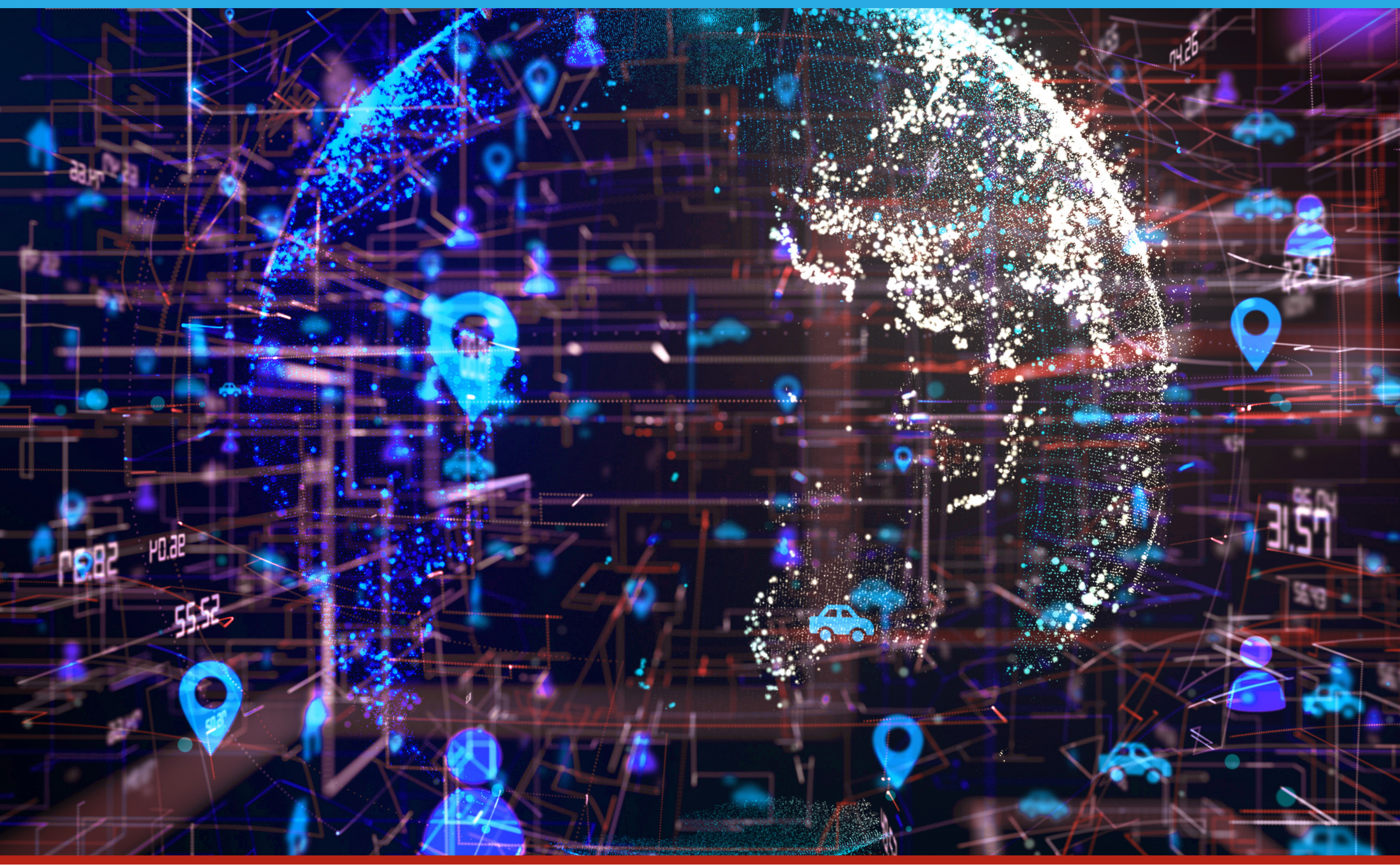
Unlocking Global Operational Resilience with Universal Asset Visibility

How cloud-based cellular location is enabling a wave of IoT use cases and poised to become a primary IoT location technology.



