Special Article on Link Systems

Basic Design Policy for DoCoMo's Transmission Networks — Toward the Construction of Economical Infrastructure —

In order to cope with rapid increase of mobile communication demands in recent days, it is required for transmission link systems to have much higher capacity as well as more efficient traffic handling capability. Also economical equipment design and high reliability hava become important factors in constructing the network infrastructure.

This paper describes basic design policy for DoCoMo's transmission networks, outline of new radio-relay systems and multiplexing equipment, and requirements for link systems toward the introduction of IMT-2000 in the near future.

Akira Hashimoto, Jun-ichi Sango and Kazuo Yamagishi

Preface

The number of mobile phone subscription has grown more than ten times in recent five years since 1994. In response to the growth, mobile communication traffic (the number of the required circuits among switching nodes) is increasing drastically. Hence, a new technology for larger system capacity and improved traffic handling capability is required for link systems connecting between Base Station and switch node and between switching nodes. Also, it has become one of important subjects to construct transmission line networks with high reliability and efficiency for basic mobile communication infrastructure.

Since its inauguration in 1992, DoCoMo has set its basic policy to build up its own transmission lines, aiming at independent business management as a Type 1 telecommunications carrier. Therefore, DoCoMo has tackled with the construction of its own transmission lines by introducing microwave system for the trunk transmission lines (long-haul and metropolitan) as the first step. In addition, it has been adopting optical transmission system for a route where larger capacity is required or construction with microwave system is difficult due to radio interference. The transmission lines in DoCoMo's possession has been increased more than ten times from 27 routes (5 routes for metropolitan optical fiber systems and 22 routes for long-haul microwave system) at the start to 313 routes (88 routes for metropolitan optical fiber system, 58 routes for metropolitan microwave system and 167 routes for long-haul microwave system) in March 1999. Furthermore at present as the second step, we are proceeding the construction of our own access transmission lines to over 8,000 Base Stations located in all parts of Japan.

In order to proceed building these transmission networks economically and speedily, new systems with larger capacity and considerable cost down have been successively introduced since March 1999, in place of the conventional microwave systems based on the NTT's specifications. Moreover, equipment capable of efficiently multiplexing access circuits with different speeds, various kinds of control circuits including common control signaling into 52Mbit/s has been made practical and its introduction has began in April 1999.

In this paper, the basic concept for constructing transmission network is summarized. In addition, brief explanation on new microwave system, multiplexing equipment, and requirements for link systems to be developed for IMT-2000 are described.

DoCoMo Network Configuration

■ Configuration of Circuit and Path Networks

The current network has 3 hierarchical configuration i.e. MLS (Mobile Local Switch) ~ MGS ~ MTS (Mobile Transit Switch) developing from the past configuration of AMS (Auto Mobile Switch) — MGS(Mobile Gateway Switch) in the analog era. From the initial network configuration with a lim-

ited transmission routes, less switching nodes, and without of route dispersion, building up of highly reliable networks has been promoted on the premise of line distribution and node distribution.

As for the measures for this purpose, the distribution of switching node buildings has been adopted accompanied with transmission distribution line route and line distribution for between MLS～MGS and between MGS～MGS. Countermeasures for securing at least 75% line survival rate have taken for between MTS～MTS (between companies) and between MGS～MTS, according to transmission line routing (Figure 1).

These "circuits" are accommodated into "path" with a constant number of the "circuits", and the "path" is set up on end-to-end transmission routes. Countermeasures are implemented to avoid complete interruption of transmission routes or complete disconnection in a node building as follows;

Path routing to specific nodes are to distributed in two separate ways.

BN (Block Nodes) connecting paths between the regional companies are distributed in two different buildings (Figure 2).

In addition, the reliability for Base Station lines (between CN (Connection Node)～MLS) is secured by accommodation of different routing into the intra-prefecture loop network.

