1.3 MOBILE COMPUTING

Mobile computing can be defined as a computing environment of physical mobility. The user of a mobile computing environment will be able to access data, information, or other logical objects from any device in any network while on the move. A mobile computing system allows a user to perform a task from anywhere using a computing device in the public (the Web), corporate (business information) and personal information spaces (medical record, address book). While on the move, the preferred device will be a mobile device, while back at home or in the office the device could be a desktop computer. To make the mobile computing environment ubiquitous, it is necessary that the communication bearer is spread over both wired and wireless media. Be it for the mobile

workforce, holidayers, enterprises, or rural population, access to information and virtual objects through mobile computing is absolutely necessary for optimal use of resource and increased productivity.

Mobile computing is used in different contexts with different names. The most common names are:

- *Mobile Computing*: This computing environment moves along with the user. This is similar to the telephone number of a GSM (Global System for Mobile communication) phone, which moves with the phone. The offline (local) and real-time (remote) computing environment will move with the user. In real-time mode the user will be able to use all his remote data and services online.
- *Anywhere, Anytime Information*: This is the generic definition of ubiquity, where the information is available anywhere, all the time.
- *Virtual Home Environment*: Virtual Home Environment (VHE) is defined as an environment in a foreign network such that the mobile users can experience the same computing experience as they have in their home or corporate computing environment. For example, one would like to keep the room heater on when one has stepped outside for about 15 minutes.
- *Nomadic Computing*: The computing environment is nomadic and moves along with the mobile user. This is true for both local and remote services.
- *Pervasive Computing*: A computing environment, which is pervasive in nature and can be made available in any environment.
- *Ubiquitous Computing*: A (nobody will notice its presence) everyplace computing environment. The user will be able to use both local and remote services.
- *Global Service Portability*: Making a service portable and available in every environment. Any service of any environment will be available globally.
- *Wearable Computers*: Wearable computers can be worn by humans like a hat, shoe or clothes (these are wearable accessories). Wearable computers need to have some additional attributes compared to standard mobile devices. Wearable computers are always on; operational while on the move; hands-free, context-aware (with different types of sensors). Wearable computers need to be equipped with proactive attention and notifications. The ultimate wearable computers will have sensors implanted in the body and supposedly integrate with the human nervous system. These are part of a new discipline of research categorized by "Cyborg" (Cyber Organism).

1.3.1 Mobile Computing Functions

We can define a computing environment as mobile if it supports one or more of the following characteristics:

- *User Mobility*: The user should be able to move from one physical location to another and use the same service. The service could be in a home or remote network. For example, a user moves from London to New York and uses Internet to access the corporate application the same way the user uses it in the home office.
- *Network Mobility*: Network mobility deals with two types of use-cases. In one use-case, the user is moving from one network to another and uses the same service seamlessly. An example could be a user moving from a WiFi network within the university campus and changing to

3G network outside while using the same online service.

In other use-case of network mobility, the network itself is mobile like in a Mobile Ad hoc Network (MANET). In MANET, each node in the network is a combination of a host and a router. As the nodes move, the routers within the network also move changing the routing table structure. These types of networks are used in battlefields or sensor networks, where routers/nodes are constantly moving.

- *Bearer Mobility*: The user should be able to move from one bearer to another and use the same service. An example could be a user using a service through WAP bearer in his home network in Bangalore. He moves to Coimbatore where WAP is not supported and switches over to the voice or SMS (short message service) bearer to access the same application.
- *Device Mobility*: The user should be able to move from one device to another and use the same service. An example could be sales representatives using their desktop computer in their home office. During the day while they are on the street they would like to use their Palmtop to access the application.
- *Session Mobility*: A user session should be able to move from one user-agent environment to another. An example could be a user using his service through a CDMA (Code Division Multiple Access) 1X network. The user entered into the basement to park the car and got disconnected from his CDMA network. He goes to his home office and starts using the desktop. The unfinished session in the CDMA device moves from the mobile device to the desktop computer.
- *Agent Mobility*: The user-agent or the applications should be able to move from one node to another. Examples could be aglets, crawler software, or even a malicious worm or virus software that moves from one node to another. There is another use-case of mobile agent in the Cloud Computing paradigm, where applications will be moving from platform to platform and infrastructure to infrastructure depending on temporal and economic considerations. In Cloud Computing, there will not be any fixed association between the application and the host running it—software agents in the cloud will constantly be mobile.
- *Host Mobility*: The user device can be either a client or server. When it is a server or host, some of the complexities change. In case of host mobility, mobility of the IP needs to be taken care of.

taken care of.

