Optimizing Wireless Networks Performance through Learning-based Spectrum Access

Sergio Barrachina-Muñoz

Advisor: Dr. Boris Bellalta

Barcelona, 09/06/2017

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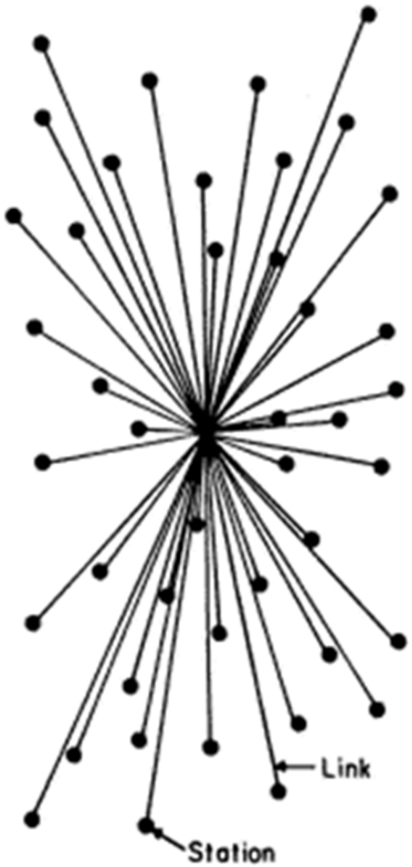
Outline

What are wireless networks (WNs)?



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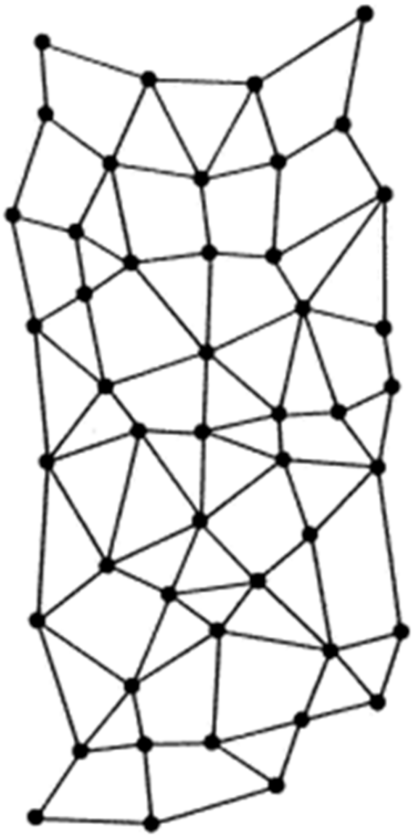

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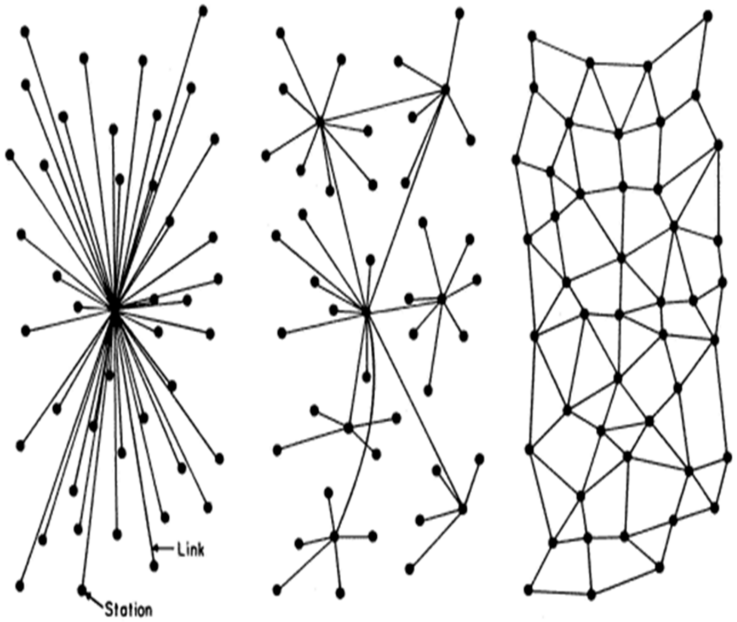

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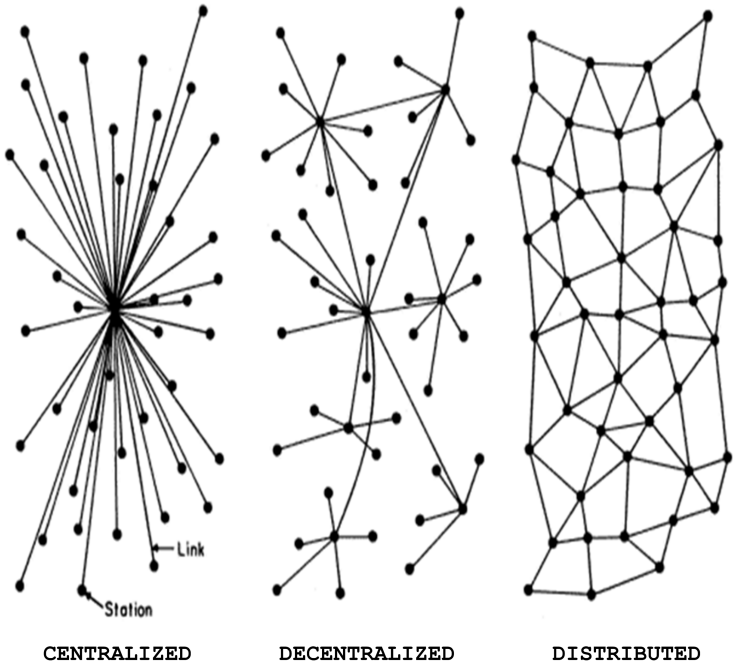

- Networks composed of **computing devices** (nodes)

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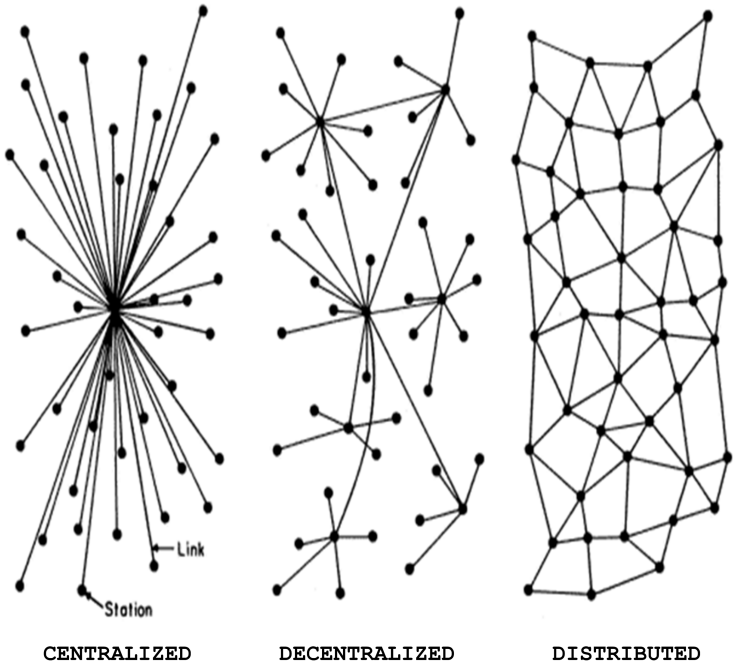

