Rural Communications in India Using Fixed Cellular Radio Systems

Seventy-five percent of India's population is in rural villages, yet almost 90 percent of the country's phones are in urban sites. The authors propose a fixed cellular radio system, combined with the existing mobile network, as a cost effective way to extend telecommunications services to India's rural areas.

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The population of India is 850 million: second largest population in the world. Nearly 75 percent of the people of India live in 575,000 villages. Presently, India has less than 10 million telephones, of which 90 percent are in urban zones [12]. Thus, the largest part of the Indian population living in villages is deprived of a telecommunications facility. The overall growth of any country in this modern technological structure entirely depends on its telecommunications facilities. Therefore, it is necessary that proper telecommunications systems should be developed in India for rural zones as well. The telecommunications system should be planned such that it puts a minimum financial burden on the Government. Considering this point, a fixed cellular radio system is proposed. Using the proposed system, a telephone facility can be provided with limited economical means in a rural area.

Because of the fixed position of the "outstation," cell sizes can be increased to cover a radio range in the order of greater than or equal to 50 km. The cellular fixed radio can be combined with the existing mobile network to reduce initial costs. The fixed cellular system can be used by adapting and/or simplifying the already developed cellular mobile transceivers. Thus it may save the cost of developing and manufacturing of new radio equipment for the terminals. A fixed cellular radio system is not a completely new concept. It is already in practice in several countries for rural communications. The concept of a fixed rural radio systems has been discussed in numerous papers and several companies supply these systems. However a serious comparison of these systems with the classical point-to-multi-point systems is still necessary.

The main purpose of this article is to give a wider publicity of using a fixed cellular system for providing telecommunication facilities to rural people in developing countries including India. Although this topic has been discussed in several conferences and many national and international telecommunication organizations, no step has been taken by the telecommunications authorities. This article presents both the economical and technical aspects.

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Background

Rural communications, especially in developing countries, has been a topic of discussion for quite some time [1-15]. Different solutions have been presented. But none have really solved the problem. The need for communications in rural areas in developing countries has been agreed upon in many studies, in which arguments used include: national integration of remote areas, reduction of the need to travel, emergencies, catalyzer, and tool for rural development, and support for trade and tourism. Chowdary sums up why access to rural telecommunications in India is desirable and justified [8].

- Distribution of the benefits of science and technology to all sections of the society, including people removed from urban habitations and activities.
- An instrument enabling rural people to be drawn into economic activities and exchanges on an extended scale.
- Conferring beneficial marketing for the agricultural surpluses being brought about by improved scientific and irrigated farming.
- Reducing the isolation from the educated sons who had migrated to the cities, distant towns and lands.

Rural telephony must be looked upon as a development tool, and not as a commercial service. We have to induce demand as well as meet it innovatively and beneficially.

The main issue however is: can rural areas in developing countries be cost effectively covered? The provision of rural telecommunications is often a high cost, low revenue business. A small proportion of the total amount of subscribers can be a

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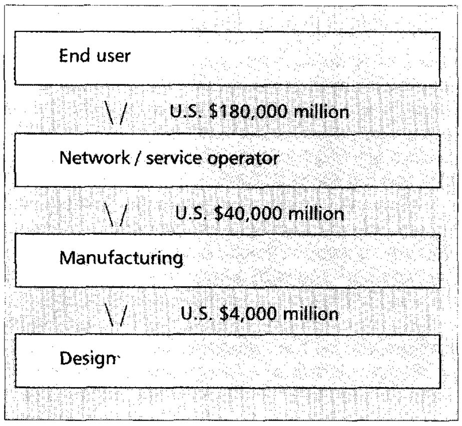

■ **Figure 1.** *Revenue chain of telecommunication procurement in Europe.*

large burden on the backs of public telecommunication operators (PTO). The high cost of "wiring and rewiring" service areas has been cited as a major reason for low penetration of telecommunication networks in rural areas (World Bank statistics) [2]. Other reasons are: low telephone demand, low utilization, dispersed subscribers, difficult terrain and remoteness from the national network, and low generated revenues [5].

