Implementation of Radio over Fibre Techniques for Low Cost Radio Access in Local Multipoint Distribution Systems

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Abstract - **In this paper we focus on the Hybrid Fibre Radio (HFR) techniques for use within Local Multipoint Distribution Systems (LMDS). In section two we introduce the concept and reasons for considering HFR in LMDS, whereas section three is dedicated to one of the main advantages; the possibility for centralised dynamic frequency allocation. Section four describes the most relevant optical modulation techniques. This leads to the selection of the most appropriate solutions for this application.**

Keywords – **Hybrid Fibre Radio, Local Multipoint Distribution System,, Optical BB modulation, Analogue RF modulation Dynamic frequency allocation**.

I. Introduction

The integration of wireless and optical networks is a potential solution for increasing capacity and mobility as well as decreasing costs in the backbone of access network. By using Hybrid Fibre Radio (HFR), the capacity of optical networks can be combined with the flexibility and mobility of wireless access networks. The concept HFR means to transport information over optical fibre by modulating the light with the radio signal. This modulation can be done directly with the radio signal or at an intermediate frequency. HFR is a relatively new concept when considering the transmission of analogue RF waves over fibre. The practical deployment of such systems will depend on the technological development of electro-optical devices capable of modulating light waves with RF signals. Such an architecture can give several advantages:

- Reduced complexity at the antenna site. This can be achieved because modulation/demodulation, up/down-converting, multiplexing, etc. can be performed at a central office serving several antenna sites.
- Radio carriers can be allocated dynamically to the different antenna sites. In this way, more efficient use of the radio resources can be made since each carrier can be allocated to the cell where it is mostly needed.

At the same time, Local Multipoint Distribution Systems (LMDS) is being deployed in various countries, as an efficient means of meeting user needs for new services, interactivity and high bandwidth at a reasonable cost. LMDS architectures consist of star networks, with several slave cells monitored from a control and co-ordination centre via a master cell. The connection from the control centre to the master cell is usually wired, but from the master cell to the slave cells many types of connection are possible. The low cost argument for LMDS normally leads to radio link connections, but sometimes infrastructure and economical aspects will favour wired connections. LMDS is becoming an attractive solution for last mile distribution to households. As users will require more and more bandwidth in the future, it is natural to consider LMDS architectures employing optical fibres between base stations. At the same time, LMDS is often a good solution when remote locations need network connection, where optical fibre will represent superfluous capacity and excessive investments. Hence, a balanced deployment of optical fibre solutions has to be sought. New technological development in HFR will reduce the base station complexity and cost, and thereby make optical solutions increasingly attractive. Techniques based on radio frequency (RF) transmission over fibre, the possibility of light wave multiplexing and dynamic frequency allocation are key issues in this context.

II. Overview of the Possible Architectures

LMDS is a generic system for local broadcast and interactive services covering both professional and entertainment services. To obtain the required flexibility LMDS must, to the extent possible, be implemented with a service independent architecture.

From a network and service point of view LMDS will interact with other networks. Although it is primarily an access network, it may also operate as a backbone or feeder network to other networks consisting of smaller cells. In areas with remote cell constellations radio, fibre or HFR may be used to connect base stations for an area covered by clusters of cells under the same management and co-ordination.

One possible realisation of LMDS is in case, when only one base station is connected to the transport network (represented by the LMDS Control Centre). The main co-ordination centre is the entrance point to the actual geographic area served by the LMDS. The cell in which they are located is defined as a master cell. All cells are individually fed from a LMDS base station connected to the co ordination centre. A base station will normally feed several cells when located at the periphery of a cell. This radio network connects to the different users within the cells and defines the LMDS access network for the cell. The distribution system of the cell is a star system with a Point to Multi-Point (PMP) down link and a point to point up link.

