# Networks and network technologies you know of …

- "The Internet"
- Wireless (802.11)
- DSL and cable
- Powerline networks
- RFID
- "3G cellular" mobile phone networks (UMTS)
- Old-fashioned phone network
- Enterprise networks, data centers, ISPs
- Satellites, space networks

- This course is relevant to all these networks/technologies

Why we build networks

- Remote communication
  - Voice, video, email, text/instant messaging
  - For people, and for computers

- Information sharing
  - The Web, content distribution, social network apps

- Resource sharing
  - 3D printer, dataset in the cloud

- To link computers and the physical world?
  - Embedded computing/sensing, e.g., RFID

A Network in 461

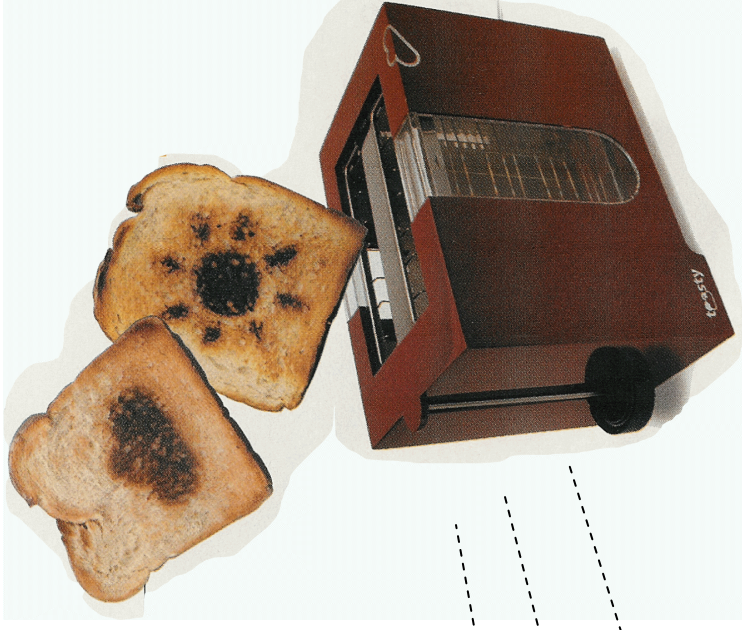- A network is what you get anytime you connect two or more computers together by some kind of a link.
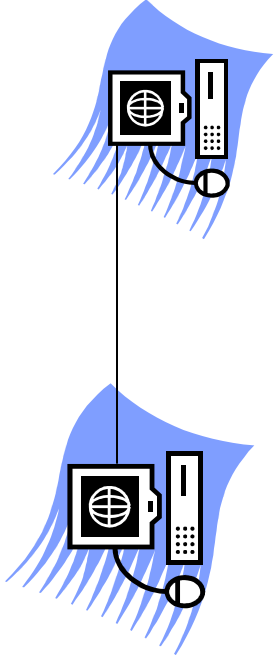
OR
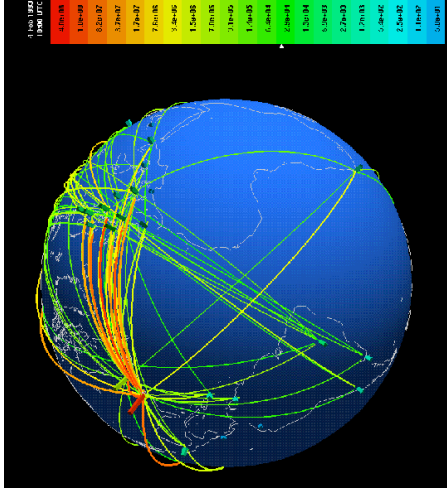
# From "Cool" Appliances

