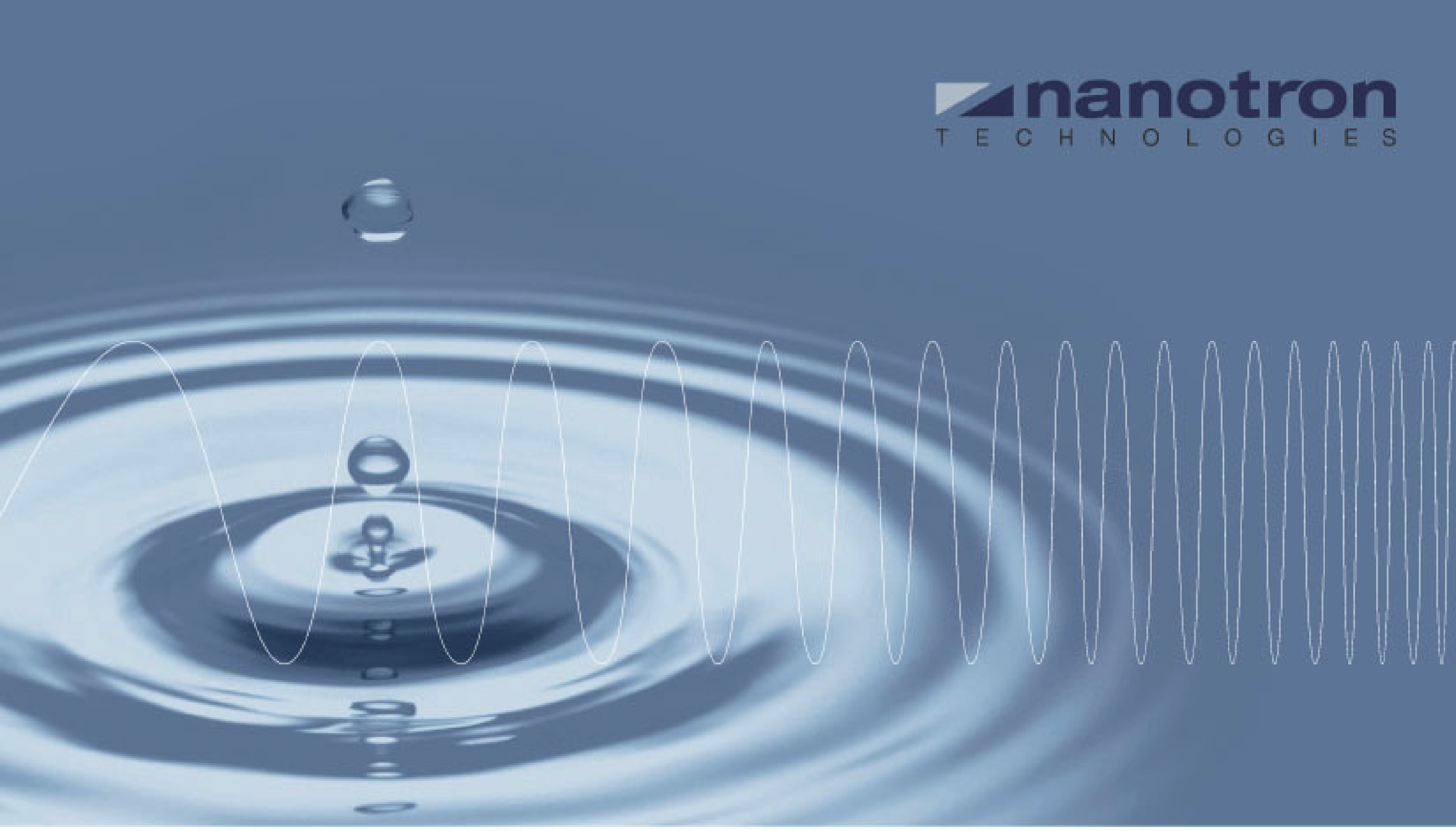

# Real Time Location Systems (RTLS)

A White Paper from
Nanotron Technologies GmbH

Chirp it.

# Table of Contents

***Abstract***

*This white paper discusses the most common methods deployed to build up Real Time Location Systems (RTLS). These include Time of Arrival (ToA), Time Difference of Arrival (TDoA), Received Signal Strength (RSS), Time of Flight (ToF), and Round Trip Time (RTT). A special case of RTT, SDS-TWR, is described which offers a solution to the complexity, high power consumption, and high cost of most RTLS methodologies. This paper concludes with a series of example applications of RTLS.*

# Introduction

The need to locate people and objects as soon as possible has always been an important part of any organization or industry, especially in manufacturing, healthcare, and logistics. With the increasing sophistication of wireless technology, it is now possible to remotely locate objects or people within a predefined time frame. Systems that accomplish this are called Real Time Location Systems (RTLS). They typically use small low-power transmitters called RFID tags attached to assets (or worn by people) as well as sets of readers that map the location of these tags. Systems that map the longitude and attitude of a object are geolocation systems and generally use GPS for location mapping. Systems that map a location relative to a fixed set of coordinates are more accurately called Real Time Location Systems. These are the types of systems that will be discussed in this white paper.

Several technologies are used to build up Real Time Location Systems. Some use dedicated RFID tags and readers while others use existing WLAN networks and add RTLS ability to those networks. This paper discusses the most common methods used by most RTLS systems to locate an object in 2D or 3D space, including Time Difference of Arrival (TDoA) and Received Signal Strength (RSSI). Symmetrical Double Sided Two Way Ranging is then introduced, which is based on the secure Time of Flight method but improves on it by reducing the complexity and cost of such systems.

