



TOWERS OF POWER

GSM Infrastructure and
Development

Power Stance!

A male athlete in a yellow singlet with arms raised, celebrating. He is wearing a yellow singlet with "Jamaica" and "Eds" printed on it. He has a yellow wristband on his left wrist. He is standing in front of a crowd of people.

Eds

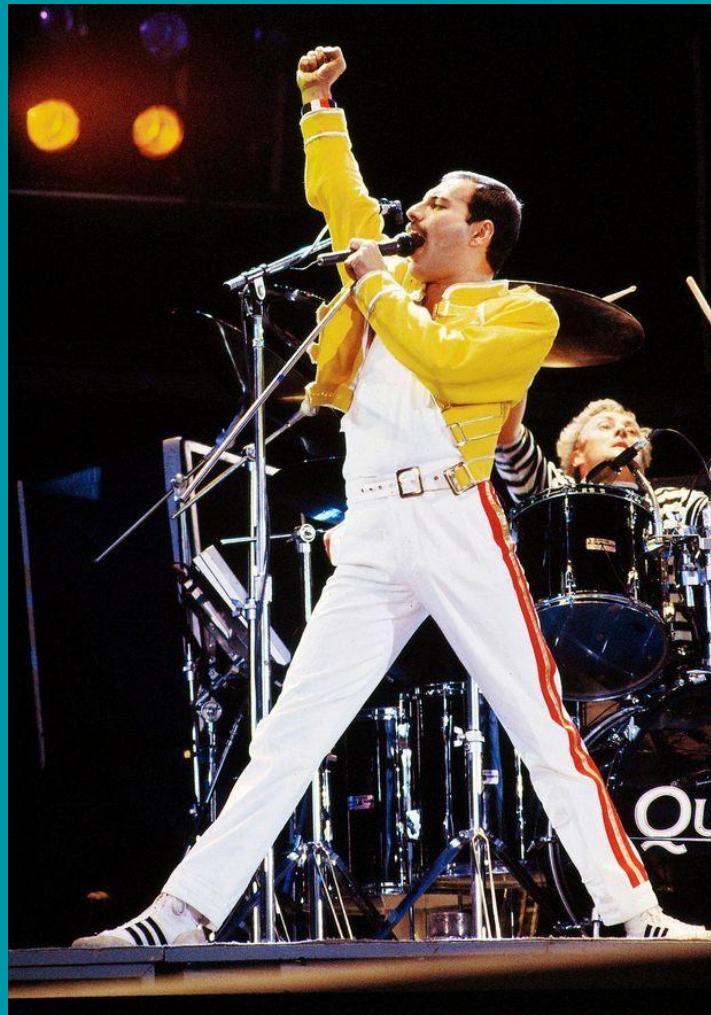
A photograph of a woman dressed as Wonder Woman, standing in a pose with her legs apart and hands on hips. She is wearing the iconic red and blue superhero outfit, including the top with the star emblem and the shorts with stars. The background shows a beach setting with a blue sky and some beach umbrellas.

It's weird... but it works!

Need a quick and easy confidence boost? Just strike a pose like Wonder Woman! Research from the US shows that standing tall with your legs apart, hands on hips and shoulders back to open up your torso increases the assertive hormone testosterone while simultaneously reducing levels of the stress hormone cortisol. A few minutes spent in this stance will do the trick.

Your Body Language Shapes Who You Are

Amy Cuddy's TED Talk:
www.ted.com/talks/amy_cuddy_your_body_language_shapes_who_you_are



Why are you here?

An ITP Tradition



Crash Course

Everything I wish I knew when
I started my company SayCel



Syllabus

github.com/saycel/towers-of-power

The History of SayCel



Communications Infrastructure
For the Developing World

SAY CEL

BLUEFIELDS SOUNDSYSTEM

Multimedia
Center

2005-2012



BLUEFIELDS SOUNDSYSTEM

Multimedia
Center

2005-2012



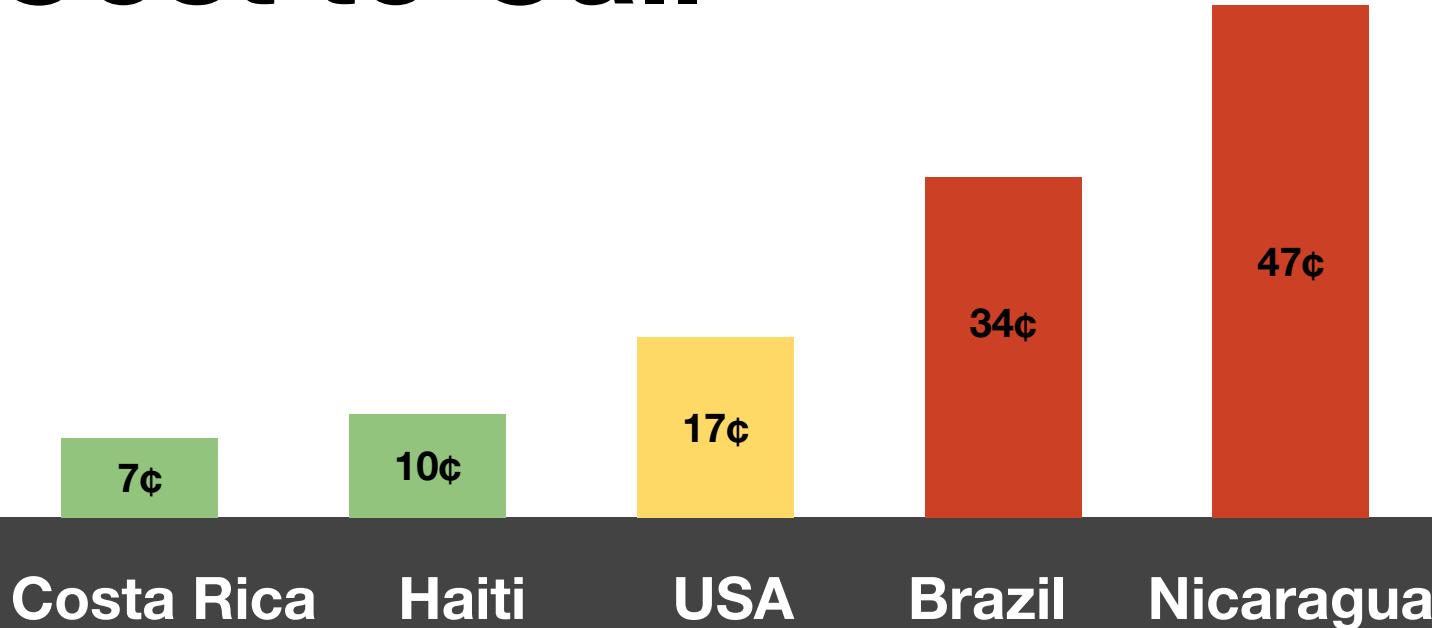
BLUEFIELDS SOUNDSYSTEM

Multimedia
Center

2005-2012



Cost to Call



Average cost of 1 minute mobile call in US Dollar. *Data from Numbeo Inc.

TO SELF RESPECT & COMMUNITY BUILDING

= IMPORTANT

IT IS IMPERATIVE THAT WE NAME OURSELVES, DEFINE OURSELVES, SPEAK
OURSELVES, AND CREATE FOR OURSELVES INSTEAD OF BEING N
DEFINED, SPOKEN FOR AND CREATED FOR BY OTHERS

"WE MU

THE CHANGE WE



TO SEE IN THE WORK

- MALAUNA

(KUJICHINCHI
RESPECT)

RES.

Teacher Salary
\$200/month



**Nicaraguans spend up to 25% of their
income on communication!**

Can this change?

Major Telecoms

**Don't Invest in
Low Density
Low Income Areas**



Monkey Point
No Network Coverage

People can't
call a doctor.



Punta Gorda
No Network Coverage



NCAR

SCAR

Indigenous &
Afro-descendants

No Roads

Limited Communication

**700 Million
users without cellular
coverage**



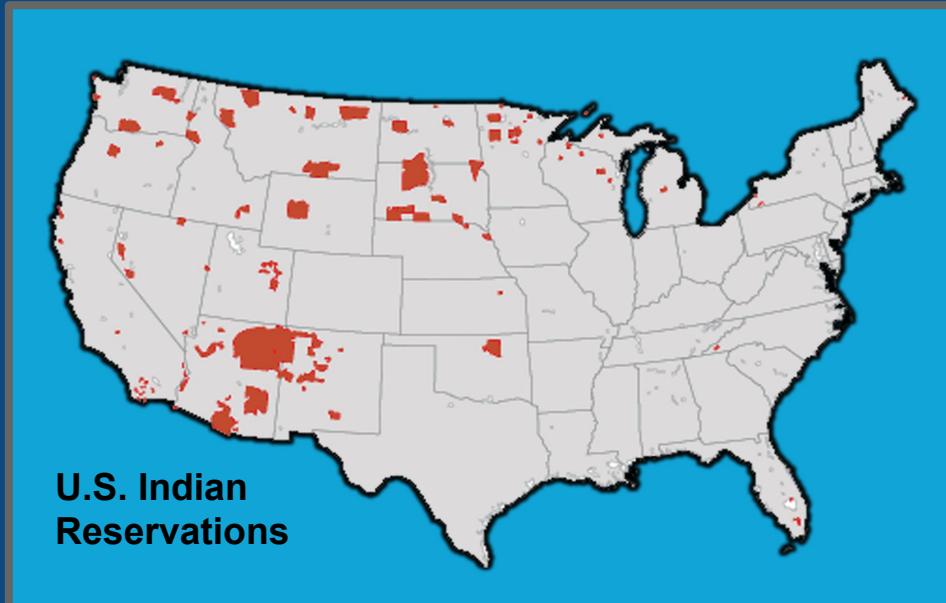
UN's International Telecommunication Union



Indigenous Communities

60.5 million people

40% in rural areas



Infrastructure



Water & Health

Roads

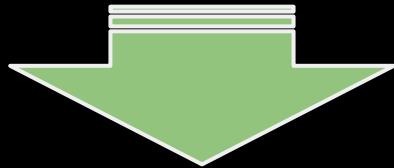
Economy

Security

**\$1.2 Billion
Spent on Infrastructure**

UK Dept of International Development Stats

International Aid



Overhead



National Government



Regional Government



Local Communities



Mexico sees its first open-source village cellphone network

158 77 Share This Story! Let friends in your social network know what you are reading about [Facebook](#) [Email](#) [Twitter](#) [Google+](#) [LinkedIn](#) Mexico sees its first open-source village...

USATODAY.COM

September 16, 2013



Interactive Telecommunications Program



Towers of Power

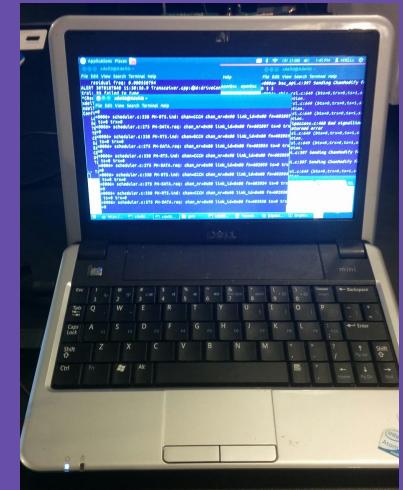
ITPG-GT.2699.001:

Learn about GSM cellular infrastructure by building your own network using open source hardware and software.

