Can India get Broadband to its village?

Can India become a Leader in Wireless Technology

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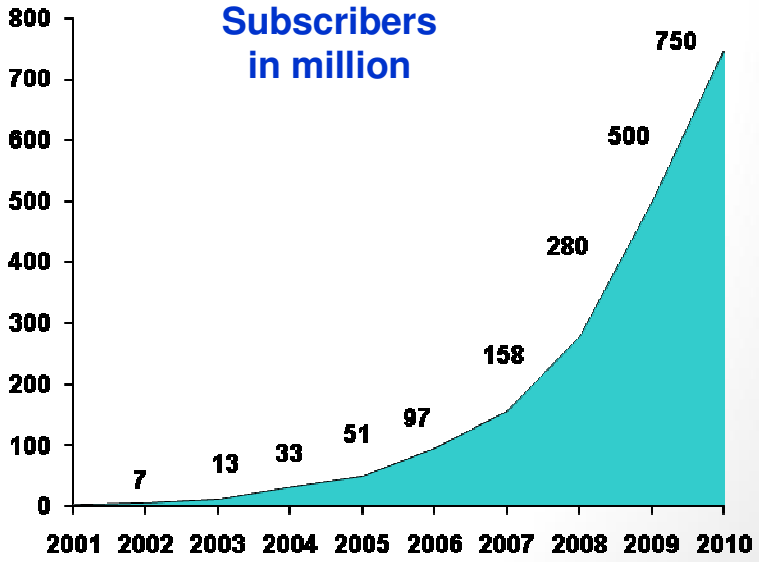
India's Telecom Story is now well known

- Growing at 15 million lines per month
  - Largest telecom market in the world
- But India was struggling at under 10 million lines in 1994
  - Growing at 1 million per year
- What happened?
  - Liberalization of Telecom
  - Wireless technology
    - Reduce CAPEX
    - Fast build-up
    - Low maintenance cost / OPEX

➢ Affordable tariff



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India has done well as a Design House today

