Enhancing Wireless Networks Performance through Learning-based Dynamic Spectrum Access

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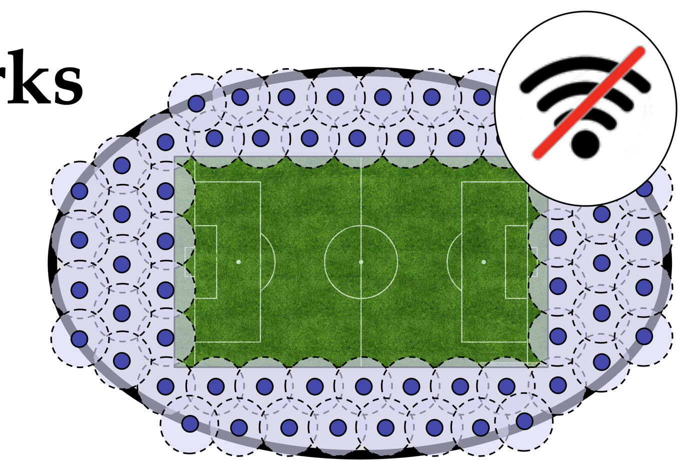
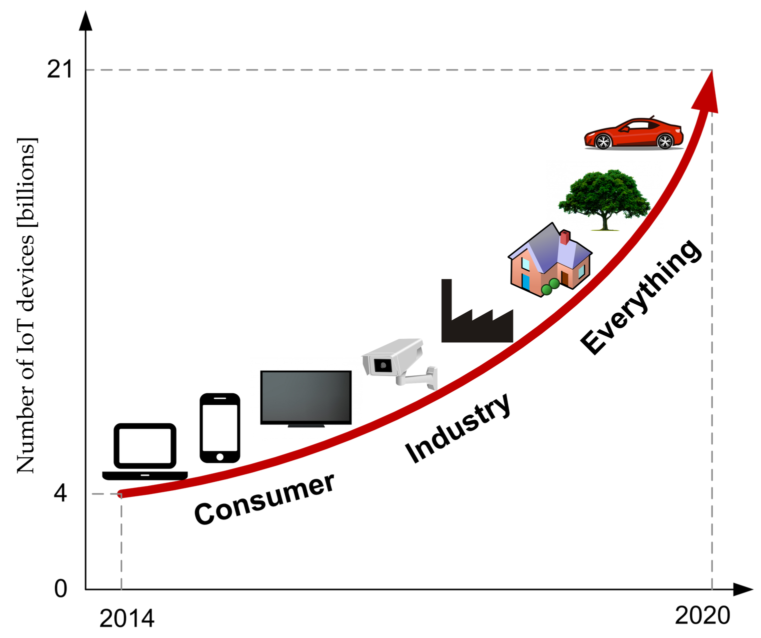
The chaos of Wireless Networks

The number of devices accessing the Internet through Wireless Local Area Networks (WLANs) is increasing drastically.

- WLANs are managed by different operators, leading to chaotic wireless spectrum occupancy.
- By means of transmitting in wider channels through dynamic spectrum access (DSA), higher short-term throughputs are achieved.
- However, the contention among nodes leads to undesirable low performance, which is critical in high-density scenarios like football stadiums and apartment buildings.
- What we propose is **a learning-based channel selection policy for optimizing WLANs throughput**.



