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Wireless Local Loop at the Bottom of the Pyramid

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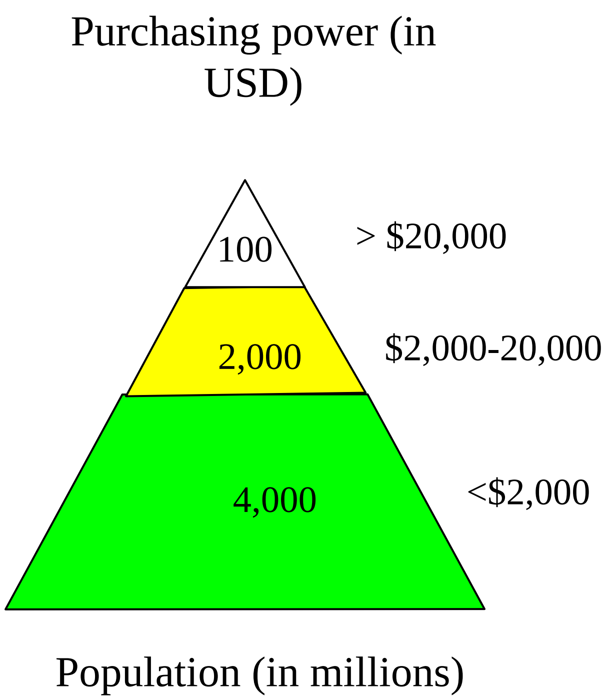
Outline

- Motivation of BoP project
- Initial WCDMA link analysis
- Initial OFDM link analysis
- Discussion
- Conclusion

Provide Communication Services to BoP



[C.K Prahalad, A. Hammond]

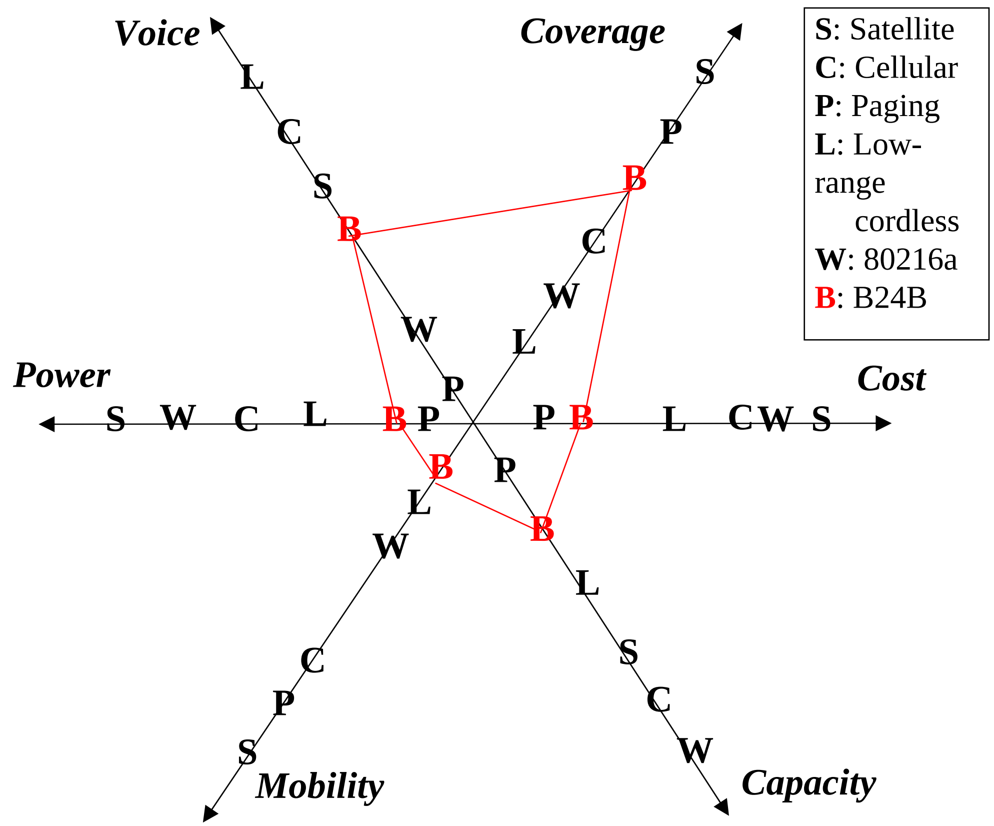
- Traditional "rich" markets for cellular service are becoming saturated.
- BoP is currently poorly connected.
- Communication is pivotal for 4 Billion poor people with income less than $2000 per year at BoP.
- 4 Billion people form the massive market with the potential of fast growth despite low disposable income of each individual.

