5G Positioning Open API Industry
White Paper

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1 Vision and Mission

In 2020, the National Development and Reform Commission (NDRC) specified the scope of new infrastructure and emphasized the acceleration of 5G network construction. As a result, the construction of 5G base stations within China intensified, and the industry entered a period of high-speed development. According to statistics from China's Ministry of Industry and Information Technology, 580,000 new 5G base stations were built in China in 2020, while 330,000 were co-constructed and shared. By the end of the year, 5G networks had reached all of China's prefecture-level cities, with more than 718,000 5G base stations deployed and the number of 5G terminal connections surpassing 200 million, more than anywhere else on earth. Thanks to such extensive infrastructure, the total number of 5G package subscribers exceeded 320 million.

At the same time, a wide range of 5G applications began to emerge. According to the White Paper on China's 5G Development and Its Economic and Social Impacts (2020), it is estimated that 5G applications related to live broadcasting and monitoring based on ultra high-definition (UHD) video and smart recognition will be first implemented in 2021 or 2022. Such applications include 4K/8K UHD live broadcast, HD video security monitoring, quality detection empowered by machine vision and 5G, and 5G remote real-time consultation. As Internet of Things (IoT) continues to develop, there is an increasing demand for services related to the indoor positioning of people and objects, and such technologies will play an important role in enterprise management, security monitoring, emergency rescue, and smart elderly care. By combining the benefits offered by 5G networks (such as multiple antennas, dense base station deployment, and high bandwidth) with indoor positioning applications, 5G location-based applications will greatly enrich the 5G ecosystem. Consequently, it is essential for operators to fully understand the development trends of 5G applications in the core fields — as 5G-based positioning capabilities represent one of the primary development directions of the future.

According to a recent analysis and prediction report from the market research company MarketsandMarkets, the global indoor location market size will grow from USD 6 billion in 2020 to USD 17 billion by 2025 (including devices, solutions, and services), at a compound annual growth rate
(CAGR) of 22.5%. As enterprises typically use positioning services indoors and outdoors concurrently, a 5G positioning network that continuously covers both indoor and outdoor areas will offer a preferred management experience. 5G high-precision positioning can be employed in vertical industries to achieve cross-industry and cross-field cooperation, while also facilitating flexible service innovations. This approach delivers value-added services for enterprise users and introduces benefits from the perspectives of security, efficiency, and business.

As an operator, China Mobile is committed to building an open positioning capability platform and creating a prosperous 5G ecosystem — in addition to constructing high-quality 5G positioning networks. As a result, 5G positioning can be used more flexibly in industrial, financial, and transportation scenarios. China Mobile is also dedicated to working with the communications industry chain, positioning service providers, and enterprise customers across various industries to continuously promote the industrial applications of 5G and help enterprises to accelerate their digital transformation and upgrade.
2 Technology

2.1 Market Demand for 5G Positioning

More than 80% of the information we process in our daily lives features spatial location characteristics. As such, there is an increasingly urgent need to quickly and accurately obtain location information from mobile terminals and provide location services in both indoor and outdoor environments.

5G positioning is a technology used by 5G mobile communications networks to determine the geographic location of a UE by measuring radio signals. 5G positioning services enable users to obtain location-based geographic information services anytime and anywhere, satisfying the need for accurate locations in terms of “who, what, when, and where” in the wireless world.

Through in-depth integration with vertical industries, 5G high-precision positioning can provide flexible and diversified service innovations for a wide range of fields, improve the industrial foundations and level of modernization for industry chains, and deliver improved security, efficiency, and business benefits to enterprise users.

5G positioning applies to the following scenarios:
Let's take the manufacturing industry as an example, as large factories need to periodically audit assets of various types and net values. By utilizing tags equipped the 5G precise positioning function, employees can obtain asset locations anytime and anywhere, saving a large amount of manpower and greatly improving overall efficiency. Another example relates to the chemical industry, where 5G positioning can locate people, materials, and vehicles within a factory by using protective devices, employee ID cards, and labels capable of 5G precise positioning. Based on specific locations, the positioning platform can offer various applications to ensure the operational safety of chemical enterprises. Such applications include loitering alarms, emergency response personnel counting, safety index thermodynamic diagram, geofence access management, SOS alarms, contractor management, specified routes and destinations of chemical vehicles, and chemical equipment positioning (including inventory audits and spare parts querying).

