MANAGING SMART BUILDING SERVICES

by

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Abstract

Motivation:

With around 50% of the UK carbon emissions arising from building [1 pp. 1-2] s, warnings of peak oil production being reached [2] [3] and the population rapidly increasing in size with an equally growing voracity for energy and resources [3], we find ourselves on the brink of a global dilemma. Indeed for a thought provoking and certainly possible scenario, watch a video called “the age of stupid” [4].

Do we continue to use resources as though there is no tomorrow and perhaps suffer the consequences, or do we respond as a mature collective and try to reduce and control our needs?

Problem statement:

Brunel University is a very large campus with many physically unconnected and disparate systems. Could these or other systems be interconnected and if so, how and by what method or system?

Approach:

Initially I met with energy, systems and maintenance managers. It became apparent that they were all very good in their area but could not fully help me in a solution. With the help of my tutor, I took on a 5 day practical course to learn about one of the world’s biggest integrators, Tridium and find how their products worked.

Results:

Previous experience with integration products and my time spent at Tridium have further convinced me that integration is the way forward. It is easy to implement, especially if installed as the start of a project build. Each product manufacturer says it can be done, but the primary research should be whether they can integrate the systems fully or only partially. This will most likely depend on what integration drivers they have and what level of functionality each driver has.

Conclusions:

See Chapter 8.

Acknowledgements

First and foremost I wish to thank my kind parents and my good friend Rashid Hosseini for the strong support and guidance they have provided me over the period of my studies. It has been a difficult year for me in many ways and I doubt I could have finished alone.

Bob Stiff, Peter Turner, Martyn King, Mel Pulmilia. Gentlemen, thank you for your valued time and help in looking at Brunel University systems. I wish I could have studied what systems you have in the university some more. Brunel campus is large, intriguing but far too big for just one dissertation and within the time available to me.

A big thank you to Alf Moroncini for his guidance and help with my dissertation content and for inviting me to Tridium.

Tridium, whom I must thank for allowing me to attend their excellent training course. The Niagara AX system has become a large part of my dissertation. The Tridium course has excellent workshops and training methods and has expanded my building controls and building systems integration knowledge superbly.

I have worked with Trend products for years and even trained their engineers. Thank you Trend for some excellent products, datasheets and information made freely available to all. Well done.

Thank you to the writers of “Web Based Enterprise and Building Automation Systems” a Barney and Lynne Capehart. I unfortunately came late to this excellent read when almost finished in my dissertation scribbling. What I have read so far has convinced me to add it to my book collection. For those interested in joining systems and Enterprise technologies together, I thoroughly recommend you start here.

Lastly, thank you to Brunel University and all their staff, both academic, support and residential. The course has been interesting, informative and I thank you all for giving me the chance to live and study on campus.

Abbreviations

BIM	*Building Information Modelling*
BMS	*Building Management System*
BEMS	*Building Environmental Management System*
SCADA	*Supervisory Control and Data Acquisition*
DDC	*Direct Digital Control*
HVAC	*Heating Ventilation and Air Conditioning*
AI	*Analogue Input*
AO	*Analogue Output*
DI	*Digital Input*
DO	*Digital Output*
UI	*Universal Input*
PIR	*Passive Infra-Red*
NC	*Normally Closed*
NO	*Normally Open*
IP	*Internet Protocol*
WWW	*World Wide Web*
JACE	*Java Application Control Engine (Tridium/Vykon product)*
GUI	*Graphical User Interface*
XML	*Extensible Mark-up Language*
API	*Application Programming Interface*
CCTV	*Closed Circuit Television*
PZT	*Pan Zoom Tilt (positional modes for cameras)*
LAN	*Local Area Network*
VFD	*Variable Frequency Drive*
NDIO	*Niagara Direct IO (Tridium device)*
PC	*Personal Computer*
VOIP	*Voice Over IP*
IP	*Internet Protocol*
TCP	*Transmission Control Protocol*

oBIX	*Open Building Information eXchange*
TOGAF	*The Open Group Architecture Framework*
AHU	*Air Handling Unit*
IAQ	*Indoor Air Quality*
IEQ	*Indoor Environmental Quality*
M2M	*Machine to Machine*
CCRE	*Cisco Connected Real Estate*

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1.1 Integration

Integration, derived from the Latin *integrat*, meaning “made whole” [(5)]. In the context of buildings and systems the meaning is generally considered to be a combining of parts, such that they work together or form a whole.

A successfully designed building has been compared to a beautiful symphony. The parts of a building, like individual instruments in an orchestra, have the capacity to make up a whole that is greater than if they were played alone [(6)]. Having seen this in action, I find this to be very true and I am sure many a building manager would agree.

It is therefore unfortunate that many buildings built previously do not have such designs, each system being designed in isolation to the rest. Why this is done is often due to the extra cost, or the way contracts are managed and the fact that many companies prefer not to be involved with anyone else due to the extra time and complexities that will ensue from integration of designs. This may suit the contractor but is not beneficial to the client, although the initial reduction in capital cost may seem so. Clients now have the advantage of obtaining consultants that are energy and carbon emission aware, consultants that have seen what can be done and are prepared to advise a client as to the needs, rather than just the wants and wishes.

Further, times are changing and rules are starting to be drawn up and enforced by local and European government policies. Soon, all public sector buildings will need to be designed using an integrated approach. The CIBSE journal [(7)] states that “Government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016”. Although not a requirement of physical system integration, the necessity of modelling all systems electronically and in three dimensions will provide an overview rarely seen before. Such transparency will highlight to clients, designers and engineers alike, the variety of systems within a building and provide an excellent starting point to integrate them. I hope that one day it will become a requirement to install an intelligent integrated control system into all buildings, especially homes.

1.2 Intelligent Systems

Buildings have a profound impact on the quality of our lives and the world around us. They enhance our communities, enrich our wellbeing and support and enable our businesses.

An intelligent building will have any number of the following;

Systems

- Environmental controls
- Lighting
- Security
- CCTV.
- Power distribution.
- Lifts.

Building utilities

- Electric.
- Water.
- Gas.
- Solar.

Facility services

- Fault detection and diagnosis.
- Maintenance management.
- Continuous commissioning.
- Remote monitoring and control.

An intelligent building should use less energy, have lower operating costs, be safer and contribute to a comfortable and sustainable environment.

1.3 Brunel University

Brunel is a campus-based university situated in Uxbridge, West London, and is home to nearly 15,000 students from over 100 countries worldwide and was founded in 1966. The campus consists nearly a 100 varied buildings, small, medium and very large, old and very new (at the time of this writing the latest building “East Gate” was still under construction).

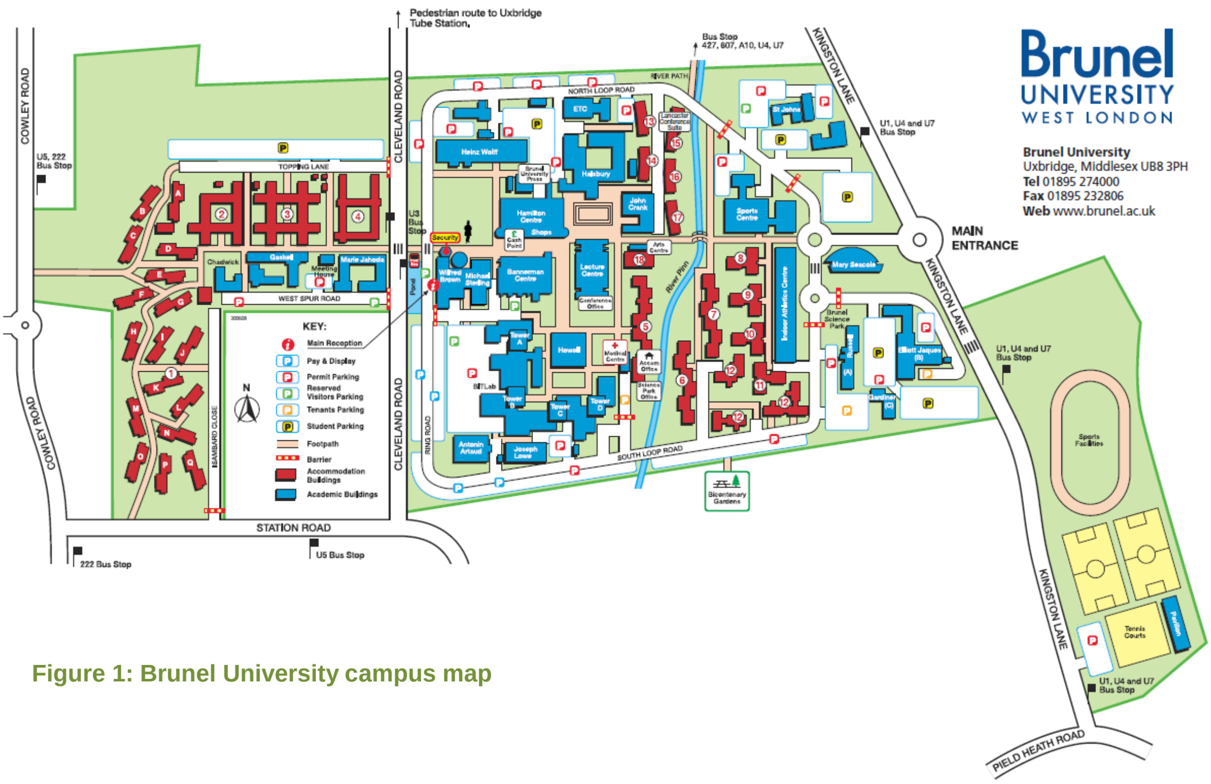

Figure 1: Brunel University campus map

Having lived and studied in Brunel, there are vast possibilities for improvement to the buildings, even the new Isambard complex where I lived for 1 year.

A couple of examples are;

Isambard residences, often the lighting is on during the day as there seems to be no lux sensor attached to the complexes. A single lux sensor could provide an override OFF condition to all the lighting controllers (they already have proximity sensors) during daylight hours.

Hallsbury often has the perimeter heating on even on warm days. Better outside monitoring (especially optimised heating) could help prevent this.

1.4 Brunel Systems

The university has, like many large complexes, a variety of disparate systems.

A meeting with the building systems manager (Mel Pumilia), provided a list of most of the essential systems as shown below;

System	Company
Wireless locking (Residences)	Salto
Access control	Grosvenor Janus
Intruder Alarm	Galaxy
Fire alarm	Kidde/Tyrrel
Barriers	StarNET
Refuge	Complus
CCTV	Pelco
Intercom	
BMS	Trend
ANPR	Citysync

Table 1: Brunel University systems

The following describes some details (where available) about the disparate systems of Brunel University.

1.4.1 Salto

SALTO wireless system is an on-line real-time battery powered access control system that uses radio frequency technology to communicate in real-time with the central computer [(8)]. Brunel use the wireless door locking systems for many of the buildings, including the new residential Isambard complex which has 1200 accommodation rooms alone, service areas and plantrooms.

1.4.2 Galaxy Control Systems (GCS)

GCS [(9)] were established in 1974, and are an award winning defence contractor that developed surveillance and tracking systems for the US Military.

1.4.3 Kidde/Tyrrel

Kidde [(10)] are now part of UTC Fire & Security [(11)]. These companies have provided fire systems for years and even the old systems usually have an RS-232 or RS-485 communications interface. Usually though, the interface is read only as Fire Officers do not like external systems interfering with life safety systems.

1.4.4 Trend

Trend [12] is one of the UKs leading BEMS manufacturers, with a worldwide distribution and support network covering over 50 countries. Trend has produced controllers that have developed and moved forward with technology, yet still are backward compatible. Initially Trend were only based in the UK, but they have now spread to other countries and are rapidly becoming accepted as a BMS package supplier throughout the world. Their fully integrated control solutions are able to meet the complex requirements of modern buildings.

For the UK, Trend has been very open and can provide excellent training to engineers. Therefore the number of Trend engineers has steadily grown, providing many companies that are able to install, service and maintain Trend equipment. This differs from other "closed" system houses that require their engineers to provide backup and maintenance to their systems. The life cycle costs to a client can be reduced with an open system and allows a client to search for a better support if they are dissatisfied with their current maintenance provider.

With the arrival of the IQ3 series of controllers, Trend joined the growing number of systems that are able to be installed on standard Ethernet building networks. This has also allowed their equipment to be easily accessed worldwide via the WWW (providing monitoring, adjustment and control).

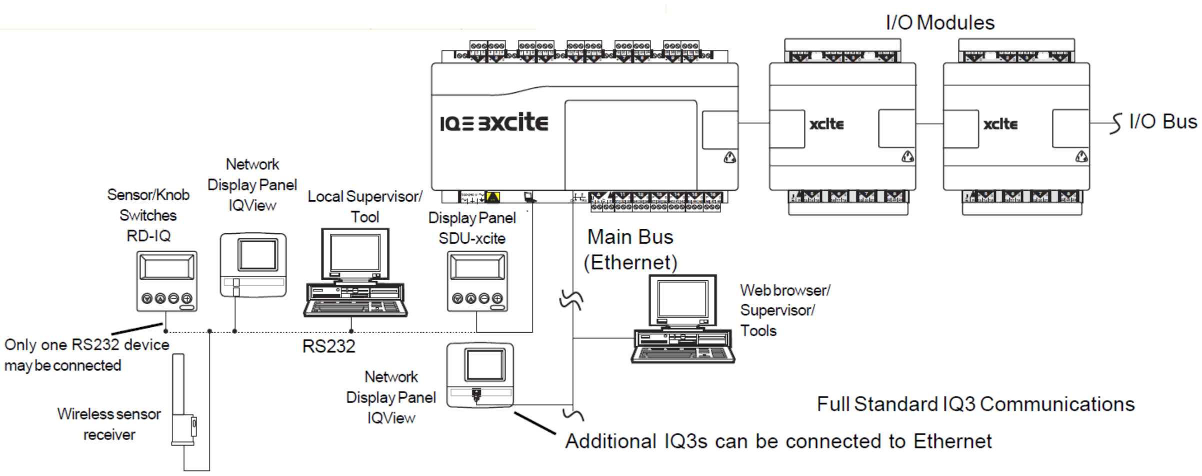

Figure 2: Trend typical system and communications layout

Chapter 2 Integration

2.1 Physical basics

Although systems have become more and more complicated the basic interface hardware is still limited to four main types. The four types (the fifth type is actually a combined IO and has been listed for completeness) are used to link controllers to field equipment and consist of;

- DI (Digital Inputs)
- AI (Analogue Inputs)
- DO (Digital Outputs)
- AO (Analogue Inputs)
- UI (Universal Inputs)

Each input or output type (commonly known as IO) can be further explained.

2.1.1 DI (Digital Input)

These read (input) a binary state (1/0), providing a statuses such as ON/OFF, Open/Closed or maybe Alarm/Normal. The field equipment is usually very basic and will consist of voltage free contacts, such as a relay. The “voltage free” is very important to many controllers as normally a voltage is supplied by the controller and then fed back to the controller to provide the feedback and status signal. If a field device has its own generated voltages, then further interfacing may be required, otherwise damage may occur to the controller. Some controllers can accept a voltage or current signal, but usually this form of monitoring is used by more sophisticated controllers with UI (universal inputs).

Figure 3: Trend IQ3 controller and IO module

2.1.2 AI (Analogue Input)

The analogue input comes in a variety of forms. Many devices these days have universal type inputs that can read most of the more common types, usually 0-10 Volt DC and 0-20 milliamps DC and a wide range of resistances. Here again, controllers will often output a regulated DC voltage/current and use it for feedback.

Most AI are used for reading field devices that provide variable values, such as temperature, pressure or lux levels.

Third party field devices sometimes have their own power supplies and voltage or current outputs that are separate from the controller. Interfacing between the field and the controller should be assured that not only will it work, but that it will not damage either of the devices in operation. It can be seen therefore that even simple interfacing can be problematic between devices of differing manufacturers. This is often why suppliers of equipment usually prefer their own equipment to be used throughout (although the selling and therefore company profit making is also preferred benefit).

2.1.3 DO (Digital Output)

Digital outputs are generally provided via relays operating a set of voltage free contacts. These give ON/OFF outputs (digital) or possibly a changeover set of contacts. This is certainly not always the case though. Controllers sometimes use thyristors or triacs to provide outputs. These normally fall into the category of a universal output (UO) and will involve using the controller's electronics and the voltages associated with it. This can further complicate integration and may not be suitable if the field device has its own voltage/currents which need to be switched externally to the controller. The old naming convention (e.g. SPDT) uses the following. The S means Single, the D means double, the P means Pole and the T means Throw. DT is often referred to as changeover (CO) contacts with more modern engineers.

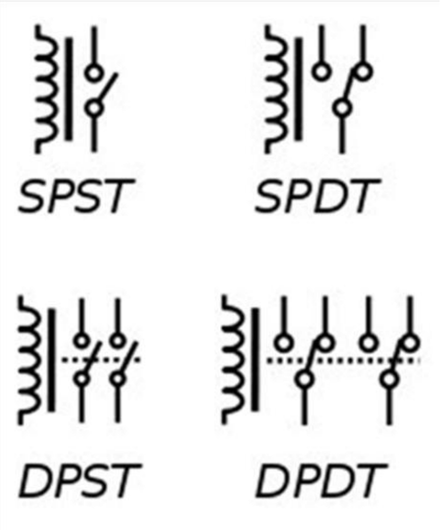

Figure 4: Types of relay contacts

2.1.4 AO (Analogue Output)

Analogue outputs. These outputs are usually thyristor or triac type devices and can be changed to represent a standard output such as 0-10 volts DC or 0-20 milliamps DC.

Any device connected to an AO should be capable of receiving and acting upon such signals. These could be positional devices such as dampers, speed controllers, VFDs, valve actuators or analogue displays.

In the field of BMS controls, often an analogue output is connected to a device that will convert the single signal to multiple digital outputs. Usually this type of device is added because there are limited digital outputs on a controller and a surplus of analogue outputs. Increasing the controller size may greatly increase cost and could be problematic due to the controller physical size increase, so analogue to digital convertor is often added.

