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BROADBAND MOBILE COMMUNICATIONS TOWARDS A CONVERGED WORLD

EMERGING TECHNOLOGY SCENARIO: WHAT ARE THE FUTURE BROADBAND MOBILE SERVICES ?

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1. Introduction

In the 1990s, people around the world began adopting digital mobile communications as part of their daily lives. No one would have suspected that this small change in information technology (IT) would be the start of the concept of convergence, the topic of this paper. The cellular phone began to evolve into something more than the phone invented by Alexander Graham Bell, and this was largely influenced by short message service (SMS), which was neither a voice message service or non-real-time e-mail service, but a portable, mobile, mailbox.

From these beginnings of mobile convergence, the integration of the mobile phone and the computer is advancing the ubiquitous era, and the introduction of wireless Internet is driving digital convergence in all conceivable areas, including DAB/DVB, P2P multimedia communications, multimedia messaging service (MMS), 3D audio, VOD/TV, digital camera, games, and cell phones.

But where will the convergence that was triggered by the advent of mobile communications end? Perhaps we will find some of the answers in the lifestyle of the twenty-first century that have been proposed by the concepts of ubiquitous networks or pervasive computing. In another facet of convergence, there has been partial adoption of mobile wallet or mobile banking solutions, replacing the traditional credit card or bank transactions and fuelling mobile convergence.

In this paper, we will analyse convergence in the context of mobile communications, which is becoming a basic infrastructure for the ubiquitous era, from a technical perspective. First, in Section two, we discuss the changes to come in the near future that would be provided by mobile convergence, which will act as a stepping stone into the ubiquitous era where value-added ubiquitous service will be available anytime, anywhere, and through any device.

In Section three, we cover the current status and future trends of technologies that are used in building the infrastructure for mobile convergence. The analyses go beyond the various network and access technologies to cover the technologies involved in ensuring continuity of service and quality of service (QoS) and technologies for broadband mobile communication.

Finally, in Section four, we discuss the basic process of mobile convergence that is either occurring now or is expected to occur in the near future. We examine ALL-IP or NGN IP based convergence of wired/wired backbone network, which may be the most rapidly deployed case of convergence. We also look at the open service environment that will integrate various wireless access technologies into services and enable interoperability between services. In addition, we discuss the future direction of the mobile communication network.

2. What will be the future mobile information society?

2.1 Synopsis

Over the past ten years, the rapid deployment of emerging information technologies, including mobile communications and Internet services, has had a great influence in changing our daily lives, and it continues to influence and affect our lives. It has brought about the innovation of conversion from analogue to digital in telecommunication media, the expansion of temporal and spatial casualness of information transfer by means of mobile technology, and the advancement of lifestyle for more Internet-based information.

This aspect has been accelerated along with the emergence of new IT visions and paradigms such as ubiquitous networks, pervasive computing, and ambient intelligence. The trend is expected to stimulate the development of progressive information technologies beyond the current technical focus on fully mobile and widespread convergence of media.

In the future vision of the "highly developed ubiquitous information society", information technology is supposed not only to take part in information exchange but also to provide the key drivers or enablers for improving the quality of individual lives and social relationships.

The easiest and the most interesting way to present the application of future technology is through scenarios. There are many scenarios that can describe a casual day in the life of an ordinary person in the world where advanced information technology has become part of everyday life In this paper, an ordinary day 10 years into the future is depicted, based on technical reality, to outline the technological developments and lifestyle that are expected to come.

2.2 Lifestyle in ten years

It is an ordinary weekday morning in the year 2013. Lee, a 28-years old single man, wakes up to a morning call that is 10 minutes earlier than his usual wake-up time. Because the traffic conditions around the city are worse than average, his personal agent running in the home server decided a 10-minute advance wake-up call was in order. The agent notifies this throughout the home network, so that all home systems start the morning services for Lee on time. An intelligent robot named Cara brings a cup of coffee and the newspaper to his bed, and lists Lee's daily schedule on its front display.

Lee is still sleepy but he remembers that he instructed the home server last night to monitor the stock markets around the world. He uses his voice to turn on the display on the wall, and the wide DTV screen opens. When he says, "show me the results", the collected market indexes are displayed, and the agent reports that there have been no notable events throughout the night except a short disturbance in the Hong Kong market caused by a rumour of a new SARS outbreak. So he commands, "note the point in the temp file, and monitor all the stock markets worldwide, throughout the day, and report every time the keyword SARS appears in the news." Lee turns the TV to a financial news channel, and gets out of bed.

When Lee is putting on his clothes, he also puts on his personal information devices, including a watch for alarm, badge for membership, belt and armband for health checks, earring for ID, wideband headset, and eyeglasses with camera. He carries a smart PDA and a small flex-keyboard for it. Lee commands the PDA to start his personal system, and his wireless PAN is started and configured for the devices he is wearing. Home server checks Personal ID and the agent status, and recently-used data are replicated into his portable devices. Then his watch alarm alerts him that it's time to leave for work.

As soon as Lee gets in his car in the garage, a vehicle area network (VAN)-based intelligent telematic service is activated to accommodate him. It notifies him that there's a message from the home server which reports two cases of world news on SARS that are affecting the stock market, but Lee wishes to see the news now. He commands his VAN to start Internet navigation with interactive voice service. Internet connection in the display is briefly read by the service and his voice acts as input control for the page. He turns to different channels to watch the traffic conditions and parking availability downtown, monitors the information for an optimal route to the office and searches for the nearest petrol station.

Lee arrives at his office and attends a briefing with his partners in the overseas branch offices. Several wall-mounted screens are open and on for the discussion, and many reference data are displayed. Some 3D graphics and display are used for more detailed presentations. While talking with the partners, Lee allows his agent to report on the SARS news from time to time and monitors the video feed from the local stock office to check out traders' responses.

After the meeting, Lee wants to have a Chinese lunch and commands the agent in his office, using voice command, to find a suitable restaurant nearby. The agent finds the restaurant that best fits the search criteria and makes a reservation. Lee selects and orders a dish from his office, which is ready for him when he arrives at the restaurant. Even while having lunch, he can access the Internet and the intranet using his smart PDA, display watch, or fixed display in the restaurant. Since convenient and easy access to the Internet is always guaranteed, he is able to buy a necktie from an Internet shopping mall while he is eating.

2.3 Workspaces on broadband mobile multimedia

Lee's lifestyle, in such a highly enhanced information environment, is an extreme example of primary use of a technological development, often described as the expansion of user access bandwidth. Broadband is a basis for enabling multimedia communications including video service, which requires transmission of a arge amount of data; it naturally calls media convergence aspect, based on packet transport, advocating the integration of various media on different qualities.

Technology development on mobility and bandwidth enhancement is nearing completion and integration of various services such as broadcasting and wireless packet access technologies is well under way. Recently, a strong trend of convergence known as "IP goes mobile and mobile gets IP" has surfaced, which is a competitive way of evolving toward the broadband mobile multimedia packet service.

This widespread convergence technology enables virtual reality communication, distance learning, remote medical services, security and remote monitoring, distributed multimedia collaboration and teamwork/telepresence and many other applications surmounting spatial distance. IP provides inherently good interoperability, such that a barrier-free connectivity can easily be achieved.

Formation of instant and temporary workplaces over temporal and spatial casualness induces a trend of making many communities, and the power of it is to be strengthened. Technology development is greatly influencing people's work and social lives, and it will ultimately lead to standardization of a highly technical culture and society in the future. New jobs will be created, and many applications designed to improve personal efficiency will be deployed.

2.4 Entering the ubiquitous information society

Advancement of user service technology based on the widespread convergence of broadband and mobile multimedia capability creates another breakthrough when it is combined with the new technological advancement of intelligent service application and micro/embedded device technology. These two technological trends produce synergistic innovation of basic communication models. Terminals and sensors are becoming the major source of data, and context-aware services are becoming common with a wide spread adoption of intelligent applications. These new challenges could bring about a new paradigm of ubiquitous information service.

Ubiquitous service refers to the maximization of users' convenience by means of user-centered, seamless services and the utilization of widely distributed resource and information. Reality communication capability based on the broadband network supports the exchange of meta data of communication parties, which carries informal information such as atmosphere, human sensitivity, and feelings.

Giving definition to the ubiquitous information society, many types of national-scale intelligent application services are expected to be introduced, such as personal identification and public control, various kinds of concierge service, social resource monitoring, road and traffic sensing, and national territory monitoring, etc. Entering to the ubiquitous information society will be initiated on such technical movements and changes to users' workplace, and can be expected to take full shape over the next ten years.

The lifestyle that our fictional character Lee will experience in the near future presents some of the changes that will result from today's rapid development of Internet based information society. Also, we can guess that, at least in the short term, the mobile communication sector will have a heavy influence in shaping the development of the ubiquitous society. Various technologies from different areas of IT will enable such changes to come about, but in mobile communications, which will act as the core infrastructure, multimedia services will be added to the existing voice services, migrating to IP-based network infrastructure, wireless Internet will be enabled, and a fourth-generation mobile communication environment that will provide large data transfer capacity. In Section three, we will examine some of the major technologies in mobile communications and the direction in which they are moving.

