RCL
RENEVO CAPITAL LIMITED

FEATURED M&A REPORT

Unified Positioning & Tracking 2.0

RCL Tech M&A Trends - April 2020

Contents

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Executive Summary

Technology advancements over the past decade in mobile wireless communications and geospatial positioning, combined with the emergence of micro-electromechanical systems (MEMS) and miniature low-power sensors, have given rise to an exciting new genre of products and greenfield market opportunities, not the least of which includes the evolution of the Internet of Things ("IoT") and autonomous vehicles. Among the building-block technologies critical to the success of IoT device tracking and autonomous vehicles, none is more crucial than the integration and unification of indoor and outdoor location positioning systems, driven by global demand for accurate location positioning with seamless traversal and uninterrupted service indoors and outdoors.

Outdoor location systems, such as the satellite-based Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS), were deployed initially for military use in the 1970s and 1980s, respectively, and improved incrementally over a three-decade period for civilian use. In contrast, indoor location systems emerged in the 1990s and advanced considerably over a 20-year period but continue to be dogged by a complexity of technical challenges, competing initiatives, ambiguous and incompatible standards (cross-industry), and geopolitical influences.

At stake is the prospect of a winner-take-all opportunity to control, as a first market-mover advantage, a fully integrated and unified indoor/outdoor location positioning system, which stands to generate billions in annual revenue. Further, the data harvested and mined from such a system will be analyzed and sold for multi-industry, government and political use, delivering an unending supply of value in terms of the trends and insights derived from the analytics.

In this edition of the RCL Tech M&A Trends report, authors Per Selbekk and Jerry Panagrossi present deep technical insights and market perspectives on two emerging trends and related M&A opportunities: *Unified Positioning* and *Tracking 2.0*.

First, a brief update on recent global M&A activity …

Global M&A Activity (in brief)

2019 year-end estimates

Global M&A activity decreased by 6.9% in 2019 with cumulative reported transaction value totaling US$3.33tn, according to a report published by Mergermarket, *Global & Regional M&A Report 2019*.

Cross-border deals were off 25% in 2019, hitting its lowest volume in five years, according to a news article published by Axios, *Global merger and acquisition activity decreased in 2019*, citing data released by Refinitiv.

Four of the five largest M&A deals in 2019 were completed in the first half of the year, according to a Bloomberg Law news article, *M&A Market Strong But Deal Lawyers Warn of Hesitation in 2020*.

Raytheon Co.'s $90 billion acquisition of United Technologies Corp.

Celgene Corp.'s $87 billion purchase of Bristol-Myers Squibb Co.

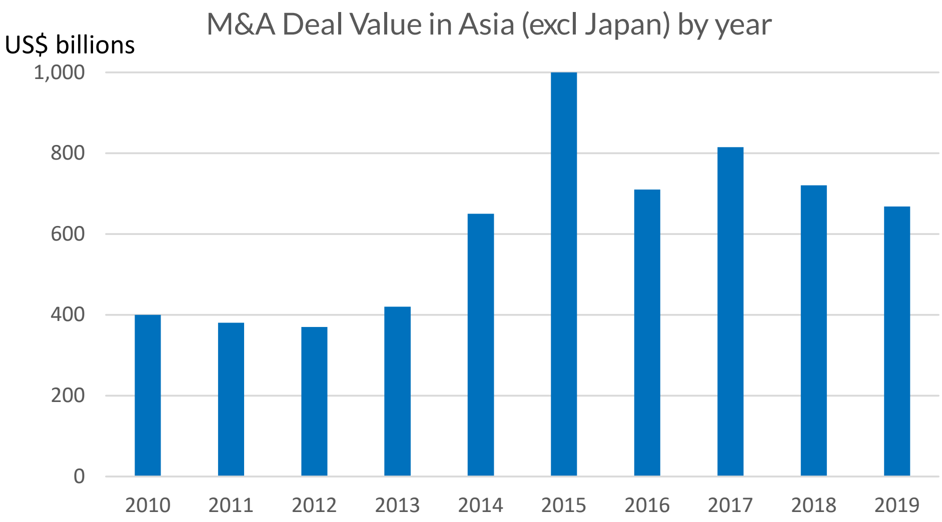
AbbVie Inc.'s sale to Allergan PLC for $83 billion

Anadarko Petroleum Corp.'s $55 billion purchase of Occidental Petroleum Corp.

M&A Deal Value by Region (sources: *Mergermarkets* & *Dealogic*)

North America	US$1.69tn	+1.50% vs 2018
Latin America	US$85.9bn	+12.5% vs 2018
Europe	US$770.5bn	-21.9% vs 2018
AsiaPac (excl Japan)	US$667.8bn	-10.3% vs 2018
MEA	US$141.2bn	+102% vs 2018

M&A activity in Asia-Pacific excluding Japan decreased by 10.3% to US$667.8bn in 2019, reported in a South China Morning Post news article, *Deal bankers see slowest M&A activity in Asia-Pacific outside Japan since 2014: Dealogic.*



Source: Dealogic

Unified Positioning

the case for a unified indoor/outdoor location system

Imagine the following scenario:

> *A customer would like to order a robo-taxi – that is, an autonomous vehicle of the future – to pick him/her up at the entrance of a hotel in downtown San Francisco, which is located in a covered parking garage, and drop him/her off at a customer-specified terminal entrance at the San Francisco International Airport (SFO).*

Given the state of technology available today, the fundamental building-block components do not exist presently at a level of maturity required to address this scenario. Although companies are continuing to make tremendous strides with their respective developments, they are still arguably 10-to-15 years away from delivering a comprehensive solution for vast commercial use. Further, if a robo-taxi were available today, one possessing the essential technology and intelligence required to support effectively the numerous navigation, safety and hazard avoidance, general operation and maintenance checks, varying weather conditions, and refueling/recharging tasks required to facilitate the end-to-end journey described in this scenario, the essential infrastructure for an indoor and outdoor navigation system needed to support this journey simply does not exist; that is, certainly not in the form of a cohesive, unified system. Rather, what we find available today are disparate indoor and outdoor location and navigation systems (plural), each of which has an inherent set of functional capabilities and limitations. These legacy systems operate primarily as independent, siloed services and, as such, are not capable of satisfying the basic technical requirements and use cases spawning from emerging product categories, including autonomous vehicles and IoT tracking devices.

