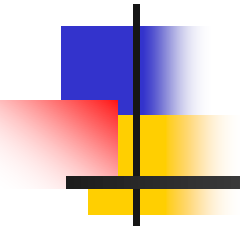

Mobile and Heterogeneous databases

Wireless Communication & Mobility

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Computer Science

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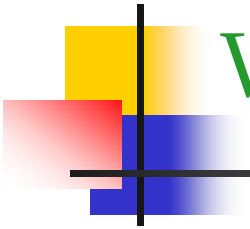


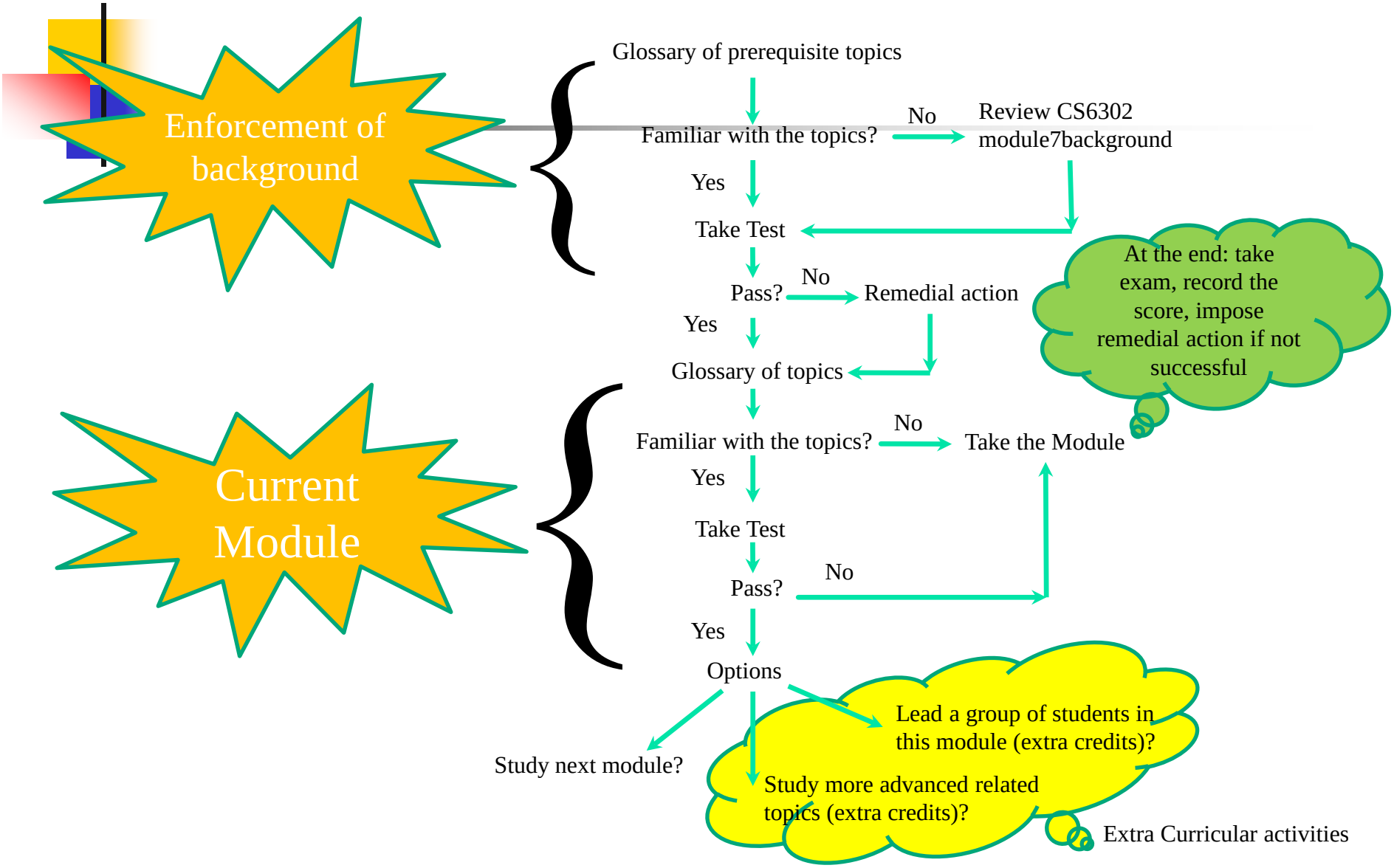
Wireless Communication & Mobility

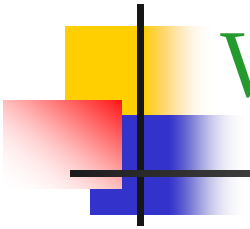
Note, this unit will be covered in three lectures. In case you finish it earlier, then you have the following options:

1) Take the early test and start CS6302.module8
2) Study the supplement module (supplement CS6302.module7)
3) Act as a helper to help other students in studying CS6302.module7

Note, options 2 and 3 have extra credits as noted in course outline.

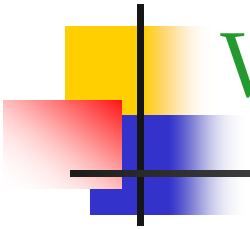
Wireless Communication & Mobility





Wireless Communication & Mobility

- You are expected to be familiar with:
  - Heterogeneous Distributed Databases,
- If not, you need to study CS6302.module4



