CprE 450/550X
Distributed Systems and Middleware

Consistency & Replication

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Readings for Today's Lecture

- References
  - Chapter 6 of "Distributed Systems: Principles and Paradigms"

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Client-Centric Consistency Models

- Data-centric consistency models
  - **Multiple concurrent processes may simultaneously update the data store**
- Today, we are focusing on a special class of distributed data stores.
  - **There are no or very few simultaneous updates on the data store.**
  - **When such concurrent updates happen, they can be easily resoved.**
  - **Most operations are reading.**
  - **We will introduce a very weak consistency model – eventual consistency.**

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Client-Centric Consistency Models

- Examples in which concurrency happens in a restricted manner:
  - **Database systems: read-only**
  - **DNS**
  - **WWW**
  - **They are in common that they can tolerate a relatively high degree of inconsistency.**
- Eventual consistency: If no updates take place for a long time, all replicas will gradually and eventually become consistent.

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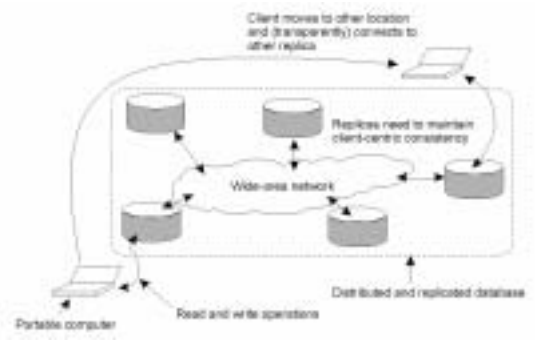
Eventual Consistency: Issue

Will work fine if client always access the same replica.

What about when different replicas are accessed?



The principle of a mobile user accessing different replicas of a distributed database.

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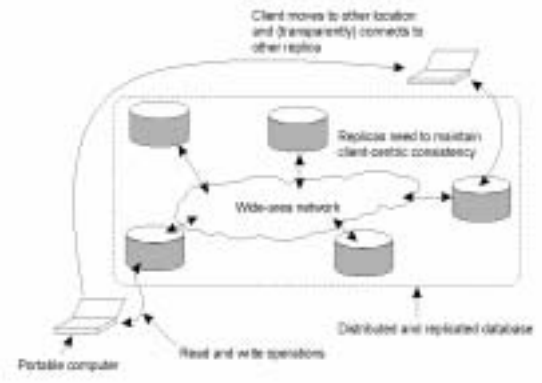
The previous problem can be alleviated

- By Using Client-centric consistency:
  - **Client-centric consistency provides guarantees for a single client concerning the consistency of accesses to a data store by that client**
  - **No guarantees are given concerning concurrent accesses by different clients.**
  - **Originated from the work Bayou.**
  - **In this model, we assume there is only one process that is permitted to update the data store.**

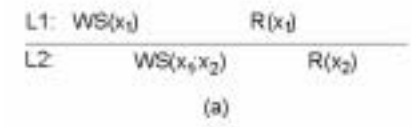
Monotonic Reads

- Condition:

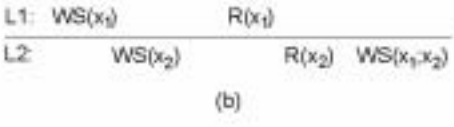
  If a process reads the value of a data item x, any successive read operations on x by that process will always return that same value or a more recent value.



Monotonic Reads



(a)



(b)

The read operations performed by a single process *P* at two different local copies of the same data store.

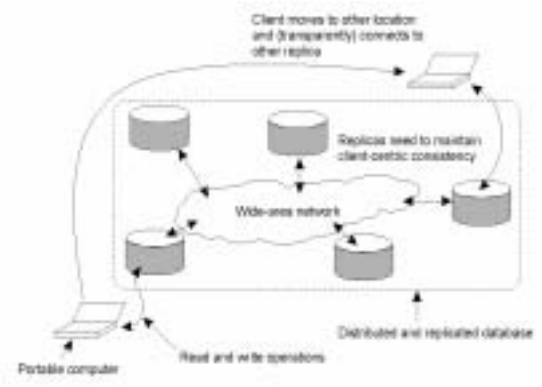
a) A monotonic-read consistent data store

b) A data store that does not provide monotonic reads.

