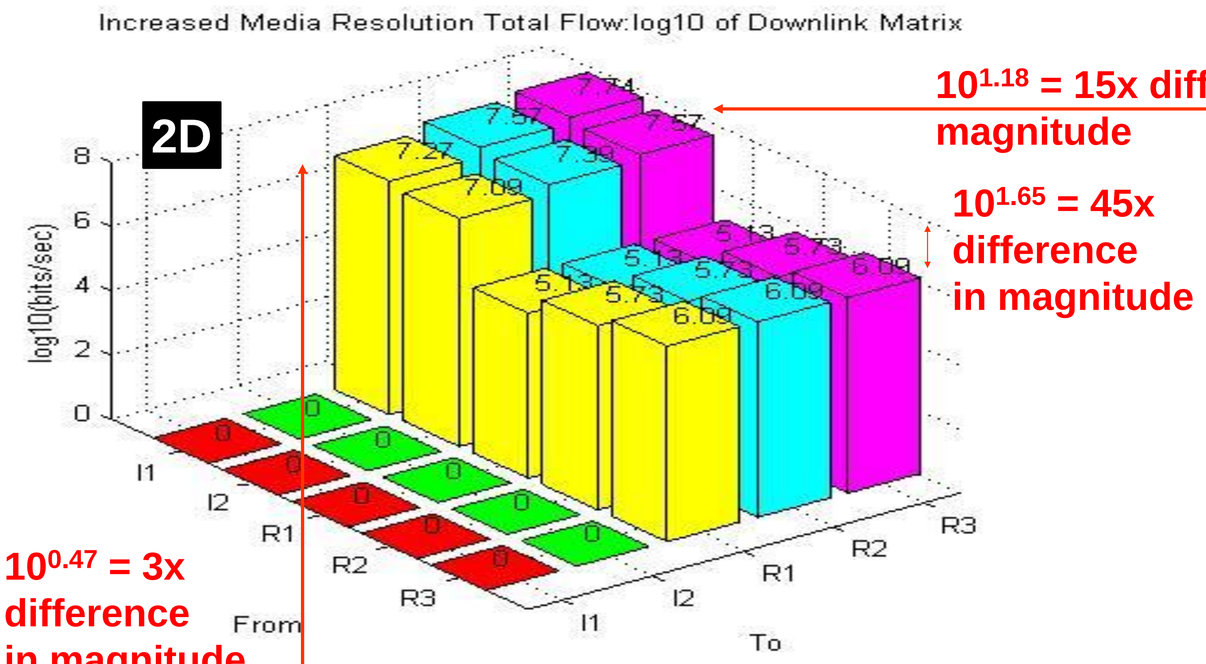
$10^{1.4}$ = 25x difference in magnitude

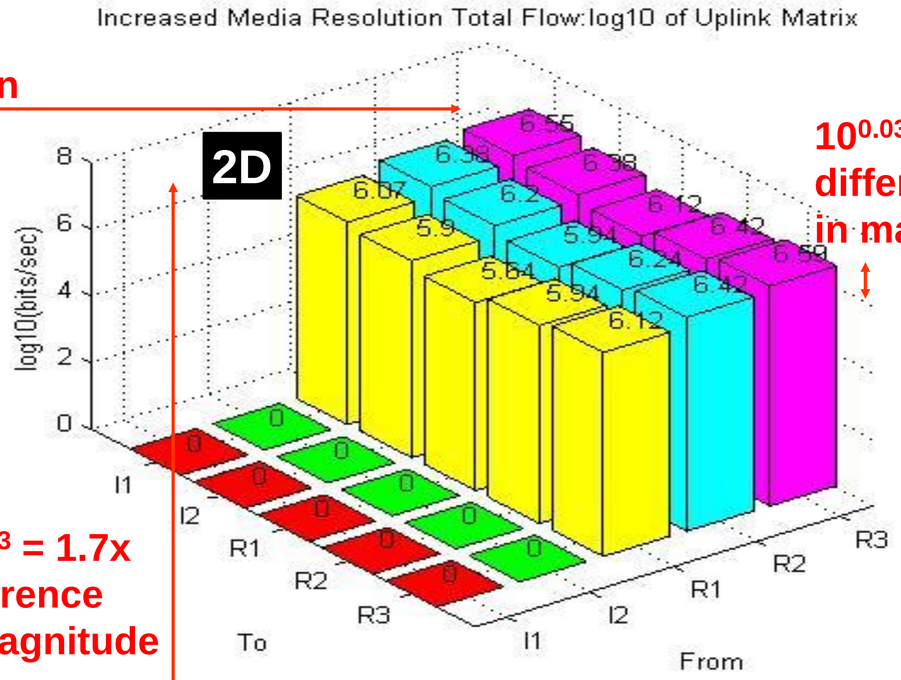


3D

$10^{0.15}$ = 1.4x difference in magnitude

End to End Flows at Peak Hour:
2D and 3D Increased Media Resolution



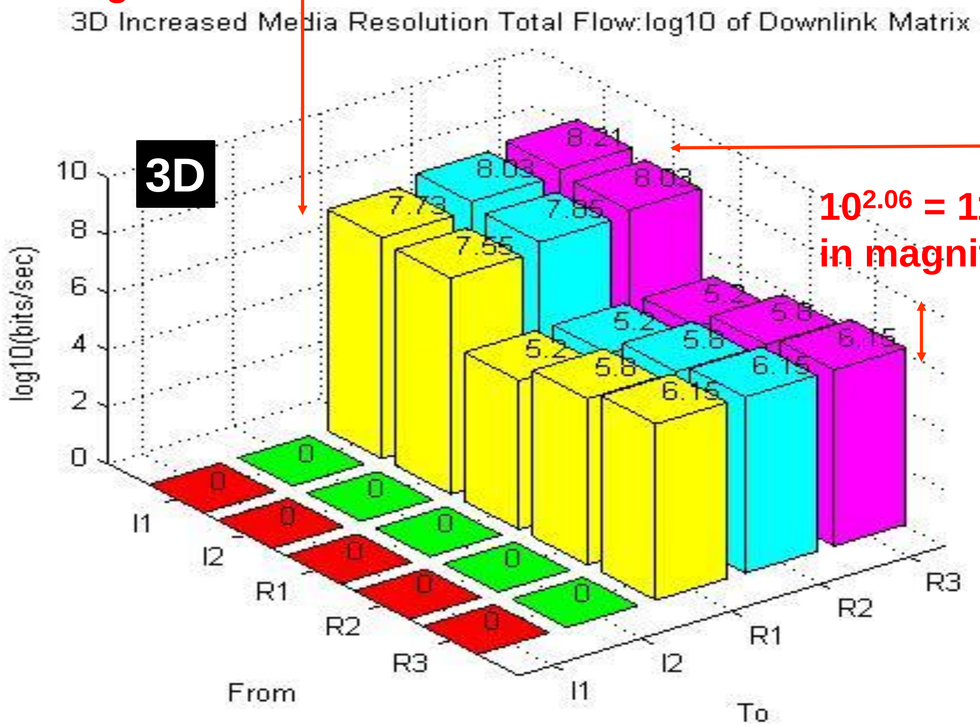


$10^{1.18}$ = 15x difference in magnitude

$10^{1.65}$ = 45x difference in magnitude

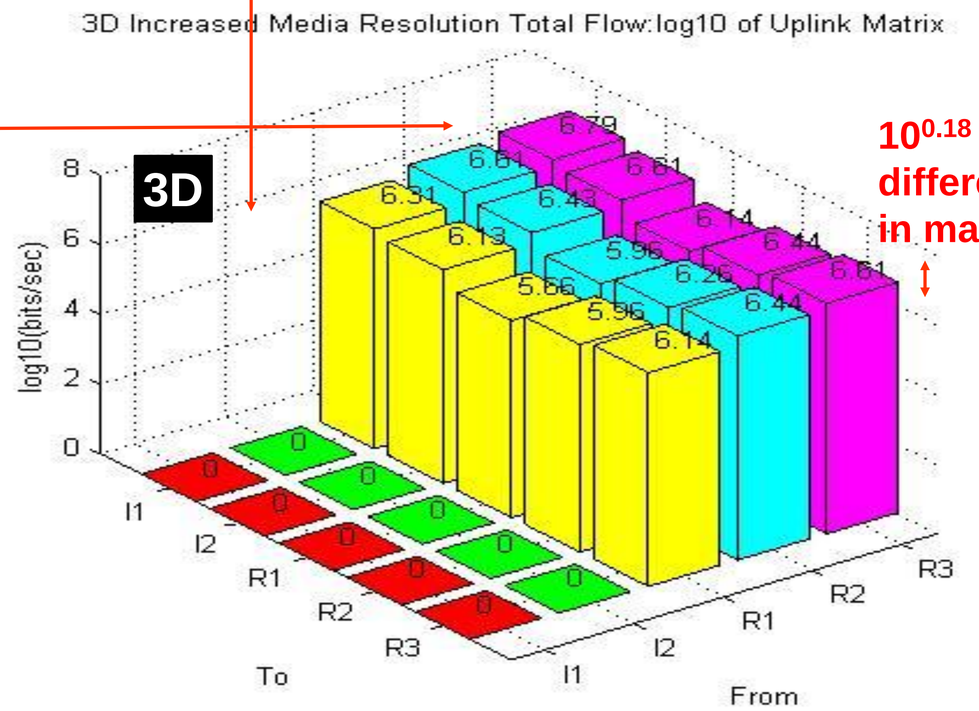
$10^{0.47}$ = 3x difference in magnitude

