All-IP – Back to the Internet Roots?

Mobility Solutions

Ambient Networks

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Outline

- **A brief historical overview of the Internet**
- **The requirements for the Internet**
- **Architectural principles of the Internet**
- **Tussle Space Internet**
- **Conclusion**

Internet History

- **1969**: ARPAnet packet-switched network
  (Installed at UCLA)
- **1974**: Cerf/Kahn paper on internetworking
  (Many elements of the final Internet protocol design)
- **1977**: ARPA research program on internetworking
  (Prototype implementations of TCP/IP)
- **1983**: Birth of the Internet
  (ARPAnet switched to TCP/IP protocols; Mil Std.)
- **1985**: NSFnet
  (General academic usage)
- **1989**: Privatization of the Internet
  (People willing to pay to use it and making money to supply services)
- **1991**: World-Wide Web introduced

Historical Decisions

- DoD chose TCP/IP as Mil Std protocol (~1983)
- CSNET chose TCP/IP (~1983)
- ARPA directed Berkley UNIX developers to implement TCP/IP
- DoD, NASA, DoE and NFS supported TCP/IP
- NSF chose TCP/IP for building NSFnet

The Competitors

- **X.25**
  (mainly in Europe)
- **OSI**
  (to replace TCP/IP – DoD initiative)
- **FAX**
  (replace TCP/IP eMail)
- **PTTs**
  (government monopoly telcos in Europe and Asia)
- **US telcos**
  (they couldn't imagine any other reality than the existing successful network)
- **ATM**
  (telcos [re-]invented packet switching)

Why did the Internet survive?

- Some good luck and clever moves
  - → The Internet worked!
- ARPAnet research community mindset:
  - → Driven by pragmatics instead of dogmatics
  - → Reductionist thinking
    scientific viewpoint, not engineering
    → Internet architecture

Primary Requirements

- **Multiplexing**
- **Robustness (Survivability)**
- **Service generality**
- **Diverse network technologies**

Multiplexing

Basis Issue:
How to send multiple, independent data streams across one physical channel?

- FDM
- TDM
- Packet switching

Robustness (Survivability)

- This requirement was a „Big Deal“ for a military funded effort
  - Messages get through, no matter what, despite “very bad” things happening…
  - Survivable protocols are a boon in peace time; we call it robustness
- Dynamic adaptation to outage
  - In some sense: Self healing protocols

Service Generality

- Support widest possible set of applications
- Support a range of communication service models
  - Virtual circuit service
    reliable, ordered, full-duplex data streams
  - Datagram service
    unreliable, unordered ("best effort") service
  - Isochronous service – not a requirement

Diverse Network Technologies

Existing („subnet“) network technologies:

- ARPAnet, Milnet
- Packet satellite networks
- Packet radio network (mobile/wireless)
- LANs – bus and token rings
- Serial lines
- X.25
- Frame relay
- ATM
- Sonet (SDH)
- WDM

Some Fundamental Internet Principles

- **Multiplexing**
- **Transparency**
- **Universal connectivity**
- **End-to-end argument**
- **Common bearer service**
- **Forwarding context**
- **Global addressing**
- **Capacity allocation**

Multiplexing

- The Internet uses a single, global approach to multiplexing: The variable length packet.
  - Self contained
  - Header contains some forwarding directive
  - Packet is universal unit for error detection and recovery

Transparency

- User data is delivered to the intended receiver without modification
  - “Don’t mess with my data” principle
  - However, today ISPs start to mess with our data
    e.g. web caches that attach advertisements

Universal Connectivity

- Any host can send packets directly to any other host (except when prohibited by policy)
- A host attached to any subnet of the Internet is „attached to the Internet".

End-to-End Arguments (1)

- The network is build with no knowledge of, or support for, any specific application or class of applications
- A function that can be entirely accomplished in an end node is left to that node, and the relevant communication state is kept only in that node.

End-to-End Arguments (2)

- Principle of “dump networks, smart terminals”
  contrary to telephone networks: “smart networks, dump terminals”
- However, today this principle is very often broken
  Firewalls, NAT boxes, web caches, web proxies etc. do application-specific processing within the network

Common Bearer Service

- A universal internetworking protocol IP forms a “common bearer service” end-to-end
  - IP packets are forwarded E2E through each subnet
  - Subnets are linked by IP packet switches called “routers”
  - The service model is loosely defined:
    “best effort” to handle diverse subnet characteristics

Forwarding Context

- The Internet is “connectionless”
  - No setup is required before sending a packet
  - Packets are self-contained within the context of a global routing computation
- Routers contain no per-flow state

Global Addressing

- A single, global address space identifies the network attachment points of nodes
- IP addresses are also used as node identifiers (“names”)

