The Internet

The last 30 years and the next 30 years.

Mark Handley

UCL Department of Computer Science.

Outline

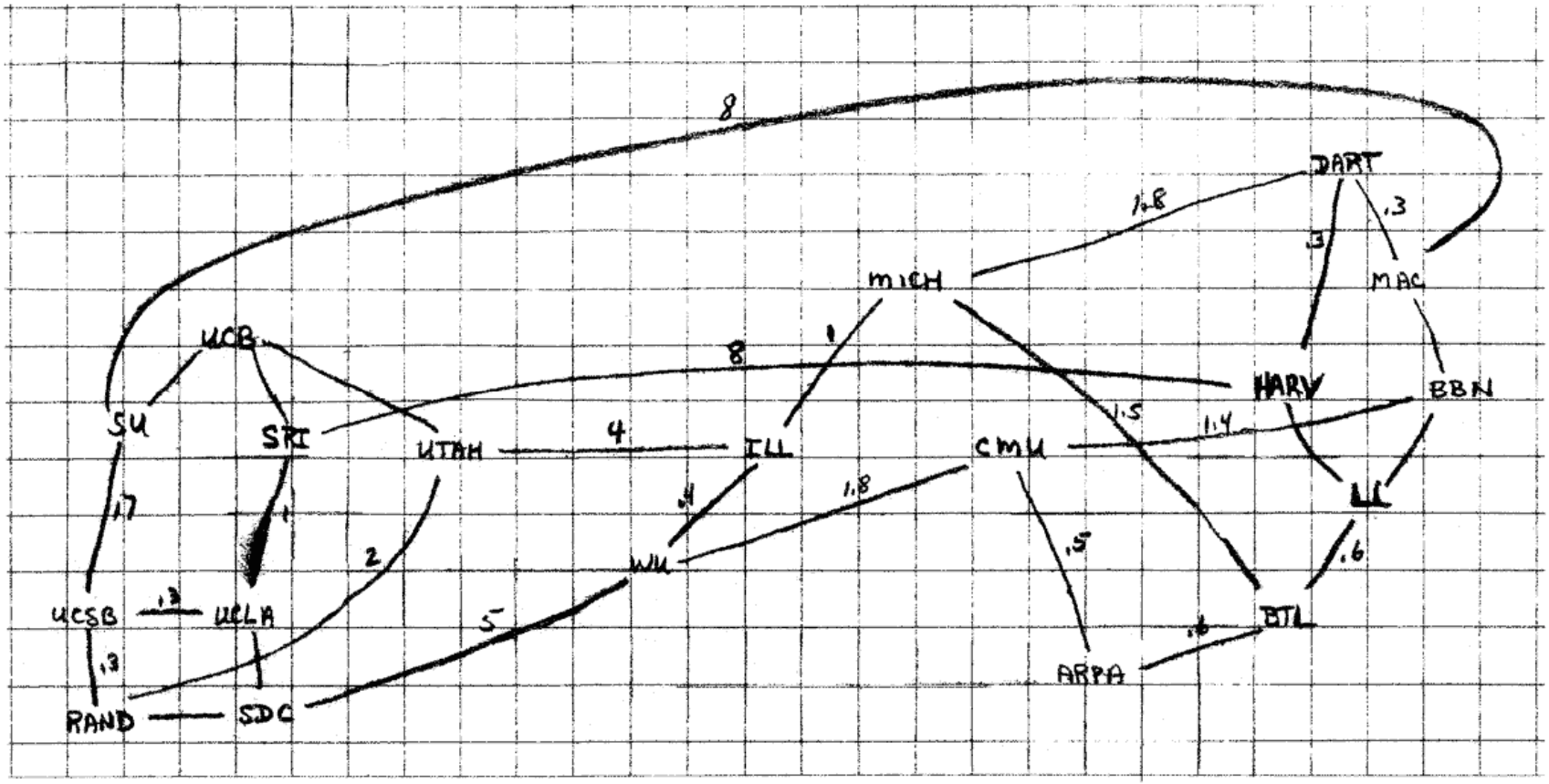
- A brief history of the Internet.
- Trends and predictions.
- Immediate problems.
- Hopes and concerns for the future.

A Brief History of the Internet

- **ARPAnet**
  - Conceived in 1966/67 to connect big academic computers together.
  - First operational ARPAnet nodes in 1969
    - UCLA, SRI, UCSB, Utah
- **NPLnet**
  - Around the same time, at the National Physical Laboratory in UK.
- Around 20 US Arpanet nodes by 1971
  - First host-to-host protocol.
  - Two cross-country links - all at 50 Kbps

ARPAnet plan

Rough sketch by Larry Roberts, late 1960s.



International Networking

- First proposed to link NPLnet and ARPAnet in 1971.
  - Use link through UK to seismic array in Norway.
  - Politics made this impossible.

- UCL connected in July 1973, via a link to Norway, and onward satellite link to ARPAnet.

