BLOP: Broadband Link to an Offshore Platform in the Venice Lagoon

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ABSTRACT

In this paper we describe the process that brought us to the deployment of a 17 GHz network in the Venice lagoon to connect remote sensors. Starting from traditional WiFi links, we moved to mesh networking as a means to deal with the interruptions caused by passing ships that would block the direct radio path. The mesh solution provided alternative paths to avoid blockages, but the indirect paths increased the latency and as the data transmission requirements grew more stringent we tried a WiMAX solution with the base station located in a high enough position to minimize blockage. To reach an offshore platform 15 km off the coast, we had to install dedicated point to point links. Since we are limited to use unlicensed bands, the first point point links were installed at 5.7 GHz, but after some time we began experiencing interference from the many WiFi systems deployed in the area. This led us to move to the 17 GHz band, which is also unlicensed in Europe but less subject to interference because of the narrower beam employed and the reduced number of users in this band. This solution has very good throughput, although it suffers from more attenuation in case of rain. We dealt with this limitation by capping the maximum throughput to 10 Mbps (down to the 100 Mbps that we obtained during the installation tests) to obtain a better fading margin, as well as by leaving a 5.7 GHz link in place as a backup for very rainy days. The amount of data coming from sensors on the platform required a broadband connection for real-time analysis, and the 10 Mbps are adequate for this purpose. The network proved to be reliable and data is openly published on websites for general divulgation purposes and shared with scientists worldwide.
The Venice lagoon is a difficult scenario for wireless communications and we have tested a wide gamut of solutions to fulfil the requirement of broadband connectivity while trying to overcome the limitations of the environment.

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Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; C.2.1 [**Network Architecture and Design**]: [Wireless Communications.]

General Terms

Performance, Measurement, Verification

Keywords

Wireless Sensors, Broadband Data transmission, Marine environment

1. INTRODUCTION

Gathering sensor data from devices scattered all over the Venice lagoon and on the open sea nearby is considered crucial to assess the environmental impact of the MOSE project [1], a project aimed at mitigating the effect of the periodic high seas episodes that cause flooding in Venice. The amount of data to be sent for real-time analysis is evergrowing [2]: from traditional meteorological data (wind, temperature, humidity, etc) to underwater videos and water current profilers. The Venice lagoon is a very challenging environment for wireless communications because of cruising ship traffic, difficult weather conditions (during the winter), salty-water and limited number of antenna masts available. We have tested different solutions to fulfil the requirement of broadband connectivity while trying to overcome the limitations of the environment. Our contribution consists of describing the deployment of several solutions to the task of wireless sensors gathering, pointing to some of the limitations encountered and how we tackled them. We hope this can be useful to people contemplating deployments in similarly challenging environments.

1.1 WiFi-based solutions

The first approach tried was to use a network with a star topology, working on the ISM band, to upload the data to a central database. Since most of the sensors were housed in buoys just a few meters above the water, one of the problems encountered was that there were occasional interruptions in the data flow, caused by the transit of big ships that blocked the radio beams. One way around to this problem was to change the topology to that of a mesh network, which provided more than one path for the data transmission, literally working around the moving obstacle. The mesh topology causes some restrictions in the throughput due to the fact that the signal has to be processed at several intermediate nodes before reaching the final destination, thus increasing the latency and decreasing the real throughput due to the fact that each intermediate node uses the same frequency for reception and transmission, in effect halving the transmission speed. Therefore we were requested to look into alternatives that could provide faster data transfer. An agreement was reached with the administrator of a 22 meter tall building called San Camillo that allowed for the installation of a base station capable of reaching all the points of our interest.

1.2 WiMAX-based solution

Since the number of points to be connected was considerable, we proposed to use WiMAX, as a technology that offers adequate bandwidth while providing better quality of service (QoS) thanks to the use of TDMA (Time Division Multiple Access). We chose devices produced by the Spanish startup Albentia [3], that offered a WiMAX base station that worked in the ISM 5.7 GHz band and is compatible with client stations sold by the Canadian vendor Trango [4]. Two vendors had to be used since Albentia did not manufacture client devices. The installation was complicated by the fact that some of the clients were too far away from the base station to be served by an omnidirectional antenna, so we had to use two sectorial antennas, fed from the same base station by means of a splitter as shown in Figure 1. One of the antennas was aimed towards North, and the other was pointed Southwards.

