

Fujitsu's Challenges in Wireless Communications

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(Manuscript received August 12, 2002)

This paper describes the challenges that Fujitsu is taking up in wireless communications and reviews Fujitsu's development history in the first, second, and third generation of cellular systems. Fujitsu is a total-system vendor of services, information, networks, and devices that derives its strength through inter-division collaboration. At the advent of 3G, Fujitsu established itself as a total-system vendor of mobile communications and started to deliver the major 3G components, for example, handsets, base transceiver stations (BTSS), radio node controllers, multimedia processing equipment, and multimedia mobile switches, to its customers. Through the development of this equipment, many technological breakthroughs have been made. Fujitsu has developed a W-CDMA power amplifier that has the highest efficiency in the world. This achievement is a testament to Fujitsu's expertise in semiconductor fabrication, digital signal processing, equipment technologies, and many other technologies. This paper also looks at the speed and complexity of digital signal processing that will need to be achieved and the trends of software defined radio (SDR), which along with the expected progress in semiconductor fine-process technology will determine the specifications for the next-generation mobile system. Finally, this paper describes the future network with which a ubiquitous communication society will be realized.

1. Introduction

There are some remarkable aspects to the rapid growth in wireless communications, as typified by the rapid growth in mobile telephony. There are also various local wireless systems, such as cellular systems, wireless LANs, and Bluetooth. The terminals used in these systems are functionally extremely complex, yet despite this they have become small, lower power consumption devices that are mass produced at low cost, which has in turn accelerated their widespread use.

These devices have become cheaper, smaller, and lower in power consumption in part because of the rapid developments that have occurred in semiconductor technology (**Figure 1**). The recent rapid growth of the Internet has led to a huge increase in traffic on the networks, bring-

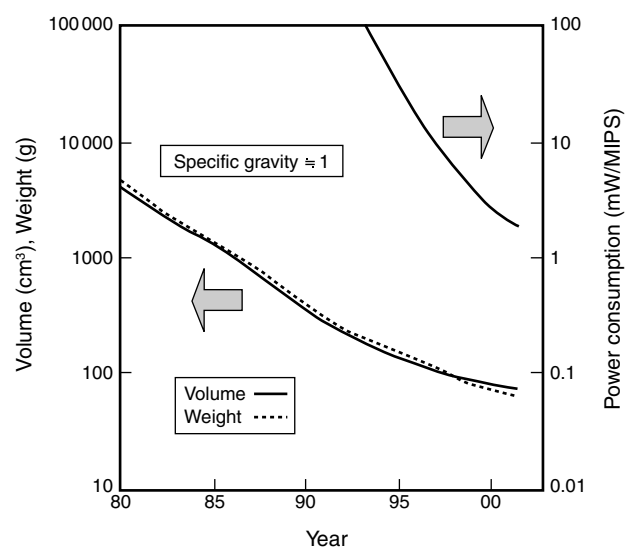


Figure 1
Miniaturization of mobile equipment.

ing about a rapid rise in data speeds, both in trunk and subscriber lines. This effect has spread to mobile telephony systems, and the extraordinary growth of i-mode in Japan is at the vanguard of the mobile Internet.¹⁾

Transmission speeds on fixed networks are increasing, and there is currently a similar trend toward increased speeds in mobile communications. Furthermore, we can expect these trends to continue in the future. In fact, even though third-generation (3G) mobile services are only now becoming available, research into fourth-generation (4G) systems has already begun.

This paper describes the efforts that Fujitsu has made in developing wireless and mobile communications in the past and the challenges it faces in the future.

2. History of cellular systems

Cellular systems have seen a change of generation about once a decade. When first-generation (1G) services were started in the late 1970s to early 1980s, a typical mobile unit was about 10 to 20 liters in volume, so it only just fitted into the trunk of a car. Also, the components in the analog section, such as the power amplifier, synthesizer, and shared antenna equipment, were all large.

TTL (Transistor Transistor Logic) was used throughout the control section. Plain analog FM was used for the radio transmission, which was the obvious choice given the technology of the time in terms of efficiency of the PA and ease of building the transceiver system. At the base transceiver station (BTS), the transceiver rack contained 50 to 100 liters of equipment for each user channel. If one is forced to say what the technological breakthroughs for 1G were, then on the radio side it would be the invention of pulse swallow frequency synthesizers, which stably accommodate multiple frequencies, and on the control side it would be the appearance of microprocessors, which made a huge contribution to the miniaturization and increase of functionality of the control section.

Miniaturization of the mobile unit was progressing a few years before the introduction of 2G services in 1990, to the point where the size of mobile phones fell below 200 cm³ (Figure 1).

Fujitsu's first forays into cellular systems were around 1976, when it participated in the Chicago Trial in the USA. The company entered the market with car phones and went on to develop its North American business with mobile phones. At that time, products based on Fujitsu's bi-CMOS technology were de-facto global standards for critical components such as prescalers and other devices. Today's analog front-end devices are the continuation of this legacy. These devices have been achieved thanks to close cooperation between systems and semiconductor device engineers, and this culture continues uninterrupted at Fujitsu.

