# LMDS Systems and their Application

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## ABSTRACT

Local multipoint distribution systems (LMDS) represent a new radio-based access technology with cellular architecture offering flexible high-capacity connections to private users and organizations. The systems employ a point-to-multipoint broadcast downlink with a total capacity of 34–38 Mb/s per transport stream, giving high flexibility for inclusion of any type of data. The interactive channel, being a point-to-point connection, may employ different technologies depending on availability and user demand for capacity. This capacity may basically range from a few kilobits per second up to at least 25.6 Mb/s. LMDS performance relative to other broadband access technologies is discussed. A major remaining development task is the establishment and verification of methods for coverage of normally shielded areas. The availability of cheap repeaters and possibly reflectors for increased coverage is a must, which will significantly improve coverage. The LMDS technology, now in its first stage of implementation, is expected to enhance development of broadband services such as e-commerce and tele-teaching.

## INTRODUCTION

The main focus area in communications today is the provision of efficient transport capacity at acceptable cost for the last mile connection, the access network. The need for on-demand broadband capacity for all types of users of communications has increased at a remarkable speed as a consequence of the use of the Internet, and the professional dependence on electronic document exchange and database technology.

The early growth phase of Internet-related applications coincides with the introduction of digital television by satellite offering new interesting possibilities such as interactive TV, and supporting new broadband services such as electronic commerce, tele-education, and telemedicine.

Network operators are facing the broadband requirement challenge by improving existing technologies and developing new operation systems. The broadband multimedia focus is the driving force in the ongoing development of technologies for both mobile and fixed networks, and with strong requirements for efficient interoperation between the different network technologies.

Broadband access network development is being forced from both the communication side and the broadcast side. Broadcast networks are developed into two-way networks through the addition of an interactive channel that very often is based on a different technology [1–3]. The conversion of broadcast satellite networks and cable TV networks into interactive networks are representative examples. From the communications side the existing copper network offers possibilities for transport capacities in the megabits-per-second range depending on the distance to the nearest node. Fiber to the home, the preferred solution, is expensive and time-consuming to install, but is gradually becoming the main connection for demanding professional user groups.

New radio-based technologies such as stratospheric platforms and local multipoint distribution systems (LMDS) are being developed and put into operation. They have the advantage of a high-capacity downlink which can be shared by many users in a flexible manner.

LMDS are now being introduced throughout the world. The U.S. frequency auction in March 1998 represented a start for mass introduction and production. In Europe there were licenses in several countries in early 2000, and systems will be in operation within the year. Broadcast in combination with the Internet will dominate the private market through the introductory phase, but there will also be a strong focus on home offices and smaller enterprises. The advantages of LMDS are easy operation and deployment, flexibility in on-demand capacity allocation, and potential support for a broad spectrum of applications, allowing for future development. This article focuses on LMDS and their operational principles, their potential and areas of application.

## THE PRINCIPLE OF OPERATION

### BASIC PRINCIPLES

LMDS are combined high-capacity radio-based communications and broadcast systems with interactivity operated at millimeter frequencies. Early systems, however, were mainly used for analog TV distribution, and it all started with Cellular Vision and Bernard Bossard proposing a system for TV distribution in central New York City [4]. Digital television opened for a combined transport of data representing TV programs, data, and communication. The possibility of implementing a full-service broadband access network by rebuilding a broadcast network into an interactive network by functionally


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adding a communications channel for the return was a reality that coincided almost perfectly with the growth of the Internet and data services.

Broadband interactivity arrived with digitalization. Interactive LMDS has a point-to-multipoint downlink and a point-to-point uplink, as illustrated in Fig. 1.

The transmitter site should be on top of a tall building or on a high pole overlooking the service area. The transmitter covers a sector typically 60–90° wide. Full coverage thus requires 4–6 transmitters. The streams transmitted contain 34–38 Mb/s of data addressed to everybody (typical TV) in the coverage zone, subgroups or individuals (typical communication, Internet). The capacity of the point to point return channels is determined by the needs of the individual user.

Operation of LMDS in an area will normally require a cluster of cells with separate base stations for co-located transmitter/receiver sites. One of the base station sites will serve as coordination center for the franchise area and connect the LMDS cells to external networks. Intercell networking may be implemented using fiber or short hop radio relay connections. Colocation with mobile base stations allows for infrastructure sharing.

