The Role of Smart Prevention Technology within the Internet of Things

Oliver Baecker
Institute of Technology Management
University of St. Gallen
Dufourstrasse 40a, CH-9000 St. Gallen
oliver.baecker@unisg.ch

Stefan Zanetti
synesix solutions AG
St. Johanns-Vorstadt 19
CH-4056 Basel
stefan.zanetti@synesix.com

Abstract: Recent advances in the areas of wireless communication and sensors led to a decline in prices for smart technologies while devices became more powerful and reliable. Yet, the deployment as well as the functional range of sensor and wireless communication technology in residential buildings is still limited. In a possible application scenario for these technologies, home safety devices like smoke detectors, motion detectors, and burglary alarm systems are equipped with wireless communication modules, thus making them a part of the Internet of Things. This means that safety devices (the "Things") in the physical world can communicate amongst each other and get integrated with the digital world of the Internet. The paper at hand discusses the role of smart prevention technologies within this emerging domain using the example of smoke detectors. The research gives an overview of costs, barriers for wide-spread use, and success factors of "smart smoke detectors" and proposes an infrastructure for smart prevention technology. Due to their natural interest in loss prevention, the paper also focuses on the relevance of smart prevention technology for insurance companies. The research examines the role of smart prevention technology within the Internet of Things from various angles and therefore represents an overview of this emerging topic that prepares the ground for future research.

1 Introduction

While prices for wireless communication modules decline and the functional range steadily increases, their deployment in residential buildings is still limited. An application scenario in home environments involves equipping safety systems like gas detectors, smoke detectors, and leak detection systems with wireless communication capabilities. This allows for the communication between different types of monitoring devices and most importantly for their integration with the Internet thus establishing monitoring devices as a part of the Internet of Things. This paper discusses smoke detectors as one instance of prevention technology applied in home environments. Even though smoke detectors have the potential to reduce the frequency and impact of fire accidents, their adoption rate in residential buildings is still low in most countries. As an example for the impact of residential fires, in Germany, annually 600 people die due to fires in residential buildings and damage costs of six billion Euros are incurred [Ge03]. However, more countries are requiring the installation of smoke detectors by law and

impose fines, if smoke detectors are not installed. This development will increase the market penetration of smoke detectors and potentially increases the demand for innovative solutions as well.

State-of-the-art smoke detectors are usually either optical detectors or ionization detectors, which indicate a detected fire via a local acoustical alarm. In addition, smoke detectors can be connected with each other to propagate alarms. Stand-alone detectors can be linked via cables or using wireless communication modules and a landline-based control center can transmit the alarm to the outside world. While low-cost smoke detectors are not equipped with a wireless communication module, improved versions contain wireless modules that use proprietary communication standards. This prevents the integration of smoke detectors with further prevention technology or other wireless devices in smart home environments. The functionality of a landline-based control center, which is used to call for example the fire department, is usually restricted to dialing a stored phone number. There is no additional intelligence embedded that provides data about the home environment to the outside world or offers services to be invoked from the outside. To overcome these shortcomings, we introduce the notion of smart smoke detectors and define them by three key properties:

- ability to communicate with other smoke detectors,
- provisioning of sensor data to external applications, and
- offering of services to be invoked from external networks.

In the event of a fire, smart smoke detectors are able to communicate amongst each other to propagate the alarm within a building and most importantly to someone outside the home environment, like the fire department or the house owner. This is especially useful, if residents passed out due to smoke poisoning or if no one is nearby to call the fire department. Besides the basic functionality of propagating alarms, the connection of smoke detectors to the Internet leads to various new application scenarios. Once a smoke detector is connected to the Internet, it becomes possible to directly access it from anywhere outside the residence and invoke services offered by the device or access data collected by it. This allows for a coupling of what is happening in the physical world with the digital world. Closing the integration gap between both worlds is also of interest to insurance companies, who could base their premium rates for household insurances on the installation of smart prevention technology. In addition, the Internet-based access to smart smoke detectors can be used for remote function tests in the context of compliance monitoring activities. The access to data gathered by smart smoke detectors is also of interest for approaching fire fighters to locate the origin and movement of a fire while they are on their way to the scene. In summary, smart smoke detectors allow for technology-enabled risk control by reacting to fires in real-time and triggering an automatic and early intervention [ZTF06].

