

SARBAU - towards highly self-configuring IP-fieldbus based Building Automation Networks

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Abstract

The SARBAU project is a study on a highly self configuring building automation and control network using IP as field level protocol. UPnP will be used for device operation and control. The paper gives an overview on the SARBAU approach. Current work-in-progress including wired and wireless experimental device hardware is presented. A focus of this paper is “nearly automatic configuration”. Using intelligent commissioning software and optional device localisation, we propose highly automated device commissioning and binding schemes.

1. Background

Building automation and control (BAU) systems are commonly employed in commercial buildings to automate light, heating and other control. Besides the fact that complex HVAC (Heating, Ventilation and Air-Conditioning) systems are hard to manage without BAU systems, important advantages of such systems are among others increased comfort and energy savings. Typically such systems are divided into three logic levels, the field level, the automation level and the management level. In currently deployed BAU networks this logical separation manifests in a physical separation of the underlying data transport networks, which may be of different type. This is on one hand attributed to optimum suitability for the distinct task of each BAU logic level, on the other hand it is an historically grown architecture [5]. Typical field layer technologies for BAU systems are LON [1] and EIB/KNX [2].

LON (Local Operating Network) is a development of echelon corporation. LONTalk describes the transport layers of the network. A variety of media is specified for the physical layer, the most common being a 78kbps twisted

pair network of arbitrary topology. Higher level device information like descriptions on what kind of device it is, and application profiles are defined by the LONMark recommendations. The LON devices get a unique 48 Bit device address during manufacture.

EIB/KNX (European Installation Bus/Konnex) is an open standard found by a consortium of leading European companies active in the BAU industry. The most commonly used media is EIB, again a twisted pair here with 9600 Baud and arbitrary network topology, but other media, as RF, infrared, powerline communication (PLC) or virtual media via IP tunneling are also specified. Addressing is by a 3 Number hierarchical system and group addressing schemes are widely used.

On the higher layers of BAU networks, communication is more and more performed via IP networks, but IP used as a virtual physical layer or tunnel, i.e. no higher internet protocols are used. The most common protocol on the automation and management layer is BACnet. BACnet operates on a higher abstraction level than typical fieldbus protocols. BACnet devices may offer services and present themselves in an object model.

2 IP as Fieldbus for Building Automation networks

2.1 Advantages and drawbacks

In the SARBAU project we investigate the deployment of IP also on the field level. An obvious advantage is the ability to employ high level internet protocols: IP as fieldbus protocol allows adopting common IT network technologies to the field devices, for example the usage of UPnP [3]. Also one network structure is used for all levels of the BAU network, potentially shared with the buildings IT network infrastructure. In Fig. 1 a sample network sce-

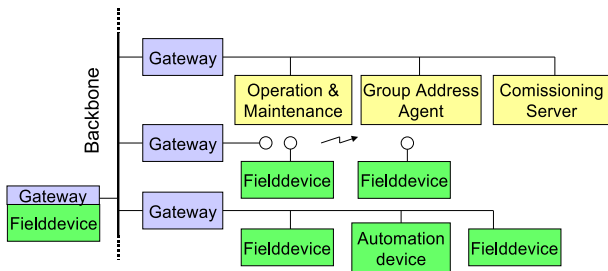


Figure 1. BAU IP Network scenario.

nario is outlined. Field devices, automation devices and high level management entities of a BAU network communicate via IP. Smaller network segments covering for example one floor of a building, are interconnected via an IP backbone. The depicted gateways are optional and perform IP routing and separate the subnets from the backbone traffic but do not perform any protocol or address translation.

In todays building automation fieldbus systems, connectivity to IP networks has been realized for example with OPC, but the field devices themselves do not communicate via IP. There exist a variety of sophisticated proxy solutions, where devices of an established fieldbus system like KNX/EIB are presented on an IP network in a UPnP facade [6] or via web-services/oBIX [13]. Also in these approaches, the BAU devices themselves operate on their native fieldbus protocols.

