Next Generation Spectrum Sharing Technology: Opportunity, Challenges and Roadmap (II)

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IEEE ICC22 WS23 workshop on spectrum sharing

Outline

I. Introduction

II. Shared Radio Spectrum: unlicensed and licensed

III. Wireless Coexistence:

   I. LTE-LAA Vs. WiFi Case Study

IV. Testing & Evaluation, Metric:

   I. Probability of coexistence and spectrum sharing

V. Challenges/Opportunity

Introduction

Dynamic Spectrum Sharing:
Maximize reliable spectrum utilization by multiple communicating terminals (primary vs. secondary, secondary vs. secondary) by exploiting frequency, time, power, and space.

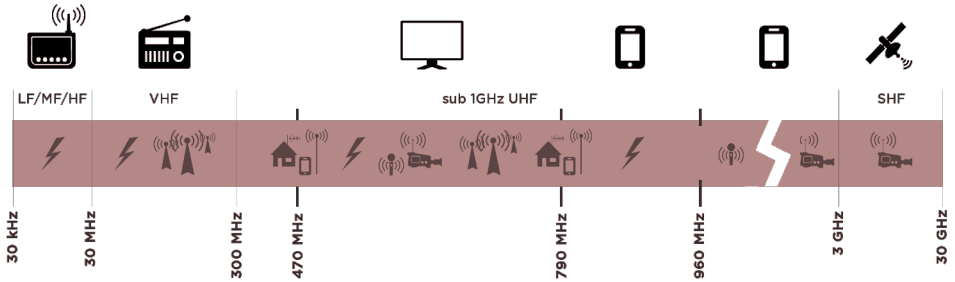
Enabling Technologies:
Cognitive radios, Software defined radios

Method:
Sensing and adapting radio operating parameters:

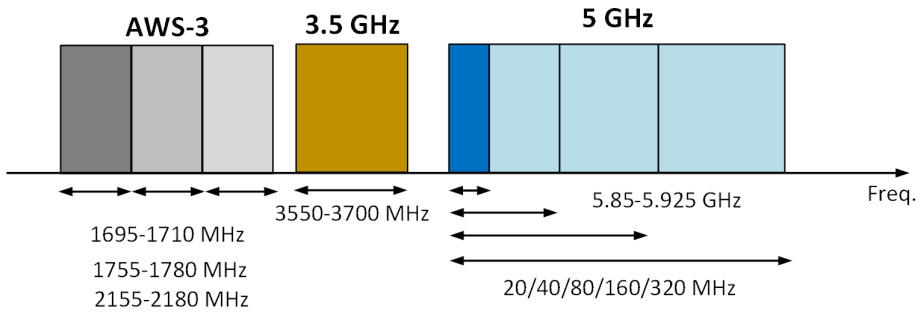
- Frequency channel, bandwidth,
- Transmission time, packet length,
- Transmission power, clear channel assessment, and receiver sensitivity.
- Modulation, coding scheme,
- Others

Shared Unlicensed Radio Spectrum (1)

- Licensed radio spectrum is underutilized
- Unlicensed radio frequency is crowded with diverse technologies
- 2.4 and 5.0 GHz bands are unlicensed (ISM)
- 1200 MHz of new unlicensed spectrum has been approved for use in the 6 GHz band (5.925-7.125 GHz)



Shared Radio Spectrum (2)



- TVWS:

Primary user: TV stations

Sharing mechanism: Database coordinator

- AWS-3:

Primary user: Federal Systems.

