1 SMART PUBLIC BUILDING – CHALLENGES AND FIRST FINDINGS

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ABSTRACT:
Recent years have seen a rapid increase in the use of innovative smart home technologies, gaining more and more user acceptance. Besides being used in private homes, these smart technologies may also complement classical building automation in public and commercial buildings. The project Smart Public Building (SPB) at the University of Applied Sciences Stuttgart addresses the needs of public institutions for the utilization of smart home technologies. It will develop and prototypically implement new concepts and applications based on openHAB, an established open source platform for smart home automation. The following paper outlines the overarching goal of the project, addresses its scientific and technical objectives and further presents first findings. Special attention will be paid to concepts that have already been created in subprojects affiliated to SPB. Finally, a conclusion of the course of the project is drawn and an outlook given.

1.1 Introduction

1.1.1 Current State

According to Statista, sales in the smart home market in Germany amount to approximately EUR 697.3 million in 2020 and will reach a market volume of EUR 2,457.1 million and a penetration rate of 6.23% in 2020 (Statista, 2016). However, the illustrated smart home market only includes sale of networked home automation devices and related services (e.g. software usage, monitoring services) to private end users. Public buildings and an assessment of the potentials of smart home technologies for corresponding smart public buildings are not subject of this study.

The smart home incorporates control, monitoring and control devices that are connected to the Internet via a central control unit or directly to control the Internet of Things. Investments in technology have been made in the private sector by enthusiasts so far. Smart home components that enhance home comfort are currently often luxury goods for a niche market (Viani et al., 2013). Economic considerations step into the background.

So far the German smart home market is very fragmented. Whether individual technologies and providers will prevail and which these are remains to be seen. A current commitment to one or the other provider could therefore turn out to be a bad investment in the short term. Furthermore, the different product lifecycles of buildings and ubiquitous technologies pose a challenge. Current technologies can become obsolete in five years, while buildings – especially in the public sector – often have life cycles of 50 years or more. One requirement for more planning security in dealing with obsolescence is manufacturer independence with regard to technologies and services in the smart home (Stengel, 2015). Open source-based approaches offer a possible solution (Hsien-Tang, 2013).

1.1.2 Motivation

With sensor and control technology in smart homes, energy consumption can be reduced, the comfort of use increased and the building's value increased. In recent years, developments in the field of smart homes have

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been detached from classical building automation. Instead of a structured but complex, mostly cabled automation technology in the private sector, wireless "single-purpose" solutions have prevailed, achieving high growth rates through simple installation, app control and use of the Internet of Things.

While private homes benefit from the dynamic development of new sensors, actuators, interfaces and applications, their use in commercial and public buildings has fallen short of expectations. Contributing to this are complex installations, a difficult-to-evaluate cost-effectiveness, heterogeneity of solutions and top-down planning without involvement of users.

In order to reduce energy consumption and CO2 emissions of commercial and public buildings while increasing their utilization and comfort, it is necessary to develop new approaches for the use of smart technologies. In doing so, specific challenges of larger institutions such as availability, interoperability, administration and maintainability must be mastered.

1.1.3 Project Goals

As part of the Smart Public Building project, corresponding requirements are being identified and examined. Furthermore, new applications for smart home components in public buildings are going to be developed where the University of Applied Sciences serves as example in a bottom-up approach – involving relevant user groups as well as developer communities in the field of smart buildings. The prototypical installation within the college also creates a showcase for other colleges and public institutions to apply and develop the tested scenarios further. For the server and client infrastructure an open source approach based on openHAB is chosen. openHAB is a Java and Eclipse-based application for integrating and controlling heterogeneous smart home components. This ensures that the project benefits from the work of an already existing global developer network and on the other hand contributes to this community with its own developments, as well.

This report presents first results and concepts for the use of smart home components in public buildings.

1.1.4 Scientific and Technical Objectives

The scientific questions to be answered in the course of the project are as follows:

1. What are the special **requirements** of smart public buildings for the use of smart technologies? First, a classification (e.g. museums, schools, offices) of public buildings is made, and an application matrix is created, which will be extended by user participation throughout the project.
2. Which smart home **technologies** are suitable for smart public buildings? The degree of eligibility is determined using a triple bottom line (environmental, social and economic aspects).
3. What special **opportunities** do public buildings offer in the use of smart technologies? On the one hand, this concerns integration and networking of other (partially) public infrastructures, such as e-charging stations, car and bike sharing and parking lots. Secondly, the role of public buildings as part of the smart technology participation and dissemination process will be explored.
4. What **impact** do smart technologies in public buildings have on privacy and how can proactive protection of privacy be ensured?

The project's technical work objectives are implemented prototypically at the University of Applied Sciences. Developed components should be made accessible to other public institutions online. In detail, the following goals should be achieved:

1. Provision of a basic software and development environment based on openHAB and Eclipse SmartHome.
2. Assembly of a room sensor based on established processor boards (for example Arduino, Raspberry Pi).
3. Development of specific example applications for smart public buildings.

1.1.5 State of Research

Home and building automation are similar in function, but increasingly different in the technologies used. According to VDI 3813 Part 2, typical sensor functions of building automation include monitoring of presence, window status, dew point, air temperature, brightness, air quality, wind speed and precipitation. Controlled by actuators are light, sunblind and drives (e.g. for fans). However, the technologies and protocols used differ greatly between home and building automation. So far, approaches to harmonize the communication of heterogeneous components by standardized network protocols (e.g. BACnet – building automation and control networks, see DIN EN ISO 16484) turn out rather as entry barrier for innovative young enterprises in the field because of their complexity. As a consequence, only few smart home components available on the market support BACnet, LonWorks, EIB/KNX or OPC UA. Though these systems can provide Internet connection, they work largely independently from the Internet (Stengel, 2015). The smart home, on the other hand, builds upon wireless sensor networks (e.g. ZigBee, Z-Wave, Bluetooth LE), Internet-based standards (e.g. IPv6, 6LoWPAN), apps and lightweight interfaces (e.g. RESTful). In addition, classic building automation requires precise, long-term planning as well as cabling that is usually expensive and therefore reasonable for new buildings, whereas the development of the smart home is modular and based on wireless technologies, showing promise also for the equipment of existing facilities.

