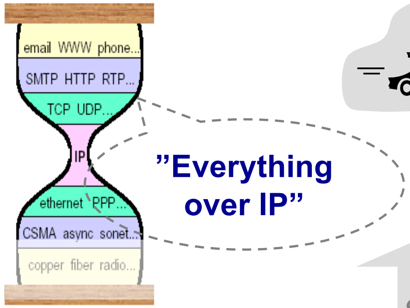
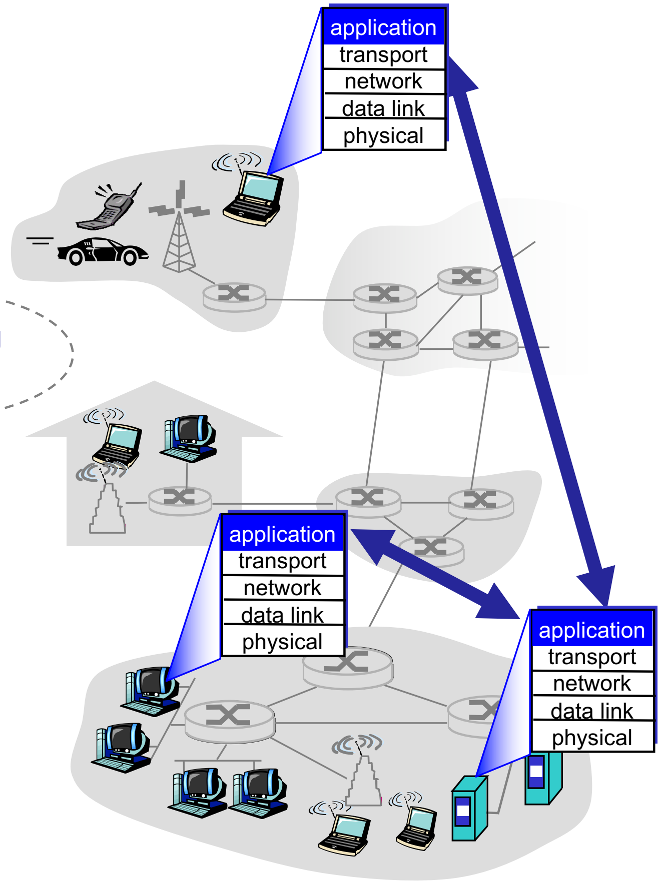
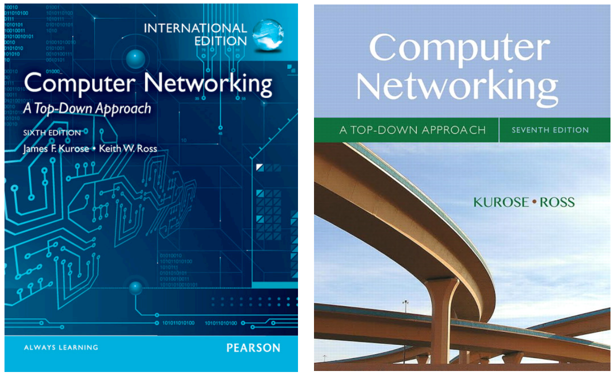
Multimedia networking

Chapter 7 (6ed) / 9 +2.6 (7ed)

Kjersti Moldeklev, Prof II
Department of Information Security and Communication Technology
kjersti.moldeklev@ntnu.no







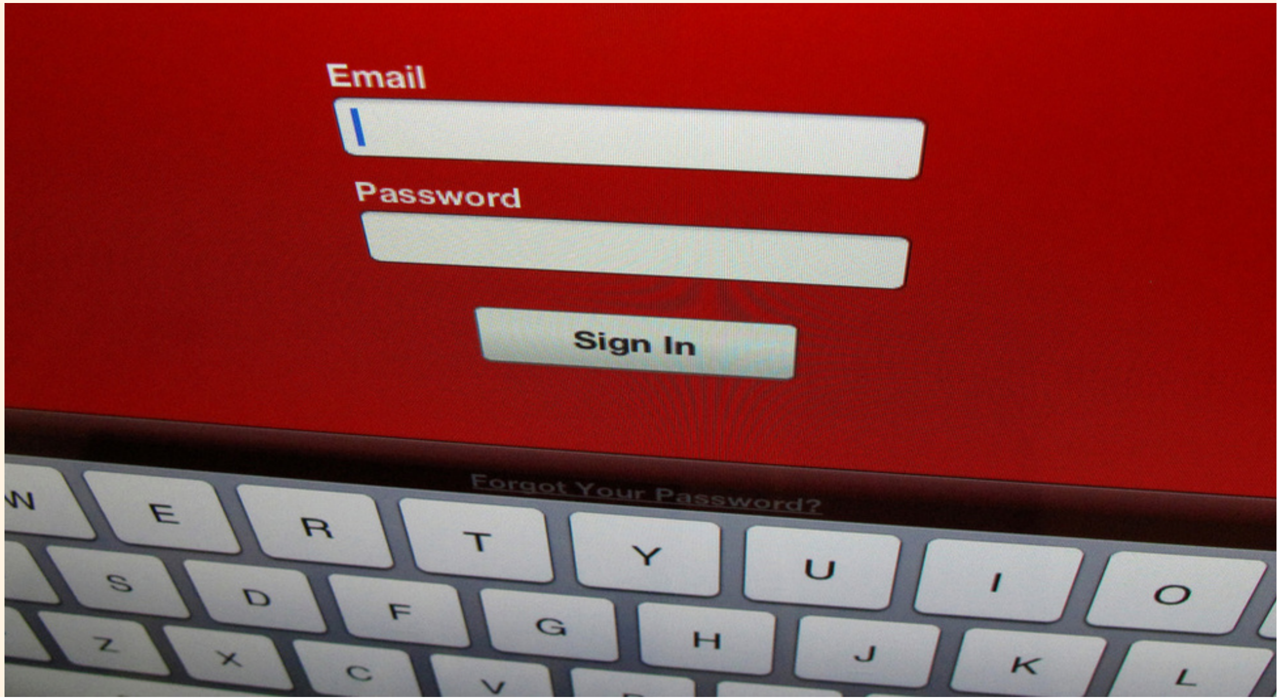
The content of many of these slides are based on slides available from the web-site of the book by J.F Kurose and K.W. Ross.

Flere foretrekker Netflix enn NRKs nett-TV

46 prosent at dem som bruker strømmetjenester minst én gang i måneden, mener Netflix er den beste tjenesten. 19 prosent foretrekker NRKs nett-TV.

NTB

(NTB) Publisert: **05:22 - 10.03.2017**, Oppdatert: **05:22 - 10.03.2017**



8 prosent liker TV 2 Sumo best, mens 7 prosent foretrekker HBO Nordic. Tallene kommer fra NRKs årlige profilundersøkelse og omtales i Dagens Næringsliv.

Andre resultater er mer positive for statskanalen: Publikum mener at NRK er suverent best på norsk innhold, og undersøkelsen viser også at sju av ti mener de får valuta for lisenspengene.

NRK forbereder seg på økt konkurranse fra Netflix når det gjelder norsk innhold, men håper også på mer samarbeid – selv om det endte med konflikt da NRK og Netflix samarbeidet om «Lilyhammer».

Multimedia networking, March 16 and 17

11	Thursday 12:15 – 14:00 Thursday 14:15 – 15:00	Multimedia Networking Theory Assignment 6: *Wireless and Mobile Networks*	R1 R1	Kjersti Assistants/ Ida/Norvald	Chapter 7 One must deliver and pass at least 5 of the 8 theory assignments.
11	Friday 09:15 – 11:00	Multimedia Networking (cont)	R1	Kjersti	Chapter 7
12	**NOTE:**	**No lecture from textbook in week 12 or 13.**			
12	Thursday 14:15 – 15:00	Theory Assignment 7: *Multimedia networking*	R1	Assistants/ Ida/Norvald	One must deliver and pass at least 5 of the 8 theory assignments.
12	**Friday 16:00**	**Deadline** for KTN2 - Project implementation		Assistants/ Magnus	Show project impl. to course assistants for approval, at P15.
13	Thursday 14:15 – 15:00	Theory Assignment 8: *Security in Computer Networks*	R1	Assistants/ Ida/Norvald	Tuition. One must deliver and pass at least 5 of the 8 theory assignments.

Chapter 7

Multimedia networking

Goals

- High-level understanding of
  - Audio and video content representation
  - Protocols and architectures for providing multimedia content ”over IP” and adapting to network conditions/performance
    - Adaptive streaming
    - Content Distribution Networks
    - Real-time conversational applications – Voice over IP






Multimedia networking: Roadmap

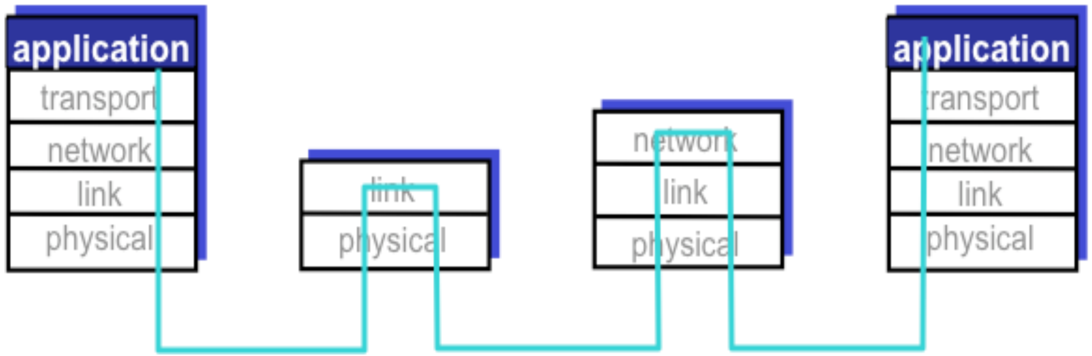
7.1 (9.1 + 2.6)
Multimedia networking applications

7.2 (9.2)
Streaming stored video

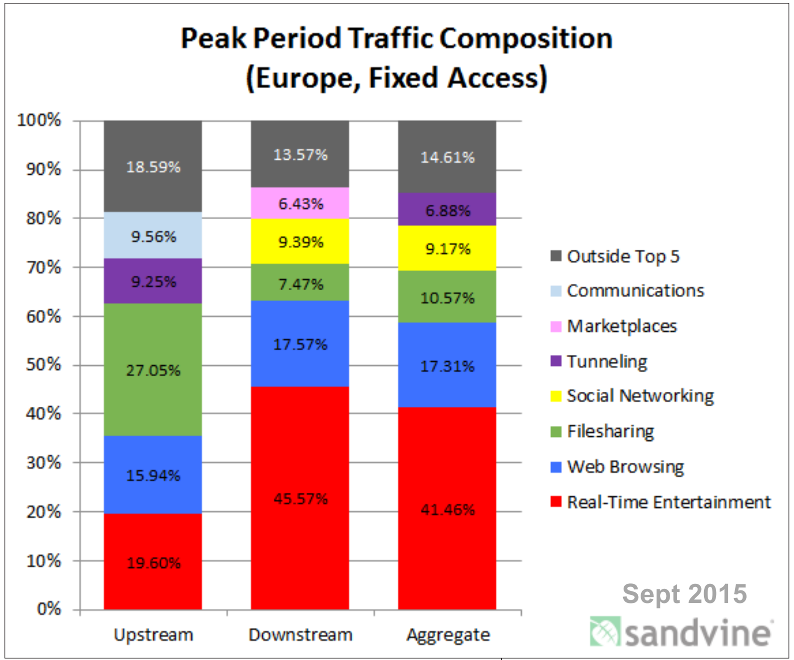
7.3 (9.3)
Voice over IP

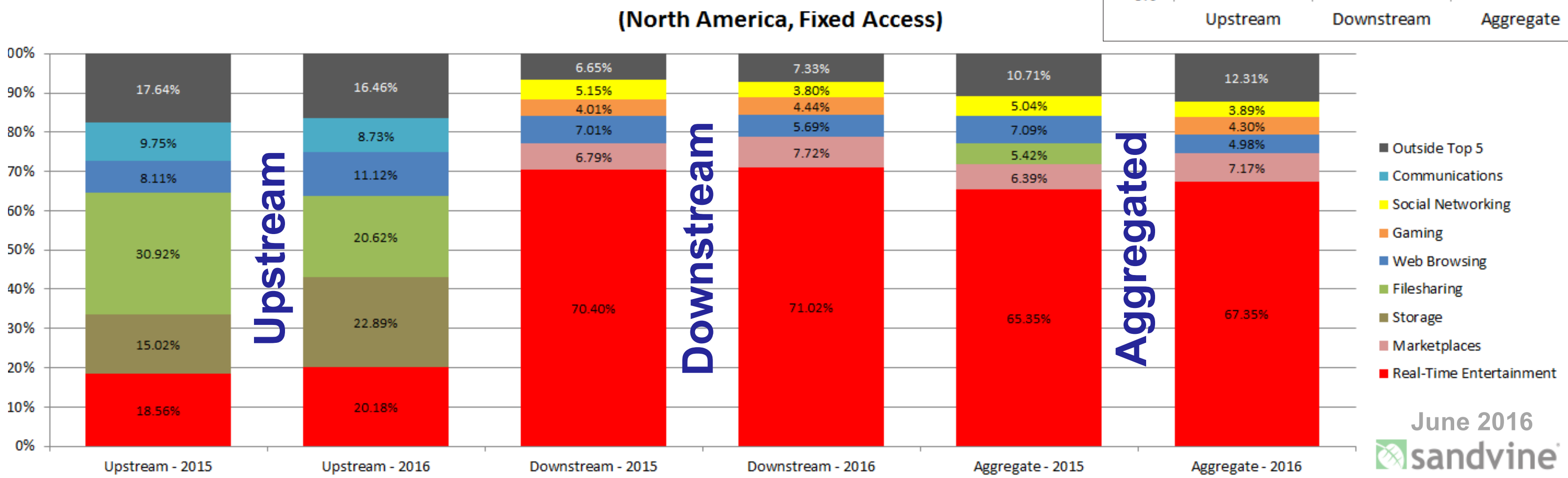
Source: Shutterstock

5-layer internet protocol stack



Video applications dominates the internet traffic volume





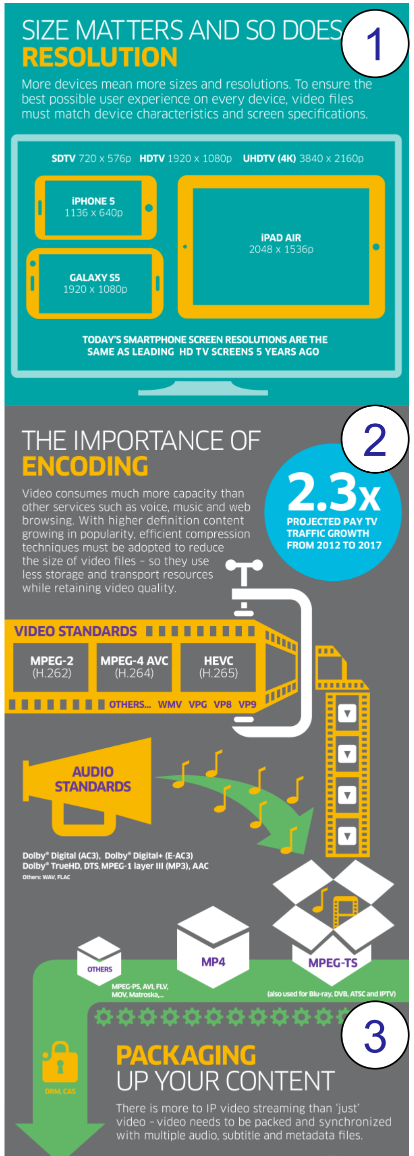
Top 10 peak period applications - US

Upstream		Downstream		Aggregate	
BitTorrent	18.37%	Netflix	35.15%	Netflix	32.72%
YouTube	13.13%	YouTube	17.53%	YouTube	17.31%
Netflix	10.33%	Amazon Video	4.26%	HTTP - OTHER	4.14%
SSL - OTHER	8.55%	HTTP - OTHER	4.19%	Amazon Video	3.96%
Google Cloud	6.98%	iTunes	2.91%	SSL - OTHER	3.12%
iCloud	5.98%	Hulu	2.68%	BitTorrent	2.85%
HTTP - OTHER	3.70%	SSL - OTHER	2.53%	iTunes	2.67%
Facebook	3.04%	Xbox One Games Download	2.18%	Hulu	2.47%
FaceTime	2.50%	Facebook	1.89%	Xbox One Games Download	2.15%
Skype	1.75%	BitTorrent	1.73%	Facebook	2.01%
	69.32%		74.33%		72.72%

sandvine

June 2016

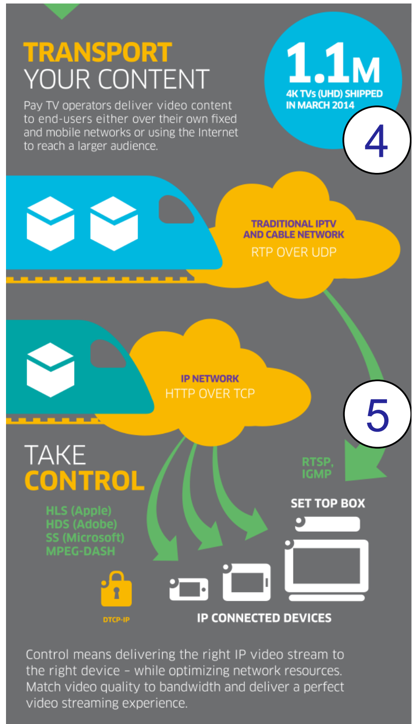
Table 1 - Top 10 Peak Period Applications - North America, Fixed Access



Video streaming to an end user device

1. Video frame **size and resolution**
2. **Encoding** and **compression** of audio and video
3. **Packaging** and **synchronization** of audio, video, subtitle and metadata
4. **Transport** of data over IP
5. **Control** of data flow towards receiver

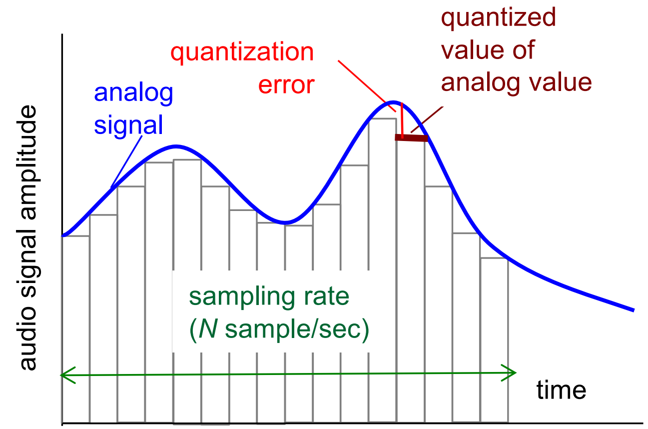
https://www.alcatel-lucent.com/solutions/video-streaming-infographic

