ECE 671 – Lecture 2

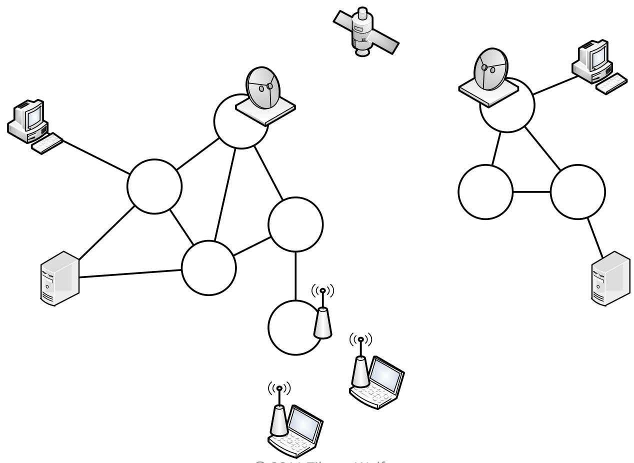
Review of Internet Protocols
Link Layer

Structuring networks and protocols

- Goal of network:
  - Provide communication for distributed applications
- How to organize networks in such a way that they
  - Work correctly?
  - Are scalable to large number of nodes?
  - Can achieve high performance?
  - Are interoperable across different technologies and uses?

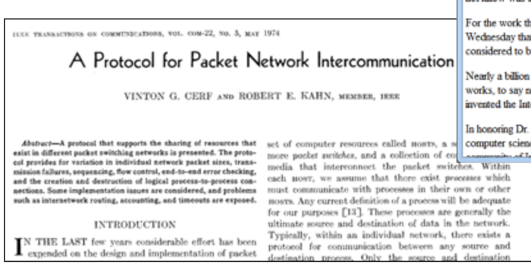
Example network

- How to achieve end-to-end data exchange?



Internet architecture

- Designing the structure of the Internet was a difficult problem
  - Many contributions
  - One example: TCP/IP



IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. COM-22, NO. 5, MAY 1974

A Protocol for Packet Network Intercommunication

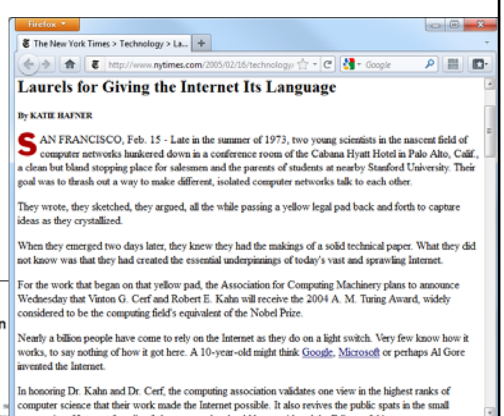
VINTON G. CERF AND ROBERT E. KAHN, MEMBER, IEEE

Abstract—A protocol that supports the sharing of resources that exist in different packet switching networks is presented. The protocol provides for variation in individual network packet sizes, transmission failures, sequencing, flow control, end-to-end error checking, and the creation and destruction of logical process-to-process connections. Some implementation issues are considered, and problems such as internetwork routing, accounting, and timeouts are exposed.

INTRODUCTION

IN THE LAST few years considerable effort has been expended on the design and implementation of packet

set of computer resources called HOSTS, a
more packet switches, and a collection of co
media that interconnect the packet switches. Within each HOST, we assume that there exist processes which must communicate with processes in their own or other HOSTS. Any current definition of a process will be adequate for our purposes [13]. These processes are generally the ultimate source and destination of data in the network. Typically, within an individual network, there exists a protocol for communication between any source and destination process. Only the source and destination



The New York Times > Technology > La...

http://www.nytimes.com/2005/02/16/technology

Laurels for Giving the Internet Its Language

By KATIE HAFNER

SAN FRANCISCO, Feb. 15 - Late in the summer of 1973, two young scientists in the nascent field of computer networks hunkered down in a conference room of the Cabana Hyatt Hotel in Palo Alto, Calif., a clean but bland stopping place for salesmen and the parents of students at nearby Stanford University. Their goal was to thrash out a way to make different, isolated computer networks talk to each other.

