Providing Mobile Web Services via Cellular Phones

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Abstract

The demand for access to the Internet by mobile users is increasing. Recent emergence of low-cost wireless appliances made it possible to surf the Internet with handheld devices. One of the competing technologies is the use of WAP (Wireless Application Protocol) phones. However, due to limited processing and memory capacity, small display and inefficient input mechanism, it is a challenge to serve Web contents to cellular phone. This paper introduces the architecture of the WAP technology, discusses the disadvantages and advantages of cellular phones as a Web browser, suggests the types of web services suitable for mobile users, and investigates the methods for converting HTML pages to WAP pages and efficient ways of maintaining a WAP site that servers diverse and incompatible WAP browsers.

1. Introduction

Conventionally, the vast majority of users access the Internet using desktop computers. However, people are no longer contented with being limited to their desktops. The development of low-cost wireless appliances, such as personal digital assistant (PDA) and WAP phones, have made mobile Internet surf possible with handheld devices [2, 4, 5]. The WAP Forum, a consortium founded by a group of cellular phone manufacturers and software companies, established a stack of wireless application protocols in 1999 to facilitate Internet services to digital cellular phones and other wireless handheld devices [17].

While the WAP technology creates opportunities for new data services, it is experiencing the growth pain that the WWW has undergone in the early 1990s [7, 10, 12]. In contrast to the ubiquity of HTML services, only a few thousand WAP sites, mostly in Europe and maintained by large corporations, are available at present. Even these services are currently facing serious usability problems [10]. Major constraints are caused by the intrinsic limitations of handheld devices (e.g., low processing and memory capacity, inefficient input mechanism, and small display screen) and the low bandwidth of wireless networks [16, 17]. Unsophisticated WAP site design also contributes to the usability problems [2]. Most current WAP sites provide WAP contents simply by converting HTML pages designed for desktop PCs to WAP pages [8], without careful consideration of the tremendous differences between desktop PCs and handheld devices. There is also a lack of design standards among different WAP phone manufacturers, resulting in serious incompatibility among different WAP phone models [16, 17], which makes it costly to maintain a WAP site that can serve cellular phones from different vendors. It is a great challenge to render high quality web contents to slow, cigarette pack-sized cellular phones. Guidelines of how to use the limited wireless bandwidth and how to present WAP contents in small screen are needed to mitigate some of the usability problems.

In this paper, the WAP technology will be briefly introduced, and the limitations of each component in the WAP architecture, and their implications for developing WAP services will be analyzed. Then the current WAP services available in the Internet will be examined from usability points of view. Finally, methods will be studied for efficiently maintaining a web site that can adaptively serve both HTML browsers from desktop PC and incompatible WAP phones.

2. WAP Architecture

The WAP architecture consists of five components (Fig. 1): WAP handheld devices, wireless networks, WAP gateway, wired network (e.g., the Internet), and content provider [16, 20].
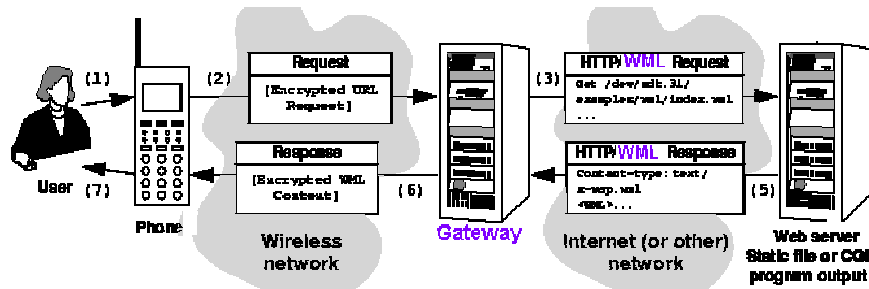
Fig. 1 The WAP architecture [16]

2.1 The WAP phones

A WAP phone is a cellular phone with WAP browser imbedded. The WAP browser can interpret web contents written in Handheld Device Wireless Markup Language (WML) and WML script [18, 19]. As a handheld device, a WAP phone must be physically small enough to be held with one hand and can be put into a pocket. Power consumption of the device should be minimal, so that the battery is adequate for at least a few hours of using and a few days of standby without recharge. Limited physical dimensions determine that a WAP phone will have clumsy keypad and small display, low processing speed and small memory capacity.

