Wi-Fi Maritime Communications using TV White Spaces

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Preparation for the MSc Dissertation

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Abstract

Currently, in the maritime environment, narrowband wireless communications are dominant. To support voice communication between shore-to-ship and between ships, HF/VHF analogue channels are typically used. The cellular networks (GSM/GPRS/3G) are an alternative option only when situated close to the shore. Broadband wireless communications are limited to near shore zones or to satellite communications, which are expensive for the majority of maritime companies.

This dissertation aims to implement a low cost communication solution based on Wi-Fi operating in the so called TV White Spaces band (700 MHz), available after the migration to the digital television service. The longer transmission ranges and better propagation characteristics make it ideal for long range transmissions in comparison with 2.4 GHz.

The major goal of this work is to study the performance and viability of such network and to analyse its behaviour in a real maritime environment with the shore-to-ship scenario. To carry out this measurements, the tests will be done with a partnering fishing company, after installing the system is their boats.
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<th>Description</th>
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<tr>
<td>AIS</td>
<td>Automatic Identification System</td>
</tr>
<tr>
<td>BER</td>
<td>Bit Error Ratio</td>
</tr>
<tr>
<td>FER</td>
<td>Frame Error Ratio</td>
</tr>
<tr>
<td>HF</td>
<td>High Frequency</td>
</tr>
<tr>
<td>INMARSAT</td>
<td>International Maritime Satellite Organization</td>
</tr>
<tr>
<td>MF</td>
<td>Medium Frequency</td>
</tr>
<tr>
<td>MRTP</td>
<td>Multiflow real-time transport protocol</td>
</tr>
<tr>
<td>NANET</td>
<td>Nautical Ad-hoc Network</td>
</tr>
<tr>
<td>OFDM</td>
<td>Orthogonal frequency-division multiplexing</td>
</tr>
<tr>
<td>P2P</td>
<td>Peer to Peer communications</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>RSSI</td>
<td>Received Signal Strength Indication</td>
</tr>
<tr>
<td>TRITON</td>
<td>Trimedia Telemetric Oceanographic Networks</td>
</tr>
<tr>
<td>TVWS</td>
<td>Television White Spaces</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over IP</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
</tr>
</tbody>
</table>
Chapter 1

Introduction

1.1 Context

Currently, broadband wireless access and expansion of terrestrial wireless networks, such as wireless LANs (802.11) and mobile communication networks have exponential increased. With the expansion of internet and system technologies, wireless broadband access started to become need. But when we talk about maritime communications the scenario is completely different. While wireless broadband access is normally available in land by installing simply base stations on the ground, in maritime environment it’s almost impossible to use the same system due to the geographically and conditions of the sea.

The current wireless communications at sea are mainly supported by HF or VHF bands [1], that are capable to transmit long distances but without supporting high data rate services. In order to get high data rate transmission are used satellite communications (e.g INMARSAT can reach 64 kbps bandwidth per link) as shown in Figure 1.1. In this situation, the cost of end device maintenance and operation is too expensive, and majority of registered ships don’t have the required satellite equipment installed. For example, the cellular network like GSM or 3G is used by most fisheries companies in comparison with satellite communication due the low cost, but it only provides near shore connectivity.

1.2 Motivation

In the actual scenario of maritime communications there are some requirements that have to be considered [4]. Including the need for low cost communications, need for high bandwidth networks and need of high speed communications up to 100km away from the shore. As expressed before, for some fishermen companies and small boats operating relatively near the shore their profit margins are too low to justify buy expensive satellite equipment, that’s why is important to establish a low cost solution that can be accessible to all. Also, more and more over is necessary to establish new information systems, which require real time data transfers, live VoIP and video surveillance streaming, to provide the minimum quality of service far away from the shore. And
Finally an important requirement is to maximize the range to include most part of the exclusive economic zone in order to cover the maximum fishermen ships possible with the broadband service.