They wrote, they sketched, they argued, all the while passing a yellow legal pad back and forth to capture ideas as they crystallized.

When they emerged two days later, they knew they had the makings of a solid technical paper. What they did not know was that they had created the essential underpinnings of today's vast and sprawling Internet.

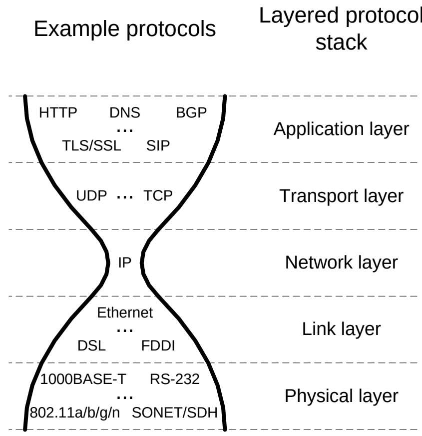
For the work that began on that yellow pad, the Association for Computing Machinery plans to announce Wednesday that Vinton G. Cerf and Robert E. Kahn will receive the 2004 A. M. Turing Award, widely considered to be the computing field's equivalent of the Nobel Prize.

Nearly a billion people have come to rely on the Internet as they do on a light switch. Very few know how it works, to say nothing of how it got here. A 10-year-old might think Google, Microsoft or perhaps Al Gore invented the Internet.

In honoring Dr. Kahn and Dr. Cerf, the computing association validates one view in the highest ranks of computer science that their work made the Internet possible. It also revives the public spats in the small

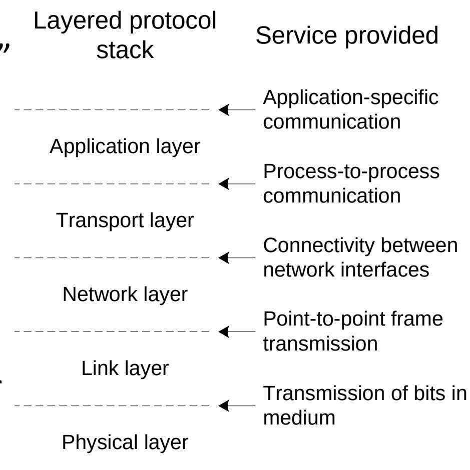
Internet architecture

- "Hourglass architecture"
- Achieves interoperability
  - Single, common network layer protocol: Internet Protocol (IP)
  - All network nodes need to support this protocol
- Supports diversity
  - Different link/physical layer protocols below
  - Different transport/application layer protocols above



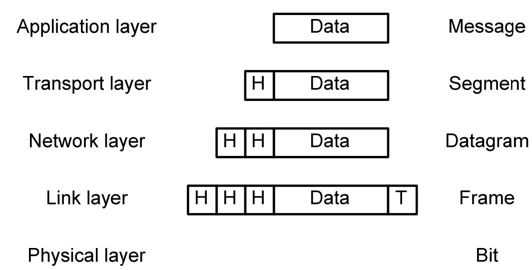
Services provided by layers

- Each layer in protocol stack provides a "service"
  - Uses service from lower layers
- Benefits of layering
  - Isolates complexity
  - Clearly defined interfaces
- Protocols implement functionality within layer