The IP deployment opens new possibilities: Using IP and UPnP will enable direct user access to building services via any IP connected device such as a PC, a PDA or a smartphone. The user may for example control illumination and blinds from the desktop or prepare meeting rooms via the notebook which is also used for the presentation.

Obvious shortcomings of IP fieldbuses for which solutions are sought in the project are the high overhead for typical XML based protocols like UPnP [11], which causes problems on low rate physical media, and security issues especially when using wireless communication or when sharing the BAU IP network with the IT IP network. In our current work we use standard ethernet and wireless IEEE802.15.4 as physical media for IP communication. IEEE802.15.4 and ZigBee are likely to play an important role in wireless building automation in the near future, and there is also work ongoing to integrate IEEE802.15.4 into existing building automation standards like BACnet [14, 15]. Currently employed fieldbuses offer 2-wire media suitable for arbitrary topology and additionally providing power, at the cost of lower data rates. Such media is also feasible for an IP fieldbus.

2.2 BAU system operation using UPnP

For building automation, ease of device and network commissioning is very important, in order to keep the network manageable and reliable and keep maintenance efforts and costs on a reasonable level [5]. The used protocols should be standardized or widely- and vendor-independently used. Therefore we chose UPnP for configuration and operation. UPnP (Universal Plug & Play) [3] is a protocol for automatic device integration into IP networks. It covers addressing, device announcement and discovery, description, control, eventing, and presentation. The initial target of UPnP technology was, among others, home multimedia and office applications for PCs, but nowadays there are also templates defined for HVAC, and yet proprietary device types can be modelled in the basic device template.

Two terms are commonly used in UPnP: a UPnP Device (UDE) offers services on a device like “set state of lamp”, or “shut blinds”, or “send a notification if the door sensor signals an open door”, and it announces itself via broadcasts. A UPnP control point (UCP) is a user of these services. Also the control point is able to receive announcement broadcasts and notifications from UDEs.

A basic use case in BAU networks is for example “switch on light”. In SARBAU this operation is implemented as follows: The switch acts as UCP and the lamp is in the role of the UDE. It is assumed that the binding has taken place i.e. the light switch itself already knows the IP addresses or (local) DNS names of the lighting devices which it shall control. The action string syntax is known as it is a defined UPnP profile. Now when the light switch is pressed, it sends “set light state to 1” action strings to the lighting devices, and checks the response to see whether communication was successful. It may repeat the command transmission if there was no response from the light.

As it can be seen from the above description, there is no group access mechanism in UPnP besides the broadcasts or multicasts for announcing of the UPnP devices. Therefore transmissions to a group of devices is implemented by sequentially contacting the individual devices. If the number of lighting devices increases, communication of the switch with each target device may not be feasible for example because the switch is connected via slow or congested media. Then there would be a undesired long delay between the pressing of the switch and the reaction of the lamps. Therefore we use a dual mode approach. First, the switch signals the state change to a group access agent, which is on a server in the network. Under normal conditions, the lamps are then accessed by the agent. Several agents in different subnets may intelligently handle group accesses to minimize traffic. Only if the light switch can not connect to an agent, it directly accesses the lamps.

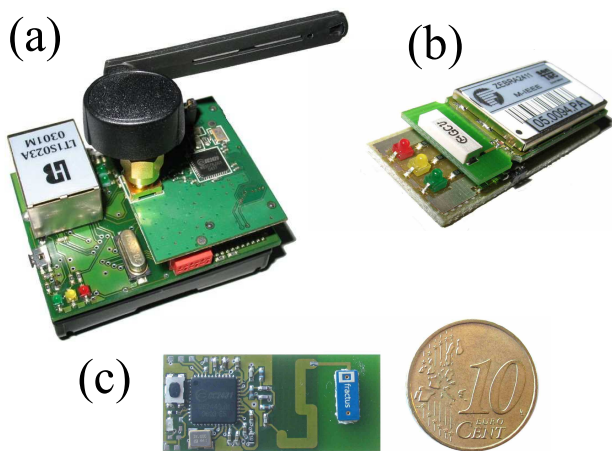


Figure 2. (a) IEEE802.15.4-Ethernet Gateway. (b) and (c): IEEE802.15.4 field devices designed for long-term battery operation

Such peer-to-peer access is mandatory in BAU networks, because link failure between different network segments may occasionally happen for example during construction work.

