

Broadband Quality of Service

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- The users
- The technologies
- The QoS metrics
- The evaluation methodology

- Dense urban areas – 10,000 people/sq. km
- Sparse rural areas
 - Village every 3-10 km
 - Population 1,000-25,000
 - Within 25 km of fibre
 - 700 m in India
- ARPU today for 100m subscribers: Rs. 350 (\$7)
- ARPU tomorrow for next billion: Rs. 100 (\$2)

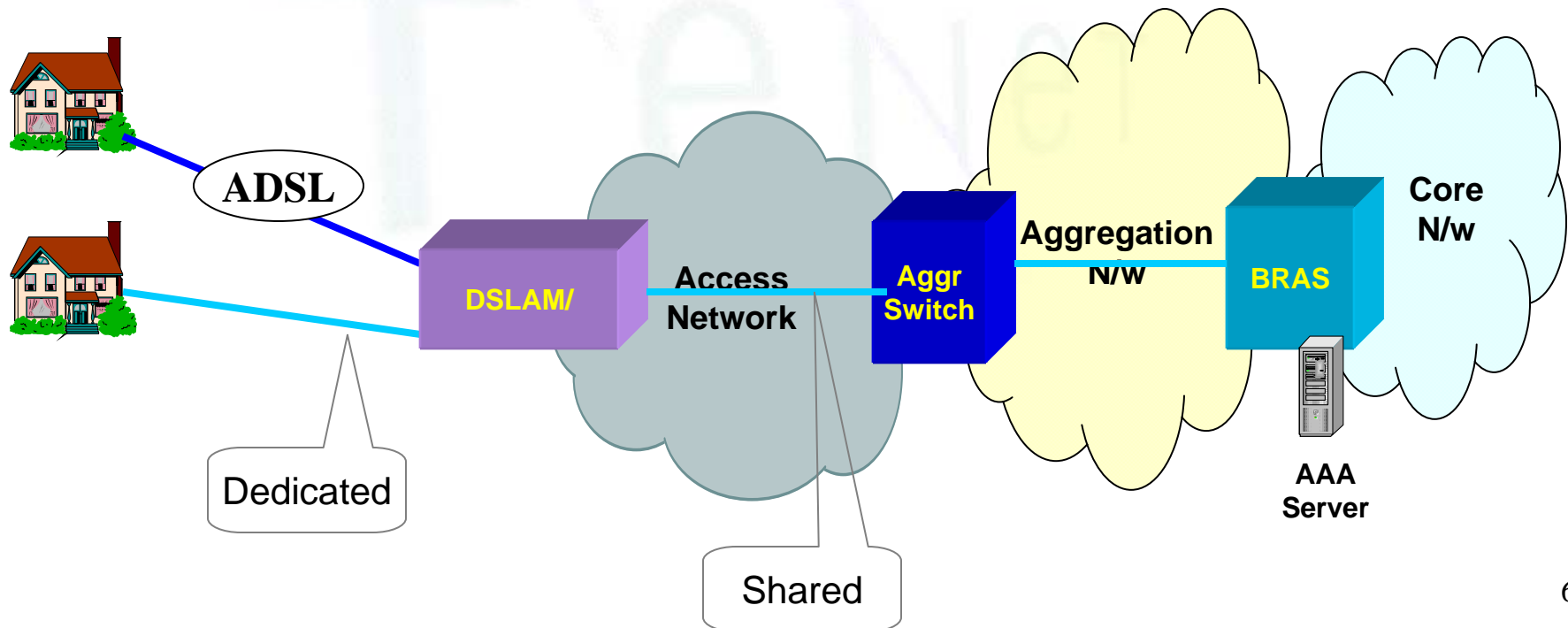
- ITU-T: 1.5 Mb/s
- TRAI: 256 kb/s
- Subscriber:

*Good experience with common services --
multi-media browsing, downloads, streaming
media, VOIP, multi-player games*

