TVWS: Challenges and Experiences from Latin America and Africa

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Motivation

- Common agreement affordable wireless broadband Internet
  - Closing the digital divide for rural and remote areas (opportunities in health, education, government and transportation)
  - Offering connection to unreachable communities maintain autonomy and increase the quality of life.
  - Free spectrum from the digital dividend.
  - Underutilisation of the UHF spectrum in emerging regions.
- An interest in **auctioning the 700 MHz** band (in Latin America, in Africa) expressed by most regional regulators.

Spectrum Allocated per ITU recommendation

- International Communication Unit recognises "*The sovereign right of each State to regulate its telecommunications*". (Regional management)
- Regulators have assigned very little considering ITU recommendation
- There are not strong reasons, just not convinced of the technology to be deployed despite the need for the service

Percentage of Spectrum Allocated per ITU Recommendation for 2015 & 2020

Market	Percentage of ITU Recommendation 2015 completed	Percentage of ITU Recommendation 2020 completed
Argentina	14.62%	11.05%
Bolivia	13.85%	10.47%
Brazil	38.65%	29.22%
Chile	30.38%	22.97%
Colombia	31.73%	23.98%
Costa Rica	20.05%	15.15%
Dominican Republic	16.49%	12.47%
Ecuador	13.85%	10.47%
El Salvador	15.69%	11.86%
Guatemala	16.20%	12.24%
Honduras	13.08%	9.88%
Mexico	18.70%	14.13%
Nicaragua	20.15%	15.23%
Panamá	10.00%	7.56%
Paraguay	16.92%	12.79%
Peru	23.38%	17.67%
Puerto Rico	25.90%	19.58%
Uruguay	20.77%	15.70%
Venezuela	15.69%	11.86%
Regional Average	**19.80%**	**14.96%**

Source: Signals Telecom Consulting

Technical Motivation for deploying TVWS

- More coverage area with the same power
- Need no line of sight
- Central system that controls the hidden terminal (and incumbent) problem and resource sharing
- Adaptation to specific conditions of the clients (distance, obstacles, erratic incumbents, channel bonding)
    - Cognitive radio approach to deal with primary users (IEEE 802.22)