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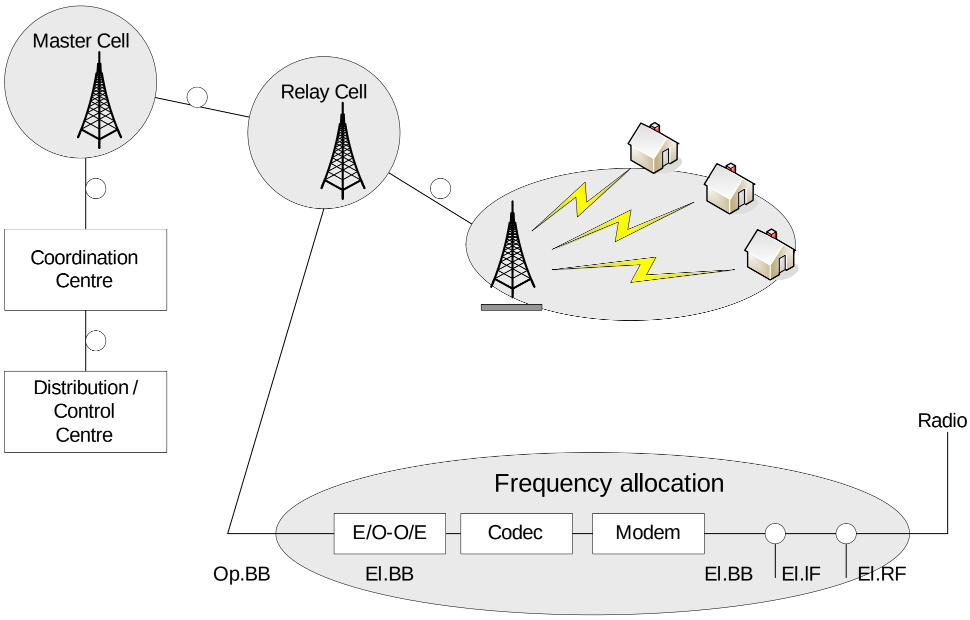

Fig. 1. LMDS with optical BB links

Normally, LMDS is operated as an interactive PMP radio access network. Both the down- an uplink is implemented via radio. The relation between the down- and uplink traffic may span between complete broadcast (no uplink) to symmetric systems. In some cases, the system is primarily used for video distribution. It is then called MVDS (Microwave Video Distribution System). In this case, the return channel (uplink) might not be implemented via the radio interface. It can be implemented in a number of other ways, depending on factors like capacity need, available technologies and cost.

There are three parts of a LMDS network where optical fibre may be an option:

- Optical fibre from a control centre out to a master cell
- Optical fibre also from the master cell out to the remote antennas
- Optical fibre for indoor distribution

Two classes of optical modulation technique are possible for LMDS systems; baseband digital (BB) and analogue radio frequency (RF). We have described some aspects connected to the use of the BB and RF techniques in the following.

A. LMDS with optical BB modulation

Optical baseband modulation signifies that the signal is conveyed through the fibre as a digital signal, and there will be a need for frequency conversion at the radio interface. Figure 1 shows a combination of optical fibre connections between LMDS base stations with radio connections to the more remote base stations.

The up-conversion from optical BB signal to RF radio signal will take place at the optical terminating LMDS base station. These base stations will have to be equipped with optical modulators and demodulators (E/O and O/E), signal processing equipment for radio links (codecs, modems, equalisers, synchronisers etc.) before up-conversion to RF signal, necessitating several local oscillators.

There are several disadvantages of such an approach however, stemming from its inherent inflexibility. There is no possibility of central, dynamic frequency allocation. Also, the LMDS base stations are relatively complex; all elements necessary for conversion between optical baseband and radio frequency waves are necessarily implemented in the base station. This is why the BB technique is not considered reliable in the LMDS case.

B. LMDS with analogue RF modulation

With RF modulation, the signal is analogue from the Control centre and is distributed at the radio frequency to be employed for the last mile radio transmission. In this case, no signal processing or frequency allocation is required at the LMDS base station, only the E/O and O/E conversions will be performed. The complexity of the LMDS base stations acting as repeaters, depends on whether baseband conversion is necessary in order to extract traffic for different destinations (i.e. for packet switching), or if this extraction can rather be based on extraction of optical carriers in a Wavelength Division Multiplex (WDM). scheme. If baseband conversion is necessary for switching, not much has been gained compared to the BB situation described previously. Therefore, extraction of optical carriers seems to be the most attractive solution for repeater base stations.

Figure 2 shows the same network as in figure 1, but now with use of RF modulation. We notice the simplicity of the LMDS base station compared to figure 1. Another advantage of this system is that the radio frequencies may be allocated at the co-ordination centre, enabling enhanced frequency reuse and more flexible bandwidth allocation.

The main disadvantage of this system is the current immaturity of the technology although systems like this will be conceivable in the future