Sharing mechanism: manual coordination pf protective zones

- 3.5 *GHz: Citizens Broadband Radio Service (CBRS)*

Primary user: Federal systems, fixed satellite

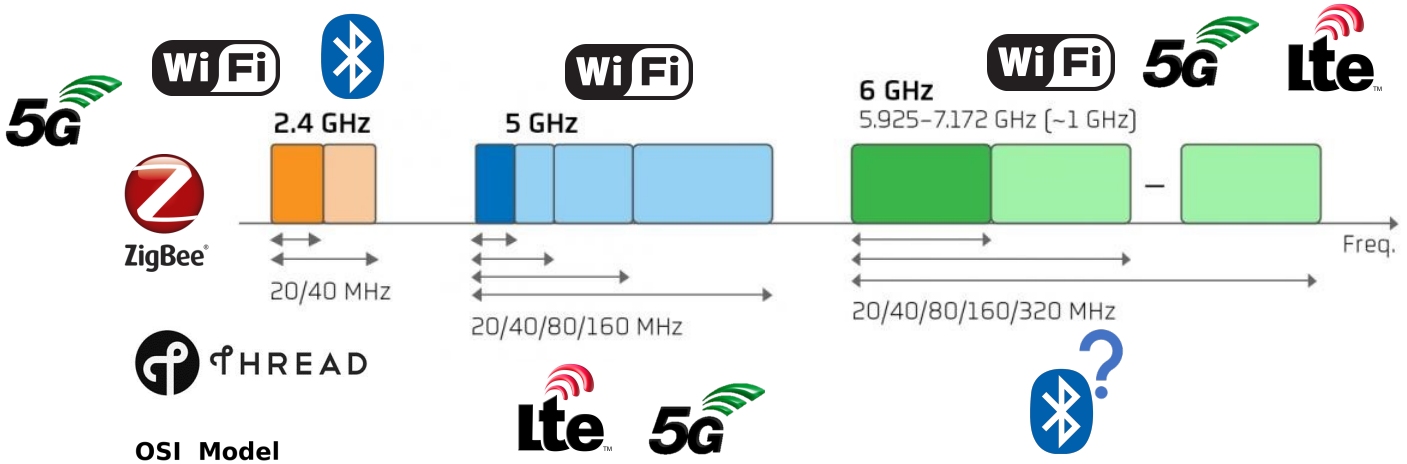
Sharing mechanism: Database coordinator-–Spectrum Access System uses of spectrum geo-sensing for automatic frequency assignment and usage policy.

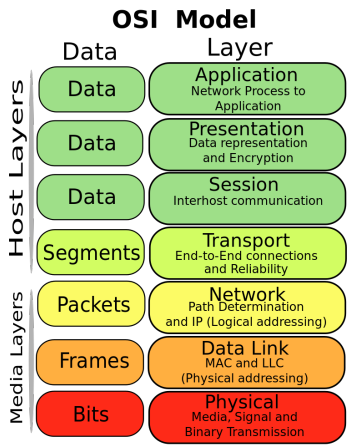
- *5.0 GHz:*

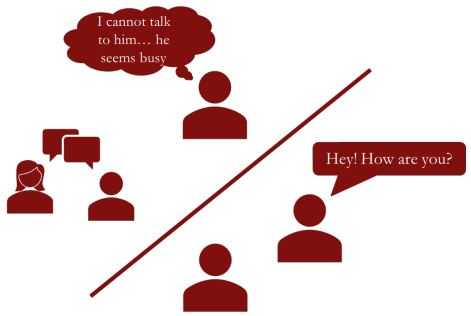
Primary user: DSRC (V2X)

Sharing mechanism: Distributed coordination

Case Studies: Wireless Coexistence in ISM Spectrum







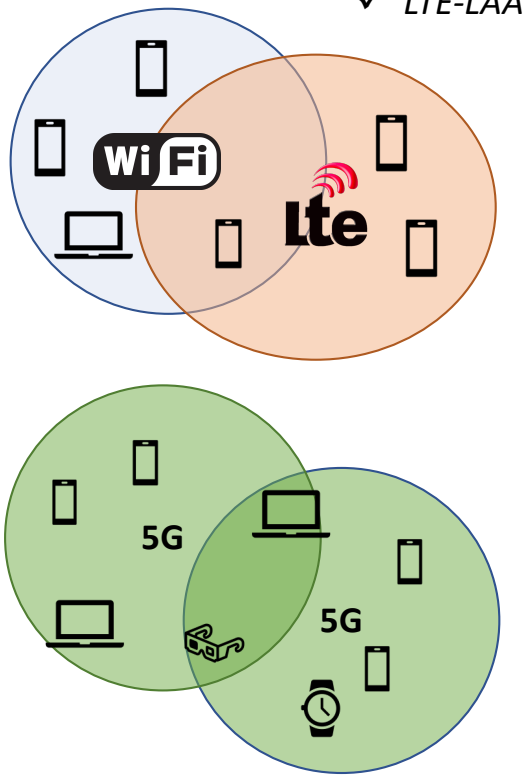
EDCA (IEEE 802.11)

LBT (Cellular)

