Use of License Exempt Bands to Enhance Broadband Services in an MMDS Network

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Introduction

Broadband services are being rapidly deployed using MMDS spectrum [1-3]. For certain applications license exempt bands (also called unlicensed bands) used in conjunction with MMDS spectrum can provide better broadband services more cost effectively in areas where coverage otherwise is difficult due to terrain or other conditions. Here we give a few examples of scenarios where this concept of using multiple frequency bands can be very effective especially for second tier markets. ADC provides many system solutions for MMDS and LMDS systems for variety of customer needs. Generally for first tier markets consisting of large cities a large number of mini cells using the MMDS band spectrum can address the capacity and coverage needs fairly well. In this paper we provide alternate system architectures and give examples of 1) a point to multi point system 2) a wireless back haul application and 3) in building wireless LAN applications using 2.4 , 5.8, 24 and 60 GHz license exempt bands.

MMDS / License Exempt band point to multi point system

High speed data services using MMDS spectrum can be deployed today using a few large cells (>20 mile radius) or many small cells (<5 mile radius) or a combination of both. Deployment of many small cells offers advantages of higher capacity and better coverage than large cell approach but has significantly higher initial deployment costs. For rural areas with very low population density large cell scenario is more applicable. For those areas of a given geographic region that do not meet the minimum number of potential subscribers to justify the expense of an MMDS base station, using license exempt solutions in the ISM bands offers an attractive solution to the coverage problem. Whether it is an area over a hill, one blocked by tall buildings, or simply beyond the range of the main MMDS central site, wireless routers operating in the ISM bands offer a cost effective and easily integrated supplemental network.

In this scenario, a remote MMDS unit is located where it can be co-located with the point to multi point central site, while still maintaining LOS to the main MMDS base station. The diagram in figure 1 illustrates the fundamental network topography being proposed. ADC has deployed MMDS systems in a number of cities in USA and has found that for many rural areas this approach can increase coverage without increasing deployment costs significantly. This technique is specially useful if the rural area to be covered is very hilly. Even in large cities like Pittsburgh with many hills our tests showed that hills can cause significant blockage of signal and the homes and businesses on the other side of the hill could not be served unless more MMDS hub sites were added. Detailed simulations with link budgets and coverage maps with EDX software for the Pittsburgh area where this approach is applicable is presented in a section below. In this manner license exempt band systems extend the reach of the broadband MMDS wireless network. We have shown in figures 2, 3 and 4 the coverage maps for Pittsburgh using realistic link budget parameters for a large cell. Since the terrain is very hilly the coverage in many of the areas shown in white, yellow and red colors is poor. These are the areas where the coverage can be improved using the combined MMDS and unlicensed band system architecture.

Architectures for servicing shadow areas in the MMDS coverage

A very important question when planning MMDS service coverage is how to provide a high speed service in areas where buildings and irregular terrain form shadow areas that cannot be covered from a central point. An operator is motivated to maximize the coverage in order to get the maximum return from initial investment of the base station, the tower real estate and all the networking, modem, transmit and receive equipment. Obviously the solution of installing new cells in the shadow area is always available, but only when the number of subscribers in the area justifies the relatively higher cost of another broadband MMDS base station.