Operation in the millimeter range imposes some restrictions. Precipitation effects lead to severe attenuation and limit the reliable range of operation to 3–5 km depending on the climatic zone and the frequency of operation. Line of sight is also required. Full coverage will however not be possible, and numbers quoted are normally in the 40–70 percent range, while something in access of 95 percent is a minimum for a service offered to the public. Improved coverage is thus required and may be obtained in different ways. The numbers quoted refer to single cells. By introducing some overlapping between cells it may be possible to obtain coverage in shielded areas in one cell from the neighboring cell transmission site. Use of repeaters and reflectors are other possibilities, but that requires some additional equipment, which is compensated for by increasing the number of users. Thus different site dependent ways of operation will solve the coverage problem. The most severe restriction may be the attenuation caused by transmission through vegetation. Buildings completely shielded by vegetation need an elevated rooftop antenna or some broadband connection to an unshielded site. Propagation issues are by now well understood and are not considered a serious obstacle for reliable operation of millimeter systems of cellular architecture. The problems are known and proper precautions can be taken [5].

Trials performed in many countries have reported promising results. The ACTS project CRABS performed operational and user trials in several European countries from Norway to Greece in the north-south direction and from UK to Central Russia in the West -East direction [6–8]. The differences encountered did not severely effect operation, and the trials had convincing effects locally. Systems planning tools for availability and coverage based on digital maps are considered important for design of local systems architecture.

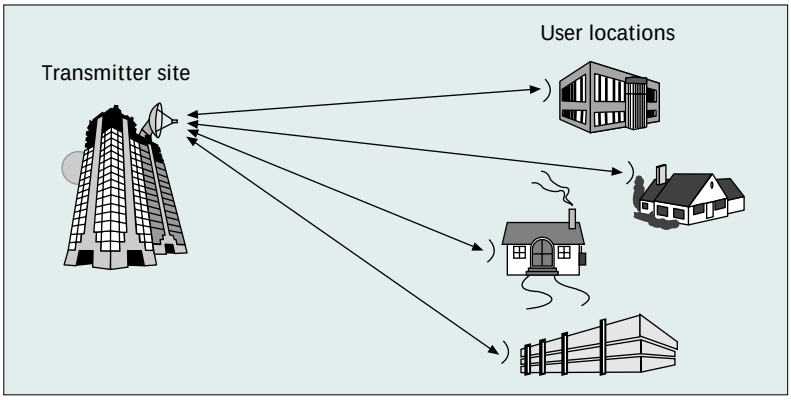



**Figure 1.** *The operation of LMDS for broadcast and interactive services.*

### FREQUENCIES OF OPERATION

Even though the capacity in the millimeter part of the spectrum is considerable, there are many systems competing for frequency allocations, and it has been difficult to obtain a worldwide allocation for LMDS.

In the United States 1.3 GHz in the 28–29 GHz band has been allocated, while European countries are allocating frequencies in different bands. The main high-capacity band is presently 40.5–42.5 GHz with a possible extension to 43.5 GHz depending on decisions at the year 2000 World Radio Frequency Conference (WRC 2000).

Licensing and deployment in Europe now indicate that there will be systems in different frequency bands from 24 GHz up to 43.5 GHz. The frequency band 24.5–26.6 GHz with subbands of 56 MHz has been opened for point-to-multipoint applications in many European countries. These bands may then be used for either LMDS or related systems called *fixed wireless access* (FWA). The systems can then be typical multipoint business systems with some capacity for private users. Only systems addressing the business domain are typically based on ATM technology.

The 40 GHz band will normally be shared among two or three licenses, limiting the available spectrum per operator to 500–2000 MHz with two polarizations. The licensing policy may vary from country to country, with stimulation to competition as the main guideline. The LMDS have the potential of becoming the high-capacity access domain for private users.

### TECHNOLOGIES EMPLOYED

Proven technologies required for service startup exist, and different companies have products available addressing the needs of small business customers and, to some extent, also demanding private users.