Energy management in buildings can make a substantial contribution to reducing energy consumption and CO2 emissions. According to Directive 2010/31/EU, buildings account for around 40% of energy consumption in the EU. The EU project Bricker is dedicated to energy reduction in public buildings through new heating and cooling technologies. However, there are also potential savings when using existing systems. For example, heating can be regulated down and light can be switched off in unused rooms – to predict the use of a building an adaptive control based on intelligent methods is necessary. But requirements for energy management in buildings go beyond heating regulation and lighting control. In cases where selective measurements aren’t sufficient, smart metering enables a time- and cost-oriented control of electric consumers to determine potential savings. Seattle’s Smart Building Center offers public and commercial building operators the option of borrowing a range of sensors and gauges. Furthermore, the integration of photovoltaic systems as well as of energy storage devices and consumers has become more important in recent years. Electric vehicles with their batteries are ideal for integration into the smart energy management of buildings (Paetz et al., 2010). In this context, a cooperation with the parallel i_City project on e-Bike sharing and the Hofdienergarage in Stuttgart, a car park with charging stations, is planned.

In addition, the needs of individual stakeholders (facility managers, space users, external partners) must be taken into account and the best compromise between comfort, economy and environmental compatibility must be achieved (Kim 2014, Carreira et al. 2014). For this purpose, it is necessary to gain information about usage behavior (e.g. room occupancy) and to involve users participatively (Yu et al., 2013). Comfort can be determined via user feedback by means of an app. The assessment of the perceived temperature in lecture rooms via students as social sensors, for example, can then be incorporated into the controller. By evaluating the actual use of space, spatial planning can be improved.

One particular interest in public buildings is data protection. Public entities are not only bound by relevant laws, but also play a pioneering role in public perception. A distinction should be made between conscious and unconscious (ab)use of data. Functional benefits and data protection issues therefore have to be considered equally from the outset, including systems for backup and control. On the other hand, recommendations of public authorities often appear to be outdated. For example, the State Criminal Police Office NRW (LKA North Rhine-Westphalia, 2014) advises to only connect devices to the Internet if necessary, e.g. for updates. However, in the Internet of Things era other measures are required.

1.2 Current Research Status

1.2.1 Classification of Public Buildings and Questionnaires

People stay up to 90% of their time in private or public spaces and buildings (Böwing, 2015), and visitors of public facilities tend to request comfort in such buildings just as in their private homes. The integration of smart home applications into public buildings may facilitate not only comfort, but also aspects of sustainability, such as the conservation of resources. These applications make it possible to detect and rectify faults faster, to respond to external influences immediately and to control the entire building technology automatically and on demand. Users and operators might therefore benefit from an increased comfort, assistance in daily routines and cost advantages. A study by *trend: research* entitled “Smart Building, Intelligent Commercial and Industrial Building Automation in Germany by 2025” amounts the demand for intelligent building systems in the industrial and public building sector to 32% (Smart Home Magazin, 2016). This number indicates a huge interest as well as a need for action to integrate and explore the possibilities of smart technologies in this area.

The aim of the undertaken classification and survey was to clarify which existing applications in the smart home sector could be used in public buildings, whether and to what extent smart applications in public buildings are already being used and what new requirements must be met during installation. Technical managers of 50 public buildings of the city of Stuttgart were interviewed. The result shows that smart applications in public buildings are not yet widely used.

Beforehand, the public buildings were classified in order to differentiate between building types reasonably.

