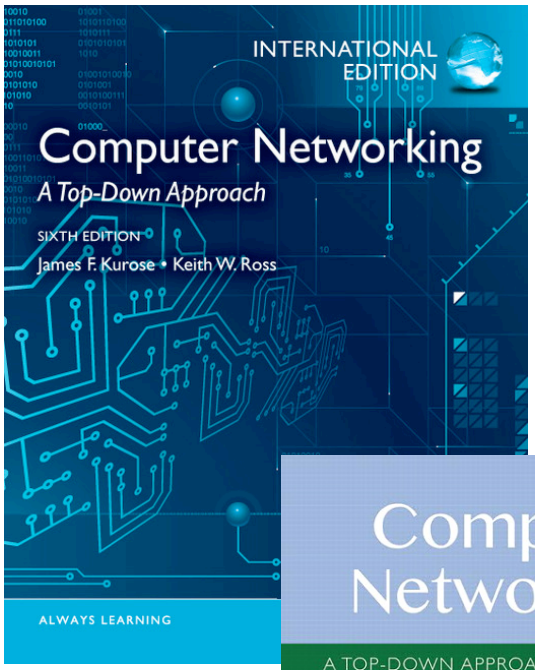
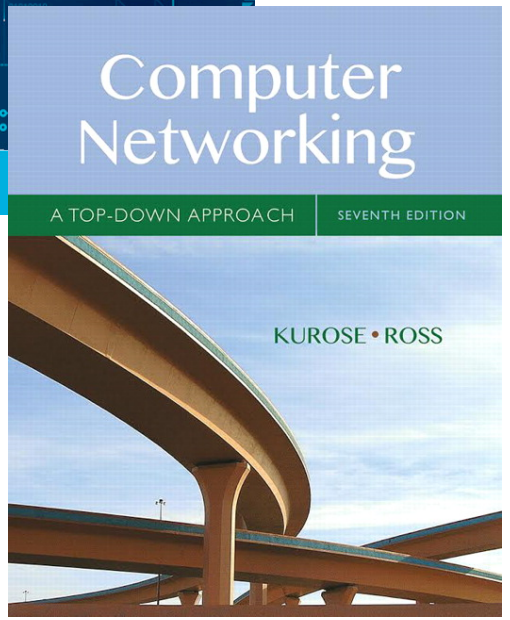
TTM4100
Communication - Services and Networks





Introduction
Chapter 1

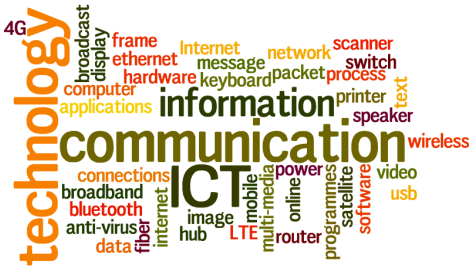
Kjersti Moldeklev, Prof II
kjmoldek@item.ntnu.no

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

Schedule

Week	Date & Time	Topic	Room	Responsible	**Remark (ref.to 6th edition)**
2	Thursday 12:15 – 14:00	Practical Information; Course Introduction Network and Internet Overview	R1	Norvald Kjersti	 Chapter 1 + brief introduction to Physical layer.
2	Friday 09:15 – 11:00	Network and Internet Overview (cont.)	R1	Kjersti	Chapter 1 Chapter 8.1
3	Thursday 12:15 – 14:00 Thursday 14:15 – 15:00	Application Layer Theory Assignment 1: *Overview of Computer Networks and the Internet* Wireshark Lab 1: *Intro (optional but highly recommended!)*	R1 R1	Kjersti Assistants/ Ida/Norvald	Chapter 2 One must deliver and pass at least 5 of the 8 theory assignments.
3	Friday 09:15 – 11:00	Application Layer (cont)	R1	Kjersti	Chapter 2 Chapter 8.2-3 and 8.5.1

Introduction gives an overview, more details to follow in later lectures…



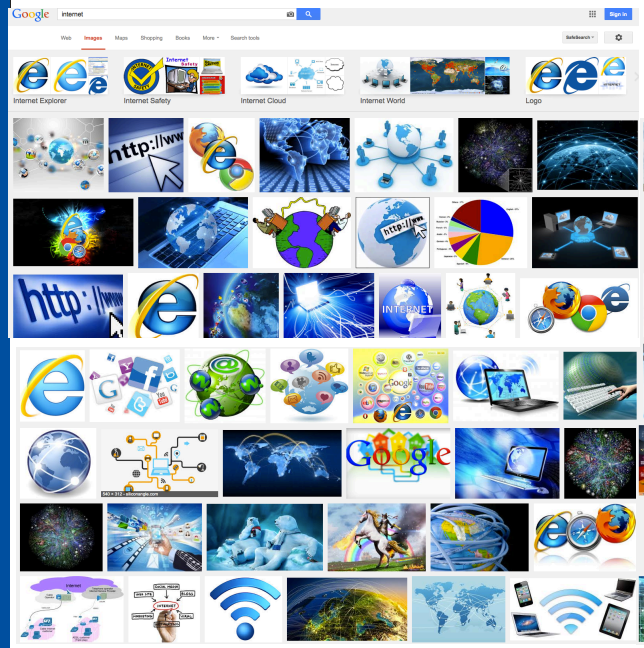
Goal:

- get "the feeling" and terminology
- being a knowledgeable home-network administrator

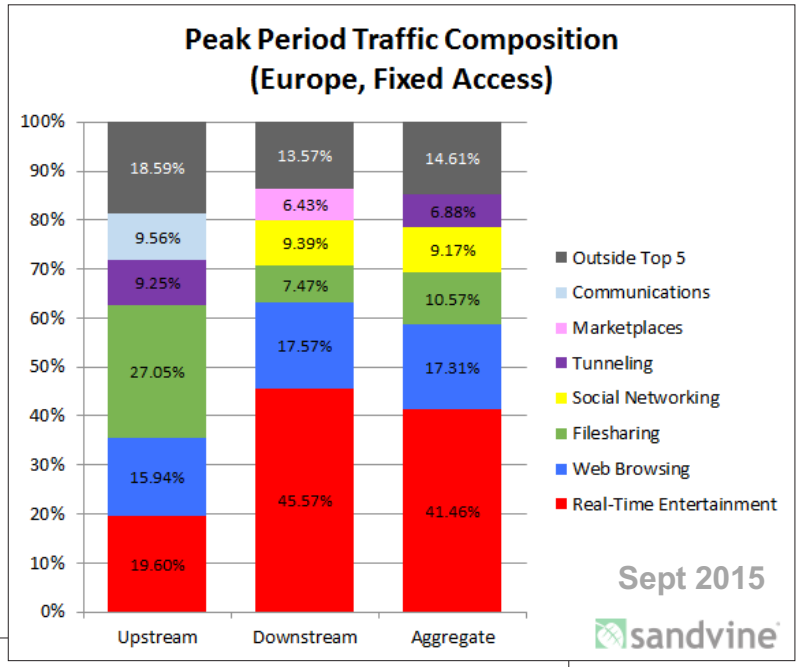
- Approach:
  use Internet as example

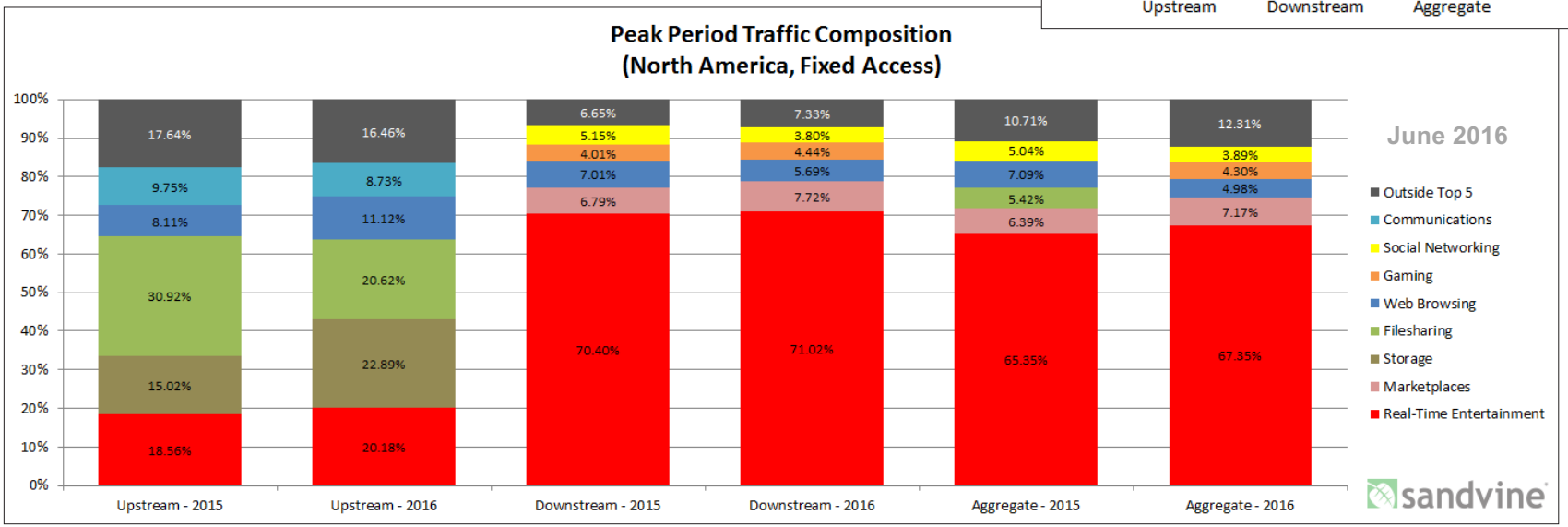
- what's the Internet?
- what's a protocol?
- the network edge vs the network core
- performance: loss, delay, throughput
- protocol layers, service models
- security
- history

What´s the Internet – search engine images view



Entertainments over the internet dominates the traffic volume





Top 10 peak period applications - US

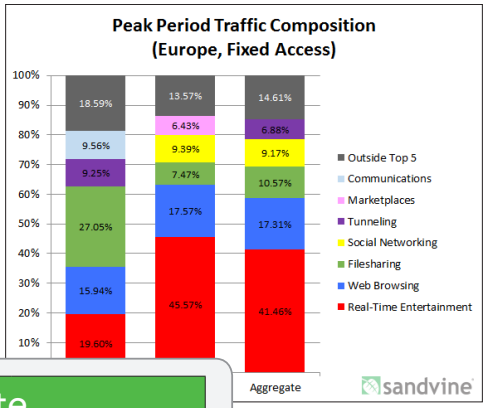
Sept 2015

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

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

Top 10 peak period applications - Europe

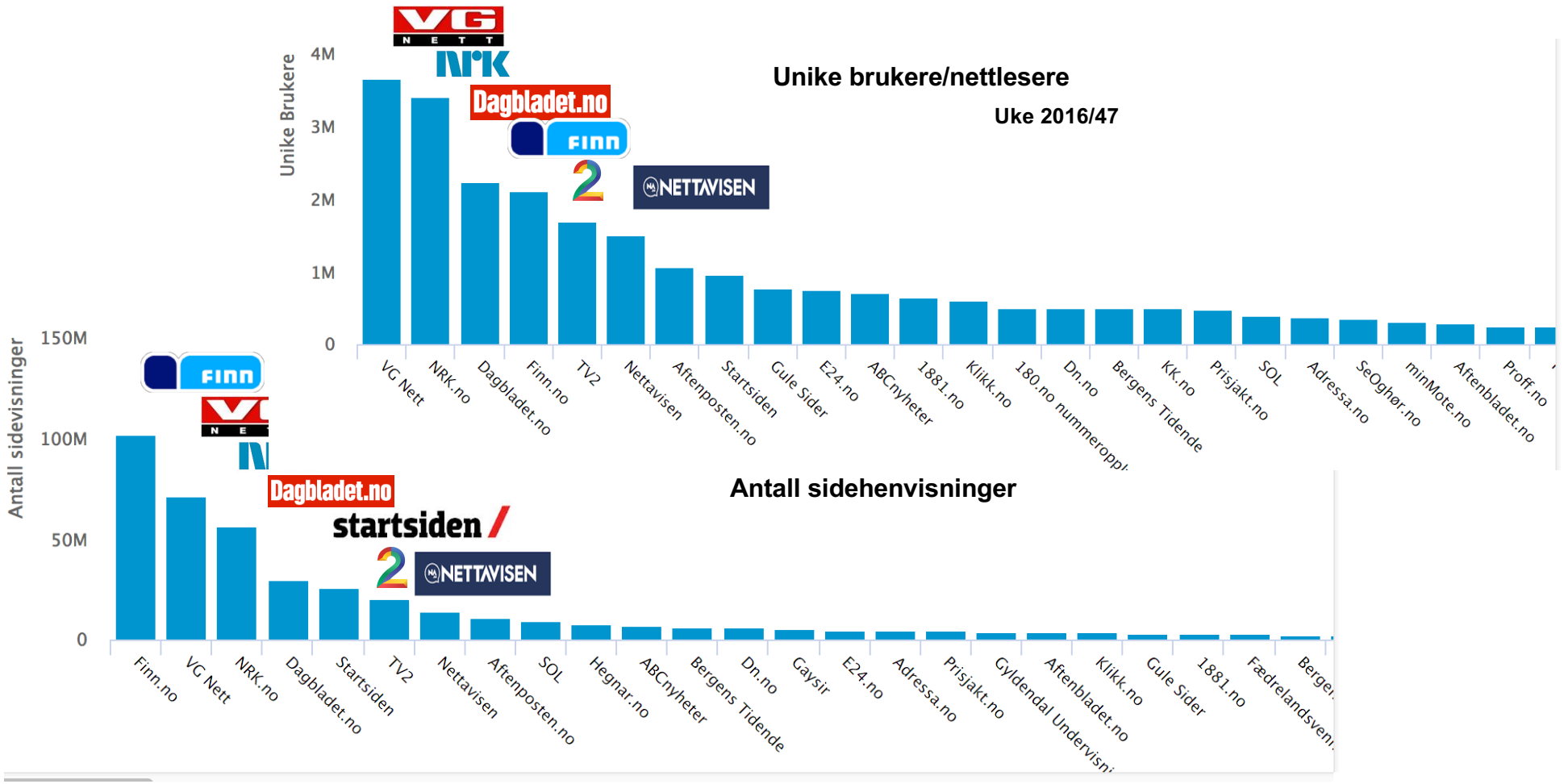


Sept 2015

	Upstream		Downstream		Aggregate	
Rank	Application	Share	Application	Share	Application	Share
1	BitTorrent	21.08%	YouTube	24.44%	YouTube	21.16%
2	HTTP	12.53%	HTTP	15.39%	HTTP	14.94%
3	YouTube	7.51%	Facebook	7.56%	BitTorrent	8.44%
4	SSL - OTHER	7.43%	BitTorrent	6.07%	Facebook	7.39%
5	Facebook	6.49%	SSL - OTHER	5.51%	SSL - OTHER	5.81%
6	Skype	4.78%	Netflix	4.82%	Netflix	4.18%
7	eDonkey	3.67%	MPEG - OTHER	3.82%	MPEG - OTHER	3.51%
8	MPEG - OTHER	1.89%	iTunes	2.24%	iTunes	2.03%
9	Apple iMessage	1.70%	Flash Video	1.85%	Skype	1.78%
10	Dropbox	1.44%	Twitch	1.65%	Flash Video	1.59%
		68.54%		73.35%		70.84%

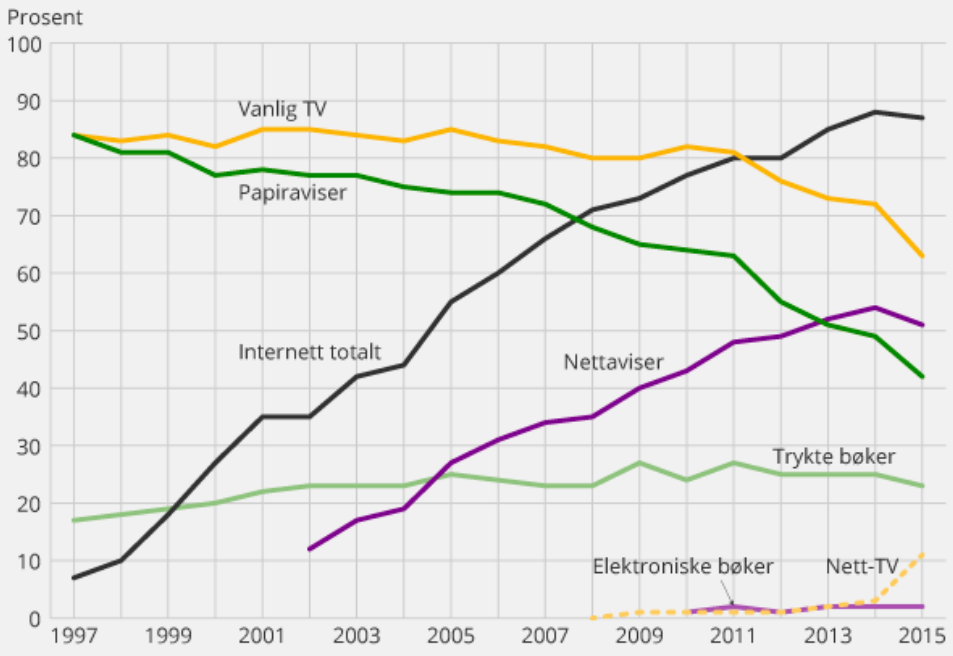
sandvine

Top Norwegian web sites



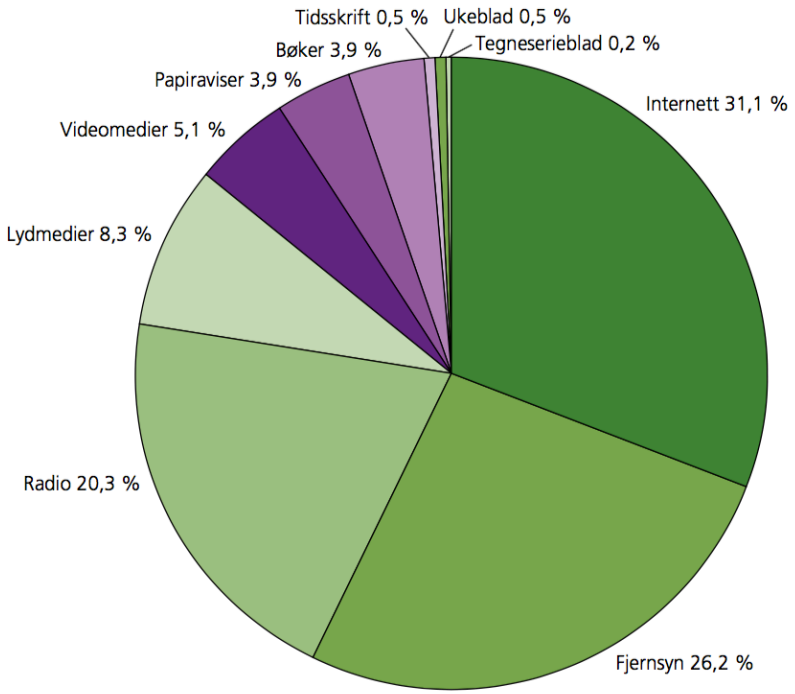
Medietilgang og -forbruk

Figur 2. Andel med tilgang til elektroniske medier



Kilde: Statistisk sentralbyrå.

. Andel av tid brukt til massemedier en gjennomsnittsdag som går med til ulike medier. 2015



SSB, Norsk Mediebarometer 2015

Fra lineær mot strømming

Når Get og Canal Digital lar deg velge bort TV-kabelen og beholde internett, vil TV-konsumet endres raskt og permanent

KOMMENTAR: Er vi langt unna «The tipping point» for lineær TV-seeing? Nei, tror innsiktsrådgiver Tor-Aksel Ødegård i IUM.

INNSENDT | **PUBLISERT:** 24. AUG. 2016 - 11:44

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BEST PICKS

Best Movie and TV Streaming Sites of 2017

The Modern Age of Television

Services / Entertainment / Movie and TV Streaming Sites Review

Author by TopTenReviews Contributor

LATEST UPDATE January 04, 2017

Summary

View Standard Lineup »

Featured								
Amazon Prime Video	Netflix	Hulu	HBO NOW	YouTube	VUDU	Google Play	FandangoNOW	iTunes
Review	Review	Review	Review	Review	Review	Review	Review	Review
Visit Site	Visit Site	Visit Site	Visit Site	Visit Site	Visit Site	Visit Site	Visit Site	Visit Site

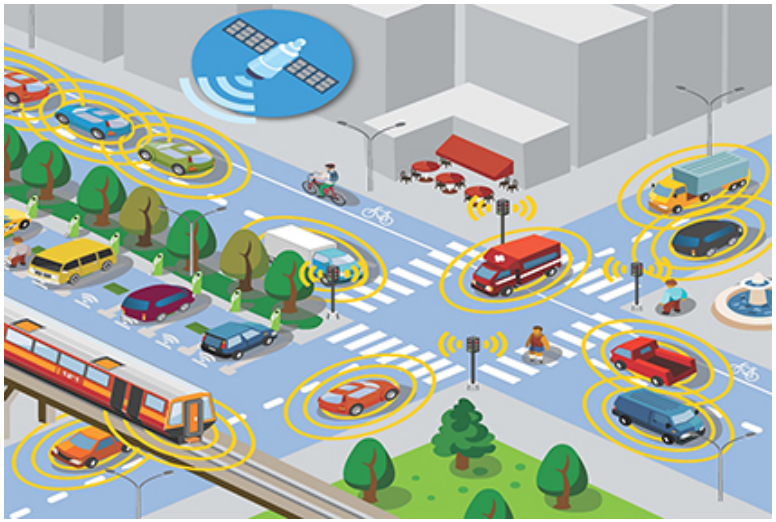
Glem DAB-maset, bruk nettradio i bilen

Mobilen er løsningen.

Artikkel skrevet av: Snorre Bryne
Sist oppdatert 08. april 2016

http://www.online.no/forbruker/nettradio-like-bra-som-dab-i-bilen.jsp

Internet of things



SHODAN FINDS COMPUTERS

FROM WEB SERVERS TO INDUSTRIAL CONTROL SYSTEMS TO REFRIGERATORS AND ANYTHING ELSE CONNECTED TO THE INTERNET.

FREE SIGN UP

Or login using Google twitter facebook

Frequently Asked Questions

General

What ports does SHODAN index?

The majority of data is collected on web servers at the moment (port 80), but there is
Telnet (21) services. There are plans underway to expand the index for other services. Le
like to see included.

Can I help out?

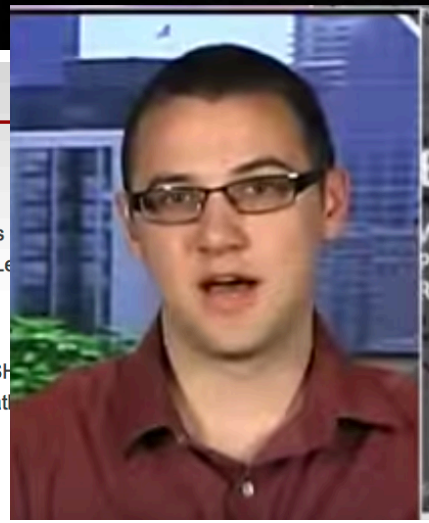
Yes and no. Currently, there's no way to directly upload your own banner data to SH
accuracy and preventing abuse, I haven't added such a system yet. But I would greatl
alive and growing. All contributions are much appreciated and make a big difference.

What is CIDR notation?

Check out what the nice folks at **Wikipedia** have written on the topic.