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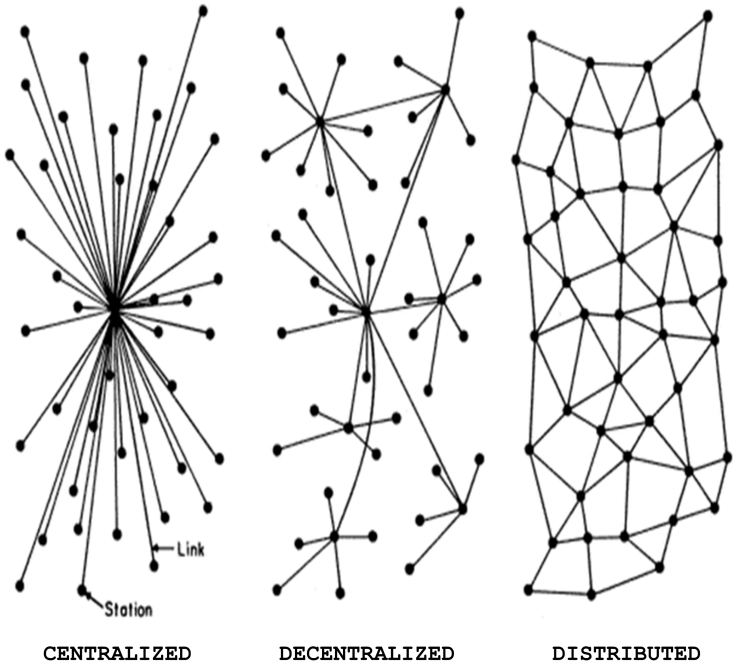
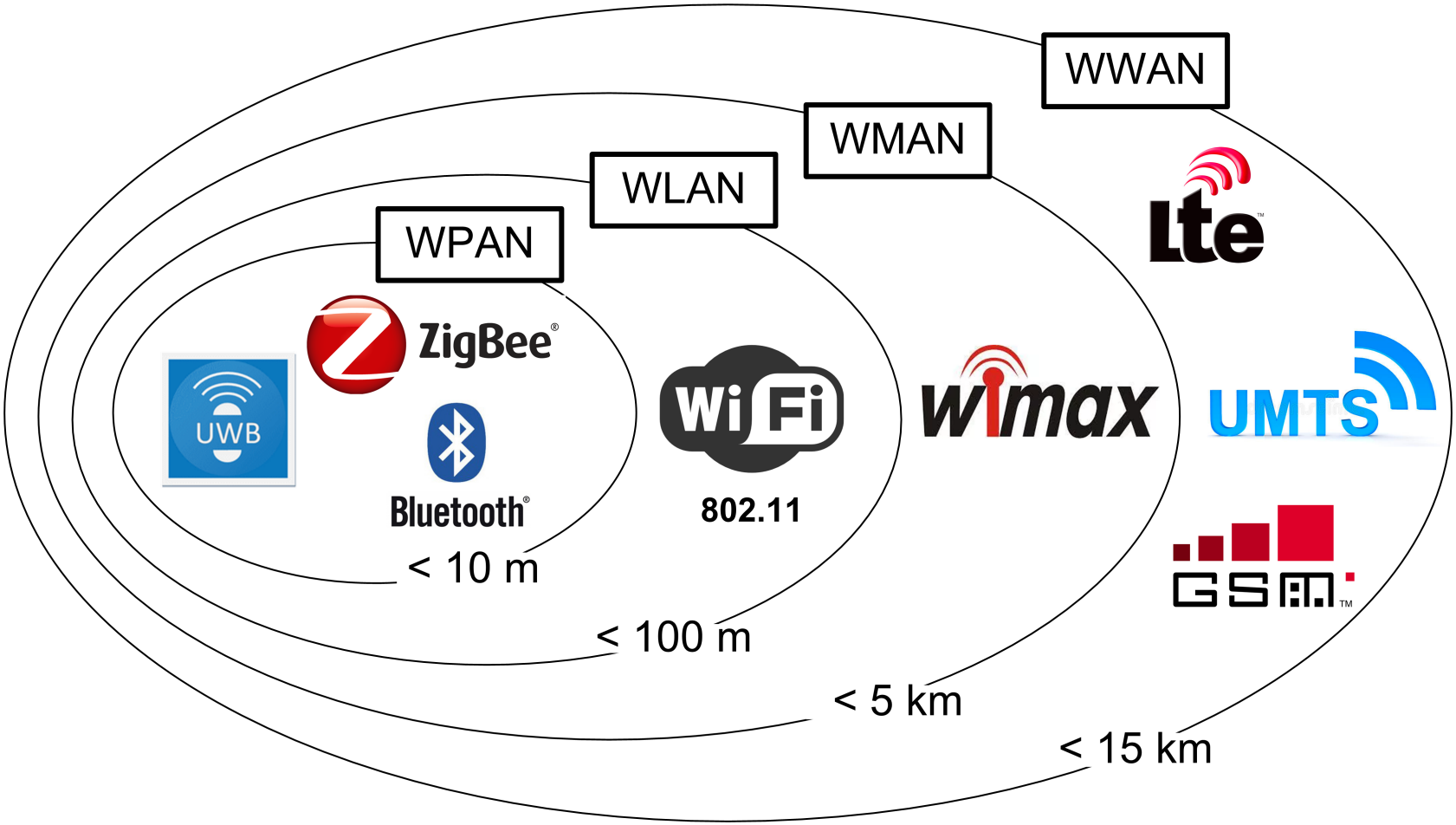
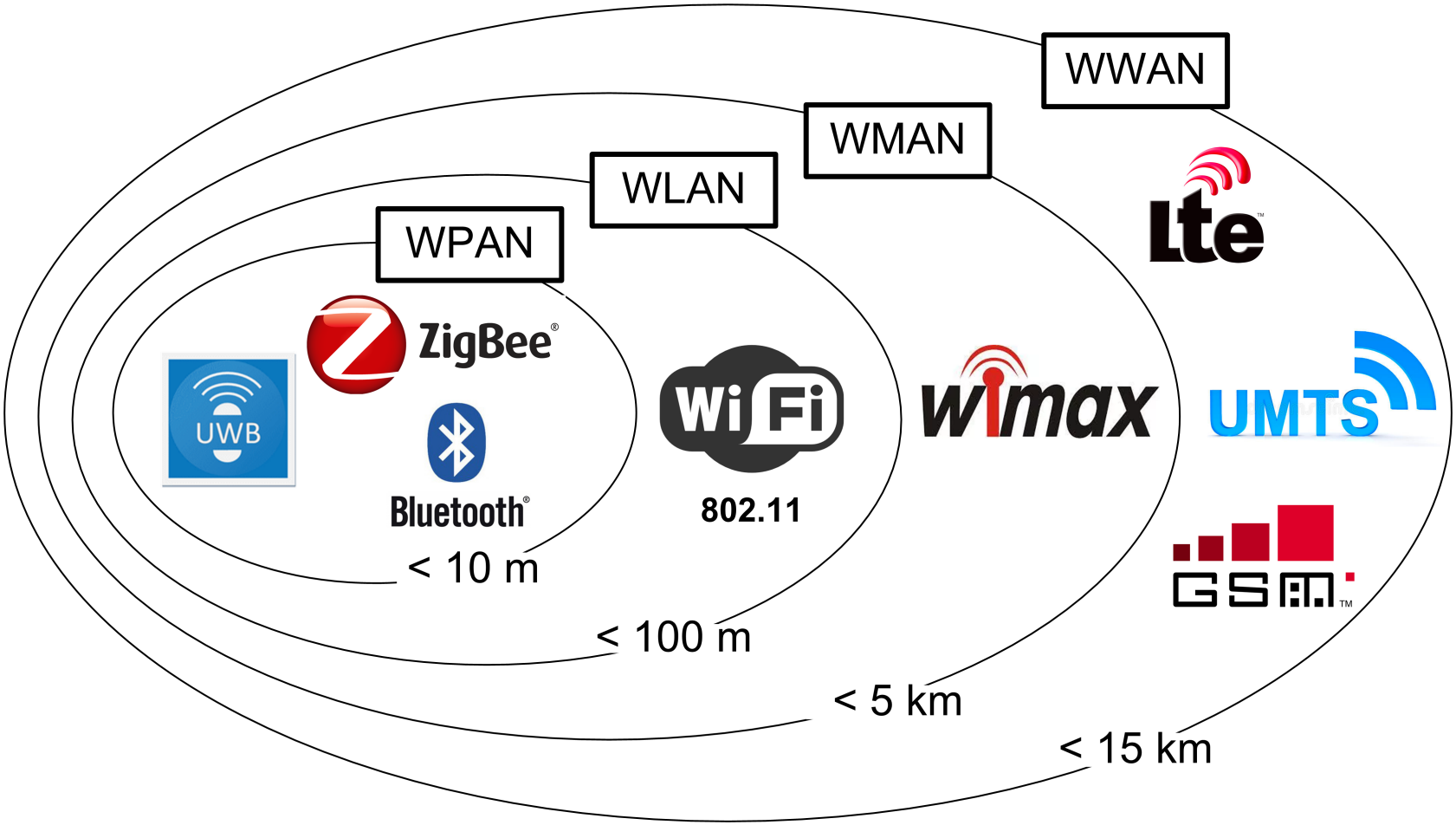


- Networks composed of **computing devices** (nodes)
- Nodes exchange data through **wireless links**
- Types of WNs: cellular, WLAN, WSN, satellite, etc.

Types of WNs

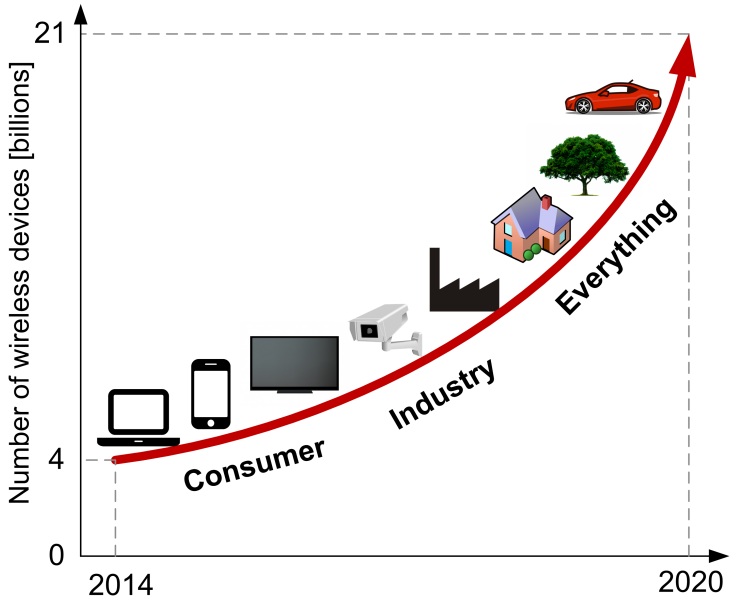

WWAN
WMAN
WLAN
WPAN
Lte
ZigBee
UWB
Bluetooth
Wi Fi
802.11
wimax
UMTS
GSM
< 10 m
< 100 m
< 5 km
< 15 km

Types of WNs



* WNs may occupy different portions (licensed or unlicensed) of the **frequency spectrum**

Next-generation Wireless Networks



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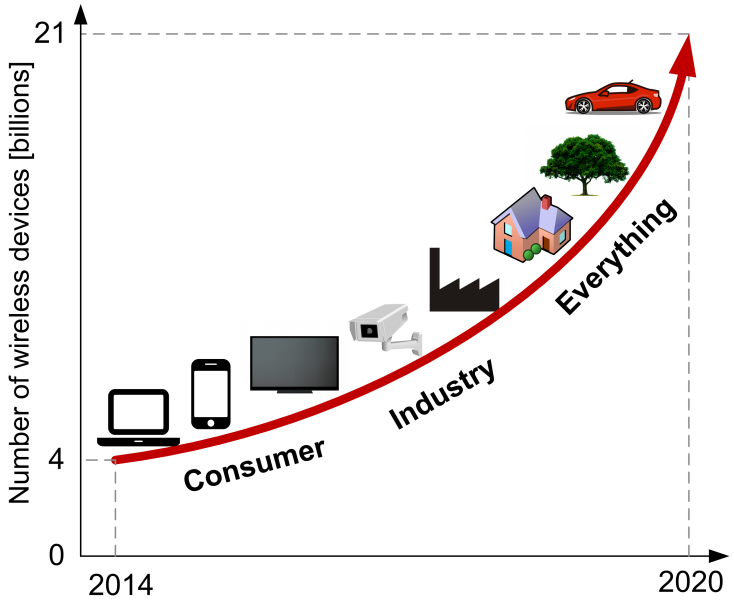
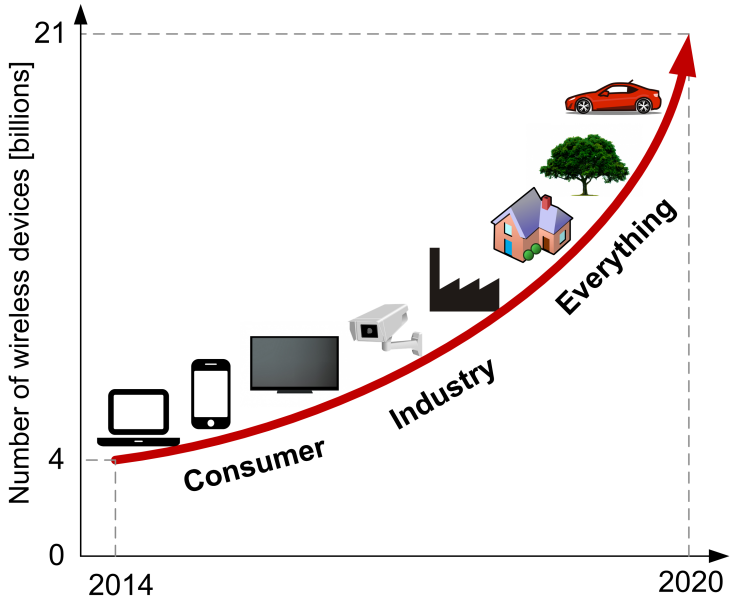


