Technology for Developing Regions

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Thanks to Sonesh Surana, Bowei Du 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
  – East Africa: $5.9B
  – South Africa: $2.0B

• Many small payments

• Critical part of the economy
  – Largely informal
  – Not always legal
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
• 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
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
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
- Email, training
- 6000 consultations/month

Routers used: PC Engines Wrap boards, 266 Mhz CPU, 512 MB
Cost: $140
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
Part 3: Electric Power
Poor Quality Power

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

Low Voltages:
- Incomplete boots
- HW watchdog fails

Frequent Fluctuations:
- CF corruptions
- Battery Damage
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
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
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

- Maintenance
- Management
- Installation
- Equipment Supply

Timeline:
- Jan’06 – Jun’06
- Jul’06 – Dec’06
- Jan’07 – Jun’07
- Jun’07 – Dec’07

2007: 5 more clinic links

Legend:
- Green: TIER, UC Berkeley
- Blue: Aravind
- Yellow: Local Vendor
# Hardware Faults at Aravind, 2006

<table>
<thead>
<tr>
<th>Instances</th>
<th>Description</th>
<th>Total Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>Router board not powered</td>
<td>63 days</td>
</tr>
<tr>
<td>7</td>
<td>Router powered but hung</td>
<td>10 days</td>
</tr>
<tr>
<td>21</td>
<td>Router powered but not connected to remote LAN (burned ethernet ports)</td>
<td>34 days</td>
</tr>
<tr>
<td>3</td>
<td>Router on, but wireless cards not transmitting (low voltage)</td>
<td>2 days</td>
</tr>
<tr>
<td>3</td>
<td>Router on, but pigtails not connected</td>
<td>45 days</td>
</tr>
<tr>
<td>1</td>
<td>Router on, but antenna Line-of-Sight blocked</td>
<td>8 weeks</td>
</tr>
</tbody>
</table>

*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-multipoint
## SW Faults

### Software Faults at Aravind (in 2006)

<table>
<thead>
<tr>
<th>Instances*</th>
<th>Description</th>
<th>Total Downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>No default gateway specified</td>
<td>4 days</td>
</tr>
<tr>
<td>3</td>
<td>Wrong ESSID, channel, mode</td>
<td>3 days</td>
</tr>
<tr>
<td>2</td>
<td>Wrong IP address</td>
<td>2 days</td>
</tr>
<tr>
<td>2</td>
<td>Misconfigured routing</td>
<td>3 days</td>
</tr>
</tbody>
</table>

*Conservative Estimate
Operational Results

Fault Incident Counts

- Weekly Manual Reboots (AirJaldi)
- Number of Power-related Router Faults (Aravind)
- Prolonged Downtimes greater than 1 day (Aravind)
- CF Card Corruptions (Aravind)

Before: Jan 07 - Jun 07
After: Jul 07 - Dec 07
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