MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SLOAN SCHOOL OF MANAGEMENT

15.565 Integrating eSystems:

Technology, Strategy, and Organizational Factors

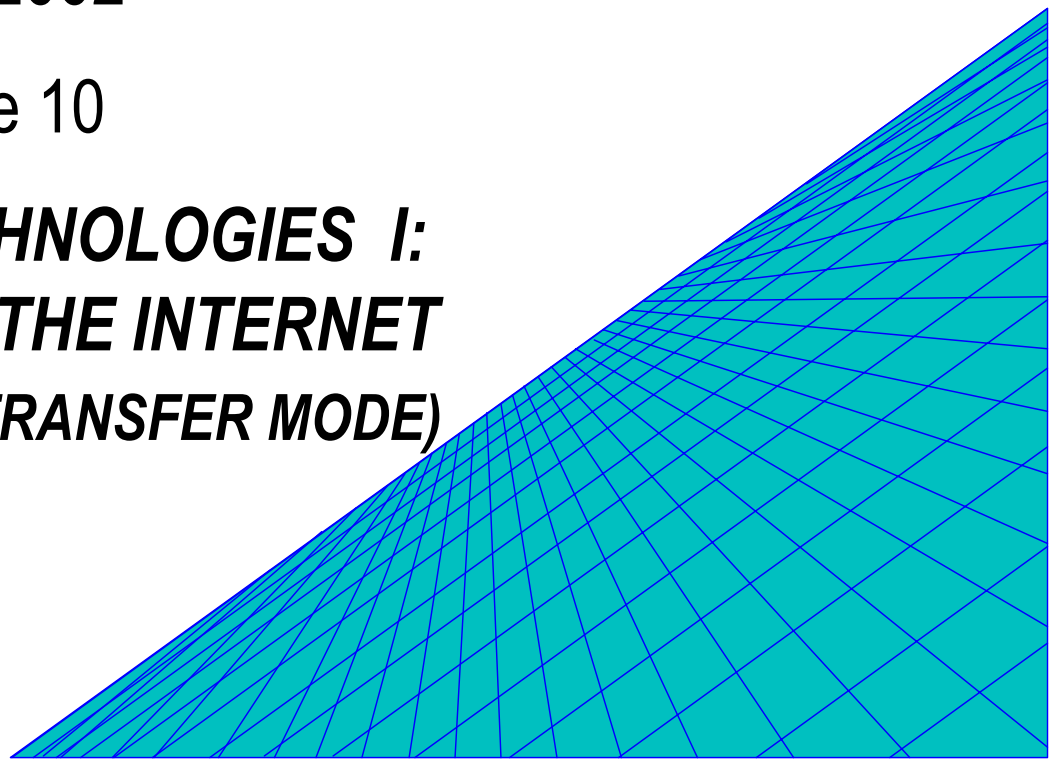
15.578 Global Information Systems:

Communications & Connectivity Among Information Systems

Spring 2002

Lecture 10

EMERGING TECHNOLOGIES I:
THE FUTURE OF THE INTERNET
(ASYNCHRONOUS TRANSFER MODE)