1) Highly increasing number of wireless devices [1]

Next-generation Wireless Networks



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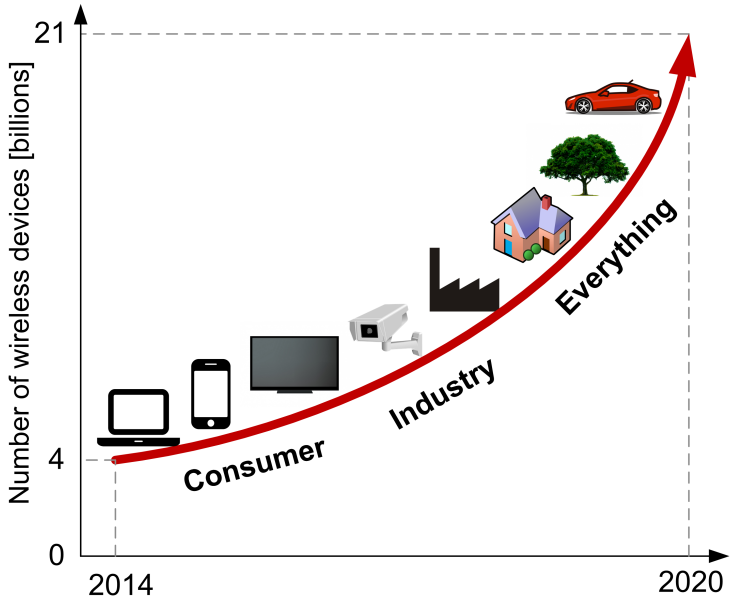

1) Highly increasing number of wireless devices [1]

2) Rising throughput demand (> 10 Gbps)

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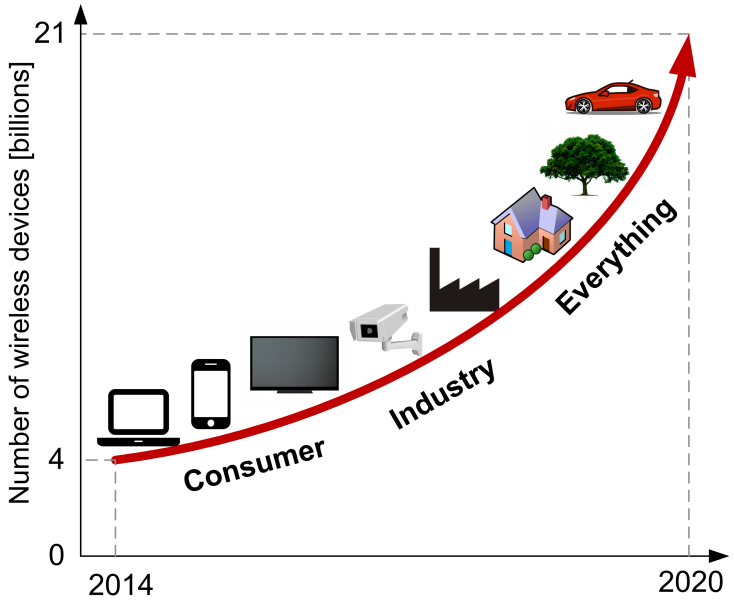

1) Highly increasing number of wireless devices [1]

2) Rising throughput demand (> 10 Gbps)

3) Complex and changing dynamics

The research problem at a glance

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Q: How to optimize future WNs performance?

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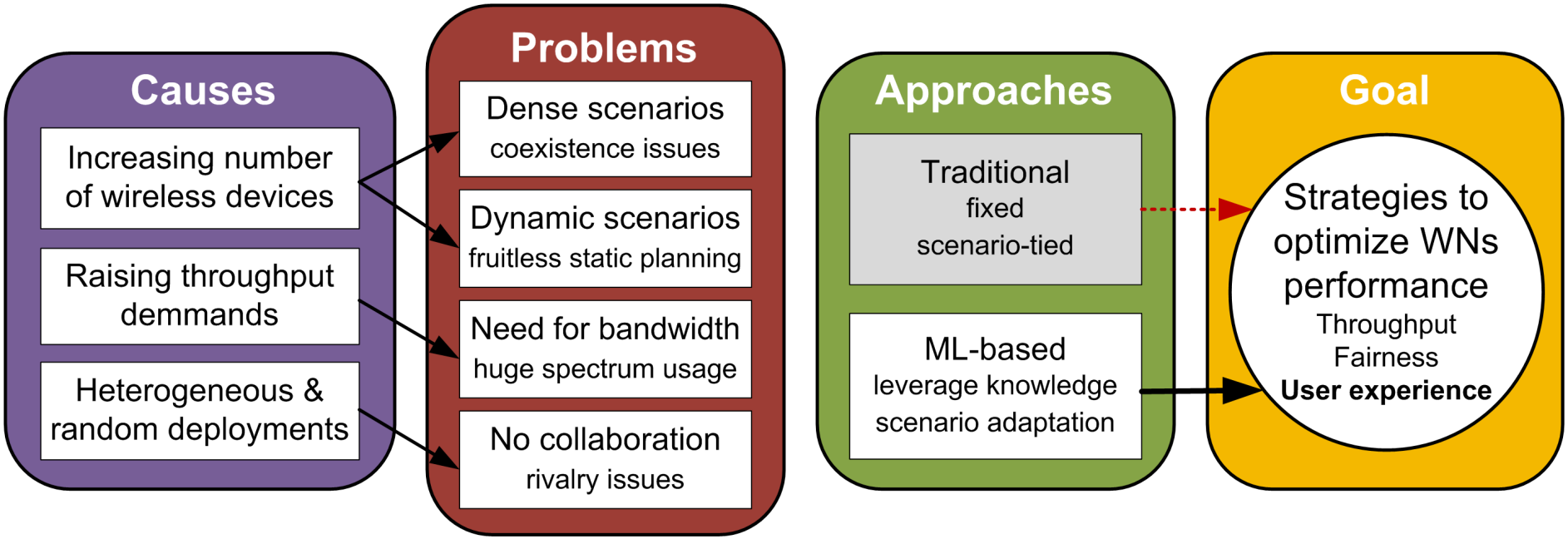

