Wide Area Network with Affordable Technologies: the case of Mérida, Venezuela

RADIO AFRICA '04

AFRICAN REGIONAL WORKSHOP ON USE OF RADIO FOR ICT IN RURAL AREAS- KCCT MBAGATHI-NAIROBI

AUGUST 2004

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Agenda

- Motivation
- Wireless Computer Networks
- Broadband Licensed Wireless Venezuela
- Unlicensed 2.4 GHz Networks in Mérida: RedUla and Fundacite
- Point to Point 5.8 GHz
- Mesh Networks

Motivation

- The university buildings at Universidad de los Andes are dispersed all over the town
- In 1991, ULA had 40000 students, a computer center, but no network
- Strong need to improve the communications both inside the university and to the outside world
- The only fiber optic deployed in the country was in a few basic industries

Background

- Very limited resources, both financial and human
- 700 km by mountain road to the capital
- Telephone communication out of Mérida by terrestrial analog microwave only
- Low teledensidity, no cell phones

Background

- Faced with the need to deploy a computer network, we concluded that despite our big technical hurdles the main obstacle was the lack of trained people
- Established a pilot computer network with two LANs connected by modems
- Started training a group of enthusiastic students in Unix, TCP/IP, and basic networking techniques
- Realized that we did not have the means to provide advanced training

Background

- The International Centre for Theoretical Physics in Trieste organized in 1990 the First International School on Computer Networks, which was attended by a member of our group
- Upon his return Prof. Luis Nunez suggested that we did something similar in our institution, counting on the fact that the need of training in the whole region would helps us getting outside resources

Background

- We decided that I would dedicate my upcoming Sabbatical Leave to prepare the Latin American Networking School, Escuela Latinoamericana de Redes, EsLaRed'92
- The time I was going to spend at Bellcore in New Jersey was cut short to make room for a stint at SuraNet in College Park, Maryland, working with Dr. Glenn Ricart and then moving to the ICTP to work on the preparation of the Second Computer Networks School, held in 1992

Background

- With this experience, and the contacts acquired we organized EsLaRed'92 during 3 weeks in November 1992
- 45 participants from 10 countries where trained in hands-on techniques in computer networks by 15 Instructors from Europe and the Americas
- The Organization of American States provided the seminal financial support through Saul Hahn's Red Hemisférica Universitaria, which prompted several other institutions to chip-in.

Background

- The infrastructure prepared for EsLaRed'92 left us with an improved network, connected to the Internet by an UUCP phone call made daily to Caracas, and a group of well trained people
- The participants suggested that we made EsLaRed a biannual event, with Mérida as the permanent venue, thanks to its favorable environment
- One of the techniques covered in our lab sessions was wireless data transmission, of paramount importance in places with low teledensity and difficult terrain

Wireless Computer Networks

- Packet Radio in HF, VHF and UHF
  - Low speed (up to 56 kbps),
  - Good range (up to 400 km)
- Spread Spectrum transmission in the ISM bands (915, 2400 and 5800 MHz)
  - Speed up to 54 Mbps
  - Ranges of up to 65 km

Wireless Computer Networks

The university network, RedUla, made good use of these technologies and in 1995 during a visit to ICTP I proposed this solution to the communication needs of the university of ILE-IFE in Nigeria. The Computer Center LAN there was thus connected by 915 MHz Spread Spectrum links to the Physical Sciences building and the Technology building

Evolution

- We were not able to held EsLaRed in 1994, but we managed to organize it in 1995, 1997, 1999, 2001and 2003
- Our training efforts where recognized by the Internet Society, that had been holding training workshops in English since 1992, later augmented with a French version

Latin American Training Workshop

- ISOC sponsored WALC'98 in Rio de Janeiro, with local support provided by the Universidade Federal de Rio, where the Spanish and Portuguese training was organized by EsLaRed
- WALC'99 merged with EsLaRed'99 in Mérida
- WALC'2000 was held at Universidad Autónoma in Mexico City
- WALC'2001 merged with EsLaRed'2001 in Mérida

Latin American Training Workshop

- WALC'2002 was held in Santo Domingo, Dominican Republic
- WALC'2003 merged with 6th EsLaRed in Mérida from October 20 to 24
- On January 2004 the UNESCO-ULA-Cisco computer networking chair was inaugurated with EsLaRed in charge of training activities

RedUla

Meanwhile, the momentum gathered by the training activities helped securing resources for our university network that led us to:

- Establishing the first Fiber Optic links with multimode fiber in 1992
- Installing a Satellite connection to the Internet
- Building the first monomode Fiber WAN that spans our city with a 100 Mbps TDM
- Deploying the first ATM network in an academic institution in Venezuela
- Installing Gigabit Ethernet over 50 km of SM fiber

University Network: RedULA

-50 Kilometers Gigabit Ethernet SM fiber

49 clients nodes 2.4 GHz
7 clients nodes 915 GHz

Hechicera

Radio Backbone
connected to F.O

RETIEM

- Our efforts to wire the city where joined by Fundacite Mérida, a government organization that provided support for a wireless network to span the state of Mérida
- The first links used packet radio techniques at 19.2 kbps, but the advent of the web made mandatory the quest for faster technologies
- We thus deployed a spread spectrum network at 2.4 GHz, installing a base station in a 3450 m mountain overlooking the city and surrounding

RETIEM

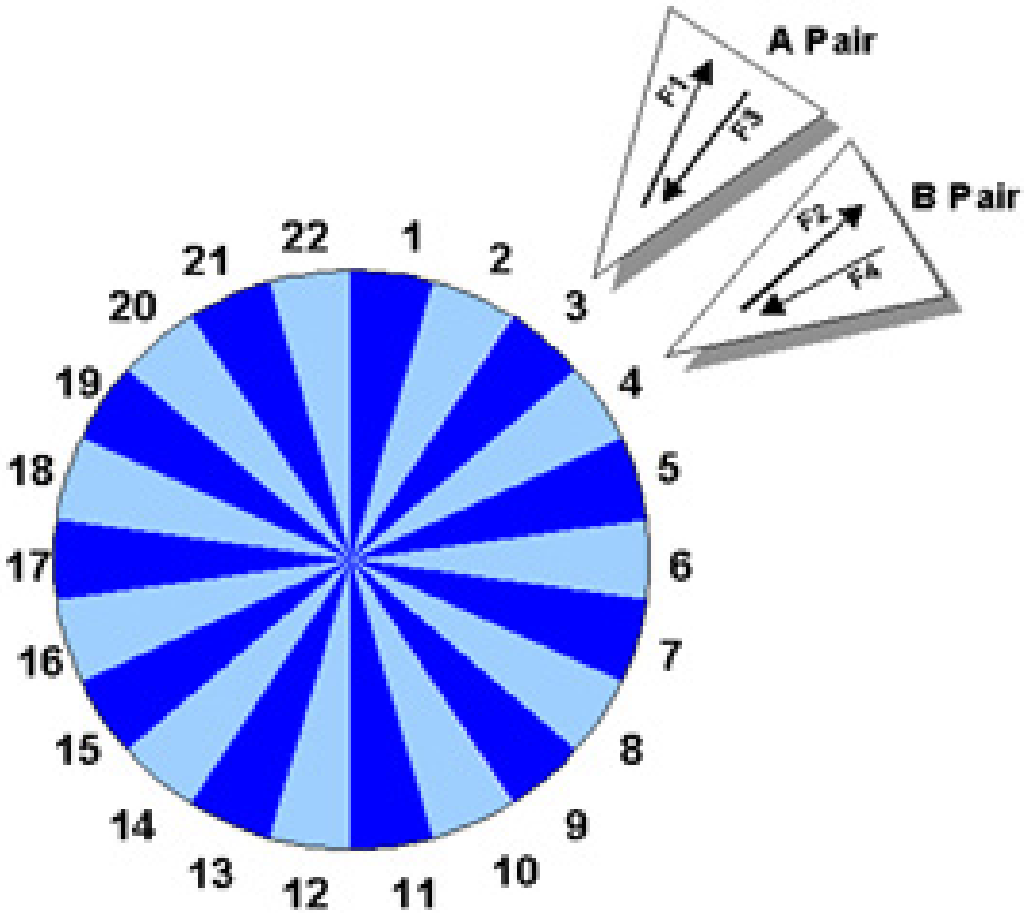
While looking at the alternatives for building a robust wireless backbone, in July 1997 I visited a small startup, Spike Technologies, that had an experimental broadband network in Nashua, New Hampshire. By using MMDS frequencies, they were able to provide full duplex 10 Mps on a pair of 6 MHz wide channels. But the real innovation was a special patented base station multisector antenna that allows for up to 24 sectors with only 3 frequencies pairs. A deal was arranged to install a base station in Mérida and a 90 km broadband backbone to reach the town of Tovar

