Localization Techniques for 5G Radio Environment Maps

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Abstract. Localization techniques are going to be a significant part of
5G networks, not only for user-plane services (e.g., navigation) but they
can also be used to improve network performance using Radio Environ-
ment Maps (REMs). The REM's operation requires an accurate local-
ization technique that can work in adequate (radio) environments with
high reliability. This paper firstly, provides comprehensive overview of the
existing localization techniques that can be used in 5G systems focusing
on cellular network-based solutions and advancement in satellite-based
localization. Secondly, these techniques are analysed and assessed against
the requirements stated for 5G REM systems.

Keywords: 5G · Localization · Radio Environment Maps

1 Introduction

The 5G networks will have to support many new, challenging use-cases [12].
These can vary from high throughput Enhanced Mobile Broadband (eMBB)
service, through Ultra Reliable Low Latency Communications (URLLC) up to
Massive Machine Type Communications (mMTC). The network has to be fully
adaptive to support either high spectral efficiency (for eMBB), high reliability
(for URLLC) or massive connectivity and high energy efficiency (for mMTC).
In order to meet these requirements various radio access technologies are to be
utilized, e.g., Non-Orthogonal Multiple Access (NOMA), Massive MIMO (M-
MIMO) or transmission in mm-waves. However, as in all previous generation,
5G requires significant amount of spectrum to be used for transmission. The elec-
tromagnetic spectrum is scarce, therefore, the promising solution is to increase
spectrum utilization by Dynamic Spectrum Access (DSA) [7]. An efficient archi-
tecture for DSA utilizes location-based database, e.g., Radio Environment Map
(REM) [16]. Such a database can be used not only to support dynamic spec-
trum licenses assignment in various scenarios (e.g., Vehicle-to-Vehicle commu-
nications [18]) but also other advanced control mechanisms in a network, e.g.,
interference management [8]. However, efficient operation of REM requires the
obtained/controlled data to be tagged with accurate localization.

The demand on localization of a user terminal in cellular networks began with definition of enhanced 911 (E911) location requirements for emergency calls by Federal Communications Commission (FCC) of United States (U.S.) in 1990's. In the cellular networks, from 2G to 4G, localization was used at the beginning to fulfill these FCC emergency calls requirements, and later also in some location-based services like e.g. navigation, mapping and geo-marketing [15]. In 5G, utilizing DSA and REM, the reliability, accuracy and low energy consumption of localization techniques plays a key role.

The aim of this paper is to overview localization techniques currently available for user devices and those to be available in the near future, for the REM-based DSA applications. The presented methods are compared taking their accuracy into account, their implementation requirements as well as the robustness in both indoor and outdoor conditions, to choose proper positioning technique to specified environment conditions.

The paper is organized as follows: in Sect. 2, the basics of the localization techniques are introduced. In Sect. 3, their utilization in the contemporary systems is presented, with the main focus on Global Navigation Satellite System (GNSS) and LTE networks. In Sect. 4, the presented methods are compared, and their usefulness for 5G REM is discussed. The conclusions are formulated in Sect. 5.

2 Localization Techniques Overview

This section describes the main positioning approaches, that are utilized to implement various localization systems, i.e., cellular, satellite and the other ones described in Sect. 3 in detail. The first reasonable classification can be done as proposed in [15] by splitting positioning techniques into two groups:

- *Mobile-based*, where the responsibility of calculating position lays on the side of a user device, with the use of its own measurements and network (which may, but does not have to be cellular) assistance data.
- *Network-based*, where, in opposite to the *Mobile-based* approach, a user device sends its measurements to the network location server which computes the final position.

Regarding specific techniques used for the localization purpose there are four basic ones. They are presented below, as concepts; their implementations and accuracy in existing systems are discussed in the following section.