PACKET ROUTING ISSUES

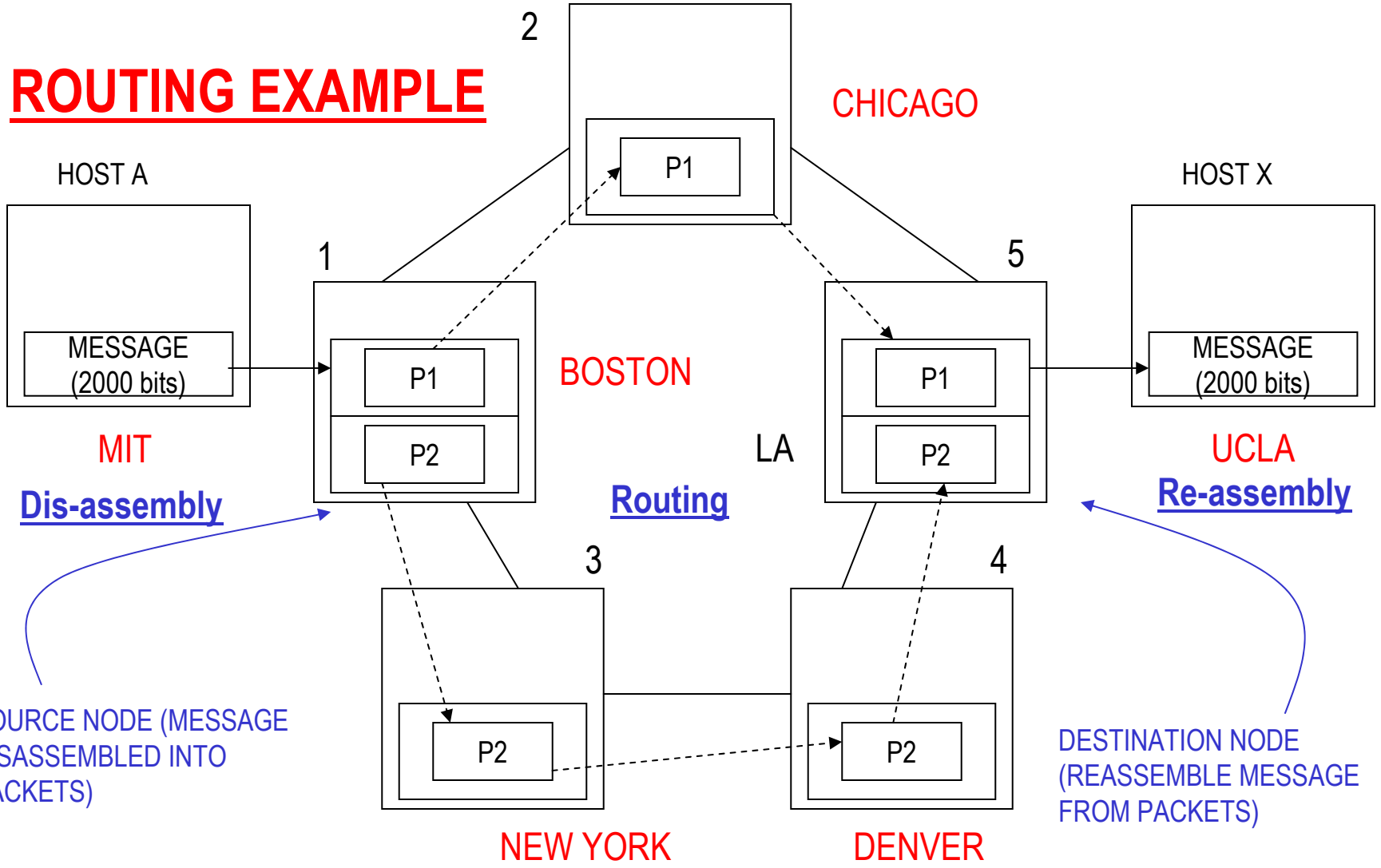
- **PHILOSOPHIES**
  - -- DATAGRAM: EACH PACKET INDEPENDENT
    - LOAD SPREAD
  - -- VIRTUAL CIRCUIT: ALL PACKETS OF A MESSAGE USE SAME PATH
    - RESERVE RESOURCES & ARRIVE IN ORDER
    - MORE "SET UP" OVERHEAD

- **ROUTING**
  - -- EFFICIENT PATH & CONGESTION CONTROL
  - -- MANY APPROACHES

- **ROUTING ALGORITHMS**
  - -- STATIC DIRECTORY
  - -- DYNAMIC ROUTING
  - -- DECENTRALIZED SCHEMES

- **CONGESTION CONTROL**
  - -- WANT TO AVOID "GRIDLOCK"
  - -- APPROACHES: PERMITS, "SLOW DOWN" REQUEST, DISCARD

ROUTING EXAMPLE



ADVANTAGES:

