

IEEE 802.15.4AB: UNLOCKING UWB'S TRUE POTENTIAL

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EXECUTIVE SUMMARY

The arrival of IEEE 802.15.4z means that Ultra-Wideband (UWB) is fast becoming another foundational wireless connectivity technology. With strong initial success within automotive digital key applications, and the ability for UWB to support an evolving combination of secure ranging, radar, and sensing, and low-latency, high throughput communication, UWB is targeting an increasingly diverse set of use cases across consumer, automotive, commercial, industrial, and smart city environments, with ABI Research forecasting the technology to be one of the fastest growing wireless connectivity technologies between 2025 and 2030.

However, this initial success in automotive digital key applications has exposed the link budget limitations of existing UWB technology. These limitations can significantly diminish the end user experience when it comes to reliability, power consumption, accuracy, and practical range of operation in real-world deployment scenarios, as well as hinder the potential to create valuable new services across automotive and other environments.

Thankfully, UWB technology is evolving rapidly, and work is already well underway on the latest IEEE 802.15.4ab amendment, also known as next-generation UWB, which is expected to arrive in 12 to 18 months. This introduces several

new features, including Multi-Millisecond (MMS) and Narrowband-Assisted (NBA) MMS UWB, that are directly aimed at improving the link budget of UWB technology by up to 30 Decibels (dB), bringing 30X the range of IEEE 802.15.4z alongside numerous benefits for automotive digital key and other secure ranging applications, including:

- Enabling more reliable location of devices in different environments due to higher link budget (e.g., for back pocket scenario and multipath environments).
- Providing lower power consumption due to the localization session only being started when really needed (e.g., walking to the vehicle in an office parking scenario).
- Minimizing disturbances and congestion between multiple users as the ranging sessions are only started when really needed (e.g., stadium scenario).
- Guaranteeing high accuracy with single measurements that are immune to multipath environments (non-line of sight scenarios).

Major automotive Original Equipment Manufacturers (OEMs) have already started to include IEEE 802.15.4ab NBA MMS ranging in their current requirement specifications. They are expecting to unlock the benefit from the existing installed base of hundreds of millions of IEEE 802.15.4ab-compatible smartphones in the market with rapidly increasing shipments expected in the next few years. This momentum is further supported by early backing from chipset vendors and UWB industry consortia, alongside new market entrants. The closed ecosystem at carmakers is further evolving with High-Frequency (HF)/Low-Frequency (LF) key fobs now being replaced by IEEE 802.15.4ab-based alternatives. This shift is now possible due to the ability of IEEE 802.15.4ab to offer a greatly enhanced user experience when compared to its predecessor. ABI Research believes that the transition to IEEE 802.15.4ab will not only be fundamental to the future success of UWB technology, but will also be relatively swift. The ability to enable a more positive, consistent, and predictable performance over greater range, to create valuable new services and experiences, and to open new use cases for UWB technology that current technology may struggle to achieve in its current form will all be vital in accelerating UWB market adoption beyond the 1.4 billion projected device shipments by 2030.

Meanwhile, another positive sign for the future trajectory of IEEE 802.15.4ab is the support from leading semiconductor vendors, such as STMicroelectronics, that are well known for their history of innovation within the smart mobility and automotive industry. ST is actively participating within the IEEE 802.15.4 Task Group that is currently finalizing development of the IEEE 802.15.4ab amendment, as well as being an established member of leading UWB consortia including the UWB Alliance, omlox, the Connectivity Standards Alliance (CSA), the Car Connectivity Consortium (CCC), and the FiRa Consortium. With this in mind, ST is committed to expanding its STM32 wireless Microcontroller Unit (MCU) family and ecosystem with its upcoming support for IEEE 802.15.4ab Next-Generation UWB technology. The future UWB offering will consist of a highly-optimized, high-performance wireless MCU that can support the growing diversity of UWB ranging and sensing capabilities, and provide a more reliable and robust experience for OEMs and end users alike.

This whitepaper provides an overview of the growing opportunities for UWB technology, discusses the existing limitations of IEEE 802.15.4z, highlights the key benefits of the next-generation IEEE 802.15.4ab standard, and discusses how its various features are able to bring real-world benefits to key applications, including but not limited to automotive digital key applications, as well as providing a strong foundation on which future UWB use cases and services can be built.

AN INTRODUCTION TO ULTRA-WIDEBAND (UWB) TECHNOLOGY

UWB, based on the IEEE 802.15.4a, IEEE 802.15.4z, and upcoming IEEE 802.15.4ab standards, is a short-range impulse radio technology that can securely and accurately calculate the relative position of other UWB-enabled devices. In the case of IEEE 802.15.4ab, new techniques such as NBA 1 MMS ranging, discussed in more detail below, can enable it to achieve a line-of-sight distance greater than 650 meters, while providing centimeter-level accuracy. As the name suggests, UWB uses a wide channel bandwidth (500 Megahertz (MHz) or more) and short 2 Nanosecond (ns) pulses to accurately measure the Time-of-Flight (ToF) between two devices (e.g., a smartphone and a car, key fob and door lock, Real-Time Location System (RTLS) anchor point and tag). Meanwhile, the relative location of the device can be tracked instantly and continuously, enabling real-time ranging. Alongside this, various supported topologies can help to determine the precise location and direction of a device. For example, UWB-enabled door locks can determine on what side of the door a user is positioned, and if they are walking toward or away from it. This ability to understand the user intent can enhance security, provide a better user experience, and enable valuable proximity-based services to be developed.

UWB also has several benefits over other technologies, particularly related to positioning accuracy, latency, robustness, and security. While other technologies often calculate distance and location information from signal strength via Received Signal Strength Indication (RSSI) techniques, these systems can be subjected to relay station attacks from unauthorized remote users, which involves the interception and spoofing of the wireless signals, causing false readings. UWB's ToF approach can better determine when a device is truly in close proximity, prohibiting such attacks. In addition, the wide bandwidths and short pulses allow for both low latency and strong performance in multipath environments, adding to the robustness and integrity of UWB ranging techniques. This allows for both real-time and highly-reliable location estimates. UWB's ToF implementation is also much more resistant to obstructions and interference, and provides strong localization performance in both line-of-sight and non-line-of-sight deployment scenarios when compared to alternative technologies.