Genesis of User Adoption and Dependence

Today, navigation applications, like Google Maps and Apple Maps, have become an integral part of smartphone users' daily lives. Whether it is driving to a restaurant or walking to a conference venue through an unfamiliar city, these and other widely-available navigation applications offer appreciable utility to people of all ages and walks of life. And, for companies of all sizes, not only navigation but also location positioning and tracking applications have become indispensable tools in an ongoing quest to improve operational efficiencies and gain competitive advantage, particularly in such areas as asset tracking, route planning, delivery, resource deployments, and preventative maintenance.

The ever-growing increase in both personal and business use of navigation and location tracking applications, along with the high rate of attachment and dependency on these applications, has driven users' and companies' expectations beyond the functional capabilities of the location systems deployed and available for use today, upon which these applications and services are directly dependent for effective operation. As a more pressing concern, new use cases evolving from the intersection of 5G wireless, IoT device tracking and autonomous vehicles (see *Greenfield Market Opportunities* on the following page) have intensified the urgency for making vast improvements to conventional indoor and outdoor location systems, including the hardware and software that enables these systems to interact with one another.

Opportunities for Improvement

To address these concerns, companies of all sizes, ranging from early-stage startups to tech industry giants, have set out to develop and commercialize innovative location solutions, which include a diverse mix of (i) *hybrid systems* – those that integrate indoor and outdoor location functionality, and (ii) *custom location solutions* designed to address specific industry needs; for example, tracking and monitoring the contents of transcontinental shipping containers, locating portable medical equipment in hospitals, and tracking and monitoring the environmental conditions of refrigerated trucks for the delivery of perishable foods and medicine.

Location system performance varies widely in terms of geolocation accuracy and accessibility, which for the sake of clarity in this report are defined as follows.

- Accuracy – a measure of the radius (usually in kilometers, meters or centimeters) within which a location system is capable of providing precise geospatial coordinates
- Accessibility – metadata describing the extent of a location system's functional scope of use; e.g., indoors and/or outdoors, 2D or 3D coordinates (i.e., latitude, longitude and altitude), and any system-specific qualifiers and limitations

Most location-based applications and services, like Google Maps, depend on the use of GPS and at least one additional wireless network, such as Wi-Fi, to serve in combination as the essential infrastructure required for calculating and refining geospatial coordinates at an acceptable level of accuracy and timeliness for supporting instant-on use – the latter referring to the duration of time required to serve-up the first set of coordinates (aka, the *initial fix*) for use by a location-based application.

A selected list of *Wireless Networks* is provided on the following page – notably those that (i) comply with specifications defined by international standards organizations, (ii) are growing steadily in terms of global deployments, and (iii) are capable of providing the essential infrastructure required to support location-based applications and services.

