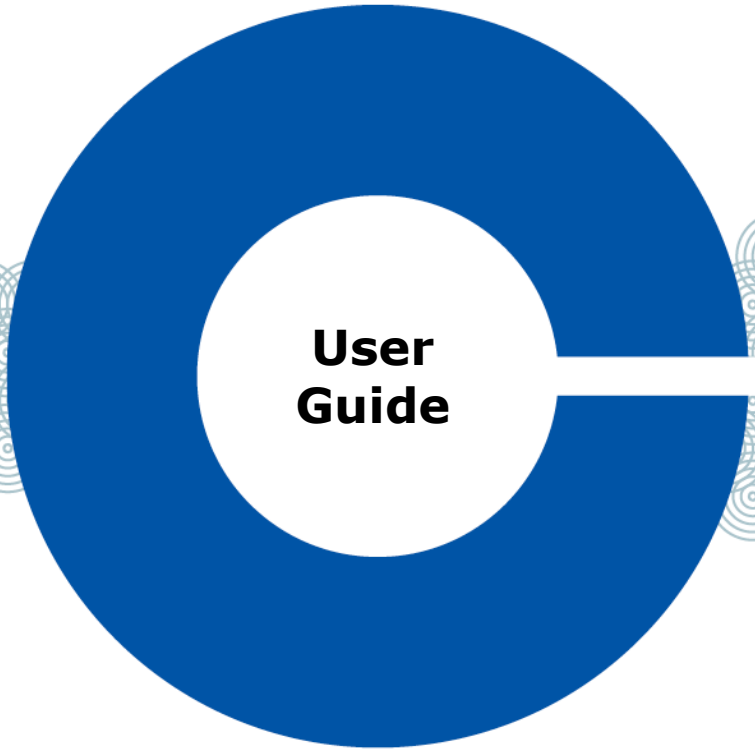

Clear-Com AoIP/AES67 Network Recommendations

Part Number:399G275 B

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Clear-Com
AN HME COMPANY

Document Reference

AES67 switch recommendations and configuration

Part Number: 399G275 B

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Table of Contents

1 Introduction to AoIP/AES67

This document offers guidance for users developing an AES67 network with Clear-Com AoIP products in mind. It starts with a general overview and then provides more detail.

- AES67 is a bridging compliance which allows any AES67 compliant device to participate with other compliant devices on a network in order to transport high quality audio over IP (AoIP).
- AES67 offers high quality, high density, low latency audio transport over a LAN.
- AES67 operates over standard layer 3 Ethernet or fiber networks and is both routable and fully scalable.
- AES67 uses the IEEE1588-2008 Precision Time Protocol (PTPv2).

1.1 Which Clear-Com devices transmit AoIP ?

- The E-IPA interface card. E-IPA-HX-XX (where xx indicates the number of ports licensed on the card).
- The IP transciever (IPT). FSII-TCVR-IP-19
- The Iris Panel. VI-PNL-XX-XX (where XX-XX indicates the number of keys and panel model).

Note: The Iris panel and the E-IPA card work with two different IP transmission modes:

- IP: Clear-Com proprietary IP technology, IVC
- IP: AoIP/AES67

This guide deals with AoIP/AES67 audio transmission, not IVC.

2 AoIP networking overview

This table shows an overview and some general rules to use when setting up a network for use with Clear-Com AoIP devices.

System size	System	Switch Requirement
Small	1 – 10 AoIP devices Up to 3 layer-2 hops between the PTP master and the IPTs Clear-Com AES67 traffic only	DiffServ QoS (and appropriate switch priority queues)
Medium	10 – 30 AoIP devices Up to 3 layer-2 hops between the PTP master and the IPTs Clear-Com AES67 traffic only	DiffServ QoS IGMPv2 snooping IGMP querier (querier is mandatory with IGMP snooping)
Large	>25 AoIP devices >3 layer-2 hops between PTP Master and IPTs Mixed network traffic	DiffServ QoS IGMPv2 snooping IGMP querier (querier is mandatory with IGMP snooping) PTP aware transparent and/or boundary clocks

The following apply:

- System sizes are for example only. For instance: even a small system would require PTP-aware switches if the set up involved using more than 3 switches between the master clock and slave.
- The recommended setting for switches is IGMP snooping enabled. If you enable IGMP snooping you MUST also have a querier on your network (1 per network). **If IGMP snooping is enabled without an IGMP querier, the IP transceiver and the IP panel will not work.**
- DiffServ QoS is mandatory to ensure high timing accuracy.
- Energy Efficient Ethernet (IEEE 802.3az)/Green Switch capabilities must be switched OFF.

For boundary clocks, you must use the AES67 Media PTP profile.

3 Precision Time Protocol (PTP)

PTP is a protocol used to synchronize clocks in a network, and it can synchronize devices with sub-microsecond accuracy.

Taking steps (discussed below) to optimise clocking accuracy in your network will ensure an efficient environment for all your AoIP devices.

IEEE 1588 PTP uses a master/slave clocking architecture, with a master clock synchronizing each network segment. An elected grandmaster will provide the root clocking reference.

Note: The E-IPA card can act as a master clock.

3.1 PTP tolerance (offset from the master clock)

3.1.1 The IP transceiver

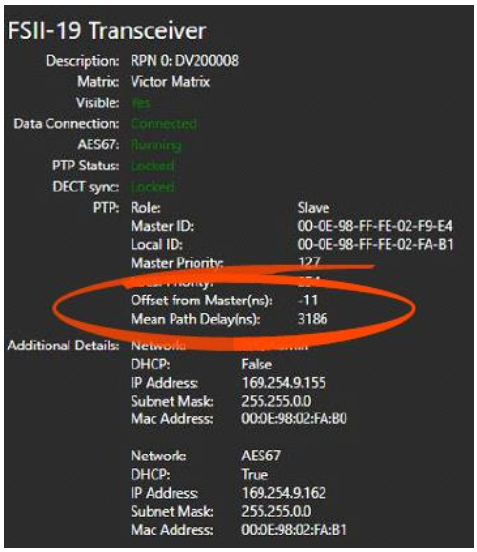
Clear-Com IP transceivers have higher than average timing accuracy requirements due to the need to synchronize the devices in a radio frequency (RF) space.

