



Panduit FMPS and Cisco Implementation Guide

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1 PURPOSE AND OVERVIEW

Organizations worldwide are under increasing pressure to reduce energy consumption, improve operational efficiency, and minimize their environmental impact. These demands, coupled with rising energy costs and stringent sustainability regulations, have created a need for innovative power distribution solutions. Through Cisco's Engineering Alliances initiative, Cisco and Panduit have collaborated to develop a validated architecture that combines Fault Managed Power System (FMPS) and Power over Ethernet (PoE) technologies, addressing these critical business and environmental challenges.

By combining Cisco's industry-leading Catalyst 9300 PoE switching platform with Panduit's UL-1400-1 certified Fault Managed Power System, we've created a comprehensive solution that has been engineered and validated to meet rigorous standards of performance, safety, and reliability while supporting organizations' sustainability and cost optimization goals

This architecture validation ensures partners can integrate the solution efficiently, reducing implementation time and risk. This is particularly important as the solution introduces new capabilities such as delivering up to hundreds of watts per copper pair over distances exceeding 1km while maintaining UL-1400-1 compliance. The detailed engineering validation and documentation provides the technical foundation for integrating building management systems with IT networks, establishing a standards-based infrastructure for power distribution and network connectivity.

The test cases covered in this document have been validated in a collaborative effort between Panduit and Cisco to show that FMPS can be implemented successfully to power Cisco's Catalyst switches with direct current (DC) power. The FMPS can power a DC power supply in a PoE solution to serve multiple purposes that include, but are not limited to:

- Serve as the primary power delivery to one or both power supplies on a PoE switch
- Serve as a backup solution to a brownfield PoE deployment with an existing power supply
- Serve as a supplementary delivery solution that requires additional power to a switch

The intended audience for this document is for all parties involved in purchasing, designing, and implementing a PoE solution with Panduit's FMPS, including but not limited to the following:

- project and/or account managers
- MEP (mechanical, electrical, plumbing) engineers and/or partners
- system integrators
- installers
- supply vendors

2 FMPS PRODUCT OVERVIEW

The Panduit FMPS delivers DC power over long distances to remote equipment.

The Panduit FMPS uses Pulse Current as its power delivery method. The Transmitter converts standard alternating current (AC), into a touch-safe pulse current waveform delivered over a Class 4 multi-conductor copper cable to the Receiver. The Receiver converts the pulse current waveform into +/- 48 VDC power, which can power the necessary devices.

For more information on Class-4 / FMP, see National Electric Code (2023) Article 726.

2.1 COMPONENTS

The following section will outline the individual components of the FMPS.

2.1.1 Chassis

The chassis is 1U rack-mountable device that will traditionally be deployed in a location where the local AC power source will be available. The chassis has three bays in the rear where the power supplies will be mounted, as well as nine bays in the front where the Transmitter modules will be mounted.

Figure 1. Panduit FMPS Chassis, PID: PXTC1ARA



Rear View, Three Bays for Power Supplies



Front View, Nine Bays for Transmitter Modules

The chassis has an RJ-45 network interface card in the front where an IP address can be configured to gain access to the graphical user interface where an administrator can manage and monitor the entire FMPS. Supported communication protocols are SNMP versions 2 and 3, and Rest APIs are also supported to allow third party applications, services, and tools to interface with the FMPS. Parameters that can be monitored from the management dashboard include temperature, voltage, current, power consumption, and power capacity.

Each component of the FMPS, the Receiver, Transmitter, and power supply, can all be remotely powered on or off through the management interface to service the needs of the administrator.

Additional information about the FMPS chassis can be found at:

<https://www.panduit.com/en/products/power-distribution-environmental-connectivity-hardware/fault-managed-power-systems/fault-managed-power-systems/pxtc1ara.html>

2.1.2 Power Supply

The power supplies are mounted in the rear of the chassis and is supplied with power through a cable connected from the C19 plug in the rear to a source such as a wall outlet or power distribution unit. Each power supply can receive up to 1600 watts, so a chassis with all three bays mounted can receive up to 4800 watts in total. It converts the AC power to 360-volt DC power and delivers it to the Transmitter modules.

Figure 2. Panduit FMPS Power Supply, PID: PXU1AJANNXX





Rear of Power Supply with C19 Plug

Additional information about the FMPS power supply can be found at:

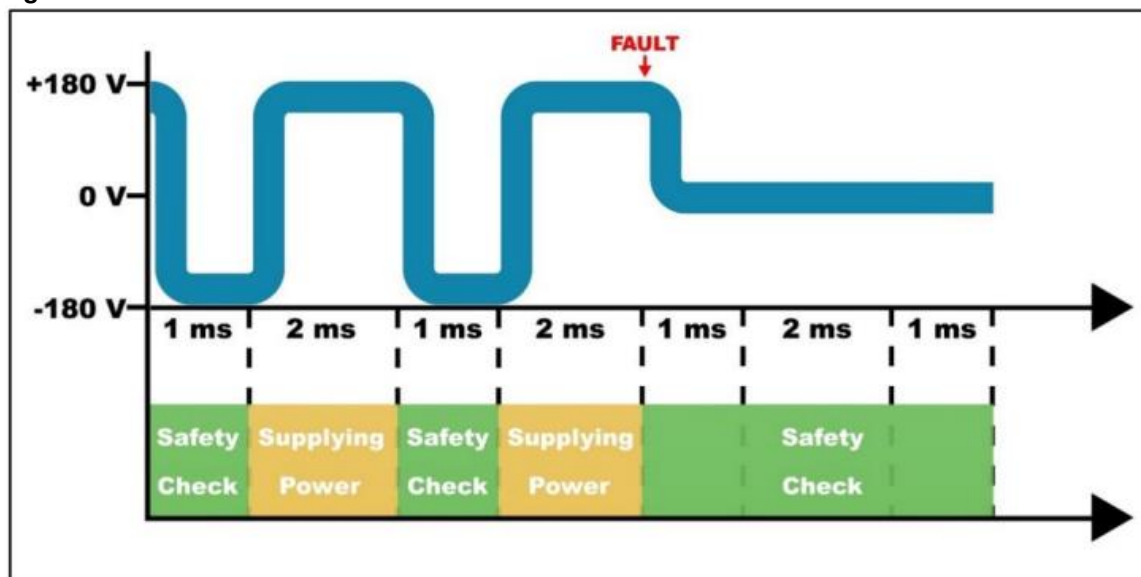
<https://www.panduit.com/en/products/power-distribution-environmental-connectivity-hardware/fault-managed-power-systems/fault-managed-power-systems/pxu1ajannnxx.html>

2.1.3 Transmitter

The Transmitter is mounted to the front of the FMPS chassis, where up to 9 modules can be connected. These modules output pulse current which can be terminated to a multiconductor cable. Section 2.1.5 addresses the Class 4 cables used in FMPS.

FMPS uses pulse current and delivers in the namesake pulses, with each cycle lasting around 3 milliseconds. Each cycle has 1 millisecond where a safety check is conducted, and 2 milliseconds where it is delivering power.

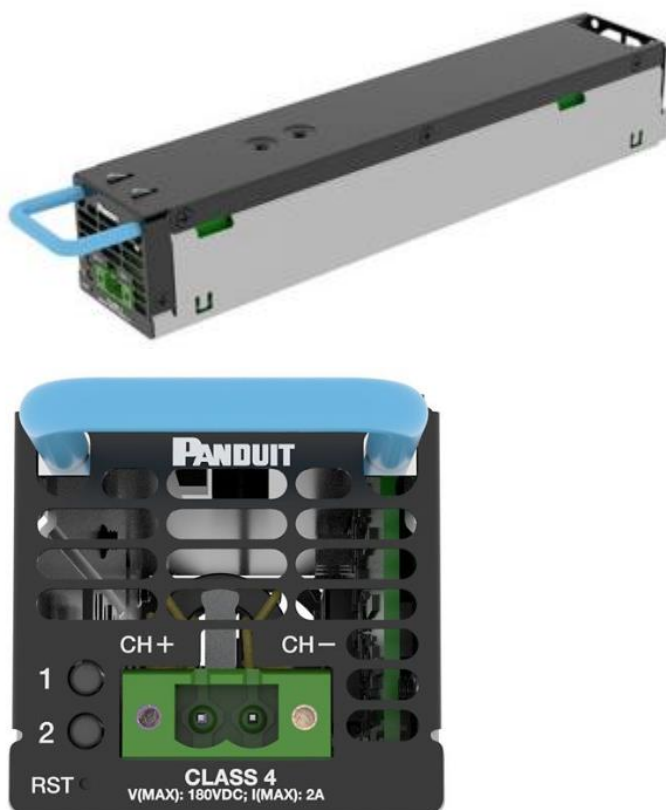
Figure 3. Chart of Pulse Current



The intent of delivering power in this fashion is to allow the FMPS to detect any faults in the circuit and to respond to the check accordingly. UL-1400-1 outlines the faults that must be addressed, and Panduit has designed the solution accordingly.

Each Transmitter module can output up to 600 watts of power at the source through Class 4 multi-conductor cables of varying gauges. The expected wattage at the termination on the Receiver will be addressed in Section 4.2.2, Distance/Length of Cables later in this document.

Figure 4. Panduit FMPS Transmitter Module, PID: PXTM1AF



Front of Module, with 1 Output Channel

Additional information about the FMPS Transmitter can be found at:

<https://www.panduit.com/en/products/power-distribution-environmental-connectivity-hardware/fault-managed-power-systems/fault-managed-power-systems/pxtm1af.html>

2.1.4 Receiver

The Receiver connects to the Transmitters via screw terminal plugs that connect to one of the three input channels available on the unit. The Receiver will draw the pulse current and convert it to traditional 48-volt DC power to output 600 watts from a single Transmitter module, or up to 1600 watts from three Transmitter modules, using the available output channels.

Figure 5. Figure 5: Panduit FMPS Receiver, PID: PXR1AJD



Input/Output Face of Receiver

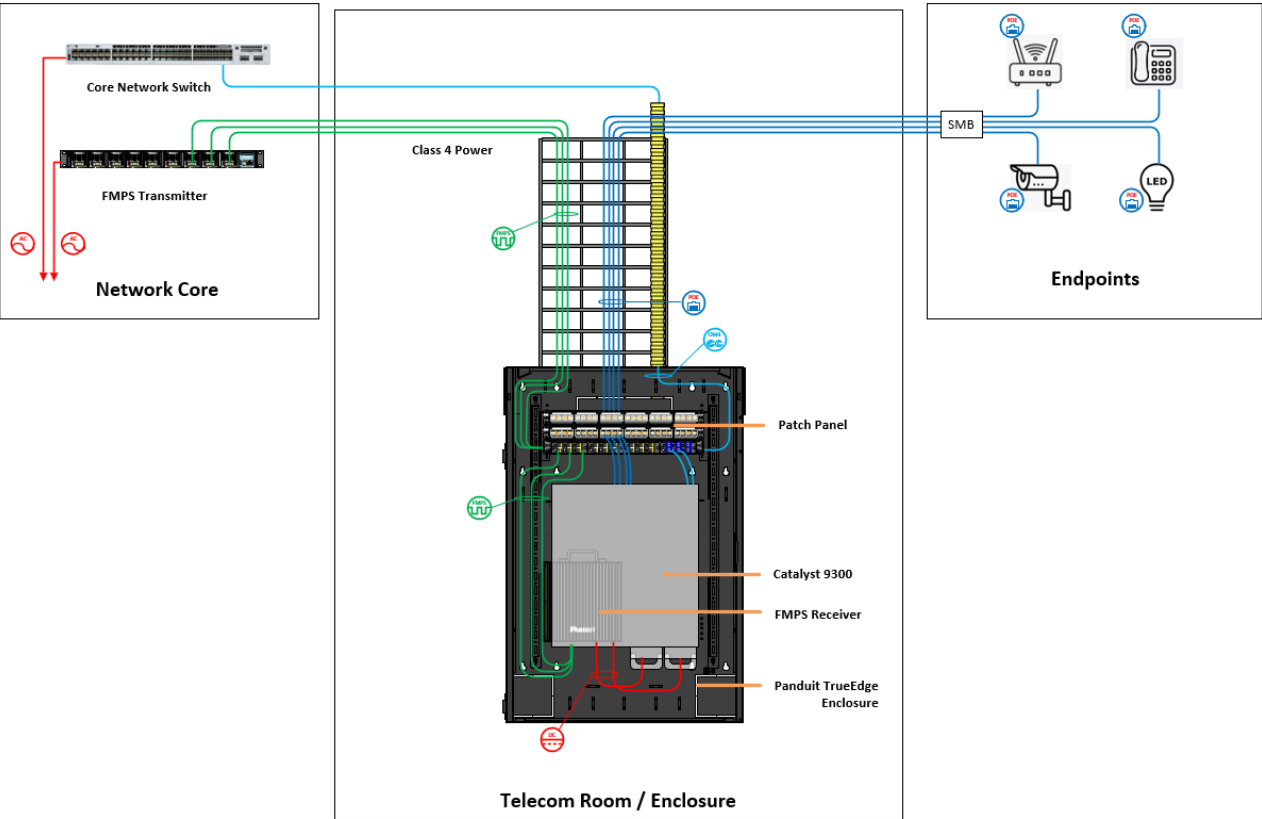
The Receiver has brackets built into the unit that will allow it to be mounted in various locations such as racks, enclosures, and other locations that can sustain and support the required operational environment.

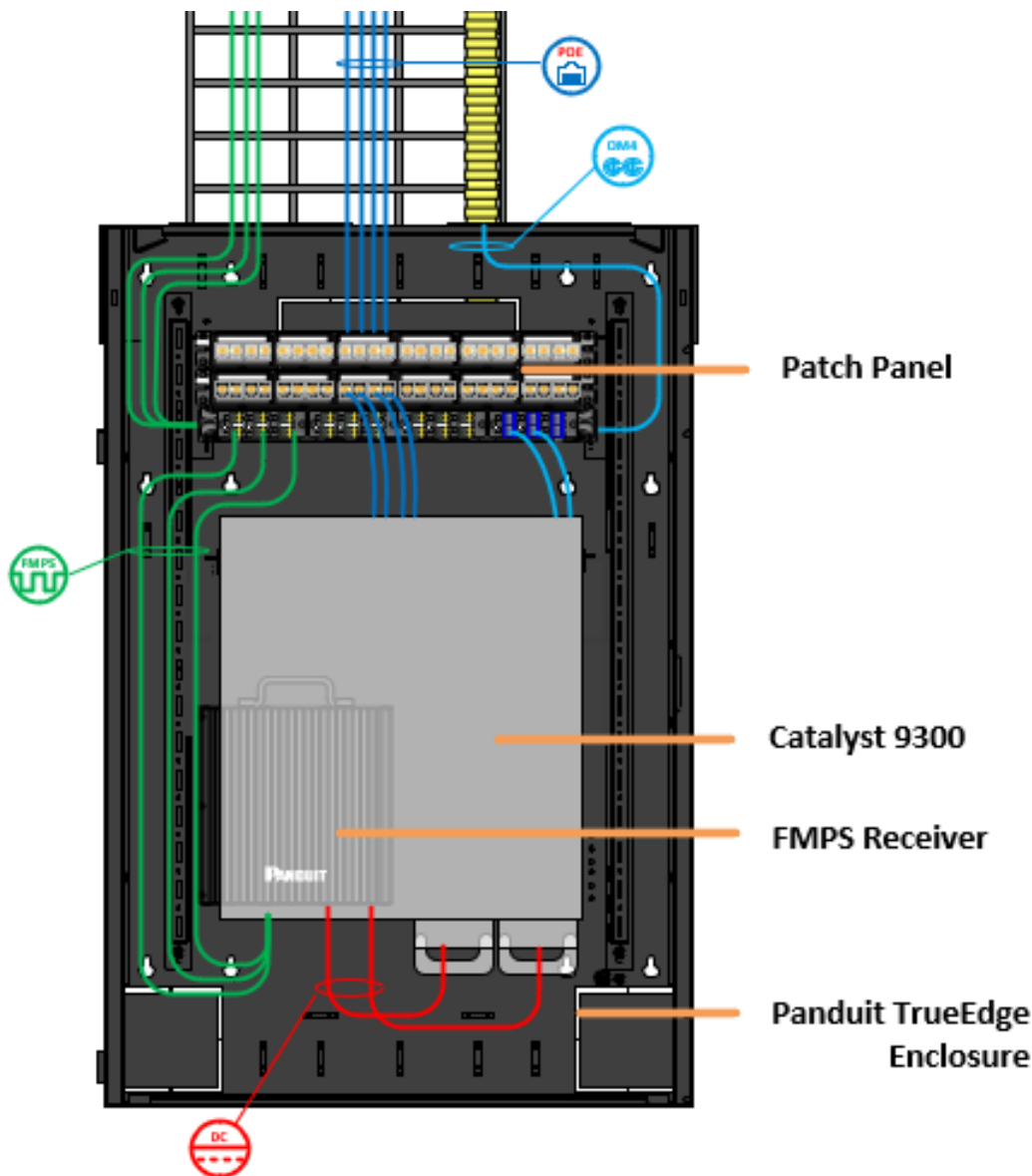
Additional information about the FMPS Receiver can be found at:

<https://www.panduit.com/en/products/power-distribution-environmental-connectivity-hardware/fault-managed-power-systems/fault-managed-power-systems/pxr1ajd.html>

Panduit has a product portfolio of enclosures to support the deployment of Receivers and accompanying devices such as PoE switches to enable a plethora of use cases. The enclosures can be modified with modules such as fans, cable management systems, and other components to meet the requirements necessitated by the use case.

Figure 6. Sample Drawing of Enclosure





Panduit TrueEdge™ Vertical Wall Mount Enclosure, 6RU, Black, WME6BL shown. Additional information about enclosures from Panduit can be found at:

<https://www.panduit.com/en/products/cabinets-thermal-management-racks-enclosures.html>

2.1.5 Cable

The cable in an FMPS solution connecting the Transmitter to a Receiver is a crucial part of the overall solution. It will be delivering the current from the headend or MDF, where the FMPS chassis is centrally located, to the remote location where the Receiver is.

The cable connecting the FMPS Transmitter to the Receiver is essential, as it carries current from the headend/MDF where the FMPS chassis is located to the remote Receiver site

Panduit manufactures a line of 3-pair 16-gauge copper cables that were designed to meet the requirements outlined in UL1400-2 class 4 standards. To meet the UL 1400-2 requirements, the cables must be tested to meet several criteria including but not limited to the following:

- Operating temperatures
- Insulation thickness
- Cable gauge range
- Part numbering for manufacturers

Figure 7. Panduit Class 4 Multiconductor Cable, Blue PID: PXUP316ABU-UQ



Additional information about Panduit's 3-pair 16-gauge Class 4 multiconductor cable can be found at:

<https://www.panduit.com/en/products/copper-systems/bulk-copper-cable/enterprise-data-center-copper-cable/pxup316abu-uq.html>

3 PANDUIT FMPS BENEFITS

Regardless of the architecture and design of the power delivery infrastructure where FMPS would be implemented, there are benefits to the solution that are gained almost universally.

3.1 INSTALLATION COSTS

The cost to install Class 4 FMPS is lower in comparison to installing other power delivery solutions due to the reduced labor costs for installers, as well as reduced costs in materials.

