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Definition of 4G scenarios, traffic and mobility characteristics for interoperating UMTS and W-LAN networks

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***Abstract*- in this paper we present system level scenarios and service related traffic analysis for 4 G networks, focusing on UMTS and W-LANs, the two strong candidates for the 4G co-existence scenarios. We first address the mobile and semi-mobile market growth in the following years for UMTS and W-LANs respectively. We then address the services that will be supported by the two radio networks along with their penetration rates. The characteristics of 4G terminals and their impact on services and user mobility are discussed. We also define hotspot areas (such as airports and city center) and examine two interoperability scenarios between UMTS and W-LAN radio networks. Traffic and mobility parameters used in the analysis are based on market forecasts and extrapolations from an existing GSM/GPRS network.**

I. Introduction

The huge growth of the number of mobile subscribers world-wide during the last decade, together with the increasing demand of higher transmission rates and flexible access to a variety of services, has motivated significant research, standardization procedures and development effort in the area of mobile communication systems. In Europe the transition from 2G to the 3G is already evolving and some IST projects e.g. FITNESS are already working on the 4G technology. ICCS/NTUA as a partner in FITNESS project is already developing a 4G system level simulator [1]. The main concept of 4G networks is to achieve a universal ubiquitous coverage across different radio technologies using a single terminal, and to provide the subscriber with a rich range of services with variable bandwidth and QoS requirements. Fourth generation communication systems will include networks consisting of different radio technologies; in our paper we will address interoperating UMTS and W-LANs in a scenario illustrated in Fig.1.

UMTS networks will be mainly deployed in outdoor walking/driving environments and targets current mobile market subscribers, while WLAN will be deployed in hotspots with main target audience being business travelers. This makes revenues of the two radio networks independent, and gives opportunities for network providers to increase their revenues income. While global economy is in recession and the telecommunication sector world wide is going through economic crises due to saturation of revenues from GSM networks, we try to shed light on factors and parameters that should be taken into account by a network provider when intending to install a 4G network

II. Mobile Market Growth And Revenues

In this chapter we present an overall study of factors and parameters that should be taken into account by a network provider when intending to install a 4G network.

A. Mobile Market Growth

Mobile voice subscribers have grown enormously in the last decade; in the year 2000 there were more than 630 million mobile phone users, and this number is expected to grow to 1 billion by the end of 2002 [2]. In line with the increase in 2G mobile subscribers a similar growth is expected in data subscribers. As depicted in Fig.2, almost 77 million users are expected to use data services by the year 2005. In particular the tremendous growth of the Internet is a key driving force in this increase.

According to a Phillips Group Research Study, “3G Wireless Market Expectations”, wireless third-generation services are expected to grow to a $63 billion annual market in 2005, indicating that the market potential for 3G is vast. A major shift in the operator's revenue distribution will occur with the operation of UMTS services. The UMTS terminal is a service platform capable of multiple radio access modes and compliant with open standards and operating systems to enable mobile Internet and mobile multimedia messaging services. The number of offered services will multiply as multimedia terminals enable new services, new entrants compete for subscribers and as continuous connection to the Internet give access to vast amounts of digitized information [3].

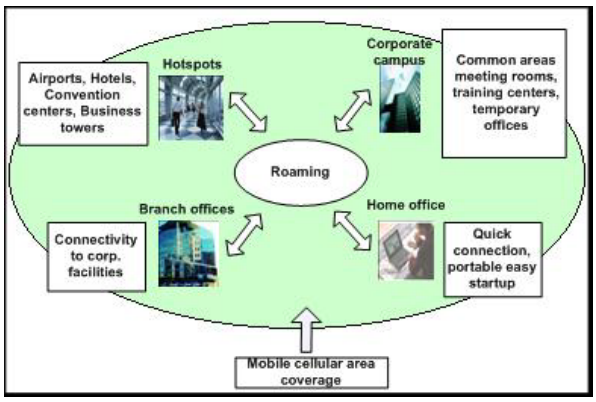

Figure 1 : 4G deployment of UMTS and W-LANs

B. The Semi-mobile Market

Traditionally, computing was an essentially deskbound activity while mobile communications were characterized by voice or basic data messaging. But this fact has changed due to the growth of the Internet coupled with the increasing number of wireless computing devices, provoking the growth of the semi-mobile market. It has to be noted that in 1999, 70% of business air travelers carried a laptop and that

