

3 Wireless Internet, Mobile IP, and Wireless Web

3.1	INTRODUCTION	3-2
3.2	INTERNET AND THE WEB: A QUICK REFRESHER.....	3-5
3.2.1	<i>Internet, Intranets, and Extranets at a Glance</i>	3-5
3.2.2	<i>The Web at a Glance</i>	3-7
3.2.3	<i>World Wide Web Technologies – The First Generation</i>	3-8
3.3	HOW DOES WIRELESS WEB REALLY WORK?– QUICK EXAMPLES	3-11
3.3.1	<i>A Simple Wired Access Example</i>	3-11
3.3.2	<i>A Simple Wireless Web Example</i>	3-13
3.4	THE INTERNET AND IP – A CLOSER LOOK	3-14
3.4.1	<i>What is the Internet?</i>	3-14
3.4.2	<i>IP Overview</i>	3-16
3.4.3	<i>The Internet Protocol (IP)</i>	3-17
3.4.4	<i>The Transmission Control Protocol (TCP)</i>	3-17
3.4.5	<i>The User Datagram Protocol (UDP)</i>	3-18
3.4.6	<i>Additional Transport Layer Protocol – SCTP (Simple Control Transmission Protocol)</i> . 3-18	
3.4.7	<i>Sample Higher (Application) Layer Protocols</i>	3-18
3.4.8	<i>Common TCP/IP Implementations</i>	3-19
3.4.9	<i>Next Generation Network and Internet</i>	3-19
3.5	MOBILE IP – SUPPORTING MOBILE DEVICES OVER THE INTERNET	3-21
3.5.1	<i>Overview</i>	3-21
3.5.2	<i>Internet Routing – A Quick Tour</i>	3-23
3.5.3	<i>How Does Mobile IP Work?</i>	3-25
3.5.4	<i>Capabilities of Mobile IP</i>	3-25
3.6	WORLD WIDE WEB FOR WIRELESS – A CLOSER LOOK.....	3-27
3.6.1	<i>Accessing the Web from Mobile Devices and the Wireless Gateways</i>	3-27
3.6.2	<i>Semantic Web and its Role in Mobile Web Access</i>	3-28
3.6.3	<i>XML Overview</i>	3-29
3.6.4	<i>Document Type Declarations (DTD)</i>	3-32
3.6.5	<i>XSL (XML Stylesheet Language)</i>	3-33
3.7	WEB SERVICES AND MOBILE WEB SERVICES	3-35
3.7.1	<i>What are Web Services and Why are they Important to Mobile Computing?</i>	3-35
3.7.2	<i>A Quick Example – Accessing Web Services from a Mobile Device</i>	3-36
3.7.3	<i>Mobile Web Services</i>	3-37
3.8	SHORT EXAMPLES AND CASE STUDIES.....	3-38
3.8.1	<i>How Mobile IPV6 is used in Cellular Networks</i>	3-38
3.8.2	<i>AOL Anywhere: The Mobile Access Portal</i>	3-38
3.8.3	<i>A Mobile Purchasing System</i>	3-39

3.8.4	<i>Wireless Internet and the Arab World</i>	3-40
3.9	CONCLUDING COMMENTS.....	3-40
3.10	SUGGESTED REVIEW QUESTIONS AND EXERCISES	3-40
3.11	REFERENCES	3-41

Wireless Web: How are IP Addresses Assigned to Mobile Devices?

Mobile devices (cellular phones, laptops, PDAs) are being used on a regular basis for Web browsing, email exchanges, and other “Internet-enabled” services. For a device to access the Internet, it has to have an IP address or it should be connected to another computer with an IP address. A natural question is: how are IP addresses assigned to the mobile devices that are always changing locations? The answer depends somewhat on the type of device. Here is a simplified discussion.

In wireless LANs, IP addresses are assigned to the devices by using DHCP (Dynamic Host Configuration Protocol). DHCP is a software program that runs on a network server and automatically assigns an IP address when a device connected to that server is turned on. But once a user moves out of the DHCP range, for example the building where DHCP has been installed, then a new IP address is needed. Consider the scenario where Sam works in an office with DHCP support. When Sam arrives at the office in the morning, his laptop gets an IP address through the office DHCP. But Sam also has a home network, and when he goes home, he gets another IP address from his home DHCP. But if Sam goes to a hotel that does not have DHCP support, then he cannot connect without using the IP address assigned by the hotel.

With DHCP, when users move from one location to another, they are typically disconnected and then reconnected. Mobile IP, discussed in this chapter, allows Sam to stay connected as he changes locations. For example, if Sam started a large download that was going to take half an hour but he moved from one DHCP zone to another, then Mobile IP steps in to keep the download running as Sam moves around.

The situation is somewhat different with cellular networks because telephone numbers are used to locate mobile devices in the cellular networks. As a cellular phone user moves from one cell to another, the cellular network is responsible for “handing off” the traffic to the new cell. We will look at the exact technology in a later chapter on cellular networks. But how are the IP addresses handled by the cellular network? The simple answer is that the telephone numbers are still used to locate a cellular user, but the telephone numbers are translated to IP addresses by the cellular network provider.

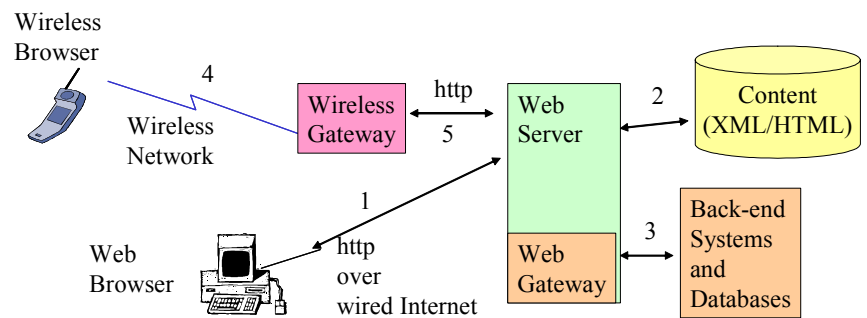
3.1 Introduction

The current and future mobile computing applications described in the previous chapter rely heavily on the capabilities of the Internet and Web in a wireless world – the main focus of this chapter. Although the Web and the Internet are usually confused with each other in popular

literature, they are two different technologies. Figure 3-1 shows a conceptual view of how Web content is accessed from regular Web browsers (steps 1, 2, 3) as well as from cellular phones (steps 4, 5, 2, 3). We will explain and expand this view in this and next chapter. The core building blocks of this view are:

- The Internet that carries the traffic between Web browsers and Web servers
- Web servers that are custodians of the Web content and also provide access to non-Web content through Web gateways
- Web browsers that display the Web content (e.g., HTML pages) on PCs
- Wireless networks that carry the data for handheld devices
- Wireless browsers that display the content on wireless handheld devices
- Wireless gateways that translate Internet protocols to wireless networks, if needed, and also convert (“render”) the Web content to be displayed on handheld browsers

Section 3.2 gives an overview of these building blocks. Because of the important role of the IP (Internet Protocol) and the Internet, Section 3.4 takes a closer look at IP and the Internet. The developments in Mobile IP that allow mobile devices to stay connected continuously while moving around the Internet are discussed in Section 3.5. Due to the popularity of the Web and its role in wireless applications, Section 3.6 takes a closer look at the Web with particular attention to the “Next Generation of Web” and XML. The emerging role of Web Services and Mobile Web Services in the future wireless Web is reviewed in Section 3.7. A few short case studies and examples conclude this chapter.



1. Access from Web browser to Web Server over wired Internet
2. Access to Web contents from HTML/XML files
3. Access to non-Web content through a Web gateway
4. Access from cellular phone over a wireless network
5. Access from wireless gateway to Web Server over wired Internet

Figure 3-1: Conceptual View of Wireless Web

Chapter Highlights

- The Internet is a network of IP (Internet Protocol) networks. Thus the terms Internet and IP networks are synonymous.
- An intranet is a private internet used by a corporation for its internal use. Intranets use Web technology for corporate services and applications.
- The Internet is evolving to an “IP dialtone” where all data, voice, and video applications can be supported as long as they have an IP address.

- Mobile IP allows mobile devices (PDAs, portable computers) to maintain Internet connectivity while moving from one Internet attachment point to another. This is done by using a concept similar to mail forwarding (the traffic is forwarded to the mobile device as it moves around).
- The World Wide Web, commonly known as the Web, is not the same as the Internet. The Web is essentially a collection of technologies that operate on top of the Internet to support a community of users and applications through GUIs.
- The First Generation Web (the conventional Web) is based on the following concepts and technologies:
 - Web servers
 - Web browsers
 - Uniform Resource Locator (URL)
 - Hypertext Transfer Protocol (HTTP)
 - Hypertext Markup Language (HTML)
 - Web navigation and search tools
 - Gateways to non-Web resources
- Web access to non-Web resources is provided through Web gateways. For example, Web access to relational databases is provided through “relational gateways” that serve as translators and mediators between Web browsers and relational database managers.
- Wireless gateways are used to connect wireless devices to the Web servers. These gateways translate between the wireless and wired world and provide compression, content conversion, and security features.
- Next Generation Web, also known as Semantic Web, is concentrating on automation of the Web through:
 - Extended Markup Language (XML) and its variants that can describe semi-structured information for automation
 - Metadata and object models such as the Document Object Model (DOM) and Resource Definition Framework (RDF)
- XML and its variants are key players in mobile applications because XML allows partners to formally specify and enforce the content and format of documents exchanged. For example, WML (Wireless Markup Language) is a variant of XML.
- Web Services (WS) are intended to provide global distributed applications through which an inventory system in Singapore can be combined with an order processing system in London to handle orders placed by someone in Chicago.
- Mobile Web Services is a specification that describes how WS can be used to handle mobile devices.



The Agenda

- Overview of Internet and Web
- IP and Mobile IP
- Wireless Web, Web Services, and Examples

3.2 Internet and the Web: A Quick Refresher

3.2.1 Internet, Intranets, and Extranets at a Glance

Technically speaking, the Internet is a network based on the TCP/IP protocol stack. At present, the term *Internet* is used to refer to a large collection of TCP/IP networks that are tied together through network interconnectivity devices such as routers and gateways. The term *cyberspace*, first introduced through a science fiction book by Gibson [1984], has been permanently transferred to our vocabulary. It represents thousands of computers and computer resources around the globe interconnected through the Internet. At present, the term Internet is used to symbolize the following two situations:

- **Public Internet**, or just the Internet, that is not owned by any single entity – it consists of many independent TCP/IP networks that are tied together loosely. Initially, the public Internet was used to tie different university networks together. With time, several commercial and private networks have joined the public Internet. The computers on the public Internet have publicly known Internet Protocol (IP) addresses that are used to exchange information over the public Internet (see discussion on addressing below). The public Internet at present consists of thousands of networks.
- **Private intranets**, or intranets, are the TCP/IP networks that are used by corporations for their own business, especially by exploiting Web technologies. Technically, an intranet uses the same technology as the public Internet – it is only smaller and privately owned and thus hopefully better controlled and more secure. Thus, any applications and services that are available on the public Internet are also available on the intranets. This is an important point for the Web because many companies are using Web technologies on their intranets for internal applications (e.g., employee information systems).
- **Extranets** are the TCP/IP networks that are owned by corporations to conduct business. These networks use the same Internet technologies; however, the physical network is collectively owned by corporations to meet the security and reliability requirements imposed by the owners. An example of an extranet is the Exchange-Net formed by GM, Ford, Chrysler, and other manufacturing organizations to conduct manufacturing b2b transactions.

Unless otherwise indicated, the discussion in this chapter is oriented towards the public Internet, although most concepts also apply to the Intranets and Extranets.

Domain Naming Services (DNSs) are used in the Internet to locate different resources. This protocol defines hierarchical naming structures that are much easier to remember than the IP addresses. For example, the machine with an IP address of 135.25.7.82 may have a domain name of shoeshop.com. A user “mills” may have an email address mills@shoeshop.com. The DNS naming structures define the organization type, organization name, etc. The last word in the domain name identifies an organization type or a country. Consider, for example, the following domain names:

bellcore.com = commercial company Bellcore
ibm.com = commercial company IBM
um.edu = educational institution University of Michigan
omg.org = organization OMG (Object Management Group)
waterloo.ca = Waterloo University in Canada
lancs.ac.uk = Lancaster University in UK
ansa.co.uk = ANSA consortium in UK
iona.ie = Iona Corporation in Ireland

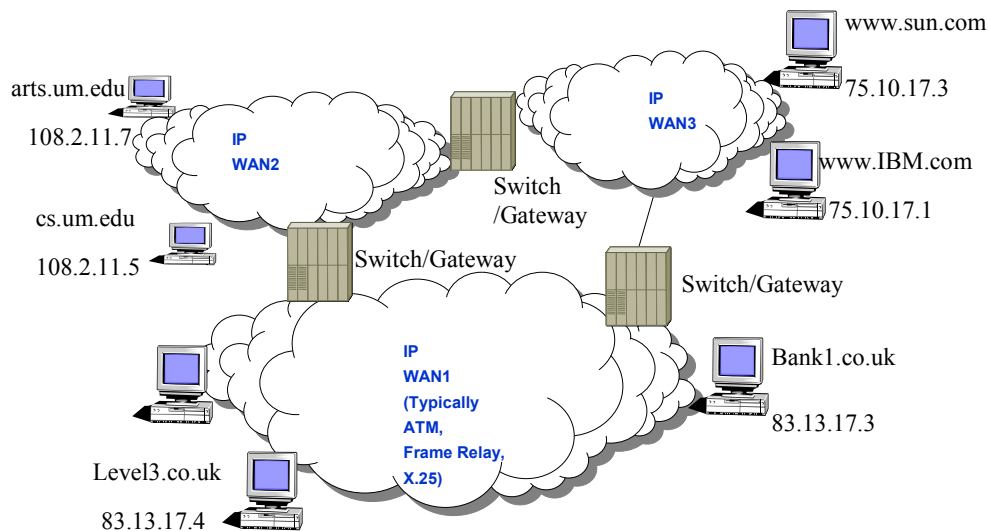
The Internet uses a large number of domain name servers that translate domain names to IP addresses (the IP routers only understand IP addresses). Domain names are used in the Internet as well as the Web.