The contribution of this paper is a multi-dimensional examination of the role of smart prevention technology within the Internet of Things based on the example of smart smoke detectors. Therewith it prepares the ground for future research in this domain and allows examining specific aspects in greater detail. The goal of this research is to investigate the potential of smart prevention technology, especially if applied in an

insurance context. The paper also analyzes why smart smoke detectors are not widely deployed, even though the necessary hardware components are readily available. The following chapters discuss the infrastructure for smart smoke detectors and focus on their costs, barriers for wide-spread use, and the success factors of enhancing smoke detectors by adding wireless communication capabilities and connecting them to external networks. Due to its business relevance, the work also focuses on the implications of prevention technology for the insurance business.

2 Related Work

The impact of emerging ubiquitous computing technologies on the insurance domain is discussed by [CBM2004], who outline new economic paradigms like risk-based insurance rates, pay-per-use models, and ride-by-ride insurances. They argue that the omnipresence of smart technologies in the evolving Internet of Things will lead to a higher resolution of insurance-relevant data, thus enabling more fine-grained pricing models. [Ob2003] concerns himself with the strategic impacts of ubiquitous computing on the non-life insurance business in the private customer segment. He conducts an in-depth analysis of the insurance market and develops an analytical framework to evaluate the strategic implications of emerging ubiquitous computing technologies. Based on expert workshops, he derives strategic implications in the areas of revenue generation, cost cuttings, reconfiguration of the value chain and expansion into new business segments. [FW2007] describe the challenges insurance companies face when assessing individual risks and deriving risk-based ratings. Using the example of car insurances, they discuss insurance-specific concepts like information asymmetry, moral hazard, and adverse selection.

The potential of applying early damage detection technology in the insurance sector is discussed by [ZF06], who describe preventive business processes based on ubiquitous computing technology. They also examine the interrelations between insurance companies, their customers and technology. To examine the monetary effect of applying pervasive technologies, [KBZ07] developed a toolset to prove the impact of prevention measures on the extent of damages. From a broader economic perspective, [Ra98] discusses the domain of fire protection. He examines the economic value of the early detection of fires and provides mathematical models for a cost-benefit analysis.

In addition, there are many technical publications in the area of wireless communication for home automation. For example, [Ca02] present the different layers of the IEEE 802.15.4 standard and describe how it can be used in home networking applications. [Ko05] research the networking of embedded devices to perform industrial control and monitoring. Even though they focus on industrial applications, the authors provide an overview of wireless standards that can be used for cable replacement in monitoring networks. Work of interest on the integration of smart smoke detectors with the Internet was conducted by [SW01], who describe new use cases like software downloads and software as a service (SaaS) models. They especially stress the point that systems need to be based on open and standardized interfaces to allow for an easy and cost-effective integration of additional components into a smart home environment.

3 The Infrastructure for Smart Smoke Detectors

In this section, an infrastructure that applies emerging Internet of Things technologies in order to overcome the shortcomings discussed in section 1 is proposed. As outlined, a key feature of a smart smoke detector is the communication with other smart devices including further smoke detectors, cell phones, wireless sensor nodes, or external networks. To communicate over short distances, every detector could be equipped with technologies like Bluetooth or ZigBee. However, long-range communication, such as sending an alarm message to a cell phone, requires technologies like UMTS, WiMax, or GSM. As long-range communication modules are usually more expensive than short-range solutions, it is not cost-effective to equip each smoke detector with long-range communication capabilities. Instead, the proposed infrastructure for smart smoke detectors relies on a wireless communication network, which contains an uplink module to communicate alarms to the outside world. This approach overcomes some of the significant shortcomings of state-of-the-art low-cost smoke detectors, which are either not equipped with wireless modules or rely on proprietary communication standards. The integration of wireless communication capabilities in smoke detectors frees the infrastructure from the costs and inflexibility associated with cable-based connections of smoke detectors. The approach also makes it easier to equip a building with interconnected smoke detectors at a later point in time, while providing additional mobility to the system by supporting the relocation of smoke detectors without impacting functionality. Another significant shortcoming of stand-alone smoke detectors is their local acoustic alarm. To overcome this problem, a smart smoke detector is able to alarm external parties in order to avoid larger damages. To keep the costs of the overall infrastructure low, a hybrid architecture is chosen where one dedicated node in the network acts as a gateway and provides the desired long-range communication uplink. Due to the limited communication range of wireless modules and the characteristics of in-door communication, not all smoke detectors are able to directly communicate with the dedicated gateway device. Thus, in case of a local alarm, the signal needs to be propagated along the network in a multi-hop manner to reach the communication gateway, which then relays this information to a communication device outside the home environment. An overview of the infrastructure is visualized in Figure 1.

