TTK1000 RTLS
System Installation Guide

A guide installing and using the TTK1000 scalable TDOA RTLS software

Version 1.0

This document is subject to change without notice

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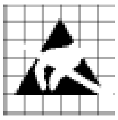


Caution! ESD sensitive device.
Precaution should be used when handling the device in order to prevent permanent damage

1 INTRODUCTION

1.1 GENERAL

This RTLS system installation guide document covers the installation, operation and use of an RTLS system based on the TTK1000 RTLS software.

1.2 THE TTK1000 SOFTWARE AND THE TTK1000 EVALUATION KIT

Decawave's TTK1000 is a software product providing Real Time Location System (RTLS) functionality based on the Time Difference of Arrival (**TDOA**) location method. The TTK1000 includes software source code for: the mobile Tag devices that are located by the system, the fixed Anchor nodes that are used to locate the tags, the Central Location Engine (CLE) Microsoft Windows PC application which includes the location solver that estimates of the tags' positions, and configuration/control and display client Microsoft Windows PC applications, along with a set of supporting documentation.

Customers taking TTK1000 are expected to develop the software further, to customise it to their application, targeting it to their own hardware designs, and building a complete end user system upon it.

The REK1101 HW evaluation platform consists of four anchors and two tags. These anchors and tags are the hardware that Decawave employs as the development platform for the TTK1000 software, and in validating our software releases. Decawave provides the TTK1000 RTLS evaluation kit, (on loan) to potential TTK1000 customers for evaluation of TDOA RTLS functionality before licencing the TTK1000 source code, we additionally provide the REK1101 to paying TTK1000 customers to act as a delivery platform to initially build and test the TTK1000 software source code delivery.

The TTK1000 Real Time Location System (RTLS) platform thus allows customers to assess and test the benefits and performance of TDOA RTLS applications based on Decawave's DW1000 IEEE 802.15.4 Ultra-wideband (UWB) compliant wireless transceiver IC, before licencing the TTK1000 software. The TTK1000 comes with a user manual about its setup and use. Customers licensing the TTK1000 software get to keep the TTK1000 as a platform for checking and validating the TTK1000 delivery.

The TTK1000 software operation is different to that of the TTK1000 in that the TTK1000 (with and its CLE) is limited to four anchors and two tags, while the TTK1000 is scalable to handle many anchors and tags. This installation guide document covers the operation of the TTK1000 RTLS software. We assume this is based on the Anchor and Tag hardware from the TTK1000 that are reprogrammed with the TTK1000 software, but most of the discussion here would also apply to customer's own anchor and tag hardware assuming that the TTK1000 anchor and tag firmware has been ported to them.

In this document the term "anchor" shall mean the anchor hardware from TTK1000 (or customer) with the TTK1000 anchor software correctly installed, and, the word "tag" shall mean the tag hardware from TTK1000 (or customer) with the TTK1000 tag software correctly installed. "CLE", "Controller" and "Displayer" refer to the TTK1000 PC applications.

1.3 DESCRIPTION OF THE TTK1000 BASED RTLS

The TTK1000 based RTLS system consists of fixed anchor nodes, mobile tags, a Central Location Engine (CLE) application running on the PC, and the software GUI control client application (Controller) used to configure and evaluate system performance. The system locates the mobile tags. These will be displayed on the Control GUI application screen. Additional multiple (up to 50) display client GUI applications (Displayer) can connect to access and display the estimated Tag locations too.

The anchors only require power and backhaul Ethernet connections.

The TTK1000 RTLS is based on a Time Difference of Arrival (TDOA) scheme.

In TDOA, tags send periodic blink messages that are received at the anchor nodes. T anchors report blink reception time-of-arrival (TOA) timestamps to the CLE. The CLE multilaterates to estimate the tag location.

For successful TDOA multilateration all tag timestamps need to have a common concept of time, which can be achieved via wired clock distribution. However, the TTK1000 includes Decawave's patent pending wireless synchronisation scheme, which employs UWB messages transmitted between anchors to track the anchors' relative clock drift and convert the tag blink timestamp values into a common time-base for TDOA multilateration. The clock tracking and blink timestamp correction is done in the CLE along with the TDOA multilateration.

Figure 1 shows the general system architecture of an installation of TTK1000 based RTLS.

Tag sends blink messages that are received at the anchor nodes. Each anchor node time-stamps these blink messages as they arrive at the anchor with their time of arrival (TOA) and reports these timestamps to the Central Location Engine (CLE) running on the PC.

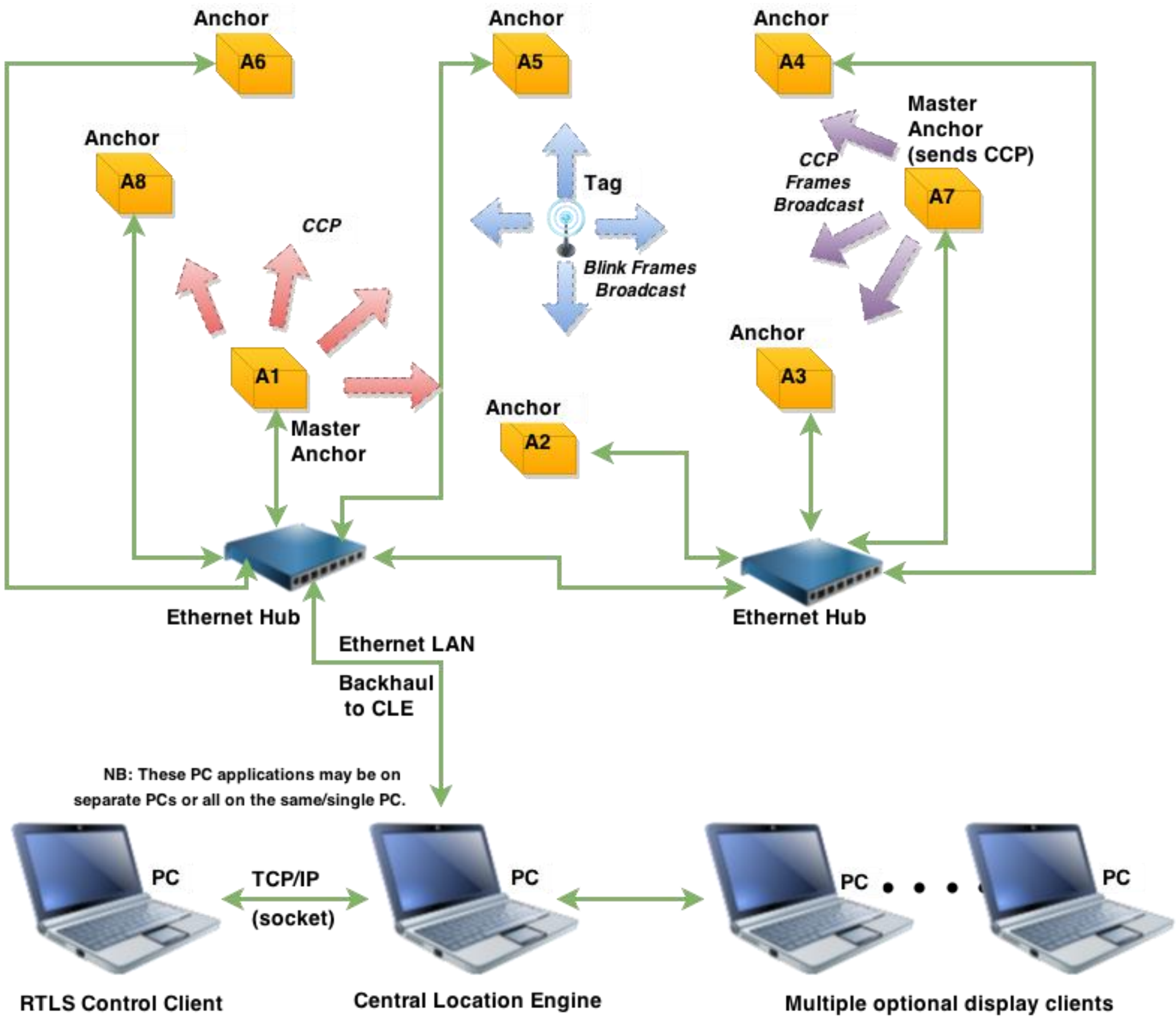


Figure 1: Overall TTK1000 System Architecture

One or more designated "Master" anchors transmit UWB clock calibration packets (CCP) that are used to track the clock differences between the anchors. The clock synchronization adjustments to blink message TOA timestamps are made in the CLE prior to *multilaterating* to solve the TDOA data and yield the estimated location of the tag. Communication between anchors and the CLE (running on Microsoft Windows PC) is achieved via wired Ethernet LAN connection.

RTLS Control client application software (running on Microsoft Windows PC) is used to configure the system operation and display resulting tag locations graphically. All the results are also can be logged to a disk for later post processing.

1.4 LAYOUT OF THIS INSTALLATION GUIDE DOCUMENT

This document is divided into a number of sections intended to guide you through the installation, setup, use and evaluation of the TTK1000. We recommend you follow them in the order in which they appear.

- Section 1 gives an overview of the TTK1000 TDOA RTLS application.
- Section 2 describes the various elements of a TTK1000 system
- Section 3 describes how to physically set up and connect the system
- Section 4 briefly describes the overall structure of the system software
- Section 5 covers the installation of the Control Client (controller) software
- Section 6 deals with the set up and configuration of the system using the Control Client
- Section 7 suggests guidelines and methods for evaluating the performance of the system
- Section 8 Appendix A: provides detailed information on the anchor unit
- Section 9 Appendix B: provides detailed information on the tag unit.
- Section 10 Appendix C: provides a glossary of terms used in this manual
- Section 11 Appendix D: provides further information on the PC based CLE
- Section 12 Appendix E: provides further information on installation of a DHCP server
- Section 13 Appendix F: is the bibliography

For additional assistance please contact Decawave.

2 THE TTK1000 SYSTEM COMPONENTS DESCRIPTION

2.1 OVERVIEW

The TTK1000 based system is comprised of:

- At least four (TTK1000) DIN-rail mounting anchor units with antennas
- At least one (TTK1000) tag units
- Ethernet cables
- Ethernet hub
- A windows PC to run the CLE and control client applications.

2.2 THE ANCHOR UNIT

The (REK1101) anchor unit is shown in Figure 2, on the left is the (top) antenna end, and (bottom) Ethernet end is on the right; with USB connector.

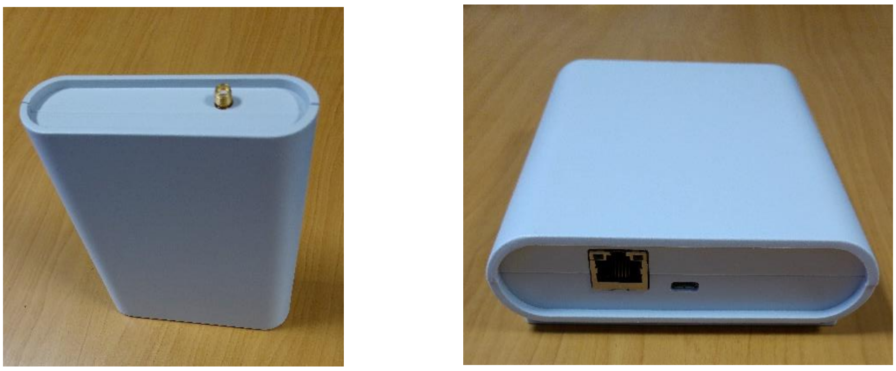


Figure 2: Anchor unit Antenna top and bottom view

2.3 THE TAG UNIT

The (TTK1000) tag is a fully integrated UWB TDOA tag. This is pictured in Figure 3. The tag has an on-board antenna, rechargeable battery and all necessary circuitry to operate independently as a TDOA tag. The on-board battery may be recharged via the Micro USB connector.

The tag incorporates a LED (on the bottom) to indicate the device status (Charging, Blinking). The tag also has a recessed on/off slide switch.

Figure 3: The Tag Unit

2.4 Other Items

- Ethernet LAN hub and cables: Each Anchor unit needs to be connected to the PC running the CLE. This backhaul connectivity is achieved using Ethernet LAN which means a multiport Ethernet Hub and Ethernet cables are needed.
- Power for anchors: the anchors need to be powered. This can be achieved using power over Ethernet (PoE) if the Ethernet Hub is capable of providing PoE and sufficient power drive capability for all the anchors in the system. Alternatively, power may be supplied to the anchors via the USB connection.
- The Central Location Engine (CLE) PC application.
- Controller PC application for configuration of the system.
- A Displayer application could be used in order to provide a display-only demonstration functionality without configuration ability.

3 SETTING UP AND CONNECTING THE SYSTEM

3.1 INTRODUCTION

There are a number of steps that need to be followed to make the system operational. These steps are outlined below, and described in detail in individual sub-sections.

a) Copy the software package onto your Windows PC. The Control Client (Controller), *RTLSController.exe*, application and the Central Location Engine (CLE), *LE.exe,* application are in the .\PC folder.

b) Physically install the anchor nodes – see section 3.3.3

c) Connect power to the anchor nodes if you are not using the Power over Ethernet option – see section 3.3.4

d) Then connect the anchor nodes to your PC using Ethernet cables and an Ethernet hub.

e) Power up the anchor nodes.

f) Launch the CLE on the PC. It should show any connected/discovered anchors in its console window – see Figure 13.

g) If the anchors are installed on a network without a DHCP server a DHCP server needs to be installed on the PC. See section 12 for this.

h) Launch the Control Client.

i) Configure parameters in the Control Client necessary to run the system (anchor x, y, z positions, etc.), see section 6 for details.

j) Start the system by pushing “Start RTLS” button in Control Client – the master anchor node begins transmitting clock sync packets to the slave anchor nodes and they report back to the CLE, see section 6 for details.

k) Switch on the tag units – you should see the tag locations appear on the tag location panel of the Control Client PC application.

l) You can then experiment and evaluate the location accuracy performance as per section 7.

3.2 GENERAL SETUP OVERVIEW

The TTK1000 supports one basic configuration. This configuration uses Ethernet as the means of communication between the anchor nodes and the PC. Each anchor unit is connected via a standard 100BaseT Ethernet interface to a hub. The PC on which the control client is running is also connected to the hub.

