Cambium Networks

Co-location of ePMP and PMP 100 systems and migration recommendations

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1 Introduction

This white paper provides information to guide the user in strategies for migrating from a PMP 100 deployment to an ePMP deployment in the 5 GHz band. The objective is to be able to provide a strategy for migrating one sector at a time, versus taking a knife switch replacement approach.
Also, co-location of the two systems is discussed, if both are deployed in the same geographical area, either during migration or as a permanent solution.

This paper focuses on two areas.
Section 2 describes the importance of selecting the correct frame parameters in both the FSK system and the ePMP system for co-location and migration. It describes each of the parameters that affect the frame structure, how to select them in each system, and it introduces the ePMP-FSK co-location tool, which aids in the selection of these parameters.
Section 3 presents examples of migration strategies from an FSK system to an ePMP system. Each example considers a different scenario of original FSK deployment and/or final ePMP deployment after migration.

2 Synchronization and timing

When co-locating systems, either for migration from an older technology to a newer technology, or for a more permanent mixed deployment, it is important to select the system parameters in order to avoid interference.

Both PMP 100 and ePMP are TDD systems, which means that the same frequency resources are used both in the downlink (AP to SMs communication) and in the uplink (SMs to AP communication), but multiplexed in time. A TDD cycle, or frame, is the minimum amount of time used to communicate in both directions, and it also includes gaps for hardware turnaround and over the air propagation delays, as shown in Figure 1.

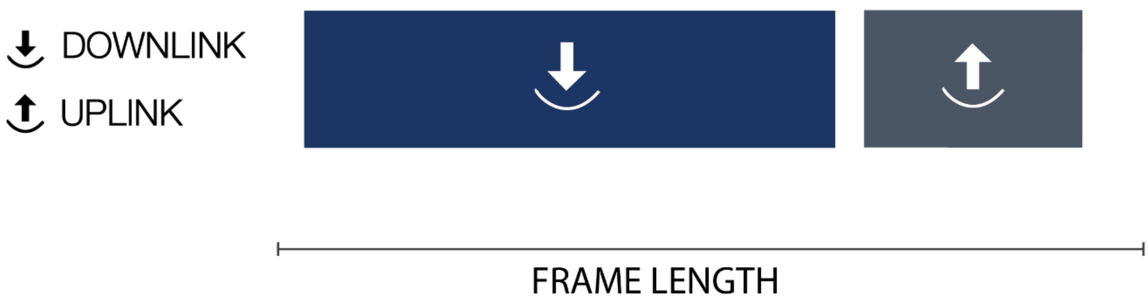

Figure 1 - TDD frame structure

When multiple access points (APs) are deployed in the same geographical area, it is important that they all transmit and receive at the same time. If one AP transmits when another receives, the one that is receiving might not be able to correctly decode the signal coming from the SMs communicating with it, because of the interfering signal coming from the other AP.

In order to avoid this type of interference, three features are needed:

1- The TDD cycle, or frame, needs to start at the same time for all APs
2- The TDD cycle, or frame, needs to have the same length for all APs
3- The frame parameters need to be selected in each AP so that there is no overlap between one AP transmitting and another receiving. An example of these parameters is the duty cycle, i.e. the ratio of the time dedicated to communication in the downlink direction over the total frame time.
   Note that these parameters don't need to be the same in all APs, but they need to be selected to avoid interference.

These features are needed regardless if the APs use the same technology or not.
Typically, when the APs use the same technology, it is sufficient to select the same configuration parameters to guarantee interference-free co-location.
However, when the APs do not use the same technology, the parameters to select may be specific to the technology used, and care has to be taken during co-location and migration.

2.1 Frame start

GPS synchronization is the way of guaranteeing that the frame start is the same for all APs. One important consideration though, is the sync source used for each AP.
If the APs are the same, and they use the same sync source, they all have the same frame start.
However, if the APs are not the same and/or they use different sync sources, the frame start times may be shifted. A shift in the frame start time may cause self-interference.

Figure 2 shows the synchronization options in the ePMP GUI, which can be found under Configuration → Radio.

