HUMBER BRIDGE
SYSTEM DESIGN DOCUMENT
25/10/2016

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1 INTRODUCTION

This document describes the proposed system, to light the Humber Bridge (Hull, UK), operating environment, system and subsystem architecture and the human-machine interfaces.

1.1 Purpose and Scope

This section provides a brief description of the Systems Design purpose and scope. The system solution proposed is based on the requirements proposed by the Hull city, which will the capital of Culture during 2017. The scope of the project is to light the Humber Bridge, to become an interactive tourist attraction during the Hull Capital of Culture duration, and therefore as a result be an iconic landmark of the city.

The Humber Bridge, near Kingston upon Hull, England, is a 2,220-metre (7,280 ft) single-span suspension bridge, which opened to traffic on 24 June 1981. It was the longest of its type in the world when opened, and is now the eighth-longest.

PHILIPS designers have proposed to install iColor Flex LMX from Philips Color Kinetics to illuminate the cables and pillars that run high above the bridge, as well as to highlight the dramatic beauty of the bridge's architecture. The nodes are going to be specifically engineered to withstand harsh weather environments like the used ones in the San Francisco Bay area.

The proposed lighting system had to be capable of washing the bridge with beautiful, controllable, color-changing light. In addition, three more requirements need to be included as an output of the designed system.

1) Content Provision
2) Dynamic Control and near real-time
3) Sensing capabilities

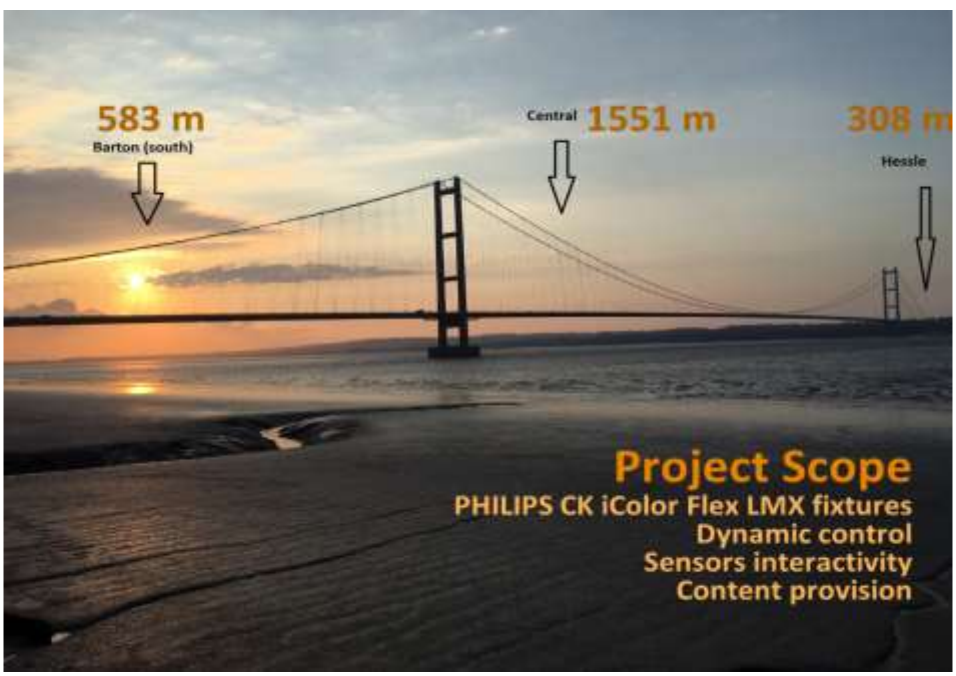


Figure 1: System Hardware Architecture.

1.2 Project Executive Summary

This section provides a description of the project from a management perspective and an overview of the framework within which the conceptual system design was prepared.

1.2.1 System Overview

This section describes the high-level system architecture from a holistic point of view.

Humber Bridge lighting project involve several stakeholders with defined tasks and activities. **Hull 2017 Partnership** will be responsible of the User Interface for interactivity and the sensors if input local parameters are needed. And PHILIPS Lighting will be responsible for the connected lighting system and services. The high-level architecture for this project is presented below.