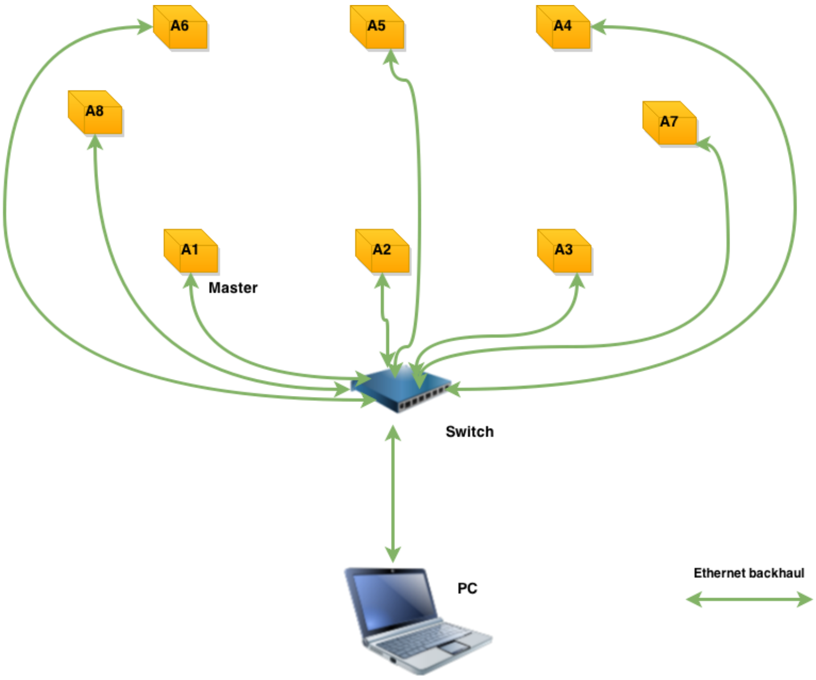


Figure 4: General setup – Ethernet backhaul

3.3 Anchor Unit Installation

3.3.1 Overview

To install the anchor units, proceed as follows:

a) Connect the external antenna. An *SMA torque wrench* is recommended to set the correct tightness to ensure good connection without damage.
b) Physically mount the anchor units in the desired locations. Note that the supplied antenna is not designed for mounting on/near surfaces so please keep the anchor >15 cm away from walls etc.
c) Connect power to the anchor unit (using USB port or PoE).
d) Connect the Ethernet LAN (backhaul) connection to the anchor unit

3.3.2 External antenna connection

The supplied antenna should be connected to the SMA connector.

Figure 5: UWB antenna connection

When the UWB antenna is connected, the unit should look as follows:

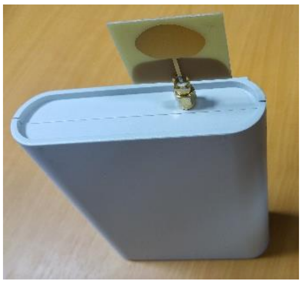


Figure 6: anchor unit with UWB antenna installed

While this antenna has a pretty good omnidirectional performance by design, we generally recommend for best/consistent results that the flat face of the antenna is facing the main area of interest for the RTLS, e.g. towards the centre of the room/area being covered.

It is possible to experiment with other commercially available UWB antennas to assess their relative performance but you should use the antenna supplied for initial installation and anchor evaluation. For references and antenna application advice, please contact Decawave.

3.3.3 Mounting and positioning of the anchor units

3.3.3.1 Mounting

The anchor units are intended to be mounted using what is known as "Top Hat" DIN rail. The plastic mouldings screwed to each end of the anchor units form a carrier at the rear of the unit which mates with the flange of standard 35 mm "Top Hat" DIN rail shown below.

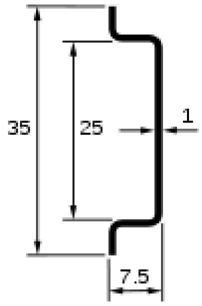
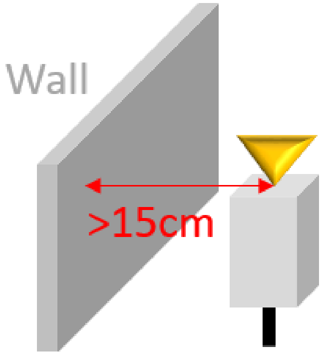


Figure 7: "Top Hat" DIN rail dimensions as supplied with kit

Slide the anchor unit onto the DIN rail segment taking care to position the UWB connector at the "top" and the USB and ETHERNET connectors at the "bottom".

The DIN rail may now be fixed to whatever surface you wish using whatever fixing method is most appropriate. For ease and flexibility of mounting a temporary mounting solution such as "Velcro" should be considered thereby allowing the anchor units to be moved to different locations as part of your evaluation process.

Note: If using the "*man*" antennas supplied with the anchors, note that these are free-space antennas, for optimum performance the antennas on the anchor units need to be at least 15 cm away from any wall or radio reflective surface. Please consult Decawave for advice on other antennas.



3.3.3.2 Positioning the anchor nodes

Note: Before mounting the anchors you should note the address of each one on the label attached to each unit. You will need this information later when configuring the system via the Control Client.

The positioning of the anchor units is crucial to the best performance of the system. There are a number of key issues to consider here:

a) *Distances between anchors:*

   One or more of the anchor units can be designated to act as "master" anchor nodes (while the others are "slave" anchors). The master anchors periodically transmit (UWB) clock calibration packets which are received by the slave anchors. Each slave anchor **must** be in good UWB wireless communications range of at least one master anchor. In the Figure 8 below, the master is at one corner.

   For a square or rectangular area, the longest communications range involved is across the diagonal. If a master is chosen at one corner, it has be ensured that it and the slave anchor diagonally opposed can communicate well (more on this later when we come to configure the system via the Control Client).

   The anchors are configured by default to their highest data rate (6.8 Mbps). This imposes a limit on the communications range of the unit to approximately 45 m on channel 5 (and 75 m on channel 2) in LOS – you should **<u>not</u>** position the anchor units at the absolute limit of this range so that there is some margin to allow for NLOS situations.

   In general, a regular arrangement of the anchors (i.e. in a square or rectangular array covering the area in which you wish to track the moving tags) is preferable and will give better performance than an irregular or ad hoc arrangement.

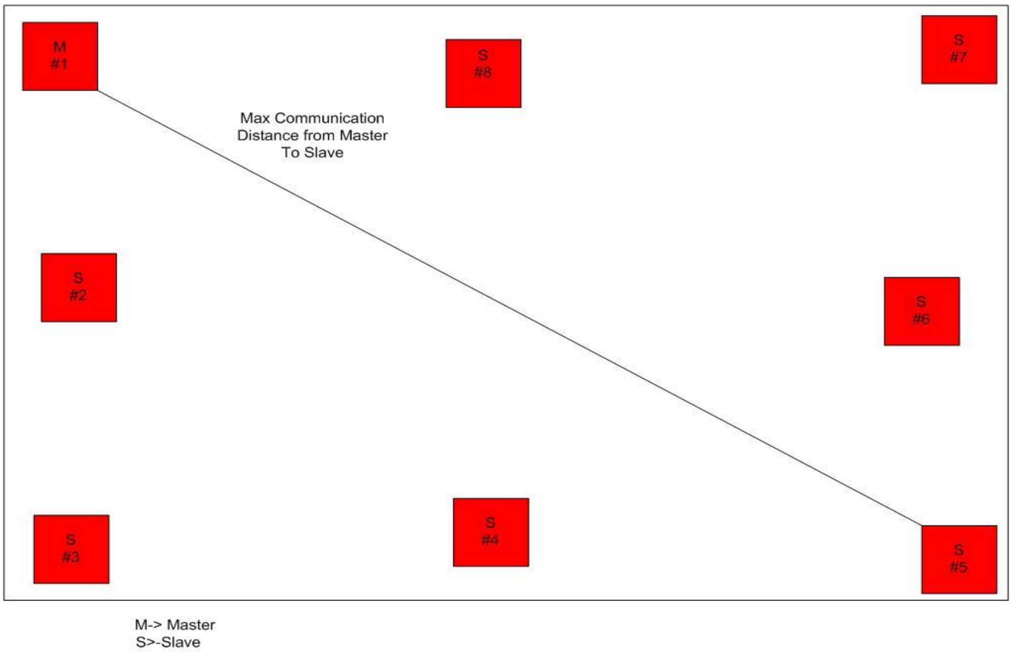


Figure 8: General arrangement of anchor nodes

b) *Measuring anchor coordinates:*
For the purposes of location, a coordinate framework is needed. The RTLS uses metric system (meters) for all its distance and coordinate specifications. Some point in space needs to be designated as the "Origin" with co-ordinates of (0, 0, 0). The positions of all the anchors, in x, y, z co-ordinates need to be determined relative to the origin. The positions of the mobile tag units, determined by the CLE relative to this origin and reported as x, y co-ordinates with 2D solver, or x, y, z co-ordinates with 3D solver. In TTK1000 RTLS system, 2D solver is configured by default.

As you install the anchor nodes you should measure their position in the X, Y and Z dimensions as accurately as you can. It is important to remember that an error in an anchor position translates directly into an error in the reported location of a mobile tag. The system must know accurately the positions of the anchor nodes because it determines the locations of the mobile tags relative to those anchor nodes. See section 6.6.4 for more details on this.

c) *X and Y dimensions separation:*
To give the best location accuracy, the anchor nodes should be positioned with the greatest possible physical separation in output dimensions. In general, small geometry systems are not as accurate as larger geometry systems. For both 2D and 3D solver, we recommend spacing the anchor nodes as far apart as possible in the x and y dimensions bearing in mind the restrictions of a) above.

d) *Z dimension separation:*
In the z dimension, anchors should be positioned in the **SAME** vertical height to give the best accuracy when using **2D solver**. To obtain the clear line of sight, we recommend that all anchors should be positioned high enough to avoid disturbance given by any possible traffic.

In 3D solver, the same spacing requirement of c) above also applies in the z dimension. The anchor nodes should **NOT** all be positioned at the same height (e.g. with four anchors in a rectangle one diagonal should be low and the other diagonal high). For larger areas we recommend a layout with alternating higher and lower anchors as shown in Figure 9. In fact, the larger the z separation you can achieve between highest and lowest anchors the better will be the location result for 3D solver. As in 2D solver, to get the good line of sight, we suggest that the lower anchors should be placed above the height of any traffic.

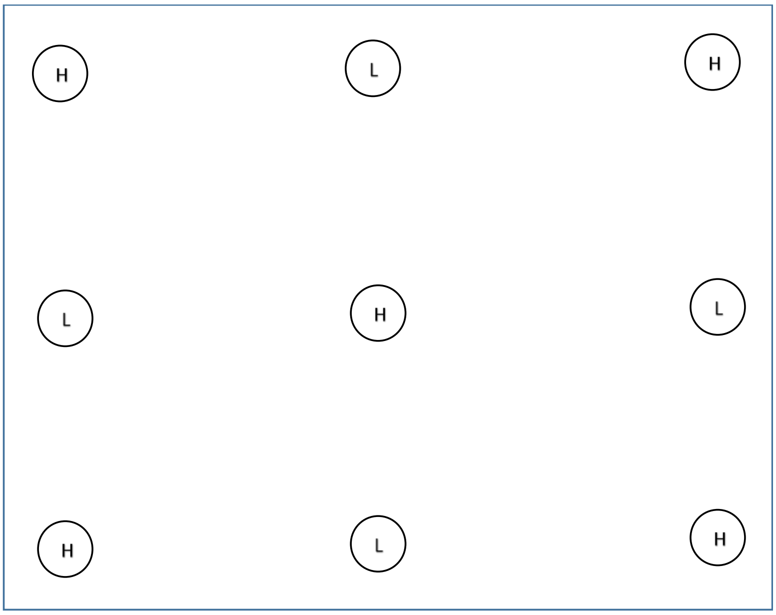


Figure 9: Z Separation of Anchor Nodes in 3D Solver

e) *Master selection:*

All the anchors in 2D solver and the lower anchors in 3D solver should still be positioned above any traffic so that they have line of sight to the master anchor sending CCP. Any disturbance (like a person walking between master and slave) which changes over-the-air propagation time-of-flight (TOF) of the CCP frames will upset the clock tracking for the slave anchor and increase the error of the location estimates as a result.

We recommend that the master anchors are the anchors having clear line-of-sight to the slaves in both 2D and 3D solver. For instance, we suggest that the master anchors are the highest anchors in 3D solver so that its line of sight path to the lower slaves is above the level of the people/traffic.

f) *RF distance*

The clock tracking algorithm needs to know the TOF between the master anchors and the slave anchors. In the absence of a measured range, the CLE calculates the TOF using the configured (x,y,z) positions of the master and slave anchors. In this case Line of Sight (LOS) path is needed between a master anchor and each of its slave anchors for best performance, otherwise any additional delays of NLOS RF paths will give an offset to the clock tracking that will give RTLS result errors. Note here that this also implies that changes in the RF path between the master and a slave, (e.g. due to traffic, people, etc. moving through that path), will disturbed the clock tracking for that slave and lead to additional error in the RTLS results based in that slave anchor's timestamps.

Note: Using the controller GUI application it is possible to initiate two-way ranging exchanges among two or more anchors. When this includes master and slave anchors, the TOF result, which is the RF measured distance between master and slave, is used by the CLE in preference to the TOF calculated based on anchor position. This feature acts to support correct synchronisation of slaves even when they are not in good LOS of the master. The assumptions are however that the NLOS path is unchanging and that the first path is being reliably seen so that the result is stable with a low standard deviation. Currently the released software does not include a direct mechanism to report the quality of the two-way ranging results, this will be addressed in the next release, so it is difficult for the user to know whether performance is good. Also, there is currently no controller mechanism to choose between the anchor positions based TOF or the TOF result from ranging, so once ranging is done that measured TOF is used, and to revert to the position-based values requires that the user manually edit the CCanch_config.xml configuration file to set the master *rfdistance* to zero for the affected slave anchors.

You may need to experiment with the anchor positions to achieve the optimum placement.

The communications test option described in 6.4.1.2 can be used to verify that the master anchor can communicate successfully with all slave anchors.

3.3.4 Powering the anchor units

The anchor units can be powered either by an external USB supply via the Micro USB connector on the unit (labelled USB) or via Power over Ethernet (PoE) via the Ethernet interface on the unit (labelled ETHERNET). You do not need to take any action to select between these two sources – the unit detects which interface is powered.

WARNING: You should **NOT** connect power to both interfaces or damage to the unit may result.

3.3.5 Connecting the anchor units to the PC

All anchor units must be connected to the same TCP/IP network (Ethernet LAN) as the CLE (PC). This ensures that the CLE will be able to discover the anchor nodes via the *mDNS* protocol.