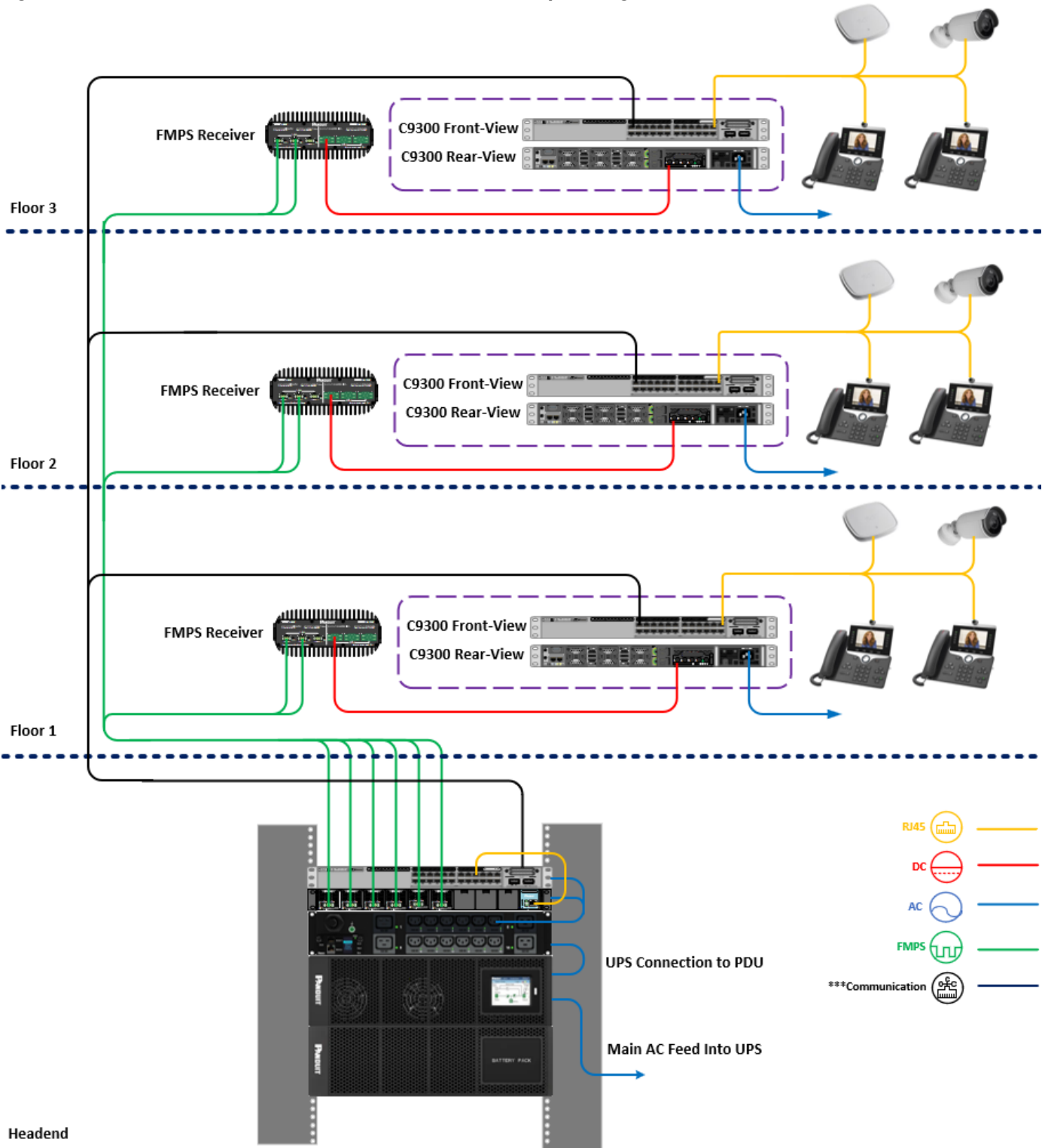
Due to the built-in safety, the Class 4 FMPS can be installed using Class 2 wiring methods, making it a faster and easier to install power solution compared to a traditional Class 1 circuit. The same low voltage labor installing data cables to the switch can be leveraged to install the Class 4 FMPS cables in the same data cable pathways at minimal additional cost. In comparison, a Class 1 Circuit requires licensed electricians to install conduit and run the electrical wiring separate from the data cables.

Material costs are also reduced by installing Class 4 FMPS cables to the required locations using the same cable pathways for data cables. In comparison, a Class 1 circuit required the installation of conduits, gang boxes, circuit breakers, and outlets for each location. As for PoE cabling, bringing the switch closer to the endpoints significantly reduce the required length of ethernet cabling to connect the switch to the endpoints.

3.2 CENTRALIZED POWER ARCHITECTURE

A recommended practice by Panduit for FMPS is to centralize the power delivery architecture to as few physical locations and square footage throughout a floor. FMPS enables this recommendation by permitting devices to be deployed at remote sites a considerable distance away. The remote sites will then converge to the FMPS in the center of the deployment.

Figure 8. Panduit FMPS Centralized Power Architecture Sample Design



In the example above, the FMPS, AC power source, uninterruptible power supply, to be called UPS henceforth, and necessary environmental controls can all be located on the main floor in the headend/main distribution frame, and the DC power from the FMPS can be distributed to provide the required power as necessary. This reduces the need for solutions infrastructure such as wall outlets, power distribution units, and other high-voltage delivery solutions to be implemented in remote locations.

Instead, enclosures containing the FMPS Receiver and PoE switch to power the access points can be installed on each floor, and the requisite connections:

- multiconductor connections from Transmitters in headend/main distribution frame to Receivers in enclosures
- ethernet connections from PoE switches to access points

can then be made to provide wireless network connectivity to the building depicted above.

The use case can be deployed to power a multitude of PoE endpoints such as access points, cameras, phones, digital signage, and any endpoint that is powered through an ethernet connection back to the PoE switch. This permits for flexible deployments as opposed to traditional high-voltage AC circuits since endpoint deployment would be dictated by location of power delivery such as power outlets along a wall, junction boxes, and other mechanisms.

By having components such as the circuit breakers, transformers, UPS, FMPS chassis, power supply, and Transmitters in one centralized location, a centralized architecture will reduce the complexity of installation, maintenance and monitoring the power system.

3.3 MONITORING AND CONTROL

Traditional power methods offer no monitoring or control capabilities of the electrical circuits. The Class 4 FMPS offers granular monitoring and control capabilities to all edge points from a single, centralized location. Users improve operational efficiency with the ability to troubleshoot and power cycle switches remotely without having to send a technician on-site. The monitoring capabilities of the Class 4 FMPS give users a view of available power capacity at each remote location simplifying future moves/adds/changes.

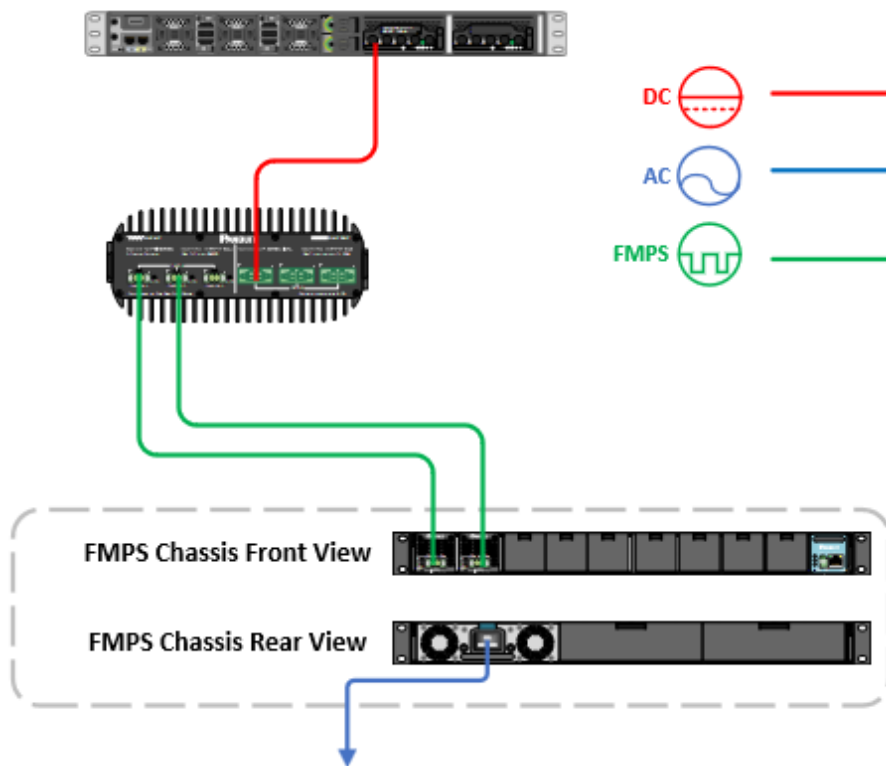
3.4 SCALABILITY

The modularity of Panduit FMPS allows the solution to be tailored to meet the immediate power delivery requirements, while allowing the solution to grow to meet the power demands of the future. FMPS is designed with Hot-Swappable components that make it easy to make move/add/change for a more flexible and scalable power infrastructure, unlike fixed local power.

As evidenced by the test case in this document, the requirement to power a single 715-watt DC power supply on a Cisco Catalyst C9300-24H can be met with the following configuration of FMPS:

- 1 chassis
- 1 power supply
- 2 Transmitters
- 1 Receiver

Figure 9. Panduit FMPS Minimum Requirements to Power Cisco Catalyst C9300-24H

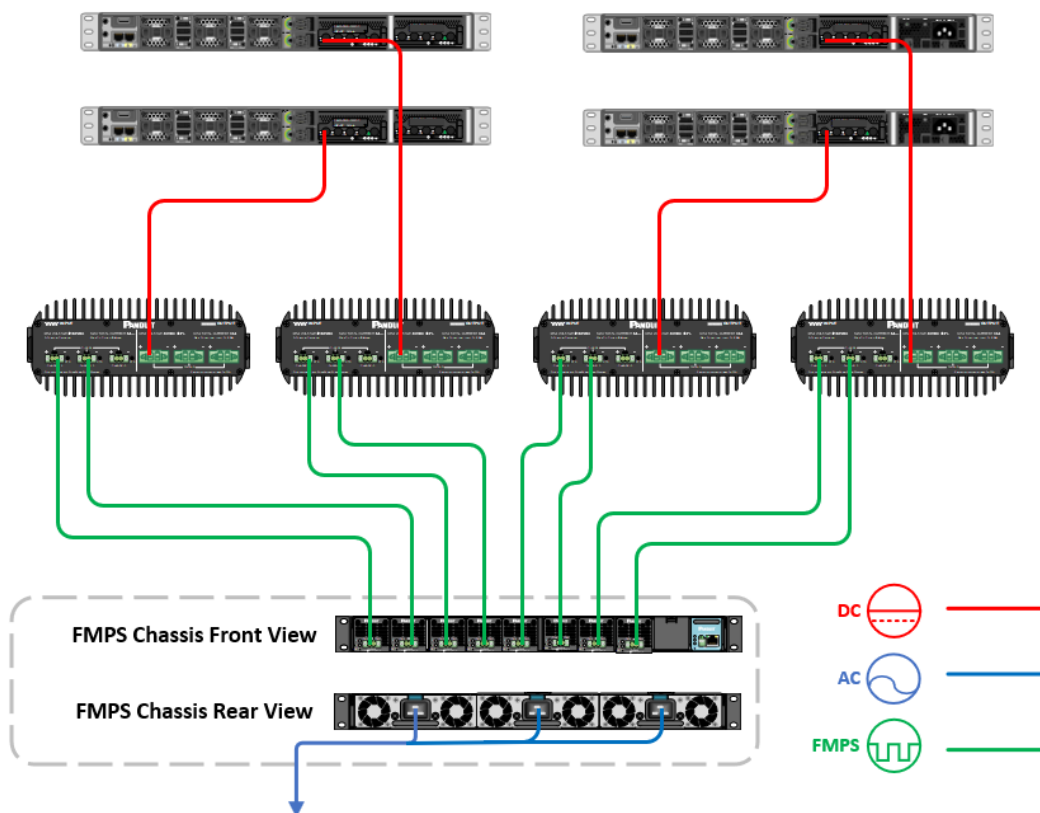


If the chassis were to be populated with the modules in the following configuration:

- 1 chassis
- 3 power supplies
- 8 Transmitters
- 4 Receivers

the system above, using 16-AWG cables to connect the Transmitters to Receivers, could power 4 C9300 switches each powered by a single 715-watt DC power supply up to 1000 meters away, as illustrated below.

Figure 10. Figure 10: Panduit FMPS Deployment for Maximum Catalyst C9300-24H Quantity



If the chassis were to be populated with the modules in the following configuration:

- 1 chassis
- 3 power supplies
- 9 Transmitters
- 3 Receivers

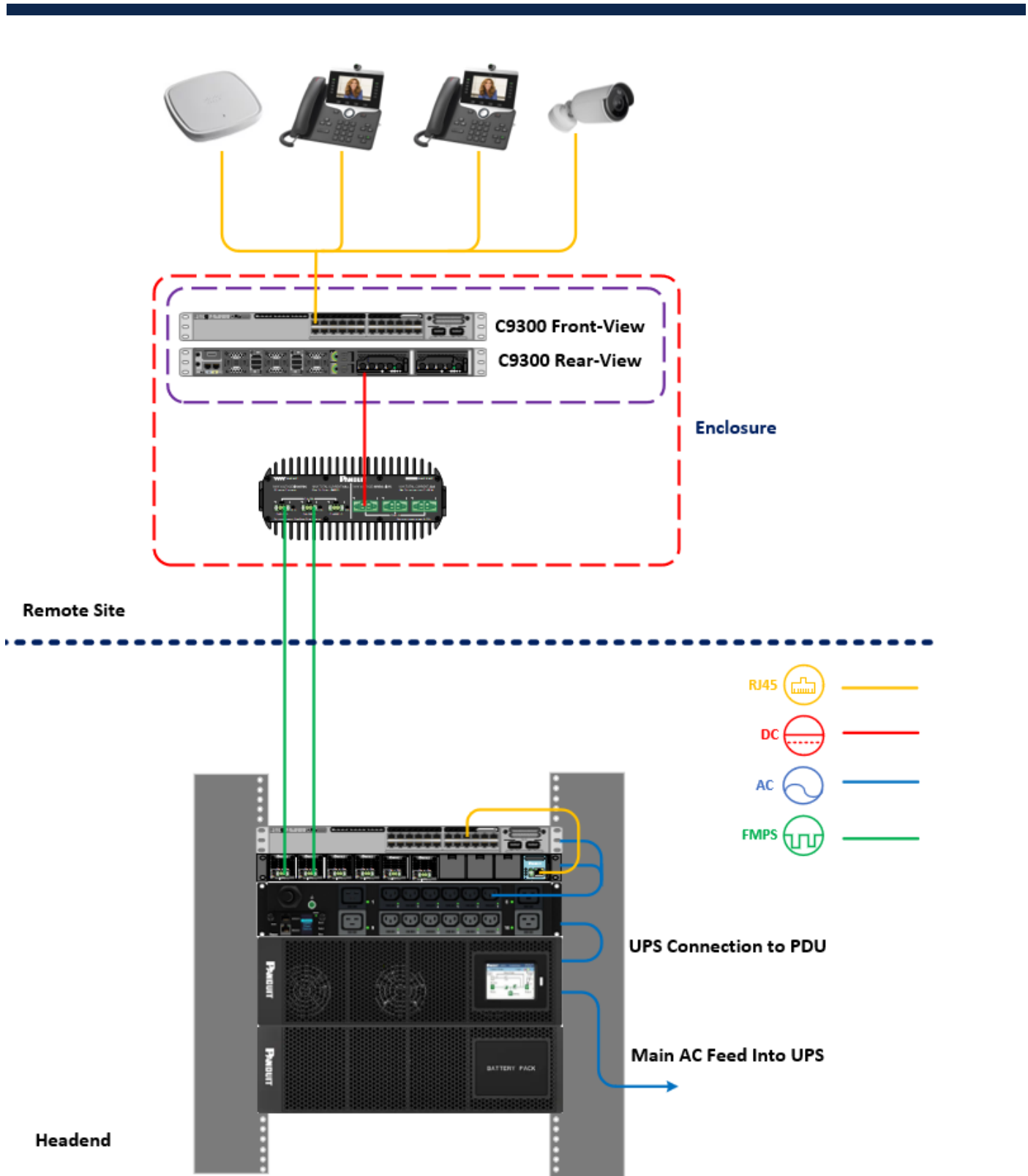
the system above, using 16-AWG cables to connect the Transmitters to Receivers, could power 3 C9300 switches each powered by two 715-watt DC power supply up to 450 meters away, as illustrated below.

Figure 11. Figure 11: Panduit FMPS Deployment for Maximum Power Supply Quantity on Cisco Catalyst C9300-24H

4 TEST CASE WITH CISCO CATALYST 9300

To demonstrate the capabilities of the FMPS, a PoE solution was deployed where the FMPS acted as both the primary method of power delivery as well as a backup to a Cisco Catalyst 9300 switch, C9300-24H. This switch The C9300 can deliver up to 90 watts to a PoE device from each interface, so certain tests were conducted with PoE endpoints drawing as low as 15 watts on each interface to as high as 90 watts on each interface. The diagram for the architecture of the deployment is below.

Figure 12. Figure 12: FMPS Catalyst PoE Network Design



4.1 COMPONENTS OF ARCHITECTURE

The FMPS will be connected to the AC power source to deliver the power to the C9300.

The C9300 will receive both DC power from the FMPS Receivers as well as traditional high-voltage AC power to power on PoE endpoints. For this test, the switch will be running software version Cisco IOS XE

Dublin 17.12.3, which at the time of writing this document is the Cisco suggested release for this specific model, the Catalyst C9300-24H.

The release notes for the software can be found at:

https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst9300/software/release/17-12/release_notes/ol-17-12-9300/whats_new_in_cisco_ios_dublin_1712x.html

The PoE endpoints will serve to act as a point of validation to confirm that the C9300 is successfully receiving power from the FMPS to turn them on.

The Panduit Class 4 3-pair 16 AWG, to be called multiconductor cable henceforth, will connect the Transmitter modules to the Receivers to deliver the pulse current.

4.2 VARIABLES

The variables that will change for individual test cases are outlined below.

4.2.1 Configuration of FMPS

The FMPS will be deployed in the PoE solution with a variety of configurations, where the number of power supplies, Transmitter modules, and Receivers will be adjusted to deliver the necessary power to the C9300.

4.2.2 Distance/Length of Cables

The distance of the multiconductor cable will vary between 1000 meters and 450 meters to meet the requirements to power the C9300. As we will demonstrate, In some test cases, the current delivered across 1000 meters will suffice to power the C9300, while in others, the current will not be sufficient, so the distance will have to be reduced to 450 meters. The calculated wattage across distance relative to the number of cable pairs and gauge of said cables can be found in the graphs below.

