



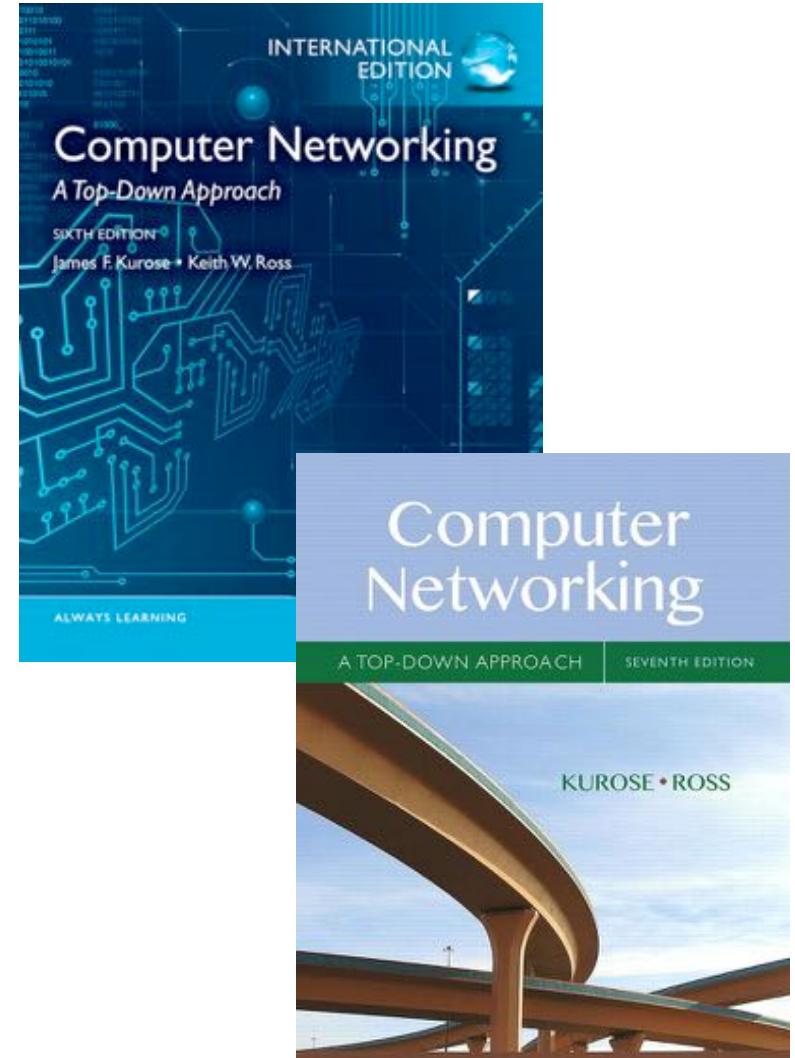
NTNU

TTM4100

Communication - Services and Networks

Introduction Chapter 1

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



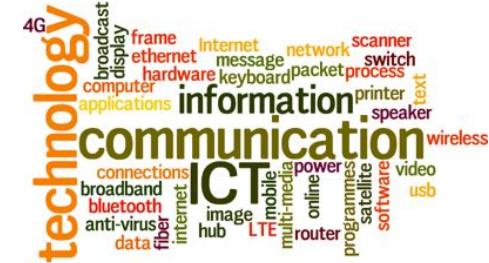
The content of many of these slides is based on slides available from the web-site of the book by J.F Kurose and K.W. Ross.

Schedule

JANUARY							
	Mo	Tu	We	Th	Fr	Sa	Su
53							1
1		2	3	4	5	6	7
2		9	10	11	12	13	14
3		16	17	18	19	20	21
4		23	24	25	26	27	28
5		30	31				29

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

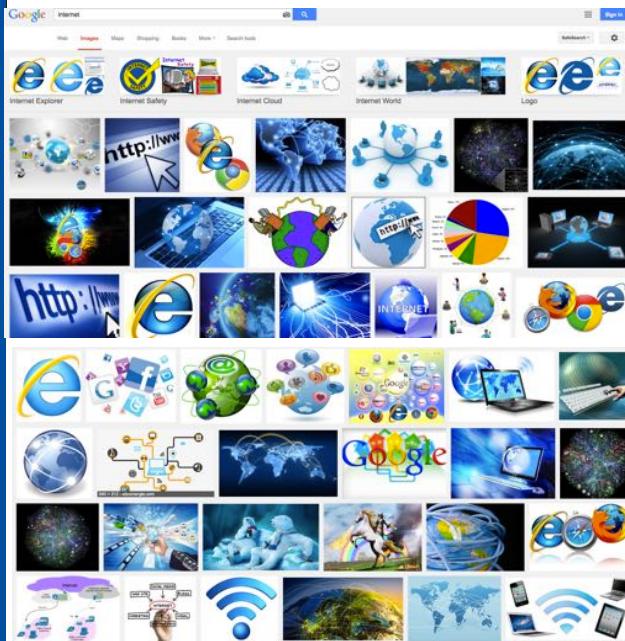
- get “the feeling” and terminology
 - being a knowledgeable home-network administrator



- **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

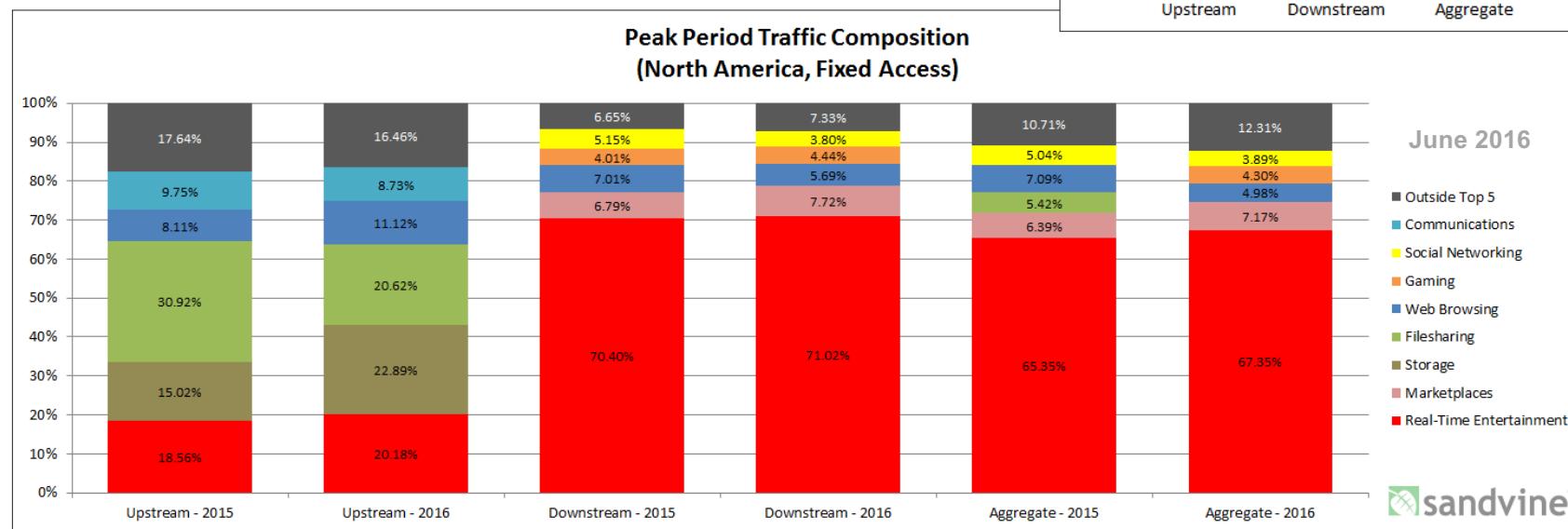
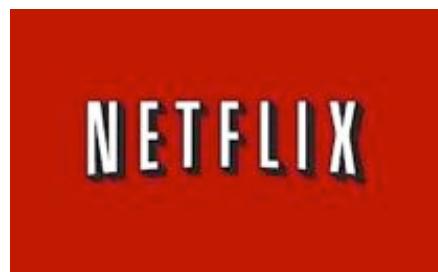
What's the Internet – search engine images view



YAHOO!



Entertainments over the internet dominates the traffic volume



Top 10 peak period applications - US

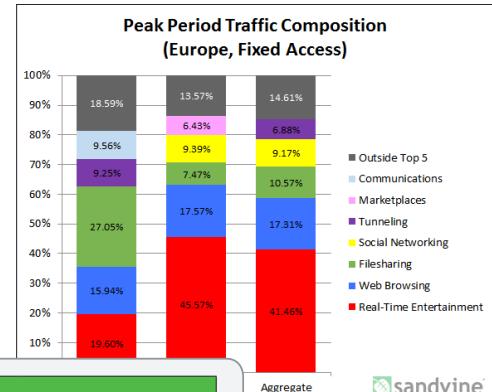
Sept 2015

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%



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

Top 10 peak period applications - Europe

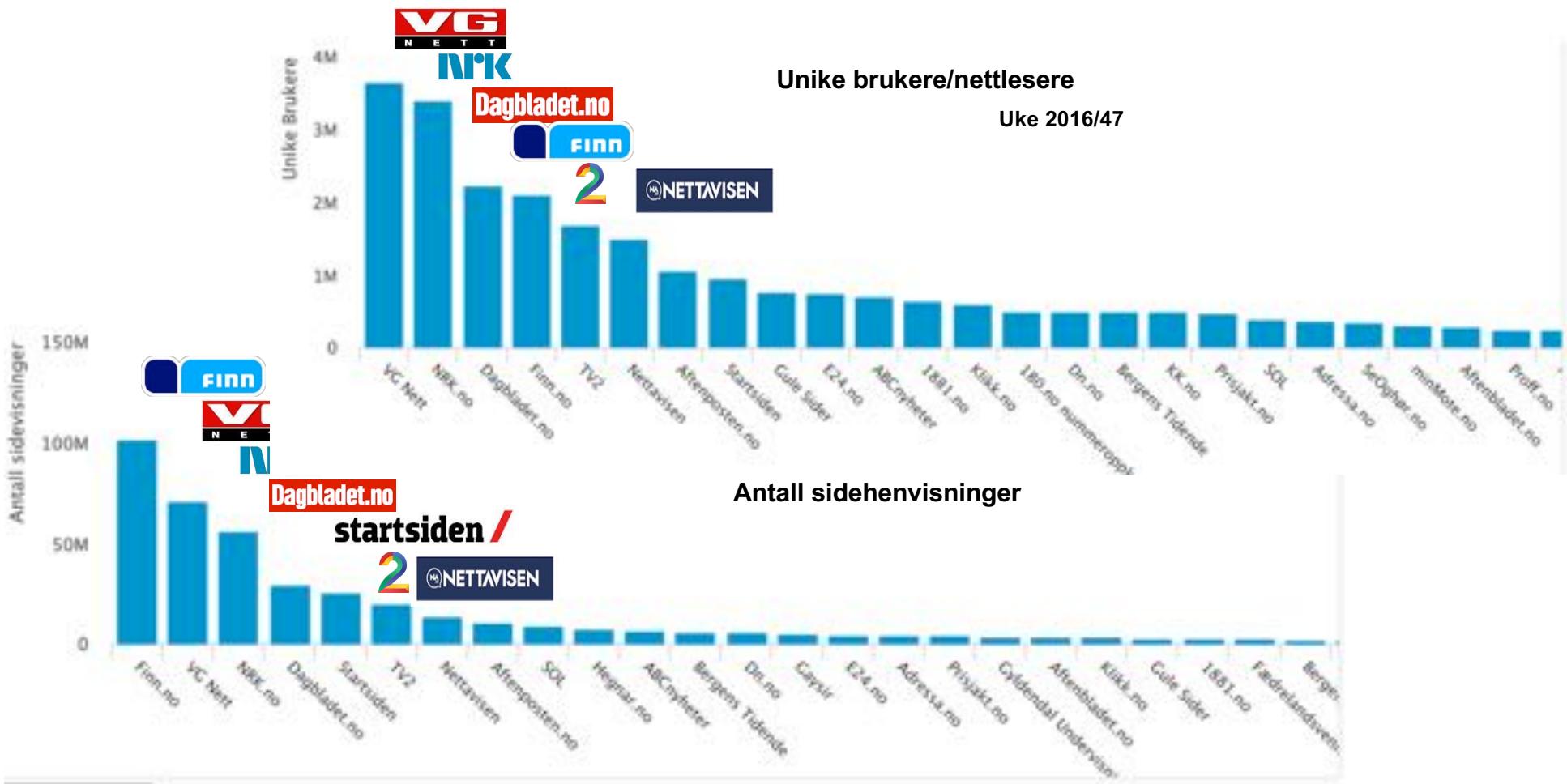


Sept 2015

Rank	Upstream		Downstream		Aggregate	
	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%

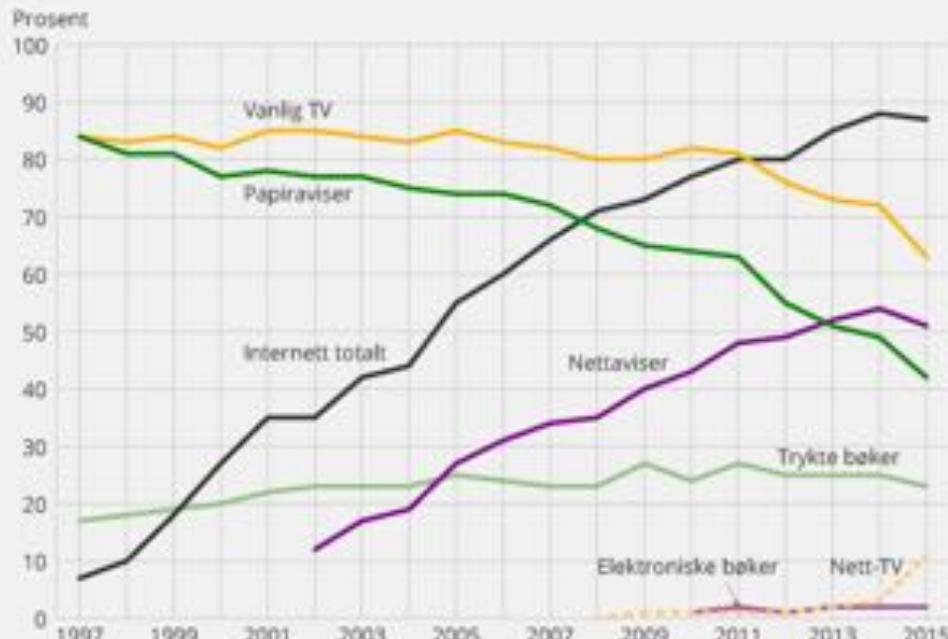
 sandvine®

Top Norwegian web sites

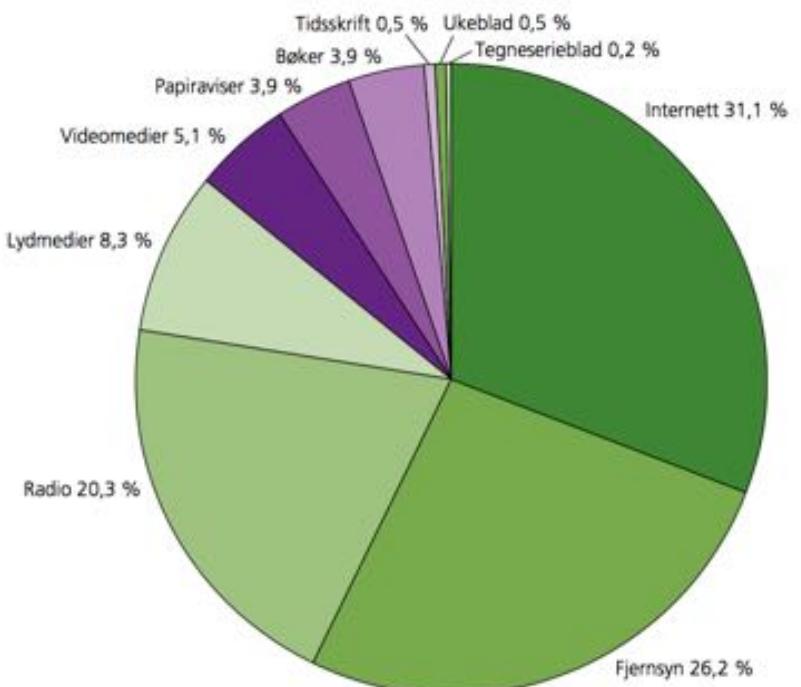


Medietilgang og -forbruk

Figur 2. Andel med tilgang til elektroniske medier



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

Our editorial staff evaluates products and services independently, but Top Ten Reviews may earn money when you click on links. Learn More

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									
Visit Site									

Glem DAB-maset, bruk nettradio i bilen

Mobilén er løsningen.

Artikkelen 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



Globalization.
Industry 4.0
Networking.
Cyber
Physical
Production
Systems.
Virtualization.



The Aachen Approach.
Process Knowledge.
Mid Tier



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. Let me know if you'd like to see included.

Can I help out?

Yes and no. Currently, there's no way to directly upload your own banner data to Shodan. To maintain the accuracy and preventing abuse, I haven't added such a system yet. But I would greatly appreciate contributions to the 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.



Any device that's connected to the Internet.

SHODAN

EXPOSE ONLINE DEVICES.

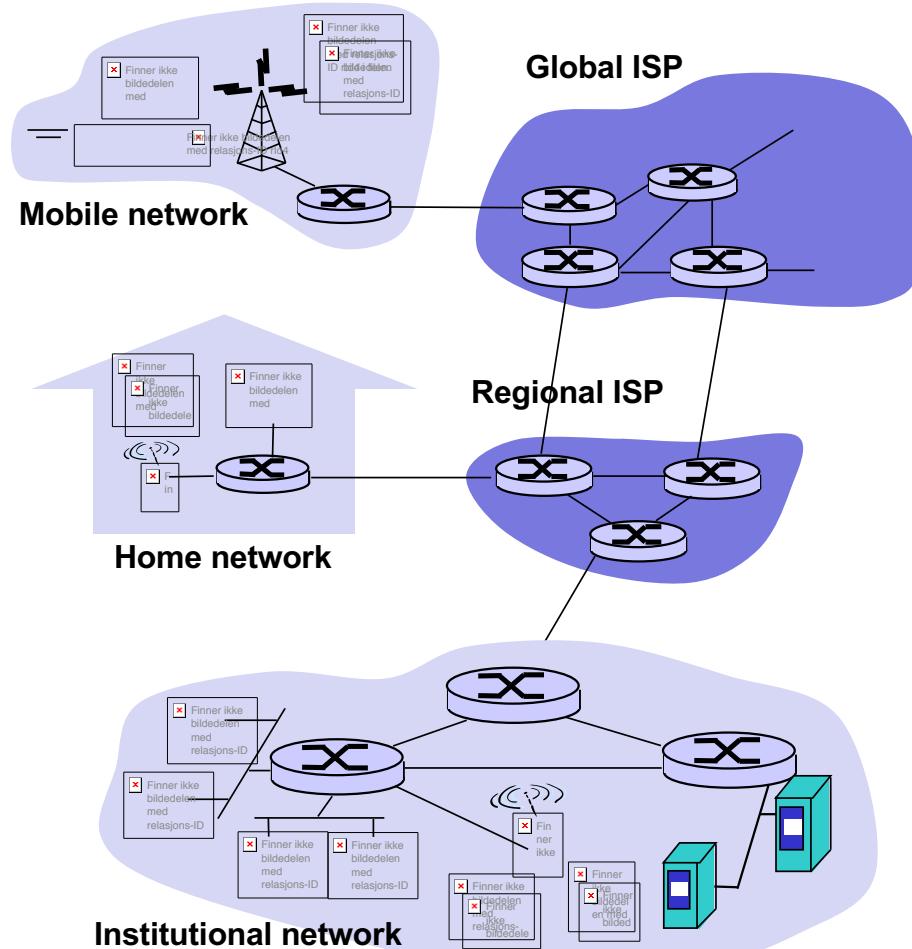
WEBCAMS. ROUTERS.
POWER PLANTS. IPHONES. WIND TURBINES.
REFRIGERATORS. VOIP PHONES.

[TAKE A TOUR](#) [FREE SIGN UP](#)

Search Queries: default password - finds results with "default password" in the banners, file names, or configuration files.

<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

How the Internet began

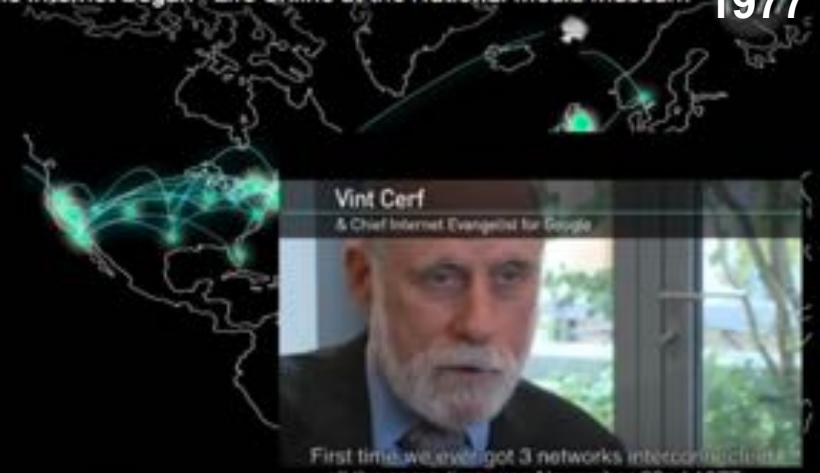


June 1973: First transatlantic satellite link

Vint Cerf & Bob Kahn
invent the TCP system
in 1973

museum 1973

How the Internet Began - Life Online at the National Media Museum 1977



Nov 1977: 3 computer networks connected for the first time

Vint Cerf
& Chief Internet Evangelist for Google

First time we ever got 3 networks interconnecting

How the Internet Began - Life Online at the National Media Museum 1983



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

everyone who is on all the research
to start using TCP/IP only.

