Long Distance Links

ICTP-ITU School on Wireless ICT Low Cost solutions in Developing Countries: best practices

Abdus Salam ICTP, February 2009

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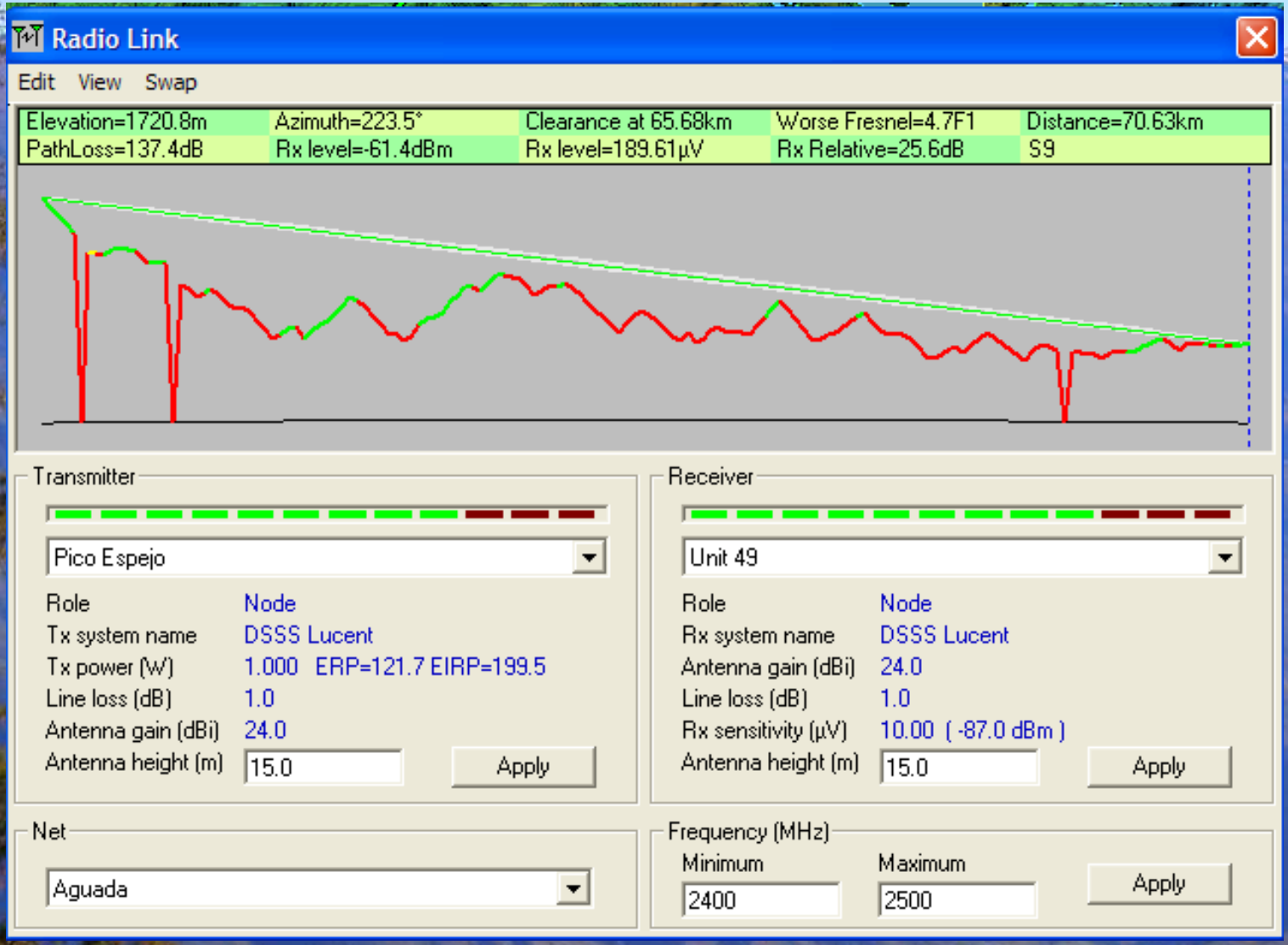
Timeline

- 1987 (Packet Radio, 400 km at 1200 bit/s)
- 1995 (Spread Spectrum, 1 Mbit/s,11 km)
- 1998 (Narrow band, 20 Mbit/s, 40 km)
- 2002 (70 km, 11 Mbit/s, Spread Spectrum)
- 2006 (279 km)
- 2007 (382 km, 6 Mbit/s)
- 2008 (130 km testbed to compare different equipment)
- 2008 (100 km, 40 Mbit/s)

Pico Espejo- Canaguá 70 km link



What is needed for a long distance link?

