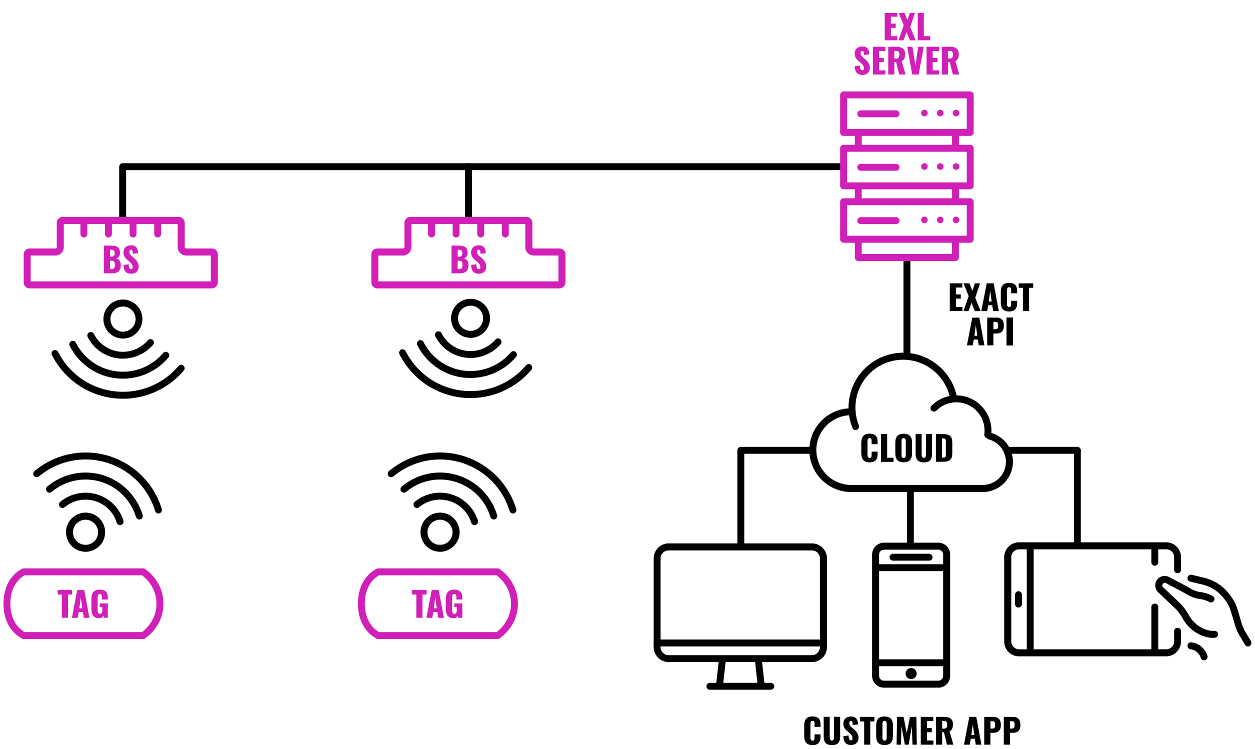


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# Intro to Exafore Horizon Positioning

## 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.

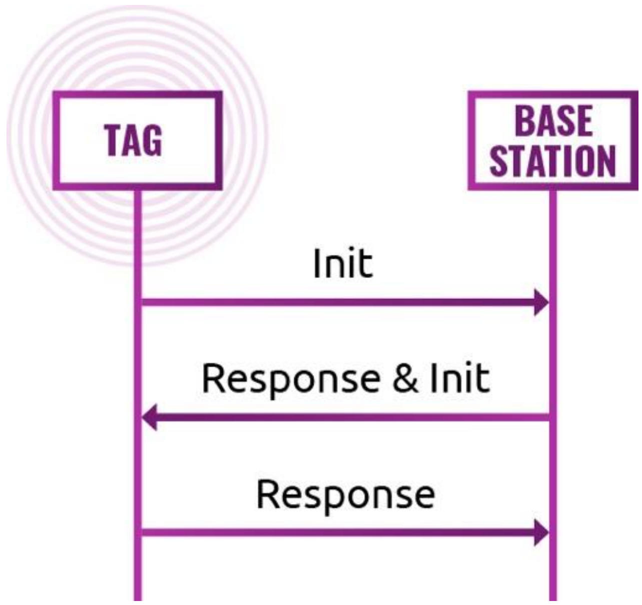
Exafore Horizon is a Real-Time Locating System (RTLS) consisting of stationary devices (base stations) and mobile devices (tags). It uses ultra-wideband (UWB) radio signaling to produce range (distance) measurements between base stations and tags. When configured for highest accuracy, it also uses inertial 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

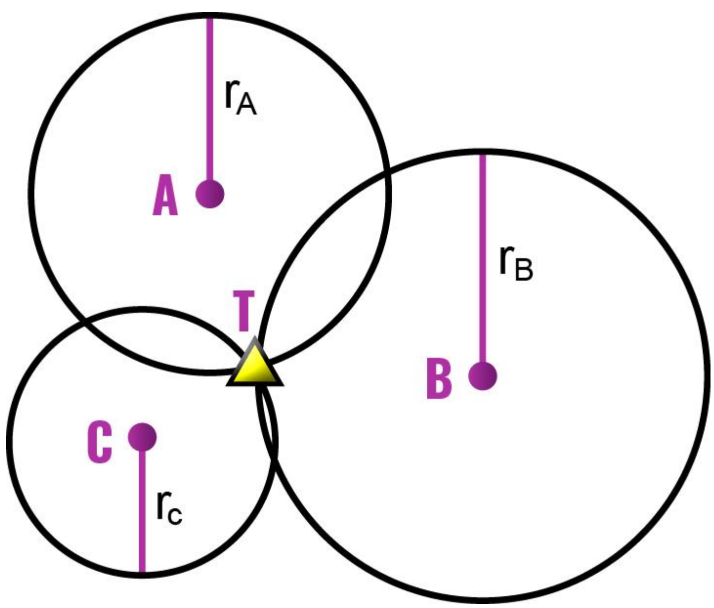
Exafore Horizon measures how long a radio signal takes to travel between two devices and multiplies the measured time-of-flight (ToF) by the speed of the signal (i.e., speed of light) to get the range. Two-way ranging (TWR) is used to produce the ToF and thus the range measurements. In TWR, both devices 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.