EUROPEAN CONFERENCE AND COOPERATION EXCHANGE 2006

SUSTAINABLE ENERGY SYSTEMS FOR BUILDINGS: CHALLENGES AND CHANCES

WIRTSCHAFTSKAMMER ÖSTERREICH
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NOVEMBER 15TH - 17TH, 2006

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THURSDAY, NOVEMBER 16TH

MORNING SESSION: ENERGY EFFICIENT BUILDINGS

9.00-10.00 **Reality Check: the example STRABAG building, Vienna**
Design, technical features, experiences from implementation
and monitoring results
Miklos Nicolics, Building Construction International, STRABAG AG (Austria)

10.00-10.45 **Sustainable office buildings**
Concepts, analyses, experiences
Karsten Voss, Bauphysik und technische Gebäudeausrüstung, Bergische Universität
Wuppertal (Germany)

10.45-11.00 Coffee break

11.00-11.45 **Low-energy retrofitting of a nursing home**
for elderly people in Stuttgart
Implemented energy concept and validation measurement results
Johann Reiß, Fraunhofer Institute for Building Physics (Germany)

11.45-12.30 **Current situation and future potential of intelligent building automation**
Peter Palensky, Institute of Computer Technology,
Vienna University of Technology (Austria)

12:30-12:45 **Biomimetic buildings: what nature can teach us to improve**
environmental sustainability
Richard Bonser, Centre for Biomimetics, School of Construction Management and
Engineering, University of Reading (United Kingdom)

12.45-14.00 Lunch

AFTERNOON SESSION: COOPERATION EXCHANGE EVENT

14.00-19.00 Cooperation exchange event

20:00-22:00 **HEURIGER**

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COOPERATION EXCHANGE 2006
SUSTAINABLE ENERGY SYSTEMS FOR BUILDINGS: CHALLANGES AND CHANCES
PAPER

Current situation and future potential of intelligent building automation

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Introduction

Building automation is not new. Depending on the technological level, man has always tried to ease daily life and to make the living environment safe and comfortable. Generally speaking, it is the goal to run things optimized. Applied to modern, contemporary buildings and homes, this means to optimize

- Energy consumption
- Logistics (maintenance, facility management, etc.)
- Safety (protection against weather, dangerous animals, natural disasters, etc.)
- Security (protection against humans), and
- Comfort.

These needs are not a phenomenon of present times. Being efficient with precious energy resources was also an issue in the mid-ages and being safe from storms and secure from other tribes was quite a concern for stone age people. To optimize the above values, mankind specialized in a number of disciplines.

The one with probably the longest tradition on satisfying the needs of home owners is architecture and civil engineering. Architects and civil engineers design and build houses that have

- thermal insulation,
- burglar protection,
- windows to the south,
- stilts against floods,
- etc.

By means of construction and design, many of the above needs can be fulfilled. What actually happens is, that the architect modifies the processes that happen with and in the building. By using certain construction materials and a special window arrangement, the "thermal process" of the building is massively modified. Instead of having outside temperatures, the building can for instance store heat, collected during the day, or offer cooling, collected during the night. The underlying physical mechanisms do not necessarily need to be known: thousands of years of experience have taught us how to build a house in Norway or in Botswana. New materials like concrete, glass or plastic permanently spin the wheel of innovation, so that modern buildings are typically safer, more efficient, more secure and offer more comfort than old ones.

A second discipline of optimizing the processes of a building is building service providers. Janitors, butlers or security staff that take over certain jobs are also interfering with building processes. In contrast to the static influence of the first discipline, service staff is playing an active, intelligent role. They reason about what they are doing, are flexible and can adapt to changing environments and requirements. In highly developed countries, however, services are getting more and more expensive, as manpower get more and more expensive. The same mechanism that is the force behind industrial automation lead to the third discipline of optimizing building processes: automation. Labour is simply too expensive, compared to machines that do not go on vacation, do not demand higher wages or get ill.

