Comment améliorer les performances d'un réseau Wi-Fi sans modifier la technologie Wi-Fi ?

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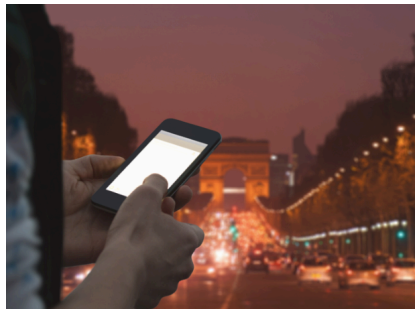
Wi-Fi network evolution

- Explosive Wi-Fi use
  - 8 billions Wi-Fi devices in use
  - Mobile + Wi-Fi traffic = 71% of IP traffic by 2022
  - Wi-Fi traffic = 51% of IP traffic by 2022
  - 549 millions public Wi-Fi hotspots by 2022 (48 millions in 2014)

- A public Wi-Fi network example
  - On the Champs-Elysées avenue in Paris
  - 58 Access Points (APs) deployed on 1.5 km
  - 5000 simultaneous users



- Very dense Wi-Fi networks with hundreds of APs
  - CentralWorld Mall in Bangkok (more than 1000 APs)
  - Bangkok airport (460 APs)
  - Dubai World Trade Center (350 APs)
  - ...

Wi-Fi maximum transmission rate evolution

802.11 in a nutshell

- Use of the same channel to communicate

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- Communication pattern

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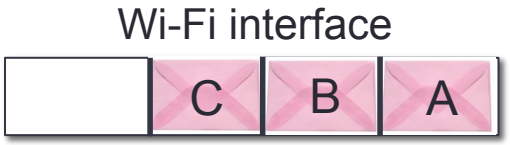
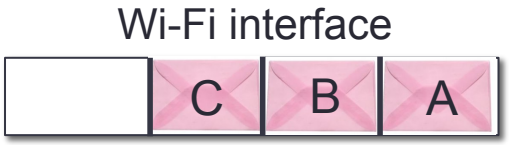