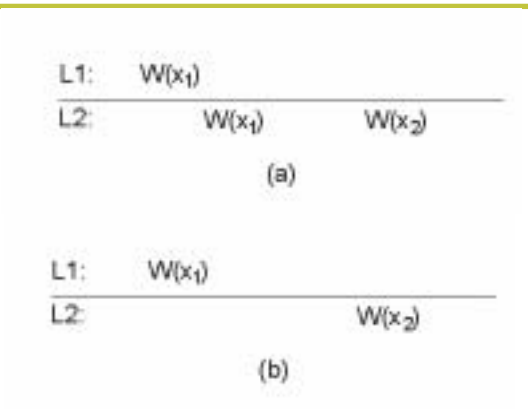
Monotonic Writes

- Condition:

  A write operation by a process on a data item x is completed before any successive write operation on x by the same process.



Monotonic Writes



- The write operations performed by a single process *P* at two different local copies of the same data store

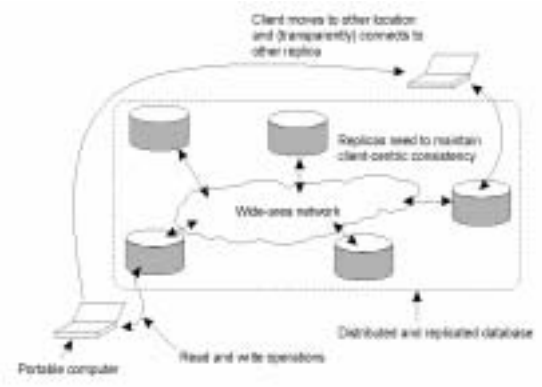
a) A monotonic-write consistent data store.

b) A data store that does not provide monotonic-write consistency.

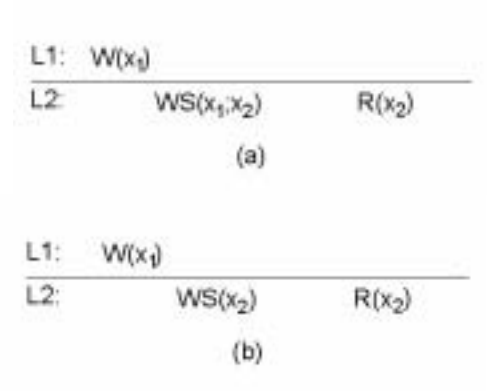
Read your Writes

- Condition:

  The effect of a write operation by a process on a data item x will always be seen by a successive read operation on x by the same process.



Read Your Writes

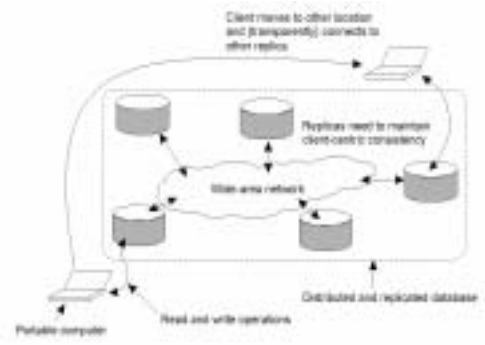


a) A data store that provides read-your-writes consistency.
b) A data store that does not.

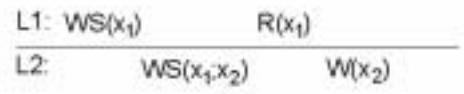
Writes Follow Reads

- Condition:

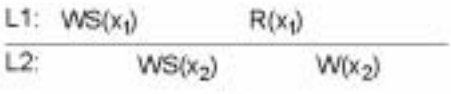
  A write operation by a process on a data item x following a previous read operation on x by the same process, is guaranteed to take place on the same or a more recent value of x that was read.



Writes Follow Reads



(a)



(b)

a) A writes-follow-reads consistent data store
b) A data store that does not provide writes-follow-reads consistency

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Implementations Issues

- Relatively straightforward without considering performance issues
- Each write operation is assigned a globally unique identifier.

