Radio Link Planning made easy with a Telegram Bot.

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Abstract. Traditional radio planning tools present a steep learning curve. We present BotRf, a Telegram Bot that facilitates the process by guiding non-experts in assessing the feasibility of radio links. Built on open source tools, BotRf can run on any smartphone or PC using Telegram. Running it on a smartphone has the added value that the Bot can leverage the internal GPS to capture the current coordinates. BotRf can be used in low bandwidth environments as the generated data traffic is very limited. We present an example of its use in Venezuela.

Key words: Telegram, Bots, Radio Frequency planning, simulator, terrain profiles, propagation models

1 Introduction

One aspect that is paramount in the planning of wireless links is the determination of the attenuation introduced by the terrain between the transmitter and the receiver, which ultimately determines the feasibility of a given link. There are many commercial programs meant to solve this problem, most of them making use of digital elevation maps. Some of them are quite costly and others restrict their usage to the radios and antennas of a particular manufacturer.

We still miss an easy to use, open source tool that can be used to assess the feasibility of wireless links. Taking advantage of the capabilities of the Bot technology and given the broad use of mobile devices, we developed a tool that minimizes the amount of data that the user needs to input and that does all the processing in the remote server, making it particularly suitable for low bandwidth environments. BotRf is platform independent as Telegram runs on smartphones (Android, iOS or Windows phones) and laptops/desktops (Windows, OSX and Linux). It provides a simulation of the terrain profile for different atmospheric refraction index values, calculating the path loss in a wireless point to point link. It shows the results in an easy to grasp interface and gives a numerical value of the link margin in dB when the radio and antenna parameters are also inserted.

We believe this tool could be particularly useful to setup Community Wireless Networks [1]. Community wireless network have sprouted in many countries, addressing needs that are not satisfied by commercial operators, either due to

the lack of a high enough return on investment or because commercial operators were not well suited to address social aspects unrelated to profits.

2 RF Propagation Models

In [2], a thorough analysis of 30 propagation models used for the estimation of path loss is performed, reaching the conclusion that there is not a single one that can offer the best results in every case. Some models make use of digital elevation maps and ray tracing techniques to estimate the path loss, while other use a completely empirical approach, based on many measurements performed in a variety of environments at different frequencies. Then there is the hybrid approach, that combines terrain information with statistical inference from field measurements. They end up stating that *"..the landscape of path loss models is precarious: typical best-case performance accuracy of these models is on the order of 12-15 dB root mean square error (RMSE) and in practice it can be much worse"*. Therefore, in our work we stick with the well known Longley-Rice Irregular Terrain Model (L-R ITM) [3], which has been widely used since its original publication in 1968. The advantage of the L-R ITM is that by making use of the terrain profile between transmitter and receiver (derived from digital elevation maps), it will readily detect any obstruction that might preclude the link. So if the model suggests that a links is unfeasible, we accept this result and search for an alternative such as raising the antenna height or looking for an alternate location. On the other hand, when the model finds a path unobstructed, we declare it a "maybe" until further information is available. In particular, the uncertainty is more significant when using SRTM3 DEM data that have a high chance of ignoring obstacles that are less than 90 m in size. This strategy has been quite successful over a number of links that we have simulated and later deployed. The path attenuation result of the L-R ITM is calculated by modifying the free space loss by incorporating the effects of diffraction and dispersion, as well as statistic losses that have been estimated based on many empirical measurements at different frequencies and over different types of terrain.

A very important factor that must be borne in mind when dealing with RF propagation is that the refraction index of the atmosphere causes a bending of the radio beam. This bending normally causes the radio horizon to extend 4/3 beyond the optical horizon, and this is accounted for by multiplying the real radius of curvature of the earth by a K=4/3 factor and then draw the radio beam as a straight line. The atmospheric refraction index can change unexpectedly as it is affected by factors like temperature, humidity, water vapor content and so on, so the K factor might adopt temporarily other values. The International Telecommunications Union (ITU) [4] recommends that for critical links in which a very high reliability is required, the obstacles of the terrain must be cleared even for K less than 1 for distances below 100 km. For K less than 1, the effective radius of the earth is smaller than the real radius, so the radio horizon is closer that the optical horizon. BotRf allows for easy modification of the K factor.

