em Solutions
Innovation in Microwave Communications

Backhauling WiMAX on Wide Channel TDD

White Paper *Created August 2008*

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Don't waste spectrum on licensed FDD. . .

Backhaul WiMAX on TDD!

WiMAX rollouts require high capacity backhaul networks. Wireless can be a cost effective backhaul solution in areas where fibre is impractical. This article illustrates some effective ways of using wide channel time division duplexing (TDD) radios to backhaul WiMAX networks.

1. Introduction

WiMAX rollouts require high capacity backhaul networks. Backhauling on a Radio technology can be a cost effective backhaul solution in areas where fibre is impractical. However spectrum is expensive, so it is important to choose the correct wireless technology. Licensed FDD PTP Radio links are often presented as the preferred Radio backhaul technology. EM Solutions argues that wide channel, time division duplexing and multiple access is a better solution for WiMAX backhaul than licensed FDD.

The two big advantages of time division duplexing and multiple access (TDD-TDMA) are:

- More spectrally efficient for internet-like data ratios
- Simpler radio network planning

The next two sections describe these advantages. Examples are included to illustrate these benefits. ***Section 4*** and ***Section 5*** present other features that are desirable in a TDD-TDMA backhaul radio. ***Section 6*** describes how base station (BS) synchronisation allows co-channel TDD operation on the same point-of-presence (POP) site.

2. TDD needs less spectrum than licensed FDD

WiMAX traffic will typically have a 70/30 downlink to uplink ratio. Optimising backhaul spectrum for asymmetric data rates is not possible with licensed FDD technology, as licensing requires the same channel width for uplink and downlink. As illustrated in ***Figure 1***, this results in over half the FDD uplink spectrum being wasted!

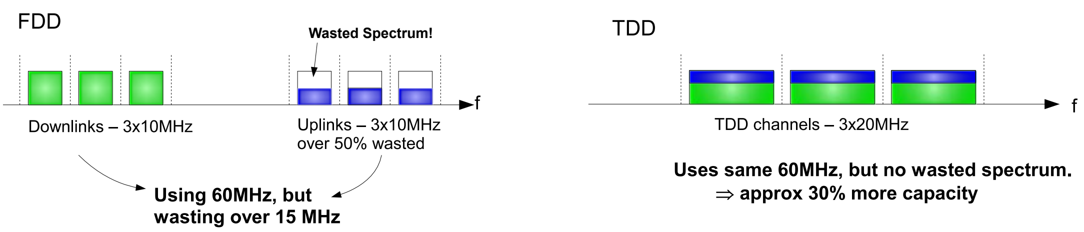

Figure 1. Benefits of TDD over FDD with asymmetric traffic flows (70/30).

TDD handles the asymmetry by simply allocating 70% of the time for downlink and the remaining 30% for uplink. The ratio can be tailored to suit the typical network data flows.

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3. TDMA makes network planning easier

A point-to-point (PTP) deployment requires a different channel for each site connected to the POP[1]. When different sites require different capacities, the only spectrally efficient option is to allocate different channel widths. This can result in a mix of different channel widths distributed over the network, making frequency planning difficult. Once the network is running, reallocation of capacity amongst the sites is extremely difficult.

A wide-channel point-to-mulitpoint (PTMP) deployment can solve this problem by aggregating a number of sites onto the one BS.[2] This has a number of important benefits:

1. Capacity can be distributed arbitrarily amongst the sites.
2. Capacity can be easily redistributed without network downtime.
3. New sites can be added to utilise spare capacity - without redesigning the frequency plan.

Figure 2 gives a simple example of how the use of PTMP technology can simplify network planning. In the example, a new low-capacity site is added to an existing network. The PTP network requires allocation of a new channel.[3] The PTMP solution, however, can make use of spare capacity on one of the existing channels. The new site can be added to the network without any disruption to existing sites. Capacity can also be redistributed between the two sites at any time.