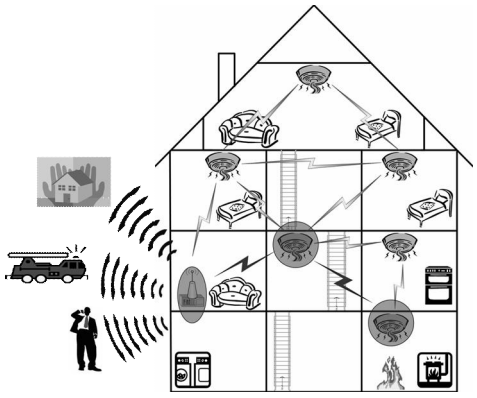


Figure 1: Overview of the Smart Smoke Detectors Infrastructure

The figure shows a one-family house, which is equipped with a total of six networked smoke detectors, which are connected to a communication gateway. A detected fire is propagated along the detectors and the gateway informs the house owner, approaching fire fighters and the insurance company.

4 Success Factors, Costs, and Barriers of Smart Smoke Detectors

Based on the description of an infrastructure for smart smoke detectors in chapter 3, this chapter indicates requirements and success factors for the mass-application of smart smoke detectors, provides a cost estimation for the infrastructure, and discusses why the solution is not widely applied in residential buildings yet.

4.1 Requirements and Success Factors for the Mass-Application of Smart Smoke Detectors

The requirements for an infrastructure for smart smoke detectors need to be examined from different perspectives. On the one hand, end users have requirements concerning the operation phase. On the other hand, there are several technical as well as legal requirements on the infrastructure and the applied technologies.

From an **end user perspective**, the following key requirements were identified:

- **Ease of installation:** End users usually do not have a technical background. Therefore, the installation of the infrastructure must be self-explanatory and should not require service by a technician.
- **Low costs:** Even though smart smoke detectors provide added value compared to state-of-the-art smoke detectors, the customer's willingness to pay is limited. Therefore, low costs are crucial for a mass-application of smart smoke detectors.
- **Safety:** The technology needs to be very reliable and robust, thus false alarms (type I errors) and absence of alarms in case of fires (type II errors) must be minimal. In addition, there must be minimal or no maintenance efforts.
- **Privacy:** If smart smoke detectors are connected to the Internet and their data is accessible from the outside, privacy issues arise. Privacy becomes even more important once the infrastructure contains more than just smoke detectors, like additional sensors that might enable an intrusion into the privacy of end users.

From a **technical perspective**, the infrastructure for smart smoke detectors has to satisfy the following key requirements:

- **Scalability:** As home environments are heterogeneous, the amount of deployed sensor nodes is not predetermined and varies. The infrastructure needs to take into account that sensor nodes join and leave the network over time and thus, should be able to cope with varying amounts of sensor nodes.

- **Performance:** The timeliness of alarms is a crucial factor for fire prevention technology. Therefore, the communication between the infrastructure components needs to be fast and fail-proof. This relates closely to the reaction time in case of bursting fires, which is affected by the implemented power conservation mechanisms.
- **Power consumption:** Solving the question of power supply is vital for an infrastructure that is based on wireless communication nodes. While the communication gateway has its own power supply, a smart smoke detector is battery-powered. It is crucial that batteries last long, so the system can operate in a pervasive and unobtrusive way without the need for frequent battery replacements.
- **Integration:** The infrastructure needs to easily and flexibly integrate into an existing system environment for home automation. In addition, it has to be open and standards-based to be extensible towards future applications. Because smoke detectors are just one example of a variety of detection systems, the integration of further prevention technology must be possible by design.
- **Security:** As for all communication systems, the security aspects of the infrastructure must be addressed. This includes protecting individual smoke detectors from external manipulation, as well as securing the data transferred during communication, especially to systems that reside outside the home environment.