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Introduction

Operational resilience is now a top initiative of enterprises large and small. Driven by the US-China trade war, COVID-19, and by increasingly demanding regulatory compliance, companies realize that their supply chains are fragile and need not only hardening but also flexibility. Creating flexible and resilient supply chains requires enterprises have more visibility into their operational assets. This includes knowing the location of material and work-in-progress (WIP) inputs from point of extraction, to transport to the factory, and within warehouses and distribution centers. It also includes understanding the status of machines and operations creating and delivering products and services.

The Internet of Things (IoT) is the class of technologies that will almost single handedly create highly visible enterprise operations. This includes not only monitoring assets for health and operational efficiency, but also for understanding the location in real time of assets and products.

While the costs for tracking and monitoring assets continues to fall, building truly resilient enterprise operations that are visible indoors, underground, and in rural and ocean locations is very expensive. Low power wide area networks (LPWAN) and satellite technologies will partially address the affordability issue both for network access and the bill of material (BOM) costs for tracker and sensing devices. But still limiting affordability are cost effective location technologies primarily due to the cost of trackers often requiring use of multiple connectivity and sensor technologies to address the unique needs by use case and operational environment. Tracking assets requires real-time location information, but even monitored stationary assets need real-time location information to enhance monitoring and servicing operations.

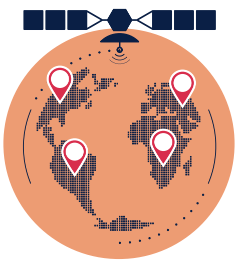
GNSS has worked for vehicular navigation or for use on powered assets, but for all other IoT applications and use cases, GNSS-based options have been a more-or-less imperfect fit forcing trade-offs in BOM costs and power requirements without clear need for high location accuracy. Low-Power GNSS which only uses GNSS when needed can reduce power consumption but still requires the added BOM costs from the GNSS chip and antenna. Fortunately, technology is evolving to enable more power-efficient, lower BOM cost location services for an emerging set of devices and use cases that will drive the majority of growth in the IoT market.

This white paper provides a review of the current location technologies including their advantages and limitations. It then reviews cloud-based cellular location technology and its benefits over existing location technology options including GNSS, Wi-Fi, BLE, and other WAN-centric approaches. The white paper concludes with an estimate of the market potential that is unlocked when cloud-based cellular location technology is employed for asset visibility.

Review of Current Location Technologies

Proprietary and standards-based technologies, either location-specific or location-enabled, are currently widespread. Multiple technologies are often hybridized in a single device to complement each other's capabilities, with key characteristics including power consumption, geolocation accuracy, range, and coverage (indoors/outdoors). The hybrid approach for location enablement facilitates a variety of use cases and operation environments, but it also drives additional requirements such as separate hardware, infrastructure, and security for each technology – driving up device BOM.

Wide Area Location Technologies



Global Navigation Satellite System (GNSS)

GNSS works through trilateration of time and orbital position data from a minimum of three satellites, calculating the signal transit time from each satellite to the end-device on an atomic clock with an accuracy up to 40 nanoseconds. Government-run GNSS regional variants – namely GPS, Beidou, Galileo, Glonass, and QZSS – are currently the most common way to track assets globally. GNSS provides the greatest outdoors coverage and the most accurate positioning of all wide-area location technologies, in particular in remote locations, at 2-meter precision in open skies. GNSS also does not require payment for access to satellite positioning data. All that is needed is the purchase of a GNSS-embedded chip or module – with average pricing of approximately $1.21 today and expected to decrease to $1.08 by 2025.

Four primary challenges specific to IoT requirements exist for GNSS geolocation, however.

- GNSS geolocation is a heavy drain on battery life: receivers themselves are power-intensive, and further typically take around 30 seconds to establish a fix to three satellites – increasing total device power-on-time and proving fatal to battery-powered long-term IoT deployments.

- GNSS signal penetration is very low: as such, while accurate outdoors, GNSS geolocation will not function without a direct line-of-sight to the sky and must be complemented in IoT by further location technologies such as Wi-Fi or BLE. The need for a direct line-of-sight further complicates satellite-fixes in built-up environments such as city buildings and tree foliage and may vary based on weather conditions, increasing Time-to-First-Fix (TTFF) and device power-on-time, and reducing accuracy.

- From a security perspective, GNSS is liable to signal jamming – limiting the utility of its geolocation capabilities for theft prevention or recovery. GNSS signal jammers are frequently used in cargo or vehicular theft.

