SWINBURNE UNIVERSITY OF TECHNOLOGY

How much bandwidth does an NBN really need to be useful?

Professor Grenville Armitage

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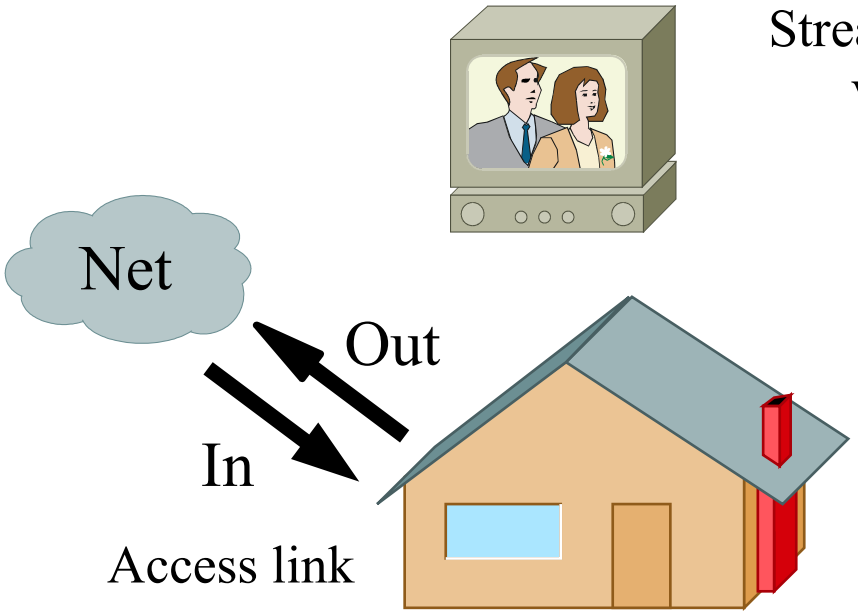
Let us continue with that in mind....

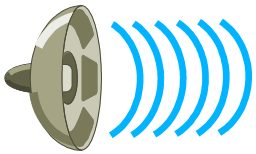
A peek at my conclusion / challenge / opinion....

A very rough, ball-park conclusion....

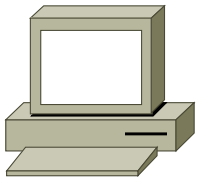
A *typical home* needs > 60Mbit/sec inbound and roughly 5 - 15 Mbit/sec outbound (using today's guesses)



Streaming/on-demand video: 30in/0.1out

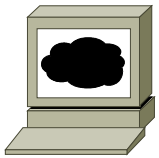


Streaming audio: 1.2in/0.1out



Online games: 1.2in/1.2out

Telephony: 0.4in/0.4out



Email, file sharing, web surfing, video conferencing: 25in/10out

("in" and "out" speeds in Mbit/sec)

Talk overview

- Background – “the internet” and the NBN
- What does “network speed” even mean?
- What do higher speeds do for us?
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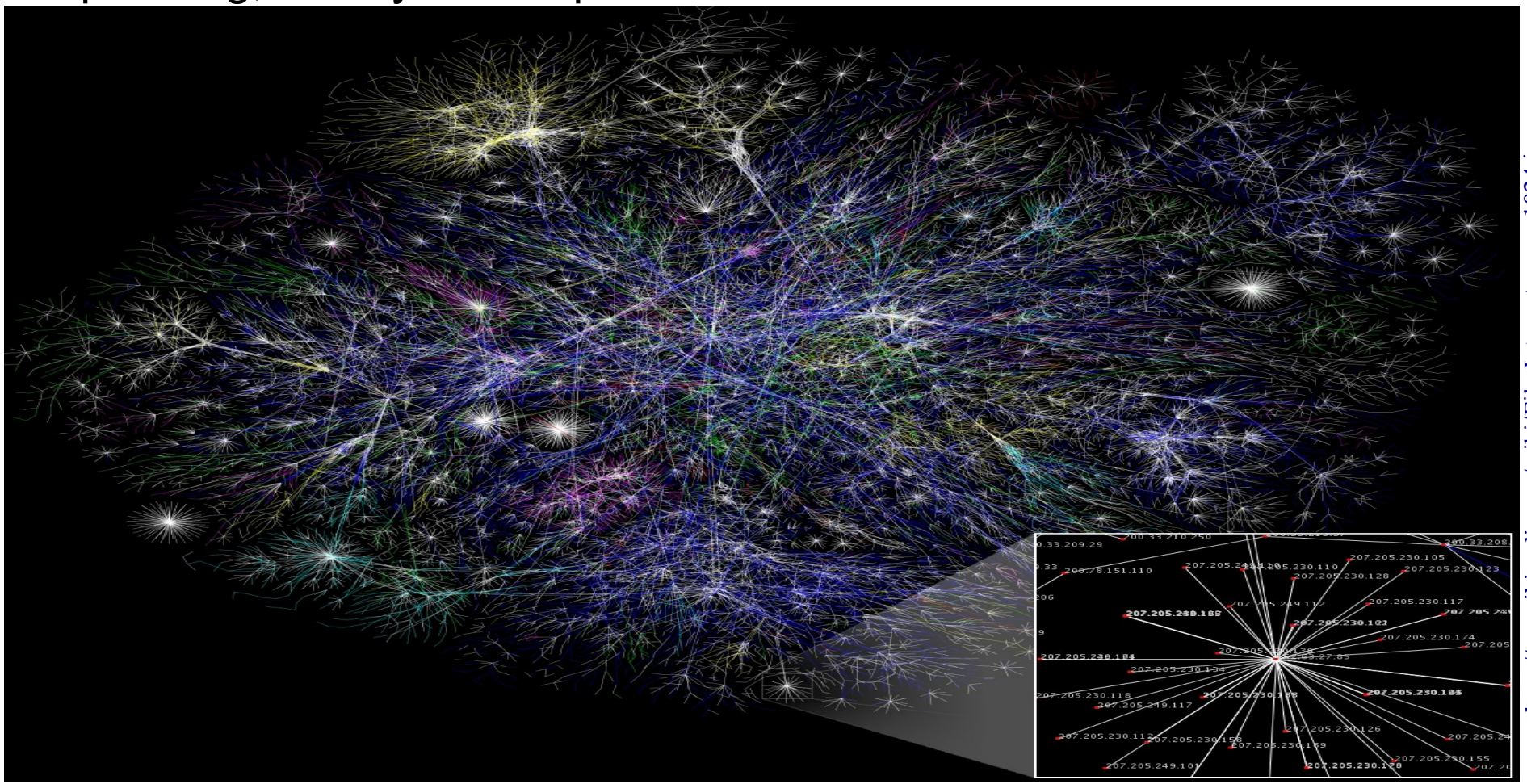
- Consumer consumption and 'useful' speed

Today: Concepts rather than simple conclusions

I'm surprised the Internet works at all

Many, many millions(+) of loosely co-operating, mostly de-coupled devices....



http://en.wikipedia.org/wiki/File:Internet_map_1024.jpg

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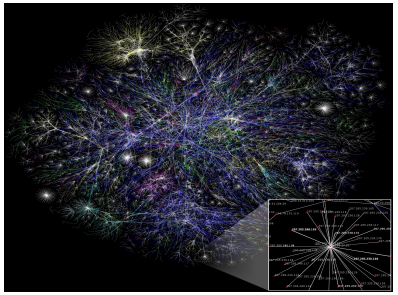

All trying to locally optimise for their preferred mix of speed,

responsiveness,

consistency,

'quality'

price....

http://ny.racked.com/uploads/2011_11_Macys-Black-Firiday-Crowd.png

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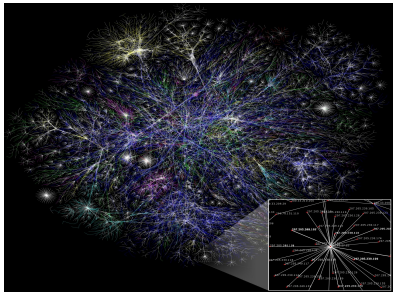

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What could possibly go wrong?

http://izismile.com/2009/12/22/how_traffic_jams_start_6_pics-5.html

This is not the internet :-)

http://www.thisiscolossal.com/wp-content/uploads/2012/10/google-3.jpg

Homes & small business – internal

Office Applications

Cloud-based applications

Web

Video conferencing

IP Telephony

File Backups

Email

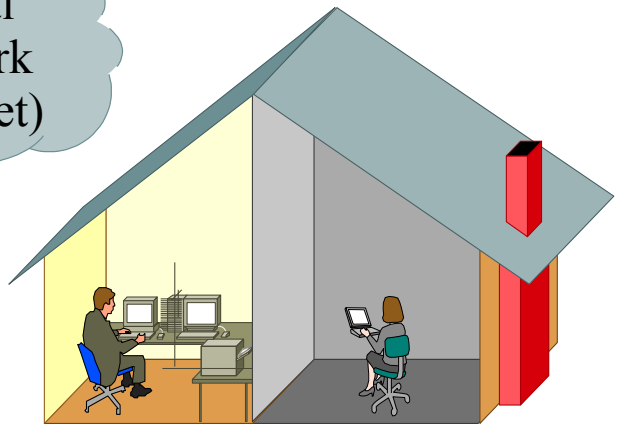
File servers

Social media

VPN / Telecommuting

Online Commerce

Internal Network (intranet)



Internet Service Providers

Homes & small business – external

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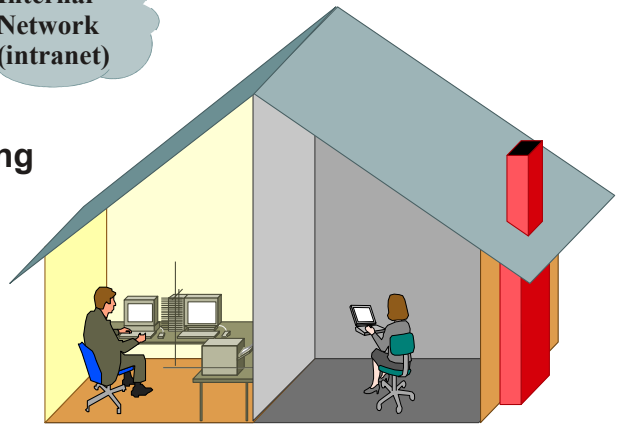

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Outlook 2010

YAHOO! MAIL

Hotmail

skype

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bing

YAHOO!

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EC2 S3 Glacier

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Google Apps for Business

Access Link speeds....

