BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iași
Volumul 68 (72), Numărul 4, 2022
Secţia
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ
DOI:10.2478/bipie-2022-0022

POSITIONING KEY ELEMENTS FOR INCREASING LOCALIZATION PRECISION OF THE VRUs IN 5G NR ENVIRONMENTS

BY

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Received: October 9, 2023
Accepted for publication: December 10, 2023

Abstract. The growing number of road accidents and fatalities created a necessity for applications exploiting communication between traffic actors like vehicles, vulnerable road users (VRUs), and infrastructure. To determine the vehicle position and to communicate this data to the traffic users, the vehicles and user's smart devices are equipped with communication modules and positioning modules. The fifth generation (5G) cellular network promises to respond to the requirements of a city traffic management by: ultra-low latency, reliability, and position determined with high precision. The 3GPP Release 16 mobile communications standard details the use-cases of the industrial verticals and their requirements, the most important key performance indicators (KPIs), and technologies that the new radio (NR) architectural component uses to obtain the position information. 3GPP Release 16 targets a positioning accuracy between 1 and 3 meters for traffic monitoring and control, as well as for wearable devices.

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Moreover, the standard specifies the most common solutions that the 5G technology can support. This paper aims at presenting the context of the positioning essentials that the 5G NR can support, which are necessary to achieve road users' protection and congestion avoidance within an urban area.

Keywords: 5G NR, positioning, localization techniques, vulnerable road users, traffic use-cases, vehicle-to-everything.

1. Introduction

As urban societies have expanded, there has been a significant increase in the number of pedestrians and automobiles, numerous buildings in proximity to intersections, thereby augmenting the complexity of intersections. As pedestrians and drivers struggle to maintain their attention, the situation is becoming increasingly hazardous. All these things led to a high accident rate among vulnerable road users (VRUs), but also among drivers. It has been reported that road traffic accidents are responsible for causing up to 50 million injuries on a global scale each year (WHO, 2018).

According to data from 2019, pedestrian fatalities constituted approximately 17% of all fatalities resulting from motor vehicle crashes. Furthermore, 21% of pedestrian fatalities resulted from incidents of hit-and-run accidents (IIHS, 2021). VRUs are suffering the most, on average, a pedestrian was killed every 1.5 hours in traffic crashes in 2016 (NHTSA, 2017). (AutoInsurance.org, 2018) reported that pedestrians are highly likely to survive a collision at speeds of 30 km/h (19 mph) or lower, with a probability of survival estimated to be approximately 90%. As of 2019, the occurrence of fatalities amongst bicyclists had declined by 16% since 1975 yet had increased by 36% since reaching their nadir in 2010.

Having all these terrifying statistics related to traffic accidents, therefore, the technology came with improvements at the level of vehicles, smartphones and the infrastructure for reducing the number of fatalities and to increase the traffic flow and pleasure of driving.

The solutions include modern technologies applied to vehicles, intelligent transportation systems (ITS) (Sehar, 2022), using artificial intelligence (AI) (Peng *et al.*, 2018) to recognize traffic signs, keep the lanes, adjust traffic lights, mobile applications for message alerting and wireless technologies to allow inter-vehicular communications, cloud storage information, and even accurate positioning.

The evolution of mobile network technologies from 1G up to 5G has played a significant role in enabling communication between vehicles and other entities, including pedestrians and infrastructure. The evolution of these technologies has enabled the development of various communication modes (Zeadally *et al.*, 2019), including V2V (vehicle-to-vehicle), V2P (vehicle-to-pedestrian), and V2X (vehicle-to-everything). The evolution of mobile network technologies has made it possible to develop and deploy these communication modes on a large scale, improving road safety and mobility for everyone on the road (Agarwal *et al.*, 2021). Enabling vehicles to communicate with one another, pedestrians, and infrastructure can foster a more interconnected and intelligent transportation system, leading to benefits for drivers and society at large. Moreover, applications as traffic control systems, platooning, safety of the vulnerable road users can be developed (Garcia *et al*., 2021).

The rollout of 5G networks marks a major milestone in the evolution of mobile communication. With its promise of ultra-fast speeds and low latency, fifth generation (5G) of wireless technology has the potential to revolutionize various industries and unlock new possibilities in areas such as virtual reality, autonomous vehicles, and the Internet of Things (IoT) (Selinis, 2018).

However, to fully realize the potential of 5G, accurate and reliable positioning techniques are essential for ultra-dense 5G networks with a minimum of 2000 connected vehicles per km and at least 50Mbps per-car downlink (DL) rate (Alliance, 2015). In (Koivisto *et al*., 2017) a computationally efficient extended Kalman filter (EKF) for joint estimation and tracking of DoA and ToA positioning methods was formulated.

Furthermore, the 5G radio networks are designed to operate with very short radio frames, sub-frames, and transmit time intervals (TTIs) in the order of 0.1-0.5 ms as described in (Ford *et al*., 2016; Ford *et al*., 2017; Kela *et al*., 2015). This is a key feature of 5G technology that enables it to support high-speed data transfer and low-latency communications, which are essential for enabling V2X.