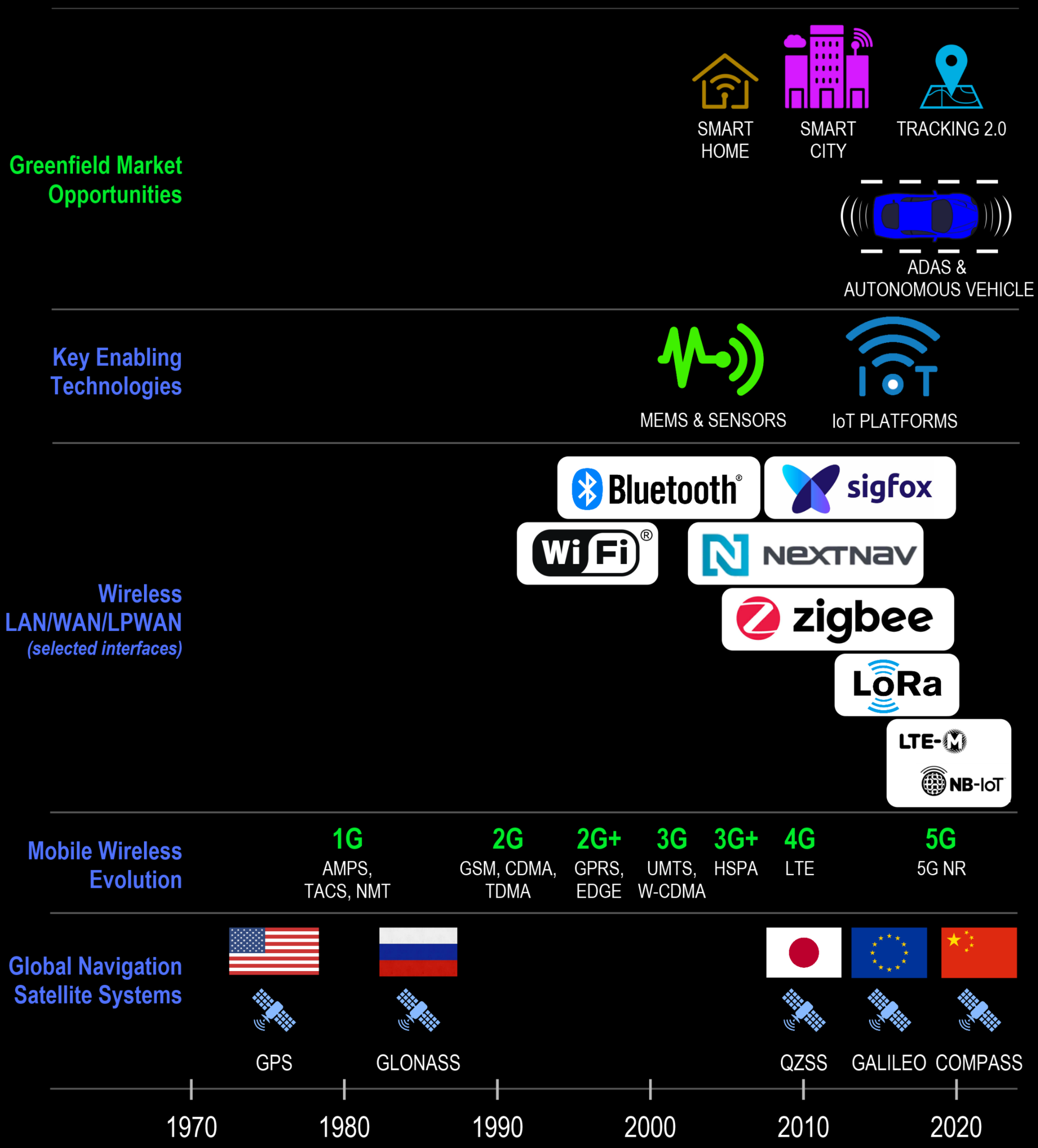
Drivers for Change

All hybrid indoor/outdoor location systems available for use today have an inherent set of functional capabilities and limitations. Regardless of whether a system is based on GPS, Wi-Fi, Bluetooth, LTE or proprietary wireless communication interfaces, or any combination thereof, no single system is presently capable of satisfying the accuracy and accessibility requirements for all personal and business use cases. For example, location systems that use Bluetooth Low-Energy ("BLE") beacons for implementation require high densification, meaning a large number

[continues on page 8]

Greenfield Market Opportunities

with selected enabling technologies and wireless standards



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Evolution of Mobile Wireless

Generation	Primary Services	Key Differentiator	Weakness (addressed by subsequent generation)
1G	Analog voice calls (MNT, AMPS)	Mobility	Poor spectral efficiency, major security issues
2G	Digital voice calls and messaging (GSM, TDMA, CDMA)	Secure, mass adoption	Limited data rates - difficult to support demand for Internet/e-mail
2.5G	Enhanced 2G (GPRS, EDGE)	Improved data rates	Support for streaming data
3G	Voice calls, messaging, data (3G, W-CDMA, UMTS)	Improved Internet experience	Real performance failed to match hype, failure of WAP for Internet access
3.5G	Voice calls, messaging, broadband data (3G, W-CDMA, UMTS)	Broadband Internet, applications	Tied to legacy, mobile specific architecture and protocols
4G	All-IP services, including voice and messaging (4G, Mobile IP)	Faster broadband Internet, lower latency	Significant improvements in latency, data transmission speed, concurrent device connectivity, concurrent call and data sessions, network handling for direct Machine-to-Machine (M2M) connectivity, and broadband support for fixed- and mobile-wireless evolution
5G	Hyper-connected; Next-generation software-defined radio access network (SD-RAN) technology; Dynamic network configurability	1-10 Gbps connections to end points in the field; 1 millisecond end-to-end round trip delay (latency); 1000x bandwidth per unit area; 10-100x number of connected devices; (Perception of) 99.999% availability; (Perception of) 100% coverage; 90% reduction in network energy usage	[N/A]

Source: GSMA Intelligence

Wireless Networks (utilized for location services)

Wireless Service	Description	Benefits	Limitations
LTE	Long-term Evolution (a reference to the 4th generation of GSM-evolved cellular networks, often referred to as "4G")	International adoption and widespread availability for use; accessible indoors and outdoors resulting from LTE cellular network deployments in most countries	Location accuracy impacted by weak signal strength (aka, attenuation) and limited points of signal reference required for triangulating precise location
LTE-M / NB-IoT	3GPP LTE CAT-M & NB-IoT LPWAN services	Both standards are ideal for low-power wide-area network (LPWAN) use	International accessibility as network operators continue deployments
Wi-Fi	A trademark owned by the IEEE standards organization – note that Wi-Fi is not an acronym	International adoption and widespread availability for use, particularly in businesses, airports, conference venues, shopping malls, universities and homes in most developed countries	Limited primarily for indoor use; Location accuracy can be impacted by large physical obstructions and signal-absorbing materials
Bluetooth	Specifically, Bluetooth Low Energy (BLE)	International adoption and widespread availability for use in nearly all smartphones, tablets and laptops; Small, low-cost, low-power BLE beacons can be installed throughout a building or warehouse to improve location accuracy	Installation and maintenance costs associated with high densification required for BLE beacon placement; Location accuracy impacted by moving large physical obstructions and signal-absorbing materials
NextNav	NextNav (late-stage, venture backed, private company, founded in 2008)	Metropolitan Beacon System (MBS) - a proprietary wide-area terrestrial network dedicated for providing 3D indoor/outdoor services; supports FCC E911 and public safety initiatives; complements GPS	Presently limited for use only in the US – still ramping deployment for rural and urban use
sigfox	SigFox (late-stage, private equity backed, private company, founded in 2009)	Global oG low-power, wide-area network to listen to billions of objects broadcasting data, without the need to establish and maintain network connections; integrated SigFox Geolocation services suite, "Atlas," complements GPS and Wi-Fi	Limited (but rapidly growing) network coverage for rural and urban use; operates in the ISM radio band which is known to have excessive network contention/ interference
LoRa	Abbreviation for Long Range Note: Core IP owned by Semtech; open standard supported by ~500 members of the LoRa Alliance non-profit organization [5]	LoRaWAN used in conjunction with BLE tags for indoor positioning; low power translates to longer battery life; wide-area network (LPWAN) ideal for IoT device communication and tracking; low frequency band (137 MHz to 1020 MHz) penetrates buildings more effectively than Wi-Fi and Bluetooth; 130+ million devices deployed by ~120 network operators in 82 countries [6, 7]	Installation and maintenance costs associated with densification required for BLE beacon placement; Overheads associated with supporting multiple radios; e.g., GPS, Bluetooth and LoRa
zigbee	IEEE 802.15.4 based specification developed by the Zigbee Alliance [8]	High-level communication protocol used to create PANs with small, low-power digital radio and low-bandwidth needs; Ideal for IoT device communication and tracking; 2500+ products certified and 300 million products deployed [9]	Limited availability for use in terms of built-in support for conventional devices (e.g., smartphones, tablets and laptops); Best suited for smart home devices and applications

