03 IP architecture

EN0746 Computer Network Implementation

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Outline

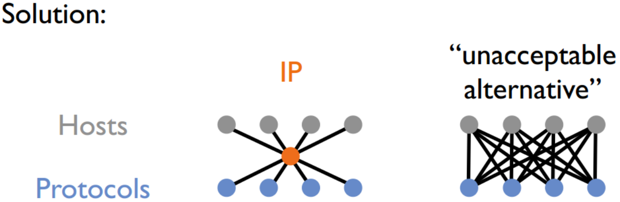
- Cerf and Kahn: TCP/IP
- Clark: Design philosophy

Interconnection challenges

Heterogeneity

- Different addressing, supported packet lengths, reliability mechanism, latency, status information, routing

Let each network operate independently



Gateways and IP

Gateways sit at interface between networks

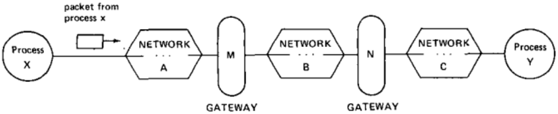


Fig. 2. Three networks interconnected by two GATEWAYS.

. . . and speak an Internetworking protocol

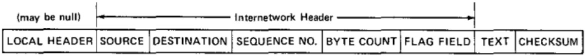


Fig. 3. Internetwork packet format (fields not shown to scale).

IP packet fragmentation

Allow maximum packet size to evolve

Protocol mechanisms to split packets in-transit

- byte-level sequence numbers

Reassemble at end-hosts

- Why not gateways?

Unreliable datagrams

No need for reliability in underlying network

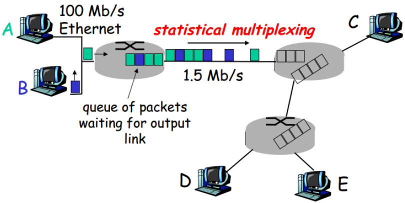
Greatly simplifies design

- Exception handling always adds complexity
- IP: Any problem? Just drop the packet

What's not a stated reason for datagrams?

- Statistical multiplexing

Statistical multiplexing



Sequence of A and B packets does not have a fixed pattern, bandwidth shared on demand – statistical multiplexing

Packet switching more efficient

e.g. 1 Mb/s link; each user uses 100 kb/s when active; active 10% of the time

- circuit switch – 10 users
- packet switch – with 35 users, probability > 10 active is about 0.0004

Addressing and routing

Routing unspecified but constrained

- Hierarchical (network, host) address
- Route computed within network, hop-by-hop
- 8 bits for network: "This size seems sufficient for the foreseeable future."
- Later: 32 bits in three size classes (A,B,C), and then CIDR.

Many new routing/forwarding designs need to change this address format

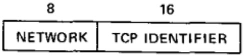


Fig. 4. TCP address.

Ports

Associated with a process on a host

Identify endpoints of a connection (“association”)

Rejected design:

- connection at host level
- packet may include bytes for multiple processes

What’s the difference between a port and an address?

TCP

Window-based scheme

Provides reliability, ordering, flow control

- Even though you might want only some of these

What else does it do today?

- Congestion control
- Three-way handshake

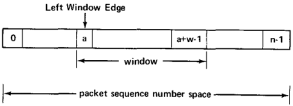


Fig. 10. The window concept.

Clark: the fundamental structure of the Internet

"...the fundamental structure of the Internet: a packet-switched communications facility in which a number of distinguishable networks are connected together using packet communications processors called gateways which implement a store and forward packet forwarding algorithm"
David Clark, Proc. SIGCOMM'88, Computer Communication Review, Vol. 18, No. 4, pp. 106–114, August 1988

Clark: Design goals

Top level goal

"The top level goal for the DARPA Internet architecture was to develop an effective technique for multiplexed utilization of existing interconnected networks"

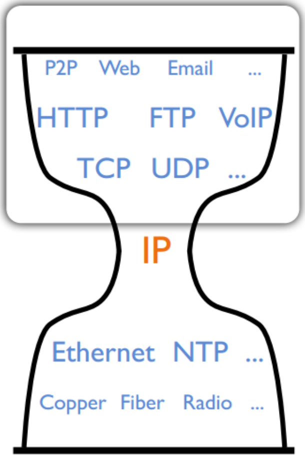
Secondary goals:

1. Survivability
2. Multiple communication services
3. Variety of networks
4. Distributed management
5. Cost effective
6. Easy host attachment
7. Resource usage accountability

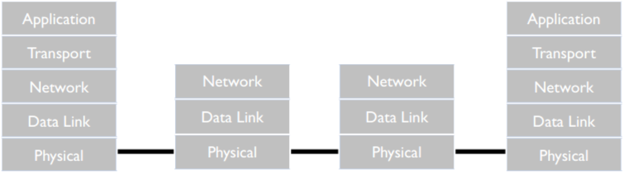
"It is important to understand that these goals are in order of importance, and an entirely different network architecture would result if the order were changed"

’Narrow waist’ enables multiple types of service

- Datagram is basic building block for many services
- Above: supports many application protocols
- Below: implemented on many different link and physical layers – “IP over everything”
    - D.Waitzman, A standard for the transmission of IP datagrams on avian carriers, RFC 1149



Layering



A kind of modularity

Functionality separated into layers

- Layer n interfaces only with layer n-1
- Hides complexity of surrounding layers: enables greater diversity and evolution of modules
- (IP) connectivity becomes a commodity

End-to-end principle

If a function can completely and correctly be implemented only with the knowledge and help of the application standing at the endpoints of the communication system,

then providing that function as a feature of the communication system itself is not possible.

J.H. Salzer, D.P. Reed, D.D. Clark, End-to-end arguments in system design, ACM Transactions on Computer Systems, Vol. 2, No. 4, pp. 277–288, November 1984

Acknowledgments

- Much of the material in these slides is taken from: Brighten Godfrey's slides on IP architecture for CS538 at Illinois University.
- The figure on statistical multiplexing is from Kurose and Ross, Computer Networking: A top-down approach (5th edition), Pearson, 2007