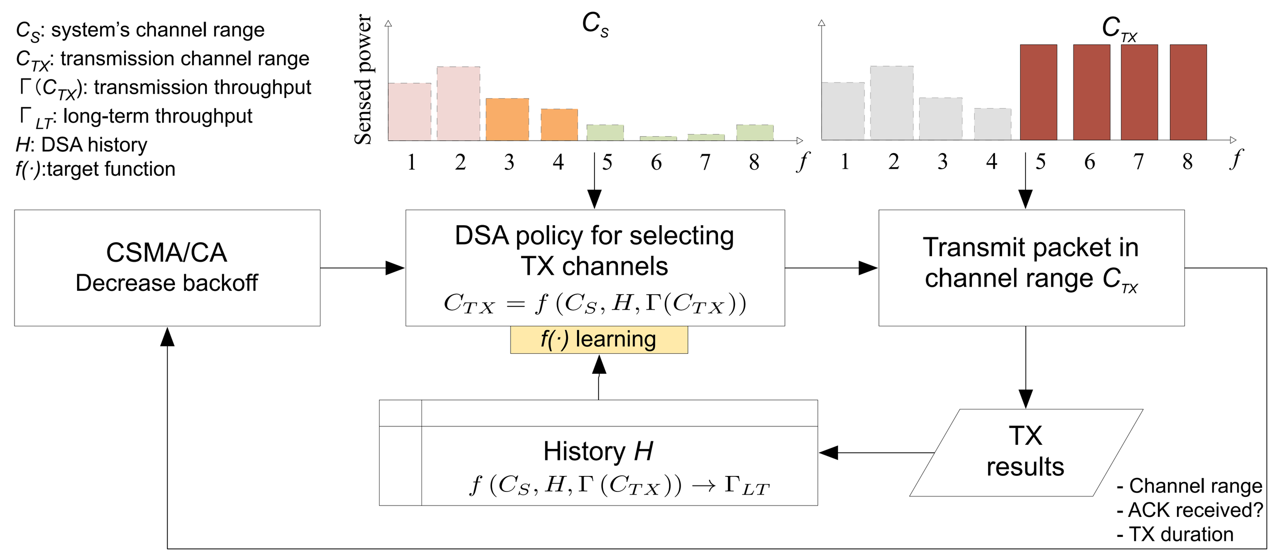
Stadium 802.11ax high-densitiy scenario.



Gartner's IoT devices population forecast [1].

Applying learning-based policies

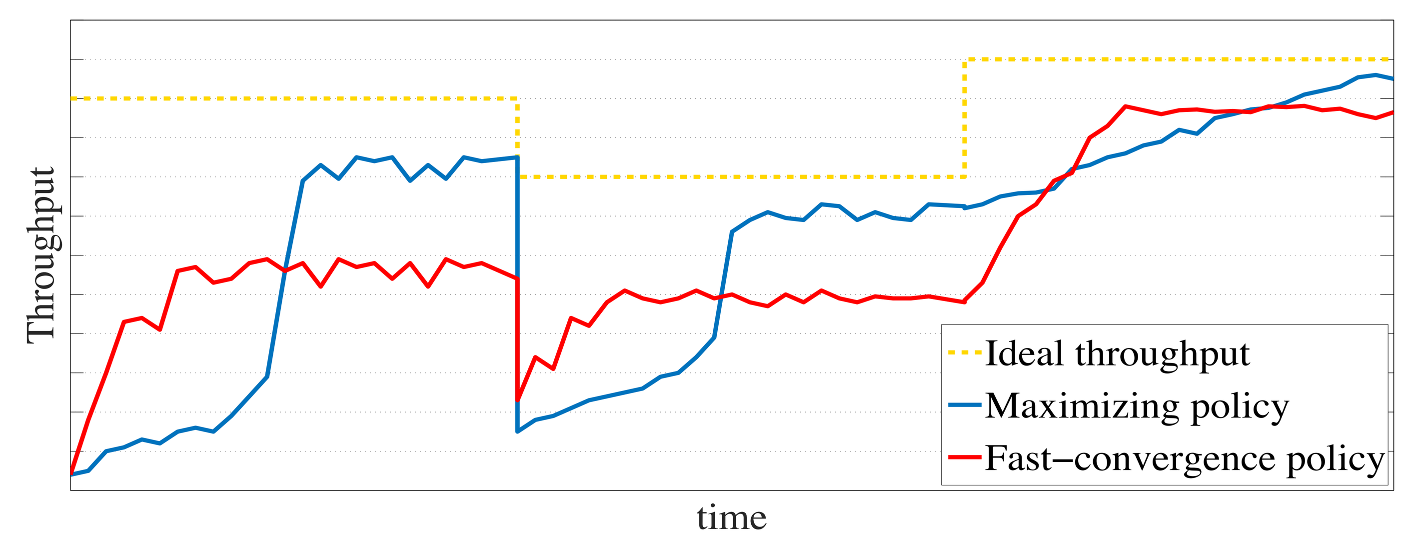
- **DSA policy**: selects the optimal transmission channel range.
- **Input**: sensed channel power and history of actions + reward.
- **Reward**: greedy, collaborative, short/long-term throughput, etc.



