
Exafore Ltd
Sales: Aki Korhonen +358 44 544 7357 aki.korhonen@exafore.com

# The Exafore Horizon Benefits for Industry

## Why Exafore Horizon?

Indoor positioning has become increasingly integral in various industrial environments, revolutionizing the way businesses operate and optimize their processes. The benefits of implementing indoor positioning in industrial settings are multifaceted, encompassing improvements in efficiency, productivity, and safety.

While the initial investment in indoor positioning technology may seem substantial, the long-term benefits outweigh the costs. The higher situational awareness, optimized resource utilization, reduced downtime, increased safety, and lower maintenance costs contribute to significant cost savings over time.

Here we will delve into the numerous advantages of Exafore Horizon indoor positioning solution in industrial settings, giving an overview of how these contribute to enhanced operations and overall business success.

### Increased Efficiency and Productivity

The primary advantage of Exafore Horizon in industrial settings is the optimization of all workflows and resources. The real-time nature of indoor positioning data empowers industrial businesses with immediate insights into their operations. Horizon enables the tracking of assets, equipment, and personnel in real-time, allowing for quick reaction to bottlenecks and inefficiencies in the production process.

Monitoring and analytics tools can leverage data from Horizon to generate actionable intelligence, allowing for quick decision-making and continuous process improvement. By analysing historical location data, businesses can identify trends, predict potential issues, and implement preventive measures. By analysing movement patterns and utilization rates, businesses can streamline operations, reduce downtime, and enhance overall productivity.

Next, we will dive into details of some Exafore Horizon use cases offering increased efficiency and productivity.

### Asset Tracking and Management

Many industrial facilities involve the use of expensive machinery, tools, and equipment. Exafore Horizon enables the tracking and management of these assets in real-time, minimizing the risk of theft or loss. This technology ensures that assets are used efficiently, scheduled for maintenance at the appropriate times, and located promptly when needed. This proactive approach to asset management extends the lifespan of equipment and reduces operational costs.

## Inventory Management

Effective inventory management is critical to avoid overstocking or stockouts, both of which can have significant financial implications. Indoor positioning systems provide accurate and up-to-date information on the location and status of valuable inventory items. This not only prevents the loss of valuable time searching for materials but also aids in the implementation of lean practices, reducing carrying costs and optimizing supply chain efficiency.

## Geofencing for Operational Control

Geofencing, a feature enabled by indoor positioning systems, allows businesses to define virtual boundaries within their facilities. This technology can trigger automated actions when a device or person enters or exits a specific area. For example, geofencing can be employed to automatically adjust temperature settings, activate or deactivate machinery, or send alerts based on the location of assets or personnel. This level of operational control enhances efficiency and reduces the margin for error in complex industrial processes.

## Collaboration and Communication

Communication and data sharing are essential elements of efficient industrial operations. Indoor positioning systems facilitate better communication and collaboration among team members by providing instant location-based information. This is particularly valuable in large facilities where coordination can be challenging. Workers can locate each other, coordinate tasks, and respond promptly to changes in the production environment, fostering a more agile and responsive workforce.

## Worker Productivity and Safety

Indoor positioning systems contribute significantly to the safety and productivity of employees. Additionally, location data can be analysed to optimize work schedules, allocate tasks efficiently, and identify opportunities for training and other skill development.

Safety is a paramount concern in industrial environments, where the complexity of operations and the presence of machinery pose inherent risks. Indoor positioning systems play a pivotal role in ensuring the safety of workers by providing real-time location data. This information allows for the implementation of proximity alerts and geofencing, preventing accidents such as collisions in high-risk zones or highly populated areas.

## Quality Control

In industries where precision and quality control are paramount, Exafore Horizon contributes to ensuring product quality. By tracking the movement of goods, quality control samples and personnel through various stages of production, businesses can identify and rectify issues in real-time, minimizing defects and waste. This level of control is especially crucial in industries such as manufacturing and pharmaceuticals, where adherence to strict quality standards is imperative.

### Regulatory Compliance

Many industrial sectors are subject to stringent regulatory requirements regarding worker safety, environmental standards, and operational protocols. Exafore Horizon assists businesses in adhering to these regulations by providing a transparent and traceable record of operations. This not only helps in avoiding penalties and legal issues but also enhances the overall reputation of the business as a responsible and compliant entity.