2.3 Device hardware

BAU fieldbus devices like room automation units, temperature sensors or fan controls are cost-sensitive units and are therefore usually based on 8 bit microcontrollers. In recent work we have implemented a TCP/IP stack on an 8 bit μC equipped with a standard ethernet controller chip. Using a device with 64 kB ROM and 4 kB RAM it is possible to have a basic stack and some high level services like an HTTP 1.0 server and a simple XML parser on the device [9]. Even when implementing a rudimentary UPnP stack there is some program memory left for a small sensor or control application. In the SARBAU project also wireless field bus devices are investigated. We chose IEEE802.15.4 as lower layer, and implemented an IP over 802.15.4 protocol [8], currently using a star topology where the field bus devices communicate with a dedicated 802.15.4-to-ethernet gateway. This gateway (Fig. 2a), also realized with an 8 bit μC , converts the IP frames to IEEE802.15.4 frames and routes them to the corresponding wireless device, and vice versa. Address translation between the ethernet MAC addresses and the IEEE802.15.4 MAC addresses is performed on the gateway.

Wireless connectivity is especially interesting for “push-only” devices, which do not normally listen to network requests but only operate when they want to signal an event. Typical candidates are for example light

switches, which are active only to transfer the switch event or temperature sensors, which are not queried but push their values periodically to a controller. This type of device can operate several years on a small battery. Since it operates wireless and on battery, it does not need any wiring which reduces installation costs. Our “WeBee3” [7] is an example of such a device (Fig. 2c).

3. Nearly automatic configuration

3.1. Commissioning and binding

Commissioning is the initial assignment of a logical name or high level address to the device, and the setting of parameters on the device. Such parameters may include information about connected sensors, actuators, parameters for HVAC systems, and others. Binding is the assignment of relationships from the given device to other devices. A common binding use case is the assigning of lighting controllers to a light switch.

Normally the commissioning and binding data is created beforehand as a database which contains the devices and the network structure. Since usually the physical devices are not yet available or installed at the time of the planning, and also for better readability, devices are identified by some high level addresses or symbolic names. Besides the name, typically also the mutually location where the device is or will be located in the building is known, for example in the form of a room number and some enumerating scheme within the room or cabinet.

It is an error prone and expensive process in commissioning and binding to relate the logic devices in the database with the physical devices in the building. A common approach is to first label the devices in the factory and record their physical ID, and then advise the field electricians to place each device at its foreseen location. A second approach is to walk through the building after all devices have been installed, and read the physical device addresses for example from a barcode which is attached to the device, and note the ID with the physical location. While the first approach relies on the accuracy of the personell on the construction site, the second approach is quite time consuming, especially if the devices are already covered by panels etc. (see Fig. 3). Using existing BAU field bus systems, the situation is somewhat relaxed because the addressing hierarchy is given by the network topology and therefore some initial relationship between addresses and location can be assumed. This does not hold true for an IP based field bus system, where MAC and IP addresses are arbitrary.

In our system the virgin devices, when initially powered up, get a unique IP address via DHCP and announce themselves at a dedicated commissioning server. This

server may already have the commissioning data, but since there exists no mapping between the device ID (MAC/IP) and the high level device name in the database, the device can not be configured at that moment.

3.2. Intelligent configuration support

The initial mapping procedure may use the same methods as described above for existing BAU networks. On the building site, a mobile commissioning tool is used consisting of a notebook or PDA which communicates with the commissioning server. The field engineer enters his current position, i.e. room number or floor number, and the tool shows a list of logical devices for that area. Field devices with a physical “user interface”, for example a light switch, will send a message to the commissioning server when touched in unconfigured state. The commissioning tool is notified of this event and allows manual assignment of the physical device to a logical device via its GUI. Devices which have no push button or are not accessible may still have to be identified manually by reading IDs or other means.

