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Future of wireless communications system
— Can Japan lead the fourth generation wireless system? —

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1.1 Introduction

For the first time in the world, Japan is to launch the third-generation wireless communications service in May 2001. This might provide a golden opportunity for Japan who strongly hopes to lead the next (fourth) generation wireless communications system.

After (1) watching how each nation promotes the practical application of the third generation currently and (2) viewing characteristics of the fourth generation system, this report analyzes whether Japan can hold a dominant position toward the fourth generation system and recommends what Japan should do to raise the position.

1.2 What is the third-generation wireless communications system?

The third generation system is called as "IMT-2000 (International Mobile Telecommunications 2000)". The "2000" includes following three meanings.

- — The practical application is scheduled around the year 2000
- — Frequency around 2000 MHz is used
- — Data transfer rate is up to 2000 kbps

The third generation system has following advantages.

- — Data transfer method is unified all over the world*1.
- — High rate of data transfer provides comfortable environment for data communications service, such as the i-mode service.

etc.

1.3 Needs for the third generation service in Japan, Europe and the US

Japan, Europe and the US have different attitude toward the third generation system based on (1) how globally data transfer methods of the current second generation system spread, (2) how much frequency the current systems remains available for new users, and (3) how much needs for high rate of data transfer are.

1.3.1 Japan

Japan has desired the third generation system earnestly because the PDC system of the second generation, despites the share close to ninety percent in the domestic market, can't be used outside Japan, and rapid spread of the i-mode service of the second generation system has caused lack of the frequency and demand for higher data transfer rate.

1.3.2 Europe

Europe isn't so eager as Japan for the third generation system*2 because (1) the GSM, European unified method of the second generation system, is available not only in Europe, but also in Asia and the US (See Table 1), (2) the GSM system still leaves enough frequency available for new users, and (3) the demand for higher rate of data transfer is smaller than Japan due to less spread of mobile Internet service, such as the i-mode. Furthermore, the methods*3 such as GPRS, EDGE, HDR, etc., which have been

Table 1: Number of subscribers for wireless communications systems (As of December 2000)

Generation	Communications method	Subscribers (in millions)	World market share (%)
Second-generation (digital)	GSM	397	60.7
	CdmaOne	76	11.6
	PDC	50	7.6
	Others	56	8.6
First-generation (analog)		75	11.5
Total		654	

Source: public release by the GSM Association http://www.gsmworld.com

improved on the GSM method, raise the data transfer rate nearly to that of the third generation method.

By the way, Europe was once excited at the third generation system with its large market potential. Many European carriers boosted up the contract price at license auction to get frequency of the third generation system. As the result, the successful bidders are at great pains to make money for facility investment of the third generation system ironically.

1.3.3 The US

The US has the least needs for the third generation service than Japan and Europe, for the first-generation analog system still accounts for large share of wireless service and the second generation systems, such as GSM, cdmaOne, etc. are on the road to spread in the US.

At the present, both the first and second generation systems leave enough frequency available for new users. Furthermore, in the US, similarly in Europe, the demand for higher rate of data transfer is smaller than Japan due to less spread of mobile Internet service, such as the i-mode. Furthermore, the methods[*4] such as GPRS, HDR, etc. raise the data transfer rate nearly to that of the third generation method.

So, the US isn't so eager for third generation communications system as Japan, too.

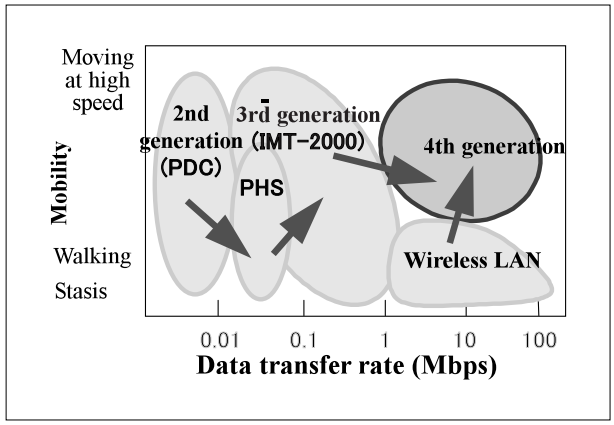
1.4 What is the fourth generation wireless communications system?

