CPET 565/CPET 499
Mobile Computing Systems
Lecture 8
Data Dissemination and Management
2 of 3

Based on the Text used in the course: Fundamentals of Mobile & Pervasive Computing, 2005, by Frank Adelstein, et. al, from McGraw-Hill

Fall 2012

A Specialty Course for Purdue University's M.S. in Technology Graduate Program

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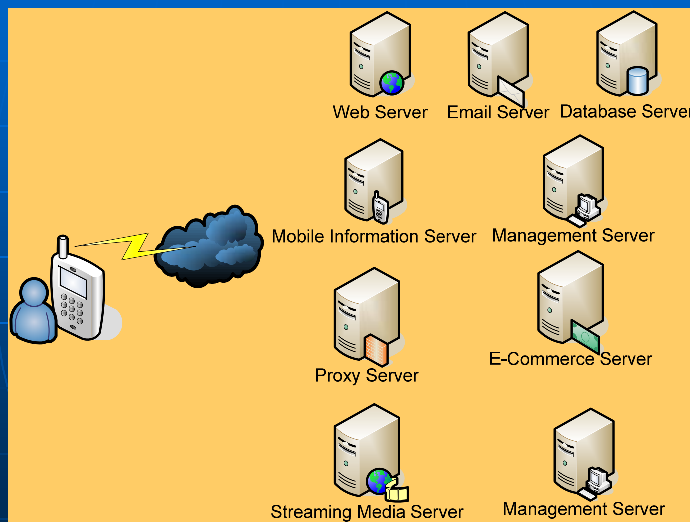
Data Dissemination and Management - Topics

- Introduction
- Challenges
- Data Dissemination
- Mobile Data Caching
- Mobile Cache Maintenance Schemes
- Mobile Web Caching
- Summary

Data Dissemination and Management – Data Dissemination



Data Dissemination

- Pull or On-Demand Mode
  - ✓Request – through uplink
  - ✓Reply – waiting for response
  - ✓Consume extra battery power
  - ✓Competing bandwidth with other Mobile users
- Push or Broadcast Mode
  - ✓Data server periodically broadcasts the data
  - ✓Indexing information: quick check for interesting or not
  - ✓Index, Stock, Traffic, Sales; Index, Stock, Traffic, Sales; …
  - ✓Down Load interesting data

Data Dissemination

- Advantages of Data Dissemination – Push Mode
  - Pull or On-Demand Mode
    - Send Hot Data Items
    - Conserve bandwidth – eliminates repetitive on-demand data transfers for the same data items to different mobile users
    - Conserve the mobile node's energy – eliminating uplink transmission

Data Dissemination – Wireless Bandwidth Utilization

- Logical Channels
  - Uplink Request Channel: Data query
  - On-Demand Downlink Channel: Reply data items
  - Broadcast Downlink Channel: hot data items
- Physical Channels
  - On-Demand
    - Distributed medium access channels
  - Broadcast
    - Broadcast schedule
    - Slotted data items (pages)

Data Dissemination
Bandwidth Allocation

- Bandwidth Allocation
  - Bandwidth for on-demand channel – B_0
  - Bandwidth for broadcast channel – B_b
  - Available bandwidth $B = B_0 + B_b$
- Data Server
  - N data items: D1, D2, …, Dn
    - D1 – the most popular data items, with popularity ratio P1 (between 0 and 1)
    - D2 – the next popular data item with popularity ratio P2 (between 0 and 1)
  - Size for each data item – S
  - Size of each data query - R
- Each mobile node generates requests at an average rate of r

Data Dissemination
Allocate All Bandwidth for On-Demand

- Compute Average Access Time T over all data items
  - T = Tb + To
  - Tb – average access time to access a data item from the broadcast channel
  - To – average access time to access an on demand item

Data Dissemination
Allocate All Bandwidth for On-Demand

- The Average Time to service an on-demand request
  - $(S + R)/B_0$
- If all data items are provided only on-demand, the average rate for all the on-demand items will be
  - M x r (queuing generation rate)
  - M – the number of mobile nodes in the wireless cell
  - r –average request rate of a mobile node

