

Outline

- Introduction
- Background
- Distributed DBMS Architecture
- Distributed Database Design
- Distributed Query Processing
- Distributed Transaction Management
- Building Distributed Database Systems (RAID)
- **Mobile Database Systems**
- Privacy, Trust, and Authentication
- Peer to Peer Systems

Useful References

- E. Pitoura and B. Bhargava, *Data Consistency in Intermittently Connected Distributed Systems*, IEEE TKDE, 11(6), 1999.
- E. Pitoura and G. Samaras, *Data Management for Mobile Computing*, Kluwer Academic Publishers, 1998.
- S. Bhowmick, S. Madria, and W. K. Ng, *Web Data Management: A Warehouse Approach*, Springer, 2003.

What is Pervasive Computing?

□ **“Pervasive computing is a term for the strongly emerging trend toward:**

- Numerous, casually accessible, often invisible computing devices
- Frequently mobile or embedded in the environment
- Connected to an increasingly ubiquitous network structure.”
- NIST, Pervasive Computing 2001

Mobile and Wireless Computing

- Goal: Access Information Anywhere, Anytime, in Any Way. and
- Aliases: Mobile, Nomadic, Wireless, Pervasive, Invisible, Ubiquitous Computing.
- Distinction:
 - Fixed wired network: Traditional distributed computing.
 - Fixed wireless network: Wireless computing.
 - Wireless network: Mobile Computing.
- Key Issues: Wireless communication, Mobility, Portability.

Why Mobile Data Management?

- Wireless Connectivity and use of PDA's, handheld computing devices on the rise
- Workforces will carry extracts of corporate databases with them to have continuous connectivity
- Need central database repositories to serve these work groups and keep them fairly upto-date and consistent

Mobile Applications

- Expected to create an entire new class of Applications
 - new massive markets in conjunction with the Web
 - Mobile Information Appliances - combining personal computing and consumer electronics
- Applications:
 - Vertical: vehicle dispatching, tracking, point of sale
 - Horizontal: mail enabled applications, filtered information provision, collaborative computing...

Mobile Data Applications

- **Sales Force Automation** - especially in pharmaceutical industry, consumer goods, parts
- **Financial Consulting and Planning**
- **Insurance and Claim Processing** - Auto, General, and Life Insurance
- **Real Estate/Property Management** - Maintenance and Building Contracting
- **Mobile E-commerce**

Mobility – Impact on DBMS

- Handling/representing fast-changing data
- Scale
- Data Shipping v/s Query shipping
- Transaction Management
- Replica management
- Integrity constraint enforcement
- Recovery
- Location Management
- Security
- User interfaces

DBMS Industry Scenario

- Most RDBMS vendors support the mobile scenario - but no design and optimization aids
- Specialized Environments for mobile applications:
 - Sybase Remote Server
 - Synchrologic iMOBILE
 - Microsoft SQL server - mobile application support
 - Oracle Lite
 - Xtnd-Connect-Server (Extended Technologies)
 - Scoutware (Riverbed Technologies)

Query Processing

- **New Issues**
 - Energy Efficient Query Processing
 - Location Dependent Query Processing
- **Old Issues - New Context**
 - Cost Model

Location Management

- **New Issues**
 - Tracking Mobile Users
- **Old Issues - New Context**
 - Managing Update Intensive Location Information
 - Providing Replication to Reduce Latency for Location Queries
 - Consistent Maintenance of Location Information