Homogenous/Heterogenous Wireless Coexistence

- Despite similarities with EDCA, LBT received research attention pertaining to coexistence with Wi-Fi
- Performance degradation can also arise in homogeneous networks
- Homogeneous LBT in the unlicensed spectrum under dense conditions merits evaluation
  - LBT defines 4 sets of priorities
    - Single-class
    - Multi-class

✓ *LTE-LAA Vs. WiFi*

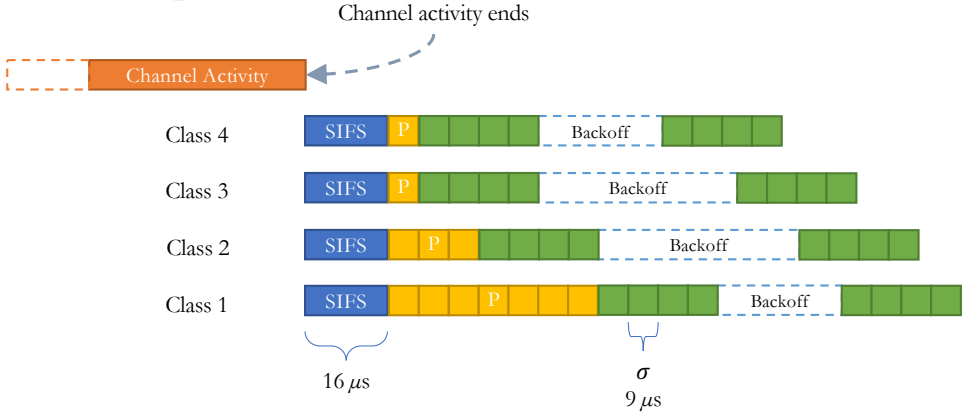


Technology Overview: LBT

- ETSI defines four sets of channel access parameters for LBT

Class	P0	CW_{min}	CW_{max}	COT [ms]
4	1	4	8	2
3	1	8	16	4
2	3	16	64	6⋆
1	7	16	1024	6⋆

⋆Can extend to 8 ms if transmission includes 100 μs



- Classes 1 to 4 possess ascending channel access priority
- P0 and CW are given in terms of observation slots (σ)
  - $1\,\sigma = 9\,\mu s$