2.1.5 UI (Universal Inputs)

Universal inputs have become more popular with newer controllers. They have the ability of the DI and AI combined. More sophisticated electronics allow digital, current, voltage and thermistor types of input to be read. Each input point will need to be either programmed or a physical link (jumper) positioned to decide what type of input will be read. Trend use jumpers as shown in the diagram but the software programmed within the controller will also need to be set to the correct type.

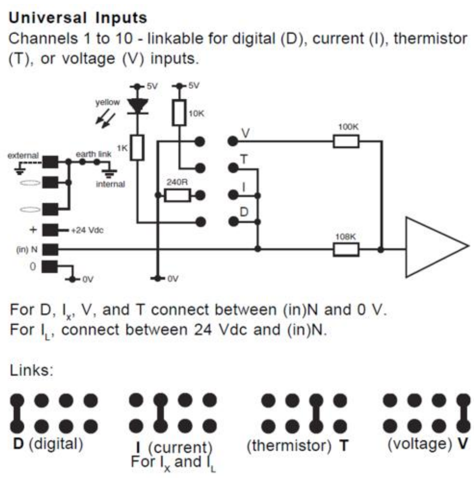

Figure 5: Trend IQ3 UI circuit layout

2.2 Communication interfaces

Taking interfacing further requires something a little more intelligent and flexible than only single inputs and outputs. The communications interfaces listed here are the most common types used today. There are many other standards but often cheapness and ease of use often prevail over sometimes better solutions.

Generally we can look at three primary parts to connecting devices together;

LAN. This comes in a variety of types cables (i.e. twisted pair, fibre optic or even radio such as Wi-Fi). A popular LAN format is Ethernet, but it is not the only type to be used, in fact RS-232, RS-485 and a variety of proprietary formats can be used to create a LAN. The connection topology can be in a ring (circular), both single or bi-directional, star or as with some of the Lon system LANs, completely ad-hoc (anyway you want).

Protocols. These are the communication handshaking and methods of exchanging information.

Physical connectors. Differing technologies often use different connections and even different pin arrangements. This can be made further complicated by devices sharing the same technology having completely different connectors.

These traits are certainly true of the following popular formats;

2.2.1 RS-232

RS (Recommended Standard) 232 has been in use for many years. The EIA (Electronic Industries Association - discontinued Feb 2011 [13]) defined it as early as 1969 and although it has gone through several modifications and name changes, it is still going strong today as a communications interface. Until a 3 or 4 years ago, desktop and laptop computers were fitted with one or two RS-232 interfaces, they being either a 25 pin (original standard DB-25 connectors) or 9 pin (DE-9 connectors). This trend has now ceased, with the USB ports now taking over the role of the RS-232. In

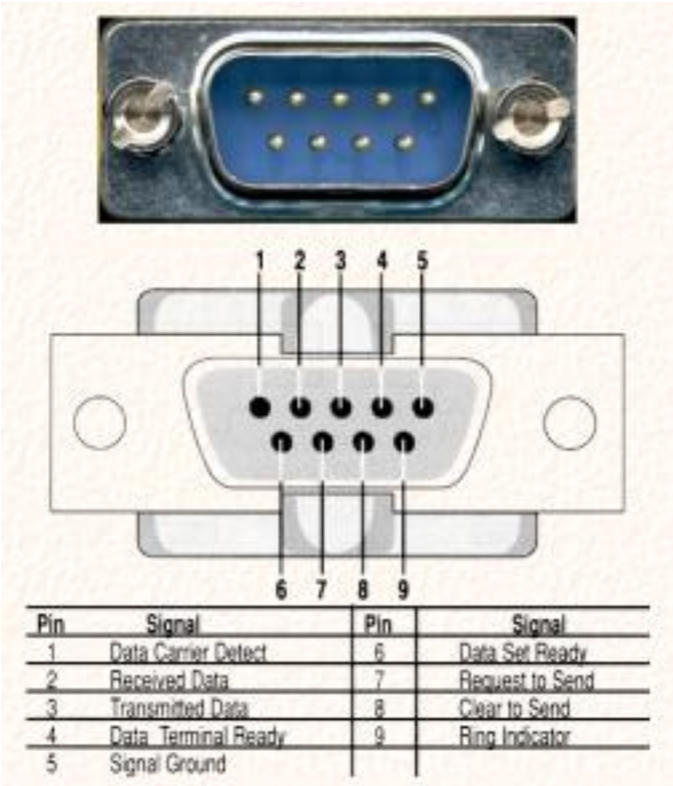

Figure 6: RS-232 DE9 connector

industry though, many items of field equipment still use RS-232 as a way of providing interfacing for communications and programming. Because of this need, RS-232 to USB or RS-232 interface cards are still readily available for PCs.

The standard does have its limitations, the recommendation of a cable being no longer than approximately 15 metres (determined by maximum capacitance, not actual length) being probably one of the most decisive reasons for designers choosing another method of communication between devices.

2.2.2 RS-485 and RS-422

Until Ethernet arrived and became fully accepted, the RS-485 and RS-422 interface was the most used for communications between field devices. The cable (often only 2 wire twisted pair) can be a maximum length of approximately 1200 metres (at a reduced data transmission speed - 100kbits/s compared to 35Mb/s at 15 meters).

EIA-485 is therefore used in building automation as the simple bus wiring and long cable length is ideal for inexpensively joining remote devices. It may be used to control video surveillance systems or to interconnect security control panels and devices such as access control card readers or linking controllers together in a LAN.

Trend IQ have a LAN interface that although proprietary, is most likely (comparing specifications) based around the RS-485 standard. The standard more defines the physical layer rather than the software layers. This means that different modes of data transfers can be designed around the basic standard. As this implies each company using 485/422 will have a different protocol, then an integration driver (as with Tridium or North) would need to be created for each system.

2.2.3 Ethernet

Ether net actually covers a family of technologies for LANs and was commercially introduced in 1980. It became a standard known as IEEE 802.3 [(14)] and has now become the worlds most used method of data transfer.

Ethernet comes in many physical forms of connection, screened co-axial cable (10BASE2 and 10BASE5) being one of its earliest incarnations, but rapidly moving on to the now widely accepted twisted pair cabling with the RJ45 connectors (10BASE-T). Fibre-optics is also used as a transport medium but is far more expensive than its 8 wire twisted pair 10BASE-T, 100BASE-TX and 1000BASE-T

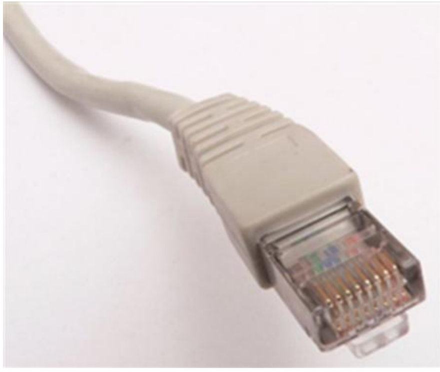

Figure 7: RJ45 Connector

brothers. Fire-optics do have the real advantage of electrical decoupling though and are often used for very long runs or where electrical disturbances would be a definite issue (fibre cables are often run along our electricity pylons).

Originally Ethernet was used for connections between servers and local PCs, but as the technology has decreased in cost and physical size, many controllers are taking advantage of Ethernet as a transport medium. Ethernet uses standard building structured cabling (twisted pair) and therefore controllers, supervisors and even field equipment can happily be connected with the building telephony, AV and VOIP systems.

2.2.4 Wi-Fi

Wi-Fi is part of a standard (IEEE 802.11) and actually a trademark and brand name of the Wi-Fi Alliance. The standard is closely related to Ethernet and is in fact a wireless progression of the standard. The standard covers communications products that use the 2.4, 3.6 and 5 Ghz frequency bands and is maintained by the IEE LAN/MAN Standards Committee (as with Ethernet).

As with Ethernet, the cost of the technology has decreased greatly allowing a multitude of devices to incorporate it and communicate wirelessly. Previous was mentioned the door locks of Brunel University (Chapter 1.4.1) which use wireless communication.

Building services are more and more utilising the technology for devices and communications where installing cables is either awkward or for temporary usage. Collecting sensor data via wireless means has become very popular.

2.2.5 USB

Nearly every person who uses a computer today is probably aware of the Universal Serial Bus or USB. It has rapidly replaced other competitors, such as the 25 and 9 pin RS-232 ports and seems to have even pushed out the Firewire (IEEE 1394) standard. With the latest addition of

Figure 8: USB Official Logo

USB 3.0, theoretical data speeds have increased to 5 Gbits/second with the "SuperSpeed" transfer mode, although realistic data transfer is probably around 3.2 Gbits/second (400 MBytes/second).

USB has allowed a variety of IO devices to be attached easily to computers. It has become a simple matter to plug in cameras, flash memory, hard drives and keyboards. Standard interfaces or the availability of online driver files make the process even easier.

2.3 Interfaces and protocols primarily for integration

A data communication protocol is a set of rules governing the exchange of data over a computer network. The building of good comprehensive drivers for a system is reliant on the provision of a full set of protocols from the companies involved. Once a driver has been built, integration between systems becomes a reality using systems such as Niagara AX from Tridium [(15)] or products like the Integrator or Compass from North Communications.

2.3.1 Lon

Echelon, the creator of LonWorks is detailed further in Chapter 4.4. The Lon open standard has become very popular due to the fact that the protocols needed to exchange data are well documented and the hardware side of things are handled primarily between each Neuron Chip (again, see Chapter 4.4). This has led to devices being created from many different companies, all having the ability to share data and receive commands from any other company (as long as the Lon standard has been fully implemented).

Echelon realised early on that it was not enough to only create an open standard, but to also allow data to be sent across a variety of interfaces and networks. To get things moving the provided transceivers for their own networking but quickly moved on to allow any form of networking as long as a transceiver could be provided by a manufacturer. The important point for Echelon was for the protocol to be open (so that others could study it and create their own devices) and that Neuron chips had to be used to keep the integration normalised and standardised.

Lon has become a tremendous success worldwide. Due to the unique number in every chip there is no real limit to the actual size of a system or number of devices connected to it. In fact, due to its ability to use radio, cable, satellite, microwave, fibre-optic or even cellular mediums, there is no limit to distance either.

2.3.2 BACnet

BACnet is primarily a protocol.

BACnet is based on a "client-server" model of the world where BACnet messages are called "service requests". A client machine sends a service request to a server machine that then performs the service and reports the result to the client.

BACnet currently defines 35 message types that are divided into 5 groups or classes. For example, one class contains messages for accessing and manipulating the properties of the objects described above. A common message is the "ReadProperty" service request. This message causes the server machine to locate the requested property of the requested object and send its value back to the client.

Other classes of services deal with alarms and events; file uploading and downloading; managing the operation of remote devices; and virtual terminal functions [16].

The BACnet protocol has been under development since 1987 but has become more and more popular due to the publicity and promotion from ASHREA (American Society of Heating, Refrigerating and Air-Conditioning Engineers).

2.3.3 Modbus

Like BACnet, Modbus is a communications protocol that can be used across a variety of transport mediums (e.g. serial ports, Ethernet). There are a variety of protocol versions whose development and updates are managed by the Modbus Organization [17].

Modbus is used in multiple master-slave applications to monitor and program devices; to communicate between intelligent devices and sensors and instruments; to monitor field devices using PCs and HMIs. Modbus is also an ideal protocol for RTU applications where wireless communication is required. For this reason, it is used in innumerable gas and oil and substation applications. But Modbus is not only an industrial protocol. Building, infrastructure, transportation and energy applications also make use of its benefits (as stated in the Modbus website FAQ).

2.3.4 M-Bus

M-Bus or Meter-Bus [18] is becoming more popular due the rapidly increasing demand for smart metering. M-bus is a European standard covering both the physical layer (EN 13757-2) and the application layer (EN 13757-2). Further, a wireless radio version (EN 13757-4) is available. The wired system is uses only 2 wires, making it simple and cost effective. Also, although it is designed using the standard ISO-OSI Reference model, only 4 of the layers are needed (3 for the transport and 1 for the application).

OSI Model (M-Bus)			
	Data unit	**Layer**	**Standard**
Host layers	Data	7. Application	EN1434-3
		6. Presentation	Empty
		5. Session	Empty
	Segment/Datagram	4. Transport	Empty
Media layers	Packet	3. Network	Optional
	Frame	2. Data link	IEC 870
	Bit	1. Physical	M-Bus

Table 2: M-Bus OSI Model representation

Although M-Bus was originally intended for metering, the data is bi-directional allowing its use for other applications such as lighting control, alarm system and even HVAC control.

Chapter 3 Systems

Systems usually cover a range of applications and for this reason I have separated some of the systems to provide a little more insight into what they are and what they do. Systems will use one or more of the interface methods as shown in Chapter 2. Most likely, a system will use a combination of interfaces due to the physical connection of field devices and the often need to interconnect more than one controller or system together.

3.1 Lighting

Most people are aware of lighting and what it can do for them. A lighting design can be provided for working at desks, at or on machinery or perhaps just living at home. Each scenario provides unique challenges. Lighting may need schedules to switch on only at certain times of the day or night. The level of lighting may need to be changed to create different moods for occupants or to change with the level of

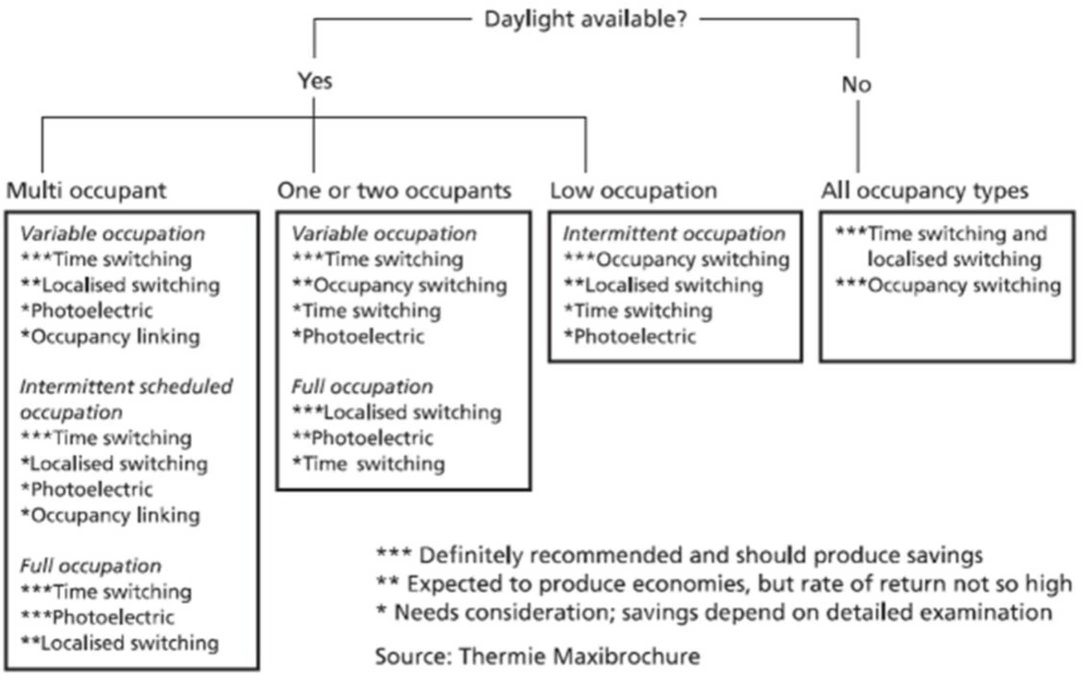

Figure 9: CIBSE Guide H - Lighting control strategy

infiltration from sunlight. Perhaps even colour changes to further enhance mood settings or draw attention (as with external illumination of buildings). Lighting engineering is complex but its operation can be enhanced (as can be seen from

Figure 9) with the addition of system integration giving extra control and flexibility to systems where previously it did not exist.

In a naturally ventilated building lighting may account for 40% or more of the total electricity cost [19 pp. 5-56]. Therefore intelligent optimisation of interior and exterior light (daylight) sources will help reduce utility costs. By integrating systems, lighting can be used to create scenes (mood, time of day, response to external conditions for other systems sensors) could further reduce expenditure and carbon emissions.

3.2 Security

Security covers a wide range of applications but often we think of intruder alarm systems. The range goes much further and can incorporate other systems such as CCTV, access control, watchman clocking and barrier controls. Many buildings have electronic locking of doors and other facilities which are usually part of the security system. Often is the case that different systems have been installed (either over time or perhaps from day one) and used standalone. Providing integration and through intelligent manipulation of the data, systems can be enhanced. Separate systems can be utilised with the security system being used as the trigger for events. I.e. If a PIR sensor in an area is triggered the lighting systems for the area (and maybe surrounding areas) could be switched on.

3.3 CCTV (Closed Circuit Television)

CCTV is usually marketed under security and often is used as such. However, CCTV is a very different system to an intruder alarm or access control system. Most CCTV systems are now very hi-tech with the use of IP addressable cameras, cameras with built in web servers, encrypted digital data streaming and storage on digital media. This is a vast change over the original analogue systems which required a cable feed to every camera and extra cabling for any PTZ motor control (pan tilt zoom). With digital systems the number of cameras has become only limited by the cost and any limitations of the CCTV system. Further, PTZ is sent over the same wire as the camera data. The digital transmission of data is usually encrypted and furthermore is bi-directional, allowing full control of cameras and interlinking of any other security devices. This digital technology has allowed communication drivers to be implemented within integration devices (such as Tridium’s equipment) wherever a CCTV company has allowed access to its protocols.

Integration of CCTV is limited only by the imagination and resourcefulness of the integrator, but typical applications are using a combination of the CCTV and intruder systems to monitor an area. Upon trigger of an unexpected event, cameras can be made to automatically pan, tilt and zoom to the affected area, recordings trigger, alarms be sent, recorded and security or management personnel summoned via mobile devices. Of course this could also be a simple trigger to display a computer graphic or illuminate a display panel.

