Long Distance Links

Training materials for wireless trainers

The Abdus Salam
International Centre
for Theoretical Physics

Long Distance Links Requirements

For a successful long distance link one must:

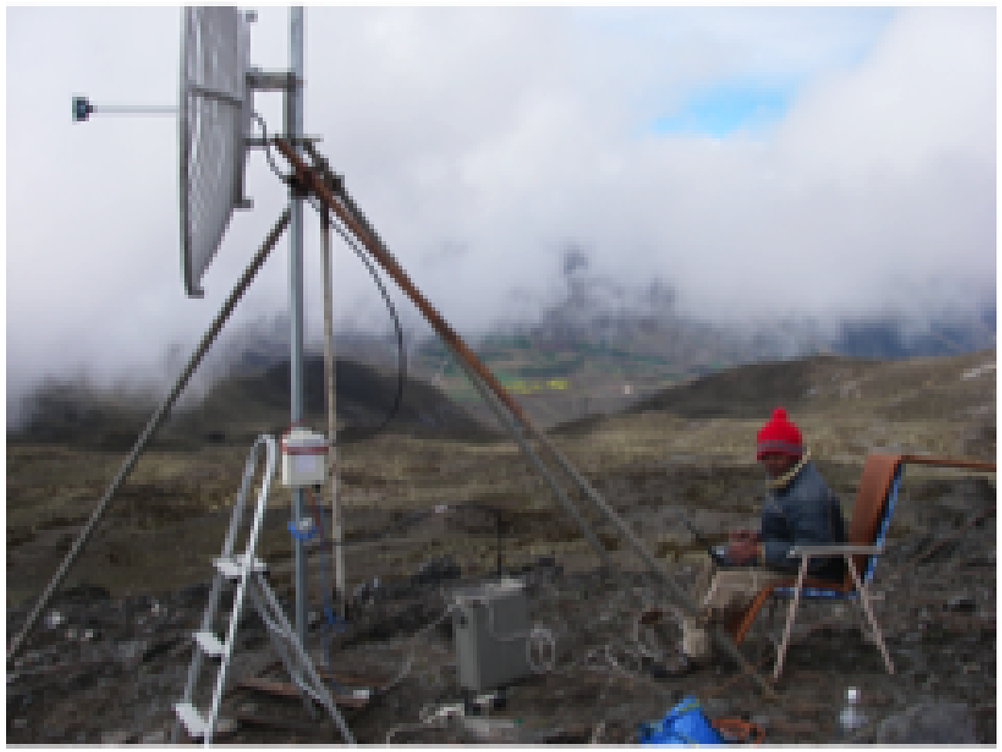
- Perform a Site Survey and simulate the link.
- Use suitable structures to hang antennas so that the Fresnel Zone and earth curvature can be cleared.
- Choose special purpose equipment or modify short distance one.
- Use proper antenna alignment techniques.

Motivation

- WiFi is by far the less expensive communications technology available, and can provide voice and data services
- It can be used both for long distance (Backhaul) and for Access (Mesh)
- Interference is less severe in sparsely populated areas
- WiFi can be installed and maintained by people with limited training making use of locally available resources

Issues

- WiFi MAC designed for up to 100 m, extending the range two orders of magnitude requires modifications
- CSMA/CA not well suited for Pt-Pt links



What is needed for a long distance link?

- Increase the power budget
- Change parameters influenced by the propagation time
- Modify the Media Access Control

What factors limits the achievable span?

Power budget

Legal regulations on maximum EIRP

Increased cost of high power devices

Increased cost of better receiver sensitivity

Fresnel zone clearance

60 % of first zone for a reliable link

ACK timeout

IEEE 802.11 MAC requires that the sending station receives an ACK for evey frame sent. Normally the propagation time is negligible, but at 300 km it reaches 1 ms

These factors are being addressed by WiMAX but at a considerably higher cost for terminal equipment

What can be done?

Power budget

Use high gain antennas (cheaper if recycled)

Use more sensitive radios

Minimize RF cable length

Fresnel zone clearance

Choose endpoints carefully using coverage prediction software like radio mobile

ACK timeout

Third party firmware allows changing of this parameter

Change the Media Access protocol to TDMA

How to improve the power budget

We will assume that all other aspects have been optimized and concentrate in:

Increasing antenna gain

This implies a narrower beam and therefore requires enhanced pointing techniques for antenna alignment

Low cost instruments have been identified to facilitate this task

Propagation time is 1 ms for 300 km

Wireless LANs were designed for distances of few hundred meters, so the transmitter is expected to receive an ACK of each transmitted packet within a few microseconds.

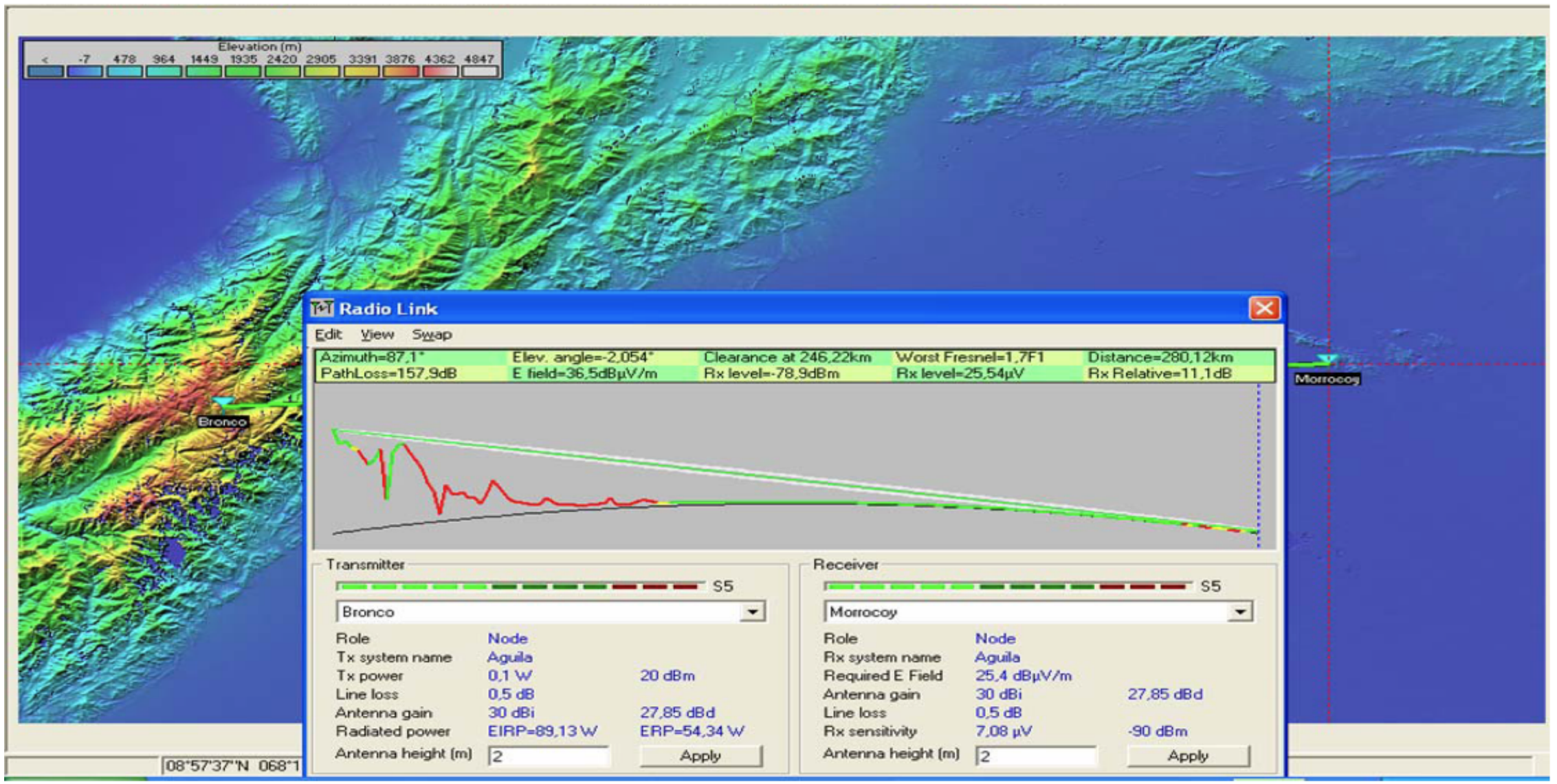
If this does not happen, the transmitter assumes that the packet did not reach its destination and resends it several times until gives up

