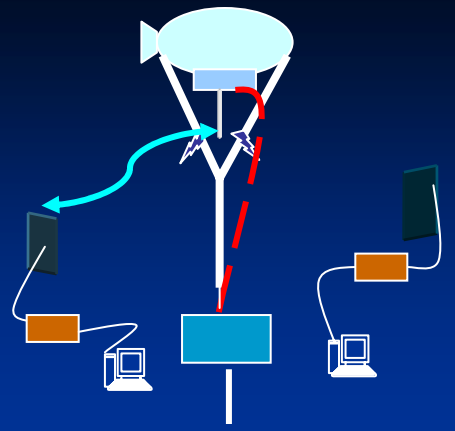
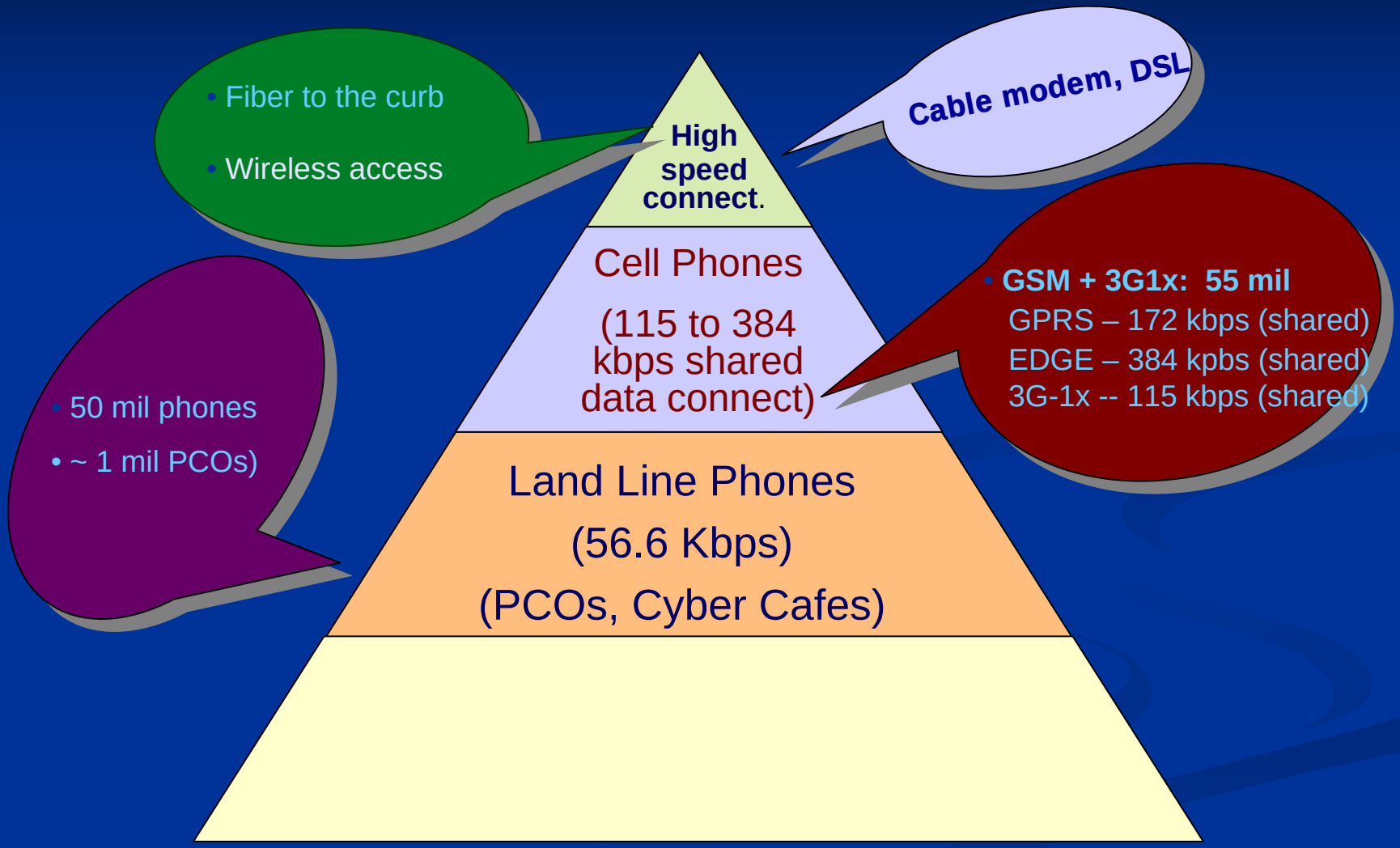
Low Cost Wireless Internet Access for Rural Areas using