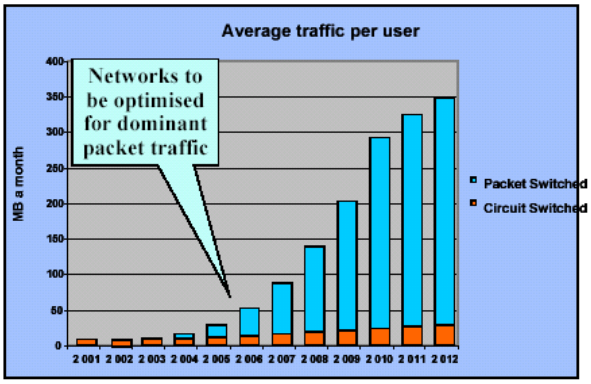

Figure 2 : Mobile Data Market towards Mass Market (Source: Merryl Lynch, UMTS MAG)

on average mobile workers went on 15 trips per year. Forecasts for the years 1999-2003 predict 250 millions of Laptops/PDA users, 800 millions of cellular phones users and 400 millions of Internet users [4, 5].

In a survey by Wi-Fi [6] it is concluded that companies consider the elimination of cabling/ wiring and its associated costs to be the primary benefit of wireless networking to the organization. A second widely cited benefit is increased mobility/ information access for the staff, Fig. 3:

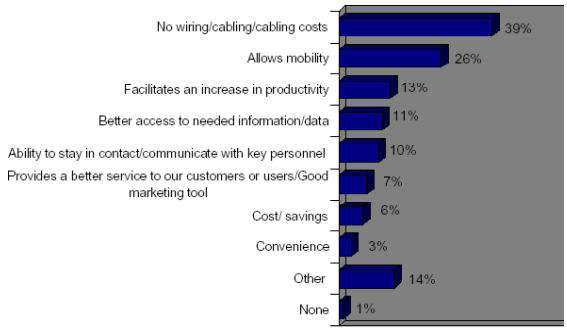

Figure 3 : Primary Benefits of Wireless Networking to Company

The main factors that will play a key roll in the semi mobile market growth are the following [7]:

- The globalization of business
- Falling cost of air travel
- The increased availability of affordable portable computers
- The growing use of the Internet as the core platform for corporate communications and information storage and retrieval
- An increased reliance on e-mail as an essential communications tool
- Ubiquity of cellular services
- Demand for broadband access
- Falling productivity levels due to increased 'gray time' spent traveling between locations
- Growth of flexible working practices
- Growth of e-commerce services

These factors provoke the need to provide the different categories of mobile users quick access to the corporate networks of their interest, in areas (hotspots) that they often visit, of course while satisfying data rates and QoS for the different kind of services they demand. Locations where mobile and semi-mobile markets are expected to grow are illustrated in Fig4.

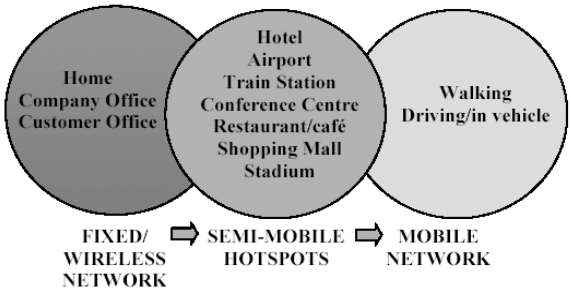

Figure 4 : Semi-mobile and mobile deployments

C. The growth in specific hotspots

In this section we focus on the semi-mobile market growth in two major hotspots: airports and city centre (represented by growth in Cafés and Restaurants).