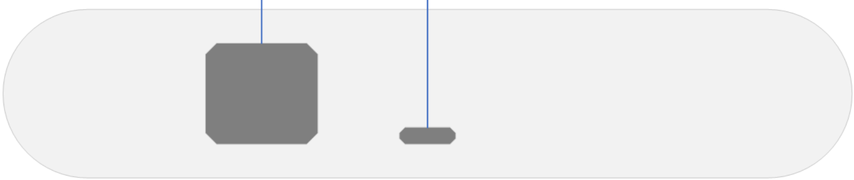


Figure 10: Power & Backhaul connections

3.4 TAG UNIT INSTALLATION

There are no specific actions required to prepare the tag units for use other than verifying that the batteries are charged.

We recommend that you recharge the tags before attempting to use them. To do this, plug a Micro USB cable into the Micro USB connector at the end of the unit. The LED on the unit will start flashing (only if the unit is turned on). If the unit is switched off, there will be no LED indication but the battery will still charge.

The tag unit is configured for the same default data rate as the anchor nodes, and does not require any re-configuration.

To turn on the tag slide the switch to the "ON" position. The LED on the unit will starting flashing after 6 seconds indicating that the tag is transmitting blink messages.

3.5 ARE YOU READY TO MOVE ON?

At this point you should have:

- ✓ Yours anchors units mounted in their respective locations in the area in which you are planning to track the movement of the tags.
- ✓ A power supply connected to each anchor unit.
- ✓ An Ethernet backhaul connection from each anchor to the Ethernet hub with an Ethernet connection from the hub to the PC running the CLE.

We are now ready to move on to the installation of the Control Client software on your PC, configuring the system using the Control Client and finally running the system so you can see the locations of the tags being reported accurately.

4 THE SYSTEM SOFTWARE

4.1 INTRODUCTION

Before moving on to the installation of the system software and the configuration of the system it is useful to understand how this software and the underlying functionality is organised.

There are two primary elements:

- The Central Location Engine
- The Control Client (controller)

These two separate Microsoft Windows PC applications are necessary to run the RTLS. The CLE communicates with the anchors over the (Ethernet backhaul) TCP/IP Ethernet LAN, while the Control Client employs a standard (Microsoft Windows) TCP/IP socket interface to connect to the CLE. This allows the controller to be co-located on the same PC as the CLE or to run on a separate PC, with TCP/IP connectivity to the CLE.

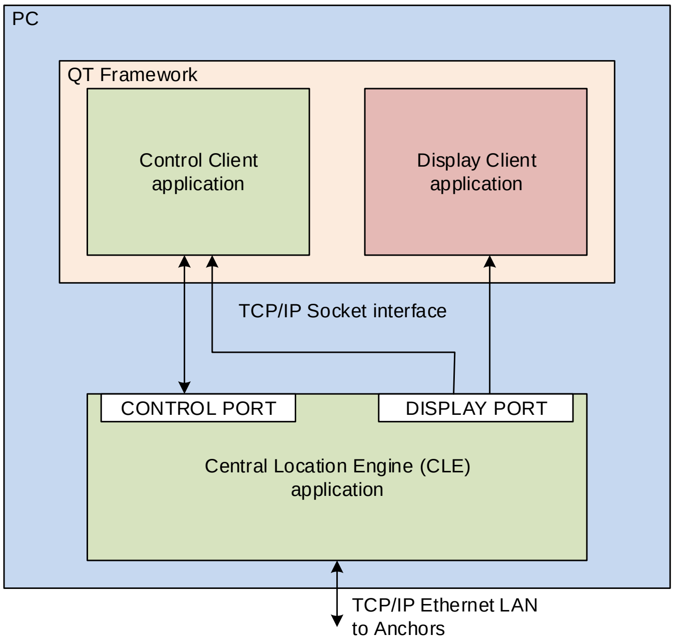


Figure 11: RTLS (PC) applications

4.2 CENTRAL LOCATION ENGINE

The Central Location Engine is the function that accepts the Time of Arrival (TOA) timestamps from the anchor nodes, calculates the Time Difference of Arrival TDOA for TOA pairs and multilaterates between appropriate TDOA values to derive the location of the transmitting tag unit(s).

This functionality resides on the PC. The Central Location engine has two connections to upper layer functionality. First of these is intended primarily for configuration and control of the system and the other is intended for consuming (e.g. displaying) the RTLS results output by the CLE.

4.3 Control Client

Decawave provides a Control Client intended to connect to both the control and display port connections to the CLE. Using this you can control and configure the system as well as viewing system output (i.e. tag positions). This Control Client is an executable intended to run on a PC.

5 INSTALLING THE CONTROL AND APPLICATION CLIENTS

5.1 INTRODUCTION

Once the infrastructure (anchor units) has been physically installed, the next step is to install the Control client software on your PC. The software is intended to run on any Microsoft Windows 7 or above machine.

5.2 INSTALLING THE CONTROL AND APPLICATION CLIENTS

It is recommended to create a new folder on your machine called "RTLS". Into this folder, copy the entire contents of the scalable software release as provided in the zip file.

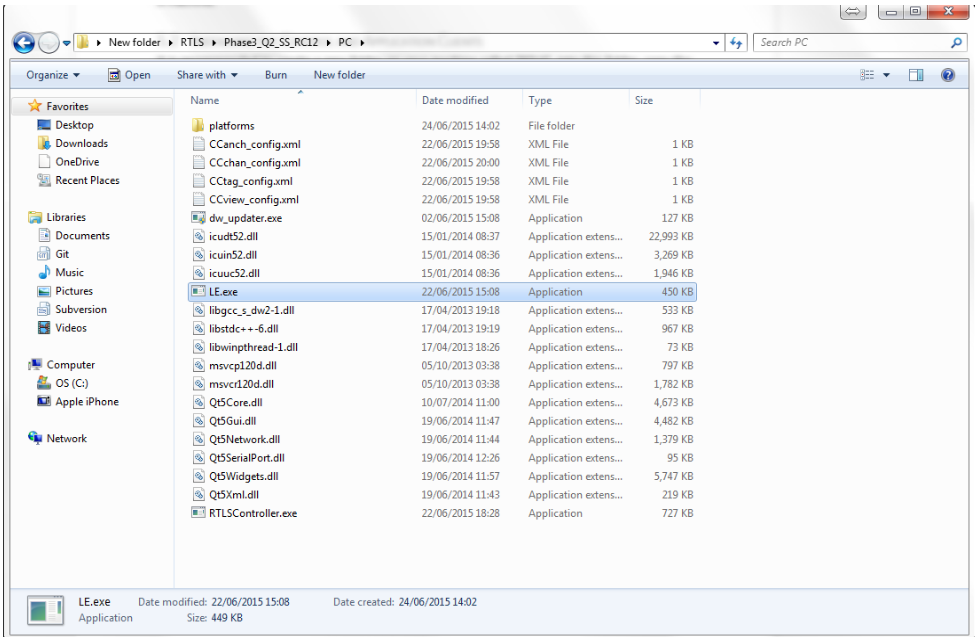


Figure 12: Copying of .exe and related files

5.3 INSTALLING THE CENTRAL LOCATION ENGINE

The CLE is a windows executable. To install the CLE simply extracting the files provided with the TTK1000 software release zip into the desired target folder, e.g. the RTLS folder created in 5.2 above.

***Note*:** The CLE can reside on the same PC as the Control client. This is intended default operation. If the CLE is on a different PC to the one on which the Controller is running, then the Controller CLE connection settings (CLE's IP address) need to be updated to the IP address of the CLE's PC as shown in section 6.5.

6 CONFIGURING AND RUNNING THE RTLS SYSTEM

6.1 INTRODUCTION

Now that the Control Client has been installed we can use it to configure and run the system.

6.2 STARTING AND CONFIGURING THE CLE

There two possible options how to discover Anchors by the CLE in a network.

The first is zero-network configuration (see section 6.2.1). Here a DHCP server must be present in the network, which will provide the IP addresses to the anchors and then the CLE will use mDNS discovery service to discover all of the anchors.

On a large networks mDNS discovery can last significant amount of time.

After initial installation and configuration, we recommend to always use the second method, which is the Static IP Anchors configuration (see section 6.2.2). In this case mDNS service is not used.

6.2.1 Installing Anchors using mDNS

Remove “dns_cle.cfg” file if exists in the location engine executable folder. Then start the CLE (by double clicking on *LE.exe)*, it will run mDNS to discover and setup Anchor’s network.

The CLE begins to run and searches for any anchors on the same network. When the anchors are powered up they will broadcast mDNS discovery messages and the CLE will discover any anchors connected to the same network.

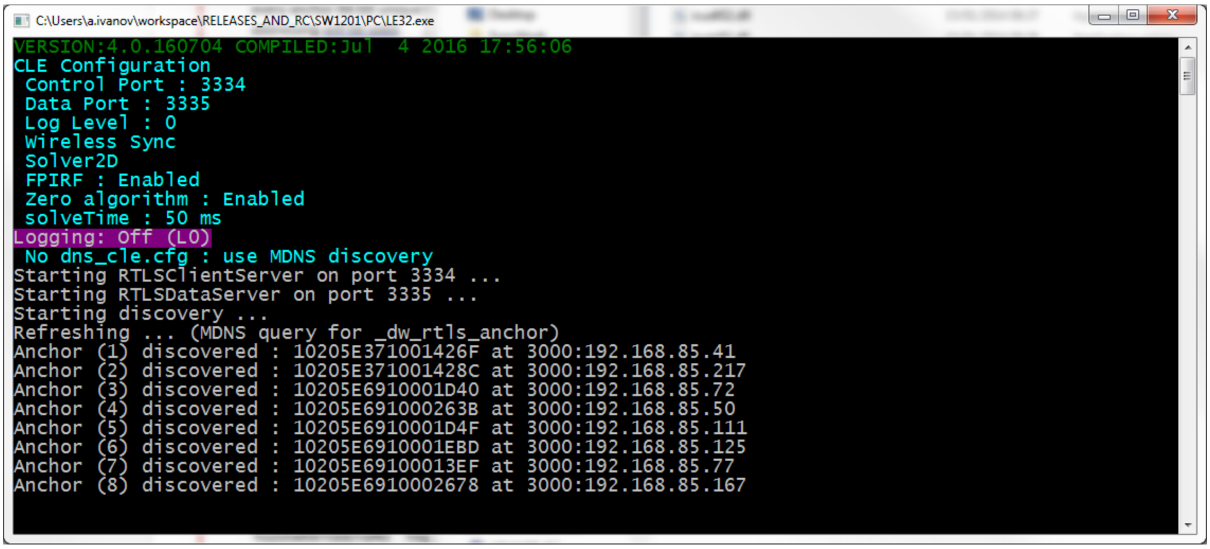


Figure 13: CLE console window with mDNS discovery

6.2.2 Installing Anchors using “Static” IP configuration

When the “dns_cle.cfg” file is present in CLE folder, the CLE does not need to discover anchors, but it needs to read their IP addresses with respect to every anchor 64-bit unique ID and check whether they are present in the network.

For large busy networks this is much faster and more stable method than an mDNS discovery. In this case the mDNS server will not be started.

To provide this static IP addressing, customer should configure its DHCP server to assign the same IP address to a specific MAC address, which is the same as 64-bit unique anchor ID.

From DHCP server copy the IP addresses to a plain configuration file “dns_cle.cfg” as follow:

```
10205e6910001ebd   192.168.85.125
10205e6910002678   192.168.85.167
10205e69100013ef   192.168.85.77
10205e371001428c   192.168.85.217
10205e691000263b   192.168.85.50
10205e371001426f   192.168.85.41
10205e6910001d4f   192.168.85.111
10205e6910001d40   192.168.85.72
```

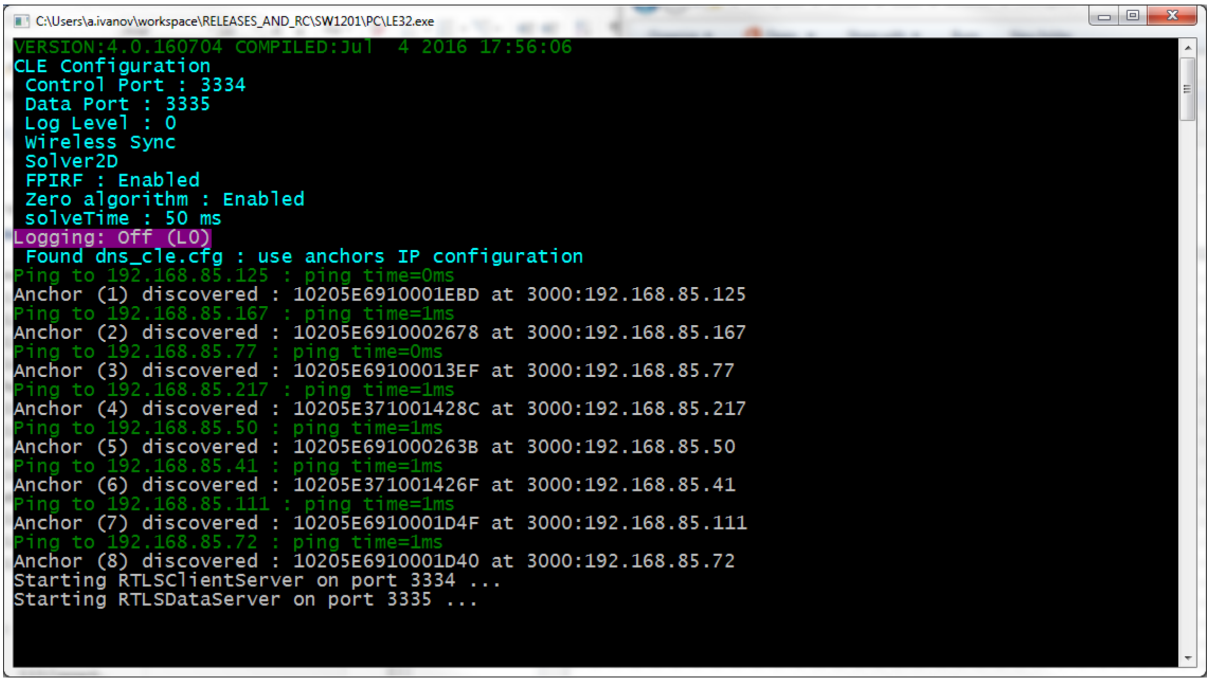


Figure 14: CLE console window with Static IP discovery

6.2.3 CLE default system configuration file

Some of the run-time properties of CLE can be changed by its configuration file named as “dw_cle.xml” in the same folder.

If this file is missing, default setting will be used as shown below.

