

Local Multipoint Distribution Service (LMDS)

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Abstract:

This is a survey paper on LMDS. With a introduction on LMDS and then a discussion on fixed wireless networks, this paper looks into different ways fixed wireless communication can be achieved and then gives a brief description on the various broadbands available for communication. It also discusses technical and design issues involved with LMDS.

See also: [Other Reports on Recent Advances in Networking](#)

[Back to Raj Jain's Home Page](#)

Table of Contents

1. [Introduction](#)
 - 1.1 [Using the Fixed wireless technology](#)
 - 1.2 [The advantages of using the Fixed wireless technology for LAN](#)
 - 1.3 [Different methods available for fixed wireless communication](#)
 - 2.0 [Usage of Broadband signal for fixed wireless LANs](#)
 - 2.1 [Issues](#)
 - 2.2 [The different omni directional High speed access broadbands.](#)
 - 3.0 [LMDS the technology for fixed Wireless LANs](#)
 - 3.1 [Emergence of LMDS and its specifications.](#)
 - 3.2 [DVB Specifications](#)
 - 3.3 [DAVIC Specifications](#)
 - 4.0 [LMDS technical and design issues.](#)
 - 4.1 [Architectural options](#)
 - 4.2 [Receiver design.](#)
 - 4.3 [Various options in access methodologies.](#)
 - 4.4 [Network planning](#)
 - 4.4.1 [Cell design issues](#)
 - 4.4.2 [Frequency planning](#)
 - 4.4.3 [Reuse schemes](#)
 - 4.4.4 [Modulation schemes](#)
 - 5.0 [Conclusion](#)
 - 6.0 [References](#)
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1.0 Introduction

Local Multipoint Distribution Service(LMDS), is a broadband wireless point to multipoint communication system that provides reliable digital two-way voice, data and Internet services. The term "Local" indicates that the signals range limit. "Multipoint" indicates a broadcast signal from the subscribers, the term "distribution" defines the wide range of data that can be transmitted, data ranging anywhere from voice, or video to Internet and video traffic(Later on in the

3rd section, the emergence of LMDS shows why it is good at transmitting such a wide variety of data.)It provides high capacity point to multipoint data access that is less investment intensive. LMDS with its wireless delivery combined with a significant amount of spectrum allocated, promises to allow for a very high quality communication services. It transmits milliwave signals with-in small cells. As it has been tested by the US military and the corporate pioneers like the SpeedUs, it is undoubtedly a proven technology.

Originally designed for wireless digital television transmission LMDS and MMDS(Microwave Multipoint Distribution System) were predicted to serve the wireless Subscription Television needs. MMDS is also a broadband wireless communication service which operates at lower frequencies. Usually, LMDS operates at frequencies above the 10Ghz range and MMDS at frequencies below the 10GHz range. Later on they were extended to offer other interactive services.

Before giving more information about LMDS, it becomes necessary to understand the importance of using Wireless technology for local LANS and then see the different methods available for wireless communication.

1.1 Using the Fixed wireless technology

Until about 1996, the only economical way to connect LAN's was through a wired infrastructure. In the last three years several new wireless LAN infrastructures are being proposed and built. wireless local loop is a new wireless option and comes under the Fixed wireless as opposed to mobile. Fixed here, refers to fixed location. It means though the data transmission is wireless, the stations are fixed,unlike in mobile where the stations could be moving(assuming a station is a subscriber). They give a very high speed communication. Dense modulation schemes are required and higher signal to noise ratio is required in a fixed wireless scheme.

1.2 Advantages of using the Fixed wireless technology for LAN

Some of the various advantages of adopting a fixed wireless paradigm are

1. The entry and setup costs are very small, ie. setup cost is very low and expansion can always be opted on demand.
2. Systems can be setup with great ease and speed. All equipment can be carried and installed with great ease.
3. Equipment can be setup only after a customer signs up. This is different from wired systems because for wired LANS, a complete infrastructure has to be built even before the customers show up.
4. Thus the build out becomes "Demand Based" which is a major advantage when compared to wired architectures.
5. Cost of upgrading can be substantially less, as there is no other infrastructure other than the end equipment, once the equipment is designed to be upgradable, upgrading becomes very easy.
6. There is less overhead of changing the transmission equipment and many problems of wired LANS such as tracing of damage in transmission equipment, do not exist at all.
7. Once the basic infrastructure is handled, quality of service can be achieved.
8. Bandwidth reuse is very high because of the cell structure used.
9. Network management, maintenance and operation costs can be very less.

The recent wireless networks have the ability to offer a wide range of one-way and two way, voice data and video service transmission capabilities with a capacity many times larger than any current wireless or non wireless service.