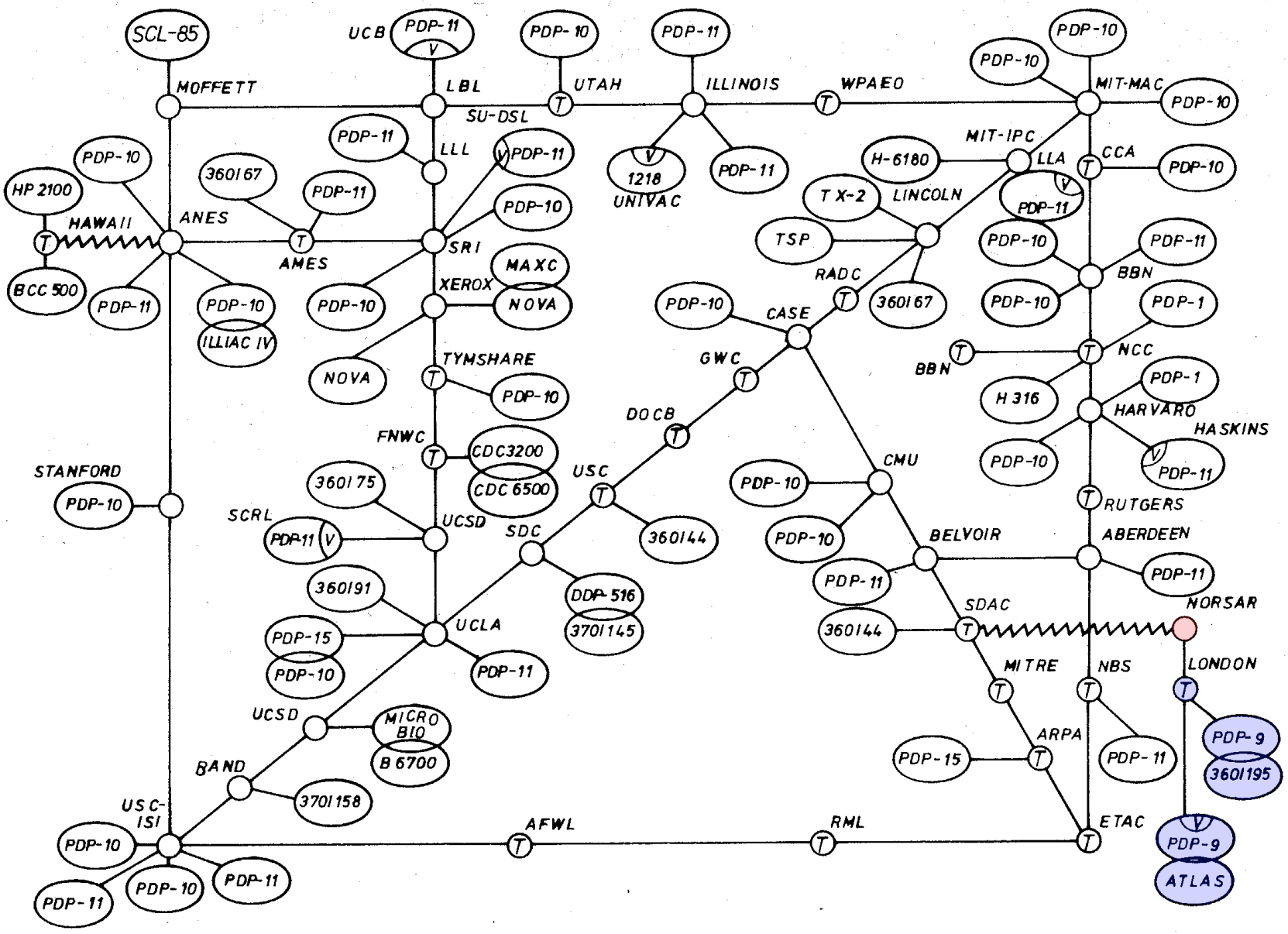


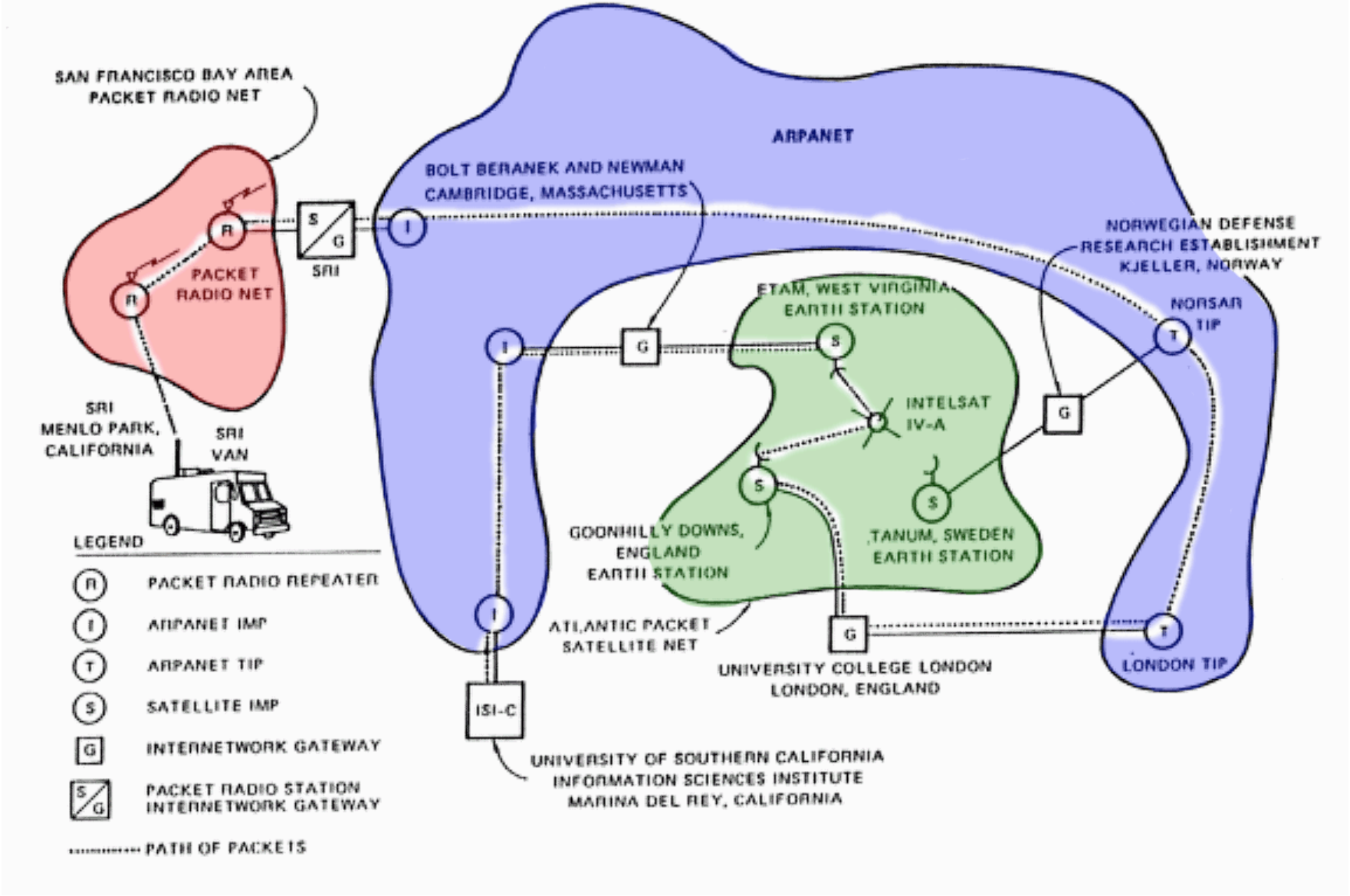
Abb. 4 ARPA NETwork, topologische Karte. Stand Juni 1974.

Towards an Internet

- ARPAnet wasn't the only network.
  - SATNET over satellite.
  - Packet Radio networking.
  - Ethernet Local Area Networks.

- Work started in 1973 on replacing the original Network Control Protocol with TCP and IP:
  - IP: Inter-network Protocol
  - TCP: Transmission Control Protocol.

