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

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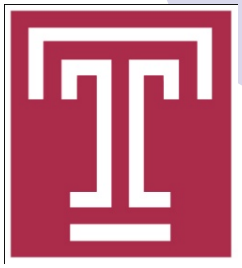
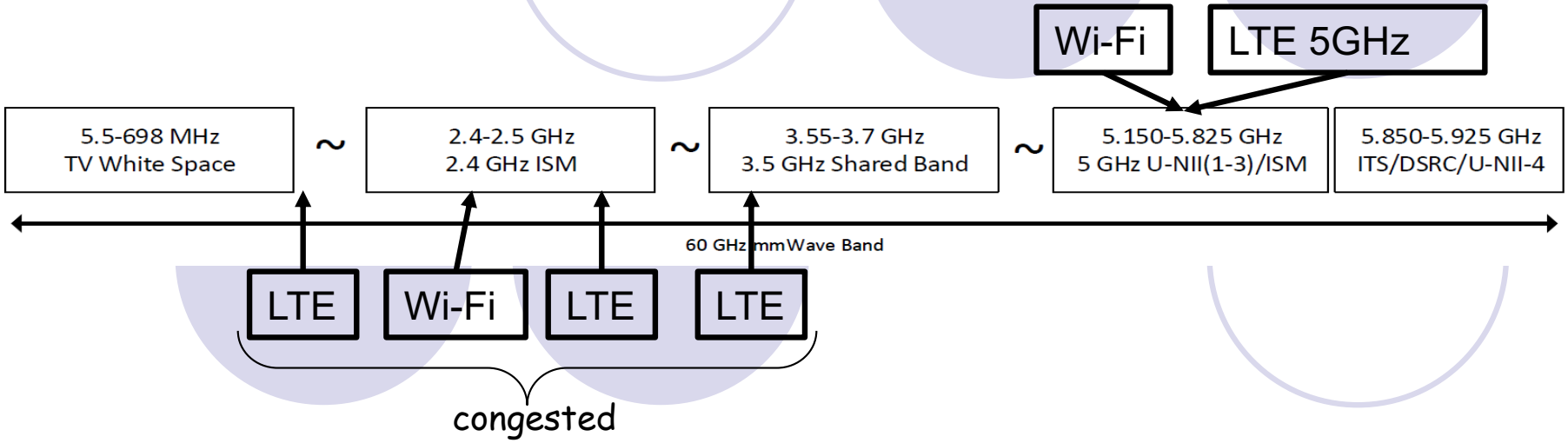


Road Map

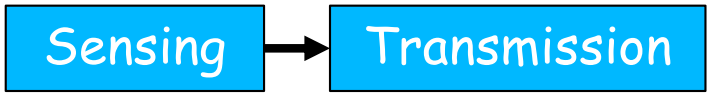
1. Wi-Fi & LTE coexistence
2. Two versions of LTE
3. Related work
4. Direct-communication between LTE and WiFi
5. Architecture
6. Simulation
7. Conclusion

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



Sensing



Wi-Fi

No sensing

Occupies whole spectrum all the time

LTE

Coexistence: Wi-Fi does not get fair share.

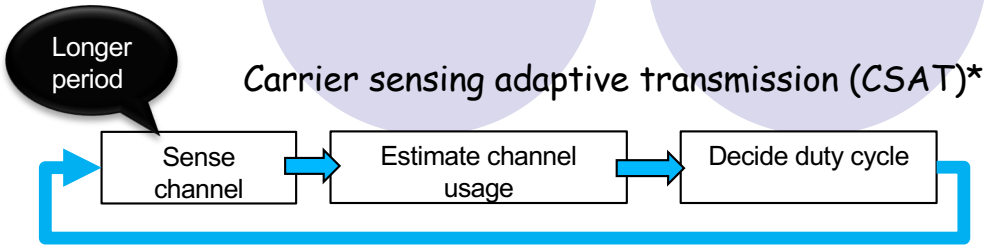
2. Two Versions of LTE for Future (5G)