C1. Airports

The potential market for W-LAN access in airports is huge. The reason is that airports have a massive throughput of passengers, the majority of whom find themselves with some time to kill as they wait to board their flight, and a significant proportion of these passengers are business travelers. An estimated 450 million passengers flew internationally during the year 2000, while the major airlines claim that around 20% of passengers are business travelers. Obviously not all of these passengers would want to use W-LAN services, but it still represents a potentially massive revenue stream. The provisional growth of W-LAN hotspots in airports in the years 2000-2006 and their geographical distribution are shown in Table 1 and Fig.5.

	2000	2001	2002	2003	2004	2005	2006
US	100	150	220	300	375	445	510
Europe	30	50	75	105	160	230	210
Asia	30	45	65	95	125	160	200
Total	160	245	360	500	660	835	1020

Table 1: Growth of WLAN Hotspots in Airports 2000-2006

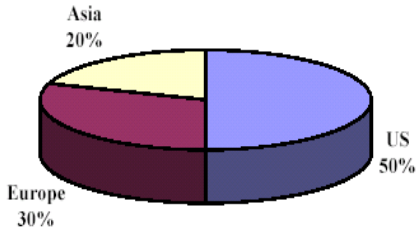

Figure 5: Geographical Growth of W-LAN Hotspots in Airports 2006

C2. City centre (Cafés and Restaurants)

In an interview with road warriors conducted by Baker Wild Consulting Services BWCS the majority (64%) of mobile PC users visited a café or a major restaurant between three and ten times a month. Away from the business traveler market, many operators are targeting customers of coffee shops, restaurants and cafés, especially in the business districts of major cities where laptop use is widespread. In addition to business users taking breaks from the office, cafés also attract non-business users such as tourists wishing to check web-based e-mail accounts or customers who purely wish to surf the internet for pleasure. For these consumers some establishments provide their own computers ready-fitted with interface cards, which are available for hire.

The number of cafés and restaurants covered by W-LANs is expected to rise from 1000 locations to 66,000 in the year 2006, while this number represents a small fraction of cafés and restaurants worldwide. It is believed that W-LAN establishment in these locations will be restricted mainly to the business districts of major urban areas. It is also expected that cafés with larger turnover of clientele and less formal atmosphere, will be more open to W-LAN use than restaurants (Table 2 and Fig.6).

	2000	2001	2002	2003	2004	2005	2006
US	900	2700	7000	14000	22000	30000	40000
Europe	60	180	600	2700	6000	11000	18000
Asia	40	120	400	1300	3000	5000	8000
Total	1000	3000	8000	18000	31000	46000	66000

Table 2: Growth of W-LAN Hotspots in Cafés

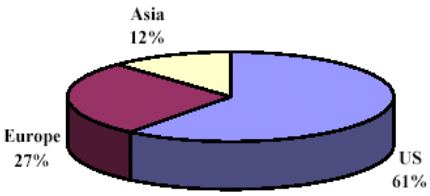

Figure 6: Geographical Distribution of WLAN Hotspots in Cafés 2000

D. Supported services

The various services supported by UMTS and WLAN are categorized as follows [8,9]:

