Cambium Networks™

Using High Capacity Multi-Point For Video Surveillance

INTRODUCTION

Video surveillance is increasingly important in crime detection, crime prevention and maintaining public safety. IP networked camera systems, often connected using wireless technology, are replacing traditional analog CCTV systems.

This paper describes why digital IP networked cameras are a good choice, why these cameras should use a wireless connection to access the network and how the High Capacity Multi-Point (HCMP) system from Cambium Networks is an ideal solution for wireless video surveillance networking.

Finally, we provide an example of a video surveillance system using HCMP and how this system is planned using Cambium Networks' LINKPlanner software.

WHAT MAKES DIGITAL IP NETWORKED CAMERAS IDEAL FOR VIDEO SURVEILLANCE?

Historically, video surveillance was conducted using analog CCTV cameras. Monitoring over large areas using multiple analog CCTV cameras or creating a long distance connection to an analog CCTV camera could be difficult. In some installations, the video signal might be subject to interference and the resulting video images may appear degraded. Analog CCTV systems typically recorded and stored video at the local system using either a VCR or DVR[1].

Digital IP networked cameras come in many forms; from simple fixed low-resolution cameras, to high-resolution Pan-Tilt-Zoom (PTZ) dome cameras that have a full 360 degrees viewing capability; from thermal cameras that sense differences in the infra-red radiation emitted by objects, to wide dynamic range cameras that can cope with objects that are in bright sunshine and dark shadow in the same scene.

In a networked camera, the video images and audio signals are converted to data that can be streamed over a network connection, perhaps to a monitoring station or to a networked storage device or to cloud-based storage somewhere in the Internet. The common feature of all digital IP networked cameras is that they provide a network connection, typically via Ethernet.

[1] *In this context, a DVR is a device that takes an analog video stream and digitizes it so it can be stored on a hard disk drive.*

BENEFITS OF DIGITAL IP NETWORKED CAMERAS

- Digital IP networked cameras are easy to install and can use existing networking infrastructure. Ethernet/IP networks make it simple to connect multiple cameras to a network and to scale this network when additional cameras and image storage are required.

- The network connection provides access for streaming, storage and control. A Network Video Recorder (NVR) or Network Attached Storage (NAS) within the network stores and retrieves the video. Alternatively the video can be recorded to and retrieved from a cloud-based storage service, eliminating the need for on-site storage and providing access anywhere at any time.

- With digital IP networked cameras, remote access for control and live monitoring is simplified and often supported with a web browser or mobile app. Tracking objects and monitoring large areas is made simpler and easier as many digital IP networked cameras provide PTZ controls

- By powering a networked camera using Power-over-Ethernet (PoE) [2], the network cables carry power to the camera, reducing cabling costs and installation time.

- Having the video data available on a network opens up the opportunity to perform analysis of the video content, from simple motion detection to complex functions such as Automatic License Plate Recognition (ALPR) or facial recognition.

- Digital IP networked cameras are offering high-definition image quality suitable for use as evidence-grade footage.

- Analog cameras do not offer encryption, so their signals are open to interception by anyone with the correct equipment. In contrast, IP cameras send digital signals that can be encrypted so that even if their data is intercepted, it is rendered useless to the interceptor.

USING WIRELESS FOR CONNECTING VIDEO SURVEILLANCE CAMERAS

Whether the surveillance camera is installed on the side of the building, on a lamp post or at a remote location, it must be supplied with power. For every camera installation, a power connection is a given but a network connection is not. Cameras mounted on the side of a building might be wired to an existing LAN or have access to Wi-Fi but in many locations, network connectivity will not be available. Even in locations where wired networks are available, it might not be appropriate to dig trenches or run cables. It is in these remote, unconnected and difficult to connect locations where a wireless camera backhaul comes into its own.

FIGURE 1 : REMOTE LOCATION VIDEO SURVEILLANCE BACKHAULED USING PTP LINKS FROM CAMBIUM NETWORKS PROVIDING VIDEO COVERAGE OF WALKERS ON MT PICO, PICO ISLAND, AZORES

A surveillance camera might be part of a temporary solution to cover a particular event, or part of a response to a threat where rapid deployment is required. In many of these situations, a wired network may not be readily available. Again, this is where a wireless backhaul provides the best solution.