Table 1. CLE configuration

Default Parameters	Function
controlPort = “3334”	Number of Port for transmitting control messages
dataPort = "3335"	Number of Port for transmitting data
logLevel = “4”	See details in 6.8.
wirelessSync = “1”	Wireless clock synchronization is used in this system.
solveTimeWait = “50”	The time for collecting all the reports for each blink to put them into solver in the unit of milliseconds.
Solver3d = “0”	2D solver is active by default.
FPRIF = “1”	First path index rejection enabled
ZERO = “1”	Zero anchor selection algorithm enabled

6.3 LAUNCHING THE CONTROL CLIENT

Launch the Control Client by executing of *RTLSController.exe*.

6.4 THE CONTROL CLIENT TOUR

When the Control Client starts you will see a screen with the primary areas as shown in Figure 15.

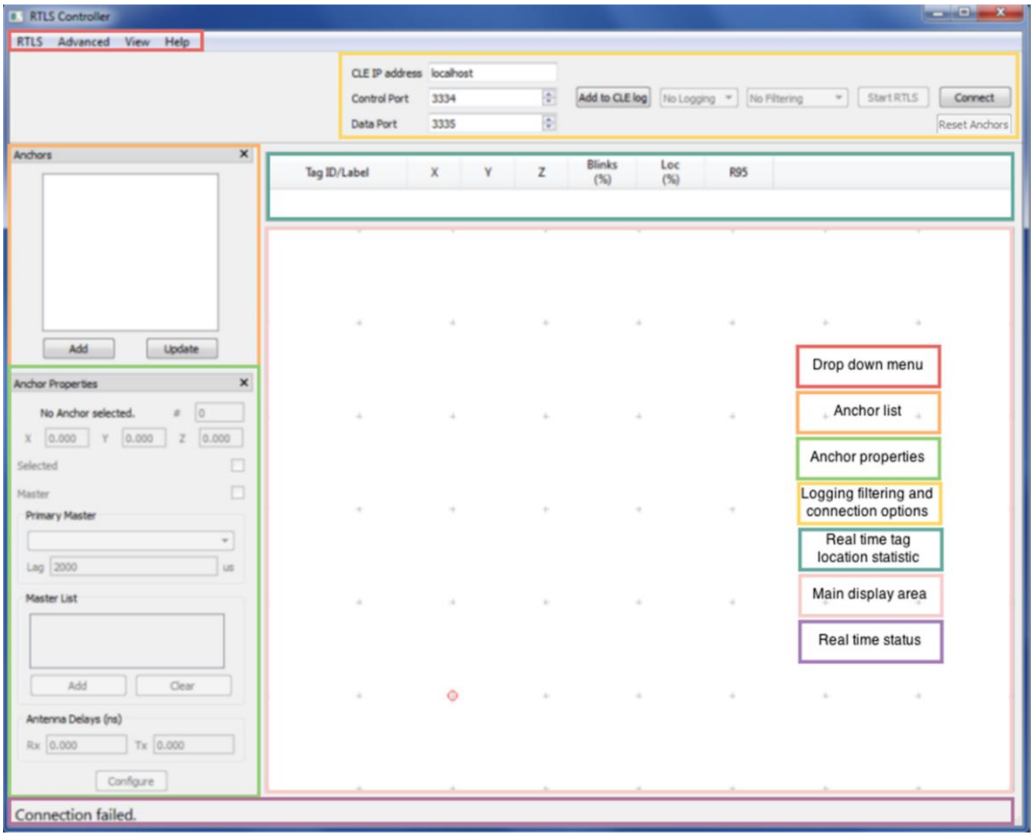


Figure 15: Control Client Main Screen Description

The highlighted areas are described in Table 2 below.

Table 2: Control client main screen areas

Area	Function
Drop down menus	Control a variety of functions described below 0 in more detail
Anchor List	Displays the list of anchors that have been entered into the system - refer to 6.6.2 below
Anchor Properties	As each anchor in the Anchor List is selected, its associated parameters appear here and may be edited – refer to 6.6.4 below
Master List	Displays the list of Masters that have been entered into the system - refer to 6.6.5 below
Real Time Status	Displays current status of controller
Real Time Tag Location Statistics	Shows the tag ID, x, y, z location results and the % of multilateration successes and blinks receive
Logging Filtering and Connection Options	Options for logging results and filtering the location data. Allows us to set the IP address of the CLE, connect to it and start the RTLS system – refer to 6.5 below
Main Display	This area displays the anchor nodes

6.4.1 Drop Down Menus

6.4.1.1 RTLS

This drop down menu presents the following options:

- *Anchor Positioning* – this positions anchors in the main display area

  Rotate 90 – rotate the anchors clockwise 90 degrees

  Flip X-Axis – flip the anchors on the display along x-axis

  Flip Y-Axis – flip the anchors on the display along the y-axis

- *Channel Configuration* – this opens a "*Channel Configuration dialog box"* shown as below through which the user can vary the system's anchor and tag UWB parameters:

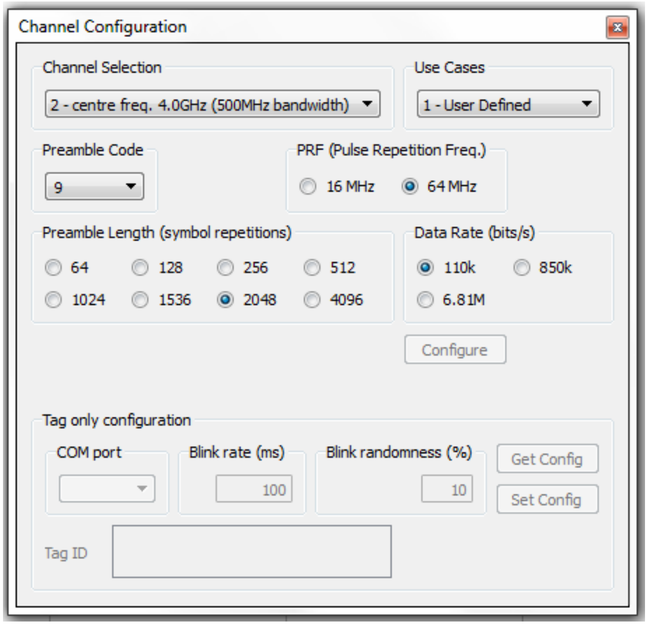


Figure 16: Channel configuration dialog box

Table 3: Channel configuration parameters

Field Name	Description
Use Cases	User Defined – the user can select any of the channel parameters Long Range – system will be configured for longest range Max Density – system will be configured for maximum density Default – system will be restored to default settings
Channel Selection	Configures the operating channel / frequency
Preamble Code	Allows the user select the preamble code to be used
PRF	Allows the user select between using 16 or 64 MHz PRF
Preamble Length	Allows the user select the preamble length
Data Rate	Allows the user choose one of the data rates
Configure	When this button is pressed the configuration is sent to the CLE which in turn passes it to the anchors
Tag only configuration	Allows the configuration of the tag to be modified. To do this, the control client needs be connected to the tag
COM port	selects which Tag to program/connect to
Blink rate	Allows the user set the Tag blink rate
Blink randomness	Allows the user set the blink randomness
Get Config	This reads the current Tag configuration (blink rate and randomness)

Field Name	Description
Set Config	This programs the Tag with new configuration (all of UWB parameters and blink rate and randomness)
Tag ID	This shows the ID of the tag connected to control client

- Re Sync – this is used for tag training in wired synchronization mode.
- *CLE Configuration* – this opens “Logging Filtering and Connection Options” shown in Figure 15
- *Load Configuration* – this lets the user load system configuration files:

  CCchan_config.xml should be selected when “Load RF Config” window shows

  CCanch_config.xml should be selected when “Load Anchor Config” window shows

  CCview_config.xml is loaded automatically.
- *Save Configuration* – this lets the user save system configuration files.
- *Save as New Configuration* – this lets the user save system configuration in new configuration files.

6.4.1.2 Advanced

This drop down menu contains the following items:

- *Log Accumulator* – this can be used to log a number of CCP/Blink frame channel impulse responses, which can be used for diagnostic purposes
- *Pan to* – this pans to the anchor on the Main Display Area window, it places the selected anchor in the centre of the Main Display Area window.
- *Two-Way Ranging (TWR)* – this performs TWR between the selected anchors, the results of TWR are used in wireless clock sync, see important description of this in paragraph (f) of 3.3.3.2
- *Power Test* – this puts the selected anchor into continuous frame mode and can be used to measure TX power of an anchor. This is a special test mode that will upset normal operation of the RTLS, it is expected that this is only done for single anchor system as part of driving that anchor into this mode for measuring compliance to regulatory spectral masks.
- *Communication Test* – this performs a communications test. It instructs the CLE to start a communication test procedure which consists of one anchor transmitting 1000 messages and other anchors reporting the number of messages received. This can be used to assess the “quality” of the link between the transmitter and each of the receivers. This can be done for each anchor and the results will help choose a suitable position for the master anchor, as it needs to have good link to all of the slaves.

6.4.1.3 View

This drop down menu presents the following options:

- *Anchors* – selecting this will open an anchor list dialog, which will list all of the known anchors in the system. To update / populate the list, the user can either add new anchors individually by pressing the “Add” button or, once the connection to the CLE is active, press the “Update” button to get the list of anchors from the CLE.

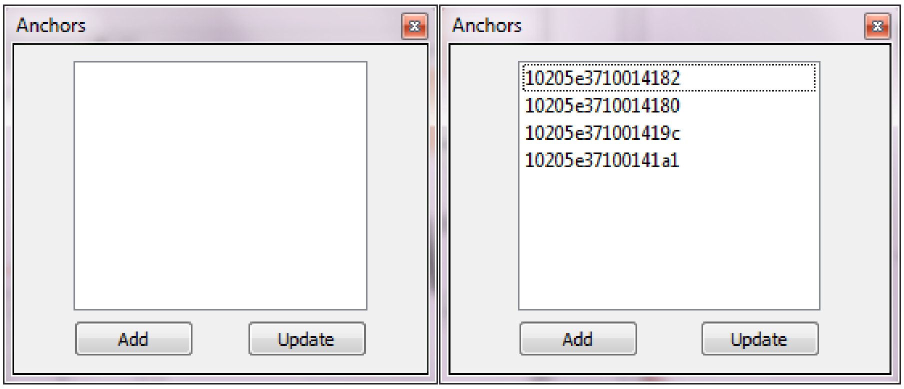


Figure 17: Anchors list dialog, showing an empty list and the updated list

- *Anchor Properties* – selecting this will open anchor properties dialog, which shows as following.

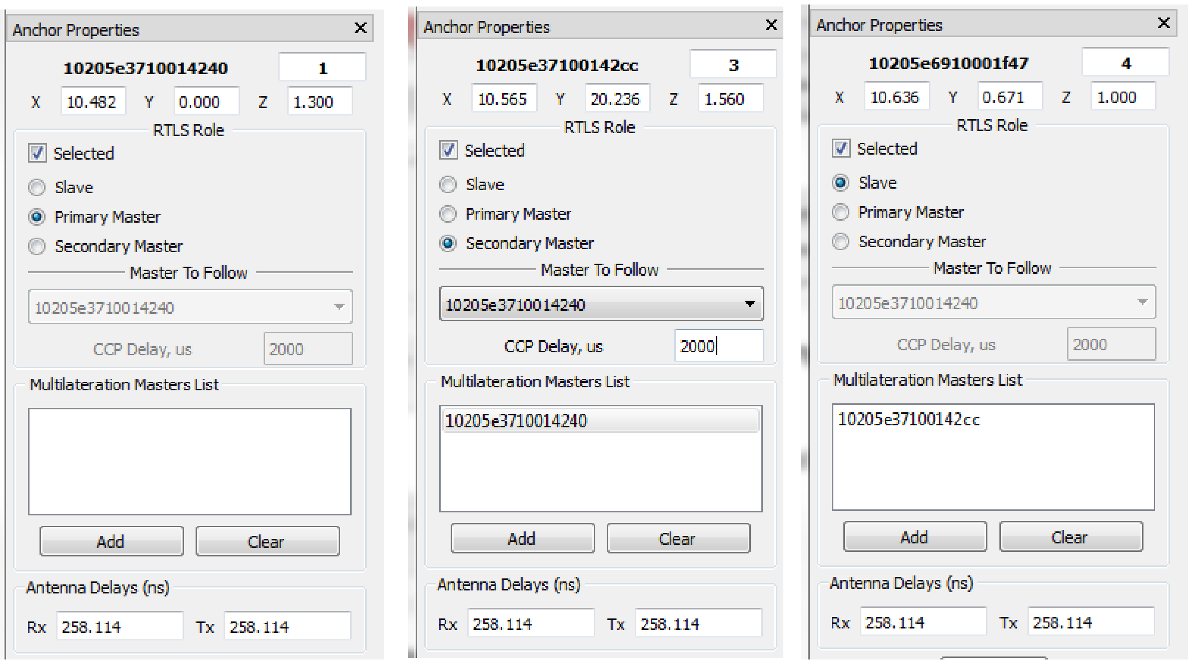


Figure 18: Anchor Properties dialog

Table 4: Anchor configuration parameters

Field Name	Description
ID	Anchor unique identifier (will be present on the anchor’s box)
#	Anchor number

X, Y, Z	Anchor x, y, z co-ordinate values
Selected	When this is true the CLE will open a connection to this anchor. This must be set for all active anchors that are part of the RTLS network.
Slave, Primary Master or Secondary Master	An anchor's role in RTLS can either be set as a slave (only reporting Blinks and CCPs) or master (Primary or Secondary). When master set as Secondary, it will send CCPs based on the delay from reception of CCP from its "Master to Follow".
Primary Master ID	This is an ID of a primary master that a secondary master will follow. If this is the same as the anchors' own ID (or 0x0) this means that the anchor is the primary master.
Lag	This is the time lag following the reception of its primary master's CCP after which the secondary master will send the CPP.
Master List	Array of Master IDs that this anchor will be synchronized with in the CLE. **NOTE:** *The anchor must have at least one master anchor in the list. If the list is empty then the CLE will not be able to synchronize the timestamps from the anchor.*
Ant Delay Rx & Tx	Transmit & Receive Antenna Delays for this anchor in nanoseconds

- ***View Settings*** – selecting this will open a view configuration dialog. This allows the user to upload a floor plan and specify the grid, X and Y axis scale and origin positions:

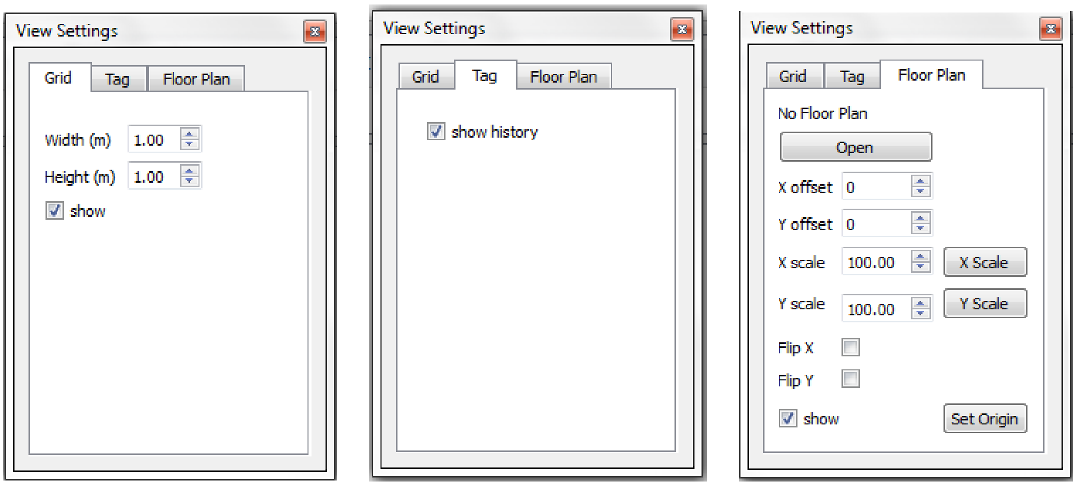


Figure 19: View Settings dialog

❖ *Grid tab*:

Field Name	Description
Width	Sets the horizontal grid spacing, unit is meters
Height	Sets the vertical grid spacing, unit is meters
show	Shows or hides the grid

❖ *Tag tab:*

Field Name	Description
History	Sets the tag history shown on the main area

❖ *Floor Plan tab:*

Field Name	Description
Open	This lets the user upload an image of the floor plan of the area where the anchors are installed
X offset	This is the origin offset in the X direction from the (0, 0) point on the floor plan
Y offset	This is the origin offset in the Y direction from the (0, 0) point on the floor plan
X scale	This is the scale (pixels per meter) of the x axis
Y scale	This is the scale (pixels per meter) of the y axis
Flip X	This flips the image in the x-axis
Flip Y	This flips the image in the y-axis
show	This shows or hides the origin in the map
Set Origin	This button lets the user click and set the origin coordinates
X Scale button	Pressing this button produces a measuring tool with which the user can firstly select a distance on the map and then enter the actual distance that range corresponds to, this sets the *X scale* value
Y Scale button	Pressing this button produces a measuring tool with which the user can firstly select a distance on the map and then enter the actual distance that range corresponds to, this sets the *Y scale* value

- *Minimap* – selecting this opens a Minimap dialog, which shows the loaded image and the zoomed in area (which is shown in the Main Display Area window).

6.4.1.4 HELP

- ***About*** – this opens the "About" window which provides information on the revision of the client.

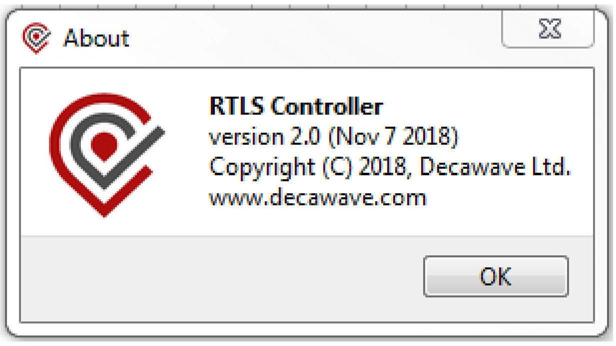


Figure 20: About window

6.5 CONNECTING THE CONTROL CLIENT TO THE CLE

Now that the CLE is running we need to connect to it to configure the system. The Control Client automatically connects to the CLE once the CLE is open.

If the CLE is **not** open the CLE configuration dialog will be shown at the top of the controller client.

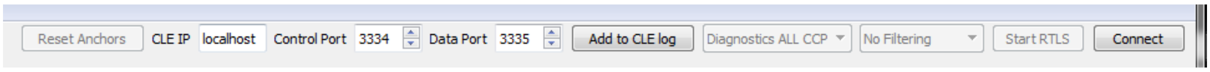


Figure 21: CLE configuration dialog

To allow the Control Client to connect to the CLE, the Control Client needs to know the IP address of the PC on which CLE is running. **"**localhost**"**[1] is used as default setting. Socket port numbers should match the CLE's settings. (By default these are 3334 for the Control Client socket and 3335 for the Display Client socket)

When the Control Client has successfully connected to the CLE, the "Connect" button changes to a "Disconnect" button indicating that the connection process was successful. "Reset Anchors" button is able to reset all the anchors without power cycling.

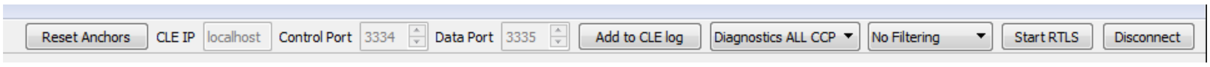


Figure 22: Connecting the control client to the CLE

6.6 CONFIGURING THE ANCHOR UNITS

6.6.1 Introduction

Before the anchor nodes can work simultaneously to form an RTLS network, the whole system shall be configured, so that:

- The CLE knows about anchors (knows their IP address and can connect to them over TCP/IP socket);
- The CLE knows where anchors are physically located – the Control Client configures the CLE;
- Each anchor knows its respective function (role) in the RTLS (primary/secondary master or slave) and the various UWB channel parameters to use. The Control Client configures each anchor with this information.

[1] It is possible to install the CLE on a different PC to the one on which the Control client is installed. In this case you should enter the IP address of the machine on which the CLE is installed.

This is achieved by:

- Setting up the information in the Control Client,
- Connecting the Control Client to the CLE,
- Configuring the CLE and the anchor nodes with the parameters been entered.

6.6.2 Discovering the anchors in the system

Once the Control Client is connected to the CLE, users can press the "*Update*" button on the Anchors list dialog, Figure 17, and the Anchor list will be populated with the discovered anchors. If an anchor is missing, please check its power supply and Ethernet connections and try again. Alternatively, any anchor can be added with the "Add" button as described in section 6.6.3 below.

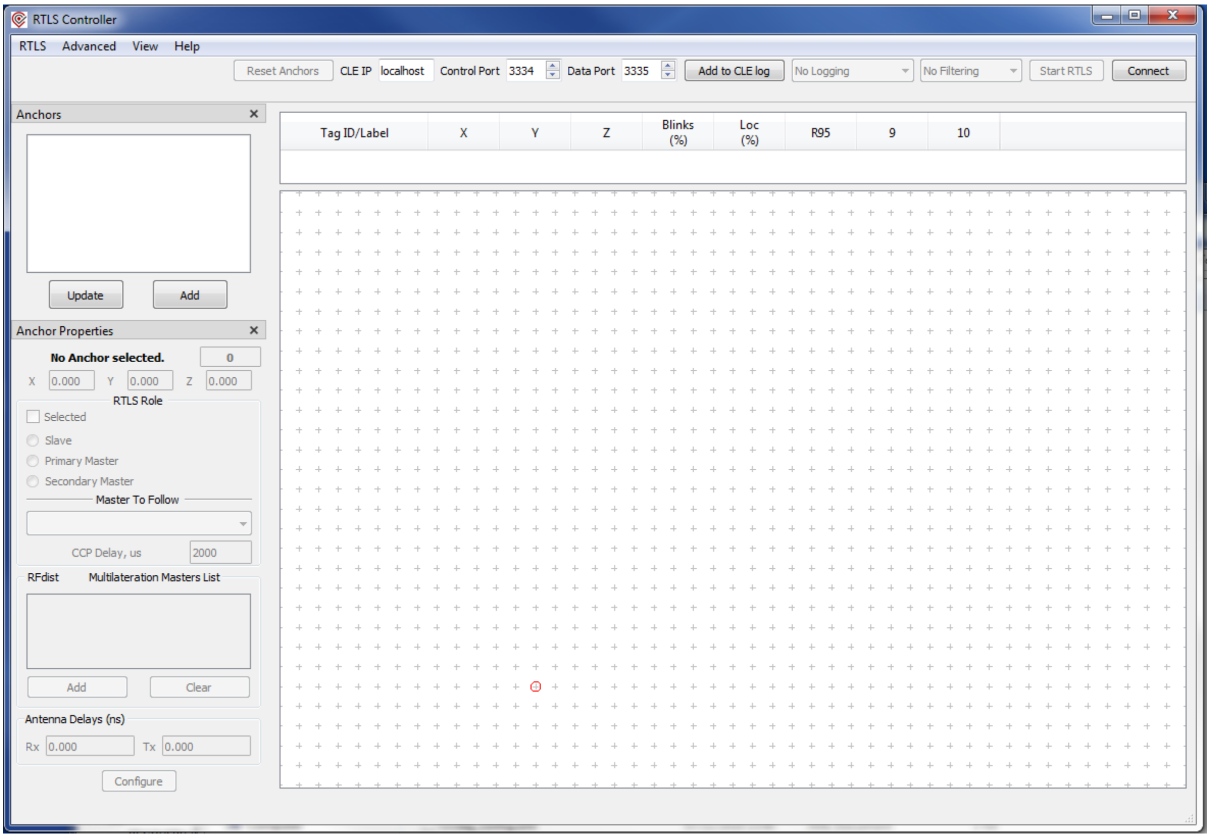


Figure 23: Adding an Anchor ID

6.6.3 Manually adding anchors to the system

You can manually add anchors to the system before they are physically connected or before the CLE is running. We start by telling the Control Client about the anchors we wish to connect to the system. To do this, click the "Add" button below the "Anchor" panel on the left of the main screen as shown below. An "Anchor ID" dialog box will open in the centre of the screen. You should type in the Anchor ID here. You can find this ID on a label on the side of the anchor unit. When you click "OK", the dialog box will close and the ID you have just entered will appear in the "Anchor" panel on the left hand side of the screen.

6.6.4 Selecting anchor nodes to be used by the CLE and configuring the number

Anchors need to be selected to be used in RTLS network by the CLE.

As mentioned in section 6.4.1.3, for each anchor, if “selected” option in “Anchor Properties” panel is ticked, it will be connected to CLE then will appear in the main display area. The anchor number can be configured for easy reference. The anchors are labelled from 1 to N, where N is the number of anchors in your system. This number future will be used in CLE reports.

Once the configuration has been entered for all anchors and the control client is connected to the CLE the *Configure* button shall be clicked so that the anchor settings are passed to the CLE (see 6.7).

6.6.5 Selecting anchors roles

6.6.5.1 Master anchors - Configuration of Wireless Clock distribution.

RTLS network need a common time base. This is achieved using a wireless clock synchronization scheme. In this scheme some of the anchors are acting as Clock Calibration Packet transmitters, for more details see Appendix F: Bibliography [1].

Wireless clock synchronization scheme needs to have at least one anchor acting as an independent (primary) master. In a large system, subordinate (secondary) masters may be needed where one primary master cannot cover the whole area, i.e. there will be anchors which cannot receive the primary master’s CCP packets reliably or at all.

The slave role is indicating that the anchor is not acting as CCP transmitter. Primary and secondary master roles are used to avoid collision between CCP transmissions during provision of wireless clock distribution via RTLS. At all other time, when masters are not transmitting their CCPs, they act the same as slaves, i.e. listen to any messages on the air.

The role of an anchor in RTLS can be selected using radio-button section of the “Anchor Properties” panel, see **Figure *18***. It can be sets to be either “*Primary master*”, “*Secondary master*” or “*Slave*”.

If anchor’s role is a primary master, it will independently transmit CCPs.

If the anchor’s role is a secondary master, then the ID of the “Master to follow”, i.e. with respect to which master to delay its CCP, shall be selected from drop-down “Master to follow” list, see **Figure *18***.

To avoid collisions, before starting of its own CCP transmission, secondary master must receive at least one CCP from its master to follow. From then each secondary master should reliably “hear” its “master to follow” and make any corrections to the lag delay time between CCP transmissions.

The secondary master can also act as a master to follow for a next secondary master etc. etc., see **Figure *24***.

The configured lag delay between sending of CCPs should be 10 x the CCP packet length. Default lag delay of 2000 µs is suitable for data rates of 6.81 Mbit/s and 850 kbit/s with preamble length of up to 256.

For data rate 110 kbit/s and preamble length 1024 the lag delay between masters should be 20000 µs.

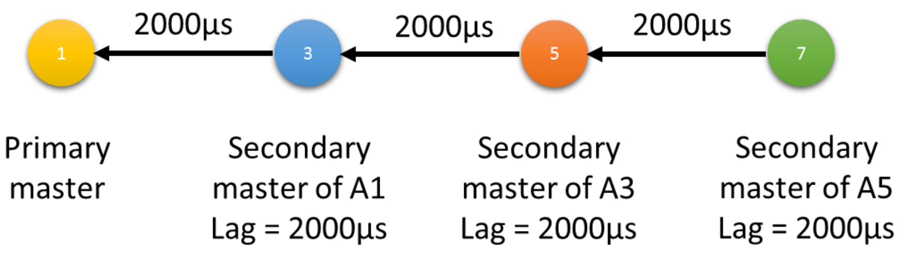


Figure 24: Primary and Secondary Master Configuration

6.6.5.2 All anchors - Multilateration master's list.

As described above, every anchor in RTLS needs to synchronize its time domain with respect to a common time base (which is supplied via CCP distribution).

As a common time base, the clock from any master within the radio range may be used.

When anchors are not transmitting, on reception of CCP from other masters, they will report this CCP RX. The CCP RX time and corresponding master's TX time will be used in CLE to track synchronization of anchor's clock w.r.t. its master.

Those masters, with respect to which clock of anchor will be tracked, are listed in the list of "*Multilateration Masters List*", see **Figure *25***. Controller GUI and CLE support of up to 16 clock synchronization tracking for every anchor in an RTLS setup.

Click "add" at the bottom of the list. A drop down menu with all possible masters in RTLS will appear.

Based on geometry, select the master (or few masters) which will be used for current anchor for its clock synchronization.

In order to participate in location algorithm, each anchor (except of masters) needs to have at least one master in its "Multilateration" master list, so that the CLE knows to run the clock tracking algorithm for it, see **Figure *25***. We are also recommending that the secondary masters should add "Master To Follow" to the "*Multilateration*" masters list too if cross-location is possible in the environment, i.e. tag is moving from one master to another, see figure below.

