# TABLE OF CONTENTS

1 PROJECT BACKGROUND .................................................................................................................. 3
  1.1 Localization .............................................................................................................................. 3
    1.1.1 AOA ................................................................................................................................. 3
    1.1.2 RSS ................................................................................................................................. 4
    1.1.3 Time Based Methods ........................................................................................................ 4
  1.2 UWB and Localization ................................................................................................................ 5
2 PROJECT DESCRIPTION .................................................................................................................. 5
3 EQUIPMENT AND PROJECT MILESTONES .................................................................................. 7
  3.1 Required Equipment .................................................................................................................. 7
    3.1.1 Transmitter ....................................................................................................................... 7
    3.1.2 Receiver ........................................................................................................................... 7
    3.1.3 Transceiver ...................................................................................................................... 7
  3.2 Project Milestones ....................................................................................................................... 8
    3.2.1 Milestone 1 – Preliminary Research ................................................................................... 8
    3.2.2 Milestone 2 – Choose Hardware Implementation .............................................................. 8
    3.2.3 Milestone 3 - Build and Test Required Transceiver .......................................................... 9
    3.2.4 Milestone 4 - Implement and Test the Positioning System ................................................. 9
    3.2.5 Milestone 5 - Web Page Design ....................................................................................... 9
    3.2.6 Milestone 6 - Final Report ................................................................................................ 10
4 GROUP BIOGRAPHIES .................................................................................................................. 10
  4.1 Dave MacLellan ........................................................................................................................ 10
  4.2 Roland Geisler .......................................................................................................................... 11
  4.3 Paul Wardell ............................................................................................................................. 11
  4.4 Henri Balikci ............................................................................................................................. 12
  4.5 Saeid Nassaji ........................................................................................................................... 12
5 REFERENCES ................................................................................................................................. 13
1 PROJECT BACKGROUND

1.1 Localization

“Positioning” or “localization” refers to the process of determining a target’s location, usually in reference to several distinct and separate detectors. This can be accomplished using a number of different technologies and methods. Some common implementations are radar, GPS satellites, and RF (radio) based locators. This project will focus on RF based localization, which has specific advantages over other implementations.

RF based localization is ideal for indoor environments due to RF signals’ ability to penetrate or otherwise navigate around intermediate structures. GPS or other methods are similarly unsuited to these environments due to the same factors. RF can also co-exist better with the radio spectrum inside the building, providing less frequency interference with existing wireless devices. The applications for RF localization are numerous and important. Some examples are robot positioning and navigation, item location within large warehouses, and personal location.

At a basic level, radio based localization methods focus on the production of signals by transmitter nodes, which are then received by the target node or vice versa. The way these signals are produced, detected, and the number of receivers/transmitters needed to accomplish the task can be accomplished in several different ways. Three of the most popular methods are outlined below.

1.1.1 AOA

The angle-of-arrival method utilizes several reference nodes which are in contact with a target node as shown below in Figure 1. This figure shows a 2D position measuring system. The angle of the signal received can be measured and used to determine the position of the target. This method has several drawbacks. First, the nodes are required to have sometimes large antennas which can be costly. Secondly, with reflection and scattering due to multipath interference, the algorithms used to determine the location precisely can become unwieldy.

![Figure 1 - Simple Angle-of-Arrival System](image)

1.1.2 RSS
A fairly simply and popular method, received signal strength (RSS) localization is carried out by measuring the relative loss of signal strength from target node to reference nodes. An example system is shown in Figure 2, where the three reference nodes are shown to be in communication with the target node. The resulting triangulation based on the signal strength arriving at the receiver nodes can be used to locate the target. The drawbacks to this method are based on distance (loss of signal due to large attenuation) and differences in the channel parameters of the receiver nodes.

![Figure 2 - Received Signal Strength System](image)

### 1.1.3 Time Based Methods

Several different time based methods exist. These methods focus on measuring the time required for a signal to pass from a transmitter to a receiver, which can then be used to calculated the distance and therefore the location. Several different time based methods exist and are used.

One-way time of arrival positioning (TOA) is the most basic. The receiver and transmitter are calibrated such that they have very accurately timed signals, then the distance between the two are calculated from the send and receive times. This is difficult to implement, however, as the synchronization between the receiver and transmitter is not easily accomplished and may deviate over time.