### Energy Efficiency

Energy consumption is a significant concern in modern industrial settings, and Ezafore Horizon can contribute to energy efficiency. By tracking the movement of personnel and assets, businesses can optimize the usage of lighting, heating, and cooling systems in specific areas. This not only reduces energy costs but also aligns with sustainability initiatives, contributing to a greener and more environmentally conscious operation.

### Conclusions

The benefits of indoor positioning systems in industrial environments are vast and transformative. The utilization of Exafore Horizon not only addresses the unique challenges posed by indoor environments but also opens up new possibilities for enhanced collaboration, communication, and data-driven decision-making.

Exafore Horizon is easy to integrate and works seamlessly across different platforms and ecosystems. This interoperability ensures that the positioning data from Horizon can be easily integrated into various IoT solutions, production management systems and ERPs.

Further, Exafore Horizon is scalable and adaptable to the changing needs of industrial environments. Whether a facility undergoes expansion or undergoes reconfiguration, Horizon can be easily scaled to accommodate changes in the physical layout. This flexibility ensures that businesses can continue to benefit from indoor positioning data as they evolve and grow. Horizon can be integrated with other emerging technologies, such as the Internet of Things (IoT), artificial intelligence, and machine learning. This integration allows for more sophisticated data analysis, predictive maintenance, and automation. The synergy between indoor positioning and other advanced technologies creates a holistic and technologically novel industrial ecosystem.

Exafore Ltd
Sales: Aki Korhonen +358 44 544 7357 aki.korhonen@exafore.com


Exafore Ltd
Sales: Aki Korhonen +358 44 544 7357  aki.korhonen@exafore.com

# UWB Positioning Technology

## What is UWB Technology?

UWB is a short-range radio technology for data communication that uses long sequences of nanosecond level RF pulses to create a signal with a wide bandwidth. With suitable transceiver hardware it is possible to measure the timing of these pulses with sub-nanosecond accuracy and therefore measure distances with decimeter level accuracy, one nanosecond being about thirty centimeters at RF signal propagation speed, i.e., the speed of light. This provides for its use in positioning systems and applications. The UWB signaling is standardized in the IEEE 802.15.4 standard.

## Timing Measurement Techniques: Time Difference of Arrival (TDoA) vs. Two-Way Ranging (TWR)

There are two timing measurement techniques that can be used with UWB to determine location: Time Difference of Arrival (TDoA) and Two-Way Ranging (TWR). Both of these methods can be used in Real-Time Locating Systems (RTLS) consisting of stationary devices (base stations) and mobile devices (tags), which perform UWB signaling and measurements between each other.

In TDoA, a tag sends a signal that is received by two base stations, and the difference between the reception times is measured. The base stations need to be highly accurately synchronized, which can be costly to arrange. One-way communication is sufficient: tags need only to send signals at regular intervals, and base stations need only to receive them.

In TWR, both tag and base station send and receive signals. Basically, a single back-and-forth messaging between tag and a base station is done in both directions, with the tag first initiating a measurement and then the base station initiating another one. This would require four messages to be sent over the air, but since the base station responding to the tag and base station initiating a measurement can be folded into a single message, a total of only three messages need to be sent.

TWR does not require accurate synchronization between base stations, or between base stations and tags, and suppresses certain error sources. It therefore provides better accuracy and lower complexity than TDoA.

Two-way data transmission allows sensor data collection from each tag and controlling of the tags remotely. The sensor data could be, for example, environmental data such as ambient temperature – or whatever else is needed by the application and supported by the tag hardware (HW). The remote tag control enables keeping the tags in clock synchrony with the base stations to an accuracy level that allows time division multiplexing (TDM) of the radio channel, resulting in efficient radio channel usage, even with tags using relatively inexpensive and inaccurate clock in their HW. It also enables sending alarms to the tag user, for example.

Since there is no messaging from base stations towards tags in TDoA, the tags will be completely asynchronous to base stations and each other, leading to RF transmission collisions as the number of tags grows, and consequently inefficient radio channel usage and variable measurement availability. In TDM operation that can be used with TWR, such collisions can be avoided completely, and measurements can be made with a continuous, constant rate.

