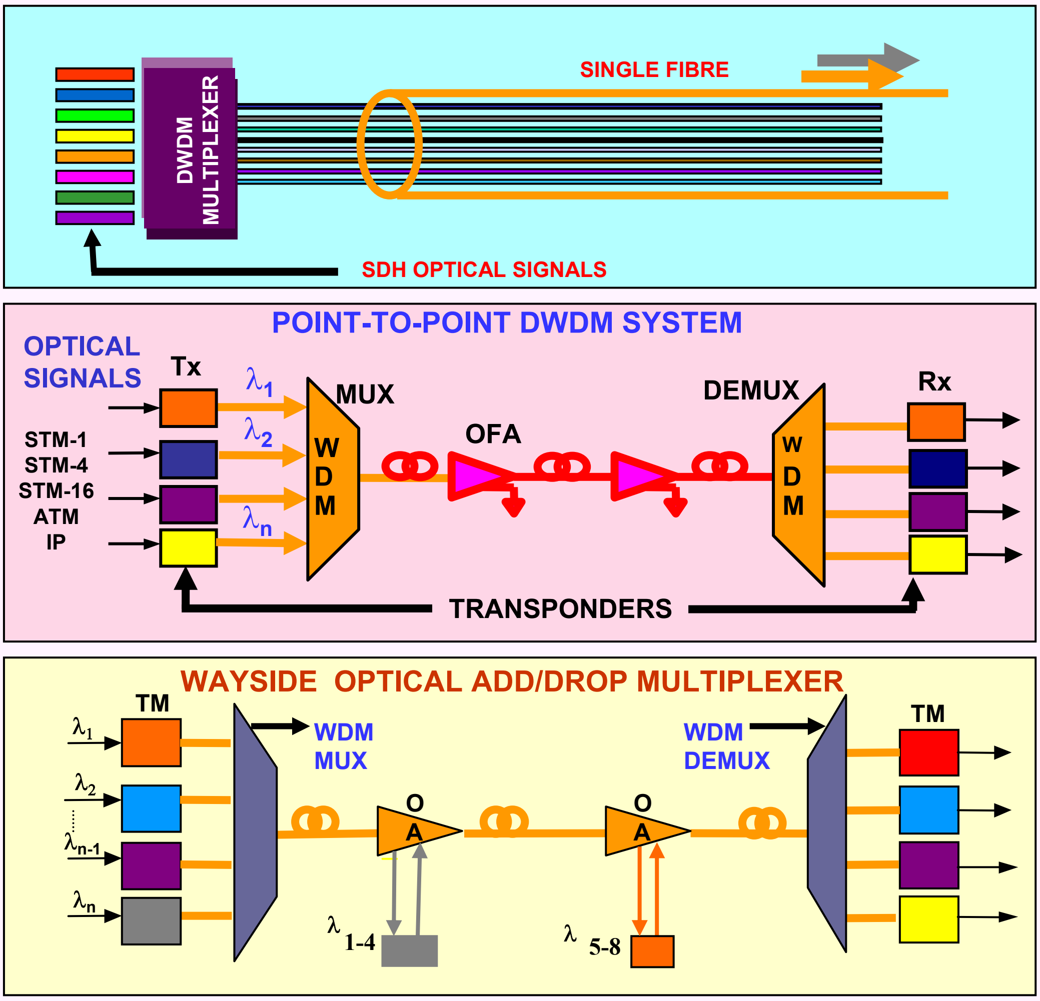
TEC
TELECOMMUNICATION ENGINEERING CENTRE

NEWSLETTER

VOL 6 APRIL 2002 ISSUE 2

DWDM



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DWDM TECHNOLOGY

The challenges of Today's Network

Dense Wavelength Division Multiplexing (DWDM) is a technology which multiplexes optical signals by assigning different optical wavelength to each incoming signal for simultaneous transmission of all of them over a single fibre.

