Advanced Computer Networks

Internet Design

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First things first

- Course website alive
  - on http://connex.csc.uvic.ca
  - see “CSC 466: 201701 A01” tab (or adjust ur prefs)
  - if you are not officially “in the system” yet, please send me an email and I can add you in manually
  - course lectures embedded in connex
    - also publicly available http://www.cs.uvic.ca/~pan/csc466
  - chat room and project websites available too
    - connex->discussion: get help and help others
    - connex->projects: host your project websites there

get your A0 to me today---help me help yourself---project hints next week!

Internet architecture and protocols

- [CK74] V. G. Cerf * and R. E. Kahn, "A Protocol for Packet Network Interconnection". IEEE Transaction on Communications, 22(5), May 1974, pp. 637-648. [TCPdesign]

- [SRC84] J. Saltzer, D. Reed, and D. Clark, "End-to-end Arguments in System Design". ACM Transactions on Computer Systems, Vol. 2, No. 4, 1984, pp. 195-206. [end2end]
- [Cla88] **D. Clark, "The Design Philosophy of the DARPA Internet Protocols". In Proceedings of ACM SIGCOMM '88, 106-114, Palo Alto, CA, Sept 1988.** [IPSdesign]

* V Cerf, “Reimagining the Internet: If we'd known then what we know now, what would we have done differently?” 2010. http://www.youtube.com/watch?v=t9M0RPNr9qg

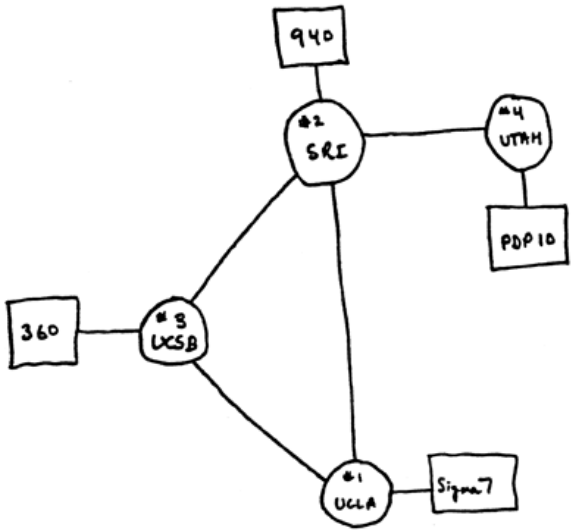
[Cla88] The design of IPS

- Originally published in Proc SIGCOMM'88
- A *retrospective* "design" document
  - "TCP/IP, was first proposed fifteen years ago."
  - "it is sometimes difficult to determine the motivation and reasoning which led to the design."
  - "In fact, the design philosophy has evolved considerably from the first proposal [CK74] to the current standards."
    - "datagram does not receive particular emphasis"
    - "layering the architecture into the IP and TCP layers"

http://groups.csail.mit.edu/ana/People/Clark.html

Fundamental goal

- “The top level goal for the DARPA Internet Architecture was to develop an *effective* technique for *multiplexed* utilization of existing *interconnected* networks.”
  - **interconnection** vs integration
  - **packet** switching vs circuit switching
  - **store**-and-forward packet switching
    - *the implication*
- Goals scoreboard
  - keep your own opinion/scoreboard as well

