Architecture for ES Receiver Systems Targeted at Commercial Wireless Communications

Warren P. du Plessis

7 November 2012

Presentation Outline

- Importance of commercial communications systems
- Challenges unique to commercial communications ES
- Proposed architecture
- Required technologies

our future through science

Importance of Commercial Communications

- New uses for cellular phones
  - Rhino poaching
  - Guiding illegal immigrants
  - Insurgent attacks
  - Military (approved or not)
- Control from network operators
  - Require legal framework
    - RICA in South Africa
  - Privacy concerns
  - Interception without suspicion of criminal activity?
  - Border regions
- Unique challenges
  - Existing ES systems are unsuitable

Low Signal Power

- Mobile devices
  - Small batteries
  - Small transmitters
- Specified maximum power
  - E-GSM 900: 33 dBm (2 W)
  - DCS 1800: 30 dBm (1 W)
  - Tolerance: $\pm$2.5 dB
- Power control
  - 15 steps of 2 dB
  - Tolerance of $\pm$6 dB
- Minimum power
  - E-GSM 900: -1 dBm (0.79 mW)
  - DCS 1800: -6 dBm (0.25 mW)

Dense Signal Environment

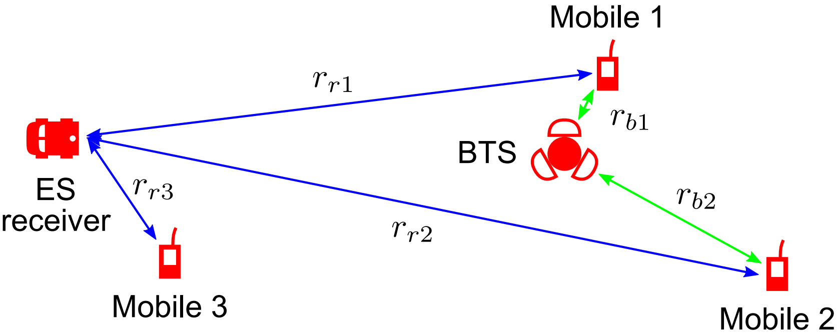
- Mobile users
  - 5.6 billion estimated subscribers
    - 649 million in Africa
  - 7 billion people in the world
- Limited available bandwidth
  - Need to reuse spectrum
  - Users overlap
    - Time
    - Frequency
- ES receiver likely to see many cells
  - Problem worse than at base stations

Interception Challenges

- Time-division
  - TDMA
  - TDD
  - GSM: 547 μs bursts
- Discontinuous transmission
  - Only transmit when data are available
  - Typically around 50% with speech
- Frequency hopping
  - Potentially a different frequency for each burst

our future through science

Scenario Geometry



- Mobile 1: Close to BTS/Node B
- Mobile 2: On far edge of cell
- Mobile 3: Close to ES receiver

ES Receiver vs BTS

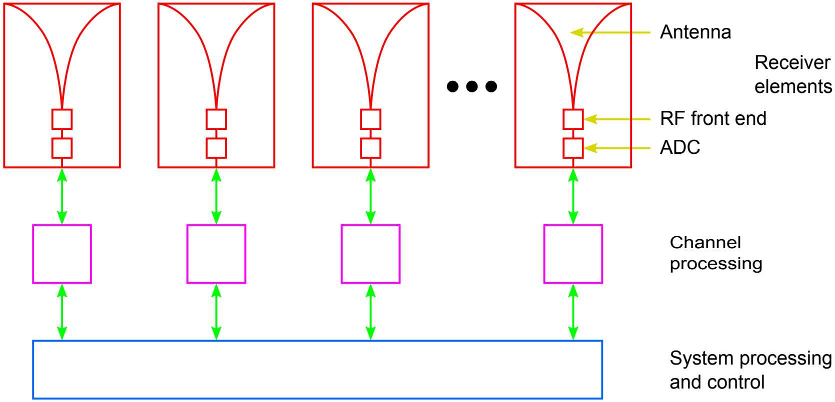
- Height
  - BTS: 30-m tower
  - ES receiver: 10 to 20-m mast
- Antenna gain
  - BTS: 15 dBi
  - ES receiver: <5 dBi
- Diversity gain
  - BTS: 3 to 5 dB
  - ES receiver: none
- Noise figure
  - BTS: 3 to 4 dB
  - ES receiver: 3 to 4 dB
- Required SNR
  - BTS: 8 to 9 dB
  - ES receiver: 10 dB

CSIR
our future through science

Requirements

- Sensitivity
  - Antenna gain
  - RF: Noise figure
  - Signal processing: SNR
- De-interleaving
  - Dynamic range
  - Narrow antenna beams
  - Many receivers
  - Signal processing
- Broad frequency coverage
  - Many widely-separated bands
- Need to outperform base stations