One of the reasons for low revenues is the lack of proper maintenance and hence a low grade or even lack of service. This results in poor availability of the systems. Initial subscribers, often people in business and government, that have a real interest in using telecommunication services, are turned away and will be looking for other ways to solve their needs. So by providing a bad service at a high cost, the necessary revenues are difficult to generate and through a consequent lack of demand, services can not be provided in a profitable way.

Radio-based technology has been developed to overcome some of the above-mentioned problems. This article discusses the use of advanced radio technologies—cellular radio systems with fixed rural subscribers. A comparison has been made with existing rural radio systems. Also the migration from analog systems to digital systems has been discussed.

Cost of Rural Subscriber Access

General Remarks

In discussions about the cost of providing telecommunications facilities to rural areas confusion exists about who is paying what. We, first of all, analyze the value chain for providing rural telecommunications. This chain starts at the manufacturing part, then the operator comes into play and finally it is the rural subscriber who has to pay the telephone bill. The price a manufacturer covers for the equipment has several elements: a pure equipment manufacturing cost element, a quantity element, and also a lot of commercial and marketing oriented aspects. It is very difficult to get price information from manufacturers as they will respond with the following questions: how many lines do you need, for which country, what project etc.? A distinction can also be made between per-line costs, common costs, and marginal costs [16]. The next step is to install and commission the equipment. Most of the work is done by the operator; but the manufacturers are also involved. A large proportion of the operator's expenses is spent on providing transport and housing and/or shelter for the equipment. Of special interest is not only the subscriber density as is often used in models of rural areas, but also the so-called grouping factor for rural subscribers; how many subscribers can be served by one access point.

And after having installed the equipment, operation and maintenance costs have to be considered. This part of the value chain is very much dependent of the local situation and can vary considerably.

Finally, we come to the rural subscriber and the amount of money he has to pay for the telephone service. That depends on many different factors related to local government or operators policy, e.g., cross subsidization policy, loan or grants conditions by international institutions, the way investments are accounted for, rate of return on investment used and depreciation rate, existing infrastructures, etc. And last but not least, the foreign currency situation of a country plays an important role, as much of the equipment has to be imported and paid for in a convertible currency.

Exact data are difficult to be found. But to get an idea of the relative values we can look at the revenue chain for general telecommunications procurement in Europe (Fig. 1). Here we see that the major amount of money flows from the end user to the service providers. And although the situation in other continents may be different, it gives an indication of where the focus must be given in discussing possibilities of providing rural telecommunications. Manufacturing prices only give a bleak indication of what the real costs are.

In conclusion, one can say that in discussions about cost of a rural telephone line per subscriber, we have to establish clear conditions and to agree on realistic models. Only then we can make meaningful comparisons between different solutions. In this article, however, we keep on using the "cost to operator" as we have no other model so far.

Comparing Wire and Radio

The use of wirelines in rural telecommunications has been considered as a barrier for rural telecommunication growth [4]. Some arguments are:

- Worldwide average cost of copper service at U.S. $2000 per subscriber (World Bank statistics) is high and stable.
- Wirelines pose physical and geographical limits.
- Wirelines are less flexible and create difficulties in long term planning.

A price comparison for an U.S. urban area [2] indicates that over the time span 1990-1996 the wire cost will stay stable at approximately U.S. $800 per subscriber and the cost per subscriber of cellular radio local loop provision will go down in that period from U.S. $1,000 to $700.

With radio-based technologies the initial investments are lower. Only the handset is a fixed cost per subscriber. The network can be dimensioned towards "day one traffic," further growing can be paced according to demand. This is important for developing countries where funds are particularly limited. Another option is in initial limited fixed

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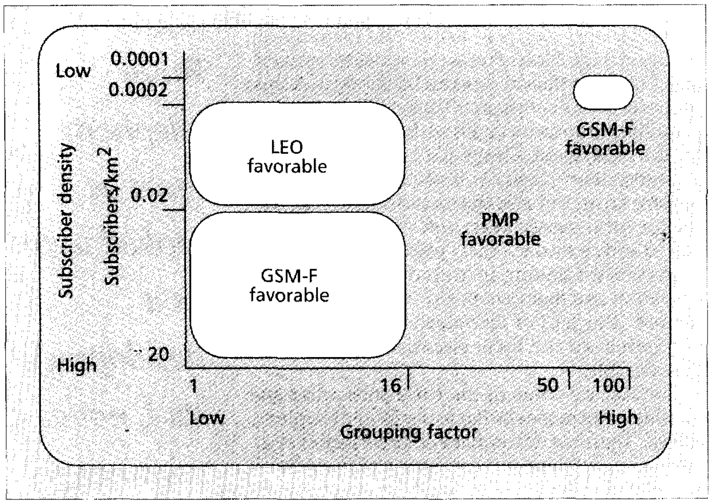

