Affordable Backhaul for Rural Broadband: Opportunities in TV White Space in India

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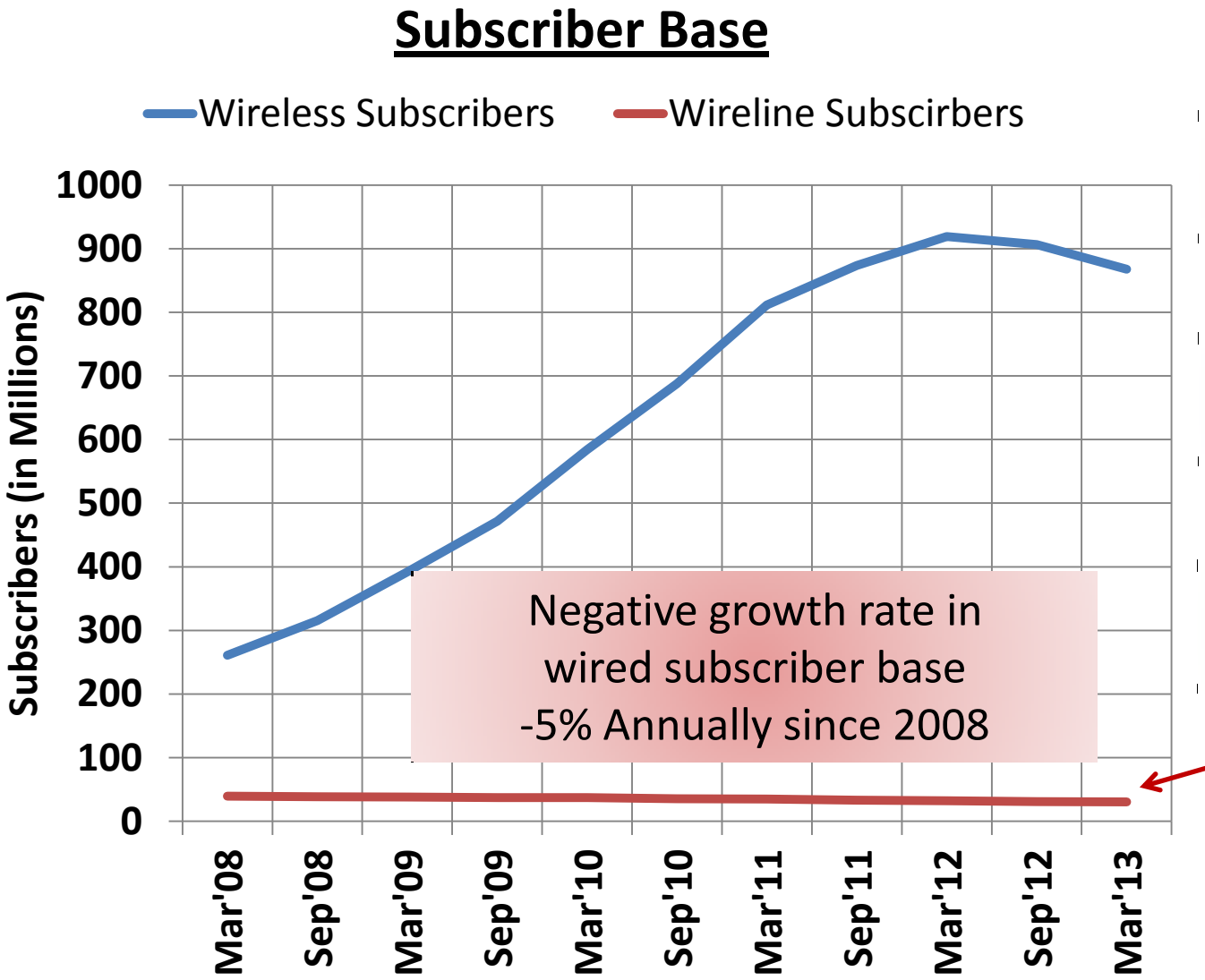
Outline

- Indian Scenario
- Broadband Access
- Rural Connectivity and Broadband
- Other possibilities? – TV White Space

Indian Scenario

Telecom in India: Subscriber Base



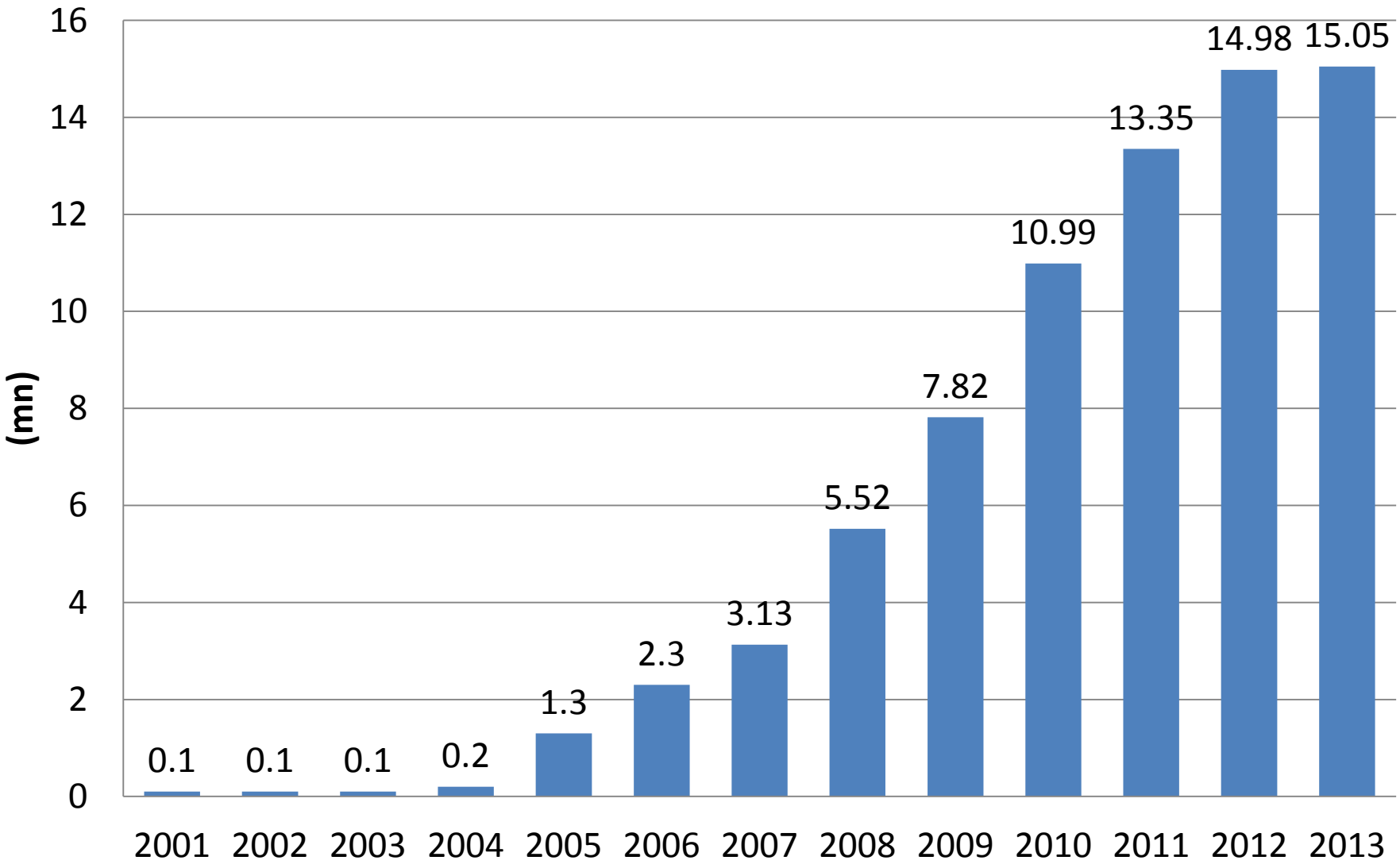
Wireless subscribers
850+ Million

Overall tele-density
73 (Mar '13)