Unique features of BoP systems

- Examples of Pioneering Commercial BoP systems
  - GrameenTelecom (GTC) in Bangladesh ($5.6 mil. Revenue in 2001)
    - Provide telecommunication services to 100 million people in 68000 villages
  - SARI (Sustainable Access in Rural Area) in India
    - Provide rural Internet and voice connectivity to 1000 neighboring villages in Madurai
- Unique Requirements
  - Demand is highly sensitive to price.
  - Both physical and institutional infrastructure may not be available.
  - Shared-access model can be profitable.
  - The User population often has low literacy and many languages or dialects may coexist within the service area.
  - The service has large coverage area and low traffic density.

Evaluation of existing technologies

- Goal:
  - New WLL technologies that cost-effectively serve few connections in a vast area
  - 50 km radius, 200 connections
- Candidates:
  - Satellite (VSAT)
  - Cellular (MiniGSM)
  - Paging (Skytel)
  - Low-range Cordless (DECT)
  - 802.16a



Link Budget Analysis

- New cost-effective BoP system is required.
  - WCDMA
  - OFDM
- Link Analysis is the balance sheet to study transmission / reception source, noise, link attenuation,and error performance.
  - Whether systems can meet the BoP requirement
  - Basic assessment of system's performance, cost
  - Tradeoff among different components

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Wireless Channel Model

- Attenuation model
  - Okumura-Hata model

$$PL(d)(dB) = 69.55 + 44.49\log f_c - 13.82\log h_{te} - a(h_{re})$$
$$+ (44.9 - 6.55\log h_{te})\log d - 4.78(\log f_c)^2 - 40.94 + X_\sigma$$

$$a(h_{re}) = 3.2(\log 11.75 h_{re})^2 - 4.97 dB$$

- Delay-spread model

$$\tau_{rms} = \sqrt{\sum_i \tau_i^2 s_i - (\sum_i \tau_i s_i)^2}$$

$$\tau_{rms} = T_1 d^{\varepsilon} y$$

  - For a rural area with flat terrain, $T_1 = 0.1\mu s$, $\varepsilon = 0.5$.

$$\tau_{rms} \in [1.12\mu s, 2.79\,\mu s]$$

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Initial WCDMA Link Analysis

- Required link margin is 162.6 dB
  - 50 km distance, 1950 MHz Carrier Frequency, 30m base station antenna, 1.5m mobile station antenna
- Link Analysis Deficit 27.7 dB (UMTS system)
  - Transmission Power 21dBm (0.125w)
  - Mobile Antenna Gain 0dB
  - Base station antenna gain 18dB,
  - Processing Gain 29 dB (4.75 kbps AMR voice)
  - Interference margin 3dB
  - Fast fading margin 4dB
  - Log normal fading margin 7.3 dB
  - In-home loss margin 15.0 dB
  - E_b / N_0 5 dB

Modifications of WCDMA

- Taller and external receiver antenna
  - Move MT antenna outside -> 15 dB
  - Increase MT height to 5m -> 4 dB
- Power
  - 3dB (0.25 mW, maximal value for WCDMA)
- Interference Margin -> Limit the number of simultaneous users

$$IM = -10 * \log(1 - \eta_{UL})$$

$$\eta_{UL} = \frac{E_b / N_0}{W / R} * N * v * (1 + i)$$

  - 3dB (191 users) -> 1 dB (80.1 users) : 2 dB gain
- Reducing fading margin
  - Fast fading margin : 2dB gain, Log normal fading margin: 2 dB gain
- Performance Degradation
  - E_b / N_0 : 2.7 dB gain