2.1 Trilateration

The user position is obtained on the basis of measured distances to the reference stations of known locations [10]. Due to fact that radio wave has the known value of the propagation speed, the simplest idea is to measure the time of the radio wave travel from the reference station to the user receiver, and to compute the distance (this concept is system based, and it is called the Time of Arrival

(TOA) method [10]). The user position is where the circles, indicating distances of a user from the reference (base) stations, intersect (see Fig. 1). To obtain the 2D position, at least three user-to-reference station distances are required. In the mathematical form, the trilateration may be expressed as solving the set of Eq. (1) for $k = 1, \ldots, K$ (where K is the reference-stations number):

$$r_k = \sqrt{(x - x_k)^2 + (y - y_k)^2}, \tag{1}$$

where r_k is the distance between the user and the k-th reference station, x, y are the 2-D user position coordinates and x_k, y_k are the k-th reference station coordinates. In [10], the authors also mention the position calculation based on the difference in TOA (TDOA). There, two pairs of measurements are necessary for obtaining the 2-D position. In [15], the received signal strength (RSS) is considered as the third option that requires at least three measurements for 2-D positioning as in TOA.
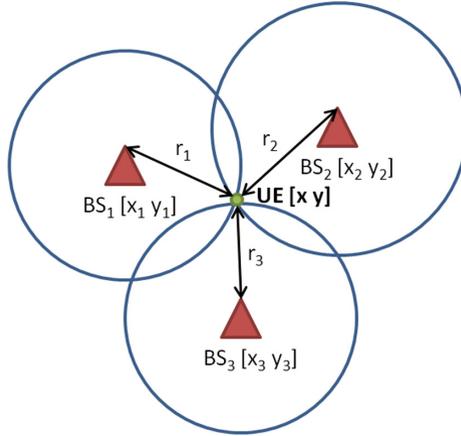

Fig. 1. The concept of the trilateration positioning technique.

The time-based positioning requires precise time interval measurements, i.e., to achieve centimeter- accuracy level, the time-errors must be of the order of 1ns [5]. The receiver and the reference stations clocks synchronization is crucial to achieve this requirement. In [5], it is noticed that a user receiver has an internal clock with much worse accuracy than that of a reference station. One additional measurement is necessary to provide the estimation of the receiver clock offset, however the reference station transmitters still must be synchronized [10].

2.2   Triangulation

In the triangulation method, the user position is obtained on the basis of angles measured between the user device and at least two reference stations of known

position (for 2-D positioning), however, performing more then two measurements can improve accuracy. This type of measurement is called the Angle of Arrival (AoA). The user position is defined where the directions of the received signals (AoAs) intersect, as it is shown in Fig. 2.
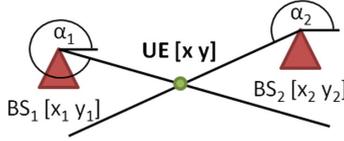

Fig. 2. The concept of triangulation positioning technique.

In the mathematical form, the triangulation method for obtaining the 2D user's position may be expressed as solving set of linear equations:

$$y - y_k = \tan \alpha_k \cdot (x - x_k), \quad \text{for} \quad k = 1, \dots, K \tag{2}$$

where x and y are the user coordinates, x_i and y_i are the ith reference station coordinates, and α_i is AoA measured between the user position and the ith reference station.

The triangulation technique does not require time synchronization, but it depends on the quality of the AoA measurements. The authors of [20] claim that the AoA measurement error is proportional to the inverse number of the antenna array elements.

2.3   Proximity

Proximity method is probably the simplest positioning method, where the user position is approximated by the closest reference station position (see Fig. 3). For example, the cell-ID of a connected cell can be used to approximately locate the user-equipment (UE) [15].
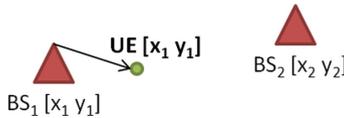

Fig. 3. The concept of the proximity positioning technique.

