Background: Connectivity, Devices, Power, and Organizational structures

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Outline

- Connectivity
- Devices
- Power
- Organizational structures

Connectivity technology options

- Land lines
- Satellite (VSAT)
- Microwave
- Wireless
  - Wireless local loop (WLL)
  - Mobile cellular
  - WiFi: 802.11
  - WiMax: 802.16

Mix and match

- Different segments
  - International
  - National, “Last 100 miles”
  - “Last mile”
- Bhutan:
  - International: satellite
  - City-to-city: microwave
  - Last mile: cable

Land lines

- Copper or optic fiber
- Land-line-based local loops
  - Costly for low-density rural areas
    - 60-70% cost in access networks
  - Overhead cables cheap
  - Usually cheaper than WLL or mobile cellular
- Cable TV
  - 15% of Indian households, > phones
  - But needs expensive equipment for data

Satellites

- Types:
  - GEO: 35000 km
  - MEO: 10000 km
  - LEO: < 1000 km
- GEOs
  - High latency
  - Mostly one-way (due to power)
- LEOs
  - Need a lot of them for good coverage
  - Smaller number: intermittent coverage

Satellites

- Pros
  - Natural for broadcast
  - Wide coverage
- Cons
  - Limited shared bandwidth
  - Mostly one-way
  - High latency
- So far too expensive to be commercially viable for the mass
  - But cheaper than land lines or microwave for remote areas

Two-way using satellites

- Option 1: transmit up to the satellite
  - Very high power required, and large antenna
  - Very low bandwidth (9600 or less)
- Option 2: use a different network
  - Telephone is most common, could use wireless
  - Tricky but possible to do TCP
- Variation: upload data later when convenient (intermittent)

Microwave

- Cuts down cost of materials
- Need line-of-sight
- Cost:
  - Lower than cable over long distances
  - Higher than satellite for the most remote places
  - Reduced cost due to theft and maintenance

Example cellular standards

System	Cell Range	Cost	Bandwidth bits/sec	Simult. Users
GSM	10 km	$100K	9600	~800
PHS	100-300 m	$3K	9600	~200
MiniGSM	35 km	?	9600	~800

- GSM: low-speed, like WAP
- GPRS: higher cost, higher speed
- UMTS: full-fledged 3G
- CDMA fixed WLL: larger subscribers

Cellular phones

- Advantages:
  - User interface works well
  - High demand for voice, but some data provided
  - High-volume phones and basestations
- Disadvantages:
  - Hard and expensive technically
  - Voice may be inefficient use of bandwidth
  - Poor fit for rural users (low density of users)
  - Typical data rate < 9600 baud

Cellular phones

- Too expensive for remote, or sparsely populated regions
- GSM (or fixed WLL) competitive for medium density rural areas
- Individual subscribers still can’t afford---need to share
- VPP: medium- to high-density areas not far from urban centers
- Curently, voice cheaper than data
- Possibility of mixing voice and data hops to lower cost

WiFi: 802.11

- Made for wireless local-area network
- Three variations:
  - b: 1 Mb/s, oldest and cheapest, $5/chipset
    - Best for long-distance links
  - a: 11 Mb/s, shorter range
  - g: 54 Mb/s, shorter range, more channels
    - Best for omni coverage of local area (if cheap)

WiFi: 802.11

- Decent for long distance: (802.11b)
  - Special directional antennas & alignment, ($20-$200)
  - 30km seems easy, 88km is current record
  - Longer distances need towers, 40’ typical

WiMax: 802.16

- New standard for metro areas
  - Target is 30km radius, $20K for basestation
    - Cost should come down (as with 802.11)
  - High bandwidth, low density
    - Receiver per village, not per person
    - 100 villages per basestation plausible
  - Probably requires licensing (not free for all)
- Complements 802.11 for local coverage
  - Expect this combo to be very popular…