The following table shows guidelines, rather than rules, as tolerances will vary depending on the use of external PTP master clocks and where transceivers (and E-IPA card) are located in the network relative to the master clock.

PTP parameters	Value (range)	Performance
Offset from the master clock (OFM)	± 100 ns	Excellent
	± 500 ns	Potential for roaming issues
	± 1,000 ns	Issues with roaming likely
	>± 1,000 ns	Cannot roam between transceivers and intermittent loss-of-lock issues
Packet travel time* + OFM	> 2,000,000 ns (2 ms)	No audio

*When E-IPA card is PTP master, mean path delay (MPD) is the same as packet travel time.

Offset from Master (OFM) and **Mean Path Delay (MPD)** are shown per transceiver in the EHX Configuration Software. Navigate to **System > Monitoring**.



3.1.2 The Iris Panel

The Iris panel has a markedly greater PTP (in this case, OFM) tolerance than the IP transceiver. This is because the panels do not have to synchronise in an RF space. Both devices, however, have the same audio buffer (link offset). Link offset is hard coded to the devices, so any audio with greater than 2 ms total packet time difference (OFM + packet travel time) will be dropped.

PTP parameters	Value (range)	Performance
Packet travel time* +OFM	> 2,000,000 ns (2 ms)	No audio

*When E-IPA card is PTP master, mean path delay (MPD) is the same as packet travel time.

3.2 Path Delay Variation (PDV)

PDV (commonly referred to as jitter) refers to the variation, end to end, between packet delivery times. In an active network, the load can change very quickly and this can cause packet delivery time to change. PDV can have a very detrimental impact on synchronization and should be limited as much as possible (see **3.3 How to improve clocking accuracy and reduce PDV**).

Clear-Com IPTs have a high clocking accuracy requirement due to the need to achieve DECT sync (RF device synchronization).

Taking steps to reduce PDV in your network will ensure an efficiently synchronized environment for all of your AoIP devices.

3.3 How to improve clocking accuracy and reduce PDV

3.3.1 Prioritization of PTP traffic using Quality of Service (QoS)

The AES67 standard imposes rules on manufacturers regarding QoS prioritization. The devices and the network must follow the AES67 recommendations to ensure a uniform understanding of priorities between all devices.

QoS is mandatory when using Clear-Com AoIP equipment.

Note:	CoS is not sufficient for use with Clear-Com AoIP devices.

The switches used must support DiffServ QoS (RFC 2474) and be set to operate with the AES67 standard values shown in the following table.

Class name	Traffic type	Default DiffServ class (DSCP decimal value)
Clock	IEEE 1588-2008 Announce, Synch, Follow_Up, Delay_Req, Delay_Resp, Pdelay_Req, Pdelay_Resp and Pdelay_Resp_Follow_Up packets	EF (46) (Expedited Forwarding)
Media	RTP and RTCP media stream data	AF41 (34) (Assured Forwarding)
Best Effort	IEEE 1588-2008 signaling and management messages. Discovery and connection management messages.	DF (O) (Default Forwarding)

3.3.2 Switch Priority Queues

The following apply:

- The Clock queue must be configured in Strict Priority mode, not Weighted Round-Robin
- The Clock class must be the highest-level priority
- The Clock and Media packets should not be placed at the same priority

- If QoS trust options are available, ensure DSCP is trusted.

3.3.3 PTP settings

Ensure that the PTP master (whichever device that is) is running the AES67 Media PTP profile.

Note:	The E-IPA card has this setting by default. This hard coded and cannot be changed.

The Clear-Com AoIP device attributes are set according to the AES67 Media PTP profile. These values are shown in the table below:

Attribute	Value	Description
Domain Number	0	The domain attribute of the local clock.
Announce Interval	1	The mean time interval between Announce messages. A shorter interval allows faster reactions to the changes in the master-slave hierarchy. The interval should be the same in the whole domain. It is specified as a power of two in seconds. 2^1 = 2 seconds between messages. ***Adapted from <https://linux.die.net/man/8/ptp4l>***
Sync Interval	-3	The mean time interval between Sync messages. A shorter interval may improve accuracy of the local clock. It is specified as a power of two in seconds. 2^{-3} = 0.125 = 8 per second. ***Adapted from <https://linux.die.net/man/8/ptp4l>***
Min Delay Req Interval	0	The minimum permitted mean time interval between Delay_Req messages. A shorter interval allows faster reactions to the changes in the path delay. It is specified as a power of two in seconds. 2^0 = 1 second. ***Adapted from <https://linux.die.net/man/8/ptp4l>***
Announce Receipt Timeout	3	The number of missed Announce messages before the last Announce messages expires. ***From <https://linux.die.net/man/8/ptp4l>***
Priority1	254 (IPT) 254 (Iris panel) 127 (IPA)	The priority1 attribute of the local clock. It is used in the best master selection algorithm. Lower values take precedence. Must be in the range 0 to 255. The default value for a generic AES67 device is 128. IPTs (transceivers) and Iris panels are priority 254. E-IPA-HXs (card) are priority 127. ***Adapted from <https://linux.die.net/man/8/ptp4l>***

The definition of *profile* may vary depending on switch manufacturers. For example, the Cisco IE 4010 switch has the concept of *profile* but none of the possible options includes an AES67 media profile.

If the AES67 media profile is not available or specified, make sure that the boundary clock switch or grandmaster clock respects the following criteria:

- PTP messages must be sent using layer 3 IP packets
- PTP QoS setting must use DSCP tagging with type expedited forwarding (that is, DSCP 46)
- Sync messages sent every 125 ms (Sync Interval above)
- Master announcement messages sent every 2 seconds

3.3.4 Spanning Tree Protocol (STP/RSTP)

Multiple possible routes between the PTP master and the slave(s) will very likely increase PDV. Do one of the following:

- Make sure that there is only one physical route between the master and slave.
- Enable STP/RSTP which closes multiple routes when they are found.

3.3.5 PTP aware switches

Although a PTP aware switch is more expensive than the alternative, its benefits are often worth the extra cost because a network consisting of PTP aware switches can almost eliminate PDV. A network incorporating PTP aware switches is less sensitive to the disruptive effects that can be generated by other network traffic.