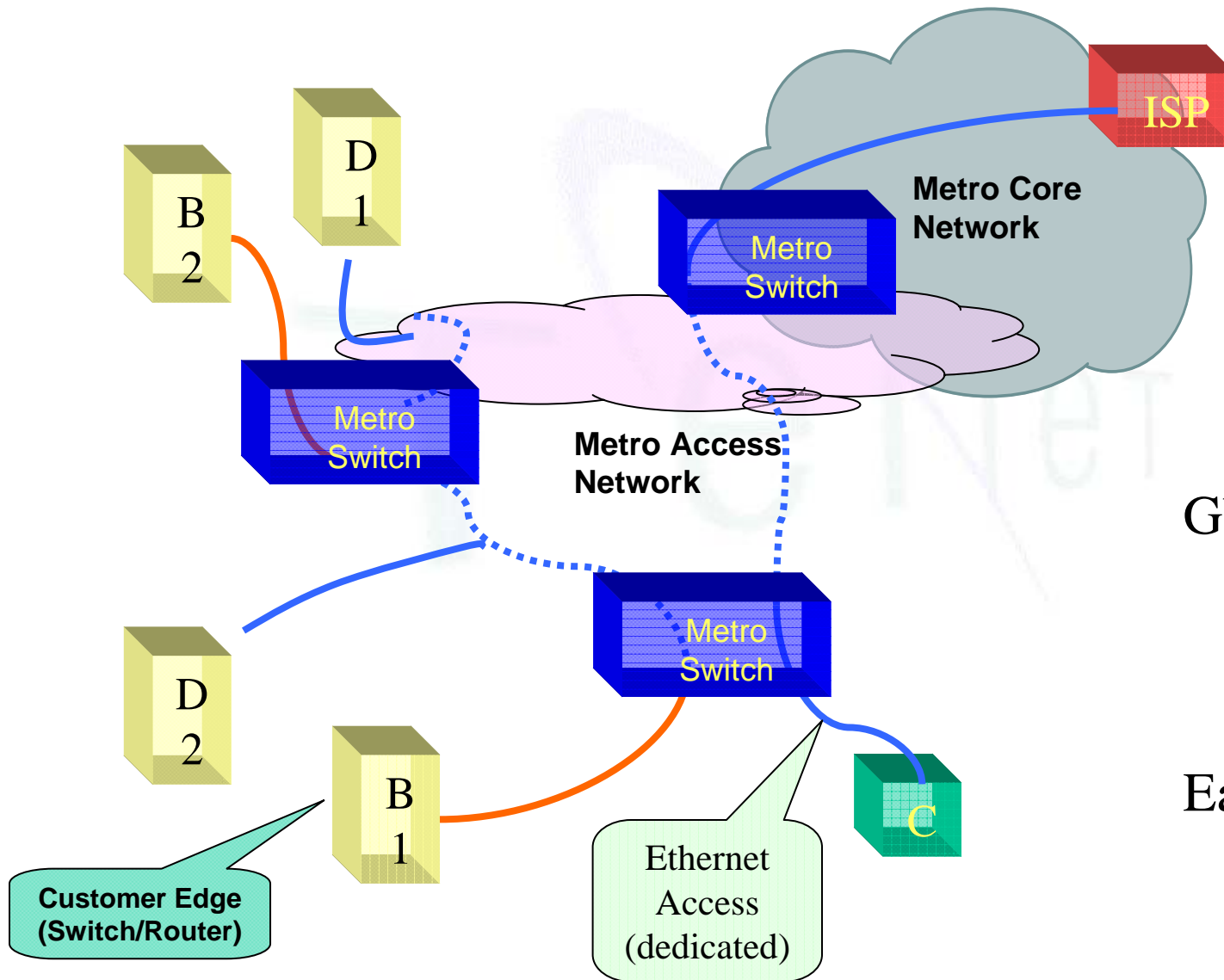
Requires 256 kb/s - 1 Mb/s

- ADSL over copper
- Metro-Ethernet
- Cable Internet
- Wireless: *urban or rural*
 - GSM
 - CDMA
 - DECT
 - WiMAX

- Downstream 8-24 Mb/s, upstream 0.5-3.5 Mb/s max
- Bandwidth guaranteed only to DSLAM, thereafter depends on how operator configures the switches/BRAS/routers
- Good for incumbent operator with many wired subscribers



