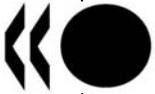


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COMMITTEE FOR INFORMATION, COMPUTER AND COMMUNICATIONS POLICY**

Working Party on Telecommunication and Information Services Policies

DEVELOPMENT OF VOICE OVER WIFI BY INTEGRATING MOBILE NETWORKS

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FOREWORD

The TISP Working Party discussed this report at its meeting on 29-30 November, 2004 and recommended its declassification by the ICCP Committee, which agreed to this at its meeting in March 2005. The report was prepared by Mr. Sung-il Ahn, of the OECD Secretariat. It is published under the responsibility of the Secretary-General.

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DEVELOPMENT OF VOICE OVER WIFI¹ BY INTEGRATING MOBILE NETWORKS

Main points

Rapid technological changes are facilitating the convergence between WiFi (short for “Wireless Fidelity”) and mobile networks, in particular with 3G networks and resulting in the development of Voice over WiFi (VoWiFi) services. While VoWiFi, also known as Voice over Wireless LAN (VoWLAN), has already been deployed in a limited number of areas, the VoWiFi market and roaming services between WiFi and 3G are expected to grow significantly in the near future. A number of companies have already started to develop network equipment and handsets which enable the provision of smooth roaming between WiFi and 3G, not only for data but also for voice. The development of dual-mode cellular/VoWiFi handsets, some of which are expected to come on the market at the end of 2004, will help stimulate this market. In addition, several solutions which provide seamless roaming across the different kinds of mobile networks and VoWiFi have recently been introduced by network vendors.

However, there are a number of technical and operational issues which may still need to be addressed before WiFi/mobile convergence becomes more widespread and emerges as a viable and sustainable service. Table 1 briefly outlines these issues as well as policy implications that are addressed in the latter part of this paper. Policy makers need to monitor the market, identify new benefits and opportunities, and examine upcoming regulatory issues so as to realise the full potential of emerging VoWiFi/mobile convergence. At this early stage, however, it is difficult to clearly flag regulatory issues since a number of potential problem areas may well be solved by the market and through co-operative arrangements in the industry including self-regulatory initiatives.

¹ Wi-Fi (short for "wireless fidelity") is a term for certain types of wireless local area network (WLAN) that use specifications in the 802.11 family. The term Wi-Fi was created by an organization called the Wi-Fi Alliance, which oversees tests that certify product interoperability. A product that passes the alliance tests is given the label "Wi-Fi certified" (a registered trademark). Originally, Wi-Fi certification was applicable only to products using the 802.11b standard. Today, Wi-Fi can apply to products that use any 802.11 standard.

Table 1. Issues related with VoWiFi/mobile convergence

Category	Issues or implications
Technical issues	Quality of service
	Adequate bandwidth
	Security and privacy
	Interoperability
	Interferences and complexity
Operational issues	Seamless roaming and single dual-mode handset
	Attractive applications
	Billing for VoWiFi/mobile roaming
	Other issues such as limited battery power, high cost of chipset
Policy implications	For fixed-mobile convergence
	For quality of service
	For security, data protection, access to emergency calls and roaming
	For spectrum

1. Introduction

The aim of this paper is to examine the emerging convergence between WiFi (wireless fidelity) technologies and services and cellular mobile technologies and services. This convergence is viewed as an emerging market which will have an impact on telecommunication service providers as well as on policy frameworks. The paper begins with an overview of WiFi technology and markets, including a brief introduction to WiFi, hotspots, WiMax¹, VoIP over WiFi technology, and drivers and dynamics that are making voice over WiFi become an integral and essential element of converged network architecture. This is followed by a description of the development of the voice over WiFi market, technology, standardisation and WiFi/Mobile convergence, in which carrier strategies and technical issues will be explored. Finally, this paper will examine the impact of WiFi/Mobile convergence on telecommunications service providers, and then try to draw some policy implications. This paper complements previous work undertaken by the OECD on WLAN², 3G³, VoIP⁴ and NGN⁵ which deal with issues and technologies closely related to this paper.

WiFi hotspots, which are specific geographic locations providing public access to wireless broadband network services through wireless local area networks, have grown rapidly in recent years. Gartner estimated in February 2004 that the number of hotspot users will total 20 million in 2004, up from 9.3 million in 2003.⁶ In the US, the number of WiFi hotspots is forecasted to grow from 3 020 in 2002 to 12 080 in 2003 and more than 72 000 in 2007, according to the Yankee Group. Access to WiFi is expected to expand as also most laptops and hand-held computers are now delivered with WiFi cards.⁷ According to the studies by Forrester Research and Strategy Analytics, the number of laptops with built-in WiFi will grow from 24% in 2003 to at least 80%, or 141 million, by 2008.⁸ The growth of WiFi access points and the fact that these have been put in place at significantly lower costs than 3G network base stations has led to an industry debate about the impact of WLAN on predicted revenues for 3G service providers.

Although WiFi was originally developed for data, the demand for voice over WiFi, or VoWiFi has been growing especially with the proliferation of WiFi from the business sector. The widespread deployment and technical development of VoIP has also facilitated the provision of VoWiFi. There have been a number of announcements regarding VoWiFi deployment in environments such as hospitals, warehousing centres, retail businesses and college campuses. It has been argued by some that VoWiFi may provide a viable, low cost alternative to mobile networks, in particular 3G. Furthermore, it has been claimed that WiFi will provide a new viable medium of convergence for seamless multi-media services through interoperability with 3G networks.

In addition to efforts by industry to provide voice over WiFi, several companies and network operators have recently started to work on seamless roaming between WiFi and mobile networks. To deploy WiFi/mobile roaming for data and also for voice, dual-mode handsets and gateways will soon be introduced in the market.

The convergence between WiFi and mobile networks is expected to bring about new converged and seamless multi-media applications such as video, audio, data and voice to customers at a lower cost and at high speeds. The convergence may create new business models and opportunities as well as challenges for both wireline network operators which have deployed WiFi and mobile network operators. However, these developments are still at an early stage and there are a number of technical and operational issues which need to be resolved in order for WiFi/mobile convergence to become a seamless and viable means of communication.

2. Overview of voice over WiFi

What is a VoWiFi?

VoWiFi is a term used for technologies or services which provide voice over WiFi. The concept, and service, was introduced several years ago, but only in the last several years has the service started to become attractive as a result of the increasing possibility of roaming between WiFi and mobile networks, especially with 3G.

WiFi refers to any wireless LAN products or services that are based on the IEEE 802.11 WLAN standard with theoretical data rates ranging from 11M to 54 Mbit/sec. A hotspot is a wireless LAN node that provides Internet connection and virtual private network (VPN) access from a given location. Public places such as airports, stations, hotels and coffee shops that provide hotspot services have been increasing. Hotspot services in some areas are free, but many service providers charge an hourly, daily or monthly rate for access.

With combined VoWiFi/cellular phone and seamless roaming between those two networks, subscribers could use voice over a WiFi network, where available, and cellular connections where WiFi is missing or outside of a WiFi area. Combining VoIP with WiFi has a great potential to reduce the cost of voice services, in particular for roaming and for access to broadband services, while increasing the convenience to users.