Figure 3-2 shows a conceptual and partial view of the Internet. This Internet shows three networks (a university network with two computers, a commercial company network, and a network in the UK). Each computer (“host”) on this network has an IP address and has been assigned a domain name as well. The Internet is very heterogeneous (i.e., different computers, different physical networks). However, to the users of this network, it provides a set of uniform TCP/IP services (TCP/IP hides many details). We will use this simple Internet to illustrate the key Internet capabilities.

Since the Internet is based on TCP/IP, the applications and services provided by TCP are also available on the Internet. From an end-user point of view, the following services have been, and still are, used very heavily on the Internet:

- Email
- Telnet
- FTP
- Gopher
- WAIS (Wide Area Information Servers)

Electronic mail on the Internet is based on the **Simple Mail Transfer Protocol (SMTP)**. This TCP-based protocol is the Internet electronic mail exchange mechanism. Email is still one of the most heavily used services in the Internet. Users on the Internet have email addresses such as `johnm@cs.um.edu`, `hevner@sun.com` and `howard@bank1.co.uk`.



- DNS (Domain Name Services) translates `cs.um.edu` to `108.2.11.5`
- Telnet `cs.um.edu` = Telnet `108.2.11.5`
- FTP `cs.um.edu` = FTP `108.2.11.5`

Figure 3-2: Partial View of Internet

Terminal emulation is used to remotely log on to other machines. **Telnet** provides terminal access to hosts and runs on top of TCP. Let us assume that a user “joe” on `cs.um.edu` needs to

remotely log on to the bank1.co.uk machine to run a program “directory.” The user would use the following steps (the steps are explained through comments in /* */):

```
> telnet bank1.co.uk /* invoke Telnet. Could have typed " telnet 85.13.17.3."*/
bank1> enter logon: joe /* prompt from bank1 for logon ID. joe is ID */
bank1> password: xxxx /* prompt from bank1 for password */
bank1> directory /* run the program "directory" */
bank1> exit /* quit telnet */
```

File transfer is used for the bulk of data transfer over the Internet. The **File Transfer Protocol (FTP)** provides a way to transfer files between hosts on the Internet. Let us assume that a user “garner” on “sun.com” needs to transfer a file from the host arts.um.edu. The following steps would be used (the steps are explained through comments in /* */):

```
> ftp arts.um.edu /* invoke FTP. Could have typed " ftp 102.52.10.7"*/
arts> enter logon: garner /* prompt from arts.um for logon ID. garner is ID */
arts> password: xxxx /* prompt from arts.um for password */
arts> get file1 file2 /* FTP file transfer command */
arts> exit (or quit) /* quit FTP */
```

Gopher is a well-known interface for the Internet. Developed at the University of Minnesota, Gopher is very similar to the Web because it provides a friendly face to tools such as FTP and Telnet, among others. However, Gopher does not support hypertext. Gopher provides a numbered list or, in some cases, icons to represent different files that you can transfer and access over the Internet.

WAIS (Wide Area Information Servers) generates and allows you to search a huge range of databases stored on the Internet based on search keys. These databases contain pointers to locations on the Internet that hold documents containing the search keys. WAIS rates its search results (e.g. a rating of 1000 means direct hit and 100 means marginal hit). WAIS allows you to keep narrowing the search until you find exactly what you are looking for. It is used in Web for full keyword searching (in most cases, you do not know that the Web is using WAIS internally).

For many years, the Internet had been used mainly by researchers, teachers, scientists, students, and programmers to transfer files and send/receive electronic mail. These users relied on text-based commands to do their job. The Web is a set of services that run on top of the Internet. The two main features of the Web are the use of GUI and hypertext to make the life of Internet users easy and fun. We will discuss the Web in the next section in more detail.

We should mention that the users access the Internet either directly or indirectly. **Direct Internet users** reside on the machines that have IP addresses while **indirect Internet users** remotely log on to the machines with IP addresses. For example, America Online is an Internet Access Provider that actually has machines with IP addresses (direct access). If you subscribe to America Online, then you dial into an America Online machine (i.e., you are indirectly accessing the Internet).

3.2.2 The Web at a Glance

The World Wide Web (WWW), commonly known as the Web, was started in 1989 by Tim Berners-Lee at the Geneva European Laboratory for Particle Physics (known as CERN, based on the laboratory’s French name) [Berners-Lee 1999, 1993]. The initial proposal suggested development of a “hypertext system” to enable efficient and easy information-sharing among geographically separated teams of researchers in the High Energy Physics community. The initial proposal had three basic components:

- A common and consistent user interface

- Incorporation of a wide range of technologies and document types
- A “universal readership” to allow anyone sitting anywhere on the network, on a wide variety of computers, to easily read the same document as anyone else

By the end of 1990, a line-browser (called www) was developed to implement the principles of hypertext access and the reading of different document types. In 1991, the line-browser was made available to the CERN community and a gateway for Wide Area Information Servers (WAIS) searches was developed. In 1992, a few more browsers were developed and around 50 websites (the machines that house Web documents) were implemented. During 1993, the Web took off – the number of websites increased to 500, the Web network traffic grew from 0.1 percent of Internet traffic to 1 percent (a 10-fold increase), and the Mosaic browser for X Windows was developed at NCSA (National Center for Supercomputing Applications at University of Illinois). Since 1994, the Web has been gaining popularity dramatically, with increases in the number of browsers, search engines, Web servers, and usage.

The “First Generation of the Web,” discussed in Section 3.2.3, is based on a few simple concepts and technologies. Due to the popularity of the Web, many limitations of the first generation started appearing. Based on this, a great deal of activity has focused on the “Next Generation of the Web,” discussed in Section 3.6.2. Perhaps the best known activity from this work is XML and what is now being called “the semantic Web.”

A good historical view of the WWW is presented by Tim Berners-Lee in his book “Weaving the Web” (Harper San Francisco, 1999).

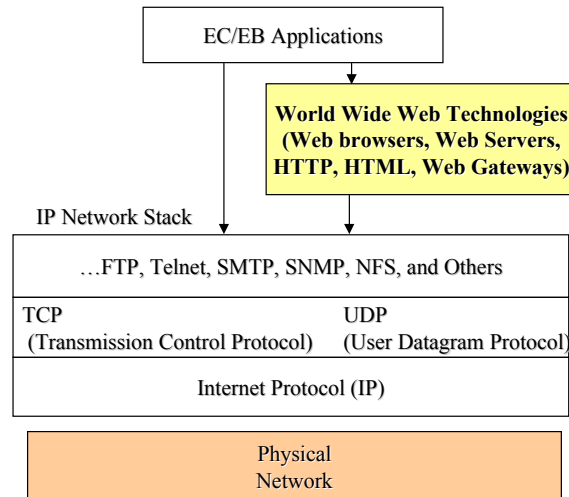


Figure 3-3: Technical View of World Wide Web

3.2.3 World Wide Web Technologies – The First Generation

Technically speaking, the Web is a collection of technologies that operates on top of the IP networks (i.e., the Internet). Figure 3-3 shows this layered view. The purpose of the WWW technologies is to support the growing number of users and applications ranging from entertainment to corporate information systems. Like many other (successful) Internet technologies, the first generation of the Web is based on a few simple concepts and technologies such as the following (see Figure 3-3):

- Web servers
- Web browsers

- Uniform Resource Locator (URL)
- Hypertext Transfer Protocol (HTTP)
- Hypertext Markup Language (HTML)
- Web navigation and search tools
- Gateways to non-Web resources

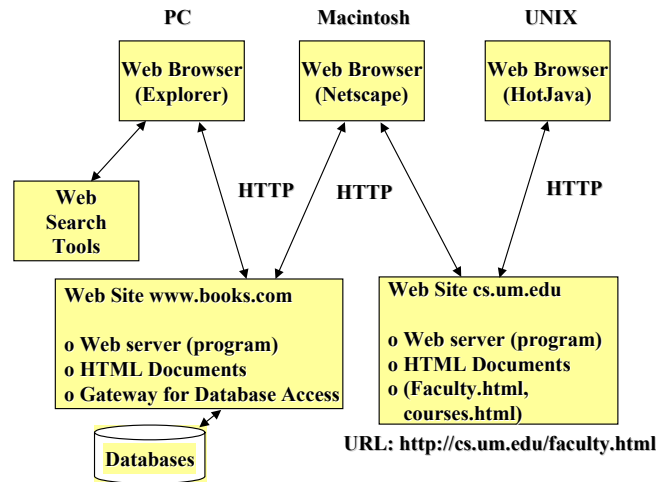


Figure 3-4: Conceptual View of World Wide Web

Let us briefly review these components and show how they tie in with each other through an example. We will discuss these components in more detail later in this chapter.

Websites provide the content accessed by Web users. Websites are populated and in many cases managed by the content providers. For example, websites provide the commercial presence for each of the content providers doing business over the Internet. Conceptually, a website is a catalog of information for each content provider over the Web. In reality, a website consists of three types of components: a Web server (a program), content files (“Web pages”) and/or gateways (programs that access non-Web content).

A Web server is a program (technically a server process) that receives calls from Web clients and retrieves Web pages and/or receives information from gateways (we will discuss gateways later). Once again, a Web user views a website as a collection of files on a computer, usually a UNIX or Windows NT machine. In many cases, a machine is dedicated/designated as a website on which Web-accessible contents are stored. As a matter of convention in EC/EB, the entry point to a website is a “home page” which advertises a company business. Very much like storefront signs in a shopping mall, the home pages include a company logo, fancy artwork for attention, special deals, overviews, pointers to additional information, etc. The large number of websites containing a wide range of information to be navigated and searched transparently by Web users is the main strength of the Web. Figure 3-4 shows two websites – one for a shoe shop (www.shoes.com) and the other for a computer science department for a university (cs.um.edu).

Web browsers are the clients that typically use graphical user interfaces to wander through the websites. The first GUI browser, Mosaic, was developed at the National Center for Supercomputer Applications at the University of Illinois. Mosaic ran on PC Windows, Macintosh, UNIX and Xterminals. At present, Web browsers are commercially available from Netscape, Microsoft and many other software/freeware providers. These Web browsers provide an intuitive view of information where hyperlinks (links to other text information) appear as underlined items or highlighted text/images. If a user points and clicks on the

highlighted text/images, then the Web browser uses HTTP to fetch the requested document from an appropriate website. Web browsers are designed to display information prepared in a markup language, known as HTML. Three different browsers are shown in Figure 3-4. Even though these are different browsers residing on different machines, they all use the same protocol (HTTP) to communicate with the Web servers (HTTP compliance is a basic requirement for Web browsers).

Most browsers at present are relatively dumb (i.e., they just pass user requests to Web servers and display the results). However, this is changing very quickly because of Java, a programming language developed by Sun Microsystems. Java programs, known as Java applets, can run on Java-compatible browsers. This is creating many interesting possibilities in which Java applets are downloaded to the Java-enabled browsers where they run, producing graphs/charts, invoking multimedia applications, and accessing remote databases. For a more detailed discussion of Java, see the tutorial on this topic in the Tutorial Module.

Uniform Resource Locator (URL) is the basis for locating resources on the Web. A URL consists of a string of characters that uniquely identifies a resource. A user can connect to resources by typing the URL in a browser window or by clicking on a hyperlink that implicitly invokes a URL. Perhaps the best way to explain URLs is through an example. Let us look at the URL “http://cs.um.edu/faculty.html” shown in Figure 3-4. The “http” in the URL tells the server that an HTTP request is being initiated (if you substitute “ftp” for “http,” then an FTP session is initiated). The “cs.um.edu” is the name of the machine running the Web server (this is actually the domain name used by the Internet to locate machines on the Internet). The term “/faculty.html” is the name of a file on the machine cs.um.edu. The “html” suffix indicates that this is an HTML file. When this URL is clicked or typed, the browser initiates a connection to the “cs.um.edu” machine and initiates a “Get” request for the “faculty.html” file. Depending on the type of browser you are using, you can see these requests flying around in an appropriate window spot. Eventually, this document is fetched, transferred to the Web browser and displayed. You can access any information through the Web by issuing a URL (directly or indirectly). As we will see later, the Web search tools return a bunch of URLs in response to a search query. The general format of a URL is:

protocol://host:port/path

where

protocol represents the protocol to retrieve or send information. Examples of valid protocols are HTTP, FTP, Telnet, Gopher, and NNTP (Network News Transfer Protocol).

host is the computer host on which the resource resides

port is an optional port number (this is not needed unless you want to override the HTTP default port, port 80)

path is an identification, typically a file name, on the computer host.

Hypertext Markup Language (HTML) is an easy-to-use language that tags the text files for display on Web browsers. HTML also helps in creation of hypertext links, usually called hyperlinks, which provide a path from one document to another. The hyperlinks contain URLs for the needed resources. The main purpose of HTML is to allow users to flip through Web documents in a manner similar to flipping through a book, magazine or a catalog. The website “cs.um.edu” shown in Figure 3-4 contains two HTML documents: “faculty.html” and “courses.html.” HTML documents can imbed text, images, audio, and video.

Hypertext Transfer Protocol (HTTP) is an application-level protocol designed for Web users. It is intended for collaborative, distributed, hypermedia information systems. HTTP uses an extremely simple request/response model that establishes connection with the Web server specified in the URL, retrieves the needed document, and closes the connection. Once the document has been transferred to your Web browser, then the browser takes over. Keep in mind that every time you click on a hyperlink, you are initiating an HTTP session to transfer

the needed information to your browser. The Web users shown in Figure 3-4 access the information stored in the two servers by using the HTTP protocol.