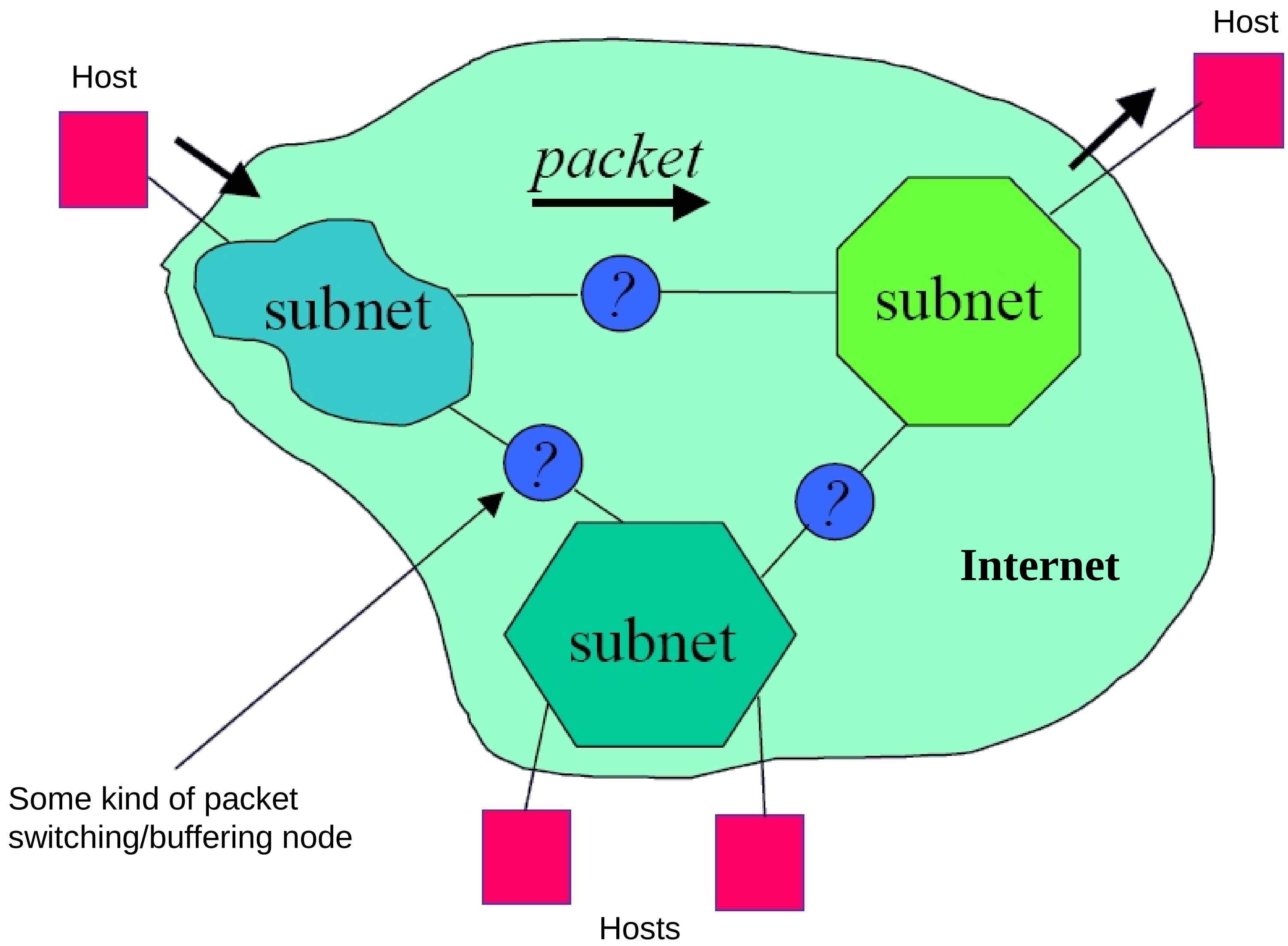
Capacity Allocation

- Fairness
  - Week requirement
    "tussle space" Internet
- Unfairness

    "some pigs are more equal…"

  - Early: DoD → precedence hierarchy (military)
  - Today: ISPs want to sell different service qualities and some users are willing to pay more for a better QoS.

The Internet



The Internet Landscape Today

- Users, who want to run applications and interact over the Internet.
- Commercial ISPs, who sell Internet services with the goal of profit.
- Private sector network providers who run a part of the Internet to facilitate their business.
- Governments, who enforce laws, protect consumers, regulate commerce, etc.
- IRP holders, who want to protect their materials on the Internet.
- Providers of content and higher level services, offered in search of profit or as a public service.

Tussle Spaces (1)

- Economics
  - ISPs try to lock-in their customers (e.g. provider-based address)
  - Value pricing (e.g. by dividing customers into classes)
  - Residential broadband access (e.g. many ISPs on one cable)
  - Competitive wide area access (e.g. choice of source routing)
- Trust
  - The users of the Internet no longer trust each other (there are too many “bad guys”)
  - Firewalls change “transparency” to a “that which is not permitted is forbidden” network (who is “in charge” to design firewall rules?)
  - The role of identity (or act in an anonymous way?)

Tussle Spaces (2)

- Openness
  - Open (Internet) vs. proprietary (closed, legacy) networks
  - Vertical integration requires some removal of openness

Separation of Policy and Mechanism

- Tussle is a fundamental property of the Internet
- Mechanisms shall be matched to problems
- User empowerment can become a basic building block and should be embedded into all mechanisms whenever possible.

Future of the End-to-End Argument (1)

- The lost of trust calls for less transparency, not more and we get firewalls.
- The desire for control by the ISP calls for less transparency, and we get application filtering, connection redirect, and so on.
- The desire of third parties to observe a data flow calls for data capture in the network.
- The desire to improve important applications (e.g. the Web), leads to the deployment of caches, mirror sites, kludges to the DNS and so on.

Future of the End-to-End Argument (2)

- Evolution and enhancement of existing, mature applications is inevitable.
- Protect maturing applications by biasing the tussle.
- The most important goal is to keep the net open and transparent for new applications.
- Failure of transparency will occur.
- Peeking is irresistible.

Conclusion

- The Internet architecture is not finished!
- The architectural principles are problematic in some manner
- They are being broken for commercial reasons
- They are being broken to obtain additional functionality
- Protected against unwise optimization only by constant struggle in the IETF
- They represent real unmet requirements

Thank you for your attention

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See also: http://www.isi.edu/newarch/