Reconfigurable Wireless Platforms for Spectrally Agile Coexistence

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NEED ADDRESSED
- RURAL BROADBAND

• 14.5M rural Americans lack broadband access
  – Too expensive for many other rural Americans
• Low population density and oftentimes difficult terrain hinder infrastructure development
• Impact:
  – Higher unemployment/lower earnings
  – Fewer educational opportunities
  – Lower quality healthcare at higher cost

Technologies are needed to supply low-cost rural broadband communications
OPPORTUNITY/IMPACT

- FCC has approved rules for *unlicensed* use of Television White Spaces (TVWS) from 54-698 MHz
  - Long range, penetrates buildings & foliage
  - Highest availability in rural areas

- Initial U.S. rural broadband opportunity is $100M-200M per year
  - White space device market projected to be ~$10B/year
• Current proprietary TVWS solutions cannot achieve economies of scale
  – High cost
  – Lack benefit of community-wide innovations
• No TVWS standard has achieved traction
  – 802.22 best for long-range TVWS operation
    • Non-Contiguous Orthogonal Frequency Division Multiple Access (NC-OFDMA)
  – Alternatives (e.g., 802.11af, 802.15.4m) are not suitable for rural broadband
• Technical challenges with 802.22 include:
  – Out-of-Band (OOB) emissions
  – Coexistence with other TVWS networks
  – Interference mitigation
  – Operation in areas without internet and/or GPS
    • Sensing only operation
TVWS SPECTRUM MASK

- Cannot easily repurpose existing OFDM designs for TVWS operation
- New methods required to limit out-of-band (OOB) emissions
SPECTRUM SENSING

- Sensing needed for:
  - Interference mitigation
    - Distant TV transmitters
    - Unlicensed microphones
  - Coexistence
    - Other 802.22 networks
    - Other TVWS networks
  - Sensing only operation

Wireless Microphones, intercoms, in-ear monitors, ...

802.11af

802.22 Basestation

TV Transmitter

802.22 Basestation
RURAL BROADBAND SOLUTION USING 802.22

802.22 Basestation

Coexist with other secondary users

Avoid Interfering with Primary Users

Backhaul links

Directly connect rural area subscribers

Wireless Microphones

802.11af

802.22

School

Hospital

TV Transmitter

802.22 Subscribers
IIR FILTERING

• Designed and demonstrated on FPGA tunable and practical IIR filters to:
  – Mitigate in-band interference
  – Reduce OOB emissions
NOTCH FILTER CREATION

- Store high-pass IIR filters spanning range of bandwidths. Choose filter with desired bandwidth and frequency shift to create notch at desired center frequency.
REDUCED COMPLEXITY SPECTRUM SENSING IMPLEMENTED ON FPGA

- Cyclostationary processing for sensing OFDM:
  - Low-SNR operation even when noise and interference levels cannot be accurately estimated
  - Known signal features allow reduced bi-frequency search space
RURAL BROADBAND PROTOTYPE

Tunable, High Dynamic Range, TVWS RF Front-End

Spectrum Sensing, Geolocation

MAC - Adaptive Modulation and Coding - Scheduling

Internet

TVWS database

Physical Layer

OFDMA Demodulator

FEC (LDPC)

Equalizer

FFT

FFT Pre-processor

Pilot Processor

Filtering

Resampling

BPF

LNA

BPF

LPF

LO₁

ADC

IIR Filtering
CONCLUSION

- Reduced complexity and effective filtering and sensing needed for practical and compliant TVWS solutions
- Proposed 802.22-based design promises low-cost, robust, and widespread rural broadband deployment