IP picture frame
http://www.ceiva.com/
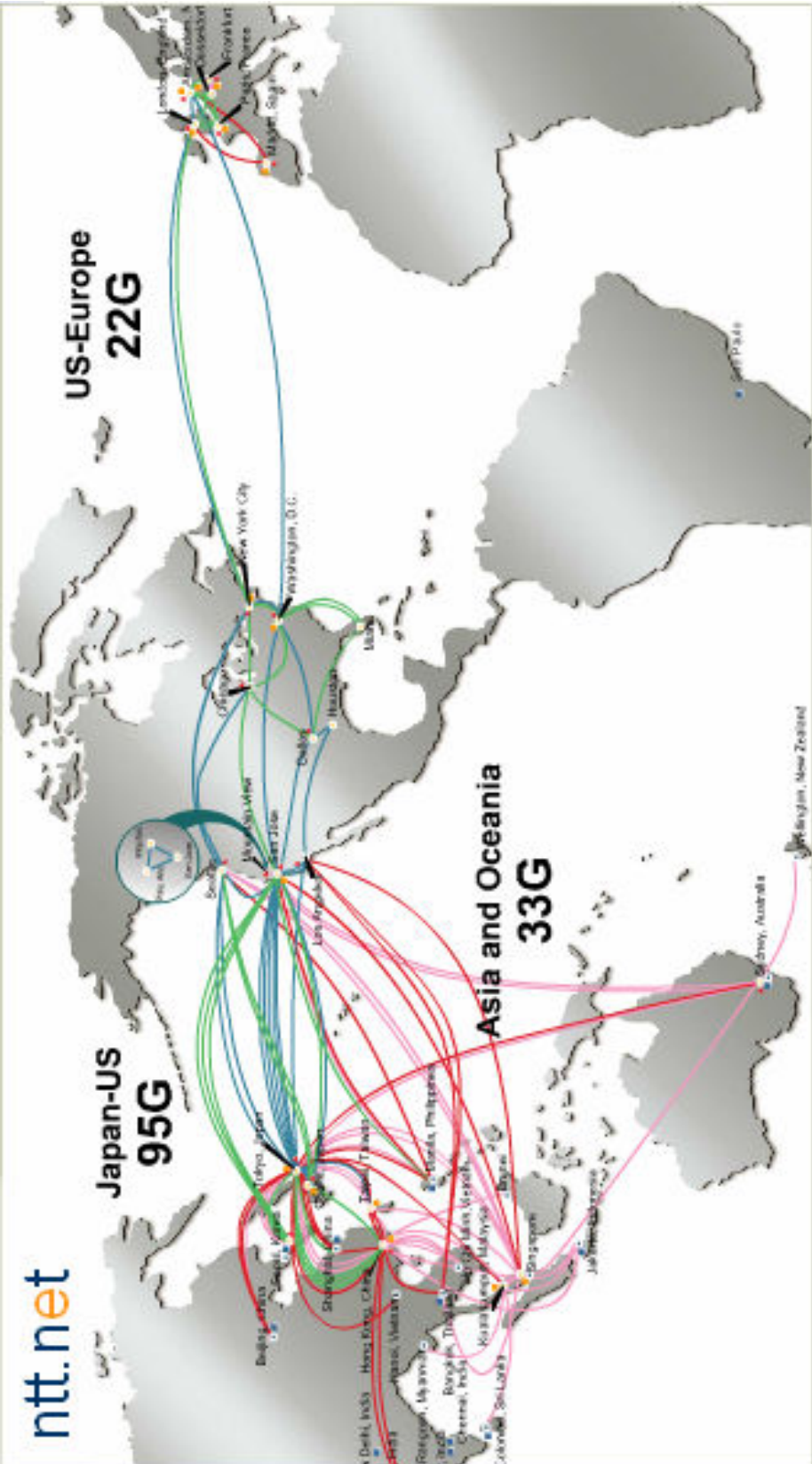
(wireless
link)

