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Global compunication — A 15-year technology forecast

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A technology forecast for 1990-2005 A.D. is made for the global compunication technology, which is a synergetic merger of computer technology and communication technology. The trends in global compunication as it metamorphoses the office, the factory and the home services, are forecast, utilising the Harvard Map of Information products and services as well as Kobayashi's concept of integration of computer and communication. From the experience of setting up a nation-wide computer-communication network, NICNET, based on very small aperture terminals (VSATs) and spread spectrum code division multiple access technology, certain VSAT technology trends are analysed. In this product environment, the emerging profile of integrated services digital network (ISDN) is outlined based on a seven-layer protocol and broad-band application spectrum. Supplementary forecasts are made on trends in value added network, switched optical communication, cellular mobile communication, and personal communication network.

1 Introduction

In his treatise '*Understanding Media*', Marshall McLuhan predicted, 25 years ago, a world-wide coalescence of human activities into a single community tending to a "Global Village". Such a coalescence is already perceptible as global communication is increasing in complexity, variety and volume of interaction between the various countries of the world. Global networks of computers are already bringing about an information exchange between countries. This infrastructure is fostering increased international trade. The convergence of computer technology and communication technology is already becoming visible in the form of facsimile service, automatic bank teller machines, international television, answering machines, compact disks, among others.

Kobayashi[1] evolved a concept of integration of computer and communication (C&C) in which he forecast the features of communication technology which would be derived from computer technology and vice versa. Building up on this concept, the system of global compunication access that is likely to evolve in the next fifteen years has been derived as shown in Fig.1. Basically this forecast is a combination of three functional elements: (a) terminals interfacing with people, (b) conventional transparent communication network, and (c) computer oriented information and communication service centres.

The transmission systems assumed are: (a) Terrestrial communication (Tercom): microwave/millimetre wave system, optical fibre cable system, coaxial cable system, paired cable system and submarine cable system, and (b) Satellite communication (Satcom): point-to-point communication with Ka-band (20-30 GHz) hubless very small aperture terminals (VSATs) and ADSATs with onboard switching facility (OBS), remote sensing satellites with OBS and high precision digital photography equipment, and mass media satellites for broadcasting.

Local area networks (LANs) in offices, factories and homes are connected to meteropolitan area switching systems. These switching systems also connect communication and information processing centres (CIPCs) (Videotex, data processing, databases, etc.), value added network (VAN) communication and information processing centres as well as radio and television broadcasting stations. The LAN and CIPC are connected to subscriber access systems which, in turn, along with VAN, are connected to the switch. The output of the switch multiplexes the radio base stations. Throughout, integrated services digital network (ISDN) will be the main infrastructure.

Broadcasting stations are connected directly to the transmission system. The radio base stations and the broadcasting station along with remote sensing satellites, point-to-point compunication satellites and mass media satellites provide the mobile compunication links for air transport, marine transport, surface transport and individual communication.

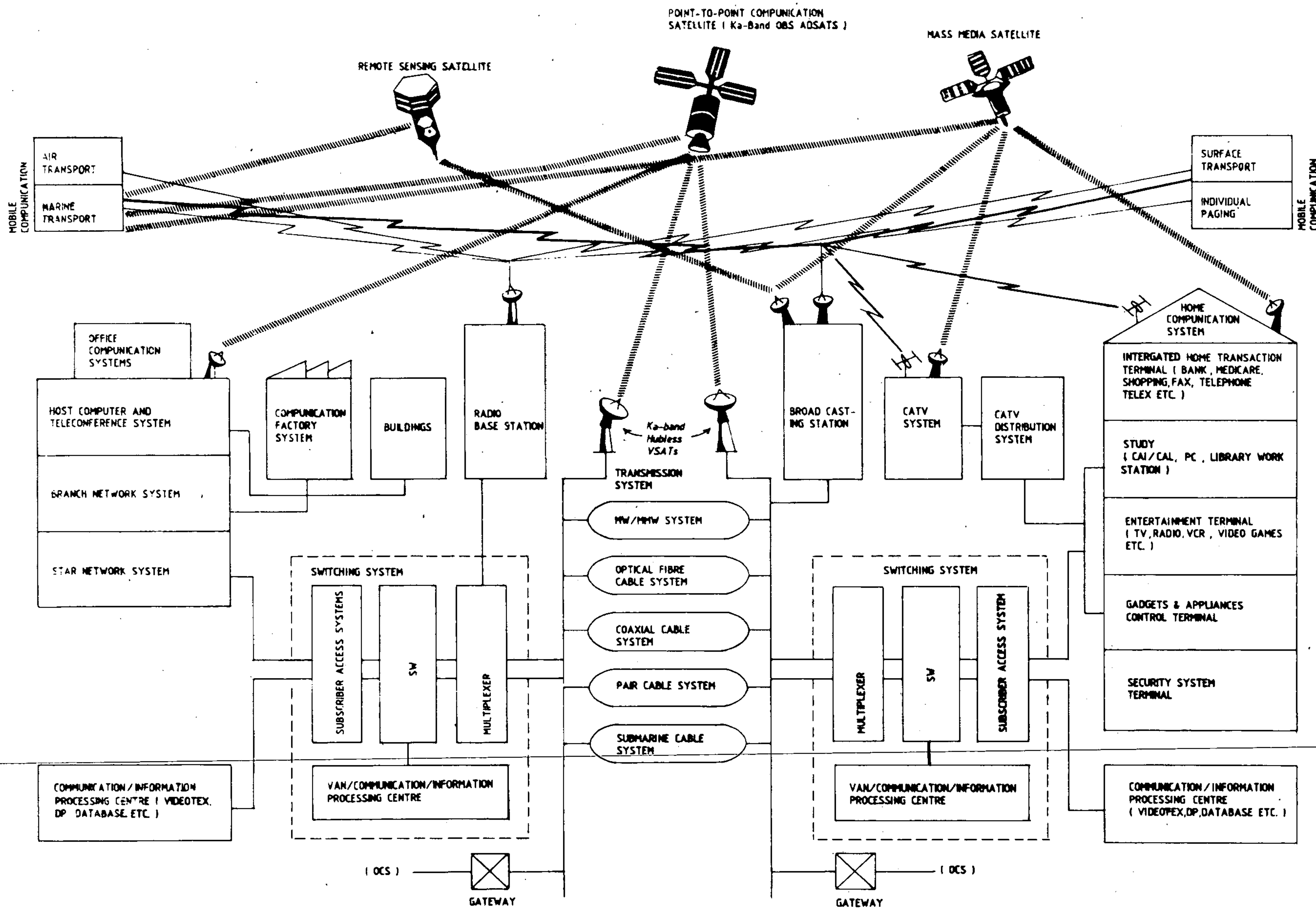

Fig. 1—Evolution of global compunication access

For realising the above technology scenario, the manner in which the technology of switches, networks and services in the telecommunication area are being converted into integrated services and the manner in which the evolution of computer technology and electronics device technology are being oriented to meet the communication technology by 2000 A.D. is shown in Fig.2 (Ref.2). By this time it is sought to realise a truly integrated system: a socket in the wall of every home, office, factory and public place following a universal standard in all countries, giving selective access to the information stored from a single international highway. Into such a socket can be plugged a telephone, a television set, a computer, a telex, a fax machine or any other terminal designed to receive, display, store, process or despatch information. All these are interlinked and are able to communicate with each other in the most efficient and economical manner. Already, the first few steps in the implementation of such integrated global networks have been taken.

