# Microsoft Airband Initiative

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Microsoft

# Outline – 45 Minutes

- Microsoft Mission
- Microsoft Airband Initiative
- Major Challenges & Opportunities for Impact
- Microsoft Airband Initiative Overview
- Partner Selection Criteria
- TV White Spaces Overview
- Examples

**Microsoft Mission**

Empower every person and every organization on the planet to achieve more.

Satya Nadella

# Major Challenges & Opportunities for Impact

## Internet Access

49% of the world is offline.

## Energy Access

1.3 billion people worldwide lack access to electricity.









**People without access to the internet and power simply won't take part in the digital economy.**

Source: ITU, 2016; World Bank, 2016

# Microsoft Airband Initiative Overview

***Mission***

Our partnership-based model delivers products, solutions, and business models designed to enable billions more customers to affordably get online and access online applications and services.

## Objectives

Develop a pipeline of new partnerships and projects to **incubate new approaches**

Commercialize, grow, and **scale existing engagements**

Develop **affordable Internet** access, **energy access**, and other enabling ecosystems

## Areas of Focus

Internet Access

Energy Access

## How

**Commercial Partnerships**

- International
- Rural America
- Hardware innovation

**Grant Fund**

- Annual grant awards primarily in Africa

**Focus on Key Enabling Verticals**

- Education
- Healthcare
- Agriculture

# Airband USA: 12 projects, 12 states, 12 months

**Challenge:**

- 34 million Americans lack access to broadband
- 23.4 million live in rural America
- 39% of rural America lacks access to broadband

**Goal:**

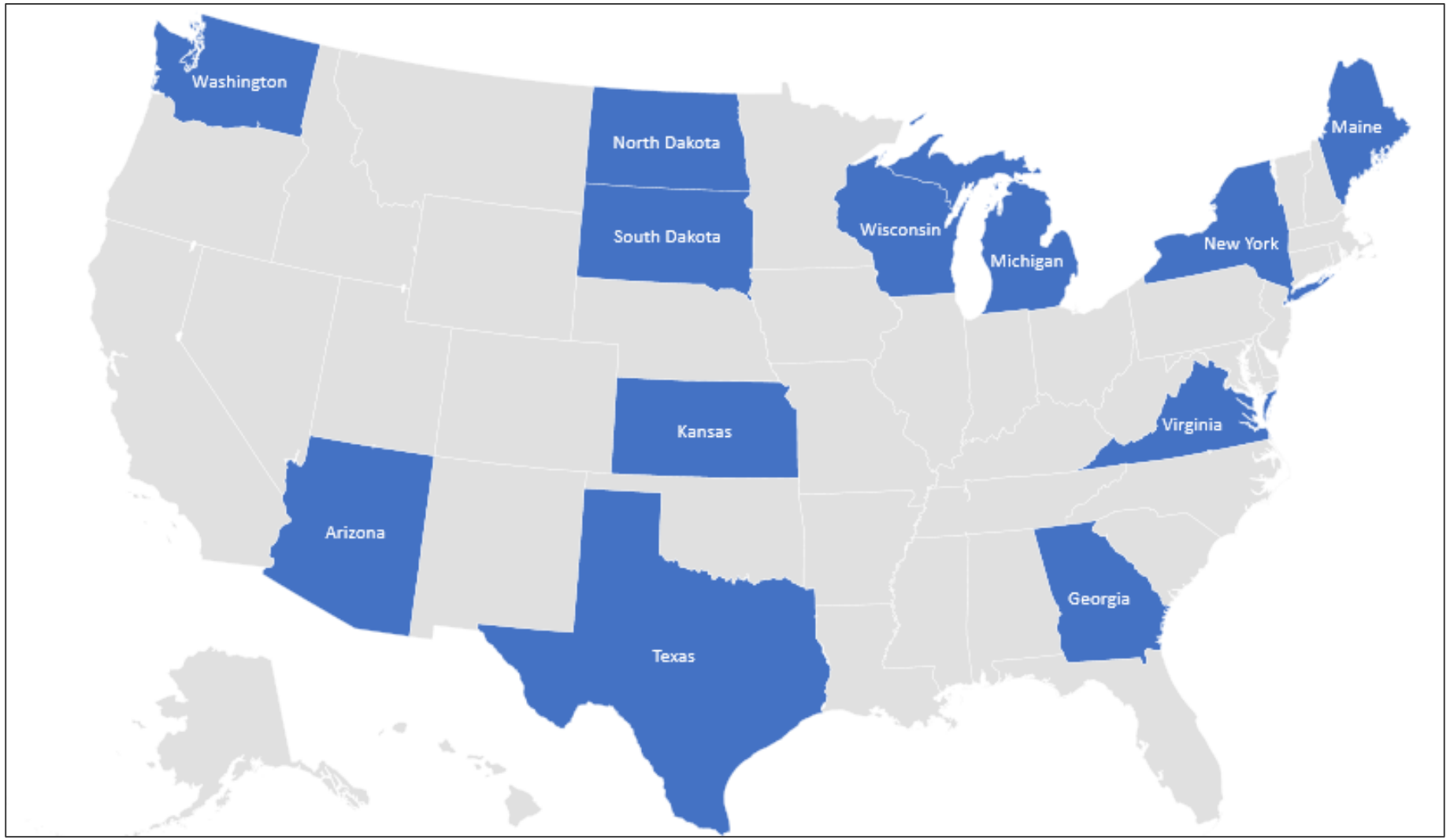
- Microsoft will invest in projects, partnerships, and programs to cover **2 million Rural Americans by July 4, 2022.**
- Close Rural America's digital divide

**How:**

- Direct projects with ISPs to bring broadband coverage to 2 million people over 5 years, including **12 projects in 12 states over the next 12 months**
- New partnerships to help deliver **digital skills training and cloud utilization**, including a new multi-year/multi-million **partnership with 4-H**
- Stimulate investments by other private-public organizations by providing **royalty-free access to 39+ TV White Spaces patents and sample source code**
- **Encourage the FCC** to ensure spectrum access in all markets; a minimum of three unique TV channels per market; 18MHz
- Influence **public sector funds-matching grants and loans for network operators**
- Improve **data collection** about rural broadband coverage

TV white spaces will provide the best approach to reach the majority of hard-to-reach rural populations.

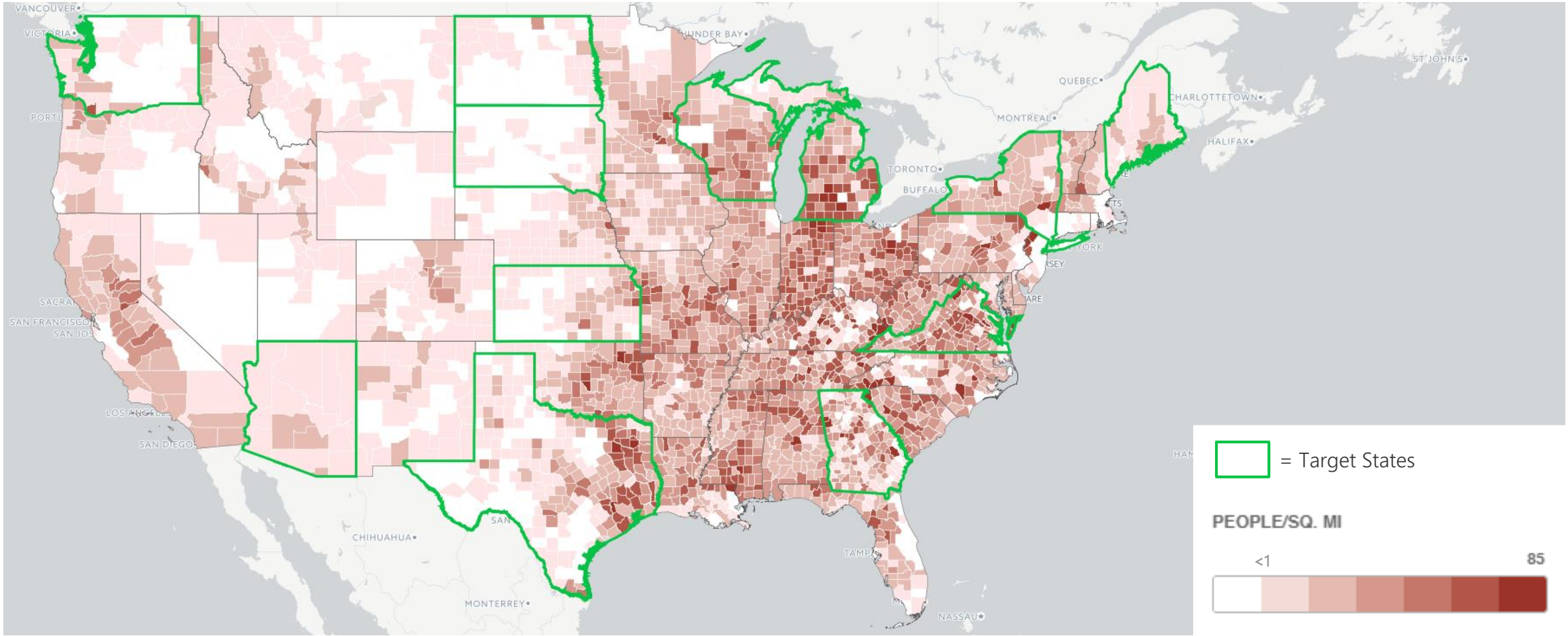
# Airband Initiative Target States



# Rural population without broadband by U.S. county

Where are the largest concentrations of people without broadband coverage, in target states and beyond?

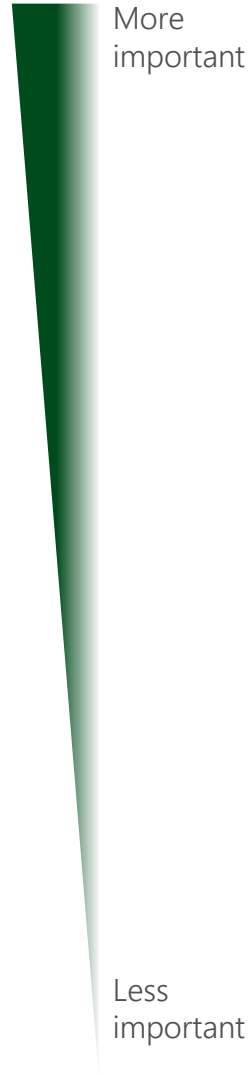
## Density of population without broadband coverage (people/mi$^2$)




Source: FCC 2016 Broadband Report – Appendix E

# Partner selection criteria along five key dimensions

| | |
|---|---|
| **Strategic fit** | ▪ Commitment to objectives & mission of Airband Initiative (e.g., demonstrated by past and current projects)<br>▪ Aspiration for growth in general, and through involvement in Airband-type projects specifically<br>▪ Access to key influencers, potential investment partners, and other key stakeholders<br>▪ Cultural fit on leadership and execution team level<br>▪ No reputational risk (e.g., questionable business practices, lobbying efforts counter to Airband goals, etc.) |
| **Execution capability** | ▪ Operates in target geographic areas, ideally in multiple States<br>▪ Current footprint: Has sufficient scale and market share to suggest successful execution<br>  • # of MAUs of partner's broadband customers in coverage area incl. market share<br>  • # of people in coverage area without broadband access<br>▪ Extent of existing infrastructure, e.g., networks / base stations, telco customer operations, etc.<br>▪ Size and scale of organization / team in general and dedicated against the joint project specifically<br>▪ Leadership team's management skills in general<br>▪ Leadership team's expertise in TVWS or other affordable access projects specifically<br>▪ Strength of relationship with customer base (e.g., churn, subscribers over time, available data)<br>▪ Typical time-to-market of projects of similar difficulty |
| **Technological fit** | ▪ Alignment of partner's tech infrastructure and IP with Microsoft's vision<br>▪ Partner can provide access to valuable third-party technology solutions |
| **Financial health** | ▪ Health of partner's business (5-year revenue CAGR, EBITDA margin, Debt/EBITDA ratio)<br>▪ Partner's continued independence (e.g., are there current M&A talks?) and subsequent commitment to affordable access initiatives |
| **Business potential** | ▪ Partner's revenue and product potential with Microsoft (e.g., partner is or can become Azure platform customer) |



# One solution in the internet connectivity toolkit – TV White Spaces

## What is TV white space?

- Unused spectrum such as traditional UHF and VHF broadcast spectrum
- Regulators allow wireless access devices to transmit on these unoccupied channels as long as they do not interfere with TV broadcasters and other licensed users.

