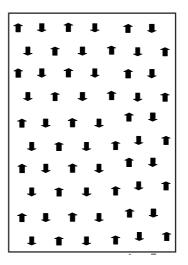
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## ECONOMIC ISSUES

# A PRIMER ON INDIAN TELECOMMUNICATIONS SECTOR

**DALJIT SINGH** 



ASIAN INSTITUTE OF TRANSPORT DEVELOPMENT

## A Primer on Indian Telecommunications Sector By Daljit Singh

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Phones: 91-11-26856117 Telefax: 91-11-26856113 Email: aitd@vsnl.com Website: www.aitd.net

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#### **ABBREVIATIONS**

1G First Generation
 2G Second Generation
 3G Third Generation
 ADC Access Deficit Charge

ADSL Asymmetric Digital Subscriber Line
AMPS Advanced Mobile Phone System
ARPU Average Revenue Per User
BSC Base Station Controller
BSNL Bharat Sanchar Nigam Ltd
BTS Base Transceiver Station

CAGR Cumulative Average Growth Rate CCI Competition Commission of India CDMA Code Division Multiple Access

CDR Call Data Records
CM Cable Modem

CMSP Cellular Mobile Service Provider CMTS Cable Modem Termination System

DARPA Defence Advanced Research Projects Agency

DCA Department of Company Affairs
DOJ Department of Justice (USA)
DoT Department of Telecommunications

DSL Digital Subscriber Line

DTS Department of Telecom Services
EDFA Erbium-Doped Fibre Amplifier
FDM Frequency Division Multiplexing
FDMA Frequency Division Multiple Access

FSP Fixed Service Provider

GATS General Agreement on Trade in Services

GBPS Gigabits Per Second (one billion bits per second)

GEO Geosynchronous Orbits GoI Government of India

GPRS General Packet Radio Services

GSC Group Switching Centre

GSM Global System for Mobile Communications

HLR Home Location Register

HPTIC High Speed Public Telecom and Information Centre

HTML Hypertext Markup Language

Hz Hertz

ILD International Long Distance

ILDO International Long Distance Operator

IMSI International Mobile Subscriber Identity Number IMT-2000 International Mobile Telecommunications 2000

IrDA Infrared Data Association

ISDN Integrated Services Digital Network

ISP Internet Service Provider IT Information Technology

ITU International Telecommunication Union

IUC Interconnection Usage Charge

kbps kilobits per second (one thousand bits per second)

LAN Local Area Network

LDCA Long Distance Charging Area

LEO Low Earth Orbit LM Limited Mobility

LRIC Long Run Incremental Costs
M&As Mergers and Acquisitions
MARR Multi Access Rural Radio

Mbps Megabits Per Second (million bits per second)

MCU Measured Call UnitMEO Middle Earth OrbitsMSC Mobile Switching CentreMSP Mobile Service Provider

MTNL Mahanagar Telephone Nigam Ltd

NCAER National Council for Applied Economic Research

NLD National Long Distance

NLDO National Long Distance Operator

NTP New Telecom Policy

OADM Optical Add/Drop Multiplexer

OASM Operator-specific Accounting Separation Manual

OSS Operations Support Systems

PAN Personal Area Network

*Abbreviations* iii

PC Personal Computer
PCM Pulse Code Modulation
PCO Public Call Office

PDA Personal Digital Assistant

PMRTS Public Mobile Radio Trunk Service

POI Points of Interconnection POTS Plain Old Telephone Service

PSK Phase Shift Keying

PSTN Public Switched Telephone Network

PSU Public Sector Undertaking

PTIC Public Telecom and Information Centre

PVC Poly-Vinyl Chloride QoS Quality of Service

RIO Reference Interconnection Offer

RPM Revenue Per Minute

SAS System for Accounting Separation
SDCA Short Distance Charging Area
SDCC Short Distance Charging Centre
SDSL Symmetrical Digital Subscriber Line

SHDSL Single Pair High Speed Digital Subscriber Line

SMP Significant Market Power
 STD Subscriber Trunk Dialling
 STP Shielded Twisted Pair
 TAX Trunk Automatic Exchange

TCP/IP Transfer Control Protocol and Internet Protocol

TDM Time Division Multiplexing
TDMA Time Division Multiple Access

TDSAT Telecom Disputes Settlement and Appellate Tribunal

TRAI Telecom Regulatory Authority of India

TSC Trunk Switching Centre

TSLRIC Total Service Long Run Incremental Costs

TTO Telecom Tariff Order

UMTS Universal Mobile Telecommunications System

USF Universal Service Fund USL Universal Service Levy

USO Universal Service Obligations

UTP Unshielded Twisted Pair

VDSL Very High Data Rate Digital Subscriber Line

VLR Visitor Location Register
VoIP Voice over Internet Protocol
VPT Village Public Telephone
VSAT Very Small Aperture Terminal
WAP Wireless Application Protocol

WCDMA Wideband Code Division Multiple Access

WDM Wavelength Division Multiplexing

WLL Wireless in Local Loop
WML Wireless Markup Language
WTO World Trade Organisation

WWW World Wide Web

## Introduction

Around the world, the telecommunications sector has seen rapid development in the recent past. In India, growth of this sector has been even more dramatic. Those of us who remember the period when one had to wait several years just to get a telephone connection would never have imagined that someday, not just landline phones but also mobile phones with advanced features would be available on demand at affordable prices. It would not be an exaggeration to say that over the last few years, change has been the only constant in the Indian telecommunications sector.

To the delight of consumers, tariffs for mobile telephone services have tumbled in the last few years. First, the advent of BSNL/MTNL as the third operator in mobile telephony led to a spate of price cuts by the existing mobile service providers (MSPs). This was followed by the opening up of national long distance (NLD) to competition which led to a steep reduction in STD charges. Subsequently, an aggressive campaign by Reliance Infocomm marketing its limited mobility service using wireless in local loop (WLL) created tremendous excitement both in the public and the media and led to a price-war with further price cuts by MSPs.

The structure of the telecommunications sector in India has also been undergoing major changes. The establishment of the Telecom Regulatory Authority of India (TRAI) in 1997 was followed by its replacement by a new TRAI in 2000. TRAI is currently working on a Unified Licensing Regime where there will be just one licence for basic service providers, mobile service providers, and national long distance service providers.

While consumers are excited due to these developments, they are often bewildered by the choices available to them and do not seem to have a clear understanding of what the various offerings really mean. Furthermore, it is not clear to them whether these price reductions would be sustainable. Are these reductions in tariffs a case of predatory pricing by a service provider that will lead to retaliatory price reductions by other service providers? Will the steep price reductions lead to financial disaster for some of the service providers? Will the dominant player raise tariffs after wiping out competition?

The changes in the telecom sector raise other questions as well. With Bharti and Reliance planning to cover substantial parts of the country network with a backbone network, and with the BSNL long distance network being in place, will there be a duplication of hardware resulting in excess capacity? What can the consumer expect from the increased capacity of the backbone network not only for telephony but for other services as well, such as Internet access?

In order to help non-specialists understand and tackle these issues, we decided to develop a primer on the telecommunications sector in India. We do not claim that this primer will provide answers to the various questions that are being raised. However, we hope it will give the readers an understanding of the technology of telecommunications and an overview of the sector so that they can deal with the issues more intelligently and participate in the related debates more effectively.

#### **Importance of the Telecommunications Sector**

One may ask where is the need to educate non-specialists on the intricacies of this particular sector when there are many fields that are left entirely to the specialists. The answer is that the health of the telecommunications sector, like some other infrastructure sectors, such as electric power and transportation, affects all sectors of the economy. Efficient functioning of the phone system Introduction 3

has indeed a great bearing on the effectiveness of a businessman in any enterprise.

Telecommunications has a special significance because of its impact on the information technology (IT) sector. India's capabilities in IT have attracted considerable attention recently and some expect them to propel the country into the international arena as an IT superpower. Without a well-functioning telecommunications sector, the success of the IT industry could be hampered. Therefore, it is important that the telecommunications sector functions efficiently.

Another reason for focusing on the telecommunications sector is the role it can play in the overall economic development of the country. Application of telecommunications in e-governance, education, and medicine would accelerate the development of rural and backward areas.

#### Intended Audience for the Primer

In addition to providing an overview of the institutional structure of the telecom sector, the primer will help develop a basic understanding of the technology involved in voice and data communications and the various components of the costs involved in these communications. The primer is intended for non-specialists who would like to have an understanding of telecom so that they can participate more effectively in the public debates related to the sector. In particular, we hope the primer will be useful for policy-makers who will be called upon to make decisions regarding the sector but may not be having the necessary educational background or professional experience in the field. Further, we feel that effective consumer advocacy in this sector has been hampered by a lack of expertise. It is hoped that the consumer advocates will be able to use this primer to develop a basic understanding of the related technical and economic issues.

While an attempt has been made to provide an overview of the sector, it has not been possible to cover everything and so we do not claim that the primer is comprehensive in its scope. Furthermore, in order to ensure that the primer is intelligible to those without a technical background, we have avoided the use of engineering or mathematical explanations as far as possible.

#### **Structure of the Primer**

Introductory Chapter 1 is followed by Chapter 2 which deals with the institutional structure of the Indian telecommunications sector. While most consumers might have heard about Department of Telecommunications (DoT) and Telecom Regulatory Authority of India (TRAI), they may not be aware of their responsibilities. Moreover, they may not be having knowledge about the activities of the players in the telecommunications sector. This chapter, apart from providing an overview of the institutional structure of the telecom sector, gives information about the working of the major players: DoT, TRAI, and the service providers.

Chapters 3, 4, 5, and 6 provide the basics of telecommunications technology. Chapter 3 introduces basic concepts that are required to understand the following chapters. Chapter 4 explains the fundamentals of telephony. It describes how plain old telephone service (POTS) works and explains the role of the Public Switched Telephone Network (PSTN). Through a description of the network hierarchy, readers will gain an understanding of how phone-traffic is routed. This chapter explains the basics of mobile telephony and how calls are completed. It also provides a basic understanding of how fixed line and mobile calls are transmitted and completed.

Chapter 5 deals with the basics of data communications and the Internet. The role of the Internet in telephony is also explained. Because the technology of telecommunications is progressing so rapidly, no primer on telecommunications would be complete without a peek at what the future is expected to look like. Chapter 6 describes various emerging developments in telecommunication technology. Some of these features or services

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such as broadband access are widely available in the developed countries, but have been introduced in India only recently. Other new developments, such as third generation (3G) telecommunications services are in their infancy even in the developed countries.

Chapters 7, 8, and 9 deal with economic aspects of telecommunications. Chapter 7 deals with the development of competition. The first part of the chapter explains the fundamentals of competition policy and the issues that need to be addressed as the sector moves from a system with a single operator to one with multiple operators. The second part of the chapter deals with the Indian experience in developing and protecting competition in telecommunications and outlines the steps being taken for this purpose.

Effective interconnection is crucial for fostering competition and for developing an efficient and effective telecommunications sector. Given its importance, Chapter 8 has been devoted entirely to this theme. The first part of the chapter explains the basics of interconnection and the issues that need to be addressed in order to develop an effective interconnection regime. The second part looks at the status of interconnection in India. It describes the efforts that have been made to develop an effective interconnection regime and the problems that still remain to be solved.

Chapter 9 deals with tariff-setting, cross-subsidization, and provision of universal service. It describes how the Indian telecommunications sector is balancing the conflicting requirements of economic efficiency and equity. The chapter begins with a brief history of tariff-setting starting in the late 1990s, and goes on to deal with the development of interconnection usage charges and access deficit charges. The chapter ends with a description of how universal service obligations are being fulfilled.

## Overview of the Telecommunications Sector in India

This chapter provides an overview of the Indian telecommunications sector - "a lay of the land" in common parlance. Here, the major players in the sector are identified and their roles and responsibilities in the functioning of the sector described. In order to provide a context for the institutions that are described later in the chapter, we begin with a short history of the period immediately after economic reforms were introduced in the early 1990s. This is followed by a description of the policy framework based on the New Telecom Policy 1999 (NTP 1999) that guides the actions of the Government and other players. Having discussed policy formulation, functions of the regulatory agencies - Telecom Regulatory Authority of India (TRAI) and Telecom Disputes Settlement and Appellate Tribunal (TDSAT) – that implement the policies of the Government are explained. Then we describe the service-based segmentation of the telecommunications market and the licensing rules that apply to the various services. Finally, a snap-shot view of the telecommunications sector as it obtains today is given in order to show how it has grown and what is the status of its various services.

#### **Historical Background**

Recognizing the need to set up world class telecommunications networks in the country, in the early 1990s, the Government of India (GoI) initiated a process of economic reforms. The National Telecom Policy 1994 articulated this commitment to reform and laid down the objectives of reform. The most important objectives were: (i) to introduce competition into the telecom sector so that customers received better service

at affordable prices; and (ii) to increase the availability of telephones in the country.

When the sector was opened up for private investment, there was no independent regulatory body for the sector. The Department of Telecommunications (DoT) which was the incumbent monopoly operator was also responsible for policy-making and implementation. This did not give the potential private investors confidence that the Government would be even-handed and fair in its decisions. Acknowledging these concerns, the GoI set up the Telecom Regulatory Authority of India (TRAI) in 1997.

Initially, the results of the reform process were not satisfactory. Private players did enter the sector and the roll-out particularly in the metropolitan cities was rapid, but most of the private operators were facing financial difficulties. Actual revenues fell far short of projections and the high licence fees that were required to be paid made most of the projects unviable.

The Government realized that the objectives of NTP 1994 were not being fulfilled, and announced a new telecom policy which came to be known as NTP 1999. This policy essentially reiterated the goals and objectives of NTP 1994 in respect of affordability, accessibility and effectiveness. The major difference between the two policy statements was the method of fixing the licence fee. NTP 1999 stated that an operator would pay a one-time entry fee and an annual licence fee based on a share of its annual revenue, in contrast to the earlier system wherein the fee was decided on the basis of auction.

It was also recognised that there were conflicts between TRAI and DoT. DoT did not pay much attention to recommendations made by TRAI on certain issues where the law required TRAI to make recommendations, such as compliance of terms and conditions of licence, introduction of new service providers, revocation of licence, and dispute resolution (Kapur, 1999). Also, DoT challenged the scope of some of the provisions

of the TRAI Act and used litigation to keep TRAI from discharging its functions.

With the conflicts between TRAI and the DoT growing, the Government decided to replace the existing regulators. It amended the TRAI Act replacing the existing TRAI with a new TRAI. It also reduced the size of the regulatory body, withdrew its adjudicatory powers and gave them instead to a new agency – TDSAT.

#### New Telecom Policy (NTP 1999)

NTP 1999 provides the policy framework for the telecommunications sector. It has guided and continues to guide the actions of the Government and the regulatory institutions. While listing the objectives of NTP 1999, GoI made the following assertions:

- Access to telecommunications is important for the achievement of India's social and economic goals, and therefore, "availability of affordable and effective communications for the citizens is at the core of the vision and goal of the telecom policy."
- NTP 1999 strives to balance the needs of urban consumers for high-level services with the provision of universal service to all uncovered areas. In particular, it encourages the development of telecom facilities in remote, hilly and tribal areas of the country.
- NTP 1999 is intended to create a modern and efficient telecommunications infrastructure and thereby facilitate India becoming an IT superpower.
- One of the objectives is to convert PCOs wherever justified into Public Teleinfo Centres.
- Through NTP 1999, GoI would like to make the telecommunications sector competitive in the rural and urban areas and provide a level playing field for all players.

• Through NTP 1999, GoI would like to enable India to become a world-class base for manufacture of telecom equipment and for Indian telecom companies to become global players.

In order to achieve these objectives, NTP 1999 set the following targets:

- Make telephones available on demand by 2002 and raise the teledensity<sup>1</sup> to 7 percent by 2005 and 15 percent by 2010.
- Use the tariff structure to promote development of rural telecommunications and to require all fixed service providers to provide service in rural areas.
- Increase rural teledensity to 4 percent by 2010 from its current level then of 0.4 percent.
- Provide telecommunication coverage of all villages in the country by the year 2002.
- Provide Internet access to all district headquarters by 2000.
- Provide high speed data and multimedia capability to all towns with a population of more than 2 lakhs by 2002.

At the time it was promulgated, NTP 1999 envisaged telephony access being provided by three categories of service providers: cellular mobile service providers (CMSPs), fixed service providers (FSPs), and cable service providers. At that time, it envisioned three CMSPs per circle, one of them being MTNL or BSNL. However, it said that more CMSPs may be added later based on recommendations from TRAI. The number of FSPs in a circle was also to be decided later based on recommendations from TRAI. While NTP 1999 treated CMSPs and FSPs as separate, there has been a merging of these technologies and there is now a technology-neutral unified licence for access. We discuss this development later in this chapter.

<sup>1.</sup> Teledensity, usually expressed as a percentage, is the number of telephone subscribers per hundred persons in the population.

At the time when NTP 1999 was promulgated, BSNL was the only National Long Distance Operator (NLDO). NTP 1999 stated that NLD service would be opened up for competition from January 1, 2000. VSNL was the sole International Long Distance Operator (ILDO). NTP 1999 said that the decision to open up ILD service to competition would be taken in 2004. We discuss the status of NLD and ILD service later in this chapter.

#### **Department of Telecommunications (DoT)**

The Ministry of Communications and Information Technology steers the telecommunications sector through the DoT which is one of its departments and is responsible for formulation of policy. In addition, it is responsible for licensing, wireless spectrum management; administrative monitoring of PSUs, research and development, and standardization and validation of equipment (DoT website).

#### **Regulation of the Telecommunications Sector**

The TRAI Act established TRAI and TDSAT "to regulate the telecommunication services, adjudicate disputes, dispose of appeals and to protect the interests of service providers and consumers of the telecom sector, to promote and ensure the orderly growth of the telecom sector and for matters connected therewith or incidental thereto" (TRAI Act, 1997; amended 2000).

TRAI consists of a Chairperson and not more than two full-time members and not more than two part-time members appointed by the Central Government. The Chairperson and other members are appointed by the Government from people with knowledge and experience in telecommunications, industry, finance, accounting, law, management, or consumer affairs. Further, the TRAI Act requires that if a person who has served with the Government is being considered for these posts, then he/she should have been at least an Additional Secretary or equivalent for at least three years. The terms of office for the TRAI members and Chairperson is three years.

TRAI's charter includes the carrying out of the following functions:

- Setting tariffs for telecom services;
- Ensuring the terms and conditions of the licence by the licensees:
- Ensuring effective interconnection between service providers;
- Setting quality of service (QoS) standards for services and ensuring compliance with those standards;
- Ensuring effective compliance of universal service obligations.

In addition, TRAI makes recommendations either *suo moto* or on a request from the Government on the following issues:

- Need and timing for introducing additional service provider(s),
- Terms and conditions of a licence and revocation of a licence for non-compliance of the terms and conditions;
- Measures to facilitate competition and promote efficiency in the sector so that growth of the sector is facilitated;
- Technological improvements in the services provided by service providers;
- Type of equipment used by service providers;
- Measures for the development of telecommunication technology or the sector in general;
- Efficient management of the available frequency spectrum.

#### **Telecom Disputes Settlement and Appellate Tribunal (TDSAT)**

The TRAI set up in 1997 had both adjudicatory and regulatory powers and was authorized to resolve disputes between the service providers. However, in the Amendment of 2000, these powers were withdrawn from TRAI and given to another body – TDSAT. TDSAT was also given powers to hear appeals against decisions by TRAI.

Specifically, the TRAI Act authorizes TDSAT to adjudicate any disputes between:

- The Government (as licensor) and a licensee;
- Between two or more service providers;
- Between a service provider and a group of consumers.

TDSAT was also authorized to hear and dispose of any appeal against any decision by TRAI.

TDSAT consists of a Chairperson and not more than two members. The Central Government selects these persons in consultation with the Chief Justice of India.

#### **Incumbent Operators – BSNL and MTNL**

Before the mid-1980s, the DoT provided telecommunication services throughout the country. In 1986, Mahanagar Telephone Nigam Ltd. (MTNL) was established as a wholly owned company of DoT to manage and provide all telephony services in the metropolitan cities of Mumbai (then Bombay) and Delhi. In October 1999, the service provision functions of DoT were separated from its policy-making functions. A new division called the Department of Telecom Services (DTS) was created and was made responsible for provision of telecom services throughout the country except Mumbai and Delhi. In October 2000, DTS was corporatized and was called Bharat Sanchar Nigam Ltd (BSNL). DoT remains responsible for all policy matters.

#### **Privately-owned Service Providers**

When NTP 1999 was announced, it envisioned a sector that was divided according to the following services:

- Access Providers including mobile service providers (MSPs) and fixed service providers (FSPs), and cable service providers;
- National Long Distance Operators (NLDOs);
- International Long Distance Operators (ILDOs);
- Providers of other services including radio-paging service and public mobile radio trunking service.

Mobile service and fixed service were considered separate and required separate licences. Also, a separate licence was required for every circle<sup>2</sup> in which the applicant wanted to provide service. Licences for mobile service and fixed service were given for an initial period of twenty years but could be extended for another ten years. For mobile service, there were initially to be only two private operators in each circle with BSNL/MTNL being the third operator. Later, a fourth operator was also added. NTP 1999 provided for addition of yet some more operators on the recommendation of TRAI.

Both MSPs and FSPs were to pay a one-time entry fee and a share of the annual gross revenues. Of course, the entry fee was different for each circle and for the two types of service. The revenue share was also different for mobile service and fixed service. For MSPs the revenue share was 12% for metros and Category A circles, 10% for Category B circles and 8% for Category C circles. For FSPs, the corresponding revenue shares were 10% for metros and Category A circles, 8% for Category B circles, and 6% for Category C circles.

Initially, there was only one NLDO – BSNL. At the end of 2000, NLD was opened up for competition and presently there are three other NLDOs – Bharti, Reliance Infocomm, and VSNL. Similarly, earlier VSNL was the only ILDO, but in 2002 this service was also opened up for competition. Now there are seven other operators – Reliance Infocomm, Bharti, Data Access, BSNL, VSNL, Essar Spacetel, and MTNL.

<sup>2.</sup> Traditionally telephone service in India has been organized by circles. Currently, there are 23 circles. For the purpose of licensing private operators, the circles have been divided into three categories – A, B, and C – based on their revenue-earning potential. Four of the circles are for each of the four large metropolitan cities – Delhi, Mumbai, Kolkatta, and Chennai. Most of the other circles cover entire states. However, some states, like UP, are made up of two circles – UP-E and UP-W. Further, some states have been combined under the same circle; for example, Bihar and Jharkand form one circle.