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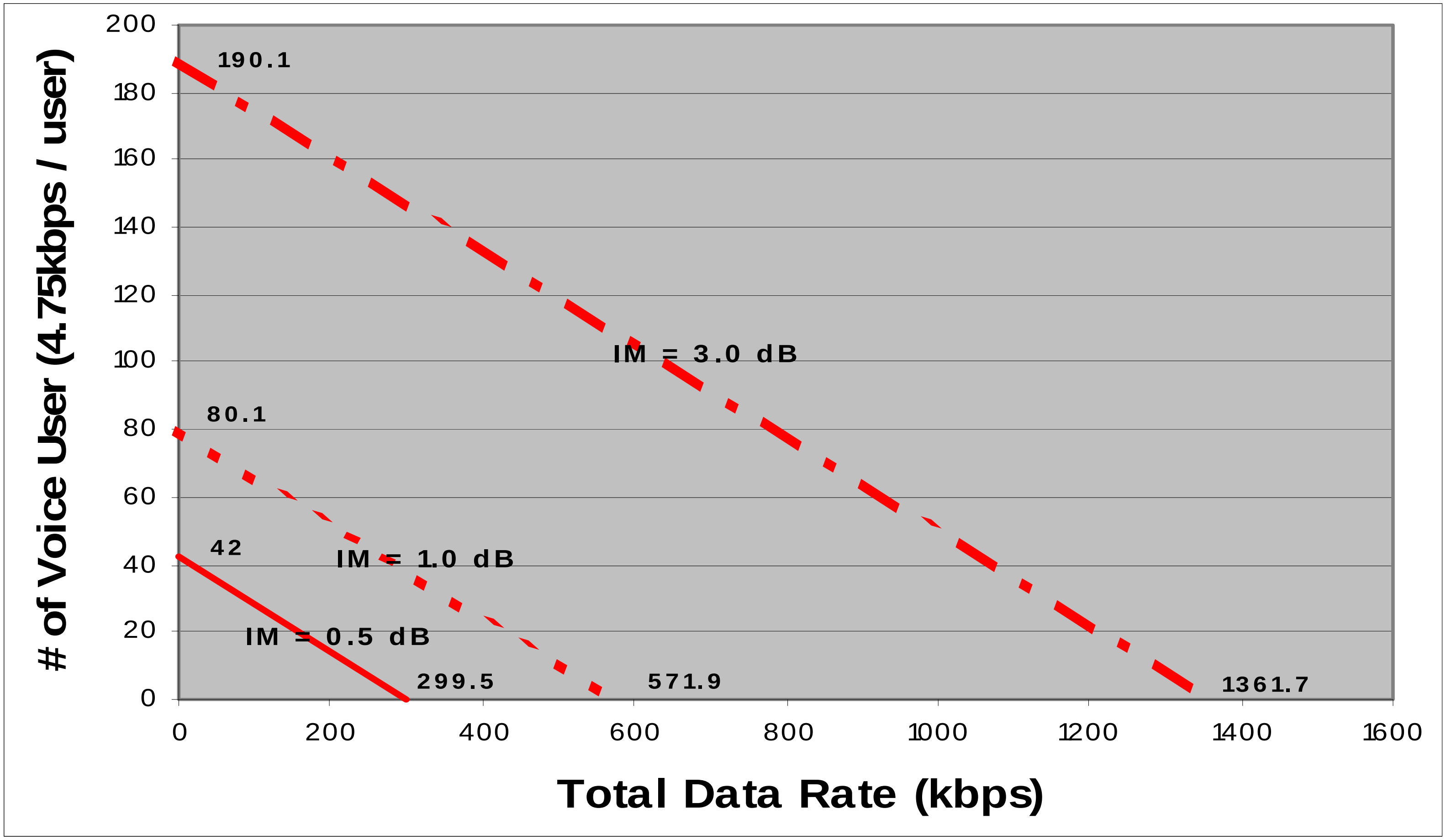
Voice vs. Data Capacity Tradeoff for WCDMA



E_b / N_0 of voice is 5 dB. E_b / N_0 of data is 1.5 dB.

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Discussion

- Voice vs. Data
  - Voice is more expensive to support
  - Data is more suitable because of less stringent QoS requirement and lower E_b / N_0
  - Emergency voice support
- Mobile vs. Fixed
  - BoP terminal is fixed to decrease body loss.
  - Local mobility is supported through multi-hop setup.

Conclusion

- Both WCDMA and OFDM can be used in BoP project with some modifications.
  - WCDMA is simpler, more robust, and cheaper but has less capacity than OFDM.
  - OFDM is more complex and expensive but has larger capacity than WCDMA.
- We propose a new design approach of dramatic cost reduction instead of performance optimization.
- We point out how the tradeoff of quality, data rate, support of voice and power can be made to avoid more expensive hardware investment.

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Future Work

- MAC and link layer design
  - PHY is error prone due to decreased loss margin
  - MAC and link layer needs to be made more error robust and adaptive to increase coverage area
- Test bed

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The end

Q & A

Initial OFDM Link Analysis

- OFDMA (802.16a system): 21.6 dB deficit
  - 6MHz BW, 2048 carriers, 32 carrier/sub-channel
  - Transmission Power 24dBm (0.25w)
  - Mobile Antenna Gain 0dB
  - Base station antenna gain 18dB,
  - Processing Gain 29 dB (4.75 kbps AMR voice)
  - Interference margin 0dB
  - Fast fading margin 6.0 dB
  - Log normal fading margin 7.3 dB
  - In-home loss margin 0 dB
  - E_b / N_0 2 dB

Modification of OFDMA

- Decrease the number of carriers of each sub-channel
  - 1 carrier/channel: 18 dB gain
- Increase Power:
  - 1W: 6 dBm
- Antenna Gain:
  - Mobile Antenna Gain : 18dBi

- Symbol time is 298.66 us, >> channel delay spread
- 1bit/HZ transmission efficiency -> 6Mbps