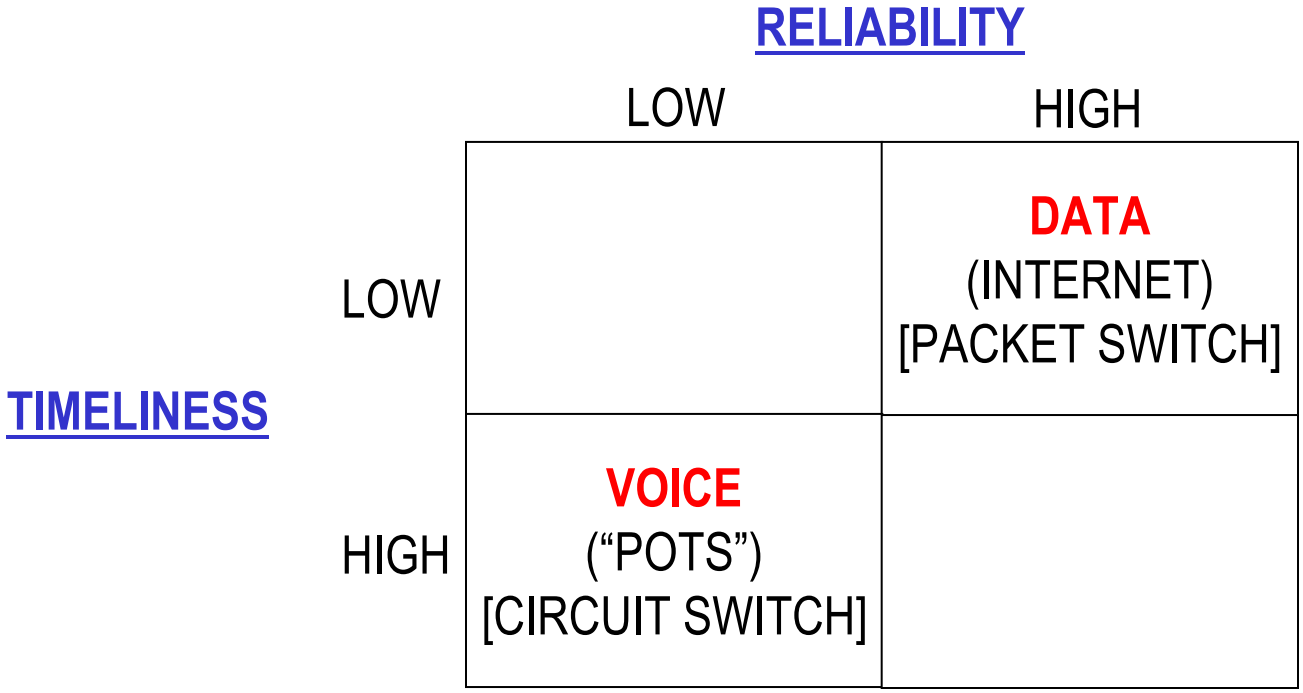
- NOT TIE UP COMMUNICATION LINES FOR LONG PERIODS (I.E., NO LONG MESSAGES) -- INTERLEAVE PACKETS
- ON COMMUNICATION ERROR, ONLY NEED TO RETRANSMIT PACKET AFFECTED RATHER THAN ENTIRE MESSAGE
- BUFFER MANAGEMENT SIMPLER / LESS DEADLY EMBRACE
- ABLE TO SHIP PACKETS IN PARALLEL (PARALLEL PROCESS)
- ABLE TO SEND PARTIAL MESSAGE (PACKET) WITHOUT WAITING TO RECEIVE ENTIRE MESSAGE (PIPELINE PROCESS)

THE COLLAPSE (IMPLOSION) OF "POTS"

- AT&T LONG-DISTANCE NETWORK
  - HANDLES 125M CALLS/DAY
  - AVERAGE CALL = 5 MINUTES
  - EACH CALL USES 64K bps
  - TOTAL = 28.8G bps (AVERAGED)
  - MUCH LESS THAN CAPACITY OF SINGLE OPTICAL FIBER !
- EVEN IF TOTAL POPULATION TALKED 24 HR/DAY
  - TOTAL = 12.8T bps
- TREMENDOUS EXCESS CAPACITY
  - "DARK FIBER"
- WHY DOESN'T / HASN'T "POTS" COLLAPSED?