The importance of DWDM & Optical Networking is better appreciated by under-standing the challenges faced by the Service Providers. The traditional telecommunication networks were designed to carry voice & voice band data. In Access Network, a bandwidth of 4 KHz for individual subscriber was the only requirement. The main bandwidth requirement was in the Core Network to interconnect the switches. The subscriber premises equipment had no built-in intelligence. All the intelligence/ protocols/ signalling were part of the Switch. The dimensioning of such voice network & future demands were fairly well predicted by statistical formulae. This scenario got severely distorted with ushering in of high speed Data Transportation. The final blow to traditional voice network came in the form of the Internet at 300 % growing rate. The new network has to take care of the traffic demands generated by World Wide Web (WWW) & related multi-media applications. It is not only the volume and speed of information, but the requirement to transfer the same content to millions of users from every corner of the globe simultaneously, has created the demand for increasing the bandwidth in the back-bone manifold. This implies that enormous bandwidth capacity is required to provide the services demanded by the customers. The customer equipment has become intelligent to the extent that many functions previously done by the switches/ core network are being handled by the Customer Premises Equipment. Thus the intelligence & bandwidth, once exclusively a core resource, is now equally distributed at the edge as well.

Such huge demands defied all forecasts and predictions. Network bandwidths started doubling every six months for most of the service providers. To cater to these demands of bandwidth, the installed fibre were rapidly lit with SDH equipment. Even the high capacity SDH systems like STM-16 or STM-64, requiring one pair of fibre per system could not fulfill the bandwidth demands. Faced with the multifaceted challenges of increased service needs, competition and fibre exhaust, the incumbent service provider was at its wit's end to meet the challenge. The equipment manufacturers responded to the need of the time by providing **DWDM** technology.

Bandwidth Expansion

The following are the driving factors for DWDM technology induction by a Service Provider:

- Fibre exhaust in installed cables,
- Speed limitations of SDH systems,
- To stay competitive vis-à-vis network cost.

To overcome the above limitations, the service provider has following choices to enhance its bandwidth capabilities:

Install new fibre - This is not only expensive but also time consuming. Requires intensive co-ordination & substantial cost for digging.

Go for higher speed SDH systems - These TDM based systems provide Gigabit bandwidth. Commercial systems up to 10 Gbps are available but consume one pair of fibre per system.

Go for DWDM – DWDM allows on a Single fibre, simultaneous transmission of multiple SDH signals by assigning a discreet carrier wavelength to each signal. DWDM is a mean to increase the transmission capacity of a single fibre from Gbps to Tbps.

DWDM COMPONENTS

A brief description of the DWDM equipment and its components are as under: (see figures on the cover page)

i) ***Transmit Transponders (Tx):*** Normal SDH systems employ MLM (multi-mode Fabry-Parot laser) with spectral widths of the order of 10 nm. DWDM systems require source with negligible spectral width, say ~0.1nm to ensure that there is no interference with adjacent channels spaced at 50 nm/100 nm/200 nm. Transponders are the wavelength adapters. It first converts optical signal to electrical & then translates it to a specified **ITU** grid wavelength. The lasers used in the transponders are **Distributed Feed Back** (DFB) lasers called **Colour Lasers** because of their narrow spectral width. If transponder performs only **O-E-O** conversion with **re-shaping & re-generating functions** – it is called a **2R** Transponder. A **3R** transponder performs **re-timing** function as well. For co-located DWDM & SDH systems, a **2R** transponder is sufficient.

ii) *Multiplexer:* The multiplexer combines several pre-assigned discreet wavelengths at its input to a composite output signal carrying all the individual discreet wavelengths spaced as per **ITU** grid.

iii) *Booster amplifier*: This is an Optical Amplifier used immediately after the Multiplexer. The light signals in the process of multiplexing get attenuated. Booster amplifiers compensate these losses and also enhance the output power to ensure specified Optical Signal to Noise ratio of the system.

iv) *Erbium Doped Fibre Amplifiers (EDFA)*: These are in- line mid span amplifiers used to compensate the preceding section attenuation and to provide the necessary output power to the light signal for the next section. The EDFAs can provide around 40 dB gain with its output power of about +30dB. EDFA can provide an almost flat gain for entire C-band. It is an analog device and suffers from noise etc. General design employs two-stage architecture. The noise performance is the task of the first stage and the output power levels are controlled by the second stage. This is like a laser without positive feed back to avoid oscillations.

v) *Pre Amplifier:* This is a low noise, high gain device used at the end of the section interfacing Demultiplexer. The cumulative noise cannot be corrected, but its own contribution compared to Line amplifiers is relatively less.

vi) *Demultiplexer:* It performs the inverse functionalities of Multiplexer. It receives a light signal in the form of single combined output of multiple wavelengths at the input port and transforms each wavelength in the band to a single pre-assigned output ports. The Demultiplexer employs optical filters each tuned to the individual wavelength in the optical band transmitted by the Multiplexer.

vii) *Receive Transponders (Rx):* These transponders receive optical line signals at one of the discrete **ITU** grid wavelength i.e. colour wavelength as assigned in the transmit side. The Receive transponder coverts it into an electrical format. After doing the formatting as applicable under 2R/3R functional ties, it converts back into an electrical format and reconverts to optical wide band signal in 1530nm-1565 nm wavelength. It may be noted that when a DWDM section comprises of multiple links, at the point of interconnection where a link terminates and next link starts, no Rx Transponder is required, for co-located systems for further distribution.