2nd largest telecom market globally

Source: **The Indian Telecom Services Performance Indicator Reports, TRAI**

The Indian Broadband Penetration



Source: **The Indian Telecom Services Performance Indicator Reports, TRAI**

Indian Scenario – summarized

- Rural teledensity is still 41 (against urban teledensity of 146)
- Broadband subscribers ~ 15.05 Million
- ARPU declining
  - 33% drop in ARPU from 2009 to 2011

Next Big Opportunity – Rural Connectivity & Broadband

Broadband Access

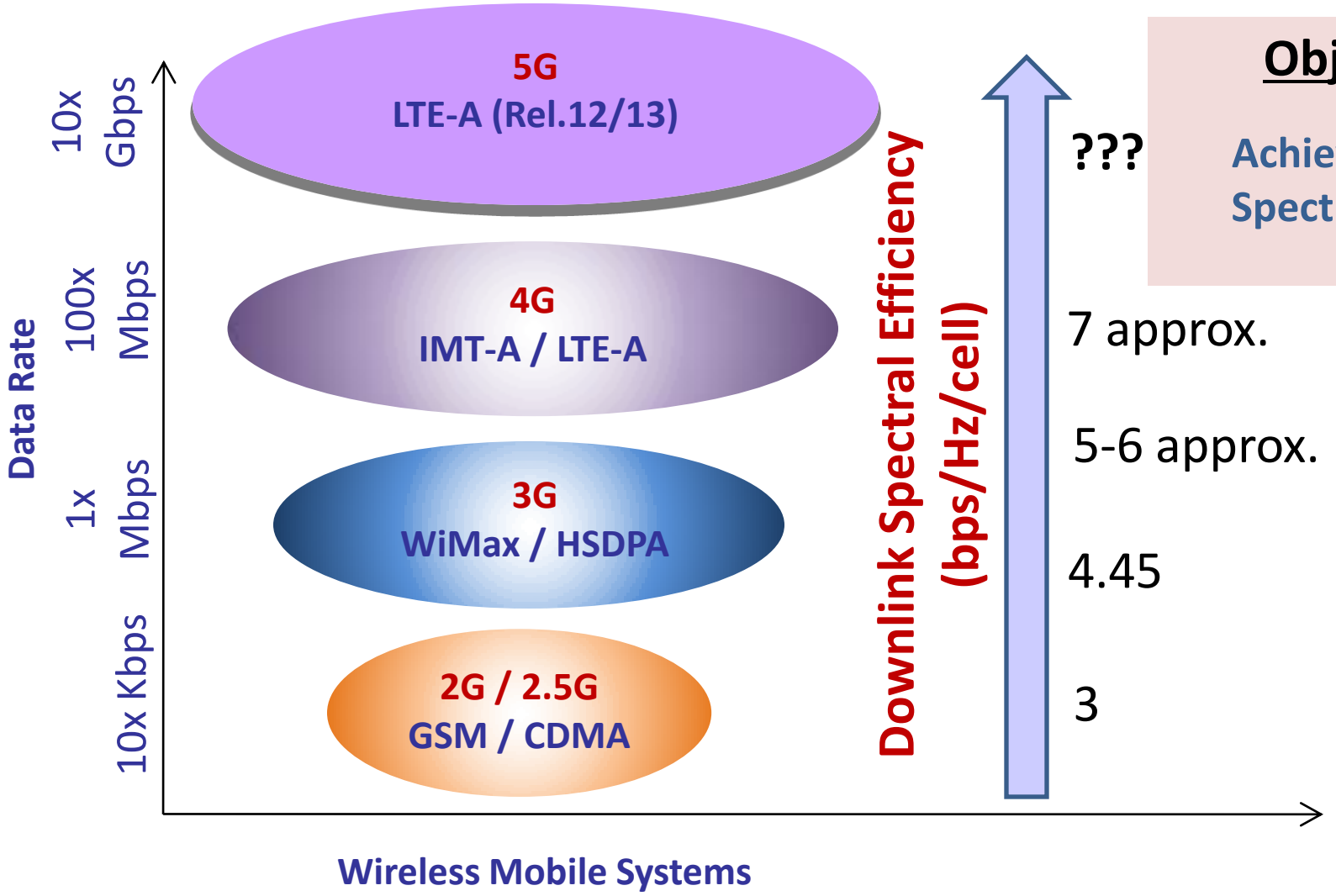
Broadband through Wireless?

- 1K users /sq km, and 2 Mbps demand per user
- Very high capacity required: 2 Gbps/sq km
  - Assuming 2-3 cells/ sq km, we need about 1 Gbps per cell

Even with 20 MHz per cell ~ whopping 50 bps/Hz/cell !!!

Moreover, with increasing power levels, emission levels are also increasing

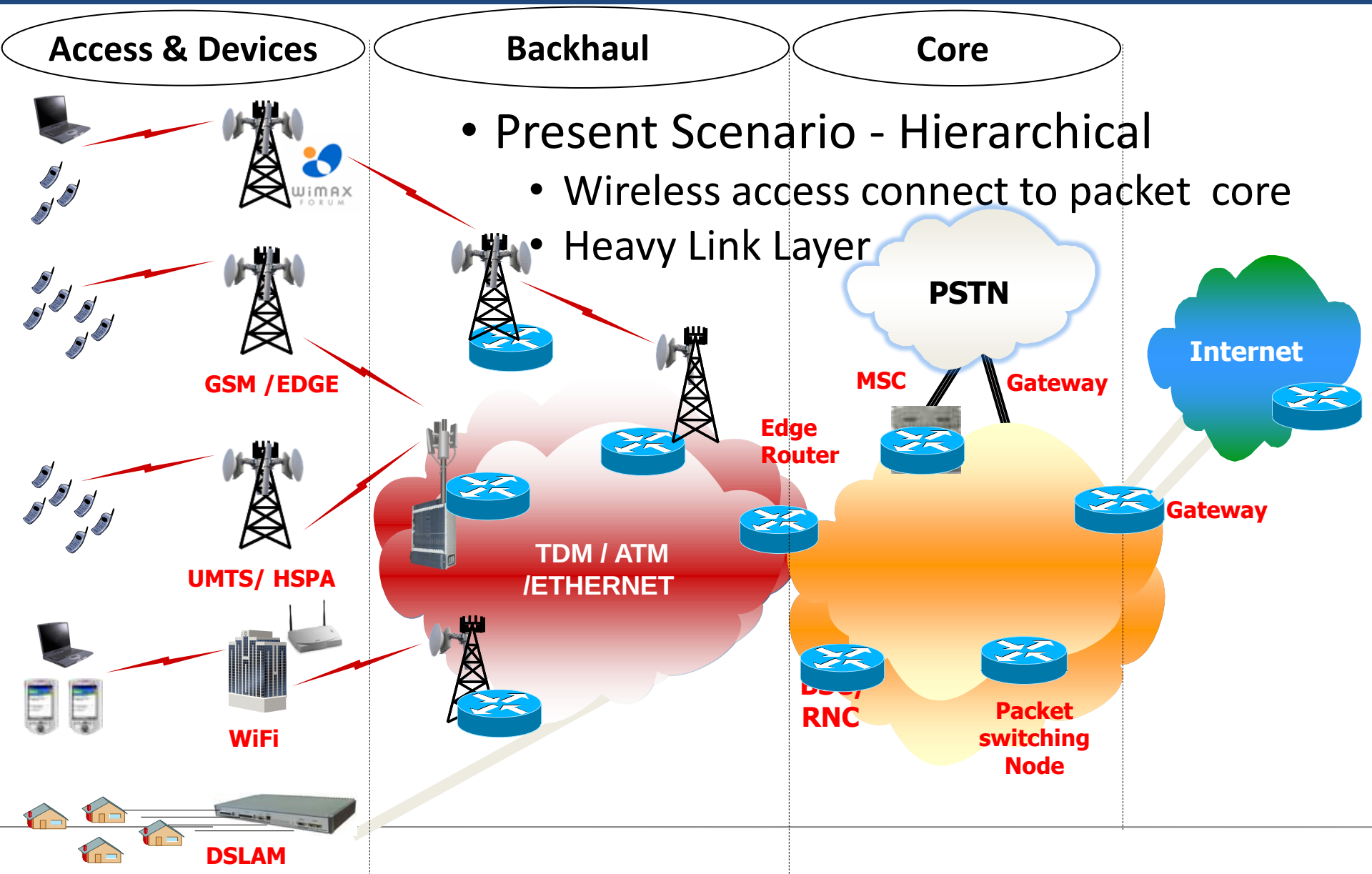
Stepping towards 5G Systems (Rel.12/13 of LTE-A)