On long very long distances, the link will not work!

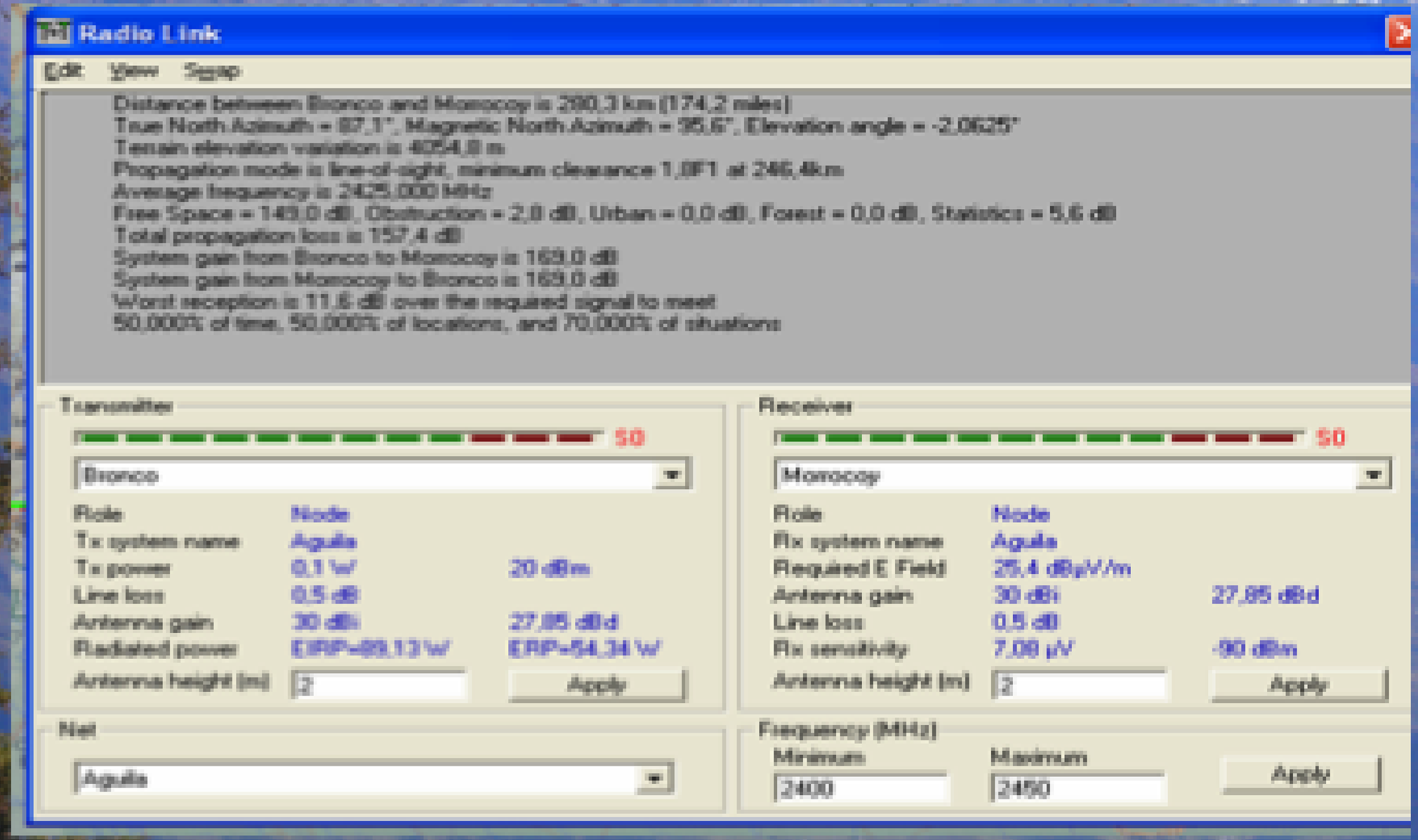
Long WiFi link

Profile of the 279 km test, 2.4 GHz, APRIL 2006

EsLaRed-ICTP team, Venezuela, limited bit rate



Links details

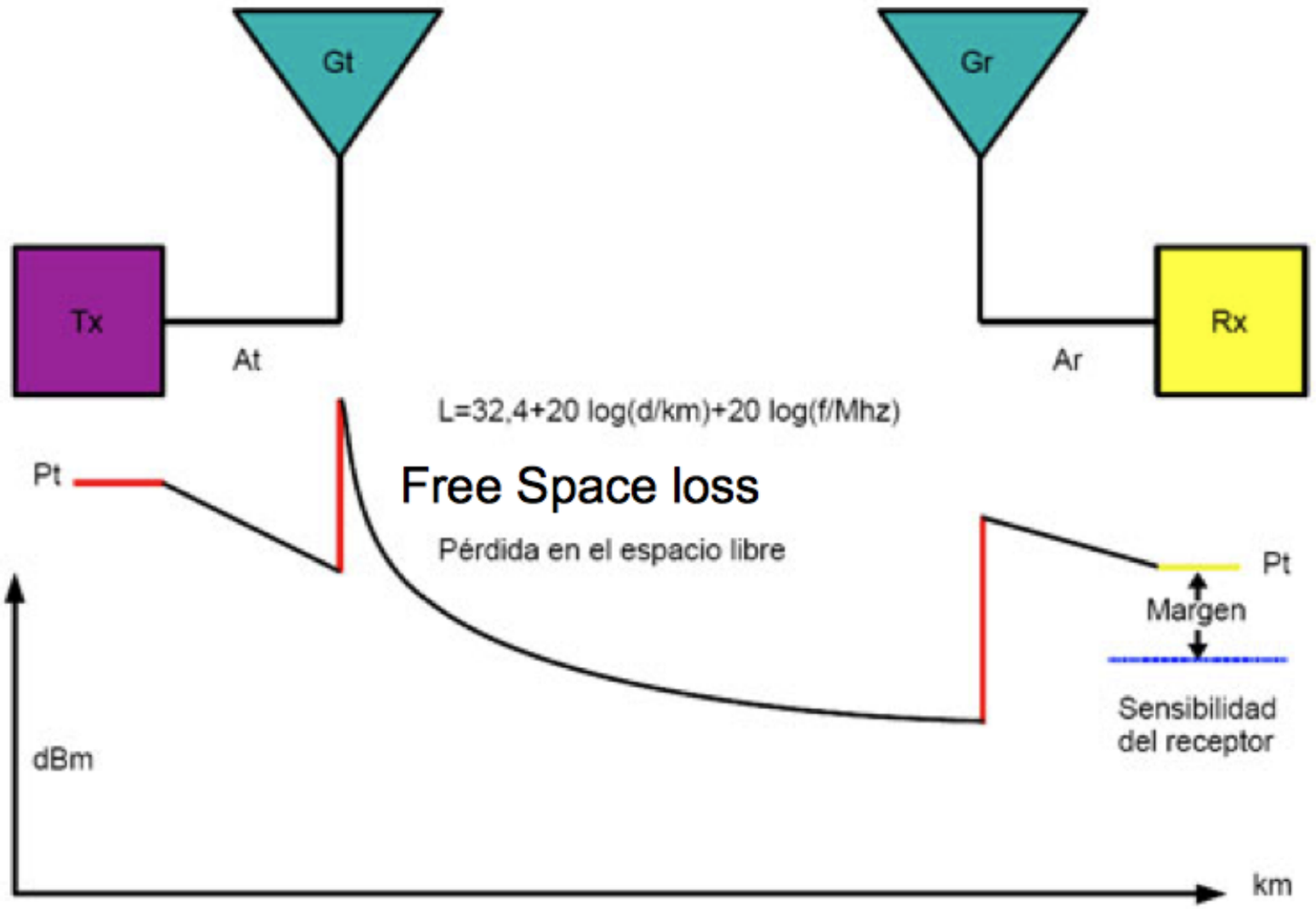


What do we need to increase the radio link range?

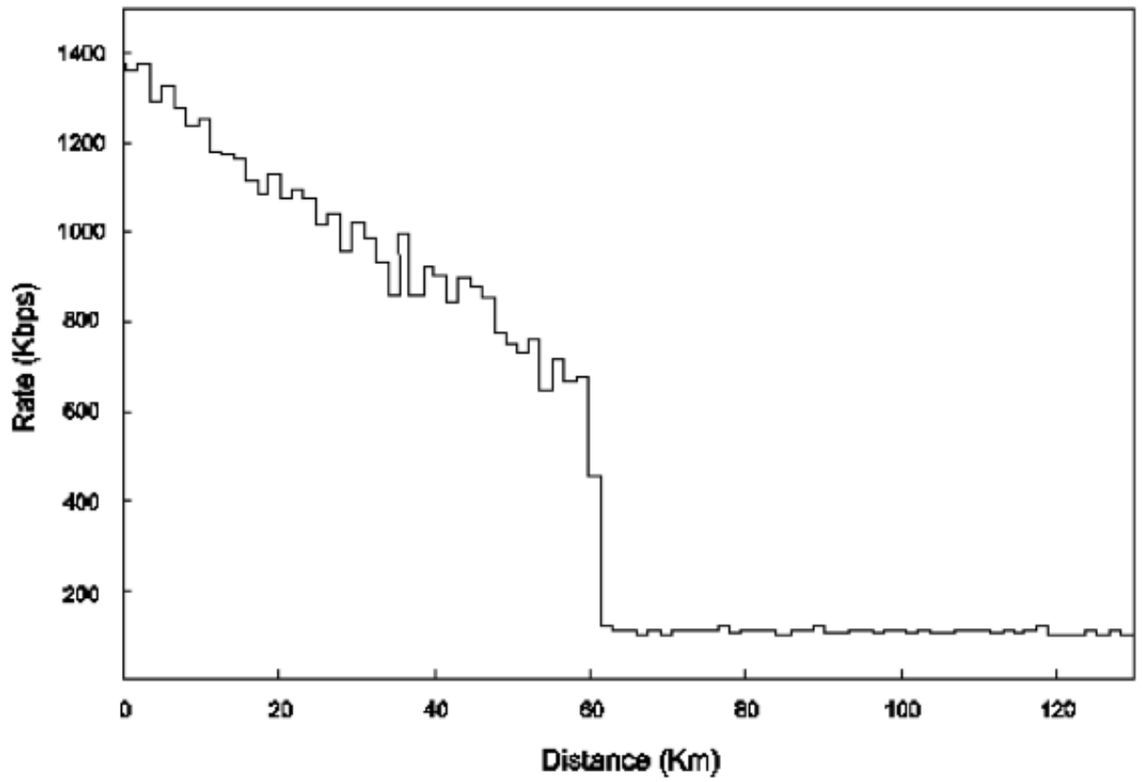
- Increase the radio dynamic range
- Increase the antenna gain
- Decrease the antenna cable loss
- Take provisions to account for the radio propagation time, which is 33.3 microseconds per kilometer and cannot be neglected at long distances.

How to improve the power budget?

- Increase transmission power
- Increase Antenna gain
- Decrease RF cable loss
- Use a receiver with better sensitivity



802.11 rate Vs distance behaviour



Rate versus distance for an FTP file transfer simulated with NS2, from:

Distance Limits in IEEE 802.11 for Rural Networks in Developing Countries

Javier Simo, Andres Martinez, Carlos Figuera and Joaquin Seoane

What can be done?

Use the *ad hoc mode*, in which ACKs are not expected.