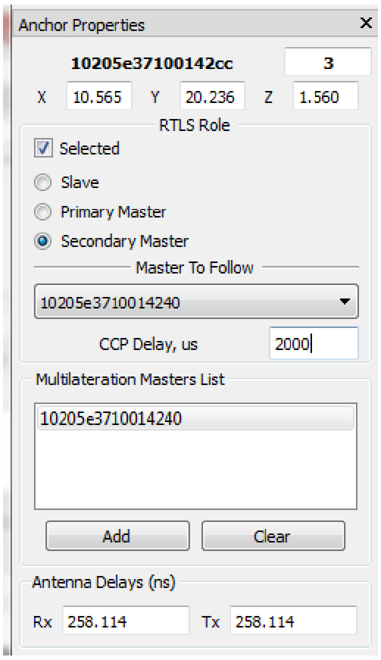


Figure 25: The secondary master's Multilateration Masters List

6.6.6 Configuring the location of the anchors

The CLE needs to know the physical position of all the anchors so that it can interpret the ToA reports and multilaterate to give a good estimate of the tag location. The anchor position can be set in one of following two ways:

6.6.6.1 Manual Anchor Position

You can manually enter the physical position of each anchor. In this method you enter the (x, y, z) location of each anchor relative to the (0, 0, 0) origin. These x, y, z values are entered in meters and need to be as accurate as possible to achieve best results.

When selecting an anchor ID in the Anchor panel, the current anchor coordinates (x, y, z) appears in the "Anchor Properties" panel as shown in Figure 18. The physical measurements you have made of the (x, y, z) position of the selected anchor should be entered and you should repeat this process for all the selected anchors.

6.6.6.2 Two-way ranging aid to anchor position

The anchor units have a Two-way Ranging whereby they can exchange messages and so calculate the time-of-flight (distance) between themselves. The user can then use the reported TWR range measurement to confirm or help estimating the x, y, z positions. Note however that this has a side-effect in that the result of ranging between masters and slaves is used as the *rfdistance* in the clock tracking algorithm, see the note in 3.3.3.2 f) above for details of this.

6.6.7 Configuring the anchor node UWB radio parameters

We may need to configure the Ultra Wideband radio interface parameters for the anchor nodes so that they are operating with the same parameters as the tag units and can receive transmissions from them.

To do this, click on “Configure” in the main drop down menu bar at the top of the screen and select the “Channel Configuration” option from the menu.

A “Channel Configuration” dialog box opens as shown in Figure 16 and you can configure various channel parameters here depending on the evaluation you wish to make. To pass the configuration to the CLE and the anchors the Configure button should be pressed.

It is suggested that you leave these parameters at their default settings to begin with – you can evaluate the effect of changing them later.

6.6.8 Configuring the anchor nodes by configuration file

From section 6.6.3 to 6.6.7, anchor nodes are configured through controller. The other possible way is to configure all the anchor node by configuration node. As mentioned in section 6.13, all the anchor configuration will be saved in the file “CCanch_config.xml” in the same folder with the following format:

Field Name	Description
addr	Anchor unique identifier (will be present on the anchor’s box)
id	Anchor number
x, y, z	Anchor x, y, z co-ordinate values
selected	When this is checked the CLE will open a connection to this anchor. This must be set for all active anchors that are used in the RTLS
master	When this is checked the anchor will behave as a master, when unchecked it acts as a slave
master_id	This is an ID of a primary master that a secondary master will follow. If this is the same as the anchors’ own ID this means that the anchor is the primary master.
master_Lag_delay	This is the time lag following the reception of its primary master’s CCP after which the secondary master will send the CPP.
master rfdistance	rfdistance is the distance got by two-way ranging to the master with following address.
Ant Delay Rx & Tx	Transmit & Receive Antenna Delays for this anchor in nanoseconds

Both configuration methods above lead to the same result.

6.7 SENDING THE ANCHOR CONFIGURATIONS

We can now send the anchor configurations, previously entered into the Control Client, to the anchor nodes. We do this by clicking the “Configure” button at the bottom of the anchor properties box, see Figure 18.

6.8 Configuring the CLE's logging level

The CLE has the capability to log various messages and events that occur in the system. This can be useful for performance analysis and for debugging system problems. The amount of data that is captured can be configured. This configuration can be changed in the CLE configuration dialog. Logging has 4 levels:

Table 5: CLE Logging Levels

Log Level	Logging Details
No Logging	None
Level 1	Errors and Warnings
Level 2	As per level 1, with RX & TX Time Stamps
Diagnostic	As per level 2, with also Blinks, Clock Sync Packets, Diagnostics, Kalman Sync Output, Multilateration Results

Note: The default level logging is "Diagnostic", which can result in large data files being created on the CLE machine's hard disk drive.

6.9 Configuring the CLE's motion filter

In the CLE configuration dialog, we can enable a motion filter which will process tag blinks and filter out any outliers. In TTK1000 we have 4 different motion filter options:

The default option is No Filtering.

Table 6 CLE Filtering Levels

Filtering Level	Filtering Details
No Fitering	None
Moving Average	Average of 10
Moving Average Ex	Average of 10 with min and max removed
Kalman	Kalman filter is deployed as motion filter

6.10 Configuring the tag units

We can configure the Ultra Wideband radio interface parameters for the tag nodes so that they are operating with the same parameters as the rest of the RTLS units.

6.10.1 Installing the Windows driver for tag

In order to change the tag configuration, the tag, when connected to the PC, needs to be recognised as a valid COM port. The first time a tag unit is connected to a USB port of a Microsoft Windows PC, Microsoft Windows recognizes that new hardware has been connected and will try to install the appropriate device driver.

The user should initially allow Microsoft Windows to automatically check for an appropriate driver in the Microsoft Windows driver update centre. In most cases, Microsoft Windows will install a driver automatically. However, sometimes, Microsoft Windows may not find a suitable driver. In this case, the user should install driver software manually. The PC USB driver should be included in the CLE package, but it may also be downloaded from ST.

On your Microsoft Windows PC, go to "Control Panel -> System and Security -> Device Manager". In the list of devices find an "Unknown device" in the "Ports" section. Right-click on the "Unknown device" item and choose "Update Driver Software". In the new window select

"Browse my computer for driver software" and select the "drv" folder inside the Decawave RTLS install directory.

This folder contains a driver entitled "atm6124_cdc_signed.inf", which will support standard "AT91 USB to Serial Converter". Once installed the Decawave RTLS GUI application will able to detect a new COM port and use it to configure the parameters of tag.

If the tag is subsequently plugged into a different USB port on the same Microsoft Windows machine it may be necessary to reinstall the driver for that USB port if Microsoft Windows is unable to automatically retain the settings of driver installed on the original port.

6.10.2 Configuring the tag UWB radio parameters

Once the tag driver is correctly installed, when the "Channel Configuration" window is opened "Tag only configuration" will have a COM port number on which the tag is connected.

The user can configure various channel parameters here depending on the evaluation you wish to make, as well as the tag blink interval and % of randomness. To apply the settings the "Set Config" button needs to be clicked.

6.11 STARTING THE WIRELESS SYNCHRONIZATION PROCESS

Once all the anchors have been configured, we need to start the wireless synchronization process. This instructs the anchor that we have previously configured as the master anchor to begin sending clock calibration packets to the slave anchors so that all time-bases in the system are synchronized and TDOA multilateration is possible.

Do this by clicking the "*StartRTLS*" button at CLE configuration dialog.

After the RTLS system has been started, you can turn on the tag units, and after a short interval you should see a coloured circle appear on the screen indicating the position of the tag relative to the anchor nodes.

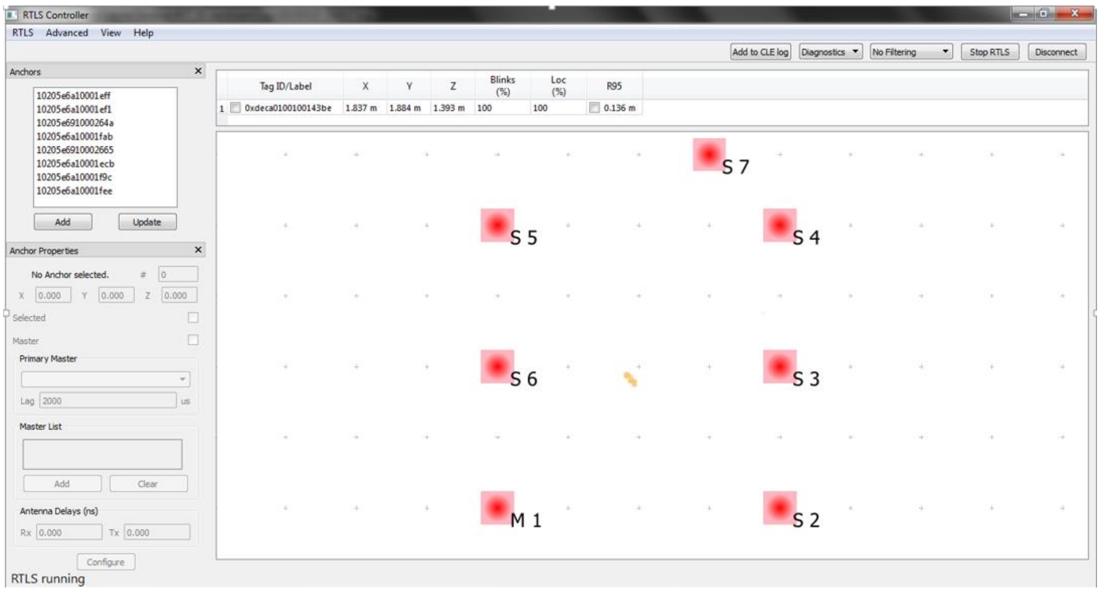


Figure 26: Tag displayed on grid

6.12 CHANGING THE ON-SCREEN DISPLAY

6.12.1 Changing the on-screen grid dimensions

The display area can be modified in various ways. The mouse scroll wheel can be used to zoom in and zoom out. To modify the grid settings click on “View” in the main drop down menu bar at the top of the screen and select the “View Settings” option from the menu. This will open a dialog with three tabs “Grid”, ”Tag” and “Floor Plan”, select the “Grid” tab. Grid size can be varied by varying the “Height” and “Width” parameters (units are meters) and also the grid can be switched on or off with the “show” parameter. The new grid settings are applied once the dialog is closed.

6.12.2 Adding an overlay bitmap such as a floor plan

To add a floor plan settings click on “View” in the main drop down menu bar at the top of the screen and select the “View Settings” option from the menu. This will open a dialog with three tabs “Grid”, “Tag” and “Floor Plan”. Select the “Floor Plan” tab. To load the image, click on the *Open* button. The image can be flipped in the Y or X axes, by using Flip X and Flip Y parameters.

6.12.3 Setting the origin

To set the origin click on the Origin button, this will give a cross-hairs tool, with which the user can then point and click at the location of the origin on the floor plan image. The origin can also be set by specifying the X and Y offset (in pixels) from the bottom left corner of the loaded image. Show parameter option shows or hides the red circle which identifies the origin.

6.12.4 Configuring the X and Y scale

When the image is loaded, X and Y scaling needs to be adjusted so that the scaling of the image is a true representation of the full-scale area. This can be done by either adjusting the X and Y scale parameters.

6.13 SAVING AND LOADING THE CONFIGURATION

Once all of the RTLS settings are configured it is recommended that they are saved. This is done by selecting “Configure” in the main drop down menu bar at the top of the screen and selecting the “Save Configuration” option from the menu. The user will be prompted to save the files. By default these are: CCanch_config.xml, CCchan_config.xml and CCview_config.xml.

- CCanch_config.xml – this file contains anchor configuration. When the Control Client is launched if this file is present the anchor configuration will be automatically loaded.
- CCchan_config.xml – this file contains the UWB channel configuration. When the Control Client is launched if this file is present the configuration will be automatically loaded.
- CCview_config.xml – this file contains view configuration (floor map, scaling &grid settings). When the Control Client is launched if this file is present the view configuration will be automatically loaded. This file is needed to configure the Display Client view settings.
- CCtag_config.xml – this file contains some tag display configuration (e.g. size of tag, label etc.). When the Control Client is launched if this file is present the tag configuration will be automatically loaded.

The XML files which contain configuration as outlined above can be manually edited. If user wishes then to load new settings, they can select “Configure” in the main drop down menu bar at the top of the screen and selecting the “Load Configuration” option from the menu.

7 EVALUATING THE PERFORMANCE OF THE SYSTEM

7.1 INTRODUCTION

The main parameter that evaluators of TDOA RTLS are typically interested in evaluating using the TTK1000 is its location accuracy:

Table 7: Main evaluation parameter of interest

Parameter	Description
Location accuracy	How accurately does the system report the position of a tag compared to the actual physical position of the tag and what are the key issues that impact this?

7.2 EVALUATING LOCATION ACCURACY PERFORMANCE

You can quickly get a sense of the accuracy of the system when you first configure it and turn on the tag unit. The tag should appear on the screen and provided the system is installed and configured correctly will appear stable and will not appear to "jump" around.

In order to more systematically assess the accuracy of the system it is necessary to compare the reported location of the tag units with their actual physical locations. There are many ways to do this. The method currently employed by Decawave is to lay out a physically measured grid in metres on the floor inside the area bounded by the anchors with the system origin coincident with the origin of the physical grid (for simplicity).

By placing the tag unit on a stand at each of the grid points in turn and noting the reported location over a significant number of blinks from the tag you can build up a "scatter plot" that shows each of the reported locations overlaid on each other as shown below. The key measurements here are:

Table 8 Parameters to evaluate location accuracy

Parameter	Definition
Multilateration success rate	For this grid point, what percentage of the multilateration attempts completed successfully and resulted in a valid (x, y, z) output?
R95 (m)	Given a reported location there is a 95% probability that the actual location is within the specified radius.

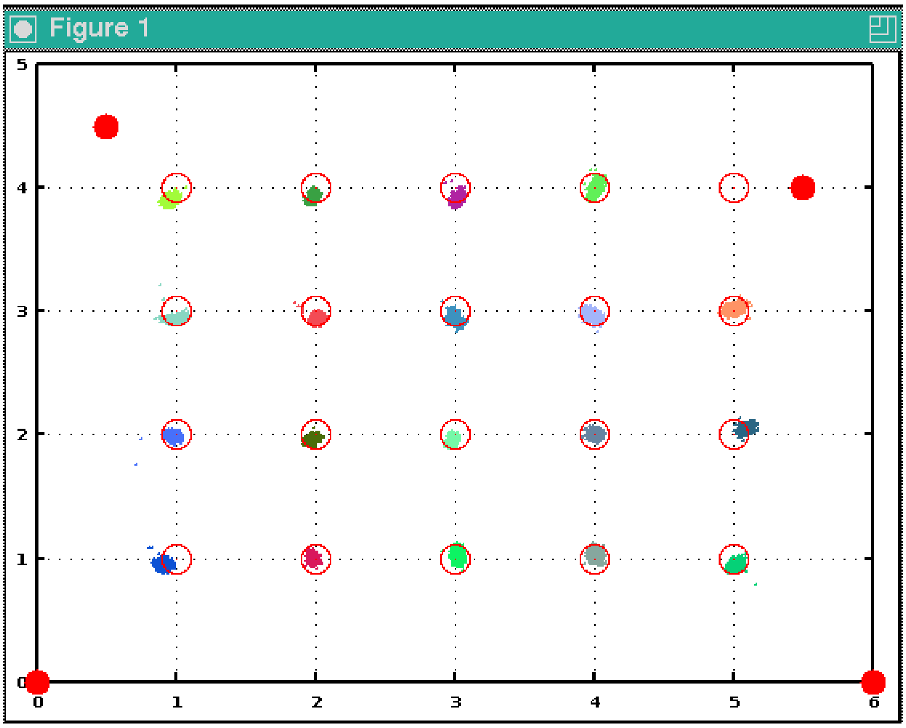


Figure 27: Example scatter plot

You should expect to achieve results similar to the above if your system is installed and configured correctly.