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

Needs sensing mechanism at LTE eNB

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

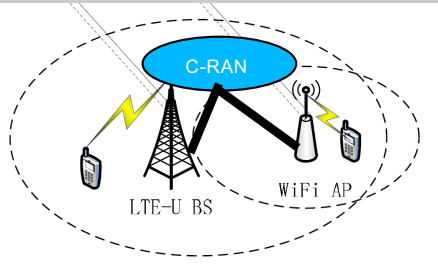
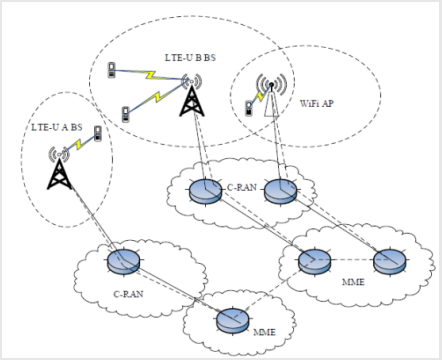
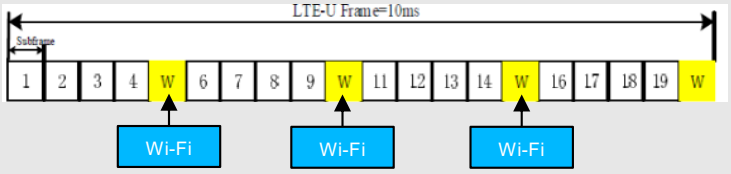
How to determine duty cycle / fair share ? Ans: CSAT



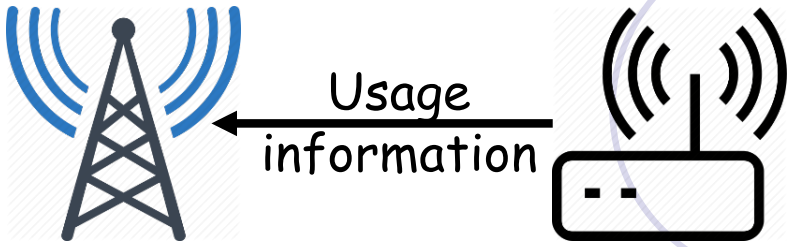
- Limitations:
  - Still sensing module is needed.
- Our solution:
  - Wi-Fi AP sends usage information to LTE eNB (tower).

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

3. Related Work

Systems	Limitations
Adaptive Almost Blank Subframe (AABS)  LTE-eNB & Wi-Fi AP sends their usage information to the C-RAN. C-RAN decides LTE channel access mechanism. An adaptive channel access mechanism for LTE-U and WiFi coexistence in an unlicensed spectrum (Jie Xiao, Jun Zheng in ICC 2016)	• Long delay of communication has bad effect on throughput. • High overhead of sensing module (LTE keeps sensing).
Reinforcement learning-based resource allocation to LTE-U and WiFi  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)	• Computation overhead is high. • Non consecutive blank space might reduce Wi-Fi throughput.