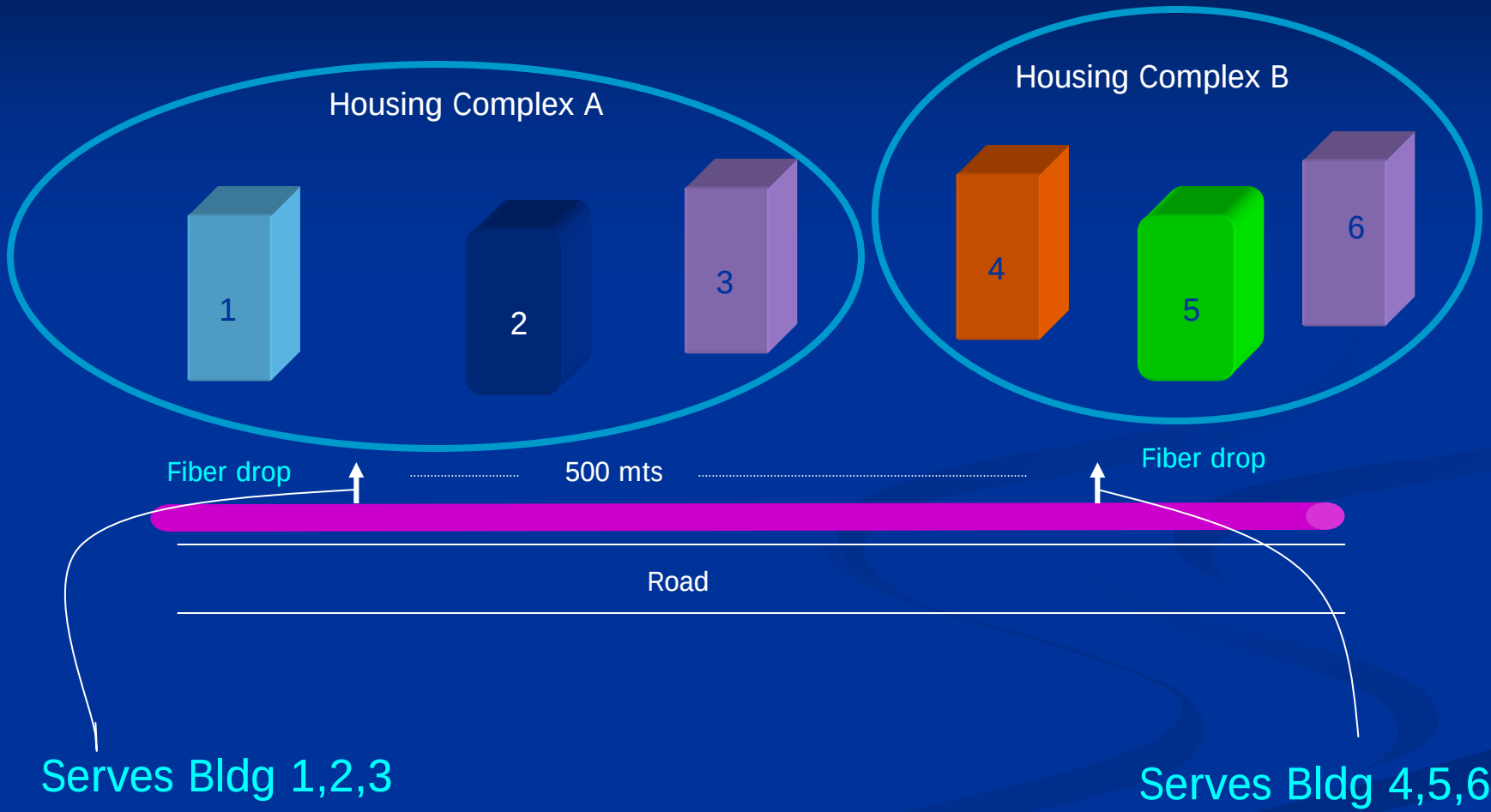


Uday Desai

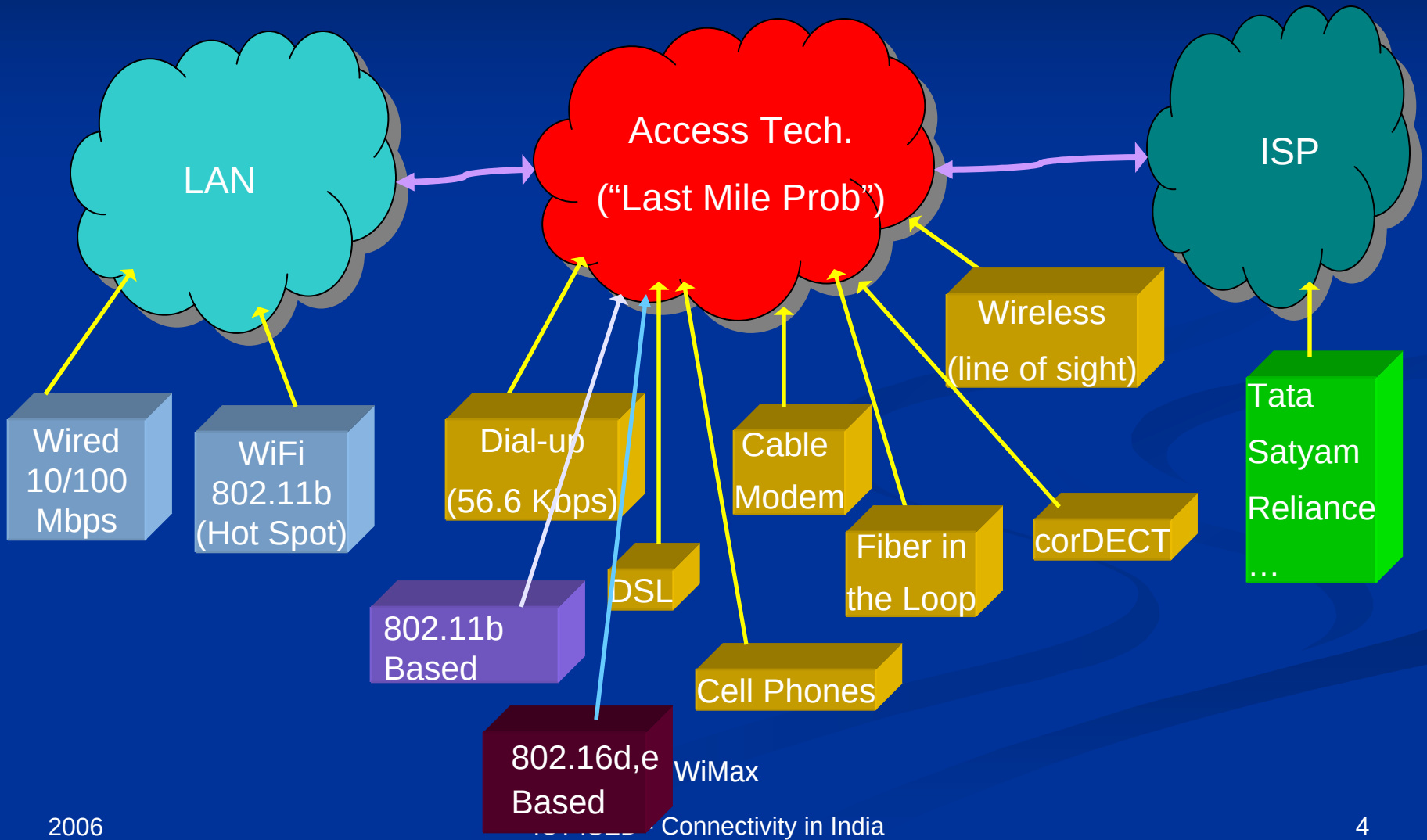
Data Communication Pyramid in India



Urban Scenario for Fiber in the Loop Technology

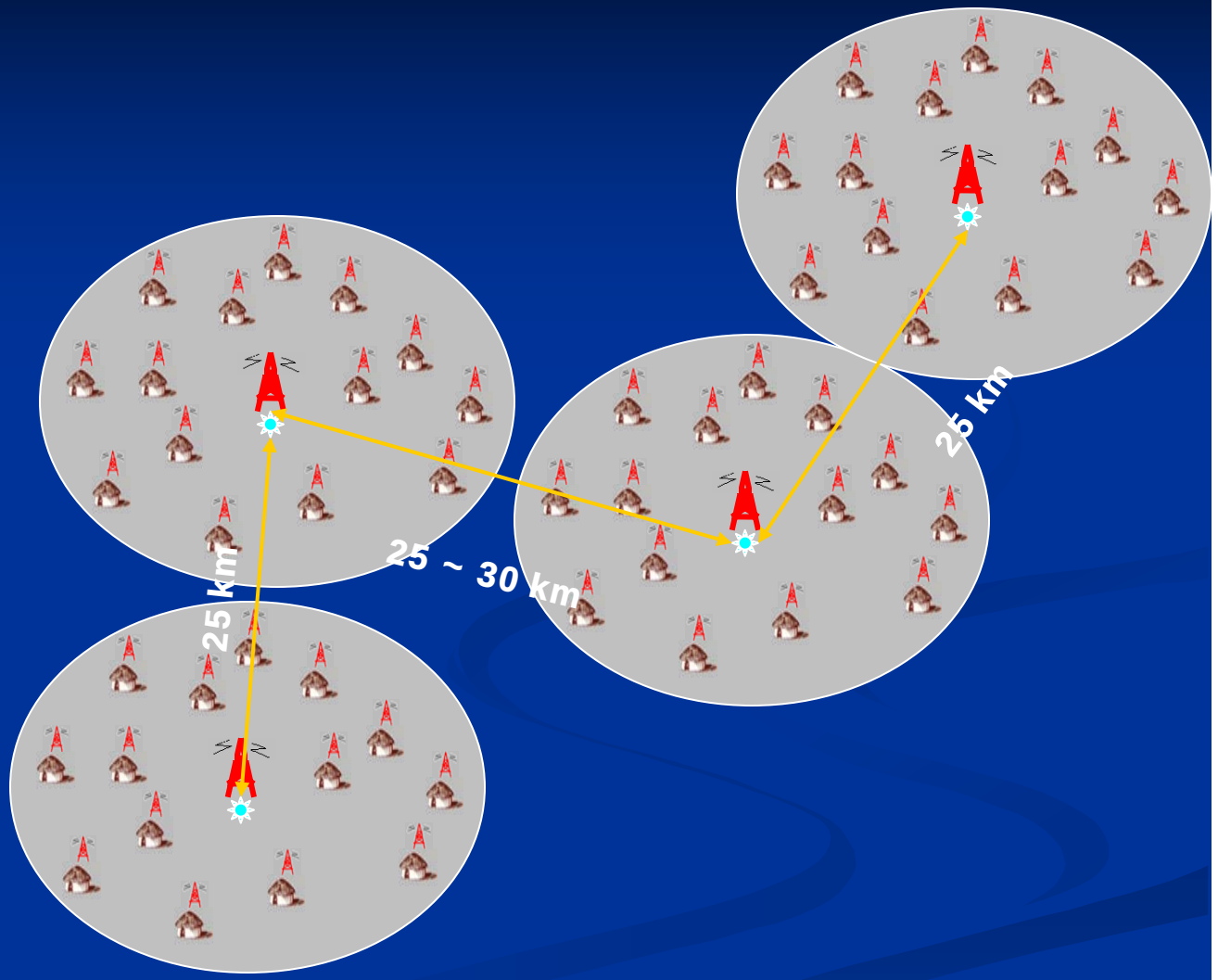


A Look at Access Technologies in India



Fiber Drop in Rural India, ~ 25 km

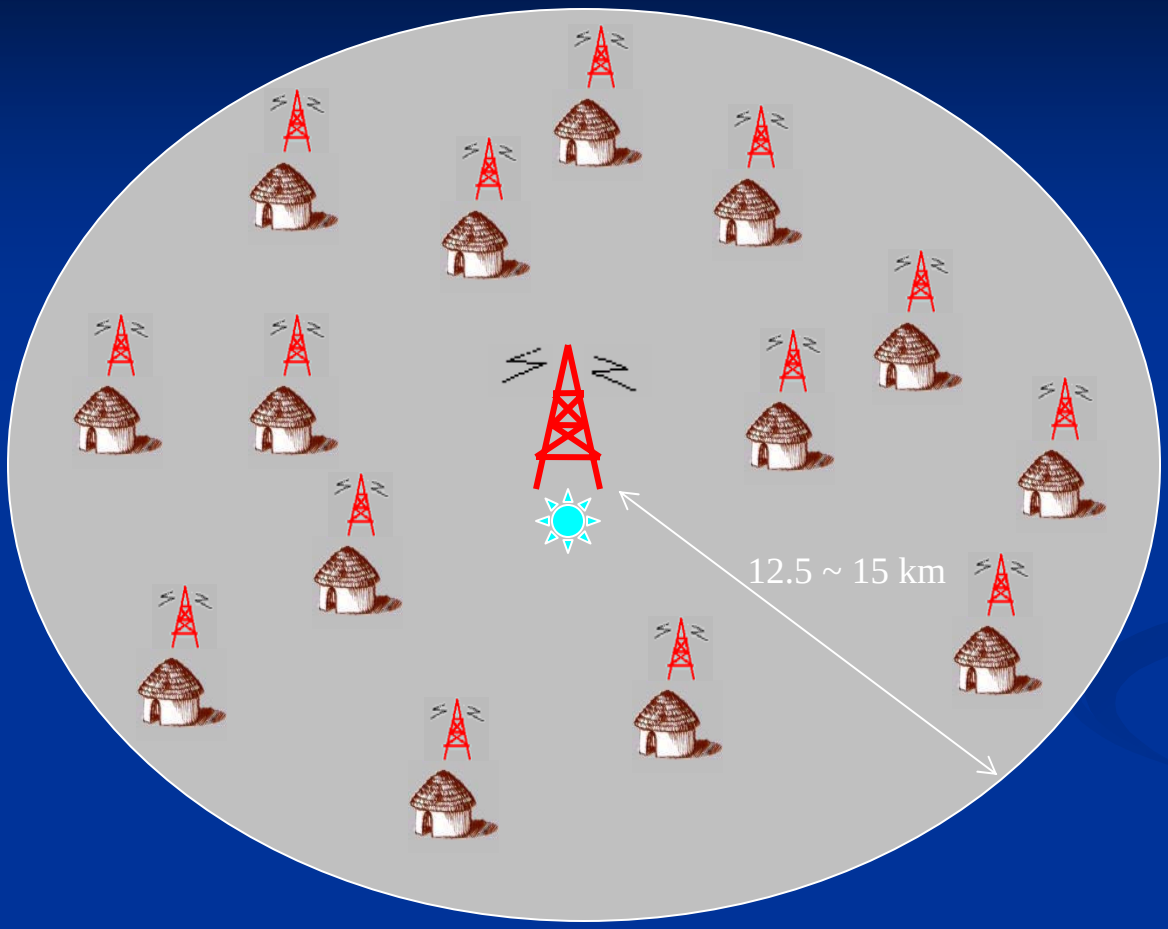
- Avg. Village Area ~ 6 sq. km.
- Total of 600,000 villages in India
- About 100 villages per fiber drop
- Population per village: approx. 500 to 1000