2.2 Introduction to 5G Positioning

2.2.1 Principles of 5G Positioning

Positioning capabilities were introduced to 5G network standards in 3GPP R16, which was frozen around the middle of 2020. In addition to traditional positioning technologies such as E-CID, OTDOA, and UTDOA, 5G positioning makes use of 5G wide spectrum and multi-beam characteristics to support additional positioning technologies such as multi-RTT, UL-AoA, and DL-AoD. 3GPP R16 requires 5G to be able to provide a positioning accuracy of 3m @ 80% in indoor areas and 10m @ 80% in outdoor areas in order to meet the requirements of meter-level positioning in typical commercial scenarios.
3GPP R17 is working on continuous enhancement of 5G positioning capabilities. In March 2021, 3GPP officially approved a new Work Item Description (WID) – Low Power High Accuracy Positioning (LPHAP) — which aims to increase the positioning accuracy to 0.5m @ 90% or higher, and the battery endurance of positioning terminals to months or even years. This indicates that 3GPP will deeply combine 5G communication and positioning capabilities to continuously improve 5G applications in vertical industries.

From the perspective of 5G positioning principles, positioning technologies can be roughly divided into three categories: positioning technology based on triangle relationship, positioning technology based on scene analysis, and positioning technology based on proximity relationship.

**Positioning technology based on triangle relationship**: Based on the measured data, this positioning technology uses the geometric triangle or hyperbola relationship to calculate the location of the measured object. It is the most important and widely used positioning technology.

**Positioning technology based on scene analysis**: This positioning technology abstracts the specific positioning scene, describes each location in the scene with specific and quantitative parameters, and integrates the information into a database. Within the industry, such quantized location feature information is referred to as a signal "fingerprint", and this is compared with the information in the database to determine the location of the object according to a specific matching rule.

**Positioning technology based on proximity relationship**: This positioning technology estimates the location based on a proximity relationship between an object to be located and one or more known location reference points. This technology usually requires the assistance of an identification system, and a unique identifier is used to determine each known position. The most common example is a cell ID in a mobile cellular communications network, where it is assumed that a certain object is located in three cells. As the location of the reference point in each cell is known, the location of the desired object can be roughly determined according to the cells in which it is located.

### 2.2.2 5G Positioning Architecture

3GPP TS 23.273 defines the 5G positioning architecture. 5G positioning involves the UE, 5G radio access network (RAN), and 5G core network (5GC). Using the advantages offered by 5G network infrastructures, operators can integrate 5G positioning capabilities with the communications network and build a unified 5G positioning platform, providing both 5G network communications and positioning services for third-party customers. The following figure shows the NEs involved:
1. **UE**

A 5G UE reports its positioning capability when it accesses the network. The UE can actively send sounding reference signals (SRSs) to the network side, which performs signal measurement and location calculation. Alternatively, the network side sends downlink positioning reference signals (PRSs), which the 5G UE measures before reporting the results back to the network side for location calculation.

2. **RAN**

Uplink measurement is used here as an example. A wireless base station measures the time of arrival (ToA)/signal strength (RSRP) of SRSs of the 5G UE, and reports measurement results to the 5GC. The wireless base station is interconnected with the 5GC through the 3GPP-defined N2 interface. The base station and LMF exchange positioning messages via the AMF, including positioning requests/responses and measurement requests/responses. The positioning messages related to the N2 interface are defined in 3GPP TS 38.455.

3. **5GC**

The 3GPP-compliant AMF is integrated and interacts with the location service (LCS) over the NL1/NL2 API, as well as the LCS of the MEC.

The 3GPP-compliant UDM is integrated and interacts with the LCS over the NL6 API.
For the MEC, user profile functions (UPFs) can be distributed in campuses to process traffic locally. The LCS uses high-precision positioning algorithms, and provides a portal through which base station planning information within a specified area can be imported for accurate location calculation.

MP1 is a standard API defined by ETSI and enhanced through basic 5G positioning capabilities. As such, it is capable of meeting operator service requirements relating to on-demand invoking of location services provided by the 5G positioning platform.

4. Operator's 5G positioning platform

The operator's 5G positioning platform bridges third-party applications and the 5G positioning network, provides customers with location services through open REST APIs, such as real-time location push, geofence, map management, location alarms, track query, location-based video monitoring, and location data analysis.

2.2.3 Advantages

- **Unified standards for global 5G ecosystem**

  5G positioning uses globally unified 3GPP positioning standards, laying the foundation for its commercial use. It was first defined for commercial use in 3GPP Release 16 and is refined to indoor and outdoor scenarios. Such technology is a key enabler for thousands of industries, and will be introduced to vertical industries.