4. Direct-Communication between LTE and Wi-Fi



$$duty\ cycle = \frac{ON\ period}{ON\ period + OFF\ period}$$

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

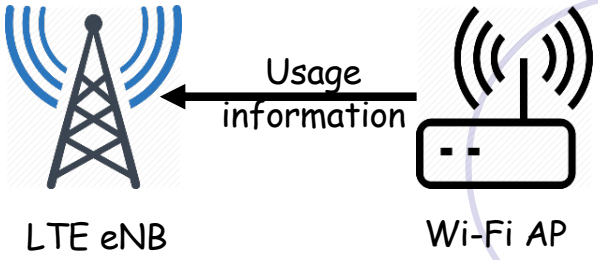
  Else
  - Less ON period

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

More ON period

More OFF period

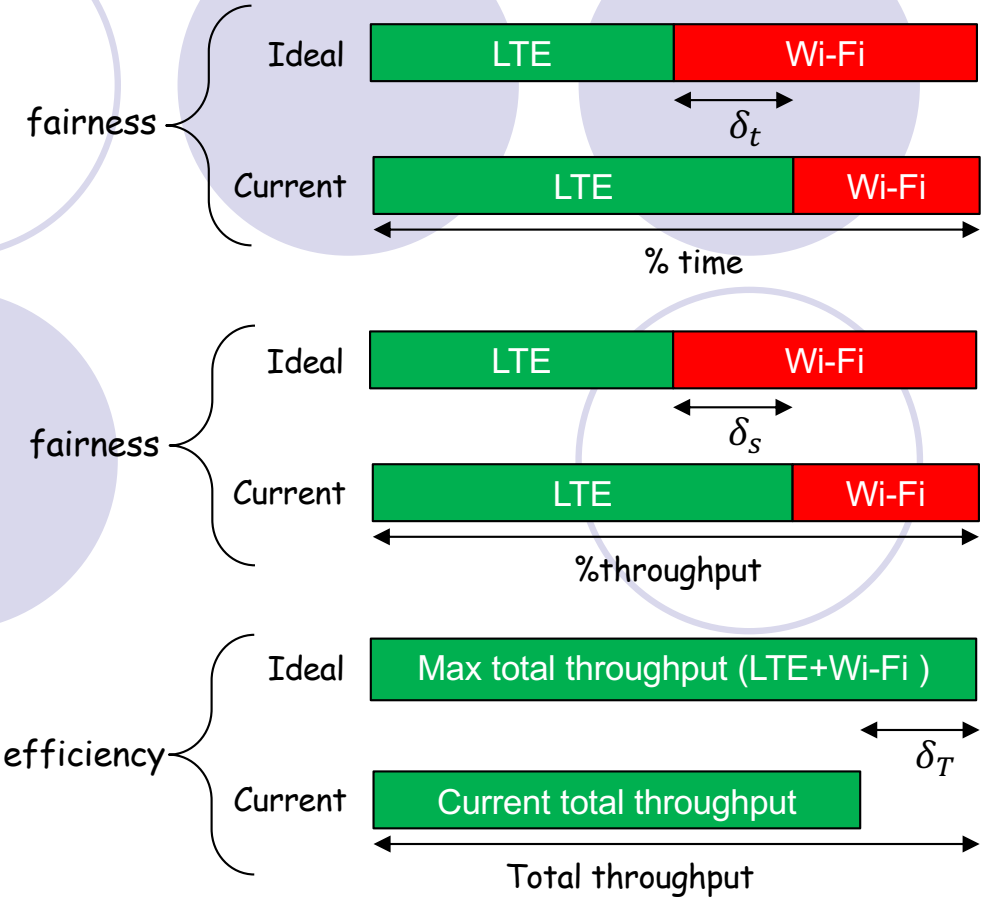
Direct-communication between LTE and Wi-Fi



- If Δ > 0.4
  - Progressive rate
    (old duty cycle x/÷ constant, 1.05)

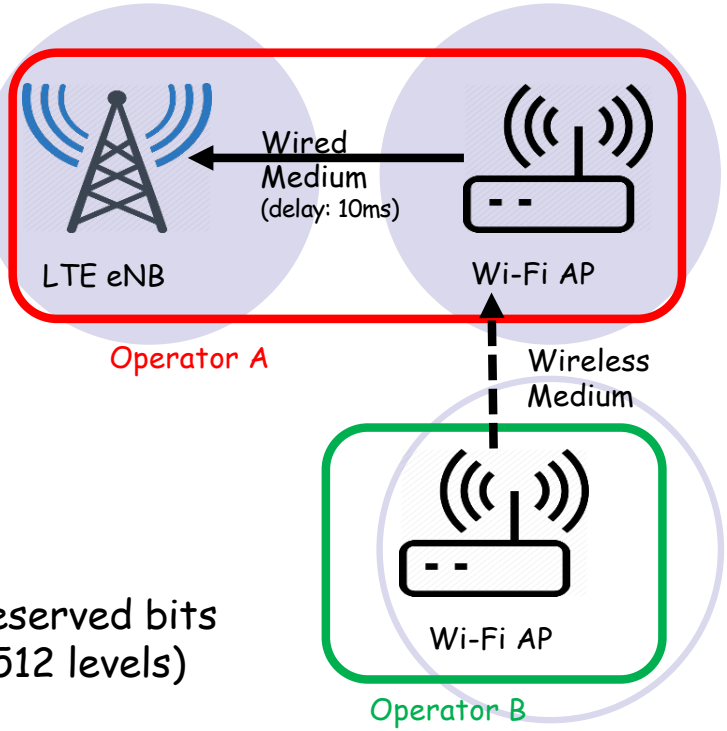
  Else
  - Linear rate
    (old duty cycle +/- constant, 0.02)

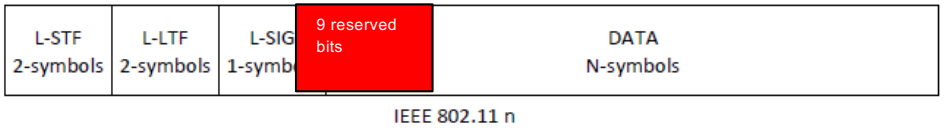
- Δ =deviation from ideal scenario
  (combination of fairness and efficiency)
  $\Delta = \frac{1}{3}(\delta_T + \delta_t + \delta_s)$, ideal scenario: $\Delta = 0$