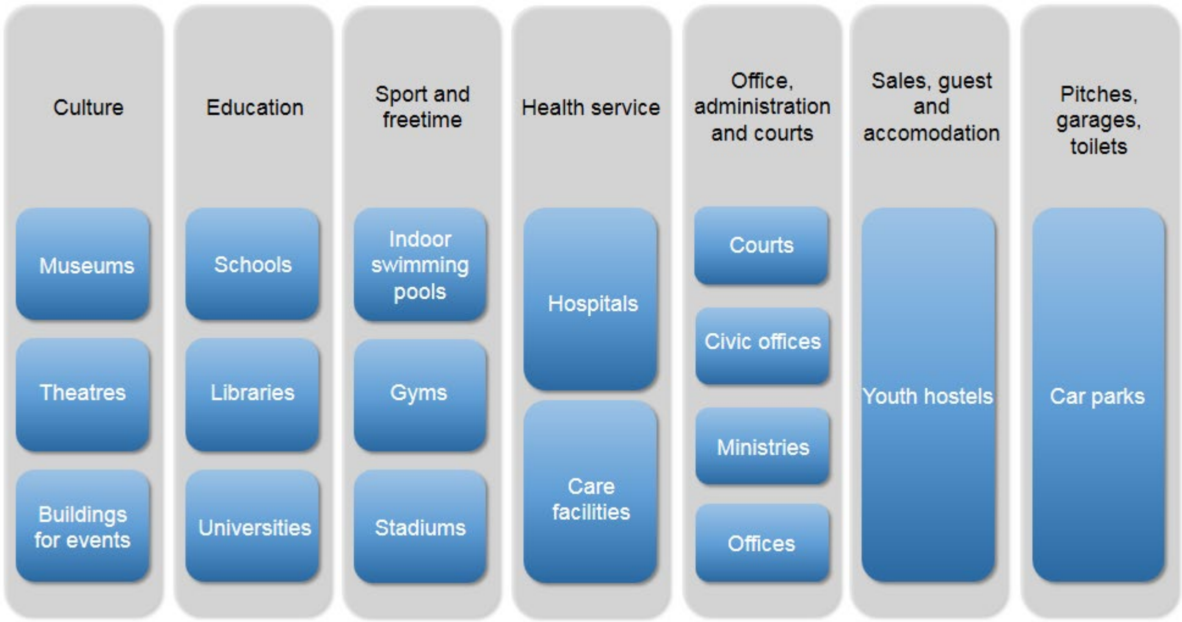


Figure 1. Building classes of public buildings

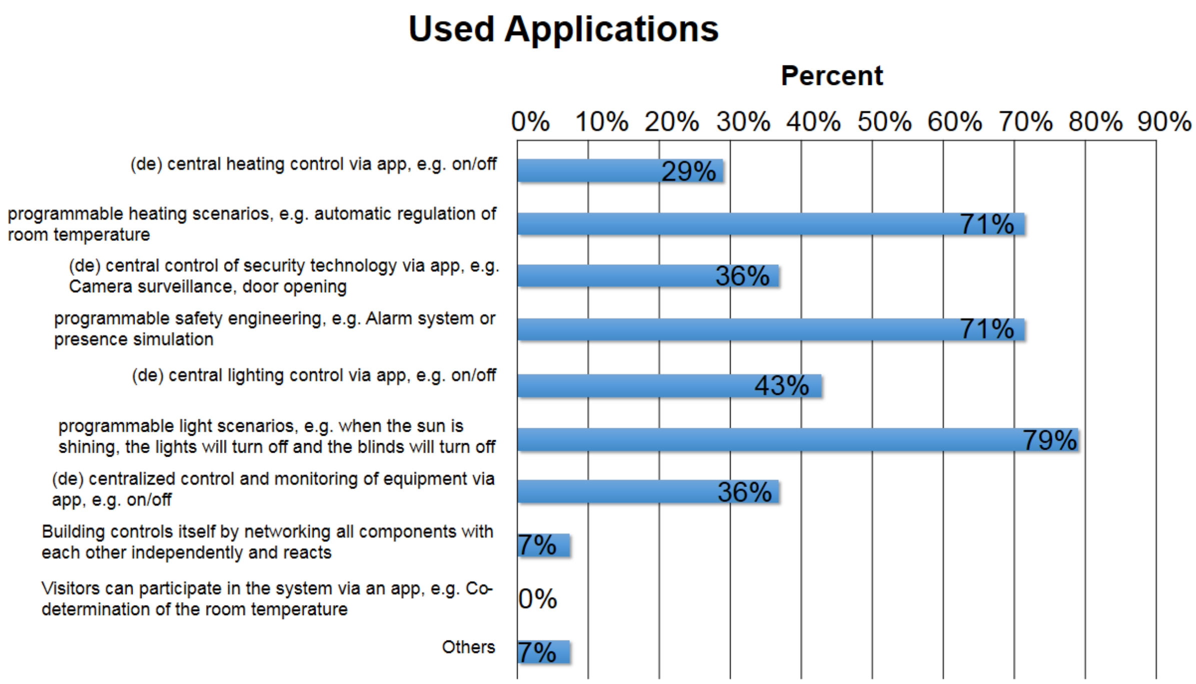


Figure 2. Applications used in public buildings (n = 14)

Current use of smart technologies in public buildings is limited to applications of classical building automation. Data transfer is largely wired and remote control via Internet is not quite an option. Many smart homes are one step ahead. Besides that, the use of smart applications is regarded critically by most respondents.

1.2.2 Implementation of Location-based Services with Bluetooth Beacons

Location-based services (LBS) provide information to users of mobile devices depending on their current location. The most popular application of LBS is navigation via the Global Positioning System. Location-based services are subdivided into reactive and proactive services (Markgraf, 2018). Reactive services must be requested by the user, e.g. search queries in the immediate vicinity. Proactive services, such as retail coupons, will be automatically made available when the user enters a certain zone. To determine the user's location, various technologies can be used. Within buildings an alternative to GPS has to be considered, as building materials such as concrete interfere with the GPS signal.

One of the technologies that can be applied both inside and outside the building is localization via Bluetooth beacons. Beacons are small hardware transmitters that communicate with mobile devices via Bluetooth Low Energy (BLE). For this communication to take place, it is necessary to have a corresponding application installed on the mobile device that can interpret the beacon's signal and perform appropriate actions.

Within SPB, the aim is to simplify orientation in public buildings with the help of Bluetooth beacons. Visitors should therefore find their way around faster and get relevant information displayed directly on their mobile devices. At the HFT campus, Bluetooth beacons were temporarily installed in lecture halls and hallways as a proof-of-concept. Via indoor navigation, visitors should be able to access maps with a marked route and a search function via their smartphone.

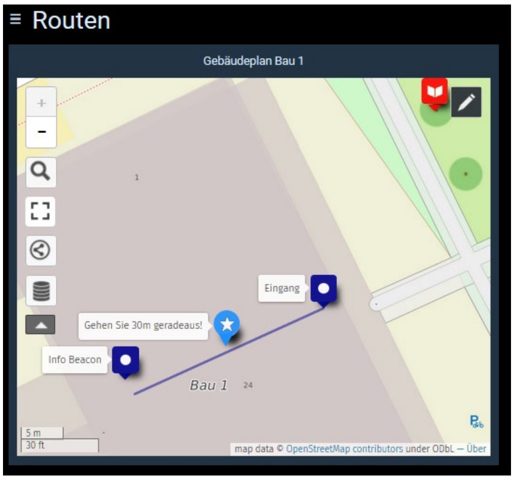


Figure 3. Indoor navigation via BLE

In addition, visitors of a room should receive selective access to data of that room, e.g. occupancy, sensor data (temperature, humidity, CO_2) as well as information about the respective event. Bluetooth beacons can therefore be installed in front of lecture halls, and visitors then get the relevant information on their smartphones using openHAB (see Figure 4).

Furthermore, a help function should be offered to present the building's layout and provide information on behavior in emergency situations.

