VERTICAL HANDOVER IN CELLULAR COMMUNICATION NETWORKS

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***Abstract* – This paper discusses vertical handover of disparate networks with emphasis on handover of Wireless LAN (WLAN) and General Packet Radio Service (GPRS). The paper covers the issues involved in vertical handover and discusses a solution being undertaken at UWC. The objective is to provide network services using various types of networks and devices for field workforce automation. The limitations of both WLAN and GPRS are discussed. Methods for re-formatting large general-purpose Internet web pages to match small form-factor wireless devices are discussed. Methods for providing access on demand, wherever, whenever and with whatever are provided and explained. Along with the seamless handover is scaling down (minimizing) of web pages to match the display capability of the small screen of a personal digital assistant (PDA). The web pages are reduced in size and complexity and high bandwidth requiring features are held back to speed up web page loading and downloads. Access to the Internet and/or the organisation's Intranet is enhanced through the intervention of proxy servers. It performs scaling down of the web pages, device matching and storing of frequently accessed web pages along with the web pages that have been placed on hold when the web pages are scaled down.**

Key Words/phrases:
Vertical handover, mobility modeling, proxy server, data transformation, Virtual Private Network (VPN), Wired Equivalent Privacy (WEP), WLAN and GPRS.

1.1 INTRODUCTION

It is essential for modern businesses to have all their employees online including the mobile employees. These employees should be able to access their organisation's communication system with various types of networks and devices. To support connectivity with any device, at any place and with any type of network, handover of disparate networks has emerged as an essential requirement to the industry. As the industry migrates towards an all IP future, it is desirable for subscribers to seamlessly use network services without paying particular attention to its type. What is important is that each subscriber has a multi-mode terminal that supports different bearers such as GPRS, WLAN, 3G.

There are two types of handover, horizontal handover within the same network and vertical handover between networks. This paper is focused on the latter.

The advantages of network handover are many. One of them being the ability of field workers to access the organisation's Intranet or Internet to receive and update their work schedules, respond to business mails from where ever they are in the field without the restrictions of network and device types. One of the many technologies that can be used for catering for such mobile employees is General Packet Radio Service (GPRS). Most GSM operators who have deployed GPRS are now working towards rolling out UMTS or its variant CDMA2000. These bearers should enable mobile field workers to have wider wireless network connectivity, to send and receive critical information to and from the office. The downside at the moment for networks such as GPRS is that connectivity is still expensive and considerably slow in terms of the available data rate, typically below 20 kbps for a single user. UMTS provides much higher data rates ranging from 2 Mbps at pedestrian speeds to 384 kbps at low speeds. Digital Enhanced Cordless Telephone (DECT) supports higher data rates up to 1152 kbps. A more bandwidth efficient solution is Wireless Local Area Network (WLAN). WLAN subscription is faster and less expensive than GPRS.

1.1.1 Essential Elements of Handover Between Networks

The major hindrance at the moment to efficient seamless connectivity using a multiple of network types is mainly network-to-network (vertical) handover. Vertical handover can be achieved either at the network level or at the device level. At the network level, vertical handover or handover between networks requires the device using the connections to be easily handed over between networks such as GPRS, UMTS and WLAN. This should be implemented based on prevailing conditions such as the most favourable signal level from a particular network, the network that provides the best quality of service (QoS) or the network that provides the least interference.

As Intelligence moves from the middle of the network to the edge, it is necessary for handover to be accomplished at the device level. This removes the need for frequent re-adjustment of network parameters. It frees base stations and nodes to perform more meaningful tasks within the network core.

It is easier and cost effective to download new software patches to hand held devices to upgrade their functions than to install new software or hardware into base stations and gateways. This means the user devices should have the capability for network discovery and selection. These two issues are currently major research topics. Network discovery and selections are particularly interesting requirements as the industry progresses towards the fourth generation (4G) of cellular communication networks. There are many advantages for achieving this. For example, to a field worker, it is essential that connectivity is continuous in device mobility regimes as his handset moves across the gamut of different bearers. The mobile worker should not notice the interchange from one network to the other. In other words at a location where only a WLAN hot spot and GPRS exist, the handover between WLAN and GPRS should be done in a seamless manner. The interchange can be made efficient through well-designed handover algorithms. This does not seem to be the case yet. Operators who recently rolled out 3G networks have observed frequent horizontal handover failures even within the same UMTS network, pointing to the fact that standardised handover algorithms are yet to be efficient.

Furthermore, being able to use various devices with different display, speed and storage capabilities requires paying attention to not only connectivity but also content transcoding and reformatting. This paper focuses on this aspect of network handover as well.