Details of the fourth generation systems haven't fixed yet. So, let's presume performance of the fourth generation system on the analogy of development history of the wireless communications system. Figure 1 characterizes each generation by date transfer rate (x-axis) and user mobility (y-axis).

The second generation system realizes high mobility, but can't realize high rate of data transfer[*5]. Next, the PHS improves the rate of data transfer up to 144kbps, but sacrifices the mobility. Currently, the third generation system is improving the mobility of the PHS system and the rate of data transfer up to 384kbps at the present. As just described, the wireless communications system has improved the performance of mobility and data transfer rate mutually. In this way, the fourth generation system may improve the mobility and the rate of data transfer more than the third generation system.

By the way, the wireless LAN system is in progress parallel to the development of the third generation system. Though the mobility of the wireless LAN is small, the data transfer rate is far exceeding that of the third generation system. Now, wireless LAN system is spreading mainly in offices and will be a formidable competitor of the third generation

Figure 1: Advancement of wireless communications systems



Source: Author's own compilation

system as a system which will evolve to the fourth generation system.

The ITU-R (Wireless Technology Department of the International Telecommunication Union) will standardize the fourth generation system around 2010 based on proposals from member nations. In Japan, the Telecommunications Council*6 is to unveil the starting draft of the proposal*7 in June 2001. This draft will be a model for other nations to make their proposals.

1.5 Key technologies of the fourth-generation system

1.5.1 IP systemization

The fourth generation system is expected to adopt IP. By doing this, wireless network can be connected seamlessly with wired one, and the Internet service will become more familiar to mobile users.

Furthermore, 3GPP (3rd Generation Partnership Project) intends to adopt the IP in the third generation system, and a mobile user may enjoy seamless communications before the fourth generation service would start.

1.5.2 MMAC

MMAC (Multimedia Mobile Access Communication Systems) is a system that realizes high-speed and high-quality wireless communications (see Table 2). Furthermore, the MMAC provides seamless communications service connected to optical fiber networks.

In Japan, the MMAC Promotion Council develops*8 the MMAC and will launch the system around 2002.

Similarly, the BRAN (Broadband Radio Access Networks) in Europe and the U-NII (Unlicensed National Information Infrastructure) in the U.S. is developing the MMAC system.

The MMAC Promotion Council works in close cooperation with the BRAN and the U-NII.

1.5.3 OFDM

OFDM (Orthogonal Frequency Division Multiplexing) is a strong candidate for data transfer method of the MMAC. Using many spectra simultaneously, OFDM realizes high-speed data transfer. Compared to a conventional method that uses a single spectrum, higher speed can be realized especially in multi-path environment.

Originally, OFDM is developed in Europe for digital broadcasting application. Only recently, Japan promotes R&D of OFDM at the initiative of private companies and universities. Also, the US established OFDM Forum in March 2000 and the Forum promotes R&D of the OFDM.

1.5.4 Software Defined Radio

Software Defined Radio (SDR) is technology that reconfigures system architecture by programming dynamically the software. When the fourth generation system spreads, various generation systems, such as PDC, GSM, cdmaOne, W-CDMA, cdma2000, etc., would coexist. If the current manner, i.e. a handset adopts a communications method, still keep the mainstream, users of different methods have to prepare for the other handset to communicate each other. This will cast a lot. However, as SDR can reconfigure characteristics of the handset system, provides an efficient and comparatively inexpensive solution.

Originally, the US started research of SDR for military use early in 1990's and converted it for civil use. Late in 1990's Japan and Europe began research of SDR for civil use, too. Table 3 summarizes major R&D activities of SDR in the world.

Table 2: MMAC specifications

	High-speed wireless access	Ultra high-speed WLAN	5GHz band mobile access	Wireless homelink
Transfer speed	30Mbps	156 Mbps	20 ~ 25 Mbps	30 ~ 100 Mbps
Mobility	Standing ~ Walking	Standing	Standing ~ Walking	Standing ~ Walking
Frequency band	25,40,60 GHz	60 GHz	5 GHz	5,25,40,60 GHz

Source: Public release by the MMAC Promotion Council http://www.gsmworld.com

1.5.5 AAA

AAA (Adaptive Array Antenna) is technology that sends and receives only signals of a particular direction by controlling each signal independently with many antennas allayed in a line. AAA is also called as smart antenna.

The fourth generation system will adopt higher frequency, such as micro one to transfer large volume of data coincidentally. As the result, there is fear that the signal might be vulnerable to interference from the reflected waves and waves from other users. Hence, AAA would be critical technology of the fourth generation system.