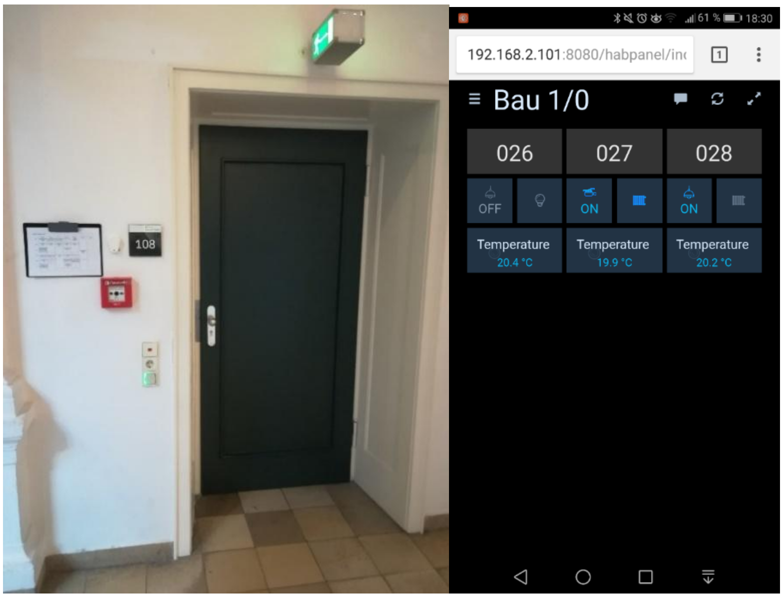


Figure 4. Display of room information in openHAB

1.2.3 Use of Social Sensors

Usually, the control of conditions in public buildings is determined by different sensors. The regulation of the room temperature, for example, is coupled with measurements of temperature sensors. Here, attention is often paid only to the prevailing, absolute room temperature. According to this temperature, the heating adapts itself. In other cases, the room temperature is controlled by a central unit of building automation. Adapting temperature according to measurements by sensors goes by absolute values – individual "perceived" values are usually ignored, why there can be a difference between measured and perceived temperature (Aschendorf, 2014).

Especially in cold months, heaters are often set to a higher temperature without regard to current outside conditions. The public utility does not need to measure and reconcile values, but automatically turns on the heating over the winter months. Here, it is ignored whether it is a warmer or colder day and whether activation of the heating is required at all. In addition, during warmer days, employees of public institutions may open the windows because the heating is set too high. The relatively large area of public facilities thus consumes a great deal of energy.

In this proposal, room users are included as "social sensors". A voting application using a smartphone should allow room users to vote on "perceived" values. As a consequence, there should be changes of state in space, e.g. automatic deactivation or activation of the heating. For this purpose, a threshold value is set, which triggers a state change when it is reached.

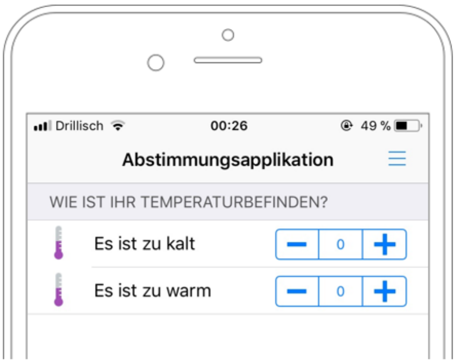


Figure 5. Voting application in openHAB on a smartphone

The professor of each lecture acts as an authoritarian entity involved in the process either through manual intervention, or passive monitoring of the voting results.

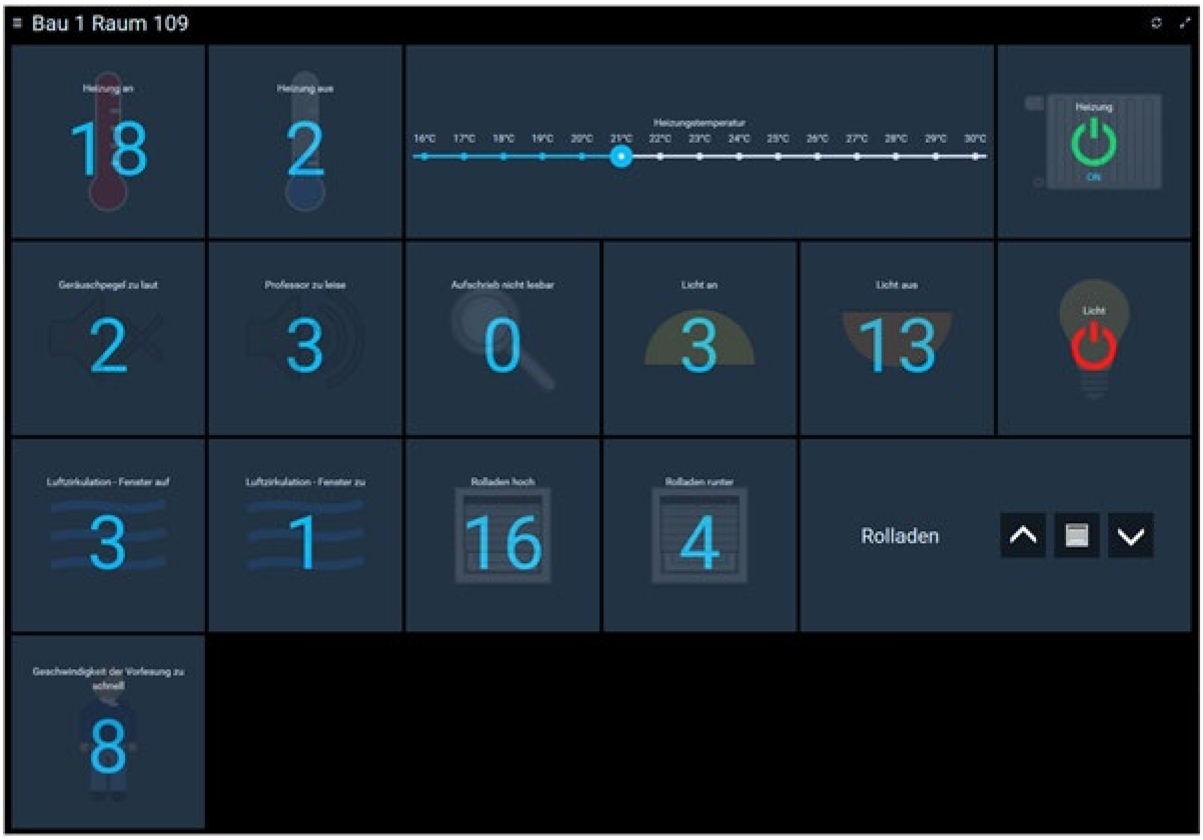


Figure 6. A HABpanel view of a lecture room, including real sensor data, perceived noise levels, ratings of lecture speed and other data influencing students

An application that presents a vote on the conditions in a lecture room has been created in openHAB, using the creation of items and their graphical representation. Generated automations pick up the values of a vote, summarize them and trigger events if certain conditions occur. The resulting prototype should be further developed to ensure usability in practice. A user administration and the integration of a tool for a more comprehensive visualization of the voting results are necessary extensions.