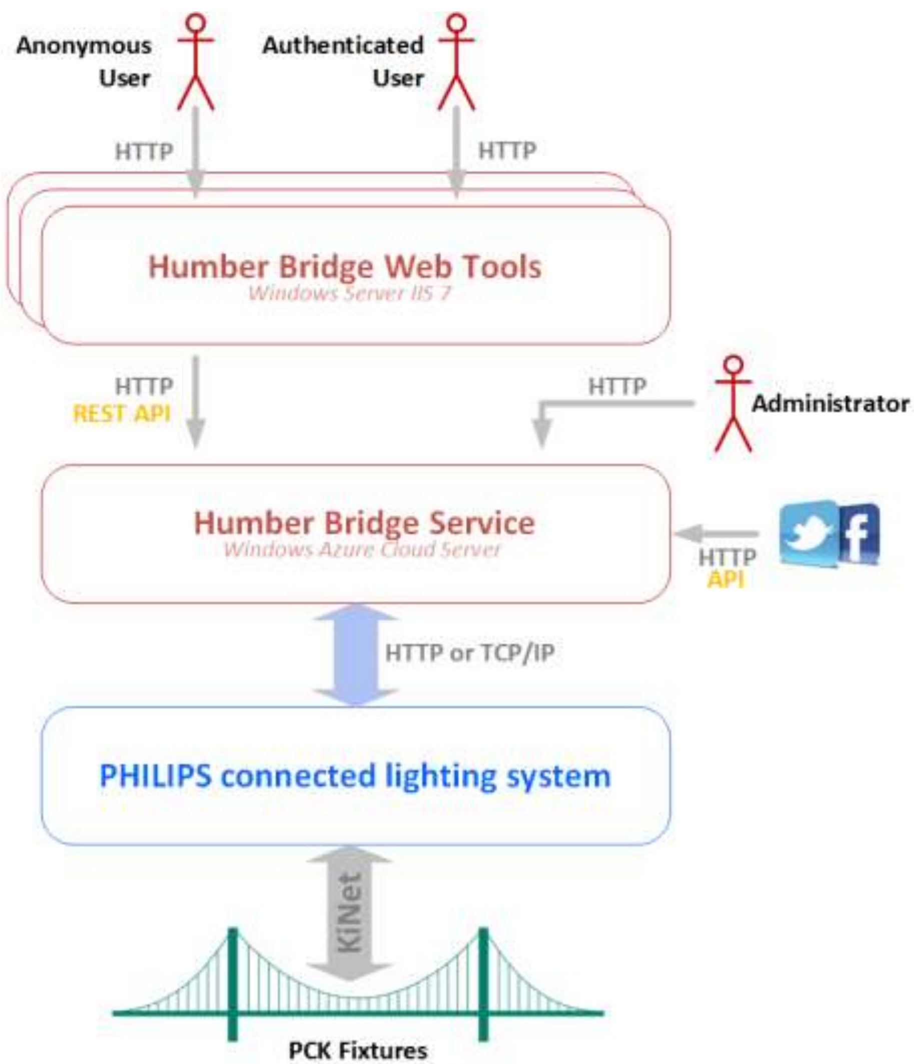


Figure 2: System Hardware high-level system architecture diagram. Source: Hull 2017 Partnership.

The **Humber Bridge Web Tools** consist of a suite of web applications or native apps to engage the public to interact with the Humber Bridge lights. Providing the UI (User Interface front end). This activity is under the scope of **Hull 2017 Partnership**.

The **Humber Bridge Services** building block is the responsible for converting user interactions into a series of data packets or API calls. Is formed by three sub-systems:

1. **Data Extraction Tool:** To extract data from third party sites such as Facebook or Twitter.
2. **Humber Bridge Admin Interface:** Web page for administrators for management.
3. **Visualizer Module:** Contains a set of components to deliver data packets as inputs to the PHILIPS Lighting Engine. This integration can be done via HTTP or over TCP/IP.

The Humber Bridge Services belongs to as an activity to be developed to **Hull 2017 Partnership**. But, there is a need to interface with the proposed PHILIPS Lighting Engine, object of this document.