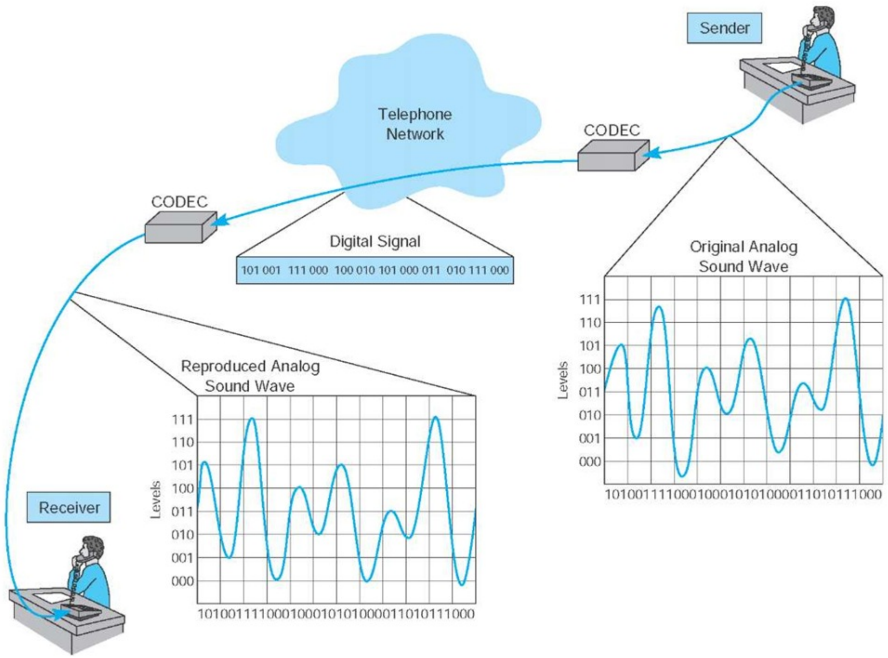


NTNU

Audio digitization and compression

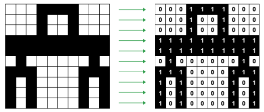
- **PCM Pulse Code Modulation**
  - Analog signal sampled at sender
    - telephone: 8 000 samples/s
  - Quantized samples
    - 8 bits: 2^8=256 possible quantized values
  - 8 000 samples/sec, 256 quantized values --> 64 000 bps
- Receiver converts bits back to analog signal
  - some quality reduction
- Example rates
  - GSM 13 kbps
  - CD 44100 samples/s, 2^{32} values → 1 411 Mbps
  - MP3 96, 128, 160, 320 kbps
  - Internet telephony 5,3 kbps and up



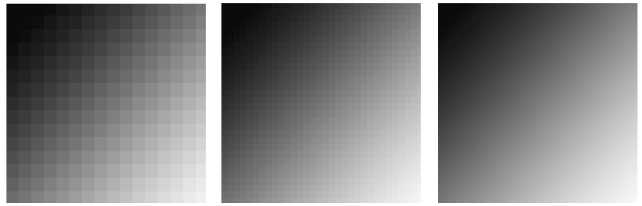


High quality images require more bytes to be transmitted

- Digital image: arrays of pixels
  - Pixel is smallest element in an image



- Bits per pixel
  - Color depth gives number of colors



- Image resolution in pixels
  - Number of pixels in image
  - Image quality: must know “pixel per inch

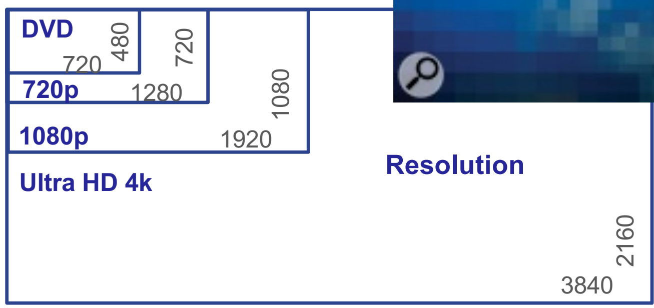
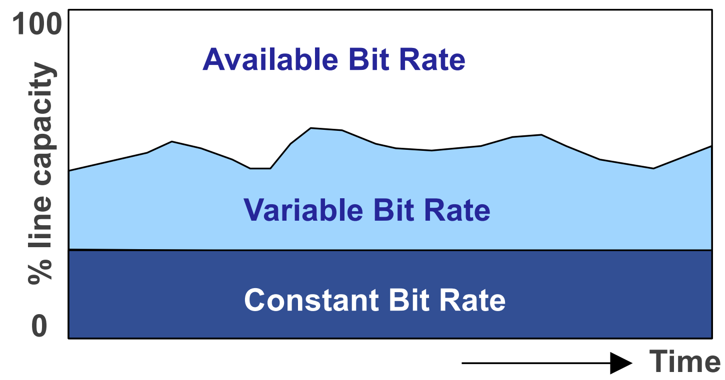


Image size =
(pixel resolution) * (bits per pixel)

Video compression exploits redundancy

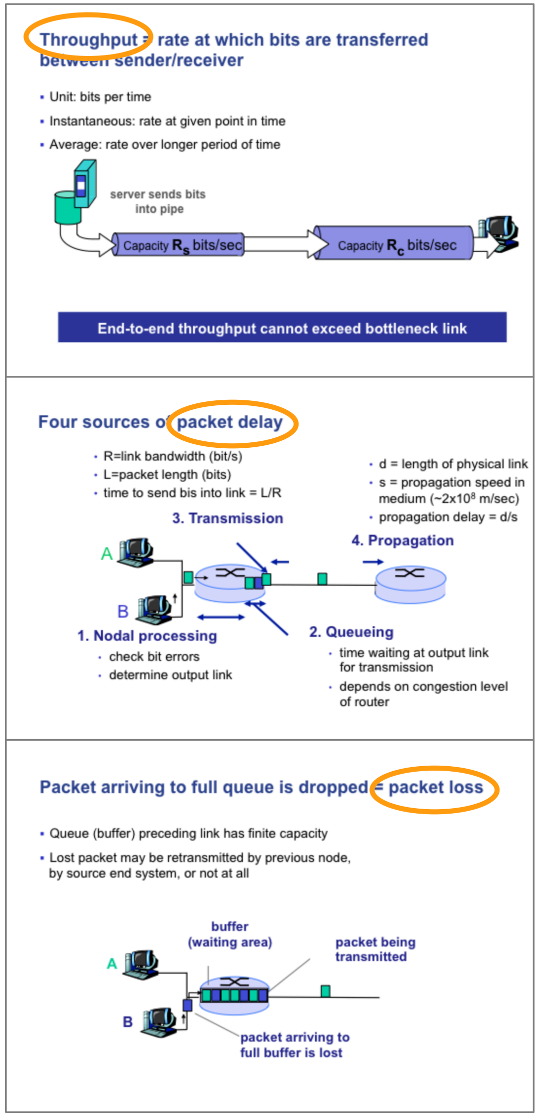
- Video: sequence of images displayed
  - **CBR: (constant bit rate):** video encoding rate fixed
  - **VBR: (variable bit rate):** video encoding rate changes as amount of spatial, temporal coding changes
- **Redundancy**
  - **spatial** (within image)
  - **temporal** (from one image to next – between images)
- Examples
  - MPEG1 (CD-ROM) 1.5 Mbps
  - MPEG2 (DVD) 3-6 Mbps
  - MPEG4 (often used in Internet, < 1 Mbps)



Multimedia application performance requirements

- Typically delay sensitive
  - **end-to-end delay**
  - **delay jitter**: variability of packet delays within the same packet stream
- **Loss tolerant**: infrequent losses cause minor glitches
- **Bandwidth** need **depends on stream**

Multimedia is antithesis of data, which are loss intolerant but delay tolerant



Hvor mye data trenger jeg?

Mobilt Bredbånd XS

1 gigabyte er cirka:

- 2560 Facebook-sider, eller
- 1700 VG-sider, eller
- 150 minutter streaming av VG-tv, eller
- 50 minutter streaming av NRK web-tv, eller
- 25 minutter streaming av Netflix, eller
- 530 minutter streaming av musikk

Mobilt Bredbånd XS passer for deg som surfer litt, lese nyheter, sjekke Facebook eller e-post.
Mobilt Bredbånd XS støtter ikke 4G-hastigheter.

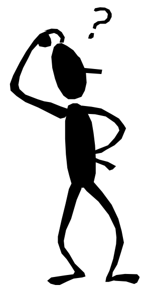
http://www.telenor.no/privat/kundeservice/mobiltbredband/datatrafikk_mbb.jsp

Datamengde	Dette kan du gjøre hver dag:
7 GB	Surfe 1 time på Facebook & andre nettsider Lese / sende 30 e-post Streame musikk 45 min Streame video / TV 10 min
15 GB	Surfe 1,5 time på Facebook & andre nettsider Lese / sende 30 e-post Streame musikk 1 time Streame video / TV 30 min
30 GB	Surfe 1,5 time på Facebook & Lese / sende 30 e-post Streame musikk 1 time Streame video / TV 30 min Streame HD-film 15 min
50 GB	Surfe 1,5 timer på Facebook & Lese / sende 30 e-post Streame musikk 1 time Streame video / TV 45 min Streame HD-film 30 min
100 GB	Surfe 3 timer på Facebook & a Lese / sende 30 e-post Streame musikk 2 timer Streame video / TV 1,5 time Streame HD-film 1 time
200 GB	Surfe 3 timer på Facebook & andre nettsider Lese / sende 30 e-post Streame musikk 2,5 timer Streame video / TV 2 timer Streame HD-film 2,5 timer

https://netcom.no/kundeservice/mobilt-bredband/gigabyte
https://netcom.no/privat/mobilt-bredband

Mars 2016

Multimedia over today's Internet



TCP/UDP/IP: "best-effort service"

- *no* guarantees on delay, loss

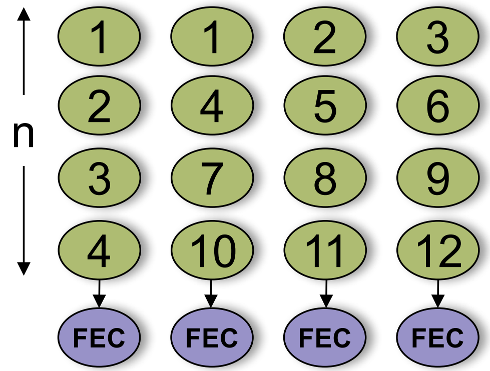
Today's Internet multimedia applications use application-level techniques to mitigate (as best possible) effects of delay and loss over the open Internet

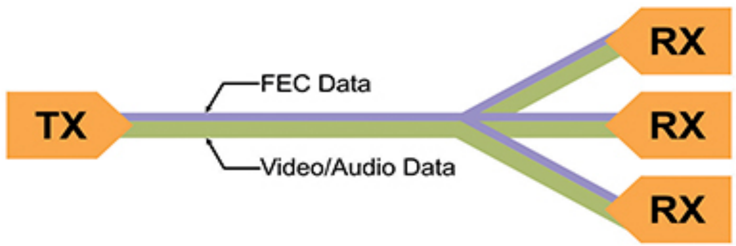
- **Higher (access) bandwidth** when needed
- **Application-level streaming techniques**
  - (Adaptive) play-out to remove jitter at the receiver client-side buffering
  - TCP versus UDP
  - Multiple encodings of multimedia – adaptive streaming
- **Content distribution networks** bring the content closer to the users
- Recovery from packet loss
  - **FEC –** Forward error correction
  - **Interleaving**

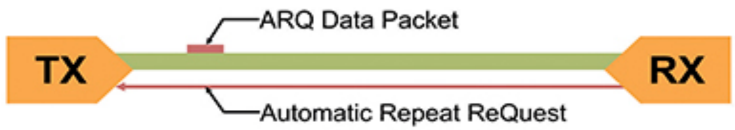
Application level recovery from packet loss

Simple forward error correction (FEC)

- For every group of n chunks create redundant chunk by XOR-ing n original chunks
- Send out n+1 chunks –> increase bandwidth need by 1/n
- From n+1 chunks can reconstruct original n chunks if at most one lost chunk
- Play-out delay: enough time to receive all n+1 packets
- Tradeoff with increasing n
  - less bandwidth waste
  - longer play-out delay
  - higher probability that 2 or more chunks will be lost





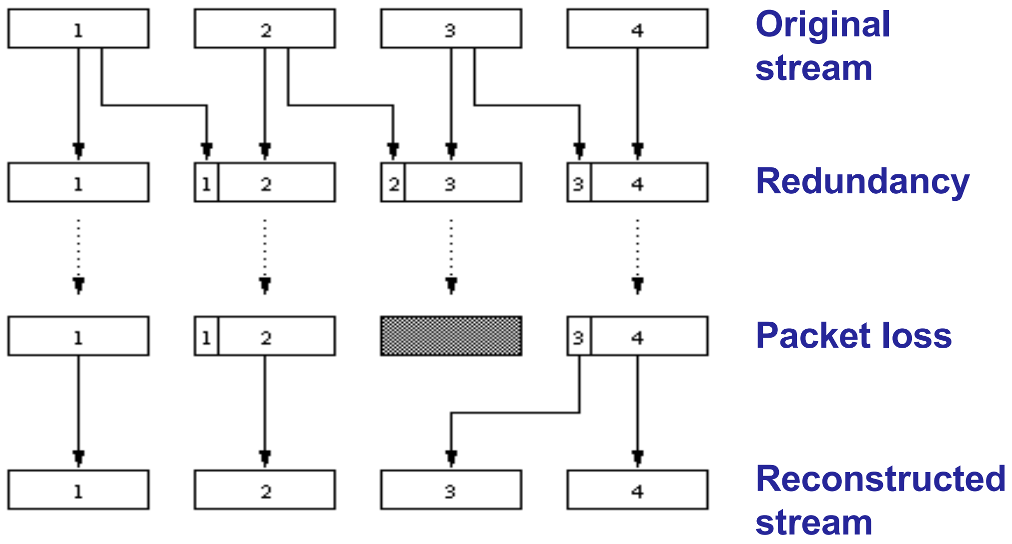


Source_ http://www.tvtechnology.com/it-&-networking/0151/the-question-to-fec-or-not-to-fec/221091

Application level recovery from packet loss

FEC by piggybacking a lower quality stream

- Send lower resolution audio stream as redundant information
- E.g. nominal stream PCM at 64 kbps and redundant stream GSM at 13 kbps

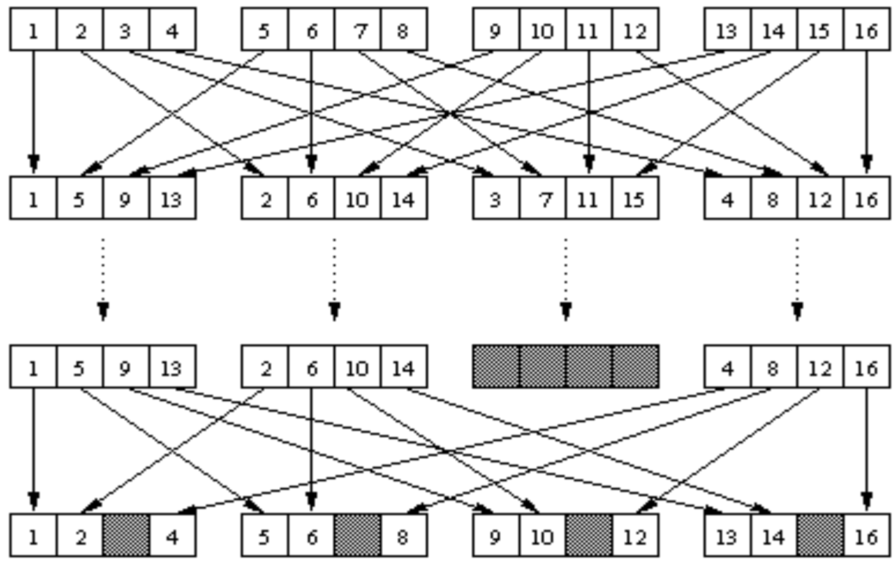


Whenever there is non-consecutive loss, receiver can conceal the loss

Interleaving to conceal packet loss

- Chunks divided into smaller units, e.g. four 5 ms units per chunk
- Packet contains small units from different chunks
- If packet lost, still have most of every chunk

No redundancy overhead, but increases play-out delay



Multimedia networking: Roadmap

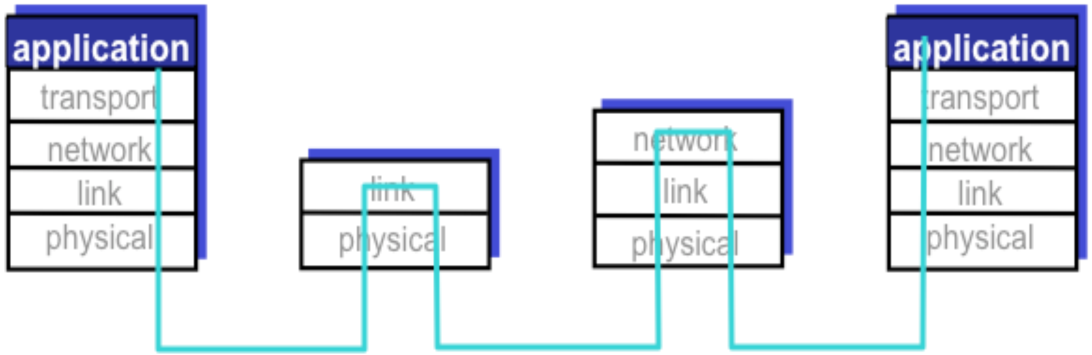
7.1 (9.1 + 2.6)
Multimedia networking applications

7.2 (9.2)
Streaming stored video

7.3 (9.3)
Voice over IP

Source: Shutterstock

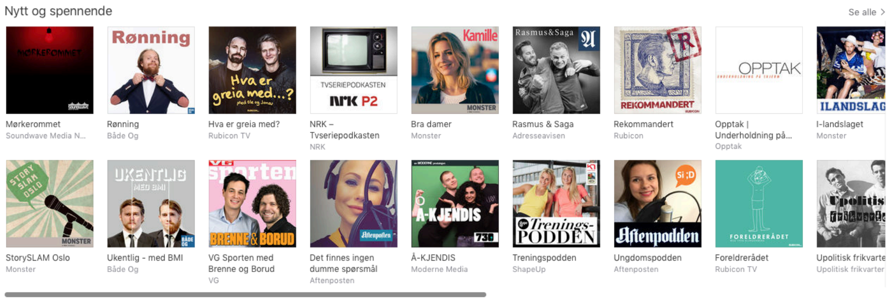
5-layer internet protocol stack



Internet multimedia applications differ in network performance requirements

Podcast – audio or video stored in file

- Files transferred as HTTP object received in entirety at client before passed to player
- No “pipelining,” long delays until play-out!

