A System Model for Mobile Commerce

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Abstract

The emergence of wireless and mobile networks has made possible the introduction of electronic commerce to a new application and research subject: mobile commerce. Understanding or constructing a mobile commerce system is an arduous task because the system involves a wide variety of disciplines and technologies. To facilitate understanding and constructing such a system, this article divides a mobile commerce system into six components: (i) mobile commerce applications, (ii) mobile stations, (iii) mobile middleware, (iv) wireless networks, (v) wired networks, and (vi) host computers. Elements in components related to mobile commerce are described in detail and lists of technologies for component construction are also given.

1. Introduction

Mobile commerce is defined as the exchanges or buying and selling of commodities, service, or information on the Internet by using mobile handheld devices. It is estimated that 50 million wireless phone users in the United States will use their hand-held devices to authorize payment for premium content and physical goods. This represents 17% of the projected total population and 26% of all wireless users [15]. Many major companies have begun to offer mobile commerce options for their customers in addition to the electronic commerce they already provide [8]. However, it requires a tremendous effort to understand or construct a mobile commerce system because it involves such a wide range of disciplines and technologies. To lessen the difficulty, this paper will divide a mobile commerce system into six components: (i) mobile commerce applications, (ii) mobile stations, (iii) mobile middleware, (iv) wireless networks, (v) wired networks, and (vi) host computers. Elements in components related to mobile commerce will be described in detail and lists of technologies for component construction will also be given. Related research on mobile commerce systems can be found in the article by Varshney *et al.* [13].

1.1. Requirements of a mobile commerce system

It is first necessary to examine what kind of features a mobile commerce system is expected to have in order to conduct effective and efficient mobile commerce transactions and what kind of challenges may be faced in the process of developing new mobile commerce systems. The requirements for a mobile commerce system are:

1. It should allow end users to perform mobile commerce transactions easily, in a timely manner, and ubiquitously.
2. It should allow products to be personalized or customized upon request.
3. It should fully support a wide range of mobile commerce applications for content providers.
4. Maximum interoperability is desirable because so many technologies are now available and new techniques are constantly being added to mobile commerce systems.
5. Program/data independence is held, that is, the change of system components does not affect the existing programs/data.

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2. Mobile Commerce System Structure

An electronic commerce system is an interdisciplinary subject and there are many different ways to implement it. Figure 1 shows the structure of a traditional electronic commerce system and a typical example of such a system. The system structure includes four components:

1. Electronic commerce applications: Electronic commerce is the buying and selling of goods and services and the transfer of funds through digital communications.
2. Client computers: Desktop computers are used by electronic commerce, whereas wireless handheld devices are used by mobile commerce.
3. Wired networks: This is the main difference between electronic commerce and mobile commerce, which must also include wireless networks.
4. Host computers: A user request, e.g., database accesses or updating, is actually processed at a host computer, which consists of three major parts: (i) Web servers, (ii) database servers, and (iii) application programs and support software. These will be examined in more detail later.

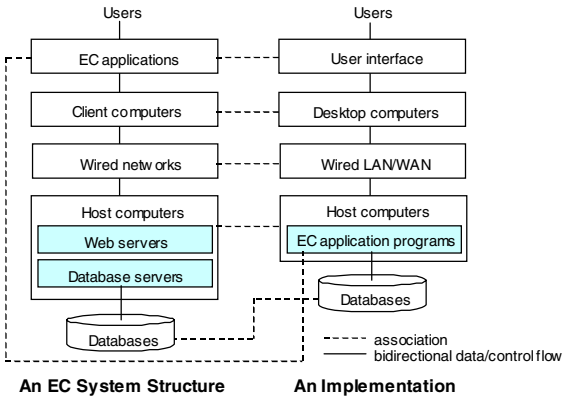

Figure 1. An e-commerce system structure

Compared to an electronic commerce system, a mobile commerce system is much more complicated because components related to mobile computing have to be included. Figure 2 shows the structure of a mobile commerce system, which consists of six components: (i) mobile commerce applications, (ii) mobile stations, (iii) mobile middleware, (iv) wireless networks, (v) wired networks, and (vi) host computers, and an example of such a system that is currently possible based on existing technology. In mobile commerce systems, the network infrastructure consists of wired and wireless networks. The wired networks component has the same structure and implementation as in an electronic commerce system. We thus devote our effort to the part of wireless networks in this paper. All components other than the wired networks and lists of the technologies needed for the component construction will be examined in the coming sections.

