Adaptive Beam Antennas

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Scenario

Can we these remote areas to the Internet in a cost effective way?

Rural Villages

Backhaul link

Cell Tower
Why Adaptive Beam Forming

- Tower dominates cost (both fixed and ongoing)
- Considerably simplifies tower design, installation, maintenance
- Possibly eliminate the tower all together (beyond the scope of this project)
- Challenges: optimal steering on both ends of a variable long distance link is very hard, especially when relying on cheap hardware
- Optimal system performance (high data-rate, low energy consumption) requires intelligent, adaptive software support
Antenna System Concept

- Low-cost adaptive beam steering antenna
  - For Wifi: 802.11b, maybe 802.11a/b/g/n
  - Where cost(antenna) < cost(access point)
  - Expect cost(antenna) < $50
- Software controllable antenna
  - Enable continuous low-frequency channel optimizations
  - Simplify deployment; increase performance and robustness
- Motivation and specialization from ICT4B context
  - 1-60km point-to-point links => 25-35dBi antenna gain
  - Standard 802.11a/b/g/n physical layer; higher maybe non-std
System Design Space

- Four classes of antennas can be controlled electronically
  - Electromechanical
  - Phased array
  - Active integrated
  - Switched parasitic
- Two of these are not relevant for us
System Parameters

- Configuration
  B   half power beamwidth
  A   dynamic azimuthal range
      +/- (A/2) right/left
  a   azimuthal precision
      (A/a overlapping sectors each B degrees wide)
  E   dynamic elevation range
      +/- (E/2) above/below
  e   elevation precision
      (E/e overlapping elevation sectors each B degree tall)
  p   polarization
  f   frequency
Phase Arrays

Phasor Array

Controller

Receiver

Transmitter

Dupx

LNA

PA

Dupx

LNA

PA

Dupx

LNA

PA

Dupx

LNA

PA

Phasor Array
Switched Parasitic Antennas

- A single active antenna surrounded by a system of passive scatters with controllable reactive loads
- Varactor diodes can serve as the reactive loads in passive scatters; use reverse bias magnitudes to control diode depletion capacitances
- Control requires DACs for analog reverse bias and RF chokes to isolate the low-frequency control circuits from the diodes
- An Antenna Control Unit implements the beam forming algorithm that optimizes channel characteristics by adjusting the loads
Modeling

- Parametric design exploration
  - Element type (dipole, monopole, patch)
  - Geometries (#, placement, spacing, reflectors)
  - Reactive loads

- Design and structure optimization
  - Parametric directional and gain control
  - High gain and directional precision in narrow azimuth
  - Low gain and wide beam width in wide field of view

- RF and system metrics for evaluation
  - Directional control (angular precision) at maximum gain
  - Rate of adaptation – maximum rate, settling time
  - Chamber characterizations
Russia Prototype #1

conductive plates

ground

antenna with active and only two passive vibrators

inductive shortening
Future Topics

- Multi-band antenna system for 802.11a/b/g
  - dual band elements; simultaneous send/receive on different bands

- Eliminate interference among co-located antennas
  - enable dense population of towers with antennas for different links or sectors

- 16 sector x 360 degree low-gain system for indoor wifi
  - can compact variant be demonstrated for localization applications

- Hybrid analog-digital phase shifting system with Golan
  - Use PCI express cards to demonstrate unique capabilities and value

- 2.4 to 3.5 Ghz up-down frequency shifting system
  - stake our claim to this currently unused bay area spectra

- System with two independently steerable beams?

- Extreme precision, 1-lambda azimuth control at 1km

- Adaptive antenna systems for WiMax terminals
Russia: People and Places

• Prof Alexey Umnov, Nizhny Novgorod State University,
• Maxim Suralev (NNSU and Intel Intern), and co.