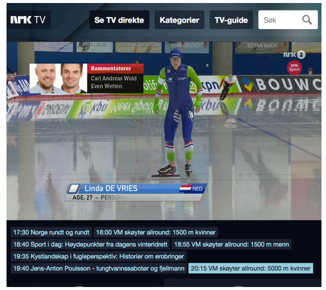


Streaming stored multi-media

- on demand download of prerecorded audio/video from servers

Streaming live audio/video –

- traditional broadcast of radio and television over Internet



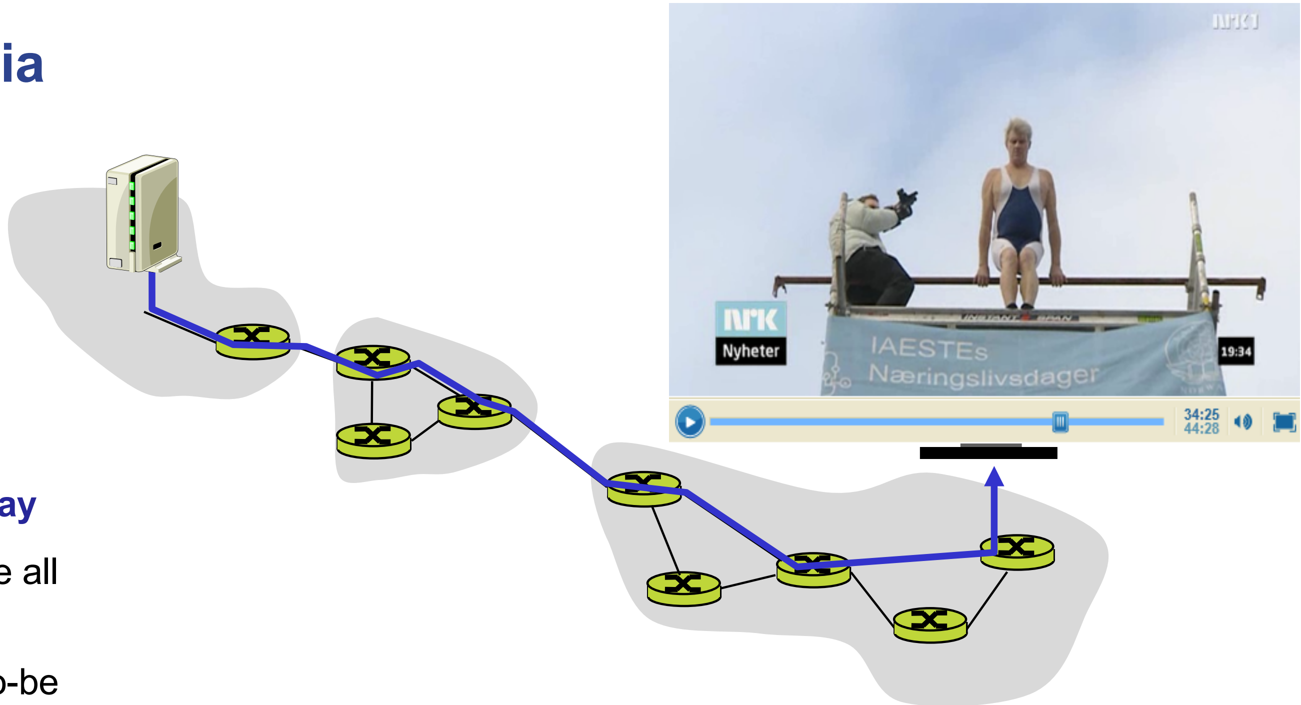
Conversational real-time voice and video

NTNU

Streaming stored multimedia

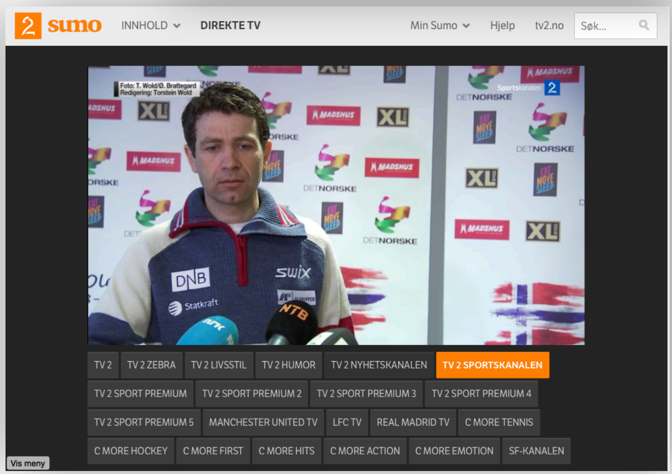
- **Recorded media** stored at servers often as part of content distribution networks (CDNs)
- Users request **on demand**

- Client side buffering – **initial buffer delay**
- **Pipelining**: client play-out begins before all data has arrived
- **Prefetching**: timing constraint for still-to-be transmitted data: in time for play-out
- **Quality adaptation** to network bandwidth availability
- Interactivity
  - fast forward rewind, pause



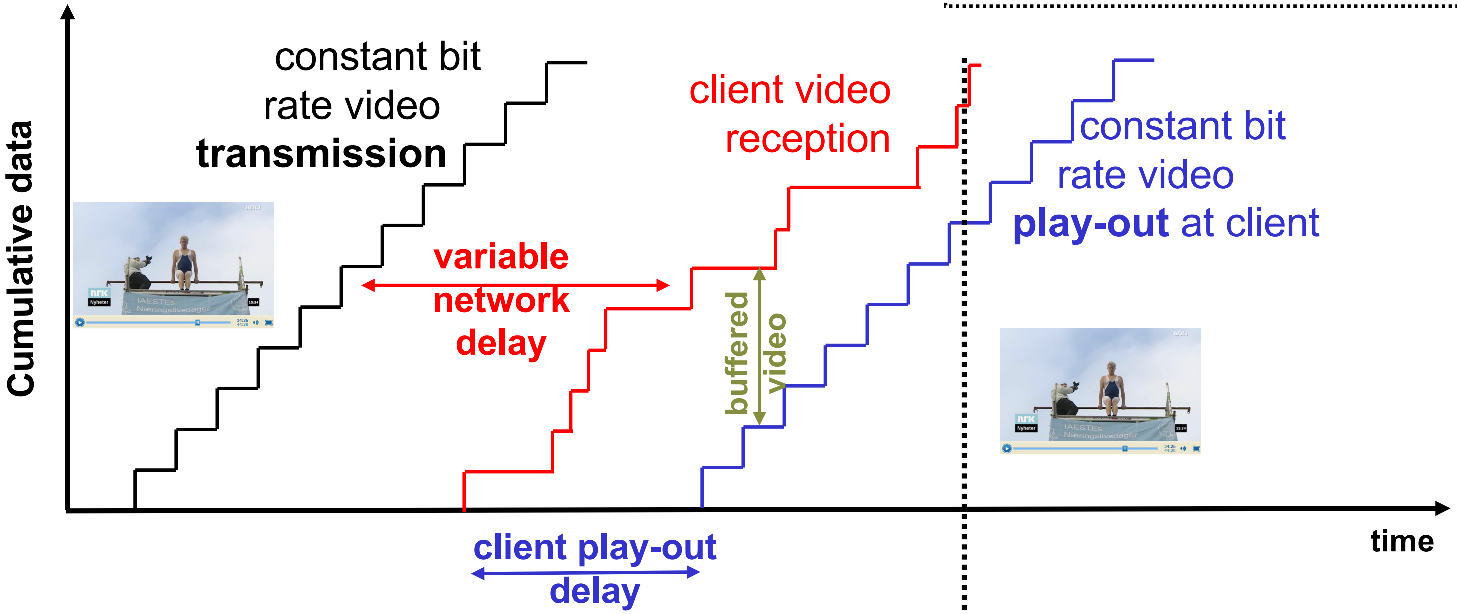
Streaming live audio and video

- Streaming **non-recorded media**
  - use of CDN (content distribution network)
- Client side **buffering**
  - playback can lag tens of seconds after transmission
- **Timing constraint**
- **Adaptive bandwidth** use
  - quality may vary dependent on network load
- Interactivity
  - fast forward impossible
  - rewind, pause possible!



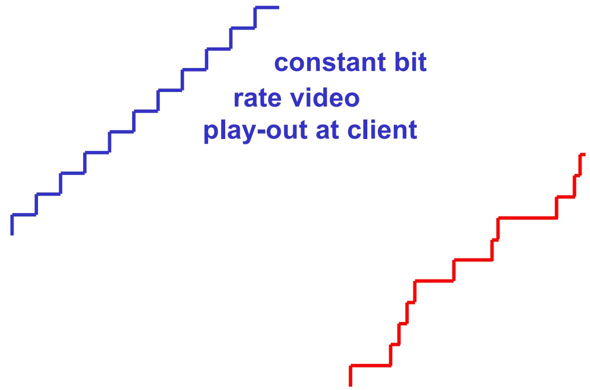
To compensate for network added jitter client buffering is used at receiver

Streaming: client is playing early part of video, while server still is sending later part of video



Streaming stored video: challenges

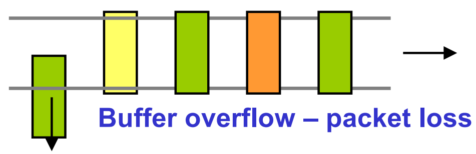
- **Continuous play-out** constraint: once client play-out begins, playback must match original timing



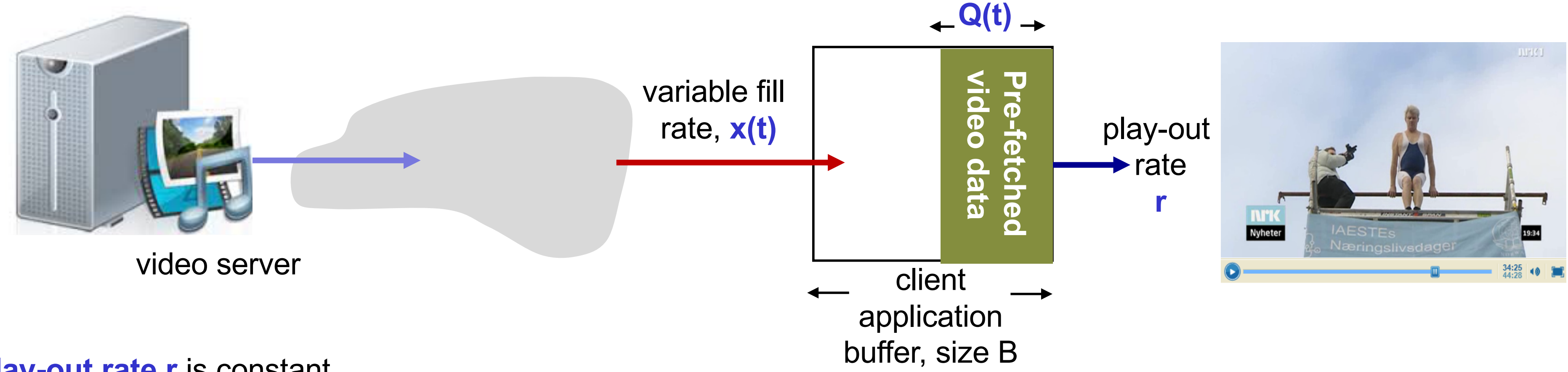
- **Network delays are variable** (jitter), so will need client-side buffer to match play-out requirements

- **Client interactivity**: pause, fast-forward, rewind, jump through video

- **Video packets may be lost** and retransmitted



Client-side buffering and play-out



- **Play-out rate r** is constant
- Initial fill of buffer until playout begins at t_p

- **Initial play-out delay tradeoff**: buffer starvation less likely with larger delay, but larger delay until user begins watching

- Buffer fill level **Q(t)** varies over time as fill rate **x(t)** varies
  - $X_{avg} < r$ buffer eventually empties, causing freezing of video play-out until buffer again fills
  - $X_{avg} >= r$ buffer will not empty, provided initial play-out delay is large enough to absorb variability in x(t)

Streaming multimedia: UDP

- Server sends at rate appropriate for client
  - often: send rate = encoding rate = constant rate
  - transmission rate can be oblivious to congestion levels
- Short play-out delay (2-5 seconds) to remove network jitter
- Error recovery: application-level, time permitting
- RTP (Real-time Transport Protocol) multimedia payload types over UDP
- UDP may not go through firewalls

Adaptive HTTP has taken over

User control of streaming media: RTSP – real-time streaming protocol

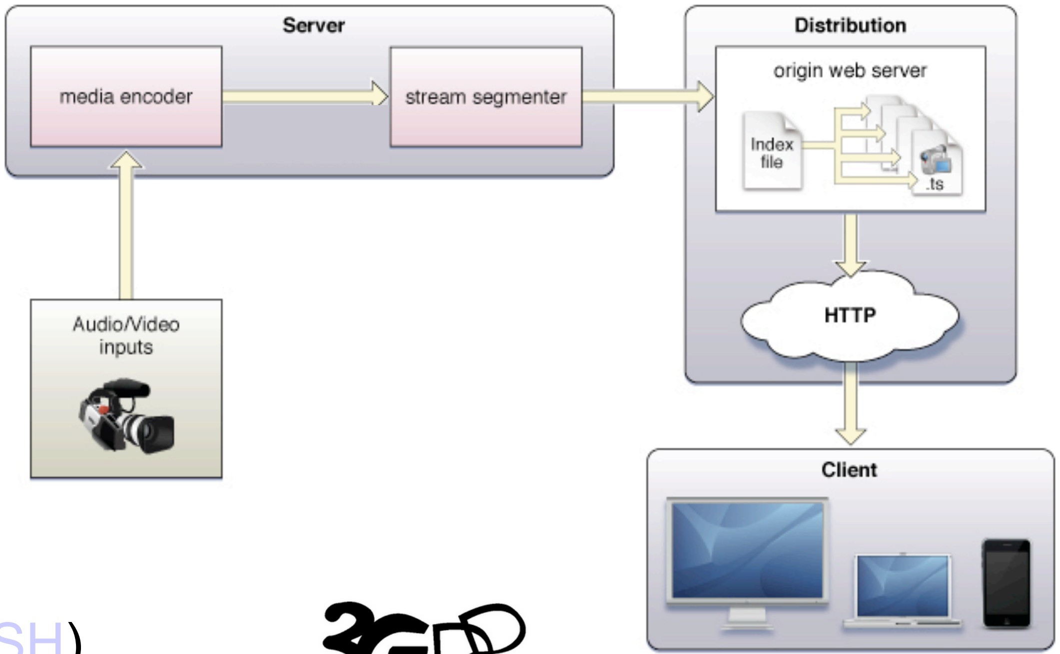
RTSP

- Client-server **application layer** protocol
- **User control**: rewind, fast forward, pause, resume, repositioning, etc…

- What RTSP doesn't do:
  - doesn't define how audio/ video is encapsulated for streaming over network
  - doesn't restrict how streamed media is transported (UDP or TCP)
  - doesn't specify how media player buffers audio/video

Rate-adaptive streaming technologies – “give the user what the user can eat”

- Adobe's **Dynamic HTTP streaming**
- Apple's HTTP **live streaming**
- Microsoft's **smooth streaming**
- **Adaptive HTTP streaming** (AHS)
- Open IPTV forum's **HTTP adaptive streaming**

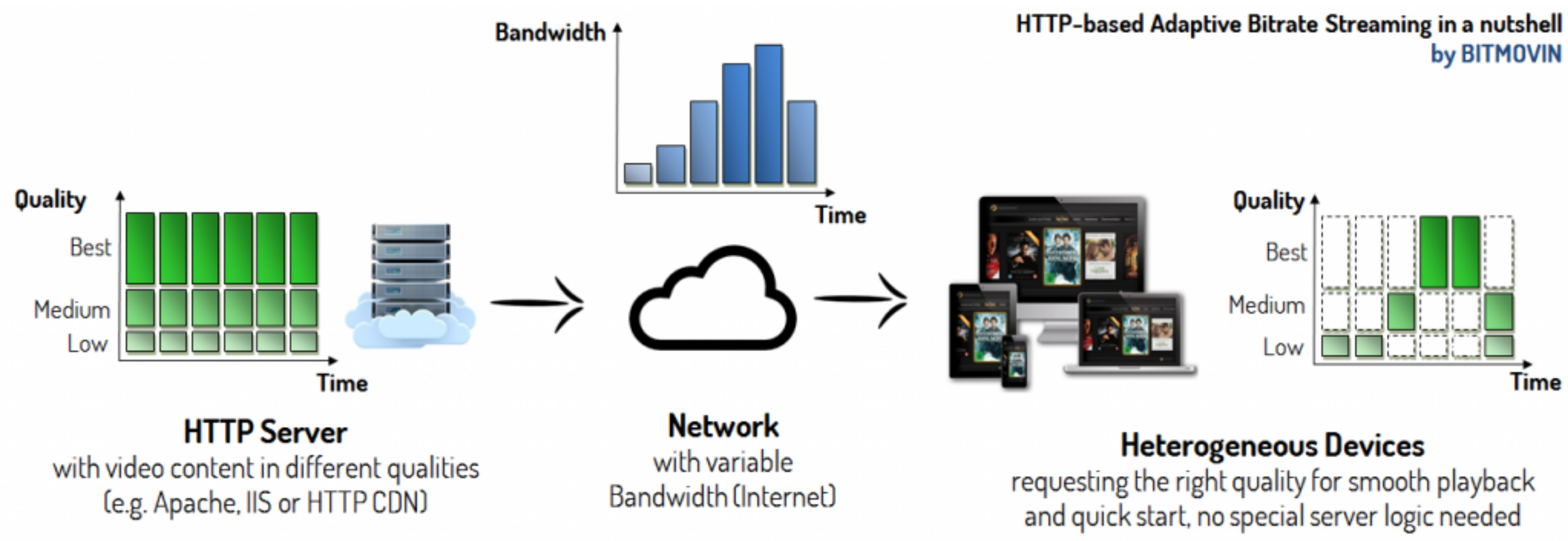


- **Dynamic Adaptive Streaming over HTTP** (DASH)
  - MPEG DASH ISO/IEC 23009-1:2012

mpeg-DASH

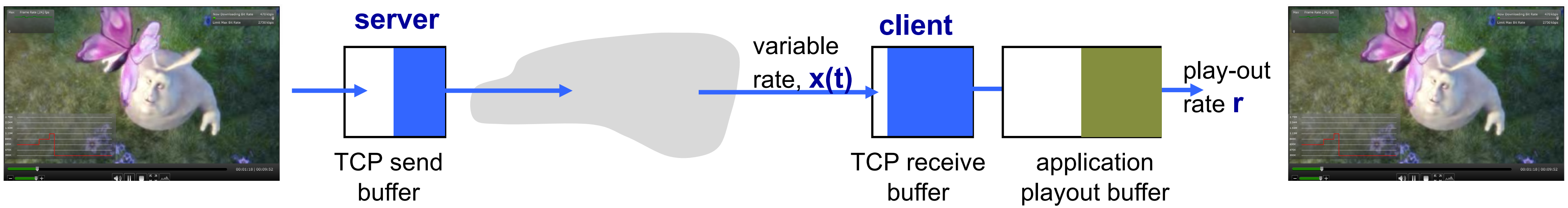
A GLOBAL INITIATIVE

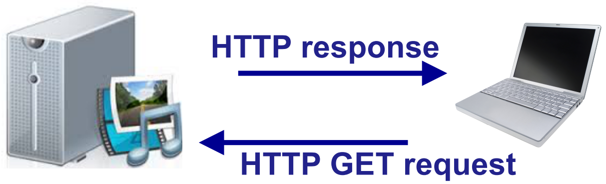
Dynamic Adaptive HTTP Streaming (DASH)