Fiber Drop

Domestically, 30,000 of BSNL's exchanges are connected by fiber, an average of one exchange for 20 villages, not including the contribution of other operators.

Around Each Fiber Drop



- Approx. area covered by each fiber drop is 600 sq.kms.
- We assume each village occupies approx. 6 sq. kms.
- Approx. 100 villages covered by each fiber drop

- **Objective:** Connect all villages to the Internet

Access Point connected to fiber drop

Village node with pole/tower antenna

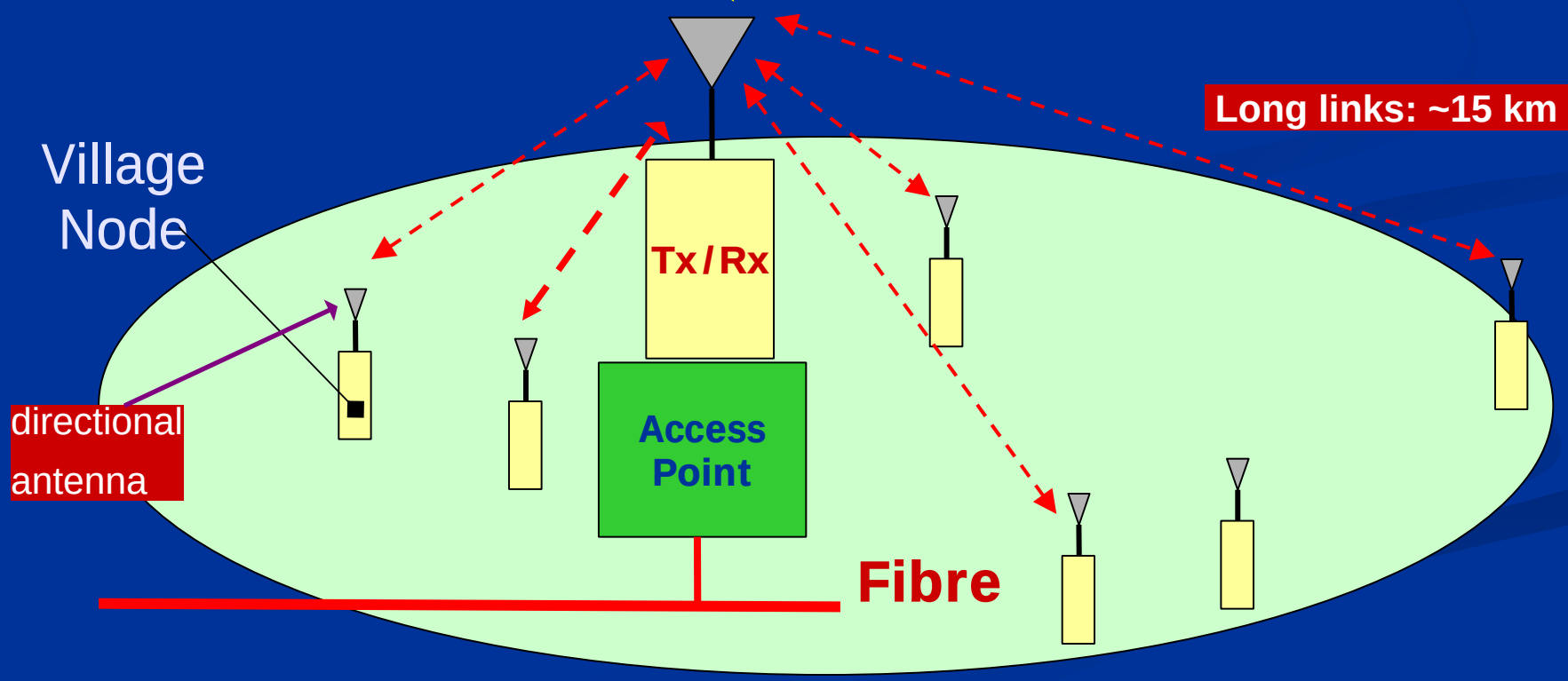
Fiber Drop

Typical Approach: Star Connected Architecture

Access Point (AP) serving ~ 600 sqkm

APs: CorDect
WiFi
Possible: VSAT (non-sectoral)
Emerging: WiMax

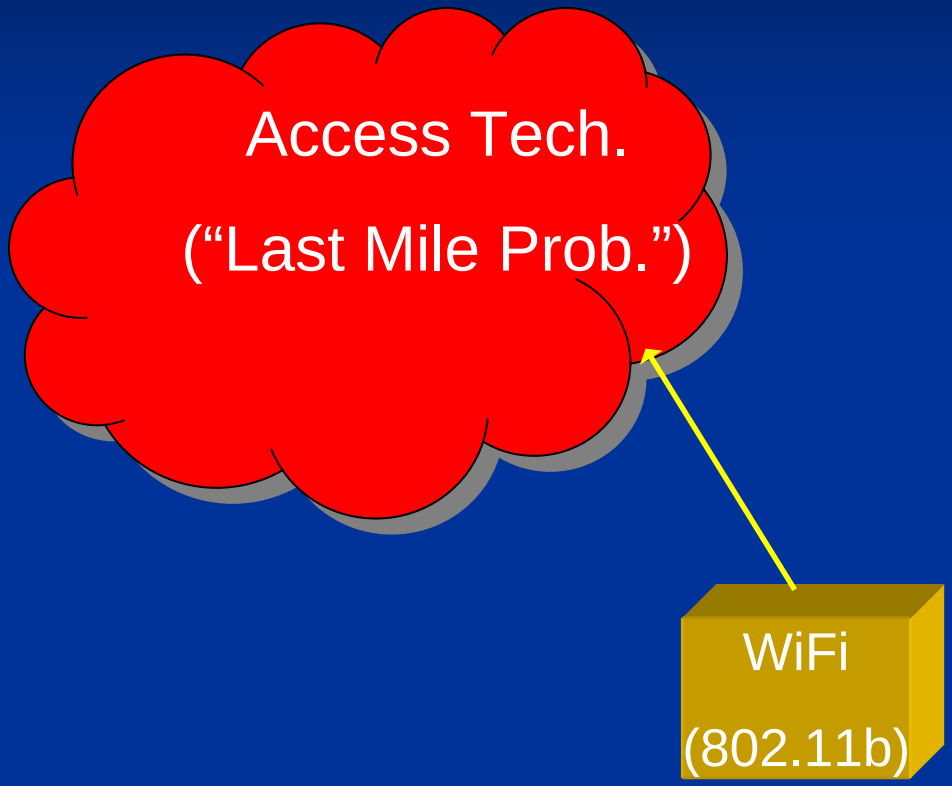
- high gain directional antenna
- sectoral (three sectors, requiring three directional antennas)



CorDECT (IIT-M, TeNeT Group)

- Pioneered by Ashok Jhunjhunwala
- Earlier version
  - guaranteed 70 kbps
- New version
  - BB CorDECT
  - 2 Mbps
- Always on, supports telephony
- Commercially deployed in few thousand villages
- Has also been deployed in Egypt, some African countries
- Manufactured by MAIDAS Communications