SYSTEM CONFIGURATIONS

- **Point-to-point:** Initially, point-to-point DWDM links are planned. These are simple chains of end to end terminals with mid-span optical amplifiers. This is to save from fibre exhaustion and provide capacity enhancement. The evolution to add/drop and optical rings are the second stage of network implementation.
- **Optical Add/drop Multiplexer (OADM):** There are two types available: dynamic Add/ Drop OADM and fixed Add/Drop OADM. In dynamic add / drop OADM, any channel in the Optical band can be dropped and re-inserted, where as in the case of fixed OADM certain pre-assigned channels are hardware assigned for the drop/insert functionality. As on date, only fixed type OADMs are available.

ITU Application Codes

ITU has specified the standard configurations in the form of Short/Long & Ultra Long Hauls for distances before requiring electrical regeneration.

- 32L8.1/2/3 for target distance 8 spans@ 80kms.
- 32V3.1/2/3 for target distance 3 spans@ 120kms.
- 32U1.1/2/3 for target distance 1 span @ 160kms.

PHYSICAL MEDIA

Single Mode optical fibre is used for transporting DWDM signals. The fibres could be either **G.652** or **G.655** type. Only **G.652** has been deployed by BSNL/MNTL till date.

▪ Operating Windows

G.652 fibre has following operating windows:

- **850 nm window:** This is not used for Telecom applications.
- **1310 nm window:** This window has zero Chromatic Dispersion for G.652 fibre but high attenuation per km. This was used initially for low capacity Optical Systems as during initial stages, optical components viz., Lasers, Detectors & other passive components were developed for this window only.
- **1550nm window:** This window has the lowest attenuation per km. & incidentally has widest bandwidth. This window has the advantage of carrying more DWDM channels than 1310nm window. The Chromatic Dispersion is the major drawback to be overcome in the system design for working in this window. G.652 fibre has Chromatic Dispersion coefficient around 17-20ps/nm.km in this window.

▪ ITU-T Grid

ITU has defined the following bands for different applications.

O-band	1260-1360nm
E-band	1360-1460nm
S-band	1460-1530nm
C-band	1530-1565nm
L-band	1565-1625nm
U-band	1625-1675nm

The application of above bands is as under:

- O-band is generally used for the PDH network
- E-band is generally used for the PDH and SDH networks
- S-band is not much in use.
- C-band is used for the SDH and DWDM networks
- L-band is used for the DWDM network
- U-band is under exploitation for DWDM applications, and is in its infancy.

ITU has defined precise wavelengths for each information bearing channels (called λs) as well as the spacing between adjacent channels. This is based on 193.1 THz centre frequency.

The spacing between two channels must be 50GHz (0.4nm)/ 100GHz (0.8nm)/ 200GHz (1.6nm). If the entire C-band were to be utilized at 0.8nm spacing, 80 information bearing channels are possible. 3.2Tb/s information user capacity packed in entire C+L band is an achieved entity. In future, 25 GHz spacing will be used doubling the info" bearing capacity.

When the L-band is fully developed and commercially available, the information carrying capacity of the fibre will be still manifold.

IMPORTANT PARAMETERS OF DWDM

The following are the parameters related to DWDM technology. Some of them have serious implications and therefore require proper link engineering as well as system modelling.

Equipment related:

- ***Optical signal to noise ratio (OSNR):*** The optical signal to noise ratio is similar to conventional Signal to Noise ratio. This is the ratio of the optical signal power to the optical noise power over a optical bandwidth Δv. The OSNR indicates the section status for recovering the data @ required BER of less than 10^{-12}. A pre-requisite OSNR value is required to sustain required SNR at individual receivers.
- ***Noise Figure*:** The Noise figure is the Figure of Merit of an Optical amplifier. This mainly relates to contribution towards OSNR by an Optical amplifier. The value of Noise Figure for good amplifier should be between 4.5 to 7 dB. This is basically a system design parameter to yield required electrical SNR at Terminal Receivers.
- ***Optical Cross Talk:*** The adjacent channel generally contributes the cross talk and it is very low from non adjacent channel. The main contributing devices are the Multiplexers and Demultiplexers only. But due to non-linearities of the optical fibres & amplifiers some spurious signals may affect the performance working channels.