Web navigation and search services are used to search and surf the vast resources available in “cyberspace.” This term, as stated previously, was first introduced through a science-fiction book by Gibson [1984] but currently refers to the computer-mediated experiences for visualization, communication, and browser/decision support. The general search paradigm used is that each search service contains an index of information available on websites. This index is almost always created and updated by “spiders” that crawl around the websites chasing hyperlinks for different pieces of information. Search engines support keyword and/or subject-oriented browsing through the index. The result of this browsing is a “hit list” of hyperlinks (URLs) that the user can click on to access the needed information. For example, the Web users in Figure 3-4 can issue a keyword search, say by using a search service for shoe stores in Chicago. This will return a hit list of potential shoe stores that are Web content providers. You, then, point and click until you find a shoe store of your choice. Many search services are currently available on the Web. Examples are Yahoo, Lycos and Alta Vista. At present, many of these tools are being integrated with Web pages and Web browsers. For example, the Netscape browser automatically invokes the Netscape home page that displays search tools that you can invoke by just pointing and clicking. It is beyond the scope of this book to describe the various Web navigation and search tools. Many books on the Internet describe these search tools quite well. For example, the book by December [1995] has an extensive discussion of Web search and navigation tools with information about how to locate and use them.

Gateways to non-Web resources are used to bridge the gap between Web browsers and the corporate applications and databases. Web gateways are used for accessing information from heterogeneous data sources (e.g., relational databases, indexed files and legacy information sources) and can be used to handle almost anything that is not designed with an HTML interface. The basic issue is that the Web browsers can display HTML information. These gateways are used to access non-HTML information and convert it to HTML format for display on a Web browser. The gateway programs typically run on websites and are invoked by the Web servers. At present, Common Gateway Interface (CGI) is used frequently. We will discuss CGI gateways and other types of Web gateways later in this chapter. “Relational gateways” that provide access to relational databases from Web browsers are an area of active work.

3.3 How does Wireless Web Really Work?– Quick Examples

3.3.1 A Simple Wired Access Example

Before discussing wireless access to the Web, let us first consider an example of wired Web access to show the interrelationships between the main components discussed so far. Figure 3-5 illustrates how the Web components can be used for purchasing from a department store, “clothes.com.” This store wants to advertise its products on the Web, (i.e., wants to be a Web content provider). The store first designates a machine, or buys services on a machine, called “clothes.com” as a website. It then creates an overview document, “overview.html,” that tells the potential customers of the product highlights (think of this as the first few pages of a catalog). In addition, several HTML documents on the website for different types of clothes

(men.html, women.html, kids.html) are created with pictures of clothes, size information, etc. (once again think of this as a catalog). We can assume that the overview page has hyperlinks to the other documents (as a matter of fact, it could have hyperlinks to other branches of clothes.com). In reality, design of the Web pages would require a richer, deeper tree structure design as well as sequential links for alphabetical and keyword searches needed to support the “flipping through the catalog” behavior.

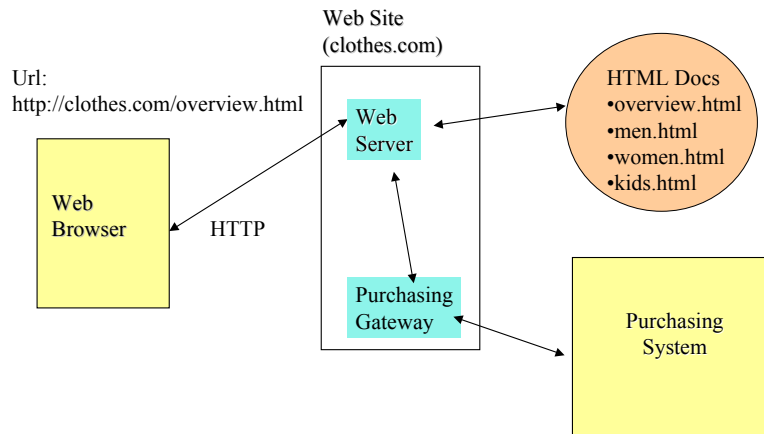


Figure 3-5: Conceptual View of an Internet-based Purchasing System

Once HTML documents have been created on the Web server, an Internet user can browse through them as if he/she is flipping through a catalog. By using the browser, the Internet user establishes an HTTP session with the website – the entire Internet machinery discussed above (IP addresses, routers, etc) is used to establish this connection. To make the connection, the customers of clothes.com typically supply the URL, directly or indirectly, for the overview (<http://clothes.com/overview.html>) and then use the hyperlinks to look at different types of clothes. Experienced customers may go directly to the type of clothes needed (e.g., men may directly go to the “men.html” document). As shown in Figure 3-5, the URL consists of three components: the protocol (http), the Web server name (clothes.com), and the needed document (overview.html). HTTP provides the transfer of information between the Web users (the clients) and the Web Servers.

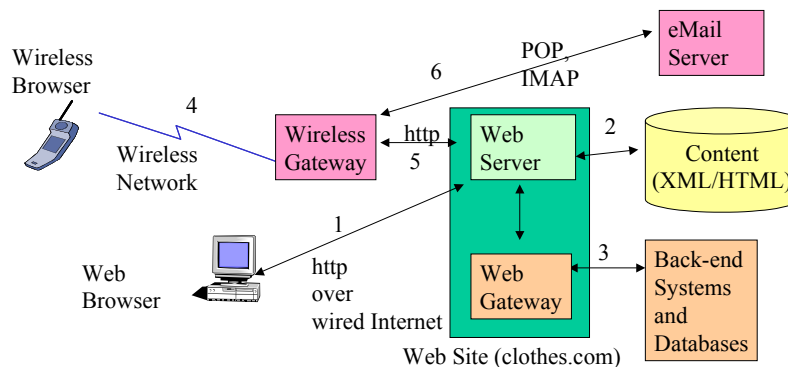
At first, clothes.com is only using the Web to store an electronic catalog. After a customer has browsed through the catalog and has selected an item, he/she calls the store and places an order. Let us say that clothes.com also wants the customers to purchase the items over the Internet. In this case, a “Purchasing Gateway” software is developed and installed at the website. This gateway program gets into action when a user clicks on the “purchase” button on his screen. It prompts the user with a form (HTML supports forms) that the user fills out. The gateway program uses this form information to interact with a purchasing system that processes the purchase (see Figure 3-5). The purchasing system can be an existing system that is used for traditional purchasing. The role of the gateway is to provide a Web interface to the purchasing system.

3.3.2 A Simple Wireless Web Example

Figure 3-1 expands and generalizes the example discussed above to include wireless access. Steps 1, 2, and 3 show how Web content is accessed and a back-end system (such as purchasing) is invoked from regular Web browsers. We have discussed these steps previously. The difference is that now the same activities (accessing clothes.com and purchasing goods) are being performed from cellular phones by using steps 4 and 5. In addition, email services are also being invoked from the same cellular phone by using step 6. Let us go through some details of these additional steps.

Steps 4 and 5 entail connection to the clothes.com site through a wireless gateway. The main purpose of this gateway is to convert the wireless network request (step 4) into a regular HTTP request (step 5) so that the web server does not know if the request originated from a cellular phone or a desktop web browser. This has a major advantage that the same Web content and mechanisms to invoke back-end systems can be re-used without any changes. The wireless gateway also does the reverse processing on outbound traffic – it converts regular web content to a format that can be displayed on the cellular phone. An example of a wireless gateway is the WAP (Wireless Application Protocol) Gateway, commercially available from companies such as Nokia. We will take a closer look at wireless gateways later in this chapter and next chapter.

Step 7 shows how email can be accessed from the same cellular phone. In this case, the wireless gateway detects that the content is not on a Web server; instead it is on an email server. Consequently, it establishes an email session by using POP (Post Office Protocol) or some other email protocol and converts the content back and forth between the email server and the cellular phone.




1. Access from Web browser to Web Server over wired Internet
2. Access Web contents from HTML/XML files
3. Access to non-Web content through a Web gateway
4. Access from cellular phone over a wireless network
5. Access from wireless gateway to Web Server over wired Internet
6. Access from the Wireless Gateway to an email server

Figure 3-6: Conceptual View of Wireless Access to Web and Email

The main message should be clear – wireless gateways play a key role in interconnecting the mobile devices to existing resources (Web content, online purchasing facilities, email services). The level of translation performed by the wireless gateway depends on the differences between the front-end (wireless) and back-end (wired) systems. For example, if

the wireless network is an 802.11 LAN that already supports IP, then the translation is minimal. But if the wireless network is a 1G analog cellular system, then heaven help you!



Time to Take a Break

- ✓ • Overview of Internet and Web
- IP and Mobile IP
- Wireless Web, Web Services, and Examples

3.4 The Internet and IP – A Closer Look¹

3.4.1 What is the Internet?

Technically speaking, the *Internet* is a network based on the TCP/IP protocol stack. At present, the term Internet is used to refer to a large collection of TCP/IP networks that are tied together through network interconnectivity devices such as routers and gateways. The TCP/IP (Transmission Control Protocol/Internet Protocol), briefly introduced in chapter 3, was developed in the late 1960s and early 1970s by the Defense Advanced Research Projects Agency (DARPA). TCP/IP was developed for interconnecting many computers in the ARPANET (Advanced Research Projects Agency Network). ARPANET initially consisted of five protocols (indicated with * in the following list) that have been augmented with other key protocols (see Figure 3-7):

- *Internet Protocol (IP) for interconnecting and routing messages to a large number of physical networks
- *Transmission Control Protocol (TCP) for reliable information transfer
- User Datagram Program (UDP) for fast, but unreliable, information transfer
- *File Transfer Protocol (FTP) for file transfer
- *Simplified Mail Transfer Protocol (SMTP) for email
- *Terminal emulator (Telnet) for terminal emulation
- Hypertext Transfer Protocol (HTTP) for Web applications
- Real Time Protocol (RTP) for audio and video applications

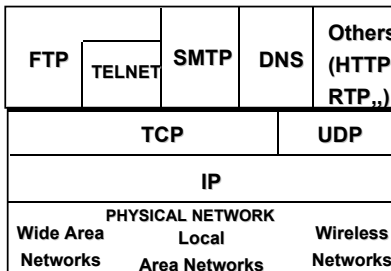


Figure 3-7: The IP Stack – Foundation of Internet

¹ If you are not familiar with networking concepts, it is a good idea to review Appendix A before proceeding.

Although the Internet at present uses TCP (i.e., higher-level protocols and applications are based on TCP), this may not be true in the future since some future (especially real-time) applications may be built directly on IP or newer alternatives to TCP. The main strength of IP is that it runs on top of a very diverse array of physical networks (wide area, local area, wireless). In fact, IP supports almost all current physical network technologies and is expected to support most of the future high speed networks. Therefore we will use the following simple definition of the Internet:

Definition: The Internet is a network of networks that is supported by the Internet Protocol (IP).

What does this mean? Basically it says that you need to have an IP network (or a gateway that translates to IP) to join the Internet. Once you have an IP network, then you can run almost any physical network under it and take advantage of voice, data, or video applications for your business that run on top of IP.

Initially, the public Internet was used to tie different university networks together. Over time, several commercial and private networks have joined the public Internet. The computers on the public Internet have publicly known Internet Protocol (IP) addresses that are used to exchange information over the public Internet (we will discuss IP addresses later). The public Internet at present consists of millions of computers (PCs, Macs, Sun workstations, HP systems, IBM mainframes) that are interconnected through thousands of networks that use different underlying network technologies (ATMs, frame relays, Ethernet LANs, and wireless networks) in different parts of the world. All these computers and networks are tied together through a global IP network (see Figure 3-8).

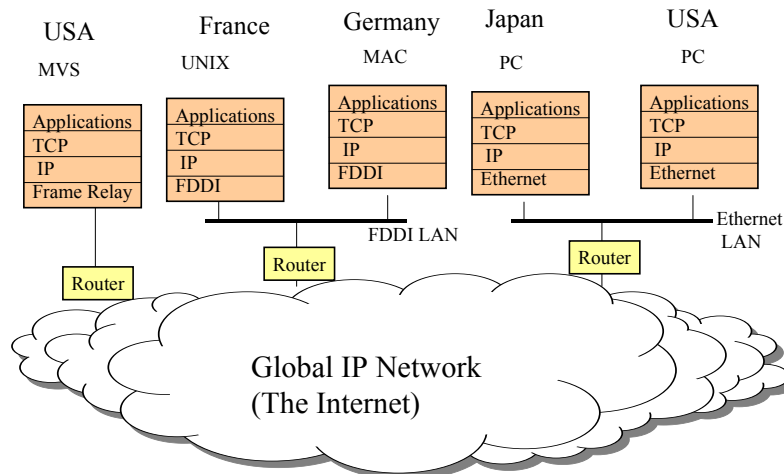


Figure 3-8: Public Internet – A Global IP Network

Let us look at an actual example. Figure 3-9 shows an example of how I, sitting in New Jersey (US) can exchange email with a friend of mine at the University of Sydney (Australia). It shows the various networks, gateways, and email servers that participate in the email exchange.

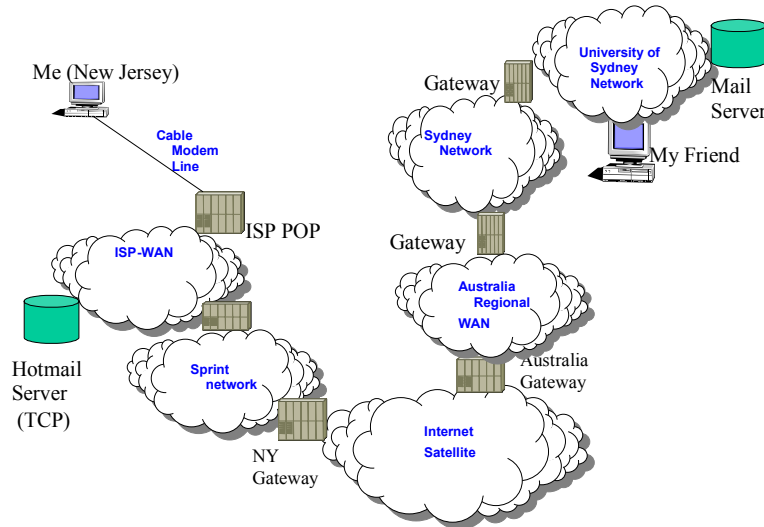


Figure 3-9: An example of IP connectivity from New Jersey (US) to Sydney (Australia)

3.4.2 IP Overview

Transmission Control Protocol (TCP) and Internet Protocol (IP) are the best-known protocols in the IP stack (they operate roughly at layer 3 and 4 of OSI). Over the years, the entire ARPANET Protocol Suite has become known as the **TCP/IP Protocol Suite**. As stated previously, TCP/IP has dramatically grown in popularity in the last 20 years and is supported very widely. For example, TCP/IP can be used to transfer files between IBM, SUN, HP, IBM PCs and several other machines. IP, the lowest protocol in this Suite, can reside on a very wide variety of physical networks such as Ethernets, FDDI based fiber optic LANs, dial-up lines, X.25-based packet switching networks, wireless networks, or ISDN digital networks. TCP, the layer above IP, supports a very wide variety of higher-level (application) protocols which allow users to emulate terminals, transfer files, and send/receive mail between different computers (see Figure 3-10):

Due to its popularity, the TCP/IP Protocol Suite continues to evolve. The TCP/IP Suite originally consisted of five basic protocols: IP, TCP, FTP, Telnet and SMTP. Later, Domain Naming Services (DNS) and Simple Network Management Protocol (SNMP) were added to the TCP/IP basic protocols. In addition, many other protocols and user applications have been developed around TCP/IP. The TCP/IP Suite addresses issues for layer 3 and above. The application layer of this network architecture provides a rich set of file transfer, terminal emulation, network file access and electronic mail services. It is important to note that a user application may choose to use any of the TCP/IP layers or may directly communicate with the physical network. Let us review the key protocols.