The mobile computing functions can be logically divided into the following major segments (Fig. 1.1):

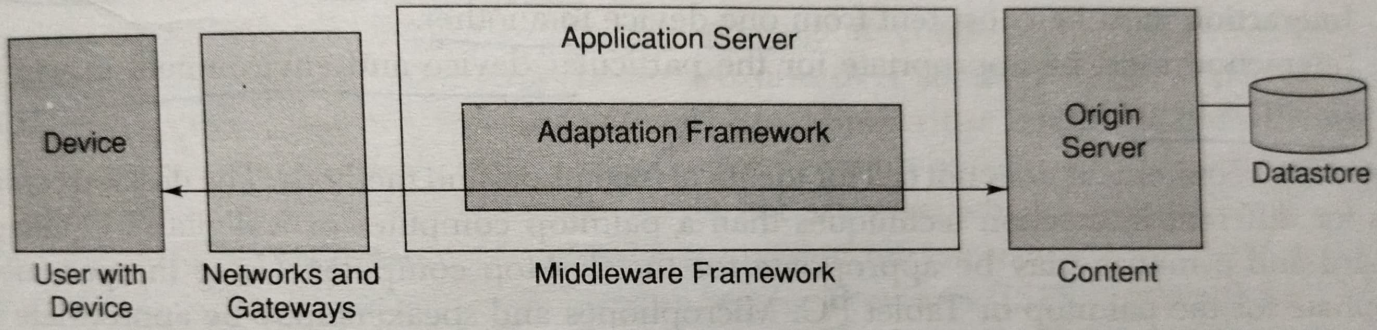

Figure 1.1 Mobile Computing Functions

1. *User with device*: This means that this could be a fixed device like a desktop computer in an office or a portable device like mobile phone. Example: laptop computers, desktop computers, fixed telephone, mobile phones, digital TV with set-top box, palmtop computers, pocket PCs, two-way pagers, handheld terminals, etc.
2. *Network*: Whenever a user is mobile, he will use different networks at different locations at different times. Example: GSM, CDMA, iMode, Ethernet, Wireless LAN, Bluetooth, etc.
3. *Gateway*: This acts as an interface between different transport bearers. These gateways convert one specific transport bearer to another. Example: From a fixed phone (with voice interface) we access a service by pressing different keys on the telephone. These keys generate DTMF (Dual Tone Multi Frequency) signals. These analog signals are converted into digital data by the IVR (Interactive Voice Response) gateway to interface with a computer application. Other examples will be WAP gateway, SMS gateway, etc.
4. *Middleware*: This is more of a function rather than a separate visible node. In the present context, middleware handles the presentation and rendering of the content on a particular device. It may optionally also handle the security and personalization for different users.
5. *Content*: This is the domain where the origin server and content is. This could be an application, system, or even an aggregation of systems. The content can be mass market, personal or corporate content. The origin server will have some means of accessing the database and storage devices.

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1.3.2 Mobile Computing Devices

The device for mobile computing can be either a computing or a communication device. In the computing device category it can be a desktop, laptop, or a palmtop computer. On the communication device side it can be a fixed line telephone, a mobile telephone or a digital TV. Usage of these devices are becoming more and more integrated into a task flow where fixed and mobile, computing and communication functions are used together. The device is a combination of hardware and software; the hardware is technically called the User Equipment (UE) with software inside, which functions as an agent to connect to the remote service—this software is called a User Agent (UA). One of the most common UA today is a Web browser. When computing technology is embedded into equipment, Human-Computer Interaction (HCI) plays a critical role in effectiveness, efficiency, and user experience. This is particularly true as mobile information and communication devices are becoming smaller and more restricted with respect to information presentation, data entry and dialogue control. The human computer interface challenges are:

1. Interaction must be consistent from one device to another.
2. Interaction must be appropriate for the particular device and environment in which the system is being used.