The second generation (2G) saw the digitization of cellular systems, but there remained three major problems to be solved. These were 1) what method to use for band compression of voice, 2) how to deal with the issue of multi-path delay spread, and 3) whether to use linear systems that have a high frequency use efficiency or a non-linear system that can use simple analog circuits for the modulation/demodulation system. The 1990s saw a huge increase in the number of cellular subscribers, and this, coupled with worries about exhausting spectrum resources, led to the choice of linear systems. There had already been a widespread take-up of digital switches in fixed networks, and while the 64 kb/s μ -law PCM was widely used, a great number of other band compression techniques were developed with the aim of making lines more economical. However, the environment for mobile communications is extremely severe and errors are an inescapable fact. Any codec that does not protect against this might cause sudden degradations in quality and generate noise that could even damage the ear. There was therefore a rapid development of voice codecs for mobile environments that dealt with this problem. It could be said that the rapid progress in

DSPs at that time was built upon this progress in codecs.

Table 1 lists the modulation method, transmission bit-rate, technological problems and breakthroughs, and DSP throughput for each generation. As can be seen, there has been a more-or-less 10-fold increase in DSP throughput with each successive generation of technology. However, when it came to dealing with multi-path delay spread, Europe, America, and Japan took very different approaches.²⁾

Europe adopted a high transmission rate of 280 kb/s per carrier, a highly multiplexed TDMA system with 8 to 16 channels, and a mandatory equalizer with a high number of taps. By comparison, America set the carrier transmission rate at 40 kb/s and chose the D-AMPS system, which reduced the computational requirements for equalization, and the new CDMA system (IS-95), which avoids the need for equalization.³⁾ In Japan, the rate was set to 42 kb/s and equalizers were made optional because the country is quite narrow.

In Europe, the air transmission rate was set high, only a light burden was placed on the band compression codec, and the problem of equalization was dealt with head-on. In America and Japan, however, the air transmission rate was set low, the burden placed on equalization was made light, and all hopes were placed on voice band com-

pression.

Finally, for modulation/demodulation, Europe chose the non-linear GMSK system, while Japan and America selected $\pi/4$ QPSK.

Table 2 shows the multi-path delay countermeasures used in each generation. The method chosen at each generation matches the throughput of the most powerful DSPs available at the time.

Since the introduction of 2G, BTSs have seen the introduction of features such as dynamic channel assignment. In addition, most BTSs began to make shared use of power amplifiers, and linear amplifiers were introduced, whether or not modulation was linear. As a result, there has been increasing demand for large, high-efficiency linear power amplifiers.

The basic design procedure for 2G systems was for various parameters to be set when they had been standardized while forecasting progress in semiconductors. At the start of 2G, to get a mobile phone to fit into 150 cm³ was as much as could be expected; but today, around 10 years later, they have reached as low as 70 cm³, which might even be too small. Further, the enormous increase in LSI and CPU performance has led to increased functionality in the handset, setting it on the path toward being a small-scale computer.

Fujitsu first started to tackle development of 2G technology as early as the start of the 1980s with basic research into many areas dealing with mobile communications. The company had al-

Table 1
History of mobile communications and technological progress.

	1G	2G	3G	4G
Modulation method	FM analog	QPSK GMSK cdmaOne	CDMA	OFDM?
Bit rate (b/s)	-	5 to 40 k	10 k to 2 M (10 M)	Up to 100 M?
Technology problems	Miniaturization of analog	Speech CODEC method	Anti multi-path method	Power reduction method?
Technology breakthrough	Synthesizer (pulse-swallow)	CELP	RAKE receiver	SDMA?
DSP throughput	4 MIPS	40 MIPS	400 MIPS	4 GIPS?

Table 2
Multi-path delay countermeasures in different generations.

	System	Bit rate	Delay countermeasure	DSP process
2G	DAMPS	40 kb/s	Equalizer	15 MIPS
	cdmaOne	1.2288 Mcps	CDMA-RAKE	Wired logic
	GSM	283 kb/s	Equalizer	Wired logic
	PDC	42 kb/s	Ant. diversity	
3G	W-CDMA	3.84 Mcps	CDMA-RAKE	200 MIPS
	cdma2000	$1.28 \times n$ Mcps	CDMA-RAKE	200 MIPS
	TD-SCDMA	$1.28 \times n$ Mcps	CDMA-RAKE	200 MIPS
4G	-----	20 M to 100 Mb/s	OFDM/CDMA?	5 GIPS?

ready proven results in multiplex microwave communications and possessed applicable technologies, including multi-value QAM, equalizers, and distortion compensation. In addition, it had voice-band compression technologies and DSP experience, enabling it to push forward with the commercialization of such 2G equipment as mobile units, BTSs (common amplifiers, modulator equipment), channel control equipment, and CODEC equipment. This, with the addition of its time-proven mobile switching centers, meant that Fujitsu was able to offer a full product line-up in cellular systems. You could say that the foundations of Fujitsu's mobile communications were established in 2G.