- While GNSS chip prices in volume can be very low, device cost increases when adding GNSS to the device due to antenna, battery and device housing costs. Average price increases for addition of GNSS ranges for 10% to 35% depending on the connectivity technology. Cheaper implementations of GNSS technology further impacts its performance.

Further advancements to GNSS geolocation, such as assisted GPS (a-GPS) or Low-Power GPS (LP-GPS), aim to address power concerns by using cellular base-station data or device-/server-based GNSS almanacs to speed up TTFF; these alleviate rather than eliminate the challenges for GNSS use in IoT. Other technologies such as Real-Time Kinematics (RTK) are generally not applicable to low-cost applications in asset tracking.

2G/3G/Long Term Evolution (LTE) Cellular and Cellular LPWAN

Cell-ID and Enhanced Cell-ID (eCID) are the most commonly used technologies for cellular Location-Based Services (LBS). In Cell-ID, devices receive base-station unique identifiers (IDs) and reference these against existing private and public ID databases to estimate the location of the device based on the base-station longitude and latitude coordinates. eCID is offered by MNOs as an enhanced form of Cell-ID, relying on the same principle as Cell-ID but augmenting this with Timing Advance (TA) data – the difference between signal transmission and reception time – when this data is available. Cell-ID and eCID technologies are enhanced by time-, signal strength-, or angle-based techniques (such as RSSI, AoA, TDoA, ToA), but the accuracy is by and large limited to the proximity of the cellular base-stations to the end device and the coverage perimeter of the base-station – limiting outdoors precision in most cases to between 800 meters and several kilometers.

Advantages of cellular positioning include widespread and global coverage by existing network operator infrastructure, good indoors penetration, fast computation and no start-up delays, and no additional hardware or network requirements enabling scalability of the solution. However, three principal challenges exist for Cell-ID positioning in IoT:

- MNOs are reluctant to share their cell site databases and open their location APIs. This results in existing Cell-ID providers mining the location of cell towers without operator partnerships: while this provides a broad database, existing suppliers lack information on exact positioning of cell antennas (such as orientation or height) – limiting accuracy. As such, suppliers such as Combain, Unwired Labs, or Google offer Cell-ID global positioning using extensive databases, but at a low accuracy. Accuracy of MNOs' Cell-ID and eCID solutions is limited because they are only using their own network cell sites.
- While requiring far less power than GNSS, Cell-ID can be power intensive through relying on continuous connectivity with the base-station.
- The accuracy of Cell-ID is low. This applies even more to IoT bands – primarily Cat-M and NB-IoT – whose narrow bandwidths limit accuracy compared to wider band cellular networks.

5G Cellular

5G is bringing additional capabilities to cellular positioning, derived from increased cell-site density, high carrier frequencies, and large bandwidth. The aim, as with Cell-ID and eCID, is to bring communication and location information under the same infrastructure. Different from 2G, 3G, and 4G network standards is the standardization of location capabilities within the 5G specifications. Release 16 standardized location accuracy and yield, with indoor/outdoor accuracy of 3 and 10 meters respectively, 80% of the time. Release 17, to be released in 2021, builds on this by setting out centimeter-level accuracy and higher network capacity. While improving overall accuracy of Cell-ID/eCID, 5G positioning will have similar drawbacks to the current cellular technologies noted above. In addition, two further challenges should be noted:

- The higher frequency spectrum used by 5G will limit the range of Cat-M and NB-IoT bandwidths, reducing the ability of devices to get signal readings from all new base stations. Cat-M and NB-IoT specifications form the baseline mMTC 5G specification.

- The high yield set out in Release 16 is only possible in areas where 5G base stations are densely deployed; the higher frequency spectrum used by 5G will limit the range of each base station, such that more extensive network rollouts with 5G radios will be necessary to achieve the promised levels of accuracy and yield. Coverage of two thirds of the global population with 5G is expected by 2025.