$10^{0.23}$ = 1.7x difference in magnitude



$10^{1.42}$ = 23x difference in magnitude

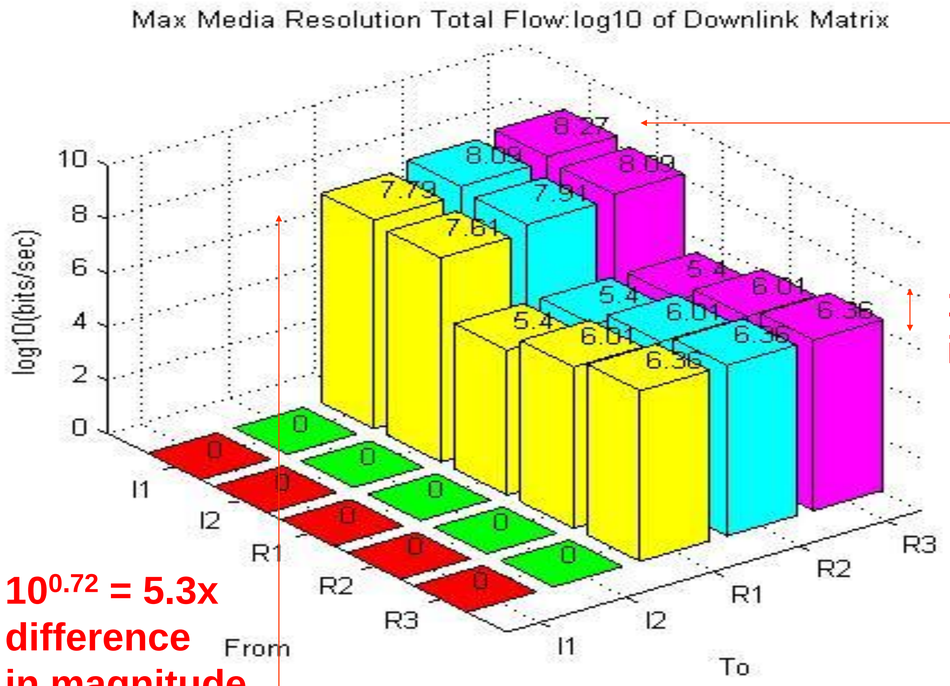
$10^{2.06}$ = 115x difference in magnitude

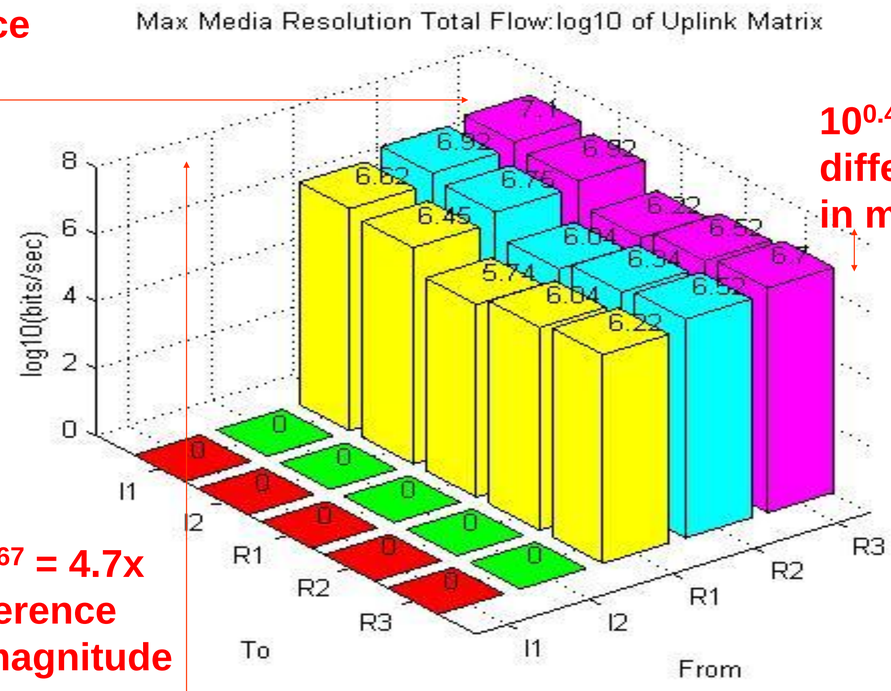


$10^{0.03}$ = 1.1x difference in magnitude

$10^{0.18}$ = 1.5x difference in magnitude

End to End Flows at Peak Hour: 2D and 3D Max Media Resolution





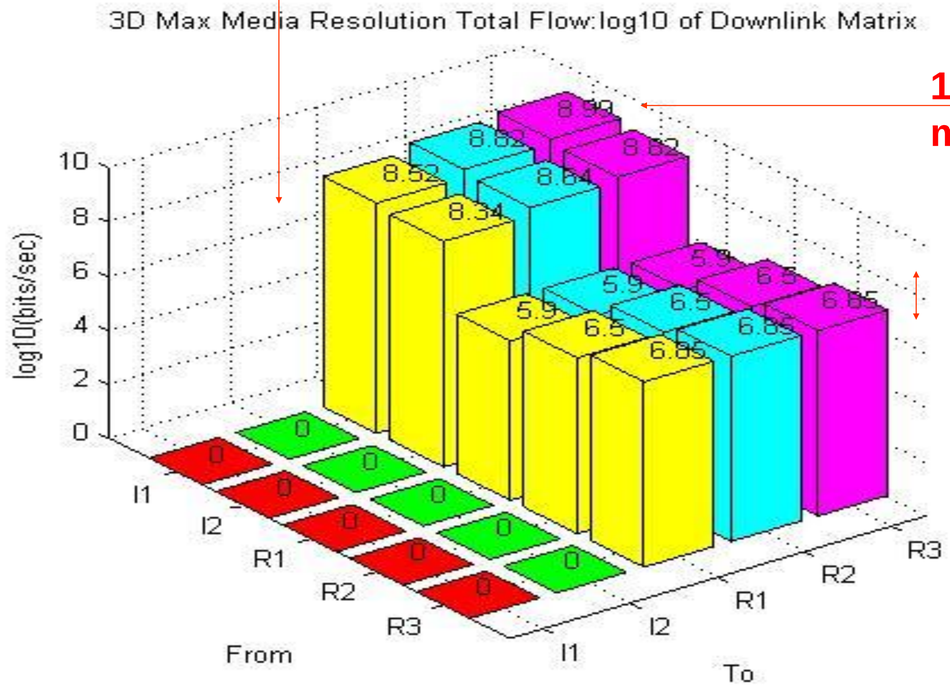
$10^{1.17}$ = 15x difference in magnitude

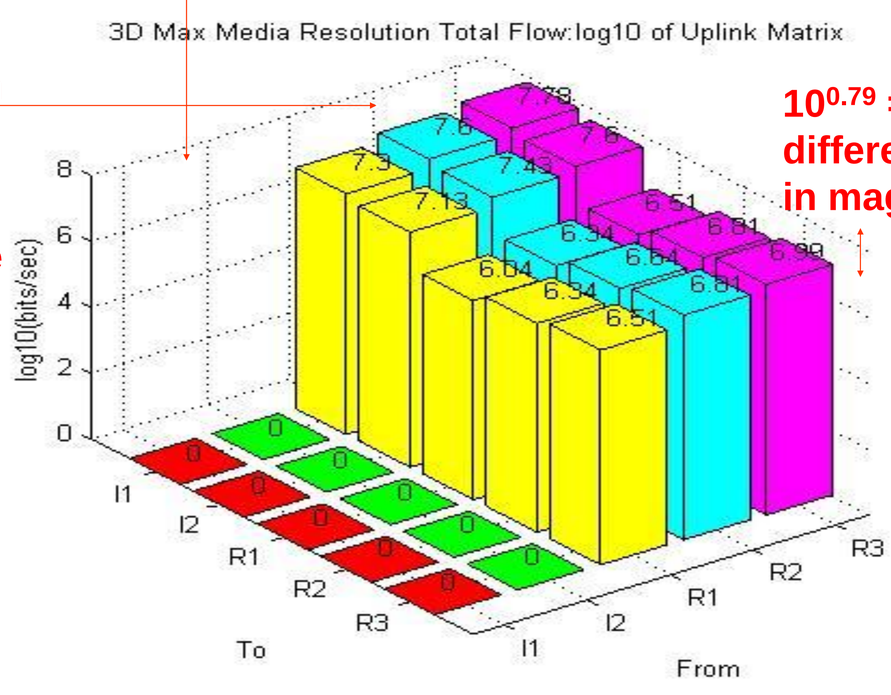
$10^{1.91}$ = 81x difference in magnitude