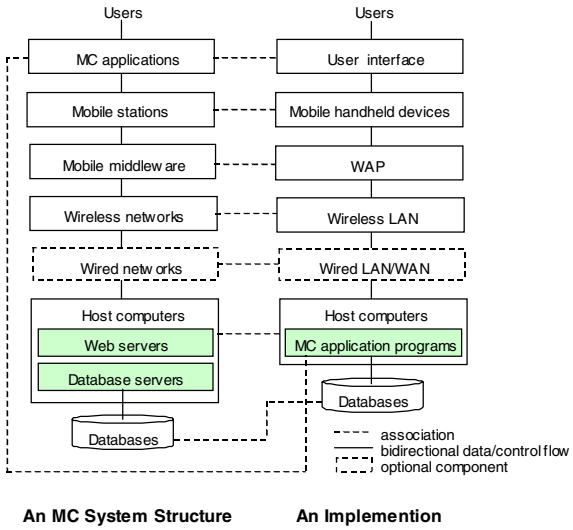

Figure 2. A mobile commerce system structure

3. Mobile Commerce Applications

The applications of electronic commerce are already widespread; mobile commerce applications not only cover these but also include new ones. For example, some tasks that are not feasible for electronic commerce, such as mobile inventory tracking and dispatching, are possible for mobile commerce. Table 1 lists some of the major mobile commerce applications [4].

Mobile Category	Major Applications	Clients
Commerce	Mobile transactions and payments	Businesses
Education	Mobile classrooms and labs	Schools and training centers
Enterprise resource planning	Resource management	All companies
Entertainment	Music/video/game downloads	Entertainment industry
Health care	Patient record accessing	Hospitals and nursing homes
Inventory tracking and dispatching	Product tracking and dispatching	Delivery services and transportation
Traffic	A global positioning, directions, and traffic advisories	Transportation and auto industries
Travel and ticketing	Travel management	Travel industry and ticket sales

Table 1. Major mobile commerce applications

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4. Mobile Stations

There are numerous mobile stations available in the market today. Table 2 lists some major mobile station specifications, although several table entries may not be complete as some of the information is classified as confidential due to business considerations.

Vendor & Device	Operating System	Processor	Installed RAM/ROM
Compaq iPAQ H3870	MS Pocket PC 2002	206 MHz Intel StrongARM 32-bit RISC	64 MB/32 MB
Nokia 9290 Communicator	Symbian OS	32-bit ARM9 RISC	16 MB/8 MB
Palm i705	Palm OS 4.1	33 MHz Motorola Dragonball VZ	8 MB/4 MB
SONY Clie PEG-NR70V	Palm OS 4.1	66 MHz Motorola Dragonball Super VZ	16 MB/8 MB
Toshiba E740	MS Pocket PC 2002	400 MHz Intel PXA250	64 MB/32 MB

Table 2. Some major mobile stations

4.1. Operating systems

Although a wide range of mobile stations are available in the market, the operating systems, the core of mobile stations, are dominated by just three major brands: Palm OS, Pocket PC, and Symbian OS.

Palm OS. The plain vanilla design of the Palm OS [9] has resulted in a long battery life, approximately twice that of its rivals. Palm was slower to add color features than its competitors because of their reluctance to lose its advantages of battery life, size, and weight. Palm OS 5, which runs an ARM processor (TI OMAP1510), has a high-resolution (320×320) color screen, 16 MB of memory, built in voice recorder, directional pad, built-in Bluetooth, and media playback capability (MP3/OGG/ WAV), complete with speaker and headphone jack.

