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MOBILE AND WIRELESS NETWORKS: SERVICES, EVOLUTION AND ISSUES

By

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Abstract

Wireless technologies in the last decade or so have attracted unprecedented attention from wireless service providers, developers, vendors, and users. The breathtaking evolution of wireless technologies, services and business applications has resulted in a wide-scale deployment and usage of wireless and mobile networks. The paper discusses mobile and wireless networks in terms of services, technical evolution, and related issues. Industries such as transportation and logistics, financial services, health services, and many others should be able to improve their performance by implementing wireless mobile technologies.

Keywords: *mobile wireless networks, mobile services, wireless LANs, wireless standards, future technologies.*

1. Introduction

The wireless network technologies (3G and forthcoming 4G wireless services) have witnessed exciting innovations and will continue to represent a rapidly growing sector in the near future. These evolving technologies have increased an organisation's ability to reach customers regardless of their locations. 3G mobile networks – that are expanding on the existing wireless network technology – offer broadband transmission with speeds of up to 2 mega bits per second (Mbps) in some areas of the world, but the international 3G networks standard known as IMT-2000 defines no less than five incompatible 3G wireless standards. Three of these five standards are currently in different stages of realisation. The existence of

these multiple standards is not likely to solve the well-known problem of interoperability of wireless networks. 3G wireless access systems provide basic data services along with voice and messaging capabilities. However, the telecommunications vendors and service providers are already researching and developing a next-generation, true broadband wireless cellular system, known as the Fourth Generation or simply the 4G. Wireless service providers and application vendors will strive to meet the expectations as new technology evolves to form tomorrow's wireless networks. What lies ahead of the next generation wireless technologies (such as 3G, 4G wireless networks, and broadband fixed wireless communications) generates great opportunities for wireless services and applications, namely m-commerce, m-business, ubiquitous business, and pervasive healthcare.

The primary purpose of this paper is to present services, evolution, and issues of mobile and wireless networks. More specifically, we present mobile services (Section 2), mobility, and access quality for mobile and wireless networks, the next-generation (4G) networks, integration and interoperability, and access to multiple networks using special devices (Section 3), and, threats or opportunities of wireless local area networks for wireless carriers (Section 4). The future of wireless and conclusions are presented in Section 5.

2. Mobile and wireless services

Mobile commerce is an emerging area involving business activities conducted over mobile and wireless networks using handheld devices (Varshney and Vetter, 2002). It not only includes mobile versions of existing e-commerce applications, but also new and innovative applications that are largely becoming possible due to mobile and wireless networks, e.g., location-based services and services requiring user attention very frequently including mobile multi-party interactive games. Mobile commerce has attracted significant attention among users, service providers, vendors, content developers, businesses, and researchers (Varshney and Vetter, 2002) due to its potential impact. It brings many unique characteristics that are significantly different from e-

commerce and wireless communications, such as location and context awareness, user-centric and personalisation, and transaction support. It will have a larger role as third party providers because wireless carriers may not able to develop and manage sophisticated and personalised contents for a large number of users. Mobile commerce has the potential to transform the ways business is conducted from many different angles. Several B2B (Business to Business) m-commerce applications can improve the efficiency of business processes, improve the quality of services to users and other businesses, and create many new opportunities and markets. There are markets of several billion dollars a year in Japan, where DoCoMo supports mobile commerce payments by scanning cell phones and other hand-held devices, e.g., several European countries with high levels of wireless adoption where m-commerce is generating billions of dollars in revenue from mobile tickets, mobile parking, mobile coupons, mobile advertising, and mobile shopping.

Several m-commerce applications have been identified, including mobile financial applications, mobile and locational advertising, location-based services, mobile inventory management, proactive service management, mobile auction, mobile entertainment services, multiparty interactive games, mobile office, and wireless data centre. However, only very few, including mobile content services, mobile financial applications, mobile advertising, and location-based services, have been offered by wireless service providers. More sophisticated applications involving increased user personalisation and context awareness must be offered to further drive mobile commerce. Mobile games, personalised contents, entertainment services, mobile auction and trading, and product recommendation systems could give a boost to m-commerce deployment and adoption. Mobile and multiparty games could become major drivers of m-commerce, especially if group connectivity for wireless users can be maintained even under periods of intermittent connectivity and brief disconnectivity. Entertainment contents will attract some users especially if the contents can be tailored to different user groups and interests.