#### Unified Access Service Licensing

As we have seen, initially the telephony market was segmented into fixed service, mobile service, NLD service, and ILD service. However, recent developments in the telecommunication markets necessitated a review of this service-based segmentation of the market. This review was prompted by the dispute over provision of limited mobility using WLL (WLL-LM). MSPs charged that allowing WLL-LM was a back-door entry into mobile service by FSPs. The issue was further complicated by the fact that one of the FSPs (Reliance Infocomm) was able to convert the limited mobility licence into an all-India roaming through the use of call-forwarding and multiple registration.

In 2003, TRAI initiated an investigation into a unified licensing regime. Giving its reasons for initiating the discussion on unified licensing, TRAI said that convergence in technologies was blurring the distinction between services. In addition, there was a convergence in markets because lower tariffs for mobile service were making fixed line service and mobile service substitutable products. TRAI felt that it would be highly beneficial to allow the best technology to serve the telecommunications needs of consumers and not to allow artificial segmentation of the market to prevent it.

During the consultation process, some parties suggested that the unification of licensing should not be limited to access services but be applied to all telecommunications services – local, NLD, and ILD. After the consultation process, TRAI came up with its recommendations to the Government. It recommended that within six months, unified licensing regime should be initiated for all services covering all geographical areas using any technology. It said that once the Government gave its in-principle approval for unified licensing, the unified licensing regime could be finalized through a consultative process.

TRAI recommended to the Government that the unified licensing regime be achieved in two steps. In the first step, the unification of licensing at the access level be done immediately. TRAI's rationale was that the growth of teledensity, a primary national objective, was determined by growth in the access network. In the second step, rules and regulations for a fully unified licensing regime should be developed and put in place.

However, even the first step of giving a unified licence for access services raised several issues that needed to be ironed out. Specifically, there were several differences between the original MSP and FSP licences and these differences had to be addressed in the unified access service licence. Regarding these differences TRAI recommended that:

- Service area<sup>3</sup> for unified licence be the same as that for the MSPs
- Entry fee for the fourth operator less any amount already paid should be used to determine what the FSPs migrating to unified access licence should pay. In addition, Reliance should be required to pay penal interest from its FSP licence date to unified licence date, because it had been advertising and operating as a fully mobile service provider.
- Rollout obligations, revenue share percentage for the fourth operator to apply to FSPs migrating to unified access licence.

The Government accepted all of TRAI's recommendations. Now there is a single licence for access services removing any distinction between mobile and fixed service licences.

#### Unified Access Regime

On August 6, 2004, TRAI released its draft recommendations for a fully unified licensing regime. The key objective of the

<sup>3.</sup> The original licence for Maharashtra for MSPs did not cover Mumbai because there was a separate Metro circle for it, while the FSP licence included Mumbai. Similar issues were present in the case of Kolkatta and Chennai.

proposed regime is to encourage the development of new applications based on the technological developments taking place in information and communication technology and to remove artificial licensing barriers that prevent this from happening. Other objectives of the proposed regime include the following:

- Simplify the licensing process;
- Allow flexibility so that resources are utilized efficiently;
- Encourage small operators to develop their own niches by providing telecommunication services in rural, remote, and backward areas;
- Ensure that no player is worse off due to the new regime and that a level playing field is maintained with low barriers to entry.

TRAI is proposing three categories of licences in the new regime:

- *Unified Licence:* This will cover all public networks capable of offering voice and data services irrespective of the medium used for transmission of signals or the technology adopted. This licence covers basic service, mobile phone service, NLD, ILD, broadcasting services, and Internet telephony.
- *Class Licence:* All services that do not have two-way connectivity with the public network shall be covered by this licence. This licence also covers VSAT services and niche operators<sup>4</sup>.
- Licensing through Authorization: This category of licence includes services that provide passive infrastructure and bandwidth to other service providers.

<sup>4.</sup> Niche operators are included in this category and not in the unified licence category in order to reduce the financial burden on them. As we discuss later, unified licensees are required to pay a one-time entry fee while class operators are not required to do so. For economic reasons again, radio paging services have been excluded from the class licence category, but are instead put in the next lower category of "licensing through authorization."

It also includes Internet service providers and those operators who provide restricted Internet telephony<sup>5</sup>.

The above licensing scheme is meant to be hierarchical with the unified licence category being at the top of the hierarchy. A licence at one level of the hierarchy also covers all the licensing categories below it in the hierarchy. For example, if an operator has a unified licence, then he can offer all services including those that are covered in the class licence category and also licensing through authorization category. He does not need to get a class licence or a licence through authorization. Similarly, an operator with a class licence does not need to get a licence through authorization if he wants to provide infrastructure or bandwidth to other service providers. Because the unified licence is at the top of the hierarchy, a unified licence holder can provide any or all telecommunication services.

The fees for the licences increase as one goes up the hierarchy. For licences obtained through authorization, there is no fee. For class licences there is no entry fee but there is a licence fee of 6 percent of annual revenue to cover universal service obligations (5 percent) and administrative expenses (one percent). Unified licensees will have to pay the same licence fee as class licensees, but will also have to pay a one-time entry fee of Rs 107 crore. TRAI recommends that the entry fee be gradually reduced from Rs 107 crore to Rs 30 lakh over a period of 5 years.

TRAI is seeking comments from all stakeholders on its draft recommendations. After considering the comments received, final recommendations will be prepared and presented to the Government.

<sup>5.</sup> Restricted Internet telephony covers telephony service where the PSTN is not used. Essentially, this covers telephony from a personal computer (PC) in India to either another PC anywhere or to a telephone outside India. See Chapter 5 on *Data Communications and the Internet* for a detailed discussion of Internet telephony and restricted Internet telephony.

#### Status of the Sector<sup>6</sup>

With the various changes in the telecommunications sector over the last decade and the more radical changes in the last few years, how has the sector performed? Where does it stand today? A review of a recently published report on the sector by TRAI shows that there has been very strong growth in the sector and its performance has indeed been heartening.

Table 2.1 gives a summary of the results. The total number of subscribers has grown at an average rate of 28 percent per year from 2000 to 2004 and stands at about 77 million giving a teledensity of 7.04 percent. NTP 1999 had set a target of a teledensity of 7 percent by 2005 and the target was achieved by March 2004. So, the sector has grown at a rate faster than the government had set as a target.

Table 2.1: Telecom Services During the Period 2000-04 (Performance Indicators)

		FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
1.	1. Subscriber's base (in million)					
(i)	Fixed	26.65	32.71	38.33	41.48	42.84
(ii)	Mobile	1.90	3.58	6.54	13.00	33.69
Gross Total		28.55	36.29	44.87	54.48	76.53
(iii)	Internet	0.95	3.04	3.42	3.64	4.55
(iv)	Broadband	NA	NA	NA	0.08	0.19
2.	ARPU (Rs./sub/month)*					
(i)	Mobile (Cellular)	1319	1113	884	634	469
(ii)	All services (fixed, mobile, NLDO, ILDO)	NA	NA	794	682	575**
3.	3. RPM (Revenue per minute) (in Rs.)					
(i)	Cellular (Postpaid)	6.55	4.82	3.67	2.55	1.79
(ii)	Cellular (Prepaid)	7.32	5.65	5.43	3.49	1.39
(iii)	Cellular (Blended)	6.70	4.98	4.05	2.82	1.55
4. Teledensity (%age)						
(i)	Fixed	2.62	3.17	3.66	3.88	3.94
(ii)	Mobile	0.19	0.35	0.62	1.22	3.10
Gross Total		2.81	3.52	4.28	5.10	7.04

<sup>\*</sup> Data regarding ARPU for fixed lines not available.

Source: TRAI, The Indian Telecom Services Performance Indicators, July 2004.

<sup>\*\*</sup> Estimated ARPU for all services combined.

The data for this section comes from the most recent quarterly report published in June 2004 by TRAI.

Most of the growth in the sector has been fuelled by the growth in mobile telephony. The growth rate over the last financial year was an astounding 160%. Today, mobile phone subscribers form 44% of the total subscriber base and it is expected that soon the number of mobile phones will exceed the number of fixed line phones.

NTP 1999 had emphasized the growth of telecommunications in rural areas and set a goal to achieve coverage in all villages in the country by the year 2002. A review of the performance of the sector shows that of the 607,491 villages in India 518,975 have village public telephones. Thus, as of March 2004, 86% of the villages have coverage as against the target of 100% by 2002.

Having looked at how the overall sector has performed, let us now look in more detail at how fixed and mobile services have performed and who the players are in these two services.

#### Fixed Service

In fixed services<sup>7</sup>, BSNL and MTNL continue to dominate with the private operators playing a limited role. There are five private operators and Table 2.2 shows the subscriber base and area of operation for each operator. Together, the five private operators have 19% of the market while BSNL has the lion's share with 72% and MTNL has 9% of the market.

Table 2.2 reveals another interesting fact. Other than Reliance which has a presence in all the eighteen circles, the private operators have a presence only in the more lucrative Category A or B circles. In addition, even in the states where the private operators are licensed to operate, their presence is only in the urban areas; their market share in rural areas is zero. This was to be expected because the private operators will naturally focus on the more economically attractive areas first.

<sup>7.</sup> Fixed service excludes provision of mobility using WLL. After the introduction of unified licence for access service, the distinction between limited mobility and full mobility disappeared. Therefore, numbers for WLL-LM have been included in the subscriber base for mobile service.

Table 2.2: Subscriber Base and Area of Operation of Fixed Service Providers

Operator	Area of operation	March 2004
BSNL	All India	36112093
MTNL	Delhi and Mumbai	4367264
Bharti Group	Madhya Pradesh, Delhi, Haryana, Tamil Nadu, Karnataka	636725
Tata Teleservices	Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Delhi, Maharashtra	1003585
HFCL Infotel	Punjab	125331
Shyam Telelink	Rajasthan	92392
Reliance Infocomm	18 circles	503353
Grand Total		42840743

Source: TRAI, The Indian Telecom Services Performance Indicators, Jan - Mar, 2004.

#### Mobile Service

Private participation in mobile service has been much more robust. Table 2.3 lists the MSPs and shows their respective market shares. The top five operators are Reliance, Bharti, BSNL, Hutchinson, and Idea and together they have captured 80% of the market. BSNL is the largest provider in terms of coverage and currently provides service in 21 circles.

Table 2.3: Subscriber Base of Mobile Service Providers (Cellular + WLL(M))

Operator	March 2004	% share for March 2004
Reliance Infocomm	72.65	21.64
Bharti Group	65.04	19.30
BSNL	54.56	16.19
Hutchison	51.48	15.27
Idea	27.33	8.11
BPL	18.83	5.59
Spice	12.08	3.55
Escotel	9.89	2.93
Tata Teleservices	6.25	1.85
MTNL	4.6	1.37
Hexacom	2.57	0.76
Shyam Telelink	0.30	0.09
HFCL Infotel	0.30	0.09
Others (Aircell, RPG, etc.)	11.03	3.26
Total Sub. Base	336.91	100

Source: TRAI, The Indian Telecom Services Performance Indicators, Jan - Mar, 2004.

As noted earlier, the growth rate over the last financial year was 160%. The growth during the last quarter (ending March 31, 2004) was 18 percent.

Let us now look at the revenues of the MSPs. A good measure is the Average Revenue Per User (ARPU). Table 2.4 gives the ARPU by Category of Circles and for the country as a whole. The all-India ARPU is Rs. 436. However, there is a big difference between the postpaid subscribers and pre-paid subscribers with the ARPUs being Rs. 930 and Rs. 277, respectively.

Table 2.4: Average Revenue Per User for Mobile Phone Service
(Rs per month during the quarter Jan-Mar 04)

Circle	Postpaid	Prepaid	Blended ARPU
Circle A	780	279	425
Circle B	783	285	395
Circle C	792	346	467
Metro	1323	258	482
All India	930	277	436
All Private CMSPs	1032	266	431
BSNL/MTNL	693	326	453

Source: TRAI, The Indian Telecom Services Performance Indicators, Jan - Mar, 2004.

What are the average rates that are being paid by subscribers for mobile service? To answer that question, let us look at the revenue per minute (RPM) that is being paid by consumers. Table 2.5 shows the RPM by type of circle. The all-India average is Rs.1.35 per minute.

Table 2.5: Revenue Realization per Minute for Mobile Phone Service
(Rs per minute during the quarter Jan-Mar 04)

Circle	Revenue realized per minute in postpaid	Revenue realized per minute in prepaid	Blended revenue realized per minute
Circle A	1.37	1.20	1.31
Circle B	1.48	0.97	1.16
Circle C	1.89	1.50	1.63
Metro	1.95	1.28	1.60
All India	1.59	1.12	1.35

Source: TRAI, The Indian Telecom Services Performance Indicators, Jan - Mar, 2004.

In addition to RPM, we may look at the minimum effective charge for local calls. TRAI calculates this by analyzing all the reported tariff plans for cellular and WLL-LM services assuming a monthly usage of 400 minutes. According to TRAI's latest report, the minimum effective charge for local calls is on average Rs. 0.44 per minute.

## Basic Concepts in Telecommunications<sup>1</sup>

Before we delve into how telephone calls are connected or how the Internet works, we need to understand some basic concepts in telecommunications. In this chapter, first we explain some of the terms used in telecommunications, such as signals, frequency, and bandwidth. Then we introduce telecommunications signals and explain the relative advantages and disadvantages of analog and digital transmission of signals. This is followed by a section on multiplexing which will help in understanding how multiple conversations are carried on a single wire or over a single wireless channel. Finally, we describe the various media used to transmit communication signals.

#### **Signals in Telecommunications**

The word telecommunications is a combination of two words: 'tele' which in Greek means distance, and 'communication' which in Latin means connection. Thus, telecommunications is the transfer of information over a distance. In the distant past, a variety of media were used to send telecommunication signals: drum beats, smoke signals, etc. However, now when we talk about telecommunication signals, we generally mean electrical signals or electrical signals that have been converted into light or radio waves.

Discussions regarding telecommunication signals often centre around waves – radio waves, light waves, electromagnetic waves,

Chapters 3, 4, 5, and 6 cover the technology of telecommunications. In preparing
these chapters, we have followed the development of the subject as enunciated
in the book *Telecommunications Essentials* by Lillian Goleniewski (2002). We
have also relied on that publication for explanation of various topics related to
telecommunication.

etc. We also encounter terms such as frequency and wavelength. In order to familiarize ourselves with these terms, we first look at what we mean by a wave in telecommunications. Figure 3.1 exemplifies a wave. The shape of the wave that we have chosen here is very common and it follows the mathematical function "sine". The wave is, therefore, called a sine wave. The amplitude of the wave is the maximum height of the wave and is an indication of the strength of the signal. The frequency of the wave is the number of cycles per second and is measured in Hertz, often abbreviated as Hz. One Hz is equal to one cycle per second. The wavelength is the distance between two consecutive peaks of the wave. The phase refers to where you are in the wave. Phase is treated as an angle and is usually measured in degrees. The starting point of the wave has a zero phase angle, and the point at which the wave begins to repeat itself has a phase angle of 360 degrees. So a phase angle of 360 degrees is the same as a phase angle of zero. The middle point where the wave starts to go negative has a phase angle of 180 degrees.

W avelength

Amplitude

Figure 3.1: A Sinusoidal Wave

The reason that sine waves are so often used to represent signals in telecommunications is that any signal can be broken up into sine waves of differing frequencies and amplitudes. The frequencies of the sine waves that make up a signal represent the frequency content of the signal. The *bandwidth* is the range of

these frequencies that make up the signal. For example, the human voice is made up of many different frequencies. While human beings can generate a higher range of frequencies, the vast majority of sounds that we make fall in the range of 250 Hz to 3,400 Hz. With these numbers the bandwidth of the human voice would be 3,150 Hz. For practical purposes, in voice communications a bandwidth of 4 kHz is considered sufficient.

#### Electro-Magnetic Spectrum

Often when discussing telecommunications we encounter terms such as frequency spectrum and scarcity of frequency spectrum. What is frequency spectrum and why is it limited?

Radio waves, TV transmissions, X-rays are all electromagnetic waves, i.e. they are waves of electric and magnetic fields. Even a beam of light is an electromagnetic wave. These categories of electromagnetic waves have different frequencies but they all travel through space at the speed of light. When people talk of frequency spectrum, they are referring to the frequencies of this spectrum of electromagnetic waves.

There are no inherent upper or lower limits to the frequencies of the waves that form the electromagnetic spectrum. However, not all the frequencies are useful for communications. The lower end of the spectrum does not have much bandwidth and, therefore, one cannot pack much information into it. While the higher frequency bands have very high bandwidths, there are problems with interference. As the frequency of an electromagnetic spectrum increases, its wavelength decreases<sup>2</sup>. When the wavelength is about the same size as a rain drop, then a rain drop can distort the wave and interfere with communications. Therefore, environmental factors such as precipitation can create interference problems with very high frequency waves.

The multiplication of wavelength and frequency gives the speed of the wave which in the case of electromagnetic waves is the speed of light. Because the speed of all electromagnetic waves is the same, the higher the frequency, the smaller the wavelength.

Therefore, the middle range of the electromagnetic spectrum is used for communications. This covers the radio, microwave, infrared, and visible portion of the spectrum. Figure 3.2 shows the portion of the spectrum used for communications. It also gives the generally used names of the frequency bands and the transmission media that operate at those frequencies.

**Label of Frequency Transmission Medium** Frequency Band 10<sup>22</sup> Gamma rays 10<sup>19</sup> Hz 10<sup>16</sup> Hz X-rays Ultraviolet 10<sup>14</sup> Hz Fibre Optics Visible light Infrared 10<sup>12</sup> Hz=1THz THF **EHF** Microwave SHF 109 Hz=1GHz TV, cellular radio **UHF** FM TV, coaxial VHF Coaxial 10<sup>6</sup> Hz=1MHz High Twisted Pair Medium Voice Low 10<sup>3</sup> Hz=1KHz Very low Extremely low 10<sup>0</sup> Hz=1Hz

Figure 3.2: The Electromagnetic Spectrum

Source: Goleniewski, Telecommunications Essentials: The Complete Global Source for Communications Fundamentals, © 2002 Pearson Education, Inc. Reprinted by permission of Pearson Education, Inc. Publishing as Pearson Addison Wesley.

#### **Modulation**

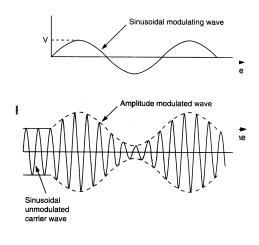
How is a section of the frequency spectrum, also called a frequency band, used to transmit information? First, a particular frequency from the allocated frequency band is selected to be used

to transmit information, and it is known as the carrier frequency. A wave at the carrier frequency is created by electronic circuits and is called the carrier wave. Recall from Figure 3.1, that a sine wave is defined by three characteristics: amplitude, frequency, and phase. Any or all three of these characteristics of the carrier wave are then modified to send information. We give some examples to illustrate how this is done.

Figure 3.3 shows how the amplitude of the carrier wave can be modulated to send information. As we can see, the envelope of the carrier wave is modulated by the signal that has to be sent. At the receiver, a detector detects this modulation of the amplitude and extracts the information that was sent. Figure 3.4 shows frequency modulation, that is, the frequency of the carrier wave being modified by the signal. Again, at the receiver, the change in frequency is detected by an electronic circuit and the information is extracted. Figure 3.5 shows frequency modulation by a digital signal.

Figure 3.6 shows the use of phase modulation to transmit a digital signal. This form of phase modulation is

Figure 3.3: Amplitude Modulation



Source: Introduction to Telecommunications by Anu A. Gokhale, Copyright @ 2000.

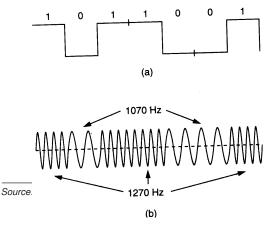
known as phase shift keying (PSK) and is the most popular method for transmitting digital signals. When a "0" is to be sent, the carrier signal is sent with one phase angle, but when a "1" is to be sent, the carrier is sent with a 180 degrees phase shift. The system used in practice is an advanced form of PSK that allows more data to be sent, but the idea remains the same as given here.

## Analog and Digital Transmission

The electrical signals that are used in telecommunications are either analog or digital. Analog signals have continuously varying amplitude. For example, when you speak into a handset, the air pressure around your mouth

Figure 3.5: Frequency Modulation Using Digital Signals (a) binary signal (b) FSK signal

Figure 3.6: Phase Shift Keying (PSK)



changes. These air pressure changes are picked up by the microphone in the handset and converted into current or voltage variations. The resulting current and voltage variations are similar to the air pressure changes around your mouth and are therefore *analogous* to the shape of air pressure changes due to your voice. This is why such signals are called analog signals.

While voice signals are generated as analog signals, transmission of these analog signals is troublesome. One disadvantage of analog signals is that they are susceptible to degradation due to noise. As any electrical signal moves down a wire, it loses power. In addition, electromagnetic interference, improper electrical contacts, and moisture degrade the signal and add unwanted signals (noise) to the original signal. So, by the time the signal reaches its destination, not only is it attenuated but it also contains unwanted signals. Amplification at the destination can make up for the lost power, but it cannot reduce the effect of noise because the amplifier also amplifies the noise.

Because of the disadvantages of analog transmission, there has been a move to adopt digital transmission. Digital signals use binary levels (ones and zeros or a high and low level) to transmit information. Digital circuits are much less susceptible to noise. Just as with other electrical signals, digital signals also degrade over distance. However, instead of amplifiers, repeaters are used to regenerate the digital signal. These repeaters examine the degenerated digital signal to determine whether it was supposed to be a one or a zero, and then they regenerate a clean (noise-free) signal for transmission further down. This process reduces the impact of noise to a considerable extent and the signal can be transmitted over longer distances without accumulating noise.

#### Analog to Digital Conversion

The most common process to convert analog signals to digital signals is pulse code modulation (PCM). In PCM, first a sample of the analog signal is taken every 1/8000th of a second (sampling frequency 8 kHz)<sup>3</sup>. The analog signals are then assigned an 8-bit digital code. Using eight bits for the code allows a total of 256 values. Because the samples can only be assigned one of the 256 values, the actual value of the sample is adjusted to correspond

<sup>3.</sup> The choice of the minimum sampling frequency or the rate at which samples are taken is dictated by Shannon's Switching Theorem. It states that we can faithfully reconstruct the original signal from the digital samples if the sampling rate is greater than twice the highest frequency in the analog signal being sampled.

to the nearest 8-bit code. This introduces some error which is often called quantizing error or quantizing noise. The equipment which does the analog to digital conversion is known as a codec (coderdecoder). The output of the codec is a 64 kbps<sup>4</sup> signal (8,000 samples per second x 8 bits per sample which gives 64,000 bits per second).