RTLS applications are extremely interesting due to the wide range of problems that can be solved with these systems. To take two such example, RTLS applications can be used for locating hospital staff in a busy hospital ward or to quickly locate and determine the availability of critical resources in a manufacturing facility. A number of practical applications of RTLS in various key industries are provided which demonstrate the real benefits of improved productivity and enhanced organizational workflow that RTLS brings.

# RTLS Basics: Ranging Sensors and Location Engines

Real Time Location Systems (RTLS) have emerged as an important new development in the increasingly widespread use of wireless technology in industrial, commercial, office, security, and military applications. Yet, significantly, most Real Time Location Systems consist of only two key parts - a set of wireless Ranging Sensors that are used to compute the range between various nodes in the system, and a Location Engine that is used to determine the position of one of the nodes.

## Ranging Sensors

Ranging sensors are a set of devices are used for measurement calculations between two or more nodes. These nodes consist of Tags and Readers. The tags, usually Active RFID Tags, are mobile nodes whose position the system needs to determine. These tags come in a wide range of configurations, from simple Active

RFID tags to more complex RF modules that can include sensors and/or actors for temperature, light, air pressure, motion, and so on. Readers are more complex nodes that usually have a known position, but which are used by the system to locate the position of the tag. Furthermore, these readers can be part of a network that includes a node or set of nodes connected to a wired infrastructure for monitoring the system via a web interface or software interface.

### Location Engines

Location Engines collects the estimated distance measurements provided by the network of tag(s) and readers in the system, depending on the configuration. These measurements are then provided as input data to the Location Engine which runs an algorithm to determines the position of the target tag or set of tags.

## RTLS Methodologies

Several methods for performing ranging calculations are possible, depending on the evaluated signal properties. These include, but not exclusively, the following:

- Angle of Arrival (AoA)
- Time of Arrival (ToA)
- Time Difference of Arrival (TDOA)
- Received Signal Strength (RSS)
- Time of Flight (ToF)
- Symmetrical Double Sided Two Way Ranging (SDS-TWR)

A combination of some of the above methods are also present in practise.

## Angle of Arrival (AoA)

The Angle of Arrival, or AoA, is a method for determining the direction of propagation of an RF signal received from a tag at a reader. Using direction sensitive antennas on a receiver (the reader), the direction to the transmitter (the tag) can be obtained. The Angle of Arrival is determined by measuring the angle between a line that runs from the reader to the tag and a line from the reader with a predefined direction, for instance the north. This method can be illustrated as follows, where $R_1$ is the reader and $T$ denotes the tag.

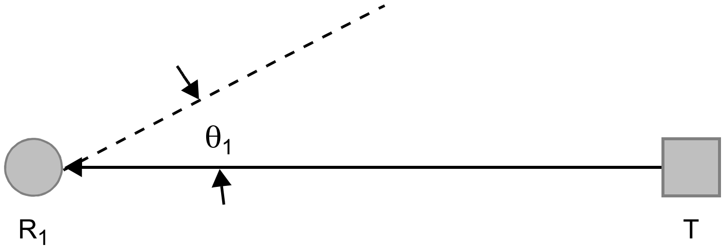

*Figure 1: Angle of Arrival (AoA) method*

### Determining Tag Position

Using the positions of two readers at known locations, the position of a tag transmitted to both readers can be determined using simple triangulation. For each reader, the Angle of Arrival of the signal received from the same tag is calculated and then an algorithm is used by the location engine to determine the position of the tag.

This method can be illustrated as follows, where two readers, $R_1$ and $R_2$, are used and where $T$ denotes the tag whose position is being determined.

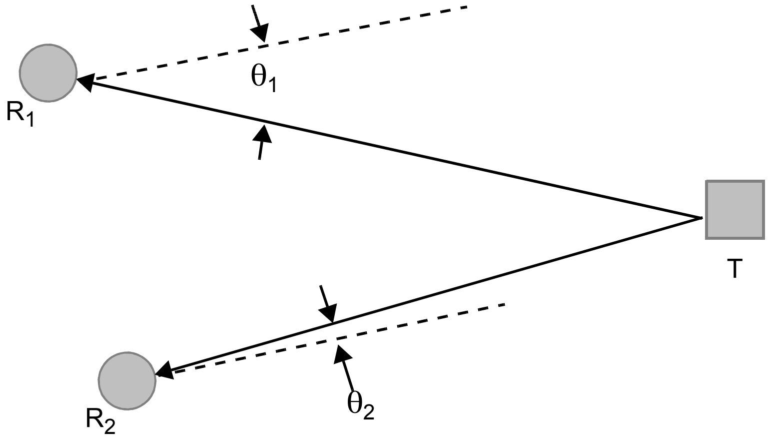

*Figure 2: Determining tag position with AoA*

### Problems Related to Angle of Arrival Method

Taking measurements using this method often requires a complex set of between 4 and 12 antenna arrays situated in a horizontal line at several cell site locations. The accuracy of this method increases with the number of antenna arrays used. In addition to the cost, the resulting angle measurements are rather sensitive against multipath propagation common in building environments. It is, therefore, best suited for direct line of sight measurements between tags and readers. Furthermore, the Angle of Arrival method is also susceptible to security threats [3] as attackers can easily reflect or retransmit from a different location.

