Internet – A Brief Tutorial

Jean Walrand
EECS
U.C. Berkeley

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History

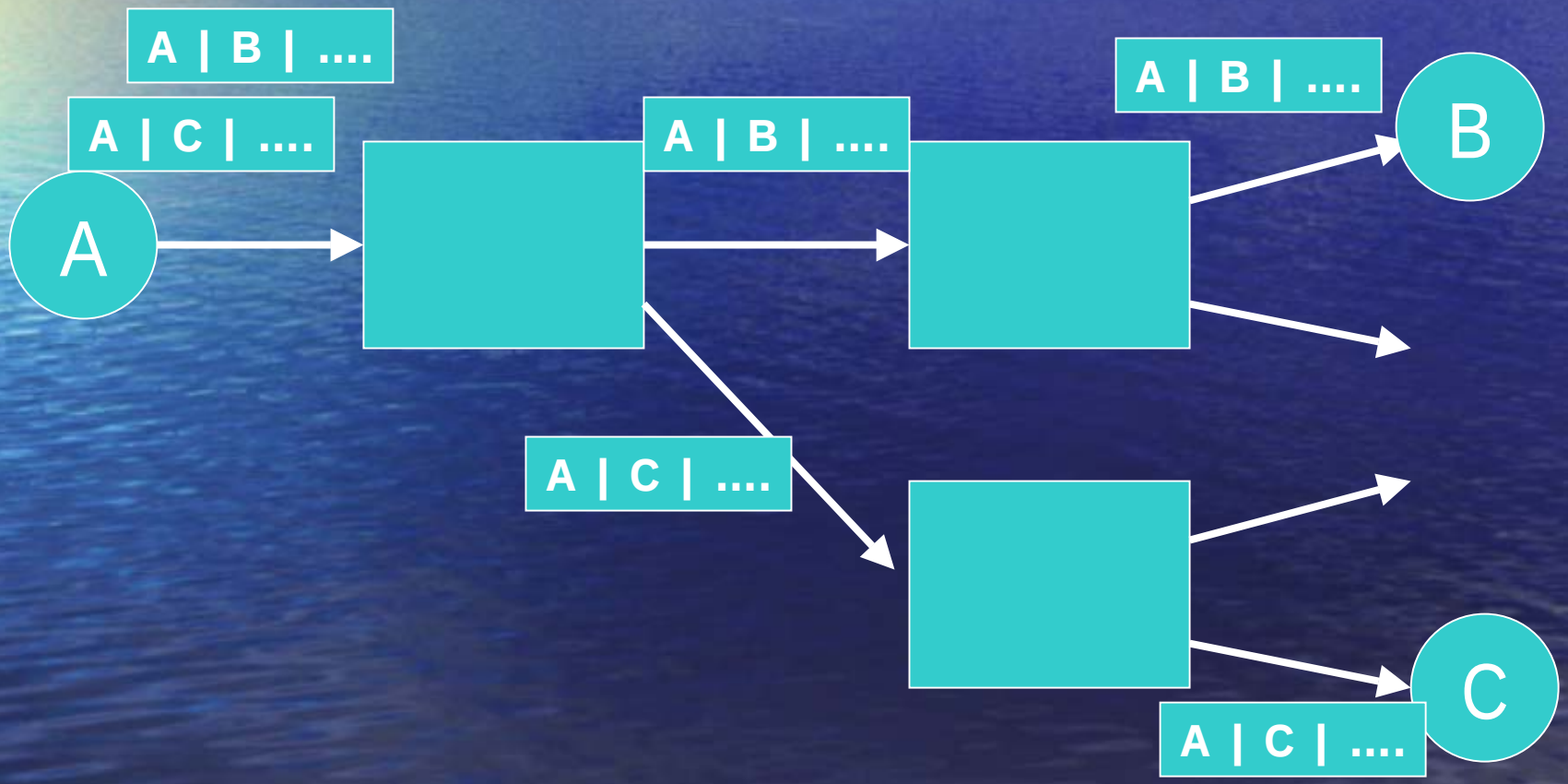
- 1962 – L. Kleinrock proposes Packet Switching
- 1966 – L. Roberts proposes architecture to Darpa
- 1969 – First demonstration of packet switching: 4-node Arpanet
- 1969 – S. Croker introduces RFCs (managed by J. Postel)
- 1972 – R. Kahn proposes an open architecture: Inter-networking with stateless routers, best effort, no control plane
- 1973 – Kahn and V. Cerf propose early ideas of IP (32-bit address) and TCP (end-to-end ACKs with a window scheme)
- 1973 – R. Metcalfe invents Ethernet
- 1982 – IGP and EGP
- Late 1970s, early 1980s – Berkeley develops BSD, a modified implementation of UNIX that includes TCP/IP
- 1983 – Arpanet switches to TCP/IP
- 1983 – P. Mockapetris invents DNS
- 1988 – Van Jacobson fixes TCP
- 1985 – 1995 – Internet supported by NSF and other agencies
- 1993? – T. Berners-Lee invents WWW
- 1995 – Internet is privatized
- 2000… - WiFi,VoIP, P2P