Lastly, and more importantly, we must also note that electromagnetic waves occupy a volume in space called the Fresnel ellipsoid, extending from the transmitter to the receiver, with maximum girth at midpoint between the two. The radius of this ellipsoid is called the Fresnel zone radius and is proportional to the wavelength. In order to capture most of the power contained in radio waves, at least 60% of the Fresnel zone must be cleared. In a wireless link, we try to avoid that any obstacle protrudes more than 40% in the Fresnel zone, this means that the antennas must be raised above the minimum required to draw an unobstructed line from the transmitter to the receiver (the optical LOS).

3 RF planning tools

There are many RF planning tools available on the market, and they can be categorized as Commercial, Vendor Specific, Free and Open.

- Commercial tools use proprietary models and digital elevation maps of varying degrees of resolution. They run on PCs, are usually quite expensive and require heavy downloads. They are therefore not well suited to the needs of developing countries.
- Vendors like Motorola, Ubiquiti Networks, Cambium and Mimosa (among many others), offer radio propagation planning tools free of charge. They are usually associated to the specific of their radios and antennas offering, often require registration in their site and in general are quite cumbersome to use. They are usually based on web interfaces and are not designed to be used on mobile devices.
- Several free radio frequency planning tools are available. In our trainings and deployments we have used extensively the Radio Mobile program developed by Roger Coude [5]. It provides very valuable information, but it is built for the Windows operating system only, and requires considerable effort to install and to use. There is also an easier to use on-line version, but it works only for the frequencies allotted to the radio amateur service and does not specify the amount of first Fresnel zone clearance [6]. As the tool is free but not open, there is no guarantee that it will be maintained in the future.
  "Hey whats that path" profiler [7] is another free on line tool that can quickly draw terrain profiles between two or more points. It does not calculate the attenuation, but allows to change the frequency and the atmospheric refraction index and show how this affects the radio beam.
  The Communications Research Centre Canada offers the Radio Coverage Prediction [8] using the Longley-Rice model, but it is only for point to area, and will not work for point to point links. Its coverage is limited regions up to 5 degrees in latitude and 10 degrees in longitude.
  The Polish National Institute of Telecommunications developed PIAST (Platform IT for an Analysis of Systems in Telecommunications) [9], a web based tool for point to point RF links planning that will provide a path profile and estimates of the attenuation, using the ASTER GDEM v2 maps.

4 Splat!, an open source RF planning tool

John Magliacane wrote Splat! [10] (Signal Propagation, Loss, And Terrain Analysis), an open source Linux based tool offered under the GNU license. It uses both the Longley-Rice Irregular Terrain Model and the Irregular Terrain with Obstructions Model to simulate the attenuation between the transmitter and the receiver as well as to estimate the point to area coverage of a transmitter for the frequencies between 20 MHz and 20 GHz. Splat! has been ported to Windows and is also the basis of QRadioPredict, an experimental software for VHF-UHF propagation prediction and radio coverage analysis.

Splat! uses the SRTM3 [11] digital elevation maps (DEM) which have a resolution of 90m. As the maps are very heavy to download and we want to serve users in low-bandwidth environments, we downloaded the maps of the entire world in our server so that users don't have to do it. This account for more than 65 GB of data. We optimized the Splat! code to work directly with the native file format of the digital elevation maps to make the calculations quicker.

5 Telegram and Telegram Bots

Telegram [12] is a cloud-based instant messaging service, similar to Whatsapp. Telegram clients exist for smartphones (Android, iOS, Windows Phone, Ubuntu Touch) and desktop systems (Windows, OSX, Linux). It differs from Whatsapp in that it does not support voice calls, but unlike Whatsapp it can be used without a phone. The client is free and has no limits on the size of media that can be exchanged. Servers are distributed in many locations around the world.

In June 2015, Telegram launched a platform for third-party developers to create Bots [13]. Bots are Telegram accounts operated by programs that respond to messages or mentions and can be integrated in other programs. They mimic the behavior of a human being in specific applications, like a help desk. Telegram acts as a "middle man" between users with a Telegram client and a server where the Bot is running. As all the processing is done in the Bot server, no powerful computer is required, only a smartphone or a tablet.

6 BotRf usage

Once Telegram is installed on a smartphone or PC, the preliminary step is to add BotRf as a contact (as would be done with a friend or colleague), as shown in Figure 1.