1.2.4 Damage Detection in Public Buildings

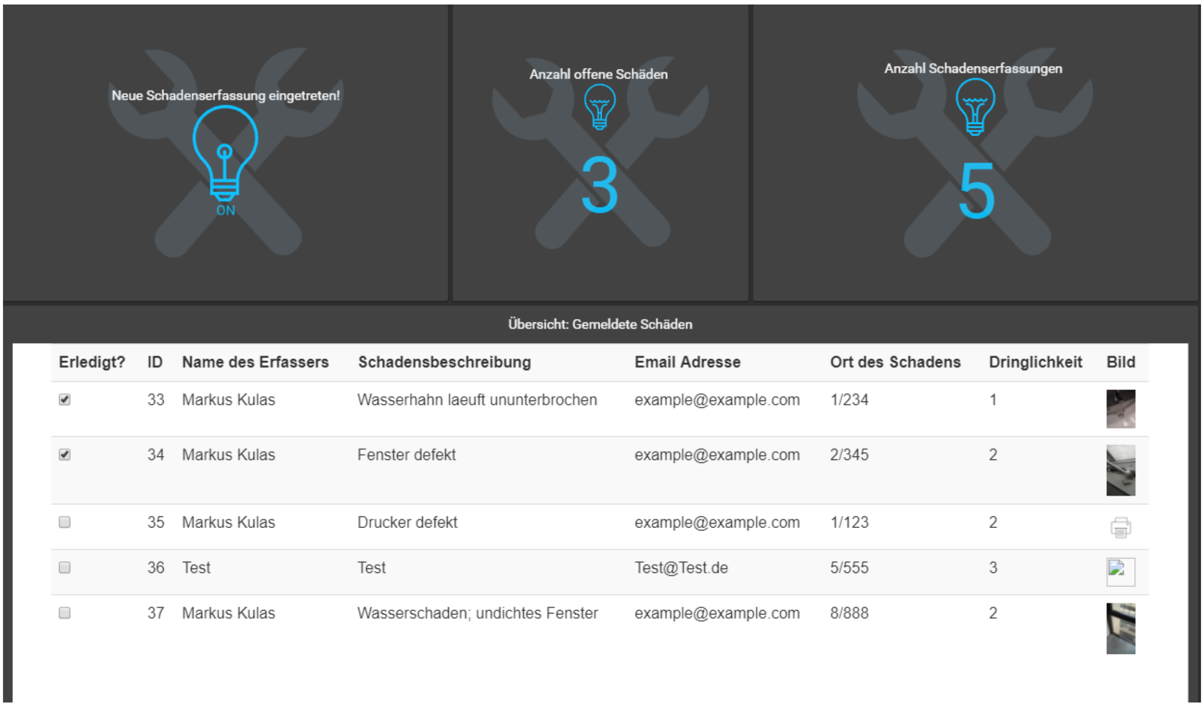
Inspection and maintenance of public buildings, often due to cost-saving measures, are challenging tasks for municipalities and those responsible for the facilities. Buildings and their equipment age, inherently they wear and loose function during this process (Offensive Gutes Bauen, 2018). It is therefore essential to deal with the associated problems.

Defective radiators, nonfunctional shutters or other missing (wear) equipment at colleges, universities or libraries are just a few examples of unavoidable damage.

Damage detection in public buildings can be achieved in different ways. Most often damage is not recognized by the responsible staff first, but rather by persons who use the affected premises on a daily basis. However, reporting of damages to the responsible personnel of a building is usually omitted. As a result, responsible staff is either late or even not aware of occurred damages and a removal may therefore be delayed accordingly.

So far, there is no standardized way to report damage or other deficiencies to the facility management. To counteract this problem, a concept has been developed, that allows damage detection in public buildings using a smartphone. The data can be made available to the responsible personnel via openHAB. Detected damage should be recorded as simple and general as possible. By reducing the effort for the user, a higher motivation to participate in the removal of damage shall be achieved, resulting in the long-term preservation of a public building.

The building management can retrieve the damage reports via smartphone as well. By means of a classification form, it is possible for the person in charge to complete the tasks prioritized. A damage can be marked as completed after rectification and triggers a notification to the damage detector.



Erledigt?	ID	Name des Erfassers	Schadensbeschreibung	Email Adresse	Ort des Schadens	Dringlichkeit	Bild
☑	33	Markus Kulas	Wasserhahn laeuft ununterbrochen	example@example.com	1/234	1	
☑	34	Markus Kulas	Fenster defekt	example@example.com	2/345	2	
☐	35	Markus Kulas	Drucker defekt	example@example.com	1/123	2	
☐	36	Test	Test	Test@Test.de	5/555	3	
☐	37	Markus Kulas	Wasserschaden; undichtes Fenster	example@example.com	8/888	2	

Figure 7. Presentation of damage reports in openHAB

A timely detection of damage by involving a building's users can lead to quicker damage repair and thus supports the error-free operation of a public building. Furthermore, standardization and simplicity of reporting increases data quality and facilitates usability and comfort on both sides – the detectors as well as the building management. Sources of error as well as transmission times are minimized, which leads to better documentation.

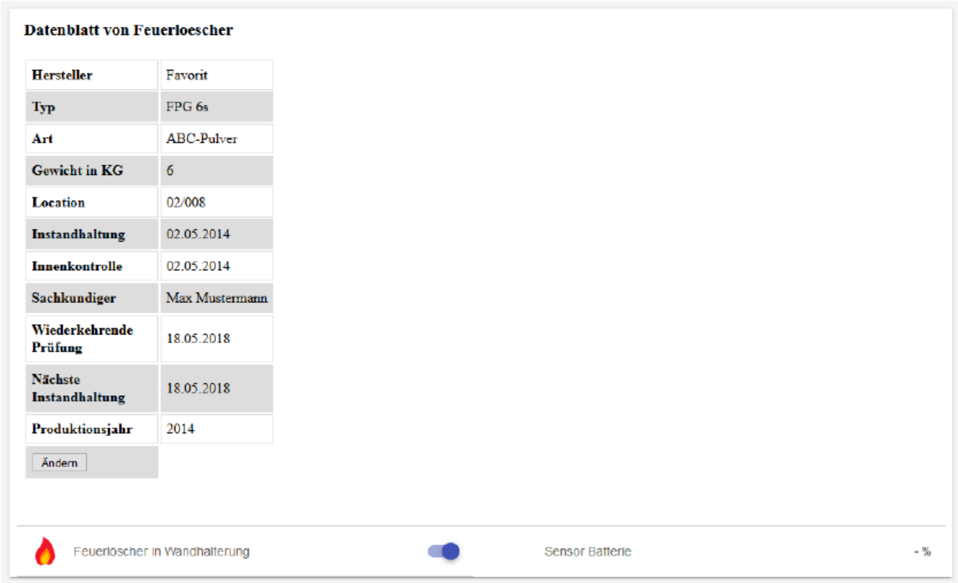
1.2.5 Collection of Safety-related Facilities