Though final realisation may take a few decades, the next fifteen years can, in principle, bring about most of the technological means required. There are three pre-requisites for accomplishing this goal — digitalisation, broad-band transmission and the adoption of international protocol standards. Of

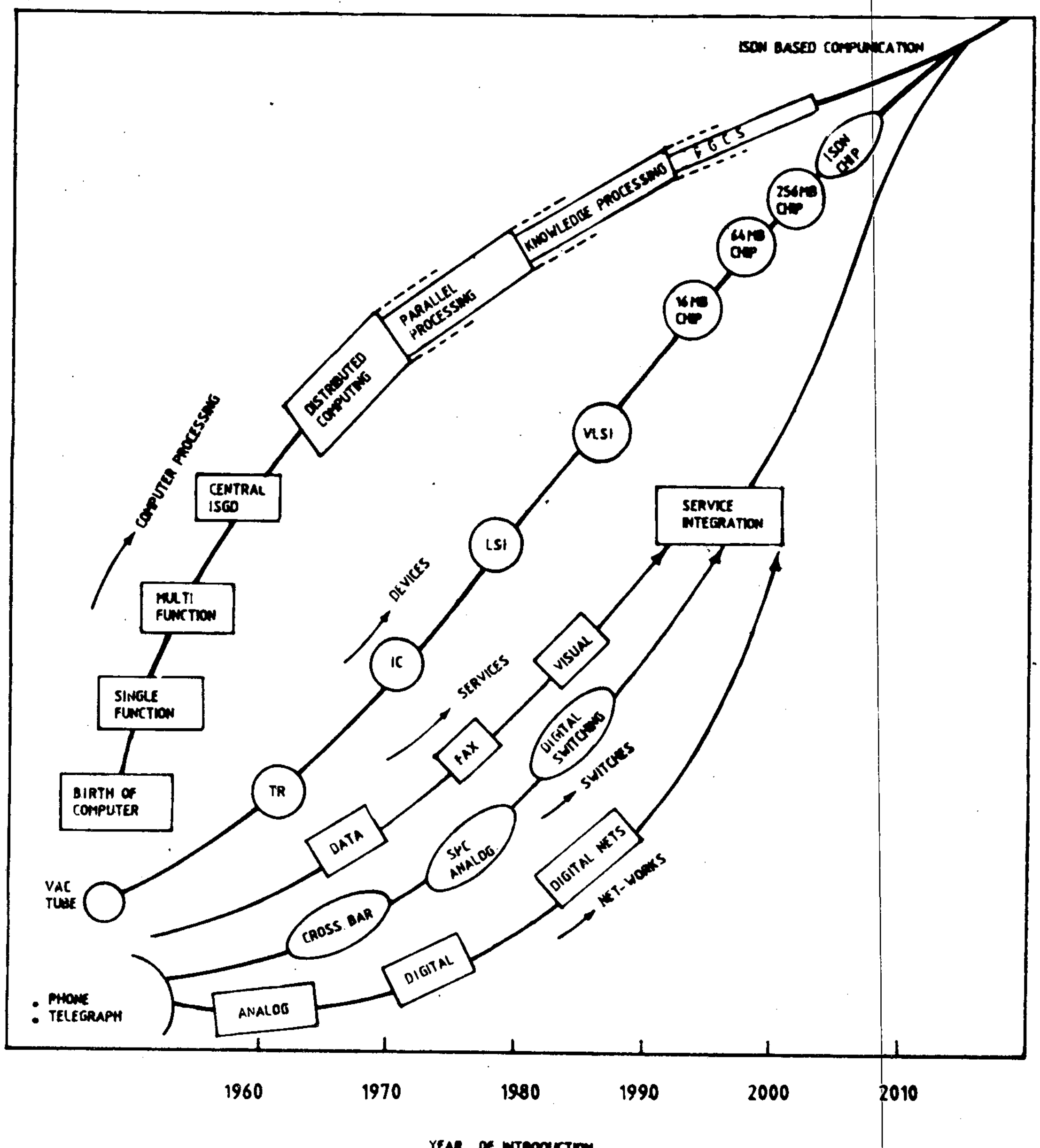

Fig. 2—Schematic of evolution of compunication services

these, technologies for digitalisation and broad-band transmission already exist. The third is well understood, but not implemented. The digital method has drawn techniques from computer technology which has demonstrated higher frequency ranges, higher transmission speed and compatibility with wide ranging information storage, processing and transmission services. The adoption of computer networks like NICNET in India has demonstrated the universality of digital methods for communication. In an environment of rapidly changing demand, the current practice of responding to diverse growing needs by developing application specific services is un-workable. The spectrum of new applications with different requirements of creation, storage and transfer of information also calls for a common basis which has now been acknowledged to be the integrated digital network. The conversion to broad-band optical system will be rapid where they are commercially attractive, but elsewhere digitalisation will be intrinsically slower. Whether at the local or national or global levels, establishment of standards is the key to the development of ISDN. In October 1984 when the CCITT adopted the first set of ISDN recommendations for standards, a milestone in the development of ISDN was created.

2 Compunication map

A map of information products and services and communication supports for the same was created by McLaughlin and Antonoff[3] at Harvard University under the programme on Information Research Policy. They have given spatial maps of information products and services according to the ratio of the degree of relevance to services and products on the one hand and form and substance on the other. This map is modified here in terms of contour maps for office equipment, consumer electronics, telecom, data processing, desk top publishing and dial for data services as shown in Fig.3. The area enclosed by the polygon denotes the products and services, which by and large, depend on computer technology. The products-services axis gives the demarcation in terms of traditional industrial activity highlighting vertical integration. The means-ends axis helps to distinguish between the providers of the means for recording,