Building automation has its roots in the industrial revolution and in industrial automation. Manufacturing processes were eventually automated by means of conveyor belts, manipulators (early robots) and other (semi)-automatic machines. With the advent of control networks and embedded systems, a revolution was started: Networked, microcomputer-based automatic machines can be controlled remotely, can be reconfigured or even reprogrammed, and can deliver important information about the manipulated process itself fast and reliably (SCADA, supervisory control and data acquisition). This key to industrial success was adopted by building automation. Virtually the same hard- and software is now applied to automated buildings and homes.
Initially called "Building Control" or "Direct Digital Control" (DDC), the idea was use control rooms with people sitting in front of a "master display", being in total control of the building. This centralized approach is long gone, modern buildings have a decentralized automation topology, both in terms of the technology as well as its usage. A network of embedded fieldbus nodes is the so-called run-time part of a building automation network. Together with a sophisticated management system it allows for accessing virtually every process and every corner of a building. The basic goals, however, are still untouched, even if they are named differently or if they are expressed more explicitly nowadays.

Nowadays, building automation and control (BAC) is seen as part of building management (BM) or more precisely technical building management (TBM, see Figure 1)

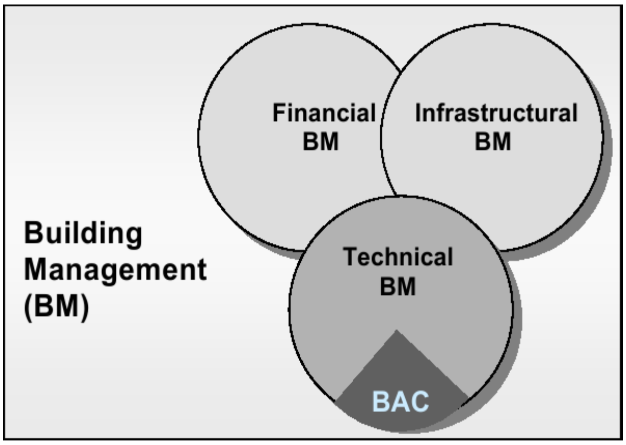

Figure 1: Building Automation and Control (BAC), [CEN/TS15379 2006]

Initially separated, BAC systems are more and more used by the other disciplines of BM. They are now used as a direct input for facility management or financial management.

Purpose of building automation networks

Building automation systems are, as already said in the introduction, used for optimizing the operation of a building. The dominant part of a building's life cycle is its usage. Running a building costs money and gives a service and building automation intends to reduce costs and to increase the value of the service. Let us pick the most popular reasons for applying an automation network in a building or a private home.

Saving energy costs

If there is one thing for sure on our planet, it is that fossil fuels are not growing. The result is constantly increasing costs for fossil fuels and derived energy types like electricity or heat. This and the increased sensibility for emissions lead to a higher awareness of energy usage. People are aware of the fact that energy does not simply come out of a power outlet, and the yearly energy bill becomes more and more noticeable.

This is especially true for industrial and commercial energy customers, which is why we find energy-optimizing technology mainly there.

Energy costs can be divided into [Firestone 2006]

- volumetric costs (EUR/kWh),
- demand costs (EUR/kW), and
- fixed costs (EUR/month).

Fixed costs do not change with the energy usage and typically consist of administrative and other costs. The other two parts, however, depend on the way how energy is consumed and are therefore subject to optimization strategies, supported by building automation networks.

Volumetric costs means energy consumption. Saving volumetric costs means saving energy. This can be achieved by a number of measures like

- changing the insulation,
- switching off the light when it is not needed, or
- running the air conditioning at its optimum.

The reason why this is not done everywhere is a lack of information. Building managers and owners simply do not know how bad their building is run: They have no comparison to similar buildings, they do not know if the light is on in the cellar during weekend, they do not know that the insulation is 30% worse than in the beginning, etc. This lack of information could be solved by a smart janitor that knows about air conditioning systems, about construction materials, about the internal business schedules and that checks the entire building from top floor down to the cellar seven days a week: just not possible.

Therefore a building automation network takes over the job of acquiring the necessary data. Large buildings have tens of thousands of sensors, and this numbers will further increase, if more and more optimization is wanted.

The acquisition of hundreds of thousands of "datapoints" leads to one of the dominant features of building automation networks: scalability. They are designed for large numbers of network nodes, unlike an office LAN (local area network) or a multimedia network like IEEE1394 (a. k. a. FireWire). A LAN was said to require one sysadmin per 10 nodes (e. g. workstations), this is not possible in a building with thousands of nodes. LANs got better network management tools in the last years, but building automation networks have these tools since the very beginning.