Learning-based basic flowchart of a DSA agent.

On-going work

- Characterize channel selection effects on throughput and fairness.
  - Identify general topologies and phenomena in dense deployments.
  - Standard protocols effect on throughput (e.g., IEEE 802.11).
- Design learning-based DSA policies for enhancing WLANs performance.
  - Identify suitable machine learning techniques [4].
  - Centralized / Decentralized: full / local knowledge available.
- Incorporate transmit power control (TPC) in the learning-based policies.



Expected outcome: possible impact of DSA policies on the WLANs throughput in dense deployments.

Channel allocation characterization

Continuous Time Markov Networks (CTMNs) allow to **analytically** capture the operation of idealized wireless networks [2].

- States: channels being used by each node.
- Transitions: DSA policies determine the transition rates.
- Throughput closed form of WLAN i:

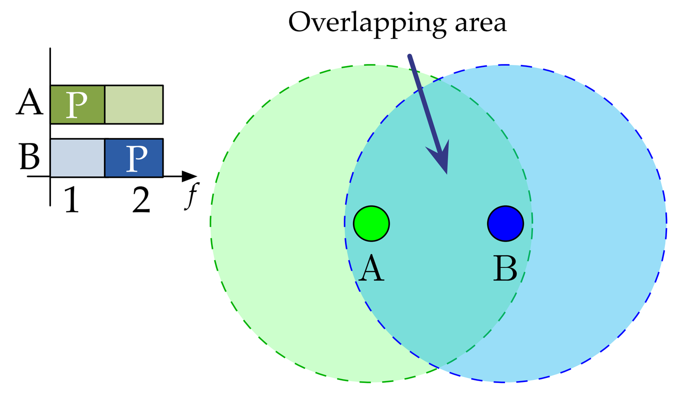
Probability of being in state s

$$\Gamma_i = L \left(\sum_{s \in S} \mu_{i,s}(c) \pi_s \right)$$

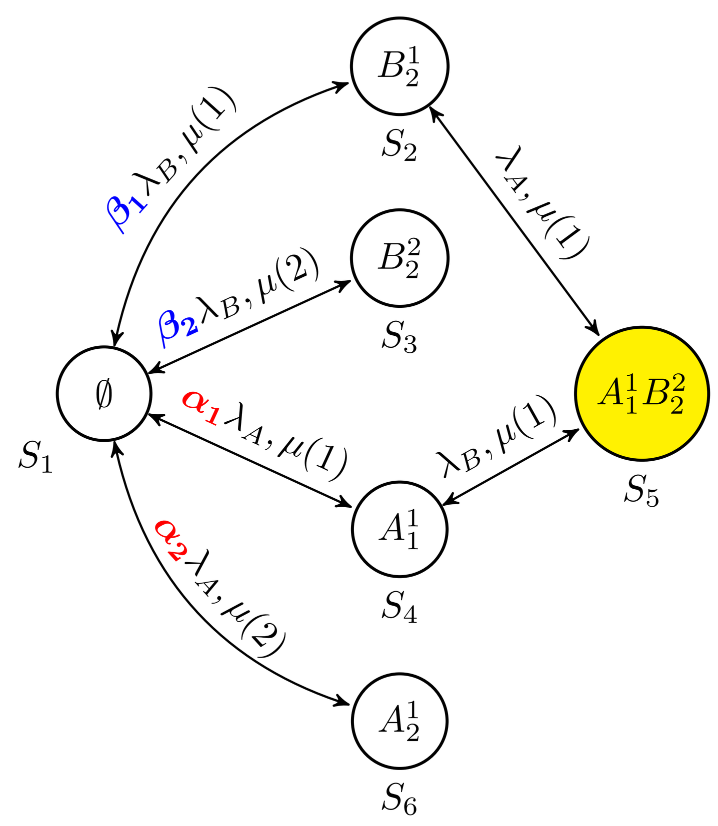
Packet length

Departure rate when using c channels

- CTMN model limitations:
  - Several assumptions must be considered such as overlapping nodes, continuous backoff, idealized channel, etc.
  - **Komondor** simulator built in COST [3] is being developed to capture real world wireless phenomena.



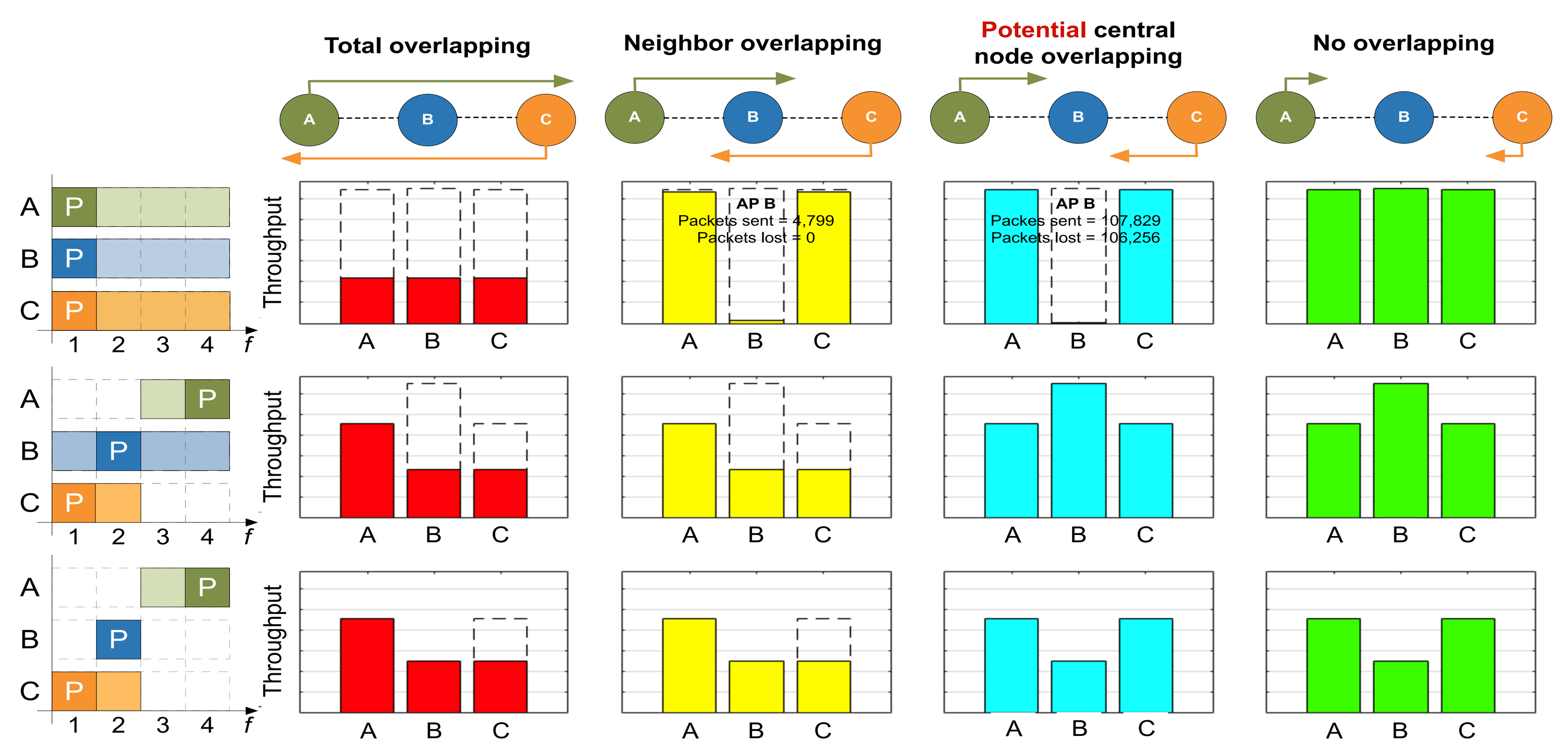
Two overlapping WLANs sharing the channel.