Broadband Delivery System

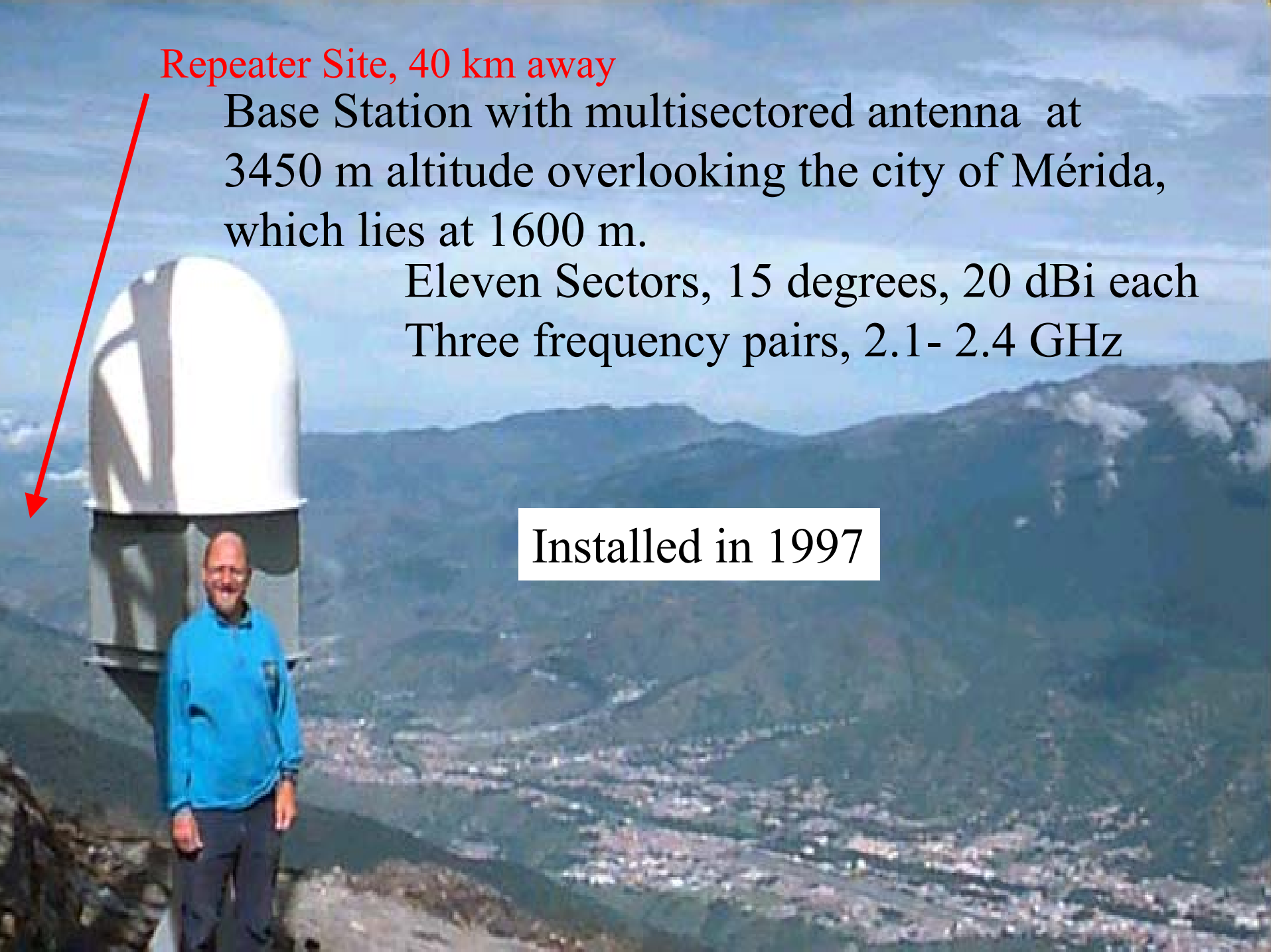
- Sectored antenna
- Frequency Reusability
- Long Range, 50 km
- High Throughput, 10 Mbit/s, Full Duplex
- Upgradable
- Standards based

