Location Aware Computing

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Abstract

Location aware computing are the ability to find the geographical location of the mobile device and provide services based on this location[i] information, and now many researchers consider location aware to be the key concept of mobile computing environment. In this paper, we discuss about the basic concept of location aware computing, its technical methods and architectures, case study, brief outlook, and challenges and issues.

1. Introduction

The Web technologies have expanded rapidly in many business fields. Like Amazon and CDNow, pure dot coms have promoted the single price and availability metric for every product, as if there were one giant warehouse serving up for customers anywhere in the world.

On the other hand, in the physical world of stores, scattered supply chains and distribution centers, location cannot be ignored. Because most store chains do not have the same product availability within each store. Moreover, pricing and promotions for a certain product may differ by region, city or store.

The key point is that unlike the dot comes if we can take advantage of this physical location metric, it would revolutionize the way of business in the Internet for regular companies. As an example, some companies, such as Circuit City and Office Depot, provide the number of laptops at store(s) pre-selected by the customer with a maximum of three. In the better scenario, the Web site shows the detail about which stores within a convenient radius of the customer's location would have the laptop in stock. And now, with the WAP and devices with the ability to determine their own location in automatic way, we can make the above scenario much more ideal.

In the near future, it will be a standard for every computer operating system to aware the location of the computer it is running on, just like every operating system of these days knows the time [1].

In this sense, it is essential to build wireless computing environments and web applications that are location-centric, which will be the key notion for the near future.

In this paper, we briefly discuss about the basic concept and environment of location aware computing and how information is presented to customers. We focus on how each mobile computing device is aware of its current location in the section of sensing

[i] The term **position** is also used as the same meaning with the **location** in this paper.

techniques. Then, we explore a case study called Portable Help Desk [12]. Finally, the challenges and problems are listed.

2. Related Work

In this section, I briefly list a couple of different kinds of location aware systems developed so far to have a chance to taste of the concept.
C-MAP [3] is a tour guidance system, which is based on location and individual interests, provides information to visitors at exhibitions. CyberGuide [4] is a collection of intelligent tour guides that provide information of tourists based on their position and orientation. Metronaut [5] is an application developed for schedule management and guidance instructions for a visitor to a university campus. City Guide [6] enables a user to see his position on map and request information about the city. These systems are using predefined content based on location.
The Olivetti Active Badge [7] was used in an office environment. Members of staff wear badges that transmit signals providing information about their location to a centralized location service, thorough a network of sensors. Augmentable Reality [8] allows users to dynamically attach digital information such as voice notes or photographs to the physical environment. Audio Aura [9] provides information via auditory cues based on people's physical actions in the workplace. These systems use predefined locations.
The Forget-Me-Not [10] is a wearable device that records interactions with people and devices, and stored this information in a database for later query. The Remembrance Agent [11] provides text information relevant to the user's context, for example class notes when entering a specific classroom. These systems associate the location information with user's past events to remind them.

3. Overview of Location aware computing

Location aware computing defines the environment that utilize the information about the current location of the person using location aware devices. Ideally the information provided should be both location-specific and personalized based on the personal profile of the user. To get more clear understand of location aware computing, let's recall the two different location abstraction levels.

- **Location-transparent:** This abstraction level completely hides the effects of mobility to applications and users. Network services and resources can be transparently accessed by means of a resource and service broker function that maps the application's service type requests on adequate service provider instances. Thus, Applications operating in this level of abstraction have higher priorities.
- **Location-tolerant**: This abstraction-level allows applications and users to tolerate those effects of mobility that cannot be hidden by the platform. Reasons can be congestion of radio cells, degradation of radio link qualities or change of terminals in case of user mobility.

Unlike these two abstraction levels, **location aware** allows applications and users to be aware of their mobility and the absolute and relative physical positions of real-world objects. Applications can take advantage of this information for customizing their functionality, and users can benefit from this information for navigation or different purposes.

There are two different ways of approach to the location aware computing. [14]

The first approach is client based which is that the mobile devices are in charge of determining their locations. Some tracking means like GPS is involved. This approach is most widely used and relatively accurate, yet requires lots of computing power on mobile devices.