- Location-based Services: An important feature of many applications that operators and vendors are exploring is location-based service delivery. These services can include location-aware information, games and community services. The main driver for mobile services is making the data service relevant to the user while they are mobile. A lot of the content delivery can be based on geographic location, i.e. advertising. Operators can earn advertising revenue because they know the user's location, personal profile information or segmented channel. Push advertisements can be subscription-based so that the mobile user can indicate to the operator the information he is interested in – i.e. his personal profile. The operator can thus send location-relevant messages based on user-search or advertising. If the user agrees to a transaction, the operator can then be entitled to a commission of the value, say 5 or 10%,
- Mobile Transactions: Most applications of mobile transactions include mobile finance (banking, brokering, payment, cash), mobile shopping (retailing, ticketing, auctions, reservations, postcards), mobile advertising, mobile entertainment (gaming, music, video, betting), telematics and mobile user care. Mobile commerce is any transaction with a monetary value that is conducted over a mobile network so that mobile terminals become 'electronic wallets'. The user can, for example, buy goods and have the value debited from his electronic wallet as a micro payment transaction. In the case of a larger purchase, the mobile terminal can be used to initiate a credit card transaction with a pin-code authorization, as the mobile operator already has the credit card details. Security features built into the terminals and network will make this a highly secure purchasing method,
- Mobile Information: News, financial, sports and traffic information are types of push services that users can subscribe to, based on need and interest. The value of these services is increased if the user can be kept informed and up to date. For instance, he can receive information about the prices of shares and latest news about companies he has intentions of investing in. Pull services, like directory services, will be enhanced with user requests based on his location. For example, a traveler can request information via his terminal for the nearest petrol station when he is driving in an unfamiliar district or country. The directory can then send him the addresses and location maps of the two nearest stations. Personalized messages can be sent to the user's terminal rather than distributed via mass communications. For instance, the user who is looking to buy an apartment can get updated information from the operator on available apartments in the district of his choice. He can then make an offer to the agent or landlord, or simply discard, depending on his interest. This is a more direct way of getting relevant and updated information than through the newspapers or the Internet, which is dependent on the user's active scanning and selection,
- Wireless Advertising: The implications of 3G's capacity to enable higher bandwidth applications are that the distribution channels to consumers will be changed in favor of the wireless. Entertainment, news information, retail transactions will find a new way of reaching their target audience, likely more effectively than traditional methods (channel marketing, printed material, retail distribution and others). Similarly, advertising targeted at businesses or consumers can be delivered directly to their personal devices, if the user permits. Advertising can also come as part of transmitted content. For example, micro movies, running for 5 minutes and custom-designed for the small screen mobile environment, can be wholly financed by on-line advertising sent together with the programming. So the 5-minute movie clip will be interrupted by a 1-minute advertisement. Another way of advertising is online auctioning. It acts like a classified ad as a viable channel for selling concert tickets, used household and stock clearances items,
- Business Solutions: Corporate-type services offer business users up-to-the-minute information, data transfer and secure connections to the Internet and corporate LAN. The most commonly used services will be email, organizer, web and WAP browsing, video conferencing and access to customer relationship management to satisfy the communications and information needs of the knowledge workers. Corporations are willing to pay a premium while their workers are on the go,
- Person-to-Person Communications: The need to communicate with other people is met with one-to-one and one-to-many sharing and talking, multimedia

messaging and mobile emailing. Person-to-person applications, such as mobile chat, create an affinity to chat groups in young people, much in the same manner as SMS has done. There will be easy market adoption for person-to-person communication as they are familiar service concepts to users,

- Mobile Entertainment: Mobile entertainment is more of a consumer application. It may include games, music, video and betting. Single-player or interactive mobile games, music downloads, video streaming of short sports highlights and horse race betting are just some examples of possible leisure time.

In Table 8 (Appendix 1) we address the main common services supported by the two networks data rates and their QoS requirements [9]. For these services two types of user terminals could be identified in a medium-term time frame [10]:

- A dual-mode mobile terminal that has small dimensions (like an existing 2G mobile terminal or a PDA), limited graphical display and limited storage space.
- A terminal that has separated modules (laptop-like), bigger dimensions, portable but not so easily used while the user moves (except for the case where the user is inside a vehicle).

A small-sized 3G terminal could be perceived in a medium-term time frame as the standard device for speech, enabling the user also to browse the Web. Nevertheless, for such a device or a PDA enabled with both interfaces, ftp services (where usually large files are considered) are limited by the storage space. On the other hand, these devices offer adequate mobility to the user. Laptops enabled with both interfaces, will be mostly used for heavy applications while they offer more limited mobility while in use (except for vehicles). Finally, the assumed speed of the user can be connected to certain services and reciprocally, services could be accessible on a certain radio access technology, depending on the speed of the user. Typically, a UMTS user could be more mobile than a W-LAN one, depending on the initiated service.

III. Definition Of Hotspots And Interoperability Scenarios

A. Hotspot Definition

Hotspots can be defined as locations with the following common characteristics:

1. High volume of visitor traffic
2. Visitors spend time waiting or lounging
3. High proportion of visitors carries laptops
4. Visitors need access to internet-based information
5. Broadband connection to the premises is in place or readily available

Note that airports, hotels, cafés and conference centers are considered the most significant hotspots for W-LAN service providers. The reason is that in addition to fulfilling all of the five criteria above, they are frequented by business people who use W-LANs in the office and are therefore equipped with portable computers with either integrated W-LAN modems or plug-in PC cards.

