Chapter 93
Innovative System and Method for Monitoring Energy Efficiency in Buildings

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Abstract Improving energy efficiency (EE) in buildings may significantly reduce the environmental impact of buildings as well as may result in a financial cost saving to consumers. With this contest, ENEA has developed an innovative intelligent sensing system, @*lisee,* for achieving energy efficiency in buildings (households, officies, campus, data centers, etc.) by a real time, distributed and continued monitoring of not only energy usage by all electrical devices but also safety and operative conditions of the several building settings, making the users aware and enabling user-controlled policies for electrical appliances. The proposed system consists in an multi-level architecture of intelligent wireless multi-sensor network realized by ZigBee-compliant and mesh based topology and sensor nodes for measuring power usage of any electric devices, locally estimating indoor air quality, controlling housing comfort and evaluating EE performance in data center. The gathered data are mining by sensor fusion techniques and modeling for building global power consumption profiles and 3D images of the sensed environment.

Introduction

With serious concerns regarding global warning on the rise, civic and corporate efforts to improve energy conservation have steadily increased. Energy efficiency and renewable energy are widely recognized as the "twin pillars" of a sustainable energy policy. They have proved to be effective strategies in order to stabilize and reduce carbon dioxide emissions. Efficient energy use is essential to slowing the

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energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use.

Extensive statistics on buildings, industrial processes and energy needs have brought to light the significant impact of buildings on the global energy demand. Commercial and residential buildings, the basis of our social and economic infrastructure, are the major consumers. In Europe, they are responsible for 41 % of the total energy (70 % of the electricity, 50 % of natural gas) against 26 % of industry and 33 % of transportation. Most of electricity demand of buildings is spent for keeping comfortable the indoor climate and improving indoor air quality. Establishing an ideal indoor air quality is important as people typically spend more than 90 % of their time in indoors, and the indoor environment can affect their health and productivity. A temperature and airflow active control over the HVAC (Heating, Ventilation Air Conditioning) systems can increase the buildings' thermal quality and together optimize electricity consumptions.

Increased energy efficiency has proved to be a cost-effective strategy for boosting energy savings in buildings. This strategy brings together a vast array of practices (e.g. PUE measurement in data centers, better energy usage awareness, indoor air quality monitoring, etc.), technologies/techniques (e.g. solar and photovoltaic technologies for sunlight use; natural building material; advanced modeling, analysis and sensing technologies for HVAC systems fault detection and, more generally, for power usage monitoring; etc.) and skills.

Scientifics and stakeholders agree that the highest-impact solutions to boost energy savings in buildings are those that allow to individuals to monitor, control the electricity demand of the appliances in the households or offices as well as of computing hardware and related infrastructures in data centers (DC*s*). These solutions have proved to save up to 10 % of the energy used in buildings, making the users more aware and enabling user-controlled policies for electrical appliances as well as timely fault detection and management actions for HVAC systems [1]. Consequently, improving energy efficiency in buildings becomes a challenging application scenario for the sensing technologies and more specifically for wireless sensor networks (WSNs).

This research work presents an innovative intelligent sensing system, *@lisee*, designed and developed by ENEA, for achieving energy efficiency in buildings (households, officies, campus, data centers, etc.) by monitoring power usage of electrical devices, indoor air quality, housing comfort and DC environmental conditions, making the user more aware of energy consumptions and enabling active control policies for electrical devices, aimed to optimize power usage.

System Architecture

Sensing systems, currently available for improving energy efficiency in buildings, essentially realize *measure and management* approaches by using sensor modules equipped with energy meters (power adapter and clamp based devices) often

