The Case for Technology for Emerging Regions

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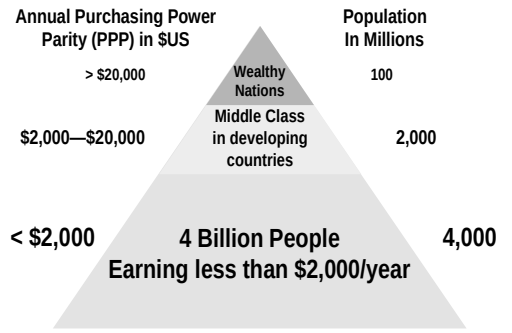
Today's Focus

- Technology can impact everyone
  - "Bottom of the Pyramid"
  - Not just Internet access:
    - Health, education, government, commerce
- Enable profitable businesses
  - Must be sustainable
    - Poor are a viable market
    - Focus on income creation, supply chain efficiency
  - Not charity, not financial aid
  - Promotes stability, entrepreneurism and social mobility
- First World technology is a bad fit
  - New research agenda

'The Bottom of the Pyramid'



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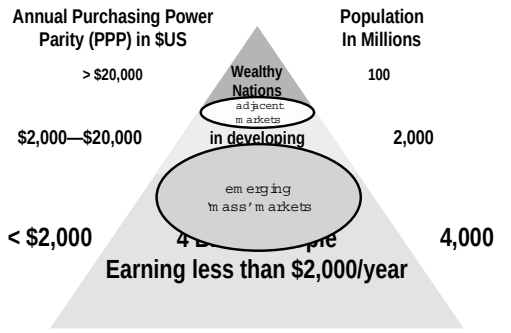
'The Bottom of the Pyramid'



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The Bottom: A Brief Description

- 3-4 billion people with per-capita equivalent purchasing power (PPP) less that US$2,000 per year
- Could swell to 6-8 billion over the next 25 years
- Most live in rural villages or urban slums and shanty towns—movement towards urbanization
- Education levels are low or no-existent (especially for women)
- Markets are hard to reach, disorganized, and very local in nature

http://www.wri.org/meb/wrisummit/pdfs/hart.pdf

The cost of being Poor

Bombay area:	Dharavi (shantytown)	Warden Road	Ratio
Credit (APR)	600-1000%	12-18%	60-75x
Water (100 gal)	$0.43	$0.011	37x
Phone (cents/min)	4-5	2.5	2x
Diarrhea Meds	$20	$2	10x
Rice ($/kg)	$0.28	$0.24	1.2x

Even the Very Poor Spend

- Dharavi, one of the poorest villages in India:
  - 85% have a TV
  - 50% have a pressure cooker
  - 21% have a telephone
  - ... but can't afford a house
- Even the poorest of the poor in Bangladesh:
  - devote 7 percent of income to communications services (GrameenPhone)
- These are valid markets...

Many experiments in progress...

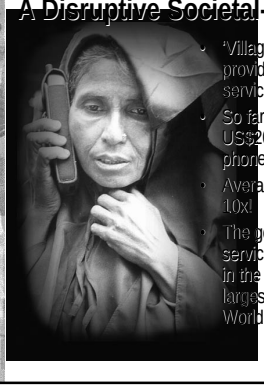
- GrameenPhone, Bangladesh
- Akshaya, e-gov in Kerala, India
- ITC Kiosks for farmers (5000 kiosks)
- Telecenters, ICT training in Brazil
- We hope to:
  - enable more of these
  - Reduce the costs, increase the quality

Grameen Bank—Bangladesh

- Owned entirely by the poor
  - Began in one village in 1976
  - 97% of equity owned by the (women) borrowers, remainder by the government
  - 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 run as a profitable social enterprise
- 46.5% of Grameen borrowers have crossed the poverty line

Grameen Telecom

A Disruptive Societal-Scale Business Model



- 'Village Phone' is a unique idea that provides modern telecommunication services to the poor people of Bangladesh.
- So far over 56,000 loans of average US$200 have been given to buy mobile phones.
- Average Phone Lady income goes up by 3-10x!
- The goal is to provide telecommunication services to the 100 million rural inhabitants in the 68,000 villages in Bangladesh—the largest wireless pay phone project in the World.