8 APPENDIX A: ANCHOR UNIT DETAILS

This section gives further details of the anchor unit including the pin-outs of all connectors and the function of all the on-board switches and Jumpers.

8.1 OVERVIEW SPECIFICATION

Table 9 Anchor unit specification

Parameter	Specification
Power Supply	micro USB or PoE
Dimensions (excluding flange)	140 mm x 110 mm x 35 mm (5.5” x 4.3” x 1.4”)
Physical mounting	35 mm “Top Hat” Din Rail (supplied)
Backhaul Connector to Ethernet hub or PC	RJ45, Ethernet 100BaseT
RF Interface	SMA connector for supplied UWB antenna
Transmit Power Spectral Density	-41 dBm/MHz
Transmit Signal Bandwidth	500 MHz

8.2 OPERATOR CONTROLS AND INDICATORS

8.2.1 Operator controls

There are no external operator controls on the anchor unit.

8.3 EXTERNAL CONNECTORS

8.3.1 Overview

All external connectors are located at either end of the anchor unit. RF connection is at what is intended to be the uppermost end when physically installed, and the Ethernet and USB connections at the lowermost end.

Table 10 External Connectors of anchor unit

Designation	Description
UWB	UWB antenna connection
ETHERNET	100BaseT Ethernet connection for backhaul to the PC, (and power over Ethernet)
USB	Micro USB connection for power and local configuration

8.3.2 “UWB” SMA antenna connector

External UWB antenna connector

Table 11: “UWB” connector pin out

Pin	Function
J1-Centre	RF signal
J1-Body	Ground

8.3.3 "USB" Micro USB connector

Table 12: "USB" Micro USB connector pin-out

Pin	Function	Description
USB-1	V_{USB} +5 V IN	
USB-2	USB DM	
USB-3	USB DP	
USB-4	ID	
USB-5	GND	

8.3.4 "ETHERNET" 100BaseT Ethernet connector

For the 8-pin RJ45 connector, the function of each pin is shown below.

Table 13: "ETHERNET" 100BaseT Ethernet connection

Pin	Function	Description
ETH-1	TX +	
ETH-2	TX -	
ETH-3	RX +	
ETH-4	DC +	
ETH-5	DC +	
ETH-6	RX -	
ETH-7	DC -	
ETH-8	DC -	

9 Appendix B: Tag Unit Details

9.1 Overview

Parameter	Specification	
Power Supply	Internal CR123	micro USB
Dimension	93 mm x 48 mm x 23 mm (3.6” x 1.9” x 0.9”)	
Power Control	One sliding on/off switch	
Tag Status Indicator	LED (Charging / Blinking)	
Configuration Interface	Micro USB	
Transmit Power Spectral Density	-41 dBm/MHz	
Transmit Signal Bandwidth	500 MHz	

9.2 Operator controls and indicators

9.2.1 On / Off Switch

To turn on the tag unit slide the switch to the “ON” position. The LED will flash after 6 seconds indicating that the unit is working.

9.2.2 LED

Multi-coloured LED to indicate the state of the unit.

LED	State	Description
Flashing	Blinking	Unit is actively transmitting “Blink” messages – the interval of blinking of the LED corresponds to the Tag Blink interval.

9.3 External Connectors

9.3.1 “USB” Micro USB connector

This is the Micro USB connector intended for recharging and configuring the tag.

Table 14: “USB” Micro USB connector pin-out

Pin	Function
USB-1	V_{USB} +5 V IN
USB-2	USB DM
USB-3	USB DP
USB-4	ID
USB-5	GND

10 Appendix C: Glossary of Terms

Abbreviation	Full Title	Explanation
CLE	Central Location Engine	
LOS	line of sight	Physical radio channel configuration in which there is a direct line of sight between the transmitter and the receiver
NLOS	non line of sight	Physical radio channel configuration in which there is no direct line of sight between the transmitter and the receiver
R95	radius of 95% confidence	Given a reported location there is a 95% probability that the actual location is within the specified radius.
RF	radio frequency	Generally used to refer to signals in the range of 3 kHz to 300 GHz. In the context of a radio receiver, the term is generally used to refer to circuits in a receiver before down-conversion takes place and in a transmitter after up-conversion takes place
RTLS	real time location systems	System intended to provide information on the location of various items in real-time.
RX	receive or receiver	Term used to refer to the receiver section of a transceiver or the operation of receiving signals
TDOA	time difference of arrival	Method of deriving information on the location of a transmitter. The time of arrival of a transmission at two physically different locations whose clocks are synchronized is noted and the difference in the arrival times provides information on the location of the transmitter. A number of such TDOA measurements at different locations can be used to uniquely determine the position of the transmitter.
TOF	time of flight	The time taken for a radio signal to travel between the transmitting antenna and the receiving antenna
TX	transmit or transmitter	Term used to refer to the transmitter section of a transceiver or the operation of transmitting signals
USB	Universal Serial Bus	Serial connection scheme originally designed for connecting external peripherals to PC's.
UWB	ultra-wide band	A radio scheme employing channel bandwidths of, or in excess of, 500MHz

11 APPENDIX D: PC BASED CLE DIAGNOSTIC MESSAGES AND SCREEN VIEWS

11.1 INTRODUCTION

In TTK1000 system, the CLE has its own message display window where relevant information is presented.

11.2 CLE START-UP

When the CLE is started by double-clicking on *LE.exe* it begins to run, opens connections to which the Control client connect and searches for the anchors on the same network.

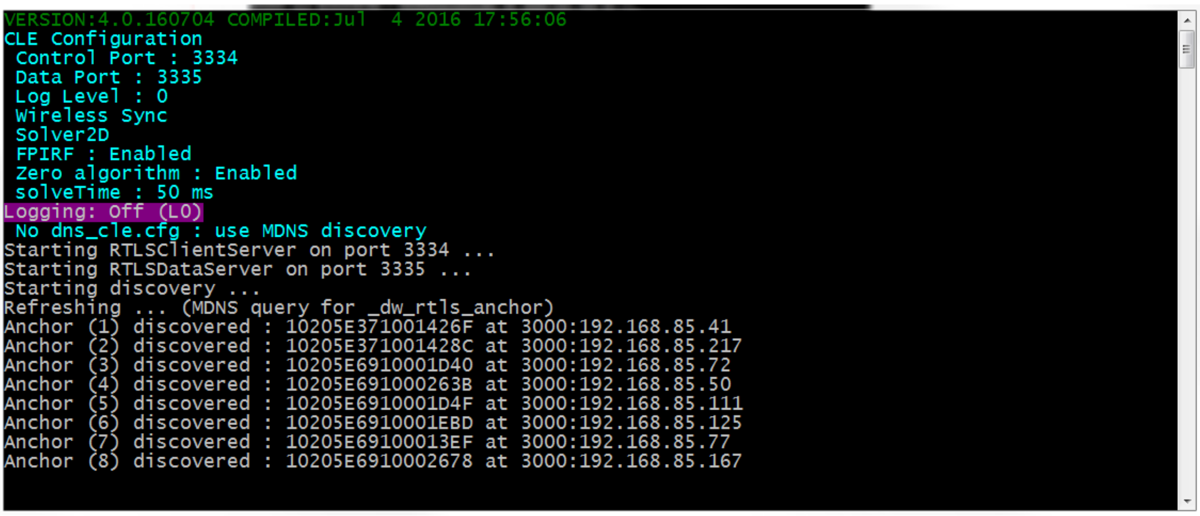


Figure 28: CLE start-up and anchor discovery with mDNS

11.3 CLE CONNECTION TO / CONFIGURATION OF ANCHOR NODES

When instructed by the Control Client to connect to the anchor nodes, the CLE connects to each anchor in turn and transfers the configuration information entered via the Control Client.

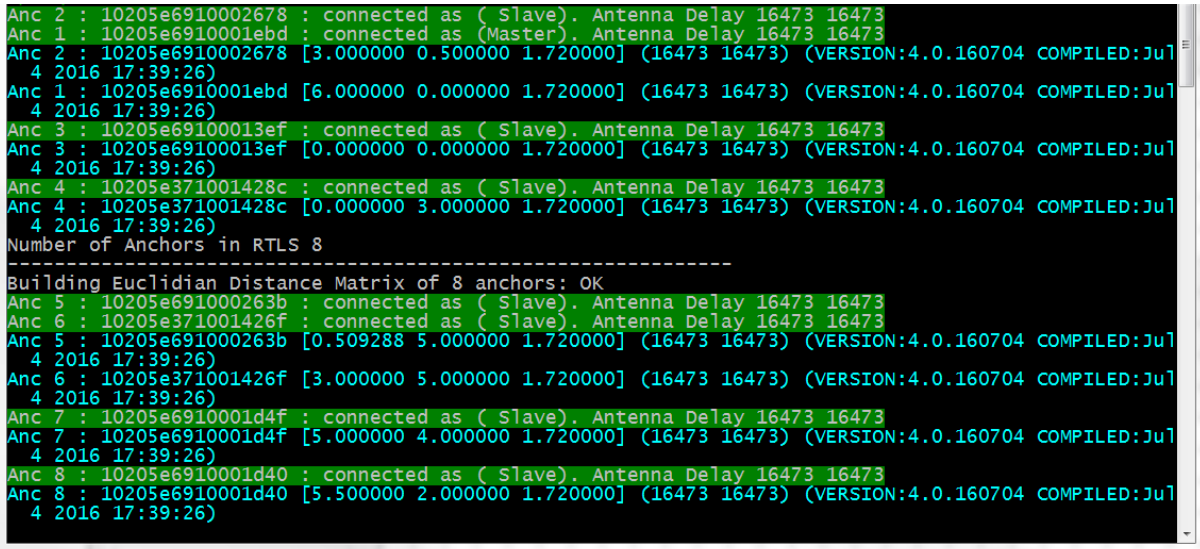


Figure 29: CLE connection to and configuration of anchor nodes

11.4 WIRELESS SYNC START-UP

When instructed by the Control Client to commence wireless synchronization the CLE instructs the anchors that are configured as the masters to begin transmitting clock calibration packets.

The arrival time of each clock sync packet at each anchor is reported by the respective anchors to the CLE and can be seen on the screen.

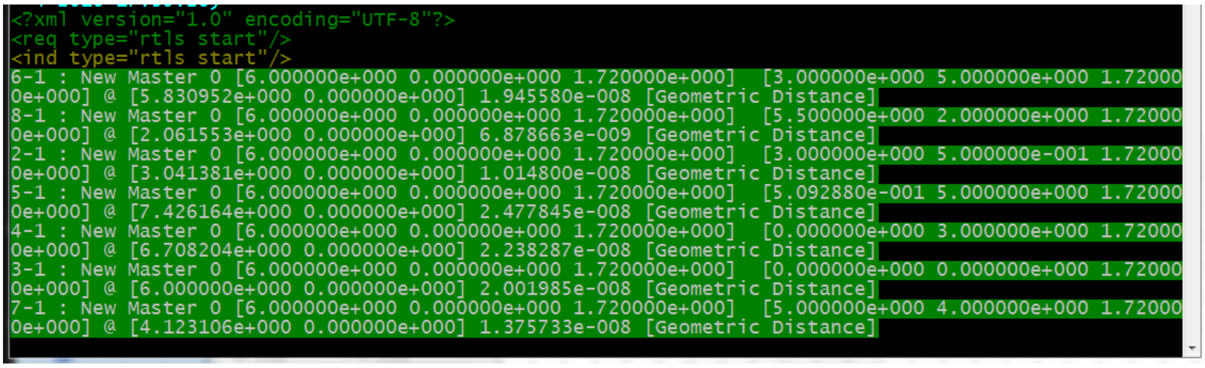


Figure 30: Wireless sync start-up

11.5 TAG BLINKS

On **Figure *31* Tag blinks** below five tags are blinking in a small single-master RTLS network.

Some of the blinks are failed due to collisions. This is an "*RX_BLINK:..* " information messages shown in the red line in the figure below which indicate that multilateration of the some blinks were failed.