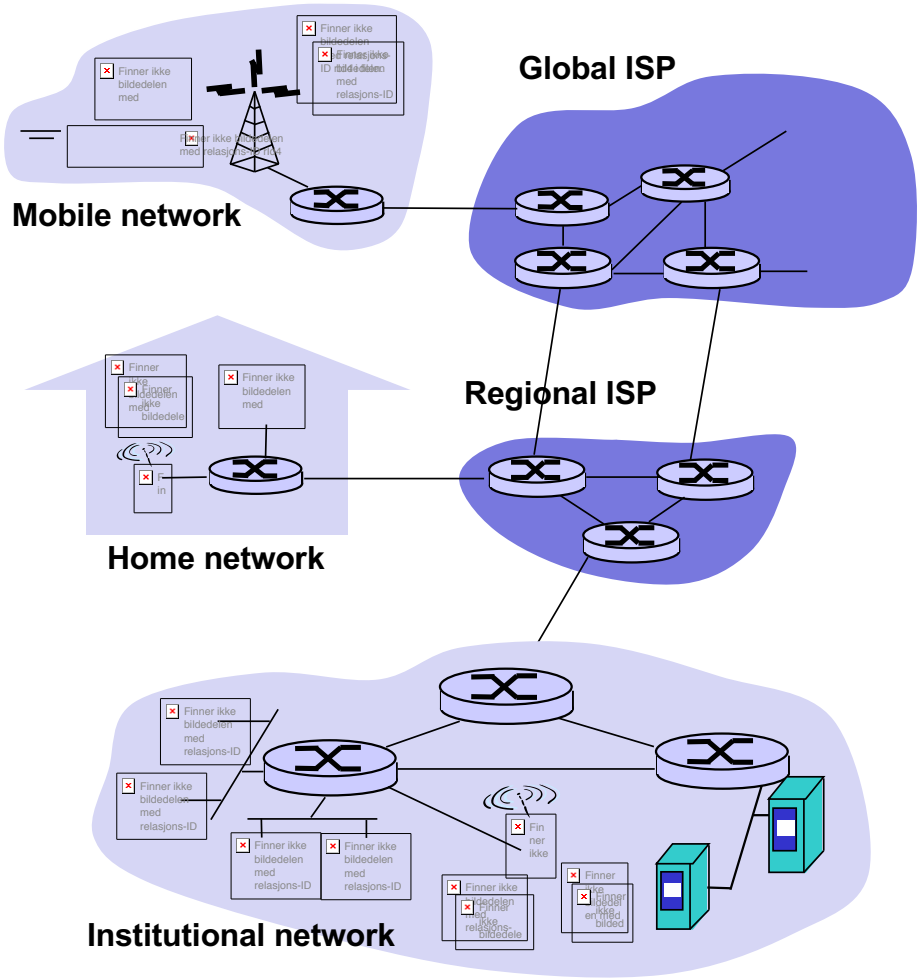
What port scanner are you using?

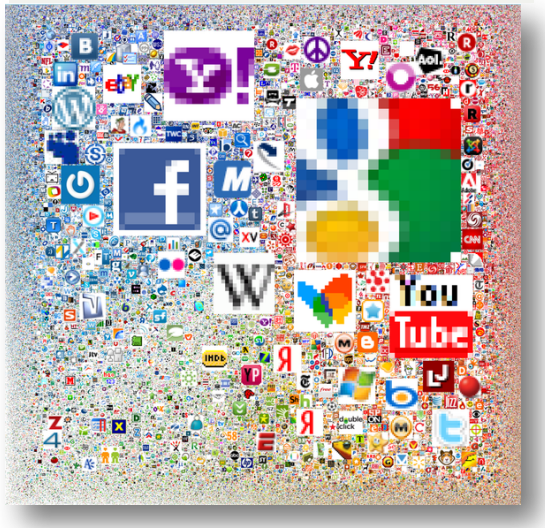
A home-grown, distributed port scanner was developed for this project.



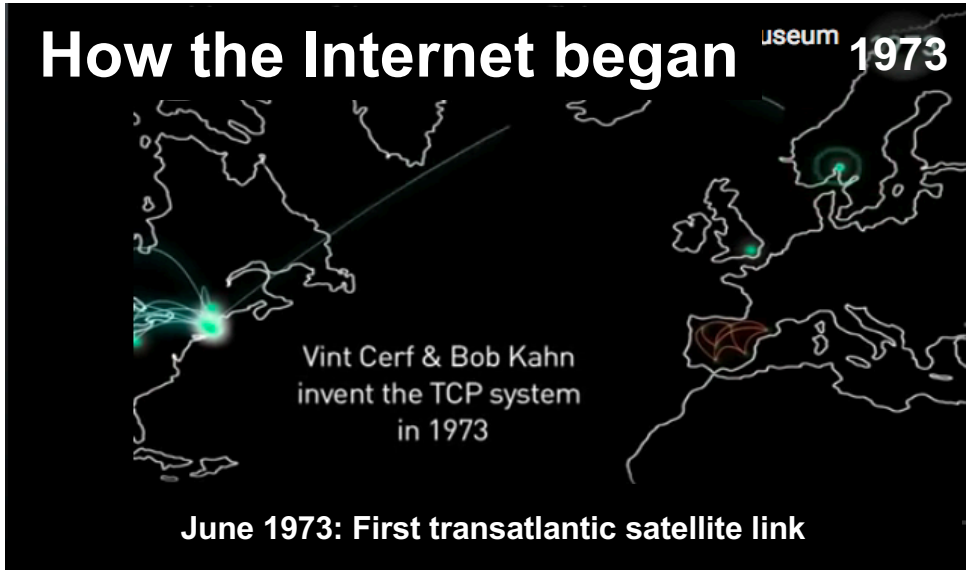
https://www.youtube.com/watch?v=6Ct9WCxenGo

Internet – a network of computer networks enabling a variety distributed applications in the end systems

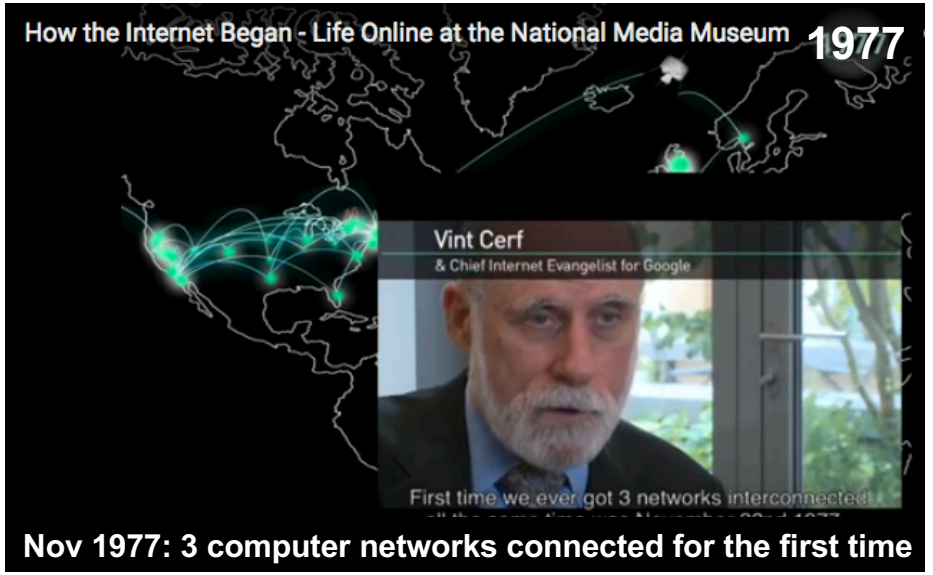




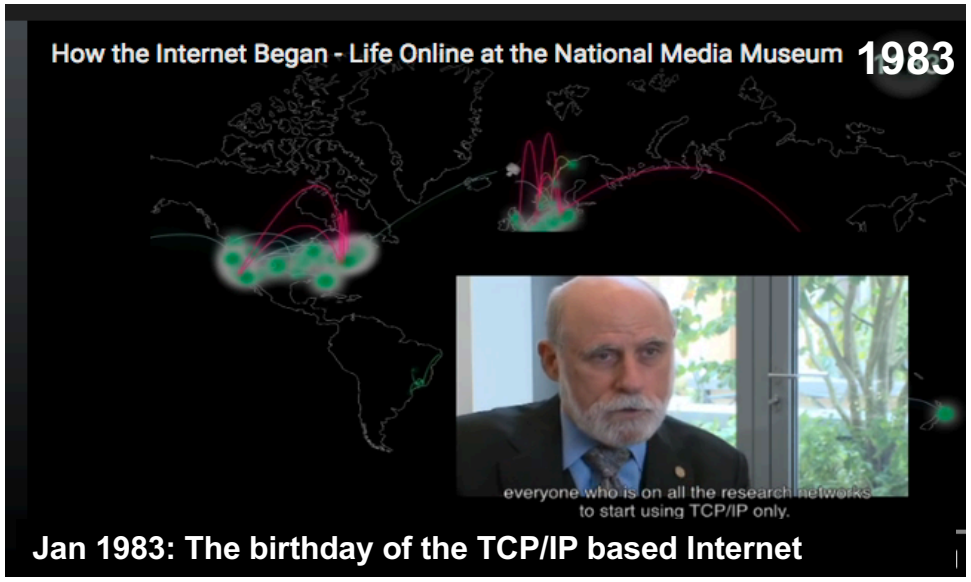
Source: http://www.huffingtonpost.com/2012/08/09/most-popular-sites-2012-alexa_n_1761365.html



June 1973: First transatlantic satellite link



Nov 1977: 3 computer networks connected for the first time



Jan 1983: The birthday of the TCP/IP based Internet

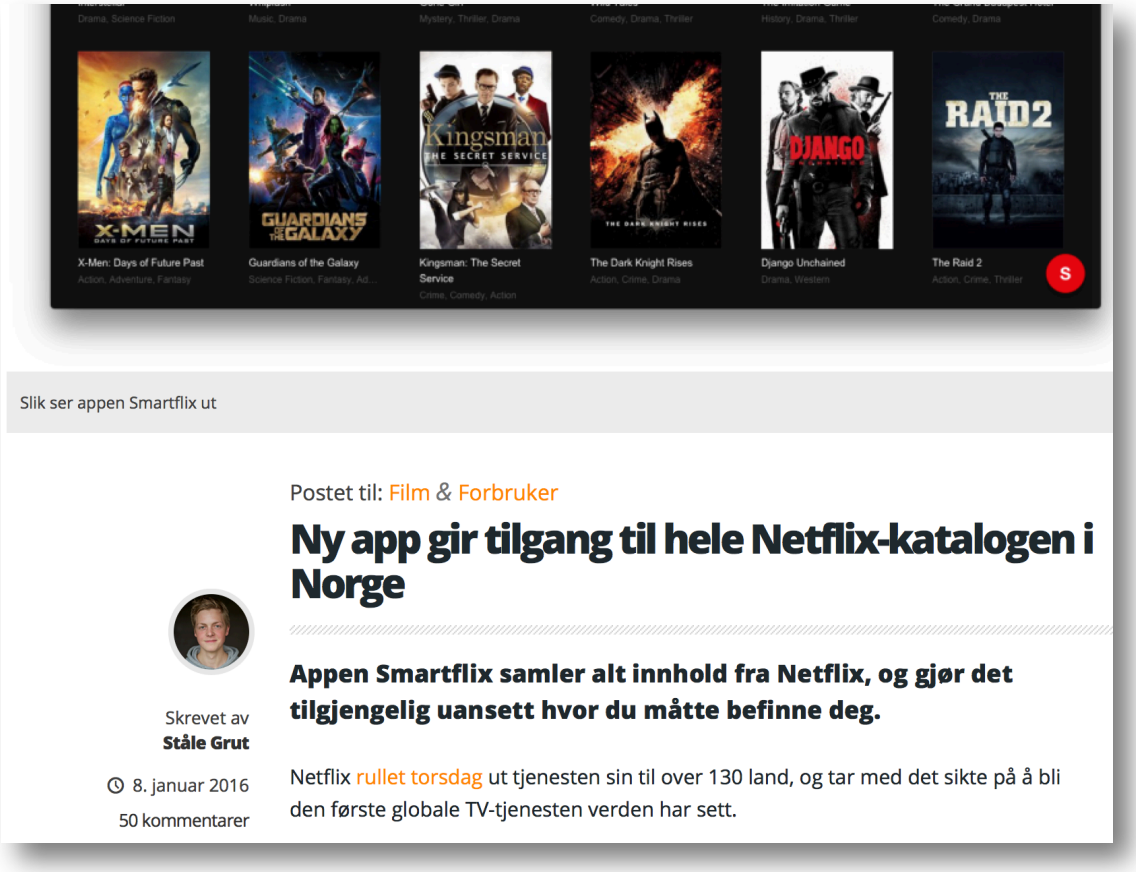
Mid ´90ies: world wide expansion, and thanks to TCP/IP Internet is what it is today

http://www.internet-history.info/media-library/mediaitem/550-how-the-internet-began.html

Hvordan kan (sofistikerte) aktører utnytte sårbarheter?

Figur 7.1 Det har vært en økning i antall registrerte hendelser. Den kraftige økningen i fjerde kvartal 2014 skyldes et målrettet angrep mot olje- og gassektoren.

Hvilken funksjonalitet ligger bak?



Slik ser appen Smartflix ut

Postet til: Film & Forbruker

Ny app gir tilgang til hele Netflix-katalogen i Norge

Skrevet av
Ståle Grut

8. januar 2016

50 kommentarer

Appen Smartflix samler alt innhold fra Netflix, og gjør det tilgjengelig uansett hvor du måtte befinne deg.

Netflix rullet torsdag ut tjenesten sin til over 130 land, og tar med det sikte på å bli den første globale TV-tjenesten verden har sett.

Dagbladet mottar European Press Prize

For avsløringen av dårlig datasikkerhet gjennom artikkelserien «Null CTRL».

AXEL DUE
axel.due@dagbladet.no
PÅL NORDSETH
pno@dagbladet.no

mandag 17. mars 2014, kl.14:39

Tweet

Null CTRL

ÅPENT KAMERA: Kameraet på utestedet Klubbteateret i Drammen sendte videostrømmen rett på nett. Video: Øistein Norum Monsen/Dagbladet

(Dagbladet): Tenk deg at du kan styre naboens web-kamera, åpne konkurrentens database eller ta kontrollen over vitale styringssystemer med et tastetrykk.

I en serie artikler avslører Dagbladet hvor enkelt det lar seg gjøre.

Journalistene Linn Kongsli Hillestad og Espen Sandli har sammen med utvikler Ola Strømman testet alt fra overvåkingskameraer til databaser og kontrollsystemer som ligger åpent på Internett.

Så langt har de avdekket:

- 2048 overvåkningskameraer i Norge ligger tilgjengelig på nett
- Disse finnes i private hjem, nattklubber, butikker og restauranter
- Over 2500 styringssystemer er koblet til nett, med minimal eller ingen sikkerhet
- 500 av disse kontrollerer industriell eller samfunnskritisk infrastruktur
- Flere tusen databaser og servere gir deg alt innhold - uten å taste et eneste passord.

Amatører

- Vi startet enkelt: «Hva kan personer uten spisskompetanse på datasikkerhet eller hacking finne åpent på nett?» Da vi begynte, ante vi ikke at det skulle bli så omfattende og med så mange funn av kritisk informasjon, sier journalist Espen Sandli.

- Det skrives mange saker i Norge og andre land om potensielle farer på nettet. Vi ønsket å gå lenger enn det. Vi ville vise helt konkret hva det er som svikter, hvor det er og hvilke konsekvenser det reelt kan få, sier Hillestad.

Dagbladet har i løpet av prosjektet undersøkt 535 320 unike norske IP-adresser og 707 358 åpne porter

- Det som er skremmende, er hva journalister i Dagbladet uten spesielle datakunnskaper er i stand til å finne. Hva da med statsmakter, organiserte kriminelle og hackere, spør seniorrådgiver Vidar Sandland i Norsk Senter for Informasjonssikring (Norsis).

http://www.dagbladet.no/2013/10/23/nyheter/innenriks/datasikkerhet/nullctrl/27898511/

Roadmap

1.1 What is the Internet?

1.2 Network edge

- access networks, physical media

1.3 Network core

- packet switching, circuit switching, network of networks

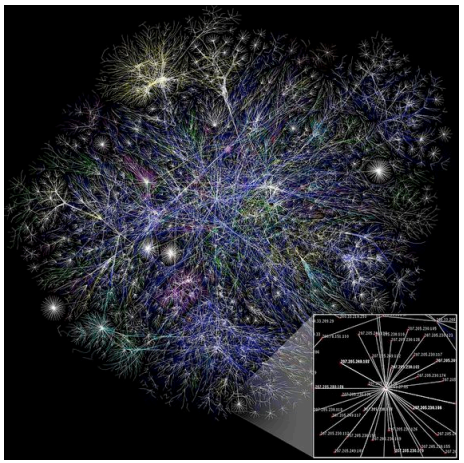
1.4 Packet-switched networks

- delay, loss and throughput

1.5 Protocol layers and service models

1.6 Security: networks under attack

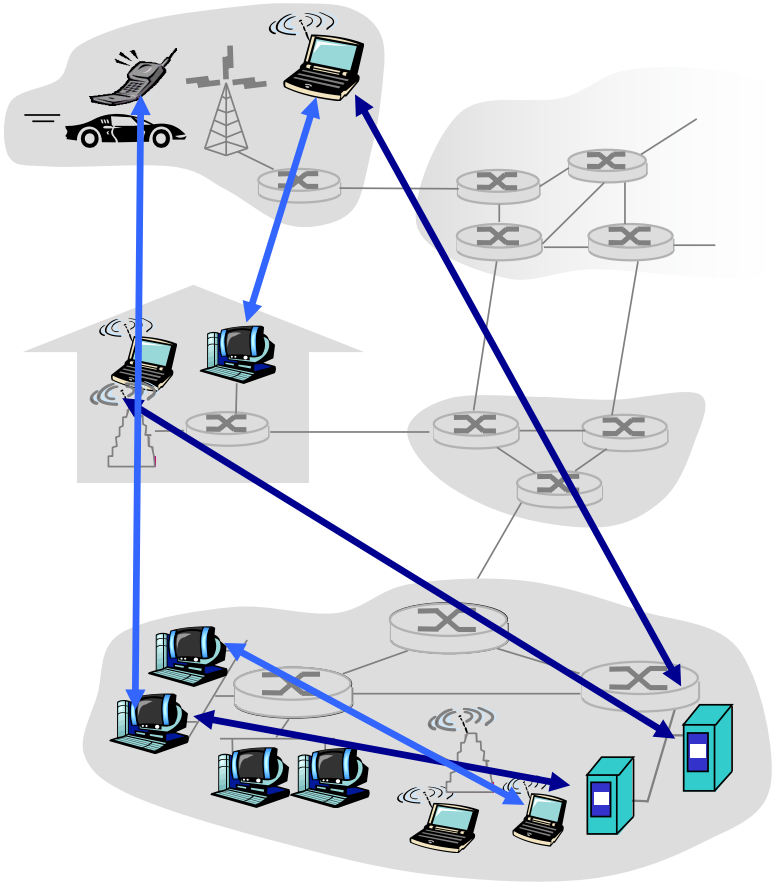
1.7 History of computer networking and the Internet



http://www.huffingtonpost.com/billrobinson/americas-internet-giveawa_b_5173318.html

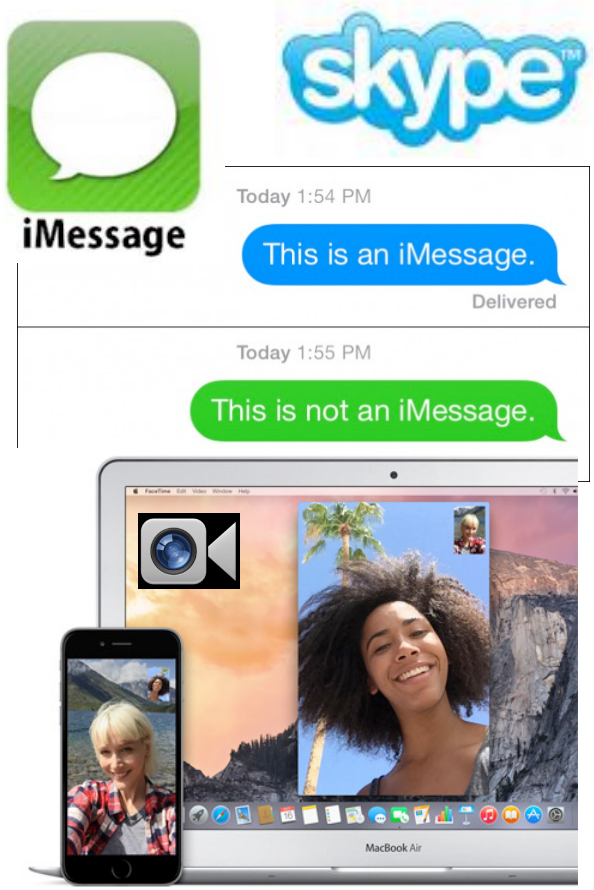
Applications run in the end systems of the network edge

- **Client/server model**
  - client host requests, receives service from always-on server
  - e.g. web browser/server
- **Peer-peer model**
  - minimal (or no) use of dedicated servers
  - e.g. BitTorrent



What is the internet?

Client-server or peer-to-peer?



Spotify™

Google Hangouts

Data rate requirements for common applications

Application	Data rate
Voice call (low quality)	3 kilobits/second
Voice call (medium quality)	30 kilobits/second
Voice call (high quality)	90 kilobits/second
MP3 music (standard quality)	128 kilobits/second
MP3 music (high quality)	256 kilobits/second
Television (low quality)	1 megabits/second
Television (standard definition)	2 megabits/second
Television (1080i high definition)	5 megabits/second
Telemedicine	10 megabits+/second

But data rate is not the only performance requirement

Source: Spectrum handbook 2013 http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2286901

Cloud services – the more advanced the higher the requirements on network performance

Basic Cloud Apps Concurrent Support	Intermediate Cloud Apps Concurrent Support	Advanced Cloud Apps Concurrent Support
Network Requirements: Download Speed: 1900 kbps Upload Speed: 600 kbps Latency: Above 160 ms	**Network Requirements:** Download Speed: 1901–20,999 kbps Upload Speed: 601–8,999 kbps Latency: 159–100 ms	**Network Requirements:** Download Speed: 21,000 kbps Upload Speed: 9,000 kbps Latency: Less than 100 ms
• Stream basic video/music • Text communications • VOIP • Web browsing • Web conferencing • Cloud based learning management system	• SD Video conferencing • Personal content locker • HD Video streaming • Electronic health records • ERP/CRM • VoLTE	• Virtual office • Connected medicine • HD Video conferencing • Stream ultra HD video • High frequency stock trading • Connected car safety applications

Back to Index

Nettverksytelse – Hva forteller dette egentlig?

