Technical Note	LIGO-T1300202-v1	2015/01/12

aLIGO GigE Camera Layout and Usage

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Distribution of this document:

Detector Group

1 Overview

This document lists the cables and hardware layout for the Gigabit Ethernet camera network and its connections to the main network. It also provides instructions on how to use the software associated with the Gigabit cameras.

2 Hardware

2.1 Hardware required

The hardware needed for the setup includes the CDS core switch, a Brocade FGS48S at LLO, a Brocade FGS624P - PoE (Power over Ethernet) switch in the CER, a Broacde FGS624P at each end, and three Supermicro computers with 2 ethernet ports each connected to both the camera network (VID) as well as the main CDS OPS network. For the TCS IR GigE cameras, two additional Supermicro computers running Windows also with 2 ethernet ports each are required. The Brocade FGS48S is connected to the Brocade FGS624P - PoE via a 10 GigE fiber connection, which is dedicated to only video camera traffic. The ends are connected by 1 GigE fiber, which share CDS and video traffic. All other connections use Cat 5e (or better) ethernet cables.

The cables for the cameras can be described as follows. You need Cat 5e or 6 in order support the power over ethernet to each camera. At LLO, several 100' ethernet cables were made, connected to the Brocade FGS48S PoE switch and then ran near various tables and chambers. In the corner we need:

- 4 need to be run near HAM3, to the LAMCB1.

- 2 need to be run near HAM2, to the LAMCA1.

- 2 need to be run to the ISCT6 table area.

- 2 need to be run to IOT1

- 3 need to be run to IOT2

- 1 each needs to be run to PSL table, BSC2 (BS), ITMX adapter section, ITMY adapter section

- 1 each needs to be run to the TCS X and TCS Y table

At the ends we need:

- 1 run to the ETMX adapter section (through a POE injector, so 2 ethernet cables)

- 1 run to the ETMY adapter section (through a POE injector, so 2 ethernet cables)

Useful references for locations and cameras include the Advanced LIGO Camera Plan, T1000632 and the Viewport Subsystem Final Design, T1000746. Individual listings of cables can be found in tables 1, 2, 4 and **??**.

2.2   Hardware set up

2.2.1   VID and OPS LANs

There are 2 networks to be considered for the cameras. The dedicated VID LAN which handles all the high bandwidth traffic from the gigabit cameras to the camera servers. The second is the general OPS LAN which handles all the control room traffic and related control signals. All VID LAN switches have been to set to accept Jumbo frames (i.e. 9000 byte MTU).

2.2.2   Multicast Switch settings on OPS LAN switches

IGMP snooping was enabled on the OPS LAN on all CDS managed switches:

- en

- config term

- vlan 5

- multicast passive

This includes the MSR core switch, as well as the X and Y end switches, the LVEA and MSR Broacde switches. As noted in section 3.6, each camera will have its server software multicast to a unique IP designated by the camera's configuration file.

2.2.3   Jumbo frames settings on VID LAN switches and ethernet cards

The gigabit camera performance is heavily impacted by the size of packets that can be used. All VID LAN switches have been set to accept jumbo fraemes (i.e. 9000 byte MTU). Similarly, ethernet cards on the server computers handling the incoming VID LAN camera data have been set to accept jumbo frames as well. The camera server code itself automatically sets the gigabit cameras to send jumbo frames.