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Distributed Protocols

- Replica Placement
- Update Propagation
- Epidemic Protocols

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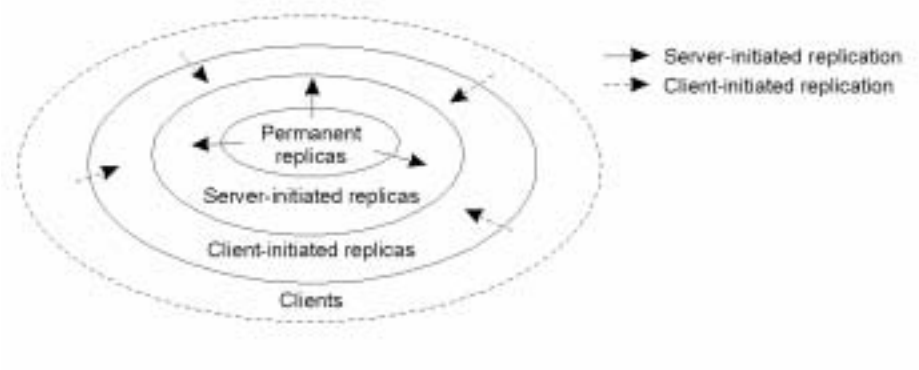
Replica Placement



The logical organization of different kinds of copies of a data store into three concentric rings.

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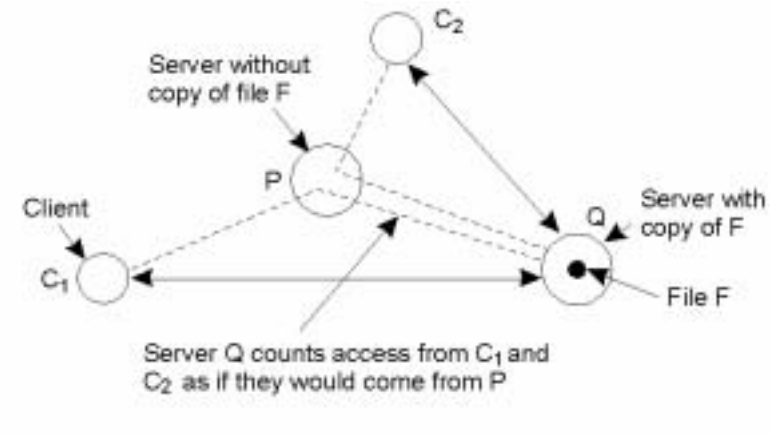
Server-Initiated Replicas



Counting access requests from different clients.

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Client-Initiated Replicas

- Client cache
- Placement of client cache

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Update Propagaation

- State versus operations
- Pull versus pull protocols
- Unicast versus multicast

Pull versus Push Protocols

Issue	Push-based	Pull-based
State of server	List of client replicas and caches	None
Messages sent	Update (and possibly fetch update later)	Poll and update
Response time at client	Immediate (or fetch-update time)	Fetch-update time

A comparison between push-based and pull-based protocols in the case of multiple client, single server systems.

Epidemic Protocols

- EP does not solve update conflicts. Propagate updates to all replicas in as few messages as possible.
- Update Propagation Models
  - **Infective if it holds an update that it is willing to spread to other servers**
  - **Susceptible if a server has not been updated yet.**
  - **Removed if an updated server that is not willing to or able to spread its update**
- Anti-entropy model:
  - **Server P chooses Q randomly and then exchanges updates with Q:**
    - » **P pushes its own update to Q**
    - » **P pulls in new updates from Q**
    - » **P and Q send updates to each other.**

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Epidemic Protocols

- Variant: Rumor Spreading/gossiping

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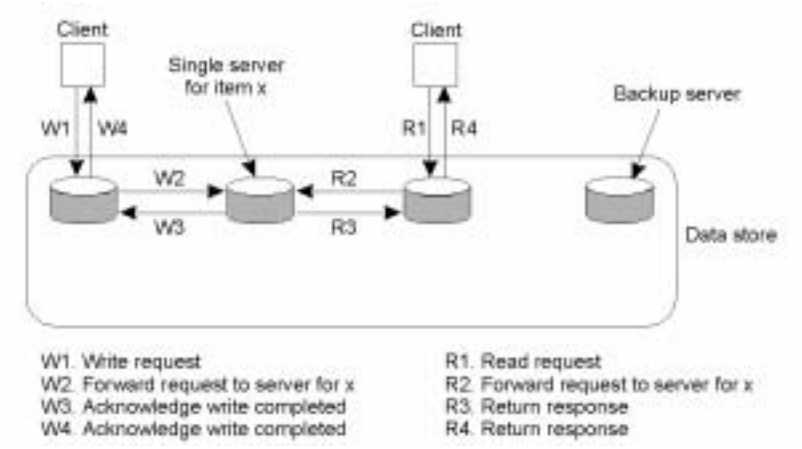
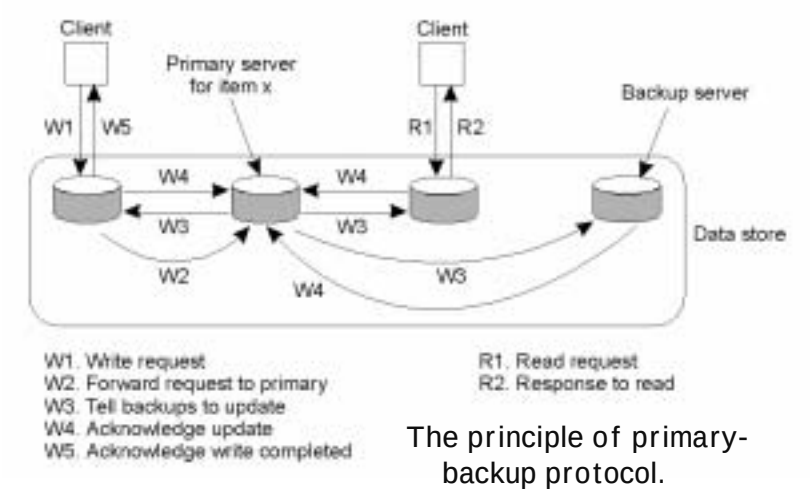
Remote-Write Protocols (1)