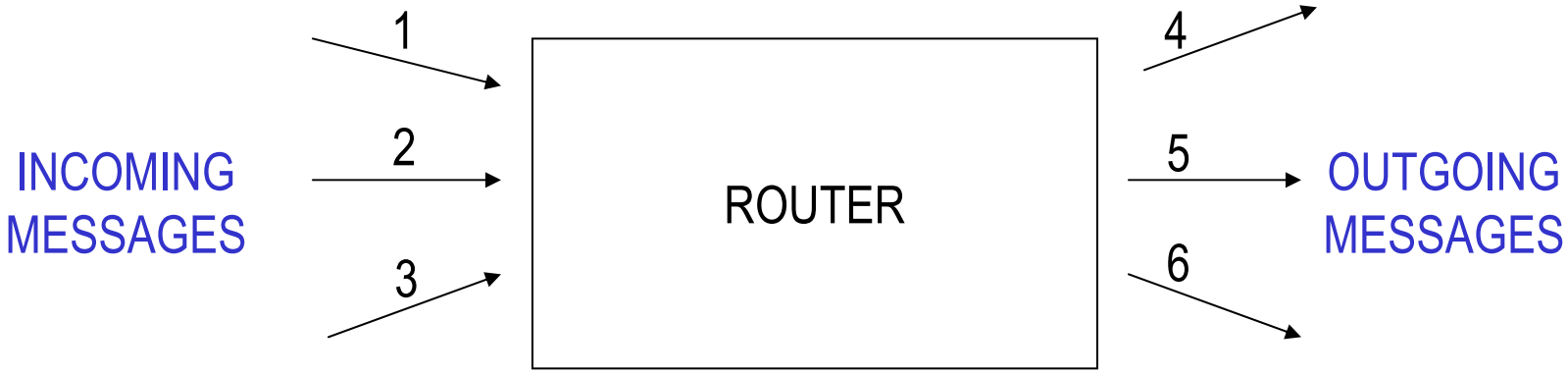
QUALITY OF SERVICE (QoS) TRADEOFFS / REQUIREMENTS

- INTERNET GIVES "BEST EFFORT", BUT NO GUARANTEE



- CAN A SINGLE NETWORK SERVICE BOTH NEEDS?
- OTHER DIFFERENCES (TERMINOLOGY, REGULATIONS, DEPRECIATION, RATE-OF-CHANGE)
- PLUS OTHER APPLICATION NEEDS (E.G., BULK FILES, MOVIES, HDTV, ETC.)

CAUSE OF DELAYS IN PACKET NETWORK



- PACKET SIZE AND BACKLOG
  - CAN'T SEND NEXT PACKET, UNTIL CURRENT ONE SENT
  - MAY ALREADY BE SEVERAL WAITING TO BE SENT OVER SAME LINE
- ROUTER SPEED
  - HOW FAST DETERMINE OUTGOING LINE
  - OTHER FACTORS: PRIORITY, ERROR DETECTION
- ALTERNATE ROUTE IMPACTS
  - PACKETS MAY ARRIVE OUT OF ORDER
  - MUST WAIT FOR CORRECT SEQUENCE TO BE RE-ASSEMBLED