1.3 Different methods available for fixed wireless communication

In order to achieve fixed wireless communication, various physical media equipment can be used ranging from infrared, microwave to radio wave. A major problem with using Infrared signal is that they can be obstructed by physical objects, thus there should be an unobstructed path between the communicating equipment, which is not always possible. Microwave systems operate at less than 500 milli watts power. For the fixed service, Broadband wireless access systems are of particular interest. Few reasons for this are, they are very quick to install, and are

economical and cost effective. And also interconnection of the base station to fixed PSTN is possible and easy. For using the broadband signal there are various issues that need discussion, one important issue being the spectrum that can be used.

[Back to Table of Contents](#)

2.0 Usage of Broadband signal for fixed wireless LANs

2.1 Issues

The primary issue that needs attention is the spectrum in broadband that is best suited for fixed wireless needs and the bandwidth required for achieving a high data transmission rate. The FCC made available several new bands of wireless spectrum. In order to create viable competitive opportunities for wireless competition to RBOCs (regional bell operating companies, they have build a wired high-speed infrastructure for data transmission), the FCC enhanced the capacity of the existing spectrum licences. It started a host of omni directional wireless HSA(high speed access) networks. The new allocations promote bi- directional transport with no receive site licence required. In the next section we discuss the new omni-directional transmission bands. There are many other bands other than the ones discussed but none with exclusive licensing structure and bandwidth.

2.2 The different omni directional High speed access broadbands

FCC has started a host of omni directional high speed access networks. They are

The 38 GHz band:

This band is primarily licensed to Winstar and Advanced Radio Telecommunications[1](ARTT). Winstar uses ATM based equipment and provides POTS and high speed data. From the cost point of view, starting with point to point links and then as the network size increases, switching to omni directional cell site is advisable. But then, If for a particular network the shifting overhead is more, its better to start with omni directional network's.

The 28 GHz or the LMDS Band:

This 28 GHz band was regulated in 1998 with only a few major companies participating. This is called LMDS band as LMDS operates in this band in the United States (It could be different for different countries for example, in Europe, it is the 40GHz band) This has got different blocks of bandwidth. The "A" block with 1150 MHz bandwidth and a "B" block with 150 MHz bandwidth. Nexlink now holds most of this spectrum in about 30 markets. A high degree of "cellularization" is required with this band. Cell size is about 2 miles in radius. Various new proposals have been made about this and some of these will be discussed in later sections.

The DEMS band:

This band was originally allocated at 18 GHz with 100MHz bandwidth. The only operator in this band is telegent corporation. They convinced FCC to allocate it to 24GHz with a 400 MHz allocation. Telegent is deploying a wireless ATM backbone solution[4.2]. Its Idea is to provide pots at 30% discount rate to RBOC.

The MMDS band:

The FCC allocated about 200 MHz of spectrum at 2.1 and 2.5-2.7 GHz frequency for television transmission. In 1995 and 1998 FCC allowed for digital transmission with CDMA(Code Division Multiple Access), QPSK(Phase Shift Keying), VSB(Vestigial Side Band) and QAM(Quadrature amplitude Modulation) modulation schemes. Companies such as SpeedChoice and Wavepath.

3.0 LMDS the technology for fixed Wireless LANs

A cost effective technology that has no hassles of physical connections and can do two way wireless microwave transmission of mixed video, audio and data. LMDS the 28GHz band in america (Europe uses the 40GHz for LMDS), is the one that is being used for wireless LAN. Basically it is a wireless service that transmits fixed broadband microwave signals in the 28 Ghz band of the spectrum within small cells roughly 2 to 3 miles in diameter. It offers wide range of one way and two-way voice, video and data service transmission capabilities with a very large capacity, better than what many current services offer. With millpond radio technology combined with appropriate protocol, access method and speed, that gives LMDS the potential to transform the society. When implemented with a multi service protocol such as Asynchronous Transfer Mode (ATM) can transport among others, voice, data and even video. As a transport system LMDS can be engineered to provide 99.999 percent availability.

The few of the various advantages of LMDS for Local loops and LANs

0. Its very cost effective.
1. Major percentage of investment is shifted to CPE (customer premise equipment) which means operator spends money on equipment only if a customer signs up.
2. A very scalable architecture and it uses open industrial standards, ensuring services and expendability.
3. Network management and maintenance is vary cost effective.

3.1 Emergence of LMDS and its specifications

The advent of the LMDS channel was initially driven by digital TV applications. Standardizing for the Digital TV was first initiated in Europe with the establishment of Digital Video Broadcasting project(DVB) by the European broadcasting union. The technical specifications given by the DVB project were passed over to European Telecommunications Standard Institute(ETSI) from publication of standards[1]. Focus on microwave transmission was then made. The DVB gave the standard for the short range millimeter wave radio systems. DVB initially called it Multipoint Video Distribution system.