■ **Figure 2.** *Preferred areas of different systems [9].*

(stationary) voice service, with later extension to data and mobile service. In this way infrastructure investments can be phased [3].

Many manufacturers are offering now solutions with relatively cheap and small subscriber terminals for internal desk or wall mounting. These systems are not only offered for use in the developing countries but are specifically aimed at rapid and flexible provision of telephone services in central Europe. This makes it even more attractive for use in developing countries because prices will go down when higher production volumes emerge. Another favorable aspect for radio systems is maintenance cost. Radio systems are more reliable and radio base stations can be positioned at relatively safe places (e.g., government buildings) to prevent tampering. Maintenance and fault diagnosis can be remotely done through more sophisticated systems [3, 10]. Personnel with higher skills are needed in that case but less of them can cover a larger area.

Comparing Different Radio Technologies

Diaz-Hernandez [9] makes an interesting comparative analysis of different radio technologies for rural communications.

Systems compared were a digital multiple access radio point-to-multipoint (PMP) system, a cellular mobile GSM system with fixed subscribers (GSM-F) and a low earth orbit (LEO) multi-satellite (48) system GLOBALSTAR (LEO). Low earth orbiting satellite systems have gained increased attention for use in rural areas in developing countries. One of the main contenders is the Iridium system with 66 microsats.

Their impact was analyzed for three scenarios: years 1992-93, 1992-97, and 2000. The study was done with an application example in a typical rural area focussed on the access network segment of the GSM-F, LEO and PMP technologies.

Uniform subscriber distribution was assumed, with subscriber densities from 1 subscriber per 10,000 square kilometers to 20 subscribers per square kilometers. The following subscriber grouping factors were used: 1, 8, 16, 50 and 100 subscribers per point. The 1992-3 and 1996-7 scenarios are both a comparative analysis of GSM-F and PMP technologies. In the later scenario, the cost of equipment is reduced by 30 percent, and the cost line transmission and infrastructure is considered to be the unchanged. The scenario 2000 includes the LEO technology which will probably enter to provide service around the year 2000.

The results of the analysis for the first two scenarios indicate that GSM is favorable considering cost for subscriber densities higher than 0.02 subscribers/km^2 and with a grouping factor less than 16. The PMP system can provide cost advantage with subscriber density from 0.0001 to 0.02 subscribers/km^2, with any grouping factor, and from 0.02 to 20 subscribers/km^2 with a grouping factor of more than about 16. There is a small group of subscribers: very low density ($<$ 0.0002 subscribers/km^2), but high grouping ($>$ 50) where GSM is still favorable. The scenario for the year 2000 positions LEO between GSM and PMP. LEO will provide cost advantage for densities lower than 0.02 subscribers/km^2 and grouping lower than approx. 16. Figure 2 gives a summary of these findings.

According to this study [9] the trend will be that for rural areas with a low grouping factor GSM-F and LEO technologies will grow and PMP will decrease for next generations. The PMP technology will continue to offer the most cost-effective services within rural areas that have moderate to higher grouping factors ($>$ 16).

Radio Technology

Radio technology has been applied in rural telecommunications for some time now. Analog point-to-multipoint (PMP) systems are provided on the market by most manufacturers of telecommunication equipment. Cost per subscribers has come down to approximately U.S. $2,000. New markets have been opened in Eastern Europe where PMP systems are now used not only in remote areas for local access, but also in semi-urban areas, such as the so-called radio in the local loop. The suitability of these technologies lies in the speed at which local radio distribution can be provided. This is likely to be perceived to offer a significant advantage. Radio systems can compete with conventional copper wire links on the following grounds: initial cost, installation time, flexibility, adaptability to terrain, reusability of equipment, and maintenance cost.