➢ ***Gain Uniformity of EDFA:*** This is due to the non uniform channel loss given by the Optical Fibre cable. The uniformity of the channel loss may be split into two categories; flatness and ripple. Flatness is the gradual variation in loss from one edge to the other. Ripple is the variation in loss throughout the pass band flatness. Both of these are important in multiple amplifier scenarios where they may result in an accumulated power imbalance.

➢ ***Polarisation Dependent Loss (PDL):*** PDL is maximum change in loss of a component over all the polarization states. The PDL causes fluctuation in power at the receiver as the polarization state in the fibre changes with stress, temperature etc.

➢ ***Optical Return Loss:*** The Optical Return loss can affect the stability of a system by multiple reflections at optical connectors and can degrade the performance of the system. This is greater of concern at 10Gb/s transmission rates.

➢ ***Amplified Spontaneous Emission (ASE):*** The ASE is a white noise in optical domain. As stated earlier EDFA is an analog device and like conventional analog amplifier this too generates the white noise. But due to imperfect isolators at the input and output of the EDFA a part of the light signal reflects back and re- propagate and appear at the output after amplification. This is amplified by EDFA just like traffic optical signals. This is a performance limiting parameter of DWDM link.

Fibre related:

- ***Non-linearities:***

➢ ***Cross Phase Modulation (XPM):*** When more than one optical wave propagates simultaneously inside a fibre e.g. in DWDM systems, the refractive index seen by a particular wave depends not only on the intensity of that wave but also on the intensity of the other co-propagating waves. Due to this, the phase of the signal in the given channel shall be shifted randomly though XPM. As a result of power fluctuation in all other channels, the signal to noise ratio at the fibre output is reduced. XPM is a form of optical jitter called "Chirping". This is more significant for systems working on G. 652 fibre (Single Mode fibre).

➢ ***Self Phase Modulation (SPM):*** The self Phase modulation refers to the self induced phase shift experienced by an optical field during its propagation in optical fibres. During the propagation, the intensity varies at the leading and trailing edge of the pulse and as a small part of the pulse is shifted in frequency in a process called the Self Phase Modulation. This leads to broadening of pulses in time domain, restricting the number of channel transportable.

➢ ***Four wave Mixing (FWM):*** The four wave mixing results from beating between the two channels, which creates new tones at other wavelengths. If these tones overlap with other channels, the crosstalk noise is increased. For DWDM systems, four wave mixing is most damaging. This will put a limit on the channel spacing.

➢ ***Stimulated Raman Scattering (SRS):*** The Stimulated Raman Scattering results from inelastic scattering in which photons transfer a portion of their energy to the mechanical vibration of the fibre lattice. The result is that the remaining energy is transmitted as a light of longer wavelength. This effect occurs at a certain power threshold, thus SRS puts a limit to the maximum power transmitted by each *channel.*

➢ ***Stimulated Brillioun Scattering (SBS):*** This is similar to the SRS, but SBS leads to the generation of acoustic photons. SBS reduces with broader laser line width. SBS places limit on the maximum channel power, but is independent of maximum number of channels supported by a DWDM system. This is more significant for systems working on G. 652 (Single Mode Fibre) and G.655 Fibre (NZDSF). SBS require much lower power level than SRS.

- ***Dispersion:*** The dispersion is the broadening of the pulse during the propagation. There are two types of dispersion generally applicable at network level:

i) ***Chromatic Dispersion:*** The refractive index of the glass varies slightly with the wavelength, resulting in different wavelengths travelling at different speeds, thereby leading to the broadening of the pulse during propagation. ITU-T has specified 12800ps/nm.km value of chromatic dispersion @ of 20 ps/nm.km upto 32 channels DWDM equipment.

ii) ***Polarization Mode dispersion:*** Polarization Mode Dispersion is the property of the fibre to transmit different polarization states with different group velocities. The random nature of coupling between these polarization states results in introducing randomly varying delay. As the different fractions of the pulse are continuously split up, shifted and recombined. As the pulse travels down the fibre, the result at the receiver is a distorted pulse that causes a path penalty. The PMD in the 2.5 Gbps

DWDM does not have any significant effect, but at 10 Gbps bit-rates DWDM systems, it a limiting parameter. The bad thing about it is that it is totally random. It has different values for fibre, cabled fibre and laid fibre. So the link design value @ 0.5 ps/Sq. km. has been specified as a rule of thumb.