Another international body called Digital Audio Video Council (DAVIC) which groups major network operators, service providers and consumer electronics, telecommunications and computer industries. Though DAVIC is not a part of any official standard making body, It is very powerful.

3.2 DVB Specifications

In order for LMDS to benefit from the mass market of broadcasting satellites, specifications for LMDS downlink channel are same as those of "direct to home" satellite services. Both use QPSK (Quarternary phase shift key) modulation and concatenated forward error correction(FEC) coding scheme with a convolutional inner code and a reed solman outer code. The transmission frame is based on MPEG2 transport data stream.

The outer code carries 188 info bytes[1]. It has a block length of 204 bytes and can correct up to 8 byte errors per each block. This code is obtained by shortening the RS(255,239) Reed_solomon code[1]. A convolution inter-leaver with interleaving depth of I=12 is inserted between inner and outer encoders. This is done in order to uniformly distribute errors which occur by bursts at the VD output in the receiver. The interleaved and de-interleaved block diagram is sketched in the figure below.

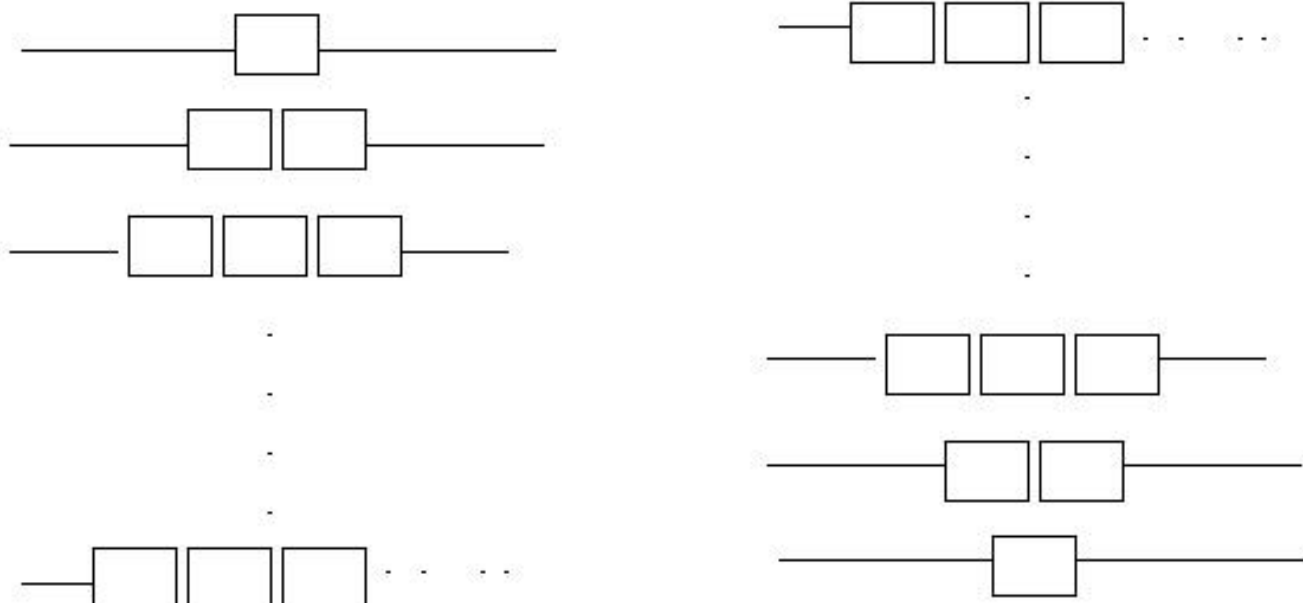


Fig-1: Convolution Interleaver

The input data bytes in the interleaver are, in a cyclic fashion fed to the 12 parallel branches which consist of simple first in first out shift registers. The delays starting from 0 are increasing by multiples of 17 with the second branch having a 17- byte delay and so on. It is given that for a convolution interleaver of length N and depth I comprises I branches and I Th. branch includes a delay of $(i-1)N/I$ units[1]. The output switch moves cyclically with input switch. Except for the reverse order of the delays, the deinterleaver also has the same structure. The DVB specifications give all the transmission and receive functions and system parameters, except for the symbol rate of modem operation. This was because no frequency planning was readily available.

3.3 DAVIC Specifications

DAVIC specification for LMDS was basically the same as the DVB specification except for a option of alpha values for channel filtering and either QPSK or 16-QAM for modulation. Basically, there is a lot of similarity between DAVIC and DVB specifications, DAVIC also seems to define future extensions. Along with the MPEG2 scheme use for detail video broadcasting (as discussed in the section above) a mapping function to ATM data in the down stream channel is also made. Two 187 byte packets are formed when 3 control bytes are appended to 7 consecutive 53 bytes ATM channel. A description of this can be in the figure below.