This solution proved adequate, but we were also asked to connect a platform 15 km away in the open sea, which required some 10 Mbps to cater to the needs of the different instruments on board, that included two underwater cameras, besides a roster of other data sources. Furthermore, the data stream had to be conveyed to an office located inside a historical building in downtown Venice. The offshore platform is shown in Figure 2. With a height of 15 meters above sea level, it is equipped with numerous environmental sensors and five webcams.

Figure 1: WiMAX base station antennas and point to point links in the roof of San Camillo.

Figure 2: The offshore platform, Piattaforma AA, 15 km from the coast.

1.3 5 GHz Point to Point links

We installed a point to point link from San Camillo to the open water platform (called ”Piattaforma AA”) using high gain parabolic antennas at the frequency of 5.7 GHz, and another point to point link to the office in downtown Venice (called ”7 Martiri”) 8 km away. We had to use the intermediate repeater point at San Camillo to overcome obstacles in the direct path, as shown in Figure 3. The two links were connected by an Ethernet switch, so the researchers in the Venice office could access the measurements gathered at the platform by means of a two hops link. This

Figure 3: Links from San Camillo to Piattaforma AA and to Riva 7 Martiri. The direct link, shown in red, is obstructed.

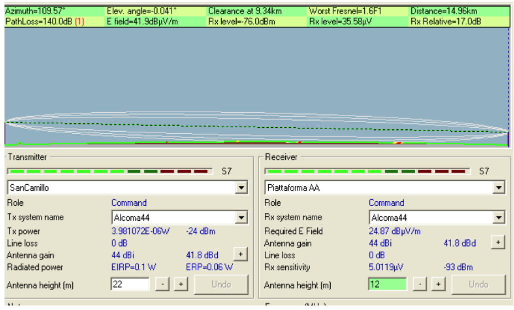

Figure 4: Radio Mobile simulation for the 15 km link from S.Camillo to Piattaforma.

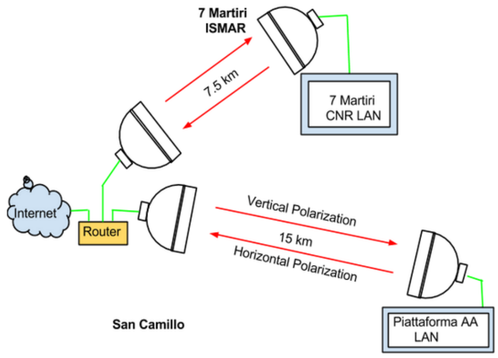

Figure 5: Diagram of the link between the Piattaforma AA and the CNR office at 7 Martiri.

arrangement worked for a while, but the 5 GHz band became very crowded after the Municipality of Venice began installing WiFi access points in many areas, so interference was impacting very negatively the performance of our network The solution was to move to a less crowded frequency. Initially, we were reluctant to move to frequencies above 6 GHz, because our spectrum analyzer only worked up to that frequency, so we could not use our standard procedure for antenna alignment using a signal generator at one end and a spectrum analyser at the other end, but we decided to use other alignment tools built in in many modern radios.

1.4 17 GHz Point to Point links

The 17 GHz frequency is now unlicensed in Europe, with a maximum Equivalent Isotropic Radiated Power (EIRP) of 20 dBm. We located a Czech vendor, Alcoma [5] that provides a 17 GHz radio directly connected to different types of antennas (thus eliminating the antenna cable loss, which is very significant at this frequency). To reach the open sea platform 15 km away, we chose the maximum gain antenna (44 dBi with a diameter of 1.2 m). The Alcoma is a split system, comprised of an outdoor unit (OU) that contains the RF front end, and an indoor unit (ID) housing the baseband and management functions. The alignment is facilitated by the received signal meter incorporated in the management software provided by the manufacturer, which also allows control of the bandwidth, modulation type and Forward Correction (FEC) code adopted. The antenna is protected from the weather by means of a special cloth that also reduces the wind resistance.

2. LINK PLANNING

Before deployment, all the links were simulated using the free Radio Mobile software written by Roger Coude [6], which is an implementation of the Longley-Rice Irregular Terrain Model [7] that makes use of freely available terrain elevation maps. Currently, most of the world has been mapped by the Shuttle Radar Topography Mission (SRTM) [8] with a resolution of 3 arc sec (about 30 m), whereas 1/3 arc sec resolution is available only for certain zones. We have been using this program since 1999 with great success [9], although as with all simulations, the results must be carefully checked against a thorough site survey.