The research problem at a glance

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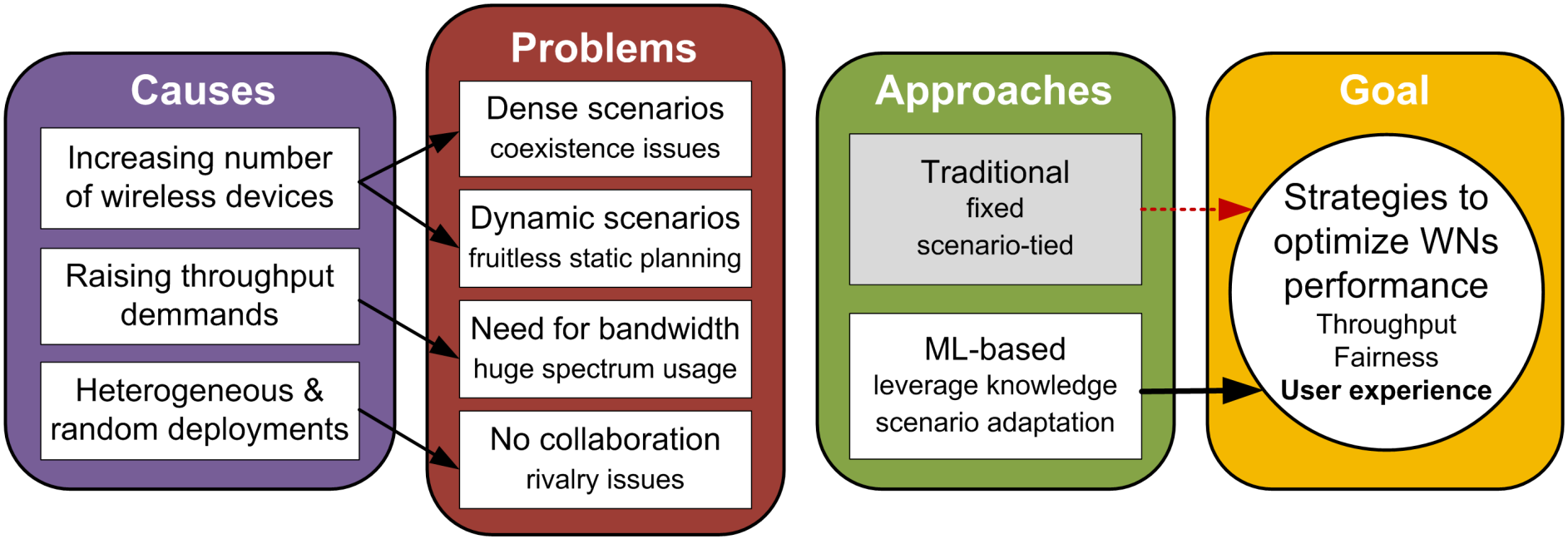
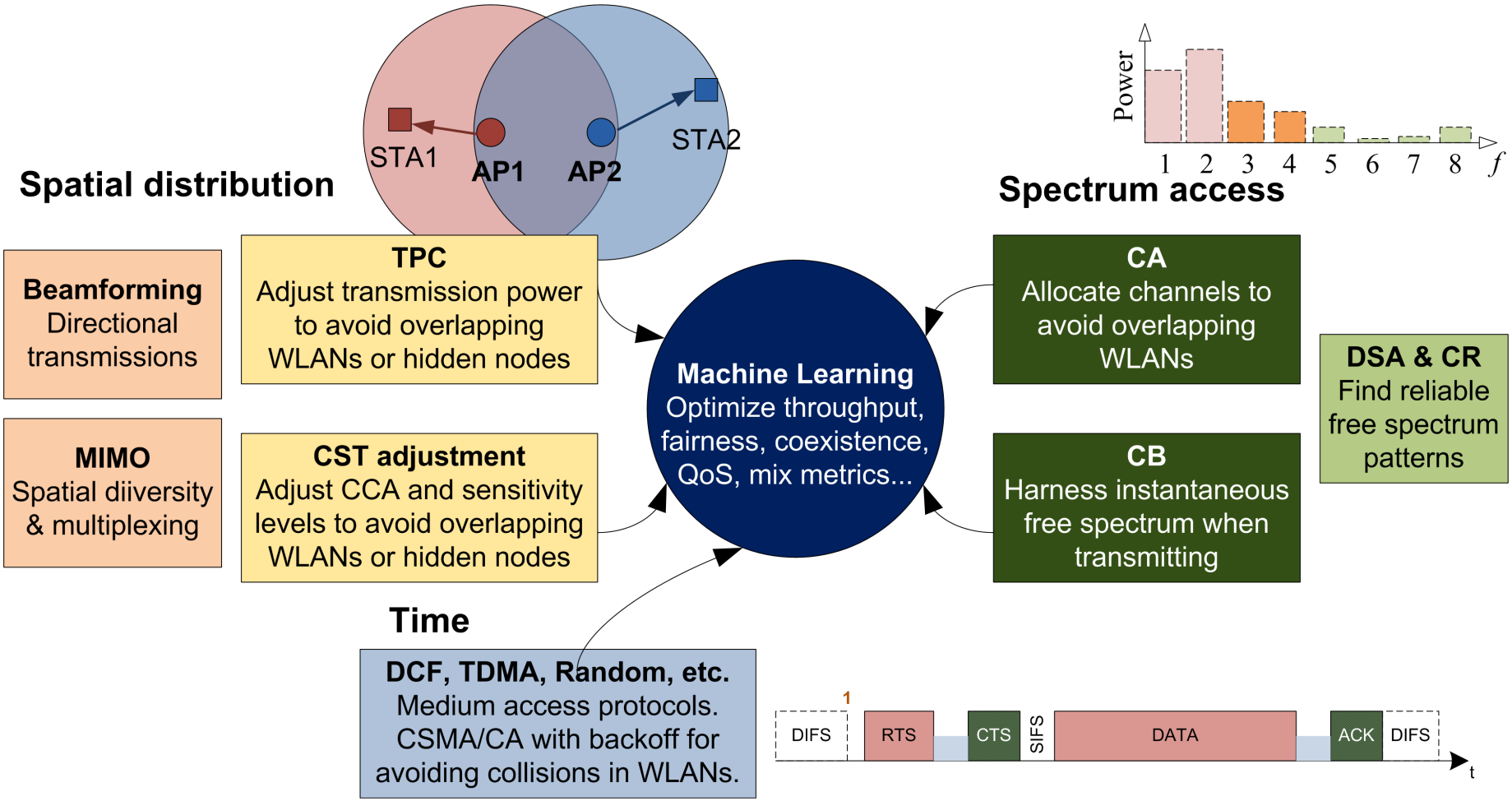


* we will focus on **WLANs** for the sake of practicality

Outline

Resources to harness for managing WNs



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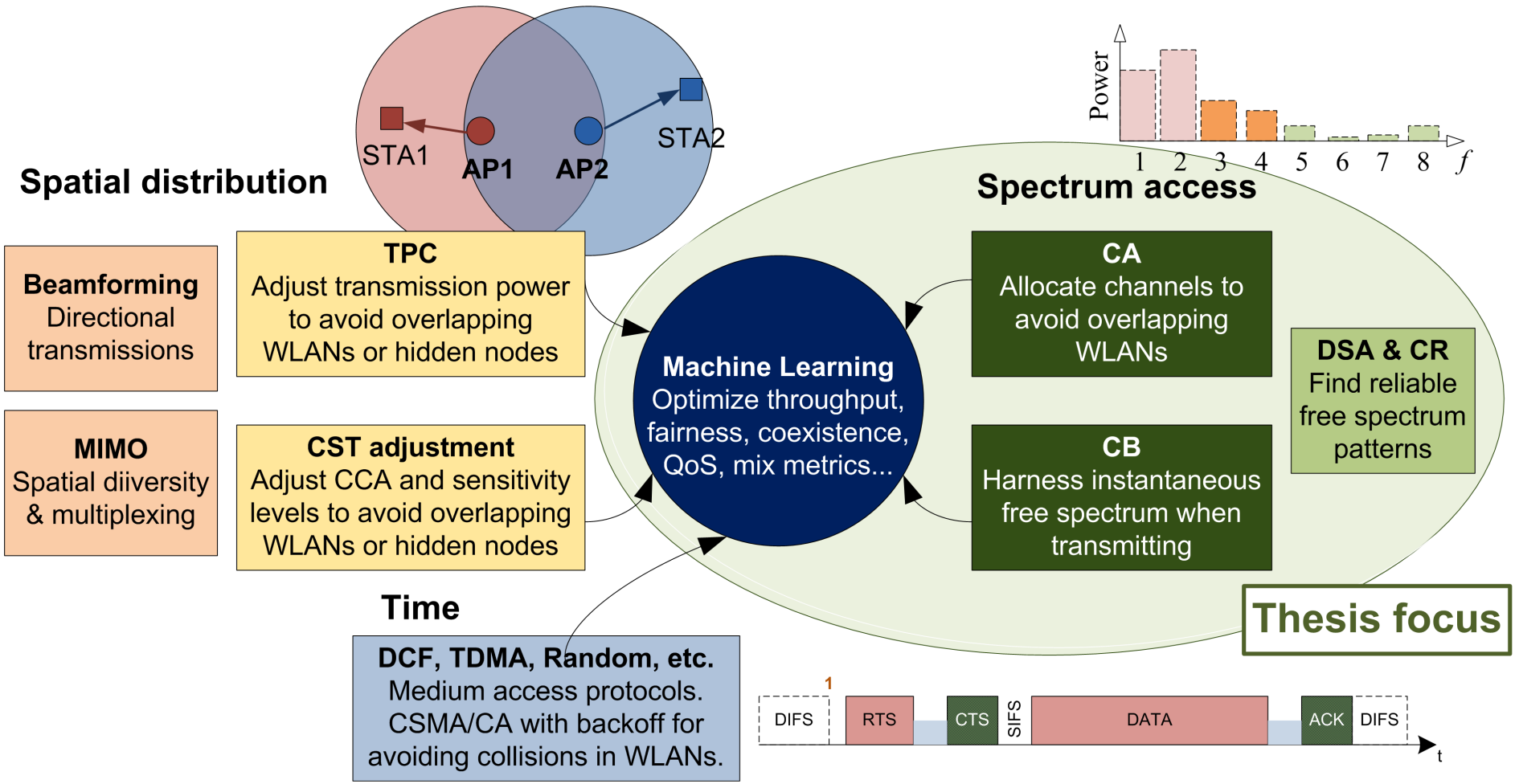
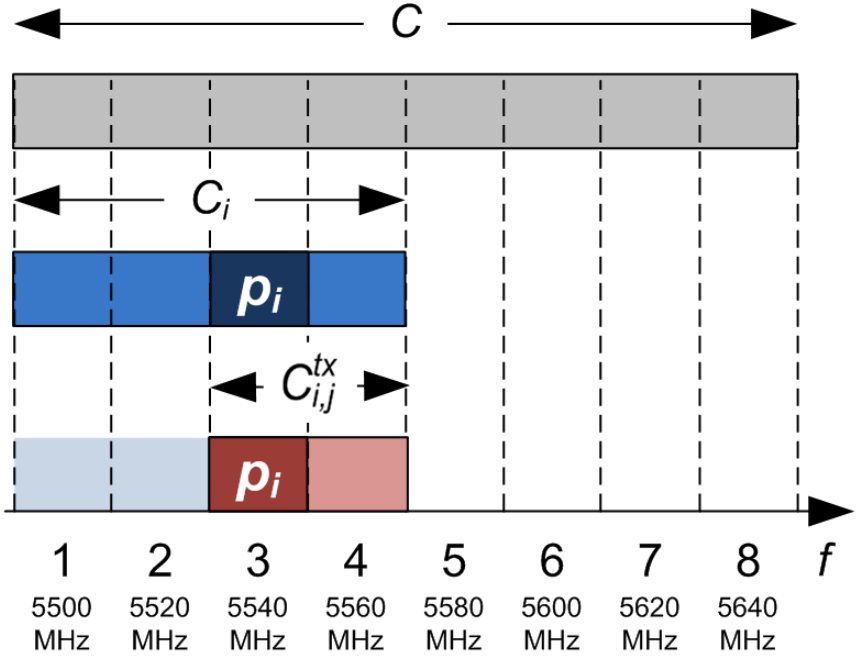
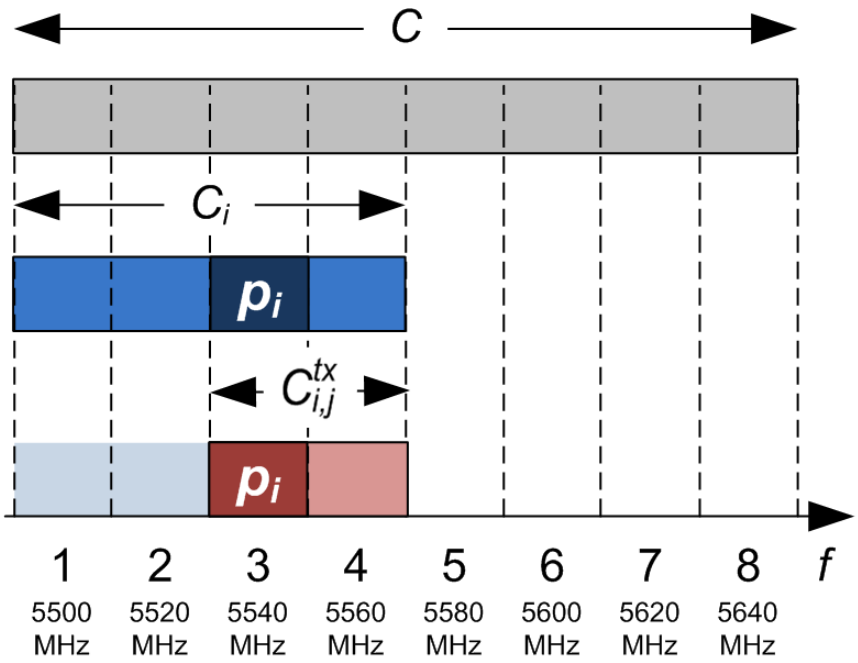