Non-Cellular Low Power Wide Area Networks (LPWAN)

Sigfox and the LoRa Alliance provide low power, low data-rate, and long-range connectivity on unlicensed spectrum. These connectivity providers also provide location services. Sigfox's Atlas Native and LoRa's Cloud Geolocation services provide GNSS-free positioning but very low-accuracy frequently measured in the multiple hundreds of meters due to the low density of network antennas. As such, hybridization with GNSS and other technologies (such as passive Wi-Fi sniffing) will remain common on these networks. For LoRa, private deployments with higher densities of gateways can achieve higher levels of accuracy eliminating the need for GNSS. Companies such as Hoopo's private LoRa network offering can achieve LoRa positioning accuracy of up to 15-meters using multiple gateways deployed in a confined area. Disadvantages of non-cellular LPWAN positioning include:

- Typical accuracy on deployed LoRaWAN and Sigfox networks is measured in the hundreds of meters to multiple kilometers. Higher accuracy can be achieved only with more densely deployed gateways – making the technology unsuitable for global high-yield positioning.
- Proprietary LPWAN solutions are usually combined with additional location technologies – such as LoRa Edge or Abeeway combining GNSS, Wi-Fi, and LoRa – driving up the total bill of materials (BOM).
- While proprietary LPWAN technologies have good indoor and outdoor penetration and range, the low global coverage of proprietary LPWAN networks reduces its utility when requiring global or even regional visibility.
- Mobility is additionally frequently a challenge, with LoRa and Sigfox experiencing high packet loss rates when travelling faster than walking speed and thus more suited for location on stationary objects.

Short-Range Location Technologies

Wi-Fi, BLE, and UWB are the most widely used location technologies for indoors positioning. While they are not a replacement or directly comparable to wide-area location technologies, they frequently complement wide-area technologies to provide higher accuracy for in-building or urban environments. Typical downsides of these location technologies for global positioning are their short range and low penetration.

- Wi-Fi is a popular location technology for urban or indoors environments due to existing widespread Access Point (AP) infrastructure. This infrastructure furthermore provides additional useful services, namely internet access, so that a separate location technology does not need to be deployed in parallel and costs of deployment are amortized. Wi-Fi is also standards-based, making it interoperable between a wide range of devices with a Wi-Fi chip. High power consumption, low penetration, and low security in both public and private networks are downsides, however. Wi-Fi is mostly deployed as a complementary location technology alongside WAN technologies where a higher degree of accuracy in urban environments is required or for low-accuracy indoors positioning.

- BLE is one of the most popular indoor positioning technologies due to its ubiquity on consumer devices – thanks to being standards-based – and due to its status as the most affordable Real-Time Locating System (RTLS) technology. BLE 5.0 and 5.1 standards further brought additional locating capabilities to the technology, in particular Angle of Arrival (AoA) and Angle of Departure (AoD) direction-finding. Coupled with greater range (400 meters indoors, and up to 1 kilometer free-field), its new location capabilities in BLE 5.0/5.1 enable centimeter-level position-finding (though more frequently in the range of 2-3 meters) with fewer intermediary gateways, diminishing what is otherwise the technology's greatest drawback – namely the need for large beacon and Access Point (AP) infrastructure deployments. BLE is furthermore increasingly added to existing Wi-Fi APs through software upgrades as a way of diminishing these requirements for new infrastructure. In addition, the Low Energy standard of Bluetooth reduces power consumption on devices, while BLE tags' ever-decreasing price point make this technology highly scalable for indoors tracking.

- UWB is a technology primarily used for pinpoint sub-20 centimeter-level location finding, as used for instance in warehouse management or industrial safety applications. The eponymous wide-bandwidth used is what enables the high precision, allowing a receiving radio to accurately measure the time of flight of the signal while avoiding interference – making it suitable in challenging Radio Frequency (RF) environments. However, while it is resilient to RF interference, the technology requires a direct LOS to achieve precision, bringing challenges in environments with lots of moving parts or walls. Secondly, the cost is often prohibitive – requiring a dense and dedicated gateway environment and low-power tags, making the technology difficult to deploy at scale.

Current Location Technologies Summary

There is no single location technology capable of addressing all use cases in IoT. Current location technologies have not yet found the balance between accuracy, cost, power consumption, and security. The principal challenges are summarized below:

- Existing wide-area location technologies offer a choice between accuracy (GNSS) and low power consumption (cellular and non-cellular LPWAN). No currently deployed technology can provide wide-area outdoor and indoor coverage with any degree of accuracy.

- Hybridization is necessary to provide more accurate and different types of location information, driving up the BOM for devices and location solutions.