Open Source GSM Network



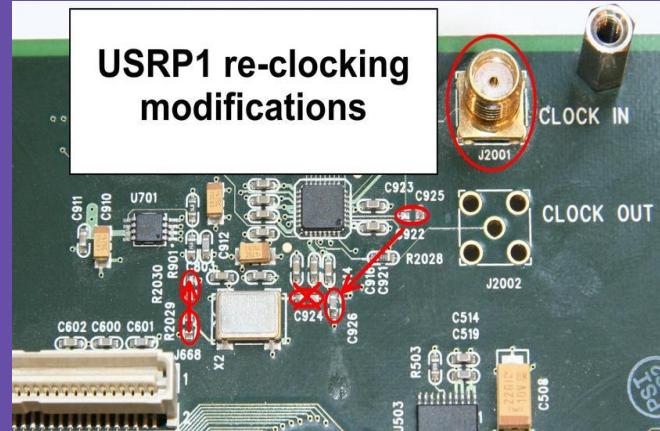
USRP 1



Linux Computer



REDIAL







RHIZO
MATICA



Oaxaca, México

Santa Inés de Zaragoza Installation

January 13, 2015

Population 1,707

Indigenous Community

No Cellular Network



Community Meeting

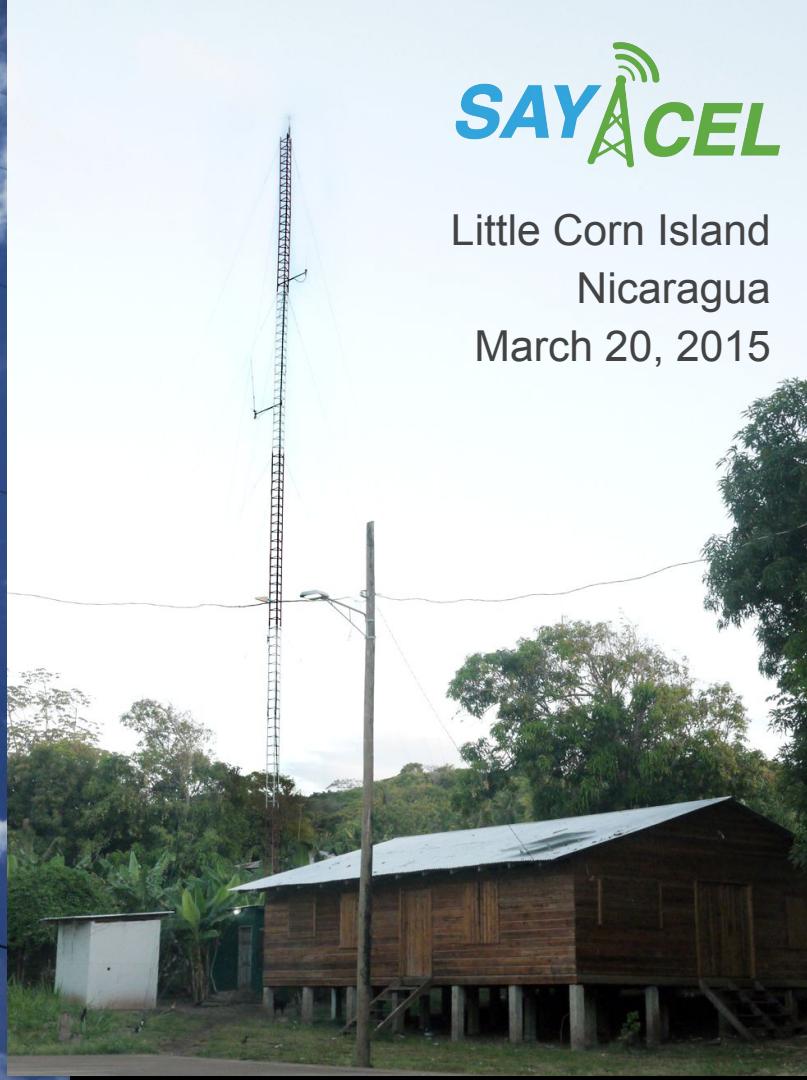




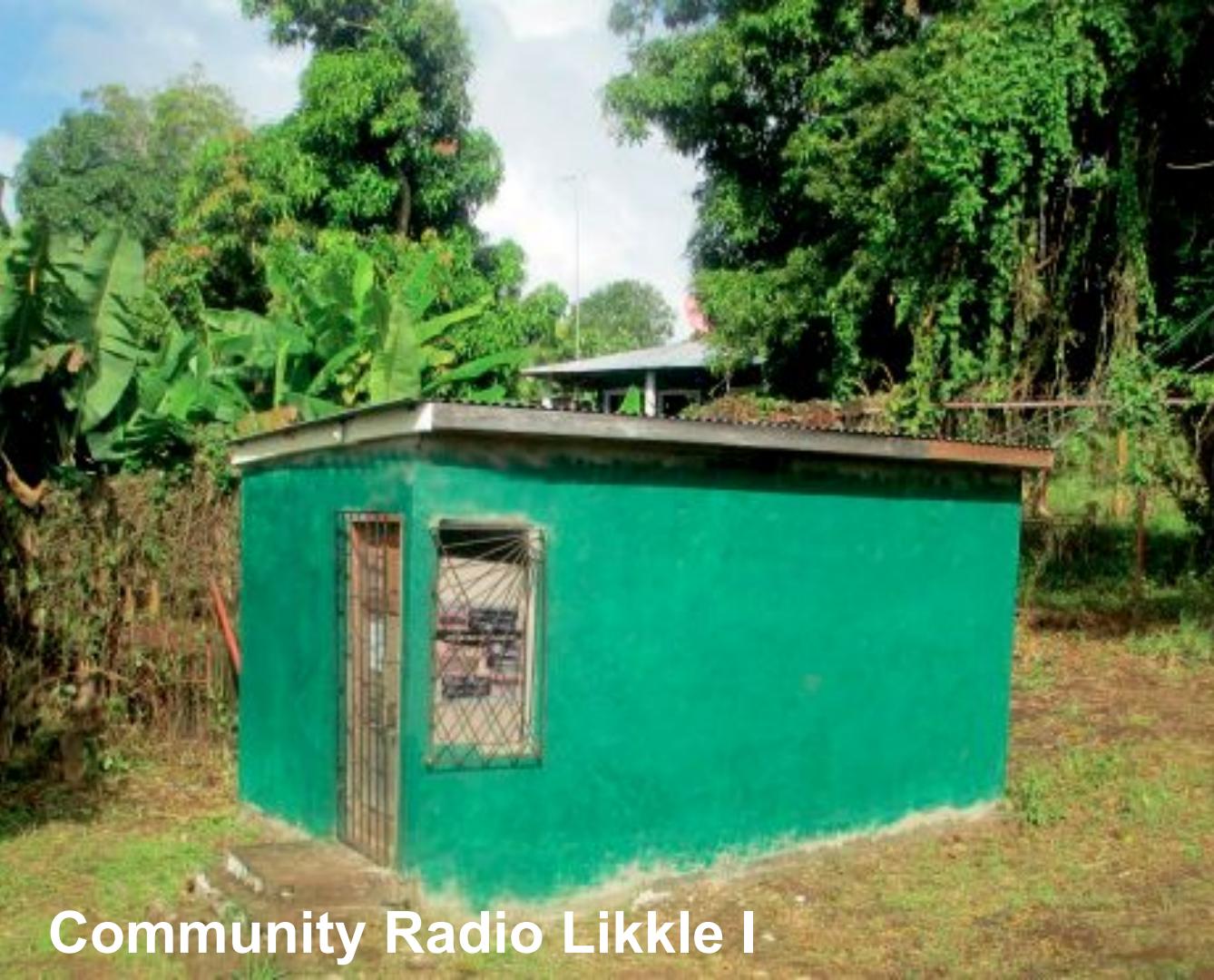




Nicaragua



Little Corn Island
Nicaragua
March 20, 2015



Community Radio Likkle I



Equipment



BSC
Base Station
Controller



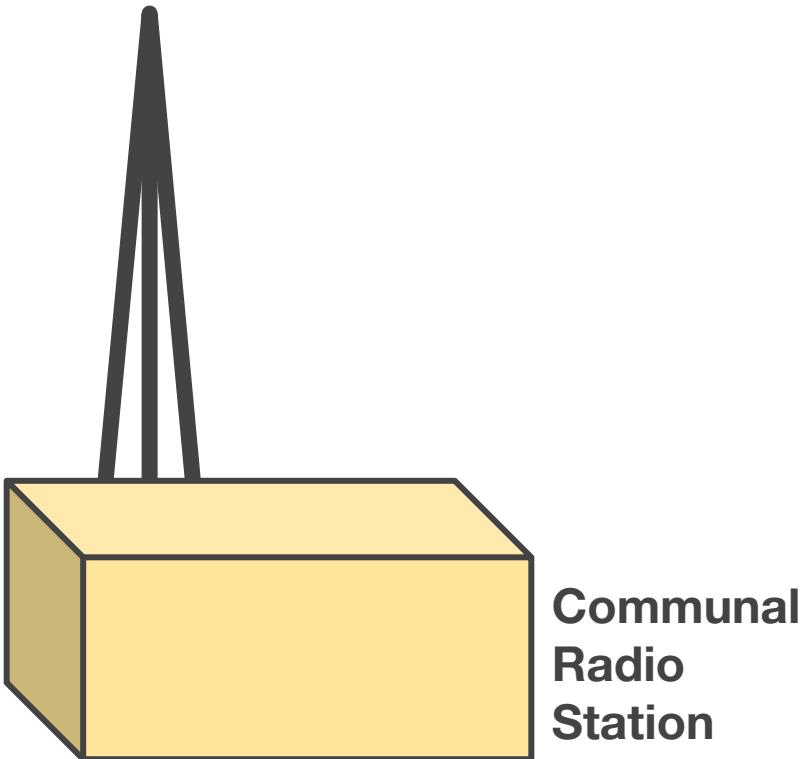
BTS
Base Transceiver
Station



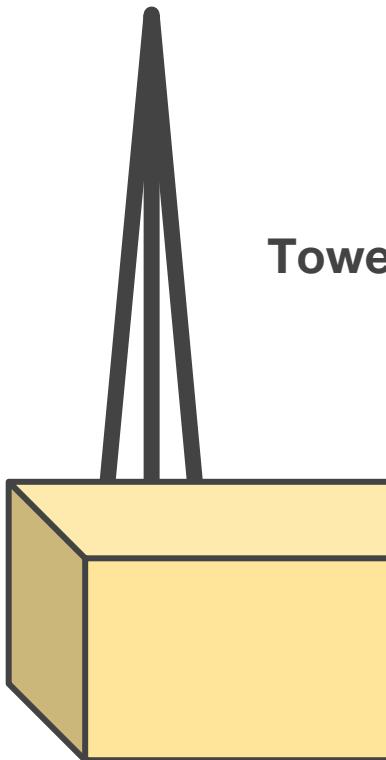
Antennas
Omni-Directional



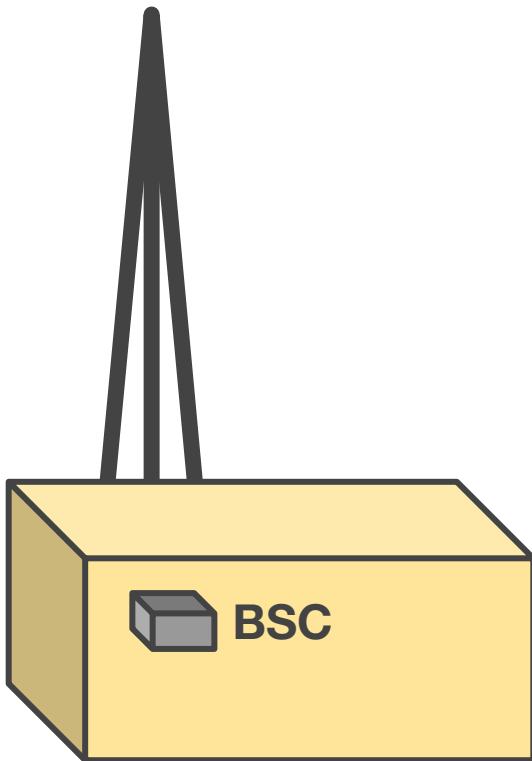
Community Cellular



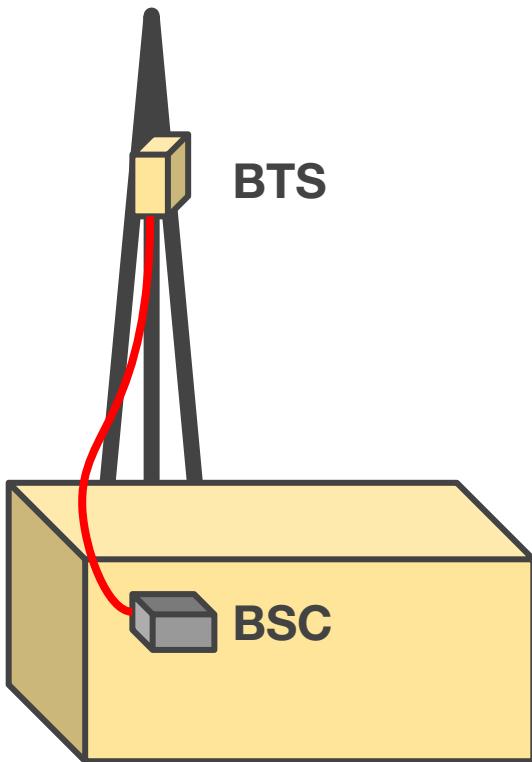
Community Cellular



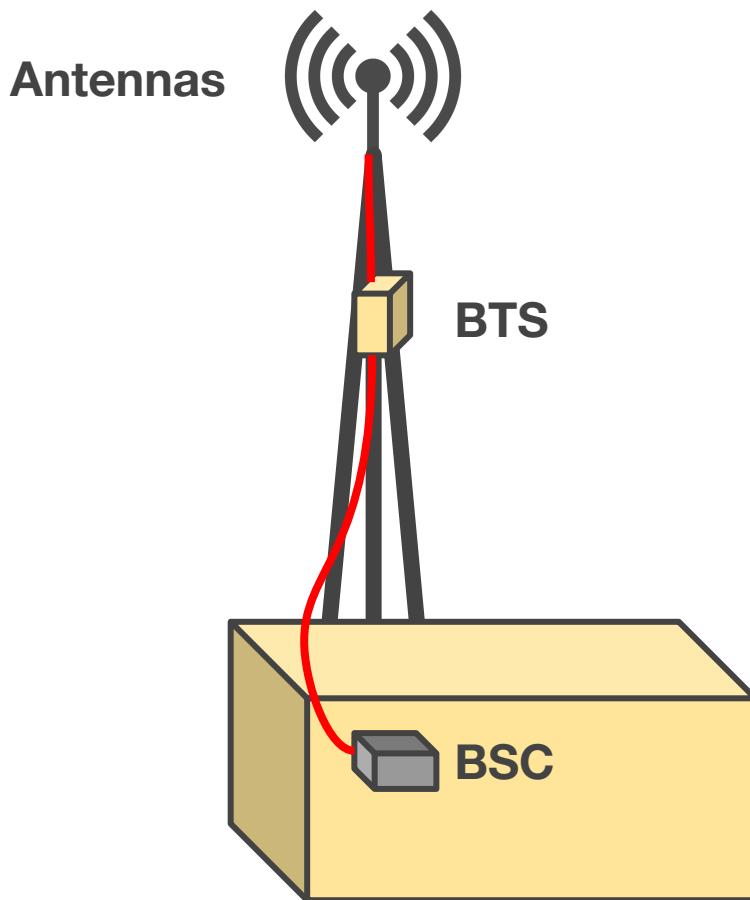
Community Cellular



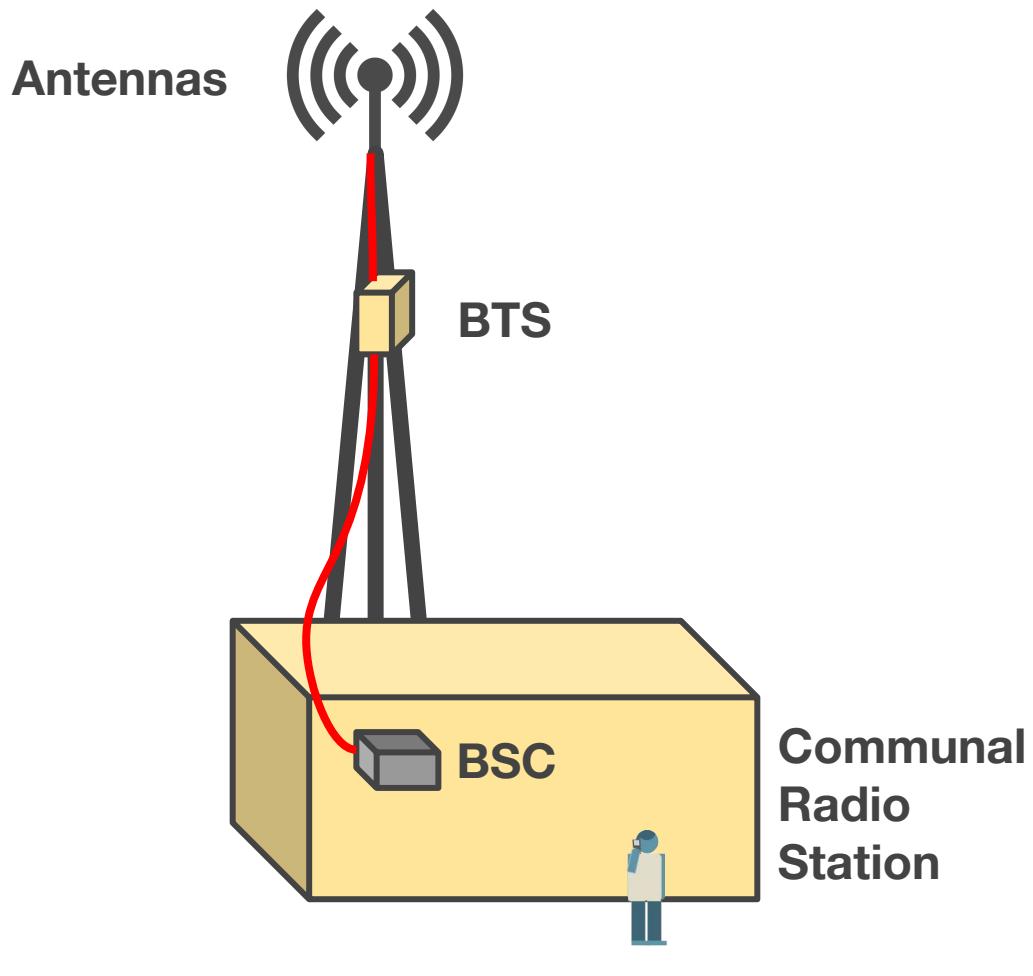
Community Cellular



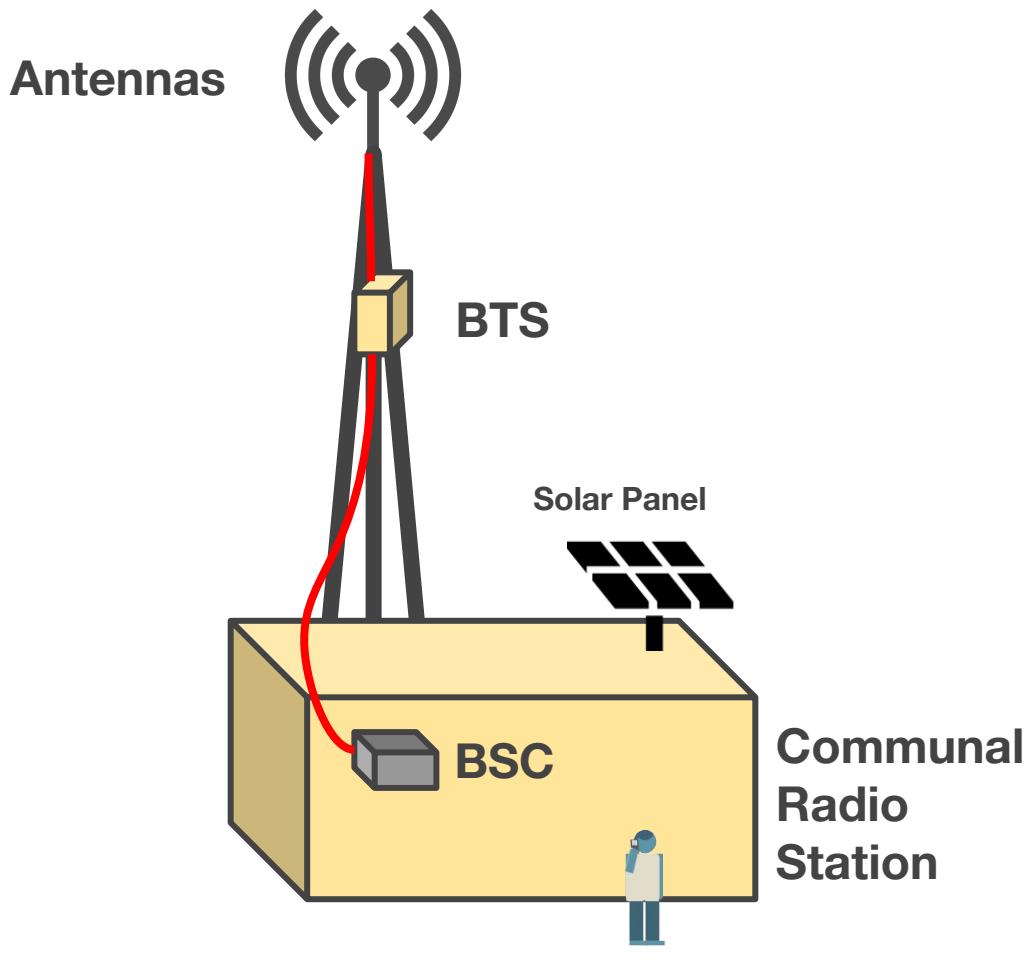