A TWR measurement is the real distance between a tag and a base station. Because of this simple physical meaning, applications can use the measurements as is, with or without computed tag positions. For example, proximity detection to each base station is possible.

## The Benefits of UWB

UWB provides various benefits in RTLS use over other technologies, allowing it to be used in applications where other systems cannot operate or where their performance or other characteristics are unsuitable or insufficient. Here is a shortlist of such benefits:

- UWB can provide decimeter level positioning accuracy independent of range. Positioning solutions based on signal strength (RSSI), for example, typically provide multi-meter accuracy levels, while in angle-of-arrival (AoA) based systems such as BLE AoA, the measurement error increases as distance between tag and base station increases.
- UWB signal can be measured through obstacles such as partition walls, furniture, pallets of goods etc.; a visible line of sight between base station and tag is not required. Consequently, UWB positioning can work also in rooms where there are no base stations, for example.
- No RF fingerprinting is required during installation or when radio environment changes, as UWB positioning is not based on fingerprinting.
- UWB tag transmission and reception times can be relatively short, providing for low power consumption for tags.
- UWB natively supports 3D operation with X, Y and Z coordinate output. 2D operation is also possible.
- UWB is resistant to interference from narrowband radio systems, since each one of them affects only a small portion of the whole UWB signal spectrum.
- A UWB tag does not need a large antenna or any other large components, providing for small and lightweight tag designs.

## Summary

UWB is a tried-and-tested technology for different types of indoor positioning applications, including both real-time tracking applications and offline location data analysis applications. It provides a number of benefits over other technologies, such as high accuracy and reliable operation even in complex environments.

horizon

# The Exafore Horizon Advantage

## Exafore Horizon

### *Key Technologies*

Exafore Horizon is a Real-Time Locating System (RTLS) consisting of stationary devices (base stations) and mobile devices (tags), which use Ultra-Wideband (UWB) radio technology for transporting data and making distance measurements between each other. Tags also include a 6-axis inertial sensor which is used for increasing position fix quality and availability, and for reducing the power consumption of the tag.

UWB is a short-range radio technology for data communication that uses long sequences of nanosecond-level RF pulses to create a signal with a wide bandwidth. With suitable transceiver hardware it is possible to measure the timing of these pulses with sub-nanosecond accuracy and therefore measure distances with decimeter level accuracy, one nanosecond being about thirty centimeters at RF signal propagation speed i.e., the speed of light. This provides for its use in positioning systems and applications. The UWB signaling is standardized in the IEEE 802.15.4 standard.

### Features and Benefits

Exafore Horizon has several functionality and performance characteristics which cater to a wide variety of indoor positioning applications. These range from continuous one fix per second real-time position tracking to one fix per hour asset tracking and offline data analysis. Here is a shortlist:

#### Positioning capability

- The system provides decimeter level positioning accuracy independent of range, using hybrid UWB+inertial positioning for best accuracy and fix availability.
- Since the UWB signal can be measured through obstacles such as partition walls, furniture, pallets of goods etc., a visible line of sight between base station and tag is not required. Consequently, positioning can also work in rooms where there are no base stations, for example.
- The system natively supports 3D operation with X, Y and Z coordinate output. Altitude/height aided 2D operation is also possible.
- Since the system measures real range between tags and base stations it can also be used for proximity detection with base stations installed in key locations.

## Architectural characteristics

- The system includes a local server with a single easy-to-use network API, supporting positioning and measurement data delivery, system state monitoring, configuration, and all other user operations. The API has built-in user role and access management, and it is straightforward to integrate with other systems, in the cloud or otherwise.
- The measurement data generated by base stations is transported to the server over an Ethernet interface for the best robustness and stability. The base stations have a master/slave architecture where each slave base station delivers data to its master over UWB, and each master delivers the data to the server over Ethernet. Consequently, only master base stations need to be connected to Ethernet, minimizing cabling need.
- Each base station can be powered with either USB or PoE (Power over Ethernet), providing for flexibility in power supply arrangements.
- The system is self-contained, and its operation does not depend on connection to the internet, or cloud. It can therefore also be used in environments where such connectivity is not desired, e.g., for security reasons.
- The system is resistant to interference from narrowband radio systems, since each one of them affects only a small portion of the whole UWB signal spectrum.
- The tag has IP67 class ingress protection: it is fully dust-tight and can withstand short-term immersion in water. The standard indoor base station has an IP40 protection class, and an IP67 base station is also available for harsher environments. The system can therefore be used even in challenging environments.