Data Dissemination
Allocate All Bandwidth for On-Demand

- Applying Queuing Theory to Analyze the Problem
  - As the number of mobile users ↑ (increases), the average queuing generation rate (M x r) ↑
  - As (M x r) approaches → the service rate [B0/(S+R)], the average service time (including queuing delay) ↑ rapidly
  - What is acceptable server time threshold?
  - Allocating all the bandwidth to the on-demand channels → Poor Scalability

Data Dissemination
Allocate All Bandwidth for Broadcast Channel

- If all the data items are published on the broadcast channel with the same frequency (ignoring the popularity ratio)
- Average waiting: n/2 data items
- Average access time for a data item:
  - $(n/2) \times (S/B_b)$
  - Independent of number of mobile nodes in the cell
  - Average access time proportional to the number of data items n
  - Avg. Access Time ↑ as the number of data items to broadcast ↑

Data Dissemination
Bandwidth Allocation – A Simple Case

- **Two data items: D1 and D2**
- **P1 of D1 > P2 of D2 (D1 is more popular than D2)**
  - Temp to broadcast D1 all the time → cause D2 access time to be infinite (D2 is never available)
- **Broadcast frequency calculation to achieve minimum average access time**
  - $F1 = \sqrt{P1}/(\sqrt{P1} + \sqrt{P2})$
  - $F2 = \sqrt{P2}/(\sqrt{P1} + \sqrt{P2})$
  - An example: P1 = 0.9, P2 = 0.1
    - sqrt(0.9) = 0.9487, sqrt(0.1) = 0.3162
    - F1 = 0.75
    - F2 = 0.25
    - D1 broadcast 3-times more than D2, even D1 is 9-times more popular than D2

Data Dissemination
Bandwidth Allocation – N Data Items

- N data items: D1, D2, …, Dn
- Popularity Ratio: P1, P2, …, Pn
- Broadcast Frequencies: F1, F2, …, Fn, for achieving minimum latency
  - Where $fi = \sqrt{Pi}/Q$,
  - $Q = \sqrt{P1} + \sqrt{P2} + .. + \sqrt{Pn}$
  - Minimum latency: P1*t1 + P2*t2 +… + Pn*tn
  - t1, t2, …, tn are average access latencies of D1, D2, …, Dn

Data Dissemination
Algorithm by Imielinski and Viswanathan 1994

- Publishing modes save the energy of mobile node
  - At the cost of increasing access latency
- Goal: to put as many hot items on the broadcast channel as possible
  - Under the constraint that the average access latency is below a certain threshold L
- Algorithm
  - What data items to put on the broadcast channel?
  - Bandwidth allocation?

Data Dissemination
Algorithm by Imielinski and Viswanathan 1994

- Algorithm

For i = N down to 1 do:

Begin

1. Assign D1, …, Di to the broadcast channel
2. Assign Di+1, …, DN to the on-demand channel
3. Determine the optimal value of Bb and Bo, to minimize the access time T, as follows
   - a. Compute To by modeling on-demand channel as M/M/1 (or M/D/1) queue
   - b. Compute Tb by using the optimal broadcast frequencies F1, …, Fi
   - c. Compute optimal value of B_b which minimizes the function T = To + Tb.
4. if T <= L then break

End

Data Dissemination
Queuing Theory – An Introduction

- The M/M/1 Queue (Makovian, Poisson arrival, with exponential service time)
  - The most basic and important queuing model with
  - Poisson arrivals (random arrival with rate λ)
  - Exponential service times (with mean 1/μ, μ is the service rate)
  - 1 Server
  - An infinite length buffer: FIFO

Data Dissemination
Queuing Theory – An Introduction

- **The M/D/1 Queue (Makovian, Poisosn arrival process, with a deterministic service time)**
  - **A single-queue single server model**
  - **Poisson arrivals (random arrival with rate λ)**
  - **Constant service times**
  - **1 Server with constant service time**
  - **An infinite length buffer: FIFO**