2.4 Radio Frequency Pattern Matching

Radio Frequency Pattern Matching (RFPM), also called fingerprinting, is based on the comparison between the measured value (for example RSS or the propagation time delay [15]) with the value stored in a database. The fingerprint is typically a geographic position associated with the signal measurement. The user position is obtained as coordinates of best matched fingerprint in database [15], as illustrated in Fig. 4.
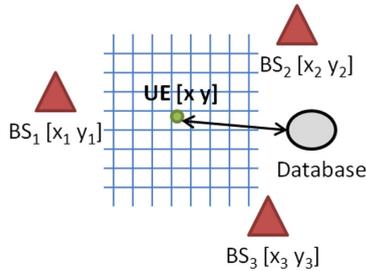

Fig. 4. The concept of RFPM positioning technique.

The fingerprinting position estimation process is divided into three steps [13]:

– *Database Building Phase*; In this step the database of fingerprints is created on the basis of performed measurements in the reference points of known locations.
– *Acquisition Phase*; In this phase, the user device is performing the same measurements as in the previous step, but in unknown location.
– *Matching Phase*; In this final step, the values measured by a user are compared (with the use of predefined matching rule) with the ones stored in database. The user position is claimed to be the position of the best matching fingerprint from database.

The position accuracy in fingerprinting is highly related to the quality of location-depend measurements, calibration of the database and the density of the measurement grid [15].

3 Contemporary Positioning Systems

In this section, utilization of the presented positioning methods in the existing systems is discussed. Implementation of REM databases requires robust positioning techniques with predictable and well tested accuracy. Thus, the main focus is on the practical positioning systems, i.e., the Global Navigation Satellite System and on the solutions described in [2] for LTE networks. Then, some other independent positioning systems and expected 5G improvements are mentioned.

3.1 Global Navigation Satellite System (GNSS)

GNSS allows users to estimate their position on the basis of signals received from satellites orbiting the Earth. Position calculations are based on TOA trilateration method [10]. Each satellite broadcasts the information about ephemerids (the detailed orbit parameters used to compute its position), almanac (basic ephemerids for the whole constellation) and clock corrections [10]. Signal transmitted by satellites is code-modulated, and can be expressed as [10]:

$$s(t) = \sqrt{2P}D(t)c(t)cos(2\pi ft + \phi), \tag{3}$$

where $\sqrt{2P}$ is the signal amplitude, $D(t)$ is the navigation data signal, $c(t)$ is the spread spectrum code, f is the carrier frequency, and ϕ is the phase [10]. All satellites internal clocks are synchronized thanks to the use of the atomic clocks. The receiver, on the basis of the received ephemerids and the TOA measurements, estimates its position. Due to the receiver's clock uncertainty, additional measurement is necessary to estimate the clock offset. To obtain the 3D position, at least four satellites must be visible, more satellites can improve accuracy [10].

Currently available GNSS systems are, e.g., GPS (USA), Galileo (EU), GLONASS (Russia), BeiDou(China). However, GPS is the most popular.

GNSS Range Measurements. There are two types of measurements, that allow to estimate the receiver-to-satellite distance. The first approach is to track the pseudo-random code transmitted by the desired satellite, the second one to obtain the range on the base of the carrier phase measurements.

Code Phase Measurements. In this approach, the distance between the user and the ith satellite is computed on the basis of aligning the spreading code replica with the one received from satellite. The distance estimate suffers from some errors, and that is why it is called pseudorange. The error sources with the biggest impact on measurements are: both satellite and receiver clock biases, the ionosphere and troposphere propagation delays and the multipath fading [10].

Code phase measurements are common in "mass market" receivers, e.g., in smart-phones. The accuracy achieved with this method in stand-alone GPS receivers is about $10\,\mathrm{m}$ for 95% of cases [10].