Community Cellular



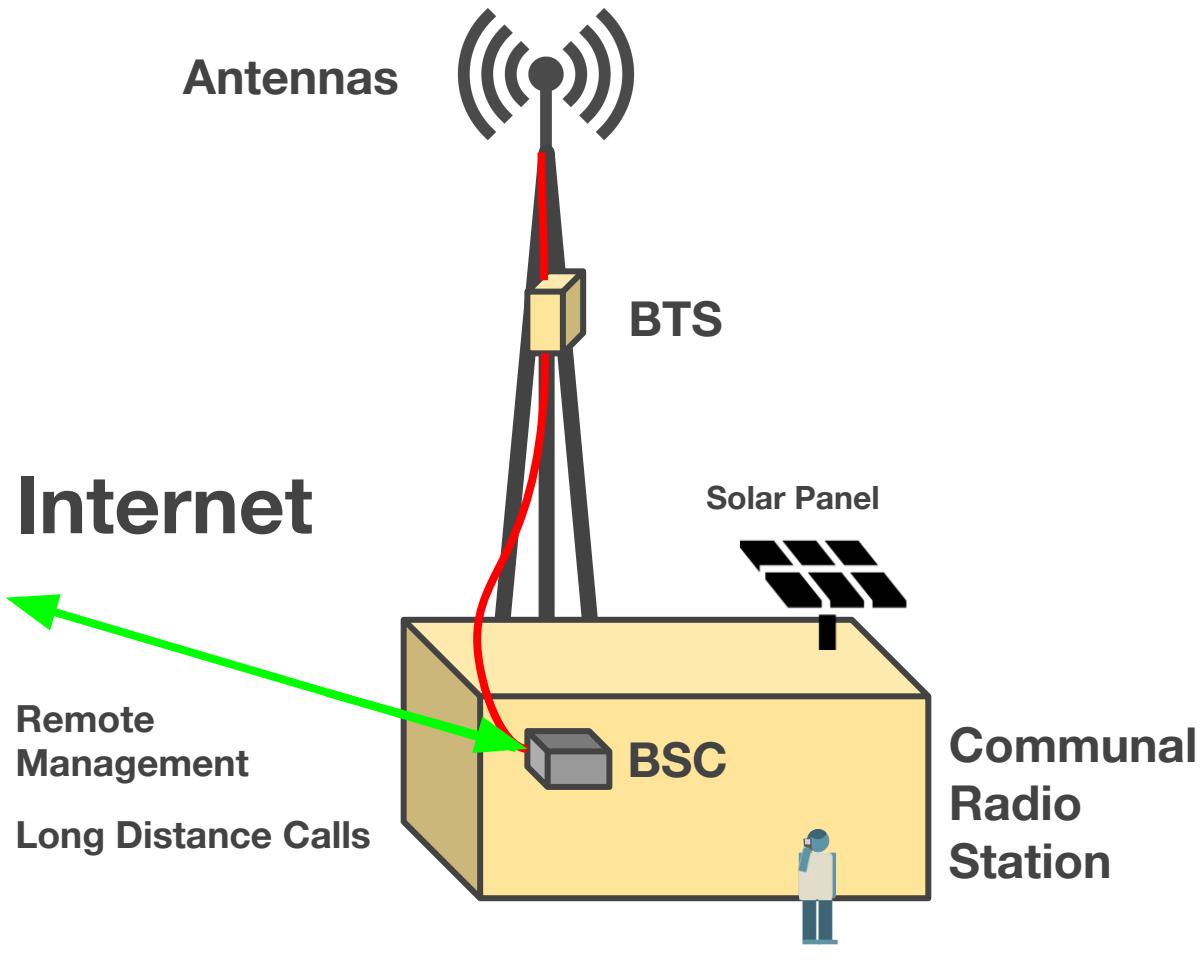
Community Cellular



Community Cellular



Community Cellular





Enables communities
to own and operate their own
Cellular Network
& Local 911



Meetings with Communal Government



Caribbean Autonomous Region

Autonomy





Autonomy gives communities the rights to manage their natural resources including cellular frequencies

Nación Comunitaria Moskitia





Communications Infrastructure



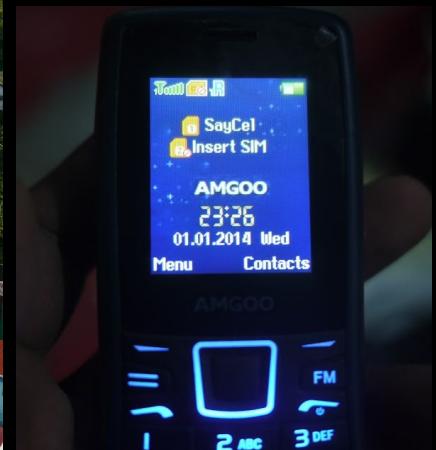
A tall utility pole stands vertically against a dark blue, slightly cloudy sky. The pole is painted with horizontal red and white stripes. It features several cross-arms supporting wires that fan out in different directions. The perspective is from below, looking up at the pole.

Cost of Installation

\$15,000



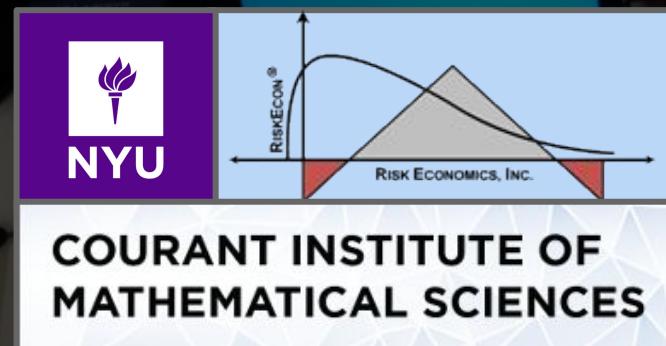
Winner of Stern Entrepreneur Competition



