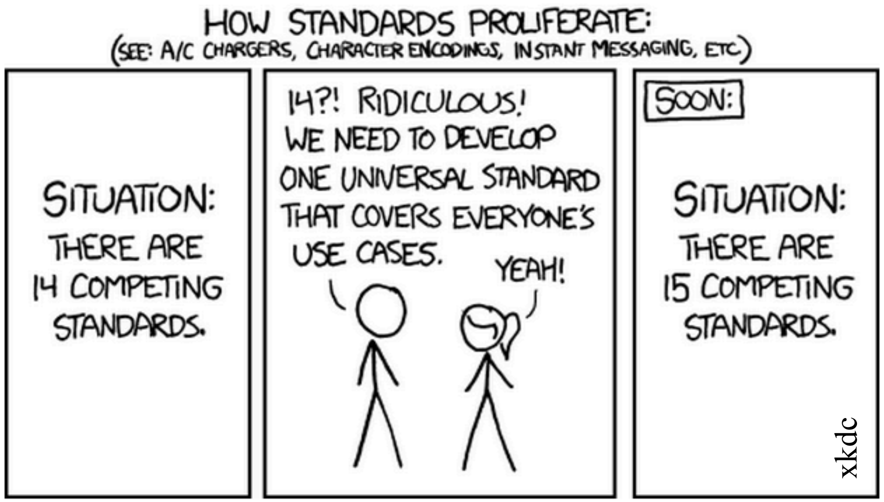
Indirect Communication

Today

- Space and time (un)coupling
- Common techniques

Next time

- Overlay networks



Indirect communication

- Indirect communication – comm. between entities through an intermediary with no direct coupling between senders/receivers
  - Differences in the nature of the intermediary
  - … type of coupling

- Forms of uncoupling
  - Space – No need to know the identity of the other party
    - Can change, update, replicate, move senders/receivers
  - Time – No need to exist at the same time
    - It's ok if either party gets disconnected for a bit
    - Not the same as asynchronous – with time uncoupling receiver doesn't have to even exist when message is sent