Primary-based remote-write protocol with a fixed server to which all read and write operations are forwarded.

Remote-Write Protocols (2)



The principle of primary-backup protocol.

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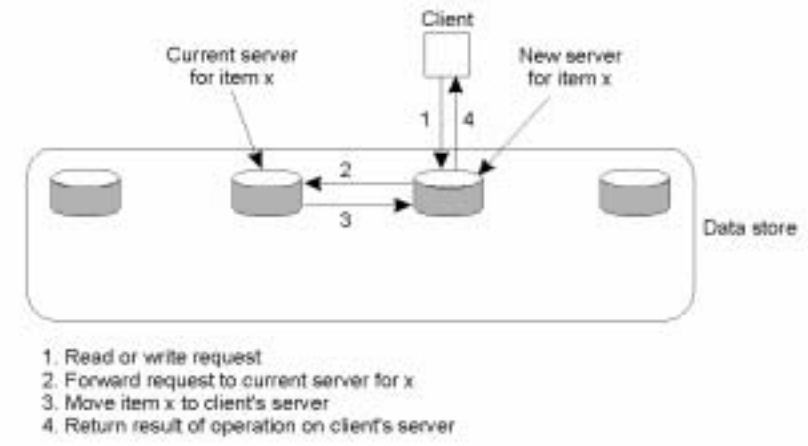
Local-Write Protocols (1)



Primary-based local-write protocol in which a single copy is migrated between processes.

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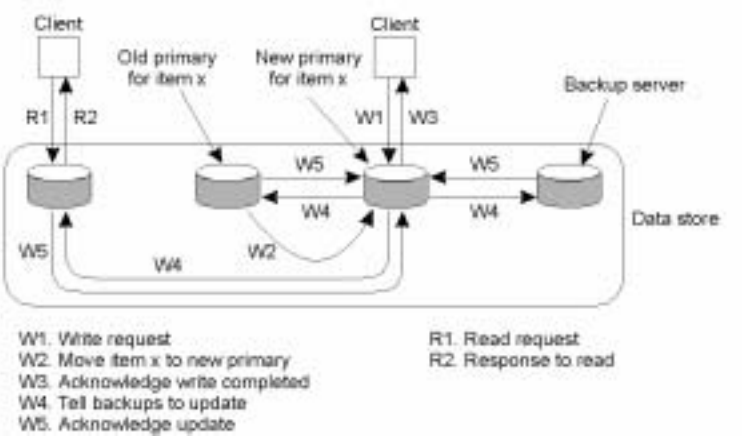
Local-Write Protocols (2)



Primary-backup protocol in which the primary migrates to the process wanting to perform an update.

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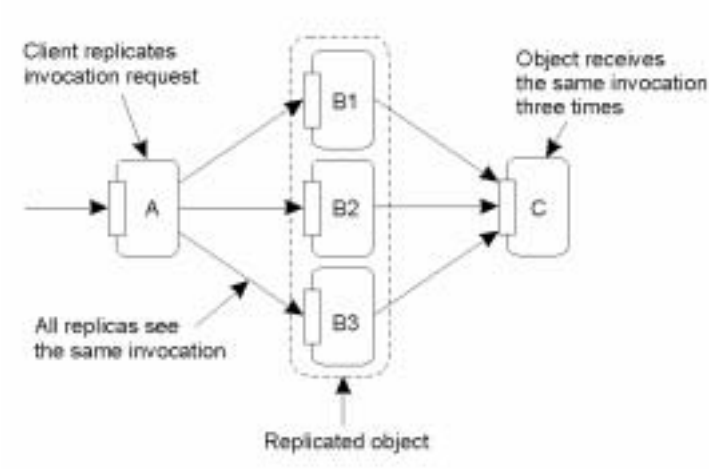
Active Replication (1)



The problem of replicated invocations.