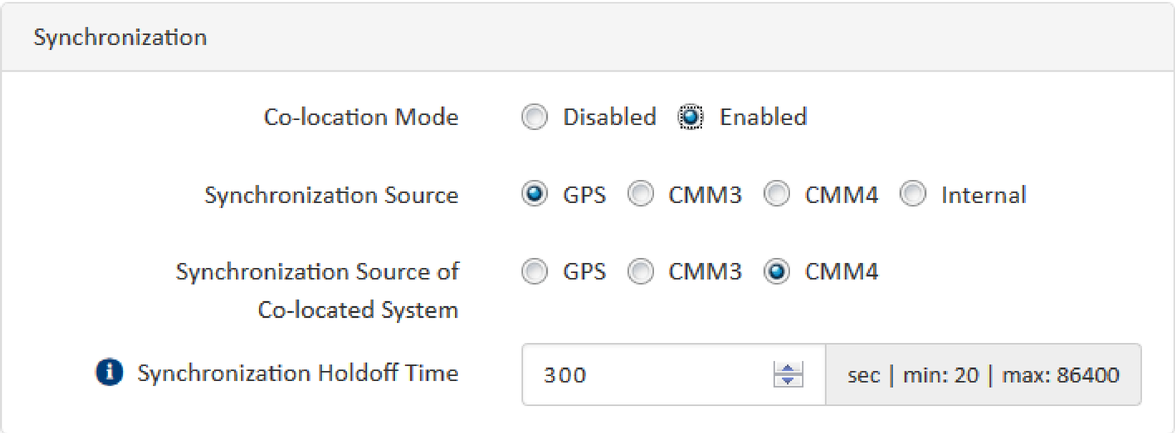

Figure 2 - Synchronization options in ePMP GUI

To co-locate and/or migrate an FSK system to an ePMP system, select Co-location Mode → Enabled.
In Synchronization Source, select the sync source used for the ePMP system.
In Synchronization Source of Co-located System, select the sync source used for the FSK system.

An additional parameter that can be selected is the Synchronization Holdoff Time. This is the amount of time the AP will transmit after losing the sync pulse when it is not able to regain it.
In the example in Figure 2, the Synchronization Holdoff Time is set to 300secs, which means that the

AP will continue to transmit for 300 seconds after losing the sync pulse. If it regains sync before the 300 seconds have elapsed, it will re-adjust the internal timing as needed and continue to transmit normally.

2.2 Frame length

At this point, all APs are GPS synchronized, and the frame start has been corrected for any shift due to different sync sources. The next parameter to select is the frame length.
In order to avoid interference, it is necessary that all APs use the same frame length. This is the reason for introducing the option of a frame length of 2.5 ms in the ePMP product, to be able to co-locate and migrate an FSK network, which only supports a 2.5 ms frame in the 5 GHz band.

Figure 3 shows why it is not possible to co-locate APs supporting mismatched frame lengths.
Let us assume that AP1 uses a 5 ms frame, while AP2 uses a 2.5 ms frame.

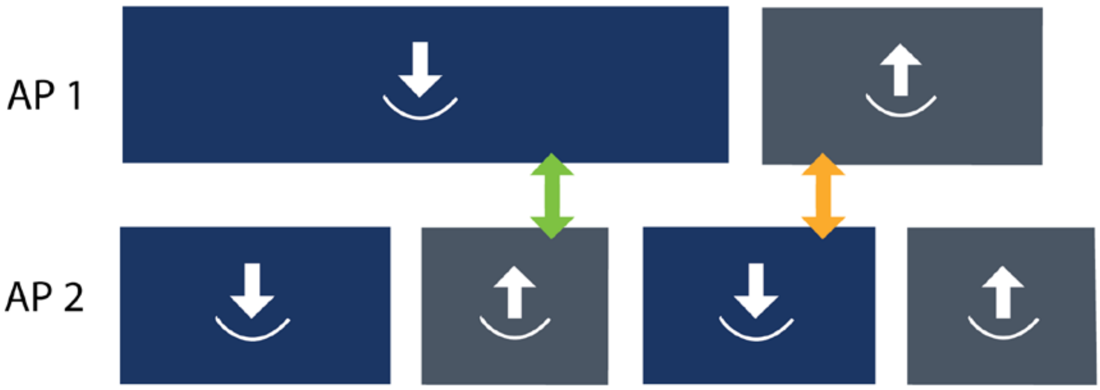

Figure 3 - Mismatched frame sizes

Figure 3 shows that in a 5 ms interval AP1 has one transmit time and one receive time, while AP2 has two transmit times and two receive times.

The interference that mostly affects the system performance is the one at the AP receiver.
For example, in the time indicated with the green arrow in Figure 3, AP1 transmits when AP2 receives. This may completely corrupt the reception of AP2’s uplink signal. Also, in the time indicated with the orange arrow in Figure 3, AP2 transmits when AP1 receives. This may completely corrupt the reception of AP1’s uplink signal.

Additional interference may be experienced at the SM. In the time indicated with the green arrow in Figure 3, the SM communicating with AP1 receives when the SM communicating with AP2 transmits. Similarly, in the time indicated with the orange arrow in Figure 3, the SM communicating with AP2 receives when the SM communicating with AP1 transmits. This source of interference is generally less critical in the overall system performance because the SMs’ antennas have a narrower beam and point at the corresponding AP. Therefore the signal received by other SMs is significantly more attenuated compared to the interfering signal received at the AP.

When co-locating or migrating an FSK system to an ePMP system, select the 2.5 ms frame option, which can be found under Configuration → Radio → Scheduler, as shown in Figure 4.