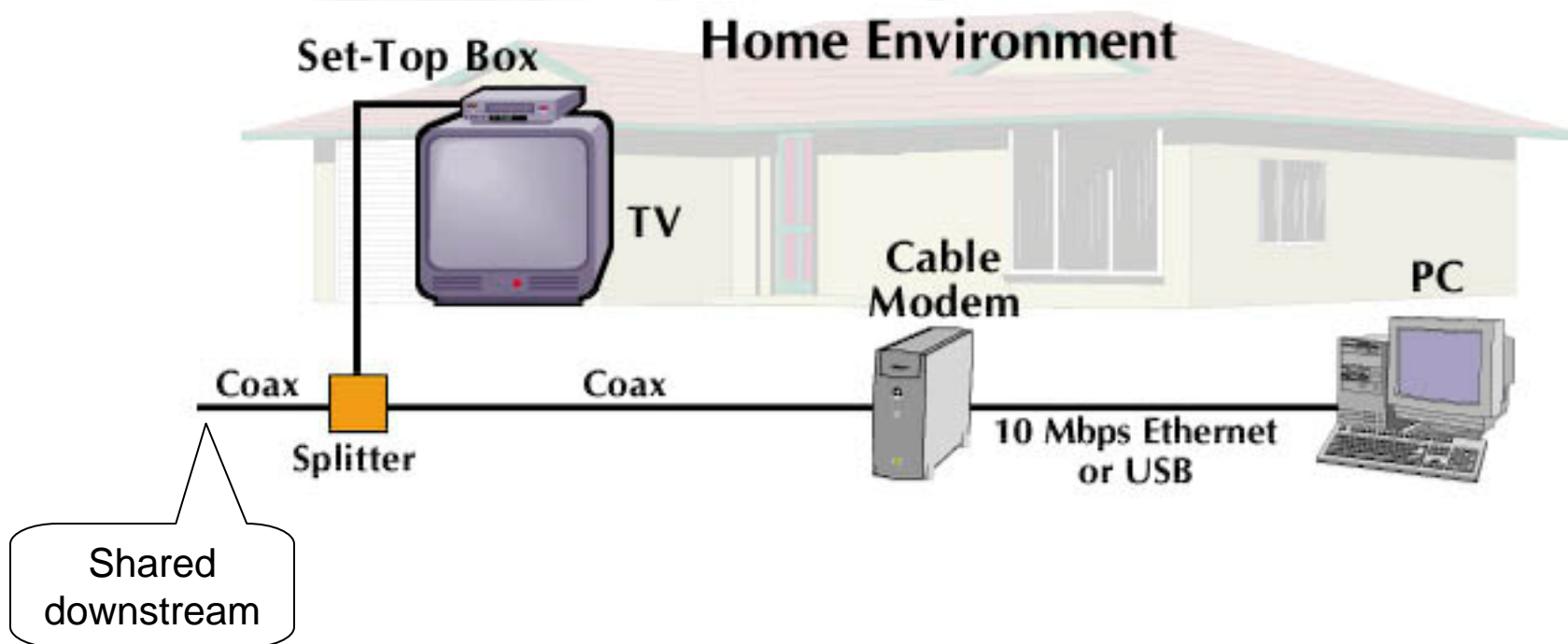
Metro Ethernet



Gb/s fibre access
with 100 Mb/s
CAT-6 in the
building

Easy provisioning
of bandwidth
limits

- Downstream 40 Mb/s shared, upstream 384 kb/s
- Requires good quality cable infrastructure