Having the necessary data online does not yet solve the problem of high volumetric energy costs. This data have to be interpreted, correlations between the customers processes (office hours, production schedules, etc.) and the consumption charts have to be discovered, benchmarking between the actual and similar building have to be done and long-term observation of the building before, during and after structural and other changes have to be done.

An example for a tool that covers all this is the JEVis system, described in [Palensky 2004]. An Oracle database is connected to a set of server programs that feed online and other data into it (Figure 2). The gateway to a local fieldbus (GW, left upper part in Figure 2) translates the fieldbus-specific protocol of the building automation network into Internet-able protocols. Another set of server programs process and analyse the data for later visualization. The customer logs in into a web-portal and can then browse through reports, charts and other ways of representing the "inner values" of his facility. A very powerful example of these charts is benchmarking. The CFO or the controlling department of a supermarket chain can easily compare his 200 branches by key values like kWh per month and customer or EUR energy costs per square meter. With such a tool it is easy to discover hidden cost factors and sub-optimal branches. If one supermarket is apparently performing bad, it is possible to "zoom" into the data in order to find out why. Depending on how many and which sensors are installed, one can determine if the air conditioning if too weak or if the freezers are too old.

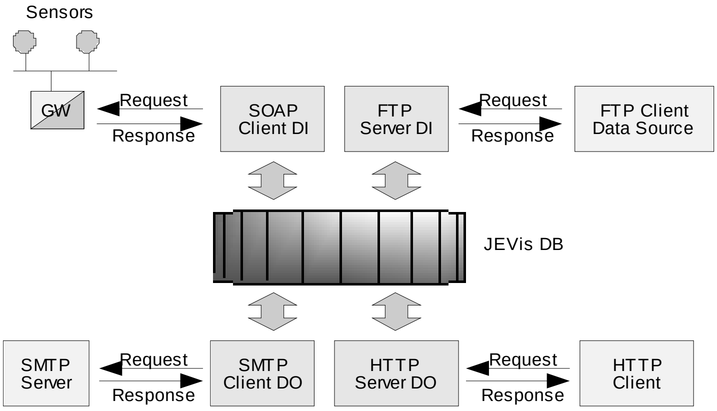

Figure 2: Typical Data Inputs (DIs) and Data Outputs (DO) of the JEVis database, [Palensky 2004]

By means of better and more detailed information of the things that happen in and with a building over time, it is possible to save volumetric energy costs. Thus building automation networks are not only used to control the blinds and the lighting but can also collect valuable measurement data.

Demand costs typically represent the available capacity of energy supply. Electric utilities can offer various capacities (i.e. potential peak supplies) to customers and charge them accordingly. Having for instance the capacity of 50 kW means that the customer may consume a power of 50 kW maximum, but might typically need a daily average of 10 kW. The possibility of this consumption peak is charged by the utility via the demand costs. The calculation of the demand costs can be much more complicated than the example above. A popular method in Germany is for instance to charge the three largest consumption peaks per year by means of a special "power price". An even more complicated tariff would be to take the load charts (typically consisting of 96 values per day, representing the average load within 15 minutes in kW) as a basis for the power bill. Deviations from a negotiated load chart (daily road map) for instance might then be used for calculating the costs.

Private customers in Europe are not charged demand costs. Only after exceeding certain consumption limits or patterns, the customer's energy costs is calculated with included demand costs. Small industries and workshops like bakeries or laundrettes can fall into this category. One solution for too high consumption peaks is a "maximum demand monitor", a device that measures the demand trend and switches off consumers when the trend exceeds certain values. Such a device can be more or less intelligent, but usually they are very primitive. A building automation network can significantly improve the performance and acceptance of such a maximum demand monitor. Instead of blindly switching off consumers, the devices can - via the network - announce when and how they "want" to be switched off. This means that the load shedding happens much more invisible, without interfering with the customers' processes. The necessary technical infrastructure is a control network that connects all relevant consumers with the maximum demand monitor. An existing building automation network is perfectly suitable for this.

A future potential for energy optimization is optimization within and amongst multiple, geographically dispersed buildings. Supposing a joint energy contract, where a collective load is charged, multiple buildings (of one owner or of one owner community) can cooperate in following a certain consumption pattern, agreed upon with the electric utility. This future system is currently under development within the IRON project [Kupzog 2006]. Beside clustering the consumption behavior of multiple buildings this systems is also supposed to enable flexible virtual power plants (VPPs).