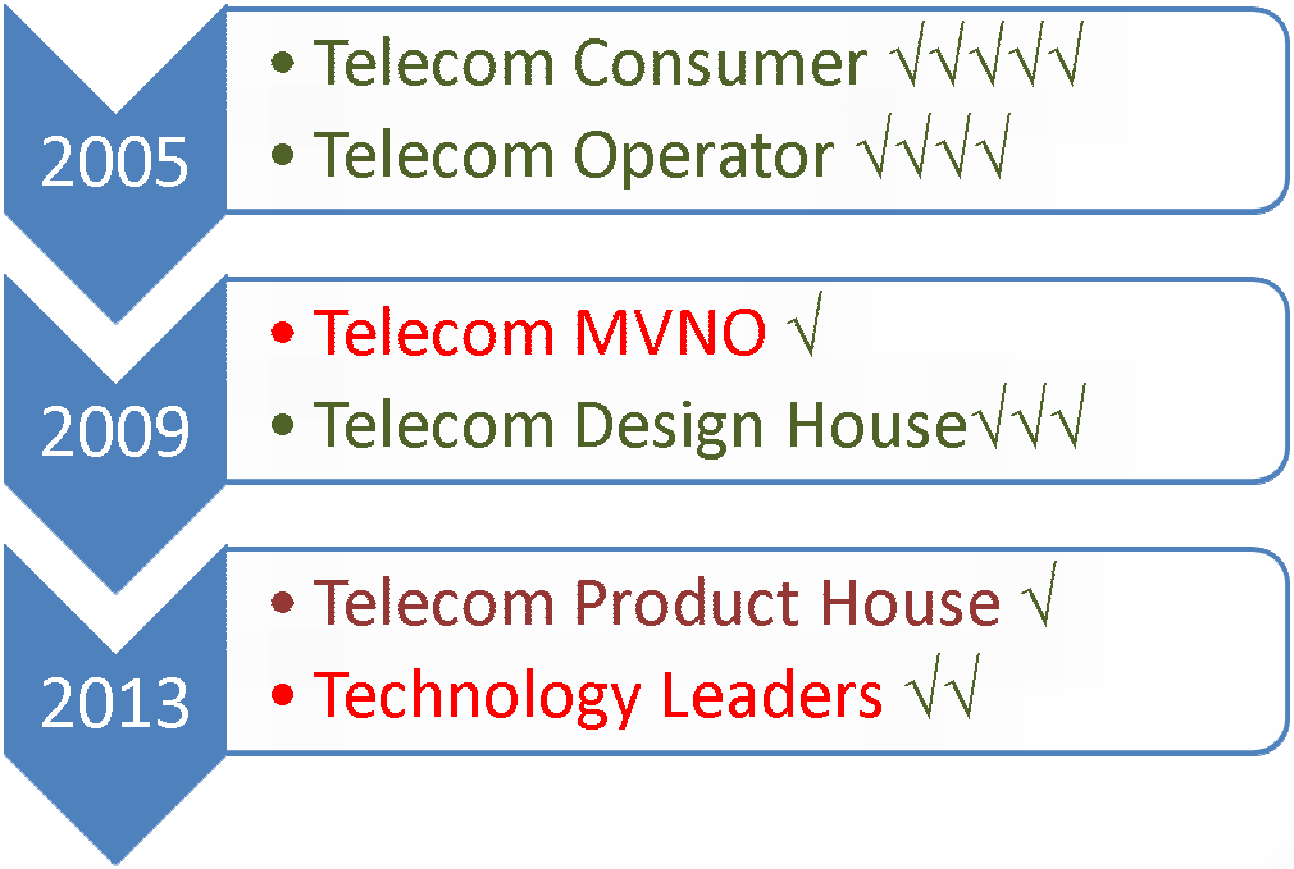
But it is not all about Telecom Service

India is already a Design house

- Systems
  - Telecom MNCs design in India
  - Indian companies excel in providing design services
    - Sasken, Wipro Infosys, TCS, Tata LXI, Hughes, Tech-Mahindra
  - Telecom Start-ups (Beceem and Telsima) sets their deign teams
  - Indian Product companies emerge (Tejas, Midas)

- Semiconductors
  - More of semiconductor development in India by MNC
    - TI, ADI
  - Indian start-ups emerging (Cosmic, Redpine)
  - Multiple companies continue to provide design services

India Amongst the Leaders



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India imports most systems today

- Except to a small extent from
  - Tejas Networks, Midas Communications, Telsima
    - who own IPR for their products
- We still pay IPR price for GSM (infrastructure / handset) even at this late stage of technology
    - Embedded in price of components, systems, software
  - Seriously impacts CAPEX investment requirements and bottom line for operators
- Typically four to five essential IPR in a standard can neutralize the royalty outflows from a country
    - Would still require business aspects to be sorted out

Short-term goal of making royalty outflow negligible

What does it take for India to become Technology Leader

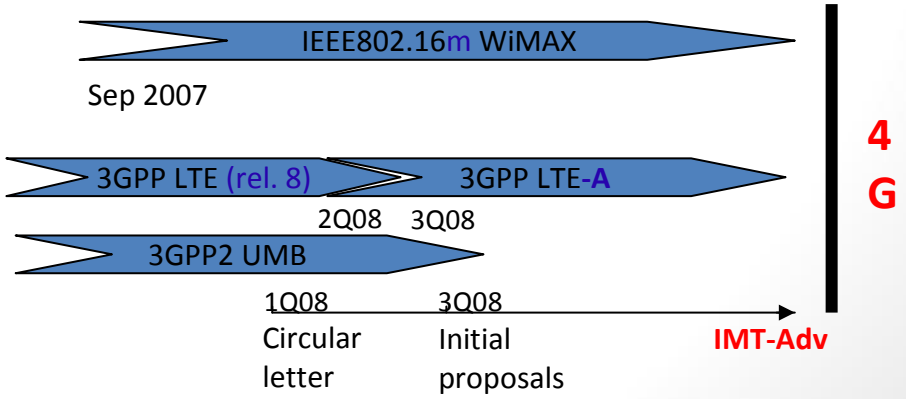
say in wireless area?