$10^{0.72}$ = 5.3x difference in magnitude

$10^{0.67}$ = 4.7x difference in magnitude

$10^{0.40}$ = 2.5x difference in magnitude





$10^{1.21}$ = 16x difference in magnitude

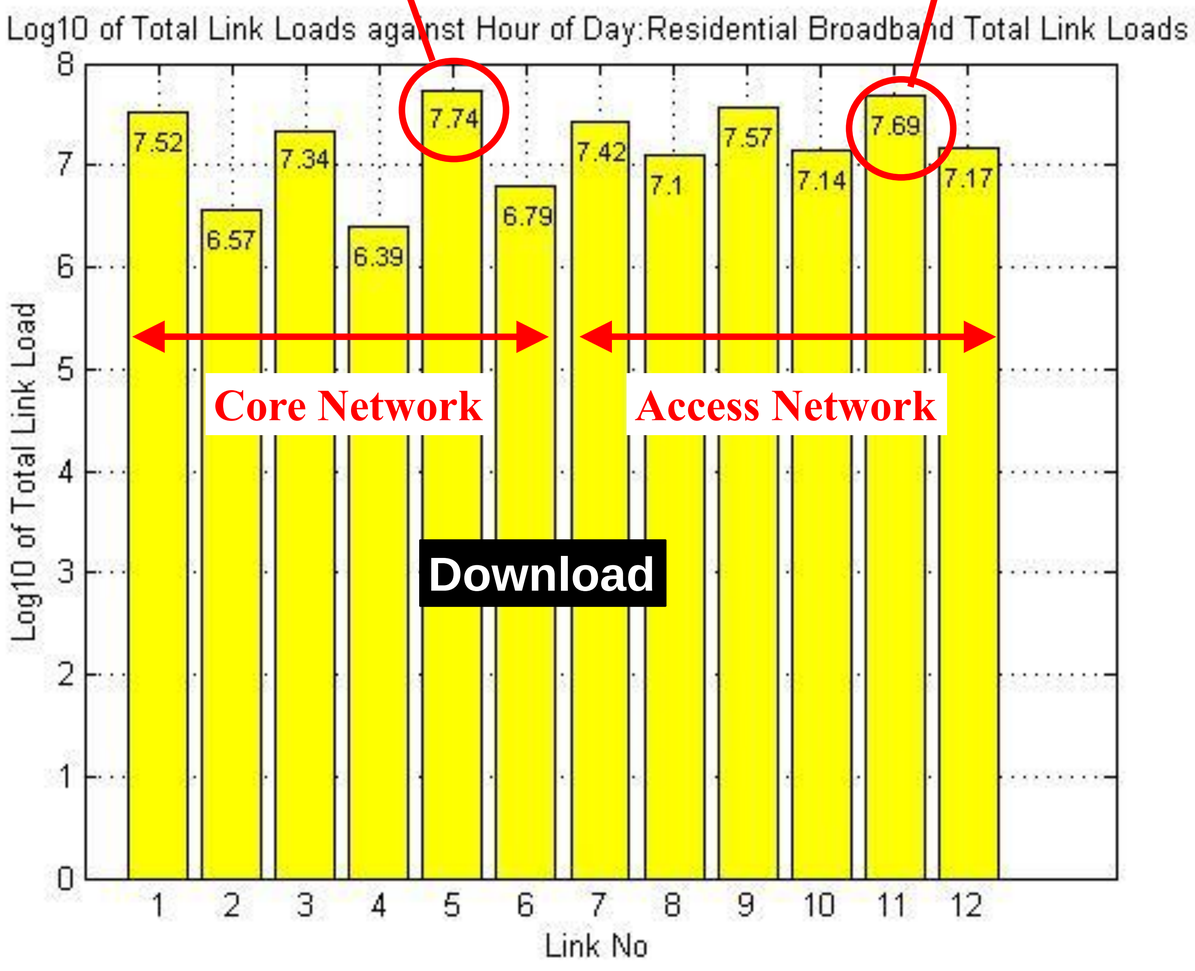
$10^{2.14}$ = 138x difference in magnitude