These requirements are being resolved with new emerging solutions and systems in nowadays maritime communications. With the transition to digital television, the band 700 MHz in analogue spectrum has been released. This spectrum, named TV White Spaces (TVWS), can operate with longer transmissions ranges, and particular characteristics make this spectrum ideal for long range communications. It's expected to have better performance with long distances due to the better propagation in comparison with Wi-Fi operating at 2.4 and 5.8 GHz.

1.3 Objectives

The proposed solution is to test the performance and feasibility of a long range Wi-Fi (802.11g) maritime connection using TVWS at 700 MHz. The experiment will be implemented in a real scenario using a fishing company ship that can give more credibility to the results.

To reach this goal the following objectives will be considered:

- Review technologies and principles of propagation models in maritime communications;
- Study experiments, proposed propagation models and results related to this topic;
- Implement a test bench for a Wi-Fi based maritime communications including land and boat equipment;
- Test the Wi-Fi performance in shore-to-boat maritime scenario;
• Analyse and compare the measured results with theoretical models and obtain conclusions about the performance of the implemented solution.

1.4 Structure

The document is organized as follows. In Chapter 2 we describe the state of the art and all related works in this field. Chapter 3 describes the methodology used. The work plan is defined in Chapter 4.
Chapter 2

State Of The Art

In this chapter, we present the solutions proposed so far to implement maritime wireless broadband. The possible solutions for maritime communications are discussed, including many scenarios, protocols and possible propagation models. In addition, related experimental results obtained in maritime environments are presented.

2.1 Maritime Communications Environment

The maritime communications environment has unique properties and challenges when compared to the land environment [9]. It is not so much in how to build new technologies, but in how to manage them to face complex and specific maritime communications characteristics. It is somehow difficult to predict maritime scenario state, because of that it provokes a weaker and not stable communication. This dynamism is due to radio frequency propagation over water, surface multipath reflection, wave occlusion, blockage of RF signal provoked by near ships and also wave rocking motion. A simple fact is that the sea surface is in constant motion (sea state), which leads to unstable connection and link quality. This causes boat rocking and contributes to a continuous changes in the antenna orientation and height, consecutively modifies the antenna gain, alignment and received signal power. Because of this fact the quality of the maritime connection link may likely experience periodic degradation, provoking long delays and increasing the number of packets retransmission. The sea state is measured by parameters of significant sea wave height, average sea wave length, and average sea wave period. The Figure 2.1 shows two ships in the sea moving and the movement effect causes in the received signal. It’s important to note that changes in antenna’s gain caused by variations in antenna’s height is relatively small compared with variations by antenna’s tilt or oscillation. The received signal strength is more significantly affected by boat oscillations as we can see in case b).
2.2 WiMAX IEEE 802.16

This protocol supports a standard interoperability with air interfaces from 2 to 66 GHz, network discovery and selection, QoS management, security and the fast user mobility up to a vehicular speeds. In this particular case (maritime communications), the ships do not move with the same speed as land vehicular devices (e.g cars) so the hand off will be less frequent and the duration of the connection link is longer. Supports a large radius coverage (up to 40 Km) and high data rate with cheap access, also permits the service availability to ships near the shore (e.g moored ships) but also ships outside of the shore.

With regard to maritime WiMAX there are a few performance experimental studies about this protocol in maritime scenario.

In [10] is presented the performance of WiMAX at 5.8 GHz in a sea port environment in the presence of multipath, Doppler shift, boat’s rocking and analyse these effects impact to the communication link. The measurements were carried out between one and two kilometres from the shore with relative calm sea conditions and no large waves. Initially for carry out the measurements in the host site was used a sector antenna with 60° horizontal beam and 16 dBi, positioned at four meters from the sea level. Relatively to the client site, for the first measurement was used an omnidirectional antenna with 12 dBi gain, and for the second measurement the same sector antenna used in the host site, both positioned at five meters and half from the sea level. The measurements concluded that when the omnidirectional antenna is used, it shows a presence of an irreducible BER floor caused by multipath, Doppler shift or both, affecting significantly the performance. The measurements concluded that Doppler shift caused irreducible BER and FER floor in the WiMAX mounted on a moving ship in the sea port, this problem can be mitigated using a sector antenna, and also boat’s rocking can increase BER and contributes to a larger received signal variation when the boat is far away from the transmitter.
2.2 WiMAX IEEE 802.16