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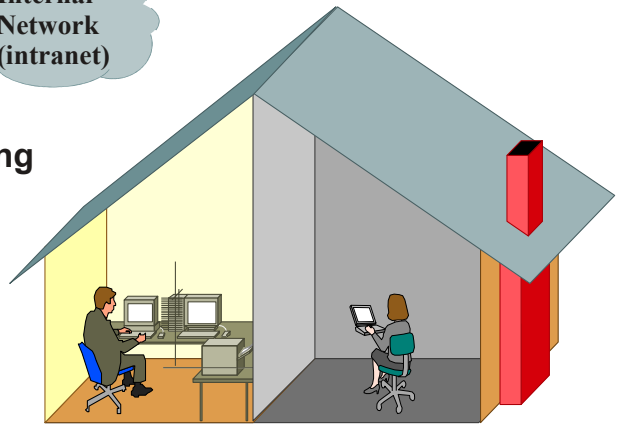

NBNCo's fiber service is a seriously fast *Access Link* to the Internet

Internet (Retail) Service Providers

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Uplink & downlink speeds differ

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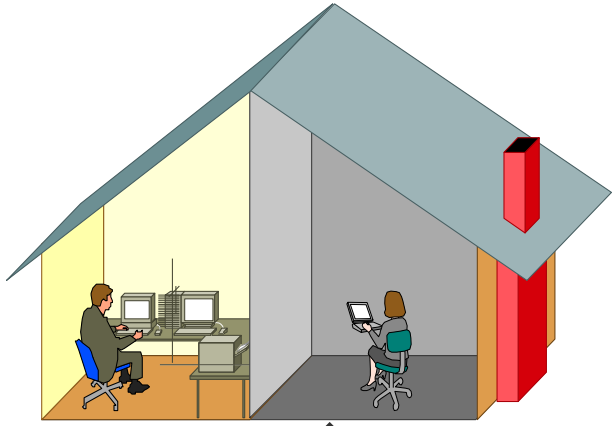

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Downlink (in to your office)
NBN fibre: 100, 50, 25 Mbps

Uplink (out of your office)
NBN fibre: 40, 20, 5 Mbps

Internet (Retail) Service Providers

Uplink matters when *pushing* data

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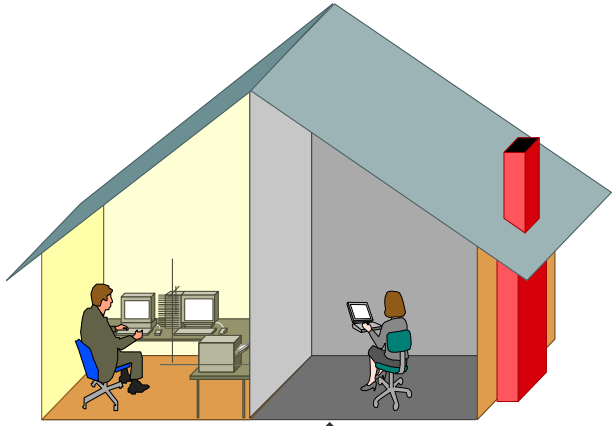

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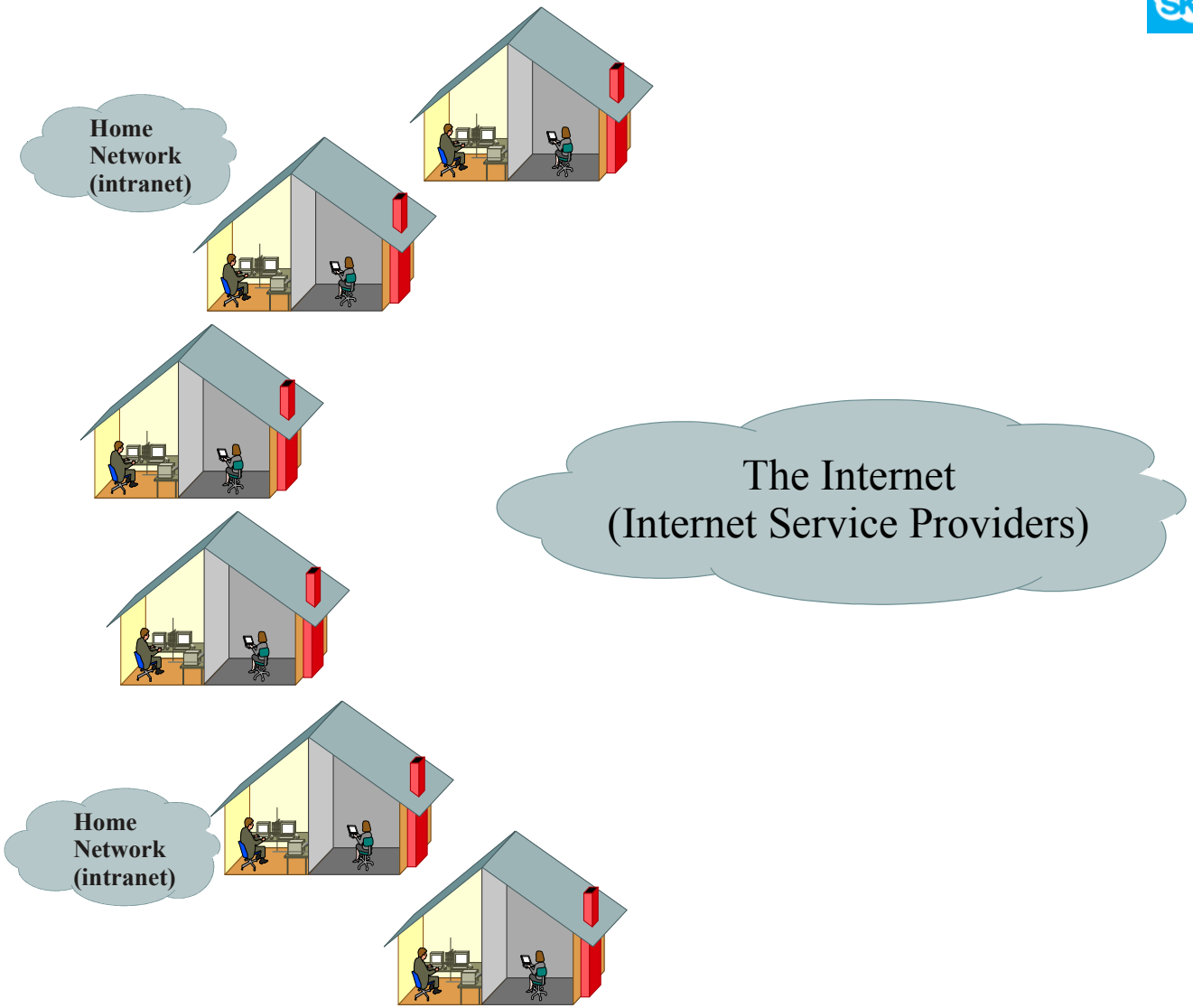
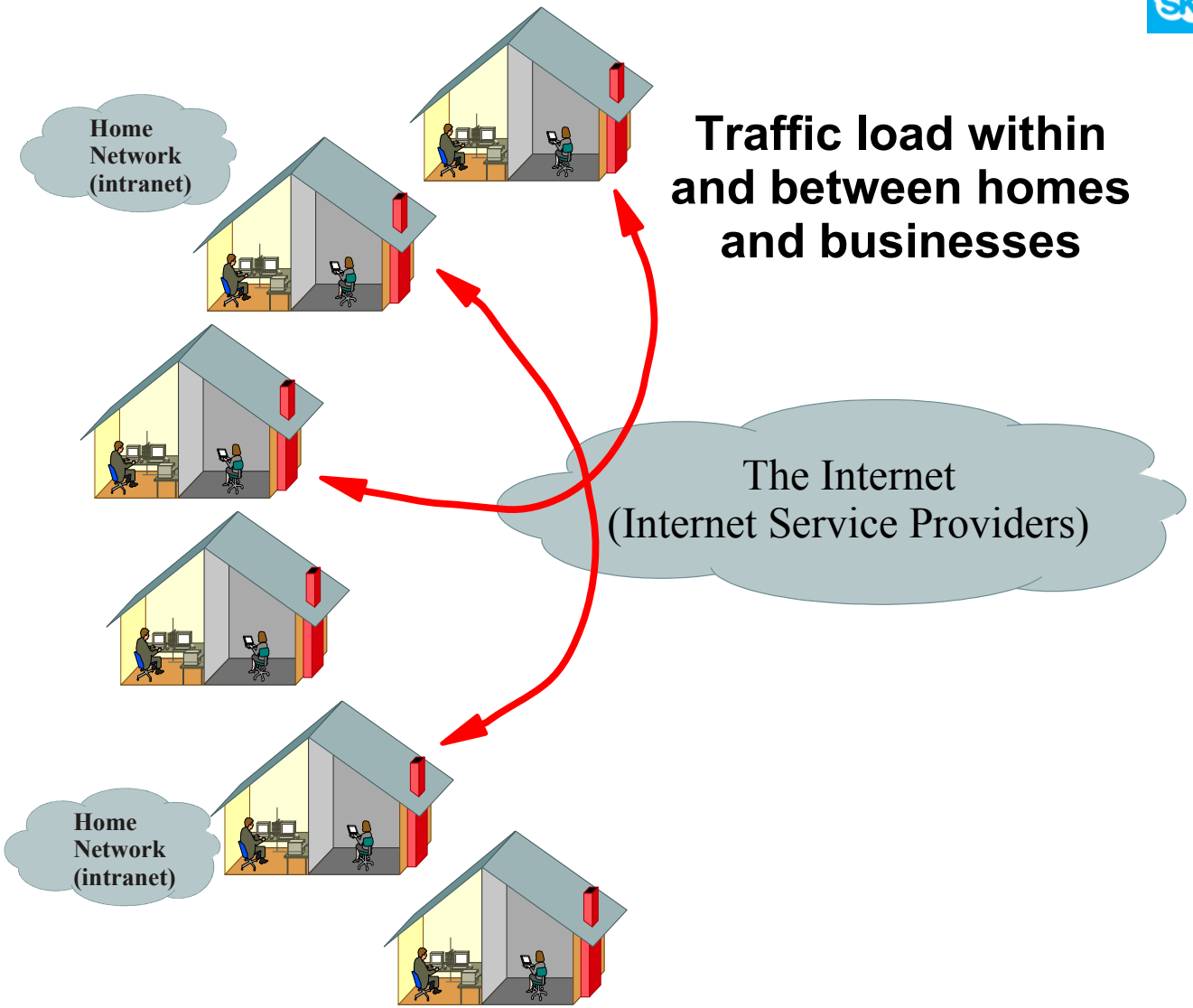
Internet (Retail) Service Providers

(Shared among multiple people and machines....)