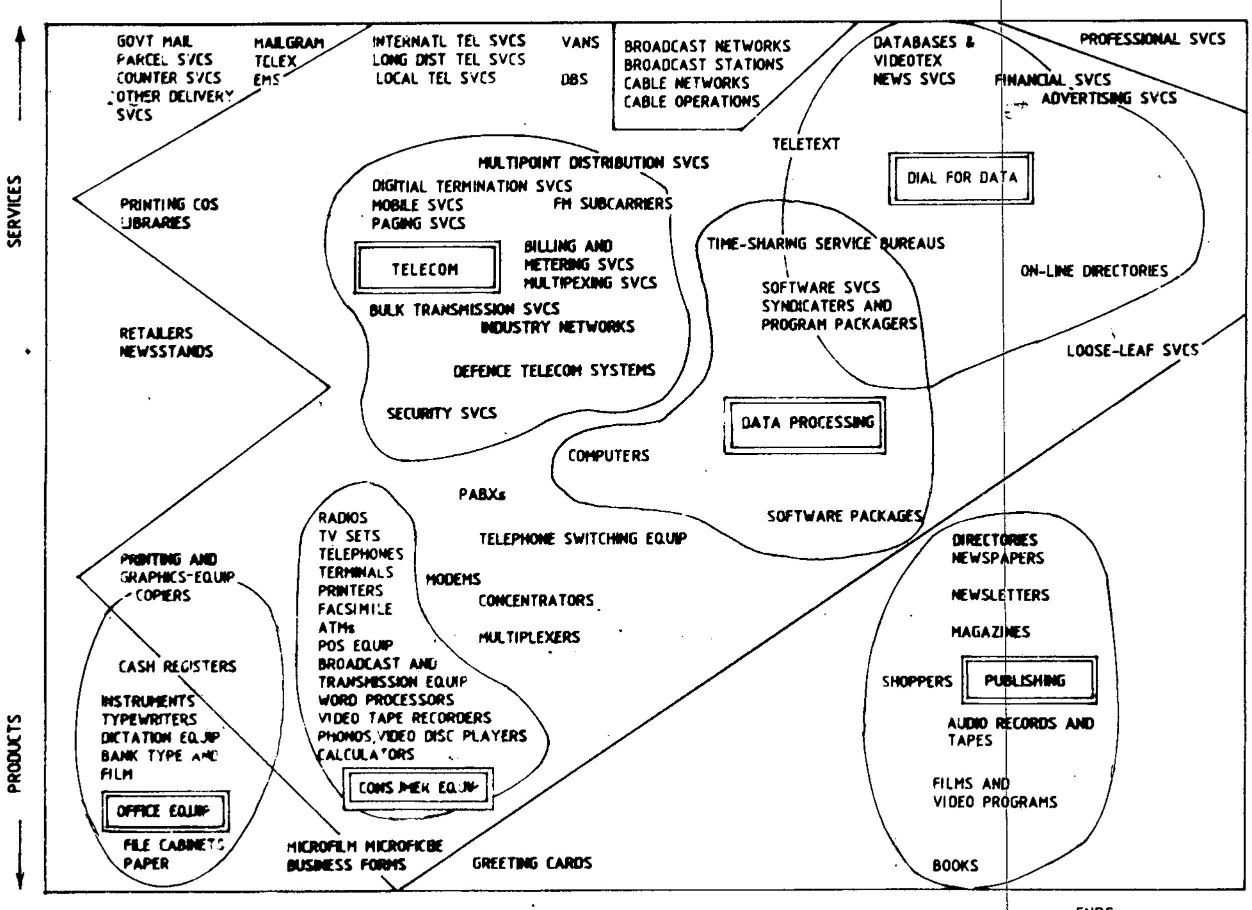

Fig. 3—Map of information products and services

processing and transmitting information and those who are producers of information as the end product.

The map broadly helps in technology forecasts as it pictorially shows how the market for office equipment has been transformed by the spread of electronic, communication and computer technologies into equipment, systems and services. Some noteworthy observations may be given as guidelines for forecasts. As the basic intention of any office is to create, store, process and transmit information in order to make and communicate management decisions and to monitor their implementation, offices become important consumers of practically all the items shown at the top left corner. The cost of the items in the corners is higher than those around the centre, e.g. that of typewriters relative to wordprocessors, that of physical delivery of mail relative to electronic mail, and filing cabinets as compared to computerised records. While shifting towards the centre of the map, one can observe improvement in selectivity, interactivity and timeliness of information flow as an organisation attempts to make trade off between manpower intensive and energy intensive corners and the continuously reducing cost of the products and serevices as one moves towards the centre. The six closed contours broadly delineate coherent industrial classes which require similar capital goods and/or technologies and show a possibility for vertical integration.

3 Profile of end services

A long term technology forecast can be carried out with higher degree of confidence level only if all the compunication services can be suitably classified. For this a two-descriptor classification is adopted in terms of:

(a) *Service categories*

(i) Mass media systems — broadcasting services and publishing services.

(ii) Point-to-point systems — telephone/telex etc. services and online computer services.

(b) *Information categories*

(i) Products/services based on information transfer only.

(ii) Products/services based on information creation and storage only.

(iii) Products/services based on creation, storage and transfer.

The linkage between the two descriptors and the categories within the descriptors are outlined in Fig.4. The categorisation of services are further sub-categorised into: (i) Terminals, (ii) Compunication, and (iii) Information services. In this background, Fig.4 is self-explanatory.

For combining the classifications given in Fig.4 with the global compunication access outlined in Fig.1, the corresponding role of videotex and teletext as well as compunication trends in office, factory and home is required to be forecast[4].

3.1 Role of videotex and teletext

Videotex communicates through the telephone network and the teletext through a broadcast network. Videotex establishes communication between an information source or database and a videotex unit with a monitor or a television set. In the latter, a modem is integrated in the telephone instrument to ensure communication between the telephone network and the television set. A decoder to decipher the digitised information transmitted through the modem transforms it into letters, numbers and graphic images. The capacity of the videotex for conversation is facilitated by a television remote control box or alpha numeric keyboard.

Teletext, on the other hand, uses a television transmission network to send coded information that requires a special decoder to make it visible on a television screen at the receiving end. The viewer can select a page by a remote control device and the decoder stops at the desired page and displays it on the screen. For a hundred page teletext programme, called INTEXT, operated by Doordarshan and the National Informatics Centre, this means a delay of about 24 s (Ref.5). This limits the volume of teletext programme. However, this is the ideal medium for transmitting up-to-date news available at any time during broadcasting hours. Videotex on the other hand has no time constraint and the information it provides is available at all time and it can be retrieved in seconds.

3.2 Office compunication

Office automation in the next fifteen years will be increasingly digitalised and hence computerised and network based. From local area networks in individual offices to the wide area computer communication networks connecting various mutually dependant offices will tend to become as widespread as the telephone network by 2005 A.D. As far as the business requirements are concerned, the local area network (LAN) connects all the divisions with an office, metropolitan area network (MAN) links various branch offices in the same city, and wide area network (WAN) connects the regional offices among themselves and with the headquarter. The