Note:	A boundary clock breaks up the grandmaster hierarchy and will take over clock synchronization if the grandmaster is lost. A transparent clock cannot do this.

3.3.6 VLANs

If you still experience synchronization problems on your network, (high jitter or offset from the master) after trying the above steps (for example, QoS and PTP profile) then consider setting up a separate VLAN for Clear-Com AES67 traffic.

3.4 Internet Group Management Protocol (IGMP)

AES67 supports both unicast and multicast streaming. For multicast, AES67 specifies the use of the IGMPv2 (RFC 2236) protocol for management of traffic. With IGMP snooping properly configured on network switches, multicast traffic is only forwarded to ports where active listeners are present. This prevents saturation of bandwidth and reduces clutter on the network. For more information about configuring switches with IGMP snooping, see **3.4.1 Configuration for network switches with IGMP snooping**.

The following apply:

- Clear-Com AoIP devices use multicast for device discovery and PTP
- IGMPv2 snooping is recommended when using Clear-Com AoIP devices .

Note:	If IGMP is enabled, without the IGMP querier, the devices will not work as the switch will stop forwarding multicast packets.

3.4.1 Configuration for network switches with IGMP snooping

The following apply:

- If IGMP snooping is enabled on a switch, one device on the network must have also have an IGMP querier enabled (one per network).
- If available, IGMP querier election should be enabled.

3.5 AES67 Audio

Clear-Com AoIP devices use:

- Unicast for audio
- 2 ms link offset (audio buffer)

Packet travel time must be < 2 ms. If greater than 2 ms, the audio packet is discarded and audio is dropped.

3.6 Bandwidth

Use a non-blocking switch.

Example switch capacity

Number of ports on the switch	Individual port capacity	Overall capacity
24	1Gbps	24 ports x 1 Gbps X2 (full duplex) = **48 Gbps**

1 x IPT bandwidth usage: ~7 Mbps.

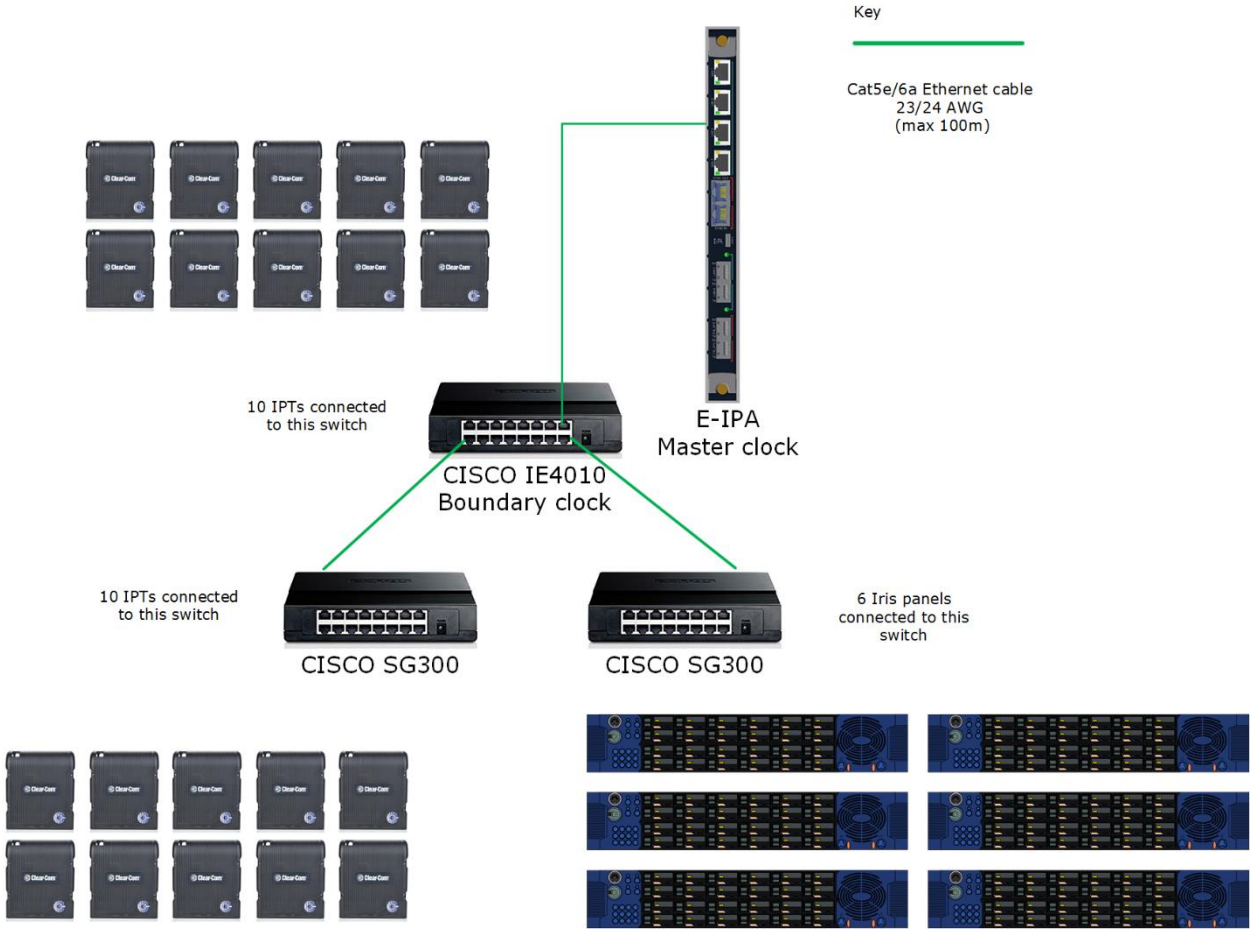
1 x Iris panel bandwidth usage: ~5 Mbps, then ~1.5 Mbps for each additional channel (up to a total of 3 channels, so ~8 Mbps).

Clear-Com recommends not using more than 75% of the bandwidth on any one switch.

