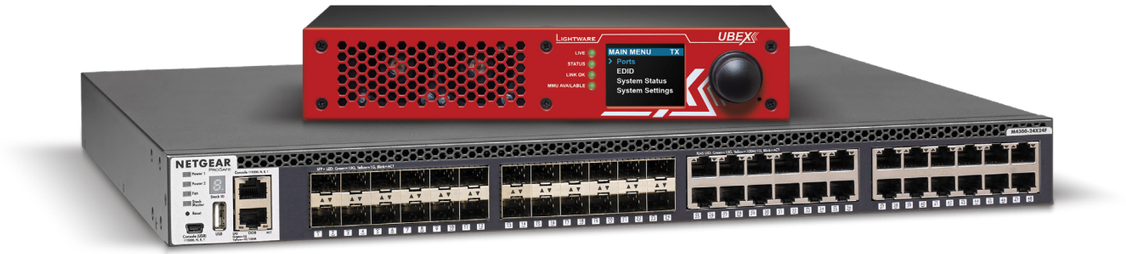
visual engineering
LIGHTWARE

Application Notes



Installation and Network Setup Guide for UBEX

Table of Contents

Document Information

All presented functions refer to the indicated products. The descriptions have been made during testing these functions in accordance with the indicated Hardware/Firmware/Software environment:

Item	Version
Firmware package - UBEX-PRO20-HDMI-F100	1.3.0
Firmware package - UBEX-PRO20-HDMI-F110	1.3.0
Firmware package - UBEX-MMU-X200	1.0.6

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Introduction

This chapter highlights the purpose of the document and gives a chance to check into the world of UBEX network in the below listed sections:

1.1. Description

Lightware's one of the most visionary development project is the UBEX (Ultra Bandwidth Extender) product family. This new optical solution allows 4K UHD@60Hz 4:4:4 uncompressed signal extension without latency. We intend to use packet-based transmission instead of the conventional method.

We use standard, certificated 10 Gbps SFP+ optical modules which are plug and play, so they are swappable by the user. There could be either duplex multimode/singlemode modules (1–1 fiber for each direction per 10 Gbps link) or bidirectional singlemode module (1 fiber for both direction per 10 Gbps link). The maximum distance is 400 m with multimode modules (OM4), and 10 km with short range singlemode modules, or 80 km with long range singlemode modules. In a typical application with standard, non-blocking 10 Gbps Ethernet switch it is necessary to use both directions of the link. Therefore the number of necessary fibers depends on the link speed and the optical module: for 10 Gbps 1 or 2 fibers, for 20 Gbps 2 or 4 fibers are needed. One of the primary advantages of the new architecture is scalability.

Matrix Management Unit

UBEX-MMU-X200 is a Matrix Management Unit (MMU) for the UBEX AV Over IP optical extender product line. With a standard Ethernet switch installed as a crosspoint, a virtual matrix can be created with UBEX devices connected to the IP network as input and output endpoints. The virtual matrix established requires to be managed and controlled by the MMU also connected to the Ethernet switch.

The MMU builds and constantly updates a database of the UBEX endpoints connected, displaying a traditional crosspoint view of the virtual matrix in the Lightware Device Controller (LDC) software, also displaying connected, but inactive units.

Users connect and communicate directly with the MMU in matrix mode, and MMU connects to and relays communication to the endpoint UBEX units.

The MMU displays information about endpoints and the overall virtual AV network, backup and restore functions are also provided to save and load the configuration. The MMU also manages the firmware upgrades of the connected endpoint UBEX devices, it is possible to initiate and update of the firmware on all UBEX units present in the network. Based on the communication with the UBEX endpoints, the MMU manages and supervises bandwidth use efficiency.

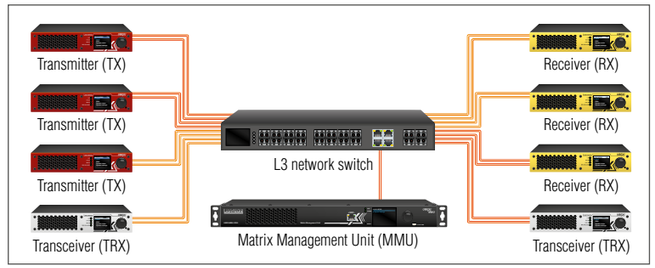
The MMU also serves as an interface for third-party control systems and includes Lightware's proprietary Advanced EDID Management technology.

1.2. The Purpose of the Document

UBEX Application Modes

At first we need to clear up the application modes of the UBEX series devices. UBEX system has two main application modes:

- **EXTENDER mode** - Point-to-point connection between a transmitter and a receiver, or between two transceiver endpoint devices;
- **MATRIX mode** - Virtual A/V matrix with more transmitters, receivers, transceivers, and a Matrix Management Unit (MMU) which controls the A/V network.



UBEX - Matrix mode

This application note is related to the **Matrix application mode** only.

About the Document

The following chapters help for the integrators and our customers to install and configure an UBEX matrix in a newly installed or existing IT network system. The sections listed below are in the document:

- Hardware requirements
- UBEX network installation step by step
- Video network designing
- The required bandwidth of a stream by resolutions
- The steps of the network switch configuration in general terms
- The steps of the network switch configuration by switch models (for Ubiquiti, Netgear, Cisco, and Juniper switch models)
- Useful tips & tricks for the best user experience
- UBEX Test Lab test cases, matrix architectures, and experiences

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Video Network Designing

This chapter gives useful practical advices to the network designers creating an effective and well-functioning UBEX A/V network.

2.1. First Steps

At first, the video network designer needs to decide what purpose needs to be satisfied with the video system - it will determine the size of the matrix and the type of the network switch. The size of the matrix primarily depends on the number of inputs and outputs. When the designer knows that, the choosing of the type of the switch can be started. The following table can help in that:

Business type	Sources / Destinations	Required UBEX devices		Required SFP+ ports in the switch	Required SFP/ RJ45 ports in the switch	Recommended switch type	
		Endpoints (TX/RX/TRX)	MMU			Type	Example
Small business	up to 12 / 12	6	1	12	1	12-ports 10G (+1 1G SFP port for MMU) L3 managed switch	**Ubiquiti EdgeSwitch 16 XG** See also: Configuration Steps - Ubiquiti EdgeSwitch 16 XG
Medium business	up to 24 / 24	12	1	24	1	24-ports 10G (+1 1G SFP port for MMU) L3 managed switch	**Netgear ProSafe M4300-24X24F** See also: Configuration Steps - Netgear M4300-24X24F
							Cisco WS-C3850-24XS See also: Configuration Steps - Cisco WS-C3850-24XS
	up to 46 / 46	23	1	46	1	48-ports 10G (+1 1G SFP port for MMU) L3 managed switch	**Cisco Nexus 5548UP** See also: Configuration Steps - Cisco Nexus 5548UP
							Cisco Nexus 93180YC-EX See also: Configuration Steps - Cisco Nexus 93180YC-EX
Corporate business	up to 94 / 94	47	1	94	1	96-ports 10G (+1 1G SFP port for MMU) L3 managed switch	**Juniper QFX5100-96S** See also: Configuration Steps - Juniper QFX5100-96S
	up to 100 / 100	50	1	200	1	Standalone/modular switching architecture with 10G SFP+ cards	**Juniper QFX10016 and QFX10000 series line cards**

Comparison table for video network designing

The Calculation

Let's see an example: the video network is designed for a small business calculated with maximum 6 source and 6 destination devices. The UBEX endpoint has 2 HDMI input ports and 2 HDMI output ports, so the network needs 3 transmitters for the 6 inputs and 3 receivers for the 6 outputs. It is 6 endpoints (the operation mode (TX, RX, or TRX) does not matter, the UBEX endpoint can be configured freely anytime by the user), moreover the network needs one Matrix Management Unit (UBEX-MMU-X200) to control the UBEX network.

The endpoints require two SFP+ ports in the switch per unit, in summary, it is 12 ports in the case of six extenders. The video network requires a 12-port 10G L3 fully managed switch to ensure the stable data transmission for the UBEX system.

ATTENTION! The SFP+ ports must support 10 Gbps Ethernet.

In the case of corporate business, the UBEX system gives an opportunity building even an 100x100 video matrix. The transmitters, receivers, and transceivers can be variated dynamically because of the MMU is able to handle it in real time. An asymmetric AV matrix can also be built with UBEX endpoints, e.g. an 1x100 or 100x1 video system. The possibilities are only limited by imagination.

The Matrix Management Unit requires one RJ45 or SFP ports with 1 GbE support to the network switch. The MMU does not transmit a video, it controls the UBEX system only.

Bandwidth Management

The next challenge of the video network designing is the bandwidth management. The next section describes how to calculate the required bandwidth based on the video resolution and refresh rate on the network and the general know-how of the bandwidth requirement calculation.

2.2. Bandwidth Requirements

The bandwidth calculation consists of two components:

- Required bandwidth of the streams (up to 2 streams per endpoint)
- Uplink bandwidth

The following sections give the details about these components.

2.2.1. Stream Bandwidth Requirements

UBEX transmitters have 2x HDMI 2.0 input ports which can receive two video streams for transmission to the receiver. The required bandwidth for the stream is calculated from the resolution, the color space, the refresh rate, and the loss ration of the video packeting (~3%).

Bandwidth Calculation

The correct formula:

$$X_{ACTIVE} \times Y_{TOTAL} \times fps \times ColorDepth \times VideoPacketizingLossRatio = \textbf{Total signal bandwidth}$$

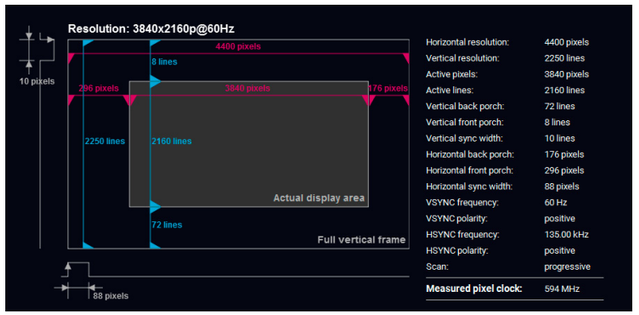
Parameters:

Parameter	Description	Example (4K UHD 60 Hz 24 bit)
X_{ACTIVE}	Number of the columns of the active resolution	3840
Y_{TOTAL}	Total number of the lines including the blanking area	2250
fps	Refresh rate	60 Hz
ColorDepth	Color depth	24 bit
VideoPacketingLossRatio	The ratio of the packet loss due to the packeting and the protocol	1.03684

For the exact calculation you should know the total resolution of the stream because the transmitted number of pixels are not equal with the active pixels which are finally displayed on the receiver side. The cause is the blanking area where the embedded audio and other information travels with the HDMI signal.

INFO: The bandwidth calculation in the case of the HDMI pipes count with the **peak bandwidth** which is the summary of the video burst.

If the stream information is unknown to the designer, to get the information of the active resolution the **Frame detector** of Lightware is a useful tool. The Frame detector is available in our control software, in the Lightware Device Controller (LDC), it can be downloaded from the website www.lightware.com.



Frame detector in the LDC software

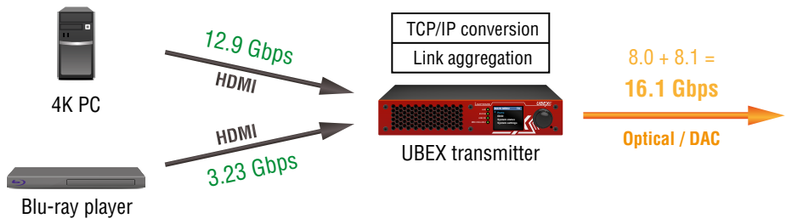
Let's see an example:

I want to transmit a UHD (3840x2160@60 Hz 24 bit) HDMI signal which is received on the HDMI input 1 port of the UBEX transmitter.

Based on the formula the calculation is the following:

3840 x 2250 x 60 x 24 x 1.03684 = 12 899 948 544 = **12.9 Gb/s**

This is the required bandwidth for the Stream 1 from the HDMI input 1 port. The HDMI input 2 receives an 1080p60 video, the required bandwidth is 3.23 Gb/s. The summary of the two values gives the final number of the required signal bandwidth for the video streams.



Bandwidth of the input streams for UBEX transmitter

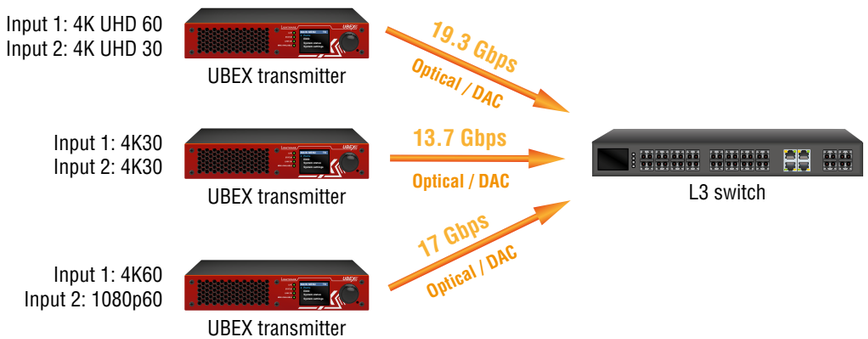
The signal bandwidth which is transmitted over the SFP+ ports is measured with the **average bandwidth** which counts with active resolution lines instead of the total resolution lines.

2.2.2. Endpoint Uplink Bandwidth Requirements

UBEX endpoints support video over an optical fiber SFP+ network connection up to 20 Gbps which means 2x 10 GbE SFP+ slots. The 20 GbE can ensure transmitting

- one 4K60 4:4:4 and one 4K30 4:4:4 signals, or
- 2x 4K60 4:2:2, or
- 2x 4K30 4:4:4 signals, or
- one 4K60 4:4:4 and one 1080p60 signals together and losslessly.

No compression, no latency, every single bit is received as it is transmitted.



Uplink bandwidth schematic

2.3. 10 Gigabit Ethernet Designing

The video transmission is taken over the SFP+ interfaces which are required to build in 2x 10 Gigabit Ethernet connection between the UBEX transmitters and receivers. The fiber optical network solutions provide stable and trustworthy signal transmission in the video network. This section describes the details about the video matrix designing in the fiber optical network point of view.

2.3.1. Multimode Fiber

Multimode fiber is used in the LAN environment where distances between the rooms are 300 m or less.

The IEEE 802.3ae 10 Gigabit Ethernet specification includes a serial interface referred to as **10GBASE-SR** (the "S" stands for short wavelength) that is designed for 850 nm transmission on multimode fiber. The table below provides the wavelength, modal bandwidth, and operating distance for different types of multimode fiber operating at 10 Gbps.

Description	62.5 micron fiber		50 micron fiber		
Wavelength (nm)	850	850	850	850	850
Modal bandwidth (MHz*km)	160	200	400	500	2000
Operating range (m)	**2-26**	**2-33**	**2-66**	**2-82**	**2-400**

10GBASE-SR operating range for various multimode fiber sizes

To address the operating range concern, a new multimode fiber specification had to be created for 10GbE to achieve multimode fiber operating distances of 300 m (as specified in the TIA/EIA-568 and ISO/IEC 11801 cabling standards). This new fiber is referred to by some as "10 Gigabit Ethernet multimode fiber" and is an 850 nm, laser-optimized, 50/125 micron fiber with an effective modal bandwidth of 2000 MHz*km and is detailed in TIA-492AAAC. Its key difference, relative to legacy multimode fibers, are the additional requirements for DMD specified in TIA-492AAAC enabled by a new measurement standard for DMD (TIA FOTP-220). As shown in the table, this fiber can achieve 400 m of distance with a 10GBASE-SR interface. Many leading optical fiber vendors are actively marketing this new multimode fiber for 10GbE applications.

2.3.2. Singlemode Fiber

Singlemode fiber is used in the LAN environment where distances between the buildings are 80 km or less. Standard singlemode fiber can address nearly any application, depending on the level of cost and complexity that an operator is willing to employ. The latter issues become more significant as higher data rates, different wavelengths, and/or longer distances are adopted.

Attenuation

> DEFINITION: **Attenuation**: Reduction in transmitted optical power. Attenuation as a function of distance in optical fiber is logarithmic. Attenuation as a function of optical wavelength is dominated by the degree to which light is scattered by the molecular structure of the optical fiber ("Rayleigh scattering").

For short fiber spans, optical transmission at 1310 nm remains an appealing option due to the price and availability of lasers at this wavelength. Several factors drive consideration of transmission at higher wavelengths, however. At higher data rates, requirements on receiver sensitivity typically grow more stringent, requiring higher received optical powers to maintain low error rates. Due to relatively high fiber attenuation at 1310 nm (see the table on the right side), maximum allowable transmission distances are reduced at 1310 nm compared to 1550 nm. At extended distances, which exceed the allowable sensitivities of optical receivers, signals in the 1550 nm region can be optically amplified (usually with an EDFA) whereas optical amplification is not commonly available at 1310 nm. As a result, 1310 nm transmission requires electrical regeneration, which is fundamentally more expensive than optical amplification.

WaveLenght (nm)	Maximum fiber attenuation per IEC 60793-2 (dB/km)	Typical cabled attenuation (dB/km)
1310	0.40	0.35
1550	0.30	0.25

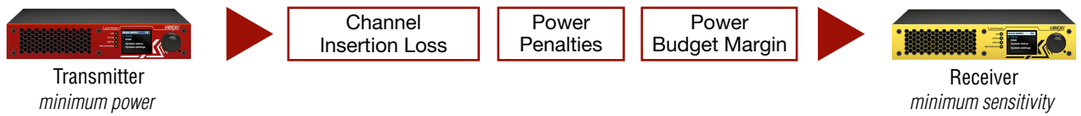
Attenuation of standard singlemode fiber at 1310 nm and 1550 nm

2.3.3. 10 Gigabit Ethernet Fiber Design Considerations

Key factors to consider in the design of 10 Gigabit Ethernet networks are:

- The network topology, including operating distances, splice losses and numbers of connectors (i.e. the link power budget).
- The fiber cabling type (i.e. singlemode or multimode fiber) and the performance at a specified wavelength. The performance is characterized by channel insertion loss (cabling attenuation), and modal bandwidth(for multimode fiber).
- The use of mode-conditioning patch cords if required. The 1310 nm CWDM solution, 10GBASE-LX4, requires the use of a mode-conditioning patch cord on multimode fiber to achieve its specified range of operating distances.
- The implementation of a cabling design, compatible with LED and laser-based Ethernet network devices, which will allow the integration of current LED based 10 Mbps and 100 Mbps networks and laser-based 1 Gbps and 10 Gbps networks.

When designing individual fiber links, the first step is the characterization of the link power budget. This value (expressed in dB) is specified in the 10GbE standard for each optical interface. Tables for all interfaces are shown in this section. The link power budget is calculated by taking the difference between the minimum transmitter power launched into the fiber, and the minimum receiver sensitivity (see the figure below). The receiver sensitivity is the minimum amount of power that is necessary to maintain the required signal-to-noise ratio over the specified operating conditions. The link power budget determines the amount of total loss due to attenuation and other factors that can be introduced between the transmitter and the receiver.



Link Power Budget = Minimum transmit power - Minimum receiver sensitivity

Link Power Budget

Link Power Budget

The 10 Gigabit Ethernet operating distances provided in the tables below are limited by the channel insertion loss, the cable bandwidth for multimode fiber, and the optical transceiver characteristics (i.e., PMD types). 10GBASE-ER distances greater than 30 km are considered “engineered links” because to support those distances the attenuation of the cable needs to be less than the maximum specified for standard singlemode fiber. Therefore, distances greater than 30 km for installed cabling should be “field-tested” for verification of conformance to the 11 dB channel insertion loss specification. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A/ method B and ANSI/TIA/EIA-526-7/ method A-1.

Parameters	10BASE-SR				
	62.5 micron MMF		50 micron MMF		
Modal Bandwidth at 850nm (MHz*km)	160	200	400	500	2000
Link power budget (dB)	7.3	7.3	7.3	7.3	7.3
Operating distance (m)	**26**	**33**	**66**	**82**	**400**
Channel insertion point (dB) [1]	1.6	1.6	1.7	1.8	2.6
Power penalty (dB) [2]	4.7	4.8	5.1	5.0	4.7

10GBASE-SR link power budget as per IEEE Draft P802.3ae/D5.0

[1] These channel insertion loss numbers are based on a wavelength of 850 nm.

[2] These power penalties are based on a wavelength of 840 nm.

Parameter	10BASE-LR
Link power budget (dB)	9.4
Operating distance (km)	**10**
Channel insertion point (dB) [3]	6.2
Power penalty (dB) [4]	3.2

10GBASE-LR link power budget as per IEEE Draft P802.3ae/D5.0

[3] These channel insertion loss numbers are based on a wavelength of 1310 nm.

[4] These power penalties are based on a wavelength of 1260 nm.

Parameter	10BASE-ER	
Link power budget (dB)	15.0	
Operating distance (km)	**30**	**40** [5]
Channel insertion point (dB) [6]	10.9	10.9
Power penalty (dB) [7]	3.6	4.1

10GBASE-ER link power budget as per IEEE Draft P802.3ae/D5.0

[5] Greater than 30 kilometers distance mandates an “engineered link” requiring “field testing” for verification of conformance to the 11 dB channel insertion loss specification. Insertion loss measurements of installed fiber cables are made in accordance with ANSI/TIA/EIA-526-14A/method B and EANSI/TIA/EIA-526-7/Method A1.

[6] These channel insertion loss numbers are based on a wavelength of 1550 nm.

[7] These power penalties are based on a wavelength of 1565 nm and other penalties.

Parameters	10BASE-LX4			
	62.5 micron MMF	50 micron MMF		SMF
Modal bandwidth as measured at 1300 nm (minimum, overfilled launch) (MHz*km)	500	400	500	-
Link power budget (dB)	7.5	7.5	7.5	8.2
Operating distance (m)	**300**	**240**	**400**	**10000**
Channel insertion point (dB) [8]	2.0	1.9	2.0	6.2
Power penalty (dB) [9]	5.0	5.5	5.5	1.9

10GBASE-LX4 link power budget as per IEEE Draft P802.3ae/D5.0

[8] These channel insertion loss numbers are based on a wavelength of 1300 nm for multimode and 1310 for single mode. An offset launch pad cord is assumed. The total insertion loss, when including the attenuation of the offset launch patch cord is allowed to be 0.5 dB higher than shown in the table.

[9] These power penalties are based on a wavelength of 1269 nm and other penalties.

Fiber	62.5 micron MMF		50 micron MMF			SMF
MHz*km	**160** [10]	**200**	**400**	**500**	**2000** [10]	**-**
SR/SW 850 nm	26 m	33 m	66 m	82 m	400 m	-
LR/LW 1310 nm	-	-	-	-	-	10 km
ER/EW 1550 nm	-	-	-	-	-	40 km
LX4 1310 nm	300m @ 500Mhz*km [11]		240 m	400 m	-	10 km

10GbE supported fiber and distances

[10] Commonly referred to as “FDDI Grade Fiber”.

[11] 62.5 micron multimode fiber has a model bandwidth of 500 Mhz*km at 1300 nm as opposed to 160 or 200 Mhz*km at 850nm.

> DEFINITION: **Modal Bandwidth**: Measure of the highest frequency signal that can be supported over a given distance of multimode fiber, as limited by modal dispersion. Modal bandwidth is typically expressed in MHz*km.

10GBASE-ER Link-loss Calculation

When designing 10GBASE-ER links greater than 30 km (i.e., the cable is not already installed) a cabling link-loss calculation, which is a simple arithmetic process, is used to make sure the combined loss of the cabling components in the link does not exceed the 11 dB channel insertion loss allocated for 10GBASE-ER. The cabling link-loss is calculated by adding the connector and splice loss to the cable loss. The cable attenuation for the link is calculated by multiplying the link distance by the loss per unit distance specified for the fiber (e.g., dB/km).

As shown in the table below (scenario 1) given a cable attenuation of 0.225 db/km, the cable attenuation for a 40 km link is 9 dB (40 km x 0.225 = 9 dB). Assuming 2 dB for singlemode fiber connector and splice losses the link-loss is 11 dB (9 dB + 2 dB = 11 dB); which is an allowable channel insertion loss for 10GBASE-ER and would insure that this link can achieve 40 km. A similar calculation can be done for scenario 2 and 3.

Parameter	Scenario 1	Scenario 2	Scenario 3
Channel insertion point	11 dB	11 dB	11 dB
Required attenuation loss	0.225 dB/km	0.225 dB/km	0.3 dB/km [12]
Connector and splice loss	2 dB	2 dB	2 dB
Maximum distance	**40 km**	**35 km**	**30 km**

10GBASE-ER link-loss calculation examples

[12] This is the maximum fiber attenuation allowed for standerd single mode fiber at 1550 nm as per IEC 60793-2. See the table in the Singlemode Fiber section for the details.

> INFO: The 10BASE-E channel shall have attenuation between 5 and 11 dB. If required an attenuator can be added to comply with this specification.

2.3.4. Conclusion

As with previous generations of Ethernet, 10 Gigabit Ethernet requires a network designer to thoroughly understand the capabilities of his/her fiber infrastructure. With 10GbE new challenges and considerations have emerged such as the effects of chromatic and polarization mode dispersion on signal integrity. In addition, decisions may have to be made regarding whether to use singlemode or multimode fiber. This paper has introduced some basic fiber related concepts and outlined some of the key points to understand and consider when designing a 10 Gigabit Ethernet network.

> DEFINITION: **Polarization Mode Dispersion (PMD)**: Difference in propagation velocity between different optical polarization states. An optical signal can be represented by two orthogonally polarized components, each of which will travel at different velocities due to inherent geometric flaws in a length of optical fiber. Since receivers used in optical communications do not discriminate between different polarization states, the two delayed polarization components will be mixed at the receiving end. This mainly applies to singlemode fiber.

Source: https://www.10gea.org/whitepapers/optical-fiber-and-10-gigabit-ethernet/

2.4. Required Bandwidth of the Resolutions

The following table contains the bandwidth requirement when transmitting one or two AV signals together. The table is grouped by resolution, color space, and color depth. The values are in Gb/s.