Web-enabled toaster+weather forecaster
http://dancing-man.com/robin/toasty/

To the Internet at large

- Internetworks = network of networks
- Hierarchical structure
- millions of connected computing
  devices: *hosts, end-systems*
  - pc's workstations, servers
  - PDA's phones, toasters
  running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
- *routers:* forward packets (chunks) of
  data thru network

router

server

workstation

mobile

local ISP

regional ISP

company
network
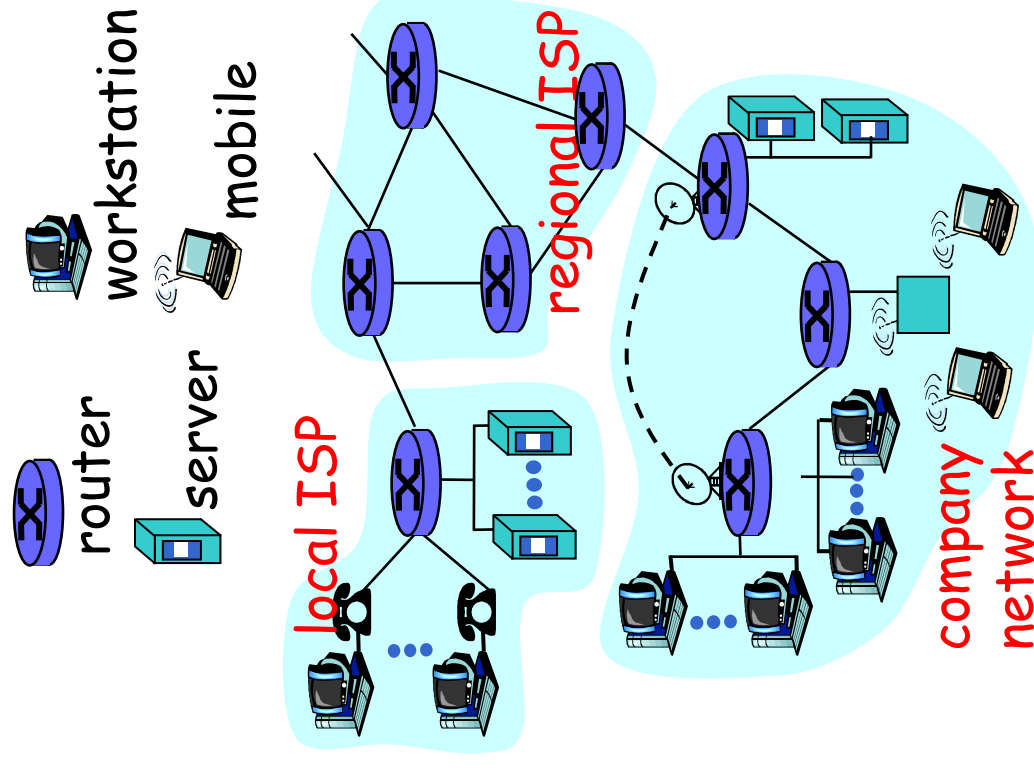
Example piece: NTT backbone

Model of a Network

- Links carry information (bits)
  - Wire, wireless, fiber optic, smoke signals …
  - May be point-to-point or broadcast
- Switches move bits between links
  - Routers, gateways, bridges, CATV headend, PABXs, …
- Hosts are the communication endpoints
  - PC, PDA, cell phone, tank, toaster, …
  - Hosts have names
- Applications make use of the network at hosts
  - Facebook, iTunes, VoIP phones, cameras, …

- Note much other terminology:
  - channels, nodes, intermediate systems, end systems, etc.

The networks we study

- We are interested in networks that are:

  - Large scale
  - Intrinsically unreliable
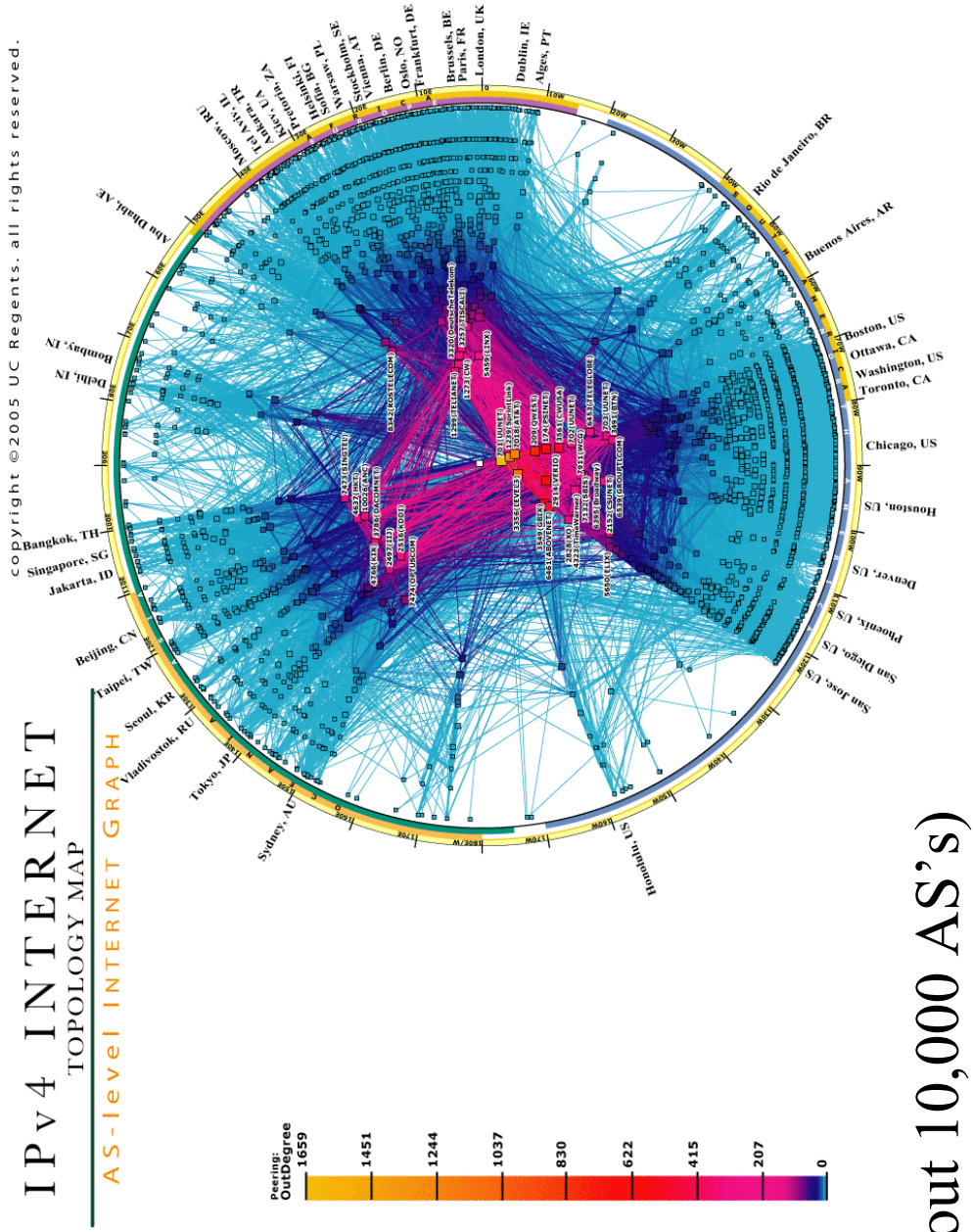 - Distributed
  - Heterogeneous

The meaning of "Large-scale"

