Technology for Developing Regions

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and the **TIER** Students & Faculty

The "Base of the Pyramid"

- 3-4 billion people
  - Equivalent purchasing power < $2/day
- Could swell to 6-8 billion over next 25 years
- Most live in rural villages or urban slums
  - Movement towards urbanization
- Education levels are low or non-existent
  - Especially for women
    - => high birth rates => more poverty
- Markets are hard to reach, disorganized

Traditional Development

- Very top down
  - International agencies fund big projects
  - Often with stings and debt attached
  - Difficult to manage (e.g. corruption)
- Little role for high technology
  - (some role for medicine, agricultural tech)
  - Agencies have almost no technical capacity
  - Technology chosen/used by large contractors

Cellphone Success Story

- 3-4B cellphone users worldwide
  - Vastly outpaces TV, PCs,
  - Africa is the fastest growing market
- 1.13 billion phones sold in 2009
  - Versus 0.3 billion PCs
- Driven by bottom-up demand:
  - Ease of use (voice)
  - Need for communications: work, remittances
  - Prepaid minutes and scratch-off cards

Bottom-up Financing

Remittances

- Money sent back home to relatives
- Remittance flows:
  - **Philippines $14B (13% GDP)**
  - North Africa: $17.6B
  - West Africa: $10.4B
  - Central Africa: $2.7B   } $40B
  - East Africa: $5.9B
  - South Africa: $2.0B
- Many small payments
- Critical part of the economy
 - Largely informal
  - Not always legal

Northern Africa (US$ million)		(GDP)
Algeria	5,399	4.7%
Egypt	3,637	3.4%
Libyan Arab Jamahiriya	134	0.3%
Morocco	6,116	10.7%
Sudan	769	2.0%
Tunisia	1,559	5.1%
Total	17,614	

Eastern Africa (US$ million)		(GDP)
Burundi	184	22.8%
Comoros	85	21.1%
Eritrea	411	37.9%
Ethiopia	591	4.4%
Kenya	796	3.8%
Madagascar	316	5.7%
Malawi	102	4.6%
Mauritius	356	5.5%
Mozambique	565	7.4%
Rwanda	149	6.0%
Somalia	790	-
Uganda	642	6.9%
United Republic of Tanzania	313	2.4%
Zambia	201	1.6%
Zimbabwe	361	7.2%
Total	5,929	

Western Africa (US$ million)		(GDP)
Benin	263	5.5%
Burkina Faso	507	8.2%
Cape Verde	391	34.2%
Côte d'Ivoire	282	1.6%
Gambia	87	17.0%
Ghana	851	6.6%
Guinea	286	8.6%
Liberia	163	25.8%
Mali	739	12.5%
Mauritania	103	3.9%
Niger	205	5.8%
Nigeria	5,397	4.7%
Senegal	667	7.5%
Sierra Leone	168	11.6%
Togo	142	6.4%
Total	10,399	

Central Africa (US$ million)		(GDP)
Angola	969	2.2%
Cameroon	267	1.5%
Central African Republic	73	4.9%
Chad	137	2.1%
Congo	423	5.7%
Democratic Republic of the Congo	636	7.4%
Equatorial Guinea	77	0.9%
Gabon	60	0.6%
Total	2,690	

Southern Africa (US$ million)		(GDP)
Lesotho	355	24.1%
South Africa	1,489	0.6%
Swaziland	89	3.4%
Total	1,979	
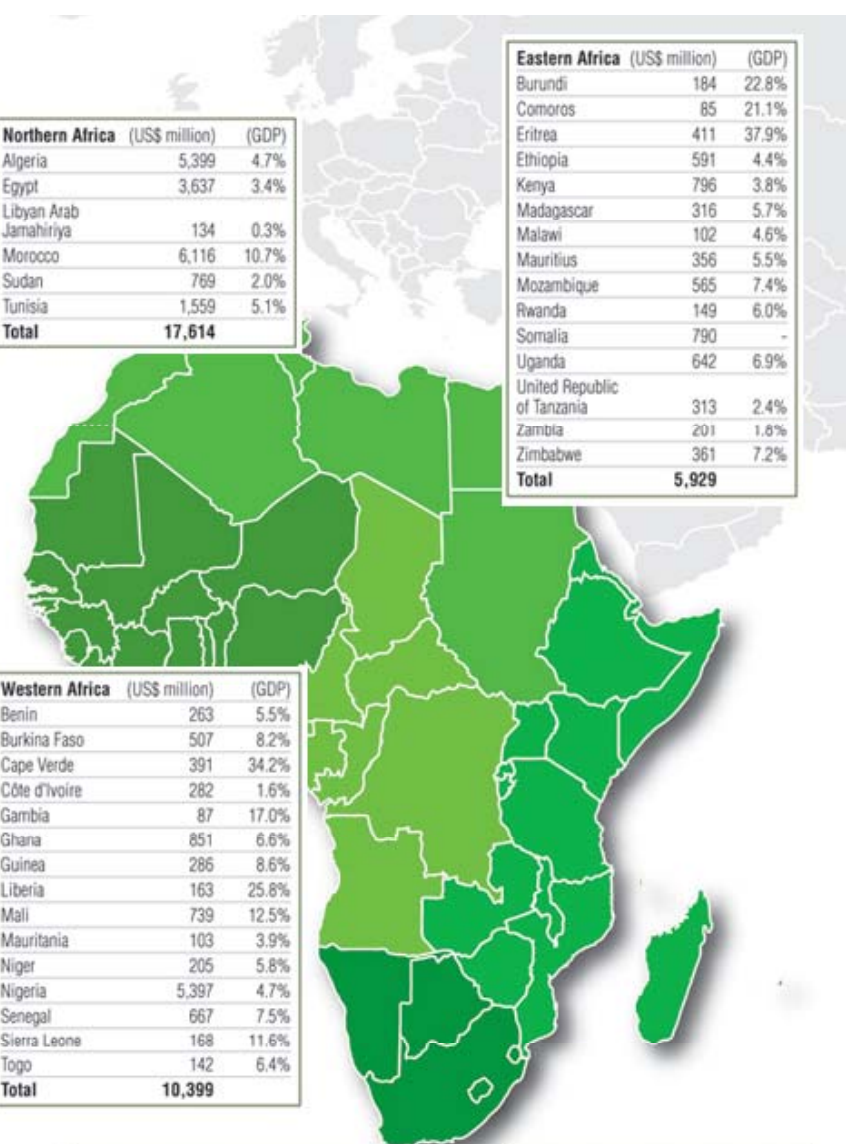
Microfinance: Grameen Bank