Carrier Phase Measurements. In this approach, the pseudorange is obtained as the number of carrier signal wavelengths between the satellite and the receiver [10]. The measured value is the phase offset between the carrier replica and the one received from the satellite. Under the assumption of ideally synchronized clocks and no other errors, this phase offset is expressed (in cycles) as [10]

$$: \phi(t) = \phi_u(t) - \phi^s(t - \tau) + N, \tag{4}$$

where $\phi_u(t)$ is the carrier-phase replica, $\phi^s(t - \tau)$ is the phase of the signal from the satellite received at time t, τ is the propagation time, and N is called

integer ambiguity. (It's estimation, namely, the integer ambiguity resolution, is the most complex part of the carrier phase measurements, but when done it allows to achieve cm-level accuracy positioning [10]).

Apart from the integer ambiguity carrier, the phase measurements are affected by the same errors as the code phase measurements (clock biases, propagation delays and multipath fading), although they can be eliminated by double difference measurements discussed later.

The carrier Phase measurement is much more accurate, but it also requires more complex computations than the code phase estimation method. Centimeter-accurate GNSS positioning with phase carrier measurements is common in geodesy, agriculture and surveying. In mass market, the receivers' main problem is in low-quality antennas causing not high enough multipath-fading effect suppression and long time correlations in phase errors, resulting in long (tens of seconds) initialization time (time to ambiguity resolution- TAR) [17].

GNSS Improvements. As the basic GNSS positioning technique for stand-alone receiver is utilizing code phase measurements, let us discuss how to improve GNSS accuracy, and how to take advantage of the carrier phase measurements with Real Time Kinematic approach. In Table 1, requirements of the presented GNSS improvements are compared.

The Dual-Frequency GNSS comes as the improvement for a stand-alone GPS receiver. All GPS satellites broadcast L1 civil signal at frequency 1575,42 MHz with the chip rate of 1.023 Mcps. The newer ones provide also the L5 signal [10] broadcast at 1176.45 MHz frequency and higher chipping rate of 10.23 Mcps [11]. Thanks to that L5 suffer less from the multipath reflections than L1. When combining these two signals in the receiver, it is possible to eliminate the ionospheric error [10]. With dual frequency receiver, about 30 cm accuracy is expected to be provided [11]. Moreover, the Broadcom company released BCM47755 chip, as the first mass-market chip which uses both L1 and L5 signals. The first smart phones equipped with that chip have been expected to appear in the end of 2018 [11]. Currently, the only phone with GPS dual frequency receiver identified by us is Xiaomi Mi 8, however no reliable localization tests results could be found.

Differential-GNSS. In Differential-GNSS (DGNSS), measurements are performed using code phase approach, but the idea of reducing errors is based on the fact that ionosphere, troposphere, ephemerids and satellite clock errors are correlated in time and space [10]. A reference receiver with known location is used which compares the position obtained on the basis of satellites' signals measurements with the known true location, and computes pseudorange corrections that are then send to a user (called rover) by the side link. The differential approach provides accuracy up to 1 m [10].

Real-Time Kinematics. Real Time Kinematics (RTK) is based on relative positioning [10]. Similarly to DGNSS, the reference station with known coordinates

is required, but it sends (to a rover) its raw measurements instead of the computed corrections. RTK also takes advantage of the carrier-phase measurements instead of the code-phase. To eliminate clock biases and atmospheric delays, position (relative to that of the reference station) estimation is performed on the basis of the double difference.

To obtain one double difference measurement, carrier-phase in both the reference station and in the rover must be measured using the same pair of satellites. The measurement result of the rover is subtracted from the reference station measurement result using the same satellite signals (resulting in a single difference). The same happens with measurements based on another satellite signal. Finally, the mentioned single differences are subtracted resulting in the double difference [10]. As the satellites' and the receivers' clocks biases are the same, they cancel out in the equation. The same happens to the atmospheric delays, when the distance between rover and reference station is small enough (lower then 5 km [17]). The main component of the remaining error is multipath fading.

Table 1. Measurements requirements for GNSS variants.