Data Dissemination
Broadcast Disk Scheduling

- The Task
  - Decide which data items to publish
  - Determine how often to publish a data item
- Logical View of Broadcast Channel
  - A memory disk in the air: an extension to the memory hierarchy of the mobile device
- Physical Structure
  - Multiple virtual disks, spinning at different rated
  - Fastest-spinning disk: hottest data item
  - Next-fast disk: next hottest data item

Data Dissemination

Broadcast Disk Scheduling

- An Example (Figure 3-5)
- 9 Data items:
  - D1, D2, …, D9
- 3 Disks
  - Disk 1: D1
  - Disk 2: D2, D3, D4, D5
  - Disk 3: D6, D7, D8, D9
- Frequency of Broadcast
  - Items on Disk 1 appear 4-times as frequently as those on disk 3
  - Items on Disk 2 appear 2-times as frequently as those on disk 3
- Speed of Spinning
  - Disk 1 – Fastest
  - Disk 2 - Middle
  - Disk 3 - Slowest

Data Dissemination

Broadcast Disk Scheduling

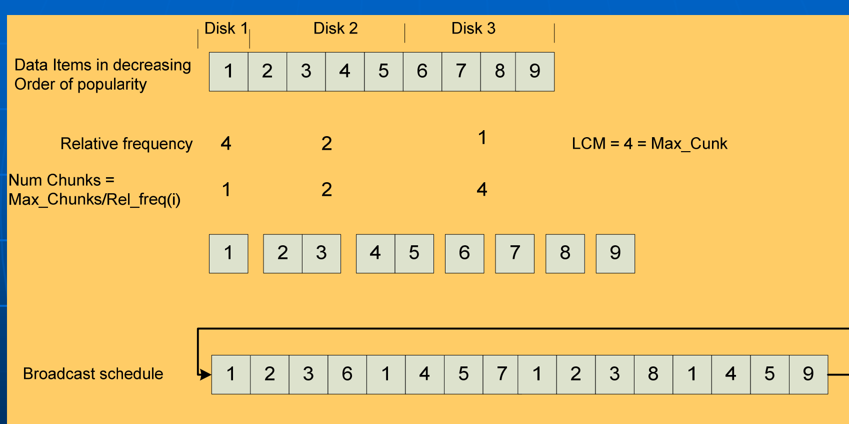


Figure 3.5 Example derivation of broadcast schedule for broadcast disks
Adapted from the book "Fundamentals of Mobile and Pervasive Computing, 2005, by Frank Adelstein, et. al, McGraw-Hill

Data Dissemination

Broadcast Disk Scheduling – AAFZ Algorithm

- Developed by Acharaya, Alonso, Franklin, and Zodnik
- Scheduling of Broadcast Channel that achieves a selected relative spinning of the disk
- Inputs
  - Number of disks
  - The assignment of data items to the disk
  - Relative spinning frequencies of the disks
- Output
  - Broadcast schedule
- An Example – Figure 3-5
  - Rel_freq(disk_1) = 4
  - Rel_freq(disk_2) = 2
  - Rel_freq(disk_3) = 1

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Data Dissemination

Broadcast Disk Scheduling – AAFZ Algorithm

1. Order the data items from the hottest to coldest
2. Partition the list into multiple ranges, called disks. Each disk consists of data items which nearly same popularity ratio. Let the number of disks chosen be num_disks.
3. Choose the relative frequency of broadcast for each disk
4. Cluster the items in each disk into smaller units called chunks; number_chunk(i) = max_chunks/rel_freq(i), where max_chunks is the least common multiple of relative frequencies

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Data Dissemination

Broadcast Disk Scheduling – AAFZ Algorithm

5. Create broadcast schedule as follows:
   a. For i = 0 to mark_chunks -1
      i. For j = 1 to n
         1. K = I mod num_chunks(j)
         2. Broadcast chunk Cj,k
      ii. End_for
   b. End_for