Inter-networks Demonstration, 1977

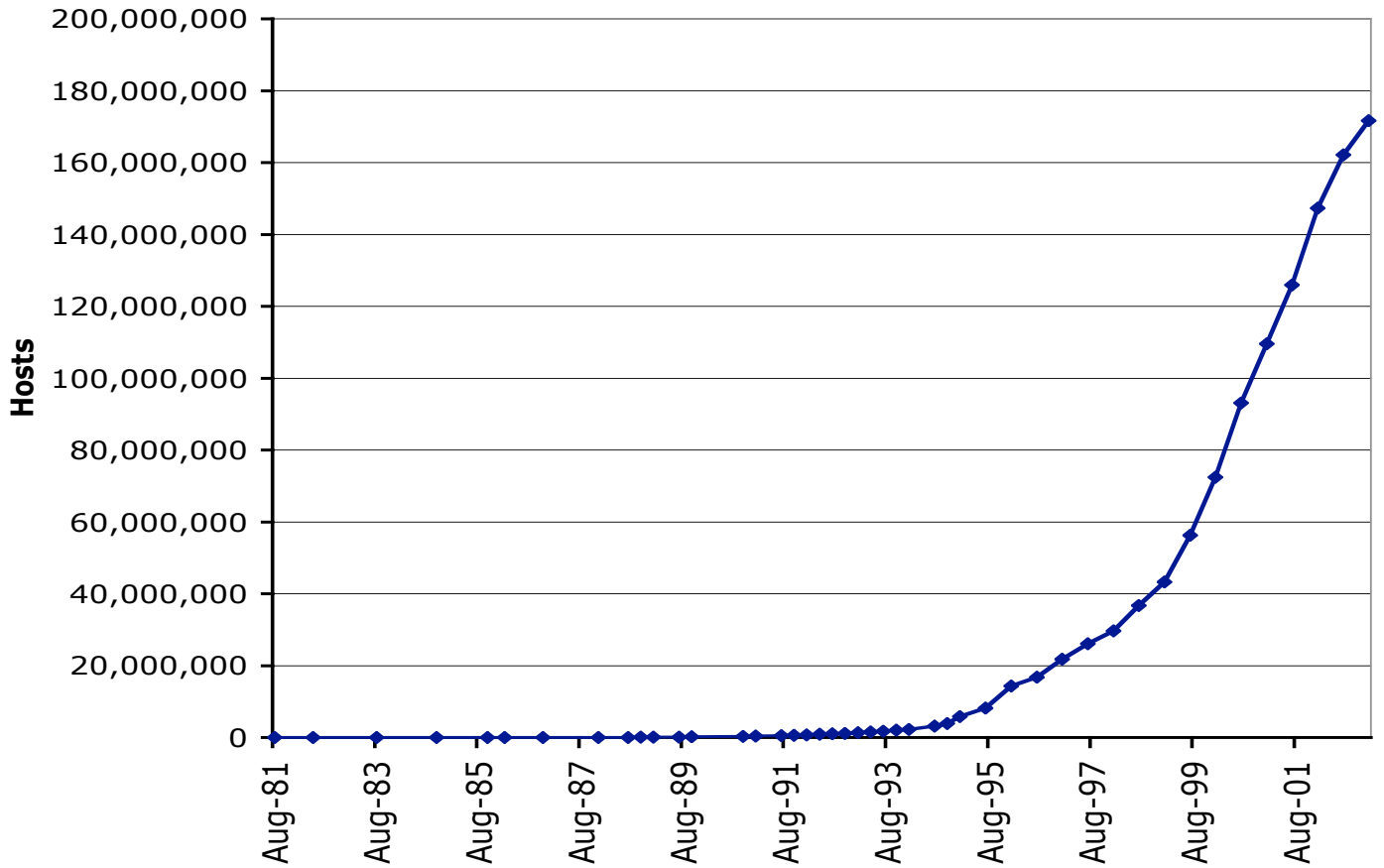


Transition to TCP/IP

- TCP/IP:
  - Standardized in 1978-1981
  - Included in Berkeley UNIX in 1981.

- 1st Jan 1983: Flag Day
  - ARPAnet transitions to TCP/IP
  - Already in use on satellite and packet radio nets.

Computers on the Net



Source:Internet Software Consortium (http://www.isc.org/)

Technical Milestones

- Domain Name System (1982)
  - replaced hosts.txt file containing all the worlds machine names.
- TCP Congestion Control (1988)
  - net suffered a series of congestion collapses
- NSFnet and BGP inter-domain routing (1989)
  - Support for routing policy.

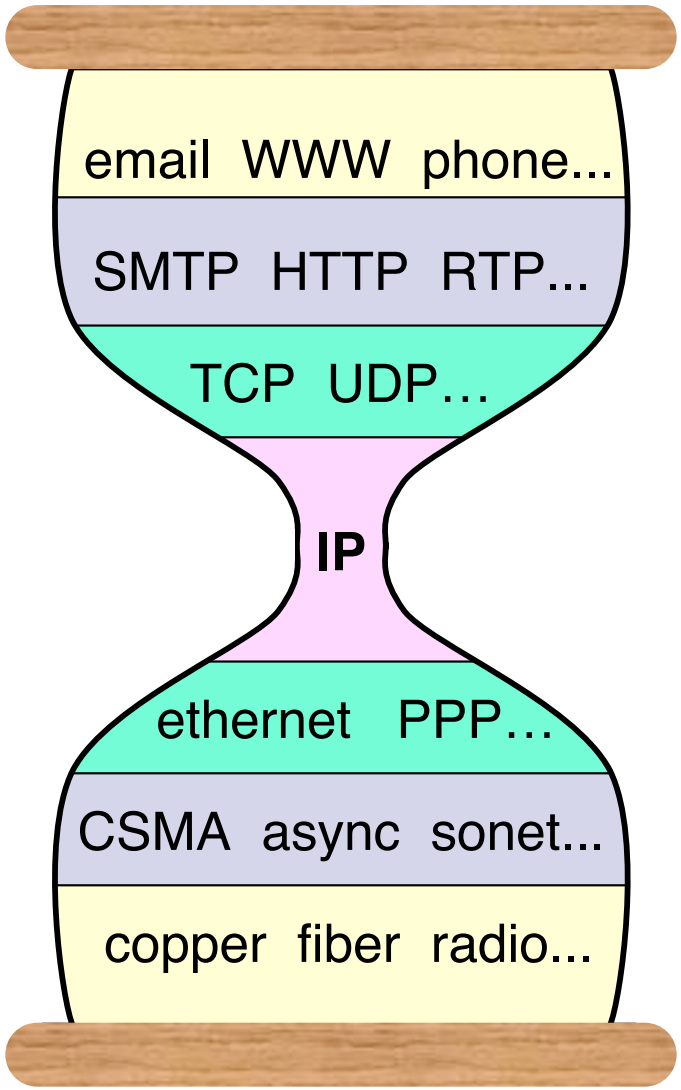
New Applications

Email, remote terminal access (telnet) and file transfer (ftp) were the original ARPAnet applications.

