Databases

Lesson 02

Data Hoarding and Caching

Large databases— kept on servers, remote computing systems, or networks

- A mobile device cannot store a large database
- Retrieving the required data from a database server during every computation— impractical due to time constraints

Hoarding (caching) of specific database in mobile devices

- A mobile device— not always connected to the server or network, neither does the device retrieve data from a server or a network for each computation
- Rather, the device caches required specific data, which may be required for future computations, during the interval in which the device is connected to the server or network

Hoarding of Cached Data

- Database architecture— Two-tier or multi-tier databases
- Databases reside at the remote servers and the copies of these databases are hoarded and cached at the client tier

Synchronizing the local copies at the device

- At tier 2 or tier 3, the server retrieves
- Server transmits the data record (s) to tier 1 using business logic and sends and synchronizes the local copies at the device
- Local copies function as device caches

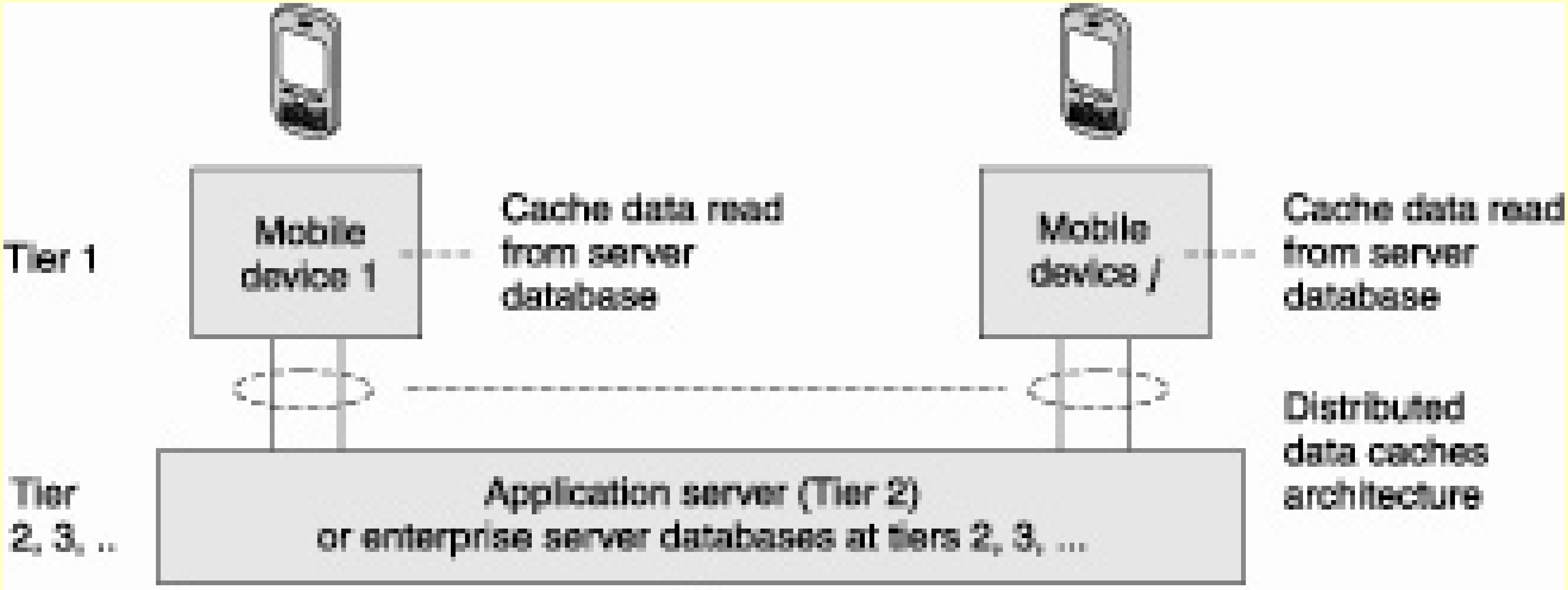
Advantage of hoarding

- No access latency (delay in retrieving the queried record from the server over wireless mobile networks)
- The client device API has instantaneous data access to hoarded or cached data
- After a device caches the data distributed by the server, the data is hoarded at the device

Disadvantage of hoarding

- Needs maintain the consistency of the cached data with the database at the server