## Multiplexing

It is natural to think that each phone conversation requires a separate pair of wires. While carrying a single conversation on a pair of wires may be appropriate to connect an individual subscriber to the local exchange, it would be very cumbersome and expensive for connections between exchanges, and even more so for connections between cities. Multiplexing is a technique used to reduce the number of transmission lines between exchanges. In multiplexing, a number of signals are combined so that they can be sent over a single transmission medium such as a cable or a radio frequency channel. By allowing many signals to use the common transmission medium simultaneously, multiplexers allow us to use transmission media to their full capacity. For example, fibre optic cables can carry signals at a speed of 10 Gbps<sup>5</sup>, or 10 million kbps, and higher, while a single voice signal requires a bandwidth of 64 kbps only. Therefore, if a fibre optic cable was to carry only a single voice signal, it would be a gross under-utilization of the fibre optic cable. That is where multiplexing comes to our help and allows us to send many signals on the cable simultaneously. Let us see how this is done.

#### Frequency Division Multiplexing (FDM)

In FDM, the available frequency spectrum is divided into bands and each communication channel is given one of the frequency bands. Because human voice covers the frequencies upto 4 kHz, the channel width for voice communication needs to be at

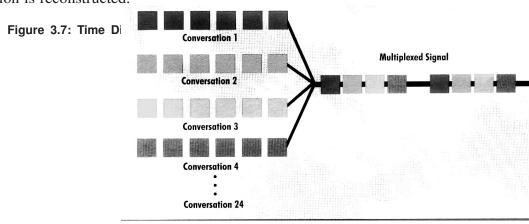
<sup>4.</sup> kbps stands for kilobits per second = one thousand bits per second.

<sup>5.</sup> Gbps stands for gigabits per second = one billion bits per second.

least 4 kHz. In order to assign a different frequency for each communication band we use modulation. For example, if the available frequency spectrum for a set of communication channels is from 600kHz to 612 kHz, then modulation is used to ensure that the first communication channel uses only 600 to 604 kHz, the next uses 604 kHz to 608 kHz, and the last uses 608 kHz to 612 kHz.

#### Time Division Multiplexing (TDM)

In TDM, a frequency channel is time-shared by users with each user being assigned a specific time for transmission. As shown in Figure 3.7, TDM can be understood by imagining a train carrying several conversations, with a piece of each conversation in one of its wagons. Assuming the channel is carrying eight conversations, as the train reaches the platform, conversation 1 is put in wagons 1, 9, 17, etc., conversation 2 is put in wagons 2, 10, 18, etc., and so on. At the destination, the process is reversed and the conversation is reconstructed.



Source: Telephony 101: An Introduction to the Public Network, Copyright © 1994 Northern Telecom. All Rights Reserved. Reproduced with permission of Nortel Networks. (The author or the Institute are not expressly affiliated with or endorsed or sponsored by Nortel Networks.)

In TDM, everyone is using the same frequency, but at different moments of time. The users perceive their conversations as continuous although in reality they are getting rapidly sampled snippets of the conversation.

There is another multiplexing technique – code division multiple access (CDMA) – which we discuss in the next chapter when we deal with mobile telephony. There, we also compare TDMA with CDMA.

#### Classes of Bandwidth

Earlier in this chapter, while discussing the term "bandwidth," we said that the term applies to the range of frequencies that make up a signal. The term bandwidth is also used to specify the capacity of a transmission channel. Just as a water pipe's capacity can be assessed by its diameter, a transmission medium's capacity to deliver information can be assessed by its bandwidth. So, when we say that the bandwidth of coaxial cable is 370 MHz, we mean that it can carry frequencies up to 370 MHz. The use of MHz or some other unit of frequency to specify the bandwidth is done mostly for analog systems. For digital systems, the capacity or bandwidth is most often measured in bits per second or multiples of it such as kbps, Mbps, Gbps, etc. There are three major classes of bandwidth that are often used – narrowband, wideband, and broadband.

#### Narrowband

A narrowband channel can accommodate data rates up to 64 kbps. As mentioned earlier, this is the capacity of a single voice channel (that carries a digitized version of one person talking). This has become the fundamental unit or building block used to develop digital networks.

#### Wideband

If we combine several 64 kbps narrowband channels, we get wideband transmission. Wideband is defined as nx64 kbps and can go up to about 45 Mbps<sup>6</sup>.

#### **Broadband**

Broadband is the most talked about class of bandwidth today. Future systems are supposed to be based on providing

<sup>6.</sup> Mbps stands for megabits per second = million bits per second.

"broadband" capability. Unfortunately, there is no standard definition of broadband and it depends on the context and the part of the telecommunications industry that is under discussion. Generally speaking, broadband is a multichannel facility that has higher capacity than the traditional voice channel.

Technically speaking, the International Telecommunication Union (ITU) defined broadband as being anything over 2 Mbps. However, this definition was given in the 1970s when 2 Mbps was considered a remarkable speed for transfer of information. Today's achievable data transfer rates are much higher.

For fixed line services, broadband services are generally considered to start where fibre optic cables are used for transmission. These speeds start at around 51 Mbps. So, when discussing fixed line services, that is the backbone or core network, the starting point for broadband is about 51 Mbps. For mobile phone services, a data transfer rate of 2 Mbps is remarkable even today, and as such if we are discussing mobile access at 2 Mbps that would be considered broadband. In the case of accessing the Internet, TRAI has defined broadband access as a data rate higher than 256 kbps.

#### **Transmission Media**

Pathways are required to carry the electrical signals between subscribers and switching stations and between switching stations. The various transmission media that provide these pathways can broadly be divided into two categories – wired and wireless. Wired media consists of twisted pairs (of wires), coaxial cables, and fibre optic cables. Wireless media covers terrestrial radio transmission and transmission by satellite.

Each transmission medium has its advantages and disadvantages. Therefore, rather than using a single type of transmission medium in the entire system, a telecommunication system uses a combination of media. Generally, a medium is

selected based on its suitability for a particular application. For example, in remote, rocky areas wires or cables may be too difficult to lay down and, therefore, some wireless medium would be a much better choice.

In the following subsections, we look at the types of media, their characteristics and their advantages and disadvantages.

#### Wired Media

Twisted Pair

Twisted pair cables are available in two varieties – shielded (STP) and unshielded (UTP). In STP, each pair is wrapped in metal foil and there is a braided metal shield that goes around all the twisted pairs in the cable. There is an outer PVC jacket that covers the metal shield. UTP has only the outside PVC jacket. STP provides more resistance to electromagnetic interference and thus supports higher data rates, but is also more expensive than UTP.

Historically, twisted pair has been used in the local loop, also known as the last mile. Now it is being displaced by Wireless in Local Loop (WLL) in places where the cost of digging would be prohibitive, such as crowded urban areas. Another reason for the decline in the use of twisted pair is that it cannot provide the bandwidth required for modern applications.

Traditionally, twisted pair has been used to carry the analog signal between a subscriber and the local exchange. Twisted pair is also being used for carrying digital signals in Integrated Services Digital Network (ISDN) lines or digital subscriber lines (DSL) which provide end-to-end digital service over the public telephone network.

The main advantage of twisted pair is its low cost. However, there are also disadvantages to its use. It has limited speed which makes it unsuitable for modern high data rate applications. In addition, it has high interference rates resulting in high error rates.

Furthermore, the signal in a twisted pair gets attenuated at a fairly short distance. In case the signal has to travel longer distances, it would require the use of repeaters.

#### Coaxial Cable

The next step up from twisted pair in terms of performance is coaxial cable. As shown in Figure 3.8, a coaxial cable has a solid conductor at the centre which carries the signal. This conductor is surrounded by plastic insulation. The return path for the signal is provided by braided-copper shielding or an aluminum foil type of covering over the plastic insulation. An outer jacket provides protection from the elements.

Return path
(braided copper Shielding)
Conductor

Conductor

Outer jacket

Plastion

Plastic Insulation

Figure 3.8: Coaxial Cable

Source: As given under Figure 3.2 (page 26).

The coaxial cable has lower attenuation and, therefore, supports much higher distances and frequencies. Its bandwidth is about 370 MHz. The higher bandwidth allows multiple channels and coaxial cable can be considered to be a broadband medium.

In addition to the higher bandwidth compared to twisted pair, coaxial cable also gives lower error rates. Furthermore, while amplifiers or repeaters are still required, they can be placed further apart, upto about 2.5 km. The main disadvantage of coaxial cable relative to twisted pair is its higher cost. Coaxial cable is generally used for inter-exchange transmission and as an under water cable.

Fibre Optic Cable

The transmission of signals has been revolutionized by the introduction of fibre optic cables. Their very high bandwidth has greatly increased the capacity of cables. Besides, due to the noise immunity of optical transmission the error rates are very low.

Figure 3.9 shows the inner construction of a fibre optic cable. It consists of a thin core of glass surrounded by cladding. The cladding acts as a mirror and reflects light down the cable. The cable has an outer jacket for protection. For optical transmission an electronic signal (a digital stream of pulses representing ones and zeros) is converted into light pulses by a laser diode. These pulses travel down the length of the cable and are converted back into electronic pulses by a photo detector. Like electrical signals, optical signals also attenuate with distance and, therefore, repeaters are required. Earlier, the light pulses had to be converted into electric pulses which were regenerated and then converted back to

light pulses. This limited the dista could be used. Now optical repea into electric pulses and back to 1

Figure 3.9: Fibre-Optic Cable Plastic shield

Kevlar reinforcing matter jacket Glass fibre and cladding

Outer jacket

Plastic shield

Source: As given under Figure 3.2 (page 26).

Fibre optic cables come in two major categories: multimode and single mode. In multi-mode cables, the diameter of the fibre

is large compared to the wavelength of the light. Therefore, the light travels in a wave like fashion rather than a straight line, resulting in dispersion of energy and requiring frequent repeaters about every 15 to 65 km.

In contrast, a single mode fibre has a diameter that is comparable to the wavelength of the light, and therefore, the light has to travel straight down the centre of the fibre. As a result, there is very little dispersion and the signal maintains its quality over a much longer distance. Therefore, repeaters can be spaced much wider apart, about 80 to 100 km. Single mode fibres are, however, more expensive and difficult to splice together. Because of its superior performance, single-mode fibre is used in most long-distance networks.

The advantages of fibre optic cables as a transmission medium are their high bandwidth, absence of electromagnetic interference, and low weight. The major disadvantage is higher installation costs and vulnerability to physical damage.

#### Wireless Media

Terrestrial Radio Links

Let us now look at the wireless transmission media. The first one in this category is terrestrial radio links, commonly known as microwave links. Microwave links are ideal for remote locations and rugged terrains where the use of wires or cables is likely to be prohibitively expensive or physically impossible.

Microwaves fall in the 1 GHz to 30 GHz range of the frequency spectrum. Microwave transmission takes place along the line of sight and a clear, unobstructed view between the two antennas is essential. As with other media, repeaters are required for microwave transmission also. Lower frequency signals suffer less attenuation and, therefore, microwave transmission in the 2GHz to 6 GHz range requires repeater about every 40 km while

higher frequency signals, for example, between 18 GHz to 30 GHz, require repeaters every 1 km to 2 km.

Because of their small wavelength, microwave signals are highly susceptible to the environment. Precipitation, rainfall, and snowfall can cause significant degradation to these signals. Therefore, in wet conditions, alternatives to microwave transmission may be required.

In addition to its use in remote and rugged locations, microwave transmission is being used in wireless in local loop (WLL). In WLL, the use of microwave links between the local exchange and subscriber is used when the cost and inconvenience of digging for laying new cables in crowded urban areas is high. Microwave links can also be used in place of leased lines.

A major advantage of using microwave links as a transmission medium is its high bandwidth which can be used to support high speed data, video, and multimedia applications. In addition, microwave links can be less expensive than leased lines. The disadvantages of microwave links are the line of sight requirements, and susceptibility to environmentally caused distortion. Furthermore, a radio frequency licence is required for setting up a microwave link.

#### Satellite

A satellite can be thought of as just another microwave station in the sky. It receives information at one frequency from an earth station, amplifies it, and transmits it at another frequency. Because a satellite has a large footprint over which the transmitted information is received, it can be used for point to multi-point communication.

There are three kinds of satellite orbits: geosynchronous orbits (GEO); middle earth orbits (MEO); and low earth orbits (LEO). GEO satellites travel around the earth at the same angular

speed as the earth rotates on its axis. Therefore, a GEO satellite appears to be stationary with respect to a point on earth. Geosynchronization requires that the satellite be in an orbit 36,000 km above the earth and thus a GEO satellite seems to 'hang in space' about 36,000 km above a point on earth. Because of the large distance that information must travel, there is a round-trip delay of about 0.5 seconds between the time information is sent and the time when it is received. In voice communication, such a delay can affect the quality of conversation. Another disadvantage of a GEO satellite is the large amount of power required on the satellite. GEO satellites have a large footprint and 3 satellites can cover the earth. GEO satellites are used in one way broadcasts or point to multipoint communication.

MEO satellites orbit around the earth at orbits about 10,000 to 15,000 km. Because they travel around the earth faster, we would need more (about fifteen) of these satellites to cover the entire globe. However, the round-trip transmission delay is only around 0.1 second. The main application of MEOs is for regional networks for mobile voice and low-speed data applications.

LEO satellites orbit around the earth at distances of 640 to 1600 km. Since LEO satellites orbit around the earth very fast, a single LEO cannot be used for communications. However, with multiple LEO satellites, as communication with one satellite drops below an acceptable level, the user is switched to the next LEO satellite coming up on the horizon. In this sense, communication using LEO satellites is like a cellular network except that instead of the users moving, the cells are moving. About twenty times as many LEO satellites compared to GEO satellites are required to cover the entire globe. However, the round trip transmission delay is only about 0.05 second which is acceptable for interactive services.

A major advantages of using satellites as the transmission media is that the costs are distance insensitive. In addition, satellite communication provides high bandwidth. The disadvantages are high initial cost, propagation delays particularly with GEO systems, and environmental interference with the signal.

# BASICS OF TELEPHONY

In this chapter, we provide an introduction to how the telephone system works. The first part of the chapter deals with fixed line service, also known as plain old telephone service (POTS). Here, we explain the necessity of switching systems and the working of the public switched telephone network (PSTN). Then we explain how telephone calls are routed from the caller to the called party through the network hierarchy. The last section on fixed line service deals with call processing; it describes briefly how the telephone system completes your call right from the moment you pick up the receiver until you hang up.

The second part of the chapter explains the fundamentals of mobile telephony. The concept of cells is explained and the basic architecture of the mobile phone network is described. Then we deal with the various events that occur in order to complete a mobile phone call. Having described the basics of the fixed and mobile phone systems, in the last part of this chapter we put it all together and give an overview of the complete telephone system.

#### The Need for Switching Systems

In the initial stages, telephones had point-to-point connections; each location was connected to every other location. However, it was soon realized that such a system was inconvenient and expensive. A caller at a location would need a different phone with a separate set of wires for every other location that he wanted to call. The first step in solving this problem was to have a switchboard at a central location. This is how the first telephone exchange was created.

These exchanges were manual and required an operator to connect the calling party to the called party. Over time, telephone switching at the exchanges was automated. Initially, automatic exchanges were mechanical, then came electrical automated switching exchanges based on relays which were followed by electronic exchanges. At present, all the exchanges in India are digital and use time-division multiplexing.

#### **Components of the Telephone System**

The telephone system is traditionally divided into three components – access, node (or switching systems), and transport (or system for transmission of signals). The access part includes the lines that carry traffic from subscribers to exchanges and vice versa. This part of the network is also called the local loop. The earlier access lines were physical connections, usually twisted pairs of wires. Now, as the cost and inconvenience of digging in crowded urban areas is increasing, wireless access (wireless in local loop (WLL)) is becoming more attractive. As Internet use is becoming widespread, broadband access is being introduced to allow for faster Internet connections in addition to transmission of voice signals. In Chapter 6, we describe broadband access in more detail.

The node or switching part of the telephone system includes the switching systems and equipment that route calls to their destination.

The transport part of the telephone network covers the transmission media such as copper wire, fibre optic cable, or microwave systems that interconnect switching systems or exchanges.

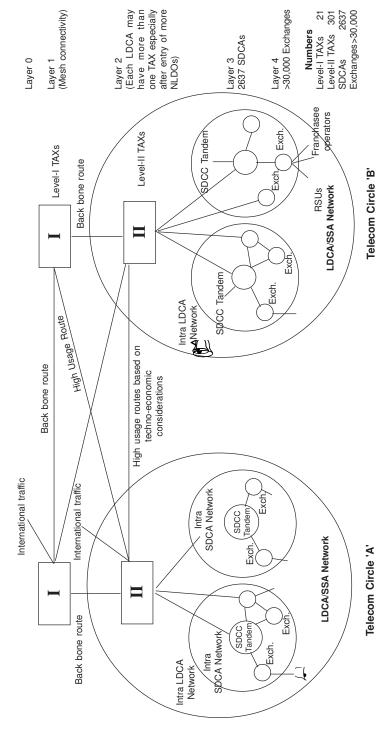
# The Network Hierarchy and Routing of Telephone Traffic

We discussed the need for switching and the importance of a telephone exchange in the previous section. It would be impractical to have just one central telephone exchange for the entire country because of the size of the switch and the length of wiring required. It would also be very expensive and inefficient because each user's line would be busy for just a fraction of the time, i.e. only when the subscriber was making or receiving a call. Therefore, in order to control costs, an hierarchy of switching centres is used. A limited number of subscribers are connected to a local exchange. Local exchanges in a small area, say a city, are, in turn, connected to a group switching centre (GSC), usually called a tandem switch. A group of GSCs are then connected to a trunk switching centre (TSC), and so on.

Figure 4.1 shows the network hierarchy that is used in India. Subscribers in a small area are connected to a local exchange. There are over 30,000 local exchanges in the country. A group of local exchanges in an area are connected to another exchange called a tandem switch, and the area is known as a short-distance charging area (SDCA). An SDCA is usually the size of a taluka, tehsil, or block, and presently there are about 2,600 SDCAs in the country. The SDCAs are then grouped together in a long distance charging area (LDCA) and connected to a TAX (trunk automatic exchange). There can be one or more LDCAs in a circle. As shown in Figure 4.1, the TAXs in LDCAs are called Level-2 TAXs. LDCAs correspond to areas about the size of a district. The Level-2 TAXs in a circle are connected to the Level-1 TAX for that circle. The Level-1 TAXs, which are interconnected, are also connected to one of the International Gateways. It will be noticed from Figure 4.1 that sometimes there is a connection between switching centres at the same level of the hierarchy. Connections between switching centres at the same level are based on technoeconomic considerations, and are usually provided for high usage routes.

How is a call routed over this complex network? If a subscriber calls someone in the same local area, then the local exchange connects the caller to the called party. However, if a subscriber calls someone in another local area, then the call travels up the network hierarchy and then across to the SDCA/LDCA/

Figure 4.1: National Network for Routing of Traffic



Source: Telecom Regulatory Authority of India

region in which the called party is located. If the called party is in another region of the country, then the call travels all the way up to the Level-1 TAX of the caller and then across to the Level-1 TAX of the called party. Once having arrived at the called party's region, the call travels down the hierarchy upto the LDCA, then SDCA, and then the local exchange of the called party is reached. How high up the network hierarchy a call travels depends on whether the called party is in the same SDCA, the same LDCA, or the same region.

Let us illustrate routing of calls using an example. Ram Kumar who has gone to visit the Vaishno Devi temple in Jammu and Kashmir (J&K) wants to call his brother Shyam Kumar who has gone to Kanya Kumari and is just outside the Vivekananda Centre there. From Vaishno Devi Bhawan the call will be carried to the SDCA centre in Katra (J&K). From there the call will be routed to Udhampur which is the centre for that LDCA. From there the call will be carried to the Level-1 TAX for the J&K circle which is in Srinagar. The call will then travel along the national backbone to the Level-1 TAX for Tamil Nadu circle which is located in Chennai Then the call will travel down the hierarchy to the LDCA with its centre in Madurai. From there, the call will be transported to Kanya Kumari which is also an SDCA centre and will be sent to the phone booth at the Vivekananda Centre.

# **Call Processing**

How are calls completed by the telephone network? There are many functions carried out by the telephone network in order to establish the connection between the caller and the called party. Here, we list the steps that are carried out in processing a phone call from the moment the calling party picks up the phone:

#### Call Detection

When the calling party picks up the phone, the switch in the local exchange detects it. The processor in the switch checks that the caller is a valid subscriber and marks the caller's line as busy.

A call register is created in the processor to store the number that will be dialled.

# Provision of Dial Tone

A dial tone is sent to the caller's line from a tone generator.

#### Digit Collection

When the caller hears the dial tone, he enters the called party's phone number. The digits are stored in the call register. In addition, when the first digit arrives, the dial tone is removed.

#### Digit Translation

The digits of the called party's number are translated by the processor as they are received. This continues until the processor has enough digits to route the phone call. If an invalid digit or incorrect number is dialled, a recorded message is sent out about the error.

#### Call Routing

After the digits are translated, the system 'locates' the phone of the called party. Then the system checks to see if there are two time slots available on each switch that will be traversed. Two time slots are required because one is for outgoing signals and the other for incoming signals. If the time slots are available, then they are reserved for the subsequent call. Otherwise, either a 'fast busy' signal or a recorded message is sent to indicate that the system is busy.

#### Call Connection

If the switch determines that the call can be completed, then the called party's line is marked as busy so that no other calls are attempted on the called party's line.

# Ringing and Ringback Sound

The called party receives a ringing sound from its local switch and the calling party receives a ringback sound from its local switch. If the called party's line is busy, then the caller receives a busy signal.

#### Establishment of Speech Path

The facilities along the speech path that were previously reserved are linked together. When the called party answers, the status of his line is changed to 'off-hook'. The system recognizes this change and removes ringing and ringback from the two lines. When the speech path is established, the conversation begins.

#### Call Termination

When the parties end their conversation, they hang up. The system detects this change of state and releases all the network resources that had been reserved for this conversation.