See http://www.isoc.org/internet/history/brief.shtml

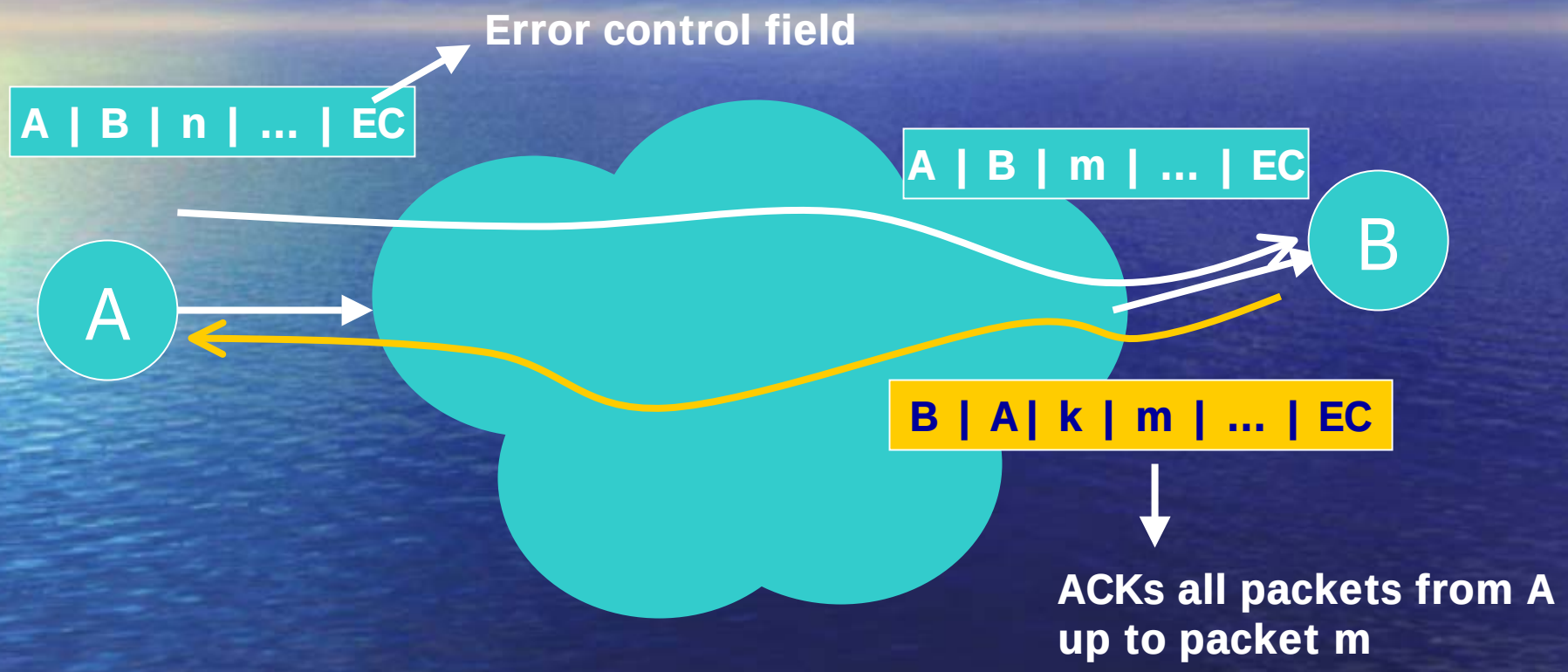
Key Ideas

- Packet Switching
- End-to-End error and flow control
- Internetworking
- Multiple Access
- DNS
- P2P
- VoIP