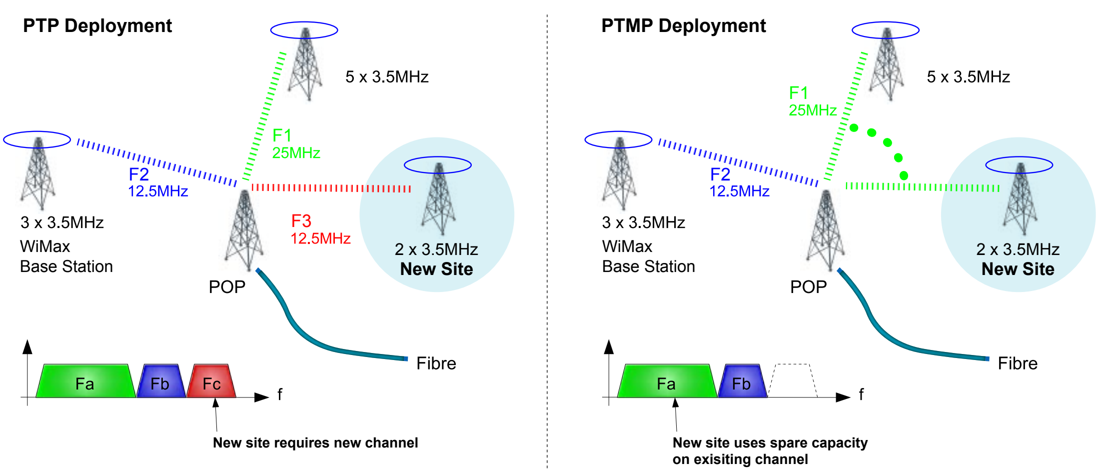


Figure 2. PTMP simplifies network planning. This example shows how adding a new site can be much simpler in PTMP.

1 Unless frequencies are reused

2 To avoid confusing terminology, in this article the term BS will be used to refer to a base station of the backhaul network. When referring to an access-layer BS, the term access layer basestation will be used. Similarly, SS refers to a subscriber station of the backhaul network.

3 Unless frequency reuse can be employed

4. Generally desirable features

The following features should be considered when choosing a backhaul radio solution:

Reliable spectrum

WiMAX spectrum is too valuable to have the a network outage due to interference on the backhaul. Avoid unlicensed bands.

High capacity

Backhaul capacity should exceed the throughput expected on the access layer. On sites where the access layer is aggregated, the backhaul channel width must be significantly greater than the access layer channel width.

Asymmetric capacity

A backhaul Radio network will be more spectrally efficient if its uplink/downlink capacity ratio matches that of the data flows.

Reliable, predictable capacity

The backhaul capacity should be reliable - it shouldn't depend upon variation in path conditions. Caution should be exercised when considering systems which rely upon multipath conditions to achieve high capacity. Multipath conditions could change frequently, possibly causing the capacity to change frequently. It is therefore desirable to ensure good line-of-sight operation.

Good adjacent channel performance

Adjacent channel interference on the backhaul uplinks can only be controlled by antenna rejection, and choosing a radio solution with good adjacent channel performance. Good adjacent channel performance requires a combination of wide analogue to digital converter (ADC) dynamic range, digital filtering, and IF filtering carefully matched to the channel width. Caution should be exercised when using a product that is not designed specifically for backhaul applications.

Adjacent channel performance can vary widely between vendors, and products targeted at different markets. For example:

- C/I of +13 dB for a 1 dB degradation to BER (10^{-6}) for 64QAM is specified in 802.16 WirelessMAN-SC 25MHz profile (profP1).
- C/I of –4 dB for a 3 dB degradation to BER (10^{-6}) for 64QAM-3/4 is specified in WiMAX profile.

where C/I is the ratio of carrier to interference power, and BER is the bit error rate.

With a careful implementation, it is possible to achieve a C/I of –15 dB for 1dB degradation to BER (10^{-6}) for 64QAM. This is important, because once the C/I performance is much better than 0 dB, antenna rejection is not required for adjacent channel operation. This gives the network planner more freedom in selecting sites and frequency planning.

5. Examples - getting more capacity

This section presents simple network examples that explain some of the concepts described above. It shows how the capacity and coverage can be increased by using PTMP and frequency reuse.

5.1 Simple Backhaul Example

A simple backhaul network for WiMAX is shown in ***Figure 3***. For the purpose of this discussion, we will assume that the network operator has a 50 MHz band available for backhauling.