Source: https://www.bitcodin.com/blog/2015/04/mpeg-dash/

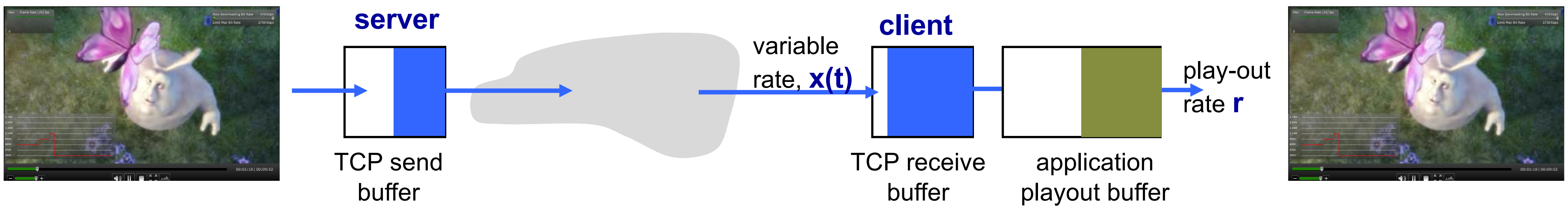
Streaming multimedia using HTTP over TCP





- **Multimedia file retrieved via HTTP GET**
  - can reuse widely deployed standard HTTP servers/caches for scalable delivery
  - traverse NAT/firewalls more easily
  - fixed-mobile convergence
- **Simple rate adaptation through TCP**
  - send at maximum possible rate under TCP
  - fill rate fluctuates due to TCP congestion control, retransmissions (in-order delivery)
  - larger play-out delay: smooth TCP delivery rate
- Enables **deployment flexibility** – live vs. stored

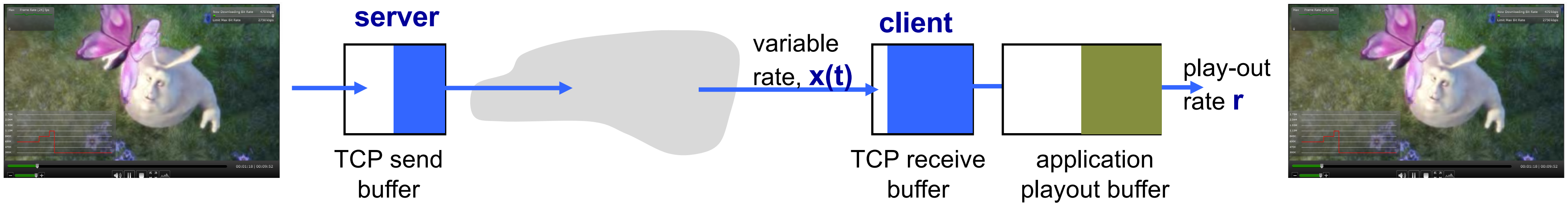
DASH - Dynamic Adaptive Streaming over HTTP



- **Encode a single source video at multiple bit rates**
  - divides video file into multiple chunks
  - each chunk stored, encoded at different rates
- **Manifest file**: a media presentation description providing URLs for different chunks
- **Periodically measure server-to-client bandwidth, adjust the quality of the video stream accordingly**
  - choose maximum coding rate sustainable at current measured bandwidth
  - consult manifest, request one chunk at a time

DASH - Dynamic Adaptive Streaming over HTTP

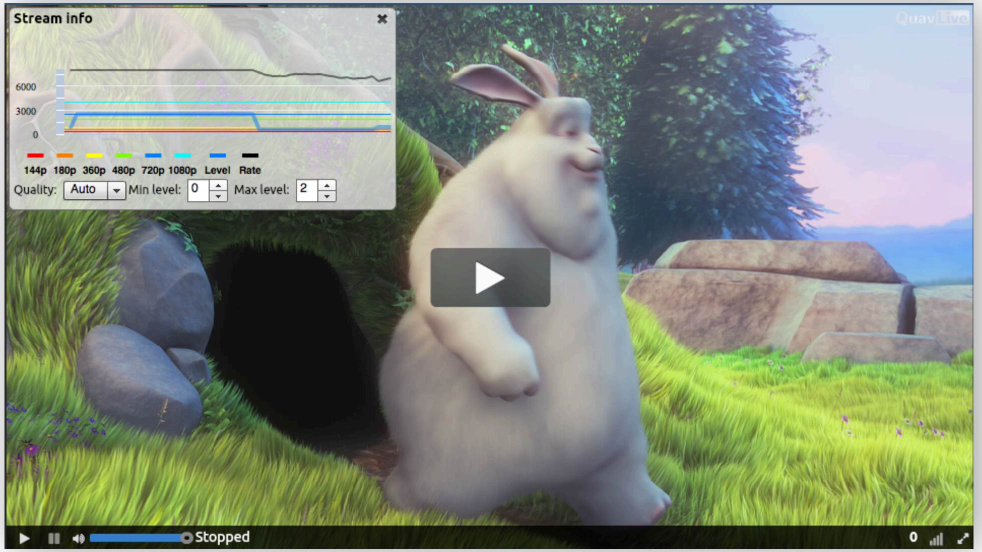
Client entirely controls delivery



- Client determines
  - **when** to request chunk: so that buffer starvation, or overflow does not occur
  - **what encoding rate** to request: higher quality when more bandwidth available
  - **where to request** chunk: can request from URL server that is “close” to client or has high available bandwidth

- Netflix estimate of data usage per hour
  - 0,3 GB (low quality)
  - 0.7 GB for SD (Standard Definition)
  - 3 GB for HD (High Definition)
  - 7 GB for UHD (Ultra High Definition also known as 4K)
  - Automatic – depends on internet available bandwidth

Eg. Adaptive streaming



http://quavstreams.quavlive.com/

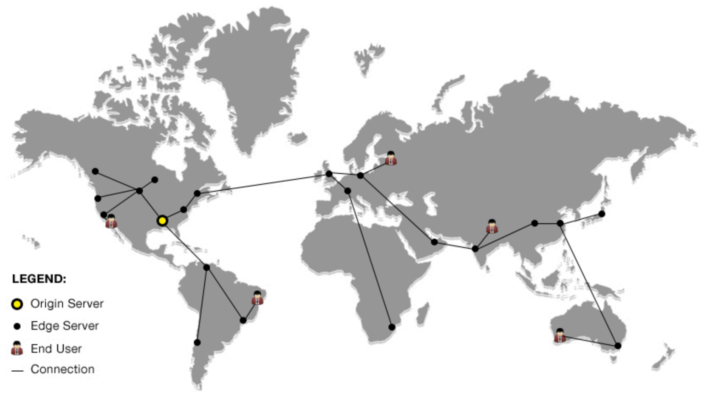
Challenge: how to stream content (selected from millions of videos) to hundreds of thousands of simultaneous users?

Single, large "mega-server"

- single point of failure
- point of network congestion
- long path to distant clients
- multiple copies of video sent over outgoing link

this solution doesn't scale

- **Content distribution networks (CDN)** store multiple copies of videos at multiple sites



- **enter deep**: push CDN servers deep into many access networks
  – close to users

Akamai

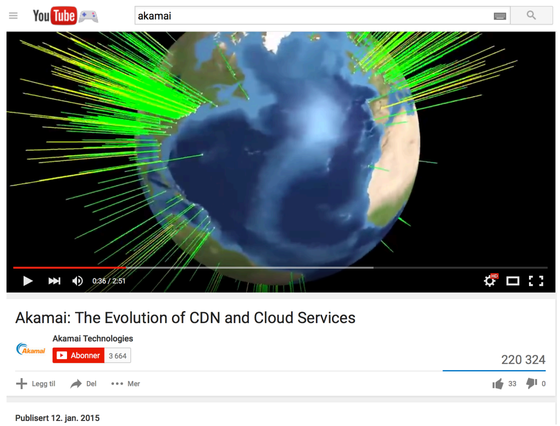
- **bring home**: smaller number (10's) of larger clusters in POPs (point of presence) near (but not within) access networks

Limelight NETWORKS

Content distribution networks (CDNs) for efficient media distribution

- **Replicate content** at hundreds of servers throughout Internet
- **Content downloaded** to CDN servers **ahead of time**
- Placing **content "close" to user** avoids impairments (loss, delay) of sending content over long paths
- CDN server typically in edge/access network

When provider updates content, CDN updates servers



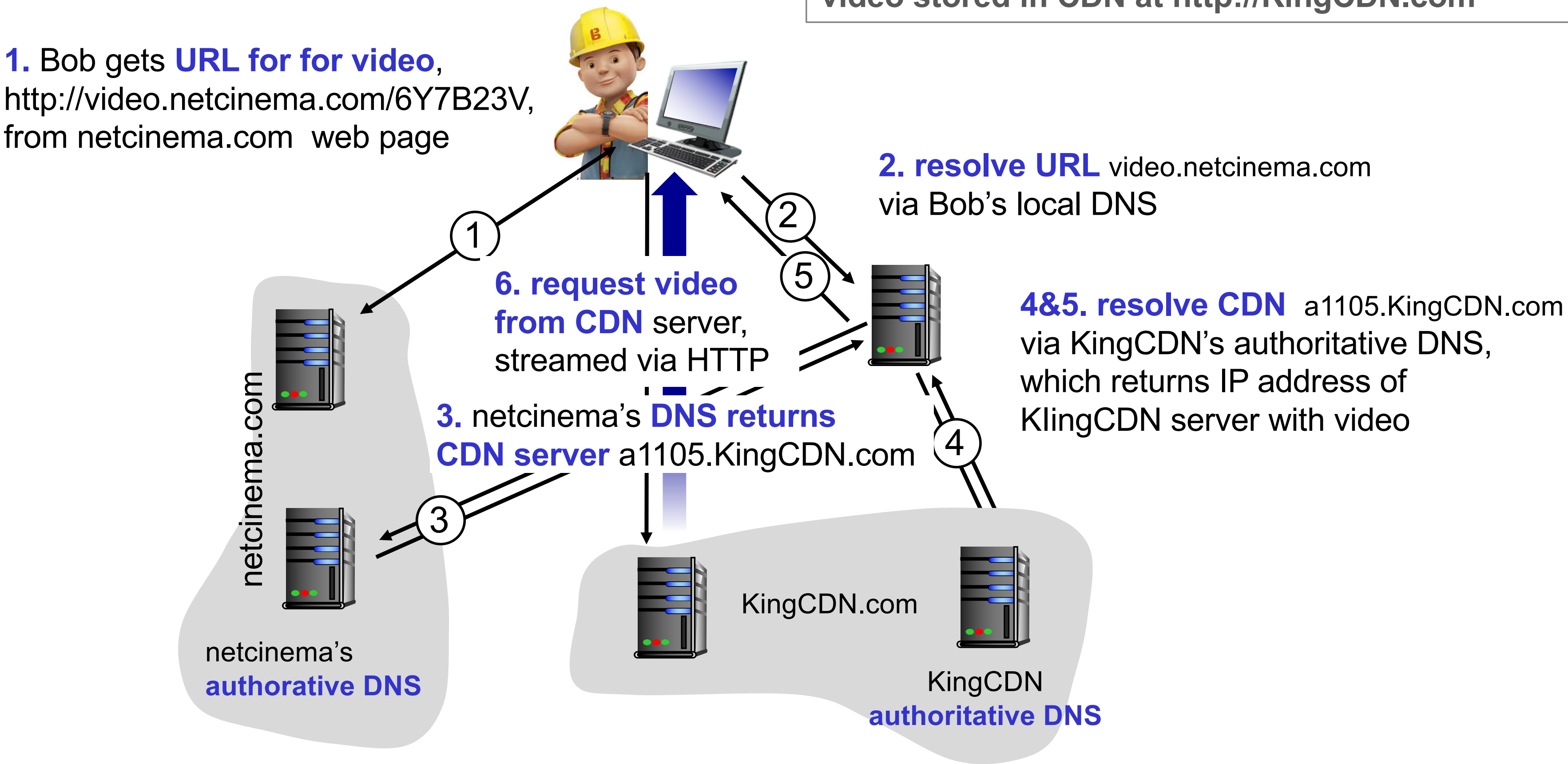
Akamai Powering a Better Internet

https://www.youtube.com/watch?v=gTYY8BuwNT0

Content distribution network

Simple content access scenario

Bob (client) requests video http://netcinema.com/6Y7B23V
video stored in CDN at http://KingCDN.com



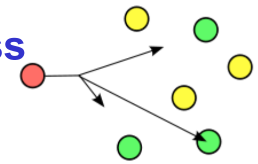
Content distribution network

Challenge: CDN cluster selection strategy

- Pick CDN node **geographically closest** to client
  - Geolocation services
  - RFC7871 Client subnet in DNS queries (no standard)

- Pick CDN node with **shortest delay** (or min # hops) to client (CDN nodes periodically ping access ISPs, reporting results to CDN DNS)

- **IP anycast address** for geolocation



```
GET /ping?h=new.livestream.com&p=%2Ffilmteametlive%
2Fkvalik2013&u=vkrd3ffa3jotg7wb&d=new.livestream.com&g=undefined&n=0&f
=1&c=3.25&x=371&y=782&w=782&j=30&R=1&W=0&I=0&E=120&b=921&t=8tqflr54y4j
n5apj&V=8&_ HTTP/1.1
Host: ping.chartbeat.net
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.8; rv:20.0)
Gecko/20100101 Firefox/20.0
Accept: image/png,image/*;q=0.8,*/*;q=0.5
Accept-Language: nb,en-us;q=0.7,en;q=0.3
Accept-Encoding: gzip, deflate
Referer: http://new.livestream.com/filmteametlive/kvalik2013
Connection: keep-alive

HTTP/1.1 200 OK
Server: nginx/0.7.67
Date: Sat, 13 Apr 2013 18:20:24 GMT
Content-Type: image/gif
Content-Length: 43
Connection: close
```

- Alternative: let client decide – among a list of several CDN servers
  - Client pings servers, picks “best”
  - Netflix approach – manifest file with **ranked list of CDNs**

Case study

Netflix – streaming since 2007, worldwide since 2016

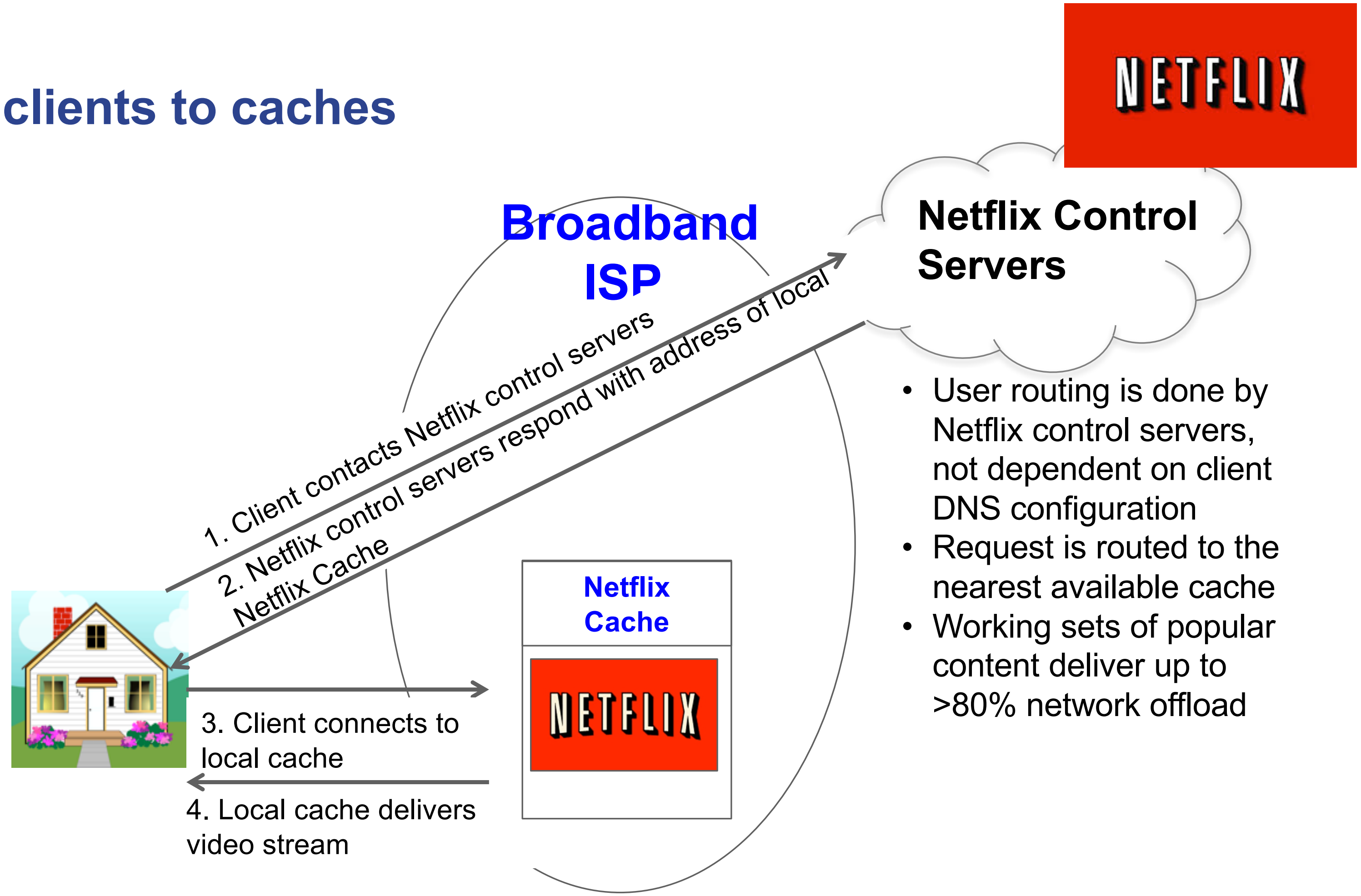
- Owns very little infrastructure, uses 3rd party services
- **Amazon (3rd party) web services** in the cloud
  - Registration, payment servers
  - Netflix web pages for user browsing
  - Netflix uploads studio master to Amazon cloud
  - Creates multiple versions of movie (different encodings) in cloud

