intersec

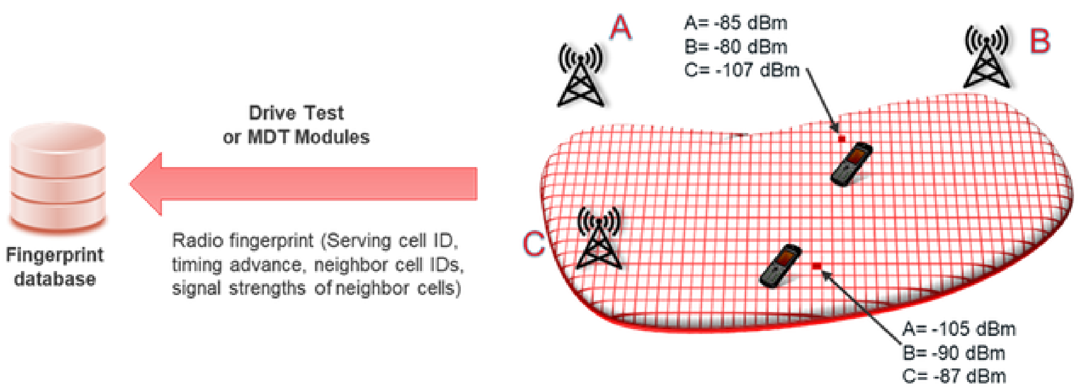
Technical Sheet
RF Fingerprinting

Positioning in wireless networks depends on many factors, for example, the mobility of users, the dynamic nature of the indoor or outdoor environment, and the nature of radio signals in that environment. The same level of positioning accuracy is expected regardless of whether a subscriber is in a rural or urban area. Looking at mobile network originated geolocation, there is no one-size-fits technique providing the best accuracy everywhere, anytime.

RF Fingerprinting-based positioning systems provide unique positioning capabilities in the urban environments, sensitive to multi-pathing effect and where other technologies based on timing measurements will suffer from the absence of direct line of sight.

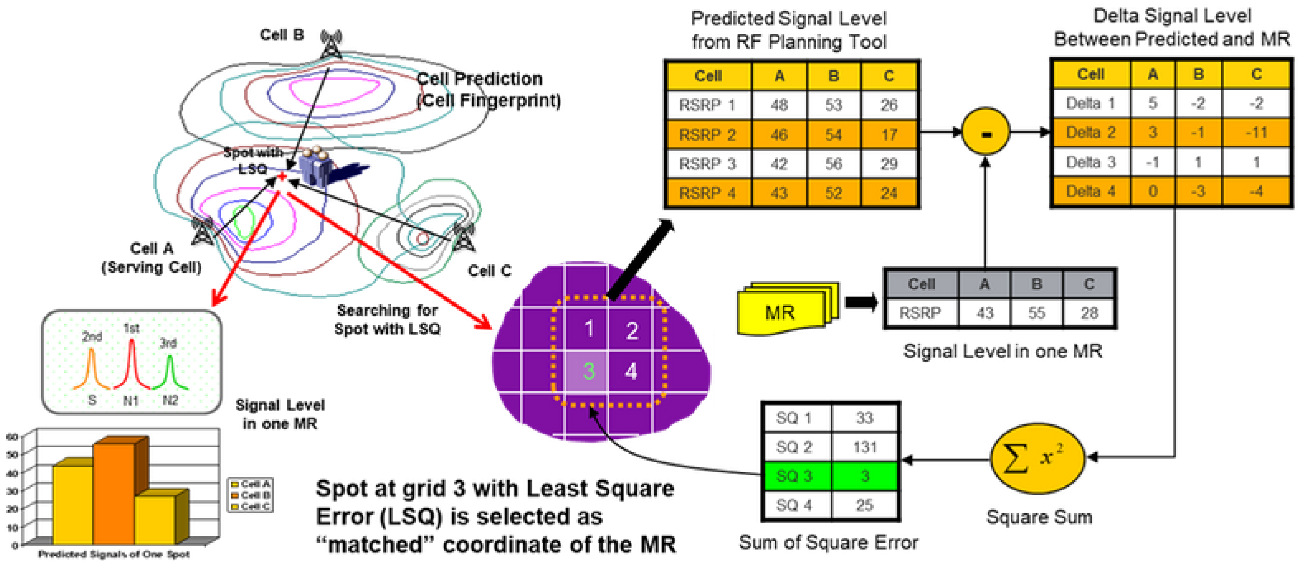
HOW DOES RF FINGERPRINTING WORK?