A simulation of the 15 km link is shown in Figure 4, with the following parameters: link margin of 17 dB at a transmission speed of 100 Mbps, with ample clearance of the first Fresnel zone and a received signal level of -76 dBm at an EIRP of 20 dBm. The total path loss of 140 dB at this frequency is compensated by the two 44 dBi antennas deployed. Since 17 dB is not enough a margin to compensate for rain fading we later capped the throughput to 10 Mbps to increase the rain tolerance. A diagram of the two links is shown in Figure 5.

2.1 Deployment

The Alcoma radio link installed is a highly integrated system with the antenna connected directly to the radio by means of a short waveguide. It can use different antenna sizes, to cater to different distance and transmission speed requirements. It is a SISO (Single Input, Single Output) single polarization system, and uses cross polarization to help isolate the transmitted from the received frequency. So if one end transmits in vertical polarization, the other end must transmit in horizontal polarization and vice versa. It can use different bandwidths and different modulation schemes for each bandwidth chosen, thus offering the versatility to accommodate user's requirements. The maximum transmit output power is 12 dBm, and the maximum antenna gain is 44 dBi, so the maximum EIRP is 56 dBm. In Italy, the maximum allowable EIRP in the unlicensed 17 GHz band is 20 dBm, so when using the maximum gain antenna the transmitter output should be capped to -24 dBm to comply with the regulation. The maximum first Fresnel zone radius at 15 km is 8.1 meters, and since the roof of the building in the coast is 22 m high and the antenna in the platform is a 12 m above the mean sea level, the clearance of the Fresnel

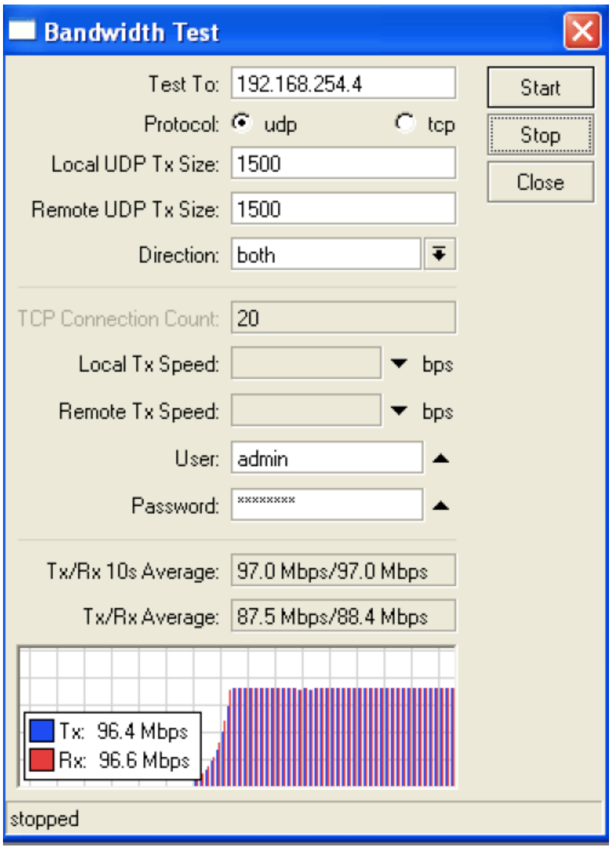

Figure 6: Bandwidth test with the Alcoma link over 15 km of open sea.

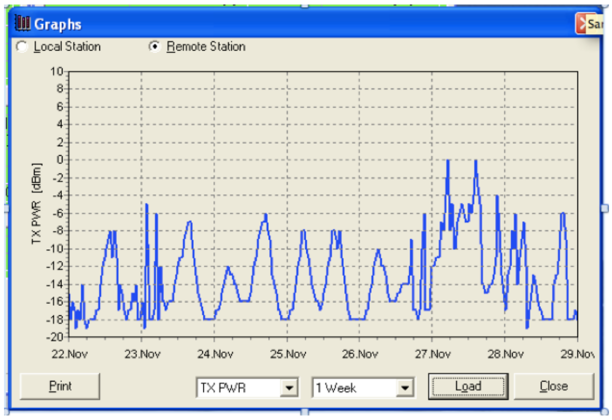

Figure 7: Output power fluctuation to maintain a constant throughput.

Figure 8: 17 GHz ODU with the integrated antenna.

zone is guaranteed even at high tides.

We performed a bandwidth test with the transmission power uncapped and obtained the results shown in Figure 6, concluding that almost 100 Mbps are possible with this set up. The Alcoma equipment allows to fix the transmission throughput, while the output power will fluctuate to maintain the required bandwidth in spite of the fading. This is shown in Figure 7.

