Positioning Technologies for Mobile Computing

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INTRODUCTION

Mobility is, as the name suggests, the defining characteristic of mobile computing and the primary differentiator between it and other computer usage paradigms. Traditionally, computers were used in what may be termed a static context. However, when computers are used in a mobile context, a number of difficulties that challenge traditional assumptions emerge. Not least amongst these are those difficulties that arise in delivering a service that is relevant and consistent with the situation in which the end-user find themselves. Should a person be waiting at a bus stop, he or she does not wish to go online and browse a bus timetable. Rather, he or she wishes to know when the next bus will stop at his or her particular stop. Thus location and time would be fundamental to the provision of such a service. Capturing time provides no major difficulties. However, identifying the physical location of a service subscriber may prove problematic.

In this review, we summarize some of the key technologies that enable the position of a mobile computer user to be determined.

BACKGROUND

Research in mobile computing and associated disciplines (Vasilakos, 2006) began in earnest the 1990s as the feasibility of the paradigm became increasingly clear. As the various research issues began to crystallize, researchers became aware of the desirability of using additional known facts of the end user's prevailing circumstances as a basis for customizing or personalizing the service for the individual end user. The term *context-aware computing* was coined to conceptualize these ideas. Pioneering research in this area was conducted at Xerox Parc in California by Schilit Adams, and Want (1996). The Oxford Concise dictionary defines context as "the interrelated conditions in which something exists or occurs." Intuitively, everybody understands what context is. Almost paradoxically, this has made the derivation of an agreed definition almost impossible, leading some researchers to reconsider its philosophical roots (Dourish, 2004) and inherently dynamic nature (Greenberg, 2001). One issue commonly agreed is that a person's location or physical position forms an indispensable aspect of his or her context—so much so that Schmidt, Beigl, and Gellerson (1999) almost remind researchers that there are other aspects of context that should be considered. The reasons for researchers' enthusiasm are understandable. In the mid-1990s, the global positioning system (GPS) was deployed, making it possible to determine position to within 100 meters for those people equipped with a GPS receiver. Thus the technological issues were being addressed in a meaningful way. However, it was developments in wireless telecommunications that provided the spur for the upsurge in business interest in what would be termed location-aware computing (Patterson, Muntz, & Pancake, 2003).

In 1996, the Federal Communications Commission (FCC) in the United States announced the E-911 directive. In brief: this obliged public telecommunication network operators to provide the position of those people making emergency calls, thus enabling police, medical, and other personnel to react quicker. It soon became clear that this facility could have other uses for commercial purposes as, in principle at least, the location of any subscriber could be identified. Thus an era of location-aware services was anticipated. This era has yet to materialize, but as outstanding technological issues are continually being addressed, it is only a matter of time before a suite of location-aware services are available for subscribers.

To deliver location-aware services, it is necessary that an appropriate technology be selected that will provide a subscriber's position within a certain range. In the next section, some of the principal technologies for determining position are described.

TECHNOLOGIES

Various technologies and techniques are described in the academic literature for determining user position. Naturally, each has its respective advantages and disadvantages. For the purposes of this discussion, it is useful to classify them as

satellite techniques, cellular network techniques, and hybrid. Each classification is now considered briefly.

Satellites Technologies

Trilateration is the basic principle for determining position using satellites. In short, the time taken for a signal to travel from a satellite at a known position to a receiver is calculated. This process is repeated for three satellites and a solution can be generated. In practice, a fourth measurement is necessary to account for the lack of synchronization between the atomic clocks on the satellite and the receiver's internal clock. The accuracy of the resultant calculation may vary due to a number of factors, including atmospheric conditions and the satellite constellation configuration. However, a reading within 20 meters of the receiver's exact geographic position may be realistically expected.

At present, there are two satellite systems in operation that broadcast signals:

1. *Global positioning system* was deployed in 1996, covers the entire earth, and is freely available. It remains under the control of the United States military. It is currently the de facto standard with specialized receivers on the market for all kinds of purposes including aviation, maritime, and leisure. To use GPS, a mobile computer user would acquire a receiver, usually in the form of a Compact Flash (CF) card. More recently, receivers are sold as separate devices that can interface with any device that supports the Bluetooth protocol stack. Interestingly, a significant number of mobile phones on the market support Bluetooth, thus offering one scenario for providing location-aware services to mobile phone users.
2. *GLONASS* was developed and deployed by the former USSR in competition to GPS. For a number of years, it was not adequately maintained. However, this situation has changed recently, and GLONASS is currently being overhauled and restored to its former state. There are very few commercial products available that use GLONASS at present.

A third satellite navigation system is scheduled for launch in 2008. *GALILEO* is an initiative by the European Union (EU) that seeks to deliver a similar service to GPS and GLONASS, but with adequate guarantees regarding signal reliability. It is designed for purely civilian and commercial use, and unlike GPS and GLONASS, it is not controlled by defense or military groups. However, the signal broadcast will be compatible with GPS and GLONASS, and it is hoped that receivers that can utilize all three systems will developed.

Cellular Network Techniques

E-911 obligated network operators and, implicitly, telecommunications equipment manufacturers to facilitate the determination of a subscriber's position within an emergency call context. A number of *cellular network techniques* were proposed as a result of ongoing research, and Zhao (2002) provides a useful overview of these. The Third Generation Partnership Project (3GPP) proceeded to standardize on four different techniques for third-generation (3G) UMTS (Universal Mobile Telephone Networks) networks (3GPP, 2005):

1. In *cell-ID*, the geographic coordinates of the base station serving the subscriber are identified. The position of the subscriber must be within the radius of this cell. Though this method is easy to implement, its principle limitation concerns the variability in cell size. Thus the precision with which the subscriber's position is calculated may range from tens to hundreds of meters.
2. *Observed time difference of arrival (OTDOA)* requires the handset to measure the time taken for a signal to arrive from three separate base stations. Hyperbolic curves must be constructed, and their intersection indicates the position of the subscriber. Though computationally expensive, a particular difficulty involves guaranteeing that the subscriber can see three base stations simultaneously. OTDOA is highly susceptible to fading and interference.
3. *Assisted GPS (A-GPS)* involves the handset measuring GPS signals from satellites. Initially, the handset is informed as to where to look for the signals, thus minimizing delay in signal acquisition. The signal measurements are then returned to the appropriate component on the network where the position is calculated. Though increasing power consumption on the device, users can expect position readings comparable with GPS.
4. *Uplink time difference of arrival (UTDOA)* is similar in principle to OTDOA, but in this case, the signals are generated at the handset and measured at a number of base stations. As the geographic positions of the base stations are known, the position of the subscriber can be calculated using hyperbolic trilateration.

With the exception of A-GPS, the accuracy of a position obtained using these techniques is variable and unpredictable. In the case of the cell-ID method, urban areas will have a concentration of base stations so the method may work well. In contrast, the diameter of cells in rural areas may be several kilometers, thus rendering the method ineffective. In the case of OTDOA and UTDOA, accurately measuring