#	Abonnement	Nedlasting	Opplasting	Svartid	Målinger
1	Altibox Fiber 500/500	502.83 Mbit/s	470.9 Mbit/s	11.58 ms	53
2	Canal Digital 500/50	500.24 Mbit/s	49.27 Mbit/s	9.12 ms	106
3	HomeNet Fiber 500/500	484.36 Mbit/s	491.39 Mbit/s	1 ms	60
4	Altibox Fiber 300/300	287.24 Mbit/s	272.29 Mbit/s	10.94 ms	558
5	Get XL kabel-TV 250/20	244.64 Mbit/s	20.17 Mbit/s	9.38 ms	52
6	Altibox Fiber 150/150	151.32 Mbit/s	144.85 Mbit/s	8.53 ms	454
7	Get L kabel-TV 150/15	147.54 Mbit/s	24.01 Mbit/s	11.12 ms	168
8	Bofiber 100Mbit	107.46 Mbit/s	153.51 Mbit/s	7.35 ms	86
9	Eidsiva Fiber 100/100	101.13 Mbit/s	97.16 Mbit/s	12.76 ms	45
10	Canal Digital 100/30	97.16 Mbit/s	22.69 Mbit/s	14.9 ms	4168

Nettfart.no

Roadmap

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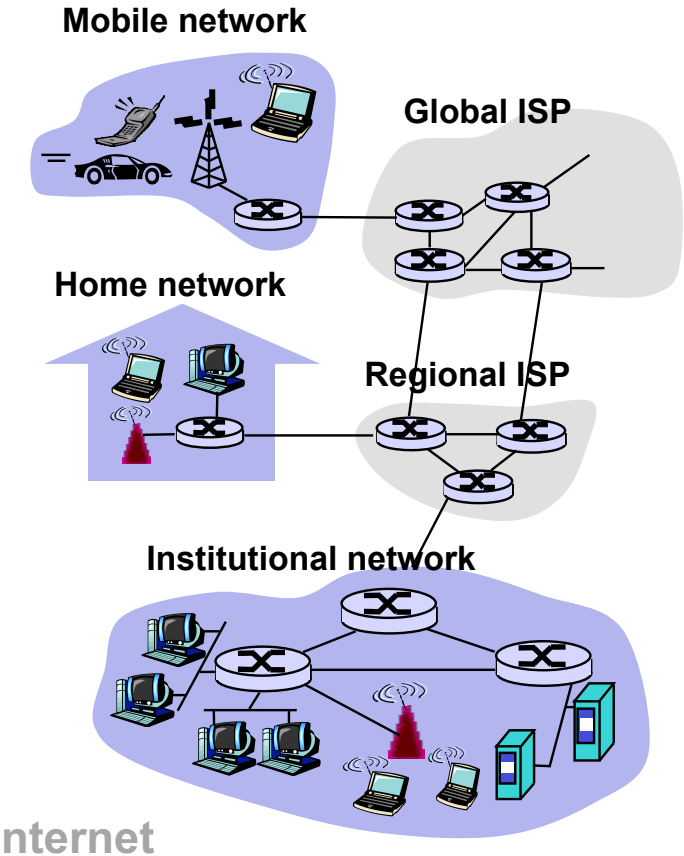
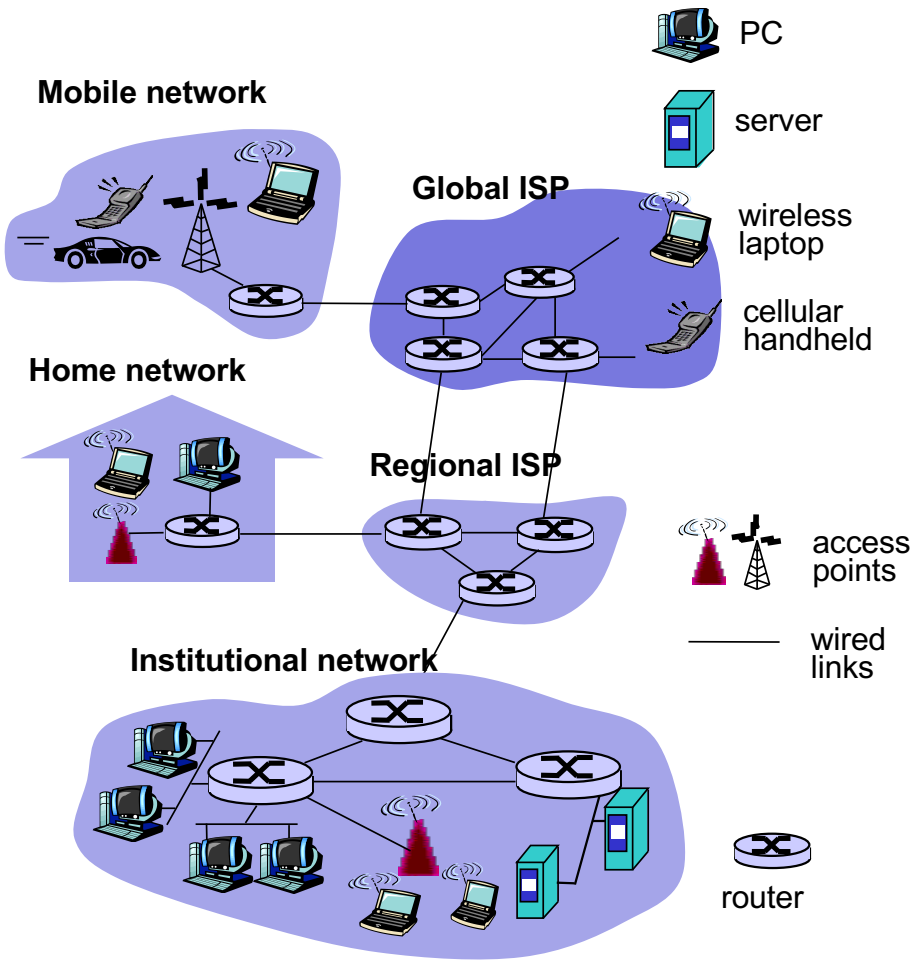


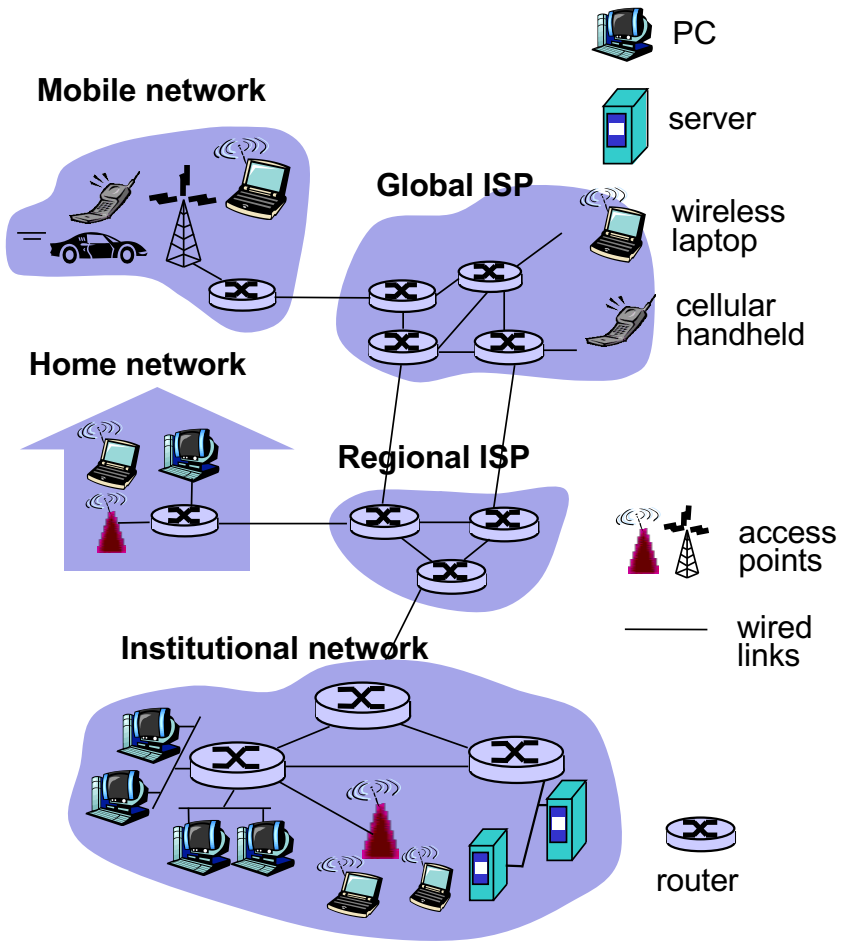
A closer look at network structure

- **Network edge**
  - applications (e.g. web, email)
  - Computing devices:
    hosts = **end systems**
    running network apps
    (e.g. PC, mobile, xbox)
- **Access networks**
  - physical media: wired,
    wireless communication links
- **Network core**
  - interconnected routers
  - network of networks



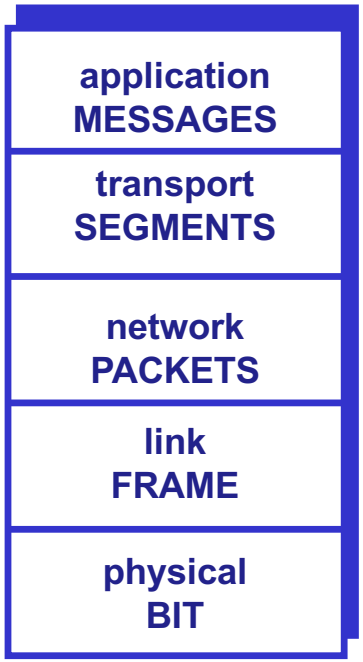
The InterNET: network structure = component view

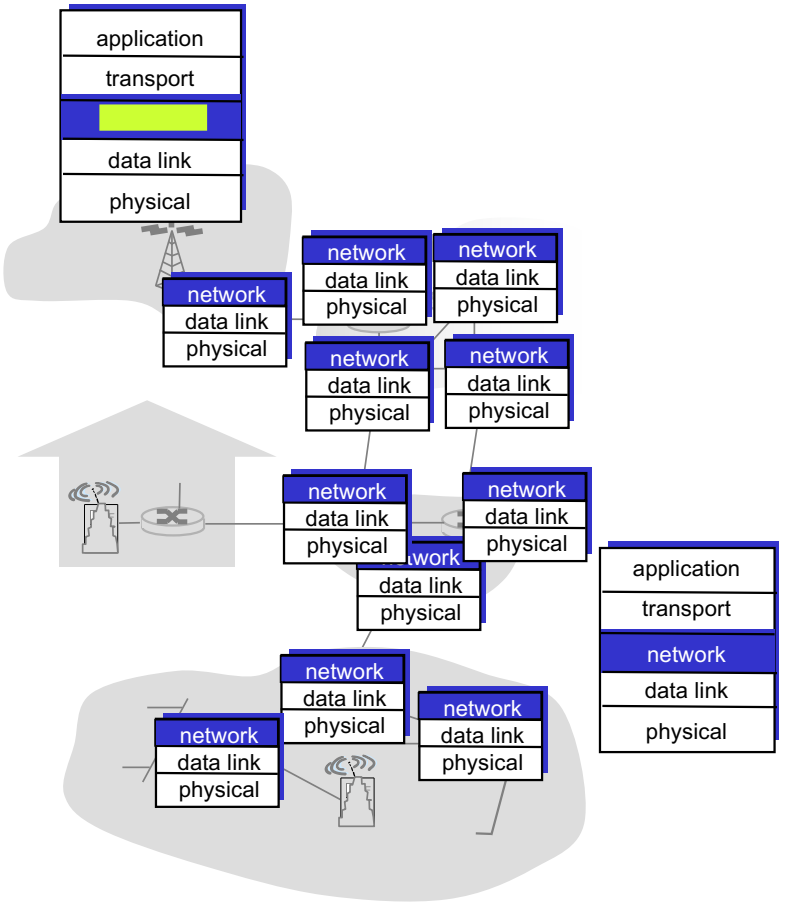
- **Communication links**
  - fiber, copper, radio, satellite
- Transmission rate = **bandwidth**
- **Routers:** forward packets
- **Packets**: chunks of data



Communication protocols send user messages as network packets between sender and receiver

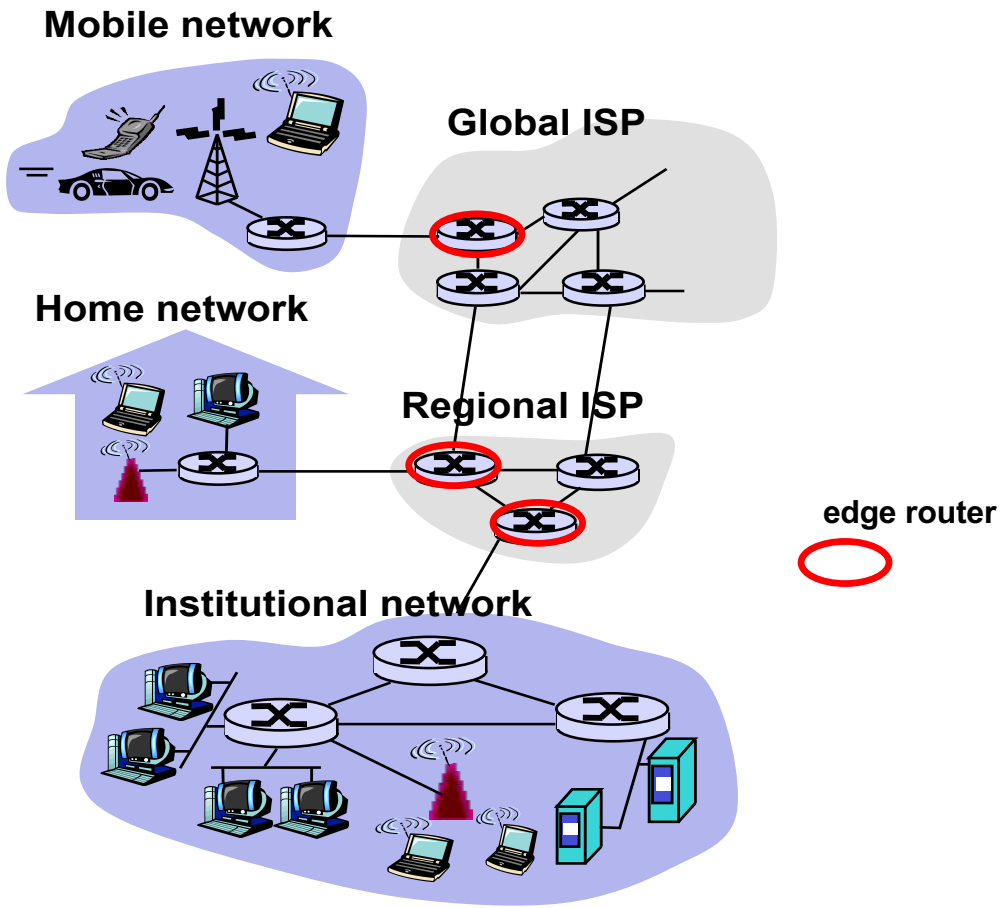
5-layer internet protocol stack





Access networks (wire line, wireless) connect end systems to edge routers

- **Bandwidth** (bits per second) of access network depends on shared or dedicated
- **Radio access** networks
- **Residential/Home access** networks
- **Institutional access** networks (school, company) (typically ethernet)



Wireless access through radio networks of local or wide-area reach

- Shared wireless access network connects end system to router via base station or “access point”

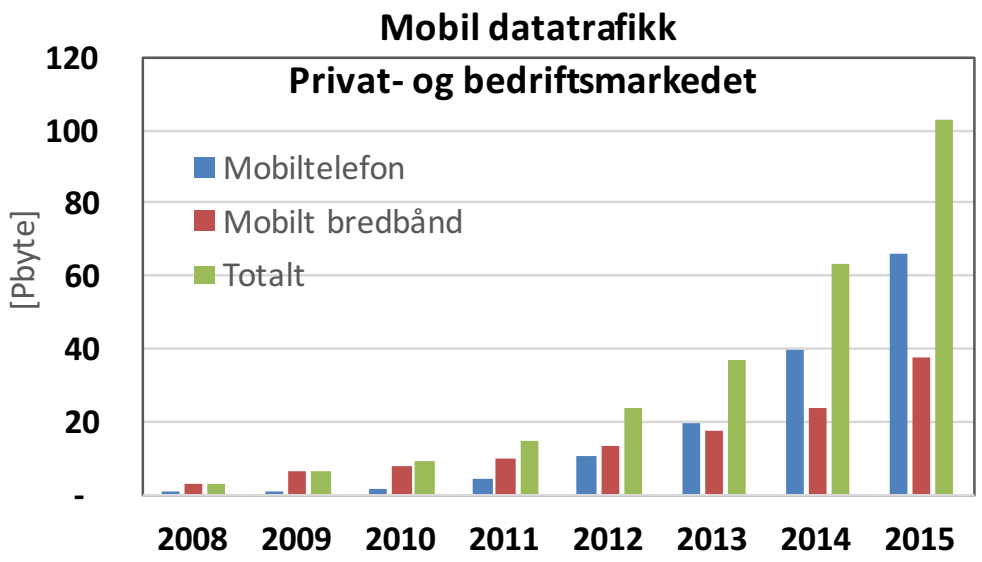
Wireless LANs (WLAN)

- within building < 30 m
- 802.11b/g/a/n (WiFi): 11/54/>100 Mbps

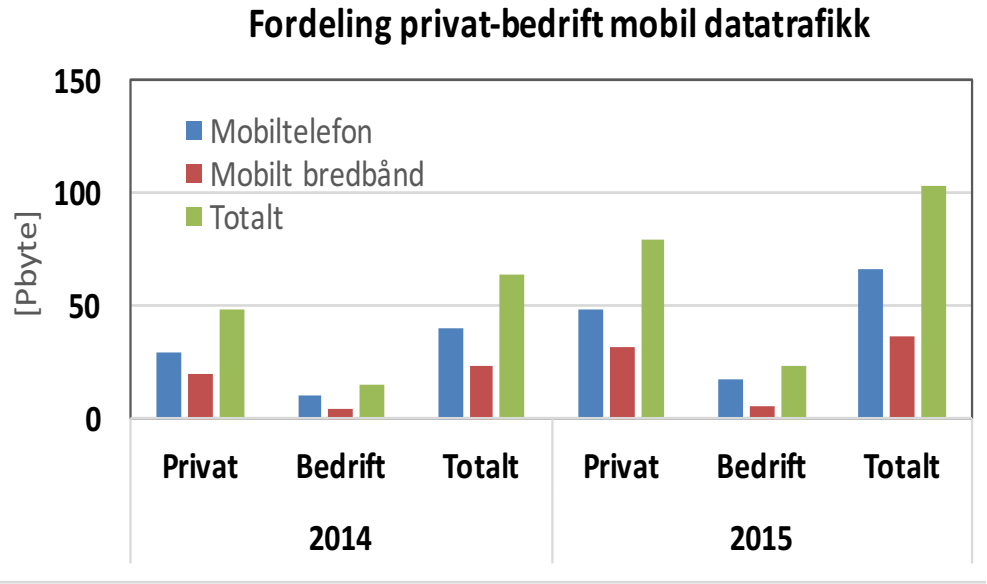
Mobile broadband –
wider-area radio access

- access provided by telco/cellular operator
- 10´s of km
  0,2 - 100 Mbps (Edge, UMTS/WDMA, HSPA, LTE)

Mobil datatrafikk er sterkt voksende



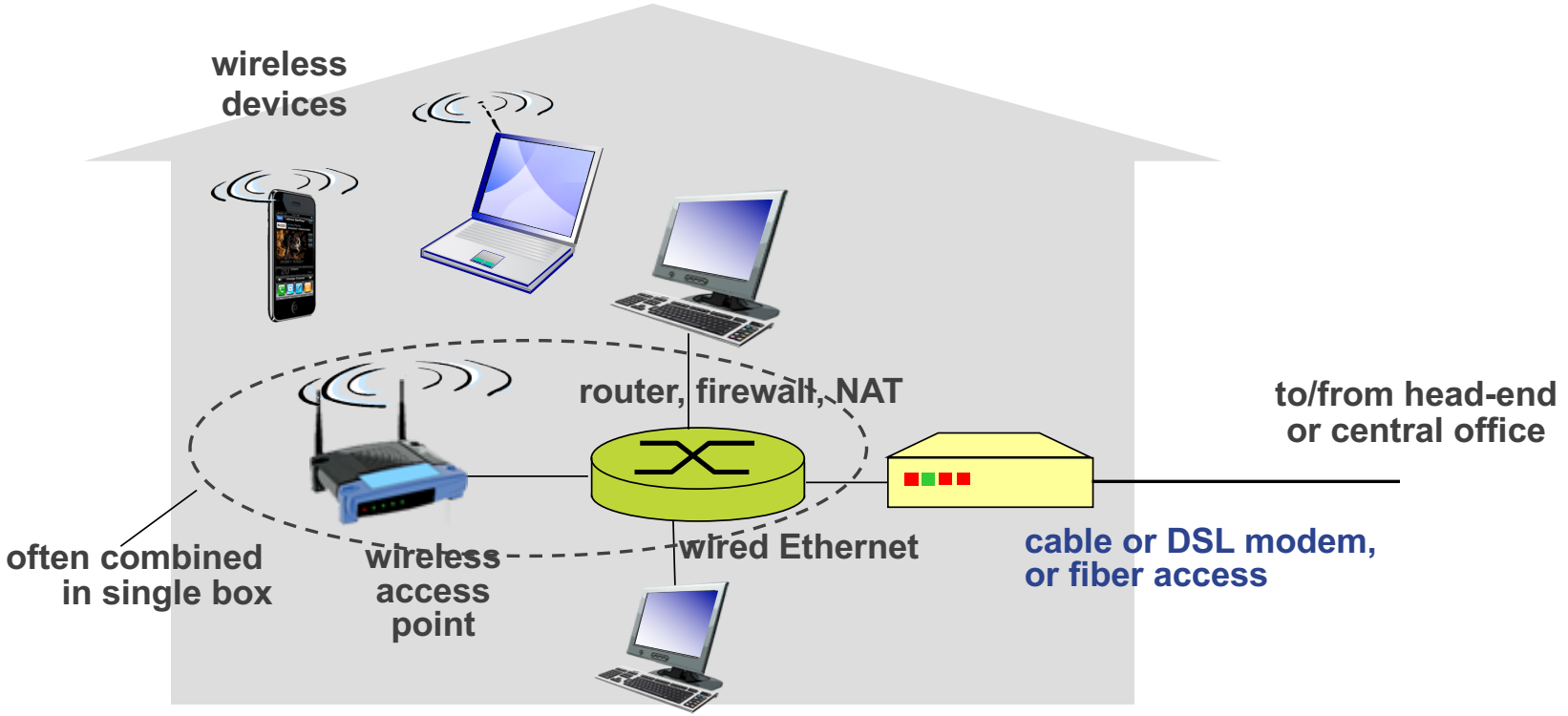
100 Pbytes =
100 000 000 Gbytes ~
20 mill/200 mill filmer TV/mobil



Source: http://www.nkom.no/marked/ekomtjenester/statistikk/det-norske-ekommarkedet-rapporter

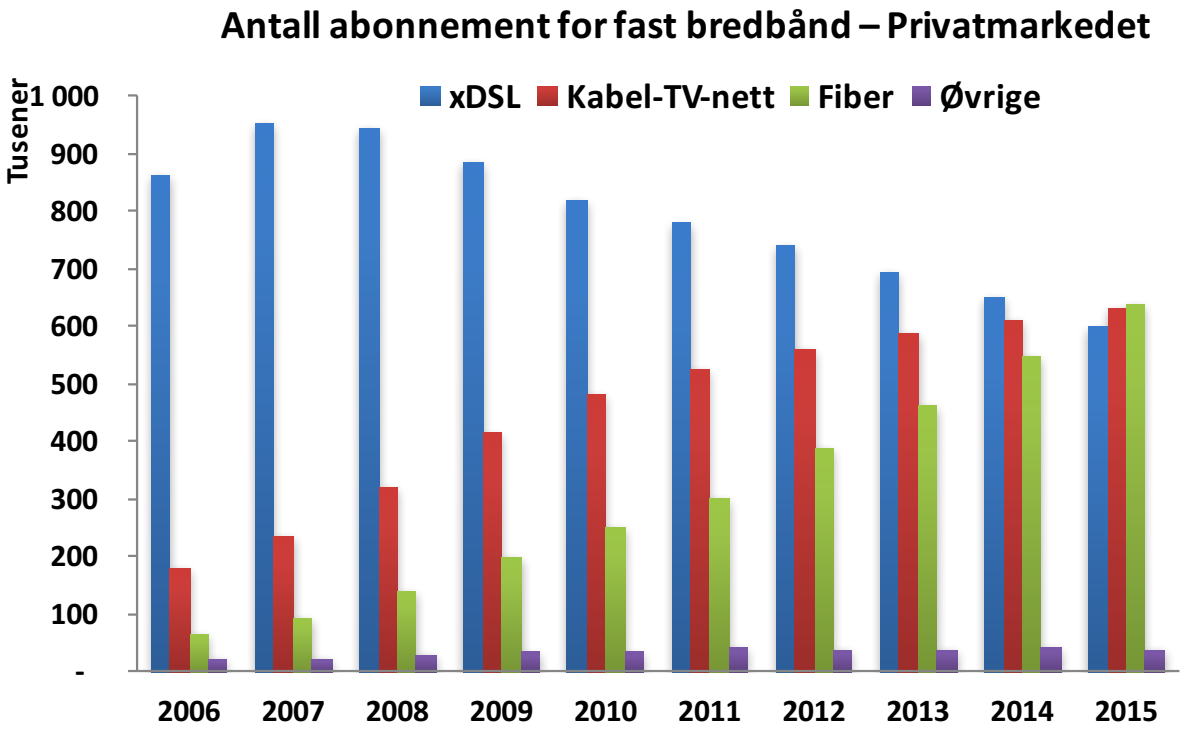
Residential access

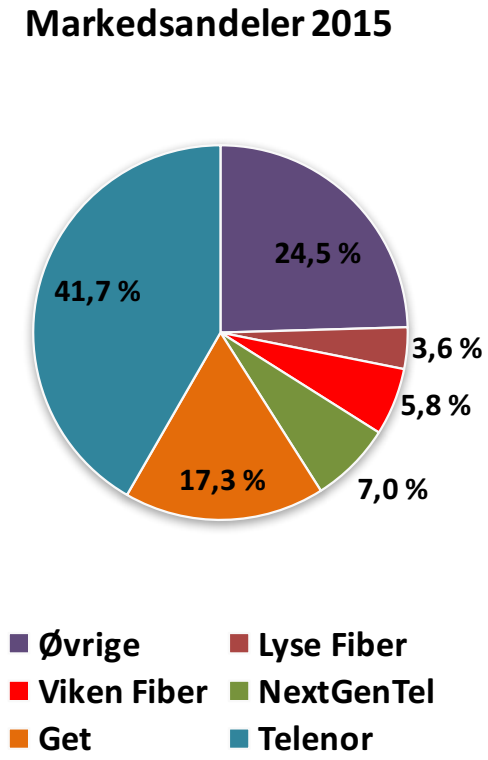
Home network



Residential access

Residential broadband access subscribers in N

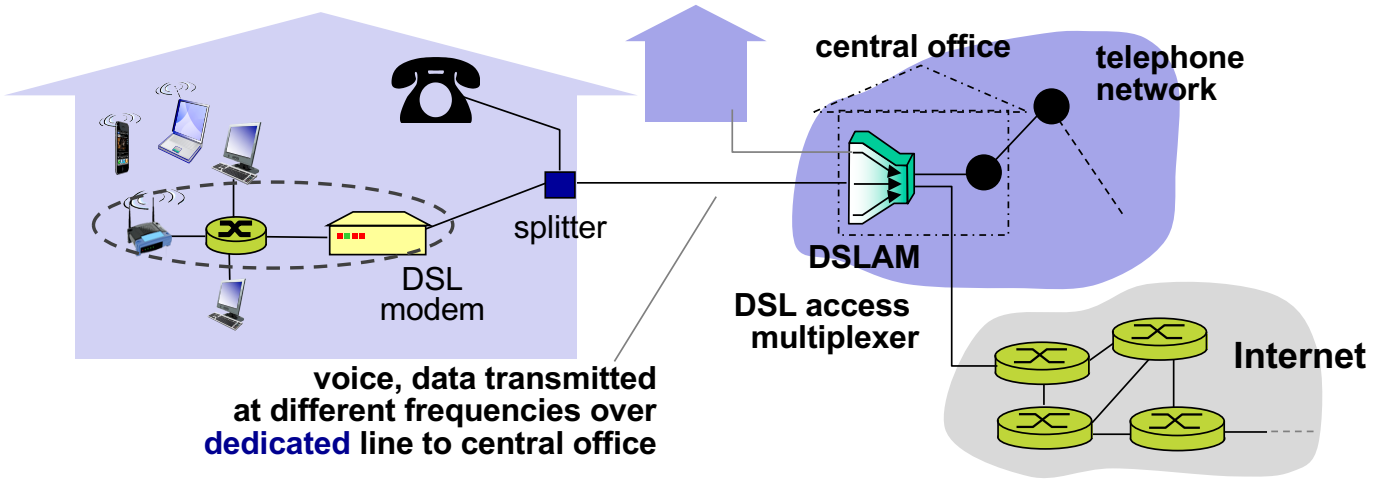




Source: http://www.nkom.no/marked/ekomtjenester/statistikk/det-norske-ekommarkedet-rapporter