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

Carlo Fonda with 2.7 m reflector

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 lenght
- Fresnel zone clearance
  - Choose endpoints carefully using coverage prediction software like radio mobile
- ACK timeout
  - Third party firmware allows changing of this parameter

How to improve the power budget?

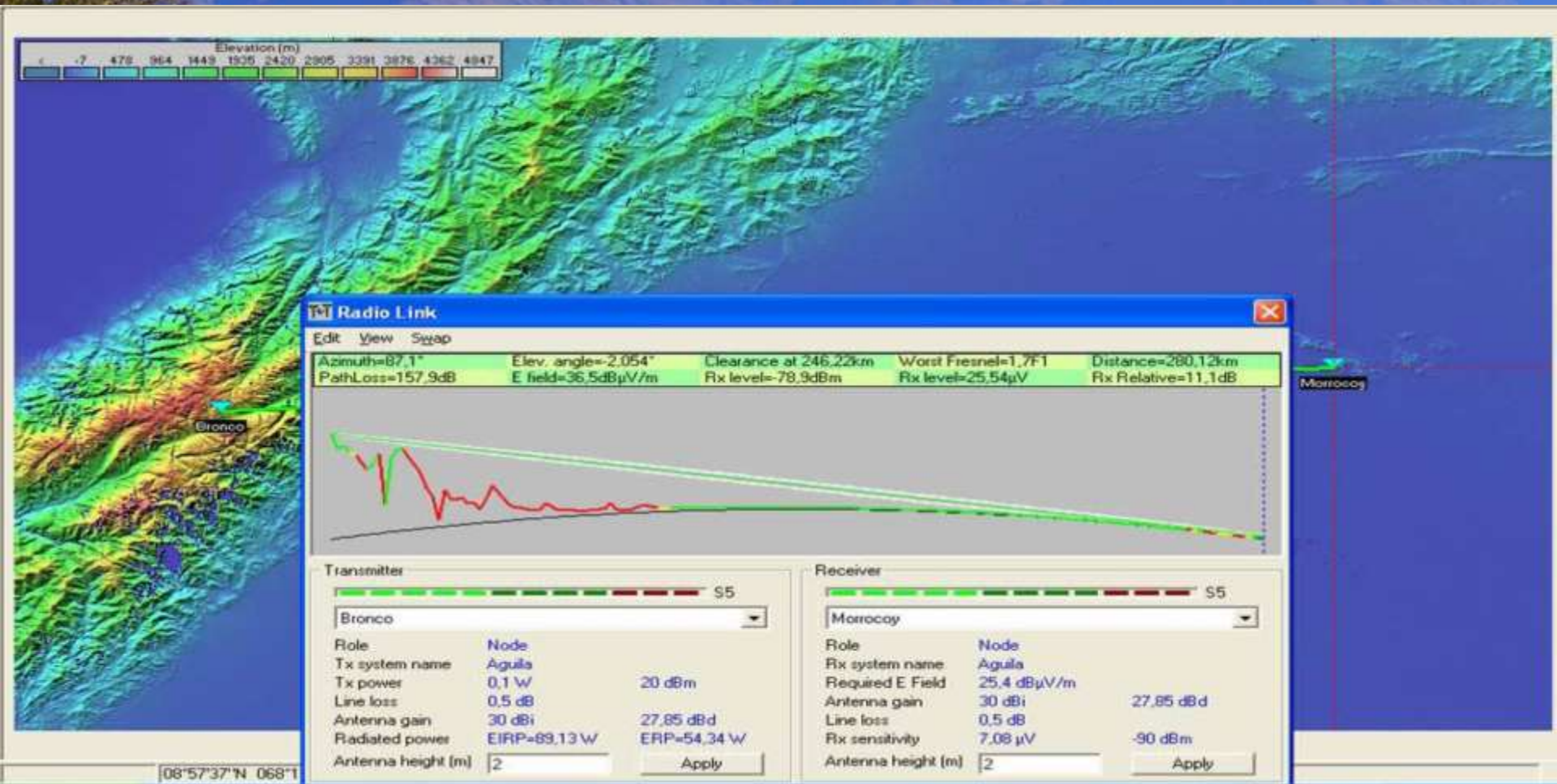
- We will assume that all other aspects have been optimized and concentrate in:

  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

Long WiFi link

Profile of the 279 km test, 2.4 GHz, APRIL 2006
EsLaRed-ICTP team, Venezuela, limited bit rate



Carlo Fonda at El Aguila with the meshed dish

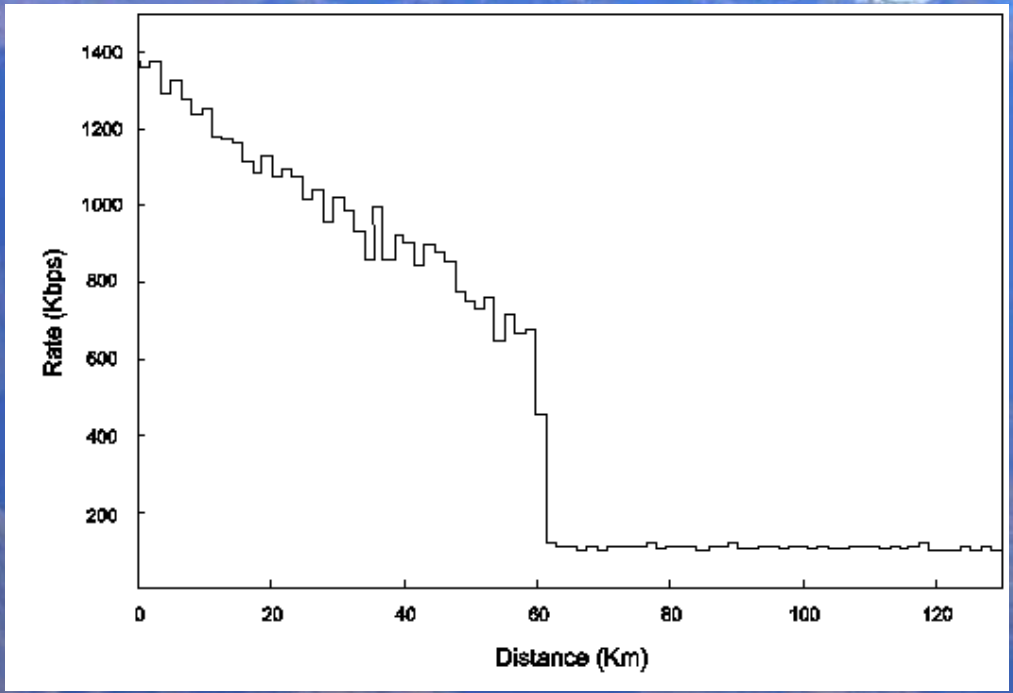

El Aguila

Javier Triviño and Ermanno Pietrosemoli in front of the 2.4 m dish

Propagation time is 1 ms for 300 km

- Wireless LANs where 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!

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

So 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 Acces Control so it will not depend on ACKs.

Media Access Control Modifications

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

- Modifications of the 'madwifi' driver for the Atheros chipset to inhibite 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