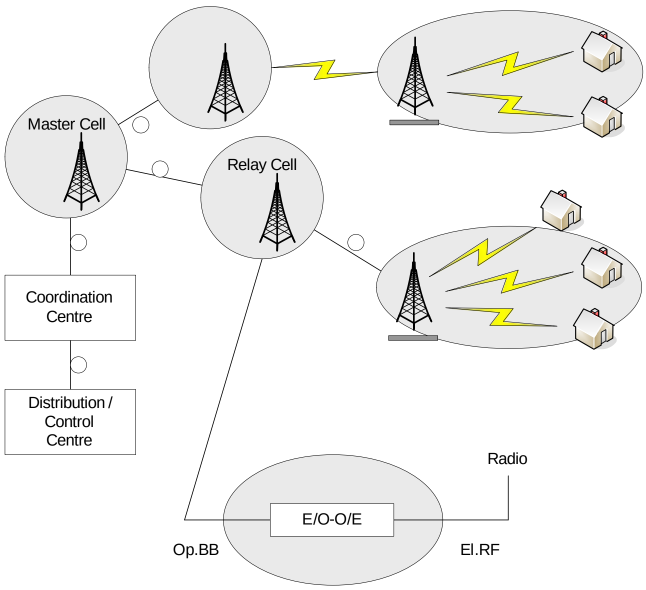

Fig. 2. LMDS with analogue RF modulation

III. ADVANTAGES OF DYNAMIC FREQUENCY ALLOCATION

An important additional feature of using an optical HFR feeder system is the possibility to apply dynamic frequency allocation to meet the varying capacity demands. Following this approach an ideal architecture for a combined HFR-LMDS system is shown in Figure 3. All radio transceiver components for the LMDS system are concentrated in a central multi-cell base station serving a cluster of radio cells.

The base station contains also the HFR headend components, which transmit the radio carriers to the Remote Antenna Units (RAU) located at the cells. For LMDS, sectorisation is an important issue, and each RAU needs to be connected with one fibre per sector. The concentration of the active components in a single location allows us to assign radio carriers dynamically, following the actual capacity demand.

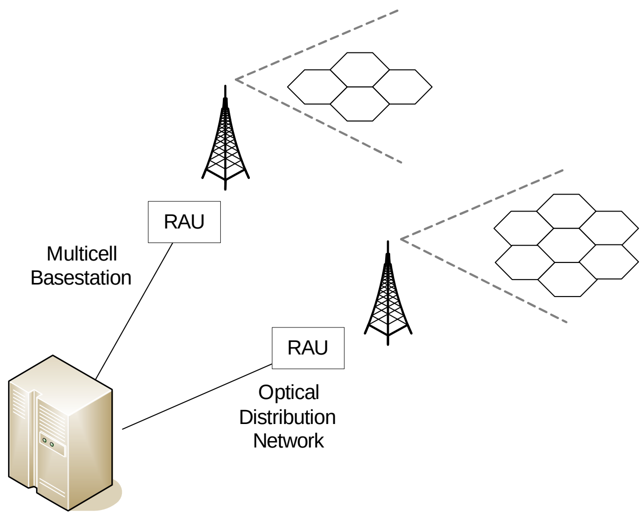

Fig. 3. Dynamic frequency allocation with HFR Feeder System

A HFR based distribution system provides the possibility of adding radio carriers without the need to modify or exchange the equipment at the RAU units and thus will allow a more flexible upgrade strategy for the network operator. This flexibility is particularly important for the roll-out of new services, where the demand is not known in advance.

The possible benefits of dynamic frequency allocation in LMDS systems depend on the absolute number of available radio carriers. It must be considered that a single operator may not own the total frequency band allocated for the LMDS service. However considering the high total frequency allocation of e.g. 2GHz in the 28 and 40GHz bands, there might be a high number of single radio carriers. The ETSI Recommendation [1] for symmetrical point to multipoint systems is based on n x 2Mbit/sec connections operating in channel widths from 3.5MHz to 112MHz. For a total bandwidth of 2GHz this relates to 18 to 572 radio carriers..

Related to the dynamic radio carrier allocation, is the relation between transmission capacity and radio bandwidth. The transmission capacity of a single channel depends on the modulation and coding format, which may be adaptive in some systems. Adaptive in this context means, that e.g. the system can switch from 4-QAM to 16-QAM in case of good transmission conditions, e.g. for near terminals. This corresponds to a twofold capacity increase using the same radio resources.

The absolute bit rate required by a customer is an uncertain factor in LMDS systems, as it will depend on the services and application scenarios. This is in particular true for the downlink/uplink asymmetry, which is a property of many applications like web browsing, audio and video-on-demand. This indicates that flexibility is an important feature and may even justify a higher installation cost for HFR components. While for video on demand, a bit rate of 4MBit/s downlink and 64kbit/s uplink might be sufficient, a business customer like a desk top publishing company might need bi-directional 100MBit/s. On the other hand the company will possibly use this high rate only for a short period of time per day. In a flexible LMDS-HFR system this capacity could be reused during the rest of the time to provide video-on-demand for another 25 customers, all using the same radio equipment.

An advanced application of dynamic frequency allocation in LMDS systems is to adapt the radio capacity to temporary customer movements. If the LMDS network detects a higher activity in a particular area, it may dynamically assign additional radio carriers to this area using the HFR feeder system.