3. Key technological issues and ongoing activities

3.1 Seamless mobility

Future broadband mobile communications aim to provide seamless services for all types of mobile communication services regardless of network or handset type. This is expected to be achieved through IP-based networks that support portability for seamless interoperation between different networks, rather than through a single new network. Therefore, in this section, we discuss the need for service continuity through interoperation between different networks and the technologies that will enable such interoperation.

3.1.1 Service continuity

With rapid advancement of mobile communications, the usage rate of circuits is reaching saturation levels and the demand for data services such as Internet is drastically increasing. As such, the mobile data service is evolving into a high-speed service capable of handling anything from simple SMS to large capacity multimedia services.

Aside from this, as connectivity to wired high-speed Internet has expanded, the demand for mobile communications to offer a similar level of high-speed data service has also increased. As a result, the technical solutions required to provide such high-speed mobile data service, such as standardization of wireless LANs (WLAN) and the development of various products have been actively occurring. Through activation of WLAN service, users can be provided with the same level of multimedia service in a wireless environment as they have been provided in a wired environment, rather than through the limited wireless Internet like wireless application protocol (WAP). WLAN service provides Internet connection through the same IP based network as in the wired Internet service, unlike the existing data service, which provides connectivity through conventional wireless telecommunications network. Therefore it can provide the same level of service through the same type of terminal regardless of whether the connection is wired or wireless, and high-speed data transfer rate of more than 54 Mbit/s is expected to become available in the near future.

However, despite its high data transmission rate and low price, WLAN service can be provided only to such limited locations as hotspot areas, companies, and households because of its limited coverage. So the possibility that the user will be provided with the data service like the Internet at any time and anywhere is limited.[1] In particular, for a user who is constantly on the move, it is difficult to provide seamless and continuous data service because the mobility management function such handover in mobile communications is limited.

Because of the advantages and the disadvantages of the mobile communication service and WLAN services like these, the interest in providing service continuity through mutual interworking between these systems is growing. In order for this to work, however, IP-based mobility management technology, that assures service continuity even when access network is switched while a user is moving, is required. In addition, the evolution to all-IP networks in mobile communication to enable the services that can operate in different networks will become an important issue for the future broadband mobile communications and the development of the Internet.

3.1.2 Horizontal and vertical mobility

Global roaming

A multimedia service that provides voice, data, and images services through wired, wireless and satellite environment and a global roaming service that can transmit all over the world are the concepts behind the 3G mobile communication system. The existing 3G systems were aimed at achieving global roaming through uniform worldwide technological systems and bandwidth frequency, but failed due to the division of the technological system into synchronous and asynchronous systems. The future broadband mobile communication system aims to achieve a seamless global roaming service through inter-system handover (vertical handover) designed to enable handover between different technological systems and different bandwidth frequencies.[2] In order to achieve this goal, various key technologies such as vertical handover technology and software definded radio (SDR) technology, providing the flexibility of the terminal structure, are needed.

Handover

Future broadband mobile communications should be based on a broadband system of wired and wireless mobile service that is able to transfer between different networks, and they should also provide the level of quality appropriate for the high-speed mobility of a terminal. One of the biggest problems in providing wireless service to fast moving subscribers is service continuity. This article hopes to explain the necessity of the fast handover technology and the inter-system technology as the major fundamental technologies required to achieve seamless service continuity in the future broadband mobile communication system.

Unlike the 3G mobile communication developed to date, future broadband mobile communications set the goal of ensuring high frequency efficiency and high transmission rate to a moving terminal at a low price, and providing various types of QoS, etc. As key technologies for this, OFDM, Multiple Tx/Rx antenna technology, enhanced coding scheme and link adaptation scheme, among others are currently being developed. In addition, the research and development of micro/pico cell structure to enhance the frequency efficiency and provide high data transmission rate are also currently under way. The development of future broadband mobile communications is expected to centre around the micro/pico cell, but the problems in mobility management functions such as overheads and decrease in system performance due to frequent handovers, must be taken into consideration. So a key technology such as fast handover algorithms is required in order for future broadband mobile communications to provide fast-moving terminals with seamless service in a micro/pico cell environment.

A fast handover basically refers to the fast performance of the handover process, but fundamentally, its purpose is to enable a service where the user does not sense the interruption of service caused by a handover. So it includes not only fast processing of the handover between cells, but also all types of algorithms that ensure that the user does not notice the service interruption or any decrease in performance.

One of the objectives of future broadband mobile communications is the development of a ubiquitous IP based system designed to utilize various wired and wireless environments and the connectivity technologies on a common infrastructure. That is, instead of a single 4G communication system existing, it aims to enable interoperation not only with the wireless personal area network (WPAN) based on the existing 802.11 WLAN or Bluetooth, etc., but also with the 2G or 3G mobile communication system. This is so that a fourth-generation mobile communication system, which cannot be built instantly to cover the entire region, can be built in localized hotspot areas for providing high-speed data communications and in regions outside the hotspot areas, a user can continue to receive optimal services through their terminal via interoperation with existing systems. In order to provide seamless service between different systems, a technology called vertical handover, which enables handover between different types of systems, must be deployed, and in order to enable the use of vertical handover, a dual-mode terminal or a terminal that supports different types of systems is needed.

Currently, dual-mode terminals that support WCDMA and GMS/GPRS systems and a handover technology between the two systems are in place and in use. Also, research on other dual-modes is currently under way. However, in the future, the SDR technology that makes global roaming possible by providing flexibility in the terminal structure that allow it to download a object-oriented structure application software on an open unified hardware platform will replace the dual-mode technology.[3] In addition, research on the overlaid cell architecture between different types of communication systems is necessary.

IP-based mobility

In the existing mobile communications system, transmission of voice traffic is most important. Therefore, services are provided on the basis of protocols for voice calls, and the handover technology is limited to handovers between cells or between mobile switching centres (MSC). However, as the demand for data traffic increases and connections to the wired network server for the World Wide Web (WWW) or FTP service become more frequent, not only is handover between cells and between MSCs needed, but so is mobility in the upper layer. In addition, because all systems on the mobile communications network are moving to an ALL-IP or pure-IP structure, mobility in the IP layer and handover have become a major issue requiring consideration.

The Internet Engineering Task Force (IETF) has defined mobile IP to support host mobility, and is working to implement standardization to enhance mobility through the Mobile IP working group and SeaMoby working group. Mobile IP is a protocol that supports host mobility. Using the concepts of home agent (HA) and care-of address (CoA), it enables a packet incoming to a moving terminal to be transferred to CoA via HA through tunneling. CoA, unlike the host address in the existing IP system, is an address that includes the location information of the host, and it can change as the terminal moves. When the host is visiting a different network, Mobile IPv4 sets the address of the foreign agent (FA) as CoA and then registers it in HA, while Mobile IPv6 sets the address the terminal has obtained in the visiting network through auto-configuration as co-located CoA, then registers it in HA.

However, because the Mobile IP technology has until now mainly focused on providing mobility in the wired Internet environment, it has many limitations so that a seamless handover that is able to process the frequent mobility cannot be supported. Especially when real time services such as voice service is provided in the wireless Internet environment, the need to resolve the issues of delay and packet loss due to handover will become even more urgent. Consequently, mobile IP technology that can support a more efficient handover process is expected to become critical.

Many proposals to improve this situation are being presented. At this time, the Mobile IP WG defines research on the fast or low latency handover in IPv4 and IPv6. The pre-registration handover carries out the layer 3 handover before the layer 2 handover is completed, and the in post-registration handover, the old FA commences the handover request to the new FA when a demand for a handover occurs. In addition, research is being conducted on hierarchical Mobile IP that is comprised of hierarchical FA for managing mobility, to prevent unnecessary signal traffic and delays that occur when mobility within the visiting network is transmitted to the home network. As for the SeaMoby WG, it is in the process of standardizing the techniques to reduce delay during handover and standardizing the paging technology to reduce the signal load and electric-power consumption caused by frequent registration. It is conducting research on the context transfer that enables transmission of context information needed between FAs at handover. It is also conducting research on the candidate access router (CAR) discovery that locates the access router to handover, as way to reduce the handover delay. In future broadband mobile communications, Mobile IP technology is a must for seamless service continuity of the terminal, however, this must be preceded by research on fast Mobile IP handover algorithms to minimize the processing delay of Mobile IP.

Application mobility

Future broadband mobile communications encompass the Internet service that includes voice and image transmission technology such as the Internet telephony (VoIP) service evolving from the existing wired IP network. Session initiation protocol (SIP) is the representative protocol for applications associated with Internet telephony. SIP is a call control protocol on the application layer that provides such functions as call set up, call information correction, and call termination, etc., for the purpose of providing Internet Telephony service.[4] Thanks to its simplicity, applicability, scalability, and modularity, the SIP is used not only in the field of Internet Telephony, but also in research associated with IMT-2000, 3GPP, intelligent network, and next-generation network (NGN) architecture.