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of beacons must be installed per square-area to achieve a specific precision level in terms of location accuracy and to maximize accessibility in terms of scope of use. High densification often translates to high up-front installation and long-term maintenance costs. Additionally, beacon-based systems tend to have a short effective operating range due to weak signal attenuation (i.e., weak signal strength) and limited coverage area per beacon – the latter resulting from the high signal frequency (2.4 GHz) and the low-power signal transmission level at which BLE beacons operate. As a general principle of radiophysics, the higher the signal frequency, the greater the susceptibility of signal impedance, where a signal is blocked by doors, walls and other physical obstructions and moving objects.

The Solution – a Unified Positioning System Platform

Considering the inherent limitations of conventional location systems deployed and available for use today, the urgency for making vast improvements to location system infrastructure is evident, driven primarily by global demand for stringent location accuracy and accessibility requirements to support IoT device deployments and the commercial release of autonomous vehicles.

IoT connected device deployments are forecast to reach 13.8 billion by YE2024, growing at a CAGR of 11.8%, according to a market research report from 451 Research.[10] On a separate evolutionary track, autonomous vehicles with tiered levels of incremental autonomy are now on a short time horizon for commercial deployment. These two initiatives, IoT device deployments and the ramp-up of autonomous vehicles to commercial production, are driving the need for an international, standards-based, Unified Positioning System – specifically, a platform that effectively integrates the functionality of the many disparate indoor and outdoor location systems deployed and available for use today, accessed via a common API framework, enabling location-based applications and services to:

- Source geolocation data from a multi-layered service infrastructure in which navigation systems and indoor location systems are registered as plug-in services, designated for public, private, government or military use, as defined in a global registry;
- Request preferred (or tiered) levels of location accuracy, along with relevant indoor and outdoor map data; and
- Request relevant metadata associated with any location system registered and available for use in a specified geographic region.

The planning for a Unified Positioning System would require a thorough reassessment of GPS, as the world's leading Global Navigation Satellite System (GNSS), for the purpose of qualifying and cataloging the extent of its functional capabilities and limitations – noting the latter concern has motivated companies of all sizes to develop hybrid location solutions with the aim of improving location accuracy and accessibility indoors and outdoors.

GNSS Limitations

A Global Navigation Satellite System (GNSS) is a reference to a constellation of Earth-orbiting satellites that broadcast time codes for use in calculating latitude, longitude and altitude geospatial coordinates. The deployment and successful operation of mapping, navigation and tracking applications and services are dependent on the widespread availability and accuracy of the geospatial coordinates provided by a GNSS.

To date, five countries and the European Union have developed and deployed Global Navigation Satellite Systems, which are described in the following table.

United States	Global Positioning System (GPS)	GPS is the oldest and most mature GNSS system. Launched in 1973 by the US military and became fully operational for civilian use in 1995.
Russia	Global Navigation Satellite System (GLONASS)	Launched in 1982. Hampered by political and technical challenges, and sizable cost overruns.
European Union	Galileo	Launched in 2016. Still in development with plans for operation in 2020.
China	BeiDuo-2 (aka Compass)	Second generation system. Launched in 2015. Still in development with plans for operation in 2020.
Japan	Quasi-Zenith Satellite System (QZSS)	Launched in 2010. Operational in 2018.
India	India Regional Navigation Satellite System (IRNSS)	Launched in 2013. Originally planned for operation in 2018. Still in development due to satellite failures.

Global Navigation Satellite Systems
Source: *Wikipedia*

Among the navigation systems listed above, GPS is by far the most mature and widely used system available today in terms of the global installed base of devices equipped with a compatible GPS receiver. Nearly every new automobile, smartphone, tablet and personal computing device manufactured is equipped with a GPS receiver to facilitate the use of a diversity of location-based applications and services.

Despite the technological advancements of GPS over the past three decades and the exponential increase in the number of devices that rely on its use, GPS continues to be hampered by functional limitations and deficiencies that can impair significantly the accuracy of the geospatial coordinates produced by a GPS receiver and limit its accessible range of use. These functional limitations and deficiencies are rooted in the physics of radio frequency transmission and reception, and are caused primarily by environmental conditions, a few of which are described below.

- **Signal interference/loss:** Time code signals broadcast by GPS satellites are incapable of penetrating most buildings and covered structures, such as tunnels, parking garages, shopping malls and warehouses, all of which block the use of GPS indoors.
- **Multipath error:** GPS signals are prone to reflect off skyscrapers and other large metallic and glass surfaces, causing errors in the calculation of geospatial coordinates reported by GPS-enabled devices.
- **Signal fade:** Mountainous and cavernous terrain can block or absorb GPS signals and can thereby impede the effective operation of GPS receivers, causing errors in the calculations of the geospatial coordinates generated by the system.

In light of these concerns, outdoor navigation systems, such as GPS, require enhancements to overcome various environmental impediments and functional deficiencies. *GPS.gov* defines such an enhancement as a "GPS augmentation" – that is, "any system that aids GPS by providing accuracy, integrity, availability, or any other improvement to positioning, navigation, and timing that is not inherently part of GPS itself." [4]

GPS Augmentations

GPS augmentation systems have been developed by both public and private sectors with a three-fold aim of (i) improving system accessibility and effective range of use, (ii) improving the accuracy and precision of the geospatial coordinates produced by the system; and (iii) overcoming and eliminating potential influences of system error. Detailed descriptions of government sponsored GPS augmentation initiatives is beyond the scope of this report; however, a list of the leading initiatives is provided on the *GPS.gov* website.

