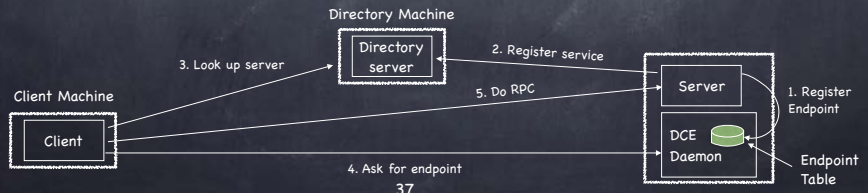
Binding: Connecting Client and Server

- Server exports its interface
  - Identifies itself to network name server
  - Tells local runtime its dispatcher address
- Client imports the interface
  - Looks up server through name service
  - Contacts server to setup a connection

Import and export are explicit calls in the code



From Procedure to Remote Procedure

- Three main concerns
  - Parameter passing
  - Failure cases
  - Performance
    - Remote ain't cheap
    - Lack of parallelism (on both sides)

RPC Marshaling

- Transforms memory representation of parameters to format suitable for transmission
  - RPC stubs call type-specific procedures to marshal/unmarshal all the parameters to the call
- On call
  - Client stub marshals parameters into the call packet
  - Server stub unmarshals parameters to call server's function
- On return, roles are reversed
  - Server stub marshals return values into return packet
  - Client stub unmarshals return values, returns to client

Passing Pointers

- Pointers are meaningful only in the address space of the sender…
  - Forbid pointers?
    - breaks transparency
  - Stub replaces call-by-reference semantics with Copy/Restore
    - for simple structures (e.g. an array), pass a copy to the server
    - for more complex structures (e.g., graphs), server's stub sends a request for the missing data to the client's stub every time it encounters a pointer

Failures

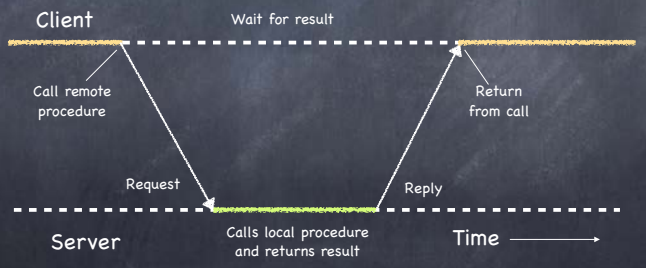
- Request or response are lost
- Server crashes after receiving request
- Client crashes after sending request
  - In local procedure calls, if a machine fails, the applications fails, but with RPC, if a machine fails, only part of application does
  - Cannot tell the difference between a machine failure and a network failure...
- Easy! Transform partial failures into total failures
  - Also, while you are at it, aim a gun to your foot

RPC Semantics

- Exactly once
  - Impossible in practice
    - Why?
- At least once
  - If at first you don't succeed...
    - Only for idempotent operations
    - Server must be stateless
- At most once
  - Zero, don't know, or once
    - Server needs to be able to identify requests, so it can resend previously computed replies
- Zero or once
  - Transactional semantics

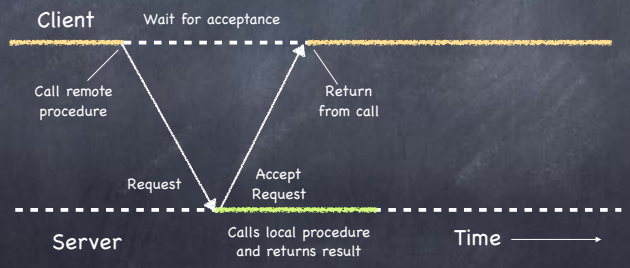
Asynchronous RPC

- In traditional RPC, caller blocks until function returns



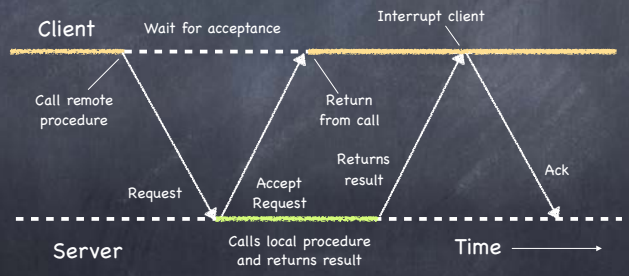
Asynchronous RPC

- In asynchronous RPC, caller only blocks until it learns the request has been accepted



Asynchronous RPC

- In asynchronous RPC, caller only blocks until it learns the request has been accepted and is interrupted when reply is received



RPC: Final Thoughts

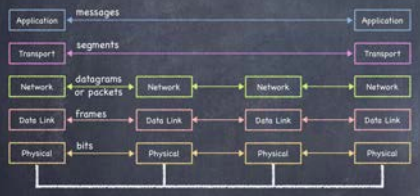
- Common model for communication in distributed applications
- Relies on language support for distributed programming
  - Stub compiler and IDL server description
- Commonly used for communication between applications running in different address spaces
  - most RPCs are intra-node!