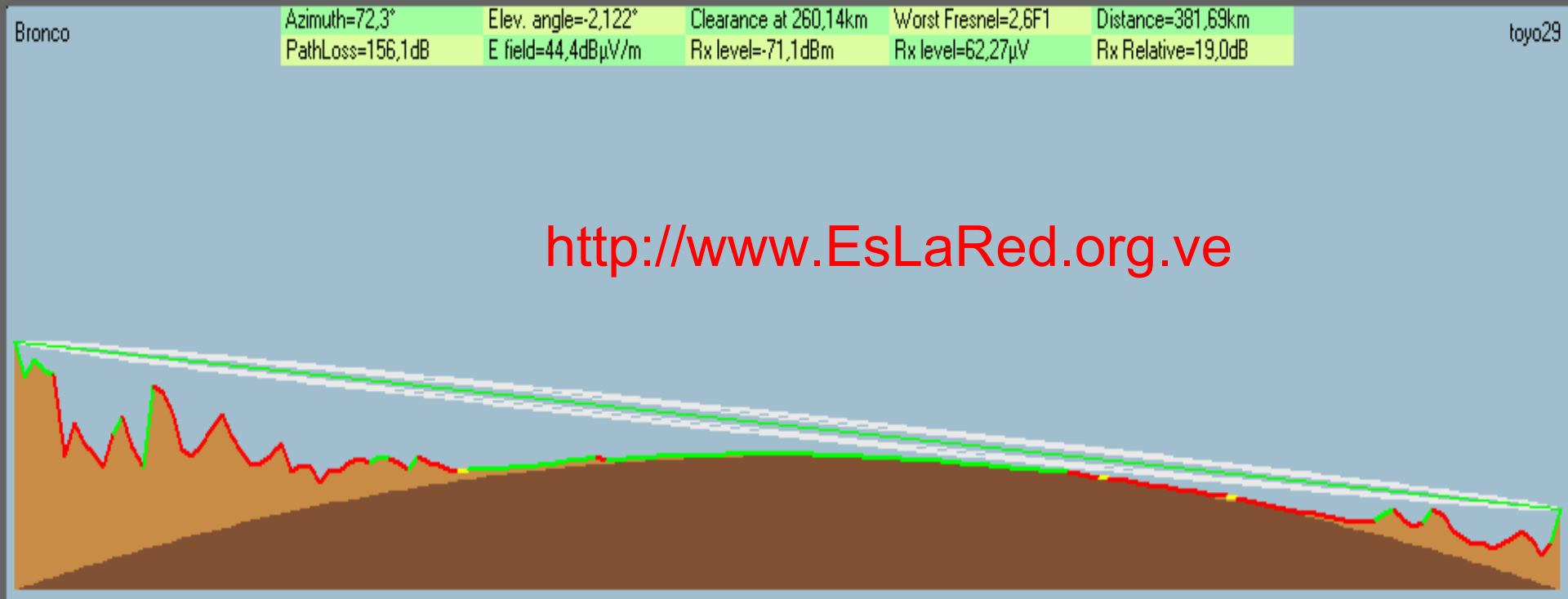
Media Access Control Modifications

Changes proposed by the TIER group:

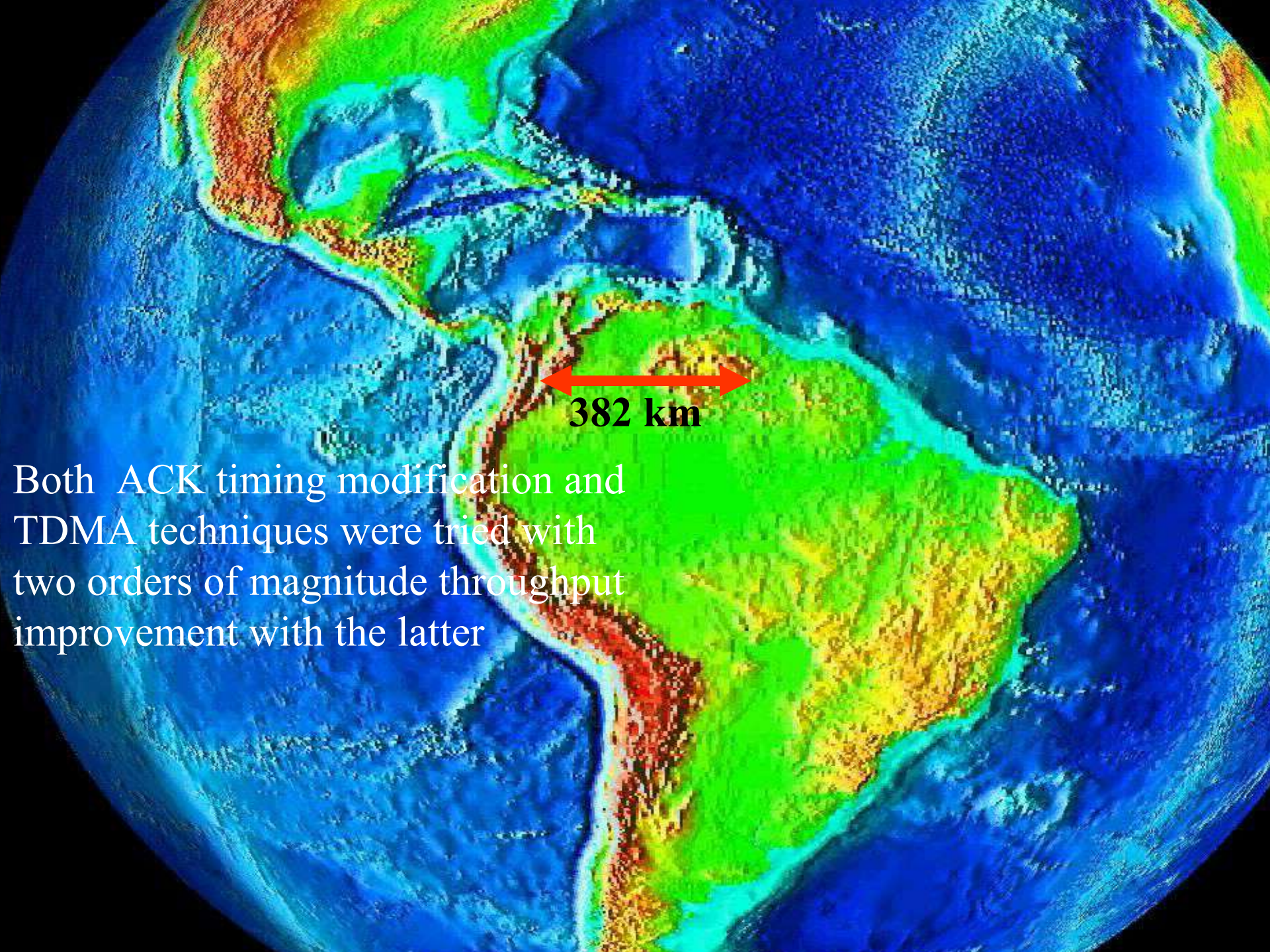
- Use of a sliding windows mechanism to acknowledge the reception of groups of packets, instead of individual ones
- Implementation of TDMA, as a replacement of CSMA. Each station will transmit half of the time and receive the other half so the media access method is now deterministic
- Use of a selective 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