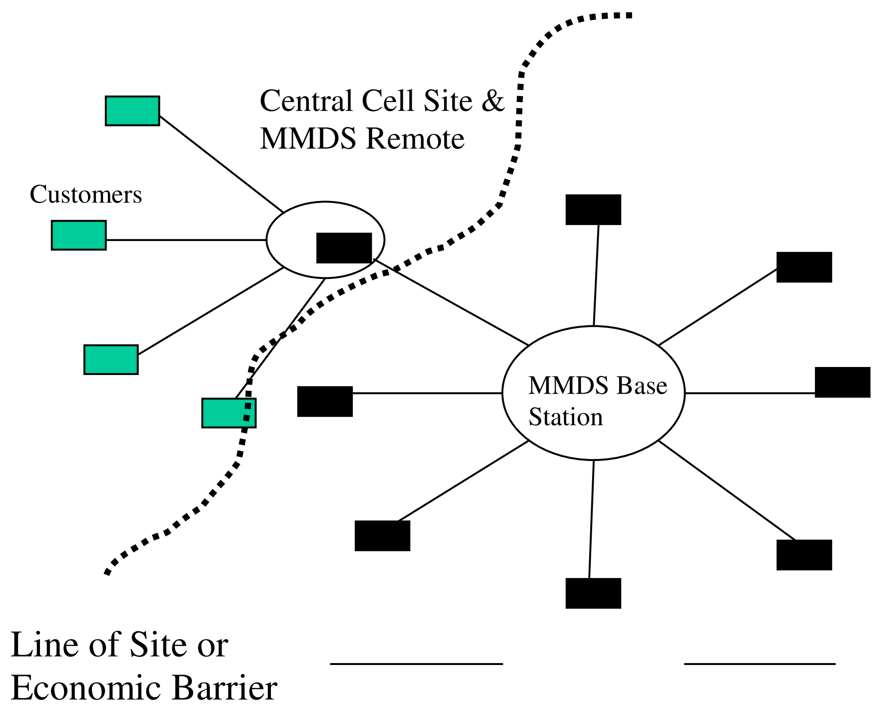

Figure 1. Network architecture showing use of unlicensed band for areas uncovered by MMDS band cell (due to hills, buildings etc.)

In this paper we shall analyze solutions based on the use of unlicensed band system. The advantages of this choice are as follows:

– The unlicensed band technologies are relatively mature and several manufacturers offer relatively low cost solutions, both for indoor and outdoor [4-11]. For a low number of subscribers at relative short to medium distances (2-10 mi), the unlicensed technologies offer solutions competitive with an additional MMDS base station.
– The use of a non-MMDS frequency spectrum in the shadow areas simplifies the MMDS interference scenario and reuse pattern
– The unlicensed band systems use spread spectrum techniques and has built-in interference mitigation techniques, so that the interference between their different segments are generally negligible.

In a system involving the combined use of MMDS and unlicensed bands one will need to analyze a number of system architecture parameters:

– Capacity of the unlicensed band system covering the shadow
– Relevant MMDS frequency and capacity planning
– Data interfaces and services.

Capacity of the unlicensed band system

The capacity of the unlicensed band cell is one of the determining factor in deciding whether to use an unlicensed band or an MMDS band minicell in the uncovered area . It is the number of subscribers and the data capacity of the shadow area that has to be estimated first. Depending on the subscriber type and number, the following unlicensed band options should be considered:

A. Outdoor wireless access systems operating under 802.11. This kind of solution may provide up to 3 Mb/s total, raw data-rate per base stationand serve several tens or even hundreds of subscribers. Lesser numbers would apply for higher capacity subscribers such as businesses or SOHO. One such product is the BreezeACCESS, an outdoor FHSS system based on 802.11 from Breezecom. As a bridged solution it is best suited for one customer or short range, campus style networks. It will be available towards the end of 1999. Up to 15 hub stations can be collocated.
   Another product with higher capacity is Wavenet IP 2400 and 2458 from Wireless' Inc. which provides coverage over up to 20 miles. As a routed or layer three based network, these products are a good fit for multi-customer networks in applications such as Internet access.

B. Unlicensed point-to-point systems. This kind of solution would apply when we want to serve a small number of high capacity subscribers. These systems operate also with a PHY similar to 802.11 (compliant to FCC part 15) but provide communication only between two points. This is a quite established technology with products capable of providing 1 E1/T1 or even more, from companies such as Breezecom, California Microwave, P-Com and others.