1993

How the Internet Began - Life Online at the National Media Museum



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

Hvordan kan (sofistikerte) aktører utnytte sårbarheter?



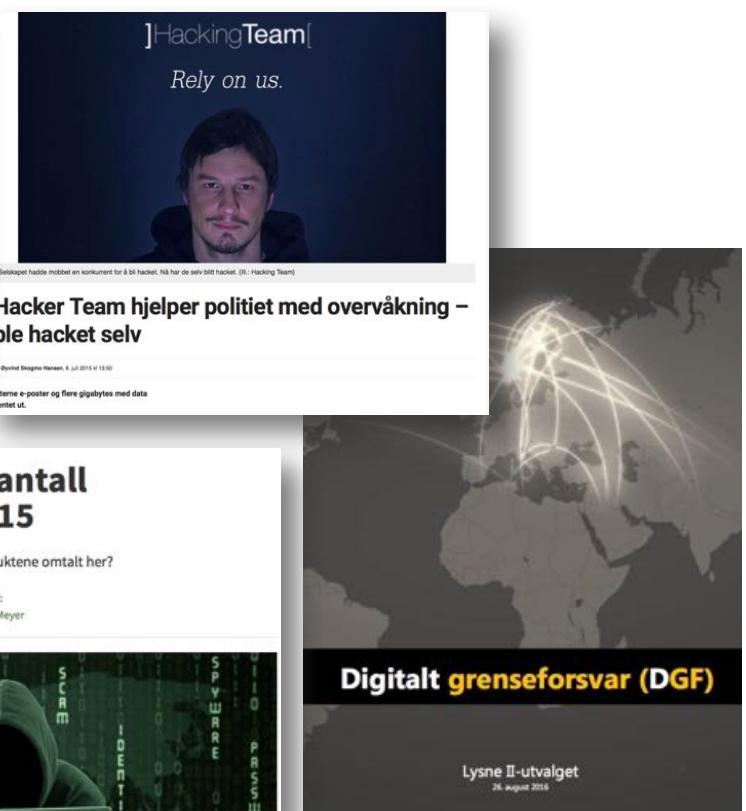
Du bør skanne portene dine
Mange mangler oversikt over hva de egentlig deler med alle på Internett.
Av Harald Brønbach
Publisert 24. oktober 2014 kl. 12:47

Du er registrert med følgende porter åpne:

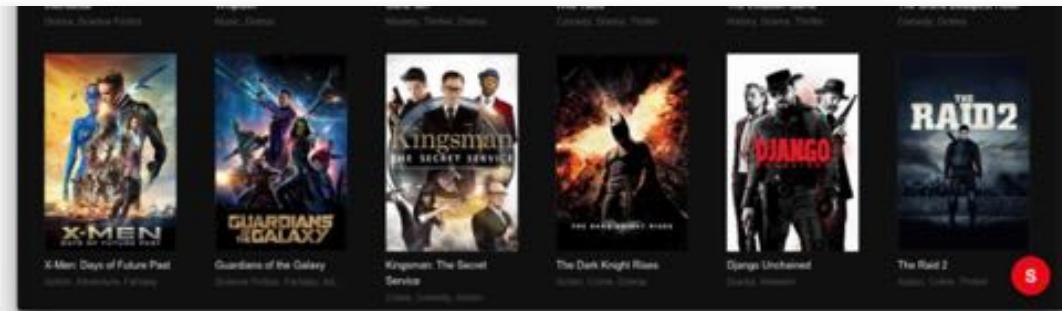
PORT 22:
SSH: Du har en åpen SSH-port. Det er ikke så vanlig i private hjem. Om du er på jobb, er det kanskje en IT-avdeling som ikke mener om hva dette er.
[Les mer](#)

PORT 443:
HTTPS: Du har en åpen port, tristig for en web-server som leverer innhold til nettlesearen din. Det kan være et web-konfigurerbar nettkort eller nettkortet din egen PC. Du kan se om du kjenner igjen innholdet her: <https://80.203.113.108/>
[Les mer](#)

PORT 1900:
UPnP: En åpen port viser at din IP-adresse er koblet til andre enheter. UPnP er en standard som dataprogrammer, nettverkskomponenter og andre enheter bruker for å koble seg sammen via IP-adressen. Du bør vurdere å installere brannmur.
[Les mer](#)



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

① 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 siktet på å bli den første globale TV-tjenesten verden har sett.

Dagbladet mottar European Press Prize

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

AXEL DUE
axel.due@dagbladet.no



PÅL NORDSETH
pns@dagbladet.no

Freitag 17. mars 2014, kl 14:39

Twitter



Null CTRL



ÅPENT KAMERA: Kameraet på utestedet Klubbleteateret i Drammen sendte videostrømmen rett på nett. Video: Øystein 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 Kongslø Hillestad og Espen Sandli har sammen med utvikler Ola Strømman testet alt fra overvåkningskameraer 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.

Dagbladet

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 lengre 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).

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

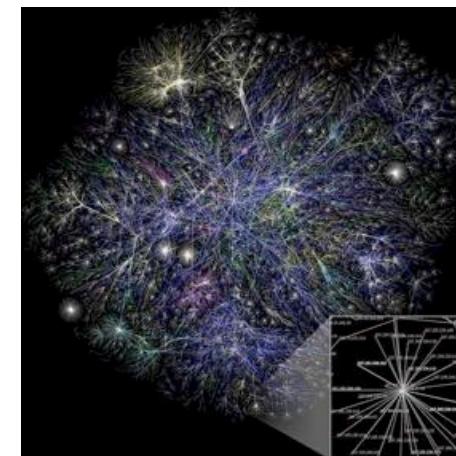
1.4 Packet-switched networks

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

What is the internet?

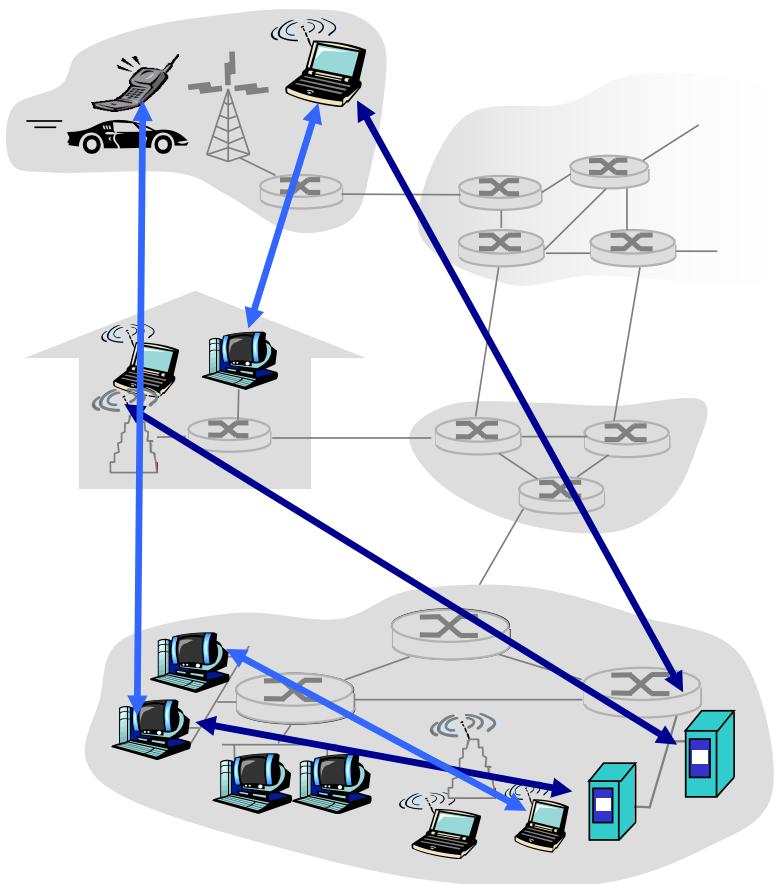
Applications run in the end systems of the network edge

- **Client/server model**

- client host requests, receives service from always-on server
- e.g. web browser/server

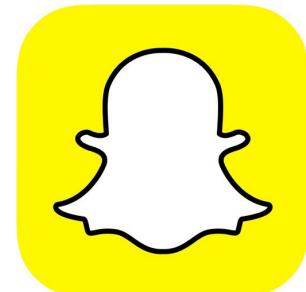
- **Peer-peer model**

- minimal (or no) use of dedicated servers
- e.g. BitTorrent



What is the internet?

Client-server or peer-to-peer?



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
<ul style="list-style-type: none">• Stream basic video/music• Text communications• VOIP• Web browsing• Web conferencing• Cloud based learning management system	<ul style="list-style-type: none">• SD Video conferencing• Personal content locker• HD Video streaming• Electronic health records• ERP/CRM• VoLTE	<ul style="list-style-type: none">• Virtual office• Connected medicine• HD Video conferencing• Stream ultra HD video• High frequency stock trading• Connected car safety applications

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



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- access networks, physical media

1.3 Network core

- packet switching, circuit switching, network of networks

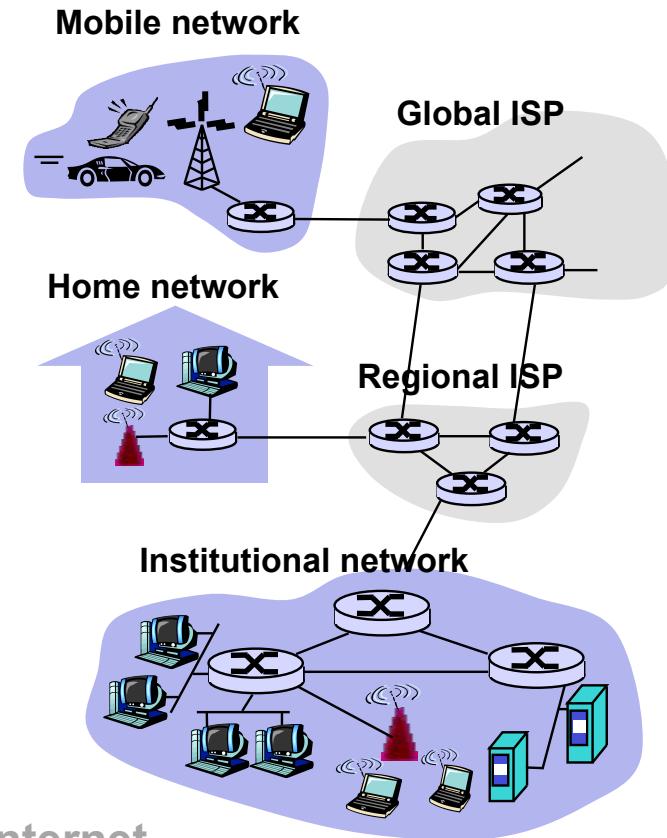
1.4 Packet-switched networks:

- 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



A closer look at network structure

▪ Network edge

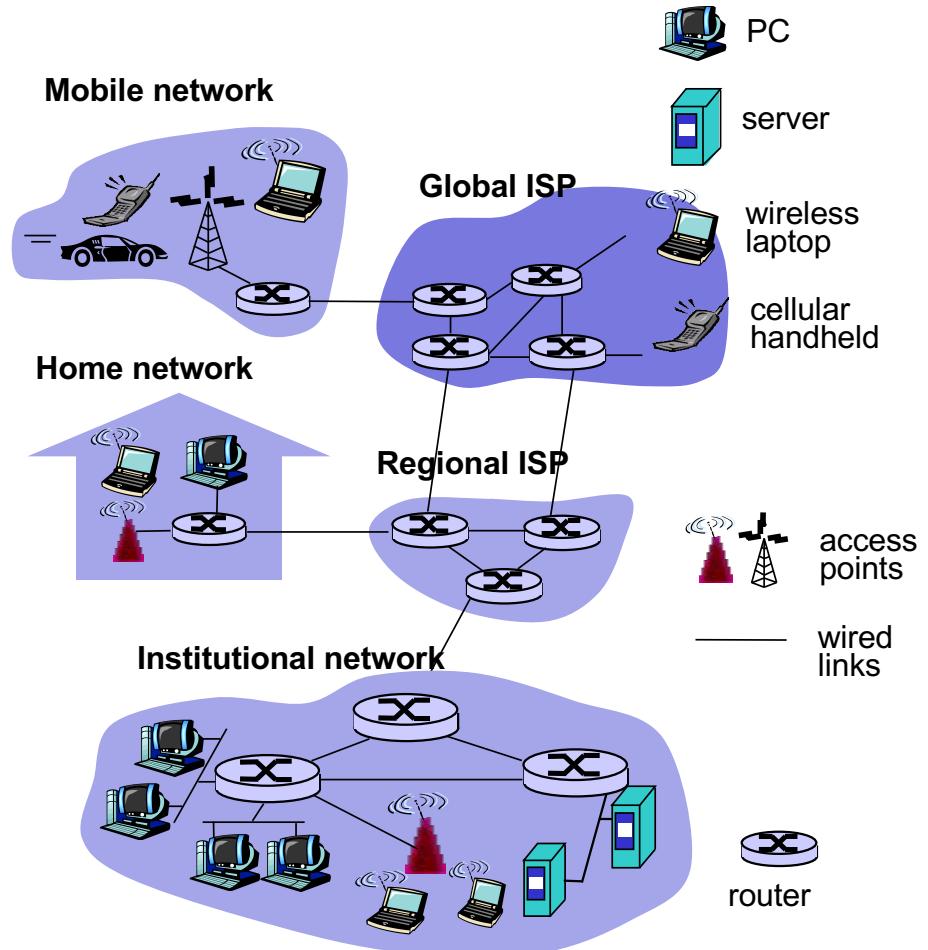
- applications (e.g. web, email)
- Computing devices:
hosts = end systems
running network apps
(e.g. PC, mobile, xbox)

▪ Access networks

- physical media: wired,
wireless communication links

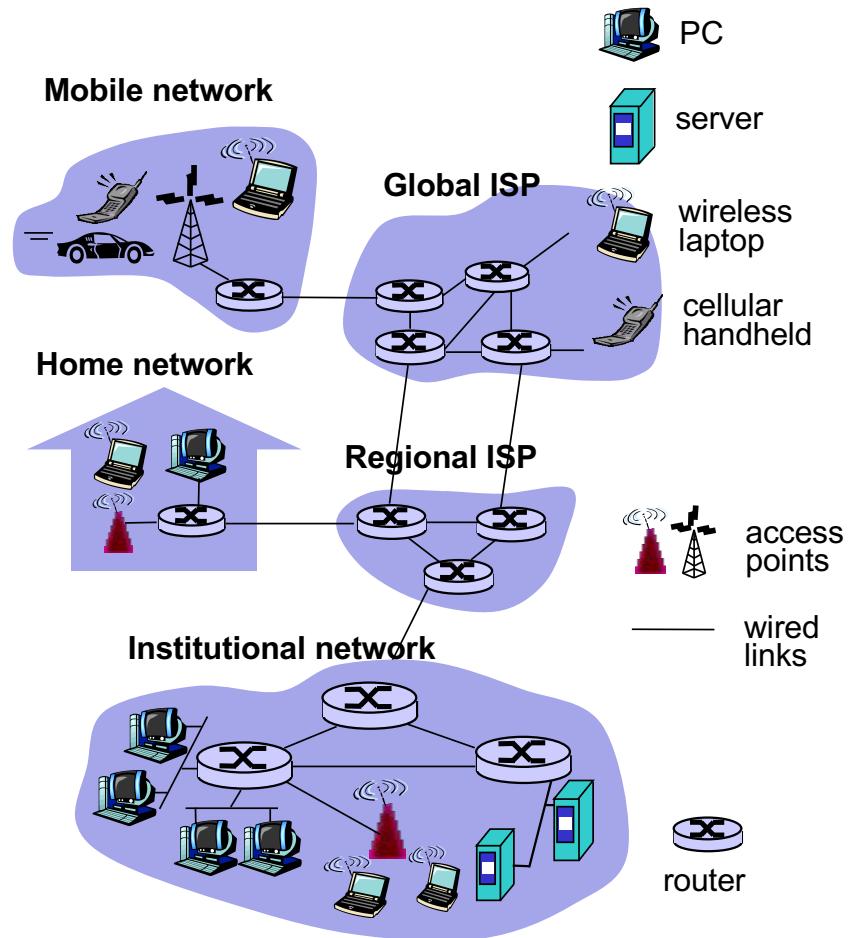
▪ Network core

- interconnected routers
- network of networks

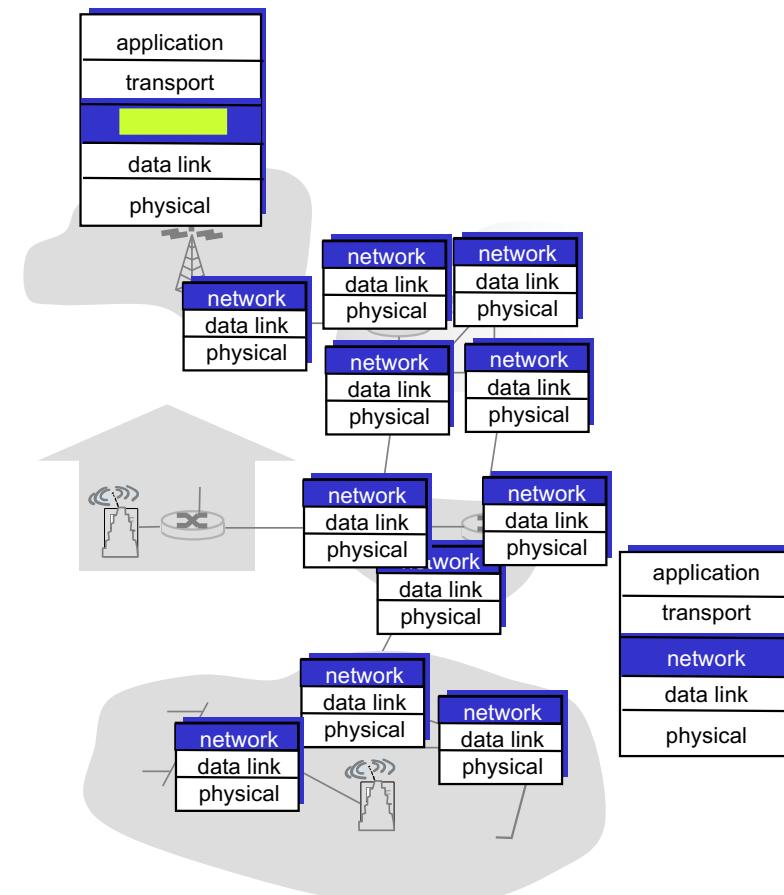
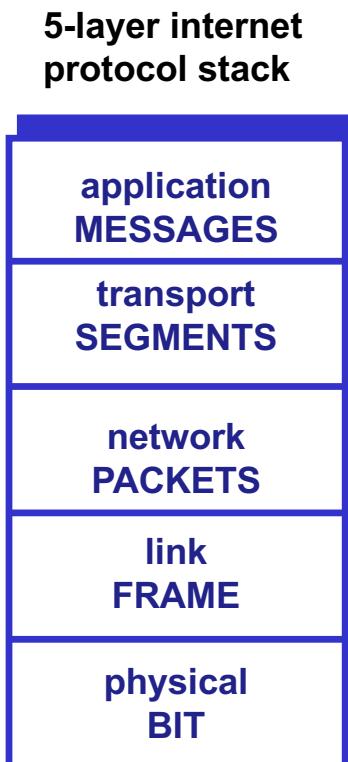