- Location technologies that provide high levels of accuracy (GNSS, Wi-Fi, BLE, UWB) have features that frequently break the business case for an IoT deployment requiring location – such as high-power consumption, additional device hardware (GNSS) or deployment of infrastructure (non-cellular LPWAN, Wi-Fi, BLE, UWB) to compensate for shortcomings in technology coverage.

- Security and privacy of data, including location data, is one of the most frequently cited concerns by enterprises wishing to deploy IoT solutions. Current location technologies such as GNSS, Wi-Fi, and BLE are all particularly vulnerable to device-based attacks.

- Only GNSS provides location data while allowing IoT devices to roam globally. Current cellular solutions are limited to single mobile network operators, while other technologies don't have a large enough infrastructure install base.

- 5G will open up new capabilities for cellular, with location at its heart. New capabilities for standards-based location over cellular ensures a sustainable growth for cellular LBS. 5G currently is in the early stages of network deployment, however, and will not be able to provide the promised levels of accuracy immediately.

Cloud-Based Cellular Location

Technology

Cloud-based cellular location is a cloud-based software-only solution, in which a device receives signals from surrounding cellular base-stations within range. These signals are compressed into a small data package and forwarded to the cloud, either through chipset-integrated firmware or through a simple API overlay. Signals are processed and computed using advanced algorithms to interrogate an extensive base-station ID database – comprised of public databases, MNO databases, and proprietary base-station location mining.

Cloud-based cellular location is different from eCID: eCID is siloed to network location data of a single MNO's location service offerings. In cloud location, a device captures and forwards signals from network base-stations across multiple operators to the cloud and references them against a base-station ID database. Cloud-based cellular location works without needing carrier permissions meaning it can operate on any cellular network in the world for global, consistent, and rapid location services. This brings a number of benefits:

- Global availability: Cloud-based cellular location is not siloed by carrier network, and is able to provide location off the massive globally-deployed cellular infrastructure. The ongoing rollouts of LTE and 5G network technologies, including Cat-1, Cat-M and NB-IoT, will further increase this technology's coverage and accuracy.
- Time-to-fix: Cell-ID's network-based location requires a continuous connection between the device and network to establish a positioning fix. A device using cloud-based cellular location may power-on momentarily to receive and forward all surrounding cellular signals before powering down again. This is particularly effective when using LTE network technologies which have a frame-length of 10 milliseconds: this allows a location time-to-fix of less than 1 second – greatly improving device power management as well as real-time tracking capabilities.
- Accuracy: Current cellular location providers rely on public databases and cellular base-station mining, with limited accuracy because of MNO-proprietary data – such as antenna height and orientation. MNOs supplying their own Cell-ID or eCID solutions are constrained to offering this using only their base-stations. By capturing all base-station signals regardless of carrier and by improving its database through base-station location mining, cloud-based cellular location enables much higher position accuracy. Based on the type and bandwidth of the IoT network, location accuracy may vary from between 20 to 700 meters, outperforming Cell-ID and eCID and bringing accuracy at the highest levels comparable to Wi-Fi. Cloud-based cellular location is not designed for centimeter-level accuracy but provides a universal solution with acceptable location data for any type of cellular connected asset.
- Security: Cell-ID location is carried out on the device through the network, making it vulnerable to device-based tampering and interference. Cloud-based cellular location provides chip to cloud security and reduces the risk of OS-based attacks.

Cloud-based cellular location addresses a number of pain points found in other location technologies.

