Dynamic Spectrum Optimization™

CONNECTIVITY IN CROWDED SPECTRUM

Reliable connectivity is critical. Service providers and private network operators implement wireless solutions because of the cost advantage, as compared to fiber and wired alternatives, while still providing the required capacity. In many cases, a wireless point-to-point link achieves a return on investment of a few months, dramatically shorter than fiber and wireline alternatives. In addition, wireless backhaul is a particularly attractive solution where leased lines are not available or for small cell deployments.

The key to successful wireless deployments is using the available spectrum effectively. Although radio techniques such as fast adaptive modulation, automatic transmit power control, multiple input multiple output (MIMO), and spatial diversity maximize system performance within a given channel, real-world environments are constantly changing. The channel that works best at the time of installation may degrade over time due to any number of fast- or slow-moving conditions, such as seasonal changes or a new emitter introduced in the area. In conventional systems, such a condition may cause degradation or a loss of service, triggering an event or alarm condition. By this time, the end customer is already experiencing poor voice or video quality and slowed data transmissions, ultimately resulting in missed service level agreements.

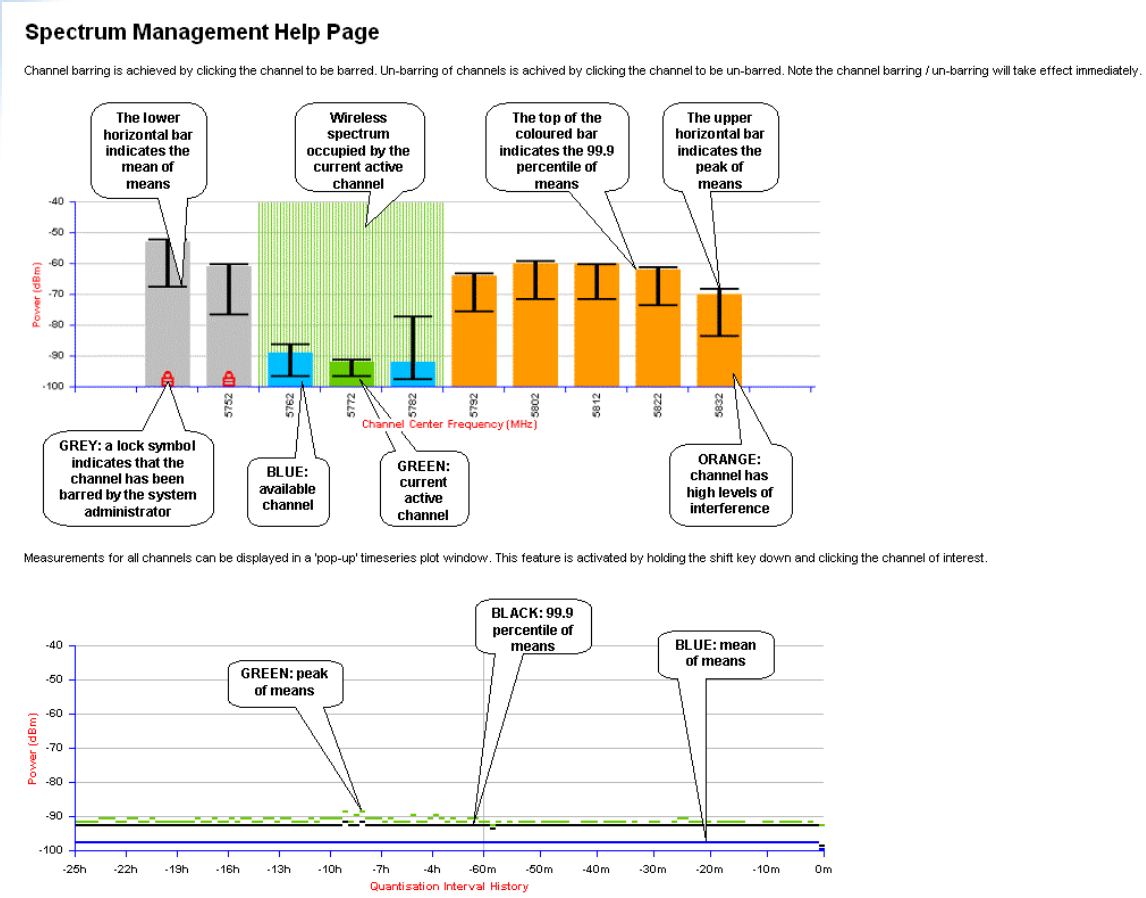
When service-affecting radio frequency (RF) interference does occur, the network operator is often forced to take the system completely offline in order to perform a spectrum analysis that can identify a less noisy set of channels. The network operator will then reconfigure the system and select a clean channel before finally restoring service. Of course, while the system is offline, the communications link is out-of-service. Even worse, this incident can occur repeatedly, thus leading to even more downtime and requiring constant monitoring and human intervention to maintain optimal configurations and customer satisfaction.