The InterNET: network structure = component view

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

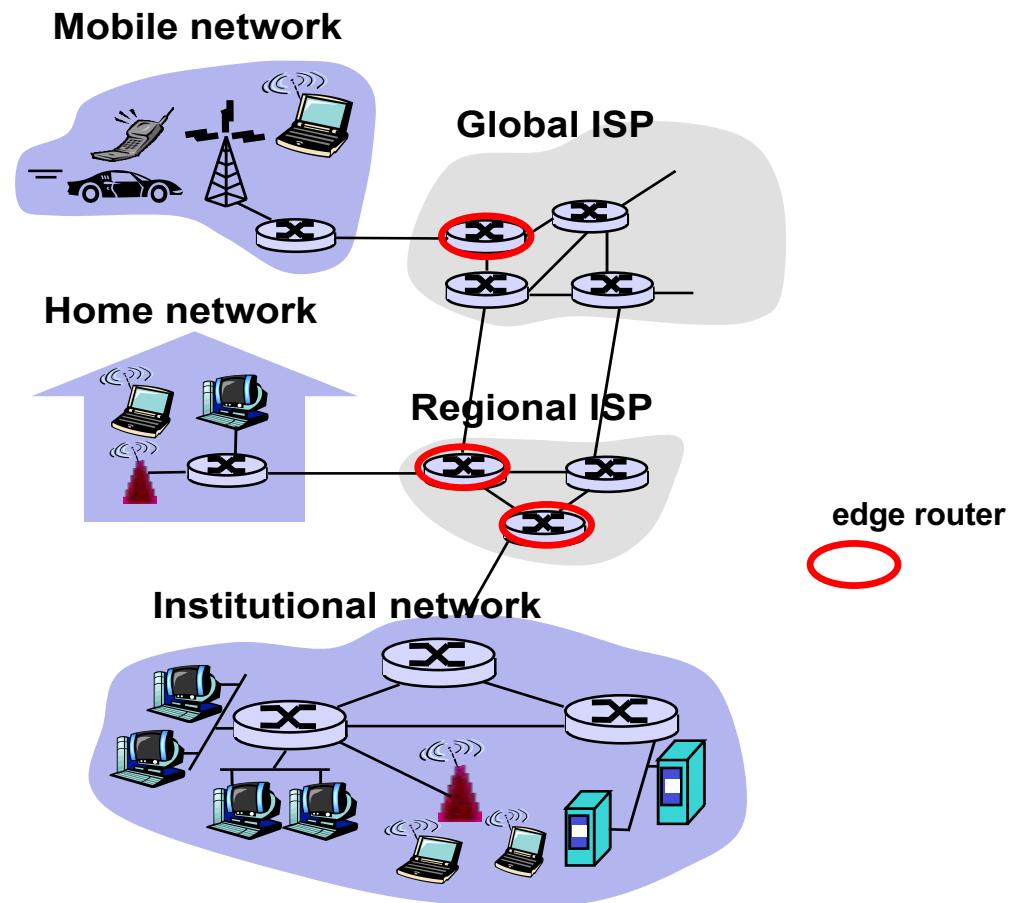


Communication protocols send user messages as network packets between sender and receiver



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)

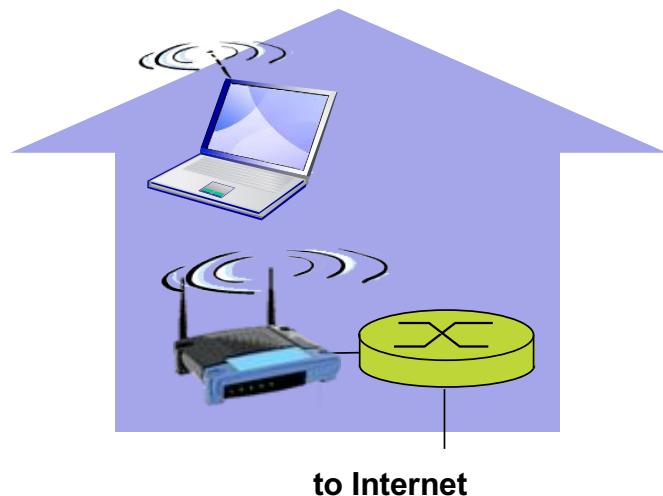


Wireless access through radio networks of local or wide-area reach

- 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

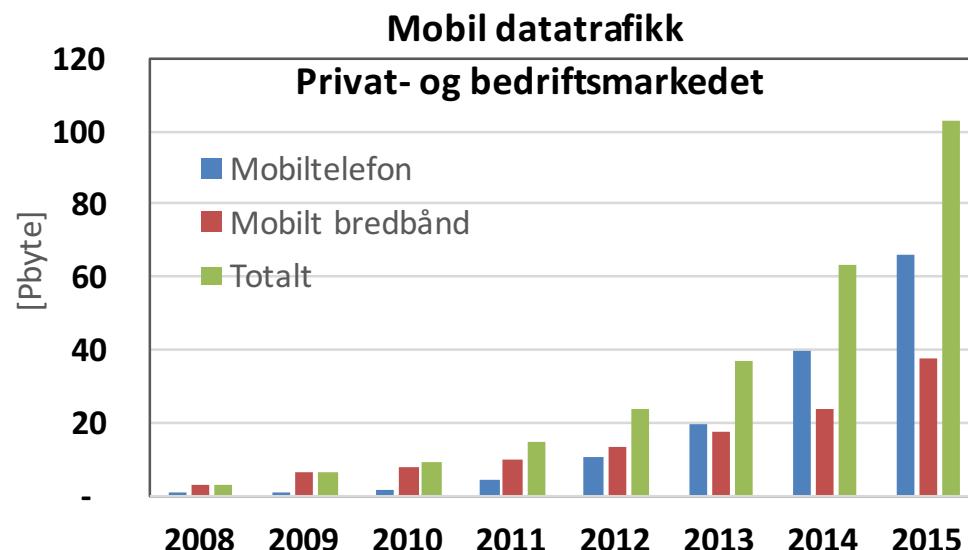


Mobile broadband – wider-area radio access

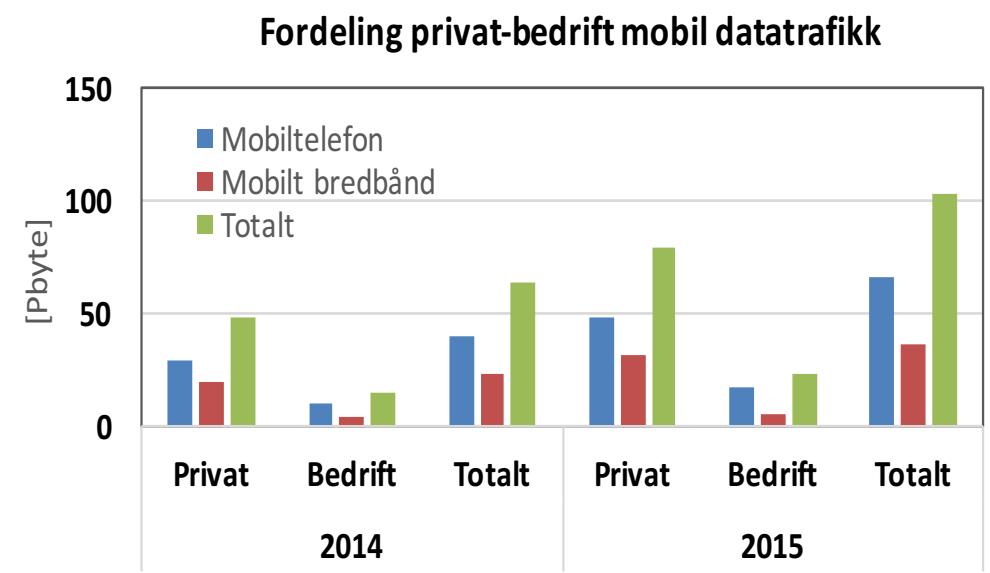
- access provided by telco/cellular operator
- 10's of km
0,2 - 100 Mbps (Edge, UMTS/WDMA, HSPA, LTE)



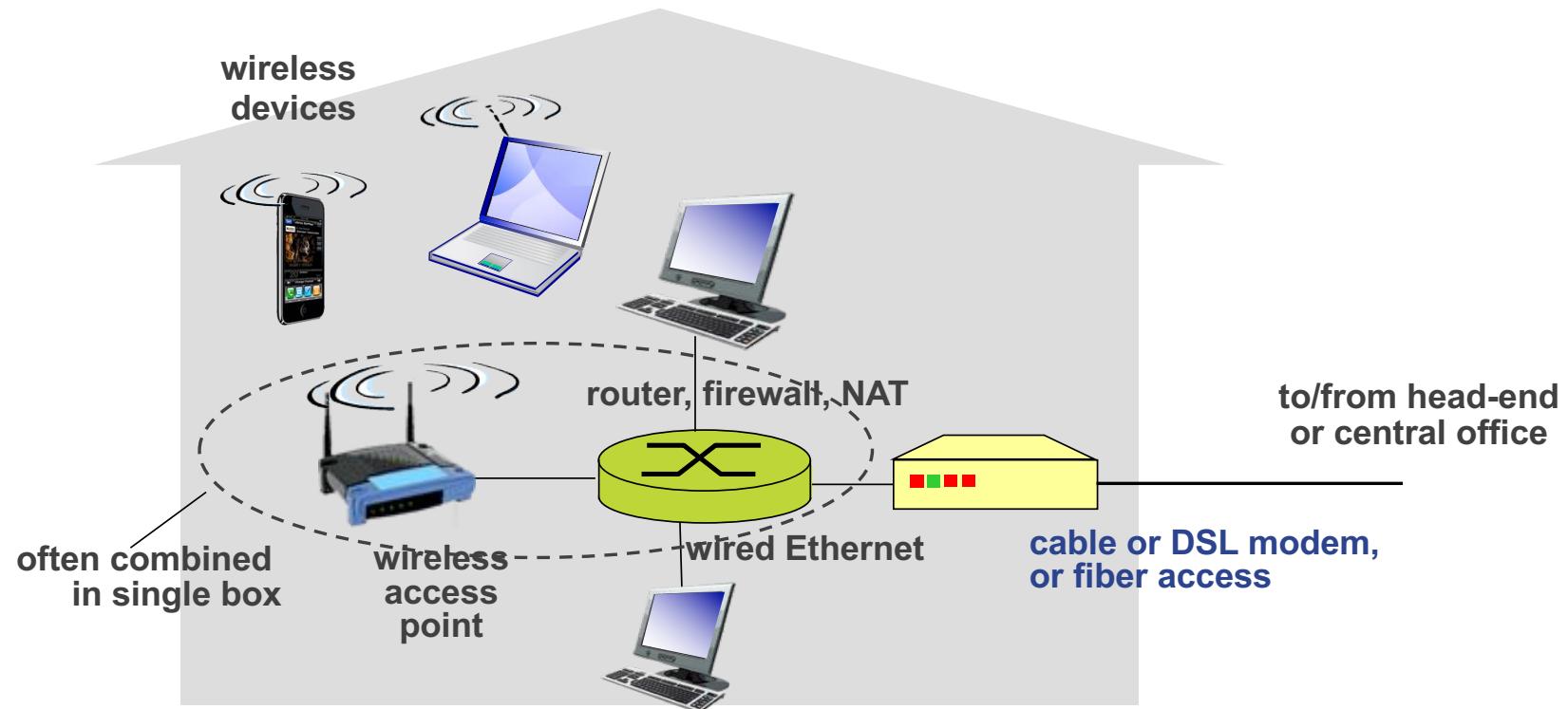
Mobil datatrafikk er sterkt voksende



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

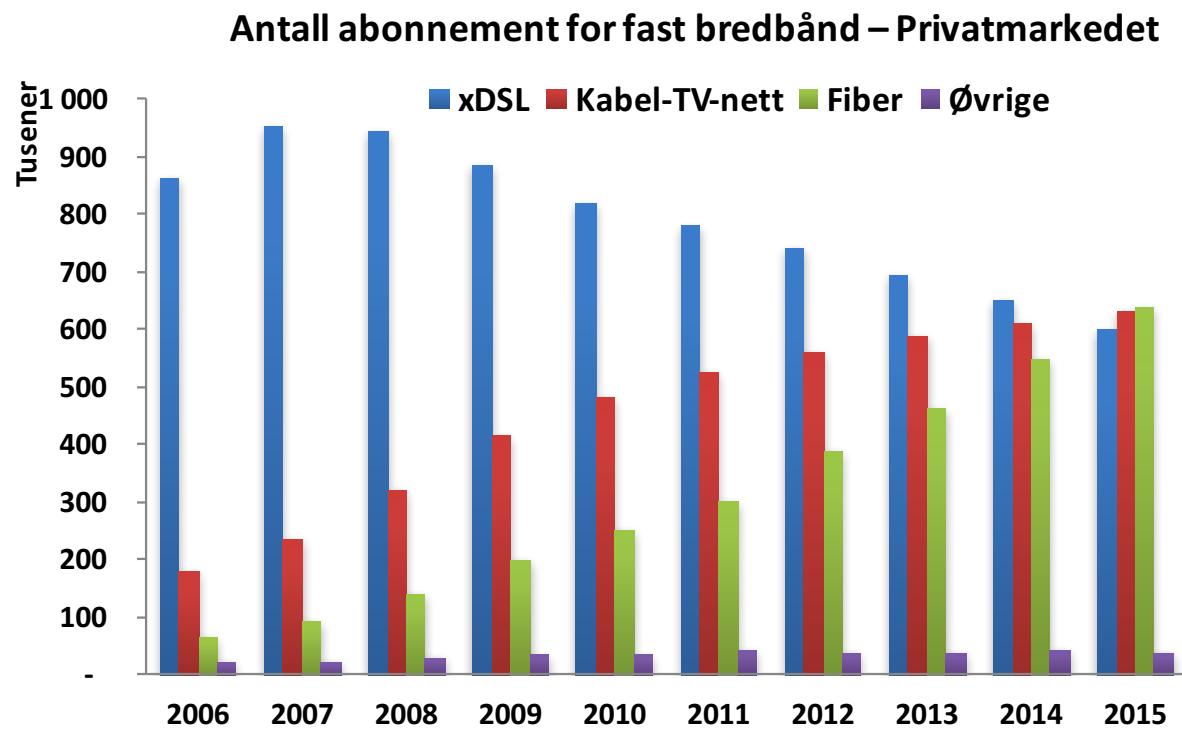


Residential access Home network

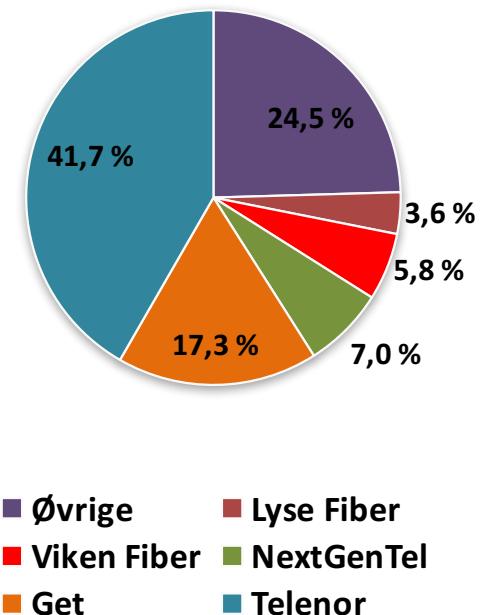


Residential access

Residential broadband access subscribers in N



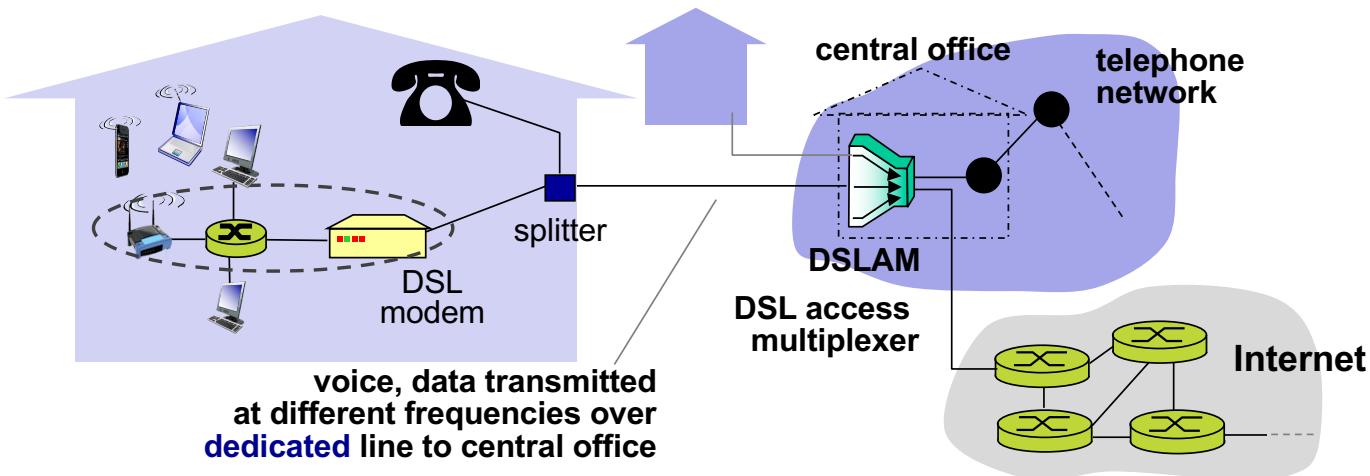
Markedsandeler 2015



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

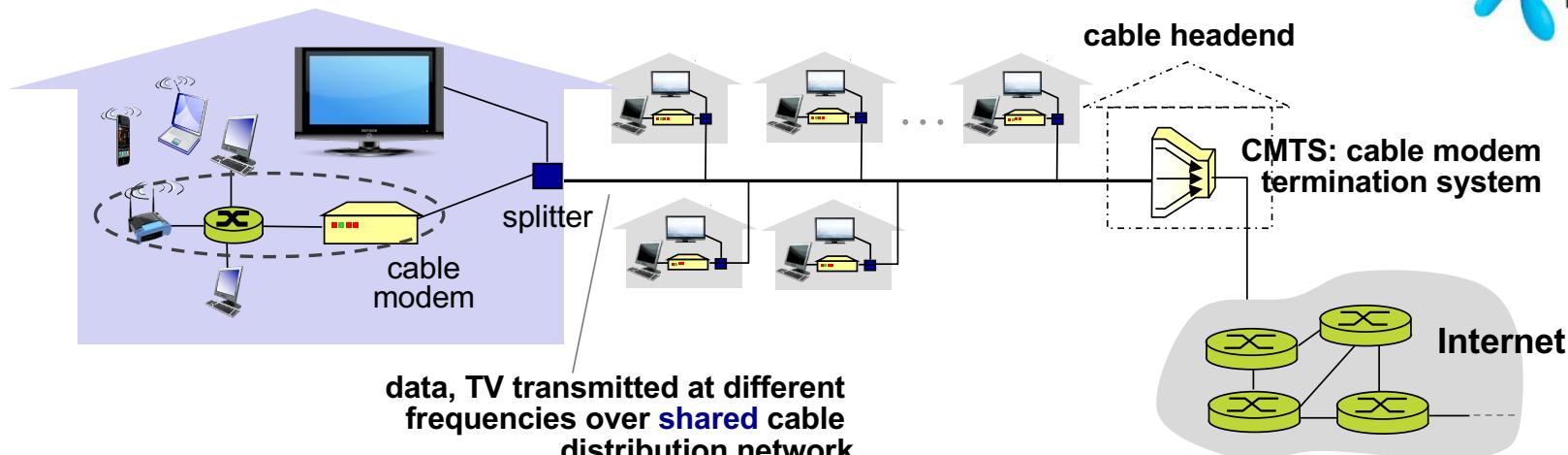
- x=Asymmetric, x=Symmetrical-high-speed, X=Very-high-bit-rate
<http://www.nextgentel.no/privat/artikler/bredband.php>
- existing physical copper line on different frequencies
- always on data to Internet, voice to telephone network
- asymmetric up and down transmission rate
- <http://www.nextgentel.no/privat/bredband/bestillingsskjema/>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



Residential access

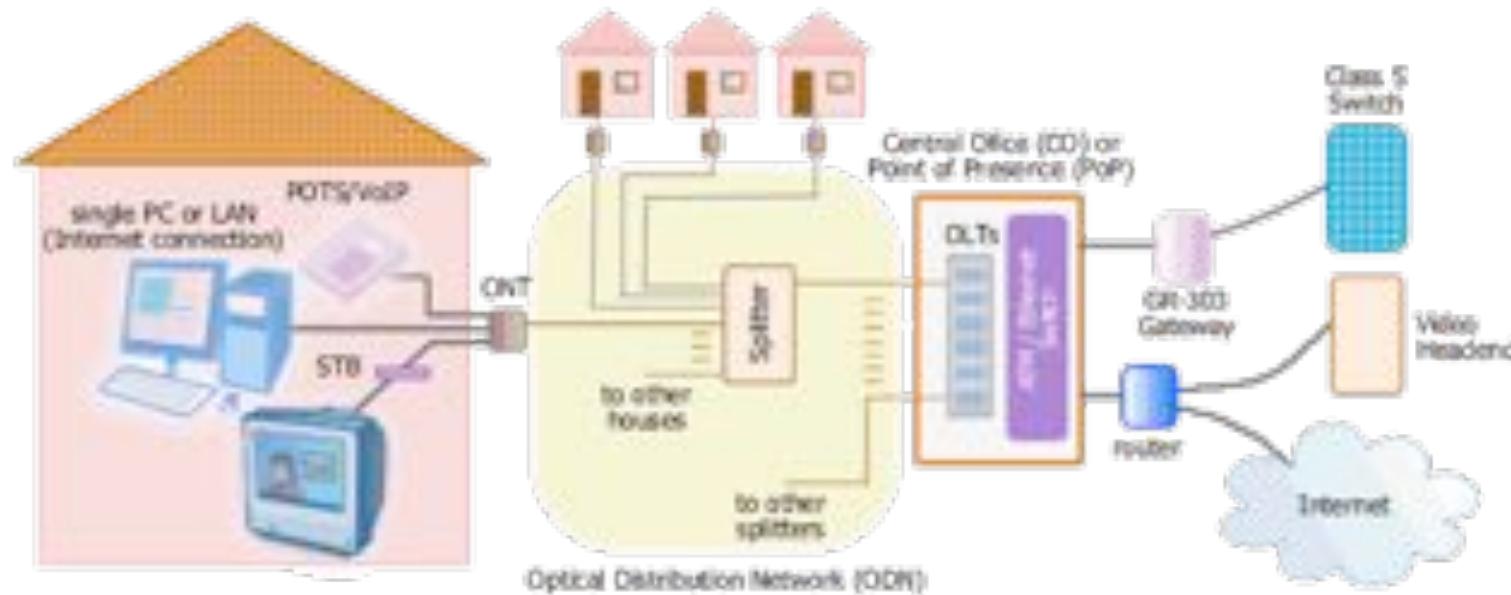
Internet access through broadcast cable lines