- **Audio/video** (1992...)
  - Telephony, conferencing, streaming media.
- **World Wide Web** (1993...)
  - browsing a mesh of hyperlinks.
  - Altavista search engine (Dec 1995)
- **Peer-to-peer** (2000...).
  - File sharing

Notable Failures

- IP Multicast?
  one-to-many service
- IPv6?
  bigger addresses
- Quality of Service?
  protected service



Outline

- A brief history of the Internet.
- Trends and predictions.
- Immediate problems.
- Hopes and concerns for the future.

The Perils of Prediction

It is hard to predict anything, especially the future.

Storm P.

The best way to predict the future is to create it.

Peter F. Drucker

Trends

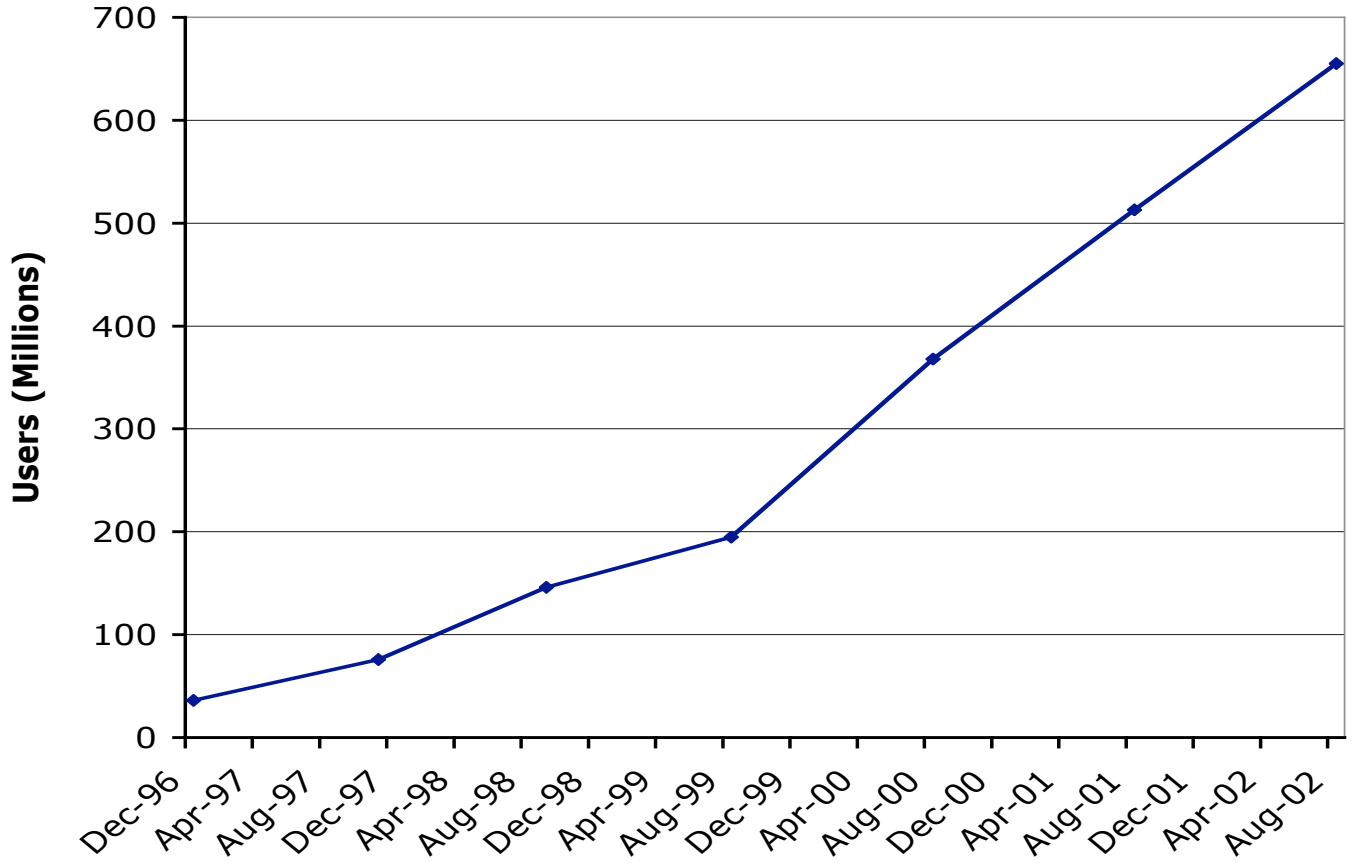
- Bigger, faster
- Wireless. Ubiquitous.
- Optical.
- International.
- Convergence.
- Viruses, worms, security problems.
- Different.

Faster!

- 40Gbit/s Internet links currently deployed.
  - 2 million voice calls (assuming 20Kb/s codec).