Residential access

Internet access using point-to-point copper lines



xDSL: digital subscriber line

- x=Asymmetric, x=Symmetrical-high-speed, X=Very-high-bit-rate
  http://www.nextgentel.no/privat/artikler/bredband.php
- existing physical copper line on different frequencies
- always on data to Internet, voice to telephone network
- asymmetric up and down transmission rate
- http://www.nextgentel.no/privat/bredband/bestillingsskjema/
- http://www.telenorwholesale.no/produkter/dsl-bredbandsaksess/

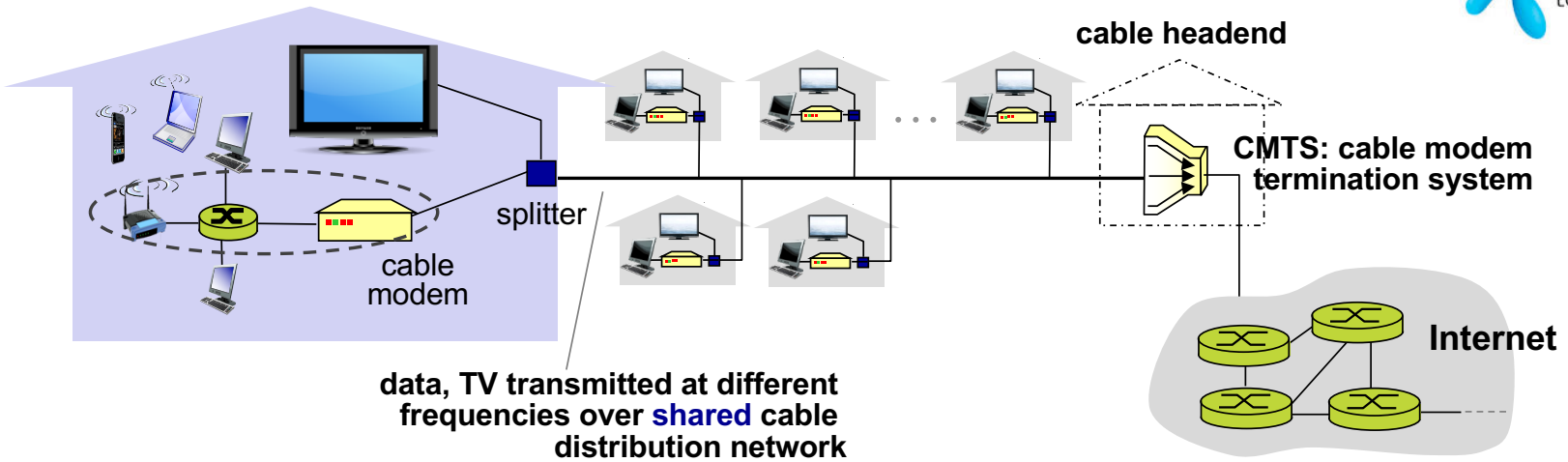
telenor

NextGenTel

Residential access

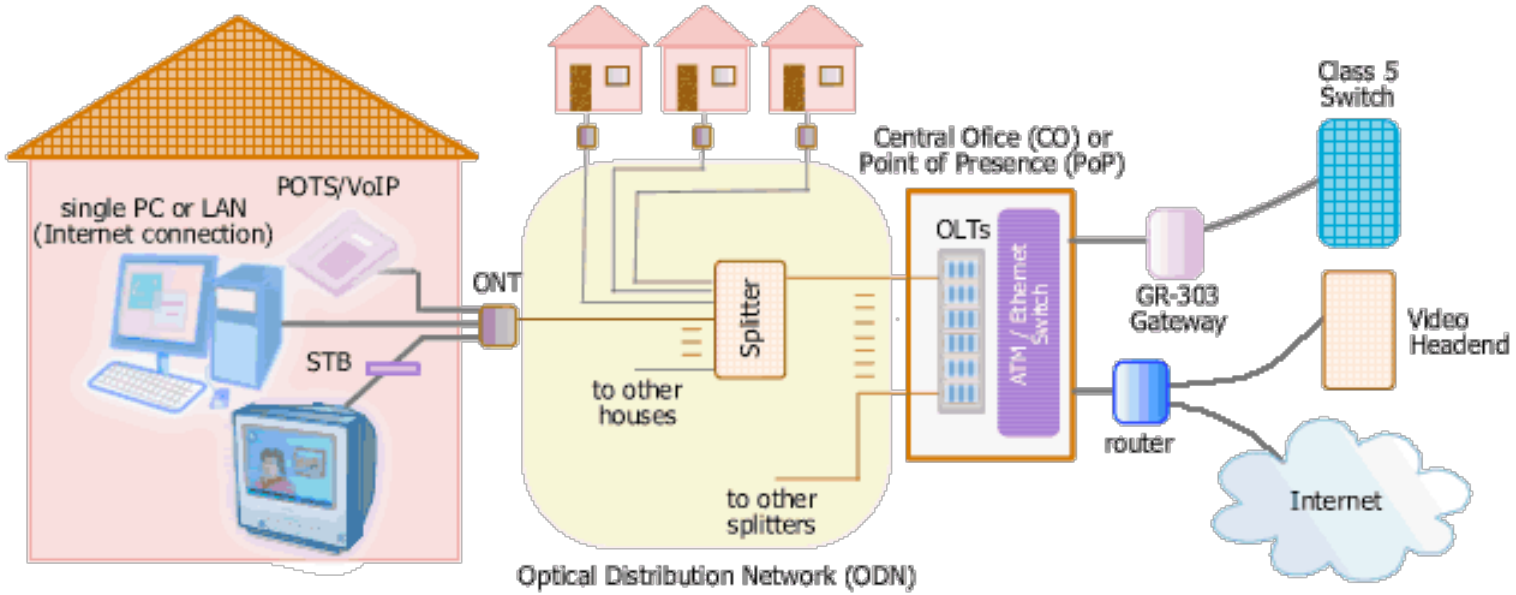
Internet access through broadcast cable lines

- Network of cable and fiber attaches homes to Internet
- Hybrid fiber coax (HFC)
  - asymmetric
- Available via cable TV companies



Residential access

Internet access through fiber to the home (FTTH)

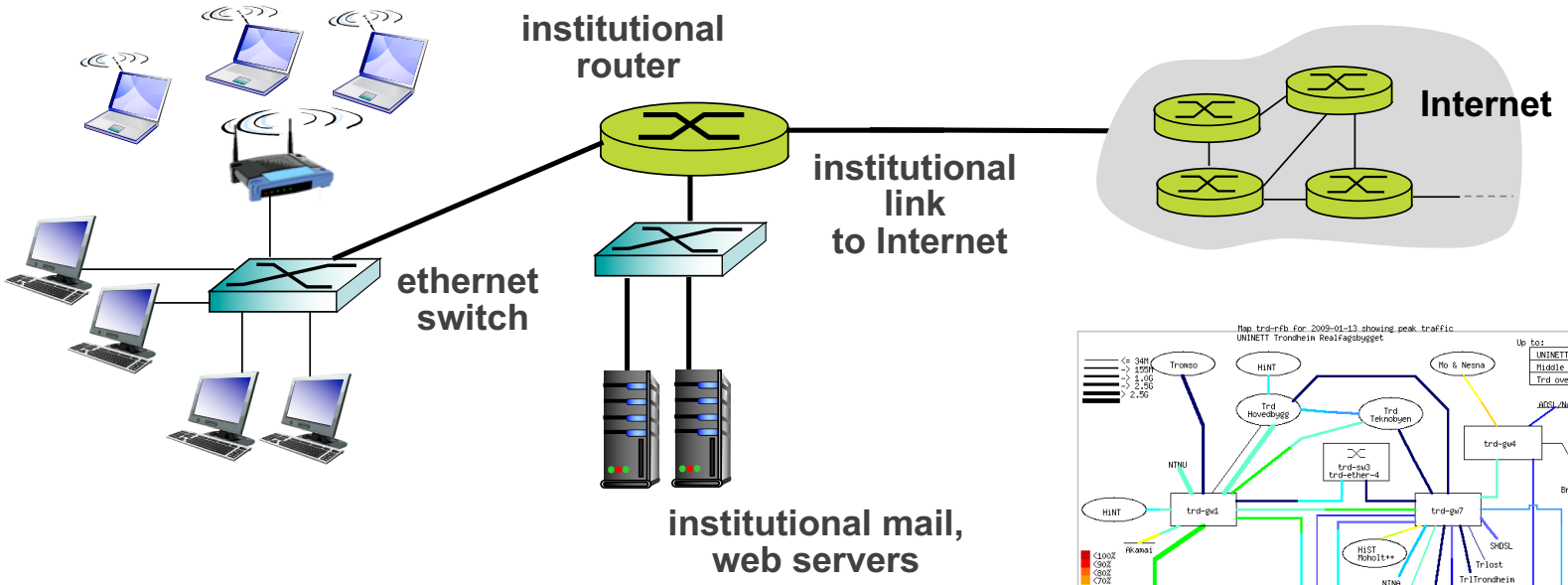


ONT Optical Network Termination
OLT Optical Line Termination
STB Set-Top Box
POTS Plain Old Telephony Service
VoIP Voice over Internet Protocol
LAN Local Area Network

http://www.conniq.com/InternetAccess_FTTH.htm

Institutional access

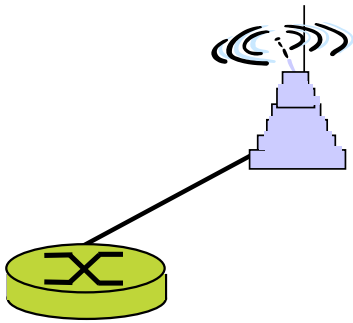
Internet access through local area networks



- Company/University local area network (LAN) connects to edge router
- Ethernet: 10/100 Mbps, 1/10 Gbps
  - shared, switched
  - wired, wireless

Network nodes are interconnected by a physical media

- **Physical link** between transmitter/receiver pairs
  - point to point vs multipoint
  - transmits bits



- **Bit** propagates between transmitter/receiver pairs – electromagnetic waves or optical pulses

Guided media - wired

- wireline signals propagate in solid media: copper, fiber, coax
- simplex, duplex

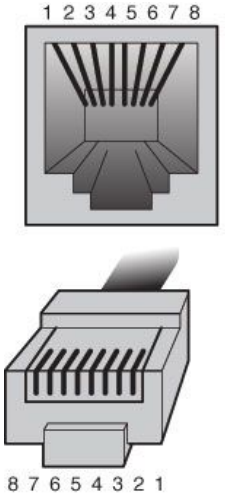
Unguided media – wireless

- no physical “wire”: air, water, vacuum
- bidirectional
- signals propagate freely in electromagnetic spectrum
  - reflection
  - obstruction by objects
  - interference

Guided physical media using copper

Twisted Pair (TP)

- two insulated copper wires
  - category 3: traditional phone wires, 10 Mbps Ethernet
  - category 5: 100Mbps Ethernet

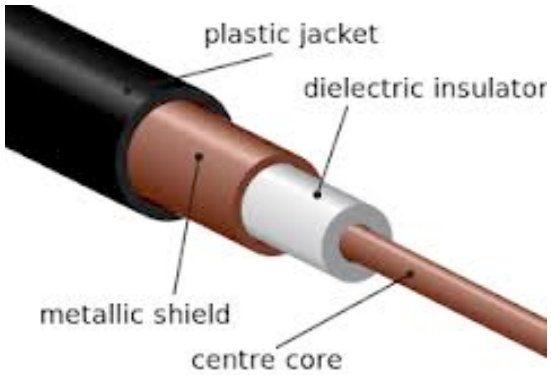


T-568B

Pin	Color	Pair
1	Orange/White	2
2	Orange	2
3	Green/White	3
4	Blue	1
5	Blue/White	1
6	Green	3
7	Brown/White	4
8	Brown	4

Coaxial cable

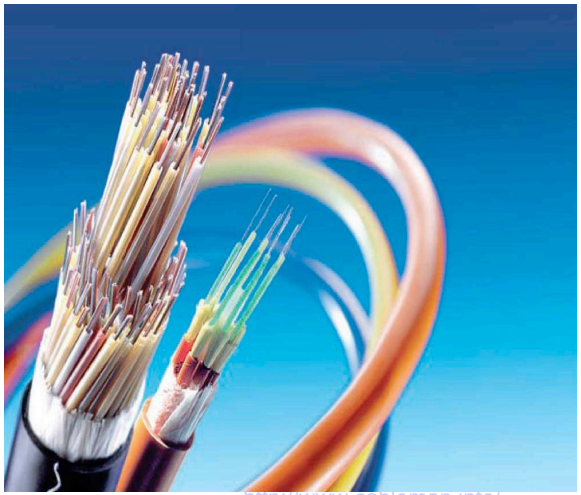
- two concentric copper conductors
- bidirectional
- baseband: single channel on cable
  - legacy Ethernet
- broadband: multiple channels on cable



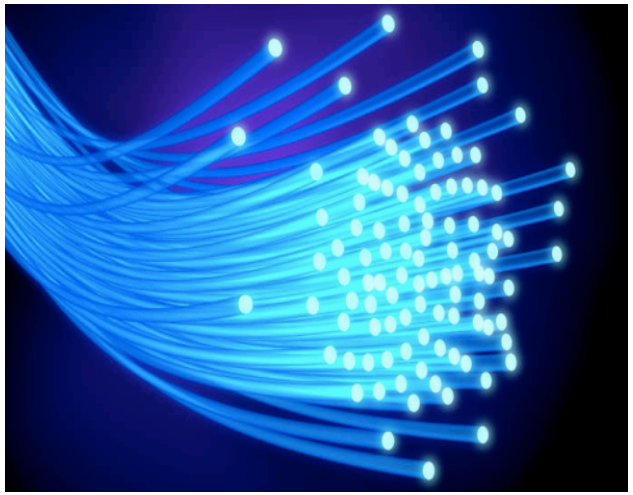
Guided physical media

Fiber is high speed and low error rate

- glass fiber cable carrying light pulses
- each pulse a bit
- high-speed operation
  - high-speed point-to-point transmission (10's-100's Gps)
- low error rate: repeaters spaced far apart; immune to electro-magnetic noise



http://www.cablemap.info/

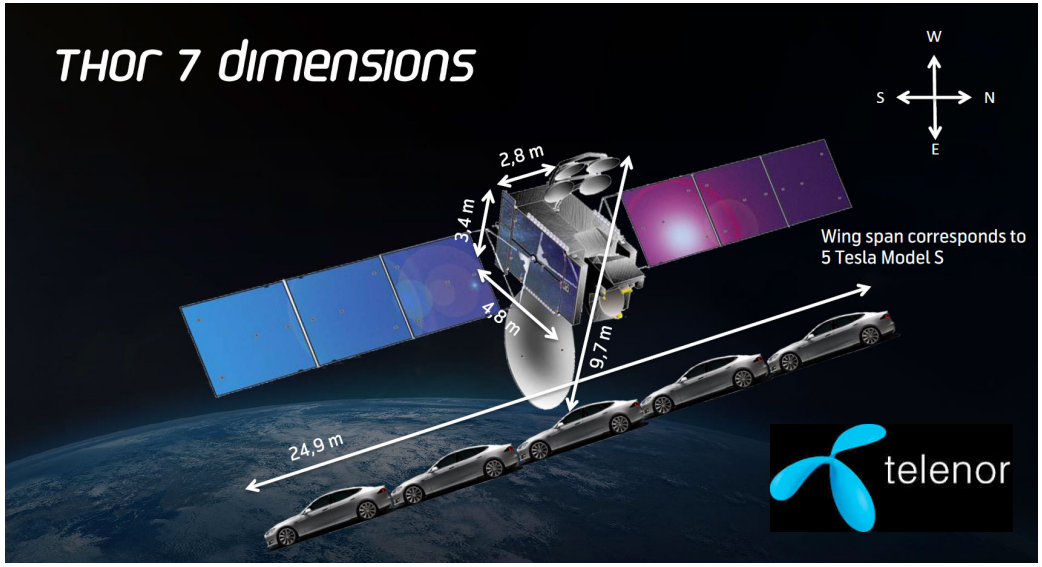


Unguided physical media

Radio signals are carried within the electromagnetic spectrum

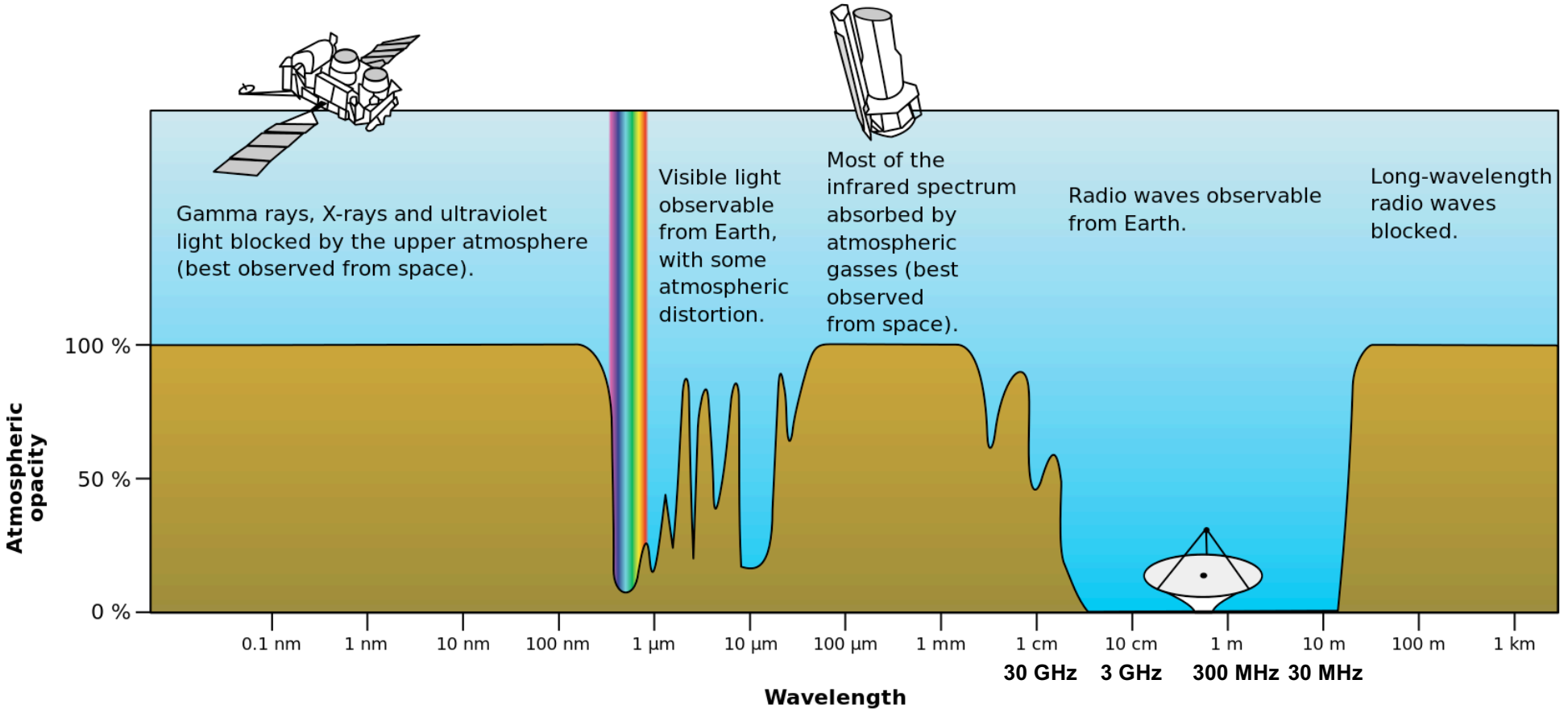
- Terrestrial point-to-point microwave
  - e.g. up to 45 Mbps channels
- Wireless LAN
  - e.g. 11Mbps, 54 Mbps
- Wide-area (e.g. cellular/mobile)
  - 3G cellular: few Mbps
  - LTE: hundreds of Mbps

- Satellite
  - kbps to 100 Mbps channels
- One way end-end delay for satellites
  - in geostationary orbit: 250-280 msec
  - in low-earth orbit 20-25 msec