Space and time coupling

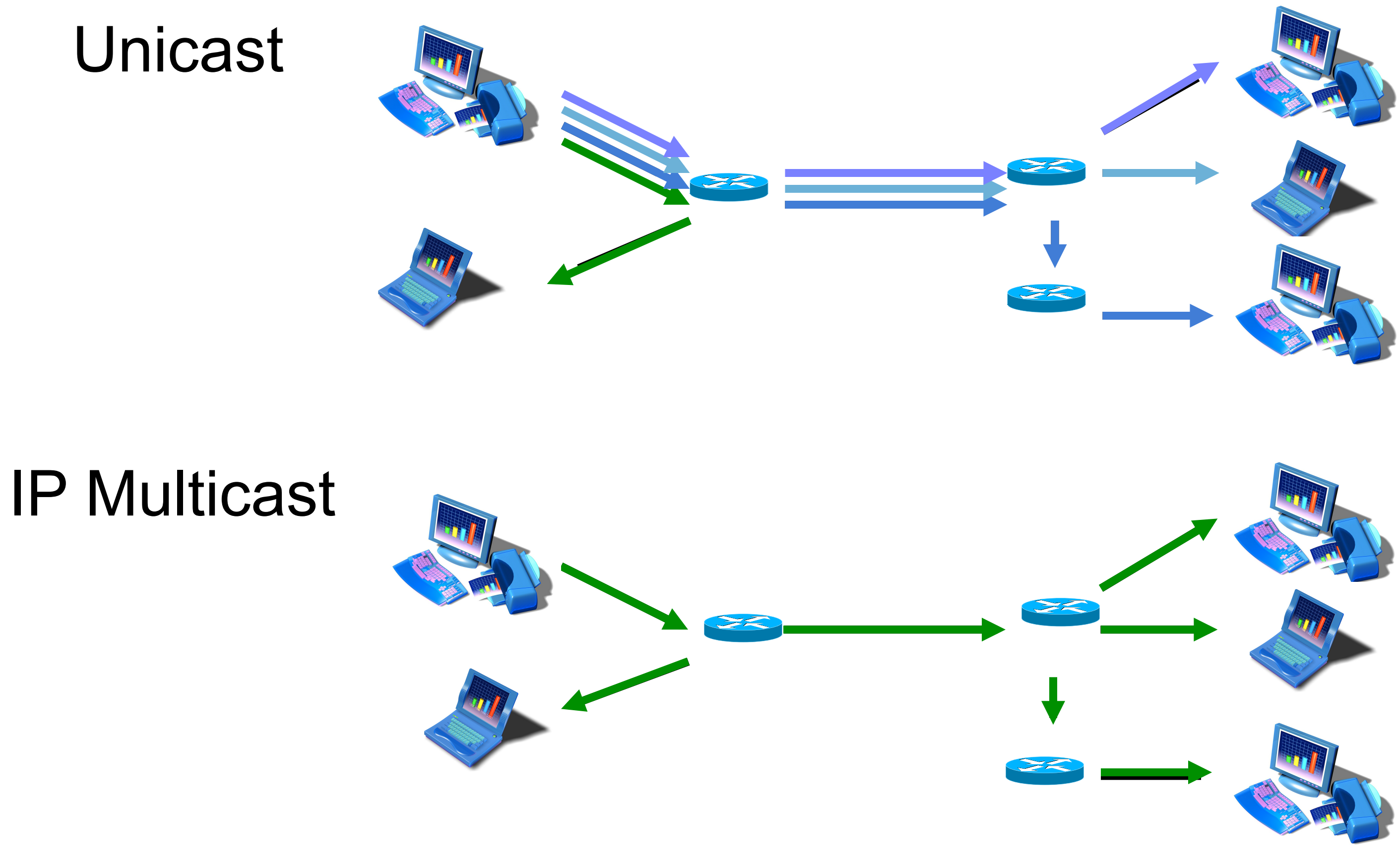
	Time-coupled	Time-uncoupled
Space coupling	Communication directed to a given receiver(s) that must be available at the time *e.g. Messaging passing, RPC*	Sender(s) and receiver(s) can have independent lifetimes *e.g. Mailbox*
Space uncoupling	Sender does not need to know ID of receiver but they must exist at the same time *e.g. IP multicast*	Sender does not need to know ID of receiver; sender(s) and receiver(s) can have independent lifetimes *e.g. Message oriented*

Group communication

- Sender communicates with a group, as a whole, without knowing the identity of members
  - An abstraction over multicast communication
- Group communication typically to process groups
  - Some work on object groups – a collection of objects, typically instances of the same class
- Some common uses
  - Reliable dissemination to many clients (e.g., financial reports)
  - Collaborative applications (e.g., multiuser games)
  - Highly-available services
  - System monitoring and management

Group communication

- Not just programmer convenience, but more efficient use of bandwidth – just once per network link



Group management

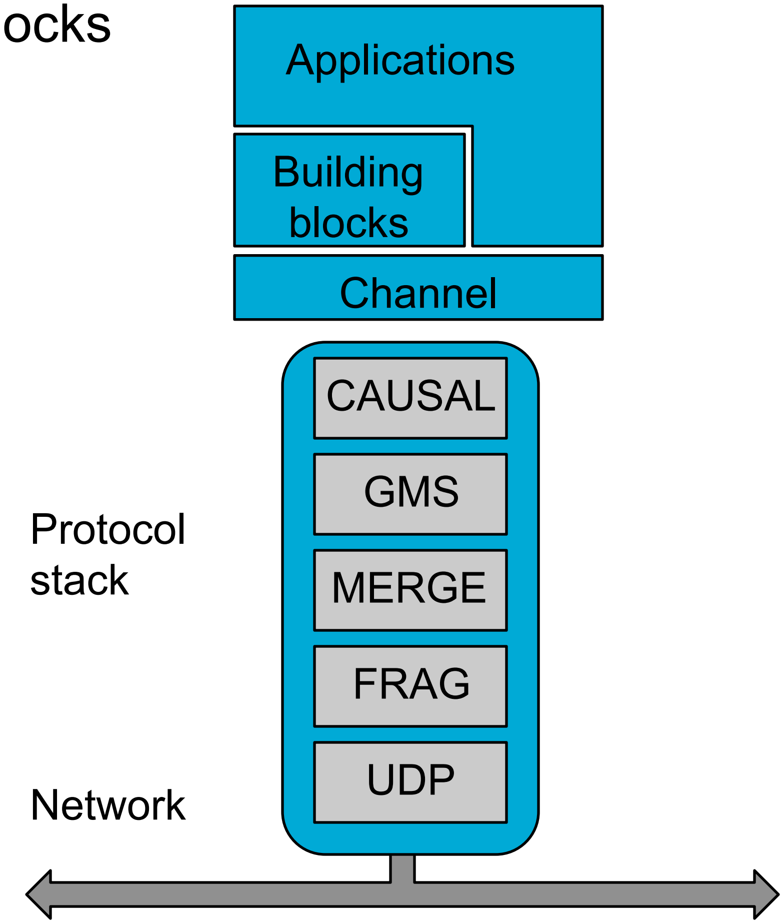
- Groups may be
  - Closed or open – only members can send, closed
  - Overlapping or non overlapping – processes can be members of more than one group
  - Synchronous or asynchronous
- Group membership
  - Membership service provides interface for membership changes, failure detection and notification