Pocket PC. In 1996, Microsoft launched Windows CE, a version of the Microsoft Windows operating system that is being used in a variety of embedded products from mobile stations to specialized industrial controller and consumer electronic devices. However, it was not well received primarily because of battery-hungry hardware and limitations in the operating system. To solve these problems, Microsoft introduces Pocket PC [10], which offers far more computing power than Windows CE.

Symbian OS. EPOC16 from Psion Software is a 16-bit version of the operating system that has been available for several years and is embedded in many mobile stations; EPOC32 is a 32-bit open operating system that supports preemptive multitasking. In mid-1998, Psion joined forces with Ericsson, Nokia, and Motorola to form a new joint venture called Symbian [12], with the aim of establishing EPOC as the de facto operating system for mobile stations.

5. Mobile Middleware

The term middleware refers to the software layer between the operating system and the distributed applications that interact via the networks. It translates requests from mobile stations to a host computer and adapts content from the host to the mobile station [11].

5.1. WAP and i-mode

According to an article in Eurotechnology.com [3], 60% of the world's wireless Internet users were using i-mode, 39% were using WAP, and 1% were using Palm middleware. Table 3 compares i-mode and WAP and details of the middleware follow.

	WAP	i-mode
Developer	WAP Forum	NTT DoCoMo
Function	A protocol	A complete mobile Internet service
Host Language	WML (Wireless Markup Language)	CHTML (Compact HTML)
Major Technology	WAP Gateway	TCP/IP modifications
Key Features	Widely adopted and flexible	Highest number of users and easy to use

Table 3. Two major kinds of mobile middleware

WAP (Wireless Application Protocol). WAP is an open, global specification that allows mobile users with wireless devices to easily access and interact with information and services instantly [14]. It is a very flexible standard including most wireless networks, which include CDPD, CDMA, GSM, PDC, PHS, TDMA, FLEX, ReFLEX, iDEN, TETRA, DECT, DataTAC, Mobitex, and GRPS. It is supported by most operating systems and was specifically engineered for mobile stations include Palm OS, EPOC, Windows CE, FLEXOS, OS/9, and JavaOS. The most important technology applied by WAP is probably the WAP Gateway, which is mainly responsible for interfaces between the Internet and the network. It functions as follows—requests from mobile stations are sent as a URL through the network to the WAP Gateway; responses are sent from the Web server to the WAP Gateway in HTML and are then translated in WML and sent to the mobile stations.

i-mode. i-mode [5] is the full-color, always-on, and packet-switched Internet service for cellular phones offered by NTT DoCoMo. With i-mode, cellular phone users get easy access to more than 60,000 Internet sites, as

well as specialized services such as e-mail, online shopping and banking, ticket reservations, and restaurant advice. In spring 2001, DoCoMo introduced its next-generation mobile system, based on wideband CDMA (W-CDMA), which can support speeds of 384Kbps or faster, allowing users to download video images and other bandwidth-intensive content with its high-speed packet data communications.

5.2. Implementation

In a wireless environment, IP and TCP require significant modification in order to adapt to features like mobility and radio communication.

Mobile IP. The Mobile IP [6] defines enhancements that permit Internet Protocol (IP) nodes (hosts and routers) using either IPv4 or IPv6 to seamlessly "roam" among IP subnetworks and media types. It supports transparency above the IP layer, including the maintenance of active TCP connections and UDP port bindings. Two types of mobile-IP capable router, home agent (HA) and foreign agent (FA), are defined to assist routing when the mobile node is away from its home network. All datagrams destined for the mobile node are intercepted by HA and tunneled to FA. FA then delivers these packets to the mobile node through a care-of-address established when the mobile node is attached to FA.