A way to get around the synchronization between the target and the reference nodes is to have only the reference nodes synchronized, and the target node can have an unknown
synchronization. Since the reference nodes are synchronized the difference in time between the signals arriving at the target can be easily calculated and used to determine the distance. Synchronization between anchor nodes can also be implemented relatively easily due to their inherently static nature; usually the target is the only moving piece and therefore hard wired synchronization can connect the reference nodes together.

1.2 UWB and Localization

Ultrawide-band radio technology describes RF signals operating at very high bandwidths (greater than 500MHz) and much lower power. This RF technology has many applications, from high data rate communications to low power radar imaging. It can also be used for localization. By using a time based localization scheme as outlined above, UWB’s high bandwidth can be used to very precisely locate the target. Additionally, it is a very robust technology as it operates at very low power relative to other equipment and thus will not cause interference, as well as its redundancy in having a wide variety of frequency components.

However, synchronization is a large problem with UWB based localization methods. The communication between anchor nodes or anchor nodes and target nodes would be costly as UWB clocks must be very precise and small errors can have large effects on the measurement. This high dependence on time necessitates the development of a different time based measurement method in order to keep costs and reliability low. A scheme based on asynchronous measurements (no synchronization between the anchor/target nodes) would be ideal, and the implementation and theory behind such a system is the focus of this project and will be discussed in the following sections.

2 PROJECT DESCRIPTION

The goal of this project is to create a low power, fully wireless, yet precise localization system. The method of choice is to use an Asynchronous Time Difference of Arrival Positioning System (A-TDOA) to eliminate the need for accurate synchronisation and wires.

The method of A-TDOA consists of using asynchronous transmitters, transceivers (targets), and a receiver. The transmitters periodically send a signal which is amplified and retransmitted by a transceiver. The receiver receives both signals and by calculating the time difference of arrival, it can place the transceiver on an ellipse with itself and the transmitter as foci. When this is done using three different transmitters, the ellipses intersect at one point and the location of the transceiver can be solved for. This system is described by Shuai He in his paper and shown on the following page in Figure 3.
Our research will consist of finding out how to obtain or build the components of this system while keeping down costs and maximizing accuracy. Another aspect of our research will focus on how to efficiently solve for the location of the target as the algorithm would eventually have to run on a slower embedded system.
3 EQUIPMENT AND PROJECT MILESTONES

This section will discuss the overall goal of the project in terms of required deliverables and the work plan to reach them. The main goal of this project is to implement the Asynchronous Time Difference of Arrival theory outlined by Shuai He in his paper titled A-TDOA Positioning System by using readily available hardware such as WiFi or Bluetooth. The following milestones show the progression that this project will take. It is still uncertain exactly which milestones will be completed for this design course, ELEC/CENG 399, and which ones we can continue with in ELEC/CENG 499. Our hope is to have a working system upon project completion, however understand some milestones may take much longer than expected.

3.1 Required Equipment

The required equipment for this project includes several pieces of hardware as well as software to integrate the system. The project will include 3 transmitter nodes, 1 receiver node, and one transceiver. The following hardware is required:

3.1.1 Transmitter

Two transmitters are required to transmit an RF signal to the transceiver and receiver with a capable range of 10 – 15 m in order to sufficiently cover a standard size meeting room (approximately 6 by 8 metres). The transmitters should be low power as they will be placed strategically throughout the room and will most likely operate from battery. These transmitters will be 2 of the three anchor nodes as shown in Figure 3.

3.1.2 Receiver

One receiver is required to receive signals from each transmitter as well as the transceiver. The receiver will be the anchor station and will be connected to the main workstation for signal processing. Because of this, it does not require low power. This receiver will be the remaining anchor node.

3.1.3 Transceiver

A transceiver capable of transmitting signals to the receiver and receiver signals from each transmitter is required. This device will the used for location finding and is thus required to be small in scale and low power.

3.2 Project Milestones
3.2.1 Milestone 1 – Preliminary Research

Our first step in this project was to complete preliminary research on A-TDOA, existing localization technologies, and UWB technology. This milestone was completed and implemented into this report as part of the project background.