1.2.1.1 PHILIPS connected lighting system

The PHILIPS connected lighting system is under the sole scope of PHILIPS Lighting and the solution is described along this document. The main building blocks of the proposed system are:

1. **Intelligent luminaires:** Dynamically controllable lighting systems.
2. **Controls and Software for dynamically control the lighting systems.**
    - The principal components of this building block are the lighting management controller and the ActiveSite Gateway.
    - The gateway is the critical component that connects the local lighting network to the cloud-based ActiveSite lighting management software, providing secure and remote access to the lighting network.
3. **Managed services packages.**

The interface between the Humber Bridge Services developed by 2017 Partnership and the proposed PHILIPS connected lighting system for this projects can be done in three ways:

ActiveSite Lighting Management Software

ActiveSite is a connected lighting system to remotely Monitor, Maintain & Manage Philips Color Kinetics installations. Is delivered as a cloud-hosted Software-as-a-Service (SaaS) platform to:

- Know the lighting system is working flawlessly
- Detect & service any anomaly in the installation faster and remotely
- Remotely access centralized real-time content management for a refreshed lighting experience

State-of-the-art software interface, with key features like: Status monitoring, temp monitoring, alarm management, email alerts, reports, data analytics, asset management & show content management

ActiveSite can be seamlessly installed in both existing and new Philips Color Kinetics installations.

API interface? Describe here the interfacing possibilities with the system proposed by 2017 Partnership.

Lighting Management Controller

The proposed **Lighting Controller** proposed for this project is a video lighting controller to make easy to play video content across an array of lighting fixtures, either from user-selected HD media files stored on the internal solid-state drive (SSD) or from the DVI live video input, which supports resolutions up to 1080p60. It is possible to fade seamlessly between any video content, and a range of creative effects is available, including options like text rendering. Based on individually controllable and independently running timelines and scenes, it lets you build dynamic, precise, **fully customizable programmed lighting shows.**

The extensive show control and scheduling capabilities makes easy to integrate with third-party systems and giving lots of flexibility to meet the precise needs for the Humber Bridge project.

We are able to create a custom web interface for the installation. To give to the users the control they need and the look they expect.

Interface between ActiveSite and the Lighting Management Controller

Using a secure VPN connection, you can remotely access to a specific lighting controller device to update lighting show content remotely. From the ActiveSite software interface a user/administrator can connect to the ActiveSite Gateway Control Panel and to the video lighting controller proposed for this project, allowing you the same access as you would have if you were connected to the local lighting network.

1.2.2 Design Constraints

This section should describe any constraints in the system design (conflicts with other systems) and includes any assumptions made by the project team in developing the system design.

1.2.3 Future Contingencies

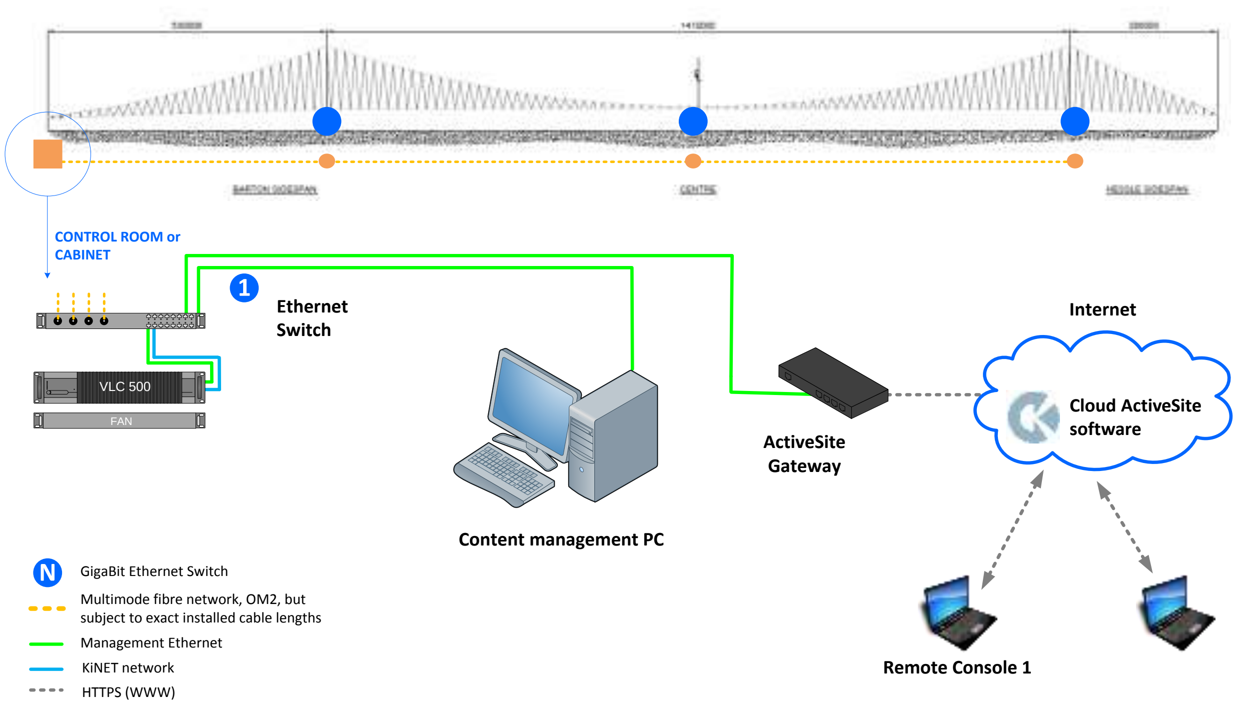
This section describes any contingencies that might arise in the design of the system that may change the development direction. Possibilities include lack of interface agreements with outside agencies or unstable architectures at the time this document is produced. Address any possible workarounds or alternative plans.