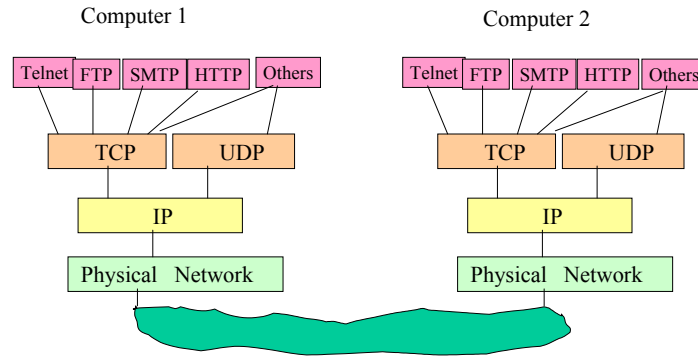


Figure 3-10: TCP/IP Network – The Initial Stack

3.4.3 The Internet Protocol (IP)

The Internet Protocol (IP) is the lowest-layer protocol defined in the IP Suite. It runs on top of whatever protocols are in use in the physical network (Ethernet, X.25, token ring, serial, ATM, Frame Relay, wireless networks, etc). IP connects hosts across multiple networks (Internet) and provides a way of moving a block of data from one host machine to another through the Internet. This block of data is known as a *datagram*.

The delivery of datagrams is made possible by assigning an IP address to every host in the Internet. These addresses are 32 bits in length and are commonly denoted as four decimal numbers separated by periods (e.g., 21.152.214.2). The first part of the address shows which network the host resides on, and the rest of the address shows where within that network the host can be found.

IP is an unreliable (connectionless) protocol. This means that datagrams sent from one host to another may not be delivered in the order in which they were sent, may be delivered more than once, or may not be delivered at all. Higher-layer protocols are expected to correct this deficiency. Unreliable protocols are much simpler and cleaner to implement and facilitate dynamic routing of datagrams (routing around problems) within the networks.

The current IP (technically known as IPv4) is more than 20 years old. IPv4 has been remarkably resilient in spite of its age, but it is beginning to have problems. Most importantly, there is a growing shortage of IPv4 addresses, which are needed by all new machines added to the Internet. The *next generation of the Internet Protocol (IPv6)* is intended to support Internet traffic for many years into the future by providing enhancements over the capabilities of the existing IPv4 service. IPv6 corrects a number of problems in IPv4, such as the limited number of available IPv4 addresses. It also adds many improvements to IPv4 in areas such as routing and network auto-configuration. IPv6 is expected to gradually replace IPv4, with the two coexisting for a number of years during a transition period. IPv6 is an area of intense activity at the IETF (Internet Engineering Task Force).

3.4.4 The Transmission Control Protocol (TCP)

The Transmission Control Protocol (TCP) runs on top of IP and is by far the most heavily used transport protocol in the Internet. It provides a reliable, ordered connection between processes on different hosts. One host may run many processes, so a process-to-process connection is needed. This means that application processes can establish a TCP connection and expect that data will arrive successfully and in order.

A TCP connection is essentially an error-free pipe from one host process to another. There is no inherent meaning at this layer to the data sent over this pipe. This generality allows a variety of higher-layer protocols to run on top of TCP. The fact that this protocol is connection-based means that some overhead is incurred at connection setup and disconnect. This is appropriate for applications that need to send a large amount of data to one place, but it might not be so appropriate for quick, short exchanges.

3.4.5 The User Datagram Protocol (UDP)

The User Datagram Protocol (UDP) also runs on top of IP and is an alternative to using TCP. Like IP, UDP is an unreliable protocol. In fact, the major function that UDP adds to IP is a way to differentiate more than one stream of data going to or from a host (IP addresses only identify the hosts and not the processes within a host). Due to the unreliability of UDP, it is up to higher-layer protocols running on top of UDP to provide reliability if it is needed.

UDP is appropriate for applications which exchange a small amount of information, such as a single request and a reply to it. In such applications, the overhead of establishing a connection is unnecessary. UDP may also be appropriate in applications requiring the exchange of data with more than one host. Since every UDP datagram is individually addressed, a host can talk to as many other hosts as necessary without having to establish a TCP connection to every one of them.

3.4.6 Additional Transport Layer Protocol – SCTP (Simple Control Transmission Protocol).

SCTP was designed originally as the transport layer for telephone signaling (ISUP, Q.931, TCAP, etc.) over IP networks, since there are intrinsic limitations for TCP for this job. But as the work progresses, the IETF Transport Area Working Group is paying more and more attention to it. It has long been recognized by the Internet community that TCP, which serves most IP applications well until recently, is limited in certain aspects for real time applications and a “Next-Generation TCP” will be needed. IETF is looking at SCTP as a candidate.

3.4.7 Sample Higher (Application) Layer Protocols

Many higher layer protocols run on top of TCP and UDP. It is also possible to define private application protocols as long as both hosts agree on the protocol. The following protocols (the first three belong to the original DOD Suite) are among the best-known application protocols defined in the IP Suite.

- **Telnet:** This protocol is used to provide terminal access to hosts and runs on top of TCP.
- **File Transfer Protocol (FTP):** This TCP-based protocol provides a way to transfer files between hosts on the Internet.
- **Simple Mail Transfer Protocol (SMTP):** This TCP-based protocol is the Internet electronic mail exchange mechanism.
- **Trivial File Transfer Protocol (TFTP):** This UDP-based protocol also transfers files between hosts, but with less functionality (e.g., no authorization mechanism). This protocol is used typically for “booting” over the network.
- **Network File System (NFS) Protocol:** This UDP-based protocol has become a de facto standard for use in building distributed file systems through transparent access.
- **Xwindow:** This is a windowing system that provides uniform user views of several executing programs and processes on bit-mapped displays. Although Xwindow is supposedly network-independent, it has been implemented widely on top of TCP.

- **SUN Remote Procedure Call (RPC):** This protocol allows programs to execute subroutines that are actually at remote sites. RPCs, like Xwindow, are supposedly network independent but have been implemented widely on top of TCP. SUN RPC is one of the oldest RPCs. Examples of other RPCs are Netwise RPC and OSF RPC. RPCs are described in detail in Chapter 5.
- **Domain Naming Services:** This protocol defines hierarchical naming structures which are much easier to remember than the IP addresses. The naming structures define the organization type, organization name, etc.
- **Time and Daytime Protocol:** This provides machine-readable time and day information.
- **SNMP (Simple Network Management Protocol):** This is a protocol defined for managing (monitoring and controlling) networks.
- **Kerberos:** This is a security authentication protocol developed at MIT.
- **RTP (Real Time Protocol).** A protocol for voice and video applications
- **HTTP (Hypertext Transfer Protocol).** Used to transfer files in the Web
- **H323.** Protocol to support voice over IP (proposed by ITU-T)
- **SIP (Session Initiation Protocol).** Protocol for voice over IP (proposed by IETF)
- **N3270.** IP-based terminal emulator for 3270

Other frequently used services in IP are Ping (an echo command), Netstat (command to display the network status of the local host, e.g., active TCP connection and IP routing tables), and Finger (displays information about users of a remote host, e.g., list of all users logged on to the remote host). In addition, the OSI upper layers can be implemented on TCP/IP as specified in the RFC1006.

3.4.8 Common TCP/IP Implementations

TCP/IP has been implemented on most machines under the Unix operating system. In many Unix systems such as SUN, TCP/IP is shipped as part of the operating system. TCP/IP is also becoming available on many other operating systems. An interesting example is the availability of TCP/IP on IBM mainframes. The IBM mainframes use two operating systems: MVS and VM. TCP/IP is currently available on MVS as well as VM. These implementations provide NFS and Xwindow support, in addition to the common Internet Application Layer protocols. MVS-NFS is especially interesting because it allows MVS files to be accessed transparently from Unix workstations. This is a major step toward file transparency in most corporations.

3.4.9 Next Generation Network and Internet

The network communication technologies are advancing at a very rapid pace. In particular, we are witnessing growth of high speed, also known as *broadband*, networks that exceed 100 Mbps data rates. Broadband is a general term that refers to “high speed” data communications, typically 1Mbps, or higher. An interest in broadband communications has taken center stage over the past few years because broadband technologies represent the speed at which users can access the Internet. In addition, we are also seeing an increased availability of wireless networks to support a variety of mobile users. The drivers for the growth of wireless and broadband services are:

- The Internet continues to be the primary driver for the communications industry. Internet traffic is doubling every year and is expected to keep growing in the future. The increased traffic is driving the need for networks that can handle the increased bandwidth levels.

- Increased use of cellular phones, palm pilots, PDAs, laptops, notebooks, and other handheld devices is driving the demand for mobile communications. "Wireless Internet" with mobile commerce has become highly desirable for "any information, anywhere, anytime" :
- The convergence of data and voice networks onto a single network infrastructure is also a driver of increased bandwidth needs. The converged networks must simultaneously support the highly interactive client /server applications and the voice/video applications (see side bar "Bandwidth Consumers").
- LAN Interconnectivity: Basically, LANs are fast but WANs are not. The demand for high speed LAN-to-LAN interconnection is driving high speed requirements (it is silly to connect high speed 100 Mbps LANs through a 56 Kbps WAN).

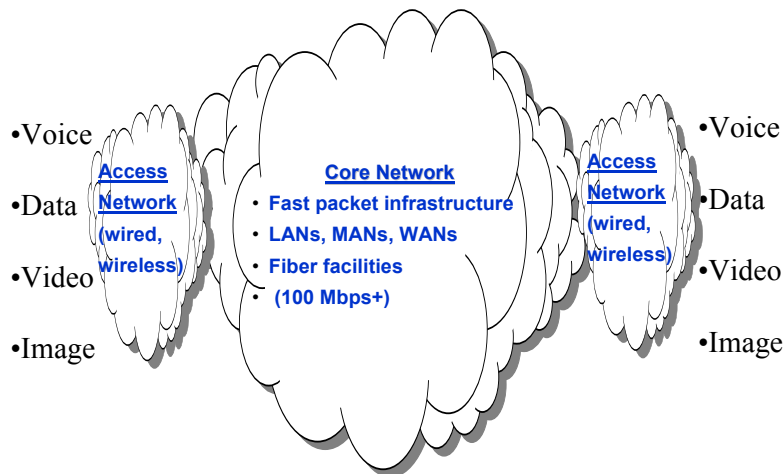


Figure 3-11: Conceptual View of "Next Generation Network (NGN)"

Figure 3-11 shows a conceptual view of a converged network that supports voice, data, and video over broadband and wireless services. Such networks are being referred to as "*Next Generation Networks (NGNs)*". The key players in NGN are:

- **Core Network** that provides the high speed short and long-haul capabilities to transfer information between end points. This network uses high speed packet switching systems (e.g., ATM, Frame Relay), fast LANs (e.g., Gigabit and 100 Mb/s Ethernet) over fiber facilities (e.g., SONET, WDM). Wireless technologies such as satellites are also increasingly becoming part of the core network.
- **Access network** that provides access from customer premise to the core network. This network, also known as the "*last mile*" uses technologies such as DSL, Cable Modem, and ISDN for broadband services. Wireless networks are playing an important role in the last mile through the use of cellular networks, wireless LANs, and wireless local loops.
- **User Services** that support the voice, data, video, and image users. . Examples of these services are ecommerce/ebusiness applications, voice over IP, web-enabled call centers, and unified messaging. In addition, these services can support a variety of appliances such as IP phone, cellular phone, Fax, building temperature controller, alarm clock, facility sensor, coffee machines and the like.

The objective of this chapter is to present an overview of the core communication technologies that will support NGN. Figure 3-12 shows a layered view of the technologies of interest to us. Basically, the emphasis in this chapter is on the technologies below the IP layer (we will discuss IP in the next chapter).

