Comparison of Price/Performance Ratios of Various Digital Transmission Systems

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Introduction

In the last decade the telecommunications infrastructure has become a major factor in the economical growth of each country.

Advanced national economies have developed many new telecoms services, which is basically due to the strong market demand and the technology progress. Common characteristics of the new services are: a comparatively big share of video and data transmission as well as a growing use of personal computers. The latter has been particularly encouraged by achievements in the computer industry and the popularization of the Internet.

The Yugoslav market is also turning to new telecoms services. However, due to on-going economic crisis in this country, the strongest demand is for development of the PSTN and increased number of subscribers.

A special field in development of telecommunications, globally and particularly in this country, are rural communications. Total benefit from the economical development of rural regions is much more significant than the profits from the telecoms services there. This is why a special attention is focused on development of telecoms services in the rural areas [1].

Transmission systems are essential in the telecoms infrastructure. There are three basic solutions: copper wire cable, optical fiber cable and point-to-point radio links (Fig. 1). There is always a dilemma which solution to choose as each has its advantages and drawbacks that should be considered before a final decision is made. The intention of this paper is to point out the most important facts that should be taken into consideration.

Copper wire cable

Copper wire cable was the first solution used for deploying communications networks. Nowadays there is a developed cabled network.

There are two types of copper cables: twisted pairs and coaxial cables.

Because of its drastically lower cost, the twisted pairs have much wider application. They are used for deploying subscribers' networks and transmission routes of lower data rate (typically up to 2Mbps per a twisted pair - in one direction). On the other hand, coaxial cables are mainly used for higher capacity routes (8Mbps, 34Mbps or more). In recent years, twisted pairs (cables of category 5) are used to support local area networks of 100Mbps rate, but of short distance (several tens of meters).

Traditionally, digital cable transmission in base band is realized by application of an appropriate line code [2]. Maximum distance between the digital signal repeaters depends on the cable characteristics: wire diameter, way of pair twisting and the insulation - they all influence the characteristic impedance, attenuation and cross talk. These magnitudes are the functions of frequency and cable length so that adaptive equalization is necessary. A typical maximum distance between repeaters is two to four kilometers. The repeaters are powered through the so-called phantom lead (from a DC source) so that they need no additional wires. There are several producers of telecommunication equipment for cable transmission in Yugoslavia.

In order to increase distance between repeaters and the binary rate, techniques of trellis coded modulation (HDSL CAP modem) have been employed recently. For example, through existing copper twisted pairs of 1.2mm diameter and 2Mbps rate, with a HDSL device it is possible to span the distance of 9km, while this distance at the rate of 8Mbps is 3.5km.

One of drawbacks of cable transmission is sensitivity to disturbances. This can be reduced by various techniques of cable protection and by careful selection of place of deployment.

Since the price of cable installation is very near the price of optical fiber and the capacity of the latter is incomparably higher, deployment of new twisted pairs is avoided nowadays; instead, the existing cable installations are being restored and their capacities increased by application of new transmission techniques (e.g. subscribers' lines are used for 2Mbps data transmission).

Optical fiber

Optical fibers are a transmission medium of an extremely high capacity, which is their main advantage over the other transmission media. Transmission systems of up to 2.3Gbps per a single fiber are in use today while the experiments are being conducted with rates over 10Gbps [3]. Other important advantages are:

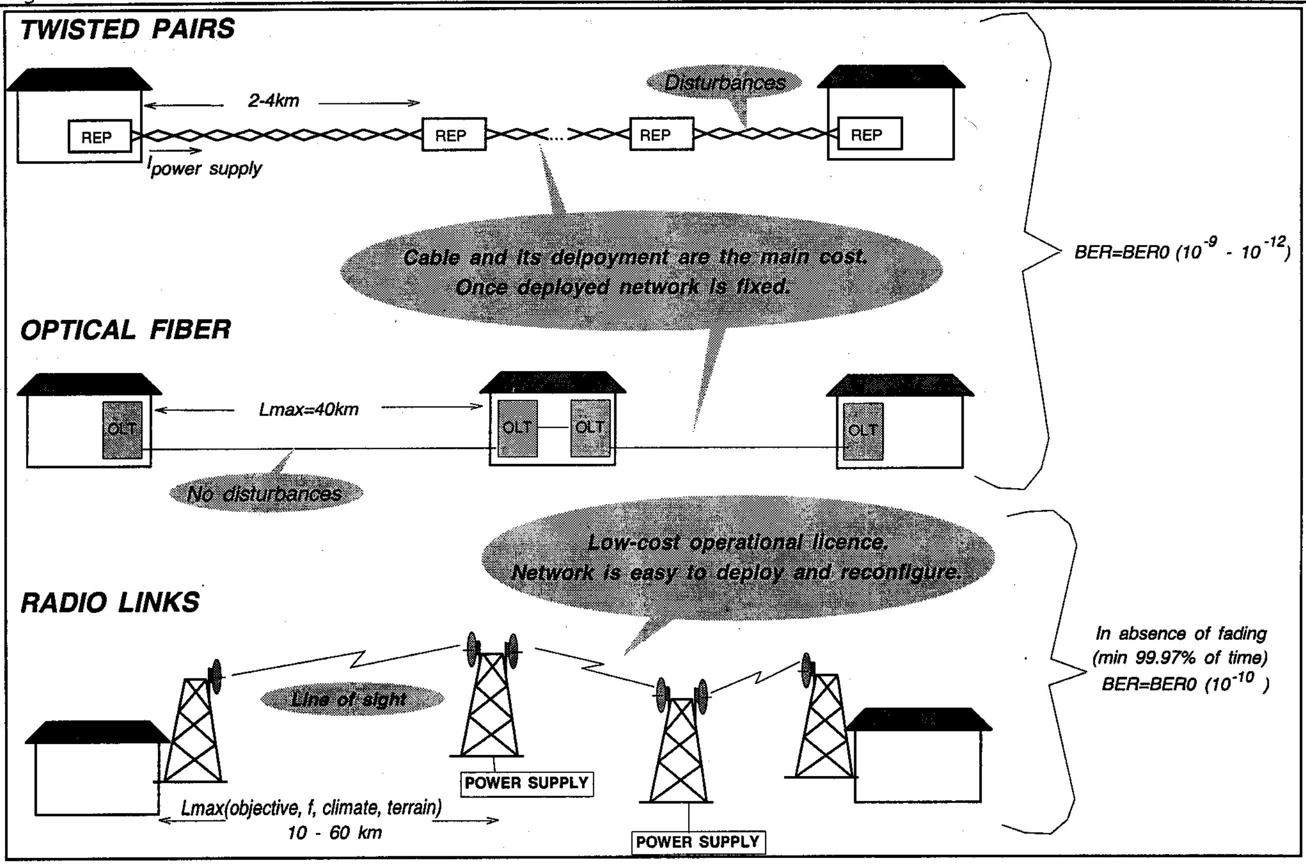

Fig. 1 Basic characteristics of transmission systems.

- low bit error rate,
- insensitivity to disturbances and atmospheric discharge,
- security of transmission (impossibility of cross talk),
- small diameter and lightweight cable, which allows use of existing cable pipes.

The most serious disadvantage of the optical fibers, as well as of all other cable installations, is their high price and inflexibility for reconfigurations.

For the optical transmission, domestic terminal equipment for 2, 8 and 34 Mbps is available, for transmission through monomode optical fiber at 1300μm. Development of 140Mbps and 155Mbps devices is in progress [3]. Maximum connection distance is 40km. The distance can be multiplied if these devices are connected in the so called "back-to-back" configuration. The main drawback of this method is the fact that the optical line terminals are indoor units and power supply must be provided for them.

Point-to-point radio links

Point-to-point radio links are an attractive solution for transmission because they offer significant advantages over the cabled network such as:

- low price per distance unit,
- short time necessary to deploy radio equipment,
- little paperwork to obtain necessary permits and licenses,
- possibility of prompt realization of transmission in rugged rural terrains, urban settings and of spanning various obstacles (rivers, roads, railroads, etc.),
- possibility of prompt dislocation of the devices (on deployment of temporary connections),
- possibility of optimum investment - invested funds match the level of real utilization and as the traffic increases so does the network with little investment.