When everyone talks to everyone...



Packets flow almost everywhere



Traffic load within and between homes and businesses

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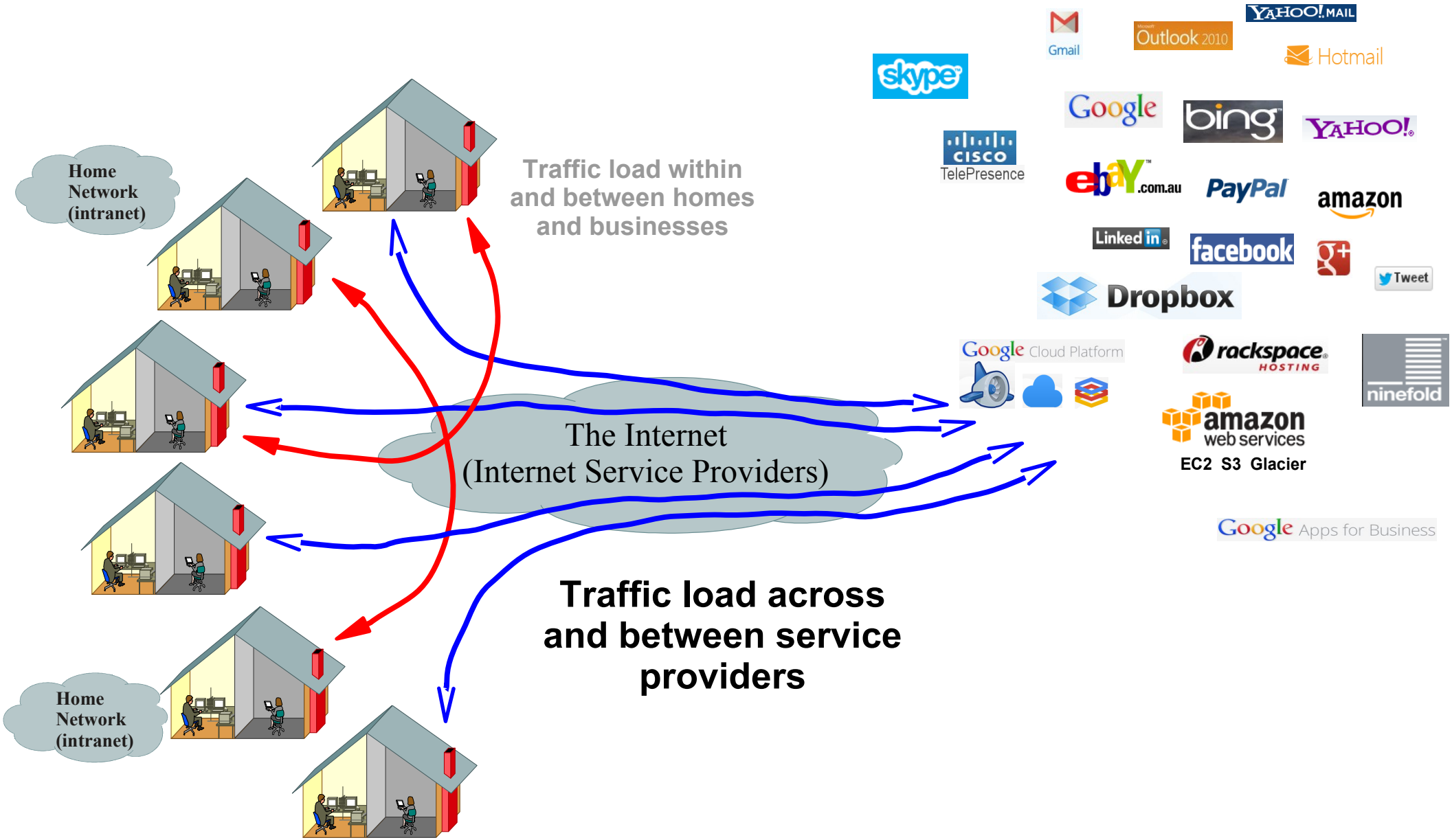
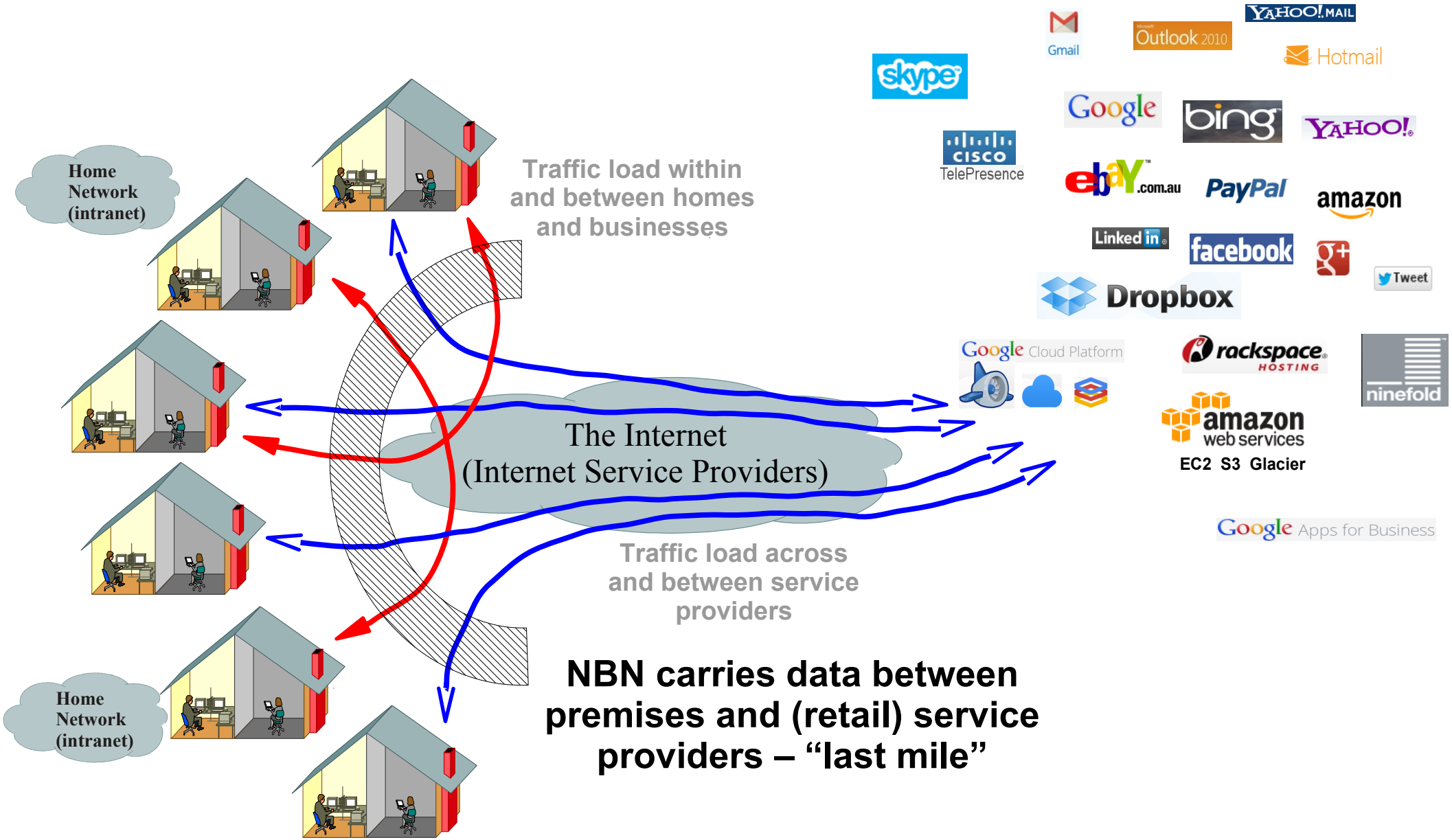


NBN is only part of the picture



NBN carries data between premises and (retail) service providers – "last mile"

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Speed can mean many things #1

- The time it takes to
  - ...download a movie DVD to my laptop
  - ...upload a collection of photos from my camera
  - ...download an electronic book to my e-reader
  - ...retrieve an email with photo or file attached
  - …send the characters in an SMS or instant message
  - ...send “bits” or “bytes”

Speed can mean many things #2

- How fast the network must be so that
  - ...IP television, YouTube (or similar) video services are delivered without shuddering or pausing
  - ...IP telephony (or “Voice over IP”) is clear and consistent
  - ...Skype (or similar) services are clear and consistent
  - ...Online interactive games are smooth and don't shudder
  - ...Medical telemetry provides un-interrupted monitoring
  - ...Web pages download promptly after each 'click'
  - ...*etc*

Terminology: Bits and bytes

- Bits and bytes → quantity of information
  - One *bit* can be “1” or “0”
  - Eight bits → one *byte*
- Bits/sec and bytes/sec → “speed” (information over time)

- “K” (kilo, or 'thousand')
  - Kbits/sec – thousand bits per second
- “M” (mega, or 'million')
  - Mbit/sec – million bits per second

Example: Skype bandwidth

Call type	Minimum download / upload speed	Recommended download / upload speed
Calling	30kbps / 30kbps	100kbps / 100kbps
Video calling / Screen sharing	128kbps / 128kbps	300kbps / 300kbps
Video calling (high-quality)	400kbps / 400kbps	500kbps / 500kbps
Video calling (HD)	1.2Mbps / 1.2Mbps	1.5Mbps / 1.5Mbps
Group video (3 people)	512kbps / 128kbps	2Mbps / 512kbps
Group video (5 people)	2Mbps / 128kbps	4Mbps / 512kbps
Group video (7+ people)	4Mbps / 128kbps	8Mbps / 512kbps

https://support.skype.com/en-us/faq/FA1417/how-much-bandwidth-does-skype-need

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Impact of network speed on lifestyle

- How do online activities intrude on our life?
  - Changing channel on IP TV
  - Downloading new podcasts
  - Sync'ing our phone's photos “to the cloud”

    …. and so on....
- As speeds go up, these tasks take less time
  - The internet begins to satisfy our transient curiosity
  - Spur-of-the-moment activities become practical
- What speed is “sufficient” and worth the cost?

What can we do with NBN speeds?

