# Building automation interoperability – A review

F. Ferreira, A. L. Osório
GIATSI
ISEL - IPL
Lisboa, Portugal
fabiorferreira@hotmail.com,
aosorio@deetc.isel.ipl.pt

J. M. F. Calado
IDMEC
ISEL - IPL
Lisboa, Portugal
jcalado@dem.isel.ipl.pt

C. S. Pedro
Grupo Sousa Pedro
Cacém, Portugal
sousa.pedro@sousapedro.com

*Abstract*— The development of building automation systems (BAS) is strategic to answer comfort, security and energy saving requirements. In large buildings energy can represent a significant percentage of the energy year's bill. An integrated BAS is expected to contribute for a significant decreased of costs, development, assembling and management cost, and it might contribute to a reduction of CO2. The goal is to develop an integration strategy aiming to establish an integrated control of the building sub-systems (e.g. heating, ventilation and air-conditioning (HVAC), lightning, security, etc.). To accomplish this integrated control there is a need to establish a communication strategy among the involved sub-systems. One of the challenges to develop such a BAS is on how to establish interoperability between sub-systems since they are from multi-manufactures and developed on heterogeneous technologies. A solution is to build a system that implements one of the emergent open protocols such as BACnet, LonWorks or KNX. They are open, interoperable, multi-vendor and provide an end-to-end solution. The paper presents a comparison between the characteristics of the mentioned protocols and the best one to implement an open building automation system is chosen.

***Keywords- Building Automation System (BAS); Interoperability; Open communication protocols; BACnet; LonWorks; KNX;***

## I. INTRODUCTION

Nowadays a Building Automation System (BAS) is a union between several subsystems, like heating, ventilation and air-conditioning (HVAC), lightning, closed-circuit television (CCTV), access control, fire alarms, etc. Some of these subsystems have been developed as closed subsystems unable to allow interoperability between them.

However, interoperability between subsystems is a very important aspect when is requested an open building automation system since it allows the incorporation of multi-vendor devices sharing resources and information between them. For example, considering such an approach it's possible to share sensors for the activation of routines in lightning and HVAC subsystems or the cooperation between access control subsystem and the others subsystems. It's this cooperation between subsystems that provides the building automation system with the so called intelligence.

The control room of a BAS not cooperative consists normally of several supervisory subsystems using different supervisory approaches corresponding to the different subsystems (e.g. CCTV, access control, fire alarm and HVAC). If a new process is developed to optimize office conditioning involving access control and HVAC subsystems, the question is how to develop such a new integrated system. Because each subsystem has different ways of communication and representing information, then, it is very difficult or even impossible to achieve interoperability between them.

The difficulty to get interoperability is mainly concerned with communications. Hence, interoperability between subsystems can only happen if two or more subsystems understand each other. To achieve this understanding it's imperative the use of a communication protocol (detailed on section 2).

It is possible to indentify three kinds of ways of achieving interoperability between subsystems of a BAS:

- Manufacturer provides a complete solution with a proprietary communication protocol between subsystems (monolithic closed solutions);
- Creating some kind of association between manufacturers and an open communication protocol;
- Design the system based on the participation (cooperation) of different subsystems considering the required interoperation that is grounded on open (standards) protocols.

The next sections will be focused on solutions to achieve interoperability between subsystems of a BAS through the use of open communication protocols.

The paper is organized as follows: section 2 presents an introduction to the communication protocols topic; section 3 presents an analysis of the three emergent open protocols, BACnet, LonWorks and KNX, summarizing the key characteristics of each one; the main features and characteristics of the three mentioned protocols are compared is section 4; section 5 provides some concluding remarks.

## II. COMMUNICATION PROTOCOLS

Building Automation Systems (BAS) aim at improving control and management of mechanical and electrical subsystems in buildings. The system functionality is broken up into three levels, as depicted in Figure 1. At the field level, the data is collected (measurement, counting, metering) and the process is controlled (switching, setting, positioning). The automation level encompasses the various aspects of automatic control, e.g., the execution of control loops. Global configuration and management tasks (e.g., visualization) are part of the management level functions.

Today, many different standards for BAS exist. The three most popular and well-known ones are KNX, LonWorks and BACnet. While these open standards are application-independent and can be used at all three levels, other standards are dedicated to the use at a single level. A mapping of the most important standards to the architectural levels in BAS is illustrated in Figure 1. It can be observed that both KNX and LonWorks are used predominantly at the field and automation level while BACnet is prevalent at the management and automation level [3].