  The 5G industry ecosystem is the world's largest communications industry with extensive development experience. Such experience can be fully reused by 5G positioning to accelerate its development in industries.

- **Dual-use network, cutting investment**

  The communications and positioning networks are integrated into one to provide wireless data communication and precise location services to UEs. UEs can use wireless positioning technologies to locate 5G-enabled mobile devices, and by doing so, it helps improve network utilization and effectively cuts costs for network construction and maintenance.

- **Gradual evolution towards better comprehensive positioning capabilities**

  - Higher accuracy: Since Release 16, 5G positioning is able to achieve meter-level accuracy, and is moving forward to a sub-meter-level accuracy, enabling more industry applications.

  - Lower delay: Since Release 16, location transmission delay can be reduced to 1s, and will be further reduced to 0.1s or even lower.

  - Higher connection density: Positioning for high-density 5G terminals can be achieved based on the 5G massive connection capability.
- Longer battery life: 5G terminals as speculated in Release 15 and 16 all support positioning and day-level battery life. As technology evolves, terminals will be able to operate for months or years.

2.3 5G Location Service Standard APIs

The 5G location service solution includes multiple network functions (NFs) as defined in 3GPP specifications, and involves signaling exchange from end to end. The location service relates to multiple sectors, including service authentication and authorization, charging statistics, and location capability exposure and service capability invocation via the Network Exposure Function (NEF). Additionally, it is also related to factors such as the deployment location of 5G NFs and application scenarios.

Considering customer requirements and product capability design, we have preliminarily defined APIs, including their types and functions, to facilitate communication with the positioning platform to obtain UE location for industry customers, as well as further collaboration among all parties for 5G positioning.

In section 2.3 "5G Location Service Standard APIs", the API client is the operator's 5G positioning platform and the LCS is on the 5G network.

2.3.1 API for Single Location Query

Application Scenario

This API is invoked by the API client to locate the target UE. The API client sends the UE ID, and the relative indoor location of the UE is returned over this API.

Service Process
2.3.2 API for Periodic Positioning – Batch Subscription by Multiple Subscribers

Application Scenario

This API is invoked by the API client, which sends parameters such as the target UE ID and positioning period to request locations. The 5G network periodically positions the target UE and returns results about its position.

Service Process

2.3.3 API for Periodic Positioning – Location Result Notification

Application Scenario

Continuous real-time positioning.

Service Process

2.3.4 API for Periodic Positioning – Unsubscription Request

Application Scenario
2.4 Operator's API for 5G Location Capability Exposure

Operators build 5G communications and positioning networks to provide the location capability for vertical industries through the positioning platform. Third-party developers can quickly obtain UE locations through the location functions of this platform, helping vertical industries build positioning applications. Through open REST APIs, location functions such as real-time location obtaining, historical track query, and geofence can be invoked. Location information is returned to subscribers in JSON format.

In section 2.4 “Operator's API for 5G Location Capability Exposure”, the app refers to a third-part app.

2.4.1 Real-time Location Subscription

Application Scenario

A third-party application can locate a device in real time through the positioning interface. The client communicates with the server through WebSocket and outputs information about their real-time location information.

API Description

WebSocket is a TCP-based technology used for real-time communication between the client and server. It creates a TCP connection for exchanging data between the client and server through HTTP requests, and the server pushes the real-time location data of the device in JSON format to the client.

Service Process
2.4.2 Proactive Location Query

Application Scenario

The client sends a location query request to the positioning platform to obtain the real-time location about a specified device.

API Description

The client sends an HTTP/HTTPS GET request to query for the location of a device in a specified area based on the IMSI or MSISDN of the device.

Service Process

2.4.3 Historical Track Playback

Application Scenario

Users can use this API to play back the historical locations and movement tracks of a specified UE between a specified start and end time from the positioning platform.
API Description

This API is used for interacting with the positioning platform, which proactively records the historical positions of UEs and stores them. Using this API, the client can obtain the historical location tracks of a specified UE within a historical time period from the positioning platform for data analysis.

Service Process

2.4.4 Geofence Alarm Reporting

Application Scenario

Administrators can specify an area on the map as a fence area. When a person is detected entering or leaving the fenced area, the administrators and subscribers will be alarmed over this API. The precise alarm push helps with in-time violation handling.