Table 4 indicates the developmental process of AAA.

1.6 Ad hoc network; new concept of network utilization

An ad hoc network connects autonomously each terminal which can communicate without passing the conventional cell station. (see Figure 2). Though a conventional wireless network has evolved with expensive cell stations, an ad hoc

Table 3: Software wireless development activities

Country	Group	Activities
Japan	Software Radio Study Group	— Established under the Communications Society of the Institute of Electronics, Information and Communication Engineering. — Members are from industry, university and government. — Promote research related to logic, technological development, system application and standardization.
Europe	SORT Program	— Members are from industry, university and government. — Promote research related to both satellite and ground waves
	SLATS Program	— Members are from industry and university. — Develop software module with both 2nd and 3rd generation systems (for commercial use).
	PROMURA Program	— Members are from industry and university. — Develop broadband wireless circuit covering 500MHz ~ 2500MHz.
U.S.	Glomo Project	— Sponsored by DARPA and researchers from industry and universities participate — Research and development of distributed-packet wireless network.
Worldwide	SDR Forum	— Non-profit and publicly open organization — Members are from industry, university and government of the US, Europe and Asia. — Explore market opportunity and promote standardization of the system interface

Source: Author's compilation of followings.

— Public release by the SORT (Software Radio Technologies)
— Public release by the SLATS (Software Libraries for Advanced Terminal Solutions)
— Public release by the PROMURA (Programmable Multimode Radio for Multimedia Wireless Terminals)
— Public release by the Glomo (Global Mobile)
— Public release by the DARPA (Defense Advanced Research Projects Agency)
— Public release by the SDR Forum (Software Defined Radio Forum)

Table 4: Developmental process of AAA

Period	Country	Activities
sprouting period	U.S.	— Military started R&D of AAA in 1960s to eliminate jamming signals from enemies
	Japan	— Universities started R&D of AAA for civil use early in 1980s.
Diversified period	Europe	— TSUNAMI (Technology in Smart antennas for the Universal Advanced Mobile Infrastructure) started in the middle of 1990s — TSUNAMI is a project to substantiate the method of AAA — TSUNAMI touched off worldwide fever of AAA
progressive period	Japan	— The Association of Radio Industries and Businesses implemented AAA project for application to PHS in 1999 and 2000 supported by industry. — The Communications Research Laboratory, major carriers, major device companies and universities is promoting R&D of AAAS independently or jointly toward the fourth generation system.
	Europe	— Several AAA projects continue without cessation
	U.S.	— Each company is tackling commercialization of AAAS independently.

Source: Author's own compilation

network can be built by connecting by connecting common terminals. On this account, an ad hoc network has great potential to spread rapidly with free or low costs. Application of ad hoc network, such as ubiquitous office, conference room, etc gets business attention. Another application is an ad hoc network where moving vehicles link each other and exchange traffic, accident or weather information (see Figure 3).

1.7 Regulation of frequency allocation for the fourth generation system

Distribution of electric waves for the fourth-generation system

Quick and sufficient allocation of the frequency is essential for the fourth generation system to spread widely and smoothly.

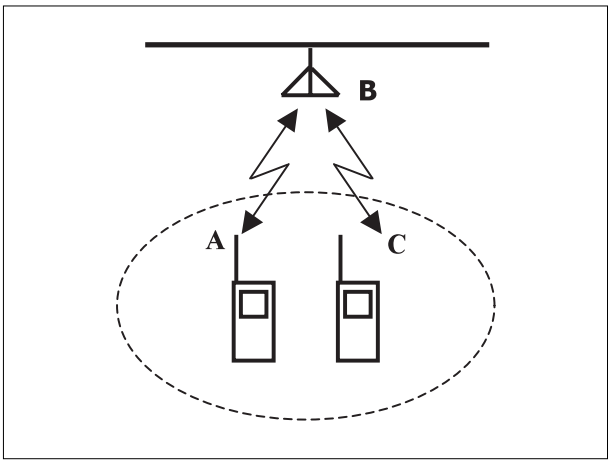
Now, Japan lacks frequency due to rapid spread of wireless services and needs to reallocate the whole frequency band to get enough frequency for the fourth generation system.