Control Byte	ATM Cell 1 53 Bytes	ATM cell 2 53 Bytes	ATM cell 3 53 Bytes	ATM cell 4 53 Bytes
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Control Byte	Control Byte	Cell 5 contd	ATM cell 5 53 bytes.	ATM cell 6 53 Bytes	ATM cell 7 53 Bytes
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Fig-2: Mapping of MPEG2 scheme to ATM cells.

The specification of the return channel was primarily done by DAVIC, because DVB was interested in broadcast services in its first phase.

The return channel that has been designed by DAVIC for LMDS is a multiple access channel and it uses TDMA. The MAC protocol allocates time slots to different users. Each user can transmit only if he has been given a time slot. The time slots as per the specification are made of 68 byte which include 4byte preamble and a one byte guard. The remaining 63 include 53 bytes of information and 10 bytes for parity check. Clearly each time slot carries a ATM cell. Error protection on the upstream channel is not as efficient it is on the downstream channel. But the compensation can be made at the design of the transmit and receive functions.

The MAC protocol is used to allocate resources to various user terminals. Both the downstream and the upstream frames are encapsulated as one ATM cell. Each frame on the down stream includes two slots. There is a frame start slot followed by a random access slot. The upstream frame has three slots namely the polling response slots, the contention slots and the reserved time slots. The polling response slots are obviously used to response to a poll message. The contention slots are shared and utilized by more than one terminal. They may result in collision and the contention when a collision occurs can be resolved in numerous ways, one by waiting for a random amount of time before retransmitting. Reserved time slots are reserved for use by the terminal. The terminal transmits on these slots when ever it has data and when it doesn't have any data it transmits an empty cell. The MAC protocol has also got an option of a combination of circuit mode reservation for constant bit rate services and it also has a dynamic reservation for the variable bit rate and unspecified bit rate services. Polls are periodically repeated at intervals of less that or equal to 2 seconds. If a new user comes in, it listens to the a downstream channel to find a message sent to it. If it doesn't find the message for 2 seconds then it switches to the next down stream channel and listens. This goes on till the terminal finds the message transmitted to it.

[Back to Table of Contents](#)

4.0 LMDS technical and design issues.

A normal LMDS setup has a central facility with a fiber-linked PSTN and internet connections relay signal via point to point microwave links which in turn pass the signal along to hubs, located on rooftops or as stand-alone towers, for Point to Multipoint (PMP)transport to the end site.

Basically, four parts in the LMDS architecture are

0. Network operations center(NOC)
1. Fiber based infrastructure
2. Base station
3. Customer Premise Equipment and NOC designs.

The network management equipment for managing regions of customer network come under the NOC. Multiple NOC can be interconnected. The fiber based infrastructure basically consists of SONET OC-12 OC-3 and DS-3 links, the ATM and IP switching systems, Interconnections with the PSTN, the central office equipment.

The conversion from fibered infrastructure to a wireless infrastructure happens at the base stations. Interface for fiber termination, modulation and demodulation functions, microwave transmission and reception equipment are a part of the base station equipment. Local switching can also be present in the base station. If local switching is present then customers communicating in the same base station can communicate with each other without entering the fiber infrastructure.

The customer premise equipment varies widely from vendor to vendor. All configurations include in door digital equipment include modulation and out door mounted microwave equipment. The customer premise equipment may attach to network using TDMA, FDMA or CDMA. Different customer premise equipment require different

configurations. The customer premise will run the full range from DS0, POTS, 10BaseT, Unstructured DS1 structured DS1 Frame Relay, ATM25 serial ATM over T1, DS-3, OC-3 and OC-1. And the customer premise locations can range anywhere from malls to residential locations.

4.1 Architectural options

There is one commonly discussed architecture with radio frequency planning. Typically the radio frequency planning for these networks uses multiple sector microwave systems. In this transmit and receive sector antennas provide service over a 90, 45, 30, 22.5 or 15 degree beam-width. The idealized circular coverage area around the cell is divided into 4,8,14,16,24 sectors.

Alternative architectures include connecting base station indoor unit to multiple remote microwave transmission and reception systems with analog fiber interconnection between indoor data unit and out door data unit.

There are manufacturers such as WavTrace, Ensemble communications and EndGate who have come up with different approaches. One idea from Angel technologies is to have an aircraft transmitting signals from overhead. They called it HALO (high altitude long operating). This Idea has various problems ranging from air traffic control to cost for medium sized cities.

While coming up with an architecture a standard issue that is considered is Point to Multipoint communication(PMP). The question that arises is if PMP is actually required. PMP allows multiple microwave paths allowing spectrum and capacity to be shared as needed. So if high bandwidth is required, then PTP (point to point) connection may be the best but otherwise, if bandwidth on demand is the case, then PMP is well suited. A new model that is ramping up quickly is IFU or the invisible fiber unit. Two IFU's that are setup in a line of sight link and placed back to back with other links. Thus in IFU transmit and receive create a link between source and destination.