Objective

Achieve higher Spectral Efficiency

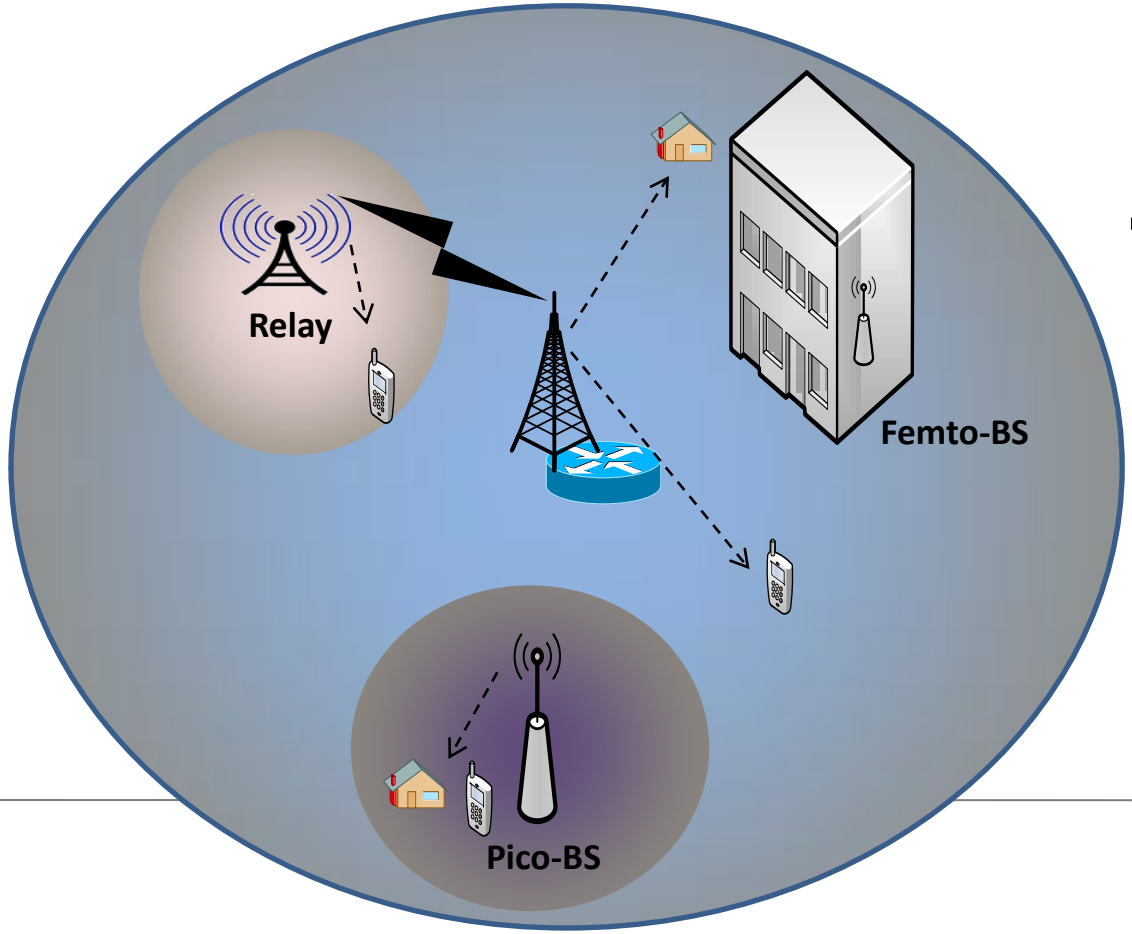
Today's Cellular Architecture

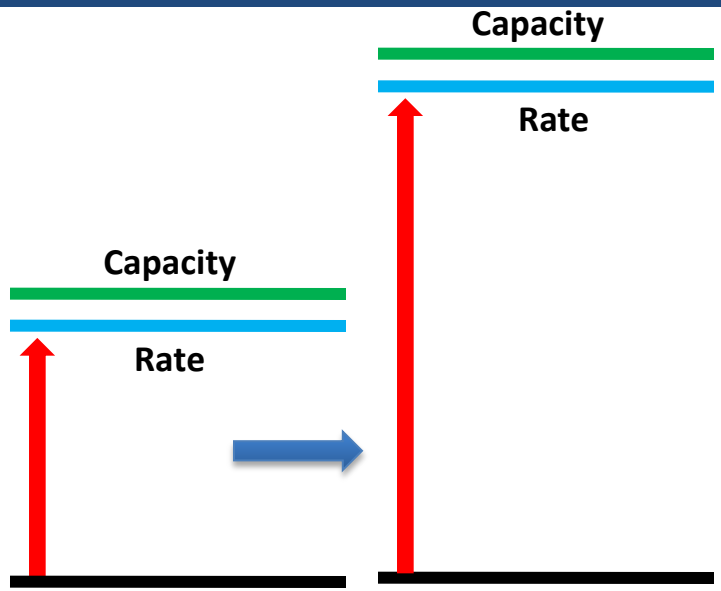


Heterogeneous Network

Features

- Low-power nodes- Pico and Femto
- Shared resources
- Macro BS provide umbrella coverage
- Capacity and/or coverage improvement





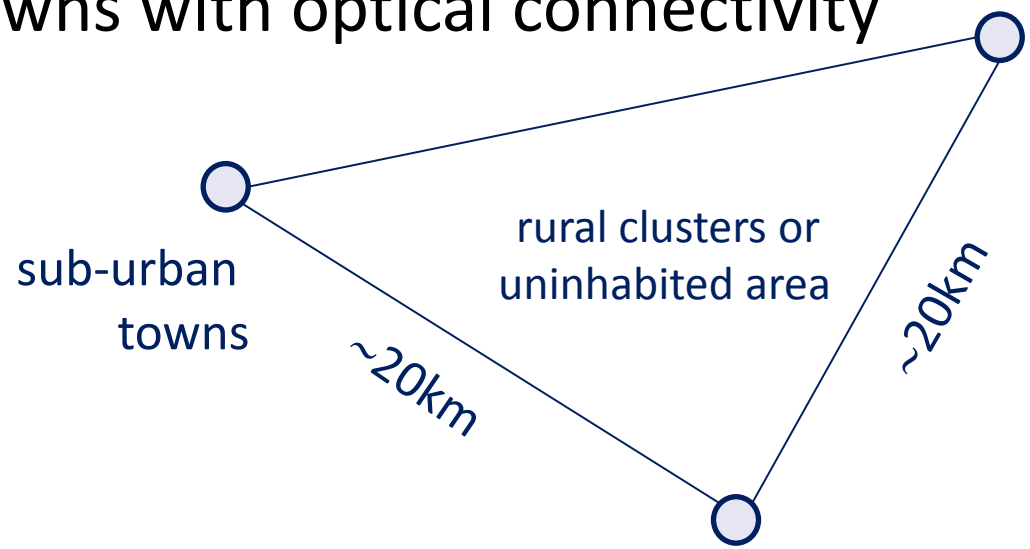
Challenges

- Backhaul – Major challenge for small cells
- Requires a mix of fiber and wireless