2 SYSTEM ARCHITECTURE

The system architecture description provides a high-level overview of the hardware, software, and interfaces that the system relies on for operations. This section includes the description of any equipment or interconnected systems and subsystems that interface with the proposed system.

The proposed PHILIPS lighting management system, is called ActiveSite, a cloud-hosted connected lighting system for remotely monitoring, managing, and maintaining architectural LED lighting installations. ActiveSite protects your brand and lighting system investments by ensuring optimal lighting system performance.

Connected luminaires are intelligent lighting fixtures that integrate with data networks to share information about their status and operation. A connected lighting system from Philips Color Kinetics (PCK) consists of intelligent luminaires, a system controller, and an ActiveSite Gateway. The gateway is the critical component that connects the local lighting network to the cloud-based ActiveSite lighting management software, providing secure access to your lighting network from anywhere in the world.



The system is delivered as a software service without the need of installing and maintaining separate dedicated IT hardware and software equipment on premise. The lighting operator shall thus be freed of any operational IT complexity and costs for maintaining such IT equipment. The system is accessible simply be logging into a standard web browser, only requiring a high-speed internet connection.

The lighting operator will receive access to ActiveSite service via hierarchical user roles. Based on this access rights, the different user groups are capable of performing different tasks and accessing levels of information.

The installation will use the Pharos VLC (Video Lighting Controller) lighting controller which makes easy to

PHILIPS

play video content across an array of lighting fixtures, either from user-selected HD media files stored on the internal solid-state drive (SSD) or from the DVI live video input, which supports resolutions up to 1080p60. It is possible to fade seamlessly between any video content, and a range of creative effects is available, including options like text rendering.

The permanent installation shall also incorporates Philips ActiveSite, a cloud-based connected lighting platform that helps to minimize downtime and allows for more efficient management of the iconic landmark with benefits including remote diagnostics, reporting, data analytics, control and content provision.

2.1 System Hardware Architecture

In this section, is described the overall system hardware and organization. Include brief description of each hardware components and diagrams showing the connectivity between the components.

The proposed system for Humber Bridge is enabled by a fully scalable system architecture which incorporates a dedicated controls network and software applications. An intuitive user interface, such as a tablet or laptop, can be used to manage full system functionality in a simple and convenient way.