Through time, geolocation systems had become increasingly complex. From a three-component system with location sensing, positioning algorithms and a display system as presented in (Roxin *et al*., 2007) to a compounded system flow illustrated in Fig 1. Moreover, the standard specifies the most common solutions that the 5G technology can support: Downlink Time Difference of Arrival (DL-TDOA), Uplink Time Difference of Arrival (UL-TDOA) and so on (Bartoletti *et al*., 2018).

This (Dwivedi, 2021) paper presents the documentation related to 5G localization according to structure of Release 16 including the use cases and KPIs necessary to be touched in applications that should make the VRUs more visible in traffic. Nevertheless, are described also the most known methods and technologies used in 5G to obtain an accurate localization. The research had in general as source the 3GPP Release 16 and follows the present European standards.

The motivation of this paper is to present how the 5G network can improve the localization and the main advantages for any traffic participant and what are the requirements that a system traffic monitoring system must accomplish based on 3GPP standards.

The rest of the paper is structured as follows. Section 2 presents the evolution of the mobile networks from 1G to 5G and a description of the 5G network's architecture. Section 3 covers the use cases and KPIs relevant for the positioning feature as these ones are described by the 3GPP Release 16 standard. Section 4 describes the positioning techniques and methods. A road traffic-related use case including positioning importance is presented in section 5. In the last section are presented the conclusions and the utility of an accurate localization of the traffic participants.

2. Fifth generation (5G) network architecture

A description of the evolution of positioning methods in the standardization of cellular systems, from 1G to 5G, is provided in this section. The focus is on the digital networks starting with the 2nd generation up to the 5th generation. The development of cellular mobile networks based on the most popular positioning techniques, including their accuracy in terms of location methods (Cell ID, Radio Frequency Pattern Matching, Time Difference of Arrival, and Assisted-Global Navigation Satellite Systems), is outlined in Fig. 1.

5G is the fifth generation of mobile network technology and represents a significant evolution from previous generations. The main expectations of 5G include faster data transfer rates, lower latency, increased capacity, and the ability to connect a massive number of devices (ITU, 2015; Dwivedi, 2021). 5G is also expected to enable new applications and services, such as virtual and augmented reality, autonomous vehicles, and smart cities.

The 3GPP Release 16 mobile communications standard outlines the use-cases and requirements of industrial verticals, along with key performance indicators (KPIs) and the technologies used by the new radio (NR) architectural component to obtain position information. It aims to achieve a positioning accuracy of 1-3 meters for traffic monitoring and control, as well as wearable devices.

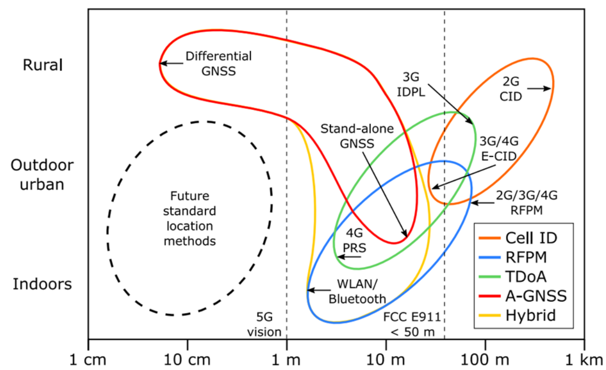

Fig. 1 – Mobile radio localization accuracy expected for indoor, outdoor, urban and rural scenarios (del Peral-Rosado *et al.*, 2018).

The 3GPP standards define a set of use cases to be supported in the future, where the positioning accuracy is one of the potential requirements. The 5G vision requires high positioning accuracy as a key requirement, (3GPP, Release 16, 2019; Wang, 2021). For example, the automotive industry requires a location accuracy as low as 10 cm for self- or assisted-driving applications, and enhanced services expect an accuracy below 10 m for 80% of the occasions and below 1 m for indoor deployments (del Peral-Rosado *et al.*, 2018). In the Fig. 3 is summarized the positioning accuracy over different environments that can be achieved by any cellular mobile network generation.

In terms of network evolution, 5G is built upon previous generations and includes advanced technologies such as millimetre-wave spectrum, massive MIMO, and network slicing. These technologies allow for higher data rates, improved coverage, and more efficient use of the spectrum. Additionally, 5G is expected to move beyond traditional mobile devices and connect a wide range of devices and sensors, creating a new era of the Internet of Things (IoT).

Moreover, the advantages of the 4.5G LTE-Advanced Pro technology can co-exist with the 5G technology. The 5G network architecture is designed to offer better performance compared to previous network generations, such as 4G. As a result, it can be designed as either Non-Standalone (NSA) or Standalone (SA) architecture as shown in Fig. 2.

5G network architecture consists of multiple network layers such as Radio Access Network (RAN), Core Network (CN), and Transport Network (Olwal, 2016). The NSA architecture operates on a legacy 4G LTE core known as Evolved Packet Core (EPC) - and manages control plane functions. The RAN is responsible for radio transmission between devices and the network. The Radio Access Network (RAN) component is a critical part of the 5G network architecture and is responsible for the radio communication between user equipment (UE) and the network. In the case of 5G networks, the RAN component uses a base station known as the Next Generation Node Base (gNodeB or gNB) to establish the connection. The CN manages the control and data plane functionality and provides connectivity between RAN and the internet. The transport network provides the backbone infrastructure for the RAN and CN (Launay, 2021).