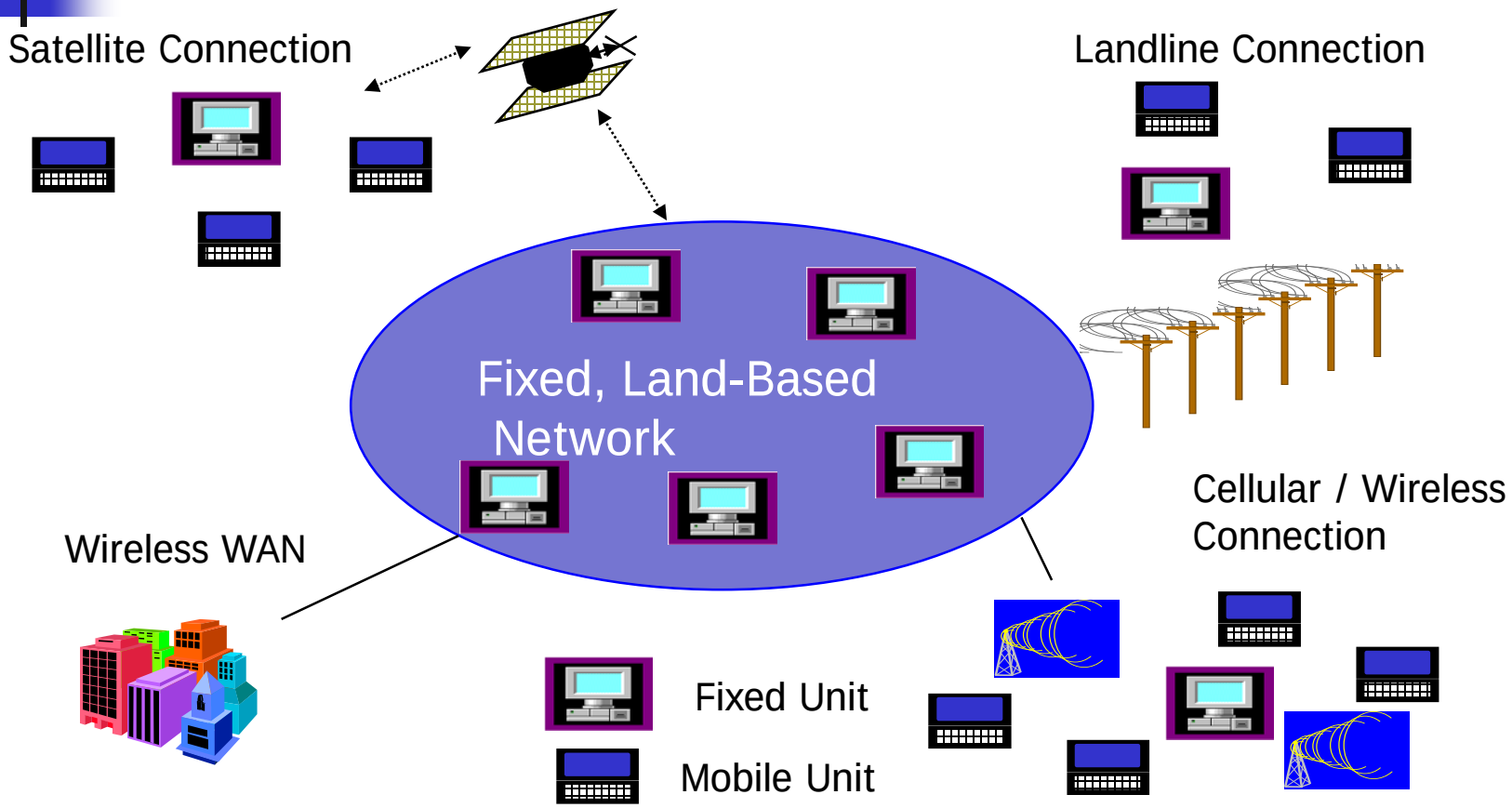
Wireless Communication & Mobility

- Previous modules addressed database issues within a wired environment. In this module, we will introduce additional physical heterogeneity in our database space, namely mobility and wireless communication. Within this new computational environment, we will visit database issues and their potential solutions.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - The traditional notion of timely and reliable access to global information in a distributed heterogeneous database system must be expanded:
    - Users are becoming more demanding — they desire or sometimes require access to information anytime, anywhere.
    - The diversity in the range of information that is accessible to a user is growing at a rapid rate.
    - A wide breadth of devices through which access to the global information is possible is made available to the user — access to the data is via a network connection that is characterized by: lower bandwidth, frequent disconnection, higher error rate, and limited resources.

Wireless Communication & Mobility



Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Concept of mobility where a user accesses data through a remote connection with a portable device has introduced several disadvantages for traditional database management systems due to:
    - Reduced capacity network connection,
    - Frequent disconnection,
    - Higher error rates,
    - Limited processing and resource restrictions, and
    - Limited power sources.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - To overcome the shortcomings of this new global information sharing process effectively, a solution must address the following issues:
    - A method to guarantee authorized access to the resources,
    - A method to deal with the degraded network connections,
    - A method to work with a subset of the global data set,
    - A method to allow different information sources to join and depart the global information sharing environment at will,
    - An efficient method to browse and process the data,
    - A method to accommodate computing devices with limited capacities,
    - A method to distinguish semantically similar/different data entities,