Understand the niche for the nation

- What will industry need -- tomorrow and day after?
  - Who is defining the standards that they would use?
- Who all are driving the emerging standards?
  - What technologies are going into those standards?
  - What, if any, is the technology gap?
  - Does India have special requirements?
    - Are those special requirements recognised?
    - Do technologies exist to full-fill these requirements?
      - Who is working on such technologies?
      - Are there scientists in India (or Indian Scientists abroad) who could take lead in fulfilling such requirements?
    - How do we get them to take a lead
      - And how does one get industry behind such efforts?
      - How does one get government behind such efforts?
      - And the funding required!

Wireless is the Key to Broadband Access

- Wireless got telephony to everyone in developing countries
  - Wired line infrastructure is too poor
- Wireless will get Broadband to everyone
  - Unlike the West, there is no wireline infrastructure for this!
    - GPRS / EDGE/ 3G-1x / EVDO available today
      - **Increasing use of wireless Internet even in rural India**
    - 3G (HSDPA), LTE and WiMax 802.16e (wireless auction)
      - But they struggle to provide 2-3 bps/Hz/cell
    - And eventually 4G technology: 802.16m and LTE-A



To make India a leader in Wireless Technology

- India takes an initiative three years ago
  - to create a public-private organization
    Center of Excellence in Wireless Technology
    - Initially funded Government: industry = 2:1

    - To be Lead by Academia
    - Attract top R&D talent from around the world
    - Drive Research towards IPR creation
    - Create a cluster of Industrial R&D around it

Broadband Wireless Consortium of India

and CEWiT initiates set up of *Broadband Wireless Consortium of India (BWCI)*

- Telecom operators, Academia, Government / Regulators, Product Industry, Semiconductor Industry

- To define and drive R&D and standardization to make India leader in wireless technology

India's 4G Requirements

- CeWiT+Broadband Wireless Consortium of India (BWCI)
  - Developed by Operators' subgroup of BWCI
  - BWCI released document in Sept 2007
    - Highlights important points of departure from international requirements
  - Primary broadband connection for the masses
    - Not just an additional mobility tool
  - Need sustained > 512 kbps per user
  - **At mobile phone cost point**
- Indian cellular ecosystem is different
  - Urban cells ~ 200 – 800 m radius ; rural ~ 15 km
  - Spectrum per operator tight ⇒ need 1:1 re-use
  - Severely interference-limited
  - 85% users nomadic and in-building ⇒ coverage an issue

Requirements derived out of business case for Broadband?

- Dense Urban (Case: Mumbai)
  - 70% of 16M people: 600 sq Km
  - ~3733 households per sq km
  - ~50% wireless internet subscribers
    - ~ 1866 wireless internet/sq km
  - cell radius = 0.75 km
    - ~ 3300 subscribers/cell
  - Assuming 5 competitive operators
    - 660 subscribers/operator/cell
- Urban (Case: Pune)
  - 70% of 4.2M people: 400 sq Km
  - ~1470 households per sq km
  - ~ 60% wireless internet subscribers
    - ~ 882 wireless internet/sq km
  - cell radius = 1 km
    - ~ 2800 subscribers/cell
  - Assuming 5 competitive operators i
    - ~560 subscribers/operator/cell

- Typical scenarios evaluated by Indian operators (similar for rural)
- Technology must have sufficient coverage (up to 3 km) within regulatory constraints without capacity loss

