Cambium Networks™

ePMP GPS Synchronization: Improving ROI

Improve your ROI up to 3X using ePMP

3x

A GPS Synchronized solution supports up to three times more subscribers than an unsynchronized solution. For example... >>>

SYNCHRONIZED GPS SOLUTION SERVING SEMI-RURAL AREA

433 SUBSCRIBERS → **$8,660** PER MONTH IN REVENUE

UNSYNCHRONIZED GPS SOLUTION SERVING SAME AREA

147 SUBSCRIBERS → **$2,940** PER MONTH IN REVENUE

... a properly designed GPS Synchronization capability directly benefits the WISPs bottom line, provides much faster return on investment.

$117,000*

Potential additional value of a GPS Synchronized solution versus an unsynchronized GPS solution

GPS synchronized solutions are more efficient in use of spectrum as they provide the ability of the WISP to reuse frequencies within the coverage area.

These solutions are more spectrally efficient.

* Over a three year period

WIRELESS INTERNET SERVICE PROVIDERS (WISPS) that utilize Outdoor, Wide Area Broadband Wireless Access (BWA) equipment to provide services to their customers find themselves operating in environments with constraints that can limit their ability to grow their business. The key constraining limits are available spectrum that can be used and the ability to find suitable, affordable sites to deploy Access Points (AP). Many BWA products on the market today are inefficient in their use of the frequency spectrum and require a large number of access point sites to cover the desired service area. BWA Products that incorporate a properly designed GPS Synchronization capability make much more efficient use of the available spectrum and require fewer AP sites for the same coverage area. The resulting networks are less expensive to deploy (when considering all costs) and have much more capacity to serve subscribers. This directly benefits both the WISPs top and bottom lines and provides a much faster return on investment.

Key Concepts

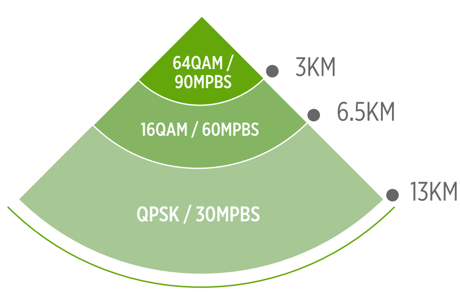
To understand how powerful GPS Synchronization is, the reader needs to understand a few key concepts. Those concepts are

- Area Average Capacity
- Bandwidth per User
- Bandwidth Oversubscription and Spectral Efficiency
- Frequency Reuse

I. Area Average Capacity:

BWA radios support adaptive modulation. When two radios are communicating, complex algorithms are used to select the modulation scheme that optimizes the throughput based on the quality of the communication path between the radios. Generally, radios that are close together communicate with the higher-order modulations that allow for higher throughput and radios that are far away from each other communicate with lower-order modulations that result in lower throughput. Figure 1 below shows a highly idealized diagram of a Point to Multi-Point (PMP) Sector deployment that illustrates the concept.

Figure 1: PMP Sector Deployment



In the coverage area shown above, the location of the subscriber modules (SMs) defines how much capacity can be delivered from the access point. If all the SMs are located within the 64QAM coverage area, then the AP has the capacity to deliver 90 Mbps. If all the SMs are located within the QPSK coverage area, then the AP has the capacity to deliver 30 Mbps. If the SMs are distributed across the different coverage areas, then the capacity is somewhere in between. In real deployments, not only is the AP capacity dependent upon the distribution of the physical location of the SMs in the coverage area, but it is also dependent upon distribution of the throughput demand across the SMs. For this discussion, we will look at the idealized case of a uniform distribution of SMs physically across the coverage area and a uniform distribution of the throughput demand across the SMs. In that case, the capacity of the AP is calculated as follows:

$$\frac{1}{\left\{ \frac{\%\,\text{AREA}_{64QAM}}{\text{TPUT}_{64QAM}} + \frac{\%\,\text{AREA}_{16QAM}}{\text{TPUT}_{16QAM}} + \frac{\%\,\text{AREA}_{QPSK}}{\text{TPUT}_{QPSK}} \right\}}$$

OVERSUBSCRIPTION FACTOR

How many times they oversubscribe the bandwidth is called the Bandwidth Oversubscription factor. This factor is typically chosen by WISPs based on experience. They learn over time what oversubscription factors result in customer complaints and what factors result in satisfied customers. Over time, the acceptable oversubscription factors have been going down as people rely more on their internet connections and the amount of data that they download and upload increases. The increasing use of broadband internet connections for entertainment and other streaming video has driven oversubscription rates down significantly. Whereas in earlier times, WISPs could oversubscribe their bandwidth by as much as 25 or 30 times, a typical oversubscription factor these days is more on the order of 10.

