2019

Sensor Installation

MONITORING OBJECT AND VISITOR ENVIRONMENTS

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1. Installation

The sensors installed in the museum measure a multitude of different environmental measurands at different areas of the museum.

1.1. Sensor Specifications

Name	Img	Specification
Air Quality		• Measurement Sensitivity: PM1: 0.3 to 1.0 µm, PM2.5: 1.0 to 2.5 um, PM10: 2.5 to 10 µm • Counting Efficiency: 50% @ 0.3 µm, 98% @ >= 0.5 µm • Effective Range: 0 to 500 µg/m^3 • Maximum Range: 0 to 1000 µg/m^3 • Maximum Consistency Error: +/- 10% @ 100 to 500 g/m^3 • +/- 10 µg/m^3 @ 0 to 100 µg/m^3 • Response Time: ~10 Seconds • Active Current: ~180 mA @ 3.3 battery voltage, ~0.6 W overall • Operating Temperature: -10°C to 60°C • Operating Humidity Range: 0 to 99% • Mean Time to Failure: >= 3 Years
Air Velocity		• Pressure Range: -500 Pa to 500 Pa • Allowable Overpressure: 100 kPa • Rated Burst Pressure: 500 kPa • Max Humidity for Long-Term Exposure: 40°C dew point • Sensing Range: Range at 0 m Altitude: 0-30m/s, Range at 5000 m Altitude: 0-40m/s, Range at 8000 m Altitude: 0-50m/s • Span Repeatability: 0.5% of reading • Span Shift Due to Temperature Variation: < 0.5% of reading per 10°C • Offset Stability: < 0.05 Pa/year • Calibrated For: Air & N2 • Media Compatibility: Air, N2, O2, non-condensing
Carbon Dioxide		• Measures 0 to 10000 ppm CO2 • Accurate to +/- 45 ppm + 3% of reading • Sensor produces instantaneous CO2 readings and 8-hour time weighted average (TWA) readings
Light Levels		• Sensing Technology: High Sensitivity Photodiode • Sensor Material: Silicon • Peak Wavelength: 580 nm • Maximum Reverse Voltage: 6V • Maximum Power Dissipation: 40 mW • Maximum Light Current: 500 µA • Maximum Dark Current: 0.3 µA • Maximum Rise Time: 8.5 ms • Maximum Fall Time: 8.5 ms • Maximum Operating Temperature Range: -30°C to +85°C

Motion		• Sensing Technology: Passive Infrared • Sensing Range: 16.4 ft (5 m) • Voltage Rating: 3 VDC to 6 VDC • Output Type: Digital • Supply Current: 170 uA
Relative Humidity & Temperature		• RH Operating Range: 0 – 100% RH • Accuracy: +/- 3% under normal conditions (10% - 90% RH) • Energy Consumption: 80uW (at 12bit, 3V, 1 measurement / s) • RH Response Time: 8 sec (tau63%)
Temperature		• Thermocouple Connection Options: 6 ft hardwired probe / 5 ft K-type connector • K-Type Fixed Probe - Accuracy above 0°C: +/- 2.2°C or 0.75% (whichever is greater) • K-Type Fixed Probe - Accuracy below 0°C: +/- 2.2°C or 2.0% (whichever is greater) • K-Type Fixed Probe - Temperature Range: -100°C to +400°C (-148°F to +752°F)

1.2. Sensor Locations

Sensor locations were split into four individual zones these being the two primary art galleries (Victorian & Langworthy) and the two of the art storage areas for objects and artworks.

Sensors for measuring air velocity weren't installed in the basement zones of the museum because they aren't likely to provide valuable data considering the very low amount of traffic because those zones are off-limits to the guests.

To take thermal stratification into account multiple temperature sensors were installed in each gallery, so four sensors were installed on two separate walls in each gallery.