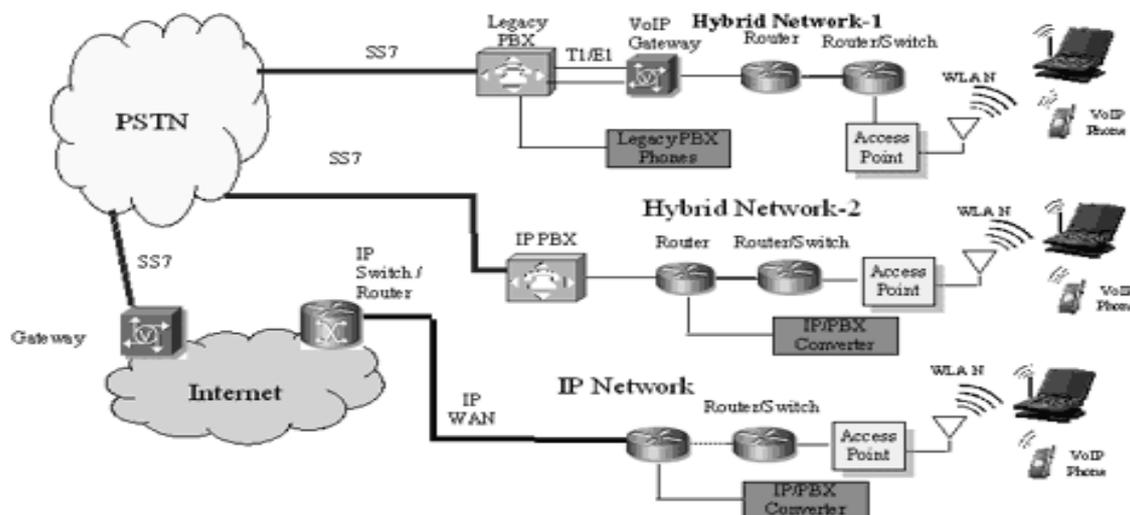
WiFi is different from WiMAX, which has recently emerged as a new technology. WiMAX, also known as 802.16, is a standards-based wireless technology that provides wireless broadband connections over long distances and hotspot/mobile backhaul. WiMAX is also a wireless industry coalition, formed in April 2001, organised to advance IEEE 802.16 standards for broadband wireless access networks. The original 802.16 standard, published in December 2001, specified fixed point-to-multipoint broadband wireless systems operating in the 10-66 GHz licensed spectrum. An amendment, 802.16a, approved in January 2003, specified non-line-of-sight extensions in the 2-11 GHz spectrum and delivers up to 70 Mbps

at distances up to 48 km, versus WiFi's radius in the region of 30 to 90 meters. While 802.16a is for fixed wireless connections, a further amendment, 802.16e, is expected to connect mobile devices.⁹ The WiMAX Forum (the Worldwide Interoperability for Microwave Access Forum) is a non profit corporation to promote the adoption of IEEE 802.16 compliant equipment by operators of broadband wireless access systems.

WiMAX should be viewed as a complementary technology to WiFi, and can be distinguished from WiFi in that WiMAX provides wireless broadband connections in metropolitan area networks (MANs) while WiFi is mainly aimed at local area networks (LAN). For comparison, IEEE 802.20 was also proposed for Wide Area Networks (WANs). To some extent WiMAX can be viewed as the next step beyond WiFi because it is optimized for broadband operation, for both fixed and mobile in metropolitan area networks. It is also regarded as a last-mile broadband wireless access which can help the deployment of hotspots and broadband connections in areas not served by cable or DSL. It is expected that the first phase of WiMAX, providing fixed wireless connections, will start in the first half of 2005. WiMAX will be incorporated into mobile computers and PDAs to support roaming between WiMAX service areas in 2006.¹⁰

In the context of VoWiFi and VoWiFi/mobile roaming many of the current deployments of VoWiFi involve integration with enterprise PBXs. One method of integrating with a traditional PBX is to use a VoWiFi gateway. The calls are routed from the VoWiFi phone to a VoWiFi gateway via the WiFi Access Point, and the VoWiFi gateway transmits calls to the existing PBX. Integration with the PBX allows calls to be placed to and received from the PSTN, and also supports PBX features such as call forwarding, messaging, and conference calling. Another way to use VoWiFi is to use softphones on mobile computers or PDAs, which route calls entirely over the Internet in WiFi areas such as hotspots. Figure 1 shows the network architecture of VoWiFi.

Figure 1. Network Architecture of VoWiFi



Source: Texas Instruments¹¹

The gateway connects to the mobile switching centre for cellular calls, and connects to the data network for WiFi calls. The gateway manages subscriber access and handoff. As the subscriber moves within range of a wireless access point, the gateway authorises the subscriber's access and all network services — both voice and data — are delivered over the WiFi. When the subscriber moves outside of the WiFi coverage area, the gateway seamlessly switches control over to another WiFi network or the mobile

network.¹² However, deploying a VoWiFi/mobile roaming solution requires dual-mode handsets that support both VoWiFi as well as mobile. Figure 2 shows the network configuration of WLAN and mobile networks roaming.

Drivers of VoWiFi Development and VoWiFi/mobile Convergence

WiFi and VoIP are being widely deployed in enterprises. WiFi is easy and flexible to deploy, and is claimed to be more reliable in terms of coverage while costing less than traditional cellular services. It is also expected that using VoWiFi new converged applications can be developed for mobile workers with new capabilities such as geographic location information and instant messaging. Ongoing technical developments, such as dual mode handsets, Session Initiation Protocol (SIP) and softphones are helping in stimulating the further deployment of VoWiFi technology.

Customer demands are also changing with the widespread use of broadband and mobile services. A growing number of users prefer to use their mobile phones, PDAs or even mobile computers in the home, office or outside at reasonable prices, which provide the convenience that they can be reached any time and anywhere with a single number if they choose. Subscribers who become accustomed to real-time video together with voice and other rich content over the WiFi at a lower cost are likely to use it outside of WiFi. In particular, 3G and WiFi seamless roaming will attract business users who want to transmit and access information and use applications continuously while travelling outside their office or WiFi area. As workers become increasingly mobile, integrated WiFi/mobile networks will be very instrumental for companies.

In this early stage of the VoWiFi market, the handsets and VoWiFi services have been focused on enterprise or corporate users and are expected to do so in the next few years. The main reason is because VoWiFi is related to the increasing deployment of WiFi and VoIP in corporate environments. The Radicati Group, a research company, estimates that the number of corporate phone lines worldwide using VoIP will jump from 4% in 2004 to 44% in 2008.¹³ Furthermore, for the companies that have already invested in VoWiFi, VoWiFi/mobile convergence is appealing for efficient IT management.

Why would mobile service providers want to provide VoWiFi/mobile roaming service for their subscribers? At first glance, it would seem that mobile operators would be disadvantaged by providing roaming services with WiFi because they may lose revenue generated by traditional mobile roaming services. Generally, WiFi services are provided at a lower price than mobile services or even free, which has induced mobile service providers, especially 3G service providers, to consider WiFi and VoWiFi services to be competitive with their mobile services.

However, with the recent proliferation of WiFi in enterprises and in the number of hotspots in densely populated areas in a relatively short period of time, several mobile service providers have started to regard VoWiFi and VoWiFi/mobile roaming as a way of reducing prices for their customers and consider WiFi as a means to enhance competition and differentiate their service from that of competitors. WiFi has also provided mobile operators with a tool to draw more customers from wireline telecommunication service providers.

Impact of WiFi and VoWiFi on 3G Development

VoWiFi, or VoIP over WiFi, allows users to make voice calls and access video and data at a low price. The development of this service will have an impact on 3G services and the way they are structured and priced. While 3G has the advantage of ubiquitous access, the data transfer speed is about a half megabit per second slower than WiFi's top speed. Furthermore, an increasing number of service providers have been planning to establish WiFi with ubiquitous coverage in urban areas. These developments have

stirred a debate on the impact of VoWiFi and it is evident that the dynamics of convergence between these two networks in the next several years will be watched with great interest.

Some analysts argue that WiFi or VoWiFi will threaten the revenue base of 3G. For example, a US report has argued that the success of hotspots in that country will result in a delay by mobile network operators in rolling-out 3G services.¹⁴ The fact that VoWiFi services offer lower start-up costs while offering a better prospect of an immediate return will certainly be a challenge to 3G providers. Another report, published in May 2003, predicted that WiFi would become the dominant mobile wireless infrastructure within the next five years at 3G's expense.¹⁵ Other reports have argued that WiFi is more efficient in most cases than 3G.¹⁶ For example, WiFi offers better Internet access in stations, airports, hotels and restaurants, which are the main target for 3G.