SAY
CEL

PEARL LAGOON

Research Funding Risk Econ Lab





Registered Business Nicaragua

**Registered with City and Regional
Government**

Opened a Bank Account

**Contractual Agreements with Local
Governments**

Apply to TELCOR

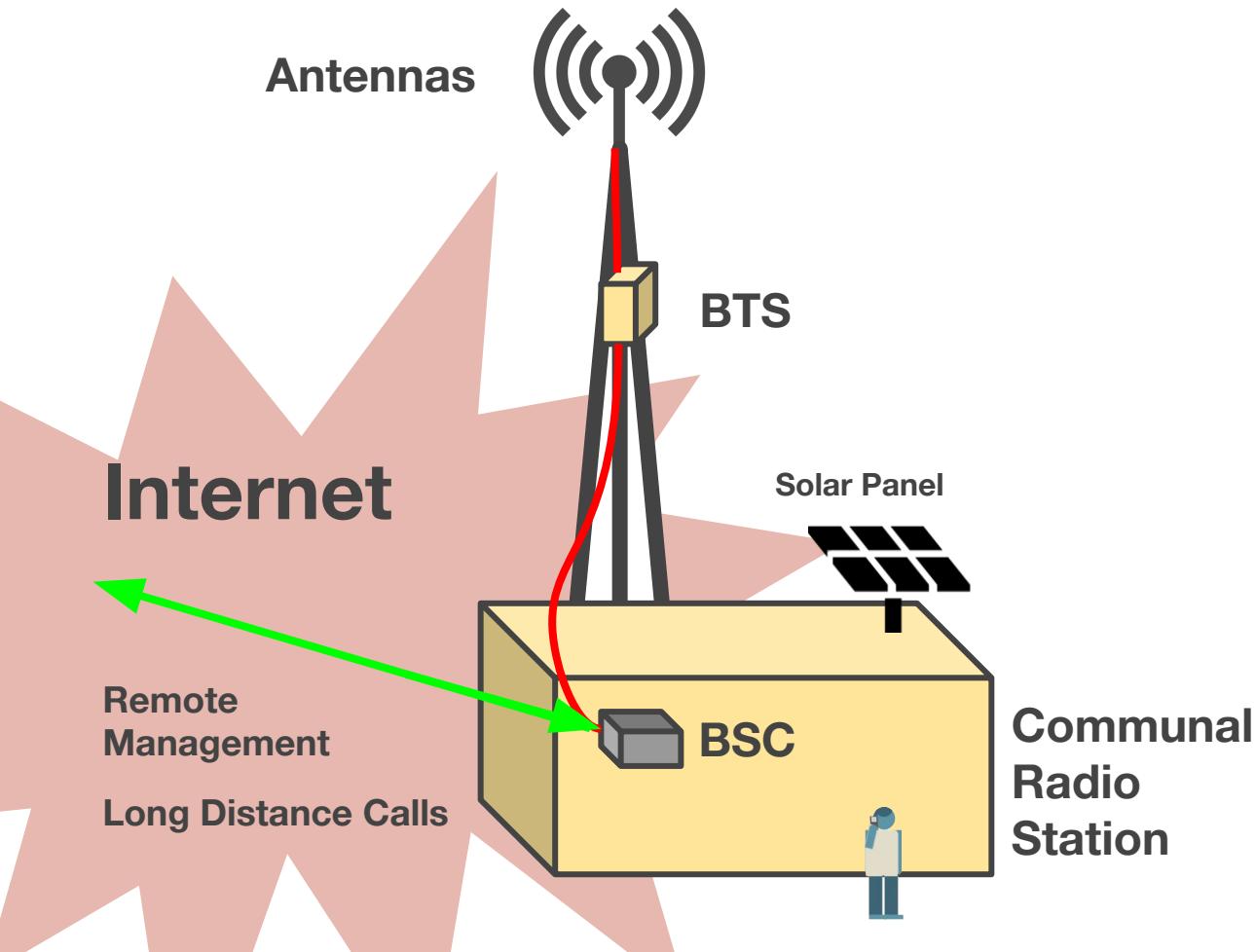
Provide Local Trainings



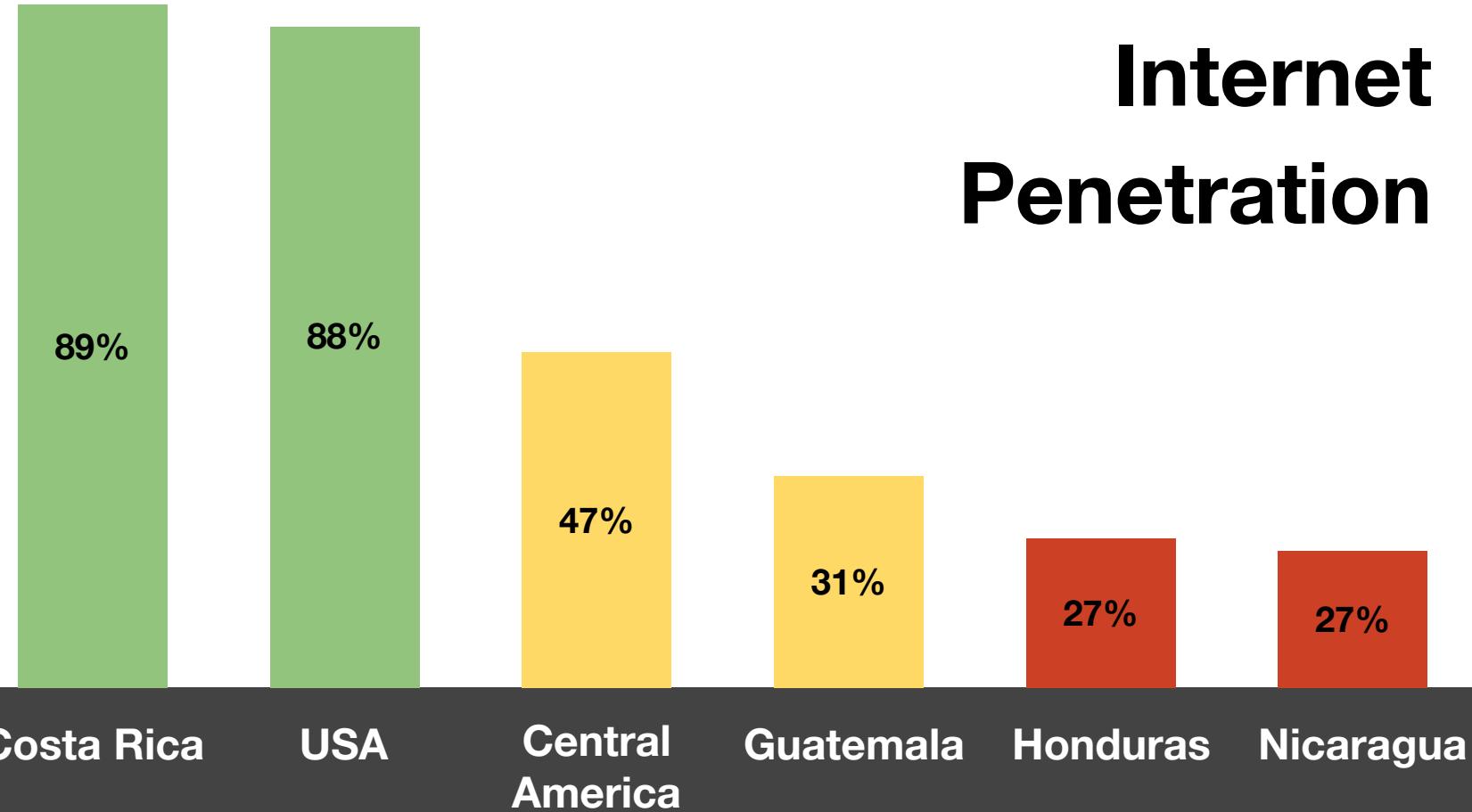
Our greatest challenge was

Internet

Community Cellular



Internet Penetration



Costa Rica

USA

Central America

Guatemala

Honduras

Nicaragua



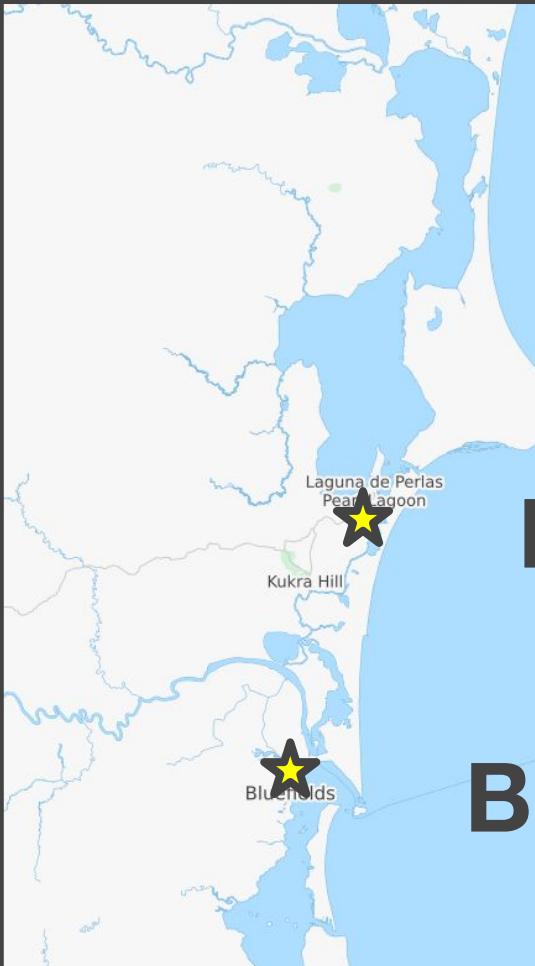
Internet



TELCOR

Nicaraguan Regulator

Submit application June 2016



Pearl Lagoon

Bluefields



Bluefields

THE LARGEST FIBER OPTIC NETWORK IN THE PAN CARIBBEAN



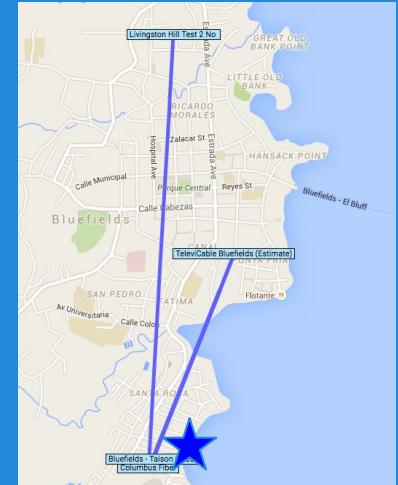
C&W Networks

A Liberty Global company





Fastest Internet Nicaragua

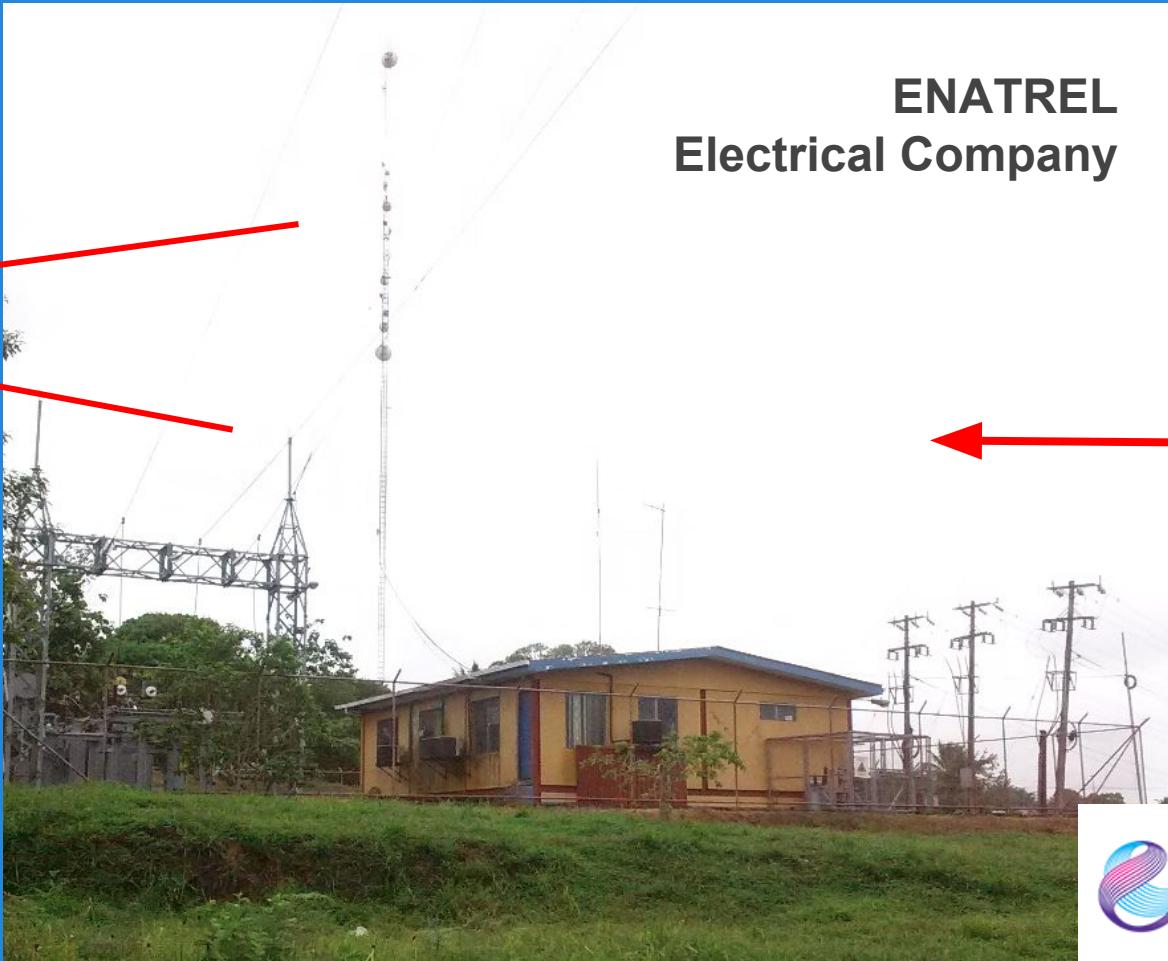


Bluefields

ENATREL

Electrical Company

Managua

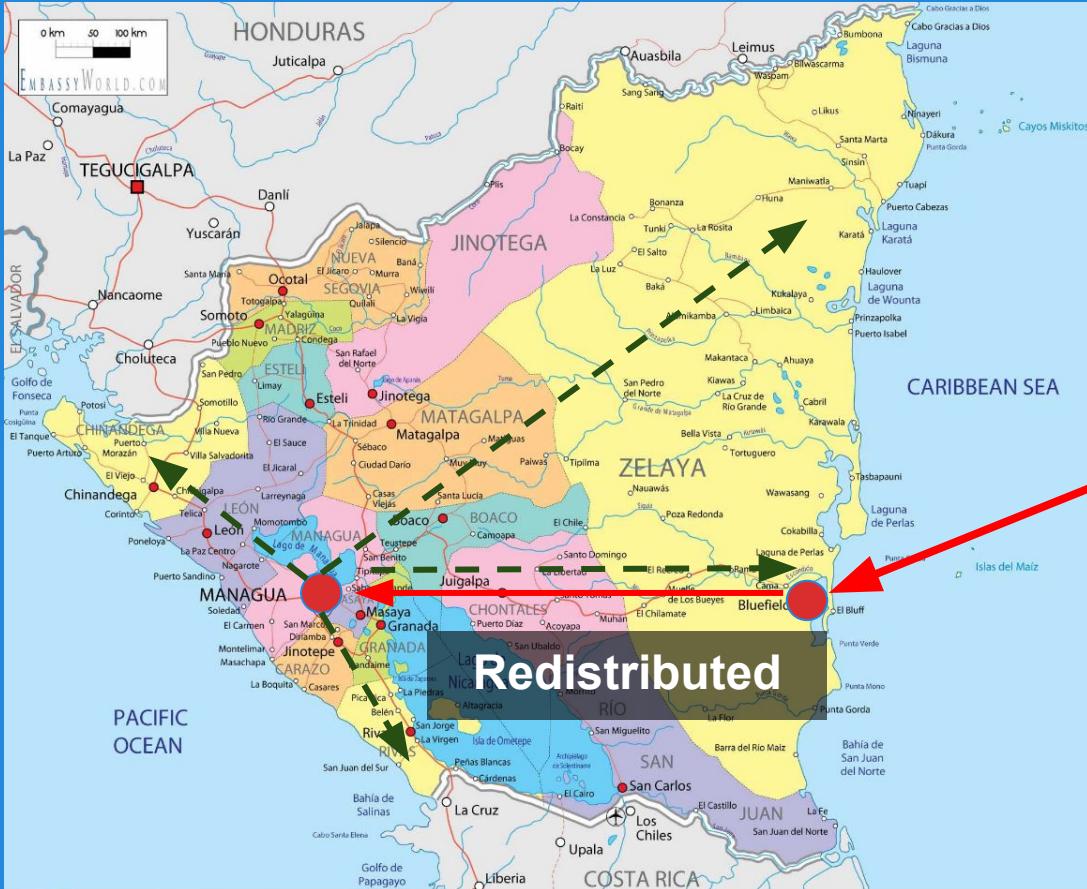




Bluefields Colocation Facility

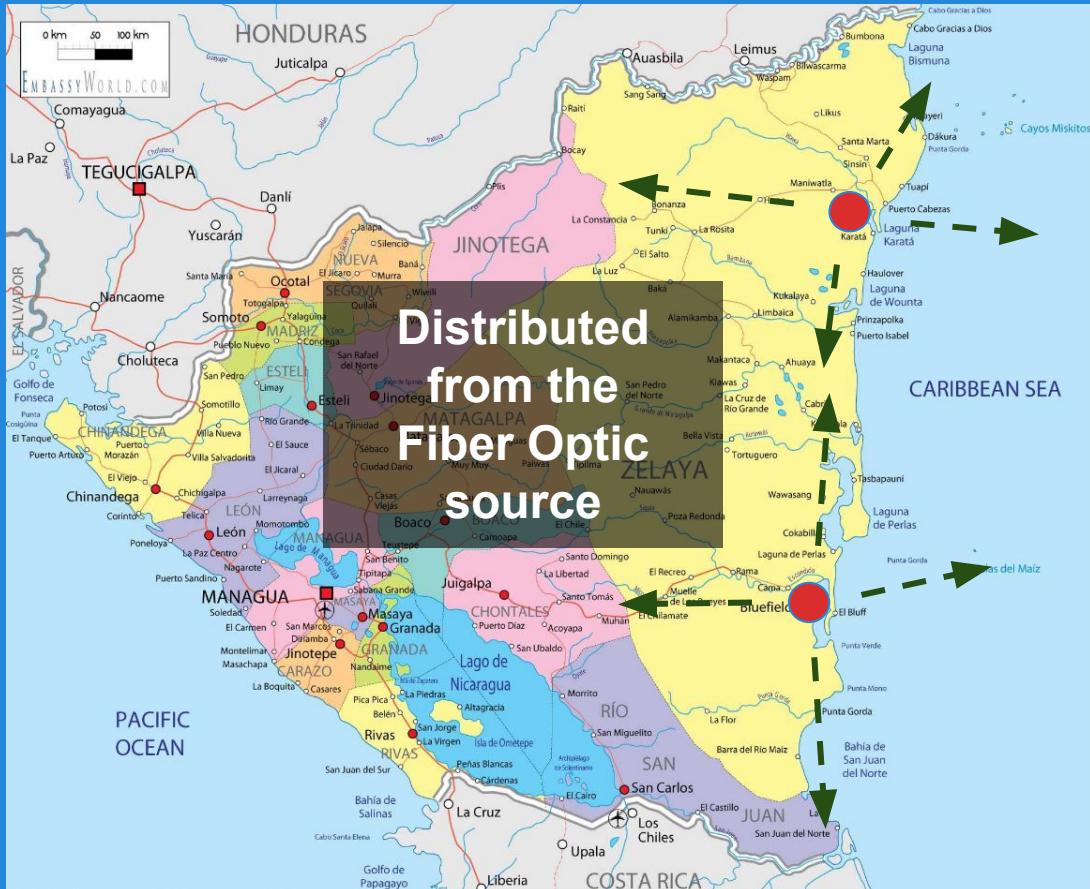


Bluefields Colocation Facility



Bluefields Colocation Facility

Redistributed



SAYACEL
Internet

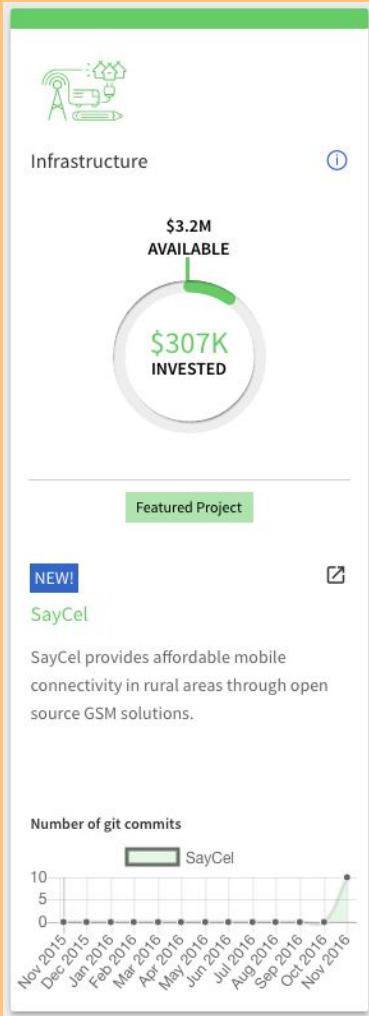
ufinet

Fiber Backhaul





Internet Backhaul



UNICEF INNOVATION FUND

\$98,000

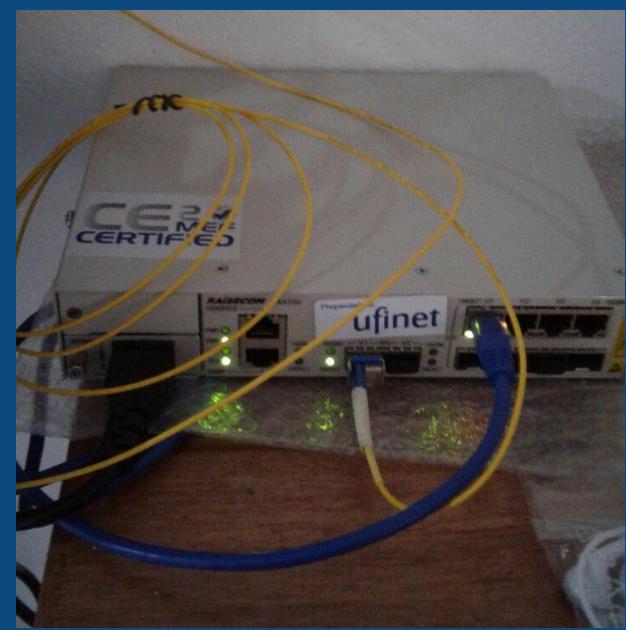
Investment



UNICEF DUBAI TRIP







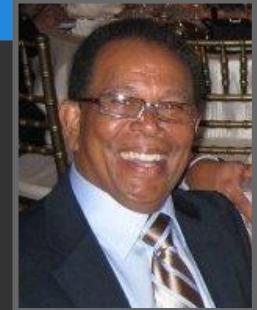
Fiber Connected



SAY CEL
Internet



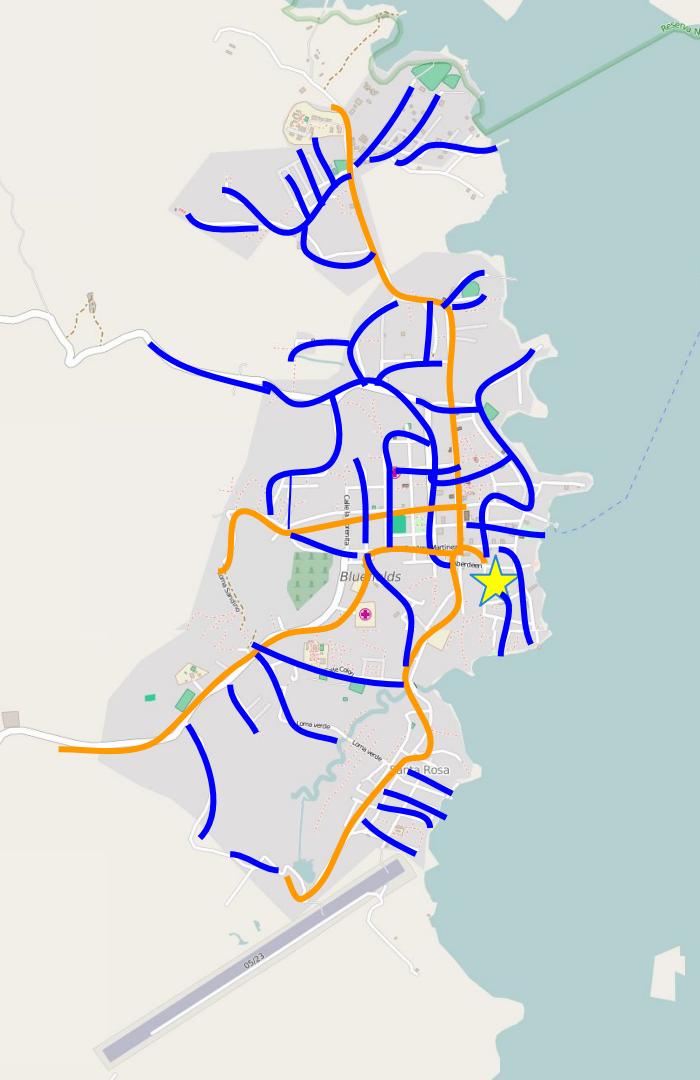
Bluefields
Televicable











Bluefields Teleicable

- **25+ Years in Business**
- **Existing Coax / Fiber Network**
- **Local Technicians**
- **Interest in Community**