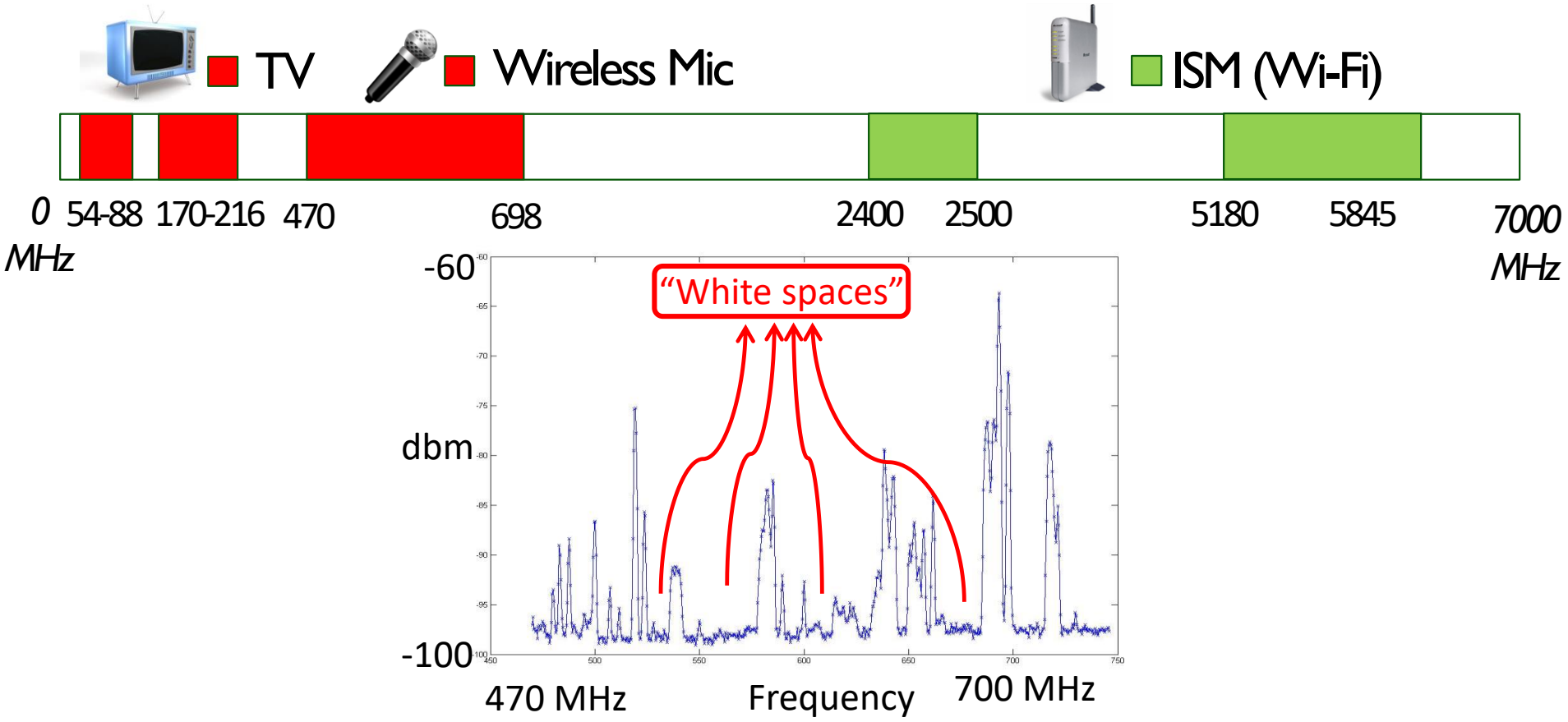
## Who does it benefit?

| | | |
|---|---|---|
| Seniors | Librarians | Families |
| Teachers | Students | Business Owners |
| Executives | Farmers | Entrepreneurs |

## How does it work?

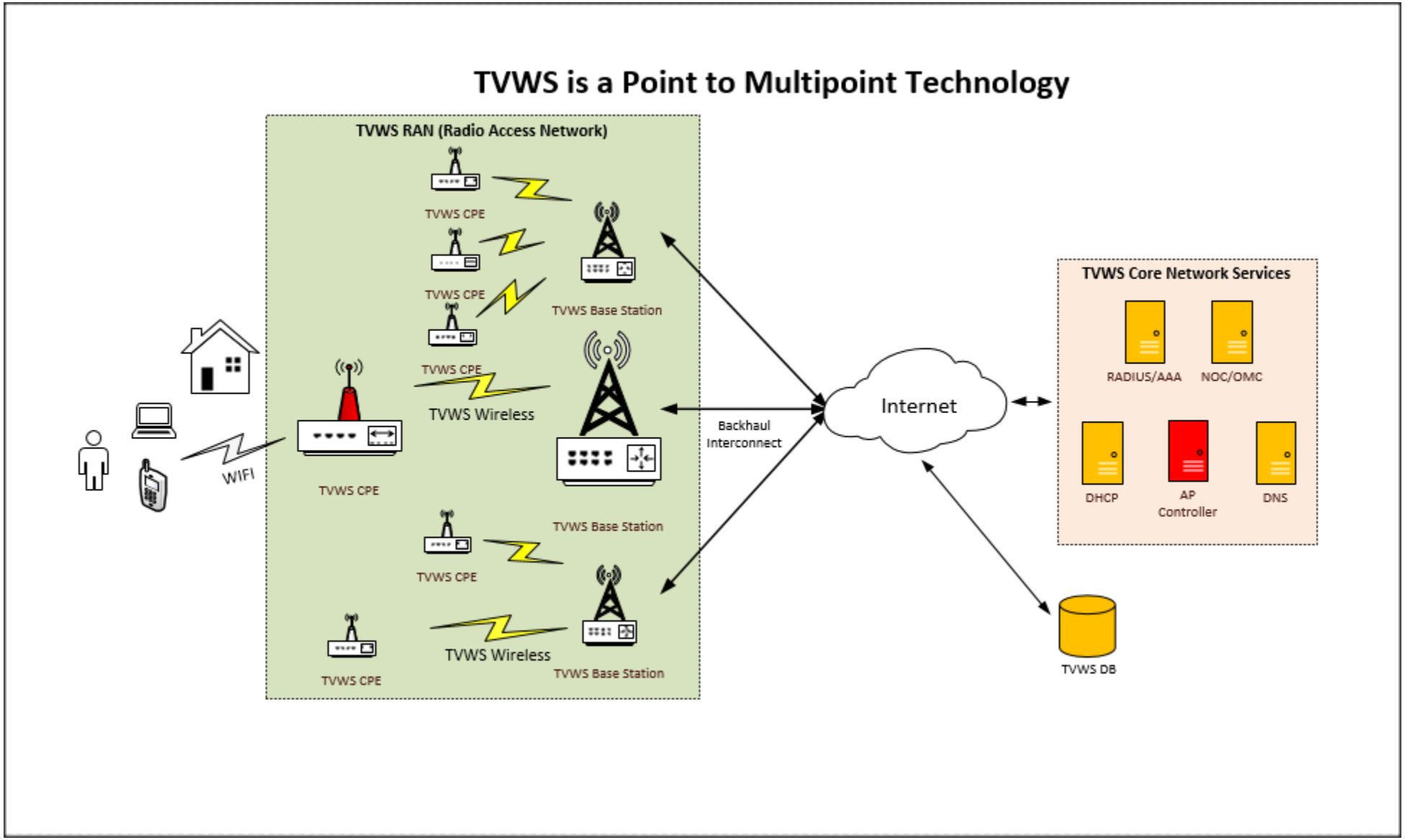
- Network operators can cost-effectively deploy wireless networks that deliver fast, reliable, and affordable Internet access in rural and underserved communities
- Leverage schools, libraries, or other anchor institutions with high-capacity connections to extend broadband solutions
- TVWS signals can travel over long distances, and penetrate natural and man-made obstacles to cover entire rural communities
- TVWS signals penetrate through more walls and obstacles, enabling whole home media distribution

# What are TV White Spaces?




White Spaces are *Unoccupied* TV Channels

# TVWS Network Architecture



# Mid-Atlantic Broadband Community – Virginia

Internet Access Project

## America's Homework Gap

- 5M American households with school-age children lack internet access at home
- 50% of students lack broadband access in Charlotte & Halifax counties
- Students unable to access the tools they need to succeed in today's workforce

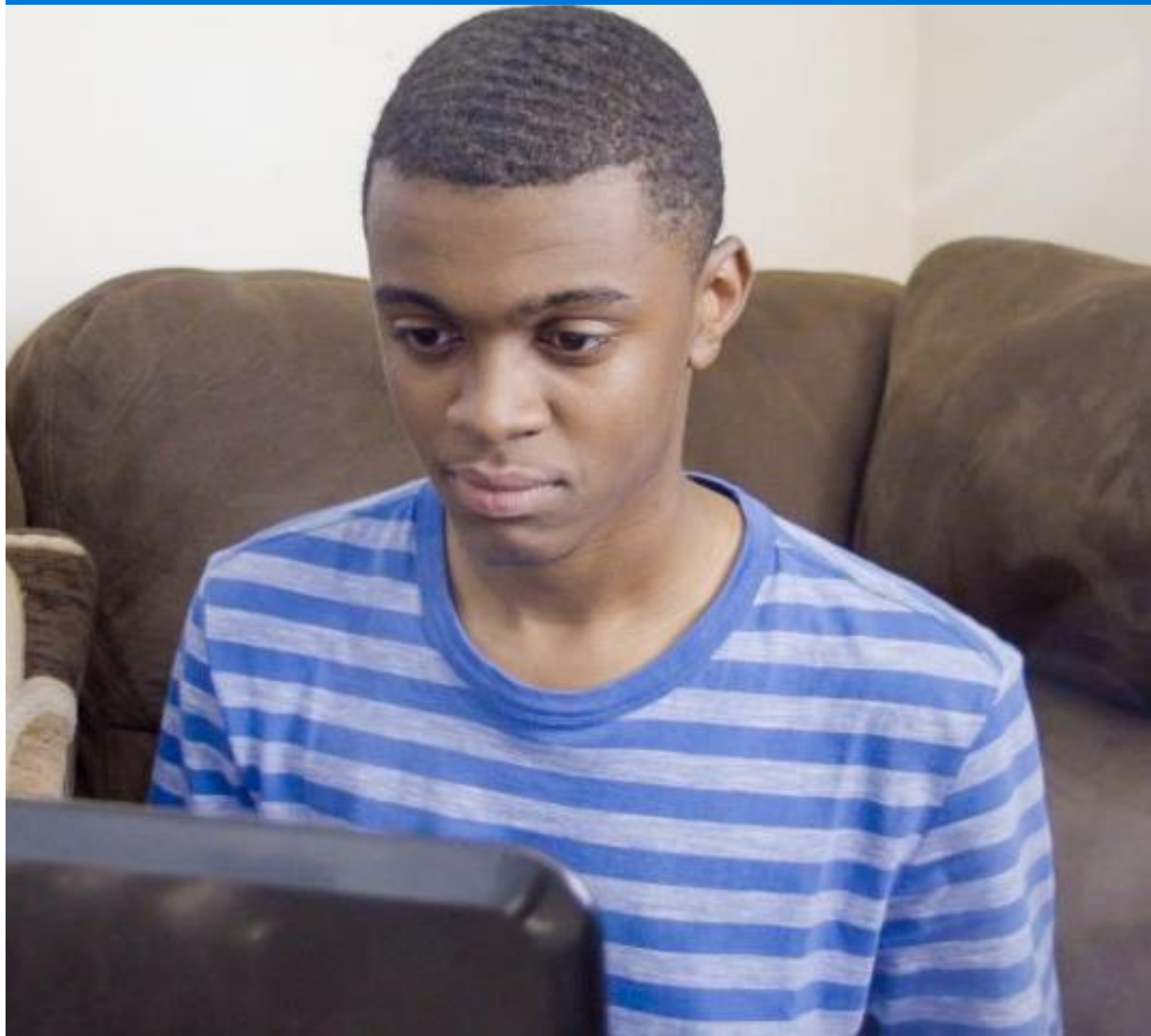
## Multi-Stakeholder Approach

- Partners: Microsoft, MBC, Adaptrum, B2X & Virginia Tobacco Region Revitalization Commission
- Solution: extended broadband connection from schools to community homes via TVWS technology

## Results

- 100 households connected
- 1,000 households to be connected by yearend

Read more



# Mawingu – Kenya

Internet Access Project

## Africa's Digital Divide

- Digital transformation of Mawingu Networks
- Connect Kenya's unconnected

## Solution

- Partners: Microsoft & Mawingu
- Solar-powered TVWS connectivity in rural Kenya.
- Nomadic Wi-Fi coverage at local shops, schools & healthcare clinics.

## Results

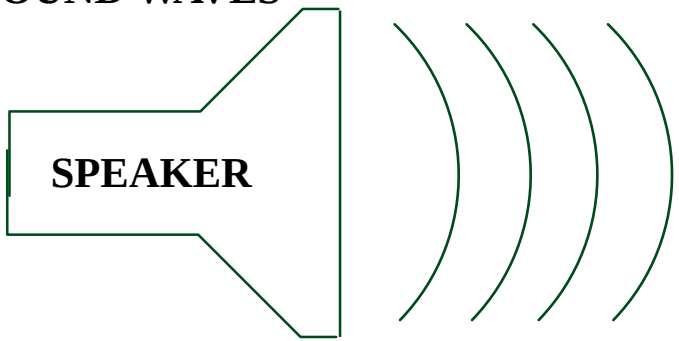
- 300K population under coverage
- 21K+ MAU
- ~20% monthly growth rate
- 519 hotspots
- 510 fixed line connections
- 23 connected schools
- Azure / Dynamics implementations