Rural Connectivity and Broadband

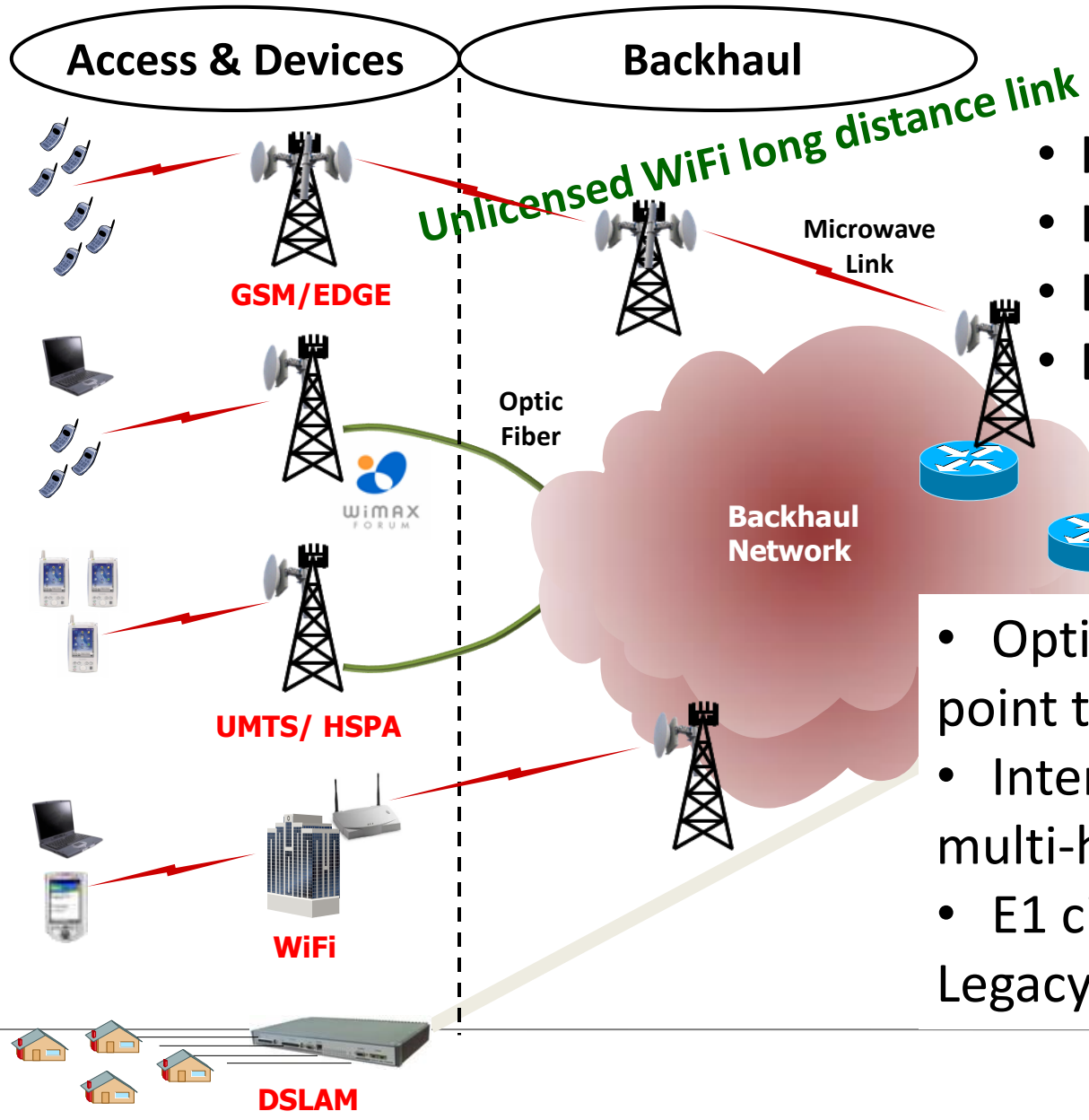
Key Problem in Broadband Coverage

- Broadband coverage in rural areas is desirable but it is difficult due to cost and low return on investment
- Recently, Government of India has announced a National optical fiber network (NOFN) to link all sub-urban towns with optical connectivity



It is a challenge to provide an affordable broadband to sparsely populated rural areas due to backhaul considerations

Unlicensed Radio Backhaul



Benefits

- Inexpensive radio (<$50)
- Low power (<10 W)
- License free band
- But designed for Indoor

Technical Innovation

- Optimized MAC for outdoor point to point link
- Interference management for multi-hop link
- E1 circuit emulation for Legacy access GSM/CDMA)

Other possibilities? – TV White Space

Terrestrial TV Spectrum allocation in India

- Government's national broadcaster named Doordarshan holds all of the terrestrial TV broadcasting license
- The frequency allocation plan (NFAP) of UHF TV band and onwards is as follows:

Frequency in MHz	Uses
470-520 , 520-585	For Fixed and Mobile services on case by case basis
585-698	Digital Broadcasting including Mobile TV
698-806	IMT and BWA applications