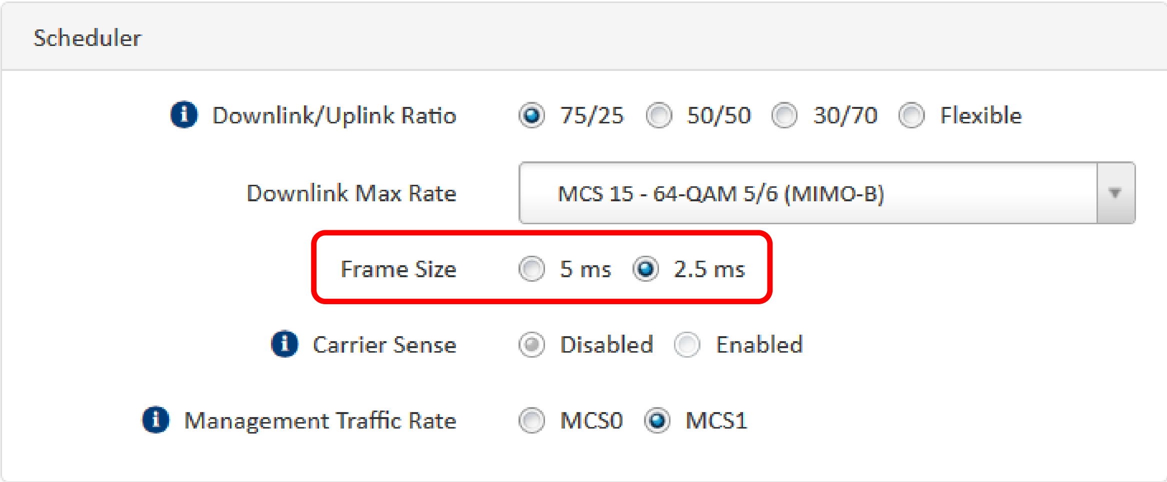

Figure 4 - Selection of 2.5 ms frame option

2.3 Frame parameters

At this point, all APs are synchronized, and the frame length is the same.

Next, the frame parameters have to be selected in order to avoid any overlap between one AP transmitting and another receiving.

As mentioned above, the parameters do not have to be the same in all APs, but they have to be coordinated in order to avoid interference. Figures 5 and 6 show one example of frames that do not interfere and one example of frames that do interfere.

In both Figures 5 and 6, the Downlink time and Uplink time of the two APs are not identical. However, in Figure 5, there is no overlap between one AP transmitting and another AP receiving, and the two APs can be co-located. In Figure 6, AP1is still transmitting when AP2 is already receiving. This creates interference at the AP2's receiver and the APs cannot be co-located with these parameters.