Read more


Technical Overview
Microsoft

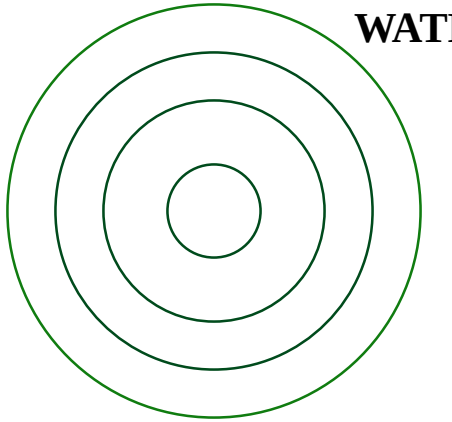
# TYPES OF WAVES IN NATURE

**SOUND WAVES**

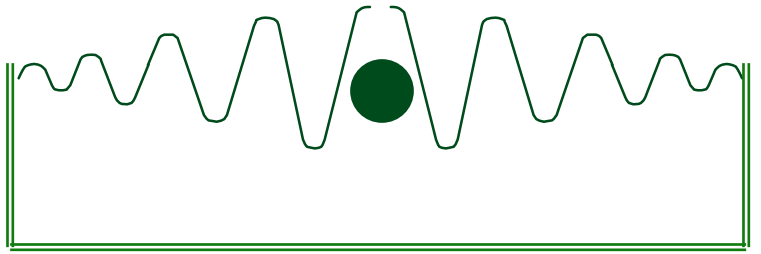



**SOUND PRESSURE IN AIR DUE TO SPEAKER**

**WATER WAVES**

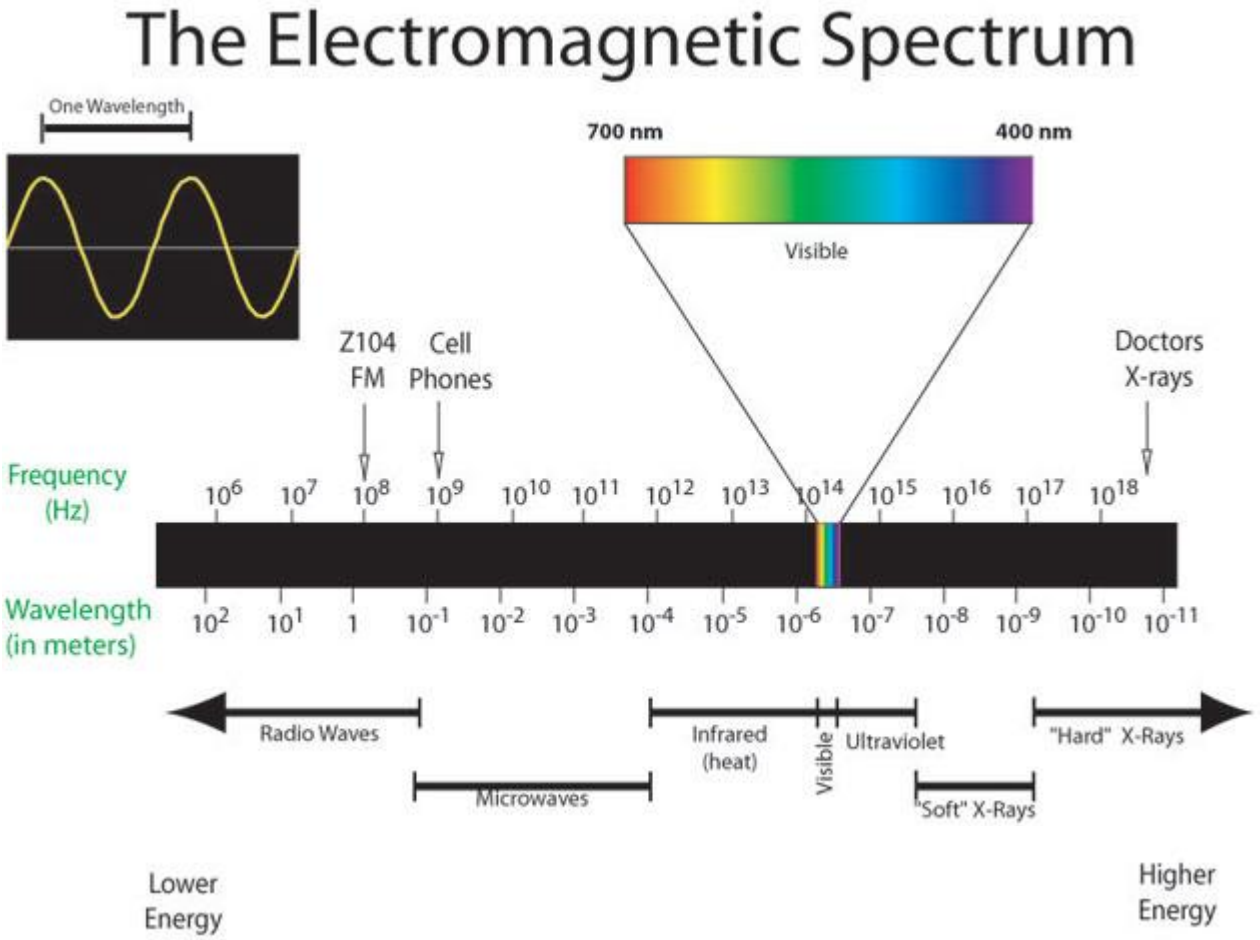


**TOP VIEW OF WATER DISH**



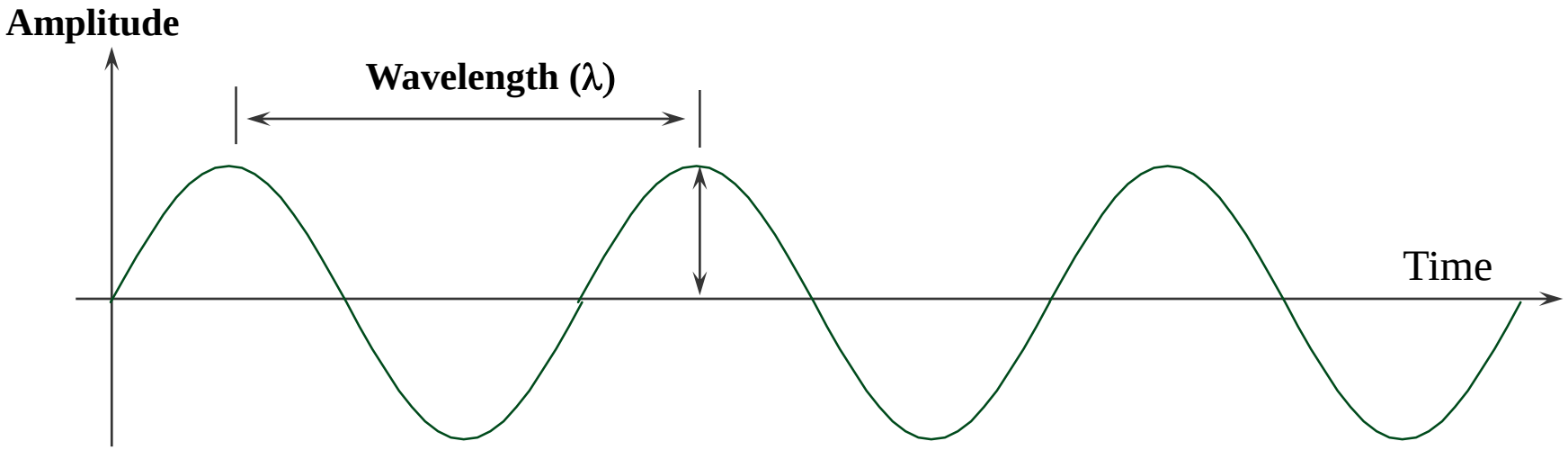
**SIDE VIEW OF WATER DISH**

# What is Spectrum?




- A natural resource of our environment like air, oil or coal
- The *electromagnetic spectrum* is the distribution of electromagnetic radiation according to energy (or equivalently, according to frequency or wavelength)
- Think about the selection of channels on the radio dial (or digital display) on your car radio

# Radio Waves



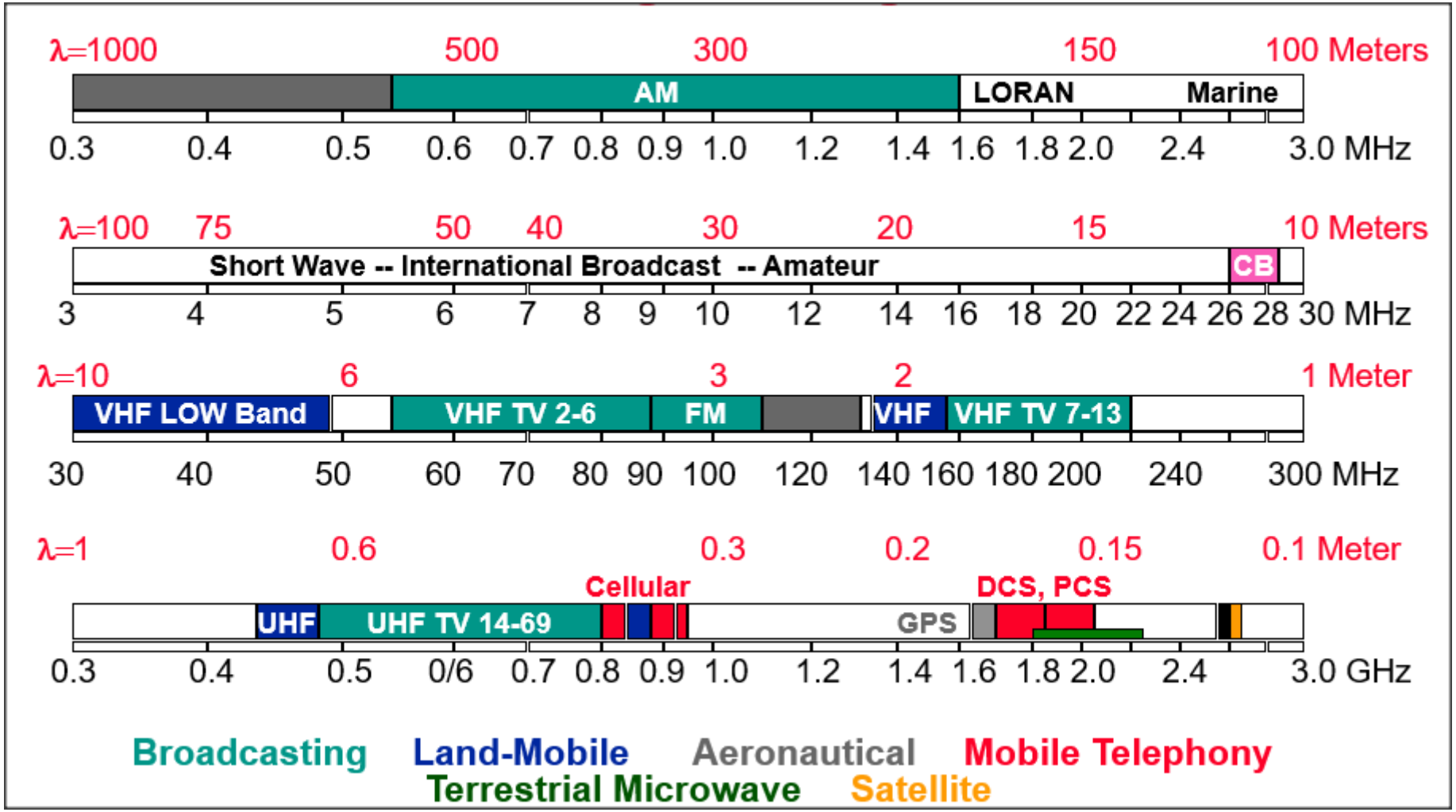

Frequency (F) is the number of cycles that occur in 1 second.

The unit of frequency is Hertz (Hz); 1 Hertz equals 1 cycle per second.

- Radio signals travel through empty space/vacuum at the **speed of light (C)**
  - **C** = 186,000 miles/second (300,000,000 meters/second)
- **Frequency (F)** is the number of waves per second (unit: Hertz)
- **Wavelength** (λ) (length of one wave) is calculated:
  - (speed of light) **/**(waves in one second)

$$\lambda = C / F$$

# Spectrum Bands and Usage



# Basic Concept of Telecom Network


**Transmission facilities**

- Twisted pair
- Coaxial cable
- Microwave
- Satellite
- Fiber optics
- Wireless

**Signaling**

- Analog
- Digital

**Switching**

- Circuit switching
- Packet switching

# Channels

**Channel: An individually-assigned and dedicated pathway transmitting one user's information over the transmission medium.**

- The physical transmission medium is a resource that can be subdivided into individual channels according to the various technologies used.

## FDMA

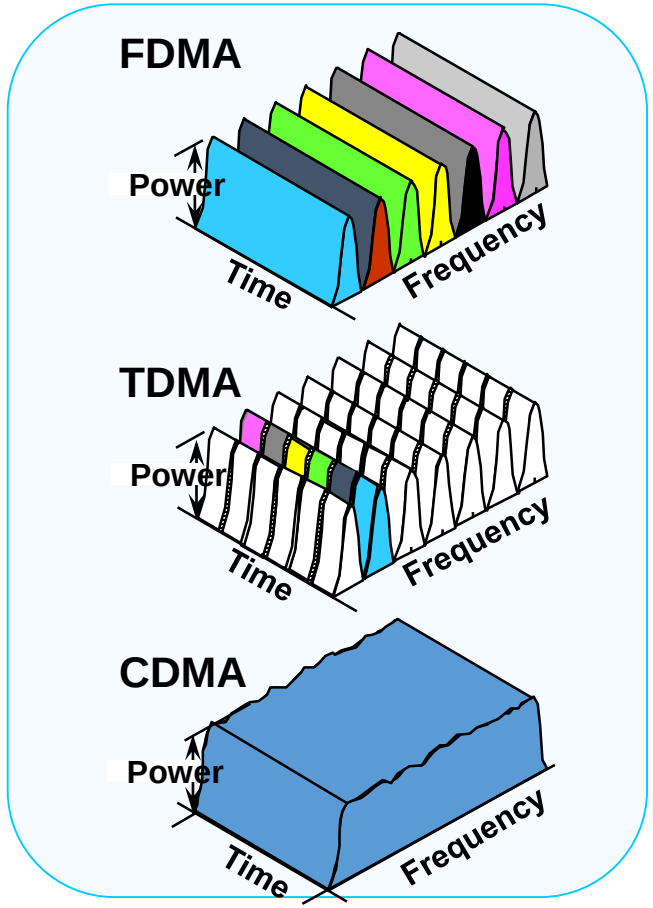
- **Each user uses a different frequency.**
- **One channel is a frequency.**

## TDMA

- **Each user uses a different time slot.**
- **One channel is a specified time slot of a specified frequency.**

## CDMA

- **Each channel is a unique code sequence.**
- **Each user uses the same frequency and coordinates a different code sequence.**



# Multiple Access Technology

**Multiple Access Technology: Multiple independent users simultaneously use the transmission medium without any mutual influence.**

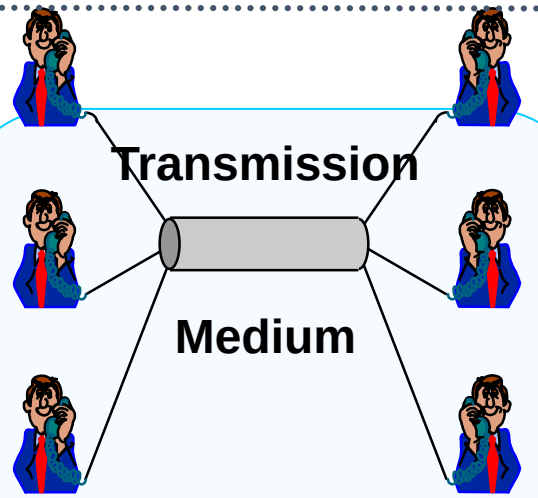
- Since the invention of telephone and radio, system operators have tried to transmit the maximum of traffic over each circuit.