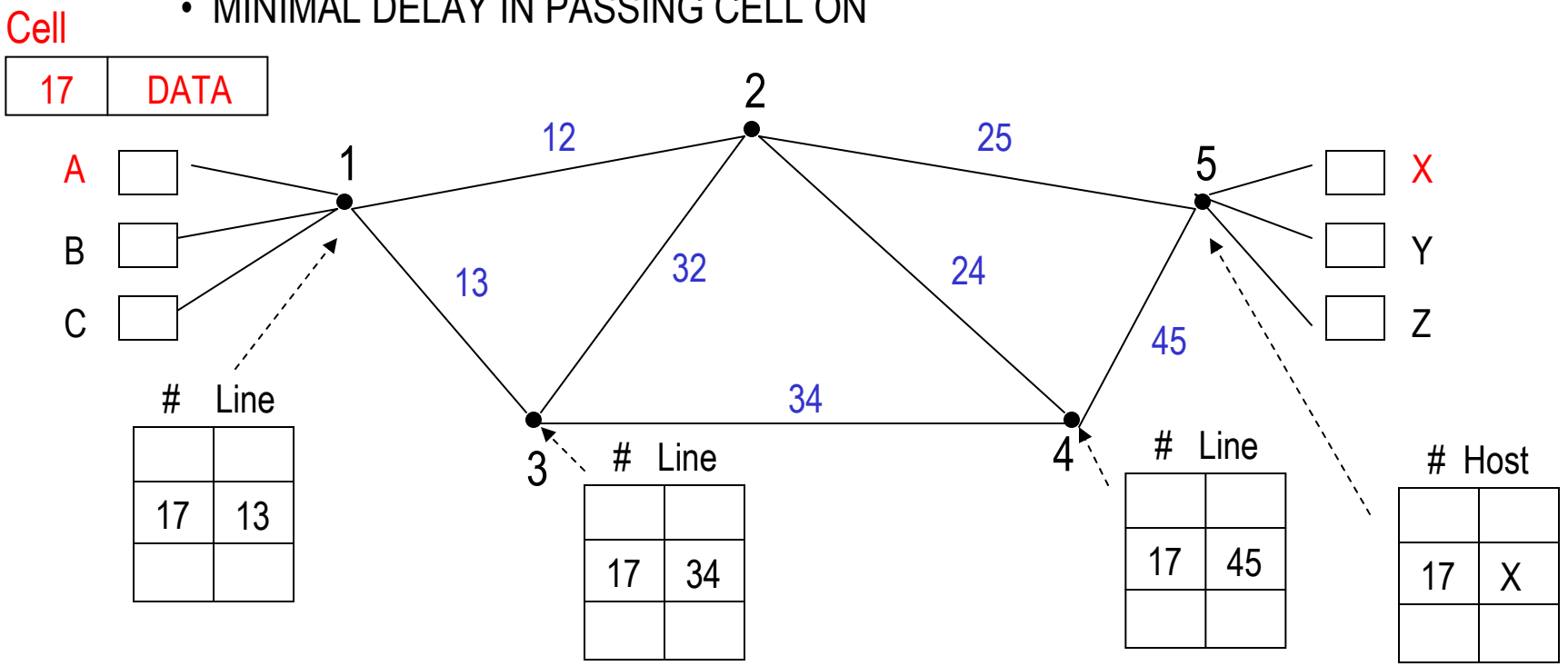
PACKET SIZE SOLUTION (AND PROBLEM !)

- ASYNCHRONOUS TRANSFER MODE (ATM)
  - ASYNCHRONOUS (E.G., PACKETS) VS. SYNCHRONOUS (E.G., TDM)
- STANDARDIZED 53 BYTE PACKET - - WHY 53?
  - 5 BYTE HEADER
  - 48 BYTES DATA

- IMPACT ON ROUTER (BASICALLY A SPECIALIZED COMPUTER)
  - PREVIOUS:
    - 1000 BYTE PACKET @ 1 M bps = 10 ms (1/100 th of sec)
    - FOR A 100 MIP NODE: 10 ms = 1,000,000 INSTRUCTIONS
    - IF ROUTING TOOK 10,000 INSTRUCTIONS = 1% ROUTER CAPACITY
  - NOW:
    - 53 BYTE PACKET @ 100 M bps = 5 μS (5 millionths of a sec)
    - FOR A 1000 MIP NODE, 5 μS = 5,000 INSTRUCTIONS
    - IF ROUTING STILL TOOK 10,000 INSTRUCTIONS = 200% OF CAPACITY !
  - FUTURE:
    - HOW HANDLE 1G+ bps LINES?

ATM PATH ROUTING STRATEGY (Virtual Circuit)

- KEY CONCEPT: PRE-CALCULATE AND PRE-ALLOCATE PATH
- NO SOURCE OR DESTINATION ADDRESSES USED IN CELL
- MINIMAL DELAY IN PASSING CELL ON