The high-level system hardware architecture is depicted in Figure 3:

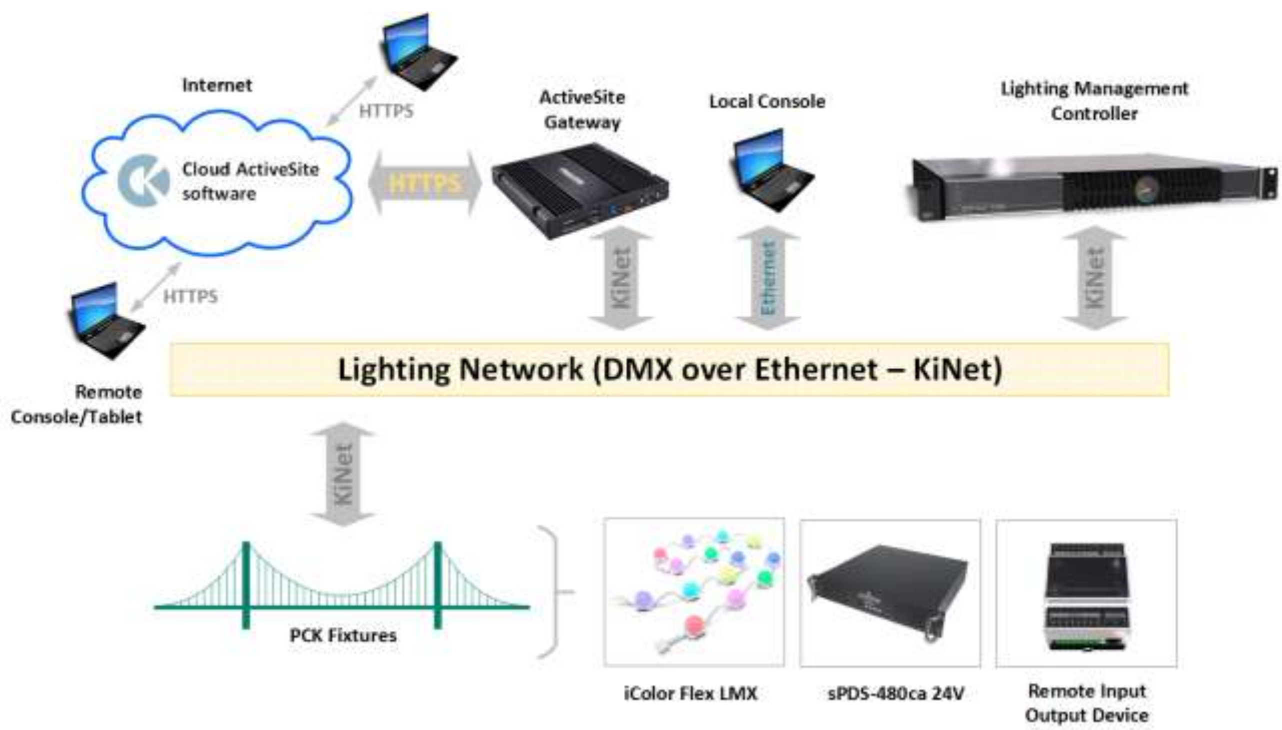


Figure 3: System Hardware Architecture.

The proposed system will use a **Lighting Management Controller** where all static and dynamic light scenes are stored within this equipment. The Lighting Controller provides a complete control of the installation. Based on individually controllable and independently running timelines and scenes, it lets you build dynamic, precise, fully customizable pre-programmed lighting shows Scenes can be triggered from the controller via commands over Art-Net, RDM/DMX over Ethernet.

A Video Controller is proposed as Lighting Management Controller, to fulfill the requirement to provide external video content and interactivity. Video controllers can coordinate tens of thousands of individually controllable points of color-changing LED light for large-scale video displays. Integration with media servers, audio systems, and advanced control solutions can create interactive and immersive multimedia experiences.

The proposed Video Controller (see Pharos VLC) supports all of the leading Ethernet communications protocols for lighting, afford native multimedia support, offer advanced if-then- else triggering and timeline scripting, and tightly integrate with motion detectors, light sensors, daylight harvesting photocells, and other building automation devices.

The proposed controller can offer a variety of triggering strategies. Through automated control through time-based triggers and astronomical clocks. You can schedule onetime events at a specific date and time, or recurring events every second, minute, hour, day, week, month, or year. Or through, advanced conditional logic for triggers and events through extensions to the Lua embeddable scripting language.