Fixed Cellular

However, cost is probably still too high for rural areas in developing countries. Therefore another solution has been proposed and implemented [1, 5, 6]: the use of existing cellular mobile telecommunication systems (CMTS) with fixed rural subscribers (CMTS-F). Rural subscribers in the vicinity (distance $<$ 50km) of large urban areas and roads could be connected to a CMTS and use the excess capacity of that system. Main advantage is the sharing of cost of installation, operation and maintenance. In this way the relatively prosperous mobile subscriber will subsidize the indigent rural subscriber also by providing the incentives for investments. Also, there will be the combined use of the frequency spectrum, that is already allocated to the mobile system. Initial users will be police, hospitals, ambulance and other emergency services, gas stations and public call offices (PCO) or coin box telephones.

Manufacturer, type	System	Freq MHz	Terminal	Max. Distance	PCO interface
NEC, DRMASS	PMP	1500-2600	Wall/pole mount	<45 km	yes
TRT, IRT2000, Microstation	PMP	1500-2500	Wall mount	?	?
Ericsson, RAS1000	PMP	380-500 or 800-1000	Table model	<80 km	no
Tadicom, TADiCell	PMP	824-878	Wall mount	<10 km (<20km)	no
InterDigital, UltraPhone 100i	PMP	450-460	Wall/pole mount	<60 km	yes
Ericsson, ATUR	NMT, cellular	450-470	Wall/pole mount	*	yes
Nokia, WLL	NMT, cellular	450-470, 900-960	Table	*	no
Codecom, TEL-CEL 200	AMPS, NMT, ETACS, cellular	820-890, 450-470, 870-950	Wall mount	*	yes
Novatel, SCS-Libra, suppl. cellular system	AMPS, cellular	820-890	Mobile	*	No
Siemens, GSM PCO	GSM	905-960	Wall mount	*	yes
JRC, Sud 401	Proprietary cellular	400	Table, mobile	30-50 km	no

* Depending on designed cellular coverage.

■ **Table 1.** *Single subscriber radio systems.*

Evolution of Systems

In the design of rural telecommunication systems the main consideration is for: cost, noise, coverage, switch capacity, reliability and transmission cost [1].

There has been a tendency to over emphasize the role of switching with rural telecommunications. But in the rural areas, transmission is even more important, especially if direct dialing is to be given and reliability and satisfactory quality are to be ensured. There is even greater need for R & D of transmission systems appropriate to rural areas [8].

For many years radio systems have played an important role to provide telephone services to subscribers at remote locations. The earlier systems were using VHF\UHF narrowband FM single channel radio.

Later on, some ten years ago, PMP systems using FDM and TDMA were successfully introduced. They provided a major improvement compared to the older systems and gave an almost transparent connection into the national and international network. Recently a new class of digital TDMA radio systems has come to the market (main suppliers are TRT, NEC, SRT and Alcatel) with an improving performance-to-cost ratio [5, 11]. These systems can not only provide high quality voice and data telecommunication services but will be able to provide interconnection to ISDN.

The available systems can provide services to a wide range of small to large subscriber groups. Low capacity systems have 10 to 15 trunks and have served groupings of approximately 100 subscribers. Higher capacity systems have become available with 30 to 60 trunks that can provide service to approximately 1,000 subscribers.

Small Systems

All these systems have in common that they can provide rural service in a cost effective way only to relatively large groups of subscribers.

Especially for small villages in developing countries there is still an initial need to provide service to a very limited amount of subscribers. When we try to add up the most likely first subscribers we do not get more than about four, e.g., a public call office (PCO) or other type of community telephone, a government/police post, a health care center and one merchant. Some of the modern systems can hardly provide cost effective service to such small groups of subscribers. Therefore new radio systems are emerging that can connect single subscribers in a cost effective way. These systems rely on self-contained, small and low cost radio terminals at the subscribers premises. Some systems are further development of the "classical" PMP systems, such as the TRT IRT2000 microstations. InterDigital has introduced its Ultraphone 100 system mainly in rural areas in the United States. Others make use of cellular radio systems originally designed for mobile subscribers. Table 1 summarizes the "single subscriber" systems with their main characteristics.