**The types of transmission medium are as follows:**

- **Twisted pair**
- **Coaxial cable**
- **Optical cable**
- **Air interface (radio signal).**

**The advantages of using the multiple access technology are as follows:**

- **Increases the system capacity to provide services for more users.**
- **Reduces the system cost because of the lessening transmission mediums as required.**
- **Decreases the user's charge.**




- **Each pair of users enjoy a dedicated and private circuit through the transmission medium, unaware that the other users exist.**


What are TV white spaces?
Microsoft

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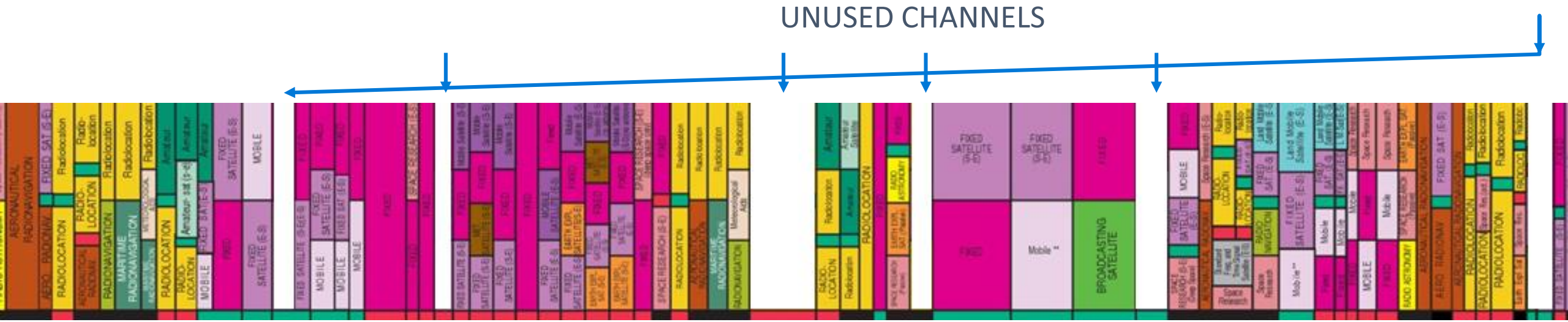
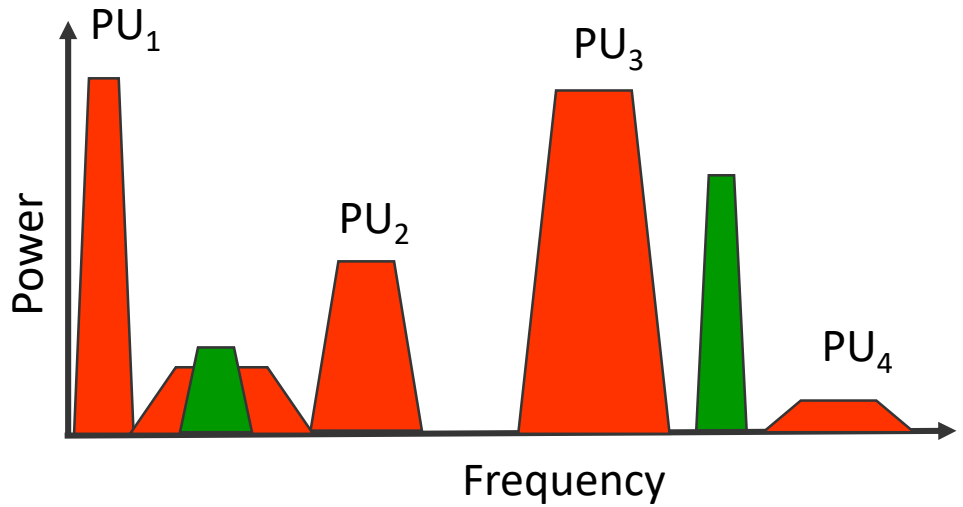
# What are TV White Spaces? (2/2)




- TV band white spaces are gaps left between broadcast channels.
- Unused channels occur in different places in the electromagnetic spectrum based on geographical location and time of day.
- 470 MHz to 698 MHz in ultra high frequency (UHF) band (White spaces also occur in VHF band)
- 6 MHz or 8 MHz channel bandwidth, depending on region of the world
- Channels are used on a secondary basis and cannot cause interference to primary users

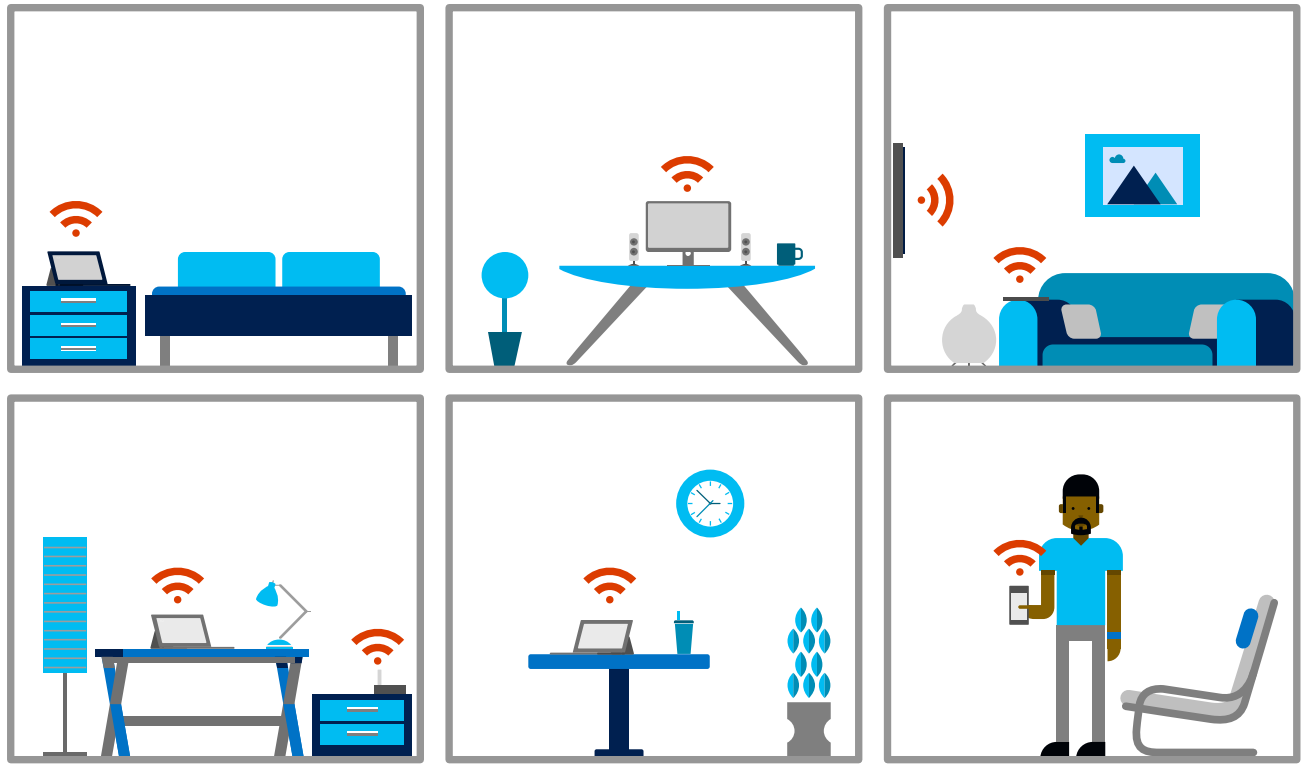
# Dynamic Spectrum Access (DSA)




- **Determine** available spectrum (**white spaces**)
- **Transmit** in "available frequencies"
- **Detect** if primary user appears
- **Move** to new frequencies
- **Adapt** bandwidth and power levels


# White Spaces transmissions travel farther

# Why use TV white space technology

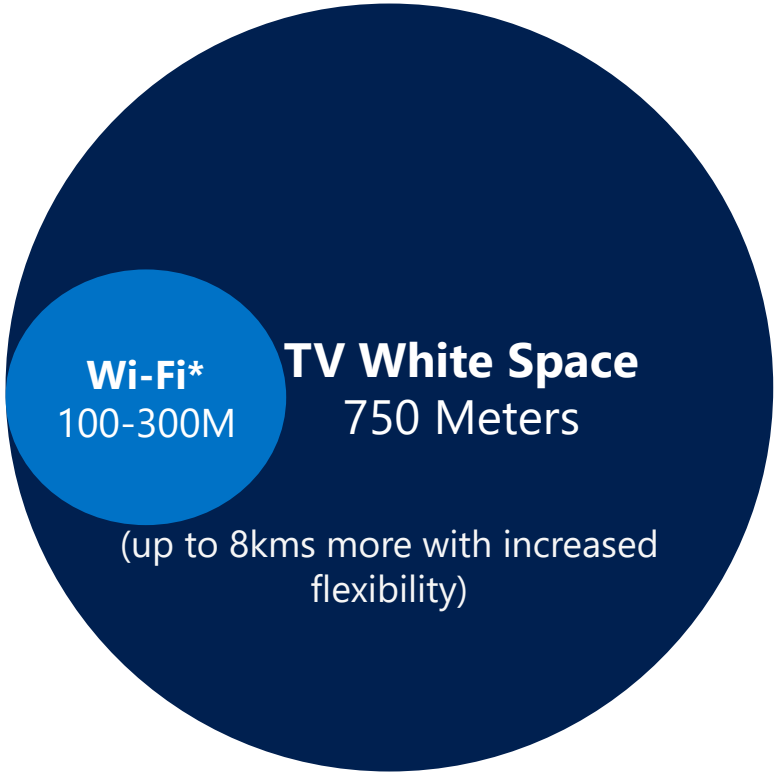


In a typical home, a Wi-Fi signal can penetrate **up to 2 walls**.

A **TV white spaces signal** can penetrate through more walls and obstacles, enabling whole home media distribution.

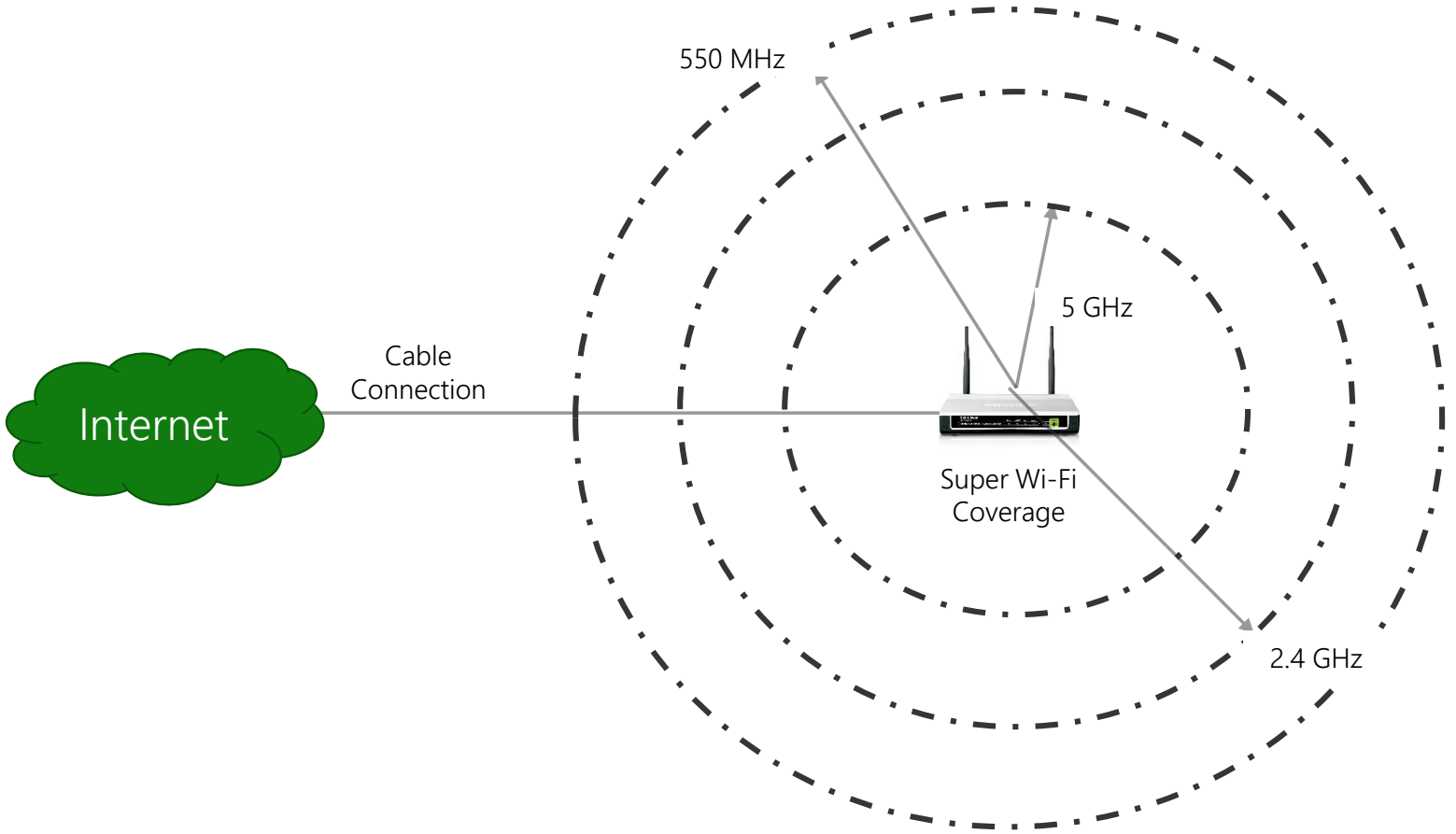
This will **simplify and enrich** in-home/in-building networking opportunities