$10^{0.79}$ = 6.2x difference in magnitude

“Link Load” at Peak Hour:
2D and 3D Residential Broadband

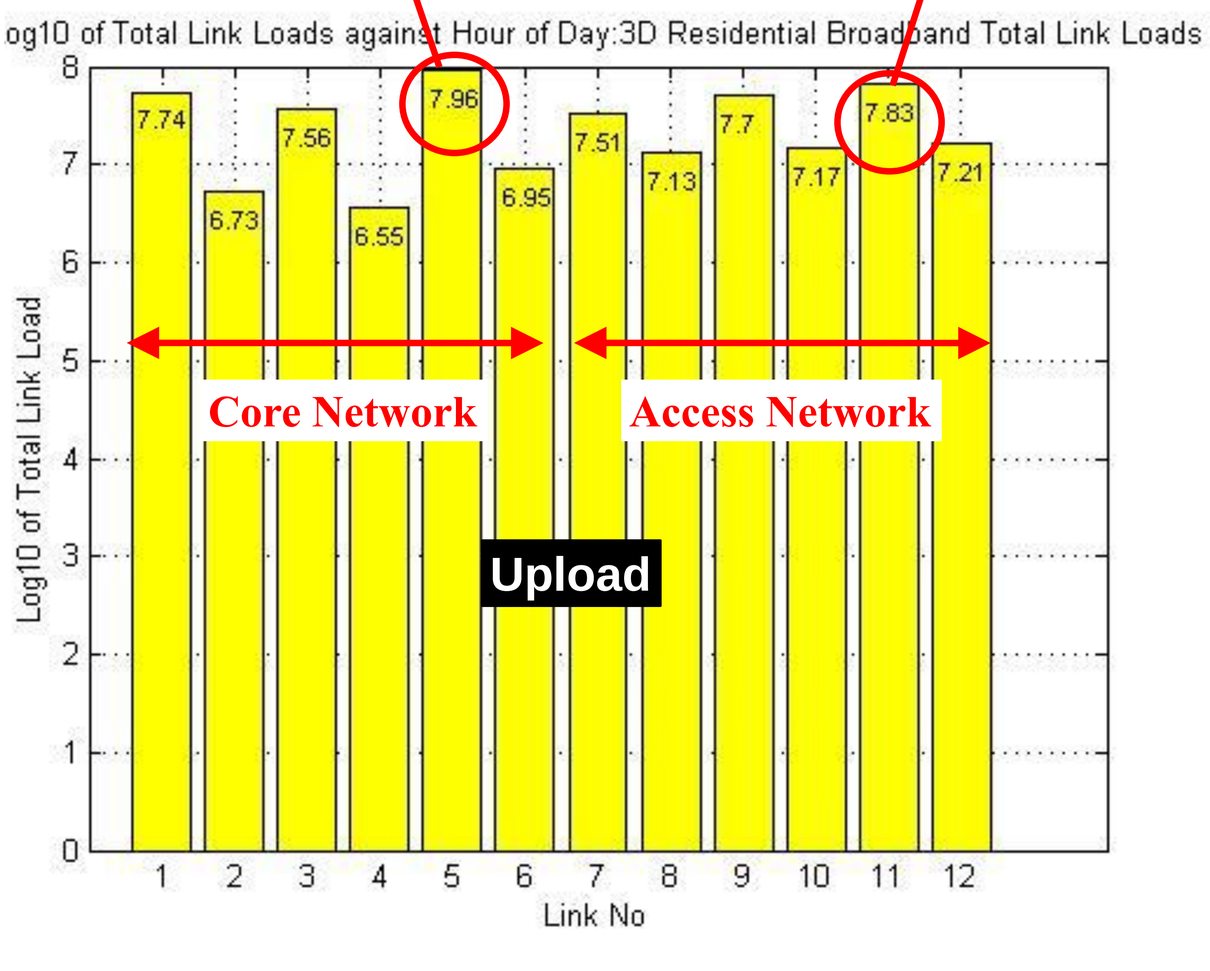
Max load ~ 55 Mbps

Max load ~ 49 Mbps

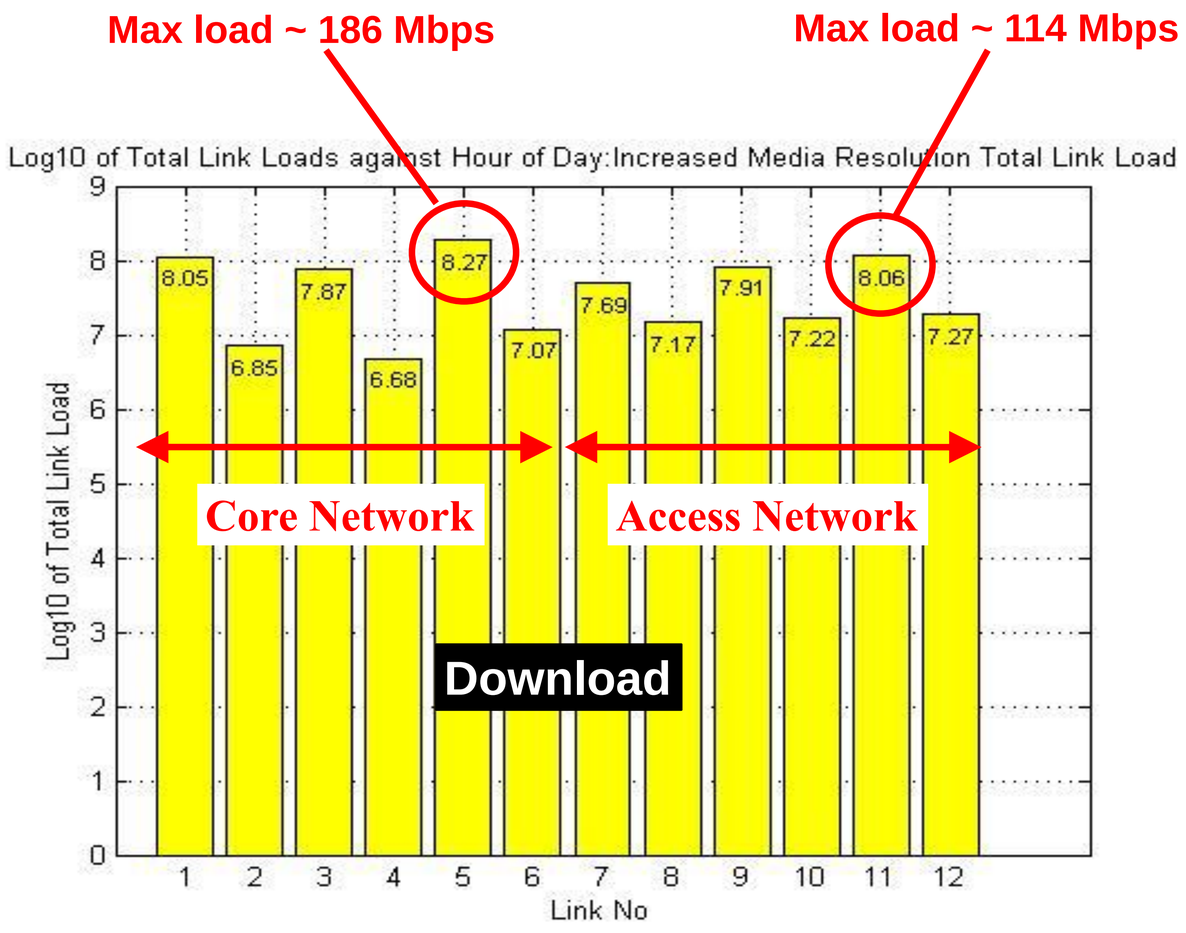