This paper focuses firstly on identifying the major problems of efficient connectivity required for vertical handover. Next several software and hardware based approaches have been studied. From the software point of view, the major objectives are network discovery, network selection, service continuity and data transcoding for vertical handover.

From the access point of view the objective is to ensure access through the gamut of multi-mode devices in the market at the moment and provide meaningful customer experience using their devices.

We advocate the use of a proxy server that would speed up downloads and access to the source considerably. We will access the source via a proxy server irrespective of the network medium at the backend, for example a landline. The size of web pages will play a huge roll as well; hence, we will need to downsize the web pages. The tools needed for this will reside on the proxy server. We will break down web pages into partitions that make logically sense and then display the partitions with tags that are directed to the other partitions to the user. The user will be viewing these pages on a Personal Digital Assistant (PDA). We do as little as possible computation on the PDA as to reserve power. Accessing the networks, especially WLAN is costly on power. The proxy server will therefore be enabled to handle most of the computation.

The rest of the paper is organised as follows. Section 1.2 covers vertical handover paying particular attention to one of its applications, field force automation. In section 1.3, we discuss the general objectives of vertical handover. Seamless handover between GPRS and WLAN is discussed in section 1.4. In this section, we also provide details of the vertical integration solution being proposed by the authors. Section 1.5 provides a brief analysis of advantages and disadvantages when using integrated GPRS and WLAN for field force automation. Conclusions are drawn in section 1.6.

1.2 VERTICAL HANDOVER FOR FIELD FORCE AUTOMATION

Field Force Automation is the regulating of the mobile workforce of a company. These employees need to communicate with the office several times a day and some employees need to be in contact with their offices all day, be it telephonic or via e-mail. Some field workers are even required to surf the Internet for information or policy documents, all depending on the company. Automating the field workforce simply refers to supplying the field workforce with the means to stay in contact with their office and utilizing their time and cost effectively.

1.3 THE OBJECTIVE OF HANDOVER

Handover promotes effectiveness of service, depending on the services that are integrated. Handover of GPRS and WLAN, is invaluable to any company that needs its field workforce to have automated access to its home Intranet and Internet.

Firstly, being able to access the Intranet with any device means cheaper options available in the market can be used. Secondly, access is provided at a wider coverage enabling the staff to work efficiently, updating his work schedule, reducing down time during which he needs to commute back to the office to acquire new schedule. It also enables the officer to be reached and managed from a central point. Thirdly, another obvious benefit is greater mobility that promotes faster job delivery, since they do not only utilize WLAN or a dial-up connection, hence more jobs can be completed within the same time frame. Again it boils down to cost reduction.

In our work, the objective is to enable a network user to move freely between networks and remain connected in an IP mode. The user should be able to maintain the QoS in use or at worst retain the essential features of QoS that can be supported by the new network. It is also important that a user have the capability to handle data of a specified type using devices with varying capabilities to overcome difficulties than may be encountered with data to be converted to match the device functions.

To assess the quality of our solution, we have enumerated the following metrics, which are ability to sense network conditions, determine available bandwidth, measure delay in the network and links, sense the busy state and user preferences. Many of these metrics can be measured by using MAC layer sensing as well as physical layer sensing. Signal conditions are sensed in the physical layer, while delay and QoS are determined in the MAC layer.

The heart of the system being developed at UWC is a content proxy server and converter. It not only holds intermediate content, but also reformats large web pages to mini and micro web pages and then match the capabilities of devices to data types and also converts data from one format to another (for example, one voice format to another, like .wav to .au etc).

The proxy server also holds the capabilities of devices, user preferences and the technical parameters of the networks it provides connectivity and services too. The experimental solution being developed is based on GPRS and WLAN.

1.4 SEAMLESS HANDOVER OF WLAN AND GPRS

Complimentary features of wireless LAN and GPRS provide efficient connectivity infrastructure that is not only widespread in some areas but also may have large bandwidth in some others like hot spots. While WLAN is limited in coverage, GPRS is limited in data rate. Therefore, there has to be a compromise if the handset used is required to access both networks.

While some may advocate the use of laptops to reduce most of these problems, cost comes in to play very quickly and dictates other solutions. For an organisation with thousands of field workers (such as utility, electricity and telephone services), the cost of providing laptops to all the field workers is prohibitive. Not all organisations are willing or able to do this.