In LMDS the high-capacity broadcast-based downlink is shared among several users in a flexible way. The front-end technology is still expensive at millimeter frequencies, but existing high electron mobility transistor (HEMT) modules offer the required performance. The output power level needed per transport beam of 36 Mb/s is about 25 dBm. A technology allowing for final stage amplification of several transport beams would reduce equipment complexity and cost. The hub transmitters, however, are shared

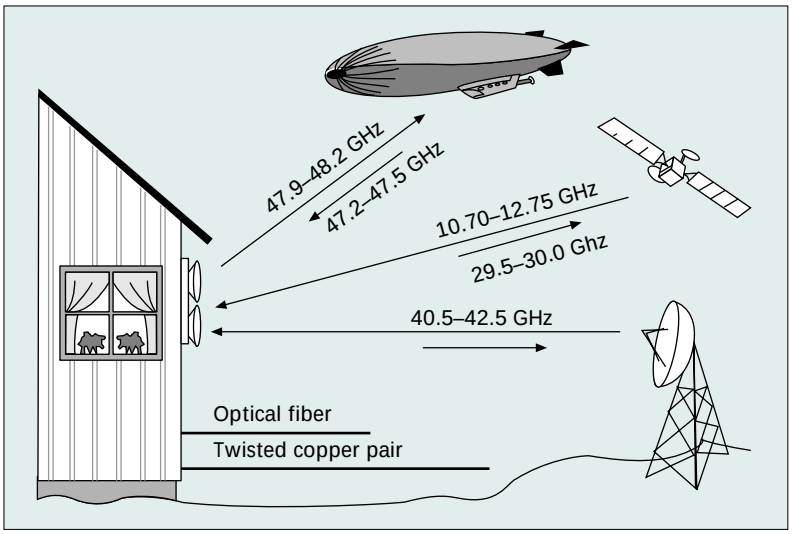



**Figure 2.** *Available access technologies.*

by many users, and cost is not directly critical.

The front-end technology at 40 GHz is more expensive than at 28–29 GHz, and attenuation by precipitation increases with frequency, favoring the lower frequency ranges. The higher capacity offered at 40 GHz may compensate for these effects in the long run.

The number of transport streams is determined by demand and limitations set by available spectrum. This gives a scalable architecture, starting with relatively low capacity and adding transmitter modules as demand increases.

The transmission format for Digital Video Broadcasting (DVB) satellite transmission based on quadrature phase shift keying (QPSK) modulation has been adopted by both Digital Audio/Visual Council (DAVIC) and the DVB project, and with the same IF interface, 950–2150 MHz, between the outdoor and indoor units. This allows for application of set-top boxes developed for reception of digital TV by satellite with data included in the transport multiplex. The IF is then fed into a set-top box interfacing a TV or a PC or both in parallel, depending on user orientation. Both options allow for interactivity since set-top boxes are also equipped with a return channel connection to the public switched telephone network (PSTN)/ISDN. There are some differences, however. In DVB IP or ATM data are included in the MPEG transport stream in combination with TV programs. DAVIC has separate high-capacity ATM-based data transmissions. Until now the PC-oriented user has dominated the interactive world; the development of interactive TV, with possibilities for manipulation of content, inclusion of more advanced text TV, possibilities for e-commerce, different games, and active participation in competitions, will lead to an increased interest in interactive television with a low-capacity return channel.

The uplink is the individual connection, and different technologies may be used depending on demand. Two of the broadband driving applications, interactive TV and the Internet, will require only low-capacity return links, and technologies like General Packet Radio Service (GPRS) and PSTN/ISDN will suffice. For more demanding customers an in-band radio return link with on-demand capacity is required. The radio-based solutions for small and medium-sized enterprises do have a radio-link-type return link, allowing for symmetric connections or connections which may be asymmetric in either direction. However, it is felt that existing radio return solutions, with their requirement for isolation between transmit and receive implemented through the use of allocated bands isolated by filtering for transmit/receive, put limitations on flexible operation and efficient resource management. A combined use of systems for broadcast and data for both private users and business organizations will necessarily result in strong variations in capacity for the two directions. Possible future time-division duplex (TDD) operation would solve this problem.

The main technological challenge is production of a real low-cost two-way user terminal for the private market; the mass market depends on it.

The total capacity of a system is mainly determined by the available frequency resource. In a cellular system employing QPSK modulation, the capacity of a 2 GHz system is easily 1.5 Gb/s per cell for downlink and uplink.