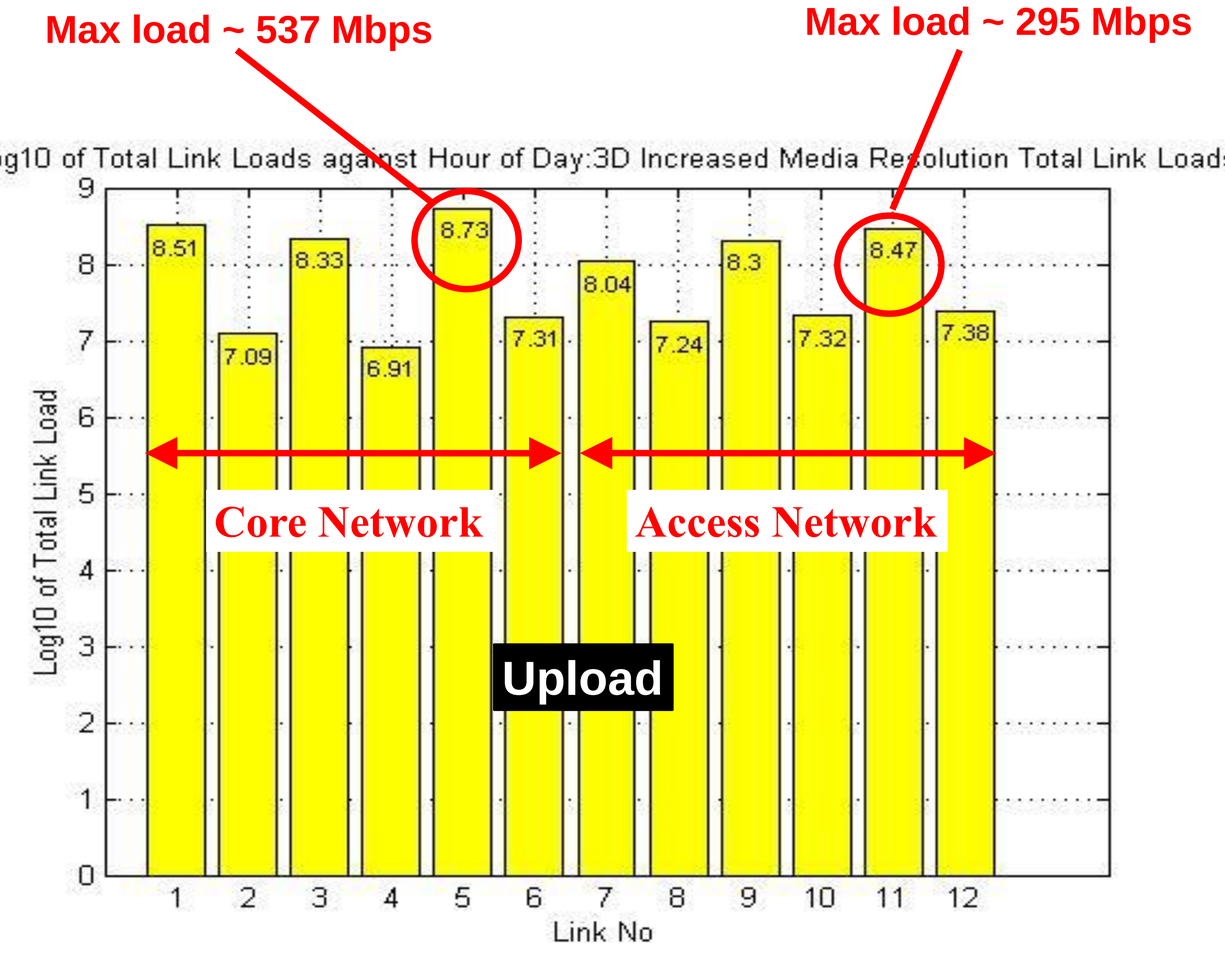
Max load ~ 91 Mbps

Max load ~ 68 Mbps

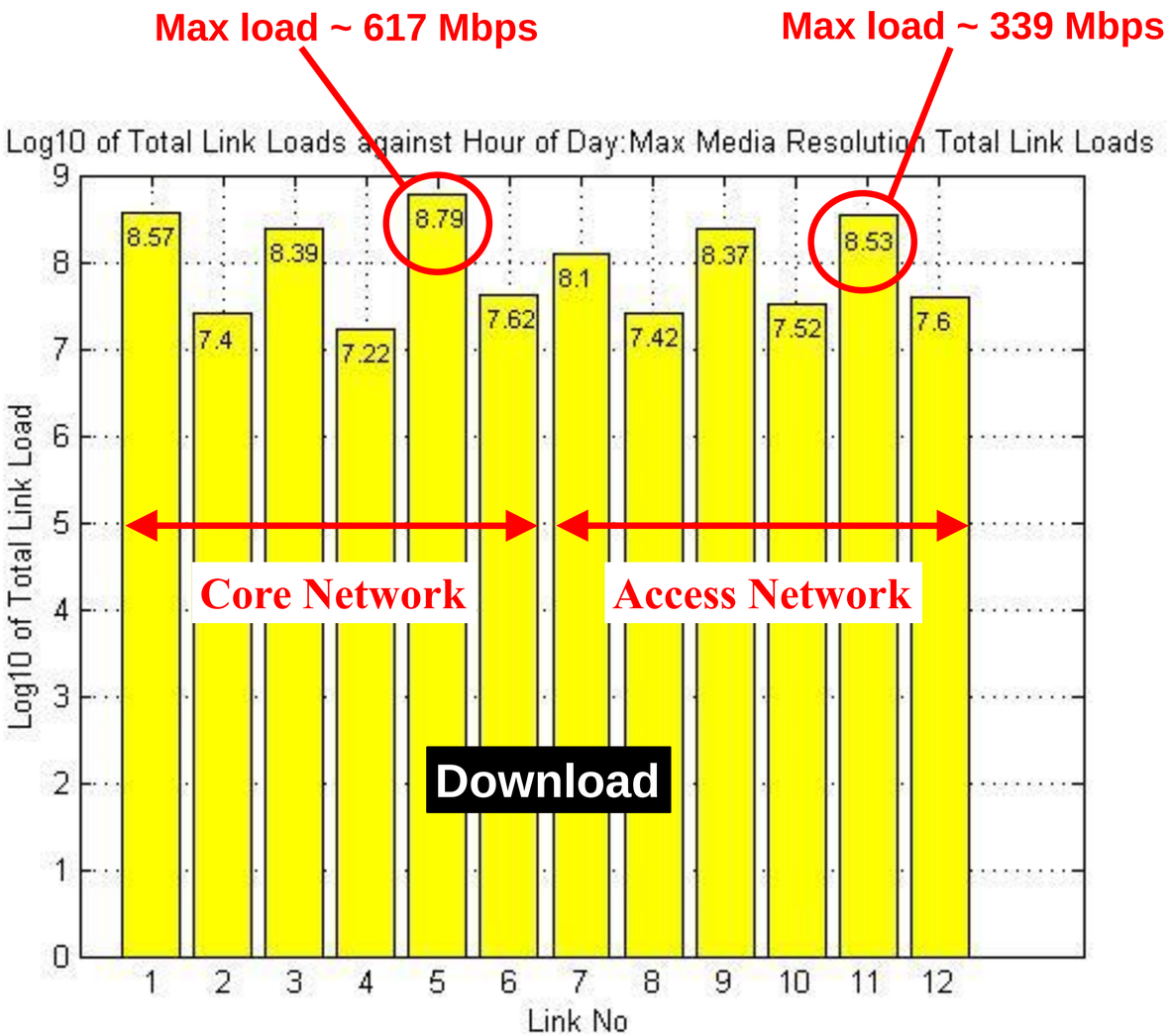


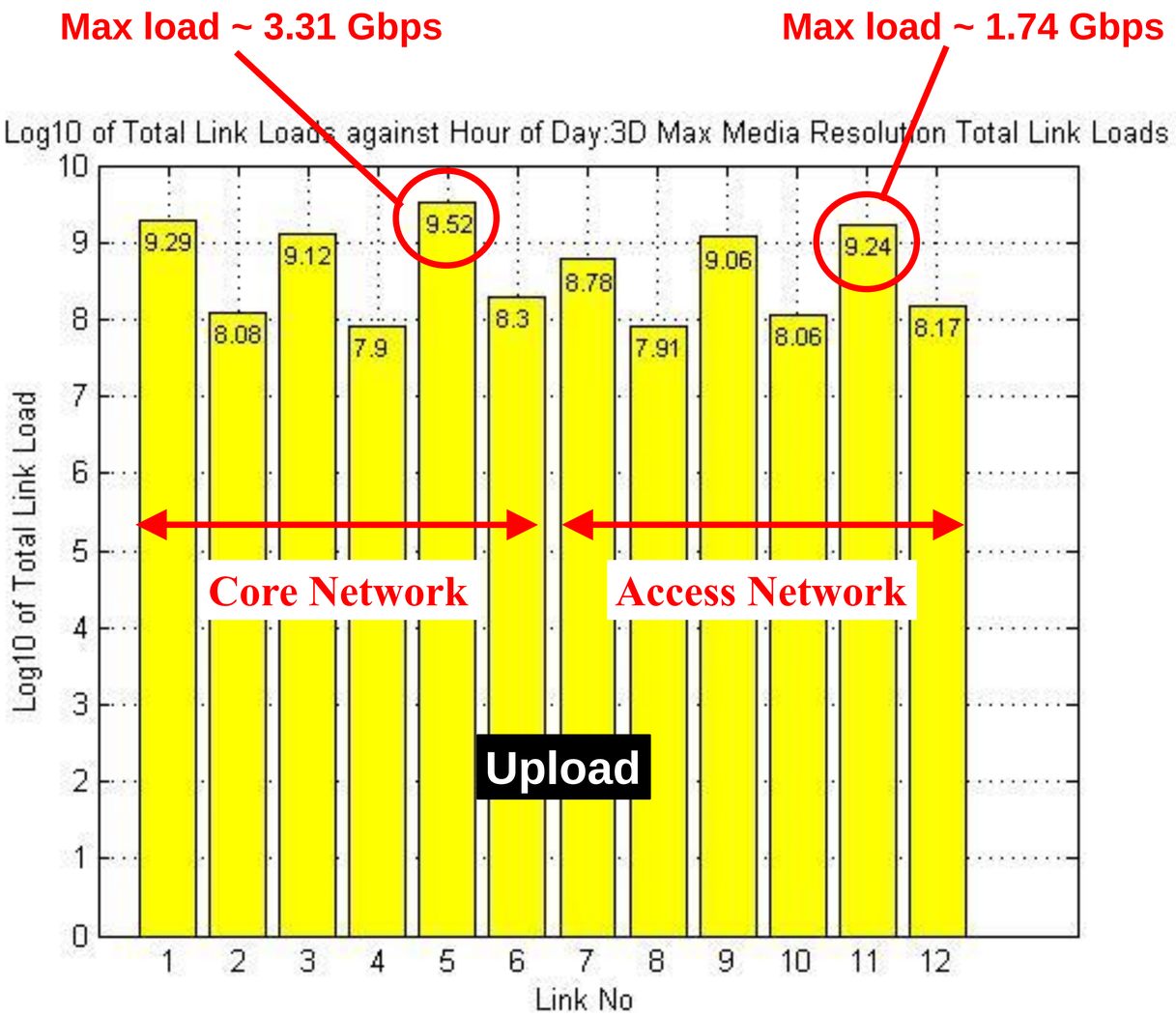
“Link Load” at Peak Hour:
2D and 3D Increased Media Resolution