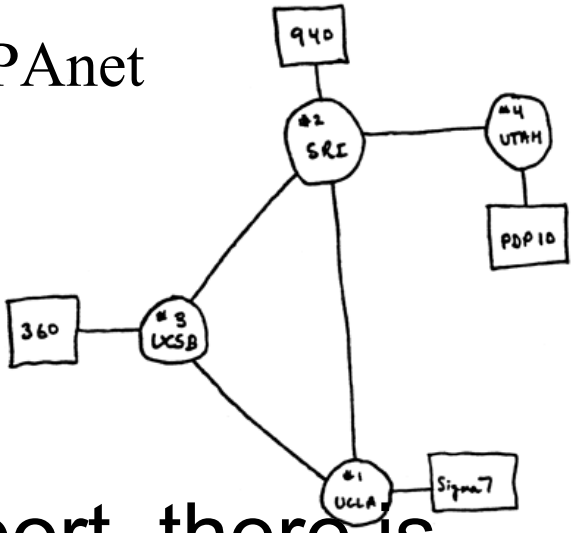


Second level goals

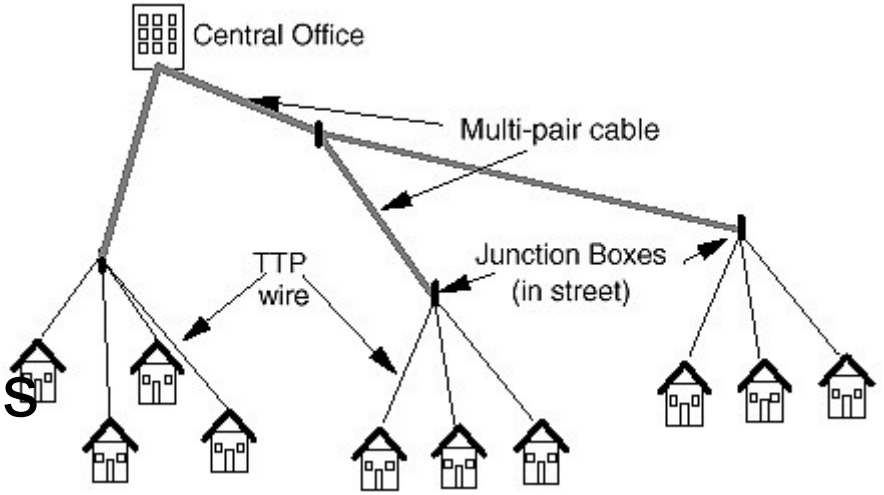
- “in order of importance”
  - “continue despite loss of networks or gateways.”
  - “support multiple types of communications service.”
  - “accommodate a variety of networks.”
  - “permit distributed management of its resources.”
  - “cost effective.”
  - “permit host attachment with a low level of effort.”
  - “accountable.”
  - any missing goals from your point of view?

Survivability

ARPAnet



- USDoD/DARPA-funded
- "In other words, at the top of transport, there is only one failure, and it is **total** partition."
  - **layering** transparency
  - **end-to-end** vs hop-by-hop
    - fate-sharing
  - **stateless** vs stateful switches
    - *dumb* networks



vs telephone networks

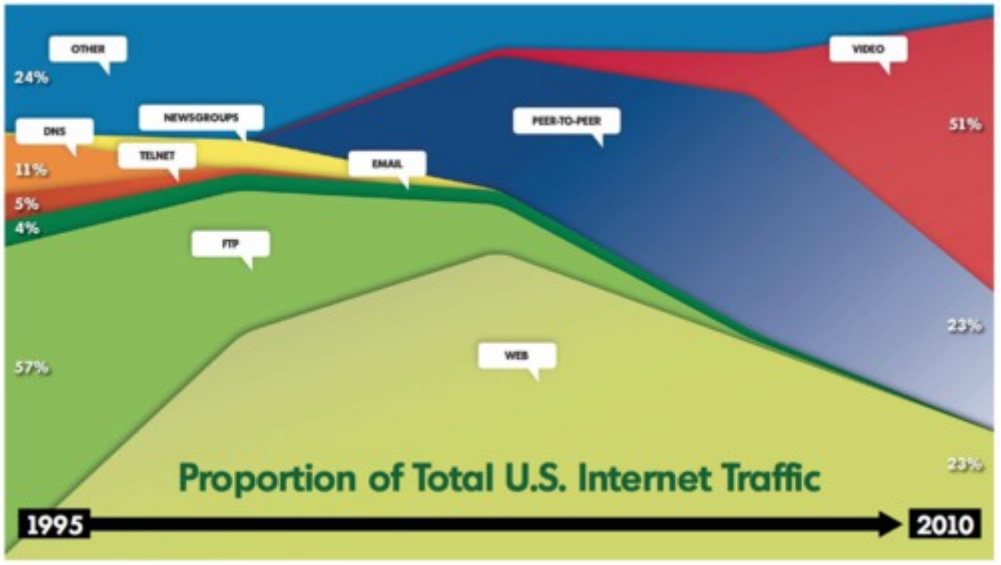
  - now: middle-box?!
    - cache, proxy, firewall, NAT, IDS/IPS, LB, accelerator, etc

* true or false: was APARNET built for a nuclear war?

* multi-homing?

Types of services

- Network is essentially driven by application requirements and communication technologies
  - QoS: throughput, delay (jitter), loss
  - e.g., email, ftp, rlogin; web; >>> IPTV, VoIP, MMOG
  - man/machine-to-man/machine communication?
- The separation of TCP and IP
  - TCP: reliable, stream-like
  - UDP: unreliable, datagram
  - reliable “network”?
    - X.25?