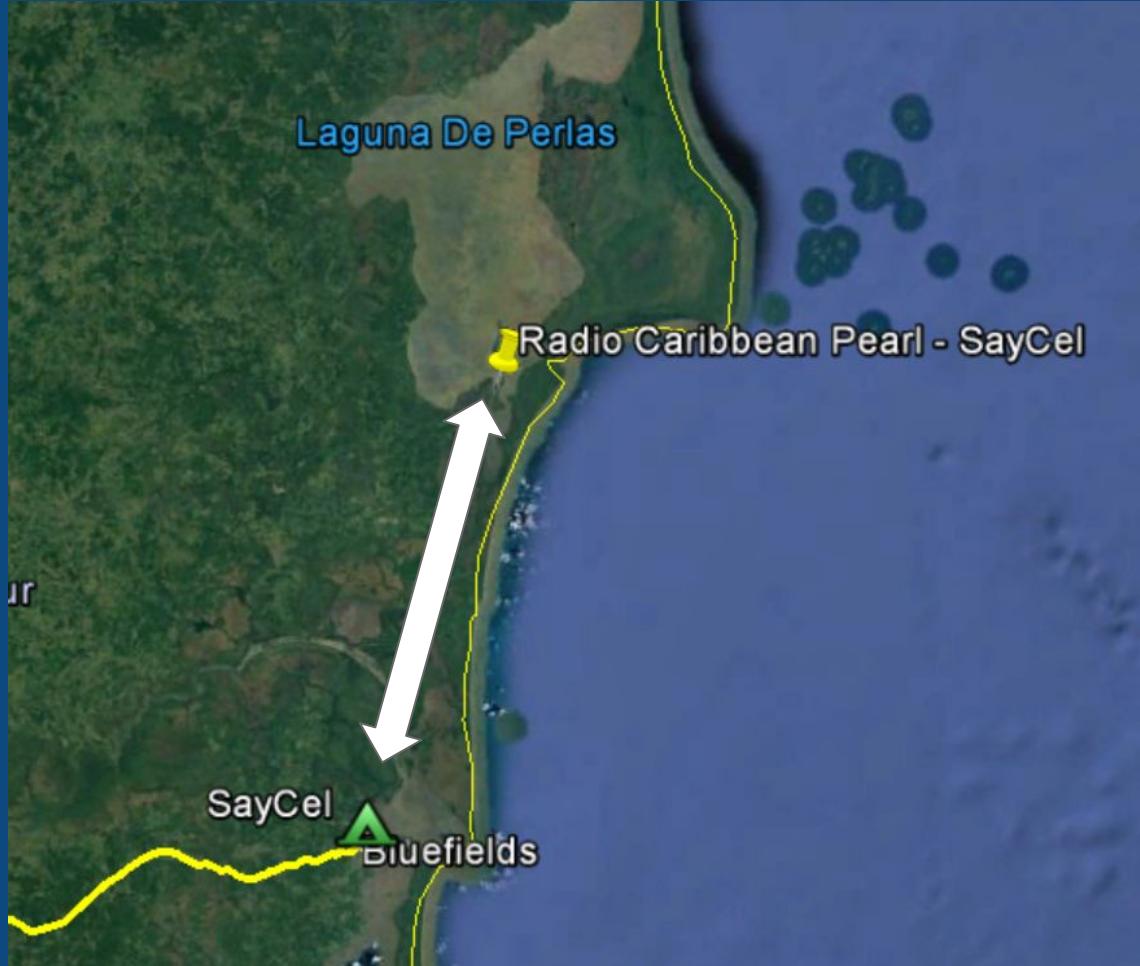
Pearl Lagoon Upgrades

Radio
Caribbean
Pearl



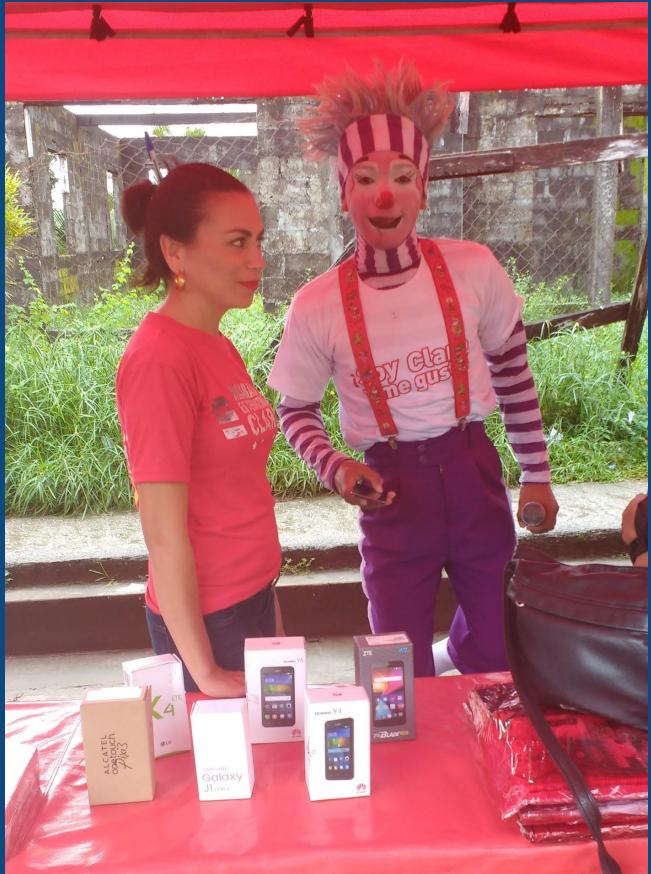
Bluefields Pearl Lagoon

40 Kilometers





REINDEER





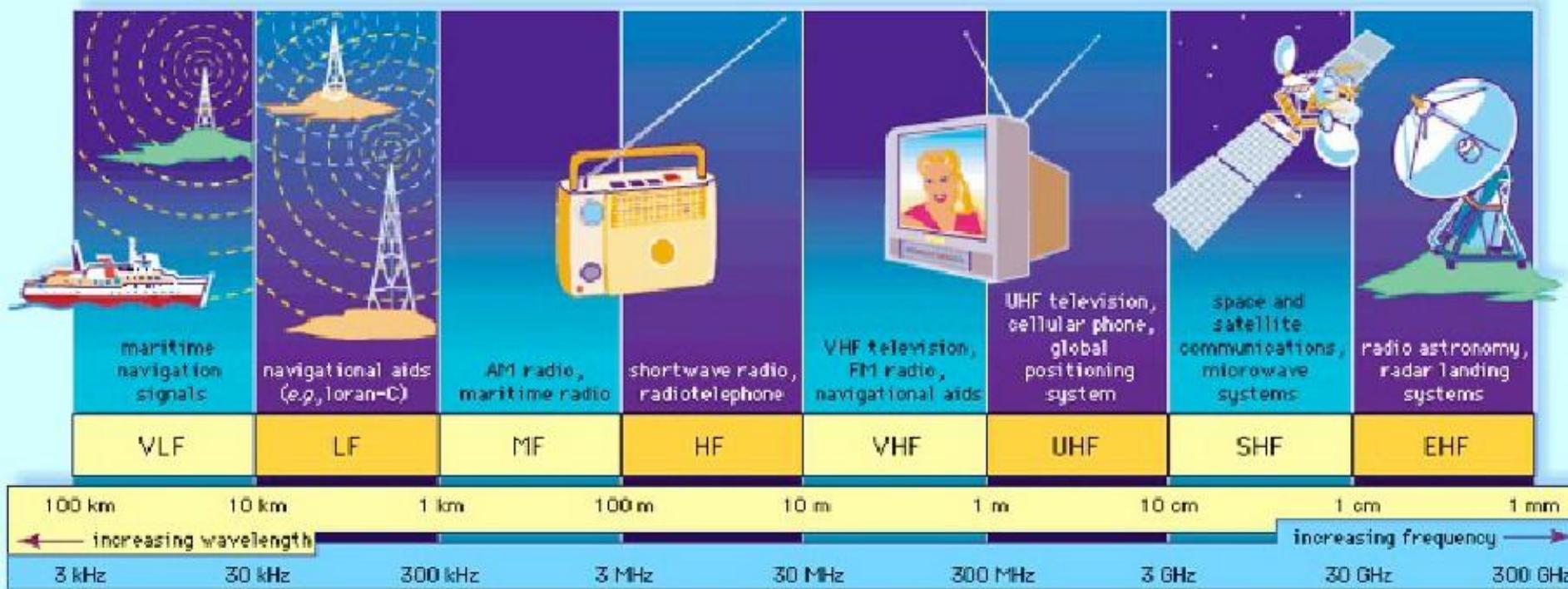
PEARL ACE
Community Cellular Network

**FOR FRIENDS & FAMILY
TO BE CONNECTED**
Unlimited Talking & Text

GSM Basics



WIRELESS COMMUNICATION



VLF - Very Low Frequency

LF - Low Frequency

MF - Medium Frequency

HF - High Frequency

VHF - Very High Frequency

UHF - Ultra High Frequency

SHF - Super High Frequency

EHF - Extremely High Frequency

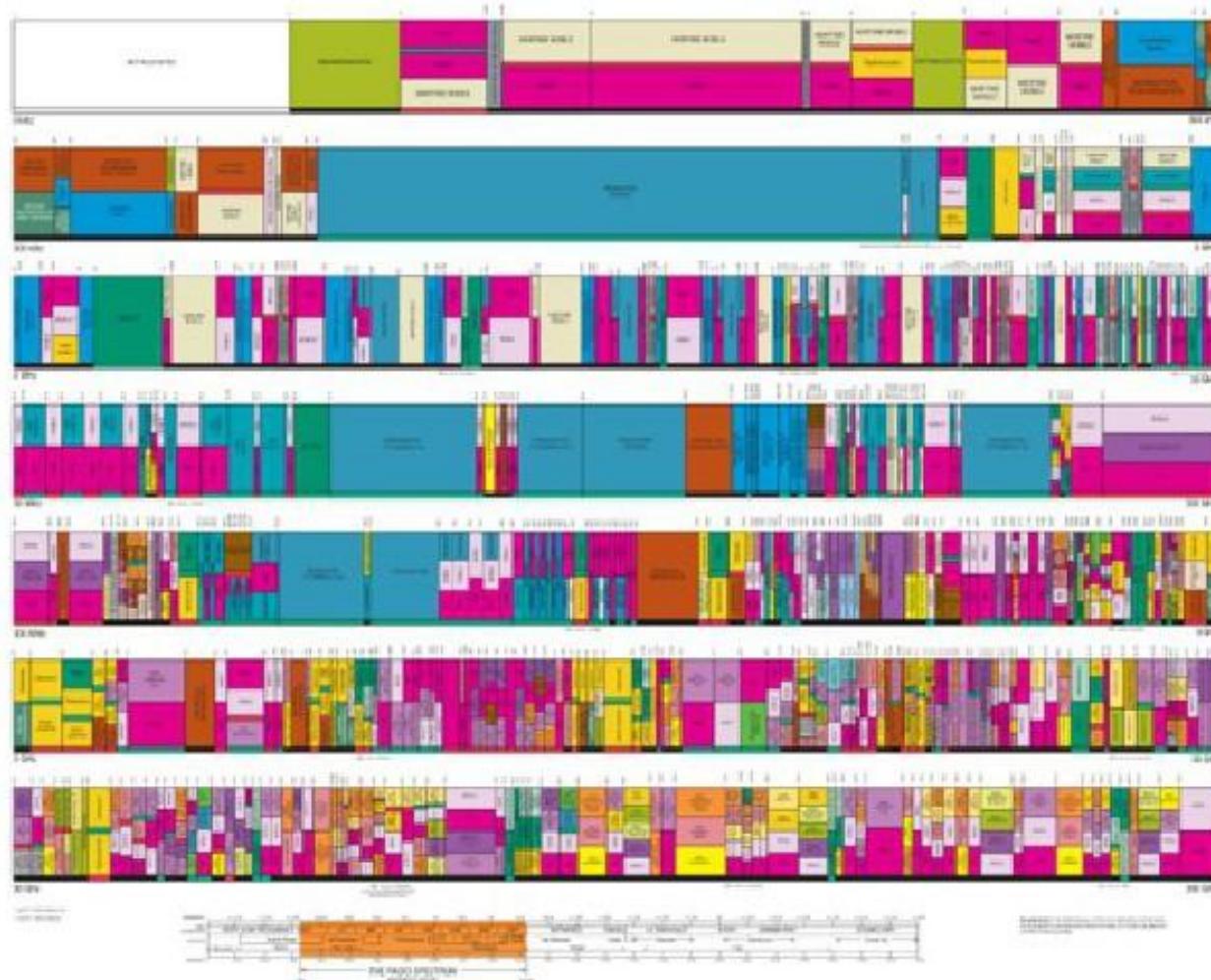
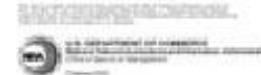
UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM



ALLOCATION/USAGE DESIGNATION

TYPE	NAME	DESCRIPTION
REGULATED	AMPS	Allocation by the FCC
NONREGULATED	PMRS	Allocation by the FCC



ONCE UPON A TIME...



1946 - MTS



1965 - IMTS



Now—from your car—you can place or receive calls from any place in the world with General Electric's Simultaneous Duplex Mobile Telephone.



NEW-FANGLED TALKING MACHINE

Available in both 11-channel MTS and 7-channel RCC models, this new solid-state mobile telephone is probably the most sophisticated, most compact available today...with all the

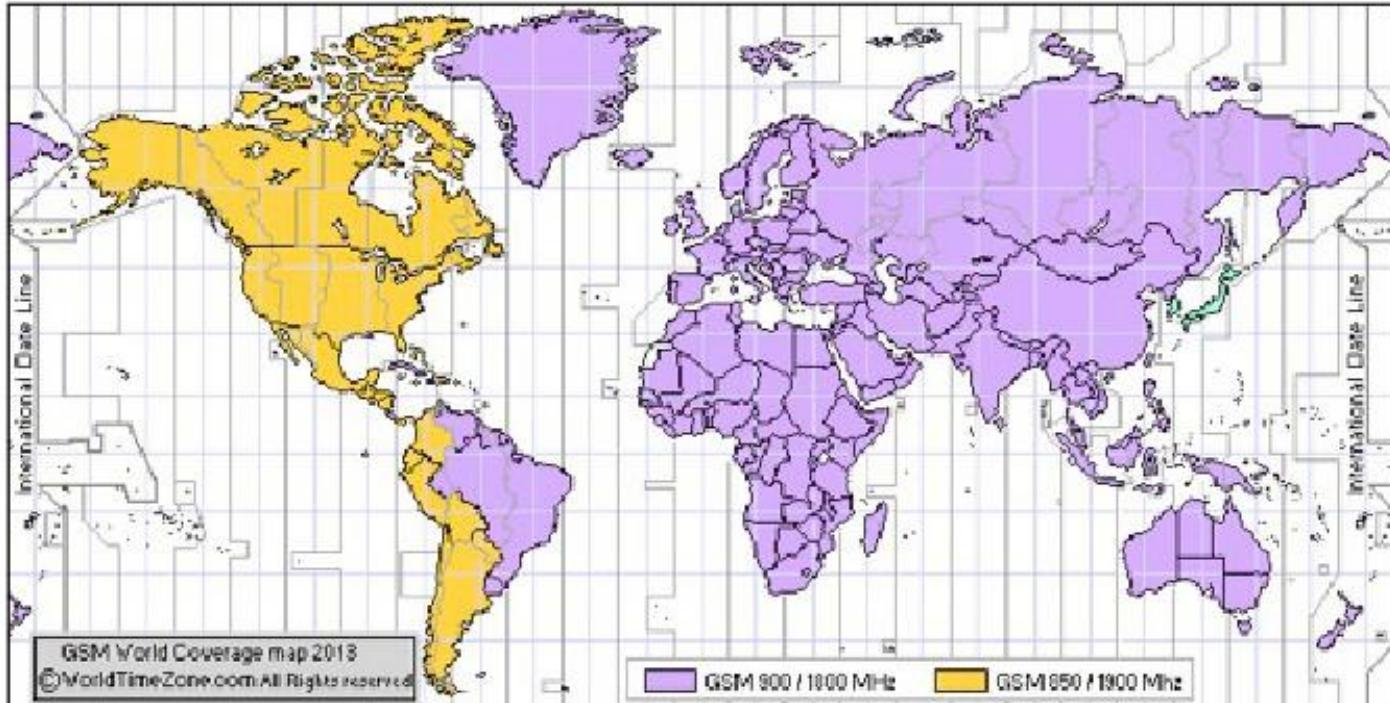
1978 - AMPS



1982 - GSM PROJECT



1991 ON - GSM WORLDWIDE



GSM Bands:

850/1900 - North American

900/1800 - European

EVOLUTION

1G	2G	2.5/2.75G	3G/3.5G	4G
Analog Cellular	Digital Cellular	GPRS/EDGE	Mobile Broadband	Native IP Networks
Communication	Communication		Data UMTS/HSPA	Long Term Evolution
Advanced Mobile Phone System - first generation cellular technology in the U.S. that used frequency division multiple access (FDMA) which assigned specific frequencies for each call. - voice only	GSM - digital communication allowing multiple users on a single channel, Code Division Multiple Access (CDMA). voice - limited data (SMS)	General Packet Radio Service / Enhanced Data Rates for GSM Evolution - Improvements to GSM by integrating packet switched data instead of circuit switched data.	Universal Mobile Telecommunications System / High Speed Packet Access - greater security - greater network capacity - faster speeds - location services - streaming video	All IP network - VOIP calls Broadband - higher speeds



2.4 kbps

64 kbps

171 kbps

547 kbps

2,000 kbps

100,000 kbps

ANALOG VS. DIGITAL



Analog

AMPS, NMT, TACS etc. used Analog air interface. The information sent over the airwaves is exactly as is.