The first step to check the feasibility of a wireless link is to set the working frequency. This is done by using the `freq` command and entering the frequency in MHz. So if you are going to use the 5.8 GHz frequency for you link, you have to write (the system is case insensitive) `freq 5800`, as shown in Figure 2.

The second step is to insert the information about the two sites you want to link. If you are using Telegram on a PC, you have to enter the information
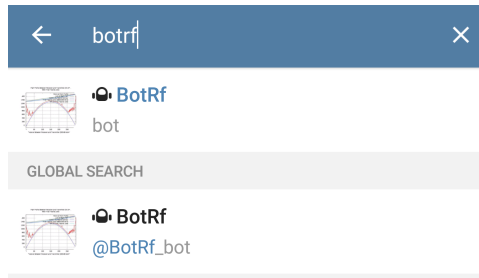
Fig. 1. Preliminary step: add BotRf as a contact.
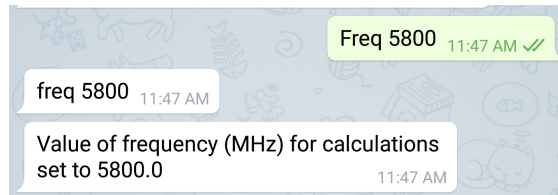

Fig. 2. Entering the frequency in MHz.

about the sites manually. For example: `site mountain_1 -4.3409 55.7450 5`, where mountain_1 is the name of the site, -4.3409 is the latitude in decimal degrees, 55.7450 is the longitude in decimal degrees, and 5 is the height of the antenna above the ground in meters. The same has to be done for the second site. If the second site is called mountain_2, then enter `site mountain_2 -4.6205 55.4413 16`

If you are using Telegram on a smartphone, you can enter your current location with the click of a button, by selecting the paperclip icon (beware that different smartphones have slightly different setups), clicking Location and then Send your current location, as shown in Figure 3. You will then be asked to enter the site name and the antenna height in meters.

Now you have all the information required to check if the path is clear or obstructed from the radio signal viewpoint, by using the `calc` command. Enter `calc mountain_1 mountain_2` to check the link between mountain_1 and mountain_2, at the frequency you previously selected. You will obtain the result shown in Figure 4, which tells you that the link is feasible since there is no obstruction due to terrain.

You can select the graph and analyze it carefully elsewhere. The graph is shown in detail in Figure 5.

The blue line represents the curvature of the earth, modified by the refraction index. The red line is the terrain profile as seen by the radio wave. In cyan we have the first Fresnel zone contour. The magenta line is the 60% of the first Fresnel zone.

If there is an obstruction that can be cleared by raising the antenna, you can use the command `alt` to choose a new value for the antenna height. For
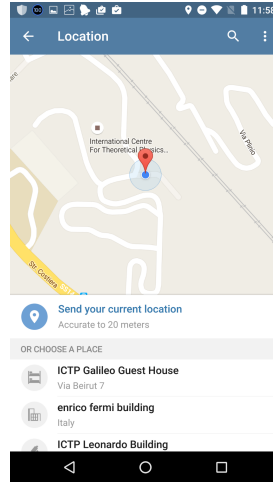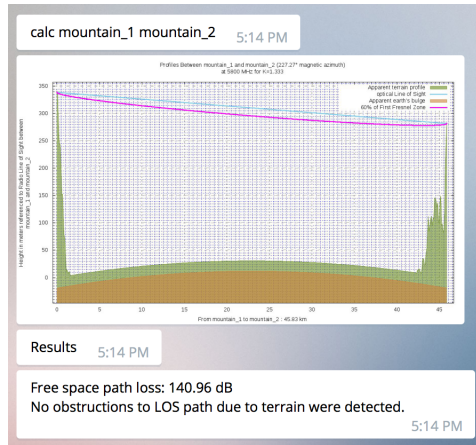
Fig. 3. Sending the current location

Fig. 4. Result of the link simulation: there is no obstruction

instance enter `alt mountain_1 30` to change the antenna height of the site called mountain_1 to 30 meters.

At any point, you can ask for help to the Bot using the `/hlp` command.