Markov chain modeling the WLAN scenario above.
Transition parameters (α and β) determine the DSA policy.

Preliminary analysis

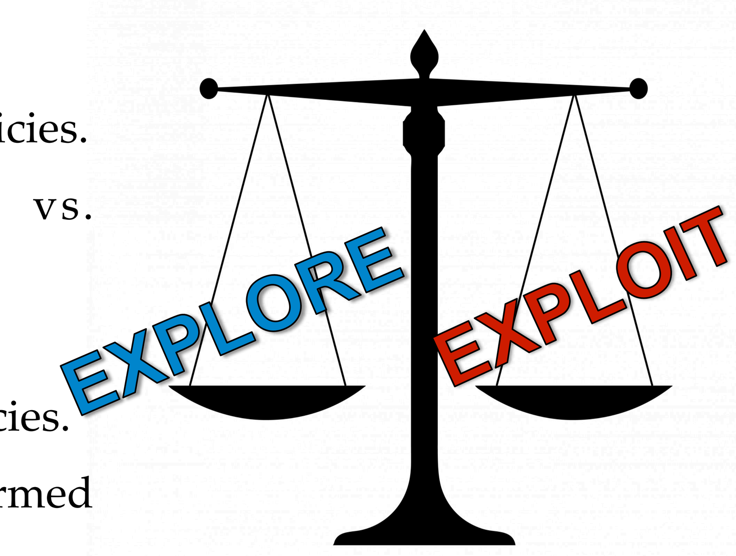
- Selecting the widest channel available may decrease the long-term throughput.
- Optimal transition rates (i.e., DSA policies) depend thoroughly on the scenario.
- The effect of hidden nodes may be critical and hard to prevent.



Komondor simulations: throughput of three WLANs (A, B and C) composing a line network in different overlapping scenarios.

Open questions

- Feasibility of identifying optimal policies.
- Knowledge extraction: control vs. overhead.
- Greedy vs. collaborative throughput.
- Non-stationarity effects on DSA policies.
- Suitability of combinatorial multi-armed bandits (MABs).



Exploration vs. exploitation.

References

[1] Gartner, "Gartner Says 6.4 Billion Connected Things Will Be in Use in 2016, Up 30 Percent From 2015", http://www.gartner.com/newsroom/id/3165317, Nov. 2015. Accessed: 27 Feb. 2017.

[2] B. Bellalta, A. Checco, A. Zocca and J. Barcelo, "On the Interactions Between Multiple Overlapping WLANs Using Channel Bonding", in *IEEE Transactions on Vehicular Technology*, vol. 65, no. 2, pp. 796-812, Feb. 2016.

[3] G. Chen and B. K. Szymanski, "Reusing Simulation Components: COST: A Component-oriented Discrete Event Simulator", in *Proceedings of the 34th Conference on Winter Simulation: Exploring New Frontiers, ser. WSC '02. Winter Simulation Conference*, pp. 776–782, 2012.

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