Figure 13. Wattage Delivered Relative to Distance Using 16 AWG Multiconductor Cable and Pair Count

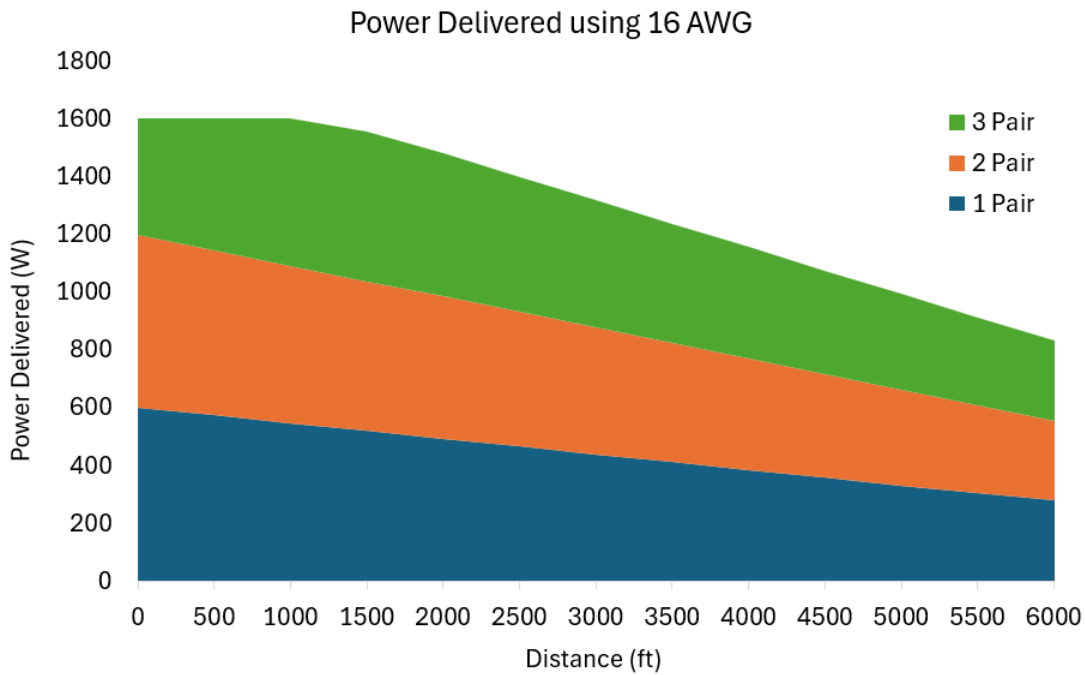


Table 1. Wattage Delivered Relative to Distance Using 16 AWG Multiconductor Cable and Pair Count

Distance (ft)	Wattage 3-Pair	Wattage 2-Pair	Wattage 1-Pair
500	1600	1150	575
1000	1600	1100	550
1500	1530	1050	525
2000	1460	1000	500
2500	1390	950	475
3000	1320	900	450
3500	1250	850	425
4000	1180	800	400
4500	1110	750	375
5000	1040	700	350
5500	970	650	325
6000	900	600	300

Figure 14. Wattage Delivered Relative to Distance Using 18 AWG Multiconductor Cable and Pair Count

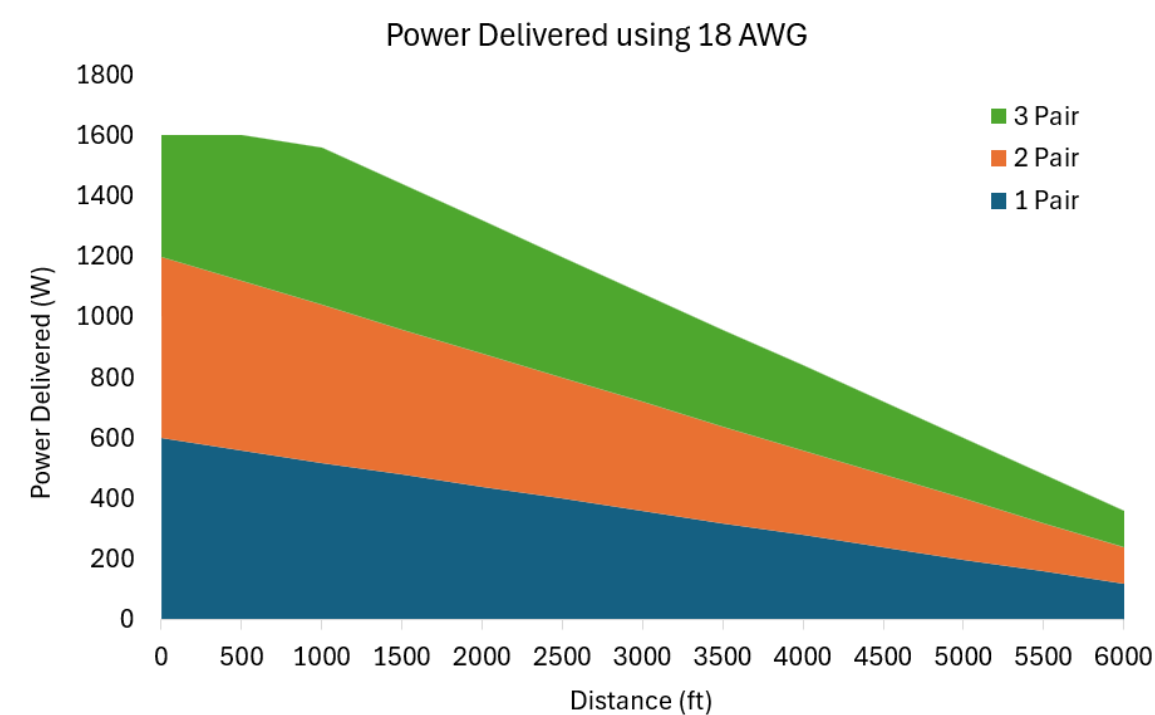


Table 2. Wattage Delivered Relative to Distance Using 18 AWG Multiconductor Cable and Pair Count

Distance (ft)	Wattage 3-Pair	Wattage 2-Pair	Wattage 1-Pair
500	1600	1100	550
1000	1491	1024	512
1500	1382	948	474

4.2.3 Catalyst 9300 Power Supply Configurations

A variety of power supply configurations for the C9300 will be tested to ensure that the desired outcomes are achieved to validate certain use cases. The quantity of AC and DC power supplies mounted will be varied to test features such as power redundancy and port priority. The configurations are as follows:

- 1. One 715 W DC power supply
- 2. One 715 W DC power supply and one 1900 W AC power supply
- 3. Two 715 W DC power supplies

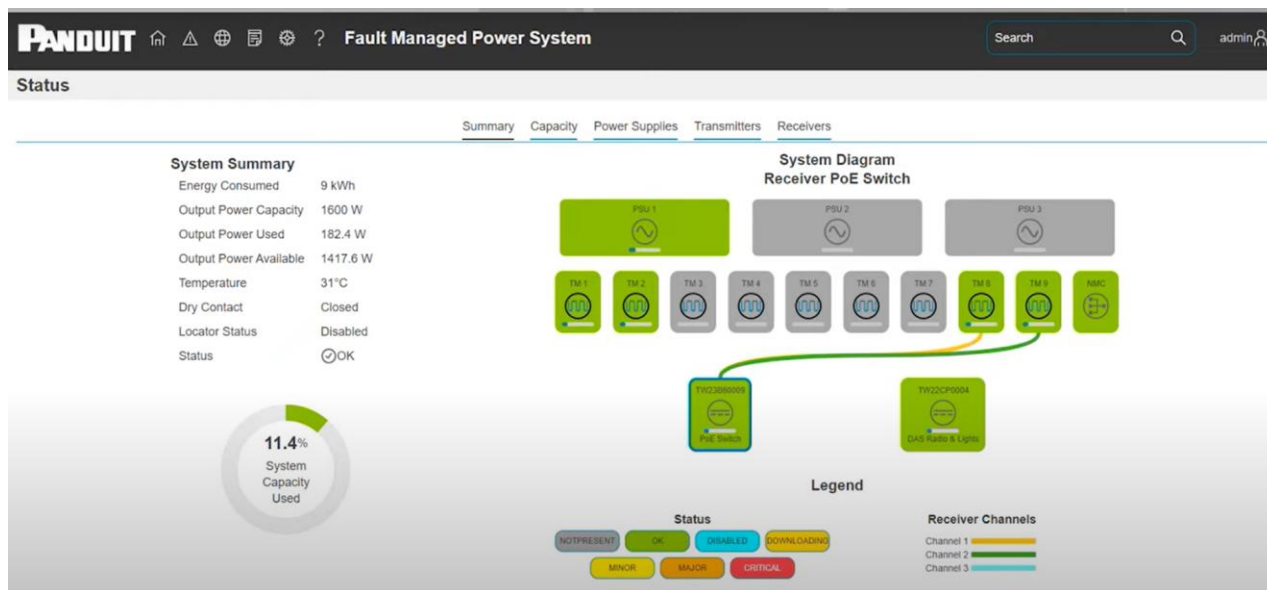
In the third configuration, a single homing and dual homing configuration will be tested, where in the single homing, each power supply will be connected to its own dedicated Receiver, and the dual homing architecture, consisting of two Receivers and two C9300’s, will have two Receivers powering one DC power supply on each C9300 for complete redundancy.

4.3 VALIDATION METHODOLOGY

4.3.1 Operation of FMPS

To validate that the FMPS is operating as intended, the management graphical user interface will be referenced to check for conditions of all the components of the FMPS.

Figure 15. Sample Image of Management Graphical User Interface



Leveraging the interface will allow the FMPS to be monitored to ensure that the system is receiving the power from the source as well as delivering the requisite amount to power on the C9300.

4.3.2 Operation of 9300

The C9300 command line interface will also be used to validate the FMPS as a viable source of power. There are several commands where the outputs will be able to verify the switch is receiving enough power to run its own systems as well as deliver power to the connected PoE endpoints.

The following commands, which will be executed with in EXEC mode with elevated privileges, will reveal the operational parameters on the switch:

- show environment all
- show power detail
- show power inline upoe-plus

For the sake of simplicity and readability, the outputs of some commands will be shown as tables with parameters of interest and not raw text outputs in the results section of the test cases. The parameters of interest have been made into bold and italics for easier viewing, and to provide an opportunity for administrators to locate the said values from the sample outputs above.

The “show environment all” command displays the fan, temperature, and power information of the internal power supplies connected to the switch. A sample of the output of the command is shown below:

Sensor List: Environmental Monitoring

Sensor	Location	State	Reading	Range (min-max)
PS1 Vout	1	GOOD	56238 mV	na
PS1 Vin	1	GOOD	48063 mV	90 - 264
PS1 CURin	1	GOOD	8250 mA	na
PS1 Curout	1	GOOD	6453 mA	na
PS1 POWin	1	GOOD	397000 mW	na
PS1 POWout	1	GOOD	362500 mW	na
PS1 FAN	1	GOOD	6736 rpm	na
PS2 Vout	1	FAULTY	0 mV	na
PS2 Vin	1	FAULTY	0 mV	90 - 264
PS2 CURin	1	FAULTY	0 mA	na
PS2 CURout	1	FAULTY	0 mA	na
PS2 POWin	1	FAULTY	0 mW	na
PS2 POWout	1	FAULTY	0 mW	na
PS2 FAN	1	FAULTY	0 rpm	na
SYSTEM INLET	1	GREEN	25 Celsius	0 - 56
SYSTEM OUTLET	1	GREEN	34 Celsius	0 - 125
SYSTEM HOTSPOT	1	GREEN	51 Celsius	0 - 125

Switch	FAN	Speed	State	Airflow direction
1	1	5440	OK	Front to Back
1	2	5440	OK	Front to Back
1	3	5440	OK	Front to Back

SW	PID	Serial#	Status	Sys Pwr	PoE Pwr	Watts
1A	PWR-C1-715WDC	DCC2316E1GU	OK	Good	Good	715
1B	Unknown	Unknown	No Input Power	Bad	Bad	Unknown

The “show power detail” command will display the cumulative power allocation information on a 9300 in detail. The values of particular interest are instantaneous power used, and the power summary which have been highlighted in the sample to follow. The instantaneous power shows the real-time value of the wattage being consumed to keep the switch in an operational state, while the power summary table shows the allocated wattage, and not the consumed wattage.



A sample of the output of the command is shown below:

SW	PID	Serial#	Status	Sys Pwr	PoE Pwr	Watts
--	-----	-----	-----	-----	-----	-----
1A	PWR-C1-715WDC	DCC2316E1GU	OK	Good	Good	715
1B	Unknown	Unknown	No Input Power	Bad	Bad	Unknown

PS Configuration Mode : SP-PS
PS Operating state : Stndaln

Power supplies currently active : 1
Power supplies currently available : 2

Automatic Module Shutdown : Enabled
Power Budget Mode = SP-PS

		shutdown	Power					Out of	In
Mod	Model No	Priority	State	Budget	Instantaneous	Peak	Reset	Reset	
---	-----	-----	-----	-----	-----	-----	-----	-----	-----
1	C9300-24H	4	accepted	240	70	99	240	50	
---	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total 240									

Power Summary		Maximum	
(in Watts)	Used	Available	
-----	-----	-----	
System Power	240	240	
POE Power	323	475	
-----	-----	-----	
Total	563	715	

The “show power inline upoe-plus” command will display the detailed PoE status of the entire switch. A sample of the output of the command is shown below:

Module	Available	Used	Remaining
	(Watts)	(Watts)	(Watts)
-----	-----	-----	-----
1	475.0	323.4	151.6

Device IEEE Mode - BT

Codes: DS - Dual Signature device, SS - Single Signature device
 SP - Single Pairset device

Interface	Admin	Type	Oper-State	Power(Watts)		Class	Device Name
	State		Alt-A,B	Allocated	Utilized	Alt-A,B	
-----	-----	----	-----	-----	-----	-----	-----
Gi1/0/1	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/2	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/3	auto	SS	on,off	15.4	14.3	3	Ieee PD
Gi1/0/4	auto	SS	on,off	15.4	14.2	3	Ieee PD
Gi1/0/5	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/6	auto	SS	on,off	15.4	14.0	3	Ieee PD
Gi1/0/7	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/8	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/9	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/10	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/11	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/12	auto	SS	on,off	15.4	14.0	3	Ieee PD
Gi1/0/13	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/14	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/15	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/16	auto	SS	on,off	15.4	14.0	3	Ieee PD
Gi1/0/17	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/18	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/19	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/20	auto	SS	on,off	15.4	13.9	3	Ieee PD
Gi1/0/21	auto	SS	on,off	15.4	14.1	3	Ieee PD
Gi1/0/22	auto	n/a	off	0.0	0.0	n/a	
Gi1/0/23	auto	n/a	off	0.0	0.0	n/a	
Gi1/0/24	auto	n/a	off	0.0	0.0	n/a	
-----	-----	-----	-----	-----	-----	-----	-----
Totals:		21	on	323.4	294.7		

Additional information regarding the commands for software version 17.12.3 can be found at:

https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst9300/software/release/17-12/command_reference/b_1712_9300_cr/interface_and_hardware_commands.html?bookSearch=true#wp3418727943

4.4 NOTABLE OBSERVATIONS

During testing, some notable observations were made:

1. Power inline port priority high command only works when total load of endpoints connected to them do not exceed the total capacity of operational power supply
 - a. If a power supply is rated for 715 watts and 240 is budgeted for system operations, the load on the interfaces configured with high port priority should not exceed the remaining 475
2. Hardware versions of the power supply must match to ensure proper function and operations. The versions of the power supply can only be found by looking at the label on the power supply. Running “show environment all” on the switch will provide the product identification, but not the version.
 - a. Using mismatching versions have led to issues and power resilience not working
 - i. switch reloading when one power supply loses power
 - ii. current overdraw and extreme fan operation in response to heat
 - b. For these tests, two pairs of 715-watt power supplies were used
 - i. PIDVID: PWR-C1-715WDC V00
 - ii. PIDVID: PWR-C1-715WDC V01
 - c. When the version of the hardware had a mismatch, the switches did not operate as intended, but when the tests were conducted with matching hardware versions, the switches operated as intended

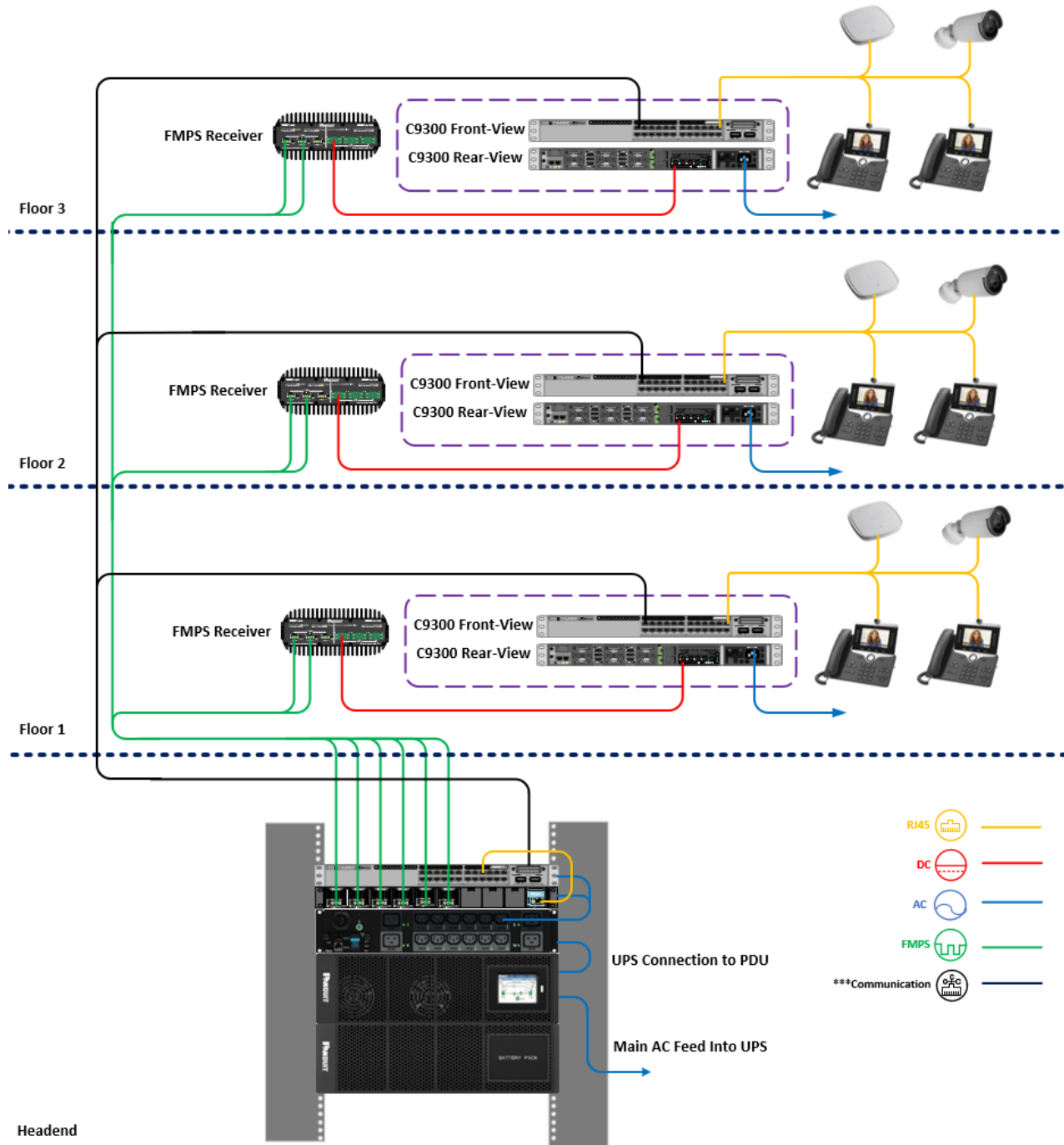
5 DESIGN ARCHITECTURES AND TESTS OUTCOME

5.1 DISTRIBUTED NETWORK ARCHITECTURE WITH CENTRALIZED POWER

This architectural design enables the placement of switches closer to PoE loads, eliminating the need for a nearby power source. Switches can be installed virtually anywhere with minimal requirements for space or power. This approach significantly reduces the length of Ethernet cabling needed to connect switches to endpoints, while also allowing for future expansion of PoE devices. The two test cases presented follow this architecture and represent two different options for power and distance at the switch.

A sample diagram of the architecture is shown below.