“Link Load” at Peak Hour:
2D and 3D Max Media Resolution

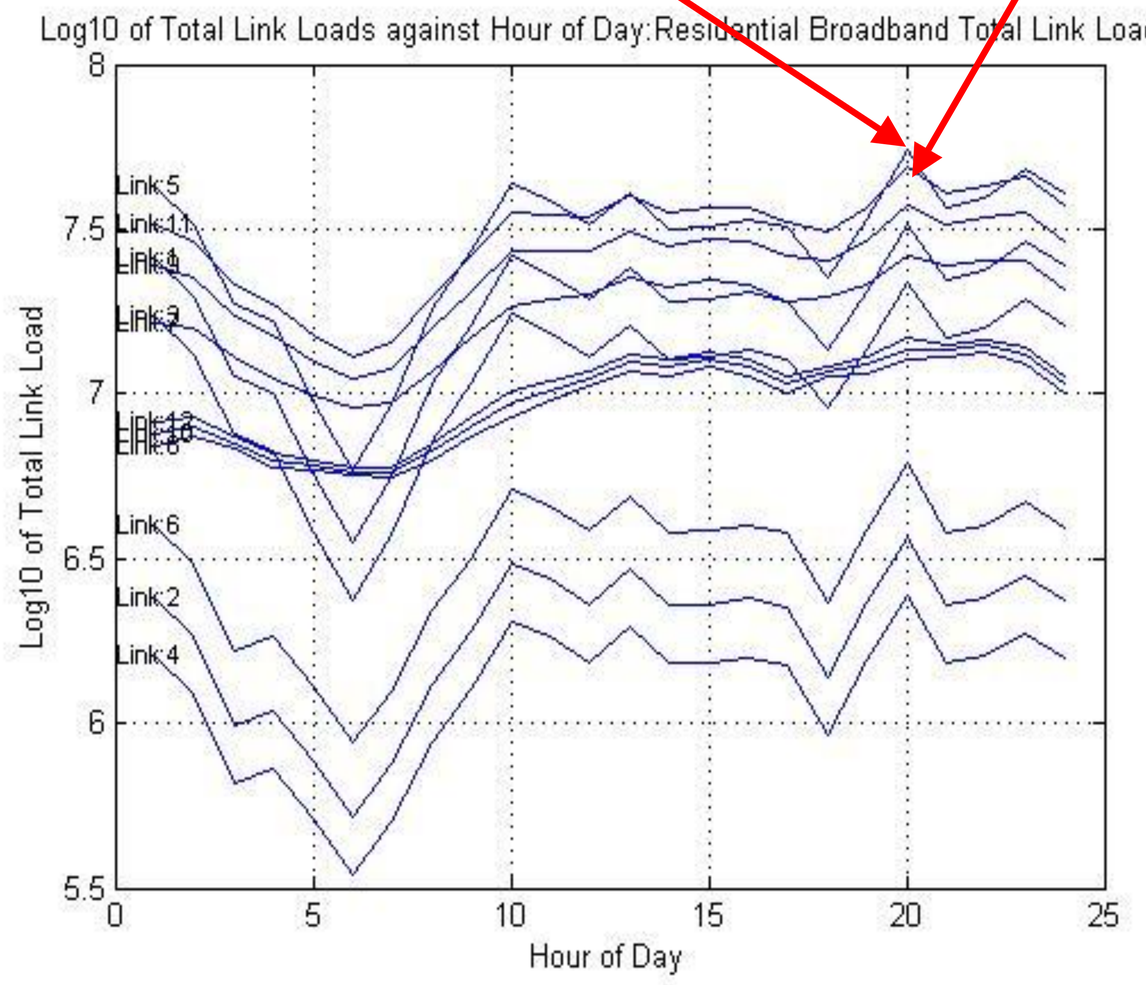




“Link Load” at Per Hour:
2D and 3D Residential Broadband

Max load (link 5) =
$10^{7.74}$ ~ 55 Mbps

Max load (link 11) =
$10^{7.69}$ ~ 49 Mbps

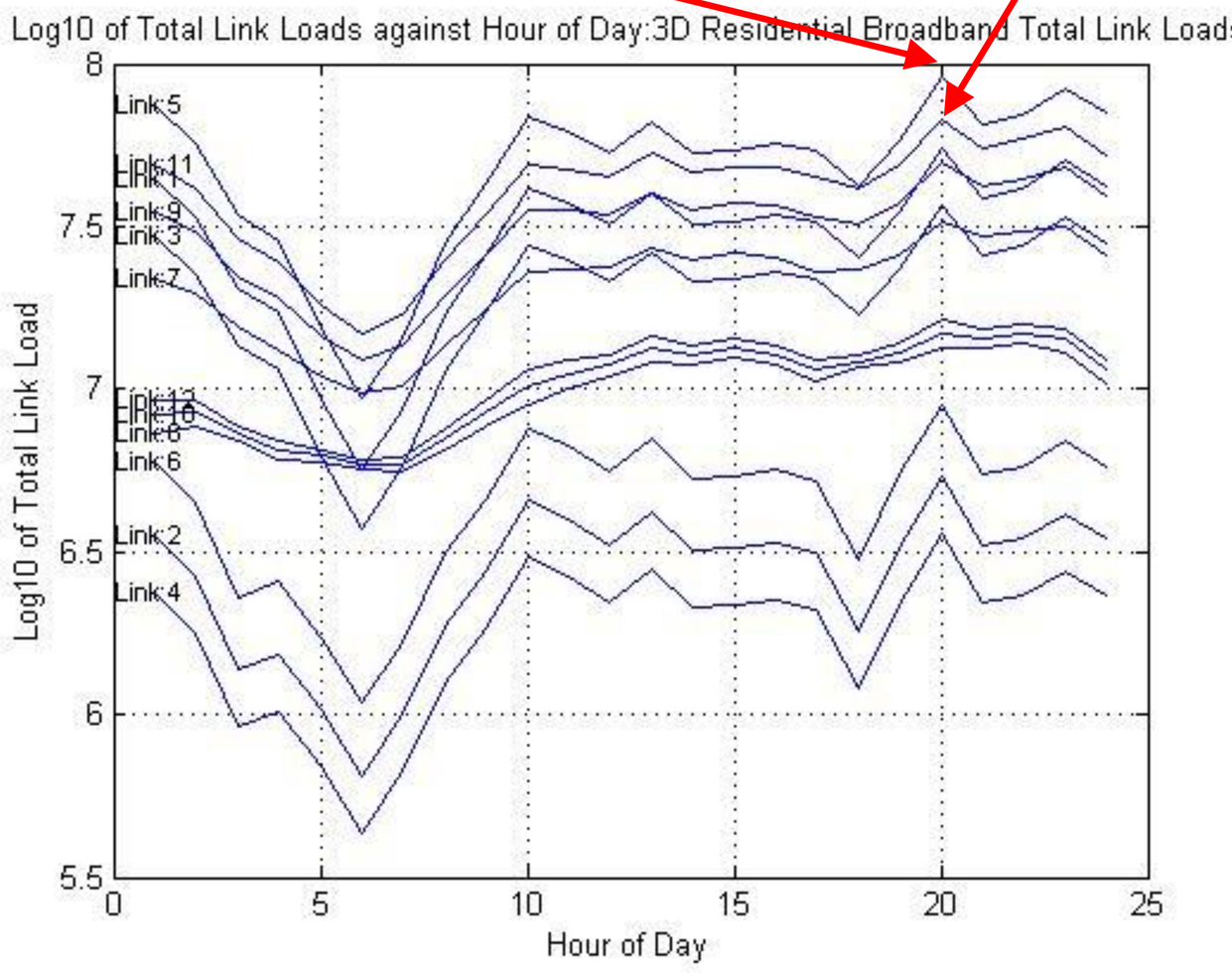


Core Network

Max load (link 5) =
$10^{7.96}$ ~ 91 Mbps