The keypad of a WAP phone has 10 numeric keys [Fig. 2]. These numeric keys are used both for dialing phone numbers and for entering text. To type in letters, the user will have to press the numeric keys for different times. For example, to enter letters "b" and "c", key 2 twice will be pressed continuously twice and thrice quickly, respectively. The keypad also has one or two "soft" keys, whose functions can be programmatically set to perform different tasks in different contexts. For example, the soft key can be toggled between different modes, such as numeric, uppercase, lowercase, and symbol. When the user presses key "1", the input may be literal "1", "a" or "A", depending on the current mode of the soft key. In addition, a WAP phone has scrolling and navigational buttons (e.g., go back, home, et al. Fig. 2) for the user to navigate between different sites or different sections of a large WAP page. Due to the difficulty in using the keypad, good WAP services should require minimal user input.
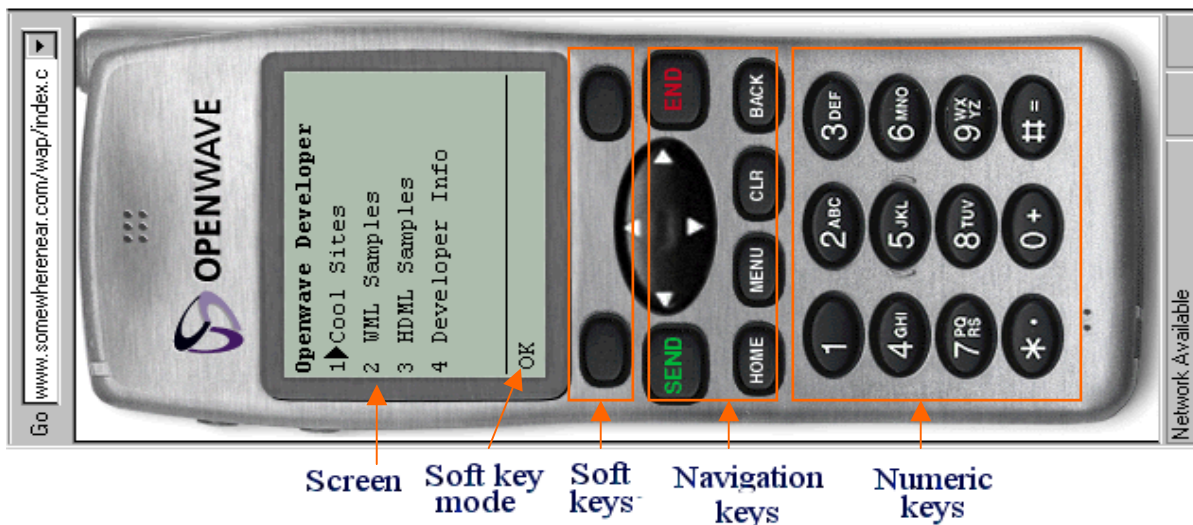

Fig. 2 The interface of a generic WAP phone [16]

The screen sizes of cellular phones range from 3 to up to 8 lines of text of about 20 characters, depending on the phone model [16]. While other limitations may fade away when technology improves in the future, no significant change can be expected to increase the physical sizes of handheld devices. The WAP page designers have to use every pixel on the screen efficiently. Large WAP pages have to be sliced into small cards. When many cards are presented, navigation between them must be efficient.

2.2 The wireless network

The wireless network carries signals between the cellular phone and wired network. Currently, two types of wireless networks are used by the WAP technology [13, 16, 21]: Global System for Mobile Communication (GSM) in Europe, and Code Division Multiple Access (CDMA) in North America. Low bandwidth and unreliability are the most frustrating aspects of web browsing with a cellular phone. For instance, the bandwidth of GSM is 9.6 kbps, which makes downloading large documents very slow, although new wireless network technology in the future may improve the bandwidth [21]. To cope with this problem, the WAP protocol requires that WAP pages be less than 1.4 KB, and be compressed into byte code before being sent to the cellular phones over the wireless network [20]. In addition, the WAP phone users are charged by the minute for air time [10, 12]. WAP services thus must be concise and relevant to mobile users, so that they are willing to pay the air time.