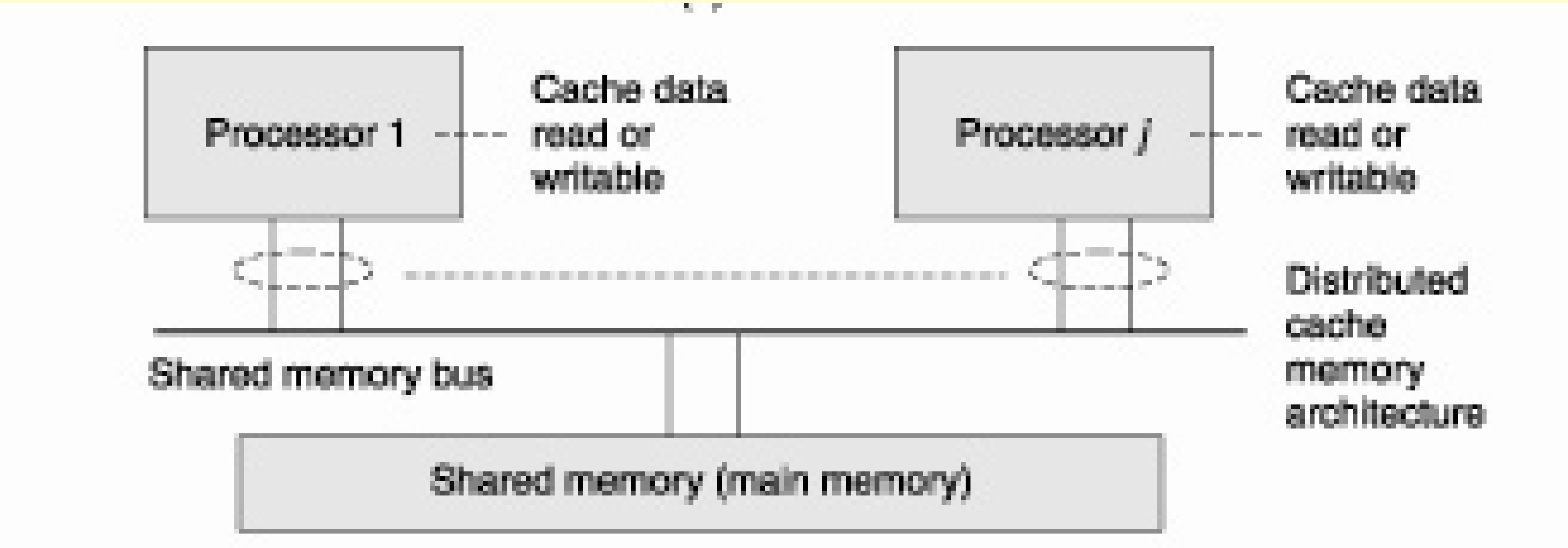
Distributed data caches in mobile devices


Tier 1
Mobile device 1
Cache data read from server database
Mobile device j
Cache data read from server database
Distributed data caches architecture
Tier 2, 3, ..
Application server (Tier 2) or enterprise server databases at tiers 2, 3, ...

Architecture of distributed data caches in mobile devices

- Similar architecture to distributed cache memory in multiprocessor systems
- The copies cached at the devices are equivalent to the cache memories at the processors in a multiprocessor system with a shared main memory and copies of the main memory data stored at different locations

Architecture for a distributed cache memory in multiprocessor systems


Processor 1
Cache data read or writable
Processor *j*
Cache data read or writable
Distributed cache memory architecture
Shared memory bus
Shared memory (main memory)

Data Caches at Client device

1. Using the pushed (disseminated) data records from a server

- Caching leads to a reduced access interval as compared to the pull (on-demand) mode of data fetching
- Also reduces the dependence on pushing precedence at the server

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Caching of data records at Client device

2. Can be based on pushed ‘hot records’
3. Cost-based data replacement or caching— Caching can be based on the ratio of two parameters— access probability (at the device) and pushing rates (from the server) for each record

Cost-based data replacement Method

- Least frequently pushed records and the pushed records having larger access time placed in the database at the device
- This access method, therefore, use the ratio of two parameters— average access time between two successive instances of access to the record and pushing rates for the record

Pre-fetching

- Alternative to caching of disseminated data entails requesting for and pulling records that may be required later
- Perfetching — keeping future needs in view instead of caching from the pushed records

Pre-fetching

- Reduces server load
- Reduces the cost of cache-misses
- The term ‘cost of cache-misses’ refers to the time taken in accessing a record at the server in case that record is not found in the device database when required by the device API

Cache consistency

- Also called cache coherence
- Requires a mechanism to ensure that a database record identical at the server as well as at the device caches and that only the valid cache records are used for computations