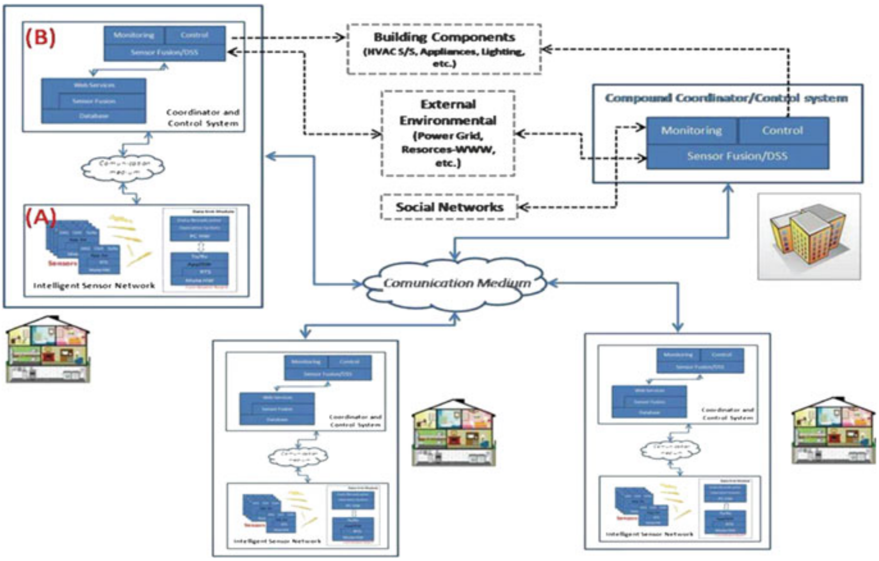

Fig. 93.1 @*lisee* software architecture for complex application scenarios (Campus, Residential settings, Commercial centres, etc.)

coupled with temperature and humidity sensors. Generally, the employed energy meters have to be directly connected to the main power panel of the building setting, monitoring the total electricity consumption of all electrical devices used in the building. Moreover, they are designed and developed ad-hoc for specific application domains (such as Smart Building, SO/HO, Data Center).

Beyond the state of the art, an innovative intelligent sensing system (Fig. 93.1) for energy efficiency in buildings (households, offices, campus, data centers, etc.) has been designed and developed by ENEA, based on an advanced energy consumptions monitoring approach. More specifically, the proposed system allows a real time, pervasive, distributed and continued monitoring of not only energy usage by all electrical devices in a building but also safety and operative conditions of the several building settings, and, on the basis of the gathered data, to control actively all electrical devices in use in the building, consequently reducing the energy consumptions.

The developed system consists in a multi-level architecture of wireless intelligent multi-sensor network realized by ZigBee-compliant and mesh (multi-hop) based topology. The main base units (Fig. 93.2) of the network are: (1) a power adapter and a clamp based smart energy meters for measuring power usage of any type of electric devices from the racks in DC*s* to the washers in the households; (2) electronic-noses equipped with local VOC (Volatile Organic Compound) discrimination and quantification capabilities by means of pattern recognition algorithms. Their cooperation allows to build 3D chemicals concentration images of the sensed environment by using advanced sensor fusion techniques [2]; (3) a multi-sensor node made up by an energy meter and two temperature and humidity sensors

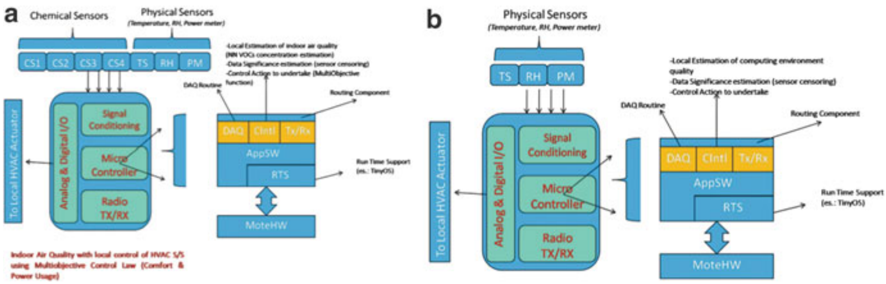

Fig. 93.2 Block diagram of intelligent multi-sensor nodes (**a**) for IAQ monitoring (**b**) for evaluating DC*s* energy eficiency performance

for specifically evaluating energy efficiency indices in data centers; (4) motion sensors that detect the motion of people in the sensed environment.

System multi-sensor nodes are equipped with on-board intelligence, namely local gathered chemical/physics variables discrimination and quantification and data selection capabilities. They realize the first level of computational intelligence of the proposed system.

The data gathered and pre-processed by system sensor nodes are sent via wireless connection to a *coordination and control system* (CCS), which collects, coordinates and processes these data and acts as gateway to the internet. In particular, the gathered data, stored in a database, are mining for building the global state such as global power consumption profiles of the electrical devices, 3D chemicals concentration images, operative state of the sensed environment, by using advanced sensor fusion techniques and modelling.

On the basis of the real time and aggregated data provided by the proposed WSN, active control strategies for the electrical devices and more generally best practise for reducing energy consumptions as well as timely HVAC fault detection and management actions may be performed and applied.

Ad-hoc web based GUIs, running on PC, smart phone or tables, provide users with relevant information about real time and aggregated energy consumptions in the selected application that may be also shared on social network platforms.

The CCS functionalities realize the second level of computational intelligence of the proposed system.

Conclusions

The multi-sensor nodes equipped with on-board intelligence, the mesh topology and the multi-level sensor fusion provide the proposed system with innovative elements, self-healing and self-configuring capabilities, and scalability to several monitoring scenarios (Smart Building, SO/HO, Data Center).

References

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