				TX - HDMI IN 1																	
				No signal	1280x720p60 (720p)			1920x1080p60 (1080p)			3840x2160p30 (4K UHD 30)			4096x2160p30 (4K30)			3840x2160p60 (4K UHD 60)			4096x2160p60 (4K60)		
					YCbCr 4:2:2	RGB / YCbCr 4:4:4		YCbCr 4:2:2	RGB / YCbCr 4:4:4		YCbCr 4:2:2	RGB / YCbCr 4:4:4		YCbCr 4:2:2	RGB / YCbCr 4:4:4		YCbCr 4:2:2	RGB / YCbCr 4:4:4		YCbCr 4:2:2	RGB / YCbCr 4:4:4	
					16 bit	24 bit	30 bit	16 bit	24 bit	30 bit	16 bit	24 bit	30 bit	16 bit	24 bit	30 bit	16 bit	24 bit	30 bit	16 bit	24 bit	30 bit
TX - HDMI IN 2	No signal			N/A	0.96	1.43	1.79	2.15	3.23	4.03	4.30	6.45	8.06	4.59	6.88	8.60	8.60	12.90	16.12	9.17	13.76	17.20
	1280x720 60 Hz (720p)	YCbCr 4:2:2	16 bit	0.96	1.92	2.39	2.75	3.11	4.19	4.99	5.26	7.41	9.02	5.55	7.84	9.56	9.56	13.86	17.08	10.13	14.72	18.16
		RGB / YCbCr 4:4:4	24 bit	1.43	2.39	2.86	3.22	3.58	4.66	5.46	5.73	7.88	9.49	6.02	8.31	10.03	10.03	14.33	17.55	10.60	15.19	18.63
			30 bit	1.79	2.75	3.22	3.58	3.94	5.02	5.82	6.09	8.24	9.85	6.38	8.67	10.39	10.39	14.69	17.91	10.96	15.55	18.99
	1920x1080 60 Hz (1080p)	YCbCr 4:2:2	16 bit	2.15	3.11	3.58	3.94	4.30	5.38	6.18	6.45	8.60	10.21	6.74	9.03	10.75	10.75	15.05	18.27	11.32	15.91	19.35
		RGB / YCbCr 4:4:4	24 bit	3.23	4.19	4.66	5.02	5.38	6.46	7.26	7.53	9.68	11.29	7.82	10.11	11.83	11.83	16.13	19.35	12.40	16.99	20.43
			30 bit	4.03	4.99	5.46	5.82	6.18	7.26	8.06	8.33	10.48	12.09	8.62	10.91	12.63	12.63	16.93	20.15	13.20	17.79	21.23
	3840x2160 30 Hz (4K UHD 30)	YCbCr 4:2:2	16 bit	4.30	5.26	5.73	6.09	6.45	7.53	8.33	8.60	10.75	12.36	8.89	11.18	12.90	12.90	17.20	20.42	13.47	18.06	21.50
		RGB / YCbCr 4:4:4	24 bit	6.45	7.41	7.88	8.24	8.60	9.68	10.48	10.75	12.90	14.51	11.04	13.33	15.05	15.05	19.35	22.57	15.62	20.21	23.65
			30 bit	8.06	9.02	9.49	9.85	10.21	11.29	12.09	12.36	14.51	16.12	12.65	14.94	16.66	16.66	20.96	24.18	17.23	21.82	25.26
	4096x2160 30 Hz (4K30)	YCbCr 4:2:2	16 bit	4.59	5.55	6.02	6.38	6.74	7.82	8.62	8.89	11.04	12.65	9.18	11.47	13.19	13.19	17.49	20.71	13.76	18.35	21.79
		RGB / YCbCr 4:4:4	24 bit	6.88	7.84	8.31	8.67	9.03	10.11	10.91	11.18	13.33	14.94	11.47	13.76	15.48	15.48	19.78	23.00	16.05	20.64	24.08
			30 bit	8.60	9.56	10.03	10.39	10.75	11.83	12.63	12.90	15.05	16.66	13.19	15.48	17.20	17.20	21.50	24.72	17.77	22.36	25.80
	3840x2160 60 Hz (4K UHD 60)	YCbCr 4:2:2	16 bit	8.60	9.56	10.03	10.39	10.75	11.83	12.63	12.90	15.05	16.66	13.19	15.48	17.20	17.20	21.50	24.72	17.77	22.36	25.80
		RGB / YCbCr 4:4:4	24 bit	12.90	13.86	14.33	14.69	15.05	16.13	16.93	17.20	19.35	20.96	17.49	19.78	21.50	21.50	25.80	29.02	22.07	26.66	30.10
			30 bit	16.12	17.08	17.55	17.91	18.27	19.35	20.15	20.42	22.57	24.18	20.71	23.00	24.72	24.72	29.02	32.24	25.29	29.88	33.32
	4096x2160 60 Hz (4K60)	YCbCr 4:2:2	16 bit	9.17	10.13	10.60	10.96	11.32	12.40	13.20	13.47	15.62	17.23	13.76	16.05	17.77	17.77	22.07	25.29	18.34	22.93	26.37
		RGB / YCbCr 4:4:4	24 bit	13.76	14.72	15.19	15.55	15.91	16.99	17.79	18.06	20.21	21.82	18.35	20.64	22.36	22.36	26.66	29.88	22.93	27.52	30.96
			30 bit	17.20	18.16	18.63	18.99	19.35	20.43	21.23	21.50	23.65	25.26	21.79	24.08	25.80	25.80	30.10	33.32	26.37	30.96	34.40

Legend: < 10 Gbps 1 pc SFP+ module is enough for the transmission. < 20 Gbps 2 pcs SFP+ modules are required for the transmission. > 20 Gbps The transmission is not possible with 2 pcs SFP+ modules.

3

Installation of the UBEX Matrix

This chapter introduces the hardware requirements of the UBEX matrix and lists the required capabilities of the network switch for the best A/V performance:

3.1. Hardware Requirements

The UBEX A/V network has the following hardware requirements.

Devices:

- **Layer 3 (L3) network switch**
  - 10 GbE support
  - IGMPv2 snooping
  - Non-blocking
  - VLAN support
  - Link Aggregation Control Protocol (LACP)
- **UBEX-MMU-X200 Matrix Management Unit**
- **UBEX endpoints (transmitters, receivers, and/or transceivers)**
  - UBEX-PRO20-HDMI-F100, and/or -F110

SFP+ modules:

- **SFP+ transceiver modules for the endpoints**
  - 1 (for 10G link) or 2 (for 20G link) modules per endpoint device
  - Singlemode or multimode
  - up to 10 GbE support
- **SFP+ transceiver modules for the L3 switch**
  - 2 modules per endpoint device
  - Singlemode or multimode
  - up to 10 GbE support
- **Singlemode or multimode fiber optical cables**
  - OM3 or OM4 is recommended

If the application does not require long cable extension, DAC cables can be applied instead of the SFP+ modules and optical cables.

DAC cables:

- **DAC cables**
  - 2 cables per endpoint device
  - up to 10 GbE support

3.2. Ethernet Switch - Detailed Requirements

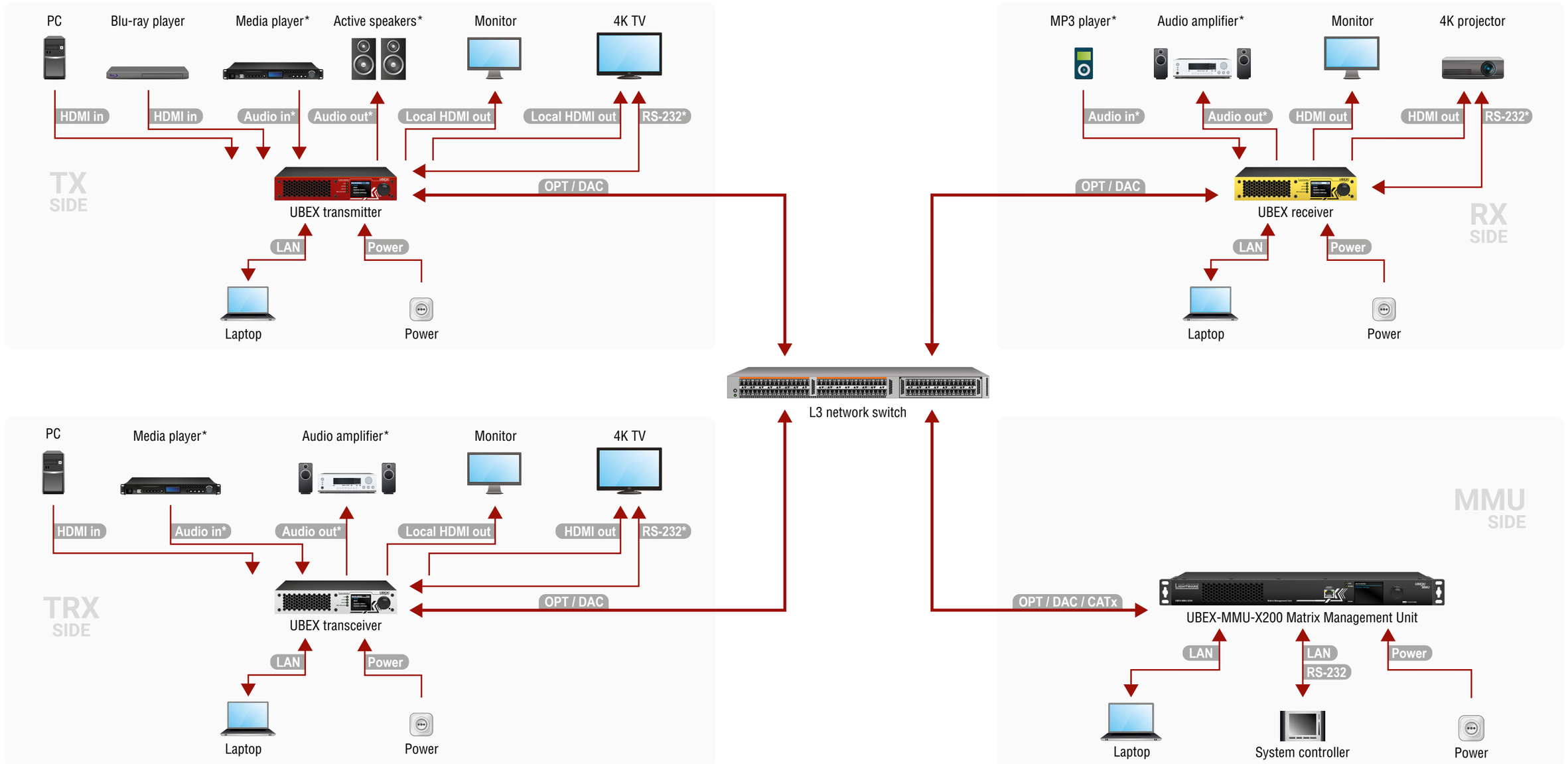
In the virtual matrix architecture, a third-party switch is used to transfer IP packets. In connection with this switch, the following criteria must be met:

- **10 Gbps non-blocking switch** (capable of full bandwidth transmission between all ports)
- Supports IEEE Std. 802.3ad-2000 **Link Aggregation Control** Protocol, with **Link Aggregation Groups for each endpoint**.
- Supports Internet Group Management Protocol version 2 (RFC 2236) snooping.
- IPv4 (or Layer 2) Multicast Forwarding based on **IGMP v2 snooping**, with at least **16 addresses available for each endpoint**, e.g. 4096 IPv4 multicast addresses for 256 endpoints.
- Supports IEEE Std. 802.1Q VLAN tagging: **1 VLAN reserved for UBEX control and media transmission**, other(s) available for user traffic.

Optional Requirements:

- Supports IEEE Std. 802.1Q (formerly 802.1p) priority code point (**PCP**), and implements priority based queuing for at least 1 prioritized traffic class. This is required to guarantee uninterrupted media transmission regardless of the user traffic.
- Supports Link Layer Discovery Protocol (**LLDP**), in order to discover network topology.
- Supports IEEE Std. 802.1s (merged into IEEE Std. 802.1Q-2005) Multiple Spanning Tree Protocol (**MSTP**), in order to detect switching loops in VLAN's.

3.3. Connections



* For the UBEX-PRO20-HDMI-**F110** endpoint model only.

4

Ethernet Switch Configuration

This chapter describes the steps of the configuration for the network switch in general terms:

> **ATTENTION!** The UBEX extenders do not support jumbo/giant frames.

4.1. Link Aggregation (LAG)

> DEFINITION: The **Link Aggregation Group** (LAG) applies to various methods of combining (aggregating) multiple network connections in parallel in order to increase throughput beyond what a single connection could sustain.

Create Link Aggregation Groups (LAG's)/EtherChannels etc. for each port pair that is used for 20 GbE transmission (LAG is not necessary for the ports which are used for 10 GbE transmission). The bonding mode is dynamic: 802.3-ad LACP has to be enabled for each group.

4.2. VLAN

> DEFINITION: A **virtual LAN** (VLAN) is any broadcast domain that is partitioned and isolated in a computer network at the data link layer (OSI layer 2). LAN is the abbreviation for local area network and in this context, virtual refers to a physical object recreated and altered by additional logic.

The UBEX network uses 802.1Q tagged frames with the VLAN ID of 286. This VLAN has to be available from each LAG, with tagged frames. The LAG's have to be in trunk mode (multiple VLAN's are available on UBEX devices, other VLAN's may be used with tagged or untagged frames).

The port where the MMU is connected is also a trunk port.

4.3. IGMPv2

> DEFINITION: **IGMP snooping** is the process of listening to Internet Group Management Protocol network traffic. The feature allows a network switch to listen in on the IGMP conversation between hosts and routers.

IGMPv2 snooping has to be enabled for each LAG in this VLAN.

4.4. Optional Configuration

Enable Link Layer Discovery Protocol (**LLDP**) on all ports to access topology information in order to speed up your installation process.

5

Configuration Steps - Ubiquiti EdgeSwitch 16 XG

The following chapter describes and explains step-by-step the procedure of the configuration for the Ubiquiti EdgeSwitch 16 XG fully managed network switch:

5.1. Description

This chapter helps you configure the Ubiquiti EdgeSwitch™ ES-16-XG fully managed switch for the UBEX matrix. This model of the Ubiquiti contains 12x 10G SFP+ slots which are enough to serve 6 UBEX endpoints and handle up to 12 source / destination devices. The switch is recommended for small businesses.

5.2. The Configuration of the UBEX Matrix

For the sake of simplicity the configuration steps of the switch are explained through a valid UBEX matrix example which contains:

Device	Pieces	Firmware version
Ubiquiti EdgeSwitch 16 XG	**1**	1.8.1 (or above)
UBEX-MMU-X200	**1**	1.0.6
UBEX-PRO20-HDMI-F100/F110	**6**	1.3.0

ATTENTION! Always check the firmware version of the network switch before starting the configuration. The required steps with older versions than v1.7.3 may differ from the following description.

5.3. First Steps

5.3.1. Installation of the UBEX Devices

The installation steps of the endpoint and the MMU devices can be found in the Connections section.

5.3.2. Installation of the Switch

Download the user's manual for the EdgeSwitch 16 XG model from the website of the vendor and follow the instructions.

Step 1. Install the switch correctly based on the instructions of the model.

Step 2. Plug the cables between the UBEX endpoints and the switch based on the following options:

- 12x 10GbE singlemode/multimode SFP+ transceiver modules and 12x singlemode/multimode fiber optical cables
- 12x 10GbE DAC cables

Step 3. Plug a CATx cable to the copper port (UBEX network) of the UBEX MMU and to one of the copper ports of the switch.

Step 4. Connect a control device (e.g. a laptop) to the switch with a CATx cable to one of the copper ports.

The factory default settings of the switch: **192.168.1.2**

Control Device Settings

Before connecting to the switch be sure the network settings of the operating system on your computer are correct. You need to set the following setting on the network card:

- IP address: must be in the in the same subnet : **192.168.1.x** with the subnet mask of 255.255.255.0)

ATTENTION! The copper ports of the switch accept 1000BaseT (1 Gbps) Ethernet connection only.

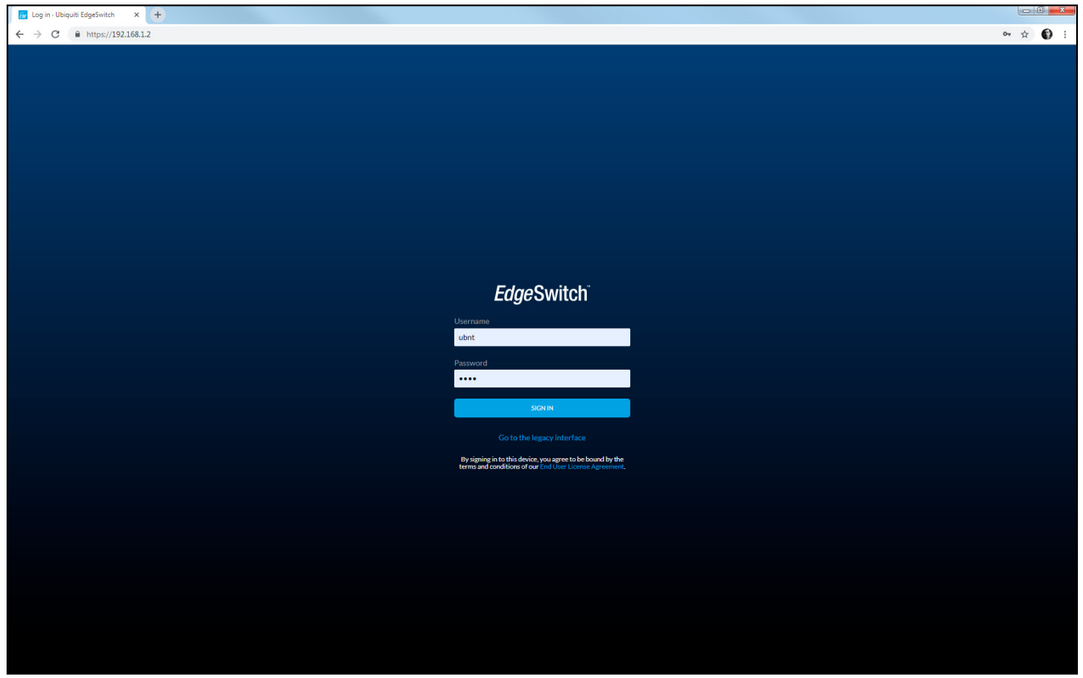
Step 5. Open a web browser on your computer and follow the configuration steps coming in the following section.

5.4. Detailed Instructions

5.4.1. Open a Web Browser

Open a web browser (e.g. Google Chrome) and enter the IP address of the switch. The login screen with the new interface appears.

You have to switch back to the legacy interface (old GUI) by clicking on the **Go to the legacy interface** link.

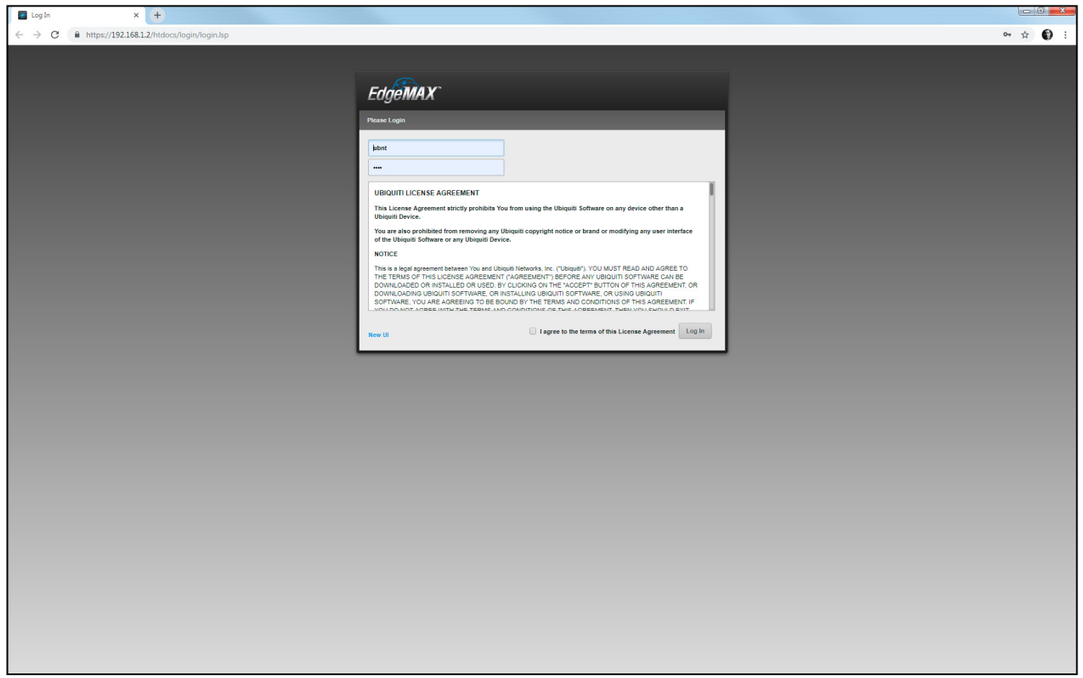


New GUI login screen of the switch

5.4.2. Login to the Switch

The login screen with the legacy interface appears. Enter the following parameters:

- **Username**: ubnt
- **Password**: ubnt



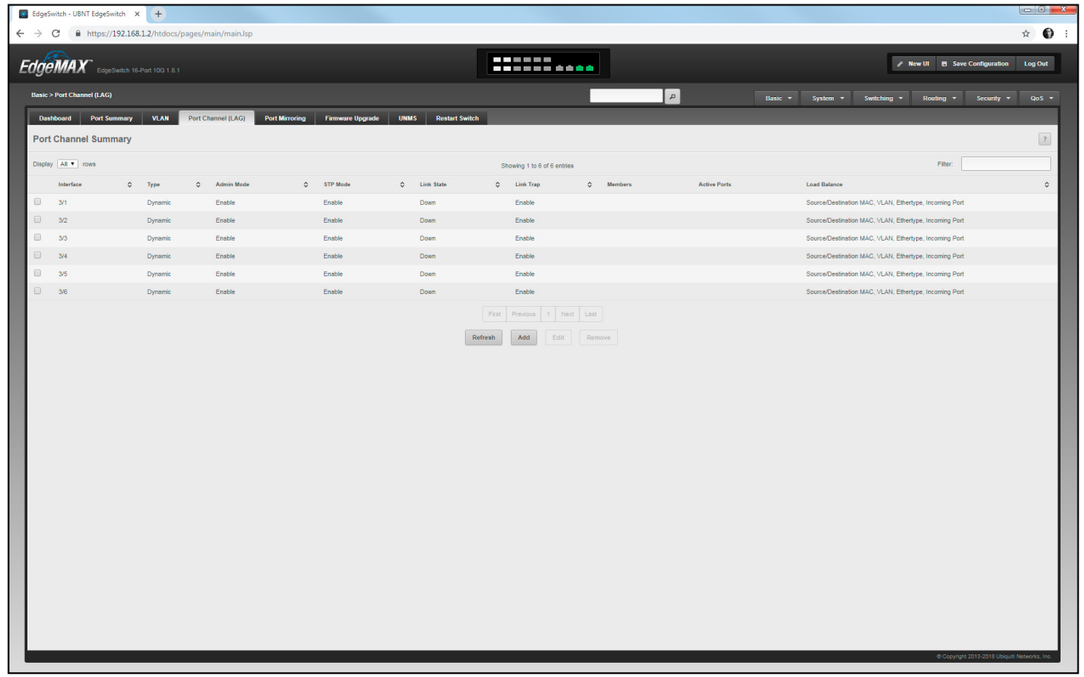
Legacy interface login screen of the switch

5.4.3. Creating LAGs

> DEFINITION: The **Link Aggregation Protocol** (LAG) applies to various methods of combining (aggregating) multiple network connections in parallel in order to increase throughput beyond what a single connection could sustain.

The UBEX endpoint devices use 2x SFP+ ports in the switch per unit. You need to create LAGs for each port pair.

Navigate to the Basic -> **Port Channel (LAG)** submenu. All ports and the current LAG states are listed here.



LAG Configuration page with no configured LAGs

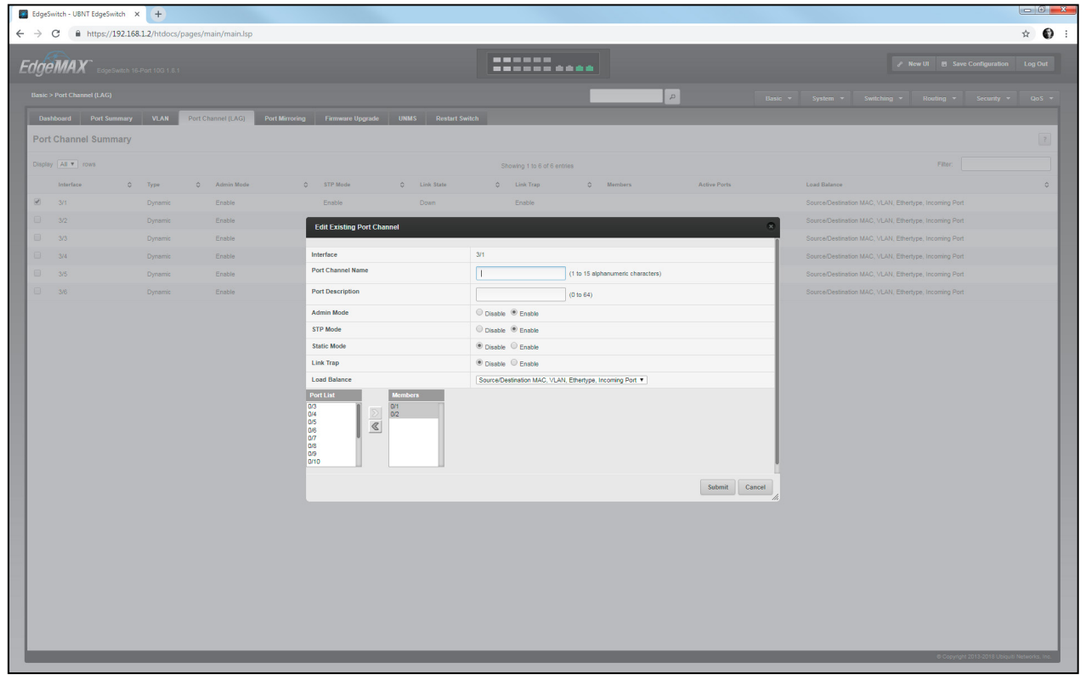
Creating LAGs

Select the port channels one by one and select the **Edit** menu. The editing window pops up, you need to add the 2 ports where the UBEX endpoints are connected to the switch and set the following values for the channel:

- Admin Mode: **Enable**
- STP Mode: **Enable**
- Static Mode: **Disable**
- Link Trap: **Disable**
- Load Balance: **Source/Destination MAC, VLAN, Ethertype, Incoming Port**

Port channel name and Port description can also be added but it is not obligatory.

When it is done, press the **Submit** button to save the configuration.