2.3 The gateway

An important component in the WAP architecture is the gateway, which serves as the interface between the wireless and wired networks [16]. When the mobile user makes a request from a WAP phone, the request is sent to the gateway via the wireless network. If the client wants to access a WAP page from a web server, the gateway sets up a connection to the WWW server, converts the user's WAP request into a conventional HTTP request, and retrieves the WAP page from the web server. Then the gateway transforms page to binary format and sends the binary code to the WAP phone. Finally, when the cellular phone receives the binary code from the gateway, the imbedded WAP browser decodes the binary code, and renders the contents on the screen of the phone. Some gateways can also convert HTML documents into WML format on the fly, thus the user can make request for an ordinary HTML page in any WWW server [8]. However, automatic conversion of HTML into WML by a gateway is not reliable, because HTML is a much richer language designed for desktop computers, and conversion by the gateway is simply striping off some HTML elements [2]. This kind of service commonly results in usability problems. Good WAP services should not rely on the automatic HTML-to-WML conversion by the gateway.

The gateway also takes care of various housekeeping chores for the WAP phones, such as keeping the WAP client's bookmarks, managing its cache, and so on, to relieve the memory and power limitations of the very "thin" browser in the mobile device [16, 20]. While the gateway reduces the bandwidth requirement of the wireless network and relieves some of the burden of the WAP phone by compressing the WML or WML scrip contents into binary code, the use of it also raises security problems [7, 10]. Since all the request and services between the client and the server have to go through the gateway, confidential information may be venerable if the gateway is mismanaged. This raises another usability problem: services involving financial transactions should take extra cautions.

2.4 The WAP server

With the use of gateway, adding WAP services to an existing web site does not impose additional requirement to the service provider. A WAP site thus can be developed in conventional web server. The only thing the developer needs to do is to add HDML, WML (WAP pages) and WMLS for (WAP script), and WBMP (for WAP pictures) as new MIME types in configuring the web server. Conventional script languages, such as Java Servlet, Perl can also be used to provide dynamic WAP contents.

3. Analysis of current WAP services

WAP technology is still in its infancy and it has yet to identify what services mobile users would like to use while being charged air time. Many WAP sites are dying out every day, because the contents provided by them are not always attractive to mobile users [10]. Given the tremendous differences between the desktop and mobile environments, typical HTML services may not fit in WAP phones. In this section, a few examples of the current WAP services are examined from the usability point of view.

Checking news of various types is probably one of the most frequent activities in the Internet. Many WAP sites such as Reuters, CNN and BBC, provide news services, usually with a main page of selections of geographical areas or news subjects, such as world, national and local, entertainment, sports, business and so on. The user would have to go though many navigation steps to load the menus before getting to the real news. Each step may take a few tens of seconds. After all these troubles and perhaps having to pay minutes of air time, what the user gets is commonly just a few tens of words for a piece of news. With the expenses and time needed for WAP news, the customer probably prefers to, and is able to find a 20-page newspaper and enjoy reading much more detailed news.

Email is a WAP service that has been over hyped by the WAP business community over the past year. It is hard to imagine that many people would use an awkward cellular phone keypad to type in a lengthy email message

while holding a phone that can be used to make voice phone calls. On the other hand, receiving an email via a cellular phone may be appropriate, because there is indeed a demand by mobile users to check email on the move. Particularly, some cellular phones have notification functions, with which the user can be notified with a ring or shaking when a new email arrives. Updated schedules can be sent to the mobile personnel with notification and short email messages. This feature has potential for some business with lots of field personnel (e.g., taxi companies), to develop automatic notification systems, such as for dispatching field workers.

Shopping and financing is another area that probably does not fit in WAP phones. Having to go through the gateway makes financial transactions with WAP phones insecure. Despite a great deal of marketing exposure [10], there is not much enthusiasm for a WAP phone from users who can shop more easily and cheaply on the web with a desktop computers, or with an old-fashioned phone call.

In spite of the limitations, a plenty of useful services could be provided via WAP phones. Travel service is a proven area where WAP is particularly attractive [5]. A number of WAP sites in Europe report live-time information on flight schedule, hotel reservations, restaurant bookings, movie schedules and sporting events, weather forecasts, and stock market [4, 5, 9]. The mobile services can notify travelers of delays, cancellations and other travel-related information. These services are concise enough to be presented in only a few lines, and yet are highly relevant and meaningful to the mobile users. Furthermore, information like this can not be easily found from other conventional sources, such as newspaper, radio or TV.