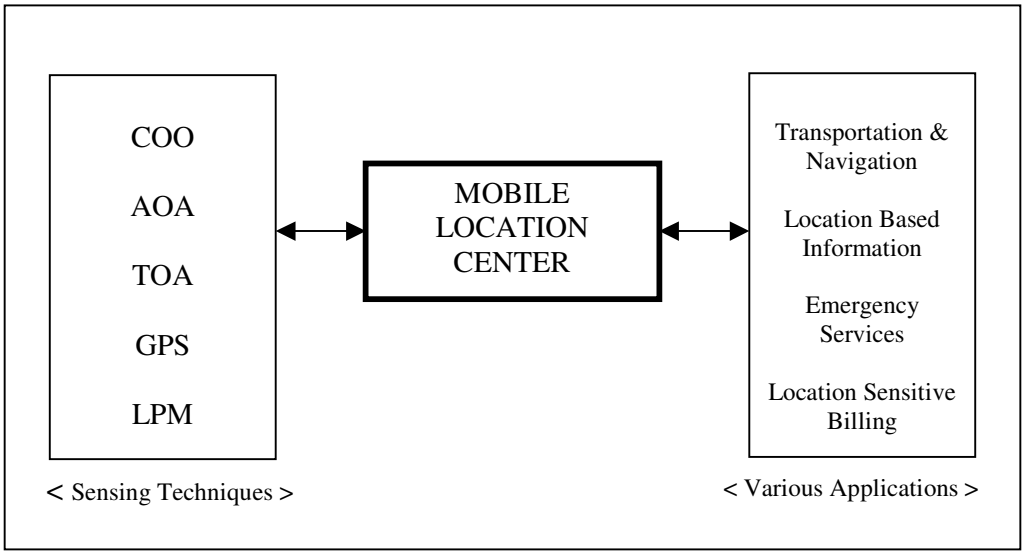
The other approach is server based which is to keep the mobile devices as simple as possible and make use of the fact that it receives the location information from the network of a certain area. This approach makes the mobile devices much more light-weighted, yet limits the amount of accessible data and available area working location aware.

The key factor of realizing the location aware computing is obviously how to let the devices determine their location in automatic fashion. Location of the user can be generally determined using a number of methods. Some of these methods include Cell of Origin (COO), Time of Arrival (TOA), Angle of Arrival (AOA), Global Positioning System (GPS), and Location Pattern Matching (LPM). We will see more detail later.

Location information, usually in terms of a latitude/longitude pair (or sometimes, a postal code for a cell site), is sent to the application in a server or back in the client device, sometimes through middleware that manages the security and quality of a wireless determined location.

In the applications, location of the user is transmitted with some additional identifying information (Vehicle ID, handset ID, user ID) to an application in a server that may reside inside or outside of the carrier's network to provide relevant information with the ID. The location information may be further tied to a database servers like restaurants, hotels or stores that may want to send an advertising message or a coupon to the consumer. From this point on, range of applications is only up to the imagination of technology and business developers.

4. General Architecture



<Figure 1> General Architecture of Location aware computing.

Mobile Location Center (MLC)
The architecture is based upon mobile location center (MLC). The MLC separates the location technologies to locate the device from the application that the location information will be put into. MLC manages the overall coordination and scheduling of resources required to perform location of a mobile devices. It also calculates the final location estimate and accuracy. In one Public Mobile Network (PMN), there may be more than one MLC.
With this flexible architecture in place, network operators can apply new applications independently.

5. Location Sensing Techniques

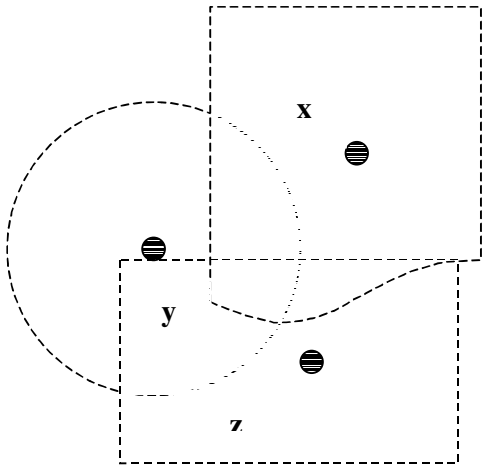
5.1 Classification [13]
The obvious technology needed in providing location aware computing is getting to know the location or the position. The three principal classification of automatic location sensing are proximity, triangulation, and scene analysis.

