

Position Location in Mobile Environments

Prashant Krishnamurthy

Telecommunications Program

University of Pittsburgh, Pittsburgh, PA 15260

prashant@tele.pitt.edu

Position Statement

In the ubiquitous and pervasive computing environment that is the focus of this workshop, one of the issues to be considered is *location awareness* and its impact on data. For example depending on the location (previous, current and future), the meaning of data could change; their relevance might increase significantly or drop drastically; the data may need refreshing; the granularity of values may differ; and so on. In order to correctly determine the nature of such changes and how they influence the applications, algorithms, and platforms for pervasive computing, it is important to determine the location of the mobile terminal. In determining the location of the mobile terminal, there are several challenges and open research problems. The evolving technological and regulatory trends also influence these problems and will need to be considered.

Introduction

Position location, geolocation, and radiolocation are terms that are widely used today to indicate the functionality and procedures to determine the location of a mobile terminal. “Location” here could imply the coordinates of the mobile terminal that may be in two or three dimensions, and could include information such as the latitude and longitude where the mobile terminal is located. In indoor areas (within buildings), alternative coordinates and visualization techniques may be employed. Position location technologies are gaining prominence in the wireless market for several reasons, primarily the United States Federal Communications Commission (FCC) mandate requiring all wireless cellular carriers to be able to provide the location of emergency 911 callers to a *public safety answering point* [1]. However, position location technology has significance for both military and commercial applications beyond just emergency location. Examples of commercial applications include the need for hospitals to locate patients and equipment in a timely fashion, in homes to locate children and pets, and providing *location aware* services (concierge services etc.). In the military and public sector, enabling soldiers, policemen, and fire fighters with knowledge of their location and the location of other personnel, victims, exits, dangers, the enemy etc. proves to be invaluable. Recently, there have been proposals to use position location information for improving the performance of several mobile network operations [2-4]. Position location involves using characteristics (time-of-arrival, angle-of-arrival, signal strength, or RF fingerprinting) of radio signals transmitted by, or received at known locations to determine the coordinates of a mobile terminal.

Challenges and Issues in Position Location in Mobile Environment

In this section we will broadly outline and classify some important challenges and issues in locating the position of mobile terminals. These span a variety of different areas ranging from technical difficulties to questions related to privacy and security. We shall see below that many of the issues are inter-related.

- a. Performance:** If we consider position location as a separate infrastructure overlaid to support applications in a mobile environment, several performance measures [5] need to be considered. The *accuracy* of the location information (the error in the estimated location is the mobile terminal), the *delay* in making the position location estimation (delay in making the position location and conveying this information to the requested party), the *capacity* (how many requests for location estimation can be processed in unit time) and *coverage* (the area where the position location service is available) are important performance measures. The accuracy of position location information depends on the technology employed, the characteristics of the radio channel [6], the bandwidth, and complexity of signal processing techniques employed. The infrastructure capabilities influence the delay, capacity and coverage. Very little work has been done to evaluate the performance of position location systems.
- b. Cost and complexity:** Deploying position location systems will require additional costs on top of the communications infrastructure. The costs arise from the infrastructure, need for additional bandwidth for position location purposes only, adding fault tolerance and reliability to the system and the nature of technology deployed. The bandwidth cost and part of the infrastructure cost could be reduced by reusing the communication signals for position location (in-band positioning) but as the signals are not designed for this purpose, the accuracy may be poor. There are tradeoffs between accuracy and complexity even for out-of-band positioning. In the case of RF fingerprinting, the size and location of databases containing the fingerprint information can have an impact on the cost, delay, accuracy, and capacity of the positioning system. The infrastructure cost could be reduced by having an umbrella positioning system that covers a large area. As in the case of cellular systems, this could affect the power consumption and capacity depending on the coverage of the positioning system. Having localized positioning systems, while solving the capacity and power consumption problems, could increase infrastructure and backbone signaling costs. The *global positioning system* (GPS) has been the most successful positioning technique in outdoor areas and we now see the GPS receiver as a relatively inexpensive commonplace gadget. While GPS has been hugely successful, it also has several drawbacks for use in several applications, especially in dense urban and indoor areas.
- c. Application requirements:** The applications in the mobile environment and data that is distributed may have different position location requirements. The major requirements are the granularity of position location information, the accuracy, performance, and where such information is available. Granularity could be temporal (how often the position location information is needed) or spatial (to what level of detail the information is required). The application may be delay and accuracy sensitive in which case the performance aspects become crucial. Positioning systems could be remote-positioning (an entity in the backbone infrastructure determines the location of a mobile terminal) or self-positioning (the mobile terminal determines its own location). The application requirements will influence the nature of the positioning system deployed. There are privacy issues in the remote-positioning systems. In self-positioning systems, the mobile terminal has to perform additional computation and processing that could affect its battery life. Certain technologies are also more difficult to employ at the mobile terminal.

- d. Security:** Privacy of location information is considered essential as this could provide extensive knowledge of the activities of any individual whose location can be continually tracked. In the case of remote positioning systems, this is particularly significant. Here, a mobile terminal transmits signals with the intent to enable their capture and processing to derive position location information making it very difficult to secure such signals. Also, if communication signals are reused for positioning, they may have to be intentionally kept open resulting in security breaches. Even in the case of self-positioning systems, the mobile terminal will have to convey its position location information in some form to obtain useful data that is location dependent. In this case, it may be possible to develop security protocols to prevent unauthorized sources from obtaining the information. There must be provisions to prevent misuse of the position location information by service providers involved in providing location dependent information. When mobile terminals move across boundaries of control, the security of their location information becomes even more important.

Conclusions and Discussion

In a pervasive computing environment *location awareness* has impact on applications and data distribution. There are several aspects of position location that need to be considered while developing applications, algorithms, and protocols for pervasive networking such as performance, cost, complexity, application requirements and security. Very little work is available that considers in-depth investigation of these issues and challenges. Depending on the mobility of the terminal, the impact of these factors may change. The tradeoffs between various application requirements, performance measures and cost are not understood very well. They could be influenced by emerging technologies and regulatory restrictions. For example, the use of ultra-wide band (UWB) signals for position location purposes alone could be attractive as they have the capability of precision ranging and they can also be overlaid (in an unlicensed manner) on existing spectrum eliminating the need for additional spectrum. However, there is a possibility that there may be regulatory restrictions on the power and coverage of UWB systems. Another issue that requires close attention is the relationship between the temporal and spatial granularity of position location information and the accuracy of the position location information.

References

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