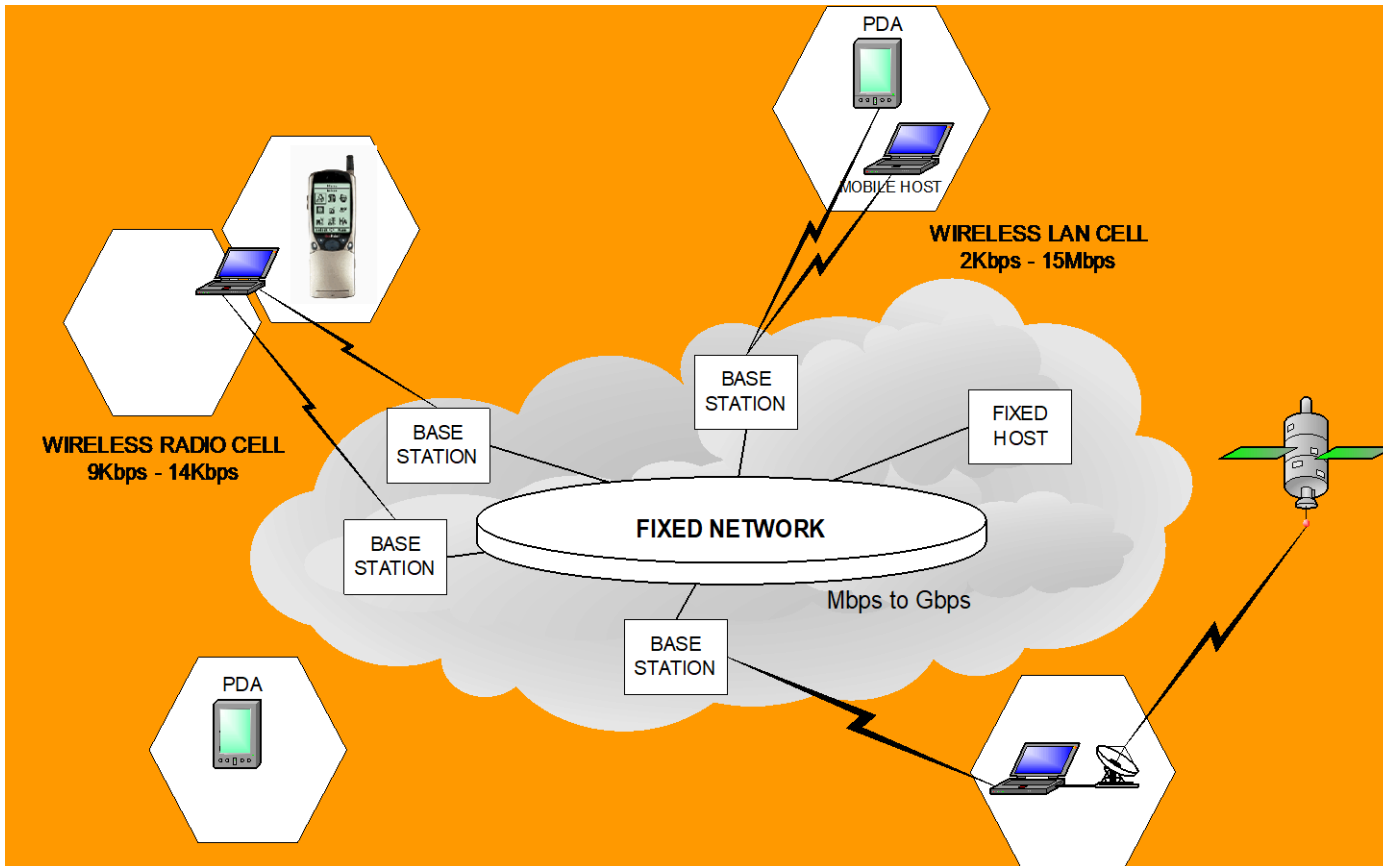
Transaction Processing

- **New Issues**
 - Recovery of Mobile Transactions
 - Lock Management in Mobile Transaction
- **Old Issues - New Context**
- **Extended Transaction Models**
 - Partitioning Objects while Maintaining Correctness

Data Processing Scenario

- One server or many servers
- Shared Data
- Some Local Data per client , mostly subset of global data
- Need for accurate, up-to-date information, but some applications can tolerate bounded inconsistency
- Client side and Server side Computing
- Long disconnection should not constraint availability
- Mainly Serial Transactions at Mobile Hosts
- Update Propagation and Installation

Mobile Network Architecture



Wireless Technologies

- **Wireless local area networks** (WaveLan, Aironet) – Possible Transmission error, 1.2 Kbps-15 Mbps
- **Cellular wireless** (GSM, TDMA, CDMA)– Low bandwidth, low speed, long range - Digital: 9.6-14.4 Kbps
- **Packet radio** (Metricom) -Low bandwidth, high speed, low range and cost
- **Paging Networks** – *One way*
- **Satellites** (Inmarsat, Iridium(LEO)) – Long Latency, long range, high cost

Terminologies

- **GSM - Global System for Mobile Communication**

- GSM allows eight simultaneous calls on the same radio frequency and uses narrowband TDMA. It uses time as well as frequency division.

