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Location Privacy in Ubiquitous Computing

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Abstract: The field of ubiquitous computing envisages an era when the average consumer owns hundreds or thousands of mobile and embedded computing devices. These devices will perform action based on the context of their users, and therefore ubiquitous system will gather, collate and distribute much more personal information about individuals then computers do today. Location information is a particularly useful form of context in ubiquitous computing, yet its unconditional distribution can be very invasive. This dissertation takes a different approach and argues that many location-aware applications can be function with anonymised location data and that, where this is possible, its use is preferable to that of access control.

Keywords: Ubiquitous Computing, Location Privacy, Location Technologies

I. INTRODUCTION

Researcher in the Computer Science Lab at Xerox's PARC (Palo Alto Research Center) first articulated the idea of Ubiquitous Computing in 1988. Ubiquitous computing is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user.

Ubiquitous computing, or Ubicomp, is the term given to the third era of modern computing. The first era was defined by the mainframe computers, a single large time shared computer by an organization and used by many people at the same time. Second, came the era of the PC, a personal computer primarily owned and used by one person, and dedicated to them. The third era, ubiquitous computing, representative of the present time, is characterized by the explosion of small networked portable computer products in the form of smart phones, personal digital assistants (PDAs), and embedded computers built into many of the devices we own – resulting in a world in which each person own and uses many computers. Each era has resulted in progressively larger numbers of computers becoming integrated into everyday life. Figure 1 represents the eras of modern computing [1].

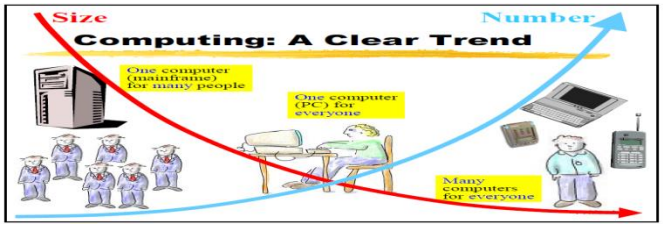

Fig 1 Three Eras of Modern Computing

Ubiquitous computing is a concept in software engineering and computer science where computing is made to appear everywhere and anywhere. In contrast to desktop computing, ubiquitous computing can occur using any device, in any location, and in any format. A user interacts with the computer, which can exist in many different forms, including laptop computers, tablets and terminals in everyday objects such as a fridge or a pair of glasses. The underlying technologies to support ubiquitous computing include internet, advanced middleware, operating system, mobile code, sensors, microprocessor, new I/O and interface, networks, mobile protocols, location and positioning and new materials. The idea behind ubiquitous computing is to surround ourselves with computers and software that are carefully tuned to offer us unobtrusive assistance as we navigate through our work and personal lives. Contrast this with the world of computer as we know them now.

II. CONTEXT-AWARE COMPUTING

Context-aware computing was first discussed in1994 by Schilit and Theimer as software that "adapts according to its location of use, the collection of nearby people and object, as well as changes to those objects over time." Context is any information that can be used to characterize the situation of an entity. Applications that use context, weather on a desktop or in a mobile or ubiquitous computing environment, are called context-aware [2].

Dey and Abowd (2000a) define context awareness more generally with the following statement: "A system is context-aware if it uses context to provide relevant Information and/or services to the user, where relevancy depends on the user's task."

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The promise of context-awareness is that computers will be able to understand enough of a user's current situation to offer services, resources, or information relevant to the particular context. The attributes of context to a particular situation vary widely, and may include the user's location, current role (mother, daughter, office manager, soccer coach, etc.), past activity, and affective state. Beyond the user, context may include the current date and time, and other objects and people in the environment. The application of context may include any combination of these elements [3].

The Active Badge system was the first context-aware system. In this application (Figure 2), users wore Active Badges, infrared transmitters that transmitted a unique identity code. As users moved throughout their building, a database was being dynamically updated with information about each user's current location, the nearest phone extension, and the likelihood of finding someone at that location. When a phone call was received for a particular user, the receptionist used the database to forward the call to the last known location of that user, rather than blindly forwarding the call to the user's office, where he may not be located. This application, along with much of the early work in context-aware computing was focused on location-aware computing, or, as they are more commonly known today, location-based services [4].

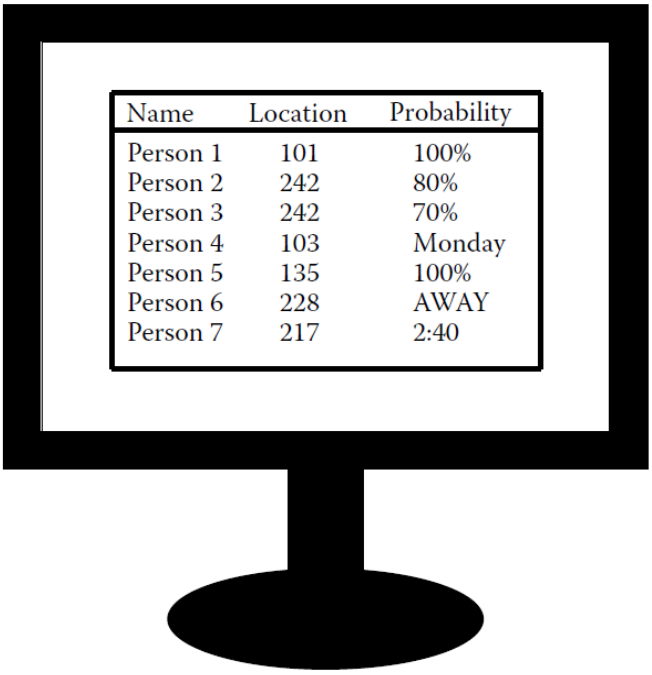

Fig 2 Rendition of the original Active Badge application showing the location and certainty of Active Badge wearers.