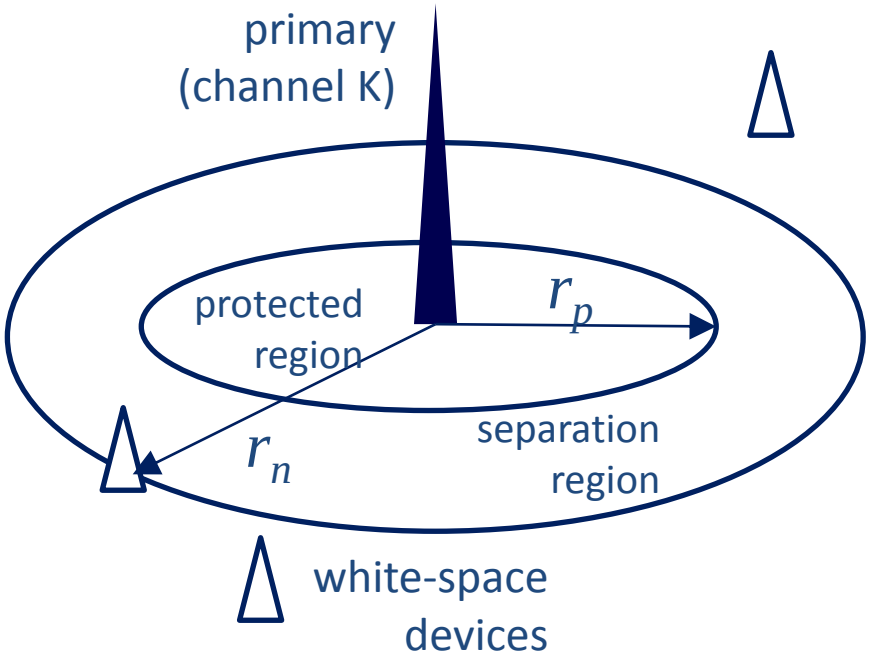
TV transmitter plan of Doordarshan

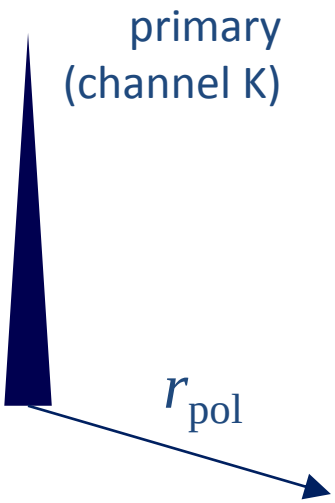
- On record, there are 1415 TV transmitters operating in India
  - UHF Band-IV (470-590MHz)
    - Fifteen channels of 8 MHz each 373 transmitters across all India
  - VHF-I Band (54-68MHz)
    - Two channels of 7 MHz each 8 transmitters across all India
  - VHF-III Band (174-230MHz)
    - Eight channels of 8MHz each 1034 transmitters across all India
- We focus on the UHF Band-IV, i.e., 470-590MHz spectrum band
- Use of microphones is very limited in India

TV white space assessment methods

- The protection and pollution viewpoints [Mishra and Sahai'2009]
- The FCC regulations [FCC'Nov2008]

The protection and pollution viewpoints





Min SINR at the primary receiver on edge of protected region should be Δ **[Mishra-Sahai'2009]**

$$P_t - PL(r_p) - N_0 = \Delta + \Psi$$

$$P_S - PL(r_n - r_p) = \Psi$$

Min SINR at the secondary receiver on edge of separation region should be γ

$$P_t - PL(r_{\text{pol}}) = N_0 + \gamma$$

FCC rules for white space calculations

The FCC specifies a formula for transmit power using electric field:

$$P(\text{dBm}) = E(\text{dBu}) - 130.8 + 20 \log_{10} (1230/(f_H + f_L))$$

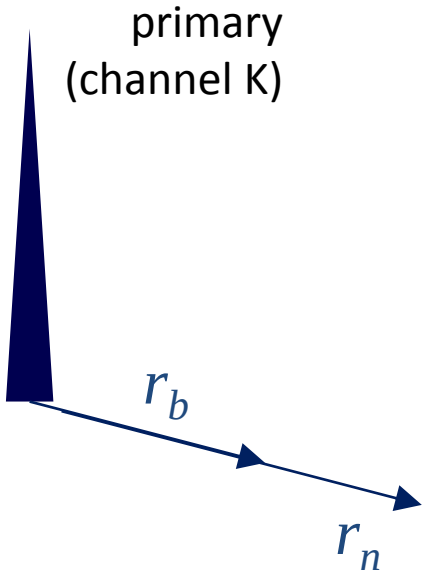
$P(\text{dBm})$ = transmit power in dBm

$E(\text{dBu})$ = electric-field strength in dBu

f_H, f_L = upper and lower frequency limits

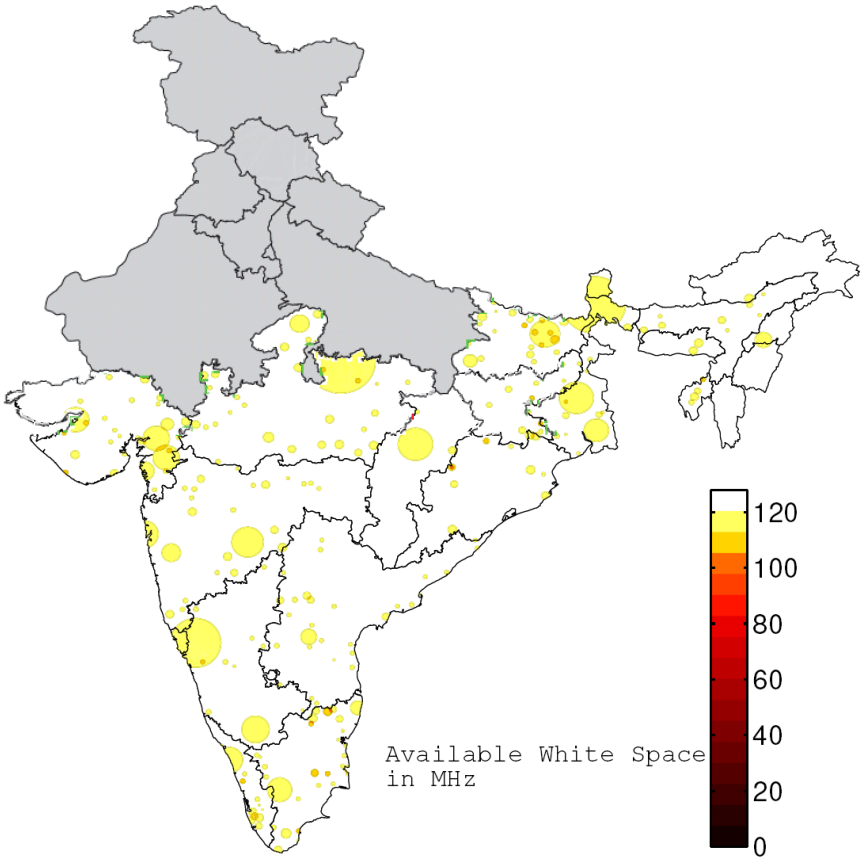
r_b = distance where $E(r_b)$ is 41dBu

r_n = no-talk distance; secondary interference is 18dBu at r_b



All these calculations require propagation models and we use existing models discussed in the Indian context **[Prasad-Ahmad'1997, Hata'1980]**

North-zone data not yet available



- So far, with significant efforts, we have been able to obtain the data for all zones except North in India
- The results will **omit** the North zone for this reason