- Owned entirely by the poor
  - Began in one village in 1976
  - 2.6 million borrowers (95% women), over 1,000 branches in over 42,000 villages. 12,000 staff.
- Has loaned more than US$3.9B since inception
  - Over US$3.5B repaid with interest (98.75% recovery rate); $290M loaned in the last 12 months.
- Has never accepted any charity — has always been a profitable social enterprise
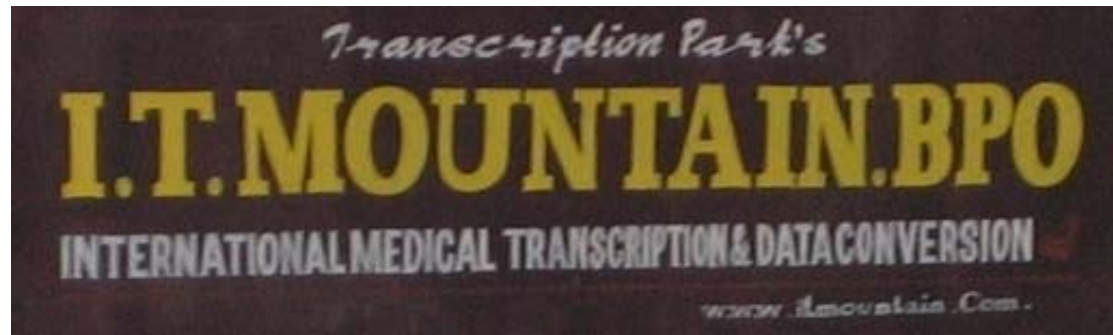- 46.5% of borrowers have crossed the poverty line

Bottom-up Businesses

Grameen Telecom
Cellular in rural Bangladesh

- 'Village Phone'
  - Buy phone, rent to your neighbors
- So far over 95,000 loans of average US$200 have been given to buy mobile phones.
- Covers 50,000 of 68,000 villages
  - 60M users
  - => Scales!
- Phone Lady income up by 2x
  - Maintains the system
  - => Works!
  - Example of new rural income

I.T. MOUNTAIN.BPO
Transcription Park's
INTERNATIONAL MEDICAL TRANSCRIPTION & DATA CONVERSION
www.itmountain.Com.

- Medical transcription
- Audio in, text out
- Customers in US, India

- Rural Kerela:
  - 30km from a small city
  - cheaper than Bangalore, Chennai, etc.
- Pays 5-8 cents/line
  - about $8/hour
- Transcribe 3 times then merge!

WiFi enabled rural income

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The Urban-Rural Divide

- Sadly, cellular is an urban phenomenon
  - Need user density to pay for basestations
- Grameen Telecom is not an exception
  - Ignores basestations (subsidized)
  - Bangladesh is a very dense country (not rural)
- The urban world might be "flat"
  - Bangalore is more like LA than Indian village
  - But rural world is on a different plane

