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Please cite this paper as:

OECD (1996), “Alternative Local Loop Technologies: A Review”, *OECD Digital Economy Papers*, No. 24, OECD Publishing, Paris.
http://dx.doi.org/10.1787/237285366867

OECD Digital Economy Papers No. 24

Alternative Local Loop Technologies

A REVIEW

OECD

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General Distribution **OCDE/GD(96)181**

ALTERNATIVE LOCAL LOOP TECHNOLOGIES: A REVIEW

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris

46437

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FOREWORD

This report was presented to the Working Party on Telecommunications and Information Services Policies (TISP) in September 1996 and was recommended to be made available to the public by the Committee for Information, Computer and Communications Policy in the same month.

The report was prepared by Jurgen Spaanderman of the OECD's Directorate for Science Technology and Industry. It is published on the responsibility of the Secretary-General of the OECD.

MAIN POINTS

This paper provides an overview of the economic and policy implications of various technologies available to provide local telecommunication access. This part of the network is referred to as the 'local loop'. For the purposes of this document the switching functions in local access networks are assumed to be part of the local loop. Building and maintaining local access networks has traditionally constituted the bulk of costs associated with the public switched telecommunication network (PSTN) not least because of its ubiquitous nature and, because it constitutes a bottleneck, the local loop is important from a regulatory and policy perspective. Management of frequencies, permission for laying cables (rights of way), for sharing physical resources and interconnection are highly important in the transition towards a competitive communication market and overcoming the local loop bottleneck.

Until a decade ago the transmission medium for the local loop was mainly based on copper. Telephone service was provided via a twisted pair of copper wires. While terrestrial wireless technologies had been used in some countries to provide communication access services, particularly in remote areas, the introduction of cellular networks for telephony raised greater possibilities for deploying radio as an economic alternative technique for the local loop. A great deal of the incentive to look for innovative alternative access technologies has been due to liberalisation. The growth of mobile cellular communication added impetus to the technical development of radio based systems for fixed connections in the local loop (wireless access). Existing coaxial cable television networks also came to be thought of as potential platforms to provide local telecommunication access although technical upgrades have to be made to allow bi-directional point-point communication, such as telephony and Internet access.

Another technology for the local loop is optical fibre, of great importance to both television broadcasters (including cable companies) and public telecommunication operators (PTOs). For broadcasters fibre optic technology became a potential alternative to satellites from the moment that it was demonstrated that analogue television signals could be transported using this medium. Hybrid Fibre Coaxial Cable networks developed as another option, as they combine the advantages of both: fibre between head-end and street cabinet (shared use) and coaxial cable for the final connection to residential premises (lower costs).

In the PSTN optical fibre technology was first deployed for long distance transmission (the inter-exchange networks) because the costs were high, but more recently fibre optic cable has also been introduced for distribution networks and for connections for some relatively high volume users. In the late 1980s and early 1990s much attention was devoted to the question of when fibre optic technology would become the standard medium of choice for the local loop. While this debate continues it is increasingly recognised that fibre optic local loop connections are only one of several paths the industry may follow. One reason for this has been the development of techniques which compress signals such as Asymmetrical Digital Subscriber Line (ADSL) and High-bit-rate Digital Subscriber Line (HDSL) and thereby increase the transport capacity of the copper network. This offers possibilities to provide video services over the existing twisted pair copper network. Consequently most companies are cautious about investing in fibre to the home. For those building broadband local loop connections today a hybrid network consisting of fibre to the curb and from there over the existing copper loop, seems to be preferred.

Due to digital coding techniques, the difference which once existed between transporting telephony data, computer data, audio and video, has disappeared. Communication services no longer need separate dedicated networks. This has led to a general trend whereby policy makers and industry prefer regulation that is 'technologically neutral'. As a general rule any remaining restrictions over what type of technology can be used to provide communication service should be eliminated in order to stimulate innovation and the provision of communication service over the most efficient local loop technologies available. Although some local loop technologies require certain regulation, such as management of the radio spectrum and laying cable, this should aim to be technologically neutral.

The distinction between local access networks and long distance networks are blurring. The architecture and capabilities of modern communication switches has changed over the past decade. Today central office switches can handle many more lines via a number of remote switches and serve larger areas than in the past. A corollary of this is that local access networks have become larger. Moreover, technologies such as direct satellite connections and terrestrial wireless technologies, once used mainly for transmission but now being introduced for 'local access' connections, provide further evidence of this trend.

A growing range of technologies can be utilised for local loop competition. Cellular networks already provide an alternative to copper wired networks for some users and some applications. Although it must be noted here that to date the introduction of mobile communication has increased the use of the fixed networks. More recently fixed wireless networks (radio in the loop) and cable communication companies have commenced service or are conducting a growing number of trials. Restrictions which prevent different types of communication services and technologies should therefore be lifted in order to allow and stimulate the diffusion of communication services using different kinds of local loop technologies. Since the cable television networks are often owned by companies other than PTOs, the coaxial network can form an alternative which can compete in the local loop with the existing telecommunication operators.

Estimates of the local loop costs per technology, made by communication companies and market research companies, vary enormously because of different definitions of the local loop. For example some approaches only count the costs of building lines which pass residences (not yet connected) in a certain area. Other methodologies apportion all the costs for building a network in an area including final connections and divide this by the number of expected or actual customer lines. Even if a local loop cost comparison is based on the same definition, numerous factors can cause variation such as number of lines, household density, distances covered and the cost of labour. Countries with low wage costs have mainly chosen copper networks for the medium term as these may be less costly than wireless networks because of lower labour costs. However in a number of other countries with higher wage costs alternative infrastructures are being developed with wireless systems as they are probably less expensive to install than fixed networks.

Estimates of cost of local loop technologies vary a great deal throughout the OECD area -- the following numbers give an indication. To connect a new customer with copper wire connection probably costs between US$ 200 and US$ 2 000 per connection. Fixed radio wireless system costs and cellular radio network costs are estimated to be US$ 500 per connection. Estimated costs per coaxial cable connection are about US$ 500, but costs to upgrade the coaxial network for interactive services need to be added. Fibre to the curb is estimated to be more than US$ 1 050 per connection, fibre to the home at least US$ 2 000, although some estimates for fibre connections range as high as US$ 5 000.