From a **legal point of view**, the following requirements are important:

- **Legislation:** Politics aim at increasing the coverage of smoke detectors by issuing laws that make their installation mandatory. For example, in Germany, six federal states now mandate the installation of smoke detectors and other states will soon be passing similar laws. In combination with educational advertising by industrial federations, the percentage of residential buildings equipped with smoke detectors has increased from 6% in 2000 to 31% in 2006 [Fo06]. The legal initiatives are driven by the understanding that a voluntary installation of smoke detectors leads to an insufficient coverage. In countries like the United States, Australia, England and Norway, the installation of smoke detectors is already required by law. For example, smoke detectors are now present in 93% of residences in the United States, which led to a 40% decrease in deaths caused by fires[1]. This is in sharp contrast to countries like Switzerland, Austria or France, which have no legal regulation around smoke detectors resulting in a low coverage.
- **Product norm:** Beginning in August 2008, smoke detectors compliant with the harmonized European product norm DIN EN 14604, are the only smoke detectors that can be legally sold in the European Union [Eu05]. Therefore, any newly developed smoke detectors need to be inherently compliant with this norm.

[1] See http://www.wdr.de/tv/service/familie/inhalt/20011219/b_1.phtml.

4.2 Costs of an Infrastructure for Smart Smoke Detectors

Based on the infrastructure description in chapter 3, this section presents two cost calculations and compares the results. The section begins with a cost analysis of a smoke detector infrastructure for residential buildings, which consists of state-of-the-art components. The second calculation is based on an alternative infrastructure that applies novel wireless communication technologies. The goal is to calculate reference prices for both infrastructures based on the necessary hardware components. The first cost calculation is based on list prices of the fire prevention specialists Hekatron[2] and CM-PAPP security[3], which can be seen as representative vendors of norm-compliant smoke detector technologies. The one-family house depicted in Figure 1, which is equipped with a total of six radio-enabled smoke detectors, is used as a reference object. In the examined infrastructure, every smoke detector "HSD IV LongLife" is equipped with a "Duo-Line" or "Duo-Line Plus" module for radio communication. To ensure a reliable communication, it is necessary to apply the "Duo-Line Plus" version on the first and second floor of our reference building due to its improved signal strength. Finally, the network is connected via the gateway module "Radio Interface Duo-Line Plus" to the "Monitoring Station CM7008" that submits the alarm to a cell phone. Figure 2 shows the cost calculation for a state-of-the-art smoke detectors infrastructure.

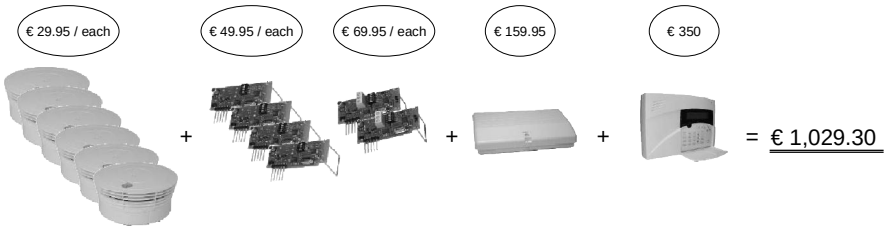


Figure 2: Cost Calculation for a State-of-the-Art Infrastructure

For the cost calculation presented in Figure 2, compatible components offered by two companies that specialize in safety engineering for residential buildings were combined to match the infrastructure sketch. Even though the choice of components represents the cheapest possible configuration and offers very limited functionality, the total price is still higher than € 1,000. At this price level, a mass-application of smart smoke detectors is unlikely. Therefore, in the following sections, an infrastructure for smart smoke detectors based on novel and emerging technologies is proposed. To be able to validate the profitability of the new approach and compare it to the previous cost calculation, the corresponding hardware costs for an alternative infrastructure, which is based on the same smoke detector models, is calculated.

An analysis of the cost structure of the presented state-of-the-art solution shows that the communication components of the infrastructure are the largest expense factor. An approach to reduce the costs is to deploy low-cost emerging technologies in the area of

---

[2] See http://www.hekatron.de/media/downloads/datei/537_gesamtkatalog_rauchwarnmelder_07.pdf.
[3] See http://www.cm-security.com/pdfs/katalog/de/CM_PAPP_Katalog_2005_07_21_Internet.pdf.

wireless communication, without altering the basic smoke detectors. In addition, the proposed approach makes use of existing infrastructure to cut costs. The selection of an appropriate technology to achieve the outlined goal is based on semi-structured interviews with several vendors of wireless communication technologies. The focus of the conducted interviews was on the functionality and costs of the respective technologies. It is important to note that for a prototype implementation of the infrastructure, the available technologies need to be further examined and compared in more detail. For the purpose of this paper, a first reference price based on data from technology vendors is sufficient. The information gathered from both, the conducted interviews and additional desk research, lead to the decision to apply ZigBee nodes and to connect those to the existing IT infrastructure. ZigBee-compliant nodes are based on the IEEE 802.15.4 standard [Ie06] and designed for low-battery consumption, ad-hoc networking and reliable multi-hop communication. Use cases describing smoke detectors are included with other existing ZigBee use cases in the areas of industrial control, embedded sensing, medical data collection, and home automation.