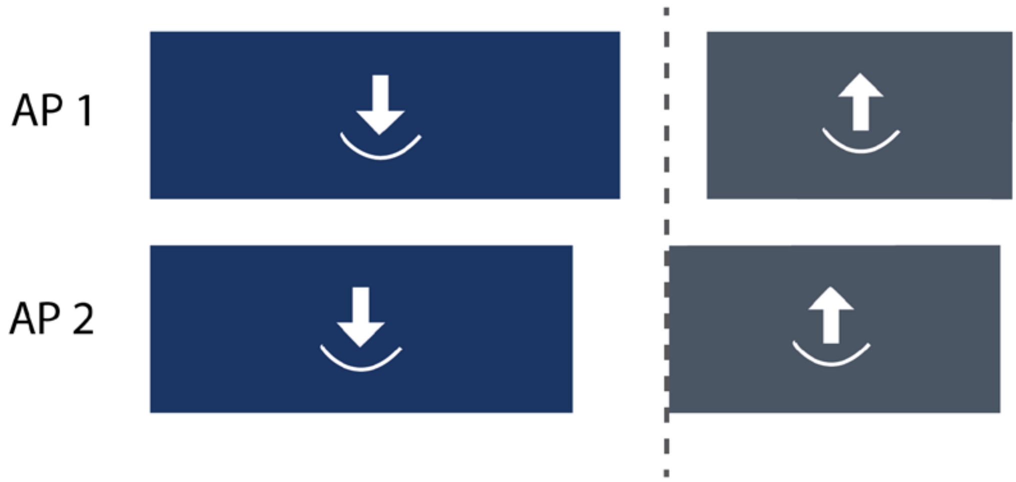

Figure 5 - Example of APs that can be co-located

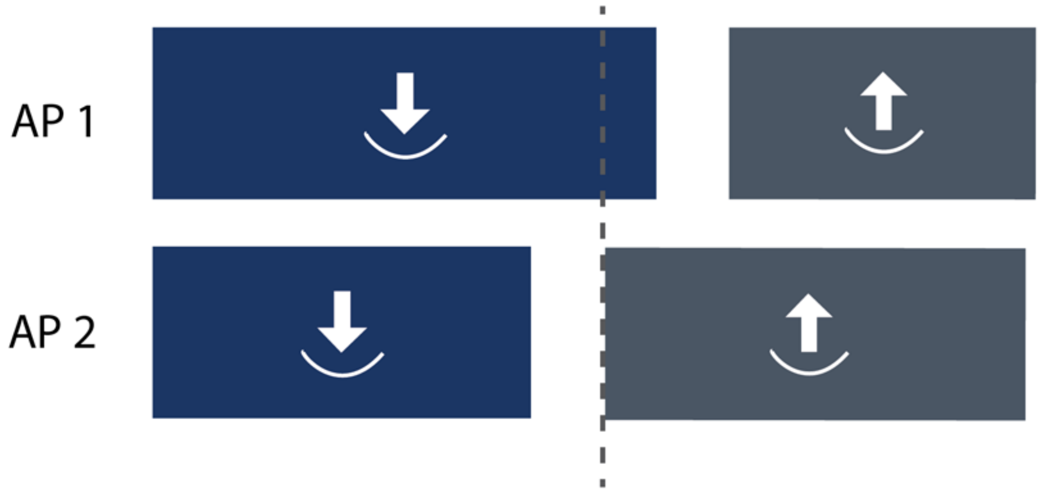

Figure 6 - Example of APs that cannot be co-located

2.3.1 ePMP frame configuration parameters

In the ePMP system, the frame structure is calculated using by three parameters: Channel Bandwidth, Max range, and Downlink/Uplink Ratio.

The Channel Bandwidth and the Max Range can be selected under Configuration → Radio → Access Point Configuration, as shown in Figure 7.
The Downlink/Uplink Ratio can be selected under Configuration → Radio → Scheduler, as shown in Figure 8.