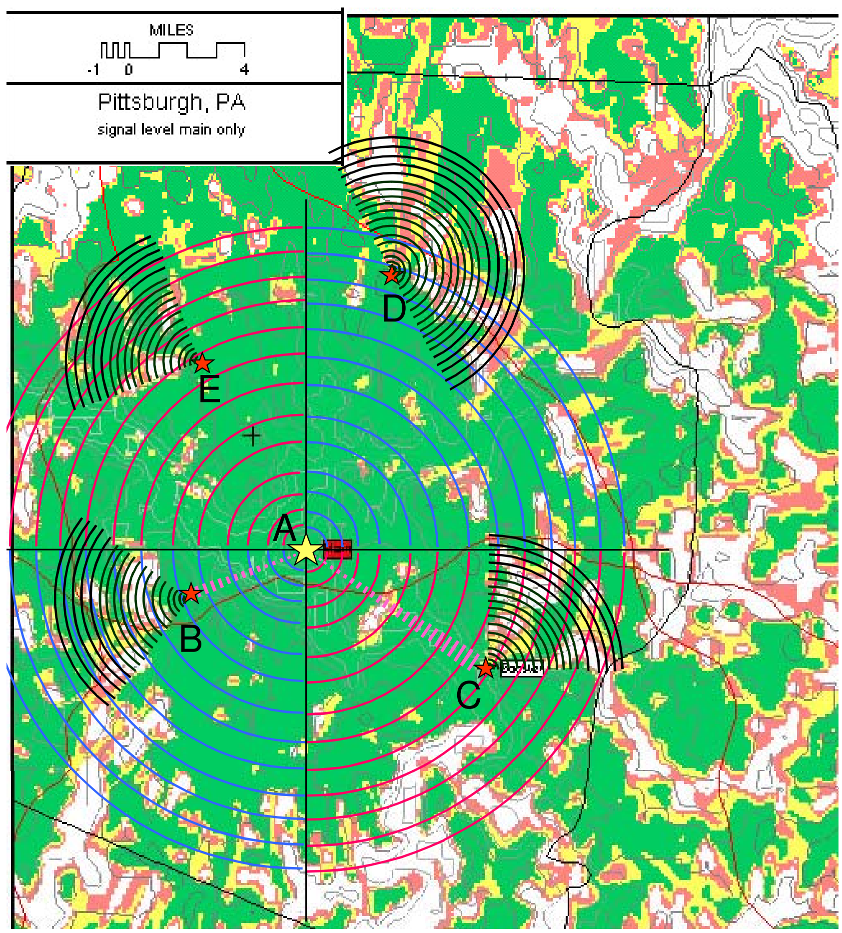

Figure 2. Service area covered with MMDS and unlicensed bands. The map coloring reflects the MMDS coverage only

C. Unlicensed wireless access systems in the 5 GHz band. These are systems operating in one or more of the U-NII bands (at 5.15 - 5.35 GHz and 5.725 -5.825 GHz) or the ISM band at 5.775-5.850 GHz. Such systems are capable of providing between 10 and 25 Mb/s. Wireless Inc offers systems with capacity in the range of 16 Mb/s either as point to point or as point to multipoint systems. Wi-LAN has promoted the ambitious 802.11a standard using OFDM. Presently they offer a point to point system migrating towards an access system. Other companies offer more established technologies such as the point to point systems from RadioLAN (10 Mb/s) and the adaptive ATM based TDD system AB-Access from Adaptive Broadband at 25 Mb/s.

Relevant MMDS frequency and capacity planning

The MMDS system acts as backhaul for the previously reviewed unlicensed systems. The interface with the MMDS system can be one of the following two options:
When the area served by the unlicensed system has high capacity, in the order of more than 3 Mb/s both ways, then the preferred option is the use of dedicated point to point links within the MMDS spectrum. Such links can be engineered with high gain antennas and the adequate amount of power that would create minimum interference and assure high link availability. One channel for upstream and one for downstream have to be reserved for this purpose, and because of the narrow beam they can be reused several times in the service area. The data rate is 27 Mb/s, so that it can backhaul one U-NII hub station. Figure 2 shows such an MMDS deployment. The MMDS hub A (yellow star) covers four sectors. Two sub-bands – red and blue – are reused in back to back sectors. Each sub-band has one or more channels. The MMDS coverage area is shown in green for sufficient receive signal level and yellow for edging levels. The unlicensed band hubs are shown as red stars: B, C, D and E. They are on high points covering the MMDS shadow areas. Two of them, the hubs B and C are fed through point to point MMDS links – shown in pink – that use channels different from the red and blue. Figure 3 is a zoom in the area covered by hub B, and shows its 90° coverage over the shadowed area. Figure 4 shows the same area as figure 1, but now the coverage given by B is taken in consideration. The simulation considers a 0.25 W transmission power at 5.8 GHz.