## Time of Arrival (TOA)

The Time of Arrival, or ToA, is a method based on the measurement of the propagation delay of the radio signal (as opposed to a data packet) between a transmitter (tag) and one or more receivers (readers). Propagation Delay, which can be calculated as $t_i - t_0$, is the time lag of the departure of a signal from a source station (TX) to a destination station (RX); in other words, it is the amount of time required to for a signal to travel from the transmitter to the receiver, as shown in the following figure.

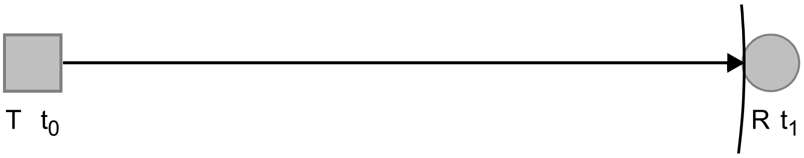

*Figure 3: Time of Arrival (ToA)*

## Determining Tag Position

Multiplying the propagation time $t_i$ - $t_0$ by the propagation speed of the signal, the propagation delay can be converted into a distance between the transmitter (tag) and the receiver (reader).

To determine the tag position in a 2D plane, at least three receivers (readers) are required to take ToA measurements. To determine the tag position in 3D space, at least four readers are required to take ToA measurements. In a 2D plane, the location of a tag can be seen as an intersection of circles, while in 3D space, the location of the tag can be seen as an intersection of spheres.

The Time of Arrival method for 2D range calculations can be illustrated as follows, where the tag is denoted as $T$, while $R_1$, $R_2$, and $R_3$ are the readers. The signal is transmitted at the time moment $t_0$ and received by readers at the time moments $t_1$, $t_2$, and $t_3$ respectively.

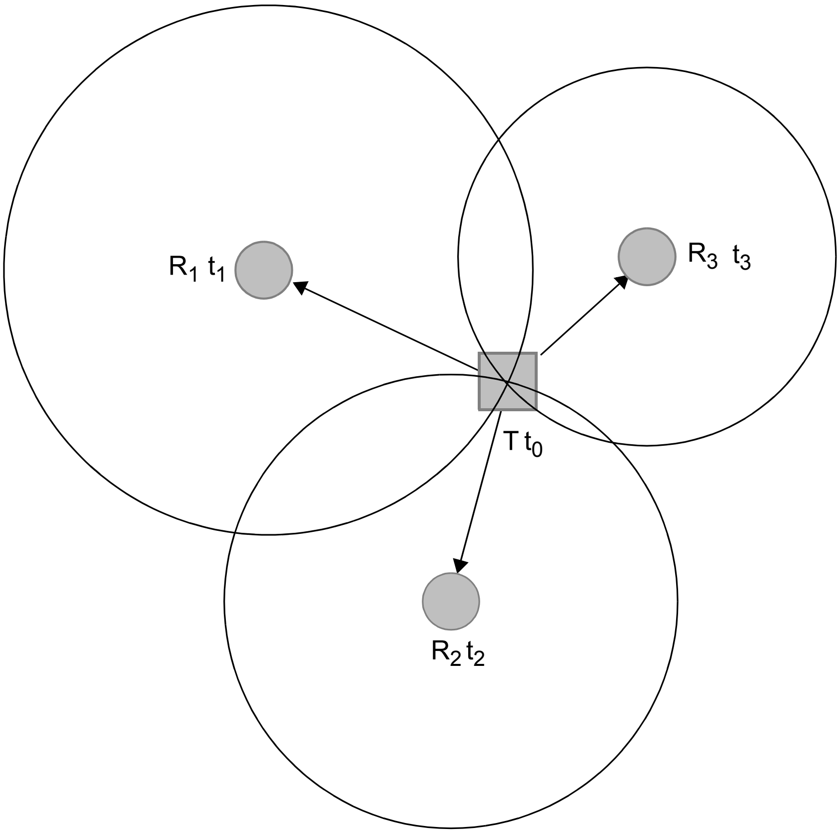

*Figure 4: Determining tag position with ToA*

## Problems Related to Time of Arrival Method

To have any reasonable confidence in the measurement of the elapsed time $t_i$ - $t_0$, the clocks of the tag and the reader must be synchronized. The distance between a tag and a reader can be determined by this method, but it comes with a considerable cost. To achieve precision up to the nanosecond scale, which results in a more precise distance measurement, an elaborate clock synchronization system must be developed which has high costs in terms of development time and effort. Furthermore, at least three readers are required in both 2D plane and 3D space, which also adds to the cost and complexity of the system.

# Time Difference of Arrival (TDOA)

While the ToA method can be seen as an intersection of spheres with center points of known locations, the Time Distance of Arrival (TDoA) method can be seen as the intersection of hyperbolas (hyperboloids in 3D). Systems that use the TDoA method measure the *difference* in transmission times between signals received from each of the transmitters to a tag. TDoA is therefore also know as Three Dimensional Hyperbolic Positioning.

Whereas ToA records the time that a transmitter (tag) sends a signal to the readers, TDoA requires that the receivers (readers) record when the signals were received. Like ToA, TDoA also requires that each signals be transmitted synchronously, either at the same time or with some known delay between signal transmissions.

With TDoA, three or four readers are required at known fixed positions. Each of the readers receive a signal synchronously from the tag and record when the signal was received. This information is forwarded to a location engine which calculates the received signal's time difference between each of the readers. This difference is transformed through an algorithm to provide an estimated position of the tag. Mathematically, the tag is located at the intersection of 3 hyperbolas in a 2D plane, while the tag is located at the intersection of 3 hyperboloids in 3D space. The location of a tag in a 3D plane can be illustrated as follows.