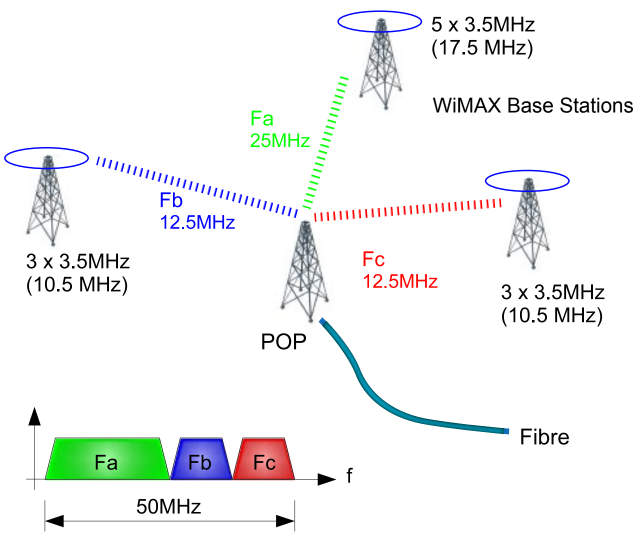


Figure 3. Example backhaul network, giving an aggregate capacity of approximately 200 Mbps.

The backhaul solution in ***Figure 3*** would achieve an aggregate capacity of approximately 200 Mbps, assuming that the paths were suitable for 64QAM operation.

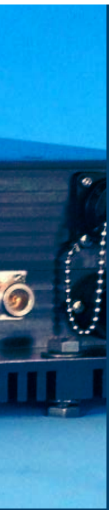
Synchronisation is used to prevent interference between the backhaul terminals located at the fibre POP. This is discussed further in ***Section 6***. Adjacent channel operation is possible due to a combination of antenna rejection and the use of transmit-power-control to ensure that the backhaul signals arrive at the fibre POP at the same level.

5.2 Using PTMP

A PTMP backhaul solution can help operators make use of spare capacity. For example, the simple backhaul network in ***Figure 3*** has some spare capacity (on the 25 MHz wide channel). An operator may wish to use this spare capacity to service a new WiMAX BS. ***Figure 4*** shows how this may be achieved without adding another POP backhaul BS terminal. This example demonstrates the flexibility of a PTMP backhaul solution. The capacity of the backhaul BS can be easily distributed amongst its subscriber stations (SS). In a PTP solution, the capacity of the 25 MHz channel could only be shared by splitting the channel. Arbitrary distribution is not possible because, in general, as only a small number of channel widths are available.

5.3 Frequency Reuse

Reuse of channels can significantly increase a backhaul network's aggregate capacity. ***Figure 5*** shows how to double the capacity to two of the WiMAX BS sites by widening the channel width to 25MHz, and reusing the channel. This increases the backhaul capacity to around 300 Mbps.



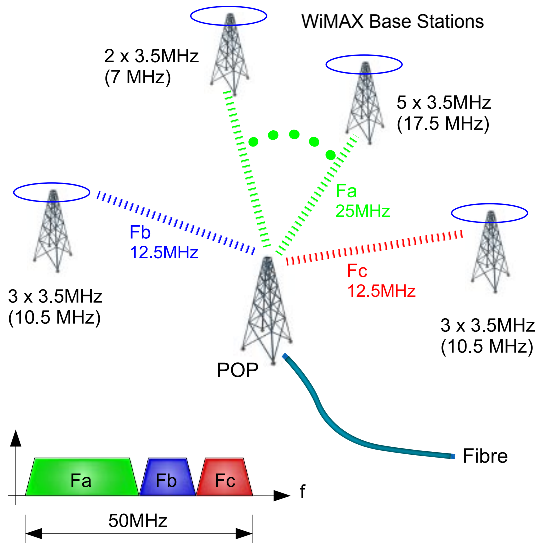


Figure 4. Using PTMP to add another WiMAX base station site.