#	Line	New #
17	13	63

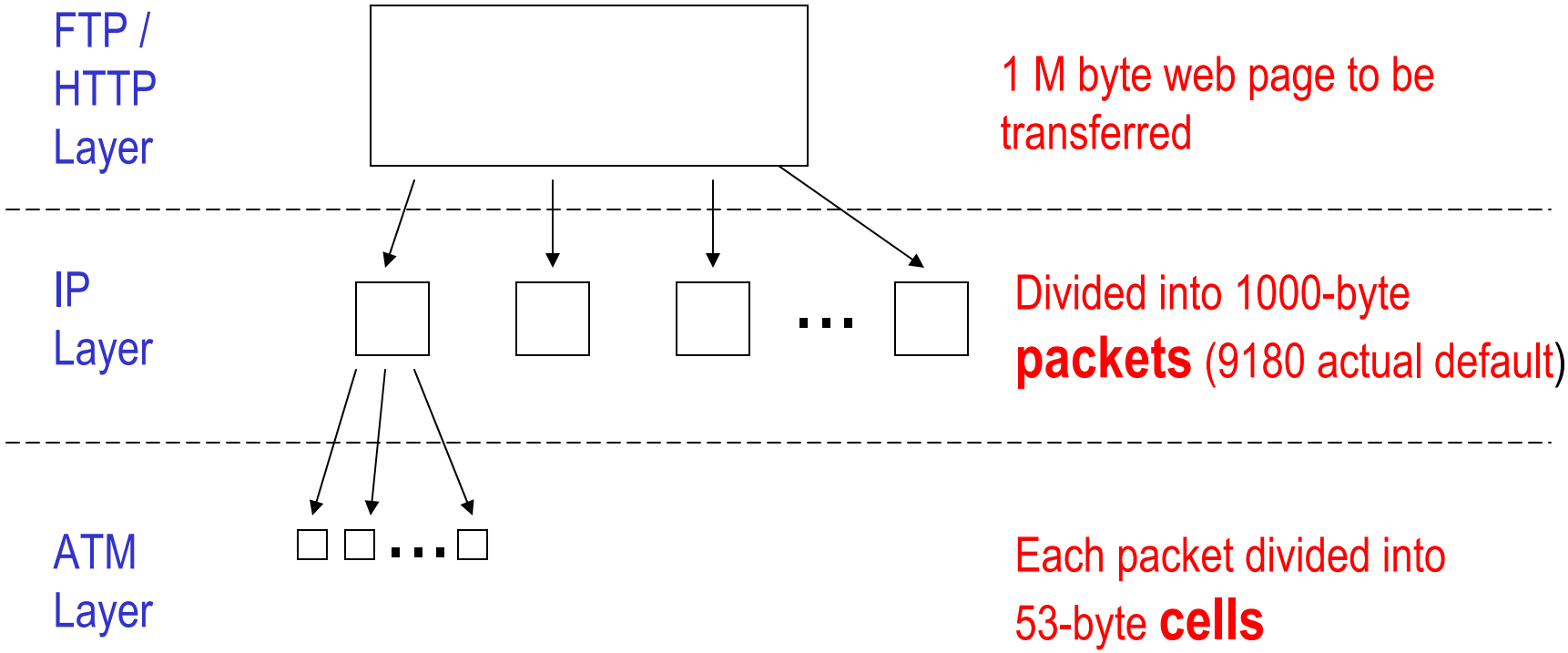
#	Line	New #
63	34	75

#	Line	New #
75	45	12

#	Host
12	X

RELATIONSHIP OF IP TO ATM

- ATM ADAPTATION LAYERS (AAL5) [See Appendix for more details]



- ADDRESS MAPPING:
  - MUST MAP IP ADDRESS TO ATM ADDRESS AT "SETUP"
    - USUALLY VIA A SHARED SERVER (WITH KNOWN ATM ADDRESS)
  - MUST MAP EACH IP ADDRESS TO ATM FOR EACH PACKET AFTER SETUP

ATM CHALLENGES / OBSTACLES

- ATM HARDWARE (CURRENTLY) EXPENSIVE
- MIGRATION COSTS AND COMPLEXITIES
- STANDARDS BATTLES/COMPROMISES
  - MULTIPLE SELF-INTERESTS
  - E.G., ATM ADDRESS FORMAT DISPUTE (BOTH SUPPORTED)
    - TELEPHONE: 8-OCTET FORMAT (ISDN PHONE NUMBER)
      - CCITT
    - ATM FORUM: 20-OCTET NETWORK SERVICES ACCESS POINT (NSAP)
      - CISCO, IBM, etc.