Reliable and ordered multicast

- Reliable
  - From one-to-one communication
    - Integrity – msg received is the one sent and no msg is delivered twice
    - Validity – any outgoing msg is eventually delivered
  - Agreement – if msg is delivered to one, it is delivered to all
- Ordered
  - FIFO ordering – source ordering, preserve order of the sender
  - Causal – causally related msgs arrive in the same order everywhere; if a msg *happens before* another msg this so called *causal relationship* is preserved in the delivery
  - Total ordering – All msgs arrive in the same order everywhere

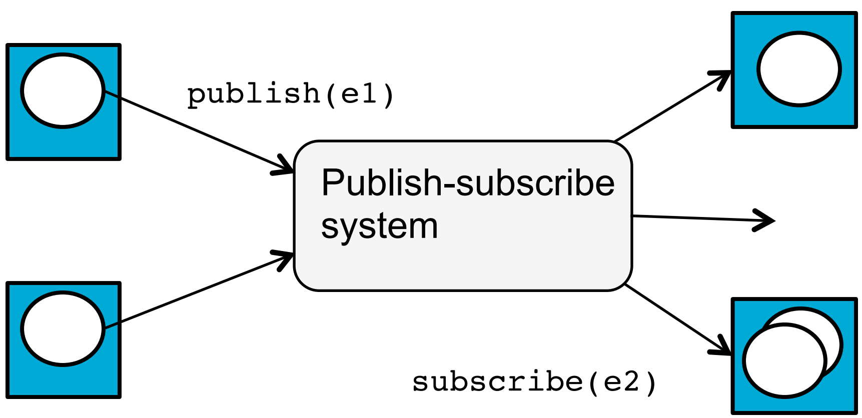
Group communication

- JGroups toolkit
  - An example based on Birman and van Renesse' work on ISIS, Horus and Ensemble
  - Includes channels, building blocks and a composable stack
  - CAUSAL – causal ordering
  - FRAG – configurable packetization
  - GMS – group membership system to maintain a consistent view of the group
  - MERGE – Network partitions and group merges
  - …



Publish-subscribe

- AKA distributed event-based systems
  - The most widely used of all indirect communication models
- Publishers and subscribers
  - Publishes publish events to an event service
  - Subscribers express interest in events via subscriptions
- The pub/sub system job – match subscriptions with published events and ensure correct delivery of event notifications

