Co-existence of LTE-U and Wi-Fi with Direct Communication

Rajorshi Biswas and Jie Wu
Dept. of Computer and Information Sciences
Temple University
Road Map

1. Wi-Fi & LTE coexistence
2. Two versions of LTE
3. Related work
4. Direct-communication between LTE and WiFi
5. Architecture
6. Simulation
7. Conclusion
1. Wi-Fi & LTE Coexistence in 5GHz Band

- Wi-Fi is already operating in 5GHz bands (U-NII)
  - 802.11 ac and 802.11 n
- Long Term Evolution (LTE) got permission to 5GHz bands

![Diagram showing coexistence between Wi-Fi and LTE in 5GHz bands]

Coexistence: Wi-Fi does not get fair share.
2. Two Versions of LTE for Future (5G)

- **LTE-LAA (sensing)**
  - Licensed Assisted Access (Wi-Fi like model).
  - Primary: 1800MHz, 1900MHz
  - Secondary: 5Ghz U-NII

- **LTE-U (no sensing)**
  - Duty cycle-based.
  - Throughput is better than LTE-LAA.

  *Gives chance to Wi-Fi*

**Sense** —> **LTE Transmission**

- Needs sensing mechanism at LTE eNB

**LTE on** —> **LTE off** —> **LTE on** —> **LTE off**

  *How to determine duty cycle / fair share? Ans: CSAT*

- **Carriier sensing adaptive transmission (CSAT)**

  Sense channel —> Estimate channel usage —> Decide duty cycle

- **Limitations:**
  - Still sensing module is needed.

- **Our solution:**
  - Wi-Fi AP sends usage information to LTE eNB (tower).

*Qualcomm Research, LTE in Unlicensed Spectrum: Harmonious Coexistence with Wi-Fi. June 2014.*
## 3. Related Work

<table>
<thead>
<tr>
<th>Systems</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| Adaptive Almost Blank Subframe (AABS) | • Long delay of communication has bad effect on throughput.  
• High overhead of sensing module (LTE keeps sensing). |
| <svg>...<svg> | LTE-eNB & Wi-Fi AP sends their usage information to the C-RAN. C-RAN decides LTE channel access mechanism. |
| Reinforcement learning-based resource allocation to LTE-U and WiFi | • Computation overhead is high.  
• Non consecutive blank space might reduce Wi-Fi throughput. |
| <svg>...<svg> | Mobile Management Unit (MMU) uses reinforce learning to determine location of blank space in LTE frame. Blank spaces are aperiodic. |
| Dynamic resource allocation using reinforcement learning for LTE-U and WiFi in the unlicensed spectrum (Ying-Ying Liu, Sang-Jo Yoo in ICUFN 2017) | Dynamic resource allocation using reinforcement learning for LTE-U and WiFi in the unlicensed spectrum (Ying-Ying Liu, Sang-Jo Yoo in ICUFN 2017) |
4. Direct-Communication between LTE and Wi-Fi

- If Wi-Fi Throughput > LTE Throughput
  - More ON period

- Else
  - Less ON period

- Assumption: LTE & Wi-Fi have unlimited data to transmit.

*Usage information*

**LTE eNB**

**Wi-Fi AP**

\[
\text{duty cycle} = \frac{\text{ON period}}{\text{ON period} + \text{OFF period}}
\]
Direct-communication between LTE and Wi-Fi

- If $\Delta > 0.4$
  - Progressive rate
    (old duty cycle $\times$ constant, 1.05)
- Else
  - Linear rate
    (old duty cycle $\div$ constant, 0.02)

- $\Delta =$deviation from ideal scenario
  (combination of fairness and efficiency)
  $\Delta = \frac{1}{3}(\delta_T + \delta_t + \delta_s)$, ideal scenario: $\Delta = 0$
5. Architecture of Proposed Model

- LTE eNB ↔ Wi-Fi AP
  - (same operator)
  - Wired connection (ethernet)

- Wi-Fi AP ↔ Wi-Fi AP
  - (different operator)
  - Wireless connection (reserved bits)

Simulator used: NS3
LTE LAA model: LTE release 13
LTE-U model: LTE-U direct communication
Wi-Fi version: IEEE 802.11n
Used channel: 5170MHz-5190MHz

Propagation model: NS3 indoor loss model
Simulations time: 15s to 50s
User packet type: UDP (1024 bytes)
Continuous UDP transmission.
6. Simulation

Settings

Operator A: LTE & Wi-Fi coverage
Operator B: Wi-Fi coverage

Random walk mobility model used for users in complex scenario

Simple:
1 LTE eNB, 1 Wi-Fi AP, 1 LTE user, and 1 Wi-Fi user

Complex:
4 LTE eNB, 4 Wi-Fi AP, 10 LTE user, and 10 Wi-Fi user
Simulation

Results: throughput

- **0.5 duty cycle:** time fairness, does not guarantee throughput fairness.
- Throughput fairness is achieved, and efficiency is acceptable.
Simulation

Results (simple): throughput over time

- High fairness and throughput achieved in LTE-U direct comm.
Simulation

Results (complex): throughput over time

- High fairness and throughput achieved in LTE-U direct comm.
Simulation

Results (simple): effect of communication delay

\[ t = \text{reporting time} \]
\[ d = \text{communication delay} \]
\[ t + d = \text{arrival time} \]

- Higher delay of communication \(\rightarrow\) Higher deviation from ideal scenario

![Diagram showing the relationship between reporting time, communication delay, and arrival time.]
7. Summary

- A model to achieve the fair coexistence
  - LTE and Wi-Fi in 5 GHz bands
- A new metric $\Delta$ to balance fairness and efficiency
  - Controlling convergence speed
- Achieving
  - Fairness while ensuring acceptable efficiency