OPTIMIZING A WIRELESS SOLUTION TO SUPPORT VIDEO SURVEILLANCE

When providing wireless connectivity for video surveillance, the data capacity required over the wireless backhaul is a key consideration. Digital IP networked cameras continue to improve, with many now capable of providing high definition video at frame rates of 30 fps or above. As camera data bandwidth requirements continue to increase, the wireless backhaul needs to be capable of supporting these demands.

An HDTV 1080p camera encoding video using H.264 [1] at 30 fps can require around 12 Mbps for a scene with lots of motion. While these rates are easily achievable with the latest generation of IEEE802.11 products, it does depend on how many others users are on that network, the amount of congestion, the distance from the camera to the access point and the interference levels seen in that wireless network.

However, there is another factor at play when considering wireless camera backhaul. Video compression algorithms are vulnerable to lost frames and in particular to the loss of their reference frame on which subsequent compressed frames depend. While H.264 is the latest MPEG coding standard and has much better compression than its predecessors provide, it is less robust and therefore more susceptible to data errors seen with interference or packet loss. Older encoders such as Motion JPEG, require much higher throughputs but are more resilient to errors or lost frames, for example an HDTV 1080p camera capturing Motion JPEG at 30 fps can require up to 70 Mbps.

When selecting the camera backhaul it is necessary to take into account the bandwidth requirements of the video encoder, the resilience of this video encoder to lost frames and the likely error rate of the wireless backhaul. Often the best approach[2] is to use a wireless backhaul that provides a guaranteed bandwidth combined with a low error rate, such as a point-to point (PTP) wireless link. Using a PTP link that has guaranteed throughput at low error rates, that adapts to the wireless conditions and provides interference mitigation, will reduce disruption of the video stream.

Good quality video is especially important when employing video analytics. Video analytics is a new and growing application, where the video content is analyzed to perform facial recognition, read license plates, count people, track objects etc. or simply detect real-time events such as motion in a scene. This analysis is only possible where the video quality has not been compromised during transmission across the network.

Information security in the network is increasingly important. Many digital IP networked cameras use security protocols that provide authentication and authorization as part of establishing a connection to the network. The information security of the wireless backhaul should not be overlooked. Wireless transmissions can be subject to eavesdropping and wireless equipment subject to denial of service and cyber-attacks, so it is important to consider the entire solution, not just the cameras. In a wireless system, it is very important to ensure only authorized devices are connecting to the network, so the wireless backhaul needs to provide not just encryption of the video data but also authentication and authorization of the radio units attempting to connect.

FIGURE 2 : VIDEO ANALYTICS INCLUDES THE USE OF ALPR CAMERAS

In any surveillance situation, the reliability of the equipment is extremely important. This applies to the camera, to the backhaul and all the network devices. The equipment operating temperature must be considered as both the cameras and wireless backhaul could be mounted at locations that experience a wide daily temperature variation or temperature extremes.

[2] *Selecting a video encoder that offers the lowest throughput requirement and then backhauling with a contended wireless data service that might result in frame loss due to contention or wireless errors might not be the best combination. If the wireless link is subject to errors then a more robust but higher throughput video encoder might be more appropriate. PTP links are often a better solution as they do not suffer from frame loss due to contention and if they are subject to wireless errors due to the propagation conditions or interference, they can support the higher data rates required by the more robust video encoders.*

USING HCMP FOR VIDEO SURVEILLANCE BACKHAUL

Wireless solutions for video surveillance backhaul may include point-to-multipoint (PMP) systems where subscriber units contend for data bandwidth or PTP systems that provide a guaranteed link capacity. Cambium Networks is offering an alternative using the High Capacity Multi-Point (HCMP) system that offers the benefits of a multipoint system but provides the uncontended guaranteed link capacity familiar to users of point-to-point wireless links.

FIGURE 3 : WITHOUT PROPER PLANNING, CAMERA INSTALLATIONS CAN SOON BECOME MESSY AND DIFFICULT TO BACKHAUL

In an HCMP network, up to eight HCMP slaves can connect to a single HCMP master in a system built from either PTP 700 or PTP 670 radios. Every connection between the HCMP master and an HCMP slave appears as if it is an independent uncontended PTP link that is continually optimizing the modulation mode to suit the wireless conditions that the link is experiencing. All the links in the HCMP system operate on the same single frequency. This is particularly advantageous where radio spectrum is limited or where there is interference, making HCMP an ideal solution when deploying multiple cameras.