Besides the wireless communication, the infrastructure also requires some uplink functionality. For this purpose, a ZigBee-to-Ethernet bridge can be used to connect the system to an existing router and use its Internet connection as a communication uplink. While this setup relies on existing infrastructure, it can be argued that Internet connections are a commodity in home environments and therefore the approach helps to further cut costs. Nevertheless, it is also possible to replace the ZigBee-to-Ethernet bridge with a ZigBee-to-Cellular bridge for a direct communication with cell phones, which is independent of an existing infrastructure, but imposes higher costs. The cost calculation in Figure 3 uses list prices for ZigBee nodes from Max-Stream[4], a provider of wireless device networking solutions. The company was chosen, because it is one out of four manufacturers that sell products certified by the ZigBee alliance and also because it offers products that match well with the requirements of the depicted infrastructure. Therefore, the products can be used for the calculation of a reference price, keeping in mind that the calculated price is an initial approximation to compare a state-of-the-art solution with one based on novel technologies.

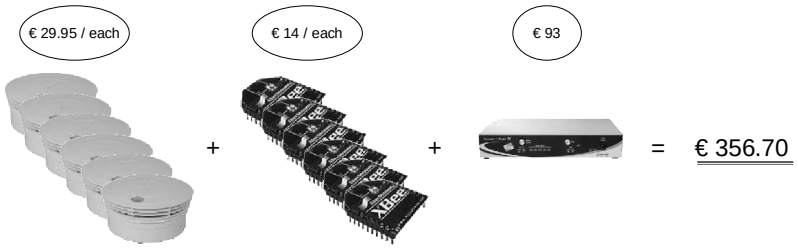


Figure 3: Cost Calculation for a Novel Infrastructure

As Figure 3 shows, the smoke detectors account for half of the price of the overall infrastructure. As mentioned before, legal directives concerning the installation of smoke

[4] See http://www.maxstream.net/products/catalog_web.pdf.

detectors will lead to an increased demand, which will lower the prices for basic smoke detectors. Moreover, [Ab06] estimates that the market for ZigBee nodes will grow from 92,000 nodes and revenue of $ 552,000 in 2005 to 124.60 million nodes and revenue of $ 174.44 million in 2011. This should lead to a decrease in prices for ZigBee communication modules. In summary, the application of the emerging ZigBee technology and its integration with the existing IT infrastructure leads to a decline in costs from € 1,029.30 to € 356.70, which equates to cost savings of 65%. The conducted cost analysis compared only hardware costs for a state-of-the-art implementation and a new infrastructure proposal. While this is a reasonable first approximation because hardware costs are the main cost factor, further cost factors need to be considered as well. For example, the communication between the network and external parties generates additional communication costs, especially for connections to cell phones. In addition, costs for system installation, maintenance and battery replacement need to be considered. As the novel infrastructure combines several components, it is also necessary to consider sunk costs associated with the initial development of integration software.

4.3 Barriers for the Market-Penetration of Smart Smoke Detectors

This section examines why smart smoke detectors are not widely applied in residential buildings, even though their benefits seem to be obvious and the individual hardware components are available. Based on the cost estimation for a state-of-the-art infrastructure, the high costs of such an infrastructure can be identified as one key hindering factor. Still, in order to fully understand the reasons for the low adoption rate of smart smoke detectors, the considerations need to start one step earlier as the market-penetration of ordinary smoke detectors is surprisingly low as well. According to a recent study on the adoption of smoke detectors in German private households [Fo05], the level of familiarity with smoke detectors is 98%. Nevertheless, smoke detectors are deployed in only 31% of the residential buildings. Even though most people are familiar with smoke detectors, their distribution is low in countries that do not regulate their deployment by law. This is largely caused by misconceptions about the danger of fires. Most people are not aware of the fact that 95% of all people who die in fires are killed by smoke poisoning from inhalation of smoke, not the actual flames. In addition, 70% of these deaths happen at night, because the sense of smell is inactive while sleeping[5]. The lack of knowledge about these facts leads to the misconception that most fires are discovered at an early stage by the increasing heat and that there is enough time to leave the house. This wrong assessment of the dangers of fires is paired with a psychological crowding-out effect. The act of concerning oneself with a life-threatening situation and actively purchasing a smoke detector is prevented by the rejection of unpleasant topics. To some extent smoke detectors are also seen as aesthetically unappealing, which is especially the case in luxury flats or architectural monuments. Another reason for the low adoption rate of smoke detectors is the high rate of false alarms. In 2005, about a third of all fire-related incidents in the United Kingdom were false alarms caused by smoke detectors [De05]. The high rate of false alarms also results in an increased