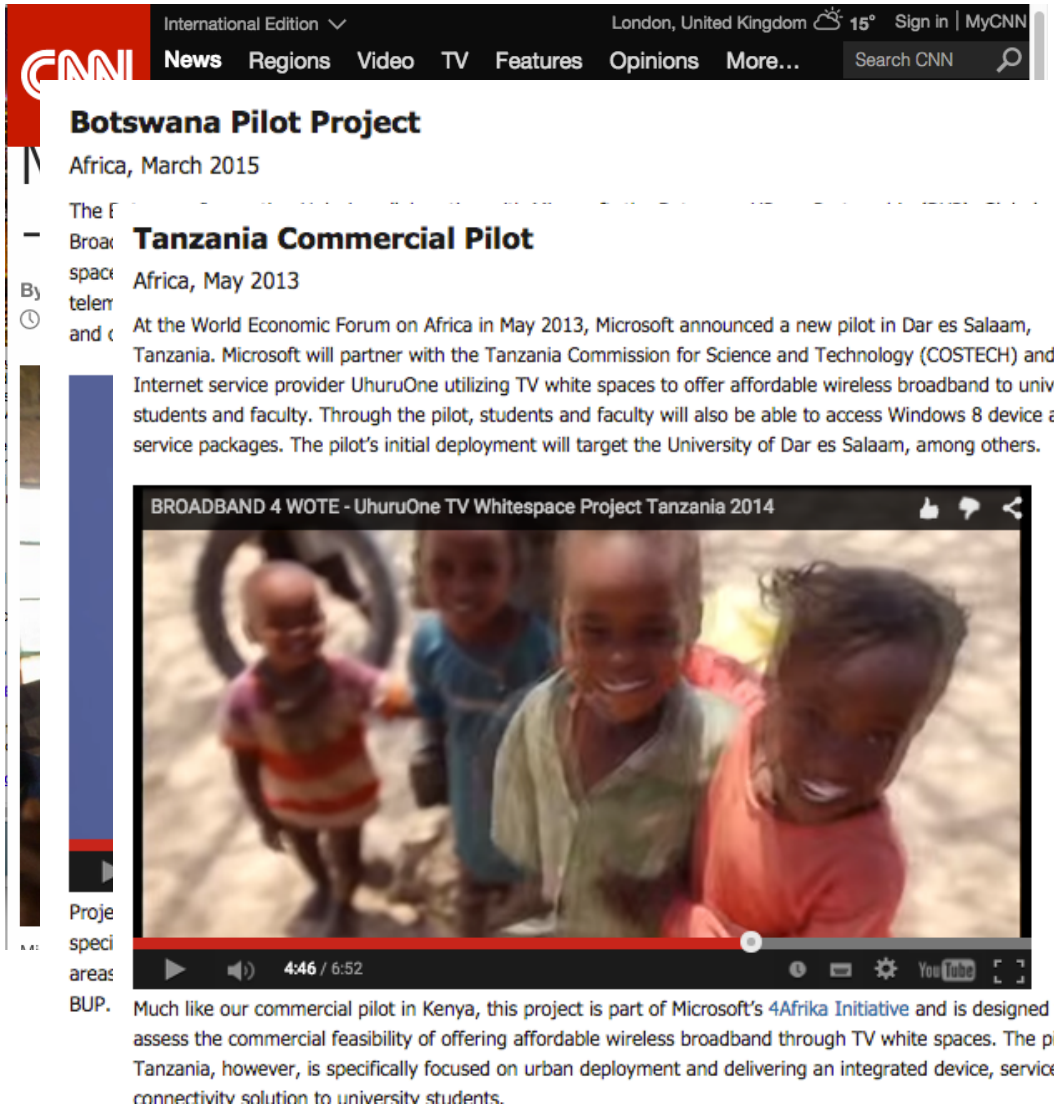
TV White Spaces

- **White Space**: frequency allocated to broadcasting service but not used within certain region.
  - Never been used
  - Becomes free
  - Spaces wisely used (like guard bands between channels)

How's White Space determined?

- Basically through a **scanning process** and detection of no activity, however:
  - Largest known incumbents TV Stations (DB registered)
  - IEEE 802.22 suggests to detect incumbent for short time periods then change the channel.

What's been done?



- Important companies (Microsoft, Google, Facebook) have invested in experimenting with TVWS in Africa (big potential because of connectivity challenges).

Deployments in:

- Botswana (43% **of people in rural areas**)
- Ghana (50%)
- Namibia (55%)
- South Africa (37%)
- Tanzania (70%)

Our trial on the quest for a use case

A practical approach to TVWS

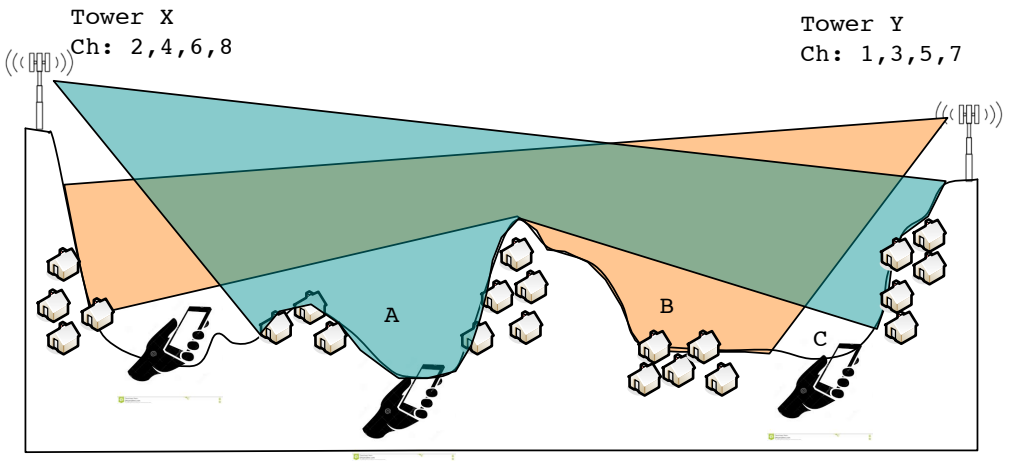
- Back in **2013**, we knew that we needed to deploy TVWS systems in developing countries, but the regulator needed to be convinced…
- There was and there is not appropriate monitoring tools, due to high costs and lack of organisation.
  - Thus mobile low-cost monitoring arises as a solution
  - But, many challenges arose as well. The most important: **Appropriate Representation**.