In many video surveillance applications, the backhaul bandwidth requirement is likely to be asymmetric. For example, most of the wireless link capacity might be required in the uplink to satisfy the demands of the video streaming, whereas the downlink will be lightly loaded with just the PTZ control and camera management traffic. HCMP allows the symmetry of each individual link to be configured to match the data requirements of the uplink and downlink, making it easier to optimize the backhaul bandwidth for any given video surveillance application.

In applications where more than one camera is required at a site, the PTP 700 and PTP 670 radios support three LAN ports connected through an Ethernet switch. When connecting multiple cameras to a single radio, it might be necessary to provide more link capacity to this radio with respect to the others in the system. With HCMP expert mode, it is possible to configure different links with different data capacities making supporting multiple cameras at a single site straightforward.

The Auxiliary LAN port on both the PTP 700 and PTP 670 provides a PoE power output capability to IEEE 802.3at that can deliver up to 25.5 W. With PoE enabled, the power is carried over the Ethernet cable to a maximum distance of 300 ft (100 m), which allows both the camera and the wireless unit to be positioned optimally. In a system where an HCMP slave connects a single camera, the PoE capability provides an ideal solution to both power and backhaul the camera.

When it comes to information security, the PTP 670 and PTP 700 radios are best in class. The management interfaces are secured using HTTPS and TLS and the data over the wireless link can be encrypted using AES with either 128-bit or 256-bit key sizes. Through the use EAP-TLS and digital certificates, radios are unable to establish a connection until they complete the authentication and authorization operations that verifies they have permission to connect.

Secure generation of the AES keys used for the wireless encryption is automatic and where there is a security policy that requires a regular key change, this can be achieved securely and without service interruptions using Over-The-Air-Rekeying (OTAR).

In summary an HCMP network using PTP 700 or PTP 670:

- Creates a single wireless frequency point-to-multipoint network but with all the advantages of point-to-point radios.
- Supports up to eight HCMP slaves per HCMP master.
- Provides uncontended access on each individual link.

- Supports adaptive modulation and NLOS.
- Offers best in class security features.
- Provides high equipment reliability.
- Supports remote management through cnMaestro ™ and SNMPv3.
- Provides PoE support on the Aux LAN port for a direct camera connection.
- Has flexible configurations that permit adjustment of the link symmetry.
- Has the ATEX/HAZLOC[3] certifications for operation in explosive atmospheres.
- Provides the quality of service that allows other user traffic to be sent in parallel with the video streams.

AN EXAMPLE WIRELESS VIDEO SURVEILLANCE NETWORK USING HCMP

In the following, we show how LINKPlanner simplifies the planning and analysis of HCMP networks in a video surveillance application.

CAMERA REQUIREMENTS

A small town needs a wireless video surveillance system to cover areas of the harbor, the marina and the main street.

Six cameras are required, all supporting 1080p video at 20 fps. To stream this video an estimated minimum of 10 Mbps is required per camera. The video streams need to be transmitted to a control center located at the police headquarters.

LINK PLAN

LINKPlanner, the free wireless link-planning tool from Cambium Networks, supports PTP, PMP and HCMP topologies[4].

The police headquarters has a pre-existing radio mast where the PTP 670 HCMP master can be located. For the purposes of this exercise, we have configured the HCMP master with 90-degree sector antenna to provide coverage of the camera sites within the town.

In this example, the Police Headquarters Mast has been added as the network site and each camera location is added as a subscriber site as shown in Figure 4