    - A method to accommodate a high degree of heterogeneity.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Nevertheless, regardless of the:
    - Heterogeneity of access devices,
    - Heterogeneity of communication medium,
    - Heterogeneity and autonomy of data sources
  - users require anytime, anywhere, transparent, intelligent, secure, timely, reliable, and Cost effective access to various types of data that are classified as follows:
    - Private data,
    - Public data, and
    - Shared data.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Private data: personal daily schedules, phone numbers, etc. The reader of this type of data is the sole owner/user of the data.
  - Public data: news, weather information, traffic information, flight information, etc. This type of data is maintained by one source, and shared by many. Consequently a user mainly queries the information source (s), and
  - Shared data: traditional databases, distributed, replicated, and/or fragmented data of a database. A processing node actually may contribute to maintaining consistency and participate in distributed decision making with this type of data — a user usually sends transactions as well as queries to the information source (s).

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - In this environment, two types of services are available:
    - On-demand based service – Based on the user request information is processed and result will be available to the user.
    - Broadcast based service – Based on some intelligent knowledge, potential information is broadcast and users pull information from the broadcast channels.
    - Pervasive based Service – Computers work in the background and based on some intelligent knowledge, potential information is pervasively accessed and made available to the users.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - On-demand service: In this case users normally obtain answers to requests through a dialogue (two-way communication) with the database server.
    - The user request is pushed, data sources are accessed, query operations are performed, partial results are collected and integrated, and generated information is communicated back to the user.
    - This requires a suitable solution that addresses the following issues:

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – On-demand service
  - Security and access control – A method to guarantee authorized access to the resources. This includes protocols for authentication, access control, inferential security, and integrity.
  - Isolation – A method to deal with a degraded network connection. This should also include a means to work off-line if an intentional/unintentional disconnection has occurred. Furthermore, if the connection is too slow or unreliable to work fully
  - Semantic heterogeneity – A method to handle differences in representation, format, structure, conflict, and meaning among information sources and hence to establish interoperability among different information sources. Techniques such as the United Nations or the Bilateral Approach could be used to accomplish this task.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – On-demand service
  - Local autonomy – A method to allow different information sources to join and depart the global information sharing environment at will. Autonomy comes in the form of design autonomy, communication autonomy, execution autonomy, and association autonomy.
  - Query processing and query optimization – A method to efficiently partition a global query into sub-queries to allow parallel execution.
  - Transaction processing and concurrency control – A method to allow simultaneous execution of independent transactions and interleaving interrelated transactions in the face of both global and local conflicts.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – On-demand service
  - Data integration – A method to fuse partial results in order to draw global result. This is particularly important because of the limited resources and capabilities of mobile devices. With a very large amount of information available, the entire set of data cannot be kept locally.
  - Browsing – A method to allow the user to search and look at the available information in an efficient manner without any information processing. This is needed due to an enormous amount of information available to the user.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – On-demand service
  - Distribution transparency – A method to hide the network topology and the placement of the data while maximizing the performance for the overall system. This is particularly important for wireless devices, which have the largest communication cost.
  - Location transparency – A method that to allow heterogeneous remote access to data sources. A mobile user can potentially access a much wider variety of systems in different locations and can also receive broadcast-type data from various locations due to mobility.
  - Limited resources – A method to accommodate computing devices with limited capabilities. This includes memory, storage, display, and power.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – Broadcast service
  - Many applications are directed towards public information that are characterized by:
    - The massive number of users,
    - The similarity and simplicity in the requests solicited by the users, and
    - The fact that users, in general, do not have the right to modify the data.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – Broadcast service
  - The reduced bandwidth attributed to the wireless environment places limitations on the rate and amount of communication.
  - Broadcasting (one-way communication) has been suggested as a possible solution to this limitation. In broadcasting, information is provided to all users of the air channels. Mobile users are capable of searching the air channels and pulling their required data.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – Broadcast service
  - The main advantage of broadcasting is the fact that it scales up as the number of users increases, eliminating the need to multiplex the bandwidth among users accessing the air channel.
  - Furthermore, broadcasting can be considered as an additional storage available over the air for the mobile clients. This is an attractive solution, due to the limited storage capability of the mobile unit.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – Broadcast service
  - Within the scope of broadcasting one needs to address three issues:
    - Effective data organization on the broadcast channel,
    - Efficient data retrieval from the broadcast channel, and
    - Broadcast content.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases – Pervasive-based service
  - The creation of environments saturated with computing and communication capability, yet gracefully integrated with human users,
  - Put computing in the background,
  - User unaware of existence of computers.

Wireless Communication & Mobility

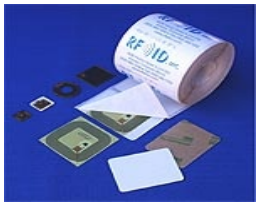
- Mobile Environment and Multidatabases –

  Pervasive-based service

  - Recently we have seen an explosion of
    - Embedded systems
    - Smart devices
    - Small, wearable devices

Wireless Communication & Mobility

UC Berkeley's Network Sensor Platform



Radio-Frequency ID TAG (RFID)

The "Digital Angel" Personal Safety and Location System

Ericsson Surfboard

Intelligent Fridge Used in IBM Pervasive Computing Lab

A Car Equipped with Telematic Devices

Wireless Communication & Mobility

- Mobile Environment and Multidatabases

Mobile Environment Issue	Description
Site Autonomy	Local control over resources and data. The degree of autonomy required depends upon the degree of mobile support offered by the system.
Heterogeneous Interoperability	Hardware and software heterogeneity.
Disconnect and Weak Connection Support	A mobile system should provide a means to provide access to data while faced with a disconnection or weak connection.
Support for Resource Scarce Systems	A mobile system should address the inherent limitations of various resource scarce access devices. These include processing, storage, power, and display limitations.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases

Mobile Environment Issue	Description
Transaction Management and Concurrency Control	Correct transaction management should satisfy the ACID properties (Atomicity, Consistency, Isolation, and Durability).
Distribution Transparency	Distribution of data is transparent to the user.
Location Transparency	The location of the data is transparent to the user.
Location Dependency	The content of the data is physically dependent upon the location of the user.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases

Multidatabase Environment Issues	Description
Site Autonomy	Local control over resources and data ─ autonomy comes in the form of design, communication, execution, and association.
Heterogeneous Interoperability	Hardware and software heterogeneity.
Intelligent Search and Browsing	The MDBS should provide a means for the user to efficiently search and browse the data contained in the MDBMS.
Intelligent Query Resolution	An MDBMS should be able to efficiently process and optimize a query submitted to the system.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases

Multidatabase Environment Issues	Description
Transaction Management and Concurrency Control	Correct transaction management should satisfy the ACID properties (Atomicity, Consistency, Isolation, and Durability).
Distribution Transparency	Distribution of data in the MDBMS is transparent to the user.
Location Transparency	The location of the data in the MDBMS is transparent to the user.
System Transparency	The user should be able to access the desired data irrespective of the system.
Representation Transparency	This includes naming differences, format differences, structural differences, and missing or conflicting data.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases

	Mobile System	Multidatabase System
Site Autonomy	♣	♣
Heterogeneous Interoperability	♣	♣
Transaction Management and Concurrency Control	♣	♣
Disconnect and Weak Connection Support	♣	♠
Support for Resource Scarce Systems	♣	♦
Intelligent Search and Browsing	●	●
Intelligent Query Resolution	●	●

Wireless Communication & Mobility

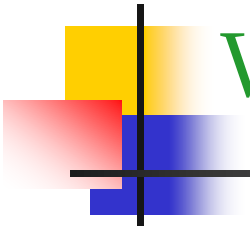
- Mobile Environment and Multidatabases

	Mobile System	Multidatabase System
Distribution Transparency	●	♠
Location Transparency	●	♠
Location Dependency	●	♦
System Transparency	●	♠
Representation Transparency	●	♠

♣ Required ● Desirable ♠ Optional ♦ Not required

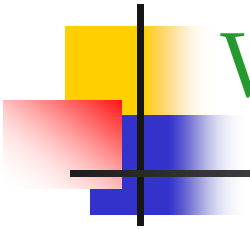
Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - There are similarities in the objectives of effectively accessing data in a multidatabase and a wireless-mobile computing environment.
  - We propose to superimpose a wireless-mobile computing environment on an MDBMS to realize a system capable of effectively accessing data over a wireless medium.
  - This new system is called a mobile data access system (MDAS).



Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - By superimposing an MDBMS onto a mobile computing environment, one should be able to easily map solutions from one environment to another.



Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Autonomy of a system implies that the system should have complete control over the local data and resources, and be able to operate independently.
    - In a multidatabase system, autonomy is referred to as site autonomy, where a local DBMS is autonomous with respect to other systems in the MDBMS.
    - In a mobile system, autonomy refers to the mobile user/application, where the level of autonomy is a function of the available resources (network, processing, storage, etc.). The level of autonomy also varies depending upon the mobile awareness of a particular application, and the support provided by the system. The quality of the wireless/fixed network connection and the processing capacity of the hardware are the primary factors in determining the level of application-autonomy that is required.
  - An MDAS should support both site-level and application-level autonomy.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Schema integration issues include data representation, system, and location transparency issues. As with heterogeneity, these issues have been extensively researched in multidatabase systems.
    - In a wireless-mobile computing environment, researchers have overlooked the importance of schema integration in a data access system. Particularly since mobility tends to increase the degree of heterogeneous data available.
  - An MDAS must address schema integration issues to present the user with a viable solution for accessing heterogeneous data. Furthermore, mobility introduces an additional challenge in that it may be desirable to have location dependence when accessing data. In such instances, the content and representation of the data could actually depend upon the location of the user when he/she accesses the data.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Query processing issues are well understood in an MDBMS. A global query is submitted to the system, and the query is decomposed into a set of sub-queries, one for each local DBMS involved in the transaction.
  - In a mobile environment, where the processing power, storage, and energy may be restricted, query processing is non-trivial.
  - If a mobile unit has sufficient resources to perform the query processing, then the query in the MDAS could be processed and executed similar to a query in an MDBMS. However, if the resources are limited, then the processing should be performed by a fixed, more resourceful computing device in the MDAS.
    - One of the disadvantages of this method is that there may be an increase in the network traffic, which poses a problem in a wireless connection.
    - Different strategies to address these issues include object-oriented designs, dynamic adjustment to bandwidth changes, data distillation, and bundle query.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Effectively accessing the data in a heterogeneous environment may require an efficient means of searching/browsing the data, in addition to an efficient mechanism to resolve and process a user's query.
  - In a mobile environment, this may be more difficult to realize due to network, storage, processing power, and energy restrictions. Similar to query processing, the processing could be performed by a fixed, more resourceful computing device in the MDAS if the local host does not have the resources to search/browse data.
  - Network traffic increases depending upon the storage capacity of the mobile unit. If the local node could store more information and data about the global schema and data, additional local processing (and hence less network traffic) could be achieved.

Wireless Communication & Mobility

Mobile Environment and Multidatabases

- Transaction processing and concurrency control is an important, yet extremely challenging aspect of data processing. MDBMS are faced with the problem of maintaining serializability for global transactions in the presence of local transactions that are invisible at the global level.
- In an MDAS environment, the system should be able to provide global serializability and local autonomy to a user using a wireless connection. The restrictions imposed by a wireless connection have led to the use of optimistic concurrency control schemes in mobile-wireless environments.
- An application in an MDAS may be required to use both weak and strong consistency rules, where the application is required to adapt to changing environmental conditions.
- In MDBMSs, weak consistency is used to increase global transaction throughput. In an MDAS, weak consistency may be required due to disconnection and/or a weak network connection.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Mobility and its consequences introduce additional complexities when a user accesses data.
  - A local cache and prefetching in a mobile unit has been extensively used to address the problems associated with disconnection and weak connections.
  - The idea is that when a disconnection occurs, the mobile unit operates in an autonomous state while performing operations. When the connection is reestablished, a resynchronization between the cache in the local unit and the server occurs. The use of various prefetch schemes should be used to ensure that the required data is available in the cache during a disconnection. Additionally, some type of queuing mechanism should be provided to perform operations on data that may not be contained in the cache.
    - Predictive schemes, where the system is actually able to anticipate a disconnection, can be used to lessen the impact of a disconnection.
    - Finally, broadcasting of data on wireless channels can be used to reduce network traffic.

Wireless Communication & Mobility

- Mobile Environment and Multidatabases
  - Processing power and display limitations in a mobile unit introduce additional challenges to an MDAS. Off-loading the processing performed on the local unit to fixed hosts is commonly used in wireless-mobile environments. Data distillation can be used to address the display network limitations of a mobile unit. Many mobile units are not capable of displaying multimedia data.
  - Data distillation is a process where incoming data is "distilled," or processed, such that only portions of the data that the unit is capable of displaying are shown on the screen.
  - If network bandwidth is limited, data distillation is used to reduce the network traffic by distilling video, images, or sound.
  - To address the limitations inherent in a mobile unit, an MDAS should use some or all of these aforementioned methods.