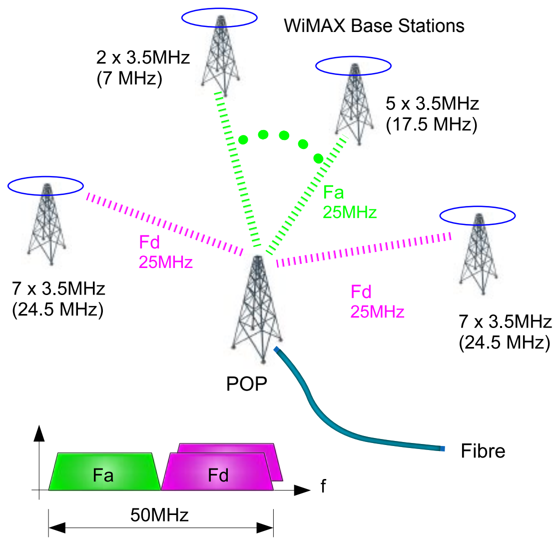


Figure 5. Using frequency reuse to increase backhaul capacity.

The same approach could be used to reuse the lower 25 MHz channel (Fa). ***Figure 6*** illustrates reuse of both channels, and also shows more use of PTMP. This example brings the backhaul capacity up to around 400 Mbps. This is double the capacity of the original simple backhaul network shown in ***Figure 3***, but still only using the original 50MHz of spectrum.

Planning for frequency reuse

Successful frequency reuse requires careful attention to antenna patterns, and the use of BS synchronisation and uplink power control. In a TDD system, interference between co-located backhaul BS's can be eliminated by using BS synchronisation. This ensures all BSs transmit simultaneously, and then all receive simultaneously, thus preventing one base station from transmitting while another is listening. To do this, all BSs must use the same framing period with the same spit between uplink and downlink, and also use the same timing reference signal (normally GPS).

Co-channel interference from other backhaul SSs can be controlled using antenna rejection and transmit power control (TPC). Transmit-power-control ensures that signals received at a POP, from SS terminals, are all at approximately the same level.

The antenna pattern needs to be good enough to reject the interference to levels at which the desired modulation can be achieved. For low-cost antennas, this generally means the terminals should be more than about 120 degrees apart.

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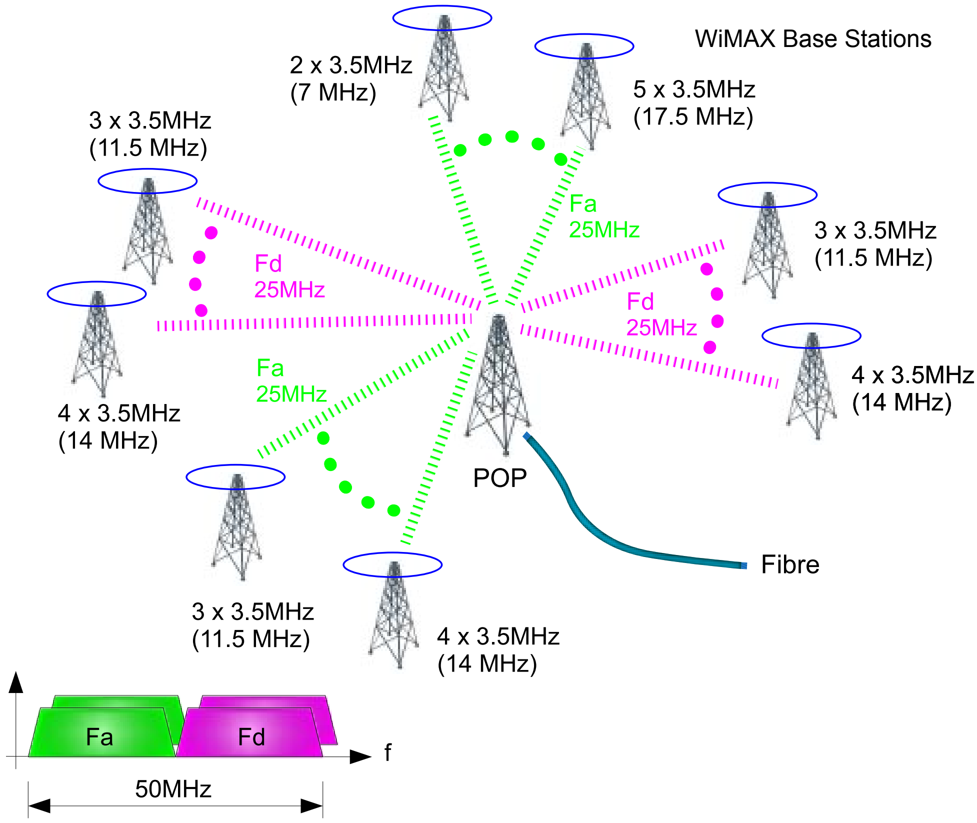

Figure 6. Using both channels twice to achieve 400Mb/s aggregate.