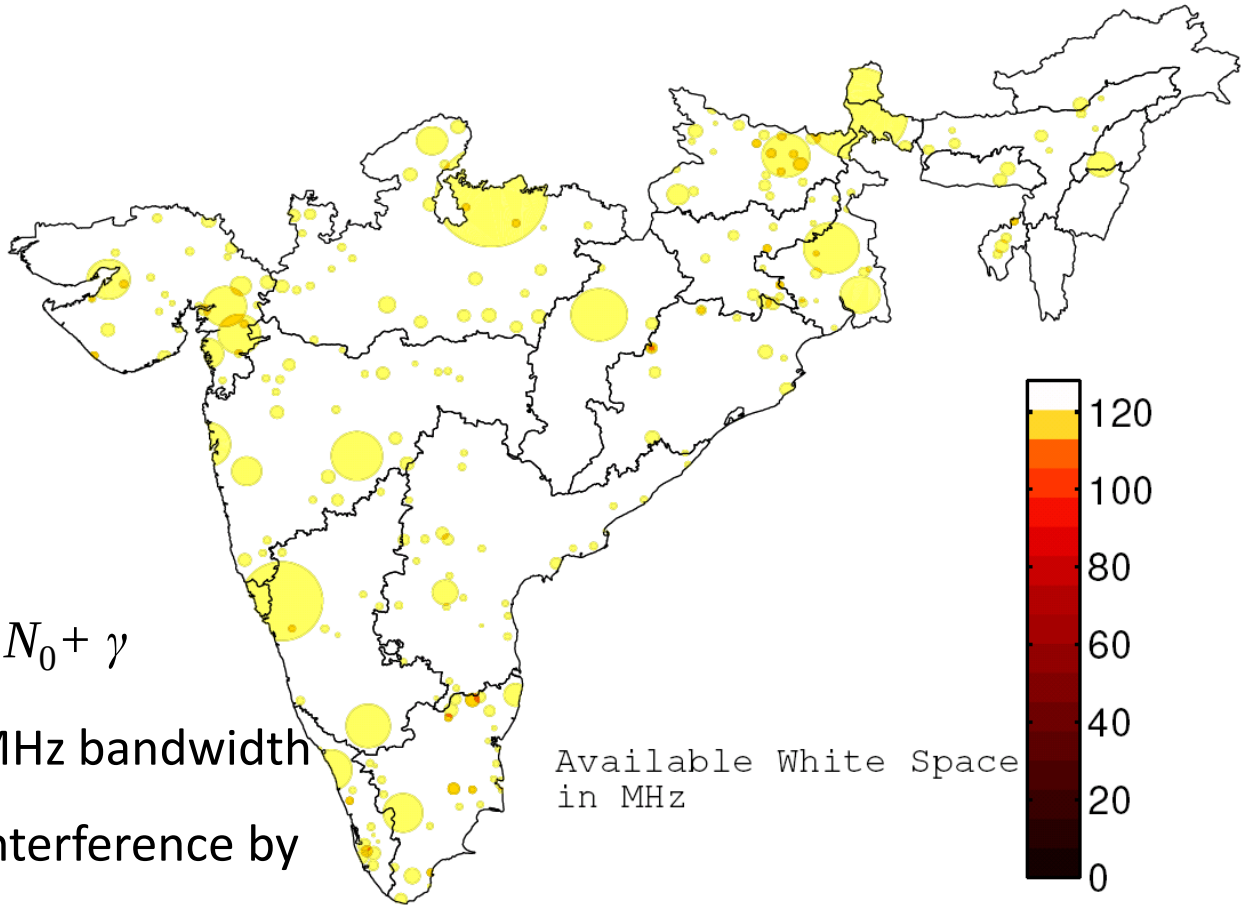
TV white space assessment: pollution view

Recall

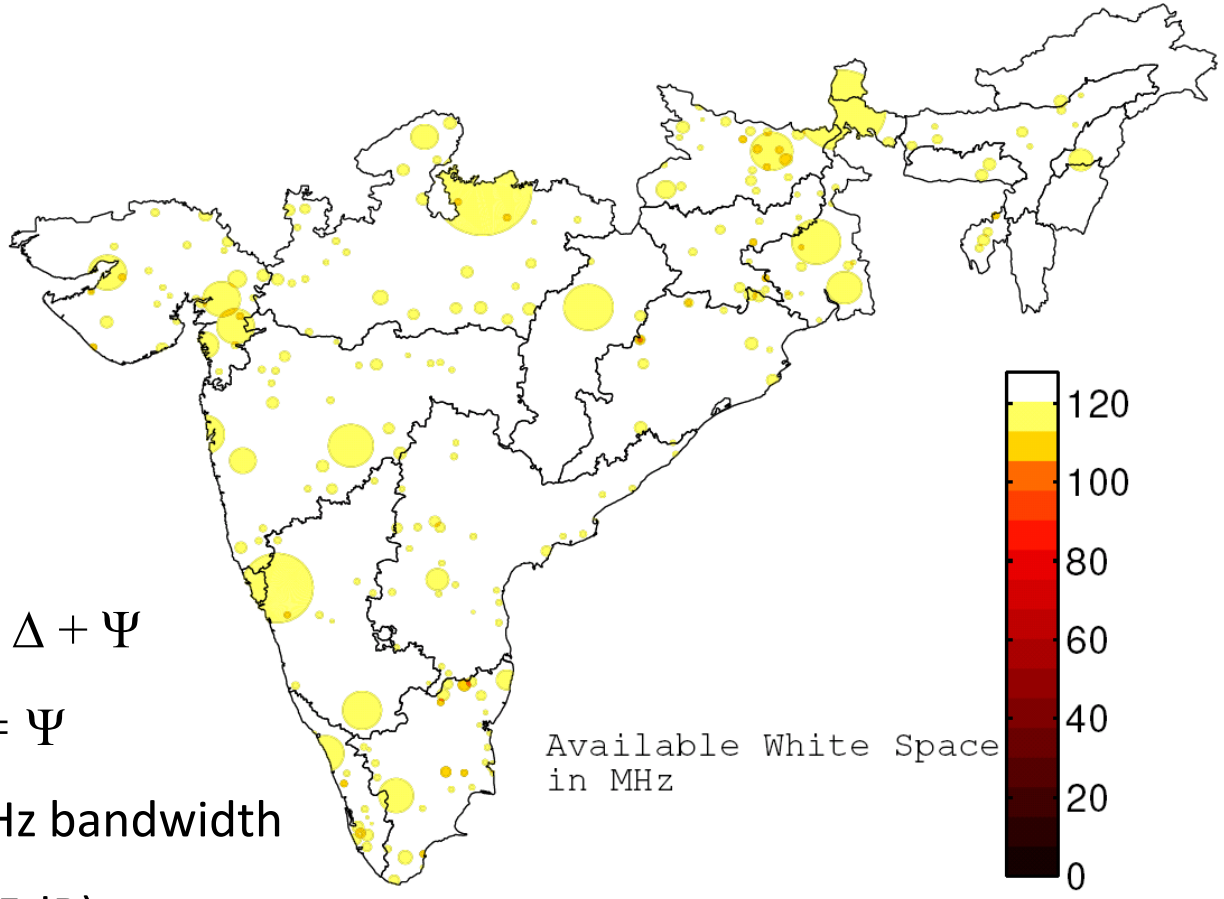
$$P_t - PL(r_{\text{pol}}) = N_0 + \gamma$$

N_0 = -105dBm for 8MHz bandwidth

γ = max. tolerable interference by secondary 5dB-15dB



TV white space assessment: protection view



Recall

$$P_t - PL(r_p) - N_0 = \Delta + \Psi$$

$$P_S - PL(r_n - r_p) = \Psi$$

N_0 = -105dBm for 8MHz bandwidth

Δ = SINR threshold (45dB)