Earth´s atmospheric transmittance to electromagnetic waves

Some frequencies are more valuable than others

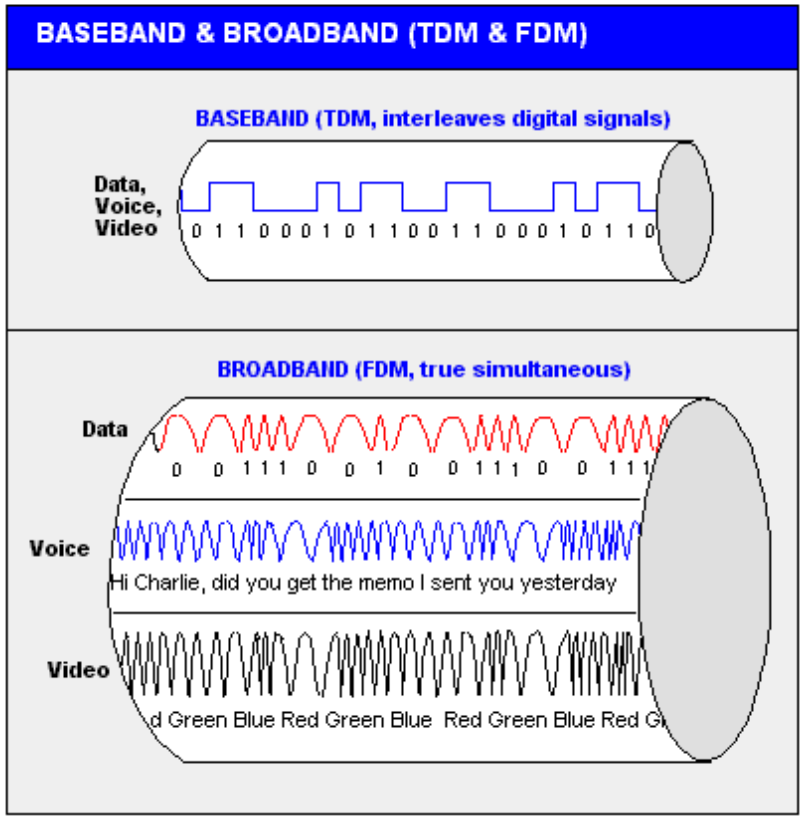


Wavelength = 1/Frequency

Source: http://en.wikipedia.org/wiki/Electromagnetic_spectrum

Baseband vs broad-/wideband digital signals

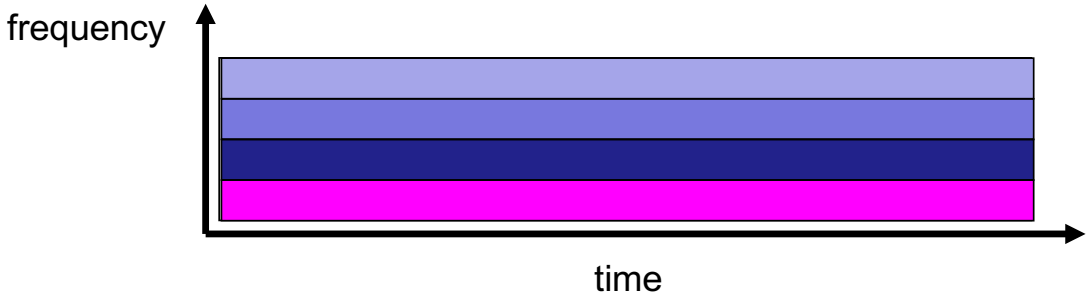
From Computer Desktop Encyclopedia



Usually, we use "broadband" when characterizing a high speed internet access

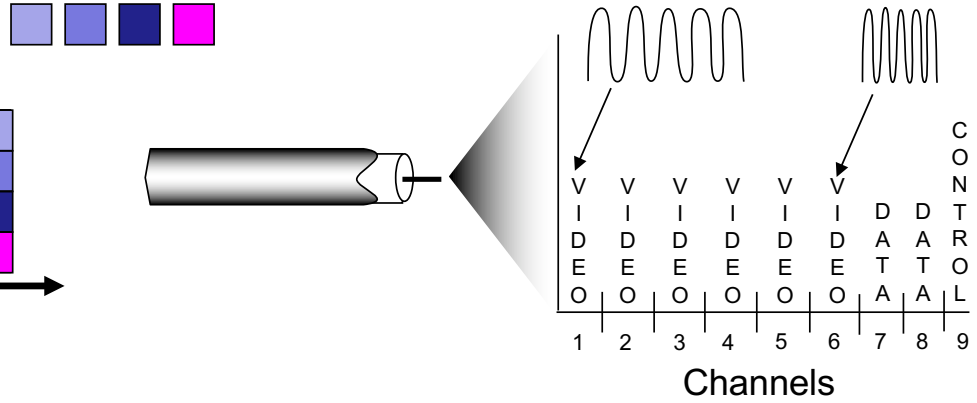
Channel division: FDM versus TDM

FDM – frequency division multiplex

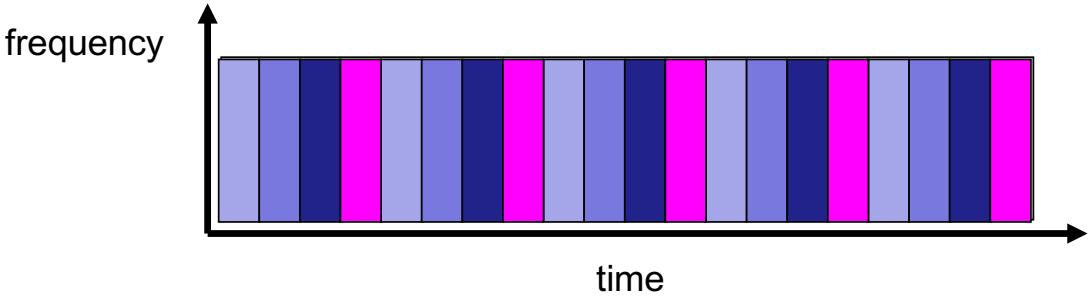


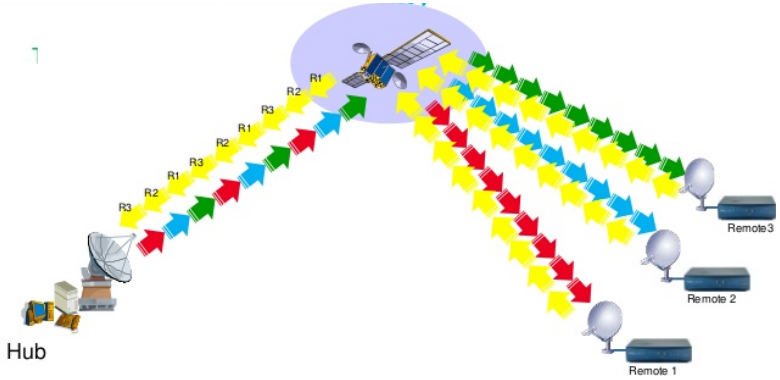
Example

4 users

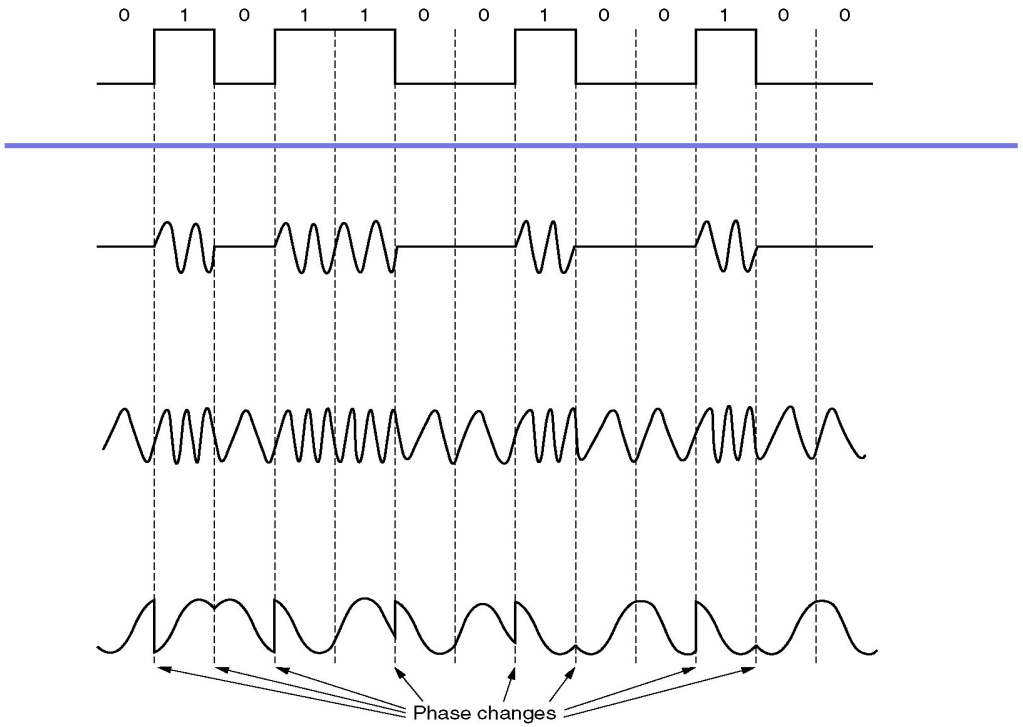


TDM – time division multiplex





On an analog channel a modem (modulator-demodulator) converts between digital bits and signals



A binary signal

Amplitude modulation

Frequency modulation

Phase modulation

Frequency, Spectrum and Bandwidth

Time domain concepts

- **Analog signal**
  - varies in a smooth way over time
- **Digital signal**
  - maintains a constant level then changes to another constant level
- Periodic signal
  - pattern repeated over time
  - s(t) = A sin(2πft +Φ)
- Aperiodic signal
  - pattern not repeated over time

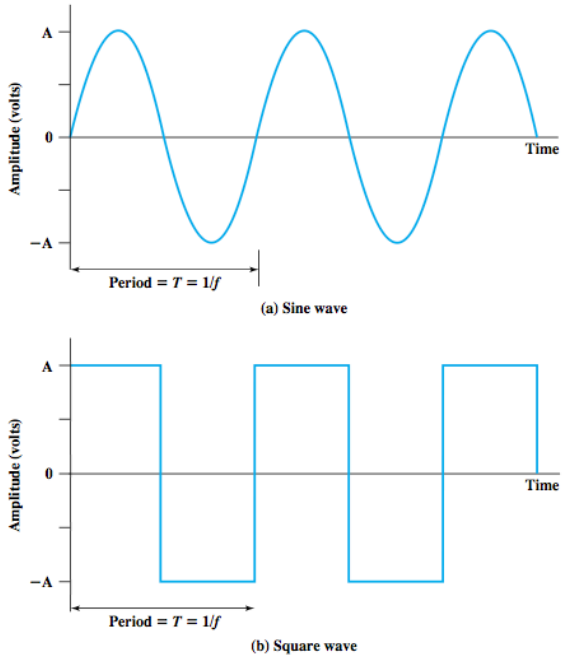


Figure 3.2 Examples of Periodic Signals

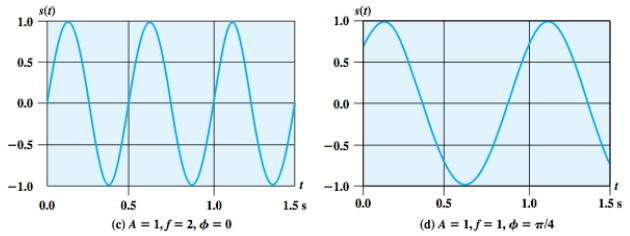
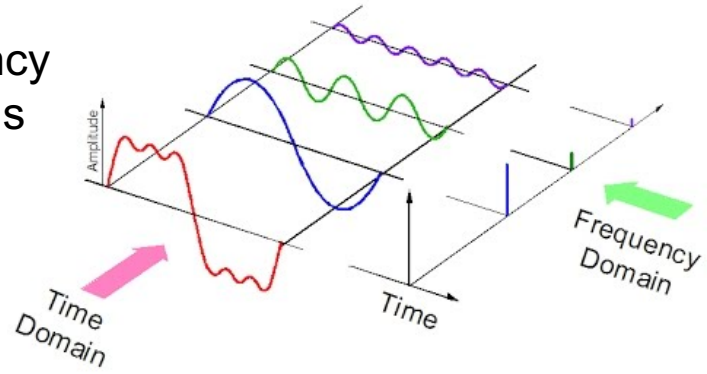


Figure 3.3 $s(t) = A \sin(2\pi ft + \phi)$

Source: William Stallings Data and Computer Communications 8th Edition

Frequency Domain Concepts

- Signal usually made up of many frequencies
- The **higher the data rate** of the signal, the **greater its required frequency bandwidth**
- Components are sine waves
- Can be shown (Fourier analysis) that any signal is made up of component sine waves
- Can plot frequency domain functions



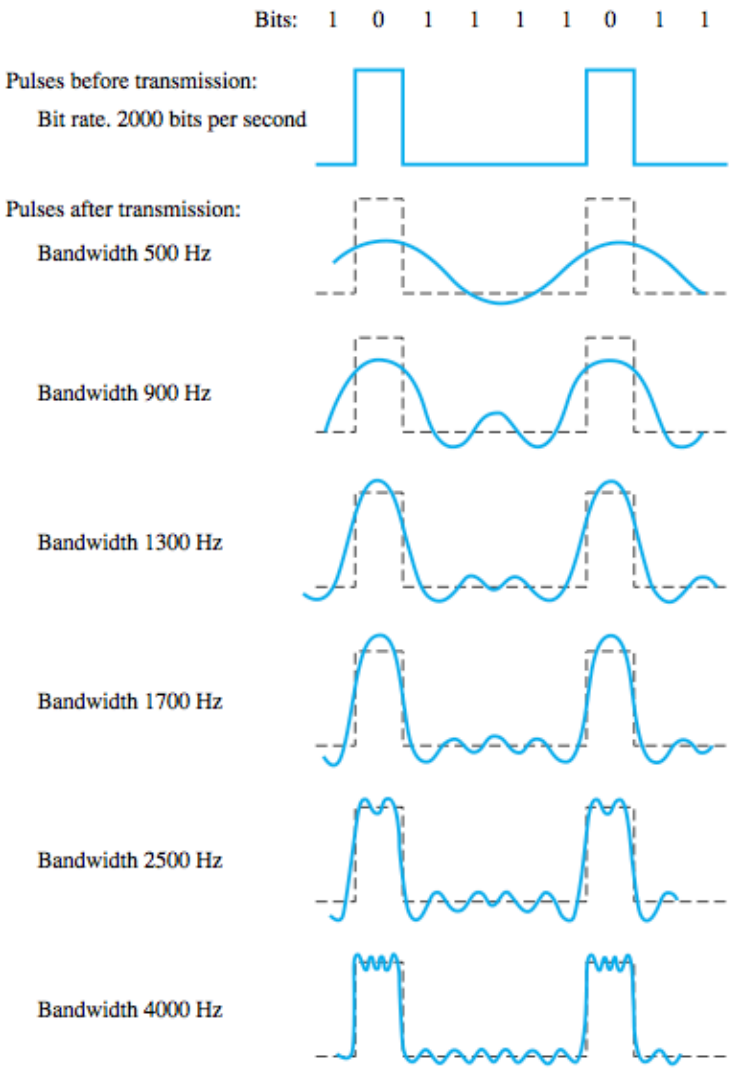
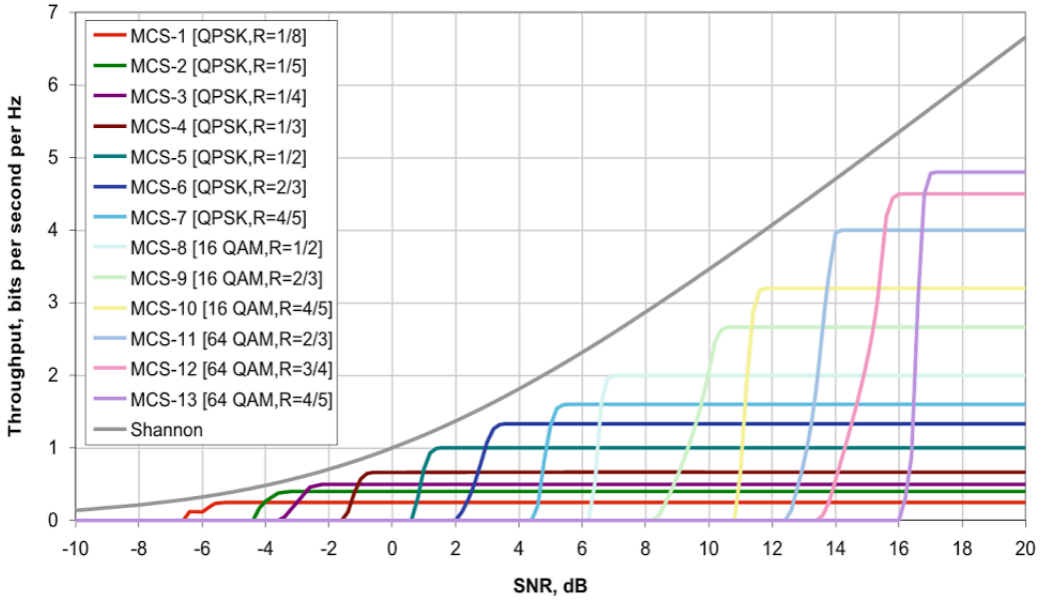


Figure 3.8 Effect of Bandwidth on a Digital Signal

Shannon´s law – an upper bound to channel link capacity

$$C = B * \log_2(1+ S/N)$$

- C= channel **Capacity** in bits per second
- B = **frequency bandwidth** of the line
- S = average **Signal power**
- N = average **Noise power**
- S/N = signal-to-noise ratio (usually expressed in decibels (dB) = **$10 * \log_{10}(S/N)$**)



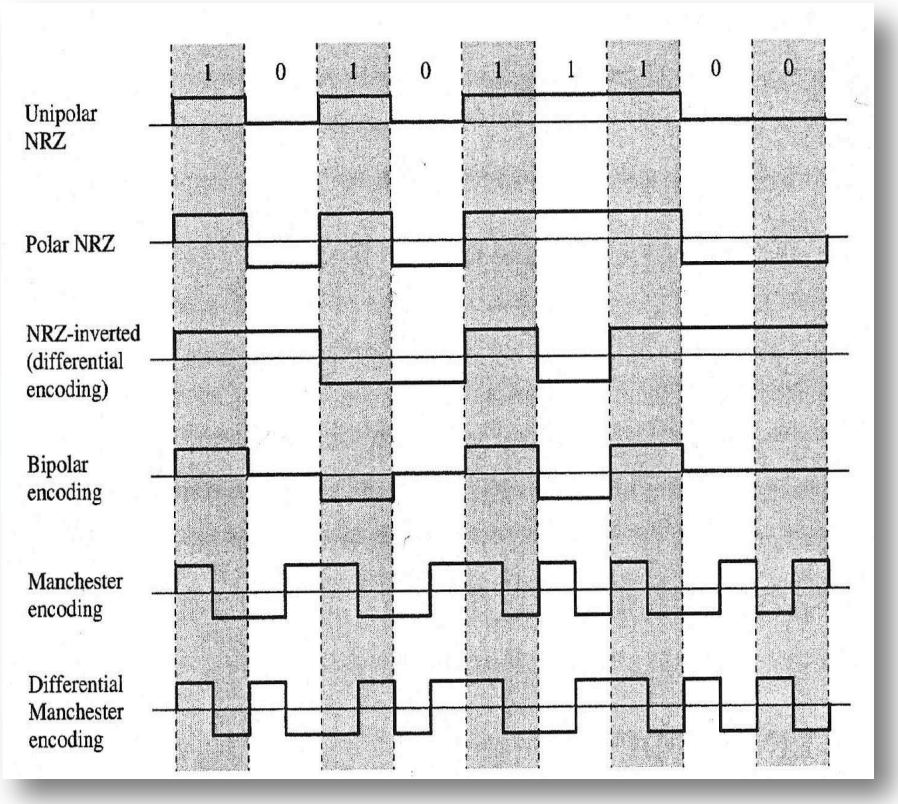
Modulation techniques for different S/N

Telephone modem channel with BW = 3 kHz and S / N = 1000 = 30 dB, maximum data rate is $C = 3000 * \log_2(1001) \sim 30$ kbps

Satellite TV channel with BW = 10 MHz and S/N = 20 dB, maximum data rate is $C=10000000 * \log_2(101) \sim 66$ Mbps

Line coding is used for low voltage digital signal transmission over limited distance

NRZ
Non-return-to-zero



Line coding represent the digital signal by an amplitude and time discrete signal

Roadmap

1.1 What is the Internet?

1.2 Network edge

- access networks, physical media

1.3 Network core

- **packet switching, circuit switching, network of networks**

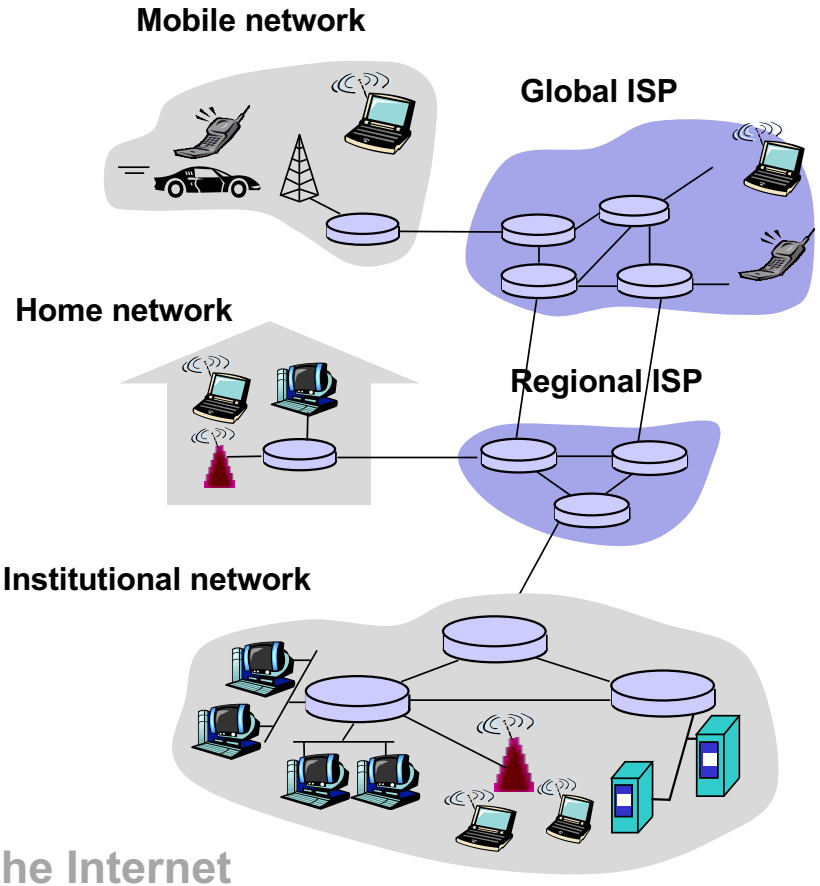
1.4 Packet-switched networks

- delay, loss and throughput

1.5 Protocol layers and service models

1.6 Security: networks under attack

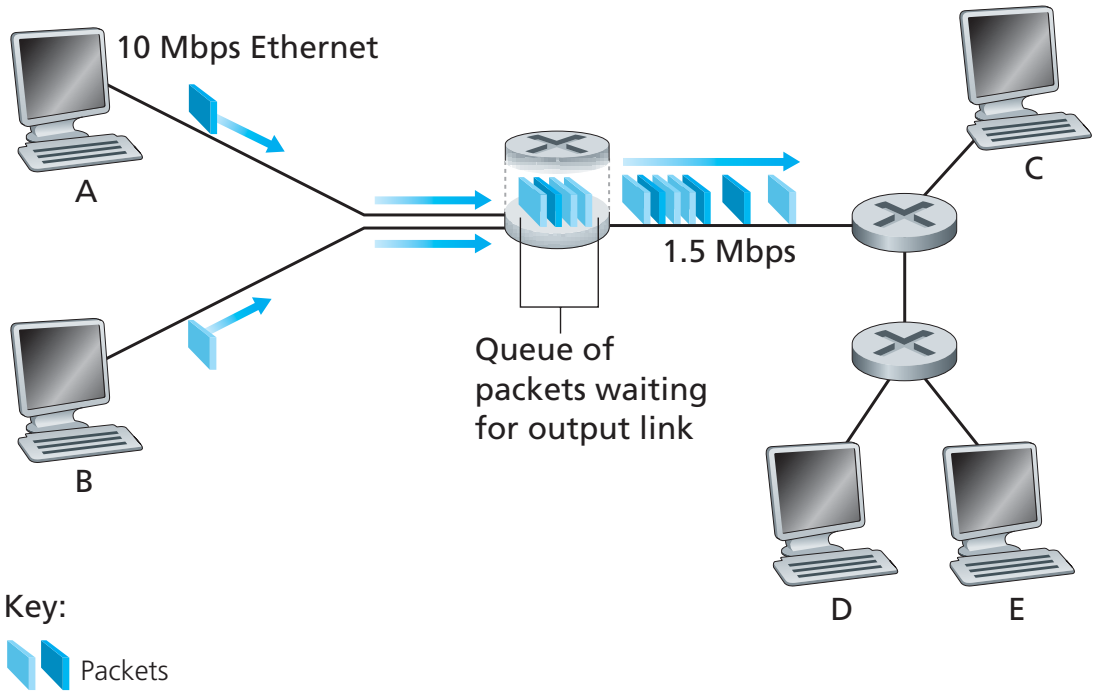
1.7 History of computer networking and the Internet



The network core is a mesh of interconnected routers

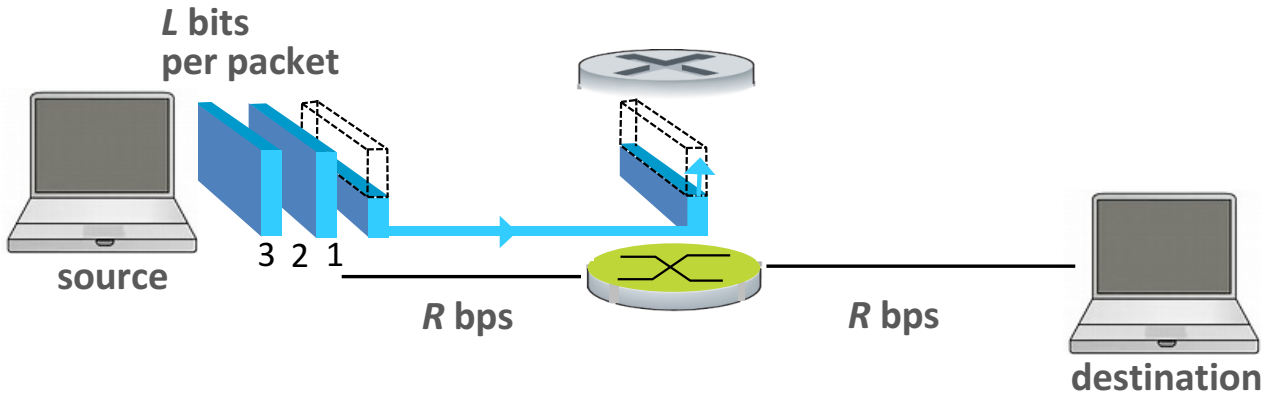
- Data sent in discrete "chunks" = **packets**
- Packets are forwarded from one router to the next, across links on path from source to destination
- Each packet transmitted at full link capacity
- Internet is based on **packet switching**

(and packet switching is used end-to-end, from sender access via core to receiver access)!!