**Range in meters:**



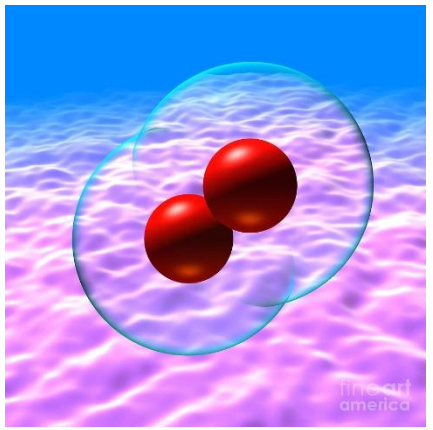

**4X the distance, 16X the area covered.** Same power comparing 2.4GHz to 600 MHz. The result is **more coverage**, **lower network costs**, and **lower power consumption**

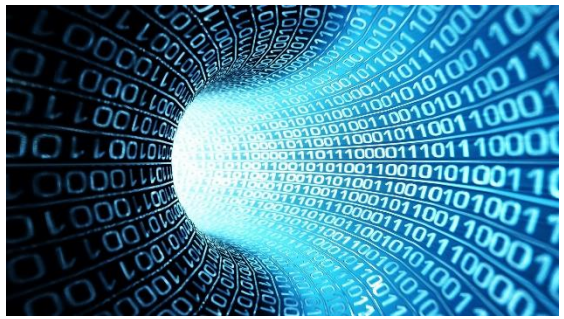
# Multi-Technology/Triple Band Access Point – TVWS and WiFi

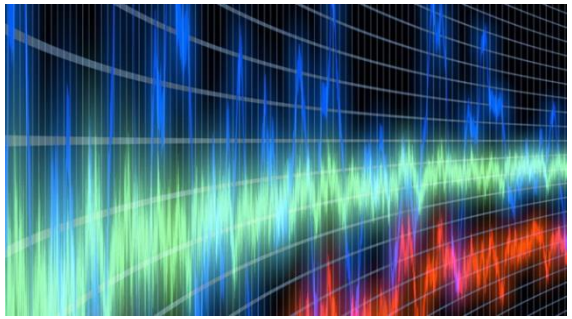



Why should we care?
Microsoft

# Transition to a Digital Economy



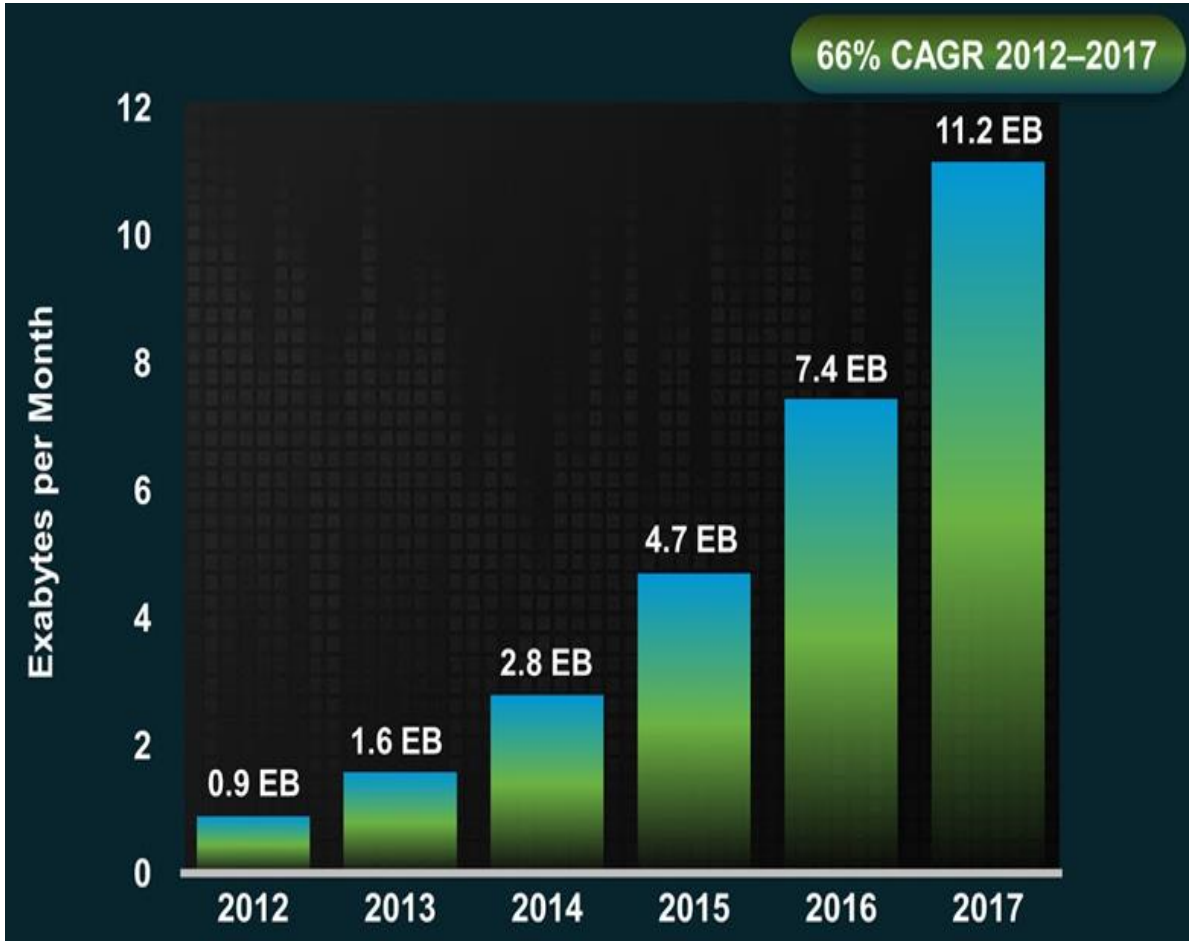

**Broadband** is the new Highway

**Data** is the new Currency

**Spectrum** is the new Fuel…

… and the new Oxygen

# Skyrocketing Wireless Data Demand




Source: Cisco VNI Global Mobile Data Traffic Forecast, 2012-2017

petabytes millionterabytes

billiongigabytes

# More Connected Objects than People …

The internet of things

50 billion by 2020

# % of data offloading to Wi-Fi from Smart Phones

**51%** Singapore

**63%** United States

**68%** Hong Kong

**82%** Spain


Network Architecture
Microsoft

# TVWS Radio Characteristics (1/2)

- Low cost point to multipoint last mile technology
- Power over Ethernet (PoE)
- Time Division Duplex (TDD) channels
- TX Power: *100mW* to antenna port; high power radios available
- EIRP limited to 36dBm or 4W by FCC; 10W in certain conditions
- Low power consumption (< 20W per radio for outdoor units; 8W for indoor unit); solar powered systems work great!
- Low latency
- Maximum of 14 Mbps per 6 MHz carrier UDP
- Maximum of 25 Mbps per 8 MHz carrier UDP

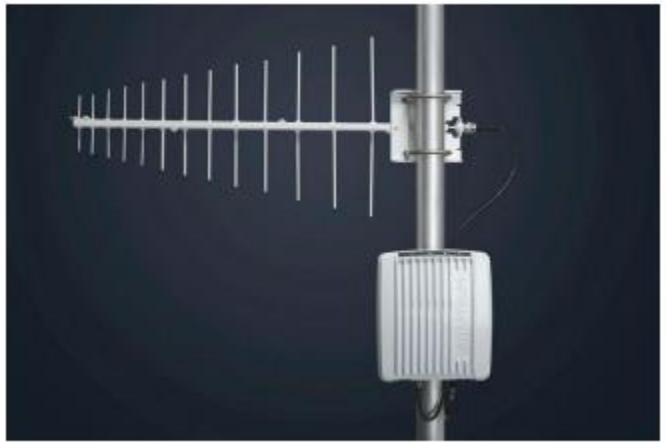
# TVWS Radio Characteristics (2/2)

- Noise floor scanning
- Radios mount externally behind antenna
- Protocols:
  - Adaptrum is based on 802.22
  - 6Harmonics is based on down banded 802.11n
- QPSK ½ to 64 QAM modulation
- Link range is terrain and antenna height dependent
- TVWS Database interaction via IETF PAWS protocol
- FCC / Ofcom certified devices
- Mobility with Handover
- Integrated WiFi coming
- Killer applications:  long distance last mile access and triple band APs

# TVWS Standardization – IEEE 802.11af

- 802.11af
  - Very 802.11ac-like, orthogonal frequency division multiplexing (OFDM)
  - Higher level modulation: up to MCS9 256-QAM 5/6
  - Channel bonding
  - Multiple input multiple output (MIMO) antennas (in time)
  - Advanced radio features
  - ASICs under development
  - Interoperability
  - Lower and lower cost and better performance

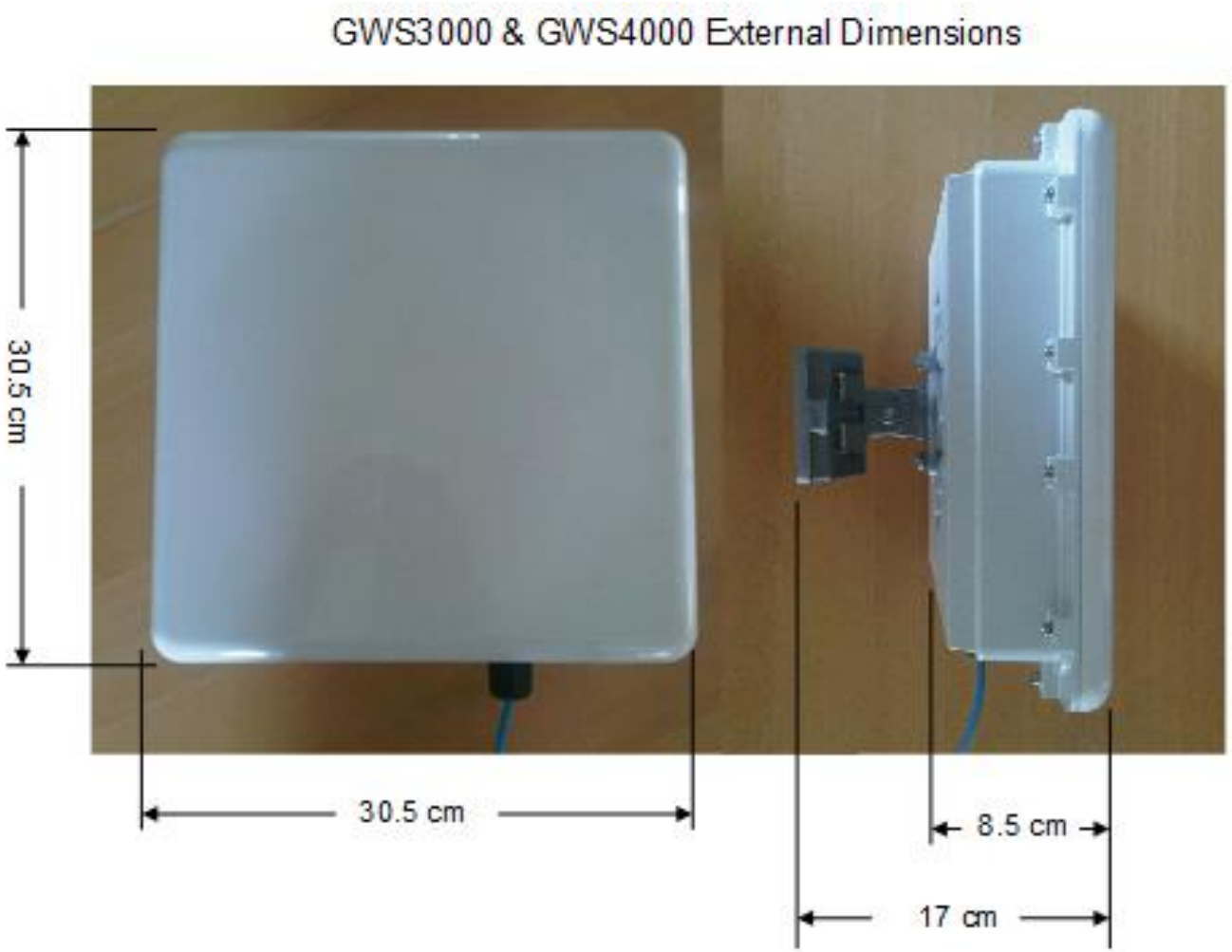
# Adaptrum Basestation (BS) or Customer Premise Equipment (CPE) Radios