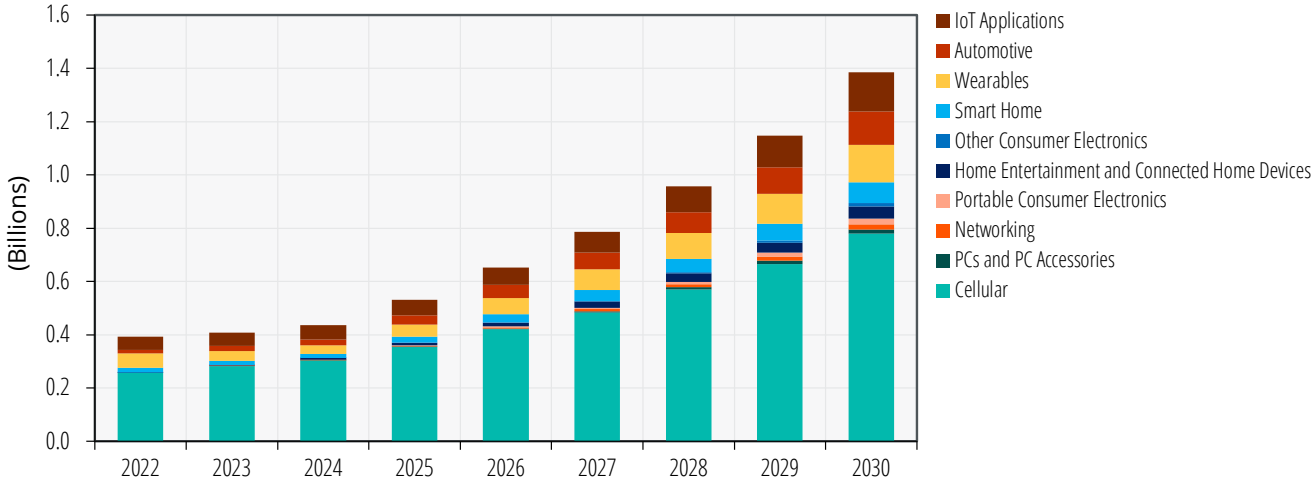
Over the last decade, IEEE 802.15.4a-based solutions have started to see increased adoption within high-accuracy indoor RTLS applications, while development of the IEEE 802.15.4z amendment to the IEEE 802.15.4 standard, published in 2020, led to additional security extensions being added to the technology. These have provided UWB with the ability to provide secure, authentic, centimeter-level accurate distance and location measurement, enabling a number of secure fine ranging and positioning applications demanded by automotive, mobile, smart home, smart building, and other consumer, industrial, and IoT solution providers. The arrival of IEEE 802.15.4z has led to a growing presence in smartphones, predominantly for automotive digital key and personal tracking applications, as defined by the CCC's Digital Key 3.0 Specification, and devices such as the Apple AirTag. Many leading automotive OEMs have already deployed IEEE 802.15.4z for secure vehicle access applications, including BMW, Tesla, Audi, Polestar, Volvo, Hyundai, Mercedes-Benz, Porsche, Toyota, and Volkswagen, among others. By 2030, ABI Research expects that 53% of vehicles will come equipped with UWB technology. These digital key applications are also now extending to home and commercial building access with UWB smart door locks and commercial access control readers.

LIMITATIONS OF EXISTING UWB TECHNOLOGY

As Chart 1 demonstrates, UWB technology has already been adopted by a significant number of devices, and its unique characteristics make it ideal for secure ranging applications when compared to alternative wireless solutions. Meanwhile, new UWB-enabled devices and chipset announcements, the proliferation of UWB chipsets and platforms, several UWB-related acquisitions, continued development of the UWB standards and industry consortia, and demonstrations of UWB technology across new use cases will enable UWB to become one of the fastest growing wireless connectivity technologies. Device shipments are expected to achieve a 21% Compound Annual Growth Rate (CAGR) between 2025 and 2030, reaching nearly 1.4 billion annual unit shipments. The automotive market alone expects more than 55 million vehicles to ship with UWB technology by 2030, each with up to 6 anchors per vehicle, alongside dedicated UWB key fobs, reaching several hundred million annual UWB chipset shipments by the end of the decade.

Chart 1: UWB-Enabled Device Shipments by Device Type World Markets: 2024 to 2030

(Source: ABI Research)

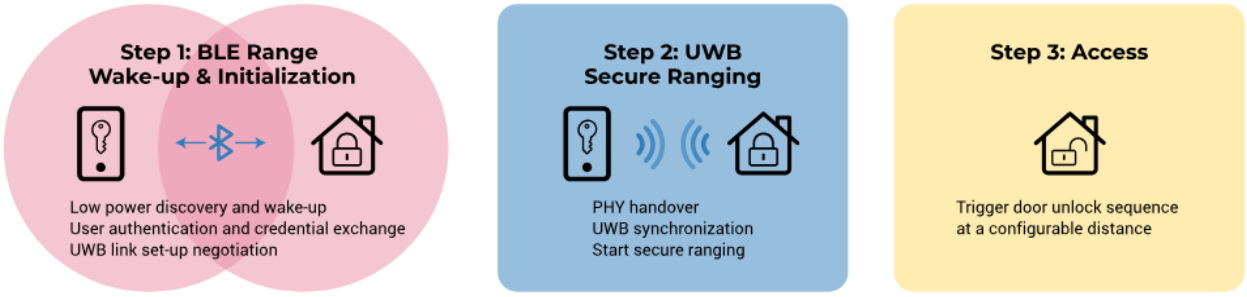


However, when deploying UWB technology in real-world environments, several limitations of the existing IEEE 802.15.4z technology were discovered. These have the potential to negatively impact the end-user experience when it comes to reliability, power consumption, accuracy, and range of operation. Key among these challenges include:

Limited Link Budget Due to Regulatory Restrictions: The transmit power of UWB technology is heavily restricted by the Federal Communications Commission (FCC) and other regulatory organizations to avoid interference with other technologies and incumbents operating in the same frequency bands. As a result, existing implementations of UWB secure ranging have a limited link budget, and the distance at which UWB can effectively perform its ranging activities is limited. To counteract this, most UWB secure ranging deployments today leverage Bluetooth® Low Energy (LE) as a low-power discovery and wake-up radio, as demonstrated in Figure 1. However, the handover from Bluetooth® LE defined for low power discovery and wake-up radio, as demonstrated in Figure 1 is compromised as the handover can happen while UWB IEEE 802.15.4z is not able to range because of the missing link budget, in addition to the high power consumption in the acquisition phase.

Figure 1: The Role of UWB and Bluetooth® LE in Secure Ranging Applications

(Source: FiRa Consortium)



Unreliable Detection of Devices: In real-world usage scenarios, such as when a car is trying to locate a UWB-enabled smartphone for keyless entry applications, this limited link budget can cause additional stability issues when users have their phones in their bags, pockets, and, in the worst-case scenario, a back pocket. While IEEE 802.15.4z theoretically offers up to 100 meters in line-of-sight scenarios, the effective range in real-world deployments is much lower than 100 meters, as UWB technology can suffer from body blocking issues, reducing the effective range or losing signal altogether. This inability to recognize the device can result in a compromised user experience, with the user arriving at the car door without the vehicle unlocking, or being unlocked too late. In order for UWB to build a positive sentiment among consumers and OEMs alike, UWB needs to always work according to user expectations.