WiFi for Access

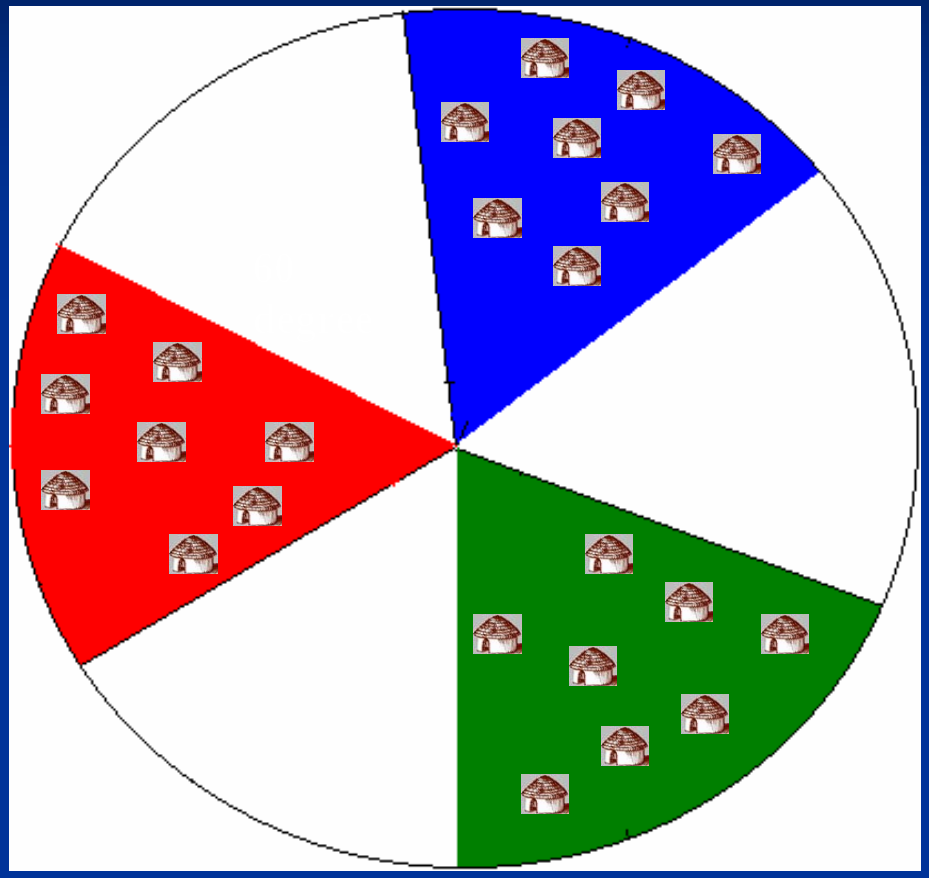


- 802.11b (WiFi, WLAN) ideally suited for hot spots
- Of late extensive R and D to see if 802.11b can be used for access.
- Motivation: Expect 802.11b access to be cheaper, easy to deploy, and obviously broadband
- Operates in the unlicensed band
- Some believe it is not a good access technology since the data spectral efficiency is 0.15/bits/sec/Hz

Key Advantages

- Open IEEE Standard
- Unlicensed Band:
  - 802.11 operates in the unlicensed band (ISM – Industrial Scientific and Medical band) ~ 3 such bands
    - Cordless Telephony: 902 to 928 MHz
    - 802.11b: 2.4 to 2.483 GHz (opened up in India for indoor use and recently for outdoor use)
    - 3rd ISM Band: 5.725 to 5.875 GHz
    - 802.11a: 5.15 to 5.825 GHz (occupies part of 3rd ISM band)
    - 802.16d: 2 to 11 GHz

60° Sectoring



Channel1 Channel2 Channel3

Sectored Coverage

- The three non-overlapping channels in the 2.4 GHz band permit us a maximum of three sectored regions.
- At the fiber drop we will need three 802.11b bridges or gateways.
- Require directional antennas

Connectivity using Cisco Wireless Bridge

Amount in US$

Base Station

Tower	**5000**
Cisco Bridge	2000
Three Directional Antenna (16 dB)	900
	$7900

Client Side

Pole	100
Cisco Bridge	2000
One Directional Antenna (16 dB)	300
	$2400

Price of PC, Printer, power supply not included

Courtesy:
Prof. Dheeraj Sanhgi
IITK

IITK- Digital Gangetic Plains: Testbed

802.11 for last-hop access within a village

Point-to-Point 802.11 link

Sep '02
Safipur

Mar '04
Rasoolabad

Aug '04
Dhaura

Mar '03
Rajajipuram/ Lucknow

5 Km

17.5 Km

39 Km

17.3 Km

22.5 Km

Dec '02
Sarauhan

Nov '02
Bithoor

12 Km

Mandhana
Jun '02

Jun '03
Banthar

37 Km

End to end distance ~80 Km

MS3
Jun '02

0.9 Km

5.1 Km

12 Km

23 Km

22 Km

Mohanpur
Sep '04

3.5 Km

2.3 Km

IITK

Dec '03
Sawayajpur

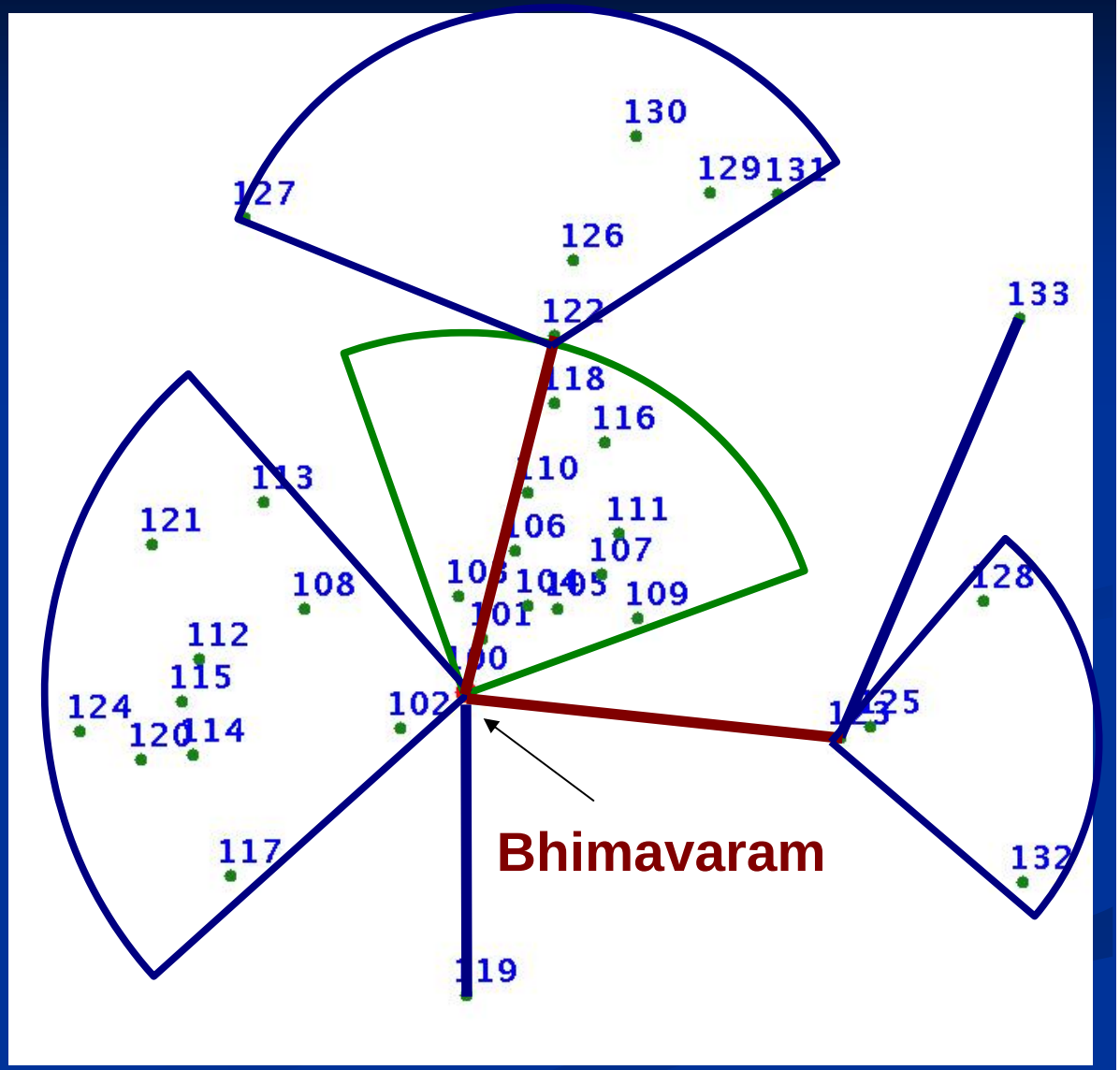
Lodhar
Apr '02

Land-line access point (close to high-population density area)

River Ganges

Not to scale

The Ashwini Deployment (partial) West Godavari District, AP



Issues with current approach

- *Tower costs ~ very high*
- Directional antennas also expensive
  - But to some extent directional antennas unavoidable
- Alignment of village based client directional antenna to base station directional antenna: *an expensive proposition*

Tower and Antenna Assembly

Tower: Most expensive

Requirements:

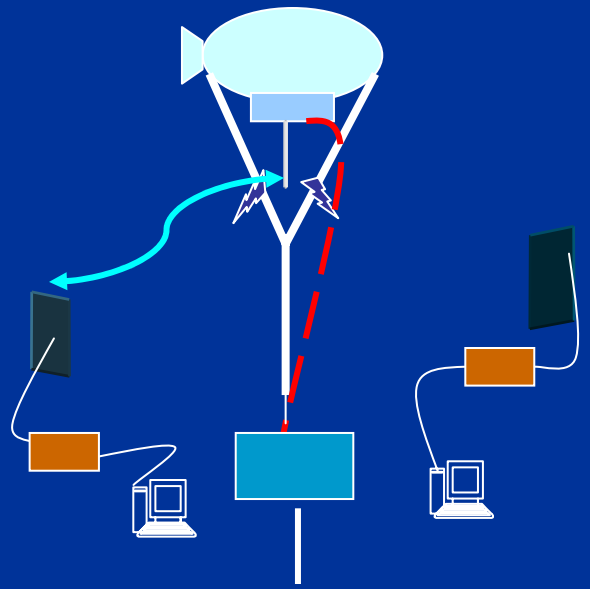
- Line of sight
- Tower (at base station) - for installing directional antennas at about

  50~100 m height
- Pole (at village node) - for installing directional antennas at about 5 m height.
- **Cost**
  - Tower ~ $5000 (50mt)
  - Antenna (16 dB directivity gain):

    60° ~ $300 120° ~ $500
  - Pole ~ $100

Alternate Approach

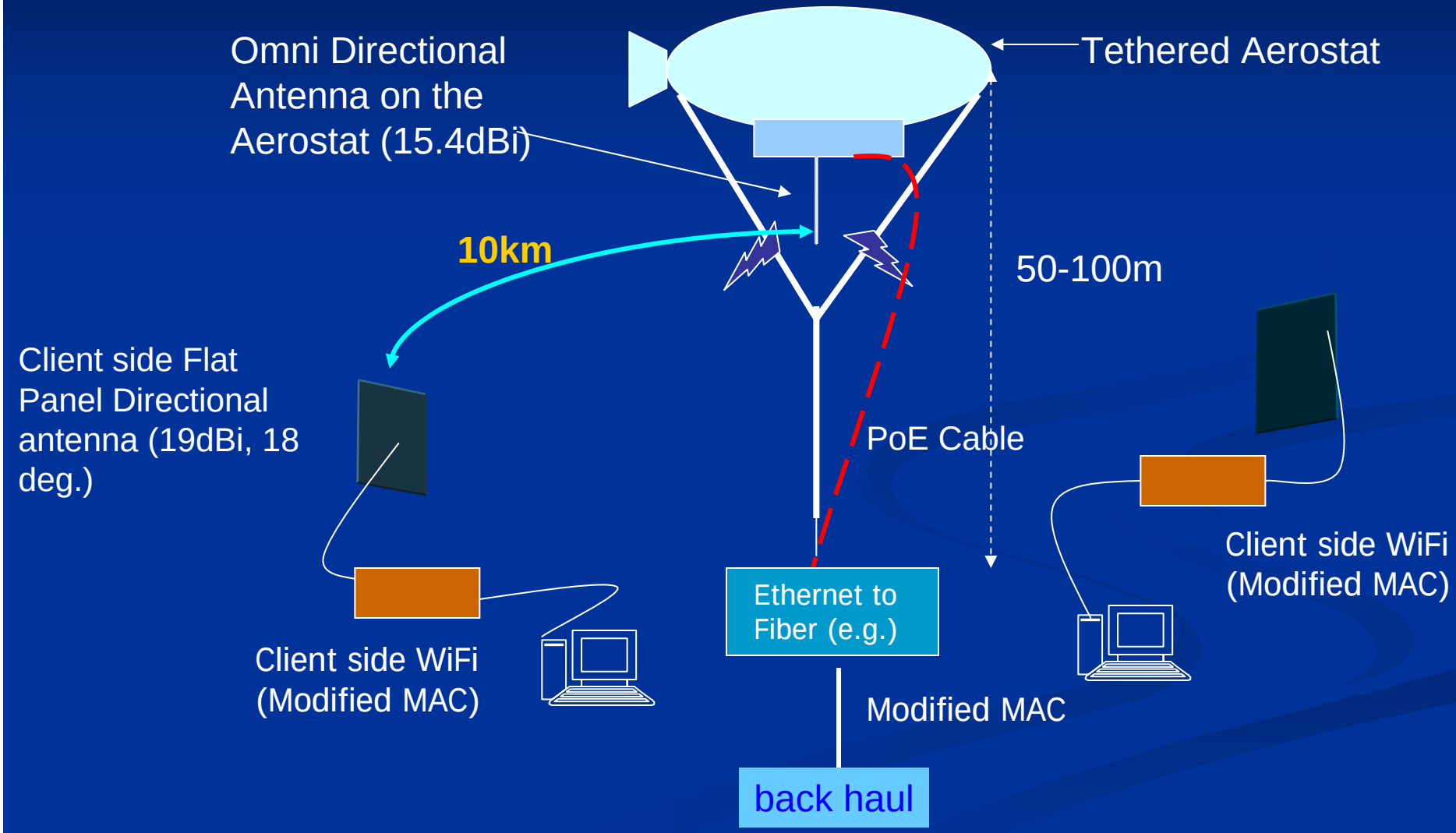
- Use Tethered Aerostat
- Omni directional antenna at the base station



- Aerostat Details :
  - Volume depends on payload
    - Our payload ~ 3kg
    - Consisting of:
      - Antenna, router, Power over Ethernet (PoE) cables
  - Height about 50 -100m
  - Tether – strong
  - Need to refill Helium in 20-30 days

Tethered Aerostat based Network

Collaborating with
Prof. Rajkumar Pant
Of Aerospace Dept., IITB



Cost of Aerostat Assembly

Aerostat		**US$**
	Envelope (1)	800.00
	Tether	80.00
	Winch	120.00
	First time Gas filling (helium)	200.00
	Total	**1200.00**

Running cost: Refilling the aerostat ~ once a month --- US$ 40.00

Cost of the Aerostat based System

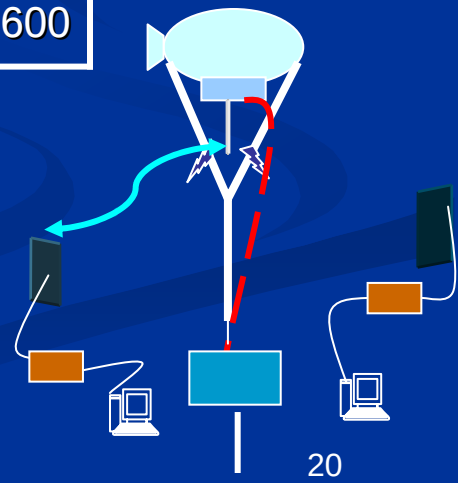
Base Station

Aerostat	1200
WiFi (Modified MAC)	300
Omni Antenna (15 dB)	400
	1900

Client Side

Pole	100
WiFi (modified MAC)	300
One Directional Antenna (18dB)	200
	600

Price of PC, Printer, power supply, etc. not included



Currently Tested in IIT-Bombay

Village Test Site

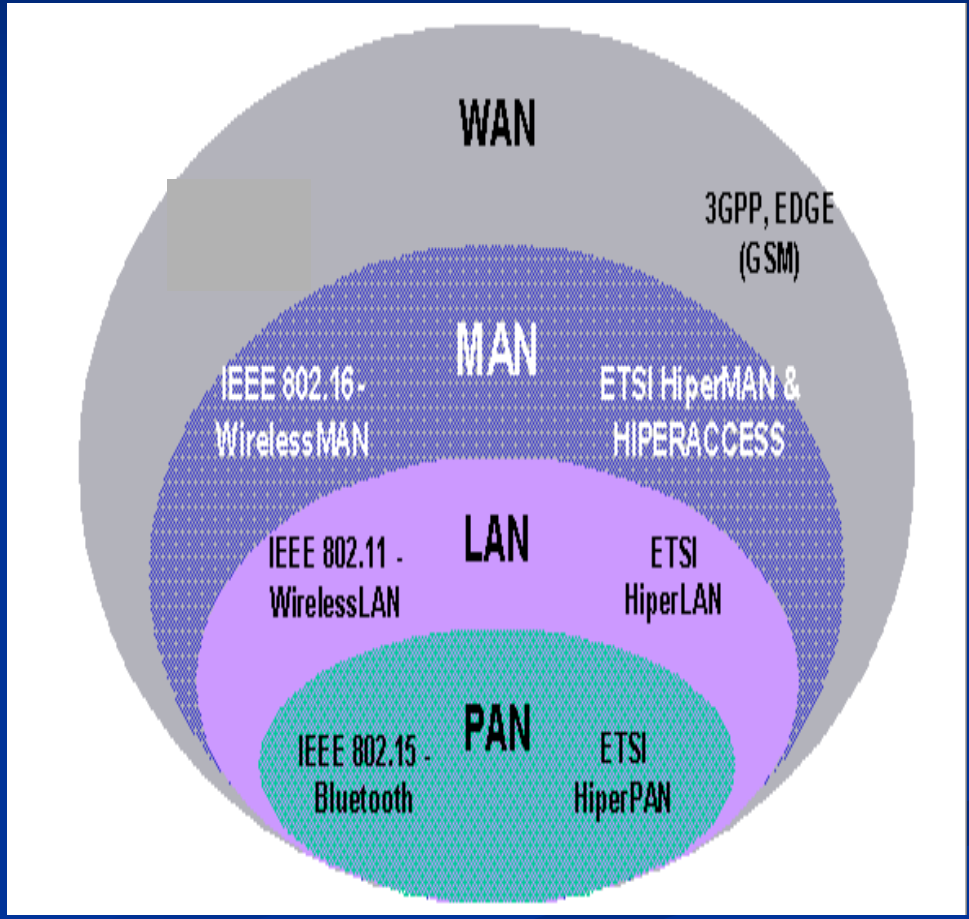
- Location – Kashele, Near Karjat ,Dist. Raigad
- Located centrally-12 villages within 10 kms radius
- About 100 families per village
- ***Hilly terrain***
- Currently no connectivity in villages around
- Difficult to give conventional solutions
- Ideal for our setup
- Partner: Academy of Development Science located in Kashele