Wireless Communication & Mobility

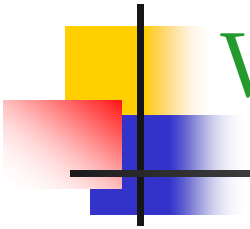
- Mobile Environment and Multidatabases

Characteristics	Issue	Solution
Site Autonomy	Autonomy is required in an MDAS system	Provide both site-level and application-level autonomy
Heterogeneous Interoperability	Heterogeneous Interoperability is required in an MDAS system	Use traditional methods for heterogeneity from MDBMSs
Intelligent Search and Browsing	Limited processing power, storage, energy, and display	Reduction of local data storage requirements, object-oriented design, multi-tiered architecture, and off-load processing to fixed hosts
Intelligent Query Resolution	Limited processing power, storage, energy, and display	Multi-tiered architecture, off-load processing to fixed hosts, data distillation

Wireless Communication & Mobility

- Mobile Environment and Multidatabases

Characteristics	Issue	Solution
Disconnect and Weak Connection Support	A wireless medium results in lower bandwidth and disconnections	Local cache, prefetching, and broadcasting
Support for Resource Scarce Systems	Limited processing power, storage, energy, and display	Multi-tiered architecture, broadcasting, off-load processing to fixed hosts, data distillation
Trans. Management and Concurrency Control	Provide global serializability to transactions	Use a bottom-up approach with optimistic concurrency control
Distribution, Location, System, Representation Transparency	Schema integration issues, and greater impact due to mobility	Use traditional methods for schema integration from MDBMSs

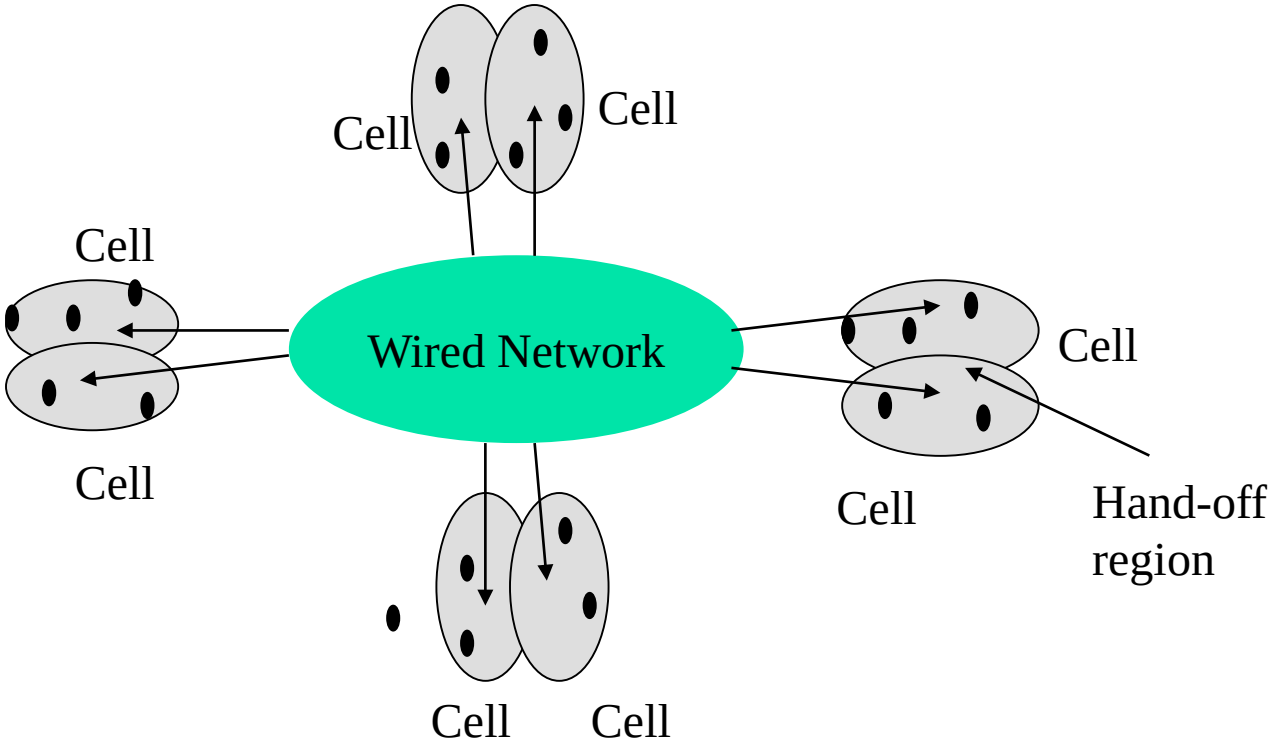


Wireless Communication & Mobility

- Mobile Computing
  - The mobile computing environment (nomadic or the ubiquitous environment) is based on wireless communication. The wireless network is composed of:
    - A number of network servers enhanced with wireless transceivers — mobile support stations (MSS) — scattered along a geographical area, and
    - A varying number of mobile hosts (MHs) free to move at will.