Increase the time the transmitter waits for an ACK.
Some configurations will ask directly for the distance setting of the link.

Modify the Media Access Control so it will not depend on ACKs.

What can be done?

Changes proposed by the TIER group led by professor Eric Brewer at Berkeley University:

Modifications of the 'madwifi' driver for the Atheros chipset to inhibit the ACKs and the carrier detection mechanism

Implementation of a new routing mechanism both at the kernel and user level, to create virtual interfaces and capture packets

http://tier.cs.berkeley.edu

Media Access Control Modification

Changes proposed by the TIER group led by professor Eric Brewer at Berkeley University:

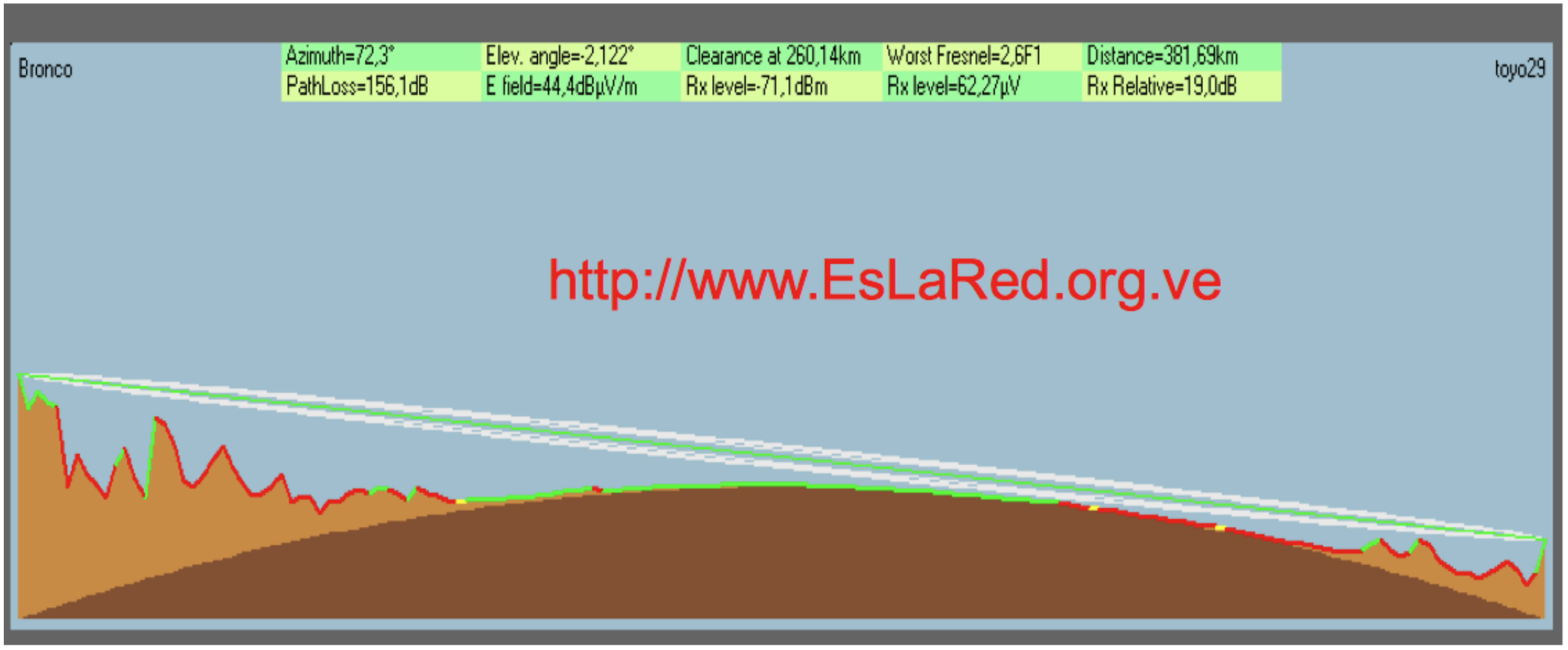
Use of a sliding windows mechanism to acknowledge the reception of groups of packets, instead of individual ones

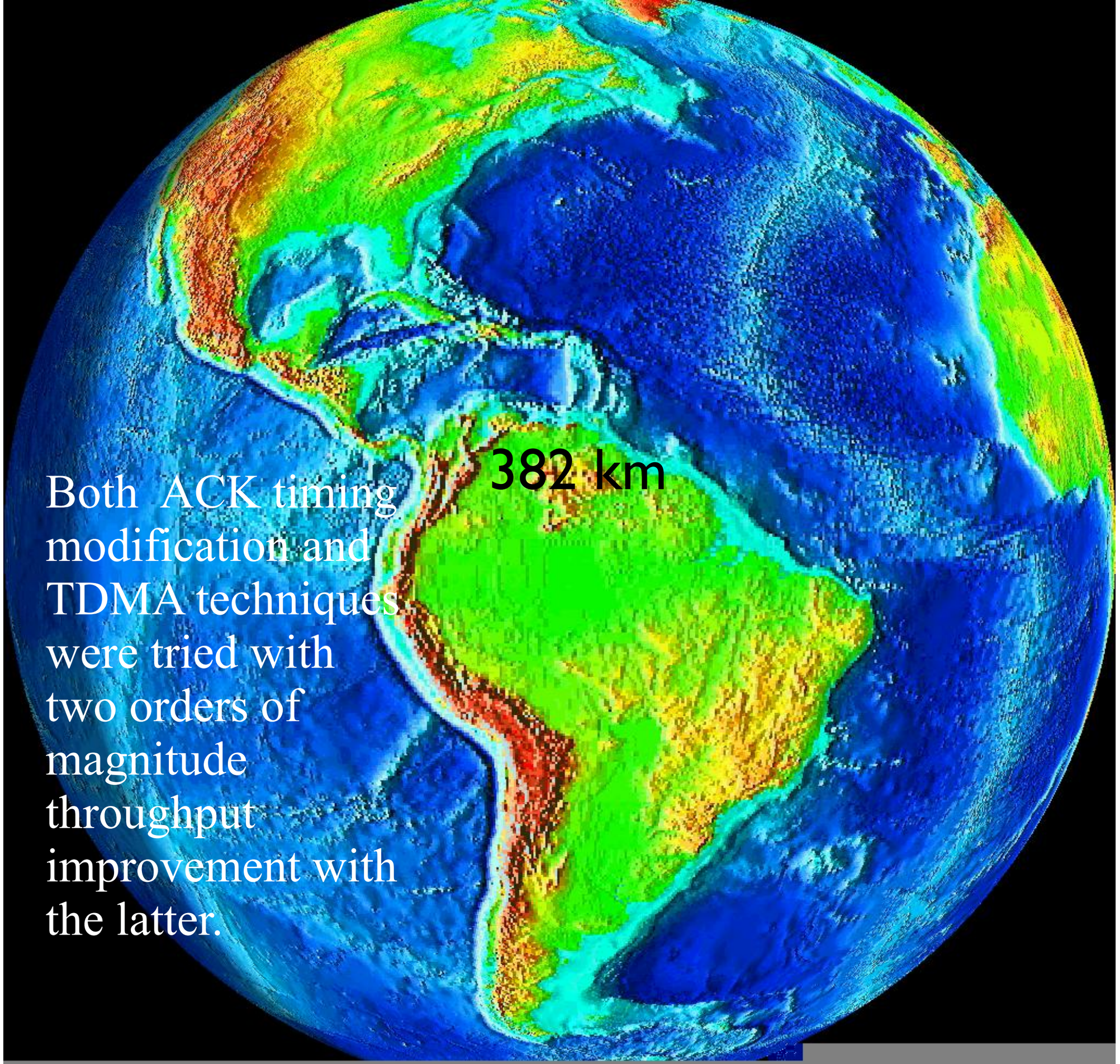
Implementation of TDMA, as a replacement of CSMA. Each station will transmit half of the time and receive the other half so the media access method is now deterministic