First Deployment in Malawi

- Required measurement campaign for convincing regulator.
- Used RFExplorer and desktop computer
- Regular representation of the data

Low-cost collection of TVWS

- Detector approach
- Using low-cost low-weight devices
- Easy to collect data



TVWS Deployment

AtoC	192.168.1.103	Base Station to St. Mary School (2.5 km	-15.398245341/35.3182983398	Zomba Southern Region MW
AtoD	192.168.1.104	Base Station to Airport (7.5 km)	-15.3881496363/35.3841304779	Zomba Southern Region MW
ICTP-BS	192.168.1.105	ICTP to Base Station	Unknown	Unknown
XtoY	192.168.1.106	X to Y	Unknown	Unknown

Network Map

The WhispPi device

Trying to substitute a 20.000 US$ device!

RF explorer spectrum analyser

+

Raspberry Pi

+

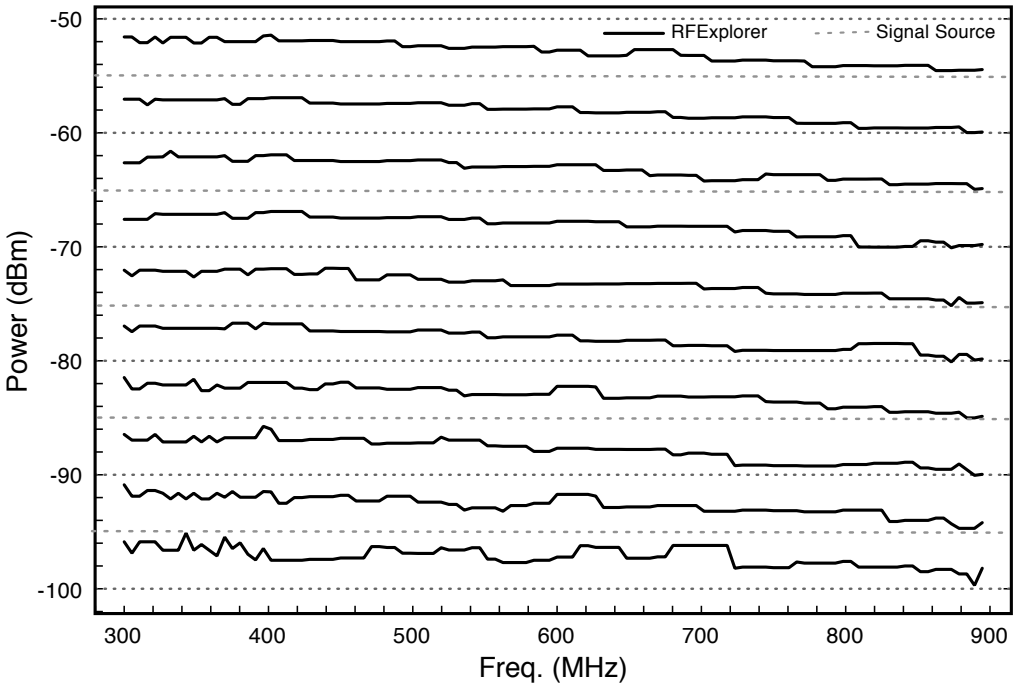
USB GPS

+

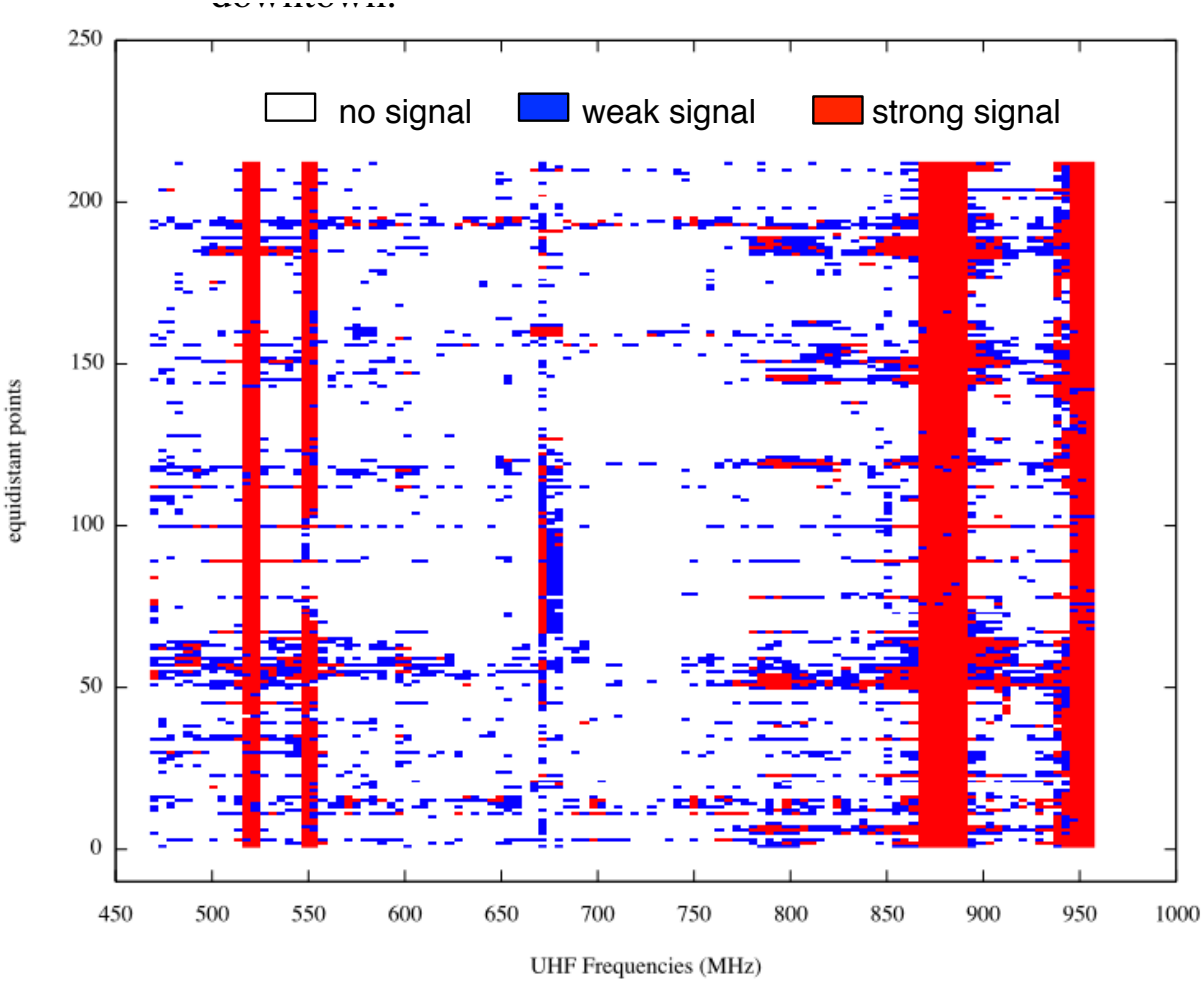
convenient 4200 mAh battery

Calibration Against Agilent 8648C (20.000 US$)