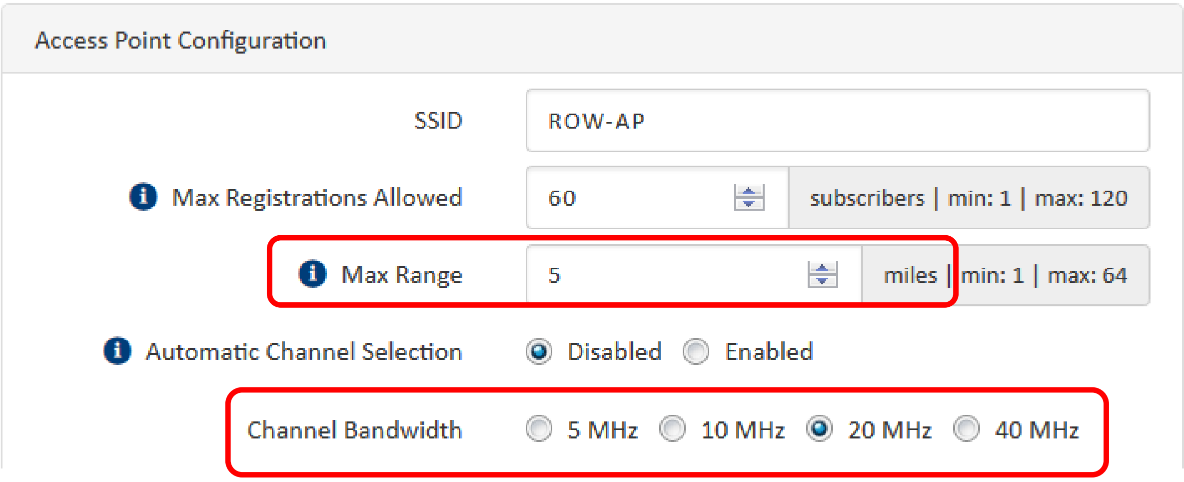

Figure 7 - Configuration of Channel Bandwidth and Max Range

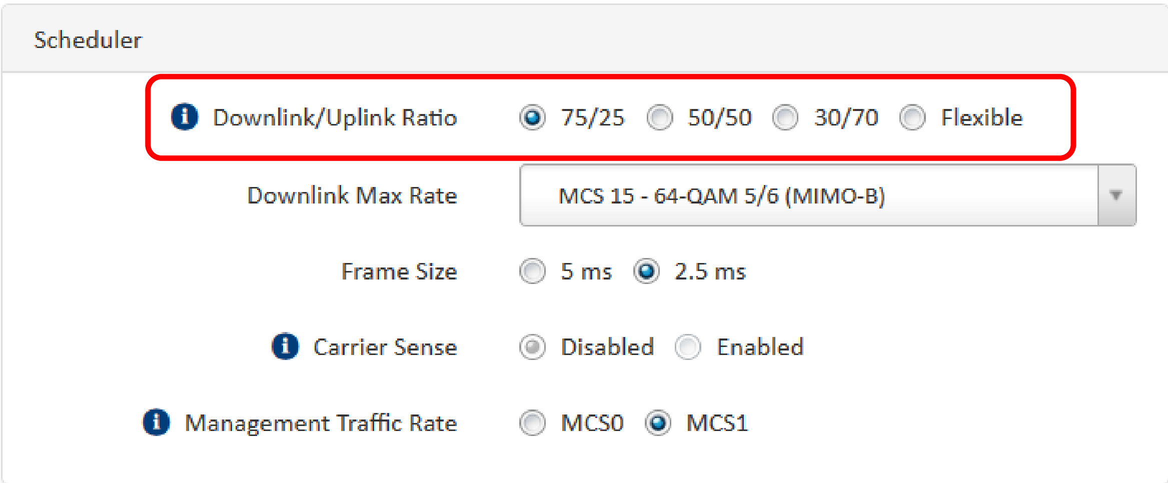

Figure 8 - Configuration of Downlink/Uplink Ratio

The Downlink/Uplink Ratio options for the ePMP system are: 75/25, 50/50, 30/70 and Flexible. The Flexible option should not be selected when co-locating with other systems. The reason is that in Flexible mode the time allocated to downlink and uplink transmissions is adjusted frame by frame according to the instantaneous traffic requirements. It is therefore not possible to guarantee that the AP will not overlap its transmit time to another AP's receive time.

2.3.2 FSK frame configuration parameters

The FSK frame structure is determined using three parameters: Downlink Data (which is the duty cycle), Max Range, and number of Contention Slots. The Contention Slots are used in the FSK system for random access, for registration and bandwidth request.

All these parameters can be configured under Configuration → Radio, as shown in Figure 9.

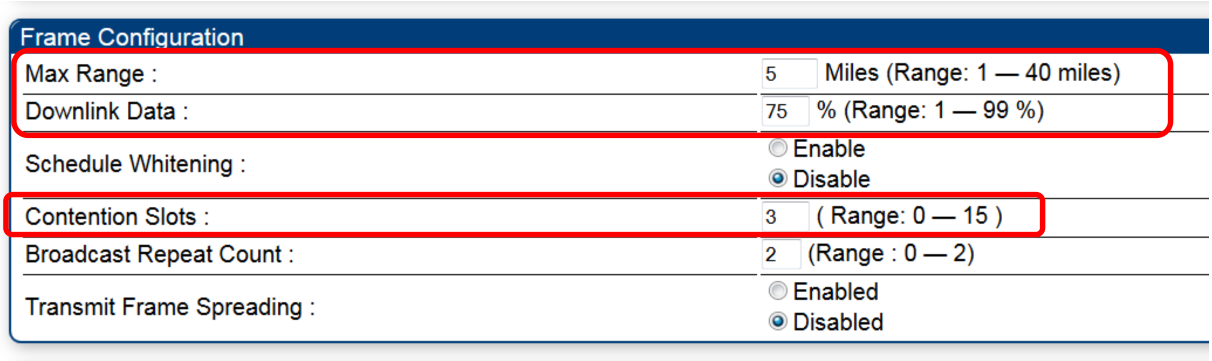

Figure 9 - Configuration of FSK parameters

Note that the duty cycle (Downlink data) granularity in the FSK system is higher. It can be selected from 1% to 99% in 1% increments. For this reason, the duty cycle should first be selected in the ePMP system, and the FSK duty cycle adjusted in order to avoid interference.

2.3.3 ePMP-FSK co-location tool

The configuration parameters that affect the frame structure, need to be selected in both systems in order to avoid any overlap between transmit and receive times. Selecting the same duty cycle, channel bandwidth and max range does not necessarily guarantee that there will be no overlap. The reason is that the two systems use a different algorithm to calculate the frame structure, and also parameters that are related to only one technology, like Contention Slots in FSK, or FFT size and guard interval (GI) length in ePMP.

In order to help with the selection of system parameters, Cambium Networks offers an ePMP-FSK co-location tool, available at http://support.cambiumnetworks.com

Let us assume that an existing FSK system is deployed with the following parameters:

- Max range: 10 miles
- Downlink data: 75%
- Contention slots: 4

The FSK AP in one sector of the existing FSK deployment is replaced with an ePMP AP. As the ePMP AP needs to replace the FSK AP, the same parameters are selected:

- Max range: 10 miles
- Downlink/Uplink ratio: 75/25
- Bandwidth: 20 MHz

In order to verify that these parameters do not create interference between the two systems, the co-location tool is used, as shown in Figure 10.

ePMP-PMP100 (FSK) CO-LOCATION TOOL

PMP100 (FSK)		
PMP100 Inputs		
Max Range (mi)	10	
Dowlink Data (%)	75	
Contention Slots	4	
PMP100 Timing		
DL end	16722	
UL start	17805	

ePMP		
ePMP Inputs		
Max Range (mi)	10	
Dowlink Ratio	75/25	
Bandwidth (MHz)	20	
ePMP Timing		
DL end	17850	
UL start	19290	

CHECKS					
PMP100 DL end	16722	<	ePMP UL start	19290	OK
ePMP DL end	17850	<	PMP100 UL start	17805	NOT OK

Figure 10 – Example of ePMP-FSK co-location tool with invalid parameters

The co-location tool shows the parameters that are important for co-location, which are the end of the downlink time (DL end) and the beginning of the uplink time (UL start) for both systems.