	Code phase	Carrier phase	Reference station	Dual frequency chip
stand alone single frequency	✓	✗	✗	✗
stand alone dual frequency	✓	✗	✗	✓
DGNSS	✓	✗	✓	✗
RTK	✗	✓	✓	✗

3.2 LTE Positioning Techniques

The LTE standard utilizes some of the above mentioned methods [2]. An overview of the most important ones is presented below [3].

Observed Time Difference of Arrival (OTDoA). OTDoA uses trilateration. Measurements are performed with the use of special positioning reference signal (PRS), defined by a pseudo-random QPSK sequence mapped to resource elements and bandwidth (the number of resource blocks), time offset, duration in subframes and its periodicity [3]. PRS is transmitted by each eNB. To obtain the position, at least four pairs of time differences must be measured. In this method, the obtained OTDoA values are send to the location server (E-SMLC) which computes the final position and sends it back to UE [10]. It may be reasonable to use OTDoA in dense urban and indoor environments where not enough GNSS satellites are visible. In [15], the accuracy of this method is claimed to be < 50 m for 67% of cases.

Enhancement Cell-ID (E-CID). E-CID is based on the proximity method and network-based approach [3], where initial UE coordinates are assumed to be coordinates of its serving base station. To improve the accuracy, several parameters specified in [2] may be requested from UE or eNB by E-SMLC. They are presented in Table 2.

Table 2. Information that may be transferred from eNB/UE to the E-SMLC. [2]

Information
Timing Advance (T_{ADV})
Angle of Arrival (AoA)
E-UTRA Measurement Results List:
- Evolved Cell Global Identifier (ECGI)/Physical Cell ID
- Reference signal received power (RSRP)
- Reference Signal Received Quality (RSRQ)
GERAN Measurement Results List:
- Base Station Identity Code (BSIC)
- ARFCN of Base Station Control Channel (BCCH)
- Received Signal Strength Indicator (RSSI)
UTRA Measurement Results List:
- UTRAN Physical ID
- Common Pilot Channel Received Signal Code Power (RSCP)
- Common Pilot Channel Ec/Io
WLAN Measurement Results List:
- WLAN Received Signal Strength Indicator (RSSI)
- SSID
- BSSID
- HESSID
- Operating Class
- Country Code
- WLAN Channel(s)
- WLAN Band

In [3], three scenarios of additional measurements are mentioned: measuring the distance to serving base station (on the basis of timing advance), measuring the distance to three base stations (trilateration) and measuring AoA (triangulation) from at least two base stations (requires large antenna arrays to be accurate [3]). In [15], the E-CID method achieves horizontal accuracy of 50 m.

Radio Frequency Pattern Matching. Although RFPM is not explicitly defined in [2], it is proposed in [1] to be implemented in the existing E-CID infrastructure with the use of timing advance and RSRP measurements already available in E-SMLC. The results provided in [1] show the accuracy up to 85 m in 67 % cases, in urban conditions using the reference signal of 10 MHz bandwidth. In [19], the use of RSRP combined with WLAN RSSI measurements for creating the location database gave the accuracy of 13 m in 67% of cases in the outdoor

environment and 10-by-10 m measurement grid, however, it decreased to 22 m with the use of larger 40-by-40 m grid. In [15] WLAN supported fingerprinting methods are found to be promising for indoor localization.

Assisted GNSS. The idea of supporting UE embedded GNSS receiver by distributing the assistance data through cellular network, is implemented in systems from GSM through UMTS and LTE. The main target of this method is to improve robustness of UE receiver positioning in urban conditions and shorten the start-up time [10]. It is reasonable to split the assistance data into the data assisting measurements e.g., visible satellite list or code phase search window and the data assisting position calculation like: reference time, satellite ephemeris [3]. According to [10], in a stand alone GPS receiver, it takes 30 s to receive satellite ephemeris and up to 12.5 min. to receive almanac containing information about the whole constellation. The accuracy of AGNSS localization equals about 10 m [15]. However, its quality depends on the implementation used by a given network operator.