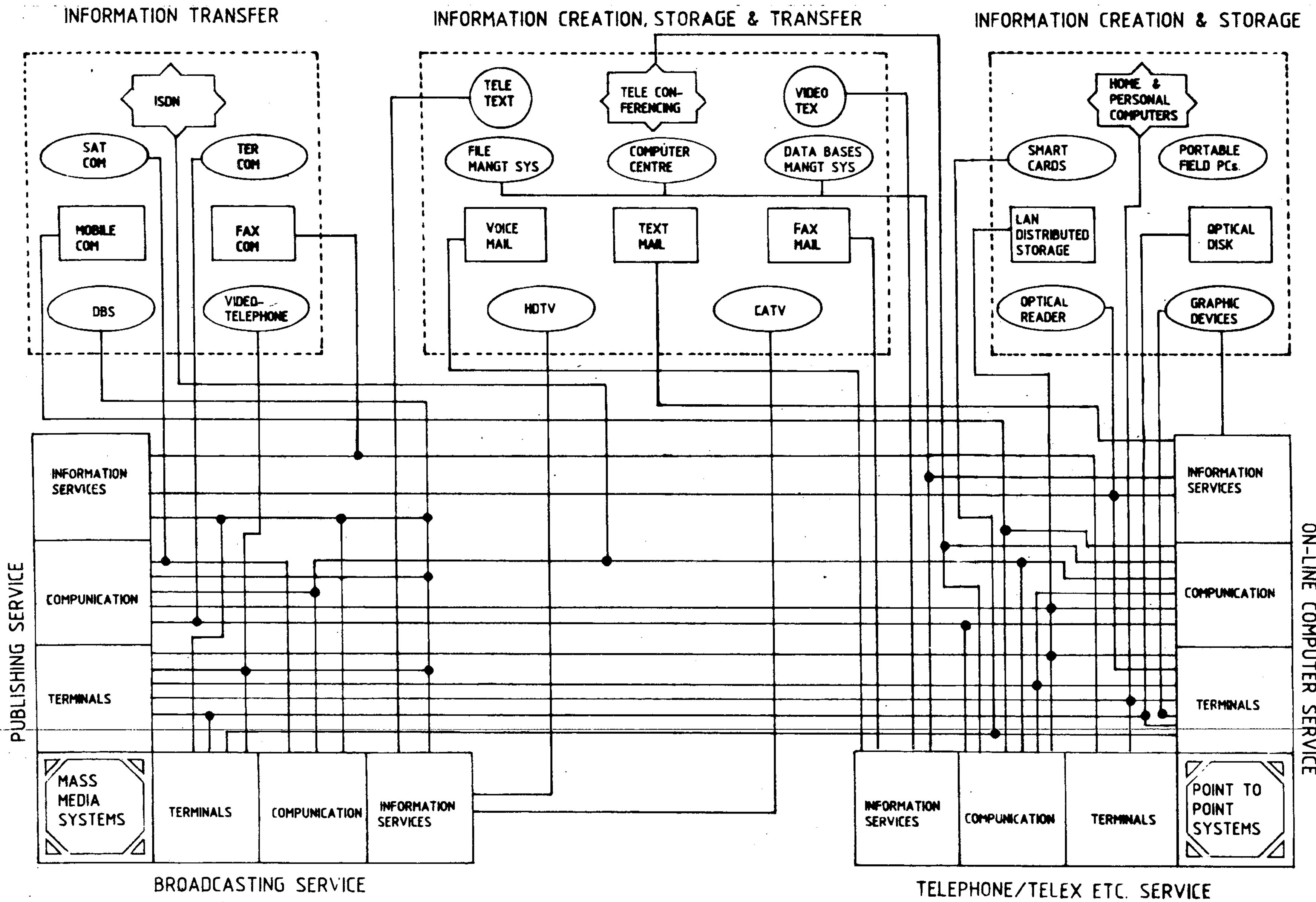

Fig. 4—Classification of compunication services

concept of integrated services will become the impetus for the development of "universal terminals and work stations". It will combine the features of terminals required for various services like voice communication, data communication, graphic communication, teletext, videotex, etc. on the same integrated channel. Such universal terminals will at the same time be a keyboard terminal for data communication, trans receptors for voice communication, FAX machine, Multi-font non-impact printer, PSTN terminal, reprographic equipment including photocopiers, low volume photo offset equipment, among others.

3.3 Factory compunication

The compunication requirement of multi-branch manufacturing organisations is somewhat different. Within the same factory different shops or units may have to be connected not only for information transfer but also for control of processes, assembly lines and stores in a dynamic manner. It is in this context that distributed digital control (DDC) for industrial automation calls for the support of computer and communication technology in an integrated manner. The ability of a computer system to store and process considerable volume of data, to carry out complex analysis at high speeds, to integrate effectively the man-machine interface for decision making functions and to adapt, through software, to changing system requirements, means that now a days it is possible for the same computer to address all aspects of data gathering, information processing, process control, online optimisation, operations control and even real time scheduling and production planning functions. This has made possible the realisation of integrated systems control in which all factors influencing plant performance, including coupling, integration and complex feedback paths in the system, are taken into account together to achieve the overall optimum performance.

To give an idea of the complexity involved in designing a computer-communication system for industrial automation, let us recount from the design made for a steel plant at a projected cost of realisation of about Rs 600 crores which is the typical cost for modernising a steel plant. The system was designed in four layers. The first one is called the direct control layer which constitutes the interface between the controlled plant and the decision making and control aspects of the system. This layer interacts directly with the plant and in the same time scale. It encompasses such sub-functions as data acquisition, event monitoring and direct control. The second layer or supervisory function is concerned with the problem of defining the immediate target to be implemented by the first layer. The third layer or adaptive function is concerned with the updating of the algorithms employed in the first and second layers, reflecting current operating experience. The highest layer is the fourth layer which is the self-organising functional layer and is concerned with decisions relevant to the choice of the structure of the algorithms associated with the three lower layers of the hierarchy. These decisions are based on overall consideration of performance, objectives, priorities, the nature of the system relationships and input patterns, structuring of the control system, coordination with the other systems and so on. In short, even within the factory, the multi-level control hierarchy in the DDC framework is necessary.

This DDC framework imposes certain LAN requirements. The LAN also is a multi-layer hierarchic network, each layer corresponding to the DDC layer. The LAN should give online and real-time response at the lowest layer and less so at higher layers. Yet there should be a good interaction between the layers.

The trend is to substitute the mainframe computer with supermini computers like those based on 486/586-chip Multibus II and UNIX 5.4 which works at more than 15 mips. If the conventional RS-232 is substituted with RS-422/423, a star-LAN with terminals distributed as far away as 2 km without either LAN cards or modems can be made. Whatever 486 CPUs which cannot be mounted on the same bus may be connected with back-end Ethernet over a LAN card, but this may not be required for medium sized factories.

3.4 Home compunication

The basic services being provided in homes in a number of countries at present are shown in Fig.5. Basically these services centre around television, radio, telephone and the personal computer with appropriate service media. The present forecast is on the basis of technical feasibility at various points in time and not necessarily affordability in any country. By the middle of 1995, certain extended services would be possible because of the increase of quality, variety and volume of information as well as the facilities for on-demand services and ISDN services. As compared to the present day coaxial pair cable, twisted pair link and RF cable, the second half of 90s will see optical fibre cables terminating in home complexes. The optical fibre cable will connect the home network bus to the broadcasting network, HDTV, HI-FI audio, teletext and facsimile through bidirectional CATV and public communication