3.2.2 Milestone 2 - Choose Hardware Implementation

We are considering the two most popular commercial products to implement our A-TDOA localization system; WiFi and Bluetooth. Both types of devices are readily available and work under the unlicensed radio frequency of around 2.4 GHz. Things to consider include cost and availability, power consumption, and integration.

WiFi is the most popular wireless communication platform on the market. It allows devices to electronically transmit and receive data, in the form of RF, over a wireless network. It operates at 2.4 GHz and is based on IEEE 802.11 standards. The 802.11 standard has had several changes over the years which lead to much higher data rates. Currently, the most popular versions are 802.11g with data rate speeds up to 54 Mbit/s and 802.11n with data rate speeds up to 600 Mbit/s. Because of these features, WiFi typically requires a large amount of power to operate.

The 802.11 standard has a basic peer-to-peer operation mode. This allows each WiFi device to be able to communicate with each other. It uses Orthogonal Frequency-Division Multiplexing (OFDM) to encode data and has a typical indoor range of 25 metres. WiFi uses WiFi Protected Access (WPA) and WPA2 security protocols to ensure privacy protection between shared WiFi users.

Bluetooth is a wireless communications standard used between small devices such as mobile phones. It operates in the 2.4 MHz frequency band and operates in 3 classes based on their range. Class 1 has an approximate range up to 100 metres and has a 100 mW maximum power output. Class 2 is the most common module as it is in most cell phones and electronic devices. It has a range up to 10 metres with maximum power output of 2.4 mW. Class 3 has a 1 mW output power but has a very limited range of up to 1 metre. To fit our project, a Class 2 hardware implementation would be selected as it fits the required range at a relatively low power.

Bluetooth uses an ad-hoc computer network called a piconet. It uses a packet protocol for communication with a master – slave interface. A Bluetooth master can communicate with up to 7 devices simultaneously. This type of interface would allow us to easily network our hardware together. Bluetooth is very compact and can purchased off the shelf for a relatively low price.

3.2.3 Milestone 3 - Build and Test Required Transceiver
Once the hardware implementation has been selected, our next task is to acquire a transceiver. We have a couple options available to us such as purchase an off the shelf transceiver to our specifications or build one to our specifications. Once chosen we will have to test that the transceiver will work properly in a basic transceiver to receiver setting.

Purchasing a transceiver would be the easiest option as no assembly would be required, only integration. Transceivers can be bought fairly cheap and a Bluetooth or WiFi model would be readily available. This would allow us to get started rather quickly on the project and start testing our system.

Building a transceiver would allow us to have a device to our exact specifications. It would give us an extensive look into what is required to build a transceiver. This may be too extensive for this project, however the experience gained during building would be greatly beneficial.

3.2.4 Milestone 4 - Implement and Test the Positioning System

After all the required equipment is acquired, we will begin testing the A-TDOA theory in the hardware implementation we have selected. By setting up a test room and connecting the receiver through a PC, we will test the theory implementation using MATLAB. MATLAB gives us a powerful processing tool that is relatively easy to use and something that we are familiar working with.

We will test the system by implementing each transmitter to ensure the receiver receives each RF signal and then implement the transceiver. This milestone will take the longest to complete as our testing will be quite extensive. In order to fully test the system will have to perform the experiment in several locations to prove the accuracy of the A-TDOA and to show that the system can be easily implemented anywhere.

3.2.5 Milestone 5 - Web Page Design

A required milestone of this project is a professional looking web page that successfully displays our project. This will include an introduction to the project, background information, and required progress reports. This milestone will be worked on throughout the project and will simply be updated on project progress.

3.2.6 Milestone 6 - Final Report
Upon project completion, a final report shall be submitted for review. The report will include a project overview, a detailed project description, workload distribution and accomplishments, project discussion, project summary, and future project goals.

The following chart displays our expected project timeline. Our first project meeting with our supervisor, 4 October 2012, is listed as day 0, and the final report due date, 3 December 2012, is listed as day 60.