Cache access Protocols based on Caching Invalidation Mechanisms

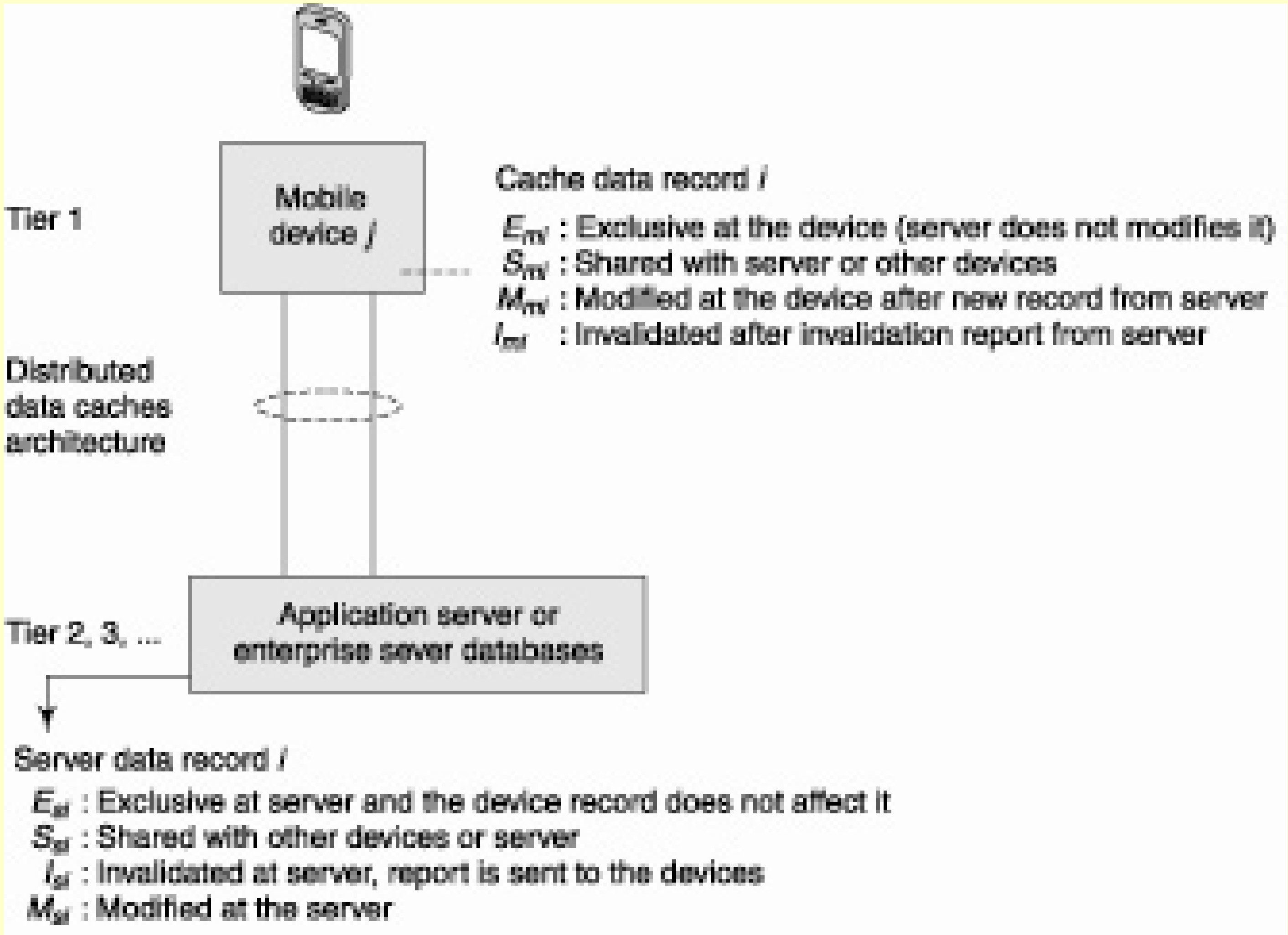
- Access protocols cached record at the client device invalidated

  – Due to expiry or modification of the record at the database server

Cache invalidation

- A process by which a cached data item or record becomes invalid and thus unusable because of modification, expiry, or invalidation at another computing system or server.
- Cache invalidation mechanisms are means by which the server conveys this information to client devices

Four possible states (*M*, *E*, *S*, or I) of a data record *i* at any instance at the server database and device *j* cache



Tier 1

Mobile device *j*

Cache data record *i*

E_{mi} : Exclusive at the device (server does not modifies it)
S_{mi} : Shared with server or other devices
M_{mi} : Modified at the device after new record from server
I_{mi} : Invalidated after invalidation report from server

Distributed data caches architecture

Tier 2, 3, ...

Application server or enterprise sever databases

Server data record *i*

E_{si} : Exclusive at server and the device record does not affect it
S_{si} : Shared with other devices or server
I_{si} : Invalidated at server, report is sent to the devices
M_{si} : Modified at the server

Cache-invalidation mechanisms under the MESI protocol

- Entail that each record (line) in a cache has a tag to specify its state at any given instant and the tag is updated (modified) as soon as the state of the record changes

MESI Protocol one of four possible tags

- Assigned cache state

1. M– Modified (after rewriting)
2. E– Exclusive
3. S– Shared
4. I – invalidated (after expiry or when new data becomes available) at any given instance.

Summary

- Two-tier or multi-tier databases
- Databases reside at the remote servers and the copies of these databases are cached at the client tiers
- Computing API at the mobile device (first tier) uses the cached local copy

… Summary

- Architecture of distributed data caches in mobile devices and a similar architecture of distributed cache memory in multiprocessor systems
- Cache Access Protocols
- Cache Invalidation Mechanisms
- MESI protocol

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End of Lesson 02
Data Hoarding and Caching