Note: The requirement does not call for identical metaphors and methods. The desktop computer

1.4 Dialogue Control

In any communication there are two types of user dialogues. These are long session-oriented transactions and short sessionless transactions. An example of a session-oriented transaction is: Reading a few pages from one chapter of a book at a time. Going to a particular page directly through an index and reading a particular topic can be considered a short sessionless transaction. Selection of the transaction mode will depend on the type of device we use. A session may be helpful in case of services offered through computers with large screens and mouse. For devices with limited input/output like SMS for instance, short sessionless transactions may be desired.

For example, consider enquiring about your bank balance over the Internet. In case of Internet banking through a desktop computer, the user has to go through the following minimum dialogues:

1. Enter the URL of the bank site.
2. Enter the account number/password and login into the application.
3. Select the balance enquiry dialogue and see the balance.
4. Logout from Internet banking.

This example is a session-oriented transaction. Using short sessionless transactions, the same objective can be met through a single dialogue. In a short sessionless transaction, the user sends an SMS message, 'mybal' to the system and receives the information on balance. The application services all the five dialogue steps as one dialogue. In this case steps like authentication and selection of transactions need to be performed in smarter ways. For example, user authentication will be done through the user's mobile number. It can be assumed that mobile devices are personal, therefore, authenticating the mobile phone implies authenticating the user account.

1.5 Networks

Mobile computing will use different types of networks. These can be fixed telephone networks, GSM, GPRS, ATM (Asynchronous Transfer Mode), Frame Relay, ISDN (Integrated Service Digital Network), CDMA, CDPD (Cellular Digital Packet Data), DSL (Digital Subscriber Loop), Dial-up, WiFi (Wireless Fidelity), 802.11, Bluetooth, Ethernet, Broadband, etc.

1.5.1 Wireline Networks

This is a network, which is designed over wire or tangible conductors. This network is called fixedline or wireline network. Fixed telephone networks over copper and fiber-optic will be part of this network family. Broadband networks over Digital Subscriber Line (DSL) or cable will also be part of wireline networks. Wireline networks are generally public networks and cover wide areas. Though microwave or satellite networks do not use wire, when a telephone network uses microwave or satellite as part of its longhaul transmission infrastructure, it is considered part of wireline networks. When we connect to Internet Service Providers (ISP), it is generally a wireline network. The Internet backbone is a wireline network as well.

1.5.2 Wireless Networks

Mobile networks are called wireless network. These include wireless networks used by radio taxis, one-way and two-way pager, cellular phones. Examples will be PCS (Personal Cellular System), AMPS (Advanced Mobile Phone System), GSM, CDMA, DoCoMo, GPRS, etc. WiLL (Wireless in Local Loop) networks using different types of technologies are part of wireless networks as well. In a wireless network the last mile is wireless and works over radio interface. In a wireless network, other than the radio interface, rest of the network is wireline and is generally called the PLMN (Public Land Mobile Network).

1.5.3 Ad hoc Networks

In Latin, *ad hoc* means "for this purpose only". An ad hoc (or spontaneous) network is a small area network, especially one with wireless or temporary plug-in connections. In these networks some of the devices are part of the network only for the duration of a communication session. An ad hoc network is also formed when mobile or portable devices operate in close proximity to each other or with the rest of the network. When we beam a business card from our PDA (Personal Digital Assistant) to another, or use an IrDA port to print documents from our laptop, we have formed an ad hoc network. The term ad hoc has been applied to networks in which new devices can be quickly added using, for example, Bluetooth or wireless LAN (802.11). In these networks, devices communicate with the computer and other devices through wireless transmission. Typically based on short-range wireless technology, these networks don't require subscription services or carrier networks.

1.5.4 Bearers

For different type of networks, there are different types of transport bearers. These can be TCP/IP, HTTP, protocols or dial-up connection. For GSM it could be SMS, USSD (Unstructured Supplementary Service Data) or WAP. For mobile or fixed phone, it will be Voice.

