PARADOXES IN INTERNET ARCHITECTURE

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Founded 1957
35,000 students
Faculty of Mathematics
- 250 faculty
- 8000 undergrads
- 1000 grads
50th Anniversary
The ARPANET in December 1969
AT&T Teletype

PC6300PLUS pc6300plus 6300plus

unixpc 3b1 pc7300 PC7300 s4

AT&T UNIX pc

Hewlett-packard

Television

DEC

(Press RETURN for more instructions)

Some other terminals may work with the Office windows and menus, but not all terminals have been tested.

Most terminals will work with most character-based software on the UNIX PC. If your terminal is "not supported", it will probably work only for simple text and line-by-line data entry. Consult your Remote User's Guide or the Hot Line for more information.

Please type the terminal name, '?' for help, or 'exit' to exit, and press RETURN: vt100...
THE VISION FOR COMPUTER NETWORKING

Anytime access to any information by anyone anywhere
ARE WE DONE?
MAYBE NOT...
WHY CAN’T WE SIMPLY BLOCK SPAMMERS?
BACK TO BASICS...

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CLIENT SERVER MODEL

Spammer

Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...

TCP, UDP

IP, ICMP, ARP, DHCP

Ethernet, PPP, ADSL

You

Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...

TCP, UDP

IP, ICMP, ARP, DHCP

Ethernet, PPP, ADSL
REALITY

Spammer

Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...

TCP, UDP

IP, ICMP, ARP, DHCP

Ethernet, PPP, ADSL

You

Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...

TCP, UDP

IP, ICMP, ARP, DHCP

Ethernet, PPP, ADSL
ISP RELATIONSHIP

Spammer
- Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...
- TCP, UDP
- IP, ICMP, ARP, DHCP
- Ethernet, PPP, ADSL

Spammer’s ISP
- IP, ICMP, ARP, DHCP

Your ISP
- IP, ICMP, ARP, DHCP
- Ethernet, PPP, ADSL

You
- Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...
- TCP, UDP
- IP, ICMP, ARP, DHCP
- Ethernet, PPP, ADSL
INFORMATION HIDING

Spammer
- Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...
- TCP, UDP
- IP, ICMP, ARP, DHCP
- Ethernet, PPP, ADSL

Spammer’s ISP
- IP, ICMP, ARP, DHCP
- Ethernet, PPP, ADSL

Your ISP
- IP, ICMP, ARP, DHCP
- Ethernet, PPP, ADSL

You
- Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, ...
- TCP, UDP
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THE REAL PROBLEM

Narrow AS-AS relationship
- Data plane: Packet exchange
- Control plane: Route information exchange

Identities (and QoS) do not traverse AS boundaries
AS behaviour is unregulated beyond packet transfer
Many of the key problems in the Internet today are due to its origins as an academic research project.
The very things that led to its success lie at the heart of its failures.
The top level goal for the DARPA Internet Architecture was to develop an effective technique for multiplexed utilization of existing interconnected networks.

1. Internet communication must continue despite loss of networks or gateways.

2. The Internet must support multiple types of communications service.

3. The Internet architecture must accommodate a variety of networks.

4. The Internet architecture must permit distributed management of its resources.

5. The Internet architecture must be cost effective.

6. The Internet architecture must permit host attachment with a low level of effort.

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Very successful!

Telecommunications

Telecom companies count $386 billion in lost revenue to Skype, WhatsApp, others

Erik Heinrich
Jun 23, 2014

It’s been a rough ride for global telecommunications companies in recent years, and it’s not because they finally started reading their fan mail. Telcos like China Mobile, Deutsche Telekom, and Telefónica are facing—and struggling to counter—a trend in which the prices of basic voice and data services are declining, like trees falling in a forest.

http://fortune.com/2014/06/23/telecom-companies-count-386-billion-in-lost-revenue-to-skype-whatsapp-
HOW TO REDUCE COST?

**FACT:** Computer communication is inherently **bursty**

**CONSEQUENCE:** Allocating a circuit (‘phone call’) to it is expensive

Cheaper to share (‘**multiplex**’) a circuit among many end-to-end communications
But this adds delay!
Amount of delay depends on the load…
M/M/1 QUEUEING DELAY

Queueing delay

\[ \frac{1}{\mu \left(1 - \rho\right)} \]
QUALITY OF SERVICE

- Four well-known approaches
  - Overprovisioning
  - Admission control
  - Differential service quality: prioritize delay-sensitive flows
  - Drop packets when the queue size grows, expecting sources to respond
QUALITY OF SERVICE

- All approaches have serious problems
  - Overprovisioning
    - Expensive
  - Admission control
    - Requires end-to-end adoption
    - Impossible to allocate costs (more later)
  - Differential service quality: prioritize delay-sensitive flows
    - Requires changes to scheduling disciplines at every multiplexor
  - Drop packets when the queue size grows, expecting sources to respond
    - Requires complex tuning
    - Assumes cooperation
The primary design goal of the Internet makes it inherently unsuitable for real-time communication.
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THE INTERNET IS A NETWORK OF NETWORKS