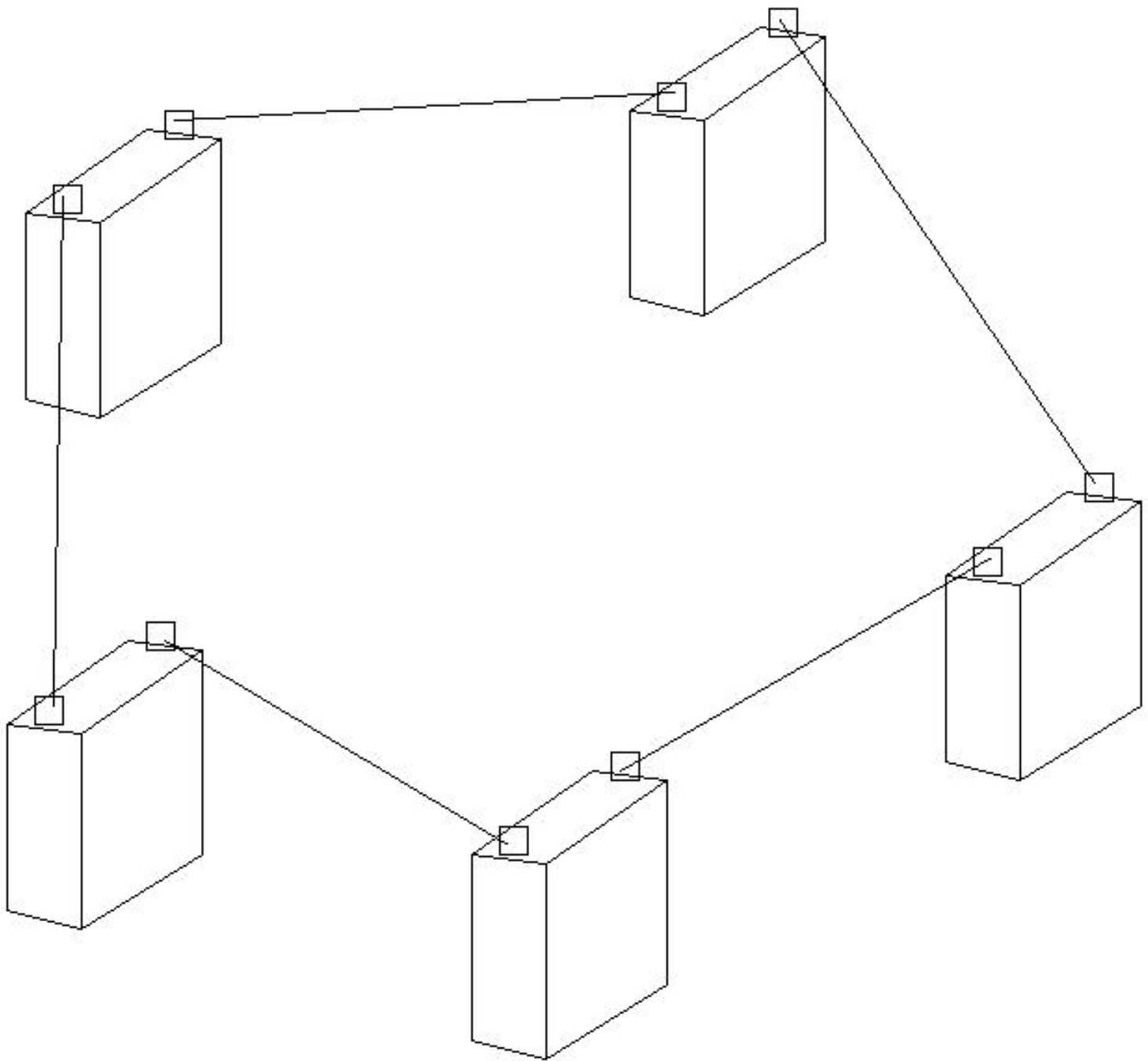


Fig-3: The IFU or the Invisible Fiber Unit connecting the buildings as a virtual network.

4.2 Receiver design.

The customer premise equipment has one outdoor unit with transmitter and receiver antenna of an indoor unit which in-turn communicates with subscribers equipment such as telephones and PC's. The indoor unit accepts the signal from the outdoor unit, demodulates and de multiplexes it and then interfaces with the connected subscriber equipment. The downstream intermediate frequency in LMDS is the satellite intermediate frequency (950-2050 MHz) in LMDS system. A major design issue of a receiver could be to achieve a large frequency acquisition range in the carrier recovery loop.