Apart from the costs per connection, the time at which the capital investment costs are incurred is important. With radio technologies (fixed wireless and partly true for cellular) most of the cost is variable and is incurred only when a connection is made. Fixed networks (copper wires, coaxial cable, fibre optic cable) require much higher cost to pass homes before a customer is connected.

The public resources needed for local loops are the radio spectrum and public rights of way. The government can manage the use of these public resources via licences and rights of way. The opportunity to obtain a licence should be equal for all parties. It is in the public interest to minimise the disturbance and the environmental impact of building new telecommunication infrastructure. Insofar as it is practical and not commercially sensitive, government agencies should encourage and facilitate co-operation between competing infrastructure providers. This can include the sharing of ducts or poles and through information exchanges about cable laying operations between network operators.

Sharing the physical local loop via resale can be an option for introducing competition among communication companies. However real costs and real prices are hard to determine. Efficient provision of local telecommunication can better be achieved with competing infrastructures, such as wireless and coaxial cable, perhaps in addition to the resale of unbundled elements of incumbent PTO networks.

There are numerous policy questions arising from the growing aray of local loop technologies and liberalisation of local telecommunication markets. There is growing recognition of the need for telecommunication policies to be technology neutral. Policies that treat certain technologies differently can distort entry to the local loop market and investment decisions. Delegates may wish to discuss some of the following issues, regarding the alternative local loop technologies:

- use of public resources, such as the radio spectrum and public rights of way;
- access rights by customers and universal service;
- operator number portability;
- security, protection of privacy and personal data;
- local loop sharing through resell versus competing infrastructures;
- interconnection and access to local loop by service providers.

1. INTRODUCTION

1.1 Definition of local loop

The local loop is commonly viewed as the connection between the subscriber's home or office and the nearest exchange. For the purposes of this document the switching functions in local access networks are assumed to be part of the local loop. For purposes of interconnection, the switch is the gateway to the local loop for new entrants and would therefore be defined as part of the local loop. From a policy perspective it is important not to be rigid in defining the local loop but rather to lay stress on the importance of ensuring that different communication services and technologies can be used to provide access for users. In this document the local loop is used as shorthand for local access network and switching. Sometimes the local loop is also called the local distribution network.

The size of the local access network is changing. In the fixed network the architecture of modern communication switches has changed. Central office switches can handle many more lines via a number of remote switches and serve larger areas[1]. These remote switches are relatively small units and are managed remotely. The central office switch is included in the access network as it contains the capability to record calls and to execute service features. It can also act as the gateway for interconnection. Consequently the number of central office switches per area is decreasing and the network hierarchy is becoming smaller. This is tending to diminish the distinction between local calls and long distance calls. Mobile networks also change the size of the local loop. A local loop connection between a mobile handset via the base-station to the first switch can be relatively long compared to a fixed network. This is even more true for satellite connections.

The local loop of the fixed network does not necessary correspond to the local call area. The latter is determined by pricing whereas the former is determined by the network architecture. Because of the growth in size of the local loop there may be less justification based on network architecture to maintain the distinction in pricing between local calls and long distance calls. Just as PTOs will change network pricing to reflect the new environment so should policy makers adjust regulation where appropriate.

1.2 Importance of the local loop

The local loop has economic and policy importance, for three main reasons:

- Due to its ubiquitous nature it is the most costly part of the network.
- In liberalising markets the inherited local loop networks form a bottleneck as most customers are connected to the incumbent network. Policy areas such as frequency management, cable laying, sharing physical resources such as cables, poles and ducts and interconnection with other networks are important in achieving competition in the local loop.
- For many OECD countries there is virtually universal access to the local loop. For other countries the local loop continues to be developed. The range of new technologies offers an important opportunity to stimulate rapid roll-out of the local loop and increase universal service.

Other important reasons to study the local loop are:

- The local loop network provider sometimes has a regulatory obligation to connect all applications for basic telephone service.
- The local loop network forms the platform for services offered by the local loop operator and by other service providers.
- To understand better the economic impact of local loop technology choices given high investment costs.
- Competition is rapidly changing this market.
- For the customer the local loop is the main way to access information infrastructure.
- Different types of services, like telecommunication, radio and television broadcasting, are converging, making it possible to provide these services by means of a single technology.
- The bandwidth of the local loop may determine and restrict the scale of (broadband) service potentially offered.
- Quality of service, reliability and security of communication play an important role in the local loop. The state of local access networks affects the quality of services offered. Reliability is highly desirable but can be expensive to realise as most local loops have a single route. Security of the local loop is also important for customers.

1.3 Scope

This paper describes the various techniques available for the local loop and their policy and economic implications. It describes the alternative local loop technologies which are commercially available now or expected within a few years. To recommend a certain technology would be beyond the scope of this paper. Technology choices are best left to the commercial judgement of PTOs and new market entrants with a view to their objectives, inherited networks and national circumstances. This paper does however assume no restrictions to services covering consumer and business markets.

The basic assumption for policy recommendations is the aim to create a regulatory framework to facilitate an efficient telecommunication market and that competition in the provision of infrastructure is increasingly being applied to achieve this goal.

2. LOCAL LOOP TECHNOLOGIES AND ECONOMIC ASPECTS

2.1 Introduction

This section describes the following local loop technologies: 1) Copper wires; 2) Cellular and Micro-cellular; 3) Radio in the loop; 4) Coaxial cable and fibre optic networks and 5) Satellite. Related economic aspects are mentioned and in most cases a cost estimate is given. The new technologies for the local loop and the increasing competition in the communication market have brought forth many economic opportunities. The importance of the local loop in the economics of the telecommunication market is increasing because of growth in all its dimensions:

- the number of alternative technologies for the local loop;
- the number of local loop connections per customer;
- the number of customers connected;
- the capacity per connection;
- the amount of traffic per customer;
- the number of companies offering local loops;
- the number of companies providing services over the local loop.

Before going on to the various technologies, the commonly used terminology is introduced and related to different technology levels. Three different levels in the local loop are distinguished: 1) the physical link; 2) the data transmission; and 3) services provision.