Drawbacks:

- Lots of bandwidth needed
- Limited amount of users
- Susceptible to fraud & eavesdropping

Digital

GSM samples the Information to be transmitted over the air and converts them into packets.

Benefits:

- Clearer call quality
- Better protection against fraud and eavesdropping
- Advanced options and features
- Longer battery life

TDMA VS CDMA

- **Frequency Division Multiple Access**

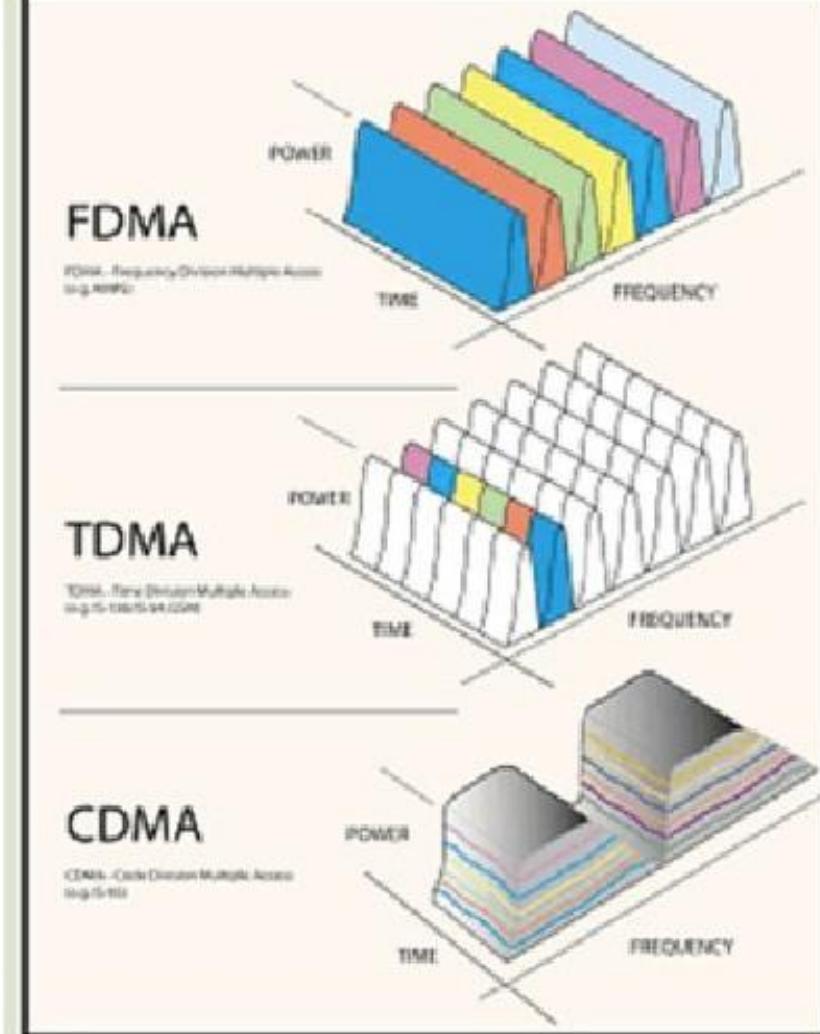
- individual allocation of a radio frequency for each conversation

- **Time Division Multiple Access**

- a radio channel is broken into time slots which allow multiple users

- **Code Division Multiple Access**

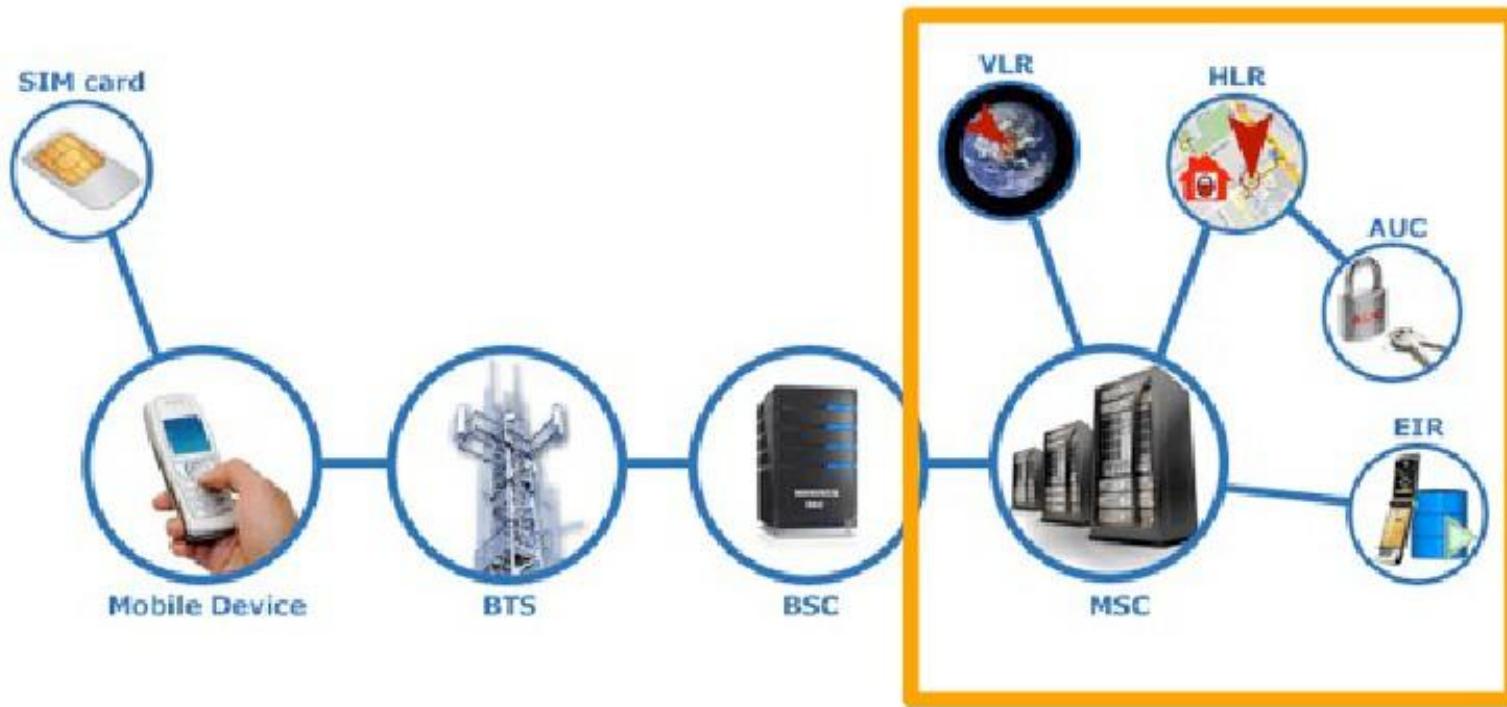
- data has a unique identifier which allows transmissions to be organized later





GSM SYSTEM ARCHITECTURE

NETWORK SUBSYSTEM



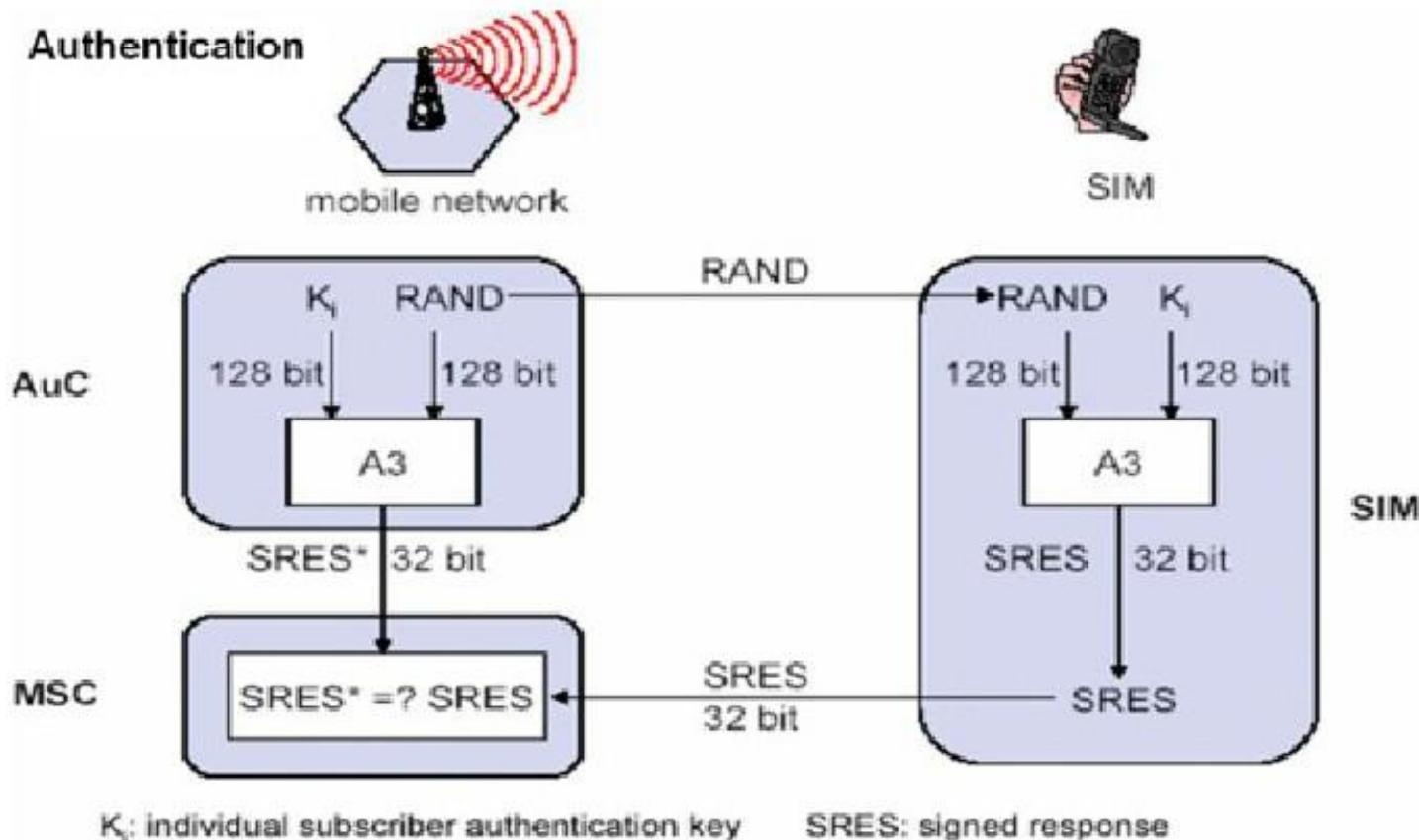
MOBILE SWITCHING CENTER



HOME LOOKUP REGISTRY



AUTHENTICATION CENTER (AUC)



VLR + EIR

Visitor Location Register:

- responsible for mobility management and handles local caller traffic
- each MSC has its own VLR

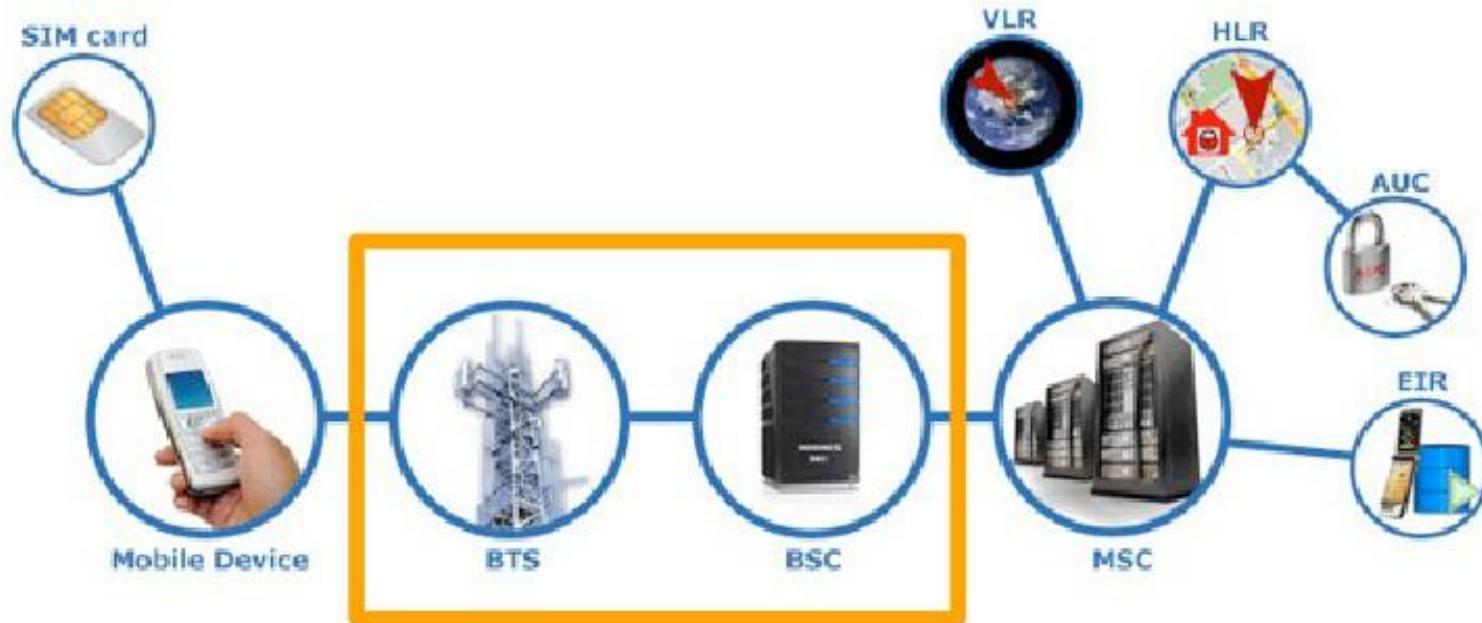


Equipment Identification Register:

- a database that contains the information about the identity of the mobile equipment (IMEI)
- Keeps track black listed phones



BASE STATION SUBSYSTEM



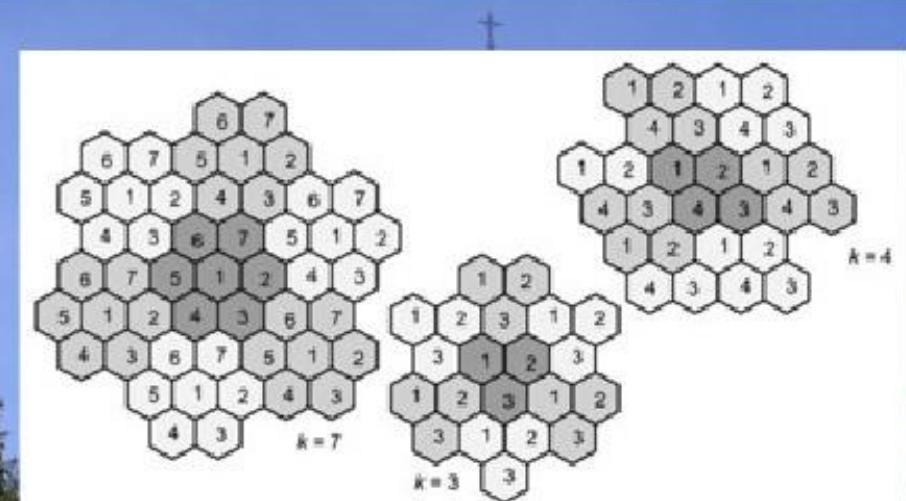
BASE STATION CONTROLLER

The **intelligence** of the BTS



BASE TRANSCEIVER STATION

The Tower of Power



Designed as cells in order for efficient **frequency reuse**

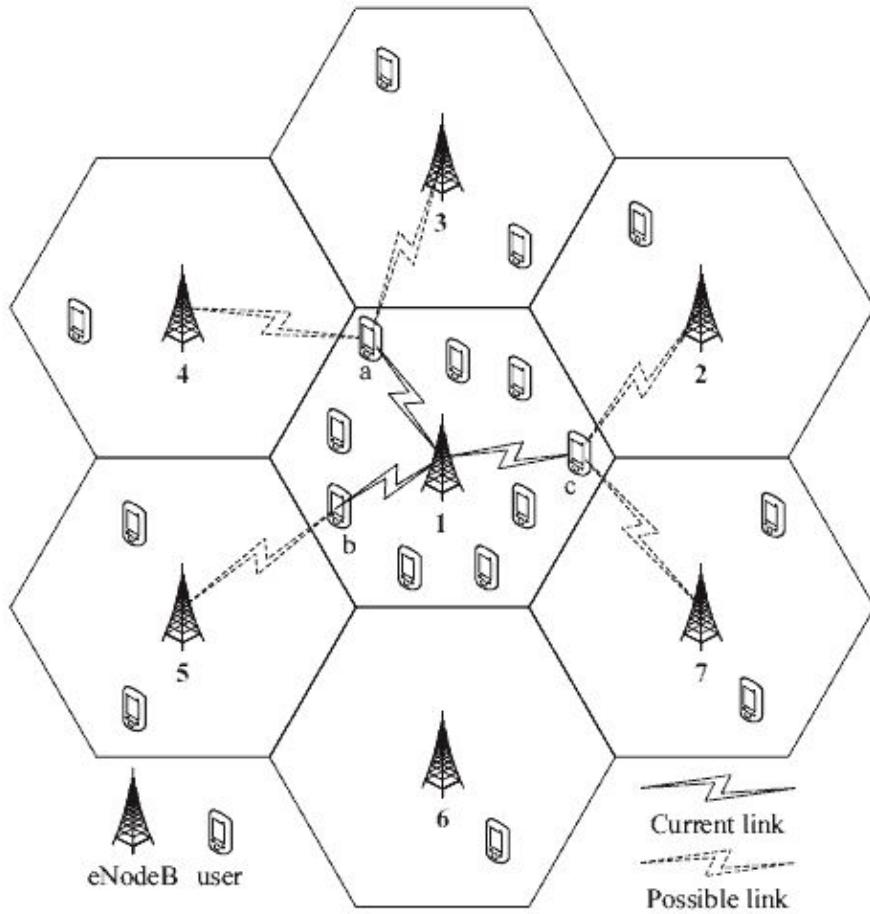


Figure 1: Network model.