The gNodeB acts as a bridge between the UE and the Core Network (CN) and provides the radio access to the UE. It handles the radio signal transmission, modulates, and demodulates data, and manages the radio resource allocation.

In simple terms, when a UE (such as a smartphone) wants to communicate with the network, it sends a signal to the nearest gNodeB. The gNodeB then communicates with the CN to manage the data transfer and control the radio resources. This way, the RAN component using the gNodeB ensures the seamless communication between the UE and the network. The (Peisa *et al.*, 2020) and (Sarakis *et al.*, 2021) were presented resources and service orchestrations for the new 5G equipment.

The Non-Standalone () architecture leverages the existing 4G network infrastructure and deployment, allowing for a smooth transition to 5G. It allows the 5G network to use the 4G network as a backbone for communication, but still provides new advantages and capabilities, such as improved data speeds, reduced latency, and increased network capacity.

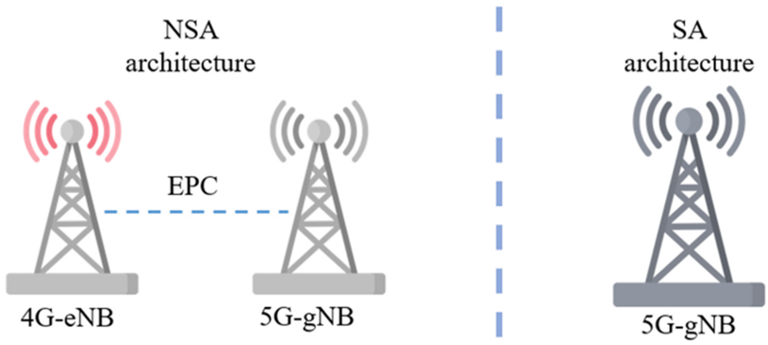

Fig. 2 – 5G network architecture options.

On the other hand, the Standalone (SA) architecture is completely independent from previous generations of networks. It is more flexible and offers more advanced features and services compared to NSA. This architecture allows for greater customization of the 5G network and is designed to provide the full potential of 5G technology.

In (Virdis *et al*., 2020), was realized a comparison between performances of 4G and 5G network to evaluate MEC deployments options. According to the study, the 4G network has a limited number of users for which can provide a high latency, while the 5G NSA can operate with several hundred of users while maintains lower latency by using the SA architecture.

3GPP Release 16 extended the capabilities in Radio Access Network and core to drive down latency, to support real-time sensitive services, providing support for more bands of spectrum.

In summary, the NSA and SA architectures both offer different benefits, with the SA architecture being more advanced and flexible, while the NSA architecture provides a more gradual transition to 5G. The architecture also includes features like network slicing, enabling multiple virtual networks to be created over a shared infrastructure, each optimized for specific use cases. Type the second section of your paper in here. Use as much space as necessary.

3. Use cases and KPIs relevant for positioning

The relationship between 5G and digitalization is often seen as close and given that positioning information plays a central role in digitalization, the implementation of 5G positioning is a critical step. In 3GPP Release 16, the positioning capabilities of LTE were expanded to include enablers of 5G technology, such as wideband signals, higher frequency bands, multiple antennas, low latency, and a more flexible network architecture. This article will discuss the recently specified methods, architecture, procedures, signals, and measurements for 5G positioning that have been outlined in 3GPP Release 16.

The subject of positioning is highlighted in this section through key performance indicators that prove the need for an increased accuracy, <3 meters precision for different commercial uses cases. Further, based on Release 16 the use cases which requires an accurate positioning are presented:

– **Location-Based Services:** bike sharing, augmented reality, wearable devices, advertisement push, flow management;

– **Transport (Road, Railway, Maritime, and Aerials):** traffic monitoring, management, and control, road-user charging (RUC), asset and freights, unmanned aerial vehicle (UAV);

– **Regulatory and Mission Critical**: emergency call, first responder, alerting service of nearby emergency responders, emergency equipment outside hospitals;

– **Industry and eHealth:** persons and medical equipment in hospitals, patients outside hospitals, waste collection and management.

The 3GPP presents diverse key performance indicators (Table 2) for 5G application to clarify the localization process on horizontals and verticals. The accuracy in localization process is defined through position accuracy, speed accuracy, bearing accuracy. The timing is described by latency, time to first fix, update rate. For application which requires a long-time availability the energy is also important: energy consumption, power consumption, energy per fix Additionally, system scalability, which encompasses the number of devices within a given time unit and a specific update rate, is of significant importance.

For good results in identifying the position of any traffic participant the continuity and the positioning system functionality to be available during the complete duration of the intended operation, reliability, provide the position-related data under stated conditions for a specified period.

All systems are vulnerable to hacker's attacks, or natural disfunctions, and the persons to have trust in a system, the integrity, and the trust in the accuracy position-related data, providing valid warnings in time to the UE and/or the user when the positioning system does not fulfil the condition for intended operation. Another critical aspect for traffic applications is the time to alert and time elapsed between change oh the integrity and the information to the UE and/or the user.