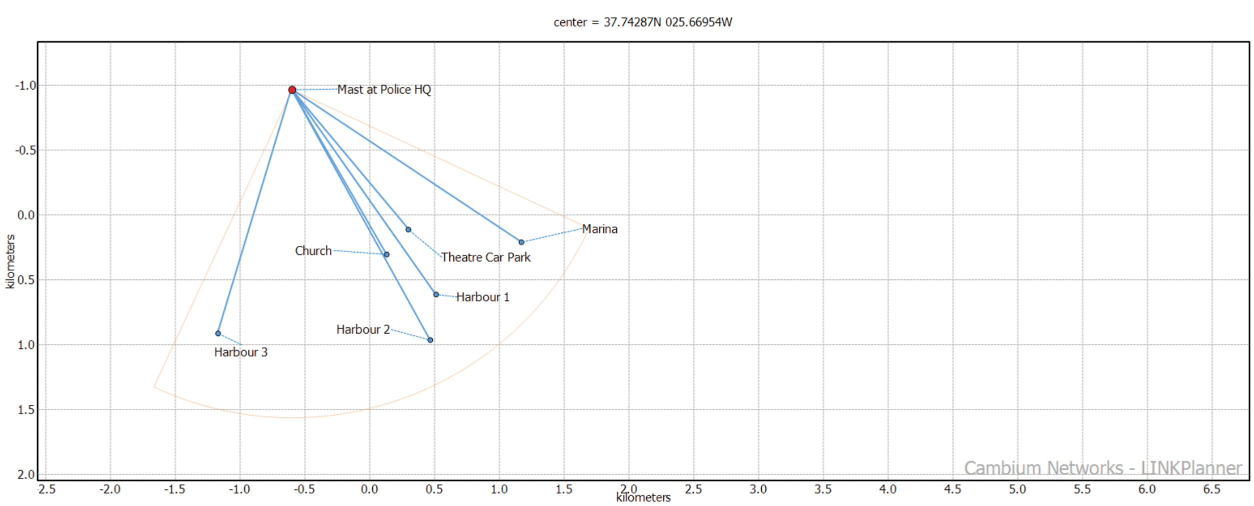


FIGURE 4 : SCHEMATIC VIEW OF THE HCMP NETWORK FROM LINKPLANNER

[3] *PTP 670 only*

[4] *To plan a HCMP network in LINKPlanner, select the option to configure a PMP Link and then choose the frequency band so that PTP 670 and PTP 700 radios are available. The equipment options then include the PTP 670 and PTP 700 operating as HCMP.*

The master has been configured as a PTP 670 operating in the 5.8 GHz band and due to the asymmetric nature of the camera data, the symmetry been configured so that there is a 1:2 ratio favoring the uplink as shown in Figure 5.

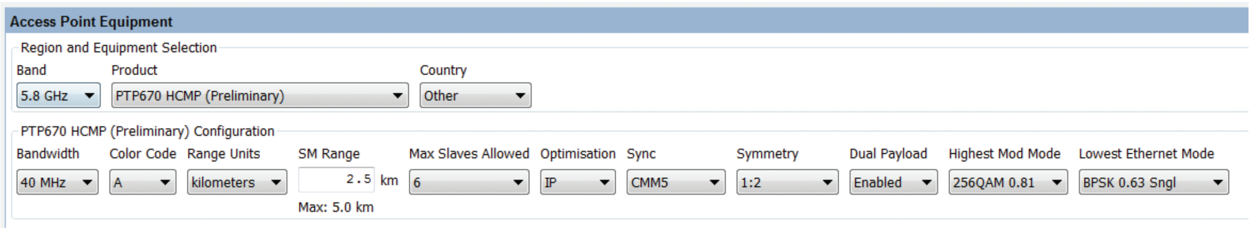
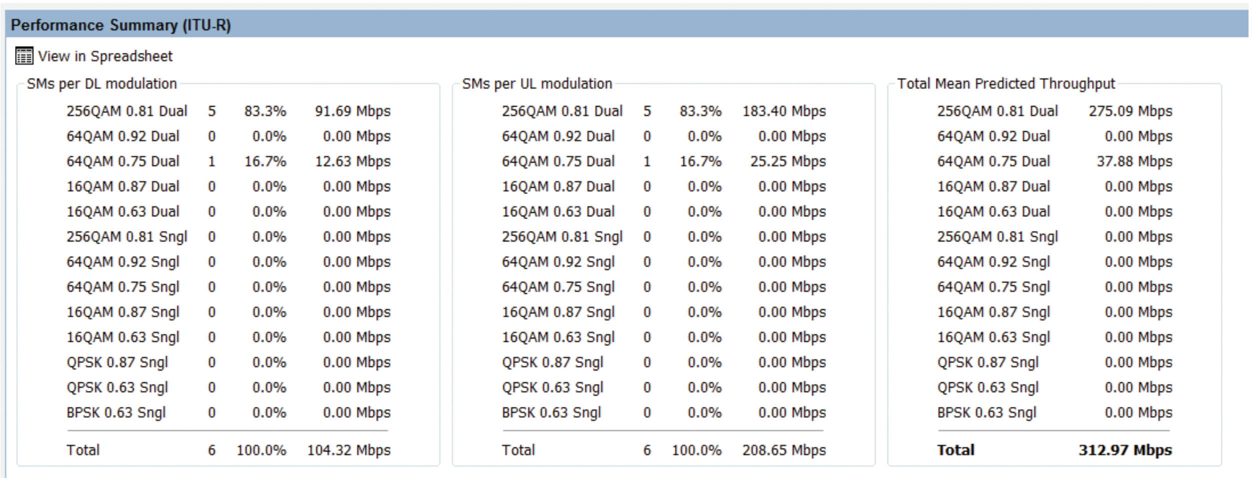