(long haul nets (the ARPANET itself and various X.25 networks), local area nets (Ethernet, ringnet, etc.), broadcast satellite nets (the DARPA Atlantic Satellite Network\textsuperscript{14, 15} operating at 64 kilobits per second and the DARPA Experimental Wideband Satellite Net,\textsuperscript{16} operating within the United States at 3 megabits per second), packet radio networks (the DARPA packet radio network, as well as an experimental British packet radio net and a network developed by amateur radio operators), a variety of serial links, ranging from 1200 bit per second asynchronous connections to T1 links, and a variety of other ad hoc facilities, including intercomputer busses and the transport service provided by the higher layers of other network suites, such as IBM’s HASP.)
The Internet architecture achieves this flexibility by making a minimum set of assumptions about the function which the net will provide. The basic assumption is that network can transport a packet or datagram.
email  WWW  phone...
SMTP  HTTP  RTP...
TCP  UDP...
IP

ethernet  PPP...
CSMA  async  sonet...
copper fibre  radio...
NARROW INTERFACE
NARROW INTERFACE

Allows interoperability across heterogeneous technologies

Easy to implement

Allows independent evolution
VERY SUCCESSFUL

The architecture has survived the transition of individual ASs from dialup lines to multi-lambda optical fibers from text-based interaction to multimedia on wireless devices while retaining interoperability!
BUT...

Allows interoperability across heterogeneous technologies
Easy to implement
Allows independent evolution

No support for quality of service
AND...

Allows interoperability across heterogeneous technologies

Easy to implement

Allows independent evolution

No support for quality of service

Unconstrained implementation

- Arbitrary layering
- Impossible to debug performance
Layers in an IP/Transport Network

- IP Traffic Flows
- Layer-2/3 VPN and Carrier Ethernet Services
- IP Routing Topology (OSPF, etc.)
- MPLS/Virtual Link/Tunnel Layer
- Layer-2 Links (Ethernet, DS1/DS3, etc.)

Source: Designing Multi-layer Carrier Networks for Capacity and Survivability, OPNETWORK 2012
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SUPPORTING MULTIPLE SERVICE TYPES

TCP and UDP support a huge variety of protocols.
An unqualified success!

But...
SUPPORTING MULTIPLE SERVICE TYPES

Even the 1988 paper abandons real-time services.

Another service which did not fit TCP was real time delivery of digitized speech, which was needed to support the teleconferencing aspect of command and control applications.
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DISTRIBUTED MANAGEMENT

Distributes the task of management using Autonomous Systems
WEAK CENTRALIZATION

ICANN
IANA
Registries
DNS TLDs
DISTRIBUTED MANAGEMENT

Allows rapid deployment
Allows independent evolution
Delegation allows massive scaling
- DNS
DISTRIBUTED MANAGEMENT

Allows rapid deployment

Allows independent evolution

Delegation allows massive scaling
  - DNS

With narrow interfaces, makes quality of service even more challenging
DISTRIBUTED MANAGEMENT

Allows rapid deployment
Allows independent evolution
Delegation allows massive scaling
  • DNS

With narrow interfaces, makes quality of service even more challenging

No network-wide identity
  • Security nightmare
  • Spam, DDOS, hacking, …
DISTRIBUTED MANAGEMENT

Allows rapid deployment

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Delegation allows massive scaling
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No single view into the network
  - Makes networks unmanageable
DISTRIBUTED MANAGEMENT

- Allows rapid deployment
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- With narrow interfaces, makes quality of service even more challenging
- No network-wide identity
  - Security nightmare
  - Spam, DDOS, hacking, …

- No single view into the network
  - Makes networks unmanageable

**Autonomous systems**
- Can inspect, modify, and drop packets
- No privacy
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REDUCING ATTACHMENT EFFORT

What is needed to get an endpoint on the telephone network?

- Verinymous identity!

- Endpoint identifier and end-user identity are closely bound
  - Allows billing and tracing
What is needed to get an endpoint on the Internet?
- IP address, netmask, and IP address of closest router
- Makes it very easy to attach a node to the Internet

But endpoint identifier and human’s identity are unbound
- Enables spam
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ORIGINAL DESIGN GOALS

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since this network was designed to operate in a military context, which implied the possibility of a hostile environment, survivability was put as a first goal, and accountability as a last goal. During wartime, one is less concerned with detailed accounting of resources used than with mustering whatever resources are available and rapidly deploying them in an operational manner.
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WHAT TO DO?
Let's revisit one of the goals

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the intermediate packet switching nodes, or gateways, must not have any essential state information about on-going connections. Instead, they are stateless packet switches
THIS DESIGN APPROACH IS LONG DEAD...

SDN

MPLS for traffic shaping

Middleboxes
  - Load balancers
  - Firewalls
  - Intrusion detectors
  - VPN endpoints
  - ...

Can we integrate the best aspects of the Internet with the best aspects of the telephone network?

- Prevent spam by allowing identities to be traced
- Require privacy from carriers
- Make the inter-AS interface richer to allow QoS
TIME TO RETHINK INTERNET ARCHITECTURE
TIME TO BE CREATIVE!

Technology trends and future demands

- Industrial Internet of Things
- Extreme sensing
- In-body Internet
- Deep Space Internet
- Hackers
- Need for privacy
- Quality of Service
TIME TO BE CREATIVE!

Technology trends and future demands
- Industrial Internet of Things
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- Spam
- Privacy
- Quality of Service

What should be our new design philosophy?
How can we design our future networks to be legacy compatible?
It's in Your Hands Now...