Where are we?
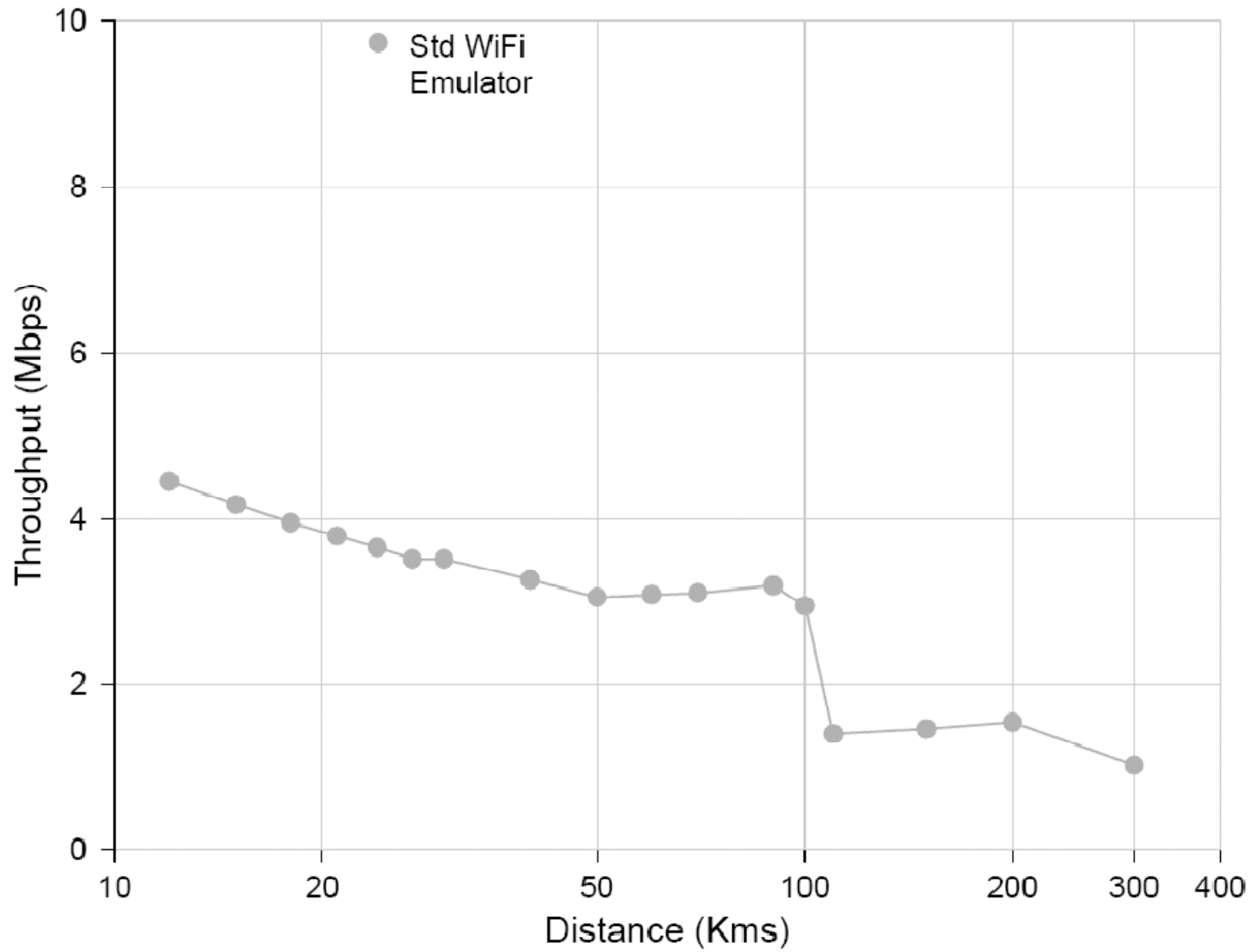

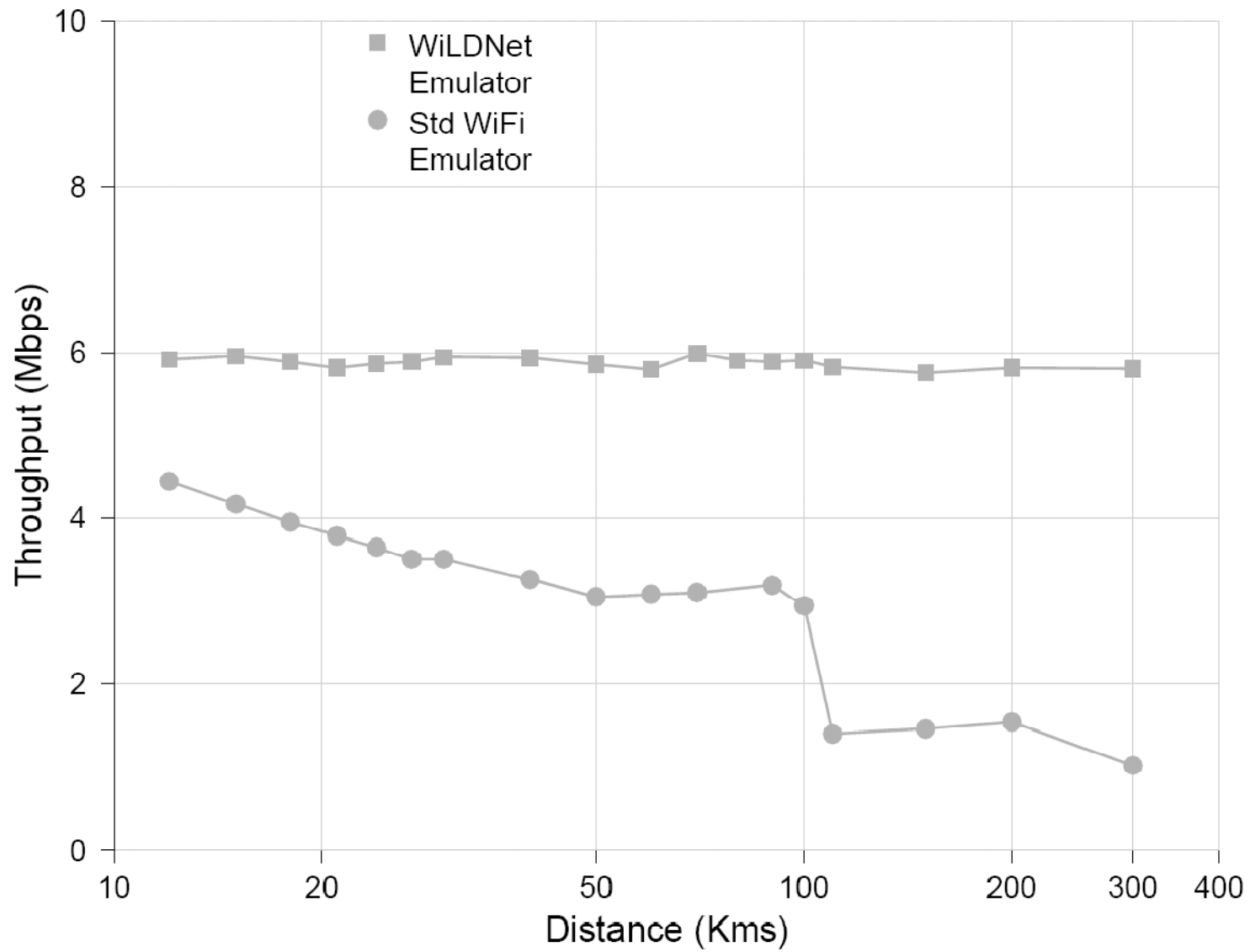Manila, Philippines   Edmonton, Canada

Part 2: Rural Connectivity

Why WiFi?

- Very low cost due to huge volume
- Unlicensed spectrum (mostly!)
- Incremental deployment
  - Limited capital
  - Start small, grow over time

- Our innovations:
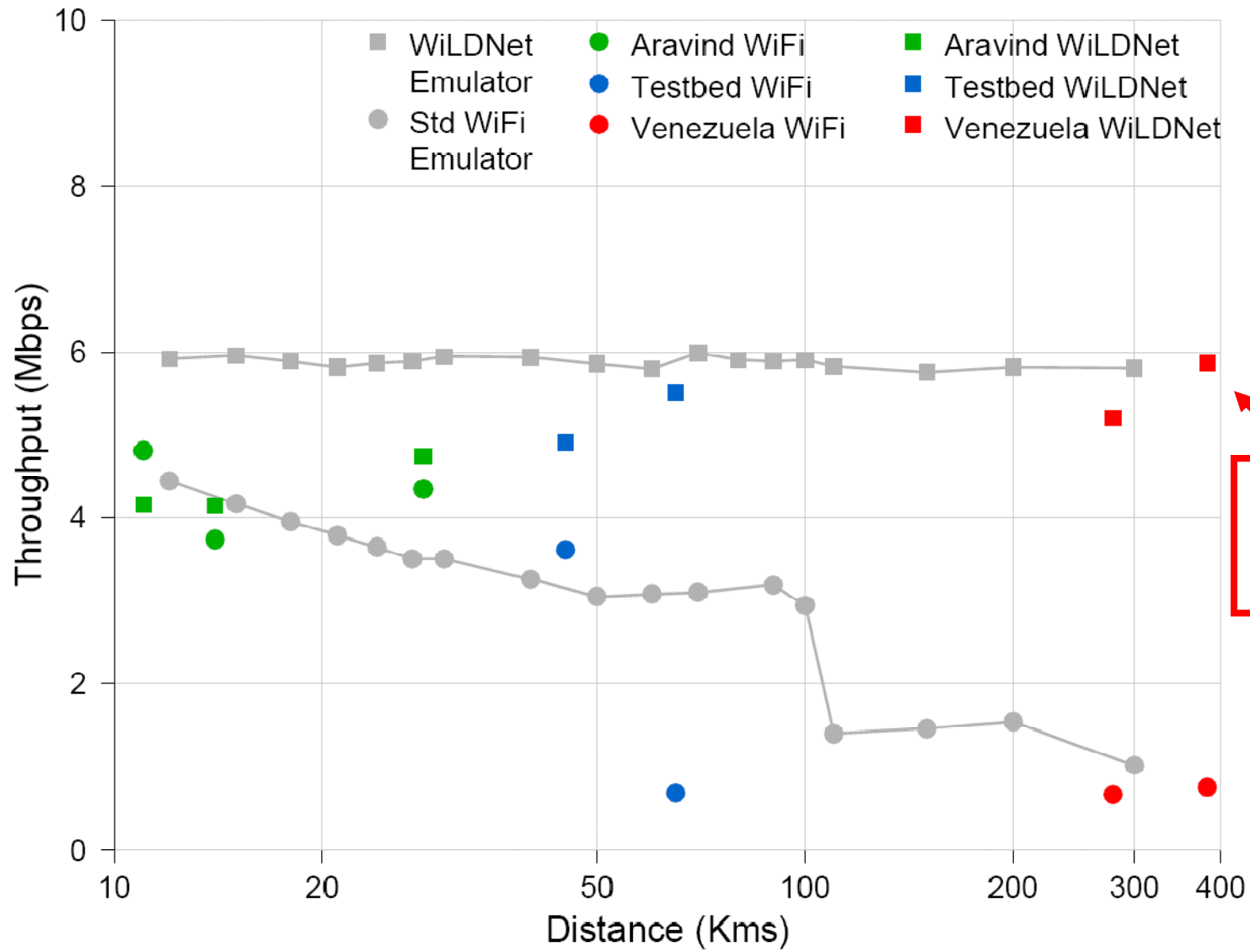 - New software for very long distances
  - Better use of spectrum