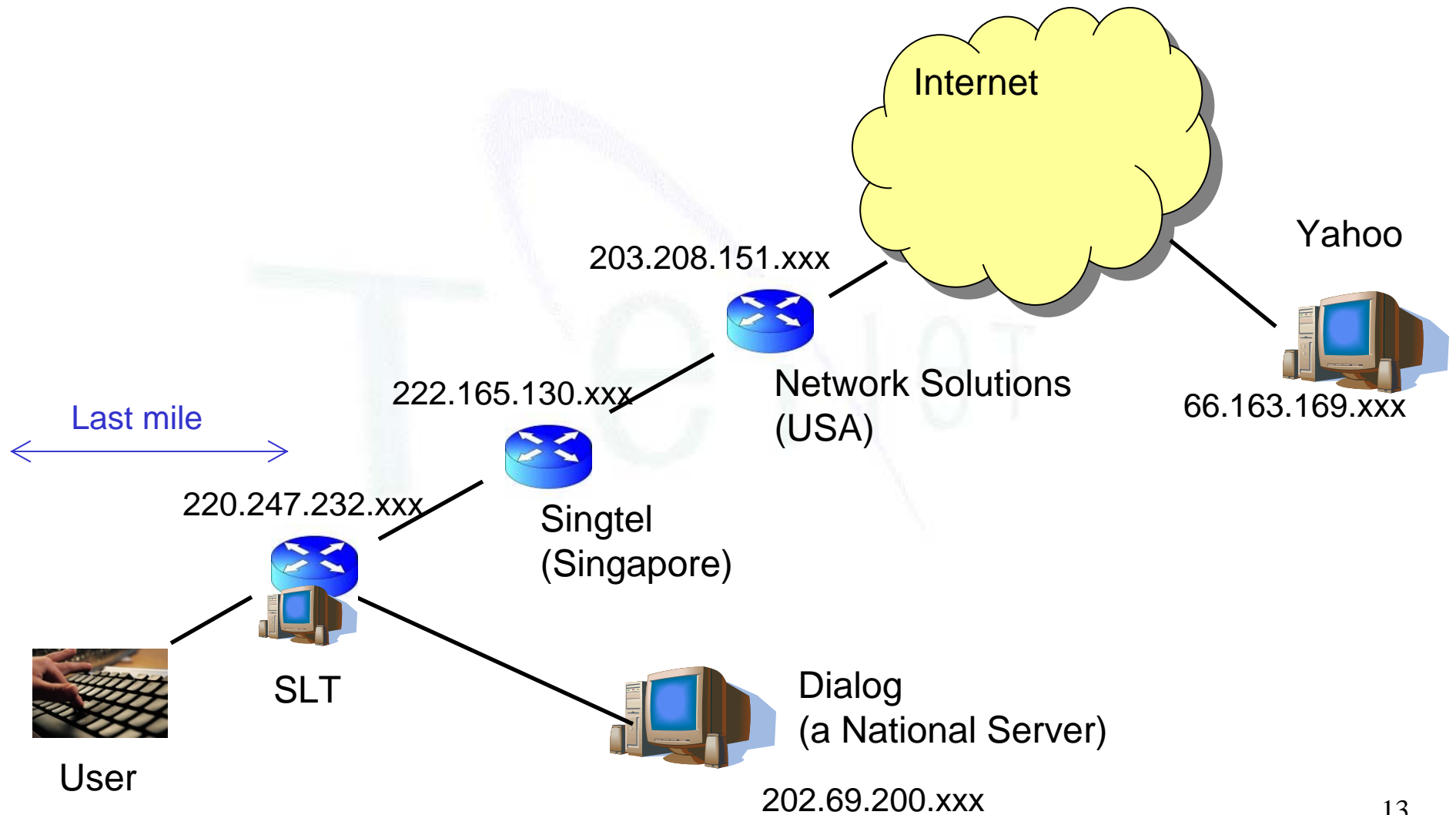
- 60,000 CATV operators serving 60m homes
- \$2-3/month
- Cable connection quality good for TV, not good enough for upstream digital
- ↳ Triple-play products from Midas provide 40 Mb/s downstream on poor quality coaxial plant:
- CITIUS: upstream on wireless corDECT – PC + TV
- CATIUS: upstream on Ethernet – PC + TV

- GSM:
 - GPRS: 56-114 kb/s
 - EDGE: upto 236.8 kb/s
 - HSDPA: Theoretical downlink 14.4 Mb/s
Deployed: 7.2 Mb/s
Uplink 384 kb/s
- CDMA:
 - CDMA 1x: 144 kb/s
 - CDMA 3x: downlink 2.4-3.1 Mb/s, uplink 154 kb/s-1.8 Mb/s
downlink minimum 38.4 kb/s

- DECT:
 - Broadband corDECT (Midas): 256-512 kb/s dedicated per subscriber plus toll-quality voice
- WiMAX:
 - 70 Mb/s shared downlink over short distances,
10 Mb/s over 10 kms
2 Mb/s over long distances

- Uses multiple tools (BW monitor, ping, tracert)
- Measures 6 parameters
- Tests three servers (ISP, National, International)
- Repeated at different times of the day
- Repeated at weekdays and weekends
- Tests for long intervals to minimize effects of short term variations (eg. 100 pings, 100 sec download)
- Variations analysed and outliers removed

Network Diagram of a Test



1. Download throughput
2. Upload throughput
3. Round-trip delay (RTT)
4. Delay jitter
5. Packet loss
6. Availability of service