The number of times a channel can be reused depends on the antenna pattern, and on the carrier to interference and noise ratio (CINR) required to achieve the desired modulation. For example, when a channel is used twice, each link will experience co-channel interference from the other link. However, when a channel is used three times, each link will now suffer interference from the other two links. This degrades the CINR.

6. Using synchronisation to control interference

Synchronisation enables TDD systems to control co-location interference. When GPS is used, synchronisation also helps prevent interference between different POP sites.

6.1 Co-location interference control

Before modern TDD systems were developed, frequency separation, as used in FDD systems, was the most common way to prevent interference between co-located terminals.

TDD systems now use synchronisation to prevent interference between co-located backhaul terminals. This is illustrated in ***Figure 7***, where synchronisation ensures all POP BS terminals transmit simultaneously, and then receive simultaneously. This means that no terminal will be listening whilst another is transmitting. FDD has no interference benefit over TDD when GPS synchronisation is used.

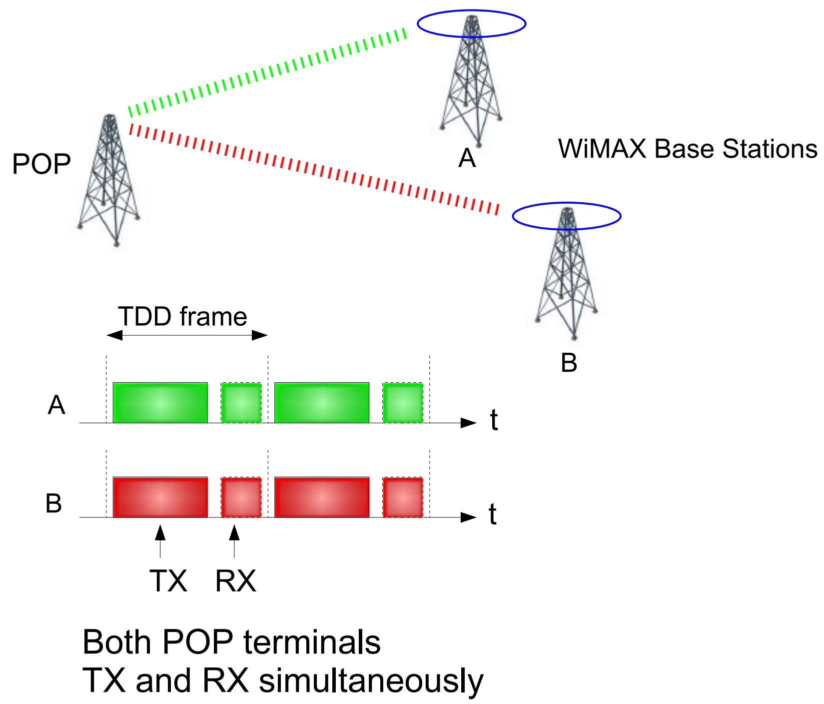

Figure 7. Using synchronisation to prevent interference between co-located terminals. GPS normally provides the reference signal.

6.2 Network wide interference management

Using GPS as the synchronisation reference allows interference between sites to be controlled. Time gaps between TX and RX can be extended to give time for potential interfering signals to propagate past a potential victim site.

7. Conclusion

This article has discussed why time division duplexing and multiple access (TDD-TDMA) is a better solution for WiMAX backhaul than licensed FDD.

TDD-TDMA is more spectrally efficient for internet-like data ratios, and simplifies radio network planning.

8. About EM Solutions

EM Solutions supplies products and design services to commercial and military customers in the telecommunications sector. Products include carrier-grade PTP microwave and TDMA Wireless Links (branded EtherMux©), and Satcom Converters and Amplifiers. EM Solutions has focused its Links product development on Backhaul and Enterprise Last Mile applications, and its Ka-band Satcom products are leading edge. EM Solutions has developed all its products in-house, and has the organisational structure and focus to offer adaptation of core technologies and products to meet specific customer requirements.

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