- Web-based services
  - Faster page loading & response times
  - Improved ease-of-use & customer experience

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[*insert imagination here...*]

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NBNCo's proposed speeds

- On offer: 100/40, 50/20 & 25/5 Mbit/sec

- These *significantly improve on* ADSL2+
  - 'traditional' broadband over copper phone wires
  - Best speeds are roughly 20/1 Mbit/sec

Optical fibre: speeds vs distance

- Using optical fibre means speed is constant versus usual customer distance from the local 'exchange'
  - cf. speed over copper wires drops off with distance
    - e.g. ADSL2+ can easily be down around 2/0.5 at edges of service areas, or where copper wiring is degraded by weather
  - cf. speed over wireless drops off with distance <u>and</u> the number of other wireless customers in your locality

Impact of distance #2

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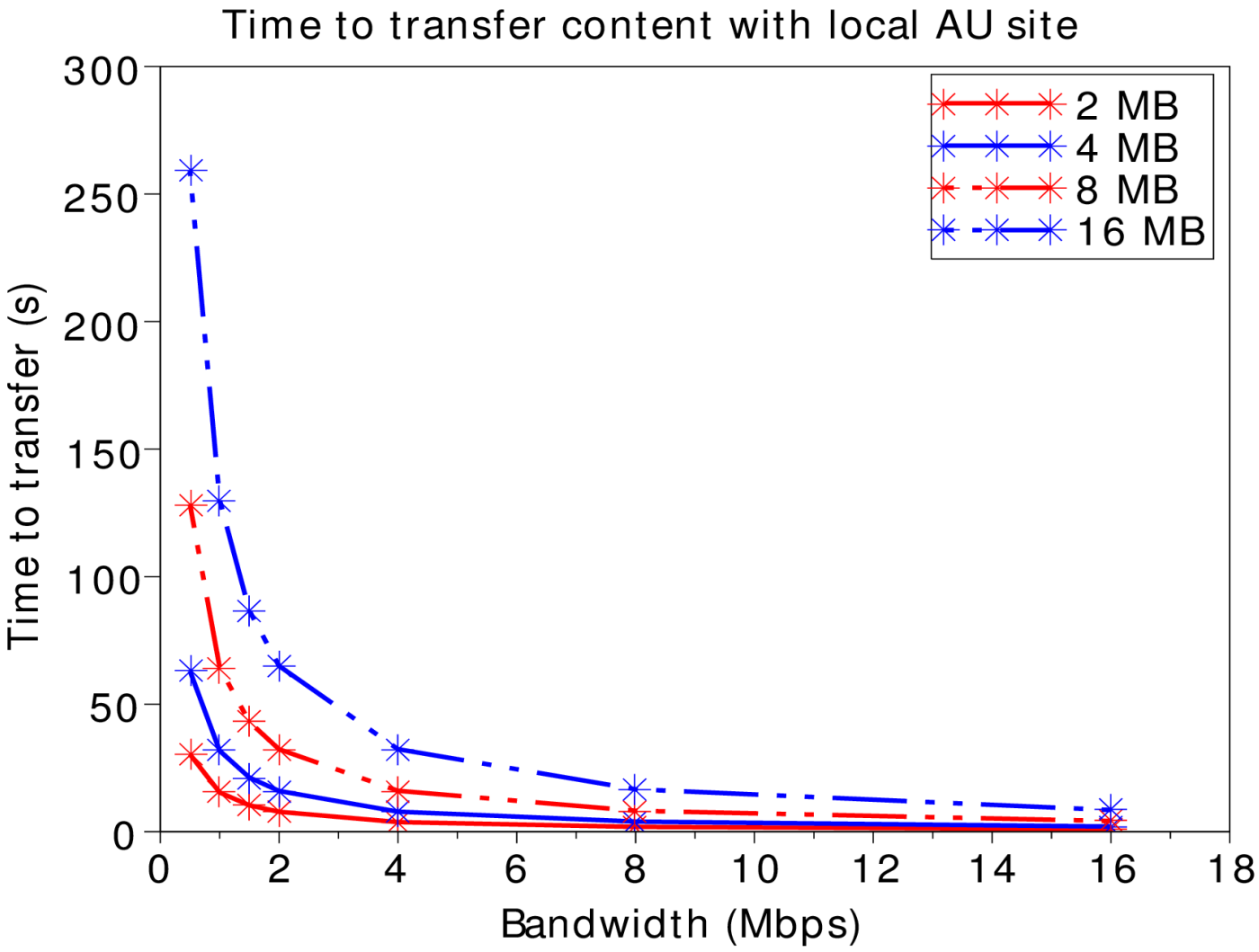
- For example: your “Cloud” service provider's location can really make a difference
  - On-shore providers will perform better than ones in the northern hemisphere

The heady benefits of speed....



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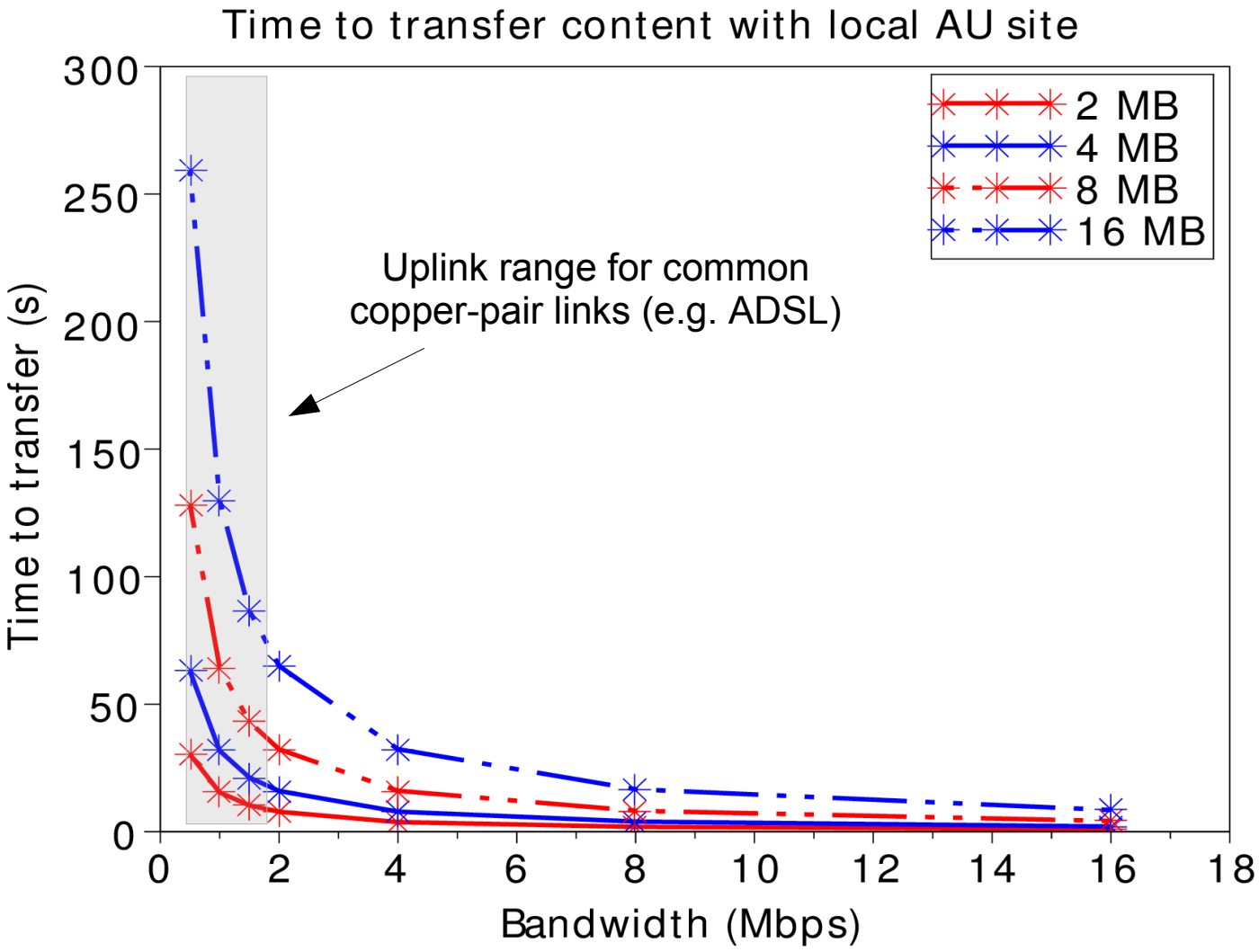