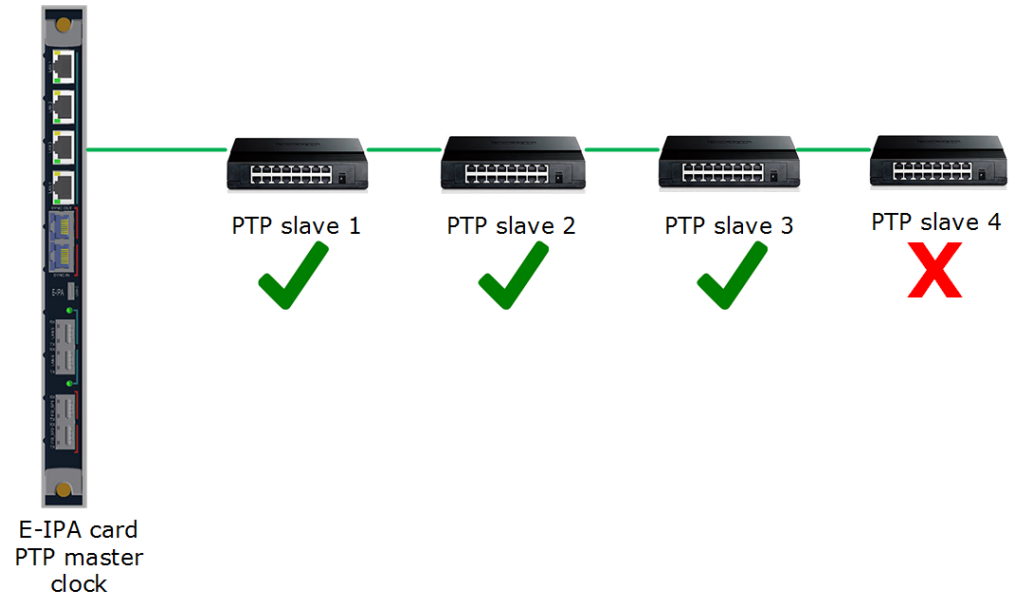
Note:	100m is the maximum cable length for copper cable, depending on cable quality. For distances over 80m you should use CAT6 cable.

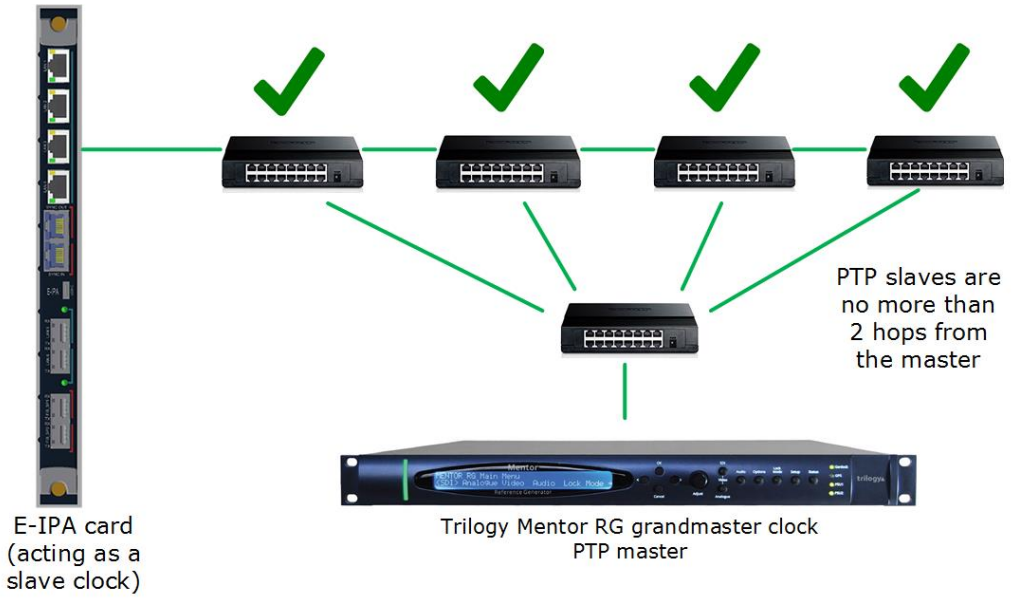
4 Switch topology

4.1 Example of a switch set up used at Clear-Com



4.2 Example using switch hops and grandmaster clock





Note: in this configuration, RSTP/STP needs to be enabled

5 Switches tested with Clear-Com IPTs

The following switches have been used successfully with Clear-Com IPTs:

Non PTP aware switches:

- **Netgear** (Prosafe JGS516PE)
- **Cisco** (SG300 and SG350)

PTP aware switches:

- **Luminex** (GigaCore26i)
- **Cisco** (EI4010)

For a description of the setup for Luminex and Cisco switches, see **Appendix A – switch settings**.

Note:	A bug in several NetGear switches resulted in dropped DNS packets when IGMP Snooping was enabled. A firmware update is available at http://www.netgear.com/support that resolves this issue. Please ensure your NetGear switch has the latest firmware installed for proper functionality.

Appendix A – switch settings

This appendix describes how to configure the Luminex GigaCore26i switch and the Cisco SC300.

Switch Settings for the Luminex GigaCore26i

All configuration can be achieved from the Web interface. QoS is pre-configured, you only need to configure IGMP and PTP.