In "e-Japan Strategy", announced in January 2001 during the IT strategy conference by the government, "examination and execution of fair and transparent allocation of electric waves with considerations of auctions, etc." is proposed concerning the distribution of electric waves. In many leading countries including the U.S., the reform of the electric wave resource distribution system is being carried out with competition entry by auctions as the axis.

Although this system is superior in the sense that it gives equal opportunity for electric wave distribution to promote competition, the price for the third-generation system license skyrocketed with Europe as the center and caused delay in the start of the service as well as shifting of the usage fee of the current system. In the Western countries, there is also the criticism of the fact the currently unused frequency band cannot be

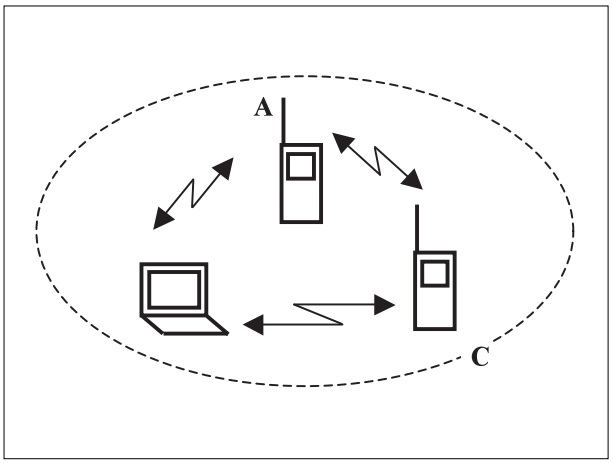
Figure 2: Conventional network vs. autonomous distributed one

(Conventional network)



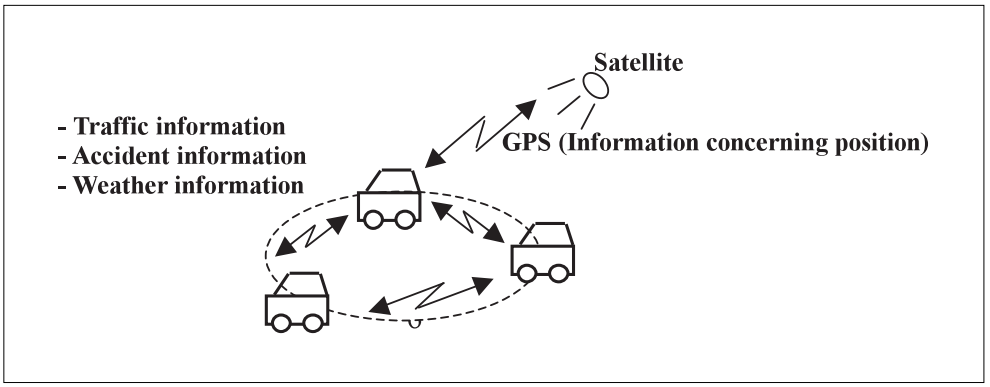
* Even if user A and user C are in the same mobile cell, communications between them have to pass the cell station B

(Ad hoc network)



* terminal is autonomously connected to others and can communicate each other without passing the cell station.

Figure 3: Adhoc network for communications among automobiles



redistributed since the license period is unclear.
It is important for Japan to fully consider these problems and examine the distribution system.

1.8 Japan's competitive force concerning wireless communications systems

Concerning wireless communications systems in general, Japan is stronger than the Western countries in terms of commercialization technology. On the other hand, Japan is relatively weak concerning system technologies.
In Europe, there are constant deliberations with complete IP usage for wireless communication, cable communication and broadcasting. It is also important for Japan to propose new services by structuring concepts of new systems without getting too focused on the research and development of technologies concerning individual elements.
Japan is also weak in terms of launching concepts of new systems such as the software wireless. Professor Ryuji Kawano of Yokohama National University, who is the representative of the Software Wireless Study Group states, "Japan is superior in the manufacturing technology of software wireless. However, there is great possibility that the patent will be held down by overseas companies, mainly US companies. If this continues, more royalties will go overseas the more we manufacture hardware." With these problem points in mind, the Software Wireless Study Group is actively making deliberations concerning not only the hardware but leading concepts such as the description conditions of interfaces, etc. There is great expectation for the future of the study group.
Furthermore, Professor Yasutaka Ogawa of Hokkaido University points out, "Japan has applied AAA in PHS before the rest of the world. The research and development level of our country is not inferior from a global standpoint. However, when considering that there were researches to apply AAA to wireless communications systems in the early 1980's, we would have had a great lead over the rest of the world in this field if there were appropriate support for the research." Our country needs to appropriately evaluate new ideas on our own and help nurture them.
On the other hand, Professor Yoshihiko Akaiwa of Kyushu University (developer of the PDC system) states, "In Japan, there is very little contribution of universities to the research and development of wireless communications systems. This prevents out competitive force from increasing." When research themes are being selected and promoted by colleges in the future, considerations of needs by the industrial world is necessary as well as mutual collaboration so that the industrial world can effectively utilize the research results of universities.