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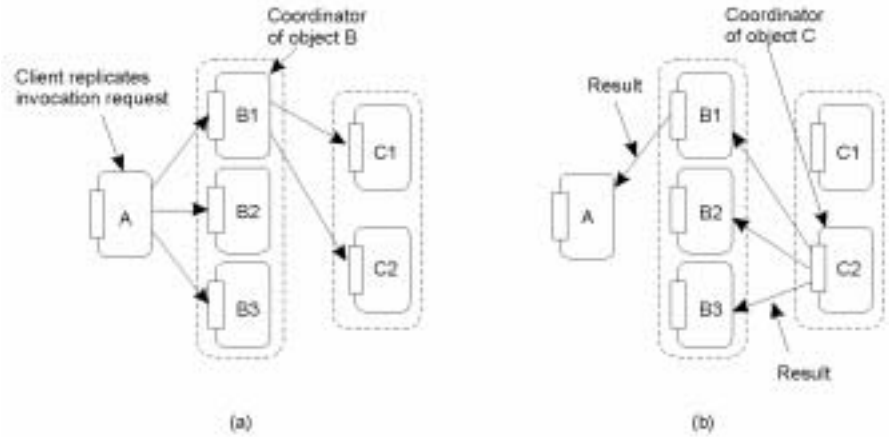
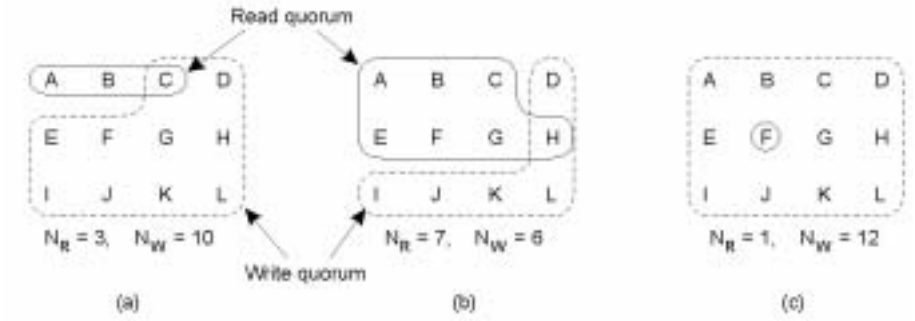
Active Replication (2)



a) Forwarding an invocation request from a replicated object.
b) Returning a reply to a replicated object.

Quorum-Based Protocols



Three examples of the voting algorithm:

a) A correct choice of read and write set
b) A choice that may lead to write-write conflicts
c) A correct choice, known as ROWA (read one, write all)

Orca

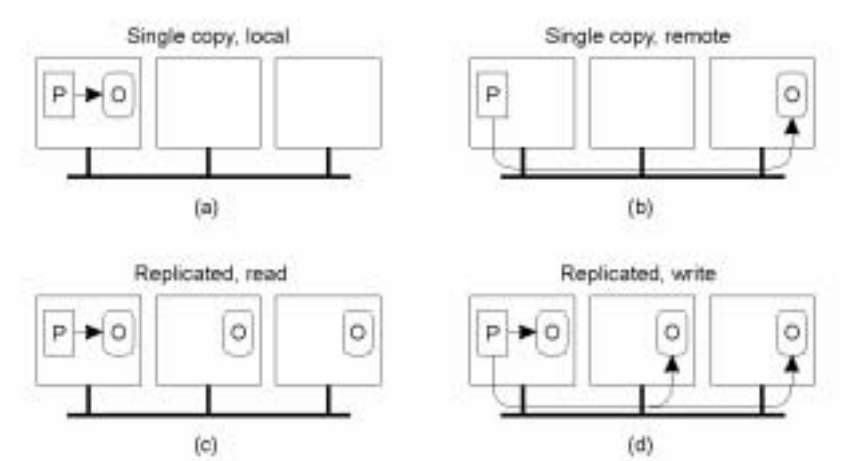
```
OBJECT IMPLEMENTATION stack;
  top: integer;                          # variable indicating the top
  stack: ARRAY[integer 0..N-1] OF integer  # storage for the stack

  OPERATION push (item: integer)         # function returning nothing
  BEGIN
    GUARD top < N DO
        stack [top] := item;             # push item onto the stack
        top := top + 1;                  # increment the stack pointer
    OD;
  END;

  OPERATION  pop():integer;              # function returning an integer
  BEGIN
    GUARD top > 0 DO                     # suspend if the stack is empty
         top := top – 1;                 # decrement the stack pointer
        RETURN stack [top];              # return the top item
    OD;
  END;
BEGIN
  top := 0;                              # initialization
END;
```