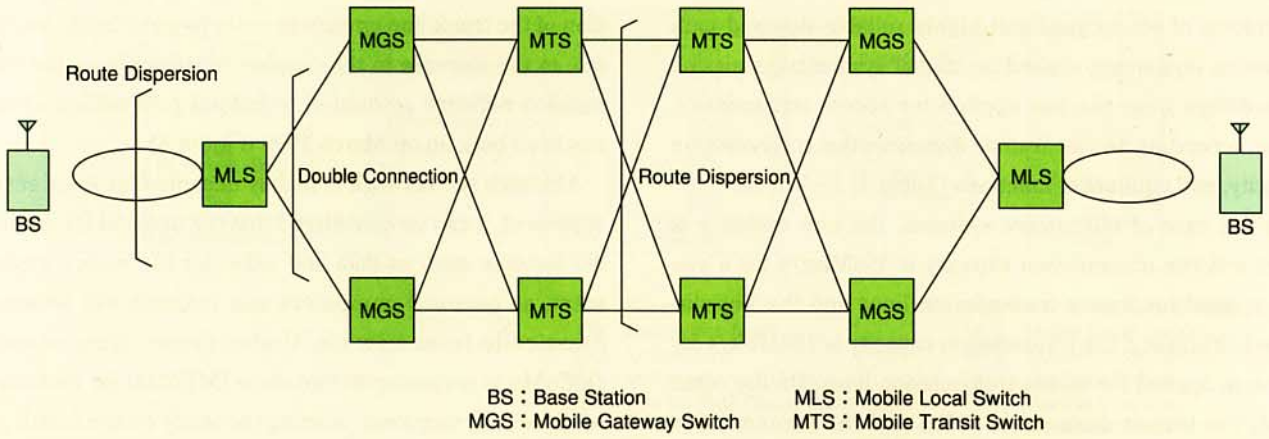

Figure 1 Line Network Configuration

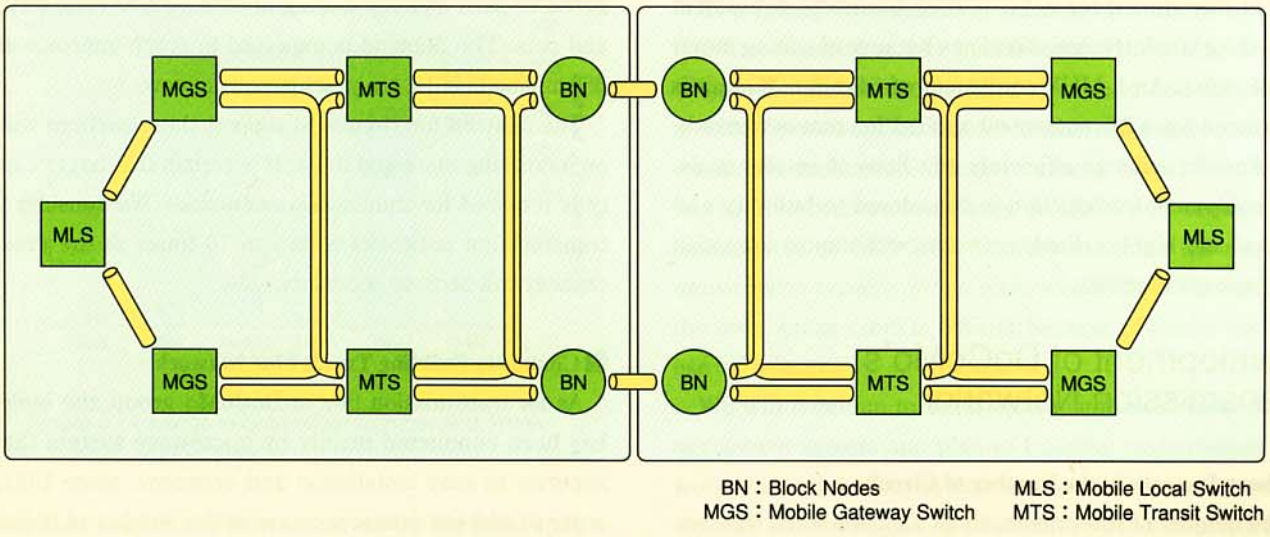

Figure 2 Path Network Configuration (Transit System)