On the other hand, another recent report from Analysys warns that radical strategies on its deployment or pricing could damage the profitability of 3G at an early stage of its development.¹⁷ For example, some mobile operators are changing their pricing from time-based to volume-based and unlimited-usage tariffs, mimicking the WiFi models. This may jeopardize revenue, and hence profitability. Thus, the report argues that mobile operators must exploit the benefits of 3G, and that they need to find a more profitable way of co-existing with WiFi, rather than competing directly with it by offering 3G services in hotspots or attempting to replicate WiFi pricing.

Arguments have also been put forward that VoWiFi will not succeed in the near future. With development at an early stage many systems or handsets are proprietary and cannot be used on any type of WiFi. For example, some argue that several new dual-mode handsets cannot be used at any hotspot due to the limited incorporation of standards or restrictive interoperability with other systems such as Access Point and gateways, and the new WiFi/GSM iPaq that HP and T-Mobile announced in July 2004 does not provide VoIP except with a softphone.¹⁸ This has led to arguments that the current closed systems and proprietary systems do not bode well for its success. Furthermore, the WiFi market still remains small compared to the size of the mobile service market. In addition, at present hotspot coverage is not sufficiently extensive to meet customer needs. This led, for example, Singapore's MobileOne to abandon plans in June 2003 to supplement its 3G network with WiFi after a four-month trial.¹⁹

A third argument put forward is that WiFi will not threaten 3G and both will co-exist in the market. These arguments are based on perceived shortcomings of WiFi in terms of its geographic coverage and security, which have led some to argue that WiFi should be viewed as a niche-technology rather than a competitor to 3G.²⁰ In addition, CDMA Development Group claimed that in terms of average transmission speeds, WiFi and 3G do not differ greatly as can be seen in Table 2.

In addition, 3G is available to users travelling at high speeds while WiFi requires users to be stationary. Based on these facts, the Universal Mobile Telecommunications System (UMTS) Forum predicted in its report that WiFi could be an additional source of competitive differentiation rather than a substitute for 3G services. It added that WiFi and 3G would be complementary rather than competitive technologies and that together they would strengthen a total mobile services portfolio. Some experts have also asserted that mobile operators would pursue a collaborative approach using WiFi to extend high-speed mobile services in areas where they lack coverage.²¹ Furthermore, operators that bundle WiFi with cellular services in the cellular handset will tend to gain customers and increase revenues.

Table 2. Data throughput comparison

WiFi			CDMA2000		
	Peak	Average		Peak	Average
T1-based service	11 Mbps	300-700 Kbps	1xEV-DO	2.4 Mbps	300-600 Kbps
DSL-based service	384 Kbps	~ 100 Kbps	1X	144 Kbps	60-100 Kbps

Source: CDMA Development Group.²²

User benefits from VoWiFi interconnecting with mobile networks

The benefits that users experience from VoWiFi will affect its demand and the market growth of VoWiFi services over the next few years. Users of dual handsets will be able to make calls more cheaply than those using mobile phones. Calls generated in hotspots or WLANs are likely to result in considerable savings by consumers. VoWiFi also provides innovative new features such as the ability to access e-mail, Internet, location information, etc. at a lower price. Another benefit for existing users of VoWiFi service is that they are no longer constrained in obtaining service from a limited area such as a hotspot or within a company, but are able to have real mobility and ubiquitous access to voice calls as well as data and video by seamless interconnection with mobile networks with a single handset or portable computer. Using free Internet within an enterprise's WLAN eliminates mobile network access charges. Therefore, those users, especially business users, are able to improve the efficiency and productivity and reduce costs. However, these possible user benefits will only be realised if the current and emerging issues raised during the deployment of technology, as indicated in the following section of this paper, are tackled.

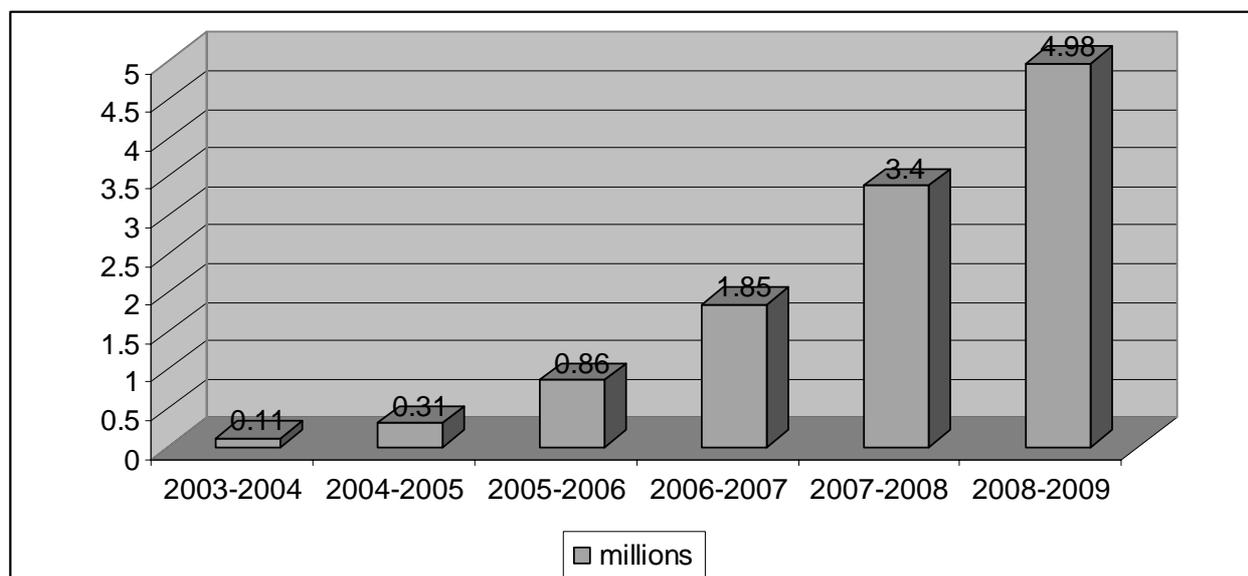
3. Market development

3-1. Overall projection on market related with VoWiFi

This paper tries to examine in detail how the market is developing in the context of VoWiFi/mobile convergence because it is important to understand the activities or efforts in the market and it is the starting point for policy makers or regulators in deciding on the relevant policy implications.

Until now, proprietary VoWiFi systems have been deployed within dedicated WiFi areas, such as within corporations or companies. These solutions have great appeal to vertical markets such as the retail sector, warehousing, manufacturing and health care. Although quite a few vendors and service providers have been working on VoWiFi roaming with mobile networks, the current market is still immature and the equipments and services are rather expensive. At the time of writing, there are only several mobile handsets that support voice over WiFi and no commercial handsets are available for VoWiFi roaming with mobile networks, although some are expected to emerge soon.

However, the VoWiFi market is predicted by some research companies to grow significantly over the next few years. According to research published in July 2004 by iLocus in the US, access points shipped are projected to grow from 0.8 million in 2003-2004 to 15.9 million in 2008-2009, while the handsets shipped will grow from 0.11 million in 2003-2004 to nearly 5 million in 2008-2009 (Figure 2).²³ It also estimated that the revenue generated for Access Points and VoWiFi was about USD 384 million and USD 61.9 million each in 2003-2004. Currently, while Cisco leads the access point market, Spectralink leads the handset market.

Figure 2. VoWLAN handset shipment forecasts

Source: iLocus.

3-2. Handset manufacturers

Only 30 000 VoWiFi handsets were shipped in 2002 according to some reports.²⁴ However several market research companies predict that the WiFi enabled mobile phones together with mobile computers equipped for WiFi access will increase over the next couple of years. ABI Research, for example, predicts that over 50 million dual-mode handsets or smartphones will be in circulation by 2009, accounting for 7 % of all handsets shipped that year.²⁵ Another research company, On World projects that nearly 90% of all handsets, handhelds and laptops will be WiFi enabled by 2007, for a total of more than 700 million devices, and half of which, at least, will include VoWiFi technology.²⁶ This increasing availability of dual-mode handsets will contribute to the growth of the VoWiFi/mobile convergence market.