Packet Switching



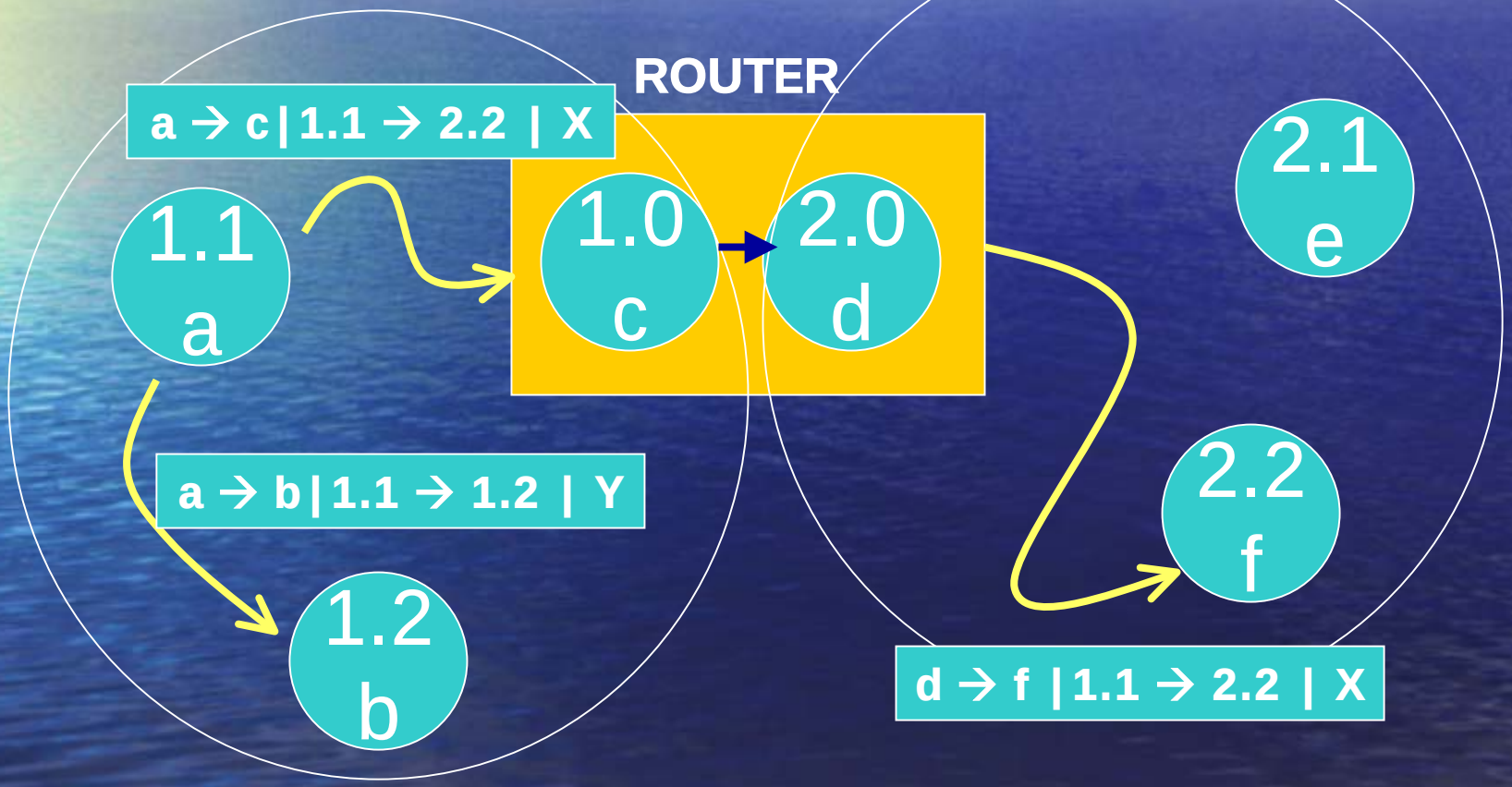
End-to-End Error and Flow Control



A can have up to N packets for B that have not been acknowledged
Selecting N adjusts the rate of transmissions: limit congestion
If ACK is late, A retransmits packets