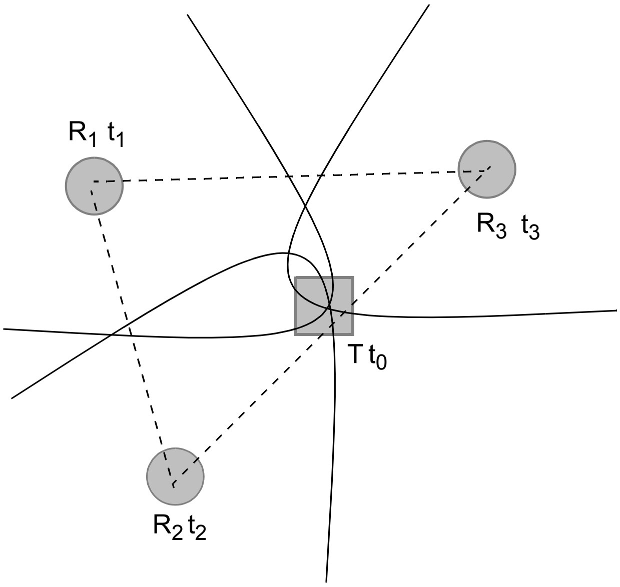

*Figure 5: Determining tag position with TDoA*

### Problems Related to Time Distance of Arrival Method

The problems related to TDoA method are similar to the ToA method. TDoA requires the clocks of each of the readers to be synchronized. The precision of the location engine is correlated to the accuracy of the clocks used in the readers (with more accurate clocks providing more accuracy, but also at a higher cost to the system). In most cases, therefore, the clocks run asynchronously with its related affect on the location precision.

Furthermore, TDoA is also affected by multipath propagation, noise and interferences, which results in inaccurate intersections of the hyperbolas. Direct line of site is preferable, such as in open space or in large open buildings.

## Received Signal Strength Indication (RSSI)

Received Signal Strength Indication method uses several 802.11 WLAN access points (AP) simultaneously to track the location of a device. The signal strength of received signals from at least three APs are used to determine the location of the object or person being tracked. To increase accuracy, more sophisticated RSSI methods use a map called an RF fingerprint that is based on calibrations of the strength of WLAN (Wi-Fi) signals at various points in a predefined area.

In an RSSI system, the distance between a tag (object or person) and a reader (AP) is determined by converting the value of the signal strength at the reader (a receiver) into a distance measurement based on the known signal output power at the tag (transmitter) and on a particular path-loss model. A location server using an algorithm to estimate the location of the tag using the computed distances between the tag and several readers. Although the determination of a particular distance between a tag and a reader differs substantially to the TOA method, the location calculation relies on similar algorithms.

The Received Signal Strength Indication method can be illustrated as follows, where the tag is denoted as $T$ and $R_1$, $R_2$, and $R_3$ are the readers. The signal strength for each reader is denoted as $S_1$, $S_2$, and $S_3$ respectively.

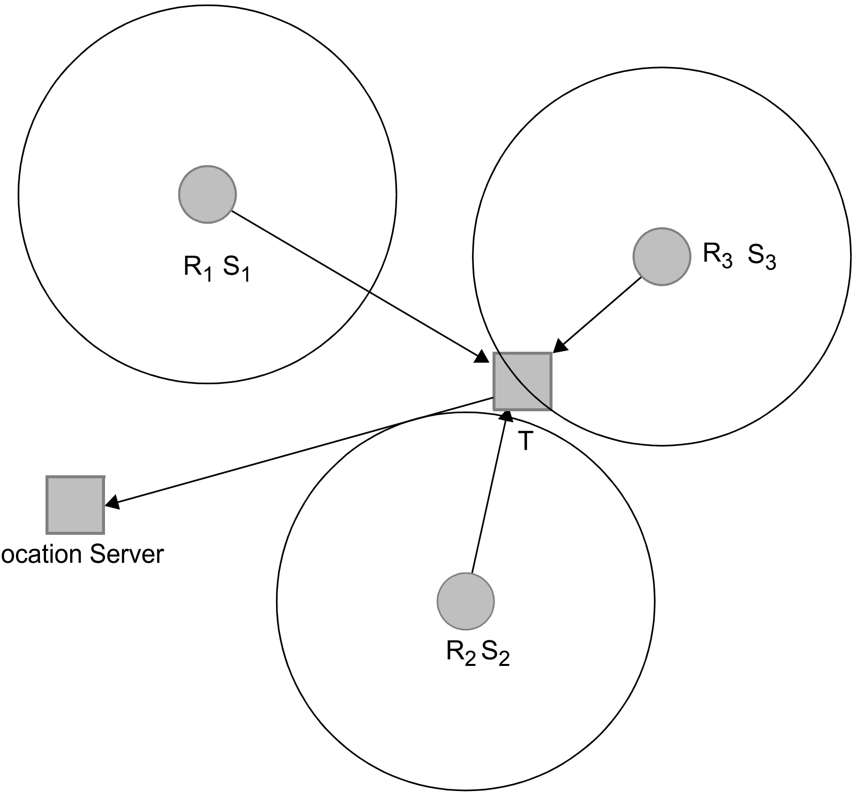

*Figure 6: Determining tag position with RSSI*

**Problems Related To RSSI Method**

To be effective, RSSI requires a dense deployment of Access Points, which adds considerably to the cost of the system. However, the key problem related to RSSI-based systems is that an adequate underlying path-loss model must be found for both non-line-of-sight and non-stationary environments. Consequently, in practise, estimated distances are somewhat unreliable. See [1] for a discussion of a particular implementation of a RSSI technique. Furthermore, systems using RSSI can be disqualified from security applications [3] as attackers can easily alter the strength of received signals by either amplifying or attenuating a signal, or by other methods. Finally, the issue of overloading a WLAN network in mission critical purposes while RTLS burdens the network with additional tasks is yet to be resolved.