Table 1 Transmission Line Classification and the Applied System

Transmission Line Classification		Applied system	
		Microwave System	Multiplexer
Trunk Transmission Line	Long-Haul Inter-company	·4/5/6G-150MD system	·Module A※1 ·Module B※1 ·Module C※1 ·L-MUX (Low Bit Rate Circuit Multiplexer) ·ATM-XC (ATM Cross-connect Equipment)※2 ·ATM-MUX (ATM multiplexer)※2
	Metropolitan	·11/15G-150MD system ·11/15G-50MD system	
Access Transmission Line	Short-Haul	·11/15G-150MD system ·11/15G-50MD system ·4/5G-50M system	
	Entrance	·11G-6M system ·4/5/6G-6M system ·22G-6MD system	·I-MUX (Multiplexer for entrance) ·ATM-MUX※2

※1 : See Figure 3. ※2 : To be introduced.

■ Transmission Network Equipment for the Network

As for transmission network equipment introduced for realization of economical and highly reliable line and path networks, equipment applied for transit system transmission lines differs from the one applied for access transmission lines, according to the transit distance, the transmission capacity, and equipment functions (Table 1).

In the case of microwave systems, the hop distance is 50km and the transmission capacity is 156Mbit/s for a system applied for transit transmission lines and the hop distance is 25km and the transmission capacity is 156Mbit/s for a system applied for access transmission lines. On the other hand, the transit distance is 15km and the transmission capacity is 6Mbit/s for entrance microwave system.

A multiplexer with the cross-connect * function is also applied by finding its niche based on the scale of the network (Table 1, Figure 3). A module B of 1.5Mbit/s cross-connect unit is introduced for a XC (Cross Connect) equipment applied for trunk transmission lines because of editing larger bundle lines. An L-MUX equipment of 64kbit/s XC unit is introduced for a XC equipment applied for access transmission lines in order to efficiently edit lines of smaller scale. The equipment introduction is considered to build up economical and highly reliable networks with utmost utilization of equipment functions.

Development of DoCoMo's Transmission Networks

■ Sharp Increase in the Number of Circuits

The number of subscribers, about 1 million when the company was established, has been tremendously increased since 1995, thanks to big reduction of calling fee and lighter mobile phones and reached 24 million (about 24 times increase) in March 1999. As a result of annual huge expansion of the trunk line circuits in order to serve traffic increase due to the increase in the number of subscribers, the transmission network amounted to indeed 1.39 million circuits has been built up on March 1999 (Figure 4).

Although the network is mainly designed for voice service at present, it can be considered that the demand for multimedia services such as data and video for the mobile environment, as personal computers and Internet will be spread drastically from now on. Under these circumstances, DoCoMo is preparing to introduce IMT-2000 for multimedia services and, moreover, starting the study on the fourth generation mobile communication system capable of up to 10Mbit/s transmission rate.

In addition, the majority of the demand for mobile communication will be expanded from the conventional human-based nucleus into any moving objects such as cars, bicycles and pets. The demand is expected to reach approximately 360 million in 2010, ten years later from now.

The demand for circuits to support these services will go on increasing more and more. It is certain that larger capacity is required for transmission networks. We consider that transmission networks with 5 to 10 times of the present capacity will become necessary.

■ Change in Building Trunk Line Network

As for transmission line of DoCoMo group, the build-up has been conducted mainly by microwave system that is superior in easy installation and economy, since 1992, in order to address drastic increase in the number of lines. An

* Cross-connect : To improve the usage efficiency of transmission line networks and conduct convergence, separation, and refilling of economical and highly reliable paths.