B. Interoperability scenarios

We propose two interoperability scenarios between UMTS and W-LANs; the identification of these scenarios along with the extrapolation of traffic characteristics mobility, and user behavior was based on data collected from the Athens valley GSM/GPRS network provided by COSMOTE (a Greek network provider) [1]. Three traffic zones can be distinguished in the Athens valley:

- Zone 1: 5-70 Erlangs/Km^2 , Mean Cell Size : 0.59 Km^2
- Zone 2: 70-100 Erlangs/Km^2, Mean Cell Size: 0.18 Km^2
- Zone 3: >100 Erlangs/Km^2 , Mean Cell Size : 0.092 Km^2

These three traffic zones correspond to urban, suburban, and dense urban areas respectively.
The two interoperability scenarios that we identify are:

- The first scenario depicted in Fig.7 represents the coexistence of the UMTS macro deployment consisting of hexagonal cells belonging to three different traffic zones with an indoor W-LAN Hotspot (Athens Airport) covered by Access Points.
- The second scenario depicted in Fig.8 represents the coexistence of the UMTS macro deployment consisting of hexagonal cells belonging to three different traffic zones with an outdoor W-LAN Hotspot (Athens City centre) covered by Access Points.

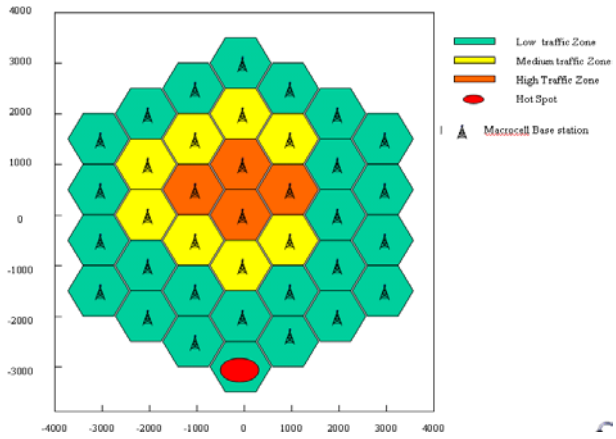

Figure 7: UMTS & W-LAN (airport) Join Deployment Scenario

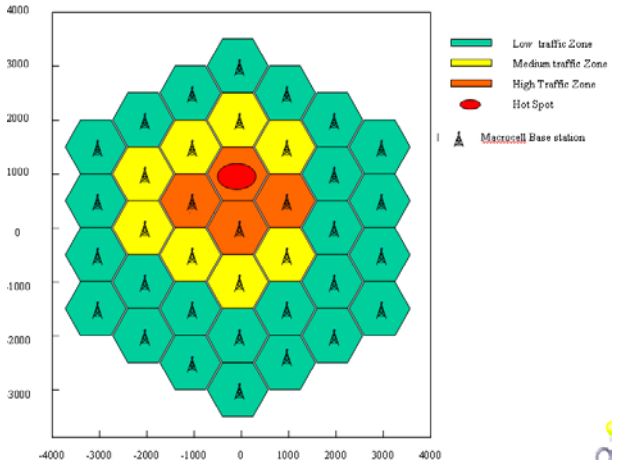

Figure 8: UMTS & W-LAN (city centre) Join Deployment Scenario

C. Traffic Parameters

C1. UMTS

The traffic data for the three traffic zones are normalized to the typical UMTS Macro cell size as defined by the 3GPP standards. The mean busy hour users for each cell zone for both real and typical 3GPP macro UMTS cell sizes are provided in Table 3. Also mean arrival rate for voice users (per cell) in Busy Hour is given. Call duration found from the original data is significantly different from the value reported in the standards, i.e. 120 seconds (Table 3).