3. Details of 3G

In October last year, Japan's NTT DoCoMo, Inc. started the world's first commercial 3G mobile communications service. It started with uplink rates of 64 kb/s and downlink rates of 384 kb/s, with plans to move to higher data rates at a later point.⁴⁾⁻⁶⁾

Fujitsu supplied some of the major infrastructure equipment for this system. For details on the equipment used, please see the other articles in this issue of the Fujitsu Scientific and Technology Journal.⁷⁾⁻¹¹⁾

Let us consider the issues that will arise in the future when 3G systems have become more widespread. One of these will be the problems associated with an increase in traffic. For BTSs, this will be a lack of channels on the one hand and an increase in the size and power consumption of the equipment on the other. This relates directly to increased power consumption in the baseband section due to increased speed and scale and to increased transmission power in the transmission section.¹²⁾

Transmission power in current BTSs is shared between the baseband section, which carries out digital signal processing, and the high-frequency power amplifier. In order for the power amplifier to maintain linearity, a lineariz-

er is required; however, linearizers are highly power-inefficient (around 8% efficient). There is scope for a new breakthrough here.

Fujitsu has been focusing on improving the efficiency of power amplifiers for a long time and has recorded many achievements in the field.^{13),14)}

Fujitsu has also been working on W-CDMA common amplifiers since early on and has managed to develop a new type of high-efficiency power amplifier that clearly outperforms conventional FF amplifiers.¹⁵⁾ The new amplifier has been installed in the company's BTSs, which is the first time this type of amplifier has been installed anywhere in the world.

By using this novel amplifier and sophisticated configuration of digital signal processing, we have been able to build a BTS with the world's highest number of channels (**Figure 2**).

It can be said with confidence that this technology could not have been realized without the close collaborations that occurred between the device, system, laboratory, and development divisions.

From the perspective of terminals, the problem of increased power consumption due to higher speeds may arise. However, due to various concerns, unlike the case with BTSs we do not believe

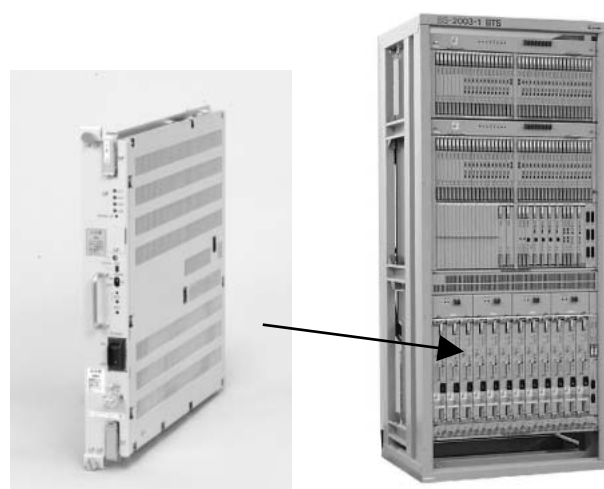


Figure 2
The world's most efficient power amplifier installed in the world's highest capacity BTS.

it will be possible to increase the amount of transmission power radiated from the antenna. As a result, the trend to even lower power consumption will continue. Because of this, a trend towards asymmetry between uplink and downlink speeds will appear in 3G and will become even more pronounced in 4G.

Fujitsu's work in 3G can be traced back to 1992, when the company began work on the system architecture based on fundamental research into CDMA that was carried out in the 1980s. We performed a field trial in 1994 at 800 kcps and accumulated basic data. In 1996, we carried out a second field trial, this time at 16.384 Mcps. At the same time, development was progressing in parallel on the higher layers of channel control⁸⁾ and multimedia switching.¹⁶⁾ For network equipment, we pushed forward with development of an architecture based on ATM, which we helped pioneer.

ATM is a fast packet protocol for multimedia communication services. As with CDMA, research and development on ATM have advanced from the 1980s. In ATM, all kinds of information, for example, voice, images, and data, are transmitted in fixed-length information containers called cells. Each cell consists of a section containing the user data (48 bytes) called the payload and a section containing information about the destination address (5 bytes) called the header. At the transmitting terminal, user information is divided into 48-byte packets. Each packet is stored in the payload of a cell and the header, which includes the destination address, is added. Then, the assembled cells are sent out to a network, where they are sent by ATM switches to the destination address indicated in the cell headers. At the receiving terminal, the original information is reproduced by joining the payloads of the arriving cells together. ATM is a basic technology for achieving multimedia communications, which is one of the most characteristic services offered by 3G systems. The main reasons for choosing ATM are that with ATM:

- Data transmission is independent of the media, because all data is transmitted in a unified format,
- variable bit rates can be realized by controlling the number of transmitting cells, and
- ultra-fast switching and transmission can easily be realized because the cell length is fixed.

However, there is a problem in converting the type of low bit-rate voice data used in mobile communications to ATM in that it takes time to assemble a cell. For example, for voice data at 8 kb/s, it can take around 50 ms to assemble a single cell, which can greatly impede smooth communication. To solve this problem, the information from the terminal is built up as short cells, and multiple short cells are stacked to form a standard ATM cell. This new cell technology has been standardized internationally as AAL2 (ATM Adaptation Layer type 2). Because a standard cell contains the information from many different terminals, it reduces the time taken to assemble cells, while still allowing the transmission of high-speed data and video (**Figure 3**).