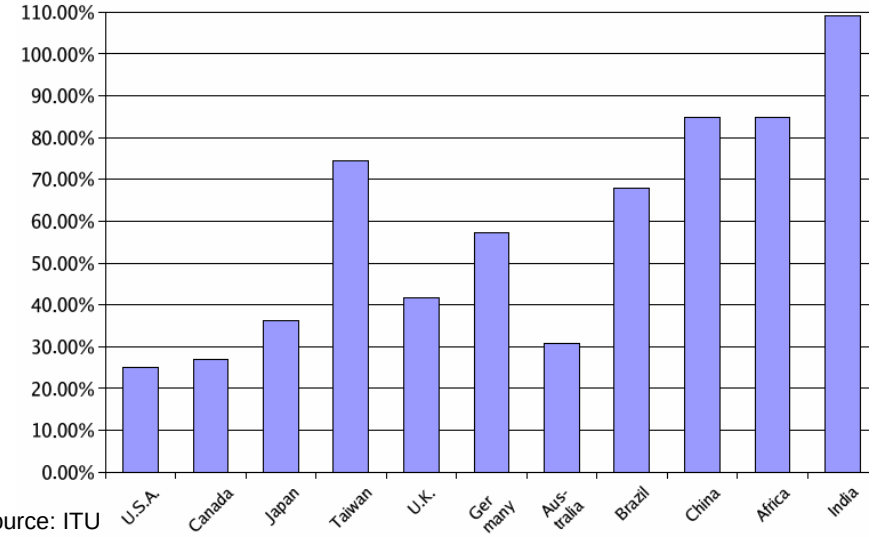
Local loop: wireless vs. wired

- Pros:
  - Quick deployment, earlier revenue stream
  - Low incremental cost, easy to add subscribers
  - Easier and cheaper maintenance
  - Can be re-deployed
  - Roaming

Local loop: wireless vs. wired

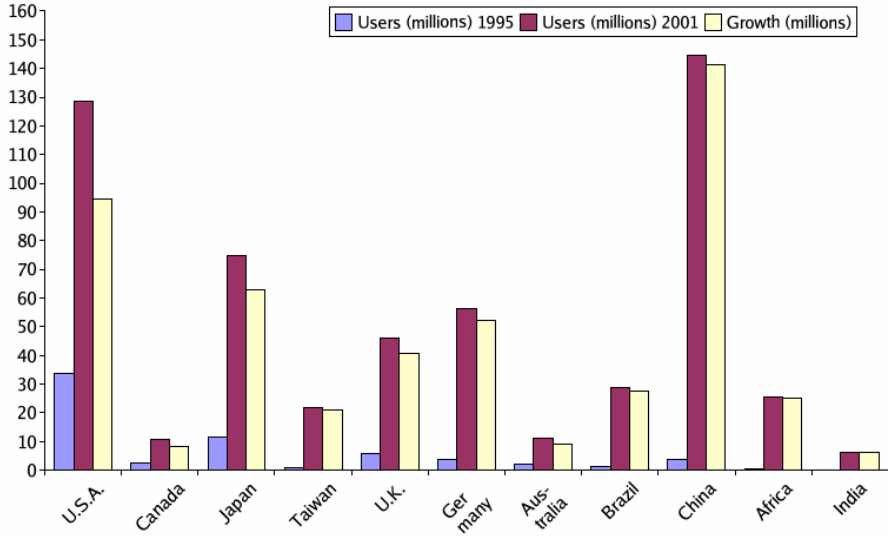
- Cons:
  - No global standard
  - Attenuation due to rain fall, foliage, etc.
  - Cost of frequency allocation for operators
  - Conflict with incumbent telecomm operators
  - Low bandwidth

Cell phones: annual growth rate
(1995-2001)



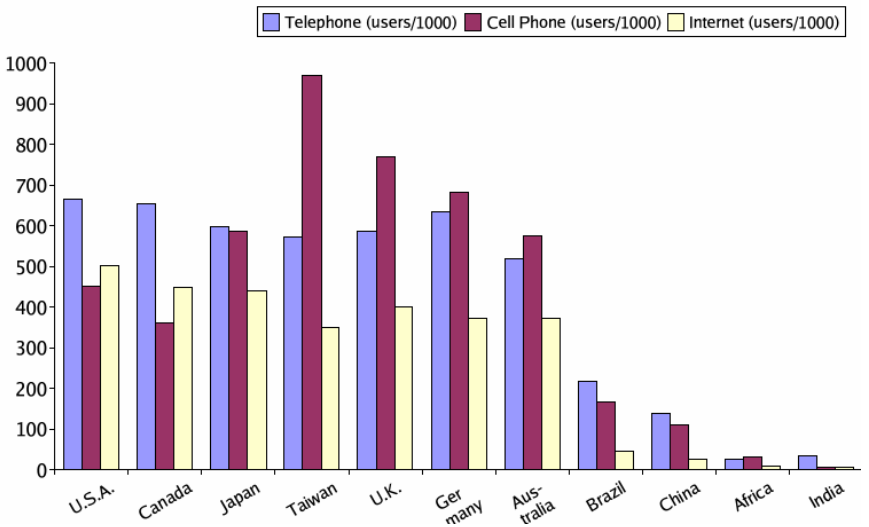
Source: ITU

Cell phones: absolute growth
(1995-2001)