Ψ = fading margin 0.1dB-1dB

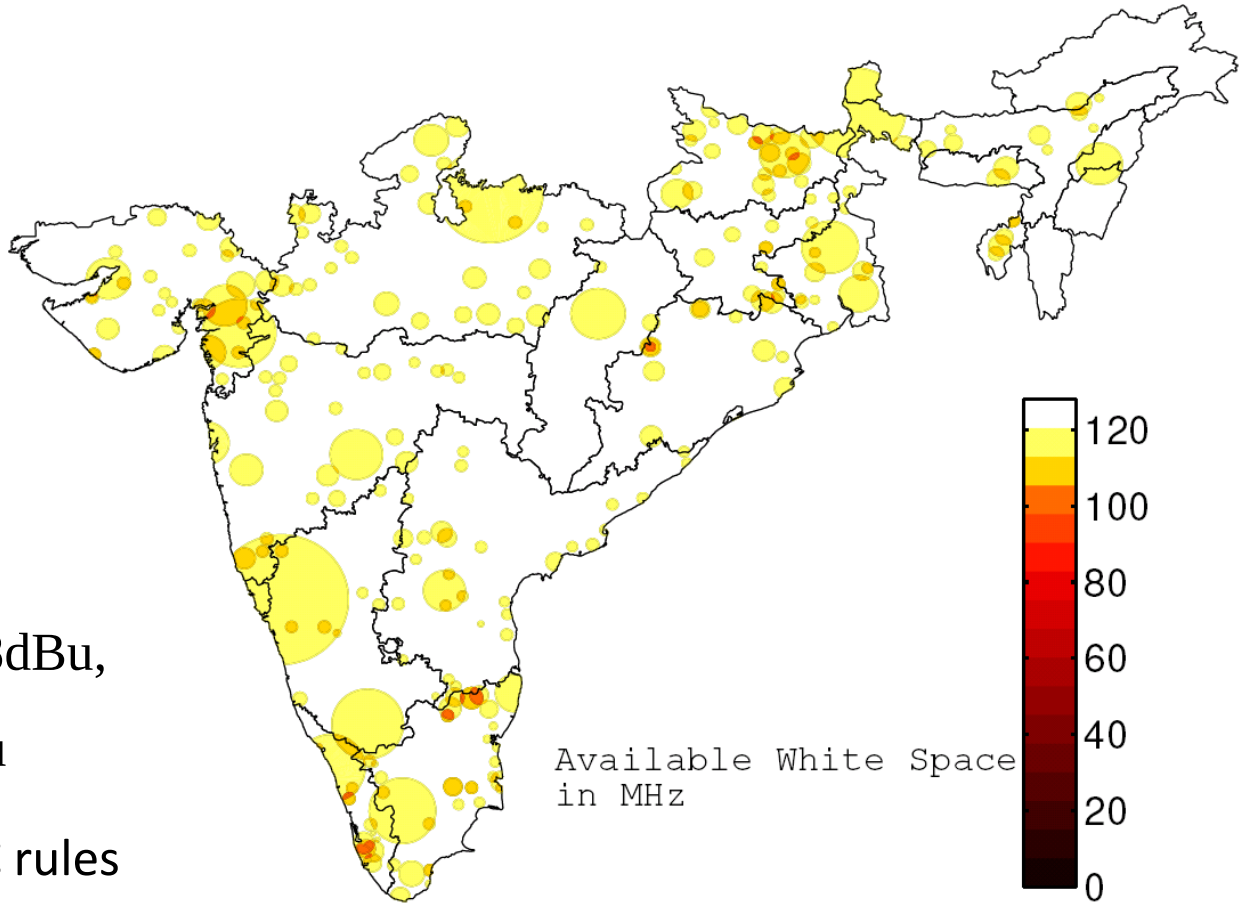
TV white space assessment: FCC rules

Recall

$$E_S(r_n - r_b) = 18\text{dBu},$$

$$E_P(r_b) = 41\text{dBu}$$

P_S = specified by FCC rules

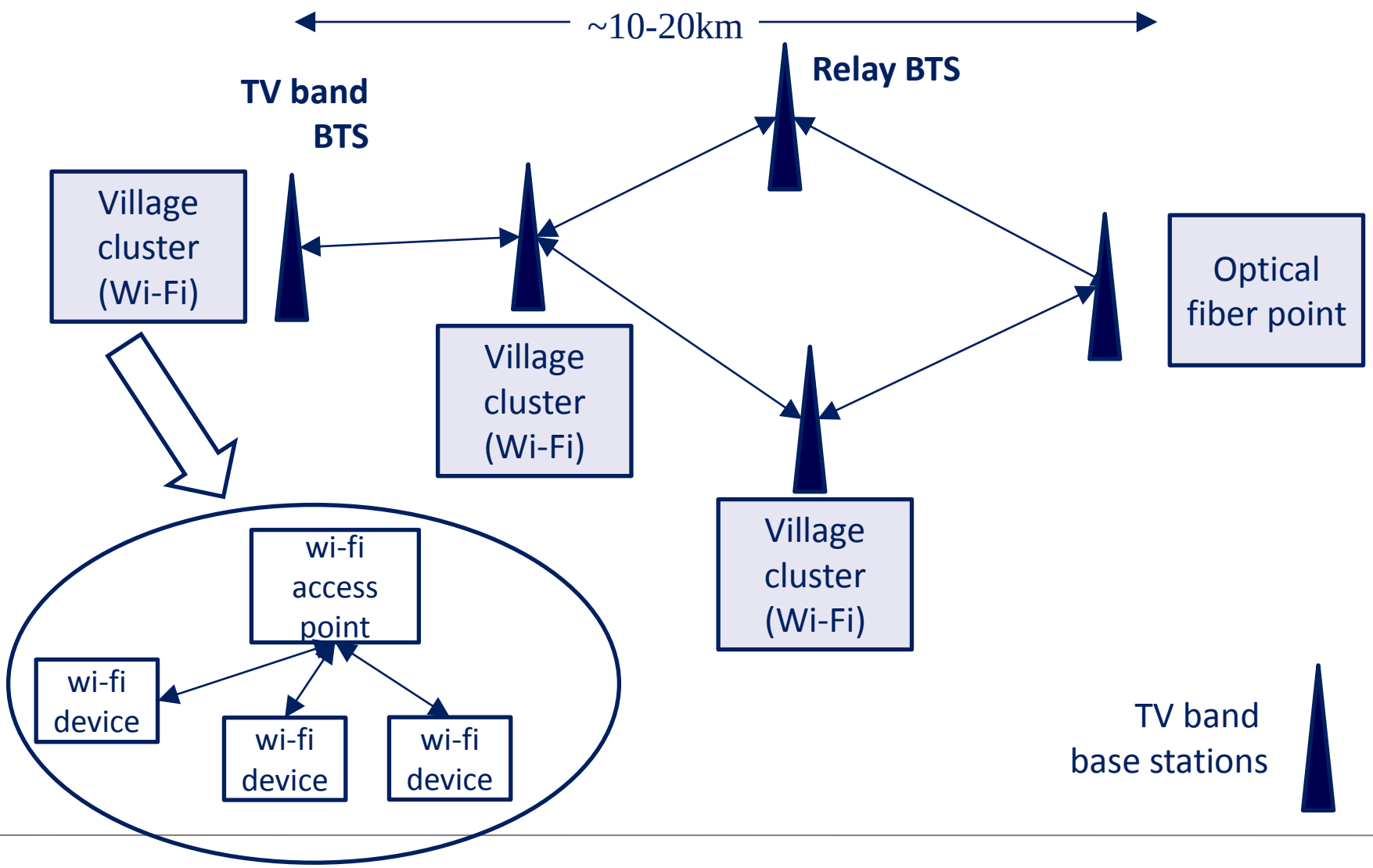


Key Observations

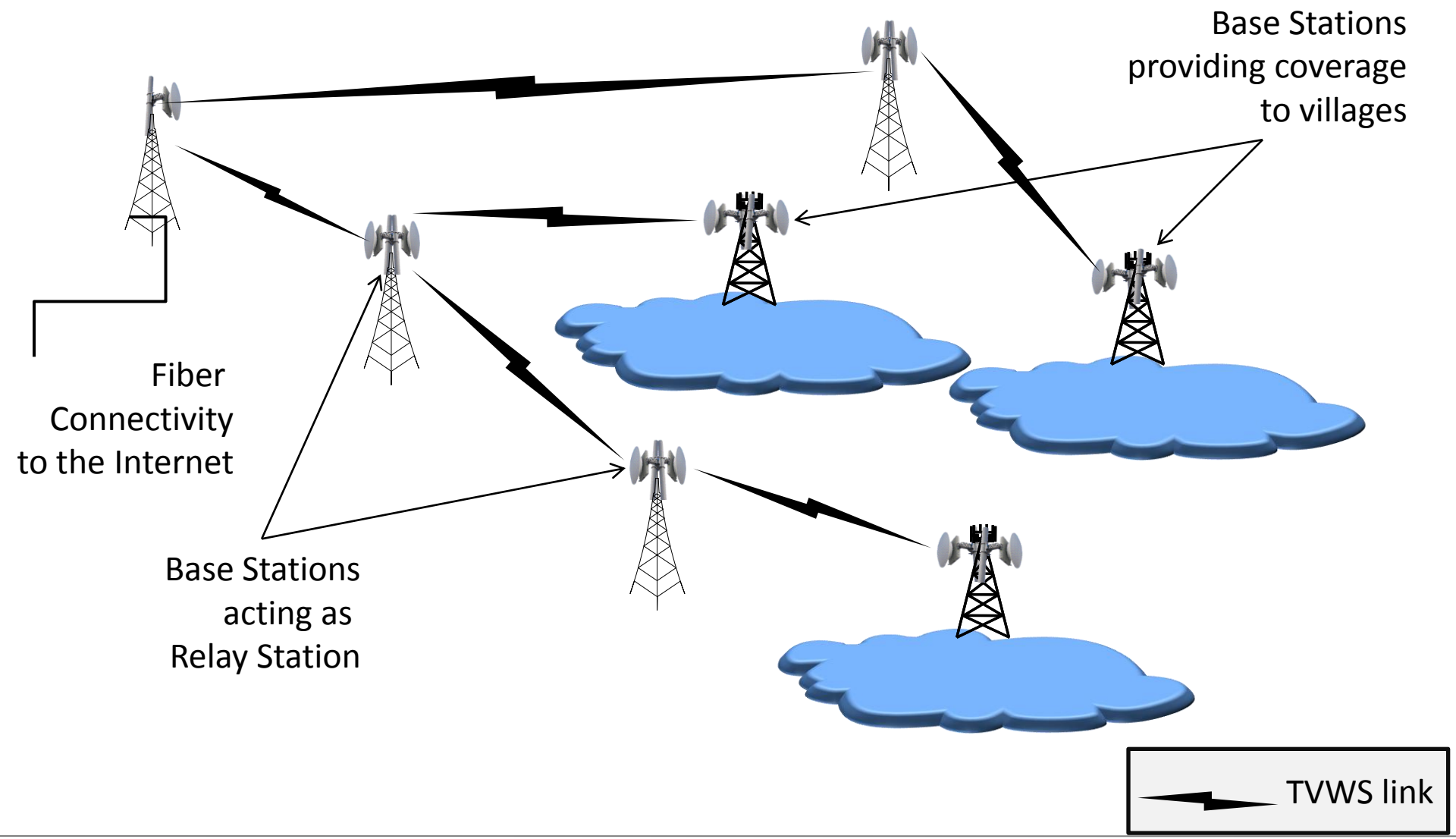
- Per unit area, a minimum of **14 out of 15 channels** is always available as TV white space!
- At any place, a minimum of **12 out of 15** channels are almost always available as TV white space
- These results hold for various values of γ = 5dB-15dB, Ψ = 0.1dB-1dB and $E(r_b)$ was fixed at 41dBu for the FCC rule calculations

Most of the UHF-Band spectrum at most of the places in India is white space

Middle-mile mesh-network in TV white spaces



Proposed Core TVWS Backhaul Network