http://www.EsLaRed.org.ve



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

RedGala
Galápagos Islands, Ecuador

RedGala
Galápagos Islands, Ecuador
Main Links

RedGala
Galápagos, Ecuador
Backup links

Monte Cesen, February 2008

130 km testbed link between Monte Cesen and ICTP, Italy

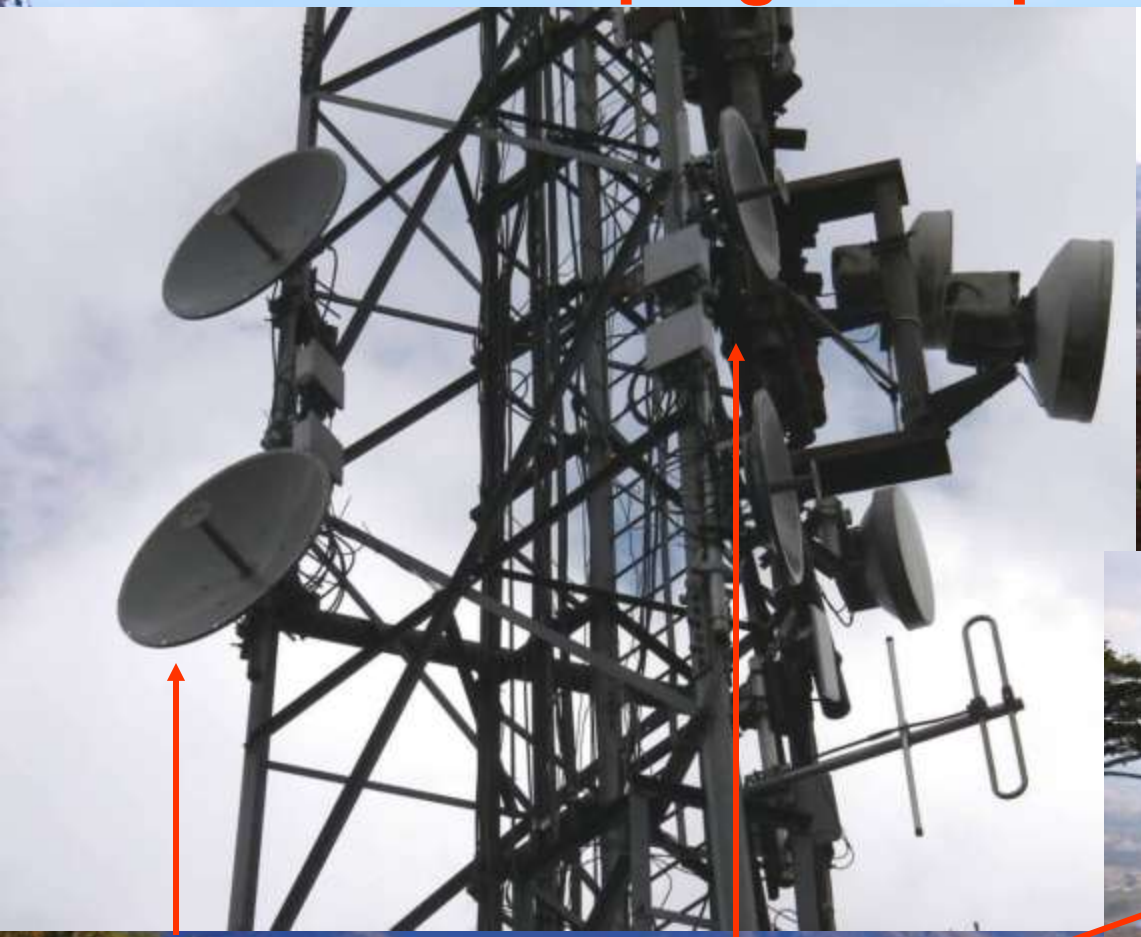
Malawi Broadband Network

Mangochi and Zomba installs

Team work for antenna hoisting in Mangochi