Table 3 shows three types of handsets available or expected to emerge soon on the market. One type is the pure VoWiFi handsets which work only over a WiFi connection and have been used mainly within a corporate network. They are primarily based on the 802.11b standard, and are not compatible with 802.11a or 802.11g. The second type is the cellular handsets that have WiFi/mobile connections for data purposes most of which will be introduced in 2004 or early 2005. These handsets are not designed for VoWiFi, but may be converted to handle such calls through firmware/software upgrades that allow transcoding. The third type of handset is a dual-mode cellular/VoWiFi handset that can be used to work and roam between both mobile and WiFi networks. The section below briefly reviews some of the VoWiFi handset developments.

Table 3. VoWiFi handsets

Type	Company	Product	Retail price	Protocol
Pure VoWiFi	Cisco	Wireless IP Phone 7920	USD 650.00	802.11b
Pure VoWiFi	SpectraLink	Wireless Telephone NetLink e340	USD 399.00	802.11b
Pure VoWiFi	SpectraLink	Wireless Telephone NetLink i640	USD 599.00	802.11b
Pure VoWiFi	Symbol	Netvision Phone	USD 600.00	802.11b
Pure VoWiFi	Vocera	Communications Badge 220-00656	USD 350.00	802.11b
Pure VoWiFi	ZyXEL	Prestige 2000W	USD 300.00	802.11b
Pure VoWiFi	Vonage			802.11b
Pure VoWiFi	RTX	VoFi VoIP phone		802.11b
Dual-mode cellular/VoWiFi	Motorola	(Cellular/VoWiFi handset)		802.11a/g
Dual-mode cellular/VoWiFi	Nokia	(Cellular/VoWiFi handset)		
Dual-mode cellular/VoWiFi	NEC	(Cellular/VoWiFi handset)		
Dual-mode cellular/VoWiFi	NTT DoCoMo	(Cellular/VoWiFi handset)		
Cellular with WiFi for data	Motorola	MPx	USD 1 000.00	802.11b
Cellular with WiFi for data	Nokia	9500 Communicator	USD 1 000.00	802.11b

Source: ABI Research.

SpectraLink, the current market leader, had about 60% of the global market for VoWiFi products in 2003. Until recently the prices of products were high, but *SpectraLink* introduced a handset, *NetLink* phone, in the latter half of 2003 which cost USD 400. Some network equipment vendors have recently tried to provide *SpectraLink*'s phones as part of their IP based solutions. For example, in March 2004, *Nortel* announced that it will add the phones as part of its suite of VoIP products. *Alcatel* also announced that it will offer the phones along with the *OmniPCX* family of IP PBXs.²⁷ *Symbol Technologies* is also among the early starters in providing VoWiFi solutions for enterprises with wireless networks. *Symbol Technologies* had the second largest market share for VoWiFi products in 2003. The *NetVision* Phone from *Symbol Technologies* supports voice and data simultaneously, employing VoIP technology based on the ITU standard H.323. *Vocera Communications* has provided VoWiFi system in particular to healthcare institutions and hospitals. The system consists of two components. The Server Software controls and manages call activity, and the *Communications Badge*, operating over a WiFi with a 802.11b standard places and receives phone calls.

A number of mobile phone vendors have also been active in developing dual mode handsets allowing for roaming between cellular and WiFi networks for voice as well as data by establishing alliances with other companies. *Motorola*, for example, has been working to develop a dual mode handset in an alliance with *Avaya* and *Proxim*, and has also entered into a similar alliance with *NEC* and *AireSpace*. In July 2004, the former alliance also formed the *Seamless Converged Communication Across Networks (SCCAN)* forum, which will co-ordinate efforts for interoperability among dual-network handsets and IP PBXs that support both WiFi and cellular networks.²⁸ *Motorola* has introduced two types of handsets. *MPx*, expected to be available in the second half of 2004, provides Internet browsing, streaming video and access to corporate applications especially for the enterprise users.²⁹ The tri-band GSM/GPRS smartphone features both built-in WiFi and Bluetooth. Another type of handset is the *CN620* and it is expected to be available at the end of 2004. It allows users to make voice calls and provides data access to both corporate Intranets and the Internet across mobile and WiFi networks through seamless roaming. The *CN620* can be used in hotspots only where the 802.11a standard is provided,³⁰ and functions in the GSM 950 and

1900 bands. *Nokia* is working on a handset, Communicator 9500, which is expected to be available by the end of 2004. The product is a WiFi enabled tri-band GSM/GPRS handset and runs on the Symbian operating system.³¹ *NEC* has set up a dual-mode strategy and been working on a SIP-based mobile phone since 2003. Through a three-way partnership with AireSpace and SpectraLink, NEC has explored possibilities for a dual-mode phone that would work over both WiFi and cellular networks. NEC plans to provide such a phone in late 2004. *Samsung* has a VoWiFi handset, available in Italy and expected to be made available in the US in October 2004, which is designed with a proprietary set of extensions to the SIP standard, and only works with Samsung 802.11b base stations. In July 2004, *Fujitsu* introduced a wireless IP phone that supports WiFi and also accepts plug-in cards to extend support to cellular networks. The phone has a Compact Flash card socket into which mobile telephone cards can be inserted thus allowing the phone to be used on both WiFi and public mobile networks.

A number of new VoWiFi vendors have emerged with the development of VoIP. These softphone vendors include TeleSym, Vonage and Skype which have developed software on mobile computers or PDA, enabling customers to use VoWiFi. In July 2004, TeleSym, a US-based Mobile VoIP vendor, unveiled its SymPhone Enterprise VoIP system, the software for making voice calls from mobile computers or PDA over the WiFi networks. VLI also developed a SIP-based VoIP communication software package, Palm Gphone, which delivers mobile voice to a Palm PDA over WiFi. Vonage have provided the softphone software for Pocket PCs and laptops that enables VoIP calls via WiFi or Ethernet.

Skype introduced the free software, called PocketSkype, which enables users of Microsoft Pocket PC-based handhelds or mobile-PDA to connect to WiFi access points to make free VoIP calls in April 2004.³² PocketSkype is essentially the same as its desktop software, which include instant messaging, directory access, contact lists, and free worldwide calling. However, Skype users can only make free VoIP calls to other Skype users who have downloaded the firm's software from the Skype Web site.

Other vendors not traditionally linked with the handset market have also emerged. Hewlett-Packard (HP) has developed the new smartphone, called iPAQ h6300 communicator, which supports 3 types of networks, *i.e.* GSM/GPRS, WiFi, and Bluetooth. The iPAQ h6300 runs Windows Mobile 2003 for Pocket PC phone Edition, and detects automatically the fastest available network connection and logs onto that when required. It supports quad-band GSM/GPRS (850/900/1800/1900 MHz networks). In September 2004, HP also released, together with KT, its first cellular-wireless PDA, called Ipaq rw6100, which is compatible with CDMA in South Korea. KT customers are able to access Internet while making a call with Ipag rw6100, which includes built-in WiFi as well. In June 2004, Net-2Com announced the development of a wireless IP mobile handset capable of seamless switching between wireless LANs and public wireless networks. The handset enables selection of public wireless networks through inserting various CompactFlash networking cards.

3-3. Network operators

Network operators are just at the initial stages of providing converged services. Some of these are outlined below. These services are expected to evolve rapidly with customer feedback and as operators obtain a better idea of customer needs.