NSDI 2007: WiLDNet Results

New World Record – 382 Kms

Pico El Aguila, Venezuela

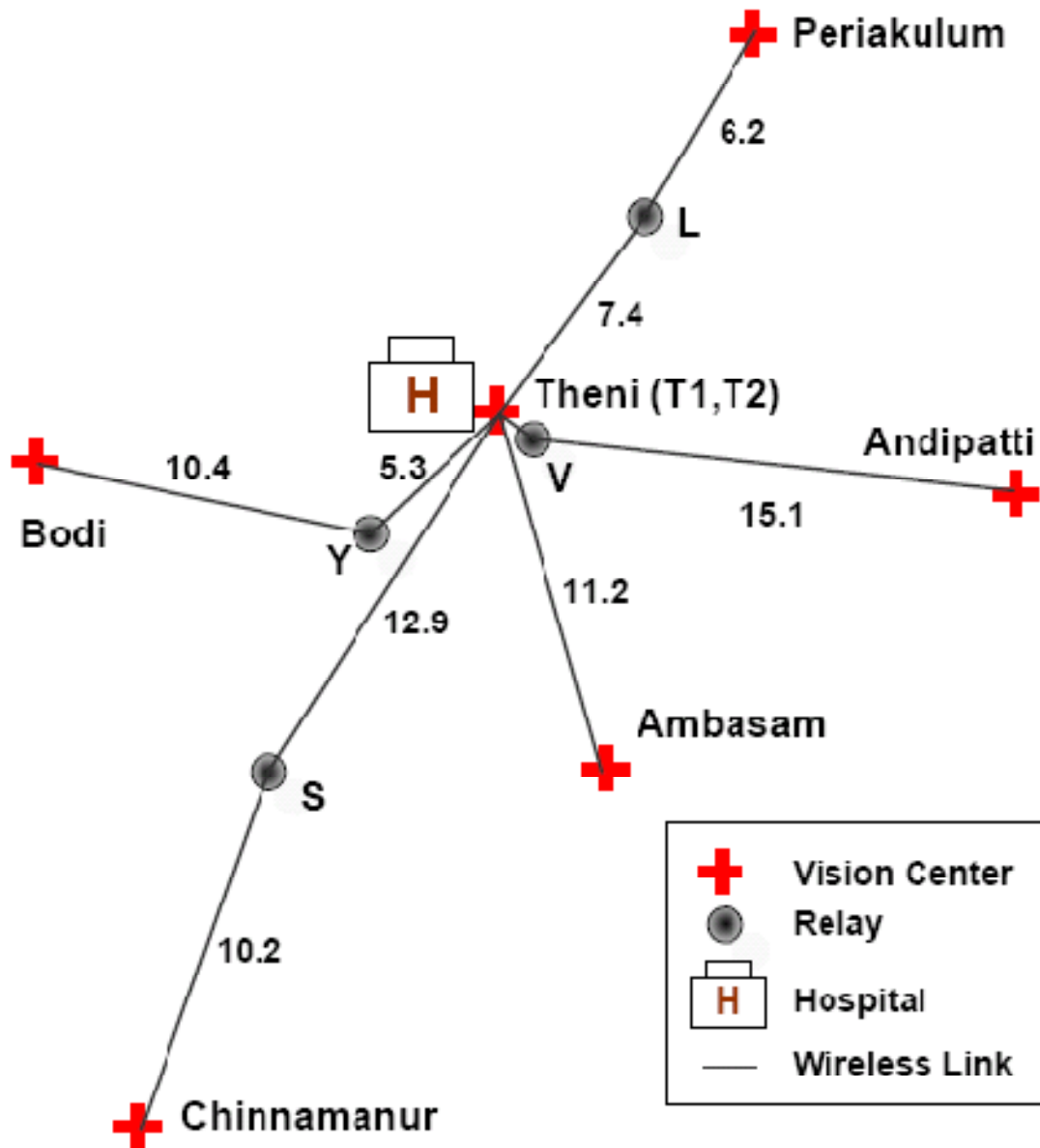Elev: 4200 meters

Rural Telemedicine

- **Aravind Eye Hospitals**
  - Tamil Nadu, India
  - 5 hospitals
  - But too far for most to walk

- **Need:**
  - 15M blind in India
  - 70% of blindness treatable
  - 7% in rural areas get care

- **Goals:**
  - 50 rural vision centers
  - Diagnosis and prevention

Aravind Eye Hospital Network

- Achieve 4-5 Mb/s per link
- Video-conferencing
- E-m ail, training
- 6000 consultations/month

Network diagram labels:

Periakulum, 6.2, L, 7.4, H, Theni (T1,T2), Andipatti, Bodi, 10.4, 5.3, V, 15.1, Y, 11.2, 12.9, Ambasam, S, 10.2, Chinnamanur

Legend:
- ✚ Vision Center
- ● Relay
- H Hospital
- — Wireless Link
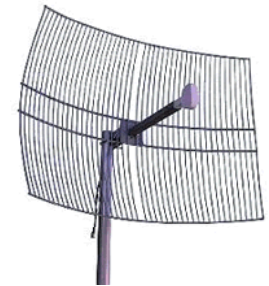
Routers used: PC Engines Wrap boards, 266 Mhz CPU, 512 MB
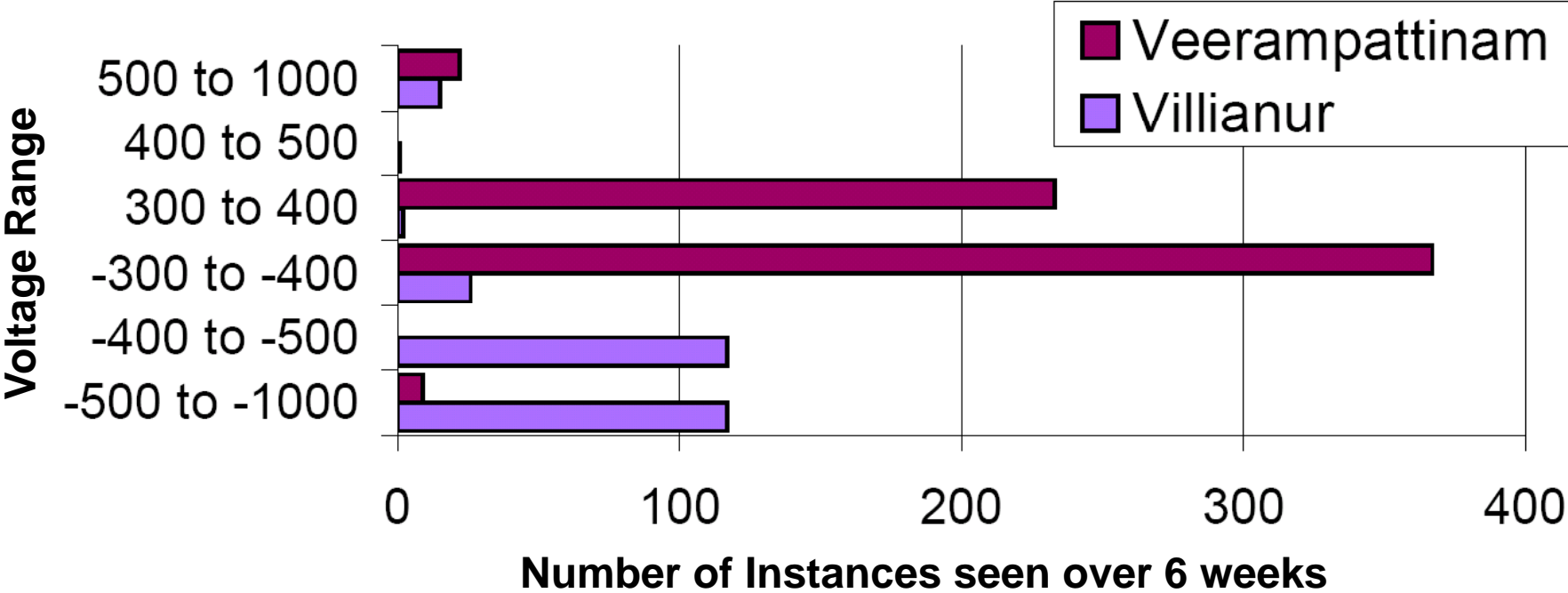*Cost*: $140

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Real Impact

- Over 160,000 patients so far
- Centers are cash-flow positive
- Over 25,000 patients have recovered sight
- Growing to 50 centers covering 2.5M people
- Hoping to replicate in other cities

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Part 3: Electric Power

Poor Quality Power

Bar chart titled with legend: Veerampattinam (dark magenta), Villianur (light purple).

X-axis: Number of Instances seen over 6 weeks (0 to 400)
Y-axis: Voltage Range

Voltage Range	Veerampattinam	Villianur
500 to 1000	~20	~12
400 to 500	~2	
300 to 400	~235	~2
-300 to -400	~370	~25
-400 to -500		~115
-500 to -1000	~10	~118

Spikes and Swells:
- Lost 50 power adapters
- Burned 30 PoE ports

Low Voltages:
- Incomplete boots
- HW watchdog fails

Frequent Fluctuations:
- CF corruptions
- Battery Damage

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What about UPS?

- "Affordable" UPS systems ($300) are of *standby-type*
  - Primary source is grid
  - Secondary source is battery
  - **Good quality power supplied only during outage!**
  - 2006 fault episodes include use of UPS

Part 4: Storage

Some Sad Stories

- Rapid loss of history in Africa
  - Radio archives destroyed in Guinea-Bissau, Madagascar
- 6000 languages in Africa
  - Most are dying
  - Few recordings
- Most African radio stations
  - … don't record their programs
  - … due to lack of storage

Digital Study Hall
Randy Wang, UW

- Idea: Capture the best lectures on DVD
  - Local language
  - Distribute them widely
  - Local teachers "mediate" them
- 1500 recordings of lessons in English, math, and science
  - in Hindi, Bengali, Kannada, Marathi, Tamil, and English
- 30 schools so far

Storage Basics

- We need shared storage:
  - To capture local content
  - To bring in global content
- Systems are mostly intermittent
  - Intermittent power, networks
- Storage is bandwidth
  - Bandwidth = DVDs + transportation
    - Or USB drives
  - Plus SMS for small updates
- Focus is on synchronization
  - (Inevitable) conflict resolution

TierStore (FAST '08)

- A mostly disconnected file system
  - Vaguely like Bayou/Coda
  - More disconnected
  - Pub/sub to limit the scope of replication
- Focus on locally self-consistent versions

Conflicts

- Conflict avoidance
  - Not possible in general, fine in practice
  - E.g. E-mail, web cache, data collection
  - Leverages application semantics

- Conflict presentation
  - In general, users must be involved
  - E.g. Wiki: page merges both versions

- Real life has consistency conflicts
  - Not a new concept for developing regions

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Some Storage Goals

- Capture cultures while we can
  - Photos, videos, languages
- Distribute educational materials
  - DVDs for the bulk
  - SMS or radio for the updates
- Keep medical records
  - Backed up, private, able to be mined