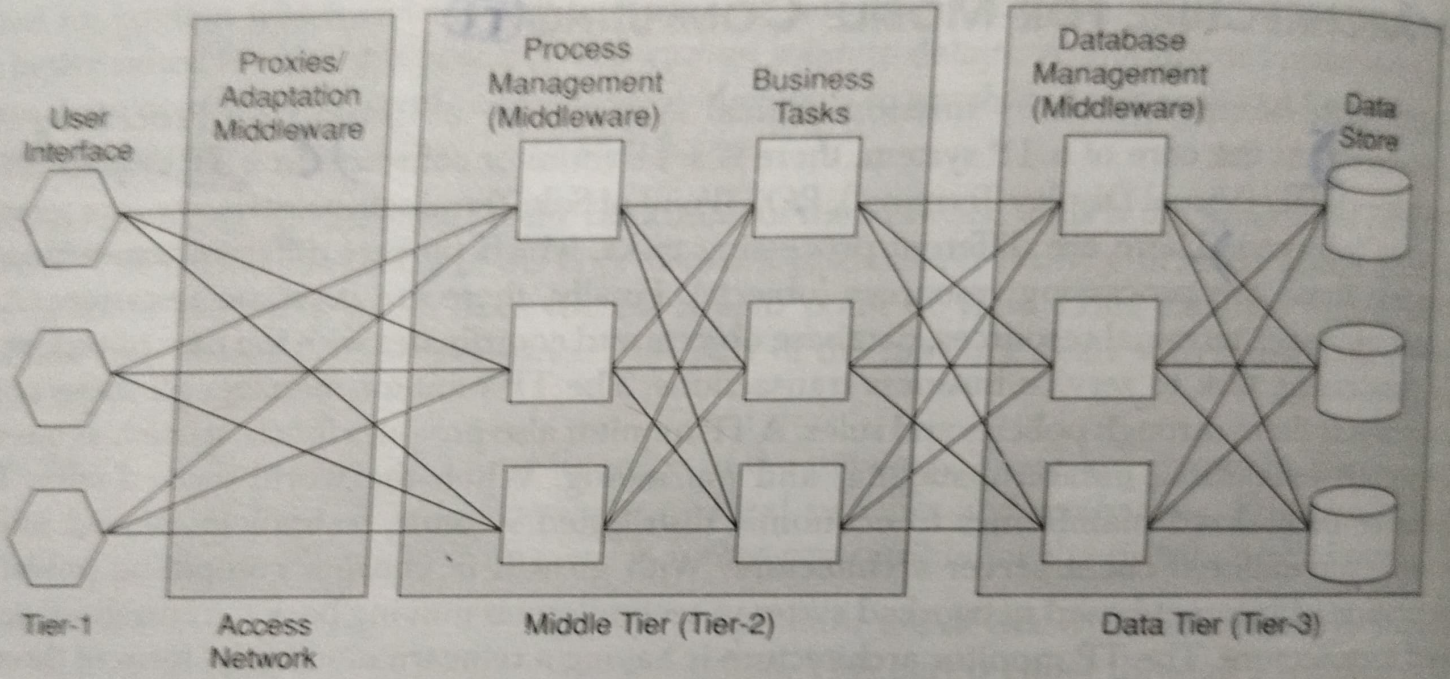

Figure 2.1 Three-tier Architecture for Mobile Computing

⋆) 3-tier Architecture of Mobile Computing (Diag).

i) Presentation Layer (UI) :- ~~(2-tier)~~
→ lets to execute all applications on the client devices & provide complete UI.
→ It has main responsibility to present info to end user.
→ Users are able to grab all information via speakers, vibration, screen etc.
→ Users can send information with the help of input devices like pen drives, mouse, keyboard, touch screen etc.
→ Enabled with WAP browsers, customized client programs, web browser etc.
→ Allows accomplishing via client side data source, Dynamic HTML & data cursors.
→ Presentation layer must be context aware & device independent.

ii) Application Layer:-

→ Here, the business logic performs all tasks as server for client requests from workstations. It works as business rules to fetch or enter data through Data layer.

→ It is enabled with few technologies such as PHP, .Net services, Java & so on.

→ Presentation & database independent

→ This layer identifies ~~that~~ which type of data is required & performs as client in relation to third tier or programming that may be situated on a mainframe computer.