- Indoor and outdoor positioning technology without affecting the lifespan of the device: cellular LTE network such as Cat-M, NB-IoT, and Cat-1 have much lower link-budgets than other cellular technologies which enable deep indoor penetration capabilities. This enables locating devices outdoors and indoors – whether in a building or in a container stack – and therefore a higher yield of location data compared to all other location technologies.
- Single universal tracking technology removing the need for hybridization: accurate cellular location reduces the need for hybridization in use-cases where super-precise location is not required, and leverages existing hardware to reduce the total device and solution BOM.
- Accuracy of positioning without any major trade-offs: cloud-based cellular location offers the most accurate location of cellular technologies with address, street, or neighborhood level visibility, sufficient for a wide array of tracking solutions – whether for supply chain visibility, rental or proprietary equipment location monitoring, or package-level tracking. 5G will furthermore significantly improve the capabilities of cloud-based cellular location while the technology is being deployed, without requiring a full 5G network infrastructure rollout. These benefits are achieved without sacrificing power consumption or range.
- No new infrastructure or hardware requirements, with a software-based solution: cloud-based cellular location is deployed as a combined on-device firmware and cloud-based software solution. As such, it utilizes existing hardware and LTE infrastructure without requiring additional BOM costs. In addition, cloud-based cellular location technology can complement GNSS, Wi-Fi, or BLE when the highest levels of accuracy are required.
- Secure technology without third party hardware or software security requirements: cloud-based cellular location does not run on an Operating System (OS) or on the device, but rather in the cloud. The technology is much less subject to jamming or device-based attacks.
- Higher location accuracy yield in urban and rural environments, regionally and globally: cellular networks are widely deployed globally. Further advancements of modernized LTE networks (through deployments of Cat-M, NB-IoT, and Cat-1 technologies) and of 5G networks will provide coverage in population-dense areas such as urban environments and transport infrastructure among others. Cloud-based cellular location's use of any cellular signals means it is able not only to generate higher accuracy than Cell-ID and eCID, but do so on a much more consistent basis across dense and dispersed cellular infrastructure in urban and rural environments.
- Cellular location technology to build and scale on existing infrastructure: as noted, the build-out of LTE and 5G networks with enhanced and standardized location specifications ensures a sustainable future for cloud-based cellular location. In the asset tracking segment of IoT alone, shipments of devices with cellular LPWAN (primarily Cat-M and NB-IoT) are anticipated to grow at a 143% CAGR through to 2024, to become more than 5 times the size of the traditional cellular share of this segment.
- Brownfield and greenfield devices: as well as being built-in to chipsets and deployed on new devices, cloud-based cellular location can be retroactively deployed with a simple API onto existing cellular devices – providing immediate additional visibility services into existing assets without requiring any further hardware, infrastructure, or compute power. The smallest and simplest cellular-connected devices are able to take advantage of this to provide location visibility without affecting their performance.

Implementation

Advantages of Cloud-Based Cellular Location exist for the entire ecosystem of suppliers offering LBS. Cloud-Based Cellular Location has the potential to become a universal solution, addressing every layer of the solution stack. This section provides an overview of the advantages for various stakeholders in location-enabled solutions.

Chipset/Module Original Equipment Manufacturers (OEM)

Chipset and module vendors currently provide Cell-ID solutions through embedded proprietary or third-party software, enabling a device to run geolocation algorithms and report its location. One of the primary challenges to the model for this supplier type is that chips and modules are locked-in to the carriers with whom their hardware is registered, preventing Cell-ID use when roaming inter-regionally or globally.

Turning to a third-party vendor for cellular geolocation solutions enables chipset and module vendors to focus on making best-in-breed hardware rather than addressing a complicated software solution. The value of cloud-based cellular location technology to these vendors centers on the universality of the solution, whereby data captured by the chipset or module can be 'pointed' towards the cloud by a simple API or through device-embedded firmware, enabling data to be gathered from any cellular carrier's infrastructure and used to provide accurate geolocation. This opens up new revenue streams for this supplier category, as well as simplifying the in-house solution development process.

Device OEMs

One of the main challenges facing this category of supplier is finding the balance between BOM cost, battery consumption, security, and accuracy within a single piece of miniaturized hardware. Manufacturers frequently turn to location technology hybridization to address different requirements for tracking an item everywhere – with variations based on the specific use case. While improving accuracy, hybridization comes at a cost to the other three elements of the equation noted above.

Embedding firmware enabling cloud-based cellular location on a device and/or pointing data to a cloud platform via an API enables an OEM to use existing cellular connectivity hardware to deliver additional functions and location-based services. As such, an OEM can reduce BOM cost, battery consumption, and security measures for each of the location technologies used while delivering accuracy suitable for a majority of tracking use cases.

Mobile Network Operators (MNO)

MNOs leverage their existing proprietary cellular infrastructure and databases to provide Cell-ID solutions. Cloud-Based Cellular Location offers significantly higher accuracy and yield over Cell-ID and eCID, enabling MNOs to offer enhanced value-added LBS without needing to provide software upgrades to existing LTE base stations. This can be provided by a cloud platform license for the carrier and a simple API for the end-user.