## Time of Flight (ToF)

The Time of Flight method uses measured elapsed time for a transmission between a tag and a reader based on the estimated propagation speed of a typical signal through a medium [2]. As this method is based on a time value, clock accuracy becomes significantly more important than in previous methods. Readers *R* with highly accurate clocks are used which transmit signals with known departure time values to tags *T* (or other readers) also with highly accurate clocks. The departure time $t_1$ is compared to the arrival time $t_2$, and using an estimating the propagation speed of the signal *S*, the distance *D* between the devices can be determined with an accuracy within 1 or 2 meters. Using three readers, an algorithm can determine the location of the tag in 3D space. This method can be illustrated as follows.

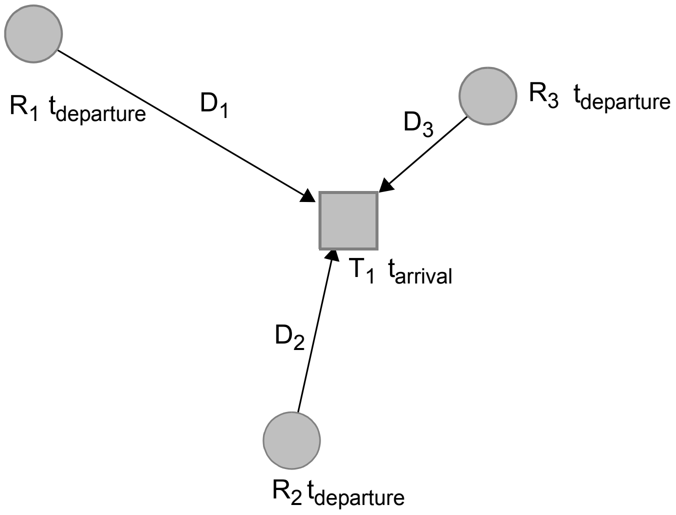

*Figure 7: Determining tag position with ToF*

This method does not add additional hardware overhead to the system as it can use the same hardware that would be used for data communication and signal processing.

### Problems Related to Time of Flight Method

An ideal ToF system requires costly accurate clocks. In reality, the clock offset and clock drift corrupt ranging accuracy. Also, the signal can be affected by interference from other signals, noise, and multipath propagation. Yet, ToF has an advantage over other systems as the cost of additional hardware is minimal. It is also reasonably successful in indoor environments, such as with concrete walls and floors, and it has a relatively high accuracy compared to other methods. Furthermore, ToF is considered to be a secure method for RTLS [3].

## Round Trip Time (RTT)

One method to overcome the inherent difficulties of the ToF method is to render the clock synchronization requirement irrelevant to the measurement. This can be done by sending a ranging signal and waiting for an acknowledgement (a process known as “round tripping”). This can be illustrated as follows.

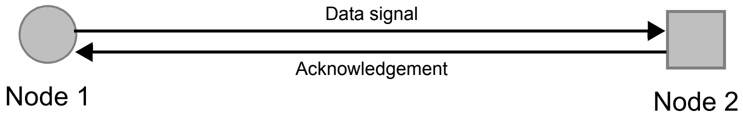

*Figure 8: Round Trip time (RTT)*

Using both a data signal and an acknowledgement mitigates against the problems with clock synchronization. RTT uses highly predictable hardware generated Acknowledgement packets where MAC processing time assumed to be equal on both nodes. Timestamps on the physical layer used, not on application layer.

Nanotron has improved on the Round Trip Time methodology by developing Symmetric Double Sided Two Way Ranging, or SDS-TWR, which is described in the following section.

## Symmetric Double Sided Two Way Ranging (SDS-TWR)

Nanotron Technologies has developed a Time of Flight method that employs a ranging signal sent by a reader and an acknowledgement sent back from the tag to cancel out the requirements for clock synchronization. It builds on that advantage by providing protection against multi-path propagation and noise by its Chirp Spread Spectrum modulation technique. To eliminate the effect of clock drift and offset, ranging measurements are taken by both the Tag and the Reader to provide two measurements that can then be averaged. This results in a reasonably accurate measurement of within a 1 meter, even in the most challenging of environments. This method is called Symmetric Double Sided Two Way Ranging, or SDS-TWR.

### Bandwidth Use and Ranging

Ranging methods such as ToF usually use the detection of the leading edge of the cross-correlation function to estimate the precise moment of signal reception. The wider the signal bandwidth, the narrower the correlation peaks. Making the correlation peaks as narrow as possible increases the time resolution of the method, which coincides with increasing precision of location. This is reason that Ultra-WideBand (UWB) technology is commonly believed to be the technology of choice for ranging systems [4]. However, there are two obstacles for deploying UWB technology. First, UWB is far from being licensed worldwide, even though the first license to use UWB communication for indoor operations in the United States was granted by the FCC in 2002 [5]. Second, UWB is still a very new technology that has not yet achieved wide acceptance outside of research labs.

The typical expectation of a 500 MHz UWB radio is sufficient to provide a reasonable ranging precision, which is much less bandwidth than conventional thinking. One such alternative is Nanotron's Chirp Spread Spectrum (CSS) technology, which uses only 80 MHz of bandwidth [5]. Furthermore, CSS is certified for operation in the EU, the United States, and Japan.