Terminals

The terminal that is used in these systems is sometimes contained in a small flat box, with a short whip antenna that can be placed under and connected to a standard telephone set. Others provide a wall or pole mounted box with an attached antenna and a normal connection for a telephone set. The systems that work in a mobile cellular network mostly use a commercial mobile transceiver without a handset and a battery. They are equipped with an adapter unit to provide an interface to an ordinary telephone set, fax machine, or modem. These adapters provide

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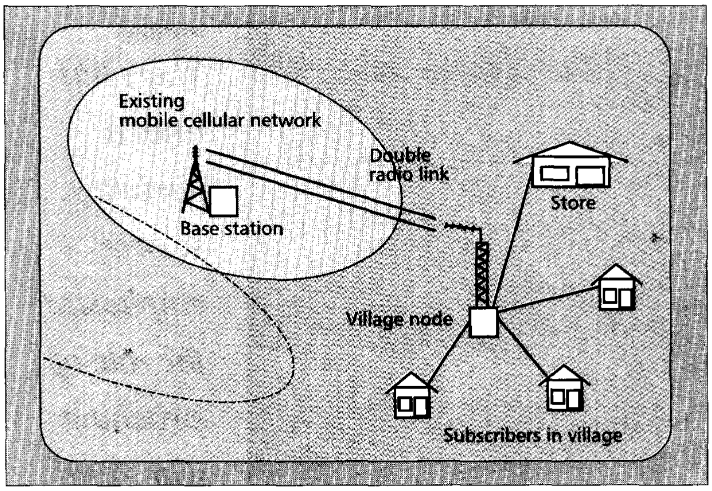


■ **Figure 3.** *Overview village telecommunications system.*

for four-wire to two-wire conversion, support for ground or loop start, pulse or tone detection, ringing current, and power supply with internal back-up in case of power interruptions.

Some of the systems are equipped with a more sophisticated interface unit for connection to a PCO. They have to provide tariffing signaling, answer detection and different types of other signaling to the pay phone. Sometimes an internal modem is added so that the stored tariffing information can be modified remotely from an O&M center.

Fixed Cellular Radio Systems

Cellular Mobile Basics — The basic design ideas for cellular radio telephone systems are: high capacity, large number of subscribers, relatively low-powered base stations, and reuse of frequencies, resulting in small cells (>10 km radius) [1].

Cellular radio gives: repeated use of frequency, increase in system capacity and channel assignment on demand [4]. It is a means of providing high density communications without consuming large amounts of spectrum (frequency reuse) [2]. Competition is now taking place between ADC American digital cellular versus Groupe Speciale Mobile (GSM). Which system will give more increase in capacity through the use of digital techniques, TDMA or CDMA [2]?

Comparison Between Fixed and Mobile Cellular — Advantages of Fixed Cellular Systems to Mobile [4]:
- Simpler logic unit -> lower cost radio
- No handoff -> simpler and cheaper switching
- High antenna's permit line of sight links and less propagation loss
- Lack of motion no short-term multipath fading -> smaller S/I requirements
- Directional antennas give increased frequency reuse and capacity.

Cellular networks in rural areas for fixed subscribers can be provided with reduced cell site costs because of less equipment is required (no handoff and Raleigh fading) [1].

Coverage — Fixed cellular systems can have a maximum cell radius of > 60 km. Because of the radio horizon effect, there will be less co-channel interference. This leads to a minimum co-channel separation (D/R value of 3 might be sufficient) [4, 17]. Here, D is the distance between the centers of the nearest neighboring co-channel cells and R is the cell radius.

Capacity — Cellular mobile systems normally provide ample capacity. Average rural traffic (developed world) is estimated at 0.25 E/Sq.km. This traffic level can easily be provided by radio systems [3]. However when systems are designed for thin route coverage along highways, special care has to be taken in the traffic capacity design to provide for the ability to mix different traffic patterns. Fixed subscribers can have a completely distinct traffic pattern from a mobile subscriber. This is for instance the case when a PCO in a village is connected. Traffic generated from a pay phone can be quite high (0.25 E).