Using the tool, the engineer can immediately verify the identification by commanding an action to the field device like “switch on and off light”. The binding is performed automatically as far as the relations are available in the commissioning database. If some relations have not been defined yet, they can be configured and tested with the tool. Such Commissioning tools are available for example for LON or EIB/KNX.

In our more sophisticated approach the tool already presents binding suggestions. This is possible because some bindings are obvious, for example a light switch will typically be connected to a lighting controller in the corresponding room. By intelligent consistency analysis of the commissioning and binding database, undefined bindings can be identified before going in the building. While it would be of course wiser to fix such inconsistencies beforehand, it is comfortable to have the ability to change a given database or insert new devices with the commissioning tool. Intelligent configuration schemes are also suggested for home automation [12].

3.3. Employing device position information

If the physical devices could detect their physical location (see Fig. 3), mapping of the physical IDs to the logical IDs could be performed fully automatically provided that the positions of the logical devices are present in the commissioning database. This may be described as “spatial name solving”. If not using simple proximity information [4], such a position detection system is too complex to be employed on each device.

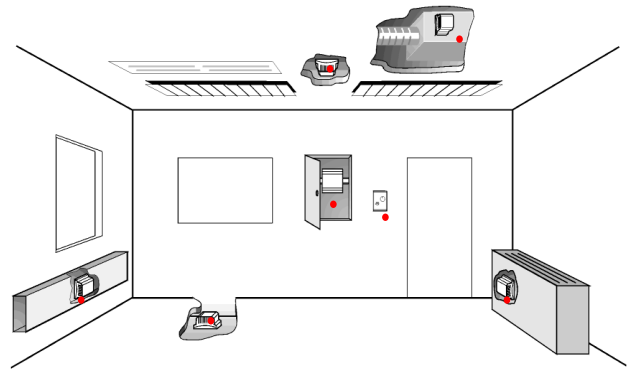


Figure 3. Room scenario. Device positions are marked with red dot.

The situation changes when the devices are located with the commissioning tool, which may be equipped with such a system. The devices itself do need a mechanism to “announce” their location. Current approaches under investigation are precise positioning via RF propagation time trilateration of devices which are equipped with a IEEE802.15.4 transceiver [10], coarse signal strength (RSSI) localisation of such IEEE802.15.4 equipped devices, devices equipped with long-range RFID tags and devices which can emit sound chirps for localisation.

We will outline the RSSI approach in more detail: It is assumed that the field devices are equipped with an IEEE802.15.4 wireless transceiver. The devices, when in uncommissioned state or when advised by the commissioning server, listen for radio beacons transmitted by the commissioning tool and provide some radio response including their IP address. The commissioning tool can thereby identify the devices in its vicinity and present them to the field engineer via the GUI. Since at a given location this will be only a limited amount of devices, the engineer can quickly identify the devices by methods described above (visual identification, toggling state via the tool or pushing buttons) and manually finish the relationship between physical and logic devices.

4. Current research progress and outlook

We suggest and investigate a building automation and control network which uses IP already on the fieldbus and uses UPnP as high level device operation protocol. We have already created suitable IP based fieldbus device prototypes using ethernet and wireless IEEE802.15.4 as physical layer. On these devices, we have implemented the needed TCP/IP and HTTP/SOAP/UPnP functionality. UPnP does not offer group addressing mechanisms. We implement a group access agent structure for proxy-based

group addressing, keeping peer-to-peer operation as fall-back. Currently the performance of the system is evaluated to identify and resolve eventual bottlenecks and drawbacks of the architecture and setup.

We are currently developing intelligent commissioning and binding support which significantly reduces manually effort in system bring-up and modification. This is particularly necessary since the IP approach does not provide intrinsic relation between physical addresses and spatial network topology. Automatic device position estimation or detection enables highly simplified and automated commissioning and binding. Security and authentication are not yet addressed in the presented IP BAU network scheme.

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