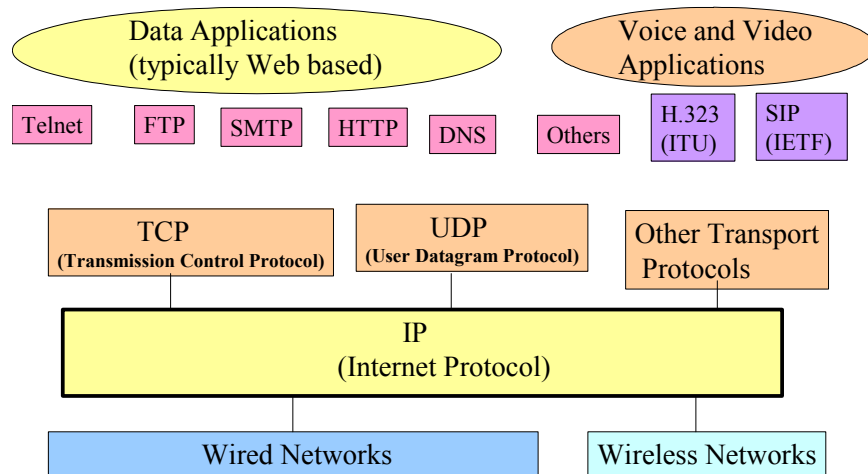


Figure 3-12: Technology Layers for Next Generation Networks

The home access network is also known as residential broadband. The two key technologies available to home users: DSL and cable modems. For wired access, the fiber optic digital technologies that typically reside at layer 1 (physical layer) of the OSI model are most common at present. SONET (Synchronous Optical Network) uses fiber optic to provide very high data rates that are in the several Gigabit per second. Growth in the use of fiber optics for local, wide and metropolitan area networks is unprecedented. Another technology, known as WDM (wavelength division multiplexing) allows multiple wavelengths representing different "colors" to be multiplexed onto a single fiber. This promises extremely high (10 gigabit per second and higher) data rates. Another development is the high speed packet switching technology being developed to run over fiber networks. Examples of fast packet switching systems are frame relay (variable sized packets) and ATM (fixed sized packets).

Due to the importance of mobile systems, wireless networks such as cellular networks, fixed wire networks, satellite systems, and wireless LANs have gained a great deal of momentum. The basic technical foundations of wireless networks (e.g., location services, frequency allocations, and multiple access) are also briefly reviewed. Most wireless networks (e.g., the fixed wireless networks, cellular networks, and wireless LANs) cover relatively small geographic areas but have many interesting applications. Satellites provide wireless support for long haul networks.

The key point about the network technology developments is that the Internet (TCP/IP) stack runs on top of all the emerging physical networks (wired or wireless). Thus the user does not need to know the underlying physical network.

3.5 Mobile IP – Supporting Mobile Devices Over the Internet

3.5.1 Overview

Mobile IP was developed so that mobile devices (PDAs, portable computers) could maintain Internet connectivity while moving from one Internet attachment point to another. Consider, for example, that you are in your office with your laptop that is connected to the Internet. Assume that you issued a database query but then detached your laptop, went to a meeting room, and reconnected your laptop in the meeting room. In this case, Mobile IP will allow the

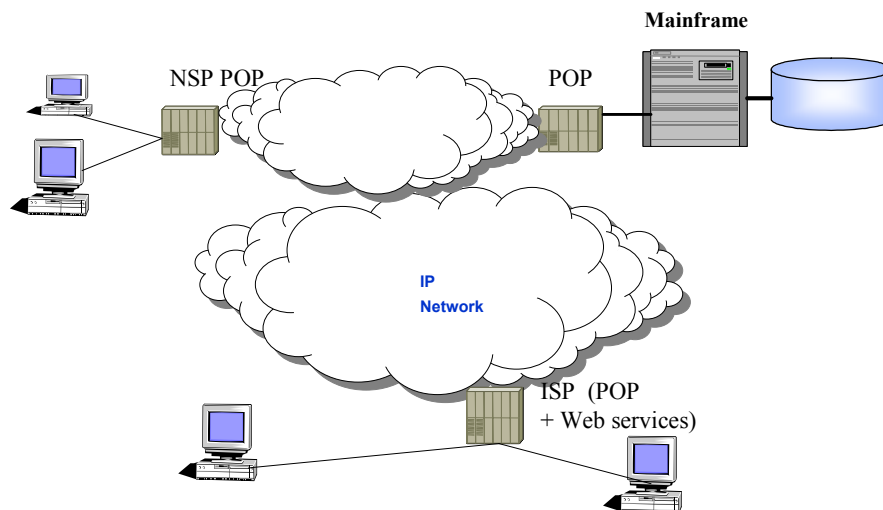
system to recognize that you have moved and will send the results from your query to your new location (the meeting room). The main idea of Mobile IP is that the same Internet connection address is maintained as you move your mobile device from one location to another. As we will see, the traffic is forwarded by using a “care of” address.

At this point, it is best to differentiate between a mobile and nomadic user:

- Mobile – user’s point of attachment changes dynamically and all connections are automatically maintained despite the change.
- Nomadic – user’s Internet connection is terminated each time the user moves and a new connection is initiated when the user dials back in. A new, temporary IP address is assigned.

Let us briefly consider how IP addresses are assigned before getting into Mobile IP. Basically, Network Service Providers (NSPs), also known as Internet Access Providers (IAPs), are the organizations that provide the physical network, i.e., give you a communication line and an access port on the Internet. You can think of IAPs as the local authorities that provide you with roads and signs to get you to the shopping malls. For dial-up users, an NSP provides a bunch of POPs (points of presence) that the users can dial into as a local call. An example of NSP is UUNET, which has POPs around the globe. I am a regular user of UUNET. A GUI shows me the phone number of the nearest POP (I just type in the name and country of the city). When I travel, I quickly locate a UUNET number and make a local call to reach my office computers.

Internet service providers (ISPs) go beyond the network pipe and offer Internet services such as email, Web hosting and Web surfing. An ISP may rent NSP, i.e., use an existing POP, or own a network and thus may own POPs. Examples of ISPs are America Online and Asia Online. Figure 3-13 shows how a computer is connected to an ISP Server through an NSP. Let us quickly review routing in the Internet (IP routing) before discussing the logistics of Mobile IP.



- POP(Point of Presence) provided by an NSP only provides a local phone access. The user can choose an ISP
- An ISP provides an IP address (user dials in)
- When the user moves, has to disconnect and redial.

Figure 3-13: A Traditional Internet Connection

3.5.2 Internet Routing – A Quick Tour

The Internet consists of several IP-based physical networks (#a network of networks) that are interconnected together. An example of an Internet (IP network) is shown in Figure 3-14. This IP network connects many disparate physical networks into a coordinated unit and hides the details of the physical network hardware; it allows computers to communicate independent of their physical network connections.

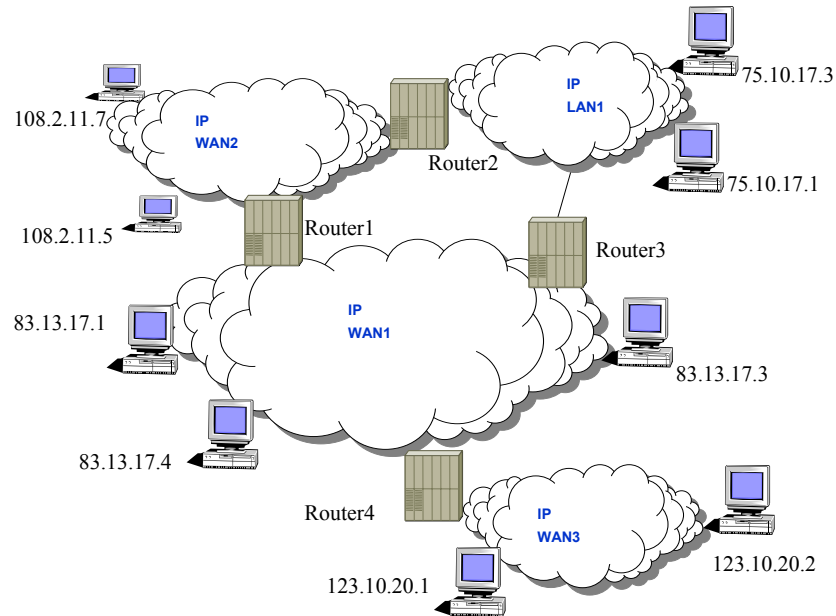


Figure 3-14: A Sample IP Network

Internet **routers**, sometime also referred to as Internet gateways, are used between physical networks of an IP network and perform the functions of a relay that directs traffic to its destination. Routers are software programs, typically residing in dedicated computers, that shuffle messages between physical networks. For example, the routers shown in Figure 3-14 pass the messages between the four networks. In general, an outgoing message from a host first checks to see if its destination is on the same physical network. If its destination is not on the physical network, then it goes to a router for routing.

The role of a router becomes more complex as the complexity of the IP network grows. In a complex network, the routers must understand the network topology and must know how to get to the next router. For example, Router4 in Figure 3-14 must know how to pass messages from WAN3 to LAN1 through the intermediate routers. In all cases, routers are responsible for routing messages to a destination network and not to a destination host. In most cases, routers are dedicated computers that house the routing tables. The size of the routing table depends on the number of physical networks and not on the number of computers in an Internet.

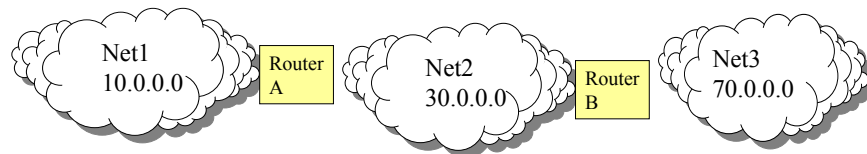
Every host and router in the Internet has an IP address, which encodes its network number and host number. The Internet address is a 32-bit address commonly denoted as four decimal numbers separated by periods, e.g., 125.102.112.5. The IP address is unique: no two machines have the same IP address. If an enterprise cannot present globally unique addresses to the Internet, The IP sends each message as a **datagram** which is its basic unit of

information transfer. Each datagram contains a header and data areas. The datagram header contains the IP addresses of the sender and receiver.

The datagrams are routed through the Internet by using a variety of routing algorithms. The choice of the routing algorithm depends on the nature and complexity of the Internet. The IP routing occurs at a higher level (global) than the physical network routing in a subnet. The IP routing is responsible for transferring messages between the physical networks of an Internet. The physical networks (subnets) are interconnected through gateways. The routing of a message within a physical network (e.g., an Ethernet) is the responsibility of the network routing (the data link protocol) mechanism of the network.

The route can be direct (within a physical network) or indirect (between networks through gateways). Internet routing algorithms usually employ routing tables which show possible destinations. An example of a routing table for a simple internet is given in Figure 3-15. A typical routing algorithm used in IP is as follows:

- Extract the destination address DA from the datagram.
- Find the route for DA from the routing table.
- If DA is a direct path (within this subnet), send the message directly.
- If DA is an indirect path, send the message to the proper subnet or gateway.
- If none, then give a routing error.



a) A Simple IP Network

Destination Network	Route Information
10.0.0.0	Direct
30.0.0.0	Direct
70.0.0.0	Indirect (route to gateway B, address 30.0.0.0)

b) Routing Table for Router A

Figure 3-15: Example of a Routing Table

Briefly, the Internet datagrams travel from router to router until they reach a router that can deliver them directly to the destination host. If a router cannot route or deliver a datagram due to an addressing problem or congestion, it needs to instruct the host to take action. The mechanism commonly employed to communicate the errors is the **Internet Control Messages Protocol (ICMP)**. ICMP messages travel across the Internet in the data portion of the datagram just like all other traffic. The destination of an ICMP message is the IP software on the destination machine and not the application process. Basically, ICMP provides a communication mechanism between the IP software at various machines (hosts and/or gateways) in the networks. ICMP is considered a required part of IP. More details about ICMP can be found in the DARPA standard RFC 792.

3.5.3 How Does Mobile IP Work?

Now let us see how the dynamic addressing will work in a mobile IP environment by using Figure 3-16. Let us assume that a mobile computer C1 is assigned to a particular network, called the *home network* for C1. The IP address on the home network is static and is called the *home address* for C1. Now, let us assume that the mobile computer has moved to another network, known as a *foreign network*. To be operational, C1 first registers with a network node on the foreign network. This node is called a *foreign agent*. The foreign agent takes responsibility of C1 and gives its address as a “*care-of address*” to the agent on the home network, called the *home agent*. As illustrated in Figure 3-16, the home agent gets all the incoming traffic for C1 (step 1), the traffic is routed it to the “care-of” address – the foreign agent (step 2), the foreign agent routes the traffic to C1 in the foreign network (step 3), and the return traffic is routed back to the IP server without having to go through the home agent (steps 4 and 5).

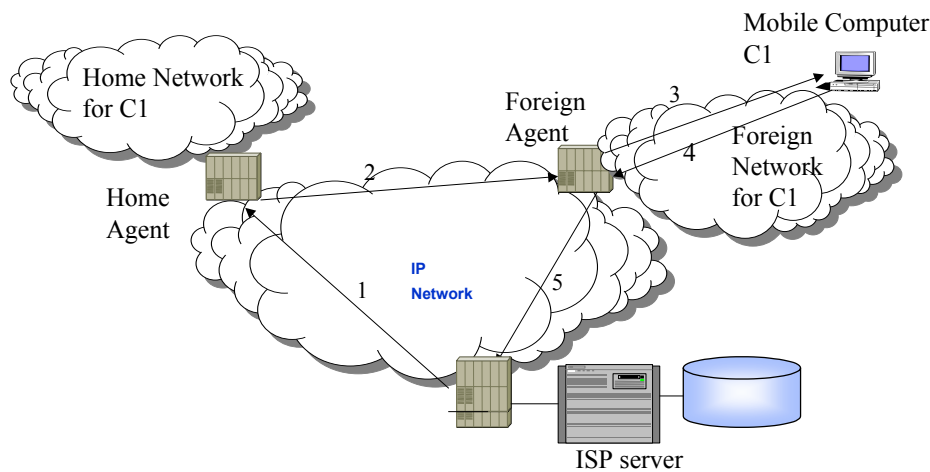


Figure 3-16: A Mobile IP Scenario

3.5.4 Capabilities of Mobile IP

Mobile IP includes three basic capabilities to support the operations shown in Figure 3-16.

- Discovery: A mobile node uses a discovery procedure to identify prospective home and foreign agents.
- Registration: A mobile node uses an authenticated registration procedure to inform the home agent of its care-of address.
- Tunneling: Tunneling is used to forward IP datagrams from a home address to a care-of address.

These capabilities are reviewed briefly.