Environmental Monitoring

- Water testing:
  - Easy: presence of Arsenic
    - Huge problem in Bangladesh
  - Hard: obscure bacterial
    - Test for fecal matter instead?
- Dam safety
  - Many earthen dams: *predict* collapse?
  - Real dams: *detect* failure for faster evacuation
    - Chinese dam failure killed 80,000 – 230,000 (1975)
    - World Bank: 0 of 25 of India's dams are adequate
    - Evacuation plan can help by 100x

Health: River Blindness

- IT used to help eradicate black fly that carries river blindness in West Africa
- Network of real-time hydrological sensors, satellites, and forecasting software determined best time to spray larvicide
- Protects 30 million people from infection
- Freed up 100,000 square miles of land – capable of feeding 17 million people

Other Health Examples

- Dengue Fever (virus)
  - Affects 110M people, mostly in latin america
  - … some cases in US, many in southeast Asia
  - Dr. Boser has a detector, based on drop of blood
  - Need to build a map of spread
    - GPS, timestamps, GIS Plot
- Air and water quality

Government

- Transparency:
  - Cost of obtaining a land title in Madhya Pradesh drops from $100 to 10 cents (reduced corruption)
  - GIS for location of roads, schools, power plants to reduce politicization (Bangladesh)
- Internet-based disclosure
  - Increased pressure for compliance with environmental regulations

TIER: Technology and Infrastructure for Developing Regions

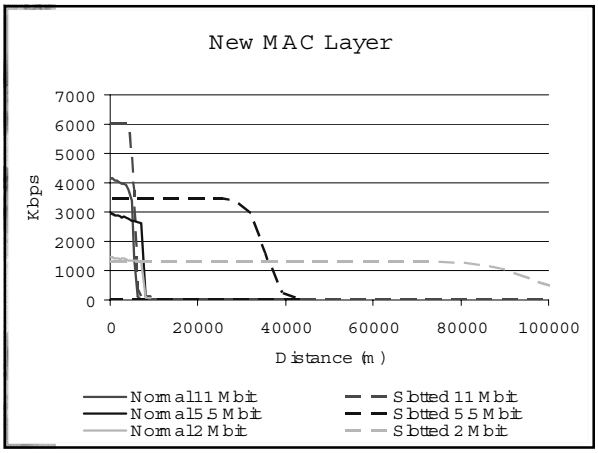
- Great Partners
  - NSF 5-year grant
  - Intel, Microsoft, HP Labs India
  - Grameen Bank, UNDP, Markle
- Working with social scientists at Berkeley
- Co-design, co-deploy with NGOs in India
  - Small deployments every 6 months
  - Must establish trust, relationships!
- Looking for second region over time

Early Research Agenda

- Rural network coverage
  - Long-distance low-cost links
  - Intermittent connectivity
- Literacy and UI issues
  - Interactive education
  - Non-English speech recognition
- Shared devices and infrastructure
- Power issues
  - Low-power networking/computing
  - Low-cost *quality* power

Long-distance wireless

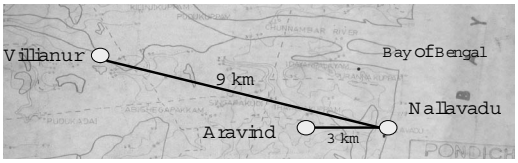
- Goal: low cost 50km links ($300?)
- Exploit $5 802.11 chipsets (or 802.16)
  - … but need new network stack (MAC+)
- Low power as well (e.g. solar)
- Longer term:
  - low-cost antenna arrays
  - Voice over IP over these links