Zomba Peak antenna install
Carlo Fonda and Ermanno Pietrosemoli

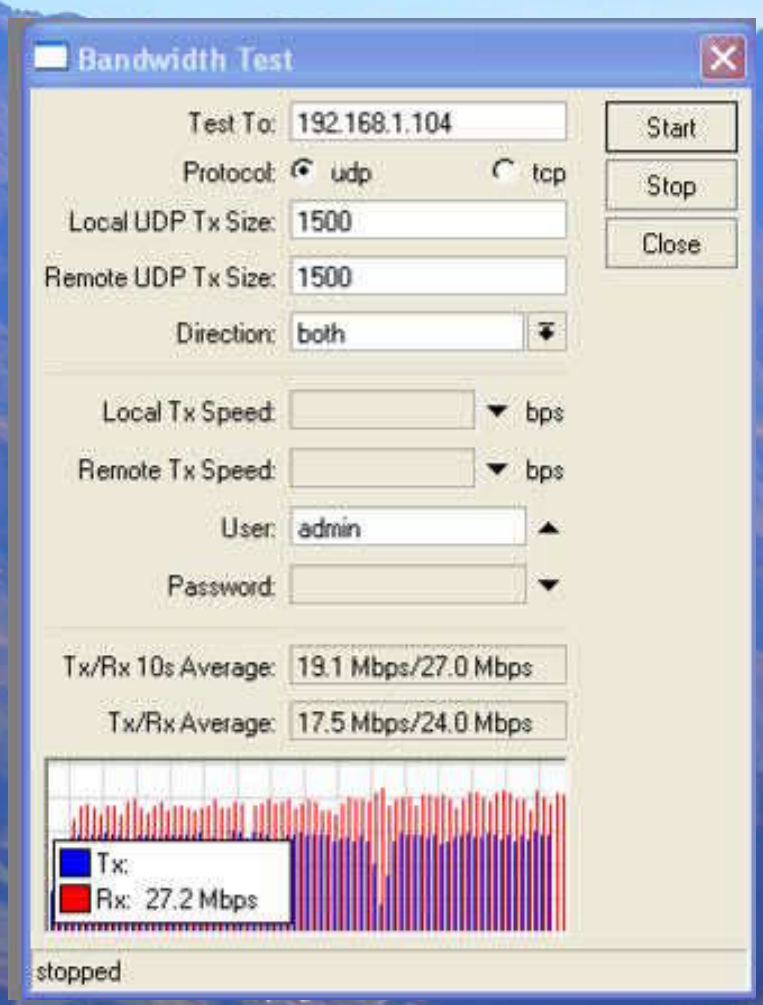
Mpingwe Repeater, Malawi

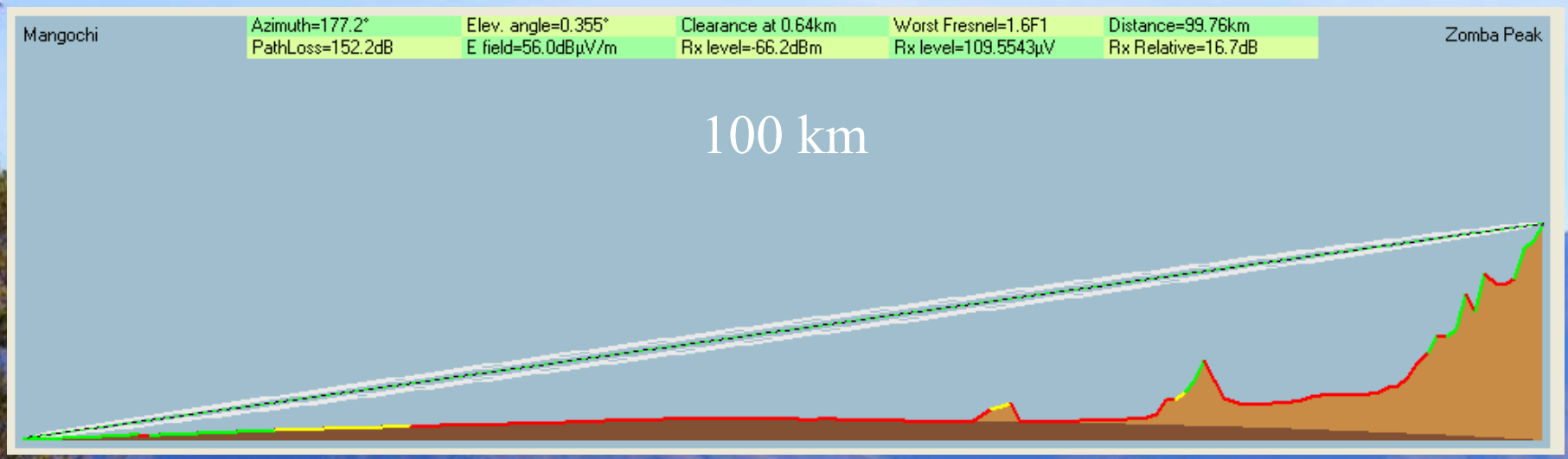


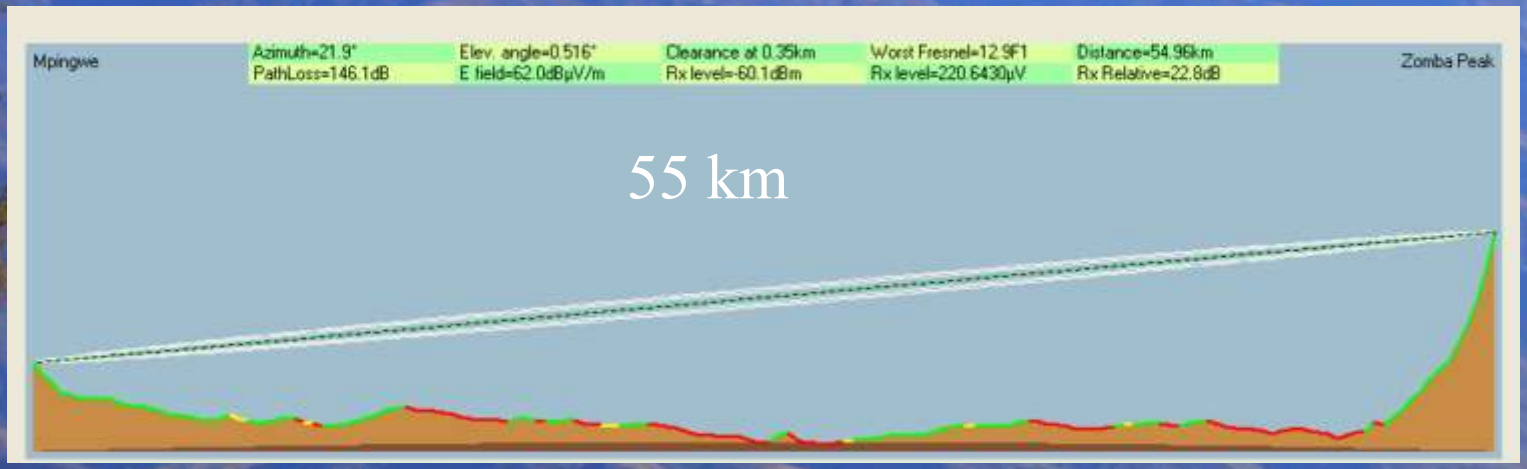
Towards Zomba Peak

Towards Blantyre

Blantyre-Mpingwe-Zomba Peak-Mangochi Backbone
August 2008

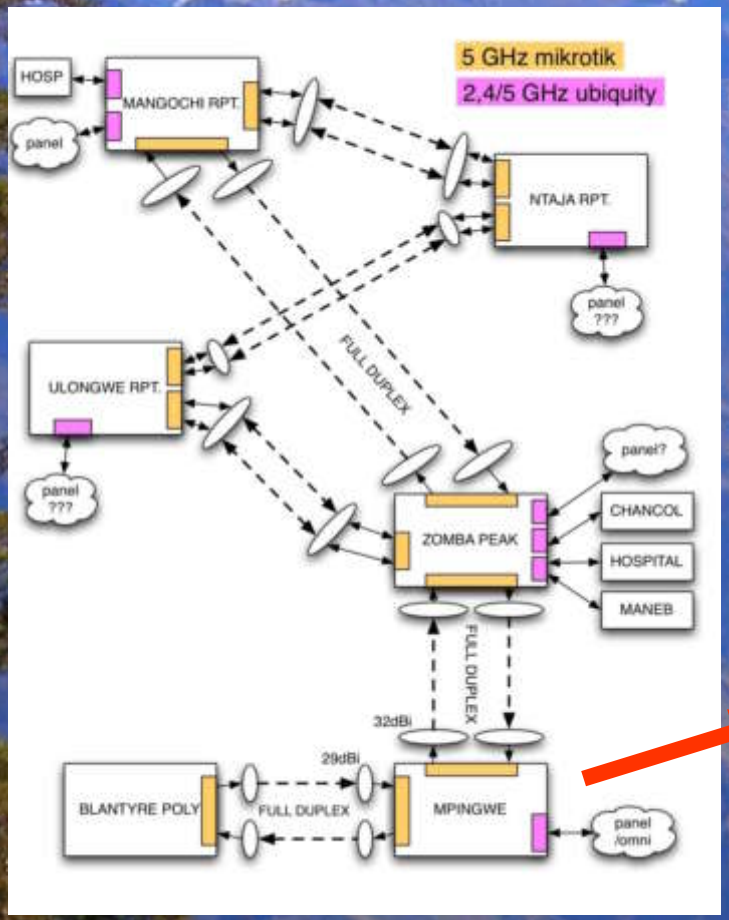



Mangochi
Azimuth=177.2°
Elev. angle=0.355°
Clearance at 0.64km
Worst Fresnel=1.6F1
Distance=99.76km
PathLoss=152.2dB
E field=56.0dBµV/m
Rx level=-66.2dBm
Rx level=109.5543µV
Rx Relative=16.7dB
Zomba Peak
100 km


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

162 km broadband backbone with frequency, spatial and polarization diversity



Wireless router with 2 mini PCI radios

Conclusions

- 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 demostrated 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