To support mobility of the terminal in an IP network, the most easy and hierarchical method is to provide transparent handover to the upper layer using Mobile IP that supports mobility in the IP layer as mentioned above. But Mobile IP is known to be inappropriate in the applications sensitive to delays due to shortcomings such as encapsulation overheads as well as triangular routing delays. Accordingly, for terminals that receive Internet telephony service, which is sensitive to delays, research is being conducted to provide service continuity by supporting mobility technology through SIP, as described below.

Extension of the existing SIP or having it based on the Mobile IP are being proposed as important issues in supporting mobility in SIP. The former method adopts an application level approach for real-time mobile communication. When the mobile terminal moves to the external network, the target terminal can obtain the address of the mobile terminal from the SIP redirect server. In this method, since the application layer handles the process regarding movement, tunneling that is needed in Mobile IP becomes unnecessary. However, access methods that do not offer mobility in the network layer cannot provide mobility to applications that are independent of SIP. Another disadvantage of this is that supporting SIP mobility is fundamentally impossible in the network that does not support DHCP, which is used by the SIP client to obtain a new IP address. Consequently, the first method will lose its relevance when the networks move toward ALL-IP, and the Mobile IP is supported, creating the need to harmonize with Mobile IP. Also, supporting mobility through the extension of SIP only applies to the corresponding applications and is not relevant to the fundamental concept of providing Internet mobility. As a result, current research is mainly focused on the latter method of providing mobility through modification of SIP based on the Mobile IP, but the current definitions of SIP functions do not satisfy all requirements for mobility in future broadband mobile communications. Accordingly, SIP is continuously being expanded, and research on enhancing the quality of the Internet service in the mobile communication network is being conducted.

3.2 Broadband content delivery

The communication service market recently moved rapidly from voice-centered service to data-centered service. Fast and high-quality IP based multimedia service is expected to become common in the future. The current voice telephony market faces subscriber saturation in both wired and wireless networks, and as the market for replacement services like VoIP grows, the voice service market is expected to stagnate or decrease. On the other hand, in the data market, the traffic is rapidly increasing every year due to the rapid expansion of the Internet. In order to process the increase in data traffic, investments in super high-speed communication systems is needed, and the need for expansion of the fundamental technology for the development of the radio transmission system cannot be over-emphasized. In this section, we will examine the capacity of the present transmission technology in comparison with the processing and transmission technology of the radio transmission system, and we will review the issues regarding new radio transmission technology.

3.2.1 Capacity and performance improvement

The present wired Internet provides a high quality service at a low price, but it has a shortcoming that limits the area of utilization. On the other hand, mobile communications provide lots of mobility so that the area of utilization is very wide, but the fees are high and service quality is very poor. Therefore there is a need for a universal super high-speed portable Internet service that provides high mobility and network speeds of several Mbit/s capable of transmitting multimedia content at a low price.

The evolution of mobile communications can be categorized into that of the North American market and the European market. In North America, the 1G system used the analogue AMPS method, and then evolved to TIA/EIA IS-95 in 2G. It is expected to evolve to cdma2000 1x and 1xEV-DO, 1xEV-DV to cdma2000 3x in the future. The European system on the other hand, is expected to evolve over the GSM network, which is a voice-centered TDMA method, with GPRS for data communication, and is subsequently expected to ultimately migrate to W-CDMA. Although 3G technology looks not so promising, people are already discussing 4G technology. Global roaming, one of the services expected to be offered in 3G, is not showing much promise, but is expected to be accomplished in 4G. The core technologies for fourth generation include OFDM, MIMO, SDR, Smart Antenna, and ALL-IP.

With the present-day technology, it is difficult to provide multimedia service over the current mobile communication network because of the low transmission rate and high price. Cdma2000 1xEV-DO, which is currently undergoing commercialization, is said to provide theoretical maximum speed of 2.4 Mbit/s but in reality, its speed is under 600 kbit/s. In addition, the W-CDMA method of asynchronous IMT-2000 is expected to be at around 384 kbit/s. WLAN is originally a technology used to establish a private network in a conference room or an exhibition room, but in the domestic market, its range of utilization has been largely extended as a result of Internet providers installing hotspots in public places such as train stations, airports, and hotels.

The currently available WLAN service, based on IEEE 802.11b, offers an actual speed of 5~7 Mbit/s, and even though its maximum speed is limited to about 11 Mbit/s, in the future, its speed will be enhanced up to maximum 54 Mbit/s with actual speed of 10~31 Mbit/s when 802.11g or 802.11a with OFDM transmission technology are introduced. The WLAN technology has difficulty in providing a broadcasting service with TV quality image, and for the voice telephony service, VoIP must be applied.

The 2.3 GHz bandwidth, which has been attracting interest recently regarding its application to portable Internet, was originally a bandwidth allotted to the fixed wireless network. Efforts to utilize this bandwidth as portable Internet are being made mainly by the communication companies in Korea to whom this bandwidth is allotted. For the future wireless access market, assuring lower price and enhanced speed using the existing cellular network, and assuring mobility to a certain degree will become critical. Currently, the standardization of this bandwidth has not yet been established, so the technologies of systems companies are being examined. As with the WLAN, the portable Internet also has difficulty in providing broadcasting service with TV quality image, and for voice telephony service, VoIP must be applied.

3.2.2 Innovative wireless technologies

Software defined reconfigurable radio

Recently in 3G communication technology, SDR, which started from the concept of programming of base band signal process, is gaining importance as a way to develop a multi-bandwidth/multi-mode system.[5] The concept of SDR is a technology that enables a system composition that can be applied to both the existing and the new system standards by using recomposable parts such as the high-speed digital signal processor, field programmable gate array (FPGA), to enable processing of signals from base band to RF/IF signals.[6]

The SDR technology that makes seamless global communication possible by allowing object-oriented structure application software to be downloaded on the open unified hardware platform for establishment of a system that is flexible and applicable to various wireless environments, is considered a system technology that can provide multi-standards, multi-processing frequency, and various services by enabling a single system to accommodate the various existing standards in the mobile communications market. The introduction of SDR technology into a commercial system, following the example of such implementation in the military system, has already begun, and the interest in SDR is increasing as the worldwide SDR standardization organizations are formed in Europe and the United States.

Differentiated service

ITU-T recommendation, E.800, defines QoS as "the collective effect of service" performance that determines the degree of satisfaction of the service user.[7] To satisfy QoS, cooperation between various elements that are different from each other is required. For example, the required QoS can be destroyed by a single network segment. Consequently, QoS must be considered in terms of cost and complexity, and capacity.

Several basic QoS functions can be already accommodated in the Internet. IP QoS mechanisms like transmission control protocol (TCP), explicit congestion notification (ECN) and real time protocol (RTP) that are commonly used on the Internet, follow mostly end-to-end mechanisms, and even in a network that does not have features characteristic of wireless or mobile environments, they are unable to support real-time services that assure instant packet transmission.

Researches have been conducted on these problems over the last several years at IETF, and until now, the development of the Internet did not take the problems brought by mobility and wireless into consideration. This is apparent in most of the new IETF standards, and the direction of future research and development should take these problems into consideration as their fundamental issues. In addition, more research must be conducted to support QoS in user mobility and wireless IP environments to resolve these issues.

The transmission capacity of the fiber optic networks is reaching levels of hundreds of gigabytes, and in the transmission network, a switch that can ensure QoS when high-volume traffic is being controlled or exchanged is being developed. This is because expansion of present IP-based transmission network cannot guarantee high-quality multimedia service. The data quality of the IP-based transmission network cannot be assured because it is a connectionless network that searches for its destination according to the best effort method which is characteristic of a router. Technology that can assure data quality in the IP network includes Int-serv and Diff-serv, but their application is not easy.

Therefore, MPLS technology, which can be applied to convert the fundamentally connectionless quality of the transmission network into a connection-oriented network, is emerging as an alternative to the QoS guaranteed network. This type of transmission network must be capable of large data transmissions, ensure QoS between subscribers, provide security and support the IPv6 address system.

Open spectrum

Wireless fidelity (Wi-Fi) is the popular name of the wireless Ethernet, IEEE 802.11b wireless local area communication protocol preferred for WLAN, and it uses the unlicensed 2.4 GHz band.[8] Currently, WLAN provides a 300-feet range from the base station and up to 11 Mbit/s in data transmission rate, and it is installed and used typically as a part of the private network connected through the interoperation of the wired backbone network. The user's cost of using the network, that is, the cost of using the network for business purposes such as private telephony, is mostly free. Although Wi-Fi was designed originally for private use, it is sometimes installed in a public locations referred to as "hotspots", where broadband Internet connection is available. The new application of Wi-Fi is an opportunity to open a new market for Wi-Fi.