Other unlicensed hub stations with less capacity – the hubs D and E are connected not through point to point MMDS, but through the basic MMDS access system, having a regular MMDS modem as its interface. In these cases the upstream capacity is the limiting factor. For close non-challenging locations, upstream channels of 3.2 MHz can be used, providing approx. 3.4 Mb/s. But in most locations the upstream channels bandwidth is required to be down to 1/4 or even 1/8 of that.

Data interfaces and services

The unlicensed band system is complementary to the MMDS system and will have to interface and to provide an extension of its services and functionality. Most of the unlicensed band systems have 10baseT or 100baseT interface. The most important service related issues relate to the extension of the following MMDS system features towards the unlicensed point to multipoint access systems:

– 1)QoS, 2)VoIP, 3)Security, 4)Remote management, either Browser based, (SNMP) or both

Some systems preserve the QoS in its native IP form such as those based on 802.11. The AB-Access, from Adaptive Broadband on the other side, translates into ATM. Others such as those developed by Wireless Inc, incorporate the feature in the base radio protocol. VoIP is also supported in both MMDS and the complementary unlicensed systems, but the exact characteristics of the interworking, still have to be analyzed for every case in particular. The security is implemented at the low level MAC layer in the MMDS systems aligned with DOCSIS, as well as in 802.11. As the interface is in non-encrypted mode, no particular problems are expected.

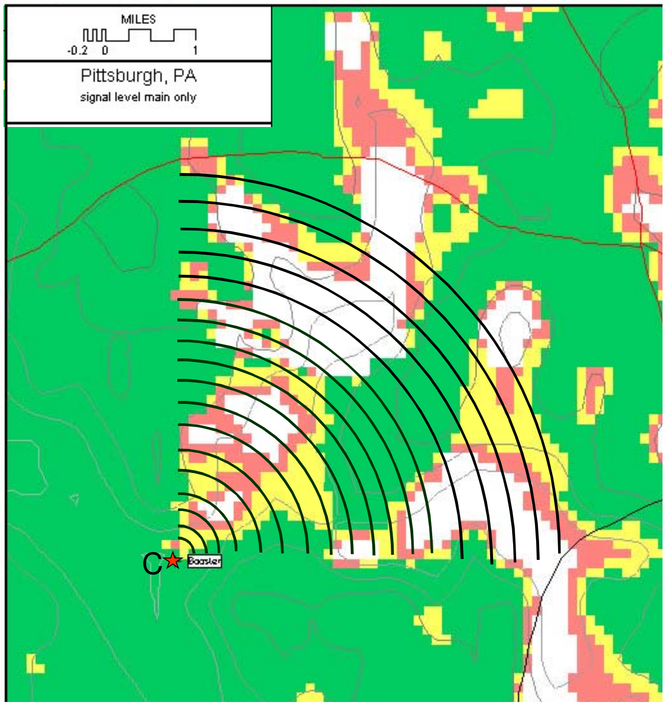

Figure 3. Zoom in the area covered by the U-NII hub C.