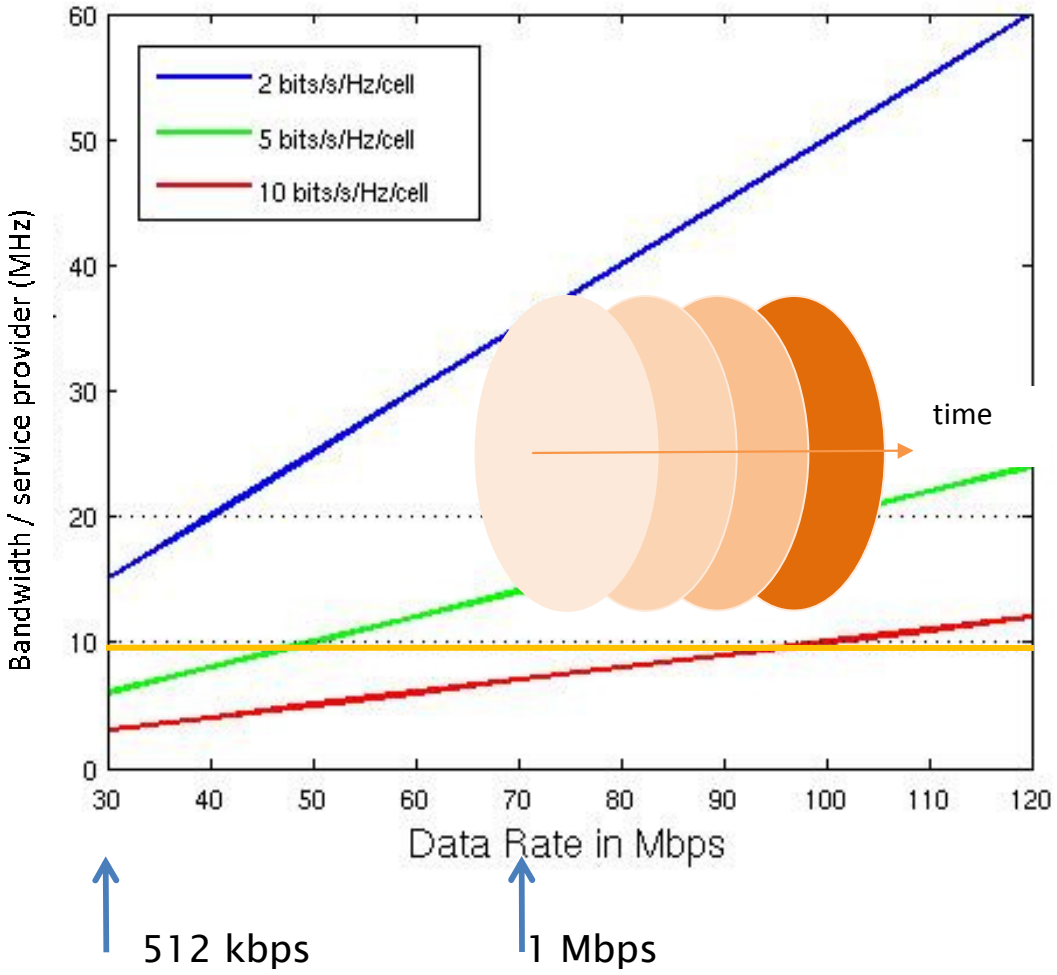
Wireless technology needs to support 500 to 800 Broadband subscribers /operator / cell

What enables a performance improvement today?

- How can one transmit more and more in a given spectrum: measure by bits per second per Hz per cell
  - reducing cell size of-course enables more reuse?
  - What limits Radio Performance?
    - Attenuation: Amplification
    - Noise: better modulation and better error-coding techniques
    - Distortion: equalisation; adaptive equalisation
    - Near-far problem
    - Interference: sectorisation, power-control, channel coding
      - Can we reuse spectrum in each sector in each cell
    - Multi-path:
      - Equalisation to compensate fading
      - Spread-spectrum to take advantage: add signals from different path
      - OFDM: split channels and transmit as much as it can support using feedback
      - Utilising space-time diversity: MIMO
      - Comprehensive feedback for power control, coding, transmitting more where interference is less
        - Is feedback fast enough? What if traffic, channel, interference has changed during feedback?
- Does simulations reflect the real-world situation? Traffic assumptions