DYNAMIC SPECTRUM OPTIMIZATION

Dynamic Spectrum Optimization (DSO) is a unique capability offered by Cambium Networks in our PTP 500, PTP 600, and PTP 650 products that enables a system to ***automatically sample and change channels*** to avoid interference without affecting link service. In addition, DSO provides a historical record of noise and service levels for further analysis. During installation, DSO can be used to automatically select the optimal channel. Then, during deployment, the system repeatedly scans the entire band (5.8 GHz, 5.4 GHz, etc.). Without interrupting customer data or taking the link out of service, an onboard in-band spectrum analyzer continuously measures the suitability of all channels. When a more suitable channel is identified that will provide higher fade margin or enable operation at a higher modulation, the system automatically switches to this new channel. DSO ensures that each PTP link is always operating most efficiently and with the highest reliability regardless of changing environmental conditions. This all takes place seamlessly in the background without human intervention. Of course, DSO can be tailored to each operator's needs depending on the level of automation desired.

The following illustration is a screen shot of the spectrum analyzer from a PTP user interface illustrating DSO in practice. Each bar represents a potential channel and conveys a great deal of practical information. The *y*-axis is the measured noise level in the channel, ranging from –40dBm to –100dBm. Each channel center is represented with a bar. The currently active center channel is

indicated with a green bar, and the 30 MHz of currently used spectrum is shown with green shading. Potentially usable channels are shown in blue, channels where noised exceeds the usable threshold are shown in orange, and channels that have been blocked by the network operator are shown in gray.



FUNDAMENTAL ELEMENTS OF DYNAMIC SPECTRUM OPTIMIZATION

DSO is comprised of a number of measurements and actions operating together under the full control of the network operator. The proprietary algorithms of the Cambium Networks' DSO feature have been developed and honed over ten years of practical global experience and improvement to optimize network performance under varied conditions while maintaining maximum throughput.

Optional Settings:

Selectable Modes of Operation

The operator selects whether the DSO functionality is enabled. When DSO is disabled, the PTP link remains fixed on the channel specified during initial installation. Even when disabled, the in-band real-time spectrum analyzer continues to collect alternate channel information that can be used for later analysis. This channel information is stored for up

to 25 hours. This mode should be used when operation is required to be on a specified frequency.

When DSO is activated, the operator can specify which channels DSO can consider and which channels to ignore by selectively restricting channels within the operating spectrum. This can be used to avoid scanning channels with known interference or other restrictions. The system scans the full band continuously, giving a complete picture of the operating spectrum.

Automatic Measurements:

Interference Sampling Frequency

To rapidly detect degradations in performance, the DSO algorithm systematically samples one channel every TDD period. The channel sample frequency therefore varies with both the number of channels sampled and the prevailing TDD asymmetry. For example, at 5.8 GHz with a 30 MHz bandwidth and symmetric TDD, the sampling rate would be more than 200 times per second.

Bandwidth Sample Size

DSO measurements are taken using the configured channel bandwidth. For example, if the wireless link is configured to use 30 MHz channels, the DSO measurement is 30 MHz wide, and any alternative identified channels will also be 30 MHz wide. The radio scans at each raster interval defined for the band (e.g., 10 MHz); in the case of a 30 MHz channel, the ultimate target list is thus a series of overlapping 30 MHz channels on every 10 MHz channel center.

Channel Quality Metric

The channel quality metric is the algorithm used by the system to determine whether to change channels. One input is a measurement of noise for each polarization; recent trends are also used. Results are aggregated and converted to a single interference measurement.

Decision Threshold

The system always operates on the best available channel. It achieves this through two processes:

- Reactive Response: The user can specify performance thresholds. When these thresholds are crossed, the system automatically switches to the best available channel.
- Proactive Measurement: The system continuously measures performance of all channels in the background and will switch when a channel that is 3 dB or better in performance is detected. The channel decision metric is derived using samples collected from the PTP radio over the previous 20 minutes.

Split Frequency Operation:
DSO can also leverage a PTP system's capability to use different channels for transmitting and receiving communication. In some situations, noise will have varying impacts at each end of the link; this is particularly likely over long distances. When this occurs, the DSO algorithm independently selects the best channel for each direction.

Actions:

Channel Change with Minimal Impact to Network Traffic
The change to the new channel is completed without outage and usually without any packet loss. Momentarily, there is a lowering of throughput capability. The system will not change channels more than once per minute.

USING THE UNLICENSED SPECTRUM

Unlicensed spectrum by definition is available to other network operators, and therefore the RF noise environment can and will change over time. Cambium PTP systems use a variety of techniques to adapt to this changing environment and optimize performance in a wide variety of scenarios. These techniques not only include DSO but also fast adaptive modulation, automatic transmit power control, and single and dual MIMO payload. Additionally, selection of narrow beam width antennas and higher gain antennas can increase the fade margin and reliability of a link. DSO is most effective at minimizing interference coming from sources like other wireless networks. To maximize performance in the presence of other Cambium Networks PTP links, it is recommended to use PTP-Sync as a means to minimize self-interference. With proper planning, configuration, and deployment, PTP links routinely deliver up to 99.999% availability.

THE BEST INFORMATION PROVIDES THE BEST CONNECTIVITY

Dynamic Spectrum Optimization and Adaptive Modulation work together to select the best possible spectrum and optimize transmission speed to yield the best throughput. With these technologies working continuously in the background, the customer experiences the highest throughput and lowest latency on their service. This enables their video, voice, and data applications to consistently operate at peak performance, meeting the required service metrics. The end customer and the network operator can focus on growing their business while their broadband connectivity continuously optimizes itself.