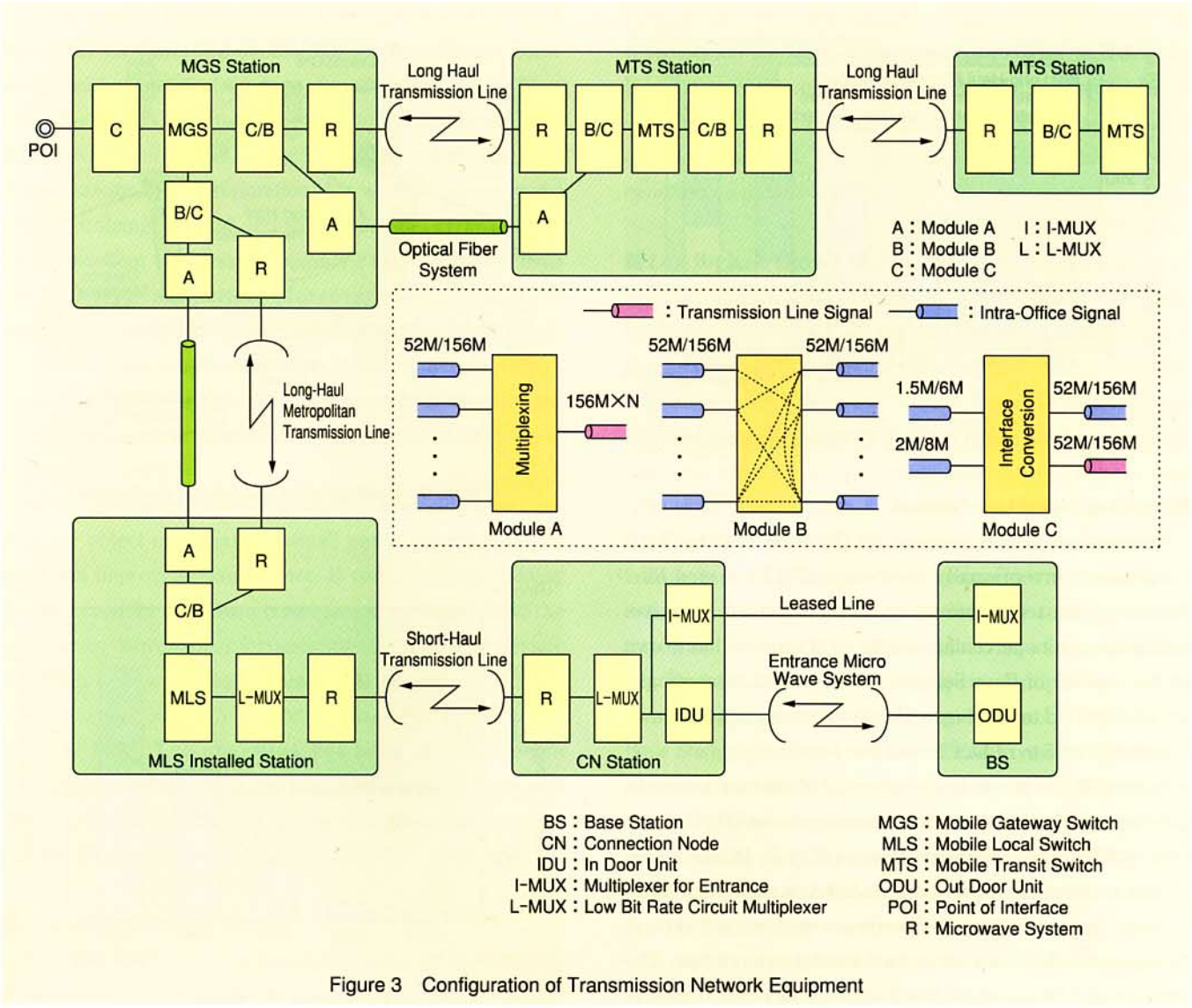

Figure 3 Configuration of Transmission Network Equipment

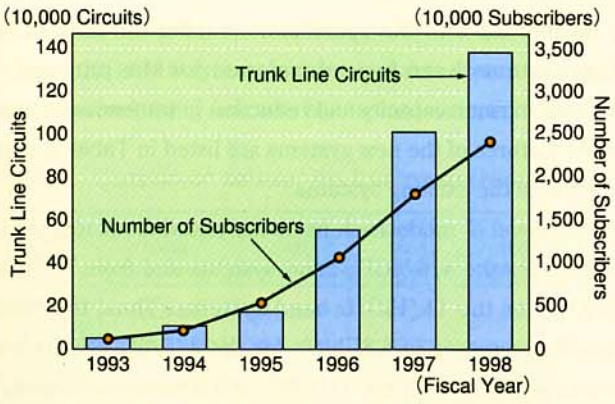

Figure 4 Change in Subscriber Number and Trunk Line Circuits

optical fiber system has been employed for the build-up in a metropolitan area where microwave system cannot serve the required capacity or an area where microwave system cannot be constructed due to radio interference.