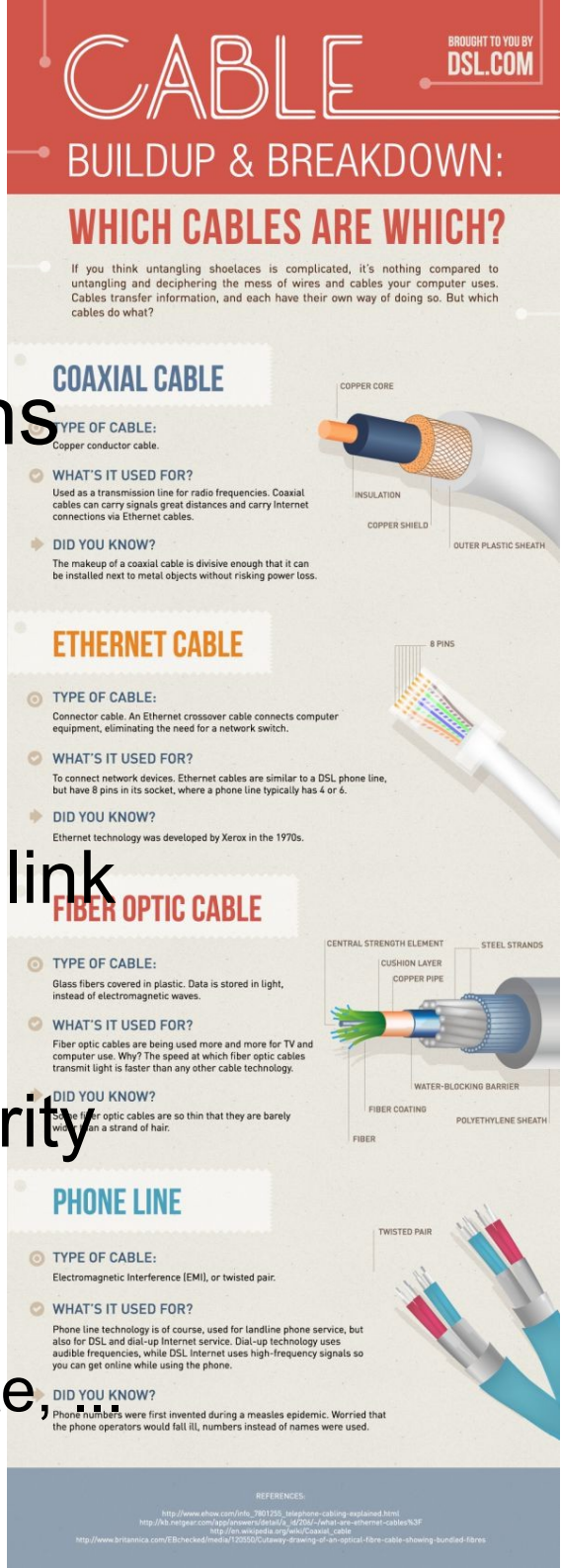


* when was your favorite app born?

Varieties of networks

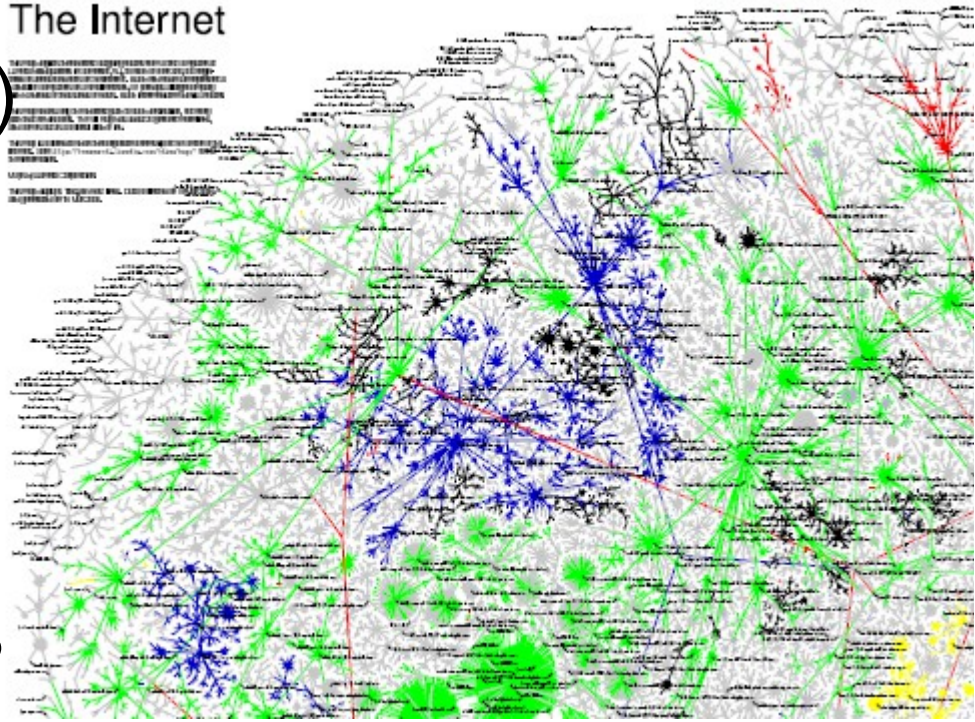
- IP sits on a set of minimum assumptions
  - move a packet
  - of a reasonable minimum packet size
  - with a reasonable delivery success ratio
  - addressing capability, if not point-to-point link
- Not assumed
  - reliable delivery, broadcast/multicast, priority queuing, internal knowledge, etc
  - now: very “heterogeneous” networks?
    - from dial-up to fiber optic, from WiFi to satellite,…

