Introduction Distributed Systems
Communication

Today

- Basics of communication
- RPC and message oriented
- Group communication

IPC in distributed systems

- IPC is based on send/receive msgs
- For this to work, both parties must agree on a number of things
  - How many volts to use to signal a 0-bit?
  - How does the receiver knows it got the last bit of a msg?
  - How longs are integers?
  - …
- To simplify this – partition the problem into layers, each layer in a system communicates with the same layer in the other end
  - International Standard Organization's Open Systems Interconnection model – ISO OSI

Protocols in communication

- Lower-level protocols
  - Physical – deals with mechanical and electrical details
  - Data link – groups bits into frames & ensure are correctly received
  - Network – describes how packet are routed, lowest i/f for most distributed systems (IP)
- Transport protocols
  - Transfer messages between clients, including breaking them into packets, controlling low, etc (TCP & connectionless UDP)
- High-level protocols
  - Session – provides dialog control and synchronization
  - Presentation – resolves differences in formats among sites
  - Application – originally to contain a set of standard apps

Middleware

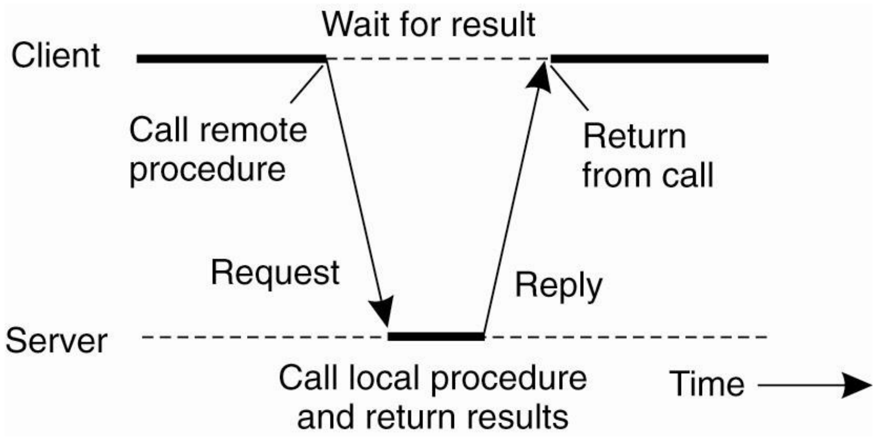
- Basically an “application” providing general-purpose, high-level protocols that can be used by others
  - Rich set of communication protocols
  - (Un)marshaling of data
  - Naming protocols so that different apps can share resources
  - Security protocols
  - Scaling mechanisms such as support for replication and caching
- What’s left are really application-specific protocols

Types of communication

- Persistent or transient
  - Persistent – a message submitted for transmission is stored as long as it takes to deliver it
  - Transient – … as long as the sending/receiving applications are execution (e.g. if transmission is interrupted, msg is lost)
- Asynchronous or synchronous
  - Sender continues or blocks until request has been accepted
  - Points of synchronization
    - At request submission, delivery or after processing
- Client/server
  - Normally based on transient & synchronous communication
- Discrete or streaming
  - Each message is a complete unit of info. or part of whole