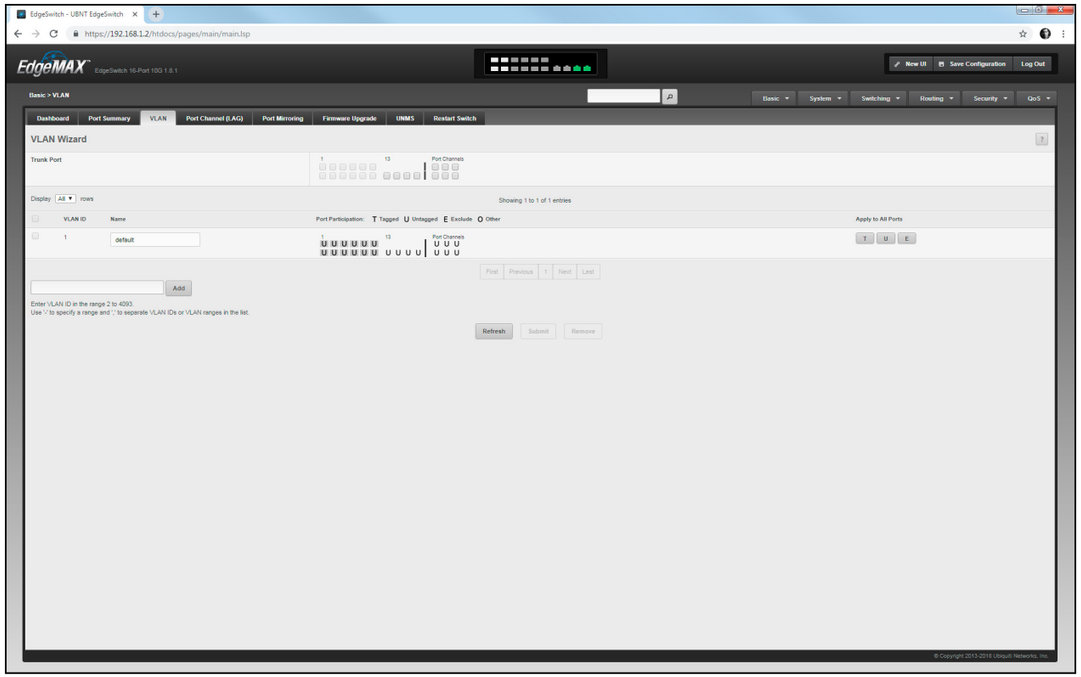
Edit Existing Port window

5.4.4. VLAN Configuration

> DEFINITION: A **virtual LAN** (VLAN) is any broadcast domain that is partitioned and isolated in a computer network at the data link layer (OSI layer 2). LAN is the abbreviation for local area network and in this context, virtual refers to a physical object recreated and altered by additional logic.

Create VLAN

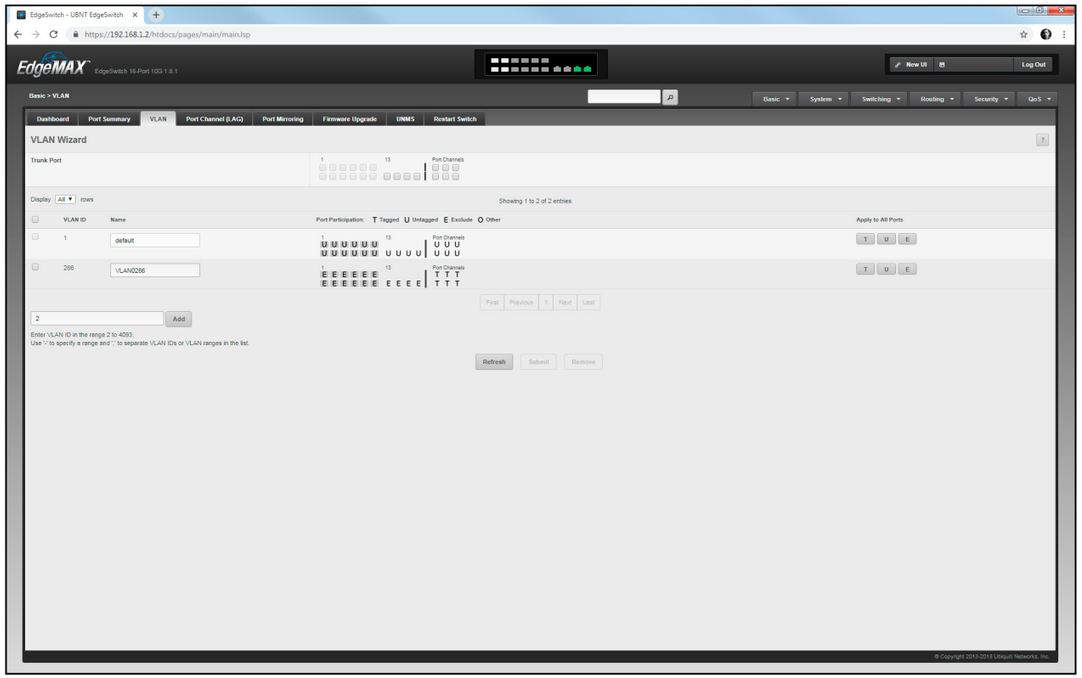
Navigate to the Basic -> **VLAN** submenu.



VLAN wizard page

Adding a New VLAN

Type to the VLAN ID the **286** and click on the **Add** button. The new VLAN appears with 286 ID. Change the port participation from Untagged (U) to **Tagged (T)** in the Port Channels section.



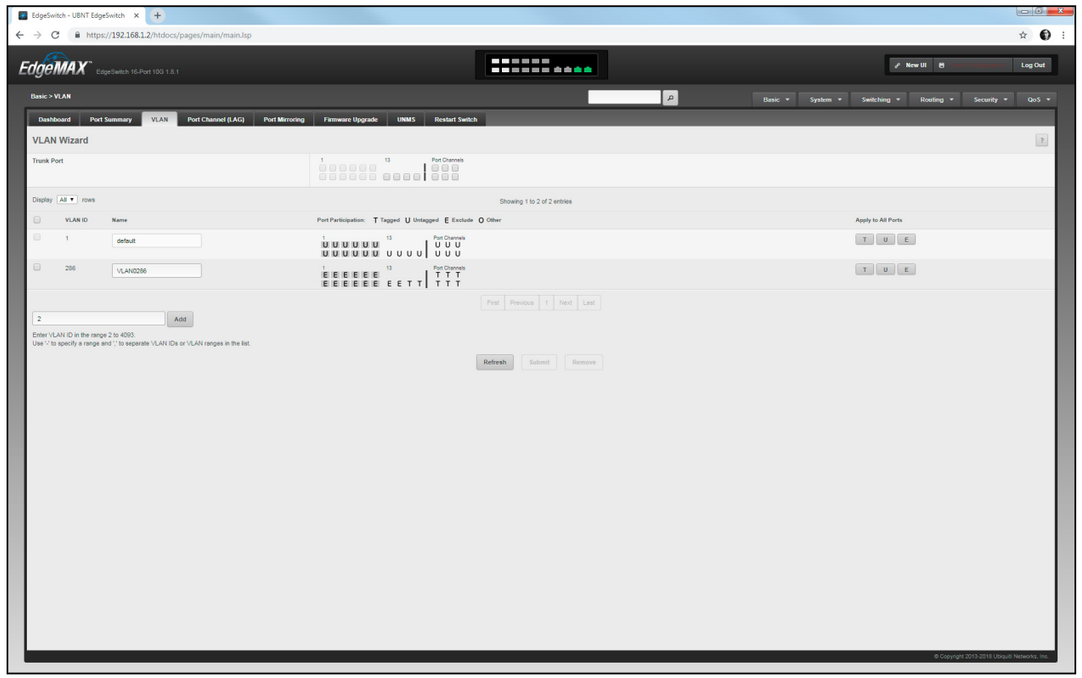
VLAN wizard page with the new VLAN

> **ATTENTION!** Do not enable **Trunk port** for the Port channels. If it is enabled, disable it.

Add the MMU's port to the UBEX VLAN

Change the port participation from Exclude (E) to **Tagged (T)** on the port where the MMU connects to the switch - this is the copper port 16 in our example. Also add the port where the control device (e.g. laptop) connects to the switch for enabling the user Ethernet - this is the copper port 15 in our example.

When it is done, press the **Submit** button to save the configuration.



VLAN wizard page with the final configuration

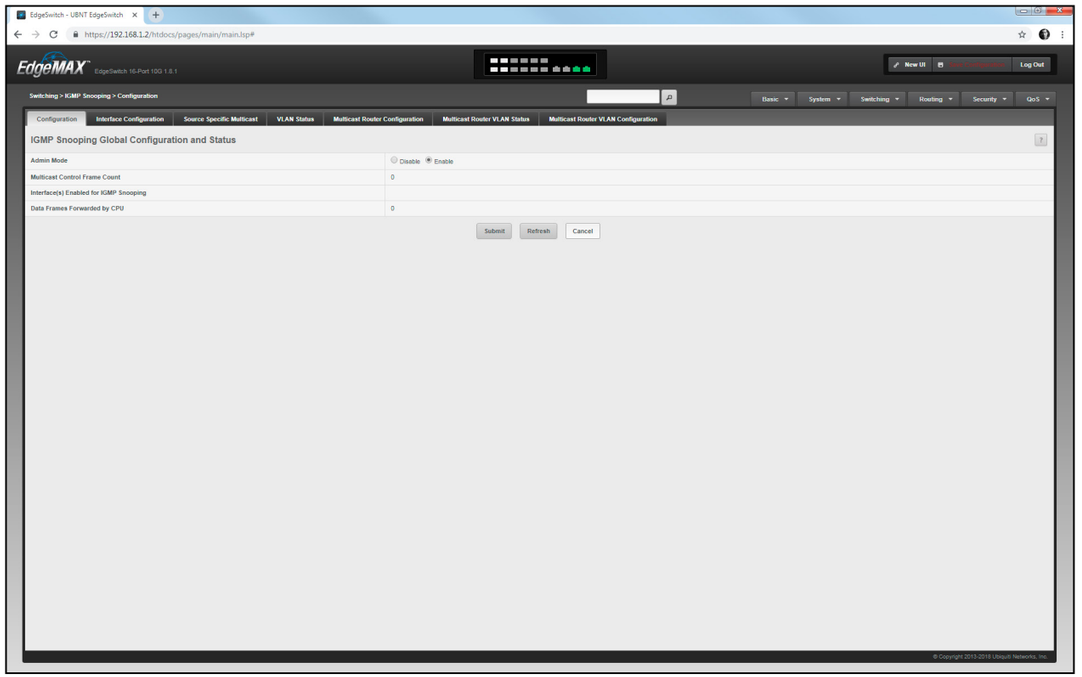
ATTENTION! Do not enable **Trunk port** for the Port channels. If it is enabled, disable it.

5.4.5. IGMPv2 Snooping

> DEFINITION: **IGMP snooping** is the process of listening to Internet Group Management Protocol network traffic. The feature allows a network switch to listen in on the IGMP conversation between hosts and routers.

Configuration

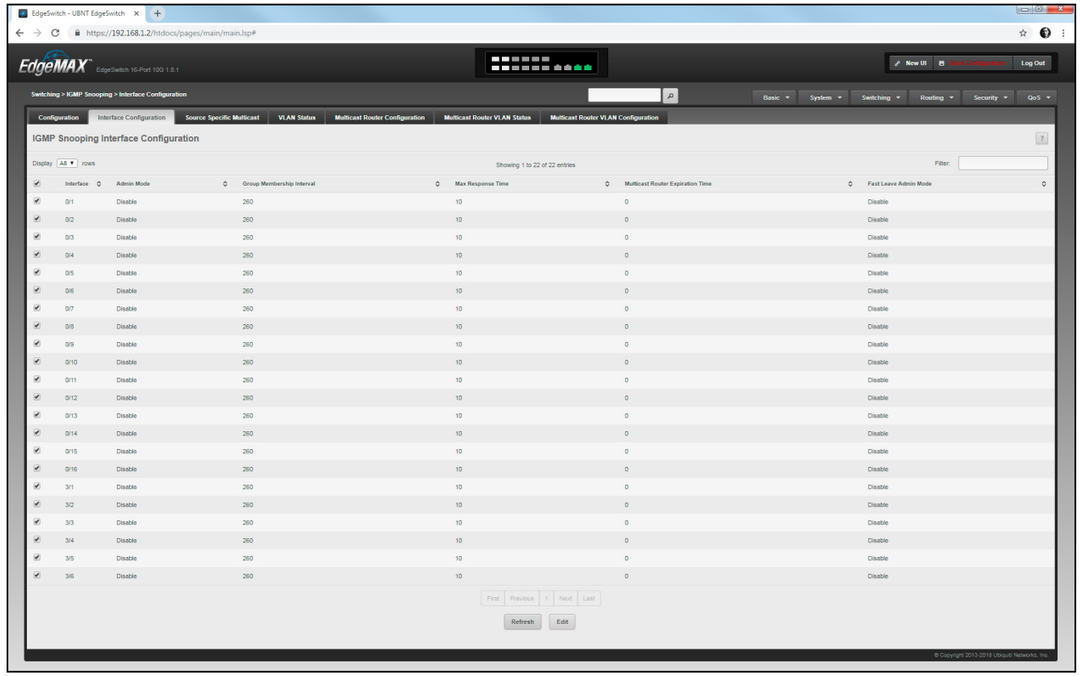
Navigate to the Switching -> IGMP Snooping -> **Configuration** submenu. Set the Admin Mode to **Enable**.



IGMP snooping configuration page

Interface Configuration

Go to the **Interface Configuration** tab. Set the **Display** to **All** rows and select all interfaces in the list. Select all ports and click on the **Edit** button.



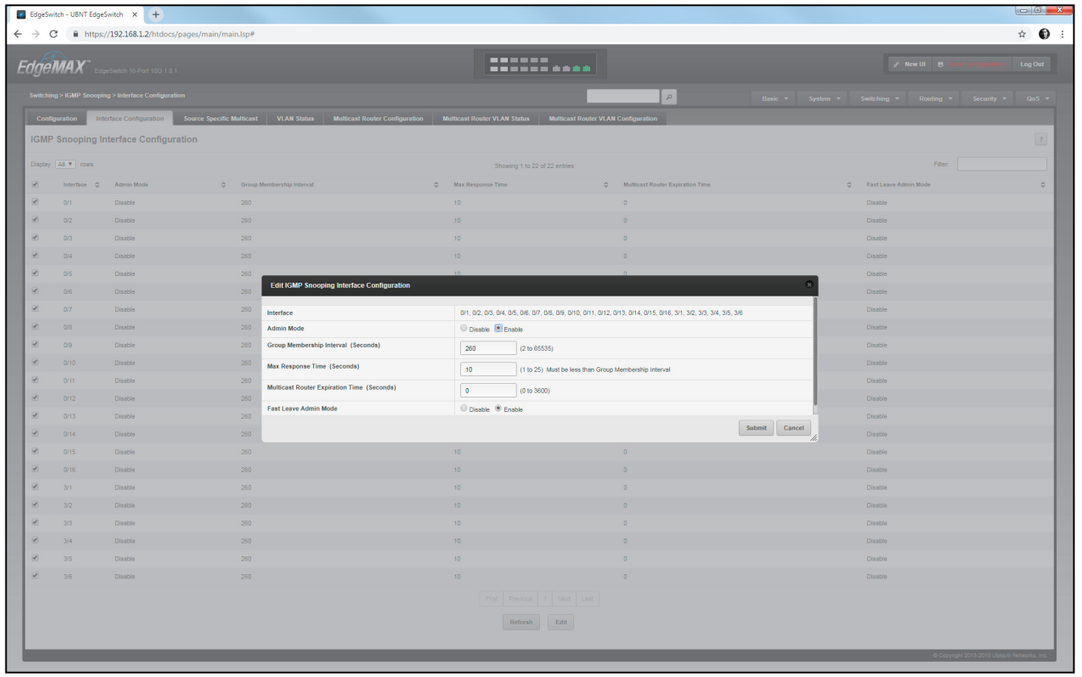
Interface configuration page

Editing the IGMP Snooping Interface Configuration

The IGMP snooping interface configuration editor appears in a new window. Set the following values for the interfaces:

- Admin Mode: **Enable**
- Group Membership Interval (Seconds): **260**
- Max Response Time (Seconds): **10**
- Multicast Router Expiration Time (Seconds): **0**
- Fast Leave Admin Mode: **Enable**

When it is done, press the **Submit** button to save the configuration.



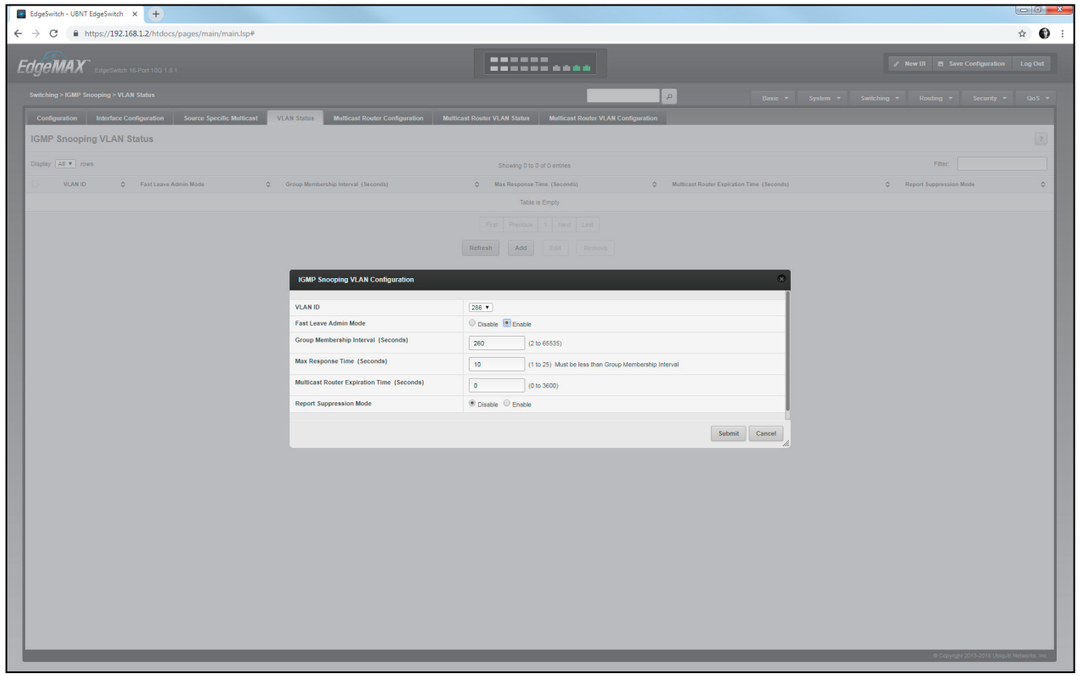
Interface configuration editor page

IGMP Snooping VLAN Configuration

Go to the **VLAN Status** tab. Click on the **Add** button to open the IGMP Snooping VLAN Configuration window. Select the **286** VLAN ID and set the following values:

- Fast Leave Admin Mode: **Enable**
- Group Membership Interval (Seconds): **260**
- Max Response Time (Seconds): **10**
- Multicast Router Expiration Time (Seconds): **0**
- Report Suppression Mode: Disable

When it is done, press the **Submit** button to save the configuration.



IGMP snooping VLAN configuration page

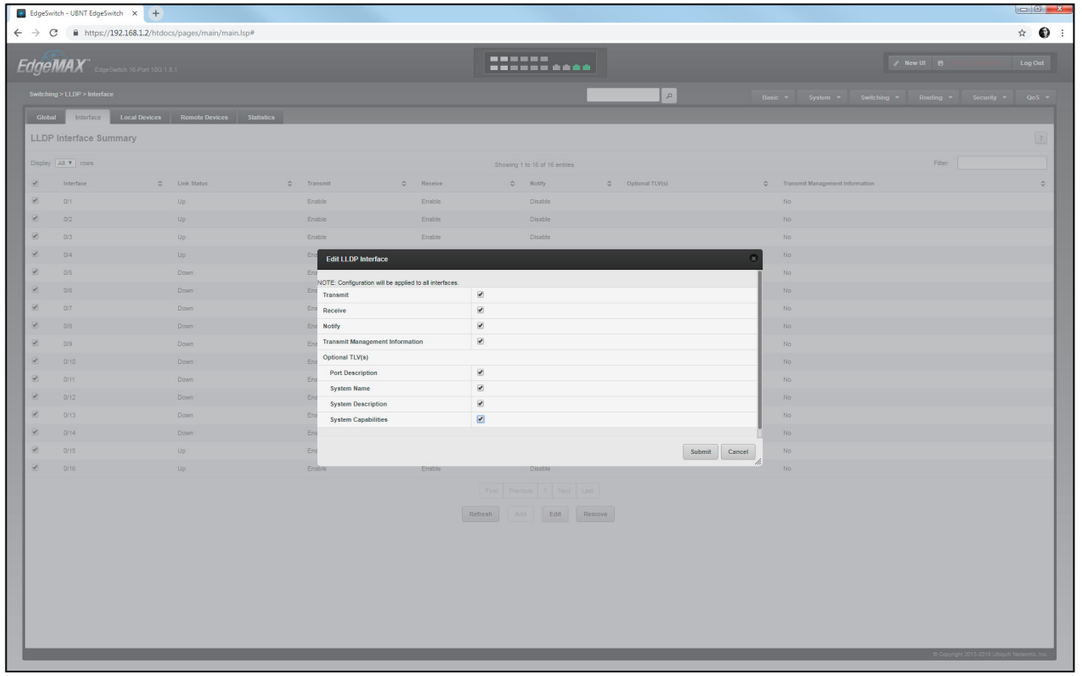
5.4.6. LLDP

> DEFINITION: The **Link Layer Discovery Protocol** (LLDP) is a vendor-neutral link layer protocol in the Internet Protocol Suite used by network devices for advertising their identity, capabilities, and neighbors on an IEEE 802 local area network, principally wired Ethernet.

Adding LLDP Interface

Navigate to the Switching -> LLDP ->**Interface** submenu. Select all interfaces and clicking on the **Edit** button opens the **Edit LLDP Interface** window. **Tick all settings** to enable them.

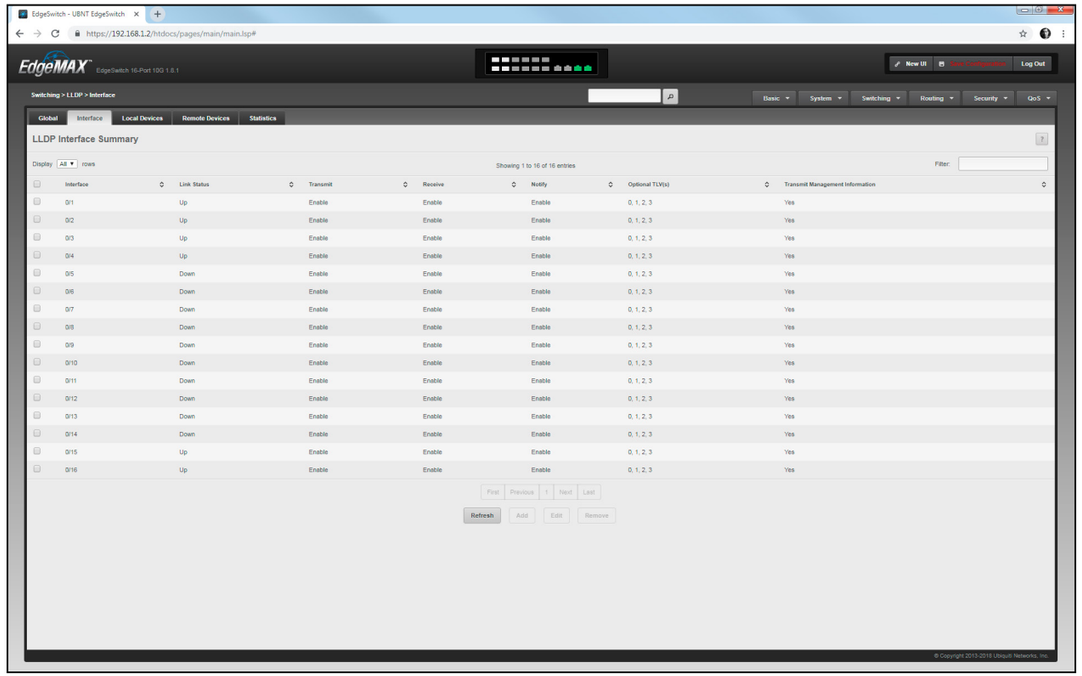
When it is done, press the **Submit** button to save the configuration.



Add LLDP Interface window

LLDP Interface Summary

After adding all interfaces you can check the list on the LLDP Interface Summary page.

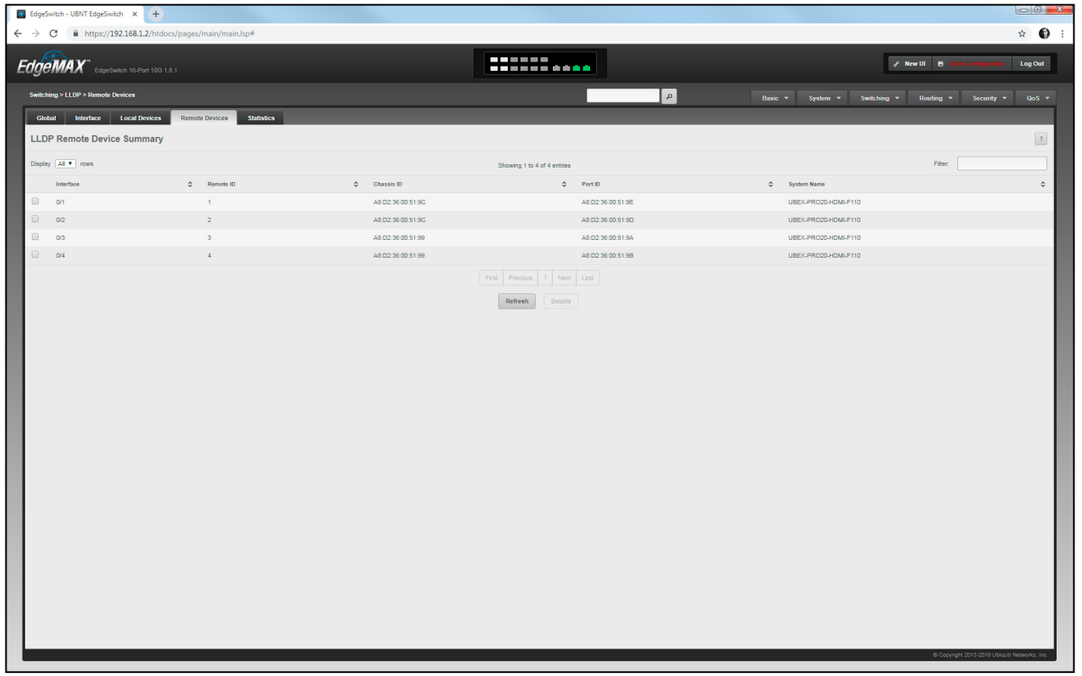


LLDP Interface Summary page

LLDP Remote Device Summary

Go to the **Remote Devices** tab.

After the UBEX endpoints and the MMU booted up you can check the presence of the devices in the LLDP Remote Device Summary page.