Use of a selective loss recuperation mechanism FEC - Forward Error Correction- to minimize transmission losses

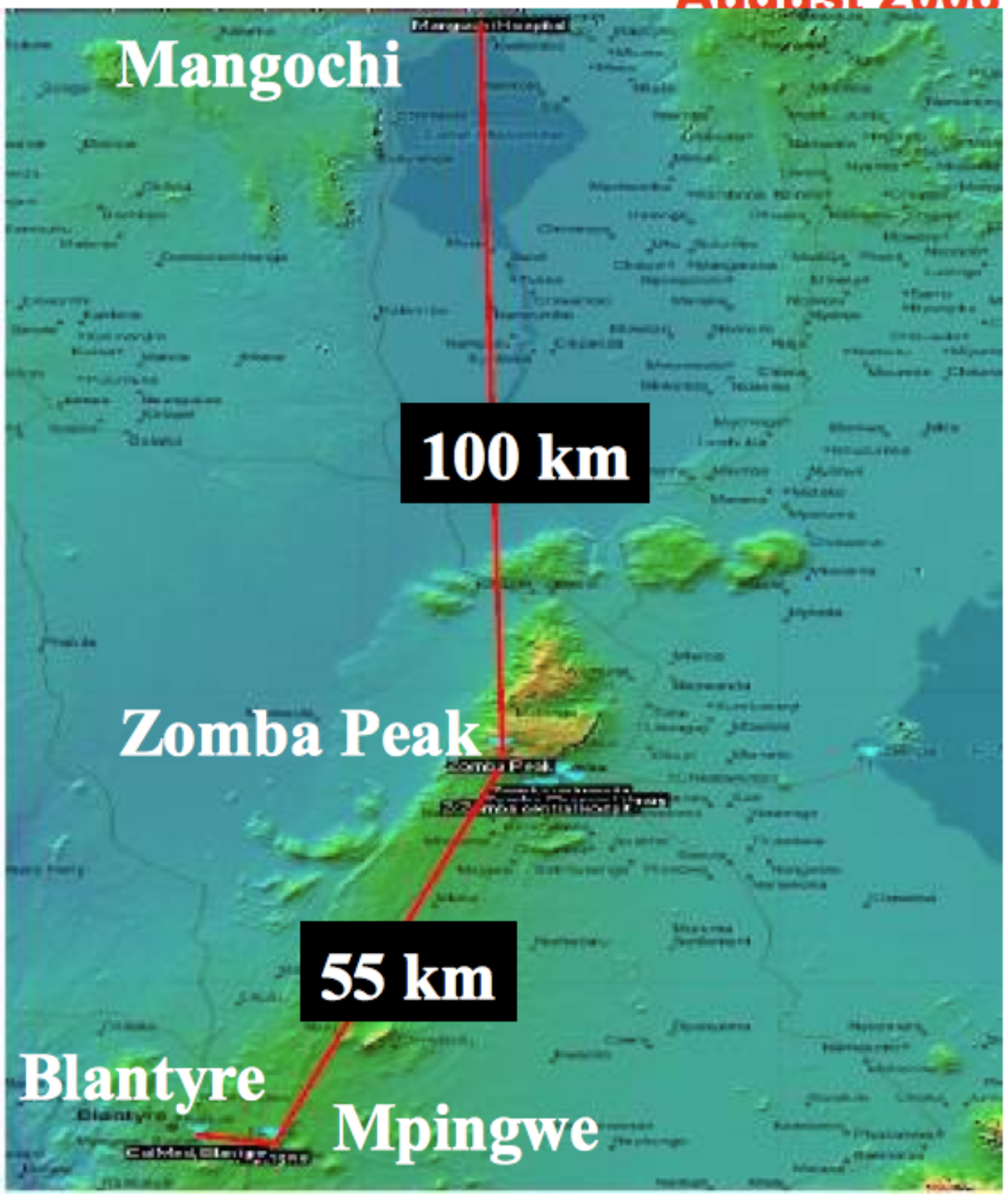
Longest WiFi link

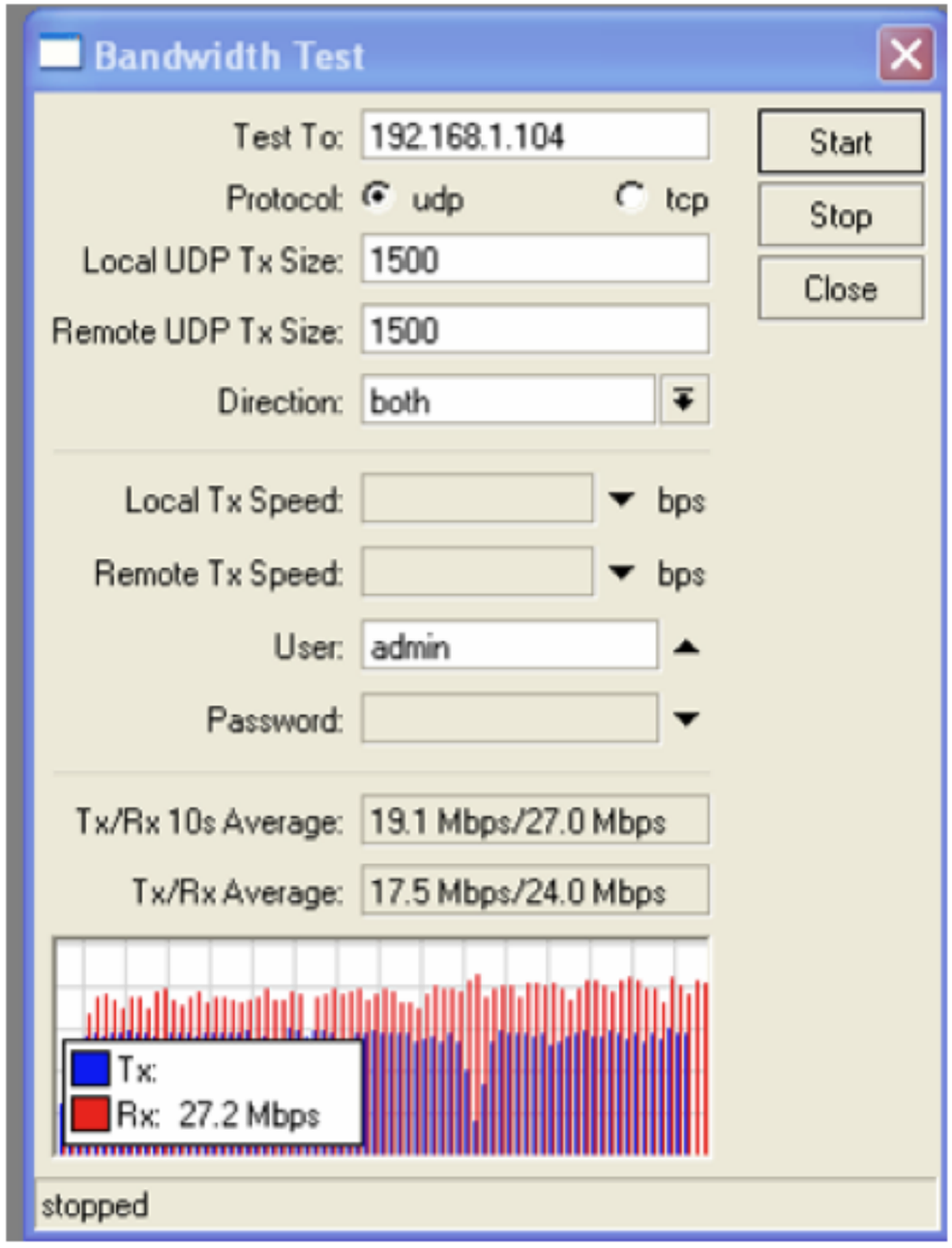
Profile of the 382 km test, 2.4 GHz