In July 2004, T-Mobile announced the launch of its 3G data cards, combined with the extension of its WiFi hotspot access points across the UK aimed at traveling business customers. With the card, customers can access WiFi, GPRS and 3G with seamless roaming between those networks. Hence, these cards enable customers to browse the Internet, e-mail on the move and access their corporate data systems, as well as provide services such as video telephony, when used in conjunction with a camera. In 2003, Verizon announced a new cordless-cellular phone that operates on regular telephone lines in the home and on the mobile networks when outside. Verizon plans to provide a bundled service which includes free WiFi

access was initially available within a limited number of areas such as lobbies, pool areas or managers' offices as well as high-speed Internet access. In order to find a solution for WiFi/mobile roaming, Sprint has created a private CDMA and WiFi network on a corporate campus. Sprint have tested dual mode mobile phones for delivering a seamless handoff between the WiFi and CDMA cellular network for both on-campus and off-campus access.³³ In October 2003, SBC announced plans for an extensive WiFi hotspot rollout, creating an integrated WiFi and 3G wireless service to deliver broadband wireless offerings to home, business and remote users. SBC will have more than 9 000 hotspots in 2 000 venues by the end of 2004, and more than 20 000 hotspots in 6 000 venues by 2006. The integrated WiFi/3G service is expected to be available in late 2004 or early 2005. To give subscribers access to more hotspots, SBC has tried to reach roaming agreements with other WiFi service providers, such as Wayport. In addition, SBC will use its relationship with wireless operator Cingular to bring an integrated WiFi/3G service to the market. SBC and Cingular have worked to allow roaming between home and office WiFi, hotspots and the Cingular network. SBC plans to use its public telephone infrastructure to establish access points and use its DSL or T-1 service to transport data from the access point to the network.³⁴

In July 2004 in Japan, NTT DoCoMo unveiled its first handset, N900iL, to operate over its 3G cellular network based on W-CDMA while also providing VoIP calls over WiFi. The N900iL is targeted at corporations and the handset acts as an internal telephone inside the WiFi networks, and is used as a cellular phone outside. In addition to voice calls, the telephone provides some extra features when used in a corporate environment, such as its ability to access and browse Web sites and instant messaging services between users. However, the phone will initially support only pages written in Compact HTML, which is the same markup language as that used by NTT DoCoMo's i-mode wireless Internet service, and users will not be able to use the wireless IP phone features outside of the office network. SK Telecom, a Korean mobile operator, plans to provide a broadband wireless Internet service, called WiBro, via cell phones, PDAs and notebooks, especially in downtown areas. KT (Korea Telecom) launched a next generation mobile Internet business center in July 2004 and set up its plan for a combined wire/wireless network infrastructure by providing roaming between mobile networks and WiFi. KT has already deployed around 12 000 hotspots nationwide as of September 2004. KT also plans to provide WiBro service over notebooks, PDAs and dual mode handsets in late 2005 or early 2006.

BT (British Telecom) has established a plan (BluePhone), which is based on a multi-network handset, compatible with 3G networks, traditional GSM networks and with WiFi networks, and is able to switch between them. The handset will make voice calls via IP over Bluetooth connecting to the fixed-line network when the customer is at home or in the office, and then normally switch to GSM or 3G networks when the customer is traveling outside. The Bluetooth base station will allow the mobile handset to surf the Net via xDSL. Alcatel, Ericsson and Motorola are currently working with BT to develop the Unlicensed Mobile Access (UMA) standards. BT expects to launch the Bluephone service in spring 2005.

In June 2004, France Telecom unveiled solutions called Business Everywhere that provide business customers with communication services when they are on the move. Wherever they are, whether in an airport, a hotel or at home, employees can access their desktop environment from a laptop, including e-mail, Intranet, directory and unified messaging. France Telecom claims that the service will be transparent to such access technologies as WiFi, ADSL, GPRS, PSTN and 3G mobile, and that thanks to roaming agreements, customers have interoperable access to PSTN networks in 130 countries, 29 countries through GPRS, 20 countries with WiFi and 66 countries with ADSL.³⁵

Broadreach Networks, a broadband Internet access provider in the UK, announced in November 2003 that it would launch its VoIP service called ReadytoTalk in 2004.³⁶ Customers will be able to make calls via an Internet-connected fixed or wireless device, just for the cost of the Internet session. Broadreach have worked with hardware and software providers, which will enable customers to use ReadytoTalk as part of their ReadytoSurf ISP roaming package. Then, customers are able to make a call by connecting their VoIP-

enabled laptop, PDA or mobile to the wireless device. Call charges will be charged and included on the bill from their ISP or mobile operator.

There are currently 14 providers of WiFi broadband services in Australia under the Higher Bandwidth Incentive Scheme (HiBIS). HiBIS is a four year Australian Government initiative that pays incentives to registered Internet service providers (ISPs) who provide broadband services to eligible customers in regional, rural and remote Australia. A number of these providers have indicated their intention to offer VoIP services in the next 18 months.

3-4. Network equipment manufacturers

A number of solutions which are aimed at forming a bridge between WiFi and high speed mobile networks are also emerging from manufacturers of network equipment as well as semiconductor companies which view this area as a potential high growth area.

Since March 2003, Nortel Networks has provided wireless solutions which provide mobile enterprise users with high-bandwidth voice and data with a seamless wireless roaming, ranging across both public and private networks. Its solutions offer seamless IP roaming across different domains, including roaming between the 802.11a and b standards. Lucent has been working on the seamless handoff of wireless data calls from a WiFi to a 3G network, enabling laptop users to browse the Internet across two networks without interruption. The product, called WiFi on the Move, would use IMT-2000 EV-DO networks to provide backhaul for WiFi access points in trains, buses and automobiles.³⁷

Ericsson introduced its emergency media wireless system, Guardian Angel, which transports medical data and video information seamlessly over a variety of wireless networks, such as GSM, GPRS, 3G and WiFi.³⁸ By choosing the best available networks in a given location and roaming seamlessly between different types of networks on the move, the system allows doctors to observe patients in the ambulance and monitor their heart rate and blood pressure. Cisco Systems introduced the CallManager and Cisco Aironet series of WiFi Access Points. In June 2004, Cisco systems also announced the Cisco Metropolitan Mobile Network (MMN) solution based on WiFi.³⁹ The MMN solutions address the demand of public sector agencies for real-time, mobile access to key applications and tools. It consists of Cisco Aironet Series of WiFi infrastructure and routers with the Wireless Mobile Interface Card that supports IEEE 802.11b/g for WiFi and mobile networks. In February 2004, Proxim introduced a WiFi switch and Access Point designed to support VoWiFi as well as seamless handoffs between cellular and WiFi networks. Access Points support 802.11a, b and g.

Kineto Wireless has introduced a carrier-class mobile network element which enables operators to support seamless automatic handover of GSM voice calls and GPRS data sessions between WiFi and mobile networks by integrating with a service provider's existing voice and data switching systems. Mobility Network Systems have developed WiFiRAN, which allows mobile operators to deploy their own WiFi networks or leverage third-party networks. It enables mobile operators to offer WiFi services without making any changes to their existing GPRS network by providing multi-access solutions roaming between GPRS and WiFi. BridgePort Networks unveiled its NormadicONE product in early 2004. With this gateway that facilitates roaming between IP networks, consumers could use their cellular phone outside the home and then use VoIP inside. The system generates call data records for VoIP calls so wireless carriers can bill for calls even when the calls are made off their network. Possio, a Swedish company, has introduced a wireless router that interconnects WiFi, Bluetooth and Ethernet users with three major cellular network technologies *i.e.* GPRS, UMTS FDD, and UMTS TDD.

The integration of VoWiFi and mobile networks has also provided new market opportunity for leading chipmakers. For example, Intel has already developed chipsets enabling dual-mode WiFi/mobile handsets, while Agere Systems expects to ship VoWiFi chipsets later in 2004. NEC has been developing WiFi handsets using Intel's PXA270 series of chips, called Bulverde, which is part of Intel's broad 'universal communicator handset' vision announced in 2004.

Texas Instruments (TI) also introduced a new, low-power WiFi chipset for use in dual cellular/wireless LAN phones earlier in 2004. TI's chip set can be configured to work under the 802.11 b/g standards or to support those standards in addition to 802.11a. The new WLAN two-chip set cuts power use by 50% from earlier generations of TI WLAN chip sets and can support both data and VoIP operations. Motorola is using TI's WiFi chips and OMAP application processors in a handset, being developed with Proxim and Avaya. TI also announced in September 2004 a new platform, TNETV 1600, that enables manufacturers to create VoWiFi phones. It is based on Texas Instruments' OMAP 16xx mobile architecture and its existing WiFi chipset and will support not only voice but also data.