Technology Overview: LBT

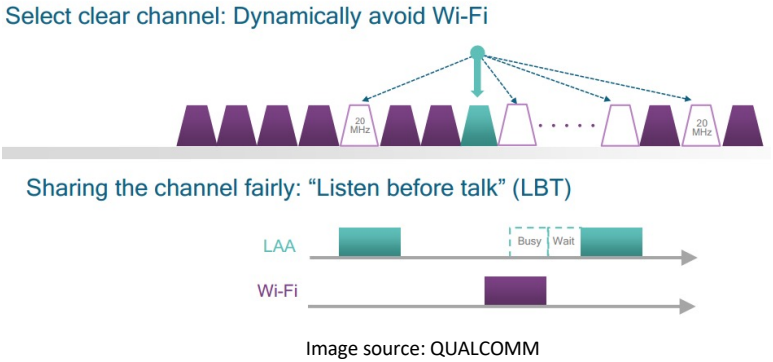
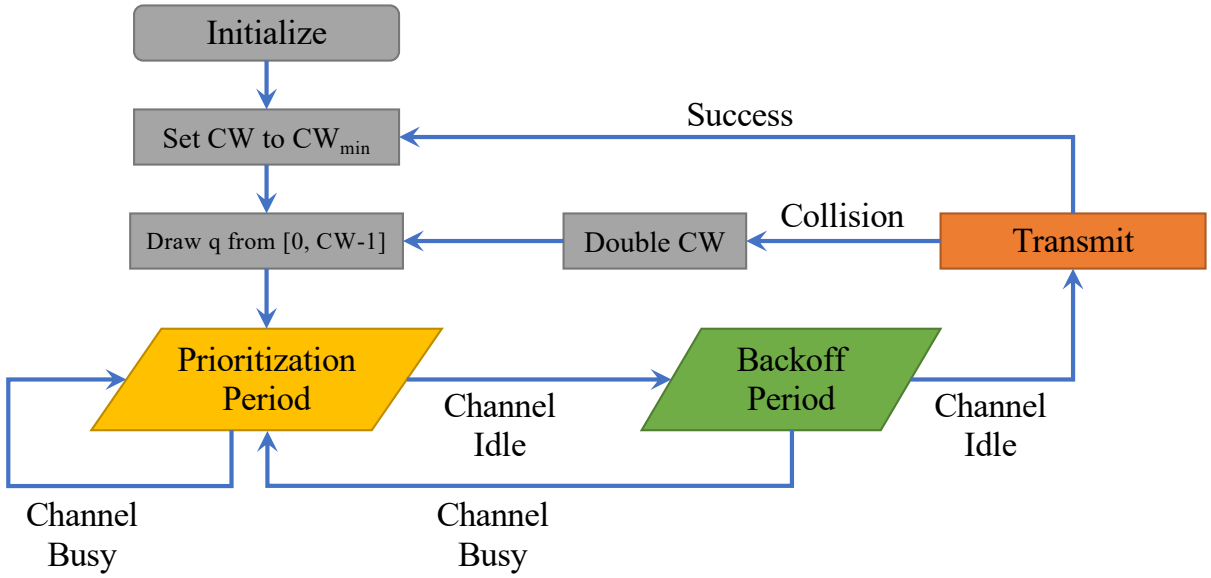
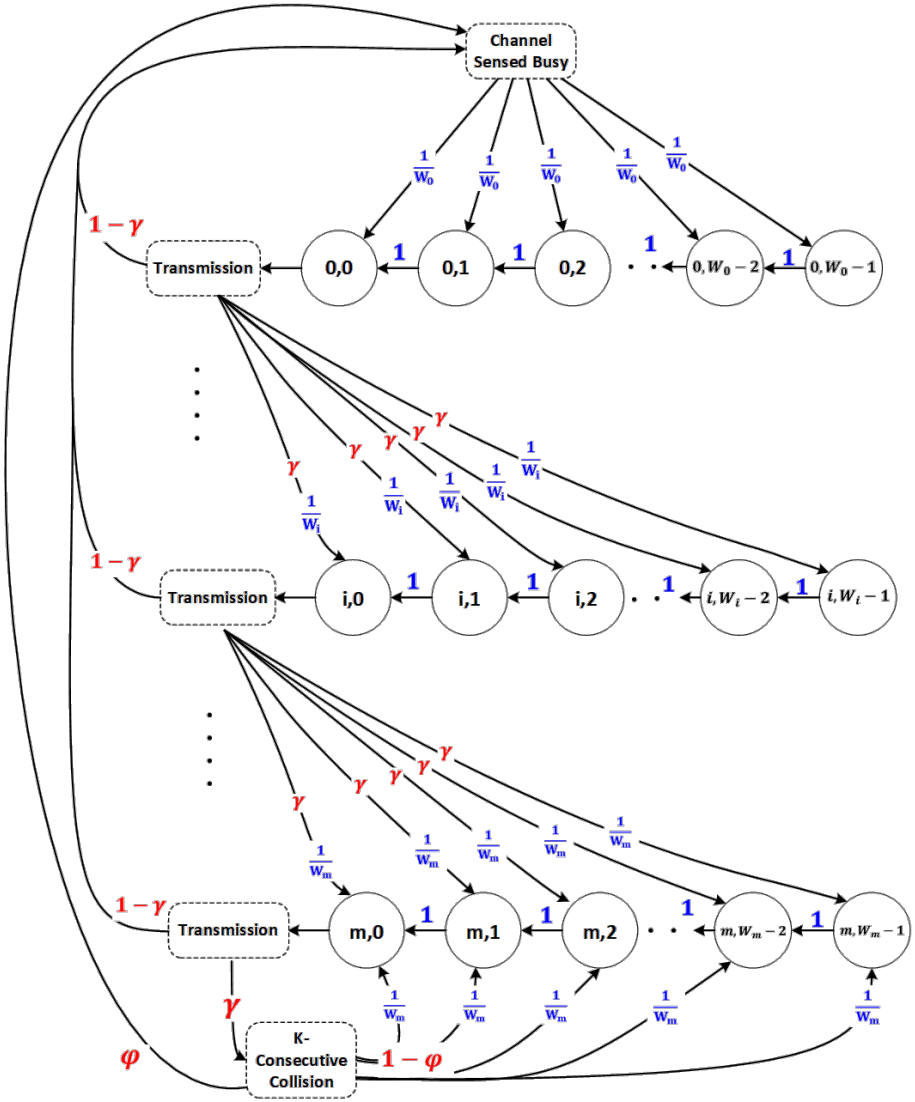