[5] See http://www.rauchmelder-lebensretter.de/10.0.html.

number of installed but inactive smoke detectors, because people disable devices after annoying false alarms. In addition, many devices are inactive as batteries were removed and used elsewhere, e.g. in a remote control. The short lifetime of batteries as well as the limited functionality of state-of-the-art smoke detectors can be seen as further adoption barriers. Besides the discussed barriers, the market-penetration of smart smoke detectors is mainly delayed by the high costs of wireless communication modules. Another retarding factor for the application of emerging technologies like ZigBee is the reliability and availability of the network, which are key requirements in the domain of safety technology. As wireless communication networks are still less reliable than cable-based solutions, the market-penetration is slowed down until the technologies are mature enough for a broad application in safety-critical environments. The discussion of network reliability also leads to questions of accountability in case of network failures at the time of disaster.

5 Value Proposition of Smart Smoke Detectors

This section discusses the value proposition of the presented infrastructure for smart smoke detectors from the perspective of end users and insurers as well as from a technology point of view.

5.1 End User Perspective

For end users the most obvious effects of installing smoke detection technology are increased safety, a decreased risk of fire, and a lower expected monetary loss. If the technology is offered for free by insurance companies or if they offer more attractive insurance rates for installed smoke detectors, the technology installation has an additional monetary effect for end users. As the system is equipped with communication capabilities, it also becomes possible to automate certain tasks like battery and function tests to increase the availability of the system while freeing the user from this burden. As technologies advance, end users will soon be able to interact with the system using cell phones or any ZigBee-enabled end device. For example, Telecom Italia is currently testing a SIM card with an integrated ZigBee gateway named Z-SIM [Tu07]. This will inherently provide access to a deployed ZigBee-based infrastructure as cell phones are a commodity. The concept allows using the cell phone as a user interface to control the system or as a dashboard to receive for example a battery replacement notification. In addition, the utilization of open communication standards enables an easy extension of the existing system. This means that every new device only needs to be equipped with a ZigBee module to be integrated with the communication infrastructure. From a cost perspective, the initial investment in the communication gateway is spread over more and more integrated devices as the infrastructure grows.

5.2 Technology Perspective

The wireless communication modules in state-of-the-art smoke detectors usually apply proprietary communication protocols. Therefore, a key contribution of the infrastructure proposal is the application of open communication standards to allow for the integration of additional systems and sensor nodes. In this respect, the smoke detectors infrastructure can be seen as a foundation for the future integration of various wireless home automation systems within residential buildings. This overcomes the shortcomings of available legacy solutions and allows for an open and extensible integration infrastructure. For example, the infrastructure can integrate further detectors like gas detectors, water detectors or burglary alarm systems. The only prerequisite is that every new technology that is integrated with the existing infrastructure supports the common communication standard.

An example of device-to-device communication in the case of smoke detectors is the following: when a smoke detector recognizes an emerging fire, it informs nearby detectors, which propagate the alarm. In addition, it sends signals to the sprinkler system as well as the smoke and heat venting system to extinguish the fire. Another example could be the integration of networks between adjacent houses. If both networks use the same communication standard, it is possible to propagate the alarm from a node at the verge of a building to the close-by neighboring house. This way it becomes possible to establish a neighborhood-spanning safety system where several buildings can even use a common communication gateway. Finally, the bidirectional communication between smart smoke detectors and the Internet allows for incoming messages as well. For example, house owners can be warned about an upcoming tornado or flood by the civil protection agency, which would trigger a dedicated acoustic alarm on the smoke detectors inside each residence.