* and wireless---cut the cord



Distributed management

- Internet: a network of networks
  - autonomous systems (AS)
  - tiers of service providers
  - hierarchical naming
  - hierarchical addressing*
  - hierarchical routing
  - distributed “coordination”?



  - who owns/regulates/operates the Internet?

* Internet neutrality?

Cost effectiveness

- Multiplexing gain
  - Ĥ store-and-forward packet switching
- Layered architectures
  - Ĥ similar functions in different layers
- Packet headers
  - Ĥ packet header vs user payload
- Protocol mechanisms
  - Ĥ end-to-end vs local retransmission

  - Ĥ the most effective way to move 1TB CA->AU?

* public Internet, e.g., national broadband network (NBN) in Australia?

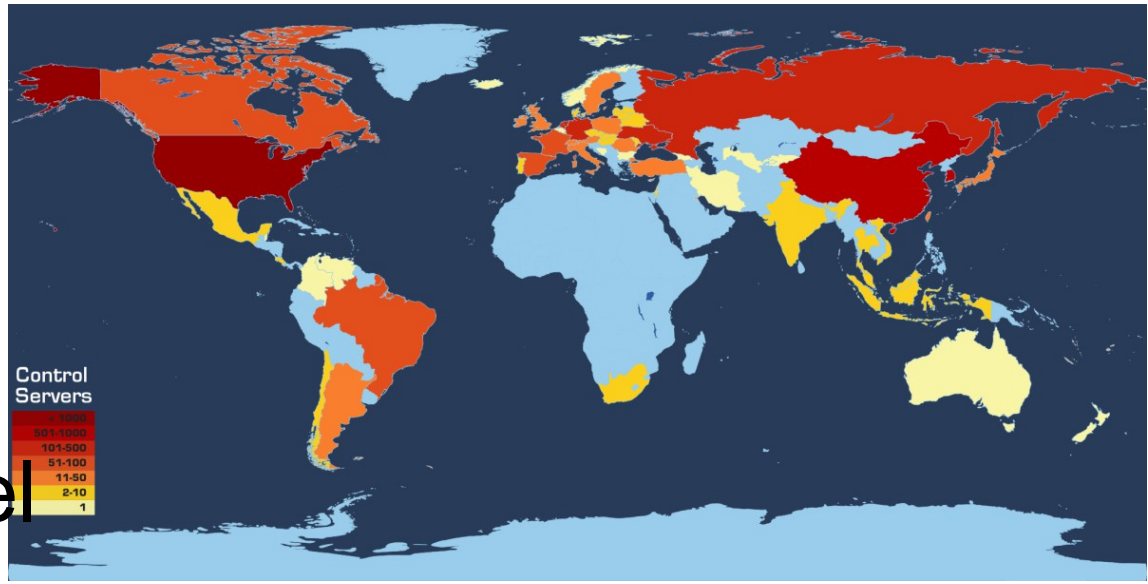
Easy attachment

- Requirements on end systems
  - anything says TCP/IP
  - smart hosts vs smart networks
- Requirements on intermediate systems
  - anything says IP and knows routing
    - IP: one number, two roles
    - i.e., addressing, and routing
  - who's connected?
    - from micro-sensors to super-computers
- how about IP mobility

"On the Internet, nobody knows you're a dog."

* free Internet?