→ It takes decision on rendering, network management, security, data store access.

→ Their components are not linked to certain client, so they can be implemented by all applications & can ~~be~~ proceed to other locations as respond time frame.

iii) Data Access Layer:

→ This layer is implemented to keep store data that is required by application and work as respository for both temporary & permanent data.

→ Data access layer is built up of DBMS that offers all data for above two layers.

→ This layer is also known as DBMS access Layer.

→ All data is stored into many format like as text files or relational DB.

→ In this layer, to ignore the dependencies on storage mechanism offers for getting to update or change without application tier clients that is affected by aware of change.

2.6 Design Considerations for Mobile Computing

The mobile computing environment needs to be context-independent as well as context-sensitive. Context information is the information related to the surrounding environment of an actor in that environment. The term "context" means, all the information that helps determine the state of an object (or actor). This object can be a person, a device, a place, a physical or computational object, the surrounding environment or any other entity being tracked by the system. In a mobile computing environment, context data is captured so that decisions can be made about how to adapt content or behavior to suit this context. Mobility implies that attributes associated with devices and users will change constantly. These changes mean that content and behavior of applications should be adapted to suit the current situation. There are many ways in which content and behavior can be adapted. Following are some examples:

1. **Content with context awareness:** Build each application with context awareness. There are different services for different client context (devices). For example, a bank decides to offer mobile banking application through Internet, PDA and mobile phone using WAP. These services are different and are http://www.mybank.com/inet.html, http://www.mybank.com/palm.html and http://www.mybank.com/wap.wml, respectively. The service http://www.mybank.com/inet.html assumes that the user will use computers to access this service. Therefore it is safe to offer big pages with text boxes and drop down menus. Also, it is fine to add a few animated pictures for the new product the bank is launching. We know that http://www.mybank.com/palm.html is a service for a PalmOS PDA. As the display size is small, we design the screen to be compact for the PDA and do not offer the same product animation. For the WAP service at http://www.mybank.com/wap.wml, we do a completely different user interface; we make all drop down options available through the option button in the mobile phone and remove all the graphics and animations.
2. **Content switch on context:** Another way is to provide intelligence for the adaptation of content within the service. This adaptation happens transparent to the client. In this case the service is the same for Internet, PDA and WAP. All access the bank's service through http://www.mybank.com/. An intelligent piece of code identifies the agent to decide what type of device or context it is. This intelligent code does the adaptation at runtime based upon the agent in hand. The simplest way to do this is to look at the user-agent value at the HTTP header and decide whether to route the request to http://mybank.com/inet.html or http://www.mybank.com/palm.html or http://www.mybank.com/wap.wml.
3. **Content transcoding on context:** Another way is to provide an underlying middleware platform that performs the adaptation of the content based on the context and behavior of the device. This adaptation happens transparent to the client and the application. The middleware platform is intelligent enough to identify the context either from the HTTP or additional customized parameters. In this case the service may be in html or XML, the middleware platform transcodes the code from html (or XML) to html, and wml on the fly. It can also do the transcoding based on policy so that the html generated for a computer is different from a PDA.

Following sections describe different types of context that can enhance the usability, reliability and security of the service. Figure 2.5 depicts the old web and web of the future for mobile computing.

2.6.1 Client Context Manager

When we humans interact with other persons, we always make use of the implicit situational information of the surrounding environment. We interpret the context of the current situation and react appropriately. For example, we can go close to a lion in a zoo, but definitely not in the wild. Or, a person discussing some confidential matter with another person observes the gestures and tone of the other person and reacts in an appropriate manner or changes the subject if someone shows up suddenly. When we use content through a PC within the four walls of an organization, we do not have any problem. A majority of the applications can safely assume that the context is the enterprise LAN. It can be assumed that the environment is secured; it can also be assumed that the user will be using the systems in a particular fashion using the browser standardized by the company. These applications are developed keeping the large screen (for mainly PC) and browsers in mind. A mobile computing application, on the other hand, needs to operate in dynamic conditions. This is due to various device characteristics and network conditions. This demands a reactive platform that can make decisions about how to respond to changes to device capability, user preferences, enterprise policy, network policy and many other environmental factors. Context can be used as the basis by which an adaptation manager or algorithm decides to modify content or application behavior. We therefore need a Client Context Manager to gather and maintain information pertaining to the client device, user, network and the environment surrounding each mobile device. All these information will be provided by a set of Awareness Modules. Awareness