5.3 Insurance Perspective

The application of smart prevention technology, like smart smoke detectors in residential buildings, is of special interest for insurance companies, since the installation of more effective early detection technology has the potential to reduce fire insurance claims. This will cause the total loss expenses for insurers to drop because of a decreased frequency of severe burnings and a lower amount of damages per case. The emergence of smart prevention technologies also has strategic potential for insurers, who could use smart smoke detectors as a new link to their customers. Besides the positive effect on the combined ratio due to reduced losses, the introduction of information technology in the relation between insurers and their customers makes the “product” insurance appear more tangible and gives it its own “look-and-feel”. This allows for a modular design of insurances, which for example consist of a household insurance, smoke detectors, water detectors, and a burglary alarm system. From a strategic point of view, the different detection systems could be introduced step by step during the renewal of the original insurance contract. Applying a more holistic insurance concept using smart smoke detectors has the potential to lead to increased customer loyalty and improves the image of the insurance company, which can position itself as a prevention insurer. The

application of technology also offers the chance that customers loose the subjective impression, that they never receive any return service for the paid insurance premiums. In addition, the technology leads to additional contact points, which are the base for cross- and up-selling opportunities. Insurance companies can also realize first-mover advantages, if they integrate smart technologies in their customer relations and therefore differentiate their product portfolio from competitors [ZTF06]. As a conclusion, the insurance business might experience a paradigm shift from selling insurance contracts to selling "safety", which means that they decrease the probability of damage from an accident while insuring the remaining risk.

An open question for insurance companies is how to distribute the technology amongst customers. Active distribution using the existing channels of insurance agents is possible, although it is unclear whether insurance companies are interested in directly providing high-tech solutions to their customers. To hide the underlying technological complexity from both customers and insurance agents, third-party technology providers could mediate between both parties. A more detailed discussion of distribution options can be found in [KBZ07]. Finally, the applied technology can act like nerve endings for insurance companies by providing data from customers that was not available before. For example, an insurer would be able to tell whether the infrastructure for smart smoke detectors is active at a given moment or which detectors are broken. If an insurer states in the fire insurance contract that claims are unjustified in case of gross carelessness, and it is assumed that powerless smoke detectors are a gross carelessness, the insurer will not have to pay for insurance claims. In general, data coming from smart home environments has the potential to enable more fine-grained and risk-based ratings of insurance contracts. As an example, an insurance company could base insurance rates on the installation of smoke detectors. If customers are expected to buy the technology themselves, the insurer could offer reductions in premiums as compensation, even though this might not be of interest to insurers. On the other hand, demanding higher premiums from customers, who do not apply the technology, poses risks, that these customers will decide to change insurers and go with a competitor instead.

6 Conclusions and Future Work

This paper introduces the vision of smart smoke detectors. It describes what the underlying infrastructure looks like and gives examples of use cases that can be realized based on smoke detectors that are wirelessly connected and integrated with the Internet. The contribution shows that this vision can be realized only to a limited extent using state-of-the-art technologies and at high costs. In contrast, novel technologies like ZigBee create the opportunity to implement the same scenarios at lower costs and enable a variety of new scenarios. This paper outlines the value proposition of smart smoke detectors from several perspectives in addition to discussing the barriers and requirements. Based on the examination of various perspectives on smart smoke detectors, it can be concluded that the concept is very promising in terms of delivering high functionality at low prices, although there are still some barriers to overcome and requirements to meet.

As this work showed, there is a trend towards a legal requirement mandating the use of smoke detectors. Therefore, a solution based on smart smoke detectors could be one alternative for an emerging mass market. To better understand the requirements and expectations of house owners, a survey amongst end users is planned. In analyzing the gathered data, reasons for the low market penetration of conventional smoke detectors, success factors for innovative smoke detection systems and the willingness to pay for innovative solutions can be discovered. This will help understanding which functionalities are requested by end users at which price to successfully manufacture and sell a smart smoke detector solution to consumers.

Another open research field is the positioning of insurance companies. While the benefits of smart smoke detectors are obvious, it is still unclear to which extent insurance companies should be involved in the distribution and operation of the technology. In addition, it has not yet been examined which data coming from home environments is of interest to insurance companies. Therefore, additional expert interviews with insurers are necessary to explain the technological concepts to them and to better understand their interests. It also needs to be explored how data coming from smart home environments allows for a more fine-grained and risk-based rating of insurance contracts.

In addition, the business case for smart smoke detectors needs to be built. While this paper shows how emerging technologies can lower the infrastructure costs of smart smoke detectors, as a next step the lowest possible price for the infrastructure needs to be calculated. For example, the smoke detectors used for the calculation in section 4.2 could be replaced by cheaper models to cut costs. Then, the costs need to be compared with the willingness to pay of end users as well as the willingness to subsidize of insurers. This, in turn, gives insights on the existing monetary gap for a mass-application and in combination with a trend analysis for hardware costs, the development of the remaining gap can be analyzed over time. Finally, after examining the technology in more detail and verifying the business potential, a prototype implementation for a smart smoke detectors infrastructure becomes possible. As most components are readily available at fair prices and most of the work concerns integration tasks, a prototype can be built at reasonable costs.