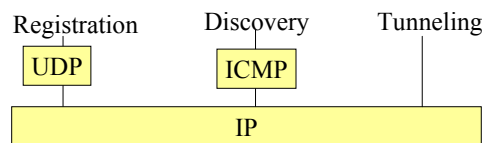


Figure 3-17: Mobile IP Processes

3.5.4.1 Discovery

A mobile node is responsible for an ongoing discovery process because it must determine if it is attached to its home network or a foreign network. The transition from the home network to a foreign network can occur at any time without notification to the network layer. A router planning to act as a foreign agent issues agent advertisement messages periodically (i.e., “I want to be your agent, do you want my services?”). The mobile node listens for agent advertisement messages and compares the network portion of the router’s (foreign agent’s) IP address with the network portion of its home address. If there is a match, then the mobile node knows that it is on a foreign network and that this router can act as a foreign agent.

Foreign agents are expected to issue agent advertisement messages periodically. However, if a mobile node needs agent information immediately, it can issue ICMP router solicitation messages explicitly. Any agent receiving this message will then issue an agent advertisement. Thus a mobile agent can explicitly ask for a foreign agent. A mobile node may move from one network to another due to some handoff mechanism without the IP level being aware. The agent discovery process is intended to enable the agent to detect such a move.

As a result of the discovery process, as stated previously, the foreign agent gives its IP address as a “care-of address” so that the home agent can route the traffic to the “care-of” address. The foreign agent then routes the traffic to the mobile node in the foreign network. If the mobile node moves to a network that has no foreign agents, or all foreign agents are busy, it can act as its own foreign agent.

3.5.4.2 Registration Process

After a mobile node finds a suitable foreign agent, it sends a registration request to the foreign agent requesting forwarding service. The foreign agent relays this registration request to the home agent. The home agent accepts or denies the request and sends a registration reply to the foreign agent, which in turn relays a reply to the mobile node.

Registration procedure security is a major problem. Mobile IP is designed to resist the following types of attacks:

- A node pretending to be a foreign agent sends registration request to a home agent to divert mobile node traffic to itself.
- An agent replays old registration messages to cut the mobile node from the network.


The techniques used to protect against these two attacks consist of message authentication, among others. For message authentication, the registration request and reply contain an authentication extension. Types of authentication extensions include:

- Mobile-home – provides for authentication of registration messages between mobile node and home agent; must be present.
- Mobile-foreign – may be present when a security association exists between mobile node and foreign agent.
- Foreign-home – may be present when a security association exists between foreign agent and home agent.

3.5.4.3 Tunneling

The home agent intercepts IP datagrams sent to the mobile node’s home address. The home agent informs other nodes on the home network that datagrams to the mobile node should be delivered to the home agent. The datagrams are now forwarded to the care-of address via **tunneling**. Basically, tunneling means that a datagram is encapsulated in an outer IP datagram. Mobile IP encapsulation options (assuming knowledge of IP addressing) are:

- IP-within-IP – entire IP datagram becomes payload in new IP datagram. Original, inner IP header basically is unchanged. Outer header is a full IP header.
- Minimal encapsulation – new header is inserted between original IP header and original IP payload. Original IP header is modified to form new outer IP header.
- Generic routing encapsulation (GRE) – developed prior to development of Mobile IP.



Time to Take a Break

- ✓ • Overview of Internet and Web
- ✓ • IP and Mobile IP
 - Wireless Web, Web Services, and Examples

3.6 World Wide Web for Wireless – A Closer Look

3.6.1 Accessing the Web from Mobile Devices and the Wireless Gateways

Wireless gateway is the bridge between two distinct worlds: the Internet model and the wireless phone/data network model. The wireless gateway shown in Figure 3-18 translates between the Web server and the mobile devices. The wireless gateway, a software module, supports a thin client model by allowing the handset to be simple and inexpensive. For example, this gateway can take over directory processing, data conversions, fraud management, and network provisioning. The gateway thus offloads these computing tasks from the handset. The gateway typically includes the following functionality:

- Protocol Adapters – the protocol adapters translate requests from the wireless network to the Web protocol stack.
- Content Encoders and Decoders – the content encoders translate Web content into compact encoded formats to reduce the size and number of packets traveling over the wireless data network.

This architecture ensures that mobile terminal users can browse a variety of Web content and applications regardless of the wireless network they use. The content and applications are hosted on standard Web servers and can be developed using Web technologies such as CGI scripting, servlets, and Java Server Pages. Several wireless gateways, such as WAP Gateways, are commercially available at present. We will look at WAP in the next chapter.

Although mobile devices can access Web content by using the traditional Web technologies, XML and the Semantic Web are playing an increasingly important role in future wireless web scenarios. The next section introduces these technologies briefly.

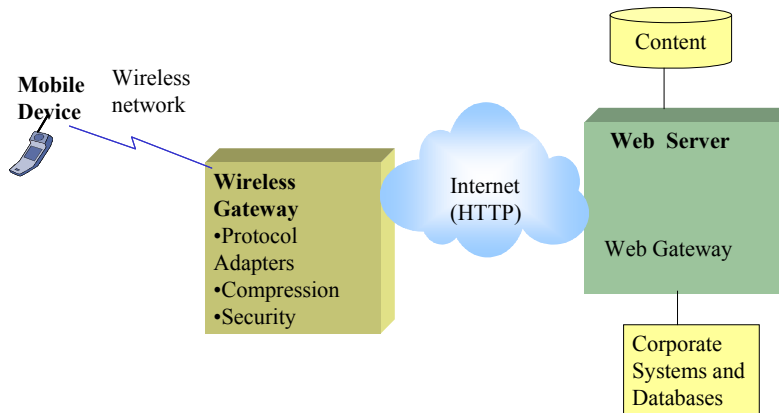


Figure 3-18: Wireless Gateway

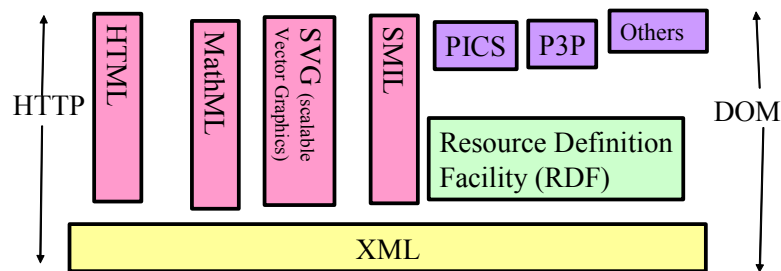
3.6.2 Semantic Web and its Role in Mobile Web Access

The first-generation Web, needless to say, gained popularity due to its simplicity and ease of use. However, the use of this technology has spread far beyond the initial design goals and imagination of the designers. Thus, some limitations of the initial Web technologies have started to show. In particular, the following limitations are worth noting for mobile computing:

- Desktop display-oriented. The original Web browser assumed a desktop display. However, mobile computing users want to access and display Web information on Palm Pilots, cellular phones, and other mobile devices.
- Technical limitations. The first-generation Web suffers from many technical problems. For example, the technology for Web gateways (CGI – Common Gateway Interface) does not scale well (i.e., is not suitable for a hundred or more users simultaneously). In addition, the original HTTP is stateless (i.e., every time you access a Web page over HTTP, it has no memory of what did you access before).
- Suited for human viewing only. The HTML documents can be only used for displays. However, in some cases, the consumer is not a human. For example, if you send an HTML document to a device, then the device has to “screen scrape” all the tags to get useful data. This is a major problem in mobile applications because many mobile devices may need to understand the HTML documents.

The WWW Consortium (known as W3C) has embarked on work in several directions to overcome these and other possible limitations. This work, under the general umbrella of Semantic Web (also known as Next Generation Web), includes the following key developments (see Figure 3-19):

- XML (Extended Markup Language) – a family of standards and services introduced to improve machine-to-machine communications. We will study XML in Section 3.6.3.
- Variations of markup languages such as WML (Wireless Markup Language), MathML, SVGML, SMIL, etc. for different applications. We will look at WML in a later chapter.
- Improvements in the core technologies such as HTTP, and also introduction of more choices for Web gateways.
- Web automation efforts that introduce an object model for the Web. These efforts include DOM, RDF, PICS, P3P and others.



PICS: Platform for Internet Content Specification
 P3P: Platform for Privacy Preferences
 SMIL: Synchronous Multimedia Interaction Language
 DOM: Document Object Model

Figure 3-19: Next Generation Web

It can be seen from Figure 3-19 that XML is at the core of the Next Generation Web. XML is also playing a key role in the future of the Wireless Web as shown in Figure 3-20. For example, WML is an XML-based language – thus it is an easy markup language for existing Web developers to learn. In addition, content written in XML-defined markup languages can be automatically translated into content suitable for either HTML or WML by using an XSL style sheet (see Figure 3-20). Basically, content written in well-formed XML can also be translated to other XML-based markup languages such as Voice XML, using a different XSL style sheet.

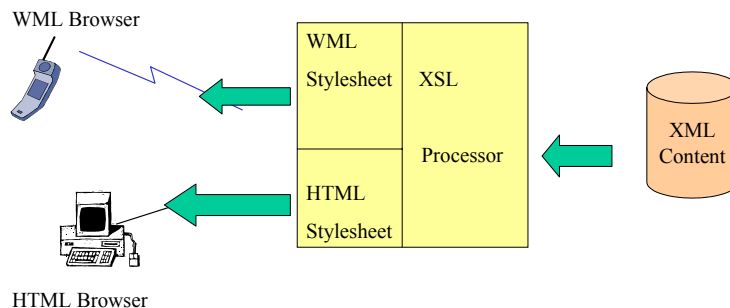


Figure 3-20: The Future of Content Description

3.6.3 XML Overview

XML is a markup language, similar to HTML, for documents containing structured information. The following statements represents an XML document that contains a customer name and address:

```
<CUSTOMER>
  <NAME> Joe </NAME>
  <ADDRESS> NY </ADDRESS>
  <AGE> 33 </AGE>
</CUSTOMER>
```

You can see the striking resemblance between HTML and XML, at least at this simple level (i.e., tags in the format <tag> that are terminated by </tag>). As we will see, you can develop

XML documents that represent customers, orders, bills, airline schedules, TV programs, bank statements, catalogs, etc. by just creating new tags. XML is very popular at present with applications ranging from e-commerce to music.

Let us now go through some details of XML by considering the following XML description.

```
<?xml version="1.0" standalone="yes"?>
< - customer example - >
<customer>
  <name>
    <first>Amjad</first>
    <last>Umar</last>
  </name>
  <address>
    <street>MCC-1C337B</street>
    <street>445 South Street</street>
    <city>Morristown</city><state>NJ</state>
    <zip>07960</zip>
  </address>
  <phone>973-829-3114</phone>
</customer>
```

The first statement in XML starts with “<?xml” to indicate an XML document. The XML document consists of elements and sub-elements that define various tags. Each element starts with a <tag> and ends with a </tag>. For example, this example describes the <customer> element with sub-elements <name> and <phone>. The sub-elements of <name> are <first> and <last>, etc. Comments in XML begin with <!-- and end with -->. XML allows definition of optional fields, repeating fields, etc.

XML basically represents the information as a tree. For example, Figure 3-21 represents the model of the customer information. This model is the foundation of automated processing of XML, as we will see in the discussion of Document Object Model (DOM).

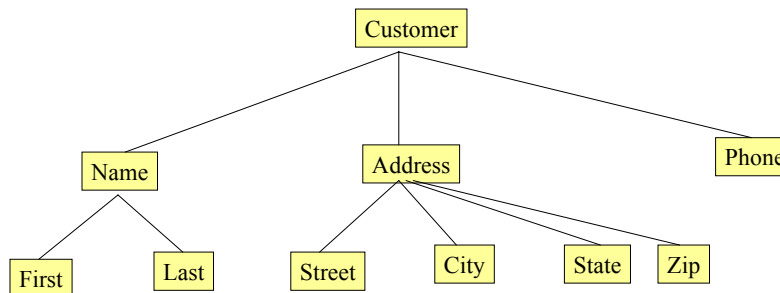


Figure 3-21: Model of Customer

Here is another example of XML – it represents a computer: located in Chicago (why not?):

```
<?xml version="1.0" standalone="yes"?>
< - computer example - >
<Computer>
  <Location city="Chicago">
    <name>
      <Type>Dell</type>
      <ID>IPX-222599</ID>
    </name>
    <Properties>
      <CPU>550 MHZ</CPU>
      <RAM> 56 Meg</RAM>
      <Disk>20 gigabyte </state>
```

```
        <Modem>56 Kbps </zip>
    </properties>
    <price>$900</price>
</Location>
</computer>
```

Once again, the XML syntax uses matching start and end tags, such as <name> and </name>, to mark up information. A piece of information marked by the presence of tags is called an *element*; elements may be further enriched by attaching name-value pairs (for example, `city="chicago"` in the example above) called *attributes*. Its simple syntax is easy to process by machine, and has the attraction of remaining understandable to humans. XML is based on SGML, and is familiar in look and feel to those accustomed to HTML.

Since 1996, XML has evolved due the work of several W3C working groups and other standards/industrial bodies. This work has resulted in a “family” of XML standards that include (see Figure 3-22):

- Variants of XML for different application areas. Examples are the Wireless Markup Language (WML), Voice Markup Language (Voice XML), Mathematical Markup Language (MathML), Chemical Markup Language (CML) and others. We will look at WML and Voice XML later.
- Document Type Declarations (DTD) to specify the set of rules for the structure of an XML document. DTDs are used to verify and validate XML documents and are thus central to XML-based e-business exchanges.
- XSL (eXtensible Stylesheet Language) to display information. XSL supports a basic premise of XML – separation of content from presentation. XSL is also useful to translate one XML description to another. XSL can be used to convert Web content for presentation on a handset.
- XML query language to support querying of XML data
- XML schema to specify the format (e.g., the character lengths) and relationships between XML elements
- Other developments such as XML Link, XML Signature, and XML Path

We will further discuss the capabilities of XML that play an important role in wireless.

The discussion of XML in this chapter is extremely brief. Our purpose is not to make you an XML expert. Instead the goal is to give you a quick conceptual overview of XML at a big-picture level. Many books on XML are available at bookstores (many more than 800 pages!). The following sidebar on XML Resources lists a few references. For an up-to-date view of XML and its developments, visit the W3C site (www.w3.org).