In [3] experimental measurements were carried out to find how the pathloss changes according the antennas height, using WiMAX at 5.8 GHz in Singapore Port. Three different scenarios were tested for various transmitter antenna heights (4 m, 76 m, and 185 m). The output signal was 30 dB, and a omnidirectional antenna was used with 12 dBi gain. The same antenna was used in the receiver, and it was placed on a boat and mounted 8 meters from sea level. The graphics shows the received power vs. normalized distance when boat was making way, also the distance $d$ takes into account the building height.

![Received power vs. normalized distance](image1)

(a) Antenna 185 m height  
(b) Antenna 76 m height  
(c) Antenna 4 m height

Figure 2.2: Received power when the boat was making way for different antenna heights [3]

The Figure 2.2(a) is related to the measurements at 185 m height and the antenna was mounted in a high building at 1 km from the shore, the graphic shows that after distances bigger than 2.5 is possible to observe a bigger variation due reflections from large anchorage ships area in comparison with the region between 2.2 and 2.5, because the receiver had a good Line of Sight to the transmitter.

In the second case the transmitter antenna was mounted at 76 m above sea level in a light house, the Figure 2.2(b) shows a good approximation to the two-ray path model and it fits quite closely to the measured data, at this frequency the sea surface satisfies good conductor condition.

The last case the antenna was placed on a tripod in the port about 4 m from the sea level, in this situation the Line of Sight wasn’t dominant during the measurement. As we can see in the Figure 2.2(c) shows a breakpoint $d_A$, when $d > d_A$ the signal attenuates very rapidly limiting the
coverage zone of WiMAX, is possible also to observe a high variation of the received power due
the transmitter antenna location.

2.3 TRITON System

Facing the difficulties of maritime communications, TRITON [11] is a solution implemented in
Singapore port to develop a ship-to-ship/shore mesh network low cost infrastructure capable to
provide high bandwidth and good QoS level using the IEEE standard 802.16 mesh and IEEE
802.16e standards at 5.8GHz and 2.4GHz. This solution is mainly redirected to areas with high
density of ships and vessels near to shorelines. They propose a new routing protocol MAC-based
routing protocol for TRITON called MRPT, developed specially for maritime communications, is
a proactive routing protocol that uses WiMAX mesh MAC control messages to spread routing in-
formation from the land station to the ships, reducing the initial packet delay also when an existing
link is broken, alternative routes are available for switching increasing the network robustness in
comparison with AODV and OLSR.

2.3.1 System Architecture

Basically TRITON architecture consists in trying to archive the maximum range by forming a
multi hop mesh network between neighbouring ships, buoys and marine beacons. To provide
the multi hop network, terrestrial stations are positioned along the coast. Also, to extend the
connectivity, there are added buoys in the sea to relay the signal, where each mesh node can route
and relay traffic from others.

Ships wireless nodes also require mesh radio with capability to switch between frequencies in
the ships, depending of location and sea conditions. For example in the deep sea or in a situation
where the ships are sparse, the TRITON system can access to the satellite communication link to
continue the service. [4] An example of the network is showed in 2.3.

![Figure 2.3: High Level Architecture of TRITON [4]](image)
2.4 WetNet Maritime Environment

In [8] is implemented a maritime solution called WetNet line-of-site technology based in 802.11g protocol operating on UHF band at 1.8 GHz. It introduces some changes in the protocol architecture including Automatic Repeat Request (ARQ) protocol, that ensures that all data packets are delivered by issuing an acknowledgement for each packet transmitted decreasing the probability of receiving wrong packets.