Fujitsu has been actively involved in AAL2 since the standardization stage. The necessary LSIs have already been developed and are already in use in BTSs, radio access controllers, media switches, and network equipment for 3G mobile systems.

Perhaps the greatest single event in Fujitsu's history of 3G development was in 1997, when NTT

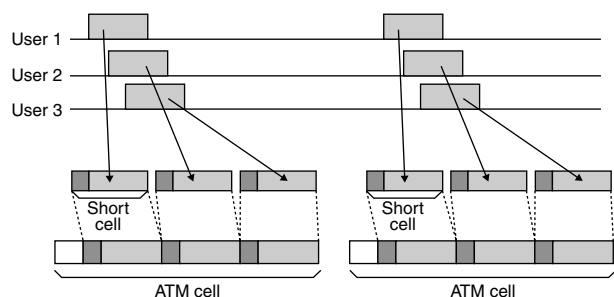


Figure 3
Construction of an AAL2 cell.

DoCoMo announced that Fujitsu had been selected as a worldwide equipment supplier for its next-generation mobile systems. This was a good opportunity for us to learn about NTT DoCoMo's advanced technology. As a result, Fujitsu has been able to establish its position as a total 3G systems supplier.

There is something that we must not forget to mention here, and that is Fujitsu's involvement in the standardization process. Because mobile communications make use of public frequencies, the need for standardization cannot be overlooked and for 3G in particular, global standardization is vital, since international roaming is seen as a must-have service. To deal with this issue, various international standardization bodies (e.g., 3GPP and 3GPP2) were established around 1998.

Fujitsu has been actively involved in Japan's domestic standardization bodies since 1993. We are also an active member of important international bodies and have made significant contributions to the drafting of standards.

All standardization activities within Fujitsu were originally dealt with by Fujitsu Laboratories. However, in 2000 a special organization was set up in the business division to allow the entire company to become involved.

The details of this change are reported elsewhere in this issue of the Fujitsu Scientific and Technology Journal.¹⁶⁾ For each generation, we have to predict what the devices in use will be like, how powerful the networks will be, and what kind of services will be required when that generation comes into full play. Fujitsu will continue to contribute to the standardization process, using its strengths as a comprehensive manufacturer of devices, system networks, and IT to the utmost.

4. Fourth-generation mobile communications

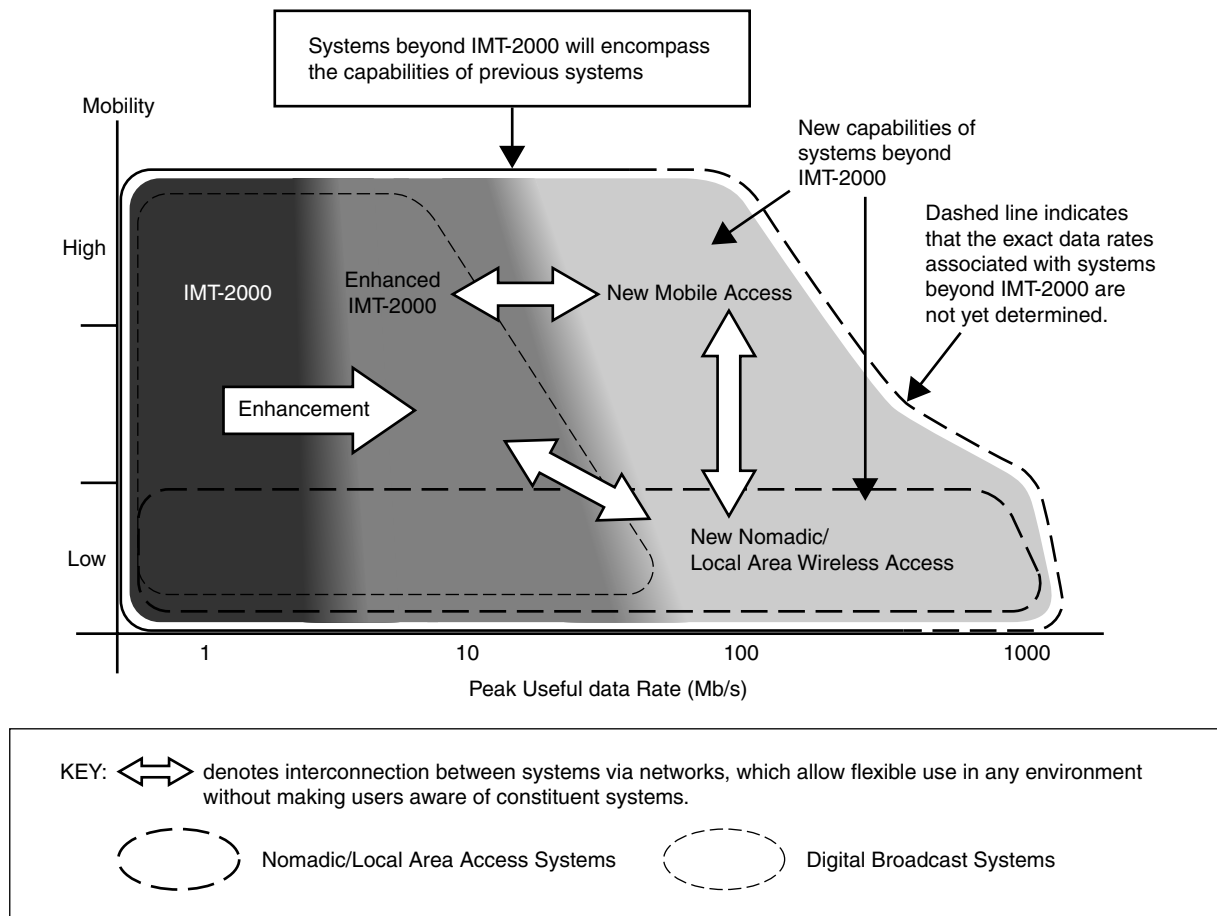
As the development and commercialization of IMT-2000 continues, research and development in connection with 4G mobile communications systems is already underway. TG8/1, the group