## Installing the system

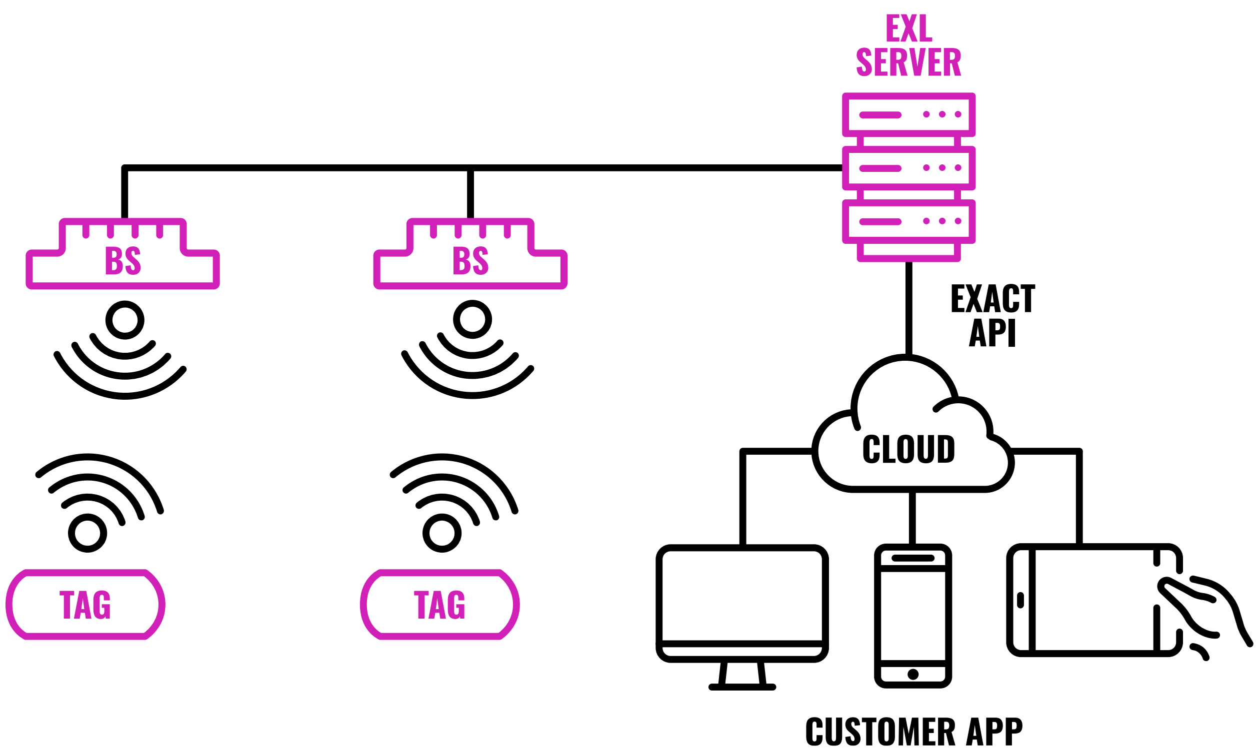
- The system includes a multi-purpose Android GUI application for all parts of system commissioning: configuration, control, visualization, and testing
- Base stations can be installed in any orientation, making installing them easy compared to systems based on angle measurements, e.g., angle-of-arrival (AoA) systems
- No RF fingerprinting is required during installation or when radio environment changes, as the positioning method used is not based on fingerprinting

#### Tag

- Battery life up to over a year depending on operating mode and fix rate
- Accelerometer-based movement detection in tags provides for lower power consumption
- Tag transmission and reception times can be relatively short, reducing power consumption significantly
- Small and lightweight tag design

### Summary

Exafore Horizon offers multiple advantages over other positioning systems and technologies. It can support many different kinds of indoor positioning needs and different indoor environments – from factory floors and warehouses to office buildings. Its system design allows flexible deployment and the optimization of each system configuration for the relevant application requirements.