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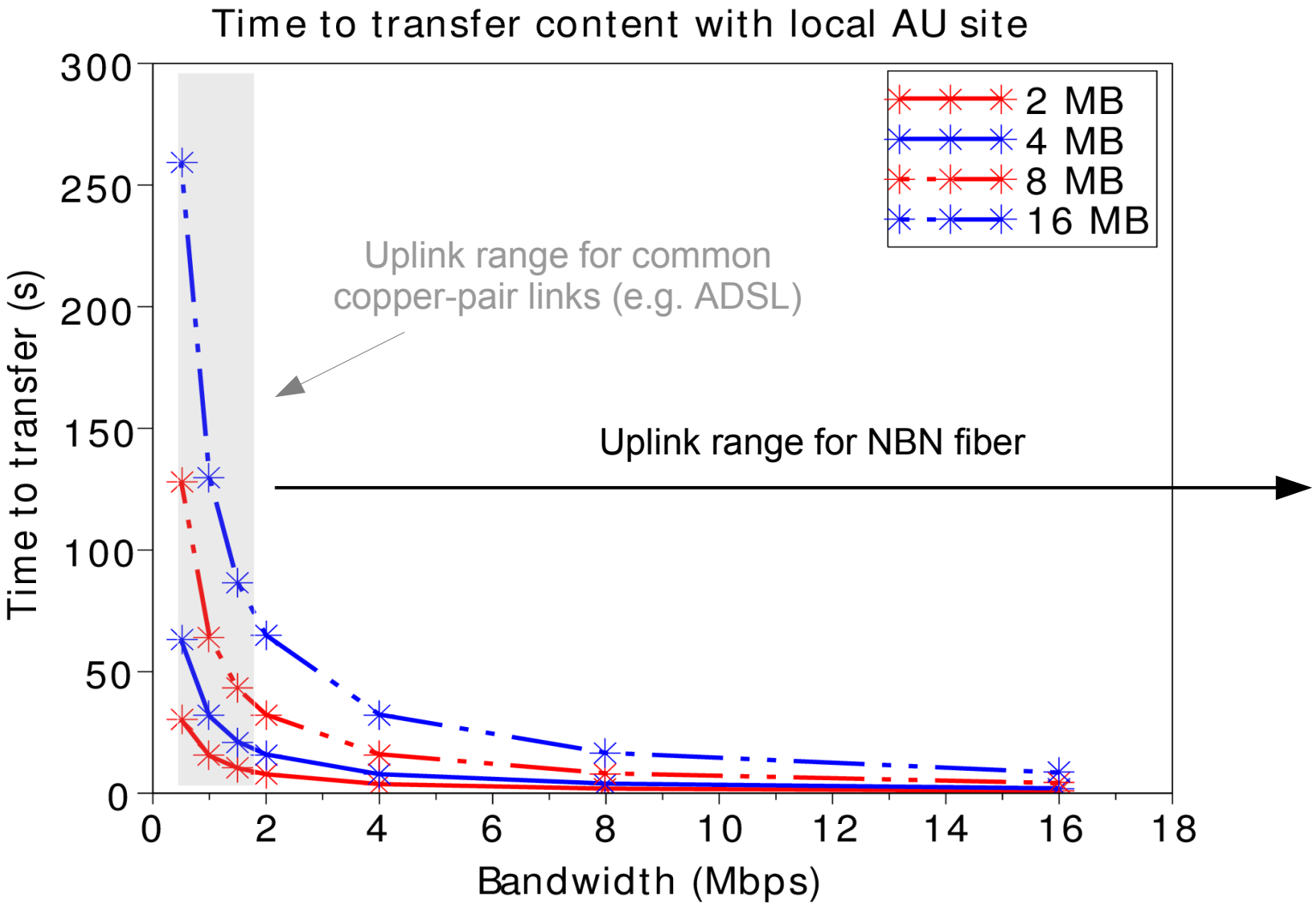
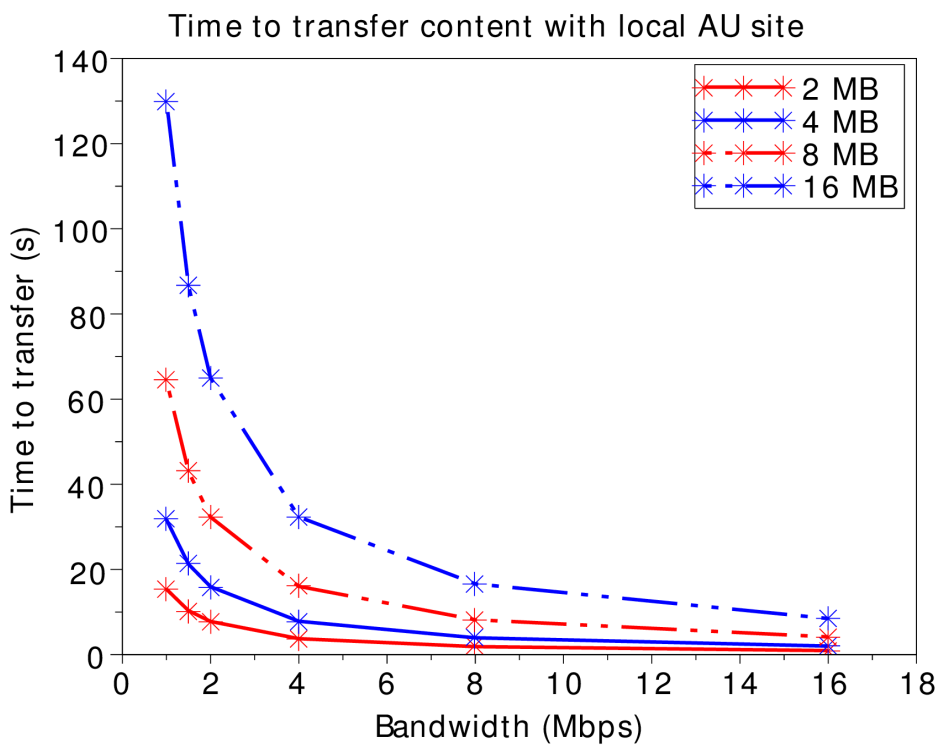
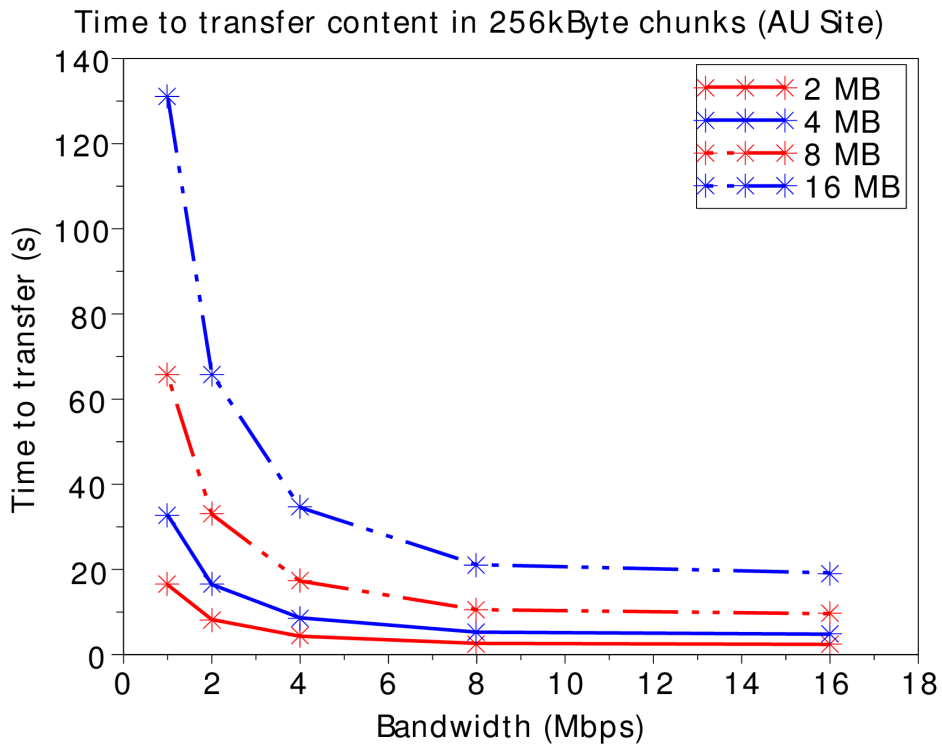


When data is in smaller chunks...





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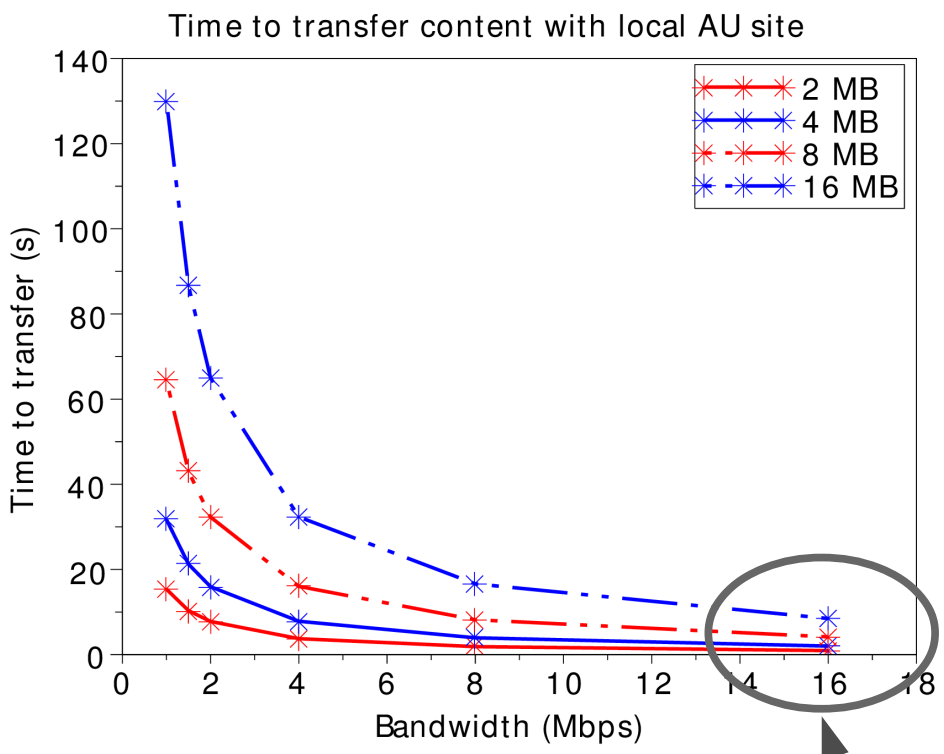
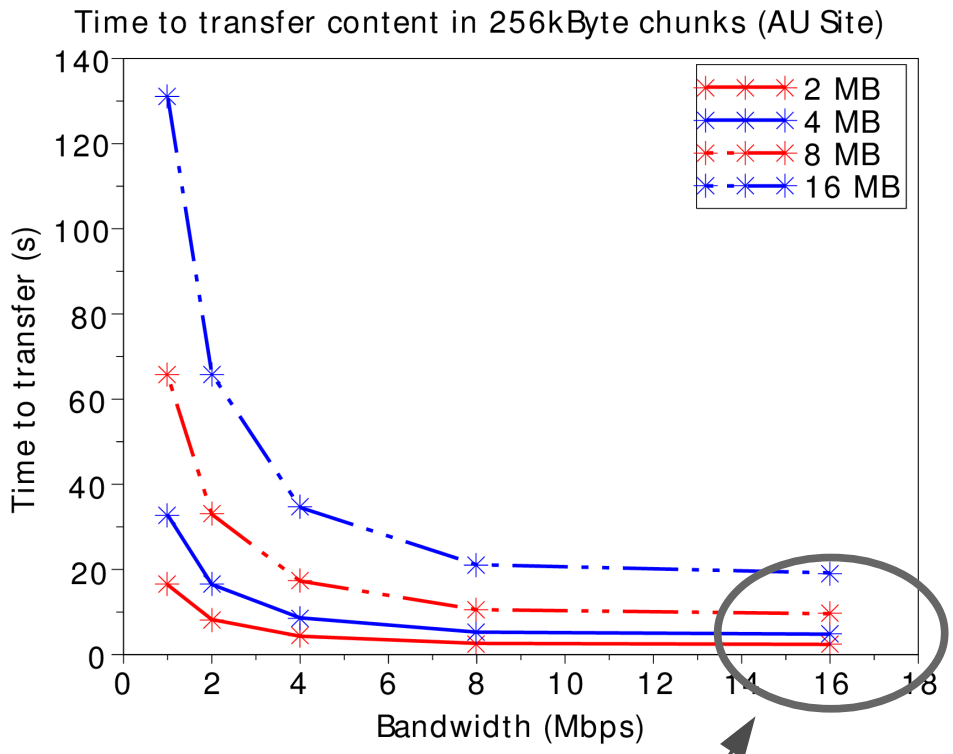
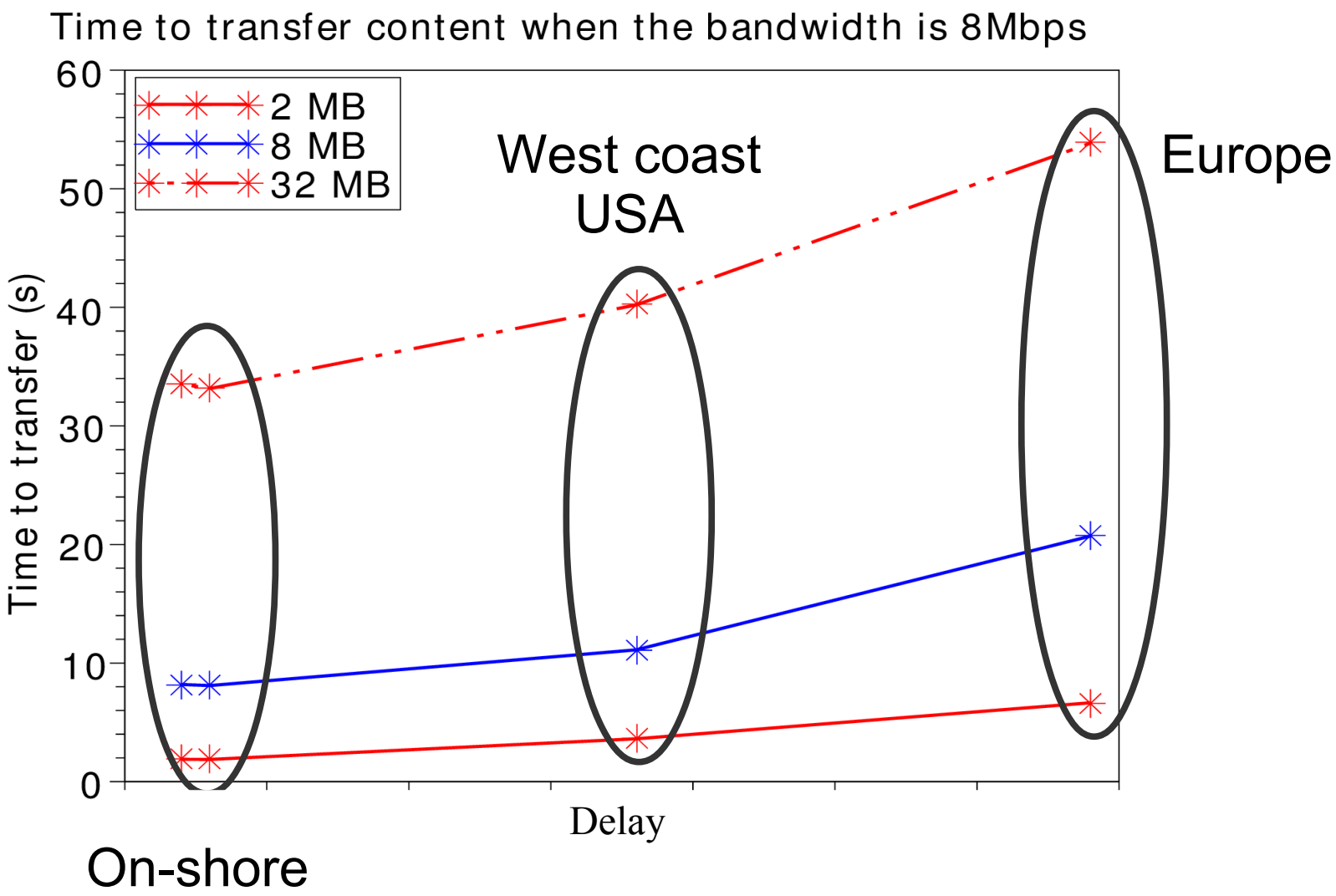