at ITU-R responsible for the radio side of IMT-2000, completed its work at the meeting held in November 1999, then WP8F was established in March 2000 to look into the "Future development of IMT-2000 and systems beyond IMT-2000". After various studies were conducted, WP8F approved the Draft New Recommendation on "Vision, framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000" in October 2002 (as shown in **Figure 4**).

Meanwhile in Japan, the Ministry of Public Management, Home Affairs, Post, and Telecommunications (formerly the Ministry of Posts and Telecommunications) has consulted the Telecommunication Technology Committee about the future prospects of next-generation mobile communications systems. The report also covers the basic concepts proposed by members of the Telecommunication Technology Committee, technological development and standardization problems that must be solved to realize these concepts, and suggestions for a promotion policy. The report was issued in June 2001.¹⁷⁾ Given that previous systems have undergone a change of generation every 10 years or so, and considering the circumstances of capital expenditures by operators, what is known in Japan as 4G systems will probably be introduced around 2007 to 2010.

Some important points regarding 4G systems are as follows:

- 1) As the Internet moves forward, there will be a growing demand in mobile and fixed contexts for "always-on" connection.
- 2) Conventional communications systems have been dominated by person-to-person communications, but communications between people and computers, and between computers and other similar equipment will become more common in the future.
- 3) From the user's perspective, there will be an increasing demand for increasingly higher speeds and easier use. Thus, there should be more support for transmission speeds



Dark shading indicates existing capabilities, medium shading indicates enhancements to IMT-2000, and the lighter shading indicates new capabilities of systems beyond IMT-2000.

The degree of mobility as used in this figure is described as follows: Low mobility covers pedestrian speed, and high mobility covers high speed on highways or fast trains (60 km/h to ~250 km/h, or more).

Figure 4
Capabilities of IMT-2000 and systems beyond IMT-2000.

Source: RECOMMENDATION ITU-R M.1645, Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000

more than 100 Mb/s in the downlink and 30 Mb/s in the uplink.

There are major problems to be overcome before data rates of 100 Mb/s become a reality. The key requirements for realizing 100 Mb/s are as follows:

- 1) Transmission power must be increased in proportion to the transmission rate in order to maintain the same quality.
- 2) Modems must perform signal processing to cope with severe delay spreads.
- 3) System capacity must be increased to provide users with wide-bandwidth, high

data-rate services.

Of these requirements, the need for higher transmission power is very important. In the uplink, transmission power will be limited to only a few hundred milliwatts because of the limited battery-life, which means that transmission speeds will be limited to around 20 to 30 Mb/s. This means that if higher transmission speeds are needed, then cell sizes will have to be reduced.

It is also becoming harder to greatly increase the power transmitted from the BTS. However, by using the adaptive array antenna, we can improve gain, reduce external interference, and

dramatically reduce the mobile unit's transmission power. At the same time, this type of antenna also makes it possible to significantly lower the downlink transmission power from the BTS. Unfortunately though, there are some not inconsiderable penalties that have to be paid when this technology is used. These include an increase in the cost of analog circuits and a considerable increase in the complexity of digital signal processing due to the need to track the mobile units and calculate their arrival angles.

The second problem is how to deal with the multi-path delay spread that was mentioned in an earlier section. As data rates get faster, even the slightest amount of multi-path delay spread can have an extremely negative effect on the demodulation of digital data. For transmission at 10 Mb/s, CDMA is effective, but as rates approach 100 Mb/s, this effectiveness is lost and the OFDM multi-carrier modulation/demodulation system must be used (**Figure 5**).^{18),19)}

Adaptive array technology can also work effectively against this problem of multi-path delay spread (**Figure 6**). That is, narrowing the spread of the angle of incidence can easily be estimated by stochastically reducing the multi-path delay spread. However, for signals that come from the same direction and have a multi-path delay spread, we believe that adaptive array technology

