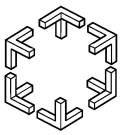
Distributed Computing and Systems
Chalmers university of technology



Group Communication

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Introduction to Lab. assignments
March 22nd, 2006

Today's schedule

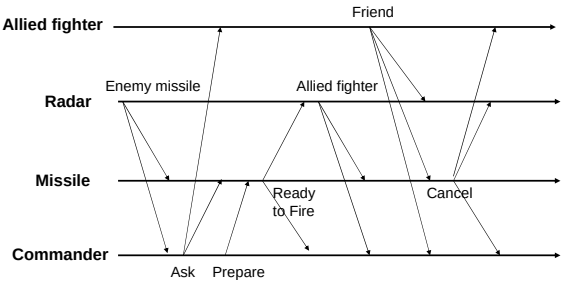
- Introduction to group communication
- Desired group communication
- Multicast communication
- Group membership service

Coordination in distributed systems

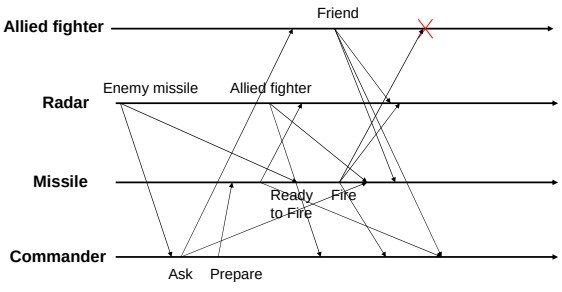
- Coordination is needed by distributed systems but hard to achieve:
  - Events happen concurrently
  - Communication links are not reliable
  - Computers can crash
  - New nodes can join the systems
  - Asynchronous environments

⇒ expect an efficient way to coordinate a group of processes

Distributed Systems in Games: A Synchronous Example



An Asynchronous Example in Games



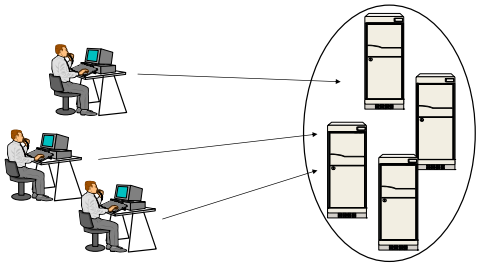
Group communication

- What is a group?
  - A number of processes which cooperate to provide a service.
  - An abstract identity to name a collection of processes.
- Group Communication
  - For coordination among processes of a group.

Who Needs Group Communication?

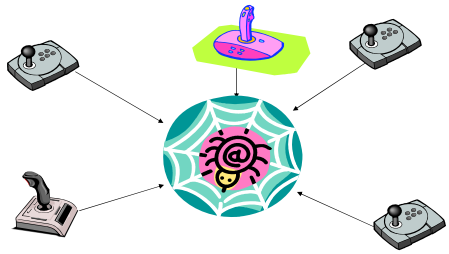
- Highly available servers (client-server)
- Database Replication
- Multimedia Conferencing
- Online Game
- Cluster management
- …

Distributed Web Servers



- High availability

Online Games



- Fault-tolerance, Order

Different Comm. Methods

- Unicast
  - Point-to-Point Communication
  - Multiple copies are sent.
- Broadcast
  - One-to-All Communication
  - Abuse of Network Bandwidth
- **Multicast**
  - One-to-multiple Communication

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Group Comm. Properties

- Name Abstraction
- Efficiency ⇒ Multicast
- Delivery Guarantee
  - Ordering
  - Failure behavior
  - Reliability
  - …
- Dynamic Membership ⇒ Group membership service

Properties of Communication

- Ordering
  - Total ordering, causal ordering
- Failure behavior
- Reliability
  - Validity, integrity, agreement

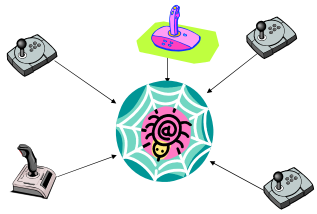
Properties of Group

- Name of group
- Addresses of group members
- Dynamic group membership

- Options:
  - Peer group or client-server group
  - Closed or Open Group

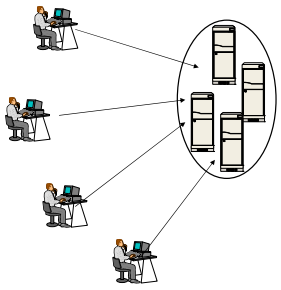
Peer Group

- All the members are equal.
- All the members send messages to the group.
- All the members receive all the messages.



Client-Server Group

- Replicated servers.
- Clients do not care which server answers.



Desired Group Communication

- Name Abstraction
- Efficiency ⇒ Multicast
- Delivery Guarantees ⇒ Reliability, Ordering
- Dynamic Membership ⇒ Group membership service

Today's schedule

- Introduction to group communication
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Multicast communication

- Use network hardware support for broadcast or multicast when it is available.
- Send message over a distribution tree.
- Minimize the time and bandwidth utilization

Reliability

Correct processes: those that never fail.