4.3 Various options in access methodologies.

For any wireless upstream link, there can be three access methodologies, TDMA, FDMA and CDMA. In the down stream direction from base station to customer premise, most companies supply TDM (time division multiplexed) streams either to a particular user(PTP) or shared among various user sites(PMP). The figures below show both the TDMA scheme and the FDMA scheme.

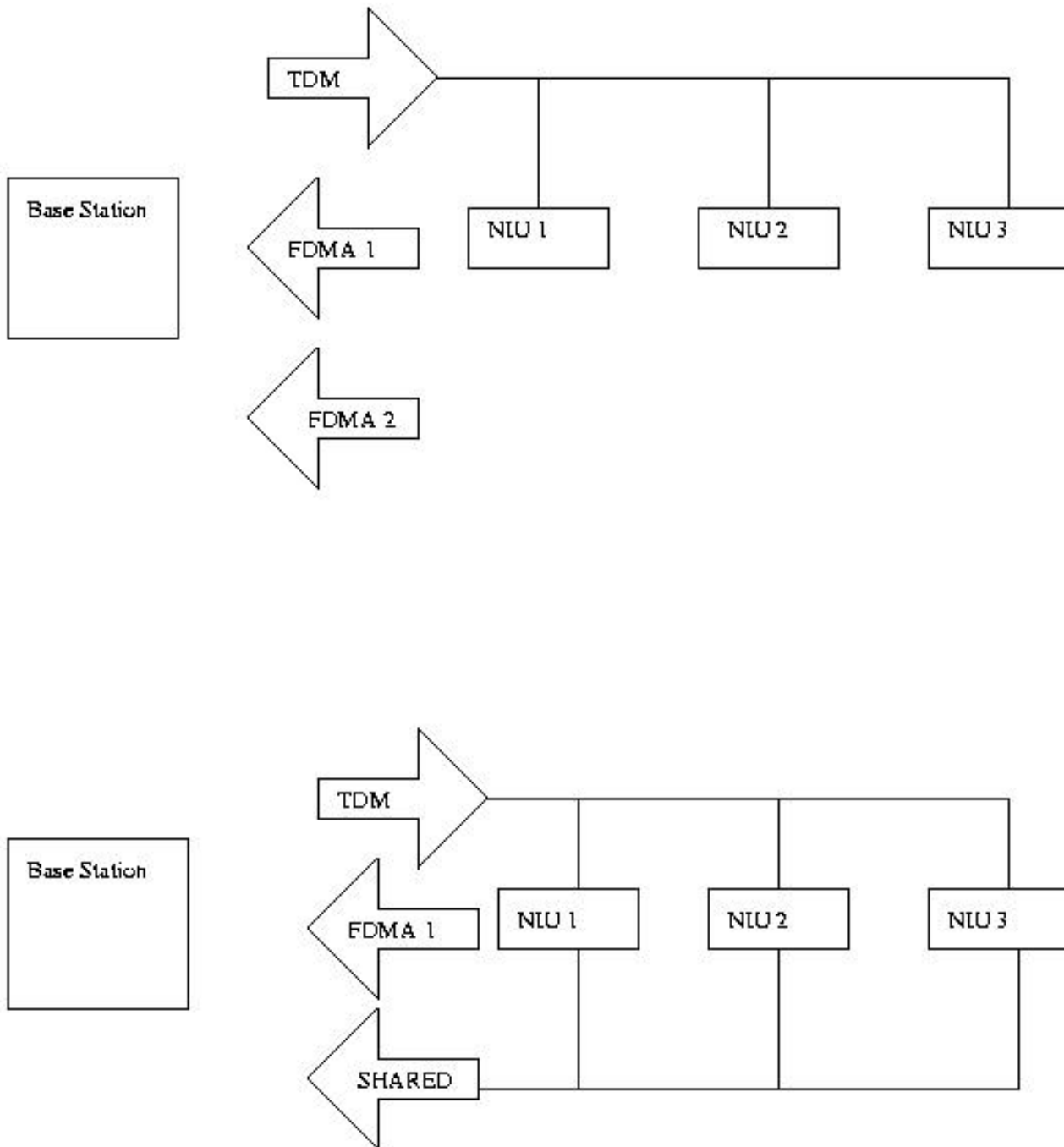


Fig -4 : The TDMA and FDMA access methodology.

FDMA schema allows a fixed bandwidth, or a bandwidth varying slowly over time. If the user requirement is a constant bandwidth (a dedicated one) and expecting continuous availability like a wireless DS3 or multiple structured DS1 connection, FDMA access links fit in well. FDMA links terminate in a dedicated FDMA demodulator, which as it should be, is in the base station. When the customer does not have a very heavy upstream traffic and just needs a 10

base T port, TDMA makes sense. So the choice is based on customer requirements and system design.