Broadband Delivery System

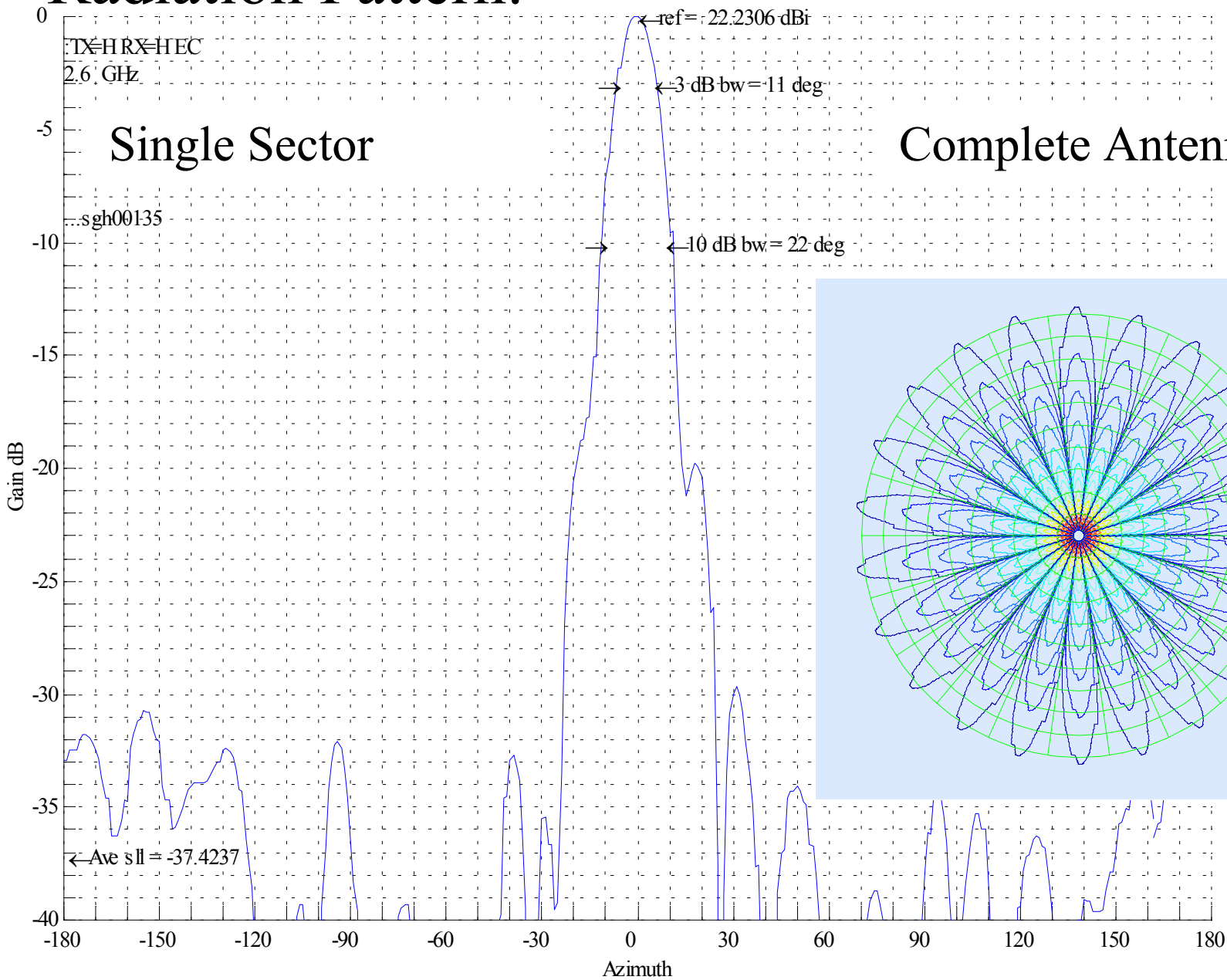
The Sectored Approach

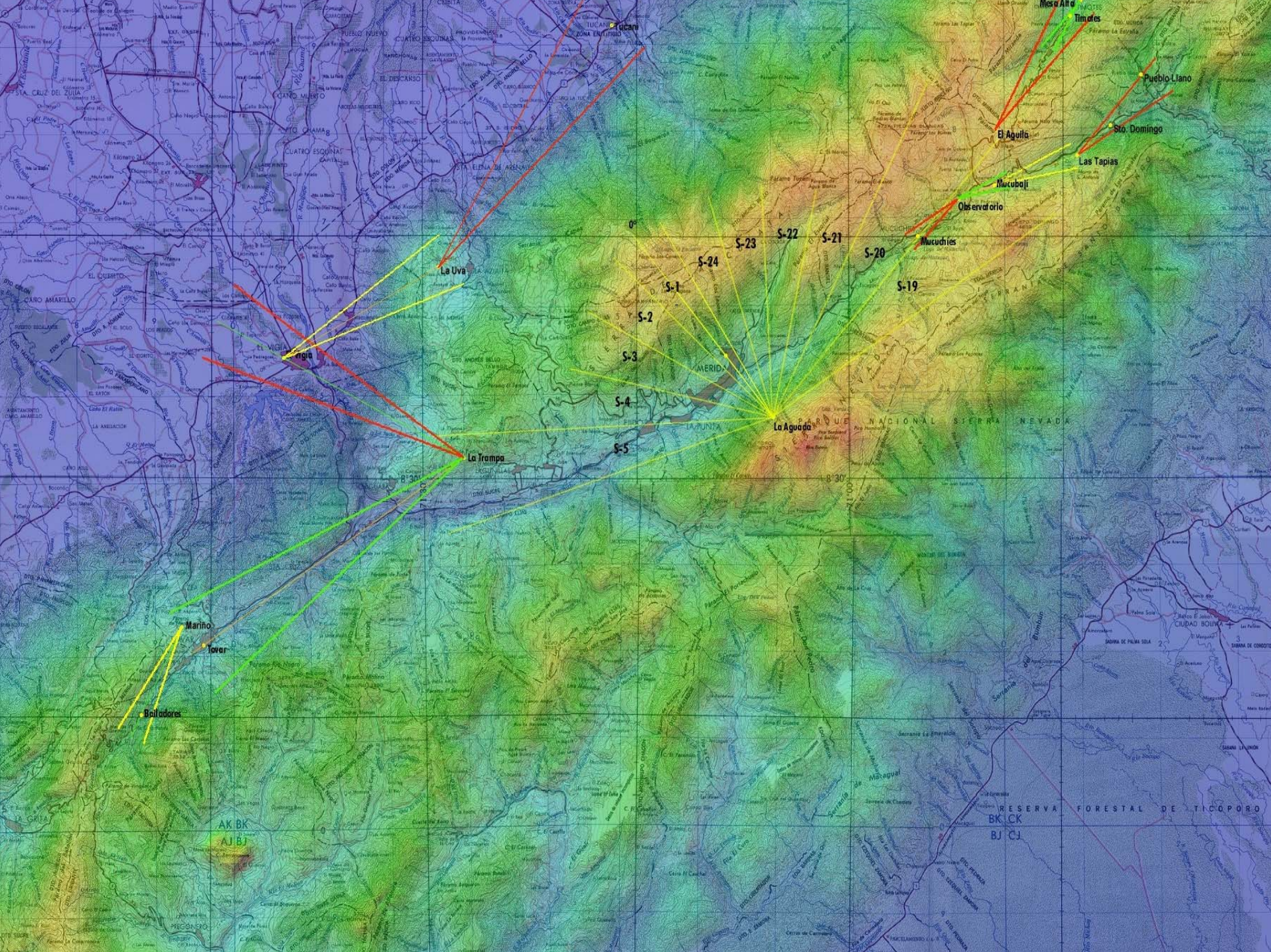


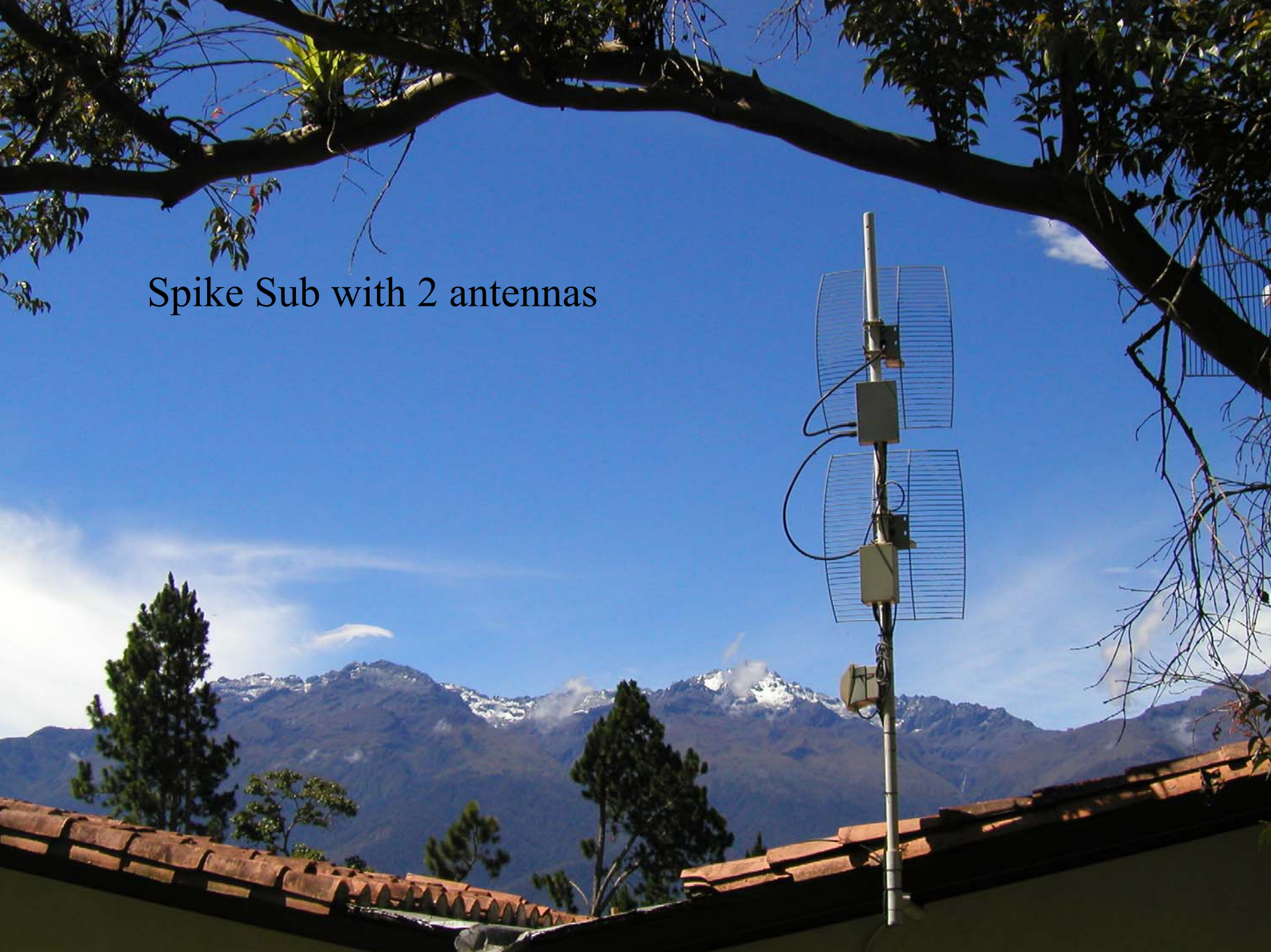
- PRIZM BDS utilizes a patented, sectored single aperture that allows spectral reuse of two channel pairs
- Spectral efficiency of this model results in a ratio of 11:1


Repeater Site, 40 km away
Base Station with multisectored antenna at 3450 m altitude overlooking the city of Mérida, which lies at 1600 m.
Eleven Sectors, 15 degrees, 20 dBi each
Three frequency pairs, 2.1- 2.4 GHz
Installed in 1997

Radiation Pattern:



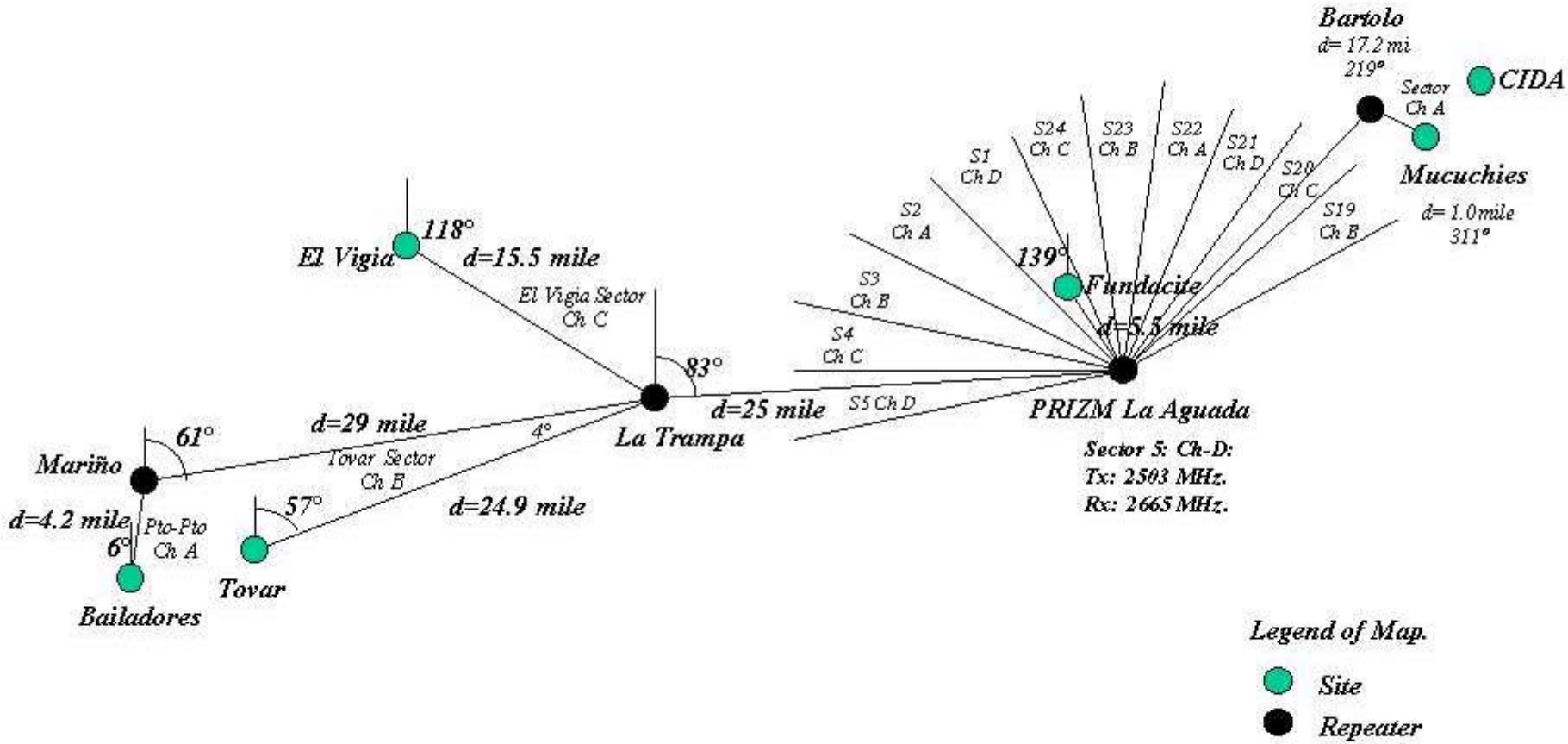

Mesa Alta
Timotes
Pueblo Llano
Sto. Domingo
El Aguila
Las Tapias
Mucuboji
Observatorio
Mucuchies
Tucani
La Uva
La Trampa
La Aguada
Mariño
Tovar
Bailadores
S-1
S-2
S-3
S-4
S-5
S-19
S-20
S-21
S-22
S-23
S-24
MERIDA
PARQUE NACIONAL SIERRA NEVADA
RESERVA FORESTAL DE TICOPORO


Spike Sub with 2 antennas

Active REPEATER

- Due to the rugged topography, repetitions points where required to serve neighboring villages
- We found a suitable repetition point at 40 km from the base station, that allowed the extension of the coverage to further 41 km

Frequency Plan



RETIEM

- Currently 150 remote stations provide broadband connectivity to schools, health centers, libraries, community centers and government institutions

CMP June 5, 1998

Ermanno Pietrosemoli

Director of Engineering

FUNDEM Universidad de los Andes Merida, Venezuela

Dear SUPERQuest Award Winner:

Congratulations !

I am pleased and honored to inform you that your company has been cited as a SUPERQuest Winner in the first annual SUPERQuest awards program.