We have studied alternative approaches that permit the use of cheaper equipment. In our study the following aspects of vertical handover solutions are identified and designed for:

- That the network be accessed through an intermediate proxy server;
- That large-scale web pages be transcoded or reformatted to match the capabilities of memory starved, display and speed limited handsets;
- That access of intermediate information be performed using proxy servers in which intermediate web pages are stored in object oriented formats;
- Progressive downloading and uploading of information from and to the Internet be used. This means for example, a large web page containing images, video, audio, graphics and text is stored to reflect its various contents. The user requests or accepts large bandwidth content only i) when it is determined that the content is required and ii) that the content can be displayed by the user terminal. If not only what can be displayed will be accepted. In most cases, this may boil down to text only - often the major requirement of field workers, to update work schedule or read text e-mail without attachments;
- That device capability information be made available to the proxy server which keeps them as a resource for matching capabilities and scaling of web pages;

Figure 1 partly illustrates this solution. In Figure 1, each of the two networks is accessed through a proxy server. For example, when the user of the PDA wants to access/retrieve information from the Internet, the proxy server is used to determine the type of network access and to transcode the web page to match the capabilities of both the handset and the type of network.

Connection from the back-end of the connection that resides between the proxy server and the source/Internet does not matter to us, but it will most likely be a Local Area Network (LAN) or a Wide Area Network (WAN), but it could also be a landline connection.

The intermission of the proxy server is focused on shortening download distance and time; therefore decreasing costs *(Figure 1) [1]*

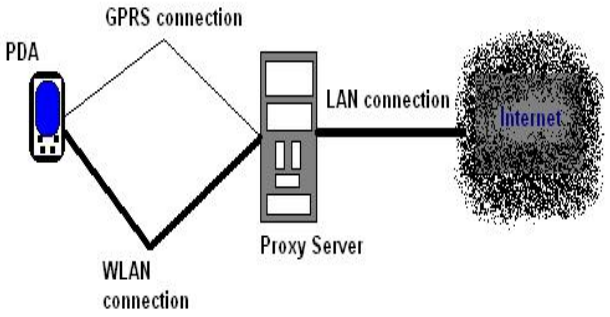

Figure 1: Vertical Handover in WLAN GSM Environment

The PDA will always be connected via GPRS whenever it is powered on, but will use WLAN as connection/download network medium only when the user is in a WLAN site. When no downloads or web site updates are made over the GPRS connection, there is also no charge for the connection itself. This means when WLAN is the network medium only WLAN usage will be charged. WLAN costs are lower than GPRS hence, WLAN is preferred above GPRS when the user steps into a WLAN site or when both are available.

The problem is when a charged link is active using GPRS while the PDA moves into a WLAN site. The network medium must change from GPRS to WLAN, but the link to the Internet must not be broken. Vertical handover should take place without disturbing the user or the download or upload at that time, this is what is meant by seamless handover.

The PDA will discover the presence of a WLAN radio frequency signal when the user enters a WLAN site. This is not too difficult to achieve. For example, the PDA measures

the signal strength of the WLAN signal. It has a built in program that measures the signal strength of the WLAN connection. Once the RF signal is captured and interpreted, it can be used to determine whether the interchange from GPRS to WLAN should be allowed. One approach for doing this uses fast Fourier transforms. Because the frequency spectrum of a WLAN signal and that of a GPRS base station are in different sections of the frequency spectrum, it becomes easy to discover the type of network being heard by the handset. Detailed measurement of the signal may be necessary. This is a precautionary measure to ensure quality of service (QoS). A message is then sent to the proxy server (an acknowledgement of the WLAN site and QoS with the WLAN site information) via GPRS so the proxy server can establish a WLAN connection between the PDA and itself. The message sent to the proxy server works on the same principle as TCP/IP works with the three-way handshake.

If the signal strength of the WLAN is sufficient, the PDA opens the account on the WLAN and opens the connection for data transfer between the PDA and the proxy server.

After the acknowledgements and authentication processes by both the PDA and the proxy server for the WLAN connection, the proxy server changes the route of the IP packets that followed the GPRS route before to the WLAN route. The PDA from this time on knows it has to listen and send information over the WLAN connection, instead of the GPRS connection.

Once efficient connection is established through the WLAN, the GPRS data transfer is halted and the WLAN data transfer is commenced without the user being disturbed or the download or upload being interrupted. It is all IP packets, so the change in network media will only be noticed in transfer speeds, since WLAN reaches much higher transfer speeds than GPRS.