- 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

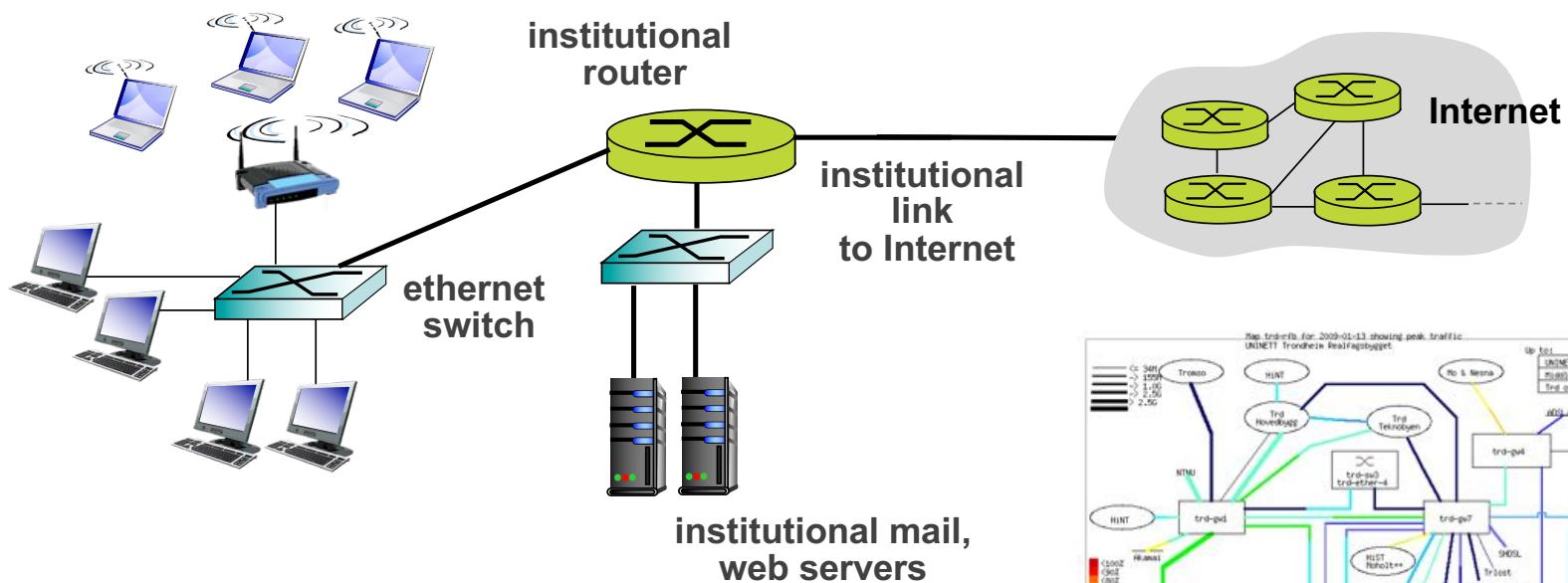
altibox

VIKENFIBER
LEVERER altibox

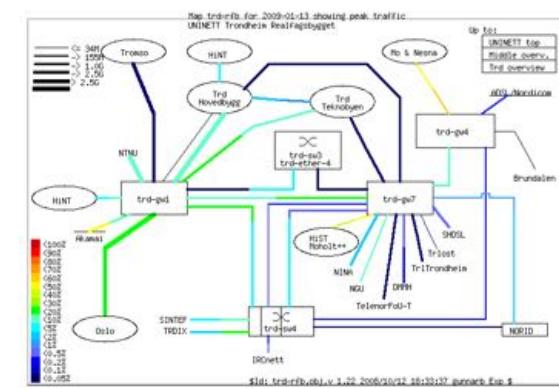
lyse

Institutional access

Internet access through local area networks

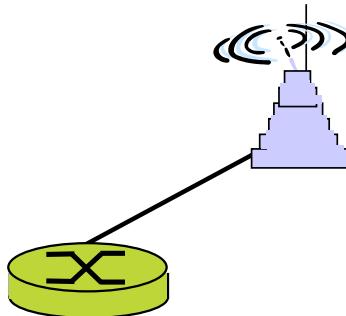


- Company/University local area network (LAN) connects to edge router
- Ethernet: 10/100 Mbps, 1/10 Gbps
 - shared, switched
 - wired, wireless



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

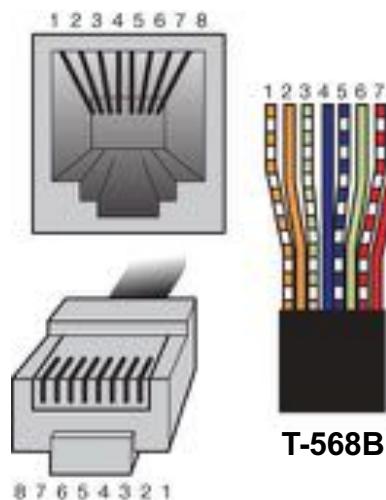
- no physical “wire”: air, water, vacuum
- bidirectional
- signals propagate freely in electromagnetic spectrum
 - reflection
 - obstruction by objects
 - interference

Guided physical media

Guided physical media using copper

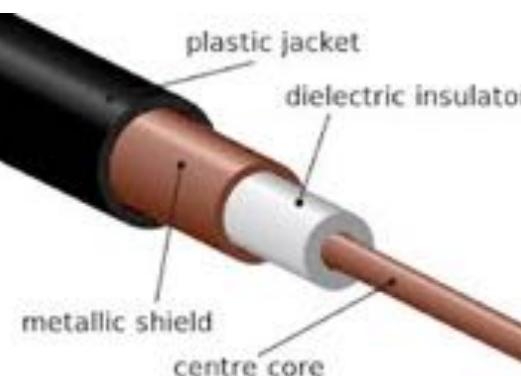
Twisted Pair (TP)

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



Coaxial cable

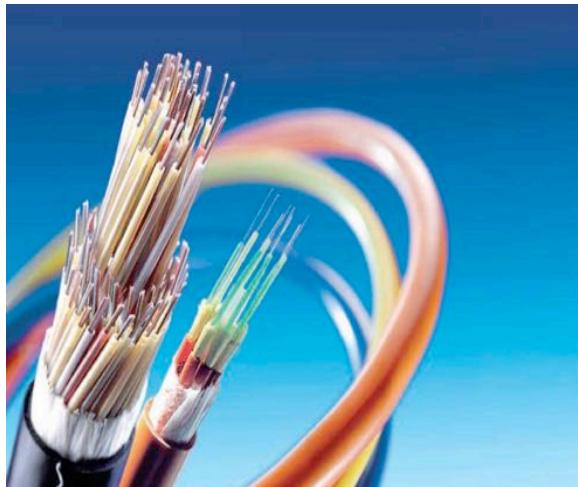
- two concentric copper conductors
- bidirectional
- baseband: single channel on cable
 - legacy Ethernet
- broadband: multiple channels on cable



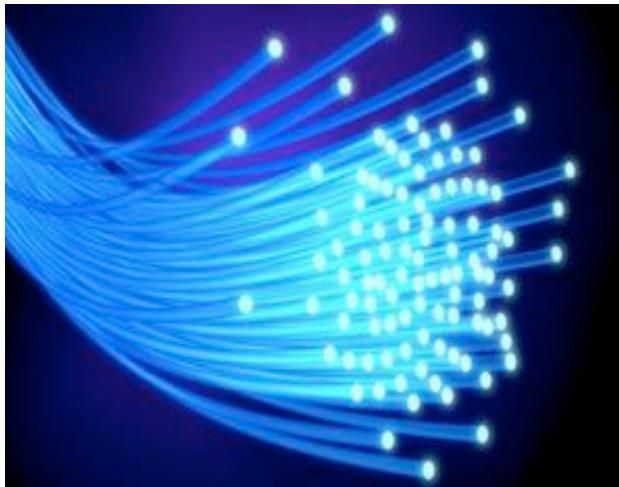
Guided physical media

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/>



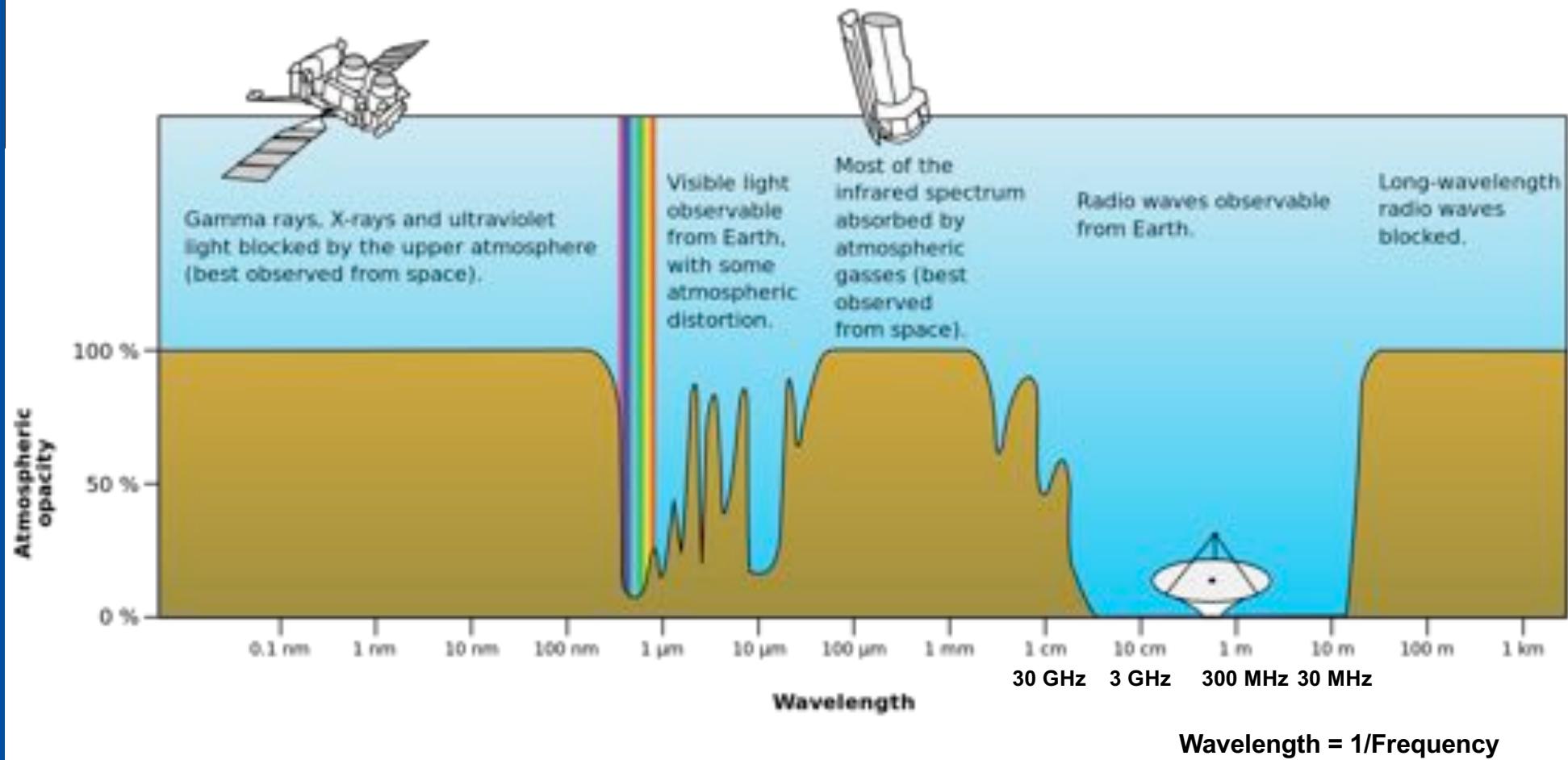
Unguided physical media

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

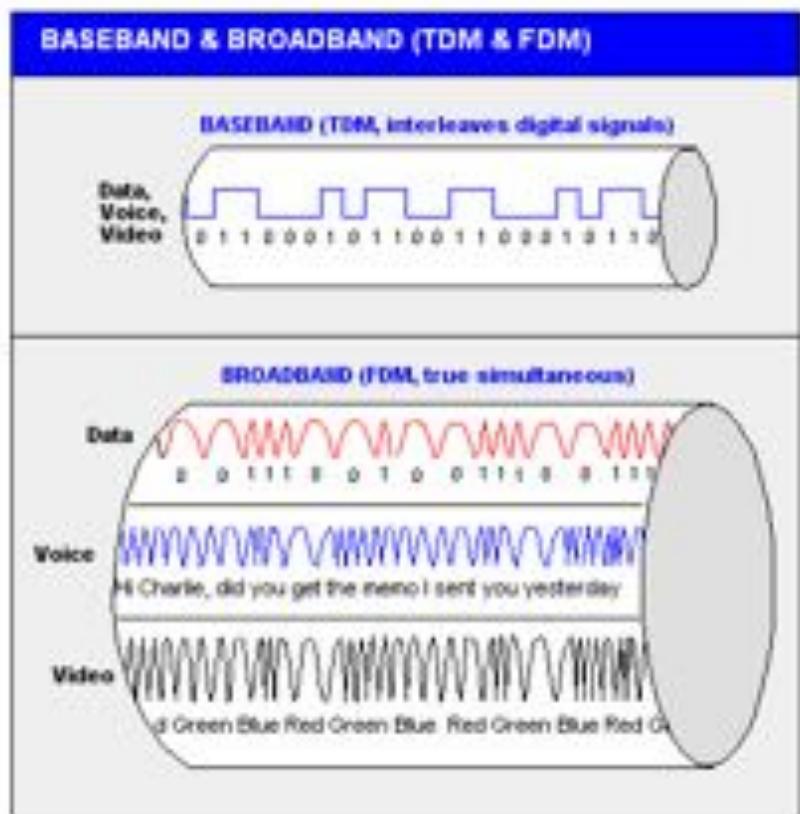


Source: http://en.wikipedia.org/wiki/Electromagnetic_spectrum

Physical layer

Baseband vs broad-/wideband digital signals

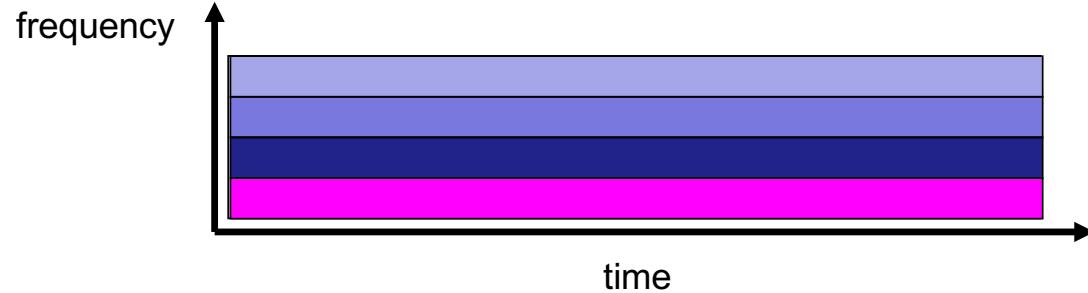
From Computer Desktop Encyclopedia
© 1999 The Computer Language Co., Inc.



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

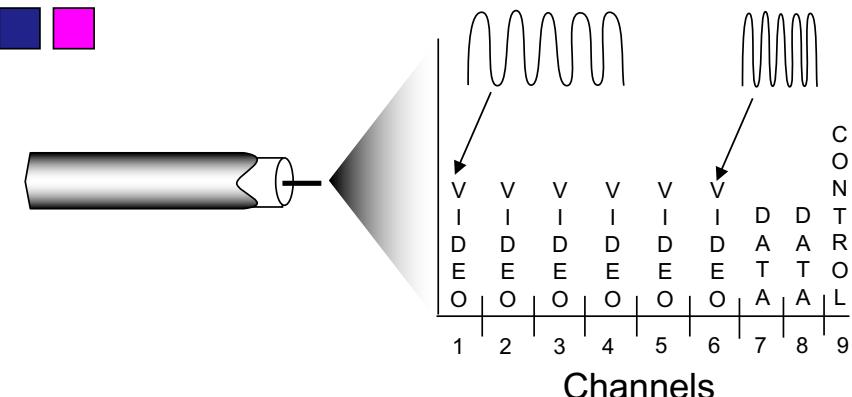
Channel division: FDM versus TDM

FDM – frequency division multiplex

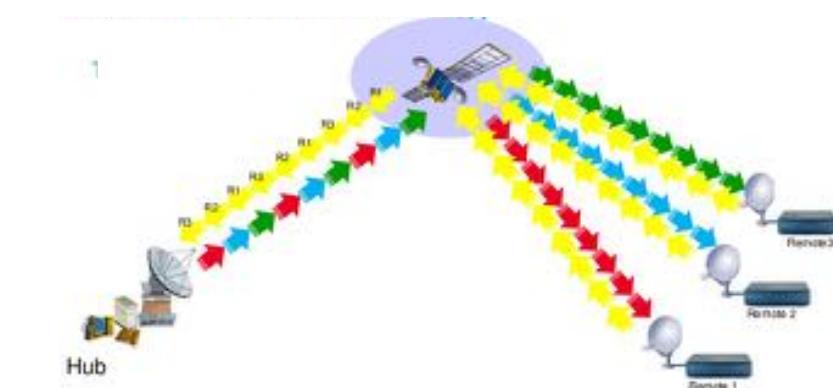
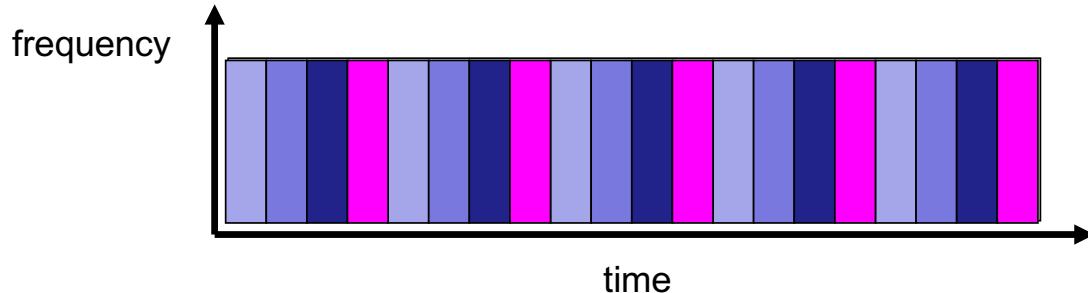


Example

4 users

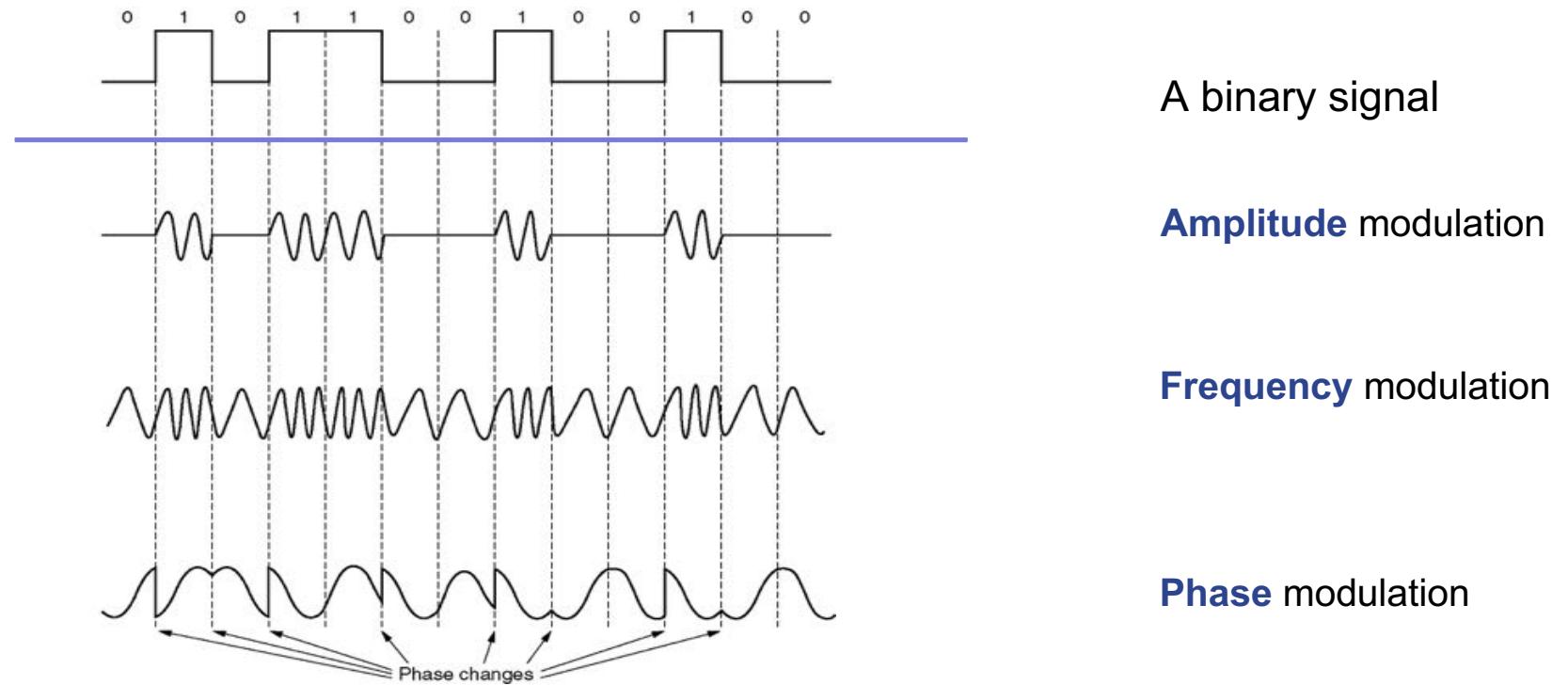


TDM – time division multiplex



Physical layer

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



Frequency, Spectrum and Bandwidth Time domain concepts

▪ Analog signal

- varies in a smooth way over time

▪ Digital signal

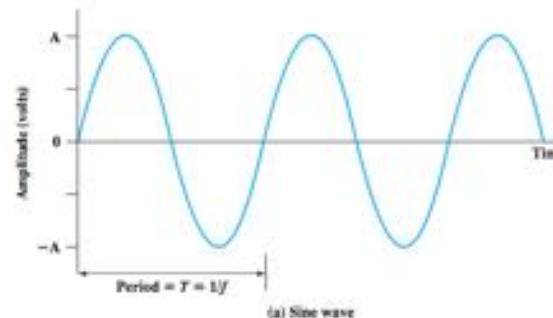
- maintains a constant level then changes to another constant level