CDMA or the code division multiple access supports significantly smaller number of users than a TDMA. There are two classes of CDMA that are available, one is Orthogonal CDMA (OCDMA) called as OCDMA and the other is Non-orthogonal CDMA. Systems may often use a combination of the two. OCDMA is said to have identical capacity with TDMA [1]. OCDMA allocates using a mutually orthogonal spreading sequence. The other class of CDMA, which is Pseudo noise CDMA (non-orthogonal), all users interfere with each other and the capacity depends on how much interference one is prepared to tolerate. Both CDMA and TDMA have once again case-based advantages and both can be advocated to be good in a particular type of situation. When using smart antennas, using TDMA is an advantage.

Smart antennas use an adaptive array to cover a sector instead of the fixed beam antennas. With the help of the sensors located, the beam can be moved in the direction of the user, dynamically. By changing the coefficients in the adaptive array, the beam can be moved horizontally or vertically. These smart antennas implement what is called as Space Division Multiple Access (SDMA). As the users in the TDMA are sequentially using the channel, it is well suited for the SDMA and smart antennas where as in CDMA, the simultaneous access makes it complicated.

For discussing the data rate capacity in both the accesses, we use the Bits per second per hertz, measurement unit. For the various modulation schemes, the rate varies. Two areas where comparisons can be made would be data rate capacity and maximum number of customer premise sites.

Maximum data rate:

For the FDMA, the bandwidth spectrum efficiency is $1.5b/s/Hz$ for a 4-QAM modulation where b is bits and s is seconds. For the 16-QAM and 64-QAM the bandwidth spectrum efficiency is $3.5 b/s/Hz$ and $5b/s/Hz$ respectively. The TDMA band doesn't use the 64-QAM modulation. For the other modulations it has a reduced data rate.

Maximum number of customer premise sites:

For the FDMA assuming a " x " MHz spectrum with a reuse frequency of " r ", the LMDS system provides x/r MHz usable spectrum per sector. If we assume the downlink spectrum to be " d " times the uplink spectrum, the downlink will have $d*(x/r)/(d+1)$ spectrum and the uplink would have a $(x/r)/(d+1)$ spectrum. If the channel bandwidth is assumed to be " b ", then the maximum number of customer premise equipment would be

$(x/r)/((d+1)*b)$.

For the TDMA for a given $(x/r)/(d+1)$ spectrum, if we assume about 16 DS0 connections possible with 1 MHz then the total number of simultaneous users would be

$16*(x/r)/((d+1)*b)$. If the values of concentration over entire sector and cell are assumed to be in the ratio 1:s then the total connections would be $s*16*(x/r)/((d+1)*b)$. Which would be very high when compared to what is possible with FDMA.

4.4 Network planning

Network planning for LMDS includes cell design where in a design of a LMDS cell is discussed. Then the issue of planning the frequency comes in. After planning the use of frequency, a very major issue, which could make a very big difference when it comes to data transmission speeds is the cell reuse and reuse optimization. Each of the following issues have been discussed in brief below.

4.4.1 Cell design issues

The attributes that require attention while designing the LMDS cell are

0. Cell size selection- Based on the desired reliability level the cell size has to be decided.
1. Cell overlap- An issue that has to be taken into consideration while designing the cells.
2. Subscriber penetration- The number of subscribers having required signal level to achieve quality of service.

3. Number of cells-The number of cells in a sector is dependent on the cell size decided.
4. Traffic capacity- Based on the traffic capacity of the area, the cell size and properties are fixed.
5. Quality of service- Cell overlaps that exceed the allowed normal ca effect the quality of service.
6. Link budget- Estimation of the maximum distance that a user can be located from the cell while the cell while still achieving acceptable service reliability.
7. Capital cost per cell-Used to estimate the network capital requirement.

Bellcore the engineering consultant firm formerly owned by AT&T, publish a study of LMDS prior to LMDS auction, concluded that only 25 cells covering only 2% of the land area should be built to yield an economical business. This may sound very attractive to the CLEC's (competitive local exchange carriers).

4.4.2 Frequency planning

The channel spacing that is usable by the operators in Europe is 112, 56, 28, 14, 7, 3.5.(All in MHz) These are obtained by successive division of 112 by 2. The capacity in upstream and down stream usually differs because, even if the bandwidth allocated is same, physical layer function of both the channels are different. So even if the bandwidth is equally distributed among the upstream and downstream channels, it is not possible to get same capacity. So physical layer issues such as channel coding and filtering have to be taken into consideration when planning channels if, equal capacity for down and up links is desired.

4.4.3 Reuse schemes

A very important issue that can substantially change the speed of transmission and utilization of bandwidth is frequency reuse. In a given geographical area how effectively can the frequencies be reused. First possibility is to use a hexagonal cellular pattern (same old mobile cells). As illustrated in the figure below, this frequency allocation scheme requires three times the bandwidth allocated to one cell.