5G Wireless

The realization of the vision for a Universal Positioning System received a boost by way of the critical infrastructure required to operate such a system via deployment of 5G networks. 5G is a reference to the latest generation of cellular network communications and services specified by the *European Telecommunications Standards Institute (ETSI) 3rd Generation Partnership Project (3GPP)* and the *International Telecommunication Union (ITU)* standards organizations.

Dawn of a New Generation

The wireless telecommunications industry began testing and promoting a 5th Generation New Radio network standard ("5G NR") in 2015, touting a 10x increase in the theoretical top-end data transfer rate compared to the top-end rate of conventional LTE networks in use today. In 2019, the industry started to realize the fruits of this initiative by way of an uptick in the deployments of 5G networks by cellular network operators around the globe. At the time of this writing, 359 operators had announced plans to invest in 5G, of which 80 operators had announced the deployment of 3GPP-compliant 5G technology in their networks, according to market data provided by the Global Mobile Suppliers Association (see *LTE & 5G Market Status: Global Snapshot – March 2020*).[2]

The market data reveals unquestionably that 5G, as a fully-invested global initiative, is picking up momentum. However, news articles and research reports have surfaced in recent years citing potential barriers to adoption, which have turned 5G into a flash-point topic for debate by various industry pundits, market analysts and watch-dog groups, all of whom who are looking beyond the industry hype in an effort to separate fact from fiction.

Potential Barriers to Adoption

One concern is that 5G, despite the momentum building with network deployments announced to date, might still be 5-to-7 years away from full realization when taking into consideration the extent and maturity of 5G networks relative to published standards and the limited accessibility of these networks for ubiquitous use in both rural and urban areas. What this means in layman's terms is that a 5G phone purchased today is unlikely to utilize the full scope of 5G network benefits simply because 5G networks are still evolving – that is, the network infrastructure does not exist presently in a comprehensive, standards-compliant level of maturity to fully-support 5G phones, thus causing the phone to default periodically to a 4G-compliant (and at times even a 3G-compliant) mode of operation.

Further, network operators around the globe are still working to payoff the huge capital investments made previously to upgrade their networks to 3G and 4G standards-compliant services. Responding to the release of the 5G standard, network operators are now stuck in the precarious situation of having to justify to shareholders the need for additional capital expenditures to upgrade their networks to 5G while still working to payoff billions in previous

[continues on page 13]

Mobile Market Stats (in brief)

8.0 billion
Mobile subscriptions globally [1] (across all mobile networks)

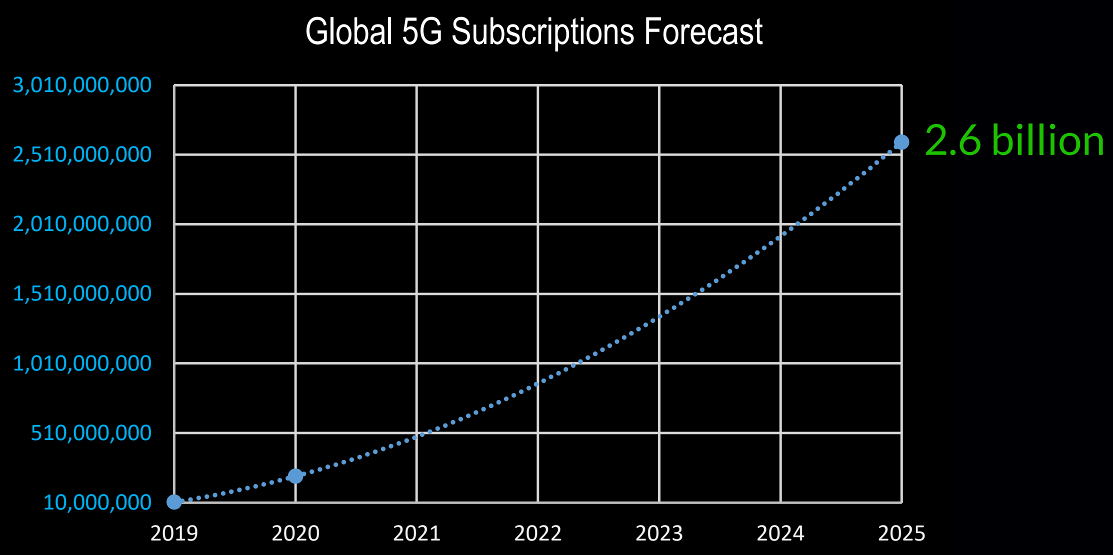
13.0 million
5G subscriptions globally YE2019 [1]

2.6 billion
5G subscriptions forecast for YE2025 [1] *(see chart below)*

788
Operators with commercially launched LTE networks [2]

325
Operators with deployed LTE-Advanced (LTE-A) networks [2]

359
Operators have announced investments in 5G for trials, testing, planned and actual network deployments [2]



Sources: RCL trend line interpolation based on forecasts published by Ericsson[1] and Strategy Analytics[3] capital expenditures. This, of course, begs the question: can network operators afford to invest in 5G at this time or would it be more prudent to wait? That is, wait until the kinks are ironed out in the evolution of the standards and in the network infrastructure equipment designed to support these standards, when the evolution of the technology reaches a settling point.

Other concerns raised in recent years, such as those pertaining to public health and safety, certainly warrant further investigation. These include claims of potential impact on human health caused by long-term exposure to radio frequency radiation (RFR) emitted by 5G transceivers (see *Scientific Research On 5G, 4G Small Cells, Wireless Radiation And Health* on the Environmental Health Trust website), and observations of excessive heat build-up in phones configured with 5G radios (see *The latest barrier to 5G speeds? The summer*. on the Ars Technica website).

Despite these concerns and potential barriers to adoption, there are numerous appreciable benefits with 5G that are motivating operators to upgrade their networks in earnest.