April and August 2007, Venezuela

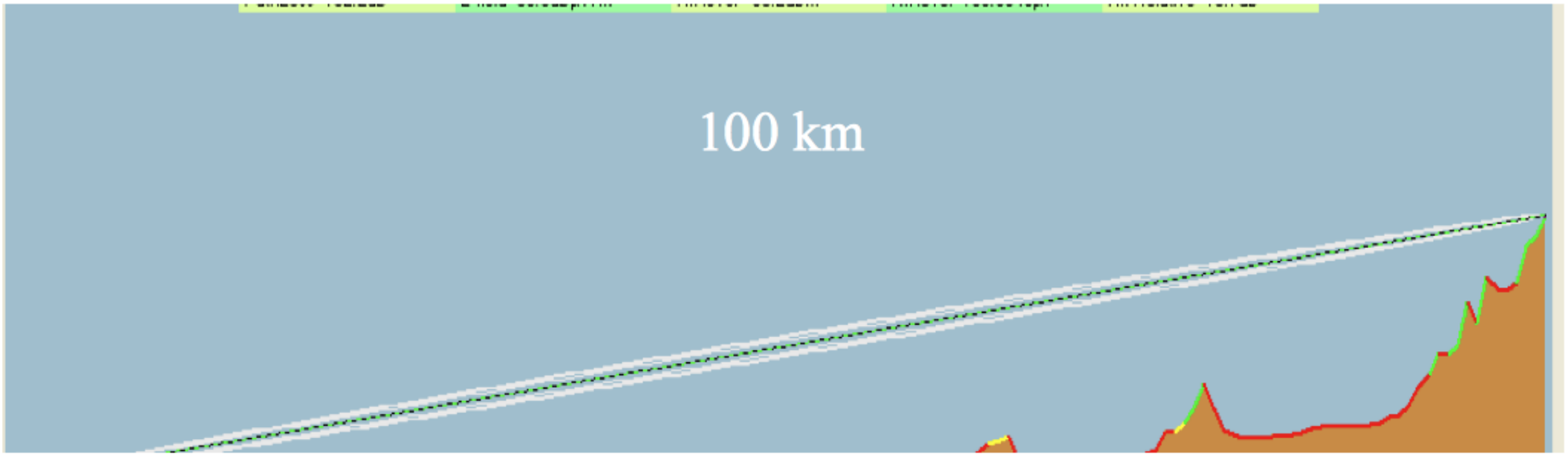


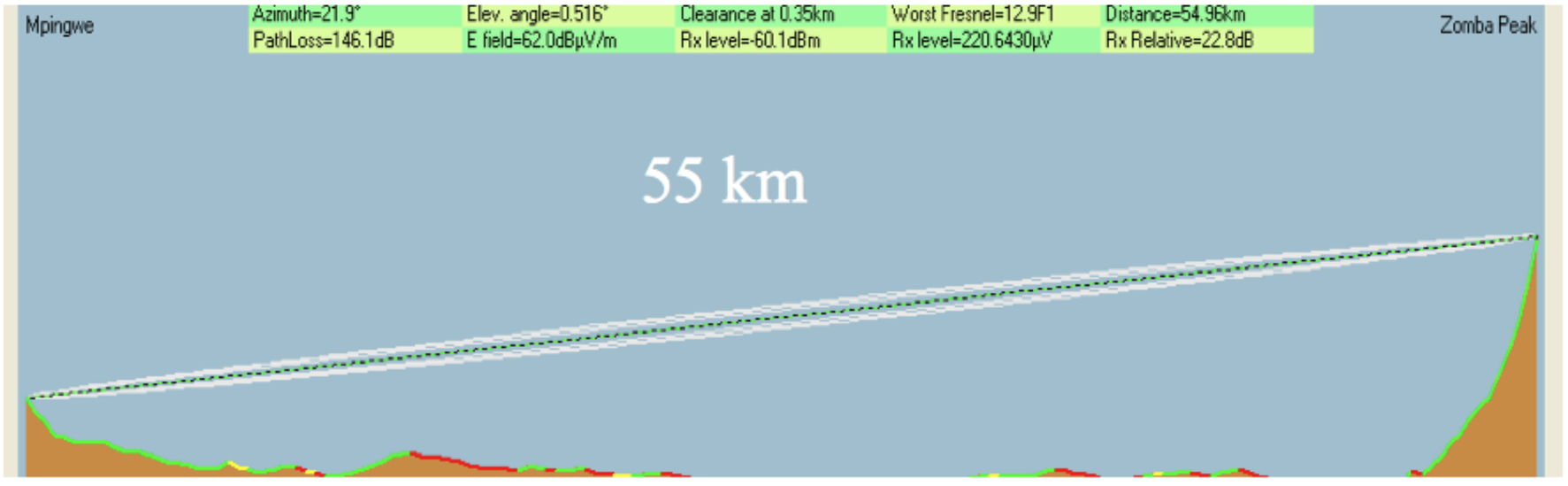

382 km
Both ACK timing modification and TDMA techniques were tried with two orders of magnitude throughput improvement with the latter.

