Smart Antennas for Better Wi-Fi Networks

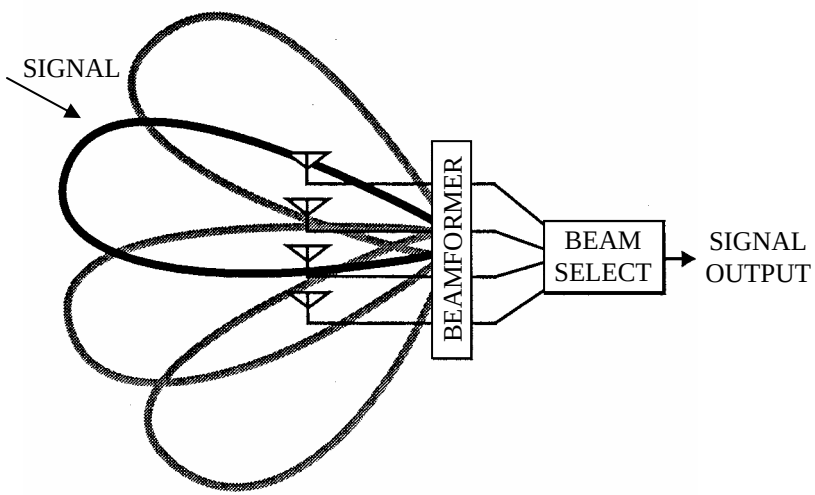
Jack H. Winters
Chief Scientist
jwinters@motia.com 732 208-5568

Service Limitations - WiFi

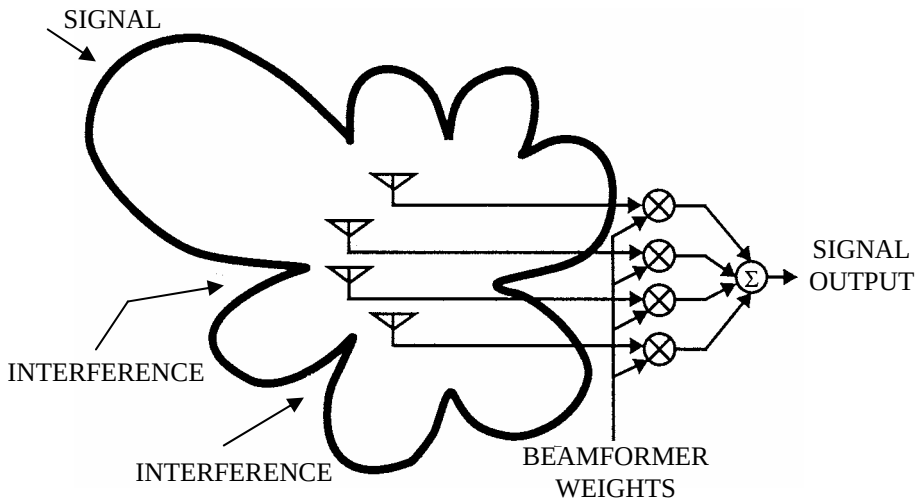
- Quality of service for each user is not consistent:
  - Too far away from the access point
  - Behind a wall
  - In a “dead” spot
  - Working off a battery, as with a laptop
  - Suffering from low bandwidth due to range/interference
- Lack of range
  - One AP cannot cover some houses

Smart Antennas

Switched Multibeam Antenna



Adaptive Antenna Array



Smart antenna is a multibeam or adaptive antenna array that tracks the wireless environment to significantly improve the performance of wireless systems

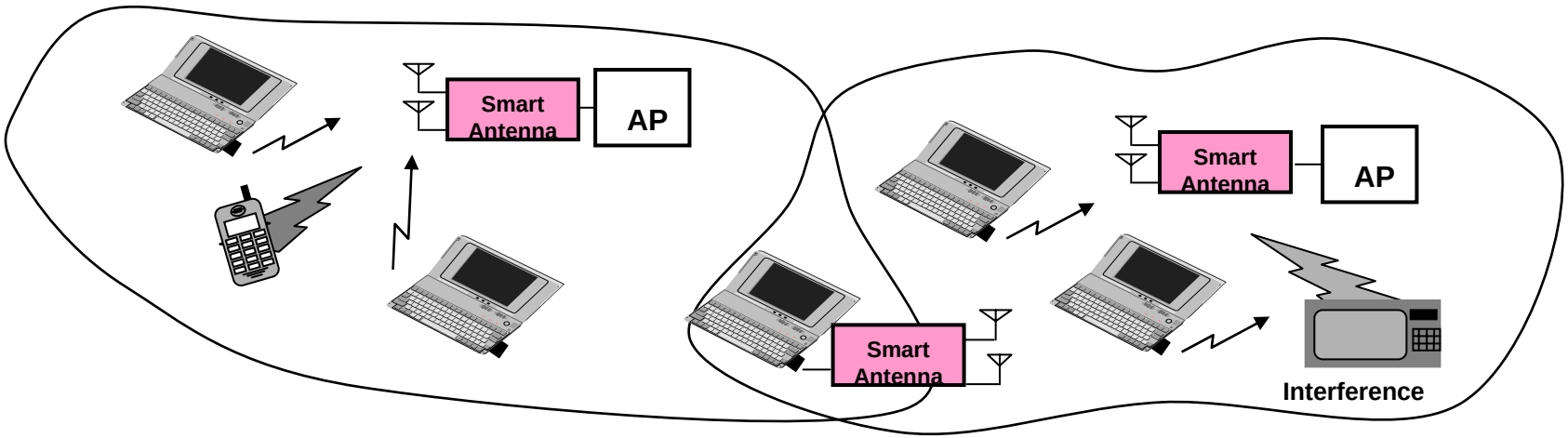
Adaptive arrays in any environment provide:

- Antenna gain of M
- Suppression of M-1 interferers

In a multipath environment, they also provide:

- M-fold multipath diversity gain
- With M Tx antennas (MIMO), M-fold data rate increase in same channel with same total transmit power

Smart Antennas for WLANs



Smart Antennas can significantly improve the performance of WLANs

- **TDD operation (only need smart antenna at access point or terminal for performance improvement in both directions)**
- **Higher antenna gain ⇒ Extend range/ Increase data rate/ Extend battery life – 4 antennas on either side can increase range 2-3X, throughput 2X**
- **Multipath diversity gain ⇒ Improve reliability (QoS for VoIP)**
- **Interference suppression ⇒ Improve system capacity and throughput (mesh networks)**

– **Data rate increase ⇒ M-fold increase in data rate with M Tx and M Rx antennas (MIMO 802.11n) – 2X2 (100 Mbps), 4X4 (500 Mbps)**

Can be Implemented Analog (RF) or Digital

Analog Advantages:

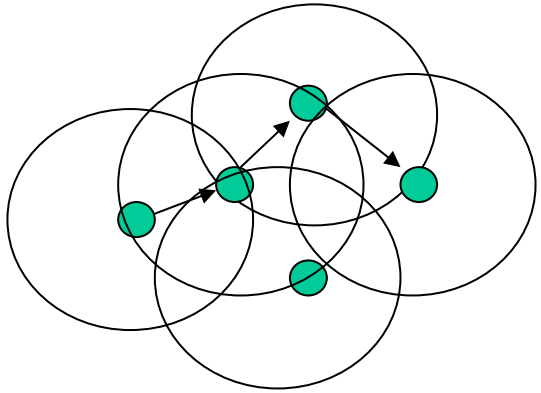
- Digital requires M complete RF chains, including M A/D's and D/A's, versus 1 A/D and D/A for analog, plus substantial digital signal processing
  - Analog is lower cost and lower power
- An appliqué approach is possible - digital requires a complete baseband – which provides flexible implementation

Digital Advantages:

- Slightly higher gain in Rayleigh fading (as more accurate weights can be generated)
- Temporal processing can be added to each antenna branch much easier than with analog, for higher gain with delay spread
- Modification for MIMO (802.11n) possible

Standard interface (JESD96) can be used to connect multiple antennas and RFIC to baseband/MAC IC for multiple technologies (WiFi, WiMax, cellular, etc.) on client (e.g., antennas on laptop lid).

Impact of Smart Antennas on Mesh Networks



- Most systems today use omni-directional antennas
  - Since this reserves the spectrum over a large area, network capacity is wasted
- Consider smart antenna advantages:
  - Directional antennas (multi-beam and scanning beam)
    - Greater gain (M-fold with M beams)
    - Greater frequency reuse
    - Topology control
    - Increased connectivity
  - Adaptive arrays
    - Interference suppression reduces hidden node problem/increases capacity further
    - Multipath mitigation for use in non-LOS systems
    - Reduces association problems

Conclusions

- Adaptive arrays can easily be added (e.g., as appliqué) to selected nodes and/or to clients (13 dB gain with 4 antennas) today
- With 802.11n, 2-4 antennas with MRC, interference suppression, and MIMO will be available
- TDD – can beamform on transmit based on received signal without DoA information
- Standard interface can be used from multiple antenna RFIC to BB/MAC for plug-n-play with a variety of systems
- 802.11s to study ad hoc networks among access points
- Combination of smart antennas and ad hoc networks can provide gains that are greater than the sum of the gains, but only if used properly