▪ Periodic signal

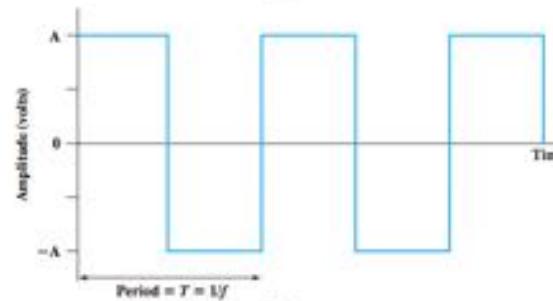
- pattern repeated over time
- $s(t) = A \sin(2\pi ft + \Phi)$

▪ Aperiodic signal

- pattern not repeated over time



(a) Sine wave



(b) Square wave

Figure 3.2 Examples of Periodic Signals

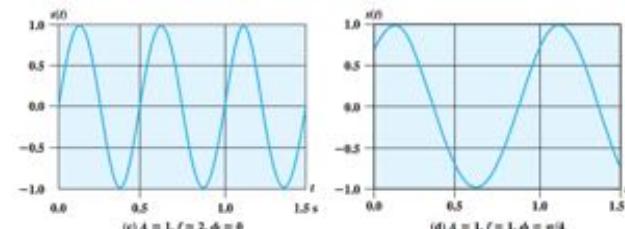


Figure 3.3 $s(t) = A \sin(2\pi ft + \phi)$

Source: William Stallings Data and Computer Communications 8th Edition

Frequency, Spectrum and Bandwidth

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

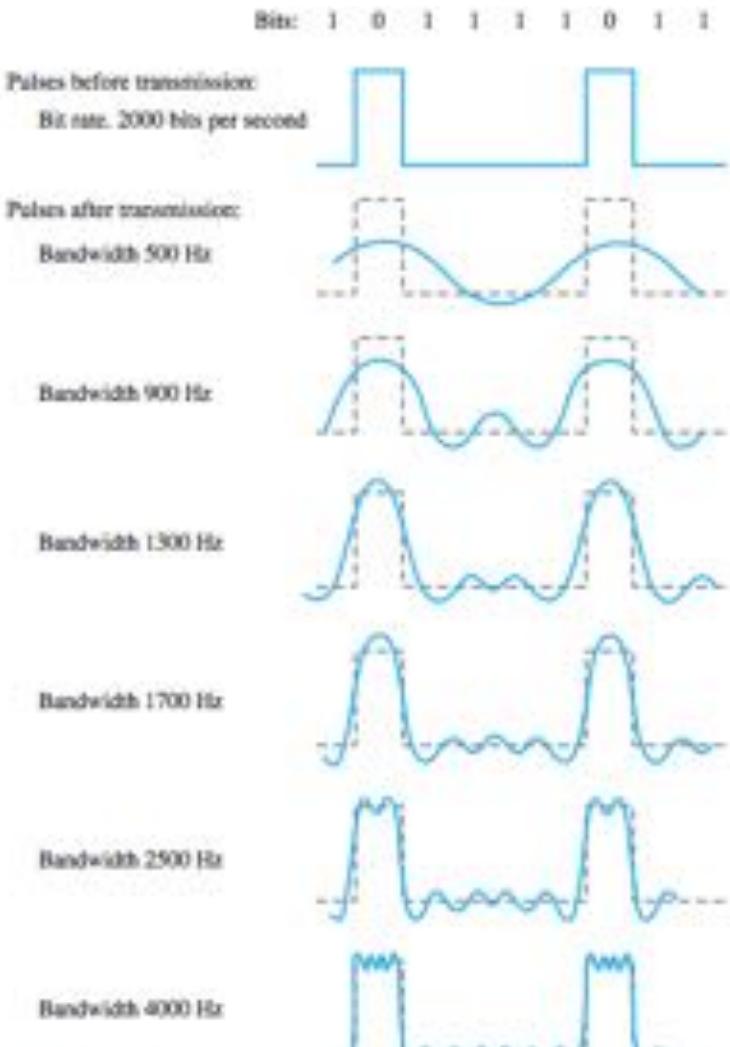
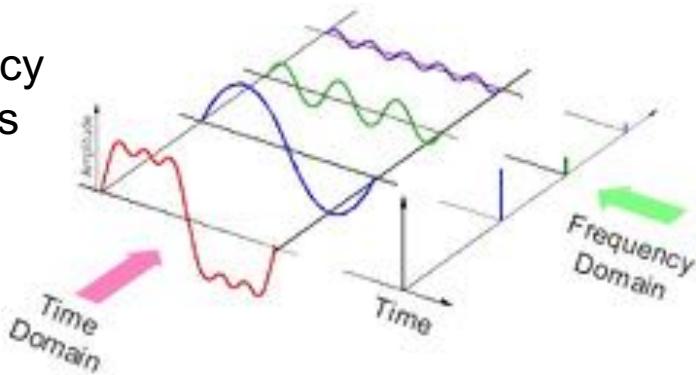


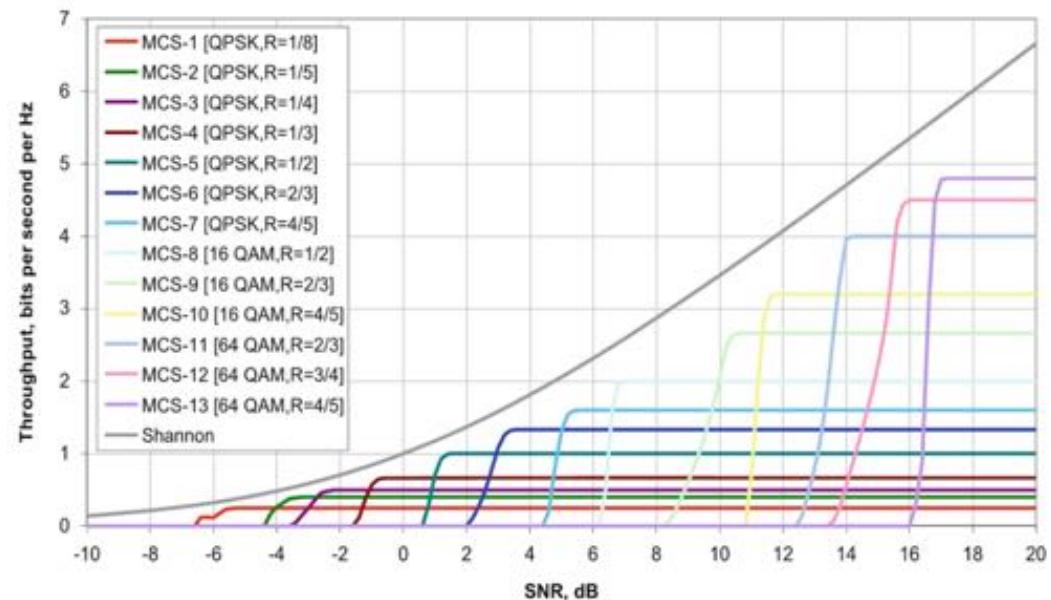
Figure 3.8 Effect of Bandwidth on a Digital Signal

Physical layer

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) = $10 * \log_{10}(S/N)$)



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

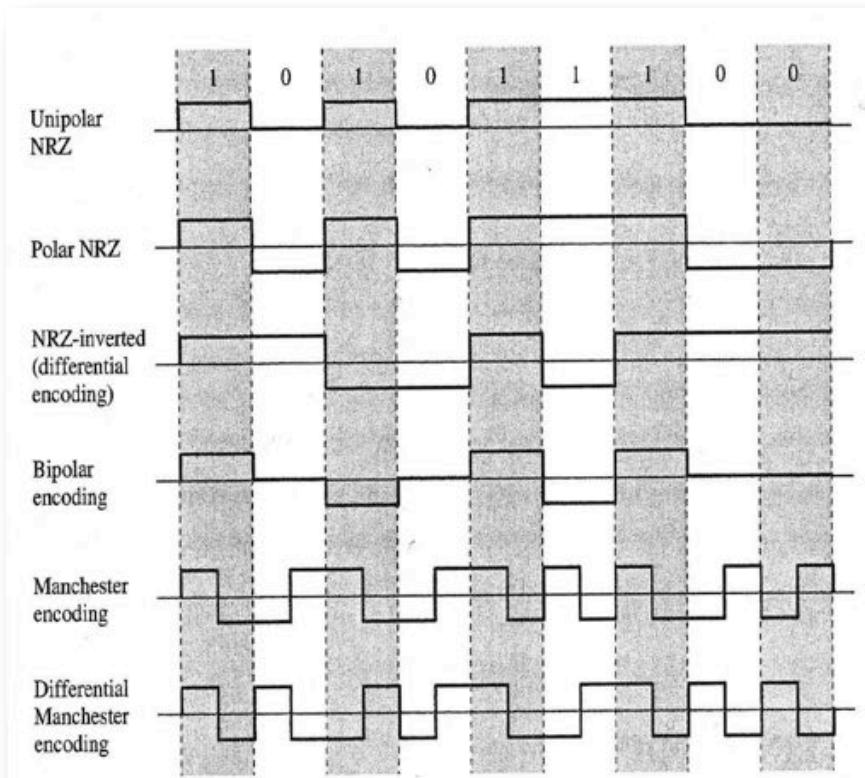
Satellite TV channel with BW = 10
MHz and S/N = 20 dB, maximum
data rate is $C=10000000 * \log_2(101)$
 ~ 66 Mbps

Modulation techniques for different S/N

Physical layer

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

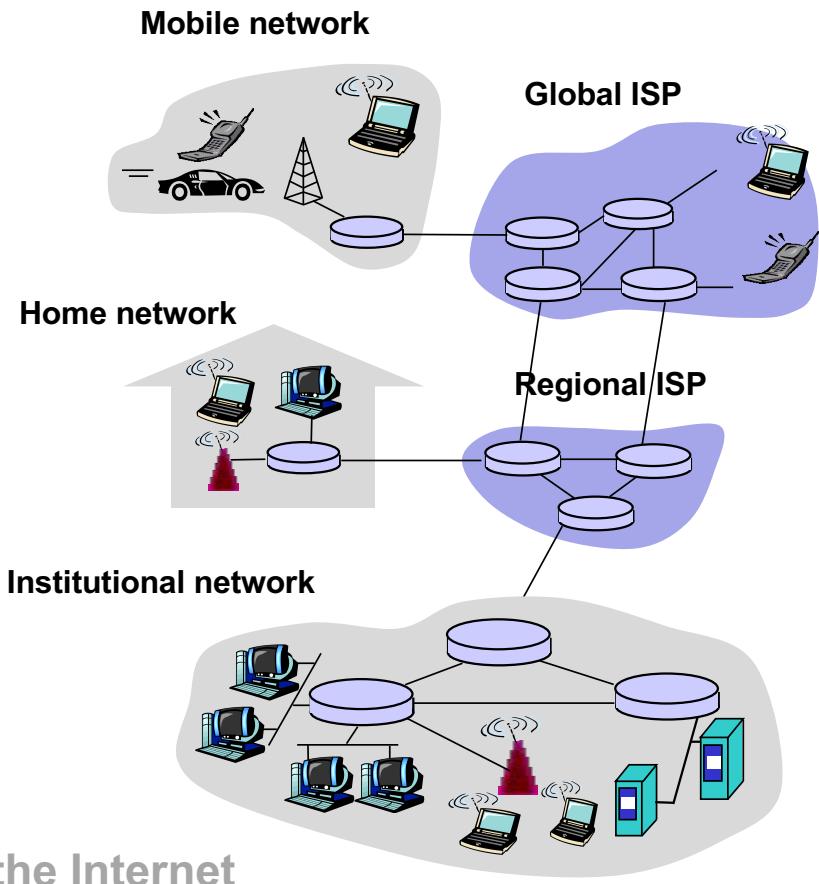
NRZ
Non-return-to-zero



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

Roadmap

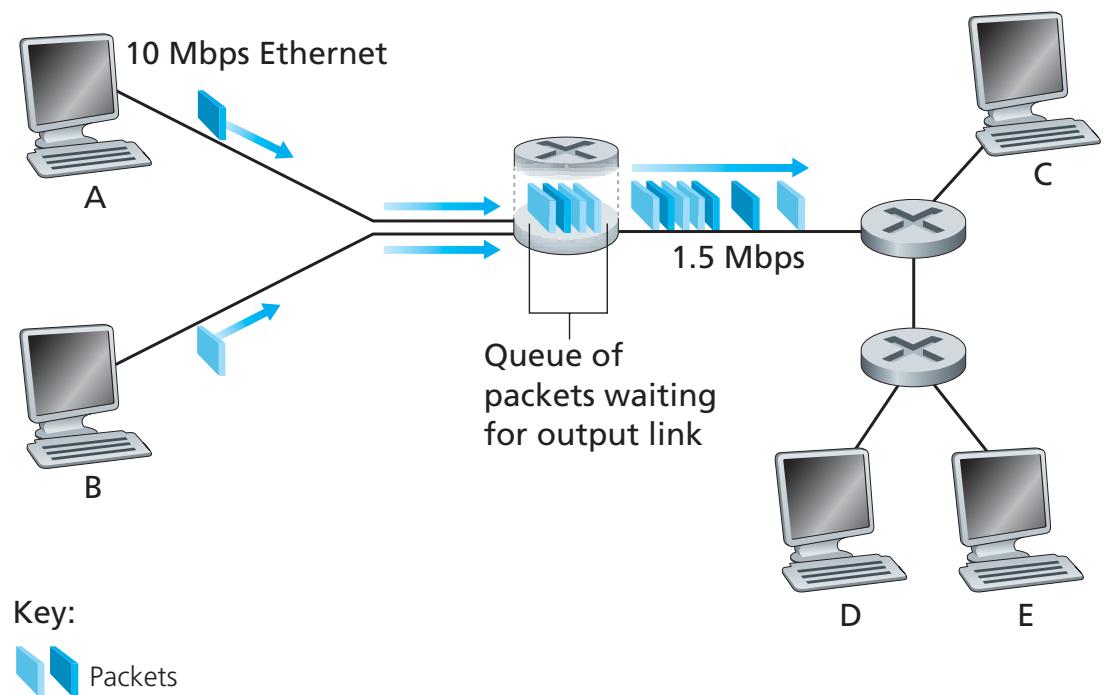
- 1.1 What is the Internet?
- 1.2 Network edge
 - access networks, physical media
- 1.3 Network core
 - **packet switching, circuit switching, network of networks**
- 1.4 Packet-switched networks
 - delay, loss and throughput
- 1.5 Protocol layers and service models
- 1.6 Security: networks under attack
- 1.7 History of computer networking and the Internet



The network core is a mesh of interconnected routers

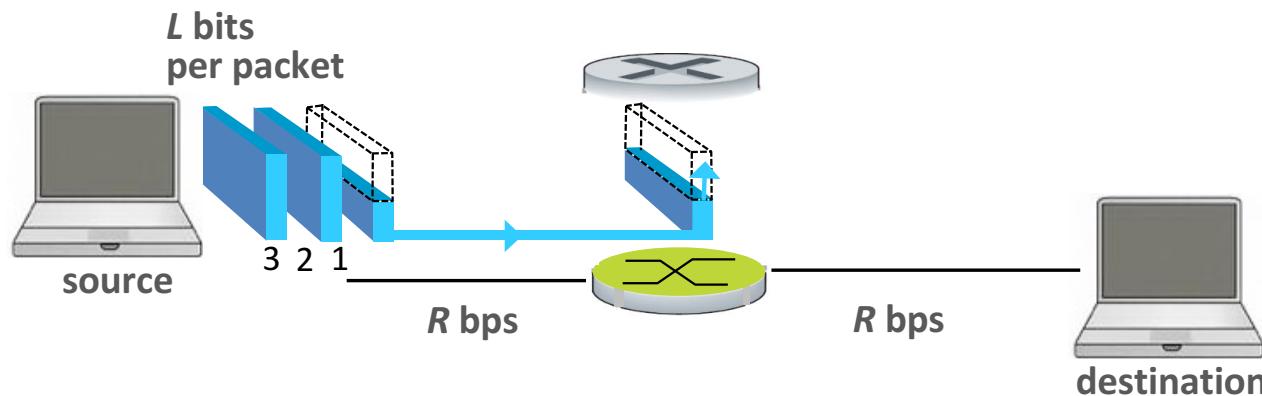
- Data sent in discrete “chunks” = **packets**
- Packets are forwarded from one router to the next, across links on path from source to destination
- Each packet transmitted at full link capacity
- Internet is based on **packet switching**

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



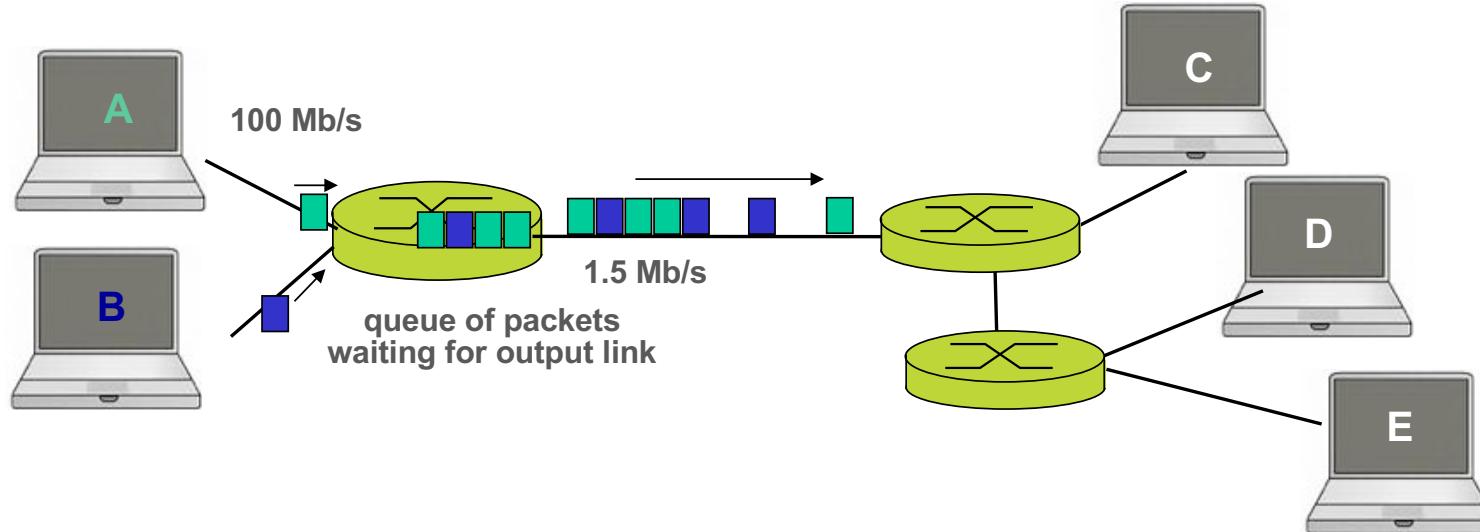
Packet-switching is store-and-forward

- **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
- $L = 7.5 \text{ Mbits}$, $R = 1.5 \text{ Mbps}$; one-hop transmission delay = 5 sec