Access Network

Max load (link 11) =
$10^{7.83}$ ~ 68 Mbps



- For upload: 100 Mbps Core and Access Network capacity is sufficient

“Link Load” at Per Hour:
2D and 3D Increased Media Resolution

Core Network

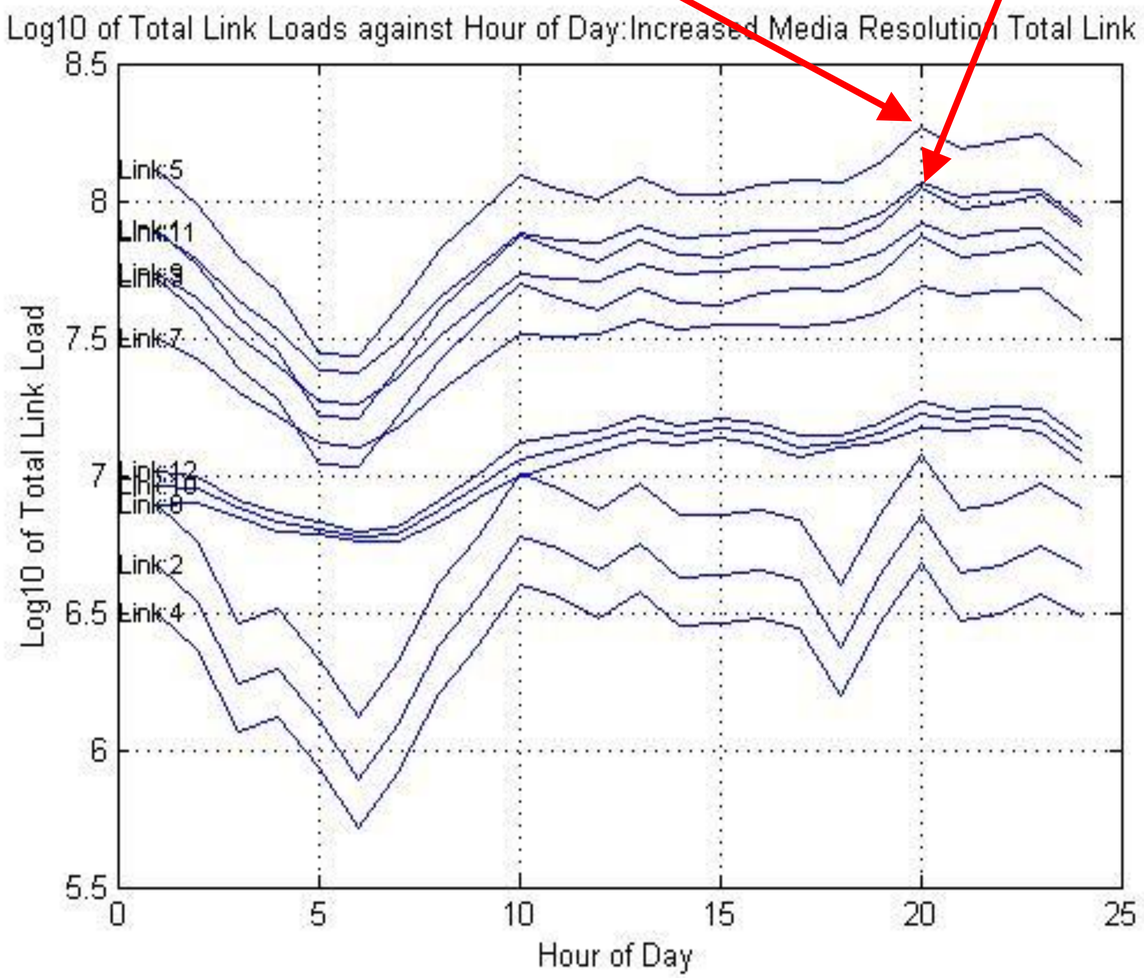
Access Network

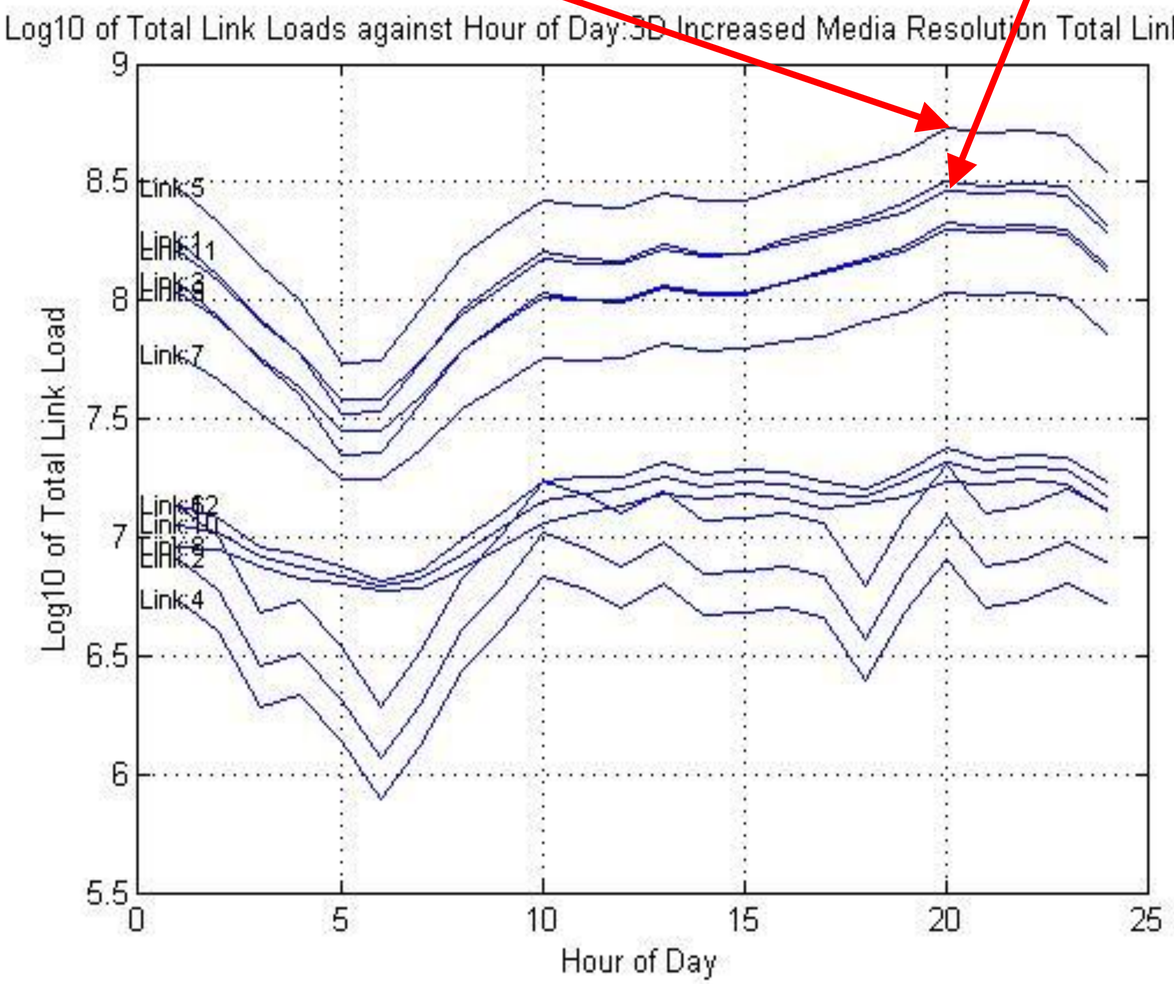
Max load (link 5) = $10^{8.27}$ ~ 186 Mbps