It has been my experience to integrate and commission such systems at a college in Hackney, London over 15 years ago. The systems were commissioned, integrated and functioned very well (for this system the North Compass Points were used for integration between BMS, Fire and CCTV systems). The college has a Trend BMS, integrated with the Fire, Lifts and Security systems. The whole integration was operated via a touch sensitive computer screen.

3.4 HVAC

Heating Ventilation and Air Conditioning, by its very nature is complex. The equipment required to service and maintain the comfort levels of an average building will consist of at least one AHU, a heating plant, often a cooling plant and a myriad of sensors and control equipment (i.e. damper actuators, valve actuators, relays and contactors). Such sophistication requires more than just an ON/OFF switch. To control well, requires a control system. BMS is the general term used for controlling HVAC, but BEMS is probably a better abbreviation of what is required. HVAC does not just affect the temperature of a building but changes the whole environment. People respond to many things but the environment probably has the biggest effect on their attitude, emotions and wellbeing.

Often the parts of the HVAC system are in various parts of the building, such distances meaning fragmentation of the control system. Controllers that can intercommunicate and LANs are normally employed to link the various BEMS controllers. The controllers need to be from the same manufacturer or capable of sharing information in some way.

For the purposes of integration, it is recommended that HVAC systems especially have communications that are standard (not proprietary) and are open protocol.

3.5 Energy Metering

Peter F. Drucker (1909-2005) a prolific influential writer, management consultant, and self-described “social ecologist, was quoted as saying “*If you can’t measure it, you can’t manage it*”. The CIBSE Technical Memoranda TM39 Building energy metering (20), subtitled “A guide to energy sub-metering in non-domestic buildings” mentions the late Mr Drucker and goes on to detail good metering practices and can be shown in a simple pyramid model (Figure 10).

Most buildings in the UK have primary meters on the incoming services, these being designed for the purpose of charging (billing) the client. Now, part L [(21)] of the Building regulations requires sub-metering for new non-domestic buildings and even for some refurbishments. Sub metering is becoming big business partly due to Part L Building regulations and as a good building manager quickly becomes aware that good metering can show where the energy is going and how much it is costing. This gives a much better perspective on building operation thereby allowing trends to be identified along with early diagnosis of problems or potential problems.

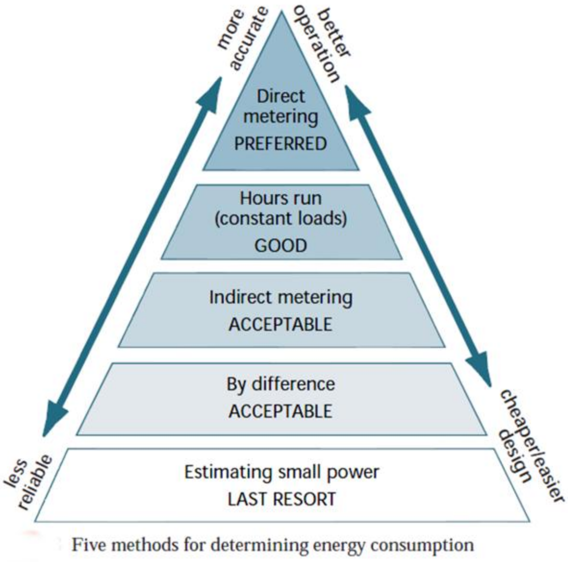

Figure 10: CIBSE - TM39 - Metering

Meters used to be of the simple pulse meter type, a VFC being triggered ON then OFF for every unit of resource delivered. In fact due the requirement of Part L stating pulse meters are still required, most meters still have this ability built in. Smart meters are capable of much more. Many smart meters can send data across LANs or wirelessly to Enterprise systems using a variety of protocols, including BACnet, Lon, Modbus and M-bus to name the most popular.

The UK government are proposing to spend in the order of 11 billion pounds to replace all the domestic and smaller non-domestic “dumb” electricity and gas meters with new “smart” meters [22]. This entails 53 million meters being replaced in over 30 million households and the intention is to do this within the next decade.

BERR (The Department for Business, Enterprise and Regulatory Reform) has since been disbanded (2009) and its works transferred to the DECC (Department of Energy and Climate Change). However a very good initial document explaining differing types and methods of smart metering for WANs can be found at www.energy-retail.org.uk [23]. The document although dated 2008 still have very relevant and useful information related to smart metering for the UK and is very worthwhile reading to see the technologies available and how they might be connected (see a simple layout of option in Figure 11).

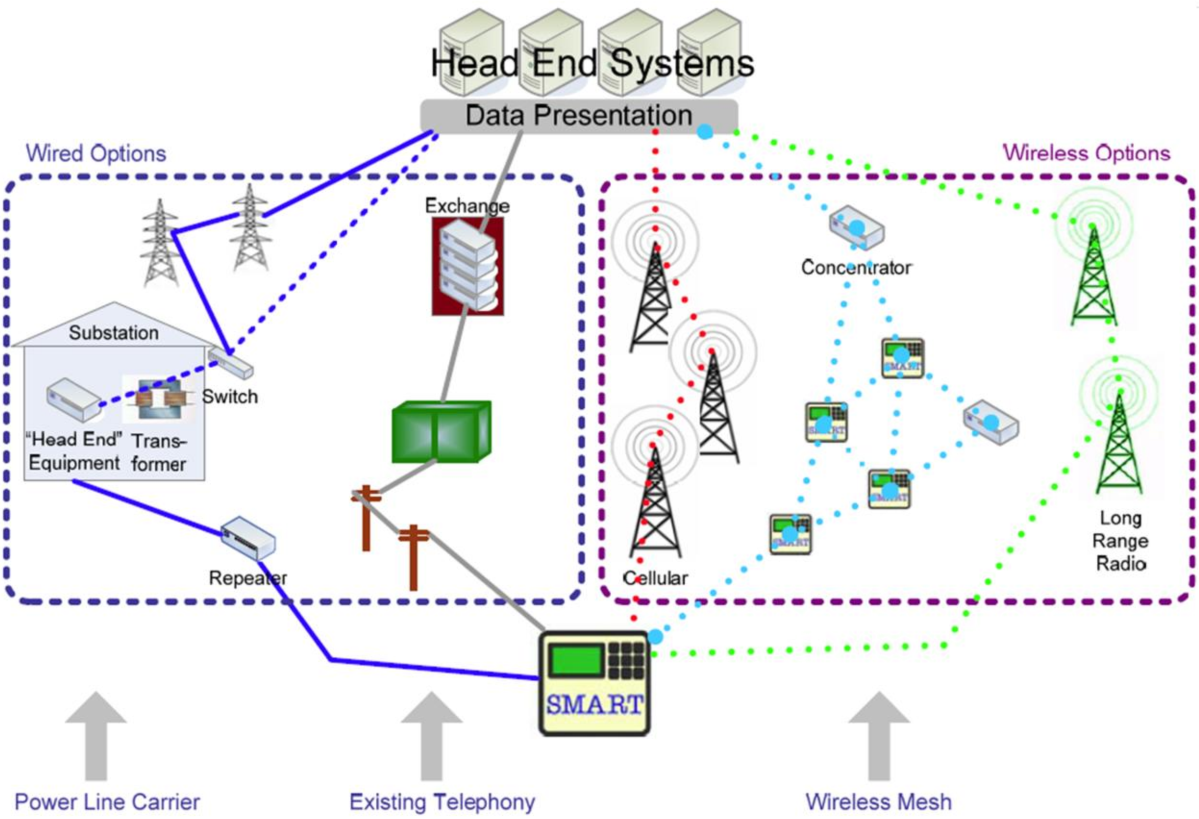

Figure 11: BERR Smart metering WAN options

Chapter 4 Integration Companies

Various forms of integration and systems have been shown in the previous chapters. There are quite a few integration companies in the UK providing equipment and the following are some of the major driving forces, both past and present;

4.1 CdC Engine

4.1.1 Introduction

The CdC engine was primarily a software based front end very similar to Doorway. No reference literature seems available to this product anymore. Eurotunnel used the CdC engine during its early days (1993) and was problematical due to the Windows version of the time (Win 3.11). Unfortunately frequent rebooting (sometimes once a day) of the PC was needed to keep the CdC software running.

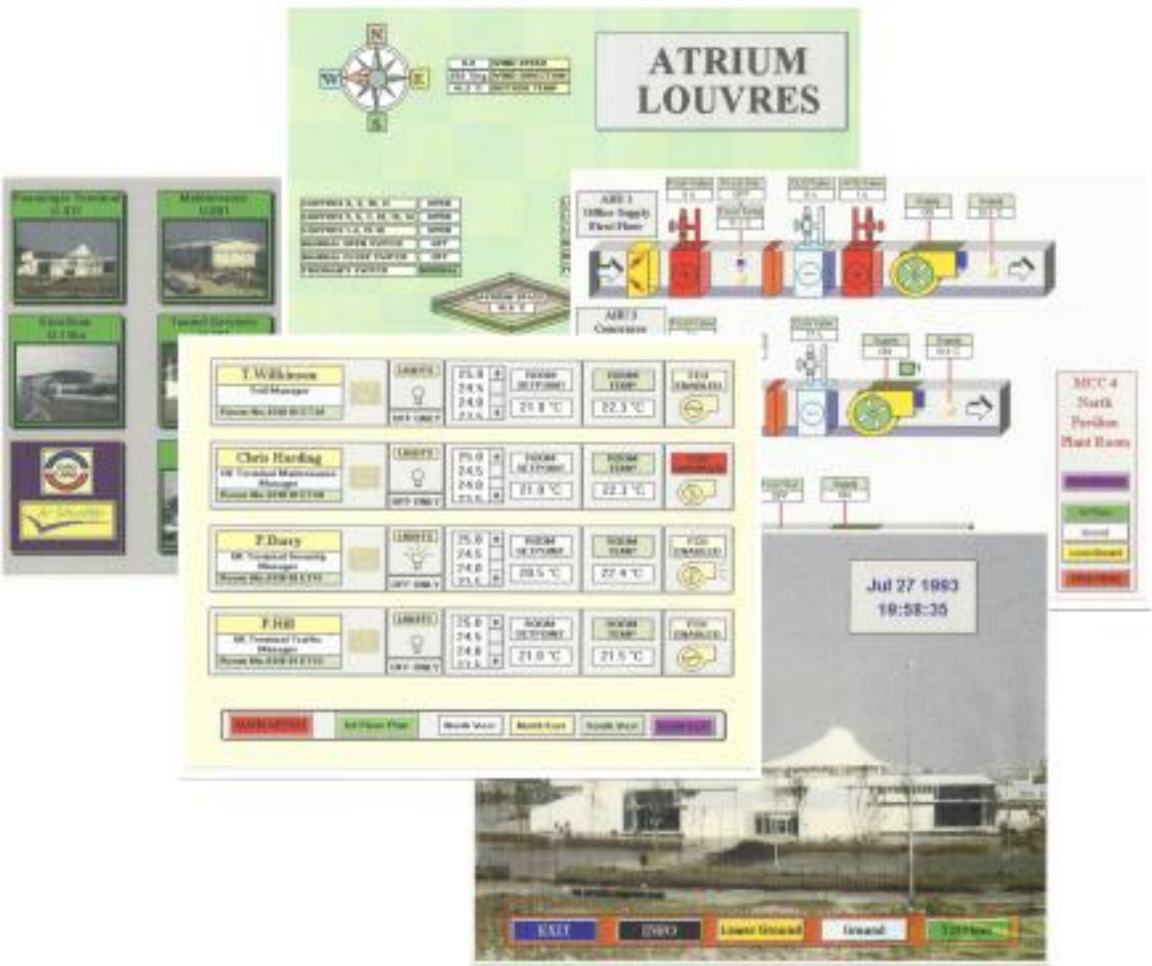

Figure 12: Overlaid views of the Eurotunnel CdC graphics

However I worked on the Eurotunnel project and successfully helped engineer integration of the Trend BMS system to the lighting and room fan coil controls. Figure 12 shows overlaid images of the graphics I created in 1993 while working there. It was possible to view (through the CdC graphical front end) what offices were occupied, the current office temperature and override the lights and change temperature setpoints. As well as building graphics, I further integrated other Eurotunnel buildings into the overall system using a Trend wireless PacNet system. PacNet has since become a trade name, but originally was a shortened version of packet radio networking.

4.2 Doorway Systems

4.2.1 Introduction

Doorway [24] is a SCADA software product for BMS controls primarily used for heating, ventilation and air conditioning services in buildings. Doorway can be used stand alone or across an Intranet in Client-Server mode.

Doorway provides a powerful yet low-cost graphical interface to BMS products from Trend Control Systems Ltd, as well as SeaChange products manufactured by ENER.G Holdings PLC distributed by their subsidiaries ENER.G Controls and SmartHome Controls , and supported by SC Controls Ltd . Doorway also works with a wide range of LonWorks® compatible products.

The advantage with Doorway (as with the CdC engine) was the ability to use a client's (or representative of the client) graphical backgrounds. This differed greatly from the simplistic systems before the time of Doorway (pre 1993) as many front end systems were purely text or very basic graphics. Now each page of a graphic could be drawn using the latest tools of the time, digital images, artistically drawn images and even CAD drawings could be inserted. This made front end systems easier to understand and more appealing to clients and the users of the systems. What is more, integration became much more apparent when a screen could show points and data gather from differing systems.

Doorway had the capability of connecting to a variety of systems via the standard PC ports, but also cards could be inserted to connect to other more proprietary equipment such as LON. What is more, Doorway was (and still is) priced in a way to make it affordable to smaller projects as well powerful enough to be used for the larger ones.

4.3 North Building Technologies

4.3.1 Introduction

North Building Technologies develops, manufactures, distributes and supports a range of products for the building control industry. Their product range allows disparate building controls systems such as fire, security, heating and ventilation and power monitoring to interoperate, and provide an integration framework for the management of buildings.

4.3.2 Compass Points

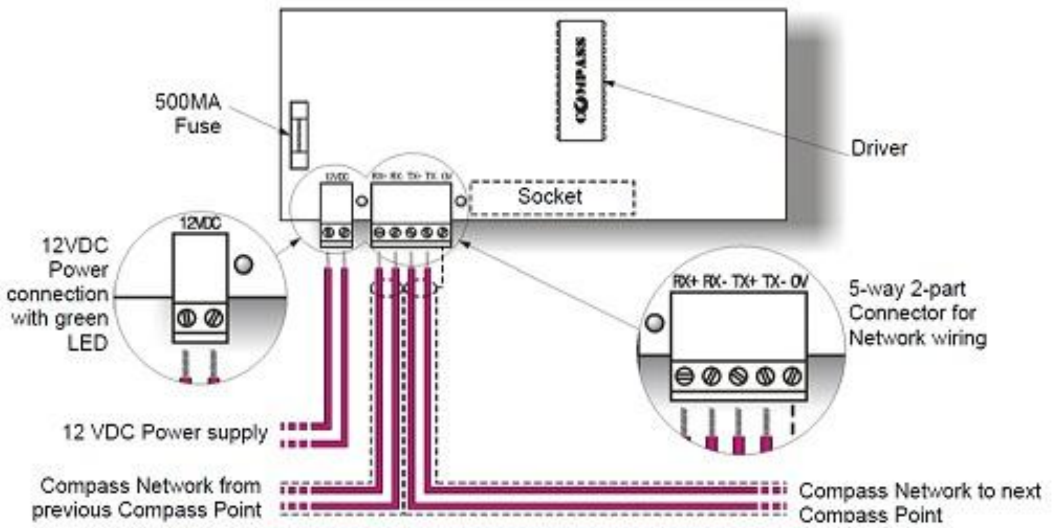

Figure 13: North - Compass point

Originally North developed a product called the Compass point [(25)]. This hardware was designed to connect to other (sub)-systems using RS-232 or RS-485. This allowed data to be transferred to or from a subsystem via a Compass node. The Compass node has a sophisticated lookup table built into it. The table contains data to be transmitted or received via either the compass node network (Figure 14) or through the compass node interface (shown simple as “socket” on Figure 13). The table contained normalised data, commands on data type and how the data should be handled (where and when it should be transferred).

Every system (i.e. Fire, BMS) and even each company system, will most likely have very different ways of handling its own data transmission have a specific protocol (handshaking initialisation, speed, data type, data size and frequency). Therefore a driver has to be written, developed and tested specifically for each system. It is the protocol drivers that are the key to integration. Most companies’ electric equipment often had ports available to connect devices for data transfers, but often the details were kept “in house” and details remained secret. This could be for a variety of reasons, perhaps security, but often due to the proprietary nature and the wish to sell their own hardware and software, rather than promote other companies equipment. North were amongst the forerunners of getting companies to cooperate and provide details of their protocols and allow integration to progress. The method of most integration companies from this point, varies very little in the initial process, that being a protocol driver being created to talk to a system and transfer data.

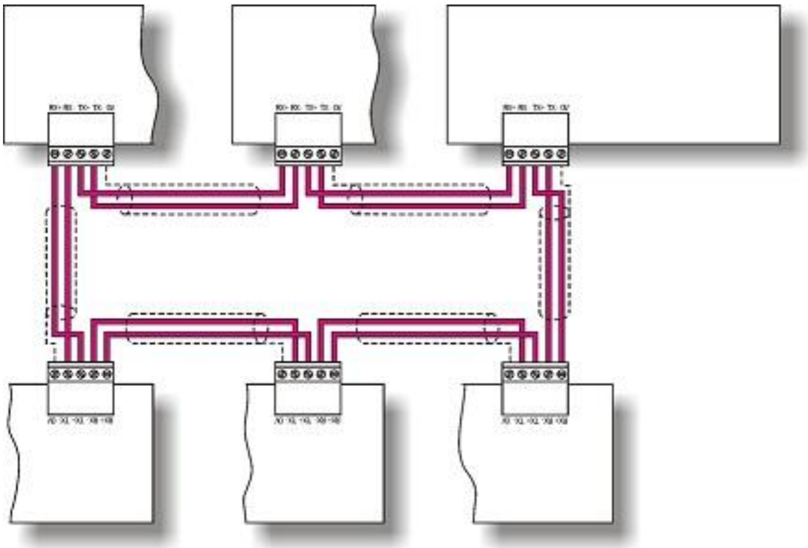

Figure 14: North - Compass point networking

Due to the fact that compass points had their own network capabilities, a system could be connected to a Compass node, data extracted, then passed round the Compass network to another point or points, then passed through to the subsystem connected. Also, Compass points could be used to provide a link to a PC. Through this provision, a variety of options present themselves in the form of supervisors, front-ends and alarm handling. A common supervisor of the time (1990s) that utilised this form of integration was a product called Doorway (Chapter 4-2).