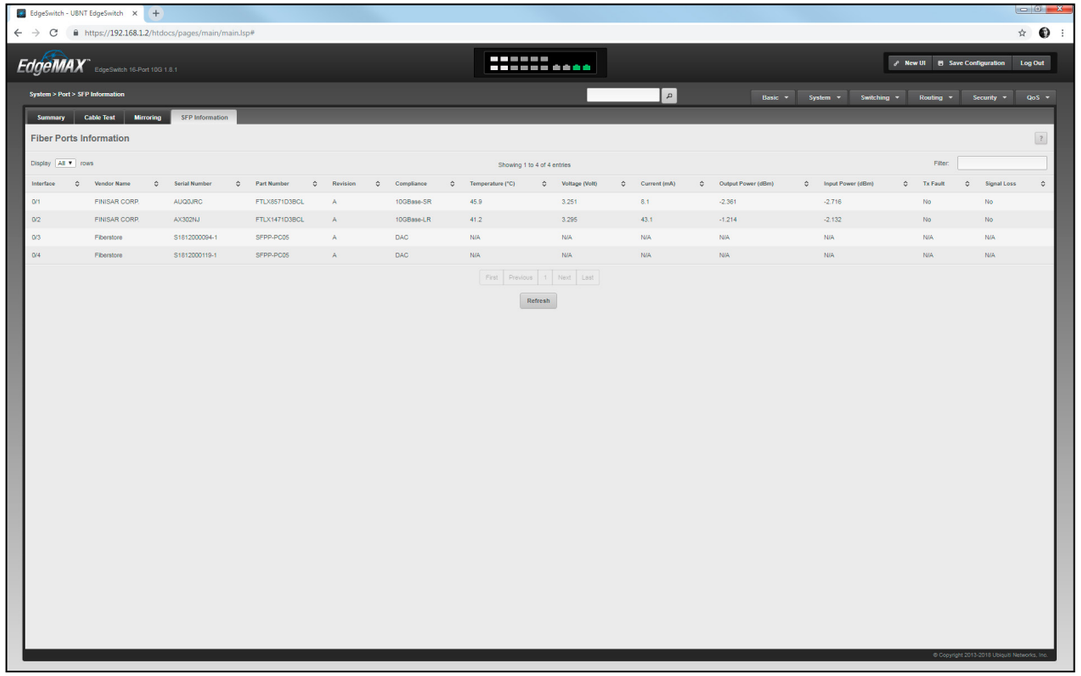


LLDP Remote Device Summary page

5.4.7. Port Transceiver Information

Navigate to the System -> Port -> **SFP information** submenu. You can check the connection interfaces by ports.

> TIPS AND TRICKS: this table can be used for debugging purpose as well. If you are sure that an SFP+ transceiver module or fiber optical cable or DAC cable is connected to a port but it is not in the table, might be the module or the cable has contact problem or it is faulty.

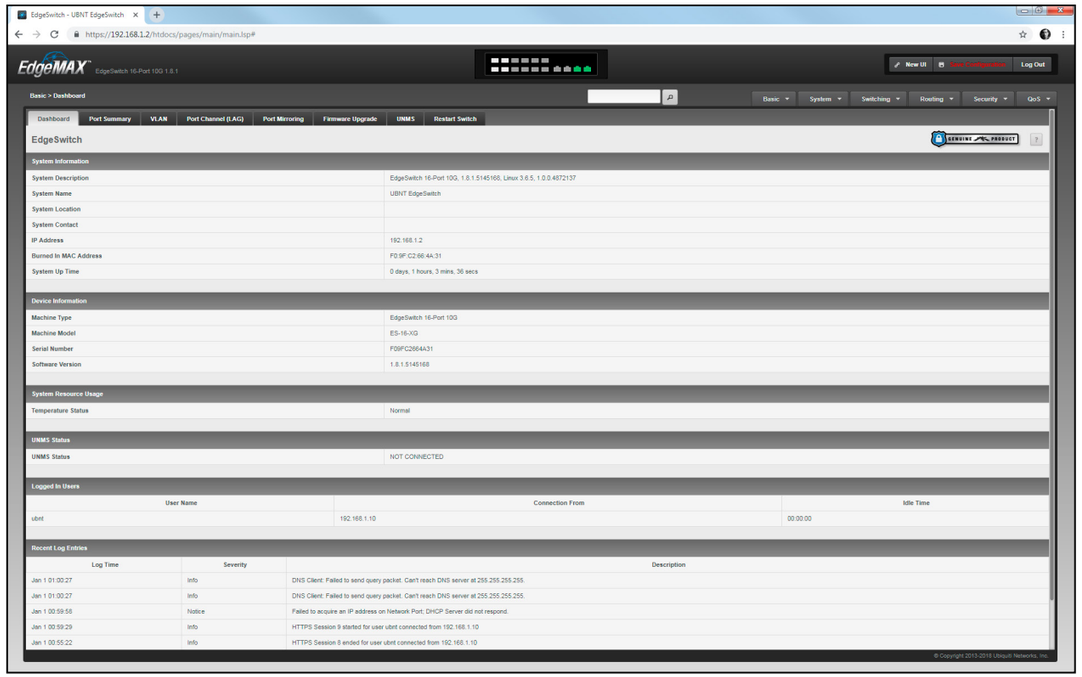


SFP information page

5.4.8. Save the Configuration

Click on the **Save Configuration** button on the upper right corner of the page to save the current configuration settings.

> **WARNING! Always save the configuration before power off the switch otherwise the settings will be lost.**



Dashboard page, the Save Configuration button on the upper right

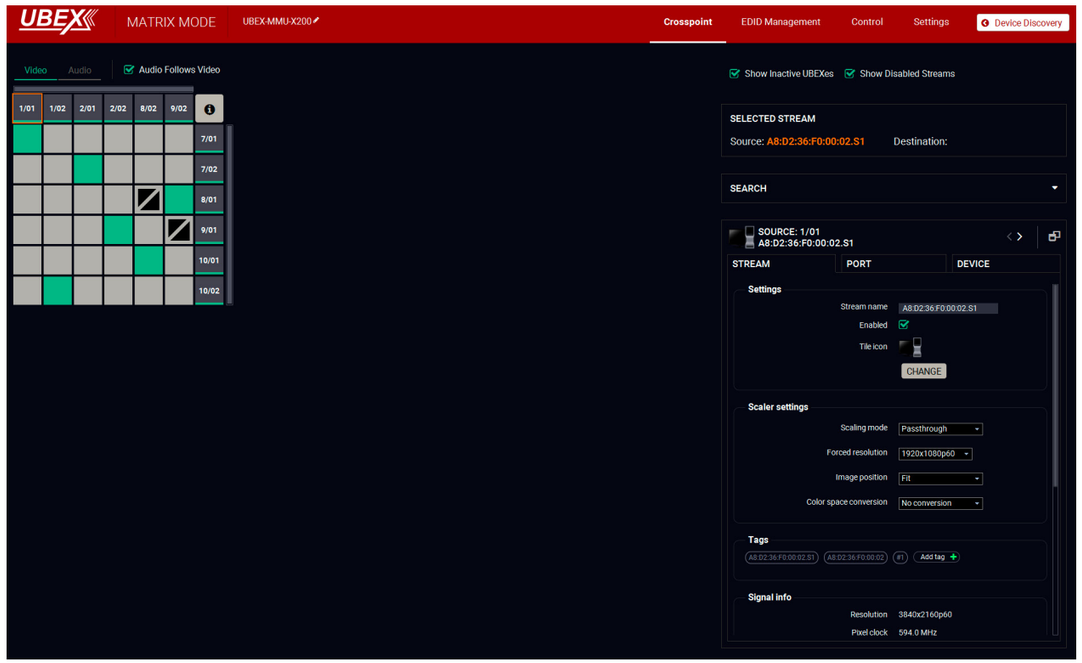
5.5. Finalizing the Matrix

The UBEX AV matrix is ready to use now.

The Lightware Device Controller software

Download the Lightware Device Controller (LDC) software from the website (www.lightware.com) to control the matrix. Install the software to a control system (e.g. a laptop). Establish the connection between the Matrix Management Unit (MMU) and the computer via Ethernet, or RS-232 interface.

Open the LDC and find the MMU in the Device discovery list. Double click on the name of the MMU to connect. The matrix crosspoint menu opens where you can configure the video system and see all information about the network.



LDC crosspoint menu

6

Configuration Steps - Netgear M4300-24X24F

The following chapter describes and explains step-by-step the procedure of the configuration for the Netgear M4300-24X24F fully managed network switch:

6.1. Description

This chapter helps you configure the Netgear ProSAFE® M4300-24X24F managed switch for the UBEX matrix. This model of the Netgear contains 24x 10G SFP+ slots which are enough to serve 12 UBEX endpoints and handle up to 24 source / destination devices. The switch is recommended for medium businesses.

6.2. The Configuration of the UBEX Matrix

For the sake of simplicity the configuration steps of the switch are explained through a valid UBEX matrix example which contains:

Device	Pieces	Firmware version
Netgear M4300-24X24F	**1**	Firmware ver.: 12.0.2.9 Boot ver.: 1.0.0.8
UBEX-MMU-X200	**1**	1.0.6
UBEX-PRO20-HDMI-F100/F110	**12**	1.3.0

6.3. First Steps

6.3.1. Installation of the UBEX Devices

The installation steps of the endpoint and the MMU devices can be found in the Connections section.

6.3.2. Installation of the Switch

Download the user's manual for the M4300-24X24F model from the website of the vendor and follow the instructions.

Step 1. Install the switch correctly based on the instructions of the model.

Step 2. Plug the cables between the UBEX endpoints and the switch based on the following options:

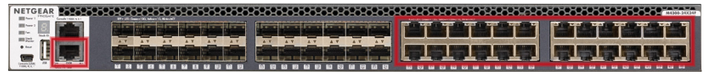
- 12x 10GbE singlemode/multimode SFP+ transceiver modules and 12x singlemode/multimode fiber optical cables
- 12x 10GbE DAC cables

Step 3. Plug the cables between the UBEX MMU and the switch based on the following options:

- 1x 1GbE singlemode/multimode SFP transceiver module and a singlemode/multimode fiber optical cable
- 1x 1GbE DAC cable
- 1x CATx cable

Step 4. Connect a control device (e.g. a laptop) to the switch with a CATx cable to one of the following ports:

- OOB port
- Any 10G copper port



The factory default settings of the switch:

- IP address of the OOB port: **192.168.0.239**
- IP address of the copper ports: **169.254.100.100**

Control Device Settings

Before connecting to the switch be sure the network settings of the operating system on your computer are correct. You need to set the following setting in the network card:

- IP address: must be in the in the same subnet : **192.168.0.x** with the subnet mask of 255.255.255.0

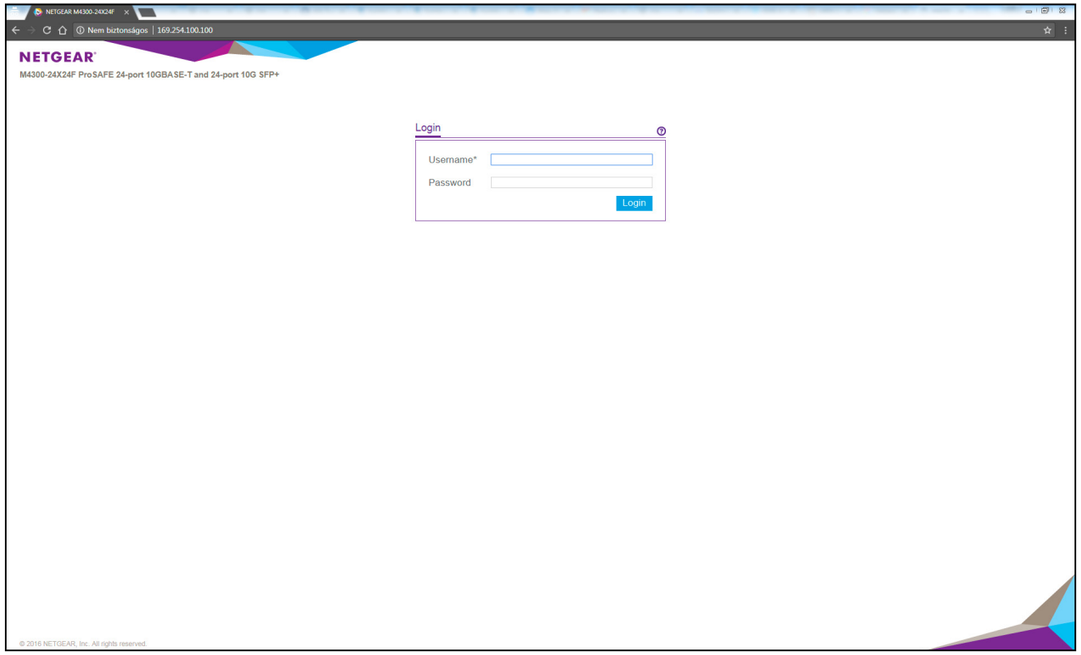
Step 5. Open a web browser on your computer and follow the configuration steps coming in the following section.

6.4. Detailed Instructions

6.4.1. Login to the Switch

Open a web browser (e.g. Google Chrome) and enter the IP address of the switch. The login screen appears. Enter the following parameters:

- **Username**: admin
- **Password**: (empty) - no password needed

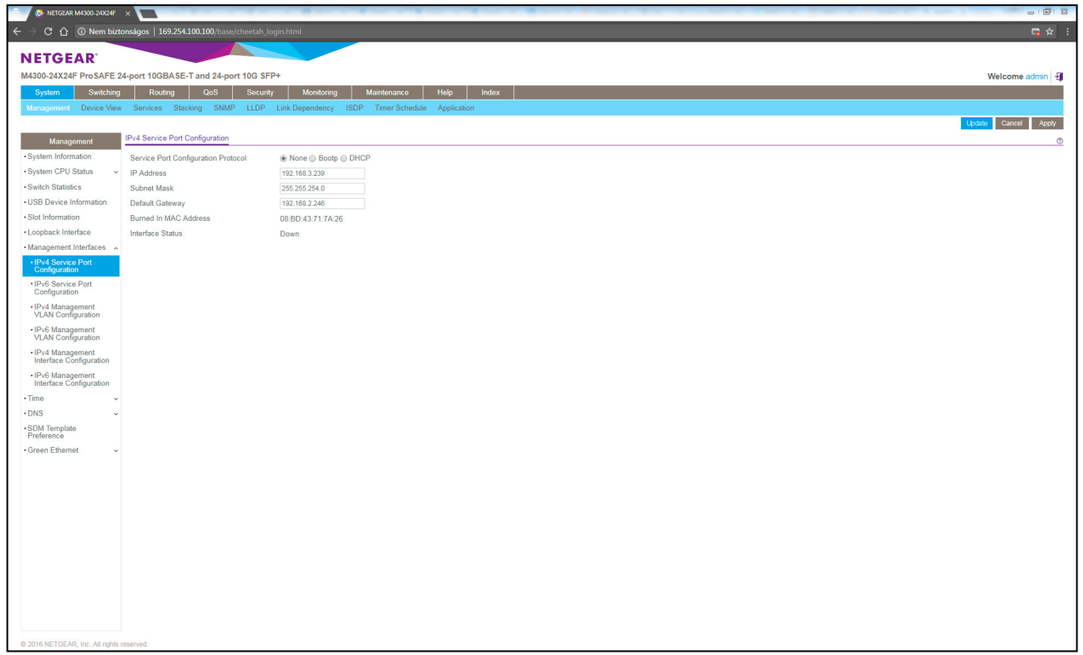


Login screen of the switch

6.4.2. IP Address Settings

You can change the default static IP address to any other one you want.

Navigate to the System -> Management -> Management Interfaces -> **IPv4 Service Port Configuration** -> submenu and check the **Service Port Configuration Protocol** to **None**. When it is done, press the **Update** button to save the configuration.



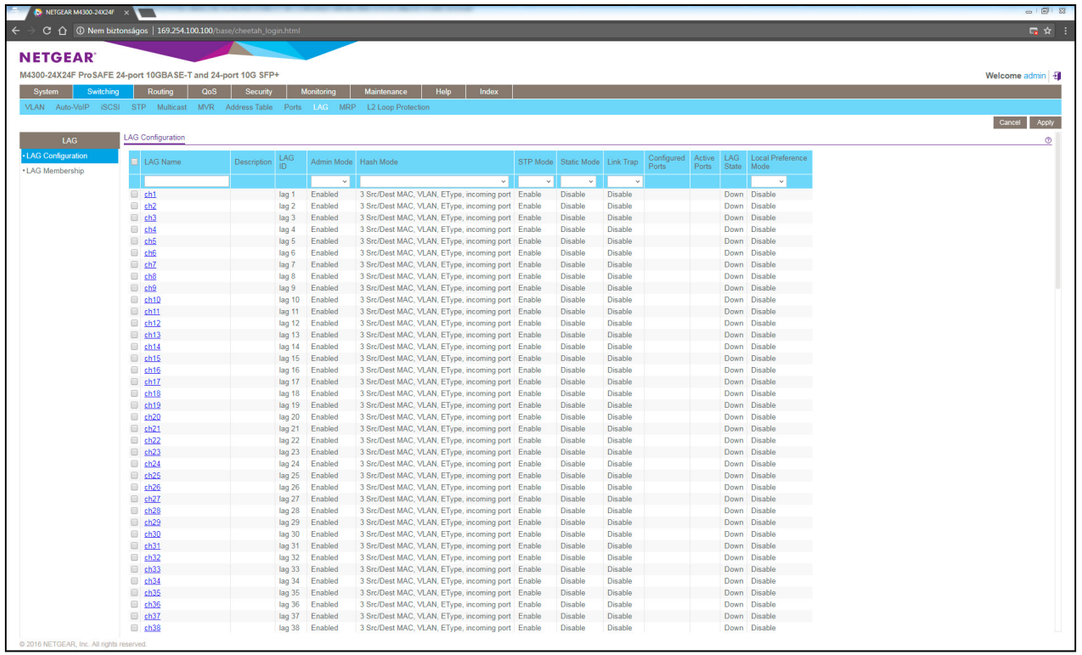
Port IP address settings page

6.4.3. Creating LAGs

> DEFINITION: The **Link Aggregation Protocol** (LAG) applies to various methods of combining (aggregating) multiple network connections in parallel in order to increase throughput beyond what a single connection could sustain.

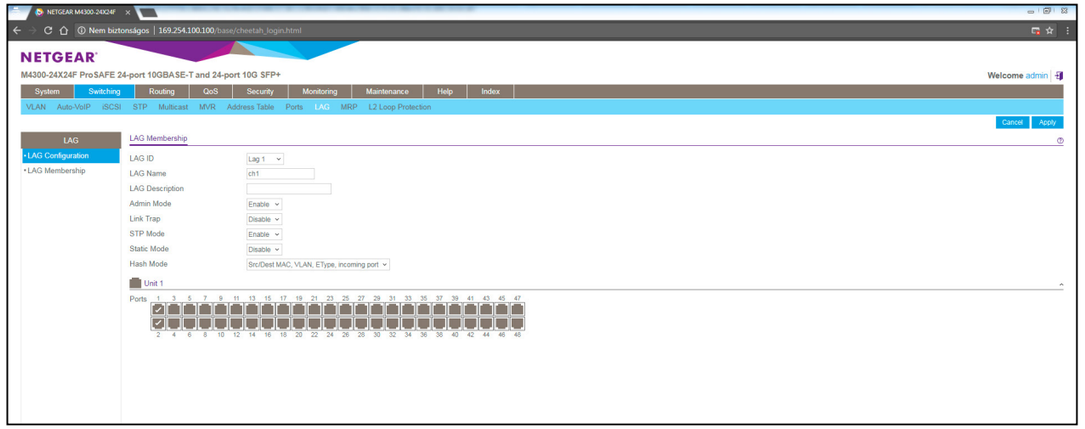
The UBEX endpoint devices use 2x SFP+ ports in the switch per unit. You need to create LAGs on the two ports.

Navigate to the Switching -> LAG -> **LAG Configuration** submenu. All ports and the current LAG states are listed here.



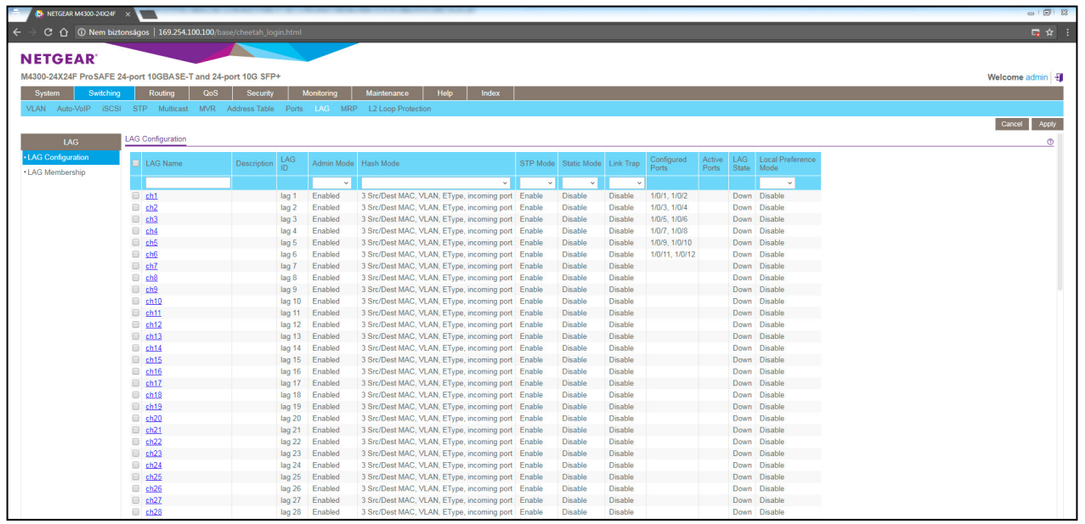
LAG Configuration page with no configured LAGs

Click on the first channel (**ch1**) to enter the LAG Membership settings page. Tick the two ports (where the two ports of the UBEX endpoint are connected to the switch) the graphic port table below. Press **Apply** when a LAG has been configured.



LAG Membership page

When all 6 LAGs for the 6 endpoints are created, check the configuration on the LAG Configuration Page in the **Configured Ports** section.

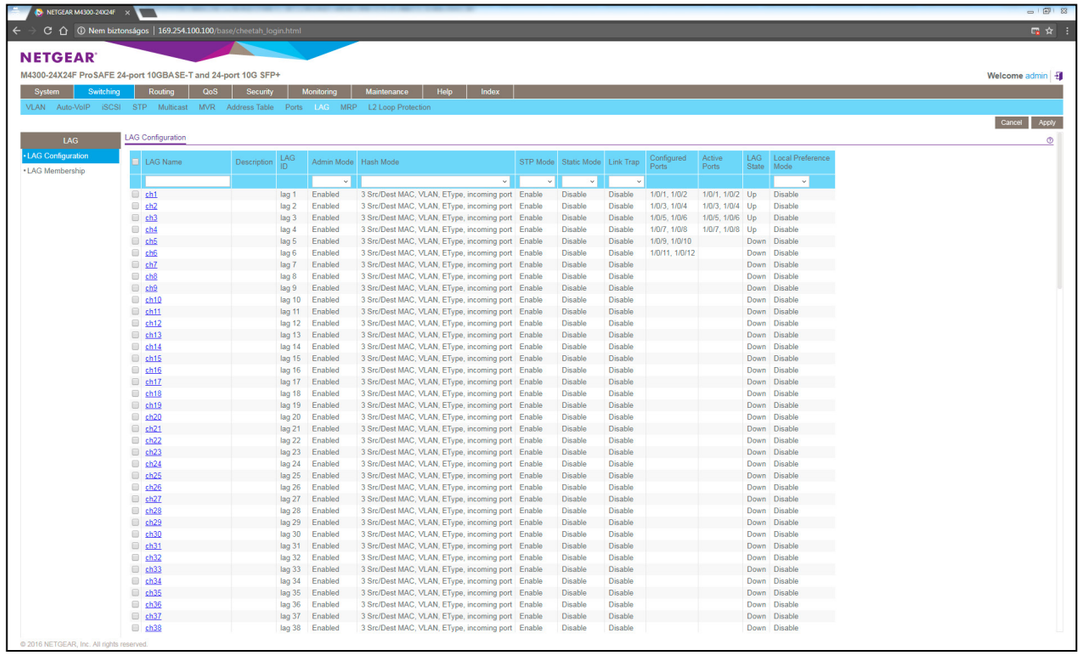


LAG Configuration page with six configured LAGs

Press the **Apply** button to save the configuration.

LAG Configuration Checking

Navigate to the Switching -> LAG -> **LAG Configuration** submenu. All ports and the current LAG states are listed here. Check the Configured Ports and Active Ports sections in the table.



LAG Configuration page

6.4.4. VLAN Configuration

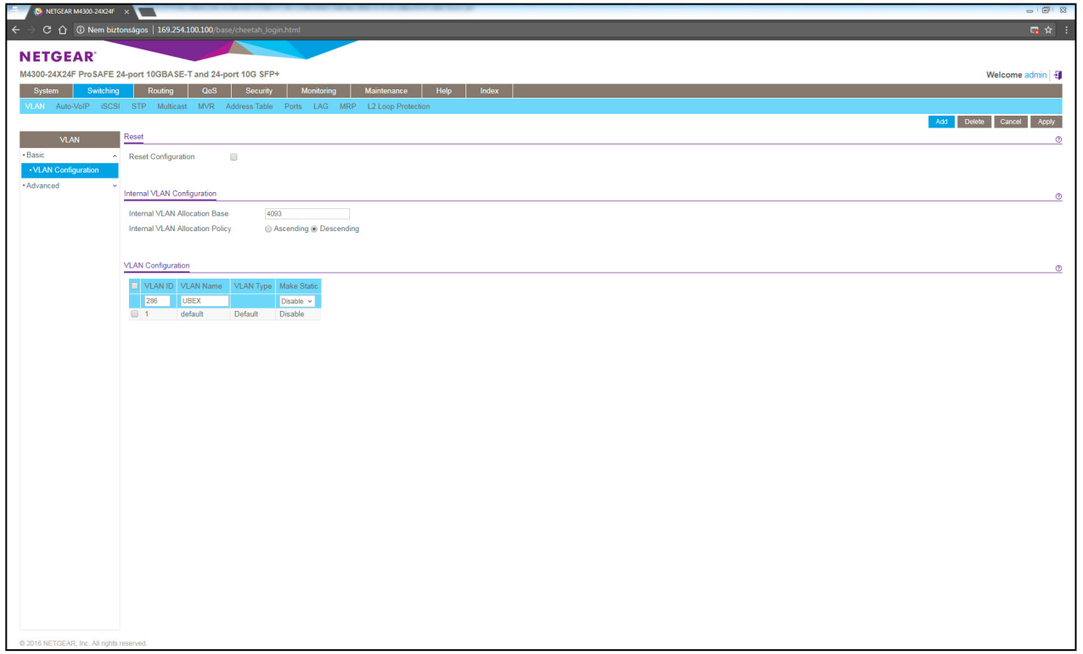
> DEFINITION: A **virtual LAN** (VLAN) is any broadcast domain that is partitioned and isolated in a computer network at the data link layer (OSI layer 2). LAN is the abbreviation for local area network and in this context, virtual refers to a physical object recreated and altered by additional logic.

Create VLAN

Navigate to the Switching -> VLAN -> Basic -> **VLAN Configuration** submenu. Create a VLAN and set the following values:

- VLAN ID: **286**
- VLAN Name: any unique name (e.g. UBEX)
- Make static: **Disable**

When it is done, press the **Add** button to save the configuration.