For the example in Figure 1, the AP capacity is 35 Mbps. This is the amount of bandwidth that the AP in this configuration can deliver to the SMs in its coverage area.

II. Bandwidth per User / Bandwidth Oversubscription:

The previous section introduced the concept of Area Average Capacity. In this example the Access Point can deliver 35 Mbps of bandwidth to the SMs in the coverage area. How many subscribers can be supported with this bandwidth? WISPs sell their subscribers different service plans that indicate the connection speeds that they can expect to get. A typical "entry level" service plan may provide for 5 Mbps download and 1 Mbps upload. To deliver the service plan throughput to a subscriber at a particular time, 6 Mbps of the capacity of the AP would be consumed. If the WISP wanted to ensure that this bandwidth would always be available to each of the subscribers, then the WISP would only be able to support (35 / 6 ~) 6 subscribers on the Access Point and it would be prohibitively expensive for WISPs (or for that matter any service provider) to provide such a service. So in practice, service providers rely on the fact that not every subscriber is demanding the full bandwidth of their service at all times and they oversell or oversubscribe the AP capacity.

With an oversubscription factor of 10 the access point in Figure 1 could support 10*35 / 6 = 58 subscribers.

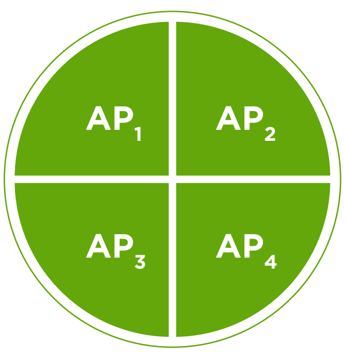
III. Spectral Efficiency / Frequency Reuse:

WISPs will often utilize multiple Access Point (AP) radios to provide service in a certain coverage area. This is necessitated when a single AP radio is not capable of providing the range necessary to reach all parts of the coverage area or when a single AP radio does not provide enough bandwidth capacity for all the subscribers in the coverage area. When more than one AP radio is deployed in a service area, the WISP needs a frequency plan. A frequency plan is the assignment of operating frequencies to the individual AP radios.

The overall achievable bandwidth capacity and the quality of the service are critically dependent upon the frequency plan. Frequencies need to be assigned to the AP radios in such a way as to minimize interference between the AP radios. The capabilities of the PMP solution determine how efficient the frequency plan is in the utilization of the available spectrum. Solutions that operate in a GPS synchronized mode are much more efficient in their use of spectrum because they provide the ability of the WISP to reuse frequencies within the coverage area. These solutions are said to be more spectrally efficient. We will use a simple example to illustrate the concepts of spectral efficiency and frequency reuse.

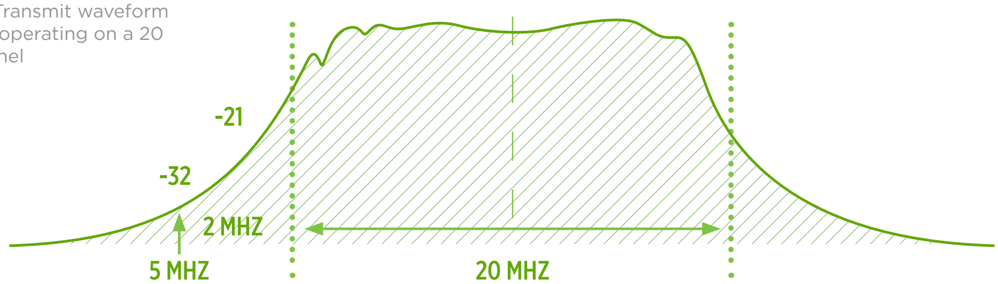
Let us take the simple example of a service area that is small enough that a single AP radio has the range to provide coverage, but not enough capacity for the subscribers in the service area. In this scenario, the most economically efficient solution is to install a sectorized Access Point site where several AP radios are installed with directional antennas covering a portion of the coverage area. Figure 2 below shows the scenario where four AP radios are used with 90 degree sector antennas to provide a full 360 degrees of coverage.