- Max. error of 4 dBm
- Underestimation bounded to 2.8 dBm in the UHF range



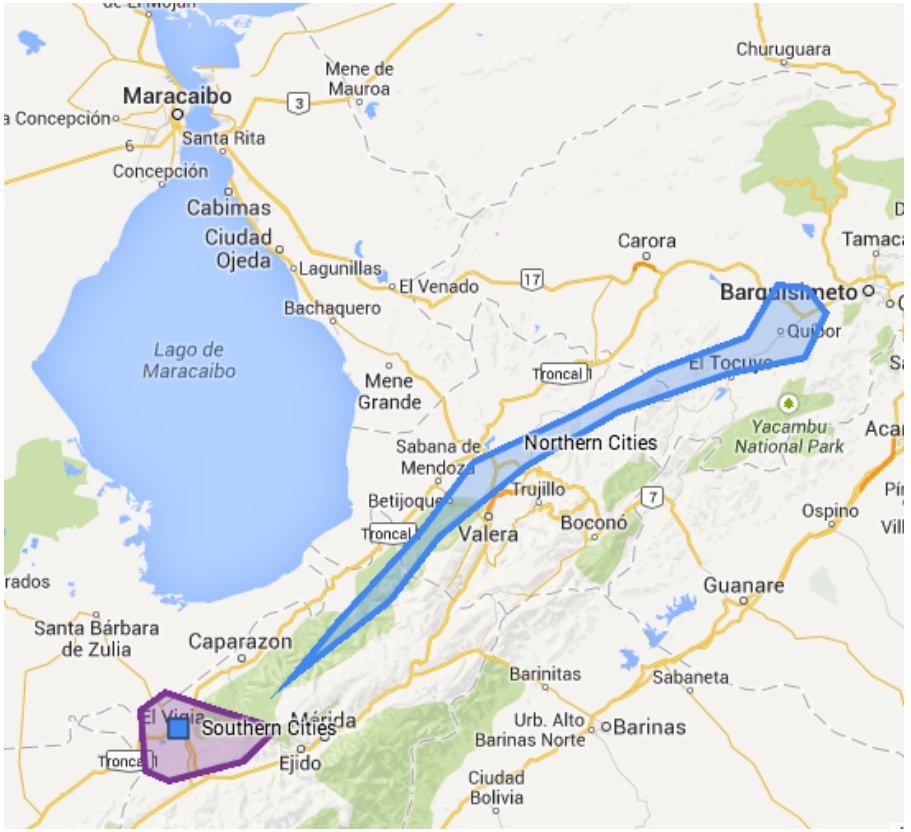
Cell signal as a Reference

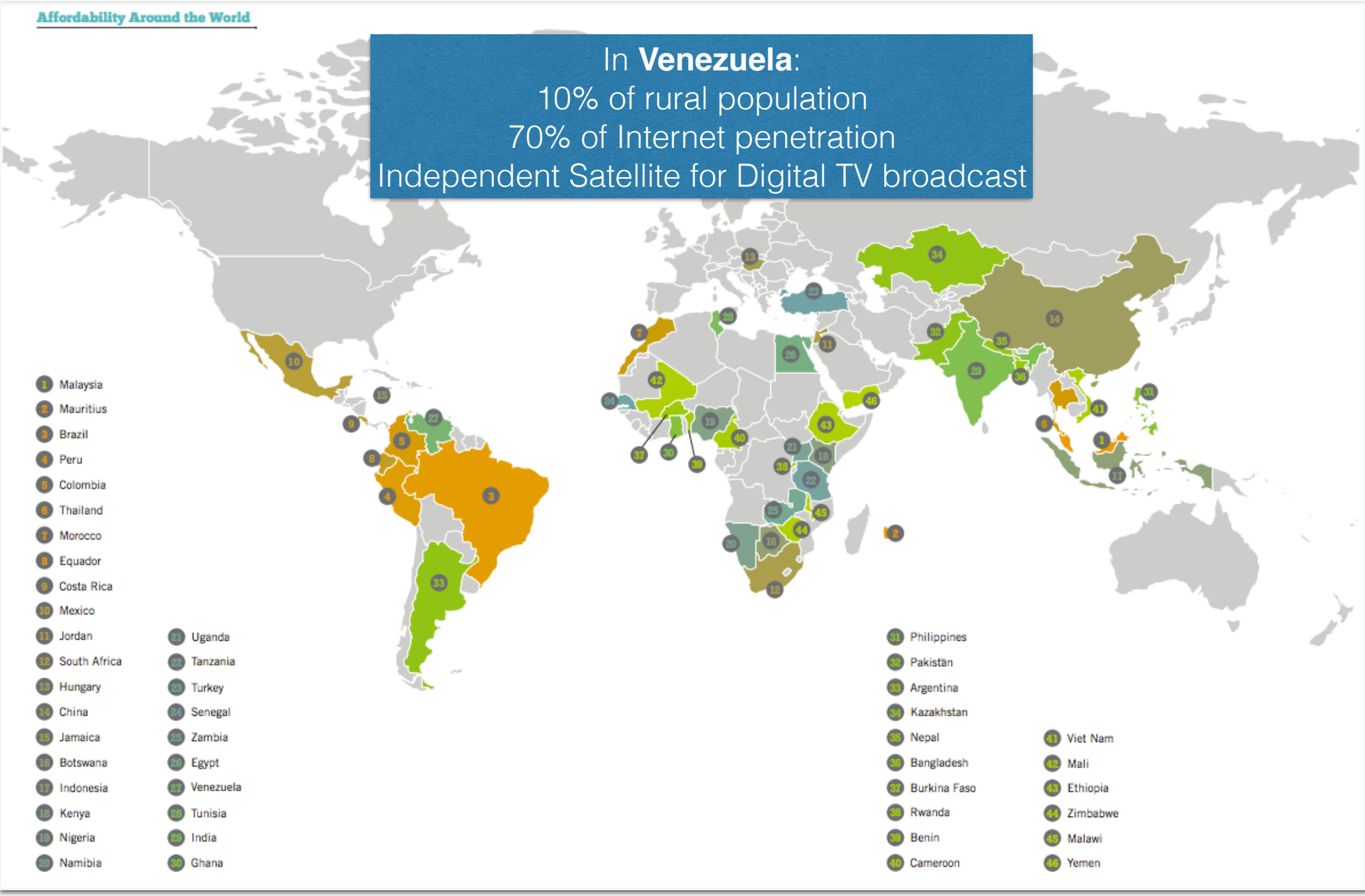


(c) Spectrum from 470 to 960 MHz in Mérida downtown.

Organisation of the 1000Km Measurement Campaign

- Two main legs to measure (Mérida city considered the center). 1000 Km in total.
  - Small cities located at the southern Mérida.
    - Big cities located at northern Mérida.




Affordability Around the World
In **Venezuela**:
10% of rural population
70% of Internet penetration
Independent Satellite for Digital TV broadcast
1 Malaysia
2 Mauritius
3 Brazil
4 Peru
5 Colombia
6 Thailand
7 Morocco
8 Equador
9 Costa Rica
10 Mexico
11 Jordan
12 South Africa
13 Hungary
14 China
15 Jamaica
16 Botswana
17 Indonesia
18 Kenya
19 Nigeria
20 Namibia
21 Uganda
22 Tanzania
23 Turkey
24 Senegal
25 Zambia
26 Egypt
27 Venezuela
28 Tunisia
29 India
30 Ghana
31 Philippines
32 Pakistan
33 Argentina
34 Kazakhstan
35 Nepal
36 Bangladesh
37 Burkina Faso
38 Rwanda
39 Benin
40 Cameroon
41 Viet Nam
42 Mali
43 Ethiopia
44 Zimbabwe
45 Malawi
46 Yemen

Summary of the Journey

Site	Leg length (km)	Population	Active Freqs	WS
Mérida (city)	20	330 537	17	75%
Ejido	10	99 837	10	86%
Lagunillas	85	42 717	6	92%
El Vigía	20	250 257	6	92%
Santa Cruz de Mora	9	23 276	9	87%

Very close

Far away

TABLE I: Measurement campaign in southern region.