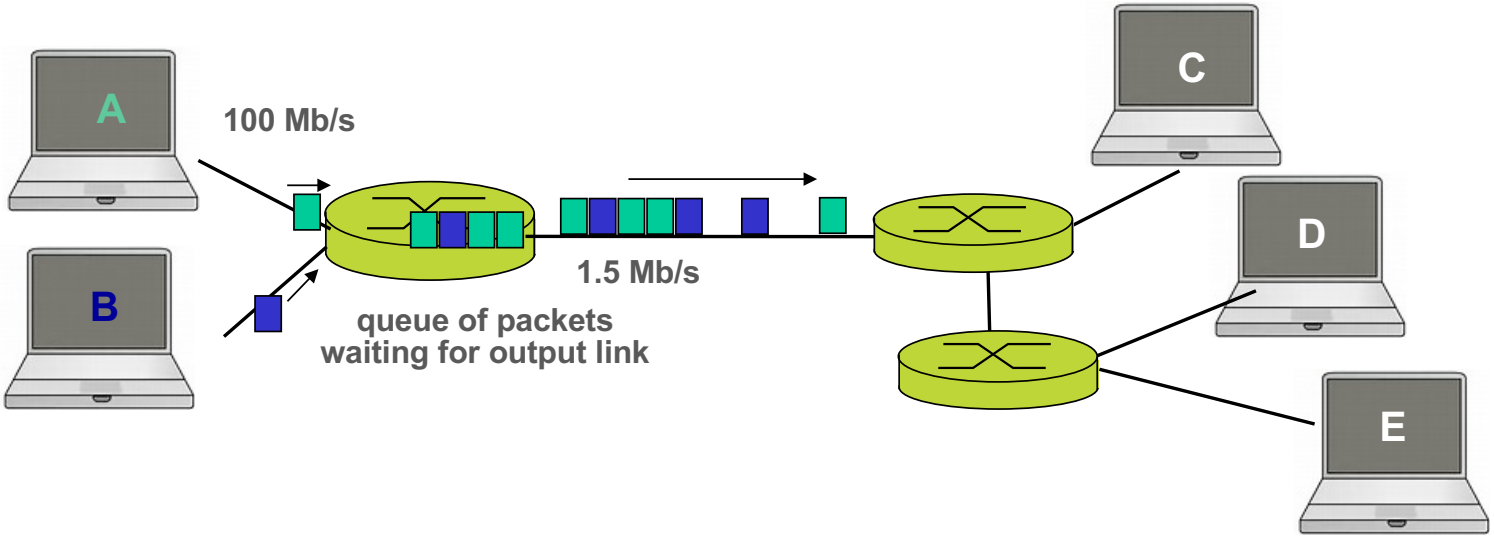
Packet-switching is store-and-forward

- **Store and forward**: entire packet must arrive at router before it can be transmitted on next link



- L-bit packet into link at R bps takes L/R seconds
- *L* = 7.5 Mbits, *R* = 1.5 Mbps; one-hop transmission delay = 5 sec

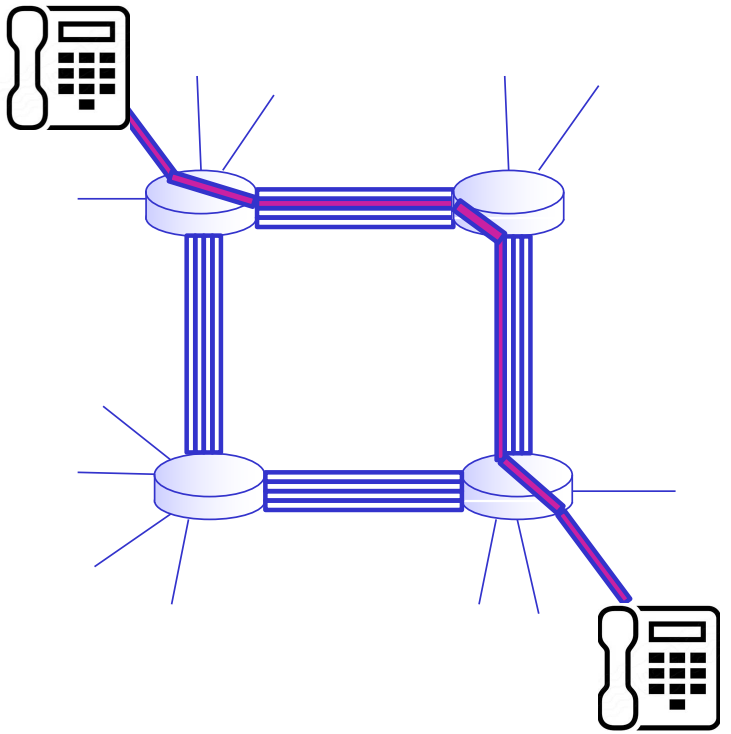
Packet switching: queuing delay and loss



- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up
- Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand ➡ **statistical multiplexing**

Circuit switching end-to-end: No longer an alternative to packet switching

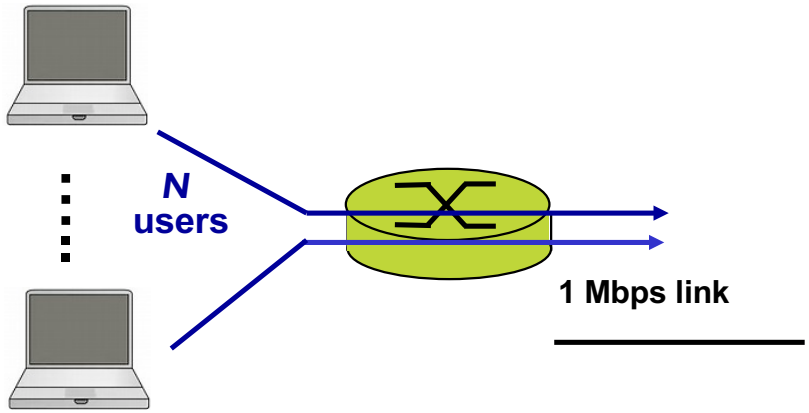
- End-end resources reserved for “call” between source & destination
- Circuit segment idle if not used by call (no sharing)
- Commonly used in **traditional telephone networks**



Packet switching allows more users to simultaneously use the network

1 Mb/s link, user needs 100 kb/s when "active" (10% of time)

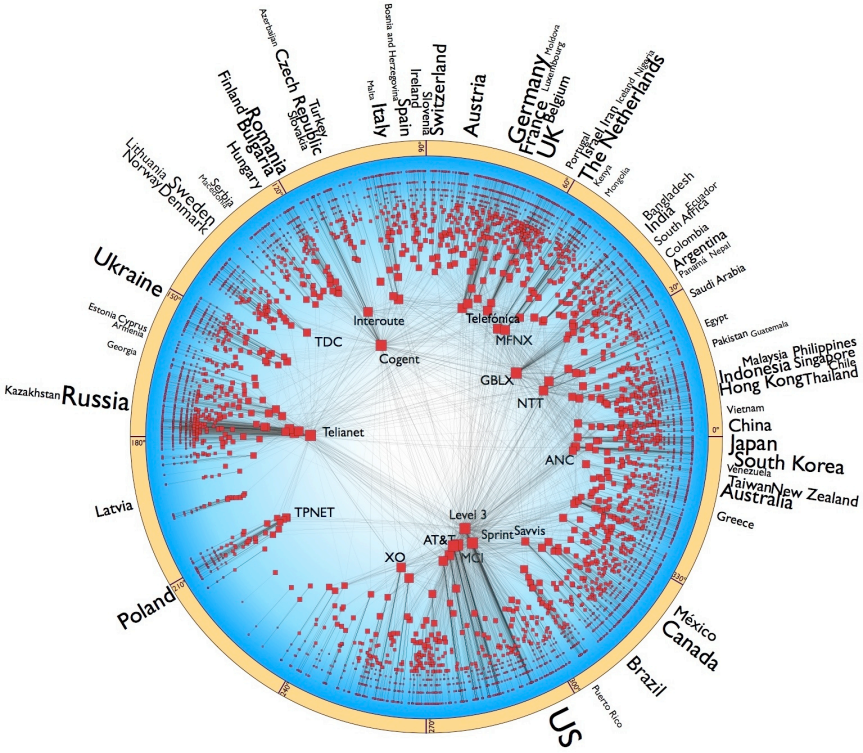
- **Circuit-switching**
  - resources reserved, also in idle periods in-between data bursts
  - max 10 users simultaneously



- **Packet switching**
  - with 35 users, P(> 10 active at same time) is less than .0004
  - 99,96 % of time all 35 users can be served simultaneously

Internet structure: network of networks

- **End systems**
  connect to Internet
  via access ISPs
  (Internet Service Providers)
  - residential, company and university ISPs
- **Access ISPs**
  must be interconnected
- Resulting network of networks is complex

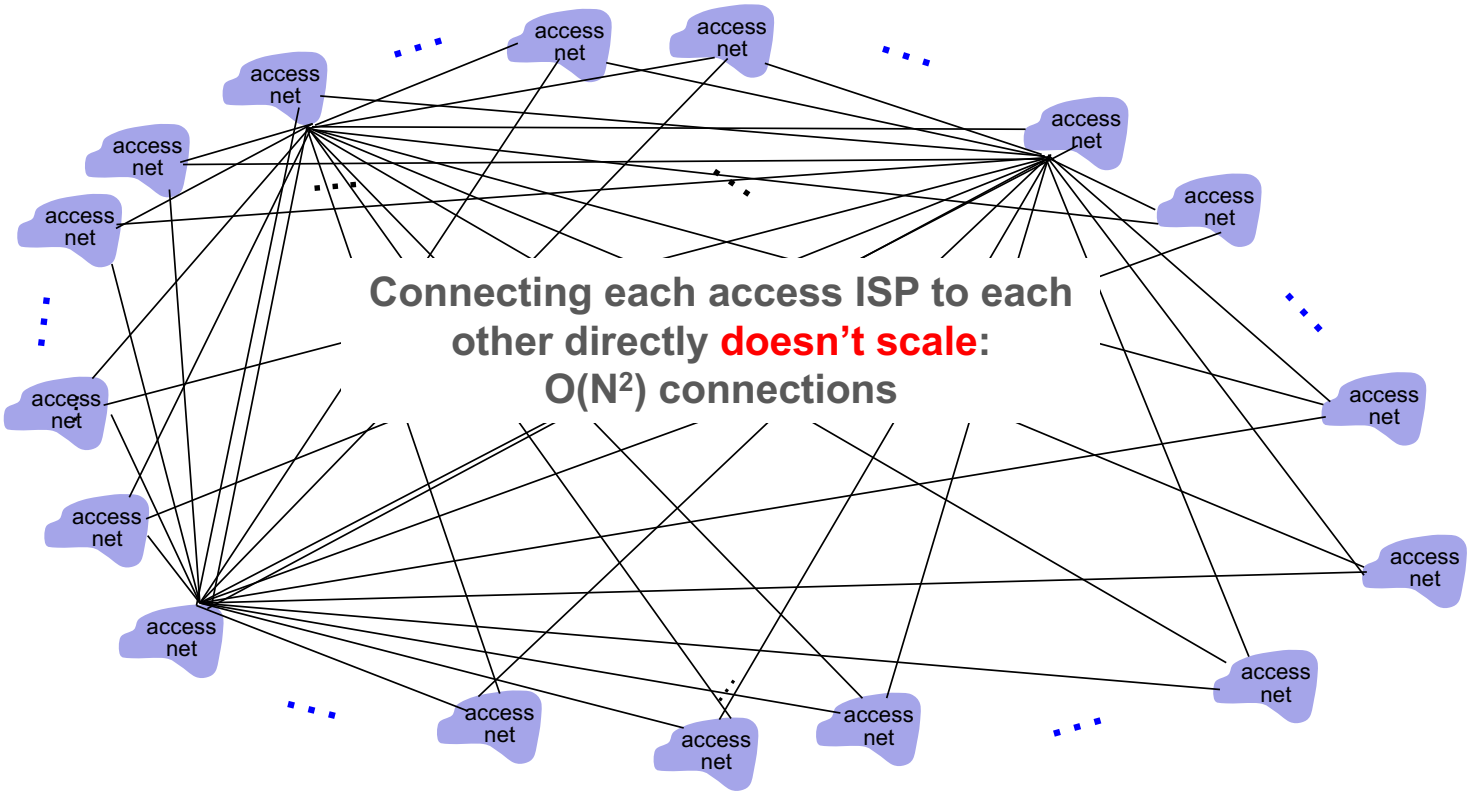


Source: http://www.drdobbs.com/architecture-and-design/first-geometric-atlas-of-the-internet-cr/227400098

Internet structure: network of networks

Given millions of access ISPs, how to connect them together?

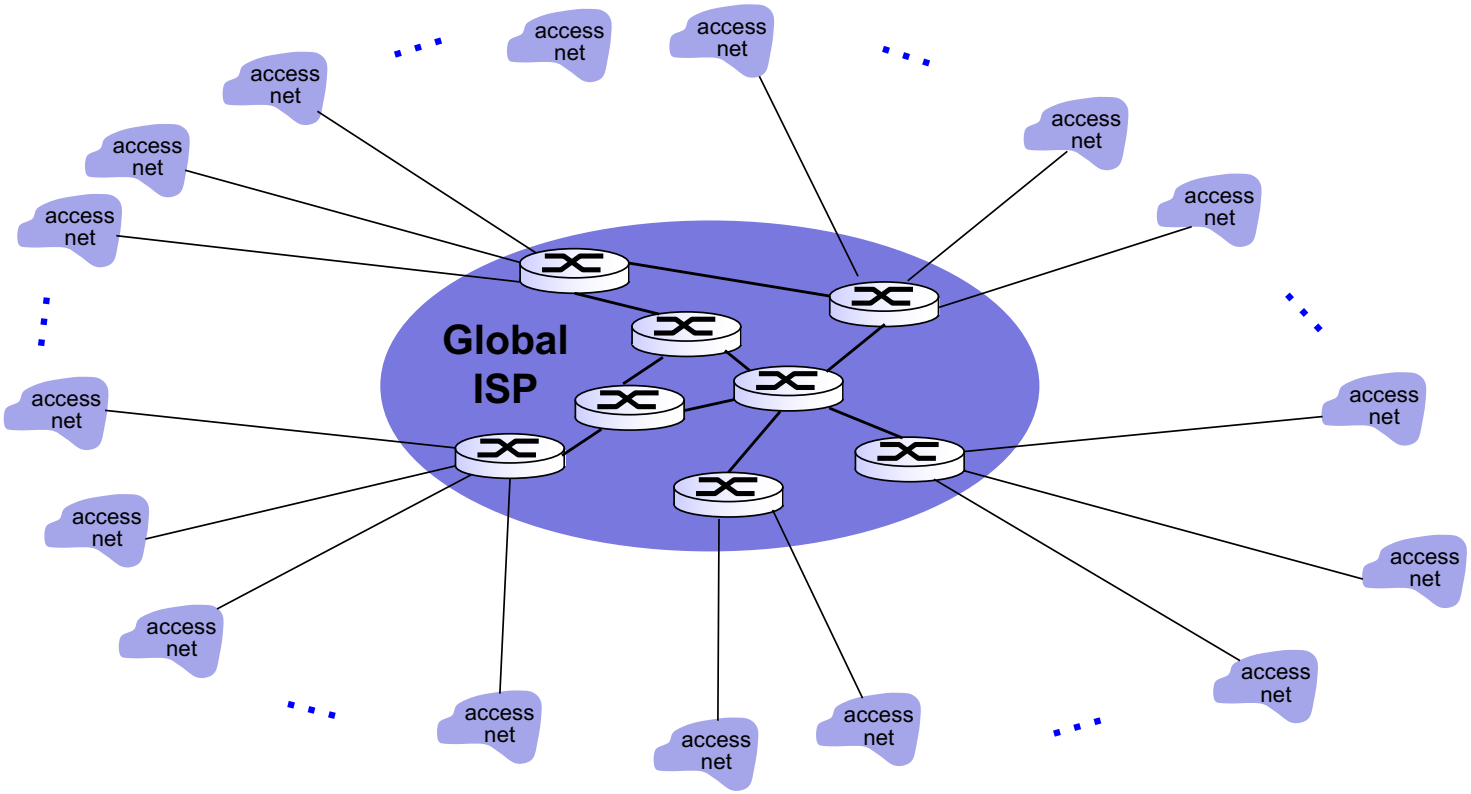
Connect each access ISP to every other access ISP?



Internet structure: network of networks

Option: connect each access ISP to a **global transit ISP**?

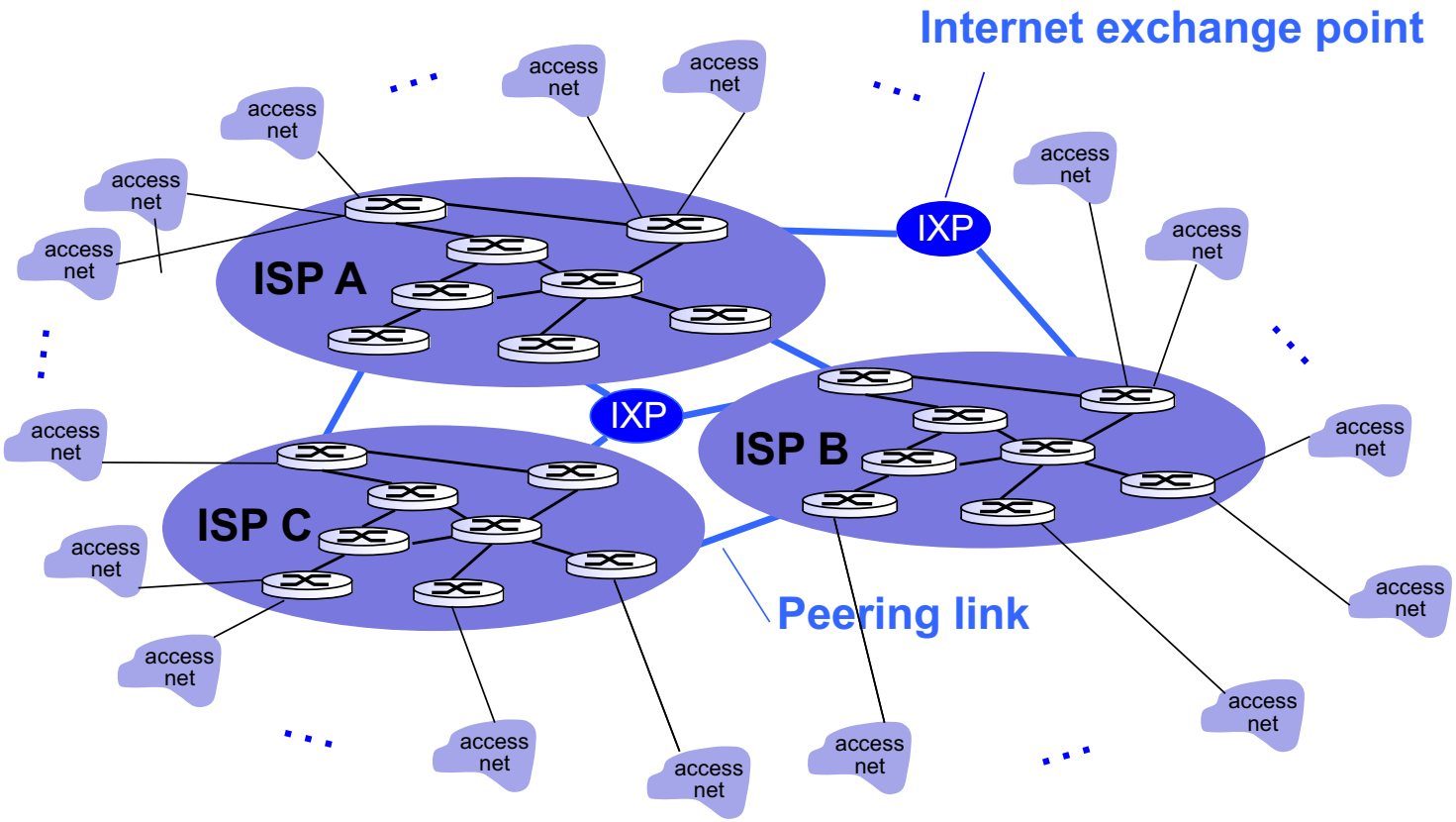
Customer and provider ISPs have economic agreement.



Internet structure: network of networks

But if one **global ISP** is viable business, there will be **competitors** ….

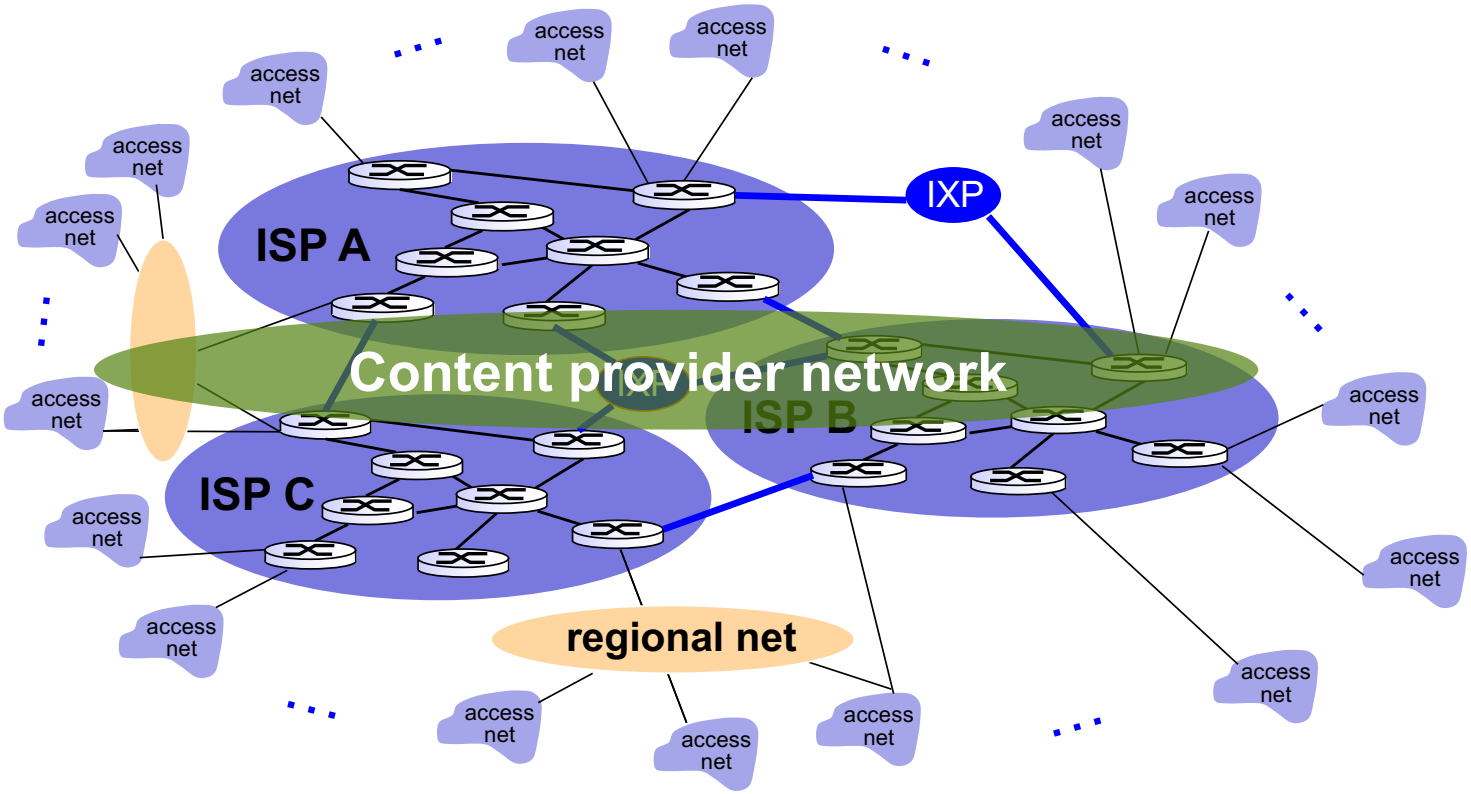
…. which must be interconnected



Internet structure: network of networks

… and **regional networks** may arise to connect access nets to ISPs

… and content providers (e.g. Google, Microsoft, Akamai) may run their own **overlay network** to bring services/content close to end users



Roadmap

1.1 What is the Internet?

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- access networks, physical media