![Figure 4 - Proposed Project Timeline](image)

### 4 GROUP BIOGRAPHIES

#### 4.1 Dave MacLellan

Dave was born in Belleville, Ontario and grew up in nearby Trenton, Ontario. After graduating High School, Dave joined the Royal Canadian Navy and received his Electronics Technician Diploma from the Marine Institute of Memorial University, in St. John’s, Newfoundland in 2006. He worked as a radar technician working with navigational radar systems, fire control systems, and passive directional and detection systems from 2003 to 2009. Throughout his time in the Navy, Dave got to visit several parts of the world and gained valuable experience working on a team in a technical environment.

Currently, Dave is taking Computer Engineering at the University of Victoria and is now in term 3B. He really enjoys the program so far and is looking forward to this design course. Outside of school, Dave’s interests include playing sports, music, technology, and spending time with his
family. He has been married 5 years and currently has two young sons. Dave feels his previous experience working in a team environment will be a great asset to this project.

### 4.2 Roland Geisler

Born and raised in the small rural town of Ashern Manitoba, Roland grew up enamoured with technology and science. After graduating from high school with some poor math grades in 2003, Roland moved to Winnipeg and enrolled at the University of Manitoba in a general Arts degree track. After a year of writing papers, he moved on to other things working for several years in retail as a bookseller. In 2007 he rekindled his love with science and Engineering and signed up for the Electrical Engineering Technologist program at the Red River College of Winnipeg. Excelling in his studies he decided to leave the diploma program and move immediately into a degree program. Roland applied at the University of Victoria because of its excellent co-op program and was accepted and enrolled in 2009.

Since that time Roland has continued to do well in his studies. He enjoys all his classes, but especially those in signal processing/communications and physics and power related fields. He has also received a number of co-op work terms working in such diverse fields as radio technology with Daniels Electronics of Victoria and Electrical Engineering Consulting with Applied Engineering Solutions. In his personal time, he loves to read science fiction novels and stay up to date with politics and news from around the world. He is also an avid gamer (both board and video) and technology enthusiast.

Roland is interested in the A-TDOA localization project because of its ingenuity and the diverse applications to which this fundamental research could assist. He is also very interested in UWB research due to the ever increasing necessity of high bandwidth technologies that can coexist with the ever increasingly crowded radio spectrum.

### 4.3 Paul Wardell

Paul is a fourth year computer engineering student at the University of Victoria. Throughout his studies at UVic, Paul has developed an interest in networks and has chosen to complete a specialization in networks, security, and privacy.

Paul’s interest in networks and security increased further during his four co-op work terms. During his first two work terms as an Application Delivery Specialist at GeoBC, Paul was responsible for deploying and configuring numerous applications for the province of British Columbia. He was also involved in a large IT restructuring project where he was responsible for migrating applications from one branch of the Ministry to another. This work allowed Paul
to develop many skills, including working within a diverse team, effective communication, and precision, while gaining valuable knowledge about networking and security for web-based applications.

Paul’s third and fourth co-op work terms were as a Consultant at CGI Group Inc, where his efforts were focused on a large healthcare related, web-based, application. His work at CGI included middleware support and performing upgrades on numerous environments. During his time at CGI, Paul increased his knowledge and interest in networks, security, and privacy, as these are key elements of a large-scale healthcare application.

4.4 Henri Balikci

Henri was born in Quebec and moved to BC in 1998. He enrolled in computer engineering at the University of Victoria after graduating high school in 2008. He is currently in his fourth year and taking the software specialization. He has completed 2 coop work terms: one as IT support for the Fleet Maintenance Facility Cape Breton and one as a software debugger for RIM.

Henri is interested in the A-TDOA localization project because of its ingenuity, possible applications and because it involves both hardware and software.

4.5 Saeid Nassaji

Saeid is a fourth year Electrical Engineering student pursuing a specialization in Network Security. Raised during the age of the internet, Saeid has always had a fascination with computer networking. This interest fuelled his desire to learn about web development and design resulting in skills that he has successfully applied to both personal and freelance projects.

As an extension of his previous work terms, Saeid is currently working as a Junior Engineer at the Naval Engineering division of Engineering and Construction giant SNC-Lavalin. While he has not been directly involved in network related projects in this position, Saeid has nonetheless been exposed to the importance of network security in a sensitive environment. The Department of National Defence is one of the primary clients of SNC-Lavalin’s naval division. Therefore any sharing of sensitive information such as Engineering drawings and surveys needs to be done over a secure and reliable network.
5 REFERENCES