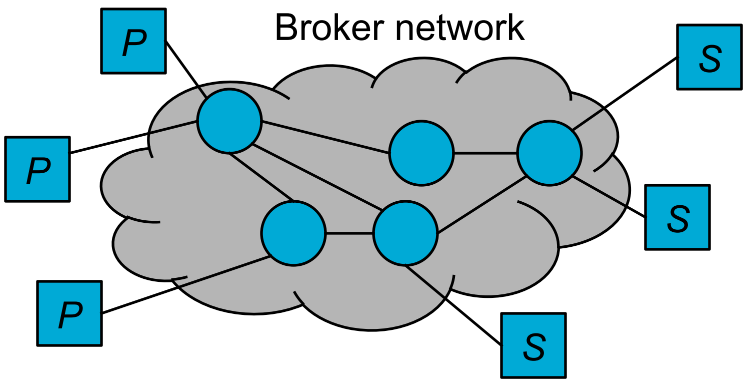


Publish-subscribe – subscription models

- Channel-based
  - Basic, publishing to named channels
- Topic or subject based
  - Notifications are expressed in terms of a number of fields; one filed denotes the topic
- Content-based
  - Allows subscription over a range of fields
- Other types explored
  - Type-, context- and concept-based and more complex event processing

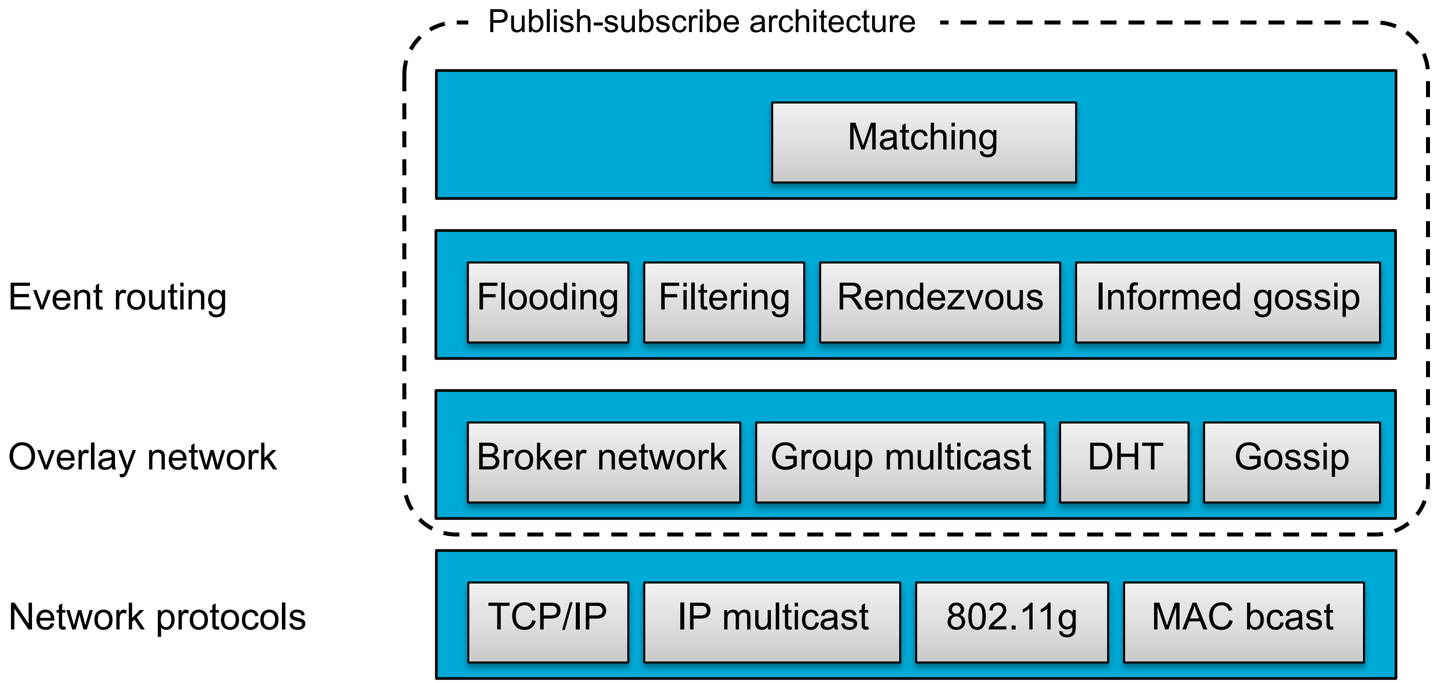
Publish-subscribe – implementation

- Goal – efficient delivery of the right events to the right subscribers with appropriate security considerations
- Some design options
  - Centralized/distributed
    - Centralized event broker
    - Network of brokers