## LMDS vs. Other Access Technologies

LMDS provides a wireless alternative to fiber, coax, and asynchronous/very high-rate digital subscriber line (ADSL/VDSL) and offers a high capacity locally compared with other radio solutions like interactive satellite systems and stratospheric platforms. The different technologies contributing to broadband access networking all have clear advantages and drawbacks.

Figure 2 shows an access scenario for competition in the home market.

There are basically two groups of technologies: wire-based, represented by optical fiber and copper pair; and wireless, represented by satellite, stratospheric platforms, and LMDS.

In general, all wireless technologies have broadcast/multicast potential, making them well suited to TV distribution and multicast data distribution. The increasing storage capacity of PCs may lead to an increasing number of home servers, favoring the use of multicast and push technology.

Satellite systems, which have low individual capacity per user within the area of coverage, have the advantage of total coverage independent of local population density. They are thus well suited to broadcast, updating of servers in more local networks like LMDS, and broadband to rural areas and in areas with poor infrastructure. LMDS is well suited to interoperation with broadcast-based satellite systems for local distribution, and the satellite system likewise for connecting remote LMDS cells. At IBC '98 in Amsterdam, a system for remote control of LMDS cells from a main cell in Norway was demonstrated by the ACTS project CRABS [6].

The stratospheric platform has yet to demonstrate its operability. From its elevated position it will have good coverage. Attenuation effects

will be approximately the same as for LMDS, and the capacity per square kilometer somewhat less. Operation in Nordic areas will be difficult due to short days with reduced solar cell charging during the winter season.

Interactive cable networks will have 500–1000 households connected to each node. They have a limited capacity for the return channel and thus are not well suited when a high-capacity return channel is demanded simultaneously by many users. They have the advantage of combining delivery of TV, Internet, and telephony in an efficient way.

The existing copper wire connections offer 2–5 Mb/s downlink and 384–512 kb/s uplink capacity through introduction of ADSL technology, sufficient for most private Internet users today, but not for TV provision. The distance to the nearest node is somewhat critical, and will typically be in the range of 2–5 km depending on the quality of the existing installations. If this distance is reduced below 1 km, the capacity may be increased to 25 Mb/s for the downlink and 2 Mb/s for the uplink. VDSL is also sufficient for TV provision in the form of separate TV programs, but not for transport streams containing four to eight digital programs. xDSL technologies belong to existing operators; they have an upper capacity determined by the distance to the node and quality of the connection. They have reduced capacity for symmetric operation, and represent a typical Internet and delivery technology.

Interactive systems are all in a way cellular systems if we consider the distance to the nearest node as the main parameter. In general, high interactive capacity of a system requires a short distance to the nearest node and either a high total node capacity, as in LMDS, or a high-capacity connecting cable, represented by the fiber solution. LMDS is favorable for operation in urban and suburban areas, and is definitely the preferred solution for operators without a copper network and as a supplement to the copper-based and interactive cable networks.

Table 1 lists the capacity of different access technologies.

Another important parameter is the total capacity per square kilometer. LMDS will, depending on cell diameter and licensed frequency range, have a total capacity of 150–1500 Mb/s/km$^2$, while other radio technologies like LEO satellites and stratospheric platforms have 100 kb/s and 1 Mb/s, respectively, per km$^2$. The smaller cell size however reduces the strength of the broadcast/multicast function outside the local domain, and makes it very efficient for distribution locally. Table 2 lists a few radio-based technologies illustrating the superiority of LMDS on local capacity.

LMDS has the potential for playing a central role in the broadband access network now under development where different broadband technologies like xDSL, interactive cable systems, multimedia satellite systems, fiber to the home systems, and LMDS will exist in both cooperation and competition as important components of the network. In the third-generation mobile network with smaller cells than the LMDS network, the capacity of the LMDS system makes it well suited for connections to UMTS base stations.