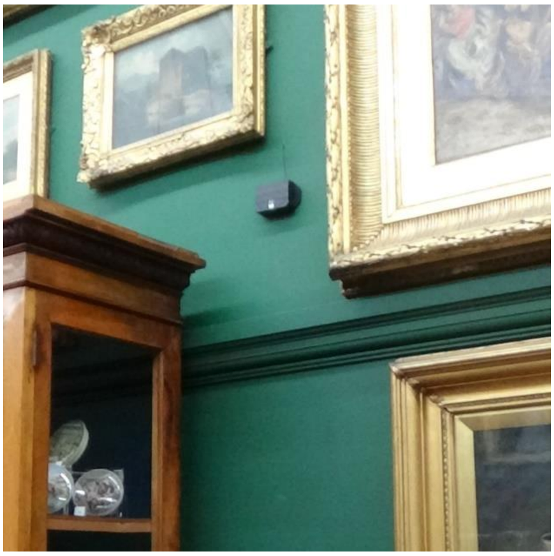
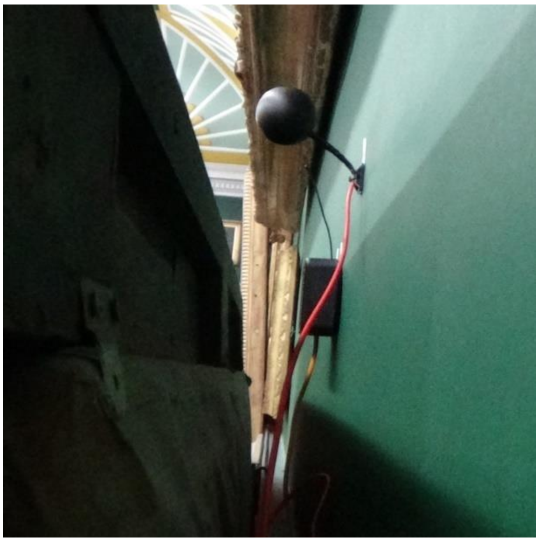
The sensors were installed on opposing walls so the climate of the gallery can be separated into two distinct zones for analysis, and so any inconsistencies in the local climate can be observed.

This consideration was not made for the basement zones because monitoring the object environment is the only consideration for the storage areas.

1.3. Visibility

One key consideration during the installation was the overall visibility of the sensors, as minimising the visibility of the sensors was a priority because it would minimise disruption to the guests and would also reduce the probability of the sensors being damaged by a curious guest.

Sensors were hidden behind existing objects and furniture where possible, but some sensors such as the motion sensors and the light sensors would have their readings effected if the sensors itself was hidden out of sight.

Victorian Gallery Light Sensor & Temperature Sensor

Where possible the sensors were disguised to minimise their presence, so any sensors that were unable to be hidden from view had their front plate coloured black using electrical tape, and the sensors can be painted to match their surroundings as long as the sensor windows aren't obscured.

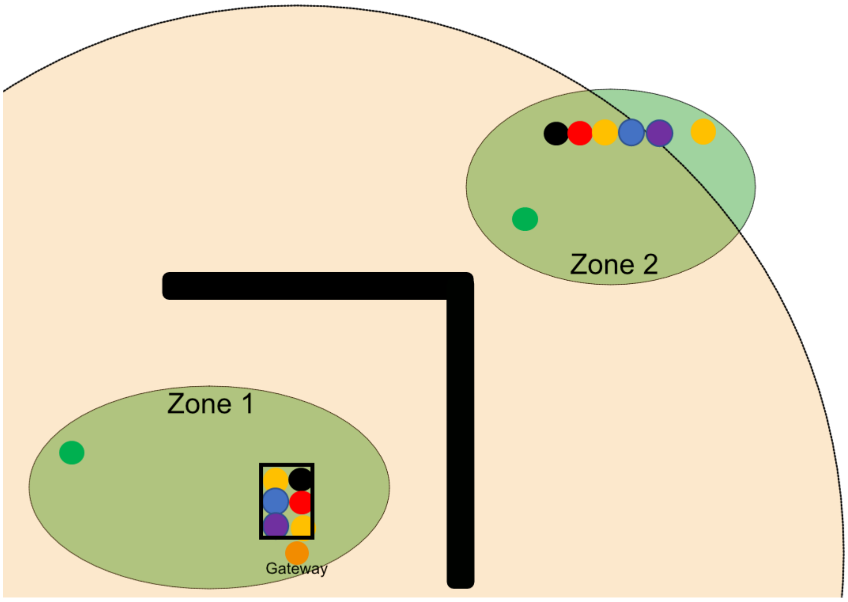
Victorian Gallery Temperature Sensor hidden behind artwork

1.4. Signal Strength

Signal strength between the sensors and their respective gateways has been an issue with the current deployment.

It has become apparent that the placement of the gateways requires special consideration when designing the layout of the sensor zones, especially when dealing with older building with especially thick walls or buildings with walls insulated against EMI and active signals.

The gateway placement for Zones 1 & 2 proved troublesome due to the composition of the walls between the two zones, as the thickness of the wall is thought to be interfering with the signal strength of the sensors in zone 2.