Summary

- Technology has a larger role to play
  - Rural areas are the right focus
- Many needs:
  - Connectivity, power solutions, applications
  - A large role for storage
  - Capacity building: continuous training/support
- Decentralized development works
  - Driven by bottom-up funding
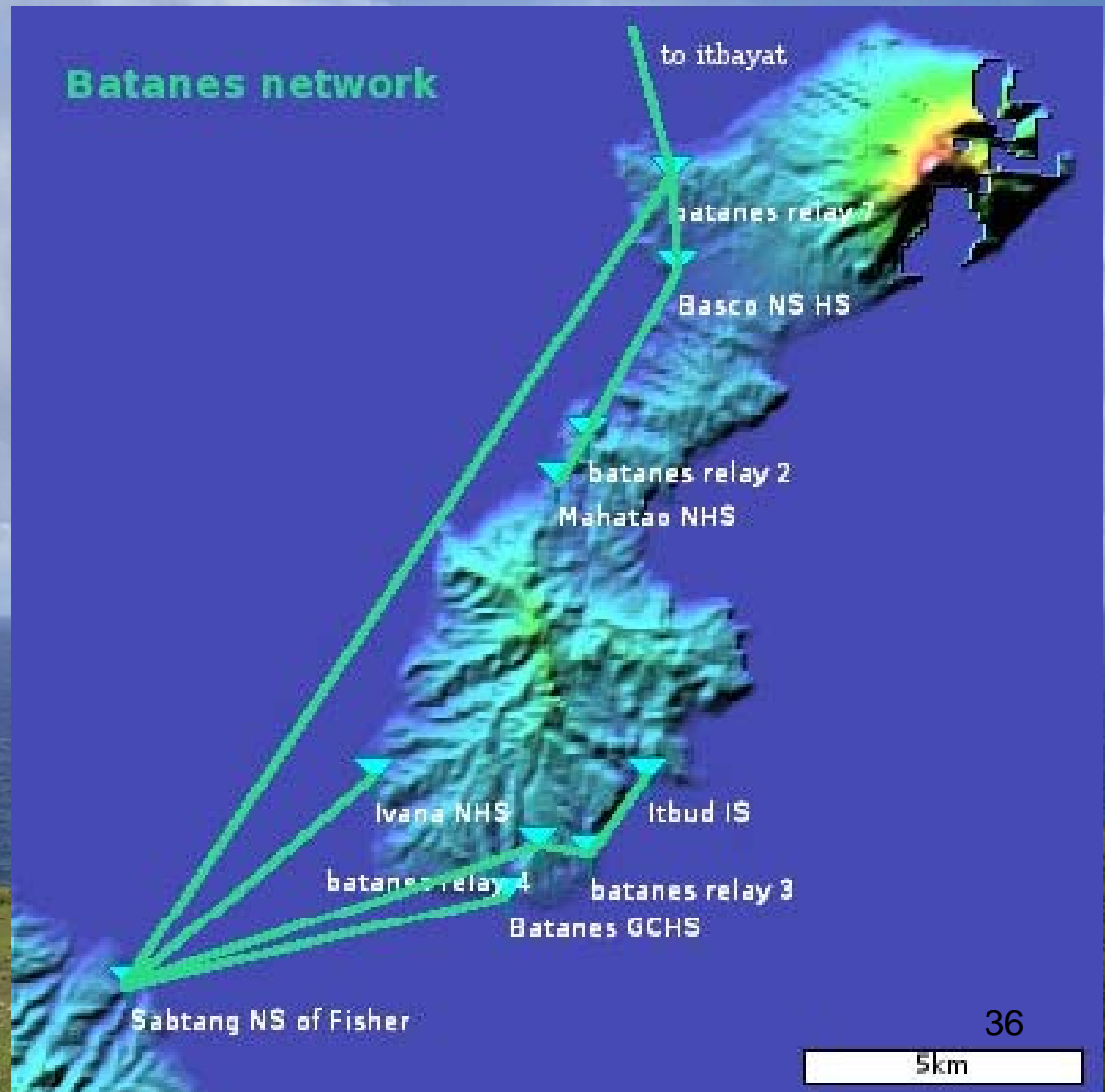 - Inherently local solutions and buy in

Backup

Decentralized Development

- **Decentralized financing exists and is large**
  - $13B/year in remittances to Philippines

- **Cellular and the Internet are enablers**

- **Bottom-up projects WORK**
  - Tend to fit the actual needs
  - Inherently localized

- **Policy should promote local development**
  - Open spectrum
  - Low taxation on IT equipment
  - Matching funds? Contests?