The current mobile commerce applications include mobile content services such as ring tones, news, and video and image downloads amounting to billions of dollars a year, including mobile financial applications, such as mobile banking, mobile money transfer, mobile payments, mobile games and entertainment services. Most games are single user games where a user downloads an application that allows him/her to play a game on a mobile phone or device when needed. Multiparty interactive games involving a large number of users would require continued connectivity and close coordination of user inputs to create a real-time experience for mobile users. Also, more work is needed in offering rich entertainment contents to mobile users such as live events and concerts. Also, location-based services, such as location and user-specific advertising and offering of specialised contents to mobile users, are being offered. Location content services utilise location information to provide specialised contents to m-commerce users including information on local restaurants, devices, users, and products. Currently, there are few examples of location-based services, not necessarily personalised or user-specific.

The power of technological development and the strength of the different m-commerce applications determine the future of mobile commerce. Mobile commerce applications are paralleling the development of wireless technologies. The capabilities of wireless devices will determine the type of frequency of the m-commerce application development. The handsets today are rich in features. For example, they offer the ability to replace paging services using the Text Messaging feature. Handsets are now capable of special ring tones, games, music, calendars, calculators, cameras, and voice recognition features. Most handsets have data capabilities to send and receive data for a laptop. A camera phone has a novelty feature for the customer to take a few pictures to send to friends and family. However, the receiver must either have a camera phone to receive the picture or access to a website to retrieve the picture for viewing. Similarly, there are valid business applications for a camera phone. One example is a delivery company. Upon delivery of goods to a customer

location, the driver takes a picture of the goods and sends the picture of the goods at the customer location to the office. If a customer were to claim goods that were damaged upon delivery, the office can easily pull up the pictures at the time of delivery and determine if there is a valid customer claim. Text Messaging is a very popular feature and is also an economical means of communication for status messages and acknowledgement of certain business activities. From a business point of view, text messaging can be used for sending user-specific or location-specific advertisements (Varshney and Vetter, 2002).