- **RTT**: Time taken for a packet to reach the destination and return.
- **Jitter**: Variation in RTT

$$\sum_{k=1}^{k=n} |M - r_k| / n$$

M = mean RTT, n =sample size , $r_k = k^{\text{th}}$ RTT reading

- Measured by pinging $n=100$ packets to destination

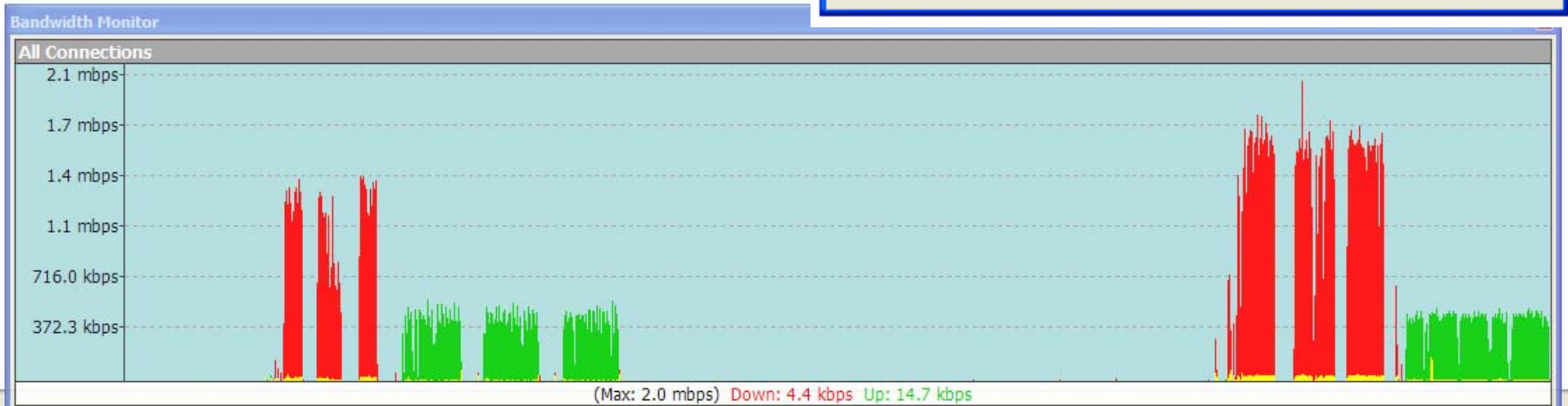
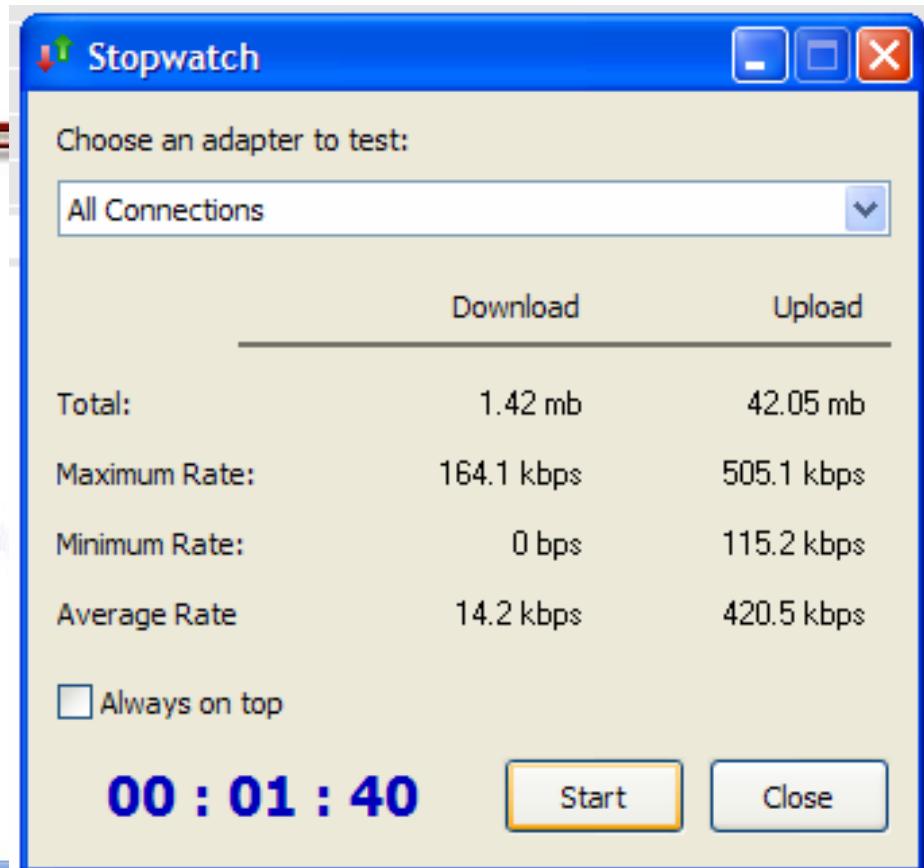
- **Packet Loss** = Number of packets (in %) which do not reach the destination (measured by pinging)
- **Availability** = $1 - \text{Prob}[\text{Service unavailable for } >30 \text{ sec}]$