Furthermore, the lower cost and smaller device footprint of tracking devices enabled by Cloud-Based Cellular Location means that higher volumes of smaller assets can be tracked using cellular technology; for an MNO, this translates to higher numbers of devices using their networks and connectivity plans.

Systems Integrators (SI)

Software providers and SIs competing in the tracking space can offer the highest precision location tracking platforms based on cellular networks, replacing existing Cell-ID and eCID technologies and delivering real-time location. Implementation of cloud-based cellular location can be carried out via a simple API from the cloud-based cellular location platform into an existing proprietary or enterprise application development platform. Cloud-based cellular location's universal indoors/outdoors and global solution means that it can be used as a single technology – simplifying the cost and complexity of implementation for SIs.

Hyperscalers

A core focus of hyperscalers is driving more data to their infrastructure for storage and compute services which in turns drives adoption of additional services such as analytics. Besides being a cloud-centric technology, the cost benefits of cloud-based cellular location when compared to GNSS will also drive deployment of more devices communicating with the cloud. The net effect is higher volumes of devices driving data to hyperscaler infrastructure and encouraging adoption of more value-added services.

In addition, large public cloud and IoT services vendors such as AWS are increasingly offering a broader range of tools and software to target the broad IoT ecosystem. These vendors frequently partner for specialist services, rather than directly competing with their partners and customers. Cellular location is one such specialist service, relying on broad MNO and public databases combined with algorithms to enhance accuracy. Cellular location currently is an MNO-dominated service, with a large number offering platforms and databases to locate a device using Cell-ID or eCID. Partnering with specialist providers for location-based services allows hyperscalers to avoid competition with connectivity suppliers and building services outside their core competencies while also extending their services to a broad IoT audience.

Enterprises

Understanding the location of assets and inventory, within or between campuses or regions, is a crucial requirement to optimize an enterprise's bottom line and build operational resilience. This means that enterprises are able to track their assets inside warehouses or factories, in the back of trucks, under container stacks, within cities, or on the open road – with a single solution. This last bit enables enterprises to focus on their priority – namely addressing particular business requirements at the lowest cost and with the greatest simplicity. Cloud-based cellular location can provide infrastructure-free positioning, as well as being integrated within existing or new IoT LTE- or 5G-enabled devices to deliver real-time visibility into enterprise asset location.

Unlocking Market Potential

Based on its numerous benefits for the IoT, cloud-based cellular location services are poised to unlock services opportunities leveraging location information as well as accelerate adoption of IoT services in emerging high-volume markets such as pallet and parcel tracking. In fact, ABI Research believes that cloud-based cellular location will add over 220 MM new connections to the IoT install base in 2026.

Qualitative assessment of the cloud-based cellular location market leveraged existing forecasts for IoT connections covering over 30 application segments. This total addressable market was then segmented into two segments of GNSS-based devices and devices without GNSS. Finally, these two segments were further split into four air interface categories of 4G (> Cat-1), 4G Cat-1, Cat-M/NB-IoT and 5G.

Forecast analysis for cloud-based cellular location services across the four air interface categories was performed by application segment and included assessment of numerous variables including average reduction in device BOM cost, eCID penetration, cloud-based cellular location service market awareness, network coverage expansion and densification, and location accuracy need by application segment. Data for these calculations came from existing ABI Research IoT market data and insights as well as from extensive interviews. The culmination of this work provides three forecasts demonstrating cloud-based cellular location adoption across the IoT market.

Air Interface Forecasts

Overall penetration of the cloud-based location installed base will reach 42% by 2026. Penetration of the technology will be moderate through 2022, as 4G LPWA networks continue expansion and device OEMs bring more LPWA devices to market. However, from 2022 to 2026, ABI Research expects a four-fold increase in penetration driven largely by devices on Cat-1, Cat-M, and NB-IoT networks. Asset tracking will be the main driver of growth on these networks, as cloud-based location becomes more important for driving down BOM costs, which, in turn, accelerates adoption by the higher volume markets, such as parcel and pallet tracking.