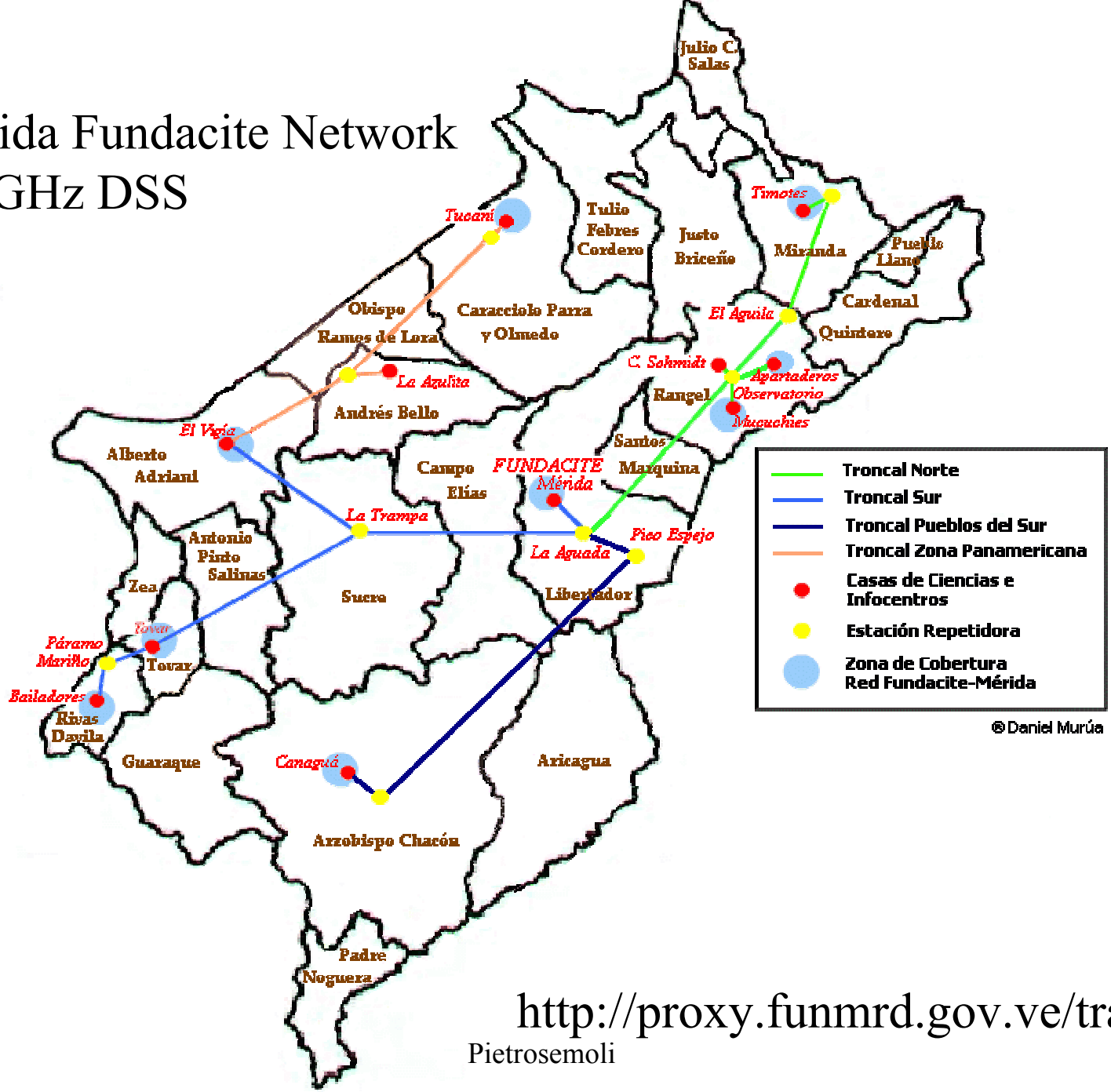
The panel of judges has chosen FUNDEM in Category 8 - Remote Access as the best in that particular field of nominees.

I speak for the entire panel of judges when I say that your company has made a real contribution to the advancement of communications technology.

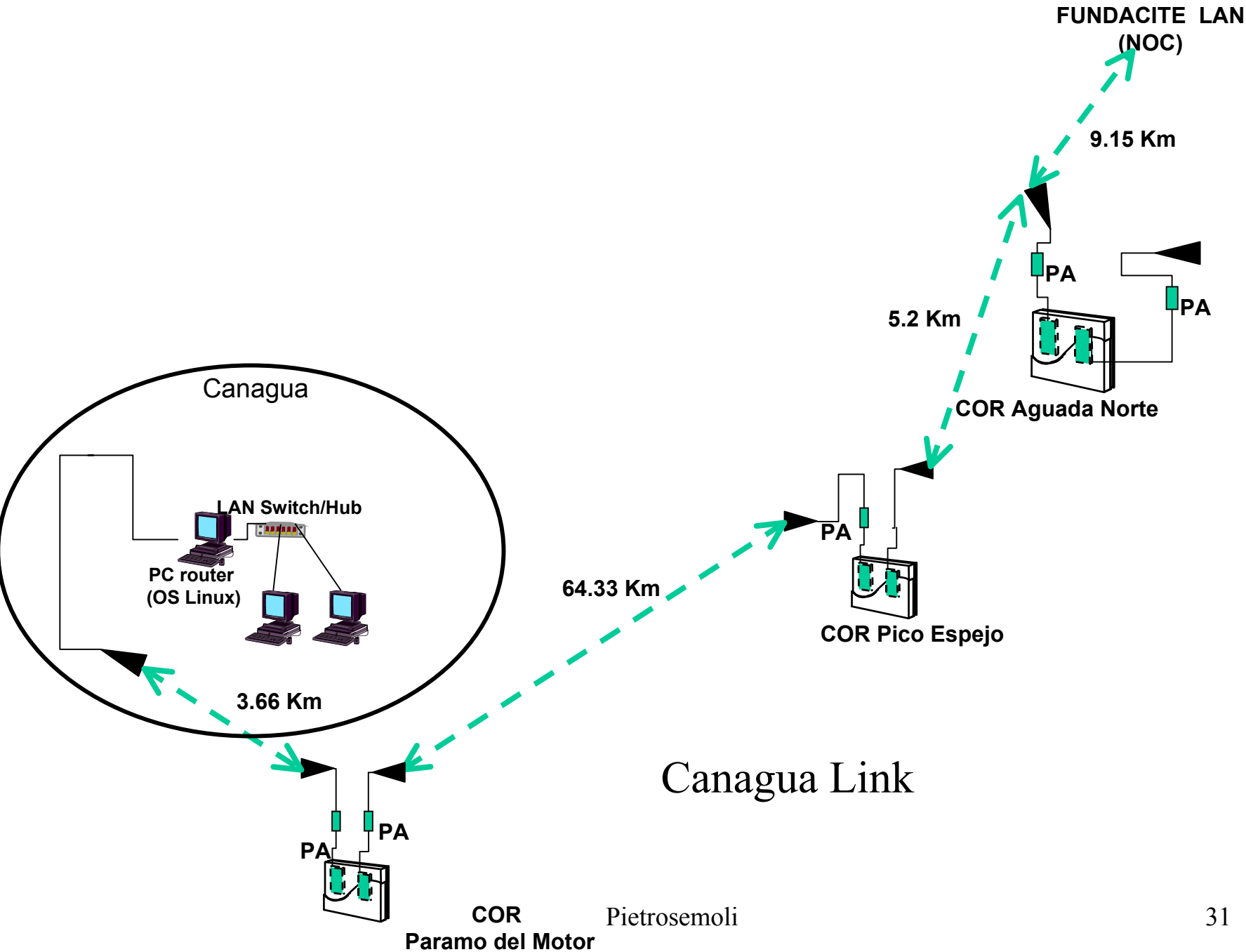
Supercomm ‘98 Atlanta Georgia, USA

During this event, RETIEM was awarded the best network prize in the category of **Remote Access, while Third Rail Technologies, a Spike Technologies subsidiary that uses the same technology got the Local Access prize.**