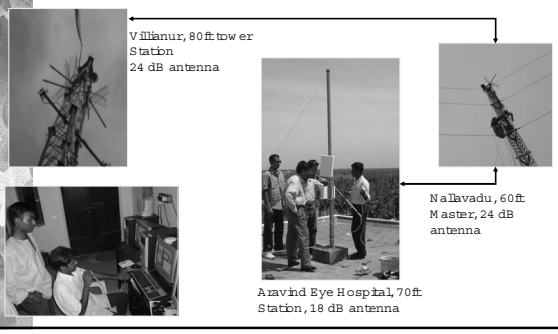
First links, Summer 2004

- Goal 1: Internet connectivity for one of the villages
- Goal 2: link between MSSRF and Aravind Eye Hospital

- Result: Aravind Nallavadu Villianur



The Installations



Some Issues

- Line of sight
  - towers expensive, need alternative
- Topology knowledge important
  - Type of vegetation, 50-60 ft in Pondicherry
- Antenna alignment is hard
  - Need spectrum analyzer
  - GPS would help + binoculars, compass, map
- Antennas
  - 18 dB gain did not work well for 7 kms
- Power problems
  - frequent power failure, solar power voltage variations

Intermittent Networking

- Developing-region networks rarely connect end-to-end
  - Power, weather, reliability issues
  - Sometimes ***intentionally*** intermittent:
    - Low-earth orbit satellites: connect only while they are overhead
    - "Mules" – moving basestation collects data
      Basestation could be on a bus/motorcyle (DakNet)
- Extended coverage:
  - User may periodically enter the coverage area (e.g. market/school)
- Internet doesn't really handle this well…
  - "Delay-tolerant Networking" Research Group (dtnrg.org)
    - Papers in last two SIGCOMMs
  - But clearly fine for e-mail and voice mail..

Tier and DTN

- DTN Pros:
  - Cost: better use of resources, more tolerant of problems
  - Reliability: delay hides transient problems
  - Ease of deployment: can be more ad hoc, less coordination than a synchronous system
  - Coverage: Intermittent coverage >> full time coverage
- Con: Not really interactive, or only interactive in some areas

- DTN: routing and storage for messages
- TierStore: Storage infrastructure on top of DTN
  - Supports e-mail, v-mail, web proxy, data collection apps, broadcast
  - Claim: Very low cost per user

Technical Results

- Proxy cache deployment
  - collecting usage logs
- Speech Collection
  - ~20 samples
  - usability issues
  - lost in translation
    - need instructions in tamil

Literacy

- Idea: make better use of speech recognition
- Novel speech recognition:
  - Easy to train, speaker independent
  - Any language or dialect, but small vocabulary (order 100 words)
  - Also speech output (canned)
  - A non-IT person can train the speech for her dialect
- Early results: digit recognition in Tamil
  - 40 samples in Tamil, most collected in India
- Have 2mm .13 micron chip design, 18mA active
  - 10000x less than Pentium, 100x less than StrongARM

Other challenges

- Low-cost complex sensors
  - Water and soil quality
  - Disease detection
  - Electricity theft
- Packaging (think toys)
- Low-cost towers
- Power systems, replace lead-acid batteries?
- UI toolkit
- Open source software

General Architecture

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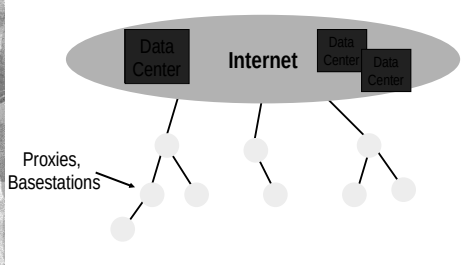