Probably, as far as the performance of a BAS is concerned, may there are no differences between open and proprietary solutions. However, in fact open solutions offer numerous benefits including competitive bidding, consistent installation, consistent maintenance, system integration and interoperability, data acquisition and product interchangeability [1].

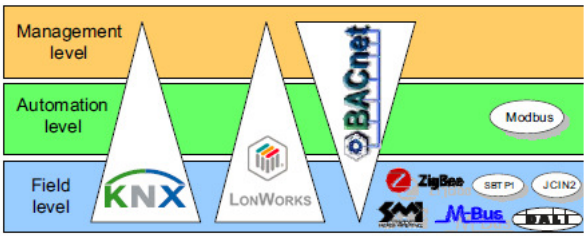


Figure 1. Standards in building automation [3]

### A. *Proprietary protocols*

In general, the performances of proprietary protocols are acceptable for the meaning that they were build. Anyway, generally speaking the owner of such protocols has a monopoly of the corresponding algorithms used by the control system, the communication channel and, even sometimes the use of specific manufacturer's hardware is needed.

With this kind of protocol becomes unreasonable or even financially impossible after the initial investment on some specific manufacturer change to another or simply making two products of different manufacturers to communicate allowing interoperability. Furthermore, the development of cooperative solutions involving subsystems from different suppliers requires the participation of all of them contributing to proprietary (monolithic) solutions lacking this way from the competitiveness advantages.

Beyond the economical aspects, proprietary communication reveals incompatible with third parties software and hardware.

### B. *Open protocols*

Open system architecture can deliver benefits far beyond any proprietary system. These benefits are derived from creating a totally integrated control network throughout an entire facility. The more integrated your control systems are the greater the saving for system installation and maintenance. Only with a fully integrated facility can benefit from data analysis products like energy management systems.

The open protocol goals and their definitions detailed have already been pointed out [1].

The use of open protocols is one viable solution to a sustainable BAS. A sustainable BAS is achievable with proper initial design considerations that include not only the use of open protocols, but also standardized Network Management tools and open access to product and training. Such requirements are detailed in [4].

## III. OPEN COMMUNICATION PROTOCOLS/SYSTEMS

BACnet, LonWorks and EIB/KNX are open systems claiming the ability to cover BA applications in their entirety. They all have achieved considerable significance in the worldwide market and are often chosen by both customers and system integrators for complete system solutions [2].

### A. *BACnet*

The Building Automation and Control Networking Protocol (BACnet) was developed specifically to address the needs of building automation and control systems of all sizes and types. The development has been made by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) project committee.

The most recent version of the standard is "BACnet—A Data Communication Protocol for Building Automation and Control Networks, ANSI/ASHRAE Std. 135, 2004".

BACnet is in constant development by the Standing Standard Project Committee (SSPC). BACnet Testing Laboratories (BTL) is another very important organization being responsible for the consistency of the diverse products of different manufacturers that implements BACnet. Hence, the interoperability between certified products is guaranteed.

Although BACnet supports four different *communication protocols.* In this paper is just named the two most implemented. Ethernet this technology is the most used worldwide and supports several types of media, UTP, fiber or even wireless. It can reach a velocity of 10 Gbps, which is normally used to form the network backbone. MS/TP (master-slave/token-passing) is defined for devices with lower requirements in terms of speed and runs at speeds of 1 Mbps or less over twisted pair wiring.

BACnet protocol uses only four of the seven layers of the Open Systems Interconnection (OSI) model detailed in [10].

All information in a BACnet system is represented in terms of objects. An object might represent information about a physical input or output, or it may represent a logical grouping of points that perform some function, such as a set point. An object is much like what is now commonly known as a "data point" in the HVAC community. Where an object differs from a data point is that a data point would typically have a single value associated with it, whereas an object consists of a number of prescribed properties.

A service is the mechanism that a building automation system uses to access a property or request an action from a BACnet object. Services are how one BACnet device gets information from another device, commands a device to perform certain actions (through its objects and properties, of course), or communicates events to other objects.

As a system developer or user, there is no need to be concerned with the execution or processing of service requests; these will be transparent and automatic.