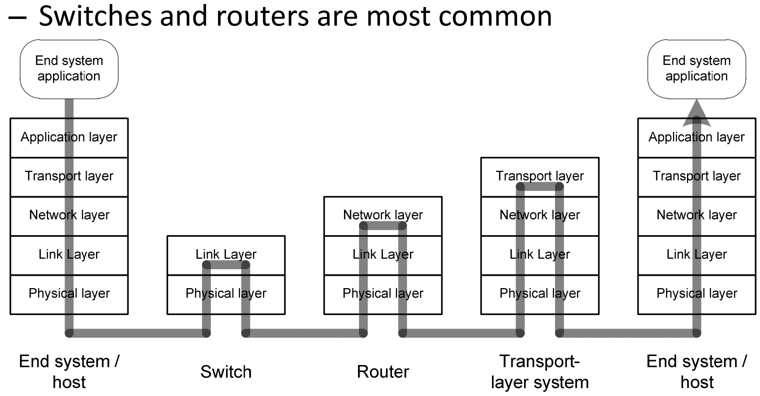
Protocols

- Protocols define communication between entities
  - Format and order of messages
  - Actions taken on transmission and/or receipt of message or other event
- Protocols use headers (and trailers) for control information
  - Naming depends on layer



Network devices

- Network devices differ by highest layer processed
  - Devices can process/modify headers up to that layer
  - Switches and routers are most common



Review of specific protocols

- We will briefly review three protocols
  - Link layer: Ethernet
  - Network layer: Internet Protocol (IP)
  - Transport layer: Transmission Control Protocol (TCP)
- For full details
  - Networking textbooks
  - RFCs

Layer	Example protocols
Application layer	Hypertext Transfer Protocol (HTTP)
Transport layer	Transmission Control Protocol (TCP)
Network layer	Internet Protocol (IP)
Link layer	Ethernet
Physical layer	1000BASE-T

Link layer

- Communication between "neighboring" interfaces
- What are the challenges?

Link layer

- Point-to-point guided medium is straightforward
  - One side sends, other side receives
    (coding, timing, etc. is handled by physical layer)
  - Duplex operation by duplicating medium
- Multiple access case is more interesting
  - Multiple nodes share guided or unguided medium
  - Need to consider:
    - Naming
    - Medium access protocol
    - "Strange" cases (e.g., hidden terminal problem)

Medium access principles

- How should nodes share a medium?

Medium access principles

- How should nodes share a medium?
  - Do not interrupt ongoing transmissions
  - When transmitting, stop after a while
  - Allow for fair sharing among all nodes
  - Allow efficient use of medium
  - Do not require central control
  - Etc.

Side note: delays in networking

- What delays are encountered in networks?

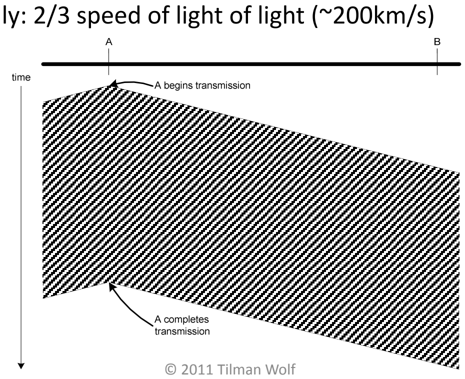
- What is a typical range of each delay?

Side note: delays in networking

- What delays are encountered in networks?
  - Transmission delay
  - Propagation delay
  - Processing delay
  - Queuing delay
- What is a typical range of each delay?
  - Assumption: 1Gbps, 1250-byte packet, 1000km, 200000km/s
  - Transmission delay: 10 microseconds
  - Propagation delay: 5 milliseconds
  - Processing delay: low microseconds
  - Queuing delay: transmission delay of queued packets

Signal propagation

- At link layer, signal propagation delay matters
  - Space-time diagram illustrates events
  - Slope of lines determined by propagation speed
    - Typically: 2/3 speed of light of light (~200km/s)

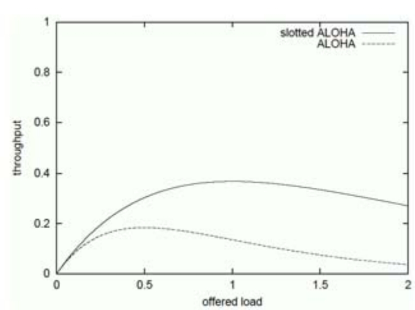


ALOHA protocol

- Propagation delay may cause collisions on medium
  - Even if all stations check to see if medium is available
- Slotted ALOHA protocol
  - Discrete time slots
  - Each node makes random choice to transmit in slot or not
- Pure ALOHA
  - No time slots
  - Each note makes random choice to transmit at any time