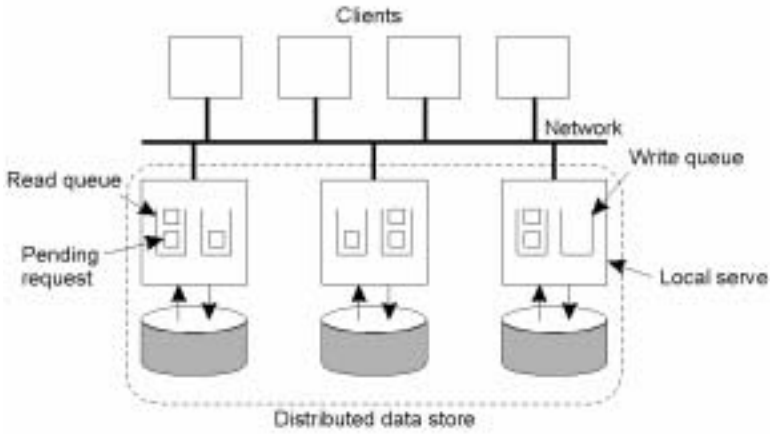
A simplified stack object in Orca, with internal data and two operations.

Management of Shared Objects in Orca



Four cases of a process *P* performing an operation on an object *O* in Orca.

Casually-Consistent Lazy Replication



The general organization of a distributed data store. Clients are assumed to also handle consistency-related communication.

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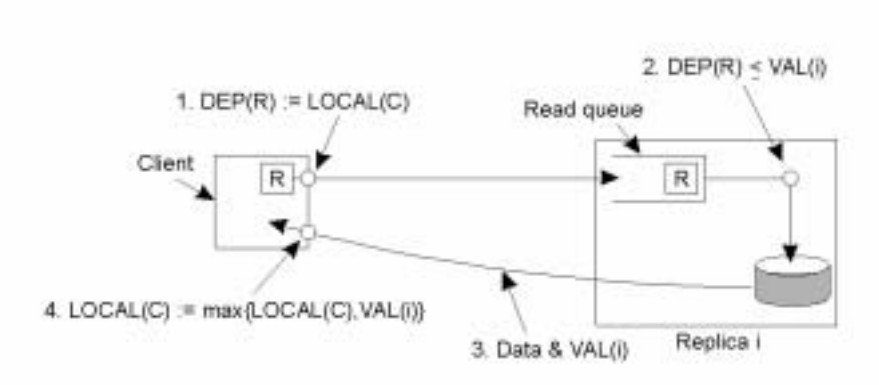
Processing Read Operations



Performing a read operation at a local copy.

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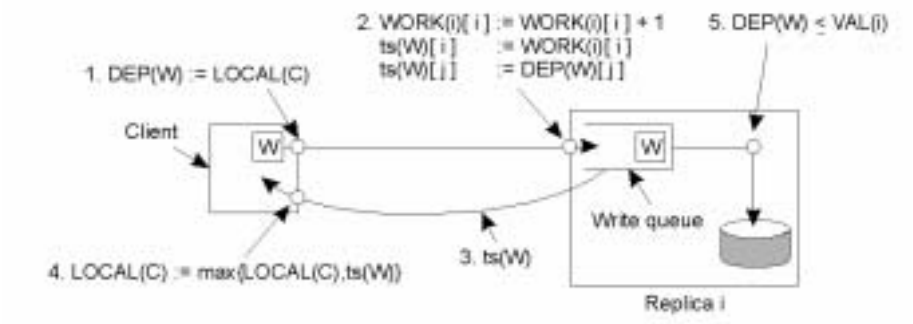
Processing Write Operations



Performing a write operation at a local copy.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