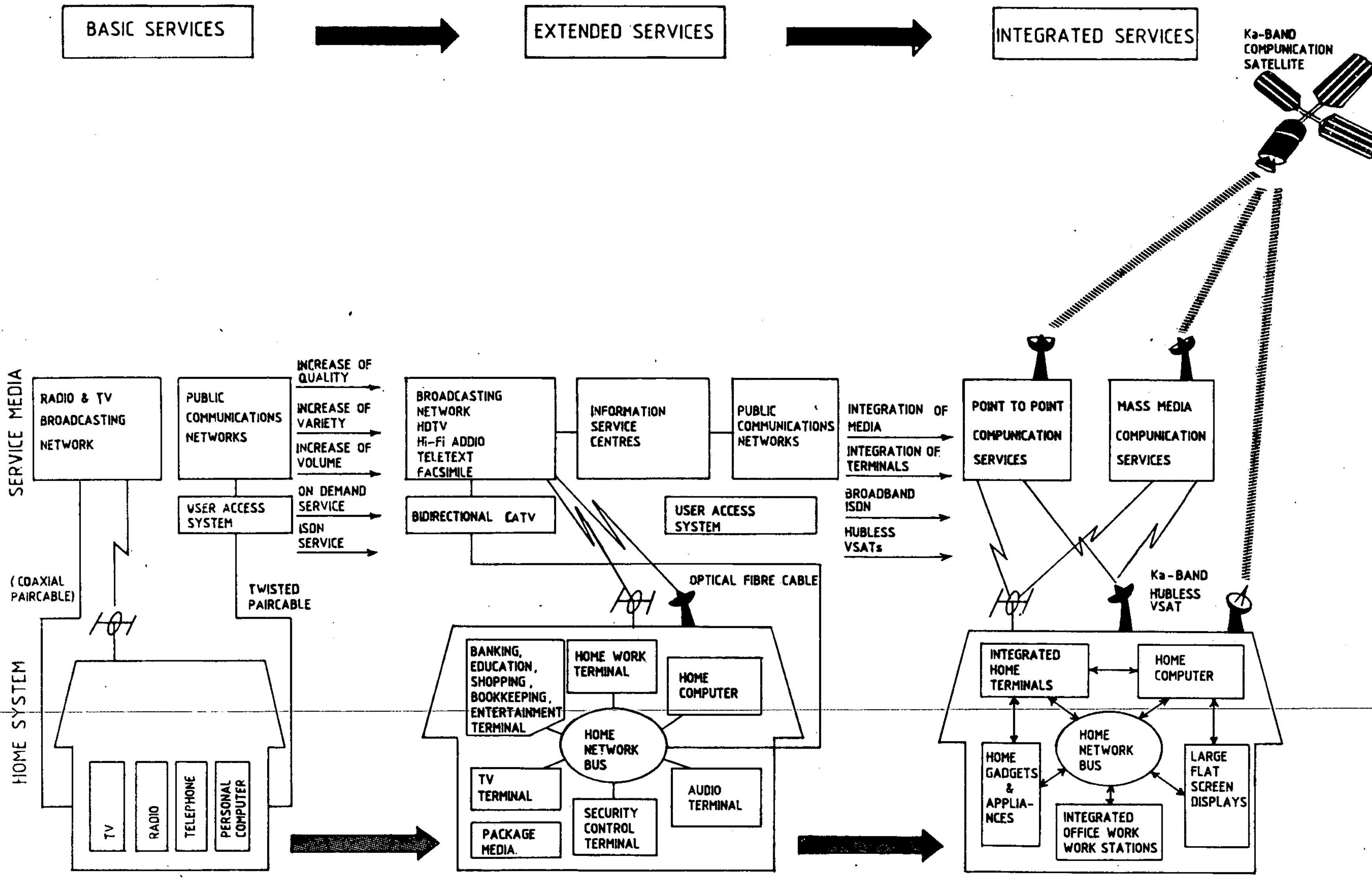

Fig. 5—Evplution of home compunication

network through user access systems. These will also be connected to information service centres. On the home front, the home network bus will be connected to a central home computer supported by terminals for various service functions like the control of air conditioning, electrical and gas supplies, television and entertainment terminals and office workstations. In addition, it is possible to install computer aided instruction (CAI) terminals, security terminals, shopping terminals, banking terminals, etc. Radio link will be supplemented by VHF/UHF links. Towards the end of the century and the first half of the first decade of the 21st century, integrated services will become available on the home front. This would be made possible by technologies facilitating integration of media, integration of terminals, broad-band ISDN and hubless VSATs. The integration will enable two major classes of services—mass media compunication services and point-to-point communication services as per the classification given in Fig.4. In addition to RF, VHF/UHF links, Ka-band hubless VSAT will become available as a low cost Satcom link. In view of the integration, the home network bus would be connected to the home computer which would be supplemented by integrated home terminals, gadgets and appliances control system, large flat-screen displays and integrat office-workstation.

4 Evolution of networks

In making a forecast of the direction of evolution of a compunication network, certain lessons are drawn from the technology behind NICNET[6] of the National Informatic Centre which has already been installed in India linking all the 440 district headquarters with a dedicated earth station and a dedicated computer in each location. NICNET is based on technologies less than four years old. However, certain new directions given in the design of NICNET have enabled extrapolation of technology and service trends for the 90s as outlined below:

4.1 Satellite route—the NICNET example[7]

As the demand for customer services cannot be assessed accurately at this point in time, networks cannot be planned merely on the basis of presently projected user service requirements. The long term approach is to design the network as a whole anticipating the user requirements for the next several years. An example of the design of NICNET is given here to illustrate this point. NICNET has a four level hierarchy in the network spanning all the district headquarters at the lowest level, the central government headquarters in New Delhi, the set of 32 State Capitals and Union Territories and the set of four regional centres. Through this, a decision support information system for the Indian Government is being evolved based on the design of a predominantly query based computer network with hierarchic distributed databases and random access communication.

With interference tolerance and random access as two guiding principles behind the choice, spread spectrum transmission and code division multiple access system of satellite communication was adopted. Each node of the network is a 32-bit computer which is capable of local bulk storage of up to three units of 300 mega bytes each for purposes of query-accessible distributed databases. The design and implementation of such a distributed database has endowed the network with the capability to distribute the data related to such databases over various nodes in the network so as to be able to accept a query from any of the nodes. The technology forecasts and appropriate technology choices were so made that the network will remain contemporary technologically for more than a decade. Such technology features are examined below:

(*i*) *Flexible network structure*—Terminals can be connected to the system directly or via telephone, telex or circuit switched network; remote terminals can be connected via packet multiplexor or PADs through satellite circuits.

(*ii*) *Board terminals integration*— Packet terminals, non-packet terminals and host computers of different speeds can be integrated.

(*iii*) *Compatibility*—The system should interface with the external communications system according to CCITT recommendations.

(iv) Network access—The system should facilitate access to the communication network, be it via leased or dedicated lines, switched telephone network or satellite circuits.

(*v*) *Line utilisation*—Each packet terminals can communicate with a number of other terminals over one physical line.

(*vi*) *Error-free transmission*—The system checks the data for errors step-by-step as it transmits.

Considering the above requirements and the need for a low duty cycle interactive network with a large number of stations, a satellite-based system was selected. Adjacent satellite interference as well as interference to and from the terrestrial system must be minimal for enabling free siting of the small aperture earth stations. In view of these considerations, a spread spectrum code division multiple access system was chosen for NICNET.

5 LAN-MAN-WAN heirarchy

The National Informatics Centre is the decentralised depository of information for various Central and State Government departments. For this purpose, large databases are being developed by National Informatics Centre (NIC) in coordination with the user departments. In order to maintain these large databases on a national scale, NIC has already installed four very large computer systems (S-1000 from NEC, Japan) at Delhi, Pune, Bhubaneswar and Hyderabad. These will be the four main nodes of NICNET. The Delhi system acts as the main host.

Local area network (LAN) clusters of mini computers/super ATs are being installed in the secretariats of the State Capitals and Union Territories. These systems will be primarily used by the State Governments to consolidate the information coming from various districts/blocks as well as within to meet their own requirements and to pass on the necessary consolidated macro level information to the Centre. The various LANs in different parts of a city will be connected by a metropolitan area network (MAN) (see Fig. 6).

As the districts are basic administrative units under the States, the consolidation of the detailed information pertaining to the districts is done by various agencies at the district level. In order to capture and consolidate the data, super ATs are being installed at the 440 districts in the country. As the block is the smallest development monitoring unit, especially for the plan scheme implementation, it is supposed to be the generator of the basic data for this purpose. In order to capture this basic data, PC-based terminals are expected to be installed in the third phase of NIC at the block level, covering more than 5000 blocks. Here again, LANs and MANs will be installed in due course of time. All these MANs will be connected into a wide area network (WAN). The LAN-MAN-WAN heirarchy will be the logical network structure that will evolve over the next decade.