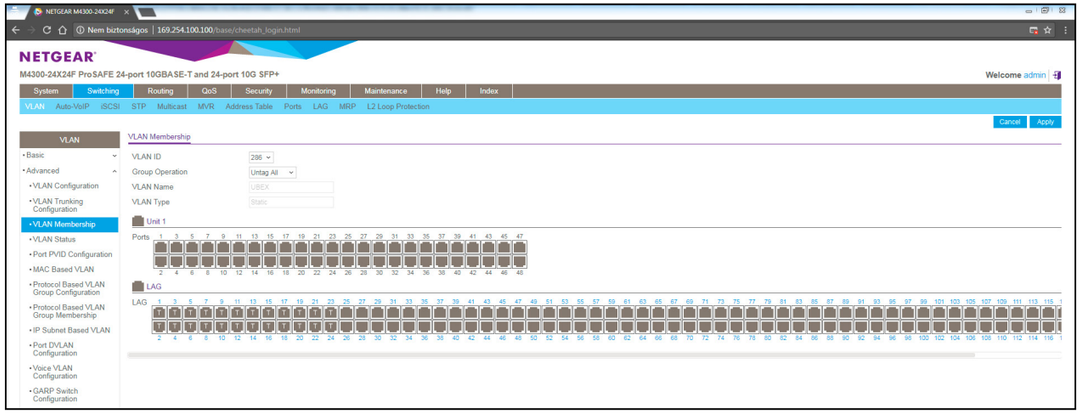
VLAN Configuration page

VLAN Membership

After that navigate to the Switching -> VLAN -> Advanced -> **VLAN Membership** submenu. Select the **286** in the VLAN ID menu.

Set all LAG's to **T** (Tagged). Also add the port where the control device (e.g. laptop) connects to the switch for enabling the user Ethernet.

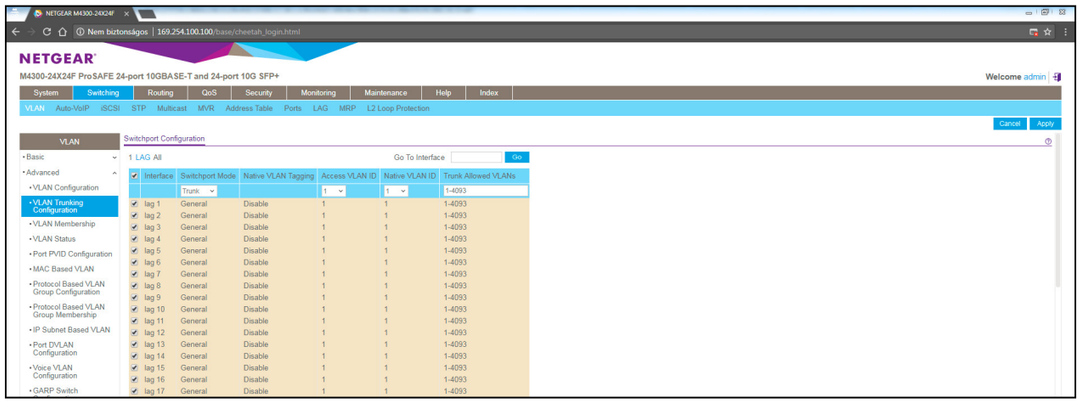
When it is done, press the **Apply** button to save the configuration.



VLAN Membership page

VLAN Trunking Configuration

Go to the Switching -> VLAN -> Advanced -> **VLAN Trunking Configuration** submenu. Select all LAGs and set the Switchport Mode to Trunk. When it is done, press the **Apply** button to save the configuration.



VLAN Trunking Configuration page

6.4.5. IGMPv2 Snooping

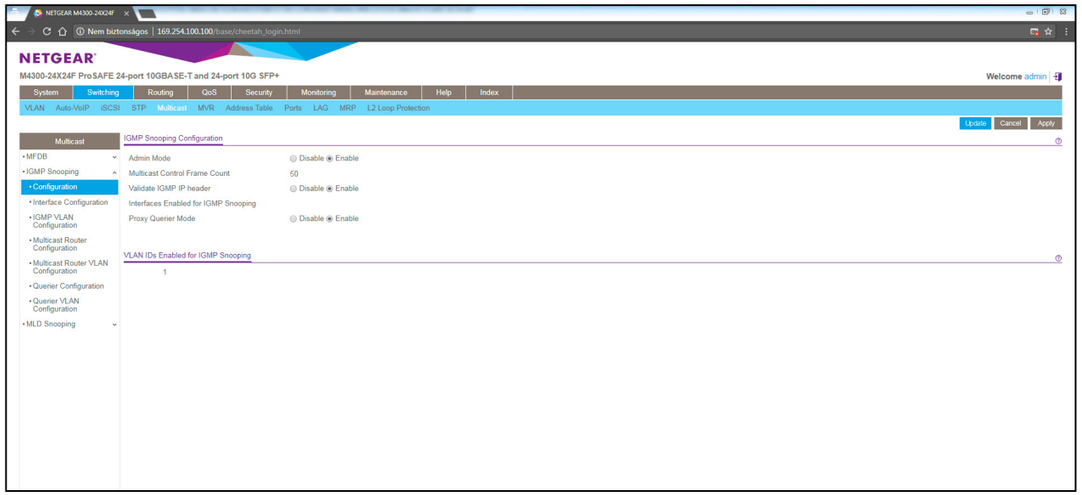
> DEFINITION: **IGMP snooping** is the process of listening to Internet Group Management Protocol network traffic. The feature allows a network switch to listen in on the IGMP conversation between hosts and routers.

Configuration

Navigate to the Switching -> Multicast -> IGMP Snooping -> **Configuration** submenu. Check the settings are set to the following values:

- Admin Mode: **Enable**
- Validate IGMP IP header: **Enable**
- Proxy Querier Mode: **Enable**

When it is done, press the **Update** button to save the configuration.



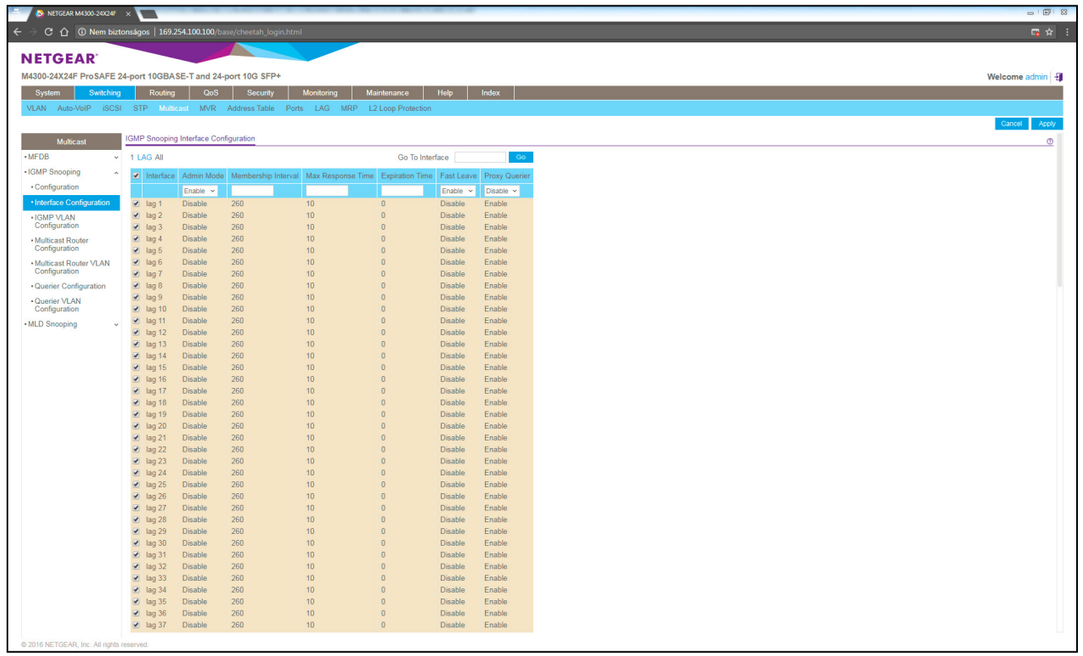
IGMP snooping configuration page

Interface Configuration

Go to the Switching -> Multicast -> IGMP Snooping -> **Interface Configuration** submenu. Select all LAGs and set the following values:

- Admin Mode: **Enable**
- Fast Leave: **Enable**
- Proxy Querier: **Disable**

When it is done, press the **Apply** button to save the configuration.



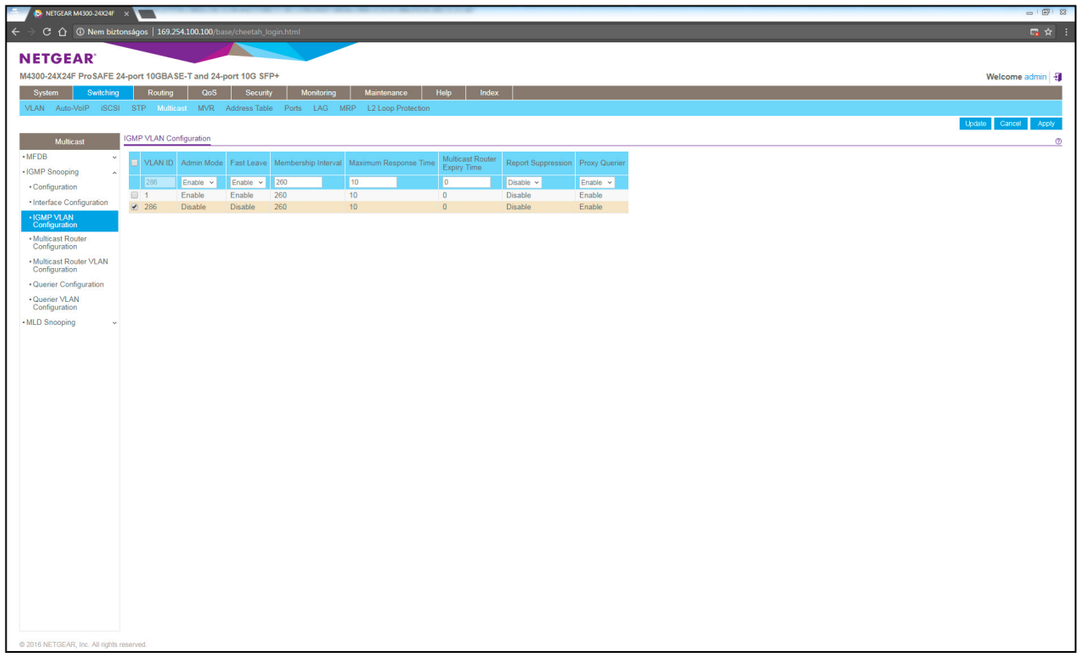
Interface Configuration Page

IGMP VLAN Configuration

Go to the Switching -> Multicast -> IGMP Snooping -> **IGMP VLAN Configuration** submenu. Select the 286 VLAN ID and set the following values:

- Admin Mode: **Enable**
- Fast Leave: **Enable**
- Membership Interval: **260**
- Maximum Response Time: **10**
- Multicast Router Expiry Time: **0**
- Report Suppression: **Disable**
- Proxy Querier: **Enable**

When it is done, press the **Apply** button to save the configuration.



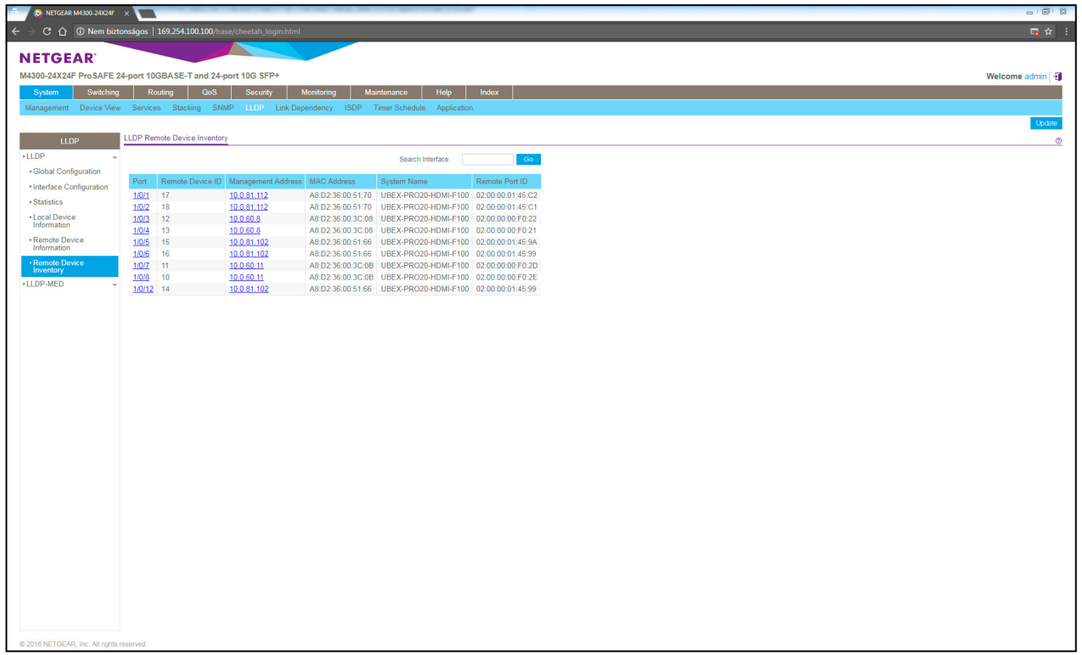
IGMP VLAN Configuration page

6.4.6. LLDP

> DEFINITION: The **Link Layer Discovery Protocol** (LLDP) is a vendor-neutral link layer protocol in the Internet Protocol Suite used by network devices for advertising their identity, capabilities, and neighbors on an IEEE 802 local area network, principally wired Ethernet.

Remote Device Inventory

Navigate to the System -> LLDP -> LLDP -> **Remote Device Inventory** submenu. Check the connected and explored devices by port or IP address.

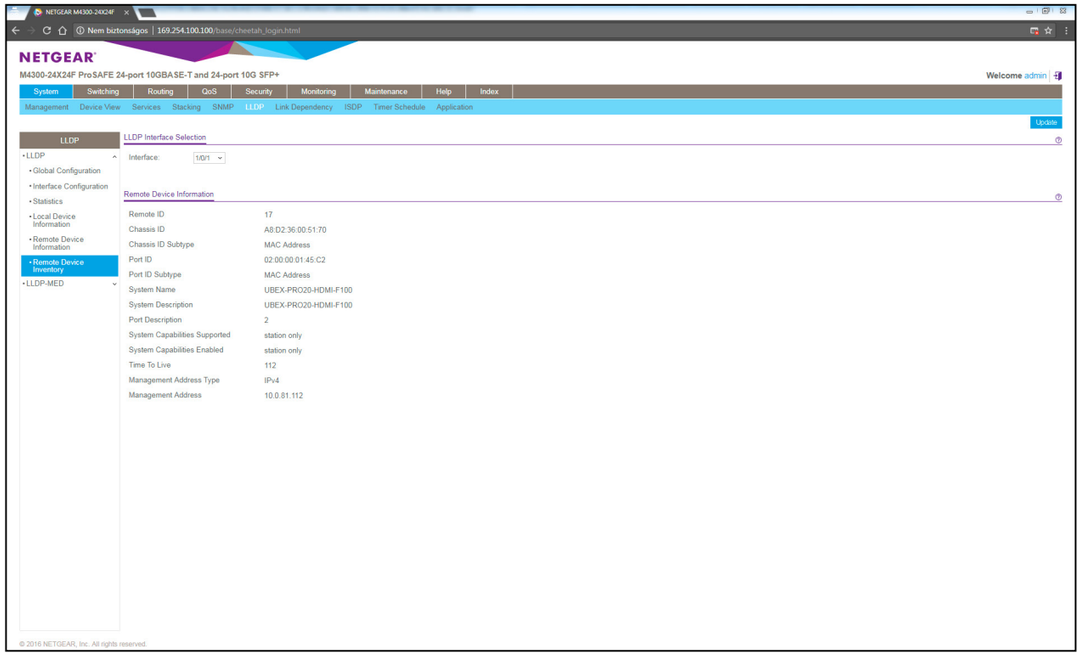


Remote Device Inventory page

> TIPS AND TRICKS: this table can be used for debugging purpose as well. If you are sure that a UBEX device is connected to a port but it is not in the table, check the SFP+ transceiver modules or the fiber optical connections or the DAC cable connections - might be the module or the cable has a contact problem or it is faulty.

Remote Device Information

Clicking on the **Port** opens the detailed information window about the remote device.

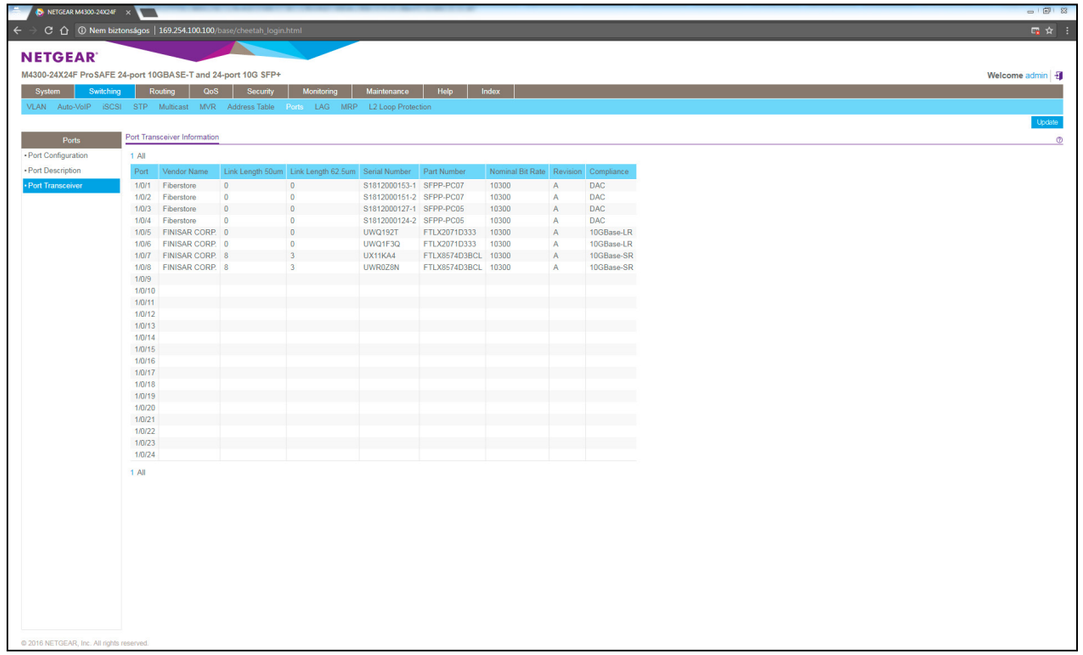


Remote Device Information page

6.4.7. Port Transceiver Information

Navigate to the Switching -> Ports -> **Port Transceiver** submenu. You can check the connection interfaces by ports.

> TIPS AND TRICKS: this table can be used for debugging purpose as well. If you are sure that an SFP+ transceiver module or DAC cable is connected to a port but it is not in the table, might be the module or the cable has contact problem or it is faulty.



Port Transceiver Information page

6.4.8. Adding the MMU to the VLAN Membership

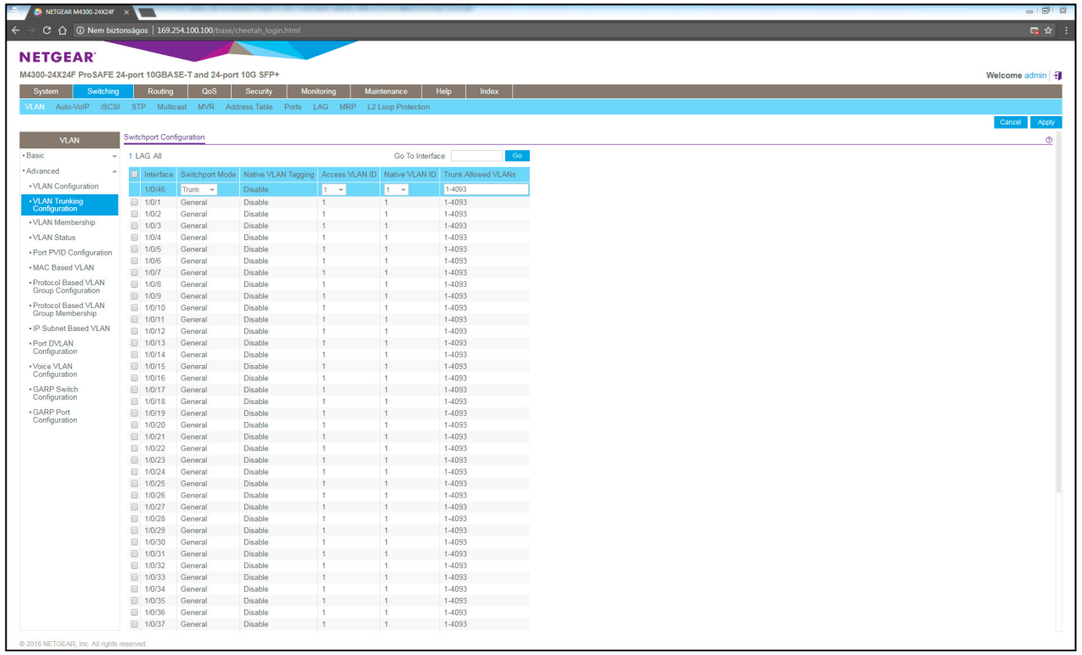
Once the MMU boots up and available, it is needed to be added to the VLAN membership.

Switchport Configuration

Navigate to the Switching -> VLAN -> Advanced -> **VLAN Trunking Configuration** submenu. Select the port of the MMU (e.g. 1/0/46) and set the following values:

- Switchport Mode: **Trunk**
- Access VLAN ID: **1**
- Native VLAN ID: **1**
- Trunk Allowed VLANs: **1-4093**

When it is done, press the **Apply** button to save the configuration.

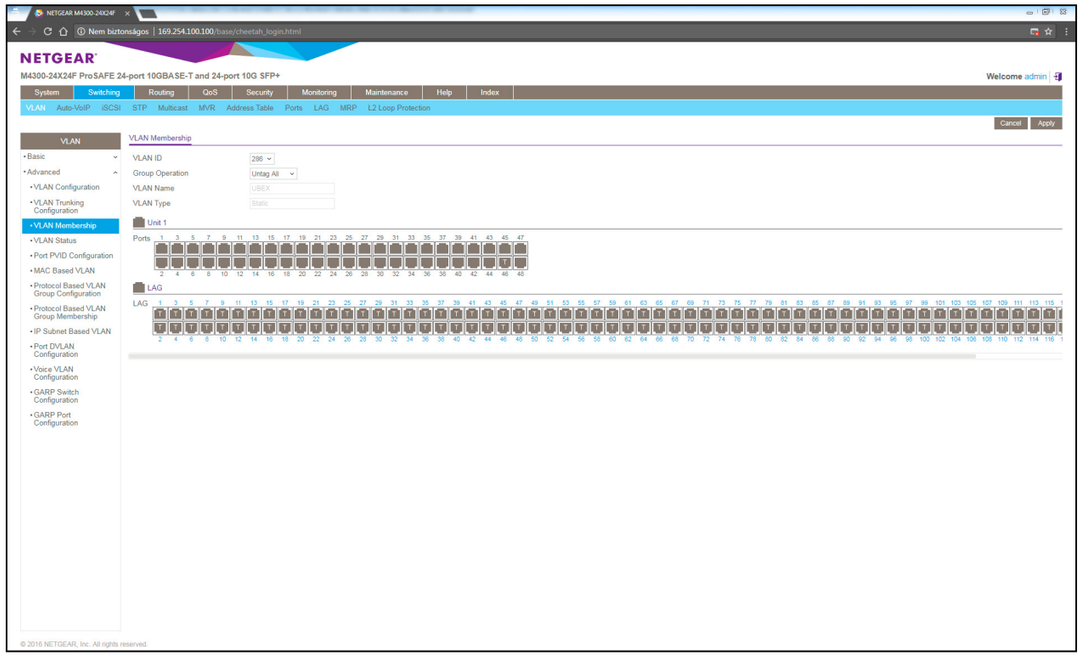


VLAN Trunking Configuration page

VLAN Membership

Go to the Switching -> VLAN -> Advanced -> **VLAN Membership** submenu. Select the **286 VLAN ID** and set all LAG's to **T** (Tagged). Select **the port in the Unit graphical layout** where the MMU is connected to the switch (e.g. 46).

When it is done, press the **Apply** button to save the configuration.

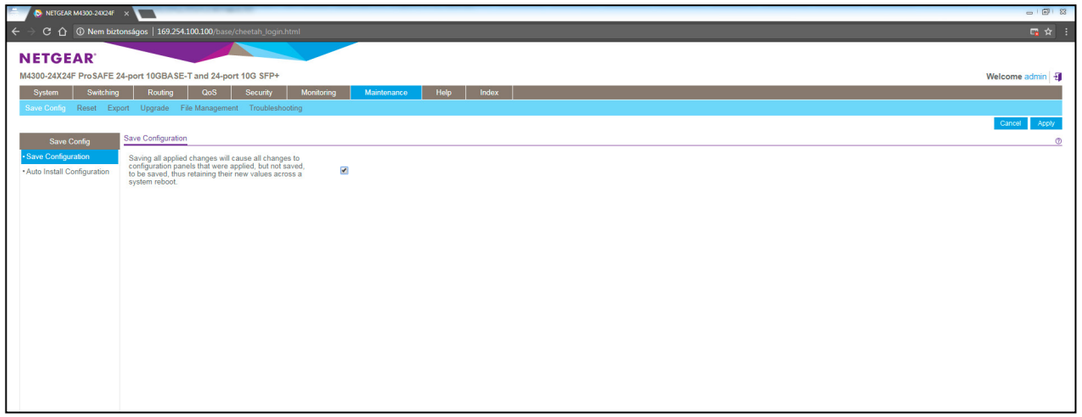


VLAN Membership page

6.4.9. Save the Configuration

Navigate to the Maintenance -> Save Config -> **Save Configuration** submenu. Tick the **Save Configuration** option and press the **Apply** button.