Image source: QUALCOMM

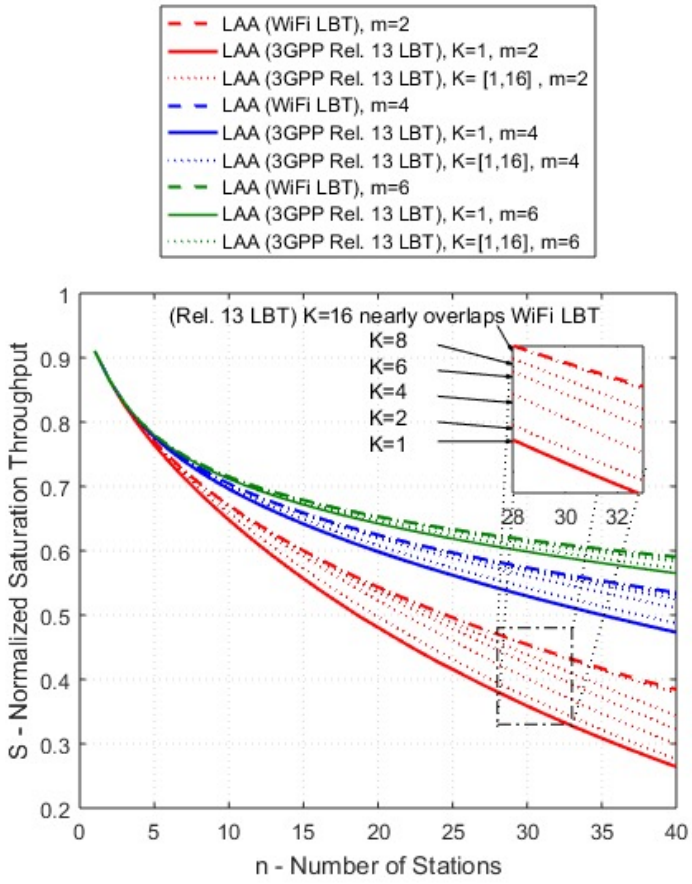


LTE-LAA Markov Model



N. Bitar, M. O. Al Kalaa, S. J. Seidman and H. H. Refai, "On the Coexistence of LTE-LAA in the Unlicensed Band: Modeling and Performance Analysis," in *IEEE Access*, vol. 6, pp. 52668-52681, 2018

K-Parameter Analysis



Coexistence Analysis (1)

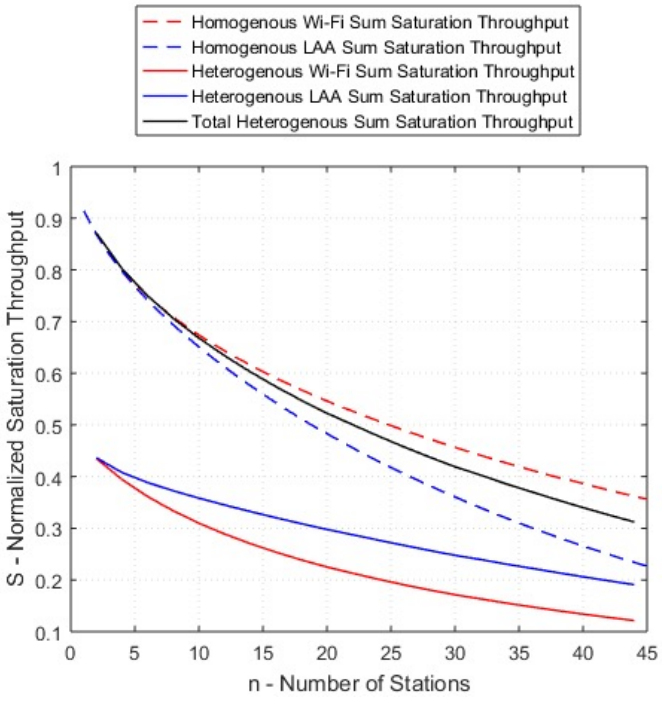
Assumptions:
A heterogeneous network consists

- *nw* Wi-Fi APs and *nl* LTE-LAA eNB stations
- all which are co-channeling and co-located
- each with a full buffer.
- We consider only the DL transmission for one client per AP/eNB, implying the contention is between only the APs and eNBs.