Physical link

In today’s communication networks various technologies are used in the physical local loop. For fixed telephone networks this connection is usually a twisted pair of copper wires. Mobile telephone networks make use of radiowaves to connect users. Alternative local loops that have emerged are fixed radio connections, coaxial cable networks for telecommunication services, fibre optics and direct satellite connections. All these technologies can transport both analogue and digital signals.

Data transmission

The main techniques in data transmission are multiplexing, coding and protocols. These techniques are needed to transport data efficiently over the various technologies. Through multiplexing a greater amount of data, from more than one user at the same time, can be transported over the same medium (either wired or wireless). This is realised by using higher speeds and more frequency channels over the same wire or radio channel. Another technique is coding, which is used to minimise transmission faults related to the characteristics of the physical medium. Apart from multiplexing and coding, service data is transported via a transmission protocol. Digital transmission protocols such as ISDN can be established over the existing copper networks and can also be used over the coaxial cable network. Transmission protocol techniques such as ADSL and HDSL[2] have been developed to increase the transport capacity of the copper network: high bit rates up to 6 Mbit/s can be realised over a twisted pair of copper wires. An advanced transmission protocol such as Synchronous Digital Hierarchy (SDH), eventually with Asynchronous Transfer Mode (ATM) on top of that, can also be used in local loops, although it has been developed for inter-exchange data transport.

The present mobile cellular local loops have a low capacity (32 kbit/s), just enough for narrowband interactive services, whereas the copper network has much more capacity: ISDN 144 kbit/s, can transport two telephone conversations at the same time, and ADSL and HDSL can pass narrowband video services. Coaxial cable networks have an enormous capacity (hundreds of Mbit/s). However these networks have different topologies and provision of interactive services over a shared medium requires adaptations. Finally, fibre optic networks can transport even more traffic (several Gbit/s and still increasing).

Services provision

The capabilities of the local loop determine what communication services can be offered. Historically, because it is here where calls are originated and terminated, different communication services had their own physical access networks with a related transmission technique (telephone, telegraph, telex, television). This sharp distinction came to an end with facsimile service and computer communication via modems, followed by digital transmission techniques that do not distinguish between the services transmitted. Therefore capacity and topology determine which services can be offered. Cellular mobile and Radio in the Loop can offer all interactive narrowband services such as telephony, fax, short message service and email and narrowband Internet services. At present the twisted pair of copper wires can transport greater amounts than existing radio in the loop systems. There is enough capacity to support narrowband video and to enable Internet access at higher speeds. Coaxial cable and fibre optic networks can potentially offer all services because of the high bandwidth available, assuming that the existing coaxial cable networks have been upgraded for bi-directional traffic.

2.2 Twisted pair of copper wires

Most existing local loops of the PSTN consist of a twisted pair of copper wires. This has, for more than a century, been the main technique to transport the analogue telephone signal and provide at the same time the power supply for the telephone set. The topology is a star network which gives each customer a non-shared direct link to the first local switch to pass data in both directions.

Copper wires can also transport digital signals such as the ISDN protocol at a speed of 192 kbit/s. The characteristics of the copper wires limit the provision of broadband services, although ADSL techniques over copper wires can pass data rates up to 6 Mbit/s over a few kilometres and Very high-bit-rate Digital Subscriber Line (VDSL is the more sophisticated version of HDSL) can even pass 50 Mbit/s over a few hundred metres.

Therefore a copper wired network can be used for all interactive communication services. In many OECD countries ISDN transmission is offered to customers to provide telephony, facsimile and narrowband video services such as videophone. Computer communication, in particular Internet access, is easy to establish via the ISDN and can be of much better quality than via a modem. Video services over the copper network can be expected in the near future because of ongoing improvements in video coding techniques and because of the increased transmission speeds over the copper network (ADSL and VDSL). One study by the Yankee Group estimates that ADSL will replace ISDN between 1998 and 2000[3].

The average cost of a typical 5 km copper wire local loop is estimated US$ 1 200-US$2 000 per subscriber[4] and a Canadian study[5] mentions the average cost per line ranging from approximately $ 900-$ 3 500. A study on local loop costs for the New Zealand Ministry of Commerce indicated average costs per circuit of about US$ 3 000 in rural areas, US$ 650 in urban areas and US$ 200 in central business districts[6]. A large proportion of this cost is laying down the cable and therefore the figures vary among countries according to differences in labour costs. In the OECD countries Hungary, the Czech Republic and Poland, the national operators chose fixed network solutions for the new lines because these are less expensive than wireless systems as labour costs (for laying cables) are relatively low in these countries.[7] Other costs are the copper cable, the line termination and electronic equipment in the switch and the network termination at user premises. Although not typically related to copper wired networks, one could also count here the costs for an ISDN transmission, covering a Network Termination and eventually a terminal adapter at the user premises and an ISDN line termination in the switch.

2.3 Cellular

Cellular systems have been primarily developed to offer mobility for the telephone service. Radio is used as the technique to establish a two-way connection between the customer's mobile terminal and a base-station, which is linked to the switch and management centre. Each base-station serves a cell and all cells concatenated cover a geographical area. When a user moves through a geographical area the call is handed over to another cell. The cell structure is chosen to reuse frequencies in non-adjacent cells. Cellular systems make efficient use of the radio spectrum by means of multiplexing[8] techniques, both for analogue and digital mobile systems. The location of the mobile user is registered in the location management centre.

The transmission in cellular networks runs at a typical speed of 32 kbit/s, enough for telephony and fax services, short message services and other computer communication such as email and Internet access. The capacity is lower than in the copper wired networks and therefore the quality of telephony service does not always meet PSTN quality. The low speed of data transmission via radio waves leaves cellular data transmission lagging behind the capacity possible on fixed link connections but the industry is working to improve data compression on radio signals.

Examples of analogue cellular systems are: NMT and TACS (countries in Europe), AMPS (mainly North America) and NTT-TACS (Japan). Examples of digital systems are: GSM and its DCS-800 derivative (all countries in Europe, Middle East, Australia and parts of Asia), D-AMPS (North America) and PHS (Japan).

