Sustainable Wireless Computing – Designing Public Information Systems to Reduce Radiation Exposure

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Abstract. Wireless devices enable place independent communication and thus provide usability advantages. Often WiFi hot spots and mobile phone base stations are installed without proper discussion about health implications. Similarly, there is seldom discussion where it is allowed to use wireless devices. The electro-magnetic fields and microwaves related possible health risks are illustrated in this paper through research findings and radiation measurements. The research question here is, how wireless information systems can be implemented risk-free in public organisations like schools and libraries. The design research methodology is utilised and design rules are implied. In the conclusions chapter some practices to reduce radiation exposure are suggested.

Introduction

Mobile devices and wireless networks are part of our everyday life. Wireless city initiatives are often implemented because of their expected economic value. As clouds and zones spring up all over the world, municipal leaders and technologists are collaborating to explore how this powerful new technology can make their communities stronger (Shamps, 2004, 6).

Lyytinen and Yoo (2001) illustrate also social and organisational components of these wireless systems.

> A nomadic information environment is a heterogeneous assemblage of interconnected technological, and social, and organizational elements that enable the physical and social mobility of computing and communication services between organizational actors both within and across organizational borders. (Lyytinen and Yoo, 2001, 377)

Often this kind of nomadic information environment consists of many overlapping layers and technologies like Bluetooth, WiFi and 3G. Luff and Heath (1998) separate these layers to micro-, local- and distant mobility. Quite often the user is connected or exposed to many wireless networks simultaneously. In Europe, the European Union is eager to provide new spectrum for ever increasing demand for new wireless networks.

> Wireless communications is one of Europe's most dynamic technology sectors and underpins European society in areas as diverse as transport, security and environmental protection. The entire industry relies on radio spectrum – a 'raw material' in short supply. (EU - Radio Spectrum Decision 676/2002/EC)

This statement of EU officials emphasises environmental protection, but what about humans? How should these technologies be applied and used in a healthier way? This discussion has emerged especially when the European Environment Agency (EEA, 2007) recommended precautionary principle and indicated health risks in wireless technologies. In our own field, information systems, the discussion about health risks of wireless systems has been almost non-existent. The work of Lin (1997; 2001) is an exception. Word 'safe' is mostly linked to data security and most scholars seem to be more concerned about privacy than health. Instead of using word safe in this article, we use word sustainable and in generally, talk about sustainable wireless computing and information systems.

When thinking about public systems, many wireless initiatives propagate the virtues of mobility and creativity by installing hot spot to schools, libraries and parks in a cloud like manner (BBC, 2007). The users of these public services are often children, therefore we will take a closer look at health risks and demonstrate the radiation issues by measuring various devices. Before that we will explain, why we have selected design research methodologies. At the end of this paper we will provide design recommendations for sustainable wireless information systems.

Research setting

The research question here is, how wireless initiatives can be implemented to reduce radiation exposure in public organisations like schools and libraries. Since we are interested improving and even re-building existing information systems, our focus is on design research.

In his seminal work, The Sciences of the Artificial, Simon (1996, 113) argued that we need a science of design that is “tough, analytic, partly formalizable, partly empirical, teachable doctrine.” He believed that design theory is concerned with how things ought to be in order to attain goals, although the final goals of design activity might not be explicitly realized, and the designer could well proceed with a search guided by “interestingness.” In our study we present first requirements (health risks and related needs and rights to minimise exposure). Thereafter we will suggest a design of a sustainable information system.

According to March and Smith (1995), design science consists of two basic activities, build and evaluate. Building is the process of constructing an artefact for specific purpose; evaluation is the process of determining how well the artefact performs. In design science, computational and mathematical methods are primarily used to evaluate the quality and effectiveness of artefacts; however, empirical techniques may also be employed (Hevner *et al.*, 2004). In our work, the evaluation phase is significantly reduced, since we don’t have resources to build a real system. Therefore, we only suggest design rules (van Aken 2004, Bunge *et al*. 1979) in the Conclusions chapter.

Health risks and recommendations

Long-term exposure to pulsed microwave radiation is risky especially for children, because of their evolvings organs and radiation-sensitive meninx (BioInitiative, 2007).

However, children’s long-term microwave exposure has not been adequately researched. Most of the microwave research has focused on adults.