<i>Service</i>	<i>Throughput</i>		<i>Delay</i>		<i>Loss</i>
	<i>Down</i>	<i>Up</i>	<i>RTT</i>	<i>Jitter</i>	
Browse (text)	++	-	++	-	-
Browse (media)	+++	-	+	+	+
Download file	+++	-	-	-	-
Transactions	-	-	++	+	-
Streaming media	+++	-	+	++	++
VOIP	+	+	+++	+++	+++
Games	+	+	+++	++	++

+++ highly relevant, ++ very relevant, + relevant, - not relevant

Download/upload speeds:

Measured using BWMonitor while downloading ~ 5 MB file (~100 secs)



```
Command Prompt
Microsoft Windows [Version 6.0.6000]
Copyright (c) 2006 Microsoft Corporation. All rights reserved.

C:\Users\user>ping www.yahoo.com

Pinging www.yahoo-ht3.akadns.net [209.131.36.158] with 32 bytes of data:

Reply from 209.131.36.158: bytes=32 time=351ms TTL=53
Reply from 209.131.36.158: bytes=32 time=337ms TTL=53
Reply from 209.131.36.158: bytes=32 time=335ms TTL=53
Reply from 209.131.36.158: bytes=32 time=336ms TTL=52

Ping statistics for 209.131.36.158:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 335ms, Maximum = 351ms, Average = 339ms

C:\Users\user>tracert 209.131.36.158

Tracing route to f1.www.vip.sp1.yahoo.com [209.131.36.158]
over a maximum of 30 hops:

  0  1 ms    1 ms    1 ms    192.168.1.1
  1  12 ms   15 ms   19 ms   220.247.232.35
  2  13 ms   13 ms   *      220.247.193.197
  3  12 ms   13 ms   13 ms   222.165.130.109
  4  13 ms   20 ms   15 ms   222.165.130.10
  5  61 ms   62 ms   60 ms   217.6.48.33
  6  350 ms  403 ms  406 ms  217.239.40.110
  7  325 ms  324 ms  331 ms  62.159.124.242
  8  335 ms  336 ms  335 ms  so-0-0-0.pat2.pao.yahoo.com [216.115.101.130]
  9  344 ms  338 ms  335 ms  ge-2-1-0-p501.pat1.sjc.yahoo.com [216.115.106.17]
10  *
11  *      336 ms  347 ms  g-0-0-0-p170.ms2.sp1.yahoo.com [216.115.107.81]
12  362 ms  325 ms  327 ms  te-9-1.bas-a1.sp1.yahoo.com [209.131.32.23]
13  337 ms  336 ms  336 ms  f1.www.vip.sp1.yahoo.com [209.131.36.158]

Trace complete.

C:\Users\user>_
```

- 08:00 hrs: Lean period
- 11:30 hrs: Peak Business hours
- 15:00 hrs: Peak business hours
- 18:00 hrs: Shift from business to residential usage
- 20:30 hrs: Early residential users
- 22:30 hrs: Late residential users

- Several broadband technologies for 256k-70m
 - Wired -- urban
 - Wireless -- urban and rural
- Tremendous potential for subscriber growth
 - Cost of service and QoS are key
- Six service-oriented objective measures for QoS
- Test methodology to minimize bias and error

- TeNeT Group of IIT-M -- <http://www.tenet.res.in>
- Broadband corDECT, Cable Internet products -- <http://www.midascomm.com>
- Articles on various broadband technologies -- <http://en.wikipedia.org>
- Broadband QoS study -- <http://www.lirneasia.net/projects/current-projects/2241/>
- Broadband testing partner: Nilgiri Networks -- <http://www.nilgirinetworks.in>

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