IP address configuration

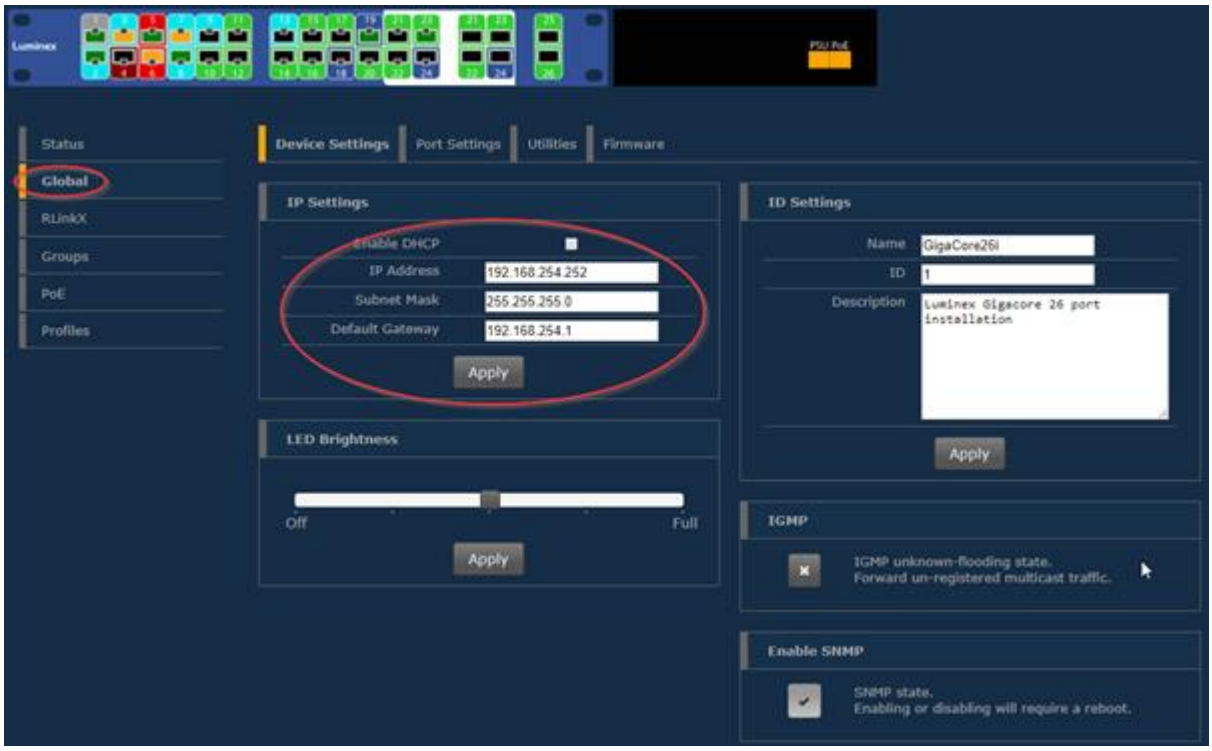
Do the following:

1) Locate the default IP address on the sticker on the back of the switch. Configure your PC/laptop to be on the same subnet with a different IP address.

2) Using a web browser, type the default IP address of the switch into your address bar. The **Settings** page will load from the switch.

3) Once on the **Settings** page, go to **Global** in the left navigation, and then change the **IP Settings** parameters

4) Click **Apply**.

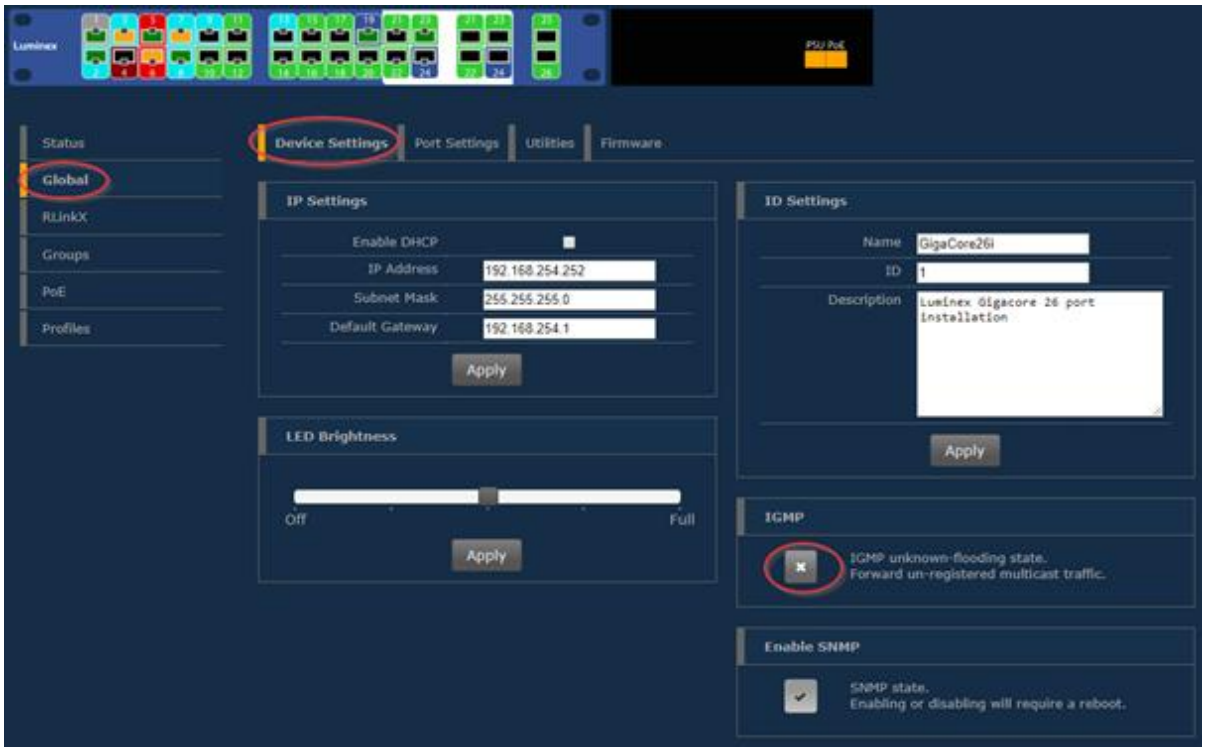


On your browser, type the newly configured IP address of the switch to bring up the Settings page.

IGMP global setting

Do the following:

1) Go to **Global > Device Settings** and deselect the **IGMP unknown-flooding state**.



Configure a group/VLAN and assign it to physical ports

Do the following:

1) Go to **Groups**.

2) Use the wheel to select a free group (that is, VLAN).

3) Click on **Advanced** and configure the **VLAN ID** that will be used on the network.

4) Click **Apply**.

5) Click on **Assign** followed by all the ports you want within this VLAN. The port color will change to match the group/VLAN color on the wheel. Click on **Assign** again to confirm.

Group/VLAN setting for IGMP and PTP

Do the following:

1) Go to **Groups**.

2) Use the wheel to select the proper group (that is, VLAN).

3) Activate IGMP by check-marking the following options:
   - **Snooping**
   - **Querier**.