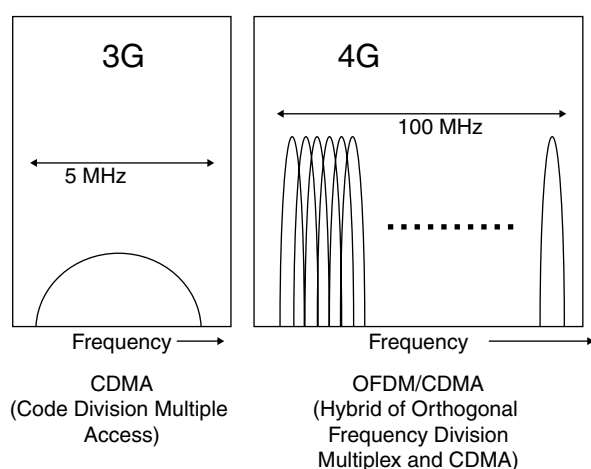


Figure 5
Comparison of access method in 3G and 4G.

can be applied in a similar way as CDMA and it can be used for the kind of equalization used in 2G. An OFDM/CDMA hybrid system that takes each OFDM carrier wave one-by-one and spreads it using CDMA could be effective for this type of signal.²⁰⁾

The third problem, that of subscriber capacity, is also serious. As soon as a wideband signal of some 100 Mb/s is emitted, nobody else can use that wave. Adaptive arrays are also effective in dealing with this issue. Even if the frequency, time, and code are the same, as long as the angles from the mobile units to the BTS are all different, each user can be assigned a sharp beam by furnishing the BTS with a multi-element array. This could be described as SDMA or PDMA.

Although adaptive arrays are fundamentally a 4G technology, we believe that they can be applied to 3G as well. More details about this technology are given elsewhere in this issue of the Fujitsu Scientific and Technology Journal.²¹⁾

5. Challenges of the next generation

As we have seen, the rapid progress in wireless systems has been tightly bound to the

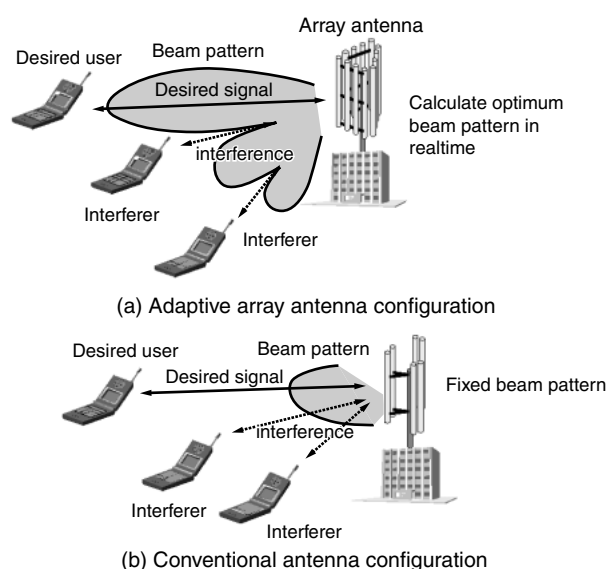


Figure 6
Adaptive array antenna is a key technology.

progress in devices. Fujitsu has taken the lead in developing devices that have been vital for the realization of these wireless systems and has applied them to the systems in a timely manner. This issue of the FSTJ contains an introduction to the main devices used in these wireless systems, including high-frequency and SAW devices used in 3G, analog devices that cover intermediate frequencies, and CMOS digital LSIs.²²⁾ For the 4G system, we are busy developing even higher output devices that can cope with the higher speeds and greater bandwidth of the signals. **Figure 7** shows the roadmap of high-power devices. We already have the commercialization of 500 W output devices in our sights. In parallel with this move toward greater output, we are also striving to increase frequencies with the aim of breaking into new frequency bands. **Figure 8** shows some details of a 76 GHz one-chip transceiver that uses 0.15 μm P-HEMTs.

On the other hand, 4G will bring about the standardization of a whole host of systems and those standards will be continuously updated. Software defined radio (SDR) technology has been widely discussed as a way of dealing with this in a flexible manner. Recently, it has been proposed not just as a way to respond flexibly to changes in specifications but also as a way of switching between different systems (W-CDMA, cdma2000,

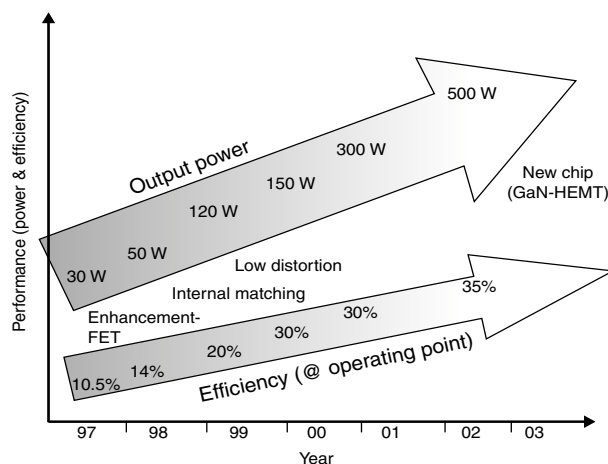


Figure 7
Road map of high-power devices.