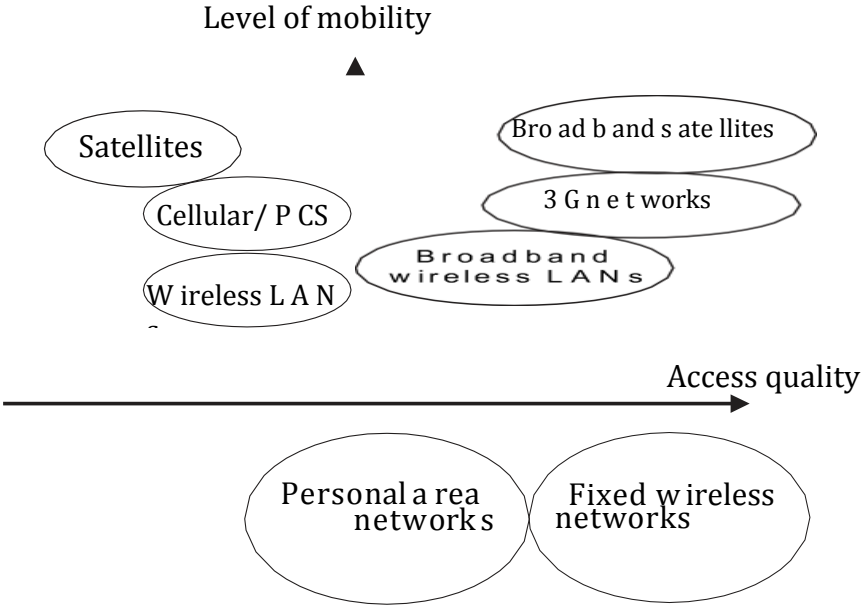
3. Evolution of wireless networks

The total number of cellular, Personal Communications System (PCS), and other wireless subscribers is expected to reach two billion by the end of 2006, if not earlier with more than 1.7 billion wireless subscribers. The current users are served by many different standards that exist in the world today. These include first and second generation (1G and 2G) networks based on one or more versions of wireless communication protocols including the Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and 3G via cdma2000 or Wide-band Code Division Multiple Access (WCDMA). It should be noted that 3G specifications offer the flexibility needed by both the existing operators to evolve their first and second-generation networks towards 3G services and the satellite or terrestrial providers in designing new 3G systems. The radio specifications allow five different choices, carefully designed to help existing first- and second-generation wireless systems to interwork with or evolve into 3G systems. However, the world wide migration to 3G has not been as fast as hyped due to the operators' perception of limited market needs, lack of incentives to carriers and operators, heavy capital investment made in the existing first and second generation wireless systems, and a monopoly of wireless carriers in many countries.

From a broader picture, mobile and wireless networks also include wireless LANs, satellites, fixed wireless networks, and personal area networks. For each of these, multiple standards exist today and the quality of service varies with each location and provider

as presented in Figure 1, which displays the level of mobility and access quality of many current and emerging networks. For example, although most of the existing wireless LANs offer total bit rates in the range of 1 to 11 Mbps (802.11 and 802.11b),two new wireless LAN standards – the 802.11a and 802.11g – offer bit rates of up to54 Mbps (Varshney, 2003). It must be noted that these rates represent the best possible throughput and are subject to reduction with increasing distance from the access point. The total bit rate is shared among multiple users which lead to a limited per-user bit rate. One emerging issue is the need to increase the bit rate per user to support higher-end applications and how to satisfy the requirements. Institute for Electrical and Electronics Engineers (IEEE) High Throughput Task Force (soon to become 802.11n) is considering ways to increase bit rates to 108 Mbps and possibly 320 Mbps (probably available in 2006) to address the demands of future wireless LANs. This example illustrates that we are, indeed, in an early stage of the evolution of wireless mobile technologies.

Figure 1. Mobility and access quality for mobile and wireless networks



3.1. 4G networks

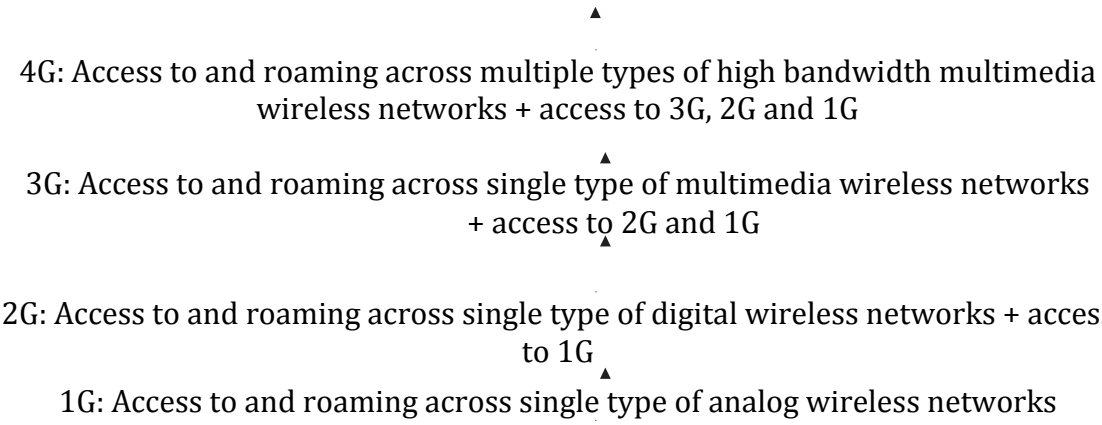
There is growing interest in the design and development of 4G wireless networks (Varshney and Jain, 2001) to support roaming across heterogeneous wireless networks (and not just one type of wireless network), very high bit rates for multimedia services, and packet-switched wireless communications. The 4G wireless networks will allow users to move from one type of wireless network to another by using multi-network devices or interconnected wireless networks. For example, when the user is at home, he/she can use the device as a cordless phone to access Public Switched Telephone Network (PSTN). When in the car, it connects to a cellular network. While in an area not covered by such service, it can switch to a satellite-based network. Upon reaching the office, it can switch to a high bandwidth Wireless LAN. The factors that distinguish the 4G networks are roaming across multiple heterogeneous networks including cellular, wireless LANs, Wireless WANs, satellites and others; IP interoperability; higher bit rates in the range of 50 Mbps or more; location tracking and dynamic quality of service negotiation across multiple networks. The 4G networks have received some interest among researchers and vendors for the last few years. While 3G networks are currently being deployed, 4G networks are scheduled for deployment in the period between 2008 and 2010. Hopefully, this time frame will allow everyone ample time to sort out any differences or problems. A comparison of the four generations is shown in Table 1 and the evolution in Figure 2.