Energy costs of buildings are gaining importance, no only because of the European Energy Performance of Buildings Directive (EPBD, [EPBD 2003]), but for the plain reason of increasing energy costs. Beside the traditional methods of construction and architecture, building automation offers a powerful tool to optimize buildings even more.

Optimized Logistics

Running a large commercial building is a complex task. Facility manager have to take care of changing the paper towels in the toilets, of repairing broken lighting, of closing all windows because of an imminent storm, and hundreds of other things. Due to the high labor costs, automation can help saving costs while increasing the reliability of there services. By means of a building automation network is is possible to detect for instance broken lamps and open windows, valuable informations for keeping the building running.

Increased comfort

Comfort can no be put into monetary figures easily, additionally, comfort is a very subjective experience. Some aspects of comfort are, however, well defined. The amount of light for working, air quality, noise or climate can be measured and kept within the required limits. Modern offices can even offer micro-climates, where each workplace has individual setpoints. This is impossible without the respective automation infrastructure.

Increased personal safety

Personal safety (or short safety) in buildings typically deals with fire alarms, smoke detectors, automatic doors, evacuation scenarios and other aspects of protecting human life (meanwhile safety also covers protection of animals and the environment). Networks for safety are special ones and need a certification by TÜV or other authorized and recognized authorities. Currently there is no TÜV-certified building automation network, which is why networks from industrial automation are used for safety-critical applications in buildings. To overcome the need for two network technologies in one building, the SafetyLon project extends the popular LonWorks building automation network with safety features, so that one and the same network infrastructure can be used for safe and unsafe applications [Preininger 2006]. It is expected that buildings with 10.000 nodes might have 100 safety-critical nodes, installing a separate network and having separate tools for these nodes would be an unnecessary cost factor.

Increased personal security

Motion- and presence-sensors, cameras, door-locks and identification systems are examples of parts of a security system. Having them networked massively increases their reliability and usability: The more sensors you have, the more reliable your application. Security applications however need a network technology that has IT-security incorporated. Unfortunately, compared to the office- and commercial IT-world, building automation networks have - like virtually all automation networks – if at all only limited IT-security features [Schwaiger 2003].

Features and limits of building automation networks

Compared to other network classes like telecommunication networks, multimedia networks and office networks, building automation networks typically have the following properties or requirements:

- Large number of possible nodes (up to 100.000)
- Segment lengths of maximum some 100 meters
- Data rates of some 10 kBit/s on end segments
- Tree topology of network segments
- Low node costs
- Wireline twisted pair channels
- Robust, non-realtime transmission

Such networks are not designed to transport real-time video streams or to cope with frequently changing topologies. They are installed and (re-)configured via a professional installation and network management tool. Plug-and-play features are typically not that much an issue as they are for home-entertainment networks. KNX (see later in "Standards and non-standards") is an exception here, as it offers – beside the normal tool-based commissioning method – and "easy" and "automatic" mode, where users can install nodes even without a network management tool.

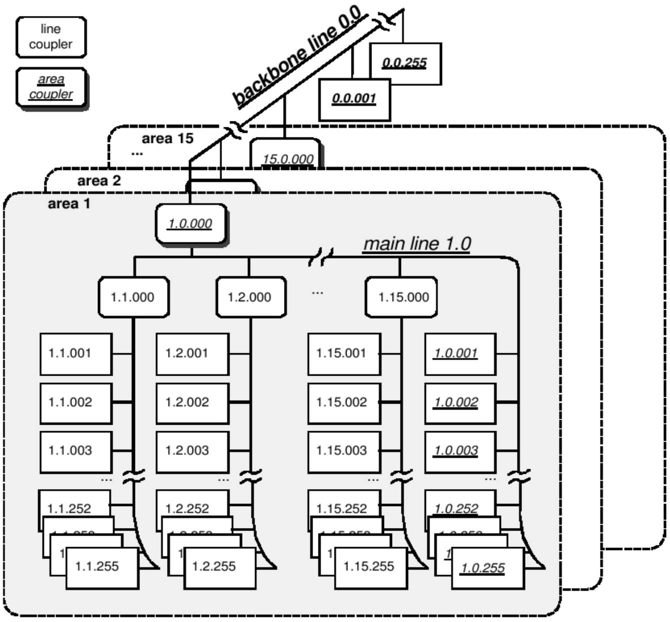

Figure 3: EIB/KNX as an example for tree topology, [EIBA 1999]