4. Technical issues and standard development

Since VoWiFi is technically based on VoIP over WiFi, quite a few technical issues and challenges are similar to those in WiFi and VoIP. This paper articulates several main issues and challenges which need more consideration for the deployment of VoWiFi. An overview is also provided of developments in the standard organisations and industry to solve those issues collectively.

Quality of Service (QoS)

WiFi has its own QoS challenges in that throughput may fluctuate when roaming among Access Points. Subscribers are more sensitive to perceptible service degradation for voice or video than for data. Therefore, more reliable QoS is necessary for voice to be delivered satisfactorily over WiFi. The issue of QoS will be increasingly important when roaming between WiFi and mobile networks is supported, given that network hand-off can result in quality of service degradation.

Currently, the IEEE is working on a 802.11e standard, which is expected to increase QoS by tagging different types of traffic, such as voice, video and data, with various priority levels. The extensions will give voice calls priority over data access. The 802.11e standard is going to be released either in early 2005. Up to now, most wireless equipments did not yet incorporate QoS because they were to emerge. Without standards, local voice systems over WiFi have been provided as bundles of proprietary wireless network hardware and software. For example, Symbol and SpectraLink have implemented their own proprietary QoS mechanisms for their hardware.⁴⁰ Some have tried to maintain the required QoS by limiting the number of voice calls on a single Access Point.

The WiFi Alliance announced a new WiFi Multimedia (WMM) program to deal with quality of service issues in September 2004.⁴¹ The WMM program combines core elements of the 802.11e draft and a simplified packet priority access category scheme borrowed from IEEE 802.11d. WMM is designed to improve the QoS for voice, audio, video and multi-media applications over WiFi.

Proper bandwidth

With the wide deployment of WiFi in hotspots and in enterprises, the need for higher-speed WiFi is also increasing. Applications over WiFi are using an increasing amount of bandwidth. In addition, the number of users and devices connecting to WiFi are increasing and the bandwidth demand is expected to increase with the provision of WiFi/mobile roaming. However, while Access Point vendors say that each existing Access Point can support 10 simultaneous calls in 802.11b mode, it has been claimed that in reality less than 10 calls, *i.e.* 5 to 8 of the calls are available with buffering for security and QoS in

reality.⁴² Although 20 simultaneous calls can be supported in 802.11a or 802.11g modes, this channel and bandwidth limitation may cause problems as service is further deployed and in coming years.⁴³

Even though some proprietary solutions to increase bandwidth have been introduced, IEEE has started its work through the 802.11n Committee to develop the standard. IEEE plans to finish collecting proposals from industry and started to evaluate them in late 2004. The 802.11n standard for increasing bandwidth is expected to be released in 2005. On the other hand, several vendors, such as Netgear, Atheros and D-Link, have already been working on a technique, Super G, to increase the speed of WiFi connections. Super G is supported in chipsets that are interoperable with other 802.11a, b, or g products. In July 2004, Agere Systems outlined a way to increase transmission speeds up to 500 Mbps.⁴⁴ In order to increase the speed, Agere Systems uses two to four sets of antennae instead of single set of antennae that is currently deployed on each wireless connection, and increases the size of each WiFi radio channel from 20 MHz to 40 MHz. This technique operates in the 5 GHz frequency range, which has less interference than the 2.4 GHz.

Security and privacy

The potential security and privacy risks arising from using WiFi for voice have been an obstacle to further development of VoWiFi/mobile roaming. Those risks include stealing packets, unauthorised access to the network and intentional interference by outsiders. This issue has a greater impact on business users than residential subscribers. Up to now, virtual private network (VPN), encryption and authentication technologies have been implemented to address security and privacy issues.

In general, encryption presently used such as Wired Equivalent Privacy (WEP) is considered weak and susceptible to outside intrusion. When granting access, WiFi relies on Service Set Identifiers (SSIDs) to verify each network component. One method for checking individual device information, called open authentication, is to require SSID of the device to access the network. This method is vulnerable in that the Access Point constantly broadcasts its SSID so that intruders are able to detect it. Another method, called shared-key authentication, requires sending a challenge test packet that is encrypted and returned to the AP from the device. If the device has no encryption key or the wrong key, it cannot access the network. But using a weak static encryption algorithm for a continuous period of time provides an opportunity for hackers to break the code.⁴⁵ Another challenge for encryption and authentication is to hand off calls quickly between different Access Points or mobile networks so as to provide a clean voice call, *i.e.* in under 50 milliseconds.

Vendors have tried to address these security problems by developing proprietary extensions, *i.e.* LEAP from Cisco and Kerberos from Symbol. However, these additional extensions have another problem such as non-interoperability with other products, and add latency creating delays. To solve the problems associated with WEP, Wireless Protected Access (WPA) has been designed. WPA provides encryption via Temporal Key Integrity Protocol (TKIP), which uses dynamic instead of static keys. IEEE has also worked on security issues by developing an 802.11i standard, which will create fresh keys at the start of each session, provide a way to check packets, and rely on the Remote Access Dial-In Service (RADIUS) standard to manage encryption key.⁴⁶ Products conforming to the new 802.11i standard are expected to be released in several months. However, a possible problem still remains in that the need for 802.11i to re-authenticate every time when users move between access points may cause delays.

Interoperability

The adoption of heterogeneous WiFi technologies may cause incompatibilities. In addition, with the advance of WiFi and VoWiFi, a growing number of vendors are trying to differentiate their products beyond existing standards, mainly by boosting speed or security. However, this may create interoperability problems with other products or systems that follow existing standards. Moreover, products run over

802.11b are not likely to support 802.11a or 802.11g standards. On the other hand, some products which support VoIP have limited interoperability with those from other vendors. The issue of interoperability may result in enterprises incurring higher costs.

To deal with the problem of interoperability the WiFi Alliance has been overseeing tests that certify product interoperability since March 2000. A product that passes the alliance tests is given the label "WiFi certified", a registered trademark. To strengthen the interoperability between products, the WiFi Alliance announced, in July 2004, a new and more stringent policy in order that extensions to WiFi products do not impair the ability of other certified products. The Alliance may withhold or revoke certification, if a product significantly impacts the ability of other WiFi certified equipment.

Interference and complexity

The spectrum for WiFi is not dedicated and licensed for use by certain entities as in the case of mobile services. Therefore, the users of WiFi share spectrum with other devices, including household devices such as microwaves. Consequently, as WiFi or VoWiFi deploys further, the spectrum will become increasingly crowded and the possibility of interferences will grow. In this regard, some experts warned that interference issues among the many new wireless hotspots could threaten WiFi's continued success, as more and more hotspots and wireless devices roll out.

There are commercial efforts to deal with this problem. For example, Propagate has worked with network gateway and switch players ReefEdge, Bluesocket and Chantry Networks to use common application programming interfaces (APIs) that automate the management of wireless networks.⁴⁷ Table 4 shows the types of WiFi technology standards.

Table 4. The types of WiFi technology

Standards under consideration	
802.11e	Enhances the 802.11 Media Access Control layer for quality-of-service features, such as prioritizing voice or video traffic.
802.11k	Creates a way for access points to pass specific radio frequency health and management data to higher-level management applications.
802.11n	Designed to boost throughput, not raw data rate, to 100M bit/sec. The idea is to make WLANs feel like 100M bit/sec switched Ethernet LANs.
802.11r	Allows fast, secure, seamless handoff of a VoWiFi connection among access points.
Standard established	
802.11a	Describes WLANs for the 5-GHz band, with a data rate of 54M bit/sec.
802.11b	WLANs in the 2.4-GHz band, 11M bit/sec data rate.
802.11d	Enables 802.11 hardware to work in various countries where it cannot today.
802.11g	Also in the 2.4-GHz band, but uses 802.11a modulation to reach 54M bit/sec.
802.11h	Supports measuring and managing the 5-GHz radio signals in 802.11a WLANs.
802.11i	Repairs weaknesses in the Wired Equivalent Privacy encryption scheme.