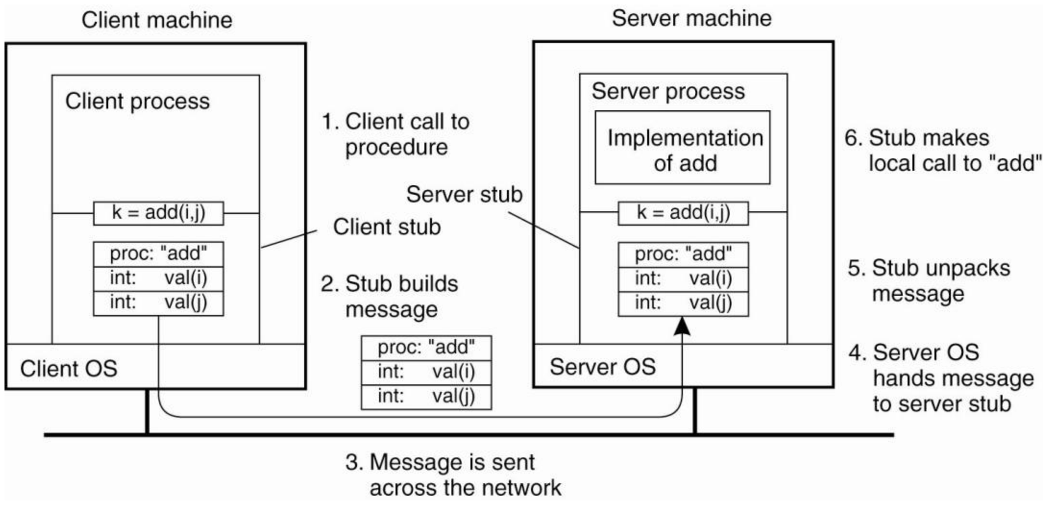
Remote Procedure Call

- Some observations
  - Application developers are familiar with simple procedure model
  - Well engineered procedures operate in isolation
  - There’s no fundamental reason not to execute procedures on a separate machine
- Can you hide sender/receiver communication using procedure calls?



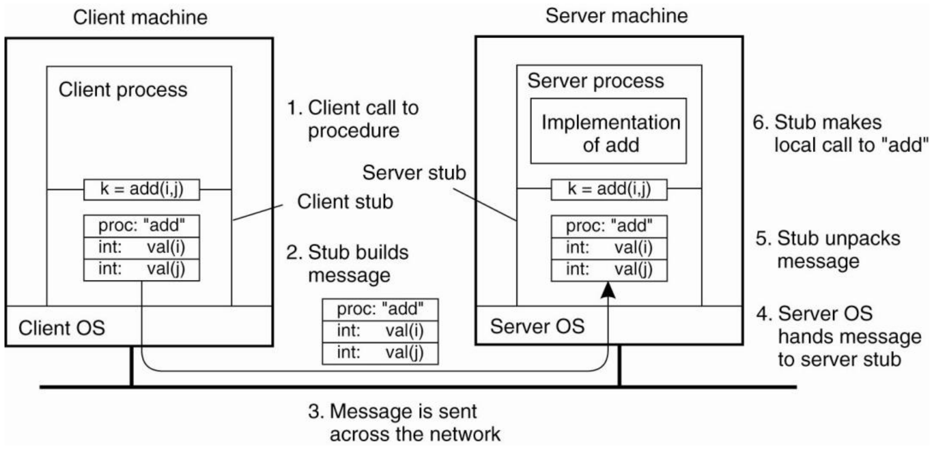
Basic RPC operation

- A RPC occurs in the following steps:
    1. Client procedure calls client stub
    2. Client stub builds msg. and calls the local OS
    3. Client's OS sends msg. to remote OS
    4. Remote OS gives msg. to server stub
    5. Server stub unpacks parameters and calls server
    6. Server does the work and returns the result to stub
    7. Server stub packs it in a msg. and calls local OS
    8. Server's OS sends msg. to client's OS
    9. Client's OS gives msg. to client stub
    10. Stub unpacks result and returns to client



RPC: Parameter passing

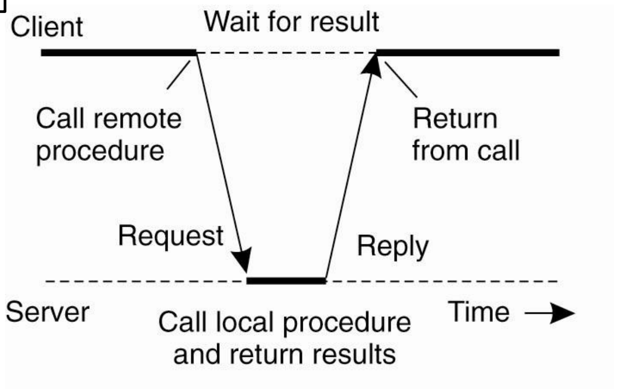
- Marshaling – more than wrapping parameters
  - Client and server may have different data representations
  - Client and server have to agree on encoding:
    - How are basic data values represented (integers, floats, …)
    - How are complex data values represented (arrays, unions)
- RPC assumes
  - Copy in/copy out semantics
  - All data to be worked on is passed by parameters
- How about pointers?
  - Copy/restore instead of call-by-reference
  - Remote reference for more complex structures