#### **Signalling Systems**

At first, we may think that in order to complete a call between two people, the telephone network simply needs to connect the two telephones and then to ensure transmission of the voice signals of the two people over the network. However, as we have seen from the previous section, this is not true and the telephone network has to perform many other functions. In order to successfully complete a call, the network needs control and signalling information that has to be transmitted between the various exchanges involved in the call. This additional information, usually referred to as signalling information consists of the following types of signals: (i) supervisory signals telling the network that you want to make a call or that your phone is busy, (ii) addressing signals which are derived from the dialled number and are essentially instructions to the network as to how to route your call; (iii) information signals such as call waiting and call forwarding; and (iv) alerting signals such as ringing and busy signals.

There are two approaches used to transmit this signalling information – the older way which is in-band and the more modern

out-of-band signalling. The old way of doing this was in-band signalling systems, where the signalling systems used the same path and switches as the voice signals. A complete path from caller to called party would be reserved for the signalling system. If there was no one at the other end to answer the call, the trunks would remain reserved for that period and would not generate any revenue. This was considered inefficient. In addition, there was greater risk of theft because the frequencies used could be duplicated by hackers.

Out-of-band systems, in contrast, use a separate network to transmit this information. These systems have many advantages such as a reduced risk of toll-theft; provision of features like caller-ID and auto-callback. Out-of-band signalling is used throughout India. CCS-7 is an advanced out-of-band signalling system which is used to give basic routing information, allow call set-up, and provide call termination functions. About 50 percent of the network in India uses CCS-7.

# **Mobile Telephony**

Mobile phones use radio waves to transmit information. Like other wireless equipment, mobile phones have a limited part of the frequency spectrum that they can use. With this limited frequency spectrum, the mobile phone system must provide acceptable voice quality and must be able to handle the expected traffic. So, using the frequency spectrum as efficiently as possible becomes a crucial task for mobile phone companies. There are two ways in which mobile telephony uses the spectrum efficiently. One is frequency reuse where efficiency comes from reusing the small amount of frequency spectrum available again and again. The other is multiple access, that is allowing as many conversations as possible to use the limited frequency spectrum available.

#### Frequency Reuse

Why do we need to reuse frequencies? In India, initially each mobile service provider was allocated 5 MHz for uplink and 5

MHz for downlink. Let us first assume that there is no reuse of frequency. Then, given that the channel bandwidth in GSM is 200 kHz and that each channel can carry eight conversations with time division multiplexing this would have resulted in only 200 ((5000/200)x8) conversations in the entire service territory. Clearly, if only 200 conversations could take place in the entire service territory there would be tremendous congestion in the mobile phone network.

One way to tackle the problem is to reuse frequencies. However, if frequencies are reused in areas next to each other, there will be interference. So, any frequency reuse strategy must ensure that adjacent areas do not use the same frequencies. One way to do so is to divide the area into hexagons just like a honeycomb (see Figure 4.2). Let us consider cell number 7 in any of the clusters of cells. Its immediate neighbours are cells 1-6. We would arrive at the same result if we selected any other cell. So frequencies can be repeated every seven.

Figure 4.2: Frequency Reuse 6 7 2 6 7 2 6 7 3 5 7 3 5 7 3

Source: As given under Figure 3.2 (page 26).

#### Multiple Access Techniques

In addition to space division that has been explained above, a second technique to use the frequency spectrum more efficiently is the sharing of the same frequency channel by multiple users. There are three commonly used multiple access techniques:

frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA).

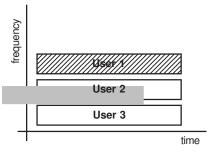
#### FDMA

FDMA was discussed under multiplexing techniques in Chapter 3. Please refer to Chapter 3 for details on this technique. FDMA is generally used with analog cellular systems. In India, it is used in combination with TDMA in GSM<sup>1</sup> networks. In systems which use FDMA, the allocated spectrum is divided into channels, and each phone conversation takes place on a different channel (Figure 4.3).

#### TDMA

TDMA also discussed under multiplexing techniques in Chapter 3. Please refer to Chapter 3 for details on this technique. Real world versions of TDMA are actually a combination of FDMA and TDMA. GSM uses TDMA in Source: As given under Figure 3.2 (page 26). combination with FDMA. In

Figure 4.3: FDMA



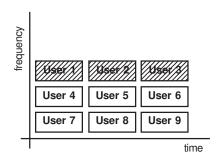
GSM, the available frequency spectrum of 25 MHz is divided into 124 channels of 200 kHz bandwidth and each channel supports eight users. Thus, there are 124 FDMA carrier frequencies and each carrier frequency is used to transmit 8 TDMA voice signals. Figure 4.4 shows how the frequency channels and time slots are used in GSM.

GSM is an abbreviation of Global System for Mobile Communications. It is a standard that originated in Europe for wireless digital communications. It is the system used by all the mobile service providers in India except operators such as Reliance Infocomm who started providing limited mobility under a fixed service licence - these operators use CDMA to provide mobility. We discuss CDMA in the next section. It must be remembered that now that there is a unified licence for access service, the separation between mobile, limited mobile, and fixed service has disappeared.

#### CDMA

CDMA is the newest of the multiple access techniques and has generated considerable interest. It is used by access service providers who were offering limited mobility (for example, Reliance Infocomm). It has also been proposed by IMT-2000 for third generation (3G)<sup>2</sup> mobile communication systems.

Figure 4.4: TDMA as Used in GSM



Source: As given under Figure 3.2 (page 26).

In CDMA, all users use the same frequency and all of them can transmit at the same time. This is possible because each user is assigned a unique code sequence to encode its data or signal. Knowing the code sequence of the user, the receiver is able to decode the received signal and received the original data.

The classic example that is given to help understand how TDMA and CDMA work is of a cocktail party. At a TDMA party, the people stand in a circle and take turns to speak. Conversations can be separated by the moment in time when each person is speaking. In contrast, at a CDMA party, everyone is speaking at the same time but in a different language. When you hear a language that you recognize, you turn your attention to that conversation. You can then filter out all the other conversations as noise. You can continue to filter out other conversations until the number of people in the party gets so large that it is impossible to distinguish between conversations.

#### Comparison between TDMA and CDMA

CDMA has several advantages over TDMA. First, it has a higher spectral efficiency which means that it can accommodate

<sup>2.</sup> We discuss 3G mobile communications in more detail in Chapter 6.

more users per MHz of bandwidth because each user can use the entire band available. As we have seen, TDMA used in the GSM system can accommodate eight users per channel of 200 kHz. It is difficult to arrive at such an exact number for CDMA because it has variable capacity whereby one can add more users but the quality of the conversation degrades. It is generally agreed that CDMA has about 2 to 3 times the capacity of TDMA.

CDMA also allows 'soft hand-off' for mobile phones. As a mobile phone user travels from one cell to another, the call is switched between the two cells and this is known as hand-off. In GSM (which uses TDMA), the phone stops receiving and transmitting on the old channel and starts receiving and transmitting on a new channel. This is known as a 'hard hand-off'. These hard hand-offs can be annoying for people who are sensitive to interruptions. Besides, calls can get dropped during these hard hand-offs.

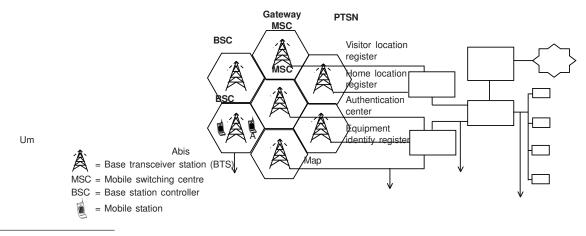
In contrast, in CDMA every cell is using the same frequency for transmission. While a CDMA call is in progress, the network chooses two or more alternate cells that would be good hand-off candidates, and transmits the call to those alternate sites also. The mobile phone can then select between the different sources for the call and can move between them as and when necessary. This is known as 'soft hand-off' and is generally not noticed by the user.

CDMA also provides better protection against multipath interference. In a wireless communication channel, there is not just one single path between the transmitter and the receiver. Signals get reflected from buildings and other objects in their path. While the signals from these various paths are all copies of the same transmitted signal, they have different amplitudes and arrive at the receiver at different times. Therefore, they may add constructively or destructively at the receiver. CDMA can combat this multipath interference through complex mathematical techniques.

#### **Basic Architecture of Mobile Telephony Systems**

There are four main components in the GSM mobile telephony system: the mobile phone; the base transceiver station (BTS); the base station controller (BSC); and the mobile switching centre (MSC) (see Figure 4.5). Each cell contains a BTS, located on a tower that transmits signals to and receives signals from the mobile phones in its area. BSC is an intermediate device that controls a group of BSTs. MSC is connected to the public switched telephone network (PSTN) for routing of calls. It interfaces with a number of databases that enable roaming, billing, and interconnection with other networks. These databases include the following registers:

Figure 4.5: The Digital Cellular Architecture



Source: As given under Figure 3.2 (page 26).

Home Location Register: It contains information about all the subscribers in a particular MSC area.

Visitor Location Register: Information about calls being made by roaming subscribers is stored here and is periodically forwarded to the subscribers' home service providers for billing.

Authentication Centre: It protects against unauthorized access and provides security.

Equipment Identity Register: Information about equipment that has been stolen or blacklisted is stored here.

#### **How Mobile Phone Calls are Completed**

When a mobile phone is first switched on, it searches for a local BTS. At least one of the channels of each BTS is assigned to carry control signals. BTS informs BSC of the call attempt and BSC allocates a dedicated bi-directional signalling channel and sets up a route to MSC. When a mobile unit initiates a call, it must transmit its international mobile subscriber identity number (IMSI).

Each mobile phone has an entry in the home location register (HLR) of its home MSC. The HLR also contains information about the services the subscriber can access. Whenever a mobile phone is switched on and periodically after that it registers with the system. In this way, the location of the subscriber is established and updated in the HLR. When the first registration occurs, the system uses IMSI to see if the subscriber is in its HLR and verifies that the customer is legitimate and allows the call to proceed. If the mobile phone is not in its HLR, then it locates the home HLR of the subscriber and interrogates it to verify its identity and adds the caller to its visitor location register (VLR).

Once the user and his/her equipment is accepted by the network, the user must specify the phone number of the destination. Then the network allocates a traffic channel and the MSC routes the call to its destination.

We have seen what happens when a mobile phone subscriber wants to make a call. What happens when a call is placed to a mobile phone? When a mobile phone number is dialled, MSC looks in its HLR for that number. If it is in its HLR, it will send out a paging signal. When the mobile phone responds to the page, MSC

connects the call. If MSC finds that the called phone is not in its HLR or VLR, then it launches a query over the CCS-7 path to find the mobile phone. When the called phone is located in a remote MSC, it asks the remote MSC to connect the call.

# **Complete Telephony Network**

So far, we have described the various components of the telephone network. While this chapter described the PSTN and mobile telephone networks, the previous chapter described the transmission media to carry information between switching centres and between subscribers and switching stations. Now we can see how the complete telephone network looks. The best visual description we could find is in the book *How Things Work Today* brought out by Scientific American. Figure 4.6 is a reproduction of a diagram of the telephone network given in the book. It shows the fixed line network as well as the mobile network and explains how the two are interconnected. It also shows how satellites and terrestrial line-of-sight microwave stations can be used for transmission of voice.

# DATA COMMUNICATIONS AND THE INTERNET

No description of modern telecommunications would be complete without a discussion of the Internet. We begin this chapter with the evolution of the Internet and data communications. Then we explain the difference between the information transfer technique used in the Internet – packet switching – from the information transfer technique used in telephony – circuit switching. This is followed by description of the basics of the Internet. In the last section of this chapter we look at the use of the Internet for telephony in India.

# **Evolution of Data Networking and the Internet**

Until now, we have discussed voice communications. In fact, by discussing the PSTN first and then mobile telephony we have followed the evolution of voice communications. While this development of voice communications was going on, there was a parallel development in data communications.

Until the 1970s, stand-alone mainframe computers dominated the data processing environment. At that time, data communications were restricted to a top-down transfer of information between the computer and smart terminals and other peripherals. Then came smaller computers or workstations which started off as stand-alone units. However, soon it was realized that there was a need for the workstations to be able to communicate with one another and this gave birth to local area networks (LANs). This, in turn, brought into focus the need for LAN internetworking.

While these developments were taking place, the Defence Advanced Research Projects Agency (DARPA) in the US was working on distributed networks whereby computer centres in some American Universities were being connected together. This development gradually led to the Internet – the global network of networks. In the 1990s, the Internet became commercialised. With the introduction of the world-wide web (www), the Internet, instead of being a mainly academic platform, became a resource used by the general public.

#### Circuit Switching versus Packet Switching

Voice, video and data have different transmission requirements. Voice communications do not require much bandwidth but are sensitive to delays. However, voice communications are quite tolerant of errors. Like voice, video transmission is also sensitive to delays and quite tolerant of errors. However, video transmission requires large bandwidth. In contrast, data transfer is generally insensitive to delays but is very sensitive to errors. In fact, strict error checking is very important for data transfer. Furthermore, data transfer is bursty in nature – data transfer is not a continuous process but instead one with long quiet periods punctuated by bursts of data. Given these differences in the transmission requirements of voice and data, it is to be expected that different mechanisms would be developed for information transfer of voice and data.

We now discuss the two techniques for information transfer that have developed: circuit switching for voice and packet switching for data. We are moving to an era where everything is becoming digitised and is represented by 1's and 0's. Therefore, we are seeing the application of packet switching to voice in some applications. The discussion in this section will help to understand the issues involved in such trends.

#### Circuit Switching

The PSTN and most voice networks until now are based on circuit switching. The key feature of circuit switching is that

network resources, such as the transmission channel and the time slot in the switch are reserved for the duration of the conversation. When the conversation is over, the resources are released. In fact, before the conversation begins, an end-to-end circuit is set up. This is done by sending a call request signal which must be acknowledged before the conversation begins.

A major advantage of circuit switching is that there is low latency<sup>1</sup> and minimal delay. The routing calculation for the path is made only once and there are no delays at the various nodes in determining the next hop to be taken. This means that the quality of service (QoS) is good and can be guaranteed to be of a certain level. However, this guarantee of QoS comes at a price. About half of the time during a phone conversation there is silence as people pause to breathe or to gather their thoughts, and, therefore, the circuits are not being used to their maximum capacity and thus there is a loss of efficiency.

#### **Packet Switching**

While circuit switching was developed for voice communications, packet switching was developed for data communications. In interactive processing, data entry takes place on line; however, data is transmitted only when the *Enter* key is pressed. So, if a data entry operator was filling out a spreadsheet, while the operator was typing out the numbers, no information would be transmitted. Only when all the data was entered and the operator pressed the Enter key or signalled that the data was to be transferred would the data actually be transferred. Thus, the data transfer was 'bursty', i.e. most of the time the data link was sitting idle and would only be used for a fraction of the time when data was actually transferred. This meant that the data links were being used very inefficiently. Therefore, packet switching was developed to improve efficiencies with bursty traffic transmission.

Latency is the delay in getting a packet from the entry point in a network to the exit point.

In packet switching, the data to be transferred is broken up into packets. Each of the packets has a header that gives its destination address and sequence number. Packets are forwarded through a series of packet switches. Each packet is routed individually and all the packets from the same data stream may take different paths to the destination and may arrive out of sequence. The sequence number is essential to allow reconstruction of the data stream at the destination.

Packets from different sources are statistically multiplexed and share transmission faciliites. Packets get queued up at the various nodes and this introduces delays in transmission. In addition, because each packet can potentially have a different destination address, the packet switches have to do a lot more routing analyses.

Because data links are shared by various sources (or data streams or connections), packet switching makes an efficient use of the telecommunication facilities. However, the efficiency comes at a price. Packet switching has three disadvantages. First, because packet switching uses a store and forward mechanism for transmission, there are delays in transmission, also known as latencies. Second, the delay between packets can be variable because the packets take different paths. This leads to jitter which can be particularly disconcerting in a phone conversation and, if excessive, can make the conversation unintelligible. Third, if there is congestion at the packet switches, then packets can be dropped and hence lost. Again, this can be a significant problem in voice communications because beyond a certain point the conversation would not be understood.

Given these drawbacks of packet switching, QoS guarantees cannot generally be given. However, protocols and processes are being developed that will enable real time interactive applications, such as voice, video and audio communication to work with reasonable levels of satisfaction using packet switching.

#### **Basics of the Internet**

We begin with first understanding what is a network. A network is a collection of interconnected computers (also known as hosts). The communication between the hosts is done under a protocol or standard that specifies how packets are to be passed between the hosts, how packets are to be formatted, and how error conditions are to be dealt with.

The Internet is a collection of networks that are interconnected and operate as a single large network. Many of the applications that run on the Internet run in a client/server mode where the term 'client' refers to a computer that seeks the services of a server. The term 'server' refers to a computer that provides services to users. Packet switching is used to exchange information. The interconnections are accomplished through routers and bridges. A router determines the most efficient route for passing data through the Internet. A bridge is a device that connects two network segments to allow the transfer of information between them. Bridges filter packets according to their destination addresses.

The protocols that are used for transfer of information in the Internet are known as TCP/IP for transfer control protocol and Internet protocol, respectively. TCP is responsible for properly sequenced and reliable data transfer. It breaks up a data stream into packets and gives each packet a sequence number. The sequence numbers enable reassembly of the data stream at the destination. It also adds the source and destination address to the header of each packet. Besides, it takes care of error control through acknowledgements and retransmission of lost or damaged data.

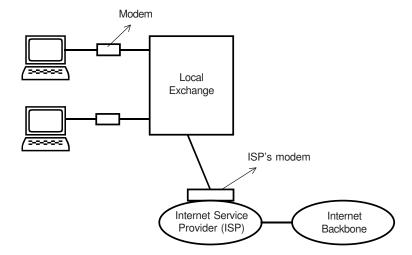
While TCP is responsible for the host-to-host communication, the IP part of the protocol is responsible for transport of the packets across the Internet. It takes care of routing the packets through the Internet to the requested destination. It makes its best effort to deliver the packet to the requested destination. However,

if it fails to do so, it simply drops the packet. Because packets can get lost or arrive out of sequence, TCP provides solution of these problems.

#### Connecting to the Internet

The most common way for an individual to connect to the Internet is through a "dial-up connection". Figure 5.1 shows a schematic diagram of a dial-up connection. A modem converts the digital signals from the computer into analog signals which can then be transmitted over the telephone line. The telephone company carries the data to the Internet service provider (ISP) who converts it back into digital signals which are then transmitted to the Internet backbone.

Figure 5.1: Connecting to the Internet Using a Dial-up Connection



For high-usage customers there are other ways to connect to the Internet. Businesses may find it economical to lease a high speed line that connects directly to the ISP. Also broadband access can be used for an "always-on" connection to the Internet. Broadband access also uses the PSTN but provides higher speeds. We discuss broadband access in more detail in Chapter 6. ISPs differ in the size of their operation and coverage areas. A small retail ISP does not usually connect directly to the Internet backbone but may interconnect with a regional ISP who may then connect with a national ISP, and so on. So, there may be many hops between the retail ISP and the interconnection and exchange points.

#### Internet Telephony

Recently, there has been considerable interest in using the Internet to make phone calls because of its lower cost. While several countries have opened up Internet telephony, until recently it was not permitted in India. NTP 1999 said that at that time Internet telephony would not be permitted but that the Government would continue to monitor technological developments and would review the issue at an appropriate time. Recently, there was considerable demand for opening up Internet telephony by potential users who expected to be able to make long distance calls both nationally and internationally at the cost of a local call. In late 2001, TRAI initiated an investigation into the issue of opening up of the Internet telephony.

As clarified by TRAI in its Consultation Paper on Introduction of Internet Telephony, the term IP telephony covers two services: Internet Telephony and Voice over IP (VoIP)<sup>2</sup>. Internet telephony refers to telephony service over the public Internet. As envisaged by TRAI, such a service would be provided either by the existing internet service providers (ISPs) or a new category of service providers – internet telephony service providers (ITSPs). By dialling a separate code, the subscriber would reach the ISP or ITSP's node and would get a second dial tone. He would then proceed to dial his long distance call. In this way, the long distance call would be routed through the Internet cloud to the terminating media gateway and from there to the destination PSTN and the called phone.

<sup>2.</sup> VoIP is a technique which uses Internet Protocol (IP) to transmit voice.

The use of VoIP means using an alternative technology. As an alternative to the circuit switched transmission of voice, the service provider uses packet switching and then IP to transmit those packets over its managed backbone. Managed VoIP does not use the public Internet because QoS cannot be guaranteed in this case. As we have seen earlier, during periods of high congestion, upto 40% of the packets are lost resulting in unintelligible conversations. Such a poor QoS cannot be tolerated in public telephony. Therefore, managed VoIP networks use their own transmission backbone.

Figure 5.2 provides a schematic description of the relationship between Internet telelphony and VoIP and public switched telephony provided through the PSTN. Historically, most NLDOs used the PSTN with TDM to carry the long distance calls. Increasingly, NLDOs are using a managed VoIP network as part of the backbone. In the future, service providers will also use the public Internet to transport the voice packets.

PSTN ong Distance Network (TDM) 2 Managed VOIP VOIP VOIP Gateway 3 **PSTN PSTN** Public Local Local Internet Internet Customer Exchange Telephony Telephony Service Equipment Service Providers Providers POP

Figure 5.2: Long Distance Telephony Network

Source: TRAI Consultation Paper on Introduction of Internet Telephony, 2001.

As a result of its consultations, TRAI recommended to the Government that Internet Telephony be allowed, but only in some

restricted situations. It also noted that, in India, service providers were already permitted to transmit voice over managed VoIP based networks.

The Government accepted TRAI's recommendations. As a result, Internet telephony is permitted but only for the following situations:

- Personal computer (PC) to personal computer;
- PC to telephone (PC in India to telephone outside India)
- IP based H.323/SIP terminals in India to another such terminal anywhere in the world.

Essentially, any Internet phone call that uses the PSTN in India is prohibited.

# EMERGING DEVELOPMENTS IN TELECOMMUNICATIONS TECHNOLOGY

With the rapid changes that are occurring in telecommunications, a primer on this sector would be incomplete without examining the emerging trends in the growth of this sector. We start with a short analysis of current drivers of growth and development in the telecommunications sector. Our analysis shows that four trends are likely to characterize the growth of the telecommunications sector in the coming years – (i) demand for increasing amounts of bandwidth; (ii) technological developments that will provide the increased bandwidths at increasingly lower costs; (iii) "any time, anywhere" applications with greater emphasis on mobility; and (iv) convergence of technologies and markets which will blur the separation between industries and between telecommunications services.