Blantyre-Mpingwe-Zomba Peak-Mangochi Backbone
August 2008






100 km


Mpingwe
Azimuth=21.9°
Elev. angle=0.516°
Clearance at 0.35km
Worst Fresnel=12.9F1
Distance=54.96km
PathLoss=146.1dB
E field=62.0dBµV/m
Rx level=-60.1dBm
Rx level=220.6430µV
Rx Relative=22.8dB
Zomba Peak
55 km


7 km

Antenna Alignment

A string a few meters long can help estimating the direction at which the antenna is pointing.

It also helps separating the compass from the influence of ferrous objects in the antenna mounting structure that might alter the compass reading

For long distances instruments are required

Long Distance Antenna Alignment Instruments

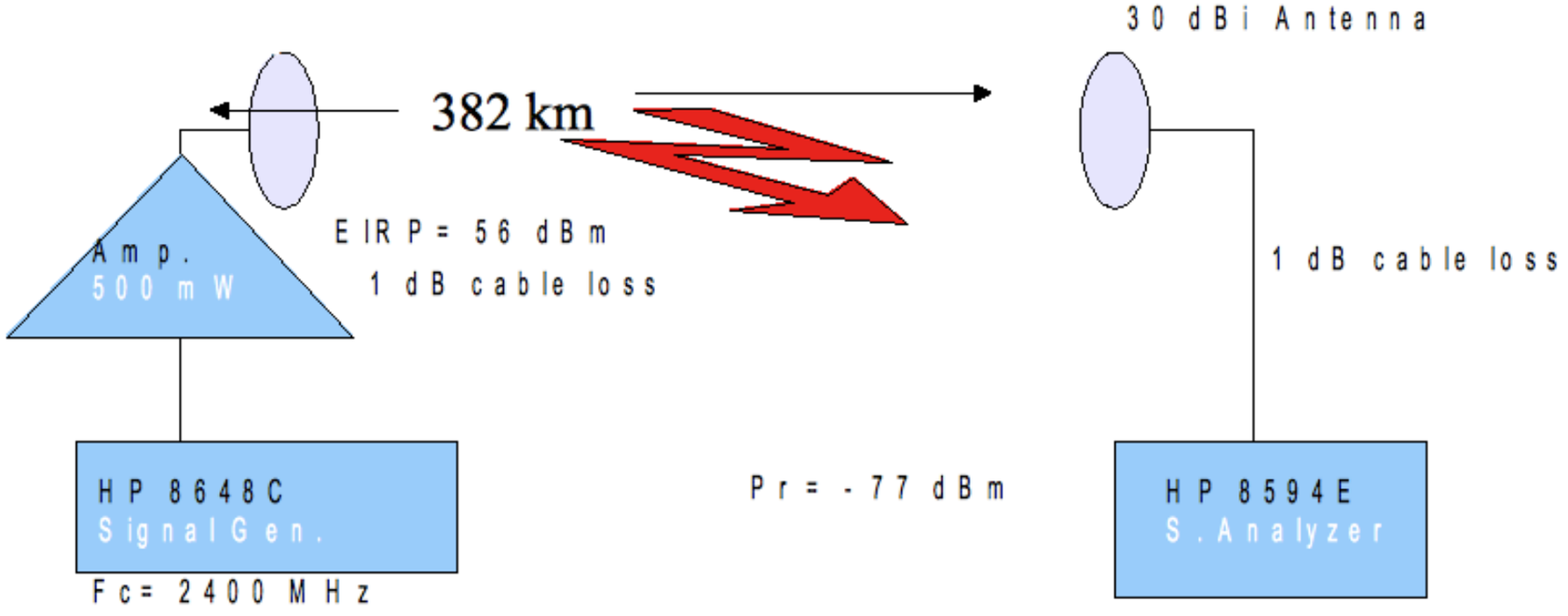
- Signal Generator
- Spectrum Analyzer

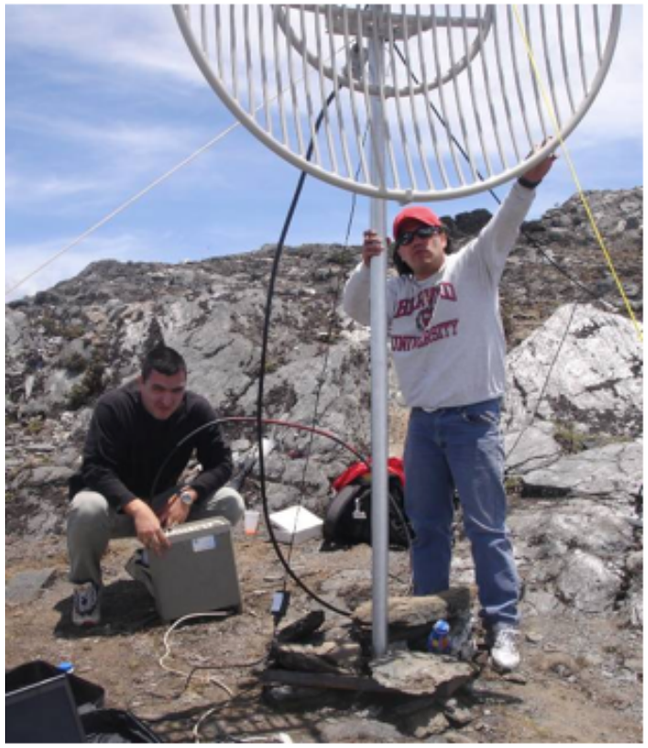
Use the *ad hoc mode*, in which ACKs are not expected