TCP for mobile networks. Transmission Control Protocol (TCP) was designed for reliable data transport on wired networks and its parameters have been fine-tuned for such environments. As a result, when it is applied directly to mobile networks, TCP performs poorly due to factors such as error-prone wireless channels, frequent handoffs and disconnections. In order to optimize reliable data transport performance, a number of variants of TCP have been proposed for mobile networks. Yavatkar and Bhagawat [16] proposed an approach that splits the path between the mobile node and the fixed node into two separate sub-paths: one over the wireless links and the other over the wired links. This approach limits the TCP performance degradation in a "short" wireless link connection. Balakrishnan *et al*. [1] proposed a "packet caching" scheme to reduce the TCP retransmission overhead due to handoff. The scheme proposed in [2] utilizes the fast retransmission option immediately after handoff is completed and shows smooth TCP performance during handoff.

6. Wireless Networks

Network infrastructure provides essential voice and data communication capability for consumers and vendors in cyberspace. Evolving from electronic commerce (EC) to mobile commerce (MC), it is necessary for a wired network infrastructure, such as the Internet, to be augmented by wireless networks that support mobility for end users.

6.1. Wireless local area networks

Devices used in wireless local area network (WLAN) technologies are light-weight (easy to carry) and flexible in network configuration. Therefore, WLANs are suitable for office networks, home networks, personal area networks (PANs), and ad hoc networks. In a one-hop WLAN environment, where an access point (AP) acting as a router or switch is a part of a wired network, mobile devices connect directly to the AP through radio channels. Data packets are relayed by an AP to the other end of a network connection. If no APs are available, mobile devices can form a wireless ad hoc network among themselves and exchange data packets or perform business transactions as necessary.

In Table 4, major WLAN technologies are compared in terms of maximum data transfer rate (channel bandwidth), typical transmission range, modulation techniques, and operational frequency bands. The various combinations of modulation schemes and frequency bands make up different standards, which result in different throughputs and coverage ranges.

Standard	Max. Data Rate (Mbps)	Typical Range (m)	Modulation/ Frequency Band (GHz)
Bluetooth	1	5 – 10	GFSK / 2.4
802.11b (Wi-Fi)	11	50 – 100	HR-DSSS / 2.4
802.11a	54	50 – 100	OFDM / 5
HyperLAN2	54	50 – 300	OFDM / 5
802.11g	54	50 – 150	OFDM / 2.4

Table 4. Major WLAN standards

In general, Bluetooth technology supports very limited coverage range and throughput. Thus it is only suitable for applications in personal area networks. In many parts of the world, the IEEE 802.11b (Wi-Fi) system is now the most popular wireless network and is used in offices, homes, and public spaces such as airports, shopping malls, and restaurants. However, many experts predict that with much higher transmission speeds, 802.11a and 802.11g will replace 802.11b in the near future.

6.2. Wireless wide area networks

Originally designed for voice-only communication, cellular systems are evolving from analog to digital, and from circuit-switched to packet-switched networks, in order to accommodate mobile commerce (data)

applications. Table 5 lists a classification of standards in the first generation (1G), second generations (2G, 2.5G), and third generation (3G) wireless cellular networks. 1G systems such as the advanced mobile phone system (AMPS) and total access control system (TACS) are becoming obsolete, and thus will not play a significant role in mobile commerce systems. The global system for mobile communications (GSM) and its enhancement general packet radio service (GPRS) have mainly been developed and deployed in Europe. GPRS can support data rates of only about 100 kbps, but its upgraded version—enhanced data for global evolution (EDGE)—is capable of supporting 384 kbps. In the U.S., wireless operators use time division multiple access (TDMA) and code division multiple access (CDMA) technologies in their cellular networks.