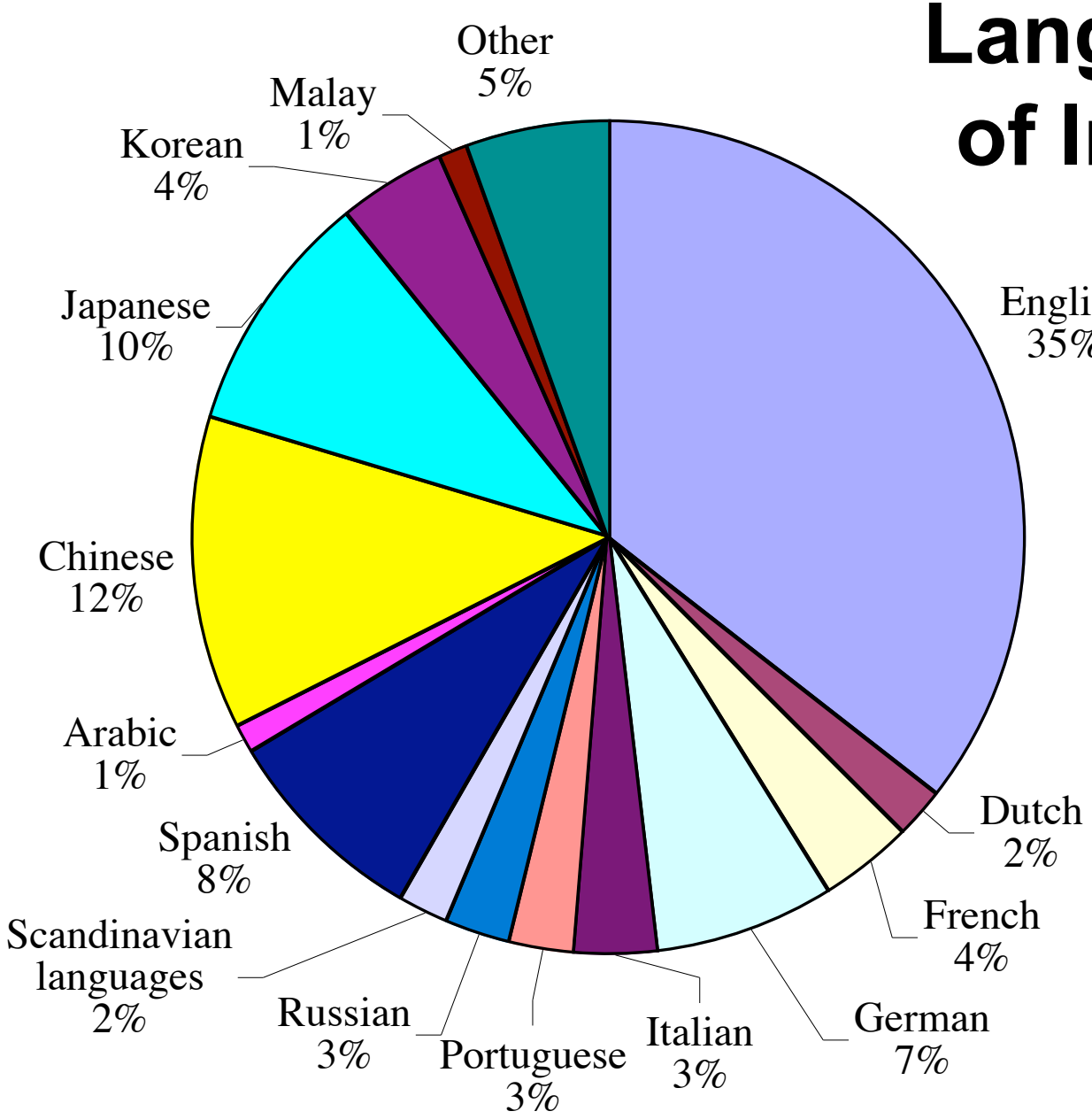
- Doubling approximately every 16-18 months.
  - Continuously connect everyone in Britain using telephone-quality audio in 6 years time via a single Internet link.
  - Continuously connect everyone in Britain using DVD-quality video in 16 years time via a single link.
  - 700Gbit/s per person in Britain on one link in 30 years (240,000 TV screens each!)

People on the Net



Sources: Reuters, ITC, NUA, ITU

Languages of Internet Users



Source: Global Reach (global-reach.biz/globstats)

Bigger...

- The net is already saturating in some countries
  - Almost everyone who wants net access has it.

- Now reaches 10% of the *world* population.
- 40% of US home Internet users now have broadband.

- Really we're just beginning
  - The net is an enabling technology, not a goal in its own right.

Wireless

"Mobile phones will never catch on."

- Too big, too heavy, too expensive...

- Wireless Internet access will be ubiquitous.
  - Wireless LANs.
  - 3G (despite the hype)
- Ultra-wideband
- Software Defined Radio

Ubiquitous wireless

- What will we do with it?
  - Mobile phones, games, music.
  - Household devices.
  - Cars.

- Always on, always connected, wearable computing:
  - News, event listings, train times.
  - Google, dictionary.com
  - Mapquest, multimap
  - Location-based information.
  - Subtitling the real world

Optical

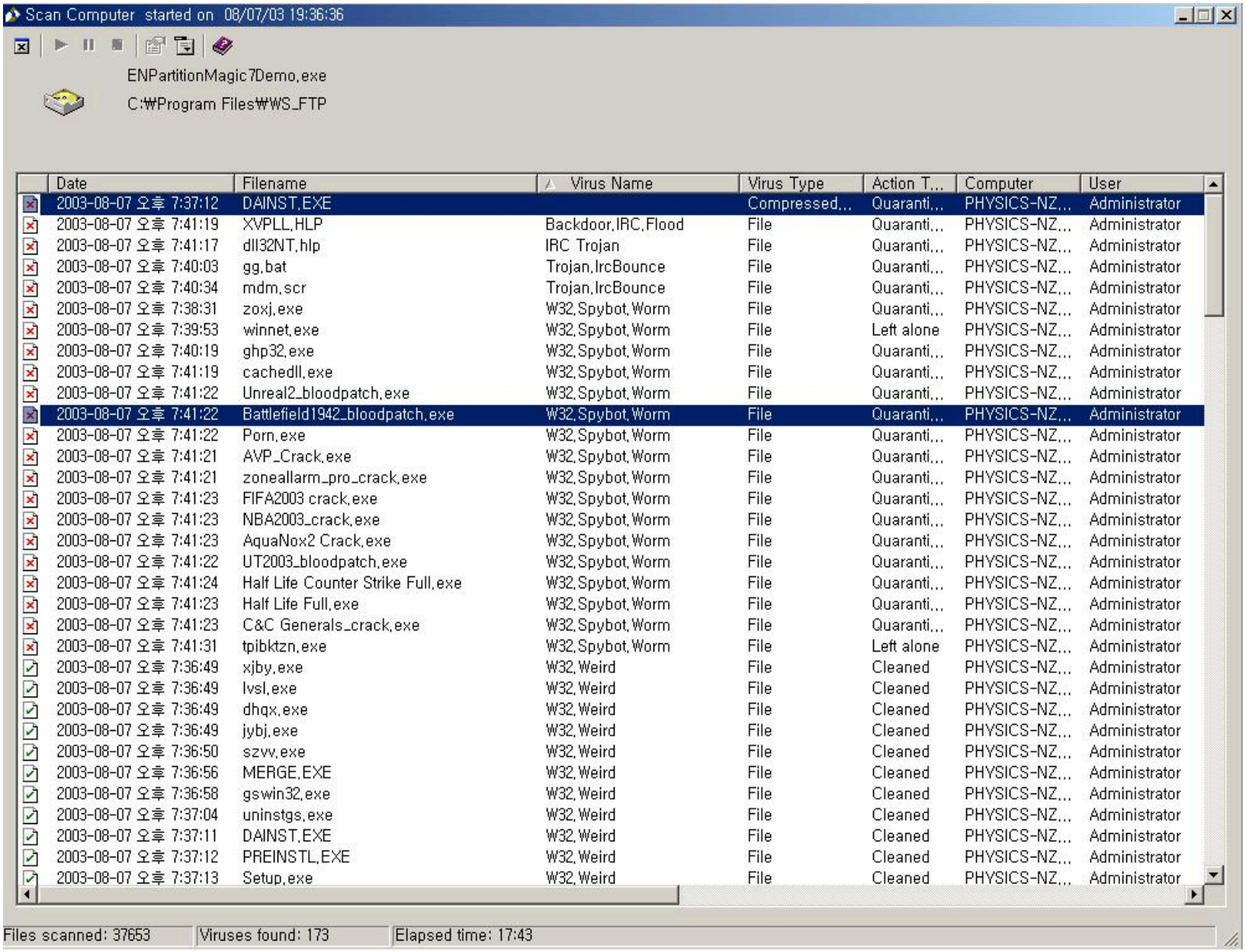
- Optical transmission has been around for a long time.
- Now the net is starting to be optically switched:
  - Many colours on a fibre.
  - Switch individual colours.