Internetworking

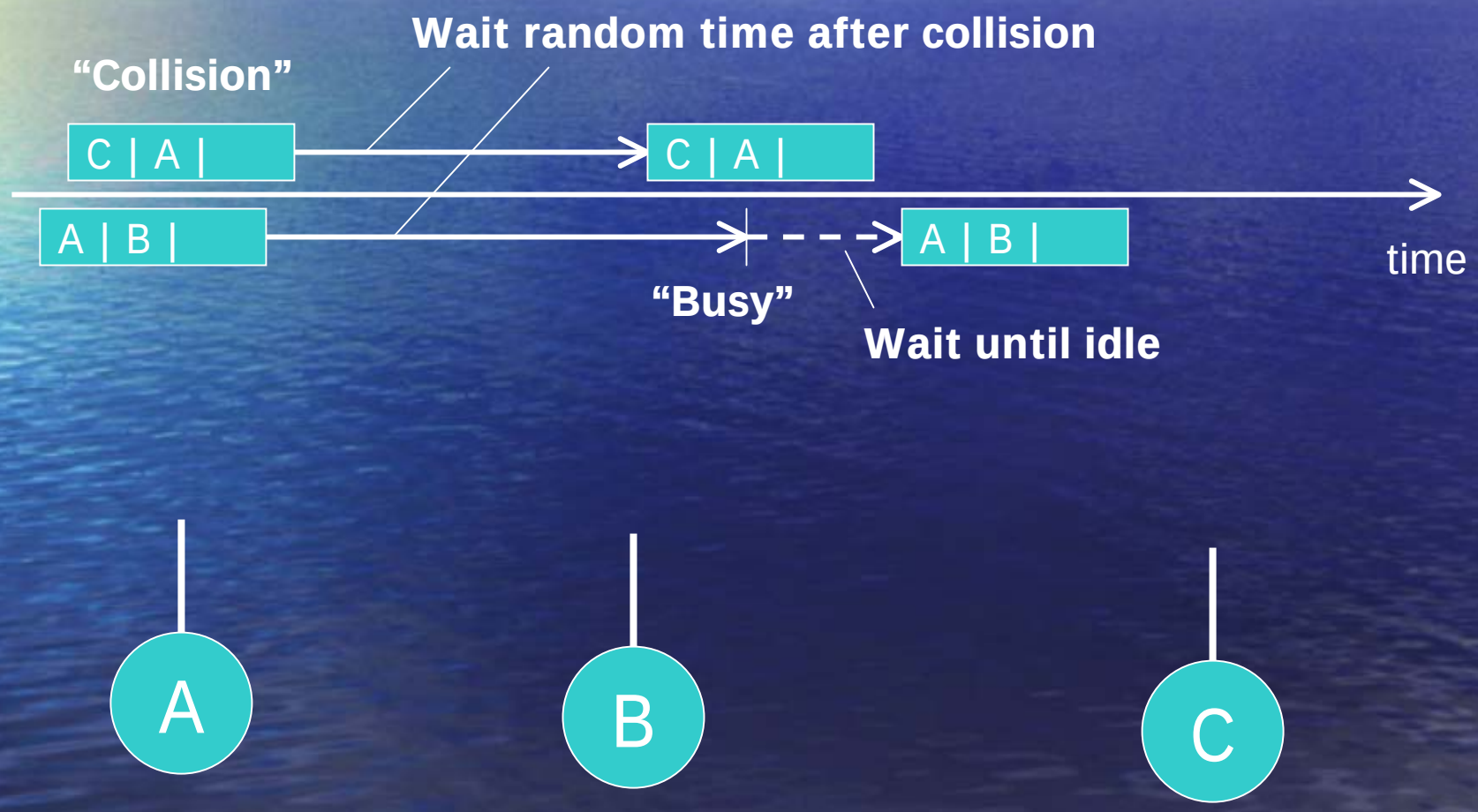
- Goal: Connect different networks



Router looks at IP addresses (1.1, ...)
Each network uses local addresses (e.g., a, b, c, ...)