Table 1. A comparison of 1G, 2G, 3G, and 4G wireless networks

The generation	*Access protocols*	*Key features*
1G	FDMA	Analogue, primarily voice, less secure, support for low bit rate data
2G and 2.5G	TDMA, CDMA	Digital, more secure, voice and data
3G	cdma2000/W-CDMA	Digital, multimedia, global roaming across a single type of wireless network (*e.g.*, cellular), 384 Kbps or higher (up to several Mbps)

4G	TBD	Global roaming across multiple wireless networks, 50 Mbps or even higher, IP interoperability for seamless mobile internet

Figure 2. Logical evolution of wireless networks



3.2.Integration and inter-operability

One of the biggest challenges in mobile and wireless networks is the number of different and incompatible standards and protocols (Table 2). For wireless solutions, integration and inter-operability are necessary for increasing the network coverage and ensuring reliable access. There are two ways to look into this issue: compatibility among wireless networks and access to multiple networks using special devices. Achieving compatibility among protocols and networks is harder due to the major differences in the protocols, coverage, and bit rates of different wireless networks. One example of compatibility is 802.11 g's backward compatibility with 802.11b wireless LANs. Another example is backward compatibility of cdma2000 EV-DV with cdma2000 EV-DO and cdma2000 1×. Access to multiple networks using special devices is more common as many wireless devices have functionality to access one or more wireless networks. These include multi- band and multi-mode cellular, PCS and GSM devices, cellular phones with satellite access, cellular and PCS

phones with bluetooth interface, and dual wireless LAN devices. Dual-band adapters, which allow access to both 802.11a and 802.11b can be used, although IEEE 802.11a wireless LAN is not compatible with 802.11b.

The access to multiple wireless networks in 4G networks could also be facilitated by the use of an overlay network or by having intelligence in the networks. This would obviate having multiple interfaces or adapters in user devices.

Table 2. Categories of wireless networks

Personal Area Network (PAN)	*Local Area Network (LAN)*	*Metropolitan Area Network (MAN)*	*Wide Area Network (WAN)*
Bluetooth	802.11b 802.11a 802.11g	802.16 802.16a 802.16e	GSM GPRS CDMA 2.5G 3G
Medium data rates 1 Mbps to 2 Mbps	High data rates 11 Mbps to 54 Mbps	Very high data rates Quality of service, up to 280 Mbps	Low to medium data rates 10 Kbps to 2.4 Mbps
Very short range 3 m (~10 feet)	Short range 100m (~300 feet)	Medium range 50 km (~31 miles)	Long range Global
Notebook to PC to peripherals devices to systems	Computer to computer and the internet	LAN or computer to high speed wire line internet	Smart phones and PDAs to WANs and the internet

4. Wi-Fi: a threat or an opportunity for wireless carriers

One of several surprising developments in the domain of wireless communications is the rapid acceptance of the IEEE family of 802.11 standards, also called Wi-Fi (short for wireless fidelity), wireless LAN, or WLAN. Wi-Fi was designed as an inexpensive alternative for the hard-wired Ethernet because it does not

cost as much to set it up since buildings do not need to be wired or rewired. Its high-bandwidth connections to the internet cost only a quarter as much as the wiring most companies use today.