Power Consumption: One of the challenges of using a less accurate Bluetooth® LE RSSI solution to activate the UWB localization mode is that it can be activated prematurely. This means that the handover from Bluetooth® to UWB can happen when the user could still be significantly outside the required vehicle localization zone (due to the limited link budget), resulting in prolonged activity of UWB ranging when it is not needed. As this UWB localization mode is more power hungry than the Bluetooth® LE discovery mode, the overall power consumption of the system is much higher than it needs to be. This also makes the user experience hard to predict and maintaining consistency a challenge in real-world scenarios due to the changing environmental circumstances.

Limited Scalability Due to Channel Congestion with Multiple Users: In more crowded environments, such as large office, airport, and stadium car parks, there is the potential for multiple vehicles (each with multiple IEEE 802.15.4z anchors) and users to attempt UWB localization simultaneously. When combined with the inability to accurately determine the correct handover to establish the localization mode (again, due to the limited link budget), this can potentially increase congestion and negatively impact the user experience.

Multipath Interference and Non-Line-of-Sight Performance: While UWB is inherently more resistant to multipath interference compared to other technologies, there are still many environments where UWB will be deployed and signals will bounce off reflective surfaces to create multiple paths from which the UWB location needs to be derived. This can diminish the overall performance and reliability of the solution. Meanwhile, many future UWB use cases have been identified that will require deployment in densely-populated and challenging Radio Frequency (RF) environments while requiring seamless, ultra-low latency ranging, such as within contactless ticketing applications.

Limited Additional Service Enablement: Related to the above, the inability to accurately and reliably determine the position of the user between discovery mode and localization mode can limit the capabilities of enabling valuable new intermediary services, such as passenger/client localization for self-driving taxis, activating welcome lights, or remotely activating other vehicle services or personalization features when the user is approaching the vehicle. Being able to determine the intent of the user while offering a consistent and reliable experience will be critical in expanding services that benefit from knowing a user's exact position, while emerging UWB hands-free payment and ticketing applications will always need to know the user's intent if they are to be successful.

IEEE 802.15.4AB AND THE QUEST FOR RANGE AND RELIABILITY

Despite the relative immaturity of IEEE 802.15.4z, having been published in 2020, work on the latest amendment to the IEEE 802.15.4 UWB standard, IEEE 802.15.4ab, began in 2021. Known as next-generation UWB, this new amendment introduces a number of major improvements that are designed to enhance the secure ranging performance and accuracy over greater distances, enable a more consistent user experience, optimize efficiency, enhance scalability, and enable new use cases that existing UWB technology may struggle to support effectively.

Beyond the enhanced secure ranging performance, IEEE 802.15.4ab also brings support for higher data rates for low-latency data and audio streaming, while standardized sensing capabilities seek to enable wider support for presence detection, gesture recognition, kick sensing, and vital sign monitoring, among other emerging UWB radar applications. The core features are now frozen, so work on this amendment is expected to be completed in 2026. Various UWB vendors have either already developed 802.15.4ab-compatible solutions or announced that they will support it in the future, with many leading 802.15.4z solution providers actively contributing to the IEEE 802.15.4ab Task Group. IEEE 802.15.4ab retains backward compatibility with IEEE 802.15.4z, and a full list of the areas of enhancement in IEEE 802.15.4ab include:

- Definitions for tightly coupled hybrid operation with narrowband signaling to assist UWB
- Additional coding, preamble, and modulation schemes to support improved link budget and/or reduced air-time relative to IEEE 802.15.4 UWB
- Additional channels and operating frequencies
- Interference mitigation techniques to support greater device density and higher traffic use cases relative to the IEEE 802.15.4 UWB
- Improvements to accuracy, precision, reliability, and interoperability for high-integrity ranging; schemes to reduce complexity and power consumption
- Enhanced native discovery and connection setup mechanisms
- Sensing capabilities to support presence detection and environment mapping
- Mechanisms supporting low-power low-latency streaming, as well as high data-rate streaming allowing at least 50 Megabits per Second (Mpbs) of throughput

However, the original raison d'être for IEEE 802.15.4ab centered on improving the afore-mentioned link budget challenges while maintaining adherence to the regulatory requirements across different regions—the key factor behind the inhibited user experience discovered in initial real-world rollouts. The goal is to significantly improve the ranging performance, which on one side extends UWB's range to hundreds of meters, but most importantly, covers the worst-case scenarios, solving existing challenges with user experiences caused by multipath, congestion, body blocking, and other attenuation issues. This will guarantee a base-level performance across all environments, and is especially aimed at real-world deployment scenarios where existing IEEE 802.15.4z has failed to meet expectations. By introducing advanced ranging capabilities in IEEE 802.15.4ab, it now becomes possible to securely, reliably, and accurately range between two or more devices over much greater distances, and, more importantly, to achieve a satisfactory ranging distance in all environments. This is achieved primarily through new techniques such as MMS and NBA MMS UWB, while additional enhancements can also help address some of the other range, power, and scalability issues being faced.

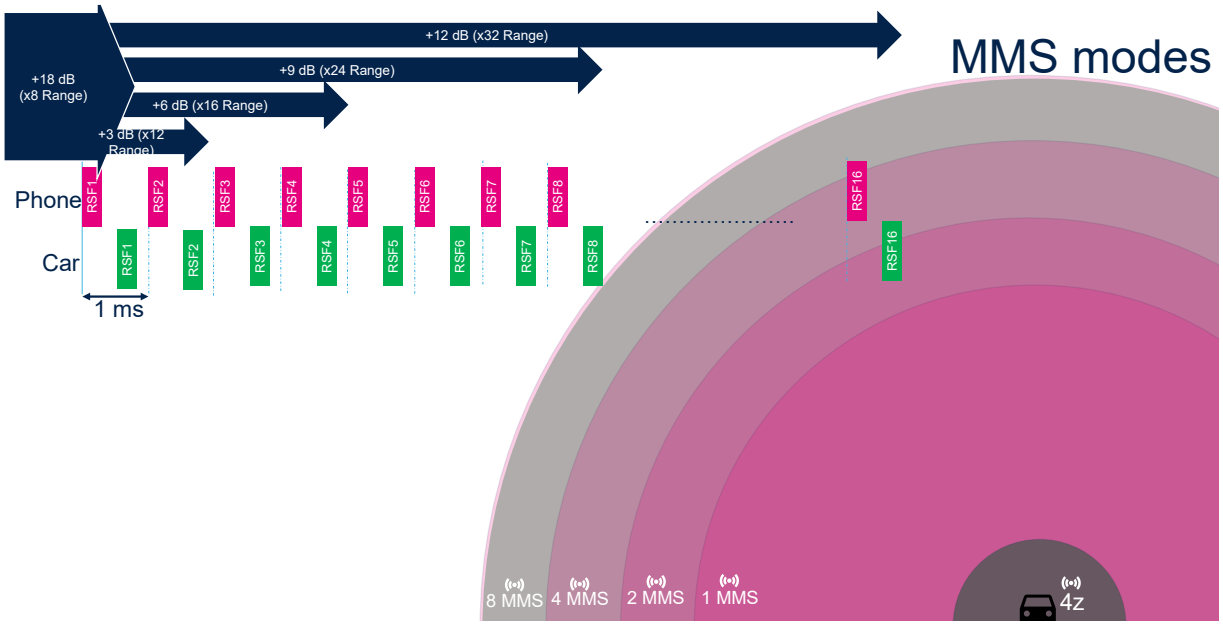
MULTI-MILLISECOND (MMS)