> **WARNING! Always save the configuration before power off the switch otherwise the settings will be lost.**



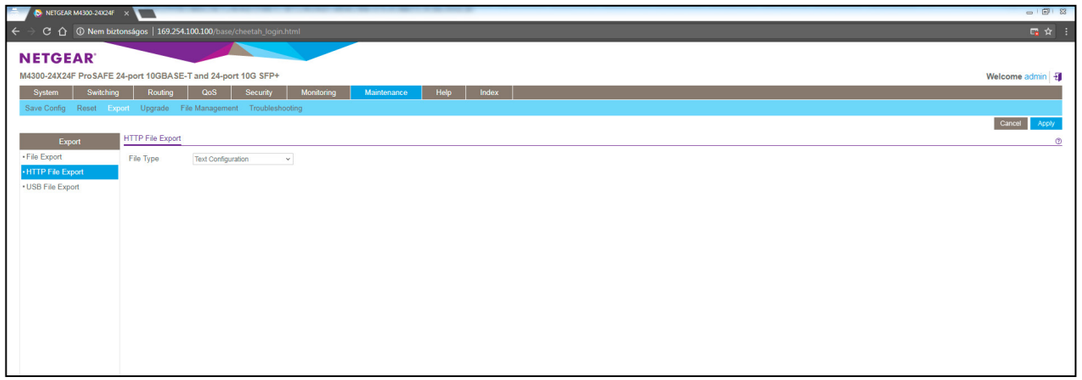
Save Configuration page

6.4.10. Export the Configuration

The configuration settings can be exported to a file and save to your local computer.

> **ATTENTION!** This safety step is highly recommended to avoid any setting loss.

Navigate to the Maintenance -> Export -> **HTTP File Export** submenu. Select a file type (e.g. Text Configuration) and save the file to a computer.



Configuration file export page

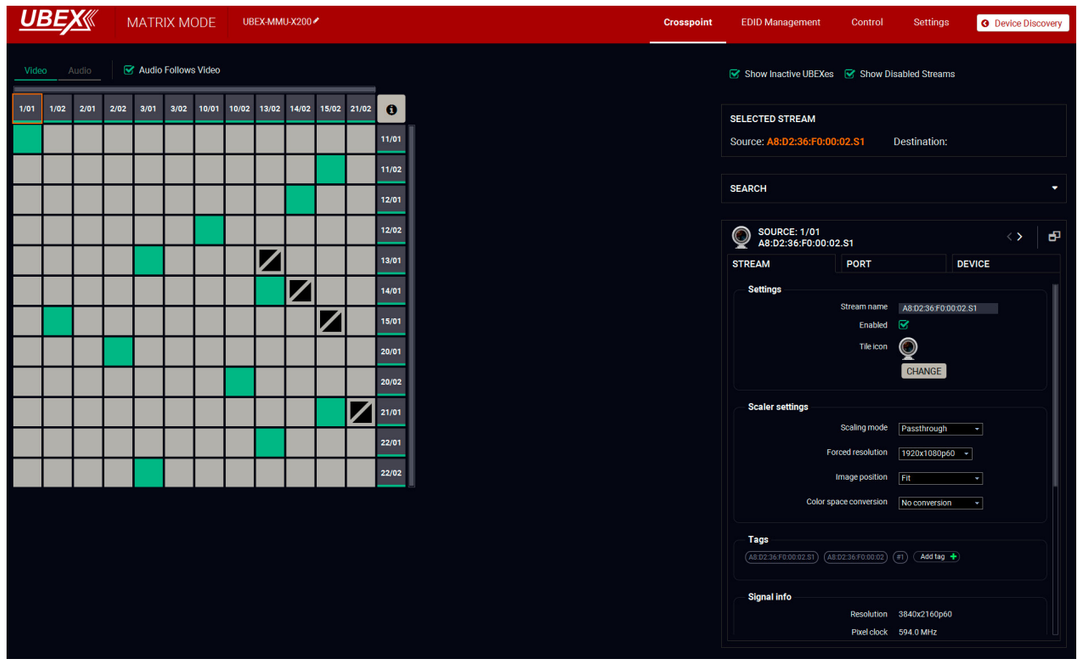
6.5. Finalizing the Matrix

The UBEX AV matrix is ready to use now.

The Lightware Device Controller software

Download the Lightware Device Controller (LDC) software from the website (www.lightware.com) to control the matrix. Install the software to a control system (e.g. a laptop). Establish the connection between the Matrix Management Unit (MMU) and the computer via Ethernet, or RS-232 interface.

Open the LDC and find the MMU in the Device discovery list. Double click on the name of the MMU to connect. The matrix crosspoint menu opens where you can configure the video system and see all information about the network.



LDC crosspoint menu

7

Configuration Steps - Cisco WS-C3850-24XS

The following chapter describes and explains step-by-step the procedure of the configuration for the Cisco Catalyst 3850 XS 10G SFP+ (WS-C3850-24XS) fully managed network switch:

7.1. Description

This chapter helps you configure the Cisco WS-C3850-24XS managed switch for the UBEX matrix. The chassis of this model contains 24x 10G SFP+ slots which are enough to serve 11 UBEX endpoints and an MMU and handle up to 22 source / destination devices. The switch is recommended for medium businesses.

The basic chassis can be upgraded with two types of expansion cards:

Expansion card	Additional SFP+slots	Additional endpoints	All endpoints
C3850-NM-4-10G	4	2	**13**
C3850-NM-8-10G	8	4	**15**

7.2. The Configuration of the UBEX Matrix

For the sake of simplicity the configuration steps of the switch are explained through a valid UBEX matrix example which contains:

Device	Pieces	Firmware version
Cisco WS-C3850-24XS	**1**	15.2
UBEX-MMU-X200	**1**	1.0.6
UBEX-PRO20-HDMI-F100/F110	**11**	1.3.0

7.3. Cisco Requirements for the Switch Configuration

Cisco Certification Program

Configuring a Cisco network switch requires the knowledge of the Cisco's own software architecture, the Cisco IOS software. This is a command-based programming language which can be applied in the switch over terminal applications, for example Putty or CLI.

Step 1. Sign up for the **Cisco Training** to get the knowledge and skill to configure the switch. Visit the following website for the available Cisco trainings:

https://www.cisco.com/c/en/us/training-events/training-certifications/overview.html

Step 2. Configurator needs the **Routing and Switching** training course - here are the details about it:

https://www.cisco.com/c/en/us/training-events/training-certifications/training-catalog/routing-switching.html#~skills

Step 3. Complete the exam and get the Cisco Network Certification about the Routing and Switching Track:

https://www.cisco.com/c/en/us/training-events/training-certifications/certifications/entry/ccent.html

7.4. First Steps

7.4.1. Configuring the Switch

At first time the switch needs to be configured locally by using the supplied RJ45 to DB9 or the USB Mini B to USB Type A adapter cable. Follow the instructions listed on the website of the vendor:

https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst3850/hardware/installation/guide/b_c3850_hig/b_c3850_hig_chapter_01001.html

Set an IP address for the Management Ethernet port (Mgmt 0) to be able to connect it and to set up the device for the UBEX network.

7.4.2. Installation of the UBEX Devices

The installation steps of the endpoint and the MMU devices can be found in the Connections section.

7.4.3. Installation of the Switch

Download the user's manual for the WS-C3850-24XS model from the website of the vendor and follow the instructions.

Step 1. Install the switch correctly based on the instructions of the model.

Step 2. Plug the cables between the UBEX endpoints and the switch based on the following options:

- 22x 10GbE singlemode/multimode SFP+ transceiver modules and 94x singlemode/multimode fiber optical cables
- 22x 10GbE DAC cables

Step 3. Plug the cables between the UBEX MMU and the switch based on the following options:

- 1x 1GbE singlemode/multimode SFP transceiver module and a singlemode/multimode fiber optical cable
- 1x 1GbE DAC cable

Step 4. Plug the cables between the switch and the possible other switch for the outgoing data traffic.

Step 5. Connect a control device (e.g. a laptop) to the switch with a CATx cable to the **1000 Base-T management Ethernet port (Mgmt 0)**:

7.4.4. Global Settings

See the details about the global settings of the switch on the website of the vendor and follow the instructions:

https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst3850/software/release/3se/system_management/command_reference/b_sm_3se_3850_cr/b_sm_3se_3850_cr_chapter_01.html#d25e837a1635

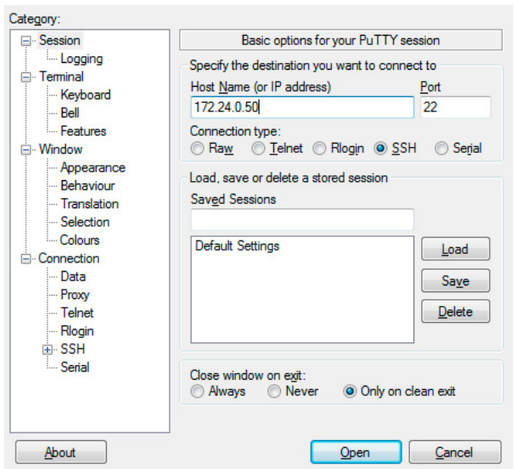
7.5. Detailed Instructions

7.5.1. Setting up the Control Device

The Cisco switch can be configured by protocol commands only. You need to install a terminal application to your control device, for example **Putty** or **CLI**.

The IP address of the switch in our example: 172.24.0.50

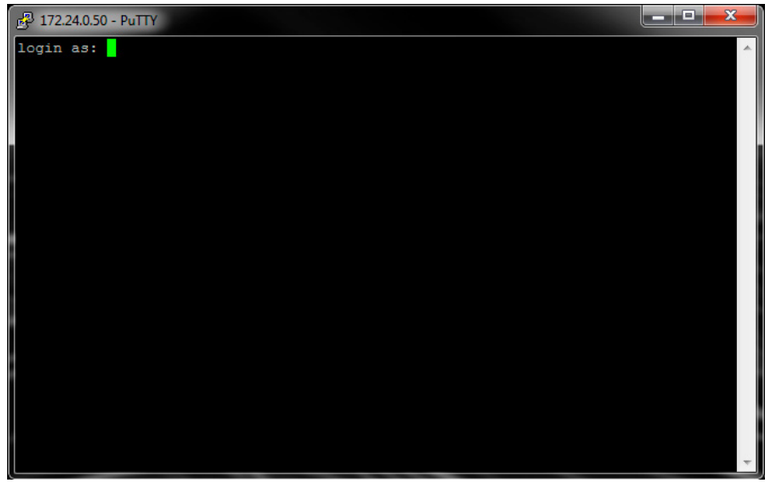
Open the terminal application (e.g. Putty), add the IP address of the switch and open it.



Putty terminal window

7.5.2. Login to the Switch

Once the terminal window is opened, you can log in to the switch by the given user name and password.



Login window in the Putty

After you logged in, the switch can be configured by protocol commands listed in the following sections.

7.5.3. IP Address Setting

The Command

Type and apply the following commands:

```
interface GigabitEthernet0/0
     vrf forwarding Mgmt-vrf
     ip address 172.24.0.50 255.255.0.0
     no ip route-cache
     negotiation auto
     exit
```

Explanation

The IP address (172.24.0.50) and subnet mask of the switch have been set for the management port (Mgmt 0).

7.5.4. Default Gateway Setting

INFO: The command required only in the case when the switch has to be accessed from different subnet.

The Command

Type and apply the following commands:

```
ip route 192.168.2.0 255.255.254.0 172.24.0.1 permanent name test-gateway
ip route vrf Mgmt-vrf 0.0.0.0 0.0.0.0 172.24.0.1 global
ip route vrf Mgmt-vrf 192.168.2.0 255.255.254.0 172.24.0.1 permanent
```

7.5.5. SSH Terminal-Line Access

If you need outbound SSH terminal-line authentication, you can configure and test SSH for outbound reverse Telnets through Putty or CLI.

The Command

Type and apply the following commands:

```
line vty 0 4
     password 12345
     login local
     transport input ssh
     exit
```

7.5.6. SSH Version Configuration

The Command

Type and apply the following command:

```
ip ssh version 2
```

7.5.7. VLAN Configuration

The Command

Type and apply the following commands:

```
vlan configuration 286
vlan 286
     name UBEX
     exit
```

Explanation

Registers VLAN number 286. Optionally a unique name can be added to the VLAN.

7.5.8. IGMP Snooping Configuration

The Command

Type and apply the following commands:

```
ip igmp snooping querier
ip igmp snooping vlan 286 querier version 2
ip igmp snooping vlan 286 querier address 10.0.0.12
ip igmp snooping vlan 286 querier query-interval 120
ip igmp snooping vlan 286 immediate-leave
```

Explanation

Enables IGMPv2 Snooping in the VLAN 286.

ATTENTION! IGMP querier v2 is required configuration setting.

7.5.9. Interface Configuration for the MMU

The Command

Type and apply the following commands:

Port ID	Command (in this example)

Port 24	`interface TenGigabitEthernet2/0/24`
	`switchport mode trunk`
	`no ip igmp snooping tcn flood`
	`exit`

Explanation

The TenGigabitEthernet2/0/24 is the last (24th) SFP+ port of the switch which is for the connection of the MMU. It is set to trunk mode and the speed (1 Gbit/s) is automatically detected when an SFP transceiver module is plugged to the SFP+ slot of the switch, no further configuration step is needed.

7.5.10. Interface Configuration for the Outgoing Data Traffic

The Command

Type and apply the following commands:

Port ID	Command (in this example)

Port 23	`interface TenGigabitEthernet2/0/23`
	`  no ip igmp snooping tcn flood`
	`  exit`

Explanation

The TenGigabitEthernet2/0/23 is the 23rd SFP+ port of the switch which is for the connection of other network switches accessing LAN and/or the Internet.

7.5.11. Port Channel Configuration for the Endpoints

The Commands

Type and apply the following commands for the desired interface ports:

Port Channel Index	Command

Port Channel 1	`interface Port-channel1`
	`  switchport mode trunk`
	`  exit`

Port Channel 2	`interface Port-channel2`
	`  switchport mode trunk`
	`  exit`

...	...

Port Channel 11	`interface Port-channel11`
	`  switchport mode trunk`
	`  exit`

Explanation

The ports between the 1 and 22 are grouped by pairs to port-channels, in this case between port-channel 1 to port-channel 11. They are set to trunk mode and the speed (10 Gbit/s) is automatically detected when an SFP+ transceiver module is plugged to the SFP+ slot of the switch

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch. In this case the **configure** command needs only once at the starting of the sequence.

7.5.12. Interface Configuration for the Endpoints

The Commands

Type and apply the following commands for the desired interface ports:

Port ID	Command

Port 1	`interface TenGigabitEthernet2/0/1`
	`  switchport mode trunk`
	`  channel-group 1 mode active`
	`  exit`

Port 2	`interface TenGigabitEthernet2/0/2`
	`  switchport mode trunk`
	`  channel-group 1 mode active`
	`  exit`

Port 3	`interface TenGigabitEthernet2/0/3`
	`  switchport mode trunk`
	`  channel-group 2 mode active`
	`  exit`

Port 4	`interface TenGigabitEthernet2/0/4`
	`  switchport mode trunk`
	`  channel-group 2 mode active`
	`  exit`

...	...

Port 21	`interface TenGigabitEthernet2/0/21`
	`  switchport mode trunk`
	`  channel-group 11 mode active`
	`  exit`

Port 22	`interface TenGigabitEthernet2/0/22`
	`  switchport mode trunk`
	`  channel-group 11 mode active`
	`  exit`

Explanation

The ports between the Ethernet2/0/1 and Ethernet2/0/22 are the SFP+ ports where the UBEX endpoints are connected to the switch.

The 'active' keyword means that the switch uses the IEEE 802.3ad-2005 Link Aggregation Control Protocol (in active mode) to combine 10G ports into 20G logical channels for the UBEX devices.

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch. In this case the **configure** command needs only once at the starting of the sequence.

7.6. Troubleshooting Commands

7.6.1. LLDP Activation

The Command

Type and apply the following command:

```
lldp run
```

7.6.2. Querying LLDP Partners

The Command

Type and apply the following command:

```
show lldp neighbors
```

Explanation

The query returns with the list of connected UBEX devices (which MAC address of the UBEX endpoint is on the ports of switch).

7.6.3. Querying LLDP Details by Ports

The Command

Type and apply the following command:

```
show lldp neighbors interface ethernet 2/0/1 detail
```

Explanation

The query returns with the details of the LLDP partner which is connected to the Ethernet2/0/1 port.

7.6.4. Switching on the Support for Unsupported SFP+ Modules

The Command

Type and apply the following command:

```
service unsupported-transceiver
```

ATTENTION! Always use high-quality SFP+ transceiver modules.

7.6.5. Querying the Details of the Installed Transceiver Modules

The Command

Type and apply the following command:

```
show interface transceiver
```

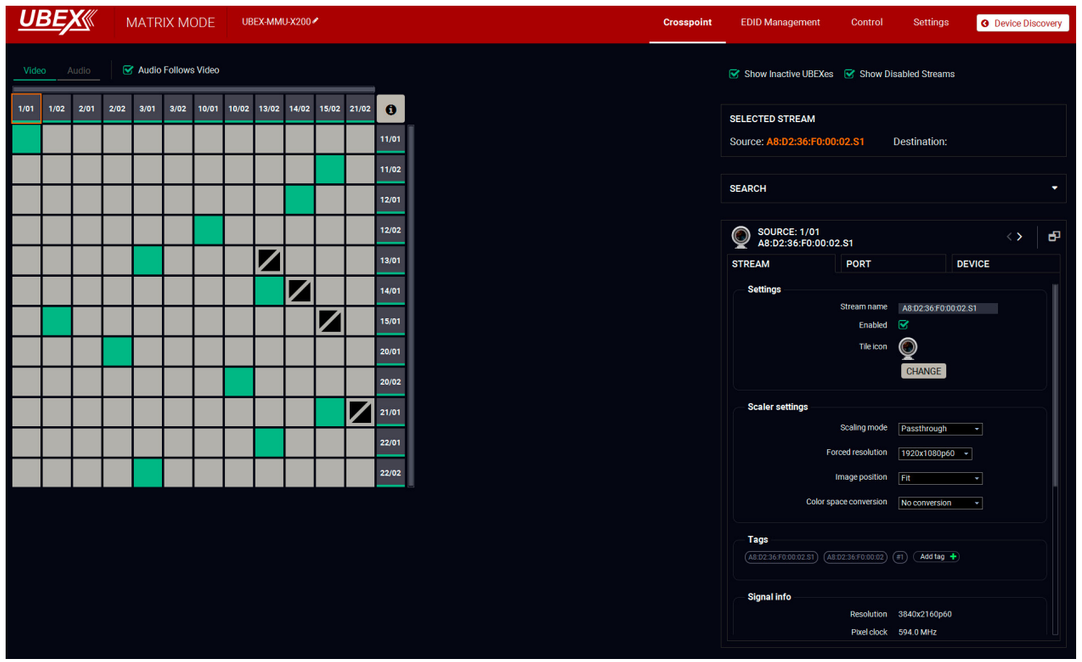
7.7. Finalizing the Matrix

The UBEX AV matrix is ready to use now.

The Lightware Device Controller software

Download the Lightware Device Controller (LDC) software from the website (www.lightware.com) to control the matrix. Install the software to a control system (e.g. a laptop). Establish the connection between the Matrix Management Unit (MMU) and the computer via Ethernet, or RS-232 interface.

Open the LDC and find the MMU in the Device discovery list. Double click on the name of the MMU to connect. The matrix crosspoint menu opens where you can configure the video system and see all information about the network.



LDC crosspoint menu

7.8. Bandwidth Limitations of the Switch

Lightware Team has done various AV tests on this switch and found limitations which might influence the audio/video configuration.

The maximal multicast load that the switch is capable of handling is **approximately 98.21 Gbps (7x 4096x2160p60 + 1x 2560x1080p60)**. This bandwidth **shall not be reached** in a live installation.

8

Configuration Steps - Cisco Nexus 5548UP

The following chapter describes and explains step-by-step the procedure of the configuration for the Cisco Nexus 5548UP fully managed network switch:

8.1. Description

This chapter helps you configure the Cisco Nexus 5548UP managed switch for the UBEX matrix. The base chassis of this model contains 32x 10G SFP+ slots and it can be expanded with +16 10G SFP+ ports with installing an expansion module. In this case the switch is enough to serve 23 UBEX endpoints and an MMU and handle up to 46 source / destination devices. The switch is recommended for medium businesses.

> INFO: The configuration steps of the **Cisco Nexus 5548P** and **5548UP** switches are exactly the same and can be applied for both models.

8.2. The Configuration of the UBEX Matrix

For the sake of simplicity the configuration steps of the switch are explained through a valid UBEX matrix example which contains:

Device	Pieces	Firmware version
Cisco Nexus 5548UP	**1**	7.3(0)N1(1)
UBEX-MMU-X200	**1**	1.0.6
UBEX-PRO20-HDMI-F100/F110	**23**	1.3.0

8.3. Cisco Requirements for the Switch Configuration

Cisco Certification Program

Configuring a Cisco network switch requires the knowledge of the Cisco's own software architecture, the Cisco IOS software. This is a command-based programming language which can be applied in the switch over terminal applications, for example Putty or CLI.

Step 1. Sign up for the **Cisco Training** to get the knowledge and skill to configure the switch. Visit the following website for the available Cisco trainings:

https://www.cisco.com/c/en/us/training-events/training-certifications/overview.html

Step 2. Configurator needs the **Routing and Switching** training course - here are the details about it:

https://www.cisco.com/c/en/us/training-events/training-certifications/training-catalog/routing-switching.html#~skills

Step 3. Complete the exam and get the Cisco Network Certification about the Routing and Switching Track:

https://www.cisco.com/c/en/us/training-events/training-certifications/certifications/entry/ccent.html

8.4. First Steps

8.4.1. Configuring the Switch

At first time the switch needs to be configured locally by using the supplied RJ45 to DB9 adapter cable. Follow the instructions listed on the website of the vendor (PDF file):

https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus5000/hw/installation/guide/nexus_5000_hig.pdf

Set an IP address for the Management Ethernet port (Mgmt 0) to be able to connect it and to set up the device for the UBEX network.

8.4.2. Installation of the UBEX Devices

The installation steps of the endpoint and the MMU devices can be found in the Connections section.

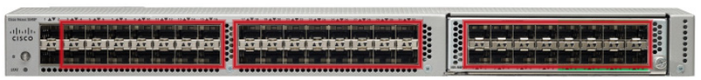
8.4.3. Installation of the Switch

Download the user's manual for the 5548UP model from the website of the vendor and follow the instructions.

Step 1. Install the switch correctly based on the instructions of the model.

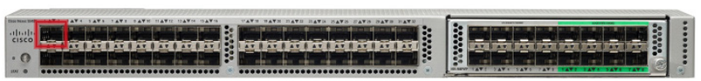
Step 2. Plug the cables between the UBEX endpoints and the switch based on the following options:

- 46x 10GbE singlemode/multimode SFP+ transceiver modules and 94x singlemode/multimode fiber optical cables
- 46x 10GbE DAC cables



Step 3. Plug the cables between the UBEX MMU and the switch based on the following options:

- 1x 1GbE singlemode/multimode SFP transceiver module and a singlemode/multimode fiber optical cable
- 1x 1GbE DAC cable



Step 4. Connect a control device (e.g. a laptop) to the switch with a CATx cable to the **1000 Base-T management Ethernet port (Mgmt 0)**:

8.4.4. Global Settings

See the details about the global settings of the switch on the website of the vendor and follow the instructions:

https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus5000/sw/configuration/guide/cli/CLIConfigurationGuide/initconfig.html

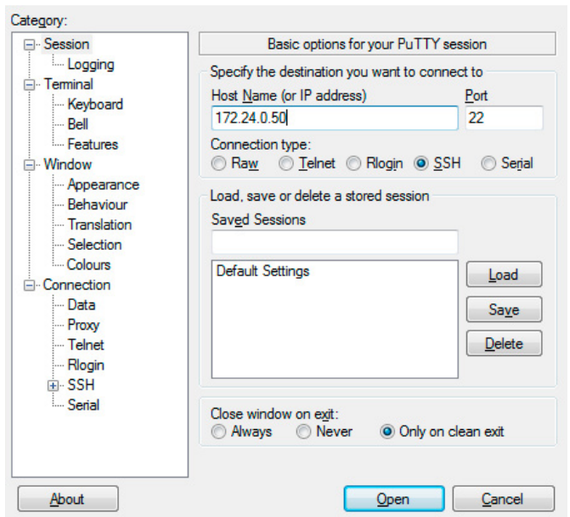
8.5. Detailed Instructions

8.5.1. Setting up the Control Device

The Cisco switch can be configured by protocol commands only. You need to install a terminal application to your control device, for example **Putty** or **CLI**.

The IP address of the switch in our example: 172.24.0.50

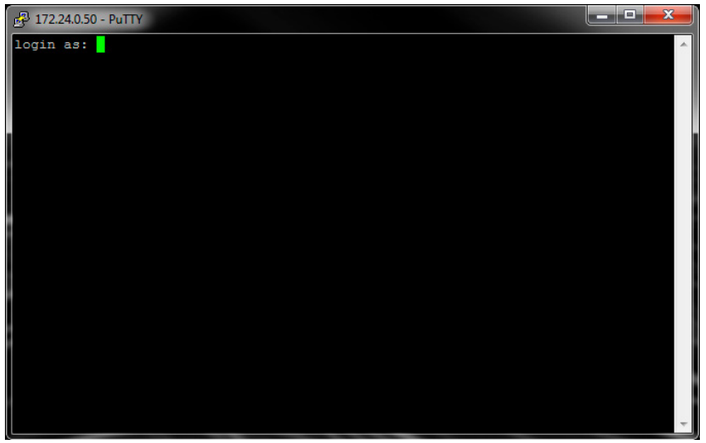
Open the terminal application (e.g. Putty), add the IP address of the switch and open it.



Putty terminal window

8.5.2. Login to the Switch

Once the terminal window is opened, you can log in to the switch by the given user name and password.



Login window in the Putty

After you logged in, the switch can be configured by protocol commands listed in the following sections.

8.5.3. Entering to Configure Mode

The Command

Type and apply the following command:

```
configure
```

Explanation

The Configure mode is enabled and the configuration commands will be accepted by switch.

8.5.4. IP Address Setting

The Command

Type and apply the following commands:

```
interface mgmt0
     vrf member management
     ip address 172.24.0.50/16
     exit
```

Explanation

The IP address (172.24.0.50) and subnet mask (/16) of the switch have been set for the management port (Mgmt 0).

8.5.5. Default Gateway Setting

> INFO: The command requires only in the case of the switch has to be accessed from different subnet.

The Command

Type and apply the following commands:

```
vrf context management
     ip route 0.0.0.0/0 172.24.0.1
     exit
```

8.5.6. Switching on the LACP and LLDP

The Command

Type and apply the following commands:

```
feature lacp
feature lldp
```

8.5.7. VLAN and IGMPv2 Configuration

The Command

Type and apply the following commands:

```
vlan 1, 286
vlan configuration 1, 286
     ip igmp snooping version 2
     exit
```

Explanation

Registers VLAN number 1 and number 286. Enables IGMPv2 snooping in both VLANs.

8.5.8. Forwarding Options

The Command

Type and apply the following command:

```
port-channel load-balance ethernet source-mac
```

Explanation

The setting ensures that traffic is shared equally between the two aggregated links.

8.5.9. Interface Configuration for the MMU

The Command

Type and apply the following commands:

Port ID	Command (in this example)
Port 1	interface Ethernet1/1 switchport mode trunk speed 1000 exit

Explanation

The Ethernet1/1 is the first SFP+ port of the switch which is for the connection of the MMU. Its speed is set to 1 Gbps (1000 = 1 GbE) and configured as a trunk port, thus has access to both of the configured VLAN's.