Source: OECD based on data from Network World Fusion.

5. Operational issues and policy implications

5-1. Operational issues and business challenges

Seamless roaming and a single dual-mode handset are critical

The market for voice service only over WiFi without roaming with mobile networks has been characterised by some analysts as not being viable or profitable, although this may not be the case for WiFi in an enterprise environment. A number of economic activities lead mobile workers to want a combined voice and data service, and also to want to cut their communication costs. Without seamless roaming, voice calls will be dropped outside the provider's service area, and users would have to subscribe independently to several service providers. Therefore, VoWiFi may not compete with cellular voice until it is possible to have seamless hand off not only from one hotspot to another but also between WiFi and cellular networks. However, at present, technical solutions for seamless roaming especially with mobile networks for voice do not seem to be enough, even though the IEEE 802.11r working group was established to address this issue and fast roaming.

On the other hand, the difficulty in implementing seamless roaming is more likely to come from the operational perspective rather than the technological one, based on the fact that seamless roaming nationwide may require the involvement of various types of service providers, *i.e.* mobile, VoIP, ISP and wired service operators, and even some companies that operate their own WiFi in their limited service areas. Some of them, especially mobile service providers, may hesitate to enter into agreements because this could impact on their revenue streams.

Despite the difficulties, an increasing number of agreements for roaming especially between WiFi service providers have been reached. These agreements, however, cover access to data from laptops or PDAs at hotspots and not from mobile terminals. For example, Sprint has signed roaming agreements with a variety of network operators, including Cingular, Wayport, STSN, Airpath, Concourse Communications and SBC Communications. Accordingly, Sprint will make at least 10 000 hotspots available to its customers by the end of 2004 through these roaming agreements. Cingular also signed a roaming deal with T-Mobile and Wayport.

In addition to the separate agreement, there are collective efforts for roaming. For example, the Wireless Broadband Alliance announced its plan to establish international roaming among member companies to 20 000 hotspots in July 2004. T-Systems, a subsidiary of Deutsche Telecom, is providing a wholesale roaming service by signing up 120 international partners for a total of 10 000 hotspots as of mid-2004.⁴⁸ RoamPoint also announced a 'global roaming hub' and partnerships with GSM networks and Wireless Internet Service Providers (WISP) to offer roaming across 5 000 hotspots in April 2004.

Network solution vendors are also involved in improving techniques for smooth roaming. For example, SkyNetGlobal, an Australian network solution vendor, announced its strategic alliance with Hotspot Global in October 2003 to create a common platform for WiFi roaming and to allow next generation WiFi enabled mobile phones to operate at hotspots. However, roaming agreements between different WiFi and cellular network operators for VoWiFi have not yet emerged, even though some telecom service operators, such as SK Telecom, have plans to provide broadband Internet by connecting its WiFi and 3G mobile networks.

In addition, having two handsets for WiFi and cellular networks creates considerable inconvenience for customers who already have mobile phones. Many users may not want to carry the extra VoWiFi handset in addition to their mobile phone when travelling. Currently, there are a very limited number of handsets commercially available on the market that are able to provide seamless roaming between WiFi

and mobile networks especially for voice, even though several handsets are expected to be made available in late 2004 and 2005. 3G experience has shown that supply of handsets is critical and it is very difficult for the market to develop without handsets. It is also important that new dual mode handsets are not proprietary and are compatible with systems of 802.11a or g as noted above.

Attractive applications are also critical for further developments

As is the case for many new technologies, attractive applications together with user convenience are a critical factor for the success of WiFi/mobile convergence. WiFi/mobile networks may increase the costs of deployment, co-ordination and adjustment to mobile network operators. To compensate for these additional costs, network operators need to create new revenue streams and attract customers by providing new attractive applications. Network operators who are aiming at converging networks and services may learn from previous experiences such as attempts at GSM/DECT (Digital Enhanced Cordless Telecommunications) convergence initiated by BT in the late 1990s. This service was designed for use either in the home, office or outside, but was not so successful due to a number of inconveniences such as manual switch off between networks, two separate bills, expensive and bulky handsets, and so on.⁴⁹

Customers may want continuous high-speed connectivity for both voice and data as they move between networks with one handset, one number and one bill. Voice alone seems not to be a killer application. In addition to voice, accelerating the development of new value added applications, such as broadcasting (DMB), mobile games, mobile commerce, mobile navigation and video conferences at a lower cost will be helpful for its further deployment. Then, customers can experience the high-speed connectivity in WiFi networks or hotspots, while having access to mobility outside in the cellular networks as well. Accordingly, the development of WiFi/mobile integration, which can support higher speed wireless access, has a potential to encourage the development of wireless broadband multimedia content.

Billing for VoWiFi/mobile roaming

Roaming between VoWiFi and mobile networks may require the involvement of various wireline, mobile and WiFi network operators, and the pricing structures may be quite different between VoWiFi and mobile services. Furthermore, multiple carriers, involved in VoWiFi/mobile roaming, need to be able to share billing records with each other. This becomes more complicated when global roaming occurs. Under these circumstances, presenting one bill for both voice and data services to the customer might be complex but is an important requirement. Settlement issues between service providers also have to be agreed on.

A number of solutions to these problems are beginning to emerge on the market. For example, Transat Technologies and Intel have developed software for mobile computing platforms to allow customers to roam across different WiFi and cellular networks and receive a single bill. Several companies have been working on solutions for sorting out billing issues during roaming handoffs. For example, CSG released billing solution, in 2003, for both packet and circuit switched networks, which is capable of integrating a cellular network billing system and a hotspot system. T-Mobile also introduced unified billing for their customers, in which the T-Mobile hotspot service is included in their monthly mobile bills. Such unified billing systems need to be extended eventually to cover commercial VoWiFi/mobile roaming services.

The billing issue may also be important if service providers offer roaming services charging flat-rate monthly payments. Flat-rate billing may erode the savings gained from moving between WiFi and the mobile network. On the other hand, it can cause a congestion problem in both mobile and WiFi networks which have limited spectrum capacity.

Other issues

Other operating issues for WiFi/mobile roaming for both data and voice include battery power, cost of chipsets, etc. WiFi/mobile roaming for voice, video as well as multi-media data is expected to use much more power than current terminals. To cope with this issue, some WiFi IC vendors such as Texas Instruments are working to decrease power consumption. The current high cost of the chipset is another issue. According to ABI Research, the cost of the chipset will drop to around \$6 by the end of 2004. More power-efficient and lower cost WiFi chips will facilitate embedding WiFi functions in the dual-mode handsets or PDAs and reduce deployment costs. And, easy and convenient non-voice input capabilities to small cell phones or telephony capabilities to PCs or PDA will also be useful.

5-2. Policy Implications

WiFi/Mobile roaming and VoWiFi may play an important role for fixed-mobile convergence

One of the significant issues for wireline network operators is the potential loss of revenues from existing voice services over the PSTN. For example, revenue loss to the US wireline carriers due to increased competition from wireless and cable operators could exceed USD 18 billion by 2010 according to Adventis Consulting.⁵⁰ Developments in other countries, where mobile penetration rates are high, are expected to follow a similar pattern.

Substitution is providing an incentive to a number of wireline and mobile network operators to seek new business opportunities through the deployment of WiFi and WiFi/mobile roaming. Some wireline operators are trying to offer WiFi access as a way to compete with mobile operators, while some mobile operators are trying to expand their offerings to a wider array of services by constructing an alternative local access network, or WiFi, and by integrating WiFi with their mobile networks, allowing them to compete with wireline operators. Both fixed and mobile network operators try to offer integrated bundles of fixed and mobile services.