Authentication increases the trustiness of the users and protects their identity and cannot expose them to mean persons and at the same time being done in a simple way using binary field: yes or no provision of positioning authentication. Even for the effectiveness of the application counts the provision that the position-related data of the UE comes from real and not falsified signals.

Security/Privacy ensure that the position-related data is safeguarded against unapproved disclose or usage and the un-authorized party cannot access privacy information. This is also done in a binary form: yes or no security and/or privacy is needed.

In addition to improved communication features, 5G networks are also expected to enable highly accurate device or user node positioning. This is made possible according to (Mchangama, 2020; Nguyen and Kountouris, 2017) by the use of advanced positioning technologies such as beamforming, massive MIMO, and network densification.

Table 1

Horizontal accuracy and availability requirements for different positioning services (3GPP, T5 38.855 (V 16.0.0) Technical Specification Group Radio Access Network; Study on NR positioning support (Release 16), 2019)

5G Positioning Services	**Horizontal Accuracy**	**Availability**	**Service Area and Environment of Use**		**Range of UE velocity**	**Range of UEs density**
			5G positioning service area	**Enhanced positioning coverage area**		
Wide area Positioning Service	< 10 m	> 95%	Indoor and Outdoor	NA	Indoor: static Outdoor: 0-180 km/h	> 10 000 UE per km²
High Accuracy Positioning Service	< 3 m	> 99%	Outdoor	Indoor and Outdoor	up to at least >160 km/h	> 10 000 UE per km²
Very High Accuracy Positioning Service	< 0.3 m	> 99%	Outdoor (unobstructed)	Indoor and Outdoor	up to at least >160 km/h	> 100 000 UE per km²

The information related to the position determined by the sensors on vehicles or infrastructure poles (cameras, radars, lidars) should be strengthened and combined with the position determined by the network for more accurate results (Căruntu *et al.*, 2021). Positioning enables a device to determine its physical location, which is crucial for a wide range of applications, including location-based services, navigation, and emergency response (Muursepp *et al.*, 2021). In the context of 5G, precise positioning can improve network efficiency and enable new use cases that were not possible with previous generations of mobile networks. In this way, positioning techniques play a critical role in unlocking the full potential of 5G and driving innovation in the years to come.

4. Positioning techniques and methods utilized in 5G network

As cities have evolved, the complexity of intersections has increased with the addition of multiple lanes, an increase in the number of vehicles, the presence of buildings, and the use of traffic lights. This complexity poses significant challenges for drivers, as well as for the authorities responsible for implementing an effective traffic management system.

Furthermore, the presence of buildings and trees can create obstacles in signal transmissions, leading to multiple reflections of the original signal, a phenomenon known as Non-Line of Sight (NLOS). The 5G network capabilities, response to these bothers with several techniques used to determine the exact position that a driver or a VRU has at some point. A wireless localization schema is presented in Fig. 3.

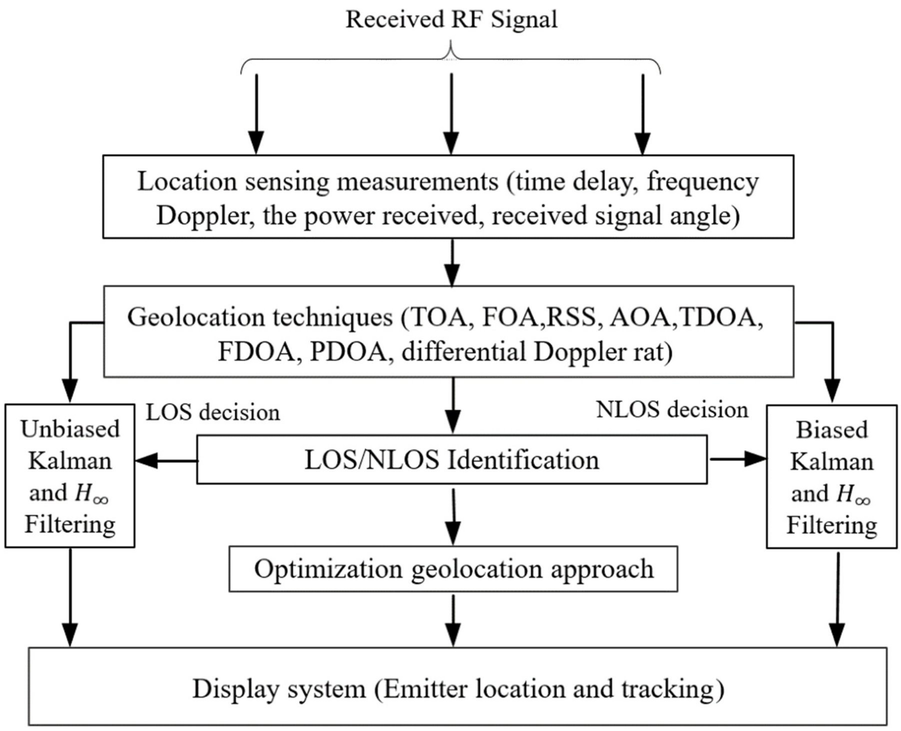

Fig. 3 – Wireless geolocation and target tracking system flow (Elgamoudi *et al*., 2021).