Spectrum access: concepts & techniques



Channel selection notation

Spectrum access: concepts & techniques



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Selects the channel range: primary and secondary channels

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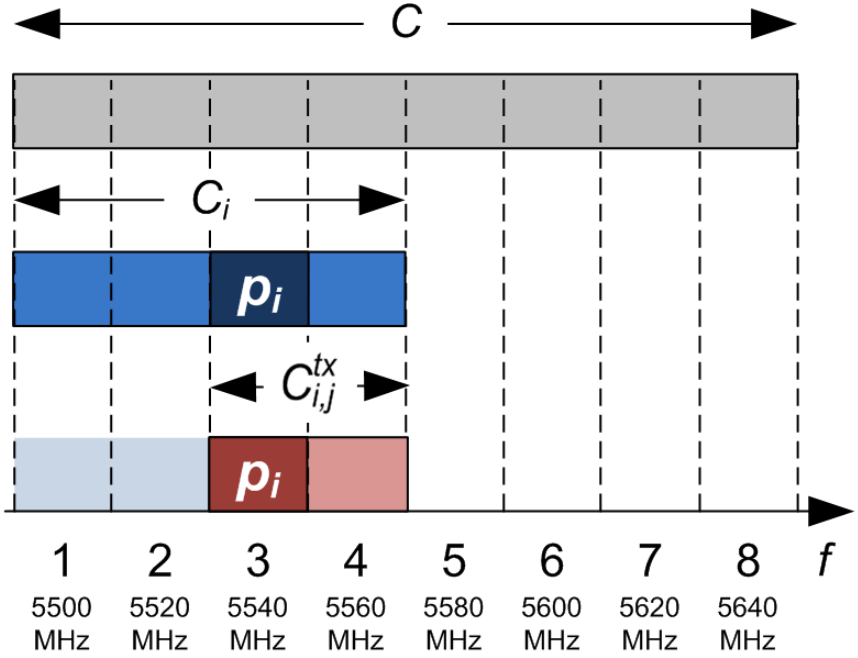

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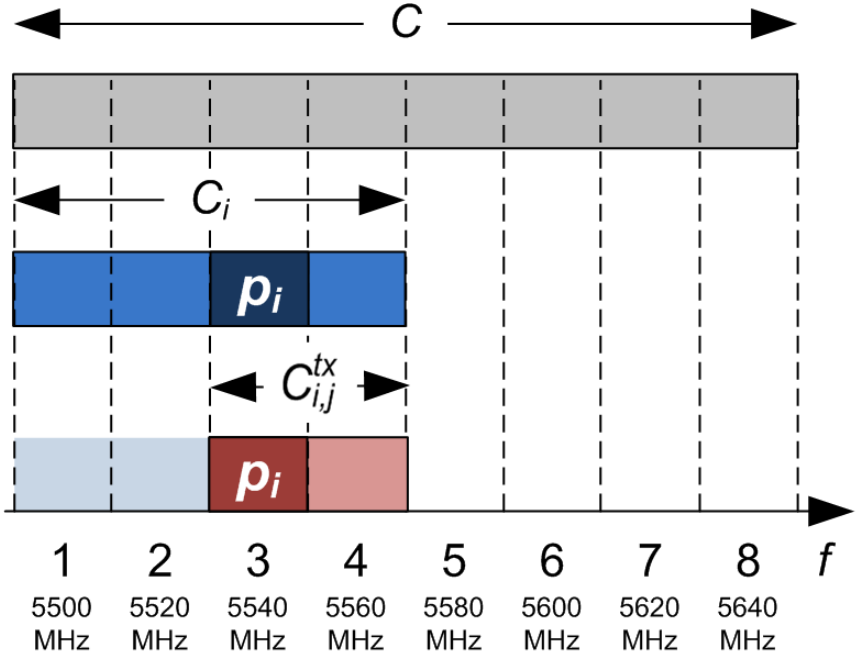

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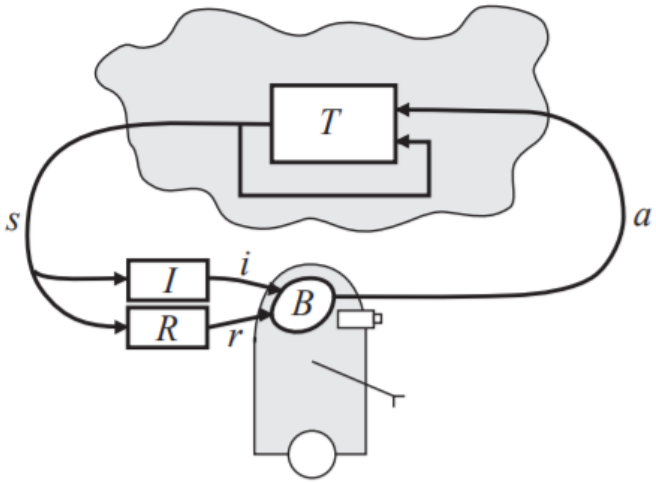
Cognitive Radio (CR)

Radio capable of changing its transmitter properties to adapt to the environment [2]

ML applied to WNs: Reinforcement Learning (RL)



RL learning model

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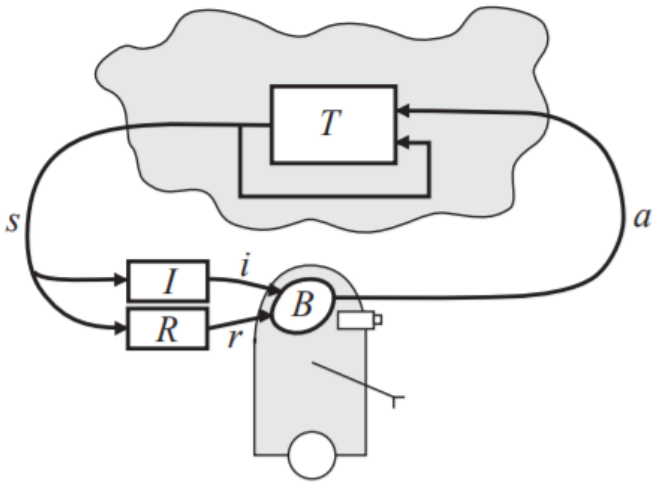

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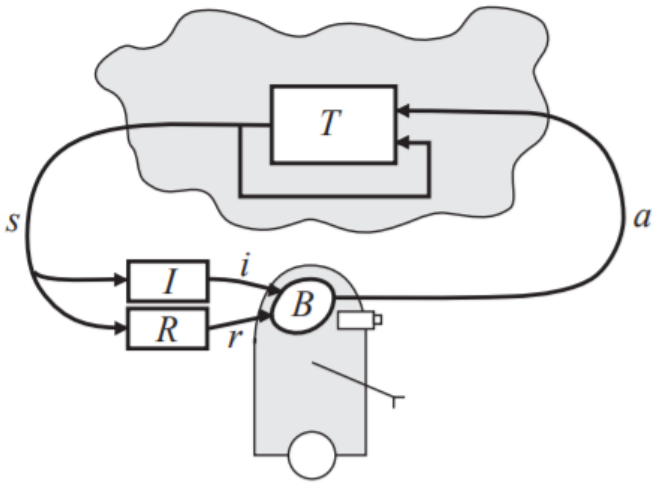

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- Works: CA [7], int. cancellation [8], ...