Advantages and Disadvantages of Aerostat Based Approach

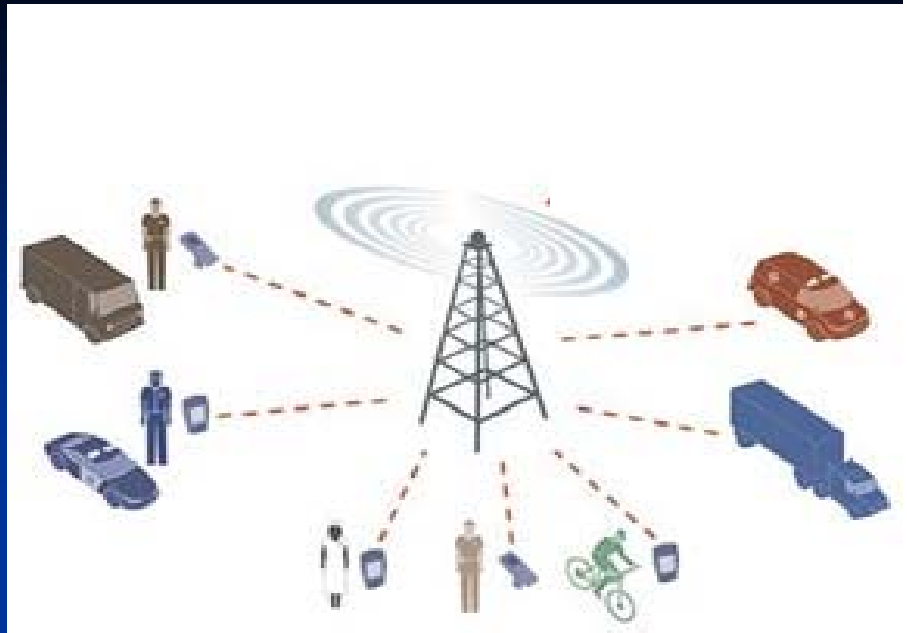
- Advantages
  - Low cost
  - Easy to deploy
  - Portable
  - Useful for hilly terrain
  - Rapid deployment
- Disadvantages
  - Periodic refilling of helium
  - Transportation of helium
  - May require more maintenance

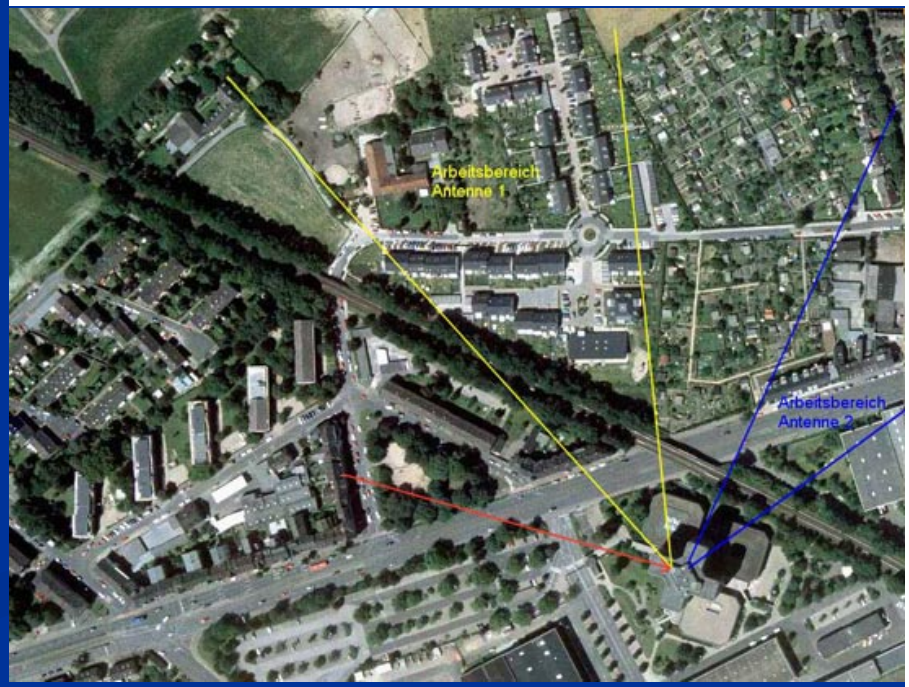
Existing Networks

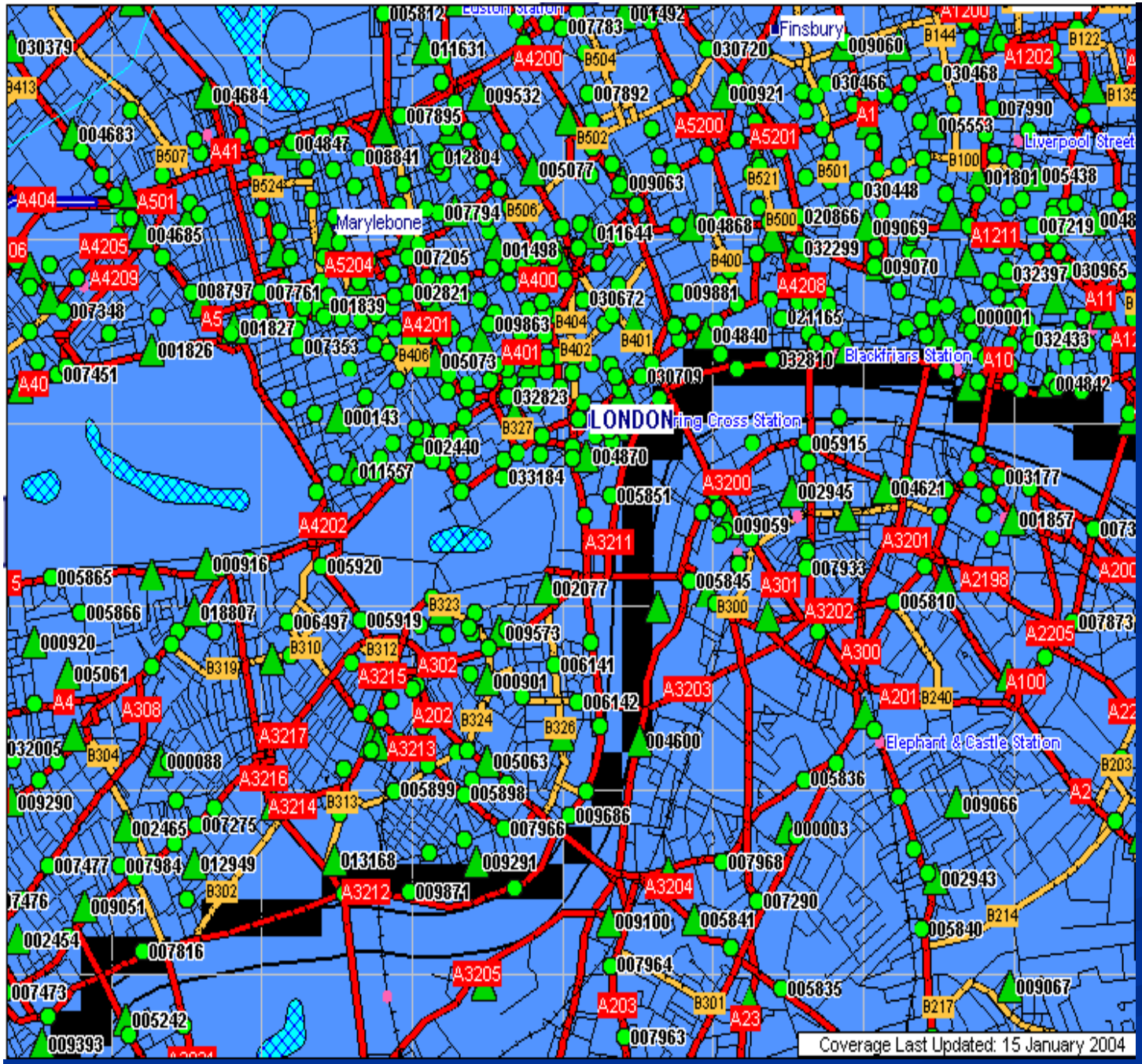
- Almost all existing networks are infrastructure based
  - Cellular networks
    - 2.5G, 3G, ...
  - WiMax
  - Access Point based WiFi networks
  - WMAN (Wireless Metropolitan Area Networks)