Network accountability



- Application level
  - email spam?
- Session/call level
- Flow/connection level
- Packet level
  - spoofed source IP address?
- Security?
  - authentication, authorization, accounting
  - confidentiality, integrity, authenticity, availability

* if no one owns/regulates/operates, who is accountable?

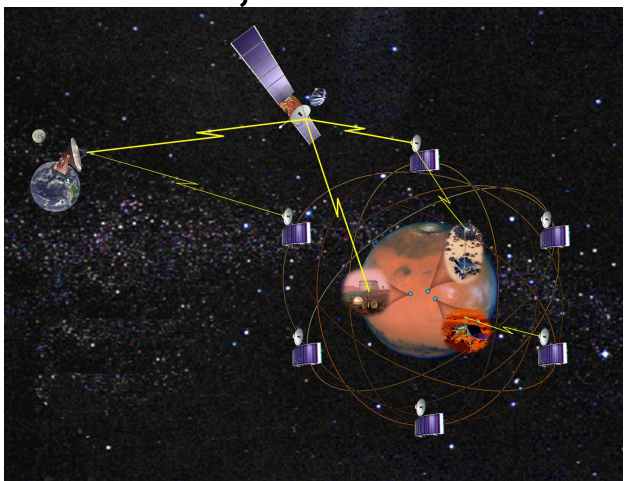
Goals scoreboard

- Well achieved
  - list:
- Not so well achieved
  - list:
- Not achieved
  - list:
- Other goals
  - should be considered then
  - should be considered now

Check with your neighbors as well

New networking environments

- Wireless networks
  - infrastructure-based or infrastructure-less
- Very high-speed (“fat”) networks
- Very “long” networks
  - interplanetary
- Resource very constrained networks
  - micro-sensor networks: power, computation, storage, communication, etc
- Often “disconnected” networks
  - mobile social networks



* has TCP/IP expected such networks?

New application requirements

- Quality of service
  - throughput, delay (jitter), loss
- High availability
- High scalability
- Security
- And more...
  - net neutrality?
  - preferred apps?

* has TCP/IP expected such applications?

Feedback on A0

[SRC84] End-to-end arguments

- One of the design principles of the Internet
- “Choosing the proper boundaries between functions is perhaps the primary activity of the computer system designer.”
- “Design principles that provide guidance in this choice of function placement are among the most important tools of a system designer”
- “Discusses one class of function placement that has been used for many years with neither explicit recognition nor much conviction”

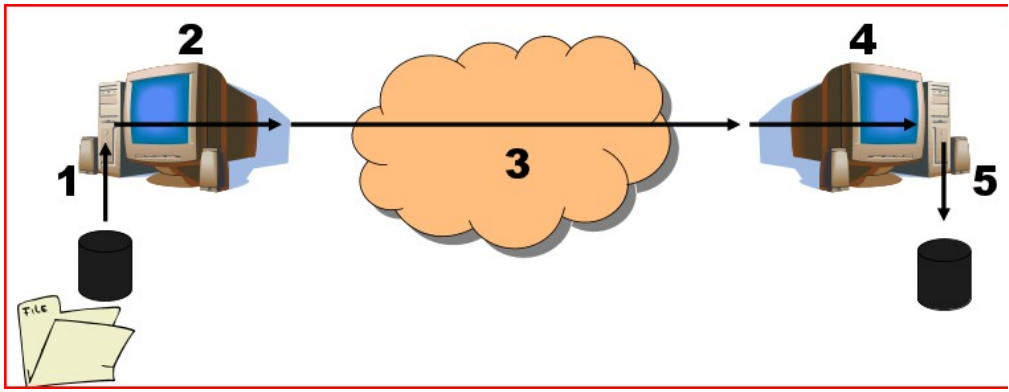
also: Blumenthal, M. S. and D. D. Clark (2001). "Rethinking the Design of the Internet: The End-to-End Arguments vs. the Brave New World"
Clark, D. D. (2007). Application Design and the End-to-End Arguments.