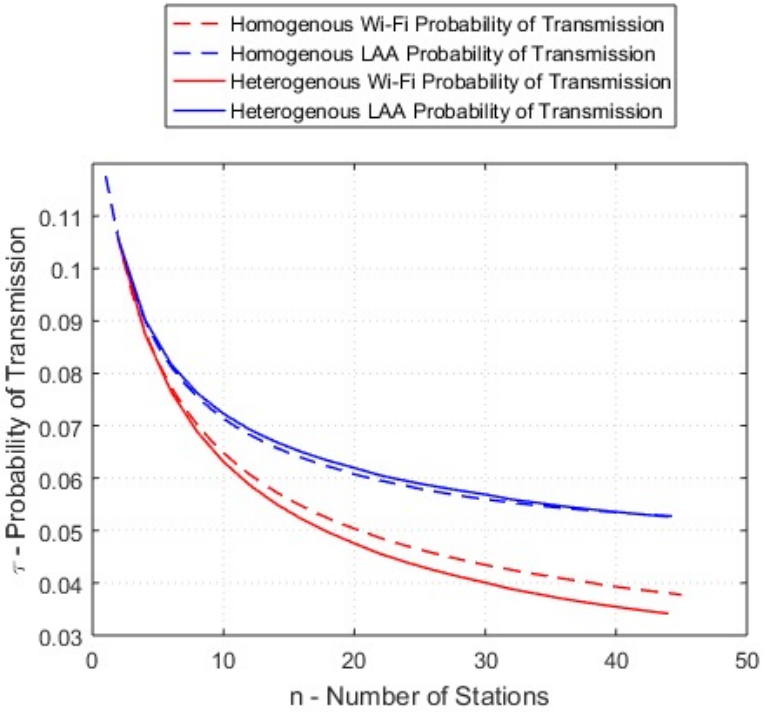
- τw and τl denote the transmission probability of Wi-Fi and LTE-LAA respectively

Coexistence Analysis (1)

Equal Parameter Coexistence for LTE-LAA and Wi-Fi



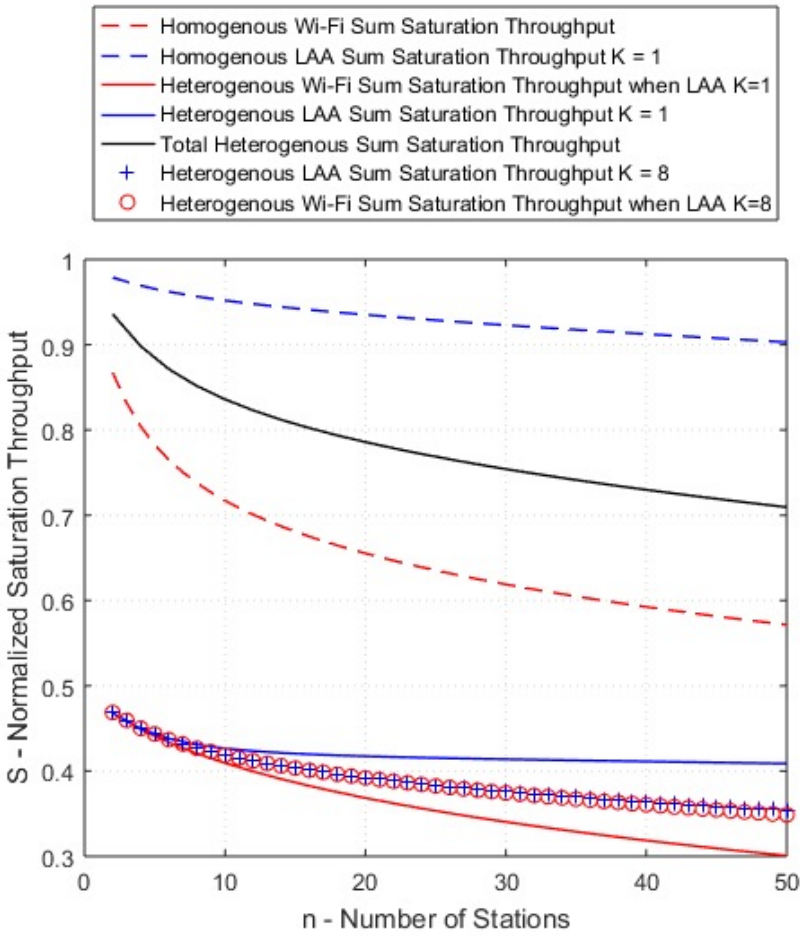
Normalized Saturation Throughput for an Equal Parameter Heterogeneous Network