At the local level, things are developing into local area network with facilities for office processing, voice mail, fax mail, text mail and electronic files. Computers can be connected to it with large databases either remotely or locally. Distributed processing will be there in the sense of a large number of terminals intelligent or otherwise. The shop floor automation of a plant can be linked to the management information system as we are doing for the digital distributed control, going over to a four-level hierarchy in Bhilai Steel Plant and others. Here, office automation is also being intrinsically linked up to shop floor automation so that the heirarchy of management information system ties up with the hierarchy in a factory or plant. Now with these kinds of applications the local area network is going to become one of the most important

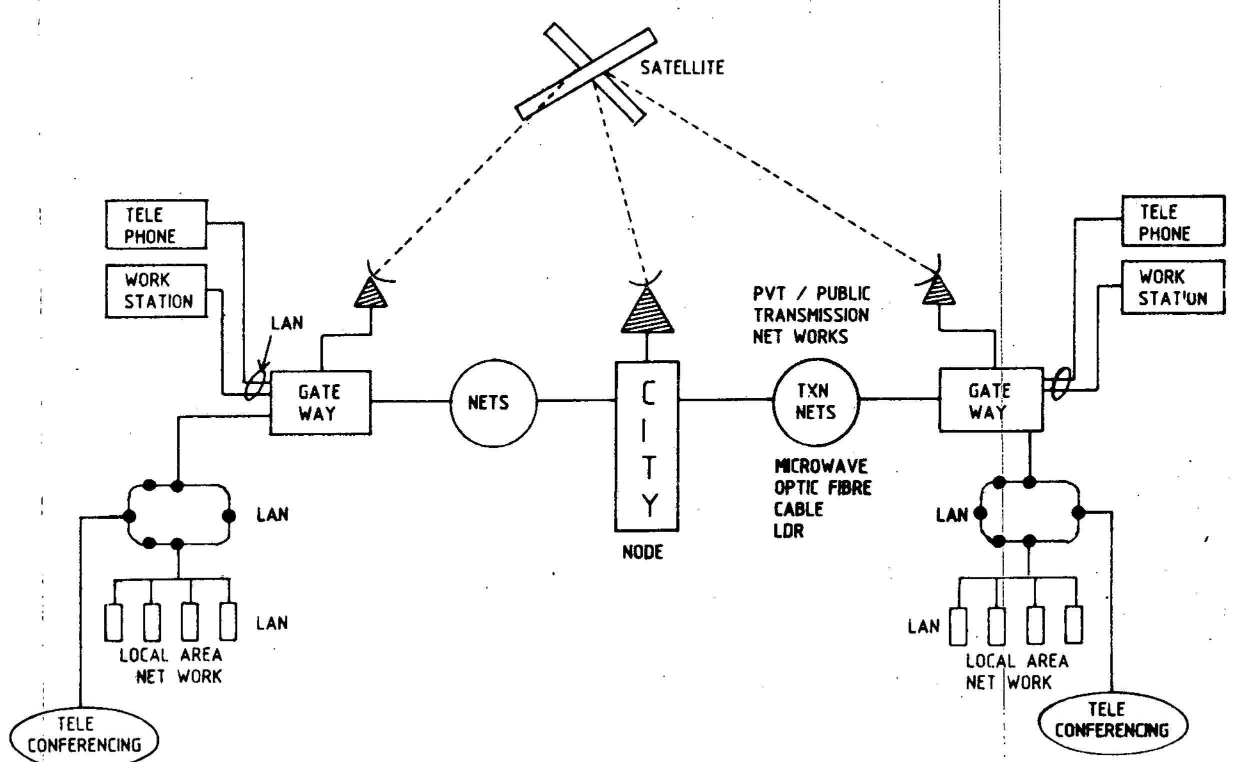

Fig. 6—LAN-MAN-WAN hierarchy

components of the computer-communication interface at the local level.

The hierarchy that we expect to develop, already exists in some measure. There are local area networks or a series of local area networks in various offices. There can be MAN system which is at the level of the city. The same local area network concept within an office or a factory is now getting translated into a wider network at the level of a city as an intra-city network because some of the concepts and the software, in many cases, remain the same. Only the medium of communication changes. For example, for the intra-city NICNET we can try a concept of UHF subscriber radio which also has packet switching, scheduling, routings and things like that in a reasonably intelligent manner.

5.1 VSAT technology trends

VSATs of today are still of the first generation technology. A long line of succeeding generations are sure to come evolving into multi-featured systems with astounding capabilities and highly cost-effective price tag. These new features are likely to be the following: (i) greater RF power generation capability, (ii) more RF bandwidth capability (by frequency re-use), (iii) higher transponder availability and service life, (iv) new technologies that reduce equipment costs, installation costs and maintenance costs, (v) phased-array antennas instead of reflector antennas, (vi) size of the antenna below 1 m even in Ku-band enabling indoor mounting, (vii) produce power at reduced cost, (viii) VSAT transmitters with higher output and power capability while reducing cost, using microwave transistor technology, (ix) use of microwave monolithic integrated circuits (MMICs) for RF stage, (x) integrated chip technology for decreasing size and cost; VLSI electronics for reducing size and cost of base-band portion, and (xi) increase functional flexibility by incorporating powerful microprocessors and digital signal processors replacing analog components.

5.2 Inevitability of the Ka-band

In the C-band and Ku-band, there is a crowding of the parking space in the sky for new satellites and we have international competition. If there are only two or three satellites in geosynchronous orbit over the country, there will be problems of the type we recently encountered with INSAT 1B, 1C and the launching of 1D. To overcome this, a statistically adequate number of satellites should be stationed in the sky. On the conventional path, the cost will be prohibitive and the international bodies will not permit that many satellites in the C-band or Ku-band. These problems can be overcome if the Ka-band satellite option in the 20 to 30 GHz frequency band is taken and the latest technology trends of microsats and VSATs are adopted. The technology of VSAT is less than five years old and the microsat option emerged only last year. Yet, there is no other solution in the long run for the Satcom option for the country. If the two-way micro earth station in the C-band costs around Rs 2 lakhs (not counting duties), the micro earth station of the same capacity in the Ka-band would cost less than Rs one lakh. It has the promise of becoming a consumer product.

In the Ka-band a high frequency is involved; hence a large number of narrow beams can be generated with very small sized satellite antennas. This enables frequency re-use by generation of multiple spot beams, which will bring about a manifold increase in the capacity of the geosynchronous arc.

Rain attenuation is a major factor in the degradation. The rain rate and total rainfall are not uniform over the year. This result in seasonal and divisional variations of rain attenuation. In areas of high rainfall, a typical value of downlink (20 GHz) fade margin required might exceed 20 dB to maintain even a low availability of 99.5%.

To overcome such infrequent but severe rain attenuation, adaptive resource sharing techniques have been demonstrated[8] to be more cost-effective than the conventional counter measure techniques of dedicated resources like power control (fixed fade margin) and site diversity. Adaptive counter measure schemes provide additional gain to overcome rain attenuation only at the time of its occurrence. In addition, they change adaptively with the intensity of attenuation. When there is no fading, these schemes are not introduced, thereby enabling full use of all the resources. Adaptive forward error control coding techniques can also be applied to such resource sharing counter measure schemes.

An interesting possibility in the not-too-distant future is VSAT network without having to have a hub or master earth station. The first general VSAT network having a hub requires a double hop (VSAT-satellite-hub-satellite-VSAT) for a VSAT-to-VSAT communication. With the evolution of higher power satellites and spot beams, direct single hop VSAT-to-VSAT communication would be possible eliminating the hub.

The forerunner for this revolutionary concept is the experimental EMAIL and video-teleconferencing project of the European Space Agency (ESA) conducted by Marconi Space System using a single beam of the Olympus specialised services payload (SSP). The application does not need a hub and the satellite access protocol allows stations in the network to share a 64 kbps channel.

The ESA has also planned a VSAT network in the 20/30 GHz or Ka-band as a point-to-mutli-point system and has been named CODE (cooperative data environment).

Looking further ahead, the introduction of satellites with on-board processing (OBP) will help VSAT networks. Most of the existing communication satellites are relatively passive. No formal processing or switching is done on-board the satellite. In the near future advanced satellites (ADSATS) will have on-board switching, processing, beam hopping, etc. These will be at higher frequencies like in the Ka-band helping to make smaller VSATS. OBP satellites will include, apart from on-board switching, banks of mutli-carrier demodulators among others. They accept a higher interference environment enabling proliferation of VSATs without special constraints. The round trip delays will be halved. Some OBP satellites are expected to be launched by 1995.