The primary goal of smart home solutions is to provide residents comfort and convenience while increasing the home's energy efficiency as well as its safety. However, requirements of public buildings are different from those of a private home. The focus of this subproject is on intelligent energy management and safety aspects, such as devices intended to guarantee or assist security (Hoffmann, 2017).

Security-specific devices may be a fire extinguisher, defibrillators, first aid kits or fire and smoke detectors. These facilities must be serviced and checked at regular intervals. The goal was to develop an application via openHAB that should facilitate the management of collections of safety-relevant facilities in buildings. Therefore, the facilities have been equipped with contact sensors in order to detect the removal of a device, e.g. a fire extinguisher or defibrillator.

Figure 8. Contact sensor attached to a fire extinguisher

A PHP form, which is presented via the openHAB interface, represents the data sheet of a device. It includes all relevant information, such as the next due date for maintenance.



Datenblatt von Feuerloescher

Hersteller	Favorit
Typ	FPG 6s
Art	ABC-Pulver
Gewicht in KG	6
Location	02/008
Instandhaltung	02.05.2014
Innenkontrolle	02.05.2014
Sachkundiger	Max Mustermann
Wiederkehrende Prüfung	18.05.2018
Nächste Instandhaltung	18.05.2018
Produktionsjahr	2014
Ändern	

Figure 9. PHP form of a fire extinguisher

Push notifications will inform responsible persons.

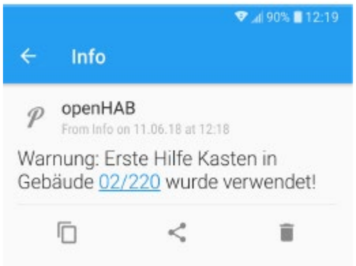


Figure 10. Push notification via openHAB

For navigation aid, a Near Field Communication (NFC) transponder can be attached to the device. Using a NFC enabled smartphone, it is possible to navigate to the device's datasheet in the app directly. This simplifies identification of security-relevant devices in everyday use. Writing the information to the transponder is done via the openHAB app. Once the transponder has been written, it is possible to navigate to the selected sitemap by touching it with the smartphone.

1.2.6 Implementation of an Intelligent Charging Station for e-Bikes

With the rise of e-mobility, electric vehicles, scooters and bicycles have become part and parcel of today's traffic. Electric bikes, for example, can easily be an alternative to cars for distances up to 30 kilometers. They are more environmentally friendly and have great potential to close the gap between the regular bike and the car. Test drivers of electric bikes were more motivated to replace the car with an electric bike instead of a regular bike. And there are even more reasons for buying an e-bike, such as "cycling without sweating", "being mobile without harming the environment" and "driving less" (Neupert et al., 2013).

This scenario deals with the design and implementation of an intelligent electric charging station for e-bikes at the University of Applied Sciences Stuttgart. With the help of openHAB, a communication between the charging station and the user is to be created. The integration in openHAB gives the user the opportunity to track the state of charge of his electric bicycle. The charging station should be able to display via openHAB whether it is available for charging or whether it is occupied, and via push notifications the user could be informed about the station's status. The scenario also includes a billing system with incentives, e.g. discounts for specific user groups such as university employees.