As a result, the number of transmission routes of trunk line has reached at 244 in 1997 and 313 in March 1999 (Figure 5). As for optical fiber system, in addition to the method by own optical cable with the existing conduit line rental, the application of larger capacity leased line, which has been institutionalized based on DoCoMo's request, has been started on May 1997, in order to secure the required transmission capacity for an route where the construction of the own optical cable is difficult because of public common use tunnels etc.

We will continue to build up transmission networks by microwave system and plan to building transmission networks by optical fiber system in an area where the routes capacity can not be met by microwave system in preparation for the demand increase by IMT-2000 in the future .

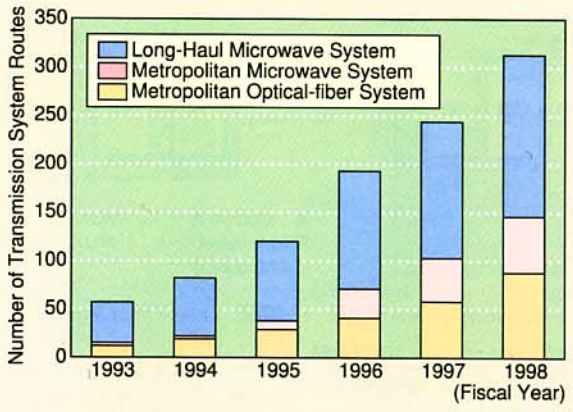

Figure 5 Build-Up Situation of Trunk Line Network

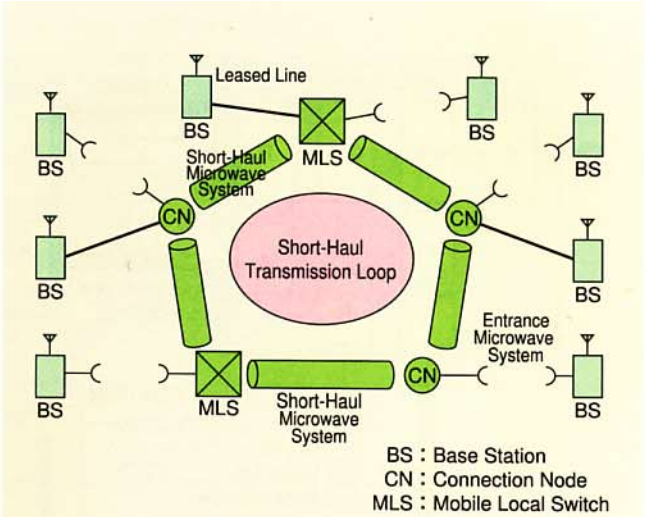

Figure 6 Configuration of Access-Line Network

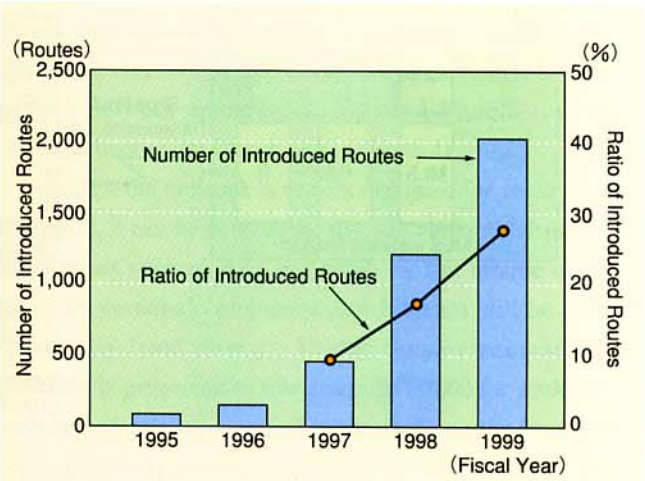

Figure 7 Change in Entrance Microwave System Introduction

■ Building Access Line Network

Transmission routes between BS (Base Station) and MLS have been conventionally composed of NTT leased line. However, the total amount of fees for leased lines has increased and its percentage in the total expense has grown as the number of Base Stations has increased. Accordingly, we have started to build up access transmission lines by own systems in 1995 to reduce leased line fees.