"Netflix operates many tens of thousands of servers and many tens of petabytes of storage in the Amazon cloud"

- Upload versions from cloud to **Open Connect** – a Netflix-specific, specialized content delivery
  - developed in response to ISP requests to help scale Netflix traffic
  - proactive caching of popular content
  - provided at no cost to ISPs
  - located in data centers within Internet service providers' networks

- Timeline: https://media.netflix.com/en/about-netflix

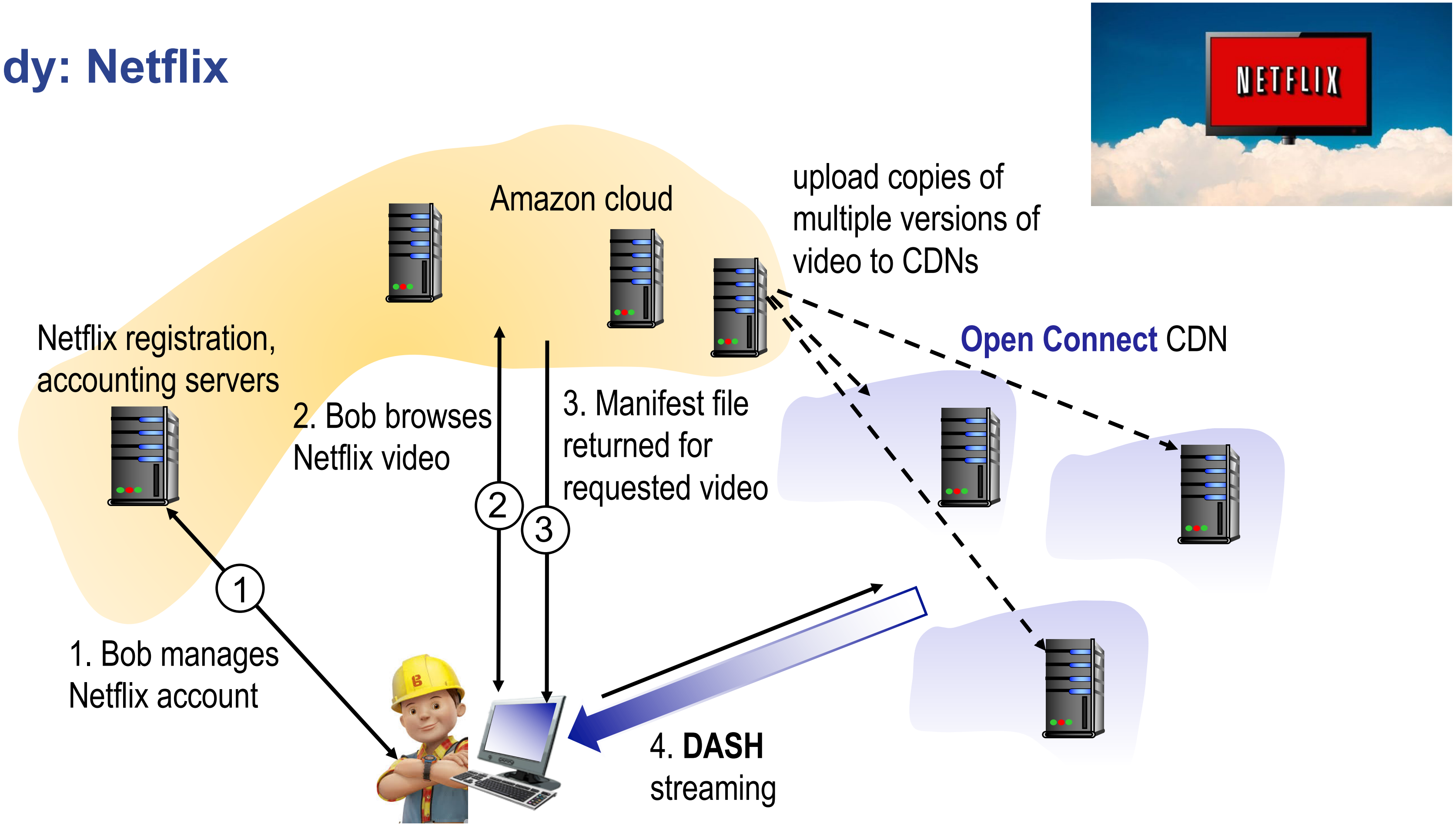
Directing clients to caches



- User routing is done by Netflix control servers, not dependent on client DNS configuration
- Request is routed to the nearest available cache
- Working sets of popular content deliver up to >80% network offload

- Used exclusively for Netflix content
- Saves on transit, transport and other upstream scaling costs
- Fill content outside peak times

Case study: Netflix



Why Netflix Built Its Own CDN

- Netflix initially outsourced streaming video delivery to three large CDN vendors (Akamai, Level3, and LimeLight). As the service became more popular, Netflix decided that building and managing its own CDN made sense, for several reasons:
  - From a **practical** perspective, the CDN vendors were struggling to expand their infrastructure at a pace that matched the growth in customer demand for Netflix's video streaming.
  - From a **financial** perspective, the expense of outsourcing was quickly becoming prohibitive as the volume of streamed video increased (a challenge experienced by many popular applications and web properties).
  - From a **business** perspective, it was clear that video streaming was replacing DVD lending as Netflix's primary source of revenue, and it didn't make sense to outsource a critical piece of the company's main business.
  - Most importantly, Netflix built its own CDN in order to have greater control over application delivery and the user experience.
- To provide optimal streaming media delivery to customers, Netflix needed to maximize its control over the three basic components in the delivery chain:
  - The **user's video player**. Netflix already controlled this component, because its developers write all the device-specific apps used by customers to view Netflix content.
  - The **network between the user and the Netflix servers**. There is no way to control this component directly, but Netflix minimizes the network distance to its customers by providing free video-streaming appliances to ISPs in exchange for rack space in the ISP's data centers for housing the appliances. (Appliances are also placed at Internet exchange points [IXPs] to serve customers whose ISPs are not interested in housing third-party equipment.) Video streaming is particularly sensitive to the packet delay and loss, misordered arrival, and unpredictable (jittery) round-trip times inherent to TCP/IP, and minimizing the network distance reduces the potential exposure to these anomalies.
  - The **video server** (Open Connect itself). Running its own CDN gives Netflix freedom to tune the CDN software to compensate for Internet anomalies as much as possible. It can run custom TCP connection-control algorithms and HTTP modules. It can also detect server and network problems very quickly and reroute clients to alternative servers, then log in to the server hardware and troubleshoot "from inside."
  - **Netflix was able to optimize Open Connect for video streaming in a way that's not possible with a generic CDN provided by a vendor. Open Connect enables Netflix to offer a superior user experience at a lower cost, and with greater visibility into the performance of the application around the world.**

Source: https://www.nginx.com/blog/why-netflix-chose-nginx-as-the-heart-of-its-cdn/

Monday, June 4, 2012

Announcing the Netflix Open Connect Network

Around the world, people are enjoying nearly a billion hours per month of movies and TV shows from Netflix. We've been delivering these petabytes of data exclusively through commercial content delivery networks.

Now, in addition to these general-purpose commercial CDNs, we are enabling ISPs to get Netflix video data from Open Connect, a single-purpose Netflix content delivery network we've established. The world's other major Internet video provider, YouTube, has long had its own content delivery network. Given our size and growth, it now makes economic sense for Netflix to have one as well. We'll continue to work with our commercial CDN partners for the next few years, but eventually most of our data will be served by Open Connect.

Like commercial CDNs, Open Connect will provide the Netflix data at no cost to the locations the ISP desires, or ISPs can choose to get the Netflix data at common internet exchanges. About 5% of Netflix data is already being served by Open Connect. Interested ISPs can find full details at: openconnect.netflix.com.

As part of Open Connect, we are also sharing our hardware design and the open source software components of the server. These cost-efficient designs are suitable for any high-volume provider of large media files. We welcome commentary and improvements, which will be shared with the community with the goal of a faster, less expensive Internet for all.

Ken Florance

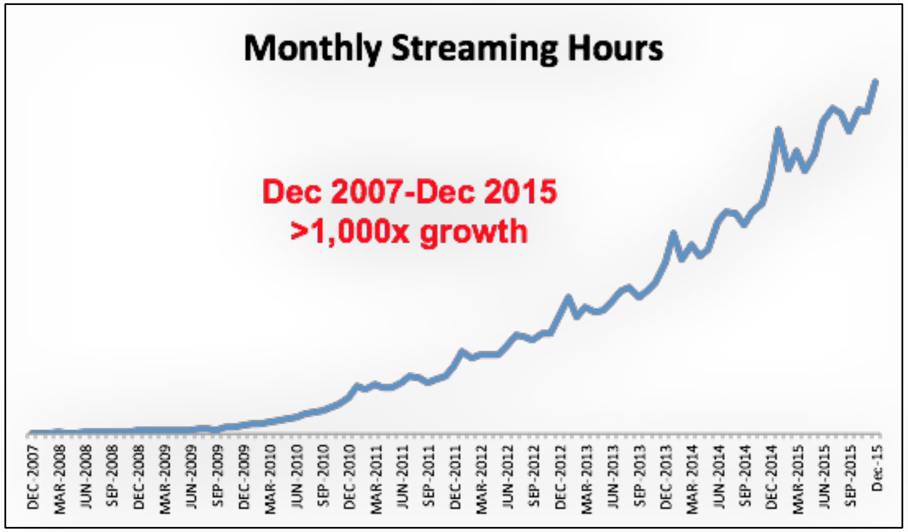
Ken Florance is Vice President of Content Delivery at Netflix

http://blog.netflix.com/2012/06/announcing-netflix-open-connect-network.html

Posted by Ken Florance at 2:48 PM

NETFLIX peering locations
https://openconnect.itp.netflix.com/peeringLocations/index.html

Netflix fyller nettverkene



https://media.netflix.com/en/company-blog/completing-the-netflix-cloud-migration

"…mer enn 50 prosent av veksten økt bruk av amerikanske strømmetjenester, med Netflix i spissen. Våren 2013 fikk Netflix utplassert servere i kjernenettet til Altibox, noe som bidrar til høyere kvalitet og stabilitet under avspillingene."

Altibox doblet trafikken

Kundene flokker særlig til én nettjeneste.

http://www.digi.no/tele-kommunikasjon/2014/11/19/altibox-doblet-trafikken

RETT PÅ NETT. «Orange Is The New Black» er blant seriene som lokker nordmenn til Netflix. Foto: Paul Schiraldi, AP/NTB Scanpix

Etterbørs Medier

Netflix fyller Telenors nett

For et halvt år siden røkte Telenor fredspipe med Netflix. Nå utgjør strømmetjenesten 20 prosent av Telenors bredbånds-trafikk.

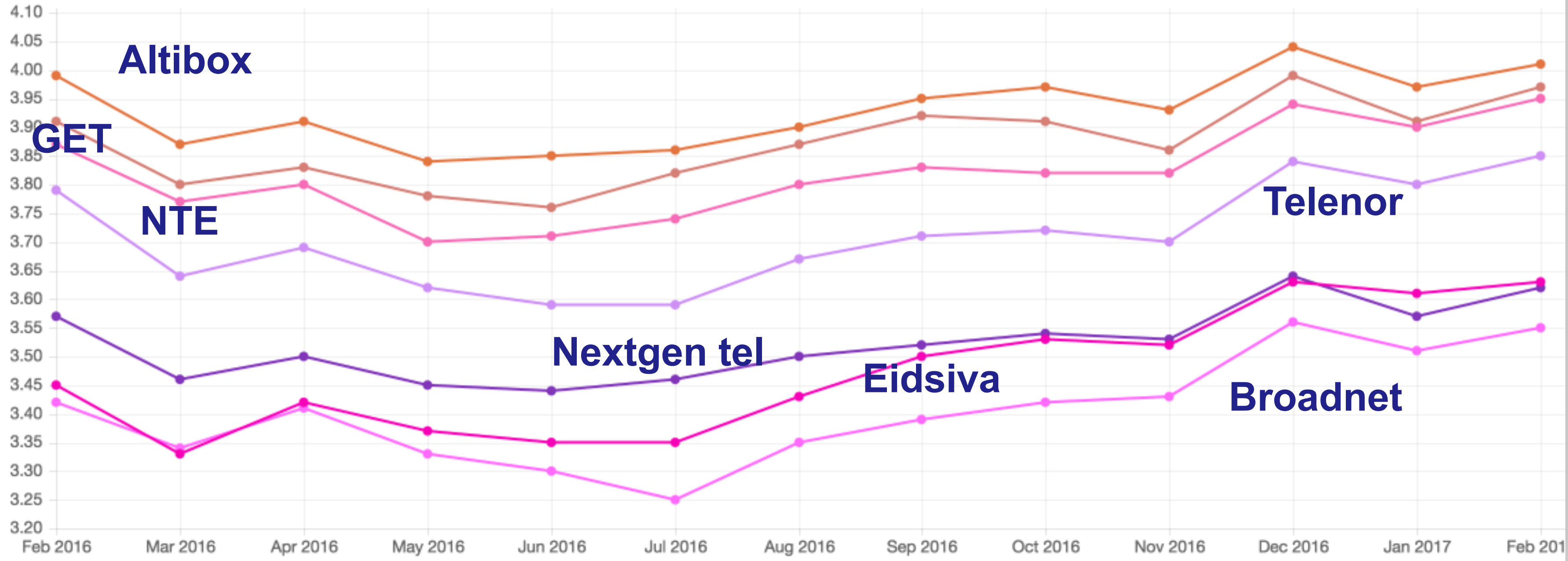
Bjørn Eckblad
Publisert: 22.09.2014 – 21:17 Oppdatert: 22.09.2014 – 21:56

http://www.dn.no/etterBors/2014/09/22/2117/Medier/netflix-fyller-telenors-nett

NORWAY

ISP LEADERBOARD - FEBRUARY 2017

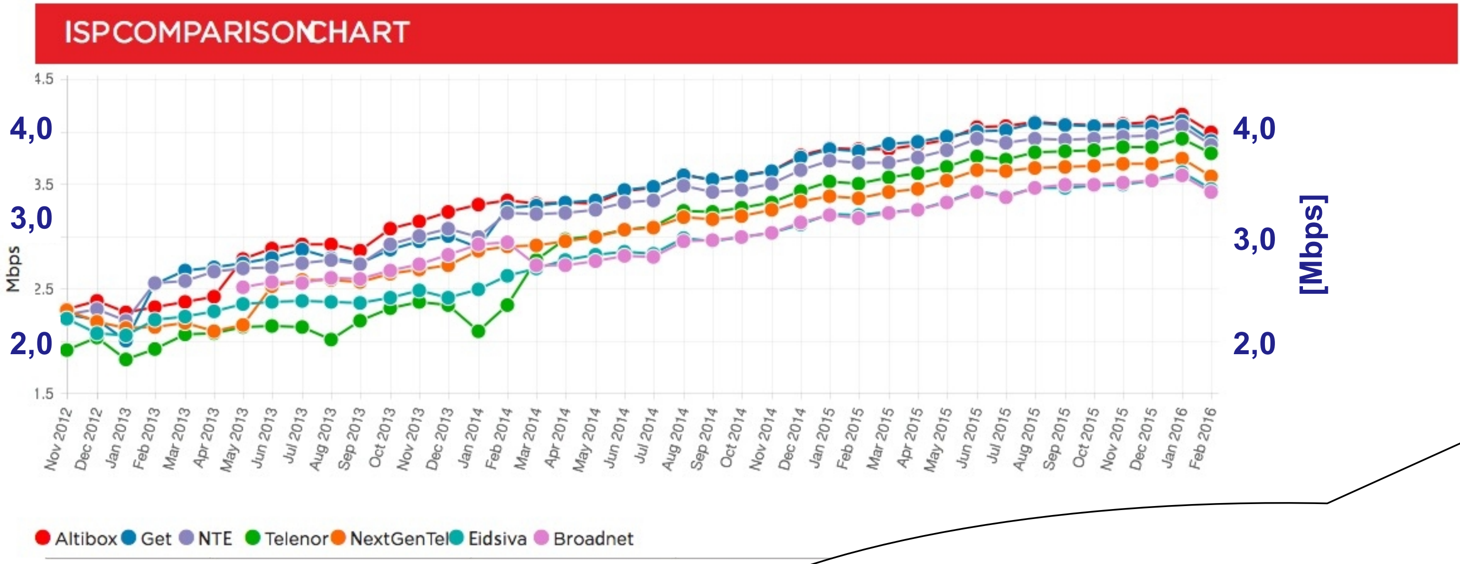
RANK	ISP	SPEED Mbps		PREVIOUS Mbps	RANK CHANGE	TYPE Fiber Cable DSL Satellite Wireless
1	Altibox	4.01		3.97		



Source: https://ispspeedindex.netflix.com/country/norway/#

NTNU

NORWAY



NETFLIX

The Netflix ISP Speed Index lists the average prime time bitrate for Netflix content streamed to Netflix members during a particular month. For ‘Prime Time’, we calculate the average bitrate of Netflix content in megabits per second (Mbps) streamed by Netflix members per ISP. We measure the speed via all available end user devices. For a small number of devices, we cannot calculate the exact bitrates and streaming via cellular networks is exempted from our measurements. The speed indicated in the Netflix ISP Speed Index is not a measure of the maximum throughput or the maximum capacity of an ISP.