### *B. LonWorks*

LonWorks is an event-triggered control network system. The system consists of the LonTalk communication protocol, a dedicated controller (Neuron Chip) and a network management tool [2].

The LonWorks system has been originally designed by Echelon Corp., and its communication protocol, LonTalk, was publish has ANSI/EIA standard 709 [1]. The authorized entity for components certification is LonMark, which in 2005 had already 600 certified components [1].

*LonTalk* is the unique protocol supported by this system. It supports the communication between all the components on the system network. Is a complete protocol that implements the 7 OSI model layers that is summarized in [6]. The LonTalk supports a variety of different communication media and different wiring topologies. Since it was designed as a generic control network, many protocol parameters are free to choose for the designer. To achieve interoperability, a number of communication *channel* profiles were defined. The most popular channel for building automation purposes is the 78.1 kb/s free topology TP profile (FT-10), which allows physical segments of up to 500 m using low-cost TP cable and more recently, building backbones turn from TP-1250 to IP tunneling mechanisms. Also known as LonWorks/IP, IP tunneling is readily supported as a standard channel for LonTalk. Both tunneling routers and fully IP-based LonWorks/IP nodes are used.

*Neuron Chip* is the main component of each node. It was specially created for the LonWorks system and on its core there are three processors. Two of them give support for the LonTalk protocol (NET, MAC) and the other for application purposes (APP). It's possible to associate these functions to each layer of the protocol.

LonWorks devices take advantage of the functions of the Neuron Chip and use it as the control processor. The Neuron Chip is a semiconductor device specifically designed for providing intelligence and networking capabilities to low-cost control devices. In the Neuron Chip three processors provide both communication and application processing capabilities [5].

For both unicast and multicast *communications*, a reliable transmission mode (acknowledged) with end-to-end acknowledgments can be selected. In addition to the "one-shot" unacknowledged mode, an unacknowledged-repeated mode is provided, where every transmission is automatically repeated a fixed number of times.

For an easier integration, the LonMark association created the standard network variable types *(SNVT)* comprising syntactic as well as semantic information, like the associated engineering unit. Over 60 functional profiles have already been published.

### *C. KNX*

Konnex (KNX) has a technology and an association, is the result of the merge, in 2002, of three European technologies for home and building control; EIB (European Installation Bus), BatiBUS and EHS (European Home System) [7]. KNX is an international standard (ISO/IEC 14543). The standard management and certification is on the responsibility of the Konnex Association.

KNX provides the choice of different network media. It supports the use of twisted-pair, power line as well as a wireless solution called KNX Radio Frequency. Additionally, a simple form of IP tunneling is also available.

KNX networks are typically implemented following a two-tier model. Field networks can assure the communication with sensors, actuators and controllers that interact with the environment and perform measurements and control tasks. These field networks are interconnected by a common backbone where management nodes (e.g., operator workstation, logging server), that require a global view of the entire KNX network, are located.

At the field level, robustness and flexibility are the most important. Therefore, the KNX network media twisted-pair (TP) with all its benefits (e.g., free topology) as well as KNX Power line and KNX RF are well-established. At the backbone level, it is more common to use high performance network media. Today, a trend towards the use of IP based networks as backbone can be observed [8].

Data-points are used to perform or receive orders. They are connected forming a logical distributed network. This connection between components is called binding as detailed in [9].

Engineering-Tool-Software (ETS) is used to project the entire KNX network like creating the previously mentioned bindings.

## IV. OPEN COMMUNICATION PROTOCOLS COMPARISSON

TABLE I. summarizes the comparison between the three analyzed technologies, LonWorks, BACnet and KNX.

*Device Architecture*:

LonWorks has the disadvantage of requiring the implementation of their devices with a specific processor, Neuron Chip. And only two companies have exclusive manufacture of this processor. But, on other hand, it has an advantage; it facilitates the creation of new devices because it's all developed over a full prepared architecture.

*Market:*

LonWorks and BACnet systems have a market disadvantage when compared to KNX, because both have a very low number of certified technicians. These systems are normally implemented in bigger and more complex buildings. So, it requires very specialized technicians. For example some of the KNX technicians are electricians. BACnet is not yet very popular in Europe. In the lead is KNX followed by LonWorks. Any way each one of them has their market space. An advantage that KNX shows is low budget system when compared to the other two.