"Distributed objects are different from local objects, and keeping that difference visible will keep the programmer from forgetting the difference and making mistakes."

Jim Waldo et al., "A Note on Distributed Computing" (1994)

Transport Layer: UDP & TCP

Transport Services and Protocols



- Provide logical communication between processes on different hosts
  - logical communication between hosts is left to the network layer
- Sender packages messages into segments, passes them to the network layer
- Receiver reassembles segments into messages, passes them to the application layer
- Apps can use multiple protocols (e.g., on the Internet, UDP or TCP)

Internet Transport-layer Protocols

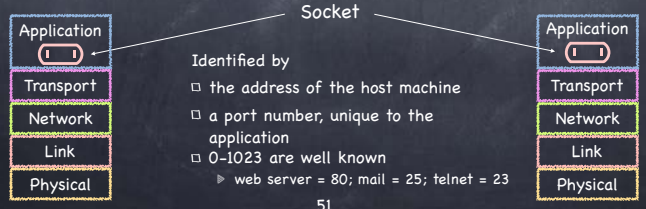
- TCP (Trusty Control Protocol)
  - Reliable, in-order delivery
    - Congestion control
    - Flow control
    - Connection setup
- UDP (Unreliable Datagram Protocol)
  - Unreliable, unordered deliver
    - no-frill extension of best-effort IP (network layer protocol)
- Services not available:
  - delay guarantees
  - bandwidth guarantees

Applications and their Transport Protocols

Application	Application-Layer Protocol	Transport Protocol
Email	SMTP	TCP
Remote terminal access	Telnet	TCP
Web	HTTP	TCP
File Transfer	FTP	TCP
Remote File Server	NFS	Typically UDP
Streaming Multimedia	Proprietary	UDP or TCP
Internet Telephony	Prioprietary	UDP or TCP
Network Management	SNMP	Typically UDP
Routing Protocol	RIP	Typically UDP
Name Translation	DNS	Typically UDP

Socket

- One endpoint of a two way communication between two application processes running on a network
  - Sending process pushes messages out the socket to the transport protocol
  - Transport protocol delivers message to the socket at the receiving process



The Big Picture (Sender's Edition)

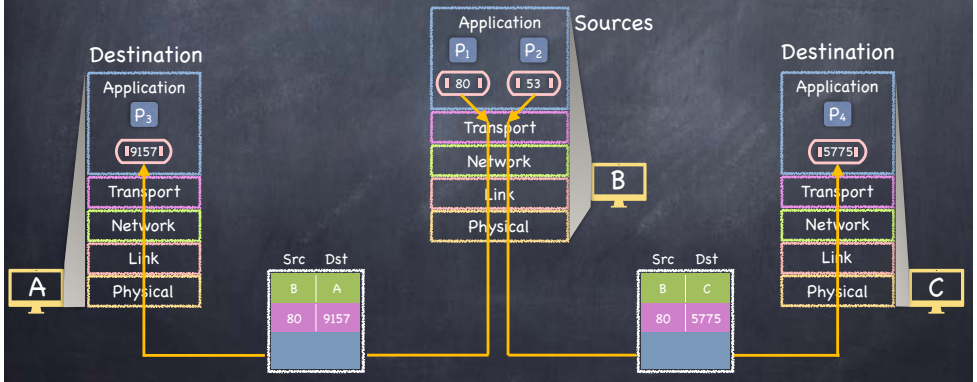
- Sending application
  - specifies IP address (to identify host) and destination port
  - uses socket bound to a source port
- Transport layer
  - breaks application message into smaller chunks
  - add to each transport-layer header
- Network layer
  - adds network layer header (with IP address)

The Big Picture (Receiver's Edition)

- Network layer
  - removes network layer header (with IP address)
- Transport layer
  - removes from each segment transport-layer header
  - reassembles application message from segment
- Receiving application
  - receives message on destination port bound to socket