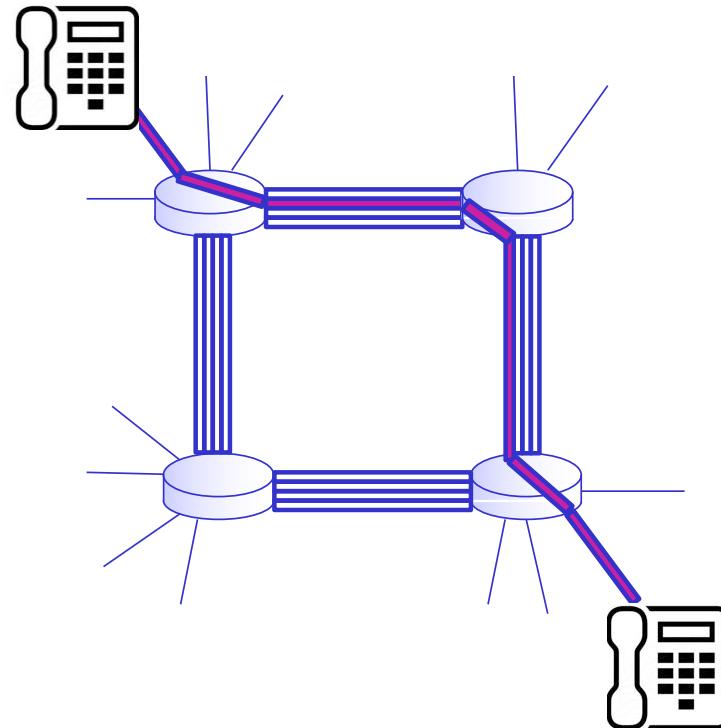
Packet switching: queuing delay and loss



- 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**

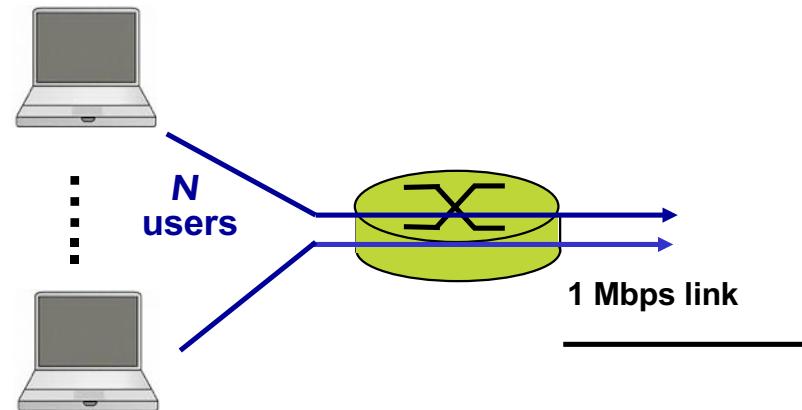


Packet switching allows more users to simultaneously use the network

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, $P(> 10 \text{ active at same time})$ 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)

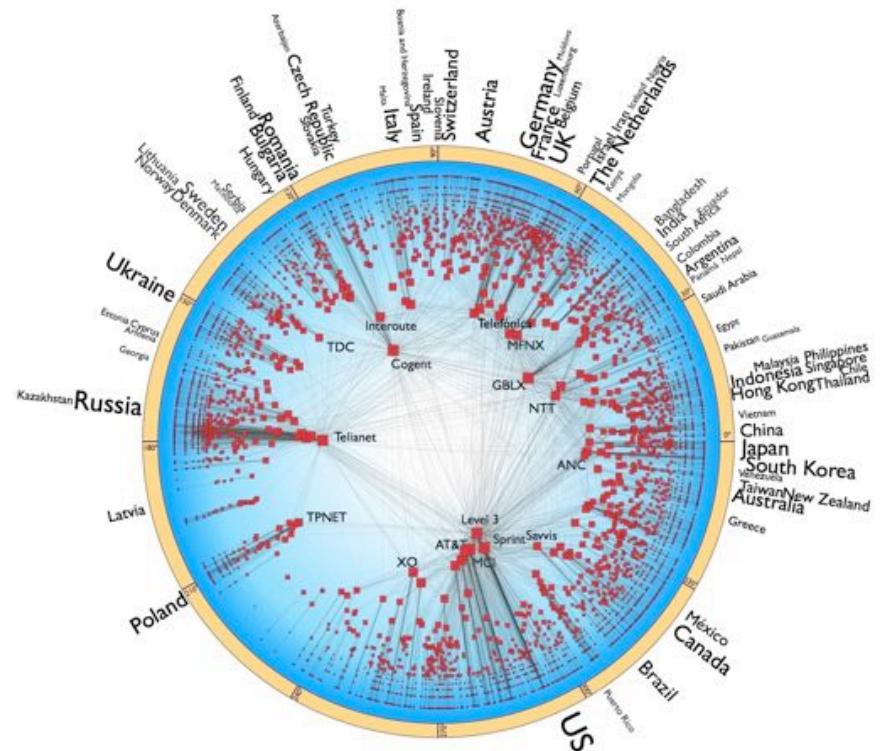
- residential, company and
university ISPs

▪ Access ISPs

must be interconnected

- Resulting network of networks is complex

- Evolution was driven by economics and national policies

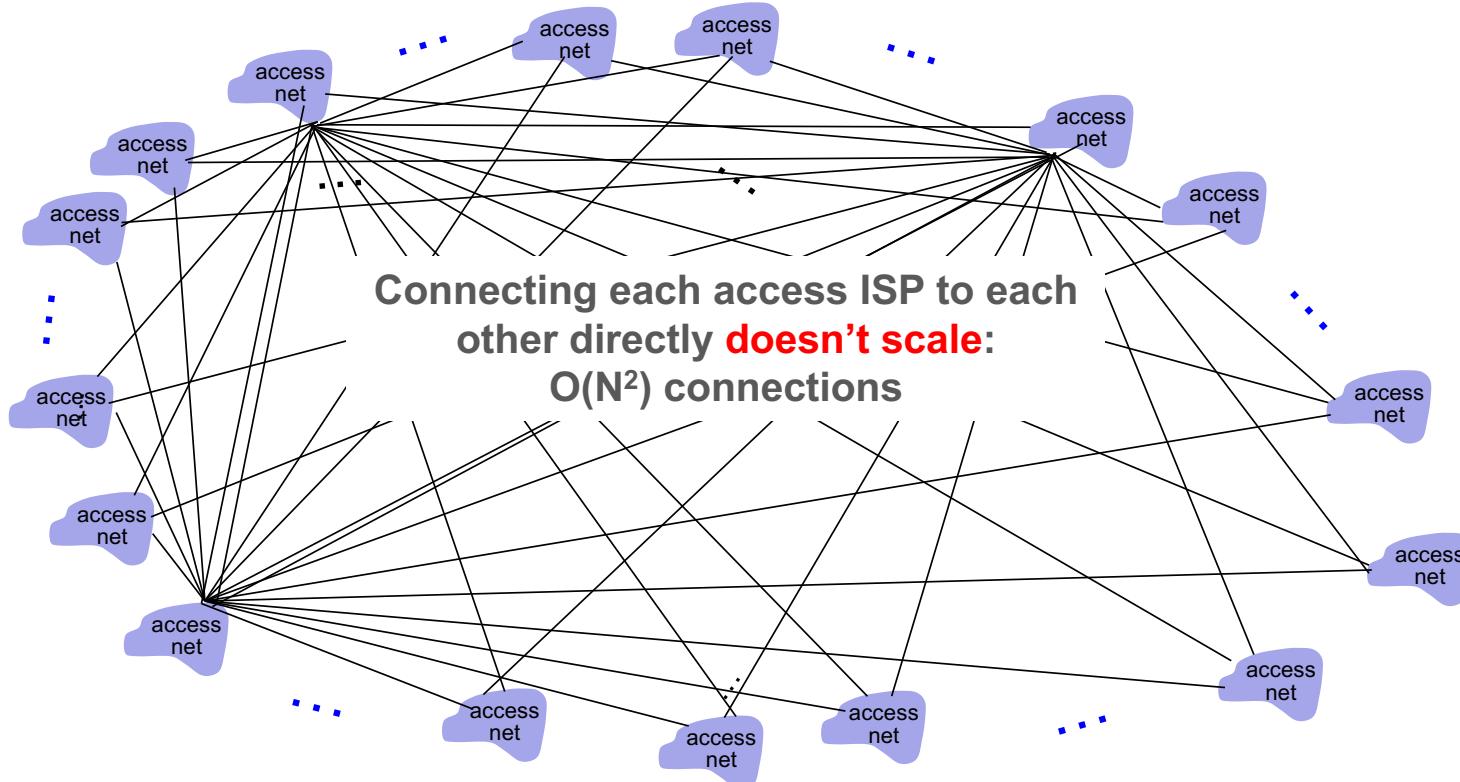


Source: <http://www.drdobbs.com/architecture-and-design/first-geometric-atlas-of-the-internet-cr/227400098>

Internet structure: network of networks

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

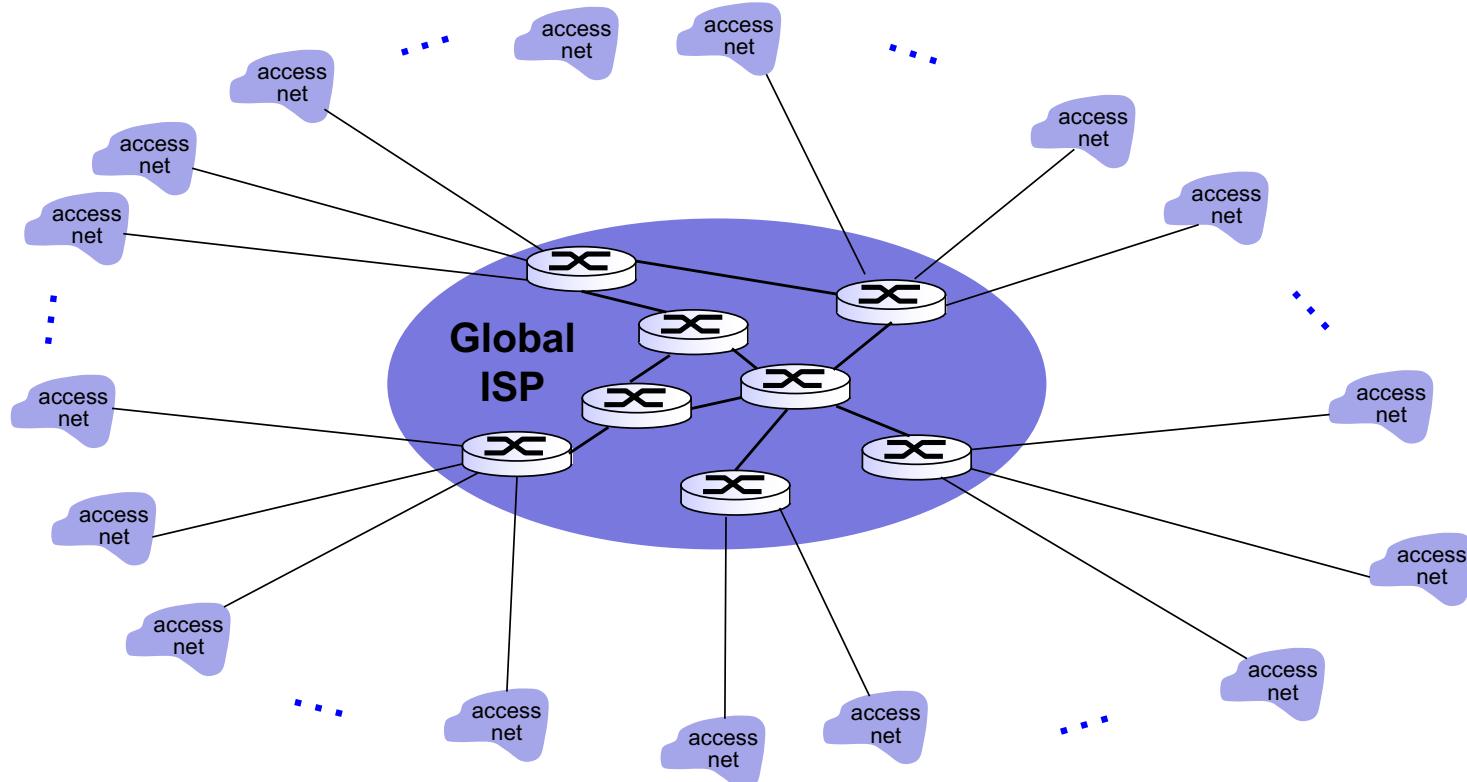
Connect each access ISP to every other access ISP?



Internet structure: network of networks

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

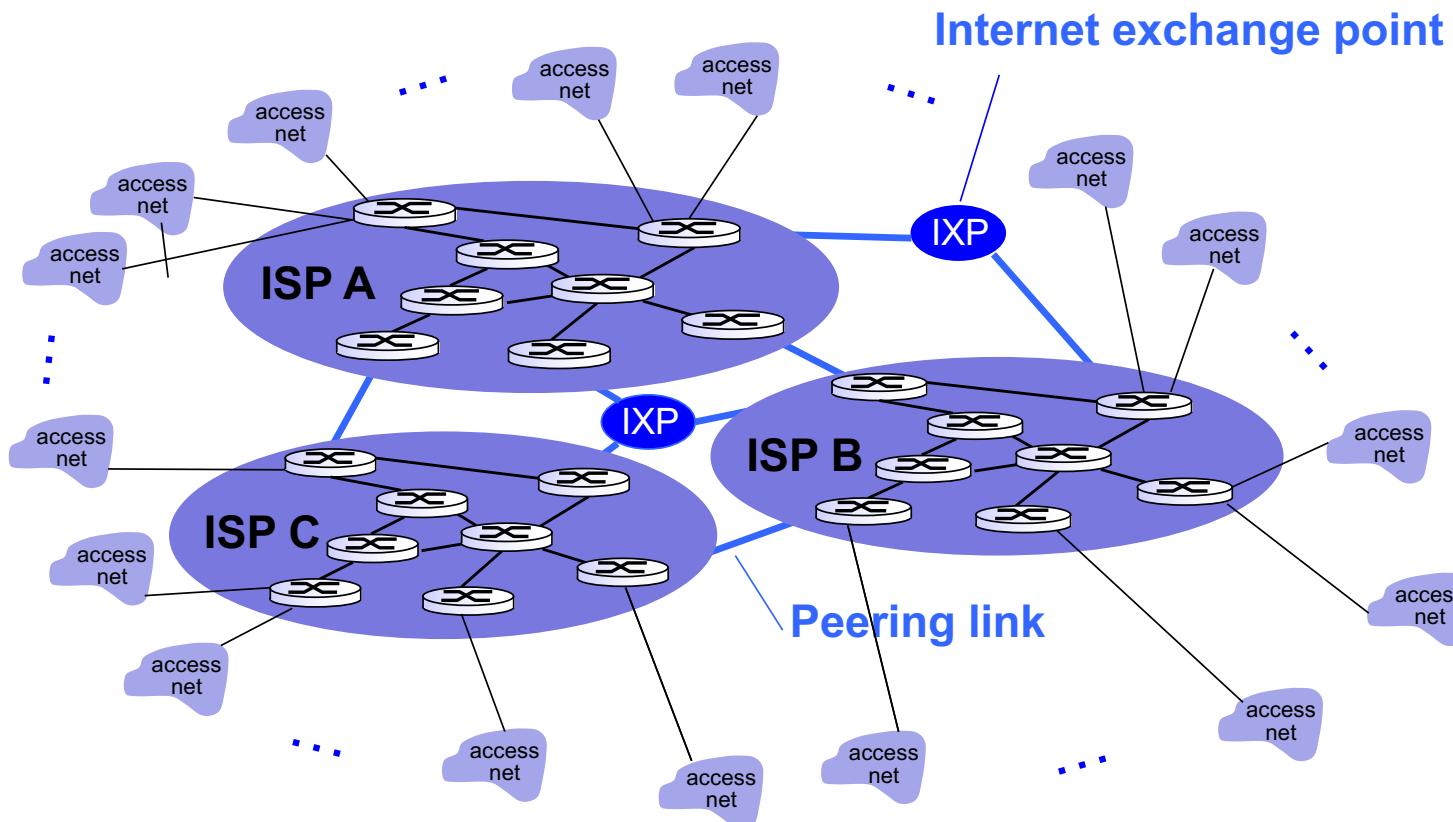
Customer and provider ISPs have economic agreement.



Internet structure: network of networks

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

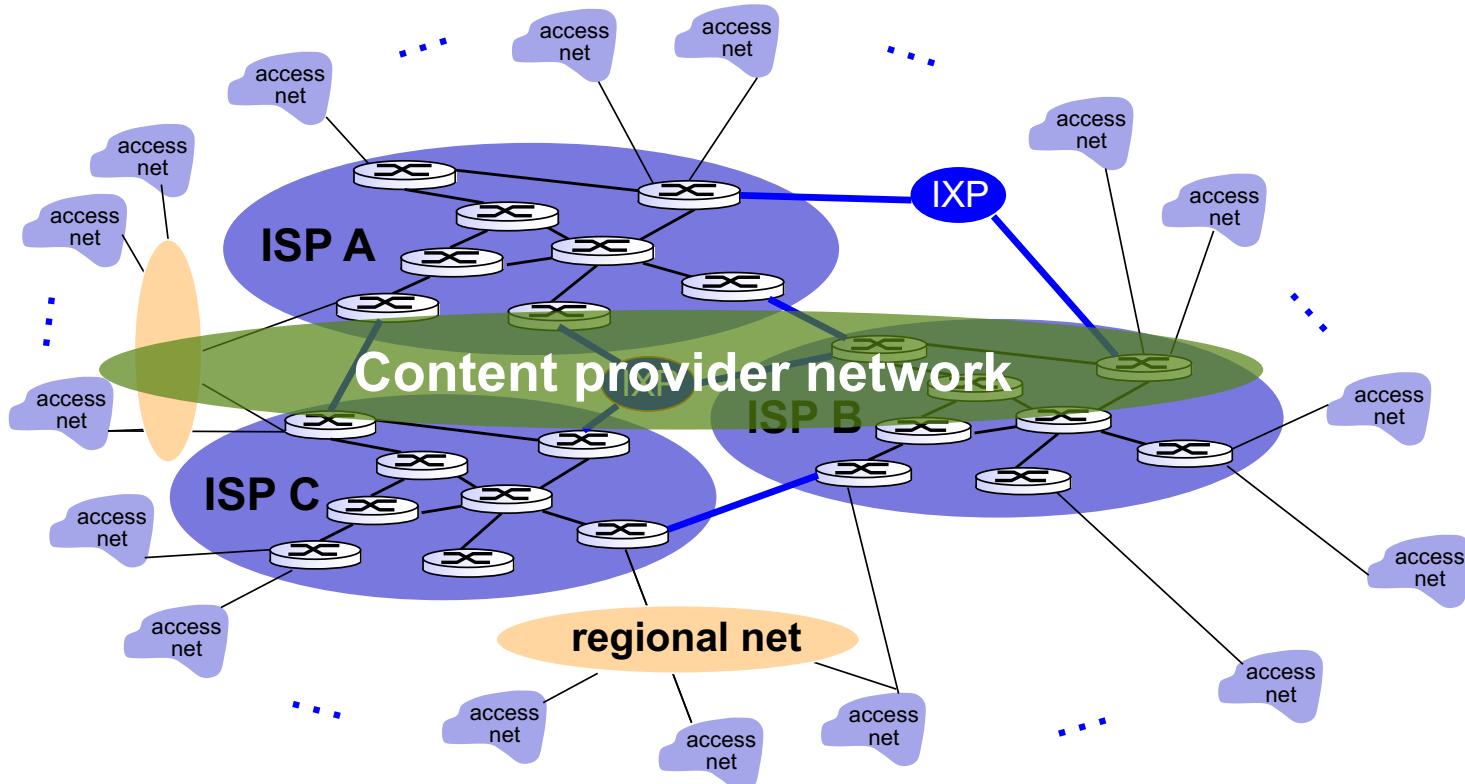
.... which must be interconnected



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?