FIGURE 5 : SUMMARY OF THE MASTER SETTINGS IN LINKPLANNER



Performance Summary (ITU-R)

View in Spreadsheet

SMs per DL modulation

256QAM 0.81 Dual	5	83.3%	91.69 Mbps
64QAM 0.92 Dual	0	0.0%	0.00 Mbps
64QAM 0.75 Dual	1	16.7%	12.63 Mbps
16QAM 0.87 Dual	0	0.0%	0.00 Mbps
16QAM 0.63 Dual	0	0.0%	0.00 Mbps
256QAM 0.81 Sngl	0	0.0%	0.00 Mbps
64QAM 0.92 Sngl	0	0.0%	0.00 Mbps
64QAM 0.75 Sngl	0	0.0%	0.00 Mbps
16QAM 0.87 Sngl	0	0.0%	0.00 Mbps
16QAM 0.63 Sngl	0	0.0%	0.00 Mbps
QPSK 0.87 Sngl	0	0.0%	0.00 Mbps
QPSK 0.63 Sngl	0	0.0%	0.00 Mbps
BPSK 0.63 Sngl	0	0.0%	0.00 Mbps
Total	6	100.0%	104.32 Mbps

SMs per UL modulation

256QAM 0.81 Dual	5	83.3%	183.40 Mbps
64QAM 0.92 Dual	0	0.0%	0.00 Mbps
64QAM 0.75 Dual	1	16.7%	25.25 Mbps
16QAM 0.87 Dual	0	0.0%	0.00 Mbps
16QAM 0.63 Dual	0	0.0%	0.00 Mbps
256QAM 0.81 Sngl	0	0.0%	0.00 Mbps
64QAM 0.92 Sngl	0	0.0%	0.00 Mbps
64QAM 0.75 Sngl	0	0.0%	0.00 Mbps
16QAM 0.87 Sngl	0	0.0%	0.00 Mbps
16QAM 0.63 Sngl	0	0.0%	0.00 Mbps
QPSK 0.87 Sngl	0	0.0%	0.00 Mbps
QPSK 0.63 Sngl	0	0.0%	0.00 Mbps
BPSK 0.63 Sngl	0	0.0%	0.00 Mbps
Total	6	100.0%	208.65 Mbps

Total Mean Predicted Throughput

256QAM 0.81 Dual	275.09 Mbps
64QAM 0.92 Dual	0.00 Mbps
64QAM 0.75 Dual	37.88 Mbps
16QAM 0.87 Dual	0.00 Mbps
16QAM 0.63 Dual	0.00 Mbps
256QAM 0.81 Sngl	0.00 Mbps
64QAM 0.92 Sngl	0.00 Mbps
64QAM 0.75 Sngl	0.00 Mbps
16QAM 0.87 Sngl	0.00 Mbps
16QAM 0.63 Sngl	0.00 Mbps
QPSK 0.87 Sngl	0.00 Mbps
QPSK 0.63 Sngl	0.00 Mbps
BPSK 0.63 Sngl	0.00 Mbps
Total	**312.97 Mbps**

FIGURE 6 : HCMP MASTER PERFORMANCE SUMMARY

The performance summary from LINKPlanner is given in Figure 6. This shows that all the HCMP slaves are all operating in mode 64QAM 0.75 Dual or above and this will provide a minimum data rate of 25.25 Mbps. Analysis of an individual slave link for Harbor 1 site, provides more detail of the throughput as shown in Figure 7. At this site, the link has a minimum capacity of 14.1 Mbps in the uplink with better than 99.999% availability, which is more than enough to meet the requirements of the camera located at this site.