For show control and integration, Remote Input Output devices can provide a convenient and scalable way to add inputs and outputs to the proposed lighting system. Each device can be placed where it is needed along the bridge and connected to the Controllers over an Ethernet network.

The connection to our Cloud Based Lighting Management System ActiveSite is done through the ActiveSite Gateway.

The buildings blocks of the system are described in the following sub-sections.

2.1.1.1 Pharos VLC (Video Lighting Controller)

The Pharos VLC (Video Lighting Controller) is an extremely capable and cost effective solution for large LED pixel arrays; such as building façades, bridges, and presentation walls. It makes it simple to play video content across your array, either from locally stored HD media files or a DVI-D video input. It also offers a range of creative, generative effects and the versatility of powerful show control and integration features.

Figure 4: PHAROS VLC (Video Lighting Controller).

The VLC is a rugged 1U 19” rackmount unit with separate Gigabit Ethernet ports for management and DMX-over-Ethernet output. It is available in multiple variants with capacities ranging from 25,600 channels up to a massive 768,000 channels from a single unit, with further scaling by using multiple Controllers connected and synchronized over Ethernet.

To fulfil the bridge dynamic lighting specifications the controller covers the following functionalities:

- Supports Ethernet communications for lighting.
- Scalable with only extending the Ethernet network. For additional integration options simply

Remote Devices needs to be added to further extend the network.

- Afford native multimedia support.
- Live video can be captured on the DVI-D input at resolutions up to 1080p60. Internal video playback at up to 1080p30 supports all major formats such as H.264/MPEG-4 AVC, MJPEG and QuickTime. The built-in 128GB SSD provides plenty of capacity for media storage.
- Allows remote management. The VLC can be connected to a network, making it possible for you to remotely manage your installation. The built-in web server lets you check the Controller's status, inputs and outputs, trigger timelines, view a full history log, etc.
- Offer advanced if-then-else triggering and timeline scripting.
- Allows the creation of web custom interfaces and multiple user levels. The built-in web server supports an extensive JavaScript API and access control with multiple user levels.

For this project the Video Lighting Controller 500 (256,000 channels eDMX) will be supplied by PHILIPS.

2.1.1.2 Remote I/O devices

The lighting controller can be triggered by any parameter that you can measure (typically data coming from sensors). The Video Controller VLC work seamlessly with remote devices, connected to the lighting controller, to gather the information from this sensors.

Figure 5: PHAROS RIO (Remote Input Output) devices.

For this project we suggest to use the PHAROS RIO 80 (Remote Input Output Device 80 - 8 input, 0 output, Serial/DMX) a microprocessor-based system specifically designed as an input/output interface for integration with lighting and audio visual controllers in an architectural or entertainment application. And should be configured by the proposed VLC over an Ethernet connection.

The PHAROS RIO 80 ("remote device") supports the following operating modes:

- A multi-mode full-duplex RS232/half-duplex RS485 serial port. The operating mode of this port shall be set by controllers over Ethernet.
- Supports DMX output via the multi-mode serial port, configurable by controllers over Ethernet.
- Supports 8 local inputs capable of digital, analogue or contact closure operating modes. The status of these inputs shall be transmitted over Ethernet to controllers.

The RIO is Power-over-Ethernet (PoE) powered, with a rugged DIN rail mounting enclosure and install-friendly connectors.

Or in addition Internet based triggers can be created in case that there is a need to request to gather input information from Internet, allowing to interface with other systems.

The RIO 80 equipment will be supplied by PHILIPS.

2.1.1.3 ActiveSite Gateway

The ActiveSite Gateway is the critical component that uses industry-proven Philips KiNET technology to communicate with the local lighting network and the cloud-based ActiveSite lighting management software.

KiNet is the network protocol used by PHILIPS Color Kinetics to control LED fixtures (KiNet stands for DMX over Ethernet protocol).

Figure 6: ActiveSite Gateway.

The Gateway must have an active Internet connection at all times in order to upload logs to the ActiveSite cloud software and to allow remote content management. The Gateway can be connected using a wireless modem, or it can be connected to a local wired Internet connection. If 3G Modem is provided by Philips, yearly data charges will be billed to the customer.

Figure 7: ActiveSite Gateway connection to the Internet and to the lighting network.