One of the enhanced ranging techniques being introduced in IEEE 802.15.4ab is MMS. In contrast to the conventional UWB Two-Way Ranging (TWR) distance measurement method in which devices exchange ranging information via longer ranging packets, within MMS, the UWB ranging packet can be divided in up to 16 smaller fragments consisting of Ranging Sequence Fragments (RSFs) and Ranging Integrity Fragments (RIFs). These are then transmitted over consecutive 1 Millisecond (ms) time slots. The receiving device is then able to accumulate information from these fragments over multiple milliseconds, significantly enhancing the combined energy compared to a single UWB ranging packet, and boosting the overall link budget. MMS maintains the average power at over 1 ms, so the transmission for each fragment can be boosted while still complying with regulatory power limits. In contrast, the link budget in the conventional approach is limited by the energy utilized in this initial packet exchange.

While using just a single MMS will already provide the most significant link budget boost of 18 dB compared to IEEE 802.15.4z-based ranging, IEEE 802.15.4ab offers multiple MMS modes that can support 2, 4, 8, and 16 repeated fragments. For each of these MMS modes, 3 dB more link budget is added. For example, 2 MMS mode can provide 3 dB more link budget compared to 1 MMS, 4 MMS mode can provide 6 dB, 8 MSS can provide 9 dB, and 16 MSS can provide 12 dB. This can enable significant enhancements to the ranging distance of UWB, provide enhanced resilience against multipath, reduce interference, and enable more robust ranging capabilities even in non-line of sight or back pocket scenarios. Figure 2 shows how the additional link budget from the 8 MMS mode can significantly extend the effective range when compared to IEEE 802.15.4z, effectively enabling IEEE 802.15.4ab and Bluetooth® LE to have the same operating zones.

Figure 2: The Impact of Different MMS Modes on UWB's Link Budget and Range

(Source: STMicroelectronics)



This immense boost on link budget for the ranging frame would be wasted if the data communication elements were not also adjusted. This brings NBA UWB into play.

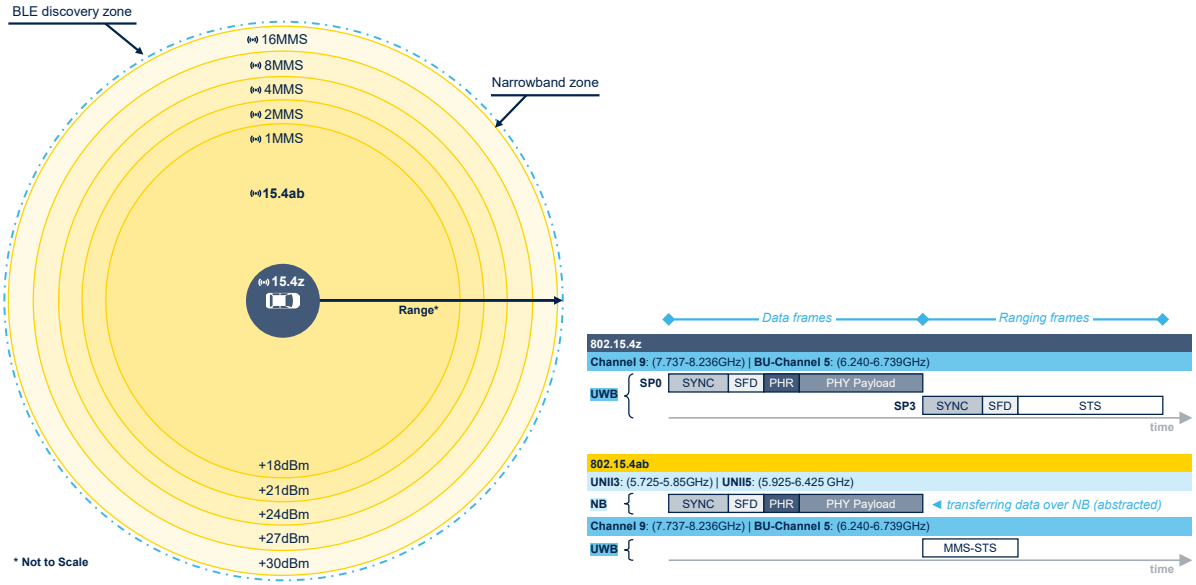
NARROWBAND-ASSISTED (NBA) UWB

MMS can be implemented in several ways, including NBA, UWB-driven, or out-of-band using Bluetooth® LE. Each has its own individual strengths and limitations, including range, robustness,

hardware requirements, and regulatory challenges. However, one approach that has demonstrated the highest link budget increase and stability to enhance the effective range and experience of IEEE 802.15.4ab is NBA MMS UWB. This utilizes a dedicated narrowband signal to provide frequency and timing synchronization during the initialization and control phases. As this narrowband signal operates in the lower 5725 MHz to 6425 MHz UNII-3 and UNII-5 frequency bands compared to UWB Channel 9, the range of these signals can extend further, up to the Bluetooth® LE discovery zone, as highlighted in Figure 3.

Figure 3: The Impact of NBA UWB for Digital Key Applications

(Source: STMicroelectronics)



In contrast, while UWB-driven MMS does not require additional hardware, one of the challenges of using the UWB PHY for both ranging and timing and sync data is that it can reduce the overall link budget and also be susceptible to degradation in challenging RF environments. By decoupling the time synchronization from the UWB band into the closely time-synced narrowband, this can already provide an up to 18 dB improvement when using the single MMS only approach. Meanwhile, an additional 12 dB can be unlocked by deploying an increased number of repeated fragments (up to 16 MMS). As this is also being defined by the IEEE, it can enable tighter coupling with the UWB PHY, enabling more predictable timing and scheduling information. One challenge of utilizing out-of-band technologies such as Bluetooth® LE for this process is that synchronizing timing with UWB can be more challenging, particularly in difficult RF environments with the presence of high congestion on Bluetooth® LE triggering transmission/synchronization delays.