The experiment included a boat-to-shore scenario with both nodes contained a 802.11 transceiver, a low noise amplifier, sector antenna with 19.6 dBi gain located at 45 m and a omni-antenna with 6dBi located in the boat at 4.5 m above sea level.

The results reflect a degradation due to an existing packet error rate (PER) using TCP streams, also because the line-of-sight coverage is limited (due to blockage caused by the curvature of the earth), as well, due the Pathloss deterioration due to interference received from the reflected-path of the transmitted signal. The system results are summarized in the Table 2.1.

<table>
<thead>
<tr>
<th>Land Antenna</th>
<th>Boat Antenna</th>
<th>Distance (mi)</th>
<th>Rate (Mbps)</th>
<th>Throughput (Mbps)</th>
<th>PER %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector</td>
<td>Omni</td>
<td>40</td>
<td>6</td>
<td>5.4</td>
<td>0.00</td>
</tr>
<tr>
<td>Sector</td>
<td>Omni</td>
<td>30</td>
<td>24</td>
<td>10.3</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Sector</td>
<td>Omni</td>
<td>30</td>
<td>12</td>
<td>9.38</td>
<td>8.50</td>
</tr>
<tr>
<td>Sector</td>
<td>Omni</td>
<td>30</td>
<td>6</td>
<td>4.76</td>
<td>12.00</td>
</tr>
<tr>
<td>Sector</td>
<td>Omni</td>
<td>20</td>
<td>24</td>
<td>16</td>
<td>5.00</td>
</tr>
</tbody>
</table>

2.5 Maritime Ad-hoc Networks

2.5.1 NANET (Nautical Ad-hoc Network)

It is strictly necessary to provide recognition, tracking, and surveillance solutions for safety sailing and transmission of information between boats. For example email, short service messages and other services are needed. In [5] possible topologies are described for mesh/ad-hoc network in maritime communication nominated as NANET. The point is construct a low cost solution but enhance the transmission speed, basically using a similar topology as Vehicular Ad-hoc Network, this will permit ship nodes communicate each other without being necessary to have base stations.

The two proposed architectures are presented below, the first case when ships are near the shore and next the case when ships are in high sea far away from the shore.

- **NANET Architecture in Shore** — In this case the ships are situated near the shore, so they are able to communicate directly with Radio Access Station (RAS), but if the ship is outside of the RAS coverage radio, it should communicate with other ship or a buoy access point and a mesh network should be configured to establish a connection with RAS. To establish
the mesh network in VFH band, they propose WiMAX or 3GPP LTE as baseline system to support high data rate with long transmission distance, as show in Figure 2.4(a);

- **NANET Architecture in Ocean** — The NANET architecture in the ocean, there are no base stations available to establish a network, and isn’t viable and not practical to install base stations in the high sea. So in comparison with shore architecture there isn’t possible to create a link from a ship to RAS by multi hop, so if there is no ship or buoy access point within the coverage to create a link, the solution is to use existing MF/HF band modem, so it can connect directly to the base station in the land, as shows in Figure 2.4(b);

![Architecture in shore](a) Architecture in shore![Architecture in ocean](b) Architecture in ocean

Figure 2.4: NANET maritime wireless communication architecture for shore and ocean [5]

### 2.6 Propagation models

In [6] is presented a definition of a 2-ray pathloss model for maritime communications carried out on a 2.5 GHz Mobile WiMAX test-bed in sea port scenario. It’s important to consider the channel propagation in the sea is different compared with typical land radio propagation, due the fact that the signal is affected by distortions of reflection and refraction due to the surface of the sea and plus the antenna equipped in the ship is moving and oscillate because of the waves movement as stated before.

To carry out the measurements was used a base station located on the roof at thirty meters of the ground, with a gain of 17 dBi transmitting at 35 dBm of power. The mobile node (boat) was equipped with a 11 dBi external omni-directional antenna located at ten meters of the sea surface attached to a laptop in order to obtain geographical location and time synchronization. At
IP level was used User Datagram Protocol (UDP) to avoid congestion algorithm’s limitations of Transmission Control Protocol (TCP).

