The Future of Wireless Broadband

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Overview of Presentation

- Disclaimer
- Common Technologies for 4G Networks
- Cellular wireless standards road maps (3GPP, 3GPP2, 802.16)
- Closing thoughts

Disclaimer

All predictions, conclusions, analyses etc. in the latter part of this presentation are based on my experience working with wireless carriers and vendors and attending technical conferences, trade conferences, standards meetings and working with members of the academic community. No proprietary or company confidential material has been used in this presentation and the conclusions do not reflect those of companies with which I am presently associated or those which I have associated with in the past.

OFDMA Radio Transmission Technology

- What: OFDMA can be described as a combination of frequency domain and time domain multiple access, where the resources are partitioned in the time-frequency space, and slots are assigned along the OFDM symbol index as well as OFDM sub-carrier index.

- Why: Capacity scales with carrier bandwidth

- Benefits:
  - Frequency selective fading (can schedule users during positive fade in both time and frequency domains)
  - Provides flexible support for MIMO
  - Multiple access support allows tighter QoS guarantees, higher multiplexing gains and higher multi-user diversity gains

MIMO Technology

- What: The use of multiple antennas at the transmitter and/or the receiver
- Why: Channel capacity increases proportionally with the smaller of the number of transmit and number of receive antennas
- Categories
  - Precoding (MU-MIMO): Use multiple beams to simultaneously serve multiple users (requires CSI at transmitter).
  - Spatial Multiplexing (SU-MIMO): Serve a single user with multiple streams to increase capacity
  - Diversity: Use space-time coding for antenna transmissions to reduce fading (increase diversity)
  - Space Division Multiple Access (SDMA): Simultaneously serve multiple (near-orthogonal) users

Cognitive Radio

- What: A paradigm for wireless communication in which a wireless node changes its transmission or reception parameters to avoid interference with licensed or unlicensed users. This requires active monitoring of the frequency spectrum (as well as possibly other environment conditions).

- Why: Licensed spectrum may be underutilized in space (location) or time and hence dynamic allocation to unlicensed users can provide such users with significant capacity gains

- Notes: Many issues are still to be addressed, in particular efficient and accurate spectrum sensing

Cooperative Communications

- What: Players (e.g., mobile stations, base stations, relay nodes) exchange information in order to enhance network-wide performance
- Why: With cooperation the system can approach global optimization at the expense of increased signalling
- Forms of Cooperative Communications:
  - Network MIMO: Antennas (transmit and/or receive) are distributed among multiple basestations
  - Wireless Ad-Hoc Network: Each node is willing to forward data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity
  - Relay Networks (cooperative diversity): A communication technique that achieves a diversity gain by using the combination of the relayed signal and the direct signal
  - Wireless Mesh Network: A type of wireless ad hoc network, where all radio nodes are static and doesn't experience direct mobility

Advanced Radio Resource Management

- What: Allocation of radio resources (subcarriers, symbols) and power with the objective of maximizing the number of supported users while satisfying all QoS demands

- Why: Resource management has become quite intricate because of the increased number of dimensions for optimization. Simple yet near-optimal algorithms can provide significant gains over present networks.

- Components include:
  - Scheduling of frequency-time resources (slots) while taking into account user (subband) channel conditions, QoS guarantees and MIMO options
  - Power control for persistently allocated frequency-time resources
  - Management of intercell interference to increase system capacity while maintaining cross-sector fairness
  - Congestion controls to prevent throughput collapse under heavy loading
  - Admission controls to ensure QoS guarantees are maintained for all admitted users

3GPP2 Wireless Standards

- The 3GPP2 standards body developed the CDMA set of standards
- cdmaOne (2G)
- cdma2000 1xEV-DO (Rev A and B) (3G)
- 1xEV-DV (3G) (never made it out of the lab)
- 1xEV-DO Rev C (Ultra Mobile Broadband or UMB) (pre 4G)
- **IMHO: The UMB standard is complete and is very well engineered. However because of the high percentage of Qualcomm IPRs this standard is essentially dead (no customers)**

TD-SCDMA Wireless Standard

- Time Division-Synchronous Code Division Multiple Access, or TD-SCDMA, is a 3G mobile telecommunications standard, being pursued in the People's Republic of China by the Chinese Academy of Telecommunications Technology (CATT), Datang and Siemens AG, in an attempt not to be "dependent on Western technology" (wikipedia).
- Other 3G Standards will not be approved (in China) until TD-SCDMA is commercial
- Poor performance in existing trials
- May eventually merge with 3GPP LTE for 4G
- **IMHO: The TD-SCDMA standard was developed with one major objective being to minimize patent royalties to western companies. This may have resulted in a poor design and hence this standard may not have much of a future**

802.16 Standards

- 802.16d (fixed WiMAX)
- 802.16e (mobile WiMAX)
- 802.16m (pre 4G)
- **IMHO: WiMAX has, until recently, been the most discussed technology for replacing 3G networks. Having been designed by the wireless LAN community (i.e. cheap bandwidth, data service) the signaling overhead and VoIP efficiency is poor compared to cellular technologies but these are being addressed in 802.16m. It has a two year head start but has been losing that advantage**

3GPP Wireless Standards

- GSM (GPRS, EDGE) (2G - 2.5G)
- W-CDMA (HSDPA, HSUPA, HSPA+) (3G)
- Long Term Evolution (LTE) (pre 4G)
- Long Term Evolution - Advanced (4G)
- **IMHO: LTE is being developed by the heavily European influenced 3GPP standards body. It is not as efficient as UMB but suffers less from IPR constraints. In many (but not all) aspects it is better designed than WiMAX and present UMTS providers can easily upgrade. Its TTM disadvantage (compared to WiMAX) is disappearing**

Personal Thoughts

In the near future only LTE and WiMAX will survive. Over time LTE will become dominant because Carriers will be able to slowly upgrade their present 3G networks to LTE while maintaining acceptable (mobile) voice performance. This will happen sooner than previously anticipated because of its reduced time to market

Beyond 4G

- Unfortunately, unlike wireline networks for which capacity can be expanded by adding more fiber, the radio resources (spectrum) available in wireless networks are limited. This implies that the QoE of an application when run over a wireline network will *always* be superior to that experienced when the application is run over a wireless network

- As the number of wireless network users increases and as the per user loading increases, pricing will have to be used to maintain differential QoE for different user classes

- There will continue to be a need for both wireline networks and wireless networks. Wireline networks will be needed for super high throughput, low latency applications. Wireless networks will be used for applications that take advantage of its unique characteristics (mobility, location sensing, small terminal, etc.)

- Future wireless networks will continue to improve on spectral efficiency but will focus more on cross layer performance aspects