ADDITIONAL ENHANCEMENTS

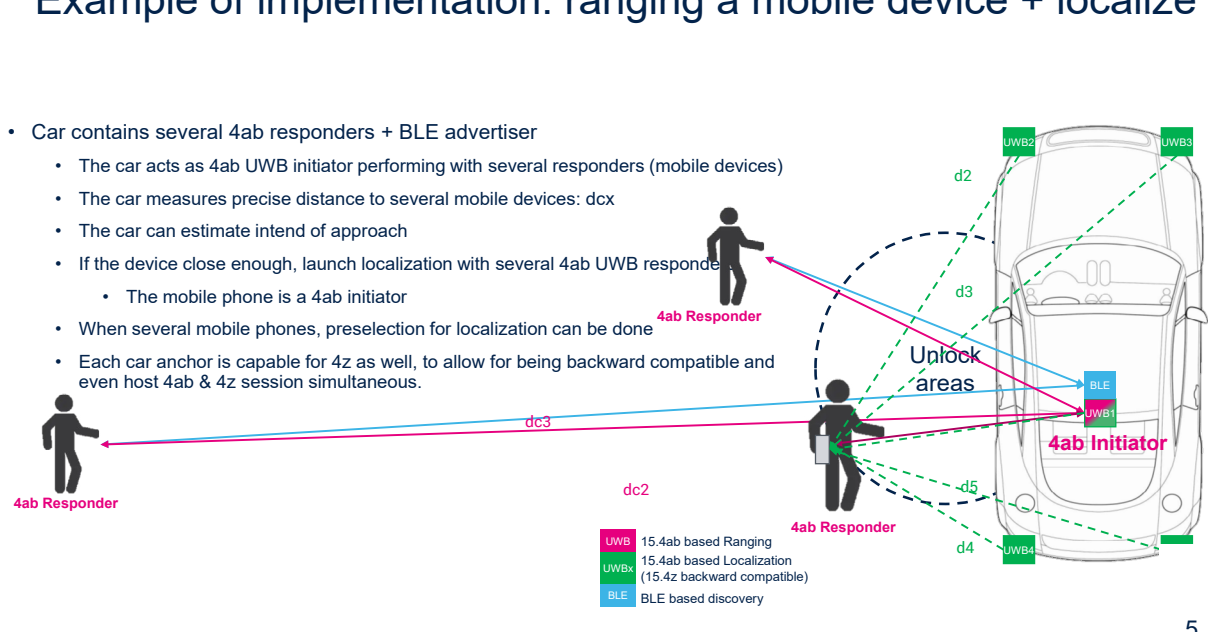
Various other improvements to the UWB PHY have also been made. IEEE 802.15.4ab introduces new modulation schemes supporting data rates of up to 1.95 Mbps, which have been specifically designed to provide a boost to signal strength to improve ranging and overcome challenges such as the back pocket scenario. Alongside this, IEEE 802.15.4ab also introduces optional Low-Density Parity-Check (LDPC) coding, which can dynamically adjust the data rate based on real-world RF conditions. In noisier environments, lowering the data rate could enhance reliability and robustness.

IEEE 802.15.4ab is also helping to standardize sensing and radar capabilities that have gained significant traction in recent years. In addition to digital key applications driving the resurgence in UWB

technology, the integration of radar functionality for child presence detection, intrusion detection, seat occupancy detection, kick sensing, and sentry mode activation, is now, in turn, boosting further digital key adoption. This combined value proposition and ability to conform to new vehicle occupancy regulations is becoming very compelling for accelerating UWB adoption in the vehicle, which is also spurring on further internal- and external-facing use cases. The standardization of these capabilities will also incentivize broader UWB adoption within automotive and other environments where sensing can bring value.

Meanwhile, the MMS feature that will be introduced in IEEE 802.15.4ab is also capable of supporting five ranging modes, four of which can support one-to-many ranging. In an automotive digital key scenario, where there may be multiple responder devices (typically smartphones) approaching a vehicle, to ensure the best possible user experience, the IEEE 802.15.4ab initiator in the vehicle needs to be able to effectively measure the precise distance to multiple devices. Based on a variety of techniques defined in IEEE 802.15.4ab, the initiator can better determine the intent of each device to approach and handover to the IEEE 802.15.4z anchor points deployed in the vehicle to enable the vehicle unlocking for only devices that enter the unlock area, as Figure 4 shows. This can help alleviate potential congestion issues where multiple vehicles and devices are attempting to localize in the same area, such as in large car parks.

Figure 4: A Typical Digital Key Ranging Session with the Ability to Support Multiple Responders
(Source: STMicroelectronics)



THE IMPACT OF IEEE 802.15.4AB ON LINK BUDGET AND REAL-WORLD PERFORMANCE

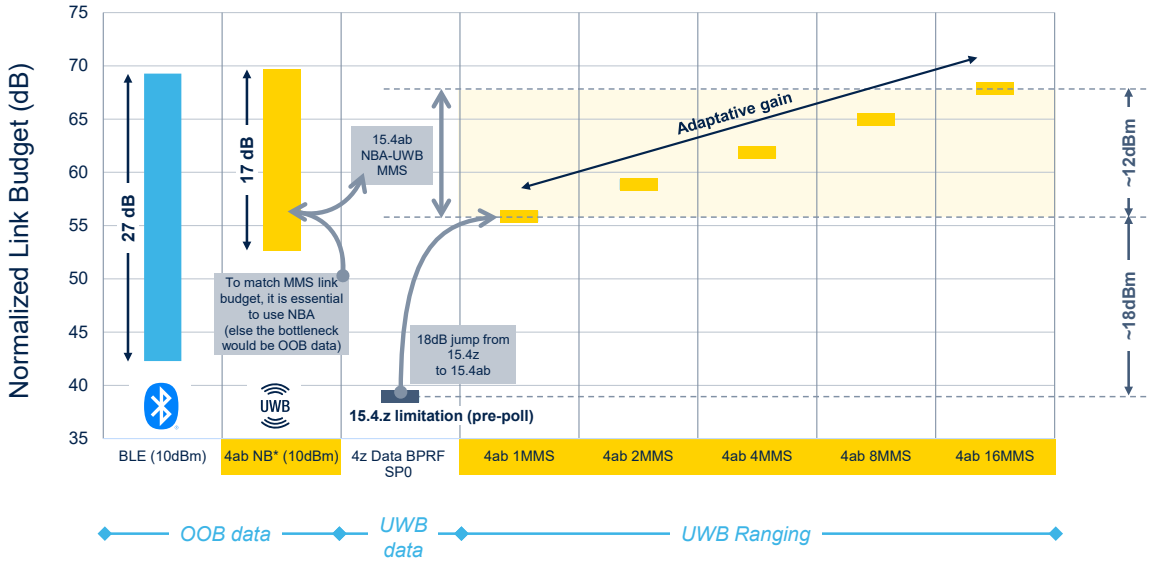
While IEEE 802.15.4z is capable of supporting several tens of meters ranging in ideal conditions, this can fall dramatically to just a few meters if body attenuation is high due to back pocket placement, or if the solution is deployed in a challenging multipath environment. Meanwhile, vehicles themselves pose unique multipath challenges due to reflective surfaces and the heavy presence of glass and metal.