- Advantages:
  - simpler, cheaper, less heat dissipation.
- Disadvantages:
  - Less control (security, denial-of-service).

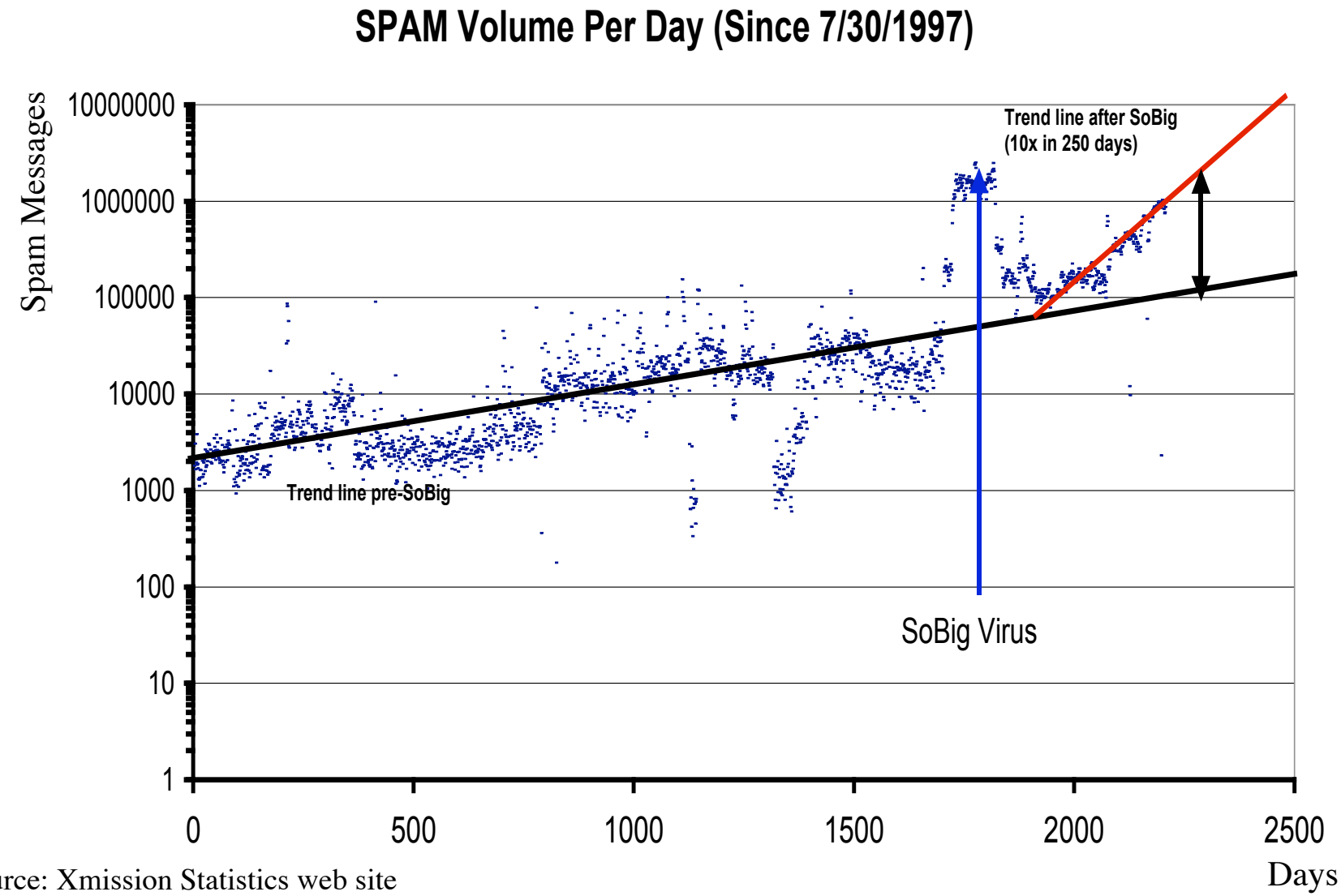
Convergence

- The net is general purpose
  - It doesn't do anything well.

- As it gets faster and more ubiquitous, it stops being cost-effective to provide special-purpose networks.
  - Phone
  - Television
  - Music, movies.


Scan Computer started on 08/07/03 19:36:36
ENPartitionMagic7Demo.exe
C:₩Program Files₩WS_FTP
Date | Filename | Virus Name | Virus Type | Action T... | Computer | User
2003-08-07 오후 7:37:12 DAINST.EXE Compressed... Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:19 XVPLL.HLP Backdoor.IRC.Flood File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:17 dll32NT.hlp IRC Trojan File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:40:03 gg.bat Trojan.IrcBounce File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:40:34 mdm.scr Trojan.IrcBounce File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:38:31 zoxj.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:39:53 winnet.exe W32.Spybot.Worm File Left alone PHYSICS-NZ... Administrator
2003-08-07 오후 7:40:19 ghp32.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:19 cachedll.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:22 Unreal2_bloodpatch.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:22 Battlefield1942_bloodpatch.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:22 Porn.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:21 AVP_Crack.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:21 zoneallarm_pro_crack.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:23 FIFA2003 crack.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:23 NBA2003_crack.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:23 AquaNox2 Crack.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:22 UT2003_bloodpatch.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:24 Half Life Counter Strike Full.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:23 Half Life Full.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:23 C&C Generals_crack.exe W32.Spybot.Worm File Quaranti... PHYSICS-NZ... Administrator
2003-08-07 오후 7:41:31 tpibktzn.exe W32.Spybot.Worm File Left alone PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:49 xjby.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:49 lvsl.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:49 dhqx.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:49 jybj.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:50 szvv.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:56 MERGE.EXE W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:36:58 gswin32.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:37:04 uninstgs.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:37:11 DAINST.EXE W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:37:12 PREINSTL.EXE W32.Weird File Cleaned PHYSICS-NZ... Administrator
2003-08-07 오후 7:37:13 Setup.exe W32.Weird File Cleaned PHYSICS-NZ... Administrator
Files scanned: 37653
Viruses found: 173
Elapsed time: 17:43

Not all communication is good...