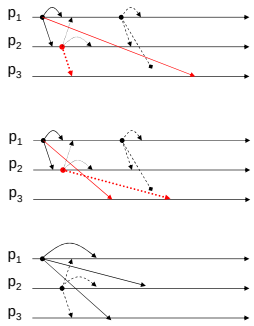
- Integrity
  A *correct* process *delivers* a message at most once.
- Validity
  A message from a *correct* process will be *delivered* by the process eventually.
- Agreement
  A message *delivered* by a *correct* process will be *delivered* by all other *correct* processes in the group.

⇒ Validity + Agreement = Liveness

Ordering

Assumptions: a process belongs to at most one group.

- FIFO
  - if $m_p \rightarrow m'_p$, all correct processes *that deliver* m'_p will deliver m_p before m'_p.
- Causal
  - if $m \rightarrow m'$, all correct processes *that deliver* m' will deliver m before m'.
- Total
  - if a correct process delivers m before m', all other correct processes *that deliver* m' will deliver m before m'.

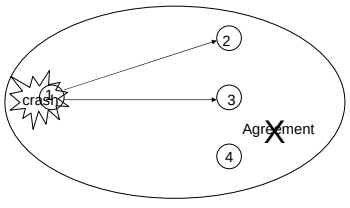


Examples

- Assumption:
  - Reliable one-to-one *send* operation (e.g. TCP)
- Basic multicast
  - Requirement:
    - All correct processes will eventually deliver the message from a *correct* sender.
  - Implementation:
    - ***B-multicast(g, m)***: $\forall p \in g$: *send(p, m);*
    - *On receive(m) at p:* ***B-deliver(m)*** *at p.*

    ⇒ Properties: integrity, validity.

Basic multicast: Agreement?



Examples (cont.)

- Reliable multicast
  - Requirements: integrity, validity, *agreement*
  - Implementation:
    - *Received := {};*
    - ***R-multicast(g, m)*** *at process p: B-multicast(g, m);*
    - *On B-deliver(m) at process q*
      if(m ∉ Received)
      Received := Received ∪ {m};
      if(q ≠ p) B-multicast(g, m);
      R-deliver(m)*;*
      end if

    ⇒ Inefficient: each message is sent |g| times to each process

  - Encourage to implement in more efficient ways (e.g. IP-multicast)

Examples (cont.)

- FIFO-ordered multicast:
  - Assumption:
    - a process belongs to at most one group.
  - Implementation:
    - Local variables at *p*: $S_p = 1$, $R_p[\,|g|\,]=\{0\}$;
    - ***FO-multicast(g, m)*** *at p:*
      B-multicast(g, <m, S_p>);
      S_p++;
    - *On B-deliver(<m, S>) from q:*
      if(S = $R_p[q] + 1$)
      FO-deliver(m)*;*
      $R_p[q]$:= S;
      else if(S > $R_p[q] + 1$)
      place <m, S> in the queue until S = $R_p[q] + 1$;
      FO-deliver(m)*;*
      $R_p[q]$:= S;
      end if
  - Encourage to implement causally ordered, totally ordered multicasts.

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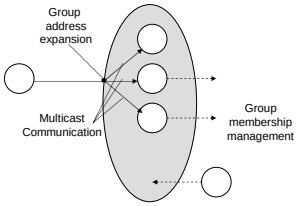
Group membership service

- Four tasks:
  - Interface for group membership changes
  - Failure detector
  - Membership change notification
  - Group address expansion
- Group partition:
  - Primary-partition
  - Partitionable

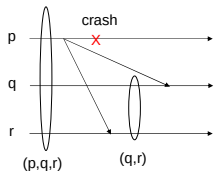


Group views

- Group views:
  - Lists of the current ordered group members
  - A new one is generated when processes join or leave/fail.
- View delivery
  - when the membership changes & a member is notified of it.
  - Requirements
    - Order
      - if *p* delivers $v(g) \rightarrow v'(g)$, no other process delivers $v'(g) \rightarrow v(g)$.
    - Integrity
      - if *p* delivers $v(g)$, $p \in v(g)$.
    - Non-triviality
      - if *q* joins a group and becomes indefinitely reachable from *p*, eventually *q* is always in the view *p* delivers.

View-synchronous group comm.

- Extend the reliable multicast semantics with group views.
  - Agreement
    - Correct processes deliver the same set of messages *in any given view*
  - Validity (closed group)
    - Correct processes always deliver the messages they send.
    - $p \in v_0(g)$ does not deliver *m* in $v_0(g)$ $\Rightarrow p \notin v_1(g)$ that *m*-delivering processes deliver
  - Integrity



Examples

- Ensemble: reliable group communication toolkit
  - Previous talk

IP-multicast

- IP: 224.0.0.1 - 224.0.0.255 (permanent)
- Multicast:
  - Yes:
    - efficiency
  - No:
    - Reliability
    - Ordering
- Group membership service:
  - Yes:
    - Interface for group membership change
    - Group address expansion
  - No:
    - Failure detector
    - Membership change notification

References

- *Distributed Systems: Concepts and Design* by G. Coulouris et al., ISBN 0-201-61918-0
  - Section 4.5 Group Communication
  - Section 11.4 Multicast Communication
  - Section 14.2.2 Group Communication
- …