Figure 2: PMP Sector Deployment



With unsynchronized PMP solutions, a different frequency needs to be assigned to each AP radio at the site. In addition, there needs to be either a large amount of frequency separation—also called guard bands—between the frequencies selected or a large amount of physical separation or a physical object between the AP radios —or some combination of all three. The reason for this is that even though the AP radios are designed to concentrate their radiated energy into the frequency channel on which they are operating, it is unavoidable that they will generate some energy into the frequencies that are adjacent to the channel of operation. When two unsynchronized AP radios are near each other and one radio is listening to a weak signal from an SM that it is serving, the adjacent channel energy from a nearby AP radio that is transmitting can be much greater than signal from the SM. Figure 3 shows a typical transmit waveform for an AP operating on a 20 MHz channel.

Figure 3: Transmit waveform for an AP operating on a 20 MHz channel



The plot shows that the energy is concentrated within the channel of operation, but there is some energy within the adjacent frequencies. Within 2 MHz of the channel edge, the transmit signal is approximately 21 dB lower. At 5 MHz, the transmit signal is approximately 32 dB lower. In the case of operation in the 5.8 GHz unlicensed band, the transmitting AP may be operating at 36 dBm of power within the channel and that signal will be at 25 dBm at 2 MHz within the adjacent channel and at 4 dBm at 10 MHz within the adjacent channel. The listening AP will be trying to hear signals coming in from the SM that are as low as -66 dBm to -89 dBm. So clearly, the adjacent channel energy from the nearby transmitting AP will overwhelm the signal from the SM.

It is not until you are twice the channel bandwidth (in this case 2 x 20 MHz = 40 MHz) away from the transmitting channel that the adjacent channel energy is low enough to not interfere with the signal coming in from the SM. In this case, 40 MHz would be the recommended guard band between adjacent 20 MHz channels when used on the same AP tower. If there is a large physical separation of the two AP radios or a significant physical obstruction between them, then a smaller guard band can be utilized. Large physical spaces between the AP radios are not always possible and where possible can add significantly to the cost of deploying the radios on a tower. The use of obstructions between the AP radios (often in the form of metal shields) is only partially effective and can introduce areas of no coverage at the boundaries of adjacent sectors.

The most efficient and cost-effective solution to this problem is to synchronize the transmit and receive cycles of the AP radios on a tower. When that is done, there is never a situation where an AP radio is trying to listen to the weak signal from an SM while one of its neighbor AP radios is transmitting at high power. When synchronization is used, there is no need for large physical separation of the radios or the use of shields and the guard bands between the radios can be dramatically reduced. For the case of the ePMP solution operating in a 20 MHz channel, a guard band of only 5 MHz is needed between adjacent frequency channels.

If, in addition to synchronizing the transmit and receive cycles of the radios two more capabilities are employed, then it is possible to utilize the same channel on AP radios that serve opposite sectors. These additional capabilities are:

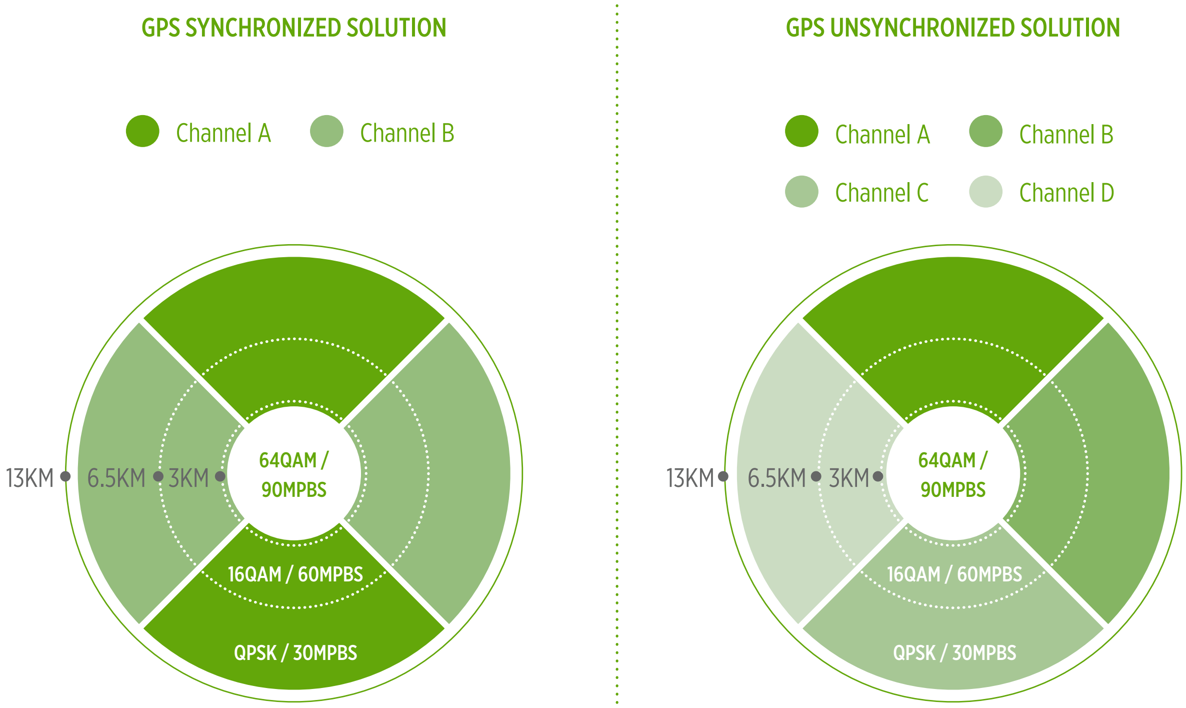
- **AUTOMATIC SM TRANSMIT POWER CONTROL** This is a feature in the AP software that remotely and dynamically controls the transmit power level at the SM. The SM transmit power level is controlled such that it is only as high as necessary to operate communication between the radios at the optimum modulation. This limits the interference that this AP to SM communication creates in other parts of the network.
- **HIGH QUALITY SECTOR ANTENNAS** If sector antennas are used that have a high Front to Back (F/B) ratio, then there is good isolation of the AP radio from interference in the opposite sector on the same tower.

Figure 4 shows two possible frequency plans for a single AP site with four sectors. Utilizing an unsynchronized solution, four channels are required for the four AP radios and then a guard band of twice the channel bandwidth is needed between the sites. Utilizing a synchronized solution, two channels are required for the four AP radios and a guard band of 25% of the channel bandwidth is required between them.

Figure four shows that for the synchronized solution, a total of 140 Mbps of capacity can be provided to the service area while utilizing 45 MHz of spectrum. The spectral efficiency is 140 Mbps / 45 MHz or 3.1 bps/Hz. For the unsynchronized solution, 200 MHz of spectrum is required to deliver the same 140 Mbps of capacity. Alternatively, the WISP could deploy the four AP radios utilizing 5 MHz channels and 10 MHz guard bands. This configuration would require 50 MHz of spectrum to deliver 35 Mbps of capacity. The spectral efficiency of both configurations is the same: 140 Mbps/200 MHz = 35 Mbps/50 MHz or 0.7 bp/Hz.

The spectral efficiency of a solution directly affects the number of subscribers the solution can support in situations with constraints on the amount of clear spectrum available. The following section shows how GPS synchronization improves the ability of a WISP to generate a good return on their investment in the network.

