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Re:	This contribution is a response to the Call for Contributions from the 802.16 Coexistence Group regarding Broadband Wireless Access (BWA) systems.
Abstract	This contribution provides a description of Frequency Division Duplexing that is applicable to the work of the IEEE 802.16 Broadband Wireless Access Working Group.
Purpose	This contribution recommends that the described Frequency Division Duplexing method be adopted for BWA systems.
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Frequency Division Duplexing for Broadband Multipoint LMDS Networks

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Overview

Many recent papers have attempted to compare various attributes of transmit/receive duplexing solutions to multipoint broadband network implementations. Most of these comparisons limit themselves to comparing the best case of one world with the worst case of the other. This paper attempts to summarize the issues and provide insight into the various underlying driving factors for Frequency Division Duplexing (FDD) which dictate the resultant network performance.

The following issues are addressed:

- Channel bandwidth and RF propagation issues
- Hardware costs
- Dynamic Channel Asymmetry Adjustment
- Cell Radiuses
- Network Capacity

Bandwidth and RF Propagation issues

FDD systems separate the up and down links in the frequency domain, essentially creating two channels within which to run traffic. The channel peak data rate has a proportional influence on the cost of modems and radio hardware required.

From a propagation perspective, the bandwidth of the RF channel being consumed in any radio system has a low pass nature defined by a number of practical elements, including Inter-Symbol-Interference (ISI). When considering the bandwidth available from a generalized RF channel operating at LMDS/CS frequencies using 90^{o} base station antennas and narrow (i.e. $1\text{-}3^{o}$) STS antennas and installed Fresnel clear, unobstructed line-of-sight (LOS), the channel response is on the order of ~ 40 MHz[1]. Other systems, which do not use FDD, must operate well above this channel bandwidth in order to achieve the same peak data rate. To avoid the dispersive effects of the channel, these non-FDD systems must apply equalization to the radio link (including within the STS).

Hardware Costs

Many legacy FDD solutions employ frequency diplexers. However, there are emerging solutions in which orthogonal up-down links are employed. In these implementations, the up-down links are not separated with an expensive diplexer but rather by an extremely low cost ortho-mode transducer (OMT) cast into the STS antenna feed.

Additionally, FDD does not require active RF components, such as T-R switches, at the STS. This increases reliability and reduces the hidden costs associated with ongoing network operations.

[1] Measured, cumulative envelope impulse responses of LMDS/CS channels in urban & suburban environments

Finally, timing synchronization problems for FDD systems is constrained to individual channels, to address such issues as bearer service operation and TDMA operation. There is no requirement for retaining a high degree of timing integrity across a given metropolitan network to control self-interference. This results in low cost timing reference equipment at each base station (i.e. instead of highly distributed GPS timing sources).

Dynamic Channel Asymmetry Adjustment

When considering a multi-cell network, a very large number of self interference sources can exist from as far away as ~ 50 – 70 km[2]. For a given metropolitan LMDS/CS network to be practically managed and to operate with optimal efficiency (in terms of managed frequency reuse plans), the network must operate with understood interference sources. Adaptively modifying up-down link ratios creates a virtually unpredictable co-channel interference scenario, which will not reliably support widely deployed business access connectivity.

A reduced scenario is to allow a given metropolitan network to be “adjusted” to the demands of the customer traffic at a macro level (i.e. on an annual basis through statistics collection within the network). In this case the “adjustment” of the network then becomes similar to the techniques employed in FDD approaches in which different numbers and bandwidths of up and down channels are deployed/activated as a function of traffic demands. In both cases, established services, governed by their respective contractual Service Level Agreements (SLAs) need to be honored. When broadband radio licenses are involved, it is relatively simple for FDD systems to be planned such they grow into various T-R splits of the allocated radio license (dictating the final/ultimate traffic asymmetry in a given metropolitan network).

Cell Radius

Cell radius is affected by a number of RF hardware parameters including the RF bandwidth and the STS noise figure and transmit power available. For a given range, performance degrades as the channel bandwidth increases. At the STS, this may be compensated by either increasing the transmit power and/or using larger antennae. Both options drive up the STS cost.

FDD systems using radio diplexers tend to have “tight” cross over requirements and therefore end up incurring losses on the order of a few dB. This loss reduces the noise figure performance and transmit power performance of the STS radio, resulting in reduced range. These systems generally compensate for this shortcoming by reducing bandwidth, increasing STS power and/or increasing antenna size, all of which increase STS costs.

In FDD systems using orthogonal polarized up/down links, virtually no loss is incurred and therefore the STS noise figure and transmit power are optimized, improving cell radius.

Network Capacity

Access capacity can be impacted by a range of factors, including the following:

- Basic Modulation Efficiency
- Guard Banding Requirements
- Frequency Reuse

[2] outcome of IC RABC/FCC investigation into US-Canada cross border interworking

The theoretically attainable modulation efficiency is limited by implementation loss, which includes the following:

- Effect of non-ideal sharp cut-off spectral shaping filters
- Effect of additional linear distortion created by realistic filters
- Effect of signalling with a peak-power-limited amplifier
- Relative efficiency between preamplifier filtering and postamplifier filtering
- Effect of practical nonlinearities encountered with real amplifiers on system performance
- Techniques for linearizing amplifiers
- Techniques for counteracting linear distortion caused by realistic filter characteristics

This implementation loss increases as a function of channel bandwidth and interference.