The tree topology (Figure 3) reflects the hierarchical structure of buildings. Rooms may have a few (or even just one) individual low-bandwidth segments, while between rooms and certainly between stories and entire buildings high-bandwidth "backbone" segments (nowadays almost every time Ethernet- or IP-based) are used. LonWorks (also see later) offers also a "free topology", where wiring can be done without caring for stubs and loops.

The typical message types that appear on building automation networks are

- measurement values (e.g. temperature, humidity, etc.),
- commands (e.g. switching commands), and
- status messages (e.g. door contacts).

Keeping the "intelligence in the field" is the general philosophy and means that a dimmer node does not get phase-cutting commands 50 times per second, but rather the command "dim to 70% within 2 seconds". The node itself is supposed to know how to operate its attached hardware. Therefore a temperature sensor does not deliver a 16-Bit value from its analogue-digital-converter, which then has to be decoded, calibrated, linearised, de-compounded, and converted in order to get a meaningful value but gives values in degrees Celsius with a defined encoding. For this, building networks have defined data types for physical quantities. Ideally the system propagates only changes in the system state and decisions are taken locally - a strategy that keeps network traffic low and increases the reliability of the system.

This distributed nature stands in contrast to "networked based control", where control information is sent via real-time networks. Network delay, jitter and latency is very critical for digital control loops, and therefore non-realtime networks are not used. In building automation networks, control commands

are generated locally "at the process". The controller sits directly at the process and simply gets its setpoint via the network: usually a non-time-critical action.
Switching commands on the other hand have some aspect of real-time requirements. A classical example is a light switch in a building. Generally it is said that 500 ms of maximum delay is accepted by the users, but existing products have way shorter delay times.

Standards and non-standards

As with all network technologies, building automation networks are available as open standards or proprietary products. In the beginning virtually every building automation network was proprietary, large technology providers were maintaining their product portfolio, binding their customers with their non-open solutions. Luckily the market and authorities did not honour this, which is why two developments happened:

- companies - forced by their customers - published their technologies as open standards
- consortia elaborated new, open standards

Both led to the same result. Technologies and specifications were (almost) freely available, and manufacturers can build and sell products based on these standards. Multi-vendor installations are now the normal case, but following a standard is usually not enough to make a product from vendor A interwork with a product of vendor B [Loy 2001].
The scope of the currently existing standards offers too many degrees of freedom in the implementation, which is why the user organizations of standardized building automation networks published "Interoperability" or "Interworking" guidelines. These guidelines limit the unnecessary freedom of the standards, leading to the wanted situation of true interoperability.

The various standardization committees (actually the respective technical committees within ISO, CEN, CENELEC and IEC) have published a number of standards for building automation networks:

- EN 14908, EIA 709 (LonWorks)
- EN 50090 (KNX)
- ISO 16484 (BACnet)
- IEC 60929, IEC 62386 (DALI)

Every technical comparison of these technologies is almost useless, since if applied professionally, there is not much difference between them. Only in extreme cases, the technical features might play a role. Table 1 is only given to get an impression of the features of these networks. Every expert will confirm that these 3 features are way to little information for selecting the right technology.

Name	*channel capacity*	*max. segment length*	*max. nodes*
LonWorks	78 kBit/s	2.700 m	32.385*2^48
KNX	9,6 kBit/s	700 m	57.600
BACnet	76 kBit/s	1.200 m	n/a
DALI	1,2 kBit/s	300 m	64

Table 1: Features of popular open standard building automation networks

The numbers in Table 1 are referring to the most popular channel types that are used "in the field" which is usually something similar to an RS-485 twisted pair channel with line topology. Since all networks can also be "tunneled" via the Internet protocol and Ethernet (or support it already natively), the figures for the channel capacity or the segment length should be read with caution. Additionally these networks also support fiber optics and other channels. A comparison is therefore not easy. Also, comparing DALI with full-fledged building automation networks is actually not correct, as it is not intended to play in this league. DALI complements and supports lighting installations and interfaces to building automation systems. The number of possible nodes in the case of LonWorks is ridiculously high, one LonWorks "Domain" can host 32385 nodes, while one LonWorks network can consists of many domains. Nobody will ever need that many nodes. Also all above network technologies allow for segment interconnection via repeaters, routers and bridges, so the maximum segment length is not much of a limit.