Location-based services should be the greatest strengths of WAP. It's possible to obtain a mobile user's location by tracing the cell in the cellular network from which the call is originated. The Global Positioning System (GPS) is capable of outdoor positioning at the accuracy of 10 to 20m. However, for security and privacy reasons, cellular network operators are presently unwilling to release customers' location information to web service providers [16, 20], thus location-based WAP services at present are underdeveloped. It can be expected that location-based WAP content will become the mainstream WAP services in the future. Imagine that you are in downtown of an unfamiliar city and want to have lunch before heading to the airport to catch your flight in one hour. You could press a few keys on your WAP phone. The phone will show you a little direction map indicating where you are and all the restaurants within three blocks from your current location. You can press the menu by following the links to order your food from the restaurant you choose. By the time when you get to the restaurant with the help of the direction map, your food will be ready. This kind services will be irreplaceable by the conventional web services and will be most attractive to mobile users on the move.

4. Converting HTML pages to WAP pages

Millions of HTML pages are in the Internet, and some of them are obviously useful to WAP phone users. An WAP service provider may incorporate some legacy HTML pages into the WAP site. However, as emphasized earlier on, converting a HTML page to a WAP page involves methods far more than stripping off some HTML tags [4]. This section will discuss the methods of converting HTML to WML.

The WAP technology specifies its own standard markup languages for rendering contents to WAP phones. The specifications of the markup languages have been evolving, starting with HDML, through WML 1.1 and 1.2, to current WML 1.3 [18]. A script language WMLScript is also specified to provide dynamic features [19]. Since most WAP phones currently only support WML1.1 [16], this section will focus on WML 1.1.

WML is based on XML (eXtensible Markup Language), thus the general rules of XML for document types, elements and attributes, are applicable to WML. WML 1.1 has only about 30 markup tags [18], as opposed to over a hundred tags and the capacity of defining style sheets in HTML. Only a few HTML tags are inherited by, and some new tags have been added to WML. An ill-designed HTML page can still be displayed in a large desktop monitor with the help of sophisticated desktop browsers. This is not the case for WML pages. Unwise layout of the WML contents requires intensive user interaction, or the contents simply can't be rendered to WAP phone at all.

A "deck" is the smallest downloadable unit that is transmitted to the WAP phone for each request [18], equivalent to a page in HTML. A deck usually contains some cohesive information about a given topic. Deck size is proprietary, and varies from 1.2KB to 1.4 KB, depending on the memory of the cellular phone [16]. A large deck needs to be divided into a series of "cards" to fit into the small screen. The user needs to navigate between different cards. Breaking down a deck into small cards by the WAP browser in the phone may affect the natural structure and the cohesiveness of the deck. A better solution is to configure the deck structure with server site programming.

4.1. Converting general structure of HTML to WML

Well-designed HTML pages should be well structured, such that the viewer can easily navigate between different sections of the page. This is usually achieved by using internal anchors and links, or hierarchical headings within the page. Conversion of well formatted HTML pages is relatively easy: sections of the page can be changed into corresponding cards (Fig. 3) or different decks. However, because of the size limitation (1.2 to 1.4 KB), a deck may not be enough for a large HTML section. Such HTML sections need to be further break down into a number of decks, with a main deck at the beginning that only lists the links pointing to the subsequent decks. Java classes have been written during this project to conduct conversion for this type of well designed HTML pages.
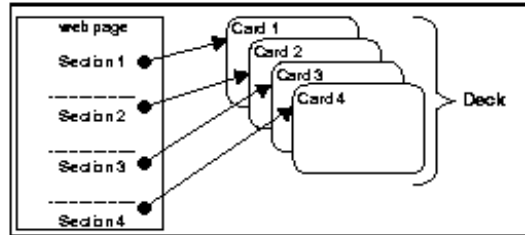