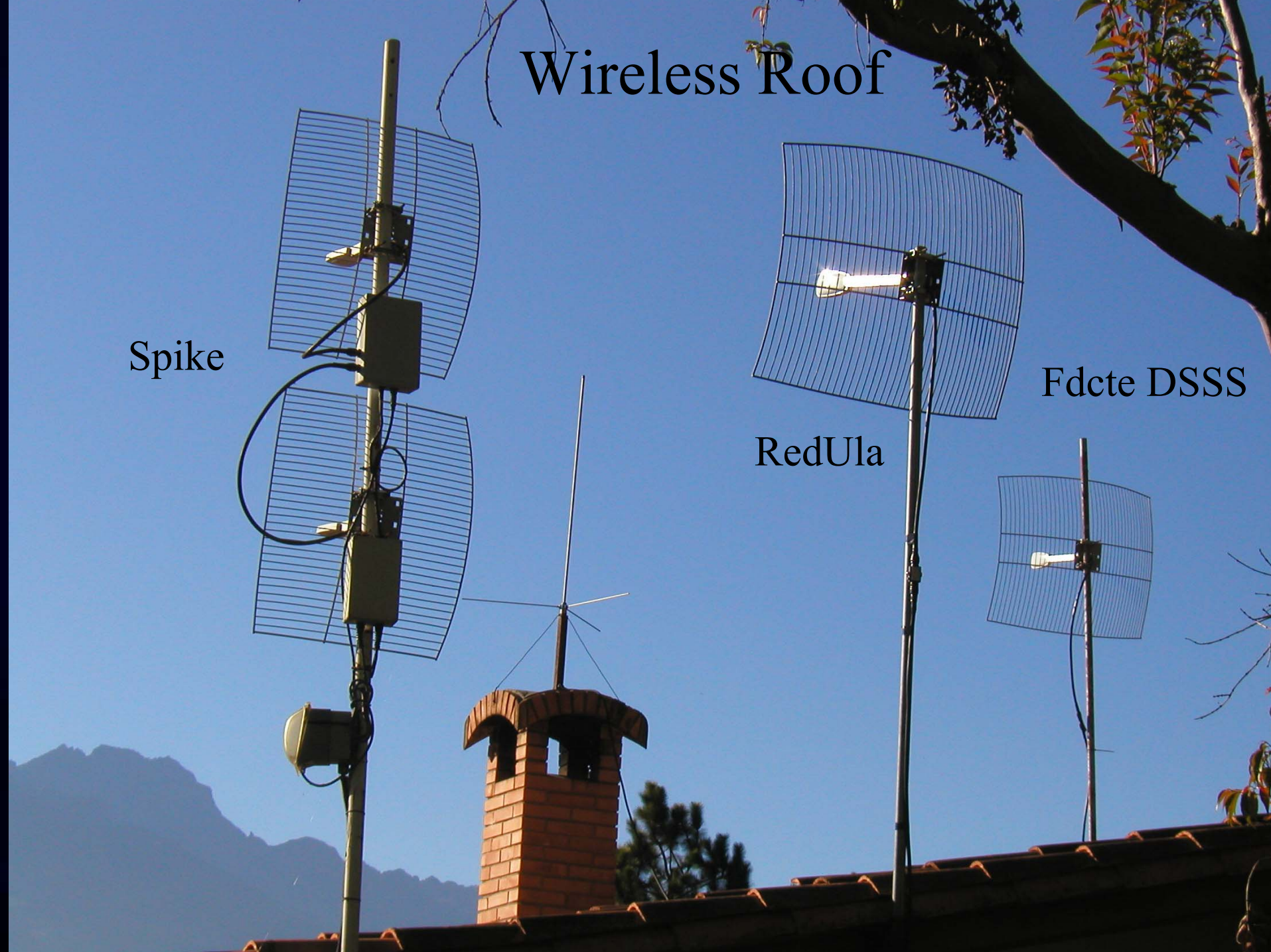
Merida Fundacite Network
2.4 GHz DSS

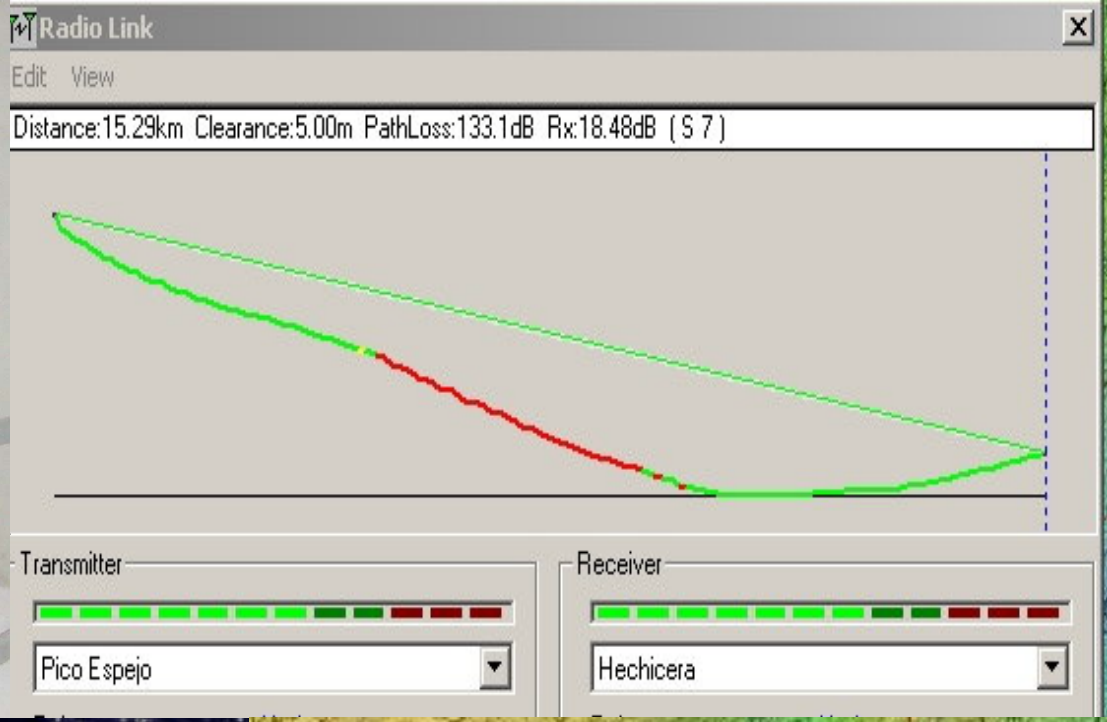


http://proxy.funmrd.gov.ve/trafico/



Canagua Link


Wireless Roof
Spike
RedUla
Fdcte DSSS



Mérida Atmospheric Research Station (MARS)

Joint Venezuelan-German project:

5.8 GHz, 16 km link

Pico Espejo. 4765 m

to Hechicera 1800 m

A webcam is at Pico Espejo pointed towards Pico Bolivar (5000 m altitude) and can be seen at:

http://www-imk.fzk.de/imk2/mira/home.html

with the details of this research project

Mesh Networks

Mesh Networks, also known as *ad hoc* networks, are those in which each node supplies connectivity to adjacent nodes.