Wireless Communication & Mobility

- Mobile Computing



Wireless Communication & Mobility

- Mobile Computing
  - The role of the MSS is to provide a link between the wireless network and the wired network. The link between a MSS and the wired network could be either wireless (shown as dashed line) or wire based.
  - The area covered by the individual transceiver is referred to as a cell. The size of the area covered by each cell varies widely, depending on the technology being used.

Wireless Communication & Mobility

- Mobile Computing
  - To satisfy a request, a MH accesses the MSS responsible for the cell where the MH is currently located and submits its request.
  - It is the duty of the MSS to resolve the request and deliver the result back to the client. Once a MH moves across the boundaries of two cells a hand-off process takes place between the MSSs of the corresponding cells.
  - As a result of hand-off, the MH's request will now be served by the new MSS rather than the old one.

Wireless Communication & Mobility

- Mobile Computing
  - The MH is relatively small, light, and portable. It is designed to preserve space, and energy. To keep the unit compact, the amount of resources that exist (memory, secondary storage, etc.) are limited.
  - The energy saving requirement stems from the fact that the MH, in many instances, might not be connected to a direct power supply and therefore, it has to depend on temporary power supplies (such as batteries) as its main power source.

Wireless Communication & Mobility

- Mobile Computing – Characteristics
  - Wireless Medium — Communication via the air,
  - Mobility — Computation at multiple locations and in transition between these locations,
  - Portability — There is no fixed connection.

Wireless Communication & Mobility

- Mobile Computing – Network Architecture
  - A remote access network consists of a variety of network connections with varying characteristics:
    - Fixed, land-based LAN Connection,
    - Modem Connection,
    - Cellular,
    - Wireless LAN,
    - Wide-area Wireless network,
    - Satellite Network,
    - Paging Network.

Wireless Communication & Mobility

- Mobile Computing – Wireless Technologies

Technology	Bit Rate (Kbps)	Cell Diameter (Km)	Indoor/Outdoor
Analog Cellular Systems	19.2	3-150	Outdoor
Digital Cellular Systems	22.8-48.6	3-150	Outdoor
Satellite Networks	10-200	500-7,000	Outdoor
Wireless LANs	1,000	0.2	Indoor
Personal Communication	500-2,000	0.1-500	Indoor and Outdoor

Wireless Communication & Mobility

- Mobile Computing – Access Devices
  - A remote connection is made through various devices:
    - Desktop Computing Device,
    - Network Computing Device
    - Portable Computers,
    - Portable Hand-held Device,
    - Pager.

Wireless Communication & Mobility

- Mobile Computing – Remote Access Devices

Device type	Computing Power	Memory	Storage	Weight	Display size	Energy Req.
Workstation, PC, Desktop	Very High	Gigabytes	Giga/Tera bytes	<500lbs	Up to 21 inches	None
Network computer	High	<128 MB	None	<100lbs	Up to 21 inches	None
Portable computer	High	<128 MB	<6 GB	4 - 5lbs	Up to 14 inches	Battery
Portable hand-held computer	Low - Medium	<32 MB	<500 MB	4 – 16 oz	Up to 6 inches	Battery
Pager	Very low/ None	<16 K	None	1 – 8 oz	Up to 3 inches	Battery

Wireless Communication & Mobility

- Mobile Comp

Mobile Environment Characteristics	Resulting Issues
Wireless Connection	§ disconnection
	Communication Channel
	-High Cost
	-Network Measurement
	-Low Data Rate
Mobility §	§ Motion Management
	§ Location-Dependent Data
	Heterogeneous Networks
	§ -Interfacing
	§ -Data-Rate Variability
	Security
	-Eavesdropping
	§ -Privacy
Portability	-Vandalism
	Limited Resources
	Limited Energy Sources
	User Interface