Figure 16. Figure 15: Sample Architecture of Distributed Network Architecture with Centralized Power



***The Communication links depicted with black lines can be made with either fiber or ethernet connections

5.1.1 Test 1: FMPS to Single DC Power Supply on 9300

For Test 1, the FMPS will provide DC power from a single Receiver to a single DC power supply on the C9300. This is a basic test being conducted to validate FMPS can deliver sufficient power to turn on the switch as well as the PoE endpoints connected to it.

The desired outcome for the test is:

- C9300 to successfully provide power to 21 PoE end devices drawing 15 watts
- C9300 to successfully provide power to 4 PoE end devices drawing 90 watts

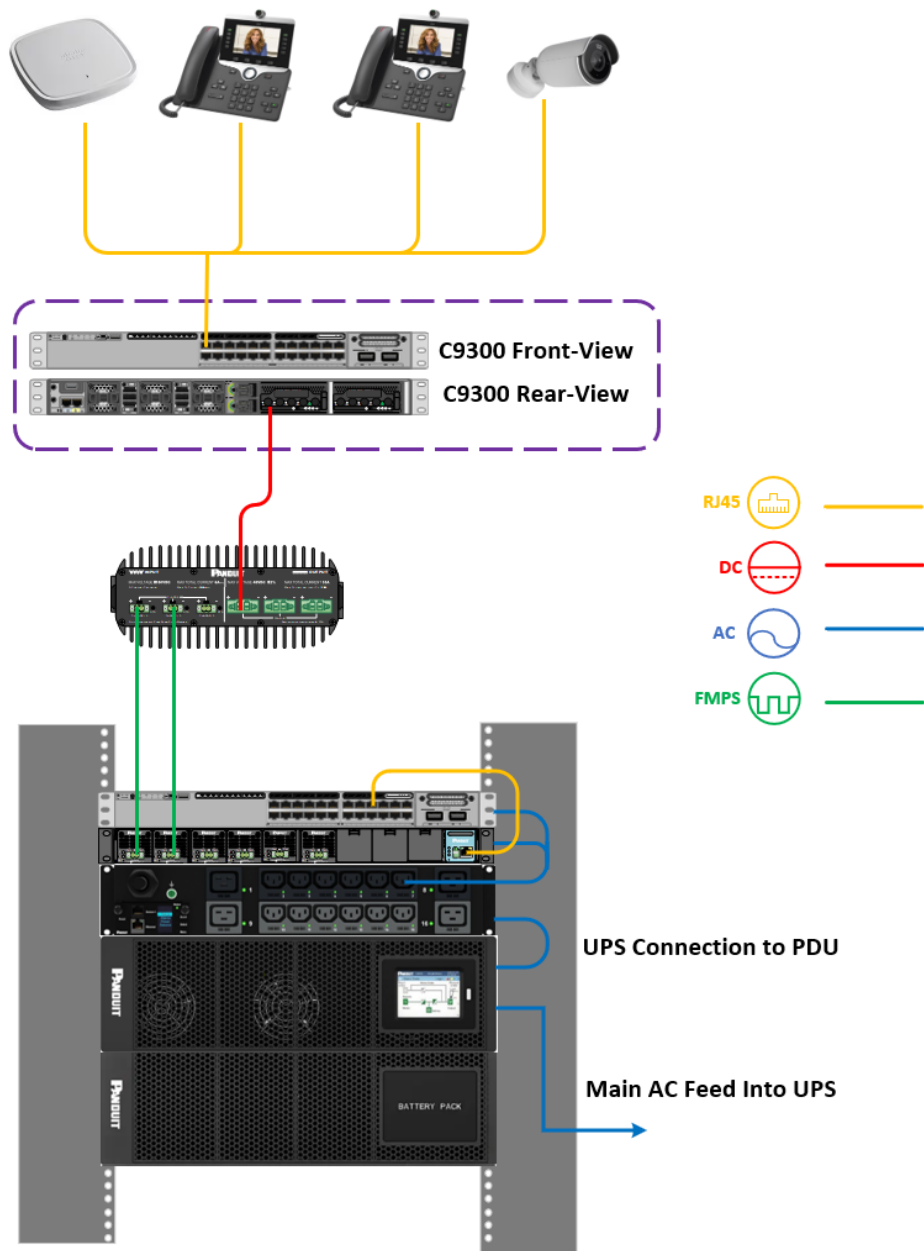
5.1.2 Intent of Design

An example where such a design would be implemented is an environment where PoE devices need to be powered a considerable distance away from a power source, beyond the 100 meters that the 802.3bt standards outline.

Using FMPS, a PoE switch can be deployed, 1000 meters tested in this case, remotely from the power source, and from the switch, so long as it is capable of meeting 802.3bt standards, the PoE endpoint to be powered can be installed another 100 meters away.

Of the 715 watts delivered to the switch, 240 will be allocated for switch operations. Therefore, this test seeks to validate that the switch is capable of 475W of PoE load and the PoE endpoints can be powered from 1100 meters away from the FMPS chassis.

5.1.3 Diagram



5.1.4 Parameters

FMPS Chassis Quantity	1
FMPS Power Supply Quantity	1
FMPS Transmitter Quantity	2
FMPS Receiver Quantity	1
Multiconductor Cable	1000 m

Length	
Multiconductor Cable Gauge	16 AWG
C9300 Power Supply Type	DC
C9300 Power Supply Quantity	1
Homing Architecture	N/A

5.1.4.1 Bill of Materials

Table 3. Panduit

Item Name	PID	Quantity
FMPS Chassis	PXTC1ARA	1
FMPS Power Supply Unit	PXU1AJANNXX	1
FMPS Transmitter	PXTM1AF	2
FMPS Receiver	PXR1AJD	1
Class 4 Copper Cable	PXUP316ARD-UQ	1000 m

Table 4. Cisco

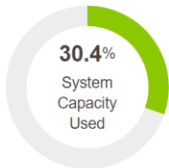
Item Name	PID	Quantity
Catalyst 9300-24H	C9300-24H-E	1
715 Watt DC Power Supply Unit	PWR-C1-715WDC=	1

5.1.5 FMPS Management Interface Screenshots for Powering 15 Watt Endpoints

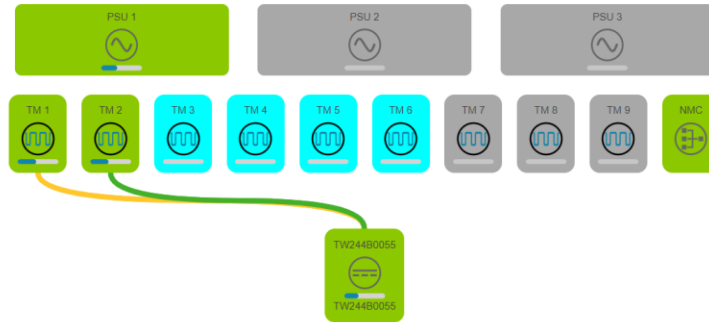


System Summary

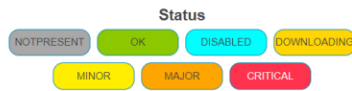
Energy Consumed	17 kWh
Output Power Capacity	1600 W
Output Power Used	486.5 W
Output Power Available	1113.5 W
Temperature	27°C
Dry Contact	Closed
Locator Status	Disabled
Status	✓OK



System Diagram



Legend



Receiver Channels

Channel 1
Channel 2
Channel 3

Status

Summary Capacity Power Supplies Transmitters Receivers

Transmitter Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Loca Stati
✓ 1	TRANSMITTER 1	TW244H0098	360.1	359.3	0.6	225.2	374.8	33.8°C	✓OK	Enabled	TW244B0055	Dis:
✓ 2	TRANSMITTER 2	TW244H0096	358	357.5	0.6	218	382	33.8°C	✓OK	Enabled	TW244B0055	Dis:
✓ 3	TRANSMITTER 3	TW244H0083	358.2	2.6	0	0	600	29.6°C	✓OK	Disabled		Dis:
✓ 4	TRANSMITTER 4	TW244H0084	358.5	0	0	0	600	28.9°C	✓OK	Disabled		Dis:
✓ 5	TRANSMITTER 5	TW244H0107	359.5	0	0	0	600	28.8°C	✓OK	Disabled		Dis:
✓ 6	TRANSMITTER 6	TW244H0088	358.5	2.4	0	0	600	28.8°C	✓OK	Disabled		Dis:
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	☐NOTPRESENT	Disabled		Dis:
✓ 8	TRANSMITTER 8	...	...	...	...	...	...	...	☐NOTPRESENT	Disabled		Dis:
✓ 9	TRANSMITTER 9	...	...	...	...	...	...	...	☐NOTPRESENT	Disabled		Dis:

5.1.6 FMPS Management Interface Screenshots for Powering 90 Watt Endpoints

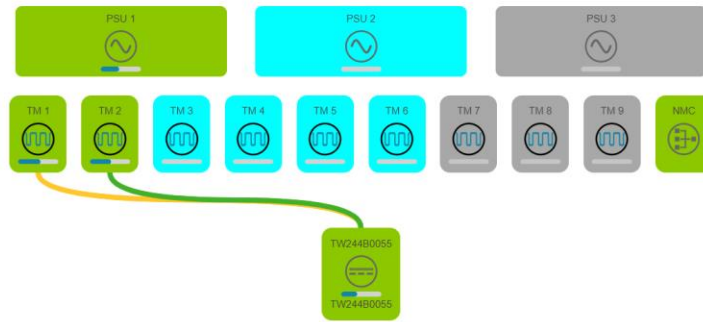
Summary Capacity Power Supplies Transmitters Receivers

System Summary

Energy Consumed	15 kWh
Output Power Capacity	3200 W
Output Power Used	616.1 W
Output Power Available	2583.9 W
Temperature	26°C
Dry Contact	Closed
Locator Status	Disabled
Status	OK



System Diagram



Legend



Summary Capacity Power Supplies Transmitters Receivers

Power Supply Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status
1	PSU 1	BG234U0064	202.3	359.9	1.7	609.6	990.4	36.4°C	OK	Enabled	Disabled
2	PSU 2	BG234U0035	204.7	0	0	0	1600	26.3°C	OK	Disabled	Disabled

Status

Summary Capacity Power Supplies Transmitters Receivers

Transmitter Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Locator Status
✓ 1	TRANSMITTER 1	TW244H0098	359.8	358.7	0.8	291.9	308.1	30.4°C	OK	Enabled	TW244B0055	Disat
✓ 2	TRANSMITTER 2	TW244H0096	358	357.2	0.8	272.9	327.1	30.4°C	OK	Enabled	TW244B0055	Disat
✓ 3	TRANSMITTER 3	TW244H0083	358.2	2.8	0	0	600	26.2°C	OK	Disabled		Disat
✓ 4	TRANSMITTER 4	TW244H0084	358.5	0	0	0	600	25.7°C	OK	Disabled		Disat
✓ 5	TRANSMITTER 5	TW244H0107	359.2	0	0	0	600	25.4°C	OK	Disabled		Disat
✓ 6	TRANSMITTER 6	TW244H0088	357.1	2.7	0	0	600	25.4°C	OK	Disabled		Disat
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Disat
✓ 8	TRANSMITTER 8	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Disat
✓ 9	TRANSMITTER 9	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Disat

Summary Capacity Power Supplies Transmitters Receivers

Receiver Modules

Serial Number	Name	Connected Channels	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status
✓ TW244B0055	TW244B0055	2 of 3	47.4	10.6	501.9	1097.9	42.9°C	OK	Enabled

5.1.7 Catalyst 9300 Show Command Outputs for Powering 15 Watts

5.1.7.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56238 mV
PS1 Vin	GOOD	48063 mV
PS1 CURin	GOOD	8250 mA
PS1 CURout	GOOD	6453 mA
PS1 POWin	GOOD	397000 mW
PS1 POWout	GOOD	362500 mW
PS1 FAN	GOOD	6736 rpm
PS2 Vout	FAULTY	0 mV
PS2 Vin	FAULTY	0 mV
PS2 CURin	FAULTY	0 mA
PS2 CURout	FAULTY	0 mA
PS2 POWin	FAULTY	0 mW
PS2 POWout	FAULTY	0 mW
PS2 FAN	FAULTY	0 rpm

The second power supply on the switch is in the “FAULTY” state since there is no power supply populating the second bay on the switch.

5.1.7.2 show power detail

Table 5. Power Supply Status

Power Supply ID	Status	System Power	PoE Power
A	OK	Good	715
B	Unknown	Bad	Unknown

Table 6. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	70

Table 7. Power Summary

Power Type	Used	Available
System Power	240	240
PoE Power	323	475
Total Power	563	715

5.1.7.3show power inline upoe-plus

Interface	Allocated Power	Utilized
Gi 1/0/1	15.4	14.1
Gi 1/0/2	15.4	14.1
Gi 1/0/3	15.4	14.3
Gi 1/0/4	15.4	14.2
Gi 1/0/5	15.4	14.1
Gi 1/0/6	15.4	14
Gi 1/0/7	15.4	14.1
Gi 1/0/8	15.4	13.9
Gi 1/0/9	15.4	13.9
Gi 1/0/10	15.4	14.1
Gi 1/0/11	15.4	14.1
Gi 1/0/12	15.4	14
Gi 1/0/13	15.4	13.9
Gi 1/0/14	15.4	13.9
Gi 1/0/15	15.4	13.9
Gi 1/0/16	15.4	14

Interface	Allocated Power	Utilized
Gi 1/0/17	15.4	13.9
Gi 1/0/18	15.4	13.9
Gi 1/0/19	15.4	14.1
Gi 1/0/20	15.4	13.9
Gi 1/0/21	15.4	14.1

5.1.8 Catalyst 9300 Show Command Outputs for Powering 90 Watts

5.1.8.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56238 mV
PS1 Vin	GOOD	48063 mV
PS1 CURin	GOOD	10313 mA
PS1 CURout	GOOD	8141 mA
PS1 POWin	GOOD	495000 mW
PS1 POWout	GOOD	459000 mW
PS1 FAN	GOOD	6736 rpm
PS2 Vout	FAULTY	0 mV
PS2 Vin	FAULTY	0 mV
PS2 CURin	FAULTY	0 mA
PS2 CURout	FAULTY	0 mA
PS2 POWin	FAULTY	0 mW
PS2 POWout	FAULTY	0 mW
PS2 FAN	FAULTY	0 rpm

The second power supply on the switch is in the “FAULTY” state since there is no power supply populating the second bay on the switch.



5.1.8.2show power detail

Table 8. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	Unknown	Bad	Bad	Unknown

Table 9. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	67

Table 10. Power Summary

Power Type	Used	Available
System Power	240	240
PoE Power	450	475
Total Power	690	715

5.1.8.3show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	90	77.3
Gi 1/0/2	90	77.7
Gi 1/0/3	90	77.7
Gi 1/0/4	90	77.5
Gi 1/0/5	90	77.4

The remaining interfaces were in a power-deny state due to insufficient PoE power.

5.1.9 Results

Test 1 was successful and validates FMPS will provide the requisite 715 watts across 1000 meters to the switch with the following parameters of the FMPS:

-
- 1 FMPS power supply
 - has capacity to provide 1600 watts, exceeding the required 715 watts
 - 2 Transmitters
 - each Transmitter can only provide 600 watts, so requires two
 - 1 Receiver
 - each Receiver has three input channels that can receive power from the Transmitters, only one required to receive input from two Transmitters
 - 1000 meters of 16 AWG multiconductor cable

The FMPS management console shows that the Transmitters delivered 1600 watts to the Receiver, and the “show power detail” output shows that the switch received all 715 watts from the Receiver.

5.1.10 How does this design scale?

A single FMPS Transmitter can support four distributed 9300 switches up to 1000 meters away from a centralized point. Refer to section 3.3 on scalability for more details.

5.1.11 Test 2: FMPS to Dual DC Power Supplies on C9300

For Test 2, the FMPS will provide DC power from a single Receiver to two DC power supplies on the 9300 for basic functionality.

The desired outcome for the test is:

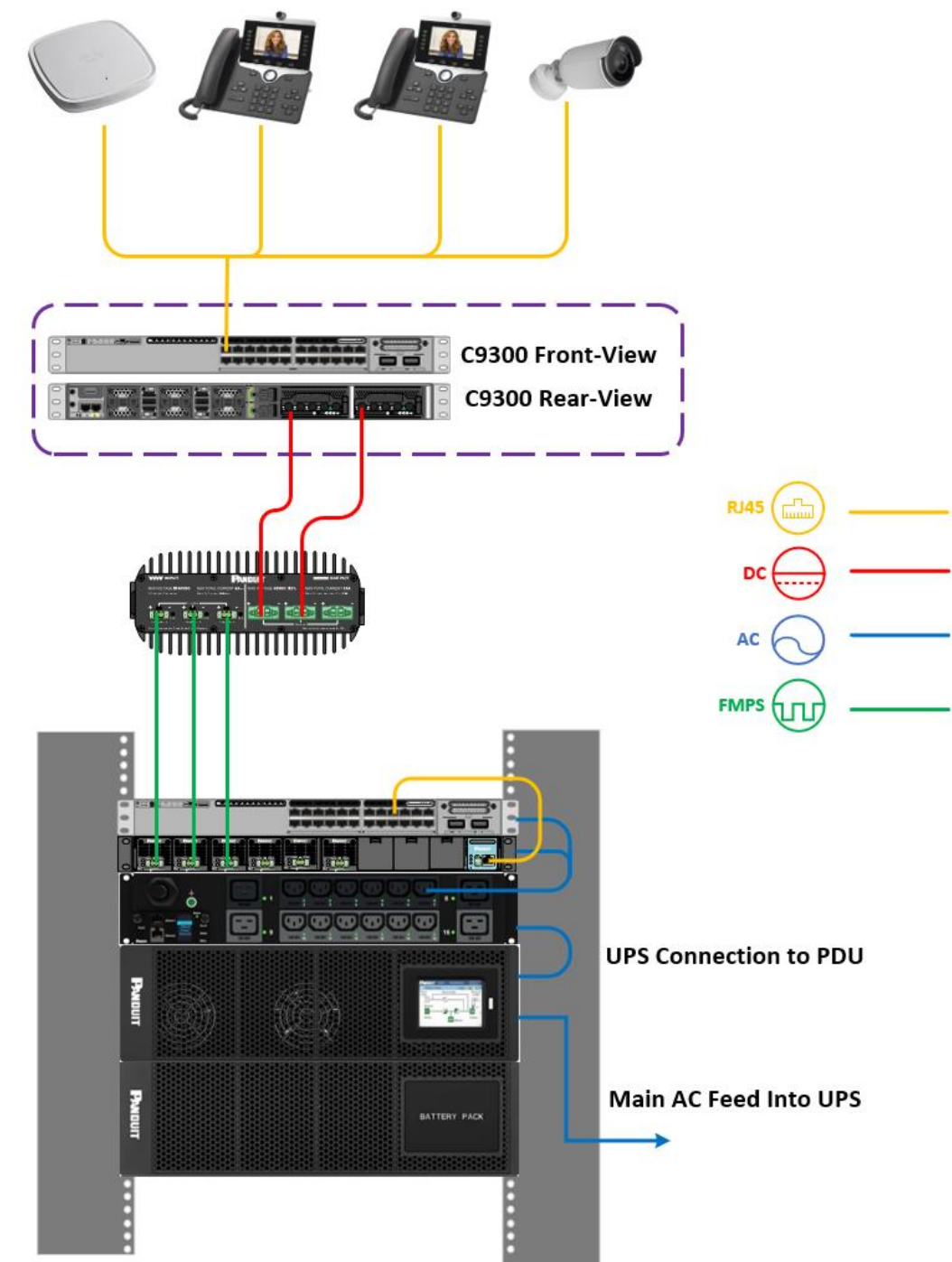
- C9300 to successfully provide power to 21 PoE end devices drawing 15 watts
- C9300 to successfully provide power to 13 PoE end devices drawing 90 watts
 - Outcomes from test 1 are expected to carry over, but with the addition of PoE wattage available from the second power supply

5.1.12 Intent of Design

An example where such a design would be implemented in such a fashion is where 715 watts from a single power supply on the C9300 is insufficient, and requires additional wattage from the second 715 watt power supply.