The costs for a mobile cellular local loop are lower than for copper because there are no cable laying costs. The costs of the network switches are in the same range as those of a fixed network. In 1994 in several countries the costs per subscriber on the cellular network have become lower than the costs per mainline of the fixed network and these data cover also development costs and all network investments: Vodafone UK, had operating costs per subscriber of about $ 526 in 1993 and $ 473 in 1994[9]. In the previous 8 years, the costs per subscriber decreased simultaneously with the increase of customers. Other factors in the cost of cellular systems are the geographical density of the population and the eventual costs of the frequency licence.

Micro-cellular

The technology of micro cellular networks is similar to cellular networks. They are called micro-cellular as the cells are smaller, so that frequencies can be reused more often which increases the systems' capacity. Consequently the mobile terminals can be smaller and have longer standby times as the distance to the transmitter is smaller. These systems are meant for areas with high density populations. Examples of micro-cellular systems are PHS and DECT.

Another important improvement is that micro cellular networks can carry data and voice over the same user channel and the bandwidth is less limited. User channels can increase up to 64 kbit/s. These systems can offer more bandwidth per customer and serve more customers in the same area. More bandwidth per customer opens the way to offer radio and narrowband video over the mobile network. The speech quality of micro-cellular systems is often better than the speech quality of the 'classic' cellular systems and can be equal to the quality of the copper network. The disadvantage over the other cellular systems is the slow handover, so that travelling through cells at high speeds is not possible. A combination of micro-cellular cells connected to a cellular network could solve this disadvantage.

The average cost for the micro-cellular local loop can be even lower than for the other cellular systems. This can be achieved by simpler location management because some systems do not offer a handover feature and because more subscribers are served by the same base-station -- meaning these costs are shared.

Flemings Research estimates the total operating costs per subscriber for Orange, one of the UK DCS1800 micro-cellular network operators which started operating in 1994, falling exponentially from actual $ 1606 in 1995, and an estimated $ 1 060, $ 727, $ 557, $ 457 respectively for the years 1996-1999, and decreasing to $ 310 in the year 2005[10].

Third generation mobile systems

In third generation mobile communication systems, developers aim at a bandwidth of 2 Mbit/s per user channel. The system should be flexible to assign this amount of capacity to the user only if needed, as a permanent assignment of 2 Mbit/s would not be efficient and probably not feasible.

A technology independent concept called Universal Mobile Telecommunication Service (UMTS) is under development in Europe through international research and standardisation[11]. It is aimed at being a successor of GSM. The network will be more flexible in signalling due to the use of Intelligent Networks and capacity and bandwidth per channel will be improved. Spread spectrum techniques such as Code Division Multiple Access (CDMA) in combination with the other multiplex techniques are being studied. A similar next generation system under development is FPLMTS (Future Public Land Mobile Telecommunication System). The most important issue of the next generation mobile systems is the efficient use of the spectrum both to provide more bandwidth per subscriber and to serve many more subscribers. CDMA is one technique favoured for next generation digital mobile networks as it uses the frequency spectrum more efficiently and in a more flexible manner, but it is also more complex.

2.4 Fixed wireless or radio in the loop

Fixed wireless systems are radio systems used to offer a fixed network connection local loop. Other names for this type of system are Radio In The Loop (RITL) and Fixed Radio Access (FRA). Although radio is used as the transmission medium, the receiver / transmitter equipment at the customer's location is fixed. Technologies for radio networks have become attractive for use in local loops because of technical developments resulting in increased quality and increased capacity. In most countries the costs of wireless local loops are lower than wired local loops because of the absence of costs related to laying down cable and rights of way. The absence of these factors saves money and time and makes these systems more flexible to install.

Most of the commercially available RITL systems are based on the cellular and micro-cellular radio systems, such as NMT, AMPS, DECT and CT-2. RITL systems can be micro-cellular systems or zonal systems. The micro-cellular systems are designed to cover urban areas. The base station of the micro-cells are wired to the local exchange. The zonal systems however, have a longer range than micro cellular and have been designed to cover the local telephone area directly from the exchange site. Many of the radio in the loop systems have their own specifications for multiplexing and frequency ranges, but they offer on top of that standardised PSTN (32 or 64 kbit/s) or ISDN connections. Although many different techniques are available for wireless local loops, no technology has yet been established as being the most popular. A variety of wireless local loop systems are available.[12] Higher bandwidths are possible and relatively easy to offer, by assigning more radio channels at the same time to one customer. Broadband RITL systems can be foreseen, but will require advanced multiplexing and coding techniques, as well as small beam radio transmitters. RITL systems need a separate power supply, normally connected to the households mains and it should also include a (rechargeable) battery backup for emergency reasons.

The installation costs of a RITL system are in the same range as costs for micro-cellular networks -- switches and base-stations to start with and no costs for laying cables to houses. Most capital investment is in the equipment which goes into the customer's premises and therefore total capital investment is determined by the number of customers actually connected to the network. Differences with cellular are firstly the extra costs for the fixed radio network termination for each customer and secondly the RITL base-station has lower demands regarding size and power. There is also a difference in who pays the network termination costs. An RITL network termination is installed and, in the first instance, paid for by the network provider while the mobile handset is bought by the customer (although many operators subsidise handsets if customers sign a contract of one year or more). The network infrastructure costs should be even lower than the costs of a (micro-)cellular network, because the network dimension can be estimated better and location management is fixed. As a result the RITL network can be tailor made allowing for optimisation in the location of transmitters.

The main difference in costs compared with wired systems is the time at which the capital investment is made. For RITL the start-up costs are relatively low and costs will increase in a linear fashion with the growth of demand, because most of capital investment is needed at the moment of connecting the customer (installing the receiver /transmitter and connecting it in the house). In contrast, in wired networks investments are made in advance to potential customers whether or not they become connected. One example of a company using fixed wireless is Ionica in the UK (Box 1).

The Yankee Group estimates the costs of RITL products are $ 500 per subscriber or less. The European Bank for Reconstruction and Development concluded that wireless is now more economical than copper where there are fewer than 200 to 400 subscribers per square kilometre (remote areas and lightly populated areas).[13]

In Hungary the licence for Matav, the national operator, requires the company to provide service to every applicant within six months by 1997. To meet this condition, Matav has contracted Motorola to build a 200 000 line wireless system to cover most of the country. For similar reasons, SPT Telecom in the Czech Republic has contracted Hughes Network Systems to supply a wireless system that could provide service to as many as 50 000 subscribers in and around Prague by the end of 1996. However, for the medium term, wireless systems may remain an exception and additional lines will be copper networks.