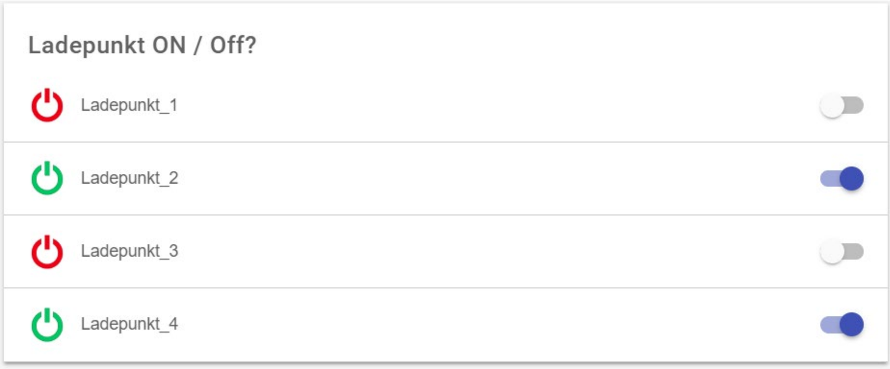


Figure 11. Status of charging points displayed in openHAB

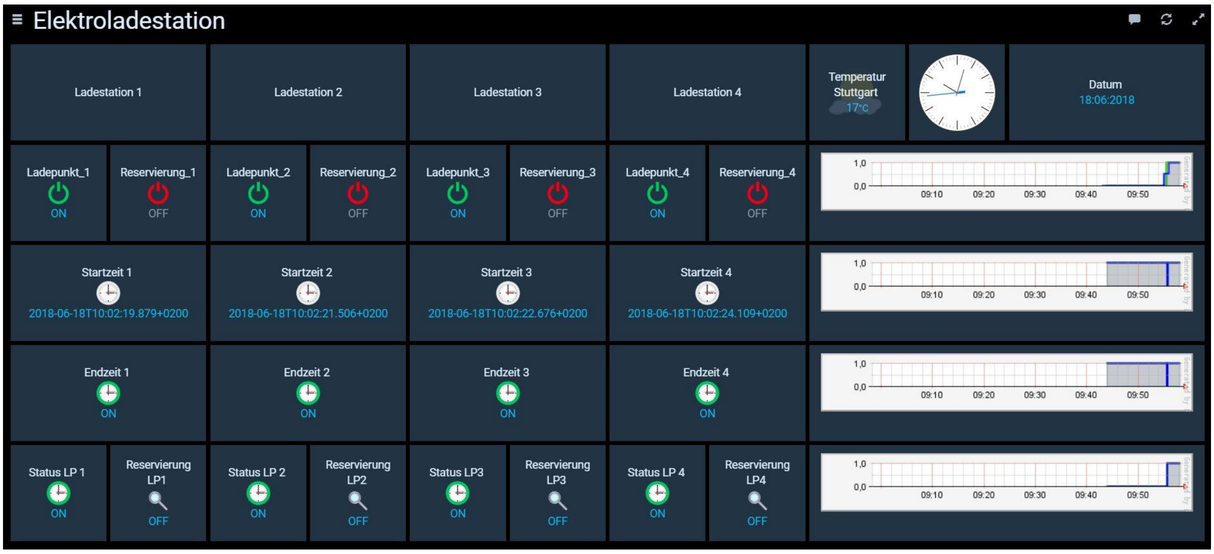


Figure 12. Illustration of electric charging stations via HABpanel

The billing system should integrate various payment methods and differentiate between user groups, e.g. external and internal users (from university's perspective), to allow specific benefits. An associated electricity tariff and billing to the minute should make the charging station available as soon as possible for subsequent users. With the help of an interface, the data can be exchanged between openHAB and the billing system and an invoice for charging can be generated. At present, there exist several free and open source projects for billing scenarios of all kinds. It has to be examined, which meets the described requirements best.

1.2.7 Smart Lecture Rooms

Only through data, which are recorded in buildings, a smart city can emerge (Mertens, 2017). Sooner or later public institutions are thus obliged to record various data via smart technology. Thereby they can contribute significantly to the development of a smart city. The newly built city library in Stuttgart, for example, has been equipped with 200 high-frequency presence detectors for energy-efficient lighting control in order to use artificial light only when necessary (Gebäudedigital, 2013).

A similar, even more extensive "Smart Lecture Room" system is currently tested at the HFT Stuttgart. A hardware platform for the monitoring of functional rooms (lectures, sessions, etc.) has been assembled and linked to openHAB. The installed sensors detect window contact, measure power consumption as well as temperature (for controlling the heater), light, presence and humidity (latter gathered by multi-sensors) and report them to openHAB. The aim is to increase energy efficiency of the monitored rooms as well as to improve comfort of use and room utilization. Three lecture rooms have been equipped with sensors so far. In a next step, long-term measurements have to be carried out and analyzed in order to gain information about usage patterns.

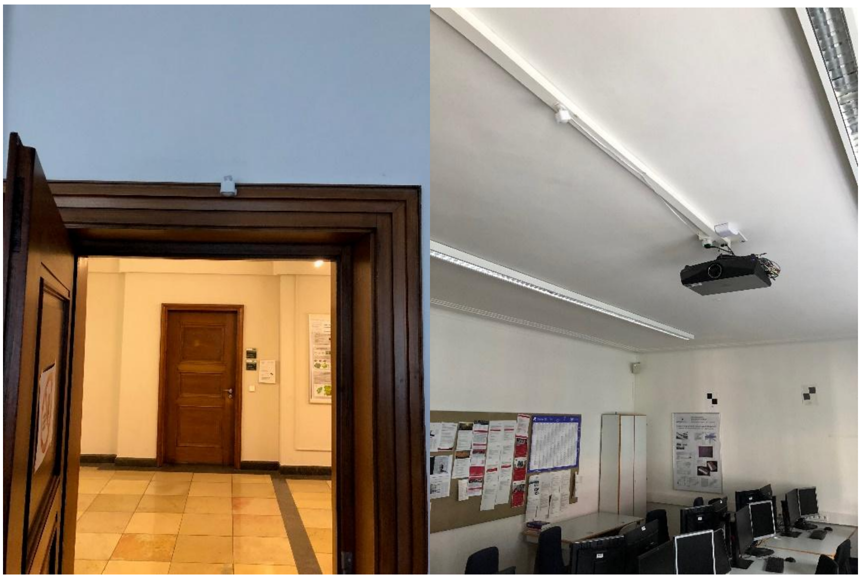


Figure 13. Multi-sensor attached above a door

The Z-Wave network accesses the various sensors from a central server. Through the use of Z-Wave extenders the signal is amplified and repeated over the different rooms.

Using a MySQL database, the sensor data is collected and stored persistently. The data is displayed via the external visualization tool Grafana and presented via the openHAB user interface.

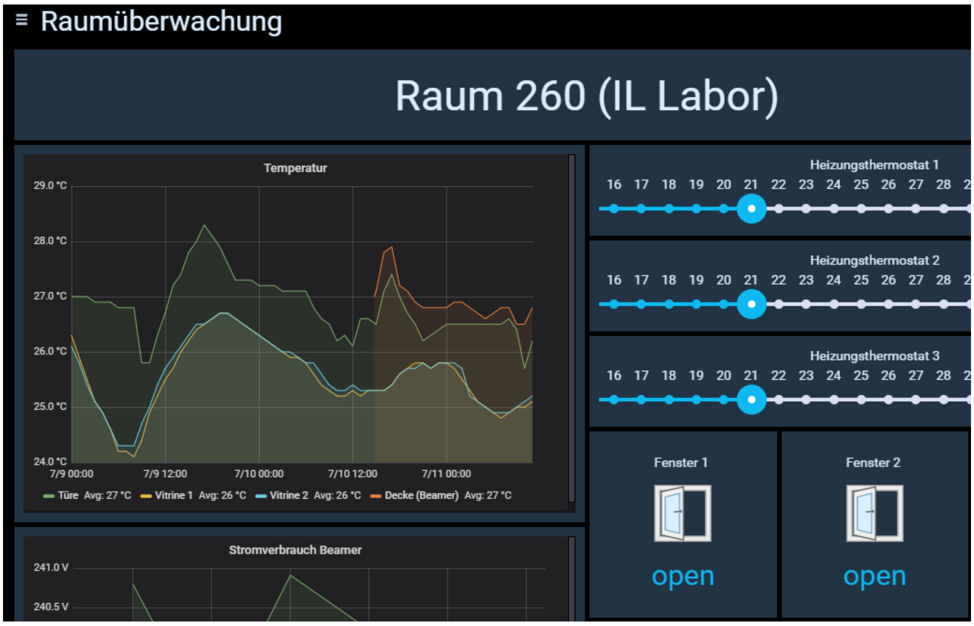


Figure 14. Representation of sensor data via HABpanel

In the future, by determining rules, the lecture rooms can be managed based on the usage patterns. Various scenarios can be applied here, such as turning off the heating at night, or the general regulation of a room in case of presence detection.