2.2.4   Camera computer servers

Each computer has 2 interfaces; for the linux computers eth0 is on the CDS OPS LAN and eth1 is on the camera VID LAN. The windows computers running the TCS IR cameras are also connected to these two LANs. All server interfaces are 1GbE. UDP Unicast is used on the VID LAN to get the camera images to the camera servers. Multicast is used on the OPS LAN to get the processed video streams from the camera servers to the control room workstations.
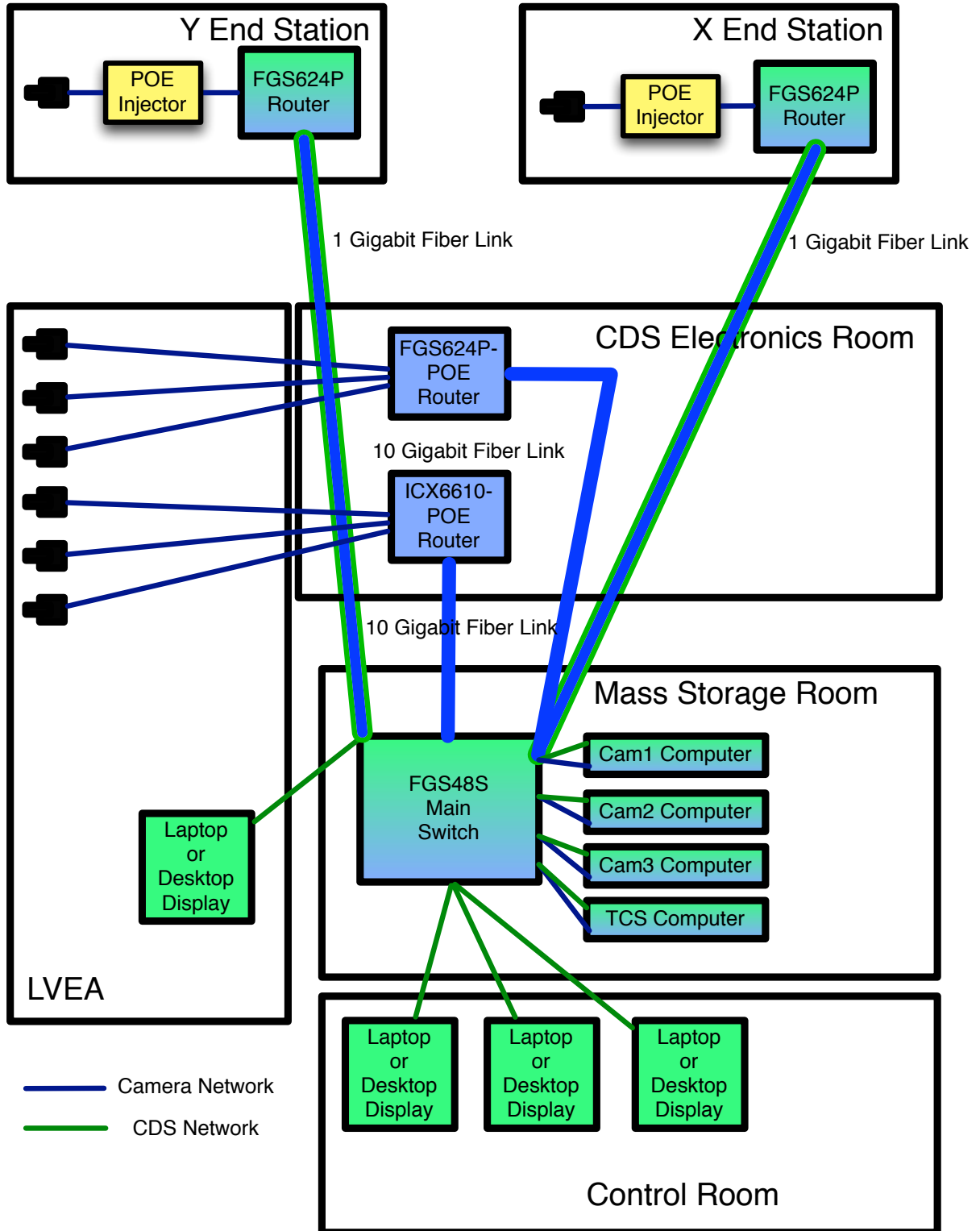
Figure 1: Diagramatic overview. Green indicates CDS network, blue Camera network, and blue-green indicates its on both. Not all cameras or control room computers shown.