Dimensions (inches): 8.5 x 7.5 x 1.5

Weight: 3.6 LB

# 6Harmonics Basestation (BS) or Customer Premise Equipment (CPE) Radios




# Redline Basestation (BS) Radio

## ELLIPSE BASE STATION

| Model | Ellipse XP |
|---|---|
| Technology | OFDM + 2x2 MIMO + TDD |
| Hardware | FPGA |
| Frequencies | 4.9 – 5.8 GHz , 3.3 – 3.8 GHz , 2.3 – 2.7 GHz , 2.0 – 2.3 GHz<br>470 – 698 MHz (SP & HP) |
| Modulation & Coding | 256QAM7/8, 256QAM5/6, 256QAM3/4, 256QAM2/3<br>64QAM3/4 , 64QAM2/3, 16QAM3/4, 16QAM1/2, QPSK3/4, QPSK1/2, BPSK1/2 |
| Combined Transmit Power<br>(model & regulatory dependent) | 2x +25 dBm/+26 dBm/+31 dBm<br>UHP 2x +38.5 dBm |
| Data Capacity/Sector | 186.6 Mbps UBR (20 MHz, C/P1/8) (9.3 b/s/Hz) |
| Channels | 0.875, 1.25, 1.75, 2.5, 3.5, 5, 6, 7, 10, 12, 14, 20 MHz |
| Processing Power | >280,000 PPS |
| Ethernet Interfaces | Ethernet 10/100 BaseT<br>802.3at Type 2 Class 4 |
| Power | PoE Accepts Either ALT A (1/2 & 3/6) or B (4/5 & 7/8)<br>36-57 VDC Input , <17W |
| GPS Receiver | Internal – Location and Sync |
| Connectors | RJ45 PoE ; 2 x N-(f) ; 1 x TNC-(f) |
| Environmental | -40 - +75C, IP67<br>High Tx power units and UHF rated to +60C |
| Size and Weight | 2.7 Kg – 6 lbs. |


# Carlson Product

## Gen3 Equipment

- IEEE 802.11af, FCC compliant
- 21 dBm, TVHT6
- Aggregate capacity : 72Mbps
- Up to 24Mbps per subscriber
- RJ45 POE connector



BS & CPE Unit : Rev-6-E-4.5

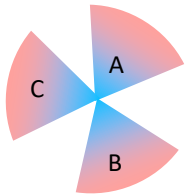
Software : rev X

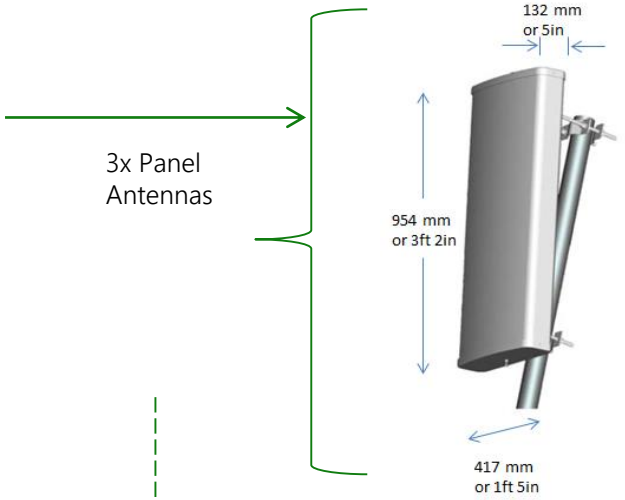
120° sector Base Station antenna

Log-Directional CPE antenna

# Base Station Setup – Default Configuration

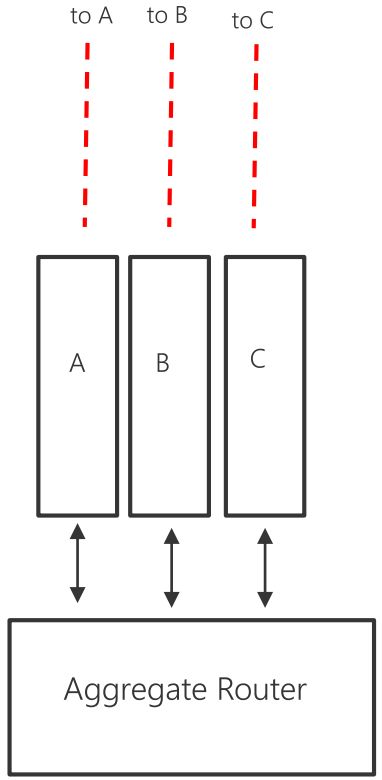
Antenna azimuth and count will be customized per specific site requirements

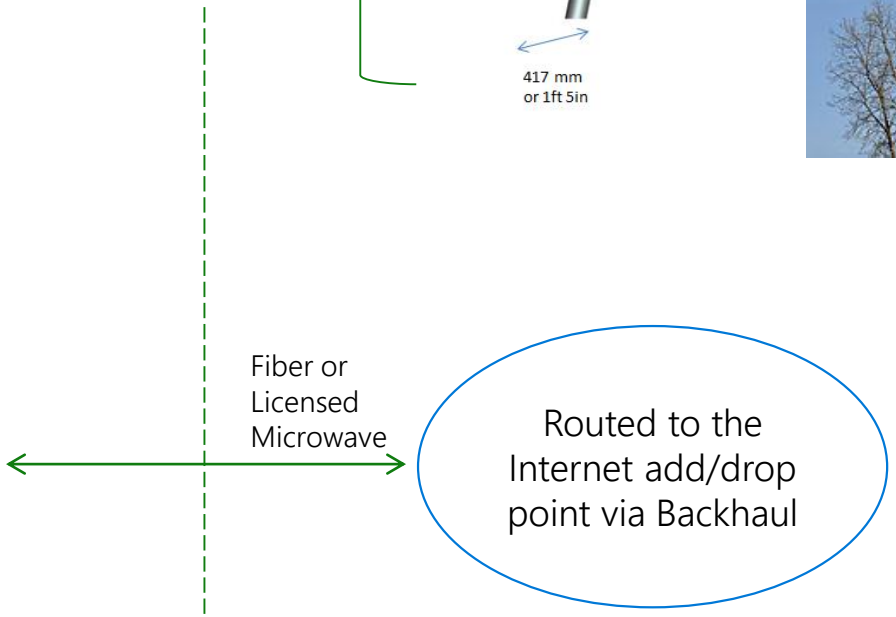



Each Base Station radio operates on a separate UHF (TVWS) Channel

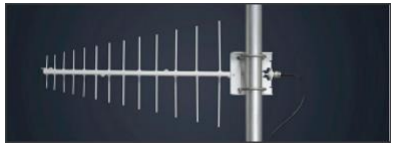
Based on need, 1 to 6 (or 8 in some cases) Base Station Radios can be used for one base station site.



# CPE Setup

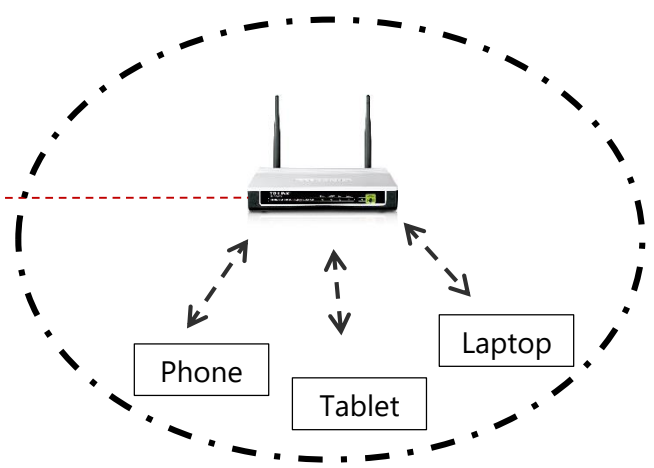
Directional CPE antenna on the building wall/rooftop



5-ft. jumper cable:
0.5 inch coax with N-connector

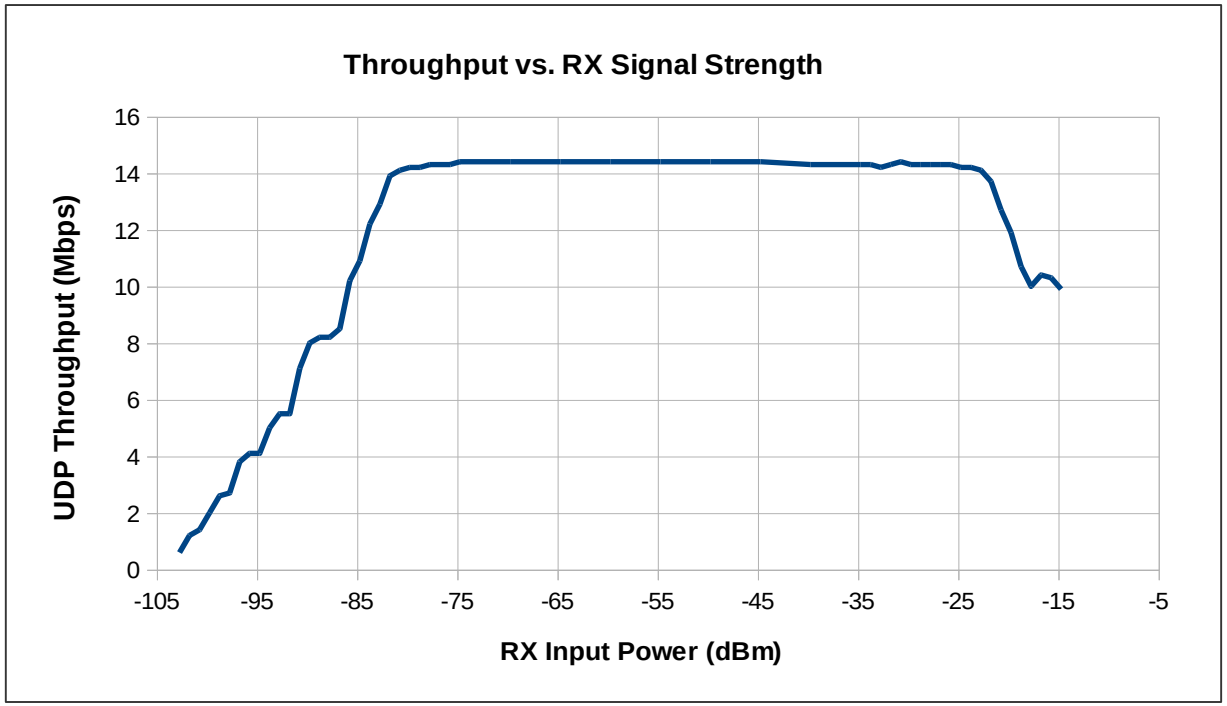
Each CPE operates on one UHF (TVWS) channel or a pair of bonded contiguous channels, as assigned from the channel list provided by the TVWS DB

Cat5/6 Ethernet cable



# CPE Installation

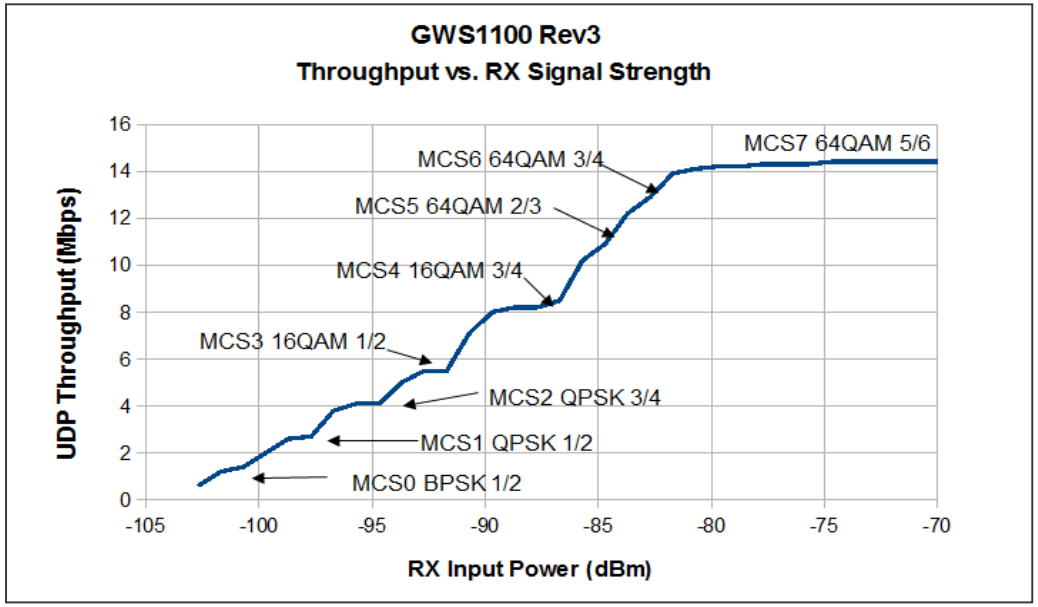
# Throughput vs. RX Signal Strength




Source: 6Harmonics Inc.