As this research shows, smart prevention technologies will play an important role in the emerging Internet of Things and the outlined development is just starting. In particular, smart smoke detectors have the potential to be a success story for the application of ubiquitous computing technologies in residential buildings and the presented infrastructure can serve as the foundation for a variety of integrated prevention systems in home environments. While smart prevention technology has the potential to increase safety, it could also impact the insurance business. Risk reducing technologies and insurances for remaining risks can be seen as complementary and offer competitive advantages for early adopters. One open question is which competitor in the insurance market will be able to successfully incorporate the implications of the emerging Internet of Things into his business model first.

References

[Ab06] ABI Research (2006): Wireless Sensor Networks: Market Analysis of 802.15.4 ICs and ZigBee, Z-Wave, INSTEON, and Other Mesh Networking Protocols, New York.

[Ca02] Callaway, E., Gorday, P., Hester, L., Gutierrez, J., Naeve, M., Heile, B. and Bahl, V. (2002): Home networking with IEEE 802.15.4: a developing standard for low-rate wireless personal area networks, Communications Magazine, IEEE, Vol. 40, No. 8, pp. 70-77.

[CBM04] Coroama, V., Bohn, J., and Mattern, F. (2004): Living in a Smart Environment – Implications for the Coming Ubiquitous Information Society, Proceedings of the International Conference on Systems, Man and Cybernetics 2004 (IEEE SMC 2004), The Hague, The Netherlands, pp. 5633-5638.

[De05] Department for Communities and Local Government (2005): Fire Statistics, United Kingdom, London.

[Eu05] European Union (2005): Smoke alarm devices, DIN EN 14604:2005.

[Fo05] Forschungsgruppe g/d/p (2005): Einsatz und Akzeptanz von Rauchwarnmeldern in Deutschland. Ergebnisse einer bundesweiten Repräsentativbefragung, Fraunhofer IRB Verlag, Hamburg.

[Fo06] forsa - Gesellschaft für Sozialforschung und statistische Analysen mbH (2006): Umfrage zur Ausstattung von privatem Wohnraum mit Rauchmeldern in Deutschland.

[FW07] Filipova, L. and Welzel, P. (2007): Unternehmen und Märkte in einer Welt allgegenwärtiger Computer: Das Beispiel der Kfz-Versicherer, in: Mattern, F.: Die Informatisierung des Alltags, Springer Verlag, Berlin.

[Ge03] GFPA German Fire Protection Association (2003): Fire Safety Research - Position Paper.

[Ie06] IEEE (2006): IEEE 802.15.4-2006: Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs), New York.

[KBZ07] Kuehnert, D., Blath, J. and Zanetti, S. (2007): Statistische Tools zum Nachweis von Schadenminderungseffekten pervasiv einsetzbarer Lösungen, M-Lab Working Report Nr. 34, Zurich.

[Ko05] Koumpis, K., Hanna, L., Andersson, M. and Johansson, M. (2005): Wireless Industrial Control and Monitoring beyond Cable Replacement, Proceedings of the 2nd PROFIBUS International Conference, Warwickshire, UK.

[Ob03] Oberholzer, M. (2003): Strategische Implikationen des Ubiquitous Computing für das Nichtleben-Geschäft im Privatkundensegment der Assekuranz, PhD thesis, University of Basel.

[Ra98] Ramachandran, G. (1998): The economics of fire protection, London: E & FN Spon.

[SW01] Schmitz, G. and Witschital, P. (2001): Internet Technology: New Perspectives for Alarm Systems, Proceedings of the 12th International Conference on Automatic Fire Detection, Gaithersburg, MD, USA, National Institute of Standards and Technology, pp. 243-251.

[Tu07] Turolla, M. (2007): ZSIM: When Zigbee meets the Telecom Operator.

[ZF06] Zanetti, S. and Fleisch, E. (2006): Wertschöpfungs- und Positionierungspotentiale durch präventive Lösungen in Versicherungsunternehmen, M-Lab Working Report Nr. 30, Zurich.

[ZTF06] Zanetti, S., Thiesse, F. and Fleisch, E. (2006): Risk-Management in einer Welt von High-Tech und Low-Cost, M-Lab Working Report Nr. 29, Zurich.