| Type | Uplink data rate | Downlink data rate | Max range (km) |
|---|---|---|---|
| Analogue modem | 14.4–33.6 kb/s | 14.4–33.6 kb/s | N/A |
| ISDN | 128 kb/s | 128 kb/s | N/A |
| ADSL | 384 kb/s<br>640 kb/s | 2 Mb/s<br>6–8 Mb/s | 6<br>2–3 |
| VDSL | 640 kb/s<br>2 Mb/s | 13 Mb/s<br>25 Mb/s | 1.4<br>0.6 |
| Cable Modems | 0–384 kb/s | 30 Mb/s (shared) | N/A |
| Satellite; DVB-RCS | 2 Mb/s | 36 Mb/s (shared) | Not limited |
| LMDS | 0–8 Mb/s typical<br>25.8 Mb/s possible | 36 Mb/s (shared) | 5 |

**Table 1.** *Capacity comparison of some available access technologies.*

| Technology | Cell area | Capacity per km$^2$ |
|---|---|---|
| Terrestrial LMDS | 2–20 km$^2$ | 1500–150 Mb/s |
| GEO satellites | Up to semi-global | Low |
| LEO satellites | 3000 km$^2$ | 100 kb/s |
| Stratospheric platforms | 5–10 km$^2$ | 1 Mb/s |

**Table 2.** *Local capacity of some radio based access technologies.*

## APPLICATIONS

LMDS is first of all a system of high flexibility, allowing for capacity on demand. Changing the cell size through reduction of either cell diameter or illumination angle increases total capacity. Its flexibility with regard to high on-demand capacity in both directions makes it well suited to home offices and teleteaching in the local domain. The first major applications are TV-, Internet-, and business-oriented, thus combining professional and entertainment use. In Europe LMDS was considered a supplement/alternative to cable TV and was actually referred to as *wireless cable*. With digital television the possibility for convergence of TV, data, and communications opened up development of new broadband applications. Hopefully, the availability of broadband capacity will stimulate the growth of applications such as telemedicine and teleteaching, which have been recognized for some time without really taking off.

### FROM TELEVISION TO INTERACTIVE TELEVISION

The TV business has had strong growth, but the time spent by individuals watching TV has not changed very much. Digital TV represents new possibilities. The first step is the introduction and development of interactive TV, adding new and interesting functionality. More local TV programs will take advantage of LMDS. Interactive TV will stimulate growth in e-commerce; and the more local part of it, such as property trading, apartment renting, car buying and selling, and many other

*The local focus of LMDS makes it excellent for high-capacity connections to schools at different levels, connecting a group of local schools as well as providing connections to remote sites.*

transactions, will take advantage of the possibilities offered by local broadband networking. Telebanking and vacation planning are applications where interactive TV offers added functionality.

### TELETEACHING

Education, and updating/reeducation, is one of the major challenges in many countries today. Lack of educated and skilled teachers, particularly in technology, is a common concern. Young people of today may have to be reeducated and change their professional focus several times during their working lifetime.

The local focus of LMDS makes it excellent for high-capacity connections to schools at different levels, connecting a group of local schools as well as providing connections to remote sites.

Locally, it would then also be possible to connect to homes and have lessons stored for the use of both pupils and parents.

Broadband access will offer possibilities in education we have barely started to explore. The advantage of LMDS in this connection is the flexibility in capacity allocation and the multicast property of the downlink, allowing very efficient delivery for this type of applications.

## CONCLUSION

The broadband access market is now emerging. In Europe, 2000 seems to represent a breakthrough for digital TV, ADSL, interactive cable networks, and LMDS. Broadband access systems are gradually taking over connections to the home.

Licenses for LMDS are now being issued in many countries; deployment will take three to five years. During this first phase, LMDS seems to first become a technology chosen by the second and third operator. The business case looks attractive. Given a license for operation, the technology is rapidly deployed and brought into operation. The cost of establishing a backbone infrastructure connecting to the hubs of the individual cells sites by fiber, satellite, or radio link can be considerable, especially in countries with a poor telecommunication infrastructure. LMDS is a technology for a time of growing demand. It offers the flexibility for on-demand capacity required by the new TV-related interactive and high-speed data services combined with the increased demand for Internet access. It represents a complement to and competition for other broadband technologies such as cable, satellite, and ADSL/VDSL. Most important, it is a contribution to broadband access technology, stimulating growth and development of new applications in areas with a certain population density. It is not yet the technology for rural areas.

It is expected that availability of high-capacity access to every home will greatly stimulate the development of the information society, and bring areas like teleteaching and e-commerce a major step forward.

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## BIOGRAPHY


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