For the coverage test the RSSI was measured for different distances, the results are presented in 2.5. Several synchronization problems were detected for distances greater than 19 Km, making impossible the connection with the BS.

![Figure 2.5: Theoretical and Measured RSSI for different distances between BS and mobile node [6]](image)

The results show that, the RSSI have an harmonic trend with deep periodical fading holes up to distances of 5 Km from the Base station. It is possible to observe also a breakpoint near 5 Km, after that the RSSI increased and seemed to be quite stable with a linear decrease of less than one dB/Km. At 14 Km from the BS the RSSI remained above -60 dBm. The measured samples had the same behaviour of a 2-ray radio propagation model, where considers both the direct ray path from the BS and the reflected one. Based on the measured samples was proposed a new 2-ray model consisting:

\[ P_r = \frac{P_t G_t G_r}{L_{2\text{ray}}} \]

(2.1)

\[ L_{2\text{ray}} = \frac{L_{fs}}{\beta} \]

(2.2)

\[ \beta = 1 + \Gamma(\theta_i, n_1, n_2)^2 - 2\Gamma(\theta_i, n_1, n_2) \cos\left(\frac{4\pi h_t h_r}{\lambda_d}\right) \]

(2.3)

\[ \Gamma(\theta_i, n_1, n_2) = \frac{n_1 \cos\theta_i - n_2 \cos\theta_i}{n_1 \cos\theta_i + n_2 \cos\theta_i} \]

(2.4)
\[ \theta_i = \arcsen\left(\frac{n_1}{n_2}\sen\theta_i\right) \]  \hspace{1cm} (2.5)

\[ L_{fs} = \frac{4\pi d^2}{\lambda} \] \hspace{1cm} (2.6)

Where \( P_r \) is the received signal strength and \( L_{2\text{ray}} \) the presented 2-ray pathloss model and \( P_t, G_t \) and \( G_r \) represents transmission power, transmitter antenna gain and receiver antenna gain respectively. The \( \Gamma(\theta_i, n_1, n_2) \) is the reflection coefficient for a parallel polarized electromagnetic wave, the 3 equation we can note that depends on the wave angle of incidence and on the refraction index of air \((n_1 \approx 1)\) and water \((n_2 \approx 1.333)\). The height of the antenna receiver and of the antenna transmitter represents \( h_r \) and \( h_t \) respectively. The \( L_{fs} \) represents the free space pathloss model, where \( \lambda \) this the wavelength and \( d \) the distance between base station (BS) and mobile station (MS).

Another pathloss model for maritime communications is proposed in [2] which focus on received signal strength perturbations due to the surface motions of the sea, because it causes variations in the antenna heights and orientations affecting the signal received and the quality link. The the measurements reveals that longer links are subjected to antenna gains fluctuations while shorter links are subjected to hight sensitivity of pathloss caused by effective height variations. The two-ray pathloss model proposed is given by:

\[ L(h_t, h_r, d) = 10\log\left(\frac{\lambda^2}{4\pi d^2}\left(\frac{2\sin\left(\frac{2\pi h_1 h_r}{\lambda d}\right)}{2}\right)^2\right) \text{dB} \]  \hspace{1cm} (2.7)

Where \( L \) is the pathloss in dB, \( h_t \) and \( h_r \) are the effective heights of the transmitter \( t \) and receiver \( r \) respectively, \( d \) is the distance between transmitter \( t \) and receiver \( r \). The \( \lambda \) represents the wave length of the radio transmission in the same dimension of the antenna height and distance.