This distance dependency property can be transformed into location dependency of RSS if there are multiple signals from different reference points using the RSRP location algorithm for example. Location can also be found from a set of drive tests. As MNO are using Drive tests for measuring and assessing the coverage, capacity, and Quality of Service (QoS) of a mobile radio network, these measurements can be used to feed the RF FP database.



Online Testing Phase: Subsequently, in the online phase, geolocation is simply the process of matching the measured fingerprints at an unknown location with those in the database by calculating the similarity and returning the location corresponding to the best-fitted fingerprint by the location estimation algorithms.

When the mobile sends its measurement report, the measurements sent are compared with the different database entries. Then, the difference between the measurements taken by mobile and the measurements recorded in the database is calculated. The sum of square error is derived for each positioning unit and the pixel which represents the sum of the smallest square error will be designated as the most probable location of this mobile.



HOW DOES IT COMPARE TO OTHER TECHNOLOGIES?

The signal strength-based fingerprint can be applied independently on the system, if one has access to the received signal strength or power measurements backscattered and processed in the database.

The estimated dense urban accuracies are about:

- 67% 2D distance error about 150 m using FP, about 300m for CID
- 95% 2D distance error about 300 m using FP, about 600m for CID

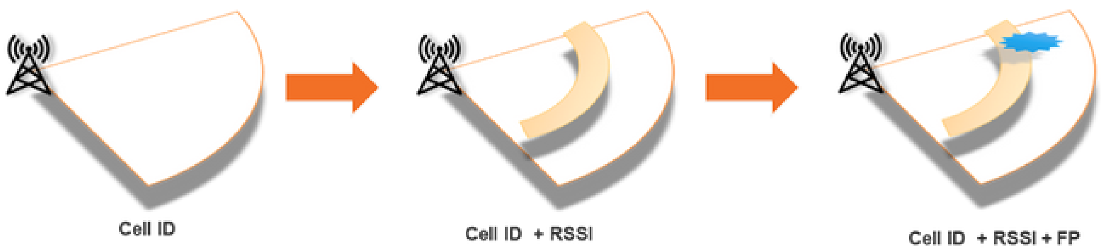
The basic performance metric for geolocation is accuracy. And the location system must also provide the location information quickly.

The following table shows a comparison between the different geolocation technologies in terms of precision and speed of detecting the position of the mobile. (FR1: Frequency Range 1)

Positioning Method			Fingerprinting RFSP		AGPS	ECID		CID	
Access Type			3G/4G	5G FR1	3G/4G/ 5G	3G/4G	5G FR1	3G/4G	5G FR1
Urban	67% (m)	Low	60	50	20	100	90	220	200
		Up	250	200	100	300	250	450	400
	95% (m)	Low	60	50	20	200	90	450	200
		Up	400	350	160	500	400	750	650
Suburban	67% (m)	Low	120	100	10	200	150	900	750
		Up	550	500	50	600	450	1100	1000
	95% (m)	Low	120	100	10	400	150	1000	750
		Up	1200	1000	100	1000	900	1650	1500
Rural	67% (m)	Low	440	350	10	500	400	1600	1400
		Up	900	800	20	1000	800	3000	2800
	95% (m)	Low	440	350	10	1000	400	2800	1400
		Up	1600	1300	100	3000	2500	5000	4000

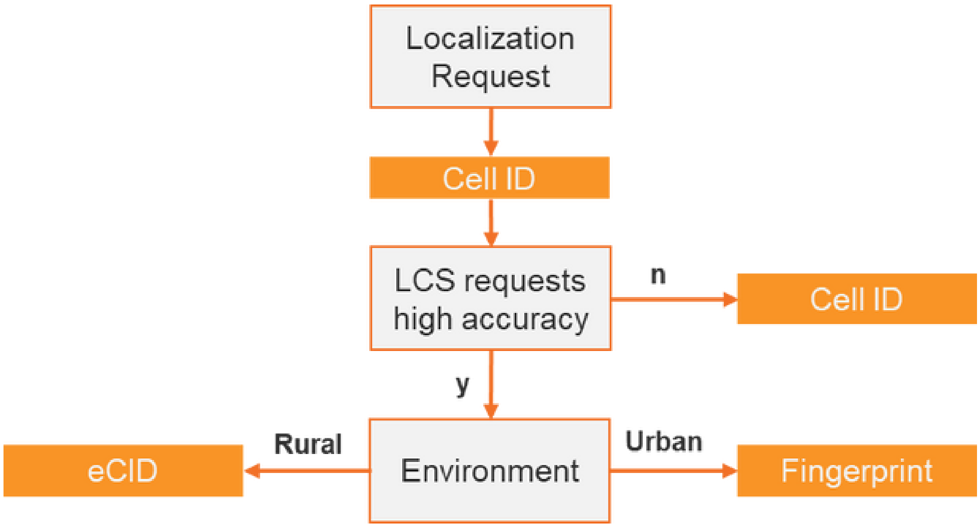
BEST APPROACH: HYBRID LOCATION

Perhaps one of the best ways to precise the location of a mobile is to cross-reference not only the results of the different algorithms but their inputs as well. We thus speak about hybrid location algorithms.
The idea is to use the computing power of the 2G-5G SMLC servers to carry out locations according to several algorithms and to refine these results by successive iterations.