    - Full P2P – not distinction between publishers and subscribers, i.e., everyone is a broker
  - Routing options …

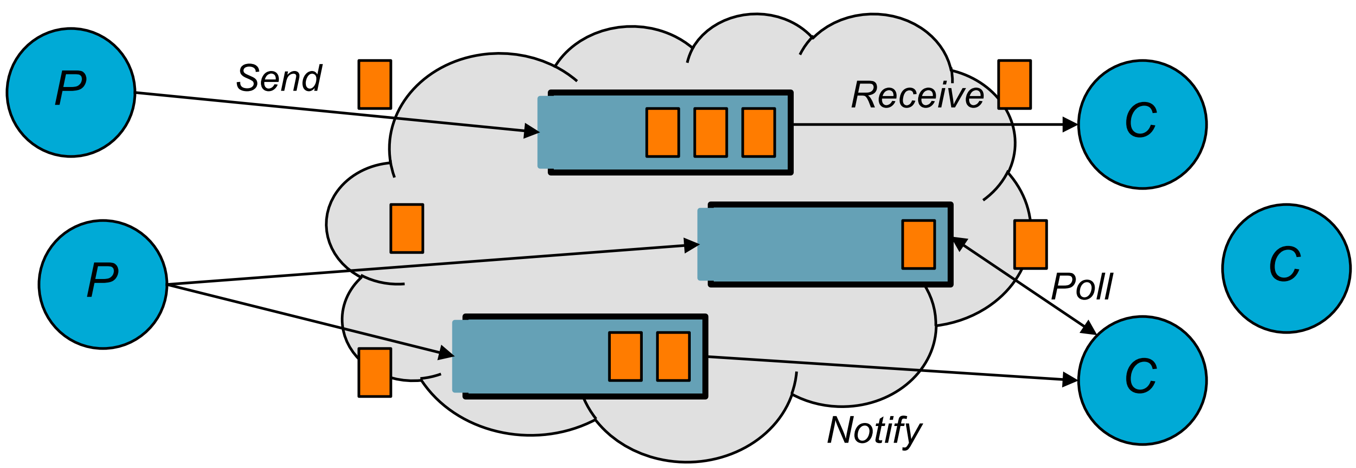
Architecture of publish-subscribe systems



- Routing options
  - Flooding – send to all, matching done at the subscriber
  - Filtering – every node in the network of brokers does filtering-based routing
  - Rendezvous – a node responsible for matching notifications and subscribers

(Distributed) message queues

- Point-to-point comm. through an intermediary queue
  - Senders place msgs into a queue, receivers removed them
    - Queues correspond to buffers at communication servers
  - E.g., IBM WebSphere MQ, Java Messaging Service, Oracle's Stream Advanced Queuing
- Styles of receive
  - Blocking – Block until an appropriate message is available
  - Non-blocking – Polling to see if a message is available
  - Notify – Notification when a message arrives



(Distributed) message queues

- Details on messages
  - Typically include dest queue, priority, delivery mode, and body
    - In Oracle's AQ, messages are rows in a DB table/queue
  - Messages are persistent
  - Typical queuing policies FIFO and priority-based
- Centralized and distributed message queues
  - In WebSphere MQ, queues are managed by *queue managers*
  - Queue managers can be inter-connected as brokers
- Use for app integration – broker takes care of application heterogeneity
  - Transforms incoming messages to target format
  - Often acts as an application gateway
  - May provide subject-based routing capabilities

Shared memory approaches

- Distributed share memory
  - Allow networked computers to share memory
  - How to make distributed memory appear local?
  - Leverage MMU
    - Page fault handler invokes DSM protocol
    - Bring page from a remote node instead of from HD
- Simplest design
  - Each virtual page in one machine at a time (no caching)
  - A directory keeps track of things, potentially a bottleneck
  - Distributed directory – hash(page#)
  - Design issues
    - Size of the page
    - Caching and consistency models

Shared memory and consistency

- Consistency model
  - When modifications to data may be seen at a given processor
  - Defines the programmer's view, placing restrictions on what values can be returned by a read (a contract)
  - Determines what optimizations are possible
- E.g., sequential consistency
  - Some basic notation
    - $W_i(x)a$ – process P_i wrote value a to x
    - $R_i(x)b$ – process P_i read value b from x