Wi-Fi has quickly gained popularity among small companies and hobbyists who extended the coverage by setting up the Wi-Fi access points or hotspots in urban neighbourhoods. Rapid acceptance has also been facilitated by the proliferation of inexpensive radio cards, and most new laptops and PDAs having built-in radio cards. It consequently gained quick support of industry giants such as Intel, Cisco, Microsoft, IBM, AT&T, Verizon Communications, T-Mobile USA, SBC Communications, and many others, not to mention a lot of smaller players and startups.

Business Week reports that 18 million people have already logged in such networks (Green et al., 2003). Wi-Fi seems set for exponential growth as the latest of the 'next big thing'. There is a problem though: no profitable business model for carriers has yet been identified. For example, SBC President William Daley said: "We are all going to give it to our customers because they want it, but we are not quite sure how we are going to make money at this point" (Kramer, 2003).

4.1. 802.11 standards

Wi-Fi (defined as a family of standards developed by the IEEE) is a radio communication technology with a high bandwidth of up to 54 Mbps, but a short range of about 100 metres. The first standard, 802.11, published in 1997, provided several modes of operation and speeds up to 2 Mbps. Work soon started on improving performance, resulting in two new but incompatible versions of the standard: 802.11b and 802.11a. The two versions use different coding schemes and operate in different frequency ranges. The '11b' version operates in the 2.4 GHz Industrial-Scientific-Medical band with speeds of up to 11 Mbps, while the '11a' version operates in the 5 GHz unlicensed band with transfer speeds of up to 54 Mbps.

The 802.11b equipment arrived in the market first because it was simpler to develop and build. However, when the 802.11a equipment became available recently, it created confusion because

users and manufacturers were forced to decide between two incompatible and non-interoperable standards (Carney and Solomon, 2002). Moreover, 802.11g was approved in June 2003 as yet another IEEE standard. '11g' offers wireless transmission at up to 54 Mbps. Like 802.11b, 802.11g operates in the 2.4 GHz range and is thus compatible with it.

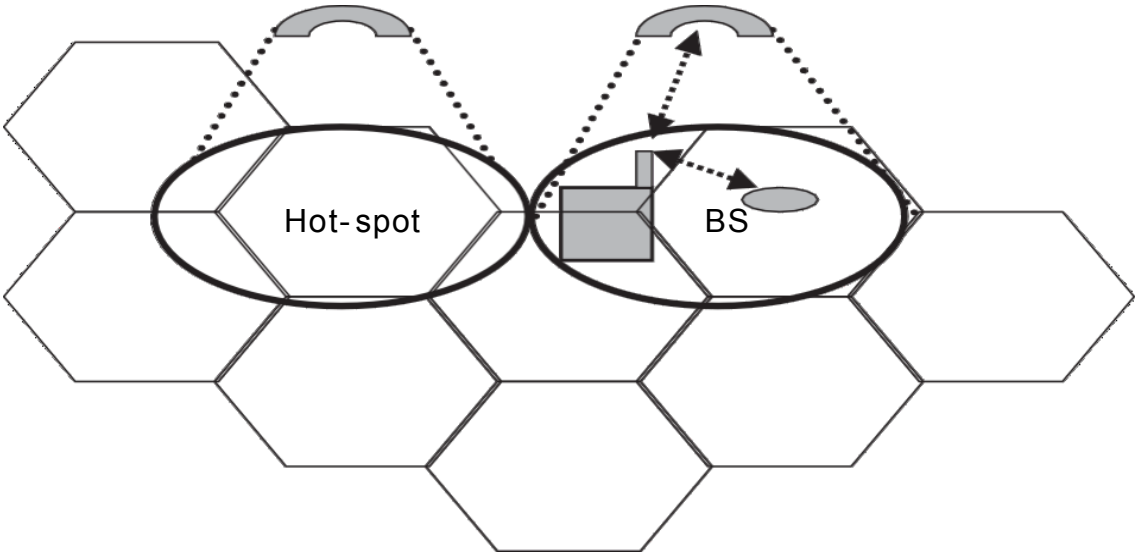
The IEEE's 802.11 standard bodies are developing several additional new specifications. For example, the 802.11i committee is addressing the security requirements of wireless networks, the 802.11e committee is defining Quality of Service (QoS) capabilities, the 802.11h committee is advancing the dynamic frequency selection feature, and the previously mentioned 802.11n committee is trying to significantly increase the bandwidth. Two other working groups are also working on standards for wireless communication: the IEEE 802.16 Working Group has defined and is now enhancing standards for broadband fixed wireless communication, known as Wireless Metropolitan Area Networks (WMAN), potentially an economic solution for the 'last mile' problem (i.e., getting broadband into living rooms efficiently) or as a back-haul for Wi-Fi hotspots. The 802.15 Working Group is working on standards for short distance wireless networks or Wireless Personal Area Networks (WPAN).