In this chapter, we describe technologies that will help satisfy the increasing demands for bandwidth. In addition, we describe developments in wireless communications to facilitate the development of anytime, anywhere applications. Some of the technologies may already be in use elsewhere but may not be as widespread in India, while others may not yet be widely used even in the developed world.

#### Trends in Telecommunications Applications and Services

# Demand for Greater Bandwidth

The most significant trend in telecommunications today is a demand for greater bandwidth at all levels of the system – access, switching, and transport. This evolution to broadband is fuelled by the greater need for information. Knowledge is perhaps the most

important asset for organisations and individuals in today's society. Therefore, in order to be competitive in the present-day environment, organisations and individuals must have access to telecommunications systems that facilitate rapid and effective exchange of knowledge.

The demand for greater bandwidth is also fuelled by new applications, such as tele-medicine and tele-education that are data-intensive. Such applications focus on providing information in visual form which requires the transfer of vast amounts of data. This trend will be accelerated further as computing and communication applications involve our other senses, such as smell, taste, and touch. The demand for bandwidth will accelerate even further as we move to an era of ubiquitous computing. Computers will no longer be stand-alone units, but instead will be embedded in almost all the gadgets that we use resulting in smart refrigerators, smart cars, smart washing machines, etc. Because these devices will need to talk to one another and be able to receive instructions from human beings from remote locations, the demand for communication capacity (bandwidth) is likely to increase even further.

The demand for bandwidth and the evolution towards broadband is probably best exemplified by the phenomenal growth in traffic on the Internet. Internet traffic is reported to be doubling every eleven months (Goleniewski: 285). This increase in Internet traffic is the result of not only greater number of subscribers but also an increase in the average time a subscriber is connected to the Internet, with the average connect time now being about one hour.

# Availability of Bandwidth at Lower Prices

While the demand for bandwidth is increasing dramatically, technological developments are making more bandwidth available at ever decreasing costs. The interplay between supply and demand of bandwidth is leading to increased growth of the sector. As more

bandwidth becomes available at reduced prices, more applications are developed that require large amounts of bandwidth. Because of the demand created by these applications, yet more bandwidth is created.

An example of how rapidly technological breakthroughs are leading to reductions in costs is provided by Goleniewksi (2002:285). She reports that for intercontinental capacity for a 155 Mbps link at the start of 1997, the cost was US\$20 million. By 1998, it had dropped to US\$10 million; in early 2000, it was down to US\$2-3 million; and in 2001 it had dropped to US\$1 million. So, in five years the price dropped to 1/20th of its starting value!

# Focus on Mobility

In the field of telecommunications, the focus now is on providing services that are available anywhere at any time. This requires that services be available even when the user is on the move. Mobility has always been important for human beings. The need to be mobile has become even more important with globalisation, as people have to travel to different countries for business. For many people, such as those engaged in marketing, their job is done mostly on the road. With the current importance of knowledge and information transfer, it is not surprising that people want to be able to communicate and obtain information while they are on the move.

Mobile phones have satisfied this need to be in touch while moving around. And now people want access to the Internet while being mobile. Mobile Internet access is already available in some places and is likely to become much more widespread. It is predicted that by 2009, there will be more mobile Internet devices than PCs connected to the Internet (Goleniewski: 425).

Currently, we think of wired services as being the norm and wireless services as being a value added service with something extra. This may change with wireless services becoming the norm. In India, this is already beginning to happen with the use of mobile

phones. As we noted in Chapter 2, the number of mobile phones is likely to exceed the number of fixed line phones very soon, and in a few years there may be far more mobile phones than fixed line phones.

# Convergence

Another important characteristic of telecommunications today is convergence of technology and markets. As GoI noted in NTP 1999, telephone and broadcasting industries are entering each other's markets, and at the same time, technology is blurring the difference between the various conduits and services, such as fixed line and wireless. The Government has responded to the changing scenario by first approving a unified licence for access services, thus removing the separation between fixed line service and mobile phone service. In addition, it has approved in-principle a unified licence for all telecommunication services. When such a unified licence regime comes into force, it will remove the separation between access services, long distance services, internet telephony, and broadcast services and, as a result, any service could be provided by any operator anywhere using any technology.

Let us now look at the products and protocols that are being developed or have already been developed to satisfy the demand for broadband capacity.

# Broadband Access<sup>1</sup>

A major bottleneck in the use of the Internet is the access at the consumer end. As we discussed in Chapter 5, many residential consumers use dial-up connections. These connections are slow, particularly for downloading information from the Internet. Those of us who have used dial-up modems to access the Internet are painfully familiar with long delays that can occur particularly as we try to download files from our favourite sites.

From TRAI Consultation Paper on Accelerating Growth of Internet and Broadband Penetration, November 28, 2003.

Technologies have been developed that can speed up the connection between the consumer and the local exchange, also known as the last-mile. Speeding up the last-mile connection has come to be known as broadband access and has been defined by TRAI<sup>2</sup> as "an always-on connection that is able to support various interactive services, and has the capability of a minimum download speed of 256 kbps." TRAI says that the threshold of 256 kbps will be raised in the future.

The benefits of providing broadband access go far beyond greater convenience for consumers. TRAI asserts: "Internet and broadband roll-out has the ability to have even farther reaching effects than the reforms in telephony did." Development of broadband access can play an important role in the country's economic development. Furthermore, development of broadband access results in a great increase in the amount of information available and this can facilitate greater accountability in governance, and wider access to government information enhances the functioning of the democracy. For these reasons, development of broadband access is significant for developing countries like India.

There are many technologies that can be used for providing broadband access. However, we will focus on only the two more popular technologies – Digital Subscriber Line (DSL) and cable modems.

# DSL Technologies

DSL technologies use existing twisted pair wires and this is a major advantage because they do not require new wiring. Because voice uses only a small portion of the available bandwidth of the twisted pair, in DSL the available bandwidth is split between voice and data services. Different frequencies are used for voice and data and they are both transmitted over the same standard

From Broadband India: Recommendations on Accelerating Growth of Internet and Broadband Penetration, by TRAI, April 29, 2004.

phone line. Splitters at both the consumer end and at the PSTN end separate voice from data.

Unlike cable modem technologies which we discuss next, DSL offers a dedicated amount of bandwidth that does not depend on the number of subscribers who are logged on in a particular area. However, DSL technologies are affected by the distance between the subscriber and the local exchange and the size of the twisted pair copper wire. There are a number of DSL technologies, including the following:

• Asymmetric DSL (ADSL): In ADSL, more bandwidth is allocated to download than upload (Figure 6.1). This is particularly suitable for using the Internet where speed is more important in the downloading of large files from the Internet. With ADSL, users can use the telephone and surf the Internet simultaneously. There are some improvements of ADSL available.

ADSL modern
ISP Existing copper wire

PSTN splitters

Telecom network

Figure 6.1: Asymmetric Digital Subscriber (ADSL)

Source: Mohan Sundara Rajan, The Telecom Story and the Internet, 2004.

- Single Pair High Speed DSL (SHDSL): SHDSL allows symmetrical data transfer at speeds upto 2.3 Mbps in each direction. It is ideal for servers and other business uses.
- Symmetrical DSL (SDSL): Like SHDSL, it provides symmetrical data transfer. The speed can be adjusted according to signal quality and distance.

• Very High Data Rate DSL (VDSL): This is the latest and fastest form of DSL and can provide transfers of up to 52 Mbps though over short distances. It is ideal for short branches from fibre optic connections, such as in an apartment building or commercial complex.

#### Cable Modems

With the widespread use of cable TV in India, the cable network is a good alternative to provide broadband access. The existing cable TV network sends different TV channels on separate blocks of 6 MHz each. For broadband access, one such channel of 6 MHz is used to send data from the Internet to the users and another 6 MHz channel is used to carry data from the households to the Internet (Figure 6.2). All cable subscribers in a small area share the same channels to send and receive data. Therefore, the amount of bandwidth a user has access to depends on how much bandwidth his neighbours are using.

Coaxial Headed CMTS Facility CM CM CM Video receivers Modulators SDH/SONET backbone **CMTS** CM CM CM Ethernet IP router hub Internet CM = Cable Modem CMTS = Cable Modem Termination System

Figure 6.2: Using Cable Modems to Provide Broadband Access

Source: As given under Figure 3.2 (page 26).

#### **Optical Networking**

Fibre optic systems have resulted in dramatic improvements in speed, cost, and capacity. In fact, the electronic equipment in telecommunications systems has now become the bottleneck. Currently, optical signals are being converted into electrical signals for regeneration, multiplexing, or other processing. This is turning out to be inefficient. There is a move towards an end-to-end optical architecture. This means that nowhere in the network is the optical signal converted into an electrical signal. This reduction in conversions between optics and electronics will result in reduced costs and improved performance.

How will this end-to-end optical network be achieved? There are four components that will make this possible:

- Optical-line amplifiers, such as erbium-doped fibre amplifiers (EDFAs) which will avoid the conversion of optical signals into electrical signals for amplification and then conversion back to optical signals.
- Wavelength Division Multiplexing (WDM) equipment. Currently, fibre optic systems use only one wavelength. By using multiple wavelengths on a single fibre, the capacity will increase.
- Optical add/drop multiplexers (OADMs). OADMs use special filters to drop signals of certain wavelengths at a given location.
- Optical switches. Optical switches are the optical equivalent of the electronic switches in today's PSTN that facilitate switching at exchanges.

# **Advances in Wireless Communications**

Earlier in this chapter, we have discussed the importance of wireless systems in providing anywhere any time services. Here we discuss developments in wireless connections that will facilitate the provision of services anywhere, any time.

Because the development of wireless systems is discussed in terms of "generation" of technologies, let us familiarize ourselves with the defining features of the various generations of technology (Goleniewski: 437):

- First generation (1G) systems used analog signals for transmission of information and were introduced in 1979. An example of a 1G technology is AMPS.
- Second generation (2G) systems used digital signals for transmission and were introduced in 1992. GSM is an example of a 2G technology.
- Third generation (3G) systems which will continue to use digital transmission but at much higher speeds. Examples of 3G technology are wideband code division multiple access (WCDMA), international mobile telecommunications 2000 (IMT-2000), universal mobile telecommunications system (UMTS).

There is even reference to 2.5G systems which are enhancements to 2G systems. We now discuss below some of the new technologies.

#### General Packet Radio Services (GPRS)

One of 2.5G technologies that has received attention recently is GPRS. It makes it possible for a subscriber to make phone calls and transmit data at the same time. It is a pre-requisite for allowing a mobile user to access the Internet. GPRS is an always-on service that works using a packet-based interface to the eight time slots available for GSM transmission.

# 3G Systems

3G standards have the ambitious goal of providing any telecommunication service anywhere, anytime and from the same terminal (or device). So, you'll be able to use your "mobile phone" to make video calls, and surf the Internet simultaneously. This means high speed transfer of multimedia (voice, audio, video)

information coupled with advanced global roaming. Some of 3G objectives are (Goleniewski: 450):

- Support for fixed applications and a broad range of mobile scenarios.
- Support for high quality voice, messaging, Internet access, and high-speed multimedia.
- Improved throughput and QoS.
- Improved battery life.
- Support for position-location services.
- Backward compatibility so that there is coexistence with current infrastructures.

The speeds of data transfer that 3G systems will be expected to achieve are: 144 kbps in a high speed moving environment; 384 kbps in a low-speed moving environment; and 2 Mbps in a stationary environment.

#### Mobile Internet

Mobile access to the Internet is already available in some locations and is likely to grow dramatically in the near future. Because of the small screen and low speeds, Mobile Internet does not provide the same visual impact as the Internet on a PC. Mobile Internet access is limited to text-based information. For those who have grown used to accessing the Internet from the PC are likely to be disappointed with Mobile Internet access because the visual images will be missing.

Wireless Application Protocol (WAP) and I-mode

WAP is a set of rules for transforming information from the Internet so that it can be displayed on the small screen of a mobile phone. WAP removes the images and multimedia to get just the text-based information, and this has led to some dissatisfaction among users of WAP based devices. In addition, users have been

frustrated by the slow speeds, the difficulties of using the keypad of the mobile phone, and a scarcity of sites that use Wireless Markup Language (WML) instead of Hypertext Markup Language (HTML).

Here is how WAP allows Internet Access:

- (i) A subscriber with a WAP-enabled mobile phone types the address of the Web site on the phone's screen.
- (ii) The microbrowser sends the request as a digital signal.
- (iii) A cell-phone tower (BTS) picks up the signal and sends it to a WAP gateway linked to the Internet. The WAP gateway searches for the requested web page.
- (iv) Software in the gateway converts the Web page from HTML to WML so that it can be displayed on the cell phone screen.
- (v) The WAP gateway sends the WML document to the subscriber's cell phone. The microbrowser in the mobile phone then displays the text on its screen.

I-mode which is particularly popular in Japan works in essentially the same way as WAP but at a higher data rate as in 3G applications.

# Wireless Personal Area Networks (PANs)

PANs are very small wireless networks and are used mainly to transfer data between a printer and a laptop or desktop computer. Essentially, PANs allow wireless connections between peripherals and computers, thus avoiding a jumble of cables. Here we briefly describe two standards that are used for this purpose.

# IrDA

IrDA allows one to point a notebook computer at a printer and "squirt" the document through a wireless connection rather than use a cable.

#### Bluetooth

Bluetooth is a standard that has been jointly developed by 3Com, Ericsson, IBM, Intel, Lucent, Microsoft, Motorola, Nokia, and Toshiba (Goleniewski: 465). The aim was to develop an inexpensive chip (for \$5) and embed it in Personal Digital Assistants (PDAs), laptops, mobile phones, and other intelligent applicances so that they can communicate with one another wirelessly. Each device with a Bluetooth chip has a coverage area of about 30 meters. Bluetooth is an important standard because it has the backing of most manufacturers and could be an important contributor to pervasive computing, and it uses the part of the frequency spectrum that does not require a licence (2.4 to 2.48 GHz).

# NURTURING COMPETITION IN THE INDIAN TELECOMMUNICATIONS SECTOR

One of the objectives of NTP 1999 was to "transform in a time-bound manner, the telecommunications sector to a greater competitive environment in both urban and rural areas, providing equal opportunities and level playing field for all players." This statement highlights the Government's recognition that in order to attract private capital into the sector and to use it most effectively to develop a modern and efficient telecommunications sector, it needed to foster an environment that was conducive to competition.

This chapter focuses on steps being taken to nurture competition in the Indian telecommunications sector. It is divided into two parts. The first part deals with the fundamentals of competition policy and spotlights the issues that need to be tackled in order to nurture competition in telecommunications. It starts with an explanation of why competition needs to be fostered and why a competition policy is necessary. Then it defines market power and describes the various ways in which a dominant operator can indulge in anti-competitive behaviour and the remedies available to counter such conduct. It also describes the issues that need to be addressed in mergers and acquisitions (M&As) in the telecommunications industry to ensure that competition in the market is not adversely affected.

Part II of the chapter deals with the Indian experience in protecting and developing competition in telecommunications and outlines the various steps that are being taken for this purpose. We start with a look at the agencies responsible for protecting competition in the sector – Competition Commission of India

(CCI) and TRAI – and their respective responsibilities and relationship with one another. Then we give a snapshot view of the level of competition in the sector. This is followed by a discussion of the two factors that are limiting competition – (i) scarcity of frequency spectrum; and (ii) inability of consumers to select their long distance carrier. Then we look at the introduction of accounting separation to aid in identifying anti-competitive conduct. Finally, we discuss the proposed regulations regarding M&As.

# Part I: Fundamentals of Competition Policy<sup>1</sup>

# The Need for Competition Policy

Why do we need a competition policy? Before we answer this question we need to understand what is meant by competition in economics and what are its benefits. When multiple suppliers supply the same or similar goods in a market, they compete with one another by offering the consumer lower prices, higher quantities, or better quality. Thus, competition motivates the various suppliers to be more efficient and to offer better products at lower prices. The main reason why competition works in this manner is that in a perfectly competitive market, no individual supplier can dictate market terms or the price of the product.

If a market is perfectly competitive as described above, then there would be no need for a competition policy or for any other kind of intervention by the Government. The invisible hand of the market would lead to efficiency, best allocation of resources, and low prices. But this does not happen in the markets for all products. Some markets fail because the conditions of perfect competition do not exist.

<sup>1.</sup> The coverage of the fundamentals of competition policy is based on the discussion on competition policy in Module 5 of the Telecommunications Regulation Handbook, edited by Hank Intven and published by the World Bank.

The most common form of market failure occurs when one or a small group of large suppliers dominates the market. When a single supplier controls the market, it is known as monopoly and when a small number of suppliers control the market, it is known as oligopoly. In these cases of market failure, one or a few suppliers can dictate terms or prices in the market. This imperfection in the market leads to inefficient allocation of resources to the detriment of consumer welfare.

Telecommunication in most countries has developed as a monopoly often with a Government-owned firm being the only or primary supplier of telecommunication services. In India, Bharat Sanchar Nigam Ltd. (BSNL), previously called the Department of Telecommunications (DoT), was the main supplier of services. Because BSNL, like other incumbent operators has an established network, it has control over essential facilities that other operators require for interconnection. By delaying or denying access to these facilities, BSNL can frustrate the efforts of its competitors. In addition, with its control over essential facilities and its 'deep pockets', it can drive out its competitors. Competition policy is required to address these concerns about unfair competition and the exercise of market power by the incumbent operator.

# **Market Power and Dominance**

# Definition of Market Power

We have used the term market power several times in the discussion above. What is market power and how is it determined? Market power is the ability of a firm to raise its price for a product or service above the market rates for a sufficiently long period without losing sales to a degree that would make such behaviour unprofitable. In a perfectly competitive market, if a supplier raises prices above the market rate, he will quickly lose sales and will ultimately go out of business. This does not happen to a firm with market power.

For determining whether a firm has market power in a market, the following factors have to be considered: market share; barriers to entry in the market; pricing behaviour in the market; profitability of the existing players in the market; and vertical integration. We now look at each of these factors briefly.

In defining market share, it is important to define the product and the geographic region properly. For example, if we want to determine whether BSNL has market power and we look at basic services only, then we will find that BSNL has a market share of about 84 percent. However, if we include substitutes such as mobile phone service, then we will find that BSNL's market share is smaller, around 54 percent. Similarly, defining the geographic boundaries of the market under consideration are important. For example, we may find that BSNL does not have significant market power in the metros because there are alternatives available to consumers, such as mobile service providers and private basic service operators. However, if we were to consider telecom circles such as Jammu and Kashmir where private operators have been reluctant to enter, then we may find that BSNL has considerable market power in that circle.

Barriers to market entry are also important in determining market power. If barriers to entry are low, then even if a dominant supplier has a large market share it is unlikely to indulge in anti-competitive behaviour because of the threat of entry by other suppliers. For example, if a dominant supplier raises price for some time, it will attract other players who will be drawn to the market by the promise of high prices and hence high profitability.

Identification of market power becomes easier if one also looks at pricing behaviour and profitability. If in a market, there is a price leader who raises prices and the others also follow by raising their prices, then it indicates that the price leader has market power. This happened in the early period of competition in the long distance market in the US. An examination of price trends shows that AT&T played the role of price leader; whenever AT&T raised

prices, Sprint and MCI would increase their prices to the same level. If there were competition between the players, then one would have expected price rivalry where each supplier would try to outdo the others by cutting prices.

Profitability of existing suppliers is also an indicator of the market power. Any market where suppliers are making high profits will attract other players, thus reducing the opportunity for high profits. If that does not happen, then one suspects that due to high entry barriers or some other reason, the existing suppliers enjoy market power.

# Anti-competitive Behaviour and Its Remedies

In this section, we look at common examples of anticompetitive conduct that dominant firms in telecommunications indulge in. We also discuss various remedies that are available to the regulators to rectify such behaviour.

# Refusal to Supply Essential Facilities

According to the World Trade Organisation (WTO), essential facilities are facilities of a public telecommunications transport network that (i) are exclusively or mainly provided by a single or small group of suppliers; and (ii) cannot be practically duplicated by competitors for technical or economic reasons. Essential facilities are also known as bottleneck facilities.

Most of the essential facilities are related to interconnection. We cover interconnection in much more detail in Chapter 8. Interconnection is more important for a small player than it is for a dominant player. If the dominant player refuses to interconnect, then the small player will not be able to complete most of the calls that his customers make and that will probably spell the death of his business. In contrast, the business of the dominant player is not significantly affected if he is not able to complete a small fraction of his calls.

Essential facilities consist of network components and services, such as (i) local loops and related functions; (ii) local and tandem switching functions; (iii) inter-exchange transmission; (iv) access to signalling links; and (v) access to call related databases. Competition can be greatly accelerated by requiring incumbents to provide access to these essential facilities.

# Anticompetitive Cross Subsidization<sup>2</sup>

Incumbents are generally present in several telecommunication markets, such as basic service, mobile service, NLD service, etc. Such an operator can increase its prices above costs in a market it dominates and then use the revenues it generates to subsidize lower prices in other more competitive markets. A possible example of this would be BSNL raising prices in the basic services markets where it dominates, and using the excess revenues to reduce its prices in its cellular service.

A new entrant may not be able to match the prices of the dominant operator in the competitive service because it cannot subsidize its competitive service from another service. By making it difficult for the new entrants to compete in competitive services, this kind of cross-subsidization raises barriers to entry in the competitive services.

# Remedies against Anti-competitive Cross-subsidies

Prohibitions Against Anti-competitive Cross-subsidies: Many countries prohibit cross-subsidies through laws, regulations, or licence conditions. It is felt that though these broad prohibitions may send a strong message to the incumbent they are not effective by themselves in removing anti-competitive cross-subsidies. We

<sup>2.</sup> Anti-competitive subsidization is different from cross-subsidization mandated by regulators or the Government in the interests of maintaining affordability and providing universal access. Anti-competitive subsidization benefits the operator whereas cross-subsidization for access and affordability is meant to benefit the poorer sections of society. We discuss cross-subsidization required for sociopolitical reasons in Chapter 9.

now look at other more direct measures that are used to identify anti-competitive cross-subsidies.