A widely known technique is based on Global Positioning System (GPS) is a satellite powered navigation system that provides location information to devices with GPS receivers. GPS can be used in 5G networks to provide an initial rough estimate of a device's location, which can then be refined using other techniques. This is a handy localization method to which any VRU with a smartphone can have access. 5G networks can also enhance the accuracy of GPS positioning with additional technologies, such as network-assisted GPS (A-GPS) or the use of cellular network information to correct and refine GPS position estimates. The integration of GPS with other positioning technologies, such as Wi-Fi and cellular, can also improve the precision of positioning in a 5G network.

Network-based positioning is a technique which uses the knowledge of the position of base stations and the strength of the signal received from them to determine the position of a device. This can be done using triangulation or trilateration as presented in Fig. 4, where the position is calculated based on the time of arrival or time difference of arrival of the signal from multiple base stations.

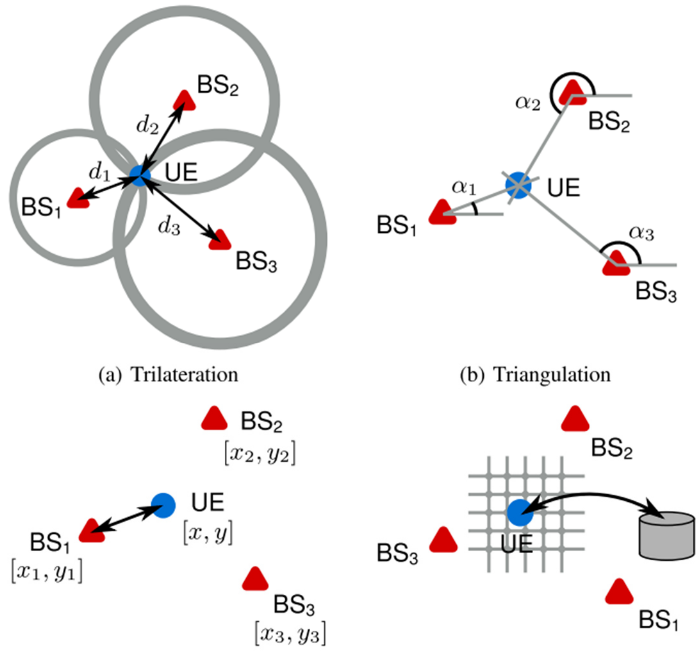

Fig. 4 – Fundamental positioning techniques used in cellular networks (del Peral-Rosado *et al.*, 2018).

Continuing with the beacon-based positioning technique that uses a low-power, cost-effective beacons that emit signals, such as Bluetooth Low Energy (BLE) or Wi-Fi signals. Devices can then use the signal strength or time of arrival of these signals to determine their position. In beacon-based positioning, the location of the device is determined by calculating the time of flight or the received signal strength of signals from multiple beacons. The accuracy of the positioning solution depends on the number of beacons visible to the device, the distribution of the beacons in the environment, and the quality of the signals received from the beacons.

Another technique called Cell ID positioning is a way of determining the location of a device in a cellular network based on the identity of the cell tower it is connected to. In a 5G network, the cell tower is called a gNodeB (gNB) and the location of the device can be determined by determining the location of the gNB. The precision of Cell ID positioning can vary depending on the density of gNBs in a particular area and the accuracy of the information about the location of gNBs that is stored in the network. Additionally, the use of millimeter-wave frequencies and new antenna technologies in 5G networks can provide improved coverage and accuracy for Cell ID positioning in challenging environments, such as indoors or in densely populated urban areas.

Machine Learning-based positioning technique uses the machine learning algorithms to predict the position of a device based on various parameters such as signal strength, signal-to-noise ratio, and previous position history. On this case, the large capacity of the 5G network avoid the bottlenecks and increases the speed of calculation that ML algorithms supposes.

Moreover, the presented techniques are combined in several methods used to determine the position of a device. Enhanced positioning methods are one of the benefits of 5G networks, along with precision and accuracy. These methods bring robustness in time synchronization and increase the coverage by using the millimeter-wave (mmWave) and multiple 5G antennas (Seker *et al*., 2018). The choice of technique or combination of techniques will depend on the requirements of the specific use case, such as the required accuracy, availability, cost, and complexity.

Positioning based on multi-cell round-trip time (multi-RTT) measurements, multiple antenna beam measurements to enable downlink angle of departure (OL-AoO) and uplink angle of arrival (UL-AoA) estimates are some of the new introduced methods. Additionally, Release 16 5G positioning specifications include NR broadcasts of positioning assistance data, such as GNSS-RTK (Global Navigation Satellite System-Real Time Kinematics).

The Multi-Cell Round Trip Time (Multi-RTT) is one of the new positioning methods introduced in 5G NR. This one operates similarly to the Distance Measuring Equipment (DME) principle in aviation. In this method, a device seeks to determine its location by sending requests and receiving responses from multiple 5G base stations (gNodeBs), not just the serving BS but also neighboring BS. By measuring the round-trip time of these signals, the device is able to calculate its location. The scheme requires bi-directional communication between the device and the BS. The network synchronization is not a critical factor for the accuracy of this method, and the accuracy is not affected even if the network is unsynchronized.