For successful co-location, the two following conditions need to be met:

PMP100 DL end < ePMP UL start

ePMP DL end < PMP100 UL start

These conditions are checked in the co-location tool:

CHECKS					
PMP100 DL end	16722	<	ePMP UL start	19290	OK
ePMP DL end	17850	<	PMP100 UL start	17805	NOT OK

Figure 11 - Checks in ePMP-FSK co-location tool

The tool shows how the first condition is met, meaning the ePMP AP starts receiving after the FSK AP has finished transmitting. The second condition, however, is not met: the FSK AP starts receiving before the ePMP AP has finished transmitting. During this period of time, any uplink signal received from the FSK SMs will be corrupted by the downlink signal coming from the ePMP AP.
This example shows how selecting the same duty cycle, range and channel bandwidth does not necessarily guaranteed that there will be no interference between the systems. As the two systems use different technologies and additional parameters (such as the number of contention slots), co-location needs to be verified for each specific combination of parameters.

For successful co-location, one or more parameters need to be adjusted, until both conditions are met. On the FSK side, all three parameters can be changed to align the FSK downlink and uplink times to the ePMP downlink and uplink times.
For example, the max range can be increased, leaving a longer gap between the downlink and the uplink time, and eliminating the overlap. However, increasing the max range beyond the distance that needs to be covered, increases the overhead of the system.
The easiest parameter to change in the FSK system is the Downlink data, as this input is offered with a granularity of 1%, and no additional overhead is introduced in the system. This is shown in Figure 12. This Figure shows the same example shown in Figure 10, with the only difference that the Downlink Data % in the FSK system is now changed to 77%.

ePMP-PMP100 (FSK) CO-LOCATION TOOL			
PMP100 (FSK)		**ePMP**	
PMP100 Inputs		**ePMP Inputs**	
Max Range (mi)	**10**	Max Range (mi)	**10**
Dowlink Data (%)	**77**	Dowlink Ratio	**75/25**
Contention Slots	**4**	Bandwidth (MHz)	**20**
PMP100 Timing		**ePMP Timing**	
DL end	17328	DL end	17850
UL start	18411	UL start	19290


CHECKS					
PMP100 DL end	17328	<	ePMP UL start	19290	OK
ePMP DL end	17850	<	PMP100 UL start	18411	OK

Figure 12 - Example of ePMP-FSK co-location tool with valid parameters: change in FSK Downlink Data

Figure 12 shows how both conditions are now valid, and these parameters are valid for co-location.

Note that in order to make a change in the FSK system, all APs in the same geographical area need to use the new selected parameters. In order to avoid this, the only parameters that can be changed on the ePMP side is the max range. As discussed above, a longer max range will leave a wider gap and eliminate the interference, at the expense of higher overhead.

Figure 13 shows how increasing the ePMP Max Range to 11 miles the two conditions are met. However, the wider gap subtracts air time to data transmission.

ePMP-PMP100 (FSK) CO-LOCATION TOOL			
PMP100 (FSK)		**ePMP**	
PMP100 Inputs		**ePMP Inputs**	
Max Range (mi)	**10**	Max Range (mi)	**11**
Dowlink Data (%)	**75**	Dowlink Ratio	**75/25**
Contention Slots	**4**	Bandwidth (MHz)	**20**
PMP100 Timing		**ePMP Timing**	
DL end	16722	DL end	17790
UL start	17805	UL start	19350


CHECKS					
PMP100 DL end	16722	<	ePMP UL start	19350	OK
ePMP DL end	17790	<	PMP100 UL start	17805	OK

Figure 13 - Example of ePMP-FSK co-location tool with valid parameters: change in ePMP max range

3 Migration strategy

The strategy to migrate an FSK network to an ePMP network depends on the specific deployment of the original FSK network. Factors like number of sectors per site, frequency reuse, and guard band between adjacent channels, all affect the migration strategy.

In this section some examples of migration strategies are described. The first three examples assume the typical FSK deployment with six sectors per site, using three channels. The last example assumes an FSK deployment with four sectors per site, using two channels.

Note that both the FSK system and the ePMP system recommend the use of a 5 MHz guard band between adjacent channels used in adjacent sectors. This section assumes that this guard band is used.

3.1 Example 1: 6-sector FSK to 6-sector ePMP

In this example, the existing FSK system is deployed using six sectors and three frequencies. At the end of the migration, the ePMP system also uses six sectors and three frequencies, keeping the same center frequencies and frequency planning, as shown in Figure 14.