They originated in the military, but have found civilian applications for their ability to overcome some of the hurdles of traditional wireless deployments, like the need for LOS from every client to the corresponding base station and the interference arising when several networks share the same geographical area. They allow for a more robust system providing alternative path to a given station, while offering the promise of ***increasing*** the available bandwidth as the number of users increases.

Mesh vs. Single-hop Networks

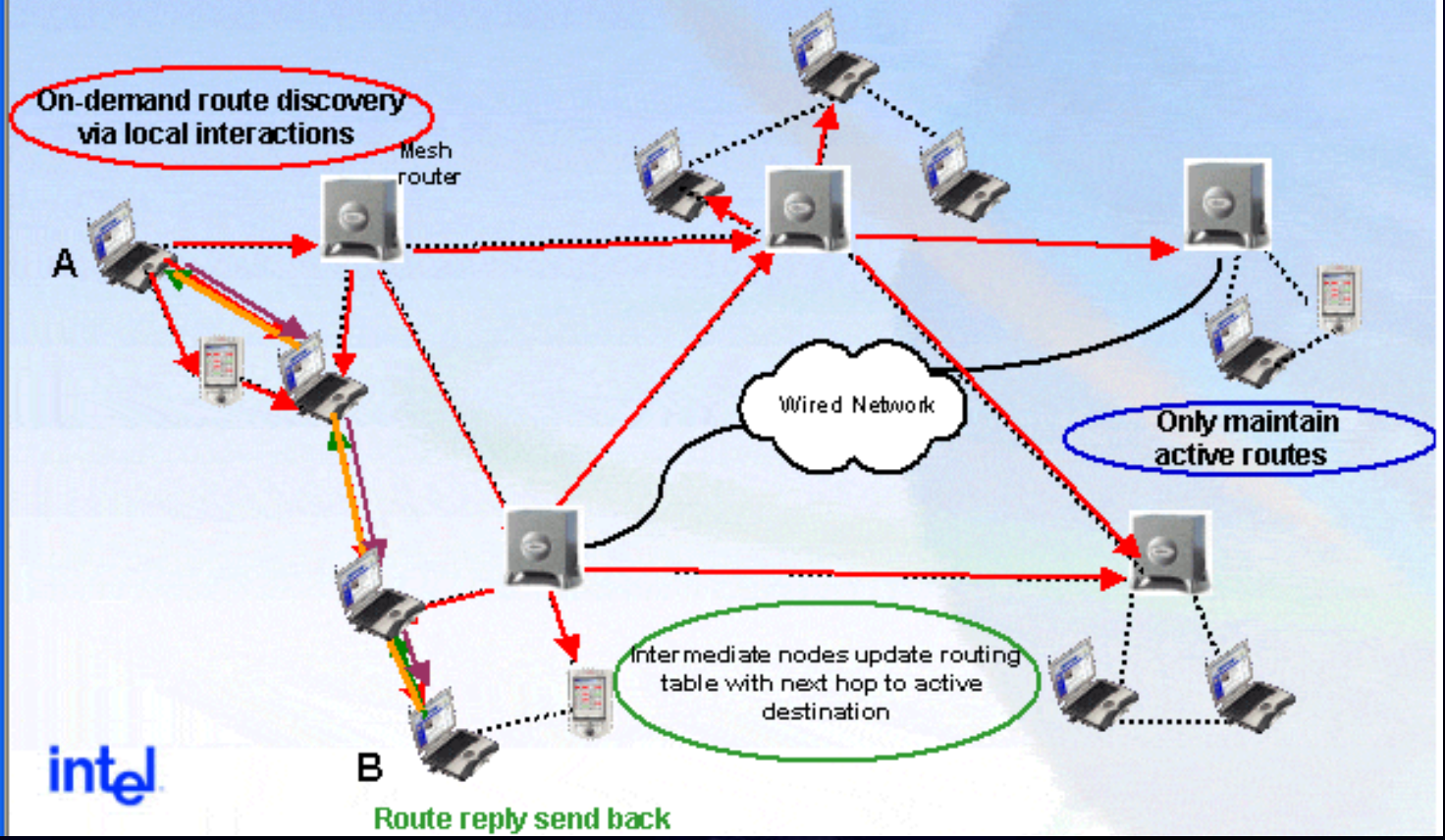
Mesh networking (also called "multi-hop" networking) is a flexible architecture for moving data efficiently between devices. In a traditional wireless LAN, multiple clients access the network through a direct wireless link to an access point (AP); this is a "single-hop" network. In a multi-hop network, any device with a radio link can serve as a router or AP. If the nearest AP is congested, data is routed to the closest low-traffic node. Data continues to "hop" from one node to the next in this manner, until it reaches its final destination.

Mesh networks have some key advantages over their single-hop counterparts. Three key advantages include robustness, higher bandwidth, and spatial reuse

Mesh Networking: How Does It Work?

- Co-operation between multiple radios using existing standards
  - Nodes leverage neighbors to route messages across multiple hops
  - IEEE 802.11 MAC
    - Implemented today with standard 802.11 MAC
    - MAC tuning to improve performance
  - Mesh Routing to select network paths
    - Several routing protocols standardized by IETF
      - Dynamic Source Routing (DSR)
      - Optimized Link State Routing (OLSR)
      - Ad-Hoc On Demand Distance Vector (AODV)
    - Can be implemented in Layer 2 or 3

Example Mesh Routing Protocol: Ad-hoc On-demand Distance Vector Routing (AODV)