![Figure 2.6: Two-ray pathloss model \((h_t = h_r = 18m, \lambda = 0.125m)\) versus free-space model [2]](image-url)
2.7 Outdoor long distance link using 802.11b at 700 MHz

The experiment presented in [7] shows the performance evaluation and some compliance issues found by Wi-Fi outdoor inner city scenario operating in the TVWS bands transmitting at long distances using off-the-shelf Wi-Fi radios. They used a relay network topology with three nodes, the node 2 is equipped with CM9 Wi-Fi card (used to create a hotspot around the node at 2.4 GHz) and a XR7 700 MHz Ubiquiti Wi-Fi card equipped with directional antennas positioned at 7 meters from the ground. Node 1 relays the signal and communicates with node 2 and node 3 and, it’s positioned at 7 Km away from node 2 and 22 km away from node 3, also equipped with 2 XR7 cards combined with two directional antennas positioned at 18 meters from the ground. Node 3 is equipped also with a XR7 Wi-Fi card and a directional antenna with gain of 14 dBi installed at a height of 50 meters on the roof of a building pointing to node 1.

The interfaces in all nodes were configured to operate with 802.11b ad-hoc mode because of its high sensitivity, robustness and good spectrum mask characteristics. The nodes were in fixed locations. During the experiment they used iPerf to test the throughput and RSSI for a 5 MHz channel as summarized in the Table 2.2.

```
Table 2.2: Throughput for 5 MHz channel width outdoor scenario using 700 MHz [7]

<table>
<thead>
<tr>
<th>Channel Width</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 MHz</td>
<td>Node 1 to 2 1.62 Mbps</td>
</tr>
</tbody>
</table>
```

The values measured shows a stable throughput and RSSI between nodes 1 and 3 (22 Km) and the throughput of the 700 MHz link was 1.8 Mbps and 1.63 Mbps with advantage of using off-the-shelf equipment. The relay node introduces a processing delay which explains the significant drop in bandwidth from node 2 to node 3, also due the packet store-and-forward mechanism between the two links with different distances.
2.8 Discussion

During this chapter was presented the research work that has been done in the field of maritime wireless communications. It was possible to conclude that the major broadband solution in maritime communications was exploring mesh and Ad hoc networks using WiMAX as main protocol, and then adapt it to face the maritime environment oppositions to the communications.

After all, the use of TVWS band in maritime communications stills an emerging topic. It is proposed in the cognitive maritime wireless mesh ad hoc networks [9], where the main point is create a low-cost and high-speed communication where users can access licensed but unused frequency bands opportunistically without interference with other services running on these frequencies.

As we could see in the measurements presented before [7], in the land scenario was possible to obtain good throughput results and range with the TVWS band using Wi-Fi, are expected also reasonable results in sea. So, this research will focus on testing the viability of use the current Wi-Fi but operating at TVWS frequency band in maritime conditions, taking the advantage of being an off-the-shelf solution that doesn’t require special hardware and also due to the low cost implementation.
Chapter 3

Methodology

In this chapter we present a description of the methodology to be used during the dissertation, defining every decision taken during the research period. In the beginning of the research, process is necessary implement all test bench in order to study the performance and efficiency of the Wi-Fi (802.11g) technology operating at 700 Mhz band (TVWS) in maritime environment.

For this is necessary to take into account several aspects to perform the required measurements: scenario including the position of the antennas both on land and on the boat, hardware and software to be used, parameters and measurement results in order to discuss and analyse them.

3.1 System Setup

3.1.1 Hardware specifications

To provide the 700 MHz Wi-Fi band it will be used a Ubiquiti XR7 card, which is a compact radio module supporting 32 bits mini-PCI type IIIA standard. It can be set to operate in four different channels within 760-780 MHz and also to 5,10 or 20MHz modulation width. The radio operates based on 802.11g (OFDM) and the transmission power is proximately 28 dBm. The Ubiquiti card outdoor range variates around 50 Km but is antenna dependent and supports data rates up to 54 Mbps [12], and it will be mounted on a ALIX3d3 board [13] connected to a miniPCI slot.

The ALIX is a miniPC board optimized for wireless routing and network security applications. Both Ubiquiti card and ALIX3d3 board are going to be used in land and boat nodes inside a plastic box made to protect the boards where the antennas are connected. It will be also used a GPS to register each location where a measurement is done.