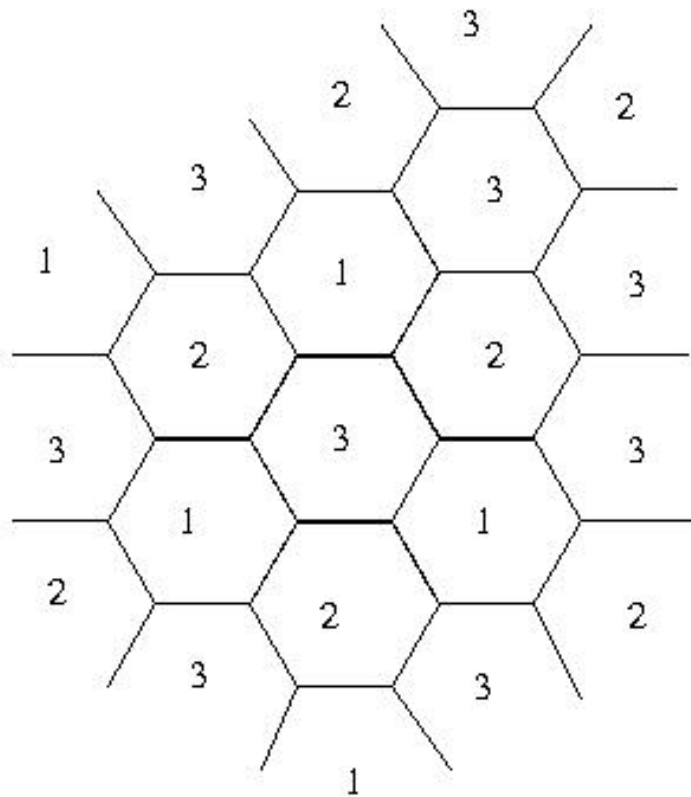


Fig-5: The hexagonal cell reuse pattern.

Another possibility will be to use rectangular cells. Each quadrant of the cell in this figure is labelled with a

digit which indicates the frequency or group frequencies used in that sector. The frequency reuse pattern reduces the bandwidth requirements by 2 by using two orthogonal polarizations. This is shown in the figure below. This is the initial state, after optimization the distribution is made only with two colors.

d	c	c	c	d	c	c	d
b	a	a	b	b	a	a	b
b	a	a	b	b	a	a	b
d	c	c	c	d	c	c	d
d	c	c	c	d	c	c	d
b	a	a	b	b	a	a	b
b	a	a	b	b	a	a	b
d	c	c	c	d	c	c	d

Fig-6: The rectangular cell frequency reuse pattern.

Antenna sectoring with in a cell has advantage of reducing the maintenance costs.

Few techniques to optimize frequency reuse are[4]

0. Maximization of Isolation between adjacent sectors by use of polarization.
1. Maximization of the directivity of the cell antennas by sectoring the distribution system. Minimization of cross-polarization and multipathing.

4.4.4 Modulation schemes

Modulation schemes can tune the data rate to some extent. Low density modulation allows greater distance at a given power, but sacrifices data throughput rates. LMDS however utilizes QPSK therefore realize about 1.8 Gbps of raw capacity even though they had five times the MMDS bandwidth (MMDS can give 1 Gbps using 64QAM for its downstream links). Recently broadband developers have been taking more risk at using advanced coding methods to achieve efficient use of bandwidth. Thoughts of using coding techniques like OFDM (orthogonal frequency division multiplexing) for LMDS have been put forth.

Another new coding scheme called the Frequency-domain reciprocal modulation(FRDM) has been proposed by Thomas Williams [[Loring](#)], founder of Holtzman Inc. (Longmont, Colo.). This has been proposed as an alternative to OFDM.

Advanced Hardware Architectures staff scientist Eric Hewitt described the use of turbo product codes for LMDS application. Radio developers could cut the number of base stations necessary for LMDS internet access system with potentially reducing the rain fade common to such broadband systems, by using their turbo product codes.

[Back to Table of Contents](#)

5.0 Conclusion

LMDS promises a wireless alternative to fiber and coaxial cables, It has the potential to replace the existing wired networks, it may prove to be the easiest way to deliver high speed data and two way video service. Its capability of handling thousands of voice channels with the existing bandwidth makes it a good contestant in the voice industry. With current industry trends, that are tending to merge the telecommunication and the networking industries, LMDS seems to be a solution that suits all their needs. For the recent digital TV world, LMDS is a very good choice considering the fact that LMDS was designed with Digital TV broadcast in mind.

[Back to Table of Contents](#)

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[Back to Table of Contents](#)

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