Fig. 3 Structure conversion of well-formatted HTML page to WAP deck

Unfortunately, the majority of the HTML pages in the Internet are not well formatted. The irregularities of ill-formatted HTML pages could be syntactic or semantic. Syntactic violation of HTML grammar (e.g., unpaired HTML tags) can be corrected with some software. For instance, a freeware software package called TidyUp, implemented both in C++ and in Java, is available [3]. The classes can be incorporated into server site programs. Extracted HTML pages can be cleaned up before being converted to WML pages. However, semantic ambiguity needs WAP developers' involvement. Analysis of the HTML contents is needed to break down the HTML page into naturally structured decks. Informative titles should be added as menu links (Fig. 4). Because of the complexity of processing natural language, commercial middleware, however advocated, is not capable of meaningful conversion [2, 8].
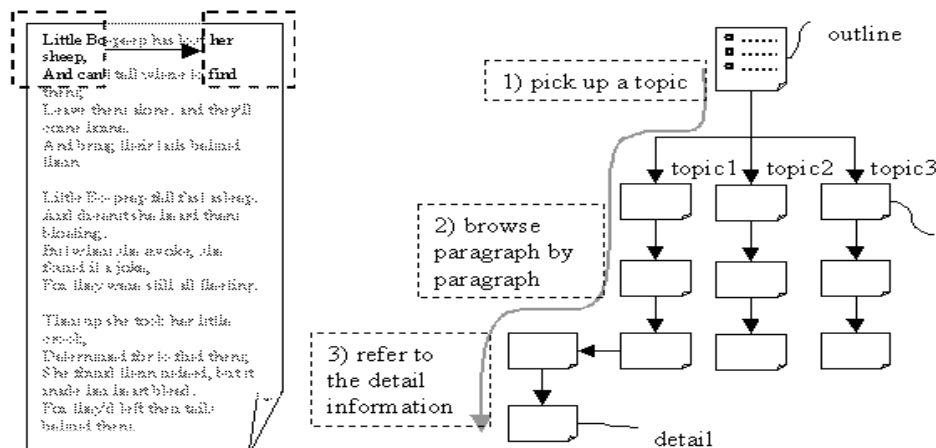

Fig. 4 Conversion of non-structured HTML page to WAP decks

4.2. Layout of long text

The screen of most WAP phones is capable of showing only about 20 characters per line [16]. Sentences in text paragraphs, or phrases in selection lists will be wrapped to the next line, resulting in irregularly alignment and waste of precious pixels at the end of wrapped lines (Fig. 5A). In a selection menu, a simple option may take a number of lines. Some WAP page designers use abbreviations for lengthy words, which sometimes lead to ambiguity. Some WAP browsers are capable of automatic flow text. A long phrase or sentence can be presented in one line, where the leftmost part of the line will show first, and then the remaining parts will show up subsequently after a few fractions of a second (Figs. 5B and 5C). An arrow at the beginning of the line indicates that the line is not finished.

The rate of text flow and repetition times can be specified to make sure the user has time to read the whole sentence. This way, the vertical space will be saved to provide as much content as possible, and reduces the time of navigation.

```
Long sentences          ▷Long sentences          exceeding the display
exceeding the display     Using abbreviations       Using abbreviations
width will be wrapped     Using automatic hori       Using automatic hori
onto the next line.
Using abbreviations
leads to ambiguity.

Back                    A Back                   B Back                   C
```
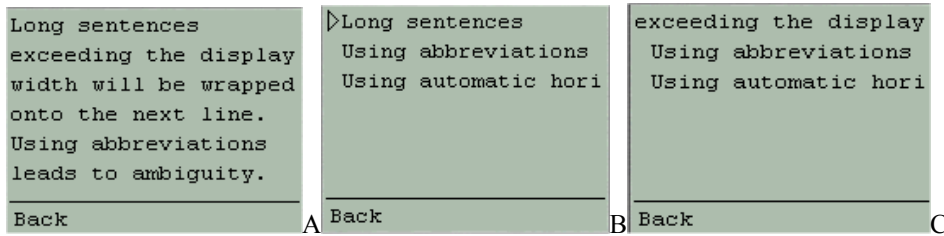
Fig. 5 Two layouts of a selection list with long option items.