Proximity
A proximity location sensing technique determines the object's location when it is near known location. The one of the approach is to monitor when a mobile device is in range of one or more access points in a wireless cellular network. COO will be explained as an example.

Triangulation
Triangulation can be subdivided by lateration and angulation.
Lateration uses distance for determining the position, while angulation uses angles.
To measuring the distances required by the lateration technique usually uses time of flight and attenuation and the attenuation. Time of flight means that with known velocity we can measure the time it takes to travel between the object and point P. For the attenuation, the intensity of an emitted signal decreases as the distance from the emission source increases. In environments with many obstacles such as an indoor office space, attenuation is less accurate than time of flight.
Angulation uses angles instead of distances. A constant reference vector like magnetic north is chosen as 0°.
TOA and AOA will be explained as the one of the examples.

Scene Analysis
The scene analysis location sensing technique uses features of a scene observed from a particular area to analyze and compare the location of the objects in the scene. The observed scenes are simplified to obtain features that are easy t represent and compare. One way of doing this is to having predefined dataset for the certain area and map the observed scene to it. LPM is the example of the method.

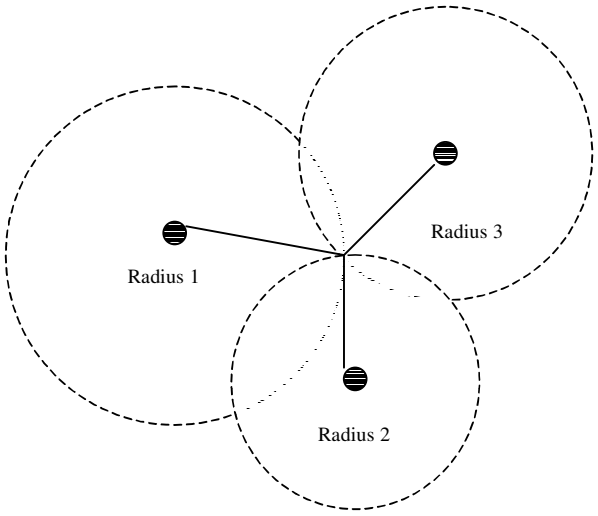
5.2 Examples



< Figure 2 **>** Different cells may have different shapes. ‘x’, ‘y’, and ‘z’ are the objects that have connectivity to one or more cell.

Cell of Origin (COO)
For COO positioning, the location of the base station is ascertained and considered to be the location of the user. COO is a variable and not a very precise locator; depending on the number of base stations in the search area, accuracy may be as close as within one hundred meters of the target (in an urban area) or as far off as thirty kilometers away from the target where base stations are less densely concentrated. For this reason, when precision is important COO is often used in conjunction with some other technologies, such as the Global Positioning System (GPS) or Time of Arrival (TOA).

Although COO positioning is not as precise as other methods, it offers unique advantages that it can very quickly identify the location (generally in about three seconds) and does not require equipment or network upgrades, which makes it easily deployed to existing customer bases, hence it is comparatively cheap to deploy.



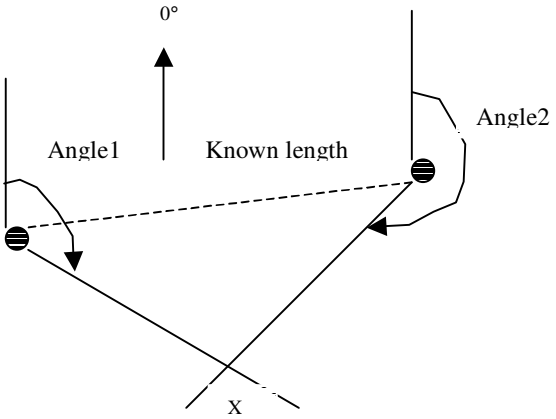
< Figure 3 **>** Determining position using distance.

Time of Arrival (TOA)

The Figure3 shows that the signal arrival time differences from the mobile to more than one base station are used to calculate the location of the device. This method needs synchronization of cellular network using very expensive atomic clocks at each cell sites. The cell sites are using location measurement units (LMUs). By measuring the signal from the mobile device, the LMUs can triangulate the user's position. Here is how.