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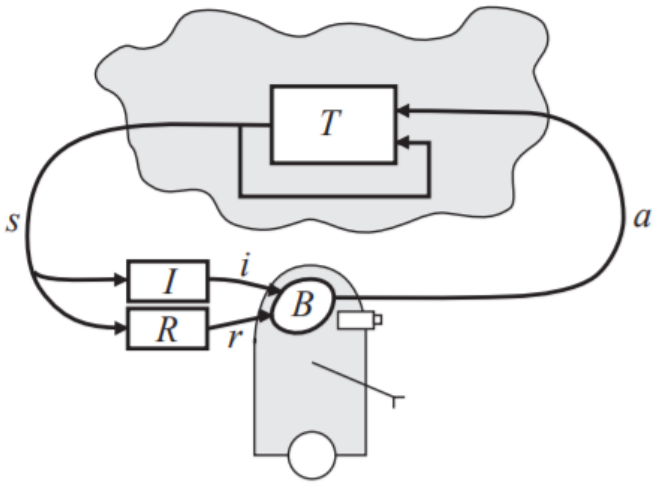

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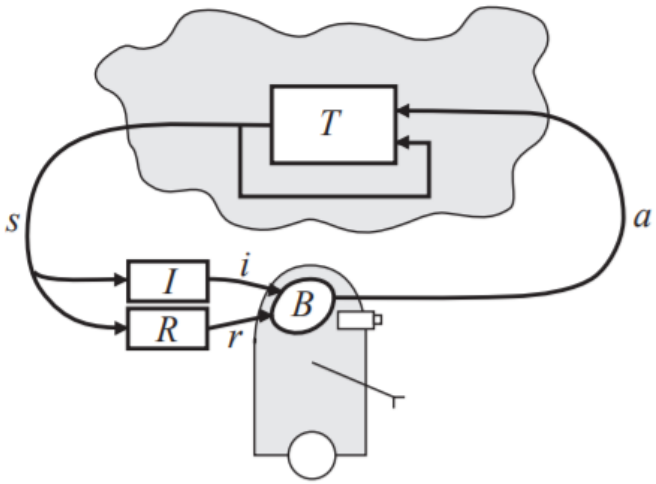

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*** RL applicable to partial/local info and non-cooperative scenarios**

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Supervised learning

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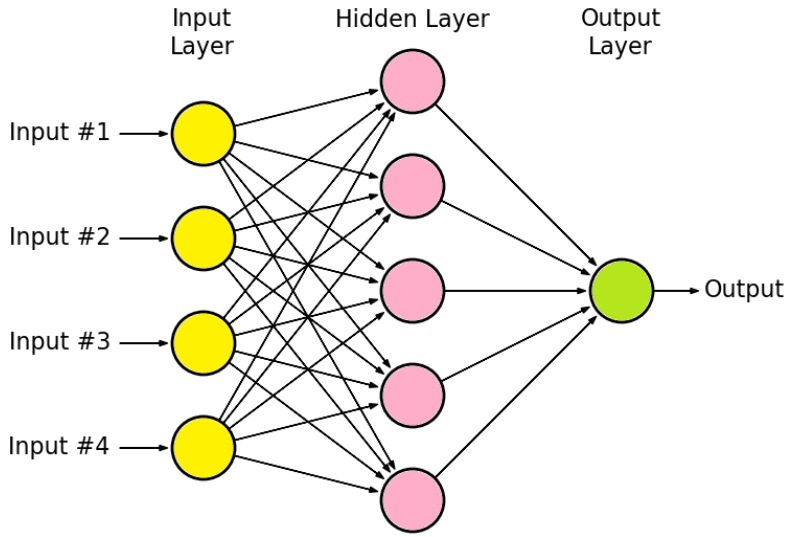
ANNs

- Black box approximator
- Works: spatial reuse [15], CA [16], ...



Artificial Neural Network (ANN) representation

Important remarks about the state of the art

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- Lots of works on spectrum access (without ML)
- RL seems appealing for non cooperative scenarios
- **Opportunity**: design CB policies for high performance WLANs

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C1. Characterization and modeling of CA & CB

- Extended CTMN framework for non-fully-overlapping WNs
- Simulator supporting next generation WNs

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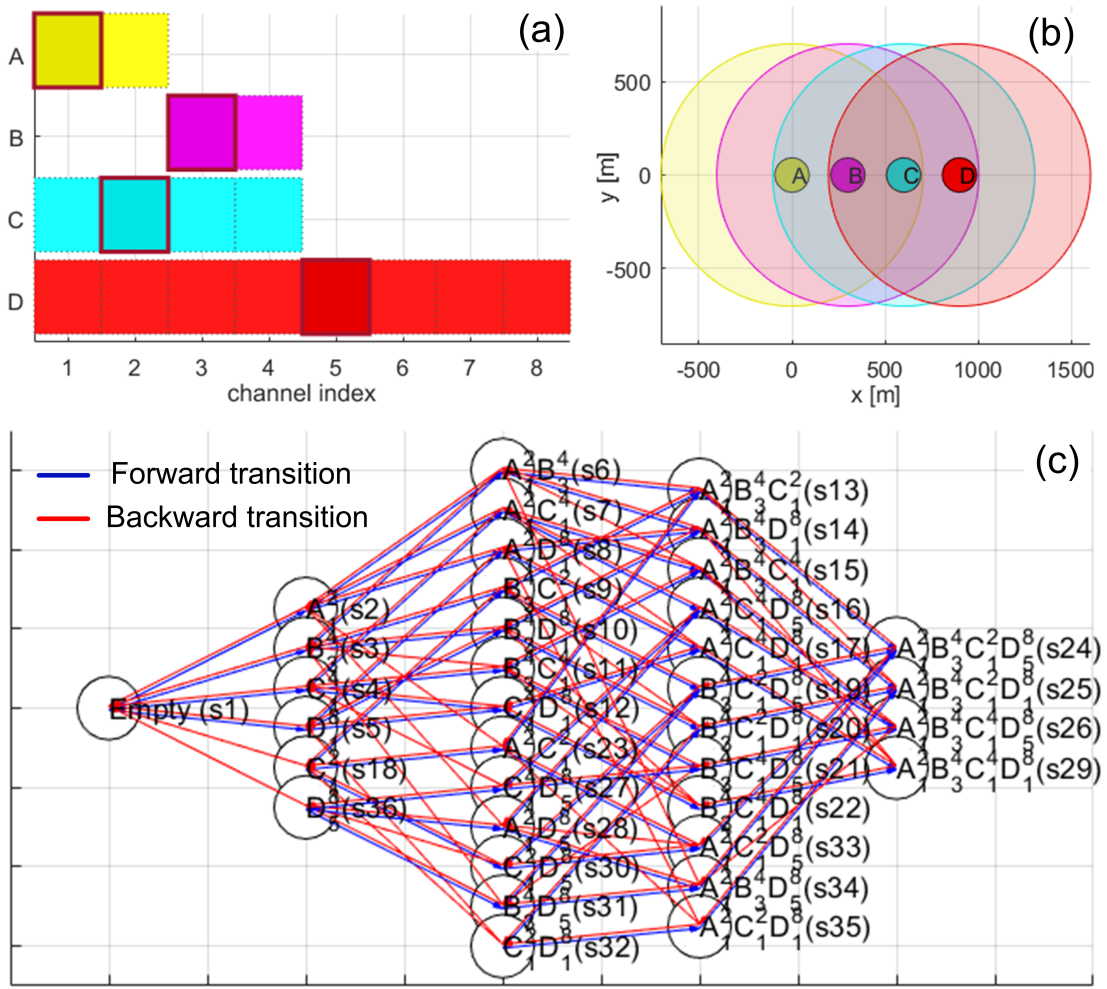
C5. (Ideally) Set of functionalities for future WN
- Inclusion of spatial distribution and other types of WNs

C1a. Spatial-Flexible CTMN framework



Generation of CTMNs using the SFCTMN framework

C1b. preliminary outcomes

CB policy	α_1	α_2	β_1	β_2	Γ_A	Γ_B	Γ
Only-max	0.0	1.0	0.0	1.0	57.62	57.62	115.23
Uniform	0.5	0.5	0.5	0.5	62.28	62.28	124.55
Only-primary	1.0	0.0	1.0	0.0	**62.30**	**62.30**	**124.61**

CB policy effect on throughput [Mbps] in a 2 overlapping WLANs scenario.