GSM, PDC, etc.) and even handing over to wireless LAN systems. We believe that progress in SDR will have enormous influence over the future shape of radio systems. Fujitsu is spending a great deal of effort in developing technologies that will enable 4G to be achieved, including C-MOS logic devices, high-speed and high-precision D/A and A/D converters, wideband direct converters, wideband power amplifiers, wideband antenna duplexers, and wideband antennas. **Figure 9** shows the configuration of SDR.

We believe that SDR will be used in mobile terminals and BTSs, and that the baseband configuration will be applied to higher level equipment, for example, routers.

In any event, the baseband section of next-generation mobile communications will require even further improvements in power consumption, functionality, and processing speeds. With this in mind, let us turn to the future development of

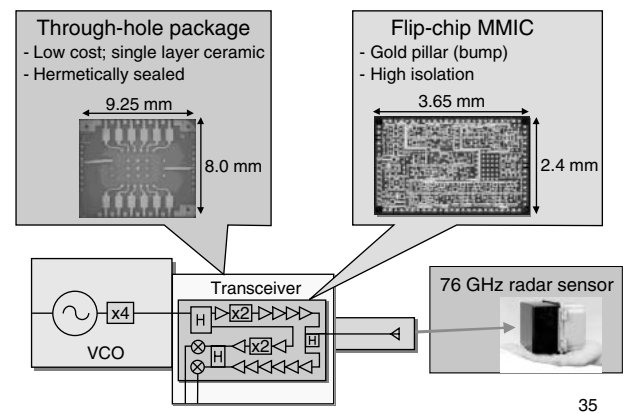


Figure 8
76 GHz 1-chip transceiver.

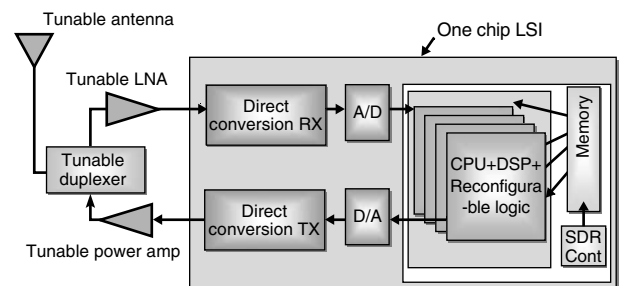


Figure 9
Configuration of software defined radio (SDR).

signal processing functions, centering on highly integrated circuitry.

Figure 10 shows the processing performance in each generation of mobile handsets. At the start of 2G, handsets centered on voice communications and almost all of the digital processing was processing done in the voice encoder.

As 2G gives way to 3G, the mobile handset is being transformed from a tool for voice communications into a high-speed data terminal. As this transformation proceeds, the range of functions performed by mobile terminals will expand to include, for example, video encoding.

Furthermore, in the 4G age, the digitization of the baseband section will progress to build a structure in which it will be common for signals to be digitized with an A/D converter at the entrance to the baseband section and all subsequent processing to be done digitally. When that stage has been reached, handsets will have to be capable of throughputs of several GIPS.

As can be seen in **Figure 11**, CMOS technology is predicted to bring a doubling in both circuit miniaturization and integration between now and 2005.²³⁾⁻²⁵⁾ This doubling should secure devices that are very capable of enabling full digitization of 3G baseband processing.

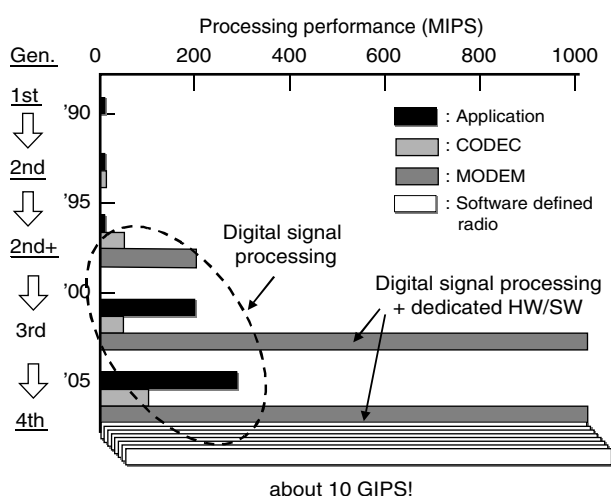


Figure 10
Processing performance in each generation of mobile handsets.

As digitization progresses even further, it will spread to the modulation/demodulation functionality of the IF section. Eventually, all analog processing will be transformed into digital processing. As a result, in the future, the only components in the radio part will be the antenna, the analog RF filters and power amplifiers, the high-speed A-D and D-A converters, and large-scale CMOS LSIs that compose the logical circuits.

The digital processing section will start to be implemented as shown on the right in Figure 9 by lining up processing blocks that use DSPs and FPGAs, with a plan to eventually integrate these blocks together. However, it is not easy to discover a system architecture that can solve problems such as the inexorable growth in memory requirements (**Figure 12**) and how to come up with a circuit structure that can deal with the heat issue. To reach the level required to launch services within the relatively short time scale of just a few years, a great deal of effort needs to be applied, not only to develop the device technology and hardware algorithms, but also to find realistic goals for the system as a whole. It is therefore vital that device engineers and system engineers work in close cooperation in order to find these goals.