*Network:*

A significant difference is the fact that LonWorks has a single communication protocol, LonTalk, while BACnet is defined by six different kinds of protocols. The advantage of BACnet on this concern is that is much more flexible and adapts easily to the building needs but on other hand, devices that implement different protocols are not interoperable and that's the advantage of LonWorks. With one protocol all devices communicate over the same set of rules and that facilitate the integration.

The triangles, depicted in Figure 1. shows that LonWorks and KNX are "bottom up" solutions, focusing more the field and control level, while BACnet has is effaces on management level with its "top down" solution. In some situations the adopted solution is based on having the management level as BACnet and then, with gateways or directly, delegates the functions of other levels to other protocols, like LonWorks, KNX, ModBus, etc., and, as it has been pointed out "engineering large buildings still requires integration of several different protocols, including BACnet, to handle the range of occupier needs" [7].

TABLE I. LONWORKS, BACNET AND KNX COMPARISON

| | LonWorks | BACnet | KNX |
|---|---|---|---|
| **Network Architecture** | "Bottom Up" solution<br>Common communication protocol<br>Peer-to-Peer | "Top Down" solution<br>Multiple communication protocol<br>Tiered network topology | "Bottom Up" solution<br>Low speed free topology |
| **Device Architecture** | Neuron Chip<br>Neuron C (Programming language) | Processor independent<br>Programming language independent | Initially used a 68HC05 processor |
| **Comm.** | Single protocol: LonTalk<br>TP, PL, Wireless, optical fiber | Multiple protocols supported: Ethernet, ARCNET, MS/TP, LonTalk, PTP | TP, PL, Wireless |
| **Internet** | LonWorks/ IP<br>i.LON – Web service device series | BACnet/IP<br>BACnet/WS | KNX/IP |

## V. CONCLUSION

To create a reliable BAS many variables have to be weighted and each one has its proper solution. It's important to understand that once the system has been implemented there is no way back. If the chosen system is for life it should be the perfect one. An open system lowers the risk, because of their four main aspects such as open, interoperable, multi-vendor and end-to-end solution.

Building Automation Systems could be splinted in two main types: building offices and homes. Clearly, that the better solution for homes is the KNX approach. But for building offices a more solid solution must be thought. Despite the need to encounter the better solution for each situation, BACnet seems to be the most flexible solution. BACnet can do everything that LonWorks and KNX can and what can't is easily delegated to other systems. BACnet operates over IP and offers certified Web Services solutions. With BACnet 6, different types of protocols are available and independent processors and programming language providing much more flexibility for the developers and manufacturers. Finally BACnet is ANSI, CEN and ISO standard.

The next step of this project will be the developing of an open and intelligent infrastructure capable of making automatic association of new building processes. The conceptual objective is a plug-and-play solution.

## ACKNOWLEDGMENT

The research work presented in this paper was financially supported by *Grupo Sousa Pedro*.

## REFERENCES

[1] Strata Resource Inc., "Investigating Open Systems - Comparing LonWorks and BACnet", 2006.

[2] W, Kastner, G. Neugschwandtner, S. Soucek and H. M. Newman, " Communication Systems for Building Automation and Control", IEEE, 2005.

[3] W. Granzer, W. Kastner and C. Reinisc, "Gateway-free Integration of BACnet and KNX using Multi-Protocol Devices", Vienna University of Technology, Automation Systems Group, 2008.

[4] P. Winkelman, "Sustainable BAS", Automated Buildings, 2009, http://www.automatedbuildings.com/news/mar09/articles/distech/090219023638distech.htm

[5] Echelon Copr. "Neuron Chips", Echelon - Developers, 2009, http://www.echelon.com/developers/lonworks/neuron.htm.

[6] Toshiba Corporation, "Neuron Chip", 2006.

[7] A. Kell and P. Colerbrook, "Open Systems for Homes and Buildings: Comparing LonWorks and KNX", 2003.

[8] D. Lechner, W. Granzer and W. Kastner, "Security for KNXnet/IP", 2008.

[9] Konnex Association, "KNX System-architecture", 2004.

[10] G. Thomas, "Connecting BACnet Devices to an IP infrastruture", Automated Buildings, 2009, http://www.automatedbuildings.com/news/mar09/articles/cctrls/090220020828cctrls.htm