Netflix og bredbåndsleverandørene krangler om regninga for videostrømming

Amerikanske Netflix-brukere har havnet i kryssilden når de store nettaktørene kjemper om hvem som skal betale for bredere bredbånd og skarpere HD-video. Også norske aktører er uenige om regninga.

Vil Telenor slutte seg til Netflix Open Connect?
https://signup.netflix.com/openconnect/application

Netflix Open Connect Content Delivery Network
signup.netflix.com
The Open Connect appliance is a directed cache appliance. Its purpose is to allow participating ISPs the ability to

NETFLIX

NORWAY ISP SPEED INDEX

FEBRUARY 2014

FIXED

RANK	CHANGE	ISP NAME	AVG SPEED (Mbps*)
1	–	ALTIBOX	3.34
2	+2	GET	3.27
3	-1	NTE	3.22
4	+2	LOQAL	3.10
5	-2	BROADNET	2.94
6	-1	NEXTGENTEL	2.90
7	–	UNINETT	2.79
8	–	EIDSIVA	2.62
9	–	TELENOR	2.34

SEE ARCHIVE

http://www.nrk.no/kultur/usa-krangler-om-strommeregninga-1.11535907

Telenor Norge Netflix velger å kun tilby sitt HD tilbud til kunder som befinner seg i nett der de klarer å levere høye videorater helt til sluttkundene. Samtidig er Netflix – i motsetning til andre video-strømmingstilbydere – ikke villige til å inngå avtale om direkte tilgang til Telenors IP nett, og de er dermed ikke i stand til å levere en slik kvalitet til bredbåndskunder i Telenors nett. Dette beklager Telenor, men vi ser det ikke som rimelig å tilby internett aksess til Netflix gratis samtidig som alle andre privat- og bedriftskunder. Dette inkluderer også andre video-strømmingstilbydere. Høykvalitetstilgang til Telenors nett kommer ikke gratis, og det har altså alle andre innsett, men Netflix krever å få dette gratis; konsekvensen er at Netflix-trafikk når bredbåndskunder i Telenors nett via det internasjonale IP-nettet, og dermed er det ikke mulig å oppnå HD-kvalitet. Merk altså at Telenor ikke på noe vis sperrer eller begrenser denne trafikken, men at Netflix styrer trafikken inn i Telenors nett på en måte vi ikke har kontroll over og dermed kan vi heller ikke garantere kvaliteten. Vi forskjellsbehandler ikke innholdsleverandører, men må dessverre konstatere at Netflix har valgt en annen distribusjonsløsning mot Telenors kunder enn for eksempel NRK, TV2, VGT, SVT og Youtube.
/Per Reidar
24. januar 2013 kl. 06:22

UTFORDRER NETTNØYTRALITETEN?: Netflix' inntog i Norge har bydd på utfordringer for Telenor, som ønsker at videotjenester som tar opp mye kapasitet i nettet skal betale. Kritikerne mener imidlertid at prinsippet om nettnøytralitet står på spill når store og pengesterke aktører blir positivt diskriminert. Bildet er fra Netflix-serien «Orange is the New Black». FOTO: PROMO

Netflix inngår hemmelig avtale med Telenor

Forbrukerrådet reagerer.

JOAKIM THORKILDSEN
joakim@filtermagasin.com
FILTER

fredag 7. mars 2014, kl.08:46

(Filtermagasin.no): Forholdet mellom
Telenor og Netflix har vært noe anstrengt
etter at den amerikanske strømmegiganten etablerte seg i Norge høsten 2012.

Når tjenesten ble så populær på kort tid la det beslag på mye av Telenors kapasitet, og internettleverandøren ønsket at Netflix skulle betale for å leie plass til sine servere i Telenors datahaller. Dette ville garantert en bedre bildekvalitet for tjenestens kunder, og man ville unngått flaskehalser som oppstår når store trafikkmengder blir overført fra Netflix' servere i utlandet.

Men Netflix nektet, og skeptikerne mente det ville utfordret prinsippet om nettnøytralitet hvis pengesterke aktører kunne kjøpe seg forrang.

Nå har Netflix likevel krøpet til korset og inngått en avtale med Telenor, ifølge Dagens Næringsliv.

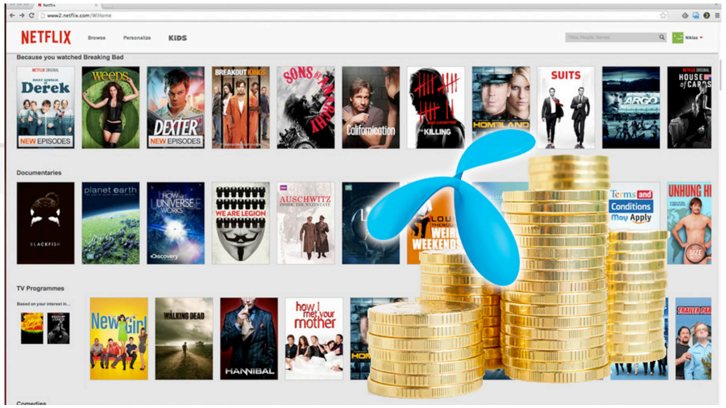
- Demonterer internett

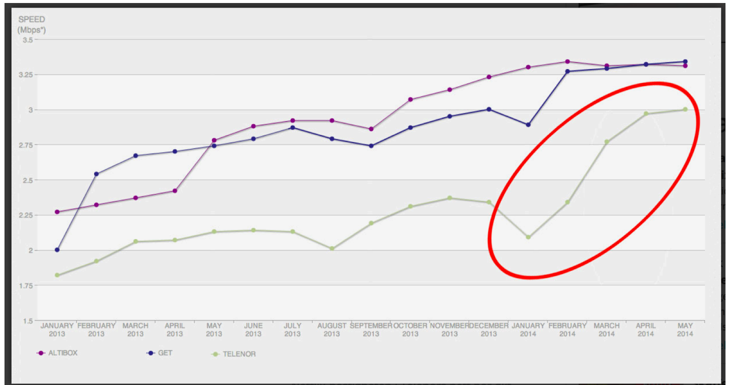
Innholdet i avtalen er imidlertid hemmelig, og Telenor ønsker ikke å kommentere overfor DN om de får betalt av Netflix.

- Men det er klart at det er en kommersiell avtale. Partene har forretningsmessige grunner til ikke å gå ut med detaljer som kan påvirke forhandlinger med andre aktører, sier Jørn Bremtun, senior kommunikasjonsrådgiver i Telenor, til Filter.

Netflix inngikk også en avtale med den amerikanske nettleverandøren Comcast for to uker siden, en avtale som ifølge New York Times innebar en «milepæl i internetthistorien».

http://www.dagbladet.no/2014/03/07/kultur/filter/tv/stromming/netflix/32183051/





Netflix-hastigheten i Telenors nett har økt markant de siste månedene.

http://www.tek.no/artikler/sa-mye-hjalp-det-netflix-a-betale-for-bedre-telenor-hastighet/161211

Netflix protecting copy rights

14 January 2016

Evolving Proxy Detection as a Global Service

If all of our content were globally available, there wouldn't be a reason for members to use proxies or "unblockers" to fool our systems into thinking they're in a different country than they're actually in. We are making progress in licensing content across the world and, as of last week, now offer the Netflix service in 190 countries, but we have a ways to go before we can offer people the same films and TV series everywhere.

Over time, we anticipate being able to do so. For now, given the historic practice of licensing content by geographic territories, the TV shows and movies we offer differ, to varying degrees, by territory. In the meantime, we will continue to respect and enforce content licensing by geographic location.

Some members use proxies or "unblockers" to access titles available outside their territory. To address this, we employ the same or similar measures other firms do. This technology continues to evolve and we are evolving with it. That means in coming weeks, those using proxies and unblockers will only be able to access the service in the country where they currently are. We are confident this change won't impact members not using proxies.

We look forward to offering all of our content everywhere and to consumers being able to enjoy all of Netflix without using a proxy. That's the goal we will keep pushing towards.

--David

David Fullagar is Vice President of Content Delivery Architecture at Netflix.

Netflix sier "Det ser ut som om du bruker en unblocker eller proxy" (You seem to be using an unblocker or proxy).

NETFLIX MEDIA CENTER

Denne feilen oppstår når systemene registrerer at du kobler til via VPN, proxy eller en "unblocker"-tjeneste.Siden innholdet vårt varierer etter region og disse tilkoblingstypene ofte brukes til å omgå geolokasjon, vil du ikke kunne strømme når du er koblet til på denne måten.

Netflix blocked your VPN? Smart DNS could be the answer

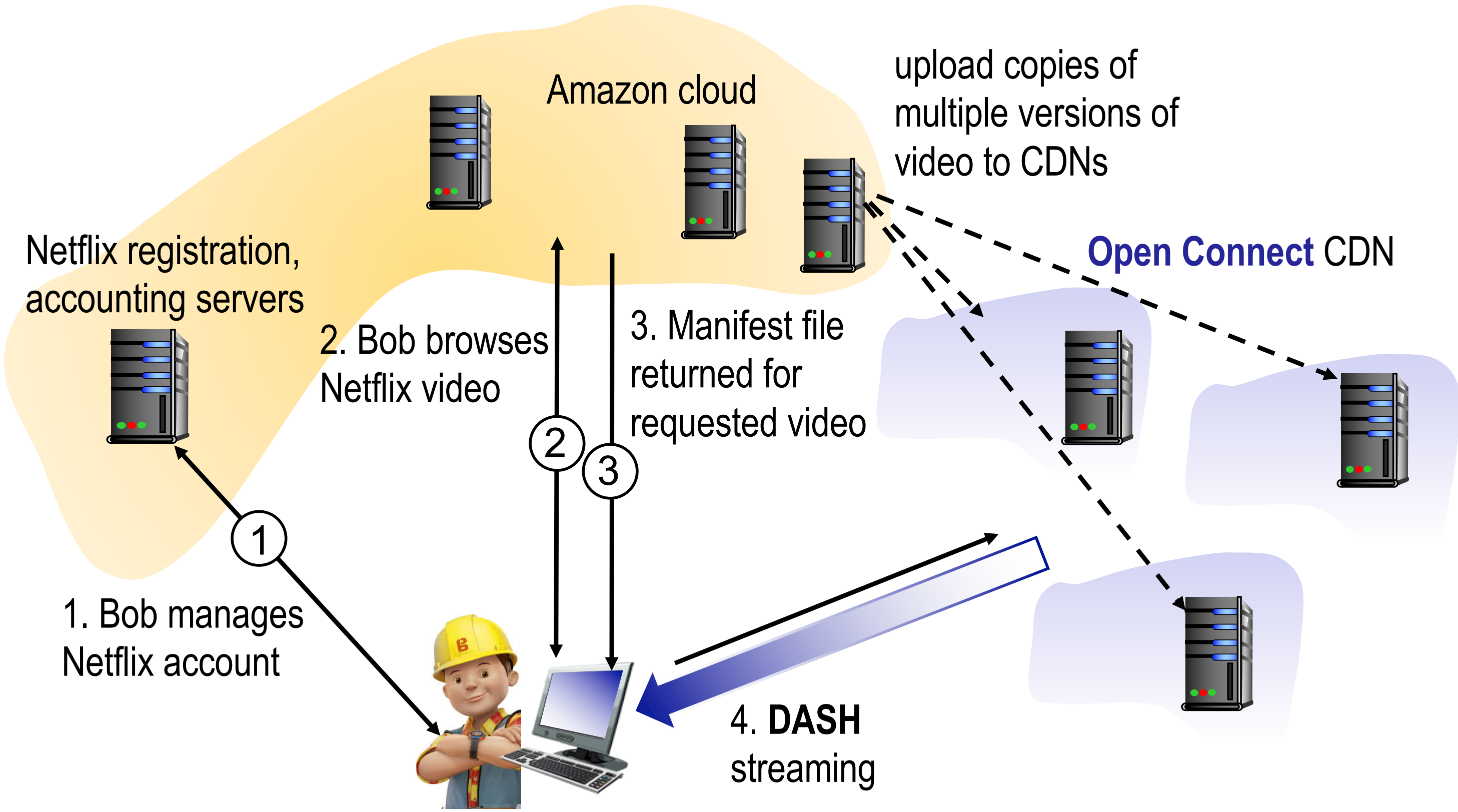
https://www.comparitech.com/blog/vpn-privacy/netflix-blocked-your-vpn-smart-dns-is-the-answer/

Netflix proxy error Fix – Here are 6 VPNs that still work in 2017

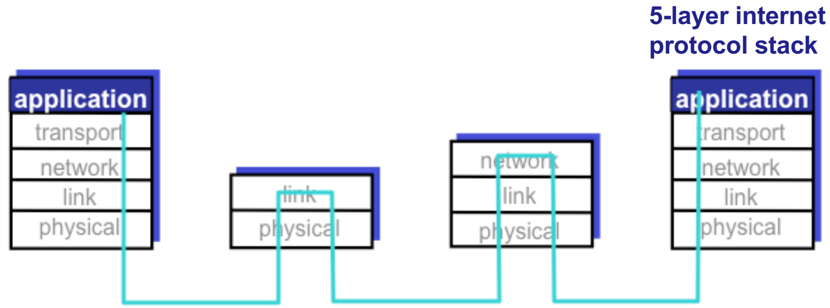
Published by **Paul Bischoff** on November 11, 2016 in **Popular Posts**, **VPN & Privacy**

@pabischoff
@Comparitech

Where/When to check geo-location?



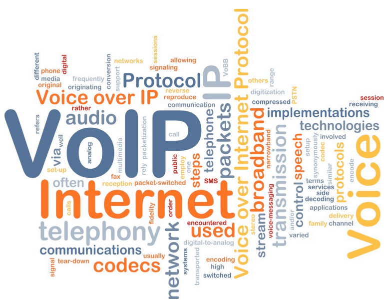
Multimedia networking: Roadmap

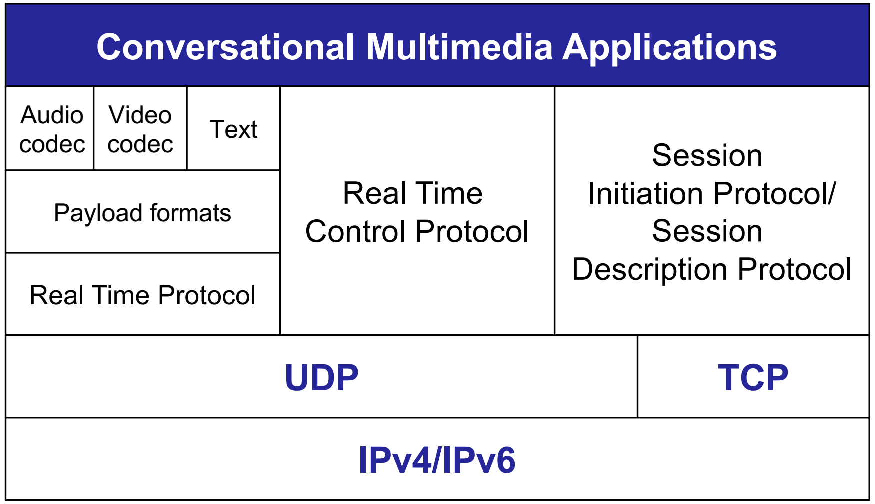


7.1 (9.1 + 2.6)
Multimedia networking applications

7.2 (9.2)
Streaming stored video

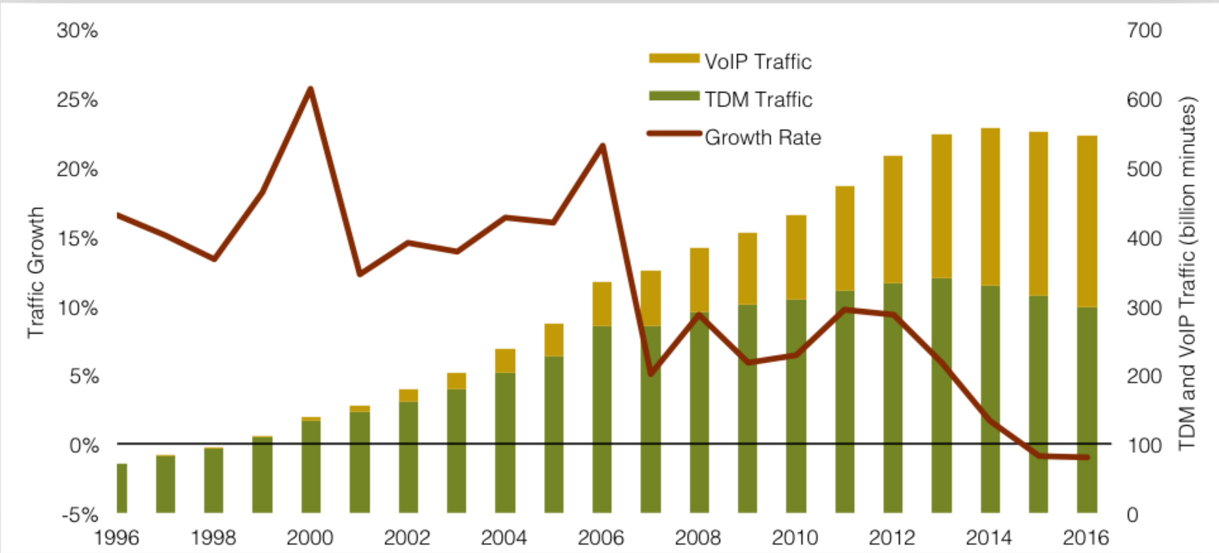
7.3 (9.3)
Voice over IP





Real-time interactive applications

Voice over IP



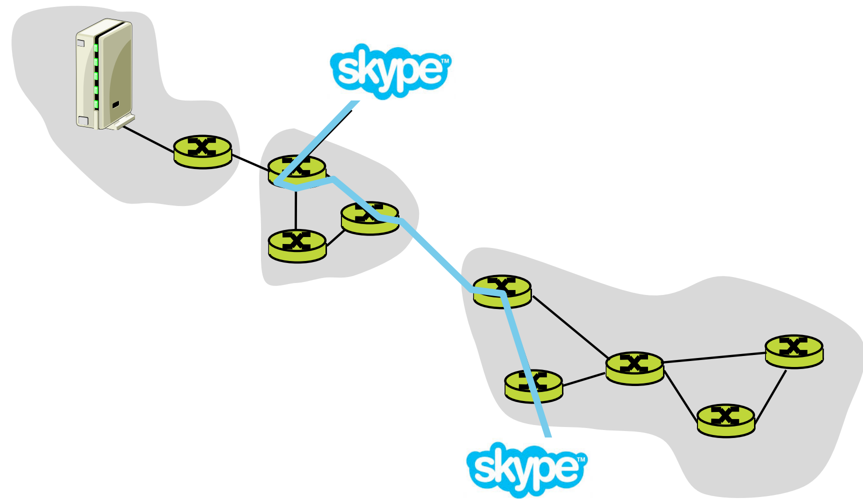
Source: https://www.telegeography.com/research-services/telegeography-report-database/