Exceptional Benefits to Adoption

Compared to previous cellular network standards, the 5G standard calls for vast network performance improvements, including faster data rates, reduced latency, energy savings, and cost efficiencies – highlighting only a few of the many new service capabilities.

> *"5G is about how legacy industries and ecosystems will change. Just as 4G brought in the rise of the Internet giants, we will see the rise of a new Phoenix from enterprise and industrial giants, changing Telecom itself."* – Upkar Dhaliwal, Founder & CEO, Future Wireless

5G differs from legacy networks in that it requires greater densification of cellular network infrastructure, meaning an increase in the number of macrocells, microcells, small cells and/or comparable cellular equipment installed per km^2 for the purpose of supporting higher bandwidths and thereby faster data rates. This increase in densification offers the added benefit of increasing the number of fixed-location cell sites, each with a recorded latitude, longitude and altitude, serving as fixed access points needed for calculating precise indoor and location coordinates using triangulation and trilateration methods.

Most significant among its improvements, 5G is designed to support massive device connectivity for use with a diversity of device types, including smartphones, tablets, automobiles and an ever-increasing number of IoT connected devices for consumer, enterprise and industrial markets. 5G also supports a significant increase in the number of phone calls (aka, "call sessions") and high-volume data connections (aka, "data sessions") that are capable of being managed concurrently by each 5G cell site. With 5G, any type of device imaginable can be connected to the Internet and communicated with via text messaging and/or streaming data services. And once connected, devices can be tracked and monitored via either in-network or third-party location positioning services.

5G represents a new epoch in mobile wireless communications. According to Upkar Dhaliwal, Founder & President of Future Wireless Technologies, "*5G is about how legacy industries and ecosystems will change. Just as 4G brought in the rise of the Internet giants, we will see the rise of a new Phoenix from enterprise and industrial giants, changing Telecom itself. 5G is not simply an incremental update in the evolution of cellular wireless communications; rather, it is a highly-dynamic, virtualized and configurable platform, which can be adapted over time by way of contributions from other international standards organizations, with more open sourcing collaborating to integrate their respective technologies as extensions to 5G, thus enabling both horizontal and vertical market solutions to be tailored and deployed for use in consumer, industrial enterprise, and government market segments, via for example Private Public Partnerships (P-P-P). We have started to develop research, standards and technology development towards 6G, beyond 5G.*"

LTE Cat-M vs. NB-IoT

The introduction of 5G expanded the scope of service options available to network operators for IoT device connectivity. To date, LTE Cat-M ('M' for "Machine Type Communication") and Narrowband IoT (or, NB-IoT) have prevailed as the two leading low power wide area network (LPWAN) standards deployed by network operators to support IoT device connections. The following table provides a high-level comparison of LTE Cat-M and NB-IoT features.

	LTE Cat M1	LTE Cat M2	LTE Cat NB1	LTE Cat NB2
3GPP Standard	Release 13	Release 14	Release 13	Release 14
Release Date	Q1 2016	Q2 2017	Q1 2016	Q2 2017
Downlink Peak Rate	1 Mbit/s	~4 Mbit/s	26 kbit/s	127 kbit/s
Uplink Peak Rate	1 Mbit/s	~7 Mbit/s	66 kbit/s (multi-tone) 16.9 kbit/s (single-tone)	159 kbit/s
Latency	10–15 ms		1.6–10 s	
Number of Antennas	1	1	1	1
Duplex Mode	Full or Half Duplex	Full or Half Duplex	Half Duplex	Half Duplex
Device Receive Bandwidth	1.4 MHz	5 MHz	180 kHz	180 kHz
Device Transmit Power	20 / 23 dBm	20 / 23 dBm	20 / 23 dBm	14 / 20 / 23 dBm

Source: Wikipedia
Trademark notice: LTE-M and NB-IOT logos are registered trademarks of the GSM Association (GSMA).

LTE Cat-M offers higher data bandwidth connections with the trade-off of higher latency and power consumption. NB-IoT, on the other hand, offers lower data bandwidth connections with the added benefit of low latency and low power consumption. NB-IoT is the faster-growing of these two standards because of its alignment with the LPWAN requirements for the IoT, and was classified as a 5G technology, standardized by 3GPP in 2016.

Tracking 2.0

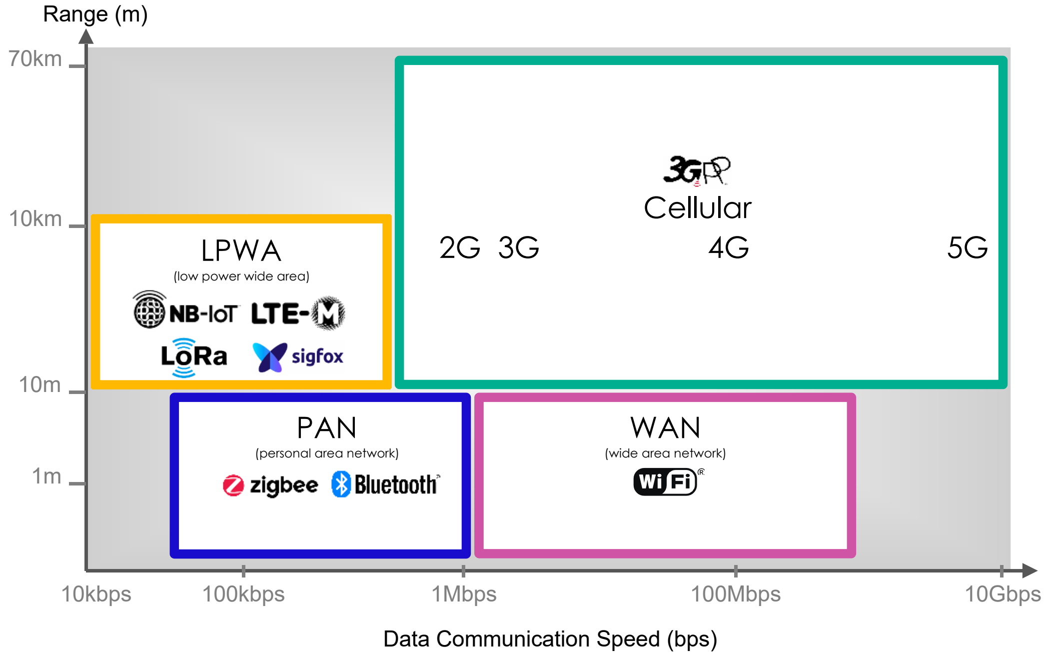
Explosive growth in the annual production of miniature-package, low-power, low-cost sensors of every type imaginable – e.g., temperature, humidity, pressure, gas detection, volatile organic compounds (VOCs), light, shock, vibration, and many others – has given rise to a new generation of tracking devices. Categorically, we define this new generation as *Tracking 2.0*, distinguishing the functional superiority of these devices to that of their minimally-functional predecessors.