Source: Xmission Statistics web site

A Recent Headline

(Financial Times, 11/11/2003)

http://news.ft.com/servlet/ContentServer?pagename=FT.com/StoryFT/FullStory&c=StoryFT&cid=1066565805264&p=1012571727088

Home US

Print article | Email

Crime gangs extort money with hacking threat

By Chris Nuttall in London

Published: November 11 2003 21:57 | Last Updated: November 11 2003 23:23

Evidence of a new type of international extortion racket emerged on Tuesday with revelations that blackmailers have been exploiting computer hacking techniques to threaten the ability of companies to conduct business online.

Gangs based in Eastern Europe have been found to have been launching waves of attacks on corporate networks, costing the companies millions of dollars in lost business and exposing them to blackmail.

Different

- In 1992 we didn't see the web coming.
  - By 1995 it was 50% of the traffic.
- In 1999 we didn't see Napster coming.
  - By 2002 peer-to-peer file sharing was 50% of the traffic.

- We won't see the next killer app coming either.
  - Need to design the network to be flexible.

Outline

- A brief history of the Internet.
- Trends and predictions.
- Immediate problems.
- Hopes and concerns for the future.

The net is a success...

- The problem:
  - In almost every way, the Internet only just works!

The net only just works?

It's always been this way:

- 1975-1981: TCP/IP split as a reaction to the limitations of NCP.
- 1982: DNS as a reaction to the net becoming too large for hosts.txt files.
- 1980s: EGP, RIP, OSPF as reactions to scaling problems with earlier routing protocols.
- 1988: TCP congestion control in response to congestion collapse.
- 1989: BGP as a reaction to the need for policy routing in NSFnet.

Immediate Problems

At UCL we're working on most of the following problems...

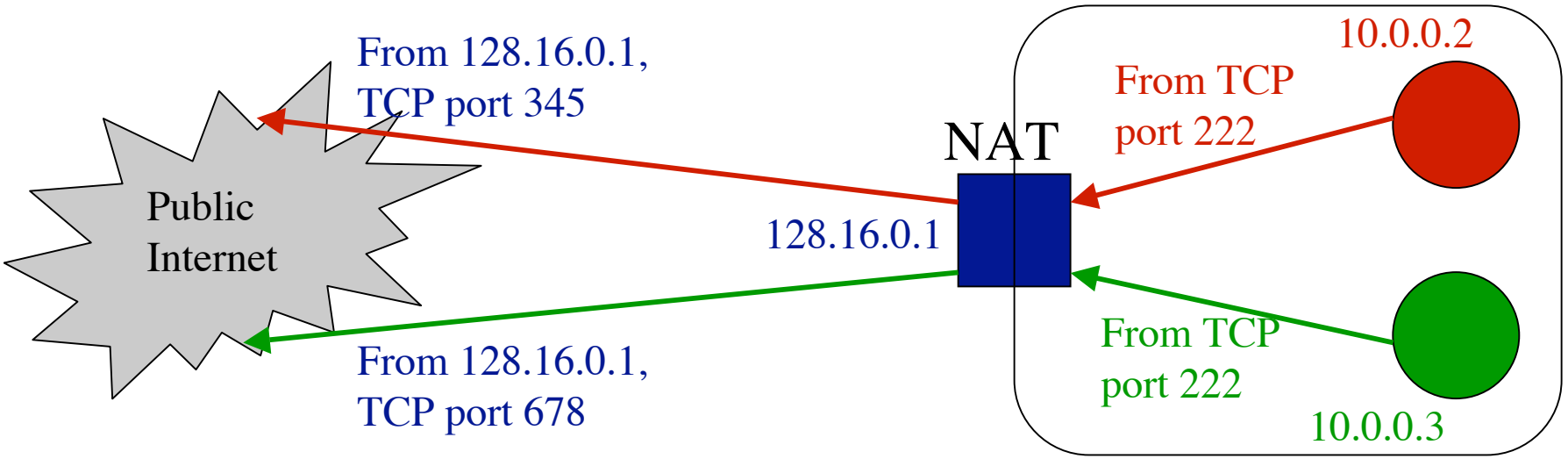
Problem 1: Running out of addresses...

- The current version of the Internet Protocol (IPv4) uses 32 bit addresses.
  - Not allocated very efficiently.
  - MIT has more addresses than China.

- IPv6 is supposed to replace IPv4.
  - 128 bit addresses.
  - We don't need to be smart in address allocation.
  - How do we persuade people to switch?

Network Address Translators

- Scarcity of addresses has made addresses expensive.
- NATs map one external address to multiple private internal addresses, by rewriting TCP or UDP port numbers.



Network Address Translation

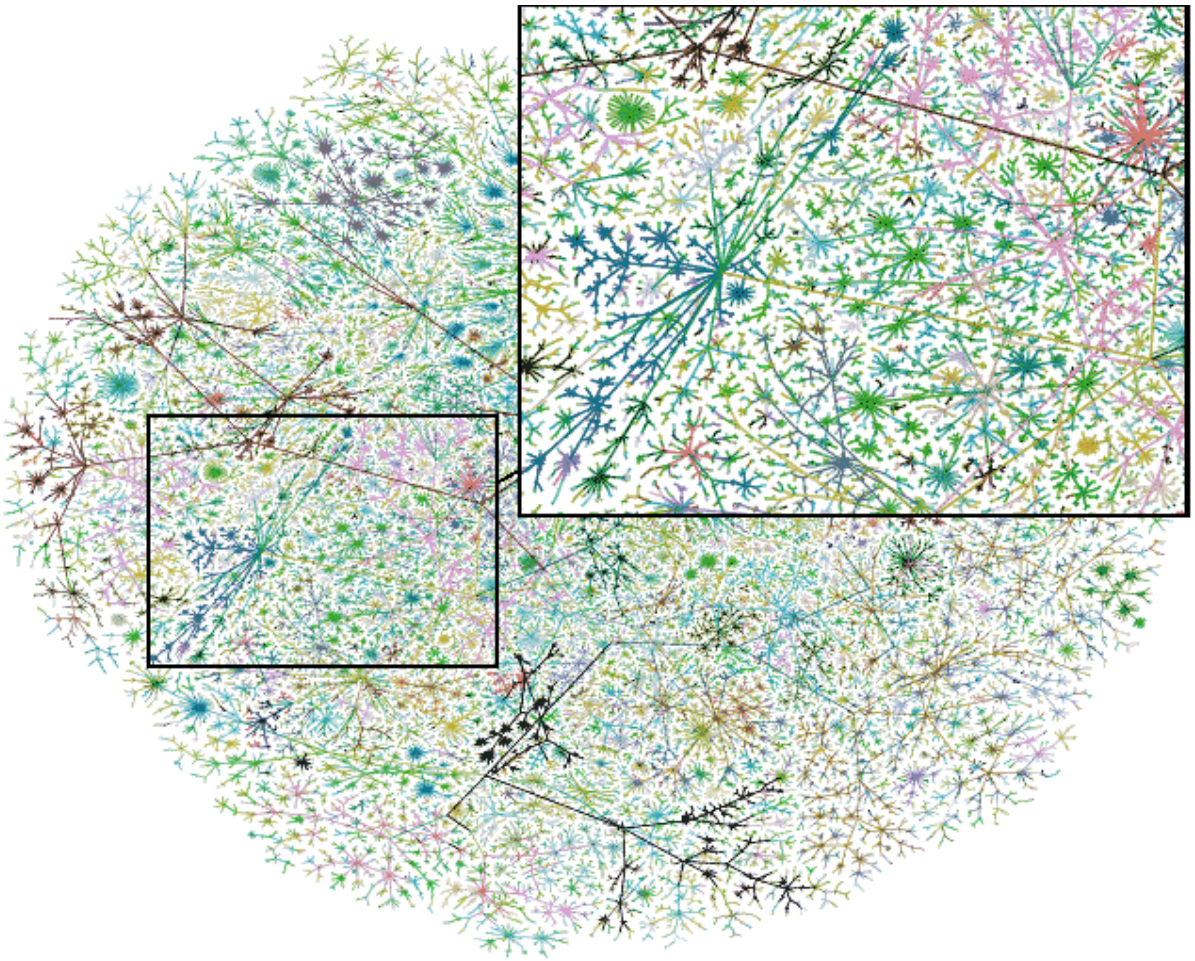
- Introduces asymmetry: can't receive an incoming connection.
- Makes it very hard to refer to other connections:
  - Signalling, causes the phone to ring.
  - On answer, set up the voice channel.