As far as the capacity is concerned, digital radio links are inferior to optical fiber solution. Devices for data rate of as many as 274Mbps are produced today [4] although for realization of higher rates systems of Nx155Mbit/s are commonly used, as a rule in N+1 configuration, which increases the connection reliability.

As for the prices, all expenses taken into consideration (hardware, installation materials, labor and paperwork), radio links are almost invariably the cheapest solution. In addition to this, prices of wireless tend to fall down, which is due to permanent advancement in the microwave technology [5].

The main disadvantage of the point-to-point digital radios is the necessity of visibility between the antenna pairs. A considerable flexibility of the system is obtained by radio devices that enable greater distance between the indoor and the outdoor units, i.e. antennas which are mounted on suitable places enabling visibility (high buildings, hill tops, etc.) This distance is typically 300m, optionally even more. In the case of the visibility absence, passive reflectors, back-to-back connected antennas or active relay stations can be applied. The biggest problem with active relay stations is their power supply.

The peculiarity of radio link connections is that this medium is liable to fading [2]. This practically means that degradation of the transmission quality (bit error rate increase) and connection unavailability must be predicted. There are performance objectives to specify the percentage of time during which degradation and unavailability are tolerable [6]. For connections of lower hierarchy (grades 4 and 3) the tolerated entity-to-entity unavailability is only 0.03% - regardless of the number of hops, while for connections of higher hierarchy (grades 1 and 2) this percentage is smaller and proportional to the route length [6]. Experience has it that the percentage of unavailability due to fading is of the same order as that due to hardware failure, or even lesser.

Fading time percentage depends on the frequency, hop length, equipment performance, antenna diameter and the climatic and terrain factors and may be calculated for a particular case. Figure 2 shows the maximum hop distance versus frequency for various connection grades and antenna diameters. Standard climate and terrain factors are assumed. Yugoslavia falls into the climatic zone K (according to ITU-R recommendations) and for the majority of locations this is a pessimistic assumption. It was presumed that the system gain (difference between the transmitting power and the receiving threshold for given BER) for BER=1E-3 amounts to 105dB, which is a typical value for radios of 8Mbps transmission rate and for good quality 34Mbps radios.

For lower frequency ranges (up to 13GHz), the limiting factor is fading due to multipath propagation. As a rule, this sort of deep fading lasts for a short time and causes the seconds of considerable error (BER>1E-3). On the other hand, at higher frequency ranges (above 18GHz), the dominant factor is fading caused by rainfall. As it usually lasts for more than ten seconds, it causes unavailability (period of time longer than 10 seconds in which BER>1E-3). Figure 2 shows that the consequence of this is a drastic drop of maximal hop range. This is the main reason why connections of class 1, in the Yugoslav climatic conditions, are mainly realized at lower frequency ranges, while higher frequency ranges are used for lower class connections.

In Yugoslavia digital radio links at 13GHz and 23GHz of 2 and 8 Mbps rates are produced and the development of a 34 Mbps radio is in progress.

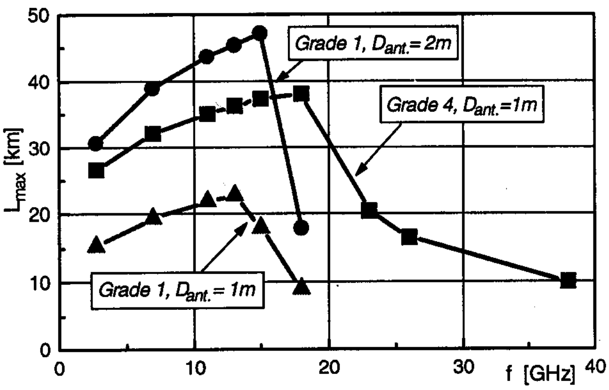

Fig. 2 Maximum distance versus frequency, connection grade and antenna diameter.

Prices of the Transmission Systems

In order to compare price/performance ratios of radio links with optical fiber solutions, as an example the simplest case of communication between two points was taken. Digital radio links of 2, 8 and 34Mbps rate and optical terminal equipment of the same rate along with additional expenses for the installation of optical fiber cables have been observed and compared. Two cases of optical fiber deployment have been considered: through the existing cable pipes, or by building completely new optical fiber routes.