North has kept up with the times and offers many more products, including TCP/IP and web browser technology into some of its products.

4.4 Echelon

"Echelon was founded in 1988 with a vision of enabling networks to extend beyond computers into control systems to enable smart utility networks, buildings, factories and homes to run more efficiently, lower costs and improve quality, productivity and comfort. The firm's energy control networking technology has a three tier architecture: intelligence at the field level within smart devices; intelligence in control nodes at the edge, where control networks connect into data networks and the Internet, and intelligence at the enterprise. The firm's patent portfolio addresses the key requirements of control networking that enable that hierarchy to deliver reliable, survivable, large scale and low cost solutions with open interfaces that support an ecosystem of partners." [(26)] As the referenced article states, echelon have now been awarded their 100th patent. This shows not only a keen eye for commerce, but a continuation of increasing their portfolio of products for energy control.

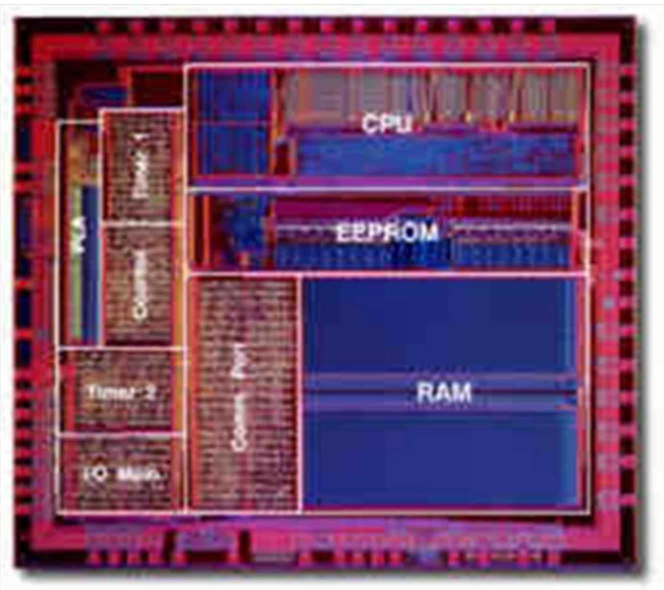

Figure 15: Echelon - Internal view of Neuron Chip

Echelon started to rapidly expand from the production of their "Neuron Chip" and LonWorks management software designed around it.

The Neuron Chip (Figure 15) is a computer system-on-a-chip with multiple processors, read-write and read-only memory (RAM and ROM), and communication and I/O subsystems. The read-only memory contains an operating system, the LonWorks protocol, and an I/O function library. The chip has non-volatile memory for configuration data and for the application program, both of which are downloaded over the LonWorks network. At the time of manufacture, each Neuron Chip is given a permanent unique-in-all-the-world 48-bit code, called the Neuron ID. Currently a large family of Neuron Chips is available with differing speeds, memory type and capacity, and interfaces. Approximately 54 million Neuron Chips had been shipped as of mid-2004. The chip is both a network communications processor and an application processor, significantly reducing the implementation cost for most LonWorks devices. (27)

With the capabilities of the Neuron Chip and LonWorks plus the ability to transmit data over various network types, integration was able to easily happen for the first time between different manufacturers equipment.

One example was for UBS (Union Bank Swiss) in London. A refurbishment gave the chance of providing true integration. Honeywell fan coil controllers were integrated with Philips Lighting equipment. Every device was a LonWorks (Echelon) enabled product. This meant that on the same LAN we could use intelligent lighting sensors to enable the local lighting by utilising the PIR part of the sensor. Through the linking (binding) of devices together, the Honeywell controllers would also be enabled. Lux levels in the lighting sensor would also set the appropriate level of illumination for an area. At night the lighting would switch off or dim to very low levels automatically and only stay on (along with the local office fan coils) if the presence of people were detected. Further, if an employee should exit an office and the area was dark (unoccupied) an illuminated path to the exit was immediately illuminated.

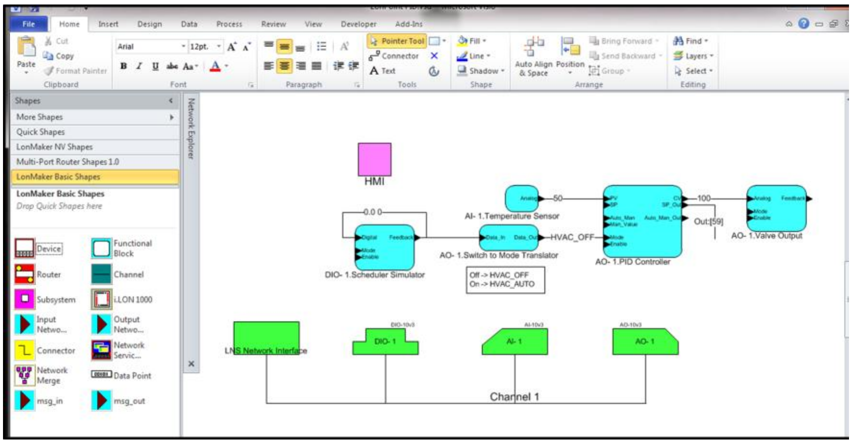

Figure 16: Echelon's LonMaker commissioning & binding tool

This is only one example of integration, Lon devices are capable of being controlled or of sharing data with any other LonWorks device capable of receiving or sending that data.

Echelon and their product range are expanding into BEM, smart meters and the Smart Grid system [(28)] in the United States. Figure 17 shows a simple relationship between sub-metering being linked through software to users of the utilities as well as to the facilities teams.

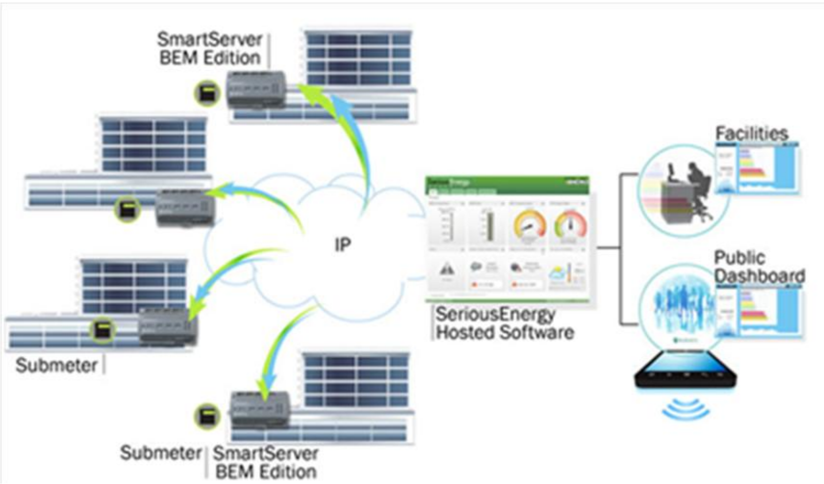

Figure 17: Echelon Building Energy Management (BEM) Solution

4.5 Tridium

4.5.1 Introduction

Using the words of Tridium;

Who is Tridium?

Tridium, is a global software and technology company. The primary technology developed and marketed by Tridium is the Niagara Framework. Niagara is a software infrastructure that helps manufacturers develop Internet-enabled equipment systems and "device-to-enterprise" applications.

Tridium created the Niagara Framework to:

- *Meet the need for a strategic, general-purpose proprietary automation/information architecture built on open standards*

- *Merge multi-vendor automation systems, Internet-enabled infrastructure and real-time enterprise integration into one single, scalable, extensible platform solution*
- *Help partners bring Internet-enabled products and "device-to-enterprise" applications to market*
- *Increase the functionality and value of "smart devices and systems"*

Tridium is currently owned by the market giant, Honeywell but was formed originally by Jerry Frank in 1996.

4.5.2 Niagara AX Framework

Niagara AX Framework is a software platform that can run under Unix or Windows. It integrates diverse systems and devices independent of manufacturer or the communication protocols used. By creating a unified platform, systems can be easily managed and controlled in real time over a variety of networks and importantly, via the Internet. Furthermore, this can be done using a standard web browser such as Internet Explorer or Firefox. Because Niagara AX is a scalable solution, the functionality and value of "smart devices and systems" is increased by connecting real time operational data to both human users and systems that manage business enterprises.

Niagara AX can be installed on PCs, servers and embedded devices. This becomes very apparent when work is performed on one of the JACE Tridium product. Whether programming on a laptop or within the JACE device, the environment is the same. This makes engineering much easier and quicker to learn. Niagara AX models the data and behaviour of attached systems or devices and normalises the data internally. This normalising creates a uniform view of device data. Any Enterprise system attached can then exchange data via a wide variety of IP-based protocols, XML-based connectivity options, and open API's. By transforming the data from diverse external systems into normalized components, Niagara AX creates an architecture that provides substantial benefits over gateway-based integration.

Niagara R1 was released in 1998 followed by R2 in 2000. Niagara AX version 3 was released in 2005 with 3.6.xx being the current version (July 2011). Tridium constantly update their software and firmware to provide improvements and fix any issues.

Tridium quoted as of July 2011, "*Today, there are over 245,000 instances of the Niagara Framework deployed worldwide.*"

4.6 Trend

4.6.1 Introduction

Trend has been added for completeness (Trend has already been discussed in Chapter 1.4.4) as they do offer integration. They have a variety of tools, supervisors (front end systems), smart devices and an integration device. The supervisors are used for integration but the primary tool being promoted by Trend is the TONN (Trend Open Network Node) device. Further analysis will show it looks like a Tridium JACE and that is exactly what it is. Tridium and Trend are owned by Honeywell, so it is no surprise that when possible, devices will start to be shared between Honeywell owned companies. Indeed, this is what integration is about, the ability to use a variety of different systems and bring them together as one functioning unit.

4.6.2 SET

A quick mention of the Trend software SET [(29)] is made here to show the likeness to Tridium Niagara platform. It can be seen from Figure 18 that the method of programming controllers (drag and drop) is very similar to Tridium's method. LonWorks also has large similarities. This is actually very good for engineers and makes the learning process somewhat easier when having to deal with different systems.

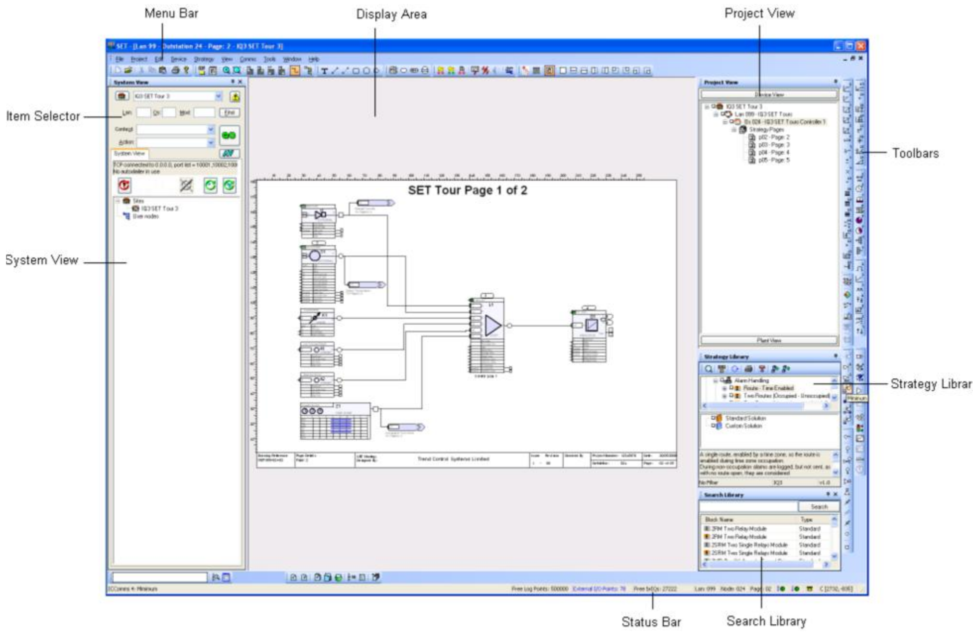

Figure 18: SET - The Trend programming tool

Chapter 5 Smart Solutions

There are no absolute requirements in the UK to install integrated systems or intelligent systems. The building regulations [21] do make mention in part L that

"Reasonable provision should be made for the conservation of fuel and power in buildings by;

(b) Providing fixed building services which

- *i. Are energy efficient*
- *ii. Have effective controls; and*
- *iii. Are commissioned by testing and adjusting as necessary to ensure they use no more fuel and power than is reasonable…"*

Now of course this could be something as simple as a thermostat, but with technology being available more and more at lower costs, it would be unwise to ignore the possibilities of what can be done to save energy, overall costs and improve building standards.

CIBSE have a complete guide (CIBSE Guide H [19]) entitled "Building Control Systems". It is recommended to Building systems designers and contractors, building owners and tenants, FM operators, engineers, engineering consultants and structural engineers.

Among the guide's 200 pages are sections on "the need for controls", "Fundamentals", "Components and devices", "Strategies for controls and buildings", Use of BMS derived data.

Wikipedia states that a smart device is a device that is digital, active, computer networked, is user reconfigurable and that can operate to some extent autonomously. Some technologies have already been mentioned previously, such as the JACE and Compass nodes .The following are three further smart examples of building control devices and integrated technologies taken from various sources.

5.1 Trend EnergyEYE

The EnergyEYE [30] is a smart software application that provides a dynamic view of a buildings energy performance, allowing building occupants and visitors to see an organisations commitment to improving the management of energy and its performance against targets (Figure 20).

Figure 20: Trend EnergyEYE example layout

A web server presents the live information onto monitors, TVs or any other form of display device. The display location can be anywhere in the world. The data is collected via the IQ EYE Collector device which presents the information to the IQ EYE Server to carry out the performance monitoring calculations. The IQ EYE Collector can retrieve data from Trend IQs and LonWorks devices without any extra management tools. Figure 19 shows a variety of ways the data can be collected and methods of data requests (XML, Trend IQ LAN/WAN, LonWorks).

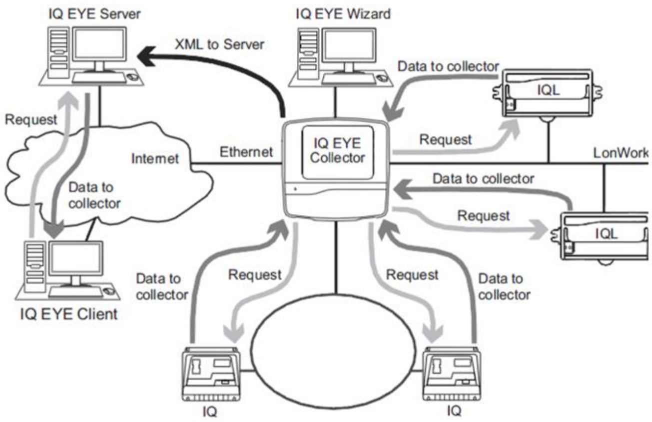

Figure 19: Trend IQ Eye Collector

5.2 ZigBee

I have mentioned ZigBee here as maybe a late addition. They are not a single device but a provider of a protocol and a multitude of devices (primarily wireless) going into areas where other providers have either not discovered or reluctant to try. You can find a wide variety of equipment available, much for the home market (audio visual, security and automation) but also for smart metering, lighting, horticulture and much more.

ZigBee are certainly worth a mention in the smart devices as that's what the majority of their equipment is, smart.

Their website [31] has many examples and success stories where their products are used. Most integrators have a ZigBee driver and they look to have a good future, especially in the smart metering market and where running cables has for some reason or another become a problem.

5.3 iPhone and iPad

It would be remiss to leave out probably the world's biggest provider of smart devices, Apple [32]. They almost disappeared into obscurity then the launch of one of their early i devices firmly put them back on the road.

Figure 21: Apple iPhone 4

The iPad and iPhone have become famous and a very much wanted product for business users and home consumers. What makes them so appealing is not just the sleek looks, but the functionality of the multimedia technology and the connectivity.

The wealth of applications (small programs to add functionality to the device, commonly called Apps) has also made these devices interesting to integrators and systems builders. In fact, even one of the automation giants Johnson Controls has jumped in on the action, stating on their website [33] that their Metasys system is now compatible with Apple iPhone® or iPod® Touch platforms.

This website [34] gives a quick idea of the number of applications available just for home automation, it is not official, definitive nor complete, but the sheer number (137 Apps at the last count) is impressive.

Of course the Apple iPhone is not the only device capable of running clever applications and accessing the web or servers through browser technology, you have to admit, they do it with style.

Chapter 6 Workshop

6.1 Tridium UK Training

The following section will describe my training (July 2011) at the Tridium training centre in Coolham, West Sussex, UK. This 5 day intensive course is designed to provide training to integration engineers on the Niagara AX platform and by performing a final 1 day practical test, give successful engineers a certificate of completion, thereby confirming a level of competence.

The primary form of training from Tridium was to use test bench equipment directly and perform tasks called labs. Using a provided laptop loaded with Windows and the Niagara AX platform we connected to a network and performed all the operations needed to set up a JACE controller, integrate multiple diverse systems and bring viewable data back to the front end user.

6.1.1 JACE (Java Application Control Engine)

The JACE controllers come in a variety of forms. The type we used in the lab was a JACE 6xx [35] series, but can also be packaged as a rack mounted solution (JACE-5R-AX) or within wall mounted enclosures (JACE 545/403) for more commercial applications. The advantage of the Niagara framework is that it can be embedded into anything capable of running the software. As Niagara AX is primarily a JAVA based application, this means most PCs, Servers and small computer systems can load the software with relative ease.