Using FMPS, a PoE switch can be deployed, 450 meters tested in this case, remotely from the power source, and from the switch, so long as it is capable of meeting 802.3bt standards, the PoE endpoint to be powered can be another installed another 100 meters away. The switch will receive 1430 watts in total from the Receiver, but 240 will be allocated for switch operations. Therefore this test seeks to validate that the switch is capable of 1190W of PoE load and the PoE endpoint can be powered from 550 meters away from the FMPS chassis.

5.1.13 Diagram



5.1.14 Parameters

FMPS Chassis Quantity	1

FMPS Power Supply Quantity	1
FMPS Transmitter Quantity	3
FMPS Receivers	1
Multiconductor Cable Length	450 m
Multiconductor Cable Gauge	16 AWG
C9300 Power Supply Type	DC
C9300 Power Supply Quantity	2
Homing Architecture	single

5.1.14.1 Bill of Materials

Table 11. Pandu

Item Name	PID	Quantity
FMPS Chassis	PXTC1ARA	1
FMPS Power Supply Unit	PXU1AJANNXX	1
FMPS Transmitter	PXTM1AF	3
FMPS Receiver	PXR1AJD	1
Class 4 Copper Cable	PXUP316ARD-UQ	450 m

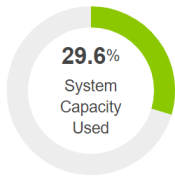
Table 12. Cisco

Item Name	PID	Quantity
Catalyst 9300-24H	C9300-24H-E	1
715 Watt DC Power Supply Unit	PWR-C1-715WDC=	2

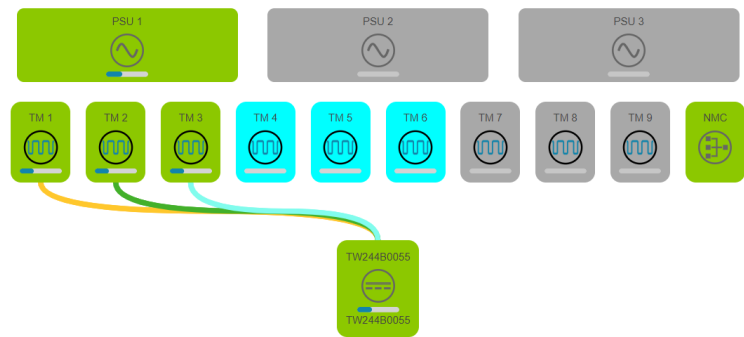
5.1.15 FMPS Management Interface Screenshots for Powering 15 Watt Endpoints

System Summary

Energy Consumed	16 kWh
Output Power Capacity	1600 W
Output Power Used	474.3 W
Output Power Available	1125.7 W
Temperature	27°C
Dry Contact	Closed
Locator Status	Disabled
Status	OK



System Diagram



Legend

Status

NOTPRESENT

OK

DISABLED

DOWNLOADING

MINOR

MAJOR

CRITICAL

Receiver Channels

Channel 1

Channel 2

Channel 3

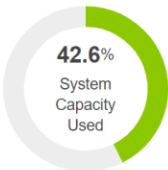
Transmitter Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Loca Stat
✓ 1	TRANSMITTER 1	TW244H0098	359.8	359.1	0.4	142.9	457.1	32.4°C	OK	Enabled	TW244B0055	Dis:
✓ 2	TRANSMITTER 2	TW244H0096	357.8	357.1	0.4	141	459	32.8°C	OK	Enabled	TW244B0055	Dis:
✓ 3	TRANSMITTER 3	TW244H0083	358.8	358.8	0.4	145.6	454.4	32.4°C	OK	Enabled	TW244B0055	Dis:
✓ 4	TRANSMITTER 4	TW244H0084	358.7	0	0	0	600	28.7°C	OK	Disabled		Dis:
✓ 5	TRANSMITTER 5	TW244H0107	359.5	0	0	0	600	28.6°C	OK	Disabled		Dis:
✓ 6	TRANSMITTER 6	TW244H0088	358.6	0	0	0	600	28.5°C	OK	Disabled		Dis:
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Dis:
✓ 8	TRANSMITTER 8	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Dis:
✓ 9	TRANSMITTER 9	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Dis:

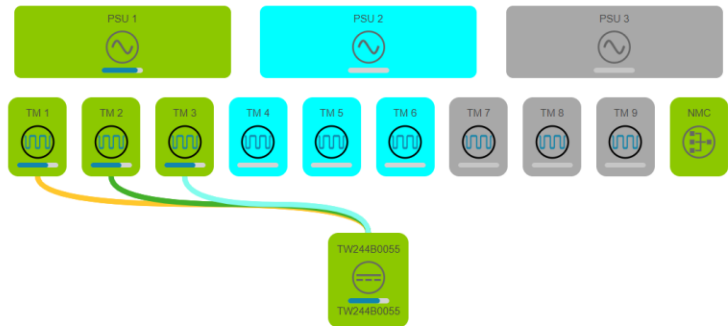
5.1.16 FMPS Management Interface Screenshots for Powering 90 Watt Endpoints

System Summary

Energy Consumed	15 kWh
Output Power Capacity	3200 W
Output Power Used	1364.3 W
Output Power Available	1835.7 W
Temperature	27°C
Dry Contact	Closed
Locator Status	Disabled
Status	OK



System Diagram



Legend

Status

NOTPRESENT

OK

DISABLED

DOWNLOADING

MINOR

MAJOR

CRITICAL

Receiver Channels

Channel 1

Channel 2

Channel 3

Status

													Summary	Capacity	Power Supplies	Transmitters	Receivers
Power Supply Modules																	
Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status						
1	PSU 1	BG234U0064	201.5	359.9	3.8	1366.5	233.5	39.8°C	🟢OK	Enabled	Disabled						
2	PSU 2	BG234U0035	202.9	0	0	0	1600	30.3°C	🟢OK	Disabled	Disabled						
Transmitter Modules																	
Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Locator Status					
✔	1	TRANSMITTER 1	TW244H0098	359.4	358.3	1.2	431.3	168.7	31.8°C	🟢OK	Enabled	TW244B0055	Disabled				
✔	2	TRANSMITTER 2	TW244H0096	357.7	357	1.2	426.2	173.8	32°C	🟢OK	Enabled	TW244B0055	Disabled				
✔	3	TRANSMITTER 3	TW244H0083	357.9	357.7	1.2	431	169	31.3°C	🟢OK	Enabled	TW244B0055	Disabled				
✔	4	TRANSMITTER 4	TW244H0084	357.9	0.2	0	0	600	27.4°C	🟢OK	Disabled		Disabled				
✔	5	TRANSMITTER 5	TW244H0107	358.9	0.2	0	0	600	27.3°C	🟢OK	Disabled		Disabled				
✔	6	TRANSMITTER 6	TW244H0088	358	0.3	0	0	600	27.3°C	🟢OK	Disabled		Disabled				
✔	7	TRANSMITTER 7	...	...	...	...	...	...	🟡NOTPRESENT	Enabled			Disabled
✔	8	TRANSMITTER 8	...	...	...	...	...	...	🟡NOTPRESENT	Enabled			Disabled
✔	9	TRANSMITTER 9	...	...	...	...	...	...	🟡NOTPRESENT	Enabled			Disabled

5.1.17 Catalyst 9300 Show Command Outputs for Powering 15 Watts

5.1.17.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56174 mV
PS1 Vin	GOOD	48375 mV
PS1 CURin	GOOD	3992 mA
PS1 CURout	GOOD	3063 mA
PS1 POWin	GOOD	193500 mW
PS1 POWout	GOOD	170250 mW
PS1 FAN	GOOD	6800 rpm
PS2 Vout	GOOD	56174 mV
PS2 Vin	GOOD	48125 mV
PS2 CURin	GOOD	4477 mA
PS2 CURout	GOOD	3438 mA
PS2 POWin	GOOD	215250 mW
PS2 POWout	GOOD	192000 mW
PS2 FAN	GOOD	5488 rpm

5.1.17.2 show power detail

Table 13. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	OK	Good	Good	715

Table 14. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	76

Table 15. Power Summary

Power Type	Used	Available
System Power	240	240
PoE Power	323	1190
Total Power	563	1430

5.1.17.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	15.4	14.0
Gi 1/0/2	15.4	14.0
Gi 1/0/3	15.4	14.2
Gi 1/0/4	15.4	14.2
Gi 1/0/5	15.4	14.0
Gi 1/0/6	15.4	14.0
Gi 1/0/7	15.4	13.1
Gi 1/0/8	15.4	12.9
Gi 1/0/9	15.4	13.0
Gi 1/0/10	15.4	13.1
Gi 1/0/11	15.4	13.1
Gi 1/0/12	15.4	13.0
Gi 1/0/13	15.4	13.9
Gi 1/0/14	15.4	13.9
Gi 1/0/15	15.4	13.9
Gi 1/0/16	15.4	14.0
Gi 1/0/17	15.4	13.9
Gi 1/0/18	15.4	13.9

Interface	Allocated Power	Utilized Power
Gi 1/0/19	15.4	14.1
Gi 1/0/20	15.4	13.9
Gi 1/0/21	15.4	14.1

5.1.18 Catalyst 9300 Show Command Outputs for Powering 90 Watts

5.1.18.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56238 mV
PS1 Vin	GOOD	47500 mV
PS1 CURin	GOOD	12047 mA
PS1 CURout	GOOD	9359 mA
PS1 POWin	GOOD	574000 mW
PS1 POWout	GOOD	526000 mW
PS1 FAN	GOOD	8576 rpm
PS2 Vout	GOOD	56238 mV
PS2 Vin	GOOD	47250 mV
PS2 CURin	GOOD	12563 mA
PS2 CURout	GOOD	9703 mA
PS2 POWin	GOOD	598000 mW
PS2 POWout	GOOD	546000 mW
PS2 FAN	GOOD	5696 rpm

5.1.18.2 show power detail

Table 16. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715

Power Supply ID	Status	System Power	PoE Power	Watts
B	OK	Good	Good	715

Table 17. System Power Status

Power Supply ID	Status	System Power	PoE Power
1	accepted	240	65

Table 18. Power Summary

Power Type	Used	Available
System Power	240	240
PoE Power	1170	1190
Total Power	1410	1430

5.1.18.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	90	77.5
Gi 1/0/2	90	77.8
Gi 1/0/3	90	77.7
Gi 1/0/4	90	77.6
Gi 1/0/5	90	77.3
Gi 1/0/6	90	77.5
Gi 1/0/7	90	77.5
Gi 1/0/8	90	77.3
Gi 1/0/9	90	77.2
Gi 1/0/10	90	77.2
Gi 1/0/11	90	77.2
Gi 1/0/12	90	77.2
Gi 1/0/13	90	77.2

The remaining interfaces were in a power-deny state due to lack of available power.

5.1.19 Results

Test 2 was successful and confirms FMPS will provide all 1430 watts across 450 meters split between the two power supplies on the C9300 with the following parameters of the FMPS:

- 1 power supply
 - has capacity to provide 1600 watts, exceeding the required 1430 watts
- 3 Transmitters
 - each Transmitter can only provide 600 watts, so requires three
- 1 Receiver
 - each Receiver has three input channels that can receive power from the Transmitters, only one Receiver required to receive input from two Transmitters
- 450 meters of 16 AWG multiconductor cable
 - distance reduced to minimize power loss

The FMPS management console shows that the Transmitters delivered 1600 watts to the Receiver, and the “show power detail” output shows that the switch received all 1430 watts from the Receiver.

Test 2 conclusively shows that should a solution require more than 715 watts, FMPS can power a second power supply to supplement the first and provide an additional 715 watts to power the endpoints connected the PoE switch.

5.1.9 How does this design scale?

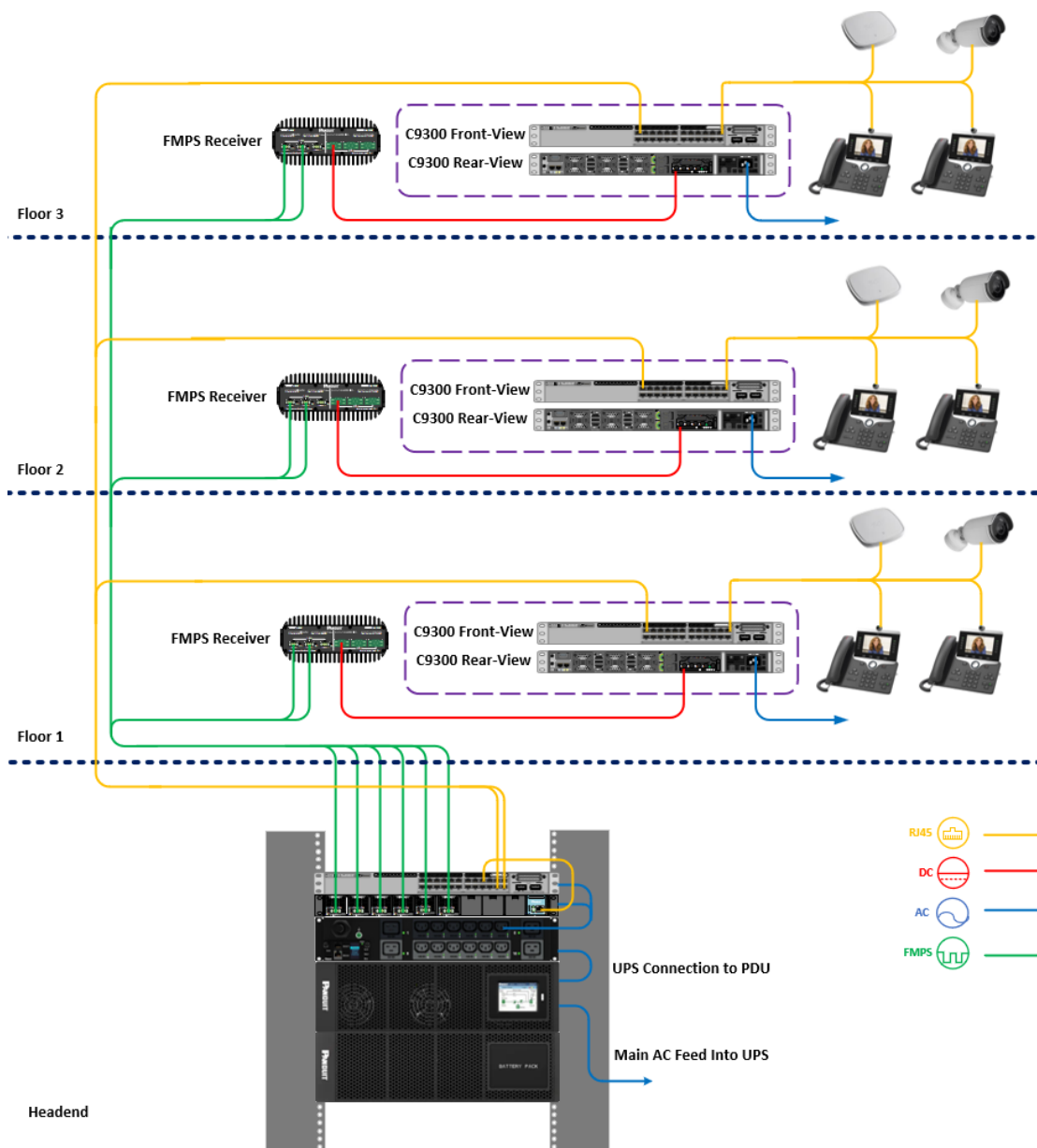
A single FMPS Transmitter can support three distributed 9300 switches up to 450 meters away from a centralized point. Refer to section 3.3 on scalability for more details.

5.2 CENTRALIZED DC POWER BACK-UP FOR POWER REDUNDANCY

This architectural design is well-suited for both new construction and retrofit projects. By utilizing a centralized UPS for DC power backup, it enhances power reliability, ensuring uninterrupted power delivery to critical PoE loads. Additionally, it improves operational efficiency by reducing maintenance costs associated with managing multiple distributed UPS units.

A sample diagram where FMPS is deployed to a brownfield PoE deployment with a pre-existing AC power connection is shown below.

Figure 17. Figure 16: Panduit FMPS Centralized Power Backup Sample Architecture



5.2.1 Test 3: FMPS to DC Power Supply as Backup

For Test 3, the FMPS will provide DC power from a single Receiver to a DC power supply on the C9300, and an AC power supply will be mounted to the other bay on the C9300. The intent of this use case is to demonstrate FMPS' ability to serve as a backup to the AC power.

To test FMPS as a backup solution to the AC power, the C9300 was turned on with both DC and AC power supplies, and once the switch was in a steady state, power was cut to the AC power supply to observe whether FMPS powered the DC power supply to maintain continuity to the C9300.

In conjunction with the power redundancy, the "power inline port priority high" command was used with the 90-watt endpoints to ensure that in the event of power shedding, the interfaces configured with high priority would continue with PoE power while the remainder of the interfaces connected to PoE endpoints would shed power and enter into a power-deny state as a result of loss of power.

The desired outcome for the test is:

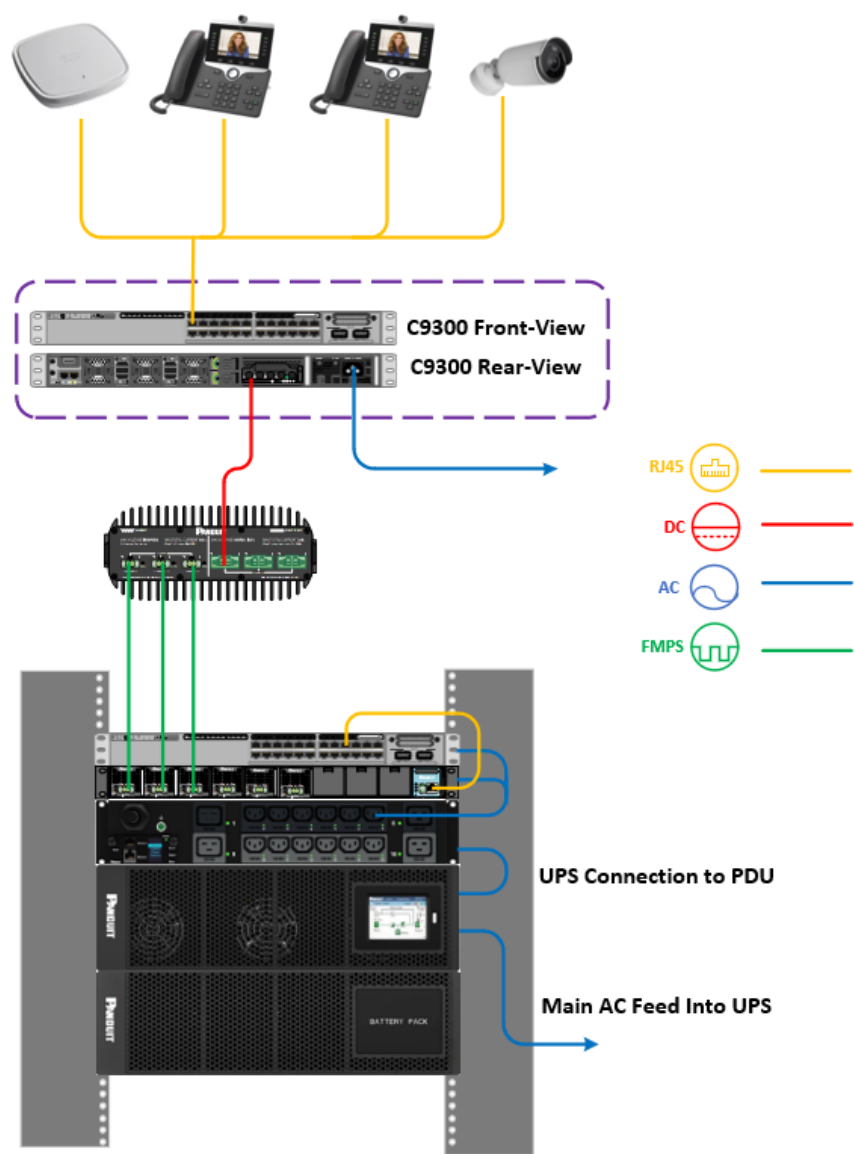
-
- C9300 to successfully provide power to 21 PoE endpoints drawing 15 watts
 - After a loss of power to the AC power supply, the switch and PoE endpoints remain unimpacted
 - C9300 to successfully provide power to 13 PoE endpoints drawing 90 watts
 - After a loss of power to the AC power supply, the switch remains unimpacted and the PoE endpoints connected to interfaces with high port priority remain unimpacted while the others are shed due to insufficient PoE power

5.2.2 Intent of Design

An example where such a design would be implemented is a brownfield environment, where PoE switches have already been deployed and operate on AC power, with no building or local backup power solution in place.