In adults the radiation induced by mobile phones has been reported to affect negatively the blood-brain barrier (Leszczynski *et al*., 2002) , DNA breakage (Diem *et al*., 2005), cognitive functions (Arnetz *et al*., 2007; Eliyahu, 2006) and fertility (Agarwal *et al*, 2008; Fejes *et al*., 2005). Of course, there are opposite results that indicate no such effects (e.g. Repacholi 2001; Koivisto *et al.* 2006). Based on current research findings, France recommended that parents should not purchase a mobile phone to their children and adults should use a hands-free equipment (Reuters, 2008). In Germany there is a similar kind of recommendation (BFS, 2007). The WHO report of Russia indicates certain risky frequencies used by mobile phones and base stations (WHO, 2007). Regarding WiFi, Sir William Stewart, who is responsible for radiation safety in the UK, recommends school not to engage WiFi (BBC, 2007). In Germany several states recommend not to install WiFi (aka WLANs) to schools and universities (Bundesregierung, 2007). Professor Lawrie Challis, who heads the committee on mobile phone safety research in the UK, emphasised that children should not use WiFi-devices on their lap. (MTHR, 2007). Since WiFi installations vary, Havas (2007) sees those city-wide clouds more risky than occasional WiFi hotspots. However, academic, well-argumented research papers are missing from this area.

Guidelines and radiation measurements

Next we will illustrate the behaviour of mobile devices by measuring several devices. The radiation power density levels of all these devices we measured comply with the existing ICNIRP (The International Commission on Non-Ionizing Radiation Protection) guidelines. However, these guidelines are rather old, which leaves some open questions:

> Although safety guidelines—to which mobile telephones and their base-stations conform—do protect against excessive microwave heating, there is evidence that the low intensity, pulsed radiation currently used can exert subtle non-thermal influences. If these influences entail adverse health consequences, current guidelines would be inadequate. (Hyland, 2000, 1833)

In other words, the current ICNIRP guidelines only restrict the intensity of the radiation to prevent tissue heating in excess of what the body’s thermoregulatory mechanism can cope with. The human body is an electrochemical instrument of exquisite sensitivity whose orderly functioning and control are underpinned by oscillatory electrical processes of various kinds, each characterised by a specific frequency, some of which happen to be close to those used in GSM (Hyland, 2000, 1834). These human body affecting non-thermal influences can be trickered in some experiments (Leszczynski *et al*. 2002, BioInitiative 2008, Hyland 2000) by certain frequencies of mobile devices and in lower radiation power density values than the ICNIRP guidelines allow.

According to Otto and von Mühlendahl (2007) the reproducibility of these non-thermal effects is usually poor, and no physiologic or pathogenic mechanism, so far, has been found to explain the alleged effects. Similarly, Lin (1997, 439) sees, that better understanding is needed of the mechanisms of interaction between RF/microwave radiation and biological systems, and of the significance of any observed effects.

These measurements took place at the University of Tampere during four days, in between October 2007 and June 2008, so the next figures are represent average values from these measuments. The instrument in use was Gigahertz HF 35C , a meter capable of measuring high-frequency electromagnetic fields between 800 MHz and 2,5 GHz. Commonly, UMTS-, GSM-, DECT- and WiFI –devices use this spectrum. The next values describe the power density of pulsed microwave radiation per square meter (µW/m²)

	Average value (from 1 m distance)	Peak value (from 1 m distance)
WiFi Access Point (on)	40 µW/m²	1850 µW/m²
WiFi in a laptop (on, downloading a large file)	10 µW/m²	450 µW/m²
GSM phone (on, in a call mode)	700 µW/m²	1500 µW/m²
GSM data (on)	1300 µW/m²	2500 µW/m²

Table 1. Various devices and their measured power density values

The measured WiFi access point (AP) produced 1850 µW/m² peak values, when the AP was turned on and there were computers connected to it wirelessly and some of these computers were downloading data. Technically the load was not heavy, in the heavier load peak values can variate between 5000-8000 µW/m², when measured from one meters distance (Moser 2005). These high data bursts may already produce symptoms like headache to some users close to APs, therefore the locating of APs has been an active discussion topic and APs have been removed for example in the City of Paris (Le Figaro 2007). The possibility of these symptoms is confirmed by studies focused on mobile phone masts, where symptoms start often from 400 µW/m² in long-term exposure (Navaro *et al*. 2003, Santini *et al.* 2003, Hacker ja Pauser 2007). The WiFi-laptop itself created 450 µW/m² peak values from one meter's distance. WiFi technology does not much raise average values, these remained in the level of 10-40 µW/m². Noteworthy in the WiFi is AP's capability in creating quite a high peak values (400-600 µW/m²) to four meter's distance.

So, is WiFi a risk for health? We definitely can not say for sure. There is hardly any research reports available regarding long-term WiFi use and health implications. Noteworthy is the research of Lee *et al*. (2005) where they used the serial analysis of gene expression (SAGE) method to measure the RF (Radio Frequency) effect on gene expression at the genome level. Their research used the 2.44 Ghz frequency found also in WiFi and provided following interesting results:

> We observed that 221 genes altered their expression after a 2-h exposure. The number of affected genes increased to 759 after a 6-h exposure. (Lee et al., 2005, 3829)

Time seems to be an important element in radiation studies, as shown by Lee *et al*. Lee et al. (2005) used an electric field of 320 V/m which is roughly 271000000 µW/m². So, their results cannot be directly applied to WiFi, because they used radically higher radiation power density.