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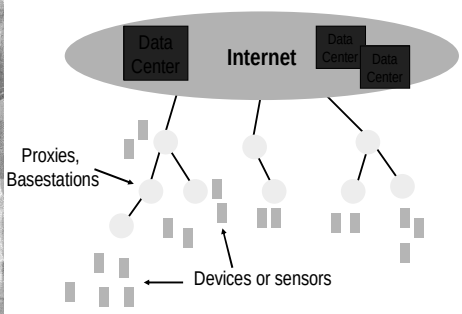

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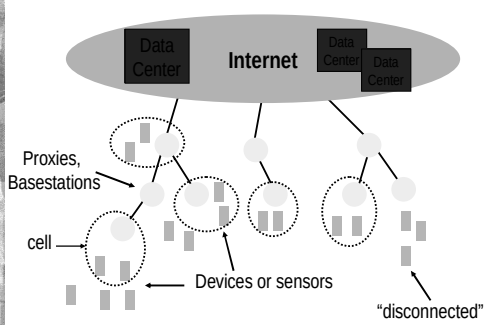


Data Centers

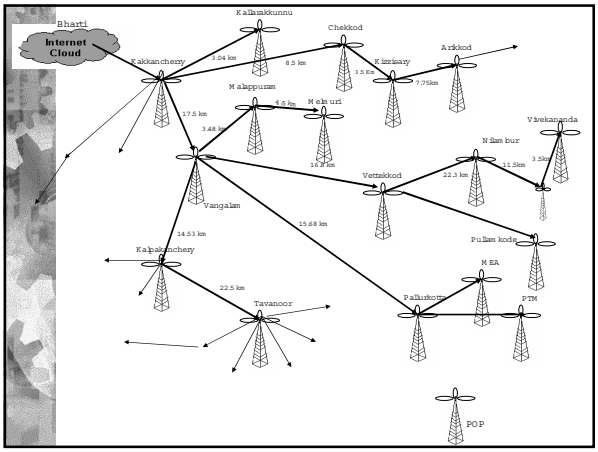
- Best place to store persistent data
  - (device is second best)
  - Can justify backup power, networking, physical security
- Cheapest source of storage/computer per user
  - 100-1000x less than a personal device (!)
  - Factors: shared resources, admin cost, raw costs (power, disks, CPUs)
- Berkeley will be the data center for our early work…
- Proxies: shared local computation and caching
  - Linux PC or Xscale box

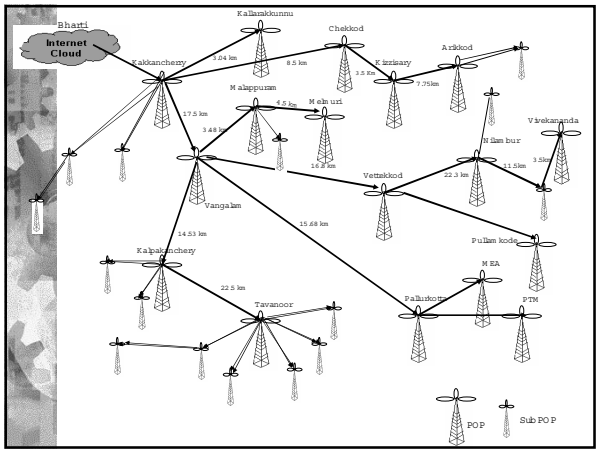
Devices

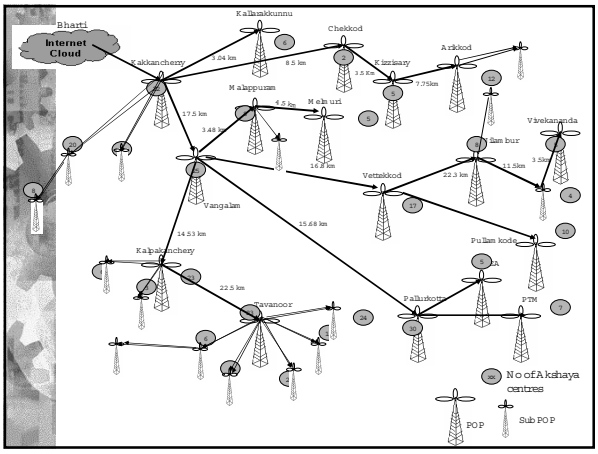
- Co-Design Devices/Infrastructure
  - => 20-40x lower cost
  - Enables more functionality
  - Storage, processing, human analysis
  - Longer battery life
- Novel low-cost OLED-based flexible displays
  - 10-50x cheaper, more robust
  - Printed using an inkjet process
- Develop standard integrated chips => $1-7 per device
  - Looking at 1mW per device (including radio!)
  - Using FPGA prototyping engine
- Packaging?