This is simple, but the network changes, not just the network media. WLAN is a completely different network than GPRS and therefore it needs to provide a different address to the PDA, an IP address. This is also true for when the user moves from one segment to another segment in the WLAN environment. The IP address is changed hence the identity of the user changes with it. To the network it is all different users, because of the different IP addresses the PDA is assigned every time. MobileIP [2] that is standardized by the Internet Engineering Task Force (IETF) in 1992 offers a valuable solution to this problem.

MobileIP allows seamless roaming between IP subnetworks and media types. MobileIP allows transparency right above the IP layer, maintaining the operation of TCP and UDP.

When the signal strength of the WLAN drops below an acceptable QoS standard for the specific session, the PDA notifies the proxy server of the drop in signal strength and the proxy server changes the routing table once again to allow the IP packets to follow the GPRS route.

If the signal does not fade away completely, but remains at a level that is not optimal, but still usable, the option will exist for the user to manually choose to remain on WLAN. The automatic interchange on the networks will only then happen when the WLAN signal is on 0% or the percentage the user sets. The algorithm specified here applies if there are also UMTS (FDD or TDD) as well as DECT connections around.

1.5 THE ISSUES SURROUNDING HANDOVER OF WLAN AND GPRS

Most Wireless Internet Service Providers (WISPs) today are aiming towards integrating the WLAN infrastructure with cellular technologies such as GPRS and UMTS.

There are five key areas design engineers will have to consider in order to build a useful, desirable product when integrating GPRS and WLAN [3]. These are power consumption, performance, size and weight, time to market and cost.

From the WLAN point of view, the key issues are power consumption, cost, performance and security. These four issues directly relate to marketability of the technology and considering field force automation [6], it directly influences the usability and likeability of the product from the field worker's point of view.

1.5.1 Power consumption

The longer a connection stays open the more battery power the PDA consumes. Any downloads or uploads should be done as fast as possible to achieve maximum battery life span. The main power reservation lies with the user. The user needs to be trained in saving energy as well or at best, experience will train the user! WLAN is a huge power consuming technology, especially during periods of extended communication, and more power is consumed when the signal is very weak as the user moves further away from the nearest access point.

1.5.2 Security:

WLAN security is a major concern [4]. A simplified solution is to use a Virtual Private Network (VPN), and every service provider needs to take responsibility for the security they provide.

1.5.3 Costs

The second problem in using WLAN is billing. Embedding information on a smart card or the SIM card will allow users to "roam" as they like and still receive one bill. Through agreements with third party WLAN hot spot operators and mobile communication companies such as Vodacom and MTN in South Africa who have GPRS services companies may conveniently aggregate their communication bills into one. When this is achieved, handover of WLAN will notably reduce the workforce automation cost, since cellular cost will be reduced to a minimum.

1.5.4 Speeding up downloads and updates

By using a proxy server download speeds have been already enhanced. We can do more than this. To speed download up even more the proxy server is set up to capture high-bandwidth-intensive elements on web pages such as images, sound clips and movie clips. It then presents it to the user as

a scaled-down web page until such an element of the web page is requested for viewing. It will then change the format of these files to even reduce the download intensiveness, e.g. .wav to .au, etc.

The proxy server can also refresh web pages that the user requested previously periodically, so that when the user accesses it again, the web page is current, but faster downloaded since it resided on the proxy server (cached). Therefore there is no need to still access the Internet for retrieving the web page(s).

1.5.5 Scaling down web pages to an acceptable view

Web pages are normally designed for viewing on the desktop computer with a "large" screen and not for viewing on the small screens of Personal Digital Assistants (PDA). Web pages viewed on a PDA are not always very user friendly since users are required to view the web page in sections and then scroll horizontally as well as vertically to view the other sections. This is very uncomfortable. To solve this problem, web pages must be made smaller in both size and content. This means web pages must be analyzed and then converted to a form that can be displayed on the smaller screen of a PDA.

1.6 Conclusions

We have described an algorithm for vertical handover for field force access using WLAN and GPRS. Achieving handover between WLAN and GPRS is not necessarily a difficult task in itself, but doing the interchange of networks seamlessly, is a challenge. There is always a chance of breaking the connection or introducing a delay when the interchange occurs.

There are various types of web pages and of different sizes. While scaling of web pages may appear to be a simple exercise, however, there are large arrays of standard web page templates that web pages are built on. Most newspapers have similarly structured web pages, but personal pages differ from person to person. To select the important parts of the web pages and display only that on the PDA screen is not an easy task, but it can be simplified to an extent. Pictures can be withheld; media files can be withheld until requested by the user. We can insert tags that the user can select to view or hear the files that have been suppressed for download and layout of the web page purposes. These are some of the ideas that have formed the basis for the field force automation research at UWC.

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