1.9 Future trend related to the fourth-generation system

Usage of IP is a precondition of the fourth-generation wireless communications system and expensive switchboards will be replaced by cheap Internet routers. The communication method will change from circuit switching to IP telephones (voice over IP) using the Internet (see Figure 4) and there is a great chance that call charges will drastically decrease.
Furthermore, the data transmission speed of the fourth-generation system will be in a different dimension and smooth transmission of color motion pictures will be possible. Mobile phones with built-in video cameras will be common and communication by looking at the called party will also be possible. Downloading of music video and transmission of sports news and digests will also be standard services.
At the present, there is a communication charge of about 150 yen for downloading a three-minute song. When using this call charge system, communication charges will be extremely high. Since there is a limit to how much a user can spend, there is a possibility that electric communication companies will be forced to lower the communication charge per bit.
There is also the possibility of ad hoc networks connecting organically and autonomously to create wide networks. Professor Susumu Yoshida of Kyoto University predicts, "There is the possibility of automobiles equipped with broadband wireless routers becoming moving base stations. In addition, placing wireless routers

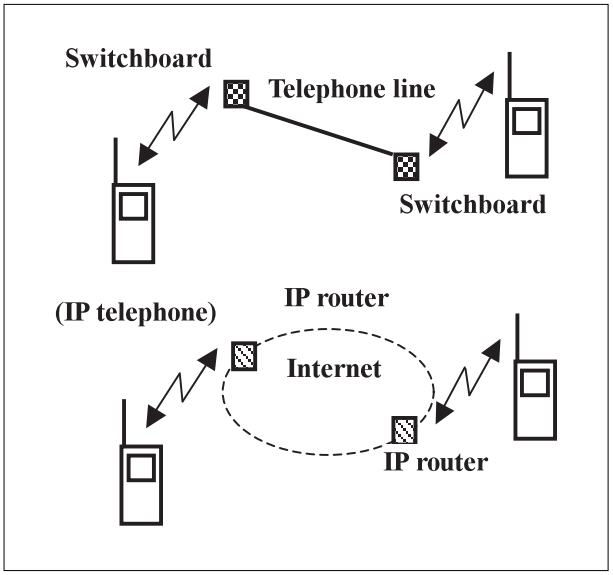
and wireless transmission devices in various locations and mutually connecting them will realize shared networks. By shared network users providing such base stations, civic sharing network that can be used at a fixed fee will be realized."

It is important for Japan to predict such changes in society and deliberate on the way the fourth-generation system is to be.

1.10 Conclusion

Japan is getting worldwide attention by starting the third generation wireless communications service for the first time in the world. Taking this good chance, Japan could also lead the fourth generation service if Japan seriously tackle issues related to frequency allocation, application development and the standardization of data transfer method for the fourth generation system.

Figure 4: Change in communication system
(Conventional circuit exchange system)



Reference

*1 In fact, the method hasn't been unified due to egocentrism conflict among nations and companies, and finally both Japan/Europe method, W-CDMA and the US method, cdma2000 are adopted into the third generation system. However, whichever method of data transfer is adopted, the user can use the third generation service.

*2 Europe will start the third-generation service in fall, 2001.

*3 These improved methods are categorized into the 2.5 generation.

*4 These improved methods are categorized into the 2.5 generation.

*5 The rate of the second generation system is 9.6 kbps.

*6 An advisory body for the Ministry of Public Management, Home Affairs, Posts and Telecommunications

*7 Currently, the data transfer rate of the fourth generation system is estimated to be up to 100Mbps when a user is still or moving slowly, and 20-30Mbs when a user is moving rapidly by a train or a car.

*8 The MMAC Promotion Council consists of major electric companies, manufacturers, etc. Currently, the member counts over 100.

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* This report is partly revised because of the situation change after April 2001.