Figure 4: Spectral Efficiency Comparison



20 MHZ CHANNEL:

- Capacity = 4 x 35 = 140 Mbps
- Spectrum = 2 x 20 +5 = 45 MHz
- **Spectral Efficiency = 140/45 = 3.1 bps/Hz**

20 MHZ CHANNEL:

- Capacity = 4 x 35 = 140 Mbps
- Spectrum = 4 x 20 + 3 x 40 = 200 MHz
- **Spectral Efficiency = 140/200 = 0.7 bps/Hz**

IV. GPS Synchronization Generates Better Return on Investment

In the last section we showed how a GPS synchronized solution has better spectral efficiency than an unsynchronized solution. Now let's discuss what that benefit is worth in financial terms to a WISP.

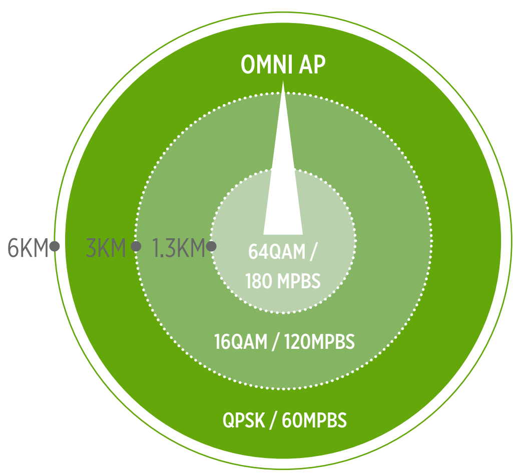
Let's take the case where a WISP wants to cover the central residential district of a moderate sized semi-rural town. The desired coverage area is approximately 6 km on each side and so is 36 square km. The WISP is able to find 50 MHz of clear spectrum in the 5 GHz unlicensed band and there is a good tower site in the middle of the coverage area on which to deploy Access Point(s). The WISP will offer subscribers a service with 5 Mbps downlink and 1 Mbps uplink for $20 per month and will operate the network assuming a bandwidth oversubscription factor of 10.

If the WISP deploys an unsynchronized solution, the deployment choices are:

- **A.** Utilize a single Access Point with an omni antenna configured to utilize a 40 MHz channel
- **B.** Utilize a sectored Access Point site with the radios configured to smaller channels

An Option (**A**) deployment would look like Figure 5.

Figure 5: Omni Access Point with 40 MHz Channel



Omni antennas have lower gain than sector antennas and so the ranges for the higher modulations are shorter. A typical omni antenna may have 6 dB of lower gain than a sector antenna. This has the effect of halving the range of each of the modulations, which can impact Area Average Capacity. An AP with an omni antenna configured with a 40 MHz channel has Area Average Capacity of 69 Mbps.

For an Option (**B**) deployment, the WISP could deploy either a three sector site or a four sector site. Since the solution is unsynchronized there must be guard bands between the channels used. The WISP would have the option of using 7 MHz channels (3 x 7 MHz channels plus 2 x 14 MHz guard bands = 49 MHz of spectrum) for a three sector site or 5 MHz channels (4 x 5 MHz channels plus 3 x 10 MHz guard bands = 50 MHz of spectrum) with a four sector site. The four sector option has a higher capacity than the 3 sector option. In this scenario, each Access Point of a four sector site using a 5 MHz channel would have 22 Mbps of Area Average Capacity so the total capacity of the site would be 88 Mbps.

Figure 6 overleaf illustrates an Option (**B**) deployment.

Figure 6: Sector Access Point with 5 MHz Channels

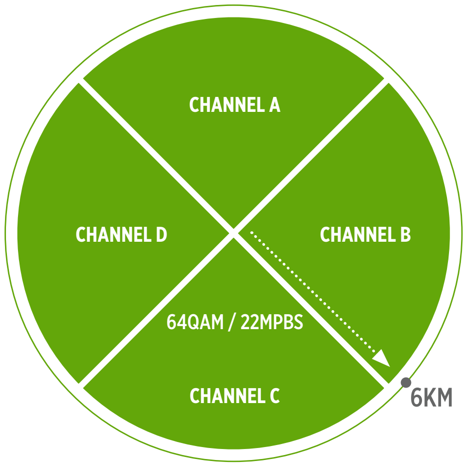
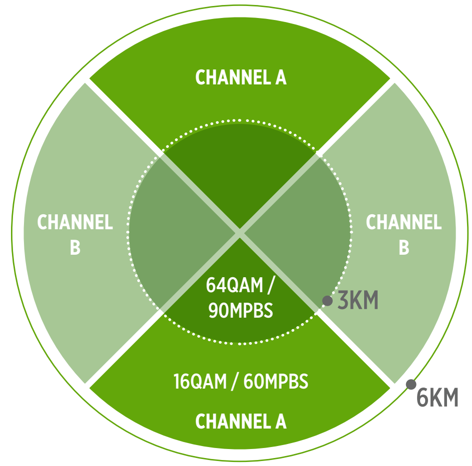