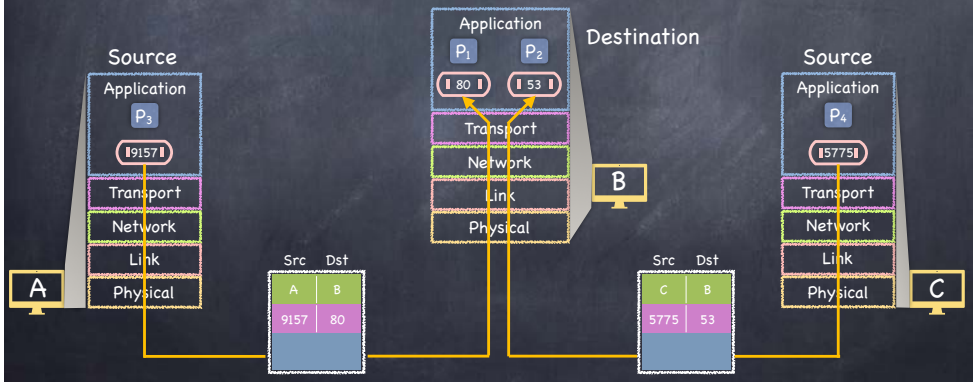
Multiplexing at the Sender

- Handles data from multiple sockets
- Adds transport header (later used for demultiplexing)



Demultiplexing at the Receiver

- Handles data from multiple sockets
- Adds transport header (later used for demultiplexing)



Socket programming

- Two socket types, depending on transport services
  - UDP: unreliable datagram
  - TCP: reliable, byte-stream oriented
- Application at end host distinguished by binding socket to a port number
  - 16 bit unsigned number; 0-1023 are bound to well-know applications
    - web server = 80; mail = 25; telnet = 23

Socket Programming with UDP

- No connection between client and server
  - no handshaking before sending data
  - Sender: explicitly attaches destination IP address and port number to each packet
  - Receiver: extracts sender IP address and port number from received packet
- Best effort: Data may be lost or received out-of-order
- UDP provides applications with unreliable transfer of a group of bytes ("datagram") between client and server

Client/Server Socket Interaction: UDP

Create clientsocket

Create message

Send message to (ServerIP, port x) via clientsocket

Create serversocket; bind to port X

Read data and clientAddr from serversocket

Modify data

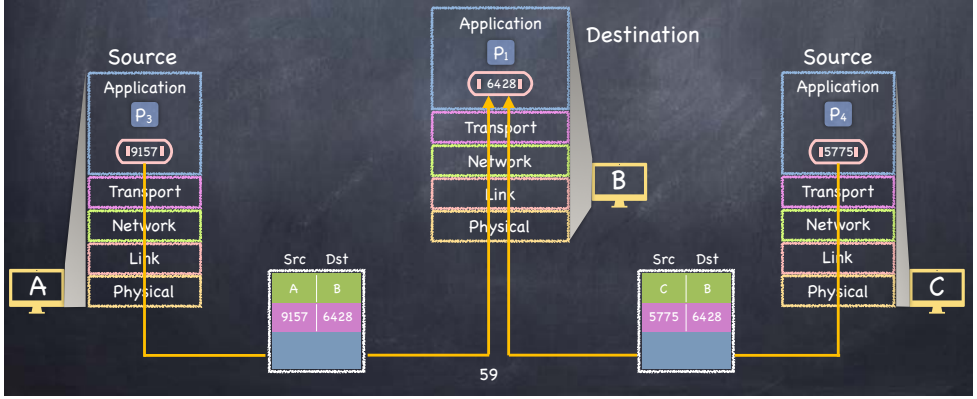
Send modified data to clientAddr via serversocket

Receive message and serverAddr from clientsocket

Close clientsocket

Connectionless Demux

- Distinct UDP segments with same dest IP address and port, go to the same socket
  - even if they come from different source IP!
- The application must sort things out!



UDP: Perspective

- Speed
  - no connection establishment (takes time)
  - no congestion control: UDP can blast away!
- Simplicity
  - no connection state at sender/receiver
- Extra work for applications
  - reordering, duplicate suppression, missing packets…
  - but some applications may not care!
    - streaming multimedia: loss tolerant, rate sensitive (want constant, fast speeds)

Socket Programming with TCP

- Server
  - Contacted by client
  - Already running
  - Already created a "welcoming socket"
  - When contacted by client, creates a new TCP socket to communicate just with that client
    - Socket identified by 4-tuple
      - source IP; source port no; dest. IP; dest port no.
    - Server can concurrently serve multiple clients
- Client
  - Creates TCP socket with server's IP address and port number
  - Client TCP establishes connection to server TCP

  TCP provides applications with reliable, in-order byte-stream transfer between client and server
    - All web traffic travels over TCP/IP
      - Enough apps demand reliable ordered delivery

Client/Server Socket Interaction: TCP