Source: ITU

Tele-density
(2001)



Source: ITU

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Base-stations and proxies

- In general: locally shared computing/storage
- Costs 10x less than devices per user
- Relay point for networking
- Caching, temporary storage, computation
- Typically stationary, may be solar powered
- Easy to upgrade in place
- Not good for long-term storage

Devices

- Wide range of devices are possible
- Two broad classes:
  - General-purpose computers: “simputers,” PDAs, laptops
  - Task-specific: phones, cameras
- Task-specific can be a better choice
  - Simpler to use (and train for)
  - Can be more cost effective
  - Volume should be high enough to justify

Shared devices

- Sharing reduces the cost per user
  - Village phones have 4-8x better cost/performance
  - May only need one per village
- Some design issues:
  - Does behavior depend on which user?
    - E-mail does, telephone does not
  - Need for authentication, accounting?
- May want to start with shared devices
  - Can move to personal devices if demand warrants…

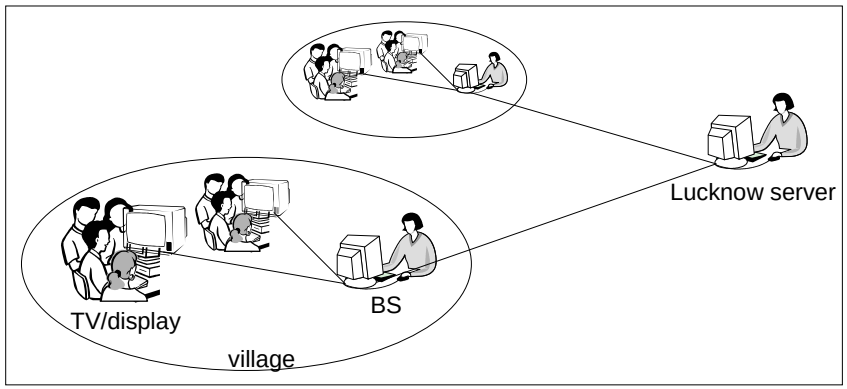
Device costs

- Big costs:
  - Packaging
  - Screen: color is >3x monochrome
  - Battery
  - UI: keyboard, buttons, touch screen, …

Considerations on devices…

- Sharing is good (but design for it)
- Task-specific is good (simpler and cheaper)
- UI and size have a lot to do with cost…
- Dependence on infrastructure is good
  - Reduces cost (and theft)
  - Can push work into infrastructure as needed
  - Increases extensibility, decreases obsolescence
  - … but requires thought about disconnected operation

In our case



- Shared “basestation” per village school: local storage, computing, communication
- Multiple “thin client displays” made from TVs: cheap, low power, dumb
- Headquarters server: ultimate repository, coordination and collaboration across the wide area

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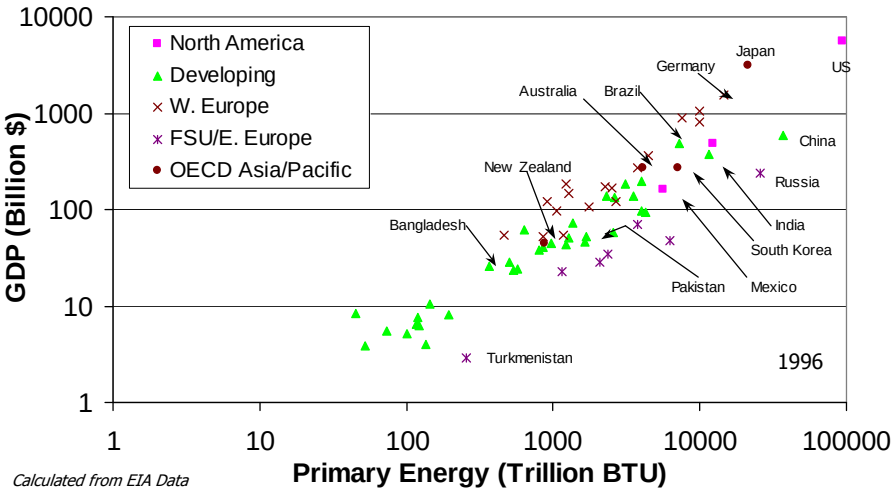
Power basics