Copper based systems may remain the medium of choice because the labour cost of laying cables is relatively low. Therefore, wireless systems are chosen by incumbent operators to fulfil short term demands and to serve rural areas. A different situation might develop if new operators are permitted to build infrastructure in countries with relatively low telephone penetration rates. In Mexico, where labour costs are relatively low, most new local loops are made with copper wire but new entrants are proposing to use wireless systems to provide local telecommunication services.[14]

Box 1: Ionica

Ionica, founded in 1991 in the UK, has developed a fixed wireless system to compete with BT on telephony and other telecommunication services. Ionica, whose investors include among others electricity companies and Telecom Finland, obtained a licence from the UK Department of Trade and Industry in 1993. The company aims at 1 million customers in the year 2001, being around 5 per cent of all telephony customers. Services offered are voice telephony, data, fax and several premium services. The company plans to offer ISDN in the near future. The system is developed together with Northern Telecom and uses radio techniques in the 3.4 GHz band to offer fixed radio network connections, with a typical cell radius of 5 km, but in rural areas this may be enlarged to 15 or even 30 km. Ionica has its own switches and is an independent telecommunication operator.

Ionica is confident that fixed radio is the most cost-effective solution. It says that cable companies need $ 480 to $ 640 to pass a home, before connecting the subscriber.[15] With radio the equivalent costs may be $ 16. However, Ionica regards as confidential the costs to connect the customer (visit the customer, install the radio transceiver unit on the roof and connect it to an internal telephone socket).

Radio LAN

Radio LAN networks can also be used as a public network. The major advantage of radio LANs is their flexibility to offer a varying capacity to subscribers, depending on their needs. A disadvantage is the short radio range, which is a few hundred metres (indoors only up to 50 metres). Wireless LANs normally operate with speeds up to 20 Mbit/s, though video services might be provided. Another type of wireless LAN is Hiperlan (High Performance Local Area Network). This is standardised by the European Telecommunication Standardisation Institute (ETSI) and will offer much higher bit rates (24 Mb/s and also the 155 Mb/s bit rate)[16]. Whether a Hiperlan will ever be used as local loop depends particularly on available standardised equipment at affordable market prices.

2.5 Coaxial cable and fibre optic networks

Present-day coaxial cable networks have been laid out for distribution of analogue television signals, but transmission of digital television is possible over existing coaxial cable networks. The number of households passed by coaxial cable varies enormously between OECD countries (from a few percent to near universal coverage).[17] Most of the backbones of cable communication networks have been upgraded with optical fibres, however the distribution networks, i.e. the local loops, are in most cases still coaxial cables. These upgraded networks are called Hybrid Fibre Coaxial cable networks (HFC). Fibre optics is usually related to digital services, but analogue signals can be transported via optical fibres and that is why the technology became widely used to upgrade the coaxial cable networks. Initially this occurred in the backbones but nowadays fibre optic cables are also used in the local loop. Fibre optic cables increase both the quality of transported signals and the capacity. The capacity of fibre optics to transport data is significant and is growing due to developments in optical multiplexing techniques and the development of more advanced fibres.

The topology of the coaxial cable networks is fundamentally different from the telephone networks. They are point -- multi-point networks and have the form of a tree or bus, with splitters to spread the television signal to all connections. The importance and value of the coaxial cable television distribution network has increased rapidly. If transformed with bi-directional capabilities, these networks can offer telephony and other interactive telecommunication services and have the advantage over the twisted pair copper networks of higher bandwidth. Therefore the cable television networks have become very popular as a potential alternative network to provide telephony service. To upgrade the coaxial cable network for interactive services, two basic adjustments need to be made. First the provision of private channels over the distributive network. Second the set up of channel management over the network to avoid colliding data streams in the splitters and to avoid cross talk. These facilities are offered by most HFC products, supporting various transmission techniques for data and telephony (standard telephony, 64 kbit/s, ISDN) and also television and other video services[18].

Although the cost for coaxial cable networks and the necessary bi-directional upgrades and fibre network upgrades are not insignificant, the advantage over the other local loop networks is obvious -- the capacity is very high and consequently the services that can be offered (telephony, television, video on demand, broadband Internet access) are increased (Box 2).

Box 2: Examples of services over cable

In November 1995 the Belgian power company Electrabel and CATV operator Iveka demonstrated telephony over Iveka's network in Geel, Belgium.[19] "This demonstrates, for the first time in Belgium and at the European Union level, the capability to use existing CATV networks for both telephony and TV distribution", according to Siemens Belgium. Optical fibre was not used in this trial.

In the UK many cable operators offer telephony. Their local loops consist of the combination of coaxial cable and a twisted pair of copper wires. To date the telephony service is transmitted over the twisted pair and the television signal over the coaxial cable. They offer packages with both services and try to attract new customers by offering innovative tariffs (such as very low priced cable-cable calls)[20].

To be able to provide broadband services, the telecommunication operators are also replacing parts of the access network with fibre cables. Fibre To The Home (FTTH) solutions are still costly because of the expense of laying cables and the costs of optical termination equipment. Fibre To The Curb (FTTC) networks form a less expensive option, linking the local switch via fibre to a cabinet in the street and using the existing twisted pair of copper wires to connect the home. Moreover, with ADSL and VDSL transmission techniques the copper wires can transport signals up to 6 Mbit/s and 50 Mbit/s respectively, enough to provide video and television services. It is difficult to know the actual cost of fibre optic technologies in the local loop (Box 3).