A text-intensive card may take a number of screen pages to render. The user would have to continuously press the "down" arrow key (Fig. 2) to navigate to the next page. Each press only moves down one line. WML defines a timer that can automatically trigger a preset event after a time interval [18, 19]. This feature is underused by current WAP services, but may be helpful to set up automatic navigation for long paragraphs of text. For instance, a paragraph can be broken into a number of sequential cards, and a time interval can be set, after which the cards automatically update themselves sequentially (Fig. 6). Since each page only displays a few tens of words, a second would be long enough for the user to view a card. The user also should be given the choice to go back to the previous card at any time if it is desired.
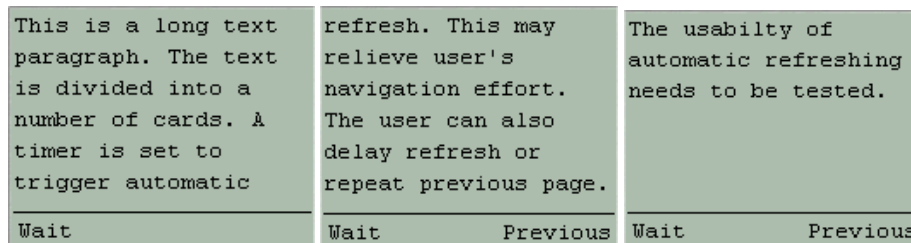
```
This is a long text     refresh. This may        The usabilty of
paragraph. The text     relieve user's           automatic refreshing
is divided into a       navigation effort.       needs to be tested.
number of cards. A      The user can also
timer is set to         delay refresh or
trigger automatic       repeat previous page.

Wait                    Wait         Previous     Wait         Previous
```

Fig. 6 Automatic timed navigation

4.3. Links

A great advantage of HTML pages is the ability to set up links to other sites. In a desktop PC, a mouse pointer can be easily pointed to any spot of the screen, allowing the user to click hyperlinks in a random fashion. This is not feasible with WAP phones because there is no pointing device. The user has to use the scroll button to the line that contains the link and press one of the soft key to go to the linked site. Mixing normal text and links will result in unpleasant layout (e.g., Fig. 7A). The soft key will change functionalities, depending on the current cursor position (e.g., Figs. 7A and 7B). Many automatic HTML-WML conversion programs produce WML decks with mixed text and link, confusing the user on the soft key's functions [8]. A better design is to extract external links into a separate card, and set a dedicated soft key pointing to it. The user can skip to the current card and choose to go to the link card and pick up external sites (Figs. 7 C and 7D).

```
▷Dept. Cmpt. Sc. -        Dept. Cmpt. Sc. - Ho    This is a WLM page     All links
 [University of          ▶[University of          that contains          1▶link 1
Saskatchewan]            Saskatchewan]            external link 1.       2 link 2
 [ ]                      [ ]                     After a few
Department of            Department of            paragraphs, it
Computer Science         Computer Science         contains link 2.

More           Menu    A Link          Menu    B Back      all links  C link 1       back  D
```
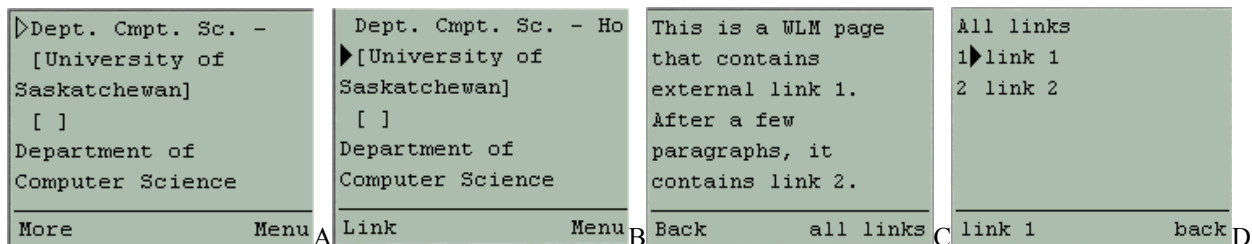
Fig. 7. Comparison between mixed and separated text and external links

4.4. Converting tables

Tables are widely used in HTML pages for better laying out the contents. Although WML supports tables, a table is difficult to be displayed in a small cellular phone screen because of its rigorous structure. A very simple table

example is illustrated in Fig. 8. The card presents a week's weather forecast with a table. For the first couple of columns, the data are aligned as desired. However, the third and subsequent columns are truncated due to the width limit (Fig. 8A). These columns can be displayed with horizontal navigation, but each horizontal scrolling only shows one line (Fig. 8B). The structure of the table can not be maintained, ending up with no alignment. The content in each cell is very short in the above table. If the content in the heading row is longer, which is the case for any meaningful table in HTML pages, even the first couple of columns can not be displayed.
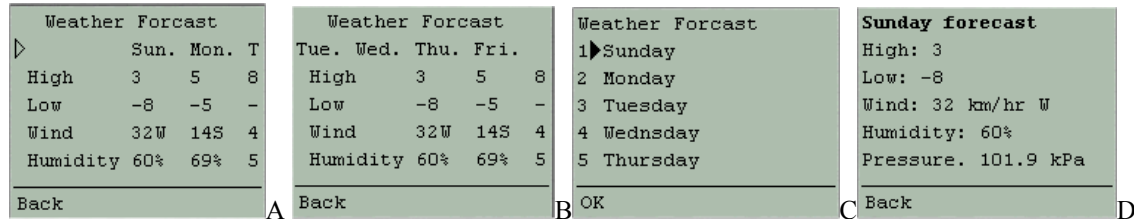