- Access to fuels (primary energy) is a key issue for developing countries
- Electricity is only about 125 years old
  - Widespread use is much more recent
  - government plays big role
- Electricity from the grid can not be easily stored (AC)
  - Most electronics use DC

Developing countries

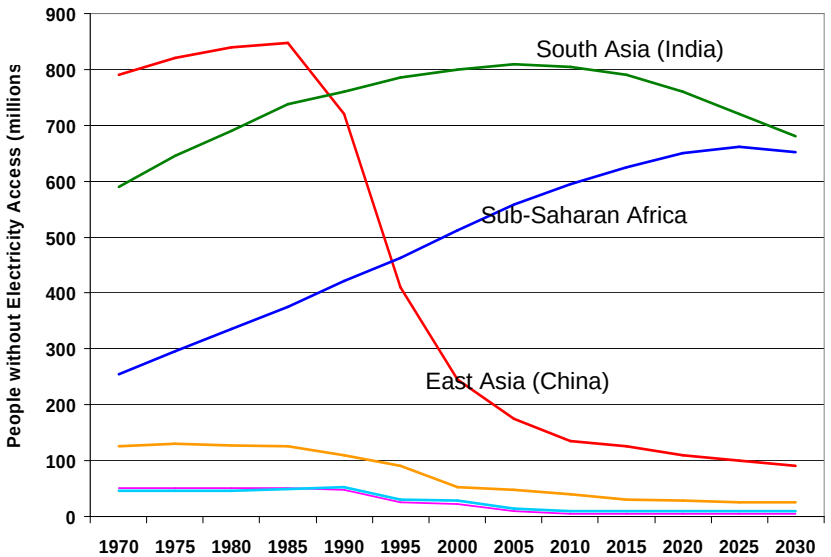
- Very low levels of electrification
  - 2 billion+ lack electricity
  - Poor quality
- Lower Level of economic development
  - Large rural agricultural sector
  - Special needs for agricultural services
  - Heavily subsidized in many countries
- Industrial-political organization
  - State-centered economies
  - Weak formal institutions

Energy-economy correlation



Calculated from EIA Data

(Lack of) access to electricity

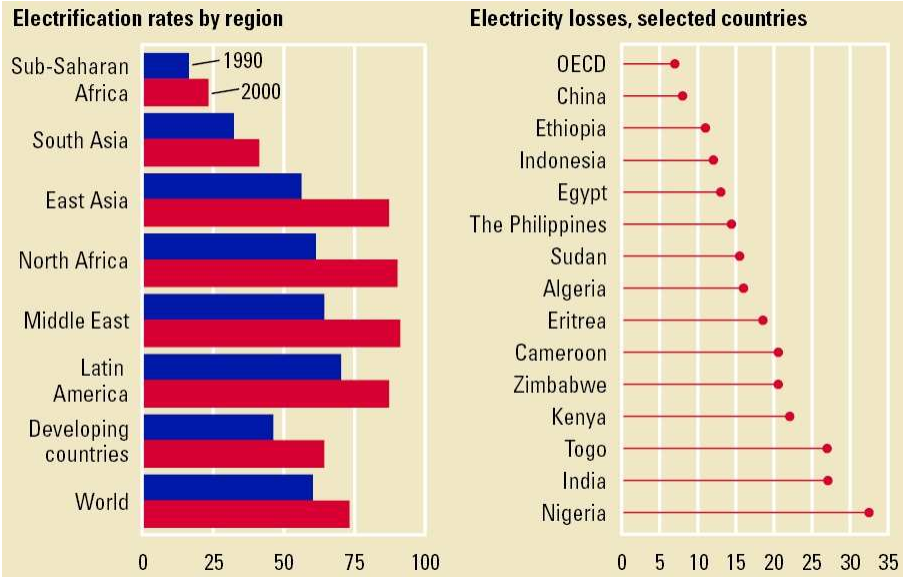


Source: WEO 2002

Where does electricity go?