Videoconference with webcams

- Skype
- Polycom
- Cisco

Real-time interactive multimedia

- **Session initialization:** callee must advertise IP address, port number, encoding algorithms
- Value-added voice services: call forwarding, screening, recording
- **End-2-end delay sensitive**
  - application-level (packetization) and network delays
  - higher delays noticeable, impair interactivity
    - audio: < 150 ms good, > 400 ms bad
- **Loss-tolerant**
  - Losses can be concealed
- Bandwidth requirement depends on media streams
- Emergency services

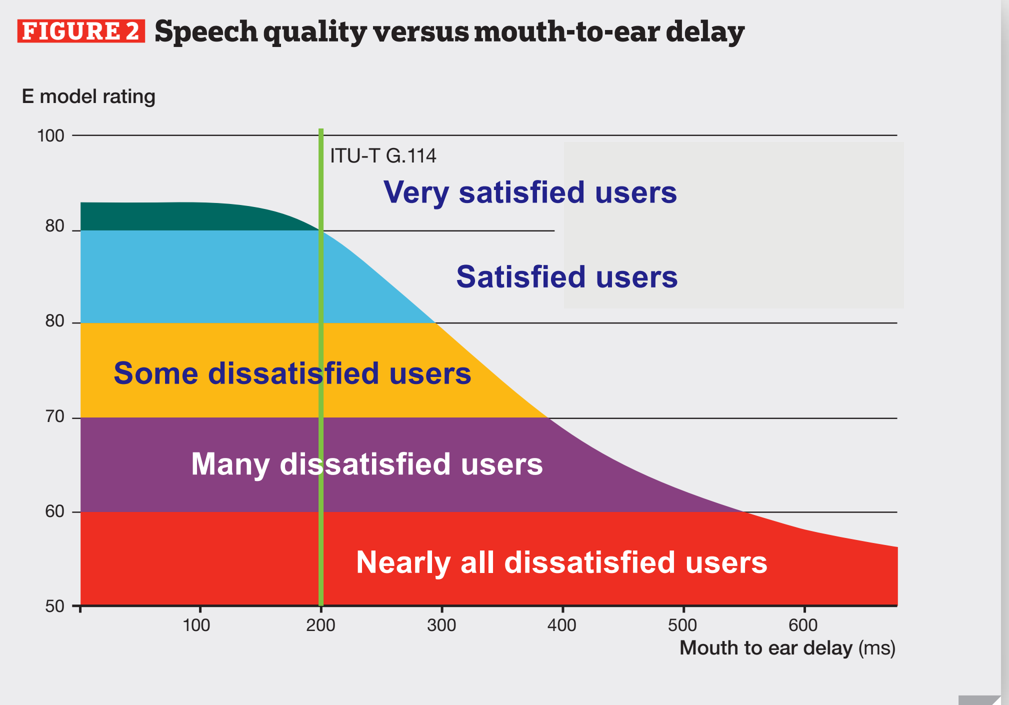


Nasjonal kommunikasjonsmyndighet

Anrop til nødnummer skal kunne skje på en slik måte at nødmeldesentralen som anropes også mottar informasjon om hvilket nummer det ringes fra, hvilken adresse (fasttelefon) eller hvilket geografisk område (mobiltelefon) det ringes fra. Denne funksjonen kalles opprinnelsesmarkering og skal bidra til at nødmeldesentralen kan dirigere hjelp til korrekt adresse, selv om oppringer ikke klarer å gi informasjon om dette selv.

http://www.nkom.no/marked/ekomtjenester/regelverk/prinsippnotat-om-bredbåndstelefoni/_attachment/2625?_ts=139d3f29b4a

ITU G.114 voice quality model – delay is an important quality parameter



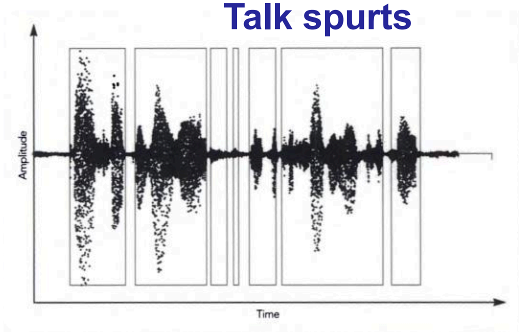
Source: Ericsson Review 1 2012

- **Network loss**: IP datagram lost due to network congestion (router buffer overflow)
- **Delay loss**: IP datagram may arrive too late for play-out at receiver
  - delays: processing, queuing in network; end-system (sender, receiver) delays
  - typical maximum tolerable delay: 400 ms
- **Loss tolerance**: depending on voice encoding, losses concealed, packet loss rates between 1% and 10% can be tolerated

Interactive multimedia

Internet phone – VoIP characteristics

- Speaker's audio: alternating talk spurts, silent periods
  - PCM: 8000 sample/s, 8 bit/sample
  - packets generated only during talk spurts
  - 64 kbps during talk spurt
  - 20 ms chunks at 8 kbytes/sec: 160 bytes data
- Application-layer header added to each chunk
- Chunk + header encapsulated into UDP segment
- Application sends UDP segment into socket every 20 ms during talk spurt

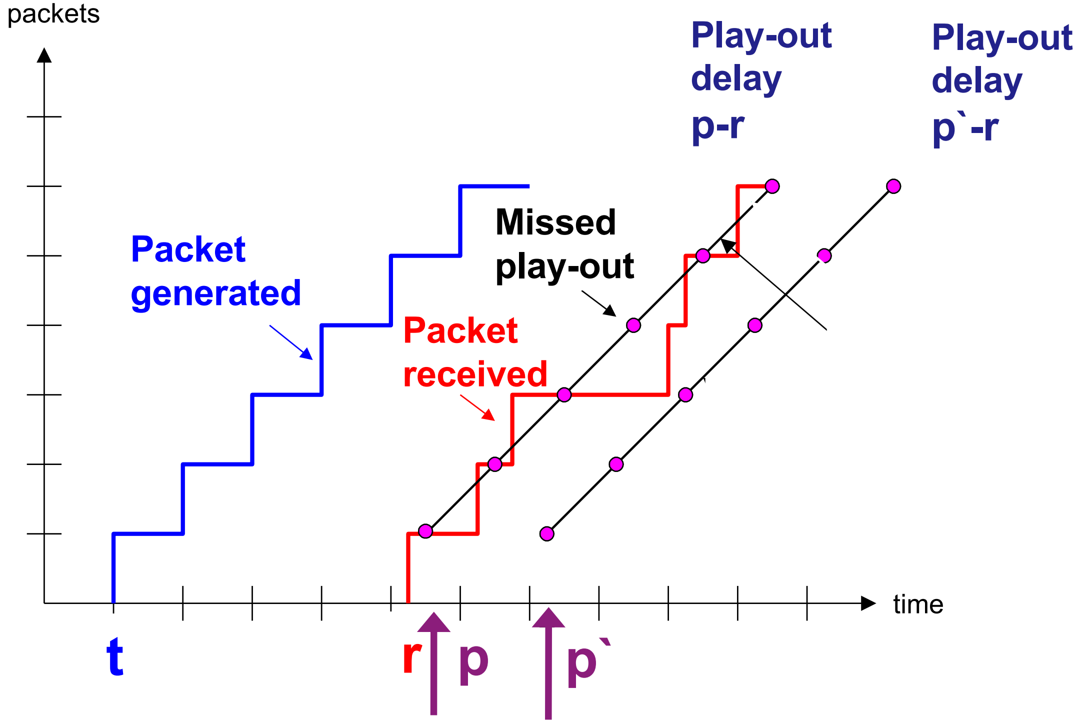


Source: Colin Perkins RTP: Audio and Video for the Internet

Telio

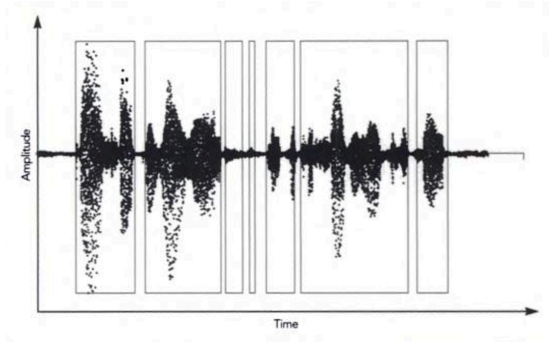
VoIP: Fixed play-out delay

- Sender generates packets every 20 ms during talk spurt
- The smaller network delay (r - t) the better the interactive experience
- First packet of talk spurt is received at time r
- Playout at p/p`



NTNU

Adaptive play-out delay: to minimize delay and keep a low late loss rate



- Approach: adaptive play-out delay adjustment
  - estimate network delay, **adjust play-out** delay at **beginning** of each **talk spurt**
  - silent periods compressed and elongated
  - chunks played out every 20 ms during talk spurt
- Adaptive play-out needs identification of the first packet in a talk spurt
  - If **no loss**, receiver looks at successive **timestamps**
    - difference of successive stamps > 20 ms -->talk spurt begins
  - With **loss possible**, receiver must look at both time stamps and **sequence numbers**
    - difference of successive stamps > 20 ms and sequence numbers without gaps --> talk spurt begins

Adaptively estimate of packet play-out delay

- Exponentially weighted moving average

$$\underbrace{d_i}_{\text{delay estimate after ith packet}} = (1-\underbrace{\alpha}_{\text{small constant, e.g. 0.01}})d_{i-1} + \alpha\, \underbrace{(r_i - t_i)}_{\text{measured delay of ith packet}}$$

delay estimate after ith packet

small constant, e.g. 0.01

time received - time sent (timestamp)

measured delay of ith packet

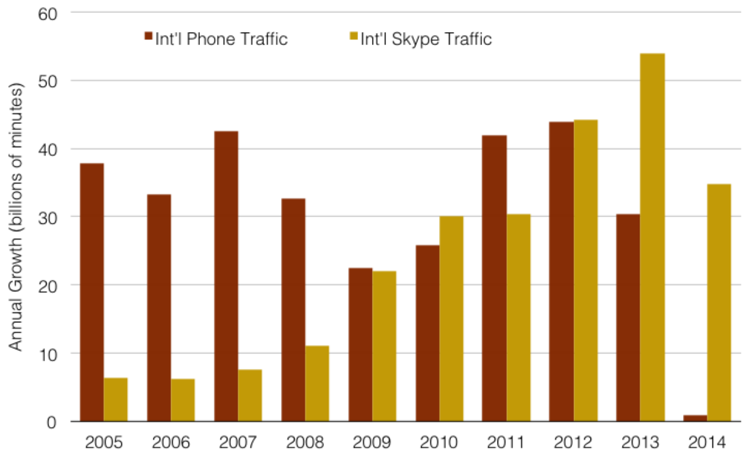
- Also useful to estimate average deviation of delay, v_i
- For **first packet** in talk spurt, **play-out time** $= t_i + d_i + Kv_i$
  - where K is positive constant (e.g. 4)
  - $v_i = (1-\beta)v_{i-1} + \beta\, |(r_i - t_i) - d_i|$ - average deviation v_i of delay
- **Remaining packets** in talk spurt are **played out periodically**
- v_i calculated for every received packet (but used only at start of talk spurt)

P2P case study: Skype – a 3rd party VoIP service

- http://www.skype.com/no/features/#calling
- Founded in 2003
- Acquired by eBay in September 2005 for $ 2,6 billion
- Acquired by an investment group led by Silver Lake in November 2009
- Microsoft acquired Skype for $8.5 billion in cash from the investor group in May 2011
- At CeBIT March 2013, Microsoft COO Kevin Turner revealed that 33% of the world's voice calls happen on Skype
- 2015 Lync Online -> Skype for business
- Microsoft cut support for Skype on TV from 2 June 2016

That sellers and buyers could commune over Skype to haggle over a sale? It never happened.

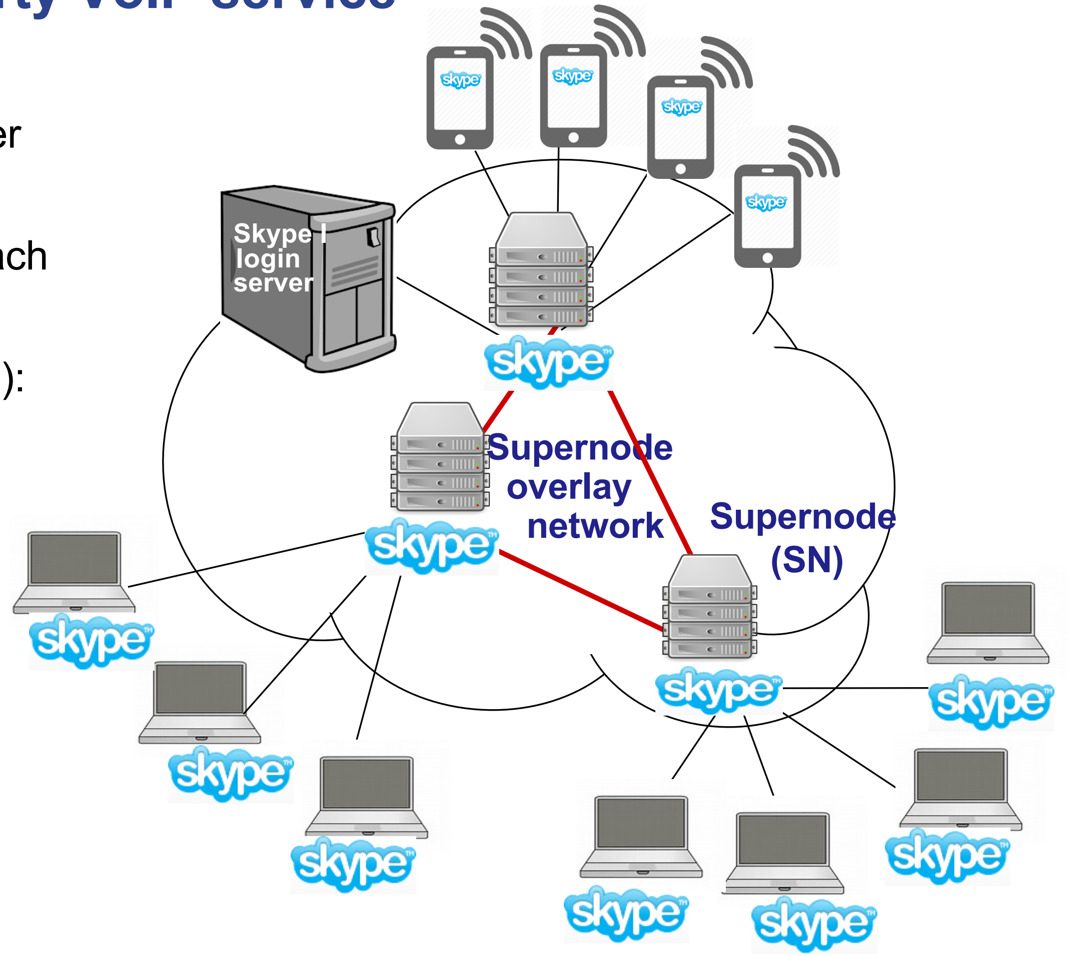
"increase the accessibility of real-time video and voice communications, bringing benefits to both consumers and enterprise users and generating significant new business and revenue opportunities." + user base, peer-to-peer video, other companies interest



https://www.telegeography.com/research-services/telegeography-report-database/

P2P case study: Skype – a 3rd party VoIP service

- Inherently P2P: Proprietary application-layer protocol (inferred via reverse engineering)
- **Clients**: Skype peers connect directly to each other for VoIP call
- Hierarchical overlay with **super nodes** (SN): Skype peers with special functions
  - index of usernames to IP addresses distributed over SNs
- **Login server**



Why Skype has switched to server-based "dedicated supernodes" …

- First is actually a more subtle issue... the Skype peer-to-peer network architecture elected certain nodes to be **"supernodes", to help maintain the index of peers as well as handle parts of the NAT/firewall traversal for other peers**. This election algorithm chose only machines with open Internet connectivity, substantial uptime, and which were running the latest version of our peer-to-peer code. The last bit unfortunately meant that most of the time, the **election winners were a monoculture of Windows desktop machines running the latest Windows Skype client**. This proved to be a problem when not once, but twice a **global Skype network outage was caused by a crashing bug in that client.**.. bootstrapping the network back into existence afterwards was painful and lengthy, and that is in part why Skype has switched to server-based "dedicated supernodes"... nodes that we control, can handle orders of magnitudes more clients per host, are in protected data centers and up all the time, and running code that is less complex that the entire client code base. (And this conversion started well before the Microsoft acquisition was even announced, during the Silverlake era.)

- The second is really what is driving Skype to move not just the supernodes but actually many other parts of our calling and messaging infrastructure "to the cloud", and that is the **amazing growth of mobile and tablet computing**. The Skype peer-to-peer network, and many of its functions (such as instant messaging) was built for a world where almost every machine is powered by a wall socket, plugged into broadband Internet, and on for many hours a day.
  Over the past few years, the number of Skype users who are **using Skype from iOS-based phones and tablets**, Android-based phones and tablets, Windows Phone-based phones, and Windows RT tablet devices has gone from a tiny percentage to a significant fraction of our user base. And these devices are a lot different: **they're running on battery, sometimes on WiFi but often on expensive (both in money and battery) 2G or 3G data networks, and essentially "off" most of the time**. On iOS devices, applications are killed and evicted from memory when they attempt to do too much background processing or use too much memory. On Windows RT and Windows 8 Modern applications, when the application is not in the foreground we only get a few seconds of CPU execution time every 15 minutes and again, strict memory limitations if we want to stay loaded. And when the Skype application is unloaded, it can no longer receive incoming calls or IMs, rendering it a lot less useful.

http://www.listbox.com/member/archive/247/2013/06/sort/time_rev/page/1/entry/6:271/20130623090855:0B714E0A-DC06-11E2-9F35-8CD4CCA160A2/

- If you've tried to use Skype on a mobile device, especially if you have a lot of contacts or a lot of IM conversations, you'll discover that it rapidly becomes a battery-powered hand warmer, and drains the battery faster that probably any other well-known application out there. And this is because it, until recently, was participating as a full node on our peer-to-peer network... exchanging packets regularly (over your 3G radio, most likely) with every single one of your contacts to keep presence status updated, exchanging packets with everyone in every IM conversation to keep those conversations synchronized, etc.