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)





9 reserved bits
(512 levels)

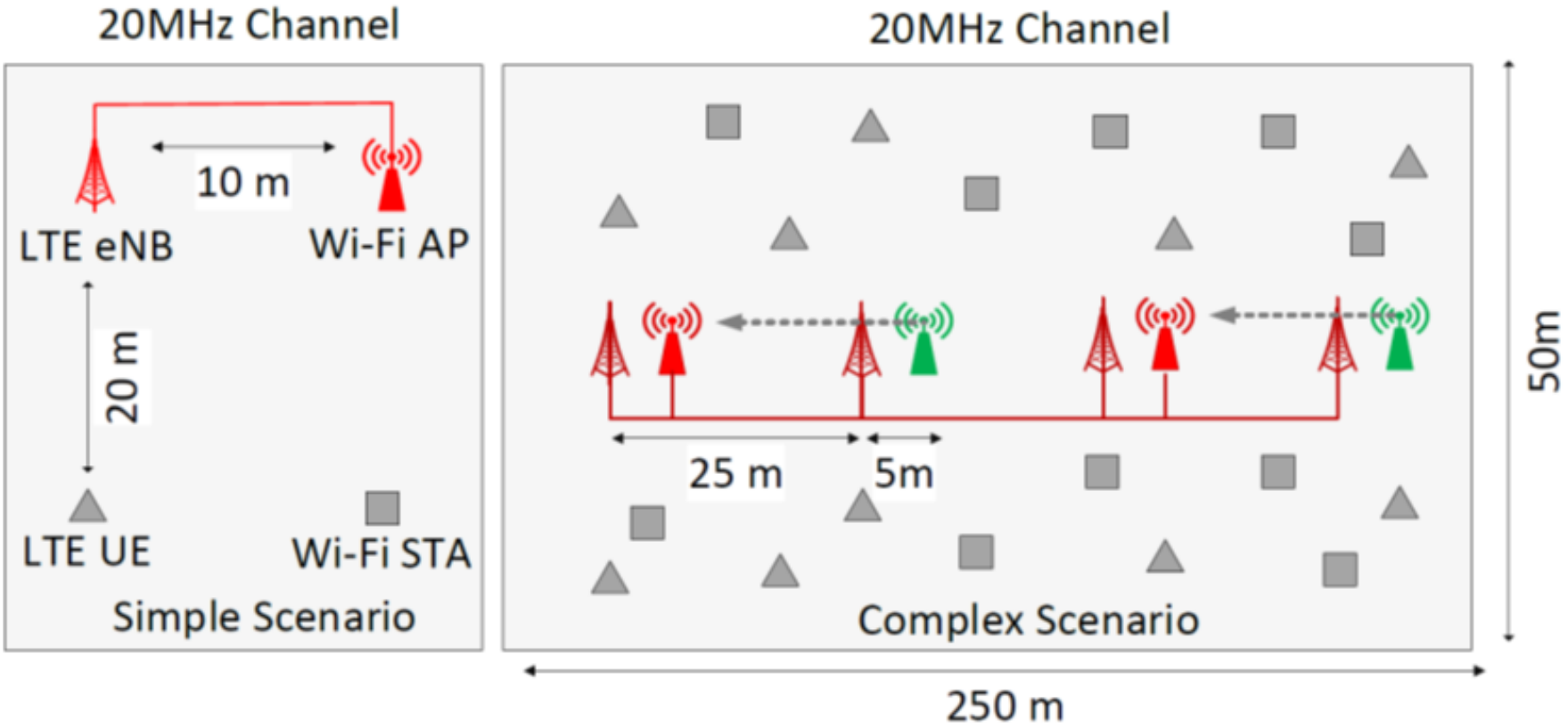
Simulator used:	NS3
LTE LAA model:	LTE release 13
LTE-U model:	LTE-U direct communication
Wi-Fi version:	IEEE 802.11n
Used channel:	5170MHz-5190MHz