Digital vs. Analog Radio Systems — Digital cellular systems are more advantageous than current analog types because of [3]:
- Cheaper than analog through VLSI.
- More efficient spectrum use through TDMA [2 to 3 times]. (American CDMA even more efficient?).

Digital cellular radio means not only voice but also easy data. Even ISDN is possible. Digital radio provides reasonable inherent security from eavesdropping and unauthorized line use.

Advantages of Digital vs. Analog

Digital:
- Prices are going down through mass production.
- Equipment more compact through VLSI.
- More efficient use of radio spectrum.
- Higher transmission quality.
- Data service possible without modem [3].

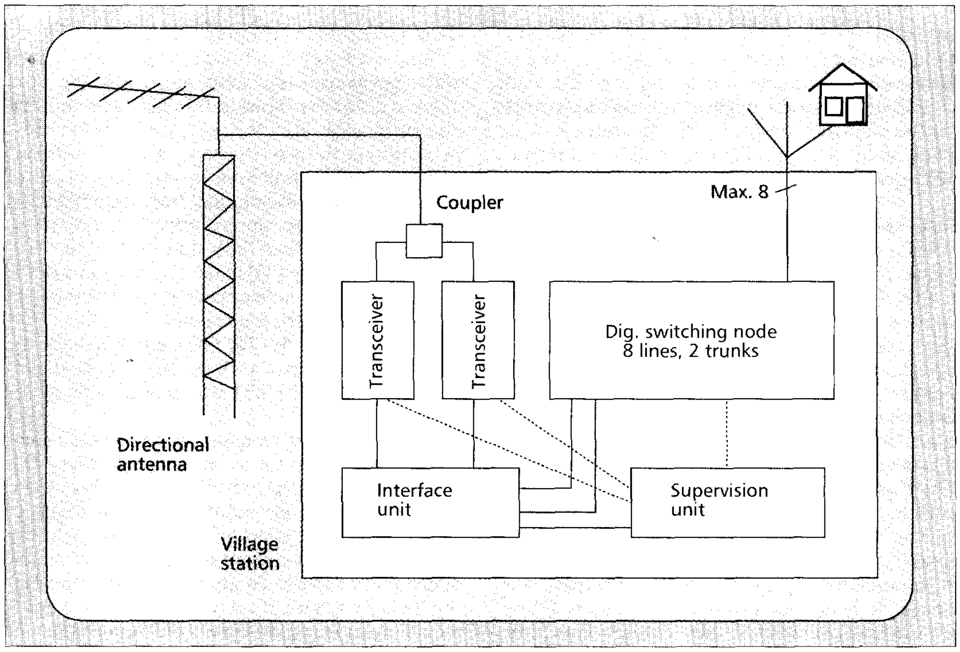
Analog:
- It is available now.
- It will remain cheaper for next two to three years.
- Maximum radius is larger because of lack of equalization transmission delays [3].

Description of Existing Systems

Malaysia — Malaysia has pioneered the concept of using the mobile telephone system to provide telephone service to rural areas via coin collecting box (CCB) public telephones. A special radio interface unit was developed by Ericsson for Malaysia which makes it possible to connect the standard CCB telephone to the Automatic Telephone Using Radio (ATUR) network and thereby eliminate the physical wire connection. There are approximately 200 CCBs in operation.

The distance from the coinbox telephone to the radio unit can be 2 km. Antennas can thus be mounted on a nearby hill or high building. Power comes from the main supply or from solar-powered batteries. The transceiver is connected to a directional Yagi antenna, so that the unit can be placed even further away from the base station site than is possible for normal mobile telephones.

Saudi Arabia — In an article describing the telecommunication development in Saudi Arabia, including the automatic mobile telephone system, a case study



■ **Figure 4.** *Village terminal.*

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is mentioned for the installation of a combination of fixed rural subscribers and the mobile cellular system [5].

Rural Communications Project for India

In India, 575,000 sparsely populated villages are geographically spread over vast distances. Less than 10 percent have telephone service limited to small electro-mechanical exchanges of 25 to 100 lines or with Long Distance Call Offices. The following facts relate to rural telecoms in India [4, 14]:

- 500,000 Indian villages do not have access to POTS.
- 75 percent of the Indian population is rural with about 10 percent of the total telephones in the country.
- Telephone penetration in rural areas is very low with a value < 0.2 per 100 (0.5/100 average for the whole country).