Proximity order

Site	Leg length (km)	Population	Active Freqs	WS
Mucuchies	10	6 354	3	96%
Barinitas	20	52 872	7	90%
Barinas	23	353 442	11	84%
Guanare	41	235 201	10	86%
Acarigua	50	203 358	7	87%
Barquisimeto	20	1 600 000	24	66%

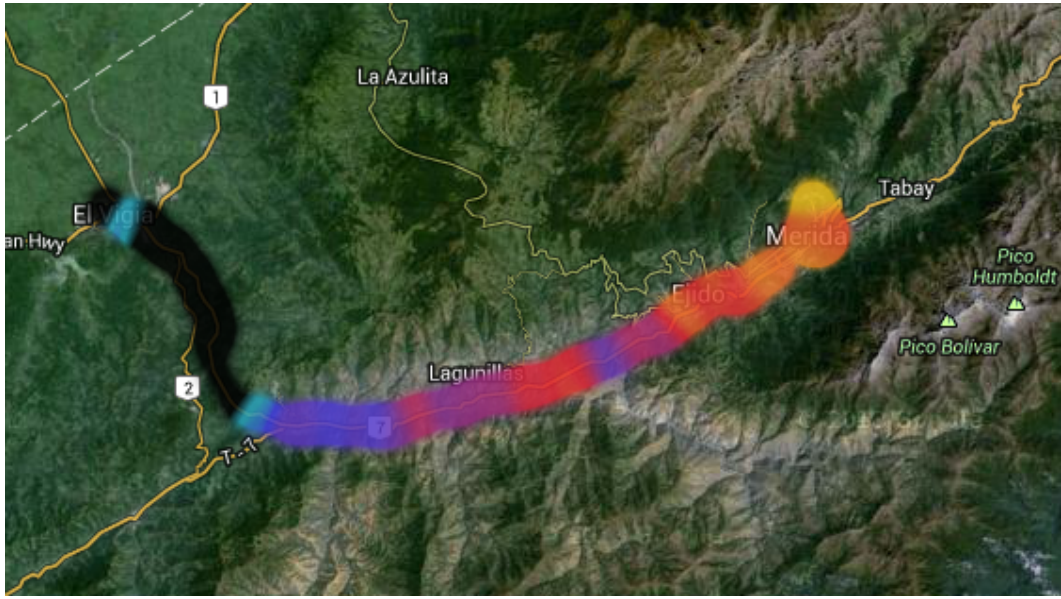
TABLE II: Measurement campaign in northern region

WhispPi System Considerations

- Used RFExplorer Sub 1 GHz model: 240 MHz to 960 MHz
  - Software interface available for desktops: windows, linux, mac os. —> **bottleneck** for the proposed portable design.
- GPS should be conveniently placed.
- One 600 MHz sample every 6 secs.
- **Need post-processing to obtain manageable heat-map**

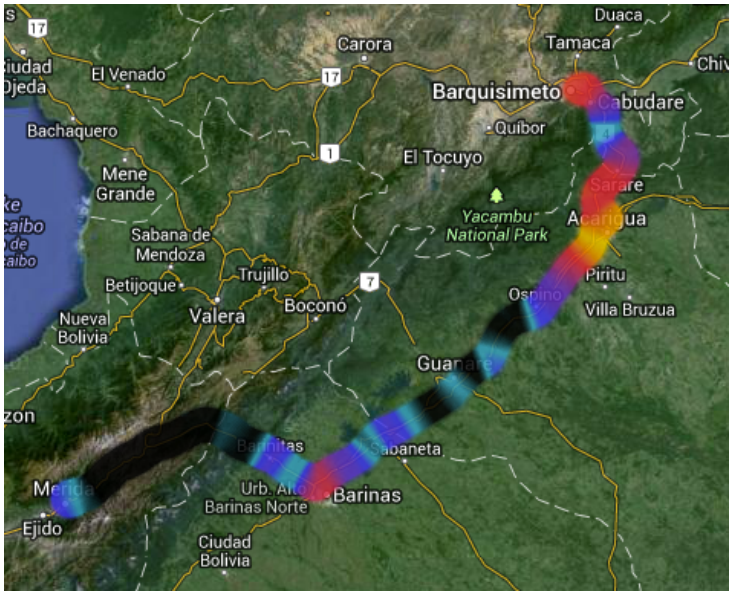
First leg: Southern Mérida

- University TV channel
- Channel 22 (518 - 524 MHz)
- 85 Km route (Mérida to El Vigia)
- Higher transmission power.