Maximum distance between radio links was taken to be 20km for 23GHz band and 60km for 13GHz band. Expenses of the machinery-aided digging and cable deployment for the easiest, first category terrain were taken (they are much higher for other terrain categories).

Figure 3 represents the relative pricing of 8Mbps radio links and of optical transmission systems versus distance (60km for radios and 40km for optical systems without repeaters).

Figure 3 shows that radio links in configuration 1+0 are more economical for all distances above 2km and that the pricing of an optical system with a newly dug 20km long trench is around 7.5 times higher than that of a wireless system. This ratio amounts to 16 for 50km distance.

For wireless links in configuration 1+1, investments are lower for all distances above 4km.

Figure 4 shows this relation for 34 Mbps rate transmission.

The analysis of expenditure is based on current prices on the Yugoslav market.

Depending on the connection configuration, e.g. for a connection with several hops and/or branching, each hop can be considered as a separate connection and then all expenses should be summed up.

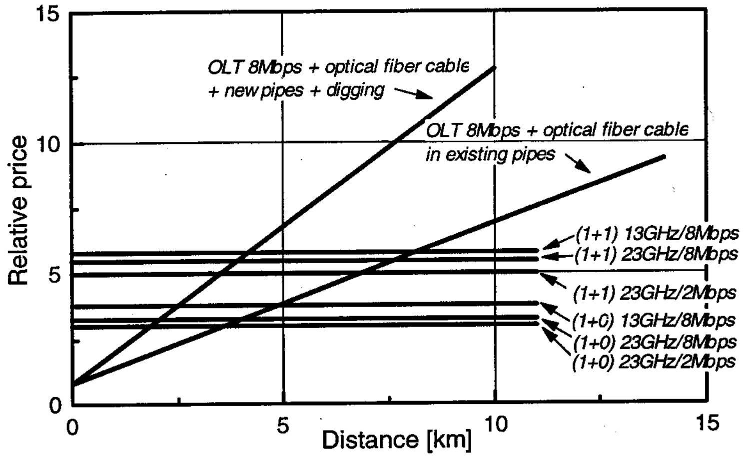

Fig. 3 Relation of prices for optical fiber and 8Mbps radio links.

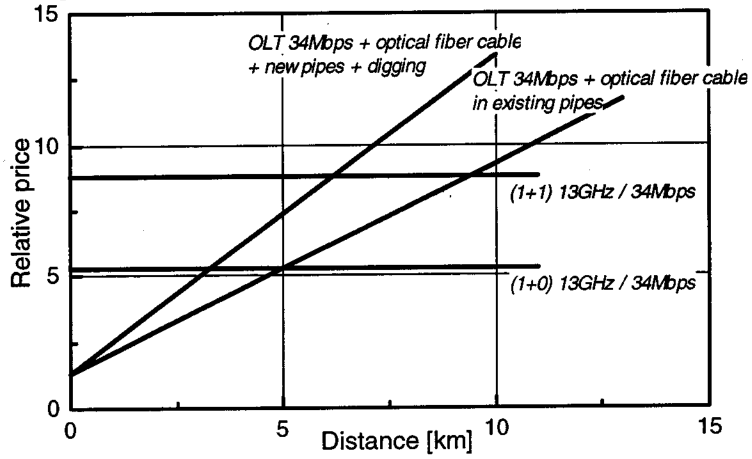

Fig. 4 Relation of prices for optical fiber and 34Mbps radio links.

Conclusion

If there are free copper leads on a desired route, which with appropriate equipment enable necessary bit rate transmission, then it is the most economical solution.

As far as investments in digital radio links are concerned, they are around 8 times lower than expenses for deployment of completely new optical cables and equipment [4], even for 144Mbps wideband radios. Besides, radio links can be installed in a very short period of time.

Optical fiber transmission is economically preferable only for short-haul connections: 2-4km if compared to 1+0 configured radios and 4-6km if compared to 1+1 configured wireless systems. For optical fiber installations using existent pipes these distances are twice as long. Optical installations can be economically justified only if more fibers are deployed parallelly at the same time for several locations on the same route, or if a very high transmission capacity is required.

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