Increase the time the transmitter waits for an ACK

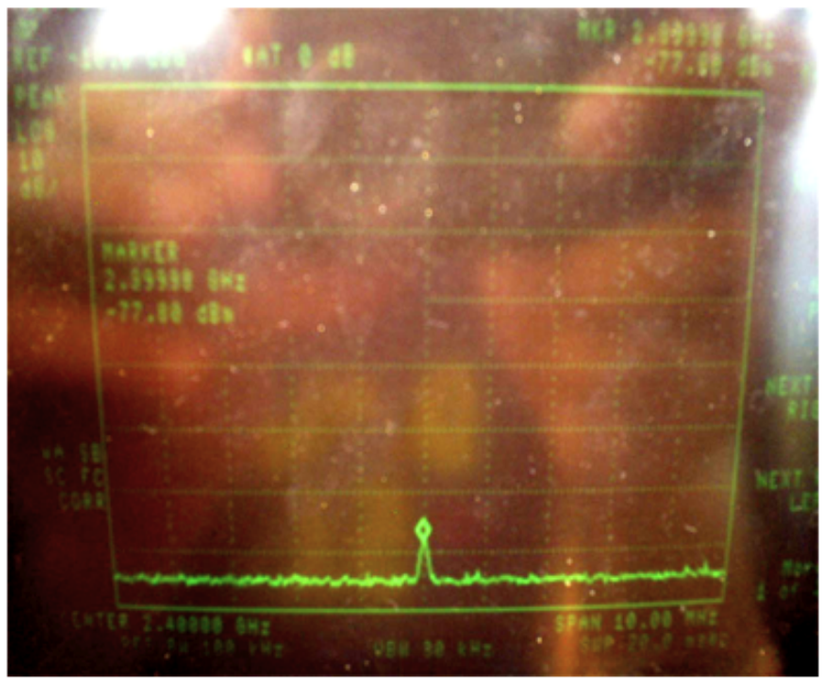
Some configurations will ask directly for the distance setting of the link

Modify the Media Acces Control so it will not depend on ACKs.





Antenna Alignment using instruments

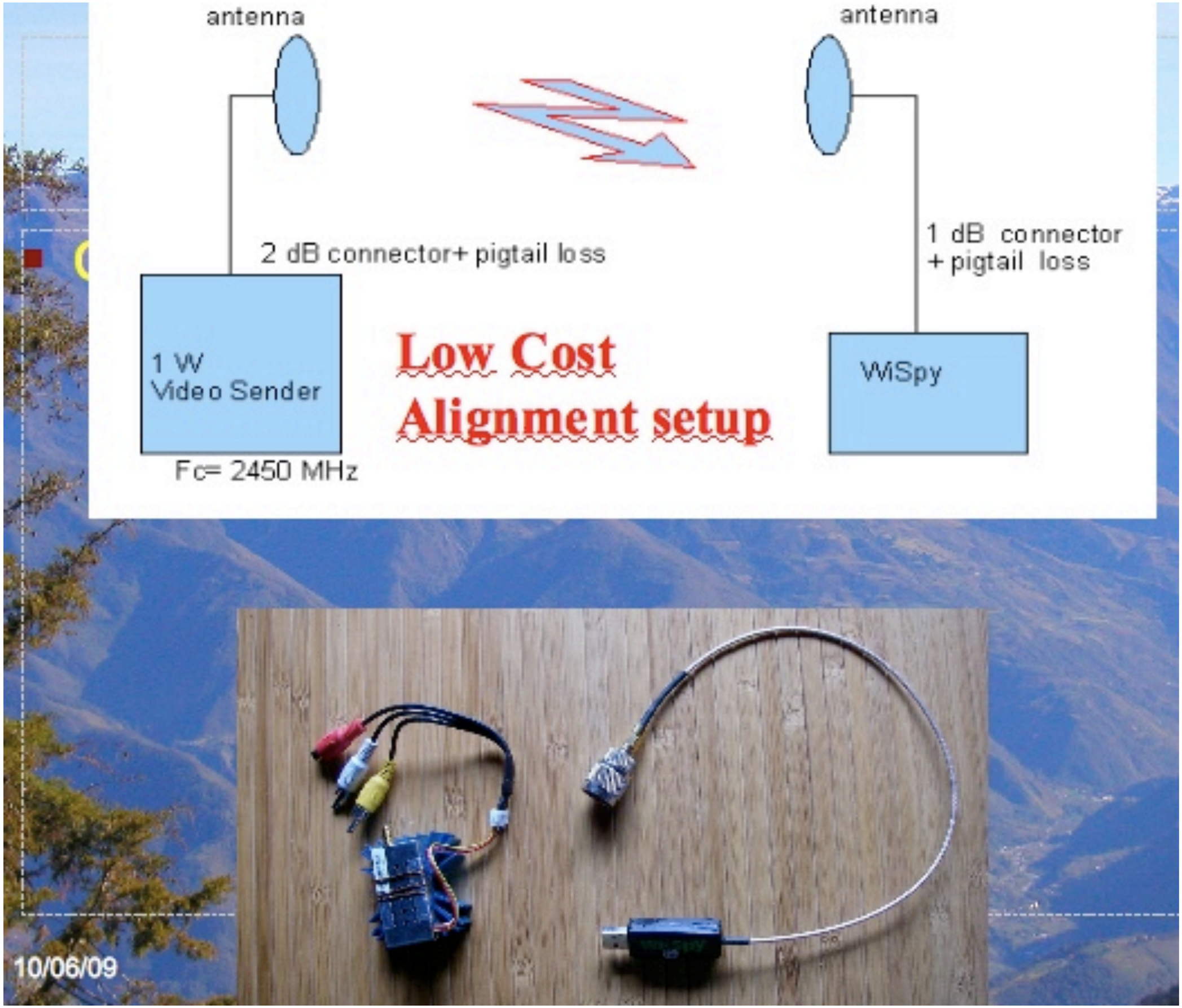


Antenna Alignment with inexpensive signal generator

Analog video transmitters in the 2,4 GHz band

- Video sender:
  - Operates at 2,4 GHz
  - Allows the choice of 8 different tones spanning the 2.4 GHz band
  - 1 W output power

Video sender and spectrum analyzer


antenna
antenna
2 dB connector+ pigtail loss
1 dB connector
+ pigtail loss
1 W
Video Sender
Fc= 2450 MHz
Low Cost
Alignment setup
WiSpy
10/06/09

Conclusions

By modifying consumer grade WiFi equipment and fitting it with external antennas, very cost effective long distance and high throughput links can be built in the non licensed frequency bands.

This techniques have been demonstrated in deployments in several countries.

They are particularly fit for usage in sparsely populated areas where interference from other users of the same spectrum is less likely.

Low cost commercial equipment that implements TDMA and polling is available from Mikrotik and Ubiquiti.

Thank you for your attention

For more details about the topics presented in this lecture, please see the book ***Wireless Networking in the Developing World***, available as free download in many languages at:

http://wndw.net