Advantages Of Mesh Networks

Reduced cost

- less wired infrastructure
- ease of installation

Extended range and coverage

- beyond wired infrastructure

Potential for energy efficiency

- low transmit power

Robustness

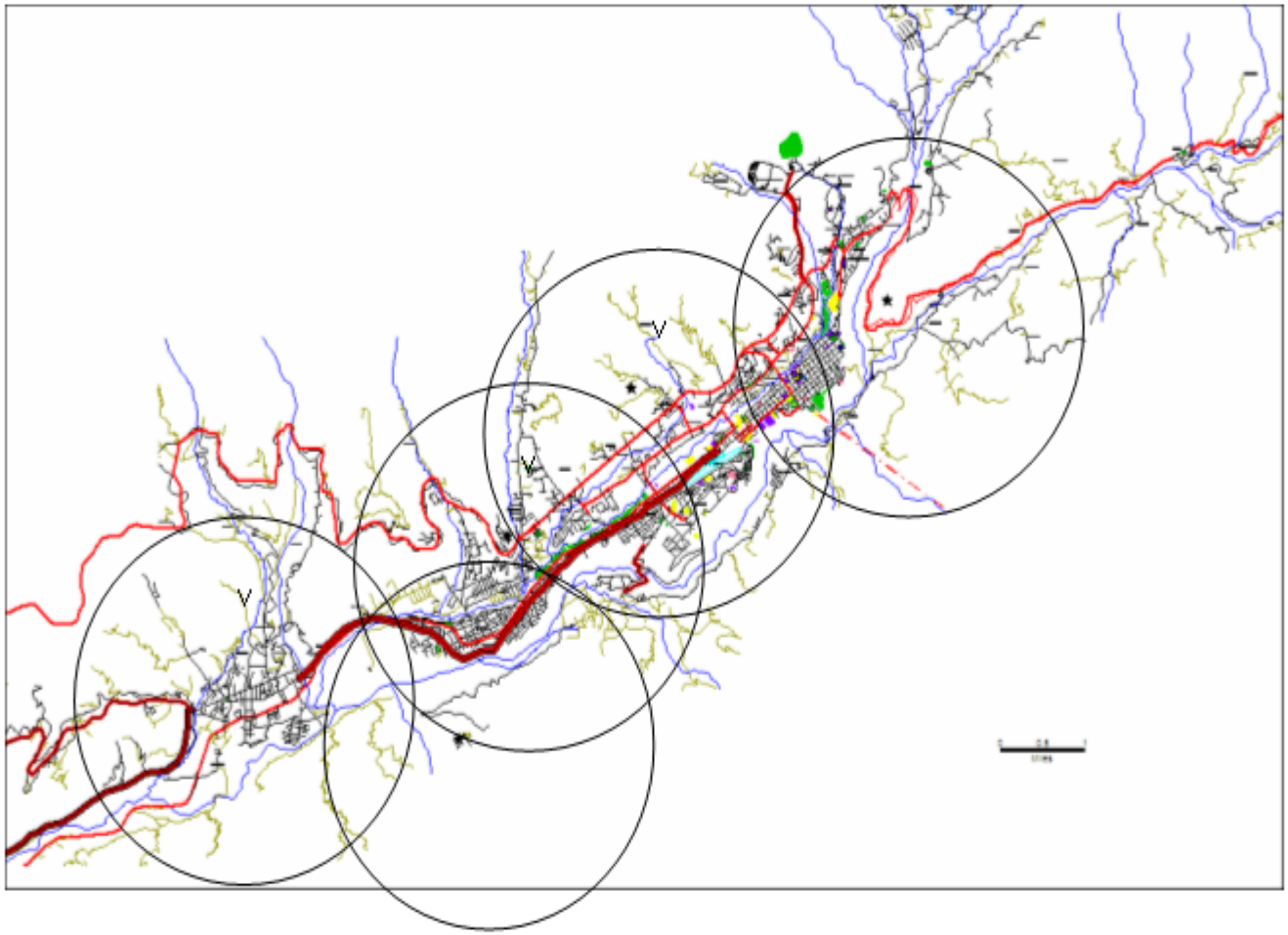
- multiple (redundant) communication paths

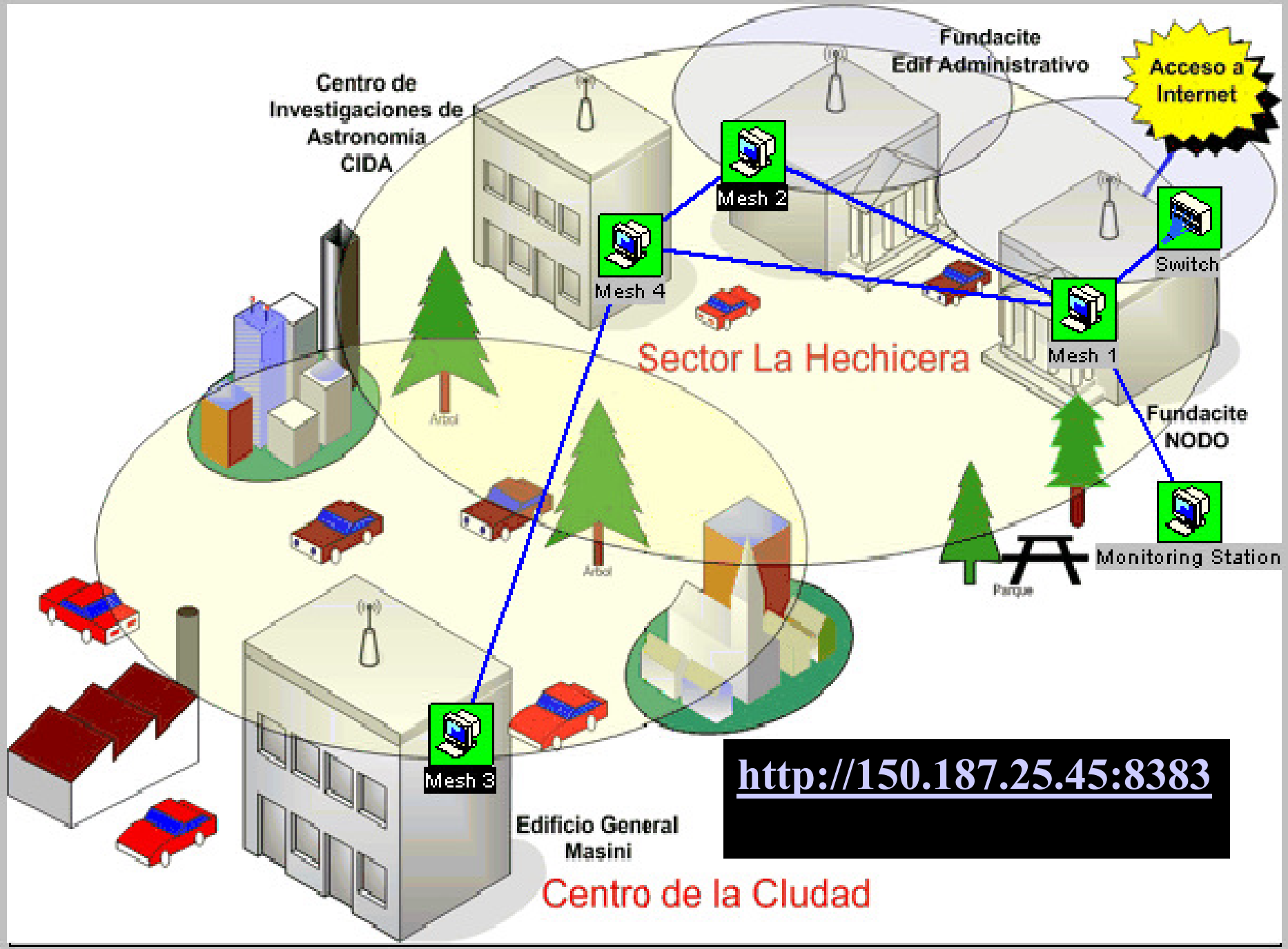
Potential for performance improvement

- throughput and capacity

Proposed Mesh Network for Merida

Red Teleinformática de Ciencia, Tecnología e Innovación del Estado Mérida (RETICyT)




Fundacite
Edif Administrativo
Acceso a Internet
Centro de Investigaciones de Astronomia CIDA
Mesh 2
Mesh 4
Switch
Mesh 1
Sector La Hechicera
Fundacite NODO
Monitoring Station
Arbol
Arbol
Parque
Mesh 3
Edificio General Masini
Centro de la Cludad
http://150.187.25.45:8383

Conclusions

- We succeeded in turning the region lack of trained personnel into an opportunity
- By focusing on manageable projects within the framework of a long term plan we were able to overcome budget limitations
- Team work was essential to accomplish our goals, and helped securing international support

urls


www-imk.fzk.de/imk2/mira/home.html
www.third-rail.net
wireless.ictp.trieste.it
www.isoc.org
www.eslared.org.ve
www.ula.ve
Earth at Night
More information available at:
http://antwrp.gsfc.nasa.gov/apod/ap001127.html
Astronomy Picture of the Day
2000 November 27