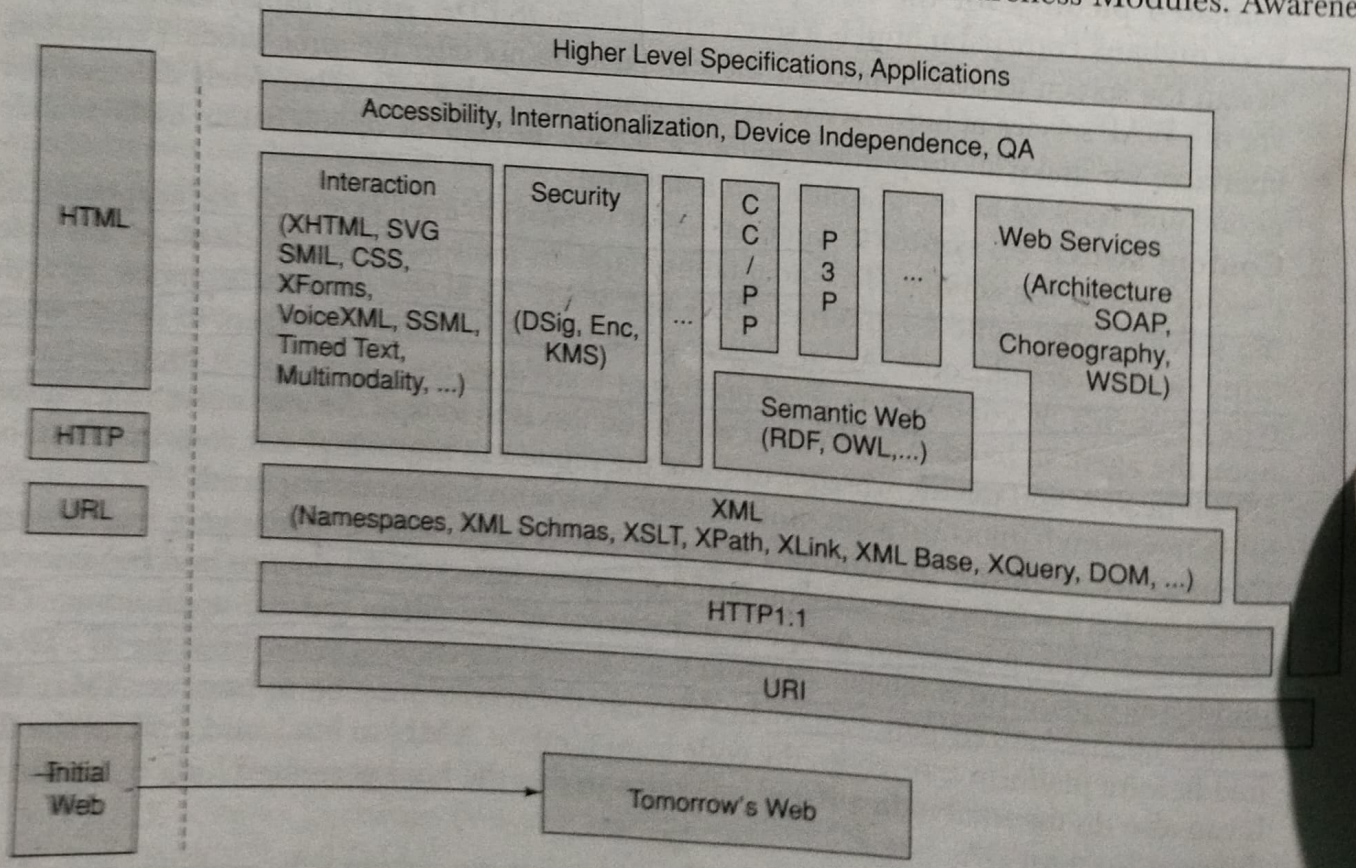

Figure 2.5 The Content Architecture with Respect to Mobile Computing