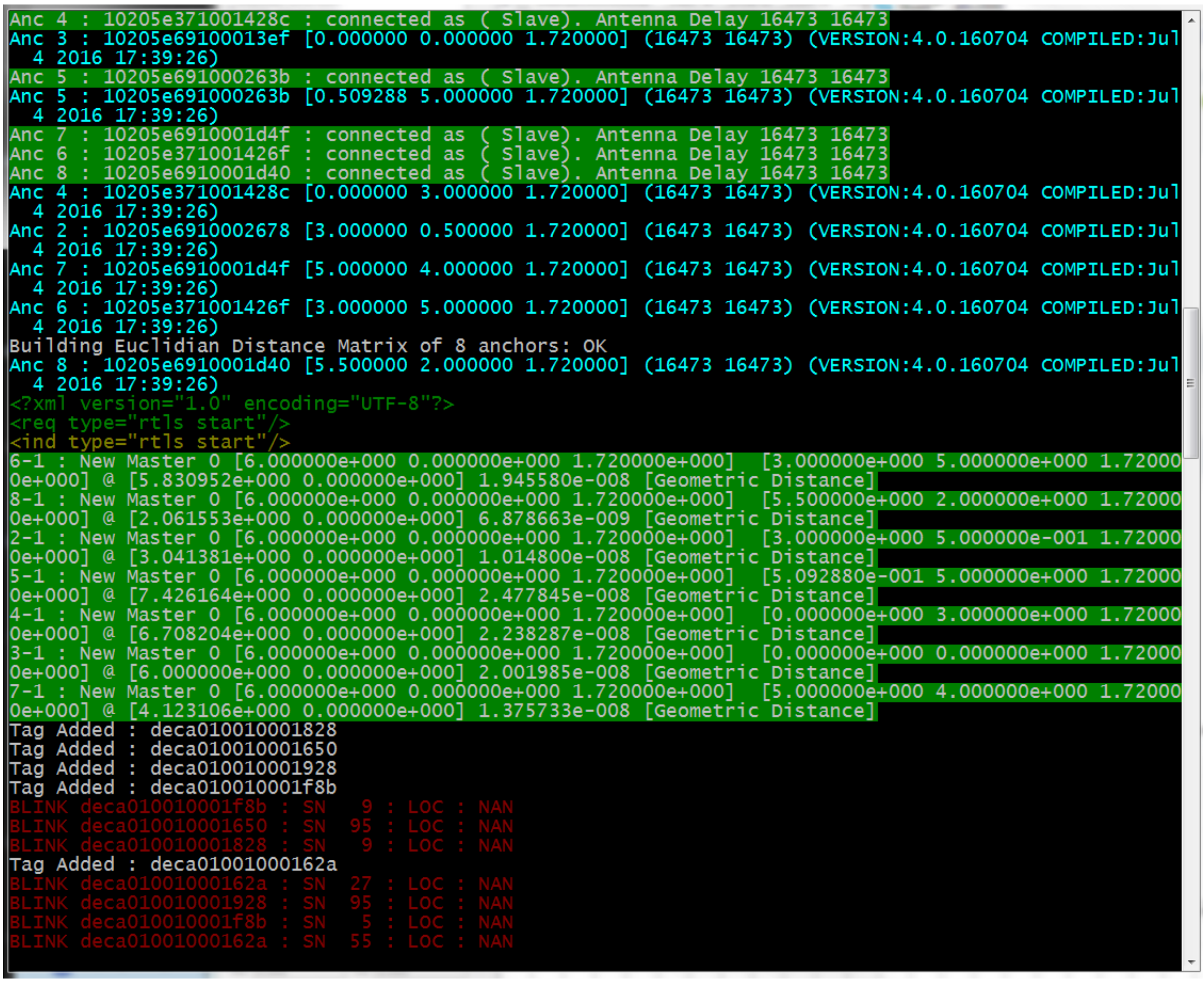


Figure 31 Tag blinks

12 APPENDIX E: DHCP SERVER INSTALLATION

12.1 INTRODUCTION

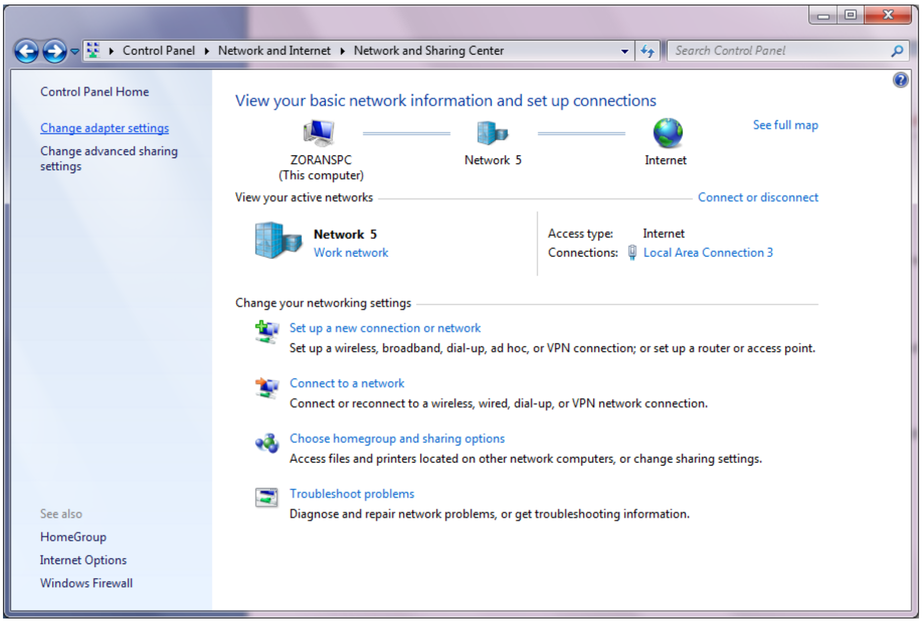
When setting up the RTLS and connecting anchors on a network without a DHCP server the user needs to install a DHCP server on the PC on which the Control Client is running.

WARNING! To avoid the DHCP server assigning IP addresses to the network, only start the DHCP server when PC is isolated from other networks, i.e. ensure Wi-Fi is disabled and no other network connection exists.

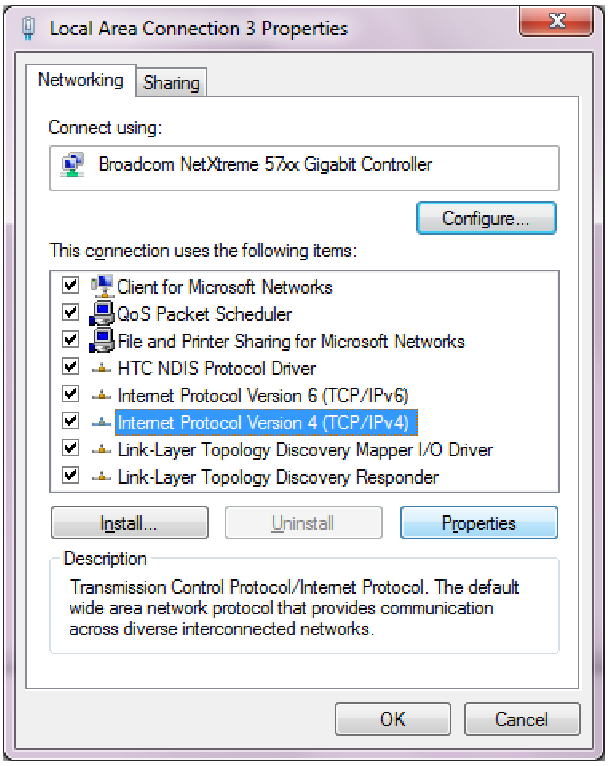
When finished with the RTLS, stop the DHCP server before enabling the Wi-Fi or other network. Click "Stop" and then "Remove" to kill the DHCP server & reset IP address automatically.

12.2 SET STATIC IP ADDRESS ON THE PC

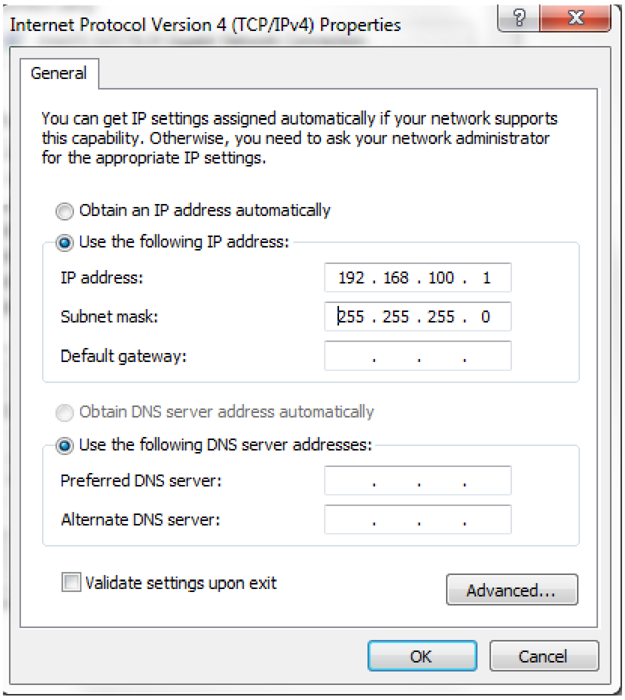
On the Windows 7 PC: open "*Control Panel\Network and Internet\Network and Sharing Centre*" then select "*Change Adapter Settings*" in the left column.



Then right click and choose "*Properties*" on the Local Area Connection. In the "*Networking*" tab select "*Internet Protocol Version 4*" and click "*Properties*" button.



In the "*General"* tab select "*Use the following IP address*" and configure the PC's IP address to match the network settings of the DHCP server. E.g. the settings below match the settings in the *Running DHCP Server*.

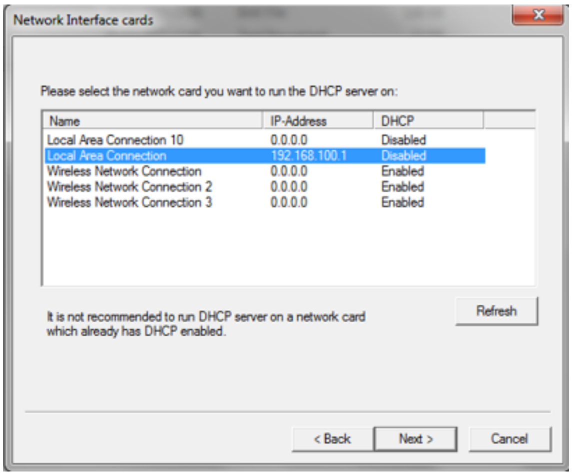


12.3 DHCP SERVER INSTALLATION

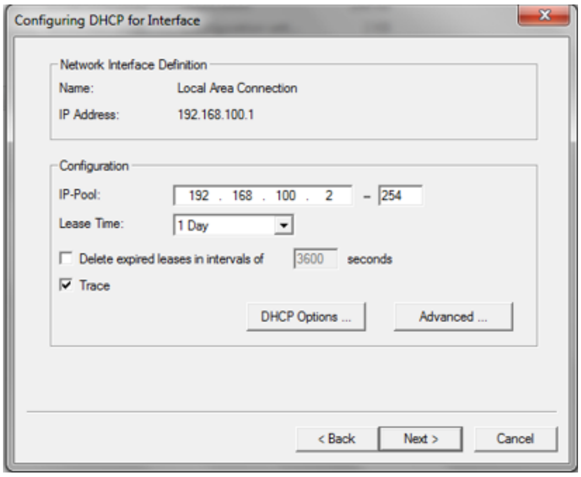
A DHCP server can be obtained from http://www.dhcpserver.de/ website. *Running DHCP Server* section on the right top of the website explains how to configure and run the server.

After unzipping the files, please follow the steps below to configure and run DHCP server.

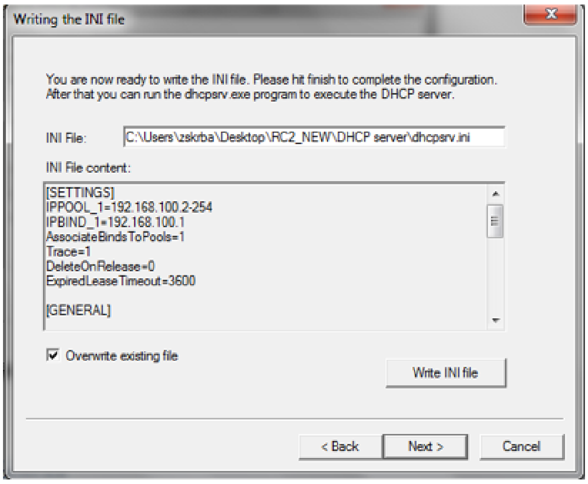
1. Run the executable file: "*dhcpwiz.exe*". Select the network that you have configured on which DHCP server will run.



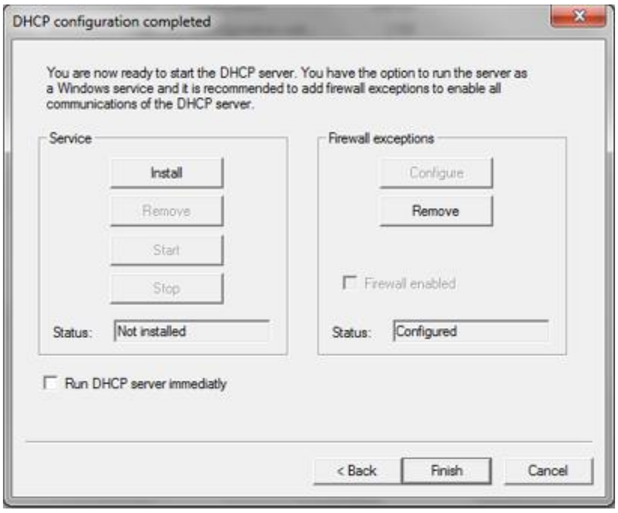
2. Enter the range of IP address which will be sent to anchor units.



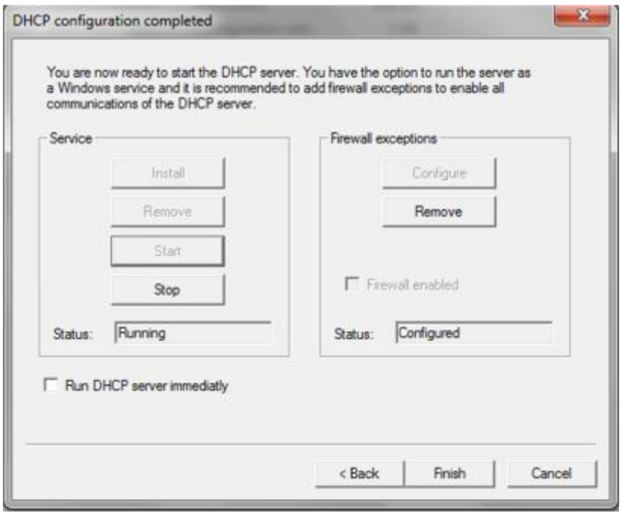
3. Tick the "*Overwrite existing file*" option then press "Write INI file" button to write the file and choose "Next" to continue.



4. Press “Install” then “Start” to run DHCP server.



5. Now DHCP server is running successfully on you PC. Then you can click “Finish” button to exist configuration.



13 APPENDIX F: BIBLIOGRAPHY

Table 15: Table of References

Ref	Title
1	TTK1000 RTLS System Architecture
2	TTK1000 RTLS CLE Architecture
3	TTK1000 RTLS CLE Controller API Spec
4	TTK1000 Anchor Software Guide
5	TTK1000 Tag Software Guide
6	APS003 Real Time Location Systems
7	Decawave DW1000 Datasheet
8	Decawave DW1000 User Manual
9	IEEE 802.15.4-2011 or "IEEE Std 802.15.4™-2011" (Revision of IEEE Std 802.15.4-2006). IEEE Standard for Local and metropolitan area networks— Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs). IEEE Computer Society Sponsored by the LAN/MAN Standards Committee. Available from http://standards.ieee.org/

14 FURTHER INFORMATION

Decawave develops semiconductors solutions, software, modules, reference designs - that enable real-time, ultra-accurate, ultra-reliable local area micro-location services. Decawave's technology enables an entirely new class of easy to implement, highly secure, intelligent location functionality and services for IoT and smart consumer products and applications.

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