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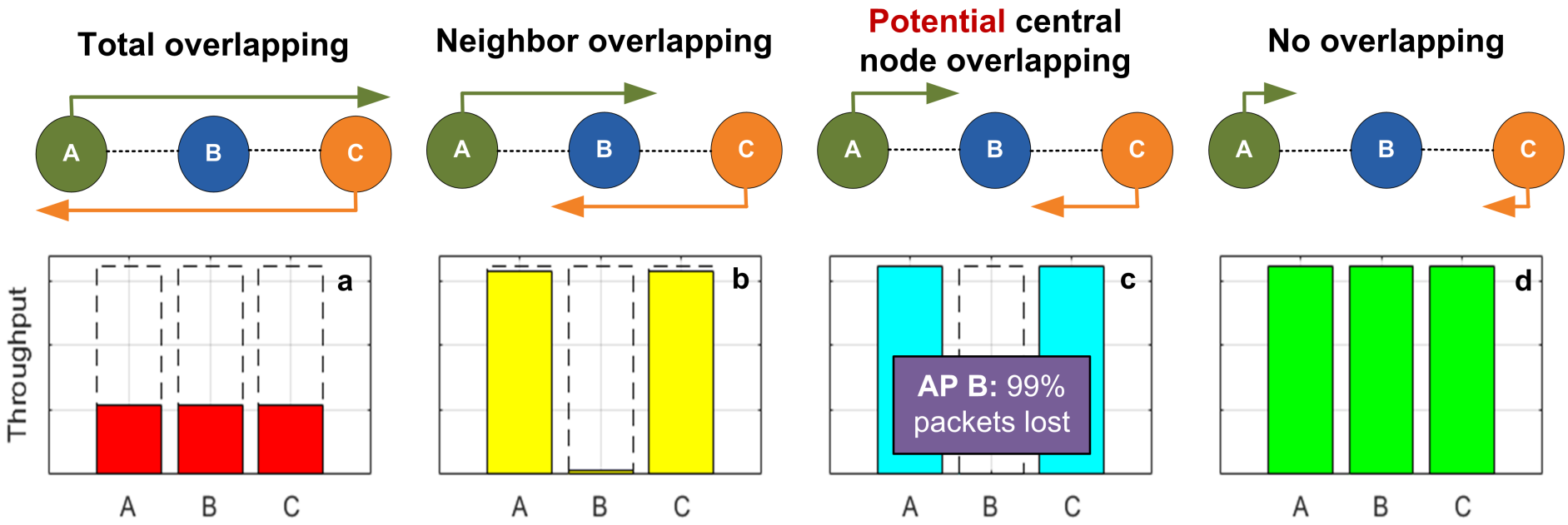
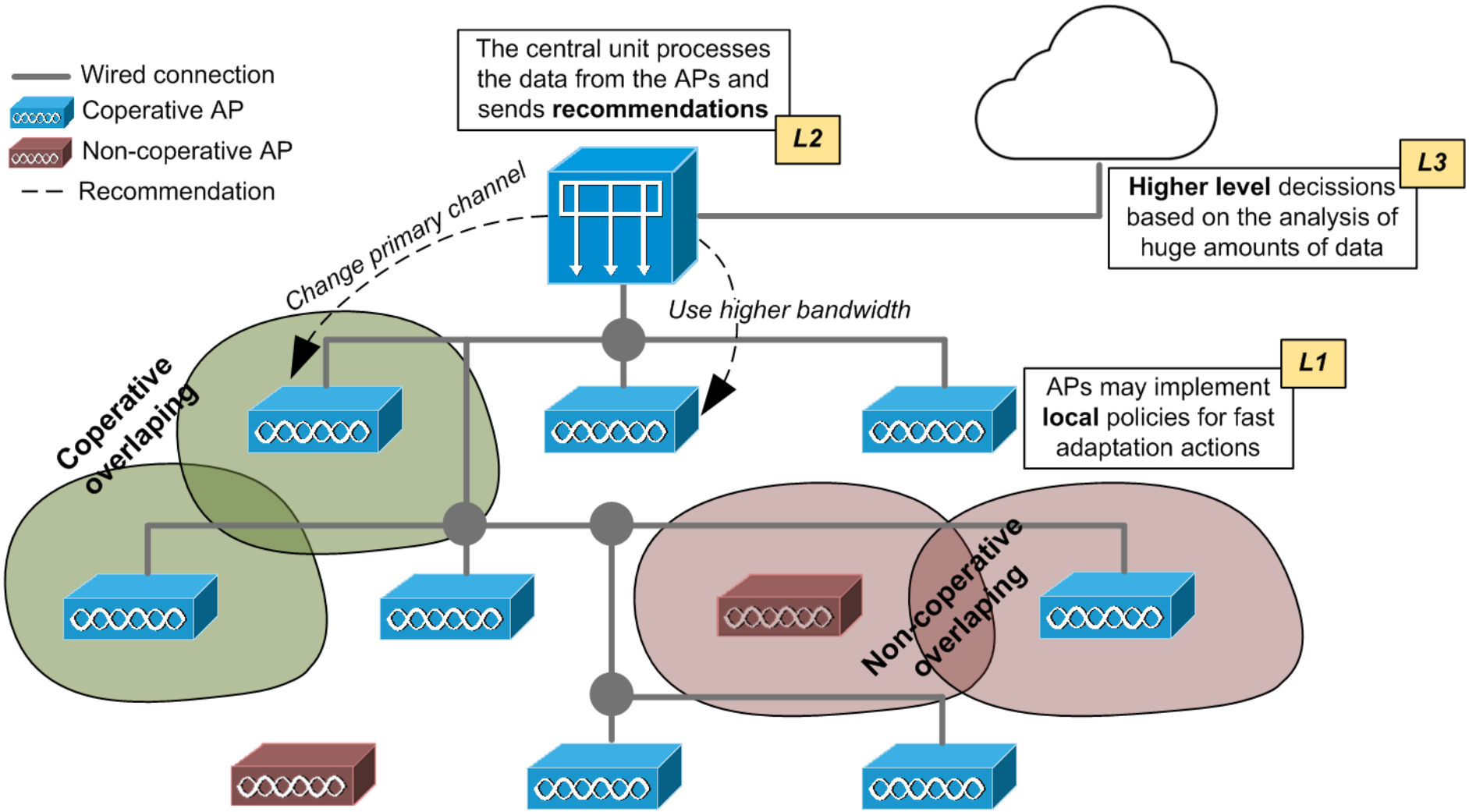
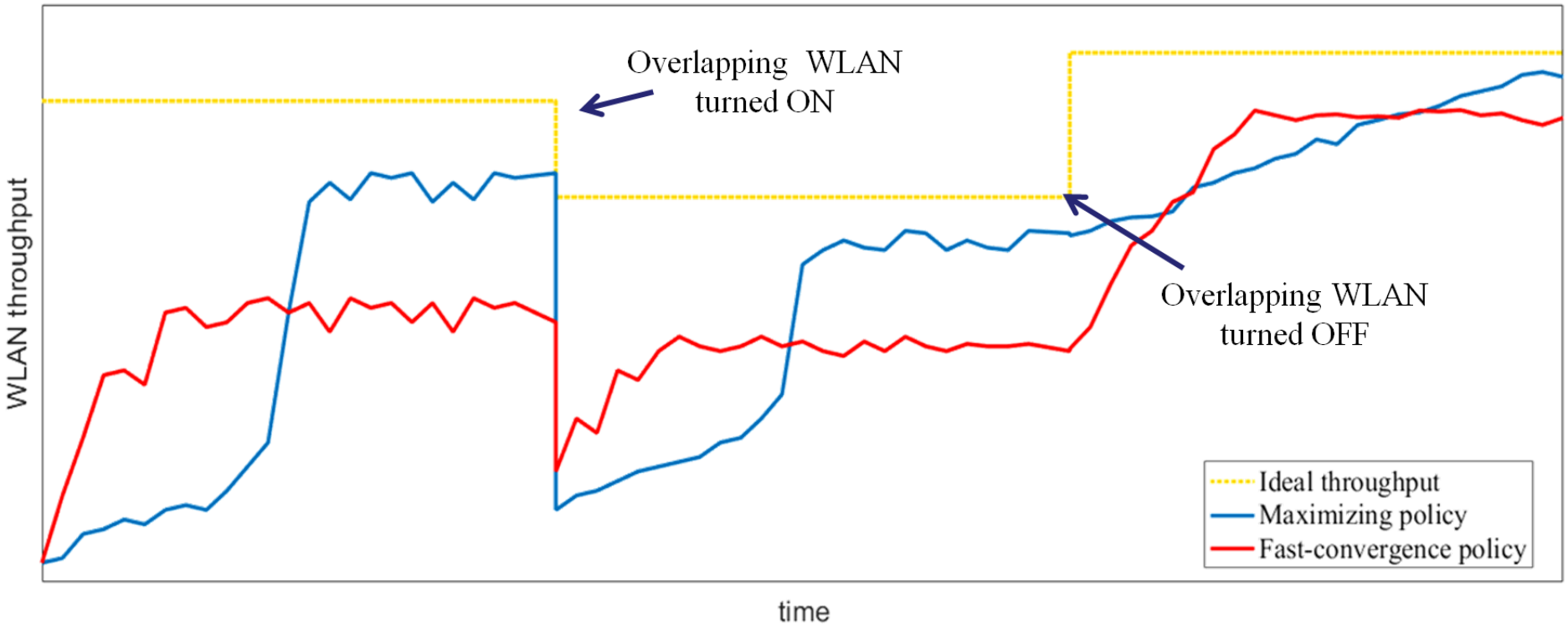


C3. Learning-based WN architecture



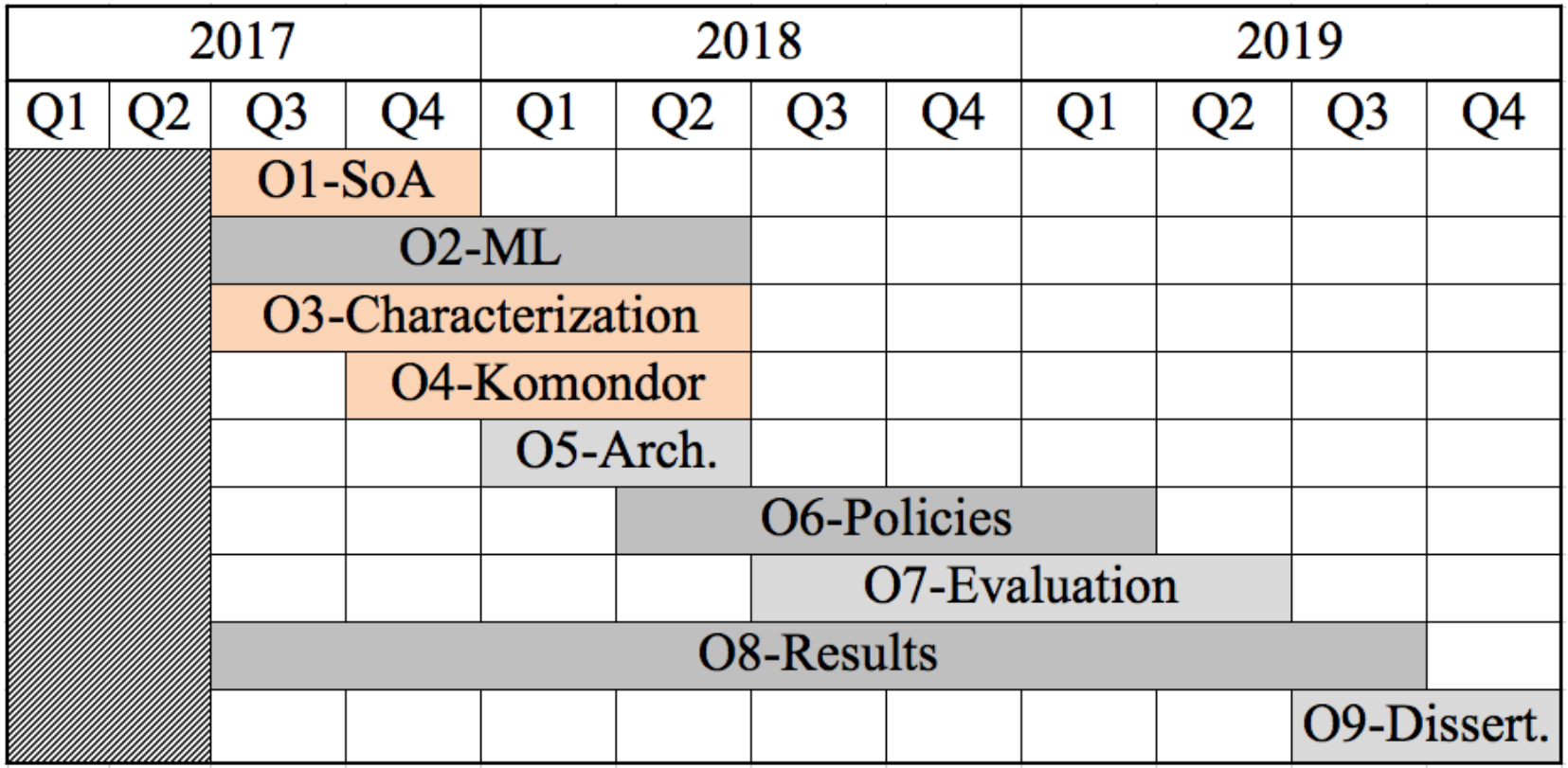
C4a. Spectrum access learning adaptability



Possible impact of learning-based spectrum access policies on throughput

Outline

Objectives & next steps



* Time for writing papers is considered in the Gantt diagram

Any questions?