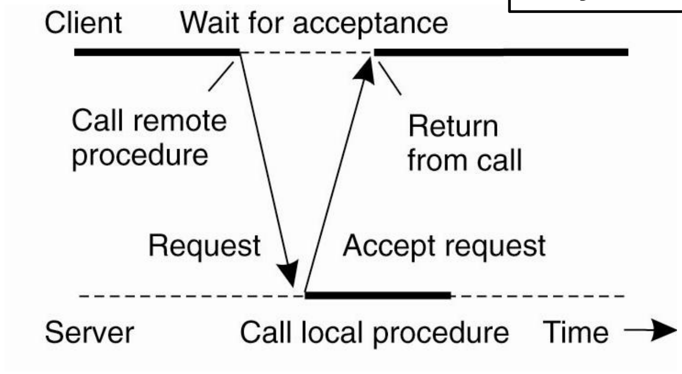
Asynchronous RPCs

- Get rid of the strict request-reply behavior, but let the client continue w/o waiting for server's answer

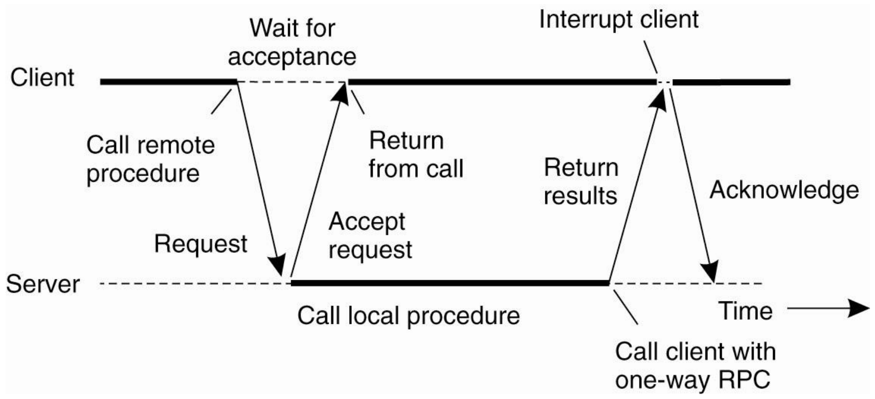
Synchronous



Asynchronous



- A variation – deferred synchronous RPC

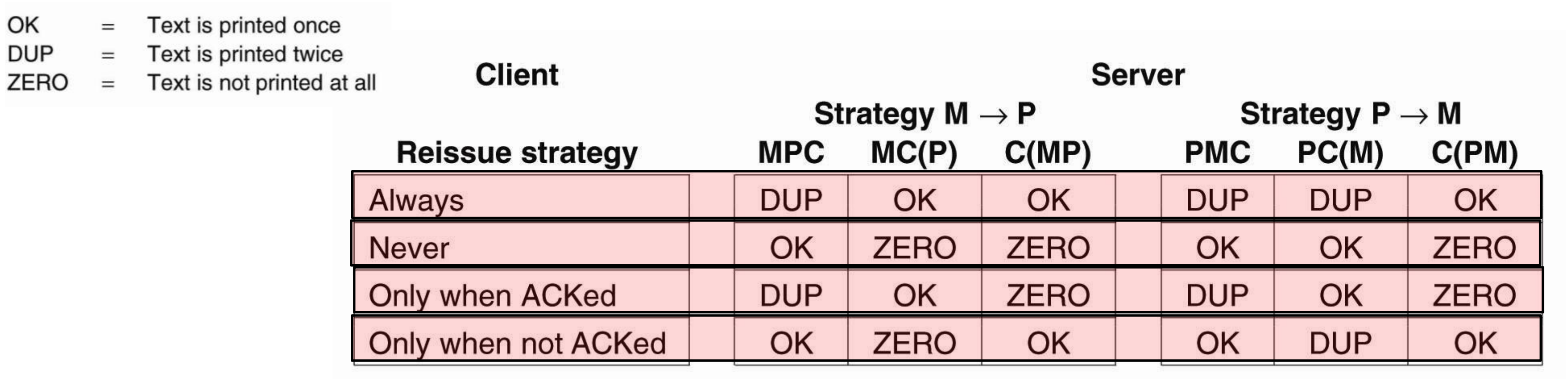


Reliable RPC

- What can go wrong with a remote procedure call?
- 1: Client cannot locate server
  - Either went down or has a new version of the interface; relatively simple – just report back to client (of course, that's not *too* transparent)
- 2: Client request is lost
  - Just resend message after a timeout
- 3: Server crashes
  - Harder to handle – we don't know how far it went
  - What should we expect from the server?
    - At-least-once – guarantees an operation at least once, but perhaps more
    - At-most-once – guarantees an operation at most once
    - Exactly-once – *no way to arrange this!*
- …