Analysis of ALOHA

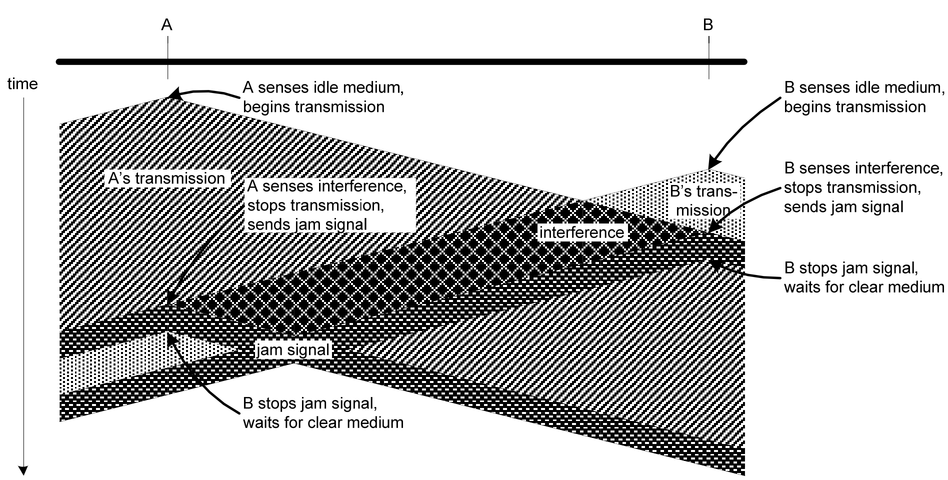
- Slotted ALOHA analysis
  - Probability that k frames are generated during interval
    - Poisson distribution: $Pr[k]=G^k e^{-G}/k!$
    - G is rate of frame generation (new and retransmission)
  - Probability of successful transmission
    - Success if no other frame generated (P_0): $S=GP_0=Ge^{-G}$
- ALOHA analysis
  - Frame overlaps two slots
  - Probability that no other frame is generated during two slots:
    - $P_0=e^{-2G}$
    - Success $S=GP_0=Ge^{-2G}$
- Max throughput:
  - 37%@G=1.0 (slotted ALOHA)
  - 18%@G=0.5 (ALOHA)



CSMA/CD protocol

- How can we improve ALOHA?
  - Don't send when somebody else has already started
  - Stop when interference is already happening
    - Why do we need to do that if we don't start sending when somebody else sends?
- Carrier Sensing (CS)
  - Listen on channel
  - Only send when nobody else is transmitting
- Collision Detection (CD)
  - Listen to own transmission on channel
  - If garbled then stop transmitting

CSMA/CD example



Ethernet

- IEEE 802.3 protocol
- Medium access with CSMA/CD
- Truncated exponential backoff
  - Wait for random number of 512 bit-times
  - After c collisions: uniform distribution over [0…$2^{\min\{c,10\}}$-1]
  - After 16 collisions: transmission aborted
- Limitations
  - Max 2.5km of cable, thus RTT limited to 51.2μs
  - Corresponds to 64 bytes @ 10Mbps

Preamble (7 octets)	Start of frame delimiter (1 octet)	MAC destination (6 octets)	MAC source (6 octets)	Ethertype (2 octets)	Payload (46-1500 octets)	CRC32 (4 octets)	Interframe gap (12 octets)

60-1518 octets

Related topics

- Next: network layer
  - Combining links to a network
- Later: switches and bridges
  - Organization of layer 2 links into local area networks (LAN)
  - Algorithms for reaching particular nodes in a LAN