TEC GRs ON DWDM EQUIPMENT

TEC took up the study of DWDM technology in 1998 and framed a GR on DWDM in 1999. This GR supports two types of DWDM equipment i.e. 8 chls and 16 chls DWDM equipment. The GR calls for three applications based upon the number of spans. These are as under:

a) Long haul equipment supporting 8 spans, each span of 80 kms
b) Very Long haul system supporting 3 spans, each span of 120 kms
c) Ultra Long haul system supporting single span of 160 k ms.

At the end of maximum permissible spans in each application, the optical signals are required to be converted into electrical signals and these are 3R regenerated before converting it again to optical signals for further transmission. This is necessary as signals during transmission in optical domain suffer degradation due to deterioration of OSNR as the signals traverse along successive spans.

FUTURE ROAD MAP

i) Optical ADD/Drop Mux: The programmable OADM, in the future will be able to dynamically drop or insert any channel in the Optical band, at any Optical Line Amplifier site and this shall be unrestricted. This will be achieved using reliable tunable Laser source and Tunable Optical Filters are possible.

ii) Optical Cross Connect: The optical cross connect is an equipment, in which it shall be possible to cross connect an optical channel at the input to any other channel at the output assigning a new wave length to the cross connected channel. The technology such as MEM switch/Bubble switch shall be used to achieve this.

iii) CWDM for Metro Applications: Most un-amplified metro access applications find DWDM to be cost prohibitive. This has resulted in a concept of deploying Coarse Wave Division Multiplexing (CWDM) in the Metro Access Networks. The key difference between CWDM & DWDM is the spacing between wavelengths. In DWDM, the wavelength spacing is between 0.4nm -1.6nm. This tight channel spacing requires equipment which must operate within very small tolerances. To cater for these tolerances, the devices become expensive. For example, a directly modulated Laser can have temperature drift of 0.12nm/ deg. C & for DWDM application precision temperature control would be required adding enormous cost. However, for CWDM systems where the channel spacing are of the order of 20nm, the 70 deg. C drift in temperature corresponding to 8.4nm shift in wavelength does not cause any interference. CWDM equipment uses 1200nm -1650nm range with 20nm spacing. On G.652 fibre this corresponds to 12 channels,. The number of channels can be increased to 16 in the low water absorption peak fibres corresponding to ITU spec. G.652.C. The cost of CWDM system is somewhere 20-50% of the corresponding DWDM systems. Cost savings come from both equipment and operational costs. Power consumption for CWDM systems is around 25% of the DWDM systems. CWDM systems hold the key for cheap services in the competitive era.

Conclusion

Optical networking provides the back-bone to support existing & emerging technologies with almost limitless amounts of bandwidth capacity. All Optical Networking (not just point-to-point transport) enabled by optical cross connects, optical programmable add/drop multiplexers, and optical switches provides a unified infrastructure capable of meeting the telecommunication demands of today & tomorrow. Transparently moving trillion of bits of information efficiently and cost effectively will enable service providers to maximize their embedded infrastructure and position themselves for meeting the capacity demand.

IMPORTANT ACTIVITIES OF TEC DURING THE 4th QUARTER OF 2001 - 2002

A. Preparation of GRs/IRs & Technical documents

Following GRs/IRs and Technical documents issued:

- Feeder Cable for CDMA and CorDECT WLL systems
- Primary Rate Digital Signal at 2048 Kbps between the Networks
- Mini Line Jack Unit
- Short Massage Service Centre
- General Packet Radio Service
- Revised 30 Chl. PCM equipment
- Revised IR for X.25 Data equipment to connect INET
- Revised GR for Self supporting Metal Free Optical Fibre Cable (Cat A & Cat B)
- Revised GR for Portable Cable Fault Locator
- Revised GR for Digital Cable Fault Locator for Low Insulation
- Revised GR for New Type Distribution Point (DP) Box for External Use
- Revised GR for Large Size Local Cum Tandem Exchange
- Revised Standard on Service Description for Analog Subscribers
- Revised GR for Buttinski Telephone Handset
- Revised GR for Cable Switch Board (Screened and Screened)
- CDR Based billing system for PSTN
- Test Schedule for Remote Station Terminal
- Test Schedule for VRLA Batteries with amendment no. 1 & 2
- Test Schedule for Billing and Customer Care system
- Test Schedule for Intelligent Network system and services for Mobile Network