Zone / Traffic Parameter	Low Traffic Zone	Medium Traffic Zone	High Traffic Zone
Mean Busy Hour Users (Real Cell Size)	1383	1682	1673
Mean Busy Hour Users (3GPP Macro UMTS Cell Size)	2029	8089	15740
Busy Hour Arrival Rate (users/sec)	0,56	2,25	4,37
Call Duration (sec)	45	49	51

Table 3: Voice Traffic Parameters per Cell

It is well known that GPRS networks around Europe have not reached yet their expected capacity and thus, meaningful results for data services cannot be extracted. Hence, here the attempt is to combine the available voice data with other reports and market analysis results. According to the UMTS Forum future market prediction [10], by the year 2005 penetration between voice and data services will be 60% and 40% respectively. Moreover, it is reasonable to assume that in a UMTS network, the operator will maintain the voice traffic expecting some extra traffic from data services. Thus, the voice data can be used, assuming that they correspond to 60% of the UMTS users. The rest 40% corresponds to data users. That way, busy hour users per cell can be estimated for data services, using the following equation:

Total busy hour users = voice users +data users
Total busy hour users = data users/0.4
Data users = voice users/1.5

Traffic parameters for data users are summarized in Table 4:

	Low Traffic Zone	Medium Traffic Zone	High Traffic Zone
Mean Busy Hour Data Users/3GPP Macro UMTS Cell Size)	1353	5393	10493
Busy Hour Arrival Rate (users/sec)	0,38	1,5	2,91

Table 4: Traffic Parameters for Data Users per Cell

Busy hour arrival rate of data users can be seen as an average over the various services. Moreover users will have either a laptop or a PDA with a penetration rate of 46% and 54% respectively according to the market analysis in [1].

C2. W-LAN

We analyze traffic parameters for the two hotspots of interest; the airport and a city center

Airport: It is not envisaged that W-LANs will support voice services and so no voice users will be considered in this scenario. Nevertheless, the traffic parameters provided by COSMOTE [1] for voice can be used to compute the provisioned number of data users of the airport, based on the 60% - 40% voice and data users scenario. According to the available traffic data, the total number of busy hour voice users, served by the 10 indoor cells of the Athens airport, is 3057. Hence, we can conclude that the total provisioned number of busy hour data users in Athens airport will be 2038. These mean busy hour data users will be uniformly distributed in the W-LAN airport deployment. In this case, mean busy hour data users per AP will be 127 and the mean arrival rate of busy hour data users (per cell) will be 0,035 users/sec**.** The above traffic parameters are summarized in Table 5. Finally, users will also have either a laptop or a PDA with a penetration rate of 46% and 54% respectively.

AIRPORT HOTSPOT		
Total BH users	**BH Users/Cell**	**BH User Arrival Rate/Cell (users/sec)**
2038	127	0,035

Table 5: Traffic Parameters for the Airport Hotspot

City Center: The number of users involved in voice calls (GSM network) at the busy hour in such an area covered by 5 cells is approximately 7000 users. Based on the 60% - 40% penetration scenario between voice and data users, W-LAN users are estimated to 4660 in Busy Hour. Thus, 274 users will be served by each AP with a mean arrival rate of 0,076 users/sec. The above traffic parameters are summarized in Table 6.

CITY CENTER HOTSPOT		
Total BH Users	**BH Users/Cell**	**BH User Arrival Rate/Cell (users/sec)**
4660	274	0,076

Table 6: Traffic Parameters in City Center Hotspot

D. Mobility parameters

D1. UMTS

Mobility data from [1] provide the mean busy hour outgoing handover attempts per cell for the three traffic zones that characterize Athens valley. The data concerns voice users who are expected to have a quite different mobility pattern from data users. Moreover, the cell sizes of the three zones are different from the considered typical 3GPP UMTS macro cell size to be implemented in our scenario, thus normalizing these numbers to our cell size would result to a misleading number of outgoing handover attempts. Hence, the data cannot be used directly but can provide meaningful information as we can extract conclusions about users' mobility behavior in the three zones. Handover statistics per cell for the Athens valley are shown in Table 7.