At high speeds, sending data in large blocks is noticably faster than lots of sequential small transfers

The headache of latency....



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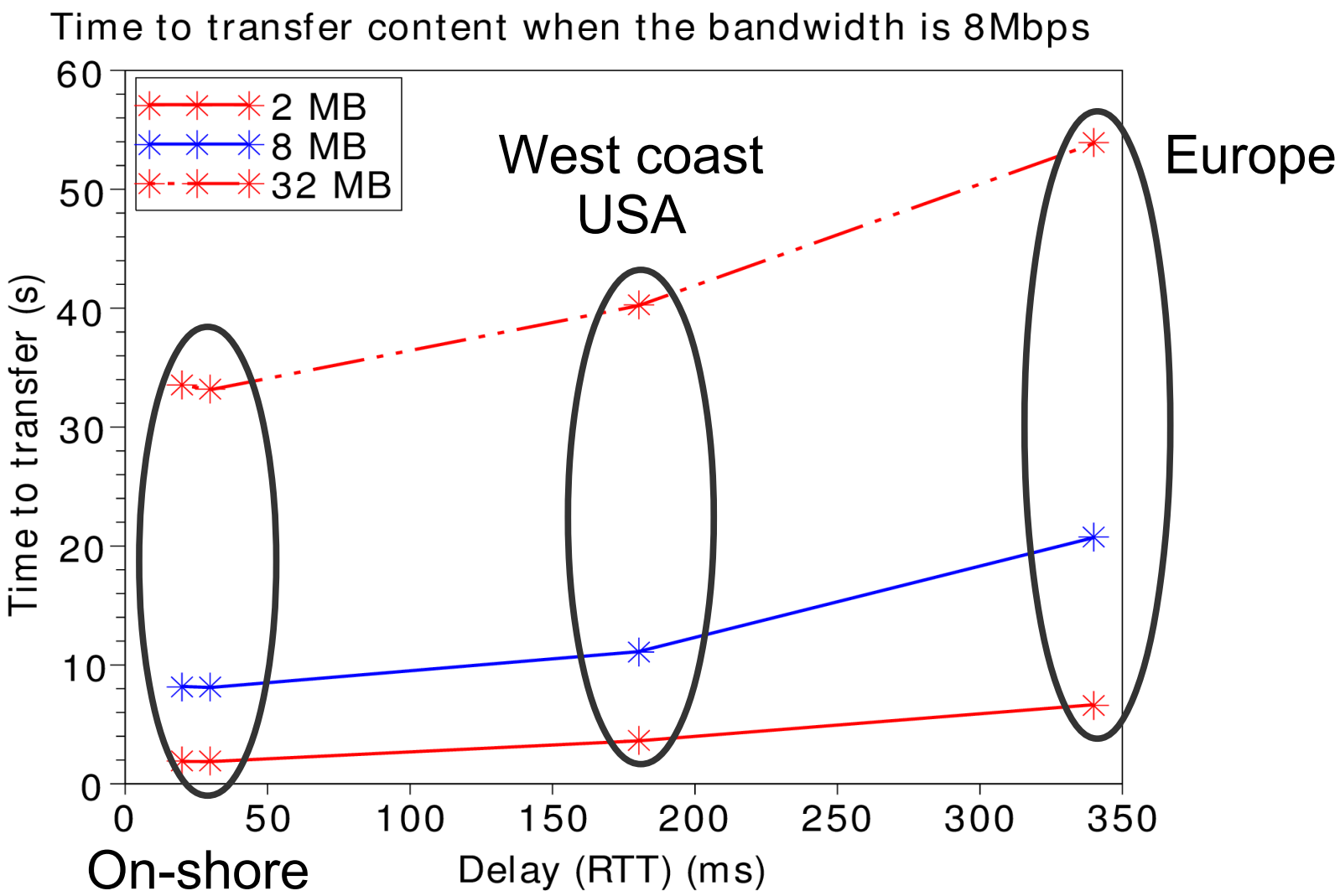
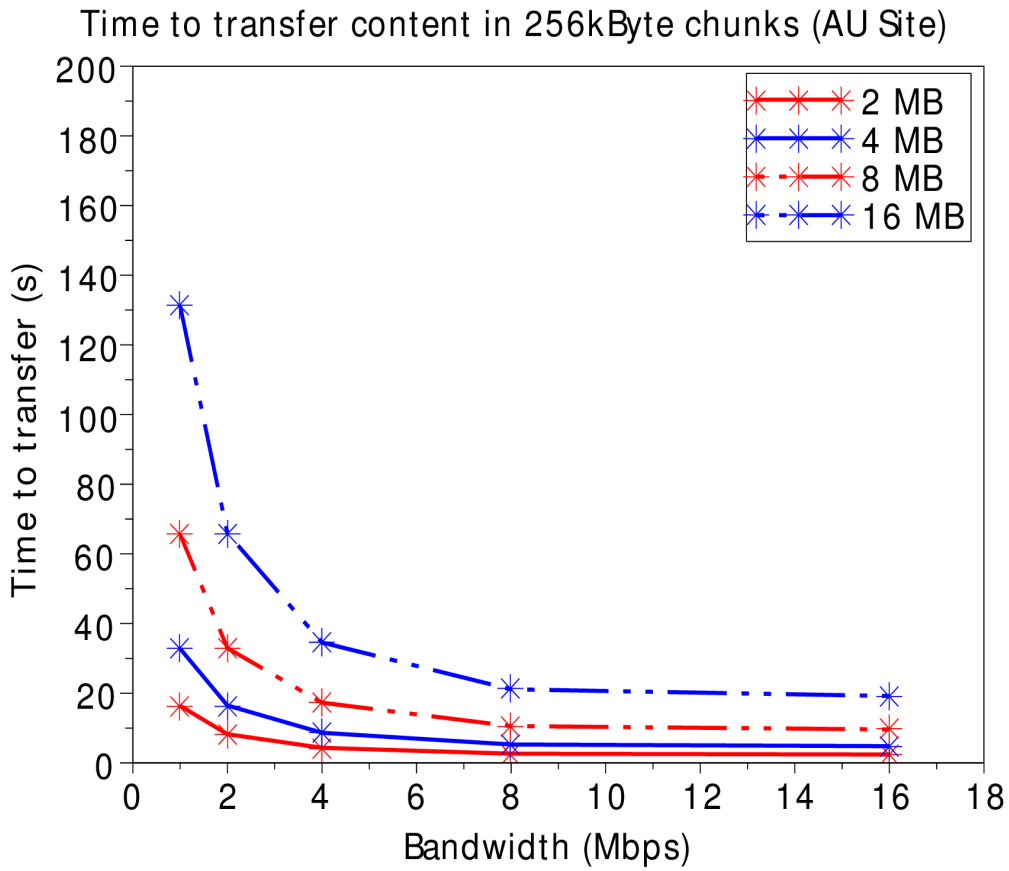
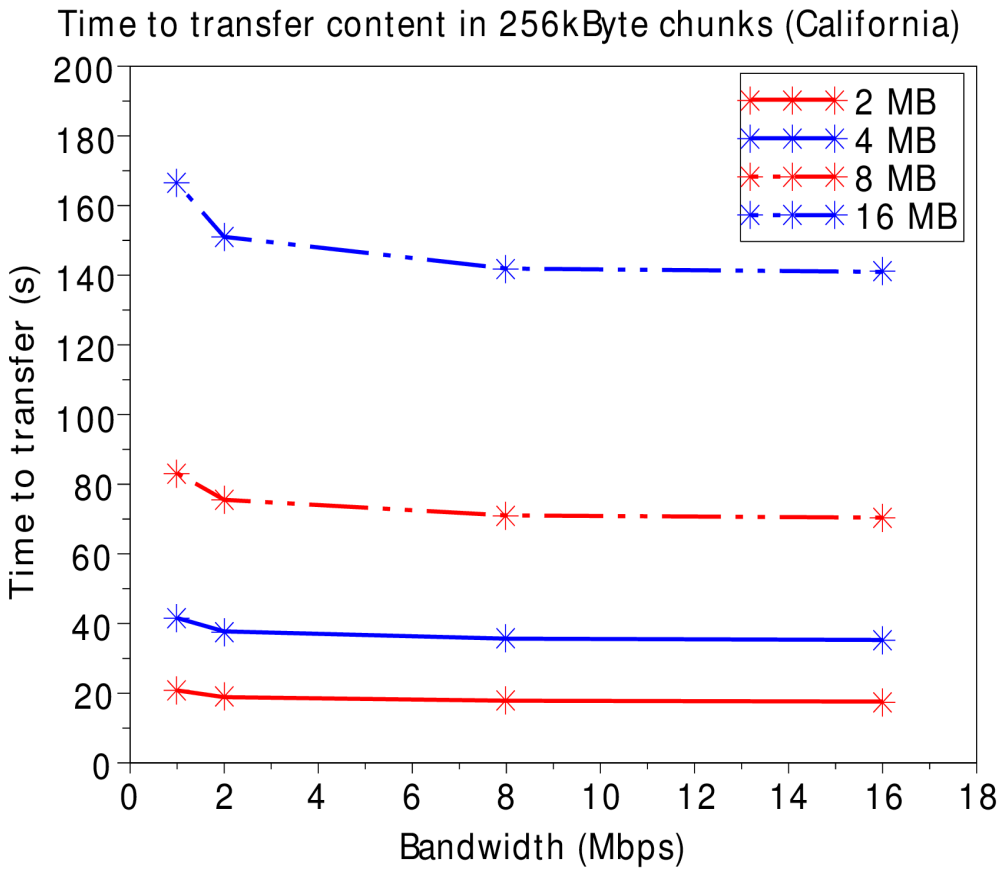