EXL
SERVER
BS
BS
TAG
TAG
EXACT
API
CLOUD
CUSTOMER APP

# Intro to Exafore Horizon Positioning

## Positioning Principle

Positioning involves taking measurements of some kind and then, together with additional data, computing positions based on the measurements and the additional data. The measurements may be based on electromagnetic signals, or they can be, for example, inertial or magnetic field measurements. The additional data may consist of base station locations or map data, for example.

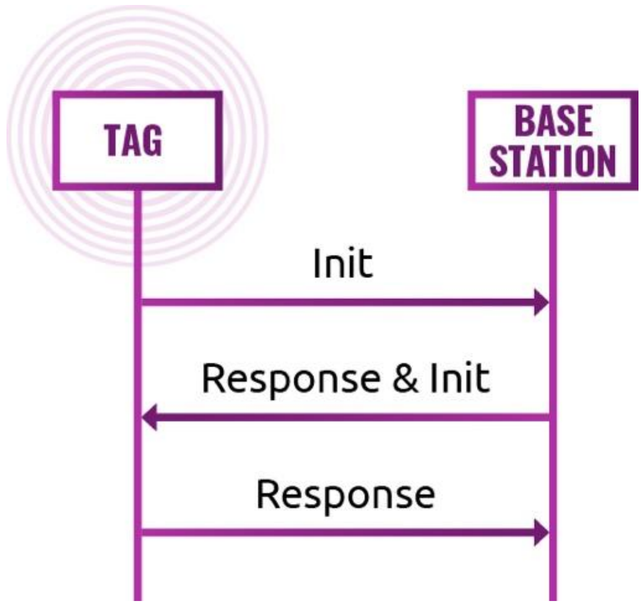
Exafore Horizon is a Real-Time Locating System (RTLS) consisting of stationary devices (base stations) and mobile devices (tags). It uses ultra-wideband (UWB) radio signaling to produce range (distance) measurements between base stations and tags. When configured for highest accuracy, it also uses inertial measurements produced by a 6-axis inertial sensor i.e., an accelerometer and gyroscope to produce a UWB+inertial hybrid position solution. These measurements, together with base station coordinates, enable position computation.

## Measurement Generation and Position Computation

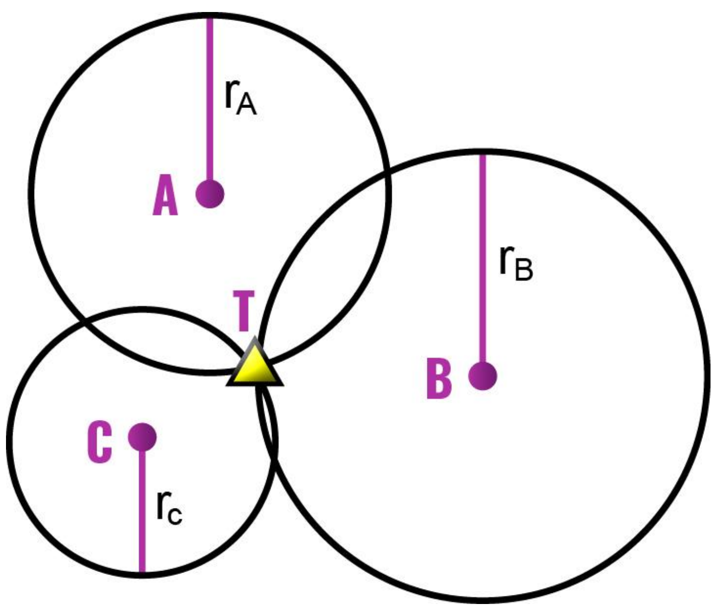
Exafore Horizon measures how long a radio signal takes to travel between two devices and multiplies the measured time-of-flight (ToF) by the speed of the signal (i.e., speed of light) to get the range. Two-way ranging (TWR) is used to produce the ToF and thus the range measurements. In TWR, both devices involved in the making of a range measurement send and receive signals, and the arrival and departure times of these signals are measured and ultimately delivered to the base station which then produces the completed measurement.