Multiple Access

- Goal: Share one medium (e.g., WiFi)



DNS: Domain Name Service

- Translate Name into IP address (e.g., google.com into 216.239.57.99)
- Directory of DNS is distributed:
  .com, .edu, ...
  .edu: berkeley.edu, stanford.edu, ...
- Mapping can depend on source address
- Mapping can be done to multiple addresses

P2P: Peer-to-peer

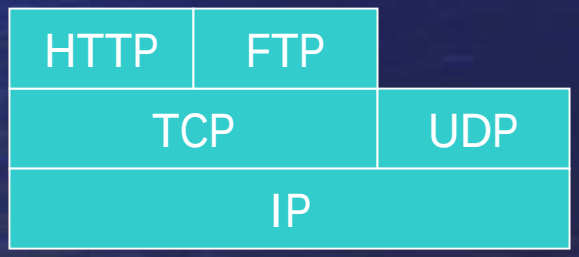
- Goal: All peers become servers
- Example:
  - Each peer knows the addresses of a set of peers: his “friends”
  - To find a file, peer A asks his friends who in turn ask their friends, and so on, until someone, B, says he has the file... (can limit search); A then asks B for the file.
  - Many variations are possible. The key idea is that there is no specialized server; every client becomes a server.

VoIP: Voice over IP

- Goal: Place phone calls over Internet (Should be cheaper because the Internet infrastructure is much lighter than that of the phone network.)
- Steps:
  - Gateway converts phone signal into IP packets and vice-versa
  - Protocol to convert phone number into gateway IP address
  - Gateway converts usual control signals (dial tone, ringing, busy, ...) into IP packets and vice-versa

Protocols:

- IP: Internet Protocol
- TCP: Transmission Control Protocol
- UDP: User Datagram Protocol
- HTTP: Hypertext Transfer Protocol
- FTP: File Transfer Protocol
- ARP: Address Resolution Protocol



IP: Internet Protocol

- Delivers packets between any two hosts
- Organizes address, manages routing tables
- Addresses: 32 bits, arranged so that prefix determines next router toward destination
- Routing algorithm: Essentially shortest path. Done in two levels: nodes are grouped; shortest path inside each group and across groups.
- Tables updated periodically to adjust to changes

TCP: Transmission Control Protocol

- Implements reliable delivery of byte stream between hosts
- Multiplexes multiple connections to and from a host: adds a “port” number
- End-to-end retransmissions
- Regulates flow to avoid congesting
  - Destination (flow control)
  - Routers (congestion control)
- Method: ACKs, control number of unacknowledged packets

UDP: User Datagram Protocol

- Unreliable delivery of packets with error detection
- Multiplexes multiple connections to and from a host: adds a “port” number
- Adds error detection code for the packet
- No retransmission, no flow control

FTP: File Transfer Protocol

- Reliable delivery of file between hosts
- Converts file into byte stream for TCP

HTTP

- Transfer of html files
- Sets up TCP connections and FTP to transfer files
- Closes connections after transfer

ARP: Address Resolution Protocol

- Discovers local address from IP address
- Example: In “Internetworking” slide, host 1.1 uses ARP to discover local address b of 1.2
- Protocol:
  - Host 1.1 broadcasts request on local network: Who is 1.2?
  - Host 1.2 replies to 1.1; local address of source (b) is in the packet.

Technology

- Communication Links
- Switches

Communication Links

- Convert bits string into signals that propagate as electromagnetic waves
- Optical: Typically ON/OFF → pulses of light; encoding makes sure there are enough transitions for the receiver to remain in sync
  - Fibers: up to 10Gbps over 100 km per wavelength; up to 128 wavelengths per fiber
- Wired and wireless: Typically pulses of sine waves at different frequencies or phases to encode groups of bits
  - Wires: 100 Mbps over 100 m
  - Wireless: 100 Mbps over 30 m with multiple antennas (802.11n)
- Error control codes: typically to detect errors

Switches

- Various links: optical, cable, wires
- Looks up destination address and sends packet to corresponding output port
- May perform some traffic policing (limit rate) and some differentiated service (e.g., priority to VoIP packets)
  - Fast router: total throughput of 500 Gbps
  - From a few to 128 ports

Research

- Security: better ways to limit worms and attacks; better filters for spam
- Searching: smarter searches (meaning), searching different media
- Switching: Optical switching
- Wireless: Faster, less power, cognitive radios (discover and use free spectrum)
- Applications: Sensors, robots, ...