Latency, and data in smaller chunks

Consider locating remote data storage in Australia vs the west coast USA





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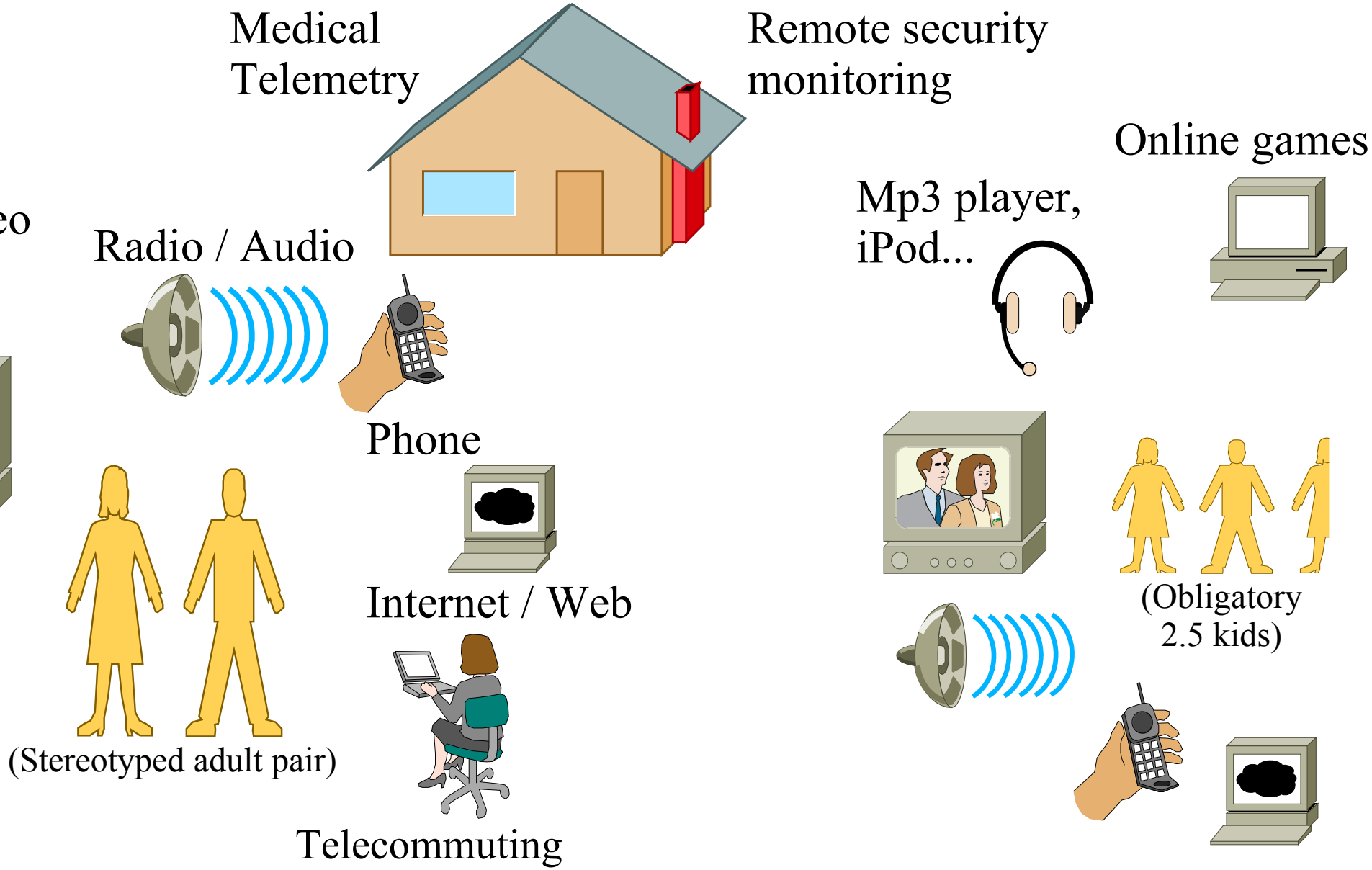
What dictates our need for bandwidth?

What are people doing in their homes?



Pressures on consumer demand

- Upward pressure
  - Desire
  - Convenience
  - Capability
- Downward pressure
  - Financial costs
  - Availability / (in)convenience
  - Ability to consume

Creation, delivery and presentation

- Creation:
  - Audio/video from live action, Studio-based TV, retrieval from DVD / HD storage, game servers

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- Presentation:
  - Media players, TV, Hi-Fi Stereo systems, iPods, mp3 players, online games, on-screen chat room interfaces, news websites, etc

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- Creation and presentation occur at the network 'edges'
- Delivery is where network resources are consumed
- Bandwidth requirements during delivery depend on the temporal relationship between creation and presentation

Further decoupling of each step

- Creation ► immediate or delayed delivery
  - Real-time streaming (immediate delivery)
  - Participatory virtual game worlds (immediate delivery)
  - Retrieve-on-demand, such as VoD or common web surfing (delayed delivery)

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  - Participatory virtual game worlds (immediate delivery)
  - Retrieve-on-demand, such as VoD or common web surfing (delayed delivery)
- Delivery ► immediate or delayed presentation
  - Real-time streaming or watching 'on demand' content (immediate presentation)
  - Participatory virtual game worlds (immediate presentation)
  - Download into (optionally portable) device for later use (delayed presentation)

Or more succinctly...

- *Delivery* may be required at:

  Faster than, at or slower than real-time

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  Faster than, at or slower than real-time

- 'Faster than' can imply *any* attainable speed...
  - Pragmatically it will be bounded by available technology and a consumer's personal cost-benefit trade off

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- 'Faster than' can imply *any* attainable speed...
  - Pragmatically it will be bounded by available technology and a consumer's personal cost-benefit trade off

- The last two are bounded by content encoding and a person's ability to consume the presentation
  - Let's consider these in more detail....

What can a typical home *consume?*

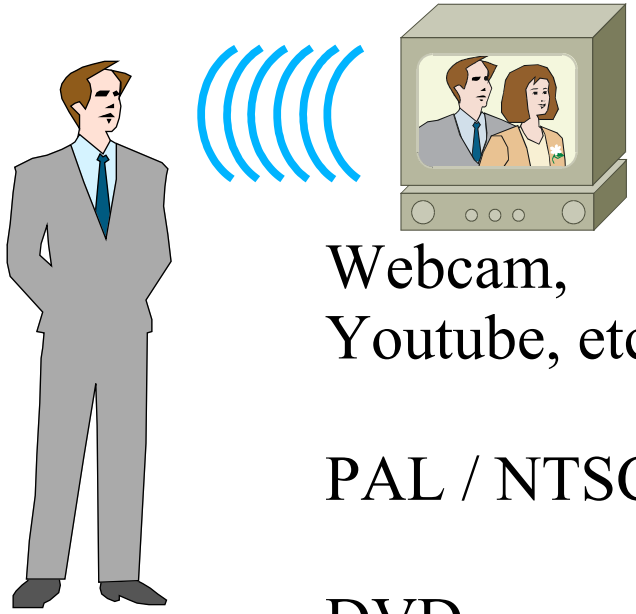
- 'Slower than' is less than or equal to 'at real-time'
- Just how much content can a home consume at real-time?