6 Evolution of ISDN

ISDN will be the backbone around which the entire compunication infrastructure over the next fifteen years will be developed. While for wide area networks, the evolution will start with narrow band ISDN, the real impact of ISDN will be felt only when broad-band ISDN becomes a reality. The earliest exploitation of the ISDN concept will be in local area networks. A forecast of the fifteen year profile of evolution of ISDN is outlined below[8].

6.1 Basic features and services

ISDN owes is existence to the following two major realisations: (a) Transport of information should be in digitised form to take advantage of economy, transit speed, switching speed, general effectiveness and binary logic behind information handling and processing in computers. (b) Networking and distributed processing of electronic devices of all types and makes are important for the effective usage of information. At present only about 7 per cent of the information available to the average information worker is actually used. ISDN will increase this percentage substantially.

ISDN technology and services will embody the following advantages:

(*i*) *Cost control*—Network resources can be utilised with computer control and flexibility with economy and scale derived from standard equipment.

(*ii*) *Network management*—More powerful, extensive and versatile network management will be facilitated by standard signalling and network management protocols.

(iii) *Coordinated evolution*—The compunication industry will progress through competition, yet with cooperation in a multi-vendor environment with open interface and evolvable protocols.

(iv) Integration of access to a variety of service options.

(v) Limited set of open, standard interfaces.

(vi) End-to-end digital connectivity wherever required including full compatibility with existing analog networks and services.

(vii) Flexibility affords digital telephone networks for integrating various non-voice services. Customers pay only for what they need and the needs can expand or contract when problems due to the large capacity and flexibility of the digital network arise.

(viii) Provision of clear-cut network terminations providing flexible access to all services at low cost; liberalise the terminal market so that the customer is able to pick and choose the most suitable one at the lowest price.

6.2 Evolving features of ISDLAN

Most of the devices and media used in communicating and for processing information, in addition to the various forms like voice, text and images, are mono-functional. Technical incompatibility and lack of integration mean that information has to undergo a great deal of unnecessary conversions from one to another. The service spectrum of the ISDLAN includes standard services like telephone, teletext, telefax, data transmission services with access to circuit switch and packet switch data network, higher level services like videotext and electronic mail for voice and text images.

The basic features of ISDLAN will be the following: (1) Only one switching system in contrast to today's specialised switching systems for voice and text data, (2) Single network where various forms of communication can take place, (3) Communication utilities will be provided at numerous points throughout the inhouse network area or submetro network area which will put an end to the tight locality constraints imposed on terminals and resources at present. This gives a flexibility to re-arrange resources depending upon the volume, and (4) Multi-function terminals which integrate various forms of communication in a hardware network to bring together processing and communication functions as well as to share the use of memory, screen processor, etc.

6.3 OSI seven-layer protocol

Evolving standard of protocol for access to ISDN networks is based on the recommendations of the International Standardisation Organisation (ISO) based on the open system interconnection (OSI) 7-layer model for ISDN network architecture. As shown in Fig. 7, the physical link and the data link layers define the electrical and mechanical aspects of connecting to a physical medium and establish an error free communication path between network nodes over the physical channel. They enable services to connect to a physical medium and to receive data over the physical channel. The upper five layers, called tele-services, are responsible for the higher levels of communication-like setting links between programmes in the different nodes, addressing information ensuring arrival in the right destination, sending data ensuring arrival in the right sequence and providing the user with an interface to the network capabilities.

6.4 ISDN public network

The vision of a universal information service on public networks will call for the evolution of the following eight key features in ISDN:

(i) Adaptive logic provides services giving users voice, data or image services on command.

(ii) Universal standard ports enabling users to plug terminal equipment into networks anywhere.

(iii) Architectural freedom enabling network providers with facilities to concentrate or distribute information processing anywhere and in any convenient configuration without posing problems for the users.

(iv) Integration of access as well as transport making it simpler to send voice, data, image and signalling end to end over common switching and transmission facilities. Integrated software systems will manage network resources, providing band width on demand, meet requirements of any application and manage operations, administration and maintenance.

(v) Wide band access giving users requisite band width for integrated voice, data and image traffic.

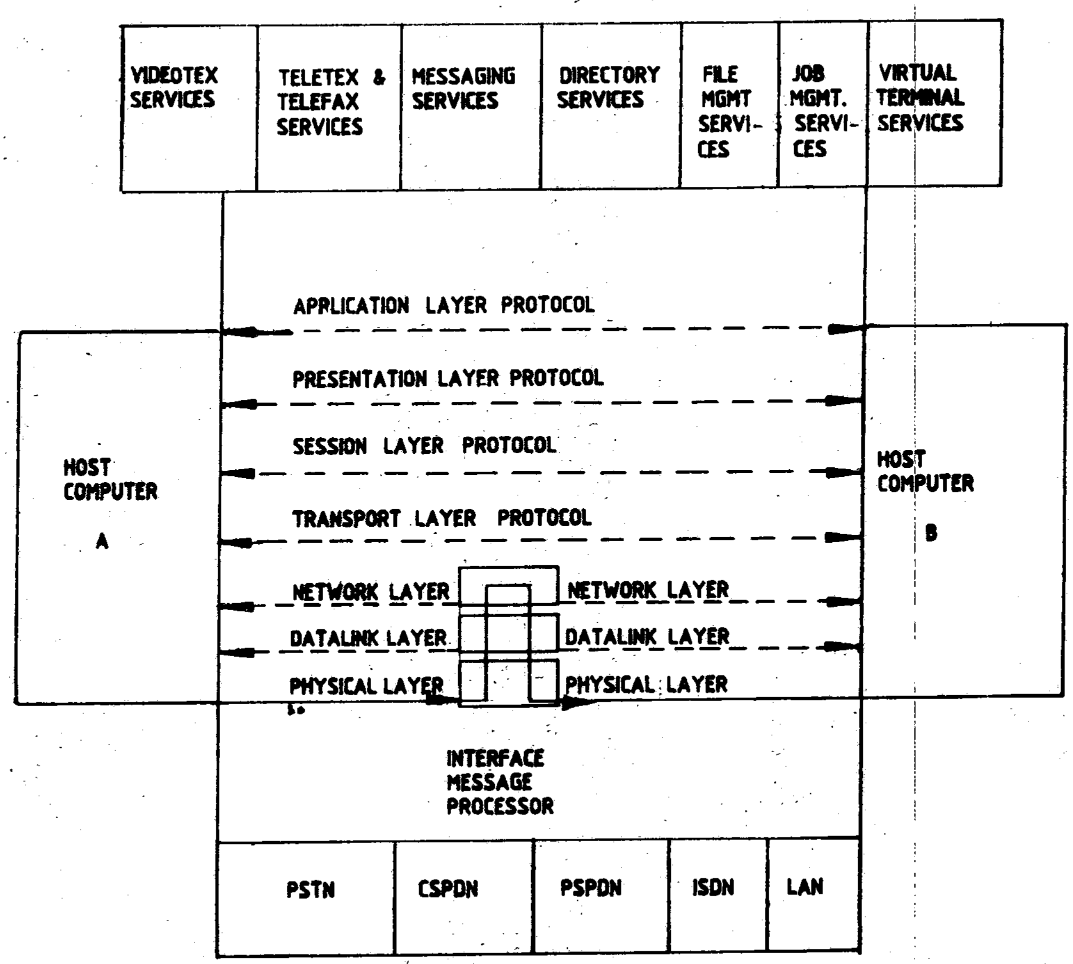

Fig. 7—OSI architecture for global compunication

(vi) Transport efficiency enabling carriers to manage the network with minimal resources.