Indian Village Network

Initial Conditions — In the near future, we may not expect many domestic subscribers in Indian villages because of the very limited financial capacity of most villagers. Most initial subscribers will be found among government/police posts, small medical posts/hospitals, store owners, and some pay phone/PCO. Thus we expect an initial demand of approximately four-to-eight subscribers per village. The design of a village telephone system has to be cost effective for such a small amount of subscribers. Therefore, a concept is chosen that relies on modern but simple digital switching technology for the small "village exchange" and for the use of fixed cellular technology for the connection to the outside world (Fig. 3).

System Concept — Figure 3 illustrates a village telecommunications system and a typical village terminal is shown in Fig. 4. The system consists basically of a small local switching node to which a maximum of eight subscribers can be connected. The system is self-contained and does not need external control for the completion of local calls. Service to the outside world is provided by two fixed cellular connections through two radio transceivers connecting to an existing mobile cellular network. These radio connections are used as trunks. No changes or adaptations will be needed on the mobile system. All necessary adaptations can be implemented on the village system side.

The two transceivers can share the antenna system. The use of two transceivers brings two main advantages: improved availability of the system and higher capacity. Of course, there is also a disadvantage of an increase in cost. However, especially the higher availability is of prime importance in a rural area in a developing country like India. In case of failure of one of the transceivers, there will be a "graceful" degradation of service, without complete isolation of the system. This also permits uninterrupted access for centralized maintenance and service restoration purposes.

Capacity and Grade of Service — For the design of a rural village telecommunications system, one has to find a balance between cost, capacity, and grade of service. To determine the grade of service that can be provided at a reasonable cost it is also necessary to have proper data on subscriber behavior. These data are not readily available, but on the basis of research from India [15] we can say that with an estimated amount of traffic of 0.05 erlang per subscriber the system can accommodate seven subscribers on two outgoing lines with a five percent loss of traffic. Village traffic is not affected by external congestion, as it is handled by the local switching node. The effects of congestion on the external lines can also be alleviated by features of the local switching node like

In order to offer a grade of service that does not differ too much from the urban areas, special measures must be taken to improve and simplify maintenance.

automatic queuing of trunk calls, automatic call-back, emergency seizure of trunks, and call timing. When a PCO with a relatively higher traffic load should be connected, it might be advisable to provide it with a radio transceiver and interface set of its own. These systems are available from different manufacturers.

Terminal Design — Connection to the outside world is made through two radio transceivers that can connect to an existing mobile cellular radio system. The transceivers are modified local cellular standard transceivers. The modification enables the extraction of signals to provide inputs to the Interface unit. These are the four-wire speech signals, dialing signals, and hook signal. Also some modification of the software is necessary to make the called number information and other signaling accessible during the call set-up process. The transceivers are connected to an interface unit that brings together the different signaling formats and protocols of the transceivers and the digital switching node. This node can provide access for a maximum of eight subscribers. The call handling is completely autonomous at the village level. There are two trunk lines implemented for connection to the interface unit. The node has many features to be found in modern exchanges likes automatic call-back, priority queuing, call timing, and emergency break-in which are especially useful when congestion conditions exist at the outside lines. Last but not least, there is a supervisory unit that takes care of all supervision and maintenance functions for the village station. It keeps contact with a central maintenance unit and preprocesses the relevant local information.

In the design attention is paid to low power consumption so, depending on local power supply conditions, solar powering can be considered for this station.

Maintenance

Rural Context for Maintenance

Providing a technical "solution" to the rural telecommunications problem for developing countries is one thing. To provide a satisfactory solution is something else.

In many reports the importance of telecommunication for rural development is stressed. However, little is said about the demotivating effect that results from the provision of a new telephone facility that breaks down after a few months and is often only available for operation after many months.

Apart from the loss of revenues when a system is unavailable, one has to consider also the indirect effects of a unreliable network. When people cannot rely on a working telephone system, they can hardly be persuaded to use it and pay for the subscription. They will not start any activities in which they become dependent on telecommunications and the often expected economical stimulus of the introduction of telecommunication services is nullified.