Accounting Separation: Several countries require accounting separation to help in identifying cross-subsidies between services. Operators are required to separate the costs of different services that they provide. The cost of each service is then compared to the revenue from that service. If a service is not recovering the cost incurred in providing that service, then it is being cross-subsidized by another service where the revenue exceeds the cost of the service.

However, separating costs by service is often more difficult than it seems. First, most incumbents when they operated as monopolies did not maintain accounts with costs separated by service because the profitability of an individual service was not an issue. The focus was usually on the overall profitability of the company. Second, telecommunication services usually involve large amounts of joint or common costs. Allocating the joint and common costs to services involves judgement and gives the operators an opportunity to shift costs. International benchmarks can be used to get a rough check on costs for services.

Another problem with accounting separations is that the cost and time required to carry out the separations can be very high, particularly if the separations are carried out at a very detailed level. Intven, *et al* give the example of Canada where accounting separation process took a decade. In countries with limited resources, it may be better to carry out the accounting separations at a high (macro) level and combine them with international benchmarks to identify anti-competitive cross-subsidization.

Structural Separation and Divestiture: When there are serious concerns about anti-competitive behaviour, two other remedies – structural separation and divestiture may be used. Structural separation means separation of a company into two or more companies so that different services are provided by different

companies. In the case of structural separation ownership does not change. Under divestiture, not only is the company separated but one or more of the resulting companies is sold off with the result that ownership also changes.

To illustrate structural separation, we can consider the example of a company that offers both fixed line and mobile phone service. If there are serious concerns about the company using its regulated fixed line service to cross-subsidize its competitive mobile phone service, then the company can be separated into a fixed line service company and a mobile service company.

Structurally separate companies have to run on arm's length basis. The companies must have separate management, offices, staff, facilities, etc. And, of course, the accounting must be separate. Separating companies is likely to result in loss of economies of scope and scale. Therefore, regulators must weigh whether the loss of economies of scale and scope is outweighed by the benefits of separation, such as the reduced chance of cross-subsidization.

Those who propose divestiture as the remedy for anticompetitive cross-subsidization argue that structural separation is not sufficient. They contend that with structural separation, a lot of regulatory effort will still be needed to monitor and detect anticompetitive behaviour between two affiliated companies.

# Vertical Price Squeezing

When incumbent operators provide both downstream and upstream services, they can indulge in another form of anti-competitive conduct known as 'vertical price squeezing'. If the dominant operator controls key inputs in the upstream market (for example, local access) that are essential for a competitor in the downstream market (for example, Internet access), then the dominant operator can raise the prices for the upstream inputs so that it becomes difficult for the competitor to compete in the

downstream market. This is similar to refusal to supply essential facilities, except that in this case instead of refusal to supply the facilities, the dominant operator uses pricing to squeeze the competitor.

# Remedies for Vertical Price Squeezing

Wholesale Cost Imputation: Regulators can require the dominant operator to provide evidence that its retail prices (prices in the downstream market) are not less than the sum of the following two items: (i) the prices it charges competitors for the wholesale service (prices in the upstream market); and (ii) the incremental cost of providing the retail service. In this way, the regulator can detect if the dominant operator is squeezing its competitors by charging them excessively for the wholesale or upstream service.

# **Predatory Pricing**

Predatory pricing is a practice whereby a dominant operator with "deep pockets" drives out competitors by lowering prices and keeping them low. When the competitors have been driven out and the dominant operator is able to monopolize the market, it can recoup its losses by raising prices.

In order for an operator to be able to indulge in predatory pricing, there must be a reasonable expectation that he will be able to recoup his losses after the competitors have been driven out. This implies that he can exercise market power at that time and that barriers to entry are high in the market.

The standard which determines whether a price is predatory varies between countries. Usually the standard for telecommunications is that the price is below the long run incremental costs (LRIC) or total service long run incremental costs (TSLRIC). In addition, the price drop should be sustained not sporadic or reactive.

# Remedies for Predatory Pricing

In order to pre-empt predatory pricing, regulators use price regulation, usually in the form of floor prices below which a service cannot be priced. In addition, where predatory pricing is detected, the offending operator is penalized and affected parties compensated. Detection of predatory pricing is, however, difficult because of the presence of large joint and common costs which are difficult to allocate to various services in a well-defined way.

# **Mergers and Acquisitions**

As in other parts of the world, the telecommunications industry in India has seen some mergers and acquisitions as the industry consolidates. Mergers and acquisitions can be beneficial for the sector if they lead to greater efficiency. They can also provide access to additional resources to fund new products and services. However, sometimes there is also a concern whether a merger or acquisition will lead to an entity with market power having the potential to indulge in anti-competitive conduct. This concern becomes more important if one of the merging entities already has a significant share of the market and consequently there is a greater danger that the merger or acquisition will lead to enhanced market power for that player.

In order to address these concerns about enhanced market power along with a greater potential anti-competitive behaviour that may result from a merger or acquisition, most countries have competition authorities or regulators that review mergers and acquisitions.

# Merger Review

Generally, large mergers and acquisitions require prior approval from the relevant competition authority in the country. The review of a proposed merger or acquisition focuses on the effect that it will have on competition in the relevant sector(s). If it is found that a proposed merger is likely to have significant harmful effect on competition, then the merger is either rejected or approved with conditions.

Most competition authorities publish guidelines which outline the process which will be used to analyze a merger. For example, the guidelines published by the US Department of Justice (DOJ) identify the following steps that will be included in the analysis of the merger by the DOJ: (i) definition of the market; (ii) identification of other firms in the market and their market shares; (iii) identification of potential harmful effects on competition; (iv) analysis of the barriers to entry; and (v) evaluation of beneficial effects of the merger in terms of increased efficiency.

# Merger Remedies

Based on its review of a merger as outlined above, the competition authority has the following options: (i) unconditional approval of the merger; (ii) rejection of the merger; (iii) partial divestiture whereby the merged firm is required to divest certain assets or operations to remove potential anti-competitive effects; and (iv) conditional approval whereby the merged entity is either subject to regulation or ordered to modify its behaviour to prevent anti-competitive effects.

# Part II: The Indian Experience in Promoting Competition in Telecommunications

# **Agencies Responsible for Overseeing Competition**

# Competition Commission of India (CCI)

On January 13, 2003, the Competition Act was passed by the Parliament and became law. The Act established the Competition Commission of India (CCI) whose purpose was "to prevent practices having adverse effect on competition, to promote and sustain competition in markets, to protect the interests of consumers and to ensure freedom of trade carried on by other participants in markets in India…"

# Functions of the CCI

The functions of the CCI fall under three categories: (i) prohibition of anti-competitive agreements; (ii) prevention of abuse of dominant position; and (iii) regulation of M&As.

Under anti-competitive agreements, the Competition Act includes collusion, restrictive agreements, and refusal to deal. Specifically, the list includes any agreement which:

- Directly or indirectly determines purchase or sale prices;
- Limits or controls production, supply, markets, technical development, investment or provision of services;
- Shares the market or source of production;
- Directly or indirectly results in bid rigging or collusive bidding.
- Has clauses with tie-in arrangement, exclusive supply agreement, exclusive distribution agreement, refusal to deal, and resale price maintenance.

Any entity that indulges in the following practices is said to be abusing its dominant position:

- Directly or indirectly imposes unfair or discriminatory conditions in purchase or sale of goods or services or price in purchase or sale (including predatory price) of goods or services.
- Limits or restricts (i) production of goods or provision of services or market or (ii) technical or scientific development relating to goods or services to the prejudice of consumers;
- Indulges in practices resulting in denial of market access;
- Mandates conditions in contracts for supplementary obligations which have no connection with the subject of the contract.
- Uses its dominant position in one relevant market to enter into, or protect other relevant market.

Regulation of M&As by the CCI is applicable to entities that meet the following conditions:

• In India, jointly have assets worth more than Rs 1,000 crore or a turnover of more than Rs 3,000 crore; or

- In India or outside India, have in aggregate assets worth more than US\$ 500 million or turnover of more than US\$1,500 million; or
- The groups to which the enterprises belong have (i) jointly in India assets worth more than Rs 4,000 crore or turnover of more than 12,000 crore; or (ii) in India or outside India assets (in aggregate) worth more than US\$ 2 billion or turnover of more than US\$6 billion.

Entities that are planning an M&A may send a notice to the CCI giving the details of the merger so that the CCI can take a decision on the M&A.

# Issues to be Considered by the CCI in Its Investigations

The Competition Act details the kinds of issues the CCI must consider in fulfilling its functions. The list of issues includes many of the items we have described in the early part of this chapter. For example, while determining whether a firm enjoys a dominant position, the CCI is required to consider the following factors: market share; vertical integration; entry barriers; social benefits brought about by dominant players, etc.

Similarly, while evaluating M&As, the CCI is required to consider the following issues:

- Extent of barriers to entry;
- Will the resulting entity be able to significantly and sustainably increase profits or margins;
- Availability of substitutes;
- Market shares;
- Extent of vertical integration in the market;
- Possibility of a failing business;
- Any benefits of the M&A;
- Whether the benefits outweigh the adverse impacts of the merger.

# Telecom Regulatory Authority of India (TRAI)

TRAI's charter includes making recommendations to the Government on "measures to facilitate competition and promote

efficiency in the operation of telecommunication services so as to facilitate growth in such services."

# Relationship between CCI and TRAI

As we have seen, both CCI and TRAI share a mandate to promote competition in telecommunications in India. CCI's scope of operations covers the entire country and includes all industries. In addition, it applies remedies retrospectively. It follows a formal investigative process with very little scope for public intervention. On the other hand, TRAI's work is industry-specific and it looks at issues both prospectively and retrospectively. It typically has multiple policy objectives and follows a transparent process with much broader scope for public participation.

How should these two agencies work so that conflicts and inconsistent regulatory rulings are reduced? The potential for such conflicts has been reduced somewhat by the Competition Act which requires that if any party in a proceeding before a statutory authority raises an issue that the statutory authority's decision would be contrary to the provisions of the Act, then the statutory authority may make a reference to the CCI. After receiving the reference and hearing the various parties to the proceeding, the CCI is required to give its opinion within 60 days. Thus, TRAI can make a reference to CCI on issues of competition.

Formal and informal coordination mechanisms between TRAI and CCI has been suggested as another way to reduce conflicts (TERI, 2002). In UK, a concurrency working party coordinates the application of the competition law by various sector-specific regulators. In Germany, coordination between the competition authority (Federal Cartel Office) and the telecommunications regulator (Reg TP) is required for certain cases which are specified in the Telecommunications Act. Similarly, in Portugal, while determining which entities have significant market power, the regulator is required to seek the opinion of the competition authority. Other countries such as Denmark, Sweden,

Mexico, Spain, Netherlands, and Canada have consultations between regulators and the Competition Authority.

# Level of Competition in the Telecommunications Sector

Earlier in Chapter 2, which gives an overview of the section, we had shown how it has grown from the year 2000 to 2004 (see Table 2.1). The total subscriber base has grown at an average rate of 28 percent per year over this period taking the teledensity from 2.81% in 2000 to 7.04% in 2004. By any standard this growth has been phenomenal, and the opening up of the sector to private participation and competition has been the main reason for it.

Now, tariffs are determined by the market for all services (basic, mobile, NLD, and ILD), except fixed line service in rural areas. Mobile service is seeing vigorous competition with dramatic decreases in tariffs. Refer back to Table 2.1, we see that the revenue per minute (RPM) for blended mobile service has decreased from Rs 6.70 in 2000 to just Rs 1.55 in 2004.

For fixed service, BSNL and MTNL are the main players. As mentioned in Chapter 2, there are five private players but they together have only 9 percent of the share of the fixed service market. Even though the tariffs for fixed line service is not regulated, for social and political reasons BSNL and MTNL are not able to raise the tariffs. It is felt that raising rentals for fixed line service would make it unaffordable for some sections of the population. Consequently, there is a deficit in the revenues of the FSPs and this deficit is paid for by the access deficit charge (ADC).

# **Competition Issues Yet to be Addressed**

# Frequency Spectrum<sup>3</sup>

The tremendous growth in teledensity that has occurred in the last few years has been fuelled by mobile telephony. Over the

<sup>3.</sup> This section is based on the Consultation Paper on Spectrum Related Issues by TRAI, 31st May 2004.

four year period 2000-04, the cumulative average growth rate (CAGR) for mobile phones has been 105%. About 2 million mobile phone customers are being added every month. This tremendous growth in wireless communications has put pressure on a limited resource – frequency spectrum. The mobile service providers (MSPs) were initially allocated 4.4 + 4.4 MHz with a possibility of increasing it to 6.2 + 6.2 MHz, respectively. Most of the MSPs today have 6.2+6.2 MHz, while some have been allocated upto 10+10MHz based on their subscriber base.

NTP 1999 had noted that with the proliferation of new technologies and the growing demand for telecommunication services, the demand for the spectrum has also grown manifold. This situation has highlighted the need for using the spectrum efficiently and economically. It said that there "...was a need for a transparent process of allocation of frequency spectrum for use by a service and making it available to various users under specific conditions."

NTP 1999 also mentioned the need for relocation of existing spectrum and associated compensation to existing users. It stated that certain frequency bands had historically been assigned to the defence services and others and that efforts would have to be made to relocate the existing users so as to have optimal utilization of the spectrum.

The move to examine utilization and pricing of the spectrum is also connected with the introduction of a unified licensing regime where spectrum allocation policy will be separate from the licensing of services. For all these reasons, GoI has sought TRAI's recommendations on the following issues: (i) efficient utilization of spectrum; (ii) spectrum allocation procedures; and (iii) spectrum pricing.

Consequently, TRAI has initiated an investigation into the matter and issued a consultation paper on spectrum related issues

on May 31, 2004. The consultation paper covers the following issues:

- Current spectrum availability and requirement;
- Technical efficiency of spectrum utilization including some basics of technical efficiency and the efficiency of various technologies, and international benchmarks of spectral efficiency;
- Need for a review of the various methods for pricing frequency spectrum;
- Development of a spectrum allocation procedure based on the information on technical requirements and efficiency, and pricing.
- Techniques for making more spectrum available, such as re-farming, spectrum trading, mergers and acquisitions, and surrender of spectrum.

# Long Distance Carrier Selection by Subscribers

Currently, subscribers in India can only select their access provider. They cannot select an NLDO or ILDO. Instead, the access provider enters into contracts with NLDO(s) or ILDO(s) to carry the calls of all his subscribers to their destinations. While this system has led to some competition and price-cutting among NLDOs and ILDOs, competition will really heat up once customers can directly select an NLDO and ILDO. The competitive pressure to provide attractive long distance packages is expected to result in significant gains for the consumers.

On December 14, 2001, TRAI released a Consultation Paper Issues Relating to Interconnection between Access Providers and National Long Distance Operators. In that paper, it discussed issues related to allowing subscribers to select their long distance operator. Specifically, TRAI looked at allowing carrier selection with "equal ease of access." TRAI noted that for healthy competition to flourish, subscribers should be able to access the services of new entrants as easily as they can access those of the incumbent operators. TRAI reasoned that without comparable ease

of access, new entrants would find it difficult to attract customers. It gave the example of the US and Canada where customers found it inconvenient to use a competitive operator's services because they had to dial more digits than they would have to if they were using the incumbent's network.

There were two approaches to providing equal access that TRAI considered – call by call carrier selection, and operator preselection. In call-by-call carrier selection, customers select the operator of their choice for each call by dialling a short code or a prefix unique to the selected operator. TRAI noted that this type of equal access required three conditions: (i) a numbering plan that allocated available numbers between the operators including the incumbent; (ii) rules requiring that new entrants have access to signalling services including calling line identification, databases, and answer and disconnect supervision functions; and (iii) billing and auditing arrangements so that each operator could bill customers directly or have another operator or a third party billing agent bill the customers.

In operator pre-selection, customers can pre-select a carrier for some or all their calls. Under pre-selection, all long distance calls would automatically be routed through the chosen carrier. TRAI determined that the major requirements for this type of equal access were: (i) switch software features that would identify each customer's pre-selected carrier and route and bill all calls accordingly; and (ii) billing and auditing arrangements that allowed direct billing by the pre-selected carrier or consolidated billing by the local access provider who may bill the subscriber and then remit payments for the long distance calls to the pre-selected long distance carrier.

TRAI recognized that introduction of these methods of carrier selection could involve significant upgradation costs. These were future costs and there were questions about how these costs should be determined. Even more important was the question of

who should bear the cost of upgradation of the incumbent's network. In case NLDOs were to bear the upgradation costs, how should the costs be divided between the various providers? And, if a new operator joins at a later date, what will be his share of the costs?

An industry-wide working group was set up to look into these issues. However, it is unlikely that carrier selection will be implemented during the year 2004.

# **Accounting Separation**

TRAI recognized that for it to effectively regulate the telecommunications sector, it needed an accounting system that would generate statements for regulatory and management purposes. Specifically, a system was needed that would allow analysis of costs, revenues and capital used in major areas of an operator's business. In fact, during the tariff rebalancing exercise started in 1999 (which we discuss in Chapter 9) and in subsequent efforts at establishing cost-based tariffs, TRAI found itself handicapped by the lack of information required. The more common financial reporting systems used by corporations present aggregate information. More detailed and disaggregated information is needed for carrying out regulatory functions such as:

- Measuring financial performance of products;
- Monitoring return on products and services regulated with price ceilings;
- Identifying and investigating cross-subsidizing, predatory pricing, discrimination and other anticompetitive conduct;
- Understanding inter-operator arrangements in terms of price and cost, and
- Monitoring adequacy of access deficit charges paid by the operators.

In order to formulate the system on accounting separation (SAS), TRAI issued a consultation paper *Accounting Separation* 

and Formats for Accounting/Regulatory Statements in May 2000 and received comments from stakeholders. This was followed by a draft manual that was then presented to the service providers for their comments.

The comments were incorporated and TRAI developed the *Guidelines on System for Accounting Separation*. In the meantime, the Department of Company Affairs (DCA) had decided that the telecommunications sector was to come not under services but under manufacturing. This required that accounts had to be maintained by product. DCA and TRAI had mutual consultations and DCA issued an order on October 8, 2002 on how accounts were to be maintained by telecommunication companies. The DCA rules were very similar to the TRAI guidelines with the main difference being that they did not specify the level of disaggregation that TRAI's guidelines did.

Subsequently, TRAI issued its Guidelines in December 2002. The guidelines are applicable to all companies which provide any of the following services:

- Basic telephone service: fixed line telephone service; and limited mobility phone service
- National Long Distance
- International Long Distance
- Cellular Mobile Telephone service
- VSAT service
- Radio Paging service
- Public Mobile Radio Trunk Service (PMRTS)
- Global Mobile Personal Communication Service
- Internet Service

The accounts are to be separated in the following manner:

- *Type of service:* To be able to evaluate the financial performance for each service separately and to identify cross-subsidization between services.
- *Geographical area:* To be able to compare results in different circles.

- *Product/Network service:* This is for a service within a service which is priced or regulated separately. This separation will allow transparency of costs.
- Network Cost: This was done so that the costs of network elements are unbundled. Such an unbundling helps in evaluating interconnection agreements and also for determining cost-based tariffs.

The reports are to be filed annually and are to consist of statements providing the following information:

- Profit and loss for a geographical area
- Product/Network service-wise profit/loss
- Network element-wise total cost and cost per unit of usage
- Allocation of network cost (network element-wise) to various products/network services
- Total network cost allocated to various products/ network services
- Capital employed in a geographical area
- Allocation of capital employed to various network elements
- Category-wise fixed assets and depreciation
- Category-wise fixed assets and depreciation for each network element
- Category-wise fixed assets and depreciation for other profit centres and cost centres
- Reconciliation of service-wise profit and loss account with company's profit and loss account
- Non-financial information relating to tariff, revenue, network, traffic, etc.

The conventional costing method is historical cost accounting where assets are valued at the price at which they were bought less depreciation. However, in telecommunications, where costs are declining rapidly and where forward looking costs are often used, current cost accounting method (CCA) is considered more relevant

for analyzing costs and revenues. But use of CCA would be difficult because of the revaluation to be done in respect of old assets. Therefore, TRAI said that initially the statements for system for accounting separation (SAS) would be prepared using historical cost accounting but operators should start preparing their systems to move to CCA within two years.

BSNL and MTNL said that their accounts had not been maintained by product or service and, therefore, it would be difficult for them to redo their accounts according to the Guidelines. Methods were suggested to BSNL and MTNL on how to convert their accounts as per the Guidelines.

In the Guidelines, TRAI noted that each operator would have to prepare an operator-specific accounting separation manual (OASM). The OASM would contain comprehensive and complete documentation of policies, principles, methodologies, and procedures for accounting and cost allocation. On February 23, 2004 TRAI issued a notification requiring every service provider in almost any telecommunications service overseen by it to submit an OASM by July 15, 2004. Now TRAI has directed the operators to provide filled out formats based on the OASMs by September 30, 2004. BSNL and MTNL have expressed difficulty in preparing the filled out formats and have requested for more time.

# Mergers and Acquisitions (M&As)

As competition matures in the Indian telecommunications sector and as private companies grow, M&As are likely to increase because companies see this as a way to expand their business or as a way to capitalize on synergies with other companies. In its recommendations on unified licensing for access services, TRAI stated that "...a sustainable market structure should be allowed to consolidate so as to achieve higher growth through efficient utilization of resources. Hence intra-circle Mergers and Acquisitions should be permitted subject to guidelines on Mergers & Acquisitions."

In keeping with international practice, in its recommendations to DoT on intra-circle M&As, TRAI has recommended that strict quantitative criteria for approving or disapproving M&As may not be laid down and instead these cases be examined on a case-by-case basis. Accordingly, instead of strict quantitative criteria for approving M&As, TRAI has provided broad guidelines for examination of M&A cases in the Indian telecommunications industry.

TRAI recommends that in defining the market for examining M&As, the access segment be treated as two different markets – fixed and mobile service. TRAI gives two reasons for this. One, because of the very large share of BSNL/MTNL in most circles, most circles would be seen as dominated by a single player even without an M&A and this would render the guidelines irrelevant. Two, mobile phone service was the driver for the "immense growth and greater affordability of access service." An operator that was dominant in the mobile service but not in the aggregated access market could still affect competition in the mobile market. This is because mobile and fixed phones are not perfect substitutes for one another as the profiles and requirements of the users of the two services are different.

TRAI has recommended the following guidelines in evaluating an M&A:

- (i) A merger should not be allowed if as a consequence of the merger, the number of operators in any circle falls below three.
- (ii) A proposed M&A should be examined in detail if it meets the following two criteria:
  - (a) The market share of the merged company exceeds 50%, and
  - (b) Concentration ratio of the top two firms (CR2) after the merger is greater than or equal to 75%.