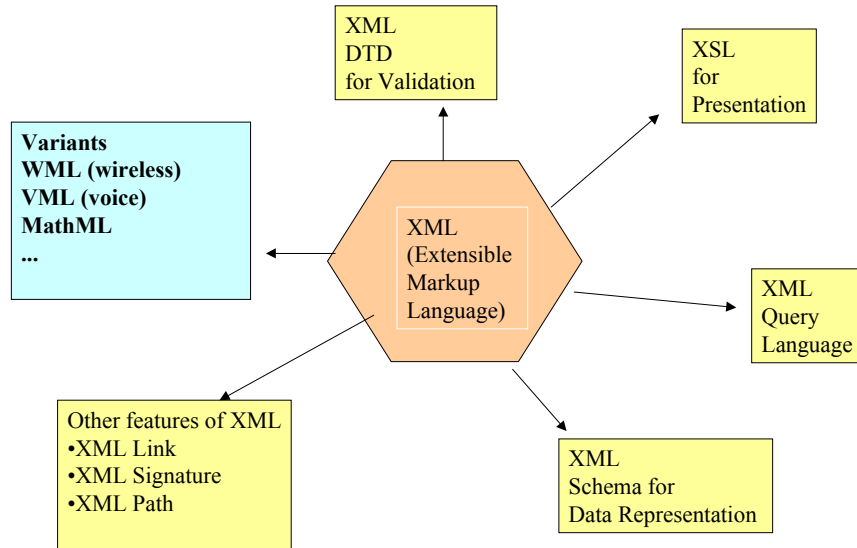


Figure 3-22: The XML Family

3.6.4 Document Type Declarations (DTD)

Document Type Declarations (DTD) are an important part of XML. Basically, a DTD specifies a set of rules for the structure of the document. For example, the following is a DTD for the customer record defined previously:

```
<!ELEMENT customer (name, address?, phone?)>
<!ATTLIST customer id CDATA #REQUIRED>
<!ELEMENT name (first, middle?, last)>
<!ELEMENT address (street+, city, state, zip)>
<!ELEMENT phone (#PCDATA)>
<!ELEMENT first (#PCDATA)>
<!ELEMENT middle (#PCDATA)>
<!ELEMENT last (#PCDATA)>
<!ELEMENT street (#PCDATA)>
<!ELEMENT city (#PCDATA)>
<!ELEMENT state (#PCDATA)>
<!ELEMENT zip (#PCDATA)>
```

In a DTD, optional fields are suffixed by a “?” For example “address?” and “phone?” indicate that address and phone number are optional, but the name is not. Thus this DTD will make sure that all XML document that describe the customer must have a name entry. Also a multi-line entry is suffixed by a “+.” (for example “street+” indicates that the street address may go over more than one line). The CDATA and PCDATA entries indicate that the element is character data or parsed character data, respectively. CDATA is just string data that is not parsed, while PCDATA is.

We can save this into a file called customer.dtd. DTDs are required in SGML but optional in XML. DTDs are the foundation of well-formed and valid documents:

- A *well-formed document* adheres to the syntactic rules defined by the XML standard; e.g., tags are delimited by < and >.
- A *valid document* is a well-formed document that also adheres to the rules of a specified Document Type Definition (DTD).

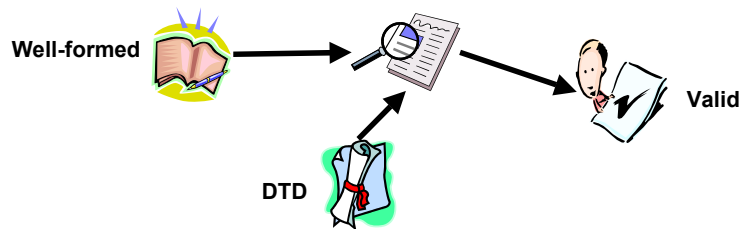


Figure 3-23: The Role of XML

Thus if you create an XML document without a DTD, then it is well formed but not valid. By creating a DTD, you make the document well formed as well as valid because XML parsers compare the document against DTD to verify if the document adhered to the DTD specifications. In e-commerce, it is always a good idea to define a DTD before creating XML documents.

The following XML definition represents a valid XML document (note that we have specified that this document is not standalone and that customer.dtd is consulted as a DTD):

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE customer SYSTEM "customer.dtd">
<customer id="12345">
  <name>
    <first>Amjad</first>
    <last>Umar</last>
  </name>
  <address>
    <street>MCC-1C337B</street>
    <street>445 South Street</street>
    <city>Morristown</city><state>NJ</state>
    <zip>07960</zip>
  </address>
  <phone>973-829-3114</phone>
</customer>
```

The following document represents a well-formed but *not* valid XML document:

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE customer SYSTEM "customer.dtd">
<fool id="12345">
  <foo2>
    <foo3>Amjad</foo3>
    <foo4>Umar</foo4>
  </foo2>
  <foo5>
    <foo6>MCC-1C337B</foo6>
    <foo7>445 South Street</foo7>
    <foo8>Morristown</foo8><foo9>NJ</foo9>
    <foo10>07960</foo10>
  </foo5>
  <foo11>973-829-3114</foo11>
</fool>
```

3.6.5 XSL (XML Stylesheet Language)

XML separates document structure from document display – separation of content from presentation is an important goal of XML. XML supports XSL (eXtensible Stylesheet Language) to display information. XSL is also useful to translate one XML description to another.

The purpose of XSL is to provide a powerful, yet easy-to-use, style sheet syntax for expressing how XML documents should be rendered. XSL is independent of any one output format – you can use one XSL style sheet to format XML for HTML, MS Word documents, email, or displays on a handset. In addition, you can create multiple XSL sheets for the same XML document. Figure 3-24 shows this processing.

An XSL stylesheet consists of a set of construction rules which specify how the XML elements will be converted to output. The following XSL statements generate a straightforward HTML document that contains children of the XML customer element.

```
<xsl>
<rule>
<!-- pattern to indicate that we want to trigger this rule for
element customer -->
<target-element type="customer"/>
<!-- Action: generate the HTML document that contains children (sub-
elements) of customer -->
<HTML>
    <BODY>
        <children/>
    </BODY>
</HTML>
</rule>
</xsl>
```

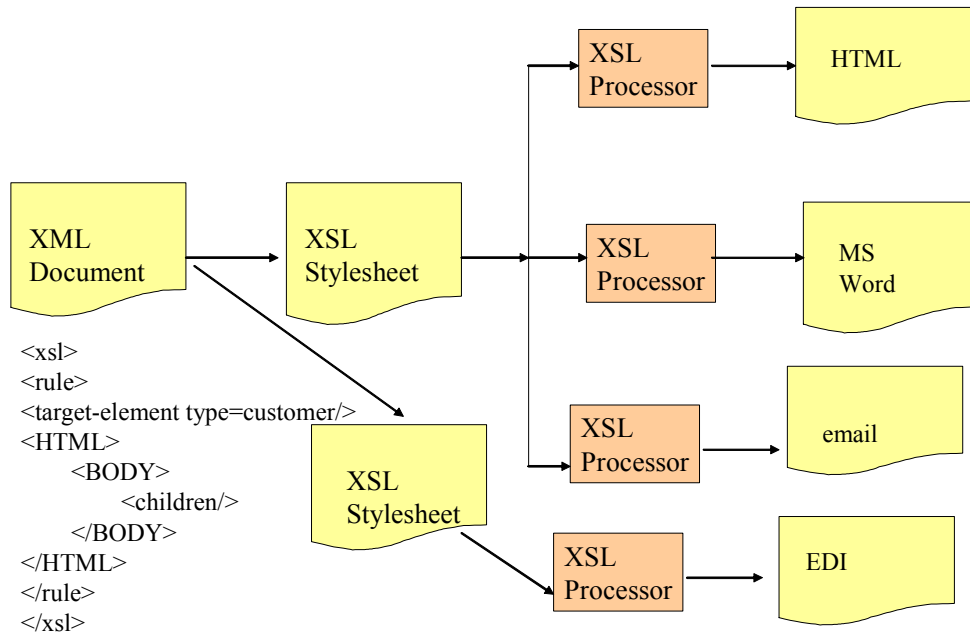


Figure 3-24: XSL Processing

A wide array of XSLT (XSL Transformation) Processors, such as the following, are commercially available at present:

- Sun's XSLT Compiler creates a Java program that performs the transformation instructions described by a XSLT file.
- XSLTC is an XSLT compiler. It takes as input an XSLT stylesheet, and generates C++ code that is expected to have the same behaviour as the source stylesheet.
- LotusXSL is a complete implementation of the W3C Recommendations for XSL Transformations (XSLT) and the XML Path Language (XPath).
- Resin is a servlet/JSP engine with integrated XPath and XSLT support.
- XT from James Clark is a free Java-based implementation of XSLT.

3.7 Web Services and Mobile Web Services

3.7.1 What are Web Services and Why are they Important to Mobile Computing?

It is virtually impossible to discuss future developments in wireless Web without mentioning Web Services and Mobile Web Services. The main idea of Web Services (WS), also known as XML Web Services, is to combine Web and component-based systems into a single framework where the user-to-component as well as component-to-component interactions are conducted by using standard Web technologies. Web Services consist of (see Figure 3-25):

- **UDDI** (Universal Description, Discovery and Integration) to provide a directory of services on the Internet. UDDI provides a yellow pages directory for Web Services so that the potential users (clients/consumers) can *locate* the needed services.
- **WSDL** (XML Web Services Description Language) to define XML Web Services in terms of the formats and ordering of messages. WSDL is an XML document that describes the location and interfaces a particular service support. It is used by the client to *open* a Web Service and is a contract between Web Services clients and servers.
- **SOAP** (Simple Object Access Protocol) through which XML Web Service consumers can send and receive messages (*transfer*) using XML. SOAP provides an explicit serialization (HTTP + XML description) protocol used in service exchanges.
- **XML & HTTP** are the core open Internet technologies that are the foundation of XML Web Services.



Figure 3-25: XML Web Services

Why are Web services important for mobile computing? The main idea is that a wide range of services could be defined by using WSDL and then advertised through a UDDI. Then any entity (a human being, a mobile device, device, a Web browser, or an application program) could invoke these services over the Web. Recognizing the role of mobility in Web Services, a new specification called Mobile Web Services (Section 3.7.3) is being developed. These developments are leading to an integrated “service oriented” architecture where different wireless/wired devices could seamlessly invoke different services around the globe. For this reason we will revisit Web Services and Mobile Web Services in a later chapter that discusses architectures and integration for wireless systems (Chapter 11).

A great deal of standards (e.g., www.w3.org, www.oasis.org) and industrial (IBM, Sun, Microsoft) activity is currently focusing on Web Services. In fact, Microsoft’s .Net and Sun’s J2EE both conform to WS. Information about various aspects of Web Services is available at

Microsoft (<http://msdn.microsoft.com/>), IBM (<http://www-106.ibm.com/developerworks/Webservices/>) and Sun (www.sunsoft.com) sites.

3.7.2 A Quick Example – Accessing Web Services from a Mobile Device

To the outside world, a Web Service is an application that accepts service requests, does some processing, and then returns a response. Suppose that a Web service called “ePurchase” is available in Singapore. A consumer in Detroit wants to invoke this service by submitting a purchase order (PO) by using a cellular phone. From a consumer point of view, the following steps take place to use this service (see Figure 3-26):

- Locate the service: The consumer sends a request to UDDI (www.uddi.org) to find where the ePurchase service is located. UDDI returns, say, the ePurchase service URL (www.epurchase.com). If more than one ePurchase service is available, then more than one URL may be returned. It is possible to search UDDI with selection criteria to minimize the number of URLs returned. Since UDDI requests and responses are in XML, the cellular phone can send the request by sending an XML document and expect an XML response. Depending on the capabilities available, the cellular phone may use SOAP, email, or any other transport protocol to interact with UDDI.
- Learn about the service so that an appropriate session can be established. The cell user now issues a call to WSDL to learn how to invoke the needed service (i.e., what method to use, what are the input/output parameters needed for submitting a PO). This discovery process is important because different ePurchase systems may use different PO formats. Once again, the interactions with WSDL are through XML, which can be sent and received by the cellular phone over different transport protocols.
- Invoke the service and transfer information. The consumer prepares a PO as a SOAP message, an XML document, that is sent to www.epurchase.com over HTTP. This transfers the PO to ePurchase for processing and may respond with another SOAP message. This step will require SOAP support on the cellular phone.
- After being satisfied with the results, the consumer may close the session.

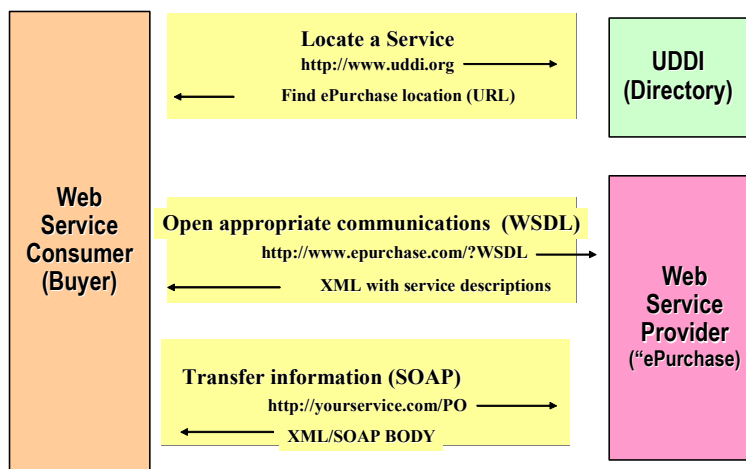


Figure 3-26: Sample Flow of Web Services

3.7.3 Mobile Web Services

Accessing WS from mobile devices is a major area of work at present. For example, Microsoft has developed a Mobile Internet Toolkit (MMIT) that supports development of mobile computing applications based on WS by using the Microsoft .NET Framework (see next chapter). But MMIT is a proprietary technology. Mobile Web Services (MWS) is a new open specification that extends the core Web Services specifications to include the special capabilities and requirements of mobile computing. A framework for Mobile Web Services has been proposed to enable new services and products to be created for mobile computing. MWS is evolving at the time of this writing. The following have been identified:

- Application of WS-Security to mobile network security services. For example, a GSM-style SIM security device has been accepted for authentication.
- Development of a set of payment mechanisms within the Web Services architecture
- SMS services and MMS services
- Location-based services

Other areas for work within the activity have also been identified and are under review at the time of this writing. The two main areas of work are optimal transmission of WS requests over slow cellular networks and efficient processing of WS by mobile devices with processor limitations.