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

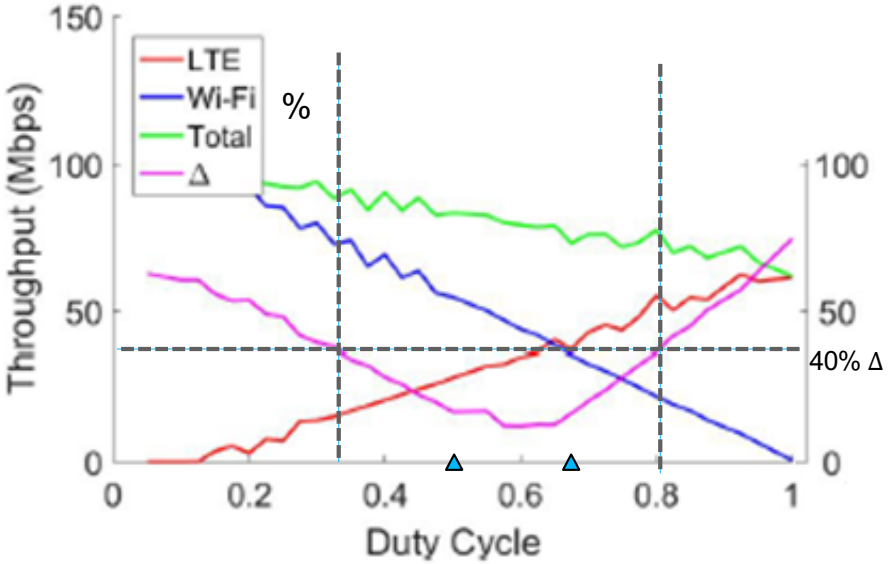
Random walk mobility model used for users in complex scenario

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

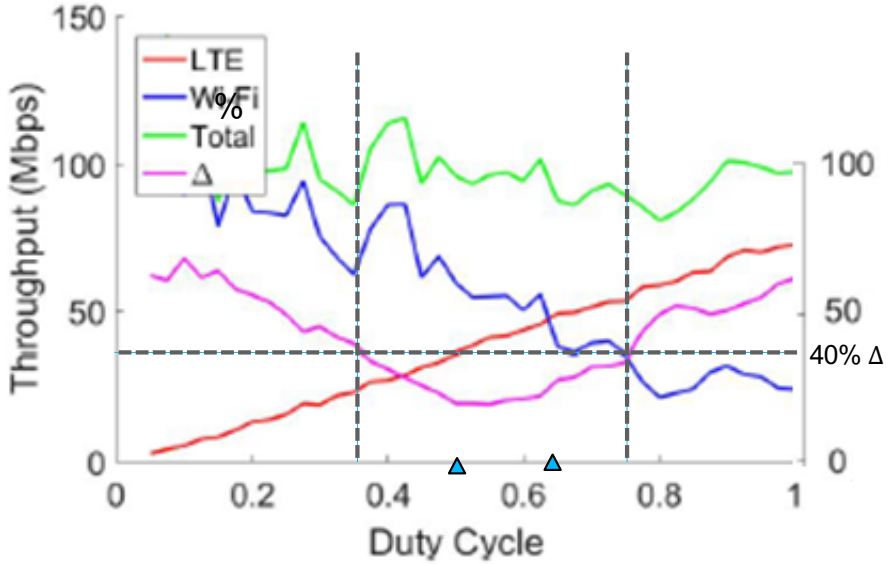
Complex:
4 LTE eNB, 4 Wi-Fi AP, 10 LTE user, and 10 Wi-Fi user

Simulation

Results: throughput



(a) Duty cycle vs. Throughput (Simple).