7 BotRf usage in Venezuela

BotRf was used to plan the wireless links needed to extend the university network from the administrative building to the printshop at Universidad de los Andes in Merida, Venezuela. There are many buildings that block the line of sight between the end points so a two legs solution had to be devised. Plan del Morro
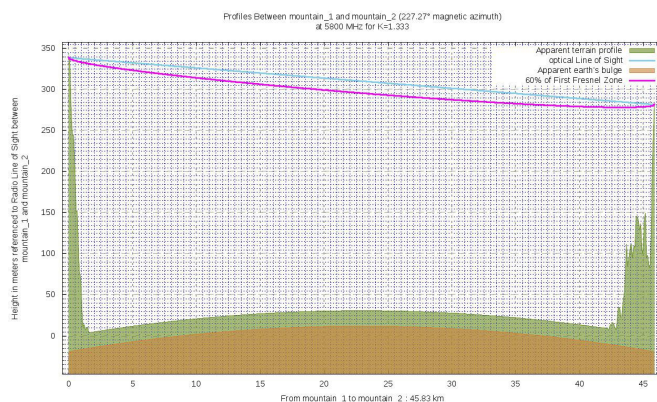
Fig. 5. Graph showing the earth curvature, terrain profile and Fresnel zone

was chosen as repeater site since due to its altitude it offers an unencumbered view of both ends. Figure 6 shows the layout of the two ends points and the proposed repeater site.

Fig. 6. Layout of the two legs link from administrative building to the printshop, Merida Venezuela.

Entering the coordinates and antennas heights of the administrative building and of Plan del Morro in BotRf and using the `calc` command, Figure 7 was produced in few seconds showing an unobstructed line of sight.

Entering `rep` in BotRF produces an extensive text report:

```
Transmitter site: edif_adm
Site location: 8.5931 North / 71.1469 West
Elevation: 1582 m above sea level,
Antenna height: 50 m above ground
```
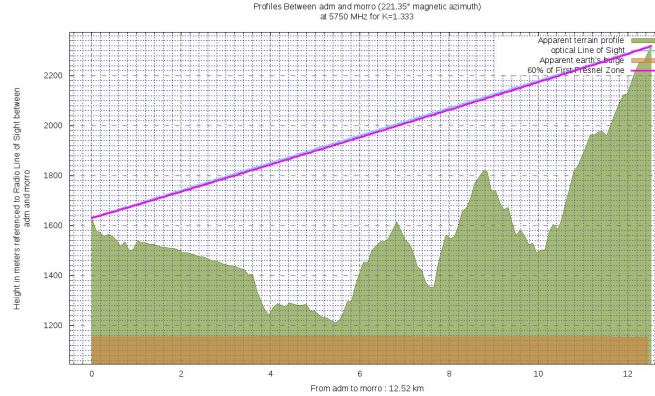
Fig. 7. Terrain profile between administrative building and Plan del Morro, Merida Venezuela.

```
Distance to plan morro: 12.52 km
Azimuth to plan morro: 221.3 degrees
Elevation: +3.1degrees
Receiver site: plan_morro
Site location: 8.5086 North / 71.2221 West
Elevation: 2311 m above sea level,
antenna height: 6 m above ground
Azimuth to edif_adm: 41.3 degrees,
depression angle: -3.2 degrees
Free space path loss: 129.69 dB
Longley-Rice path loss: 129.55 dB
Attenuation due to terrain shielding: -0.13 dB
Mode of propagation: Line-Of-Sight
The first Fresnel zone is clear.
```

No obstructions to LOS due to terrain were detected by BotRf, as per the last line of the report.

Similarly, the link between Plan del Morro and the printshop was simulated with BotRf and proved to be feasible. As both links are feasible from the LOS point of view, the link will work provided that the system gain of the radios and antennas is greater than 130 dB plus the required link margin.