- **TDMA - Time Division Multiple Access**

- With TDMA, a frequency band is chopped into several channels or time slots which are then stacked into shorter time units, facilitating the sharing of a single channel by several calls

- **CDMA - Code Division Multiple Access**

- data can be sent over multiple frequencies simultaneously, optimizing the use of available bandwidth.
- data is broken into packets, each of which are given a unique identifier, so that they can be sent out over multiple frequencies and then re-built in the correct order by the receiver.

Mobility Characteristics

- Location changes
 - location management - cost to locate is added to communication
- Heterogeneity in services
 - bandwidth restrictions and variability
- Dynamic replication of data
 - data and services follow users
- Querying data - location-based responses
- Security and authentication
- System configuration is no longer static

What Needs to be Reexamined?

- Operating systems - TinyOS
- File systems - CODA
- Data-based systems – TinyDB
- Communication architecture and protocols
- Hardware and architecture
- Real-Time, multimedia, QoS
- Security
- Application requirements and design
- PDA design: Interfaces, Languages

Mobility Constraints

- CPU
- Power
- Variable Bandwidth
- Delay tolerance, but unreliable
- Physical size
- Constraints on peripherals and GUIs
- Frequent Location changes
- Security
- Heterogeneity
- Expensive
- Frequent disconnections but predictable

What is Mobility?

- A device that moves between
 - different geographical locations
 - Between different networks
- A person who moves between
 - different geographical locations
 - different networks
 - different communication devices
 - different applications

Device Mobility

- Laptop moves between Ethernet, WaveLAN and Metricom networks
 - Wired and wireless network access
 - Potentially continuous connectivity, but may be breaks in service
 - Network address changes
 - Radically different network performance on different networks
 - Network interface changes
- Can we achieve best of both worlds?
 - Continuous connectivity of wireless access
 - Performance of better networks when available

Mobility Means Changes

- **Addresses**
 - IP addresses
- **Network performance**
 - Bandwidth, delay, bit error rates, cost, connectivity
- **Network interfaces**
 - PPP, eth0, strip
- **Between applications**
 - Different interfaces over phone & laptop
- **Within applications**
 - Loss of bandwidth trigger change from color to B&W
- **Available resources**
 - Files, printers, displays, power, even routing

Bandwidth Management

- Clients assumed to have weak and/or unreliable communication capabilities
- Broadcast--scalable but high latency
- On-demand--less scalable and requires more powerful client, but better response
- Client caching allows bandwidth conservation

Energy Management

- Battery life expected to increase by only 20% in the next 10 years
- Reduce the number of messages sent
- Doze modes
- Power aware system software
- Power aware microprocessors
- Indexing wireless data to reduce tuning time

Wireless characteristics

- Variant Connectivity
 - Low bandwidth and reliability
- Frequent disconnections
 - predictable or sudden
- Asymmetric Communication
 - Broadcast medium
- Monetarily expensive
 - Charges per connection or per message/packet
- Connectivity is weak, intermittent and expensive

Portable Information Devices

- PDAs, Personal Communicators
 - Light, small and durable to be easily carried around
 - dumb terminals, palmtops, wristwatch PC/Phone,
 - will run on AA+ /Ni-Cd/Li-Ion batteries
 - may be diskless
- I/O devices: Mouse is out, Pen is in
- Wireless connection to information networks
 - either infrared or cellular phone
- Specialized Hardware (for compression/encryption)

Portability Characteristics

- Battery power restrictions
 - transmit/receive, disk spinning, display, CPUs, memory consume power
- Battery lifetime will see very small increase
 - need energy efficient hardware (CPUs, memory) and system software
 - planned disconnections - *doze mode*
- Power consumption vs. resource utilization

Portability Characteristics Cont.

- Resource constraints
 - Mobile computers are resource poor
 - Reduce program size – interpret script languages (Mobile Java?)
 - Computation and communication load cannot be distributed equally
- Small screen sizes

- Asymmetry between static and mobile computers