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

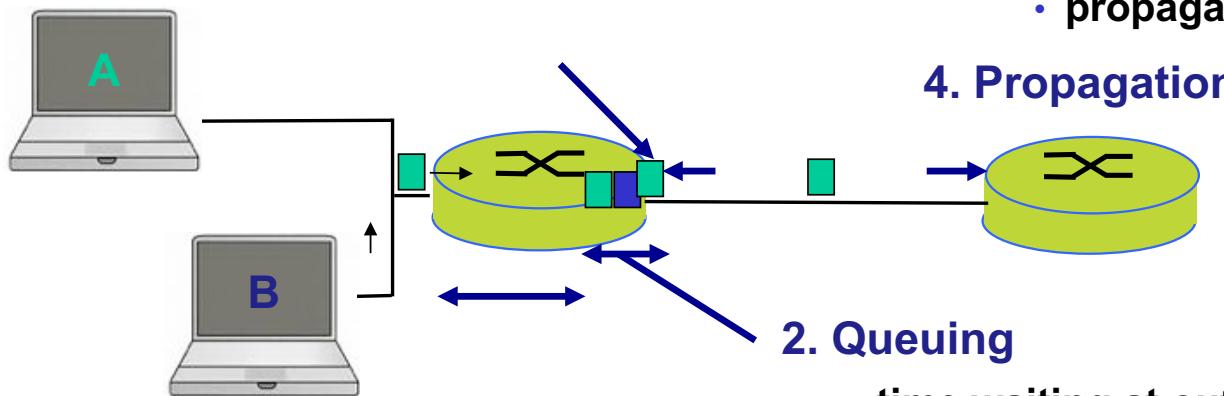
1.6 Security: networks under attack

1.7 History of computer networking and the Internet

Four sources of packet delay

- $R = \text{link bandwidth (bit/s)}$
- $L = \text{packet length (bits)}$
- time to send bits into link = L/R

3. Transmission



1. Nodal processing

- check bit errors
- determine output link

- $d = \text{length of physical link}$
- $s = \text{propagation speed in medium } (\sim 2 \times 10^8 \text{ m/sec})$
- propagation delay = d/s

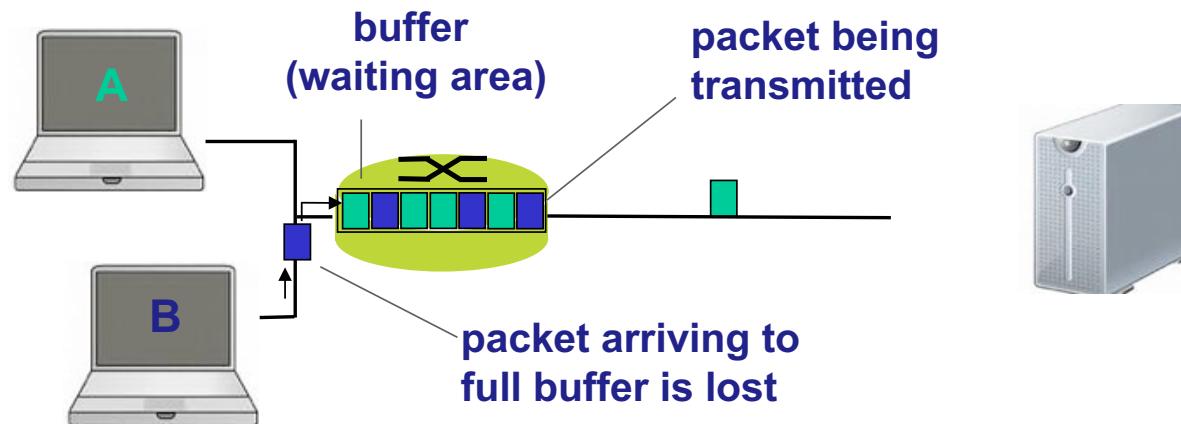
4. Propagation

2. Queuing

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

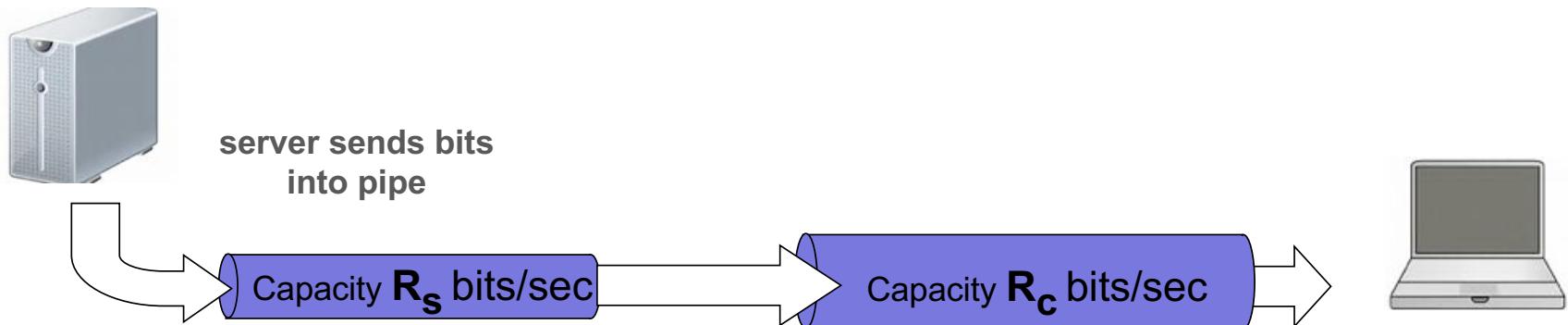
Packet arriving to full queue is dropped = packet loss

- 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

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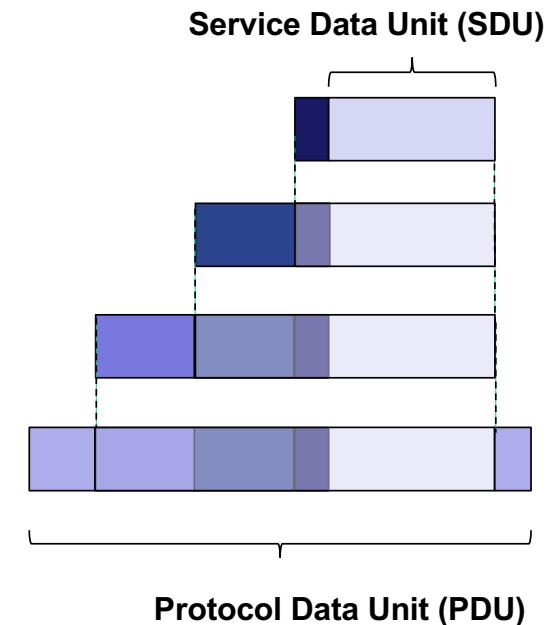
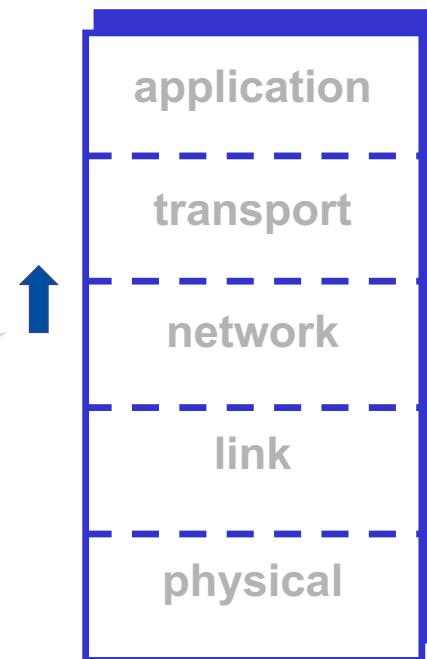
1.6 Security: networks under attack

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

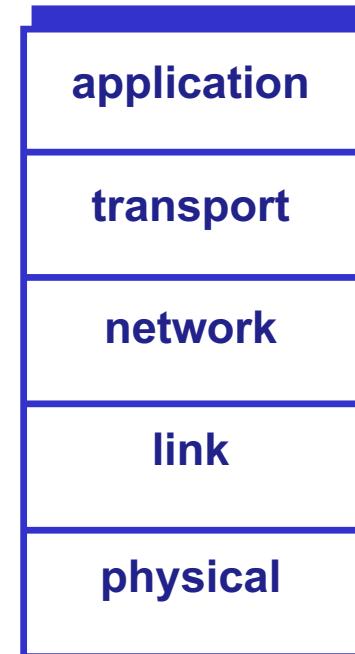
The service model
of a layer =
services the layer
offers to the layer
above



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”

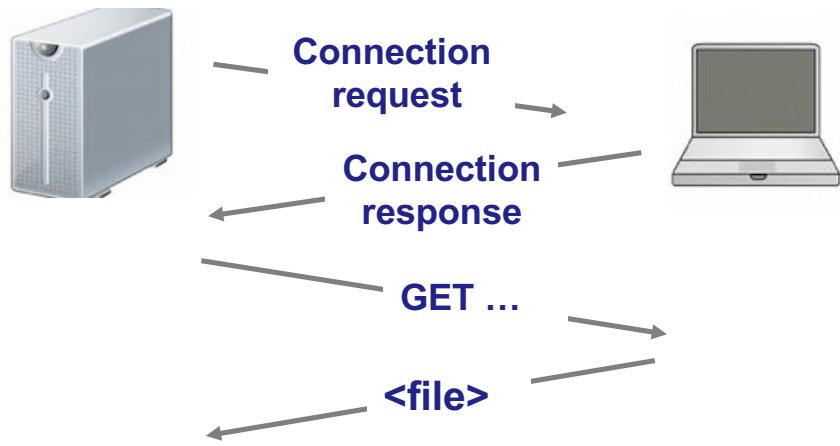
5-layer internet protocol stack



What's a protocol?

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

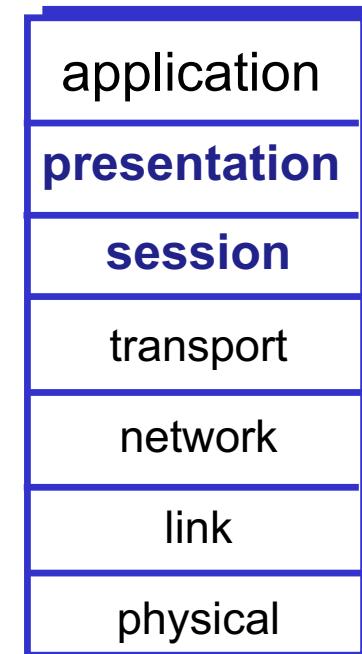


Protocols define format, order of messages sent and received among network entities, and actions taken on message transmission/receipt

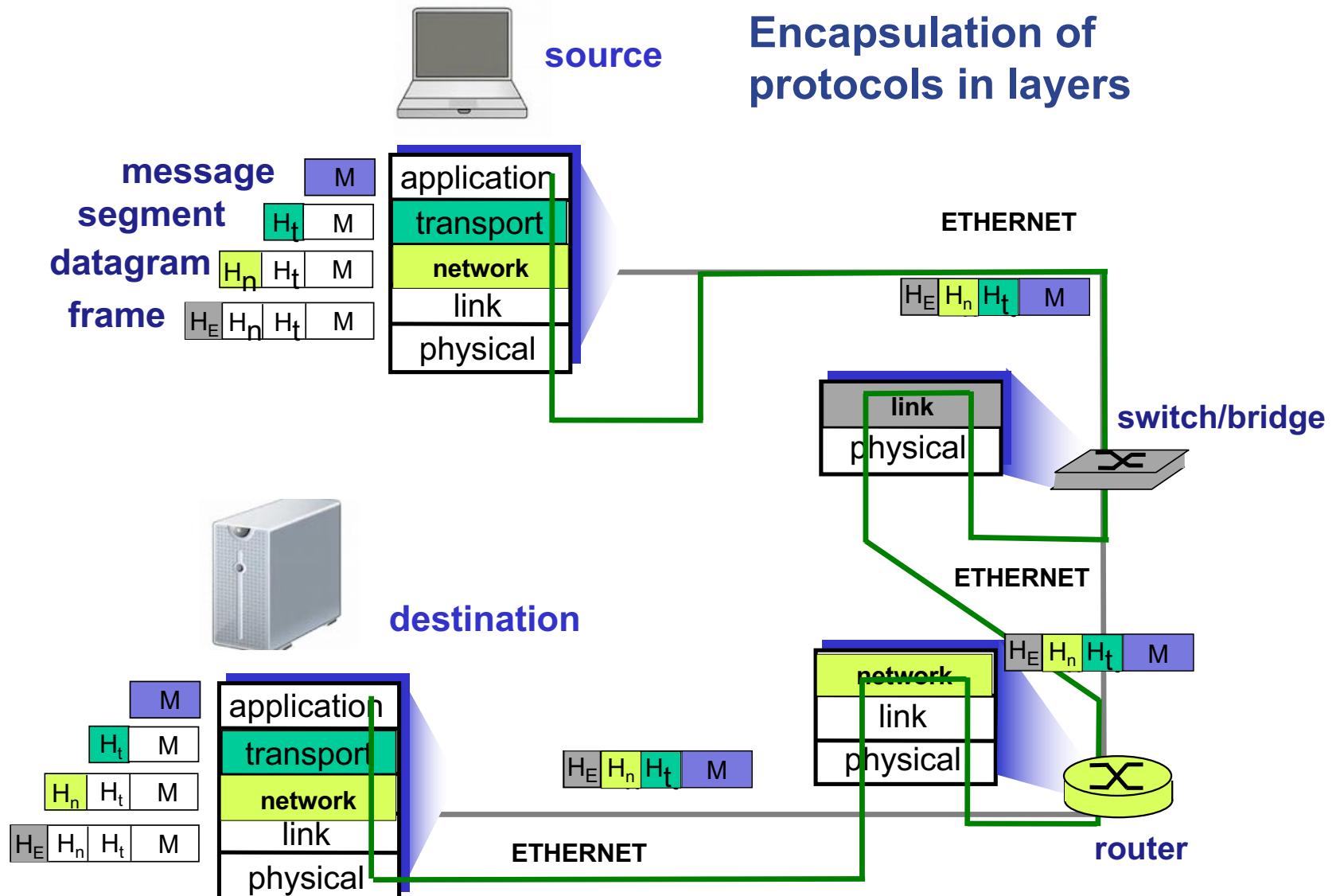
ISO/OSI reference model

- **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

7-layer ISO/OSI protocol stack



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)

Tjenestenektangrep og utpressing

Nasjonal Sikkerhetsmyndighet melder at flere norske bedrifter blir utsatt for datakriminalitet.

A screenshot of a Facebook post from a page called "blogg.no". The post is titled "Tjenestenektangrep og utpressing" and discusses various types of cyber attacks, including DDoS, proxy, and denial-of-service attacks. It includes a graphic of red and white blocks spelling out words like "FAKTA", "PING", "DDOS", "PROXY", "ATTACK", "HACKER", "WORM", and "SPYWARE". Below the post is a snippet of a Wikipedia article about "Tjenestenektangrep" (service disruption attacks), mentioning DDoS and other types of attacks.

Attackers could use Internet route hijacking to get fraudulent HTTPS certificates

A graphic featuring a red padlock in the center, set against a background of binary code (0s and 1s). This image represents the concept of route hijacking, where attackers might use manipulated certificates to intercept traffic on the Internet.

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

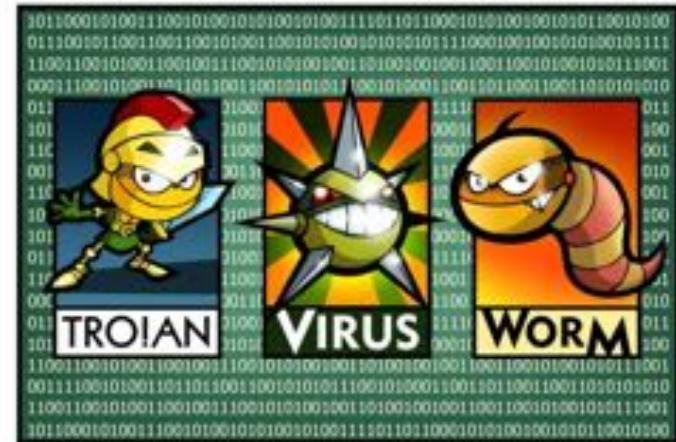


- **Spyware** malware can record keystrokes, web sites visited, upload info to collection site



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?



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

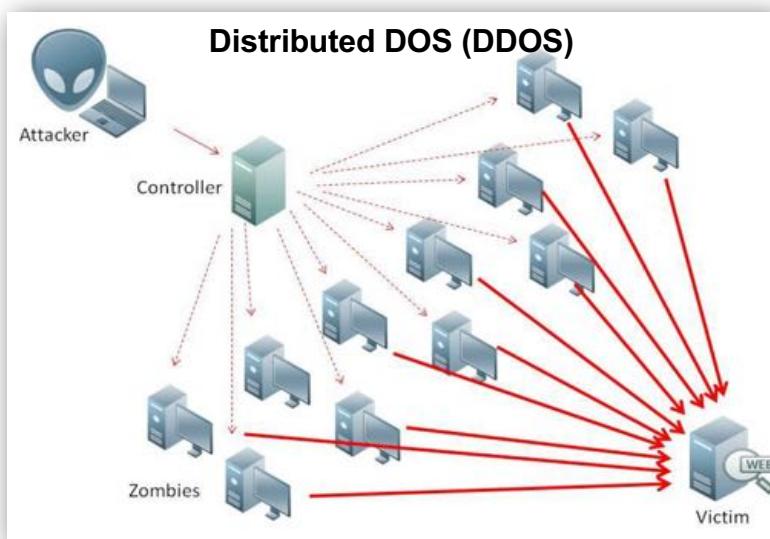


Source: <https://en.wikipedia.org/wiki/File:Botnet.svg#file>

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](#)

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

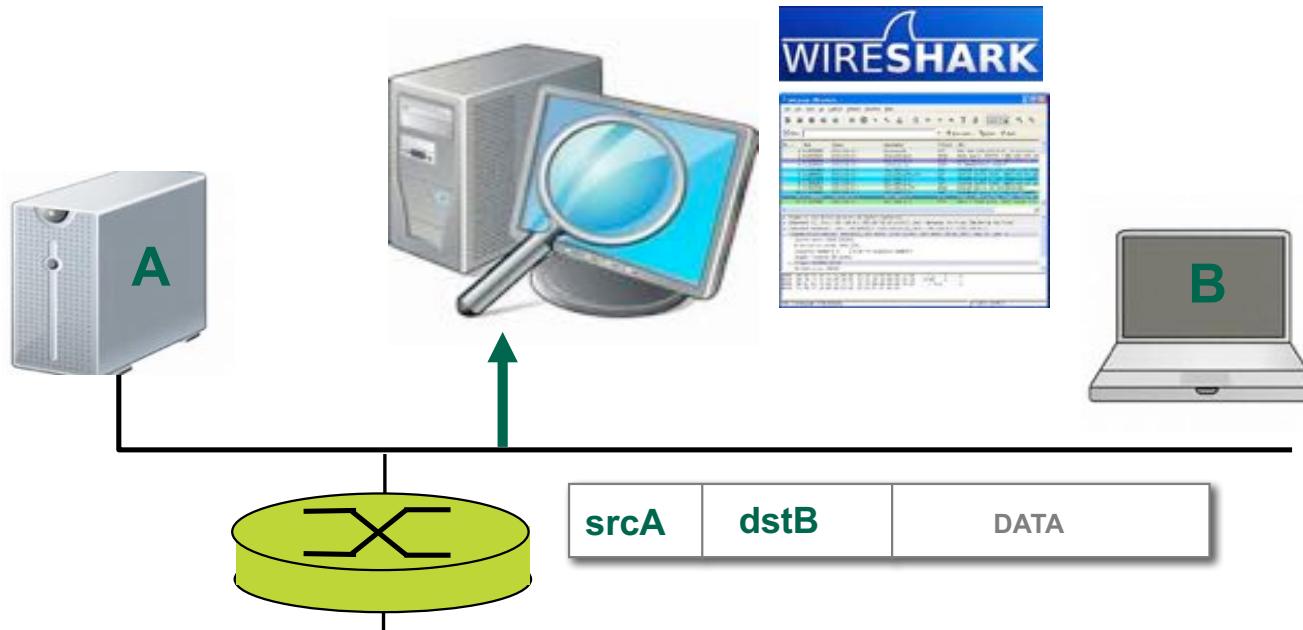
The **DDoS attack** targeted New Hampshire-based company Dyn and its managed DNS infrastructure, and began early Friday morning. The company originally said that it restored operations around 9:30 a.m. Eastern Time, but a second attack followed that knocked Twitter and others offline again for some users, 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



ars TECHNICA SIGN IN

RISK ASSESSMENT —

How the NSA snooped on encrypted Internet traffic for a decade

Exploit against Cisco's PIX line of firewalls remotely extracted crypto keys.

DAN GOODIN - 8/19/2016, 10:11 PM

Stavanger Aftenblad Meny

Forslaget om digitalt grenseforsvar bryter personvernet

Lysne II-utvalgets forslag om digitalt grenseforsvar bryter med befolkningens person- og kommunikasjonsvern, mener juristkommisjonen ICJ-Norge.