IV. OPTICAL TRANSMISSION TECHNIQUES SUITABLE FOR LMDS

Here we look at four of the most promising optical technologies for a wide variety of applications, suitable for LMDS. The candidate technologies are:

A. Digital baseband (BB)

Conventional optical link that is used extensively in transmission systems. Base station hardware must detect, demodulate, demultiplex, remodulate, and upconvert to the radio frequency. One transceiver is needed per carrier frequency. Dynamic reconfiguration of the signal format and number of transceivers is not possible.

B. Direct RF modulation of a single mode laser (DFB)

This is an Intensity Modulation–Direct Detection (IM-DD) link.

C. Optical single sideband (OSSB)

This is a special type of externally modulated optical link in which the modulator is driven in such a way that only one modulation sideband is produced [3]. This results in a link that is tolerant to fibre dispersion since only one signal is generated in the base station photodiode. Conventional IM-DD links use double sideband modulation that produces two signals in the base station photodiode that cause periodic fading in the presence of fibre dispersion, especially at high frequencies. OSSB is therefore suitable for systems requiring high frequency capability.

D. Electro-absorption modulator transceiver (EAM)

This is a new approach that avoids the need for a light source in the base station for the return path, which leads to the lowest complexity. The EAM device is an optical modulator that can also be used as a photo detector. As a base station transceiver, it acts as a photodiode for the send path and as a modulator for the return path. The light source for both directions is located in the central unit.

E. Comments on IHDN based on plastic fibres

In-house distribution networks (IHDN) based on optical plastic fibres have gained a lot of attention lately. The use of plastic fibres is convenient when short distances are involved and the price must be kept low. One of the main interests is that one single connection (antenna) can transmit all the traffic of the household. LMDS may then very well become the transport network carrying all the traffic into the house, In order for LMDS to become interesting as a provider for IHDN, HFR may very well be the solution.

The key features required of any HFR system are:

- Frequency range. Not all of the candidate technologies can support high radio frequencies. This is obviously of high importance to LMDS, which operates in bands around 30GHz.
- Dynamic range. Analogue optical links have limited dynamic range. This is not an important feature for LMDS however, since the path loss is not likely to change substantially once the radio link is in place.
- Flexibility. The ability to dynamically change the frequency plan, signal format and number of carriers is very attractive since it allows the network to be managed, reconfigured and upgraded effectively. Only the BB technology will not allow this.
- BS cost. The analogue technologies (BB, OSSB and EAM) have the potential to enable low BS cost since most of the system complexity is located in the Control Unit (CU).
- Reliability. If most of the system complexity is located in the CU then reliability will be increased. The analogue technologies are therefore relatively more reliable than BB digital.

V. Conclusion

We have investigated the possible use of Hybrid Fibre Radio techniques for Local Multipoint Distribution Systems. For analogue optical techniques, the advantages of such a combination were identified to be the simplicity of the base stations and the flexibility, in addition to the increased capacity, which is a valid argument both for analogue and digital optical modulation. The simplicity will reduce the base station cost and increase the reliability. Increased flexibility is illustrated by the possibility of dynamic frequency allocation. There are two restrictions connected to the analogue optical modulation, the first being the maturity of the technology, a second restriction is the need for baseband conversion in relay stations when packet switching systems are used. Of the optical modulation techniques analysed in this paper, only two were identified as of interest for the LMDS application; BaseBand and Optical Single SideBand. The BB technique is the digital technique employed in optical fibre systems today, whereas the OSSB is an analogue technique meeting the most important requirements of LMDS systems.

References

[1] ETSI TM4: "Draft New Recommendation EN301 213 Point to multipoint digital radio relay systems in frequency bands in the range 24.25 - 29.5GHz"

[2] Balzaretti S., Janković M., Odadžić B., Szomolanyi T.: "Techno-economic analysis of Radio and Hybrid technologies for mobile networks", 3th Conference on the Design of Reliable Communication Networks-DRCN2001, Budapest, Hungary, October 2001, pp.78-83.

[3] G. H. Smith et al,.: "Technique for optical SSB generation to overcome dispersion penalties in fibre-radio systems", Electron. Lett. vol. 33, 1997.

[4] Paxal V., Janković M., Odadžić B., Gospić N.,: Hybrid Fibre Radio usability for future broadband wireless access, Proccedings of International Conference TELECOM 2000, Varna, Bulgaria, October 2000.

[5] E. Vergnol et al,: "Fully integrated millimetric single sideband light wave source", Electron. Lett., vol. 33, 1997.

[6] D. Wake, D. Johansson and D. G. Moodie : "Passive picocell - a new concept in wireless network infrastructure", Electron. Lett., vol.33, , 1997.

[7] ETSI BRAN : http://www.etsi.org/bran/

[8] Peha J.: Approaches to Spectrum Sharing, IEEE Communi-cations Magazine, Vol 43, No 2., February 2005.