ARFCN	Frequency (MHz)	
	Downlink	Uplink
128	869.2	824.2
129	869.4	824.4
130	869.6	824.6
131	869.8	824.8
132	870	825
133	870.2	825.2
134	870.4	825.4
135	870.6	825.6
136	870.8	825.8
137	871	826
138	871.2	826.2
139	871.4	826.4
140	871.6	826.6
141	871.8	826.8
142	872	827
143	872.2	827.2
144	872.4	827.4
145	872.6	827.6
146	872.8	827.8
147	873	828
148	873.2	828.2

ARFCN

http://niviuk.free.fr/gsm_arfcn.php

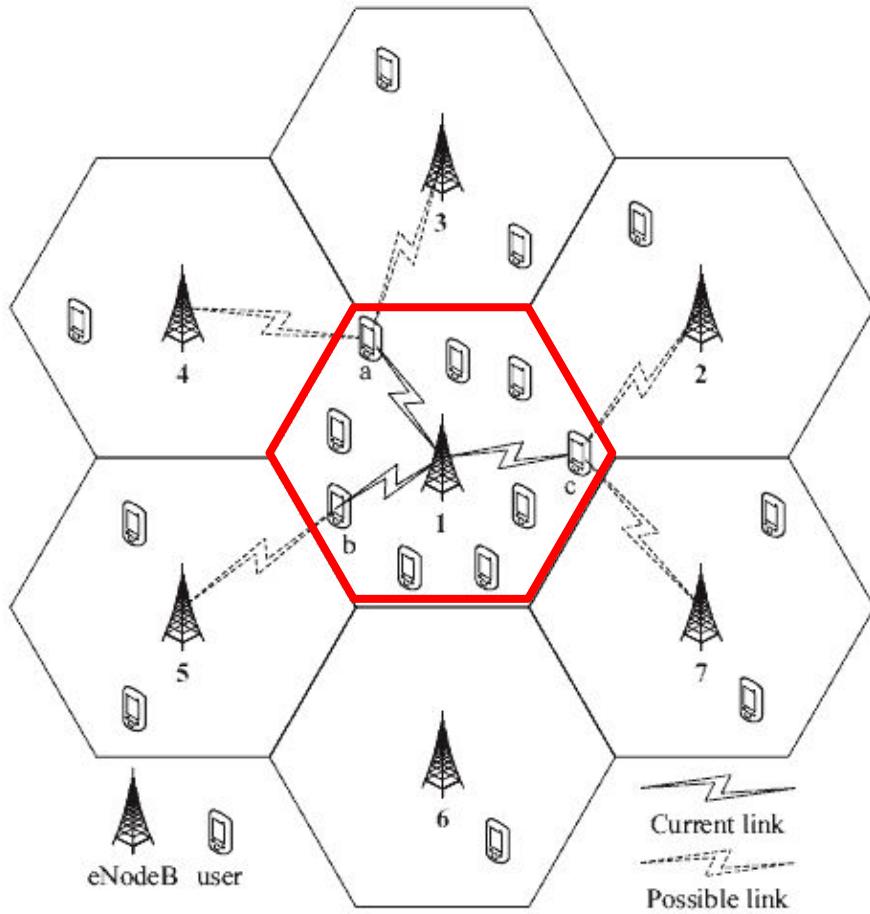


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143	872.2	827.2
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ARFCN

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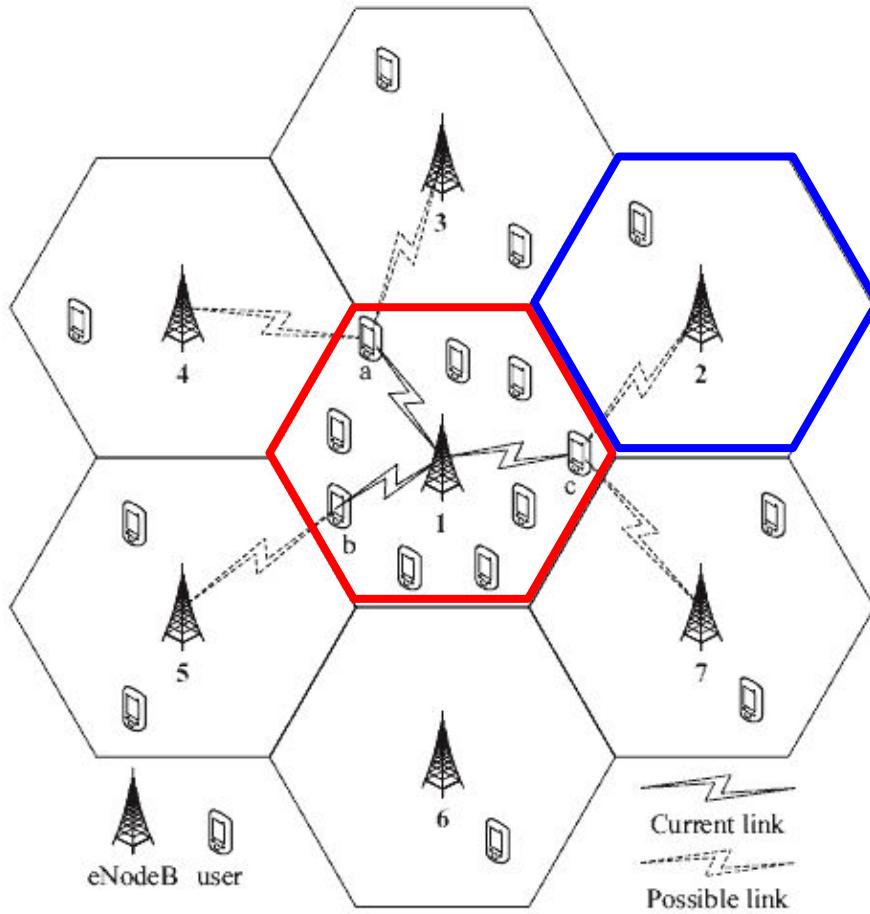


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ARFCN

http://niviuk.free.fr/gsm_arfcn.php

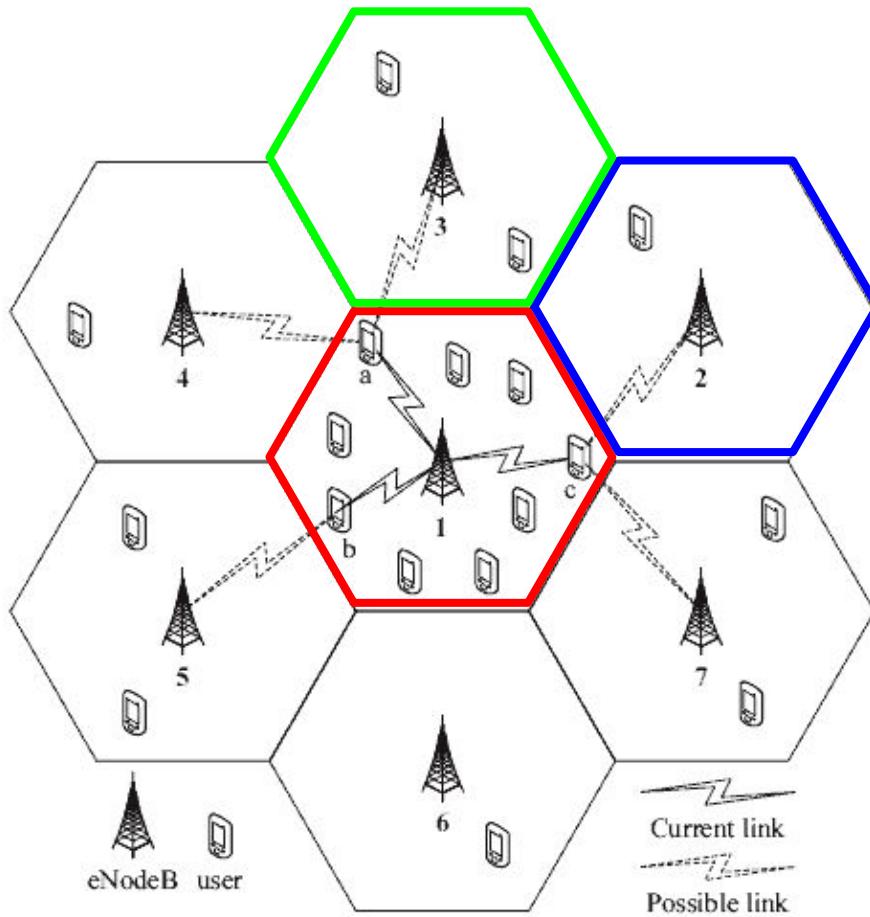
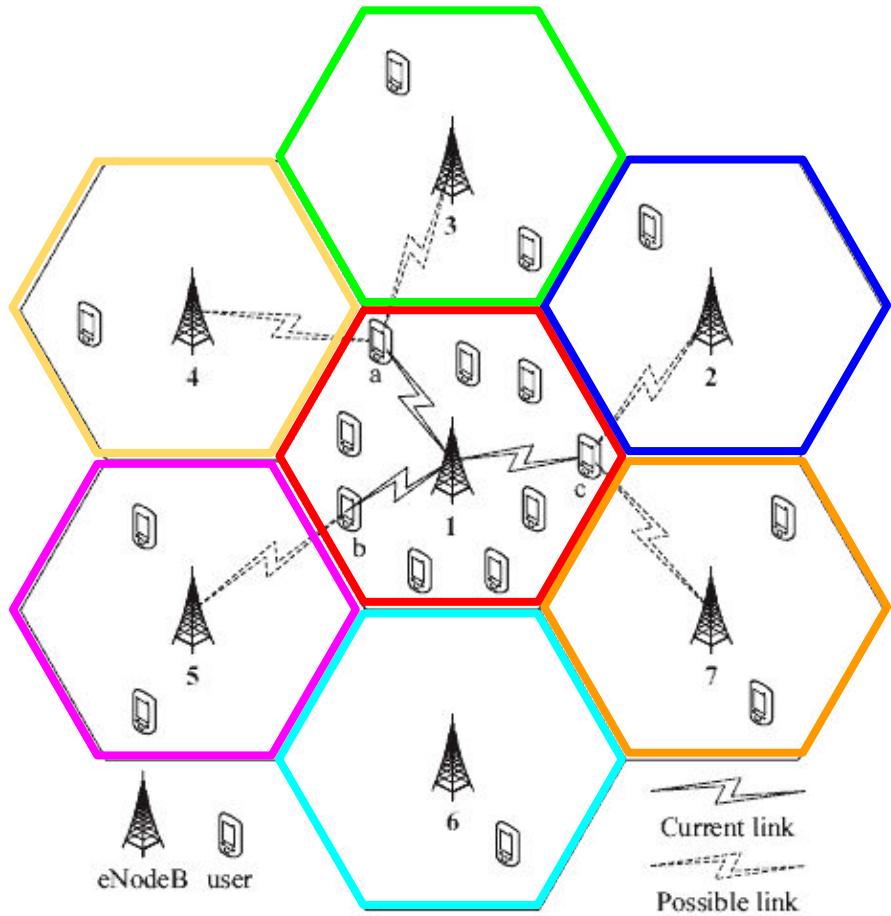


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ARFCN

http://niviuk.free.fr/gsm_arfcn.php

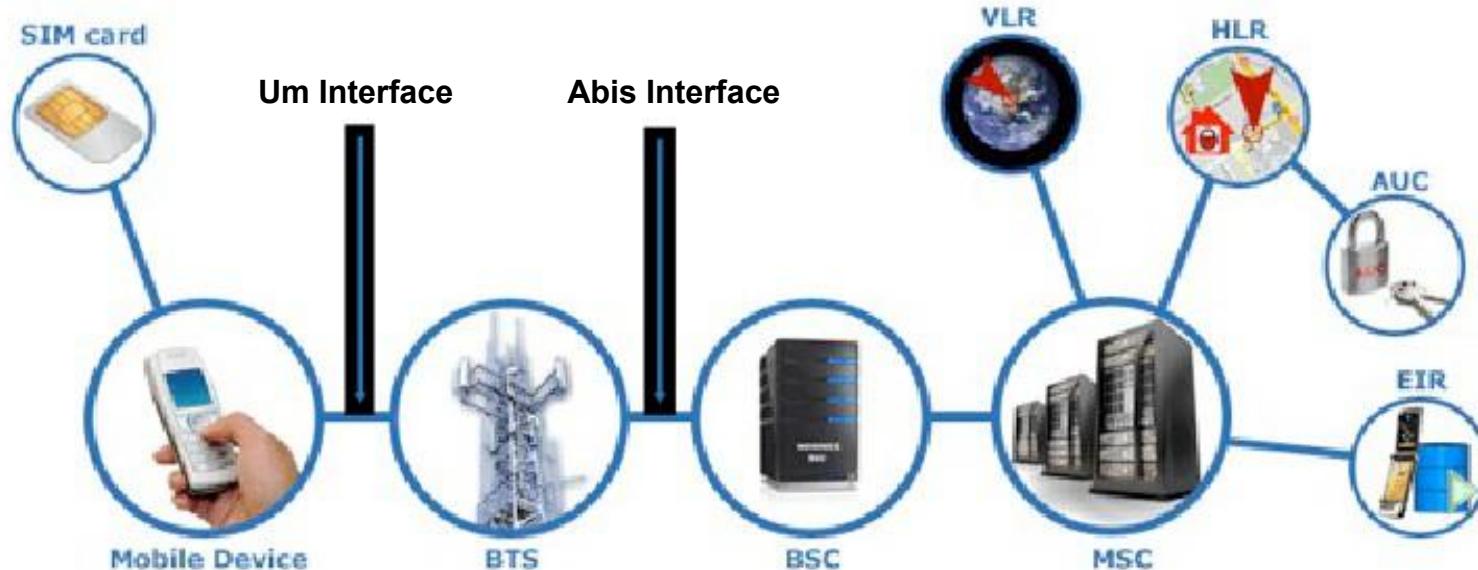


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ARFCN

http://niviuk.free.fr/gsm_arfcn.php

INTERFACING



Um Logical Channels

Traffic Channels

Full rate traffic channel

Half rate traffic channel

TCH/F

TCH/H

Dedicated control Channels

Standalone Dedicated Control Channel

Fast Associated Control Channel

Slow Associated Control Channel

SDCCH

FACCH

SACCH

Common control Channels

Broadcast Control Channel

Synchronization Channel

Frequency Correction Channel

Paging Channel

Access Grant Channel

Random Access Channel

BCCH

SCH

FCCH

PCH

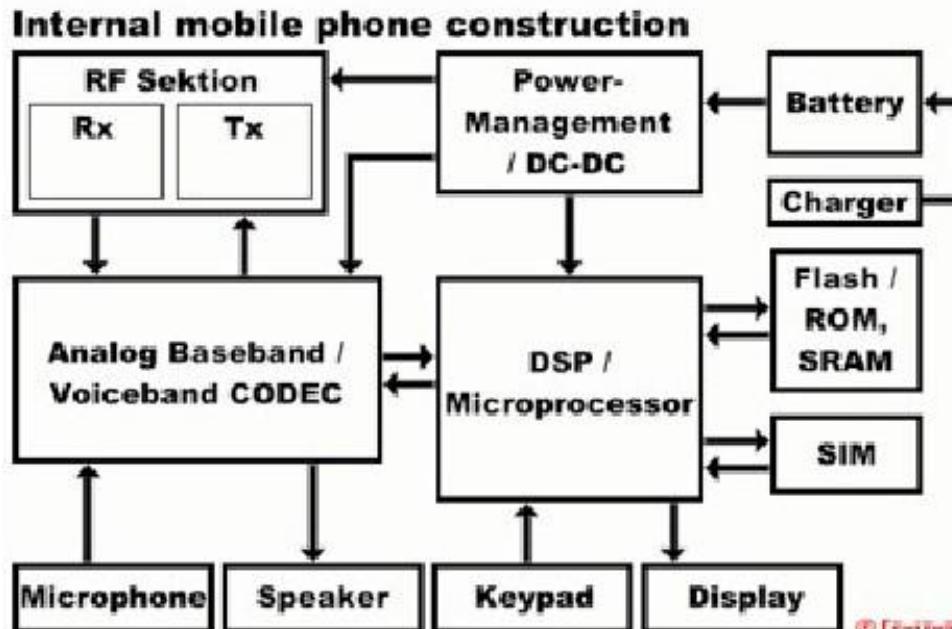
AGCH

RACH

MOBILE STATION SYSTEM



MOBILE DEVICE



SUBSCRIBER IDENTITY MODULE

International Mobile Subscriber

Identifier (**IMSI**)

Unique number of the mobile subscriber.