Whereas tracking devices of previous generations were comparatively simple or basic in functional terms, Tracking 2.0 devices are considerably more complex, configured with at least one and oftentimes multiple sensors in its design and integrated with long-life, rechargeable batteries capable of maintaining a charge over periods measured in months or years.

Tracking 2.0 devices are uniquely distinguished by the following features and benefits:

Feature	Benefit
Configurable Hardware Platform	Enables tracking device manufacturer to configure devices to meet specific customer needs and use cases
Includes one or more low-power sensors integrated into the hardware design	Enables customers to monitor and collect data relevent to specific use cases; e.g., tracking perishables In refrigerated trucks
Integrates wireless communication over a low-power wide-area network	Enables devices to communicate with a backend service for geolocation tracking (indoors and/or outdoors), sensor data reporting, and data analytics
Integrates geolocation tracking indoors and/or outdoors	Enables enterprise customers to track their assets/cargo and establish geolocation fences and trigger alerts
Brings intelligence to the tracking system - both at the edge and at the backend	Maximizes the ability for businesses to collect and analyze data and iteratively adapt to deal with changing conditions

Trade-offs between functionality, power consumption, wireless network scope (e.g., LAN, WAN, indoor/outdoor accessibility, transcontinental reach, and over-the-air data transmission speed) are important considerations for Tracking 2.0 device configuration. The following chart shows a comparison of range and data transmission speed of the leading wireless networks.



Companies to Watch

The evolution of IoT device tracking and autonomous vehicles, supported in large part by technology advancements in mobile wireless communications and geospatial positioning, has given to rise to an exciting range of M&A opportunities, particularly as major industry players continue to jockey for position with the aim of building and refining end-to-end value propositions and expanding market reach.

Following is an RCL-selected list of companies that are continuing to push the envelope with their respective innovations – a unique mix of pioneering companies that are contributing to the advancement of indoor/outdoor location positioning, Tracking 2.0 and related services.

Company	Est.	HQ	Category	Description	Key Features
alertGPS www.alertgps.com	2012	Scottsdale Arizona USA	Tracking 2.0	AlertGPS provides wearables and a powerful IoT safety platform that quickly alerts, locates and enables communication and emergency response to mobile workers	IoT safety platform Alerts, locates and enables communication Threat and safety protection
arviem www.arviem.com	2008	Barr Switzerland	Tracking 2.0	Arviem provides intermodal cargo monitoring service that enable organizations to monitor the location, condition and security of shipments in real-time and react proactively to disruptions	Temperature fluxuations Intrusion detection Shock detection Humidty fluxations Geolocation Geo-Zone entry/exit
combain www.combain.com	2009	Lund Sweded	Tracking 2.0	Combain provides a comprehensive Next Generation indoor/outdoor IoT Asset Tracking platform solution with global coverage	Accurate Cell ID and Wi-Fi positioning World's largest database Complement or replace GPS in devices Precise indoor 3D positioning
Forkbeard™ www.forkbeardtech.com	2019	Oslo Norway	Precise Indoor Location	Forkbeard provides the Fast Ultrasound Echo Location - FUEL™, delivering near 100 times better distance accuracy than Bluetooth signals alone, enabling centimeter-level location accuracy indoors	Centimeter-level location accuracy ultraBeacon combines BLE and ultrasound Smart mounting and built-in intelligence Latency of only to 1 – 2 seconds 100% room-accuracy