Figure 22: Tridium - JACE Controller

The JACE 2xx and 6xx series controllers are ideal in panels and are DIN rail mountable. The basic JACE 2/6 series has two Ethernet ports, one RS-232 port, one RS-485 port and one USB port. Although the labs used a JACE 6, the 2 and 6 differ only in processor speeds and maximum memory available. Furthermore, a JACE can be upgraded in terms of functionality by buying higher licenses. This releases more memory and functionality in the device. This keeps costs to a minimum, upgrading only when necessary. The processor cannot be changed, therefore a choice between a JACE 2 or 6 needs to be made at the outset.

Various options can be seen from the following Table 3: Tridium product list.

Order Code	Product description
JCX660	JACE 6 with 96MB Java Heap Memory
JCX650	JACE 6 limited to 48MB Heap Memory
JCX250	JACE 2 with 48MB Java Heap Memory
JCX240	JACE 2 limited to 16MB Heap Memory
JCX230	JACE 2 limited to 16MB Heap Memory 450K resource limit 200 points max/network
JCX220	JACE 2 limited to 16MB Heap Memory 350K resource limit 8 points max/network 34 points max NDIO Niagara + 1 other network
ION16P	16 point IO module
ION34P	34 point IO module with built-in 24Vac/dc PSU
PMPEUP	90-240Vac Plug Top PSU Europe 2 pin
PMPUKP	90-240Vac Plug Top PSU UK 3 pin
PMD24V	24Vac DIN rail mounting PSU
JOCLON	Plug-in LON FTT card
JOC485	Plug-in RS485 card (2 ports)
JOC232	Plug-in RS232 card
JOCGPR	Plug-in GPRS modem card
GPREXT	Extension cable and bracket for modem

Table 3: Tridium product list

Extra communications cards are optional and allow more connectivity. The lab units were fitted with a Lon adapter (78Kbps FTT10A) so we could integrate with the Lon devices.

6.2 Lab workshops

The labs combined to create a practical project using the key skills needed to operate the Niagara software and build a Niagara project using a single JACE controller, adding a Tridium IO module and using some of its IO points, integrating a LonWorks device, a Modbus device and a BACnet device.

The following subsections describe the methods and processes used in the labs to build the final project (a simulation of a building using real IO and software programming).

6.2.1 Commissioning a JACE

The Niagara AX platform was already installed on our test bench laptops. It is software and therefore easily installed on a windows environment. Tridium use their own proprietary installation software (not install shield or some other standard installer).

The GUI is within a window and a tree directory displayed on the left side (as seen in Figure 23) to provide navigation to each device and its sub components.

Commissioning a JACE controller is relatively simple. The software handles most of the details automatically and a handy wizard can be used. Only the IP address of the JACE device is needed to initiate data transfer.

First a new station is created using the wizard. The station is the GUI embodiment of the JACE. It details all the components that will be stored in the JACE controller. At this stage the name of the JACE can be defined and the administrator password.

Next a platform is created. The platform is the interface the user will talk through to the JACE devices. Here a Username/password should be set up and the IP address of the JACE can be input.

Once the JACE is shown to be connected the option for the commissioning wizard was selected. The station that was created earlier is now installed and commission on the physical JACE controller. It is this way that almost identical stations can be set up. A copy of a station can be downloaded into different JACE devices with minimum alteration, thus saving time on large jobs.

The Niagara AX software has many extra modules that can be loaded. These modules speed up the process of programming. Essentially the modules are JAVA applets that can contain anything from individual objects (such as IO definitions) to whole strategy programs. The modules can also be expanded or added and new modules programmed and created as needed.

6.2.2 Basic Components

JACE devices are fully programmable. Each part of the hierarchical tree shown on the Niagara AX platform contains various views to represent the data contained within that part of the tree. One view is called the "Wire sheet". Effectively this is a programming page. Anyone used to programming Trend devices using SET [(29)] or especially LonMaker [(36)] will be very familiar with this type of programming.

Components are placed on the wire sheet page and linked together to create event driven applications. Almost any control and data routing program can be built using this method and if not, a programmer can be employed to build a JAVA component that will do the necessary task.

Components are the primary building blocks that are used to engineer a JACE controller. They provide a way of normalising data, giving standard symbols and icons regardless of the system being represented. This allows a fairly seamless approach to programming across networks with different equipment and protocols. In the wire sheet, IO points from disparate systems look and react the same in the Niagara GUI. This makes programming far easier to perform.

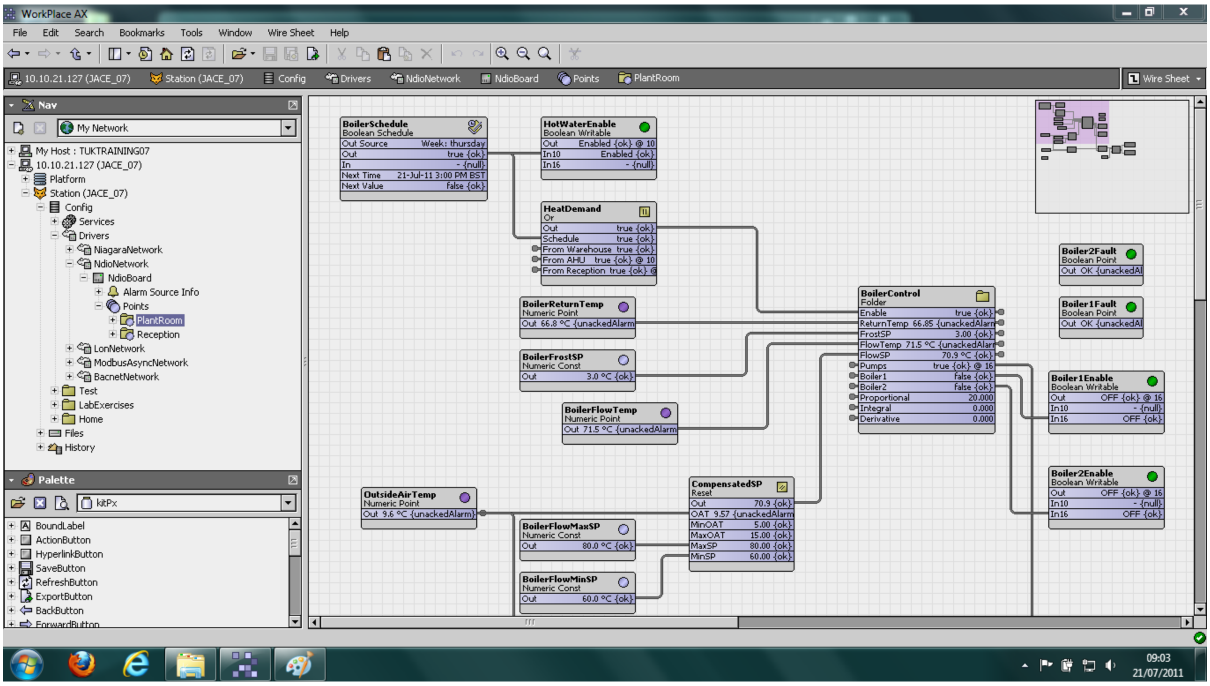

Figure 23: Tridium Niagara AX screenshot

Each component has a collection of slots. There are three types of slots;

- Property slots, representing storage locations for other Niagara data. These could be settings such as timer values.
- Action slots. These allow links to be connected from other components and event driven operations. Also action slots often have the capability of being overridden by an operator (a right click in wire sheet or perhaps through a graphical button).
- Topics. These are used as placeholders for events sources, such as alarms.

Slots can be frozen and therefore fixed, or dynamic, allowing changes or to be linked.

As can be seen from Figure 23, the components can be linked in intricate ways. Generally the approach is quite logical, an output slot of a scheduler or perhaps a sensor is linked to the next part of the strategy programming and thereby data is fed through and appropriate actions taken (i.e. on/off control, output adjustment of loops).

Within the labs we first started with very small linking of components, finally building up to a fully working strategy designed for a small plantroom.

6.2.3 Drivers

During the labs, Tridium taught us that a Niagara AX driver is the collection of components for integrating to a specific network or other source of external data. The driver also presents the data to Niagara components in a normalised form.

Drivers are quintessential to the Niagara AX framework and allow integration between similar or dissimilar networks and systems. A driver holds the method and protocols needed to communicate and exchange data between Niagara AX and the connected devices (attached physically or via a network).

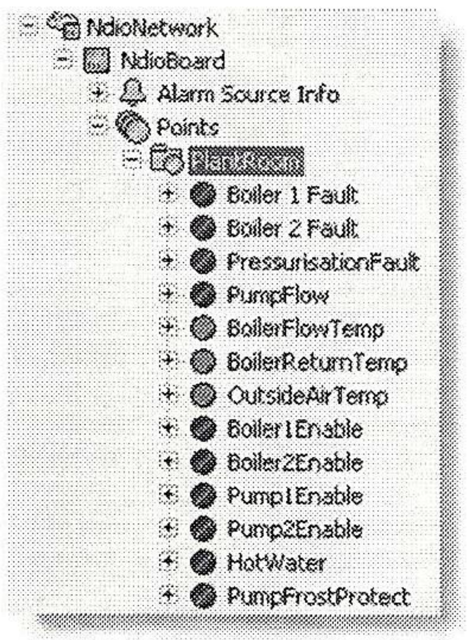

Figure 24: Tridium driver extensions

When installed, a driver has the following common components;

- Network component – this typically represents the physical network connections (i.e. NdioNetwork).
- Device component – representing any devices physically connected to a network (i.e. NdioBoard).
- Proxy point – a modelled component representing an external value or part of the connected device.

Device components can have more than one extension folder, each representing a family of data that is supported by the driver's protocol. It was found that due to the nature of the Niagara AX programming, proxy points must reside under the device point's extension and the device must reside under the driver's network folder. If this is not so, the components will not function.

6.2.4 Niagara Direct IO (NDIO)

The JACE controllers do not have any IO, only interface ports such as RS-232, Ethernet. Essentially the JACE is the heart of a Tridium integration system but control of physical equipment needs to be done by extra devices. Part of the JACE controller is an interface port on the right side of the unit that allows Niagara IO modules to be daisy chained onto the device providing a maximum of 66 points (two 16 point modules plus a 34 point module.

The ION16P (16 point module)	The ION34P (34 point module)
8 x Universal Inputs (UI)	16 x Universal Inputs (UI)
4 x Analogue Outputs (AO)	8 x Analogue Outputs (AO)
4 x Digital Outputs (DO)	10 x Digital Outputs (DO)

Table 4: Tridium NDIO points

The maximum number of points gives good scope to physically control equipment. If 66 points is not enough more JACE controllers and their IO can be added to the network.

A Niagara IO module is treated as with any 3rd party device, a driver needs to be associated with it. In this case we added the NDIO network to the lab JACE station with the "Add new network" command in the Niagara platform GUI.

Using the discover button we could then see the attached NDIO module board on our JACE and add it to our system (as depicted in Figure 25).

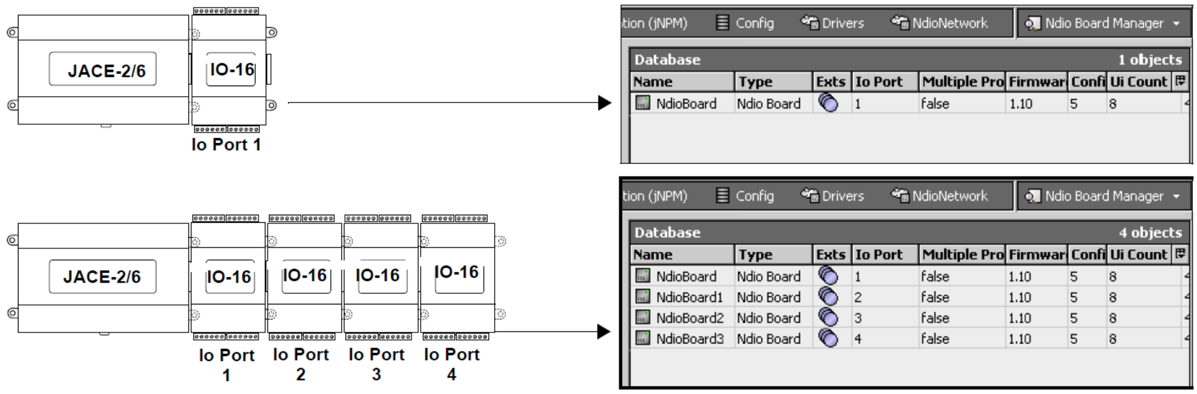

Figure 25: Tridium NDIO configuration examples

Within the NDIO device is a collection of proxy points (software representation of the physical points). By double clicking the NDIO points extension in the GUI tree, we could then view the NDIO points manager. From here we can add the proxy points to our tree structure (all in one folder or creating folders for different parts of a building or functions). From the folders a wire sheet will show the proxy points, thereby making the points available to the rest of the software.

Each point is still only partially defined at the beginning. For example, a UI type point is capable of many different inputs (digital, voltage, current, thermistor). But when we drag a point across to a destination we should also set the point type up. During the labs we did this with each point. It is possible to often simplify the process by selection of all points of the same type and performing a group operation on them (i.e. making them a BooleanInputPoint). The name BooleanInputPoint is a Niagara defined name and allows the data to be further normalised. There are many different point names defined but the amount is manageable and quickly learnt.

As mentioned previous, when a point is dragged to a folder within the hierarchical tree a component is added to the wire sheet. This then allows access to the defined slots and for further parameters to be added or changed. Further most proxy points have parameter called a facet. This makes display of the data much more comprehensible. For example, a digital input will normally show a Boolean (digital) representation (ON/OFF). By changing the facet of the point, the display can read Normal/ALARM or maybe RUN/Off. The choice is limitless and as the Niagara software remembers previous choices, quick selection can be made from a generated list. Of course this does not apply to just Boolean points, but to the complete range of point types. Therefore a temperature can be displayed as more than a simple number, it can have the number of decimal places defined and an extension such as °C or °F. Even complicated point types, such as those of a LonWorks device can be represented in a normalised way. The process is two-way and data inputted by a human user in the normalised form (in a way we can understand) is automatically converted back to data that the device can understand. This conversion back and forth of data is handled completely automatically by the drivers that have been written specifically for the devices.

If a driver exists from Tridium for a device, it can be integrated into the whole of the system, a human user need not be aware that that the devices are dissimilar in any way. This is a powerful function of the Niagara AX framework.

6.2.5 Alarm Monitoring

Alarms are an important part of any system. Many managers keep alarms for months or even years as a record of events that have occurred. A good engineer or manager can analyse the data and provide proof of problems or possible upcoming problems.

Alarms differ from system to system and Niagara AX can be used to collate and normalise the data. Further, many devices do not natively create or handle alarms, they being simple IO with no extra functional logic. Niagara AX can overcome this by generating alarm events itself. The alarms can then be forwarded and integrated into the whole.

It has already been outlined what a component is within the Niagara framework. Alarms are also component. Some components are extensions that can be added to another component. The extension become a child component and can be viewed as such within the hierarchical tree. When looking in the properties view of a component, often a small + symbol can be seen. This can be clicked on to expand and show the properties of a child item (component extension).

Proxy points can have an alarm extension added to provide alarm capabilities for;

- High/Low (analogue points)
- Out of range (analogue points)
- Alarm/Normal (digital points).

Alarms can also be given a class, which allows filtering and priority of alarms.

As will all components, the data from a device is normalised. Extra text can be added and the source of the data described in various detail depending upon the client's needs.

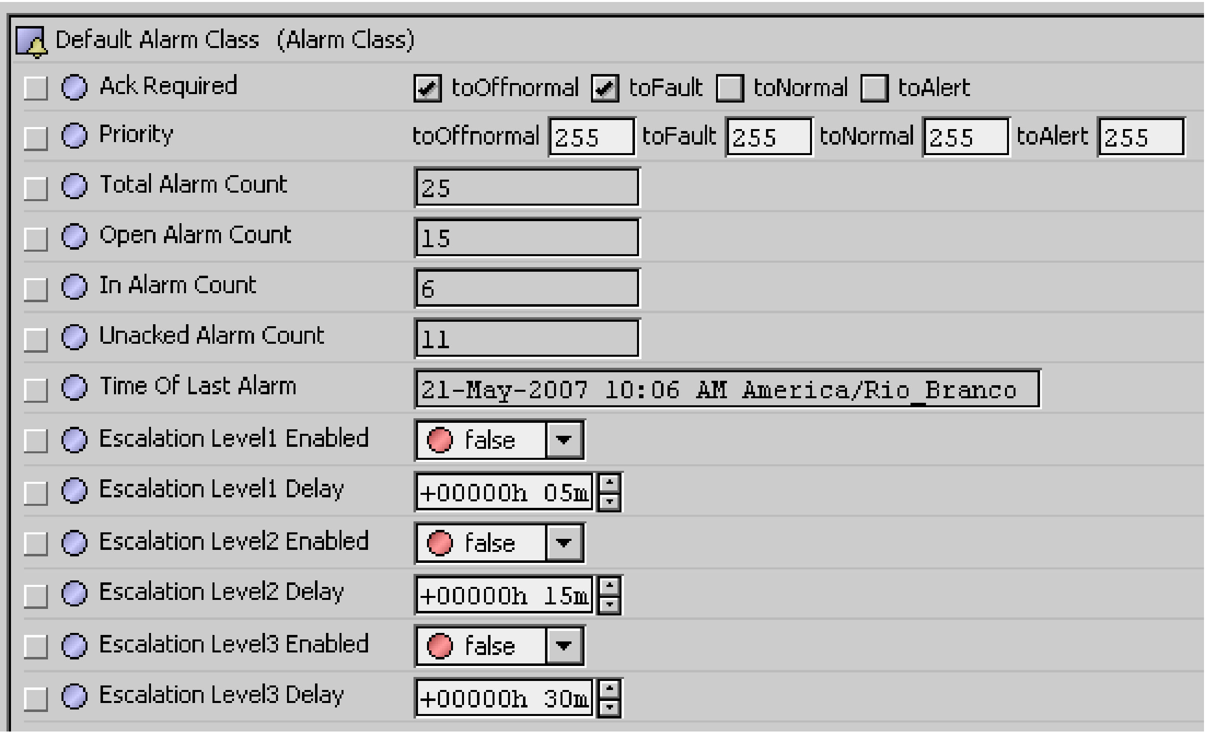

Figure 26: Tridium Alarm Class setup

In a graphic, colours can be set and animation shown. Text changing colour to quickly highlight a viewed item on a page and blinking effects can be enabled to further emphasise a status.