Although - because of the above reasons - a comparison or classification does not make much sense, it is (or was) widely accepted to distinguish the following application areas for the mentioned networks:

- LonWorks: medium and large buildings, all automation tasks
- KNX: homes and small buildings, lighting and blinds
- BACnet: medium and large buildings, management functions
- DALI: low-cost lighting interface, supports other building networks

Recently, all networks (except DALI) penetrated new markets and can now be found in previously "foreign grounds", therefore the above classification is more or less outdated. The choice of a certain technology is nowadays less one of missing and present features, but rather one of the available support, of product variety and the available tools.

The complexity of tomorrow

New applications and new technology are sometimes in a chicken-egg relation. If there would be a faster, cheaper, easier and smaller network technology, we would use it for new applications that can not be implemented today. There are promising ideas to use "Smart Dust", embedded into concrete and paint that measures structural integrity or temperatures. Such "Smart Dust" is an extreme version of an ad-hoc wireless sensor network, incredibly small and gaining its energy from the environment

(e. g. out of light or temperature gradients). In parts, this scenario is already possible, it is just a question of time until is is broadly available. So there is no doubt that technology will be faster, smaller and cheaper in future, but this leads to a problem, where we do not yet have a solution for.
Having a building with billions of small sensors, floors that "see" footprints, walls that "smell" the presence of persons and many other exotic sensors, together with traditional ones like cameras or infrared sensors would lead to a tremendous amount of data. Interpreting this flood of information is impossible for traditional building management systems. Nevertheless a higher number of redundant and diversified sensors will be necessary to get a higher quality of services. Detecting a potentially dangerous suitcase in an airport needs more than cameras. Many different measurement values must be combined in order to get a reliable information. Interpreting this information is the next problem. How does a machine distinguish between an "evil" and a "good" suitcase? How does a building distinguish between a sleeping person and one that has a heart attack? Things that are so easy for humans seem to be impossible for machines. This is why public security always involves people sitting in front of the screens of some surveillance cameras: a task that seems to be impossible for a machine.

This explains the strategy of the ARS project [Pratl 2005] with its ambitious goal to re-implement (parts of) the human mind. With the support of an international team of neurologists, psychologists and psychoanalysts, a group of engineers is designing a system that (very simplified)

- perceives sensor data of the environment and itself,
- compresses and remembers perceptions,
- classifies situations with emotions,
- has drives and goals,
- recognizes scenarios, and
- takes actions based on knowledge.

The evolutionary successful "features" of the human mind are believed to be of great advantage when it comes to evaluating and classifying complex scenarios. The goal of this project is to build building automation systems that reason about things that happen and support the people living or working in the particular building. The two main applications are currently

- support of independent living for the elderly and
- security of public buildings like airports or football stadiums.

Both are dynamic environments with complex rules and represent tough test cases for the ARS system. The two applications are again traditional services – comfort and security – optimize by technology. The difference is that the level of optimization is beyond the possibilities of today's technology.

In short, the ARS system consists of two main layers. A "lower" layer condenses and classifies perceived data into "symbols" of increasing information and decreasing number. Early symbols in this

layer may still be associated with their originating sensors ("grounded") while higher symbols are already abstract concepts of the world representation. An example would be a symbol for the room temperature and a symbol for the postman.
The second, the "higher" layer of the ARS system implements the model of the human mind, as modern psychoanalysis defines it. Various types of memories, classification and evaluation entities, desires, drives, emotions and strategies form a complex apparatus that takes and reasons about the higher symbols delivered by the lower, the perception layer.

Conclusion

Building automation is a mature technology, reliable and flexible. Having such a system can greatly increase the value of a building, as it is potentially more safe, more energy efficient and more comfortable. Building automation networks can already have large number of nodes, in future we expect even larger ones. Traditional software is not capable of keeping a reasonable "overview" of the expected measurement data, new concepts, psychologically and bionically inspired ones, are necessary.

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