Access line network is composed of short-haul transmission loop by short distance microwave systems (11/15G system) and entrance microwave system (Figure 6). BS is connected to the nearest CN Station located on short-haul transmission loops by entrance microwave system, and then is connected to MLS via short-haul transmission loops. The number of BSs accommodated in one short-haul transmission loop is determined to be around 40～50 stations at maximum, taking into account the capacity of microwave transmission system.

The approach for the shift to entrance microwave system from NTT leased lines has been started since April 1998, in parallel with the build-up of short-haul transmission loops. The shift will be conducted at 2,000 routes throughout the country by March 2000 (Figure 7).

Link Equipment Forming Transmission Networks

■ Long-Haul and Short-Haul Microwave Systems

We have built up transmission lines mainly by long-haul microwave routes inherited from NTT and partly by new routes constructed recently.

The 4/5/6G-150M system has been used for long-haul routes and the 11/15G-150M and the 11/15G-50M have been used for short-haul routes and urban areas. They were initially introduced with the specifications inherited from NTT. New systems have been developed for the purpose of increase in route capacity and reduction in transmission cost. Major features of the new systems are listed in Table 2, compared with the existing systems.

Multi-level of modulation has been raised from 16QAM to 64QAM for the 4/5/6GHz-band systems and from 8PSK to 16QAM for the 11/15GHz-band systems. Thus, the route capacity increases to 5.8Gbit/s for the 4/5/6G-150MD system and 2.3Gbit/s for the 11(15)G-150MD system (1.7Gbit/s for 15G system). These figures show about one and half increase, respectively, and contribute to the frequency usage efficiency.

For the 4/5/6GHz-band systems, notable cost reduction is realized by the single-carrier method instead of 3-carrier method used in the former systems. Recent modem technol-

ogy and use of full digitized DFE(Decision Feedback Equalizer) for canceling waveform distortion make it possible to adopt economical single-carrier method.

For the 11/15GHz-band systems, a newly employed XPIC (Cross Polarization <XPD> Interference Canceler) adequately compensate XPD deterioration that would increase in the system utilizing 16QAM and the co-channel arrangement. Thus, excellent transmission quality can be obtained even during heavy rain period. Moreover, the equipment is designed for smaller volume to save the required floor space. In addition, the improvement in maintenance is accomplished by improving the failed area identifying function and the quality telemeter function through the use of alarm information processing.

As for the 11/15G-150MD system, it has been developed with the object of realizing a small and economical equipment and improving maintenance. It contributes to building medium capacity short-haul transmission routes, making the best use of conventional features such as non regenerative repetition.

The introduction of these systems has been started partly in fiscal 1998. The operation has been commenced in November 1999 for the 4/5/6G-150MD system, February 1999 for the 11/15G-150MD system, and November 1999 for 11G-50MD system.

■ Entrance Microwave System

The 11G-6M system is mainly introduced as entrance microwave system. Besides, the 4/5/6G-6M system is used for the case that a long hop distance is necessary, and the 22G-6M system is used for the case that the 11G system can not be used due to severe interference.

A new 22G-6MD system with remarkable economizing and protection switching function has been developed. Since the existing system is not equipped with stand-by equipment, reliability is improved by the introduction of the new system. It is expected to contribute to the build-up entrance micro lines in an area such as big cities where radio routes are very densely populated. The operation of the system has been commenced in October 1999.