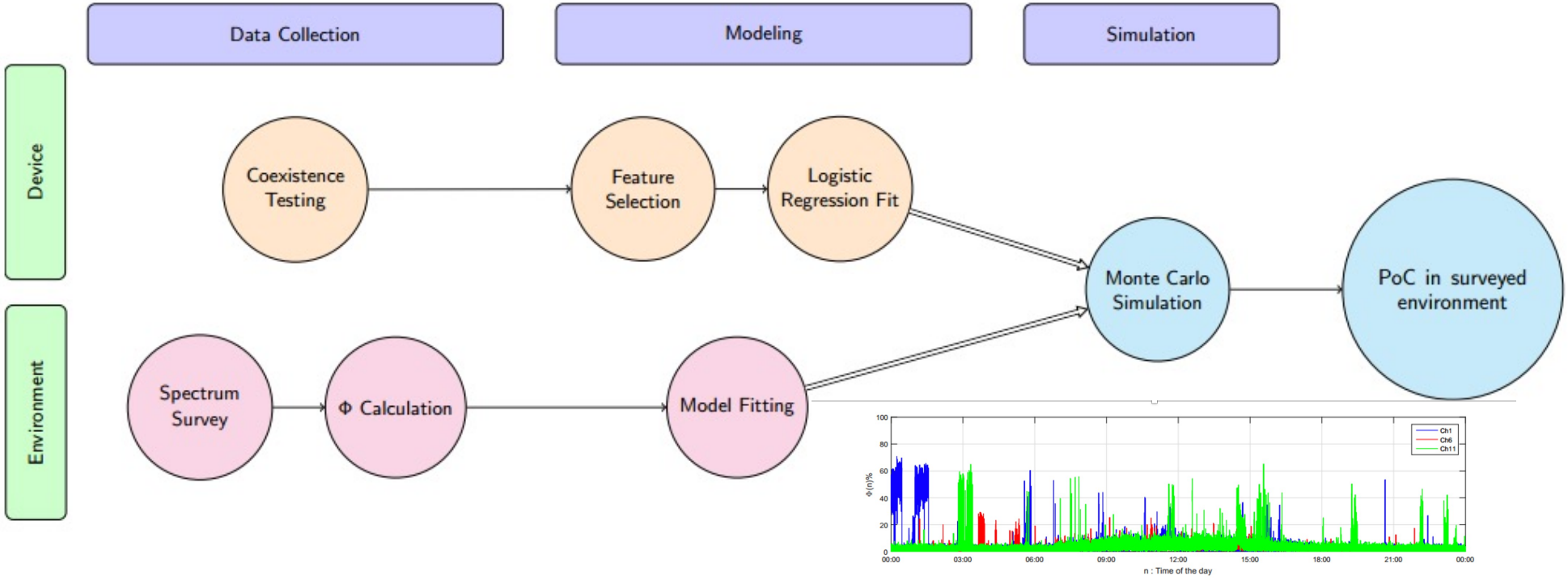
Probability of Transmission for an Equal Parameter Heterogeneous Network

Coexistence Analysis (2)

LAA Priority = 4, $m_p = 7$, $m_{wifi} = 7$ and contention window steps
W ∈ [15,31,63,127,255,511,1023]



Testing & Evaluation:
Metric—Probability of Coexistence (ANSI63.27)



M. O. Al Kalaa, S. Seidman, D. Witters, H. H. Refai, "Practical Aspects of Wireless Medical Device Coexistence Testing", *IEEE Trans. Electromagn. Compat.*, vol. 6, Issue:4 no. 1, pages:47-52, 2017.

Challenges/Opportunities:

- Security implementation, especially for the databased coordinator
- Frequency, time, space, power protocols that real-time adjust radio hardware and software to accommodate spectrum sharing requirements.
- Sensing radios (mobile and stationary) that monitor the state of the channel, spectrum, etc. to report back to spectrum coordinator.
- Agile/flexible testbed in real-world setting to evaluate new technologies for coexistence and fair spectrum sharing in homogenous or heterogenous settings. And metric development for spectrum sharing.

Thank You!