- And you probably also have started to notice things like missed IM delivery, **as the peer-to-peer delivery algorithm requires that both the sender and the receiver be running at the same time in order to deliver a message**... not a problem with two broadband-attached always-on PCs, but rare if you're both on Windows Phone or Windows RT tablets that only run that algorithm when the application is in the foreground or for 3-5 seconds after it is backgrounded.

Skype Now Runs On Windows Azure

By Edwin Kee on 12/16/2013

Windows Azure

- How do we solve that for our users? Servers. Lots of them, and more and more often in the Windows Azure cloud infrastructure. In the case of instant messaging, we have merged the Skype and Windows Messenger message delivery backend services, and this now gets you delivery of messages even when the recipient is offline, and other nice features like spam filtering and malicious URL removal. For calling, we have the dedicated supernodes already, and additional services to help calls succeed when the receiving client is asleep and needs a push notification to wake up. And over time you will see more and more services move to the Skype cloud, offloading memory and CPU requirements from the mobile devices everyone wants to enjoy to their fullest and with maximum battery life.

- Making this transition has been difficult and taken the hard work of hundreds of developers, especially to make it as seamless as possible for users who don't particularly care how we get it done or that we are changing it... but I would say that it makes strategic and business sense to be doing, otherwise we wouldn't bother, and I hope the above at least partially explains why I think that.

  Matthew Kaufman

http://www.listbox.com/member/archive/247/2013/06/sort/time_rev/page/1/entry/6:271/20130623090855:0B714E0A-DC06-11E2-9F35-8CD4CCA160A2/

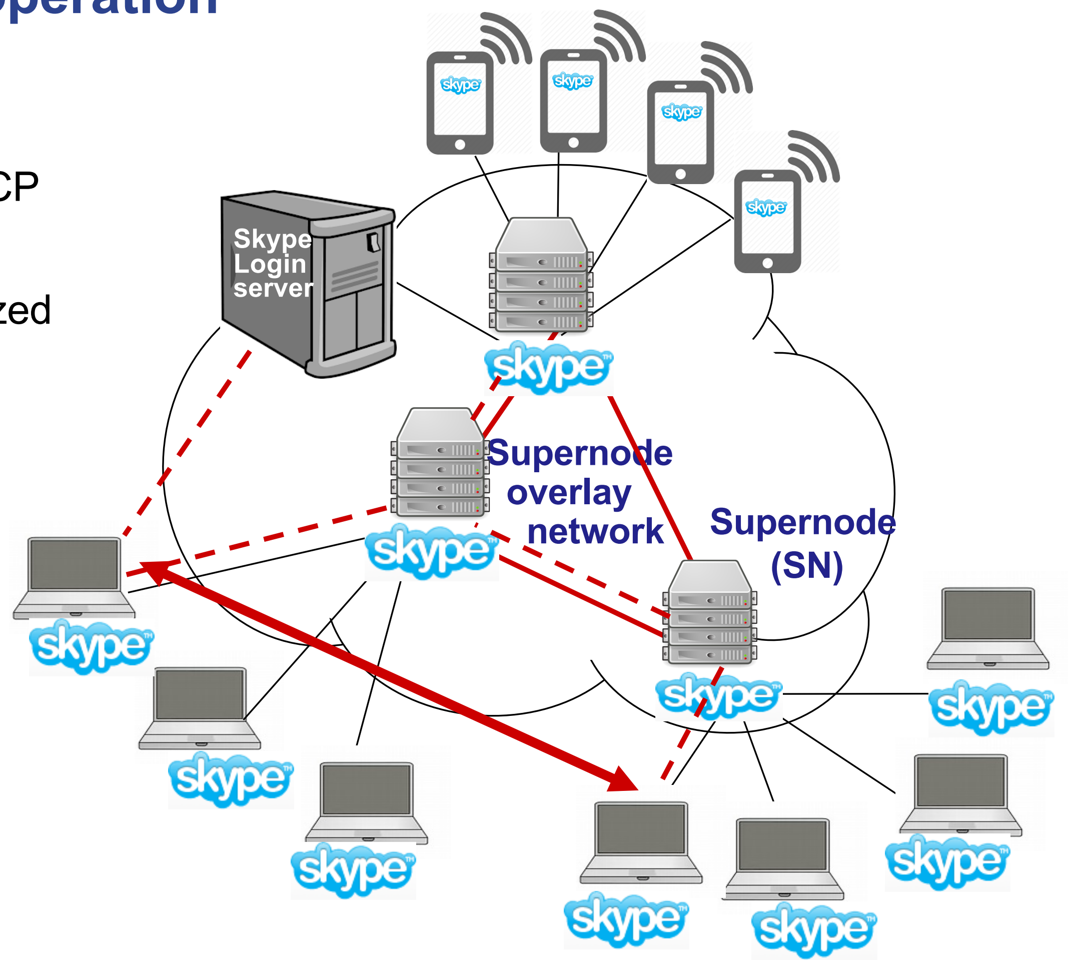
P2P voice-over-IP: Skype client operation

1. Joins Skype network by contacting SuperNode (IP address cached) using TCP

2. Logs-in (usename, password) to centralized Skype login server

3. Obtains IP address for callee from Super Nodes, SN overlay or client buddy list

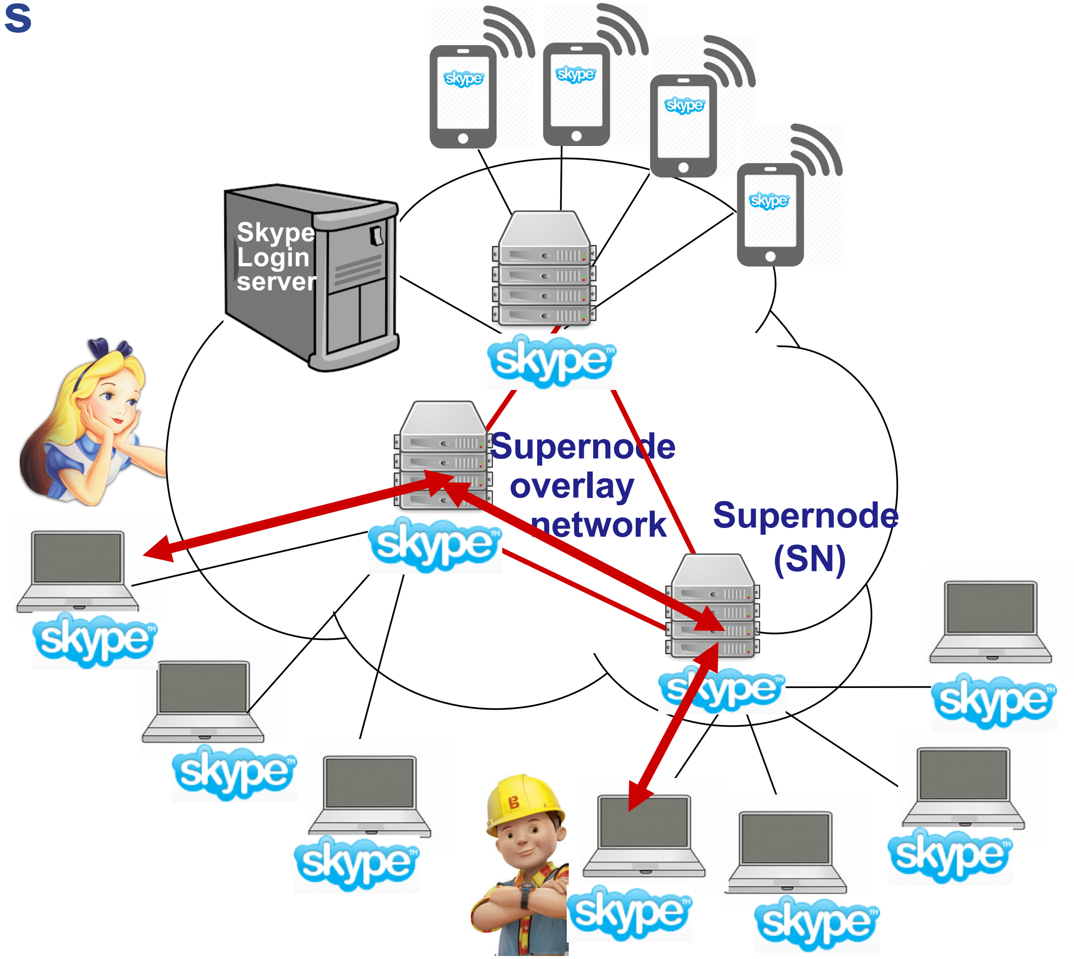
4. Initiate call directly to callee



NTNU

Relays to handle peers behind NATs

- NAT prevents an outside peer from initiating a call to insider peer
- Solution: a **relay** is chosen
- Alice, Bob maintain open connection to their SNs
  - Alice signals her SN to connect to Bob
  - Alice’s SN connects to Bob’s SN
  - Bob’s SN connects to Bob over open connection
    Bob initially initiated to his SN
- Peers can now communicate through NATs via relay



SkypeIn is out in Norway:

Topic: Microsoft *Follow via:*

Forget the conspiracy theories: Skype's supernodes belong in the cloud

***Summary:** Putting Skype's supernodes in the Microsoft datacentres is about improving performance and not appropriating bandwidth*

By Mary Branscombe for 500 words into the future | July 27, 2012 -- 13:52 GMT (06:52 PDT)

Follow @marypcbuk

Skype Won't Say Whether It Can Eavesdrop on Your Conversations

By Ryan Gallagher | Posted Friday, July 20, 2012, at 4:37 PM

Share 814 Like 1.6k Tweet 1,244 EMAIL PRINT COMMENT 23

Since Microsoft bought Skype, has the chat client started working more with law enforcement?

Photo by Justin Sullivan/Getty Images

Derfor ble SkypeIn lagt ned i Norge

Skypein fikk en kort visittid i Norge, noe som skyldes teletilsynets EU-tolkning av IP-telefonitjenester.

AV: HARALD BROMBACH , ANN KRISTIN BENTZEN | ANN KRISTIN BENTZEN | PUBLISERT: 25. JULI 2005 - 10:33

Arne Litleré, underdirektør i Post og teletilsynet, sier at de i prinsippet ikke har noe imot å gi Skype en egen nummerserie.

– Men dersom Skype tilbyr både SkypeOut og SkypeIn blir det å anse som en offentlig telefontjeneste, og da stiller vi visse krav, blant annet hva gjelder nødnumre, sier Litleré.

Tilsynet er også opptatt av at norske nummerserier er en begrenset ressurs som ikke fritt skal kunne selges på verdensmarkedet.

Skypes Norden-sjef Jonas Kjellberg beklager tilsynets vurdering, men aksepterer den.

http://www.digi.no/220005/derfor-ble-skypein-lagt-ned-i-norge

What Does Skype's Architecture Do?

07/26/2012 in Big Blog by Mark Gillett

In the last few days we have seen reports in the media we believe are inaccurate and could mislead the Skype community about our approach to user security and privacy. I want to clear this up.

At Skype, we continue to be humbled and grateful for the commitment to our product that we see from our truly global user community. We focus every day on building the best possible product for sharing experiences whenever people are apart. We want Skype to be reliable, fast, easy to use, and in most cases – free. It works for Moms and Dads, teachers, soldiers, kids and sisters, brothers, grandparents, lovers and old friends all over the world. Our growth during the last nine years shows we are on the right path, and to our entire community, we say "thank you." We are privileged to serve 250 million active users each month and support 115 billion minutes of person to person live communications in the last quarter alone. We believe that communication is a fundamental human need and that while we've been privileged with tremendous success we are just scratching the surface of the communications experiences that we plan to create.

Voice over IP over WiFi access – WiFi Tale

https://www.youtube.com/watch?v=WB4h9yrvEvE

Fordeler med WiFi Tale

- Forbedret innendørs taledekning
- Fungerer på alle WiFi-nett i Norge
- Du trenger ikke mobilsignal for å ringe og sende SMS, kun tilgang til et WiFi-nett
- Du ringer på vanlig måte, du trenger ingen app
- Sømløs overføring mellom WiFi Tale og 4G hindrer tapte anrop og samtalebrudd

Gjennom lydmuren med ny teknologi

30. september 2016 av Petter Gerner

Det er ikke bare professorer og studenter som ønsker å være i forkant av utviklingen ved NTNU. I flere måneder har NTNU IT testet WiFi Tale, en ny mobiltjeneste, for å bli kvitt dårlig innendørsdekning.

Aldri før har det vært bedre mobildekning i Norge, men aldri før har det vært bedre isolerte bygg heller. Bygningsmasse kan redusere mobilsignaler opptil hundre ganger, og spesielt mange bedrifter og institusjoner har slitt med dårlig innendørsdekning. Nå kan problemet være løst.

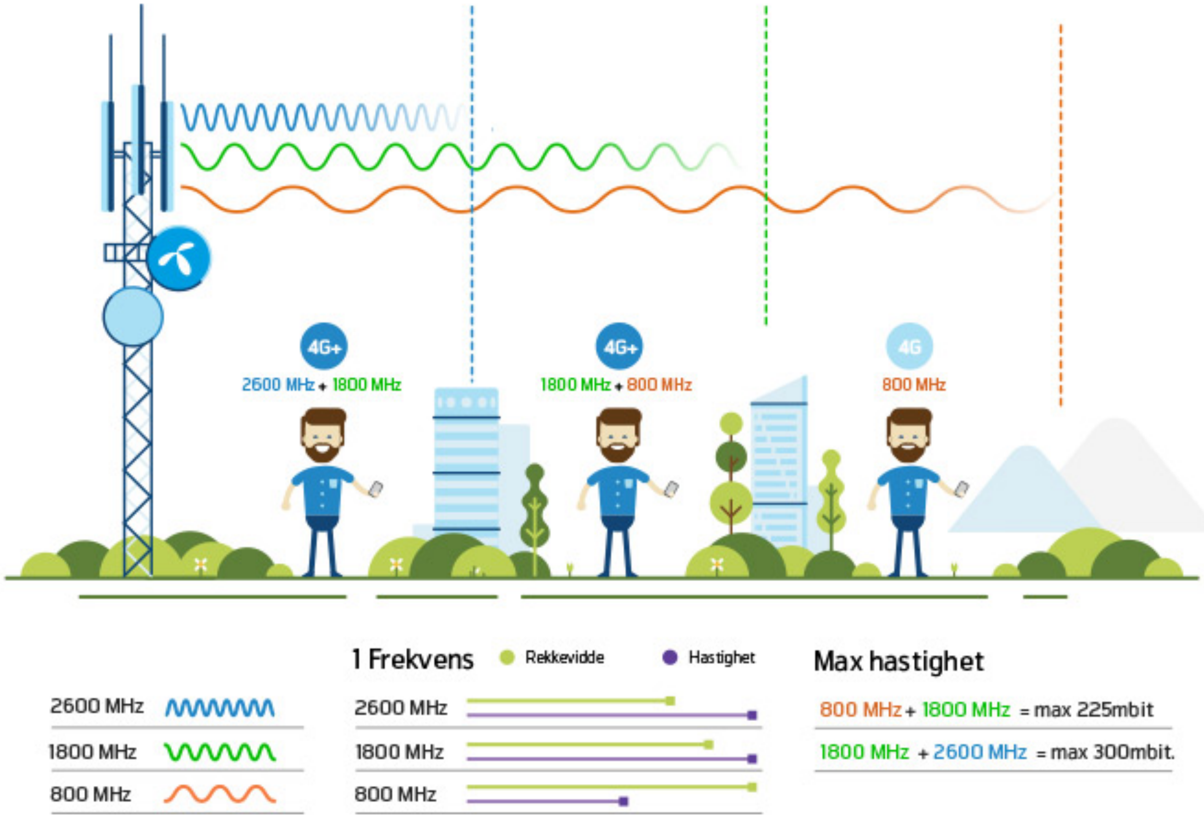
I februar startet NTNU IT å betateste en ny teknologi, WiFi Tale fra Telenor, som lar deg ringe og motta samtaler med mobilen via trådløse nett, helt uten bruk av apper eller andre programmer. Resultatet har vært over all forventning.

NTNU

Voice over IP over LTE access (VoLTE) – 4G Tale

- LTE has no circuit-switched bearer to support voice, so carrying voice over LTE requires a migration to a voice over IP (VoIP)

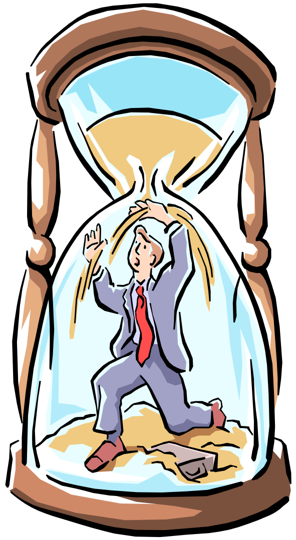
Dette er 4G Tale
- Lydinformasjonen sendes som datapakker
- Bedre dekning
- Raskere oppkoblingstid
- Lavere batteriforbruk
- Bedre samtalekvalitet



Source: Telenor

Summary internet multimedia

- Server side **matches stream bandwidth** to available client-to-server path bandwidth
  - chose among pre-encoded stream rates
  - dynamic server encoding rate
- **Content Distribution Network** brings content closer to clients
- Client-side **adaptive play-out delay** to compensate for delay
- **For time-sensitive traffic** use **UDP** to avoid TCP congestion control (delays)
- Error recovery (on top of UDP)
  - **FEC**, **interleaving**
  - **retransmissions**, time permitting



Summary, April 6 and 7

12	**NOTE:**	**No lecture from textbook in week 12 or 13.**			
12	Thursday 14:15 – 15:00	Theory Assignment 7: *Multimedia networking*	R1	Assistants/ Ida/Norvald	One must deliver and pass at least 5 of the 8 theory assignments.
12	**Friday 16:00**	**Deadline** for KTN2 - Project implementation		Assistants/ Magnus	Show project impl. to course assistants for approval, at P15.
13	Thursday 14:15 – 15:00	Theory Assignment 8: *Security in Computer Networks*	R1	Assistants/ Ida/Norvald	Tuition. One must deliver and pass at least 5 of the 8 theory assignments.
14	Thursday 12:15 – 14:00	Course Content Revisit	R1	Kjersti	
14	Friday 09:15 – 11:00	Course Content Revisit Information about Exam	R1	Kjersti Norvald	
21	22 May	Final exam, 09:00-13:00			