Alarms can be saved to work stations (independent PCs) along with other history data. There is need for this normally due to the limited memory of a JACE. By default, 500 items are stored and at 501, the oldest is deleted. This default can be altered but will have an impact on available memory for the rest of the controller's components. Therefore it makes good sense to export the data. This can be programmed as an automatic procedure.

With simple wire sheet programming, alarms can be routed and if necessary, escalated after a delay. The escalation can be a variety of options, but email tends to be a favourite (mobile SMS, external displays and external alarm panels are some of the other options).

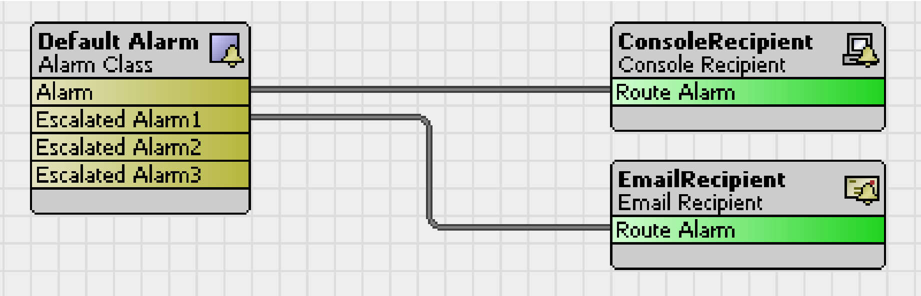

Figure 27: Tridium wire sheet alarm routing

A separate utility is available for remote workstations called the Alarm Portal. This is actually a slim version of the Niagara AX framework and is used in places such as a night porter or receptionist's desk. Alarms of any class can be routed to be seen and when necessary, acknowledged without giving full access to the system.

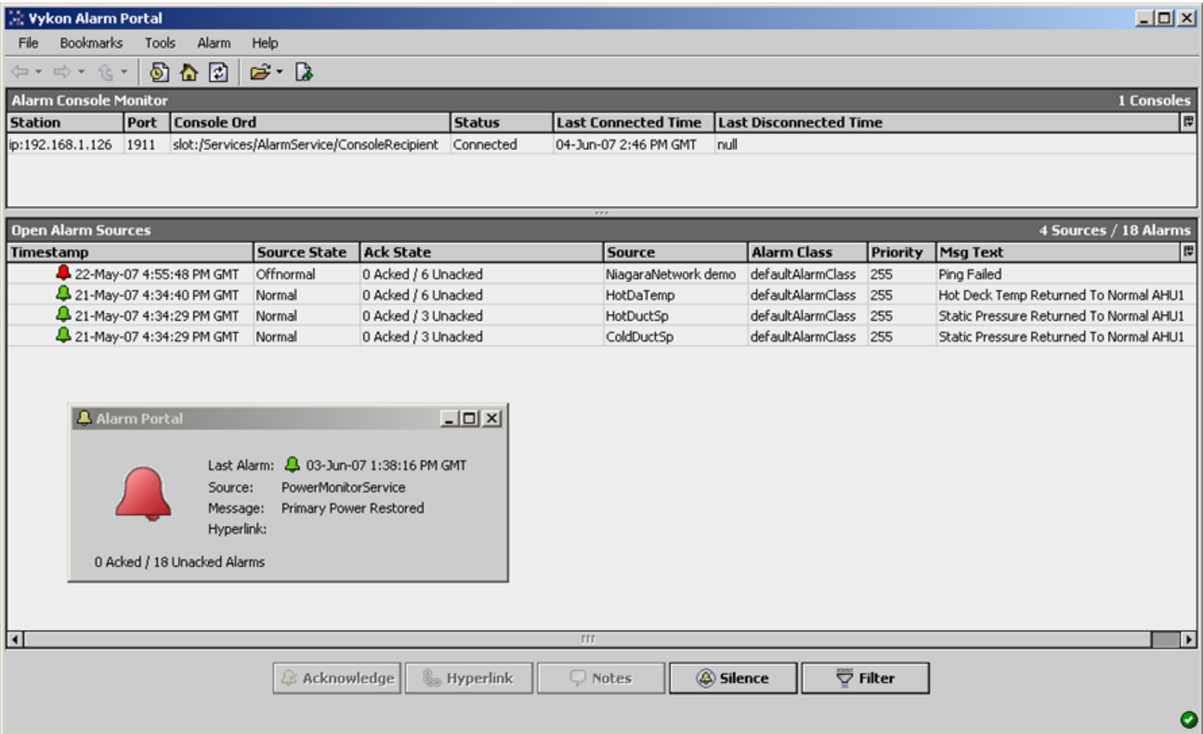

Figure 28: Tridium Alarm Portal

6.2.6 History Monitoring

Histories are somewhat similar to alarms in that they are collated and stored for posterity and use in external, possibly 3rd party software. Alarms are driven by a change of state in the monitored point or data going outside of set ranges, whereas history data is generally collected at intervals dictated by user settings. However, data recordings (samples) can also be made on a COV (change of value).

The lab showed that history extensions can be added to control components in the same way that the alarm extensions are added (a drag and drop operation from the palettes provided). The extension properties define when the data is to be logged and what the displayed text name will be. As with an alarm extension, the actual displayed text can be made as verbose as needed, showing not only the point name, but exactly where the data originated (controller, LAN and more).

Again, as with the alarms, by default, 500 entries are collected before the oldest data is overwritten. 500 entries at an interval of 1 sample per hour is approximately 21 days, but often sensitive point data needs to be collected more often. It can be seen that 1 sample per minute will only provide 8 hours of data. Any data not collected will be lost and so it is recommended to collect data from JACEs at regular intervals and where possible, not to set unreasonably short sample collection intervals.

Histories take up memory within JACE controllers and therefore some care should be taken if adding lots of history points.

6.2.7 Palettes

Palettes are Niagara's way of providing templates for components. Standard palettes come with the basic AX package but new ones can be added if necessary.

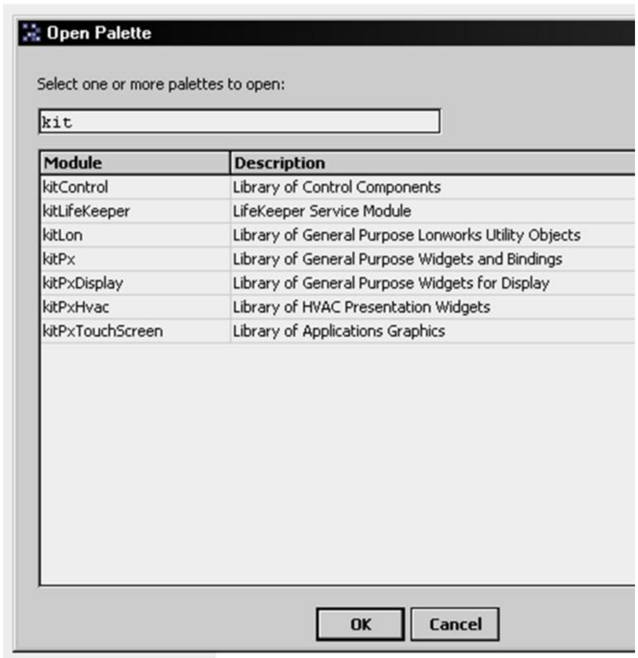

Figure 29: Tridium - Palette selection

The primary palette that most programmers will use will likely be KitControl. This has a library of commonly used and very practical components.

Within kitControl the Logic section contains the usual AND, OR, XOR and other Boolean operators. The MATH section contains similar components for operation on numbers. TIMER contains delays and other timing triggers. There are also special components used primarily for testing purposes. The SineWave component in the UTIL section produces exactly what it says. Although unlikely to be used as an end program, sine wave generation is ideal to simulate an input and watch the controller output for correct functionality. This is a valuable commissioning tool and something I have not seen in other manufacturers' software.

Palettes are an invaluable source of components for programming and working with graphics. Components, linked component, graphical objects, whole graphics, component extensions, in fact almost anything that can be copied within Niagara can be made into a new component and placed into a palette for future use. This makes the building of libraries very easy. Especially useful when working on projects with multiple copies of a design (i.e. fan coils, room layouts and even as a database for future projects).

6.2.8 Schedules

Schedules are essentially time clocks within Niagara AX. They have the ability to output a digital values or an analogue. This gives greater flexibility as a value can be set for a different setpoint at certain times. In the workshop we used this ability to provide a night time reduction in temperature (Night setback).

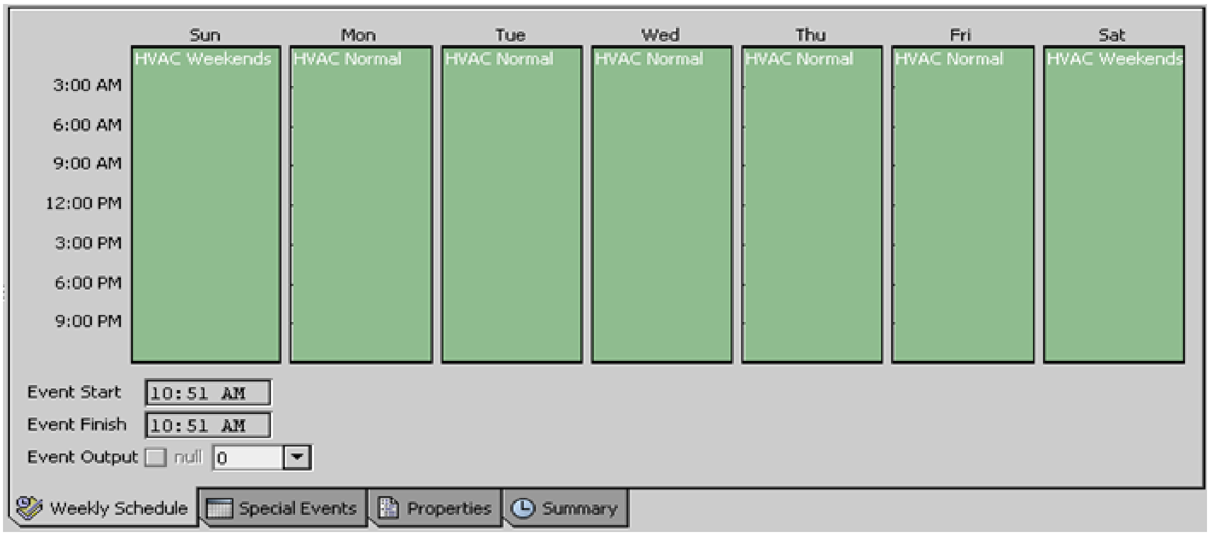

Figure 30: Tridium - Time scheduler example

Figure 30 shows an example view of such a scheduler. A special holiday scheduler can be setup which is accessed in the special events tab of the schedulers. Again this provides a flexible approach to holidays, festivals or any event which is not an everyday event.

6.2.9 Lon and other networks

As with 6.2.4, addition of any other network is a fairly simple affair. A new network is added (in our labs these were to be a LonWorks network, A BACnet network and a Modbus network. Our lab JACE units were already supplied with the various hardware IO ports and connected to physical devices. All that was required was to install the components and then import the points where available. Devices that were “intelligent” could be discovered along with their points. Some devices however need to be told the exact details and the points built one by one within the controller. This was true of the Modbus device which needs both input type and physical address within the device to be defined. This knowledge was provided for us on the worksheets, but in real life would require more intimate knowledge of the devices.

Programming of logic/strategy control remains standard however and the JACE automatically handles all IO once the points and components are linked within the JACE. This makes integration between field devices very easy to perform.

6.2.10 PX Graphics

A library of graphics is provided by Tridium as part of the package. If you visit the Tridium webpages or even look at some sites with Tridium you will often see these graphics.

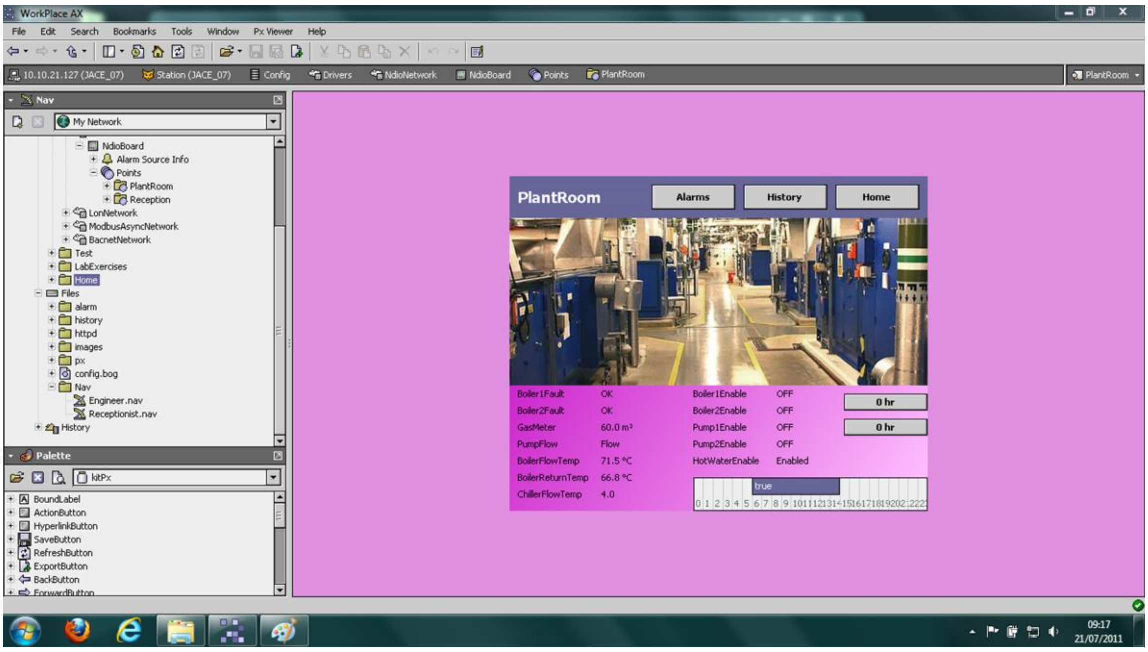

Figure 31: Tridium JACE graphic built during workshop

However, it is possible to create graphics that are unique as has been done with many previous BEMS systems, in fact if your company already has a library it is very likely these could be used as an alternative. We were warned though that the JACE units have a limited memory and it is wise to use a compacted format such as JPEG. It was noted that many of the smaller graphical components are GIF files as they can be used for individual items on a page, are multi layered and can therefore be animated.

Graphic pages are built within the Niagara platform, were easy to set up and very functional. Our labs enabled us to very quickly build professional looking pages within a very short time as shown by Figure 31. Admittedly this was a predefined workshop and therefore working on a real system might be slower.

6.2.11 PX Security and Users

The Niagara platform has an extensive setoff security features. Users can be created and assigned to groups or given each their own set of rights to access features, programming and also the graphics pages and control of graphics points. Graphical points and pages can be made to disappear to lower level users if necessary or simply be displayed but have no override functions.

A tabular view is given with selection of parent/child architecture to assign or remove rights to a user or group. Some care needs to be taken at this stage, but was generally easy to understand. SuperUser rights are possible to be given, but of course this overrides all other security and should be restricted to as few personnel as possible (perhaps none at all).

6.2.12 Web Supervisor

The JACE units are also web servers. This means that virtually all the functions available on the PC version of the Niagara AX software are available through a web browser connecting directly to the IP address of the JACE.

This means the graphics are available too. In fact a special menu layout is usually built when programming a JACE that presents the graphics (or a simple menu list) when a user first logs on to the JACE. The menu structure can even be altered (restricted) for different levels of user.

The Niagara AX software can be a web server when loaded on a PC. This gives greater capabilities of storage for collected alarm or point data. For this reason alone it is advisable that a PC based system is added to draw off and store any information that is to be collected long term. Another method is to draw out data into some other form of Enterprise system.

6.2.13 Final day's exam

The final part to the Tridium training was to sit a practical exam on the fifth day. The exam layout was presented in a folder for each candidate and was a culmination of everything we had learnt in the other four days. Although we could ask for minor help, the format of the test was for each candidate to commission a JACE controller, build the internal structures incorporating points from a BACnet network, Lon network, Modbus network and from the Niagara IO device.

Once the points were discovered and made functional, various programs/logic needed to be devised and built such that some basic controls could be implemented. These formed lighting, heating and cooling controls with manual overrides and time schedules.

Graphics had to be built from the Niagara AX library databases using our own choice and layout.

Alarm and history points had to be created, alarms generated (triggered) and then sent to a central supervisor (first setting up user accounts with various access).

Each candidate was given the whole day to provide a complete solution. Once a candidate had finished or could go no further, they would call the instructor to ask for a summation and final mark.

Such was the nature of the equipment that each candidate was monitored at various stages by the examiner. This was facilitated by the fact that all the controllers were networked and the examiner had overall access to view a candidate's work at any time.

Figure 32: Tridium training completion certificate

The course structure was very well thought out and comprehensive. Anyone passing this course will have a good overview of the Niagara AX framework, JACE controllers and how to begin integration projects using such equipment.

Each candidate was given a final summary of their efforts and awarded a certificate if they passed.

6.3 Further Training

Tridium have a selection of courses available [37] and are described below.

The labs attended and described in this document were from the;

6.3.1 Niagara AX - Certification

The goal of the 5-day Niagara AX Certification Technical Training course is to educate students to a basic level of technical expertise necessary to effectively and efficiently design, engineer, and program projects using the Niagara AX Framework. Students who pass the testing at the end of this class will receive a Certificate of Achievement testifying to their ability.