In FDD solutions, the use of diplexers in co-polarized up-down link implementations usually results in creating a set of STS radios for broadband licenses so that guard banding is avoided. At the base station, however, the roof-top limited T-R physical separation can drive requirements for significant guard banding (on the order of a few hundred MHz). This is needed to prevent transmitter signal leakage into the receiver, resulting in receiver desensitisation.

In FDD solutions using orthogonal polarized up-down links, guard banding at both the STS and BTS can be reduced to ~ 0 (although a few tens of MHz is usually employed).

Frequency reuse performance is a function of cell topology and RF network layout. However, when “dynamic” up-down link asymmetry is employed, the resultant frequency reuse will degrade significantly.

The figure below illustrates a three-dimensional worst-case interference model[3] of a 25 cell metropolitan network. Assuming a QPSK solution with a ~ 15 dB C/(N+I) performance requirement, very close to 100% of the coverage area can be addressed. The underlying issue is that this can be achieved when all transmission is occurring at known frequencies. When considering a dynamic asymmetry solution in which co-channel interference will occur, the C/(N+I) requirement will increase to ~ 25 – 30 dB. When considering this requirement, it can be seen that very little of the network is able to support this performance level. The resultant frequency reuse plan needed to realise the fix for this translates into comparatively poor frequency reuse (typically 20 – 40%) which is a direct indication of net efficiency loss.

[3] Winplan simulation tool

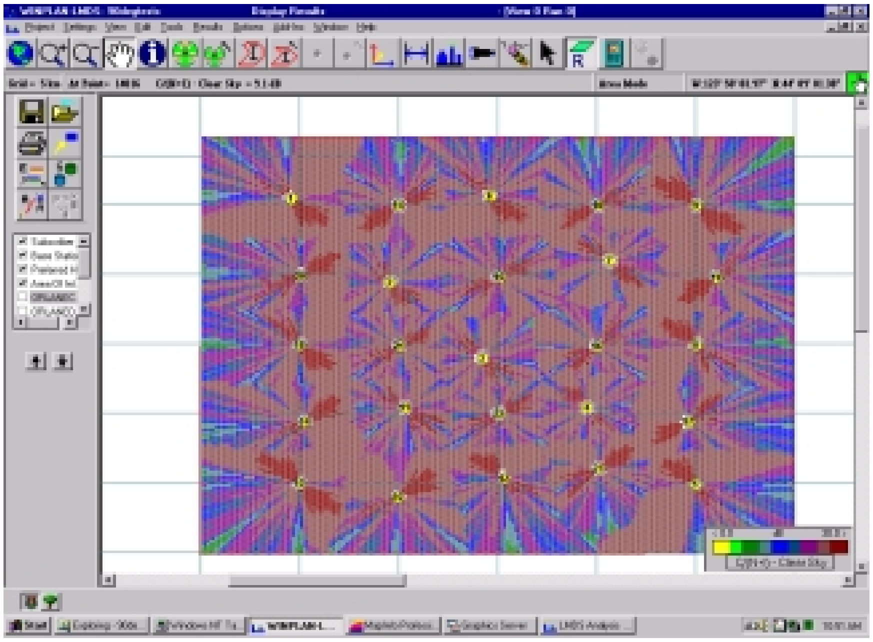

Figure 1 – A Worst Case Metropolitan RF Network Interference Simulation (28 GHz)

Coping With Global License Assignments

Global licensing tends to fall into three general categories, namely:

- Broadband contiguous blocks licensed in a given geographical area to a single operator: These are generally self-regulated, where the operator can design the up-down linking allocations independent of the regulatory body.
- Narrow channel assignments (similar to those allocated to point-to-point applications) licensed in a given geographical area to a single operator: These licenses tend have fixed T-R spacing and symmetrical go and return channels. Some of these are self regulated (i.e. US LMDS B-band) but in most global cases the multipoint down and up links are defined by the regulatory body.
- Large split blocks of spectrum licensed in a given geographical area to a single operator in which the multipoint down and up links are defined by the regulatory body.

When reviewing the above categorisation, it is clear that up-down link allocations are already regulated. Although US LMDS B-band is self regulated, deployments there must still be co-operatively interwork with those in A-band to mitigate interference.

Co-polarized FDD solutions can be made to work in many of the global allocations using interleaved diplexer designs in the STS. However, license blocks such as the popular 500 MHz contiguous block and US LMDS B-band do not afford an appropriate T-R spacing for cost effective implementations. Additionally, in narrow channel assignment cases (i.e. Europe/ETSI 26 GHz, US 38 GHz) it is possible for a given operator to have more than one license. In these cases it is possible for the licenses to be at the extremes of the allocation, causing the base station T-R separation to be problematic (see figure below) when attempting to exploit multi-carrier operation of the base station resources (i.e. all RF channels processed through a single TX and RX per sector covered.

FDD solutions using cross polarized up-down links are not inhibited from operating in any of the generalized license categories outlined above. This solution allows for both large T-R splits as well as narrow ones (~ 0) and can operate multicarrier without base station deployment limitations.

For the operator, the more highly applicable architectures will likely end up with larger global installed base and therefore are more likely to yield cost reductions through volume deployments.

Statement on Intellectual Property Rights

Newbridge Networks has patents, either accepted or pending, which may be relevant to this proposal. Newbridge Networks has read the IEEE patent policy and agrees to abide by its terms.

References

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