Box 3: Example of costs of a hybrid fibre-coaxial cable network

Estimates of the cost of cable systems vary a great deal throughout the OECD area. One example comes from the US:

"Outside of Chicago, for example, Ameritech wants access to five north-western suburbs, representing about 75 000 homes passed. The telco, which has asked the five-community consortium there for an extension on its request for franchise proposals, said it will spend $ 25 million to build a 750-megahertz, two-way system in a hybrid fibre-coax configuration (this is equivalent to $ 333 per home passed). Executives at Continental Cablevision Inc., which stands to compete with Ameritech in that region, have estimated that it would cost $ 80 million to $ 100 million for a rebuild/upgrade there ($ 1 067 -- $ 1 333 per home passed). Comments from Equitable Security Inc. and Tele-Communications Inc. find these figures far too low; Ameritech confirmed that the estimation did not include set-tops."[21]

According to a Canadian report on the local network infrastructure there exists a substantial difference between the networks employed by the telephone and cable-television industries.[22] A star-based, narrowband, two-way infrastructure of a telephone company has average cost per line ranging from app. $ 900-$ 3 500. Cable operators are able to provide broadband, one-way, tree-and-branch systems for approximately $ 500 per subscriber. However, additional costs are in place to upgrade the cable networks to two-way communication.

Ovum Ltd. estimates per line costs of $ 1 050 for fibre to the curb and $ 2 050 for fibre to the home, at production volumes of at least a million lines and that fibre to the curb would be initially used just for telephony. Additional services would add to those costs. Other estimates put fibre-based solutions in the $ 3 000 to $ 5 000 per line range.[23] Digital subscriber line-based copper products (such as ADSL) are priced at about $ 2 500 per subscriber, though vendors say these prices will drop to $ 500 to $ 600 by the end of 1996."

Wireless cable

Wireless Cable is a multichannel terrestrial microwave distribution technology used for the transmission of multiple channels of video and data services to an area from a central location. This is sometimes refered to as 'wireless cable' because it started as a way to distribute cable television via airwaves, so it is a direct competitor to coaxial cable technology. Wireless cable systems were developed for distribution of television signals, but the technology can also be used to transmit interactive telecommunication services, including high-speed Internet access and telephony, if adaptations are made for two-way communication. Wireless cable is also known as Multichannel Multipoint Distribution System (MMDS).

In the US wireless cable has about 900 000 subscribers for television. In the US the FCC has held auctions to license service provision over wireless cable, where each licence is for thirteen 6 MHz channels which can be used to provide wireless cable services in competition with cable television companies. Digital technology makes it possible to carry five or more programs on each channel. At present a typical data speed is 10 to 30 Mbit/s downstream, but with digital compression techniques it is foreseen that transmission speed can go up to 180 Mbit/s.[24]

Similar to RITL systems, wireless cable is also relatively inexpensive. It has been reported that “A transmitting station, or "head-end", from which television programmes or Internet data can be broadcast to any house in the line of sight within 40 or 50 km (25-30 miles), only costs around $ 1m (although it will be four times that for digital broadcasts). The costs at the "foot-end" -- an antenna, modem and installation -- are only incurred when a paying customer signs up. The costs of wiring up a customer are therefore matched by immediate revenues -- a dramatic contrast with the wired-cable business, where providers are still paying off the debts they took on to lay their underground lines.”[25]

2.6 Satellite networks

In times past the main purpose of telecommunication satellites was to connect fixed networks. Today, on a still relatively small scale, satellite services are also used for direct user connection, particularly in remote areas. Moreover satellite can provide mobile services for maritime users. Satellite local loops are also used at places where a large amount of temporary lines are necessary such as for major sporting events or in restoring service after natural disasters. Direct satellite connections are further evidence that the distinction between local call and long distance call is fading away. Due to technology improvements, satellite receivers become smaller, which make them appropriate to be used as a local loop in some circumstances and new systems potentially offer increased global mobility. However the large cost of deploying these systems may make prices relatively high compared with terrestrial options. A satellite local loop is not meant as a replacement of existing local loops, but should be seen as a complement to mobile local loops. Systems under development are the low-orbit Iridium and GlobalStar and the geo-stationary Inmarsat-P system[26].

3. LOCAL LOOP POLICY FACTORS

3.1 Introduction

The local loop takes on greater importance in a liberalised market. For the customer, the local loop potentially provides access to all types of electronic communication. From the perspective of a communication company, the local loop is the link to the customer and the main requirement for the distribution of their products (telecommunication services).

Regulatory policies should enable operators to use all available technologies to provide local communication access. Policies that treat certain technologies differently can distort entry to the local loop market and investment decisions. Policies should be fair and non-discriminatory to all market players and promote competition. For instance, licences for the radio spectrum needed for cellular and wireless system, should be obtainable by each party able to offer the service. The right to chose one or more technologies for the local loop should be available to the investor. Regulation is needed to protect customers from not being able to obtain a connection because of excessive pricing through misuse of power by a dominant player; for instance in the case of a rural area where only one service provider is active.

The most important issues regarding the local loop which require policy and regulation by national governments, are the following:

- use of public resources;
- access rights by customers and universal service;
- number portability;
- security, protection of privacy and personal data;
- local loop sharing;
- interconnection and access to local loop by service providers.

3.2 Use of public resources

The public resources needed for local loops are the radio spectrum and public rights of way (e.g. streets). The government can manage the use of these public resources via licences and rights of way.

Licences for laying cables

Some public and private services need the streets for their cables, such as gas, electricity, public transport and communication services. It is in the public interest to minimise the disturbance due to work and to minimise the chance that work on one service disturbs the others. Governments can encourage co-operation and information exchanges between the various cable owners to avoid damage to other networks and to develop policies for duct sharing and pre-notification of laying cables, recognising in some cases the commercial sensitivity of such information. Those companies that need to install a fixed network should be allowed to lay cables, however within a framework of national rules covering time, location, duration etc.

Licences for use of frequencies

Availability of radio spectrum for mobile communication is essential. Strong growth in the number of mobile connections and increasing number of different networks and technologies for mobile networks reinforce the demand for radio spectrum. Alternative technologies such as fixed wireless communications (RITL) and wireless cable network also need radio spectrum. It is in the public interest that other services that rely on radio, such as defence, police, etc., not be disturbed by public mobile communication and therefore the frequencies for mobile communication should be clearly *allocated*[27] for the various services. One of the main ways governments manage spectrum for communication use is through the licensing of mobile telecommunication operators.

Licences can be freely given or sold, either for a fixed amount or via an auction. Depending on the competitiveness of the market where the new licence will be used, the price of the licence could be passed on to the end users. As long as it is clear what part of the spectrum public mobile communication is allowed to use, governments may leave it to the industry to *assign* the parts of the spectrum to the various parties. However, new market entrants may find the attractive frequencies all occupied which could make it unattractive for them to enter the market. For fixed wireless communication free spectrum use is an option. If governments charge for this some fixed wireless operators may start at a disadvantage relative to the fixed networks against which they are competing.