Six telecom companies, including BT, KT, NTT, Swisscom, Rogers Wireless and Brasil Telecom, have announced the Fixed-Mobile Convergence Alliance to promote combined wireline and mobile services in July 2004.⁵¹ They will share information and expertise on converged fixed-mobile services and work jointly on common standards. Among them, BT is focusing initially on 3G handsets with Bluetooth capability. These phones will allow users at home or in the office to link to Bluetooth base stations with their fixed broadband connections, and to roam onto mobile networks when outside the Bluetooth footprint. However, if 3G phones providing seamless roaming with WiFi become available, the focus seems to change from Bluetooth to WiFi, which will play an important role in the liaison between fixed and mobile networks.⁵²

Although some mobile operators are hesitating to consider fixed-mobile convergence because of the potential for revenue loss, several efforts have been made to promote such convergence. For example, In January 2005, IBM, VeriSign and Airespace joined an alliance programme, called MobileIGNITE (Mobile Integrated Go-to-Market Network IP Telephony Experience) and initiated by BridgePort Networks, which will conduct interoperability testing for roaming between mobile and VoIP networks and help mobile service providers to deliver mobile VoIP services. On the other hand, 3GPP standardised IP multimedia subsystem (IMS) that gives mobile operators a common service environment and allows for smooth integration of new IP based services. With IMS, users on mobile networks or WiFi can communicate with users in other fixed or mobile networks by allowing wireless packet data to have a same 'find and connect' ability as traditional voice. Hence, IMS provides the basis for a wide range of multimedia communication services or applications, such as interactive applications, sharing content or presence information, and VoIP.

Several vendors including Lucent, Motorola and Nokia have been working on the solutions based on IMS, and some are testing the interoperability of IMS. For example, in March 2004 Lucent Technologies introduced its Accelerate IMS, a service solution that enables mobile operators to provide VoIP and multimedia services across mobile, WiFi and wireline networks.⁵³ Nokia and NEC announced that they had completed the first phase of interoperability testing between two companies' IMS in September 2004. As these kinds of converged technologies and solutions develop, some experts say that 3G and DSL will converge as a broadband access service via dual-mode handsets or terminals, allowing customers to use 3G outside and hand off to WiFi through VoIP when they are at home.⁵⁴

Such developments in the telecommunication and technology sectors have a potential to facilitate competition and play a catalyst in the development of fixed mobile convergence through seamless roaming across WiFi/mobile networks and WiFi combined with wired VoIP access points.

With the technical development and further deployment of WiFi/mobile roaming for voice and data over converged networks, the benefits to customers are likely to grow through one-stop shopping, reduced cost, increased mobility, increased options for modes of access and multiple choice for multi-media and a variety types of content. In order for this to occur it is important to share information related to customers, accounting and networks between different network operators. Regulations should not hamper the ability to share such information or combine network resources across different networks while protecting users' data including customer proprietary network information (CPNI), or the data collected by telecommunications service providers about a consumer's telephone calls such as type of service, number of telephone lines, amount of usage and billing records.

Such convergence will have significant implications for existing regulatory frameworks based on relatively rigid definitions of services and networks. Such service classification issues are already occurring with the deployment of VoIP services and are likely to become more complex with new converged services. As an example, in early 2004, in Korea, there were discussions as to whether WiBro, a new high-speed mobile Internet service, is a mobile service, in which case only mobile network operators should have the right to provide WiBro service, or whether fixed network operators need to establish a separate enterprise to provide WiBro. Some regarded WiBro as a reinforced model of wireless Internet used by cell phones, and others argued that it is an extended model of broadband Internet so fixed network operators should have the right to provide this service. The Ministry of Information and Communication (MIC) decided to allow both fixed and wireless network operators to provide this service on the basis that it is a combination of wire and wireless technology. Regulators or policy makers elsewhere are likely to have to cope with these kinds of issues when considering service and network convergence enabled by WiFi and mobile roaming, VoWiFi or fixed-mobile convergence. In that regulatory policy has increasingly emphasised technology neutrality and places emphasis on benefits to consumers and the creation of effective competition, it is unlikely that there should be any significant regulatory obstacles to these new developments.

Policy Considerations for Quality of Service

In contrast to the cellular mobile networks, WiFi uses unlicensed spectrum. Accordingly, potential entrants cannot be excluded regardless of increased congestion. In addition, VoIP is unregulated in quite a few countries. Some issues may arise from the fact that VoIP over WiFi, an unlicensed and unregulated service, is integrated with voice service in mobile network which is licensed and regulated, and one of these issues could be quality of service. Degradation of QoS in VoWiFi service may affect the QoS of voice service provided by mobile service providers as well in integrated VoWiFi/mobile network environments.

The degradation in QoS caused by interference is already occurring in crowded areas, such as airports and apartment buildings. This raises the issue on how to resolve this problem to ensure that VoWiFi/mobile roaming is viable while minimising regulation and maintaining market innovation. The apprehension of policy makers or regulators is likely to be that applying technology neutrality to new emerging technologies may hamper further investments of service providers, consumer benefits and innovation from new technologies. Self-regulatory initiatives could be one option. Another solution could come from technology which allows for the automatic choice of channels to reduce interference or reduce transmission power to avoid interference.

Policy considerations for security, data protection, access to emergency calls and roaming

Security and data protection issues will become more significant as VoWiFi services which are integrated with mobile networks become more widespread. Sharing spectrum with other users and the free-roaming nature of VoWiFi may present additional challenges. The business model or environment for VoWiFi service has been changing with technological development and innovation. Even though issues of security with VoWiFi are not fully resolved as of now, security is expected to improve as a result of efforts from industry and standards organisations. It will be unnecessary for regulators or policy makers to set minimum criteria on security for commercial WiFi/mobile roaming service to guarantee that service is safe and reliable for the public if the market is able to attain a satisfactory solution.

The handling of emergency calls will also be increasingly important with further deployment of VoWiFi. VoWiFi is subject to the same challenges as VoIP in terms of the access to emergency calls in that VoWiFi will be based on VoIP technology. The difficulty in identifying the location of emergency calls has cast serious challenges to policy makers as well as the industry in recent years. In case of wireless environments, emergency calls especially from private LANs can be more difficult than wireline in identifying the location of callers, in that the IP addresses of callers are not allocated by service providers and callers are moving. In this regard, technical developments to identify the location of dual-mode handset users are important. Employing GPS technology in the VoWiFi handsets as well as mobile computers can be one solution. However, it is also necessary to guarantee access to emergency calls for public safety without establishing burdensome regulations on service providers. In addition, policy makers or regulators may need to make sure that consumers of VoWiFi are fully aware of the capabilities related to the access to emergency calls.

Mobile network operators in many countries have to provide roaming services to users of other network operators if it is technically feasible, as a condition of their licenses. As WiFi is unlicensed spectrum, network operators, in general, do not have this type of regulatory obligation for roaming with other network operators. Another question is whether access to Access Points should be required, or left to agreements between industry participants (for example, the mobile operators in France have an agreement to allow access to each other's hotspots by their subscribers). Subscribers would clearly benefit if access opportunities were maximised allowing for widespread of WiFi/mobile roaming.

Policy considerations for spectrum

In the context of WiFi/mobile roaming, there is a view that creating secondary spectrum markets might be of some help for mobile network operators to use their licensed spectrum more flexibly. With the advance of WiFi/mobile integration, mobile network operators may require change or adjustment of their initial plans or strategies for the deployment of mobile networks. In some countries, spectrum policies have already progressed towards allowing secondary spectrum markets and reallocation for more flexible and efficient use. Successful WiFi/mobile integration will be likely to accelerate these policy changes.

NOTES

- 1 WiMAX refers to the Worldwide Interoperability for Microwave Access Forum aimed at promoting the adoption of the IEEE 802.16 standard for broadband wireless access systems.
- 2 See DSTI/ICCP/TISP(2002)10/FINAL.
- 3 See DSTI/ICCP/TISP(2003)10/FINAL.
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