API Description

The location-based geofence can be adjusted to a variety of shapes (including circles, rectangles, and irregular polygons). The positioning platform determines the relative position of a UE against the fence based on its real-time location, and then generates alarm notifications based on the configured alarm rules. Multiple alarm types are supported, such as entry/exit, entry/exit prohibition, and overcrowding alarms.

Service Process
3 Ecosystem Development

The ecosystem buildout for 5G positioning is more complex compared to traditional 5G services, as the industry ecosystem comprises many parties and requires much cross-industry collaboration. It involves the E2E industry chain, where the upstream industry chain concerns the manufacturers of chips, sensors, communication modules, and components; the midstream industry chain involves the device vendors (for UEs, base stations, and network devices), operators, map providers, and algorithm vendors; and the downstream industry chain includes the parties engaged in solution set formulation, industry application, data analysis, and system integration.

The location service is a key 5G capability. As a breakthrough point for 5G penetration in vertical industries, the 5G positioning ecosystem buildout demands collaboration of multiple sectors involving chips, modules, UEs, networks, operations, and vertical industry applications. Through extensive collaboration, the positioning accuracy will be improved, product functions and forms will be expanded, device costs and prices will be reduced, and the positioning solutions will be optimized. These all help 5G positioning become ideal for vertical industries and bring more business value.

The freezing of 5G Release 16 in 2020, and the progress of Release 17 have driven 5G positioning technology towards maturity. However, the 5G positioning industry is still in its infancy. The positioning accuracy, UE forms and costs, and UE power consumption need to be optimized, and the 5G positioning solution for vertical industries needs to be strengthened. These improvements require comprehensive collaboration among all industry parties.

As a conventional communications service provider, China Mobile is ready to bridge the 5GtoB industry and system integration, and provide reliable and satisfactory basic information services for vertical industries. It will collaborate with upstream and downstream partners to break through the barriers in accuracy, power consumption, and costs for positioning, and will continuously diversify products, as well as develop and optimize the 5G positioning industry solutions. It will also provide APIs to cooperate with ecosystem partners, to nurture 5G positioning capabilities, tailor 5G positioning solutions for vertical
industries, and build benchmark cases in digital factory and intelligent manufacturing, to create a thriving industry.
## 4 Appendix

### 4.1 Abbreviations

<table>
<thead>
<tr>
<th>NF</th>
<th>Full Name</th>
<th>Function</th>
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<tbody>
<tr>
<td>UE</td>
<td>User Equipment</td>
<td>Reports its positioning capabilities to the location management function (LMF), and sends sounding reference signals (SRSs) on the location allocated by the radio access network (RAN).</td>
</tr>
<tr>
<td>RAN</td>
<td>Radio Access Network</td>
<td>Receives or sends NRPPa-related positioning messages, and responds to the SRS resource configuration requests delivered by the LMF and allocates SRS resources to specified UEs. It also measures the time of arrival (ToA)/reference signal receiving power (RSRP) for SRSs, and reports the measurement results to the LMF.</td>
</tr>
<tr>
<td>AMF</td>
<td>Access Management Function</td>
<td>Receives and manages positioning requests initiated by the UE/gateway mobile location center (GMLC)/AMF, interworks with the RAN for positioning based on NRPPa, and transparently transmits positioning-related messages between the LMF and RAN, UEs, or other entities.</td>
</tr>
<tr>
<td>LMF</td>
<td>Location Management Function</td>
<td>Receives and processes positioning requests or positioning-related data requests from the AMF, receives the NRPPa messages reported by the RAN, sends ToA measurement requests (SRS resource configuration requests) to the RAN near the serving cell, and collects ToA measurement results from the RAN for location calculation.</td>
</tr>
<tr>
<td>NF</td>
<td>Full Name</td>
<td>Function</td>
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<tr>
<td>GMLC</td>
<td>Gateway Mobile Location Center</td>
<td>Processes UE location requests from the location service (LCS) client, that is, obtains the longitude and latitude information of the UE and returns it to the LCS client.</td>
</tr>
<tr>
<td>UDM</td>
<td>Unified Data Management</td>
<td>Stores the LCS privacy profiles and routing information.</td>
</tr>
<tr>
<td>LCS Client</td>
<td>Location Service Client</td>
<td>A logical function entity, which may be within the public land mobile network (PLMN), for example, the O&amp;M tool, or may be outside the PLMN, for example, a third-party location server.</td>
</tr>
<tr>
<td>API-GW</td>
<td>Application Programming Interface Gateway</td>
<td></td>
</tr>
</tbody>
</table>

### 4.2 References