Reliable RPC

- Exactly-once semantics
  - Client asks to print text, server sends completion
  - Server can
    - Send completion before (M→P) or after printing (P→M)
  - Client can
    - Always reissue, never reissue, reissue request only when ACK, reissue only when not ACK
  - *Not good solution for all situations!*



OK	=	Text is printed once
DUP	=	Text is printed twice
ZERO	=	Text is not printed at all

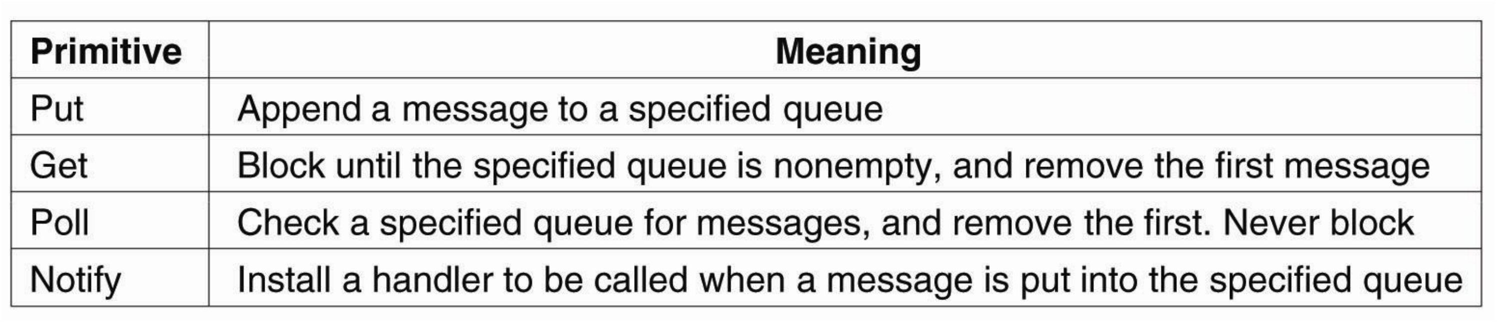
Client	Server					
	Strategy M → P			Strategy P → M		
Reissue strategy	MPC	MC(P)	C(MP)	PMC	PC(M)	C(PM)
Always	DUP	OK	OK	DUP	DUP	OK
Never	OK	ZERO	ZERO	OK	OK	ZERO
Only when ACKed	DUP	OK	ZERO	DUP	OK	ZERO
Only when not ACKed	OK	ZERO	OK	OK	DUP	OK

Reliable RPC

- 4: Server response is lost
  - Hard to detect, the server could also had crashed. Did it get it done? Solution: No much, try making operations idempotent
- 5: Client crashes
  - Server is doing work and holding resources for nothing (doing an orphan computation)
    - Orphan is killed (or rolled back) by client when it reboots
    - Broadcast new epoch number when recovering ⇒ servers kill orphans
    - Require computations to complete in a T time units.
  - Old ones are simply removed