1.3 Network core

- packet switching, circuit switching, network of networks

1.4 Packet-switched networks

- **delay, loss and throughput**

1.5 Protocol layers and service models

1.6 Security: networks under attack

1.7 History of computer networking and the Internet

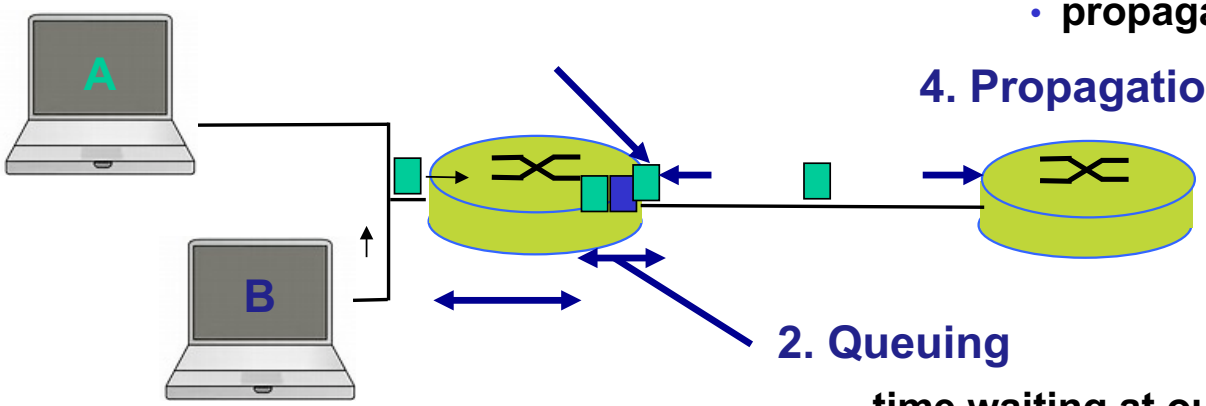
Four sources of packet delay

- R=link bandwidth (bit/s)
- L=packet length (bits)
- time to send bis into link = L/R

3. Transmission

- d = length of physical link
- s = propagation speed in medium (~$2x10^8$ m/sec)
- propagation delay = d/s

4. Propagation



1. Nodal processing

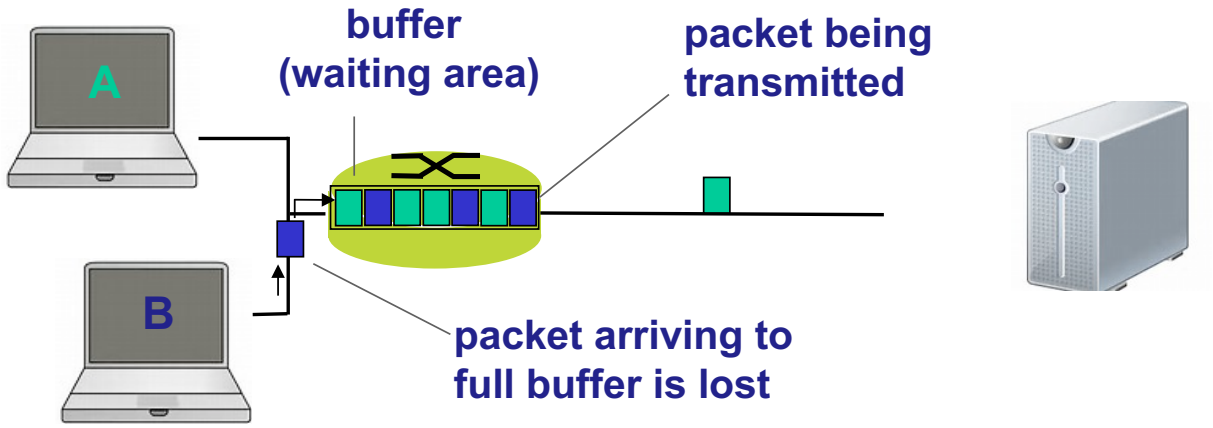
- check bit errors
- determine output link

2. Queuing

- time waiting at output link for transmission
- depends on congestion level of router

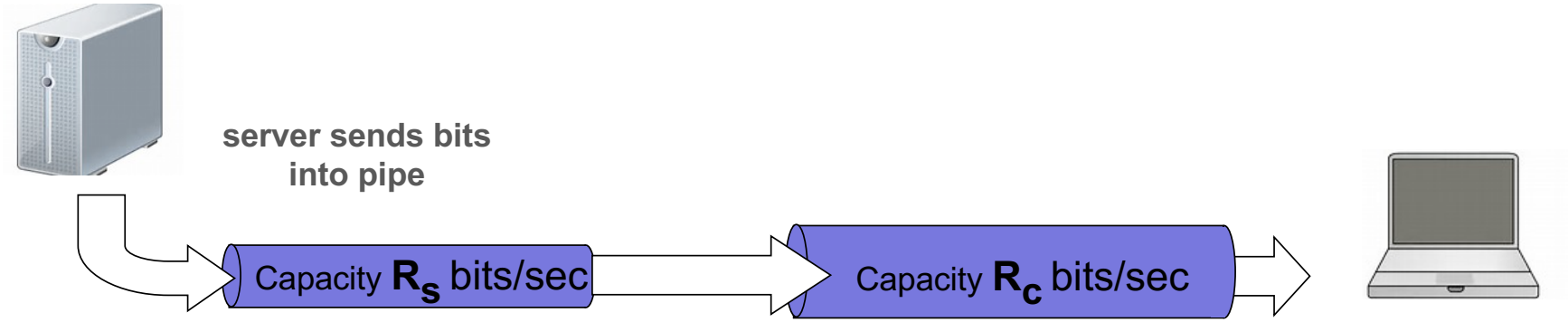
Packet arriving to full queue is dropped = packet loss

- Queue (buffer) preceding link has finite capacity
- Lost packet may be retransmitted by previous node, by source end system, or not at all



Throughput = the rate at which bits are transferred between sender/receiver

- Unit: bits per time
- Instantaneous: rate at given point in time
- Average: rate over longer period of time



End-to-end throughput cannot exceed bottleneck link

Roadmap

1.1 What is the Internet?

1.2 Network edge

- access networks, physical media

1.3 Network core

- packet switching, circuit switching, network of networks

1.4 Packet-switched networks

- delay, loss and throughput

1.5 Protocol layers and service models

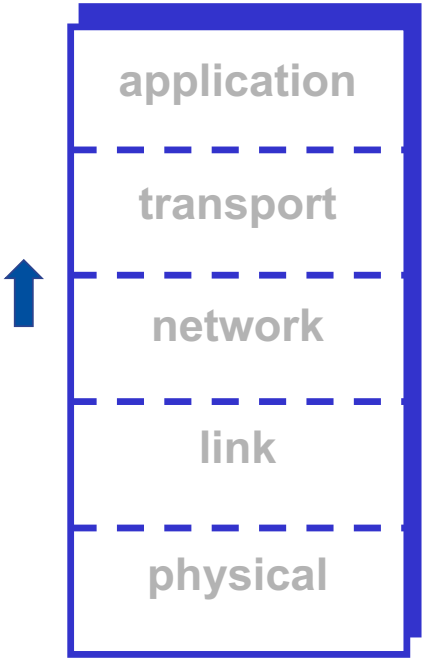
1.6 Security: networks under attack

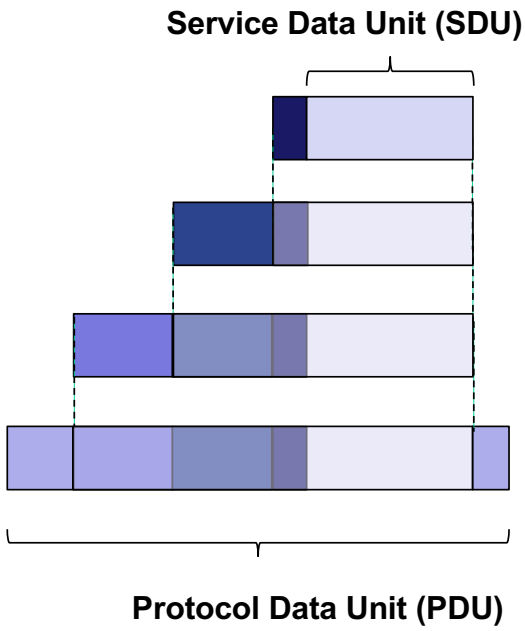
1.7 History of computer networking and the Internet

Many “pieces” make the network a complex structure
But there is a structure to the design of the network: “layers”

- Components
  - hosts
  - routers
  - links of various media
  - hardware, software
  - applications
  - protocols

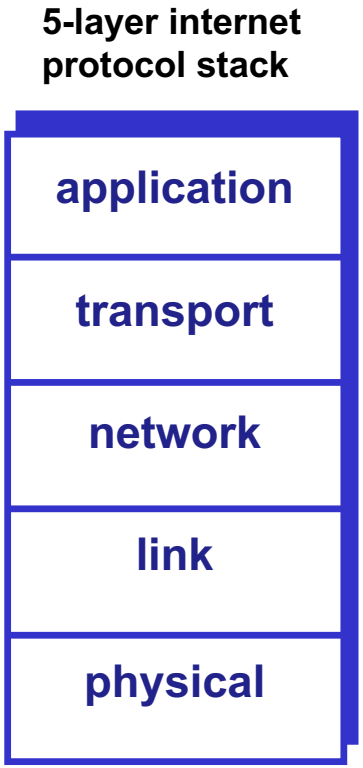
The service model of a layer = services the layer offers to the layer above





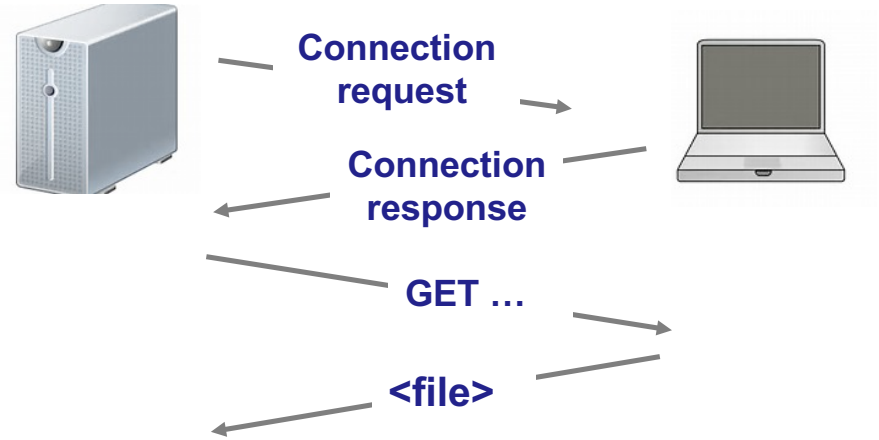
A protocol stack is the protocols of the various layers

- **Application**: supporting distributed applications
  - FTP, SMTP, HTTP
- **Transport**: process-process data transfer
  - TCP, UDP
- **Network**: routing of datagrams from source to destination
  - IP, routing protocols
- **Link**: data transfer between neighboring network elements
  - PPP, Ethernet
- **Physical**: bits "on the wire"



Protocols are used throughout the internet

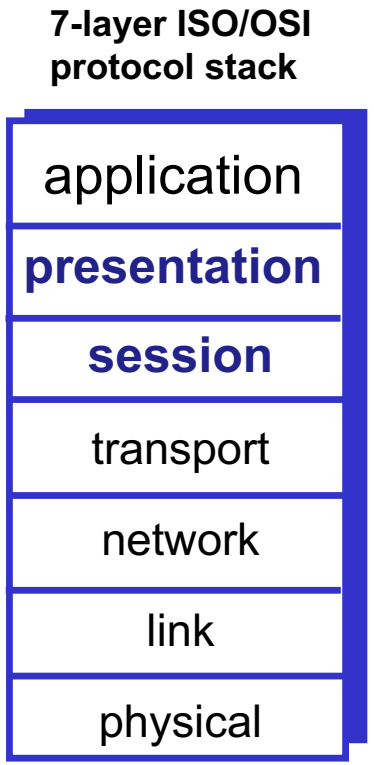
- Human protocols
  - "What's the time?"
  - "I have a question"
- **Network and end-to-end protocols**
  - Between machines
  - All communication activity in Internet governed by protocols



Protocols define format, order of messages sent and received among network entities, and actions taken on message transmission/receipt

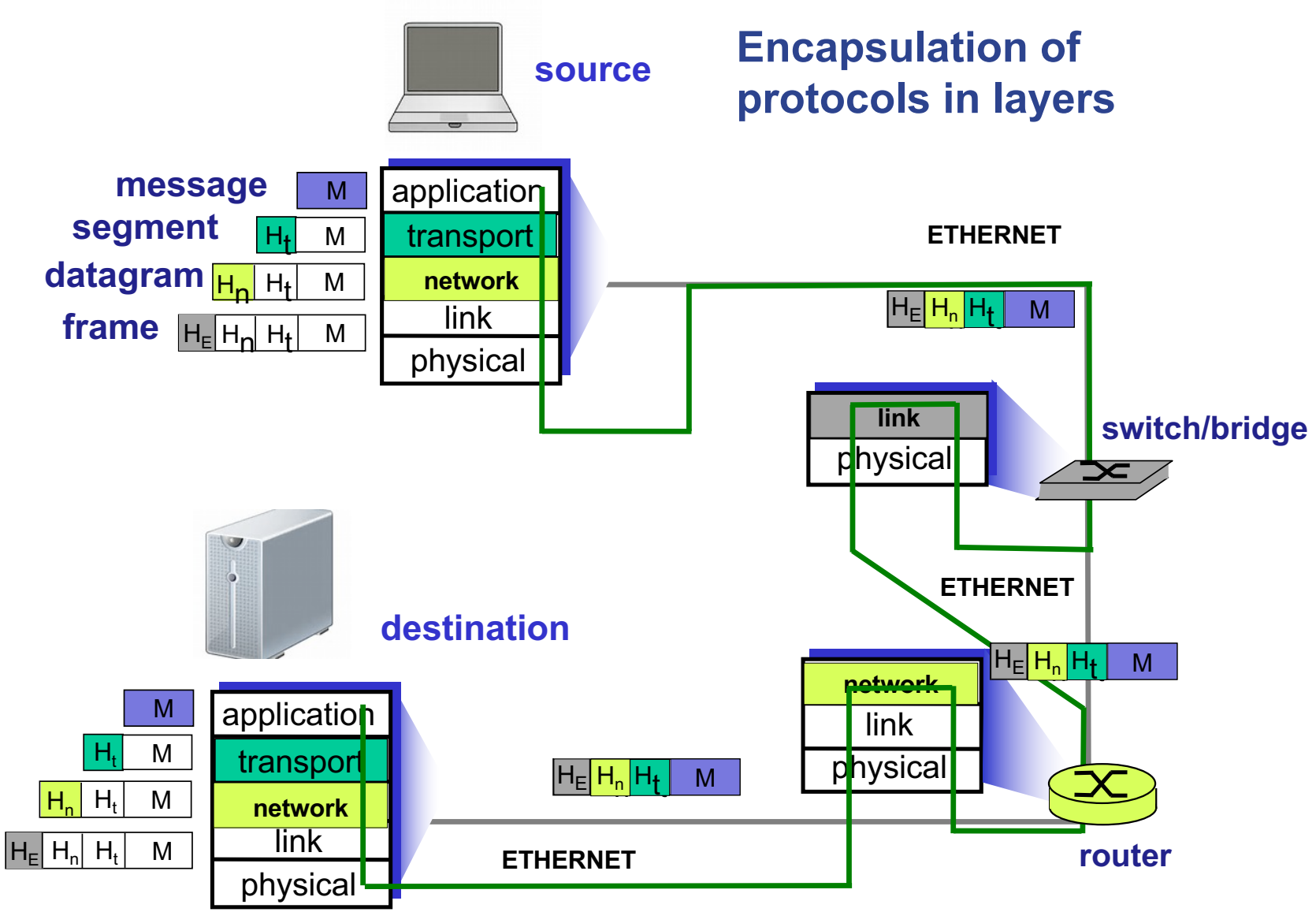
ISO/OSI reference model

- **Presentation:** allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- **Session:** synchronization, check pointing, recovery of data exchange
- **Internet stack "missing" these layers!**
  - these services, *if needed,* must be implemented in application



ISO/OSI International Standard organization/Open Systems Interconnection

Encapsulation of protocols in layers



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Network security

- **The field of network security is about**
  - how bad guys can attack computer networks
  - how we can defend networks against attacks
  - how to design architectures that are immune to attacks

- **Internet not originally designed with (much) security in mind**
  - original vision: “a group of mutually trusting users attached to a transparent network” ☺
  - internet protocol designers playing “catch-up”
  - security considerations in all layers!

Network security: There are bad guys (and girls) out there, and they can

- **Eavesdrop**: intercept messages
- Actively **insert messages** into connection
- **Impersonation**: fake (spoof) source address in packet (or any field in packet)
- **Hijacking**: "take over" ongoing connection by removing sender or receiver, inserting himself in place
- **Denial of service**: prevent service from being used by others (e.g. by overloading resources)

Bad guys can put malware into hosts via Internet

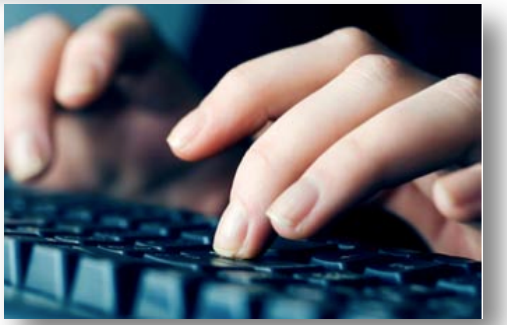
- **Malware (malicious software)** can get into host from a virus, worm, trojan horse or malicious URLs, often **self-replicating**: from an infected host, seeks entry into other hosts

Skadevare Source: NSM NorCert https://www.nsm.stat.no/Documents/NorCERT/2012/Q2-12-WEB.pdf

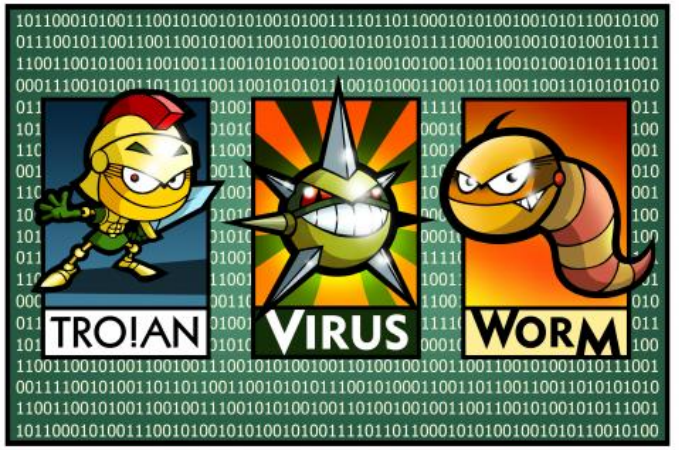
- Skadevare spredd gjennom reklame på norske nettsider er en betydelig utfordring
- Dette har rammet flere store norske nettsider
- Reklameannonser har blitt kompromittert og har blant annet angrepet besøkende på nettsidene

NSM
NorCERT

- **Spyware** malware can record keystrokes, web sites visited, upload info to collection site



Bad guys can put malware into hosts via Internet



- **Trojan horse**: **hidden part** of some otherwise **useful software**
  - often on a Web page (Active-X, plugin)
- **Virus**: **infection by receiving object** (e.g. e-mail attachment) actively executing
  - self-replicating: propagate itself to other hosts, users
- **Worm**: infection by passively receiving object that **gets itself executed**
  - Self-replicating

Verdens første dataorm?

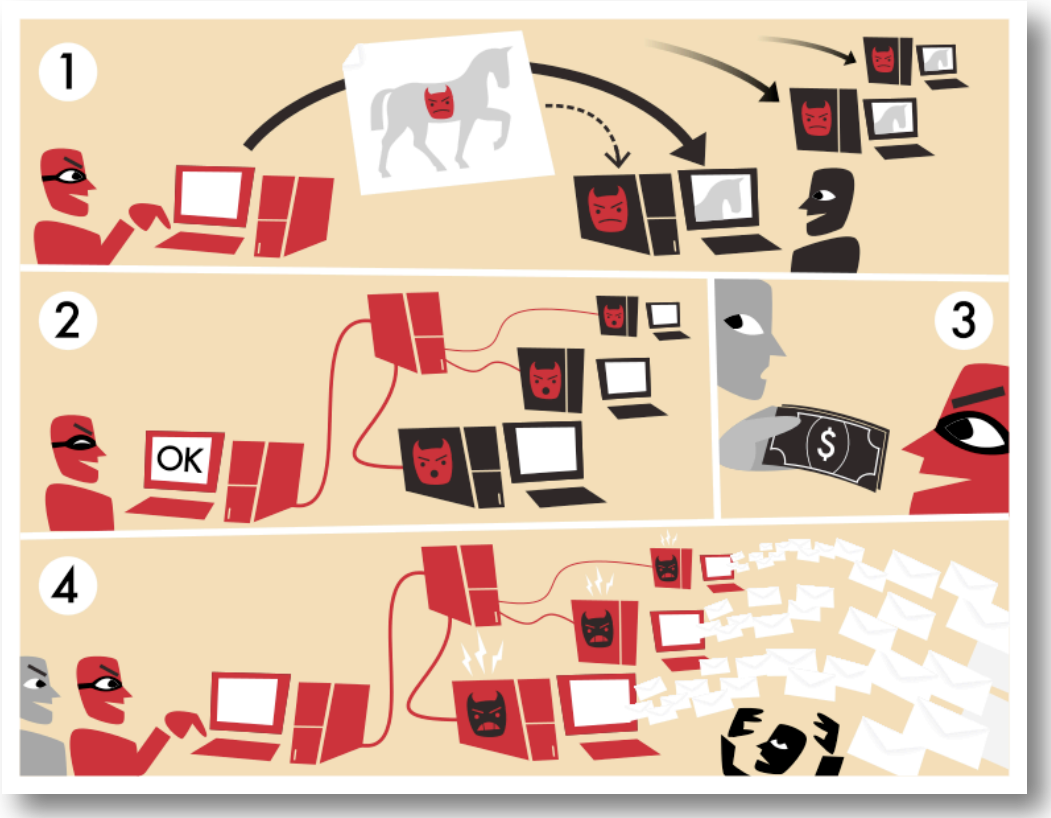

Forhindret norsk data-katastrofe

Bad guys can put malware into hosts via Internet

- **Malicious URL**
  (contained in spam or phishing messages, to download any type of **malware** to the affected computer

- Infected host can be enrolled in a **botnet**, used for spam and distributed DoS attacks

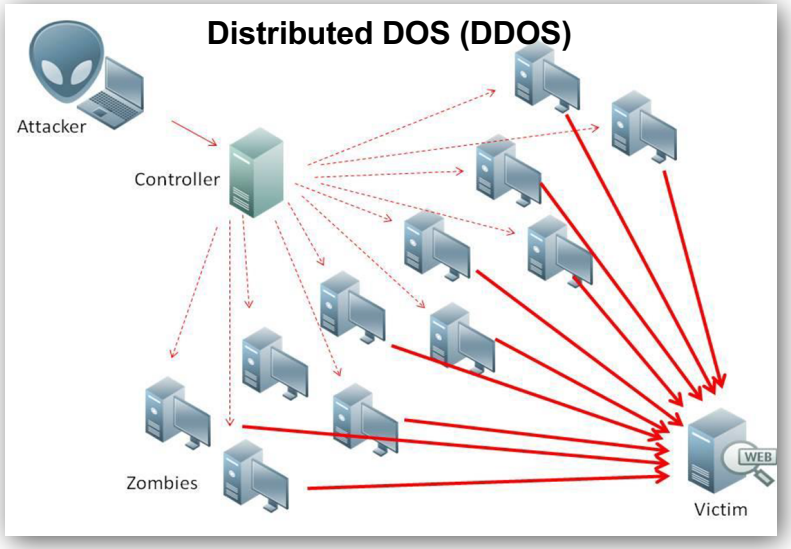
- “Zombie army” – owners unaware



Source: https://en.wikipedia.org/wiki/File:Botnet.svg#file

Bad guys can attack servers and network infrastructure

- **Denial of service (DoS)**: attackers make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic
  1. select target
  2. break into hosts (e.g. botnet)
  3. send packets toward target from compromised hosts



Tara Seals US/North America News Reporter, Infosecurity Magazine
Email Tara

Oct 2016

A massive, ongoing DDoS attack is affecting Twitter, Spotify, Box, SoundCloud, Reddit and other top websites.