With the new features introduced in IEEE 802.15.4ab, the link budget can be improved by up to 30 dB. This can enable secure ranging implementations that can operate over greater distances, work

reliably in different environments even in back pocket scenarios, be more power efficient, potentially open up valuable new intent-driven use cases, and reduce the infrastructure requirements of UWB technology over time. Figure 5 shows the link budget comparison between IEEE 802.15.4z and IEEE 802.15.4ab.

Figure 5: IEEE 802.15.4z and IEEE 802.15.4ab Link Budget Comparison

(Source: STMicroelectronics)



Figures 6 and 7 provide a visual representation of how the ability to detect a responder device (e.g., smartphone) more accurately, more reliably, over greater distance, and with lower power, enabled by the various IEEE 802.15.4ab enhancements, can help optimize the handover process between the single anchor ranging and the multi-anchor localization mode used for unlocking vehicles today. By adding a new IEEE 802.15.4ab ranging mode after the Bluetooth® LE discovery mode, enabled by the new enhanced and controllable link budget, the handover from the single IEEE 802.15.4ab anchor to the multiple in-vehicle IEEE 802.15.4z anchors can now happen much later, more consistently, and only when needed, improving the user experience and reducing overall power consumption.

Figure 6: Challenges with Existing IEEE 802.15.4z UWB Digital Key Implementations

(Source: STMicroelectronics)

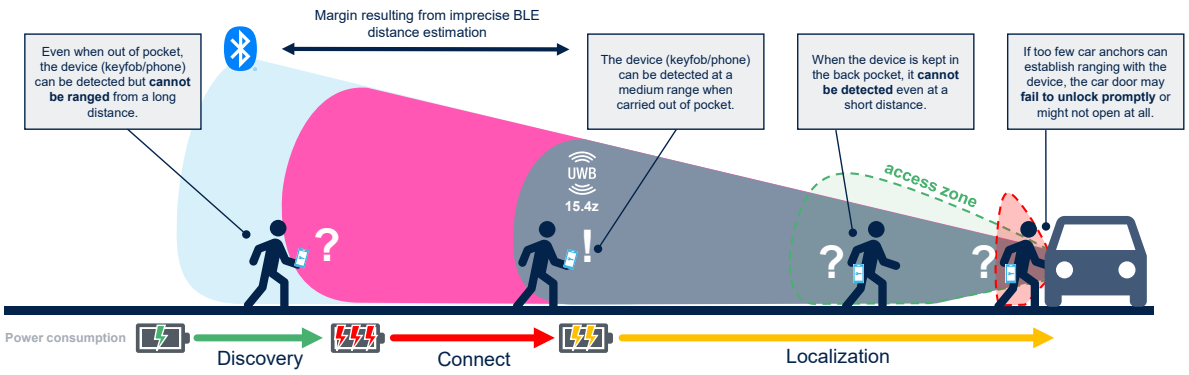
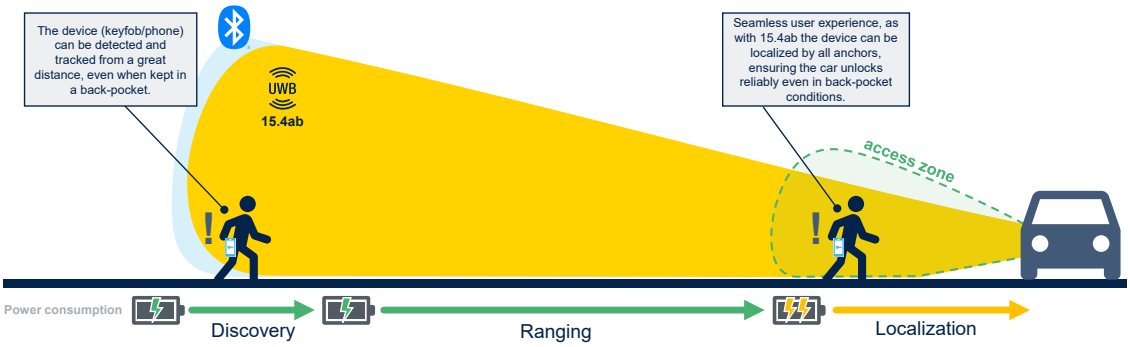


Figure 7: How IEEE 802.15.4ab Can Enable Enhanced Digital Key Performance
(Source: STMicroelectronics)



In a nutshell, IEEE 802.15.4ab bridges the current gap between the Bluetooth® LE discovery zone and the localization zone, offering more precise, multi-path, and immune one-to-one and one-to-many distance measurements. By ensuring that the localization mode starts much more precisely, this can also ensure that multiple sessions in the same vicinity, e.g., densely populated stadium car parks, do not cause as much disturbance, further improving the user experience. Meanwhile, thanks to the ability to enable precise secure ranging from a much greater distance, alongside much greater visibility into the user intent to approach, this can enable valuable new services, such as find my car, welcome light activation, climate control, infotainment personalization, and adjusting seat heights, among other features, which can be enabled depending on predetermined thresholds.

In contrast to IEEE 802.15.4ab, within existing IEEE 802.15.4z solutions, the margin for error in this handover is higher due to the limited accuracy of Bluetooth® LE RSSI. As a result, the UWB localization mode is started early (sometimes far outside of the ranging zone), which can increase the power consumption of the solution. Furthermore, the UWB localization attempts can last for a long time if the device owner stays in the vicinity of the vehicle, further increasing the power consumption. Meanwhile, due to the limited link budget, phones in the back pocket may not be detected until the last moment or at all, compromising the user experience, and preventing the rollout of these additional valuable remote services such as welcome lights or vehicle personalization that can be based on different distances and intent to approach.

Table 1 provides a summary of the major objectives and differences between the IEEE 802.15.4z and IEEE 802.15.4ab amendments.