Table 2 Comparison between the Existing and New Systems

System Name	4/5/6G 150M (Existing System)	4/5/6G 150MD (New System)	11/15G 150M (Existing System)	11/15G 150MD (New System)
Modulation Scheme	16QAM	64QAM	8PSK	16QAM
Route Capacity (bit/s)	3.6G	5.8G	1.6G (11GHz) 1.1G (15GHz)	2.3G (11GHz) 1.7G (15GHz)
Frequency Utilization Efficiency (bit/s/Hz)	5	7.5	3.75	5
Number of Multi-Carriers	3 carriers	Single	Single	Single

■ Low Bit Rate Circuit Multiplexer (L-MUX)

A low bit rate circuit multiplexer is introduced when short-haul transmission loop are built up between CN and MLS. It is a multiplexer that multiplexes efficiently circuits of different bit-rate such as Base Station lines, CCS (Common Channel Signaling) networks, and OPS (Operation System) lines etc with the cross-connect function of 64kbit/s unit (Figure 8). Furthermore, it is equipped with the auto switching function to the stand-by transmission line in the case of a failure in the1.5M path. The measures are remarkably improved for the case that the1.5M path accommodating important lines such as CCS is failed. The new equipment has joint function of the existing two equipment, i.e. the existing type multiple translating equipment (I-MUX) for Base Station entrance lines and a TCM-1 type multiple translating equipment (Module C). Moreover, it can be said that the equipment is equipped with the function of improving path reliability. It is expected to contribute to building future short-haul transmission networks and promoting enlargement of the company common line signal networks.

In addition, the introduction of the equipment was started in April 1999. The operation of the equipment will be commenced in March 2000.

Future Transmission Network Toward IMT-2000

The ATM (Asynchronous Transfer Mode) is adopted to allow efficient transmission. In this method, information in multimedia calls ranging from voice, data to video with a great variety of bit-rate is transmitted in the form of "cell" composed of a 48byte length payload portion and 5-byte length header portion with cell identification information.

However, the previously standardized AAL (ATM Adaptation Layer) type1 is a method that information is accumulated to fill up a 48byte cell information frame in order to raise the transmission efficiency. Hence, there is a problem that transmission delay occurs for the case of low speed information such as video communication.

Therefore, the newly standardized AAL type 2 that multi-

plexes multiple user information of short packet type in one information frame (48 bytes) is applied to a transmission line and this problem is solved (Figure 9).

ATM is applied for user information from mobile terminals in BTS (Base Transceiver Station), and the information is accommodated into 52M path of short-haul transmmision lines by ATM-MUX (ATM Multiplexer) at CN Station and then transmitted to L-MMS switch station. At L-MMS, the information is switched to each destination for each cell, and it is accommodated into a 52M path of transmission line by ATM-XC (ATM Cross-connect Equipment) and is transmitted to the associated transit switch.

The application of ATM to a multiplexer allows to conduct non hierarchy multiplexing and to improve the accommodation ratio of transmission lines, different from the conventional STM (Syncronous Transfer Mode) that the accommodation ratio reduces as it conducts hierarchy multiplexing.

Conclusion

The basic configuration of DoCoMo transmission networks and major link systems are summarized. The details