Schools in Batanes
Prof. Manuel Ramos Jr., UP

Batanes network

to itbayat

batanes relay 1

Basco NS HS

batanes relay 2

Mahatao NHS

Ivana NHS   Itbud IS

batanes relay 4   batanes relay 3
Batanes GCHS
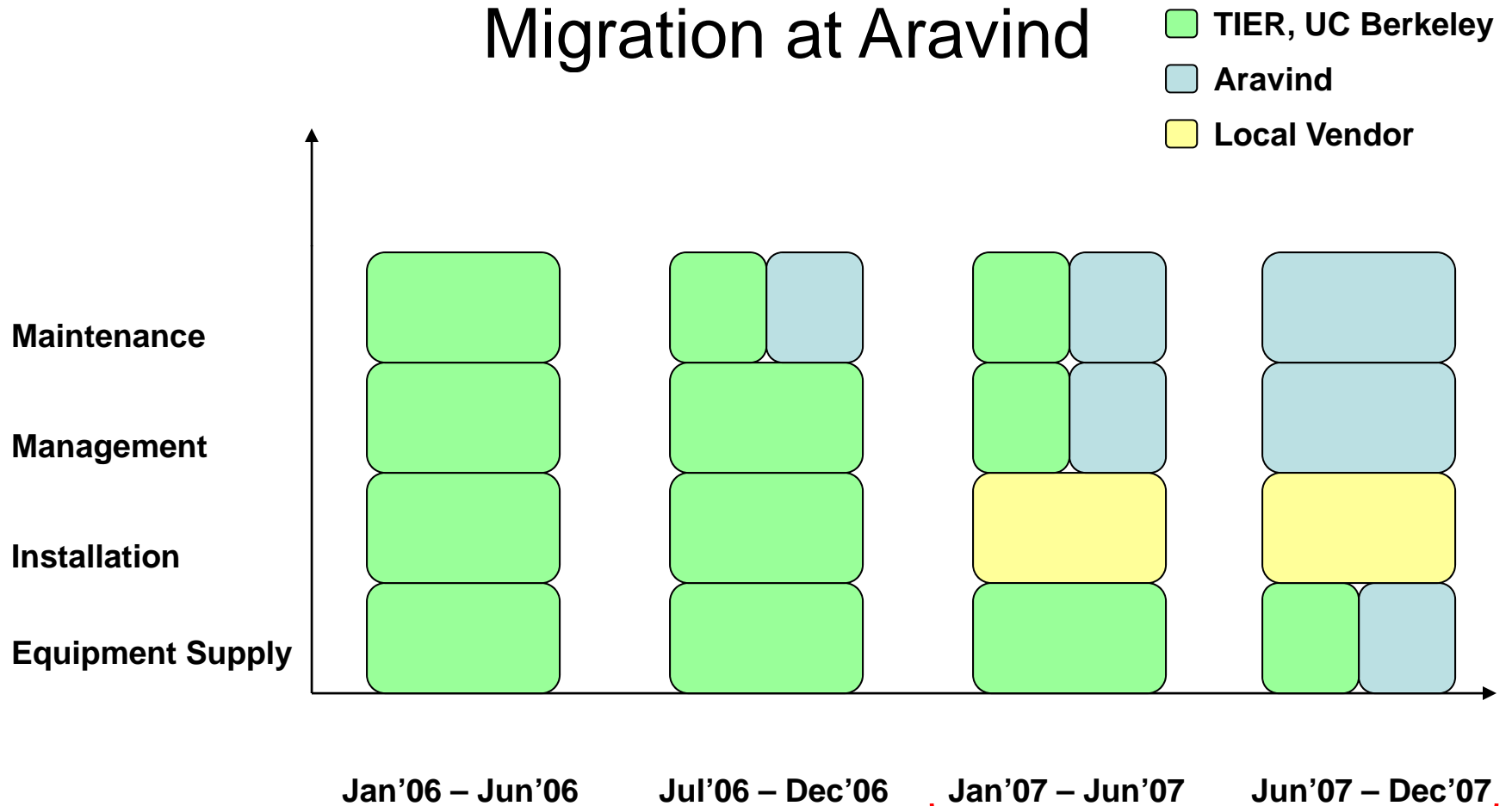
Sabtang NS of Fisher

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5km

Other Tier Technologies

- Delay Tolerant Networking (DTN)
- Phone-based Applications
  - Health records & diagnostics
  - Voice-messaging phones
- Education
  - Learning English from on a cellphone
  - Multiple Mice per PC improves learning

Local expertise: Training and Migration

Migration at Aravind

Legend:
- TIER, UC Berkeley (green)
- Aravind (blue)
- Local Vendor (yellow)

Rows (top to bottom): Maintenance, Management, Installation, Equipment Supply

Columns: Jan'06 – Jun'06 | Jul'06 – Dec'06 | Jan'07 – Jun'07 | Jun'07 – Dec'07

2007: 5 more clinic links

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Hardware Faults at Aravind, 2006

Instances[*]	Description	Total Downtime
63	Router board not powered	63 days
7	Router powered but hung	10 days
21	Router powered but not connected to remote LAN (burned ethernet ports)	34 days
3	Router on, but wireless cards not transmitting (low voltage)	2 days
3	Router on, but pigtails not connected	45 days
1	Router on, but antenna Line-of-Sight blocked	8 weeks

*Conservative Estimate

>90% of faults are power-related

WiLD: Slotted WiFi MAC

- Move to TDMA with coarse slots
  - Rate-based flow control (due to high RTT)
  - Exponential backoff is bad for voice
- Move to bulk acks
  - Turn off automatic acks
  - Normal ack timeouts too short
- Add some forward-error correction
- Support multiple antennas per pole
  - "burst synchronization" => all send or all receive
  - Turn off carrier sense (to co-transmit with neighbor)
- Working on:
  - better MAC for mixed voice/data
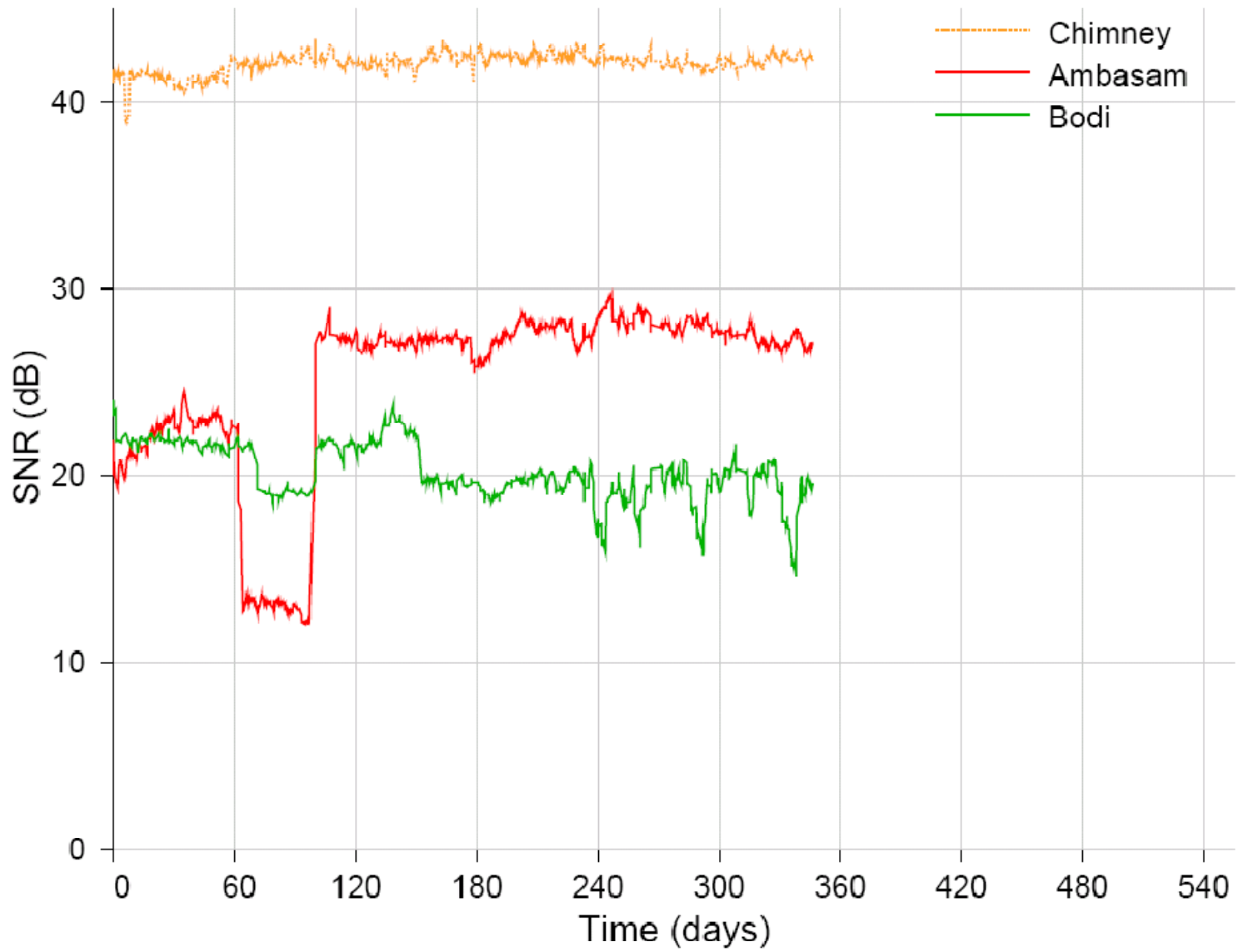 - point-to-multipiont