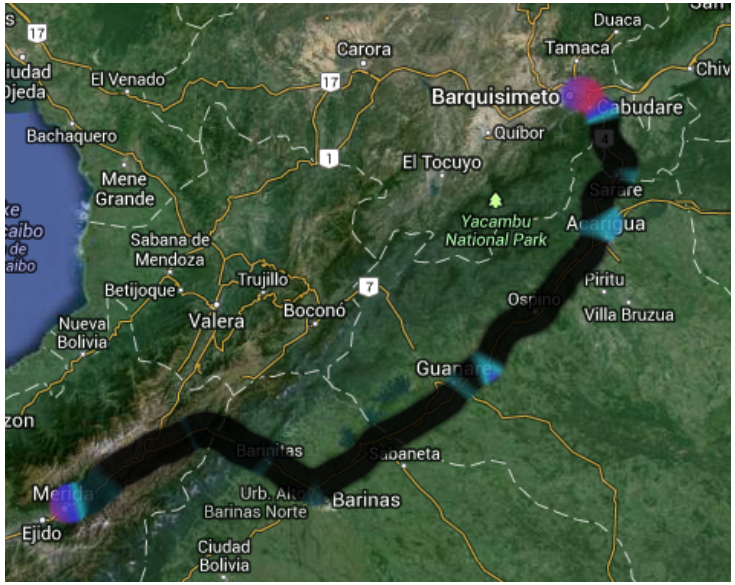
Second Leg: Mérida Northern Region

Busy Channel



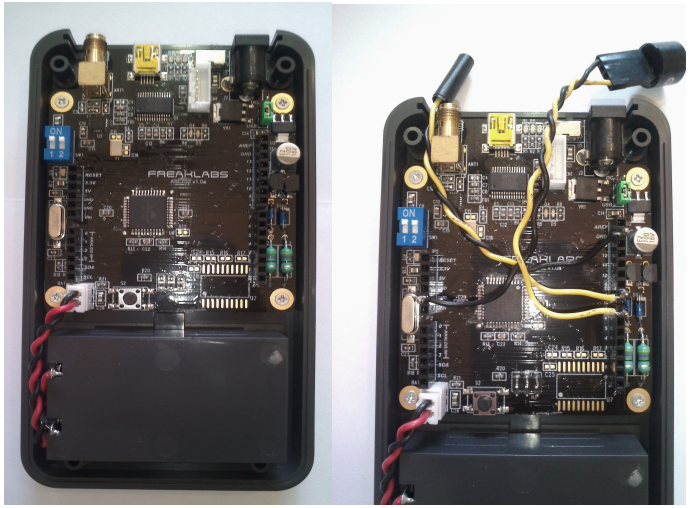
Heatmap of channel 23 (524 - 530 MHz) within the route from Mérida to Barquisimeto

Non Busy Channel



Heatmap of channel 16 (482 - 488 MHz) within the route from Mérida to Barquisimeto

New Low-cost devices



- ASCII 32: High speed device, stand alone, less accurate.
- Android Interface to RF Explorer: under development. High speed device.

Collecting Data

- Different speeds for mobile sampling
- Different sampling rates
- Heterogeneous devices (radio, antenna, storage capacity)
- Different formats for storing the data
- No means for assessing the White Spaces!

http://www.zebra-rfo.org

collecting spectrum fingerprints

- Web system that stores spectrum samplings from different apparatus
  - Proposes a uniform simple data format (and compact)
  - Deals with mid-size scale for formatting the data
  - Offers different perspectives on the same set of data

DEMO

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