The wireless device' s signal is received at various base stations. Since each base station is a different distance from the device, the signal arrives at a slightly different time. The technique requires signal timing information from at least three different base stations. The receivers, synchronized by the atomic clock, send the user' **s**ignal and timing data on to the LMU, where the times are compared and computed to generate a latitude and longitude for the user's device by triangulation.

The cost benefit analysis is not very much in favor of the usage of this technology, as the cost of implementing this is very high as compared to the enhancement in the performance. While TOA is more accurate than COO technology, it is expensive because of the large number of LMUs required.



< Figure 4 > Using angulation to locate a position

Angle of Arrival (AOA)
AOA requires also a complex antenna array at each cell site. These antennas are doing main work together to determine the angle from which a cellular signal is originated. The wireless device's signal is received at various base stations' antenna. Each site is equipped with additional gear to detect the angle from which the user's signal is arriving. Generally, at least three sites must receive the signal to provide an accurate location. Then, the receivers send the compass data to the LMU, where the angles are compared and computed to generate a latitude and longitude for the user. The Figure 4 shows how angulation method works. Since the only difference from TOA is to use angles instead of time of flight, this method does not much differ from the TOA.

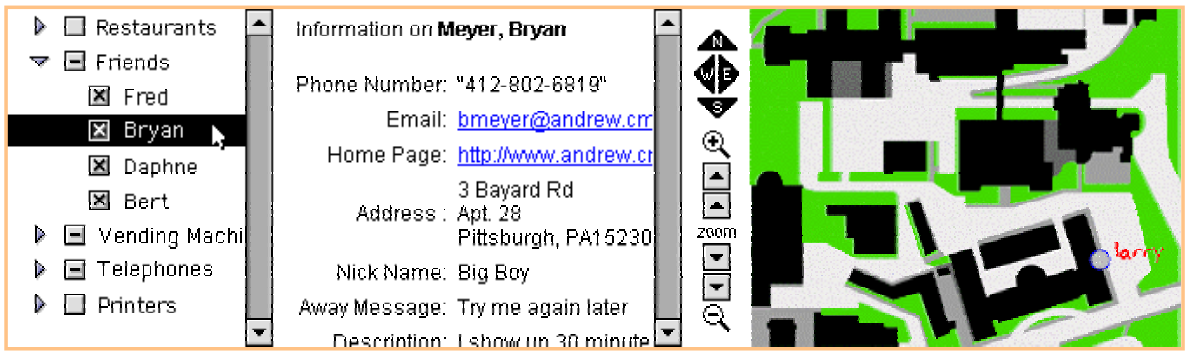
Location Pattern Matching (LPM) [13]
The technique is effective in urban environments that include tall buildings and other obstructions, where other techniques might not succeed. LPM exploits this distortion of the signal caused by the obstacles.
The wireless device's signal is reached at the base station equipped with special gear, and the receivers send the signal to the special LMU, where sophisticated equipment analyzes the acoustic radio signal and compares it to a database of previously identified locations with standard signal characteristics, and match is made. These characteristics include signal reflections like multi-path, echoes and other signal anomalies.
The LPM eliminates the need for line of sight triangulation involving multiple cell sites. This is particularly important in dense urban environments where buildings tend to obstruct the line of sight, and in sparse rural environments where it is unlikely that three or more base stations will be available to receive the signal.

Global Positioning System (GPS)
While the methods that we have looked at so far are network based, which is that the location calculation is performed at network, GPS is mobile device based. Here is how. Wireless subscriber must use a device specially equipped with GPS receiver to make a signal of current location. Either continuously or when a signal is placed, the GPS receiver determine the device's latitude and longitude using data such as distance and orbital map received from at least three satellites. The receiver can use this information

to plot a radius, with the satellite as the center. It knows that the distance is "*X*" miles from a particular satellite, so a line can be "drawn" from it' s location towards Earth. Using the same method for all three satellites, your receiver can find a point that intersects with all three radii. This point is your GPS receiver' s location and is usually updated at least once every second, depending on the receiver model.
GPS is the most widely used method, because it is available to users anywhere on the earth and provide three dimensions of information without any network support. However, when getting inside a building or under a wet tree it' s likely not to work at all. Most of all, the GPS receivers consume battery too much.