Zone	**Low Traffic**	**Medium Traffic**	**High Traffic**
Mean Busy Hour outgoing Handover Attempt	670	760	680
Percentage of Busy Hour users attempting Handover	48%	45%	40%

Table 7: Handover Parameters in the Three Traffic Zones

Percentages in Table 7 reflect users' mobility behavior and speed for each traffic zone. In the low traffic zone, it appears that although the cell size is 6.5 times larger than the high traffic zone, the percentage of users attempting handover reaches 48%, meaning that the users of this zone are characterized as vehicular while in high traffic zone, users' speed can be characterized as pedestrian.

D2. W-LANs

Airport: Mobility data for the airport area are provided for voice users and for a different network deployment. Thus, the available data cannot be used directly in our scenario but can provide valuable information. Interesting statistics are related to the behavior of indoor voice users where only 9,8% attempt an Indoor-to-Indoor handover and only 5% attempt an Indoor-to-Outdoor handover where interoperability issues appear. Approximately, the same number of Indoor-to-Outdoor and Outdoor-to-Indoor handovers have been observed at the Athens airport.

City Centre: Mobility considerations undertake the same restrictions mentioned in section D2. Interesting statistics are related to the behavior of a Hotspot user, where 33% of the users attempt a handover. Moreover, 40,45% of the handovers occurs within the Hotspot and the rest 59,55% is directed outside the hotspot. Hence, only 13,3% of the users attempt a handover within the Hotspot and 19,7% of the users are leaving the Hotspot where interoperability issues appear. Approximately, the same number of users enters and leaves the Hotspot.

IV. Conclusions

From the study in the previous sections we can conclude the following:

- A significant outcome from our study shows high potential growth of the mobile and semi-mobile markets in the following years. This gives positive signals to network providers that, after the recovery of the global economy (expected to start in the second half of year 2003), they are to expect a high increase in demand by service providers to launch UMTS and WLAN networks.
- Since UMTS and WLAN networks differ in location deployment, and target audience, services offered are expected to be complementary and revenues are believed to be independent
- We addressed the common characteristics that define a hotspot and identified the airport and a city center as the most promising WLAN hotspot deployments.
- Finally we identified two of the most likely interoperating scenarios between UMTS and WLAN, and concluded that traffic parameters extracted from a real network may differ from the defined parameters by the 3GPP standards.

V. References

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VI. APPENDIX 1

Service	Terminal	Air Interface	U/D	Tx Rate	QoS
Conversational Voice	Cellular	UMTS	Uplink	12.2 Kbit/s	<3% FER <400 ms one way delay
			Downlink	12.2 Kbit/s	
Videophone	Cellular PDA	UMTS	Uplink	384 Kbit/s	<1% FER <400 ms one way delay
			Downlink	384 Kbit/s	
		WLAN	Uplink	2 Mbit/s	
			Downlink	6 Mbit/s	
Streaming video	Cellular PDA Laptop	UMTS	Uplink		<1% FER <10 msec delay
			Downlink	384Kbit/s	
		WLAN	Uplink		
			Downlink	1,5 Mbit/s	
Streaming Audio	Cellular PDA Laptop	UMTS	Uplink		<1% FER <10 msec delay
			Downlink	144 Kbit/s	
		WLAN	Uplink		
			Downlink	384Kbit/s	
Web-Browsing	Cellular PDA Laptop	UMTS	Uplink	12.2 Kbit/s	0% FER <4sec delay per page
			Downlink	384 Kbit/s	
		WLAN	Uplink	32 Kbit/s	
			Downlink	1 Mbit/s	
E-mail	Cellular PDA Laptop	UMTS	Uplink	12.2 Kbit/s	0% FER <4sec delay
			Downlink	12.2 Kbit/s	
		WLAN	Uplink	64 Kbit/s	
			Downlink	64 Kbit/s	
File Transfer	Laptop	UMTS	Uplink	384 Kbit/s	0% FER <10 msec delay
			Downlink	384 Kbit/s	
		WLAN	Uplink	2,5 Mbit/s	
			Downlink	2,5 Mbit/s	

Table 8: Common services supported by UMTS and WLAN