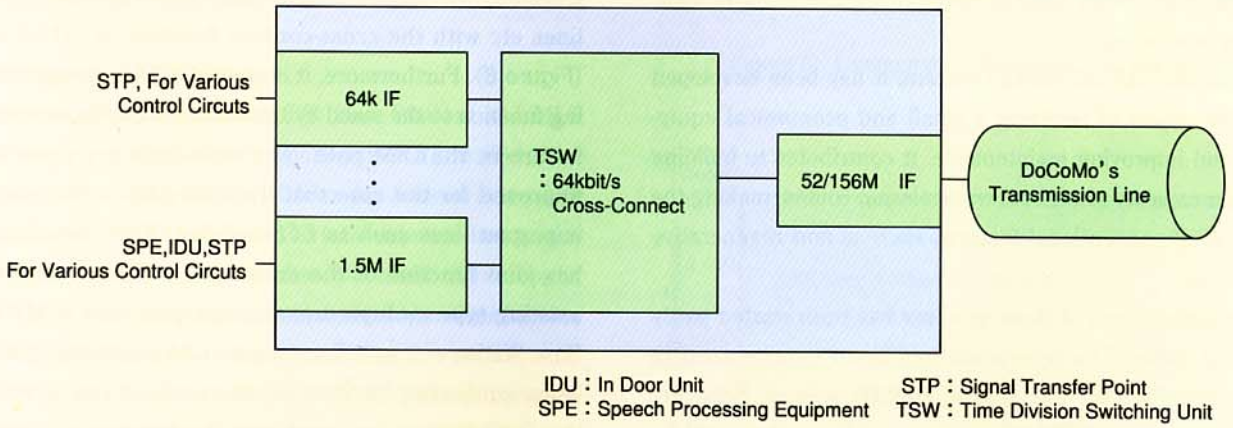

Figure 8 L-MUX Basic Configuration

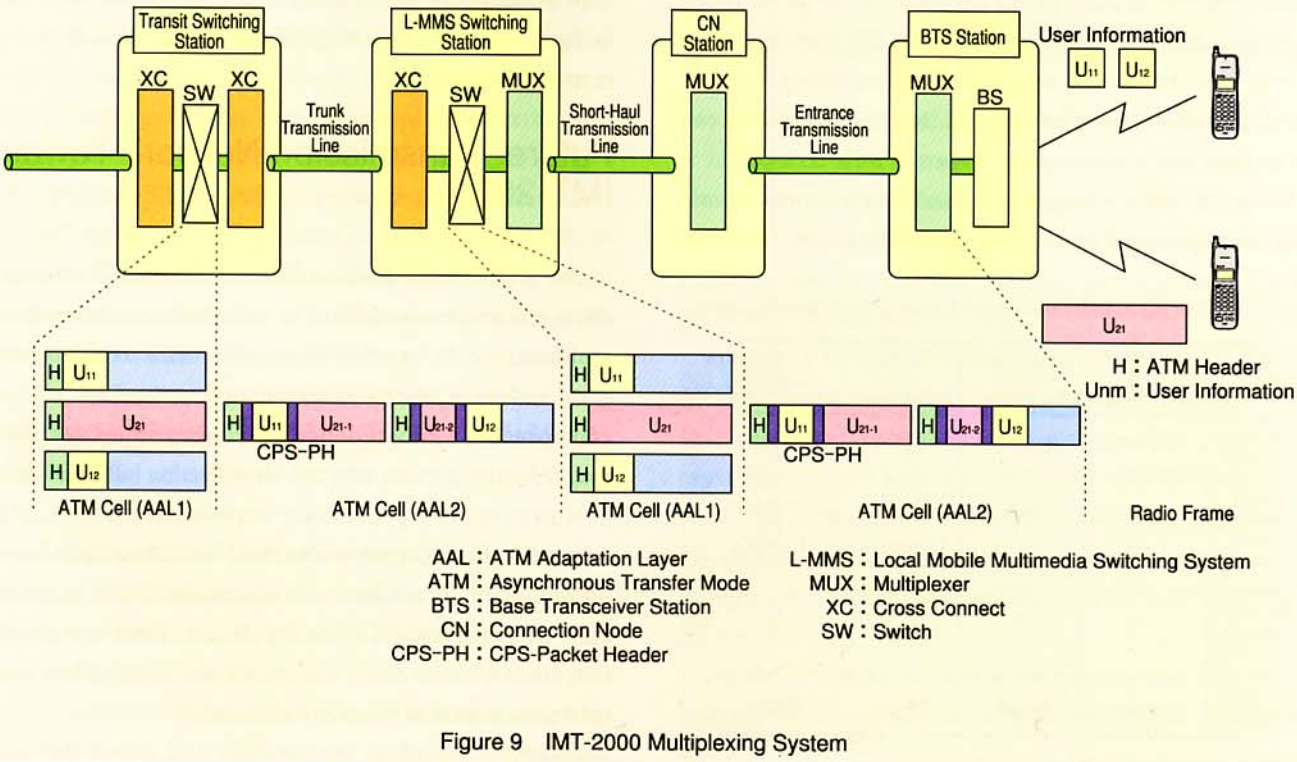

Figure 9 IMT-2000 Multiplexing System

of each system and equipment are described in the separate papers in this special article.

At present, we are studying capacity increase of Base Station entrance link and developing ATM multiplexers in preparation of IMT-2000 introduction. We will continue our effort to construct transmission networks with excellent economy and reliability, in order to support mobile communication traffic that is predicted to grow even more in the 21st century.