- AMC algorithm dynamically adjusts modulation across the full range of received input powers (-15 dBm to -103 dBm)
- MCS7 (64 QAM 5/6) is maintained down to -80 dBm
- Between -80 dBm and -101 dBm modulation gradually reduces from 64QAM 5/6 to BPSK 1/2 (see next page for details).
- Link drops at -102.7 dBm

# Modulation Coding Scheme Chart




Source: 6Harmonics Inc.

| GWS1100 Measured Throughput, 6 Mhz Channel | | | | | | |
|---|---|---|---|---|---|---|
| MCS | Modulation | bits per symbol | UDP Throughput (Mbps) | RX Sensiivity (dBm) | SNR (dB) | PER |
| 7 | 64 QAM 5/6 | 5 | 14.2 | -80 | 23 | 2% |
| 6 | 64 QAM 3/4 | 4.5 | 12.78 | -82.7 | 20.3 | 2% |
| 5 | 64 QAM 2/3 | 4 | 11.36 | -84.7 | 18.3 | 2% |
| 4 | 16 QAM 3/4 | 3 | 8.52 | -86.7 | 16.3 | 2% |
| 3 | 16 QAM 1/2 | 2 | 5.68 | -91.7 | 11.3 | 2% |
| 2 | QPSK 3/4 | 1.5 | 4.26 | -94.7 | 8.3 | 2% |
| 1 | QPSK 1/2 | 1 | 2.84 | -97.7 | 5.3 | 2% |
| 0 | BPSK 1/2 | 0.5 | 1.42 | -100.7 | 2.3 | 2% |

Note: RX Sensitivity depicts the received signal strength to achieve a 2% PER at the MAC, at the selected modulation. Throughput is measured UDP throughput over the radio link.

# Network Design Basics

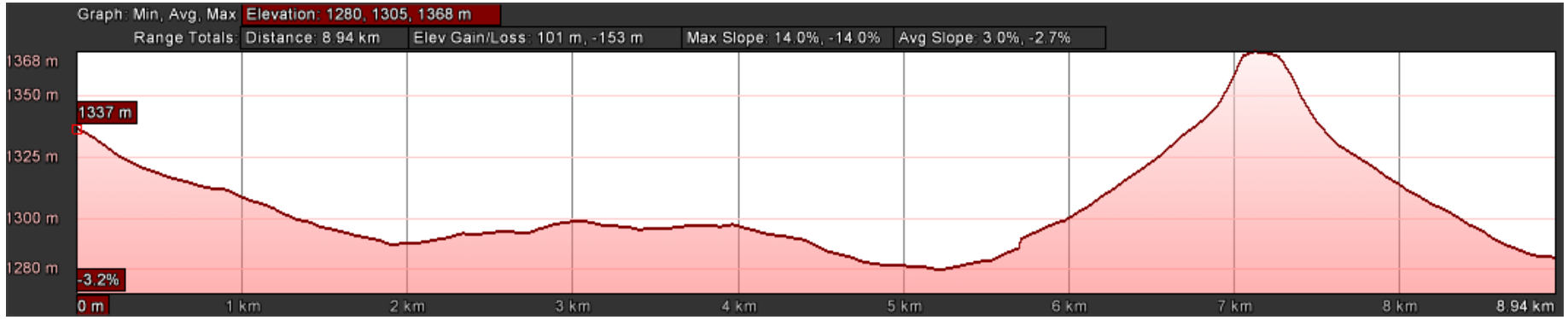
Microsoft

# Information Required to Plan a TVWS Pilot Network

- Written authorization from spectrum regulator to use UHF band.
- Highlight the proposed coverage area on a map (in Google Earth or similar tool).
- The GPS coordinates of the potential TVWS basestation locations, in decimal format. Typically the TVWS basestation antenna and radios will be on a building or tower with close proximity to the intended service area. Please provide the tower or building height.
- The GPS coordinates of the fiber POP(s), in decimal format. And the cost of internet access at the POP. If the pilot network consists of 1 TVWS basestation radio then we need to be able to drain at least 20 Mbps to the internet for maximum performance. If the need is to provide 360 degree coverage, using a 3-sector site configuration, the required backhaul drain would be at least 3x20 = 60 Mbps. (newer radios will have twice the capacity)
- The GPS coordinates of the customer premise equipment (CPE) locations, in decimal format. The CPE is the TVWS device that connects to the Wi-Fi access point. The CPE location would typically be a school, enterprise, clinic or government location where we intend to distribute the Wi-Fi signal so that local devices and computers can connect. Please provide the tower or building height where the CPE will be mounted as to investigate if we'll have line-of-sight (LOS) or non-line of sight (NLOS) link with the TVWS basestation.
- The number of subscribers you intend to serve in the pilot network, including the minimum throughput per subscriber, the number of concurrent subscribers and the over-subscription ratio. If you don't know either of the last three items I can make suggestions.
- Is electricity available at each location proposed tower location?

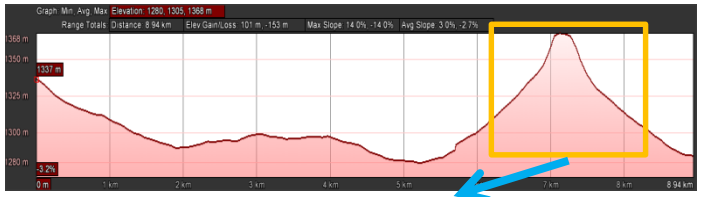
# Google Earth Path Elevation Profile

| | |
|---|---|
| Distance between Base and CPE | 8.94 km |
| Ground elevation at Base (without tower height of 25m) | 1337 m |
| Ground elevation at CPE (without CPE antenna height of 3m) | 1285 m |
| Highest elevation in the path between Base and CPE | 1368 m |




- Terrain profile is without Transmit or Receive Antenna Height
- LOS of Near-LOS for TVWS link **<u>may not be</u>** available
- Detailed breakdown of the profile on the next slide

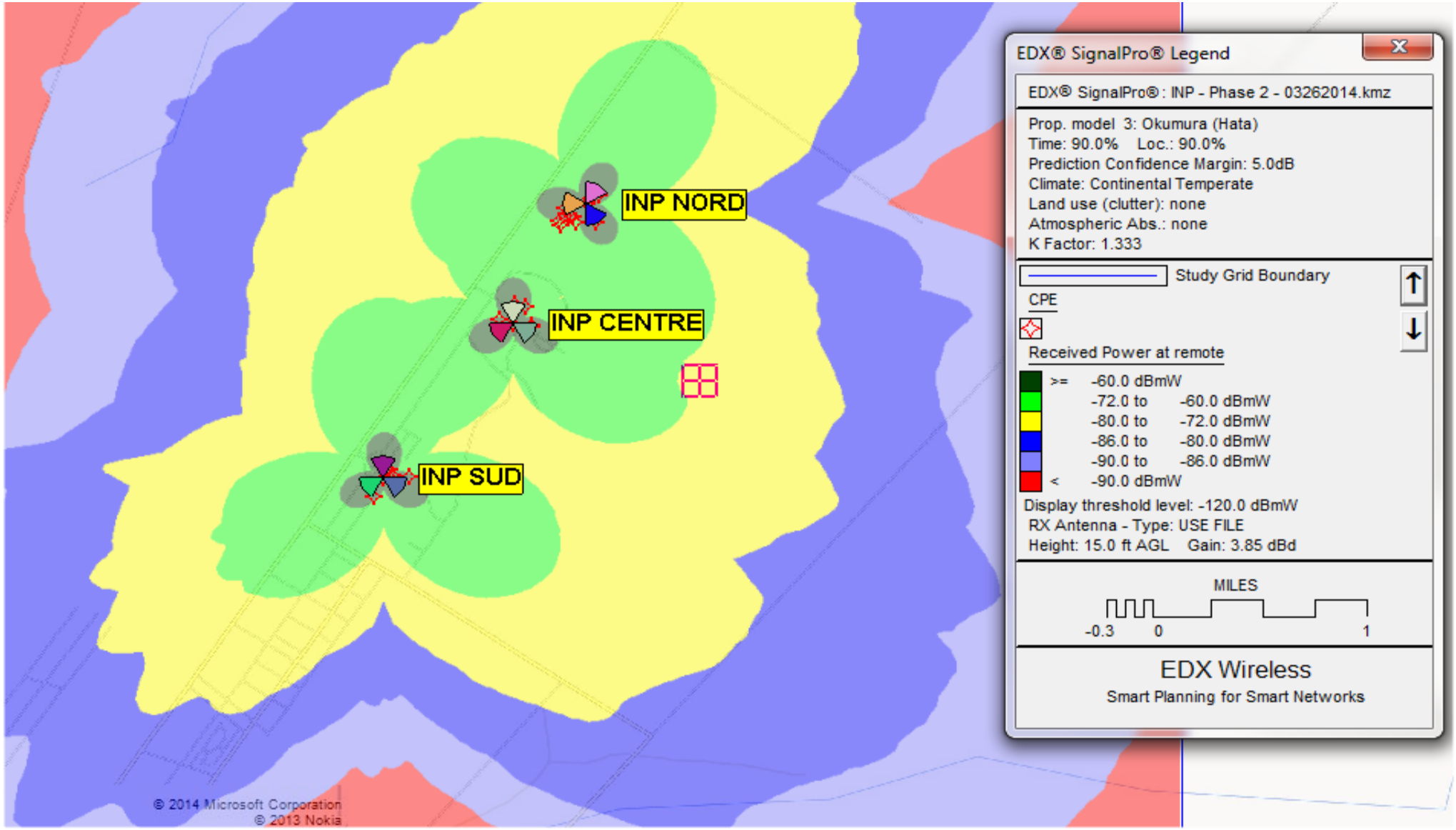
# Path Elevation Profile Saves the Day!

| | |
|---|---|
| Distance | 8.94 km |
| BTS elevation (without tower) | 1329 m |
| Highest point in path | 1368 m |
| CPE elevation (ground level) | 1285 m |

TVWS RF signal in the 500-600 MHz frequency range may be able to diffract over and around the modest hill in the near-LOS path.

# RF Propagation Model- Sample



# Capacity Analysis

- The goal of the capacity analysis is to ensure that the TVWS base radio(s) can support enough capacity to provide the end user service based on the following inputs:
  - ___ Mbps DL throughput
  - 10 to 1 over-subscription ratio
  - No of users to be served by N-sector site (total __ radios on the tower)
  - Number of recommended CPE's to be connected to base radio

**Yellow highlighted boxes are drop down in excel**

| User Input Boxes | | |
|---|---|---|
| Minimum required DL throughput per user | 5 | Mbps |
| Over-Subscription/Contention Ratio | 5 to 1 | ratio |
| Delivered TCP Throughput per Ch. | 10 | Mbps |
| Channel Expansion Enabled (2 UHF Channels) | Yes | Mbps |
| Delivered TCP Throughput for 2 Channels | 20 | Mbps |

| Town/City | # of Users | Required Throughput per user (Mbps) | Over-Subscription ratio | Total Capacity Requirement (Mbps) | Delivered TCP Throughput per Ch. (Mbps) | Number of n-sector Base Station Site locations | Number of Base Station radios recommended |
|---|---|---|---|---|---|---|---|
| Pilot Location | **No. of users** | 5 | 5 to 1 | Total Tput | | | |

# Channel Planning

| UHF Ch. Range | Freq. Range | Total Ch. | Min. Ch. required | Available Ch. Name |
|---|---|---|---|---|
| Ch. 21-40 | 470-630 MHz | 20 | 9 | X1,X2…X9 |
| Ch. 41-60 | 630-790 MHz | 21 | 9 | Y1,Y2…Y9 |

| Base Station Name/Location | Latitude | Longitude | # of Sectors (antennas/pies) | # BS radios per sector | | | Channel allocation per Base Station Radio | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | A1 | A2 | B1 | B2 | C1 | C2 |
| Base Station 1 | x.xxx | x.xxx | 3 | 2 | 2 | 2 | X1 | Y1 | X2 | Y2 | X3 | Y3 |
| Base Station 2 | x.xxx | x.xxx | 3 | 2 | 2 | 2 | X7 | Y7 | X8 | Y8 | X9 | Y9 |
| Base Station 3 | x.xxx | x.xxx | 3 | 2 | 2 | 2 | X4 | Y4 | X5 | Y5 | X6 | Y6 |
| Base Station 4 | x.xxx | x.xxx | 1 | 1 | 0 | 0 | X1 | n/a | n/a | n/a | n/a | n/a |

# Free Tools

- Google Earth Pro
- Radio Mobile Propagation tool: http://www.g3tvu.co.uk/Radio_Mobile.htm

