

## Protecting Privacy in Context-aware Systems - Necessary or superfluous?

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Over the last decade the advances in sensing and tracking technology has led to a proliferation of our world and lives with sensors and mobile devices often connected by wireless networks. Today, applications on those devices such as cell phones or personal assistants go beyond telephoning, messaging, or maintaining address books as those devices often include various sensors. Those sensors might create spatial information (such as information on the user's location or speed, or information on horizontal/vertical orientation), environmental information (such as information on temperature, noise, or brightness), or personal information (such as information on user's body temperature, the blood pressure, or pulse frequency). All these information items describe (part of) the current context of the user. This context might also be determined by other, non sensor created information such as user profiles or preferences, temporal information (such as time of day, season, year), social or activity information (such as "in a meeting", "interviewing", or "at a party"), resource information (such as information on available wireless access, battery status), or explicitly or implicitly stated user goals of current activities ("have to be in Stuttgart by 9 am").

These new sources of information create broad opportunities for new applications and application classes. Most of these applications support people and organizations to better manage their tasks and business related issues. For example, based on the user's current location a navigation systems might help the user reach his/her destination in a timely manner.

This recent development of ubiquitous devices and applications that access, combine, and transform context information from different sources has lead to the class of **context-aware systems**. Baldauf et al. [BD04] claim that one of the first context-aware systems developed was the *active badge aware system* by Want et al. [WFG92]. They also trace back the term of context-aware systems to Schilit and Theimer who describe context as "...location, identities of nearby people, objects, and changes to those objects" [ST94]. Dey et al. gives a more general definition; they define context as "...any information that can be used to characterize the situation of entities (i.e. whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves." [ADB<sup>+</sup>99]. Using context information as an important source for configuring and driving the system behavior has lead to the class of *context-aware systems*. Baldauf et al. review and classify existing approaches to context-aware systems before developing a generic architecture to design and implement

such systems efficiently [BD04].

If these context-aware systems are predominantly location oriented we call them *location-aware systems*. Since location based information reflects and describes properties of real-world scenarios and situations it is important to develop *context models* that provide a general basis to interpret sensor based information in a coherent, consistent and meaningful manner. The NEXUS project is one example project whose goal is to "... to provide an infrastructure to support spatial-aware applications" [HKL<sup>+</sup>99] by developing "... methods and approaches for designing and implementing global and detailed (location-based) context models for mobile context-aware applications. Context models should include stationary as well as mobile objects of the real world. In addition, these objects should be complemented by virtual objects and services." (translated into English [REF<sup>+</sup>06]).

When people use location-aware systems to support them in their tasks they usually take those around with them. Thus, these systems reveal location information about the user since the location information created by a sensor is identical with the location information about the user of such system. If, for example, the location of a device (and therefore of the user) is transmitted to another system (let it be a mobile or stationary system) this information might be essential to perform a user-requested task such as helping two people to meet or to generate a list of nearby restaurant. However, such information might also be used to the disadvantage of that user, either at the time of transmission – for example to send unwanted advertisement – or at a later point in time - for example, to determine that the user violated the speed limit while driving a car.

It is the goal of our work to investigate these kinds of leakage of personal information from various points of view. Based on the general notion privacy we review existing approaches and systems which protect the privacy of users of such systems. Furthermore, we discuss a list of general privacy principles that - from our point of view - should guide the development of any context aware system that manages personal data thus giving the user the freedom and the control over his/her private data that (s)he shares with other systems. Finally, we briefly describe the EU-funded project PRECIOUSA (**P**rivacy **E**nabled **C**apability **I**n **C**o-**O**perative **S**ystems and **S**afety **A**pplications) as an example of a location-aware system to demonstrate how to protect private information in intelligent traffic information systems.

## Literatur

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