- Application-level gateways get embedded in NATs.
  - It should be easy to deploy new applications!

Problem 2: Congestion Control

- Congestion Control matches offered load to available capacity.
  - TCP congestion control has done this since 1988
- Problem: insufficient dynamic range:
  - Slow and flakey wireless links.
  - Very high speed intercontinental paths.
- Some possible solutions do exist, but:
  - Change is hard, all deployed solutions must interact well.
  - How to decide what is “good enough”?
  - How to get consensus on which solution to deploy?

Problem 3: Routing
(Internet map, 1999)



Source: Bill Cheswick, Lumeta

Problem 3: Routing

(which path to take through the net)

BGP4 is the only inter-domain routing protocol currently in use world-wide.

- Lack of security.
- Ease of misconfiguration.
- Policy through local filtering.
- Poorly understood interaction between local policies.
- Poor convergence.
- Lack of appropriate information hiding.
- Non-determinism.
- Poor overload behaviour.

Problem 3: Routing

- BGP works!
- BGP is the most critical piece of Internet infrastructure.

- No-one really knows what policies are in use.
  - And of those, which subset are intended to be in use.
- No economic incentive to be first to abandon BGP.

Problem 4: Security

- We're reasonably good at encryption and authentication technologies.
  - Not so good at actually turning these mechanisms on.
- We're rather bad at key management.
  - Hierarchical PKIs rather unsuccessful.
  - Keys are a single point of failure.
  - Key revocation.
- We're really bad at deploying secure software in secure configurations.
  - No good way to manage epidemics.
  - Flash worm: infect all vulnerable servers on the Internet in 30 seconds.

Problem 5: Denial of Service

- The Internet does a great job of transmitting packets to a destination.
  - Even if the destination doesn't want those packets.
  - Overload servers or network links to prevent the victim doing useful work.

- Distributed Denial of Service becoming commonplace.
  - Automated scanning results in armies of compromised zombie hosts being available for coordinated attacks.

Biggest Problem:
Managing Change to the Infrastructure

- Most of these problems require changes to the basic Infrastructure.
  - Providers struggle to keep up with high growth.
  - Hard enough to think 12 months ahead.

- Changing the basic infrastructure is hard.
  - Not even clear what the process is to achieve consensus on changes.

The sky is falling!!!

- No.
- But we're accumulating problems faster than they're being fixed.

Outline

- A brief history of the Internet.
- Trends and predictions.
- Immediate problems.
- Hopes and concerns for the future.

Architectural Ossification

- The net is already hard to change in the core.
- IP Options virtually useless for extension.
  - Slow-path processed in fast hardware routers.
- NATs make it hard to deploy many new applications.
- Firewalls make it make to deploy anything new.
  - But the alternative seems to be worse.
- ISPs looking for ways to make money on “services”.
  - They’d love to lock you into their own private walled garden, where they can get you to use *their* services and protocols, for which they can charge.

Information Overload

- Email, instance messenger, web, TV, radio, DVD....
  - Too much information, too little time to take it all in.
  - Too hard to find out where you heard something.

- Need serious research into managing information.
  - Need *relevant* information.
  - Need *trustworthy* information.
  - Need an *audit trail* - find something you vaguely remember.

Fragility

- The tendency to move everything onto the net is irresistible.
  - But the net was not designed to be this trustworthy.
  - 80% of the functionality for 20% of the cost.
- The net doesn't have any embedded knowledge of services.
  - It can't tell when it's working.
  - It can support unknown services.
- There is a conflict between *generality* and *predictability*.
  - What's the worst-case scenario?

Connecting People

- Distance is no longer a barrier to the flow of information.
  - The decentralized nature of the net makes censorship harder.
  - Reduces centralized control over populations.
  - Spreads rumours easily (for good or bad).
- Different people will interpret differently.
  - The hope is that despite this, they'll be closer in understanding than ever before.
- Beware: the net is young.
  - It doesn't have to stay this way.

Making us dumber

- I used to be able to spell.
- I used to be able to add.
- I used to be able to write with a pen.
- I used to be able to remember phone numbers.

What will easy continuous access to data to do us?

Making us wiser

- In an information poor world, data is power.
- In an information rich world, it's more important to know how to use information.

- What you *know* becomes less important.
- What you *understand* becomes more important.

David Clark

RFC 1336 (1992)

"*It is not proper to think of networks as connecting computers. Rather, they connect people using computers to mediate. The great success of the internet is not technical, but in human impact. Electronic mail may not be a wonderful advance in Computer Science, but it is a whole new way for people to communicate. The continued growth of the Internet is a technical challenge to all of us, but we must never loose sight of where we came from, the great change we have worked on the larger computer community, and the great potential we have for future change.*"

Summary

- In almost every way, the net only just works.
- This is a *critical* time.
  - The net is moving out of it's infancy.
  - The problems are significant.
  - The hopes are great.
  - *We* get to influence it's future.

The End

of the beginning...