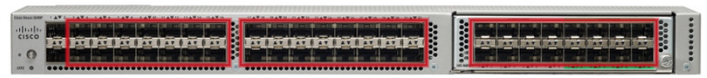
8.5.10. Port Channel Configuration for the Endpoints

The Commands

Type and apply the following commands for the desired interface ports:

Port Channel Index	Command
Port Channel 3	interface port-channel1 switchport mode trunk speed 10000 exit
Port Channel 4	interface port-channel2 switchport mode trunk speed 10000 exit
...	...
Port Channel 48	interface port-channel46 switchport mode trunk speed 10000 exit

Explanation



The ports between the 3 and 48 are grouped by pairs to port-channels, in this case between port-channel 3 to port-channel 23.
They are set to trunk mode and speed to 10 Gbps (10000 = 10 GbE).

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch. In this case the **configure** command needs only once at the starting of the sequence.

8.5.11. Interface Configuration for the Endpoints

The Commands

Type and apply the following commands for the desired interface ports:

Port ID	Command

Port 3	`interface Ethernet1/3`
	`  switchport mode trunk`
	`  channel-group 1 mode active`
	`  exit`

Port 4	`interface Ethernet1/4`
	`  switchport mode trunk`
	`  channel-group 1 mode active`
	`  exit`

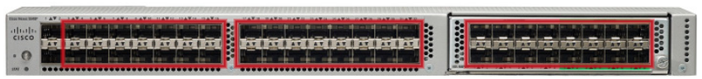
...	...

Port 47	`interface port-channel1/47`
	`  switchport mode trunk`
	`  channel-group 23 mode active`
	`  exit`

Port 48	`interface port-channel1/48`
	`  switchport mode trunk`
	`  channel-group 23 mode active`
	`  exit`

Explanation

The ports between the Ethernet1/3 and Ethernet1/48 are the SFP+ ports where the UBEX endpoints are connected to the switch. They are set to 10 Gbps (10000 = 10 GbE).



The 'active' keyword means that the switch uses the IEEE 802.3ad-2005 Link Aggregation Control Protocol (in active mode) to combine 10G ports into 20G logical channels for the UBEX devices.

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch. In this case the **configure** command needs only once at the starting of the sequence.

8.6. Troubleshooting Commands

8.6.1. Querying LLDP Partners

The Command

Type and apply the following command:

```
show lldp neighbors
```

Explanation

The query returns with the list of connected UBEX devices (which MAC address of the UBEX endpoint is on the ports of switch).

8.6.2. Querying LLDP Details by Ports

The Command

Type and apply the following command:

```
show lldp neighbors interface ethernet 1/1 detail
```

Explanation

The query returns with the details of the LLDP partner which is connected to the Ethernet1/1 port.

8.6.3. Switching on the Support for Unsupported SFP+ Modules

The Command

Type and apply the following command:

```
service unsupported-transceiver
```

8.6.4. Querying the Details of the Installed Transceiver Module

The Command

Type and apply the following command:

```
show interface transceiver
```

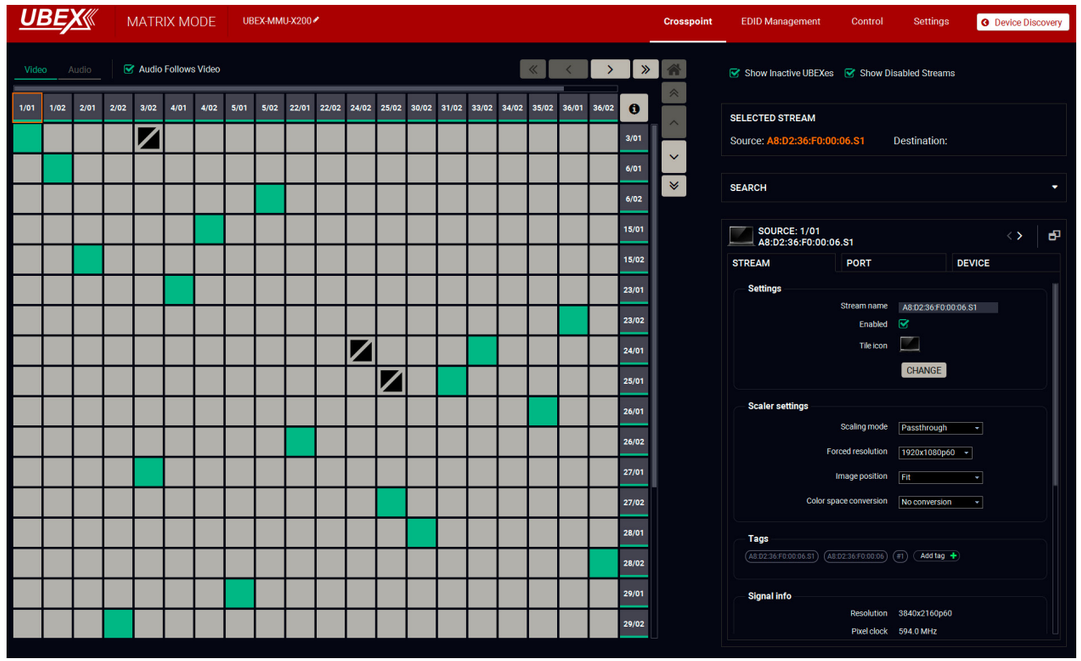
8.7. Finalizing the Matrix

The UBEX AV matrix is ready to use now.

The Lightware Device Controller software

Download the Lightware Device Controller (LDC) software from the website (www.lightware.com) to control the matrix. Install the software to a control system (e.g. a laptop). Establish the connection between the Matrix Management Unit (MMU) and the computer via Ethernet, or RS-232 interface.

Open the LDC and find the MMU in the Device discovery list. Double click on the name of the MMU to connect. The matrix crosspoint menu opens where you can configure the video system and see all information about the network.



LDC crosspoint menu

9

Configuration Steps - Cisco Nexus 93180YC-EX

The following chapter describes and explains step-by-step the procedure of the configuration for the Cisco Nexus 93180YC-EX fully managed network switch:

9.1. Description

This chapter helps you configure the Cisco Nexus 93180YC-EX managed switch for the UBEX matrix. The chassis of this model contains 48x 10G SFP+ slots which are enough to serve 23 UBEX endpoints and an MMU and handle up to 46 source / destination devices. The switch is recommended for medium businesses.

9.2. The Configuration of the UBEX Matrix

For the sake of simplicity the configuration steps of the switch are explained through a valid UBEX matrix example which contains:

Device	Pieces	Firmware version
Cisco Nexus 93180YC-EX	**1**	9.2(1)
UBEX-MMU-X200	**1**	1.0.6
UBEX-PRO20-HDMI-F100/F110	**23**	1.3.0

9.3. Cisco Requirements for the Switch Configuration

Cisco Certification Program

Configuring a Cisco network switch requires the knowledge of the Cisco's own software architecture, the Cisco IOS software. This is a command-based programming language which can be applied in the switch over terminal applications, for example Putty or CLI.

Step 1. Sign up for the **Cisco Training** to get the knowledge and skill to configure the switch. Visit the following website for the available Cisco trainings:

https://www.cisco.com/c/en/us/training-events/training-certifications/overview.html

Step 2. Configurator needs the **Routing and Switching** training course - here are the details about it:

https://www.cisco.com/c/en/us/training-events/training-certifications/training-catalog/routing-switching.html#~skills

Step 3. Complete the exam and get the Cisco Network Certification about the Routing and Switching Track:

https://www.cisco.com/c/en/us/training-events/training-certifications/certifications/entry/ccent.html

9.4. First Steps

9.4.1. Configuring the Switch

At first time the switch needs to be configured locally by using the supplied RJ45 to DB9 adapter cable. Follow the instructions listed on the website of the vendor (PDF file):

https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus9000/hw/n93180ycex_hig/guide/b_n93180ycex_nxos_mode_hardware_install_guide.pdf

Set an IP address for the Management Ethernet port (Mgmt 0) to be able to connect to it over SSH and to set up the device for the UBEX network.

9.4.2. Installation of the UBEX Devices

The installation steps of the endpoint and the MMU devices can be found in the Connections section.

9.4.3. Installation of the Switch

Download the user's manual for the Nexus 93180YC-EX model from the website of the vendor and follow the instructions.

Step 1. Install the switch correctly based on the instructions of the model.

Step 2. Plug the cables between the UBEX endpoints and the switch based on the following options:

- 46x 10GbE singlemode/multimode SFP+ transceiver modules and 94x singlemode/multimode fiber optical cables
- 46x 10GbE DAC cables

Step 3. Plug the cables between the UBEX MMU and the switch based on the following options:

- 1x 1GbE singlemode/multimode SFP transceiver module and a singlemode/multimode fiber optical cable
- 1x 1GbE DAC cable

Step 4. Connect a control device (e.g. a laptop) to the switch with a CATx cable to the **1000 Base-T management Ethernet port (Mgmt 0)**:

9.4.4. Global Settings

See the details about the global settings of the switch on the website of the vendor and follow the instructions:

https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus9000/sw/6-x/fundamentals/configuration/guide/b_Cisco_Nexus_9000_Series_NX-OS_Fundamentals_Configuration_Guide/b_Cisco_Nexus_9000_Series_NX-OS_Fundamentals_Configuration_Guide_chapter_0100.html

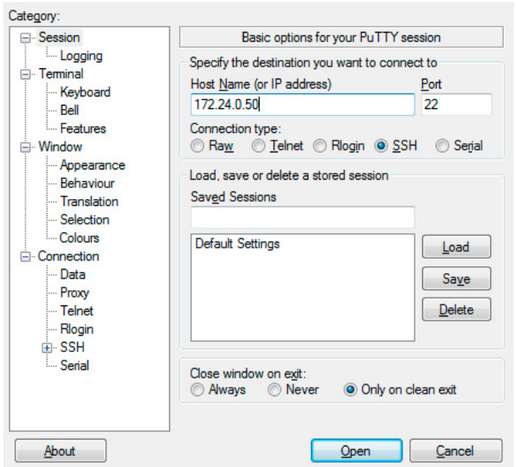
9.5. Detailed Instructions

9.5.1. Setting up the Control Device

The Cisco switch can be configured by protocol commands only. You need to install a terminal application to your control device, for example **Putty** or **CLI**.

The IP address of the switch in our example: 172.24.0.50

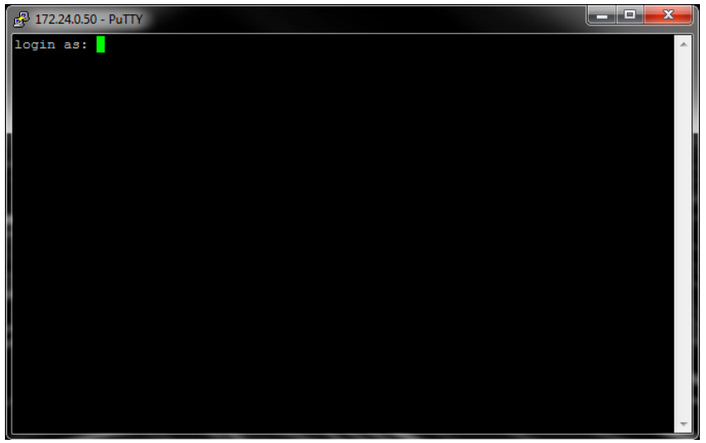
Open the terminal application (e.g. Putty), add the IP address of the switch and open it.



Putty terminal window

9.5.2. Login to the Switch

Once the terminal window is opened, you can log in to the switch by the given user name and password.



Login window in the Putty

After you logged in, the switch can be configured by protocol commands listed in the following sections.

9.5.3. Entering to Configure Mode

The Command

Type and apply the following command:

```
configure
```

Explanation

The Configure mode is enabled and the configuration commands will be accepted by switch.

9.5.4. Setting up IP Address of the Switch

The Command

Type and apply the following commands:

```
interface mgmt0
     vrf member management
     ip address 172.24.0.50/24
     exit
```

Explanation

The IP address (172.24.0.50) and subnet mask (/24) of the switch have been set for the management port (Mgmt 0).

9.5.5. Default Gateway Setting

> INFO: The commands are required only in the case when the switch has to be accessed from different subnet.

The Command

Type and apply the following commands:

```
vrf context management
     ip route 0.0.0.0/0 172.24.0.1
     exit
```

9.5.6. Switching on the LACP, LLDP, and VLAN

The Command

Type and apply the following command:

```
feature lacp
feature lldp
feature interface-vlan
```

9.5.7. VLAN and IGMPv2 Configuration

The Command

Type and apply the following commands:

```
vlan 1-2,286
vlan configuration 286
     ip igmp snooping fast-leave
     ip igmp snooping version 2
     exit
```

Explanation

Registers VLAN number 1 and number 286. Enables IGMPv2 snooping and the fast-leave feature which is required for the instant switching.

9.5.8. Forwarding Options

The Command

Type and apply the following commands:

```
port-channel load-balance src ip
```

Explanation

The setting ensures that traffic is shared equally between the two aggregated links.

9.5.9. Interface Configuration for the MMU

The Command

Type and apply the following commands:

Port ID	Command (in this example)
Port 1	interface Ethernet1/1 switchport switchport mode trunk switchport access vlan 2 no shutdown exit

Explanation

The Ethernet1/1 is the first SFP+ port of the switch which is for the connection of the MMU. The port accepts **SFP+** and **SFP** transceiver modules either.

9.5.10. Port Channel Configuration for the Endpoints

The Commands

Type and apply the following commands for the desired interface ports:

Port Channel Index	Command
Port Channel 3	interface port-channel3 switchport switchport mode trunk switchport access vlan 2 exit
Port Channel 4	interface port-channel4 switchport switchport mode trunk switchport access vlan 2 exit
...	...
Port Channel 48	interface port-channel48 switchport switchport mode trunk switchport access vlan 2 exit

Explanation

The ports between the 3 and 48 are grouped by pairs to port-channels, in this case between port-channel 3 to port-channel 23.

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch. In this case the **configure** command needs only once at the starting of the sequence.

9.5.11. Interface Configuration for the Endpoints

The Commands

Type and apply the following commands for the desired interface ports:

Port ID	Command

Port 3	`interface Ethernet1/3`
	`  switchport`
	`  switchport mode trunk`
	`  switchport access vlan 2`
	`  channel-group 1 mode active`
	`  exit`

Port 4	`interface Ethernet1/4`
	`  switchport`
	`  switchport mode trunk`
	`  switchport access vlan 2`
	`  channel-group 1 mode active`
	`  exit`

...	...

Port 47	`interface port-channel1/47`
	`  switchport`
	`  switchport mode trunk`
	`  switchport access vlan 2`
	`  channel-group 23 mode active`
	`  exit`

Port 48	`interface port-channel1/48`
	`  switchport`
	`  switchport mode trunk`
	`  switchport access vlan 2`
	`  channel-group 23 mode active`
	`  exit`

Explanation

The ports between the Ethernet1/3 and Ethernet1/48 are the SFP+ ports where the UBEX endpoints are connected to the switch.

The 'active' keyword means that the switch uses the IEEE 802.3ad-2005 Link Aggregation Control Protocol (in active mode) to combine 10G ports into 20G logical channels for the UBEX devices.

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch. In this case the **configure** command needs only once at the starting of the sequence.

9.6. Troubleshooting Commands

9.6.1. Querying LLDP Partners

The Command

Type and apply the following command:

```
show lldp neighbors
```

Explanation

The query returns with the list of connected UBEX devices (which MAC address of the UBEX endpoint is on the ports of switch).

9.6.2. Querying LLDP Details by Ports

The Command

Type and apply the following command:

```
show lldp neighbors interface ethernet 1/1 detail
```

Explanation

The query returns with the details of the LLDP partner which is connected to the Ethernet1/1 port.

9.6.3. Switching on the Support for Unsupported SFP+ Modules

The Command

Type and apply the following command:

```
service unsupported-transceiver
```

> **ATTENTION!** Always use high-quality SFP+ transceiver modules.

9.6.4. Querying the Details of the Installed Transceiver Module

The Command

Type and apply the following command:

```
show interface transceiver
```

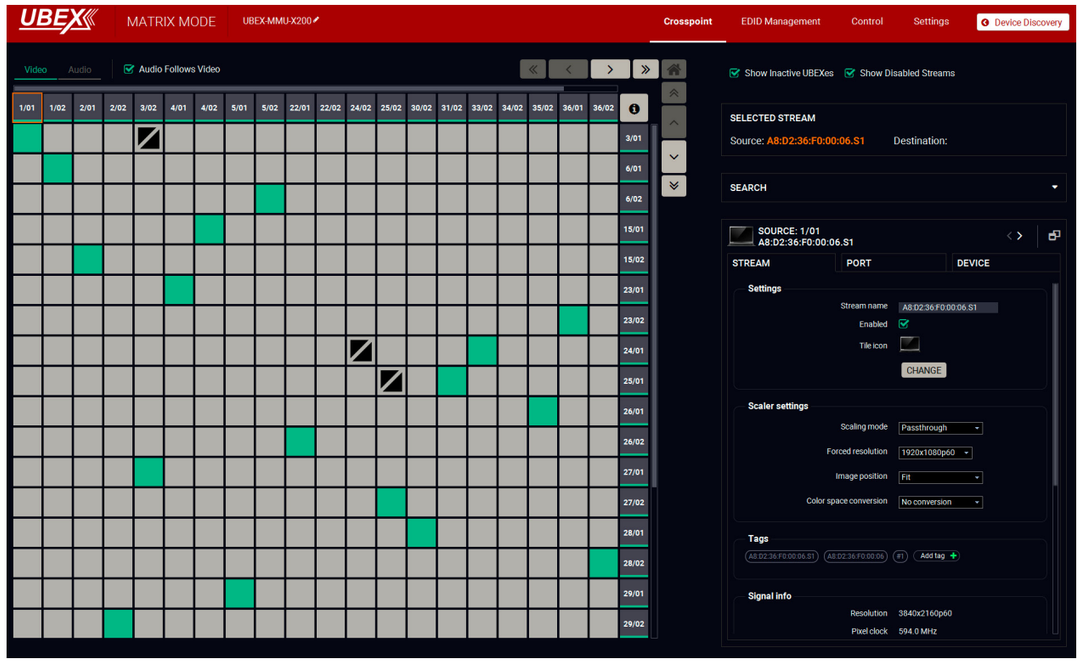
9.7. Finalizing the Matrix

The UBEX AV matrix is ready to use now.

The Lightware Device Controller software

Download the Lightware Device Controller (LDC) software from the website (www.lightware.com) to control the matrix. Install the software to a control system (e.g. a laptop). Establish the connection between the Matrix Management Unit (MMU) and the computer via Ethernet, or RS-232 interface.

Open the LDC and find the MMU in the Device discovery list. Double click on the name of the MMU to connect. The matrix crosspoint menu opens where you can configure the video system and see all information about the network.



LDC crosspoint menu

10

Configuration Steps - Juniper QFX5100-96S

The following chapter describes and explains step-by-step the procedure of the configuration for the Juniper QFX5100-96S fully managed network switch:

10.1. Description

This chapter helps you configure the Juniper QFX5100-96S managed switch for the UBEX matrix. This model of the Juniper contains 96x 10G SFP+ slots which are enough to serve 47 UBEX endpoints and an MMU and handle up to 94 source / destination devices. The switch is recommended for corporate businesses.

The configuration steps are compatible with the following switch models:

- Juniper QFX5100-48S
- Juniper QFX5110-48S
- Juniper QFX5100-96S
- Juniper QFX5110-96S

10.2. The Configuration of the UBEX Matrix

For the sake of simplicity the configuration steps of the switch are explained through a valid UBEX matrix example which contains:

Device	Pieces	Firmware version
Juniper QFX5100-96S	**1**	18.1R3-S4.2
UBEX-MMU-X200	**1**	1.0.6
UBEX-PRO20-HDMI-F100/F110	**47**	1.3.0

10.3. Juniper Requirements for the Switch Configuration

Juniper Networks Certification Program

Configuring a Juniper network switch requires the knowledge of the Juniper's own software architecture, the Junos OS. This is a command-based programming language which can be applied in the switch over terminal applications, for example Putty or CLI.

Step 1. Sign up for the **Juniper Training** to get the knowledge and skill to configure the switch. Visit the following website for the available Juniper trainings:

https://www.juniper.net/us/en/training/

Step 2. Configurator needs the **Enterprise Routing and Switching** training course - here are the details about it:

https://learningportal.juniper.net/juniper/user_activity_info.aspx?id=8057

Step 3. Complete the exam and get the Juniper Network Certification about the Enterprise Routing and Switching Track:

https://www.juniper.net/us/en/training/certification/certification-tracks/ent-routing-switching-track/?tab=jnciajunos

10.4. First Steps

10.4.1. Configuring the Switch

At first time the switch needs to be configured locally by using the supplied RJ45 to DB9 adapter cable. Follow the instructions listed on the website of the vendor:

https://www.juniper.net/documentation/en_US/release-independent/junos/topics/task/configuration/qfx5100-initial-configuration-cli.html

Set an IP address for the Management Ethernet port to be able to connect it and to set up the device for the UBEX network.

10.4.2. Installation of the UBEX Devices

The installation steps of the endpoint and the MMU devices can be found in the Connections section.

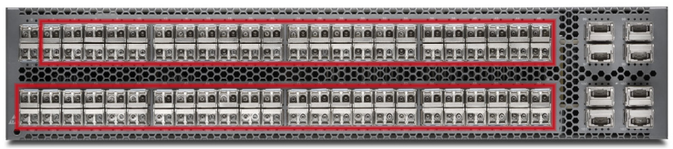
10.4.3. Installation of the Switch

Download the user's manual for the QFX5100/QFX5110 series model from the website of the vendor and follow the instructions.

Step 1. Install the switch correctly based on the instructions of the model.

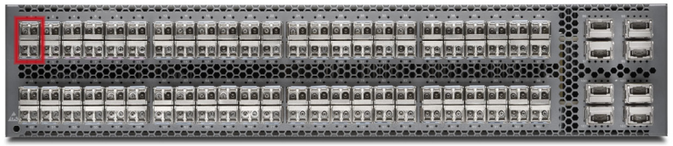
Step 2. Plug the cables between the UBEX endpoints and the switch based on the following options:

- 94x 10GbE singlemode/multimode SFP+ transceiver modules and 94x singlemode/multimode fiber optical cables
- 94x 10GbE DAC cables



Step 3. Plug the cables between the UBEX MMU and the switch based on the following options:

- 1x 1GbE singlemode/multimode SFP transceiver module and a singlemode/multimode fiber optical cable
- 1x 1GbE DAC cable



Step 4. Connect a control device (e.g. a laptop) to the switch with a CATx cable to the **1000 Base-T management Ethernet port (C0)**:

10.4.4. Global Settings

See the details about the global settings of the switch on the website of the vendor and follow the instructions:

https://www.juniper.net/documentation/en_US/release-independent/junos/topics/task/configuration/qfx5100-initial-configuration-cli.html

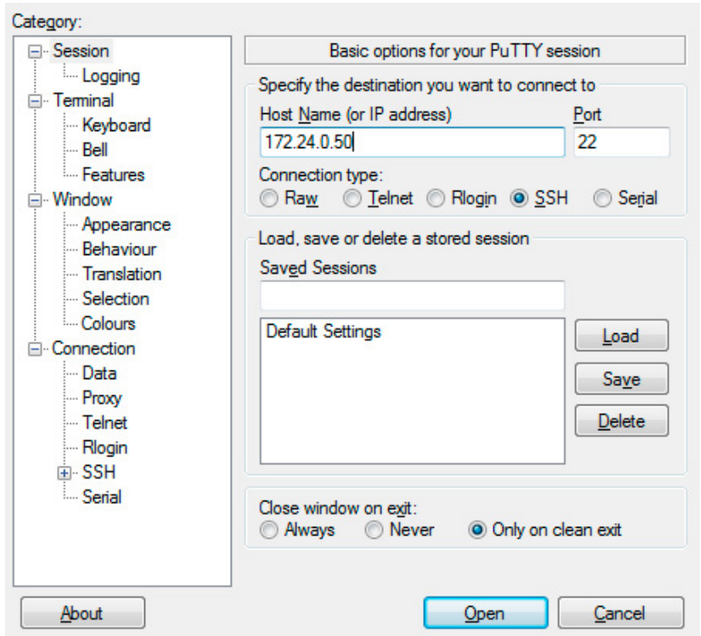
10.5. Detailed Instructions

10.5.1. Setting up the Control Device

The Juniper switch can be configured by protocol commands only. You need to install a terminal application to your control device, for example **Putty** or **CLI**.

The IP address of the switch in our example: 172.24.0.50

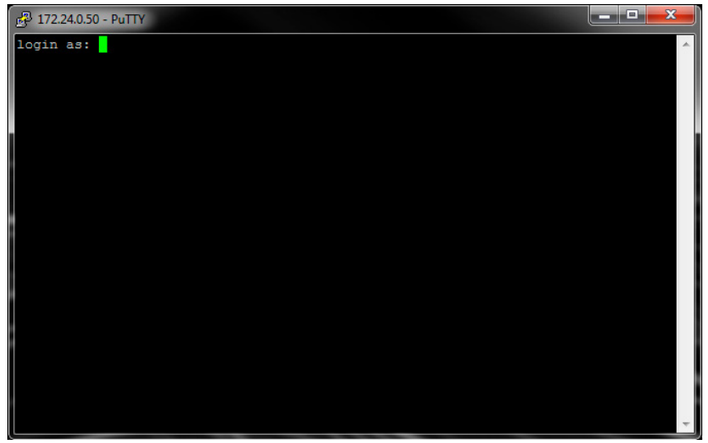
Open the terminal application (e.g. Putty), add the IP address of the switch and open it.



Putty terminal window

10.5.2. Login to the Switch

Once the terminal window is opened, you can log in to the switch by the given user name and password.



Login window in the Putty

After you logged in, the switch can be configured by protocol commands listed in the following sections.

10.5.3. Entering to Configure Mode

The Command

Type and apply the following command:

```
configure
```

Explanation

The Configure mode is enabled and the configuration commands will be accepted by the switch.

10.5.4. Aggregated Ethernet Interface Configuration

The Command

Type and apply the following commands:

```
set chassis aggregated-devices ethernet device-count 47
```

Explanation

This setting reserves the resources of the switch for it. The `device-count` parameter needs to be set to the number of the connected endpoint devices. It is 47 in our example.

10.5.5. Interface Configuration for the MMU and the Uplink

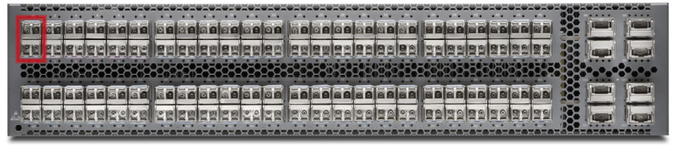
> **ATTENTION!** The switch needs one of the interface configuration command sets (for 10 Gbps SFP+ modules **OR** 1 Gbps SFP modules). The **xe** or **ge** interface parameter will be accepted when SFP+ (xe) or SFP (ge) modules are inserted to the switch.