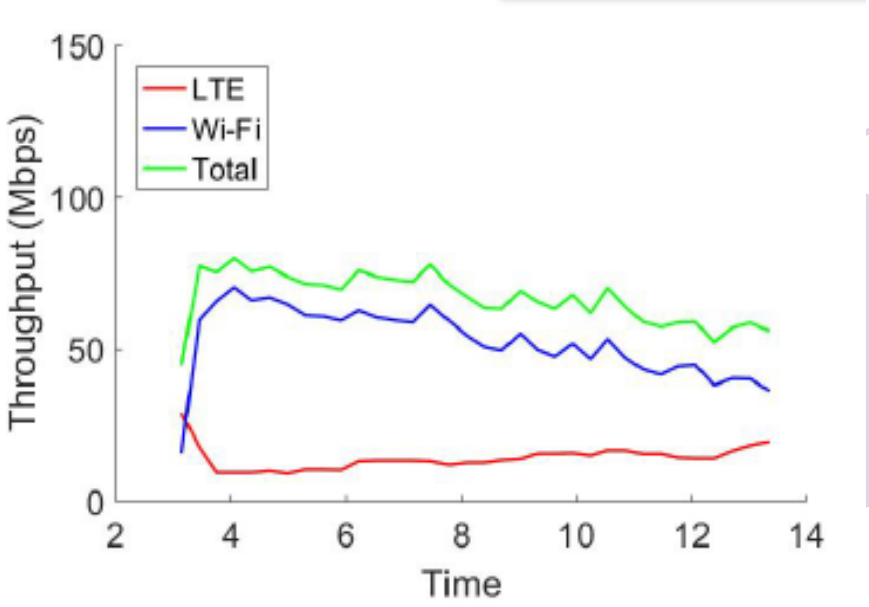


(b) Duty cycle vs. Throughput (Complex).

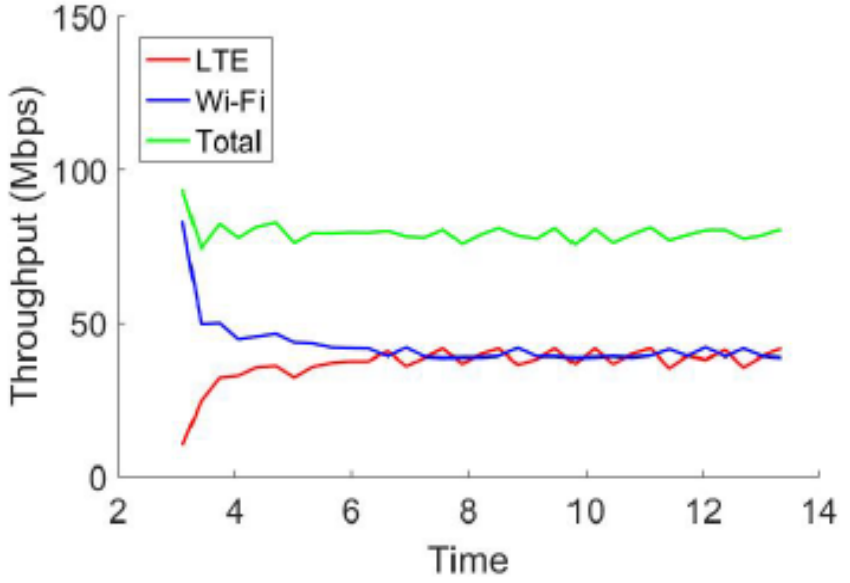
- 0.5 duty cycle: time fairness, does not guarantee throughput fairness.
- Throughput fairness is achieved, and efficiency is acceptable.

Simulation

Results (simple): throughput over time



(c) LTE-LAA and Wi-Fi (Simple).

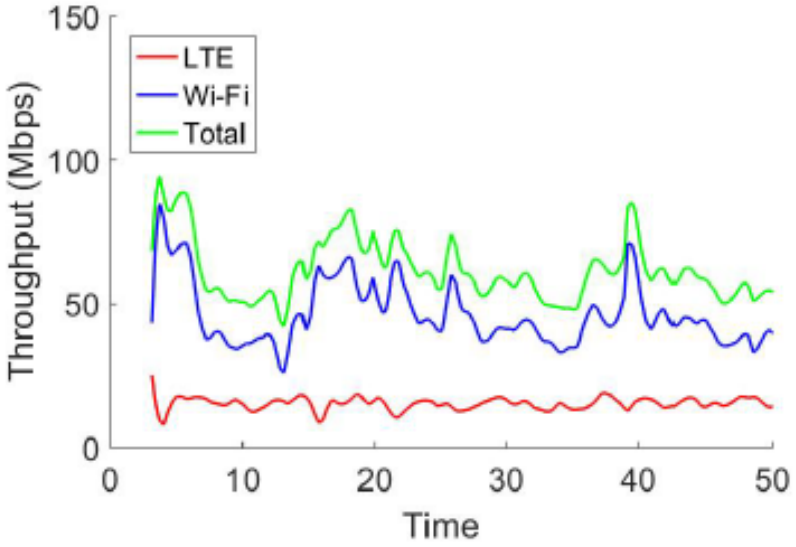


(d) LTE-U direct comm. and Wi-Fi (Simple).