TOP 20 COUNTRIES WITH HIGHEST NUMBER OF INTERNET USERS

#	Country or Region	Internet Users, Latest Data	Penetration (% Population)	% of World Users	Population (2008 Est.)	User Growth (2000 - 2008)
1	China	253,000,000	19.0 %	17.3 %	1,330,044,605	1,024.4 %
2	United States	220,141,969	72.5 %	15.0 %	303,824,646	130.9 %
3	Japan	94,000,000	73.8 %	6.4 %	127,288,419	99.7 %
4	India	60,000,000	5.2 %	4.1 %	1,147,995,898	1,100.0 %
5	Germany	52,533,914	63.8 %	3.6 %	82,369,548	118.9 %
6	Brazil	50,000,000	26.1 %	3.4 %	191,908,598	900.0 %
7	United Kingdom	41,817,847	68.6 %	2.9 %	60,943,912	171.5 %
8	France	36,153,327	58.1 %	2.5 %	62,177,676	325.3 %
9	Korea, South	34,820,000	70.7 %	2.4 %	49,232,844	82.9 %
10	Italy	34,708,144	59.7 %	2.4 %	58,145,321	162.9 %
11	Russia	32,700,000	23.2 %	2.2 %	140,702,094	954.8 %
12	Canada	28,000,000	84.3 %	1.9 %	33,212,696	120.5 %
13	Turkey	26,500,000	36.9 %	1.8 %	71,892,807	1,225.0 %
14	Spain	25,623,329	63.3 %	1.8 %	40,491,051	375.6 %
15	Indonesia	25,000,000	10.5 %	1.7 %	237,512,355	1,150.0 %
16	Mexico	23,700,000	21.6 %	1.6 %	109,955,400	773.8 %
17	Iran	23,000,000	34.9 %	1.6 %	65,875,223	9,100.0 %
18	Vietnam	20,159,615	23.4 %	1.4 %	86,116,559	9,979.8 %
19	Pakistan	17,500,000	10.4 %	1.2 %	167,762,040	12,969.5 %
20	Australia	16,355,388	79.4 %	1.1 %	20,600,856	147.8 %
	TOP 20 Countries	1,115,713,572	25.4 %	76.2 %	4,388,052,548	284.5 %
	Rest of the World	347,918,789	15.2 %	23.8 %	2,288,067,740	391.2 %
	Total World - Users	1,463,632,361	21.9 %	100.0 %	6,676,120,288	305.5 %

http://www.internetworldstats.com/top20.htm

The meaning of "Large scale"

IPv4 INTERNET
TOPOLOGY MAP

AS-level INTERNET GRAPH

(About 10,000 AS's)

The meaning of "Large-scale"

Internet Domain Survey Host Count

Source: Internet Systems Consortium (www.isc.org)
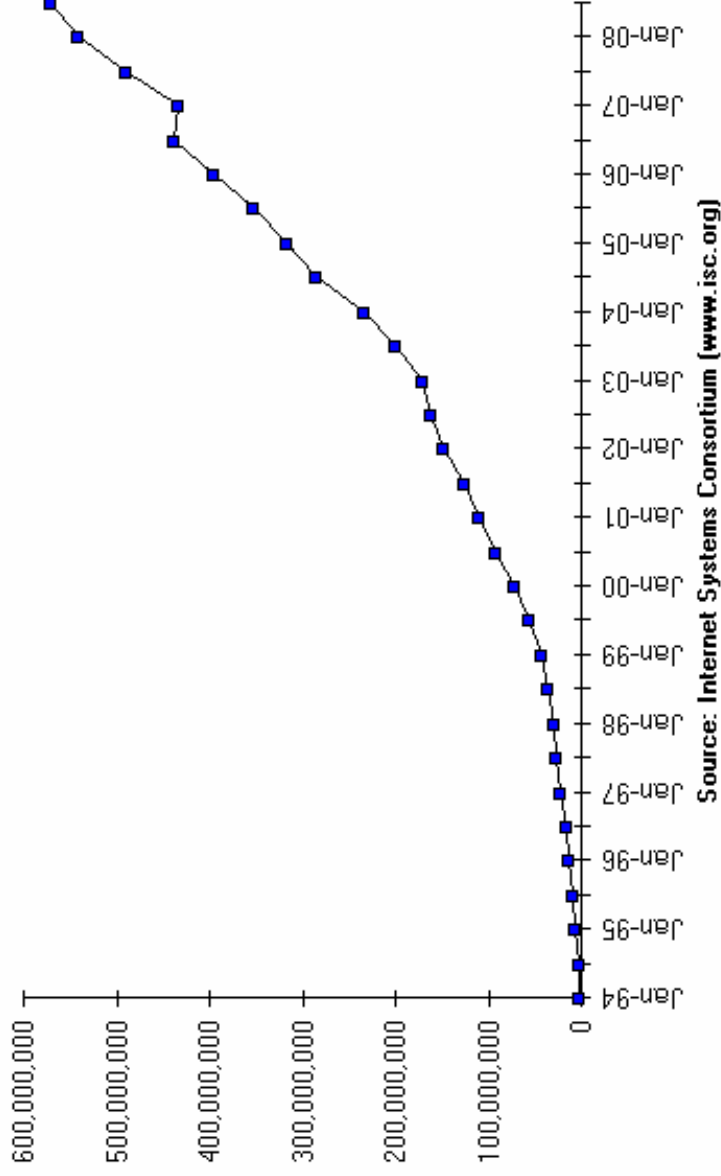
But why build large networks?