Depending on the requirement or the LCS client, a location technique with very specific precision could be chosen.
For example, although the Global Positioning System (GPS) provides relatively accurate position estimates (5 to 50 meters), it is not suitable for indoor, dense urban, and other NLOS environments. On the other hand, in some environments such as rural areas where the cell size is relatively large, the fingerprint accuracy can be lower than the GPS. It would be preferable in this case not to trigger the FP.

An example of the mechanism flow is shown here:



5G UNLEASHES RF FINGERPRINTING LOCATION ACCURACY

The arrival of 5G in the market opens a wide door to new services and new applications. Geolocation is more important than ever in multiple use cases.
5G positioning achieves great accuracy thanks to the use of millimeter waves and also the beamforming.
In the context of the fingerprint, 5G considerably increases the precision knowing that, in addition to the level of power and quality measurements, the use of beams precisely the refinement beams allows a higher resolution in the database.

ULTRA-PRECISE LOCATION AT SCALE WITH PASSIVE LOCATION

RF fingerprinting technology is not limited to an active geolocation paradigm.

Mobile device radios measurements can also be extracted from data passively collected from mobile networks, typically through RAN traces.
This unleashes the potential of RF fingerprinting technology and the spatial accuracy it brings when scaling to a continuous stream of improved locations for the whole subscriber base.
Many use-cases can benefit from this increased accuracy: geo-statistics, geo-marketing, missing person location.

PERFORMANCE

Accuracy:
Fingerprinting can be used for positioning UEs with an accuracy of 150 m and 500 m in 67% and 95% of all positioning attempts, respectively.
The accuracy also depends on the Radio Access Technology (RAT) and the used frequency. For instance, the fingerprint method for 5G networks using mmWaves has a median prediction error of 55 m when it is trained with deep learning (DL) methods.

Latency:
One of the main problems of fingerprinting methods is the relatively high computational complexity. With today's microprocessors, this would not create a latency issue in most situations. However, in certain scenarios, in which many training points are required, or if the position estimates are required very frequently, latency becomes an important factor. The latency is estimated to be between 1 – 3 seconds.

	Cell-ID	E-OTD	A-GPS	RSSI-based fingerprint
Time-to first-fix	1s	5s	5-10s	1-3s

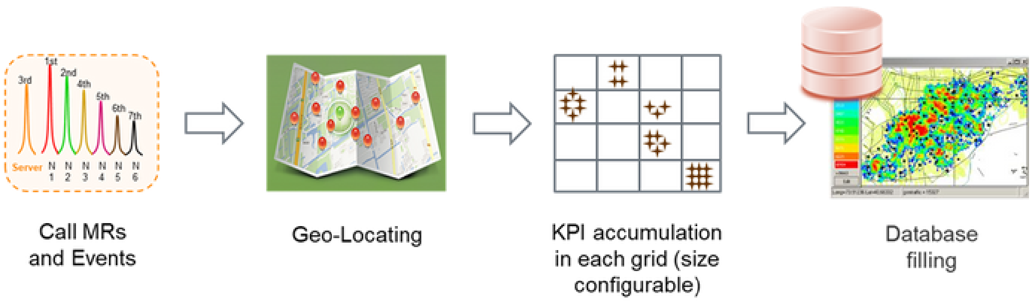
FINGERPRINTS DATABASE CREATION

The basic idea of a signal fingerprinting approach is to find the location of a mobile device by comparing its signal pattern received from multiple transmitters, such as cellular Base Station (BS) to a predefined database of signal patterns.

Location fingerprinting benefits from a pattern-matching mechanism, which comprises the offline training phase and online location estimation phase. Specifically, in the offline phase, wireless signatures are collected at a set of geo-tagged Reference Points (RPs) in the area of interest to construct the fingerprint database (a.k.a. radio map). During the online phase, the measured signature at an unknown position is matched with the offline radio map to return the best-fitted location estimation.