## Signal Detection

The mechanism for signal detection in SDS-TWR combines a time resolution of a correlation function of a few nanoseconds with averaging over correlation measurements while receiving a packet. The achieved distance resolution is close to that obtained by the Time of Arrival (ToA) method based on UWB.

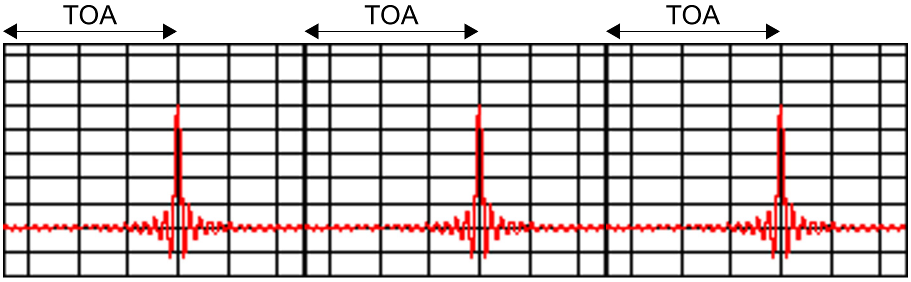

*Figure 9: Correlation function and averaging*

## Avoiding Clock Synchronization by Two Way Ranging (TWR)

As SDS-TWR is similar to the ToF method, it avoids the need to synchronize the clocks of the nodes used in ranging measurements. During the SDS-TWR measurements, a signal propagates from one node to a second node AND back to the original node (Round Tripping - or Two Way Ranging). The time a signal propagates from Node 1 (for example a Reader) to Node 2 (for example a Tag) is measured by Node 2. This can be illustrated as follows.

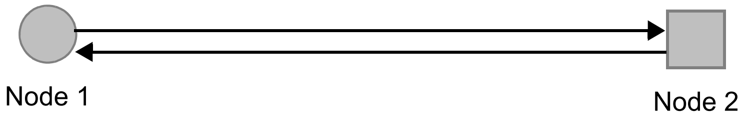

*Figure 10: Measuring distance with Two Way Ranging (TWR)*

Time measurements begin in Node 2 only when it receives a packet from Node 1 and then stops its time measurement when it sends a packet back to Node 1. In this case, Node 2 does not need to synchronize its clock with Node 1.

When Node 1 receives the acknowledgment from Node 2, the accumulated time values in the received packet is used to calculate the distance between the nodes. The difference between the time measured by node 1 minus the time measured by node 2 is twice the time of signal propagation through the air.

## Limitations of Clock Generating Oscillators

Although the internodal synchronization is no longer required, an another problem appears in the TWR scheme - the problem of the quality of a clock generating oscillator. This is because the round trip time is a rather long interval compared with the time required for a signal to propagate through the air. The time a transceiver uses to transmit and receive packets requires hundreds of microseconds rather than the tens of nanoseconds which is required to propagate a signal through air. An acceptable error of the round trip measurement due to oscillator drift should not exceed one nanosecond, but this would require a crystal roughly 10 ppm tolerance or better. However, that is beyond the quality of the crystals typically deployed in most Real Time Location Systems.

## Zeroing Out Errors - Symmetric Double-Sided (SDS)

A simple way to avoid the drawback of clock drift is to perform the ranging measurement twice and symmetrical. The first ranging measurement is calculated based on a round trip from node 1 to node 2 and back to node 1. The second measurement is calculated based on a round trip from node 2 to node 1 and back to node 2. This double-sided ranging measurement zeroes out the errors of the first order due to the clock drift. SDS can be illustrated as follows.

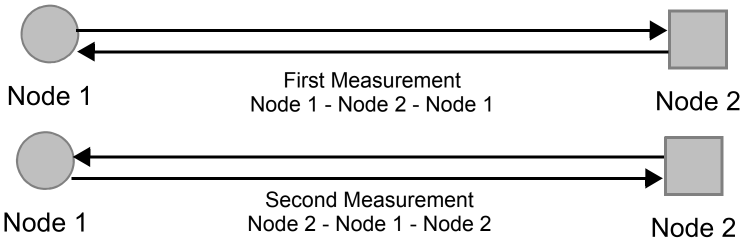

*Figure 11: Measuring distance with SDS-TWR*

The SDS-TWR approach provides the required time resolution of one ns using a standard quality crystal of 40 ppm (for more detailed consideration see [6], Annex D1). Although several packets need to be exchanged rather than only one packet, as would be required by synchronized ToA, the effect of clock drift is eliminated and the clocks do not need to be synchronized.

SDS-TWR can be illustrated as follows.