III. LOCATION TECHNOLOGIES

Location technology is a combination of methods and techniques for determining a physical location of an object or a person in the real world. Location-aware applications use the location of the target to add value to the services they provide. The ability to determine a user's location enables a variety of ubicomp applications that provide services and functionality appropriate to the specific location and context. Today, people use location-aware applications in almost any life domain, including entertainment, navigation, asset tracking, health care monitoring, and emergency response [5].

A. Location Representation

Location is a position in a physical space and it can be represented in absolute, relative, or symbolic form.

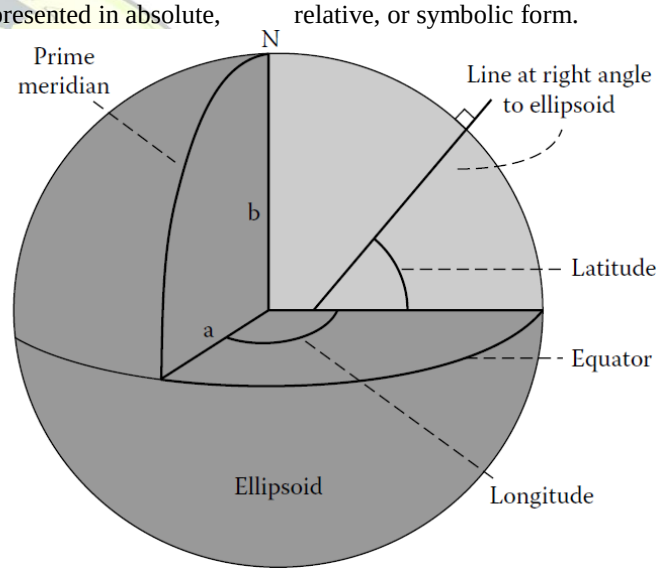

Fig 2: An example of a latitude and longitude angles to a point on Earth.

The most common means of specifying a precise absolute location is using the points' degrees of latitude and longitude on the surface of the Earth, as defined by the geographic coordinate system. If Earth were a perfect ellipsoid, the latitude would measure the angle between the point and the equatorial plane from the center of Earth. In reality, however, the latitude, or the geodetic latitude, measures the angle between the equator and a line that is normal to the reference ellipsoid, which approximates the shape of Earth. The longitude measures the angle along the Equator to the point. A line that passes near the Royal Observatory, Greenwich, England, is accepted as the zero-longitude point and it is called the Prime Meridian. Lines of constant latitude are called parallels and lines of constant longitude are called meridians. Meridians, unlike parallels, are not parallel and all intersect at the North and South Poles. This

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form of representation is often used in outdoor location systems such as GPS. See Figure 2 for an example.

B. Infrastructure and Client Based Location Systems

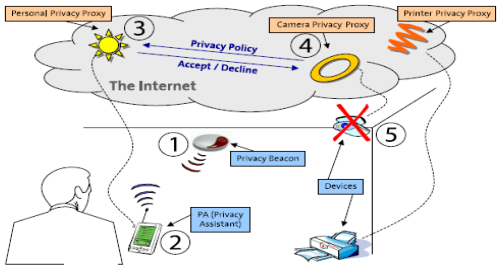

Fig 3: Overview of Privacy Management System.

There are three classes of location systems: client-based, network-based, and network-assisted. In a client-based location system, a device computes its own location without relying on the network infrastructure. An example of a client-based location system is GPS, in which a device equipped with a GPS chip calculates its own location using signals received from at least four GPS satellites.

In a network-based location system, the network infrastructure calculates the position of a device. An example of a network-based location system is the Active Badge system (Want et al., 1992), in which a badge carried by the user emits infrared (IR) signals captured by the IR receivers in the ceiling. The receivers, in turn, transmit signal data to a networked processor that computes the badge's location.

In a network-assisted location system, both the device and the infrastructure participate in computing the location of the device. An example of a network-assisted location system is the Assisted GPS, in which a device calculates its own location based on its GPS measurements and additional information about the GPS constellation received over the cellular link from the cellular network infrastructure.

IV. Privacy In Ubiquitous Computing

To build ubicomp systems that are privacy-aware or privacy-respecting, one obviously has to first define what exactly is meant by privacy. A privacy can be defind as: .a key value which underpins human dignity and other key values such as freedom of association and freedom of speech [6].
Privacy Awareness System (pawS)

Figure 3 shows an example of pawS in operation: Upon entering in an ubicomp environment with a number of available services a privacy beacon (1) announces the data collections of each service and their policies using a wireless communications channel such as Bluetooth or IrDA. In order to save energy, the mobile privacy assistant
(2) the user is carrying delegates this information to the user's personal privacy proxy residing somewhere on the Internet
(3), which contacts the corresponding service proxies at their advertised addresses
(4) and inquires their privacy policies. After comparing those privacy policies to the user's privacy preferences, the user proxy decides to decline usage of the tracking service, which results in disabling the location tracking service of the video camera

V. Conclusion

Not all applications can be written to use anonymised (or indeed pseudonymised) location data; therefore access control methods are still required in particular instances. However anonymised location data can enable a large class of location-aware applications. A significant subset of this class of applications can also provide services to the user with reduced temporal or spatial accuracy of data.

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