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Universitat Pompeu Fabra (Barcelona)

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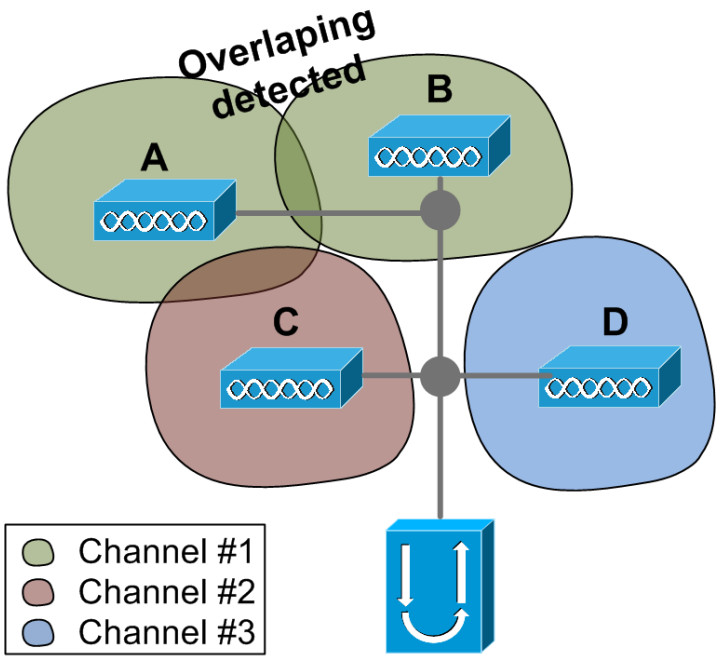
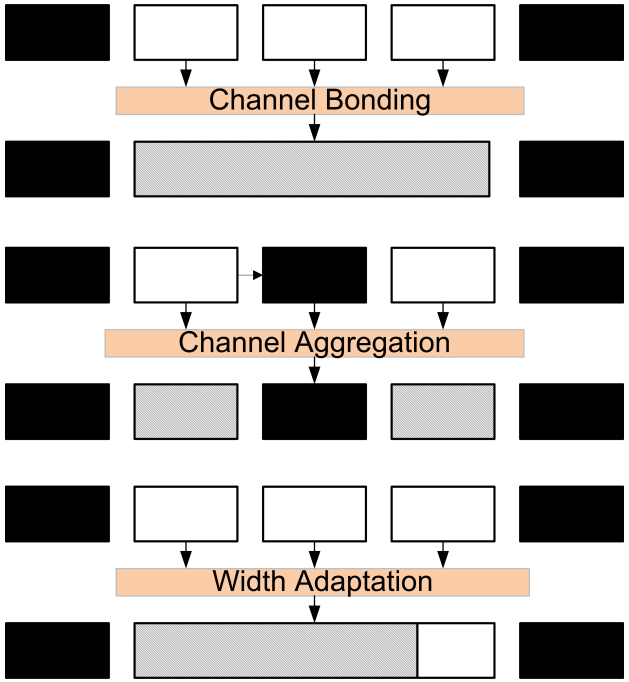
Backup I: Channel Allocation (CA) & Channel Bonding (CB)

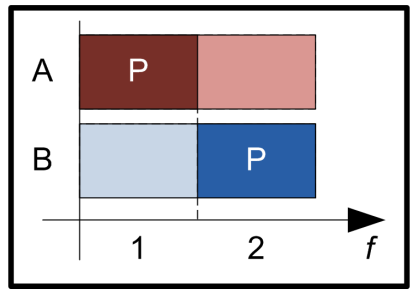


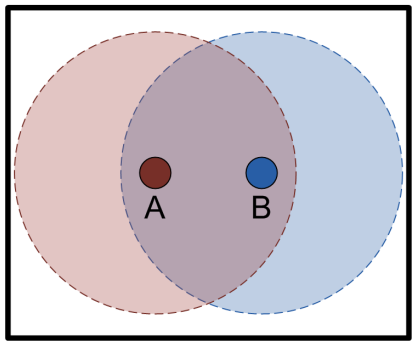
Centralized dynamic CA would order WLAN A to switch to the blue channel [3]

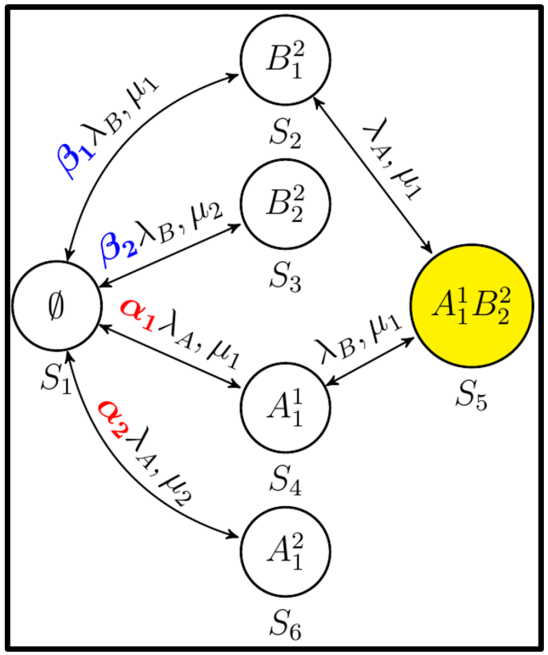


CB for WLANs introduced in 802.11n [4]
CAgg mostly applied to cellular nets [5]
WA in next generation WNs [6]

Backup II: CTMN for CSMA/CA WNs

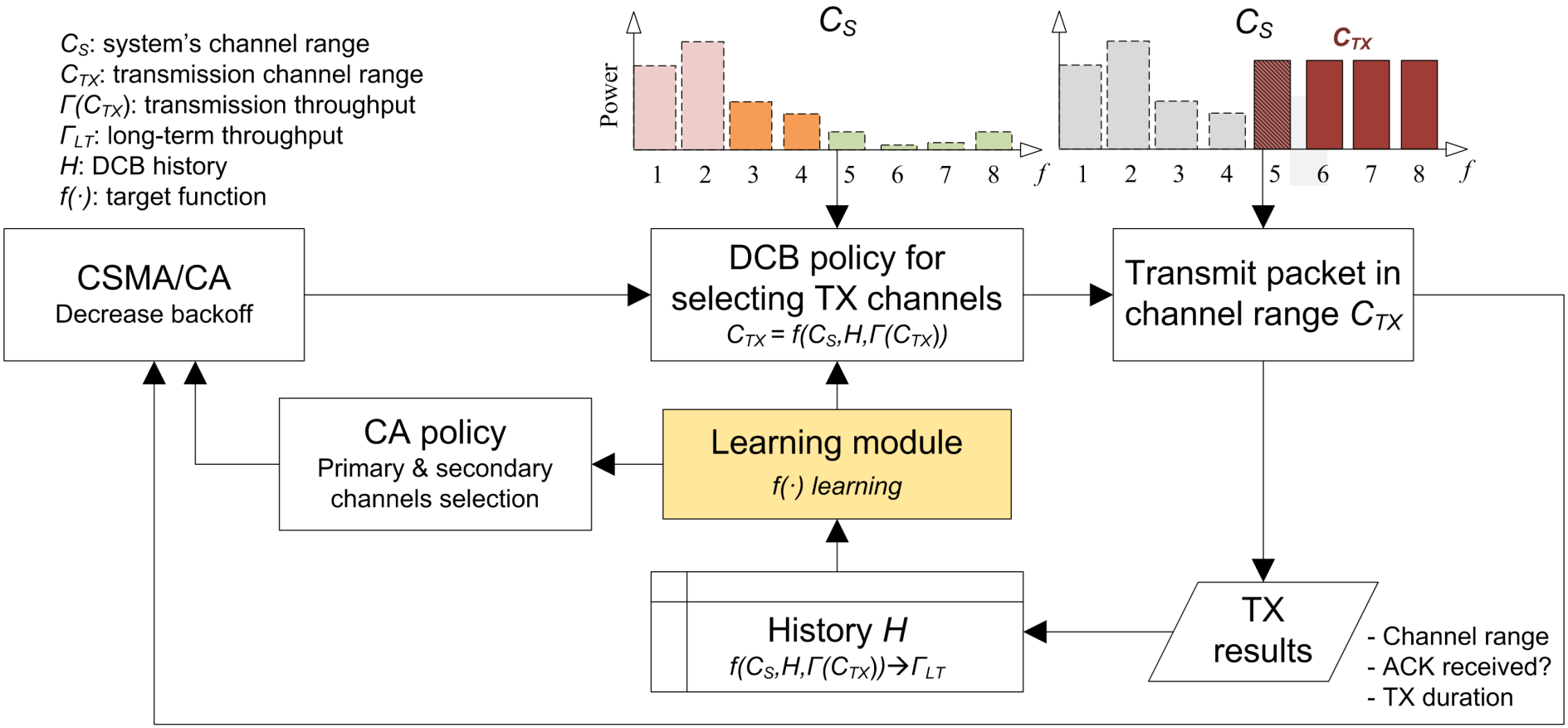






$$Q = \begin{pmatrix} -(\lambda_B+\lambda_A) & \beta_1\lambda_B & \beta_2\lambda_B & \alpha_1\lambda_A & 0 & \alpha_2\lambda_A \\ \mu_1 & -(\mu_1+\lambda_A) & 0 & 0 & \lambda_A & 0 \\ \mu_2 & 0 & -\mu_2 & 0 & 0 & 0 \\ \mu_1 & 0 & 0 & -(\mu_1+\lambda_B) & \lambda_B & 0 \\ 0 & \mu_1 & 0 & \mu_1 & -2\mu_1 & 0 \\ \mu_2 & 0 & 0 & 0 & 0 & -\mu_2 \end{pmatrix}$$

Backup III: C4b. Spectrum access learning flowchart



Backup IV: Contribution to projects 2015-2019