Max load (link 11) = $10^{8.1}$ ~ 126 Gbps

Max load (link 5) = $10^{8.73}$ ~ 537 Mbps

Max load (link 11) = $10^{8.47}$ ~ 295 Mbps



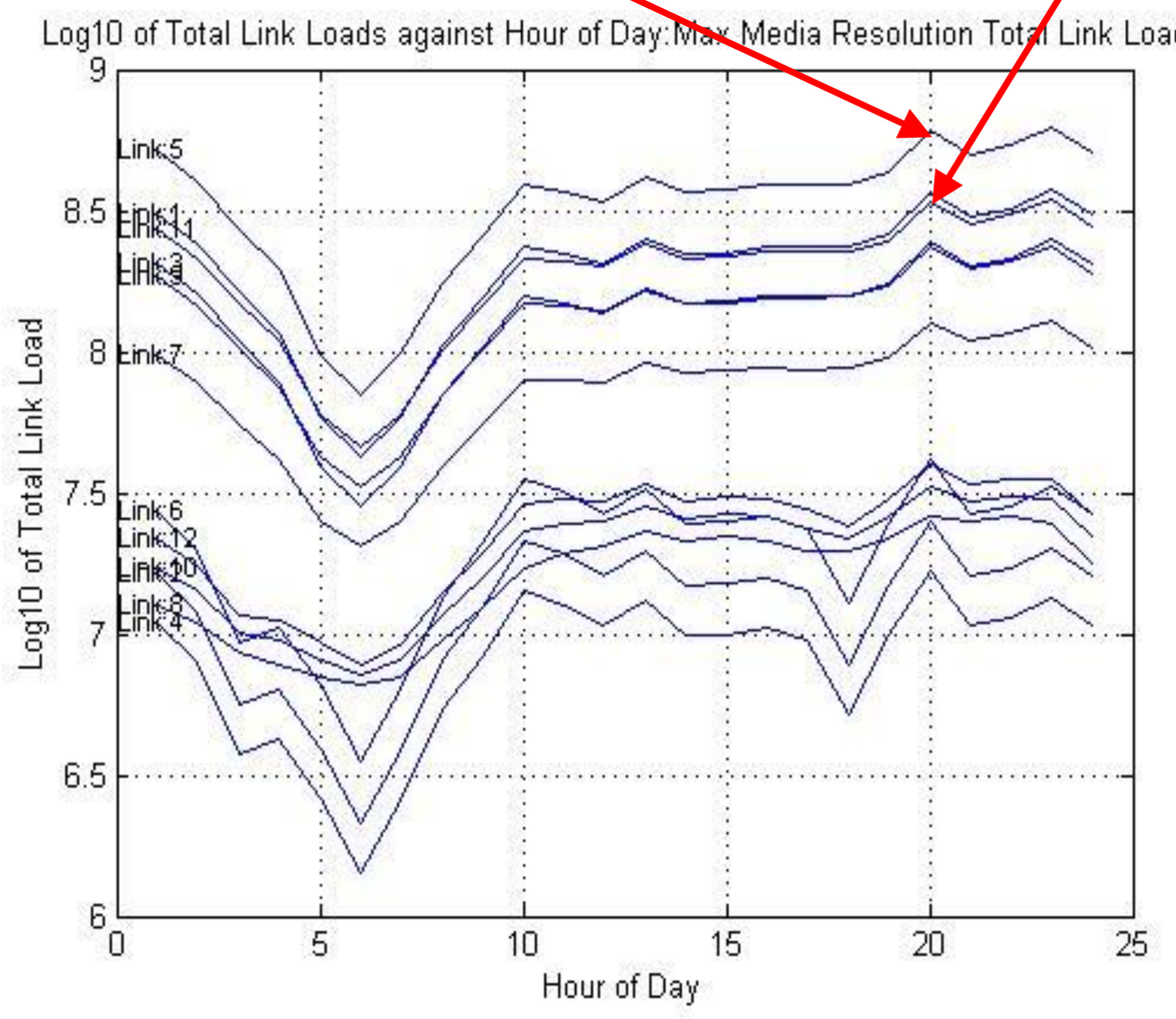


- For upload: 300 Mbps Access Network capacity is sufficient

“Link Load” at Per Hour:
2D and 3D Max Media Resolution

Max load (link 5) = $10^{8.79}$ ~ 617 M bit/s

Max load (link 11) = $10^{8.53}$ ~ 339 M bit/s

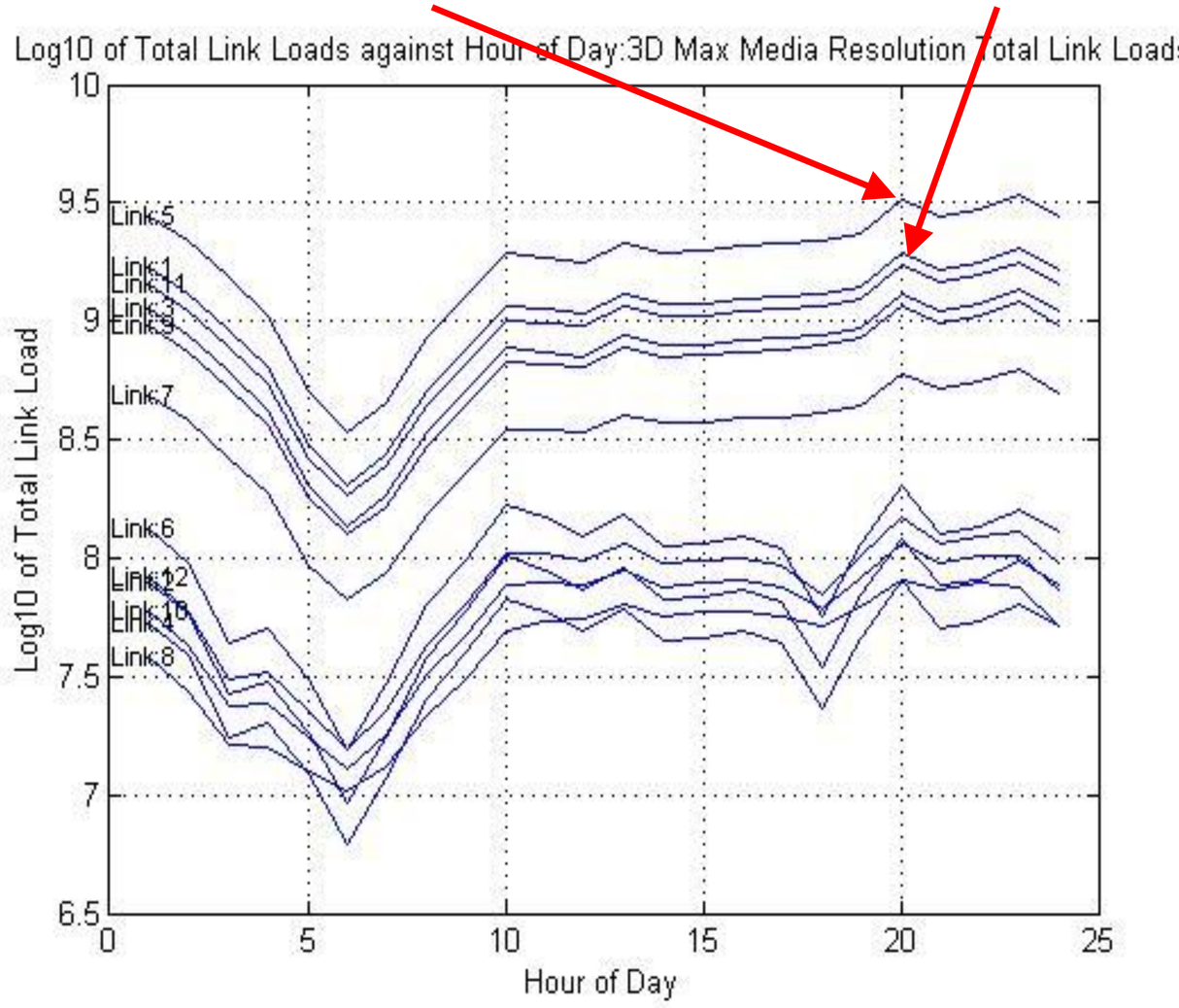


Core Network

Max load (link 5) = $10^{9.52}$ ~ 3.31 G bit/s

Access Network

Max load (link 11) = $10^{9.24}$ ~ 1.74 G bit/s

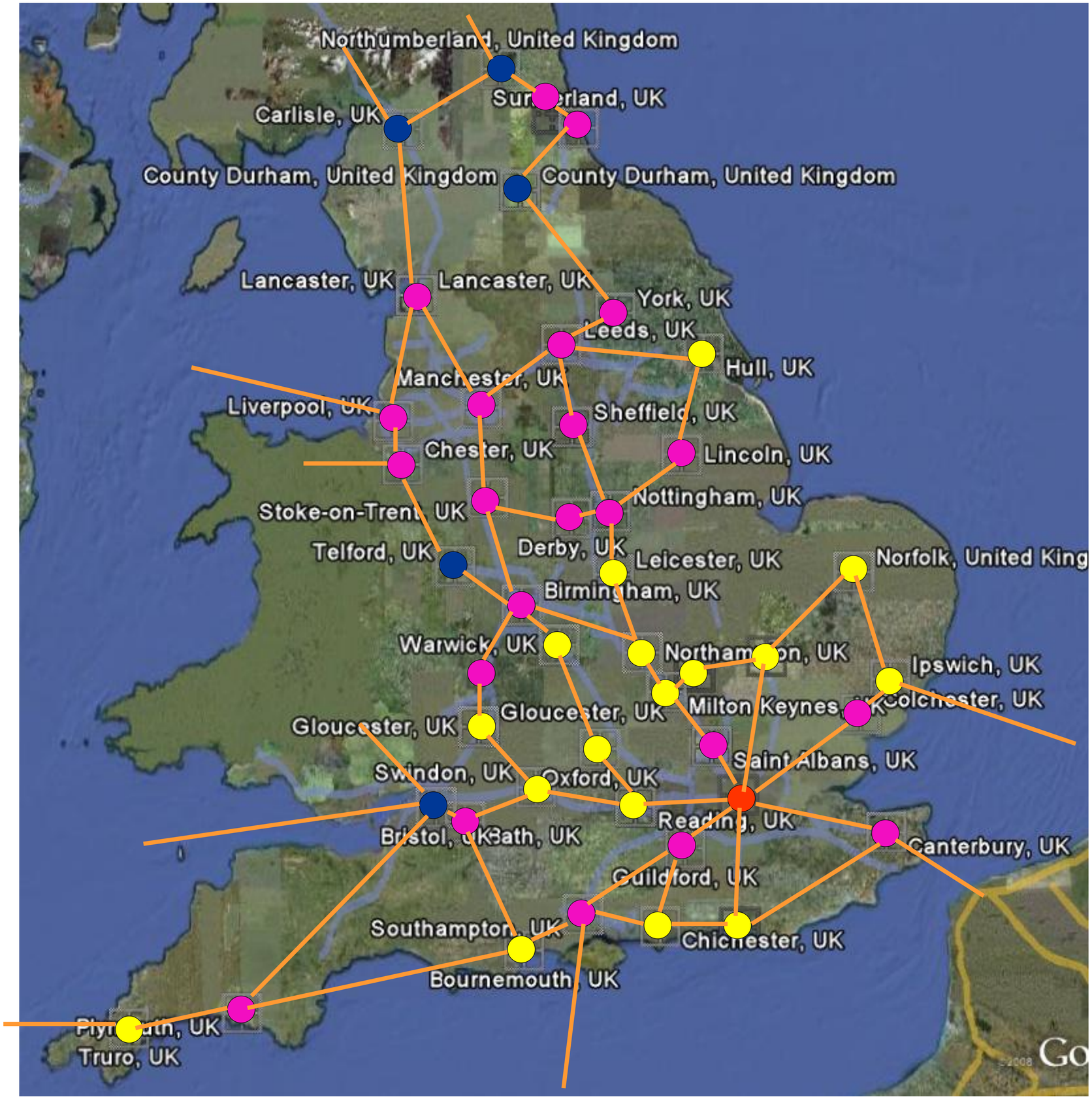


- For upload: 2 Gbps Access Network capacity is sufficient

Conclusion

- The study shown that Introducing the increased media resolution and 3DTV traffics to Internet
  - Total traffic demand is enlarged due to the increase intensity and duration of online media access.
  - Link load increased by a factor of about ten if 3D Holoscopic video with horizontal parallax is used and by a factor of hundred if 3D Holoscopic video with horizontal/vertical parallax is used.
- The dominant effect on networks will be due to video applications with the rest of the traffic mix making a very minor effect.
- This study is in line with European research priorities.

Possible UK Optical Network



Population

- >5M
- >1M
- > 500k
- >100k
- <100k

Iraqi National Optical Fiber Cable and Backbone Transmission Network

Reference Network and Network Model