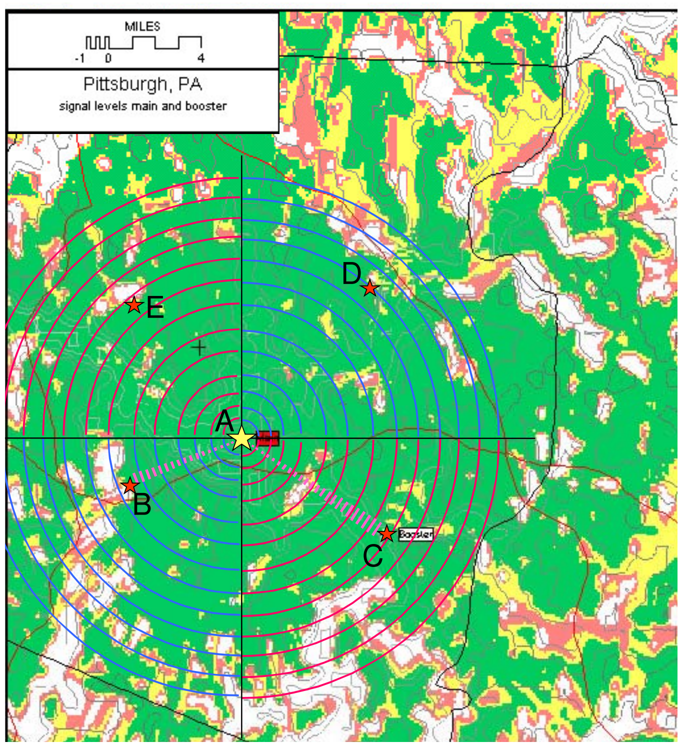

Figure 4. Service area covered by MMDS and the U-NII hub C. Coloring reflects combined coverage, MMDS and unlicensed band

Interference Mitigation

One of the concerns with operation in a license exempt or ISM band is that of interference from other unlicensed band users. With proper use of the spread spectrum technology and network planning interference can be almost eliminated There are four primary methods or factors that contribute to addressing these interference issues and each of them is discussed briefly below:

Spread Spectrum Technology – When deploying networks that are point to multipoint in nature in the ISM bands, there are essentially two choices or spread spectrum technologies to be considered; Direct Sequence (DS) and Frequency Hopping (FH). It is generally acknowledged that the DS systems can support higher bit rates than FH systems, however at a cost of reduced immunity to interference.

For resisting narrow band transient or even non-transient interference in point to multipoint networks, FH systems will have an edge over DS networks. If the FH system experiences a bad hop, or possibly even more, it will merely send the data out on the next clear hop. No data is lost. With a DS system, if the interference is high enough, the link will fail and data transmision will be interrupted.

Split Band Operation – The large majority of license exempt equipment deployed today operates in the 2.4GHz ISM band, with a small percentage in the 5.8GHz ISM band. Wireless Inc. uses both of these bands to allow full duplex operations and reduce the effects of interference as follows.

When operating a point to multipoint wireless network, the central units typically use an Omni or sector antenna. The remote units will have a directional antenna pointing back to the central site. Thus it is at the central units where most of the interference occurs with the wide beam antennas. The system is architected to transmit from the central to the remote at 2.4GHz and receive data from the remotes at 5.8GHz. Thus the band that has the greatest amount of potential noise, 2.4GHz, is only seen through a narrow beam directional antenna at the remote.

Locating the Central Sites – It is a common misconception that wireless network providers want the highest point in town for their central site equipment. While this may be true to a limited extent, Line of Site issues will almost always result in several central sites being deployed. Once this is acknowledged the question becomes where best to situate these central sites. Most of the interference that occurs in the 2.4GHz band comes from the dense urban areas with business' that are being served by 2.4GHz point to point equipment. This means that the 2.4GHz radiation is emanating outward from the city center. With the split band system, the central sites are located on the edges of the city., The remote units are situated facing outward to the central sites with the backs of their antennas exposed to the 2.4GHz interference sources.

Rural or Edge Deployment – In the US market, where the wireless access plays best is where the infrastructure is weakest. There is little need in downtown New York for instance for wireless fractional T1 connectivity because the fiber or copper are already installed and are easily obtained. Where wireless networks can make the largest contribution and reach the "low hanging fruit" are in the tier two and tier three markets. These markets are typically less built out and as a result have far less ambient 2.4GHz radio signals floating around. In these environments coverage of up to 20 miles is easily achievable as a network deployment strategy with the Wireless Inc. system.

In summary by employing the techniques described above, a service provider can be extremely successful in deploying license exempt networks in a fashion that will provide the promises and benefits of these networks not only in the beginning, but for several years after installation.

Case Study – W-DSL in Las Vegas using license exempt band

Unlicensed band networks providing Wireless Digital Scriber Line (W-DSL) technology from Wireless Inc. have been deployed in a number of areas. Here we describe one successful deployment in Las Vegas showing that this technology is deployable today. As development of W-DSL networks progressed in the spring of 1999, it became apparent that the final proof of concept was going to require a complete citywide network as a final test case. The city of Las Vegas was chosen as this test city for several reasons:

- Lack of adequate copper infrastructure. In Las Vegas business customers had the choice of 128kbps or 1.5Mbps, with nothing in between.
- There was a demand for these fractional T1 services from the business community.
- The relatively near by location made logistical support for installation and operation much less complicated.