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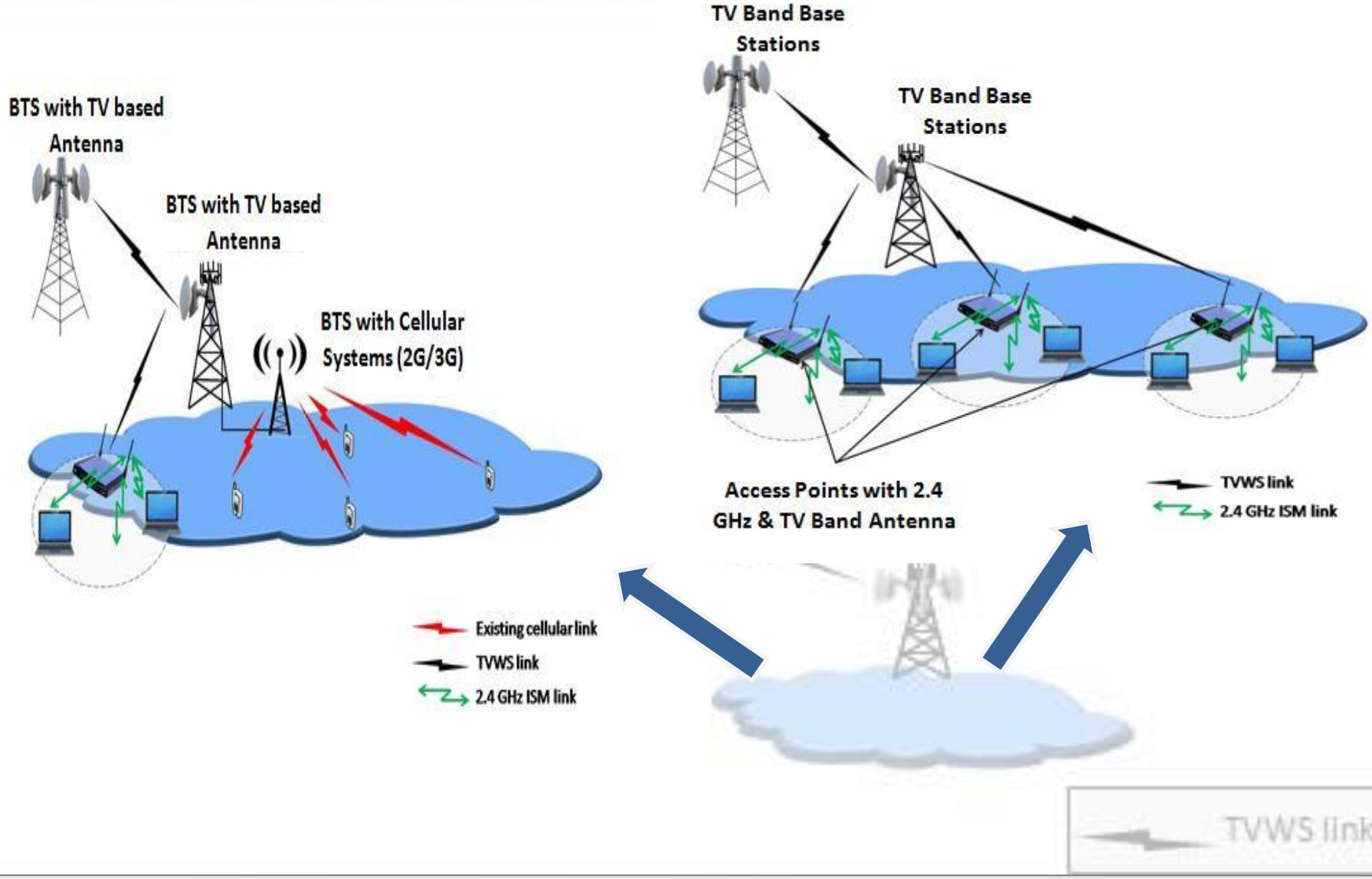

What we should do in sub-1 GHz ?

- Categorize licensing of sub-1GHz spectrum as:
  - Licensed (may follow market dynamics and spectrum auction)
  - Lightly licensed
  - Unlicensed
- Develop a Regulatory model based on the above licensing regimes
- We should facilitate deployments for low cost broadband technologies
  - Based on evolving standards such as 802.11af and 11ah (WiFi in 470-585 MHz band)
  - Make 5/10/15 MHz bandwidth make available for backhaul
- Develop Test-bed and conduct field trial
- Work towards frequency harmonization with rest of the word

Conclusions

- Lots of TV white space in India in the 470-590MHz band
- While it is in inception, we believe that a suitably designed mesh-network in the TV band will significantly address the lack of rural broadband coverage in India.