Two other Niagara AX courses are available;

6.3.2 Niagara AX - Advanced

The goal of the 2-day Niagara AX Advanced Technical Training course is to educate students beyond the basic level to effectively and efficiently design and engineer Web Supervisor and JACE stations in larger systems. The course also covers some advanced user interface techniques.

6.3.3 Niagara AX - Developer

The goal of the 5-day Niagara AX Developer Training course is to educate JAVA software engineers in techniques for developing with the Niagara AX Framework. Students typically aim to develop custom drivers and applications after attending the course, which includes teaching and supervised project work. The course is practical based and students are encouraged to make a start on their project during the course. Past students have been able to complete an early prototype by the end of the course and went on to complete successful projects using the rapid development tools in Niagara.

Chapter 7 Enterprise Solutions

7.1 Enterprise

Enterprise is another word for business or a project or undertaking (especially a complex or bold one) [5].

The Enterprise "buzz" word is becoming very popular in articles and is often associated with integrated building systems, bringing a whole variety of components together under one final solution, usually a combination of software and IT hardware.

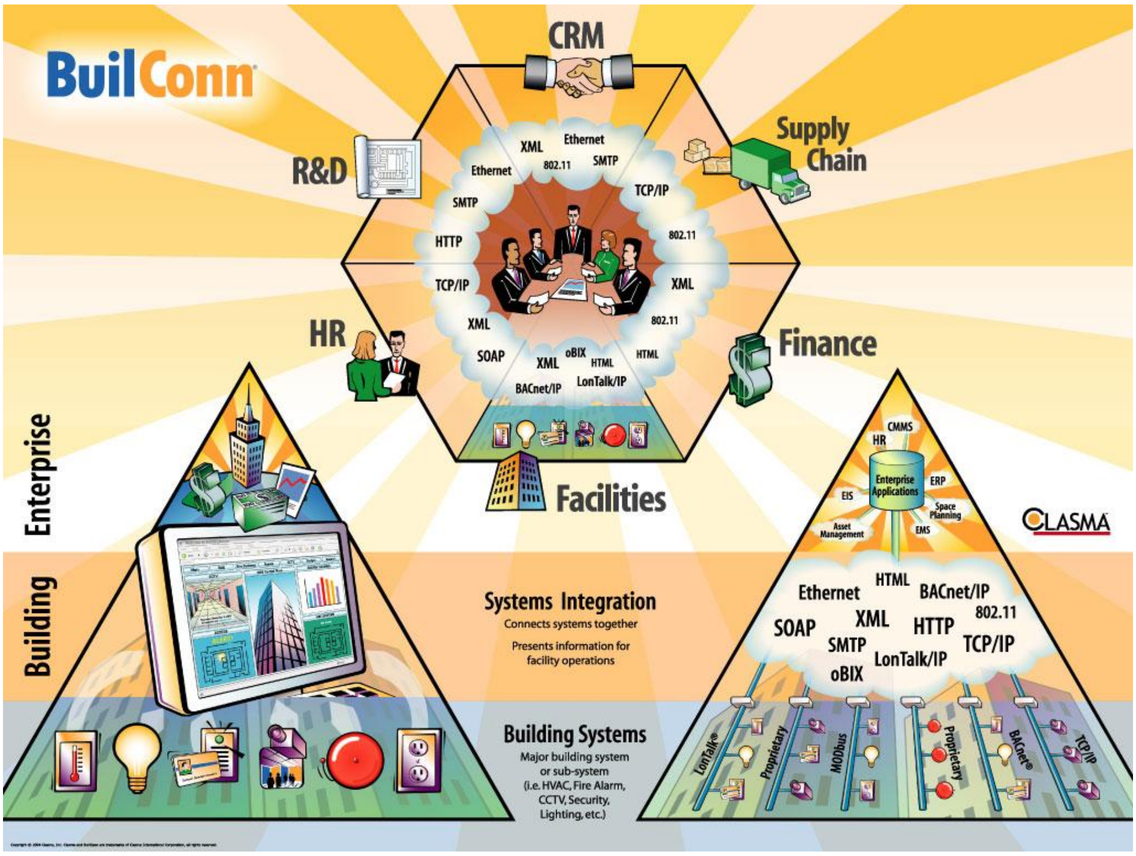

Figure 33: BuilConn.com -Systems, Integration & Enterprise hierarchy

However, Enterprise should not be taken lightly in its effect and usefulness to the running of a building. If we look at all the separate systems each has a job to do, but only with further integration can we combine the roles of the systems. Without Enterprise we cannot easily oversee the whole picture and react accordingly.

7.2 Enterprise Architecture

Enterprise architecture is now being added to clients' requirements. Usually this will bring together the following;

- A comprehensive and phased approach to design and construction.
- Clearly defined interfaces.
- Complete life cycle management.
- Reduced complexity due to the understanding of what will be needed early in the design.
- Better managed services overall.

Companies are appearing to help train and provide Enterprise Architecture. One such company "Architecting the Enterprise" has created its own software to help people with TOGAF (The Open Group Architecture Framework). TOGAF is a vendor and technology neutral consortium. Its vision of Boundary-less information flow is about access to integrated information within and between enterprises based on open standards and global interoperability (38).

This integrated approach is further driving Enterprise solutions for buildings, linking building services together, both physically and through software front end systems. The data collected can be used to provide improved performance of a building, both in carbon reduction and energy reduction. Further it can oversee equipment, life cycles and help to foresee any problems. Data can be collated, meshed with other sources of data and presented to managers, users and clients in ways that help understanding and are informative.

Because an Enterprise Solution can usually be tailored for a specific business, displays can be clearly presented, in different formats and even language or cultural differences can be accounted for. Typical enterprise applications include energy analysis, asset and maintenance management, tenant billing and measurement and the verification of carbon footprint.

As often is the case, the United States (US) seem to be ahead of the UK regards Enterprise solutions. The size of the markets in the US drives technology and efficiency. The US has a variety of conferences each year aimed at smart buildings (BuilConn (39)), smart homes (HomeConn (40)) and Industry (IndConn (41)). The

BuilConn pyramid (Figure 33) shows the entire structure of building systems hierarchy and methods by which they can be interlinked at each level.

As can be seen from the pyramidal representation, the wealth of connectivity allows Enterprise software builders to create almost anything the imagination allows. XML has become a standard for many of today's programs (including MS Word) and therefore allows many programmers to incorporate links into building integration platforms such as Niagara AX. Using ether net and TCP/IP communications has created a standard way to send and receive data. oBIX (Open Building Information eXchange) is a development of XML and is rapidly becoming a building services protocol allowing information exchange with integrated systems and Enterprise (see Figure 34).

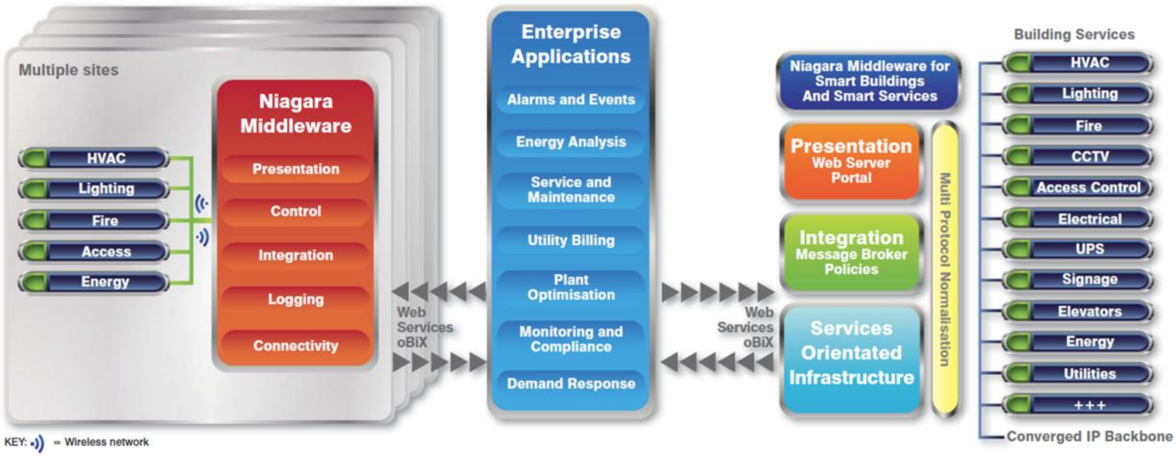

Figure 34: Tridium Infrastructure representation

Whatever protocol is used, most Enterprise solutions are more than capable of using them. The protocols being already imbedded into the software and therefore the ability to share information from devices and software lower on the hierarchical tree.

7.3 The Business Case

7.3.1 Energy

Energy is probably our single most important driver of everything we do. First it enables us to do most things simply not possible by our hands alone. No energy, no digital age. Computers would not be able to function, machinery unable to work autonomously, mass transport of people and goods would stop and buildings would unable to be heated or cooled. Life simply would cease to be as we know it if our energy failed us tomorrow. Therefore EEMS (Enterprise Energy Management Systems) are rapidly developing and evolving allowing careful, detailed study of what and where our energy is going. Through the emergent IT technologies energy professionals (and others) have realised through Enterprise tools they can data mine systems and extract not only important, but useful information about a building.

7.3.2 EEMS

Barney Capehart (PhD) book [42] delves succinctly and accurately into the Enterprise world providing a sound business case for EEMS. He states it is not just about energy and utility savings, cost control, but also about the increased productivity that will be gained. This productivity increase is due to increased comfort and satisfaction with their surroundings through better understanding and control of the lighting, HVAC temperatures, indoor air quality (IAQ) and general indoor environmental quality (IEQ). This increase in productivity will lead to greater cash flow from buildings and facilities leading to an increase in the asset value of the Enterprise.

7.3.3 Is the expenditure worth it?

Installing extra systems is costly and may require improvements or additions to the current IT systems. Can such a cost to facilities be justified?

An accounting principle already exists that can help and it comes along with a “magic” number called the Capitalisation Factor (typically a value from 5-10).

As an example, “Our Company Inc.” has an assumed capitalisation factor of 7. A EEMS could save the company £100,000. The resultant asset value can be shown with this simple formula;

Asset Value Increase	=	Capitalisation Factor x Annual Savings
	=	7 x £100,000
	=	**£700,000**

With only a simple calculation we can see that an initial £100,000 saving has also increased the asset value by almost three quarters of a million pounds. This should be an eye opener and attention grabber for any property or property management owner.

7.4 Cisco Connected Real Estate (CCRE)

Cisco produced a white paper in 2005 [43] showing the idea of CCRE. Taking the fact that the internet had already permeated homes and businesses alike and building a capstone design that would put it all to good use.

As can be seen from Figure 35 , CCRE is an Enterprise venture linking all the various systems as shown previously in this chapter.

However, CISCO are a world leader in producing web communications and making it happen.

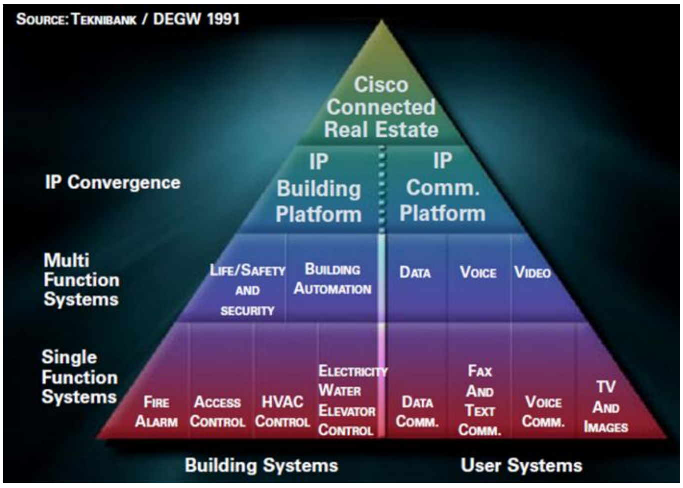

Figure 35: CISCO - CCRE Pyramid

CISCO put forward a valid business case and first set up the idea of understanding a building Life Cycle Costs. In their whitepaper they explain that the life cycle consists of four phases;

- Conceptualise
- Design
- Construct
- Maintain and Operate

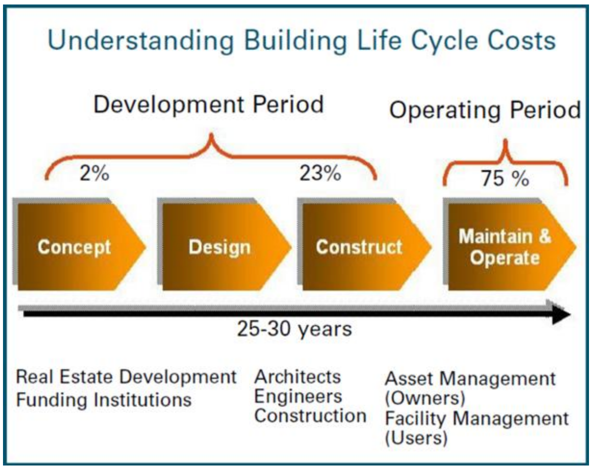

Figure 36: CISCO - Building Life Cycle Costs

Figure 36 also shows the percentage costs for the lifetime of a building. With 75% of the building costs tied up with running a building, it makes good sense to do this as efficiently and productively as possible. CISCO promote a single IP network. This is of course their expertise, but it does make sense if performed from the initial conceptual design.

As CISCO state [(43)], higher levels of connectivity between building systems provides an array of benefits through access to and sharing of real time data including;

- Optimised remote control, monitoring and reporting of building systems, including centralised management of a distributed property portfolio.
- Intelligent HVAC and lighting and cooling systems, leading to reduced costs through increased energy efficiency.
- Improved staff productivity (maintenance, facilities and security personnel) and enhanced Health & Safety compliance.
- Improved asset management and tracking – together with automated work scheduling, billing and help desks, linked to existing enterprise resource planning (ERP) systems.

The whitepaper goes on to show various case studies and their CISCO solutions.

7.5 Enterprise summary

It can be seen from articles and further study that “facility management is no longer about how the HVAC system or other individual building systems perform… but how the Enterprise performs” [(42 p. 7)].

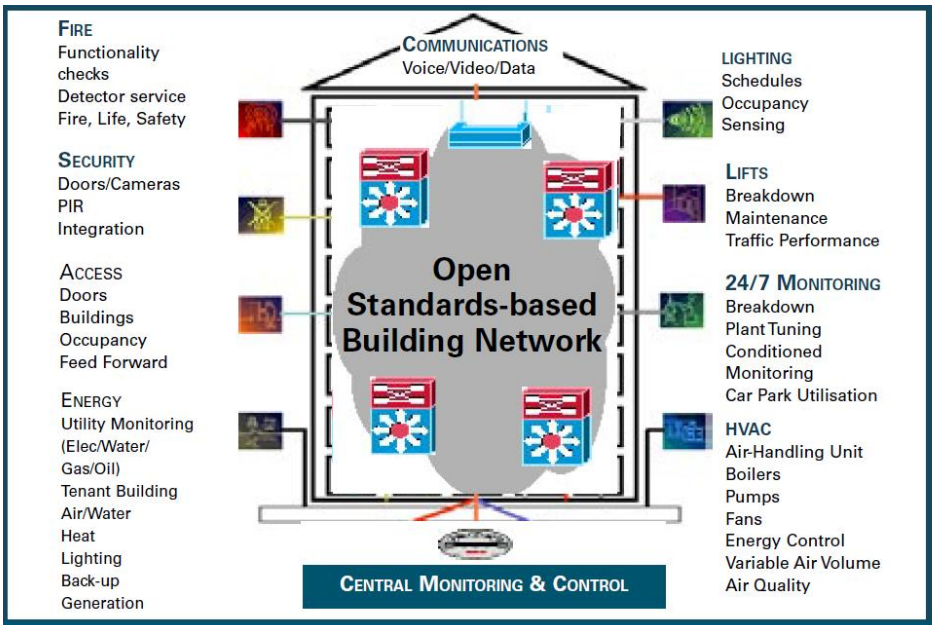

Figure 37: CISCO - Promoting an Open Standards Building

Chapter 8 Conclusions

Without a doubt, many of Brunel University's systems can be integrated and put to good use, the past examples and experiences of other buildings show this. As seen in the enterprise chapter, various solutions are possible. A good scenario is the Tridium Niagara platforms being used as integration between disparate systems and as middleware to any Enterprise solution (this could especially be true of the central control room planned for the new "East Gate" building). See Figure 38 below.