4.2. National Wi-Fi networks

Startups are trying to tie the hodgepodge of Wi-Fi networks into a usable national network by recognising the promise of high-speed wireless communication, but everybody wants to be an aggregator, because installation of base stations involves substantial capital investment and few companies are actually adding the hotspots. Even large corporations, not all of them from the telecommunication sector, do not want to miss the opportunity and are exploring and testing the deployment of Wi-Fi networks. Can they build a national service with a wide range of hotspots? Some are suggesting that such a network would enable users to reach the nearest hotspot, at least in urban areas, in at most five minutes. Others believe that such networks can bridge the last mile and supply broadband connection to homes.

An important characteristic of Wi-Fi is its use of the unlicensed spectrum. This means that companies do not need to make huge investments in spectrum acquisition, which would in turn require that they first develop a working business model and raise capital. They can afford to experiment and test the technology while searching for the most appropriate business model with Wi-Fi. For example, T-Mobile USA has built hotspots at venues such as Starbucks, Borders bookstores, and American Airlines Admirals Clubs, where users can pay per use or get unlimited access on a monthly basis. Verizon Communications is testing the market by converting pay phones in Manhattan to hotspots. Customers can pay per day or subscribe to unlimited monthly access. A possible scenario for WLANs in hot-spots is shown in Figure 3.

Figure 3. Deployment of wireless LANs in hotspots



Several municipalities from Portland, Oregon to New York City are building free Wi-Fi 'clouds' covering a certain urban area as a service to attract more

visitors or businesses. For example, the University of Georgia and local government created the Wireless Athens Group (WAG) covering 24 blocks called 'WAGZone' in downtown Athens and launched it on 10 December 2002. The nine access point boxes are mounted on lightpoles around downtown. The WAGZone welcomes laptops and PDAs fitted with wireless networking cards. Users can access to WAGZone content, and they also have access to the internet (Kanell, 2003) if they are University of Georgia students or faculty. The city administration considers WAGZone as just another service to high tech industries that may relocate to Athens and make its downtown an even-more vibrant place. In the WAGZone case, student volunteers did all the work, and investment in equipment was only about $40,000. People involved in the project admit, however, that nobody has yet figured out where the project is going and how to make money on it.

4.3. Small and big business models

Most public Wi-Fi models have suffered both high deployment costs and disappointing customer user rates. The Kerton Group observed a clash between big business economics and small business services. It is true that one can set up Wi-Fi at home for $100 in equipment and $40 a month for a lease of a DSL line, but it is also true that a commercial hotspot provider, Mobilstar, went bankrupt (Kerton, 2003). There appears to be two business models: a small business model which makes sense, and a big business model which has yet to be proven.

For example, a restaurant can set up a hotspot and offer free Wi-Fi access to the internet to stimulate its core business, hoping to just cover the costs and possibly earn some extra income. Such a setup is simple, does not provide e-commerce strength, and does not require logins. Characteristics of this model are small business, small investment, and small returns.

The Big business model is different. When a Wi-Fi operator deploys hotspots in an airport, it must provide multiple access points to cover the area, use union labour to install the wiring above the suspended ceiling, lease a T3 line for back-haul, provide

Virtual Private Network (VPN) technology, authentication, e-commerce strength, ongoing support, and an operations centre. The required investment in this case is hundreds of thousands of dollars. So far, the user demand for such service has been lukewarm. Consequently, instead of the predicted 70 000 total hotspots in the USA in 2003, T-Mobile USA has 2400 commercial hotspots (about half of the US total) and Boingo had some 850 at the end of 2002. Cometa, a joint venture of AT&T, IntelCapital, and IBM, originally planned to build 20000 US hotspots in 2003, but is still testing the service in selected McDonald's restaurants and now plans to set them up overa two-year period. Highly frequented areas such as airports have a potential to make service profitable, but they need significant investments and industrial grade service and support.