Methods can be based on angle or on time of the signal transmitted or received by the user equipment to the base station. For instance, Angle of Arrival (AoA) is a method that uses the angle at which a signal arrives at a device to determine its position. By using multiple antennas at the base station, the angle of arrival of a signal from a device can be determined, and its position can be estimated.

Time of Arrival (ToA) is a method which uses the time it takes for a signal to travel from a base station to a device to determine its position. By measuring the time, it takes for a signal to reach multiple base stations, the position of the device can be estimated. Similar with ToA technique is the Received Signal Strength (RSS) technique, where the transmitting device is required to be within the coverage area. The measured distance is used to establish a circular boundary centered around the receiver.

Time Difference of Arrival (TDoA) uses the difference in time it takes for a signal to reach multiple base stations to determine the position of a device. By measuring the time difference of arrival at multiple base stations, the position of the device can be estimated using triangulation or trilateration. In 5G networks, base stations (BS) can broadcast their own location information on a broadcast channel. This approach eliminates the need for devices to send measurement messages to the network, which then calculates and returns the location. Instead, a large number of devices can calculate their own location at a high rate, reducing the latency and processing overhead of the network. This feature provides significant benefits for applications that require real-time location information and can handle high data rates. Frequency Difference of Arrival (FDoA) is similar with TDoA technique, FDoA being the difference between two Doppler shifts of arrival signals.

Enhanced Observed Time Difference (E-OTD) method is an extension of the time difference of arrival method, which uses additional information such as the phase difference between signals to improve the accuracy of positioning.

Using a joint ToA and DoA algorithm, the simulation presented a position accuracy below one meter in 95% of cases for signal bandwidths below 10 MHz, by using one or two base stations in an urban 5G ultra-dense network. Combining positioning techniques presents some difficulties, including synchronization, accurate clock offset, and how to compensate the variations in real-time. A combined 3D positioning and network synchronization approach is introduced in the paper (Koivisto *et al*., 2016) that relies on merging the methods DoAs and ToAs for determining device position.

Analyzing the strength of the signal received by the UE can be also a solution for determining the position. Thus, the Received Signal Strength Indication (RSSI) method uses the strength of the signal received by a device from a base station to determine its position. By measuring the strength of the signal received from multiple base stations, the position of the device can be estimated using triangulation or trilateration.

These methods can be used in combination to provide improved accuracy and reliability of positioning in 5G networks. The choice of method or combination of methods will depend on the requirements of the specific use cases.

Besides base station – user equipment-based methods, the Device-to-Device (D2D) communication enables cooperative positioning in ultra-dense networks. To determine the quality of D2D communication between vehicles, a network simulator was used to simulate the communication (Militaru *et al*., 2022). Cooperative positioning is possible due to direct communication between mobile devices and the high density of small cells. Combining ranging and angle measurements can also be used to exploit ultra-dense 5G networks with relatively narrow bandwidth, as shown in (Koivisto *et al*., 2017).

5. 5G use cases and a road traffic-related use case analysis

5G technology is expected to bring about significant advancements in various industries and applications as shown in Fig. 5, including industry automation, augmented and virtual reality, smart cities, healthcare, self-driving cars.

Overall, 5G technology has the potential to transform a wide range of industries and applications, making them more efficient, effective, and convenient.

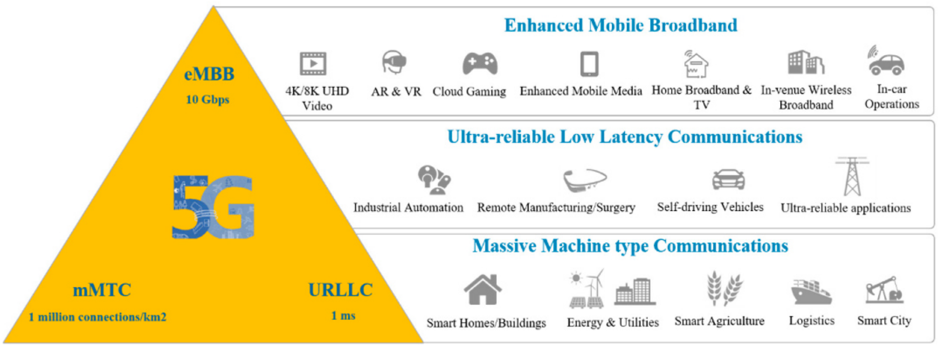

Fig. 5 – Use cases envisioned by 5G technology (O'Connell *et al*., 2020).

In 3GPP releases, the road traffic-related use case is described as one of the key areas of 5G technology application. The 3GPP specifications for 5G include specific requirements and solutions for the road traffic-related use case, such as Vehicle-to-Everything (V2X) communication and traffic management server, which enables vehicles to communicate with other vehicles, infrastructure, and the environment. This analysis aims to identify specific areas within the road traffic sector that can benefit from the implementation of 5G technology and evaluate the potential impact it may have. Such as an example is a dynamic one, where the positioning-related data determined involving usage the 5G system.

In (Bartoletti *et al.*, 2021) is presented a scenario (see Fig. 6) with stringent positioning requirements for four use cases. Coordinated driving maneuver (green arrows), interactive VRU crossing (yellow), environment perception assisted by infrastructure (magenta), and left turn in a multilane street with oncoming traffic (orange). Also, several measurements in terms of accuracy and latency are detailed in Fig. 7.