Basically, a single back-and-forth messaging is done in both directions, with one device initiating a measurement first and then the other. This would require four messages to be sent over the air, but since the second device is responding to the first device, and the second device initiating a measurement can be folded into a single message, a total of only three messages need to be sent.

This is shown in the diagram below, with tag initiating the measurement procedure. TWR does not require accurate synchronization between any devices involved in the measurement generation and it also suppresses certain errors.




The position computation principle used by Exafore Horizon is based on the base station location coordinates being known and measurements being true ranges between base station - tag pairs. Basically, if a range r has been measured between a base station and a tag, then the tag must be on a circle with radius r centered on the known position of the base station. If measurements are made to two base stations, two such circles can be formed and they should intersect in one or two points, and with three measurements there will be three circles and one uniquely defined point where the tag is, as shown in the diagram below.



This method is called trilateration, and often, when more than three measurements are involved, multilateration, or more specifically, true-range multilateration.

The problem of computing the user position using multilateration can be formulated into a system of nonlinear equations, which can be solved using different mathematical methods. These methods are often such that they benefit from measurement redundancy. That is, when there are more measurements and thus equations than required for solving the system, they try to estimate the best numerical solution based on some criteria. Position computation is consequently often called position estimation. Since measurements invariably contain errors, and these errors are often not correlated, having more measurement redundancy typically leads to a reduction in positioning error.

Exafore Horizon does multilateration in three dimensions, in which case each measurement describes a sphere instead of circle around a base station, and the end result of the position computation is three coordinates X, Y and Z. The user can freely choose the orientation of the coordinate system to, e.g., match the orientation of the building where the system is installed.

Three-dimensional positioning requires a minimum of four measurements, but two-dimensional requires only three. If a tag is known to be at a fixed altitude and therefore moves only horizontally, the user can configure this altitude for the tag, restricting the position computation to that altitude and therefore onto a two-dimensional plane, thus requiring one less measurement for full position computation, and yielding better error performance.

During continuous positioning, Exafore Horizon uses a state-based position estimator which combines position and velocity computation with a filtering function. It also includes fix qualification and error estimation functions. The estimator can also take inertial measurements as an input and produce a unified position and velocity output computed from both UWB and inertial measurements. The inertial data provides for smoother continuous positioning and covers situations where UWB measurement availability is poor.

### Summary

Exafore Horizon uses range measurements between tags and base stations together with multilateration and advanced position computation algorithms to provide exceptional position output quality. The TWR measurement method is used for the best measurement quality. Continuous positioning is enhanced with data from an inertial sensor included in each tag. With this combination of features, Exafore Horizon provides best-in-class indoor positioning accuracy and robustness.


# Guide to Exafore Horizon Deployment

## Overview

Exafore Horizon is a Real-Time Locating System (RTLS) consisting of stationary devices (base stations) and mobile devices (tags), which use Ultra-Wideband (UWB) radio technology for transporting data and making distance measurements between each other. It can be deployed flexibly since, after an initial deployment, more devices can be added or removed later – one or more at a time.

Deploying an Exafore Horizon system consists of the following key steps:

- Planning the deployment
- Installing base stations in the planned locations
- Installing EXL server software
- Configuring UWB Express
- Configuring the system through an EXL server
- Verifying system operation by testing

A key tool for commissioning the system is a multi-purpose Android GUI application called UWB Express. It can be used for all phases of system commissioning: configuration, control, visualization, and testing. It should be installed on at least one Android tablet. It is delivered as a single APK file which, once downloaded onto the tablet file system, can be installed in the usual way.

### Planning

A key task in planning is to determine how many base stations will be needed and where they will be installed. Base station locations ultimately define the positioning coverage area and affect positioning accuracy and robustness, so they should be selected accordingly.

The base stations have a master/slave architecture. Typically, there are multiple slave base stations per master. Each slave delivers data to its master over UWB, and each master delivers the data through its Ethernet connector to the server over local area network (LAN). Consequently, only master base stations need to be connected to LAN, minimizing cabling need. Part of the planning therefore is to define which base stations will be masters, which slaves will be tied to which master, and consequently what Ethernet cabling will be needed.