Table 1: Table of non-camera hardware and locations for L1

Hardware	Purpose	Location
Brocade FGS48S	Core Switch	MSR, L1-MSR-02
10 Gb Fiber transceiver	10 Gigabit connection	Brocade FGS48S
Brocade FGS624P - POE	PoE switch for Cameras	CER, L1-FAC-C1, row 24
10 Gb Fiber transceiver	10 Gigabit connection	Brocade FGS624P - PoE
Brocade FGS624P	CDS End station switch	CERX, L1-FAC-XC1
Trendnet TPE-113GI PoE Injector	Power over Ethernet Injector	CERX, L1-FAC-XC1
Brocade FGS624P	CDS End station switch	CERY, L1-FAC-YC1
Trendnet TPE-113GI PoE Injector	Power over Ethernet Injector	CERY, L1-FAC-YC1
Supermicro computer (Front End style /w 12 cores)	Camera server L1CAM1	MSR, L1-MSR-10, row 38
Supermicro computer (Front End style /w 12 cores)	Camera Server L1CAM2	MSR, L1-MSR-10, row 36

Table 2: Table of End station cables for L1

Cable	Start Location	End Location
L1-CAM-ETMX Cat 5e cable	TPE-113GI PoE Injector L1-FAC-XC1	ETMX Camera ETMX A-1 Adapter LA-1C, VP6
L1-CAM-ETMY Cat 5e cable	TPE-113GI PoE Injector L1-FAC-YC1	ETMY Camera ETMY A-1 Adapter LA-1D, VP1
L1-CAM-ETMX-INJ Cat 5e cable	Brocade FGS624P L1-FAC-XC1	TPE-11eGI PoE Injector L1-FAC-XC1
L1-CAM-ETMY-INJ Cat 5e cable	Brocade FGS624P L1-FAC-YC1	TPE-11eGI PoE Injector L1-FAC-YC1

Table 3: Table of corner cables for L1

Cable	Start Location	End Location
MSR 2 CER Fiber 1	Brocade FGS48S MSR, L1-MSR-02	Brocade FGS624P - POE CER, L1-FAC-C1, row 24
cam1 CDS/VID network 2x Cat 5e cables	Brocade FGS48S L1-MSR-02	L1CAM1 L1-MSR-10, row 38
cam2 CDS/VID network 2x Cat 5e cables	Brocade FGS48S L1-MSR-02	L1CAM2 L1-MSR-10, row 36
L1-CAM-MC1 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	MC1 Camera LAMCB1, VP10
L1-CAM-MC3 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	MC1 Camera LAMCB1, VP3
L1-CAM-PRM Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	PRM Camera LAMCB1, VP9
L1-CAM-PR3 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	PR3 Camera LAMCB1, VP12
L1-CAM-MC-REFL Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	MC REFL Camera IOT1
L1-CAM-MC-TRANS Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	MC TRANS Camera IOT1
L1-CAM-PRM-REFL-90 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	PRM REFL 90 Camera IOT 2
L1-CAM-PRM-REFL-180 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	PRM REFL 180 Camera IOT 2
L1-CAM-IM4-TRANS Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	IM4 Trans Camera IOT 2
L1-CAM-MC2 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	MC2 Camera LAMCA1, VP9
L1-CAM-PR2 Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	PR2 Camera LAMCA1, VP3
L1-CAM-BS Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	BS Camera BSC 2, VP G8
L1-CAM-ITMX Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	ITMX Camera ITMX A-1 Adapter L1-1A, VP5
L1-CAM-ITMY Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	ITMY Camera ITMY A-1 Adapter L1-1B, VP2
L1-CAM-OMC-REFL Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	OMC REFL Camera ISCT 6
L1-CAM-OMC-TRANS Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	OMC TRANS Camera ISCT 6
L1-CAM-PSL Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	PSL trans-periscope Camera PSL Table

Table 4: Table of TCS corner cables for L1

Cable	Start Location	End Location
CDS/VID network 2x Cat 5e cables	Brocade FGS48S L1-MSR-02	L1FLIRX computer L1-MSR-12, row 30
CDS/VID network 2x Cat 5e cables	Brocade FGS48S L1-MSR-02	L1FLIRY computer L1-MSR-12, row 28
TCS X IR Camera Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	TCS X IR Camera TCS X Table
TCS Y IR Camera Cat 5e cable	Brocade FGS624P - POE L1-FAC-C1, row 24	TCS Y IR Camera TCS Y Table

3 Software

3.1 Software Overview

The GigE cameras are on their own dedicated network, while the camera server computers act as gateways between the camera network and the main CDS network. Full data comes into the camera server, but only compressed video at a much lower data rate comes out to the main CDS network, and is viewed with an approriate client. The servers are always running and publishing a stream to a multicast group. When a user wants to view a camera stream, they run a client which connects to that multicast group and presents the stream.