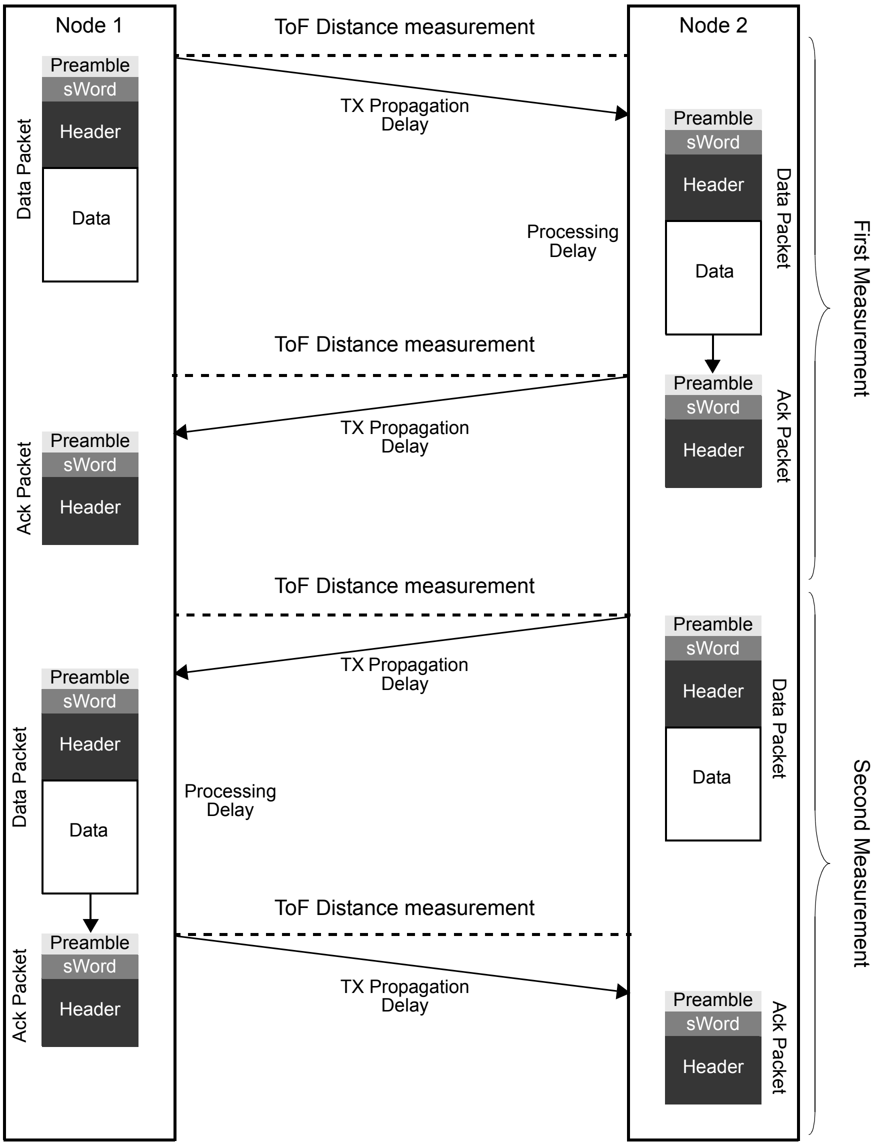

*Figure 12: Symmetric Double Sided Two Way Ranging*

# Example Applications of RTLS

The ability to track an electronic tag worn by a person or attached to some type of object provides a significant improvement over previous manual methods of tracking, which was usually someone physically searching for the person or object. This leads to increased efficiency in many types of organizations and industries, thus becoming an enabler for entirely new applications. Several application examples are provided in the following sections.

## Industrial/Logistics Yard Equipment Management

In an industrial or logistics yard, a constant interchange between manufacturing, distribution and transportation takes place. A steady flow of equipment and assets move continuously into and out of the yard area. The main task of yard management is to provide current information about the status of the yard - what equipment is available, what is the status of the equipment, and where is this equipment located. Usually, data input into the yard management software is done manually using devices such as hand scanners and manually recording every movement of the equipment. Unfortunately, manual data input is prone to errors and is often out of date. To mitigate the implications of such unreliable information, a buffer stock of yard equipment is required. This excess expenditure leads to higher costs of running and maintaining the yard. A deployment of RTLS, on the other hand, eliminates the need for manually scanning bar codes attached to objects, as equipment and assets automatically send their status and position data directly via a wireless link to the yard management software. Consequently, at any given moment a complete inventory and status of all yard equipment is available, even when the yard is closed for holidays or other non-operational times.

## HealthCare Services - Patient, Healthcare Provider, Asset Tracking

The deployment of RTLS in healthcare environments, such as the tracking of patients, staff, and assets in a hospital, provides many benefits to both patients and healthcare providers. Take, for instance, the fact that patients are not always confined to the ward, but are often encouraged to wander throughout the ward, visit the cafeterias, or even take short walks outdoors on the hospital grounds. However, for some types of patients, vital statistics may be continuously monitored and these patients, would of course, be confined to their hospital beds. An ability to remotely monitor patients who are encouraged to take walks for their healing can be immensely beneficial to both the patients, who can now freely roam, or for the healthcare providers, who can be alerted when the patient needs attention and quickly locate that patient within the hospital.

Furthermore, a healthcare provider, such as a doctor or nurse, could be quickly located within the hospital or clinic to help estimate how long the attending physician will take to arrive at the ward. To take a longer term view, the location and movements of physicians throughout a ward or clinic could be used to better understand their workload with a view to better organize the ward or improve staffing levels.

Finally, typical hospitals have limited numbers of very expensive mobile medical equipment. When an attending physician or nurse requires a specific piece of equipment, an RTLS system can immediately locate this item. Tracking of the location of these assets can reveal when and where a particular piece of equipment is often used, and where pooling equipment may reduce the need for additional equipment. Sadly, hospital equipment is subject to theft and abuse like other high tech equipment. A tracking system can be used to recover these devices, and to alert security when it is taken off the hospital premises.

## Emergency Services Trainee Tracking

Fire departments, and other emergency services personnel have extensive training programs that provide safe, but realistic environments in which recruits learn how to deal with scenarios that they should expect once they begin working in the field. Accidents do occur during these training exercises. To mitigate against such incidents, RTLS can be employed to aid in the tracking and locating of recruits and trainees to ensure that explosions or fire simulators are not accidentally set off in the vicinity of these personnel.