Intrinsic Unreliability

- Information sent from a first place to a second
  - May not arrive
  - May arrive more than once
  - May arrive in garbled fashion
  - May arrive out of order
  - May be read by others
  - May be modified by others
- Why build intrinsically unreliable networks?

Distributed

- (Hopefully) independent failure modes
- Exposed and hidden dependencies

  - *"A distributed system is a system in which I can't do my work because some computer has failed that I've never even heard of." – Lamport*

- Independent administrative controls

Heterogeneous Networks

- Heterogeneous: used for and made up of different kinds of stuff (versus homogeneous, the same kind of stuff)

- Heterogeneous networks are harder to deal with but:

  - They are more flexible
  - They are inevitable. Why?

Goal of this Course

- You will understand how to design and build *large, distributed computer* networks.
  - Fundamental problems
  - Design principles
  - Implementation technologies

- This is a systems course, not queuing theory, signals, or hardware design.

- We focus on networks, and a bit on applications or services that run on top of them.

Applications & services

Distrib. systems

Networks

You Are Here

Communications

Signals
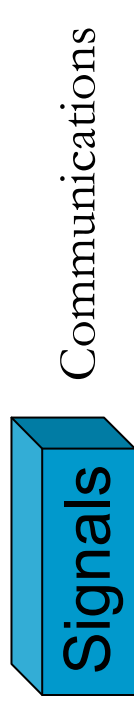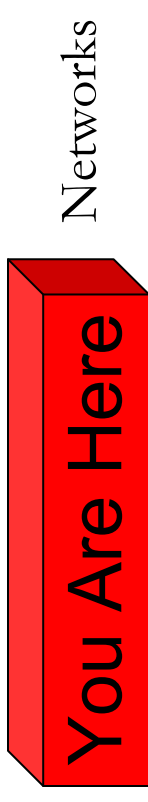
TeraScale SneakerNet: Using Inexpensive Disks for Backup, Archiving, and Data Exchange.

Jim Gray, Wyman Chong, Tom Barclay, Alex Szalay, Jan Vandenberg

May 2002, Technical Report, MS-TR-02-54

Table 2: The raw price of bandwidth, the true price is more than twice this when staff, router, and support costs are included. Raw prices are higher in some parts of the world.

Context	Speed Mbps	Rent $/month	Raw $/Mbps	Raw $/TB sent	Time/TB days
home phone	0.04	40	1,000	3,086	6 years
home DSL	0.6	70	117	360	5 months
T1	1.5	1,200	800	2,469	2 months
T3	43	28,000	651	2,010	2 days
OC3	155	49,000	316	976	14 hours
100 Mpbs	100				1 day
Gbps	1000				2.2 hours
OC192	9600	1,920,000	200	617	14 minutes

Table 3: The relative cost of sneaker-net, using various media. The analysis assumes 6MBps tape, 10MBps CD/DVD and robots at each end to handle the media. Note that the price of media is less than the fixed robot cost.

	Media	Robot$	Media$	TB read + write time	ship time	TotalTime /TB	Mbps	Cost (10 TB)	$/TB shipped
CD	1500	2x800	240	60 hrs	24 hrs	6 days	28	$2,080	$208
DVD	200	2x8000	400	60 hrs	24 hrs	6 days	28	$20,000	$2,000
Tape	25	2x15,000	1000	92 hrs	24 hrs	5 days	18	$31,000	$3,100
DiskBrick	7	1,000	1,400	19 hrs	24 hrs	2 days	52	$2,600	$260