Leveraging FMPS, a centralized architecture for backup power can be implemented where rather than implementing redundancy solutions at each remote location, the centralized architecture will allow the FMPS to distribute backup power to the remote locations.

5.2.3 Diagram



5.2.4 Parameters

Chassis Quantity	1
Power Supply Quantity	1
Transmitter Quantity	2
Receivers	1
Cable Length	1000 m
Cable Gauge	16 AWG

9300 Power Supply Type	AC and DC
9300 Power Supply Quantity	2
Homing Architecture	N/A

5.2.4.1 Bill of Materials

Table 19. Pandu

Item Name	PID	Quantity
FMPS Chassis	PXTC1ARA	1
FMPS Power Supply Unit	PXU1AJANNXX	1
FMPS Transmitter	PXTM1AF	2
FMPS Receiver	PXR1AJD	1
Class 4 Copper Cable	PXUP316ARD-UQ	1

Table 20. Cisco

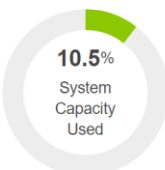
Item Name	PID	Quantity
Catalyst 9300-24H	C9300-24H-E	1
715 Watt DC Power Supply Unit	PWR-C1-715WDC=	1
1900 Watt AC Power Supply Unit	PWR-C1-1900WAC-P=	1

5.2.1 Test 3 with 15-Watt Endpoints and Two Power Supplies

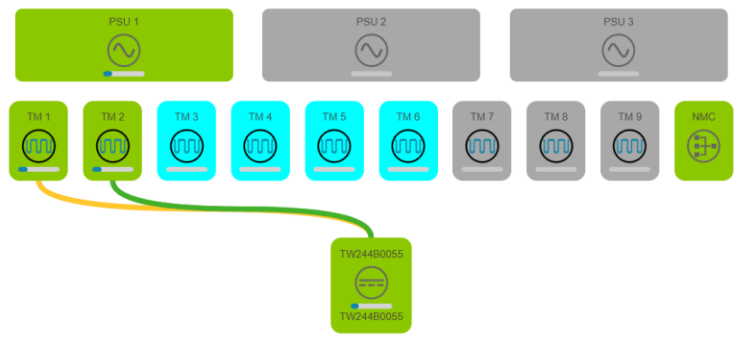
5.2.1.1 FMPS Management Interface Screenshots

System Summary

Energy Consumed	17 kWh
Output Power Capacity	1600 W
Output Power Used	168.1 W
Output Power Available	1431.9 W
Temperature	27°C
Dry Contact	Closed
Locator Status	Disabled
Status	✓OK



System Diagram



Legend

Status

NOTPRESENT

OK

DISABLED

DOWNLOADING

MINOR

MAJOR

CRITICAL

Receiver Channels

Channel 1

Channel 2

Channel 3

Power Supply Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status
1	PSU 1	BG234U0064	204	359.9	0.5	168	1432	36.3°C	✓OK	Enabled	Disabled

Transmitter Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Loc Sta
✓ 1	TRANSMITTER 1	TW244H0098	360.1	359.4	0.2	71.1	528.9	34.1°C	✓OK	Enabled	TW244B0055	Dis
✓ 2	TRANSMITTER 2	TW244H0096	358.7	358.2	0.2	69.8	530.2	33.9°C	✓OK	Enabled	TW244B0055	Dis
✓ 3	TRANSMITTER 3	TW244H0083	358.5	2.5	0	0	600	28.8°C	✓OK	Disabled		Dis
✓ 4	TRANSMITTER 4	TW244H0084	359	0	0	0	600	28.4°C	✓OK	Disabled		Dis
✓ 5	TRANSMITTER 5	TW244H0107	360.2	0	0	0	600	28.3°C	✓OK	Disabled		Dis
✓ 6	TRANSMITTER 6	TW244H0088	358.9	2.2	0	0	600	28.4°C	✓OK	Disabled		Dis
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	☐NOTPRESENT	Disabled		Dis
✓ 8	TRANSMITTER 8	...	...	...	...	...	...	...	☐NOTPRESENT	Disabled		Dis
✓ 9	TRANSMITTER 9	...	...	...	...	...	...	...	☐NOTPRESENT	Disabled		Dis

5.2.1.2Catalyst 9300 Show Command Outputs

5.2.1.2.1 show environment all

In the outputs below, power supply 1 is the 715-watt DC power supply, and power supply 2 is the 1900-watt AC power supply.

Parameter	State	Reading
PS1 Vout	GOOD	56174 mV
PS1 Vin	GOOD	48688 mV

Parameter	State	Reading
PS1 CURin	GOOD	2363 mA
PS1 CURout	GOOD	1719 mA
PS1 POWin	GOOD	116500 mW
PS1 POWout	GOOD	98250 mW
PS1 FAN	GOOD	6768 rpm
PS2 Vout	GOOD	56064 mV
PS2 Vin	GOOD	205000 mV
PS2 CURin	GOOD	1477 mA
PS2 CURout	GOOD	4672 mA
PS2 POWin	GOOD	299000 mW
PS2 POWout	GOOD	261500 mW
PS2 FAN	GOOD	4768 rpm

5.2.1.2.2 show power detail

Table 21. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	OK	Good	Good	1900

Table 22. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	53

Table 23. Power Summary

Power Type	Used	Available
System Power	240	455
PoE Power	323	2160

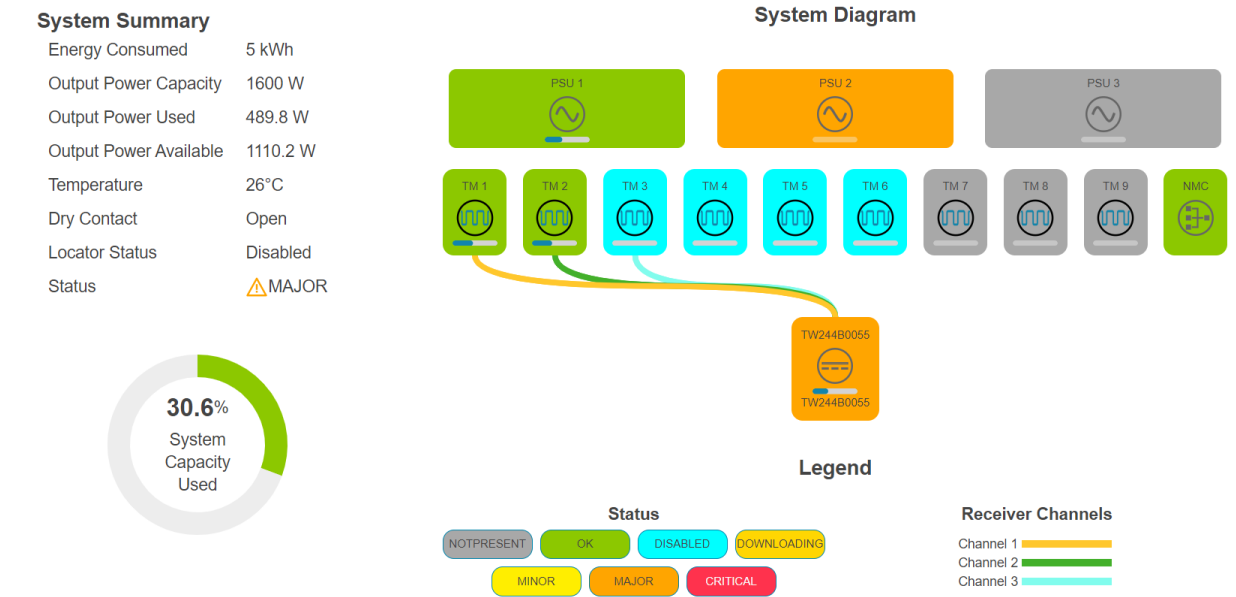
Power Type	Used	Available
Total Power	563	2615

5.2.1.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	15.4	14.1
Gi 1/0/2	15.4	14.1
Gi 1/0/3	15.4	14.2
Gi 1/0/4	15.4	14.2
Gi 1/0/5	15.4	14.0
Gi 1/0/6	15.4	14.0
Gi 1/0/7	15.4	14.1
Gi 1/0/8	15.4	13.9
Gi 1/0/9	15.4	14.0
Gi 1/0/10	15.4	14.1
Gi 1/0/11	15.4	14.1
Gi 1/0/12	15.4	14.0
Gi 1/0/13	15.4	13.9
Gi 1/0/14	15.4	13.9
Gi 1/0/15	15.4	13.9
Gi 1/0/16	15.4	13.9
Gi 1/0/17	15.4	13.9
Gi 1/0/18	15.4	13.9
Gi 1/0/19	15.4	14.1
Gi 1/0/20	15.4	13.9
Gi 1/0/21	15.4	14.1

5.2.2 Test 3 with 15-Watt Endpoints and Loss of AC Power Supply

5.2.2.1 FMPS Management Interface Screenshots



Power Supply Modules												
Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status	
1	PSU 1	BG234U0064	209.4	359.9	1.4	484.4	1115.6	33.8°C	OK	Enabled	Disabled	

Transmitter Modules													
Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Lo St	
✓ 1	TRANSMITTER 1	TW244H0098	359.3	358.5	0.6	225.4	374.6	34.3°C	OK	Enabled	TW244B0055	Di	
✓ 2	TRANSMITTER 2	TW244H0096	358.3	357.6	0.6	220.2	379.8	33.5°C	OK	Enabled	TW244B0055	Di	
✓ 3	TRANSMITTER 3	TW244H0083	358.1	2.6	0	0	600	28°C	OK	Disabled	TW244B0055	Di	
✓ 4	TRANSMITTER 4	TW244H0084	358.5	0	0	0	600	27.5°C	OK	Disabled		Di	
✓ 5	TRANSMITTER 5	TW244H0107	359.6	0	0	0	600	27.5°C	OK	Disabled		Di	
✓ 6	TRANSMITTER 6	TW244H0088	358.6	2.1	0	0	600	27.7°C	OK	Disabled		Di	
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	NOTPRESENT	Enabled		Di	
✓ 8	TRANSMITTER 8	...	...	...	...	...	...	...	NOTPRESENT	Enabled		Di	
✓ 9	TRANSMITTER 9	...	...	...	...	...	...	...	NOTPRESENT	Enabled		Di	

5.2.2.2 Catalyst 9300 Show Command Outputs

5.2.2.2.1 show environment all

Power supply 2, the 1900-watt AC power supply, was removed from the equation to demonstrate FMPS' capability to serve as a backup.

Parameter	State	Reading
PS1 Vout	GOOD	56238 mV
PS1 Vin	GOOD	48125 mV
PS1 CURin	GOOD	8250 mA
PS1 CURout	GOOD	6508 mA
PS1 POWin	GOOD	396500 mW
PS1 POWout	GOOD	364000 mW
PS1 FAN	GOOD	6736 rpm
PS2 Vout	FAULTY	0 mV
PS2 Vin	FAULTY	0 mV
PS2 CURin	FAULTY	0 mA
PS2 CURout	FAULTY	0 mA
PS2 POWin	FAULTY	0 mW
PS2 POWout	FAULTY	0 mW
PS2 FAN	FAULTY	0 rpm

5.2.2.2.2 show power detail

Table 24. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	No Input Power	Bad	Bad	1900

Table 25. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	70

Power Summary

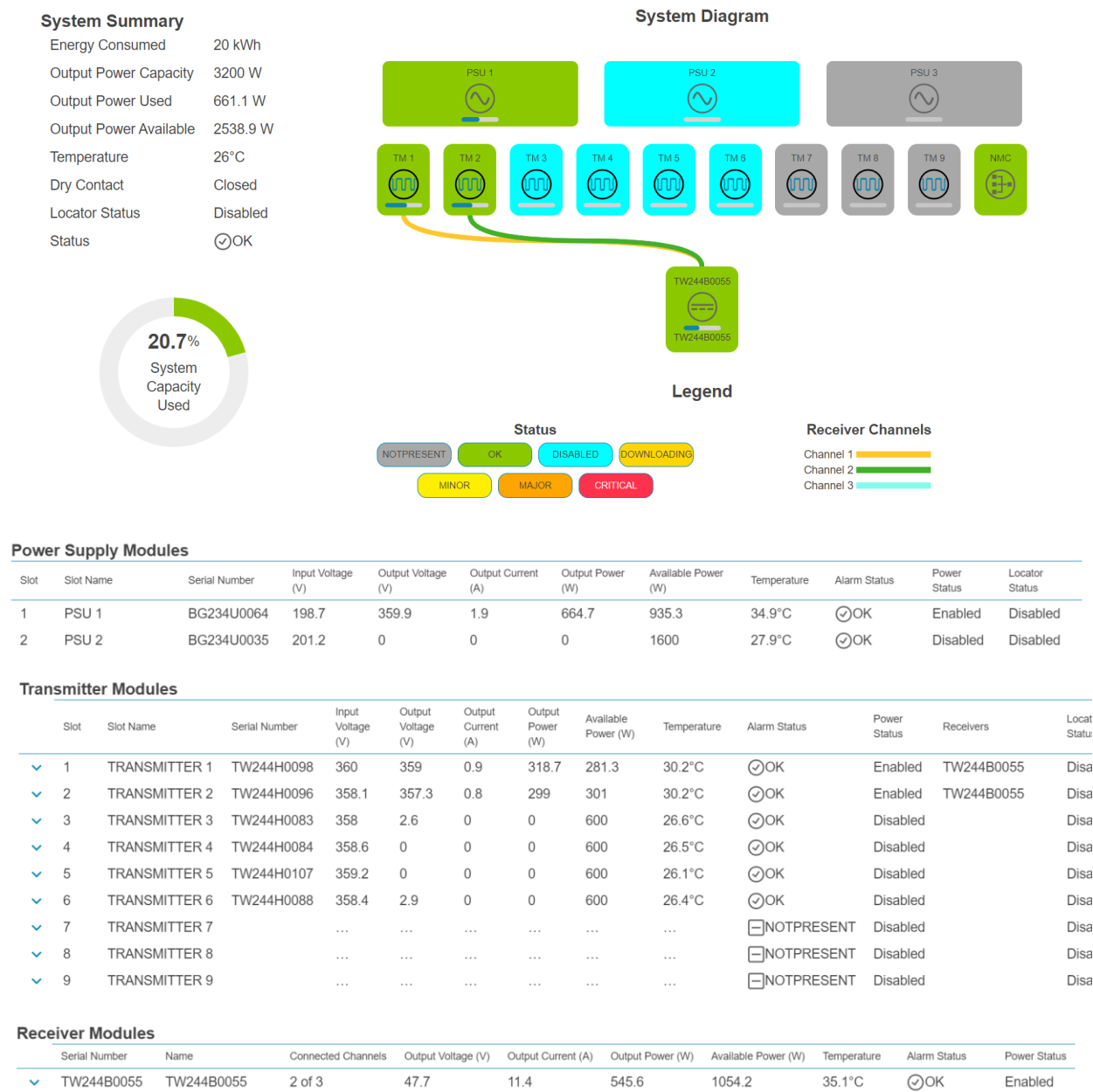
Power Type	Used	Available
System Power	240	2140
PoE Power	323	475
Total Power	563	2615

5.2.2.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	15.4	14.1
Gi 1/0/2	15.4	14.1
Gi 1/0/3	15.4	14.2
Gi 1/0/4	15.4	14.2
Gi 1/0/5	15.4	14.0
Gi 1/0/6	15.4	14.0
Gi 1/0/7	15.4	14.1
Gi 1/0/8	15.4	13.9
Gi 1/0/9	15.4	14.0
Gi 1/0/10	15.4	14.1
Gi 1/0/11	15.4	14.1
Gi 1/0/12	15.4	14.0
Gi 1/0/13	15.4	13.9
Gi 1/0/14	15.4	13.9
Gi 1/0/15	15.4	13.9
Gi 1/0/16	15.4	14.0
Gi 1/0/17	15.4	14.0
Gi 1/0/18	15.4	13.9
Gi 1/0/19	15.4	14.1
Gi 1/0/20	15.4	13.9
Gi 1/0/21	15.4	14.1

5.2.3 Test 3 with 90-Watt Endpoints and Two Power Supplies

5.2.3.1 FMPS Management Interface Screenshots



5.2.3.2 Catalyst 9300 Show Command Outputs

5.2.3.2.1 show environment all

In the outputs below, power supply 1 is the 715-watt DC power supply, and power supply 2 is the 1900-watt AC power supply.