During the summer of 1999 Wireless Inc installed a W-DSL network in Las Vegas with the intention of operating as a wireless CLEC. As a wireless CLEC, several ISP's would be able to support customers on one wireless network.

Basic Architecture

For a W-DSL network there are three basic components:

1. The central cell sites – this is where the point to multi-point (pt/mpt) equipment is located.
2. The backhaul of the traffic from each cell site to a distribution node.
3. The distribution node itself, where all wireless traffic is aggregated and then based on which customer belongs to whom, that traffic is sent off to the proper ISP.

The diagram below is a logical description of this design.

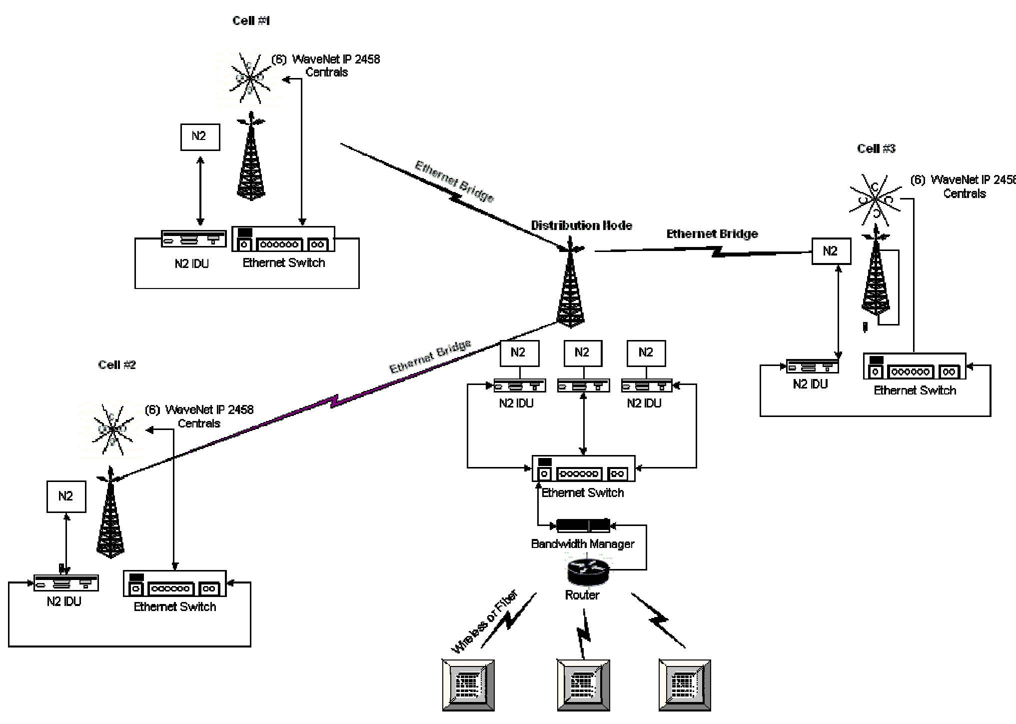

Figure 6. Block diagram of the Las Vegas W-DSL network

For the cell sites, point to multi point (pt to mpt) routers are used to ensure adequate security and segregation of IP traffic from each customer. For mixed customer networks, it is acknowledged that a routed solution must be used, and thus it is of critical importance that these first layer local access devices be routed solutions.

With the advantages of using license exempt pt to mpt routers as the first layer wireless access device, it is important for the same reasons to have the pt to pt backhaul solution be license exempt as well. In the Las Vegas W-DSL network this was accomplished by using a UNII band Ethernet bridge, which had the ability of co-existing with the full duplex 2.4GHz/5.8GHz wireless routers.

At the distribution node the pt to pt traffic comes into an Ethernet switch which then passes it to a bandwidth manager to offer different classes of service. At the back end of the distribution node, another router with multiple T1 ports segregates each customer's traffic based upon which ISP they belong to, and then sends it out the appropriate port.

Central Cell Sites

The central cell sites can have from one to twelve central routers depending on market demand for that cell sector. In Las Vegas, the initial deployment has six central routers at each cell site. This equipment was mounted in a variety of ways, some bolted to the side of stairway walls, and some suing non-penetrating roof mounts. The picture below shows the former method.