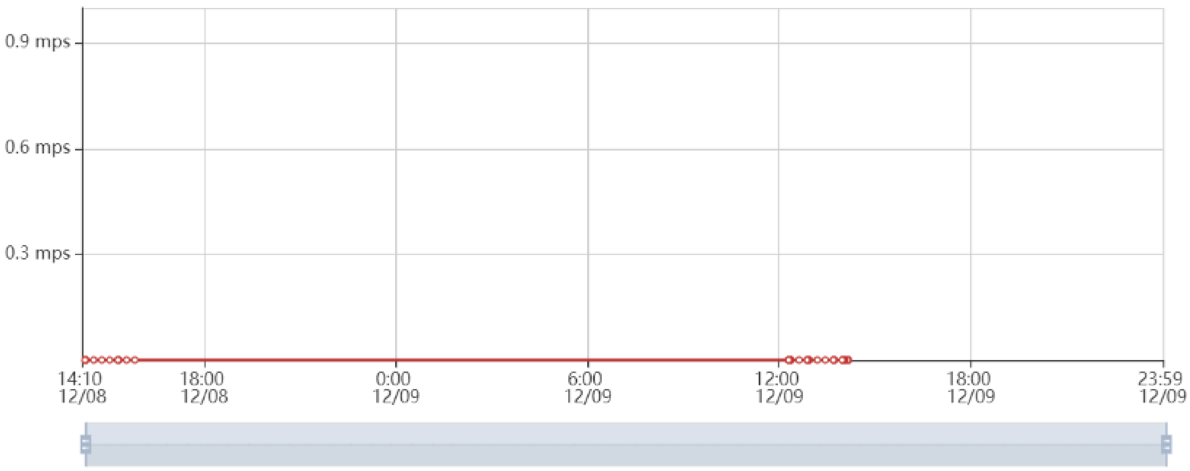
Sensors in Zone 2 have weak signal due to the gateway position & wall thickness

1.5. Air Velocity Sensors

As part of the initial sensors installation air velocity sensors were installed into the galleries (zones 3 and 4), but these sensors provide to be inadequate for measuring the airflow in the spaces because the sensor units were designed to measure airflow in constrained spaces such as air ducts where the airflow would be funnelled into the sensor.

If air velocity is a factor that needs to be monitored in the GEM appropriate sensors will need to be sourced.

A possible solution to this may be to implement an open-air anemometer connected to an ALTA Voltage Meter, as this would allow anemometer measurements to be sent through the Monnit system like the other measurands.



Air Velocity data for Langworthy Gallery

This solution does have its drawbacks, and those being that the anemometer will need a dedicated power source so the deployment is not as self-contained as preferable, and that the anemometer used still may not be sensitive enough to detect air velocity in areas with low air movement.

2. Data Platform

2.1. Data Collection

Data from the sensors is transmitted to the local gateway, and from there the gateway will transmit the data to the Monnit servers over a wired Ethernet connection.

The data is stored on the Monnit servers and can be sent to the cloud platform used for processing and visualising the data using the integrated Azure IoT Hub functionality of the Monnit platform.

Once the Monnit platform is streaming data to the IoT hub it can be streamed from the hub into a database for storage and processing before representation on the dashboard solution.

Each sensor connects to the gateway, and the gateway to the Monnit platform, using an encrypted tunnel using 128-bit AES so sensor data cannot be intercepted and used outside of the sensor network.

Additionally, no external communication is possible through the sensor network because the sensors and gateways are designed to transmit nothing but their sensor data to the gateway and Monnit platform, so any unexpected attempts to transmit data to the gateway to redirect traffic will fail.