- (iii) M&As should be considered for approval in case one of the parties to the M&A is a failing firm and if it meets the following criteria:
  - (a) The failing firm would have to exit the market in the near future without the merger;
  - (b) There should be no alternative of restructuring the business without the merger;
  - (c) The parties to the M&A would have the burden of proof that the M&A will substantially improve the prospects of the firm and ward off failure.
- (iv) The spectrum of the merged companies should be merged subject to the following limits per operator: 15 MHz for Metros and Category A circles; 12.4 MHz for Category B and C circles.

As we outlined in the earlier part of this chapter, TRAI recommends that the merger be evaluated to determine if there would be "substantial lessening of competition" as a result of the merger.

# Interconnection

In a multi-operator environment, interconnection is a key requirement for an efficient and effective telecommunications sector. In the extreme case, if no operator wanted to interconnect with any other operator, one would only be able to communicate with those who were getting service from the same operator. In addition, each operator would have to build his own network resulting in gross over-capacity and underutilization of resources. While things are not quite as bleak as this extreme case, lack of effective interconnection remains a major stumbling block for the telecommunications sector in many countries. Incumbent operators having large networks with wide coverage would not like to make things easy for the new entrants. Since most of the bargaining power is with these incumbents, there are many ways in which they can stymie effective competition – by charging excessive amounts for interconnection; by refusing to build or make available adequate interconnection capacity; and by refusing to unbundle network elements required for efficient interconnection. Therefore, ensuring adequate and good quality interconnection must remain a top priority for telecommunications regulators in order to have effective competition.

Part I of this chapter explains the basics of interconnection. Based on the experience of other countries that have opened their telecommunications sector to private participation and competition, it describes the issues that need to be addressed in developing an effective interconnection regime. It then describes the various procedures for developing interconnection agreements and their relative advantages and disadvantages. Next, it covers what goes into an interconnection agreement and describes the financial, technical and operational terms of interconnection.

Part II of the chapter looks at the status of interconnection in India and describes the efforts that have been made to develop an effective interconnection regime and the problems that remain to be solved.

### Part I: Basics of Interconnection<sup>1</sup>

#### **Definition of Interconnection**

What do we mean by interconnection? Interconnection is the physical and logical linking of public electronic communications networks to allow users in one network to communicate with users in another network or to access services provided by another network. When we refer to "services provided by another network," this covers many items including: network elements and associated facilities and services; physical infrastructure including buildings, ducts, and masts; software systems; number translation systems; and mobile networks, particularly for roaming.

# **Interconnection Issues**

Cost of interconnection is the most important issue for new entrants. However, there are other issues that also need to be considered and these fall into three categories: (i) procedural issues; (ii) commercial issues; and (iii) technical and operational issues.

*Procedural issues include:* regulatory guidance for interconnection negotiations; access to standard interconnection terms with incumbent operator; dispute resolution mechanisms; non-discriminatory access to interconnection facilities and services; and treatment of universal service and access deficit charges.

Commercial issues include: level and structure of charges and the basis for their calculation; unbundling of interconnection charges for different network components and related services.

<sup>1.</sup> The coverage of the basics of interconnection is based on the discussion on interconnection in Module 3 of the Telecommunications Regulation Handbook, edited by Hank Intven and published by the World Bank.

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Technical and operational issues include: location of points of interconnection (POI); access to signalling systems, billing systems, operations support systems (OSS), call related databases and other software to provide advanced services; collocation and sharing of infrastructure; and quality of interconnection and availability of sufficient interconnection capacity to avoid congestion.

# **Interconnection Principles**

What constitutes a good interconnection regime? The following list gives some of the features of good interconnection regimes:

- Charges for interconnection should be based on costs;
- Terms for interconnection should be non-discriminatory;
- Process for obtaining interconnection should be transparent;
- Obligations to interconnect should be focused on the incumbent operator; and
- Regulators should be proactive and should set regulatory guidelines in advance.

# **Interconnection Procedures**

We give below the various approaches combinations of which have been tried in different countries in order to work out interconnection agreements between operators:

- Prescribed interconnection arrangements from the regulators;
- Negotiation between operators;
- Establishment of general regulatory guidelines for operators to negotiate;
- Regulatory prescription (ex-ante) of default interconnection arrangements that will apply if negotiations fail;

- Interconnection disputes resolved by regulators;
- Independent arbitration or mediation of interconnection disputes; and
- Regulatory review, modifications and approval of negotiated agreements.

Many countries started developing interconnection agreements based on negotiations between operators. However, these efforts have mostly been failures. The reason is that the incumbents who hold most of the bargaining power in the negotiations have very little incentive to complete an interconnection agreement. Many incumbents feel that interconnection allows new entrants access to their networks at subsidized rates. Moreover, interconnection results in a loss of the market share for the incumbent.

So, most experts in the sector now believe that ex-ante guidance by the regulators is necessary to achieve effective interconnection agreements. Nowadays, this job of developing guidelines has become easier for the regulators because of the experience accumulated by other regulators and the availability of published guidelines already developed.

Regulators can also set default interconnection arrangements in advance of negotiations. Because guidelines are fairly general, there are disputes in interpretation. Default interconnection arrangements cut short these disputes. In addition, the establishment of technical working groups with representation of all the operators and other stakeholders in the industry may help in hammering out the details of interconnection arrangements.

#### **Financial Terms of Interconnection**

Interconnection charges form a very significant portion of an operator's costs. Therefore, careful attention needs to be paid to the manner in which these charges are calculated.

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# Approaches to Determining Interconnection Charges

Various approaches have been used to calculate interconnection charges. These include: forward-looking incremental costs; historical accounting costs; sender keep all (also known as bill and keep); revenue sharing; charges based on retail prices; and negotiated rates.

Most regulators and experts believe that forward-looking incremental costs are the ideal approach for calculating interconnection charges. This approach provides an estimate of the costs to an operator in a fully competitive market. The bill and keep approach is most appropriate where two operators exchange nearly the same amount of traffic.

# Components of Interconnection Charges

There are three components of interconnection charges:

- Start-Up Costs: These are costs for the modifications to the interconnection provider's switching and transmission facilities and associated software to permit connection with multiple operators.
- Interconnection Links Costs: These are the costs of the physical links that are required between the networks of the interconnecting operators. These also include the rental charge for use of ports by the operator seeking interconnection.
- Usage Charges: These charges are for the use of network elements of one party by the other party for carriage of traffic. Usage charges are usually based on the time of usage in minutes.

Generally, the start-up costs and the interconnecting link costs are borne by the party seeking interconnection. TRAI also follows this approach. However, some regulators believe that these start-up costs are due to the introduction of competition which benefits all consumers and so they apportion the costs between

various operators and these costs are ultimately passed on to the consumers.

# **Technical and Operational Conditions**

While there are many technical and operational conditions that need to be considered in an interconnection agreement, we focus on two of them here: points of interconnection and quality of service.

# Points of Interconnection

The WTO Regulation Reference Paper<sup>2</sup> requires that interconnection be provided at any technically feasible point. Most countries follow this approach. The costs of interconnection incurred by the two operators depends on the points of interconnection (POIs). Incumbents sometimes propose standard POIs that are set out in the Reference Interconnection Offer (RIO). If a new entrant wishes to interconnect at a non-standard point then the Reference Paper says that interconnection should be provided but the interconnection seeker should pay the additional cost.

# Quality of Service

Attention needs to be paid to the quality of interconnection service provided by the incumbent to new entrants. Otherwise, the incumbent could hamper the development of a competitor's business by unusually long delays in providing interconnection when requested.

The WTO Reference Paper requires that interconnection services provided by the incumbent to a competitor should be no worse than the service that the incumbent provides itself. Such

<sup>2.</sup> The 1997 WTO Agreement on Basic Telecommunications was the first widely accepted multilateral trade agreement that included binding interconnection rules (Intven et al, 2000). The principles negotiated among WTO members were distilled in an informal text that came to be known as the Reference Paper. The Reference Paper is binding on WTO members that include it as part of their "additional commitments" in their GATS commitments on telecommunications market access. We refer to it here to give an idea of generally accepted principles regarding interconnection in telecommunications.

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non-discriminatory interconnection can be facilitated by the establishment of interconnection quality of service (QoS) measures. These measures should be such that they compare the incumbent's performance with international benchmarks and compare the provision of service to a competitor with the service provided by the incumbent to itself. Table 8.1 shows some QoS measures that can be used for such monitoring.

Table 8.1: Some Key Interconnection Quality of Service Measures

Provisioning measures	<ul> <li>Average time for provisioning interconnection circuits and other interconnection facilities and services (including unbundled components).</li> <li>Percentage of installation appointments met for competitors service installations.</li> <li>Average time for processing changes in customers from incumbent operator to competitor (in an equal access regime).</li> <li>Percentage of repair appointments met for competitors.</li> <li>Comparative provisioning performance for (i) competitors, (ii) affiliates, and (iii) self-provisioning (including measures such as those set out in the previous points).</li> </ul>
Switching and transmission quality measures	<ul> <li>Probability of blockage in peak hour on interconnecting circuits.</li> <li>Transmission delay.</li> <li>Transmission loss.</li> <li>Noise and distortion</li> <li>Other transmission quality standards.</li> </ul>

Source: Infodev, Telecommunications Regulation Handbook, 2000.

# Part II: The Status of Interconnection in the Indian Telecommunications Sector

The TRAI Act requires TRAI to "ensure technical compatibility and effective interconnection between the service providers." TRAI is empowered to "..fix the terms and conditions of inter-connectivity between the service providers." The Act also requires TRAI to maintain a register of interconnection agreements and keep them open for inspection by the general public.

TRAI's initial approach to developing interconnection agreements was to rely on negotiations between the operators and to step in only when there was a dispute. In its May 28, 1999 Interconnection Regulation, TRAI enunciated certain principles that were to be followed, such as: charges were to be based on costs; there was to be no discrimination between operators, etc.

Referring to the process for developing interconnection agreements, it said that "...if interconnection facility cannot be provided in the form that is sought or required by the interconnection seeker, the issue may be decided between the seeker and provider of interconnection. In case such mutual agreement is not possible, the matter may be reported to the Authority for a decision."

Similarly, TRAI forbore from setting interconnection charges, depending instead on negotiations between operators. It said: "Where mutual agreement for interconnection charge cannot be reached within three months of initiating such a process for charges with respect to which the Authority has forborne, the Authority may intervene to settle the matter *suo moto* or on the application of either party" (TRAI, 1999).

As was the experience in other countries, this approach was not successful and led to protracted negotiations and endless disputes (Sinha, 2002). Even after six years, the mobile service providers did not have a formal interconnection agreement with BSNL. The failure was attributed to a reluctance on the part of BSNL to reach an agreement.

# **Reference Interconnect Offer (RIO)**

In order to facilitate the successful completion of interconnection negotiations, in July 2002, TRAI issued a Reference Interconnect Offer (RIO) regulation along with guidelines. In the Explanatory Memorandum attached to the regulation, TRAI stated:

"Internationally, there is a growing consensus for formulation of advance regulatory guidelines for establishing proper environment to facilitate interconnection. ...Delay and disputes in the interconnection process hamper the growth and scuttle competition. With a view, therefore, to avoiding such incidences, a framework has been devised taking into consideration the practices followed in other countries as well as the situation in our country.

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An accepted Regulatory practice in many countries is to ensure that the service provider with significant market power publishes a Reference Interconnect Offer (RIO) stipulating the various technical and commercial conditions including a basis for interconnect usage charges for origination, transit and termination. Following these, the new entrants can seek interconnection and agree upon specific usage based charges".

The RIO regulation contained a model RIO giving the basic framework that had been prepared by TRAI in consultation with the service providers. Any service provider with significant market power (SMP) was required to publish within 90 days of the issuance of the regulation, a RIO based on the model RIO. The RIO was to be published after approval by TRAI. Any service provider having a share of 30% or more of the total activity in a licensed telecommunications service area was deemed to have SMP. These services were categorized as basic service, cellular mobile service, NLD service, and ILD service.

The published RIO was to form the basis of all interconnection agreements to be executed subsequently. Furthermore, the published RIO could be changed only with the prior approval of TRAI. Agreements between service providers were to be based on the published RIO; however, by mutual agreement the parties involved could modify the published agreement in order to arrive at an individualized agreement.

In response to the RIO order, BSNL filed an RIO. BSNL's proposed RIO allowed BSNL to disconnect a company if it defaulted on its interconnection charge payments (Intelecon, 2002). TRAI rejected this feature that BSNL had requested. In addition, TRAI asked BSNL to incorporate a clause making it mandatory for the incumbent to bill subscribers in case new operators did not want to do the billing. There were some other changes that TRAI wanted BSNL to make in its proposed RIO. BSNL protested and

appealed against TRAI's order to the Telecom Disputes Settlement and Appellate Tribunal (TDSAT) and the order was stayed. The issue has not yet been resolved and is still before TDSAT.

#### **Interconnection Issues**

There is considerable dissatisfaction with regard to the issue of interconnection. Mobile service operators say that they do not yet have a formal interconnection agreement with BSNL. The complaints regarding BSNL/MTNL's unwillingness to provide interconnection cover the following issues:

- BSNL and MTNL claim that they do not have the kind of interconnection capacity that is being requested. Furthermore, they point out that they need the money upfront and it will take them a year to provide the interconnection. As one MTNL official said, "We need network implementation of technology to be able to provide switches for interconnection; to implement across, say 5,000 exchanges is not an easy task; it needs an advance notice of at least one year. It is easy enough for private operators with the latest equipment to ask for changes overnight (cited in Raman, 2002)."
- Disputes arising over where calls will be handed over (see following subsection);
- New entrants claiming that BSNL is not making available the capacity that is being requested.
- New entrants asking TRAI to intervene because BSNL is threatening to cut-off their interconnection.
- Tariffs not being set appropriately. For example, earlier
  port charges had been set in a way which increased the
  demand considerably (This situation was, however,
  rectified by TRAI). Similarly, charges for leased lines
  were set arbitrarily. Now competition is used to arrive
  at an appropriate price.

Interconnection 111

# Number and Level of Interconnection

To give a flavour of the kind of disputes that arise, we now describe in some detail a dispute regarding points of interconnection between BSNL and the mobile service providers. Earlier TRAI had ordered BSNL to provide multiple POIs at every technically feasible location. As a result, the MSPs were requesting interconnection at the short distance charging area (SDCA) level. They argued that in the absence of multiple POIs, they would have to haul their calls to the Long Distance Charging Area (LDCA) level which would mean higher costs for them.

In response, BSNL argued that with 2647 SDCAs, it would become unmanageable to provide POIs at the SDCA level. They cited problems relating to the maintenance of accounting information and making technical arrangements. They further argued that this type of interconnection would violate the network hierarchy because MSP networks which cover large geographical areas should be interconnected only with the long distance network of the PSTN. BSNL also contended that MSPs could bypass the long distance network of the FSPs. On this basis, BSNL requested that the number of POIs be limited to 3-4 to a circle – Level I TAX and a few Level II TAXs.

Evaluating these conflicting requests, TRAI noted that it would probably be in the consumers' interest to allow multiple POIs. However, it would violate the network hierarchy and would be difficult to manage. Furthermore, multiple POIs would probably reduce the long distance revenue of the FSPs and thus ultimately result in higher Universal Service Obligations (USO) requirements.

Balancing the conflicting interests, TRAI decided that:

• In metro circles, the lowest level would be the level of the tandem exchanges (equivalent to short distance charging centre (SDCC));

• For the other circles, the calls would normally be handed over at the Level I TAX. However, for traffic terminating in the same LDCA, the MSP could request bypassing the Level I TAX and hand over the call at the Level II TAX. In addition, by mutual agreement, the POIs could be below the TAX level.

# TARIFFS, CROSS-SUBSIDIES, AND UNIVERSAL SERVICE OBLIGATION

Economic efficiency requires that customer charges for any service be based on the cost of providing that service. However, cost-based charges may make the service unaffordable for a section of the population. In addition, remote and/or backward regions of the country may not get the service at all if one relied on economics alone, because such areas are not economically attractive to service providers. Thus, there is a conflict between economic efficiency and ideas of fairness, equity, and universal service. This tussle between economics and equity is present in almost all countries, even rich countries like the US. The tussle is particularly problematic for poorer countries like India where there are large numbers of people who cannot afford cost-based rates and where necessary resources to provide subsidies are limited.

In this chapter, we discuss how the Indian telecommunications sector is balancing the conflicting requirements of economic efficiency and equity. We begin with a short history of tariff-setting in the telecommunications sector in India starting in the late 1990s. We describe the initial attempts at tariff rebalancing. We show how the opening up of NLD necessitated the introduction of an access deficit charge (ADC). We also explain how the use of a revenue share as a proxy for interconnection usage charge (IUC) gave way to cost-based IUC. Having reviewed tariff setting from the late 1990s to date, we describe a new proposal for collecting ADC. Finally, we spell out universal service obligations and how they are being implemented.

We have followed a historical approach to describing tariff setting in the Indian telecommunications sector for two reasons. First, it helps put issues of cross-subsidization and cost-based pricing in perspective. Second, the various charges – interconnection usage charge (IUC), access deficit charge (ADC), and retail tariffs for communications services – are intertwined, and it would have been difficult to treat them separately.

# **Tariff Setting for Retail Customers**

Before TRAI was established and given the authority to set tariffs in the sector, DoT was setting rates for telecommunication services. At that time, for socio-political reasons, rates for basic service were kept low and the resulting revenue deficit was made up by keeping long distance rates, both NLD and ILD, artificially high. Thus, basic service was being cross-subsidized by long distance service.

When the sector was opened to participation by private players, it was realized that in order to make the sector attractive to private capital, a competitive environment was necessary. Competition was also expected to bring about increases in efficiency. It was felt that prices had to be more closely aligned with costs in order to facilitate the transition to competition. It was argued that cost-based pricing would prepare service providers for competition; otherwise, there would have to be major adjustments in tariffs when competition did take place in the sector. Therefore, tariff rebalancing became a top priority for the first tariff setting exercise.

# First Phase of Tariff Rebalancing<sup>1</sup>

The first telecom tariff order (TTO 99) was passed in March 1999. For fixed services, the tariffs were specified in terms of standard packages that all providers were required to offer. FSPs and MSPs could offer alternative packages also. Users were categorized as rural and urban, and each category was further

<sup>1.</sup> The account of the three phases of the tariff rebalancing exercise is based mostly on the paper *A Review of Telecom Regulatory Authority of India's Tariff and Interconnection Regulation* by Rekha Jain in India Infrastructure Report 2004, Oxford University Press, 2004.

subdivided into low use, general, and commercial. As Table 9.1 shows, rentals for rural customers were lower than those for urban customers. Furthermore, rentals also depended on the capacity of the exchange to which a subscriber was connected. TTO 99 envisaged a phased rebalancing over a three-year period with rentals increasing and NLD and ILD rates decreasing to bring them nearer to costs in 3 phases over 3 years. It was hoped that the phasing would help cushion the impact of changes.

Table 9.1: Rates from TTO 1999 Rental rates (Rs. per month)

Customer category	Exchange capacity No. of lines	1999/ 2000	2000/01	2001/02	
Rural	•				
Low-use	≤999	70	70	70	
	1000-29999	120	120	120	
	30000-99999	180	180	180	
	100000-299999	250	250	250	
	≤300000	250	250	250	
General	≤999	70	95	120	
	1000-29999	120	140	160	
	30000-99999	180	200	220	
	100000-299999	250	280	310	
	≥300000	250	280	310	
Commercial	≤999	120	120	120	
	1000-29999	160	160	160	
	30000-99999	220	220	220	
	100000-299999	310	310	310	
	≥300000	310	310	310	
Urban	1	T	1	T	
Low use	≤100	120	120	120	
	100-999	120	120	120	
	1000-29999	120	120	120	
	30000-99999	180	180	180	
	100000-299999	250	250	250	
	≥300000	250	250	250	
General	≤100	120	140	160	
	100-999	120	140	160	
	1000-29999	120	140	160	
	30000-99999	180	200	220	
	100000-299999	250	280	310	
	≥300000	250	280	310	
Commercial	≤100	160	160	160	
	100-999	160	160	160	
	1000-29999	160	160	160	
	30000-99999	220	220	220	
	100000-299999	310	310	310	
	≥300000	310	310	310	

Per call charged (Rs. per 3-minute call)									
Customer category	Nun	nber of calls	1999/2000		2000/01		1	2001/02	
Rural		≤75	Free		Free			Free	
		76-150	0.80		0.80			0.80	
		151-250		0.80		0.80		0.80	
		251-450		0.80		0.80		0.80	
		451-500		0.80		0.80		0.80	
		501-1000		1.20		1.20		1.20	
		1001-2000 >2000		1.20 1.20		1.20 1.20		1.20 1.20	
Urban		≤60		Free		Free		Free	
		61-75		1.00		1.00		1.00	
		76-150		1.00		1.00		1.00	
		151-250		1.00		1.00		1.00	
		251-450		1.00		1.00		1.00	
		451-500		1.00		1.00		1.00	
		501-1000		1.20		1.20		1.20	
		1001-2000	1.20			1.20		1.20	
		>2000		1.20 1.20		1.20			
	•	per 3-minute c	all)					T	
	Type o			1999/2000		2000/01		2001/02	
Monthly rental				600		600	)	600	
		s (Rs per minute		6 6				6	
<b>STD charges</b> calls per month		er 1-minute call	<b>)</b> (for (	customers w	<i>i</i> ith	more tha	ın 200	0 metered	
Distance (l	km)	1999/2000		2000/01		1	2001/02		
0-20		1.2		1.2			1.2		
21-35	21-35		1.2		1.2		1.2		
36-50		1.2		1.2		1.2			
51-100		6.0		6.0		4.8			
101-200		6.0		6.0		4.8			
201-500		15.6		12.0		10.8			
501-1000 21.6			18.0				16.8		
>1000 30.0  International calls (Rs per minute)			- 1 / (	25.2			II	21.6	
calls)	calls	(Ks per minut	<b>e)</b> (to	r customers	s w	ith more	than	2000 metered	
		countries		1999/200	0 2000		/01	2001/02	
SAARC and neighbouring countries				30.00		25.20		21.60	
Africa, Europe, Gulf, Asia, and Oceania			ia	49.20		40.80		32.40	
American continents				61.20		49.20		40.80	

Source: TRAI, Telecommunication Tariff Order, 1999.