- US
  - ~ 1/3 residential, 1/3 industrial, 1/3 commercial
- Developing Countries
  - Varies significantly by country
  - Grid penetration to rural areas is very low
  - A big fraction is lost/stolen on the way

Electricity in developing countries



Source: World Bank (2003)

India's power sector

- 5th largest in the world, but
- Per capita consumption is very low
  - 350 kWh, vs. world average over 2,000 kWh
  - 40% of households (60% of rural HH) lack electricity
- In very dire straits
  - Supply << demand, common blackouts
  - Most utilities incur heavy losses: -30+%
  - High levels of electricity losses: 25+%
    - Technical losses – poor design and operation
    - Commercial losses (aka theft) often over 10%

Quality of Power

- India is focusing on quantity of power only
- Quality norms are often missed
  - Voltage – often deviates by 25+%
  - Frequency – often deviates by 5% (!)
- Even farmers pay a lot for their bad quality power
  - ~1 cent/kWh implicit, even higher in some regions
- Use of voltage stabilizing equipment
  - Additional capital costs (in the multiple percent range)
  - Efficiency losses (2-30% lost!)

Reasons for the problems

- Agricultural sector
  - Consumes 1/3 of the power, provides <5% of revenues
  - Pumpsets overwhelmingly unmetered: flat rate based on pump size
- Utilities as social institutions
  - Utilities typically State Owned Enterprises
  - Utilities run with social engineering goals
- Reforms began in 1991
  - Vertically integrated government monopolies being broken
  - Initial focus was on generation
  - New realization: distribution is key

Average power of appliances (watts)

CB radio	5
CD player	35
Ceiling fan	10-75
Clock radio	1
Coffee maker	800-1200
Computer	80-150
Laptop	20-50
Microwave	600-1500
Printer: laser	300-475
Printer: ink jet	60-75

Average power of appliances (watts)

Refrigerator (20 cf.)	150
Satellite dish	30
TV: 19 inch, color	70
TV: 12 inch, b/w	20
VCR	40
Washing machine	500

Power consumption of IT components

- Computing
  - Processor is largest component
  - Pentium 4 uses 50+ watts!
- Display
  - CRT 80 W normal 10 W suspend
  - LCD 15-25 W normal 5-10 W uspend
- Storage (HDD) 10-30 W
- Uplinking 12 W Wifi 40 W VSAT
- Laptops – much less power

Details of desktop power

AGP video card - 20-30W
PCI video card - 20W
AMD Athlon 900MHz-1.1GHz - 50W
AMD Athlon 1.2MHz-1.4GHz - 55-65W
Intel Pentium III 800MHz-1.26GHz - 30W
Intel Pentium 4 1.4GHz-1.7GHz - 65W
Intel Pentium 4 1.8GHz-2.0GHz - 75W
Intel Celeron 700MHz-900MHz - 25W
Intel Celeron 1.0GHz-1.1GHz - 35W
ATX Motherboard - 30W-40W
128MB RAM - 10W
256MB RAM - 20W
12X or higher IDE CD-RW Drive - 25W
32X or higher IDE CD-ROM Drive - 20W
10x or higher IDE DVD-ROM Drive - 20W
SCSI CD-RW Drive - 17W
SCSI CD-ROM Drive - 12W
5400RPM IDE Hard Drive - 10W
7200RPM IDE Hard Drive - 13W
7200RPM SCSI Hard Drive - 24W
10000RPM SCSI Hard Drive - 30W
Floppy Drive - 5W
Network Card - 4W
Modem - 5W
Sound Card - 5W
SCSI Controller Card - 20W
Firewire/USB Controller Card - 10W
Case Fan - 3W
CPU Fan - 3W

Source: FLECOM

Standalone power
(decentralized generation)

- Issues of scale
  - For ICT or more (single point or village level)?
  - Backup or primary supply?
  - Theft is a big concern
- Sources (depends on local availability)
  - Solar
    - Only 3-5 hours equivalent per day (1 kW/m^2 of panel; ~10% efficiency)
  - Wind
    - highest efficiency for megawatt class turbines
  - Microhydro
    - typically 10s of kW
  - Diesel
    - Expensive to run, typically AC output