To comply with the 20 dBm EIRP, the transmission power was set at -24 dBm, and the expected received signal strength was -76 dBm, 70% of the time. Capping the throughput at 10 Mbps, the receiver sensitivity is improved to -98 dBm, obtaining a link margin of 25 dB. Although the antenna beamwidth is only 1 °, the sturdy mount allows for a very stable installation, as shown in Figure 8.

2.2 Rain Attenuation

The rain attenuation is significant at the 17 GHz frequency, and affects the availability of the link. The percentage of availability as calculated according to the procedure established in ITU-R P.530-13 [10] is presented in Table 1 for both polarizations, for different bandwidths, different maximum rain rates in millimeters per hour and for different modulation schemes, for the 15 km link over the sea. The stated receiver sensitivity is for a BER (Bit Error Ratio) of 10^{-6} (one errored bit for million bits transmitted). Notice that most of the trajectory is over open sea, but the maximum tide variation expected is only 2.5 meters. From the table, we can appreciate the difference in rain attenuation for the two polarizations. If we settle for a modest transmission rate of 17 Mbps on a bandwidth of 14 MHz, the worst case availability is 99.912 %, which corresponds to 8.7 hours of unavailability per year. Depending on the application, this might or might not be tolerable, but for the present one is acceptable, since the data are not critical, and this is a worst case scenario.

3. DATA USAGE

Data collected at the offshore platform is sent to a Local Area Network of the Institute of Marine Science (ISMAR) located in Riva 7 Martiri. All the devices in the Platform including the radios share a class C private IP address range. A Mikrotik router is used to provide a bridge between the ISMAR LAN and the radios installed for the links. For remote management an Alix board with openvpn allows secure access from outside the LAN.

The LAN itself is protected by an open source iptables firewall, and allows the devices to send and publish data to the CNR server in different ways: webpages, standard OGC services, webcams. Additionally direct access to some devices for remote control, debug and management has been provisioned. The access is restricted to a specified IP source

TX	RX Sens	RX Level	BW	Mod Type	TX Rate	Max. rain Horizontal	Max. rain Vertical	Percentage Availability	Percentage Availability
dBm	dBm	dBm	MHz	Mod Type	Mbps	mm/h	mm/h	H Pol	V Pol
-24	-91	-77	3.5	16 QAM	9	19.73	22.69	99.9367	99.9540
-24	-92	-77	7	4QAM	9	21.08	24.36	99.9456	99.9611
-24	-89	-77	14	4QAM	17	17.02	19.34	99.9121	99.9338
-24	-86	-77	28	4QAM	40	12.87	14.3	99.8399	99.8718
-24	-83	-77	56	4QAM	80	8.59	9.24	99.6364	98.6852
12	-83	-41	56	4QAM	80	56.8	9.7	99.9948	99.8598
12	-74	-41	65	32QAM	240	56.8	55.8	99.9948	99.994

Table 1: Link availability comparison at different transmitter power levels (dBm), bandwidth occupancy, modulation type and maximum rain rate (mm/hour) for 15 km link over sea at the carrier frequency of 17 GHz. Antenna gain is 44 dBi at each end, polarization diversity is adopted between the two directions to reduce the self-interference induced by the transmitter in the receiver.

so it can be controlled even when it is not possible to have authentication through username and password due to software limitations of the device.

Data are stored in different servers and most are publicly available on ISMAR's website [11]. The collected data include meteorological data (air temperature, atmospheric pressure, wind speed and direction, rain rate, global radiation and UV index), which are immediately published in a web page and also made available through a web app for mobile devices. Other data transmitted include waves height, period and direction, and water current profiles (speed and direction) at 15 levels gathered by a Nortek Awac Acoustic Doppler Profiler (ADCP) [12]. Water temperature, salinity chlorophyll, turbidity and oxygen concentration are provided by three SBE 37 Microcat CTDs [13] probes installed at -3, -6 and -14 m.

All these data are recorded every 30 minutes and stored both locally and remotely by means of internal dataloggers and the wireless network. Software is not installed onboard but runs on virtual machines connected to the remote instruments by virtual serial ports. For security reasons as well as for divulgation purposes three surface webcams (Mobotix M12) [14] are installed on the platform structure well above the sea level.

Two additional Mobotix have been installed underwater at depths of 5 and 13 m respectively, as shown in Figures 9 and 10. This video system also relies on dual local and remote storage devices and is directly linked to the LAN through an Ethernet powered (PoE) switch that acts also as power supply.