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Company	Est.	HQ	Category	Description	Key Features
HANHAA www.hanhaa.com	2014	London United Kingdom	Tracking 2.0	Real-time cargo tracking & monitoring for truck, ship, air and rail transportation, monitoring the location, condition and security of cargo consignments	Geolocation Temperature & humidity monitoring Tilt & orientation Shock detection Shipment breach
Kolmostar www.kolmostar.com	2016	Fremont California USA	Precise Outdoor Location	Kolmostar is a positioning technology company that is reinventing the industry's GNSS (GPS, Beidou, etc) positioning approach to achieve ultra-low-power (mW-level) and instant cold boot positioning in harsh metropolitan environment for IoT devices and autonomous vehicles.	Advanced silicon technology High-dimension statistical signal processing Cloud computing to reduce GNSS positioning Reduced error and power consumption
LOSANT www.losant.com	2015	Cincinnati Ohio USA	Tracking 2.0	Losant is an enterprise Internet of Things platform that helps enterprises build connected solutions, including asset tracking	Delivery confirmation Vibration detection Temperature monitoring Humidity Real-time location tracking End-user alerts
nullmax 纽劢科技 www.nullmax.ai	2016	Shanghai China	Tracking 2.0 Autonomous Vehicle	Nullmax provides a complete autonomous-driving solution consisting of multi-sensor fusion, high-speed processing, flexible customization and strong extensibility, enabling L3/L4 level autonomous-driving	Advanced AI Autonomous Vehicle Platform Beacon-based wide band location solution Precise indoor location positioning
Pointr www.pointr.tech	2013	London United Kingdom	Tracking 2.0	The Pointr Deep Location™ platform is an all-inclusive location solution, which includes mapping, navigation, asset tracking, location-based analytics and engagement.	Real-time indoor positioning Turn-by-turn navigation Contextual notifications Augmented reality Crowd simulation & heatmaps
POLTE www.polte.com	2005	Addison Texas USA	Precise Indoor/Outdoor Location	Polte IoT Cloud (PIC) provides seamless indoor and outdoor location positioning, leveraging cloud computing and existing 4G and 5G cellular networks	PoLTE's C-LoC technology Reduces size, cost and power requirements Ideal for IoT device tracking
Quuppa www.quuppa.com	2012	Espoo Finland	Tracking 2.0	The Quuppa Intelligent Locating System™ is a platform for location-based services and applications. Its unique Direction Finding methodology and positioning algorithms enable real-time tracking of Bluetooth® Low Energy (Bluetooth LE) Tags and devices with centimetre-level accuracy	Accurate real-time positioning Exposing the onboard sensor data Backchannel for location-based commanding and configuration of tags OTA firmware upgrading
Sensire www.sensire.com	2001	Rantakatu Finland	Tracking 2.0	Sensire provides Complete Digital Solutions for Managing Food Safety and Monitoring Temperature-Controlled Logistic.	IoT-based temperature monitoring Digital Food Safety Quality Monitoring and Management Digital Environmental MonitoringOperational Excellence in warehousing and Storage
STALKIT® www.stalkit.no	2017	Snasa Norway	Tracking 2.0	StalkIT provides a simple to use tracking service, with a tracking device, an app to use on a smartphone, and a portal to see active devices in a map	Container lifetime product Unique tracking device for sheep Up to 10 years battery life Waterproof and impact resistant Maintenance free Built on waste industry & value chain
seeyourbox www.seeyourbox.com	2013	London United Kingdom	Tracking 2.0	See Your Box is a tech-service platform that leverages IoT devices and sensors to collect, analyze and extract information across all steps of the supply chain, monitoring goods in real time.	All inclusive data service Real-time smart data collection Turnkey solution (HW, SW, & telco) Packed with virtual & physical sensors State of the art data protection
tive www.tive.co	2015	Boston Massachussettes USA	Tracking 2.0	Tive provides a real-time in-transit visibility system, with device trackers and a cloud-based management system for tracking cargo and shipping containers	Location tracking Chemicals conditioning monitoring Vibration, Shock and Orientation detection Environmental monitoring Pharmaceutical temperature monitoring
trax www.traxfamily.com	2012	Stockholm Sweden	Tracking 2.0	Trax provides real-time, live GPS tracking devices with dedicated 2G, 3G, 4G solutions for a range of users and use cases, including enterprise and consumer solutions; e.g., a kid tracker	Real time tracking (2G, 3G, 4G networks) Geofence & proximity alerts Speed alerts Augmented Reality (AR) Waterproof design
TRAXENS www.traxens.com	2012	Marseille France	Tracking 2.0	Traxens provides a comprehensive, end-to-end tracking and IoT data collection and aggregation platform for tracking cargo and shipping containers	Real-time location tracking Geofence alerts Theft mitigation For sea, road and rail cargo shipping Range of sensors integrated for data tracking

RCL M&A Trend-watch

Following is a selected list of technology trends and related M&A opportunities to watch in 2020, tracked by RCL's international team of tech M&A experts and research analysts.

Trending

Augmented Reality (AR): AR is expected to outpace and overtake virtual reality (VR) as the preferred product path to an economically feasible and internationally scalable market.

Autonomous vehicles: A recalibration of the expectations and ambitions for autonomous vehicles is anticipated, as manufacturers and customers for these vehicles face the enormity of the technical challenges and hurdles yet to be overcome as a precondition for bringing these vehicles to market, while placing higher priority on minimizing/averting human fatality and addressing liability concerns.

Micro-LED Displays: At the 2020 Consumer Electronics Show (CES) in Las Vegas, the world's leading display manufacturers demonstrated a new generation of stunningly beautiful displays based on Micro-LED technology, scalable to any size and costing less to manufacture than comparable OLED displays.

Sensors: The burgeoning market for miniature-package, low-cost, low-power sensors will continue to grow as new sensors of every type imaginable (e.g., environmental, gas, volatile organic compounds, vibration/shock, and light, to name only a few) are introduced and delivered in volume to market.

Tracking 2.0: Low-power, rechargeable tracking devices with integrated geolocation positioning, sensors and wireless data communication will proliferate in 2020 and beyond, as companies continue to experiment with and discover new ways to benefit from the use of these devices.

Fading

Cryptocurrency: Having exceeded its lengthy run as an over-hyped technology and with governments around the world proactively enacting laws restricting and regulating its use, cryptocurrencies are beginning to lose momentum.

LiDAR: Once a darling of tech-savvy investors, LiDAR has transitioned beyond the market hype, as manufacturers have come to realize that LiDAR is simply a means to an end but is not an end in itself – noting many additional complementary technologies are needed to provide comprehensive solutions, particularly for use with ADAS systems and autonomous vehicles.

OLED Displays: Plagued by high manufacturing costs and a propensity for image burn-in, OLED displays are now expected to be displaced by micro- and mini-LED displays – noting the latter two display technologies can be manufactured at considerably lower cost, offer more vibrant color and contrast, and are not as susceptible to image burn-in compared to OLED displays.

Virtual Reality (VR): Introduced in the mid-1990s, VR has struggled over the past two decades to find its stride in any appreciably-sized market. Aside from simulators and military training applications, VR has consistently failed to resonate with consumers, due primarily to the bulkiness and discomfort of VR headgear, cumbersome tethering, and health and safety concerns. AR, on the hand, is expected to surpass VR as a more viable and economically feasible commercial opportunity.

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Additional information

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