In considering Wi-Fi, there are some key challenges that must be overcome technically and with regard to its business model. These challenges are classified into four broad categories: ease of use, security, mobility, and network management.[9] That is, Wi-Fi must represent a hassle-free, convenient solution, resolve the existing security and mobility challenges, (it is relatively easy to enable the mobility of Wi-Fi within a building, but it is very difficult to expand into public hotspots any time), and overcome network management difficulties, which means that the Wi-Fi network service which includes hotspots must be resistant to attacks from users and hackers, and interference from other systems. As seen thus far, this section has covered the development of major technologies that are required to establish future mobile information society. The future information society will evolve to provide an infrastructure that can transmit multimedia data in wired and wireless environments, without limitation on time or space, through interoperation of existing and newly developed networks. In other words, seamless mobility technology must be developed to remove existing restrictions in using services, and in order to enable the use of large amount of multimedia data, new mobile technologies, such as radio transmission and efficient use of frequencies, must be developed to allow large data transmissions over the wired and wireless environments alike. In the end, the continued development of these technologies is expected to bring about an information society centered on mobile communications, and the much talked-about ubiquitous environment will be realized in the near future. In the following section, we will discuss the development and evolution of the new mobile communications network from the viewpoint of the convergence paradigm.

4. Broadband mobile convergence network

Following relatively successful trial periods, many mobile operators worldwide have started to deploy 3G wireless networks. Broadband connectivity of up to 2 Mbit/s, terminal mobility and multimedia services will provide a substantially wider and enhanced range compared to 2G systems.

Unlike the exemplary 2G story, however, 3G has had to face a difficult economic situation worldwide, which affected the communication sector and created a vicious cycle in which communication manufacturers could not afford to invest in new mobile systems research, and operators could not afford the risk of immature technologies. Moreover, the success of 2G voice and SMS applications contrasted with the lack of a new killer 3G application, apart from the mobile Internet, and the expensive and time-consuming spectrum licence auctions further delayed 3G system deployment. On the other hand, this situation provided an opportunity for emerging free-free WLAN and WPAN technologies to be deployed, capturing a fast growing market with minimum initial investment and operating costs.

It is an appropriate time to look beyond 3G and search for breakthroughs that will bring true broadband mobile wireless technologies. Mobile operators and application developers are continuing to seek new applications and services that could potentially generate additional revenues and increase usage. The vision of future mobile networks in the converging environment, will be the provision of broadband access, seamless global roaming, widely available multimedia, and utilization of the most appropriate connectivity technology.[10]

In addition, the current communication era of connectivity in cyberspace, such as building up the intranet, Internet and mobile networks, is being augmented by a growing focus on connectivity in the real-space. Over the next 10 years, the application of smart, embedded computing power in everyday objects and places will be the next major area of focus.

4.1 Perspectives on mobile convergence

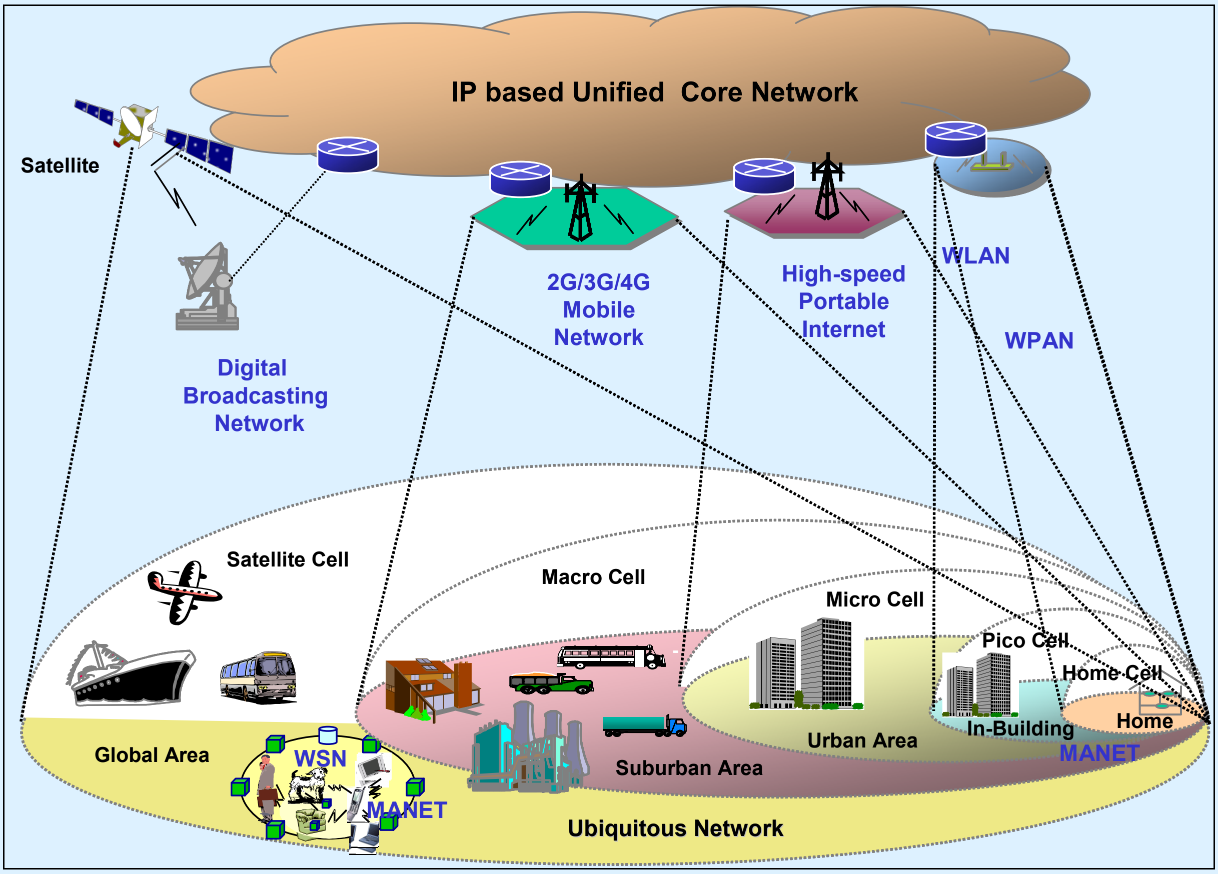
In general, there is a definite movement towards integration and convergence of heterogeneous wireless access networks. This trend not only includes cellular network but also emerging systems, such as WLAN, WPAN, wireless sensor networks (WSN), mobile ad-hoc networks, digital broadcasting networks, and the Internet, which will complement or expand current and next-generation cellular networks. Based on this trend, it is envisioned that the network environment for future broadband mobile communications will consist of an IPbased packet network infrastructure offering converged services. In considering this future prospect, consolidating various media and services as well as wired and wireless network is an efficient approach, and establishing the standards for these services is arousing worldwide interest. Communication service providers are increasingly trying to introduce new services in the wired and wireless integration service area that combines the quality of the fixed line and convenience of the mobile wireless network.

4.1.1 Concepts and characteristics

The concept of convergence refers to creation of the environments that can ultimately provide seamless and high-quality broadband mobile communication service and ubiquitous service through wired and wireless convergence networks without spatial and temporal constraints, by means of connectivity for anybody and anything, anytime and anywhere. As a result, new entrants from other areas and strategic countermeasures by the current market participants accelerate convergence between different areas and ambiguity of business area definition. Convergence among industries is also accelerated by formation of alliances through participation in various projects to provide convergence services.

Various mobile wireless access systems will coexist to provide integrated services. Satellite, cellular, WLAN, digital broadcast, and other access systems will be connected to provide integrated and seamless services via a common IP-based core network. The heterogeneous access systems may be organized in a layered structure according to their application areas, cell ranges, and radio environments. This allows flexible and scalable environments for system deployment. Seamless interoperation between the different access systems will be performed by vertical handover or session continuation. In the layered cell environments, various systems can be used simultaneously — the hotspot layer for very high data-rate applications, the personal network layer for short-range communications, and the cellular layer for wide-area communication.[11]