(vii) Virtually provides networks, provides on demand for supporting specific user applications.

(viii) Use of optical switching by which signals are processed as pulses of light and not converted to electrical form enabling the increase of switching speed from mega bit to giga bit per second. This will enhance the capacity and flexibility of wideband systems.

6.5 Evolution of broadband ISDN (BISDN)

The development of BISDN encompasses four broad categories of services: Interactive, messaging, retrieval and distribution as classified in a self-contained manner in Table 1 (Ref. 9).

7 Switched optical communication system

An amplification of the foregoing paragraphs on switched optical communication systems is a necessity in view of the possibility of increasing switching speed to the giga bit per second (gbps) range so necessary for enhancing the capacity and versatality of wide band systems.

A switched optical communication system within the subscriber loop could have initial transmission capacity of 560 mbps for each subscriber, both business and residential. Such a system can be

Table 1—Evolution of broadband ISDN

ISDN broadband services	Class of services	Form of communication	Type of broadband service
Point-to-point services	Interactive services	Video-com	—Video-telephony —Video-telephone conference —Video-conference —Surveillance —Video/audio transmission
		Data-com	—High-speed data transmission —High-volume file transfer —Computer aided services —Real-time control and telemetry Services for LAN
		Docu-com	—High speed facsimile —Document communication service (text, graphics, audio, images, animation)
	Messaging services	Video-com Docu-com	—Picture mail —Document mail service (text, graphics, images, animation)
	Retrieval service	Videotex Retrieval for text, data, graphics, images, animation	—Broadband videotex —Audio retrieval —High resolution image retrieval —Film retrieval —Document retrieval
Mass media services	Mass media services without user presentation control	Audio broadcasting Television broadcasting	—Radio progrmme broadcasting —TV Programme broadcasting —Enhanced TV, HQTV, 3DTV, HDTV —Pay-TV
		Publishing service	—Electronic newspaper
	Mass media services with user presentation control	Broadcast videography	—Teletext —Cable text

designed to provide any number of service configurations. It is forecast that transmission capacity will be limited to 560 mbps only in 1997 and reach 1 gbps by the first half of the first decade of 21st century.

At Hitachi's Central Research Laboratory, a carrier injuction optical switch form the basis for fabrication of 4×4 switch array for photonic switching applications. Switches are fabricated at 16 locations where one set of four waveguides intersect another set of four waveguides. Each switch consists of a Y-junction optical switch and X-crossing waveguide. Single mode optical waveguide with only one propagation mode has far greater information carrying capacity and speed than a multi-mode fibre. Therefore, they are employed in the newly developed switch array. Large scale integration has been achieved by optical switches having a 'single slip structure' giving rise to what is called the S-cube switch.

As far as photonic switching is concerned, development is still at the experimental stage. However, optical switches are important because they are essential components in an optical communication which will use two-dimensional image processing. The development of the S-cube optical switch and the related packaging technology is an important step towards making the next generation of telecom and computer systems possible.

8 Value added networks

The value added network (VAN) is a communication network which goes beyond simple information transfer and provides some added value.

Examples of VAN in the context of information processing and storage are: to express as data, human interventions that can be handled by data communication; to analyse and recognise the contents of data; to process necessary data in desired form; to select only necessary data from among numerous pieces of information; and to take out necessary data at the requirerd time.

Examples in the context of information processing are: (1) adjustment of communication speeds, compensation for differences in internal codes and adjustments to communication protocol; (2) sending the same data to more than one recipient in broadcasting mode; (3) conversion of formats into forms; and (4) media conversion from coded information to image information and vice versa.

9 Towards integrated mobile communication

Mobile communication equipment of the future consists of not only units individually designed for each system, but also some common units. Communication services for road vehicles, ships, trains and air planes are similar in that they employ concentrated control systems and hence will be integrated at the level of control stations. Full integration of mobile communication system and their digitalisation are expected to be realised in the 90s. The ultimate goal of mobile communication, however, is the portable telephone which may be realised before 1995.

The limited availability of radio spectrum frequencies will force innovations in mobile radio technology which will help improve the efficiency of use and re-use of available frequency bands. One such innovation is the cellular systems using millimetre wave spectrum which permits massive reduction in cell size and promotes the development of micro cellular systems with large user capacity.

Satellite technology has considerably increased the prospects of mobile communication resulting in mobile satellite services of the type provided by INMARSAT.

According to an optimistic forecast, by 2000 A.D. there will be more than 1 billion telephones in the world, half of which connected over radio cellular mobile communication (CMC) and personal communication networks (PCN). In view of the importance and anticipated predominance of these two new services, a brief description of the state-of-the-art and projected technology trends are given below.

9.1 Cellular mobile communication

Bell Laboratories in USA developed cellular technology over the past three decades. Essentially, the cellular system divides the entire service area into a number of cells. Each cell is served by low power base stations. Within the cell low power mobiles can operate and quick processing takes place at a number of locations: mobile, high speed common channel, signalling between the base stations and the mobile and logic function control digital switch. Current features include: (i) prompt use of channels, thereby optimising the frequency specialisation; and (ii) calls are passed between one base station and another when the mobile travels from a base station to the next, thereby enabling a nation-wide service.

9.2 Personal communication network

It is aimed at providing a wide range of services to users with a mobile terminal which is small and of low cost. Integration of a range of services of a cordless office will become possible as soon as a portable terminal is developed which can provide most of the ISDN services. The ultimate global objective is to provide one terminal per person to cover the entire population of the earth. This however would call for numerous innovations in mobile radio technology for coping with the volume of traffic which its likely to be realised by 2005 A.D.

References

1 Kobayashi K, *Computers and Communications—A Vision of C&C* (MIT Press, Cambridge), 1986.

2 Seshagiri N, *Electron Today (India)*, 20 (1987) 45.

3 McLaughlin J F & Antonoff A L, *Mapping the Information Business*, PIRP Research Report (Harvard University, Massachusetts), 1987.

4 Seshagiri N, *IT as a tool for development—Experience with Computer-communication Network and Future Vision*, APO Workshop on Information Technology, Asian Productivity organisation, Kuala Lumpur, 4-7 Dec. 1989.

5 Vijayaditya N, *New teletext services in large metropolis*, Paper presented at the Seminar on the Role of Telematics in National Development, National Telematics Forum, Bombay, 13 Jan. 1990.

6 Seshagiri N, Kutty K K K, Vijayaditya N, Sharma Y K, Bobde D P & Moni M, NICNET—A Hierarchic Distributed Computer Communication Network for Decision Support in the Indian Government, *Proceedings of the International Conference on Computer-communication for Developing Countries* (*CCDC* 87) *ICCC, New Delhi* 27-30 *Oct.* 1987, 367.

7 Seshagiri N, *Proceedings of the Workshop on Very Small Aperture Terminal (VSAT) Technologies* (International Telecom Union, Jakarta), 3-7 July 1989, 67.

8 Otsu Y, Iso Akio & Kido Yoshihisa, *IEEE Trans Aerosp & Electron Syst (USA)*, 22 (1986) 222.

9 CCITT, *Report of the Task Group on ISDN Broadband Aspects*, CCITT Study Group XVIII, (International Telecommunication Union, Switzerland), 1985.