1.3 Conclusion and Outlook

Smart Public Building focusses on the applicability of smart home technologies for public buildings. The prototypical implementation of such technologies at the HFT campus will ideally have a positive effect in terms of adoption and further development at other universities and public facilities. Extending the open source system openHAB for home automation to public buildings offers above-average prospects of technical success and dissemination of the developed extensions. In addition, with the openHAB community there is a backup of continuation beyond the project.

First concepts and basic installations within subprojects have been taken place. However, further investigations on the central use of the openHAB infrastructure in public buildings are required, taking into account specific (also technical) demands of public facilities, such as network restrictions.

Affiliated to the Smart Public Building project further bachelor's and master's theses will be created. One of the next steps includes development and prototypical implementation of a concept for automatic presence detection in public buildings. Furthermore, the power and water meter of the University of Applied Sciences (building 2) should be equipped with sensors to measure consumption continually.

The already existing concepts will be further developed and put into operation prototypically in the course of the project. For example, lecture rooms will be equipped with CO2 sensors as well as with intelligent light switches. Furthermore, access to the installed openHAB prototypes via smartphones and tablets will be made possible.

1.4 References

Aschendorf, B., 2014. *Energiemanagement durch Gebäudeautomation: Grundlagen - Technologien - Anwendungen.* Springer Fachmedien, Wiesbaden.

Böwing, R., 2015. *SmartHome und SmartBuilding - Zukünftiges Wohnen und Bauen*. https://www.makeyourhome.de/story-artikel/smarthome_und_smartbuilding_-_zukuenftiges_wohnen_und_bauen-56 (accessed December 1, 2016)

Carreira, P., Resendes, S., & Santos, A., 2014. Towards automatic conflict detection in home and building automation systems. In: *Pervasive and Mobile Computing*, Vol. 12, pp. 37-57.

Gebäudeautomatation, M. -M., 2012. *Marktstudie Gebäudeautomation Schweiz 2012.* http://www.mega-planer.ch/fadaladdondlz/files/.addonpublikationeintragfile/publikationen/63.pdf/Marktstudie%20Geb%C3%A4udeautomation%20Schweiz%202012.pdf (accessed April 4, 2016)

Gebäudedigital, 2013. *Gebäudedigital*. https://www.gebaeudedigital.de/allgemein/stadtbibliothek-stuttgart/ (accessed January 18, 2018)

Hoffmann, D. A., 2017. *Smart Home und Smart Building.* https://www.bitkom.org/Presse/Anhaenge-an-PIs/2017/02-Februar/Bitkom-Pressekonferenz-Smartphone-Markt-Konjunktur-und-Trends-22-02-2017-Praesentation.pdf (accessed May 10, 2018)

Hsien-Tang, L., 2013. Implementing Smart Homes with Open Source Solutions. In: *International Journal of Smart Home*, Vol. 7(4), pp. 289-296.

Kim, B., 2015. Consensus-Based Coordination and Control for Building Automation Systems. In: *IEEE Transactions on Control Systems Technology,* Vol. 23(1), pp. 364-371.

LKA North Rhine-Westphalia, 2014. *Smart Home und Connected Home: Empfehlungen zur Sicherung digitaler Haustechnik.* https://www.polizei.nrw.de/media/Dokumente/Behoerden/LKA/140811_LKA_SmartHome_Empfehlungen.pdf (accessed November 19, 2018)

Markgraf, D., 2018. *Definition »Location-based-Services«. Gabler Wirtschaftslexikon.* Springer Fachmedien Wiesbaden.

Mertens, O., 2017. *Haufe*. https://www.haufe.de/immobilien/wirtschaft-politik/smart-building-als-baustein-zur-smart-city/smart-building-als-baustein-zur-smart-city_84342_410364.html (accessed January 18, 2018)

Neupert, H., Schröder, J., & Schulz, M., 2013. *The eBike Book. Future. Lifestyle. Mobility.* teNeues, Kempen, pp. 15-59.

Offensive Gutes Bauen, 2018. *Offensive Gutes Bauen*. https://www.offensive-gutes-bauen.de/praxishilfen-und-unterstuetzung/das-instrument-fuer-gute-kommunikation-und-kooperation-aller-am-bau-beteiligten/praxishilfen-der-inqa-bauen-partner/ (accessed January 15, 2018)

Paetz, A., Jochem, P., & Fichtner, W., 2010. Smart Home & E-Mobility - Effekte von Anreizsystemen. In: *VDE-Kongress 2010 - E-Mobility: Technologien - Infrastruktur - Märkte.* VDE, Leipzig.

Smart Home Magazin, 2016. *Intelligente Gebäudetechnik heute und morgen*. http://smarthomemagazin.eu/studie-zeigt-wachstumspotenzial-fuer-intelligente-automation-in-gewerbegebaeuden/#more-699 (accessed November 30, 2016)

Statista, 2016. *Smart Home*. https://de.statista.com/outlook/279/137/smart-home/deutschland# (accessed April 4, 2016)

Stengel, B., 2015. Ethische Überlegungen zu Smart Home. In: *International Review of Information Ethics,* Vol. 22, pp. 92-100.

Viani, F., Robol, F., Polo, A., Rocca, P., Oliveri, G., & Massa, A., 2013. Wireless architectures for heterogeneous sensing in smart home applications: Concepts and real implementation. In: *Proceedings of the IEEE,* Vol. 101(11), pp. 2381-2396.

Yu, D.-Y., Ferranti, E., & Hadeli, H., 2013. An intelligent building that listens to your needs. In: *Proceedings of the 28th Annual ACM Symposium on Applied Computing,* ACM, New York, pp. 58-63.