4) Activate PTP by check-marking **PTPv2**, and then select the **E2E** mode.

5) Click **Apply** to save the configuration.

Note:	All ports will be access ports (that is, untagged) UNLESS assigned to the ISL group, in which case the port will be configured as a trunk and all traffic coming in and out will be VLAN-tagged.

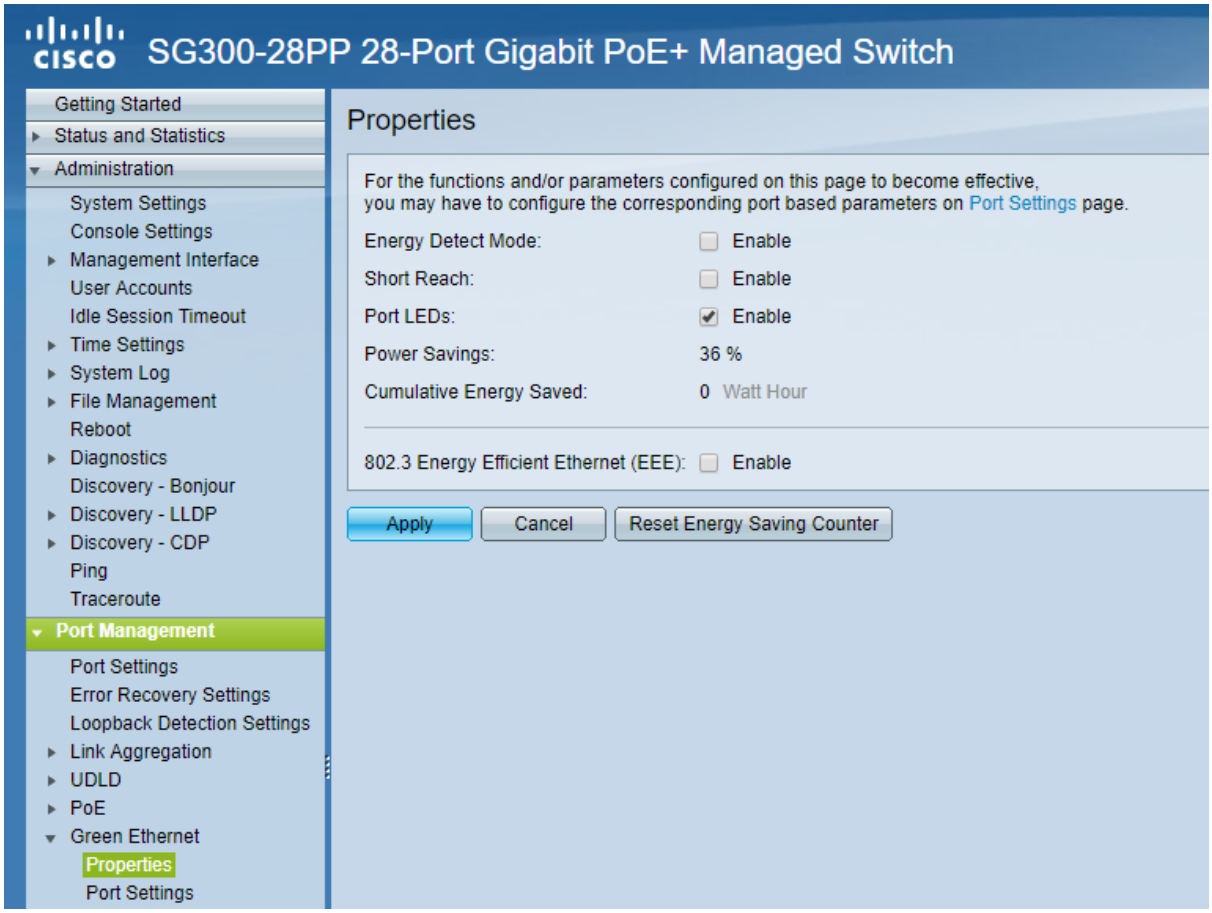
Note:	Only one group/VLAN can have PTP activated at a given time. Make the activated group/VLAN transporting PTP data and AES67 media traffic.

Note:	All changes done through the Web interface are activated immediately and automatically saved.

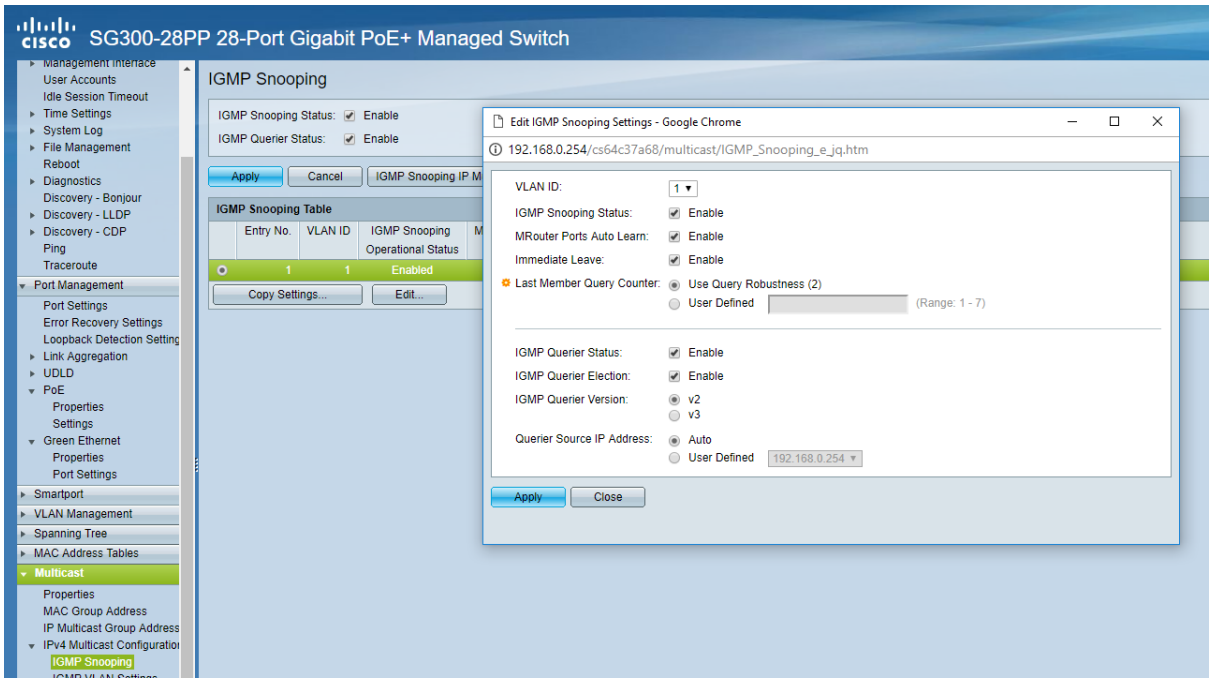
Switch settings for the Cisco SG300

Do the following:

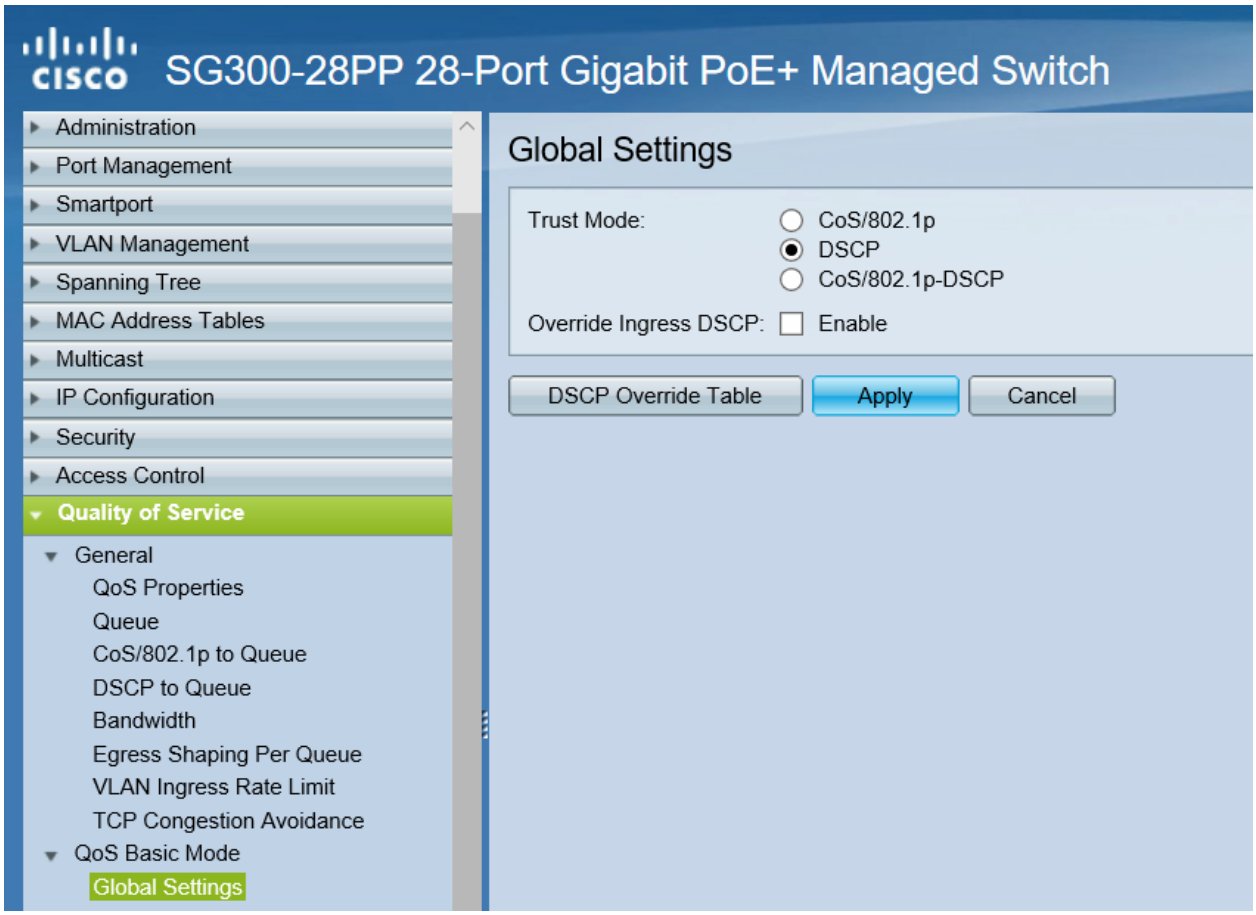
1) Disable the Energy Efficient Ethernet (EEE).



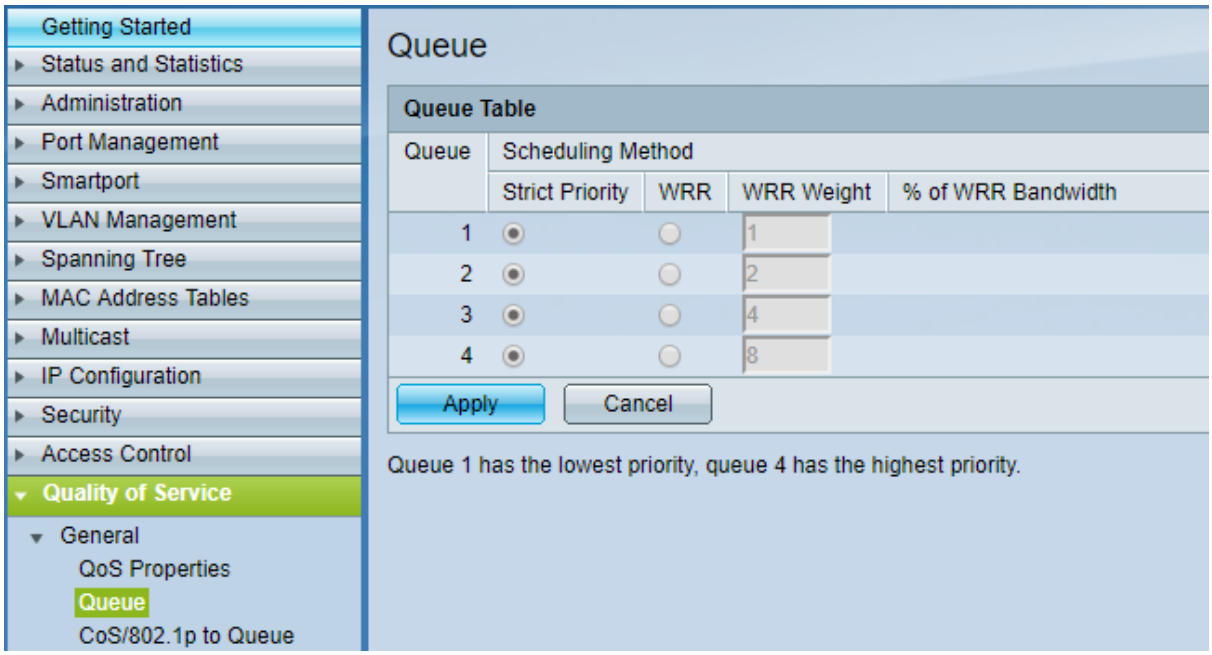
2) Enable IGMP Snooping and Querier.