3.1.2 Software specifications

The related software that will be used to proceed the experimental measurements during the maritime scenarios is:
Methodology

Figure 3.1: Hardware equipment to be used during the measurements

- OpenWRT Linux platform — It’s a linux distributed version supported by Ubiquiti hardware. It has a very low memory footprint and is module-based distribution that permits to the user a full customization of the wireless card [14];

- Iperf — It’s a network testing tools software. It permits to create UDP/TCP data streams in order to measure throughput, bandwidth performance, delay jitter and packets loss in both scenarios [15];

- Wireless tools — It’s a set of tools that allows to manipulate parameters and get the state of wireless connections [16];

3.1.3 Parameters

In order to analyse the performance of the system a few parameters have to be considered during the experimental measurements. These tests will be performed both in TCP and UDP:

- Range — Average range in kilometres possible to establish a connection between the land base station and the boat;

- Connection throughput — Average download and upload rate for different ranges between the land base station and the boat;

- Packet delay and packet loss — Packet delays consists the time it takes the packet to reach the destination after it leaves the source, and packet loss is the number of packets that fails to reach their destination during;

- Jitters — Variation of time between arriving packets;

- RSSI throughput — Received Signal Strength Indication is measure of the power in the received radio signal;
3.2 Measurement Scenario

The experimental test scenario will take place at Porto de Leixões [17] in a partnership with a fishing company that will cede their boats to test and implement this solution on a real scenario, so it’s possible to reach more reliable results and interpretations about the usability of the implemented solution.

The scenario to be implemented aims to establish a single connection between land base station and mobile node mounted in the boat, which will be located at Porto de Leixões. The land base antenna will be located on the top of a fishing company building inside the port. The fishing boat will depart from the port and it will follow the usual fishing route. At the end of it’s functions, it will return again to the port. After ending this step an analysis of the data will be made.

Due to some restrictions imposed by the authorities involved to minimize the interference level with other services, the frequency band that will be used during the measurements will be between 770-780 MHz and the maximum transmission power of 27.8 dBm.

A simple scheme of the proposed implementation scenario is showed in the image below.

![Scheme of using single connection between land base station and fishing boat](image)

**Figure 3.2:** Scheme of using single connection between land base station and fishing boat

3.3 Analysis of results

Finally, during the experiments, a script will be used to periodically retrieve and save the results. Afterwards, results will processed and analysed. These results will be compared with theoretical models presented in Chapter 2.
Chapter 4

Work Plan

In this chapter we detail the work plan to be implemented during the dissertation. The project is mainly divided by: 1) Creation of the test bench to proceed the measurements; 2) Carry out the measurements and compare the results; 3) Writing the dissertation;

The following plan is proposed:

- **17th of February until 29th of March** — Preparation and implementation of all logistical problems and create the test bench to be used during the measurements, including boat and land communications systems;

- **1st of April until 3rd of May** — Study of the performance of Wi-Fi technology using 700 MHz (TV White Spaces) band in maritime environment between land and boat nodes using the implemented test bench;

- **6th of May until 31th of May** — Comparison of the experimental results obtained with the theoretical propagation models and reach a concern about viability of a possible system implementation;

- **3rd of June until 28th of June** — Writing of the dissertation;
Chapter 5

Conclusion

This dissertation aims to test the performance of a new possibility and alternative broadband communication to the existing maritime environment, using the current Wi-Fi 802.11 standard protocol as starting point, but operating in a different band.

During the analysis of the state of the art, it was possible to conclude that the current wireless broadband solutions for maritime environment doesn’t cover most of the requirements needed to serve a network with minimum stability and quality link, in comparison with land wireless networks, due to the uncertainty state of the sea that is changing constantly every second.

With the transition to the digital television, a new possibility of introducing a study and analyse the behaviour of TV white space band (700 MHz) in maritime environment is open.

During the next semester the proposed solution will be implemented and tested, then the measurements results are going to be analysed and compared mainly with the theoretical models.
References


