Demo Abstract: Cross-Technology Communication between LTE-U/LAA and WiFi

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Motivation

- WiFi dominated 5GHz band
- LTE started moving to 5GHz band (LTE-U)

- Advanced technologies
  - data rates in order of Gbps
- Performance degradation
  - Increased contention
  - Mutual interferences
Coexistence Issues
Coexistence Issues

碰撞
We are connected!

BigTelco

LTE-U eNb

collision

WiFi AP

Bob
Let’s setup a control channel

![Diagram showing a control channel setup between BigTelco, LTE-U eNB, Internet, and WiFi AP with a collision point.]
But how?
Over-the-air Neighbor Discovery

- How to perform neighbor discovery between nodes of heterogeneous technologies?
  - Common belief: heterogeneities cannot talk with each other

TX: My ID is 12

LTE-U eNb

RX: $%^#()@

WiFi AP
Cross-technology Communication (CTC)

- CTC enables heterogeneous devices to talk directly
  - Simple side-channel on top of normal transmissions
    - e.g. CTC data encoded in frame duration

- We design CTC scheme for WiFi and LTE-U

**TX:** My ID is 12

LTE-U eNb

**RX:** My ID is 12

WiFi AP
LTE and WiFi are both OFDM

- Both use OFDM in PHY layer, but with different grid parameters
  - WiFi – symbol time 4us, subcarrier spacing 312.5kHz
    FFT 64, used subcarriers 56
  - LTE – symbol time 71.4us, subcarrier spacing 15kHz
    FFT 2048, used subcarriers 1200

- They can use their FFT blocks to perform spectrum scanning
  - modern WiFi cards supports it (ath9k, ath10k)
  - they can measure each other signals in frequency domain!

- **CTC idea**: modulate CTC message into 2D power pattern
Superposition Coding - communicate two messages simultaneously by encoding them into a single signal in two layers.
2D Nyquist sampling:

\[ \Delta T_{\text{CORB}} = a \cdot \Delta T_{\text{TX}} + \epsilon_a \geq b \cdot \Delta T_{\text{RX}} + \epsilon_b \]

\[ a \geq 1, b \geq 2 \quad \text{where} \quad a, b \in \mathbb{N}, \quad \epsilon_a \rightarrow 0, \epsilon_b \rightarrow 0 \]

\[ \Delta f_{\text{CORB}} = n \cdot \Delta f_{\text{TX}} + \epsilon_n \geq m \cdot \Delta f_{\text{RX}} + \epsilon_m \]

\[ n \geq 1, m \geq 2 \quad \text{where} \quad n, m \in \mathbb{N}, \quad \epsilon_n \rightarrow 0, \epsilon_m \rightarrow 0 \]

\[ \Delta B_{\text{PP}} = (F_{\text{TX}}^{\text{start}}, F_{\text{TX}}^{\text{end}}) \cap (F_{\text{RX}}^{\text{start}}, F_{\text{RX}}^{\text{end}}) \]

1 out of N encoding

1 out of 8 = 3 bits

2 x (1 out of 4) = 4 bits
Prototype Implementation

**Tx Side**
- LTE-U: srsLTE + USRP B205mini
- WiFi 802.11n: Atheros AR928x and USRP B205mini

**Rx Side**
- LTE-U: srsLTE + USRP B205mini
- WiFi 802.11n/ac: Atheros AR928x (n) and QCA988x (ac)

Connections:
- **LTE-to-LTE**
- **WiFi-to-WiFi**
- **CTC**
Punched Cards in LTE-U

- **RB Blacklisting**: a scheduler do not allocate blacklisted RBs
Punched Cards in LTE-U

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- **Problem**: *srsLTE* does not support RB blacklisting
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- **Prototype Implementation**: Modulate power of sub-carriers
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- **Problem**: *srsLTE* does not support RB blacklisting
- **Prototype Implementation**: Modulate power of sub-carriers

**LTE-U -> WiFi Data Rate: 24kbps**
Punched Cards in WiFi

- How to generate power pattern in WiFi?
- 64-QAM – different phase and power levels
- 1 LTE symbol equals 18 WiFi symbols in time -> power averaging

\[
\text{AvgPwr/MnPwr} = 10\log_{10}(42/2) = 13.2 \text{ dB} !!!!
\]
Punched Cards in WiFi

- Add only few bits in proper places, i.e. pattern generating bit sequence to force usage of min power constellation points at proper places in OFDM grid.
Punched Cards in WiFi

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WiFi-> LTE-U Data Rate: 84kbps
Demo Setup
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- eNB
- LTE Network
- UE

- STA
- WiFi Network
- AP
Part I: LTE-U -> WiFi
Part II: Partial CSI Measurements

- Frame detection and synchronization based on 2D cross-correlation
- Channel estimation during preamble detection
Part III: WiFi -> LTE-U
Part IV: Cross-technology Broadcast Channel
Conclusions

Thank you!

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