THE NORTHERNMOST UNIVERSITY
of Technology in Scandinavia

Real time localization of objects in LTE and WiFi networks

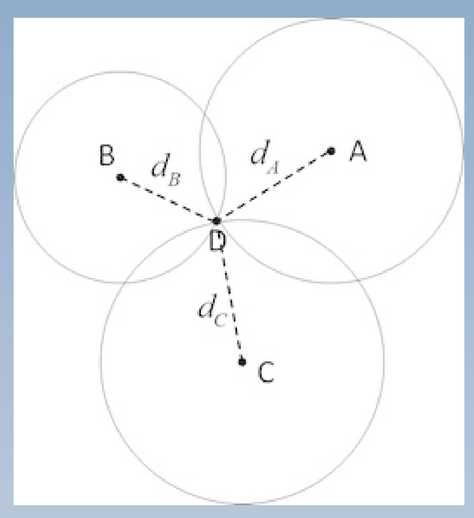
When we think about positioning, GPS is typically the first technology that comes to mind. However, GPS is not well suited for indoor or underground positioning, as the signal fails to pass through the walls. Since this technology is meant to be used with a direct line of sight to the satellites, its accuracy is also degraded in urban environments due to delay introduced by reflections on the surfaces of various structures.

Nonetheless, there are applications that require accurate positioning in those contexts. Indoors, this includes augmented reality, health care or robot navigation (in warehouses for example). In urban environments, it can as well be used on construction sites and for autonomous vehicles. Some applications have also been found for underground mining.

Using these network to determine the position of people or objects seems like a good idea, as they are already widely deployed. Furthermore, in the case of WiFi, the cards are relatively inexpensive.

Signal strength based techniques

This first positioning method relies on the measurement of the signal strength (RSSI in the case of WiFi) from the device to several access points. If we estimate that the signal strength is a function of the distance, this information can be used to perform trilateration, in a manner analogous to GPS. However, this is not very accurate, as the RSSI is a measurement that can fluctuate greatly over time at a fixed point. The precision can be improved with the use of other sensors, such as cameras, geomagnetic sensors, inertial sensors or even Bluetooth.



There are databases for the positions of WiFi access points in cities, but the biggest ones are proprietary. They include public WiFi APs, but also the APs of residents that can be detected from outside their homes. If one does not want their private AP to be registered in some databases, they should add “_nomap” at the end of the SSID (at least for Google and Mozilla).

Fingerprinting (mainly for WiFi)

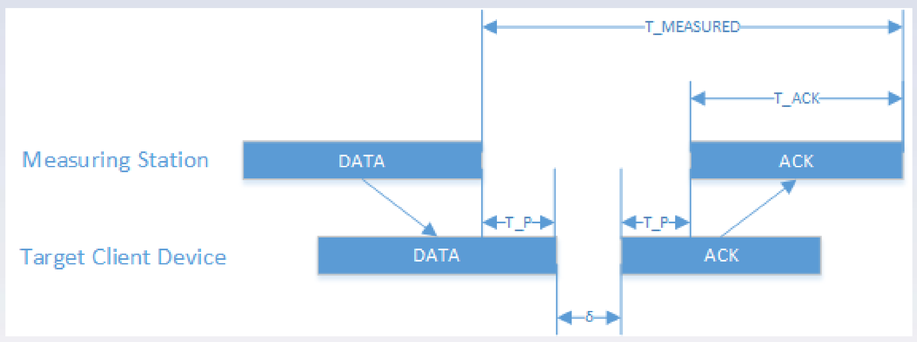
Fingerprinting is a method related to the previous point. The idea is to build a database of points in space associated with signal strengths for multiple APs. When we want to get the position of a device, we measure the signal strengths to the nearby APs and we take the nearest entry in the database, which gives us an approximate position.

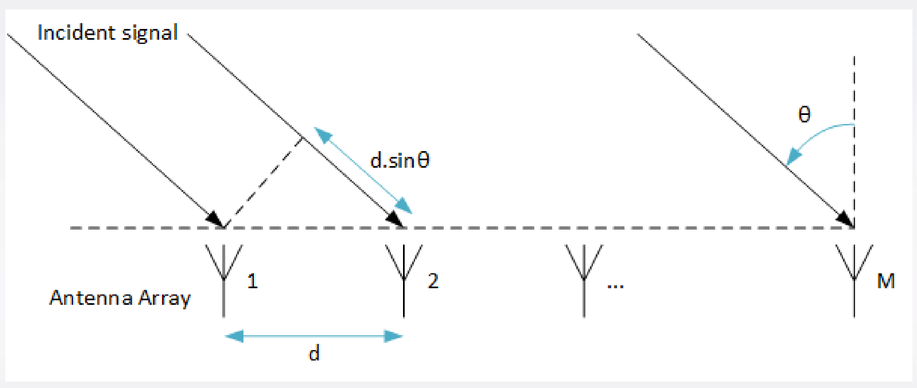
The advantage of this method is that we can spend time and resources to make accurate measurements of the position in the first place, and then reuse those accurate measurements. However, changes in the environment or in the APs will require rebuilding parts of the database in order to keep a good accuracy.

Time-based techniques

The other approach relies on time measurement. Once again, the objective is to find geometric parameters allowing to perform triangulation/trilateration. There are two main ways of doing so :

- Measuring the **arrival times** of packets or the time **differences between the arrivals** of several packets, which give us distances to the APs. If we only measure for a one-way trip, there is the obvious drawback that the APs and the device must have synchronized clock, which is difficult to achieve. To solve this problem, we can measure the time it takes for a round trip and divide by two, but there will be a delay added by the treatment performed by the AP, that can vary. There is also the problem that the electromagnetic waves travel at the speed of light, hence we need very high accuracy for time measurements.
- Measuring the **angle of arrival** of a signal. This is typically done using an array of antennas recording the phase shifts of a signal, each set of phase shifts being mapped to an angle of arrival.





Techniques exclusive to LTE

LTE provides built-in features for determining the position of devices in the network :

- **Enhanced Cell ID (ECID)** estimates the position of the device using primarily the position of the cell it is currently in, along with some time-based techniques (round trip time, angle of arrival).
- **Assisted Global Navigation Satellite Systems (A-GNSS)** is used to improve the performances of traditional satellite-based systems.
- **Positioning Reference Signal** blocks to help with computation of the time difference of arrival.

Some of the techniques described here are used by smartphones to get a rough estimate of the position, however this is still considered less accurate than GPS (with the exception of A-GNSS), which is to be expected since the urban environment changes continuously. We can expect better results in a controlled space, more specifically spaces where we can at least control the placement and availability of the APs.

Finally, when working with these kinds of technologies, we must keep in mind the security aspect, as it can be dangerous to disclose publically the positions of devices (and potentially people).

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