Akshaya Project

- Kerala E-gov project
  - Provide e-gov kiosk for every 1000 households
- Deployed in one district so far (Mallapuram)
  - Largest wireless network in the world? (400 sites)
- Partially subsidized:
  - Subsidized training in "e-literacy"
    - One person per household
  - Entreprenuers must make it go after that
- Looks sustainable, but too early to tell
- Working with the technical contractor to study and improve the technology







Current India Plans

- Winter 2005:
  - Deploy new network stack, DTN support
    - MS Swaminathan: Pondicherry villages
    - Test data collection application/infrastructure
  - Work with Akshaya for new deployment (Kerala)
  - Aravind Eye Hospital:
    - Rural health centers
    - Computer evaluation of retina images
- Sum 2005:
  - Deploy links to 10+ villages
  - Bangladesh, Uganda, Ghana, Brazil?

Summary

- **Tier.cs.berkeley.edu**
- **Technology for emerging regions**
  - **Valid research topic, can have huge impact**
  - **Needs "systems" help**
  - **Needs novel technology (not just hand-me-down)**
- **Deployments must be sustainable**
  - **Can't depend on ongoing financial aid**
  - **Franchise model seems key to scalability**
  - **Multi-disciplinary research…**

Backup

Services for BoP

- Top three:
  - Education (20% of Digital Dividend projects)
  - Credit (micro-loans)
  - Wireless phones

Being poor is expensive…

- Drinking Water
  - 4-100x the cost compared to middle class
  - Lima, Peru: 20x base cost, plus transportation
- Food: 20-30% more (even in poor areas of US)
- Credit:
  - 10-15% interest/day is common (>1000% APR)
  - GrameenBank is 50% APR
- Cell phone:
  - $1.50/minute prepaid (about 10x) in Brazil

More on Dharavi

- Represents **urban poor**
  - 1300 cities with >1M people
  - Urban ICT could reach 2B people by 2015
- Dense: 44,000 people per square mile
  - Berkeley: 9700 Pittsburgh: 6000
- 6 churches, 27 temples, 11 mosques
- About $450M in manufacturing revenue
- Lots of small inefficient businesses already…

TARAhaat Portal

- Portal for rural India
  - Franchised village Internet centers
  - Revenue from commissions and member fees
- Biggest success: for-profit educational services
- ICT: telephone, VSAT, diesel generators
- Local content developed by franchisee
  - Mostly 2 languages, moving toward 18
- Social goals met, financial unclear…

GrameenPhone (2)

- Rural phones: $93 per phone per month
  - > Twice as much as urban phones (not shared)
  - Some phones > $1000/month
  - But only 2% of total phones (but 8% of revenue)
- Monopoly phone company is a real problem
  - Anti-competitive, outdated laws
  - Limiting factor for the number of villages reached
    - 4200 outof65,000 so far
- Room for better technology (for the rural users)

Commerce: Market Efficiencies

"Price dispersion is a manifestation—and, indeed, it is the measure—of ignorance in the market" (Stigler, 1961)

- Badiane and Shively (1998) on Ghana: "…the estimated time to fully transmit a price shock to each of two outlying markets is about four months."
- China: accurate price information (via phone) can increase farmer revenue by 60% and improve regional productivity.