Parameter	State	Reading
PS1 Vout	GOOD	56174 mV
PS1 Vin	GOOD	47563 mV
PS1 CURin	GOOD	11344 mA
PS1 CURout	GOOD	8563 mA
PS1 POWin	GOOD	540000 mW
PS1 POWout	GOOD	499500 mW
PS1 FAN	GOOD	5568 rpm
PS2 Vout	GOOD	56014 mV
PS2 Vin	GOOD	200500 mV
PS2 CURin	GOOD	6594 mA
PS2 CURout	GOOD	22250 mA
PS2 POWin	GOOD	1314000 mW
PS2 POWout	GOOD	1250000 mW
PS2 FAN	GOOD	10432 rpm

5.2.3.2.2 show power detail

Table 26. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	
A	OK	Good	Good	715
B	OK	Good	Good	1900

Table 27. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	102

Table 28. Power Summary

Power Type	Used	Available
System Power	240	455
PoE Power	1890	2160
Total Power	2130	2615

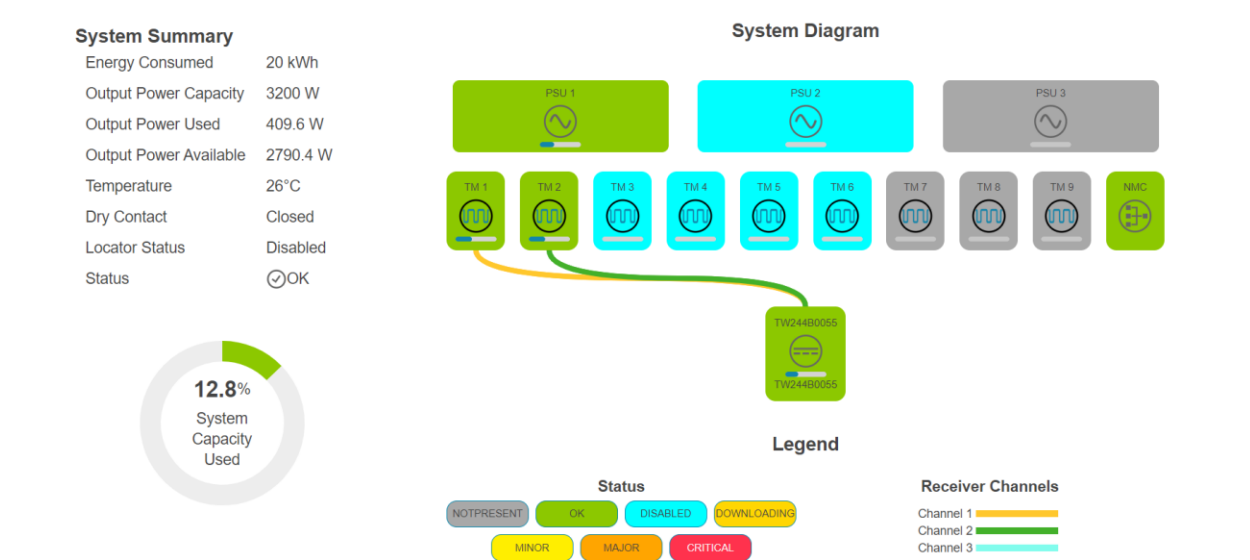
5.2.3.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	90.0	81.1
Gi 1/0/2	90.0	81.3
Gi 1/0/3	90.0	80.9
Gi 1/0/4	90.0	81.0
Gi 1/0/5	90.0	80.7
Gi 1/0/6	90.0	81.4
Gi 1/0/7	90.0	80.9
Gi 1/0/8	90.0	80.4
Gi 1/0/9	90.0	80.8
Gi 1/0/10	90.0	80.4
Gi 1/0/11	90.0	80.7
Gi 1/0/12	90.0	80.5
Gi 1/0/13	90.0	80.7
Gi 1/0/14	90.0	80.4
Gi 1/0/15	90.0	80.6
Gi 1/0/16	90.0	80.7
Gi 1/0/17	90.0	80.7

Interface	Allocated Power	Utilized Power
Gi 1/0/18	90.0	80.4
Gi 1/0/19	90.0	81.4
Gi 1/0/20	90.0	80.4
Gi 1/0/21	90.0	80.9

5.2.4 Test 3 with 90-Watt Endpoints and Loss of AC Power Supply

5.2.4.1FMPS Management Interface Screenshots



Receiver Modules

Serial Number	Name	Connected Channels	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status
▼ TW244B0055	TW244B0055	2 of 3	47.9	7.2	345.8	1254	36.2°C	✓OK	Enabled

5.2.4.2 Catalyst 9300 Show Command Outputs

5.2.4.2.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56238 mV
PS1 Vin	GOOD	47875 mV
PS1 CURin	GOOD	7125 mA
PS1 CURout	GOOD	5594 mA
PS1 POWin	GOOD	342500 mW
PS1 POWout	GOOD	312500 mW
PS1 FAN	GOOD	5568 rpm
PS2 Vout	FAULTY	0 mV
PS2 Vin	FAULTY	0 mV
PS2 CURin	FAULTY	0 mA
PS2 CURout	FAULTY	0 mA
PS2 POWin	FAULTY	0 mW
PS2 POWout	FAULTY	0 mW
PS2 FAN	FAULTY	0 rpm

5.2.4.2.2 show power detail

Table 29. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	
A	OK	Good	Good	715
B	Unknown	Bad	Bad	Unknown

Table 30. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	71

Table 31. Power Summary

Power Type	Used	Available
System Power	240	2140
PoE Power	450	475
Total Power	690	2615

5.2.4.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/7	90.0	80.0
Gi 1/0/10	90.0	80.1
Gi 1/0/11	90.0	80.4
Gi 1/0/12	90.0	80.3
Gi 1/0/13	90.0	80.5

5.2.5 Results

Test 3 was successful and validates FMPS successfully delivers the requisite 715 watts to the switch with the following parameters of the FMPS:

- 1 FMPS power supply
 - has capacity to provide 1600 watts, exceeding the required 715 watts
- 2 Transmitters
 - each Transmitter can only provide 600 watts, so requires two
- 1 Receiver
 - each Receiver has three input channels that can receive power from the Transmitters, only one required to receive input from two Transmitters
- 1000 meters of 16 AWG multiconductor cable

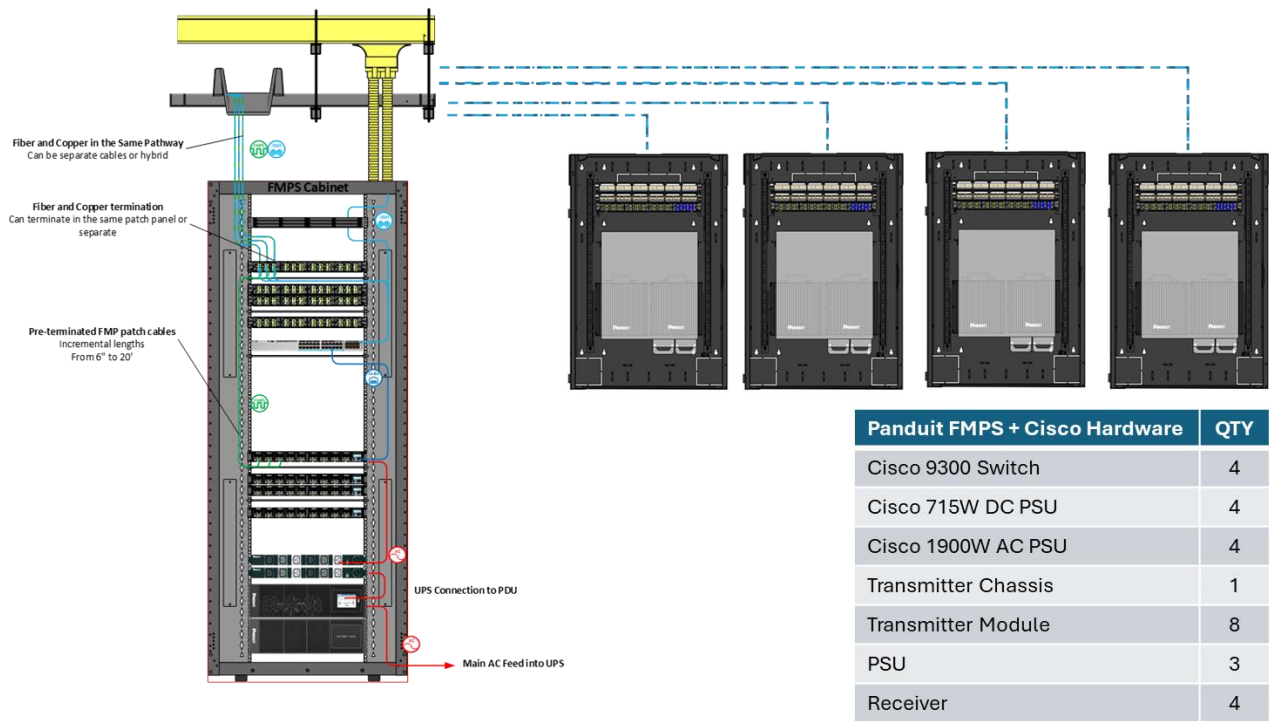
At 1000 meters, the FMPS delivered the full 715 watts required to load the power supply on the switch to maximum capacity. This performance was conclusively demonstrated by the power summary from the "show power detail" command as well as the FMPS management console.

When AC power was lost to the switch, FMPS sustained operations of the DC power supply to power both the switch and PoE endpoints, showing FMPS can serve as a solution to achieve power redundancy at remote locations.

When the load on the interfaces were increased to 90-watt endpoints, when AC power was lost, the switch remained operational, but power was shed and the interfaces where port priority was configured to high, interfaces 11, 12, and 13 in this test, those endpoints were unimpacted while the remaining wattage available was used to power the endpoints on interfaces 7 and 10.

5.2.6 How does this design scale?

A single FMPS Transmitter connected to a centralized UPS can support four distributed 9300 switches up to 1000 meters away from a centralized point. Refer to section 3.3 on scalability for more details.



5.3 DUAL HOMING POWER AND NETWORK ARCHITECTURE

This architectural design is well-suited for critical applications where network uptime and reliability are paramount. From a power perspective, using two FMPS Receivers provides redundant power supply to two 9300 switches, where it reduces the risk of a single point of failure. It allows for maintenance on a Receiver without affecting the operation of the switch.

From a network perspective, using two 9300 switches helps ensure that a network remains operational even if one part of the network fails. It can also help manage network load by distributing traffic across multiple connects.

Having two switches will allow for more PoE devices to also be connected and powered by FMPS, should the need arise for additional endpoints to be deployed in a space.

5.3.1 Test 4: FMPS to DC Power Supply in Dual Homing Configuration

For Test 4, the FMPS will provide DC power to the C9300 in a dual homing configuration, where two Receivers will each power one dedicated power supply on the switch, so that one Receiver does not act as a single point of failure and the FMPS architecture provides power resiliency.

In conjunction with the power redundancy, the “power inline port priority high” command was used with the 90-watt endpoints to ensure that during the power shedding, the interfaces configured with high priority would remain unimpacted while the remainder of the interfaces connected to PoE endpoints would shed power and enter into a power-deny state as a result of loss of power.

The desired outcome for the test is:

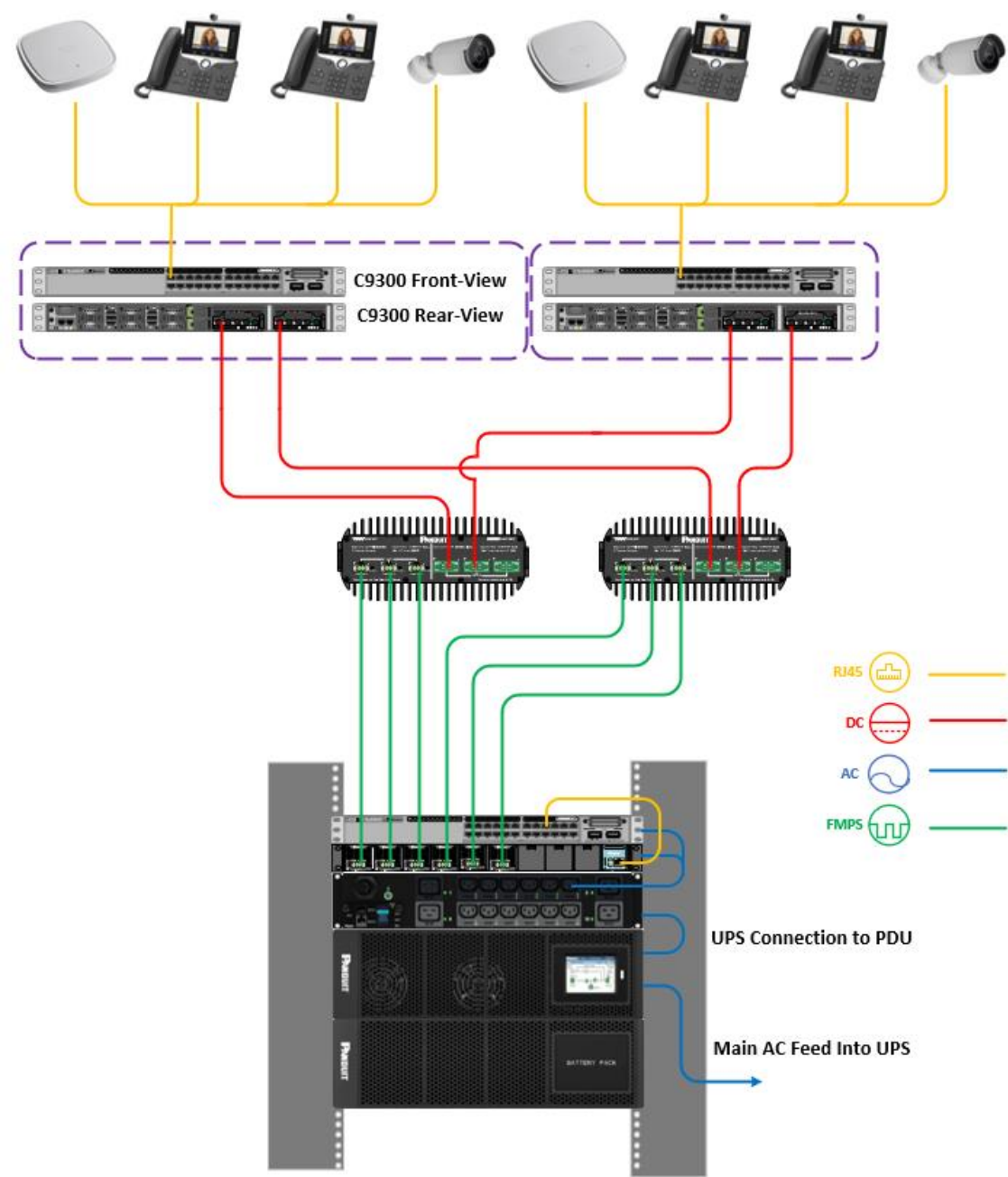
- C9300 to successfully provide power to 21 PoE endpoints drawing 15 watts
 - After a loss of power to one of the power supplies, the switch and PoE endpoints will be unimpacted
- C9300 to successfully provide power to 13 PoE endpoints drawing 90 watts
 - After a loss of power to one of the power supplies, the switch and PoE endpoints connected to interfaces with high port priority remain unimpacted, while the others are shed due insufficient PoE power

5.3.2 Intent of Design

Dual-homing architectures would be implemented in high-availability environments where continuous power is crucial for business operations, such as financial services, healthcare, and cloud service providers.

The dual homing configuration achieves redundancy by allowing the switches to be powered by two Receivers rather than one, alleviating the sole responsibility of powering the switch to one single Receiver.

5.3.3 Diagram



5.3.4 Parameters

Chassis Quantity	1	Chassis Quantity
Power Supply Quantity	2	Power Supply Quantity

Transmitter Quantity	6	Transmitter Quantity
Receivers	2	Receivers
Cable Length	450 m	Cable Length
Cable Gauge	16 AWG	Cable Gauge
Power Supply Type	DC	Power Supply Type
Power Supply Quantity	2	Power Supply Quantity
Homing Architecture	dual	Homing Architecture

5.3.4.1 Bill of Materials

Table 32. Panduit

Item Name	PID	Quantity
FMPS Chassis	PXTC1ARA	1
FMPS Power Supply Unit	PXU1AJANNXX	2
FMPS Transmitter	PXTM1AF	6
FMPS Receiver	PXR1AJD	2
Class 4 Copper Cable	PXUP316ARD-UQ	1

Table 33. Cisco

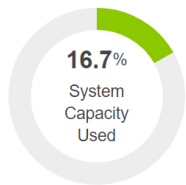
Item Name	PID	Quantity
Catalyst 9300-24H	C9300-24H-E	1
715 Watt DC Power Supply Unit	PWR-C1-715WDC=	4

5.3.5 Test 4 with 15-Watt Endpoints and Two Power Supplies

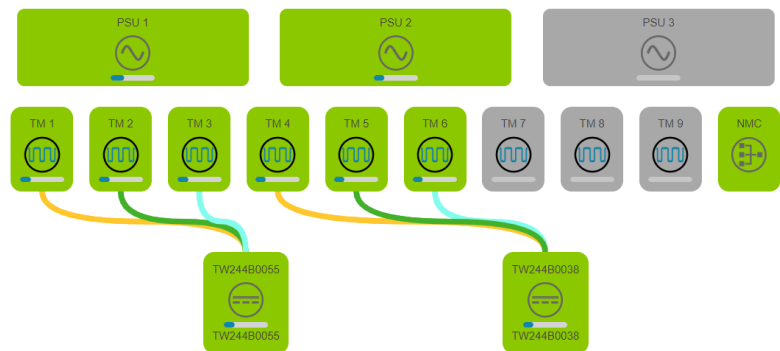
5.3.5.1 FMPS Management Interface Screenshots

System Summary

Energy Consumed	16 kWh
Output Power Capacity	3200 W
Output Power Used	535.6 W
Output Power Available	2664.4 W
Temperature	27°C
Dry Contact	Closed
Locator Status	Disabled
Status	🕒OK



System Diagram



Legend

Status

NOTPRESENT OK DISABLED DOWNLOADING

MINOR MAJOR CRITICAL

Receiver Channels

Channel 1

Channel 2

Channel 3

Summary Capacity Power Supplies Transmitters Receivers

Power Supply Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status
1	PSU 1	BG234U0064	202.7	362.9	0.8	297.9	1302.1	35.5°C	🕒OK	Enabled	Disabled
2	PSU 2	BG234U0035	203.3	362.7	0.7	240.1	1359.9	33.4°C	🕒OK	Enabled	Disabled

Transmitter Modules

	Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Loc. Stat
✓	1	TRANSMITTER 1	TW244H0098	362.9	362.2	0.2	81.4	518.6	30°C	🕒OK	Enabled	TW244B0055	Dis
✓	2	TRANSMITTER 2	TW244H0096	361.3	360.8	0.2	82.6	517.4	30.7°C	🕒OK	Enabled	TW244B0055	Dis
✓	3	TRANSMITTER 3	TW244H0083	362.9	362.2	0.2	86.5	513.5	30.6°C	🕒OK	Enabled	TW244B0055	Dis
✓	4	TRANSMITTER 4	TW244H0084	362	363.9	0.2	72.4	527.6	30.8°C	🕒OK	Enabled	TW244B0038	Dis
✓	5	TRANSMITTER 5	TW244H0107	362.8	360.8	0.2	72.8	527.2	30.3°C	🕒OK	Enabled	TW244B0038	Dis
✓	6	TRANSMITTER 6	TW244H0088	362.4	361.6	0.2	66.1	533.9	30.2°C	🕒OK	Enabled	TW244B0038	Dis
✓	7	TRANSMITTER 7	...	...	...	...	...	...	...	🗒NOTPRESENT	Disabled		Dis
✓	8	TRANSMITTER 8	...	...	...	...	...	...	...	🗒NOTPRESENT	Disabled		Dis
✓	9	TRANSMITTER 9	...	...	...	...	...	...	...	🗒NOTPRESENT	Disabled		Dis

Summary Capacity Power Supplies Transmitters Receivers

Receiver Modules

	Serial Number	Name	Connected Channels	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status
✓	TW244B0055	TW244B0055	3 of 3	48.6	4.6	224.5	1375.3	37.4°C	🕒OK	Enabled
✓	TW244B0038	TW244B0038	3 of 3	48.2	4	193.7	1406.1	40°C	🕒OK	Enabled



5.3.5.2Catalyst 9300 Show Command Outputs

5.3.5.2.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56174 mV
PS1 Vin	GOOD	48500 mV
PS1 CURin	GOOD	4023 mA
PS1 CURout	GOOD	3047 mA
PS1 POWin	GOOD	193750 mW
PS1 POWout	GOOD	171000 mW
PS1 FAN	GOOD	6800 rpm
PS2 Vout	GOOD	56174 mV
PS2 Vin	GOOD	49500 mV
PS2 CURin	GOOD	4234 mA
PS2 CURout	GOOD	3438 mA
PS2 POWin	GOOD	217000 mW
PS2 POWout	GOOD	191250 mW
PS2 FAN	GOOD	5328 rpm