Table 1: Key Features of IEEE 802.15.4z and IEEE 802.15.4ab
(Source: ABI Research)

Amendment	IEEE 802.15.4z	IEEE 802.15.4ab
Release year	2020	2026
Objective	Improvements in ranging integrity and security via Scrambled Timestamp Sequence (STS) and several updates to the High Rate PRF (HRP), and Low Rate PRF (LRP) UWB PHY and MAC layers based on the underlying IEEE 802.15.4 standard	Aimed at increasing link budget to offer enhanced ranging performance over longer distances, but mostly seeking to guarantee base-level performance in real-world environments to mitigate issues caused by multipath, congestion, body blocking, and other attenuation
Range	Typically a few tens of meters in real-world deployment scenarios	Up to several hundred meters

Amendment	IEEE 802.15.4z	IEEE 802.15.4ab
Link budget	Baseline	Up to 30 dB improvement over 802.15.4z based on NBA
Performance in multipath	Strong (line-of-sight)	Very strong (in all conditions)
Key techniques	STS	NBA UWB MMS
Power consumption	Introduces enhanced modulation schemes for improved energy efficiency	Improvements achieved via more reliable handover to UWB alongside additional power saving mechanisms
Sensing	Emphasis on secure ranging, sensing not supported as standard	Standardizes radar/sensing capabilities to enable emerging use cases such as presence detection, gesture recognition, vital sign monitoring
Data rates	Typically, 6.8 Mbps with support for 850 Kilobits per Second (kbps) at greater distances	IEEE 802.15.4ab introduces new modulation schemes supporting data rates from 1.95 Mbps up to 27.2 Mbps and 31.2 Mbps
Scalability	Can support both single user and one-to-many ranging	Better support for multiple users thanks to one-to-many ranging enhancements

With these benefits in mind, in addition to bringing further enhancements via its upcoming Digital Key 4.0 specification, the CCC is also actively working toward implementing IEEE 802.15.4ab technology, and has established a dedicated working group to help achieve this. Meanwhile, several automotive OEMs are already including IEEE 802.15.4ab with NBA ranging in their requirement specifications, while those contributing to the standard development expect there to be a more accelerated transition toward the new technology when compared with traditional automotive technology cycles. This is due to various factors including:

- IEEE 802.15.4ab being a relatively straightforward hardware upgrade from existing IEEE 802.15.4z solutions
- The expected parallel transition toward IEEE 802.15.4ab in smartphones and other applications over the next few years
- The wider penetration of UWB in automotive and smartphone applications
- The added value proposition of combining ranging and radar functionality for additional in-vehicle use cases
- New entrants to the market based on IEEE 802.15.4ab technology
- Backing from multiple UWB-related industry consortia
- The arrival of new IEEE 802.15.4ab chipsets targeting a range of UWB applications.

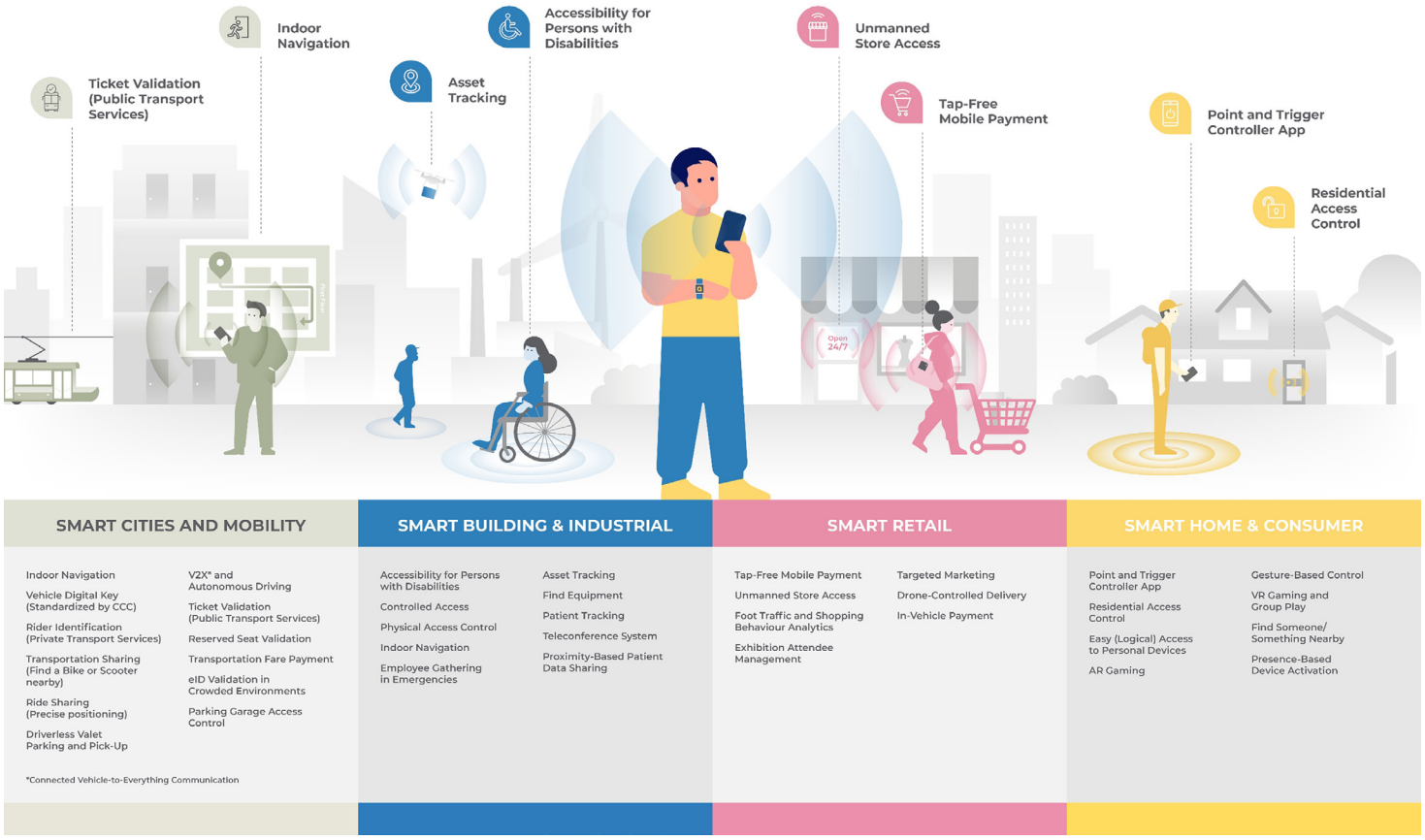
As a result, by 2030, almost 80% of vehicles supporting UWB are expected to have transitioned to IEEE 802.15.4ab technology, while hundreds of millions of smartphones supporting the technology are expected to ship in the next few years, on top of the existing installed base of several hundred million IEEE 802.15.4ab-compatible devices.