B. Tests and Field trials

Tests have been carried out for:

- SIM cards offered by M/s ITI at Palakkad, Kerala.
- CDOT Call Monitoring system for IMPCS
- Interfaces for Integrated Media Gateway of M/s Cisco and M/s Vocaltec
- CorDECT system of M/s ECIL ltd. at Hyderabad.
- EPBT with CLIP of M/s Bharti Teletech and M/s HFCL.
- Premium Rate service (PRM) through VCC at Bangalore
- NLD service features in different types of exchanges at Gurgaon, Faridabad and Ghaziabad.

C. Other Activities

- Manufacturer Forum conducted for:
  - Up Converter and Down Converter in C band.
  - Next Generation Network (NGN)
  - Telephone Answering Machine
  - Cable Record Purification system
  - Computer Telephony Integration
  - Interactive Voice Response system
- Review of National Numbering Plan.
- Assisted Airport Authority of India in Tender evaluation for its dedicated satellite communication network
- Technical tender evaluated for BSNL for 500 K lines and Subscriber Terminals for WLL systems.
- Prepared Planning Guidelines of Synchronization for transmission

Approvals issued by TEC during the period January 2002 to March 2002

Type Approvals	133
Interface Approvals	57
Service Test Certificates	44
Total	**234**

Approvals issued by TEC upto 31.03.2002

Type Approvals	5488
Interface Approvals	3273
Service Test Certificates	1417
Grand Total	**10178**

WORLD TELECOMMUNICATION DAY : 17TH MAY 2002

ITU has chosen the theme 'ICT for all – empowering people to cross the digital Divide' for this year's World Telecommunication Day on 17th May 2002.

Information Communication Technology (ICT) is an increasingly dominant and powerful tool that is being used to shape and re-shape the world that we live in. The global transition from an industrial society to an 'information society' has been the most profound and has had an impact on social, economic and political spheres of all countries across the globe.

The world is no more divided by the Cold War, but there is a new separating phenomenon, the "Digital Divide". Foreign policy is increasingly being shaped by this divide. Many reports and results of studies reveal important synergies between general well being of populations and Internet penetration. The UN's Human Development Index illustrates correlation between the increase in human development indicators, such as education and income, and increased Internet use. The G-8 summit that took place in July 2000 at Okinawa, Japan reinforced this, by the importance placed on addressing the growing Digital Divide, resulting in the development of an Okinawa Charter in Global Information Society.

This Charter led to the birth of the Digital Opportunity Task Force (DOT Force), as an unprecedented first step towards the goal achieving digital access and education for all by the year 2010.

There are many who question why it is important to prioritise the development and dissemination of ICTs, when there are a number of more pressing issues at hand, such as lack of clean water, adequate nutrition and so forth. The current discourse essentially comes down to a question of practical needs versus strategic interests. Addressing developmental issues does not have to be a trade-off and both basic needs and steps towards empowerment can be addressed in parallel. The knowledge gap is just as important as an income gap and it is vital to address all spheres of this. ICTs can be leveraged across sectors to enhance development programmes. **(Source: ITU web site)**

Extracts from Message by Mr.Yoshio Utsumi, Secretary General, ITU

Information and Communication Technology (ICT) may be the most powerful tool for social and economic change since Gutlenberg and the invention of the printing press. But, we must not forget that much had to be done before people had access to books on widespread scale. And so is with access to ICT.

But ICT access has not been equitable. The use of the technology and the access to it varies greatly among the countries, and within countries, too, between urban and rural areas, between the rich and the poor, between the educated and the illiterate, between men women.

Much has already been done in the way of technology, but more action is needed by governments and by civil society, if all humanity is to benefit from ICT. The technology is only the beginning and, in a sense, the easy part. The hard part is how the technology is used in the less tangible areas of politics, business, culture and law.

Considering the enormous power of ICT for socio-economic development, it is essential that opportunities to access ICT be given to all those who have been unable to participate fully in a knowledge-based digital economy.

We must use the power of ICT in such a way that people can improve their economic, social and cultural well-being. We need strong government commitment to strategies that increase the spread of ICT. This is crucial for the success of any development initiatives and for the future of the millions of people in the world today who still have not heard a dial tone. The task is daunting, but we must overcome it if we are to keep the promise of the information society.

TEC NEWSLETTER
April 2002
Volume 6
Issue 2

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