2.1.1. Weather Data

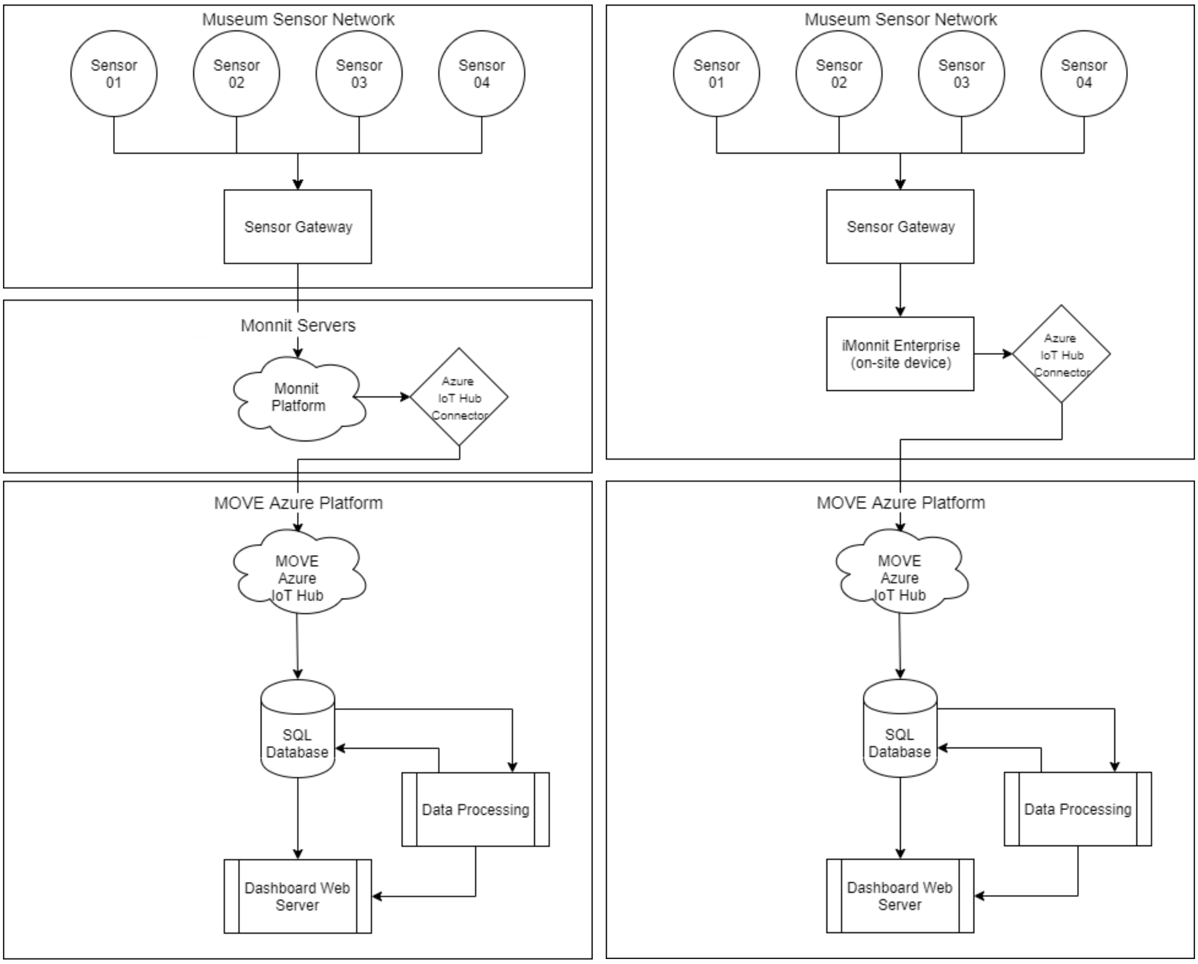
The university has multiple sources of local climate data, such as weather stations deployed at various locations across the campus, that can be easily aggregated into the cloud platform and used for climate comparison between the external conditions and patterns that may occur with the internal conditions of the museum as they regulate the internal climate.

Additionally, there are dedicated pollution sensors installed on campus that may be useful for a comparison between the external and internal pollutant levels.

2.1.2. Data Platform Abstraction

Data that is collected by the sensor network is stored on the Monnit account that was used to create the sensor network, and from there the owners of the Monnit account must specifically configure the data to be sent to the Azure platform for additional processing and dashboarding.

This approach allows the sensors and the raw data to remain in the possession of their respective teams.



The sensors can be configured to send and store data on an on-site server owned by the client if necessary otherwise sensor data is sent to the Monnit servers.

If collecting sensor data on-premises is critical it can be achieved using the iMonnit Enterprise software that will allow sensor data that is collected to be sent to, and stored on, a local device such as a server.