Differentiation between low-use and general consumers were based on usage in terms of measured call units (MCUs). Low-use customers were those that made fewer than 500 MCUs per month and general customers were those who made more than 500 MCUs per month. Call charges varied with usage. For rural customers, for

upto 500 MCUs the charge was Rs 0.80 per call; additional MCUs were charged at Rs 1.00 per call. For urban users, the corresponding charges were slightly higher: Rs 1.00 and Rs 1.20 per call. Rural and urban consumers got 75 and 60 calls free, respectively.

TTO 99 provided for change in rentals every year for three years for the general category only. For STD and ILD calls, there was a different pulse rate for different distance slabs. These were expected to be reduced over the three-year period. For cellular mobile phone service, TTO 99 gave cost-based rentals of Rs 600 per month and air time tariffs of Rs 6 per minute.

# Second Phase of Tariff Rebalancing

During the review for the second phase of tariff rebalancing, DoT (now BSNL) claimed that its long distance revenues were reduced by Rs 2000-2200 crore due to rebalancing. However, TRAI estimated that of this amount revenue loss of Rs 1200 crore was caused by BSNL's decision to charge a lower rental to some customers through an alternative tariff instead of the standard tariff. TRAI's estimate of the revenue loss due to rebalancing was only about Rs 250 crore.

TRAI decided to go ahead with the second phase of rebalancing but with two changes. First, the second phase was to continue until March 31, 2002 instead of March 31, 2001. TRAI reasoned that the longer time period would allow the effects of elasticity of demand to be felt and would also allow BSNL more time to make structural changes. Second, TRAI decided not to increase the rentals for the general category as originally envisaged. According to TRAI, the loss on this account was small (Rs 200-220 crore) compared to BSNL's total revenues and could be made up by improvements in efficiency. TRAI also did not want to increase rentals because it wanted to increase teledensity and also because it had found that the costs of telecommunications equipment were declining.

# Third Phase of Rebalancing

In the third phase of rebalancing, through an order dated March 14, 2002 TRAI decided to combine the categories of low-use customer and general customer into a single category of non-commercial customer. Also because a detailed tariff review was in progress, TRAI decided to maintain the existing level of tariffs for all customers except for commercial customers for whom it implemented the tariffs as per the earlier order. TRAI also lowered the number of free calls to 30 MCUs for urban commercial customers and 45 MCUs for rural commercial customers. The NLD and ILD rates were already lower than those specified in the third tranche of rates in TTO 99. So, TRAI notified the third tranche of tariffs for NLD and ILD as ceilings.

# Tariff Order of January 24, 2003 (TTO 2003)

During the year 2002, TRAI undertook a detailed review of the tariffs for basic service. Based on the review and the associated consultation process, it issued a tariff order on January 24, 2003 (TTO 2003). Noting the sharp declines in the NLD and ILD prices after long distance was opened up to competition, and the consequent loss of a source of cross-subsidy, TRAI stated that there was a need for two types of policy changes. One, there was a need to increase the below cost prices to some extent. Two, it was necessary to have an access deficit charge to make up for the loss of the source of cross-subsidy.

Regarding increases in tariffs for below-cost items, TRAI reasoned that using increased rentals to cover ADC would not be a good strategy for two reasons. First, raising rentals would have a relatively low impact on the ADC. According to TRAI, an average increase in rentals of Rs 4.50 per month is equivalent to a general increase in call charge of 1 paise per minute. Second, raising rentals would adversely affect the demand<sup>2</sup> for phone

<sup>2.</sup> This assertion by TRAI is based on two studies done by NCAER for TRAI titled "Telephone Study, 2002" and "Affordability of Telephone Services, 2002."

connections and would make it difficult to achieve the teledensity targets set out in NTP 1999. Therefore, TRAI argued that some increases in local and short distance call charges would be necessary and the remaining ADC would be recovered from long distance calls.

TRAI decided not to increase the monthly rentals for exchange capacities upto 29,999 lines and to increase minimally the rental for higher capacity exchanges. Most of the rural subscribers were in the category for which rentals had not been increased. This was done in order not to affect the growth rate of rural teledensity which is already low.

There were conflicting concerns regarding raising local call charges. Balancing the various concerns, TRAI decided not to change the existing call charge and instead to alter the pulse duration, the free call limit, and the threshold above which the call charge of Rs 1.20 applies. Specifically, TRAI made the following changes:

- No change in the charge for initial calls at Rs 0.80 and Rs 1.00 for the first 300 pulses rather than the first 500 pulses and Rs 1.20 after that limit.
- Pulse duration was to be 120 seconds because a predominant portion of the calls is less than two minutes long.

The number of free calls was also changed. For rural customers, the number of free calls was now 50 per month instead of 75 and for urban customers it was 30 instead of 60. For sociopolitical reasons, BSNL did not implement the changes in call rates.

As mentioned earlier, TRAI had said that two policy changes were necessary. We have covered one regarding some tariff increases. The second issue of recovery of the access deficit was addressed in an Interconnection Usage Charge (IUC) Regulation

also issued on January 24, 2003. We cover IUC and ADC in more detail in the next section.

# Tariffs for Mobile Phone Service

So far we have mostly discussed tariffs for basic service. In 2002, TRAI also undertook a detailed review of tariffs for mobile phone service. The focus of the review and the associated consultative process was on determining whether there was a need to regulate the mobile service market or whether reliance on the market would be sufficient. TRAI noted that there had been increased competition in the market with a higher growth in the number of pre-paid subscribers compared to post-paid subscribers. It expected that the trend towards greater competition and lower tariffs would become more pronounced with the entry of the third operator (BSNL) and a private operator as the fourth. Furthermore, TRAI reasoned that the newer entrants would come in with lower costs (because of declining costs in telecommunications) and would focus on acquiring a substantial subscriber base which would exert further downward pressure on the rates. Based on these considerations, TRAI decided to forbear from setting rates and let the market determine tariffs. Tariffs for roaming were to continue to be regulated.

# Interconnection Usage Charge (IUC) and Access Deficit Charge (ADC)

The first IUC Regulation issued by TRAI in May 1999 outlined IUC based on revenue sharing. FSPs were required to pay Rs.0.48 per measured call unit (MCU) to the transit and terminating carrier which was BSNL (erstwhile DoT). The MSPs were required to pay Rs.1.20 per MCU to BSNL.

At the time, TRAI stated that the revenue sharing arrangements were interim, and were not based on detailed cost analysis. It said that the application of an access/carriage charge regime would provide more logically tenable usage charges, but that required a detailed assessment of the underlying costs.

On January 24, 2003, TRAI issued an IUC Regulation whereby the charges were developed from an assessment of the various cost items attributable to the different network elements involved in setting up a call in a multi-operator environment. In that regulation, TRAI noted two things: (i) with the opening up of the NLD and ILD markets to competition, there had been a significant reduction in long distance tariffs. This had drastically reduced the margin available to fund the deficit caused by below-cost rentals for basic service; and (ii) in a multi-operator environment it is important to specify an IUC regime that gives greater certainty to inter-operator settlements and facilitates interconnection agreements.

Regulation listed cost-based origination and termination charges for various kinds of calls. However, there were several problems linked with these charges. There were three major reasons for these problems: One, in the Regulation, the amount of ADC calculated was large (Rs. 13,000 crore per year or about 30% of the annual revenues of the sector). Two, ADC was to be collected from calls involving fixed line subscribers either at one end or both ends. As TRAI noted, "This meant that the IUC/ADC charges differed widely for calls from and to fixed line, cellular mobile and wireless in local loop with limited mobility (WLL(M)) (TRAI Regs, 2003)." Three, two kinds of ADC regimes were specified – one with uniform ADC, and the other with ADC increasing with distance.

It was soon found that the IUC charges based on the Regulation led to major problems in implementation and the sustainability of the IUC and ADC regime became questionable. Therefore, TRAI initiated another review of the IUC and ADC charges and released another IUC Regulation on October 29, 2003. The new Regulation resolved the problems encountered in the implementation of the previous Regulation. Specifically, the following changes were brought about:

• Using more recent financial and traffic data and by accounting for concessions and compensation from the

Government to BSNL, TRAI revised the access deficit to be only Rs. 5,340 crore. While still large, this deficit was considered to be manageable.

- The same termination charge (Rs 0.30 per minute) to be paid for all calls to access providers fixed line, mobile, WLL (M). This has simplified the IUC regime and is likely to prevent disputes in reconciliation between operators.
- Only one type of ADC has been specified.

Tables 9.2 and 9.3 show the carriage charges and ADC charges to be paid by operators. These are the IUC and ADC charges prevailing currently.

Table 9.2: Carriage Charges for Long Distance Calls within India (Amount in Rs. per minute)

Carriage charges per minute for long distance calls within India	Distance slab				
	Below 50 km	50-200 km	200-500 km	Above 500 km	
	0.20	0.65	0.90	1.10	

Table 9.3: Access Deficit Charge Applicable to Various Types of Calls
(In Rs per minute)

Access deficit		Intra-circle calls		Inter-circle calls			
charges	Local	0-50 km	>50 km	0-50 km	50-200 km	>200 km	ILD
Fixed – Fixed	0.00	0.00	0.30	0.30	0.50	0.80	
Fixed – WLL(M)	0.30	0.30	0.30	0.30	0.50	0.80	4.25
Fixed – Cellular	0.30	0.30	0.30	0.30	0.50	0.80	
WLL(M) - Fixed	0.30	0.30	0.30	0.30	0.50	0.80	
WLL(M) - WLL(M)	0.00	0.00	0.00	0.30	0.50	0.80	4.25
WLL(M) - Cellular	0.00	0.00	0.00	0.30	0.50	0.80	
Cellular - Fixed	0.30	0.30	0.30	0.30	0.50	0.80	
Cellular – WLL(M)	0.00	0.00	0.00	0.30	0.50	0.80	4.25
Cellular – Cellular	0.00	0.00	0.00	0.30	0.50	0.80	

Source: TRAI, the Telecommunication Interconnection Usage Charges (TUC) Regulation, October 29, 2003.

# New ADC Regime Being Contemplated<sup>3</sup>

However, there have been several problems in the application of the ADC regime described in the previous section. The underlying issue is that this regime requires comprehensive and accurate data and detailed calculations. TRAI states that there have been long delays in the provision of these data. There is also delay in the raising of bills on other operators and carriers. As TRAI noted, in the four months that had passed from the time the regime was introduced in February 2004 very few settlements had taken place. Most of the operators were yet to issue a bill to other operators and carriers.

Furthermore, the present regime has substantial variation of the ADC amounts varying from Rs 0.30 per minute to Rs 0.80 per minute for domestic calls, and Rs 4.25 per minute for international calls. This variation creates an incentive for an operator to misreport the category of calls. In addition, because some of the calls on which ADC is imposed do not involve fixed line subscribers, the verification of the information becomes difficult.

These problems are compounded because of the delay in the implementation of the call data records (CDR) based billing system by BSNL. The system was expected to be installed by June 2004. However, it now seems that it will take much longer and thus problems with reconciliation of data will continue.

In addition to the problems with data availability and reconciliation, there are technical problems with the current ADC regime. Because the ADC varies with distance and is different for intra-circle and inter-circle traffic, more circuit groups are required. This results in an inefficient use of resources. Besides, there is also more pressure on the inter-carrier billing system.

For all these reasons, TRAI began looking for a simpler method of collecting ADC which is not distance-based and

The discussion of ADC is based mostly on the Consultation Paper on Access Deficit Review brought out by TRAI, 23 June 2004.

call-based, and which would also be easier to verify. In its Consultation Paper on this issue, TRAI has proposed the use of a revenue share to collect ADC. It argues that such a system would not impose a different burden on different types of calls and thus the incentive for bypass will be reduced. It will also allow the service provider flexibility to collect revenue as it chooses rather than the current ADC scheme which brings about changes in the competitive field by imposing ADC charges only on certain types of calls. Furthermore, calculation will be much easier because the total revenue of each operator is already being calculated for determining licence fees.

Who should get the entire ADC that is collected? In the current ADC regime, all the FSPs collect a part of the ADC that is paid out by the other operators. In its Consultation Paper, TRAI proposes that BSNL should be the sole beneficiary of the new ADC regime. It gives the following reasons in support of its proposal:

- If there are multiple beneficiaries of a revenue share based ADC regime then some basis of allocation will have to be developed.
- Usually ADC is provided only to the incumbent.
- Because of the implementation of a unified access service licensing regime the roll-out obligations on FSPs have been reduced. So, they can choose to provide service in lucrative areas and do not incur much of an access deficit.
- New entrants are operating with modern networks with lower costs and therefore are less likely to incur access deficits.
- While MTNL is not a new entrant and does not have a modern network, it is providing service in lucrative metro markets. It has a substantially higher rental and, therefore, does not incur much of an access deficit.

• In any case, TRAI is considering phasing out the ADC regime in a few years and merging it with the universal service obligation (USO) regime.

# Amount of ADC to be Collected

In its Consultation Paper, TRAI has proposed that the new ADC regime be implemented in October 2004. The amount of the ADC is to be reviewed every year. So, in its Paper, TRAI has estimated the ADC required for the period from October 2004 to September 2005.

The ADC required is estimated by first calculating BSNL's expected capital expenditure for the year. Then the revenue generated from rentals is deducted from this expenditure. For this purpose, TRAI has used two estimates of the average rental – Rs156 and Rs 200 per month. Rs 156 was used in the previous ADC calculation by TRAI. However, TRAI notes that because of its forbearance from tariffs, rentals are likely to be higher. Therefore, it has proposed a rental of Rs 200 per month. The rental is then multiplied by the average subscriber base for the period. Based on this calculation, TRAI arrives at an ADC of Rs 6,190 crore and Rs 4,156 crore if the monthly rental is Rs 156 and Rs 200, respectively.

From the amount of ADC calculated so far, TRAI deducts Government compensation, local call surplus, and surplus from termination charge. The final amount for the access deficit is calculated to be Rs 3,436 crore and Rs 1,402 crore for the two values of rentals.

In order to arrive at a revenue share, TRAI estimates the expected revenues in the sector for the applicable period. This is done by multiplying the average ARPU by the projected subscriber base. TRAI estimates that the total revenue for the sector for the period October 2004 to September 2005 will be Rs 65,000 crore. Based on these calculations, TRAI estimates that the revenue share that will be required to collect the requisite amount of ADC will

be 5.3% if the average rental is Rs 156 per month and 2.2% if the average rental goes up to Rs 200 per month.

# Universal Service Obligation (USO)<sup>4</sup>

In NTP 1999, the Government declared that it was committed to providing access to all people for basic telecommunication services at affordable and reasonable prices. In addition, the Government had set three goals regarding universal service:

- (i) To provide by 2002, voice and low speed data service to the villages that were not yet covered by telecommunication services;
- (ii) To provide Internet access to all district headquarters by the year 2000; and
- (iii) To achieve telephone on demand in urban and rural areas by 2002.

The resources for meeting these universal service obligations (USO) were to be raised through a 'universal service levy' (USL) which would be collected as a percentage of the revenues of the providers of the telecommunications service providers. On the recommendations of TRAI, the Government has decided that 5% of the revenues will be used to cover the USL. In NTP 1999, the Government stated that the implementation of USO would be done by the FSPs who would be reimbursed from the USL. It further stated that other service providers would also be encouraged to participate in the fulfilment of USO obligations subject to technical limitations and would be reimbursed from the USL.

While there has been progress in providing access to telecommunications services, not all the villages have been covered by these services. Of the 607,491 villages in the country, 522,263 villages have village public telephones (VPTs). Almost all of these

<sup>4.</sup> This section is based on the *Guidelines for Implementation of Universal Service Support* given on the DoT website www.dotindia.com.

VPTs have been provided by BSNL. The performance of the private FSPs in fulfiling their roll-out obligations in rural areas has been abysmal with a total of only 12,581 VPTs in the entire country having been provided by all the five private operators together!

Because the universal service goals of NTP 1999 have not been met, DoT has extended the support for USO. In addition, instead of relying on roll-out obligations in the licences of FSPs, it has developed an alternative mechanism to accelerate the progress in meeting universal service goals.

The guidelines for implementing USO are based on three principles:

- Funds from the USL<sup>5</sup> shall be spent in rural and remote areas on (i) public access or community phones meant for public use; and (ii) individual household phones in rural and remote areas in high net cost areas, that is areas where the cost of providing phones is higher than the expected revenues.
- Funds from the USL shall be provided to meet the net cost (cost minus revenue) of providing universal service.
- The revenue share for USL may be increased if the USO requirements are higher than expected. However, the excess amount will be taken from the amount collected by the Government as licence fees. Therefore, the burden on service providers and ultimately the consumers will not increase.

### Implementation of USO

The DoT has divided USO into two streams: (i) provision of public telecommunications and information services; and (ii) provision of household phones in high net cost areas.

Receipts from the USL will be credited to a special fund – Universal Service Fund (USF) – which will be administered by DoT.

# Provision of Public Telecommunications and Information Services

In this stream of USO activities, the Government has included the following items:

Installation of VPTs in the uncovered villages: DoT has decided that for the 607,491 villages that were identified in the 1991 census and were required to be covered by the end of FY2002 according to NTP 1999, capital costs will not be covered by the universal service fund (USF). However, the net operating costs (costs minus revenues) will be reimbursed from the USF. For additional villages that were identified in the 2001 census, the net capital and net operating expenses will be reimbursed from the USF.

Provision of additional rural community phones: For villages that already have one VPT and have a population of more than 2000, a second phone will be covered. The second phone will be in a public place such as school, primary health centre, etc. In this case, net costs for capital recovery and operating expenses will be reimbursed.

Replacement of VPTs using MARR systems installed before April 1, 2002: Earlier a large number of VPTs using Multi Access Rural Radio (MARR) systems were installed but they have not worked. The replacement of such phones will be reimbursed from the USF. Here too net costs for capital recovery and operating expenses will be reimbursed.

Upgradation of VPTs to Public Telecom and Information Centres (PTICs): With the importance of data communications and the Internet increasing, the Government has decided to endeavour to provide data transmission facilities within 5 km of every village and at least in those villages where regular post offices are located. A PTIC will at the minimum consist of a PC, a modem, and a UPS. Both capital recovery costs and operational costs will be reimbursed from the USF for such upgradation of VPTs. The DoT

is to draw up a plan to upgrade about 35,000 VPTs to function as PTICs by the end of 2004.

Installation of High Speed PTICs (HPTICs): DoT would like to upgrade some VPTs to HPTICs by providing wideband applications, such as tele-education and tele-medicine using two basic channels to give data rates of 128 kbps. In the first phase, by the end of 2004, the plan is to install 2 HPTICs in each short distance charging area (SDCA). Both capital recovery costs and operational costs will be reimbursed from the USF.

Provision of Household phones in high net cost areas: DoT will draw up a list of SDCAs where on average the costs are higher than the revenues. The SDCAs on this list will be designated rural SDCAs. For phones installed in the rural SDCAs after April 1, 2002, both capital recovery and operating expenses will be reimbursed. However, when the SDCA becomes a revenue surplus area, i.e. net cost becomes zero or negative, the subsidy will be withdrawn.

Both streams of activities will proceed simultaneously, but the first stream regarding provision of public services will receive priority. Operational expenses support for household phones installed in high net cost areas before April 1, 2002 will be treated as stream I activity.

# Process for Implementing USO

As mentioned earlier, relying on roll-out obligations to cover USO has been a disaster, particularly as far as the private operators are concerned. In addition, such a measure has not proved to be economically efficient. Many countries have used an auction where bidders quote the amount of subsidy they will require and the winning bid is the one that quotes the lowest subsidy. DoT has now decided to switch to a similar system

The implementation of USO will now be done through a multi-layered bidding process where the bidding parameter will be the least quoted subsidy support. The first round of the bidding will involve the existing access providers (FSPs and MSPs) in the circle under consideration. If no bids are received from any of the FSPs or MSPs in the circle, or if the lowest bid is higher than the benchmark, then a second round of bidding will be called where all the FSPs and MSPs in the country including those in that particular circle will be invited to bid.

The winning bid will be the one with the lowest quoted required subsidy. No bid will be accepted that exceeds the benchmark determined by DoT. For calculating the benchmark subsidy amount, fully allocated current costs will be used with the most effective solution for that circle. Operating costs will be based on the costs of an efficient provider. If no bid below the benchmark is received, then there may be negotiations or another round of bidding.

Reimbursements from the USF will be made on the basis of actual physical performance. Money will be released only after the completion of targets and the necessary verification. Any shortfall in achievement of targets will invite liquidated damages.

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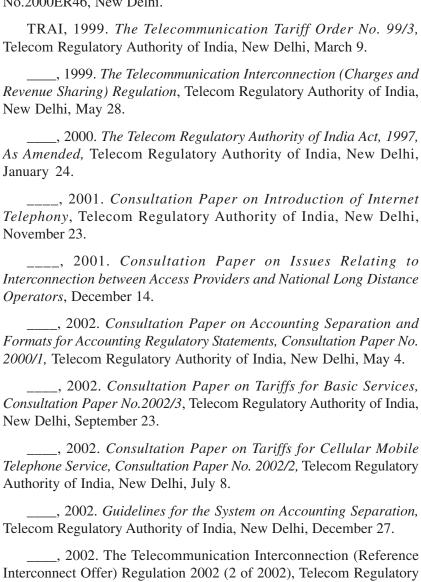
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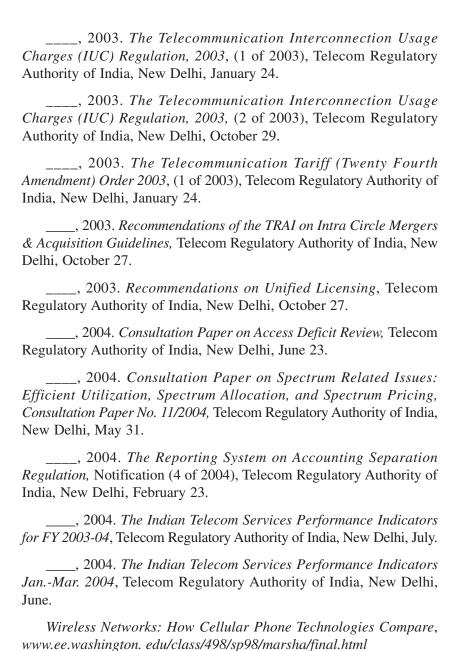
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