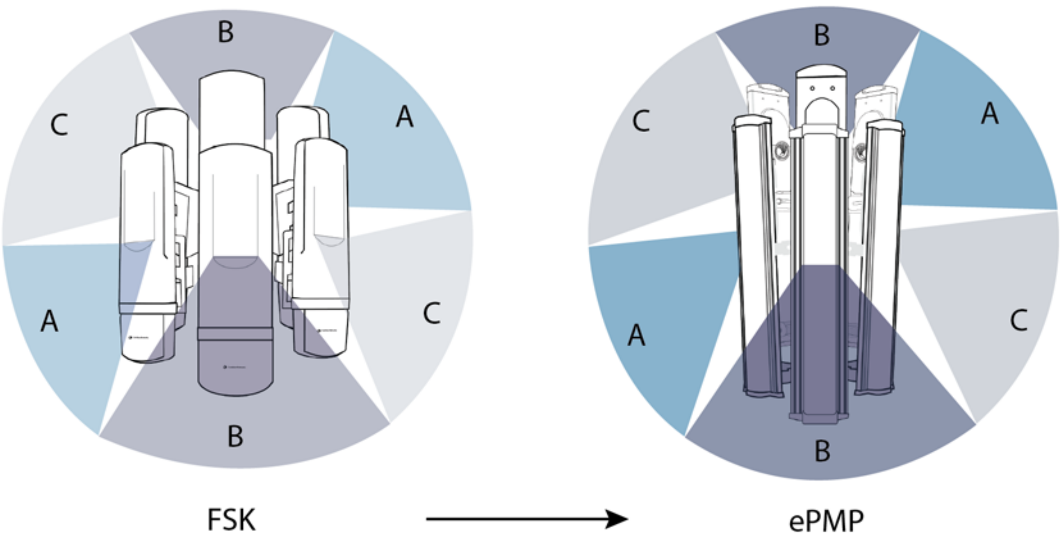

Figure 14 - Migration from 6 FSK sectors to 6 ePMP sectors

For this migration, the FSK sectors can be replaced, one by one, with ePMP sectors using a 60° sector antenna and the same 20 MHz channel bandwidth. Note that Cambium Networks offer a 90° and 120° sector antenna options, but any antenna with the right specifications for co-location, including a high front-to-back ratio, can be used with the connectorized ePMP AP.

Note that the front-to-back ratio of the AP antenna required for back-to-back operation of FSK APs on the same frequency is not has high as the front-to-back ratio required for back-to-back operation of OFDM APs. The reason is that the OFDM AP can operate at higher order modulation, which requires a lower interference level. For this reason, it is recommended to replace the two back-to-back APs using the same frequency at the same time, or within a short period of time. For the time during which two back-to-back sectors on the same frequency use an FSK AP on one side and an ePMP AP on the other, the ePMP AP performance is expected to be affected by the additional noise generated by the FSK AP.

3.2 Example 2: 6-sector FSK to 4-sector ePMP

In this example, the existing FSK system is deployed using six 60° sectors and three frequencies. At the end of the migration, the ePMP system uses four 90° sectors and two frequencies, as shown in Figure 16.

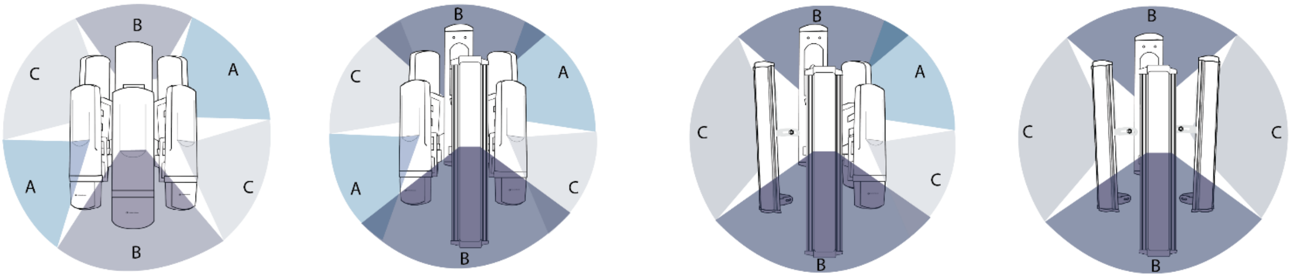

Figure 15 - Migration from 6 FSK sectors to 4 ePMP sectors

For this migration, first replace the FSK APs on one of the frequencies (60° sectors), for example frequency B, with ePMP APs also on frequency B (90° sectors). Note that the FSK SMs at the edge of the cells covered by frequencies A and C now experience interference from the ePMP AP on frequency B. However, if the correct guard bands are used, this interference level is very low and it does not affect the regular operation of the FSK system.
Also, as explained above, it is recommended to replace the two back-to-back APs on the same frequency within a short period of time to achieve the full capacity of the ePMP system.

Next, replace the FSK APs on frequencies A and C with ePMP APs on either frequency A or frequency C. Note that the ePMP APs will now have a different orientation compared to the two original FSK APs.

Note that the ePMP system after migration only uses two of the original three channels. After the migration is complete, the operator can:

- Use the third unused channel to update the frequency planning
- Widen either used channel to a 40 MHz channel

3.3 Example 3: 6-sector FSK to 3-sector ePMP

In this example, the existing FSK system is deployed using six 60° sectors and three frequencies. At the end of the migration, the ePMP system uses three 120° sectors and three frequencies, as shown in Figure 16.