To access to the cloud-based ActiveSite lighting management software, the lighting operator only needs to have access to Internet and is easy to access to the SaaS through any web browser compatible with Google Chrome, Mozilla Firefox, and the Apple Safari browsers.

The ActiveSite will be supplied by PHILIPS.

2.2 ActiveSite Software as a Service (SaaS)

ActiveSite is a cloud-hosted connected lighting system for remotely monitoring, managing, and maintaining architectural LED lighting installations.

A connected lighting system from Philips Color Kinetics consists of intelligent luminaires, a system controller, and an ActiveSite Gateway as described in the System Hardware Architecture. The gateway is the critical component that connects the local lighting network to the cloud-based ActiveSite lighting management software, providing secure access to the lighting network from anywhere in the world.

ActiveSite offers all the benefits of a Software as a Service (SaaS) system:

- No software to install or servers to buy and maintain. All that is required is the ActiveSite Gateway, a standard internet connection, and a computer or tablet.
- Web-based software is easy to access with any authorized device
- Rapid deployment of software updates with minimal downtime
- Data backup, recovery, and security operations supported by Philips

The ActiveSite web interface is an intuitive and easy-to-use software interface that contains a horizontal navigation menu and a vertical navigation menu. The horizontal navigation menu is the primary navigation aid, providing access to information from a broad perspective that draws data from all the installation sites you can access. The tabs accessible from the horizontal navigation menu include: Dashboard, Sites, Reports, Alerts, and Users.

The vertical navigation menu is a secondary navigation aid that is only accessible from the Sites tab. This menu provides access to information specific to an individual installation site. The tabs accessible from the vertical navigation menu include: Site Overview, Devices, Site Alerts, Site Reports, Content Management, Archived Assets, and Advanced.

The remote ActiveSite content management allows the following operations:

- Schedule content
- Upload new shows
- Trigger shows
- Create dynamic scenes
- Trigger scenes
- Control content both from desktop computer or iPad/iPhones
- Create custom web interface to meet customer preferences (part of services offered)

2.3 Interned Based Triggers

The lighting controller can be triggered by any parameter that you can measure (typically data coming from sensors). This can be done using input modules, connected to the lighting controller, to gather the information from this sensors.

Or we can create Internet based triggers (gathering information coming from Internet), allowing to interface with other systems.

2.4 Lighting communication network

This sub-section is delighted to present the communication network for controlling the proposed LED lighting system for the Humber Bridge project. As currently, Ethernet is the most widely used and effective network infrastructure for medium to large architectural lighting installations we have choose this solution to provide the internal communication of the proposed system.

The lighting communication network consists of dedicated scalable local area networks (LAN) with KiNet network protocol, an Ethernet protocol defined by PHILIPS Color Kinetics to control LED fixtures (KiNet stands for DMX over Ethernet protocol). Its purpose is to allow transfer DMX512 data over a wide area using standard networking technology. All system components are connected to the same network and can be controlled via this network through a user interface (local console) or through the main controller, the VLC. This network must be a standalone LAN, not connected to any other IP network in the bridge.