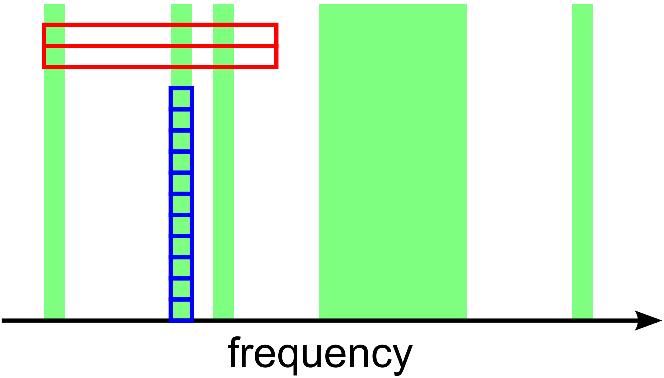
Proposed Architecture



Benefits

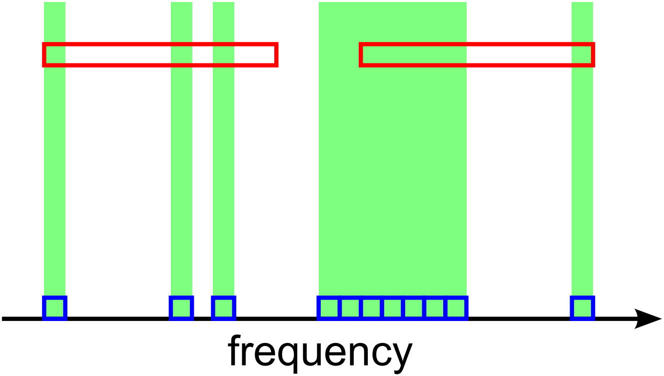
- Large antenna gain
- More samples for de-interleaving
- RF front end integrated with antenna
- Lower instantaneous bandwidth per channel
  - Higher-resolution ADCs
- Received signals are digitised at antenna
- Many low-rate data streams
  - Well matched to DSP technologies
  - Better algorithms?
- Inherently scalable
- Redundancy for higher reliability
- Versatility

Versatility: Antenna Gain

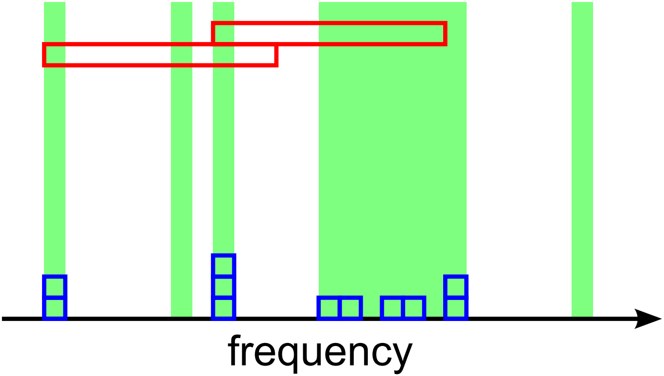


our future through science

Versatility: Frequency Coverage



Versatility: Combination of Gain and Coverage



our future through science

Element Cost

- Cost drivers
  - Maximum operating frequency
  - Sampling rate
  - Production volumes
- Conservative estimate: $<$R 11,000
- Ettus N210 with WBX daughterboard
  - FPGA capable of 32 GMACS
  - Transmitter included
  - Cost: R 20,000

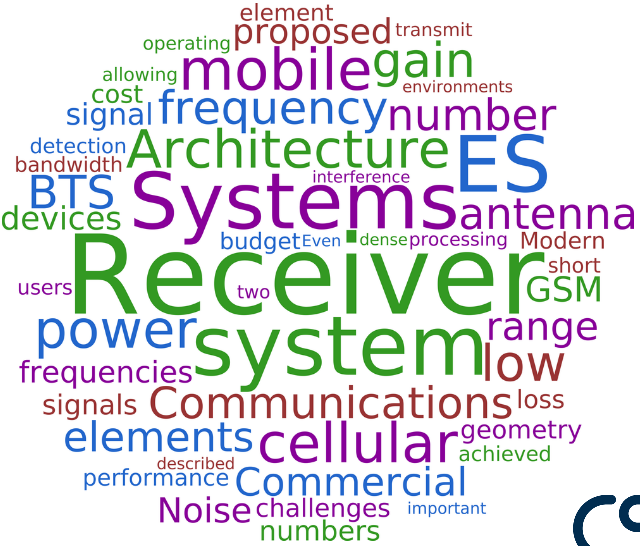
Required Technologies

- Low-cost integrated receivers
- High-performance signal processing
  - FPGA
  - DSP
  - GPU
  - Clusters
- Calibration
  - Can adapt existing techniques
- Thinned antenna arrays
  - Research since at least 1960s
- Detection and estimation
  - Can adapt existing algorithms
- Similar challenges to SKA

Summary

- Unique challenges
  - Low signal power
  - Dense signal environment
  - Evasive transmissions
  - Scenario geometries
- New architecture proposed
  - Many independent receivers
  - Many benefits
    - Matched to commercial communications' ES requirements
    - Versatility
- Required technologies largely already exist
  - Strong overlap with radio astronomy

Thank You!



our future through science