The opportunity to obtain a licence should be equal for all parties. Conditions to be met by applicants should be related to the quality of the company (continuity, financial capabilities) and the ability to offer the service with the right quality of service. Restricting the number of licences could be necessary because of technological limitations. A competitive communication market will determine the optimum number of players.

The available spectrum for communication purposes may become saturated. New ways can be found to continue the development of the communication market through extension of the spectrum used, particularly by using higher frequencies (1 GHz up to 60 GHz or more). Another way is by making more efficient use of the available spectrum, by promoting the replacement of analogue systems by digital ones and by promoting the development of systems that use spectrum more efficiently.

3.3 Access rights by customers and universal service

Universal service is generally defined as affordable access to basic telephony service. A number of countries are studying proposals to broaden the definition of universal service to possibly include basic data communication and service features. To the extent that governments need to further define universal service this should aim to define the level of service, not the various technologies used to accomplish this goal. PTOs should be free to exercise commercial judgement on the best mix of technologies.

With the development of the National and Global Information Infrastructures, citizens' access to data available on these networks is becoming increasingly important, particularly when governments are using these networks to provide information on public services. This information should be accessible via commonly used local loop technologies.

In those regions in the world where local loop telephone service is poor, fixed wireless and cellular networks are a relatively quick and relatively inexpensive alternative for provision of infrastructure for communication services. However, the available spectrum might restrict the growth of broadband communication in the near future.

Accessibility via mobile communication technologies prefers standardised solutions for the technologies used, in order to allow subscribers to roam throughout an area other than the subscribers' local region.

3.4 Number portability

Number portability is related to local loop competition. The term number portability is used for changing location, changing operator and changing local loop technology -- in all cases having number portability allows customers to retain their phone number[28]. Location portability is not new to the telecommunication industry. In most existing fixed networks telephone numbers are related to the local exchange areas meaning that PTOs are generally able to enable a customer changing location within a local area to keep their existing number. On the other hand this is generally not possible if, for example, a customer changed cities.

The introduction of competition raises the issue of 'operator portability' for the first time. The most commonly cited benefits for customers in being able to retain their number when they change PTO is that it saves them the cost and inconvenience of informing others of a change. The corollary is that it also saves others from having to update their records in which people have lodged their number. For new market entrants the benefit may be the elimination of a barrier to some customers changing service supplier in the absence of 'operator portability'. For incumbent PTOs a less well recognised benefit is that it also make it easier for them to win back customers.

It needs to be understood that there are costs imposed by adding the functionality of 'operator portability' to existing networks and that these costs need to be recovered. Available options include sharing the cost between operators and customers to various degrees. It also needs to be recognised that given inherited network capabilities call set-up time can be greater because of call transferring and access to a telephone number management system.

Technology portability, that is retaining number while changing from one technology to another, has yet to emerge as a large issue. This is mainly because even where service has been possible via different technologies (e.g. fixed line or cellular) the pricing of different services has meant that a significant scale of migration has not occurred. For example, mobile communication customers generally keep their fixed lines. When a customer changes technologies with the same operator, number portability will probably become a commercial service issue, e.g. personal numbering service.

3.5 Security, protection of privacy and personal data

The local loop is vulnerable to security threats, because this part of the network is close to the customer's location and the transported data is in a simple format. Threats are, among others: eavesdropping, attacks on the integrity of the data transported, fraudulently making calls on another's account and attacking the availability of communication facilities.

The risks of these threats differ according to the local loop technology. Mobile local loops, such as cellular and wireless networks, have the highest risk as radio signals can be received or sent freely, without being noticed or changed in the local loop systems, whether these systems are analogue or digital. Modern digital communication systems contain technical security mechanisms such as authentication and data encryption. Other security measures to detect fraud are credit limitation, data mining, frequent billing and quick verification of identities in case of international roaming.

The fixed local loop, such as copper wire, coaxial cable, and fibre networks, is less vulnerable as mostly the cable is underground which makes access more difficult. However fixed local loop on poles is more vulnerable to fraud. Since the digital cellular connections have better integrated security mechanisms, they are more secure than the fixed network. Coaxial cable networks and fibre networks have a different topology which brings extra security risks when these networks are used for interactive services. A signal sent downstream is received by all cable terminations as it is a distributive network; although the de-multiplexing function at the network termination should filter the right signal, most systems lack a secure system that prevents people from eavesdropping the other incoming signals. In the upstream direction, a network termination identity and a ranging protocol should ensure that the customer' s signal gets into the right time-slot; but most systems do not have high level security mechanisms to protect against fraudulently changing identity or influencing the ranging protocol.

Resale of local loop capacity implies that more than one party uses the same physical link. This new usage of local loops results in higher risks of breaches of security or privacy. Legislation to protect customer' s privacy (protection against disclosure of personal data) should be independent whether the medium is shared or not. Another privacy issue raised by changes in the local loop is the question of whether the line identity may be disclosed when a call is interconnected to the network of another network provider.

3.6 Local loop sharing

Local loop competition is essential to achieve real competition in communication services. When only one physical local loop is available, the owner can resell capacity to other service providers. A service provider can reach his customers via another network without investing in his own infrastructure. The service provider, however, remains dependent on the owner of the network and real costs are difficult to determine. Competition in the local loop can best be achieved with competing infrastructures, and resale where it is believed to be the most effective option.

Recently the US FCC has provided rules and tariffs for opening the local telephone market.[29] Under the new legislation, the local companies must open up their own markets and resell capacity on their local loops to providers of long-distance and mobile phone services. In the European Union it is not a requirement in EU legislation that operators have to make available local loops to competitors. The EU expects to see considerable competition from other local loop technologies, such as wireless and cable networks.

3.7 Interconnection and access to local loop by service providers

Networks must be interconnected in order to offer subscribers of any service the ability to call and be called by any other subscriber of any other service. With the opening of the telecommunication market and fast growth in the number of network operators, interconnection has become very important to guarantee end-to-end services.