Analysis of the remaining camera sites shows that all locations have a throughput that meets the minimum 10 Mbps requirement apart from the Marina that has an uplink throughput of 7.1 Mbps with better than 99.999% availability. By performing some what-if analysis within LINKPlanner, this can be improved to 14.1Mbps with better than 99.99% availability by a small increase in antenna height at the slave.

Performance Summary (ITU-R)

Performance to AP - Mast at Police HQ

Predicted Receive Power : -56 dBm ± 5 dB
Min Mod Mode Required : BPSK 0.63 Sngl
Min Availability Required : 99.0000 %
Max Usable Mode : 256QAM 0.81 Dual
Predicted Availability : 100.0000 %

Link Summary

Lowest Mode Availability : 100.0000 %

System Gain Margin : 44.29 dB
Free Space Path Loss : 113.33 dB
Gaseous Absorption Loss : 0.02 dB
Excess Path Loss : 0.00 dB
Total Path Loss : 113.35 dB

Performance Details

Common details													
Mode:	256QAM	64QAM	64QAM	16QAM	16QAM	256QAM	64QAM	64QAM	16QAM	16QAM	QPSK	QPSK	BPSK
Code Rate:	0.81	0.92	0.75	0.87	0.63	0.81	0.92	0.75	0.87	0.63	0.87	0.63	0.63
Payloads:	Dual	Dual	Dual	Dual	Dual	Single	Single	Single	Single	Single	Single	Single	Single
Aggregate Max Data Rate (Mbps):	55.0	46.4	37.9	29.5	21.2	27.5	23.2	18.9	14.7	10.6	7.4	5.3	2.6
Performance to Access Point													
Max Data Rate (Mbps):	36.7	30.9	25.3	19.6	14.1	18.3	15.5	12.6	9.8	7.1	4.9	3.5	1.8
Fade Margin (dB):	11.8	15.3	19.1	23.1	28.8	15.3	18.5	22.2	26.2	31.8	34.8	39.8	44.3
Mode Availability (%):	99.9995	99.9995	99.9995	99.9995	99.9995	0.0005	0.0005	0.0005	0.0005	100.0000	100.0000	100.0000	100.0000
Receive Time in Mode (%):	99.9995	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Performance to Subscriber Module													
Max Data Rate (Mbps):	18.3	15.5	12.6	9.8	7.1	9.2	7.7	6.3	4.9	3.5	2.5	1.8	0.9
Fade Margin (dB):	11.8	15.3	19.1	23.1	28.8	15.3	18.5	22.2	26.2	31.8	34.8	39.8	44.3
Mode Availability (%):	99.9995	99.9995	99.9995	99.9995	99.9995	0.0005	0.0005	0.0005	0.0005	100.0000	100.0000	100.0000	100.0000
Receive Time in Mode (%):	99.9995	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FIGURE 7 : THROUGHPUT SUMMARY FOR THE HCMP SLAVE AT HARBOR 1

CONCLUSIONS

Video surveillance solutions using digital IP networked cameras are easier to install, can connect to existing network infrastructure and are more scalable than their analog CCTV predecessors.

Digital IP networked cameras are now the solution of choice for video surveillance installations. Connecting these cameras in remote, unconnected and difficult to connect locations or as part of temporary solution can be achieved simply and reliably using wireless for their backhaul.

Both PTP 700 and PTP 670 offer the reliability, security and throughput required for video surveillance wireless backhaul. Deploying these radios in an HCMP network offers many of the benefits of a multipoint system, including single frequency operation, and yet still provides an uncontended guaranteed link capacity for the camera data.

LINKPlanner simplifies HCMP network planning and what-if analysis allows the optimization of site selection and radio configuration.

REFERENCES

1 ITU-T Recommendation H.264 : Advanced video coding for generic audiovisual services.

2 IEEE Std 802.3-2015 IEEE Standard for Ethernet, Section 2, Clause 33. Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)

Cambium Networks™

Cambium Networks, Ltd.
3800 Golf Road, Suite 360,
Rolling Meadows, IL 60008