What can a typical home *consume?*

- 'Slower than' is upper-bounded to 'at real-time'
- Just how much content can a home consume at real-time?
- Constraints include:
  - Number of occupants
  - Number of rooms
  - Concurrent visual media consumption
  - Concurrent audio media consumption
  - Concurrent telemetry, immersive 'game' participation, etc

A person consuming visual content

- Not an unbounded system
  - We tolerate various sizes and quality (vs cost or convenience)
- Visual resolution limits
  - Ability to resolve pixels
  - Screen sizes limit the required resolution
  - Home theater screens in *typical* homes are bounded by possible seating arrangements



Webcam, Youtube, etc

PAL / NTSC

DVD

High Def

Home Theater

Some visual limits

- Bandwidth of a human eye-brain connection ... ~10Mbit/sec

  Koch et al., "How Much the Eye Tells the Brain", Current Biology 16, pp.1428-1434, July 25 2006

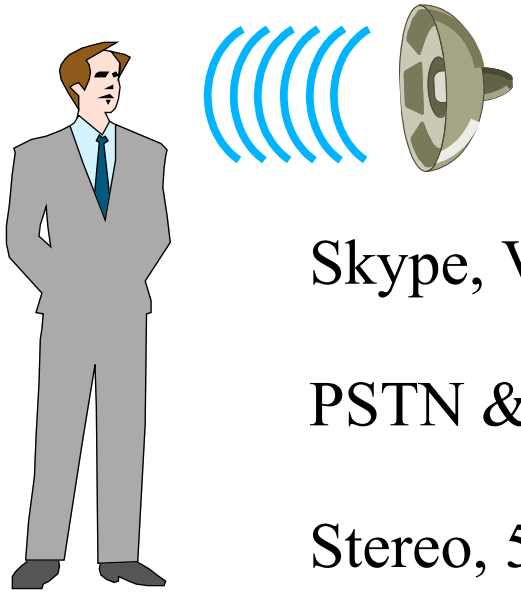
- Optimal viewing distance for current HD content (at 1888x1080) is ~3 to 4 times the height of the screen
  - “HDTV displays: How good do they need to be?” 24 May 2004. http://broadcastengineering.com/hdtv-displays/

Video on Demand / Streaming

- Consumed in real-time, and no need to deliver faster than it is consumed
  - If you need it now then download in real time, if you need it later then we download at ≤ real time
- Compression is common and improving:
  - E.g. Apple's H.264 literature claims: 1-2Mbps for 640x480@24fps, 5-6Mbps for 1280x720@24fps and 7-8Mbps for 1920x1080@24fps
    - http://www.apple.com/quicktime/technologies/h264/ (24jun07)
- Perhaps 3 concurrent HD channels? < 30 Mbit/sec
  - Or perhaps 3 concurrent regular TV channels and some 'youtube'-style video? < 10 Mbit/sec

A person consuming audio content

- Not an unbounded system
  - We tolerate various levels of quality and 3D immersion (vs cost or convenience)
- Spatial and frequency resolution limits of hearing
  - How many channels?
  - In how many rooms?



Skype, VoIP, etc

PSTN & mobiles

Stereo, 5.1, 7.1, ...

Home Theater

Streaming audio

- Consumed in real-time, and no need to deliver faster than it is consumed
  - If you need it now then download in real time, if you need it later then we download slower than real time
- Under 0.5 Mbit/sec for ridiculously good quality
  - Large market happy with CD-quality @ 128Kbit/sec
    - (smaller markets of audiophiles notwithstanding)
- Perhaps 5 concurrent channels? -> 2.5 Mbit/sec

Voice and Games

- Voice over IP / Telephony
  - Primary requirement is low loss/latency
  - Worst case ~100kbit/sec per active call
  - perhaps 4 concurrent calls? -> 400kbit/sec

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  - perhaps 4 concurrent calls? -> 400kbit/sec
- Online games
  - During periods of activity the multiplayer games typically aim for well under 100kbit/sec per player
  - During game update (non-playing) periods perhaps one or two megabit/sec is desirable, but 100-300kbit/sec tolerable
  - Perhaps 4 concurrent players? -> 400 to 1200kbit/sec

Email and File Sharing

- Email
  - Fast as possible, but we tolerate 10s of seconds delay
  - e.g. 5 Mbyte email in 30 secs (1.3 Mbit/sec) is okay
  - Allow extra, so perhaps 4 Mbit/sec per user and 2 concurrent emails at any given time -> 8 Mbit/sec

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- File sharing
  - Fast is good, but tolerate 1000s of seconds delay
  - e.g. 400 Mbyte file in 30min (1.8 Mbit/sec) is okay?
  - So perhaps 4 Mbit/sec per user and 4 concurrent full-rate sharing at any one time -> 12 Mbit/sec

Web surfing and ???-casting

- Web surfing
  - Goal is to render pages 'fast', but diminishing returns
    - Does the user care about 0.1sec vs 0.3 sec render time?
    - For pages under 80Kbyte in 0.3 sec -> 2.1 Mbit/sec
    - Allowing for multiplexing of users, perhaps 5 Mbit/sec ?
      - Linked content falls under previous categories

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      - Linked content falls under previous categories
- ???-casting (podcasting, etc....)
  - Download content for later playback/consumption
    - “Need it now, am going mobile in XX minutes”
    - Genuine case for download speeds faster than rate at which the content can be consumed by human
  - Difficult to characterise realistic bandwidth need...

A modest house, perfect b/w sharing

• Voice over IP	0.4 Mbit/sec
• Online games	1.2
• Video on Demand	30
• Streaming Audio	2.5
• Email	8
• File sharing	12
• Web surfing	5

A grand total of ~60 Mbit/sec

(assuming worst-case high quality video, no guesses for pod-cast style downloads, all services in use at once)

(and yes, I'm waving my arms vigorously – approximations abound....)

My “60 Mbit/sec” estimate assumes each class of application has a protected slice of bandwidth

Is perfect bandwidth sharing realistic?

Is perfect bandwidth sharing realistic?

- Short answer: No
  - File transfers, sync'ing of phones, etc collide with online games and voice/video at your home gateway...

http://img.caixin.com/2013-02-18/1361180890900859_840_560.jpg

So, bump up the speed estimate

- Provide > 60Mbit/sec ?
  - Previous estimate up by factor of 5-6? -> 360+Mbit/sec
- Opportunistic data-/file-transfer traffic flows can still cause transient starvation of capacity to other apps
  - But the impacts will be of much shorter duration
- Or traffic sharing technology in home gateways
  - (“quality of service”, QoS)
    - Well beyond scope of this talk / difficult in consumer products

How much for 'Faster than real-time'?

- A difficult category to predict
- Download content into portable device, quickly, so delayed presentation (playback) can occur while disconnected from the network
  - e.g. Podcasts, personal CD collection, ...
  - Download size bounded by presentation medium

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- A difficult category to predict
- Download content into portable device, quickly, so delayed presentation (playback) can occur while disconnected from the network
  - e.g. Podcasts, personal CD collection, ...
  - Download size bounded by presentation medium
- What is this worth to a customer?
  - ~1.5Mbit/sec to load 6Hrs of 128bit/sec audio in 30min
  - ~15Mbit/sec to load 6Hrs of 128bit/sec audio in 3min
  - What would customer pay for higher-speed physical layer just so they can burst for 3 – 30min once or twice a day?

What *could* I do with 20:1 Mbit/sec ?

- 20 down and 1 up is plausible with ADSL2+
  - IF we had perfect bandwidth protection between classes of IP traffic, we *might* provide:
    - 4 concurrent SD TV channels (H.264) (10 Mbit/sec down)
    - 2 concurrent 'radio' stations and 2 high quality streaming audio stations (1.5Mbit/sec down)
    - 2 concurrent VoIP calls (0.2Mbit/sec up/down)
    - 2 concurrent online game players (0.2 Mbit/sec up/down)
    - ~8Mbit/sec down and 0.6Mbit/sec up for other elastic, non-realtime applications (email, web, etc...)

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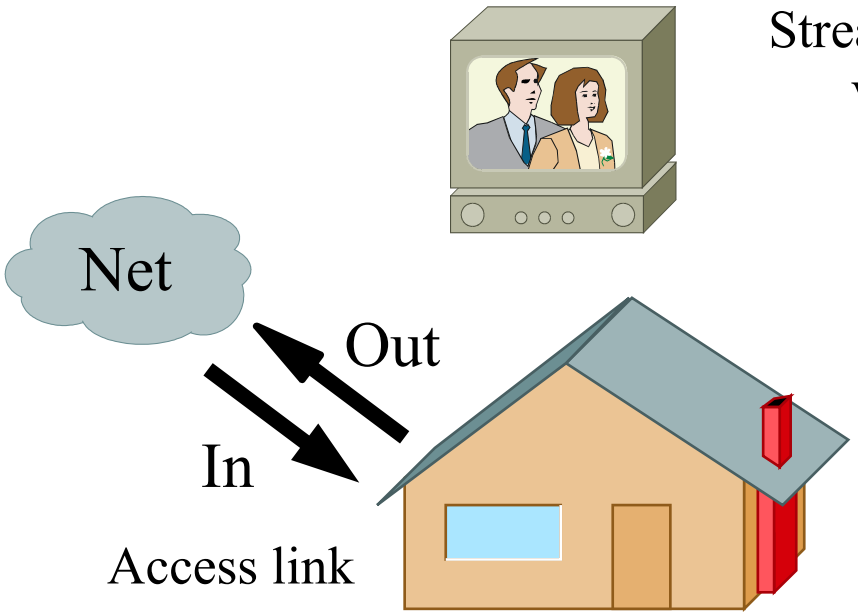
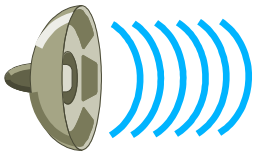
    - 2 concurrent online game players (0.2 Mbit/sec up/down)
    - ~8Mbit/sec down and 0.6Mbit/sec up for other elastic, non-realtime applications (email, web, etc...)
  - But <u>practical</u> bandwidth protection doesn't exist....
  - And home users need to *push* (video calls, upload their latest creations to YouTube, etc), so “1 up” isn't enough

A very rough, ball-park conclusion....

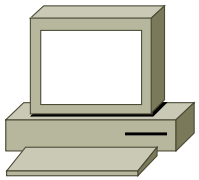
A *typical home* needs more like 60Mbit/sec inbound and 5 - 15 Mbit/sec outbound (using today's guesses)



Streaming/on-demand video: 30in/0.1out

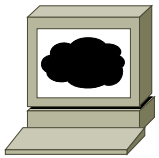


Streaming audio: 1.2in/0.1out



Online games: 1.2in/1.2out

Telephony: 0.4in/0.4out



Email, file sharing, web surfing, video conferencing: 25in/10out

("in" and "out" speeds in Mbit/sec)

Questions...