Fig. 8 Example of converting multiple column HTML table to WAP decks.

A better solution to converting complicated HTML table to a WML deck is to use multiple cards. The heading row or column, depending on the original table configuration, can be used to construct a main card that only contains the table headings as links (Fig. 8C). The text in each cell can then be viewed in subsequent cards pointed by the links (Fig. 8D).

4.5. Dealing with pictures

Pictures are ubiquitous in HTML pages. WML only supports black-white bit map pictures in the format of WBMP (Wireless Bit Map Picture) [16, 18]. Software is available to convert GIF and JPG pictures to WBMP [e.g., 14]. However, direct converting pictures in HTML pages and presenting them to a cellular phone is unrealistic due to the restrictions in bandwidth and display space. Some cellular phones have standard icons imbedded, which can be rendered at the server's request and need not to be transferred over the wireless network, thus reducing bandwidth usage. Still, only familiar and standard icons should be used to replace lengthy text and save space.

4.6. Handling user input

WAP phone users can submit forms to the server. However, some familiar form elements in HTML pages, such as radio button and checkbox, are not supported by WML. The user would have to use the laborious keypad to fill the form. A good WAP form should preset all the possible options in a selection menu, and let the user to choose from the preset list. Although this may involves many steps of navigation when the selection list is long, but it is less unpleasant then typing on the keypad. An example of submitting a form for a restaurant search is shown in Fig. 9. In the first design (Fig. 9A), the user would have to type more than 30 key strokes (including toggles between different input modes), whereas the second design requires only four strokes.
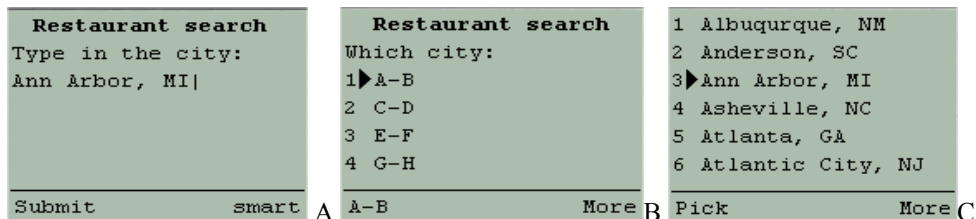

Fig. 9 Comparison of the methods of capturing user input

Another important aspect in handling user input is error prevention. Feedback could be sent from the server after the incorrect input is received and processed. However, transferring incorrect input to and getting feedback from the server would take the precious bandwidth. Check the input on the client side is far more efficient. This could be implemented with WMLScript. Although WMLScript is a much less capable language than desktop script languages, such as Java script, experience in programming in WMLScript during this project suggests that it can prevent most common typo and omission of required entry in a form.

4.6. Incorporating telephony function into WAP services

As WAP phone is a simple information appliance, intensive text WAP pages will probably never be attractive to customers, because of air time cost and the stress involved in reading from a small device. The telephony function may complement the small screen display. A WAP site can be designed as a search engine for telephone numbers for related personnel. Once the phone number is found, it can be automatically dialed. Larger amount of information recorded as voice messages, can be read to the user via conventional telephony service. The WML supports alternation between telephony and WAP services. However, currently, no such integrated WAP-telephony services are available in the Internet.

5. Cellular phone adaptation and user modeling

As mentioned earlier, there is a lack of standards in the design of WAP phones. This leads to serious incompatibility problems both in terms of browser capabilities and the interfaces. Currently there are more than a dozen of WAP phone manufacturers and about 50 different phone models, all with some proprietary features [16]. For instance, some phones are only HDML capable, whereas the others are only WML capable. Unlike in the desktop environments where web browsers can be easily updated, WAP browsers are imbedded firmware that can not be upgraded unless the user changes to a new phone. As a result, a WAP page may fit one cellular phone perfectly, but may look miserable, or simply cannot be displayed at all in another phone. Many content providers just provide service to a set of pre-decided phones, which creates the "walled garden" [10].