Full data images can be saved by taking a "snapshot" by setting an approriate EPICS channel to 1. On the next camera server loop a raw data image will be saved to a file defined by the another EPICS channel, whose name will have an appended timestamp. The channels are described in section 3.5.

3.2 Directories

3.2.1 Configuration directory

Configuration files (ini files) which are used to setup the camera_server and client codes are located in:

`/ligo/cds/<site>/<ifo>/camera`.

3.2.2 EPICS IOC directory

The In/Out controller (IOC) code which provides EPICS channels for the camera_server to interface with is located in:

`/opt/rtcds/<site>/<ifo>/target/<ifo>cam/<ifo>camepics`.

3.2.3 Installation directory

Code is to be installed to the following directory:

`/ligo/apps/linux-x86_64/camera`

3.3 Getting the code and installing

- Install pylon on the server that will run the camera software. Pylon is the vendor's software that has been repackaged by Michael Thomas as a .deb package. Due to redistribution restrictions, it has only been made available from within CDS. You can get it by logging into LLO and running:

  curl -L -O http://opspxe/ligo/ubuntu/precise/pylon-2.3.3-1.deb

- Check out the camera software from the projects area:

  https://redoubt.ligo-wa.caltech.edu/svn/projects/trunk/camera/SnapPy/

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- The Makefile will install into /ligo/apps/linux-x86_64/camera by default.

  Set the APPSROOT environment variable to install into a different directory.

- Run "`make && make install`"

3.4 Setting up the Cameras

To setup the Cameras initially we used a windows laptop with the latest version of the basler Pylon software, which can be downloaded from http://www.baslerweb.com

We connected the camera (with a PoE injector in path) to the laptop's ethernet port. Then set the laptop to the same IP range as the camera's default IP address. Cameras default to IPs in the range 169.254.0.XXX. Setting the Laptop to 169.254.0.99 generally works for example.

We then ran the Pylon Configuration tool on the Windows laptop and set the cameras to use permanent IPs of our choice.

A full step by step instruction manual for this is available from the Basler website. It is titled "INSTALLATION AND SETUP GUIDE FOR CAMERAS USED WITH BASLERS PYLON API" and can be downloaded from http://www.basler.web.com. It is called the Install and Setup Guide for Cameras used with Basler's pylon API for Windows.

3.5 Setting up EPICS IOC

First, a camera EPIC IOC needs to be started containing all relevant EPICs channels which are used to interface to the camera server. For each camera, the following channels need to be defined:

- (BASE_NAME)_X (X centroid position)
- (BASE_NAME)_Y (Y centroid position)
- (BASE_NAME)_WX (Gaussian width in the X direction)
- (BASE_NAME)_WY (Gaussian width in the Y direction)
- (BASE_NAME)_XY (Gaussian width along XY line)
- (BASE_NAME)_SUM (Pixel sum)
- (BASE_NAME)_EXP (Exposure time in microseconds)
- (BASE_NAME)_SNAP (Control signal for taking snapshots)
- (BASE_NAME)_FILE (File name for image to saved to - time stamp automatically appended)
- (BASE_NAME)_RELOAD (Reloads configuration file)

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- (BASE_NAME)_AUTO (1 means autoexposure on, 0 means autoexposure off)

(BASE_NAME) is generally something like L1:CAM-MC2 or L1:CAM-MC_REFL. An example database file is included in the SVN, called example_camera.db. The IOC is run on a script machine, (i.e. l1script1 at LLO). This must be up and running before starting and camera servers.

3.6 Setting up configuration files

An example configuration file is included in the SVN, called L1-CAM-MC1.ini.

To configure for each camera, change the file name to something approriate. You'll need to change the Camera Name, Camera IP, Base Channel Name, Snapshot Directory Path, Multicast Group and Multicast port lines.

- "Camera Name" is just that, a user friendly name which gets overlayed on transmitted images to clients.

- "Camera IP" is the IP of the camera on the camera network.

- "Base Channel Name" must match the BASE_NAME part of channels running on the IOC, i.e. L1:CAM-MC1.

- "Snapshot Directory Path" is where snapshots of images generated by sending a "1" to the *_SNAP EPICs channels will be saved to.