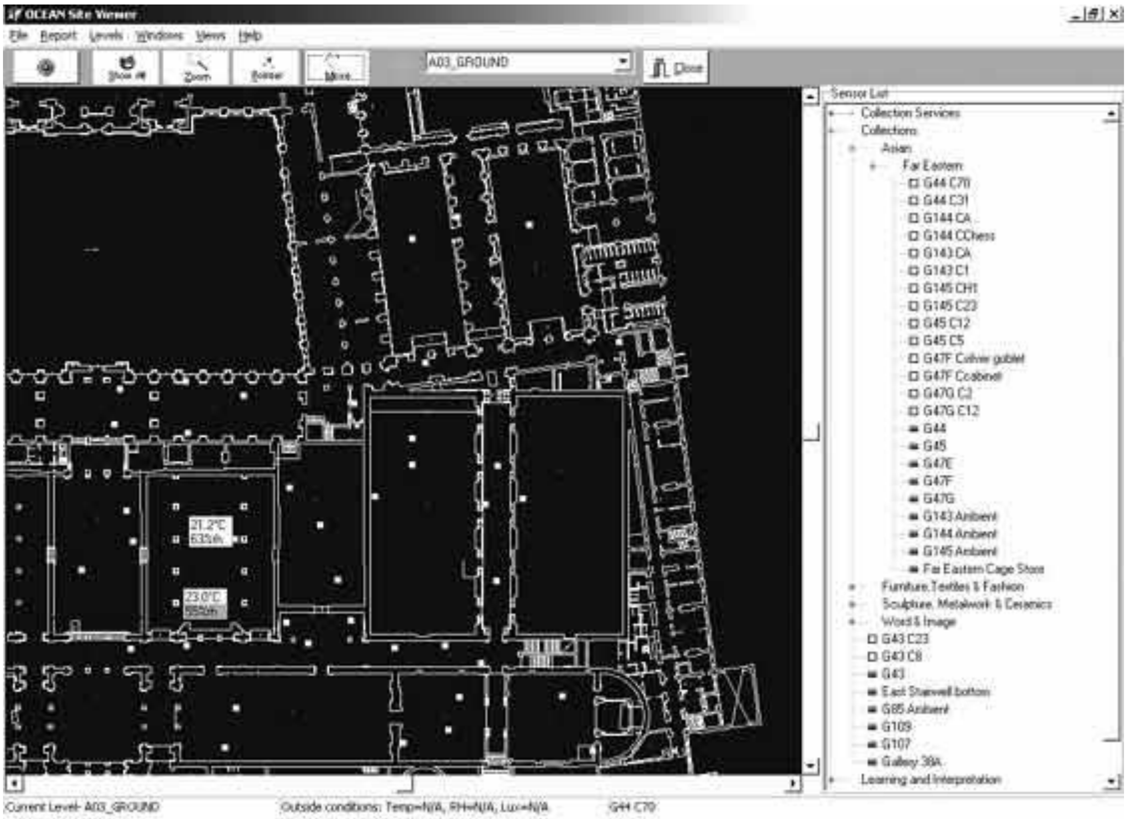
The iMonnit Enterprise software requires a device running Windows Server 2008 or higher with an SQL Server 2008 or higher database server.

3. Dashboarding

There are few examples of dashboard that meet the requirements of the MOVE project, the closest being the OCEAN project developed for the Victoria and Albert museum.

From what data is available from published papers the V&A dashboard is implemented using a Win32 application using a map to position the available sensors, and with all data being housed on-site.

This approach limits overall expandability of the system as any improvements to the dashboard will require changes to the source code and recompilation of the system.

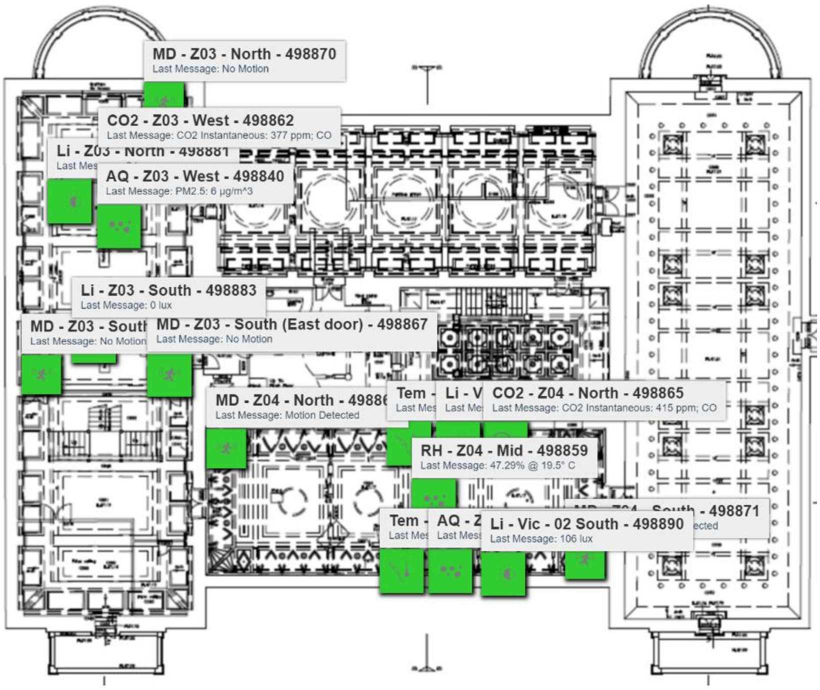


Example of the OCEAN dashboard used in the V&A Museum

Details about the measurands of the OCEAN dashboard and how it visualises them are scarce and considering the available images of the dashboard are in greyscale it's difficult to see how the dashboard uses colour to illustrate sensor status.