The rural environment, in many developing countries in particular, puts a lot of stress on equipment. There are not only the harsh climatological conditions that influence the availability of telecommunication equipment. Failure of power systems and unforeseen human interventions also cause interruptions of operation.

And when a system breaks down, maintenance and repair is hard to get. Centers of maintenance are at great distances. Transport facilities are limited and rural areas are often very difficult to access in certain periods of the year. Also, the limited skills of field technicians and the lack of spare parts, proper documentation, test equipment and other maintenance support impede rapid repair. Hence, the Mean Time To Restore (MTTR) or Time of Non-availability (Ti) in developing countries is quite long and in no way comparable to those in the western industrialized countries.

To calculate the MTTR, one has to add the actual Mean Time to Repair with the Mean Time due to Logistics (MTL). The MTL is in many cases the determining factor.

When designing an appropriate rural telecommunication system for developing countries, with the required high level of availability, one has to take in account the special conditions mentioned before.

The equipment must be designed for high reliability. It should be more reliable than ordinary telecommunications equipment, considering that the higher costs involved will pay back through a reduction of maintenance costs and higher revenues. This high reliability can be achieved by careful selection of components, conservative design of circuits, use of inherently trouble free IC families, doubling of vital circuits, spacious lay-outing of printed circuit boards, the use of robust enclosures, low energy consumption design and, last but not least, careful thermal design, to avoid any need of air conditioning equipment. Improving reliability alone is not enough. The MTTR has also to be reduced by all means.

Maintenance Features for Improved MTTR

Remote Monitoring and Diagnostics — Nodes in a rural system have to communicate with a maintenance center and will have to signal not only that something went wrong, but preferably also what module(s) is(are) causing trouble. This permits a maintenance crew to come well prepared at the site.

Controlled Shutdown and Auto-Reconfiguration — A well behaving node should try to shut down step by step, possibly permitting operation with a limited grade of service through reconfiguration. In case of detected software malfunctioning the node will try to restart with internal or external reloading of software.

Auto Diagnostics and Repair Assistance — During repair the built-in node software and supervision and maintenance module has to assist technicians as much as possible in clearing the faults.

A New Approach to Maintenance

A telephone system should be able to cope with several constraints imposed not only by its (future) users and the technical possibilities but also by the characteristics of the area of operation. Some of the particular constraints on telephone systems in rural areas that have to be dealt with are:

- Continuity of service and maintenance in exigent circumstances.
- The unattended operation of the rural system nodes.

• The lack of skilled personnel.

In order to offer a grade of service that does not differ too much from those in urban areas, special measures have to be taken to improve and simplify maintenance. Construction and maintenance operations should be supported by a modular design of switching nodes. Moreover it should be possible to have access to reports on nodal functioning in a remote Operations and Maintenance Center (OMC). To enhance maintenance procedures, these reports should not only instruct on what module has to be replaced but also give information on the future repair of the malfunctioning module.

Even more important are immediate service restoring actions taken in the occurrence of a malfunction. As the majority of calls will have a local nature, a partially operational node is more preferable to the subscribers then a non-operational node.

Due to the unattended operation of the nodes and the lack of trained personnel all maintenance actions, except for the actual module exchange and repair, should be executed automatically. This poses a requirement for monitoring, diagnosis, and control facilities.

Conclusions

This article proposes a telecommunication system for rural India that can be used for any other developing country as well. Furthermore, it is shown that it is possible to provide a cost-effective telecommunications solution for a rural village in India using a fixed cellular radio system. This solution makes use of the capacity of an existing mobile cellular network of which the investment cost can be spread over a large amount of subscribers with a higher financial capacity than the average village dweller.

The grade of service that can be provided is not the highest available, but under the circumstances acceptable. In particular as some features have been implemented to guarantee fair access to the trunk lines. Through the design of the village station with a double radio transceiver, the availability of an outside connection is improved substantially and also the access from a central maintenance center is better guaranteed.

The proposed system can readily be implemented on existing standard analog mobile cellular radio systems. However, further study is recommended to look into possibilities of the use with digital mobile systems as a promising reduction of system cost can be achieved.

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Further study is recommended to examine the possibilities of using digital mobile systems to reduce system costs.