- "Multicast Group" is a group which is subscribed to by clients. We are using 239.192.0.XXX. Each camera needs it own unique multicast IP. We have been using the same final 3 numbers as the camera's VID network IP.

- "Multicast Port" we have been setting to 65000.

The other settings can be used to tweak the behavior of the server and client.

- "Height" and "Width" set the size of the image to be sent from the camera.

- "X" and "Y" changes where the image taken from, relative to the pixels of the CCD. For example a X = 10 and Width = 10 will send columns of pixels 10 through 20, as measured from the left side of the image.

- "maxX" and "maxY" are fixed for each camera, and indicate the size of the CCD in pixels.

- "Default Exposure" is the exposure the code starts with until overridden by the *_EXP epics channel.

- "Default Analog Gain" should almost always be 100. It sets an analog gain inside the camera, 100 is equivalent to a gain factor of 1.0.

- "Auto Exposure Minimum" is the minimum value of the bright pixel before it tries to change the exposure time. Pixels vary from 0 to 255 currently.

- "Name Overlay" turns the printed name of the camera on and off for the images sent to clients.

- "Time Overlay" turns on the time overlay of the camera on and off for the images sent to clients.

- "Calculation Overlay" turns on the overlay of calculated values like X and Y centroid values for the images sent to clients.

- "Do Calculations" turns on calculation of gaussian width and similar calculations.

- "Auto Exposure" determines if auto exposure is sent on or off by default at start up.

- "Calculation Noise floor" is the level of which pixels are excluded from centroid and gaussian width calculations.

3.7   Running the server code

- Log into the camera server computer (either l1cam1 or l1cam2 at LLO)

- Start a tmux session or join one already running for the cameras (tmux a)

- Open a new tmux window and run the following command:

  `camera_server.py -c /ligo/cds/<site>/<ifo>/camera/CONFIGURATION_FILE_NAME.ini`

3.8   Running the client code

There are 3 options for a client, which are all invoked in the same way:

- `client.py -c /ligo/cds/<site>/<ifo>/camera/CONFIGURATION_FILE_NAME.ini`

- `client_auto.py -c /ligo/cds/<site>/<ifo>/camera/CONFIGURATION_FILE_NAME.ini`

- `client_aa.py -c /ligo/cds/<site>/<ifo>/camera/CONFIGURATION_FILE_NAME.ini`

The one to use in most situations is client.py.

The client_auto.py allows one to resize the screen on a display and have the image get bigger to match the size of the window. However this requires a free xvideo port. Most ATI video cards in the LLO control room only have 4 xvideo ports, although types of hardware can have more, like 32 on some Nvidia cards.

The client_aa.py is an easy way to see small changes, as it maps the 0 to 255 of the 8 bit values to ascii characters, effectively making it easier to see the small changes, like 0 to 1 or 1 to 2.

There is a generic medm screen available in the USERAPPS repository, under cds/common/medm called CUST_CAMERA.adl which can be used to bring up a client and also set various EPICs channels related to a camera.

3.9 Notes on camera settings

The current camera server C code sets the following parameters on each camera when first connecting.

- Pixel Format is set to 8 bits

- Packet size is set to 8192

- FrameRateAbs is set to 25

The Pixel format determines the bit depth, or how many bits are used per pixel in the frame. Currently the code has been setup to only handle 8 bit data, although the cameras do have a 12 bit ADC.

Packet size is set to 8192, so as to make efficient use of the jumbo frames settings on the network and ethernet cards.

FrameRateAbs sets the maximum frame rate of the camera, in order to limit the bandwidth of each camera, and ensure we have enough capacity on the network. For an individual camera running at a maximum of 25 frames per second and with a frame size of 640 by 480 pixels at 8 bit depth, the approximate maximum bandwidth used is:

$$25 \text{ frames/second} \times 640 \text{ pixels} \times 480 \text{ pixels} \times 8 \text{ bits/pixel}^2 = 6.144 \times 10^7 \text{ bits/seconds} \quad (1)$$

The 25 frames/second value was chosen based on smoothness for human vision, as well as being able to fit 10 streams into a single 1 gigabit/second connnection to a server computer. Requesting exposure times greater than 0.04 seconds through the EPICS interface will reduce the frame rate further.