RTK Support. As can be seen in [2], currently (up to LTE rel. 15) DGNSS corrections are already available. Interestingly, rel. 15 introduced new types of the assistance data in LTE Positioning Protocol (LPP) with the main purpose to support high accuracy (HA) GNSS, i.e., mentioned RTK [17]. As RTK requires continuous carrier phase tracking, in [2], it is proposed to apply LPP Periodic Assistance Data Transfer procedure for measurements transmission between UE and E-SMLC. UE GNSS receivers do not support carrier phase measurements yet, but [17] shows that it is possible, and including RTK assistance in LTE rel 15. should be commonly available in a near future.

3.3   Other Positioning Systems

Apart from mentioned cellular and satellite systems, there are several other methods, suitable mostly for indoor environment. One of them is trilateration used in IEEE 802.15.4a ultra wide band (UWB) system [9]. Large bandwidth (> 500 MHz) results in accurate TOA measurements, and easy multipath components estimation. In [6], UWB is expected to provide the accuracy below 1 m for at least 90% of cases. So far, it is common in public or enterprise domains using WLAN 802.11 standard, that the use of RSS measurements give positioning accuracy from 3 to 30 m [9]. WLAN and UWB are only mentioned examples, other ideas are based on utilizing Bluetooth, barometer or augmenting existing methods with various sensors' or cameras' data [20].

3.4   5G Expected Improvements

Although 5G positioning protocol is not fully defined yet, some of the expected improvements of the basic concepts can be discussed. Requirements for positioning in 5G systems expect accuracy up to 10 cm [15]. The way to fulfil them

is to take advantage of 5G features like: high carrier frequencies, larger bandwidth, MIMO and high density networks [20]. Higher carrier frequencies (near 30 GHz and more) result in the possibility of utilizing larger bandwidth (hundreds of megahertz), what causes improvement in trilateration based methods (TOA, TDOA, OTDoA). In [14], below 20 cm accuracy was achieved for 100 MHz bandwidth. By using MIMO systems AoA estimation may be much improved. In [5], a single-anchor (with only one reference station) method is mentioned as the benefit from 5G system features. Apart from cellular methods, high accuracy GNSS (e.g. RTK) is also taken into account in [15].

4   Localization Techniques for 5G REM

The existing positioning techniques have been presented above with the main focus on LTE and GNSS systems, as they are well described, and researched solutions available. Below, in this section, their utilization for radio-network efficiency-improving REMs in various environment conditions and applications is considered by analysis of their accuracy (in Table 3) and other features (in Table 4).

The REM may be utilized on various network levels for different purposes, e.g., global REM for Quality of Service (QoS) or Quality of Experience (QoE) management or local REM for distribution of available radio resources. Data stored in REM may be used for several purposes: DSA, traffic steering or massive MIMO (M-MIMO) transmission optimization. In all mentioned cases UE is the unit obtaining it's position. There are different requirements on accuracy and update rate of localization service for different REM levels (associated with the OSI layers) and applications. The higher the level of REM, the lower the update rate and required accuracy [4]. The key feature of localization for REM in all cases is robustness. Without accurate enough localization data, the network performance will be decreased, and in the worst case, may lead to disconnection of UE from the network.

For global-level REM with QoS and QoE data, focused on large scale traffic analysis, high accuracy is not necessary. Stand alone GNSS should be enough. When not enough satellites are visible (e.g., in an indoor environment) any of the presented cellular-system-based positioning may be utilized. Even E-CID without additional measurements could be enough for high level traffic analysis.