Figure 4.1: Hierarchical Cell Configuration of Mobile Convergence Network



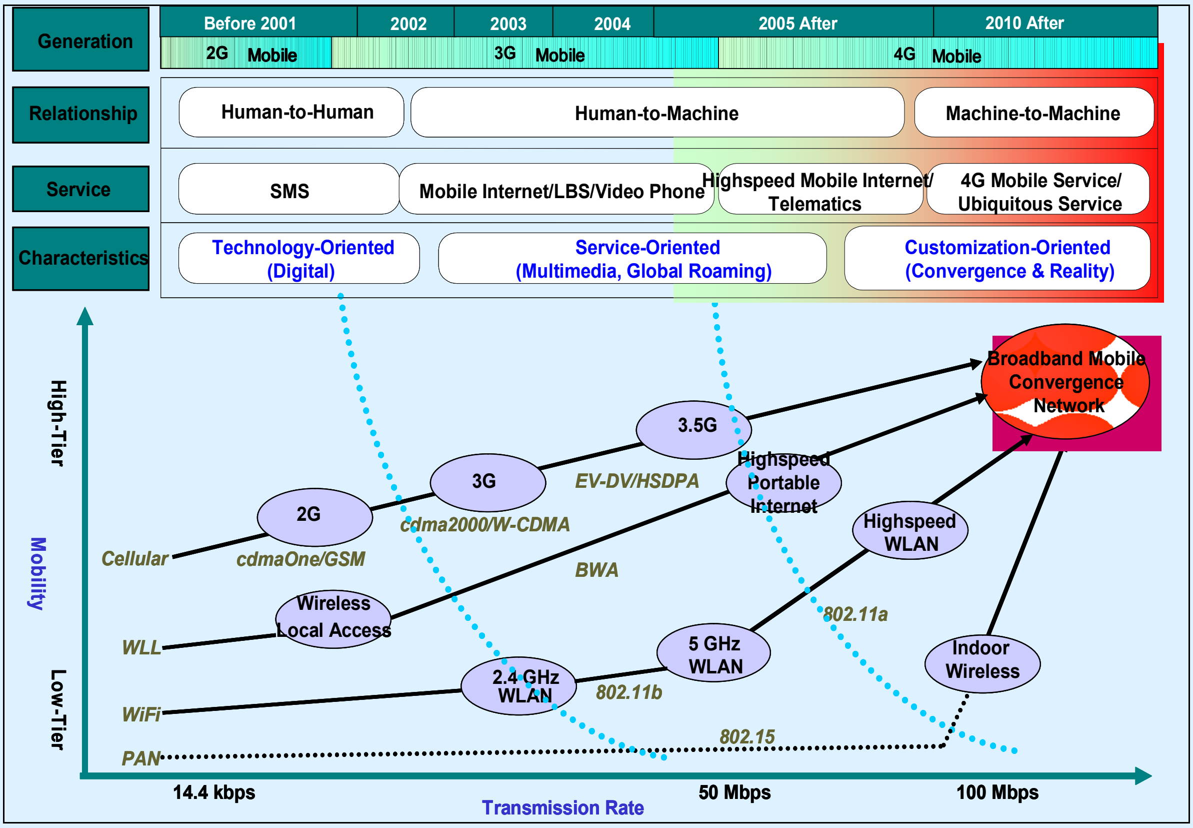
Source: ETRI (internal document).

Deployment of a global ALL-IP mobile wireless network, however, is expected occur through evolutionary rather than revolutionary steps. As a result, the mobile wireless network infrastructure may be organized into a cell hierarchy as shown in Figure 4-1, based on technology either already deployed or still under development. Starting from the home cell with coverage in private buildings such as a house or officeto public hotspot locations such as airport, train station, conference center, service may be provided through an access point. In a hierarchical multi-layered cell environments, extra intelligence is required so that the network can find a specific terminal or the terminal can determine the boundaries between wireless networks and switch to the most appropriate one.

4.1.2 Visions and directions

The idea of 3G became evident with the need for more capacity, new frequencies, and higher data transfer rates. It was expected that a unique, truly international standard would be established, but unfortunately attempts to do so remained unsuccessful. Although 3G standards have created some harmony in global cellular standards, differences remain and new emerging networks must coexist with existing ones. In addition, the technology wave that emerged including such technologies as WLAN, WPAN, mobile ad-hoc network and WSN has added even greater diversity to the range of coexisting technologies. Many of these technologies will continue to evolve quickly and most cellular industries have been propelling the research of future broadband mobile communications while deploying 3G networks.

Figure 4.3: Visions for broadband mobile communications



Source: ETRI (internal document).

In order to discover new growth sectors in the area of future mobile information communications, many active research projects on next-generation broadband mobile communications are being conducted by related international organizations or research centres such as the Wireless World Research Forum (WWRF), the Next-Generation Mobile Communication Forum (NGMCF) in Korea, the Mobile IT Forum (mITF) in Japan and FuTURE in China. The objective of the WWRF is to formulate visions among industrial and academic circles on the direction of future strategic research in the wireless fields, and to generate, identify, and promote research topics and technical trends for mobile wireless system technologies. It is thus intended to contribute to the work done within the UMTS forum, ETSI, 3GPPx, IETF, ITU and other relevant bodies in relation to commercial and standardization issues deriving from the research.[12]

In addition, cellular communications providers and carriers have been taking part in the Third-Generation Partnership Projects(3GPP and 3GPP2), which are revisiting the design of third-generation networks with the goal of enhancing IP mobility-related solutions to deliver seamless mobility without impairing cost effectiveness, application flexibility, and transparency of IP technologies. Currently, 3GPP and 3GPP2 are working at developing harmonization for converged IP-based mobile communication networks. On the basis of this trend, it is expected that the future broadband mobile communications may evolve as shown in Figure 4.2.

4.1.3 Possibilities and challenges

In the future, stakes will be higher than ever. Rapid consolidation in the communication market is driving a number of mobile operators to the edge. To stay competitive, carriers need to develop new technologies and create new areas for growth. With the expanded sensing and tracking capabilities, the ubiquitous networks will bring about a convergence of the virtual and the real worlds. The realization of a barrier-free networking environment is the essence of ubiquitous networks that offer communications access for anyone, anywhere, at anytime.

Now is the time for us to review the necessary technologies to sow the seeds for new services. Technical magazines and conferences are bursting with articles and discussions comparing WLAN and 3G cellular environments. This is based on the phenomenon that WLANs are being deployed not only in residential and small offices, but also in large-scale enterprises and public areas such as airports, shopping centres, and neighborhoods. Carriers are struggling to take advantage by offering public WLAN services and integrating them with their own infrastructure. In addition to cellular and WLAN, we will see a number of fundamentally new wireless network architectures and services. Mobile ad hoc network, WPAN and WSN will be an important components for service paradigm shift in the future broadband mobile information society, and these may produce give rise to drastic new challenges.

In accordance with the new multimedia service requirements such as intelligent location-based, high-speed with large-capacity, and cost effective service, future broadband mobile networks will provide much greater service differentiation and customization. In particular, managing the location information itself will need new approaches since many new differentiating services will rely on location information. In addition, a key challenge for the future mobile communications is service continuity across diverse wireless access network environments. There are important questions to be resolved on how to most efficiently adapt to diverse conditions such as networks and bandwidths, when to switch between systems, and how to determine which layer should be responsible for different functions. Also, new Radio Transmission Technology (RTT) for expanding system bandwidth capacity and improving spectral efficiency is another crucial technical challenge.

In this way, search and analysis of core technical issues, and finding a solution for these challenges will accelerate the realization of future mobile information society with broadband, seamless mobility and convergence being the key buzzwords.

4.2 Technical approaches to mobile convergence networks

Convergence may be defined as an integrated or coupled phenomena associated with diverse networks, services and providers. In terms of the business value chain, convergence is considered from the perspectives of services, networks and terminals. Network convergence enables wired and wireless services to be provided using the same infrastructure and highlights the importance of interoperating networks and inter-networking.

In this way, future broadband mobile communications may involve a mix of concepts and technologies in the making. Some can be recognized as deriving from 3G, and are called evolutionary, while others involve new approaches to mobile wireless, and are sometimes labeled revolutionary. What is important, though, is the common understanding that technologies beyond 3G are of fundamental relevance in the movement towards a converged world. In particular, the major drivers toward ubiquitous communications and services will provide a new paradigm for a generation of convergence communications with value-added features and applications.[13]

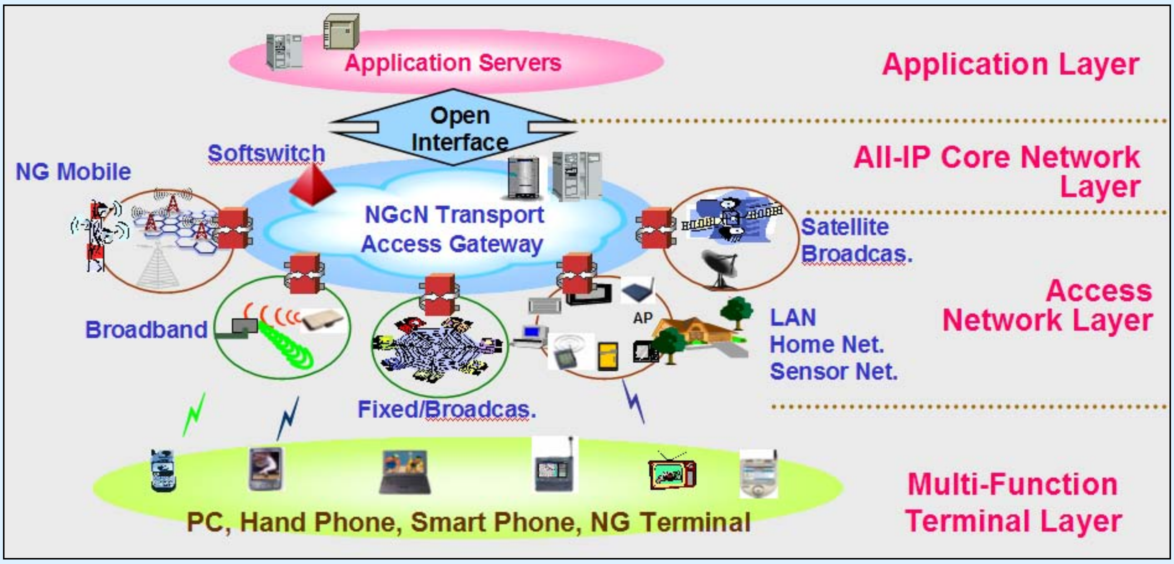
Meanwhile, the trends from the service perspective include integration of services and convergence of service delivery mechanisms. In accordance with this trend, mobile network architecture will become flexible and versatile, and new services will be easy to deploy. This is likely to be realized along the following general principles, such as network architecture based on IP technology, modular construction using expandable components, and open interfaces between various systems. The IP-based network platform includes core network components and access network components. IP-based core network components are access technology independent, and access network components are access technology dependent, consisting of functional components such as control functions and transport functions.[14]