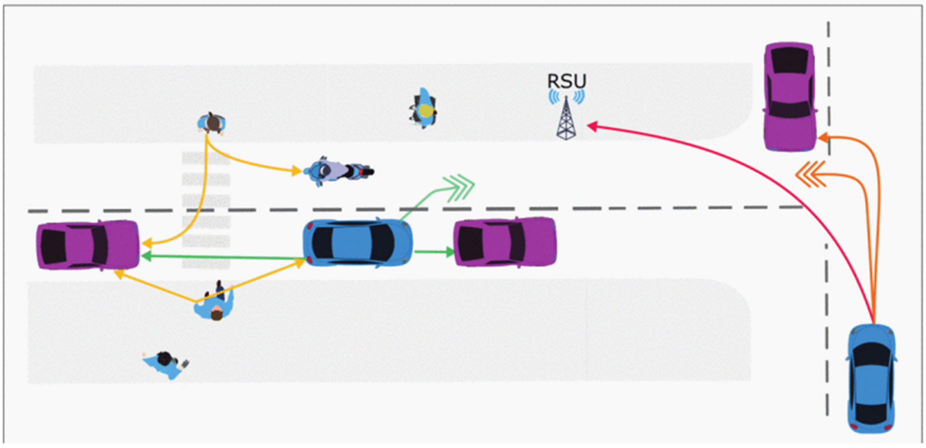

Fig. 6 – Four-use cases traffic scenario for localization (Bartoletti *et al.*, 2021).

Use cases	Environment	Accuracy	Latency
Coordinated, cooperative driving maneuver	Urban, rural, highway, intersection	1.5 m (3 σ)	160 ms
Interactive VRU crossing	Urban	0.2 m (3 σ)	100 ms
Infrastructure-assisted environment perception	Urban, highway, iIntersection	0.1 m (3 σ)	100 ms
Drifting out of lane	Urban (highway)	0.08 m (1 σ)	200 ms
Left turn in multilane street	Urban, intersection	0.13 m (1 σ)	10 ms

Fig. 7 – Service level requirements and safety-critical use cases (Bartoletti *et al.*, 2021).

In (3GPP, 2017), were defined the relative positioning requirements for platooning using the LTE positioning technologies. Consider a scenario where there is a busy intersection with multiple lanes and vehicles that need to make left turns (see Fig. 6). The safety and efficiency of this intersection is greatly impacted by the precise positioning of the various road users, particularly the vehicles. It is crucial to have a clear understanding of the exact location of each vehicle at any given moment. With the implementation of advanced positioning technologies in a 5G network, real-time information about the location and movement of vehicles can be gathered and analyzed to help improve the flow of traffic and ensure the safety of all road users.

In these cases, the Traffic Management System (TMS) gathers data, including user location, crash alerts, driving speed, etc., from road traffic participants within its coverage area. It provides traffic guidance to road users and adjusts the rules and priorities applied to different lanes. The TMS utilizes the positional data to verify compliance with the new rules and priorities. The positional data provided to the TMS by the User Equipment (UE) or the System (such as vehicle location, speed, heading, etc.) must be trustworthy and capable of being verified for trustworthiness. To prevent fraud, users or third parties should not be able to manipulate the positional data and, for example, drive on an unauthorized lane.

Flow of localization processes up to traffic management systems is shown in the Fig. 8 to demonstrate how positioning works within a traffic scenario.

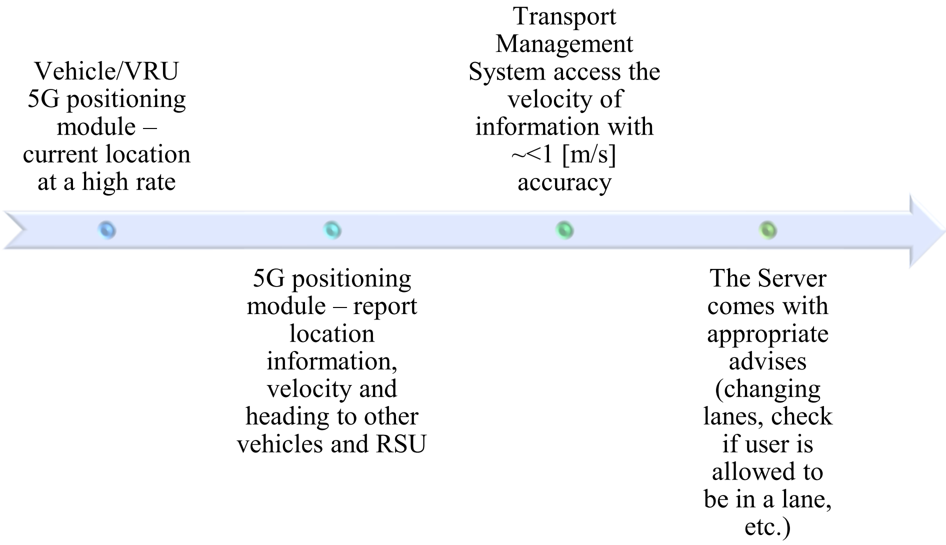

Fig. 8 – Road Traffic-related Use Case service flow described in 3GPP Release 16.