- The key ingredients of an infrastructure based wireless network are
  - Central Coordination unit (Base Station, Mobile Switiching Center in celluar comunication)
  - *Single-hop architecture*
  - *Non-coperative:* Individuals don't have to cooperate
  - *"Dumb"* client side terminal. All the "*Intelligence" resides with the* Central Coordination Unit



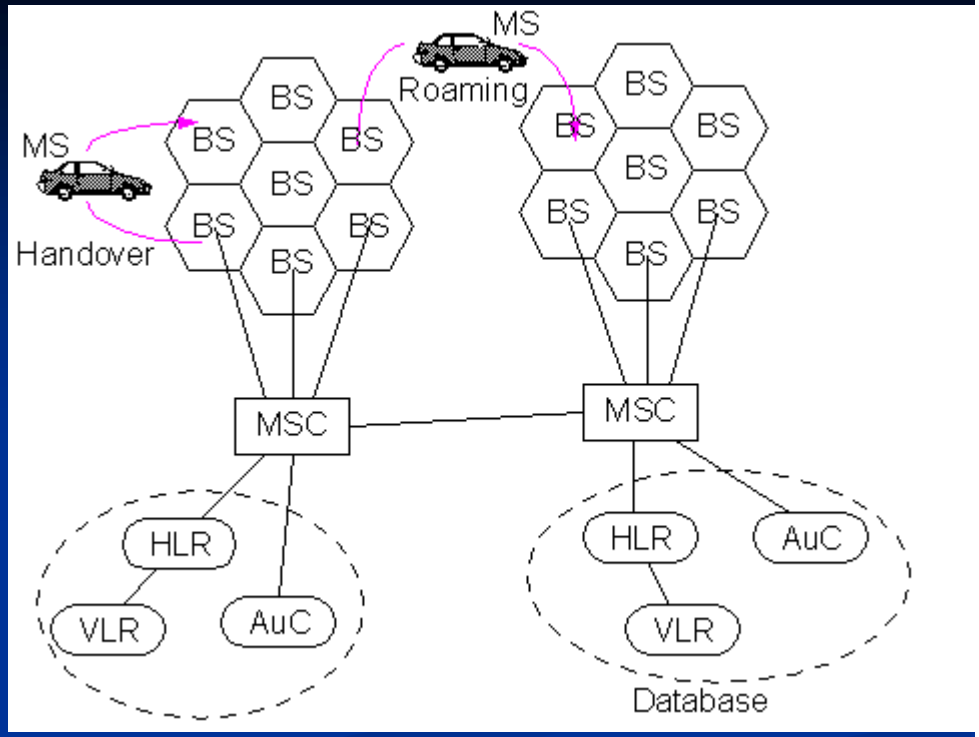




The webmap of the network infrastructure of 02, a major mobile phone provider in the United Kingdom. Green triangle and circle symbols represent cell sites

http://www.cybergeography.org/atlas/wireless.html

- Key Advantages :
  - Ease of Management (Tech. and Business)
  - Reliability
  - Ease of monitoring and billings
- Key disadvantages
  - Cost of infrastructure
  - Cost to consumer
  - Spectrum use can be made more efficient using alternate technologies
  - Time for deployment
  - Capacity increased by increasing infrastructure
  - Cell size in metros being reduced 300 m radius
  - Almost approaching the cell size of a WiFi network ~ 100 m
  - ...



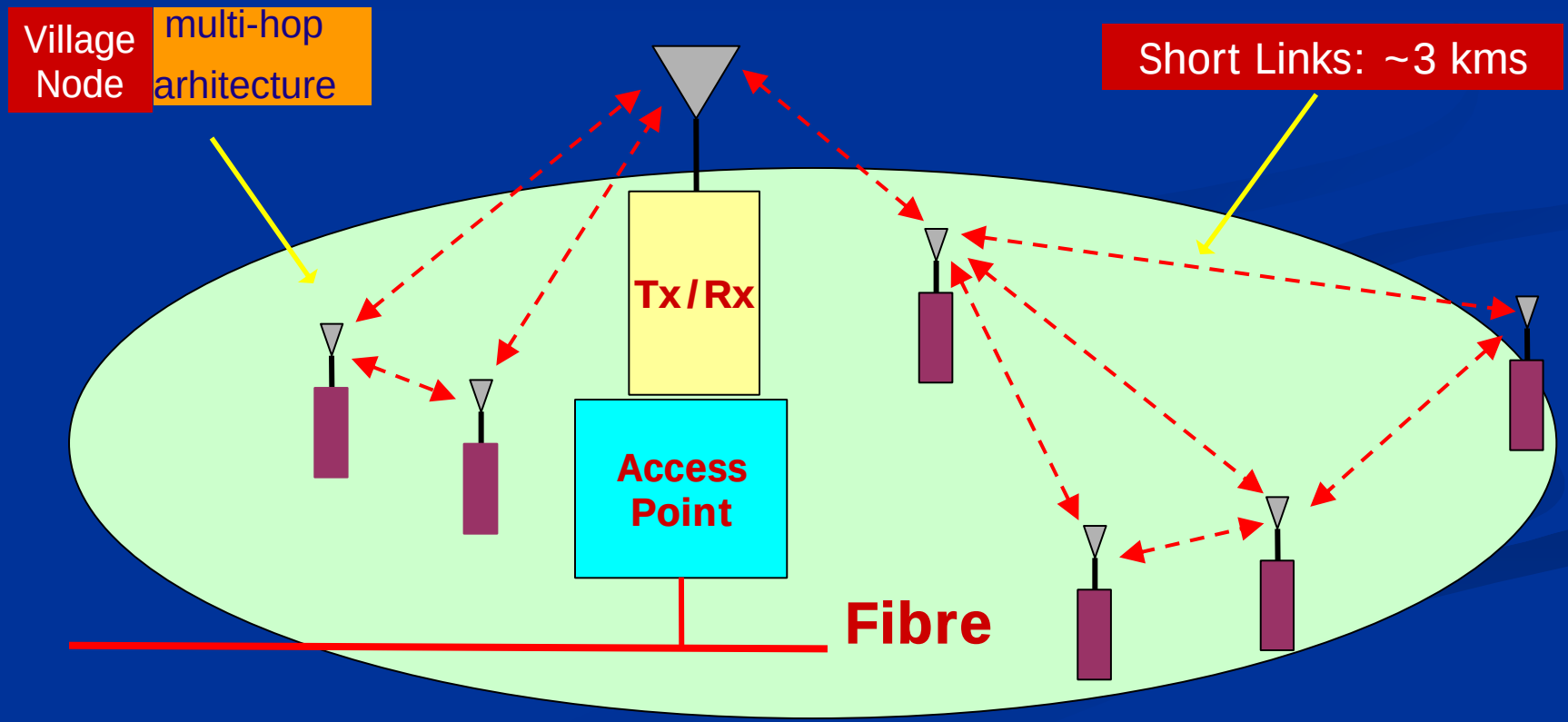
Infrastrucuture*less* Networks
A Paradigm Shift

- Minimal dependence on infrastructure
- Work cooperatively
- Basic communication over short range
- Requires a Smart user terminal
- Tolerance to base station failures

- Typically talked about under
  - Ad hoc networks
  - **Mesh networks**
  - Multi-hop cellular networks
  - Cooperative networks