4.2.1 All in one

ALL-IP networking and IP multimedia services are the major trends in the wired and wireless network. The concept of the next-generation convergence network (NGcN) incorporates the provision of a common, unified, and flexible service architecture that can support multiple types of services and management applications over multiple types of transport networks as shown in Figure 4.3. There are essential attributes of this next-generation service architecture such as layered architecture, open service interface, and distributed network intelligence. It has characteristics such as open network architecture for ease of deploying new services, ALL-IP based integrated transport networks, integrated services and billing management, heterogeneous access network and multi-function terminals.[15]

For the "all-in-one" service under the NGcN paradigm, the service platform evolves a unified network architecture for all services irrespective of service type, contents, and connected network, which is flexible, scalable, logically integrated but physically distributed. It utilizes low-cost commodity servers and gateways physically separate bearer and transport from session control while maintaining reliability and manageability. In particular, the benefits of open network application programming interface (API) provides network operators a migration path to future networks independent of network technology, allows operators to deploy new and innovative services, allows operators to use third-party developers to create new applications and services, and enables operators to explore new business models. The Parlay group is the open industry consortium focused on defining an open network API to enable software developers to exploit this power.

Figure 4.3: Conceptual model of next-generation convergence network



Source: ETRI (internal document).

Currently, the number of mobile communication service providers capable of entering into the market is limited, as, unlike fixed-line communication, they have to utilize the limited resources of the frequency bandwidth. This constraint has brought about the emergence of the mobile virtual network operator (MVNO), an unlicensed mobile communication service provider that provides service through a mobile network operator (MNO) network licensed to use the frequency, which is a prerequisite for providing the mobile communication service. The MVNO implies full opening of the mobile communication network since it separates mobile communication network operators and service providers. This may result in more competition in the mobile communication market, utilize unused frequency resources in the mobile communication network, and provide an opportunity for the fixed-line service providers to effectively enter into the wireless communication area, as well as contribute to wired and wireless integration.

4.2.2 Integration, interworking and interoperability

One of the development objectives of future broadband mobile communications is the development of IP-based systems designed to utilize various wired and wireless environments and connectivity technologies over a common infrastructure. That is, rather than a single future broadband communication system, it requires interoperation not only with WPANsor WLANs, but also with the 2G or 3G mobile communication system. As a result, different types of mobile technology are being deployed and developed. Consumers need to be able to access consistent services easily regardless of the type of device they are using or the type of network that is being accessed.

In this way, wireless communications systems will be more heterogeneous, and seamless integration of these heterogeneous wireless systems will be important to enable interoperation among them. Interoperability means the availability of well-defined gateway points and functions between networks. Consequently, interoperability is likely to be a key technical issue to be addressed to ensure widespread adoption of services. From the perspective of system interoperability, the future mobile network will be required to support global standards such as standardized interfaces between networks, effective and user-friendly operation, administration, maintenance and provisioning (OAM&P) facilities, and backward compatibility with existing legacy mobile networks.

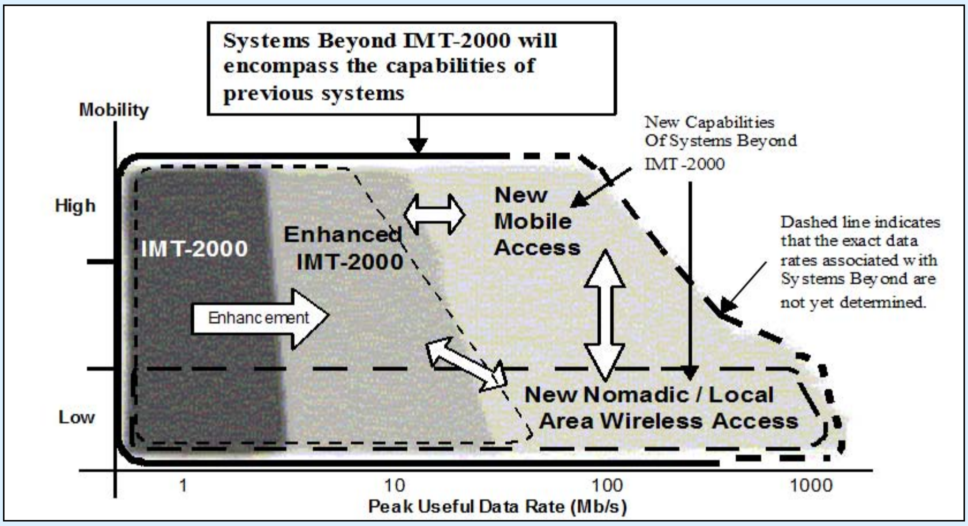
4.2.3 Enabling mobile network technologies

Evolving mobile networks

Mobile communications have evolved from the first-generation analogue system to second-generation systems such as CDMA and GSM. Now, the third-generation IMT-2000 system has begun to provide a high-quality multimedia service and global roaming. Despite the delay in the commercialization of IMT-2000 services due to the worldwide economic recession, next-generation mobile communication technology is being anticipated with enthusiastic interest. Next-generation broadband mobile communications, so-called fourth-generation, or beyond third-generation, is a system that will be able to provide diverse multimedia convergence and ubiquitous service.

The ITU Radiocommunication Sector (ITU-R) has a working group (WG) to develop a vision and technology roadmap for IMT-2000 and system beyond IMT-2000 as shown in the Figure 4.4. The vision for the future development of IMT-2000 as an evolutionary phase is that there will be a steady and continuous evolution. IMT-2000 systems are being enhanced and many will incorporate an ALL-IP network and mobile wireless access will offer increased capabilities such as transmission speeds up to 10 Mbit/s. In conjunction with IMT-2000, there may be an inter-relationship with WLAN and digital multimedia broadcasting. For beyond IMT-2000 systems, there may be a requirement for a new complementary wireless access technology, sometime after the year 2004. This will complement the future development of IMT-2000 and future development of other radio systems. The vision for a potential new radio interface is to support up to 50~100 Mbit/s in the mobile environment and up to 1 Gbit/s in the stationary environment on downstream transmission. Timelines may be considered from various perspectives such as market trends, spectrum availability, technical capabilities, standards development and infrastructure deployment.[16]

Figure 4.4: Visions of broadband mobile communications



Source: ITU-R Working Party 8F.

Right now, research on core technology is desperately needed to build up the multimedia information and ubiquitous society based on high-speed mobile communication. It is expected that studies will be conducted in various areas such as, high-speed packet wireless transmission technology, IP-based diverse access network integration technology, fast horizontal and vertical handover technology, mobile ad hoc networks, mobile multimedia service control technology, broadband WLAN technology with improved security and

QoS, WLAN and cellular network interoperations technology, and seamless service control technology between heterogeneous networks. In addition to this, we have to take into account the ubiquitous era when people's daily lives are changing rapidly as a consequence of new technologies that resolve difficulties and improve quality of life, as well as providing simple information transmission and multimedia services. That is, research should be conducted into the various sensor network technologies and associated status detection, as well as user-centric service provision using location and context-aware based technologies.

IP-based unified core networks

The new generation of mobile multimedia applications will be developed in IP environments guaranteeing optimal synergy between the ever-growing mobile world and the Internet. In the IP environments, mobile networks will benefit directly not only from all the existing Internet applications, but also from the huge momentum behind the Internet in terms of the development and introduction of new services. It is important to stress that these evolutions are independent of each other and can also be deployed in a fully independent way. This means that the operator can make an independent yes or no decision for each of these evolutions.[17]

The WWRF is driving a single open mobile wireless Internet architecture that enables seamless integration of mobile telephony and Internet services, meeting the needs of network operators and Internet service providers. It is driving the adoption of a single open mobile wireless Internet architecture that can lower infrastructure cost, accelerate services development, facilitate multi-vendor interoperability, and complement and harmonize global mobile wireless and Internet standardization. It removes the classical separation of core and access networks via uniform adoption of IP technology.[18]

As we move towards 3G mobile services, there is a strong need for global and collaborative standards for global market needs. The Operator Harmonization Group (OHG), by the 3GPP and 3GPP2, has affirmed their belief that a single global ALL-IP network standard for IMT-2000 will provide maximum benefits to customers, such as global roaming and affordable handsets. Also, OHG believes that eventual convergence of mobile IP-based networks and fixed IP-based networks is crucial for transparent and seamless communication services in the future. From the standpoint of the harmonized reference model, the 3GPP and 3GPP2 architectures incorporate similar IP multimedia functions providing for IP transport at all interfaces and supporting gateways. Gateways are in charge of interoperating between heterogeneous networks with composed of media gateway and signaling gateway. Especially, addition of an IP-based multimedia core network subsystem (IMS) that introduces the capabilities to support IP-based multimedia services, such as VoIP and multimedia-over-IP (MmoIP), and makes use of the packet switched network for the transport of control and user plane data.