Implementing a multi-page dashboard is part of the current design plan, and separate pages for the galleries and basement will be used along with the floor plans of their respective floor in a similar fashion to the OCEAN dashboard.

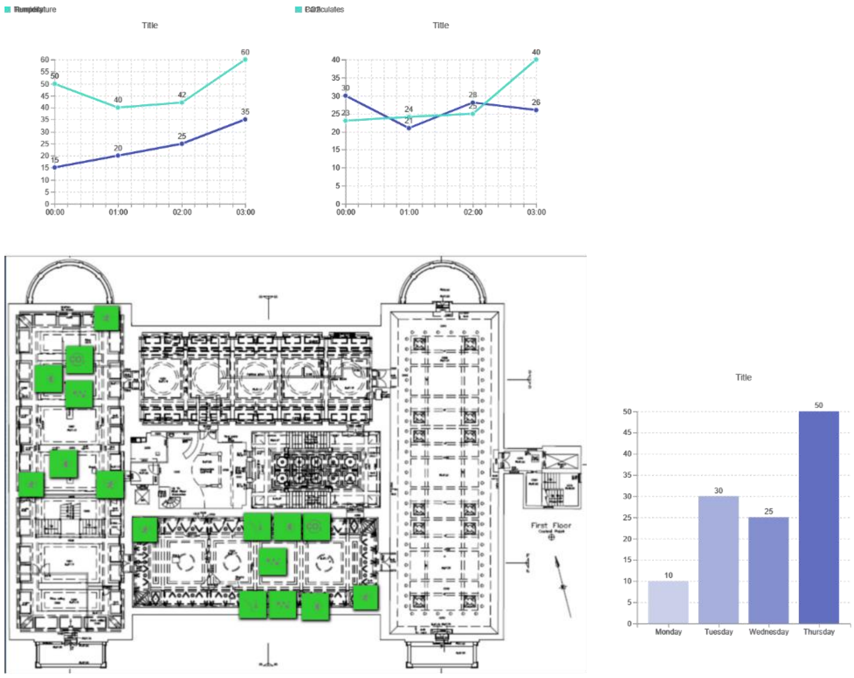
The master page of the dashboard will primarily consist of visualisations to encompass all the current zones, and how suitable they are for object longevity.



The Monnit platform provides a similar functionality by allowing individual sensors to be positioned on an uploaded image, and while this is a convenient feature the functionality is relatively restricted, and the icons aren't scalable.

In the dashboard it's intended that the sensor icons are scalable relative to the size of the floorplan image or the scale of the dashboard itself.

This can then be further expanded upon to include additional visualisations stemming from the sensors shown in the plan itself.



Basic design sketch of the dashboard page relating to the Salford galleries monitoring

4. Alternative Sensor Providers

4.1. IAconnects' 'Mobius'

The Mobius platform is an IoT solution designed to adopt open-source communication protocols for its sensor connectivity as this will allow user to connect more sensors to the Mobius network than those that are provided by IAconnects themselves.

The Mobius system works in a similar fashion to the Monnit system because they both use a sensor-to-gateway system operating in the 868MHz EU frequency range that completely abstracts the sensor network traffic from any networks useable by end-user devices.

IAconnects offer a range of sensors such as temperature and humidity, CO2, Air Quality, and PIR, sensors and even offer 'people counting' sensor so the occupancy of a room can be estimated

This contrasts with other solutions that provide sensors that operate using the 2.4GHz WiFi frequency bands, and while this isn't necessarily negative using a high frequency band such as this will drastically reduce the operating range of the sensors.

4.2. DIGI's 'Smart Sense'

The Smart Sense system isn't as extensible as the Mobius system as the system appears to only support sensors offered by DIGI for the Smart Sense system.

The system operated like many other IoT systems by operating in a sensor-to-gateway hierarchy with the connection from the gateway connecting directly to the providers own server system over a cellular LTE network.