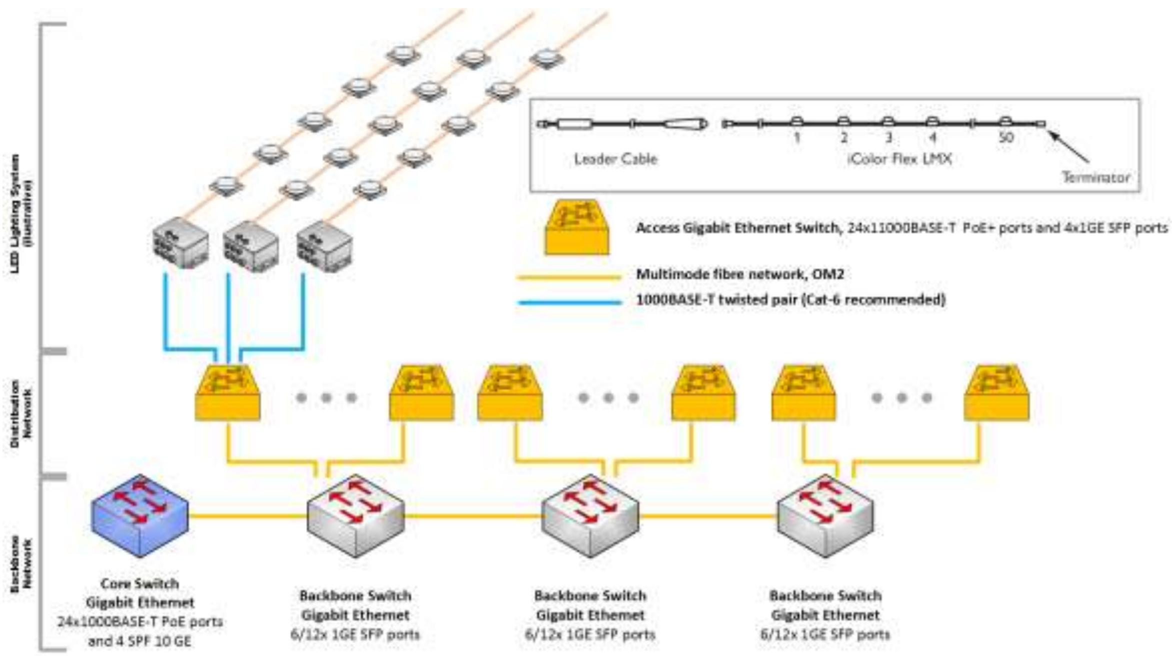


Figure 8: Lighting communication network topology.

All the hardware components proposed in section 2.1 are compliant with Gigabit Ethernet (1000Base-T) standard, therefore the bit rate requirement for the whole system is Gigabit Ethernet, which allows bit rates up to 1000 Mbps. Depending on the distances that we need to achieve the medium can be a **twisted pair (Cat-6 recommended)** or fiber optics if we need to fulfill distances above 100 meters.

Twisted pair cable requirements

Physical Layer Standard	Medium	Ethernet Standard	Speed	Specified Distance
100BASE-TX	Cat-5, Cat-5e, Cat-6	Fast Ethernet	100 Mbps	100 m
1000BASE-T	Cat-5, Cat-5e, Cat-6, Cat-7	Gigabit Ethernet	1000 Mbps	100 m
1000BASE-X	Cat-6, Cat-7	10-Gigabit Ethernet	10 Gbps	100 m

Fiber optics cable requirements

Physical Layer Standard	Medium	Ethernet Standard	Speed	Specified Distance
1000BASE-SX	Multimode fiber optic	FO Gigabit Ethernet for operation over multi-mode using 850 nm.	1000 Mbps	OM1 (62.5/125): ~300 m OM2 (50/125): ~600 m OM3 (50/125): 1000 m OM4 (50/125): 1040 m
1000BASE-LX	Multimode fiber optic	FO Gigabit Ethernet for operation using a long wavelength laser 1300 nm.	1000 Mbps	OM1 (62.5/125): ~600 m OM2 (50/125): ~600 m OM3 (50/125): 600 m OM4 (50/125): 600 m

The backbone of the network shall be provided through a multimode OM2 (50/125) fiber optic (850nm). Single mode fiber, because of the more expensive electronics required for it is usually used for much greater distances and this project doesn't consider to use single mode fiber optics.

The distribution network, will be done with done as well with a multimode OM2 (50/125) fiber optic (850nm), to link with the distribution network switches. From the Access switches to the Power Data supplies the communication will be done through Cat-6 twisted pair.

For Ethernet switches, it is recommended to use products that support Gigabit Ethernet compliant switches as physical Ethernet speed and provide a typical average packet latency of less than 0.2 msec.

The type of recommended switched are listed in Figure 8.

2.4.1 Physical separation between lighting and IT network

The lighting and IT network shall be separated: the only connection is formed by the Ethernet switches.

2.4.2 Installer scope of works

The installer will supply the following equipment:

- Supply, installation and commissioning for the fiber optic backbone
- Supply, installation and commissioning for the optical switches
- Supply, installation and connections for the Ethernet bus between the switches and the Power Data Supplies (sPDS-480ca 24V)
- Supply, installation and connections for the Supply Cable between the Power Data Supplies and the strands of LED nodes (iColor Flex LMX)