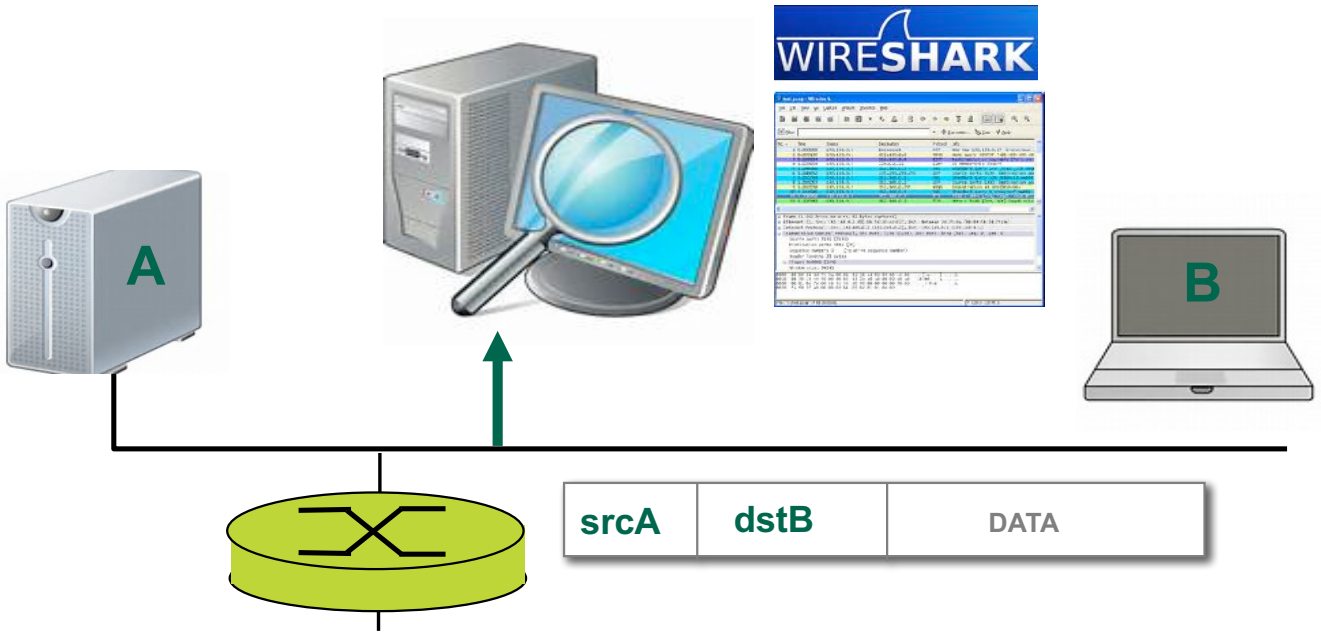
The DDoS attack targeted New Hampshire-based company Dyn and its managed DNS infrastructure, and began early Friday morning. The company originally said that it restored operations around 9:30 a.m. Eastern Time, but a second attack followed that knocked Twitter and others offline again for some users, especially those on the East Coast of the US. The attack is ongoing and is causing outages and slowness for many of Dyn's customers.

The White House press secretary said that the US Department of Homeland Security is investigating, but so far no one knows who might be behind the attacks.

http://www.infosecurity-magazine.com/news/massive-ddos-attack-knocks-out/

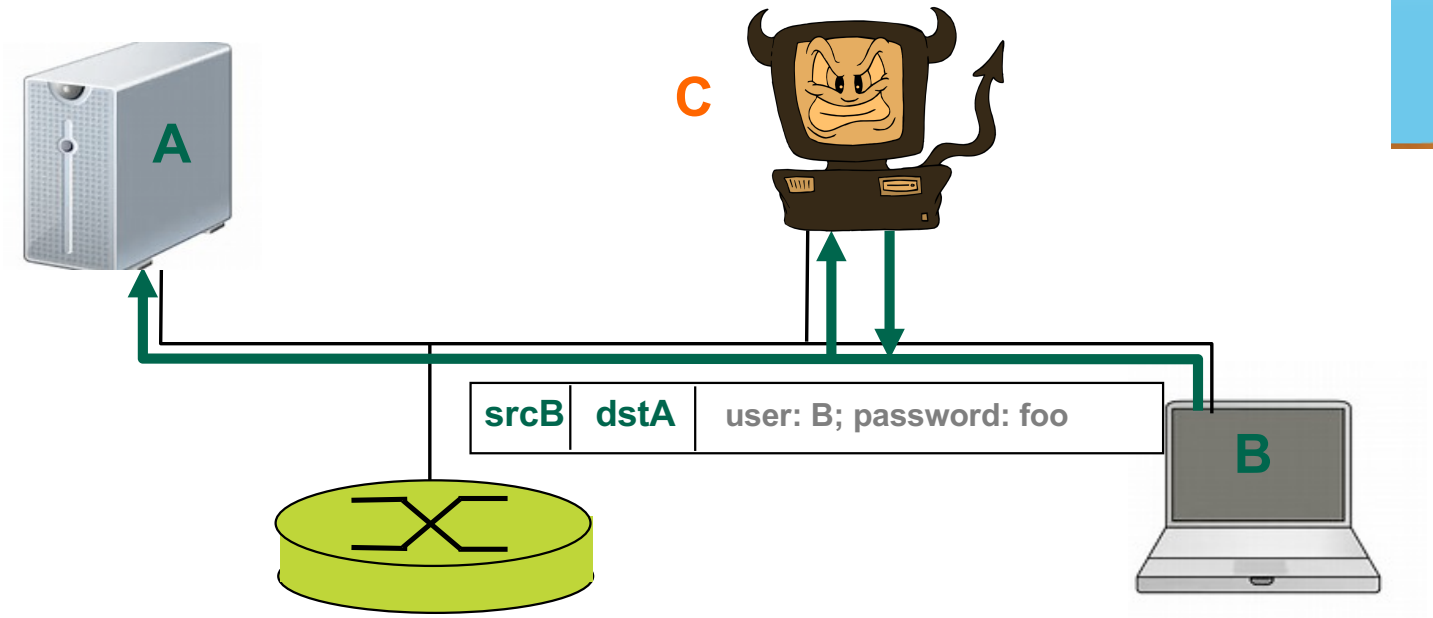
Bad guys can sniff packets

- Broadcast media (shared Ethernet, wireless)
- Promiscuous network interface reads/records all traffic (including passwords!) passing by



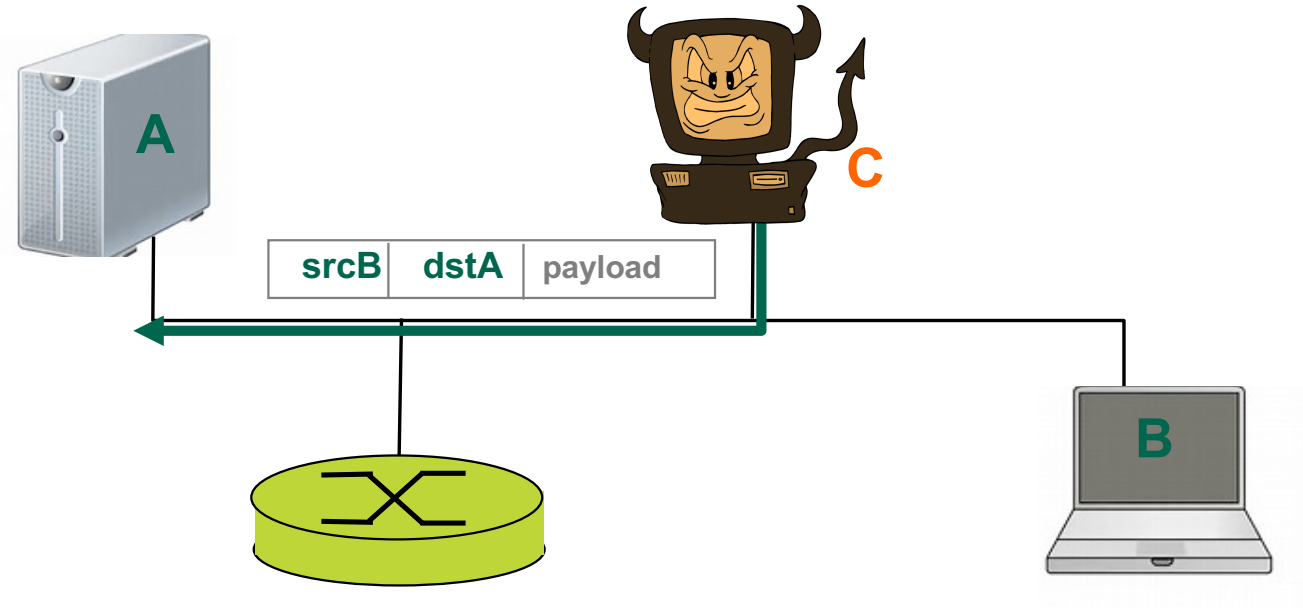
Bad guys can record and playback

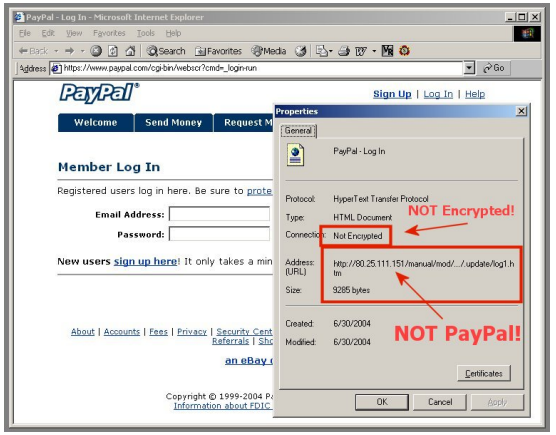
- Sniff sensitive info (e.g. password if not encrypted) and use later
- From system point of view password holder is that user



Bad guys can use spoofed source addresses

- Send packet with false source address (MAC, IP) or spoof URLs
- IP spoofing used in combination with DOS (denial of service) attack





Friends and enemies: Applications need secure communication

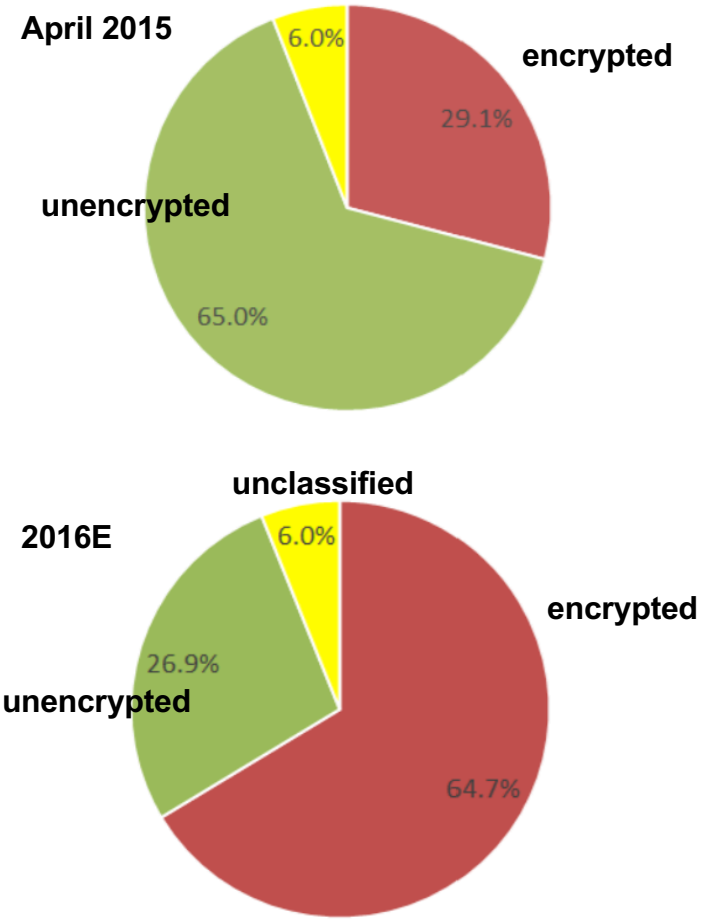
- web browser/server for electronic transactions (e.g. on-line purchases)
- on-line banking client/server
- DNS (domain name servers)
- routers exchanging routing table updates

data, control messages

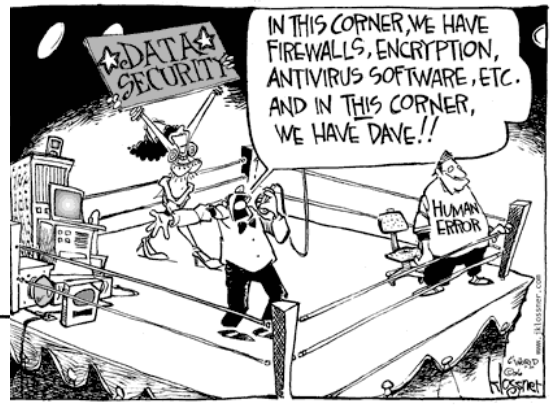
Trudy (intruder) may intercept, delete, add messages

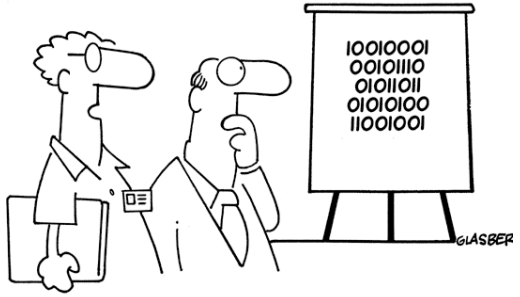
Trafikkryptering øker

North America, Fixed Access Service Provider

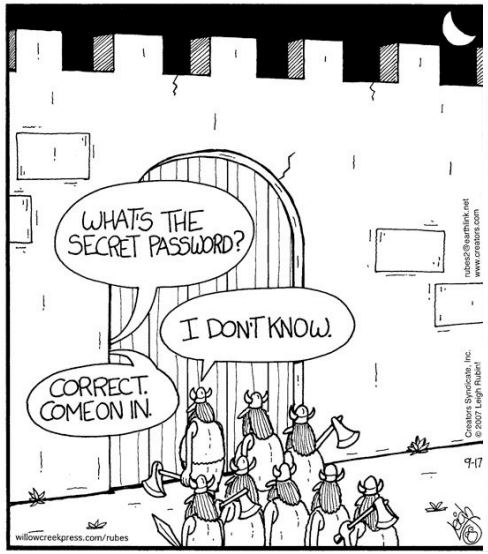


"Somebody broke into your computer, but it looks like the work of an inexperienced hacker."





"We've devised a new security encryption code. Each digit is printed upside down."



Why great care and consideration should be taken when selecting the proper password

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1.7 History of computer networking and the Internet

Internet History in brief – I

- 1972-1980: **Internetworking**, new and proprietary nets
- 1980-1990: **New protocols**, a proliferation of networks
  - TCP/IP
  - SMTP (e-mail), DNS (domain name system), FTP (file transfer)
  - TCP congestion control
- 1990, 2000's: **Commercialization**
  - WWW
  - Instant messaging
  - Social networks
  - Peer-to-peer file sharing
- 2010+
  - Software as a service
  - Streaming
  - Cloud services

Nettoperatører utfordres fortsatt I

Mark Zuckerberg 'deeply disappointed' SpaceX explosion blew up $200m Facebook satellite

'We will keep working' to make up for satellite's shortfall, vows Facebook CEO.

By Mary Papenfuss
September 2, 2016 02:23 BST

Video captures SpaceX rocket fiery explosion (Reuters)

The SpaceX rocket that exploded on the launch pad at Cape Canaveral also blew up a pricey Facebook satellite it was supposed to deliver into orbit, leaving social network company boss Mark Zuckerberg "deeply disappointed."

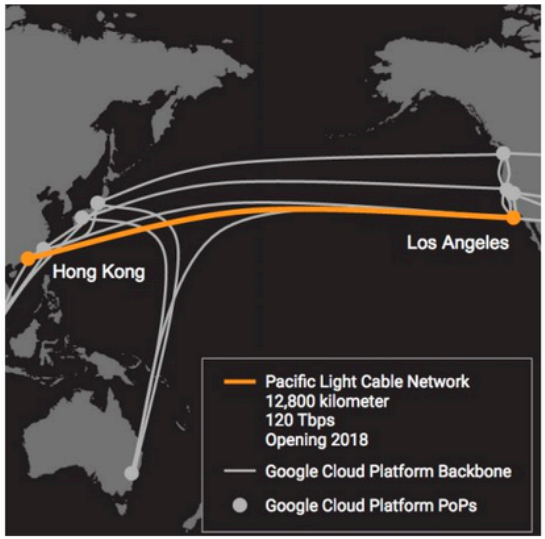
FierceTelecom

TELECOM INSTALLER ENTERPRISE

Telecom

Facebook, Google shake up submarine cabling market with planned 8,000-mile network

by *Sean Buckley* | Oct 12, 2016 1:06pm



A map showing Google and Pacific Light Cable Network's planned submarine cable route. Image: Google

Facebook and Google have hatched a plan to build a 8,000 submarine mile cable from Los Angeles to Hong Kong, a move that reflects the growing movement by content-driven companies to take their network matters into their own hands. The pair is being joined by PLDC (Pacific Light Data Communication Co.).

http://www.ibtimes.co.uk/mark-zuckerberg-deeply-disappointed-spacex-explosion-blew-200m-facebook-satellite-1579256

Nettoperatører utfordres fortsatt II

Project Loon is Latest Google Research Project to Get a New Business Leader

Mike Cassidy steps aside for a satellite broadband industry veteran tasked with taking company's internet balloon project from stratosphere to profitability

by **Brad Stone**
24. august 2016, 00.00 CEST

Bloomberg Technology

FORTUNE 500

Google Fi Mobile Service Adds Coverage From US Cellular

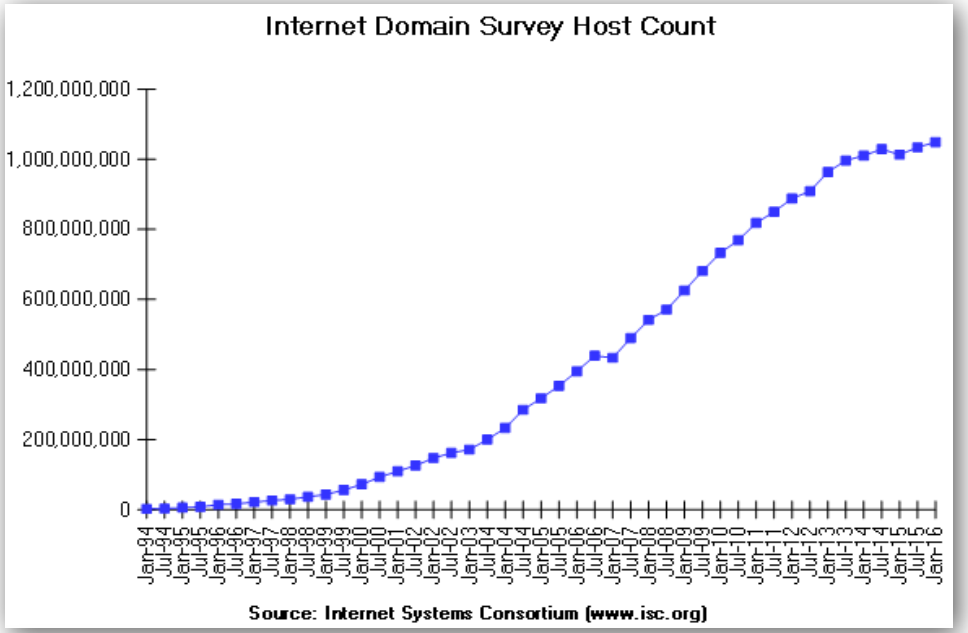
Aaron Pressman
Updated: Jun 08, 2016 9:46 PM CEST

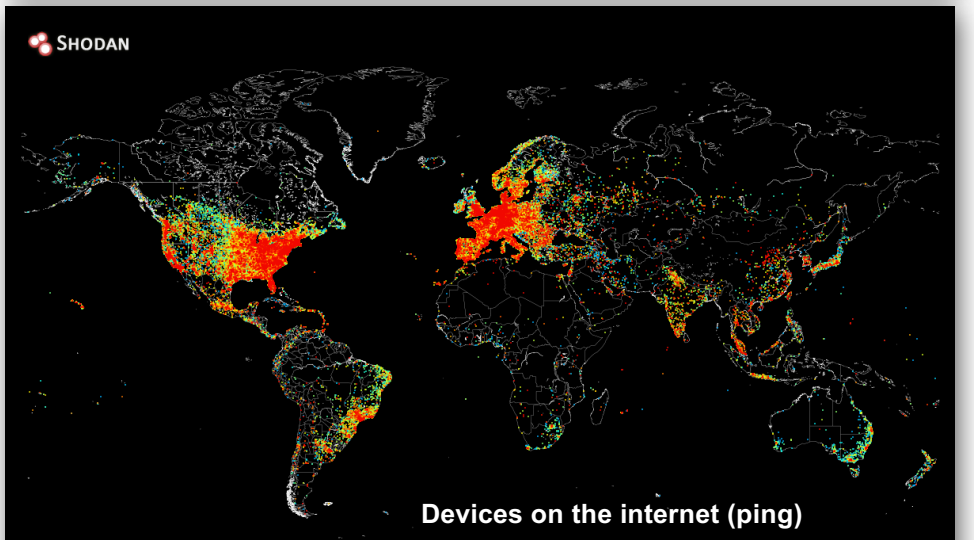
Google is adding a third mobile carrier, U.S. Cellular, to its Fi wireless service to improve coverage for subscribers.

Subscribers to the Fi service, which currently relies on coverage from Sprint and T-Mobile, get phones that automatically seek out the strongest signal. The third network will become available via a software update to Fi subscribers in "coming weeks," Fi product manager Evan Jacobs said in a blog post on Wednesday.

Internet History in brief – II

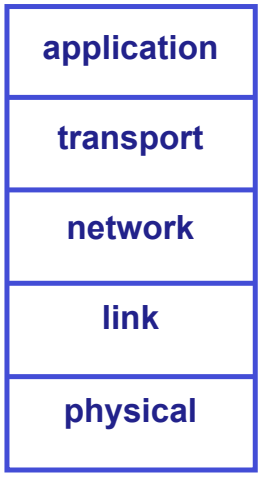
- ~1 billion hosts, smartphones, tablets etc
- Aggressive deployment of broadband (and mobile) access
- Increasing ubiquity of high-speed wireless access
- Emergence of online social networks: Facebook
- Service providers (Google, Microsoft, Facebook) create their own networks
- E-commerce, universities, enterprises running their services in “cloud”

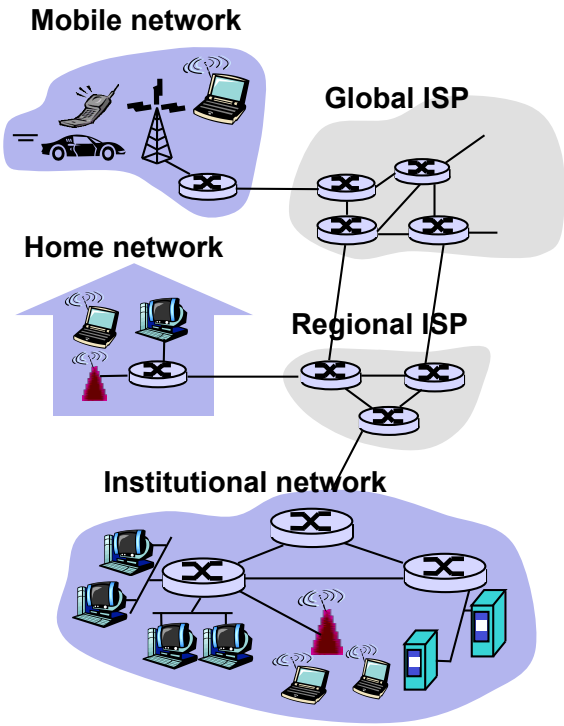




Summary: More depth and details to follow in coming lectures!

- what's the Internet?
- what's a protocol?
- packet vs. circuit switching
- network edge; hosts, access network, physical media
- network core: Internet structure
- performance: loss, delay, throughput
- protocol layers, service models
- beware of security
- history





Next week: Applications

Week	Date & Time	Topic	Room	Responsible	**Remark (ref.to 6th edition)**
2	Thursday 12:15 – 14:00	Practical Information; Course Introduction Network and Internet Overview	R1	Norvald Kjersti	 Chapter 1 + brief introduction to Physical layer.
2	Friday 09:15 – 11:00	Network and Internet Overview (cont.)	R1	Kjersti	Chapter 1 Chapter 8.1
3	Thursday 12:15 – 14:00 Thursday 14:15 – 15:00	Application Layer Theory Assignment 1: *Overview of Computer Networks and the Internet* Wireshark Lab 1: *Intro (optional but highly recommended!)*	R1 R1	Kjersti Assistants/ Ida/Norvald	Chapter 2 One must deliver and pass at least 5 of the 8 theory assignments.
3	Friday 09:15 – 11:00	Application Layer (cont)	R1	Kjersti	Chapter 2 Chapter 8.2-3 and 8.5.1