BEYOND THE DIGITAL KEY: HOW IEEE 802.15.4AB CAN ENABLE FUTURE UWB USE CASES

While the focus of this whitepaper has centered primarily on UWB digital key applications, expanding UWB's secure ranging capabilities over greater distances can enable many new UWB use cases, enhance existing ones, and create valuable new services and features. If one looks at many of the future UWB use cases highlighted by the FiRa Consortium in Figure 8, it is easy to see how IEEE 802.15.4ab's enhanced range performance and robustness will be vital to their future success. Many of these can benefit from the ability to determine the exact location of a user between the discovery mode and localization, as well as offering a more accurate picture of user intent and direction.

Figure 8: FiRa UWB Use Cases

(Source: FiRa Consortium)



Perhaps the most obvious benefits can be found in other secure access applications, such as smart door locks in residential environments, or commercial access control readers. Not only are these typically difficult multipath environments, but they are also likely to face similar challenges from users leaving phones in their back pocket. IEEE 802.15.4ab can ensure a more consistent user experience, while also enabling remote home services on approach, e.g., light activation.

In applications where intent needs to be verified at multiple stages, such as within contactless ticketing and transportation fare payments, IEEE 802.15.4ab is likely to be fundamental to the future success by reducing the cost and complexity of UWB infrastructure rollouts. As many localization anchors are usually ceiling mounted, the height from floor to ceiling can sometimes already push the range limits of IEEE 802.15.4z in some deployments. Meanwhile, in other localization applications, the extended range can also help reduce the density of anchor points, reducing infrastructure costs and enabling quicker Return on Investment (ROI), especially as such localization anchors are usually

ceiling mounted and here sometimes the height from floor to ceiling is already pushing the limits of 15.4z range in some cases.

Extended range tracking applications for UWB can now also be enabled without the need for a dense deployment of localization anchor points. For example, thanks to the enhanced range provided by IEEE 802.15.4ab, find someone/something use cases and experiences can also be enhanced. This will enable users to more easily and precisely locate friends or family in densely populated areas, or to find lost items like keys or luggage over significant distances, allowing UWB to be used as an indoor Global Navigation Satellite System (GNSS)-like solution. In congested car parks, users could be directed to their vehicle based on precise positioning, or at a shopping mall, family and friends could more easily be located within a large crowd. There is also a whole host of potential vehicle-to-infrastructure applications that can benefit from extended range capabilities and better performance in multipath environments such as parking garages. This is potentially even more potent in vehicle applications such as parking barriers, toll collection, and drive-throughs where additional range and robustness benefits are obvious.

At this time, it is clear that the ecosystem has barely scratched the surface of UWB's true potential opportunities. However, the enhanced ranging and link budget performance that IEEE 802.15.4ab can provide will be vital in enabling future use cases alongside enhancing existing ones already on the market. Many of the future targeted FiRa use cases above can significantly benefit from the enhancements brought about by IEEE 802.15.4ab, and the FiRa Consortium very recently launched a new initiative to update its specifications to incorporate new features being introduced by this standard. Meanwhile, some of the use cases defined in the FiRa 3.0 specification, such as logical access to personal devices, alongside retail, car park, and public transport tap-free mobile payments, can benefit from these enhancements.

To summarize, IEEE 802.15.4ab is directly addressing some of the major limitations in existing UWB technology highlighted earlier on in this paper. This has a number of benefits, including:

- Enabling more reliable location of devices in different environments due to higher link budget (e.g., for back pocket scenarios and multipath environments).
- Providing lower power consumption due to the localization session only being started when really needed (e.g., walking to the vehicle in an office parking scenarios).
- Minimizing disturbances and congestion between multiple users as the ranging sessions are only started when really needed (e.g., stadium scenarios). This will also be critical as more and more users begin to use UWB ranging in public environments.
- Guaranteeing high accuracy with single measurements that are immune to multipath environments (non-line of sight scenarios).

Ultimately, ABI Research believes that IEEE 802.15.4ab will be fundamental to the future success of UWB technology. This is due to its ability to enable a more positive and consistent end-user experience, to create valuable new services and experiences, and to open new use cases for UWB technology that current technology may struggle to achieve in its current form. The successful rollout will be vital in accelerating UWB market adoption beyond the 1.4 billion projected device shipments by 2030.

HOW STMICROELECTRONICS AND ITS NEW ST64UWB ARE AT THE FOREFRONT OF UWB AND DIGITAL KEY INNOVATION

STMicroelectronics is a leading semiconductor company with over 30 years' experience in automotive electronics, delivering safer, more sustainable, and more connected driving experiences through its Smart Mobility portfolio. Building on this foundation, ST is driving the transition to the new era of car electrification, advanced driving systems, and secure car connectivity for software-defined vehicles.

Today, ST's wireless connectivity portfolio targets applications within automotive, industrial, consumer, and a wide range of IoT applications. This spans a wide range of technologies, including Bluetooth® LE, IEEE 802.15.4 (Zigbee, Thread Matter), and Near Field Communication (NFC), and a Wi-Fi portfolio targeting industrial, healthcare, and smart home environments. This portfolio now includes the ST64UWB family, ST's first monolithic IEEE 802.15.4ab UWB system-on-chip.

The ST64UWB family offers three SoCs: the ST64UWB-A100 and ST64UWB-A500 for automotive digital key, hands-free access, and in-cabin radar sensing, and the ST64UWB-C100 for consumer and industrial hands-free access control, including full Aliro compatibility. With this new family, ST is actively participating in the IEEE 802.15.4 Task Group, which is currently finalizing the amendment. Alongside this, ST is an established member of the UWB Alliance, omlox, the Connectivity Standards Alliance (CSA), the Car Connectivity Consortium (CCC), and the FiRa Consortium, reflecting ST's role in shaping the future of UWB.

Beyond UWB, ST already has a strong portfolio of NFC solutions for automotive digital keys, enabling a secure way for users to access their vehicles. Based on an embedded Secure Element (eSE), a secure gateway, and a contactless NFC reader, ST offers a turnkey solution for secure NFC car access, supporting the CCC Digital Key Specification. In addition, several ST product families support the Aliro standard for smart building access.

ST64UWB brings together ST's unique differentiators in RF performance, multi-use-case convergence, and high MCU integration without the need for a dedicated companion chip. Built on ST's 18 nm FD-SOI process, the family delivers approximately 3 dB of additional link budget over standard bulk CMOS, extending range by roughly 50% beyond what the IEEE 802.15.4ab standard alone provides. On the digital side, ST64UWB pairs an Arm Cortex-M85 core running at up to 100 MHz with integrated PCM and SRAM. By taking full advantage of IEEE 802.15.4ab NBA MMS, ST64UWB directly addresses the back-pocket, multipath, and handover challenges described earlier in this paper, delivering a more reliable and robust experience for OEMs and end users alike. Combined with ST's Secure Element, Bluetooth LE, and NFC technologies, ST64UWB positions ST as the ideal partner to lead the industry's transition from IEEE 802.15.4z to next-generation UWB.



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We Empower Technology Innovation and Strategic Implementation.

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