The reality is that because of the short range, about 700 Wi-Fi hotspots would be needed to cover the same area as one mobile phone base station. If we assume that a nationwide mobile phone network consists of 10 000 base stations, then it would take seven million Wi-Fi hotspots to provide the same coverage. The back-haul costs alone for seven million Wi-Fi hotspots would be astronomical. Wi-Fi is currently not a viable substitute for 3G wireless services. Please note that Wi-Fi does not support voice services and any use of Voice over IP with WiFi will only make the quality of voice services evenworse! Wi-Fi and traditional wireless services are complementary, as they can exist and succeed together, but only after roaming, billing, security, seamless authentication, handovers and other such issues are resolved.

4.4. New threat: metropolitan area networks

The 802.16 standard is a Wireless Metropolitan Area Network (WMAN) technology that will provide broadband wireless connectivity to fixed, portable, and nomadic devices. It is officially known as the IEEE Wireless MAN standard and can be used to connect 802.11 hotspots to the internet, provide campus connectivity, and provide a wireless alternative to cable and DSL connections for the last mile broadband access. It provides up to 50-kilometre service area range, allows users to get broadband connectivity without needing direct

line of sight with the base station, and provides total data rates of up to 280 Mbps per base station. A single base station provides enough bandwidth to simultaneously support hundreds of businesses with speeds equivalent to a T1 line and thousands of homes with speeds like DSL lines (Anonymous, 2003).

5. The future and conclusion

The future of wireless and mobile networks will involve increasingly sophisticated services that will be context-aware, personalised and user-programmable. These services will offer significant user-empowerment by utilising user preferences and history. Many new applications such as pervasive and vehicular commerce will become reality as the number of vehicles with significant computing and communications power increases substantially. The mobile devices will become increasingly intelligent, personalised and owner-centric devices and carry personal, health, and financial information.

It is possible that global roaming and internet working issues could be resolved in the future 4G networks, which are being designed to provide much higher bit rates. Added complexity could exist in the networks or in the devices, depending on the architectures used. The bandwidth limitations for many existing and emerging applications will become a thing of the past due to increasingly higher bit rate wireless networks, e.g., 3.5G and 4G become reality along with 300+ Mbps high-speed wireless LANs in the next few years. Many other technical advances such as Multiple Inputs Multiple Outputs (MIMO), dynamic spectrum management, and Ultra-Wide-Band (UWB) will offer higher bit rates. The use of IP-backbone for internet compatibility and to support different levels of mobility, from local to global will also become common. The deployment of short- range sensor and ad hoc networks will further extend the reach of wireless networks.

Asian countries such as Japan, Korea, and Hong Kong once lagged behind the West in information technology. Despite its late development and entry into the market, Asian wireless operators have been able to become global leaders with the implementation of the 3G technologies and with the assistance of government policy. NTT

DoCoMo rolled out the world's first 3G services in Japan. The 3G service is a disruptive technology because it allows 3D games, videoconferencing, full motion videos, and high-speed internet access on full roaming mobile phones (Shim, 2005). The telecommunications market in Japan, Korea, and Hong Kong has always been highly regulated by the government. This contrasts with the telecommunications market and liberal policies set forth by the USA (Shim, 2005). The mobile services and applications have begun to experience some success, due to the Asian wireless operators' close relationship with their equipment makers and their enormous influence over this value chain. The future success of m-commerce depends on whether the wireless application developers are able to make good use of wireless technology and wireless devices and ensure that desired applications are delivered to the users. M-commerce applications can be complicated due to the increased customer demands and expectations. The success of m-commerce applications relies on the user's trust which will play a critical role in acceptance and widespread deployment in the world market.

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