A typical setting

- A networked computer system
  - communication subsystem (intermediate system)
  - the rest of the system (end system)
- A list of functions to be implemented
  - in intermediate system?
  - in end system?
  - in both intermediate and end system?
    - in collaboration, or
    - in redundancy

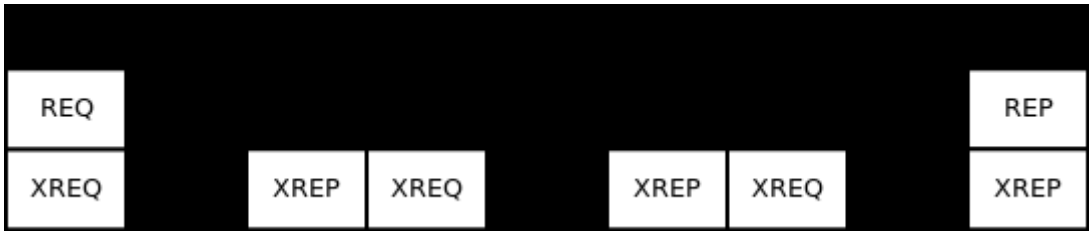
An example

- Careful file transfer
  - from computer A to B
  - across the communication subsystem
- Where can things go wrong?
  - almost every where
  - read error at A
  - process error at A
  - communication error
  - process error at B
  - write error at B

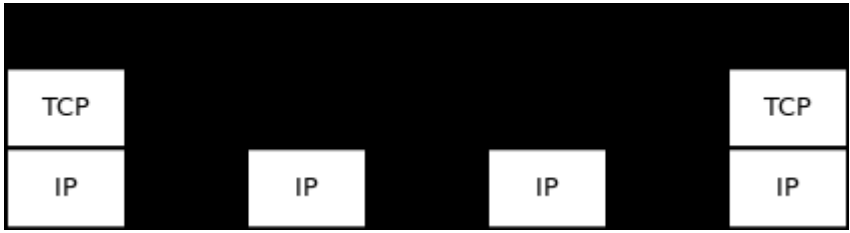


Possible approaches

- For each step
  - duplication
  - timeout and retry
  - error detection and recovery
  - crash recovery
  - goal: reduce error probability everywhere



- For end-to-end
  - checksum generated at A
  - checksum verified at B
  - if checksum fails, end-to-end retransmission



The end-to-end argument

- “The function in question can completely and correctly be implemented only with the knowledge of the application standing at the endpoints of the communication system. Therefore, providing that questioned function as a feature of the communication system itself is not possible.”
- The messages/insights
  - do it only when you can do it best
  - do it only where it really matters

Performance aspects

- Some lower level functions are helpful
  - Ĥ e.g., non-persistent local error recovery
    - WiFi vs Ethernet
  - Ĥ no need to provide perfect reliability
    - Ethernet vs X.25
  - Ĥ still cannot replace higher level functions
    - i.e., for performance, not for correctness
  - Ĥ some can be replaced by higher level functions
    - e.g., multi-block vs file checksum
  - Ĥ some may not be needed by all applications

More examples

- Delivery acknowledgment
  - e.g., delivery notice to end-host or endpoint
  - acknowledgment piggyback
- Secure data transmission
  - e.g., end-to-end encryption
  - encryption keys and parameters
- Duplicate message suppression
- FIFO message delivery
- Transaction management

Where is the “end”?

- Application specific
  - e.g., conversation vs playback
- The application of “end-to-end argument”
  - Internet architecture
    - dumb networks
  - TCP end-to-end control
    - flow, error, congestion
- The end of “end-to-end” arguments?
  - middle-box
  - cross-layer design
  - edge-to-edge?

This lecture

- Internet design
  - at architecture level
  - design goals
  - end-to-end arguments
- Do not forget A0 (due by email Friday, Jan 6)
  - see the Introduction slides
- Explore further
  - [CT90] D. Clark and D. Tennenhouse, "Architectural Consideration for a New Generation of Protocols". In Proceedings of ACM SIGCOMM '90, Philadelphia, PA, September 1990. [ALF/ILP]

Next lecture

- The evolution of the Internet architecture
  - Ĥ required reading
    - [She95] S. Shenker, "Fundamental Design Issues for the Future Internet". IEEE Journal on Selected Areas in Communications, Vol. 13, No. 7, September 1995, p p. 1176-1188.
    - [FG01] P. Francis and R. Gummadi. "IPNL: A NAT-extended Internet architecture." In Proceedings of ACM SIGCOMM, San Diego, CA, Aug. 2001. [IPNL]
    - [CWRB02] D. Clark, J. Wroclawski, K. Sollins, and R. Braden, Tussle in Cyberspace: Defining Tomorrow's Internet , Proceedings of ACM SIGCOMM '2002. [tussle]
    - [SAZSS04] I. Stoica, D. Adkins, S. Zhuang, S. Shenker, S. Surana, "Internet indirection infrastructure," IEEE/ACM Trans. Networking, Vol. 12, No. 2, pp. 205- 218. [I3]