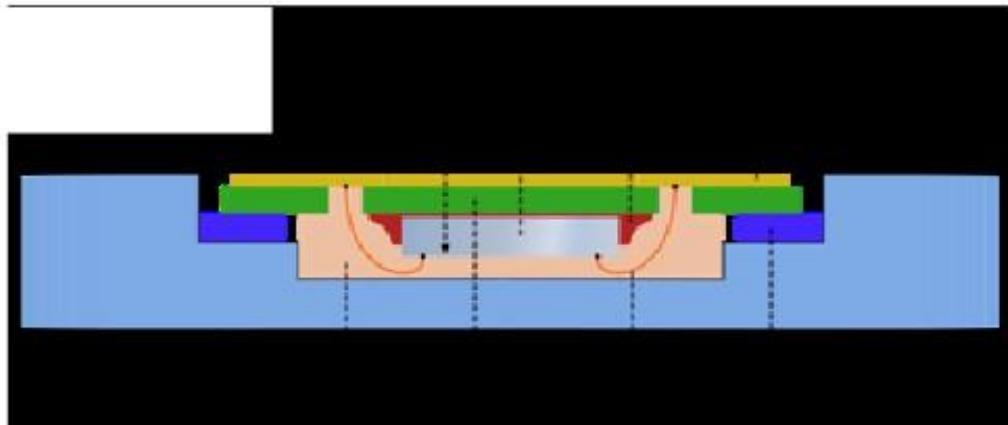
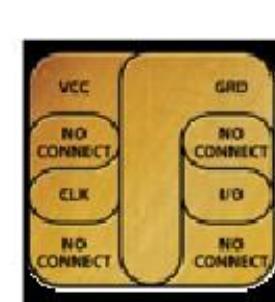
MCC + MNC + MSIN

Mobile Country Code + Mobile Network Code

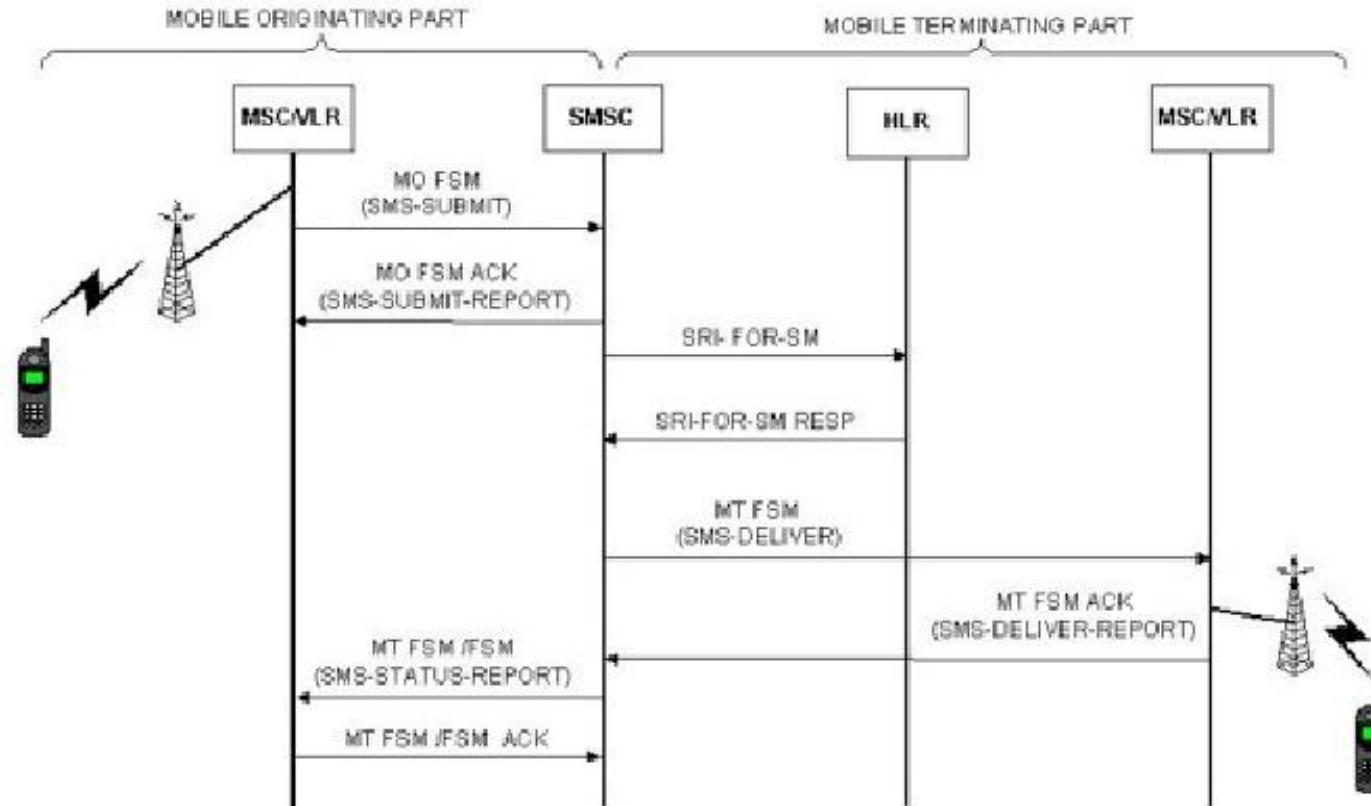
+ Mobile Subscriber Id Number

International Mobile Equipment

Identifier (**IMEI**) - a number stored on the hardware devices describing it - unique to each phone - like a serial number



OTHER NETWORK COMPONENTS



OPEN SOURCE BTSs

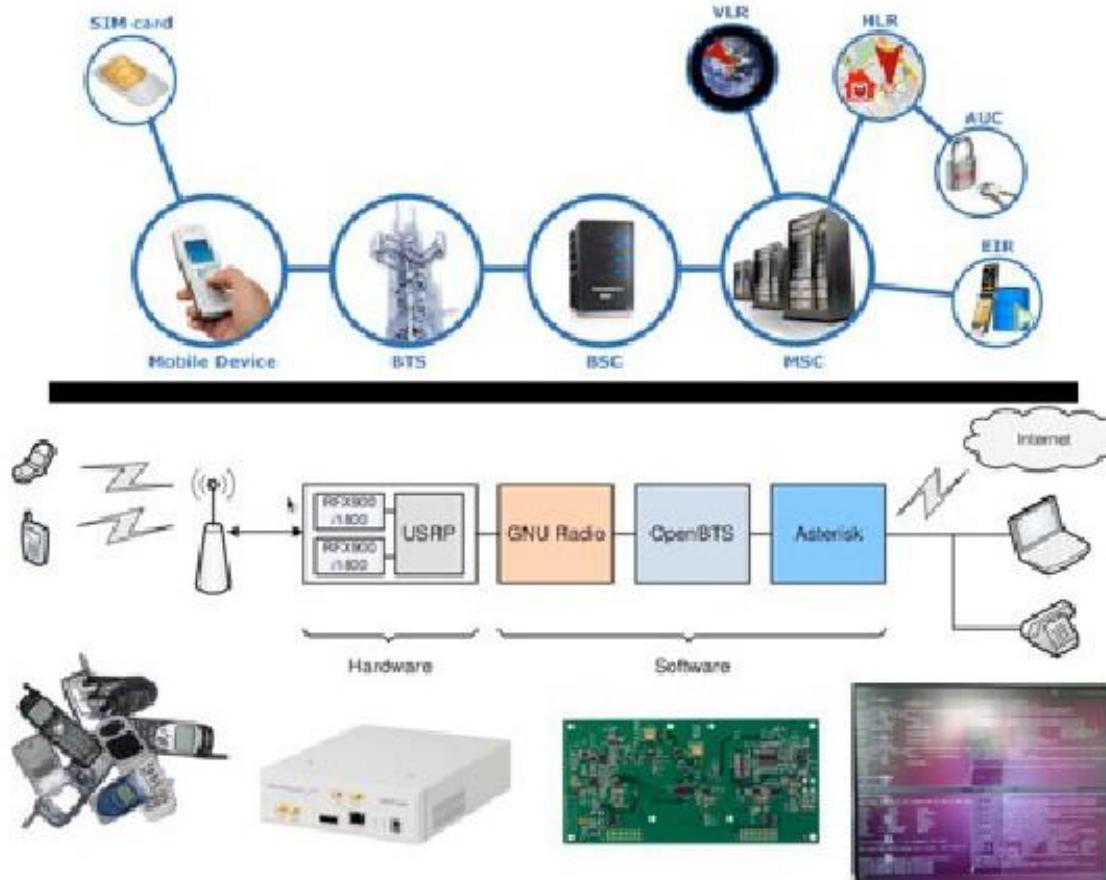
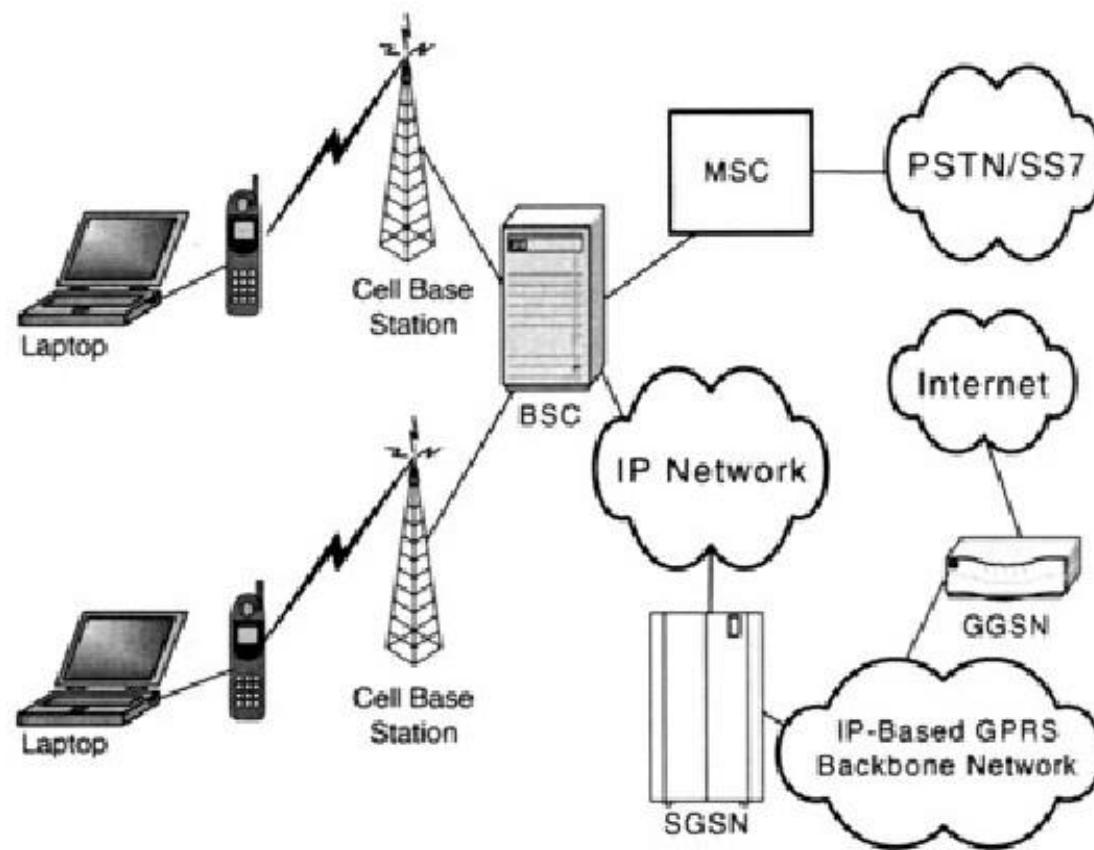


Figure 16-3
Basic GPRS
network
architecture



From Wireless Crash Course by Paul Bedell

Terminal Workshop

https://docs.google.com/presentation/d/1vC4GRdBTTGGHK3SpnnhADtaiHsZ4400bR32sulqZbREQ/edit#slide=id.g34324c9b55_0_174



(Virtual Private Network)

Public IP
186.245.124.111



Cloud Server

Public IP
186.245.124.111



Cloud Server

VPN Server
10.99.0.1

Public IP
186.245.124.111



Cloud Server

VPN Server
10.99.0.1



BSC1

Public IP
186.245.124.111



Cloud Server

VPN Server
10.99.0.1



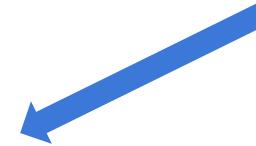
BSC1
VPN Client
10.99.0.2

Public IP
186.245.124.111



Cloud Server

VPN Server
10.99.0.1



BSC1
VPN Client
10.99.0.2

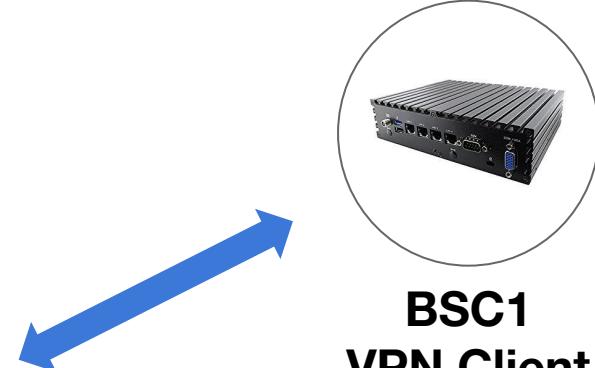


Public IP
186.245.124.111



Cloud Server

VPN Server
10.99.0.1



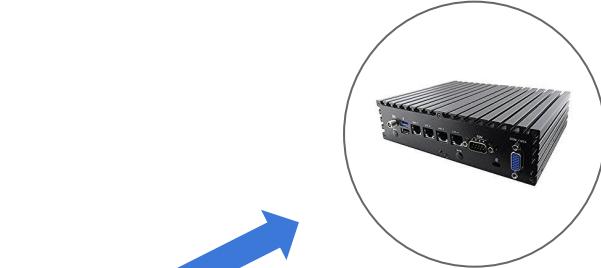
BSC1
VPN Client
10.99.0.2



Public IP
186.245.124.111



Cloud Server
VPN Server
10.99.0.1



BSC1
VPN Client
10.99.0.2