Message Oriented Communication

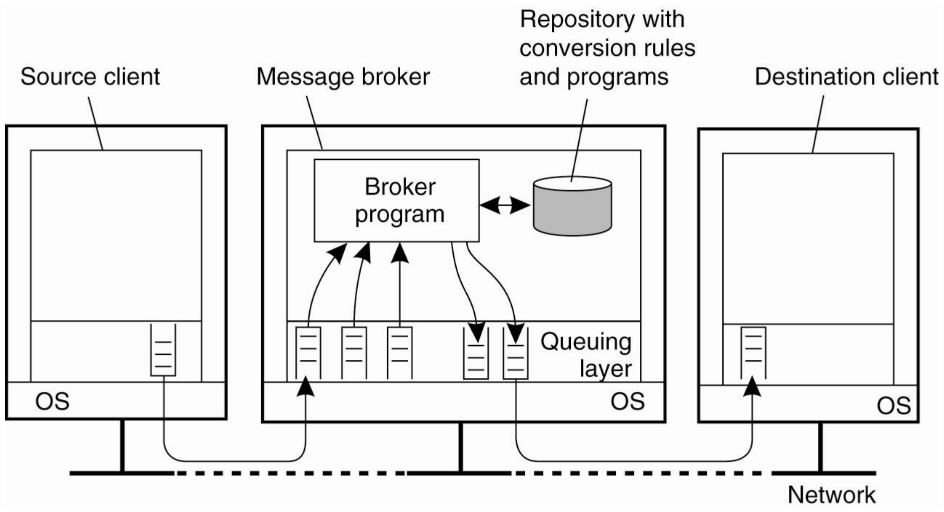
- *What if we cannot assume the receiver side is going to be executing at the time the request is issued?*
- Asynchronous persistent communication through support of middleware-level queues – queues correspond to buffers at communication servers



Primitive	Meaning
Put	Append a message to a specified queue
Get	Block until the specified queue is nonempty, and remove the first message
Poll	Check a specified queue for messages, and remove the first. Never block
Notify	Install a handler to be called when a message is put into the specified queue

Message brokers and apps. integration

- Message queuing systems assume a common messaging protocol: all applications agree on message format
- To use MQ systems for integration – message broker: takes care of application heterogeneity
  - Transforms incoming messages to target format
  - Often acts as an application gateway
  - May provide subject-based routing capabilities



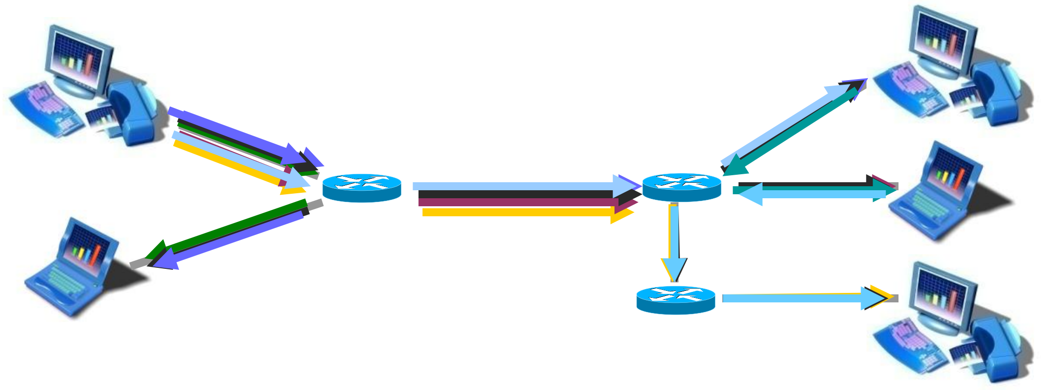
Group communication – multicast

- A key service for many interesting applications
  – Online gaming, video conferencing, content distribution …
- Approaches to group communication

Multicast
Decouples # of receivers from amount of state kept at nodes
Reduces redundant network communication

Basic unica
Scalability is
replication at
link stress, …

group state)



Application level multicast - issues

- Minimize link stress – how often does an overlay message cross the same physical link
- Minimize stretch – delay between overlay path and network-level path
- Performance-centric or DHT-based?
- Churn, i.e. high transiency of end systems
- Root-bottleneck problem for bandwidth-intensive applications
- Uneven load distribution of tree-based protocols

Gossip-based data dissemination

- Assuming there are no write-write conflicts
  - Update operations initially performed at one (few) nodes
  - Node passes its updated state to a limited set of neighbors
  - Update propagation is lazy, eventually each update should reach every node
- Anti-entropy
  - Node chooses another at random, and exchanges differences
  - Push, pull or push/pull
- Gossiping
  - Node just updated, tells others about it; if the node contacted already knows about it, the source stops w/ probability 1/k
  - If you need everyone to know, gossiping along doesn't do it
- And how do you delete items?!
  - Death certificates and dormant death certificates

Question 4

- *Would any form of a* "new" *Internet render overlay network approaches pointless?*