FUTURE OF TCP/IP (IPng, IPv6)

- CURRENT IPv4 (SINCE 1970s) LIMITATIONS
  - IP ADDRESS = 32 BITS (MAX 4 BILLION NODES)
  - REAL-TIME AUDIO AND VIDEO POOR
- MAINTAIN
  - CONNECTIONLESS DELIVERY (EACH DATAGRAM INDEPENDENT)
  - SENDER CHOOSES DATAGRAM SIZE (MAX = 64K BYTES)
  - SENDER SPECIFIES MAXIMUM HOPS
- NEW (IPv6)
  - ADDRESS = 128 BITS ($2^{128} = 3.4 \times 10^{38}$) - WHY?
  - PRE-ALLOCATION OF NETWORK RESOURCES (“FLOW”)
    - RESERVE AND RESTRICT
  - MAXIMUM FRAGMENT SIZE DETERMIINED IN ADVANCE
    - NOT AS DYNAMIC
  - PROVISION FOR PROTOCOL EXTENSION
  - MORE FLEXIBLE HEADER FORMAT/OPTIONS
  - SUPPORT: UNICAST, CLUSTER, MULTICAST

IPv6 ADDRESS ISSUES

- FORMATS:
  - TRADITIONAL IPv4 = 104. 230. 140. 100
  - IPv6 = 104. 230. 140. 100. 255. 255. 255. 255. 0. 0. 17. 128. 150. 10. 255. 255
  - IPv6 = 68E6: 8C64: FFFF: FFFF: 0: 1180: 96A: FFFF (HEXADECIMAL)
  - ALSO PROVISIONS FOR ABBREVIATIONS, ESP IF SEQUENCES OF 0's (::)

- ADDRESS SPACE ALLOCATION
  - TRADITIONAL IPv4 - 2 PARTS:
    - NETWORK PREFIX (CENTRAL MANAGED)
    - HOST SUFFIX (ASSIGNED BY ORGANIZATION)
  - IPv6 OFFER VARIES POSSIBILITIES, SUCH AS:
    - PROVIDER ID
    - SUBSCRIBER ID
    - SUBNET ID
    - NODE ID (E.G., IF 48 BITS CAN = ETHERNET ADDRESS)

OTHER INTERNET EMERGING TECHNOLOGIES & ISSUES

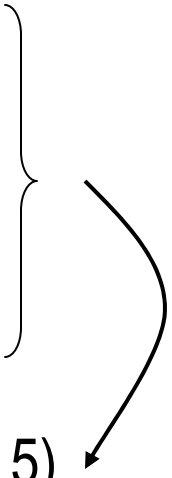
- TECHNOLOGIES
  - SATELLITE (POINT-TO-POINT, SYNCHRONIZED)
  - PACKET RADIO
  - etc.
- MULTI-MEDIA
  - REAL-TIME AUDIO AND VIDEO

EXPERIMENTS

- NEXT GENERATION INTERNET (NGI)
  - DARPA FUNDED
  - 1G bps $\rightarrow$ 1 T bps (OVER ATM)
- INTERNET II (www.internet2.org -- *not .com*)
  - 170 UNIVERSITIES
  - 622 M bps $\rightarrow$ 2.4 G bps
- OTHER EXPERIMENTS

APPENDIX: ATM ADAPTION LAYERS

- TYPE 1 - CONSTANT BIT RATE (CBR)
  - VOICE AND VIDEO
- TYPE 2 - VARIABLE BIT RATE (VBR)
  - PACKET VIDEO
- TYPE 3 - CONNECTION-ORIENTED VBR DATA TRANSFER
  - FILE TRANSFERS
- TYPE 4 - CONNECTIONLESS VBR DATA TRANSFER
  - SHORT BURSTY
- TYPE 5 - SIMPLE & EFFICIENT ADAPTION LAYER (SEAL/AAL5)
  - TYPE 3 WITHOUT ERROR DETECTION
    (REPLACES 3 AND 4)



ATM NETWORK INTERFACES