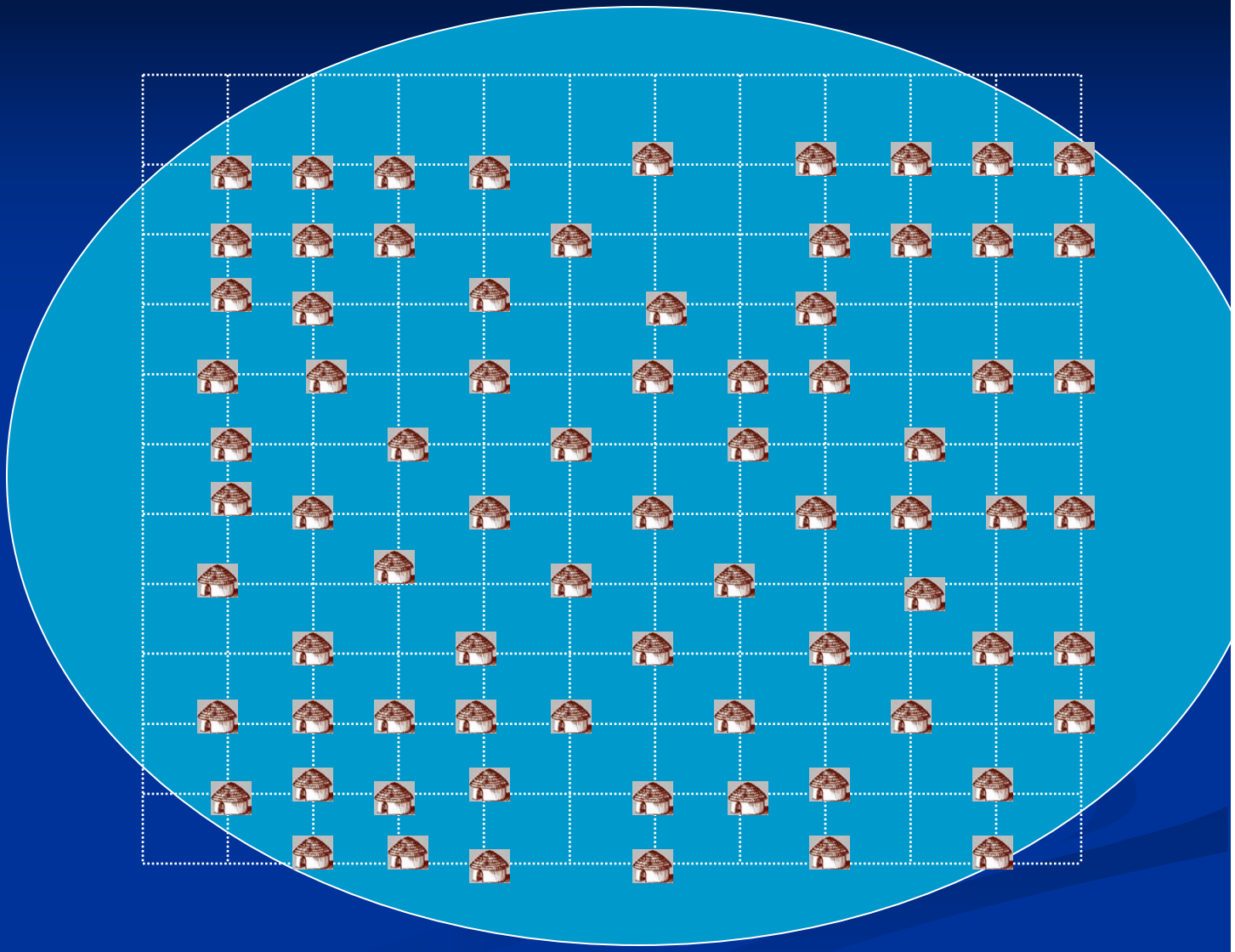
Future Work: Mesh Networks

Mesh network serving ~ 600 sq km



Assumptions

- 600 sq kms
- 120 villages
- On avg. dist. between villages approx. 2 to 2.5kms
- Each hop is approx 2 to 2.5 kms
- Max. hops to fiber drop, approx. 6



Cost of a typical Client / Base station

Equipment	Cost
10-15m Mast	100
Access Point	100
8 dB Omni-Directional Antenna	75
Total	**275**

Cisco Aeronet Bridge based System

Base Station

Tower	**5000**
Cisco Bridge	2000
Three Directional Antenna (16 dB)	900
	$7900

Client Side

Pole	100
Cisco Bridge	2000
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	1900

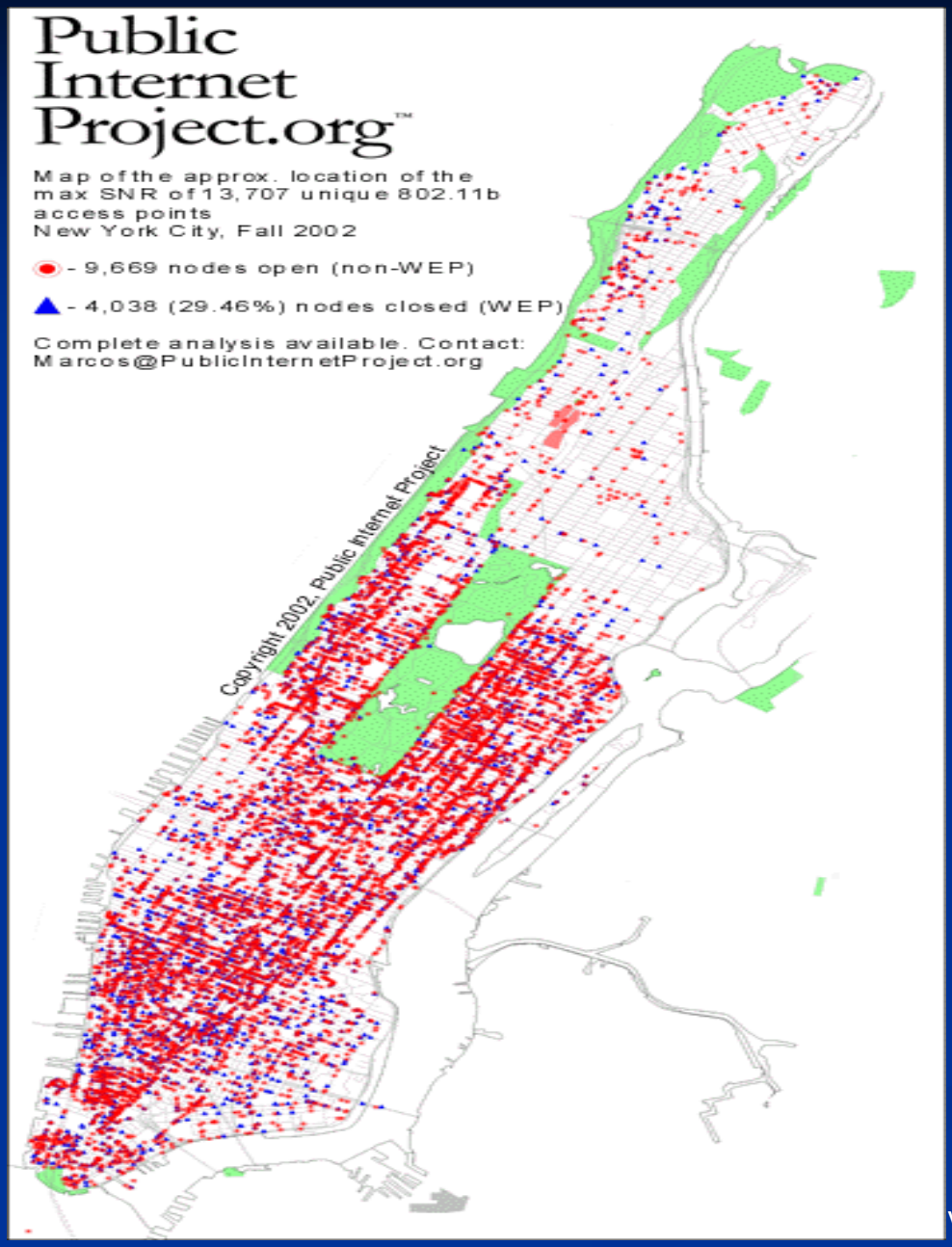
Pole	100
WiFi (modified MAC)	300
One Directional Antenna (18dB)	200
	600

Mesh Network Based System

Equipment	**Cost**
10-15m Mast	100
Access Point	100
8 dB Omni-Directional Antenna	75
Total	**275**

- WE are currently experimenting with Micrisoft Research's public domain mesh networking software http://research.microsoft.com/mesh/

Community Networks



- Manhattan area in NY
- 13707 unique nodes
- 9669 nodes not secure protected
- 4038 secured
- Nodes identified by probing using a 802.11b card from a car with GPS capability
- Case of Bryant Park community network

Some Community Mesh Network Projects

- Apirede, Ghana
- Elgin, IL, USA
- Farragut Park, DC, USA
- Homer, IL, USA
- Lawrence, KS, USA
- Mamelodi, South Africa
- New Orleans, LA, USA
- N. Lawndale, IL, USA
- Pilsen, IL, USA
- Tribal Digital Village, CA, USA
- Urbana, IL, USA
- Google Launches City Wide WiFi Network for Mountain View, CA
- CUWiN/UIUC Partnership Awarded $500,000 NSF Grant To Develop High-Performance Open Source Mesh Wireless Technologies.
- Kingsbridge Mesh Goes Live!
- Community Mesh Network for Mahavilachchiya, Sri Lanka
- Philly to Defy Telecom Giants, Set Up Public Wireless **Network ...**
- New book about Philadelphia municipal wireless network

Mesh Networks will make an impact soon; 802.11s

Welcome to MeshAP Steps

- *These pages are intended to guide you through a step by step setup of a mesh. This is intended as basic education and training to get a mesh online following LocustWorld best practices*
- A moderated mailing list exists for the purpose of asking questions relating to each step and for providing model answers as well as extending this wiki. For information on joining this mailing list, please see MeshApStepsMailingList
- The steps that should be followed are outlined below:
- MindSet
- HardWare
- SoftWare
- FirstNode
- WianaRegistration
- AccessControls
- MoreNodes
- DeployingNodes
- TestingMeshConnectivity
- FeedbackAndTuning
- ContributingToLocustWorld

- http://www.locustworld.com/meshapsteps/wiki

Commons Model for Spectrum Usage

- Spectrum is typically is licensed (except for 2.4 GHz band)
- Approach to spectrum utilization is analogous to real estate – property model
- What is proposed in many countries is Commons Model

- Why do I mention this?
  - Cooperative sharing of spectrum
  - Close links with idea of Multi-hop cellular networks
    - *Essentially a cooperative network*

- Tragedy of Commons:
  - Different users will co-exist in the commons band
  - Some users could use the spectrum inefficiently causing degradation in performance for other users
- How to overcome this problem
  - Technological challenge
    - Development of novel protocols
    - Development of novel Physical layer algorithms
  - There is strong possibilities for this because of the success of 2.4 GHz (WiFi) in public parks and public spaces
- *I believe, there is need to delicense more spectrum under the commons model*