6. Case Study: Portable Help Desk [12]

The Portable Help Desk (PHD) developed by Carnegie Mellon University "allows a user to determine the location of other users on campus as well as information about them. It also provides other services such as notifying the user of the closest available printer or where food might be available."
The following figure shows the screen shot of the PHD.



< Figure 5 > Portable Help Desk Screen Shot.

The left most pane displays people and resources defined by user, and the result of the queries are shown in the middle pane. The right most pane is now showing the location of people or resources that are queried by user.

CMU-TMI
The location sensing technique used for this system is CMU's Triangulation Mapping Interpolation (CMU-TMI) with client based, which is a combined sensing method of triangulation, mapping, and interpolation. The signal strength from access points is sensed by client devices and used as a metric for measuring distances.
This method claims that it increases the accuracy by using the combined method and averaging the multiple calculations in different time.
The CMU-TMI needs to know of an initial dataset about all the possible physical position of all the access points. An offset vector is generated at each trained position for more correct mapping later on. The brief algorithm is follow.

- Scanning: The device scans all the access points to sense the signal and noise within range. An average five access points is sufficient for three dimension mapping, and the five scans are averaged to reduce the variance due to noise.
- Triagulation: The signal strength are used to determine the distance. Contours are generated around each access point, and intersections are found. Since the weak signal strengths do not help to the accuracy, use only five most strongest signal to get the possible location points.
- Mapping[ii]: When the signal space position is generated, the nearest set of mappings from signal space to physical space are found.
- Smoothing: Whether the device is moving, due to noise, a result position maybe different. To minimize the this type of error, CMU-TM performs multiple calculations in different time, and gets averaged data.

7. Market Outlook

According to a poll, two-thirds of Americans want wireless location-based services, with safety and security issues (emergency call, roadside assistance, and driving directions) as the primary reasons for wanting location-based services. This points out that services such as 'Where's My Nearest ATM?' will not generate significant medium-term revenues. Instead operators should concentrate on services focused on personal safety, security and transport.

Different surveys point out that in 2006 70% of mobile users will access local information on their personal handheld device and there will be 296million location aware services users in the world wide. Mobile operators will generate 20% of their data revenues through mobile location services.

However, the results so far are somewhat different from the rosy picture.

The following figure shows that the growth of LAS market revenues by region.

8. Challenges and Issues

Challenges

- Mobile device position determination is costly to implement on a massive consumer scale ($10Billion is expected to spent in the U.S. alone on replacement handsets and network infrastructure)
- Public policy issues especially for emergency quality of service (accuracy) and privacy.
- Many variables in position determination and mobile application usability make this complex, challenging subject fraught with misperceptions about capabilities.

[ii] can be pattern matching in another term.

Issues

- Technology is still being delivered in piece by piece, without total focus, so far.
- Carriers need strong IT partner for application content.
- Major players have not got into the market since the market is not large, which causes lack of standard.
- Lack of universal API for developing local applications.

9. Conclusion

I have presented an overview of location aware computing based on my survey. In the basic environment of location aware computing, the sensing techniques are the key factor, and the techniques are classified by three basic classifications, which are proximity, triangulation, and scene analysis. Each of the techniques trade off their characteristics one to another. Figure 4 shows brief summary of the techniques.
A case study called portable help desk using the hybrid sensing technique were presented, and by using the combined hybrid sensing method, it can increase the accuracy. Market outlook for location-based services varies from one study to another. The one key fact surveyed is that people will pay for a service related to their security, safety, and transport.
The main issues are there is no standard because still the market is not large, and big IT leaders have not participated actively yet. Also the privacy and quality of service issues remain to solve.

	Proximity	**Triangulation**	**Scene Analysis**	**Hybrid**
Metric	Near known location	Time/Angle/Attenuation	Mapping	Combine
Good	Simple, Cheap	Relatively accurate	No need to triangulate, for both urban/rural	Better accurate
Bad	Less accurate	High cost	Trained dataset needed	Relatively complex
Example	Cell of origin	Time of arrival Angle of arrival	Pattern matching	CMU-TMI

< Figure 4 > The sensing techniques summary.

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