Solar systems

- Components
  - Panels
  - Power conditioning equipment
  - Housing
  - Batteries
  - Inverter, if AC is required
- Costs
  - $600-$1000 per unit
  - Gives an operating cost around 20-30 cents/kWh

Designing a solar system

Hours per day operational	**12**		
Days back-up required	**3**	**(1 current day plus 2 days of no sun)**	
Power needs	**50**	**Notebook PC**	
	20	**Communication**	
	15	**Lighting**	
	15	**Other**	
	100	**Watts**	**AVERAGE**
	3,600	**W-hrs**	**required to charge up per day**
Equivalent peak sunlight	**5**	**hrs**	**per day**
System size calculation	**720**	**peak watts**	
Sizing - 1 meter panel	**1,000**	**W**	**input** **(peak)**
	10%	**efficiency (net)**	
	100	**W**	**electricity out** **(peak)**
Thus need	**7.2**	**sq. m**	**panel**

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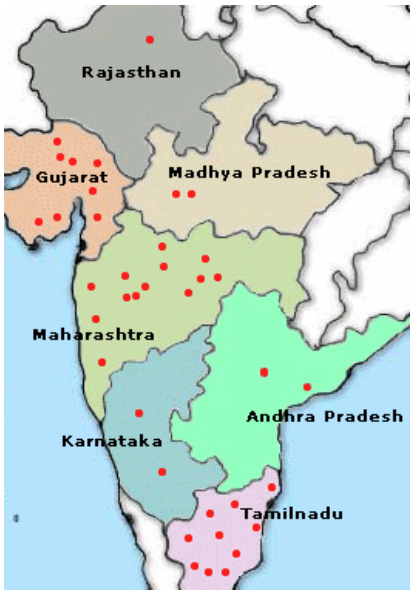
Grameen Village Phones

- Bangladesh: village (pay) phone ladies
- Communication opportunities valued by villagers
- Encountering significant obstacle for scaling up: bound by broken wired infrastructure

"Telecenters"

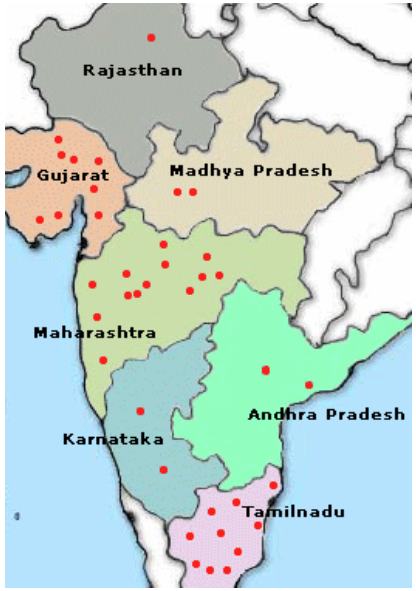
- South Africa community telecenters:
  - not used, not commercially viable
- Need anchor application
- Small internet cafes only viable in cities

N-Logue



- Multi-tiered franchise business model
- Equipment providers, NGOs, content providers, government
- Regional network of franchise service partners (LSPs)
- Local entrepreneurs, village-level kiosks

N-Logue



- LSPs work on generating local content
- Kiosks sometimes only connected to intranet: useful for local content
- WLL: 25km line-of-sight connections
- Each basestation supports 200-1000 subscribers

Comparison

- Applications
  - Grameen: one “killer app”
  - South African telecenters: no compelling app
  - Indian N-Logue: suite of plausible localized apps
- Organization
  - Grameen: tight management and fate sharing
  - South African telecenters: disconnect between donors and operators, no business model, little economic incentive
  - Indian N-Logue: intermediate level of loose coordination, potentially balancing independent innovation vs. franchise discipline

Variations on voice mail and email

- Brazil
  - “virtual telephones”---voice mail boxes
- South Africa
  - Email address for every postal address
  - Send/receive emails at post offices
- India?
  - Send/receive email with dictation
  - Didn’t work.

Approaches that work

- Develop useful local content, applications, services that solve real problems
- Work with (local) domain experts
- Encourage local participation
- Train people to use/maintain the system

Application is the key!

(Next “lecture”)