The Commands for 10 Gpbs SFP+ Modules

Type and apply the following commands:

Port ID	Command (in this example)
Port 0	edit interfaces xe-0/0/0 set native-vlan-id 1 edit unit 0 family ethernet-switching set interface-mode trunk set vlan members all set storm-control default exit exit
Port 1	edit interfaces xe-0/0/1 set native-vlan-id 1 edit unit 0 family ethernet-switching set interface-mode trunk set vlan members all set storm-control default exit exit

Explanation



The xe-0/0/0 and xe-0/0/1 are the first two SFP+ ports of the switch. One of them is for the connection of the MMU, the another one is the "uplink" for the user Ethernet connection and for controlling the MMU.

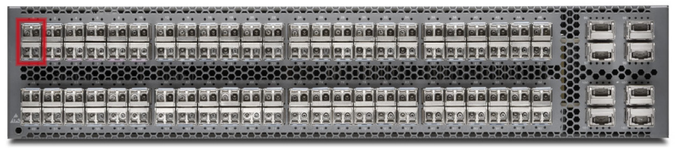
The link speed is applied to 10 Gbps (xe = 10 Gigabit Ethernet) automatically by the switch and the interfaces have membership to the all VLANs.

The Commands for 1 Gpbs SFP Modules

Type and apply the following commands:

Port ID	Command (in this example)
Port 0	edit interfaces ge-0/0/0 set native-vlan-id 1 edit unit 0 family ethernet-switching set interface-mode trunk set vlan members all set storm-control default exit exit
Port 1	edit interfaces ge-0/0/1 set native-vlan-id 1 edit unit 0 family ethernet-switching set interface-mode trunk set vlan members all set storm-control default exit exit

Explanation



The ge-0/0/0 and ge-0/0/1 are the first two SFP+ ports of the switch. One of them is for the connection of the MMU, the another one is the "uplink" for the user Ethernet connection and for controlling the MMU.

The link speed is applied to 1 Gbps (ge = 1 Gigabit Ethernet) automatically by the switch and the interfaces have membership to the all VLANs.

10.5.6. Interface Configuration for the Endpoints

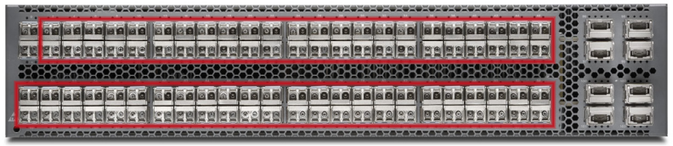
The Commands

Type and apply the following commands for the desired interface ports:

Port ID	Command
Port 2	`set xe-0/0/2 ether-options 802.3ad ae1`
Port 3	`set xe-0/0/3 ether-options 802.3ad ae1`
Port 4	`set xe-0/0/4 ether-options 802.3ad ae2`
Port 5	`set xe-0/0/5 ether-options 802.3ad ae2`
...	...
Port 94	`set xe-0/0/94 ether-options 802.3ad ae47`
Port 95	`set xe-0/0/95 ether-options 802.3ad ae47`

Explanation

The ports between the xe-0/0/2 and xe-0/0/94 are the SFP+ ports where the UBEX endpoints are connected to the switch. They are set to 10 Gbps (xe = 10 GbE).



The switch uses the IEEE 802.3ad-2005 Link Aggregation Control Protocol (in active mode) to combine 10G ports into 20G logical channels for the UBEX endpoint devices.

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch.

10.5.7. Aggregated Ethernet Settings

The Commands

Type and apply the following commands:

Aggregated Ethernet ID	Command

ae0	`edit interfaces ae0`
	`  set native-vlan-id 1`
	`  set aggregated-ether-options lacp active`
	`  edit unit 0 family ethernet-switching`
	`  set interface-mode trunk`
	`  set vlan members all`
	`  exit`
	`exit`

ae1	`edit interfaces ae1`
	`  set native-vlan-id 1`
	`  set aggregated-ether-options lacp active`
	`  edit unit 0 family ethernet-switching`
	`  set interface-mode trunk`
	`  set vlan members all`
	`  exit`
	`exit`

...	...

ae47	`edit interfaces ae47`
	`  set native-vlan-id 1`
	`  set aggregated-ether-options lacp active`
	`  edit unit 0 family ethernet-switching`
	`  set interface-mode trunk`
	`  set vlan members all`
	`  exit`
	`exit`

Explanation

The aggregated Ethernet is set and finalized with these commands. The ae<x> increases till the last LAG interface.

> TIPS & TRICKS: The recurring commands can be scripted (e.g. in Python) and run in batch.

10.5.8. Forwarding Options

The Commands

Type and apply the following commands:

```
set forwarding-options storm-control-profiles default all
set enhanced-hash-key hash-mode layer2-header;
```

Explanation

The setting ensures that traffic is shared equally between the two aggregated links.

10.5.9. Creating VLAN

The Command

Type and apply the following command:

```
set vlans ubex-vlan vlan-id 286
```

Explanation

The VLAN ID 286 has been created now.

10.5.10. IGMPv2 Setting

The Commands

Type and apply the following commands:

```
set protocols igmp-snooping vlan default
set protocols igmp-snooping vlan ubex-vlan immediate-leave
```

10.6. Troubleshooting Commands

10.6.1. Enabling LLDP

The Command

Type and apply the following commands:

```
set protocols lldp interface all
```

Explanation

The LLDP setting is optional but it is helpful for further troubleshooting.

10.6.2. Querying LLDP Details

The Command

Type and apply the following command:

```
show lldp detail
```

Explanation

The query returns with the basic information about the LLDP.

10.6.3. Querying LLDP Details by Ports

The Command

Type and apply the following command:

```
show lldp neighbors xe-0/0/4
```

Explanation

The query returns with the details of the LLDP partner which is connected to the `xe-0/0/4` port.

10.6.4. Querying LLDP Statistics by Ports

The Command

Type and apply the following command:

```
show lldp statistics xe-0/0/4
```

Explanation

The query returns with the statistics of the LLDP partner which is connected to the `xe-0/0/4` port.

10.6.5. Verifying the Status of a LAG Interface

The Command

Type and apply the following command:

```
show interfaces ae0 terse
```

Explanation

The query returns with the status of the `ae0` LAG interface. When the link is **up**, the link aggregation (LACP) is working on the selected LAG interface.

10.6.6. Querying the Details of the Selected Interface Port

The Commands

Type and apply the following command:

```
show interfaces ge-0/0/1 detail
show interfaces xe-0/0/4 detail
```

Explanation

The query returns with the details of the `ge-0/0/1` and `xe-0/0/4` ports. The answers contain either that the inserted SFP / SFP+ module is supported or not by the switch.

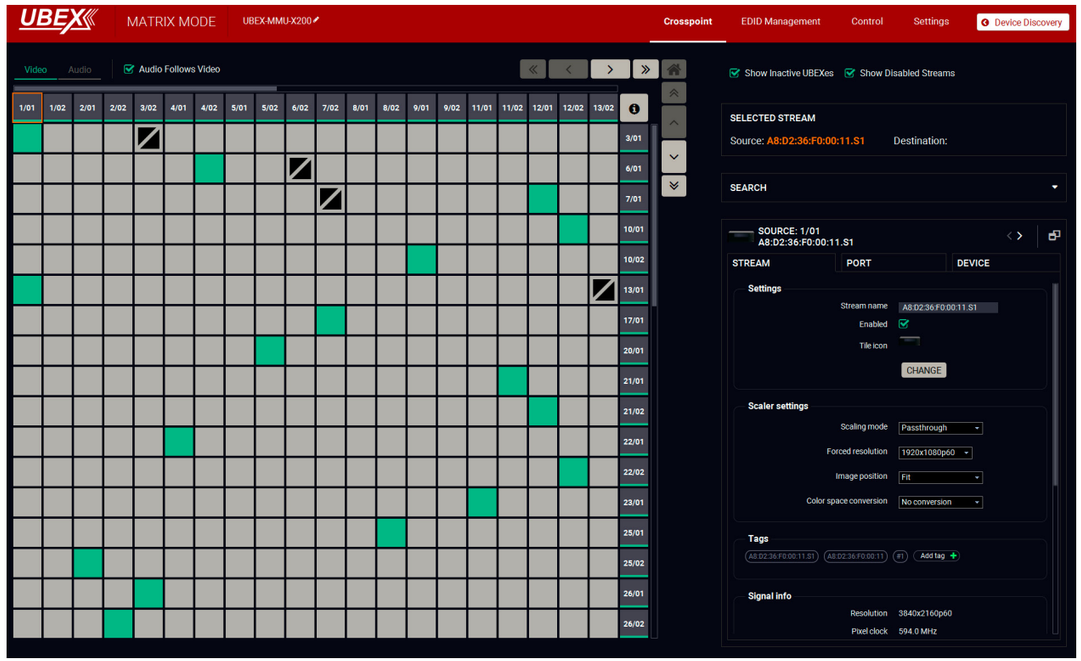
10.7. Finalizing the Matrix

The UBEX AV matrix is ready to use now.

The Lightware Device Controller software

Download the Lightware Device Controller (LDC) software from the website (www.lightware.com) to control the matrix. Install the software to a control system (e.g. a laptop). Establish the connection between the Matrix Management Unit (MMU) and the computer via Ethernet, or RS-232 interface.

Open the LDC and find the MMU in the Device discovery list. Double click on the name of the MMU to connect. The matrix crosspoint menu opens where you can configure the video system and see all information about the network.



LDC crosspoint menu

11

UBEX Test Lab

This chapter describes the experiences collected in our 24/7 testing laboratory using multifarious network environments and different AV equipments.

11.1. Introduction

We, at Lightware are proud of all advertised features and properties of our products are tested in our 24/7 laboratory to create perfect AV systems.

The UBEX matrix is one of the most complex AV product family which is developed by Lightware. The Test Engineering Team must specify complicated test cases with various AV peripheries and install the UBEX system into different network environments.

Hundreds of DAC cables run into the Juniper switches in the 24/7 testing room

UBEX Matrix Configurations

Two main UBEX matrix configurations were built and tested in the testing room beside of some smaller ones for special tester/developer jobs:

- **10 Gbps matrix**: stress test for the MMU in the matrix control point of view. See the layout of the architecture in The 10 GbE Matrix section.
- **20 Gbps matrix**: stress test for the MMU and the endpoint devices in the video transmission point of view. See the layout of the architecture in The 20 GbE Matrix section.

The third system was a simulated logical UBEX matrix which was run on a computer - it functioned as the control point beside of the real ones.

11.2. The Concept

The basic idea is building up a real matrix and a simulated one, both have exactly the same parameters. The two systems are controlled by the same LW3 commands in the same time. The answers of the commands are compared by the comparator software. If their status are not equal, one of the system has failure.

UBEX endpoints wait for the passed test result

All communication between the elements of the system is logged and analyzed after every test sequences. If the problem is deterministic, the failure status can be duplicated by resending the commands based on the system log files.

11.3. The Elements of the Test

More software elements have been made for the UBEX test which are done the bigger/smaller subtasks.

Test Case Commands

LW3 commands which modify the status of the MMU and the endpoints. See the details in the Test Cases section.

Message Repeater / Distributor

The component duplicates all test case commands - one is for the real UBEX matrix, another one is for simulated system.

MMU Model

The virtual Matrix Management Unit (MMU). Its functionality and features are similar like the real one but it is more simple because the persistence and the other network communication is unnecessary in the test point of view.

Endpoint Model

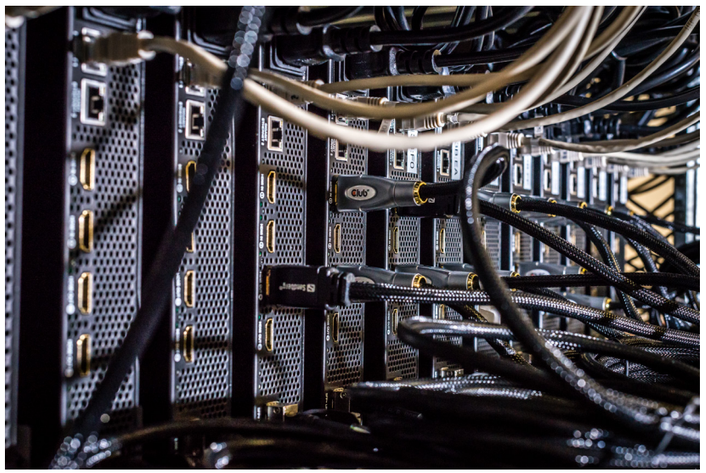
This component consists of a database which copies the internal states of a real endpoint, and some parts of its internal logic, that describes the connections between certain settings.

Comparator

The comparator queries the actual status of the MMU and compares it to the MMU model. In the case of difference the comparator notifies the test engineer about the catch.

Emulated Endpoint

LW3 servers which can model the entire functionality and the inner status of the real endpoint in the MMU point of view. Managing of the emulated endpoints can provide realistic stress test but they does not require building a physical network capable of video transmission.



One of the tested UBEX matrix under construction

Additional advantage of the emulated endpoints is that a special failure status can be generated as well. These cases help for the software developers preparing the UBEX devices for any specific situation in the future.

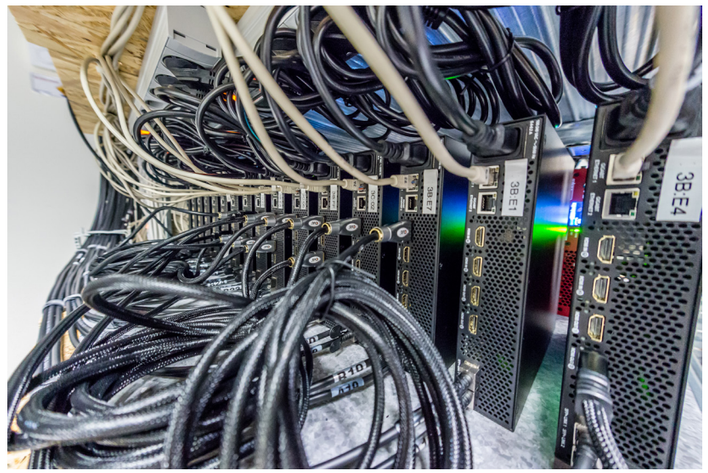
11.3.1. Test Cases

This section describes some significant test cases which were applied in the UBEX systems as listed above.

- **Restarting of the endpoints in random times**: the MMU must detect the disappearance of the devices from the network, must establish the connection as the endpoints are rebooted, and restore the last configuration for the right device.
- **Operation mode changing in random endpoints**: the MMU must configure the Device Map, must detect and invalidate the ceased video streams in the receivers, and must add the new streams to the crosspoints.
- **Virtual crosspoint status changing**: the MMU must set the source stream on the receiver based on the actual Device Map.

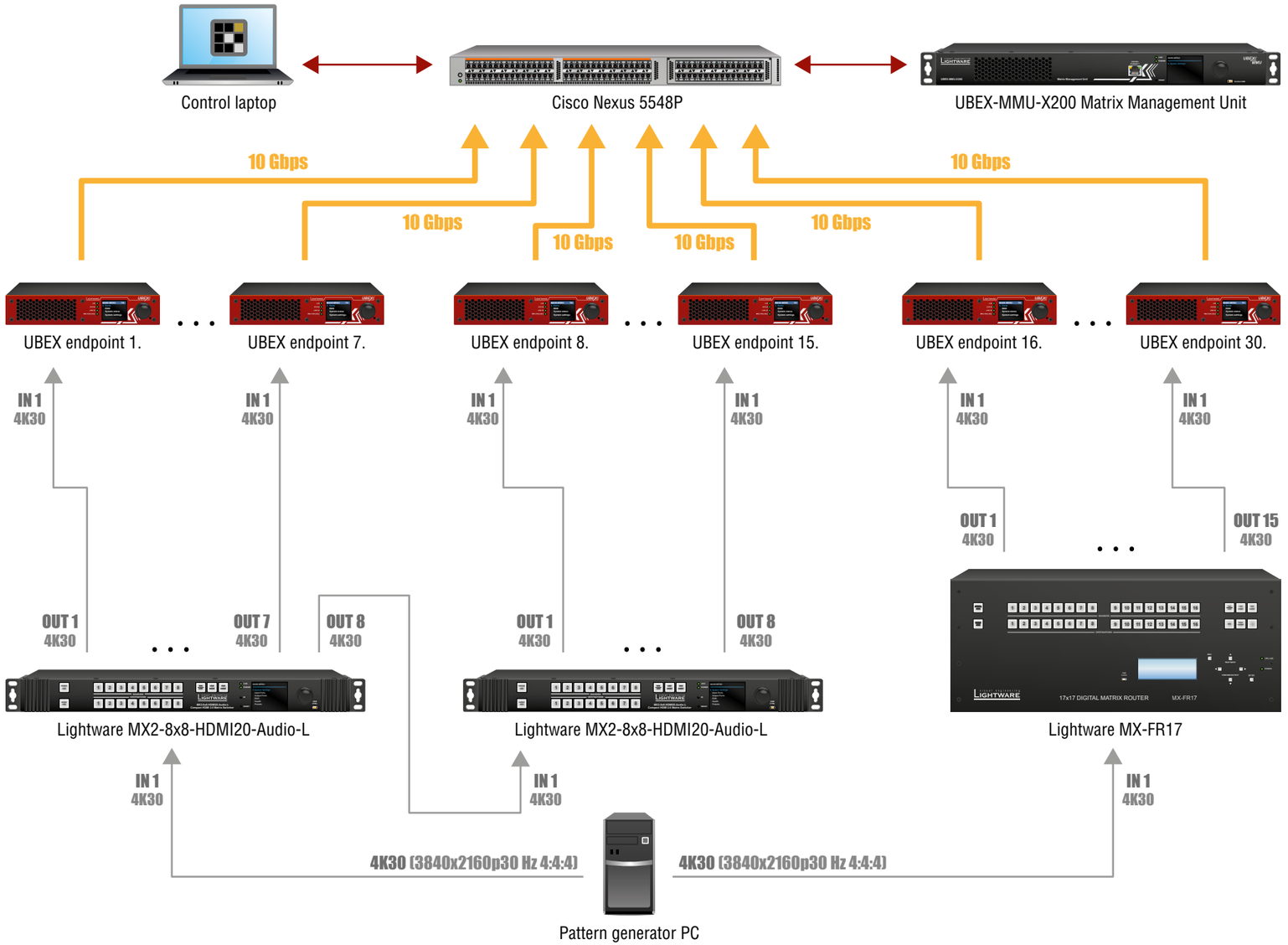
11.3.2. Self-Diagnostics

The firmwares of the MMU and the endpoints contain a self-diagnostic software as well. The log files which were created during the tests were saved and analyzed. This procedure helped for the software developers to find the causes of the temporary loss of functions and eliminate them.



Curly HDMI and DAC cables meanders between the endpoint devices

11.4. The 10 GbE Matrix



The 10 GbE UBEX test matrix

11.4.1. The Architecture of the Matrix

The matrix is built with 30 UBEX endpoints and a Matrix Management Unit (MMU). The network switch is a Cisco Nexus 5548P with 48 pcs 10GbE SFP+ ports. The matrix is controlled by the MMU, the control commands are sent from a laptop which runs the LDC software.

All UBEX endpoints receive **4K UHD 30** (3840x2160p30 Hz 4:4:4) video signal on their HDMI in 1 ports (the HDMI in 2 port is not used in this test). The source is a pattern generator PC which transmits 4K30 signal on both output ports. The HDMI signal is distributed by 2 pcs Lightware MX2-8x8-HDMI20-Audio-L matrix switcher and a Lightware MX-FR17 modular matrix switcher built with HDMI input and output I/O boards.

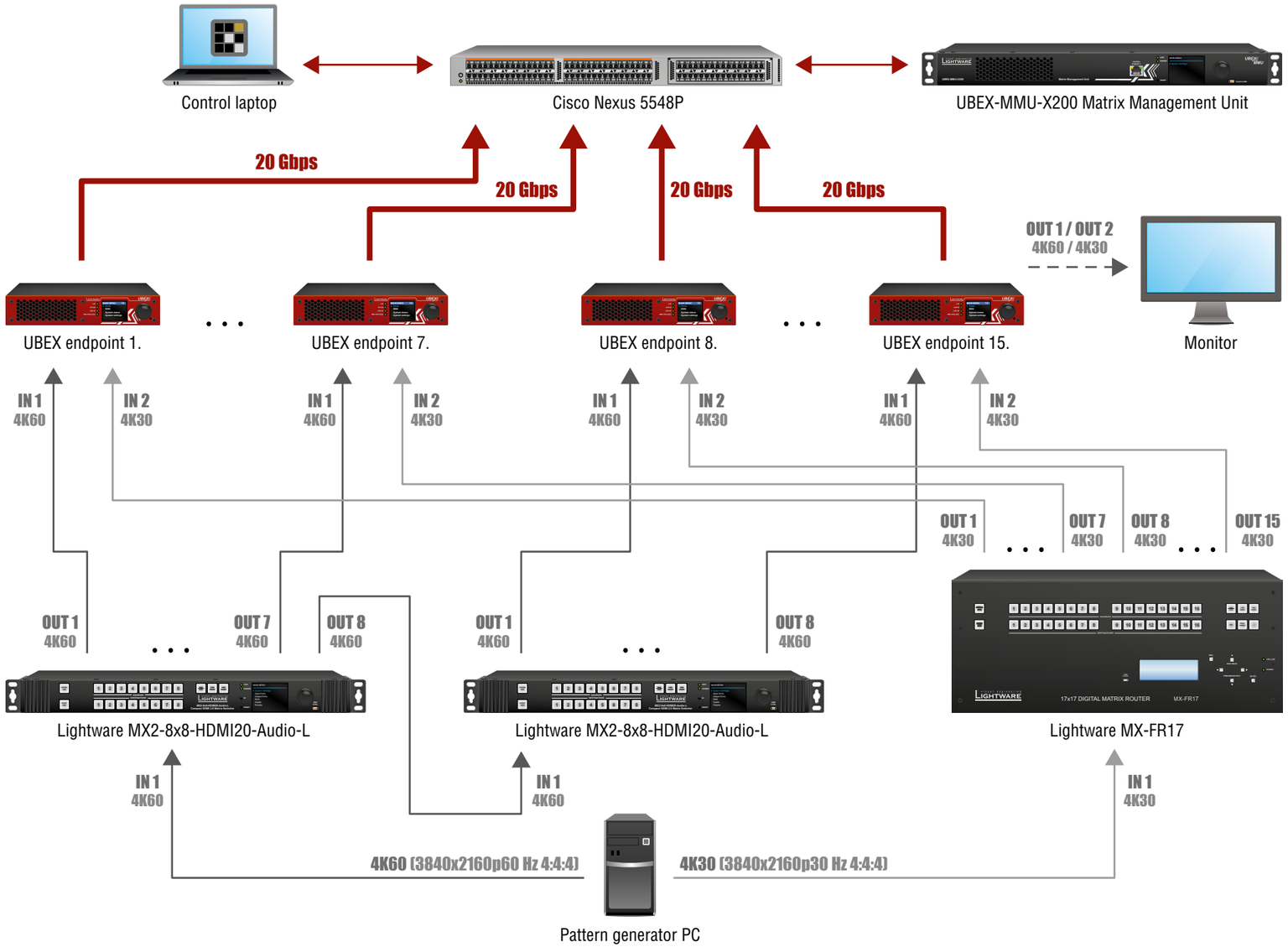
Each UBEX endpoint is installed with one 10 GbE SFP+ module or DAC cable which is enough to transmit the 4K30 signal.

11.4.2. Test Equipment

The following table lists the most important parts of the test equipment which are installed in the UBEX matrix.

Device	Pcs	Description
MX2-8x8-HDMI20-Audio-L	2	8x8 matrix switcher with HDMI 2.0 support
MX-FR17	1	Modular multimedia matrix switcher up to 16 inputs and 16 outputs
Cisco Nexus 5548P	1	Layer 3 managed switch with 32+16 10G SFP+ ports
Club 3D HDMI cable	33	Premium high speed HDMI 2.0 4K60Hz UHD cable, 5m
Finisar FTLX8571D3BCL	12	10Gb/s 850nm multimode SFP+ transceiver module
Finisar FTLX1471D3BCL	16	10Gb/s 1310nm singlemode SFP+ transceiver module
Fiberstore OM3 50/125	6	OM3 50/125 850nm multimode fiber optical cable with LC connectors, 5m
Prysmian Group Draka BendBright-XS 60019441	8	OS2 1310nm singlemode fiber optical cable with LC connectors, 15m
Fiberstore SFPP-PC05	16	10G SFP+ DAC cable, 5m

11.5. The 20 GbE Matrix



The 20 GbE UBEX test matrix

11.5.1. The Architecture of the Matrix

The matrix is built with 15 UBEX endpoints and a Matrix Management Unit (MMU). The network switch is a Cisco Nexus 5548P with 48 pcs 10GbE SFP+ ports. The matrix is controlled by the MMU, the control commands are sent from a laptop which runs the LDC software.

All UBEX endpoints receive a **4K UHD 60** (3840x2160p60 Hz 4:4:4) video signal on their HDMI in 1 ports and a **4K UHD 30** (3840x2160p30 Hz 4:4:4) video signal on their HDMI in 2 ports. The source is a pattern generator PC which transmits the 4K60 and 4K30 signal on the output ports. The HDMI signal is distributed by 2 pcs Lightware MX2-8x8-HDMI20-Audio-L matrix switcher and a Lightware MX-FR17 modular matrix switcher built with HDMI input and output I/O boards.

Each UBEX endpoint is installed with two 10 GbE SFP+ modules or DAC cables which are able to support the successful transmission of the 4K60 and 4K30 video signals together.

11.5.2. Test Equipment

The following table lists the most important parts of the test equipment which are installed in the UBEX matrix.

Device	Pcs	Description
MX2-8x8-HDMI20-Audio-L	2	8x8 matrix switcher with HDMI 2.0 support
MX-FR17	1	Modular multimedia matrix switcher up to 16 inputs and 16 outputs
Cisco Nexus 5548P	1	Layer 3 managed switch with 32+16 10G SFP+ ports
Club 3D HDMI cable	33	Premium high speed HDMI 2.0 4K60Hz UHD cable, 5m
Finisar FTLX8571D3BCL	20	10Gb/s 850nm multimode SFP+ transceiver module
Finisar FTLX1471D3BCL	8	10Gb/s 1310nm singlemode SFP+ transceiver module
Fiberstore OM3 50/125	10	OM3 50/125 850nm multimode fiber optical cable with LC connectors, 5m
Prysmian Group Draka BendBright-XS 60019441	4	OS2 1310nm singlemode fiber optical cable with LC connectors, 15m
Fiberstore SFPP-PC05	16	10G SFP+ DAC cable, 5m