In the end, there could well be a groundbreaking development in devices, for example, a replacement for CMOS, that would give rise to ultra high-speed signal processing. With such a

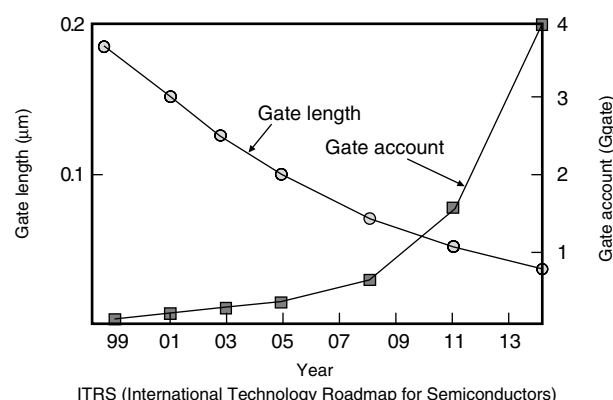


Figure 11
Road map of C-MOS technology.

development, it may even be possible to have an “everything on a single processor” solution. That in turn would mean that compatibility with multiple radio systems could be achieved with software alone, enabling the development of simple terminals that can communicate from anywhere in the world. In addition, the users would be able to customize their communications, with complete freedom to select their own individual style of services irrespective of networks and operators. When this becomes possible, the ultimate dream of SDR^{(26),(27)} will become a reality.

From the network point of view, one of the essential features of the 4G mobile communications system network is its ability to accommodate a variety of access systems and inter-work between them. As mentioned before, not only the 4G wireless system, but also other access technologies already in commercial use, for example, Bluetooth, Ir-DA, and DSRC, can be considered to be 4G access technologies. In addition, there will be a variety of terminal equipment: not just conventional equipment such as mobile phones; laptop PCs; and PDAs; but also devices such as refrigerators; portable CD players; wristwatches; pens; and even virtual, robotic, and real pets will be connected to the 4G network. The Internet is continuing to explode, and the 4G mobile communications system will become a ubiquitous network

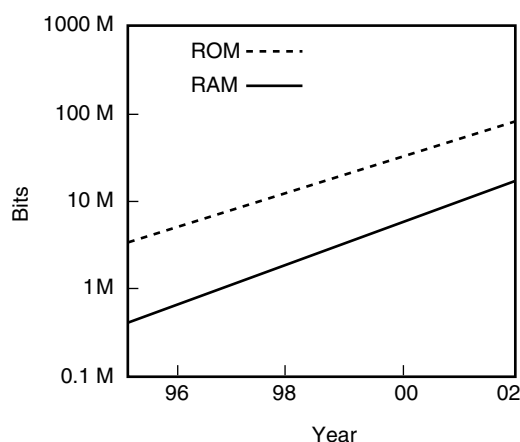


Figure 12
Memory size of terminals.

that will accommodate a variety of accesses and terminals in an integrated IP (Internet protocol) core network (**Figure 13**).⁽²⁸⁾

IPv6 is one of the technologies being considered to cope with the increased number of terminals that will be in use in the 4G mobile network. Especially, Mobile IPv6 will play an important role in concealing the differences between access systems and realizing seamless roaming/handover from one access system to another. There are many research bodies and standardization bodies that have investigated Mobile IPv6. Fujitsu has also developed improved technology for Mobile IPv6.⁽²⁹⁾ Also important will be a technology that selects the access system that can best meet the needs of, for example, the current application or a user's policy.

Mobile IPv6 is one of the network technologies for realizing the 4G mobile communications system. Discussions about the 4G mobile network, especially from the network viewpoint, has just started. Many more discussion will be needed to realize the 4G mobile network and learn how to use it.

6. Conclusion

By taking an overview of the history of cellular communications and noting the progress made in devices, we have been able to predict the future development of the 3G and 4G communication systems.⁽³⁰⁾ Through this process, we have seen how much work Fujitsu has done in the development of technologies for wireless and mobile

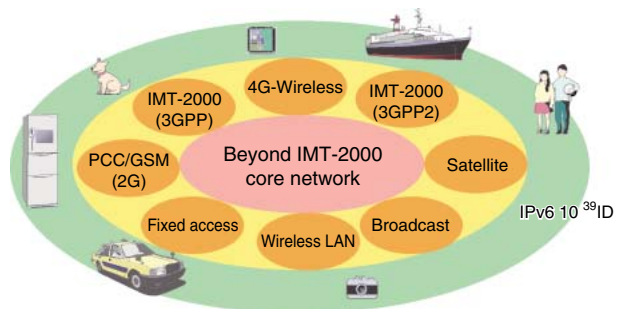


Figure 13
4th-generation mobile network architecture.

communications. Fujitsu is a comprehensive vendor of services, computing, networks, and devices, and we can combine all of our strengths to cope with sectors such as mobile communications that span all of these IT areas. We will use these strengths to the utmost to continue the close integration of our many areas of expertise and push the limits of cutting-edge technological development so we can continue contributing to wireless and mobile communications.

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