More complex instruments like the one performing wave spectrum analysis (fitted with 3D Hi Resolution cameras) are not always on-line but can be remotely activated and monitored from the Venice office. Some of these data are stored in a multilevel system according with the OGC (Open Geospatial Consortium) [15] web services standard. SOS (Sensor Observation Service) is an OGC service built for standard metadata integration of different type of sensors on the web. This goal is achieved through a standard interface for the the search, request, filtering and retrieval of the of the sensors readings [16].

4. TRAFFIC MEASUREMENTS

A traffic monitoring system based on vnStat, a console-based network traffic monitor, has been put in place in 7 Martiri. Figure 11 shows traffic as measured for four weeks

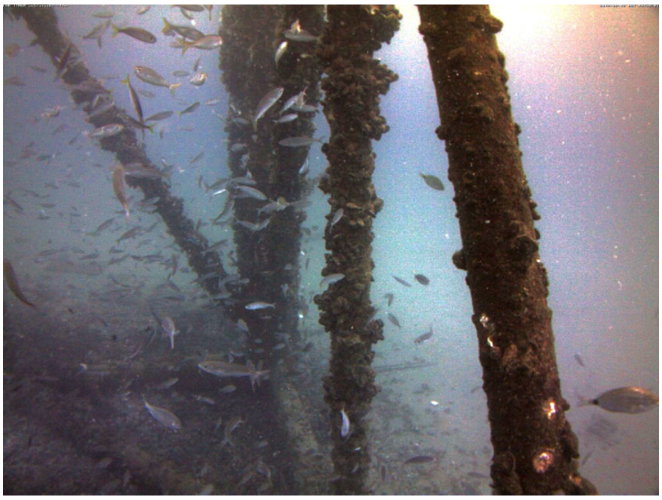

Figure 9: A screenshot of the 13 m depth camera.

Figure 10: A screenshot of the 5 m depth camera.

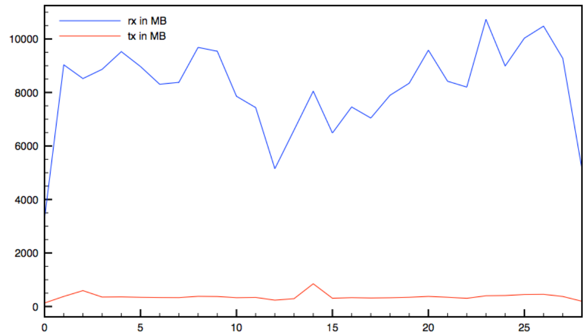

Figure 11: Daily traffic as measured in 7 Martiri.

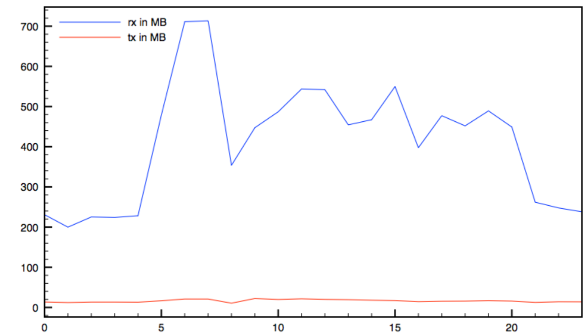

Figure 12: Hourly traffic as measured in 7 Martiri.

in the month of April 2014. Most days witness a traffic of about 8 GB from the platform. This shows that the broadband network deployed has enough capacity to allow for remote operation of sensors and cameras. Reasonable data usage increase can also be accommodated.

Figure 12 shows traffic as measured hourly on May 7th 2014 in Riva 7 Martiri.

5. CONCLUSIONS

We described different wireless networking solutions installed in Venice to connect remote sensors. Starting with low cost WiFi equipment used to collect low speed data from a central point, we migrated to a mesh topology to solve the blockage caused by cruising ships. As the amount of data and number of stations to be connected increased, we moved to a WiMAX base station located in a high building that provided visibility to all our required nodes. To reach an offshore platform at 15 km, we needed a dedicated link, which was first installed at 5.7 GHz, but suffered from interference in the ISM band. We then opted for two 17 GHz links to connect the offshore platform to the Marine Biology research center in the city of Venice, which allows scientists and the general public to benefit from the large amount of data gathered by the sensors in the particularly critical environment of the mediterranean sea. Although the 17 GHz frequency is more attenuated by the rain, by restricting the throughput to 17 Mbps, with the consequent raise in Signal to Noise ratio, the performance of the two links has proved satisfactory over the past two years.

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