India needs higher than 5 bps/Hz/cell

as operators unlikely to get more than 20 MHz



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India has small cell-size

- Need Special focus on cell-edge performance
  - As one attempts to get higher bps / Hz/cell
  - And at lowest possible costs
- India's focus on Physical layer lead by CeWIT and IITM
  - significant improvement in cell-edge performance
    - With modest complexity in terminal
    - Responsible for focus on nomadic, cell-edge user in LTE-A and 802.16m
- India's focus on Network performance and services lead by TCOE and IITB
  - Evolved IP Services
  - Layer 3 Radio Protocols
  - Packet Transport Networks and Evolution

Improving Cell Edge Performance

- 2-D Phase Offset Diversity (2D POD) Scheme for 2/4-antenna BTSs
  - Better than existing Alamouti code for cell-edge in terms of receiver implementation
    - Can suppress interference from neighboring BTSs with no additional complexity
- Conjugate Data Repetition (CDR) + 2D POD for cell edge downlink data
  - Can suppress 1 - 4 interferers at 0 – 9 dB
- Inter-Cell Interference Cancellation (ICIC)
  - Low bit-rate, low latency links between neighboring BTSs used to implement BTS co-operation
  - Ensures 1:1 re-use for nomadic cell-edge users
- Better preamble for synchronization and Orthogonal pilots with PN cover
- Pilot density reduction targeting low-mobility situation
  - Will result into higher payload
- Relays for Coverage extension as well as data rate enhancement

India's Achievements so far

- takes India's Broadband Wireless Requirements into 4G standard bodies
  - Both LTE-A as well as 802.16m
  - Has six essential and 6 other IPRs accepted in the 802.16m standards
    - Many in LTE-A under consideration
- CeWiT and TCOE were evaluators of standards for IMT-A (of ITU)
  - Year long process where claims of all standards were validated, strengths and shortfalls documented
- At the same time
  - Creating industrial infrastructure around itself
  - Jointly Building Hardware Software Blocks for 4G standards
  - Conducting field trials and evaluations
  - Connecting Indian academia to Design / Manufacturing Industries

3G and BWA deployment focus

After the recent spectrum auctions

BWA Technology choices & performance

Technology	DL Spectral Eff. (bps/Hz/sector)	UL Spectral Eff. (bps/Hz/sector)	Availability
HSPA Rel 6*	0.53	0.33	today
HSPA Rel 8**	1.51	NA	soon
DO Rev B***	1.0	NA	today
DO Rev C	Target: Rev B x 2,	no published results yet	2011?, standard in progress
TD LTE (2x2)*	1.64	0.81	2011?
LTE (4x2)* (assume same for TDD)	1.93	NA	Late 2011?
WiMAX 16e* (2x2)	1.15	0.62	today
WiMAX 16e+# (2x2)	**1.6**	1.05	Dec 10 soft-upgrade
WiMAX 16e+# (4x2)	1.85	NA	2011?
WiMAX 16e+i (2x2)$	**2.23**	**1.05**	Dec 10 soft-upgrade

Sources: *NGMN Ph2 Report 2008; **Ericsson; ***Motorola, IEEE Globecom2007; #Wimax Forum 2009; $CEWiT 2010

802.16m or LTE-A being examined by IMT as 4G standards: Availability 2012

CEWiT's key contribution to 802.16m
based on its IPR

- Open Loop Region (no closed loop MIMO adaptation)
  - SINR stable: get the data rate you expected when you fed back SINR
- Best-Band Scheduling based on stable post-processing SINR
  - Till now, best-band scheduling was to exploit varying channel conditions
  - Now, exploit (stable) interference variation across bands too
  - receiver processing cancels some of the interference
- Conjugate Data Repetition (CDR) with associated Collision Free Pilots (CoFIP)
  - Can cancel 3 or more interferers
- Net Impact
  - Full-blown spectrum reuse 1 possible
    - No "fractional" reuse (FFR), etc
  - Ideally suited for Indian scenario
  - Very good performance with 2x2 configuration itself
    - 40% lower infrastructure cost than 4x2