For comparison purposes we measured also a GSM phone in a listening mode producing 700 µW/m² average and 2500 µW/m² peak values. Interestingly, the GSM phones change their radiation average value from 50 µW/m² to over 2000 µW/m² depending on the distance to the base station. So, the GSM phone automatically and radically adds transmitting power when the connection to the base station is poor. Therefore, using mobile phones far from base stations or in vehicles may be risky as demonstrated by Sadetzki *et al*. (2008).

GSM phone with data connection on raised the average radiation level to 1300 µW/m², from one meter's distance. This measurement proved difficult because of extensive frequency switching. We were not able to measure radiation values in a setting where the mobile phone is attached to user's head. These values are in tens of thousands of microwatts to hundreds of thousands of microwatts per square meter (see exact figures: Handywerte, 2008). In overall, our measurements and figures can be interpreted as indicative, not comprehensive

Conclusions

Within this paper we discussed about wireless technologies, provided a short overview of health risks and demonstrated how the mobile devices and their radiation can be measured.

As a summary, we can say that GSM- and 3 G devices seem to be risk-averse by radiation average values, while WiFi has high radiation peaks values 24/7 (BioInitiative, 2007). Noteworthy in mobile devices is the pulsed signal and extensive frequency jumping, which differs from TV- and radio signal, which is continuous.

Since we are utilising design research methodologies, we will next imply design requirements as basis of design rules.

If you want to achieve Y	**In situation Z**	**Then do X**
Minimal radiation exposure	In a place where children spent time.	Implement fibre optics - based solutions. Provide enough Ethernet cable slots for laptops. Do not allow WiFi or 3 G connections in that space.
WiFi access	Where WiFi is provided/needed.	Restrict this service to a certain area by adjusting the transmitting power of the WiFi access point. Inform users where WiFi is available 24/7 and where it is not.
3G or GSM access	Where needed	Keep the connection short. Do not use in places where devices are close to children or where there is poor connectivity (trains, busses etc.)
Make software work independent of connection	Accessibility and availability everywhere	Focus on software with replication and synchronisation features. Change programming and IS design models.

Table 2. Design rules of Sustainable Wireless Information Systems, based on Bunge (1967) and van Aken (2004).

If wireless connections pose even a minimal risk, their usage hours should be kept as minimal as possible. This is possible by using applications which do not constantly need connection to the network. If the wireless network connection (GSM data, 3G Data, WiFi) is used, it should be short and well-planned. Similarly, the distance of user to access points and devices should be maintained long enough, and the wireless device should definitely not be pressed against body or head. The space to use these connections should be clearly marked and it should be voluntary to enter these areas. Those systems that use synchronisation and replication are more favourable than systems requiring constant connection to the external server.

> “Replication is especially important in mobile environments, since disconnected or poorly connected machines must rely primarily on local resources. The monetary costs of communication when mobile, combined with the lower bandwidth, higher latency, and reduced availability, effectively require that important data be stored locally on the mobile machine.“ Ratner *et al*. (2001)

Replication questions have been earlier discussed in the context of adaptive information systems (Ahonen *et al*., 2005). In schools and libraries more sustainable alternative would be to provide enough Ethernet-cable slots instead of WiFi. Similarly, there may be a need for docking stations for PDAs and mobile phones (Soloway, 1999). In overall, asynchronous communication is more favorable than synchronous communication. Experience of mobility is embedded in an experience of temporality which includes mutually negotiated rhythms of contact, availability and accessibility (Churchill & Wakeford, 2002, 173). These practices may need some extra planning, but the end result may even provide time management advantages. In summary, sustainable wireless information systems are not too dependent on connection and external resources. These information systems are designed for low radiation power-density values and for minimal exposure time.

Discussion

This paper is our first attempt to address ethical questions and especially health risks in the use and implementation of ICT use. We were surprised how little academic publications about this topic is available. This may be due to the sensitivity of the research topic. We admit that our research is not complete one, our health risks related overview was not a complete one.

Since we needed to understand the phenomenon, we made a set of laboratory experiments, namely radiation measurements. The height of previously mentioned ICNIRP guidelines was another surprise to us. The allowable radiation power frequency values are over 4244031 µW/m². When we measured the devices from one meters distance, their radiation power frequency values were below 3000 µW/m². A specific question is raised here: Is it normal or healthy to live or work in a location where the radiation level from mobile phone base stations is the same as if the mobile phone would be continuously transmitting 1 meter or less from your body? We can not answer this question. According to Guangbin and Jingyuan (2004, 230), when 3G networks are deployed, the carriers should try their best to keep some important sites such as schools, hospitals, or residence buildings at a safe distance away from the base stations. Therefore, we suggest that the radiation levels in schools and libraries should be kept as low as possible. Additionally, we see that these radiation risks related topics should be discussed more in the public. Citizens should have more opportunities to decide when and where they are exposed to various wireless networks and devices.

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