However, the deployment of a global ALL-IP mobile network is not a straightforward decision. First of all, the potential advantages and added value of such an evolution are not clear to subscribers, and operators have to carry out significant investments to enhance their network infrastructure and obtain expensive frequency licences. Moreover, although IP is by far the most widely accepted protocol, it still has intrinsic weaknesses, like limited address space, lack of inherent mobility and QoS mechanisms, and poor performance over wireless links.[19]

There is therefore a worldwide IPv6 movement for a next-generation Internet addressing system to resolve the IP address problem. But, in order to expedite the deployment of IPv6 it is important to find a killer application. It is expected that IPv6 will be applied best where its distinctive features can support a promising application. That is, it is forecasted that, in the initial stages, IPv6 will be adopted for wireless Internet service on the mobile communication network, information household appliances based on home networking, military and disaster-related business areas. Currently, IPv6 has been actively adopted in Asia and Europe where there is a relatively critical IP address shortage, whereas North America is still watching development as there, IPv4 addresses are readily available. However, terminals and routers are announced that support the IPv6, and official IPv6 addresses are already allocated for each country and region, which shows that IPv6 deployment is in fact fairly close at hand.

Heterogeneous access networks

Ongoing WLAN standardization and research and development (R&D) activities worldwide, which target data-rates higher than 100 Mbit/s, combined with the recent successful deployment of WLAN in numerous hotspots, point towards the fact that WLAN technology will play a key role in wireless data transmission.

Cellular network operators have recognized this fact, and are striving to exploit WLAN technology and integrate it into their cellular data networks. For this reason, there is currently a strong need for interoperating mechanisms between WLAN and cellular data networks. There is no doubt that the recent evolutionary and successful deployment of WLAN systems has fuelled the need for interoperating mechanisms of this kind. There are two generic approaches for WLAN and cellular integration.

In the loose coupling approach, WLAN is deployed as a complementary access network to the cellular network. Namely, WLAN services are likely to be positioned in a complementary relationship with cellular services because of the difference in the size of end-user terminal, coverage, and service characteristics. In this case, WLAN may utilize the subscriber databases of the cellular network. Loose coupling is mainly based on IETF protocols, which are already implemented on live WLANs, and it imposes minimal requirements on WLANs. This is because loose coupling utilizes standard IETF based protocols for authentication, accounting, and mobility. As a result, it is not necessary to introduce cellular technology into the WLAN network, as is the case with tight coupling.

In the tight coupling approach, the WLAN, is connected to the cellular core network in the same manner as any other radio access network. To generate revenue in the WLAN space with cellular customers, it is commonly believed that operators must provide a seamless user experience between the cellular and WLAN networks. This calls for interoperating mechanisms between WLAN and cellular network capable of providing integrated authentication, billing, and mobility. WLAN service capable of roaming with cellular network is believed to substitute cellular traffic, if the service is deployed in time to the dual-mode terminal. Tight coupling indeed provides a firm relationship between the WLAN and cellular network, and its main advantage is enhanced mobility across the two domains, entirely based on cellular mobility management protocols. Nevertheless, tight coupling is primarily tailored for WLANs owned by cellular operators and cannot easily support third-party WLANs. More important still, it cannot support legacy WLAN terminals, which do not implement the cellular protocols. These are some of the reasons that account for the current trend towards loose coupling.[20]

Meanwhile, there is a movement to introduce IP transport technology within the radio access network (RAN) as an alternative to the ATM-based RAN. IP-based RAN offers several advantages. It makes more efficient usage of transport resources. Furthermore, IP technology is cheaper, and a homogenous transport technology can save operation expenses. It reuses the existing transmission of the layer two independence. Apart from the pure replacement of transport technology towards IP, it also enables a smooth evolution. Moreover, the WWRF has proposed a virtual RAN approach to evolve from the pure hierarchical architecture that we have today, towards an open and distributed architecture. IP also enables easier evolution toward an NGcN architecture within the RAN, where control plane functions are physically separated from user plane, which allows for improved scalability and flexibility feature.[21]

Digital broadcasting networks

The media environments where communication and broadcasting are separated tend to converge rapidly, owing to digital multimedia contents. In particular, expansion of bandwidth in the mobile communication network and development of IT technology accelerate fusion of mobile communications and broadcasting. Convergence of communications and broadcasting occurs as demarcation between these services becomes obscure. As a result, the service providers in each area can easily provide value-added services that are beyond their unique business boundary. The main advantage of broadcasting services is their always-on nature, such that services can be accessed without any setup effort. A certain casting service may be offered in large areas or in limited areas only, according to coverage of the broadcast programme. The received information can be displayed immediately or can be stored for later retrieval.

From the service provider’s point of view, the convergence of mobile communications and broadcasting services involves on the one hand the mobile communications broadcasting service which is provided by mobile communications service providers over the mobile communication network, and the interactive data broadcasting service which is provided by broadcasting service providers using the up-link channel in mobile communications networks. Cooperation with the broadcasting network is included to open up new applications such as navigation, traffic information, and interactive multimedia services.[22]

Mobile communications broadcasting services started from SMS and developed into MMS, to accommodate mobile communication subscribers’ needs to exchange music, images, videos, and animation, as the multi-functional terminals are distributed widely that are equipped with a digital camera and camcorder function. However, it is difficult to apply the concept of broadcasting since the SMS and MMS transmit the data with the point-to-point method between the base station and the terminal. To improve this shortcoming, the cell broadcasting service (CBS) has been developed and a concept of broadcasting with the point-to-multipoint method is being applied. Recently, 3GPP multimedia broadcast multicast service (MBMS) and 3GPP2 broadcast multicast service (BCMCS) with high data-rate for multimedia service, have appeared to help address the problem for CBS of low data-rate. A performance improvement by the broadband mobile convergence network will create the basis for providing various multimedia contents in the future and lay the groundwork in advance for a converged mobile communications broadcasting service.

On the other hand, convergence technology is also presented to show the interactive data broadcasting service in terrestrial and satellite DMB systems. It is suitable to transmit entertainment and information programmes as well as traffic information and events into cars, buses or trains. The satellite and terrestrial DMB service is quite similar, but different in the service coverage, number of channels, and service fee as they are currently.

Mobile ad hoc networks

Mobile ad hoc networks are a technology to temporarily create a network to perform communications among the multiple terminals located in a certain area. Namely, it is a network that is formed without any central administration or infrastructure. The possibility to build a network in a spontaneous and fast way gave rise to the name ad hoc networks. Because a mobile ad hoc network does not involve the use of existing networks, and it can be constructed even in extraordinary conditions like a disaster. In a mobile ad hoc network, nodes communicate with each other without the help of any pre-existing structure. The network is autonomously formed among many nodes such as PDA, laptops with varying functionalities and power levels. It will be the enabler for ubiquitous computing as well as perform significant functions during natural disasters where pre-existing infrastructure may be destroyed. Another area of greater interest is military applications, which require dynamic autonomous architectures formed on the go.[23]

Recently, research on multi-hop communications using ad hoc networks has been undertaken aggressively, and is expected to provide an effective solution for building robust networks even in the event of an emergency. Methods to participate in or leave a network, and to discover services available in the network must be established. Because packets are relayed between terminals in multi-hop communications, it is also indispensable to realize security, encryption and authentication techniques from the perspective of privacy protection.

Additionally, the mobile ad hoc network is configured autonomously between nodes without centric control. Therefore, it should support a peer-to-peer communication since all nodes in the network should be able to establish a communication with the equal function capability, and minimize the influence of one node removal on operation of the entire network. The most representative ad hoc network is the multi-hop mobile ad hoc network based on IP, and this is being standardized by IETF’s mobile ad hoc networking (MANET) working group.

The most conspicuous features of the mobile ad hoc network are dynamic network topology change associated with node mobility, which directly affects the routing protocol that manages the routes. Each node broadcasts its presence periodically, and maintains information on the neighbouring nodes that can be connected directly and update the route information based on it. Route information is generated and managed by the routing protocol, which can be classified into the proactive and reactive protocol.

The proactive protocol enables all nodes to keep most recent route information. If route information is updated by network topology change or the periodical check, it is broadcast across the entire networks. The proactive routing protocol is always able to transmit the data through the optimal route without delay when traffic occurs, since the recent route information is continually updated. However, it has a problem of too many control messages for route information management. Recently, research is being carried out to minimize the amount of the control messages. In addition, the reactive routing protocol explores the route upon traffic occurrence. It resolves the control message overhead issue of the proactive protocol, and processes the route information in a soft state. That is, if no traffic occurs on the route that keeps in the routing table, the applicable route information will be removed from the routing table. Delay can be generated due to route exploration in the reactive protocol, and priority is given to minimization of route exploration time rather than optimal route exploration.