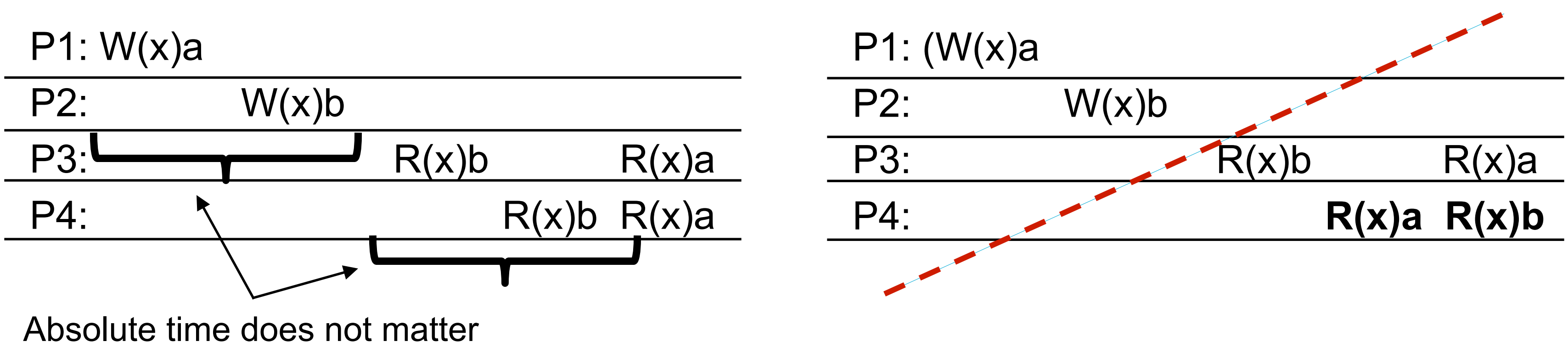
P1: W(x)a

P2: R(x)NIL R(x)a

Time to propagate

Sequential consistency

- *Result of any execution is as if operations of all processes were executed in some sequential order, and the operations of each process appear in this sequence in the order specified by its program*
  - i.e., Any valid interleaving of operations is OK, but all processes see the same interleaving



- Lineralizable – interleaving is consistent with real time at which operations occurred in the actual execution

The burden of sequential consistency

- Processor must ensure that previous memory operation is complete before proceeding to the next
- So …
  - Determine completion of write; get ack for all
  - If caching, write invalidates or updates all cached copies
  - Hold off on read requests until all writes are complete
- Maybe we can relax this a bit if next steps don’t depend on the value
  - Causal consistency …

Shared memory – tuple spaces

- First introduced with *Linda* by D. Gelernter
  - Adopted by IBM Tspaces, JavaSpaces, etc.
- Programming model
  - Processes communicate through a tuple space
  - Tuple space – a shared collection of tuples
  - Tuple – a sequence of 1+ typed data fields
  - Operations
    - Write – adds a tuple
    - Read – returns the value of a tuple w/o affecting the content of the tuple space
    - Take – returns the value of a tuple and removes the tuple
    - For read/take, provide a template; system returns any tuple that matches
  - Tuples are immutable - to modify a tuple, take it and write a new one

Shared memory – tuple spaces

- Original Linda model had a single, global tuple space
  - Aliasing of tuples; read/take matching tuples by accident
- Linda was anticipated as a centralized system
  - Performance and reliability concerns
- Distributed tuple spaces
  - Replication and alternative approaches

Summary

- The power of indirection in communication – communication through an intermediary
  - Uncoupling in space and/or time

	Group	Pub/sub	MQ	DSM	Tuples
Space uncoupled	Yes	Yes	Yes	Yes	Yes
Time uncoupled	Possible	Possible	Yes	Yes	Yes
Style	Comm	Comm	Comm	State	State
Comm pattern	1-m	1-m	1-1	1-m	1-1/1-m
Scalability	Limited	Possible	Possible	Limited	Limited
Associative	No	Content-based only	No	No	Yes