Generation	Radio Channels	Switching Technique	Standards (Examples)
1G	Analog voice; Digital control	Circuit-switched	AMPS TACS
2G	Digital	Circuit-switched	GSM TDMA
		Packet-switched	CDMA
2.5G	Digital	Packet-switched	GPRS EDGE
3G	Digital	Packet-switched	CDMA2000 WCDMA

Table 5. Major cellular wireless networks

Currently, most of the cellular wireless networks in the world follow 2G or 2.5G standards. There is no doubt that in the near future, 3G systems with quality-of-service (QoS) capability will dominate wireless cellular services. The two main standards of 3G are Wideband CDMA (WCDMA), proposed by Ericsson, and CDMA2000, proposed by Qualcomm. They both use direct sequence spread spectrum (DSSS) in a 5-MHz bandwidth. Technical differences between them include a different chip rate, frame time, spectrum used, and time synchronization mechanism. The WCDMA system can inter-network with GSM networks and was strongly supported by the European Union, which called it Universal Mobile Telecommunications System (UMTS). CDMA2000 is backward-compatible with IS-95, which is widely deployed in the U.S.

7. Host Computers

A host computer produces and stores all the information for mobile commerce applications. Because it is the mobile commerce application programs, rather than the host computers themselves, that are aware of the targets, browsers or microbrowsers, they serve, this component is similar to that used in an electronic commerce system. Most of the mobile commerce application programs reside in this component, except for some client-side programs such as cookies. It contains three major components: a Web server, a database server, and application programs and support software.

Web servers. A Web server is a server-side application program that runs on a host computer and manages the Web pages stored on the Web site's database. There are many Web server software applications, including public domain software from NCSA and Apache, and commercial packages from Microsoft, Netscape, and others. Since April 1996, Apache has been the most popular HTTP server on the Internet; in May 1999, it was running on 57% of all web servers. It was developed in early 1995, based on code and ideas found in the most popular HTTP server of the time, NCSA httpd 1.3. It has since evolved to rival (and probably surpass) almost any other Unix based HTTP server in terms of functionality and speed. It features highly configurable error messages, DBM-based authentication databases, and content negotiation.

Database servers. Other than the server-side database servers, a growing trend is to provide a mobile database or an embedded database to a handheld device with a wide range of data-processing functionality. The functionality is frequently very sophisticated, and the flat file system that comes with these devices may not be able to adequately handle and manipulate data. Embedded databases have very small footprints, and must be able to run without the services of a database administrator and accommodate the low-bandwidth constraints of a wireless-handheld network. Some leading embedded-databases are Progress Software databases, Sybase's Anywhere products, and Ardent Software's DataStage [7].

Application programs and support software. Web and database servers are mandatory for mobile commerce systems; application programs handle all server-side processing. However, to facilitate mobile commerce applications, some other support software is needed. For example, various programming languages, including Perl, Java, Visual Basic, C/C++, etc., and the CGI (Common Gateway Interface) for transferring information between a Web server and a CGI program are necessary.

8. Summary

The emerging wireless and mobile networks have extended electronic commerce to another research and application subject: mobile commerce. A mobile commerce system involves a range of disciplines and technologies. This level of complexity makes understanding and constructing a mobile commerce system an arduous task. To facilitate this process, this

paper divided a mobile commerce system into six components, which can be summarized as follows:

1. Mobile commerce applications: Electronic commerce applications are already broad. Mobile commerce applications not only cover the existing applications, but also include new applications, which can be performed at anytime and from anywhere by using mobile computing technology.
2. Mobile stations: Mobile stations are limited by their small screens, limited memory, limited processing power, and low battery power, and suffer from wireless network transmission problems. Numerous mobile stations, such as PDAs or Web-enabled cellular phones, are available in the market, but most use one of three major operating systems: Palm OS, Microsoft Pocket PC, and Symbian OS. At this moment, Palm OS leads the market, however it faces a serious challenge from Pocket PC.
3. Mobile middleware: WAP and i-mode are the two major kinds of mobile middleware. WAP is widely adopted and flexible, while i-mode has the highest number of users and is easy to use. It is difficult to predict which middleware will dominate the market in the future; it is more likely that the two will be blended somehow at some point in the future.
4. Wireless and wired networks: Wireless LAN, MAN, and WAN are major components used to provide radio communication channels so that mobile service is possible. In the WLAN category, the Wi-Fi standard with 11 Mbps throughput dominates the current market. It is expected that standards with much higher transmission speeds, such as IEEE 802.11a and 802.11g, will replace Wi-Fi in the near future. Compared to WLANs, cellular systems can provide longer transmission distances and greater radio coverage, but suffer from the drawback of much lower bandwidth (less than 1 Mbps). In the latest trend for cellular systems, 3G standards supporting wireless multimedia and high-bandwidth services are beginning to be deployed. WCDMA and CDMA2000 are likely to dominate the market in the future.
5. Host computers: Host computers produce and store all the information needed for mobile commerce applications, and most application programs can be found here. They include three major components: Web servers, database servers, and application programs and support software.