Alle venter på Datatilsynet

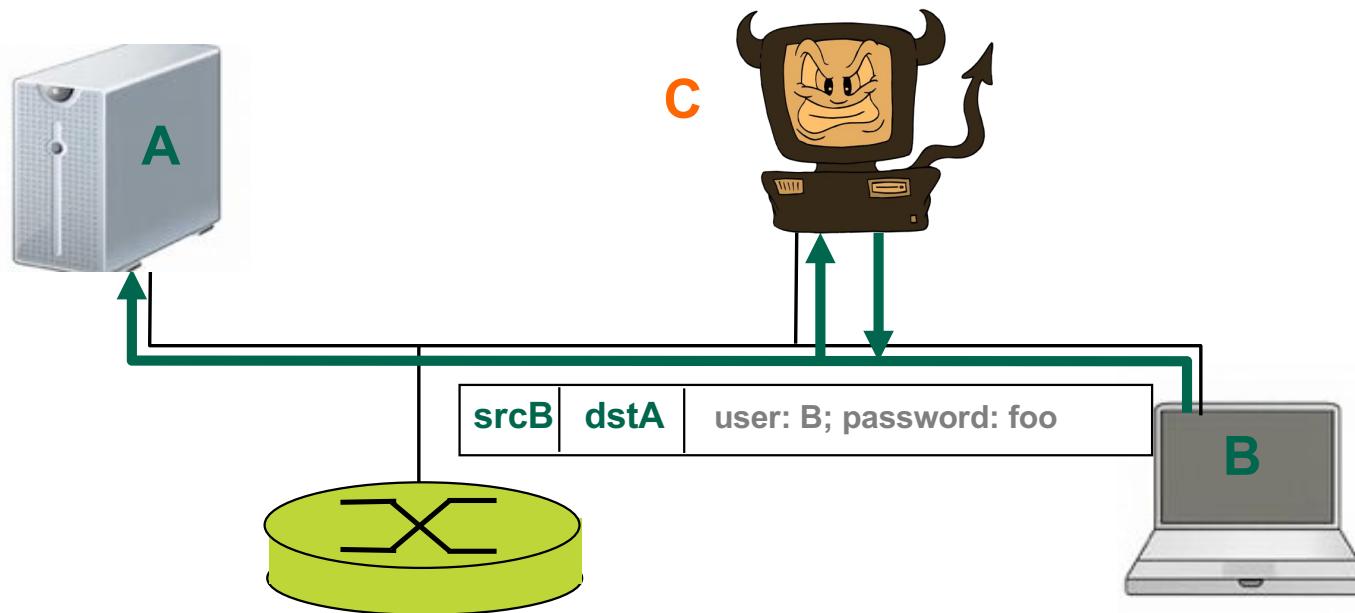
Fredag 6. januar stenger høringen for forslaget til «digitalt grenseforsvar». Debatten om ekstrem statlig overvåking har foreløpig vært sped.

Digitalt grenseforsvar (DGF)

Lysne II-utvalget
26. august 2016

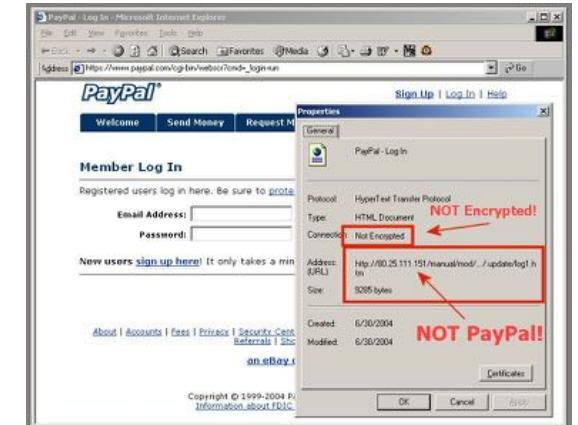
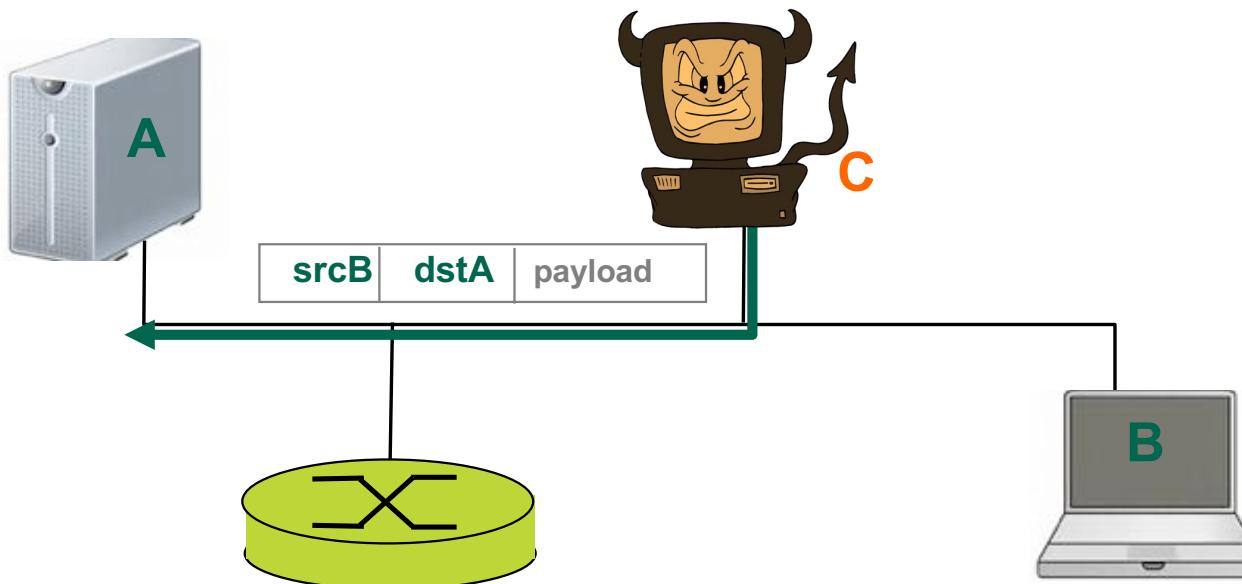
Bad guys can record and playback

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



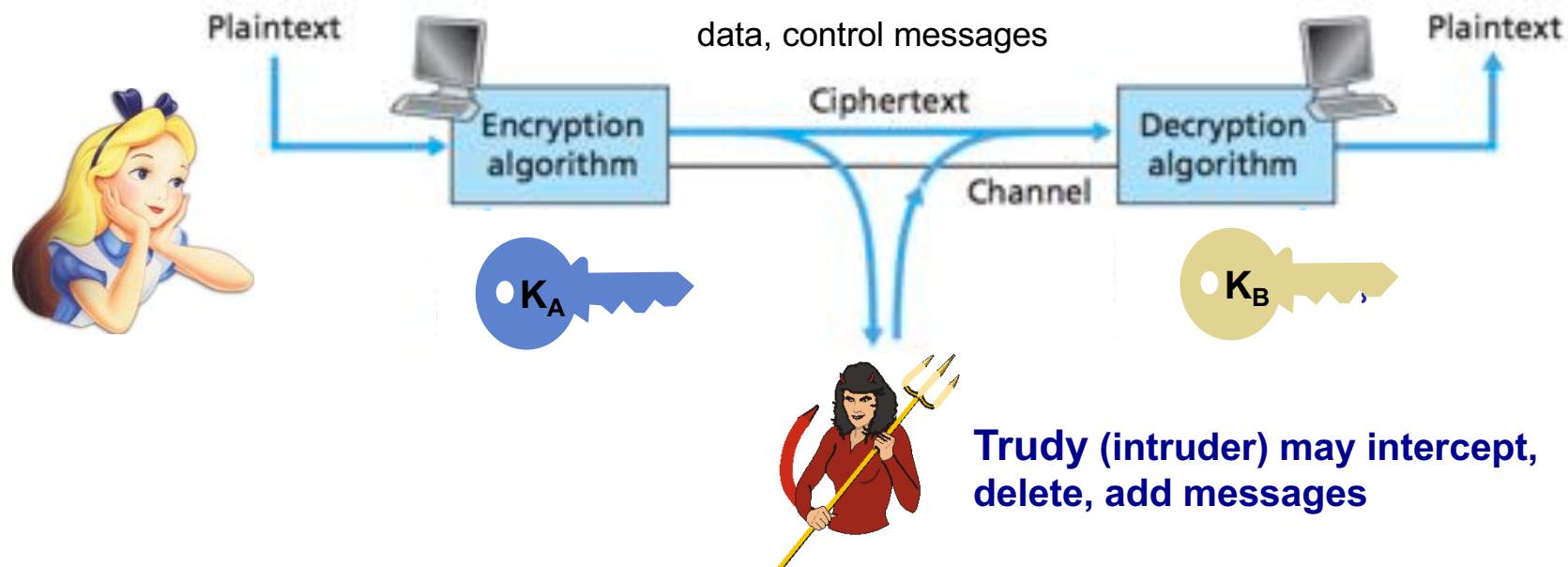
Bad guys can use spoofed source addresses

- 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

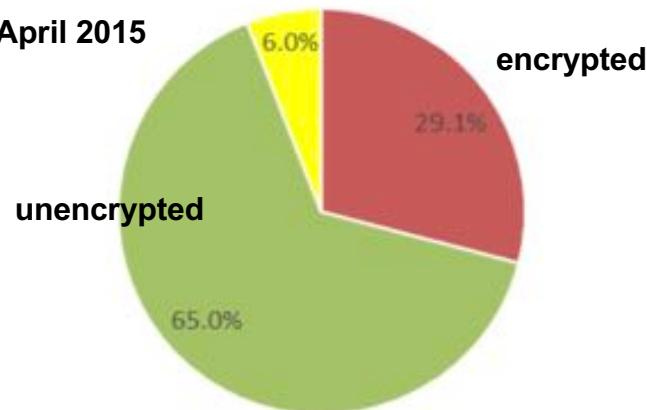
- web browser/server for electronic transactions (e.g. on-line purchases)
- on-line banking client/server
- DNS (domain name servers)
- routers exchanging routing table updates



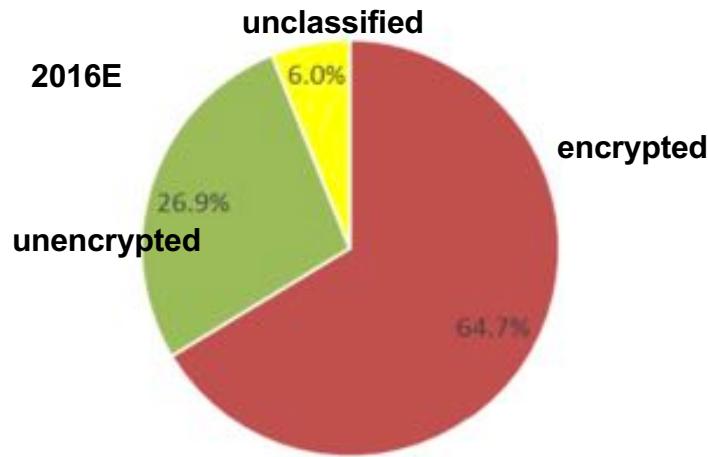
Trafikkryptering øker

North America, Fixed Access Service Provider

April 2015



2016E



A screenshot of the NRK beta website. The header includes the NRK logo, a menu icon, and the word "beta". The main content area features a blue banner with the text "NRK & Sikkerhet" and "Vi slår på kryptering for NRK.no". Below the banner, a news article is displayed with the headline "Vi slår på kryptering for NRK.no", the author "Henrik Lied og Vegard Storstad", the date "31. mai 2016", and a view count of "57". To the right of the article is a small image of a padlock on a screen.

NRK & Sikkerhet

Vi slår på kryptering for NRK.no

Skrevet av [Henrik Lied og Vegard Storstad](#) 31. mai 2016 57

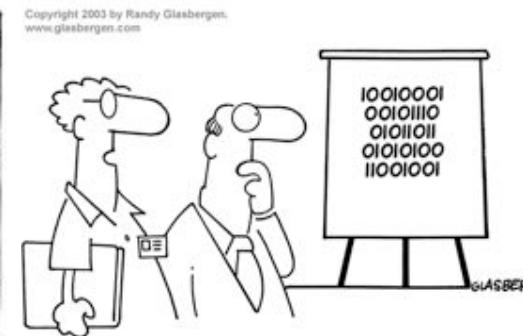
I dag slår vi på kryptering for [NRK.no](#) – en viktig endring som styrker sikkerheten og påliteligheten til NRKs nettsider.

De siste årene har kryptering blitt stadig mer vanlig, og de fleste store aktører, som Google, Facebook og Twitter kjører krypterte forbindelser mellom alle sine tjenester og dine enheter.



De fleste store nettsesere viser en grønn hengelås hvis forbindelsen mellom nettsiden og nettleseren er kryptert.

Copyright 2002 by Randy Glasbergen. www.glasbergen.com



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

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

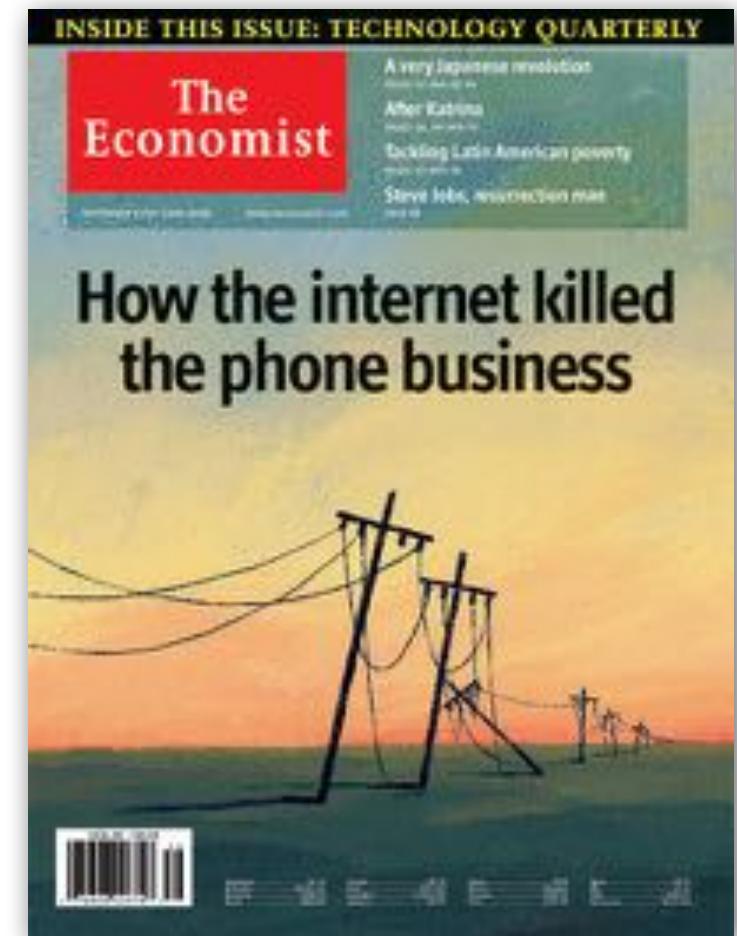
1.5 Protocol layers and service models

1.6 Security: networks under attack

1.7 History of computer networking and the Internet

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!

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."

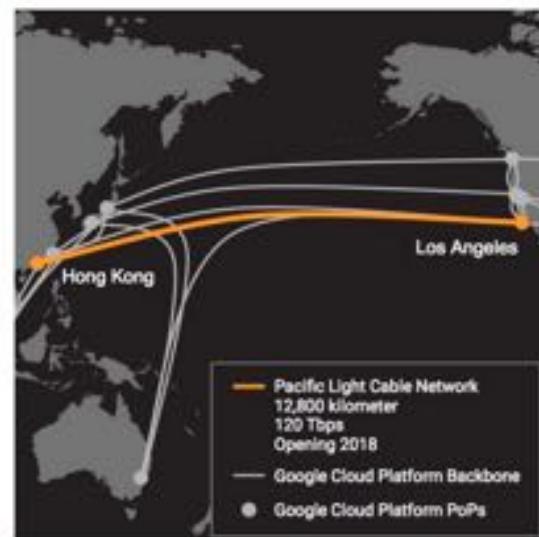
FierceTelecom

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.).

Nettoperatører utfordres fortsatt II



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](#).

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

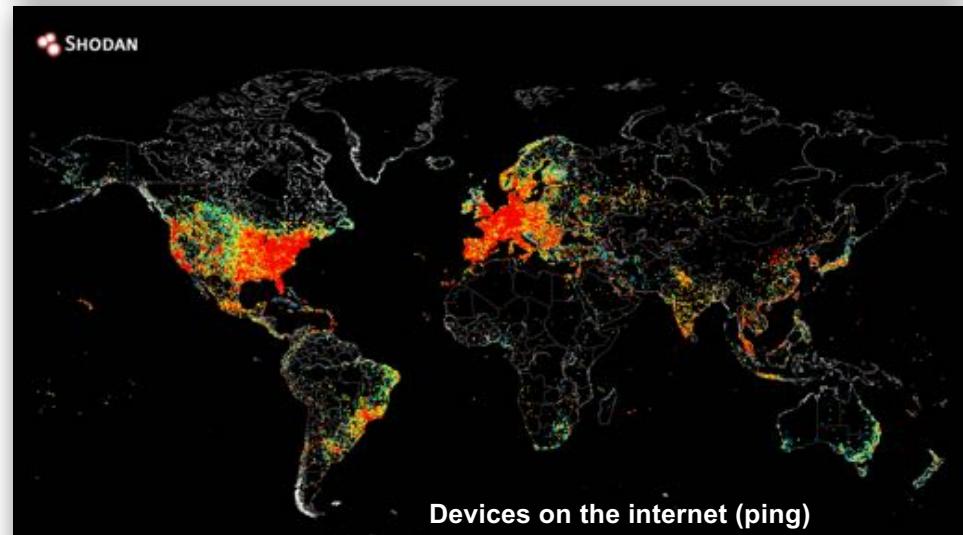
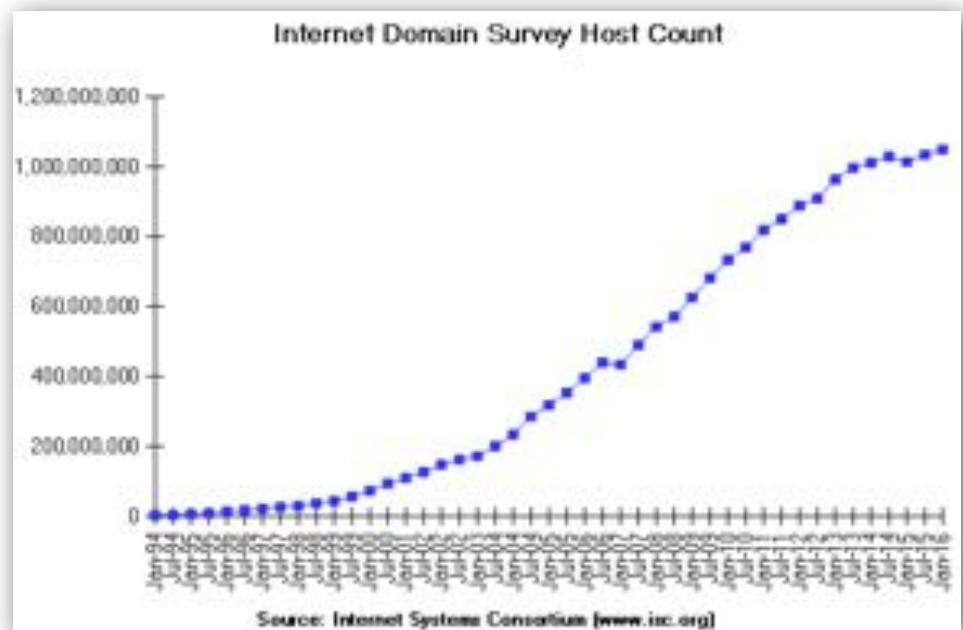
Mike Cassidy steps aside for a satellite broadband industry veteran tasked with taking company's internet balloon project from stratosphere to profitability

by Brad Stone
24. august 2016, 00:00 CEST



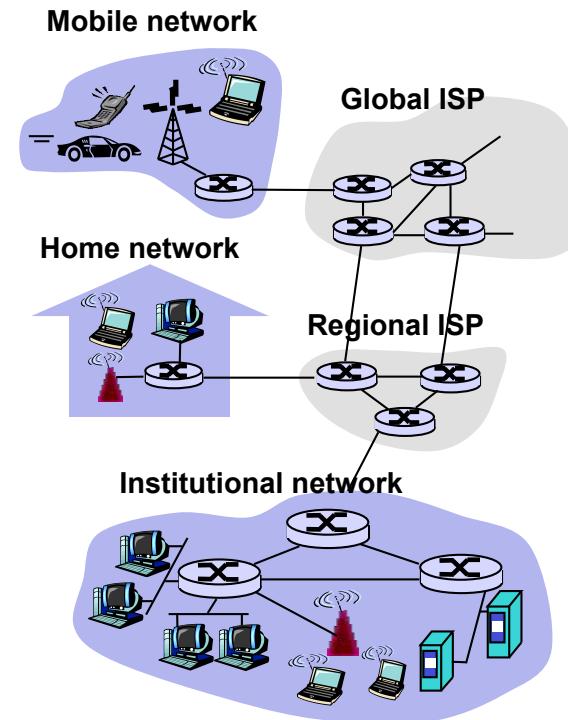
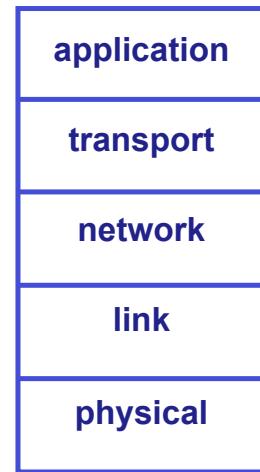
Internet History in brief – II

- ~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

JANUARY							
	Mo	Tu	We	Th	Fr	Sa	Su
53							1
1	2	3	4	5	6	7	8
2	9	10	11	12	13	14	15
3	16	17	18	19	20	21	22
4	23	24	25	26	27	28	29
5	30	31					

Week	Date & Time	Topic	Room	Responsible	Remark (ref.to 6 th 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: <i>Overview of Computer Networks and the Internet</i> Wireshark Lab 1: <i>Intro (optional but highly recommended!)</i>	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