The power supply arrangement for each base station also needs to be planned: each station can be powered through either USB or PoE.

Finally, a local coordinate system needs to be defined. In practice, the origin and the orientation of the coordinate system need to be selected. Since Z axis is always up (in reference to gravitation) and the coordinate system is orthogonal and right-handed, it is sufficient to define the orientation of either the X or Y axis. In a typical setup the origin is at a corner of a building or room, and both X and Y axes are oriented along some walls.

### Installing Base Stations

By default, base stations are configured as slaves, so each device selected to be a master should first be configured with UWB Express to be a master. Masters are to be connected to LAN and by default their IP addresses will be set using DHCP. If a static IP address is desired, it can be configured with UWB Express.

Base stations should then be installed in the planned locations, their cabling (USB and/or Ethernet) installed and connected, and the red power LED of each station checked to verify power supply. Ethernet connection LEDs on each master should be checked for the “link up” condition. Base stations can be installed in any orientation, making installing them easy compared to systems based on angle measurements, such as angle-of-arrival (AoA) systems.

Finally, the X, Y and Z coordinates of each base station should be measured in relation to the chosen origin and orientation of the local coordinate system. This can be done, e.g., by using a laser distance measure.

No RF fingerprinting is required during installation or when the radio environment changes, as the positioning method used by Exafore Horizon is not based on fingerprinting.

### Installing EXL Server Software

EXL is the Exafore Horizon positioning system server software running on a Linux PC. Most of the system operations and output data feed can be accessed by communicating with the EXL server using the EXACT API protocol, but some system maintenance and configuration operations require logging in to the server with a remote terminal.

There is one EXL server in each system installation. The EXL server communicates with all master base stations in the system and provides a single point of connection to a user cloud or other server(s) using the EXACT API. The system operation does not depend on access to the Internet or any computational service beyond the EXL server, and a self-contained installation on a single site with no external network connections is therefore feasible.

EXL is delivered as a single .deb file and can be installed in the normal fashion by using a Linux installation package utility.

### Configuring UWB Express

Once the EXL server details, such as server address, have been provided, UWB Express connects to EXL over the network and controls it through its API. For visualizing the actual building floorplan of the coverage area, a bitmap image of the floorplan needs to be configured into UWB Express. Adding the floorplan image can be omitted if desired; UWB Express will then visualize tag positions etc. against a white background. The configuring entails specifying the orientation, scaling and origin for the image. If the positioning area has multiple floors, a separate floorplan image can be added for each floor.

### Configuring the System

Each base station and tag has a unique ID printed on it, and can be added to the system with UWB Express using the ID. Base station coordinates measured during installation need to be included, as well as master base station IP addresses. Additional information, such as human-readable descriptions on base stations and tags, can also be added. Finally, system-level configuration elements such as mapping between local and global coordinate systems can be defined. Such configuration elements are optional and can be omitted if desired.

Once everything has been configured, a restart command should be issued to EXL using UWB Express to reset the state of the system. UWB Express will automatically reconnect to EXL after the restart.

After this, the system is ready for the final step of deployment – testing operation.

## Verifying System Operation

The first step of system verification is to check the network connection between the EXL server and each master base station using a ping command issued through an SSH connection to the server.

A tag with a charged battery can then be used to verify that each base station can provide range measurements. The tag should be moved within the system coverage area so that it is within communication range to each base station at least at some point. UWB Express can be used to check which base stations can provide measurements at any given time, and it can also visualize the measurement result as a circle around each base station in the floorplan.

Once it has been established that all base stations are operational and can provide range measurements, the positioning performance should be verified by moving a tag around coverage area and monitoring positioning results for accuracy and availability. Once that has been successfully done, the system is ready for production use.

## Summary

Exafore Horizon can be deployed in a straightforward manner using the tools and documentation provided in the delivery package, as outlined above. It can be laid out and set up flexibly to cover complex environments where indoor positioning is needed, and the installation can be augmented later with more base stations and tags when desired.