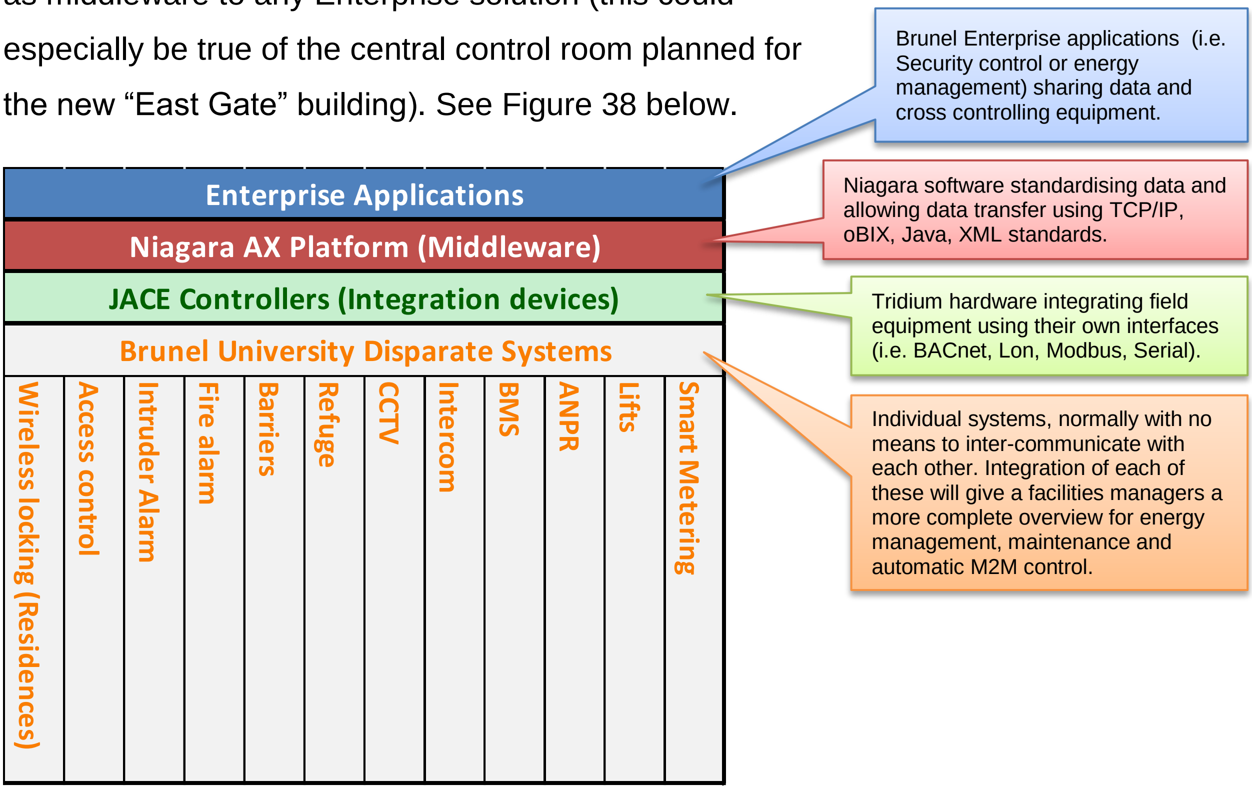

Figure 38: Brunel University possible system layout

Tridium (or another integration system) can be implemented to save money, carbon emissions, integrate systems or simply to make life easier for people by drawing the information out of the field devices and providing the information in a structured and understandable format. Integration provides a high level of transparency across systems allowing multiple systems to be viewed, accessed and controlled with no prior knowledge needed. The difficult stuff (data transfers between disparate systems) is handled automatically by the integration equipment.

Unfortunately addition of extra integration equipment, commissioning and on-going maintenance also comes at a cost. Whether Brunel will undertake the initial challenge to investigate a solution and then provide the funds to upgrade and improve their building will likely depend on whether the accountants get to action the work, or the visionaries and practical engineers, who know what is right and what should be done. Of course, a joint effort would be best for all, providing a worthwhile solution at a reasonable cost.

I mention this conflict between engineers and accountants as it has been my unfortunate and unpleasant experience to witness mechanical contractors reducing a BMS system specification to nothing more than a time clock and thermostat control. This indeed saves the initial capital cost (good for the main contractor) but will cost the client much more over the life cycle of the building. Clients need good advice and the ability to remove the control of the purse strings from the contactor, thereby keeping the clients initial vision whole and putting the building contractor back into their real role, that being to build the project and give the client what they want as well as what they need.

So far I have not fully defined Enterprise Solutions and it is likely I shall be unable to do so. Because every business (Enterprise) has its own requirements, the solution is therefore different for each business. This is why most companies end up with a bespoke system solution. Companies like North Communications can provide more generic solutions such as ObSys 2.0 [(44)] or Tridium's Niagara AX platform [(45)]. Even these will have a different look for each company, different graphics, different services, and different approaches to how the information is presented. Again, every company will have its own idea as to what the final solution will be.

Tridium describe Smart services as Machine to Machine or M2M. Allowing buildings to be run more efficiently, use less energy and help reduce service costs whilst lowering downtime. The downtime reduction is primarily attributed through site problems being identified and fixed more quickly due to the helicopter view that an integrated system provides.

The Tridium solution offers a wealth of opportunities for Enterprise to access field equipment through the Niagara AX Software Stack (as shown in Figure 39). Discussed in previous chapters, but it can be seen that most systems are readily accessible through a wide variety of device interfaces and available drivers. The most popular Enterprise interfaces are catered for. Human interface is also provided including the tools needed to modify existing or add new ones.

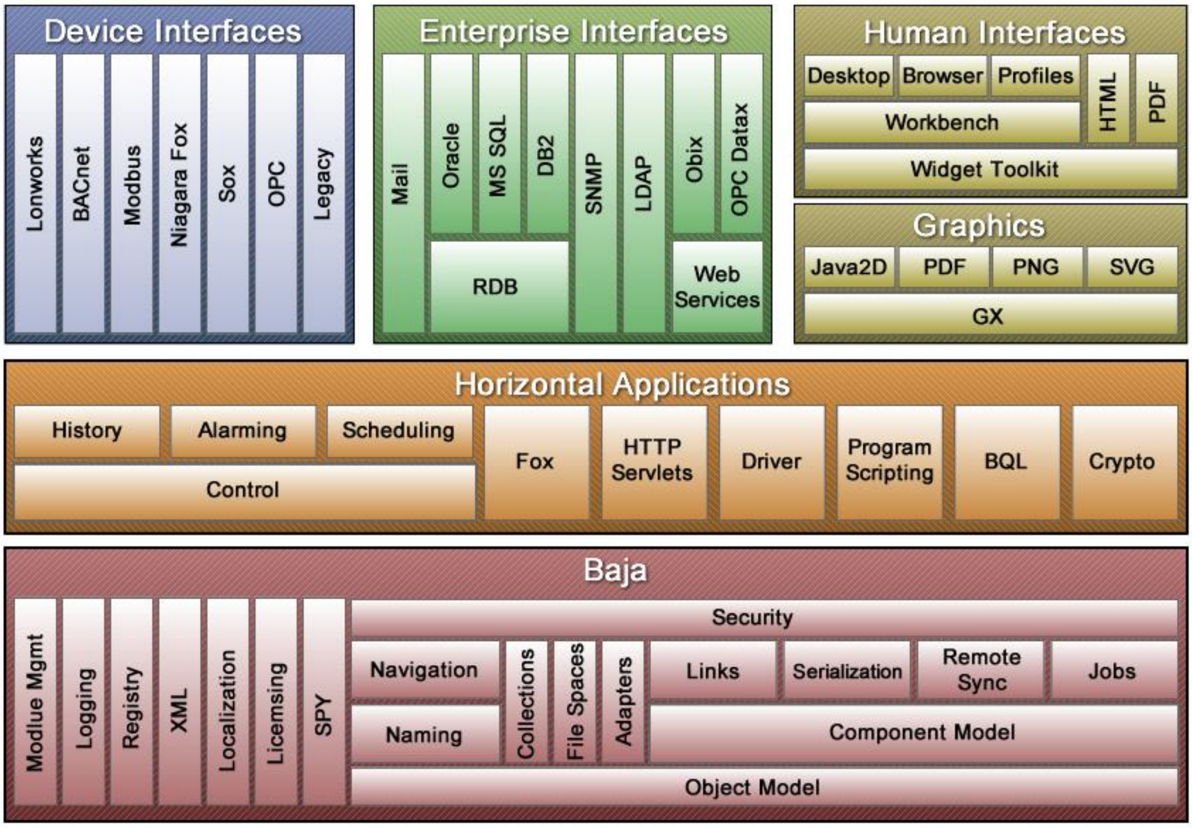

Figure 39: Tridium - Niagara AX Software Stack

To deliver Smart Services, systems within the building must be connected to the various enterprise applications so that we know when to act and provide us with more information about what to do. Service can be based on need prompted by actual plant conditions, not just scheduled on a calendar.

Engineers can diagnose the type of problem before arriving on site and ensure that the people with the right skills and the right equipment are there on the first visit. Service can be initiated because of degrading performance and efficiency, not just as an emergency response to faults and breakdown.

The CISCO world [(43)] is perhaps not far from the truth of what buildings need. An open standards policy will help link the whole Enterprise together (as shown in Figure 37 on page 7-6) but this should be started from the initial concept. IT should no longer be seen as a department to be avoided, but should be accepted for the resource they are, embraced and moulded into a whole vision.

I am advocating the use of Tridium for Brunel, primarily due to the fact I have seen it working, have been able to engineer it with only 4 days of instruction and because it seems to be being rapidly adopted throughout the whole world. Of course this is a somewhat impartial judgement, but until I get the opportunity to try other systems, I can see (being an integration engineer myself), Tridium can offer most of what an integrated and smart building needs.

Whether Tridium, North or another integrator is used, either part or wholly, the uses and need for smart systems are becoming apparent to more and more clients and their businesses. The BEMS technology is starting to mature providing more and more proof of energy reduction, efficiency increase and carbon reduction. European directives [46] are driving us all to a hopefully better and sustainable lifestyle. It will be with machines of greater and greater intelligence that we can hope to monitor and maintain such systems.

“Control systems have been with us many years, intelligent control systems almost as long, but smart systems are our future.”

Paul Robert Hillman - 2011

Appendices

Contained in the following appendices are;

Appendix A: Project Management

Appendix B: References

Appendix A Project Management

A.1 Original Proposal

Brunel University **Full time Learning Programme** **MSc in Building Services Engineering**		BRUNEL UNIVERSITY WEST LONDON
Project Form III: Project Proposal		
Name:	**Paul Hillman**	Date: **20 June 2011**
Student Number	**0834760**	
Proposed Title	**Managing Smart Building Services**	
Dissertation Tutor	**Mr Alf Moroncini**	
External Advisor (if any)	**Dr Peter Warren**	

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A.1.1 Introduction

The following proposal is intended to give the reader an outline of the forthcoming dissertation work related to interconnecting disparate systems. Initial discussions with the Brunel University energy manager indicate a variety of disparate systems exist on the university campus and are available to be studied. Studies will include the current energy monitoring used within Brunel University and what will be possible if an interlinked “intelligent” gateway between the systems is incorporated. Such gateways can facilitate unattended two way information flow between field equipment (i.e. data sharing between energy metering and HVAC equipment) and furthermore provide value added information at a higher level to facilities management teams. Further investigation of system integration may be considered incorporating the access control system and any other systems found during my research period. The final scope will depend somewhat on the available time of this dissertation and the accessibility of the equipment available to be studied. Brunel University primarily uses a Trend BMS system with a site wide network linking the buildings and equipment. For this reason is shall look to the Trend TONN (Trend Open Network Node) and Tridium integration devices for the purpose of system integration.

A.1.2 Background to the Project

Building services technically are becoming more intelligent and therefore require a higher level of specialists to maintain and operate.

Additionally there are compliance requirements with legislation to meet building regulations and carbon reduction commitments that are continually changing.

The aim of “Smart Building Services” is to initially investigate the convergence of different building services (BMS, Fire, Security, CCTV, Access Control and Energy Metering) onto common building services backbones. This could allow data to be shared for inter-process control and remotely accessibility via the internet. “Intelligent Services” should allow utilisation of central/remote bureau services thereby allowing specialists to maintain and operate a building in the most cost effective and energy efficient manner.

A.1.3 Aims and Broad Objectives

- Benefits/disadvantages of sharing inter process data.
- Operational cost (additional or savings) associated with centralising.
- Understanding and overview of continuous plant and alarm monitoring.
- Understanding and overview of condition based monitoring.
- Understanding and overview of continuous energy monitoring and targeting.
- Overview of remote support.
- Overview of facilities management.

A.1.4 Methods to be Adopted

- The dissertation will involve an initial study of the Brunel facilities and systems related to BMS and energy monitoring.
- Research of Tridium/Trend TONN technologies for use in system integration.
- Consult with industry (initially Tridium and Trend for integration technology, but will include any companies where field equipment is studied and extra data needed).
- Detail any findings, benefits or disadvantages.
- If time permitting and suitable equipment provided, actual experimentation with integration tools and devices (this may be lab simulation only due to risks associated with working on real and live systems).

A.1.5 Time-Plan

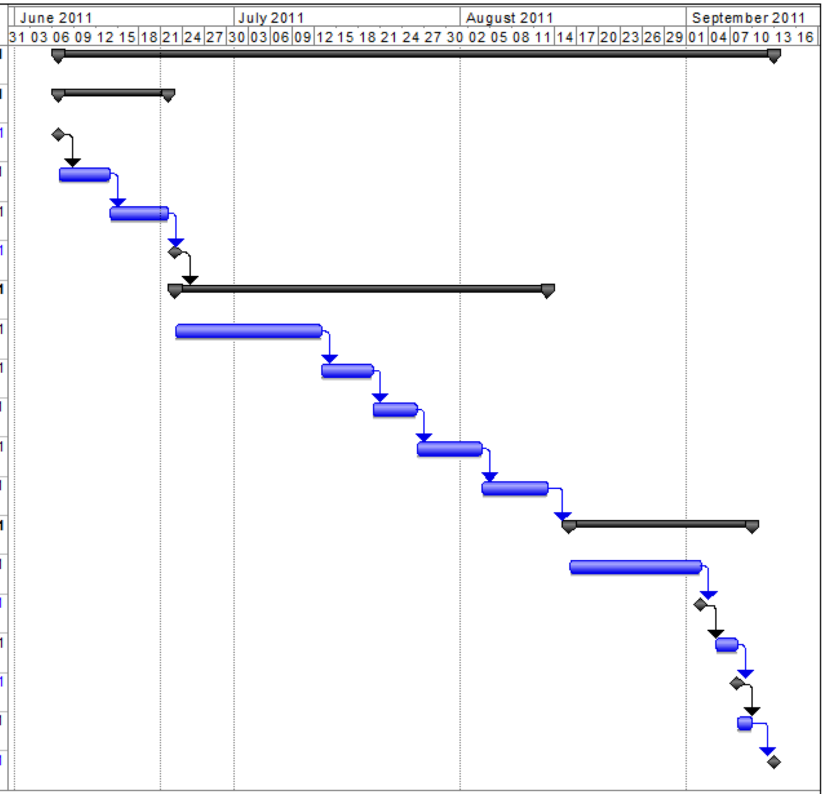
See Gantt chart on next page.

A.1.6 Deliverables or Specific Outcomes

- Is disparate system integration possible within the Brunel University campus and to what extent.
- A greater knowledge and understanding of the possibilities of integrated systems and its necessary technology.
- Any costs involved or extra issues (i.e. extra maintenance or supervision) related to installing this type of technology.
- Advantages and disadvantages of system integration plus practical implications needing to be considered.

A.2 Time Plan (Gantt Chart)

ID	Task Name	Duration	Start	Finish
1	**Managing Smart Building Services**	**70 days**	**Tue 07/06/11**	**Mon 12/09/11**
2	**Startup Phase**	**11 days**	**Tue 07/06/11**	**Tue 21/06/11**
3	Meeting & receive topic	0 days	Tue 07/06/11	Tue 07/06/11
4	Other commitments	5 days	Tue 07/06/11	Mon 13/06/11
5	Proposal	6 days	Tue 14/06/11	Tue 21/06/11
6	Dissertation start	0 days	Wed 22/06/11	Wed 22/06/11
7	**Research Phase**	**37 days**	**Thu 23/06/11**	**Fri 12/08/11**
8	Brunel systems study	14 days	Thu 23/06/11	Tue 12/07/11
9	Study Tridium	5 days	Wed 13/07/11	Tue 19/07/11
10	Study Trend TONN	4 days	Wed 20/07/11	Mon 25/07/11
11	External systems study	7 days	Tue 26/07/11	Wed 03/08/11
12	Create systems overview	7 days	Thu 04/08/11	Fri 12/08/11
13	**Writeup Phase**	**19 days**	**Tue 16/08/11**	**Fri 09/09/11**
14	Document collation	14 days	Tue 16/08/11	Fri 02/09/11
15	Draft submission/meeting	0 days	Fri 02/09/11	Fri 02/09/11
16	Document revision	3 days	Mon 05/09/11	Wed 07/09/11
17	Draft submission/meeting?	0 days	Wed 07/09/11	Wed 07/09/11
18	Document revision	2 days	Thu 08/09/11	Fri 09/09/11
19	Submission	0 days	Mon 12/09/11	Mon 12/09/11



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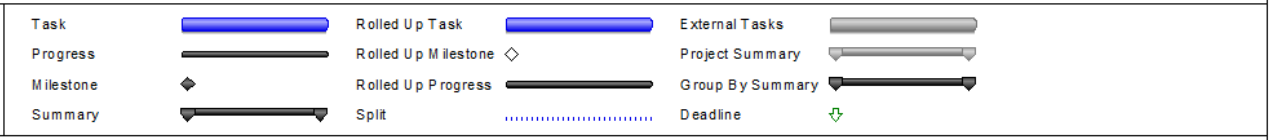

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A.3 Project Issues

A.3.1 Problems Encountered

The primary issues were related to obtaining information about the Brunel systems. Each system seems to be completely separate and in the hands of a manager. The engineers and managers I approached were very helpful but also very busy.

Unfortunately I had very little time to research the Brunel systems due to personal situations in my life at the time. The primary issue was the need to have an operation during my dissertation and which caused me to have a few weeks of disability during the latter part of my studies.

The Brunel library has a very limited and somewhat dated selection of BMS and especially controls/integration related information. This is a little surprising as Brunel regards itself highly in engineering and this could be addressed by approaching industry and maybe setting up links with industry.

However one book [(42)] from the library was an enormous help to my study needs, both now and probably for the future. In general, the Brunel facilities are very good, however, during the summer the 24hr opening times drop back to 9am-5pm and whole floors were closed for refurbishment. As a resident this did not affect me as much as I expected as I rarely used the library post graduate centre (preferring either my room or Hallsbury Post Graduate centre) and the books were still available upon request.

A.3.2 Resolutions

The lack of response I solved by going to see the mangers directly, rather than relying on emails. Each time I found the managers very helpful and informative and again I thank them for this.

My immobility was just a matter of time and waiting for my operation to heal.

I increased my access to information by contacting companies and other industry colleagues directly, by using my large collection of IET/CIBSE/BSEE magazines and of course through the internet.

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The End?

This is not the end, only the beginning…

As one of my favourite authors Douglas Adams (1952-2001) once wrote.

“So long and thanks for all the fish”