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SW Faults

Software Faults at Aravind (in 2006)

Instances*	Description	Total Downtime
4	No default gateway specified	4 days
3	Wrong ESSID, channel, mode	3 days
2	Wrong IP address	2 days
2	Misconfigured routing	3 days

*Conservative Estimate

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Operational Results

Fault Incident Counts

Before: Jan 07 - Jun 07

After: Jul 07 - Dec 07

Count

Weekly Manual Reboots (AirJaldi)

Number of Power-related Router Faults (Aravind)

Prolonged Downtimes greater than 1day (Aravind)

CF Card Corruptions (Aravind)

Incidents

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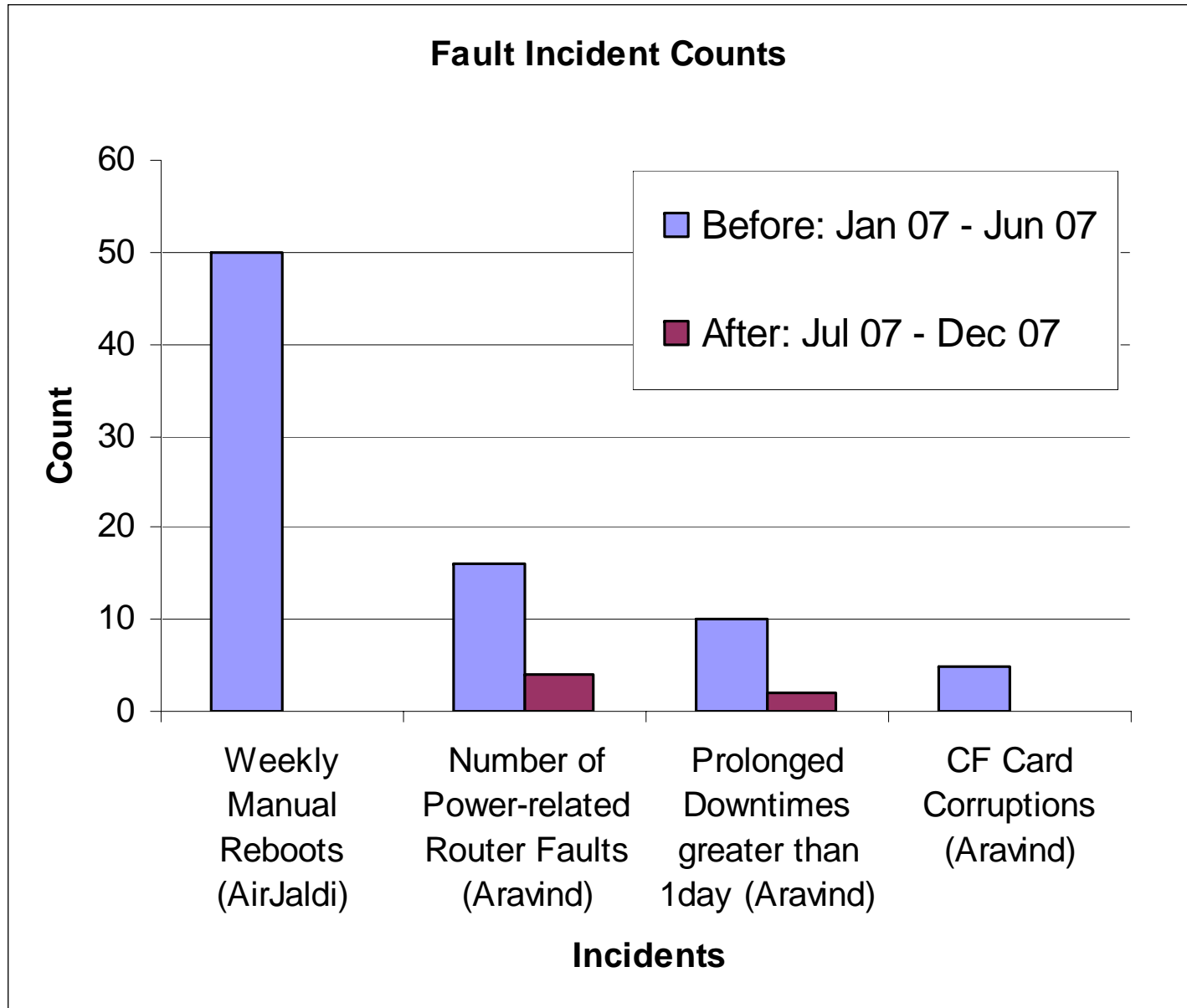
The Wireless Hypothesis

1. **Wireless infrastructure is the first viable infrastructure for rural areas**

    – Much lower cost than rail, water, electricity, roads

    – (ignores dirt roads and mandates, e.g. aqueducts)

2. **… but it can lead to the rest**

    – By improving health care, education, government

    – And by creating rural income.

And particularly WiFi

Schools in Batanes
Prof. Manuel Ramos Jr. UP

Batanes network

to itbayat

batanes relay 1

Basco NS HS

batanes relay 2

Mahatao NHS

Ivana NHS

Itbud IS

batanes relay 4

batanes relay 3

Batanes GCHS

Sabtang NS of Fisher

5km