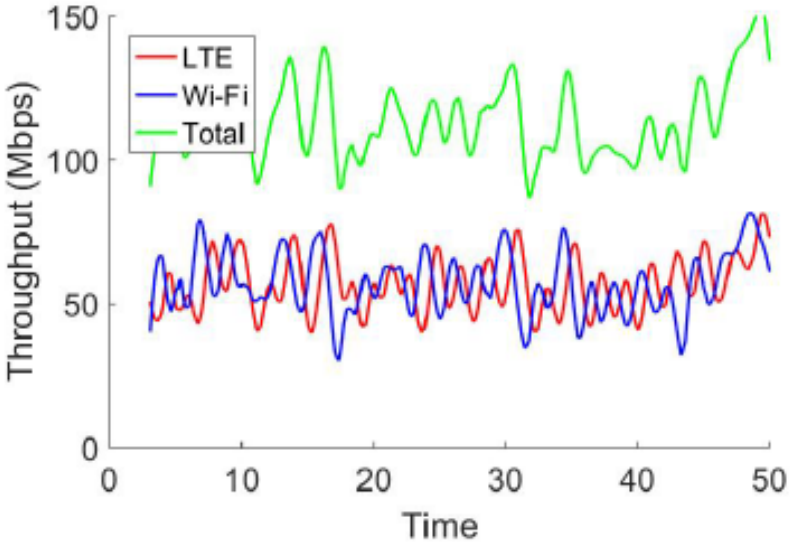
- High fairness and throughput achieved in LTE-U direct comm.

Simulation

Results (complex): throughput over time



(e) LTE-LAA and Wi-Fi (Complex).

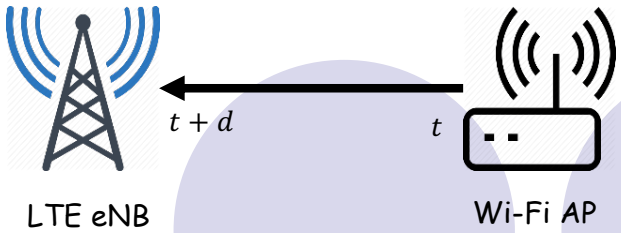


(f) LTE-U direct comm. and Wi-Fi (Complex).

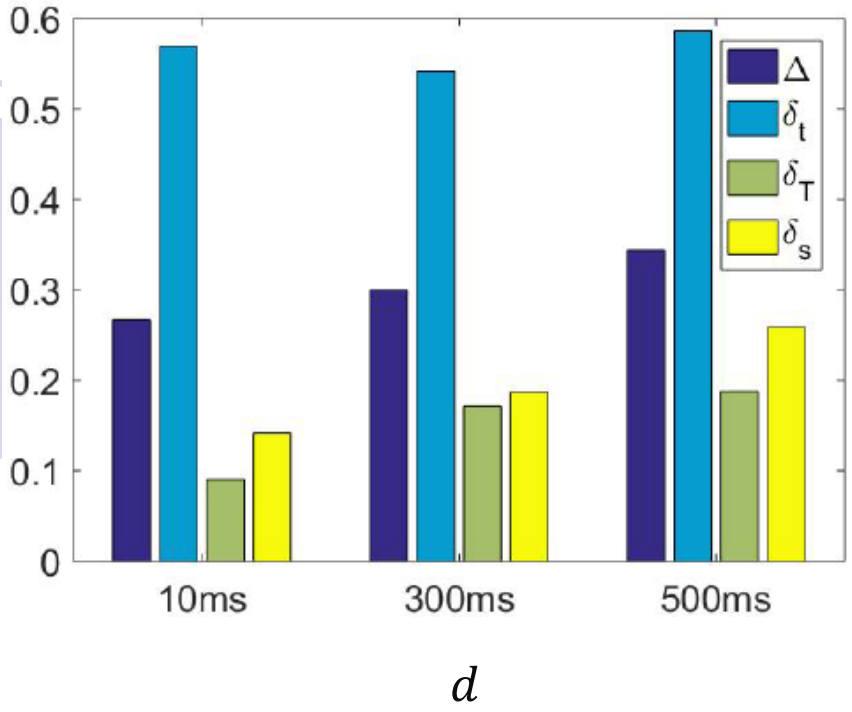
- High fairness and throughput achieved in LTE-U direct comm.

Simulation

Results (simple): effect of communication delay



t = reporting time
d = communication delay
$t + d$= arrival time



- Higher delay of communication-> Higher deviation from ideal scenario

7. Summary

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