Another important issue for mobile commerce is mobile security and payment. Security issues (including payment) include data reliability, integrity, confidentiality, and authentication and are usually an important part of implementation in wireless protocols/systems. Solutions are updated frequently, due to the lack of a comprehensive wireless security infrastructure and standard. A unified approach has not yet emerged.

9. Acknowledgments

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10. References

[1] H. Balakrishnan, S. Seshan, E. Amir, and R. Katz. Improving TCP/IP performance over wireless networks. In *Proceedings of the 1st ACM International Conference on Mobile Computing and Networking (MobiCom)*, Berkeley, California, 1995.

[2] R. Caceres and L. Iftode. Improving the performance of reliable transport protocols in mobile computing environment. In T. Imielinski and H. Korth, editors, *Mobile Computing*, pages 207–228, Kluwer Academic Publishers, 1996.

[3] Frequently asked questions about NTT-DoCoMo's i-mode. *Eurotechnology*. Retrieved December 16, 2002 from http://www.eurotechnology.com/imode/faq.html

[4] P. Gordon and J. Gebauer. M-commerce: Revolution + inertia = evolution. *Working Paper 01-WP-1038*, University of California, Berkeley, 2001.

[5] i-mode. *NTT-DoCoMo*. Retrieved November 28, 2002 from http://www.nttdocomo.com/

[6] IP routing for wireless/mobile hosts (MobileIP). *The IETF Working Group*. Retrieved November 6, 2002 from http://www.ietf.org/html.charters/mobileip-charter.html

[7] S. Ortiz, Jr. Embedded databases come out of hiding. *IEEE Computer*, 33(3):16-19, 2000.

[8] Over 50% of large U.S. enterprises plan to implement a wireless/mobile solution by 2003. *The Yankee Group*, 2001. Retreived December 10, 2002 from http://www.yankeegroup.com/public/news_releases/news_release_detail.jsp?ID=PressReleases/news_09102002_wmec.htm

[9] Palm OS. Retrieved December 22, 2002 from http://www.palmsource.com/palmos/

[10] Pocket PC. Retrieved November 25, 2002, from http://www.microsoft.com/mobile/pocketpc/

[11] S. Saha, M. Jamtgaard, and J. Villasenor. Bringing the wireless Internet to mobile devices. *IEEE Computer*, 34(6):54-58, 2001.

[12] Symbian. Retrieved December 10, 2002 from http://www.symbian.com/

[13] U. Varshney, R. J. Vetter, and R. Kalakota. Mobile commerce: A new frontier. *IEEE Computer*, 33(10):32-38, 2000.

[14] WAP: Wireless Application Protocol. *Open Mobile Alliance*. Retrieved November 21, 2002 from http://www.wapforum.org/

[15] The Yankee Group publishes U.S. mobile commerce forecast. *Reuters*, 2001. Retreived December 16, 2002 from http://about.reuters.com/newsreleases/art_31-10-2001_id765.asp

[16] R. Yavatkar and N. Bhagawat. Improving end-to-end performance of TCP over mobile internetworks. In *Proceedings of the Workshop on Mobile Computing and Applications*, Santa Cruz, California, 1994.