Research on the mobile ad hoc network has been under way for a long time now, but is not applied to our daily lives. The reason is that most current networks were developed based on the infrastructure type instead of the mobile ad hoc one, and there are only few areas that the mobile ad hoc network can be applied, with many problems left unsolved for practical application. When configuring the home network with information devices in the house using wireless access technology however, the mobile ad hoc communication concept can be applied. The mobile ad hoc network can also be applied to the sensor network where the sensors are installed in the dangerous or inaccessible area, and it is configured to exchange information between these sensors.

Wireless personal area networks

A wireless personal area network (WPAN) is a small-scale network configured through the wireless interface among personal operating space (POS) equipment. It has the characteristic of being moved together with the individual, since the network is configured by the individual's portable device. Newly entered devices into the POS can be added to the current network, or devices can be removed.

Once the smart home environment is built that can exchange information between the household digital appliances and the information devices, TV, audio, digital camera, refrigerator, electronic range and computer can be connected to the wired and wireless network and the Internet connection function can be activated. Therefore, everybody can access enhanced information capability without limitation on time and space, such as home management, leisure and entertainment, education and business support. For example, WPAN encompasses situations such as transmitting between mobile phone and PDAs, and printing from laptop to printer in the same room. In addition, telemetry and control involve lighting and audio/video controls, external monitoring and control of electricity and gas, home security including external access to monitoring video cameras, home appliance servicing, and in-home communication between appliances. Smart home can operate over various physical media. Existing wiring makes use of electrical, telephone, or coaxial wiring already installed in the walls. However, wireless networking is perhaps the most attractive approach for the home, since it avoids the cost of pulling new wires and the challenges of using existing wiring.[24]

There are many competing technologies and associated standards and advocacy groups. IEEE 802.11 is a family of evolving standards, originally designed for enterprise networking and now moving into the home. HomeRF is a family of WLAN technologies specially for the home. HiperLAN is a family of European Telecommunication Standard Institute (ETSI) standards for WLAN. These are similar to the 802.11 standard, but include QoS and support ATM as well as Ethernet.

The IEEE 802.15 working group has established a standard for WPAN specification. IEEE 802.15.1 selected Bluetooth as a wireless specification for WPAN. IEEE 802.15.3 developed the high-rate WPAN that supports faster than 20 Mbit/s data-rate so that the multimedia can be provided such as large amount of data transmission or streaming service, whereas IEEE 802.15.3a is conducting a research to replace UWB with 802.15.3.

Finally, IEEE 802.15.4 is standardizing the low-rate WPAN specification that supports 20~250 kbit/s data-rate in the small-range with low-price, long-battery life and simple structure. Furthermore, the non-profit organization Zigbee alliance has been formed to design the upper layer of IEEE 802.15.4 to define and develop the application profiles that can be easily applied to diverse application areas.

Wireless sensor networks

Recent advancement in wireless communications and electronics has enabled the development of low-cost low-power, multi-functional sensor nodes that are small in size and communicate untethered over a short-distance. This is carried out by tiny sensor nodes, consisting of sensing, data processing, and communicating components. Sensors are to detect sense information, and to recognize signs expressed by human and to monitor environments. For example, biometric information sensor monitors body temperature, pulse, perspiration, and detects emergency conditions so that automatic emergency notification can be made when a person is at risk.

WSNs are composed of a large number of sensor nodes that are densely deployed either inside or very close to the object in question. The position of sensor nodes need not be engineered or pre-determined. This allows random deployment in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self-organizing capabilities.

Realization of sensor network applications may require mobile ad hoc networking techniques. But, although many ad hoc network techniques will be applicable, WSN differ from ad hoc networks in several areas. The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network. Sensor nodes are densely deployed and prone to failures. The topology of a sensor network changes very frequently. Sensor nodes mainly use a broadcast communication paradigm, whereas most ad hoc networks are based on point-to-point communications. Sensor nodes are limited in power, computational capacities, and memory. Finally, sensor nodes may not have global identification because of the large amount of overhead and large number of sensors. Therefore, the design of the sensor network is influenced by many factors, including fault tolerance, scalability, production costs, operating environment, sensor network topology, hardware constraints, and power consumption. The successful realization of sensor networks needs to satisfy these constraints with highly stringent and specific for sensor network.[25]

In the future, a wide range of application areas such as military, health, and home will make sensor networks an integral part of our lives. In the military, for example, the rapid deployment, self-organization, and fault tolerance characteristics of sensor networks make them a very promising sensing technique for application. In health, sensor nodes can also be deployed to monitor patients and assist disabled persons.

4.3 Opportunities and threats to the mobile converging service market

4.3.1 Pros and cons

The world is becoming faster, riskier and more complex. Enterprises need to prepare themselves for this turmoil. Therefore, it is imperative to implement a strategic planning that consistently monitors trends and assesses business effects. Especially, service is a matter of great significant driver in the future mobile information society. Therefore, it is very important to create a beneficiary business model for promising applications, and to provide enabling key technologies in a timely way. Although predicting the future is a risky business in the mobile communication industry, an understanding of the core technologies for everywhere and anytime mobile communications can allow us to have some grasp on the shape and direction of the future broadband mobile communications.

Generally speaking, opportunities and threats will almost always coexist in the youth market, and high risks imply a possibility of high return. Now, we are making efforts to search and focus for the seed technology issues, and it is a crucial time to decide whether we drive an investment for the future promising broadband mobile convergence technology actively or not. Moreover, it is desirable to keep in mind the facts that flexible rolling-plan and time-to-market strategy for propelling a successful project are indispensable.

What are the most disruptive trends and most significant opportunities arising from emerging broadband mobile communications? Technology is bringing to society vast opportunities, including new ways to interact and organize. In many ways, technology empowers individuals by providing the potential for better information and services and greater flexibility. As a result, the availability of new mobile applications and services on broadband mobile convergence networks will help to lead an easy and amusing life for everyone fairly. By adopting advanced mobile technologies, operators could potentially generate new sources of revenue through useful or appealing new applications and services. But, there are many problems in propelling the technological research and development related to future broadband mobile communications. Neither a killer application nor a proven business model has yet emerged to guarantee the commercial success of such activity. Therefore, both industries and manufactures may have a conservative tendency that the best way is a vigilant approach to improve existing business processes a little or to maximize the return on investments already made.

4.3.2 First mover vs. fast follower

To cope with the future broadband mobile communications toward a converged world, how can technology planners identify the technologies and applications that will generate maximum benefit for their enterprises? Once an enterprise has decided that an emerging technology will play a major role in its future business processes, it must determine the optimal time to invest seriously in the technology. If an enterprise launches its efforts too soon, it will suffer unnecessarily through the painful and expensive lessons associated with deploying an immature technology. It delays action for too long, it runs the even greater risk of being left behind by competitors that have succeeded in making the technology work to their advantage. Technology planners should assess the relative impact of a technology and act early for high impact technologies, while waiting for others to move first on the technologies that are less relevant to the core of their business.

Generally, there is a natural desire for enterprises to become the top innovation leader in a new market. The so-called first mover advantage is one of the most discussed aspects of the new economy, the theory that profits will inevitably follow market penetration without price competition initially. The first movers acquire many patents and licences, and have the prospect of high quality through more market savvy. The first movers will seek to initiate a number of important global trends in mobile service and applications, and attempt to glean a glimpse of the future mobile landscape. In a fortunate case, they will be rewarded with the contribution to ROI. On the other hand, the major issue with this approach is that the likelihood of market adoption and the speed of market penetration are very large unknowns. Even if these risks were low, the first mover advantage is often more of a disadvantage, and more resource-intensive such as the need to create the demand. The new products are typically more immature, and may subject the brand to a risk such as danger of poor quality of new products. Fast followers can sometimes learn faster and avoid some of the costly mistakes of first movers. First movers make all expenditures without knowing market reactions well and risk the danger of employing wrong marketing approach. They take the risk that followers improve faster on the first movers' failures. Therefore, technology providers need to consider an appropriate time-to-market strategy carefully.[26]

5. Conclusions

The advancement of IT that began with the Internet has converged with mobile communications, to create a new paradigm of mobile convergence. Up to now, these technological advancements have centered around intelligent, multifunction terminals, and these all-in-one terminals have lead advancements in network convergence to a limited degree.

However, the services of the near future that take the user's lifestyle and environment into consideration must be driven by network and service convergence, in addition to device convergence. Therefore, the information technology of the future must drive mobile convergence that eliminates the boundaries between wired and wireless networks and home appliances and terminals, to provide easier interoperation and guarantee mobility.

In addition, mobile communications, that are at the centre of these changes, will act as a content delivery network between various user-centered pico-networks or ad hoc networks, and value-added ubiquitous services, and convergence centered around mobile communications will become the core component of the ubiquitous infrastructure.

The ubiquitous concept, which eliminates spatial and temporal limitations and uses various forms of multimedia to provide the optimal service for the user, absolutely requires the mobile communications centered convergence paradigm. Broadband mobile communications, which will incorporate the technologies discussed in this paper, are expected to go beyond the realm of IT to greatly influence the formation of converged world.

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