16e+i proposal

- Fast forward CEWiT contributions into 16e+ to create 16e+i
  - Part 1: Open Loop Region with best-band scheduling - possible with software changes only in BTS and terminal
    - BTS software change only in scheduler, can be done anytime
    - Can time release along with WiMAX Open-Retail 1a/1b in Dec 2010
  - Part 2: CDR and CoFIP - requires minor PHY hardware change in terminal
    - Can time it with Open-retail 1c whenever next tape-out is done
- 16e+i is backward compatible with 16e/16e+
    - Legacy terminals will work
    - Can roam into 16e/16e+ networks

16e+i Advantage

- Spectral efficiency of 2.23 bps/Hz on DL in Phase 1 itself
  - Both SINR stability and channel estimation errors in high interference scenario addressed
  - UL of 16e+ already good
  - VoIP performance of 16e+ already good (not as good in 16e)
    - Performance of 16e+i 50% better than TD LTE, HSPA, DO Rev C
      - all with 2x2 configuration itself
    - Performance of 16e+i better than TD LTE 4x2 configuration also
      - TD LTE performance in any case doubtful due to SINR fluctuation
- **16e+i can actually make 4G a reality**
  - No other technology comes close
    - Cost effective: 2x2 configuration (much cheaper than 4 x 2 configuration)
    - Mature platforms: Roaming possible in US, Japan
- Based on Indian IPR
  - Will result in India becoming leading voice in WF and 802.16
    - development of India-based vendor ecosystem

What does it take to obtain Technology Leadership?

- Quality Faculty: 100
  - Research Scholars: 300
- Industry: 10
  - R&D personnel: 300
- State funding per year: Rs 20C

- Complete Coordination of Academia, Government, industry (COAI and AUSPI) & CEWiT efforts

2005
- Telecom Consumer
- Telecom Operator

2010
- Telecom MVNO
- Telecom Design House

2015
- Telecom Product House
- Technology Leaders

Broadband in Indian Villages

How will all this play out in deployments?

Till Recently

- Indian villages hardly had any telephones
  - Just like very unreliable electrical power (even though grid exists)
- Years of efforts of taking wire-line did not work
  - Even though huge money has been spent (as subsidy)
    - Did not make business sense
    - Maintenance never worked
- All these years, cellular wireless focus was cities and towns
  - As it did not make business case in rural India
  - As urban areas saturated and tariffs went down, operators found huge market in Rural India
    - Business case break-even started getting achieved
    - Helped by
      - Tower spin off – enabling tower sharing
      - USO subsidy for towers in rural India
        - Power still a major problem
        - Back-haul mostly microwave
  - Mobiles in villages started growing very rapidly -- most villages connected

Can this evolve quickly to Broadband wireless?

- Spectrum Auction price was to high (due to shortage)
  - Most operators are bleeding
  - Would focus first on high-end service for high-end market
    - Rural areas would have to wait
- What needs to be done?

A move not as well thought-out

- Government spends money to put a fibre to each village
  - Huge funds
  - Maintenance night-mare
- From the village end-point, how does it take to homes / individuals
  - Wireless has empowered India – mobiles are there in village; this network does not add to commercial viability of wireless
  - Is there any business case?
  - Are there real applications?
- And where will power come from?
  - Battery back-ups: inefficient, wasteful
  - Solar -- too expensive

Instead (doable in a year)

- Take fibre back-haul to each cell-tower
  - Then only 3G / BWA base-stations need to be deployed
    - Not as expensive
    - Will require work on solar-power backed base station infrastructure
  - Broadband can then quickly reach each village
    - Accessible to all customers
    - Enabling a commercial solution

- But will it provide real broad-band
  - 4G should be able to give 150 Mbps from each tower for each 20MHz spectrum
    - Three to four operators could share tower
    - Back-haul fibre will ensure full BW access
  - cellular operators know how to multiply bandwidth as demand grows by adding towers
    - New towers will also need fibre backhaul

A challenge

- But as rural broadband demand increases
  - And fibre can indeed be taken to village
  - What about access?

- Can our community respond by building a wifi like adhoc mesh network which really works, is self-maintainable?
  - In 3 Km radius (from a fibre point)
  - With one to two storied houses and tall trees
  - solar-powered low-cost self-deployable units
  - Enabling each customer to get 2 -4 Mbps sustained