It is a great challenge to maintain a general purpose server that can serve all browsers [9, 15]. In the HTML world, it is achieved by using script language to find out what type of user agent is rendering the content, and the same HTML page may be displayed in different formats accordingly. Doing this requires the browser to have the power to processing the complicated script programs, which is infeasible with a WAP phone. An common approach taken by many WAP servers is to prepare many versions of a WAP page on the server side, each is meant to fit one particular WAP phone model [9, 15]. However, maintenance of many versions of a WAP page is costly, and the integrity of the contents may be compromised when many versions have to be updated.

Using XML can relieve the burden of writing multiple versions [4, 15]. XML is fast becoming the common way of storing contents in the Internet. Unlike other markup languages, XML separate the contents from how to present them. All the tags in XML are user-defined and have semantic meanings, and thus can be parsed to extract desired data. The extracted data can be used to construct different pages according to the presentation formats, either separately defined in an XSL (eXtensible Stylesheet Language) document, or with other techniques such as Java SAX package.

To reduce the user's navigation involvement and increase the efficiency of screen space usage, user modeling techniques can also be employed to tailor the contents to the user's preference. For instance, a user's behavior and preference can be recorded and modeled after a number of visits to a WAP sites. WAP contents can be tailored according to the user's previous navigation behaviors, e.g., the user's favorite links are put on top of a menu, thus the user does not have to navigate for many steps before getting what the user wants.

6. A testing WAP site: the Saskatchewan Movie Schedule Report System

To test some of the ideals discussed above, a movie schedule report WAP application was developed in Java servlet and socket programming. The system consists of two parts. A Java thread wakes up three times everyday, at 8 pm, 10 am, and at noon, and extracts movie schedules from the web sites of various cinemas in Saskatoon and Regina. The thread also converts the HTML pages into XML documents. The second part dynamically generates WML pages from the XML document.

The HTML pages of the cinemas vary from very simple to moderately complicated (Fig. 10). All the pages contain various amount of content irrelevant to movie schedules. They had to be analyzed to locate the movie schedules in the page. Even for these relatively simple HTML pages, retrieving desired information was a great challenge. Each HTML page had to be treated individually and the retrieving methods had to be hard-coded, because no generalization of the HTML page design could have been summarized. The experience of converting these pages during the project suggests that no middleware software would be capable of producing a meaningful HTML-WML conversion.

Once the XML document is generated, the task of programmatically converting the XML into WML and HDML was not difficult. The methods of presenting WAP contents discussed above were used. Fig. 11 illustrates the navigation steps and the layout of the results.

Fig. 10 Partial layout of HTML pages for two Saskatoon cinemas that were converted to WAP pages [1, 6].
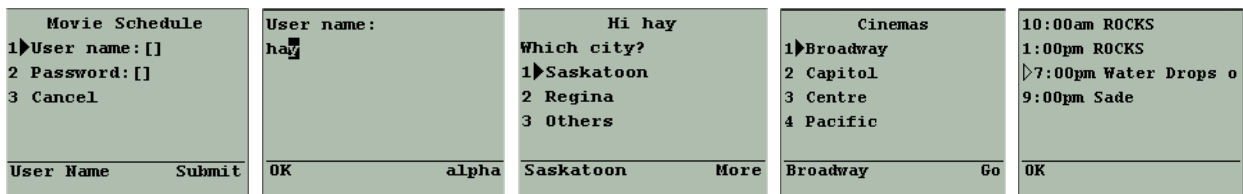

Fig. 11 WAP pages for the movie schedules

7.   Conclusions and Further Research

Although the demand for mobile Internet access with WAP phones is increasing, not all the web contents can be provided to mobile users due to limitations of wireless networks and WAP phones. Identifying proper services suitable for WAP phones is critical for the WAP technology to attract customers. Nice layout of the contents is needed to efficiently use the limited screen space, and reduce user's involvement in navigation. This paper presented some results of a preliminary study. Most of the ideals were generated by using simulators in desktop PC. The experience of using simulators may be different from using real WAP phones on the move. The next step of the research is to use real WAP phones to test the ideals discussed above on real users.

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