Figure 7: Sector Access Point with 20 MHz Channels



- 88 Mbps of Area Average capacity would allow the WISP to serve 147 subscribers.
- 88 Mbps / ((5 + 1)/10) = 147 subscribers

With the system fully loaded, the WISP will receive $2,940 per month in subscriber revenue.

If the WISP deploys a synchronized solution such as the ePMP, then the most efficient and highest capacity configuration is a four sector Access Point site. Figure 7 above shows this type of deployment.

Only two channels are required for the site and the guard bands between the channels can be as small as 5 MHz channel size. With this configuration, each Access Point is assigned a 20 MHz channel and can provide 65 Mbps of capacity. The entire site can provide 260 Mbps (4 x 65 Mbps) of Area Average Capacity. This capacity can allow the WISP to serve

- 260 Mbps / ((5+1)/10) = 433 subscribers

With the system fully loaded, the WISP will receive $8,660 per month in subscriber revenue.

Another way to look at this is to measure how much a synchronized system is worth financially to a WISP. The way to measure this would be to look at the present value of the additional cash flows over time that the WISP would receive from deploying a synchronized system. The present value of cash flows is calculated by applying a discount to cash flows that occur in the future. If we assume that we will apply an annual discount rate of 15% to future cash flows and if additionally we make the following conservative assumptions:

- The lifetime of the system that the WISP deployed is 3 years
- The WISP will spend 30% of revenue for operational expense

Then the present value of the additional monthly subscriber revenue is $117,000. A deployed synchronized PMP solution is worth $117,000 more than an unsynchronized PMP solution. Please refer to Figure 8 for the ROI summary.

By almost any financial measure, a WISP will be better off deploying a synchronized solution.

GPS Sync Improves ROI	
WISP Network Considerations:	
Coverage area: 36 square km 50 MHz of clear specturm in the 5 GHz unlicensed band Subscriber service: 5 Mbps downlink and 1 Mbps uplink Monthly fee: $20 per month Subscribers oversubscription factor of 10	
No GPS Sync	**GPS Sync Solution**
Antenna: • Four Sector • 5 MHz Channel width • 10 MHz guard bands • 22 Mbps capacity per sector **Area Average Capacity:** • (4 x 22 Mbps) = 88 Mbps **Subscribers Number:** 147 • 88 Mbps / ((5+1)/10) = 147 subscribers	**Antenna:** • Four Sector • 20 MHz Channel width • 5 MHz guard bands • 65 Mbps capacity per sector **Area Average Capacity:** • (4 x 65 Mbps) = 260 Mbps **Subscribers Number:** 433 • 260 Mbps / ((5+1)/10) = 433 subscribers
TOTAL MONTHLY REVENUE: **$2,940**	TOTAL MONTHLY REVENUE: **$8,660**

Figure 8

Summary

BWA Products that incorporate a properly designed GPS Synchronization capability make much more efficient use of the available spectrum to provide coverage to a service area. This efficiency has real and significant impacts to the financial bottom line of a WISP. With a GPS synchronized solution such as the ePMP, deployed BWA systems can support nearly three times the number of subscribers as they could with other unsynchronized solutions. Three times the number of subscribers means three times the monthly revenue from the Access Point site. Over the operational life of the Access Point site, this increased revenue will significantly increase the profitability and value of the WISP. The best investment that a WISP can make to increase the value of their business is to deploy the ePMP solution which provides significant value at a breakthrough price.