An additional benefit of RTLS in the training of emergency services personnel is to record the path of motion of these trainees, which can be used to evaluate their performance during the training exercises. Were they located in the correct position to effectively fight the fire with the equipment, did they move too slowly or too quickly, or did they find themselves in a position where they are likely to be trapped with their life potentially threatened. The range of possibilities for the use of RTLS in the training of emergency personnel is only limited by the imagination of the training staff.

## Security and Personnel/Visitor Identification

Visitor identification tags have long been used to provide security for office and industrial facilities. Bar codes were added to allow computers to track when and where a particular tag has been scanned by a scanner, typically by an entrance gate or door reading device. The effectiveness of these tags is limited by the depth of the network of readers. Once the tag is within a secure area, no more status information is available, until the tag is scanned again.

The deployment of RTLS to employee or visitor identification tags adds the ability to track and locate personnel and visitors within a facility. Through the use of movement detectors distributed throughout the facility and the ID tags enhanced with RTLS worn by visitor or employees, areas that are restricted can be better policed. Furthermore, at any given time, security officers can identify who is within each section of a facility and track their movements to ensure compliance with security regulations are maintained at all times.

## Critical Asset or Dangerous Asset Tracking

Similar to identification tags worn by visitor or employees, ID tags enhanced with RTLS can be fixed to critical assets in a facility. Movement detectors distributed throughout the facility as well as RTLS-enabled ID tags attached to these asset provide security officers the ability to track their movement and locate them at any time. When an unauthorized attempt to move the asset within a facility occurs, or even when the asset is taken from the facility, the device can alert security to take corrective actions to ensure compliance with security regulations.

Furthermore, the storage of dangerous goods, such as explosives or weapons can be made more secure. In this case, however, these goods can be additionally protected to ensure that only authorized personnel can be permitted to be within range of these assets. An alarm or other type of signal could be provided when tags on the critical asset become too close to the tags worn by the unauthorized personnel.

### Industry Conference/Amusement Part Attendee Tracking

A typical Industry trade show or conference may have hundreds, or perhaps even thousands of attendees, exhibitors, cleaning personnel, security staff, administrators, and other support staff. With modern conference halls often as spacious as an aircraft hanger and larger than many football fields, locating a particular person in such an environment is almost impossible. The only current option is to call the person's cell phone, if they have one, or broadcast a message on the Public Announcement system and hope they hear it and make contact somehow. An RTLS-enhanced ID tag enables the conference to provide an additional service by allowing companies or other attendees to locate and contact an attendee while they roam throughout the conference facility.

Similar to trade shows, amusement parks and county fairs can also have hundreds or even thousands of attendees. With each visitor provided with an ID tag enhanced with RTLS, should someone, such as a child, become lost or separated from their group, booths throughout the park or fair could be provided which can be a place of refuge for lost people, as well as a place for visitors to go to locate their lost group member. Security staff could then use a Location application running on a PC to locate the ID tag within the park or fair and proceed to locate and reunite the individual with their group.

## Summary

Many methods have been developed, and are being developed, to build up Real Time Location Systems. This enthusiasm is based on an exploding market for such systems, as they increase productivity, reduce costs and ensure security, amongst much else. We have only covered briefly the main contenders for RTLS, which are roughly divided into methods that employ 802.11 WLAN, such as RSS, and others that use dedicated hardware with AoA, ToA, TDoA, and ToF. Many more methods and variations of these methods are being developed, but the key problems with many of these methods are location inaccuracies caused by multipath interferences, clock synchronization, and clock drift weaknesses. Also, some methods also require costly antenna arrays, have inadequacies locating objects either indoors or outdoors, and most are at risk of security attacks caused by amplifying or attenuating signals.

Many of these difficulties have been addressed through the use of round tripping and a symmetrical doubling-up of the measurements with SDS-TWR. Because of the energy efficiency of Chirp Spread Spectrum, the required reader infrastructure does not have to be wired. Rather, a wireless sensor network can be used with a connection to ethernet for web-based monitoring and control of the system. Furthermore, deployed hardware can be kept as simple as possible because synchronization is not required amongst the nodes in the system.

One additional benefit of using SDS-TWR is that the same technology can be used for both range sensing and the RF communication, similar to WiFi based RTLS, but without necessarily overloading the system in mission critical deployments. For instance, the same sensors can provide both status information (such as temperature, light, pressurized, powered on, and so on) as well as location information. And of course, equipment based on CSS has been already licensed to operate in the license free 2.44 GHz ISM band, and certified for us in both Europe and North America.

First samples of silicon, nanoLOC, that support SDS-TWR ranging have been available since September 2006 (see [8]).

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Nanotron Technologies GmbH develops world-class wireless products for demanding applications based on its patented Chirp Spread Spectrum – an innovation that guarantees high robustness, optimal use of the available bandwidth, and low energy consumption. Since the beginning of 2005, Nanotron's Chirp technology has been a part of the IEEE 802.15.4a draft standard for wireless PANs which require extremely robust communication and low power consumption.

ICs and RF modules include the nanoNET TRX, the nanoLOC TRX, and ready-to-use or custom wireless solutions. These include, but are not limited to, industrial monitoring and control applications, medical applications (Active RFID), security applications, and Real Time Location Systems (RTLS). nanoNET is certified in Europe, United States, and Japan and supplied to customers worldwide.

Headquartered in Berlin, Germany, Nanotron Technologies GmbH was founded in 1991 and is an active member of IEEE, the ZigBee alliance, and ISA-SP100.

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