Cloud-Based Cellular Location Installed Base (MM)	2020	2021	2022	2023	2024	2025	2026
4G	0.008	1.1	4.7	14.5	24.8	34.8	42.9
Cat-1	0.012	1.8	10.3	37.0	98.6	152.2	213.9
Cat-M/NB-IoT	0.008	1.5	8.9	46.4	155.9	553.3	1,079.2
5G	0.000	0.0	0.0	0.1	0.4	8.2	25.1
Total	**0.027**	**4.5**	**23.8**	**97.9**	**279.8**	**748.6**	**1,361.1**
Total 4G/5G IoT Installed Base (MM)	349	515	725	1,032	1,488	2,142	3,251
Penetration	0%	1%	3%	9%	19%	35%	42%

Asset Tracking Market Forecasts

Machines and things for tracking cover a wide range from the large and heavy such as intermodal containers and construction equipment, to the more numerous such as containers and parcels. In the majority of cases, the assets are unpowered so asset tracker device size and cost, as well as battery life are critical elements in the ROI of the solution and for driving scale. Cloud-based cellular location technologies provides device OEMs and service providers new options for designing devices and assembling innovative services that meet the unique needs of each asset tracking segment.

Besides the BOM and battery life benefits, asset tracking use cases will evolve around the accuracy of location needed to address the business case. ABI Research expects that GNSS level accuracy will not be needed in many asset tracking use cases while cloud-based cellular location accuracy continues to improve over time due to densification of networks and improvements in cloud-based cellular location technology. Asset tracking will grow to 78% of the cloud-based cellular location market and penetrate over three quarters of the asset tracking installed base by 2026.

Asset Tracking Installed Base (MM)	2020	2021	2022	2023	2024	2025	2026
Cloud-based cellular location	0.01	1.3	6.7	44	170	579	1,043
GNSS and non-GNSS	66	96	145	216	301	308	326
Cloud-based cellular location	0%	1%	4%	17%	36%	65%	76%
GNSS and non-GNSS	100%	99%	96%	83%	64%	35%	24%

Non-Asset Tracking Market Forecasts

Non-asset tracking markets cover a wide range of assets that are typically stationary and can reside in locations ranging from rural to inside buildings. As a result, location information for these assets was either derived from Cell-ID technologies or a hybrid solution, or more often was not requested. But location information applied to business processes that use these assets can offer the enterprise significant benefits. For instance, field service operations can become more efficient using a live location fix of an asset helping technicians more quickly find an asset. Theft monitoring of industrial assets such as pumps or compressors is another use case that can be inexpensively facilitated with cloud-based cellular location technologies. Overall, cloud-based cellular location technologies offer the best option for incorporating location into business processes due to not only lower cost and longer battery life devices, but also from multiple service options that allow fees of less than one cent for delivery of a single location event.

Non-Asset Tracking Installed Base (MM)	2020	2021	2022	2023	2024	2025	2026
Cloud-based cellular location	0.01	3.2	17	54	110	169	318
GNSS and non-GNSS	283	415	557	719	906	1,085	1,564
Cloud-based cellular location	0%	1%	3%	7%	11%	13%	17%
GNSS and non-GNSS	100%	99%	97%	93%	89%	87%	83%

Summary

Enterprises increasingly require visibility into their distributed assets. This is an essential requirement in many applications, as with asset tracking or telematics, but it can also add value to existing solutions for any number of portable or fixed assets.

The discussion around location until the present day has focused on providing the most accurate location using existing technologies, with GNSS becoming the most common method for providing IoT asset location. But this discussion is shifting towards practicality based on the use-case. Will a hybrid solution achieve the needed business benefits if the cost and complexity of the solution limit reaching the desired scale? Furthermore, for a location solution that can be provided globally, what level of location accuracy is realistically needed? GNSS' visibility down to 2 meters is not required for most IoT use-cases, and comes with power consumption and BOM cost drawbacks. On the other end of the spectrum, cellular positioning is rarely employed for IoT in the present day except as a secondary or tertiary location technology – as a last resort, when all other location technologies fail.

Cloud-based cellular location can provide low-power, global indoors and outdoors coverage, high yield, and acceptable accuracy for a number of IoT use cases – all at a low price point and power consumption. As a cloud software solution, it can be used as an overlay on any IoT device using cellular LTE, without requiring additional hardware, infrastructure, or embedded software. Its many benefits relative to other location technology choices demonstrates that its biggest hurdle is a more holistic assessment by enterprise of location use case requirements. Through greater market awareness and the push to enable a wave of emerging IoT use cases, cloud-based cellular location has the potential to join the ranks of GNSS as a primary location technology for the IoT.

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