Initially the vehicle or the VRU through a smartphone is able to provide the information related to its position, speed, velocity and time with the 5G communication and the 5G positioning module. Following that, road users can share this information among themselves in order to gain a rapid and accurate understanding of the road environment. As a result, the data is sent to the regional

TMS, which is connected to the 5G network and has an overview of the surrounding traffic conditions. It is then able to decide which lanes need to be managed based on the new conditions that have been introduced.

On Release 16, is mentioned that the TMS has access to velocity information with a certain accuracy less than 1 m/s. Positioning service shall be provided by the 5G System with vertical accuracy of 2.5 [m] for speeds up to the maximum speed allowed on highways (e.g., 130-160 km/h). Also, the standard specifies that the 5G System is designed to offer a positioning service with an availability rate of 95%. It is required to have a time to first fix (TTFF) less than 10 seconds. The system must have an update rate of 10 Hz for positioning information. It should have a latency of less than 30 milliseconds for the positioning service. The 5G System must implement secure measures for the protection of positioning-related data. It should also support mechanisms for protecting against tampering and spoofing of the positioning data. Detection mechanisms must be in place to identify any attempts to tamper with or spoof the positioning-related data. Finally, the 5G System must prioritize the protection of the user's privacy during positioning services.

6. Conclusions

This paper presents a comprehensive analysis of the various elements involved in the positioning procedure based on the 5G network. It concludes that the implementation of positioning techniques in 5G networks is crucial for improving traffic flow and ensuring the safety of road users in applications as protection of the vulnerable road users, intelligent traffic monitoring systems, crowd monitoring and many others. Designing a positioning system in 5G networks requires careful consideration of several essential elements, such as availability, time-to-first-fix, update rate, latency, security, protection against tampering and spoofing, and privacy protection. With these elements in place, the positioning system in 5G networks can provide accurate and reliable location information to the traffic management system. This enables authorities to make informed decisions and provide better traffic guidance to road users. The outlook for 5G location methods is promising, and standardization bodies must recognize positioning support as a key feature of cellular networks. Ultimately, this will result in a more efficient, safe, and seamless road traffic experience for all vulnerable road users and drivers.

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ELEMENTE CHEIE DE POZIȚIONARE PENTRU CREȘTEREA PRECIZIEI LOCALIZĂRII UTILIZATORILOR VULNERABILI ÎN TRAFIC FOLOSIND REȚELE DE TIP 5G

(Rezumat)

Numărul tot mai mare de accidente rutiere și de decese a creat necesitatea pentru aplicații care exploatează comunicarea între participanții la trafic, de exemplu vehicule, utilizatori vulnerabili ai drumurilor (VRU) și infrastructură. Comunicarea vehicul-la-vehicul (V2V), pieton-la-vehicul (P2V) și vehicul-la-infrastructură (V2I) permite

transmiterea de mesaje de răspuns în timp real şi conştientizarea care oferă informaţii precise despre locația fiecărui participant la trafic, alături de informații despre starea unui utilizator al drumului (de exemplu, poziție, viteză, direcție etc.) spre utilizatorii din proximitatea apropiată pentru a înțelege ce acțiune ar trebui să ia: să reducă viteza, să fie mai atenți la cazuri speciale, cum ar fi un pieton cu dizabilități care traversează strada, și așa mai departe.

Vehiculele sunt dotate cu diverși senzori (cum ar fi radar, lidar, cameră, GPS, etc.) pentru a înțelege mediul înconjurător și a-și determina localizarea în cadrul acestuia, dar acest lucru nu îmbunătățește siguranța rutieră decât în cazul în care aceste caracteristici de locație sunt cunoscute cu precizie de către celelalte vehicule sau pietoni, sau chiar și de către infrastructură. Pentru a determina locația vehiculului și a comunica aceste date utilizatorilor de trafic, vehiculele și dispozitivele inteligente ale utilizatorilor sunt dotate cu module de comunicare și module de poziționare. Informațiile legate de poziția determinată de senzori ar trebui consolidate și combinate cu poziția determinată de rețea pentru rezultate mai precise.

A cincea generație (5G) de rețele celulare promite să răspundă cerințelor unei gestiuni a traficului urban prin: latență ultra-redusă, fiabilitate și determinarea poziției cu înaltă precizie. Standardul de comunicații mobile "3GPP Release 16" detaliază cazurile de utilizare ale verticalilor industriali și cerințele acestora, cei mai importanți indicatori de performanță cheie (KPI-uri) și tehnologiile pe care componenta arhitecturală nouă de radio (NR) le utilizează pentru a obține informații privind locația. "3GPP Release 16" vizează o precizie de poziționare între 1 și 3 metri pentru monitorizarea și controlul traficului, precum și pentru dispozitivele purtabile. Mai mult, standardul specifică cele mai comune soluții pe care tehnologia 5G le poate susține: Downlink Time Difference of Arrival (DL-TDOA), Uplink Time Difference of Arrival (UL-TDOA), etc.

Această lucrare își propune să prezinte contextul elementelor esențiale de localizare pe care 5G NR le poate susține și care sunt absolut necesare pentru a realiza protecția utilizatorilor de drumuri și evitarea congestiei într-o zonă urbană.