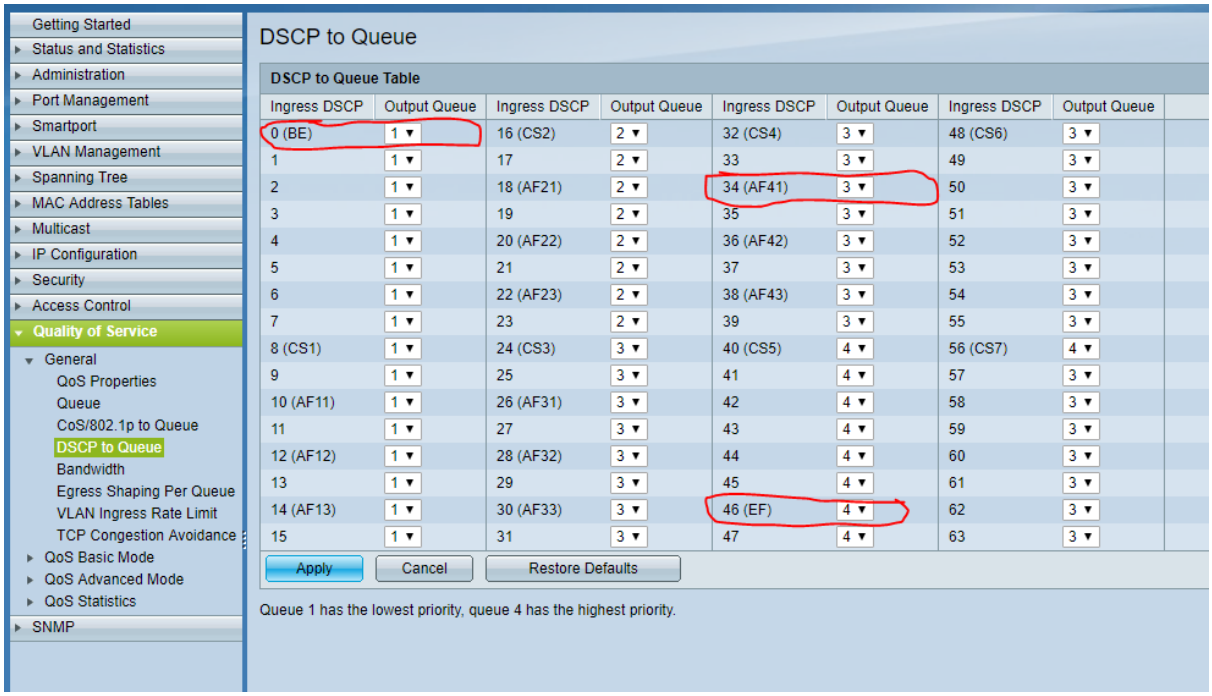
3) Configure the QoS Trust settings.



4) Configure the Queue Priorities.



5) Configure the QoS to Queue mapping.



Appendix B - troubleshooting tips

This appendix provides general network troubleshooting advice, and specific configuration rules for the Eclipse HX E-IPA card.

General network troubleshooting

The following general troubleshooting tips apply:

- Minimum switch spec: 1 G ports, switching or line speed is 2 x port count, supports DiffServ QoS.
- Check network topology: how many hops between the grandmaster PTP clock and the IPT transceiver/Iris panel.
- DHCP or static IP addresses: check for IP clash
- Ensure all the switches have the same DiffServ QoS settings
    - PTP data packets set to DiffServ EF(46) and placed in the highest queue
    - Media (RTP/RTCP AES67 audio) packets set to DiffServ AF41 (34) and placed in the 2nd highest queue.
- If possible separate the Clear-Com equipment onto a separate LAN or VLAN without any other manufacturers' equipment. Then check for errors.
- Use the EHX monitoring screen to check PTP status of the transceivers
- Use Wireshark to verify PTP packets are getting to the correct devices
- Use the mirrored port function on the Ethernet switch to help with the Wireshark capture
- Use the EHX monitoring screen to check which device is the PTP grandmaster clock and if that device is stable.
- Check that the PTP profile of the master clock device is set to AES67 media profile.
- Ensure that IGMP snooping is enabled on the LAN/VLAN that the IP Transceivers are connected to.
    - Ensure that only one IGMP querier is enabled on this network
- If using a Spine Leaf network topology, ensure that RSTP is enabled on inter-switch connections
- Double check that any boundary clock device is set up correctly

- Ethernet switches can be programmed so that each port:
  - Only allows one device per port and this is controlled by the MAC address of the device (sometimes known as 'sticky ports'). If a device with a different MAC address is connected it will shut the Ethernet port down.
  - Port slowly learns if the connected device is another Ethernet switch or a host (end) device. The time take to learn about the connected device can be over 30 secs before the ort starts to forward data.
  - Contact your IT administrator about STP and PortFast settings on your Ethernet switches.

E-IPA configuration rules

The following apply:

- **Admin & IVC** must be on different subnets if split.
- AES67 must not be connected to the same LAN/VLAN as **Admin & IVC**, unless sharing the same rear connection.
- Do not connect more than one cable from the E-IPA to the same LAN/VLAN. Otherwise, a broadcast storm could occur.