Interconnection is needed in achieving a competitive market, as blocking mutual transport and call termination would restrict free choice by customers. It should be required that customer' s privacy is protected when communication is conveyed to other networks -- line identity, credentials and location information are customer and company related and should be secured.

ABBREVIATIONS

ADSL	Asymmetrical Digital Subscriber Line
AMPS	Advanced Mobile Phone Service (D-AMPS is the digital version of AMPS)
ATM	Asynchronous Transfer Mode
CDMA	Code Division Multiple Access
CT-2	Cordless Telephony 2
DECT	Digital European Cordless Telecommunications
ETSI	European Telecommunication Standardisation Institute
FDMA	Frequency Division Multiple Access
FITL	Fibre In The Loop
FPLMTS	Future Public Land Mobile Telecommunication System
FRA	Fixed Radio Access
FTTC	Fibre To The Curb
FTTH	Fibre To The Home
GSM	Global System for Mobile communication
HDSL	High-bit-rate Digital Subscriber Line
HFC	Hybrid Fibre Coaxial cable networks
MMDS	Multichannel Multipoint Distribution System
NMT	Nordic Mobil Telephone (analogue cellular communication systems)
PCS	Personal Communication System
PHS	Personal Handy Phone System
RITL	Radio In The Loop
SDH	Synchronous Digital Hierarchy
SDSL	Symmetrical Digital Subscriber Line
TACS	Total Access Communication System
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunication Service
VDSL	Very high-bit-rate Digital Subscriber Line

NOTES

1 Between 1992 and 1995 the number of central office switches in the USA fell 5.3 per cent, the number of remote switches rose 82 per cent, whereas the number of switched access lines rose by 8 per cent; "Statistics of communication common carriers", Federal Communication Commission, 1991/1992 edition and 1994/1995 edition.

2 ADSL (Asymmetrical digital subscriber line) is a transmission technique, launched in 1993 by AT&T to provide Video On Demand service to ordinary telephone subscribers at a speed up to 6 Mbit/s. The technique is asymmetric as the upstream channel is only narrowband, to order movies etc. Recently a symmetric version, called SDSL, has been introduced which provides symmetrical 3 Mbit/s channels over a single subscriber loop. HDSL (High-bit-rate DSL) is a transport technology from 1992 (ANSI T1E1.4) offers T1 facilities over *two* pairs of wires over several kilometres. For some time past a full T1 can be provided over *a single* pair of wires. In late 1995 the VDSL (Very high-bit-rate DSL) was announced, which provides up to 50 Mbit/s over a few hundred meters of drop wire.

3 Via "Will Cable Modems speed delivery?", Communications International, July 1996.

4 "The death of distance", The economist, Sept. 30th, 1995.

5 "Convergence, competition and co-operation", Local Networks Convergence Committee, Canada, 1992.

6 "Local Loop Telephone Access Circuit Cost Study", Ministry of Commerce, New Zealand, June 1996 (US$1=NZ$1.53).

7 "The local loop: place your bets", CommunicationsWeek International, 18 Sept. 1995.

8 Today's systems make use of FDMA and TDMA to get an optimal number of communication channels in the available radio spectrum. FDMA (Frequency Division Multiple Access) is a technique where the communication channels are transposed to a number of other frequencies, that can be sent at the same time. TDMA (Time Division Multiple Access) is a technique to use more communication channels in one frequency channel. By increasing the speed of data transmission, one channel at a certain frequency can be split in various time-slots for different calls. CDMA (Code Division Multiple Access) is another multiplexing technique, using unique codes to separate calls. Instead of assigning a call to a certain frequency channel and time-slot, the CDMA call is transmitted in parts through a high bandwidth spectrum and does not get a fixed frequency or time-slot but is identified with a code. Although more complicated, the CDMA technique uses a broad spectrum which is more efficient and can therefore service more customers and at varying bandwidth.

9 "Mobile cellular communication, Pricing Strategies and Competition", OECD, Paris 1996, page 71 (1 £=1.54$).

10 "Orange, an initial assessment", Flemings Research, 11 March 1996 (1 £=1.54$).

11 UMTS is standardised by ETSI (European Telecommunication Standardisation Institute), see "Europe's new policy maker", P. Donegan, Mobile Communications International, Apr. 1996.

12 "Today's wireless Local Loop Options", D. Chow, Mobile Communications International, issue 28, Feb. 1996.

13 “The local loop: place your bets”, CommunicationsWeek International, 18 Sept. 1995.

14 “The local loop: place your bets”, CommunicationsWeek International, 18 Sept. 1995.

15 “Overthrowing the tyranny of Europe’s local loop”, Global Telecoms Business: Aug./Sept. 1995.

16 “Wireless Local Area Networks”, T. Rune, Telecom 95 Technology Summit by ITU, Oct. 1995.

17 “European audiovisual observatory”, statistical yearbook, 1996.

18 “The Optus Vision: Telephony, Internet and Video”, Australian Communications, Aug. 1996.

19 “ PTTs beware”, Global Telephony, May 1996.

20 Internet TIS Cambridge Cable Group, http://jumper.mcc.ac.uk/%7Eafs/telecom/std/operators/cambridge-cable.html.

21 Multichannel News 4/15/1996. Vol 3 No16, via Internet ‘PR Newswire’.

22 “Convergence, competition and co-operation”, Local Networks Convergence Committee, Canada, 1992.

23 “The local loop: place your bets”, CommunicationsWeek International, 18 Sept. 1995.

24 “The Economist”, 20 July 1996; “Communications Daily” via Individual Inc.; ‘Oregon Reference’ via http://elaine.teleport.com/.

25 “The Economist”, 20 July 1996.

26 “Satellite Communication: Structural change and competition”, OECD Paris 1995, OECD/GD(95)109.

27 Frequency *allocation* divides the spectrum between services. Frequency *assignment* divides the spectrum between users of the spectrum, i.e. network operators.

28 “The economic and regulatory aspects of telecommunication numbering”, OECD/GD(95)117, Paris 1995, p.21.

29 “Commission adopts rules to implement local competition provisions of telecommunications act of 1996 (cc Docket No 96-98)”, FCC (Federal Communication Commission), NEWSReport No. DC 96-75 Action in docket case, Aug. 1, 1996.