The mobiles in the area are logged and their Measurement Reports are processed to calculate the UE location. The area is divided into multiple grid points. The size of the grid point can be tuned. Then the grid can be associated with geographical shape and indexed with the average values of the different MRs.

This information is stored in the FP database and can be associated with a heatmap.



RF fingerprints of the desired area are collected through multiple devices, but to collect this huge amount of data from every possible point of the coverage is a time-consuming and costly process. 3GPP release 10 (3GPP TR 32.827) opens the opportunity to collect data autonomously from user devices called Minimization of Drive Test (MDT), which can be used to create a fingerprint database if activated by MNO.

Using MDT or the drive tests, the RSS values are collected at each of the grid points. This data is stored in a database that consists of the very important parameters for location such as the pixel values of the collection points (the relative physical locations) and the RSS values corresponding to each of the reachable BSs at collection points.

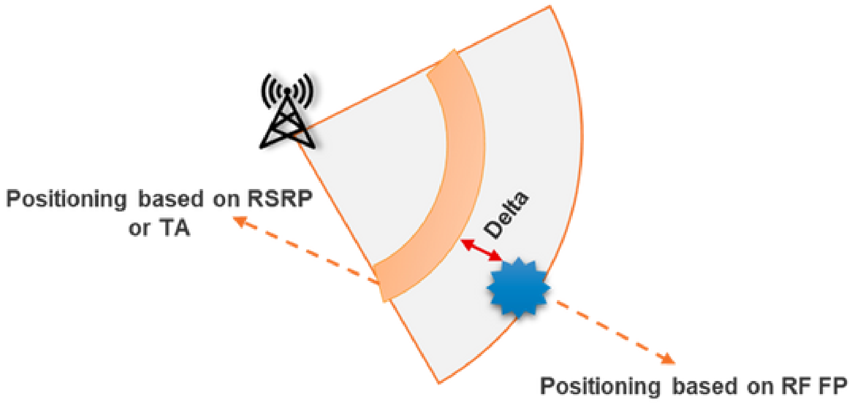
FINGERPRINTS DATABASE REFRESH

The operator's network is an active network that never stops changing settings, growing, and being optimized. This is the reason why the database relating to power measurements must be systematically updated. MNOs regularly carry out drive tests to assess their coverage and troubleshoot the network. These DT are essential, and they should be used as often as possible to update the database.

However, some modern network features change the network settings more quickly and at higher frequencies. We are of course talking about the self-optimized network (SON) features. Certainly, some optimizations do not modify the coverage or the power level, for example, Mobility Robustness Optimization (MRO) where only the thresholds change. In any case, the frequency of the update of the database depends on the optimization campaigns of the operators and it is important to synchronize the update according to the change of a parameter.

It is well-known that fingerprinting methods may fail in dynamic environments, i.e., if the positions of the antenna or their tilt or power frequently change. In principle, this problem can be solved with online training, assuming that enough drive tests are performed using a mobile vehicle with GPS capability.

Leveraging on its hybrid geolocation capabilities, the Intersec Agora performs automatic self-checks on the RF fingerprint database consistency and marks zones as prioritized to be updated through drive tests.



DATABASE SIZE

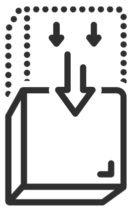
The positioning system is expected to use the RSS fingerprints obtained at measured (and known) locations. For higher accuracy, more training measures should be obtained, which would affect the database size. An efficient data compression technique should be used.
Tests results are: 8 hours to process 150,000 cells with 1,000 reference measurements each in a database of 950 GB.

THE INTERSEC GEOLOCATION PLATFORM

1- Collection of terabytes of anonymized mobility and activity datasets through a combination of location technologies

- Active location: SMLC, GMLC, SAS, E-SMLC, LMF
- Passive location: Cell and subcell accuracy at scale
- RF Fingerprinting: Highest accuracy

2- Mobility and activity data are processed and turned into actionable location insights



Equipment vendor-agnostic platform

Anonymized datasets

5G geofencing accuracy

3- A comprehensive set of mission-critical and high value-added applications for any use cases

About Intersec

Founded in 2004, Intersec is a global leader in activity and mobility data solutions. Intersec offers innovative and disruptive software enabling fast data analytics, mass communication, and AI-based decisions. Its industry-focused products enable private and public organizations to turn geodata into actionable insights in the fields of public safety, contextual marketing, geolocated advertising, smart cities, and the management of connected object fleets (IoTs). With more than 100 clients in 80 countries, Intersec currently enables its customers to leverage the location of nearly one billion humans and connected objects. Learn more at intersec.com.

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