Figure 7. central site antenna and other hub equipment

Note that this picture shows only three of the six central units, the other three are mounted on the opposite side of the roof.

With a scalable technology, more central routers or more cell sites can be added as the business case warrants, the W-DSL network was to meet a market demand that copper just was not fulfilling. As a complete wireless solution, the city of Las Vegas local ISP's can now offer fast Internet Access without reliance on the local RBOC, who may be a competing ISP in the future.

Wireless Backhaul application

In a many cell, cellular MMDS architecture the cells need to be connected together with a backhaul solution capable of high data rates.. There are many backhaul options available for MMDS networks based on customer requirements including backhaul capacity, cost, use of customer's existing fiber network, phased cellular deployment etc. As an end to end system provider ADC in conjunction with its partners provides the following backhaul options: 1) ATM over SONET based fiber ring   2) Microwave link backhaul using licensed frequency bands, 3) Microwave link backhaul using unlicensed frequency bands at 2.4, 5.8 GHz and other frequency bands etc.

There are many system tradeoffs in selecting an optimum backhaul solution. For small towns (of less than 100K population) with less data traffic 2-8 T1 backhaul capacity may be enough. For larger towns with large number of subscribers with high data rate needs, OC3 and higher capacity may be needed. For lower backhaul capacity needs multiple T1 connection or point to point radio link connections may be sufficient. Point to Point microwave links are appropriate for backhaul when the required capacity is less than a few T1s to DS3 and the cost of fiber near the base station is too high. This is generally the case in the rural and less populated areas. Also many times the base station hub is located on a ridge which may be inaccessible by fiber.

There are unlicensed band (ISM and U-NII bands) products available for backhaul aplications from a number of companies. The capacity of these products is generally low (16 Mb/s) for MMDS cell backhaul applications. N2-X is one one such product operating in the 5.3 and 5.7 GHz band. This type of low capacity is only useful in cell in a rural area with less population. A typical MMDS cell in a lager city needs OC-3 or higher backhaul capacity.

In a combined MMDS / unlicensed band system, MMDS point to multipoint system can satisfy the backhaul needs of the unlicensed band cells as shown in figure 3. In this scenario the upstream link will be the limiting factor in terms of capacity since the MMDS system modulation rates in the upstream are typically QPSK and 16QAM. Down stream capacity is generally higher due to availability of 64 QAM modulation.

In Building Broadband Wireless LAN

Many applications in a building require portable broadband connections to a notebook or a laptop PC. In building wireless LANs at 2.4, 5.8 and 24 GHz are now available at multimegabit data rates. Integration of MMDS network with the in building wireless LAN will be required for many of these applications. Also as Bluetooth and HomeRF technology is developed, a low cost in build network will provide an easier way for mobile computing and communications devices to communicate with one another and connect to the Internet at high speeds without the need for wires or cables. Bluetooth technology will also make it easier for users of mobile computers, mobile phones and handheld devices to keep their data synchronized. The Bluetooth radio operates in a globally available 2.4 Ghz ISM band, ensuring communication compatibility worldwide. Connections are instant and they are maintained even when devices are not within line of sight. The range of each radio is approximately 10 meters, but it can be extended to around 100 meters with an optional amplifier. In Bluetooth technology each channel supports 64 kb/s synchronous (voice) link. The asynchronous channel can support an asymmetric link of maximally 721 kb/s in either direction while permitting 57.6 kb/s in the return direction, or a 432.6 kb/s symmetric link. A broadband MMDS network in the future needs to be able to interface seamlessly in these advanced inbuilding wireless networks

Summary

Various architectures are proposed to use license exempt bands to supplement and enhance the broadband MMDS networks. Specifically unlicensed band network can be used in conjunction with MMDS network to fill holes in coverage due to hills or buildings etc. or extend the coverage of the MMDS network. MMDS and Unlicensed bands can be also used for low to medium capacity backhaul requirements. As more devices become available which comply with Bluetooth and Home RF and other in building networks it makes sense to integrate these networks seamlessly with broadband MMDS networks.

Acknowledgment

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