# TV White Space Pilot Projects

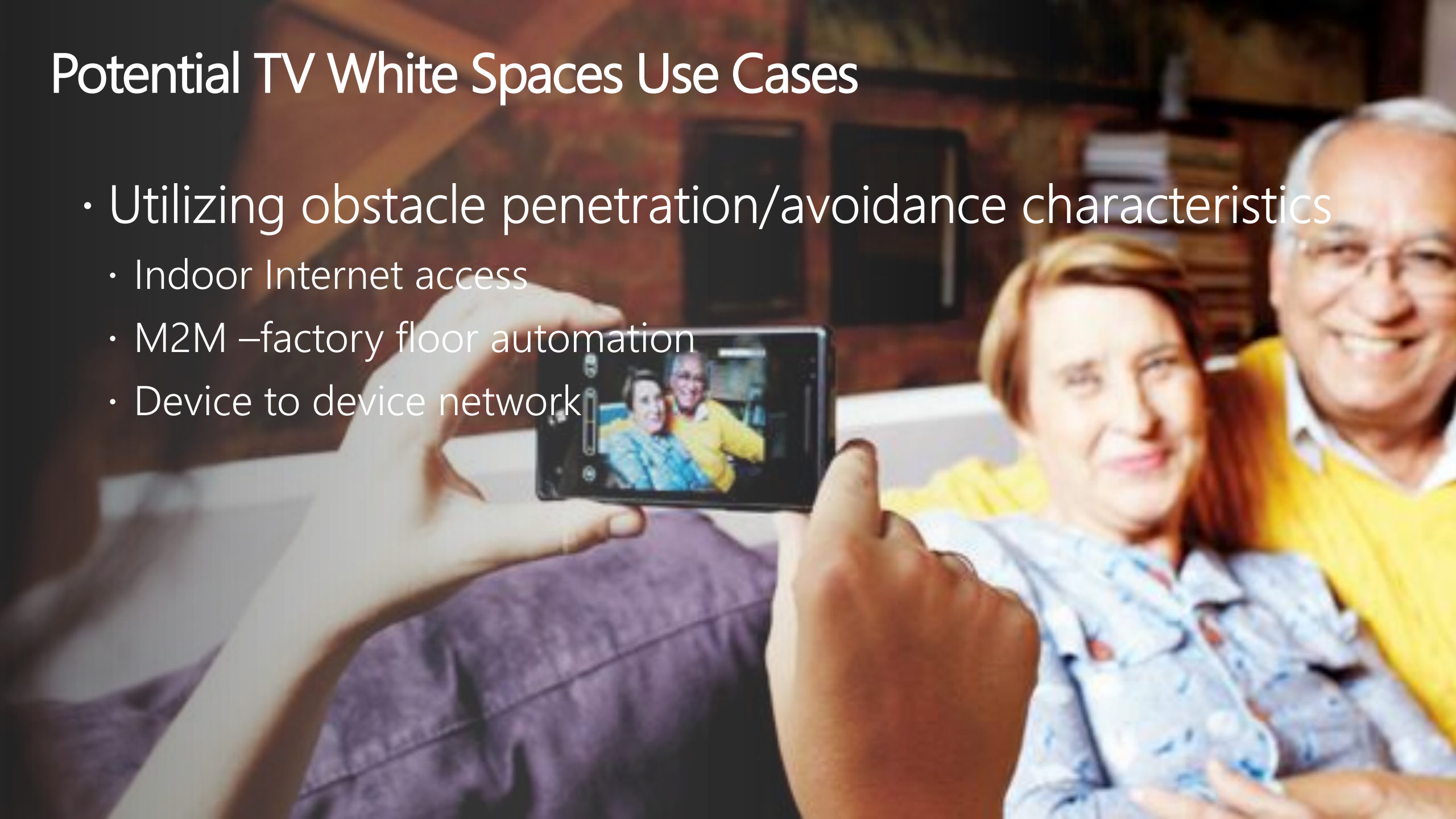
Microsoft

# Potential TV White Spaces Use Cases

- Utilizing long range characteristics
  - Cellular offloading
  - Rural broadband/backhaul
  - Wide-coverage hotspots
  - Bridge among small networks
  - Sensor network (IoT and M2M)
  - Wireless surveillance system

# Potential TV White Spaces Use Cases

- Utilizing obstacle penetration/avoidance characteristics
  - Indoor Internet access
  - M2M –factory floor automation
  - Device to device network



# Our Portfolio: 40+ Active Projects

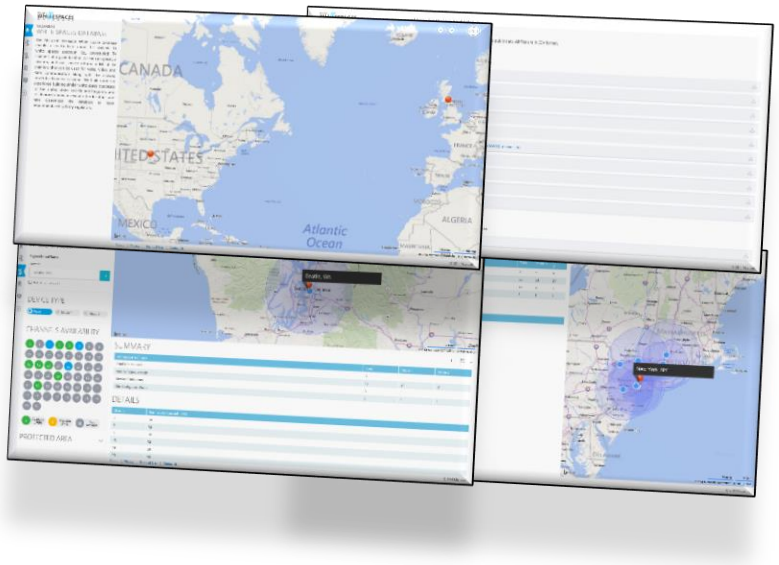

| Internet Access | | | | Energy Access | |
|---|---|---|---|---|---|
| 4.1M Population Under Coverage | 200K Monthly Active Users | 210 K-12 Schools Connected | 85K K-12 Students Connected | 6 Azure IoT & AI Lab Residencies | 500,000 Azure Clean Energy Connections |

# Key Lessons Learned from Pilot Projects

- TV White Space Technology Can Help Reduce the Cost of Broadband Deployments – It Works! (this is not just a science experiment)
  - This is a great building block technology
- CPE Pricing Remains a Barrier to Scale Deployments
  - Investment & standardization are key to enabling use cases
- Finding Motivated and Competent Private & Public Sector Partners is Key
  - Network operators need to share the vision
- Access to Financing Remains a Challenge in Emerging Markets
  - Donor funding, universal service funding, development banks are key
- Regulation is the Most Critical Piece to Unlocking this Opportunity
  - Regulators needs to open up more frequencies for spectrum sharing (example of US FCC & NTIA in UHF, 3.5 GHz, 5 GHz . . . )
  - The lead pack of regulators should mentor the fast followers


TV White Spaces Database
Microsoft

Microsoft WHITESPACES DATABASE

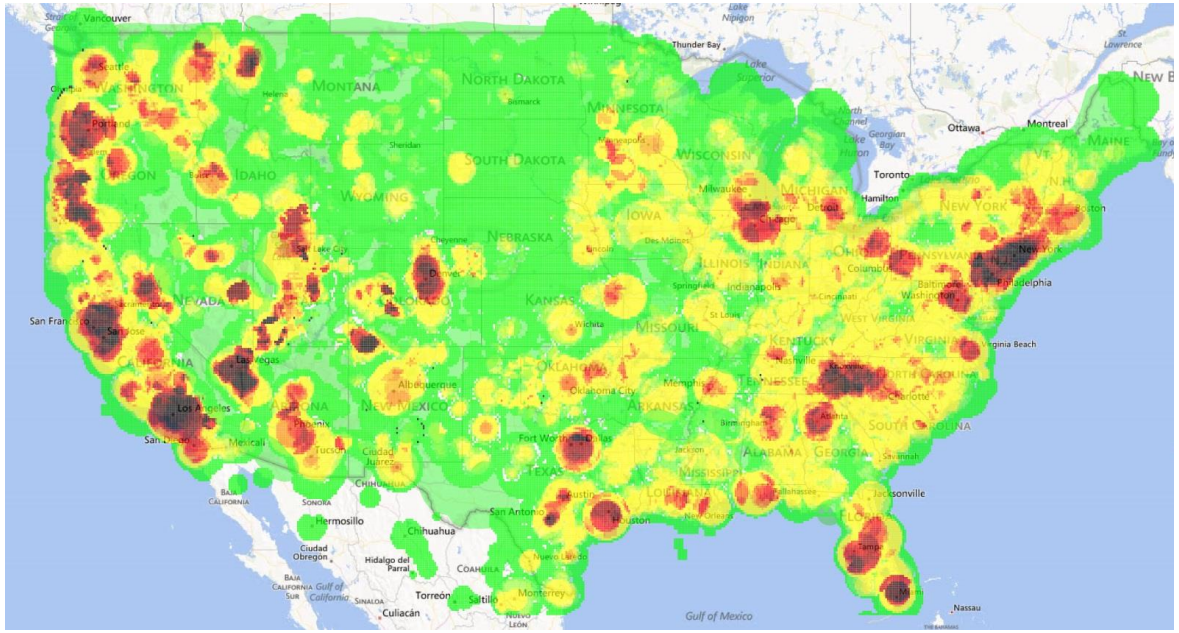



- Whitespace Purpose
  - Sharing of wireless spectrum that is not assigned or is not being used by licensees.

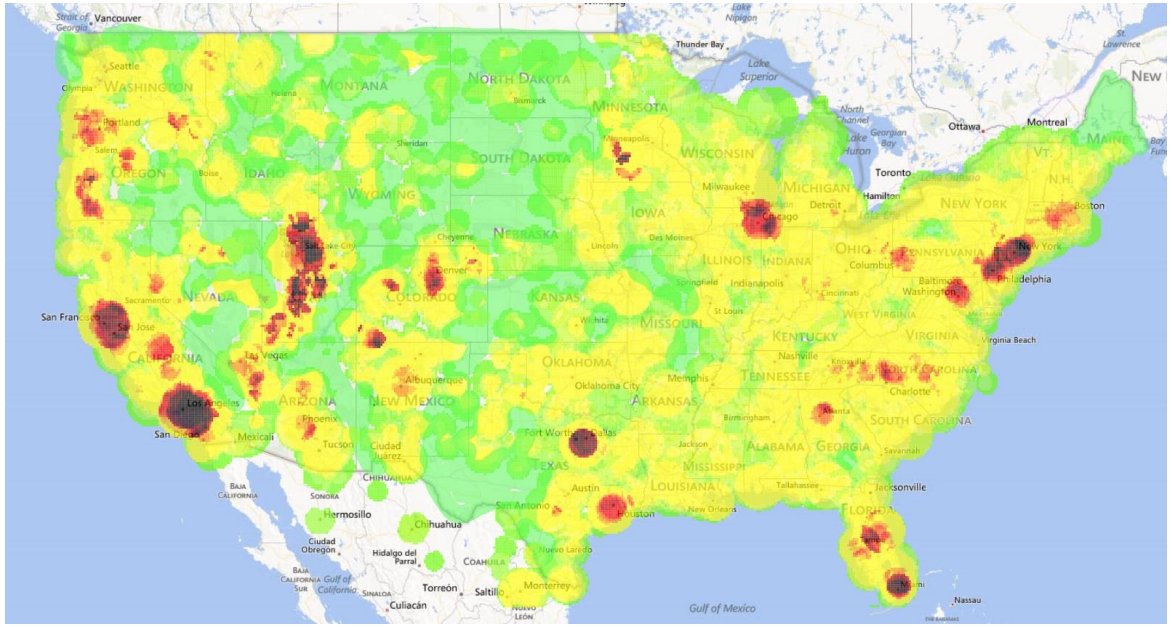
- Microsoft is working with in multiple regions in generating TV Whitespace databases including:
  - United States (FCC)
  - UK (Ofcom)
  - Singapore (IDA)
  - Ghana
  - Tanzania
  - Philippines
  - …

# US White Space Availability Heat Map

Fixed




Mode 1

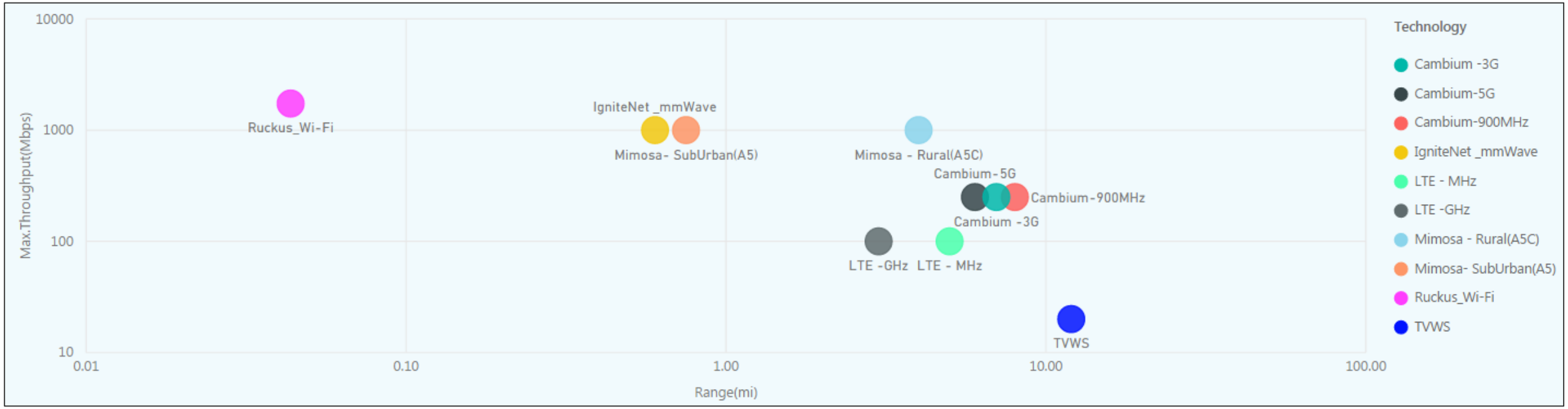



Black: Zero channels available
Red: 2 to 10 channels available
Yellow: 11 to 20 channels available
Green: 20+ channels available


# TV White Spaces Database Demonstration

https://spectrum.iconectiv.com/main/home/contour_vis.shtml
https://www.google.com/get/spectrumdatabase/channel
http://whitespaces.spectrumbridge.com/whitespaces/home.aspx#Search

# Technology Guidelines




- TVWS is best suited for:
  - Medium to long range (~10km) NLOS paths
  - Relatively low throughput requirements
  - Point to multi point applications
- Microwave is best suited for:
  - Fiber extension: low cost, high capacity point to point LOS links
  - Excellent link economics due to commodity pricing
  - Aggregation nodes where multiple capacity points need to be backhauled

# Backhaul MW Vendors

Here is a list of a few high quality unlicensed microwave equipment vendors (in no particular order of preference):

- Ubiquiti
- Mimosa
- Deliberant
- Cambium
- Mikrotik
- Ligowave
- Radwin
- Redline

# Links to further information

More about TVWS technology

http://research.microsoft.com/en-us/projects/spectrum/default.aspx

The Dynamic Spectrum Alliance

http://www.dynamicspectrumalliance.org/

Microsoft projects

http://research.microsoft.com/en-us/projects/spectrum/pilots.aspx

Microsoft

# Thank you!!