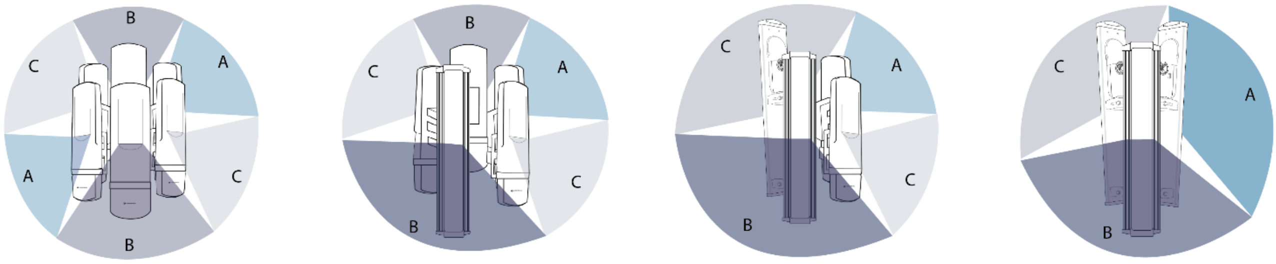

Figure 16 - Migration from 6 FSK sectors to 3 ePMP sectors

For this migration, first replace two adjacent FSK APs on frequencies A and B with one ePMP AP on either frequency A or B, using a 120° sector antenna. Note that the orientation of the ePMP AP is different from the orientation of the original FSK APs. One ePMP sector now covers the area originally covered by two FSK sectors.

Next, replace two adjacent FSK APs on frequencies B and C with one ePMP AP on frequency C, using a 120° sector antenna. Again, one ePMP sector covers two of the original FSK sectors, and the orientation of the ePMP AP has to be changed to point towards the middle of the new 120° sector.

Finally, replace the two remaining adjacent FSK APs on frequencies A and C with one ePMP AP on frequency A, using a 120° sector antenna. As before, one ePMP sector covers two of the original FSK sectors.

As explained above, if during migration one ePMP sector operates with an FSK sector using the same frequency facing the opposite direction, the ePMP sector will experience additional interference until the FSK sector is replaced by an ePMP sector.

The three ePMP channels are 20 MHz wide, like the original FSK channels.

3.4 Example 4: 4-sector FSK to 4-sector ePMP

In this example, the existing FSK system is deployed using four 90° sector and two frequencies. At the end of the migration, the ePMP system also uses four 90° sectors and two frequencies, as shown in Figure 17.

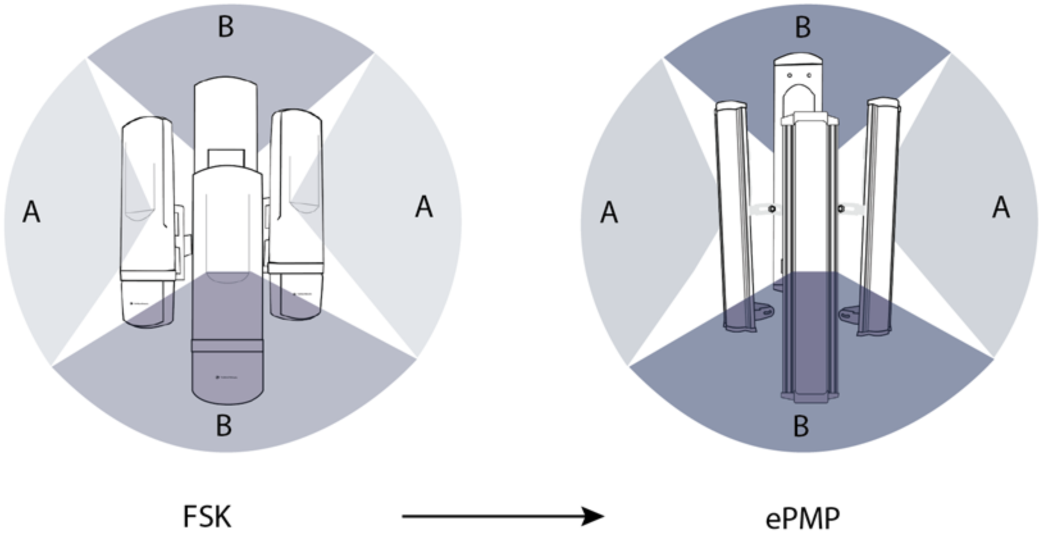

Figure 17 - Migration from 4 FSK sectors to 4 ePMP sectors

This migration is similar to the one shown in Example 1, but with 90° sectors instead of 60° sectors. Each FSK AP is replaced by an ePMP AP with a 90° sector antenna, using the same frequency and channel bandwidth. Again, back to back operation of an FSK AP and an ePMP AP should be avoided.