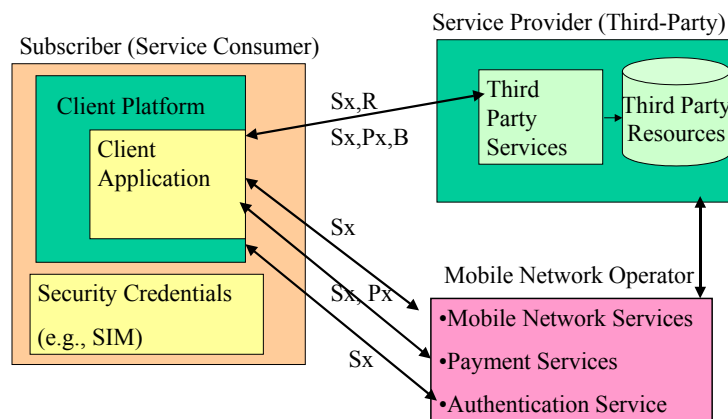


Figure 3-27: Mobile Web Services

Figure 3-27 shows a conceptual view of the initially proposed three principal components of MWS and the interactions among them. The Subscriber is a service consumer (a client) that needs services of a Third-Party Service Provider (SP). One or more Client Applications are used by the subscriber – these applications run under the control of a Client Platform (e.g., a Symbian operating system) and use Security Credentials such as a SIM card. The SP offers a set of services that are defined through WSDL and possibly stored in a UDDI. For example, a bank could be an SP that provides account review, bill payment, and fund transfer as three possible services that have been defined through WSDL. A Mobile Network Operator is the third player in MWS – it provides authentication and payment services in addition to its own services, known as Mobile Network Services. These Mobile Network Services are Web Services and represent SMS, MMS, Location or other proprietary services. The Authentication Service and the Payment Service are also Web Services operated by the Mobile Network Operator to perform authentication and payment authorization, respectively. The subscriber has a business relationship with a Mobile Network Operator and subscribes to one or more of the Operator services (e.g., SMS). We will go through more details of this example in Chapter 11.

3.8 Short Examples and Case Studies

3.8.1 How Mobile IPV6 is used in Cellular Networks

Mobile IP is a key component of future cellular networks. These networks are all digital, IP-based systems that use Mobile IP to locate a mobile unit as it moves from one network to another. For example, Flash OFDM, a 3G cellular network technology, uses Mobile IPv6 to control handoffs. Figure 3-28 shows a conceptual view of flash OFDM architecture. The key architectural players of this architecture are the Radio Routers that act as base stations in the flash OFDM architecture, the IP routers that move the IP traffic, and the media gateways that convert IP to PSTN traffic.

During handoffs, Radio Routers are used to maintain continuous connections with a mobile user. Handoffs between a public to a private network are also handled at the IP level. Mobile IP is used to move traffic between home agents and foreign agents so that it reaches the target mobile device. Figure 3-28 shows a sample situation where a Mobile unit (Node) A moves from a home network to a foreign network. Suppose a user in Cell 1 wants to send a message to Node A. In this case, the home agent intercepts packets sent to Mobile Node A's home address and redirects packets to the care-of address of the foreign agent, from where it is sent to Mobile Node A. The mobile node always transmits packets directly to the origin node in Cell 1. Thus as mobile devices move from one location to another and acquire new IP addresses, Mobile IP shuffles the messages to the new IP addresses.

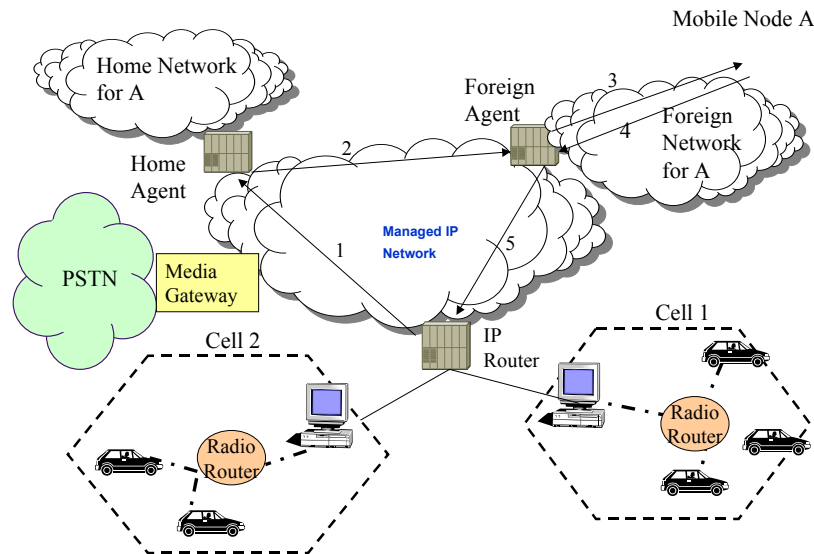


Figure 3-28: Flash OFDM Architecture

3.8.2 AOL Anywhere: The Mobile Access Portal

AOL has aggressively entered the mobile applications market by announcing AOL Anywhere, which makes AOL services available on numerous mobile devices such as cell phones, PDAs, and TVs. Different products aimed at different market segments is one of the main strategies of AOL. For email and instant messaging, for instance, the AOL product

Mobile Communicator is available to subscribers. The Communicator uses Cingular's Mobitex network and is a customized version of Research in Motion's (RIM's) two-way pager. This product is not designed for surfing the Internet because it is basically a short messaging services (SMS) – it displays only a few characters at a time and can be used for real-time access to crucial information and to respond to email through short messages. For Web surfing and online shopping, another service called AOL Handheld is offered.

AOL is planning to offer a variety of services to mobile users. These include entertainment, information, communication, and commerce. Many of these services are being packaged together as value-added services. For example, AOL can send sales information about nearby stores to a subscriber who is in a suburb of Boston. If the subscriber needs directions to the store, she can easily use her cell phone to access AOL MapQuest. In an effort to become a mobile portal leader, AOL is expanding its service offerings through acquisitions and partnerships. In this spirit, AOL has acquired several companies such as MovieFone, MapQuest, Quack, and Tegic Communications. It has also entered into business agreements that ensure consumer access to AOL services via a variety of mobile devices.

Source: http://www.ebstrategy.com/mobile/case_studies/aol_anywhere.htm

3.8.3 A Mobile Purchasing System

Figure 3-29 shows a simplified view of mobile purchasing that was developed by a department store in Ohio. The store's online purchasing system could be invoked from mobile devices over a GSM cellular network. A great deal of time was used to develop the wireless gateway that translates the wireless protocols and presentations to the standard HTML over HTTP. The wireless gateway, developed by a consulting company, also provides security services and compresses the data before it is sent over the GSM network.

The seller decided to open up wireless access to the front-end applications only. A new online order processing application residing on the Web server handled all the wireless as well as wired users. No back-end applications were accessed from the wireless devices. This provided security benefits because the company was concerned about allowing wireless users to access back-end systems. In addition, the external suppliers were not directly exposed to the mobile users.

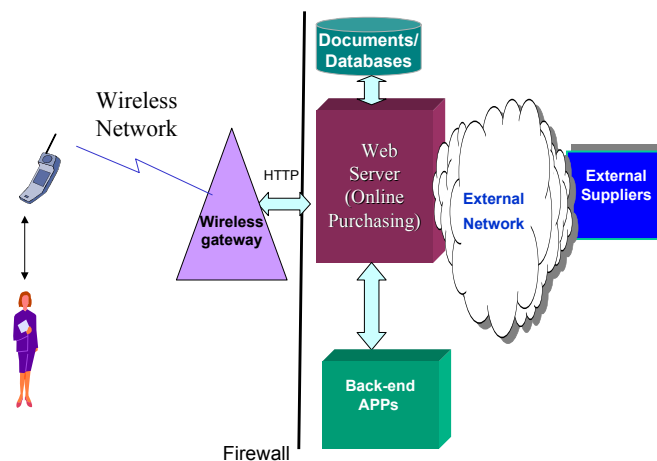


Figure 3-29: A Simple Internet-based Purchasing System

3.8.4 Wireless Internet and the Arab World

Besides the technical aspects of wireless Internet, discussed in this chapter, some social implications should also be noted. In many underdeveloped countries and regions, Internet access over wireless networks is the most effective way of bringing new opportunities to the masses and delivering social-service applications to support health, education, and government services. In future chapters, we will discuss many examples such as delivering Internet over wireless networks to far-off villages in India, Korea, Angola, and others. Here is an example of a noteworthy initiative.

The Wireless Internet Institute (W2i) and the UN ICT Task Force (UNICTTF) have launched the “Wireless Internet and the Arab World” series to accelerate the adoption of broadband wireless Internet in underdeveloped areas of the Arab world. Private organizations such as IBM and Intel, international development organizations such as UNDP, and industry groups are also supporting the effort to raise local awareness about the wireless Internet as a tool for economic, social, and educational development throughout the region.

The wireless Internet has the potential to bridge the digital divide by providing low-cost broadband Internet connectivity to underdeveloped areas and local communities. Wireless technologies may be deployed rapidly to help foster economic development, workforce productivity and enable delivery of social-service applications in the areas of e-health, e-education, and e-government. Its deployment can become a critical factor in improving productivity and security and in bringing Internet-based services and connectivity to whole new segments of underdeveloped populations at a fraction of the cost of wired technologies. The “Wireless Internet and the Arab World” series is designed to help Arab countries define clear and attainable local objectives, establish consensus on favorable policies and regulations, build sustainable business models, and share best practices among field practitioners, fostering universal connectivity in support of economic, social and educational development. The program is being overseen by a multinational, multidisciplinary steering committee.

Source: <http://www.w2i.org/pages/wsis/track3/index.html>

3.9 Concluding Comments

Access to the Internet and the Web through mobile devices is a major area of growth. It is a good idea to develop an overall understanding of IP (Internet Protocol) routing and addressing because it is used in wireless networks also. In particular, Mobile IP is increasingly playing a key role in allowing mobile devices to stay connected continuously while moving around the Internet. Finally XML, Semantic Web, and Web Services are fundamentally important to the future of wireless Web.

3.10 Suggested Review Questions and Exercises

- 1) What is the difference between the Internet and the Web? Explain through an example.
- 2) Why is an understanding of wired Internet and conventional Web important to an understanding of Wireless Web?

- 3) What is the difference between the public Internet, intranets, and extranets? Give one example of each.
- 4) Graphically show the evolution of the TCP/IP protocol stack.
- 5) Choose an industrial website and analyze it in detail in terms of its website, unique features, ease of use, etc.
- 6) Compare and contrast HTTP with IP.
- 7) Choose and analyze one Web gateway in detail.
- 8) Choose and analyze a wireless gateway.
- 9) Explain Mobile IP through an example.
- 10) Compare and contrast Mobile IP with dynamic addressing assigned by DHCP.
- 11) Explain the role of XML in wireless Web through an example.
- 12) What are Web Services and Mobile Web Services and why are they important to Wireless Web?
- 13) Suppose you need to support video conferencing on your mobile devices. What short range and long range issues do you need to consider?

3.11 References

Barron, B., Ellsworth, J., and Savetz, K., eds. *“Internet Unleashed.”* latest edition, Samsnet book

Berners-Lee, T., et al. “The Semantic Web.” *Scientific American*, Special Issue, May 2001.

Berners-Lee, T. *Weaving the Web*. Harper San Francisco, 1999.

Berners-Lee, T. and Cailliau, R. “World Wide Web.” *Computing in High Energy Physics 92* (Anney, France, 1992).

Berners-Lee, T., Cailliau, R., and Pellow, N., and Secret, A. “The World Wide Web Initiative.” *Proc. INET '93*, Internet Society, San Francisco, USA, 1993.

Berners-Lee, T., and Connolly, D. “Hypertext Markup Language 2.0,” *RFC 1866*, IETF, Nov. 1995.

Chandler, D. *Running a Perfect Web*. Que Books, latest edition.

Comer, D. *Internetworking with TCP/IP: Principles, Protocols, Architectures*. Prentice Hall, 1988.

Comer, D. *Internetworking with TCP/IP*, Two Volumes, Prentice Hall, latest edition.

December, J. and Randall, N. *The World Wide Web Unleashed*. Sams Net Book, latest edition.

Gibson, W. *Neuromancer*. Ace Books, New York, 1984.

Goldfarb, C. *XML by Example: Building E-Commerce Applications*. Series on Open Information Management. Charles F. Goldfarb, 1998.

Graham, I. *HTML Source Book*. Wiley, latest edition.

Hahn, H. *Internet: Complete Reference*. latest edition.

Hunter, D. *Beginning XML*. Wrox Press, 2000.

Kalakota, R. and Robinson, M. *M-Business: The Race to Mobility*. McGraw Hill, 2002.

Krishnamurthy, B., and Rexford, J. *Web Protocols and Practice: HTTP/1.1, Networking Protocols, Caching, and Traffic Measurement*. Addison Wesley, 2001.

McGrath, S. *XML by Example : Building E-Commerce Applications*. Series on Open Information Management. Charles F. Goldfarb, 1998.

Mullender, S., ed. *Distributed Systems*. Addison Wesley, latest edition.

Schulzrinne, H. "World Wide Web: Whence, Whither, What Next?" *IEEE Network*, March/April 1996, pp. 10-18.

Stallings, W. *Wireless Communications and Networks*. Prentice Hall, 2001.

Tittel, E. and James, S. *HTML for Dummies*. IDG Books, latest edition.

Umar, A. *e-Business and Distributed Systems Handbook: Network Module*. 2nd ed. NGE Solutions, 2004.

Umar, A. *e-Business and Distributed Systems Handbook: Middleware Module*. 2nd ed. NGE Solutions, 2004.