Local REMs responsible for radio resource management requires higher accuracy (which is further dependent on utilized radio frequency band) and high updates rate. For outdoor scenarios utilizing LTE frequency band, 5 m spatial resolution should be enough for REM [4]. Such a localization accuracy can be provided by a dual frequency or differential GNSS. For outdoor, mm-waves M-MIMO transmission optimization, spatial resolution of 0.5 m is required (as mm-waves wavelength is order of magnitude smaller then cm waves utilized in LTE scenario). This accuracy can be supported by RTK. However, it is a very energy consuming solution, resulting in fast UE battery discharge. The way out of this problem may be to use RTK for REM data acquisition, and less accurate and energy consuming dual frequency GNSS (UE must have dual frequency

Table 3. Mobile positioning methods accuracy.

Method	System	Horizontal accuracy	Type	Reference
OTDoA	LTE	63 m (95% cases)	Trilateration	[15]
E-CID	LTE	~50 m (67% cases)	Proximity	[15]
RFPM	LTE	85 m (67% cases)	Fingerprinting	[1]
RFPM	LTE+WLAN	13 m (67% cases)	Fingerprinting	[19]
GNSS	GPS	10 m (95% cases)	Trilateration	[10]
DGNSS	GPS	$\geq$1 m (95% cases)	Trilateration	[10]
RTK	GPS	~1 cm	Trilateration	[10]
DF-GNSS	GPS	~30 cm	Trilateration	[11]
A-GNSS	GPS/LTE	~10 m (67 % cases)	Trilateration	[15]

Table 4. Mobile positioning methods comparison.

Method	Advantages	Disadvantages
OTDoA	- No satellites - Operates indoor	- Reference stations clocks must be synchronized - Accuracy depends on bandwidth, - Dense BS network is necessary
E-CID	- Simplicity - Base infrastructure for RFPM - No satellites - Operates indoor	- Low accuracy
RFPM	- No satellites - Implementation without Infrastructure modification - Operates indoor	- Accuracy depends on matching algorithm, database design and measurements grid - Requires huge number of measurements
GNSS	- Good accuracy, - Almost in all smartphones	- At least 4 satellites visible - Clocks, atmospheric and multipath errors,
DGNSS	- Reduces clocks and Atmospheric errors	- Requires reference station
RTK	- Centimeter level accuracy	- Requires reference station - Computationally complex and energy consuming carrier phase measurements
DF-GNSS	- Decimeter level accuracy	- Requires dual-frequency chip
A-GNSS	- UE GNSS receiver cellular Assistance data, - Improves GNSS robustness - DGNSS or RTK corrections Possible	- The same errors like previous GNSS methods

chip) to send current location to the REM manager to obtain the transmission parameters. Discussed RTK and DGNSS corrections are claimed to be provided by A-GNSS.

In the indoor or urban-canyon conditions, GNSS methods couldn't be utilized due to the lack of enough satellites visible. RFPM utilizing LTE combined with WLAN signals measurements provides the best accuracy. However, it is much worse in terms of accuracy then the GNSS methods, and sure not good enough to support mm-waves transmission optimization. Fingerprinting is also highly implementation dependent (various matching algorithms, database design and measurement grid). It should be taken into account that measured values chosen for RFPM, should be stable in time (not dependent on the network optimization protocols). However, OTDoA method does not seem to be accurate enough for local REM. With the introduction of larger bandwidths and mm-waves it may be much improved and serve as indoor localization method. Also E-CID could be improved with the use of M-MIMO providing accurate AoA measurements.

5   Conclusions

The GNSS-based methods seem to be best solutions for the REM and should be used whenever is possible. Highly accurate RTK, highly energy-consuming though, could be helpful for REM data acquisition to provide extremely accurate localization tags for measurements. Due to lower accuracy of cellular positioning techniques, their utilization is reasonable under urban canyons or indoor conditions (where not enough satellites are visible), however it is expected to be improved in 5G networks with the use of larger bandwidths, M-MIMO and mm-waves. As the REM contains a lot of measurements-data related to position, an interesting field of future research is to check if REM could serve as fingerprints database, or even if it could perform fingerprinting by it's own to determine UE position. Another direction of future research is to obtain trustful position error models for mentioned localization methods to be used in REM operation modeling.

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