The `pow` command in BotRf is used to obtain the power levels in the link. The user needs to input the name of the transmitter site, the name of the receiver site, the transmitter power output in dBm, the cable loss between the transmitter and the antenna in dB, the gain of the transmitter antenna in dBi (dB with respect to an isotropic antenna), the gain of the receiver antenna in dBi, the cable loss in dB between the antenna and the receiver and the receiver sensitivity in dBm. Using the data from our equipment, we have:

```
pow edif_adm plan_morro 20  0  24 24 0 -87
```

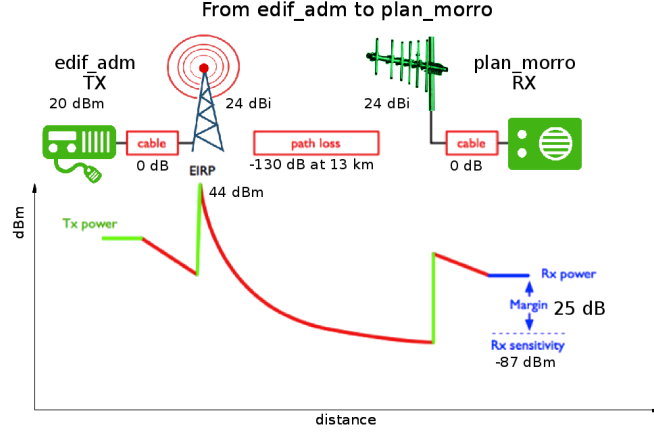which will automatically generate the graph in Figure 8.

Fig. 8. Power versus distance of the link between administrative building and Plan del Morro

We can see the values of the EIRP (Equivalent Isotropic Radiated Power), as well as the link margin, 25 dB, providing a quite reliable signal that will support the highest modulation schemes. The path loss used is derived directly from the free space loss previously calculated by BotRf. The additional attenuation that might be present must be considered in each case and added to the free space loss to obtain the new margin.

It is worth noting that all the input data, as well as the results, are stored in the server under each user's account, so they can be retrieved for future use. BotRf `list` command provides a list of all the sites ever entered by the user with their respective coordinates.

8 Bandwidth Usage

We measured the bandwidth usage of BotRf by installing a network monitoring application [14] on a smartphone. Entering information for two sites using the "Send your current location" and running one simulation requires 750 kB to be transferred over the network. This is a very limited amount of data, making BotRf usable in low-bandwidth environments.

9 Conclusions and future works

We have presented a user friendly and platform independent tool that can be used for the planning of RF links even by people with limited telecommunications background. BotRf can also be used as a learning tool to asses the impact of the different elements of the communication channel in the final performance. In particular, the apparent radius of curvature of the earth can be modified to determine the effect of the changing of the refractive index. The terrain profile is derived from publicly available digital elevation maps of high resolution that are housed on the server where all the calculations are made in real time, whereby the Internet traffic used is at a minimum. The tool can be used in sites with very limited Internet connectivity. We are currently working on the point to area coverage prediction and on the implementation of other RF propagation models.

Acknowledgments

References

1. Saldana, J., Ed., Arcia-Moret, A., Braem, B., Pietrosemoli, E., Sathiaseelan, A., and M. Zennaro, "Alternative Network Deployments: Taxonomy, Characterization, Technologies, and Architectures", RFC 7962, DOI 10.17487/RFC7962, August 2016, http://www.rfc-editor.org/info/rfc7962
2. Caleb Phillips, Douglas Sicker, and Dirk Grunwald,Bounding the Practical Error of Path Loss Models, in Hindawi Publishing Corporation International Journal of Antennas and Propagation, Volume 2012, Article ID 754158, 21 pages, 2012.
3. Longley, A. G., and P. L. Rice , Prediction of tropospheric radio transmission loss over irregular terrain, ESSA Tech. Report ERL 79-ITS 67 (1968).
4. Propagation data and prediction methods required for the design of terrestrial line-of-sight systems, ITU-R P.530, 2015
5. Radio Mobile, http://www.cplus.org/rmw/english1.html
6. Radio Mobile On-Line, http://www.cplus.org/rmw/rmonline.html
7. HeyWhatsThat Path Profiler, http://www.heywhatsthat.com/profiler.html
8. CRC Radio Coverage Prediction, http://lrcov.crc.ca/main/
9. PIAST, http://piast.edu.pl/
10. SPLAT!, http://www.qsl.net/kd2bd/splat.html
11. SRTM3 - Shuttle Radar Topography Mission Global Coverage, http://www.webgis.com/srtm3.html
12. Telegram, https://telegram.org
13. Wikipedia entry for Internet Bot, https://en.wikipedia.org/wiki/Internet_bot
14. Databit, https://itunes.apple.com/al/app/databit/id1052616692?mt=8