5.3.5.2.2 show power detail

Table 34. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	OK	Good	Good	715

Table 35. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	67

Table 36. Power Summary

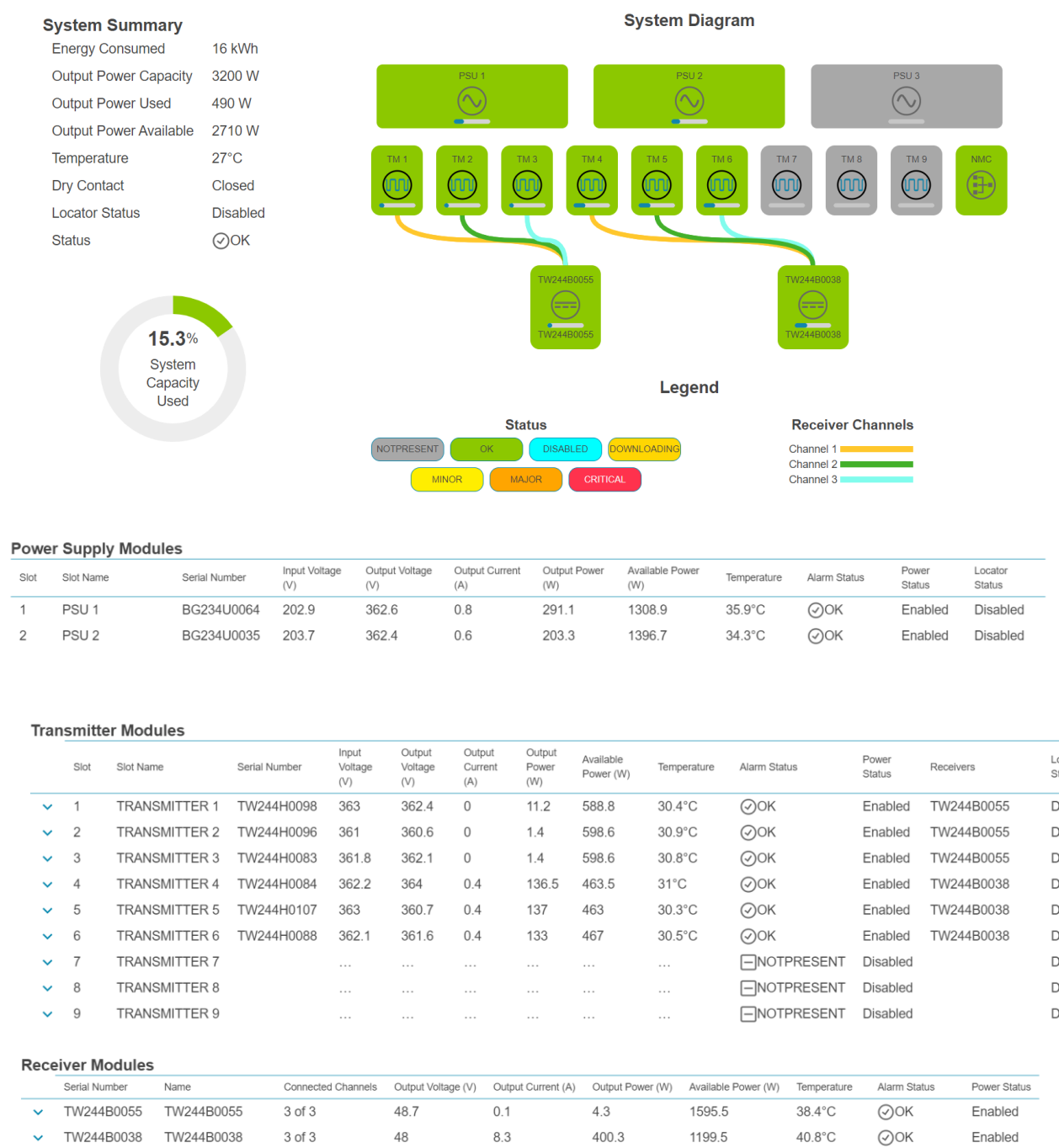
Power Type	Used	Available
System Power	240	240
PoE Power	323	1190
Total Power	563	1430

5.3.5.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	15.4	12.8
Gi 1/0/2	15.4	14.0
Gi 1/0/3	15.4	14.2
Gi 1/0/4	15.4	14.2
Gi 1/0/5	15.4	14.1
Gi 1/0/6	15.4	14.1
Gi 1/0/7	15.4	14.1
Gi 1/0/8	15.4	14.0
Gi 1/0/9	15.4	14.0
Gi 1/0/10	15.4	14.1
Gi 1/0/11	15.4	14.1
Gi 1/0/12	15.4	14.0
Gi 1/0/13	15.4	13.9
Gi 1/0/14	15.4	13.9
Gi 1/0/15	15.4	13.9
Gi 1/0/16	15.4	13.9
Gi 1/0/17	15.4	13.9
Gi 1/0/18	15.4	13.9
Gi 1/0/19	15.4	14.1
Gi 1/0/20	15.4	13.9
Gi 1/0/21	15.4	14.0

5.3.6 Test 4 with 15-Watt Endpoints and Loss of One DC Power Supply

5.3.6.1 FMPS Management Interface Screenshots



5.3.6.2Catalyst 9300 Show Command Outputs

5.3.6.2.1 show environment all

The output below shows the result of a simulated failure on the Receiver powering power supply 2.

Parameter	State	Reading
PS1 Vout	GOOD	56238 mV
PS1 Vin	GOOD	48125 mV
PS1 CURin	GOOD	8219 mA
PS1 CURout	GOOD	6508 mA
PS1 POWin	GOOD	396500 mW
PS1 POWout	GOOD	365000 mW
PS1 FAN	GOOD	6800 rpm
PS2 Vout	FAULTY	0 mV
PS2 Vin	FAULTY	0 mV
PS2 CURin	FAULTY	0 mA
PS2 CURout	FAULTY	0 mA
PS2 POWin	FAULTY	0 mW
PS2 POWout	FAULTY	0 mW
PS2 FAN	FAULTY	0 rpm

5.3.6.2.2 show power detail

Table 37. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	No Input Power	Bad	Bad	715

System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	70

Table 38. Power SummaryPow

Power Type	Used	Available
System Power	240	955
PoE Power	323	475
Total Power	563	1430

5.3.6.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/1	15.4	14.1
Gi 1/0/2	15.4	14.1
Gi 1/0/3	15.4	14.3
Gi 1/0/4	15.4	14.2
Gi 1/0/5	15.4	14.1
Gi 1/0/6	15.4	14.1
Gi 1/0/7	15.4	14.1
Gi 1/0/8	15.4	13.9
Gi 1/0/9	15.4	13.9
Gi 1/0/10	15.4	14.1
Gi 1/0/11	15.4	14.1
Gi 1/0/12	15.4	14.1
Gi 1/0/13	15.4	13.9
Gi 1/0/14	15.4	13.9
Gi 1/0/15	15.4	13.9
Gi 1/0/16	15.4	13.9
Gi 1/0/17	15.4	13.9
Gi 1/0/18	15.4	13.9

Interface	Allocated Power	Utilized Power
Gi 1/0/19	15.4	14.1
Gi 1/0/20	15.4	13.9
Gi 1/0/21	15.4	14.0

5.3.7 Test 4 with 90-Watt Endpoints and Two Power Supplies

5.3.7.1FMPS Management Interface Screenshots

System Summary

Energy Consumed

19 kWh

Output Power Capacity

3200 W

Output Power Used

1388.9 W

Output Power Available

1811.1 W

Temperature

26°C

Dry Contact

Closed

Locator Status

Disabled

Status

OK

43.4%

System Capacity Used

System Diagram



Legend

Status

NOTPRESENT

OK

DISABLED

DOWNLOADING

MINOR

MAJOR

CRITICAL

Receiver Channels

Channel 1

Channel 2

Channel 3

Power Supply Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status
1	PSU 1	BG234U0064	200.8	362.6	2.1	762.5	837.5	40.5°C	OK	Enabled	Disabled
2	PSU 2	BG234U0035	200.9	362.1	1.7	622	978	39.1°C	OK	Enabled	Disabled

Transmitter Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Locator Status
✓ 1	TRANSMITTER 1	TW244H0098	362.6	361.6	0.6	206.1	393.9	30.7°C	OK	Enabled	TW244B0055	Dis
✓ 2	TRANSMITTER 2	TW244H0096	360.7	360.1	0.6	206.3	393.7	31.1°C	OK	Enabled	TW244B0055	Dis
✓ 3	TRANSMITTER 3	TW244H0083	360.7	360.6	0.6	213.4	386.6	30.9°C	OK	Enabled	TW244B0055	Dis
✓ 4	TRANSMITTER 4	TW244H0084	360.8	362.6	0.6	214.2	385.8	30.9°C	OK	Enabled	TW244B0038	Dis
✓ 5	TRANSMITTER 5	TW244H0107	362.5	360.3	0.6	216.5	383.5	30.3°C	OK	Enabled	TW244B0038	Dis
✓ 6	TRANSMITTER 6	TW244H0088	361.6	360.9	0.6	215.4	384.6	30.2°C	OK	Enabled	TW244B0038	Dis
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	NOTPRESENT	Disabled		Dis
✓ 8	TRANSMITTER 8	NOTPRESENT	Disabled		Dis
✓ 9	TRANSMITTER 9	NOTPRESENT	Disabled		Dis

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Receiver Modules

Serial Number	Name	Connected Channels	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status
✓ TW244B0055	TW244B0055	3 of 3	47.5	12.5	595.6	1004.2	36.2°C	✓OK	Enabled
✓ TW244B0038	TW244B0038	3 of 3	47.9	13.1	625.5	974.3	37.8°C	✓OK	Enabled

5.3.7.2Catalyst 9300 Show Command Outputs

5.3.7.2.1 show environment all

Parameter	State	Reading
PS1 Vout	GOOD	56432 mV
PS1 Vin	GOOD	47875 mV
PS1 CURin	GOOD	12422 mA
PS1 CURout	GOOD	9734 mA
PS1 POWin	GOOD	597000 mW
PS1 POWout	GOOD	545000 mW
PS1 FAN	GOOD	7456 rpm
PS2 Vout	GOOD	56238 mV
PS2 Vin	GOOD	47938 mV
PS2 CURin	GOOD	12922 mA
PS2 CURout	GOOD	10063 mA
PS2 POWin	GOOD	620000 mW
PS2 POWout	GOOD	566000 mW
PS2 FAN	GOOD	6736 rpm

5.3.7.2.2 show power detail

Table 39. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	OK	Good	Good	715

Table 40. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	65

Table 41. Power Summary

Power Type	Used	Available
System Power	240	240
PoE Power	1170	1190
Total Power	1410	1430

5.3.7.2.3 show power inline upoe-plus

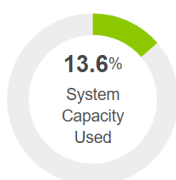
Interface	Allocated Power	Utilized Power
Gi 1/0/1	90.0	80.6
Gi 1/0/2	90.0	80.9
Gi 1/0/3	90.0	80.5
Gi 1/0/4	90.0	80.6
Gi 1/0/5	90.0	80.3
Gi 1/0/6	90.0	80.9
Gi 1/0/7	90.0	80.4
Gi 1/0/8	90.0	80.0
Gi 1/0/9	90.0	80.3
Gi 1/0/10	90.0	80.0
Gi 1/0/11	90.0	80.4
Gi 1/0/12	90.0	80.0
Gi 1/0/13	90.0	80.0

5.3.8 Test 4 with 90-Watt Endpoints and Loss of One DC Power Supply

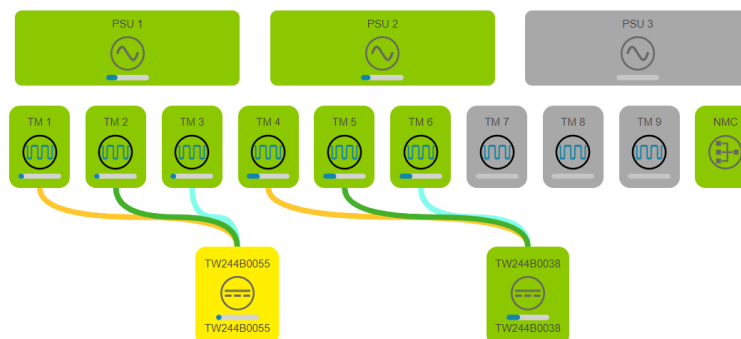
5.3.8.1 FMPS Management Interface Screenshots

System Summary

Energy Consumed	19 kWh
Output Power Capacity	3200 W
Output Power Used	435.7 W
Output Power Available	2764.3 W
Temperature	26°C
Dry Contact	Closed
Locator Status	Disabled
Status	⚠ MINOR



System Diagram



Legend

Status	Receiver Channels
NOTPRESENT	Channel 1
OK	
DISABLED	
DOWNLOADING	

Status

Summary Capacity Power Supplies Transmitters Receivers

Power Supply Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Locator Status
1	PSU 1	BG234U0064	201.8	362.9	0.7	258	1342	37.4°C	✓ OK	Enabled	Disabled
2	PSU 2	BG234U0035	200.8	362.7	0.5	182.4	1417.6	36.8°C	✓ OK	Enabled	Disabled

Transmitter Modules

Slot	Slot Name	Serial Number	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status	Receivers	Locator Status
✓ 1	TRANSMITTER 1	TW244H0098	362.9	362.3	0	5	595	30.7°C	✓ OK	Enabled	TW244B0055	Disabled
✓ 2	TRANSMITTER 2	TW244H0096	361.4	360.9	0	2.1	597.9	31.3°C	✓ OK	Enabled	TW244B0055	Disabled
✓ 3	TRANSMITTER 3	TW244H0083	361.3	361.4	0	7.2	592.8	31°C	✓ OK	Enabled	TW244B0055	Disabled
✓ 4	TRANSMITTER 4	TW244H0084	361.8	363.7	0.3	121.8	478.2	31°C	✓ OK	Enabled	TW244B0038	Disabled
✓ 5	TRANSMITTER 5	TW244H0107	363	360.9	0.3	124.1	475.9	30.4°C	✓ OK	Enabled	TW244B0038	Disabled
✓ 6	TRANSMITTER 6	TW244H0088	362.3	361.7	0.3	120	480	30.2°C	✓ OK	Enabled	TW244B0038	Disabled
✓ 7	TRANSMITTER 7	...	...	...	...	...	...	...	☐ NOTPRESENT	Disabled		Disabled
✓ 8	TRANSMITTER 8	...	...	...	...	...	...	...	☐ NOTPRESENT	Disabled		Disabled
✓ 9	TRANSMITTER 9	...	...	...	...	...	...	...	☐ NOTPRESENT	Disabled		Disabled

Receiver Modules

Serial Number	Name	Connected Channels	Output Voltage (V)	Output Current (A)	Output Power (W)	Available Power (W)	Temperature	Alarm Status	Power Status
✓ TW244B0055	TW244B0055	3 of 3	48.3	0.1	4.8	1595	34.6°C	✓ OK	Enabled
✓ TW244B0038	TW244B0038	3 of 3	48.1	7.2	348.2	1251.6	35.7°C	✓ OK	Enabled

5.3.8.2Catalyst 9300 Show Command Outputs

5.3.8.2.1 show environment all

The output below shows the result of a simulated failure on the Receiver powering power supply 2.

Parameter	State	Reading
PS1 Vout	GOOD	56432 mV
PS1 Vin	GOOD	48750 mV
PS1 CURin	GOOD	7258 mA
PS1 CURout	GOOD	5555 mA
PS1 POWin	GOOD	352000 mW
PS1 POWout	GOOD	316000 mW
PS1 FAN	GOOD	11392 rpm
PS2 Vout	FAULTY	0 mV
PS2 Vin	FAULTY	0 mV
PS2 CURin	FAULTY	0 mA
PS2 CURout	FAULTY	0 mA
PS2 POWin	FAULTY	0 mW
PS2 POWout	FAULTY	0 mW
PS2 FAN	FAULTY	0 rpm

5.3.8.2.2 show power detail

Table 42. Power Supply Status

Power Supply ID	Status	System Power	PoE Power	Watts
A	OK	Good	Good	715
B	No Input Power	Bad	Bad	715

Table 43. System Power Status

Module	State	Budget	Instantaneous
1	accepted	240	75

Table 44. Power Summary

Power Type	Used	Available
System Power	240	955
PoE Power	450	475
Total Power	780	1430

5.3.8.2.3 show power inline upoe-plus

Interface	Allocated Power	Utilized Power
Gi 1/0/11	90.0	80.4
Gi 1/0/12	90.0	80.0
Gi 1/0/13	90.0	80.0

5.3.9 Results

Test 4 was successful and confirms FMPS is able to act as a backup solution to itself by using multiple Receivers to power a PoE switch with 1430 watts with the following parameters of the FMPS:

- 2 FMPS power supply
 - tested power redundancy, necessitating the use of two power supplies
- 6 Transmitters
 - each Transmitter can only provide 600 watts, simulated the use of two separate Receivers, requiring 6 Transmitters
- 2 Receivers
 - simulated power loss to single Receiver to demonstrate dual-homing architecture that one Receiver can power a power supply on multiple switches
- 450 meters of 16 AWG multiconductor cable
 - distance reduced to minimize power loss

Each Receiver in the FMPS was able to deliver all requisite 715 watts across 450 meters to load each power supply on the switch to full capacity, as evidenced by the power summary from the “show power detail” command as well as FMPS management console corroborating said state of PoE switches.

Power redundancy was successful in keeping the switch operational while also powering all the 15-watt endpoints when power to a DC power supply was lost through the failure of one Receiver.

When the load on the interfaces were increased to 90-watt endpoints, when one DC power supply lost power, the switch remained operational, but power was shed and the interfaces where port priority was configured to high, interfaces 11, 12, and 13 in this test, remained unimpacted.

6 CONCLUSION

The tests conducted and outcomes observed have shown the capability of FMPS to play an integral role in a PoE solution. The battery of tests conducted to validate its capabilities shows that so long as the requisite components and modules are present in the FMPS to ensure the Receiver can draw the necessary power, it can deliver it as required, as evidenced by the operations of both the C9300 as well as the PoE endpoints connected to it.

The amount of power expected to be delivered to the Receivers relative to the distance of the 16-AWG multiconductor cable in the graph referenced in section 4.2.2 was successfully delivered to the Receivers.

There are additional factors to consider when designing the power delivery infrastructure using FMPS. Such things include, but are not limited to:

- Selected cable must be UL 1400-2 certified and must be listed under the Panduit UL 1400-1 listing. Contact Panduit for the most up to date listed cables.
- gauge of multiconductor cable connecting Transmitter to Receiver
- distance from headend/MDF to remote location where Receivers will be deployed
- environmental conditions to which FMPS components will be exposed to
- requirements such as redundancy and scalability

As evidenced in the tests conducted, many of the factors can be adjusted to fit the needs of a deployment as simple as powering a single DC power supply on a PoE switch to power connected PoE endpoints, to as complex as implementing a dual-homing architecture to provide power redundancy to multiple switches to eliminate a single point of failure. The modularity and scalability of the individual components allows for FMPS to be deployed to meet immediate needs while permitting for growth in the future both near and distant.

Panduit's FMPS, combined with Cisco Catalyst 9300 PoE switches, extends network reach and delivers high-wattage power over long distances, allowing Cisco switches to maintain performance and utilize PoE features effectively. FMPS not only enhances network flexibility but also simplifies installation by reducing local power source requirements. The integrated power and network management tools support efficient distributed network architectures.

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