Access control mechanism

802.11 in a nutshell

- Use of the same channel to communicate
- Communication pattern

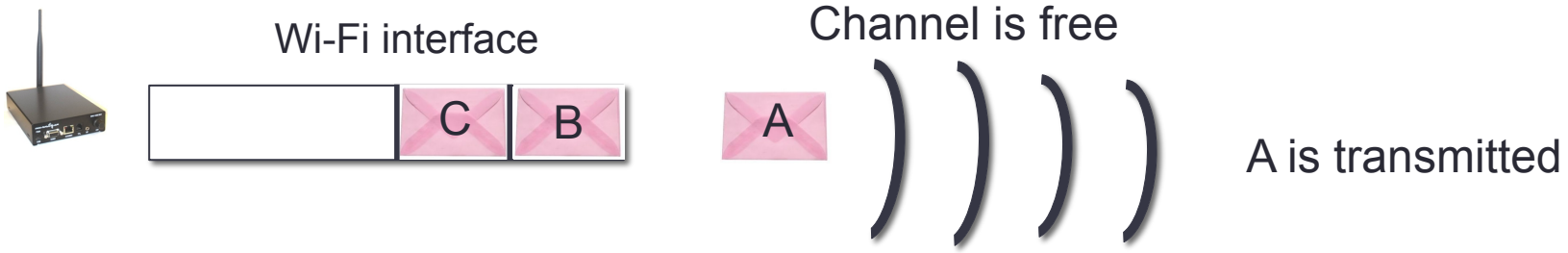


Access control mechanism

CSMA / CA approach

802.11 in a nutshell

- Use of the same channel to communicate
- Communication pattern



➔ **2 stations which hear each other share the channel**

802.11 in a nutshell

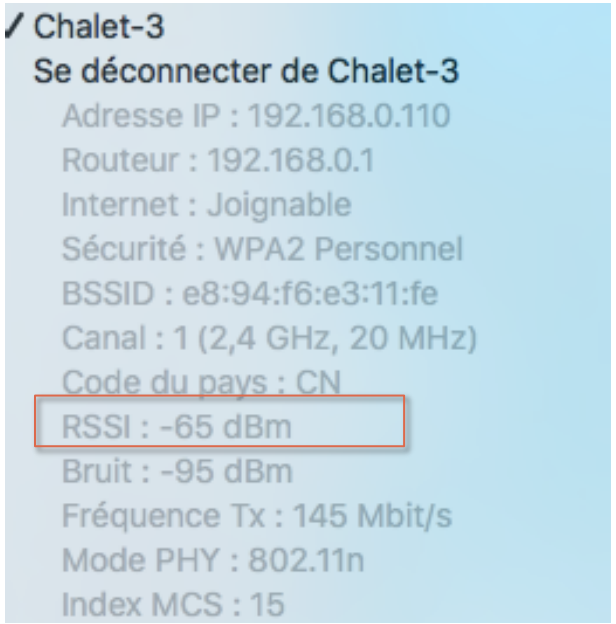
- Use of the same channel to communicate
- Communication pattern
- Multiple possible transmission rates
  - 128 with 802.11n & 312 with 802.11ac
  - Dynamically adapted by a **transmission rate adaptation algorithm**
  - Adaptation based on link quality evaluation

802.11 in a nutshell

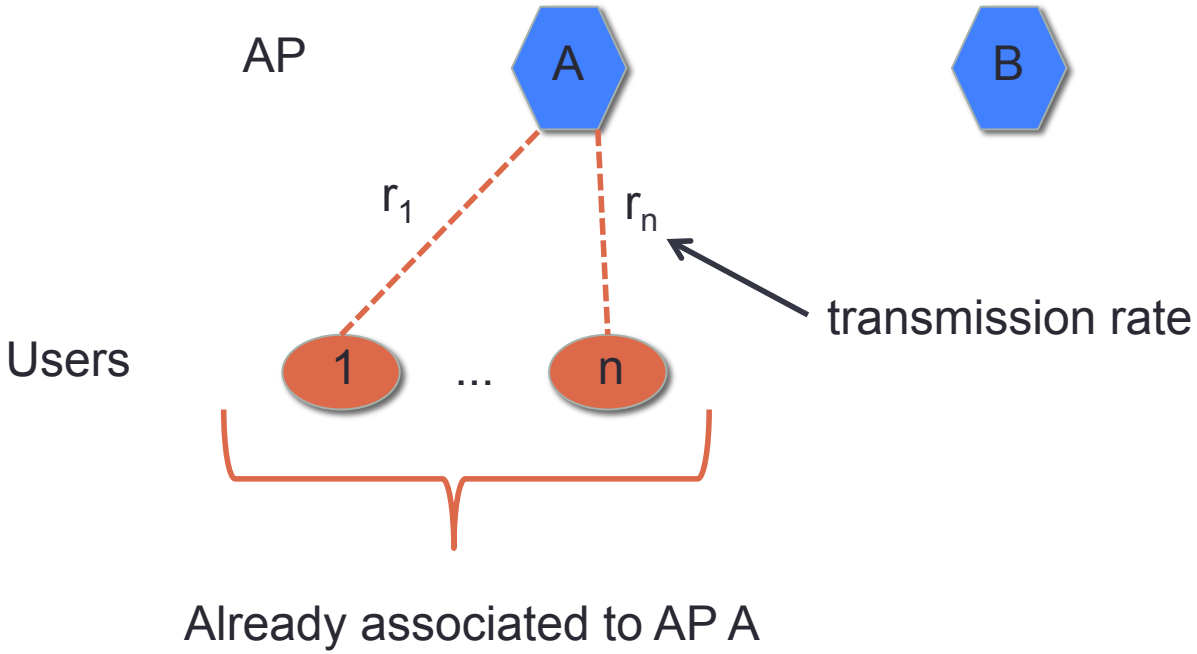
- Use of the same channel to communicate
- Communication pattern
- Multiple possible transmission rates
- Infrastructure mode
  - Each station must be associated to exactly one access point

AP association

- Often executed by the device / interface
- Choose the AP with the highest Received Signal Strength Indicator (RSSI)
  - Potentially corresponding to the highest possible transmission rate
- Advantages
  - Simple
  - Distributed (local)



Is it a good choice?: toy example



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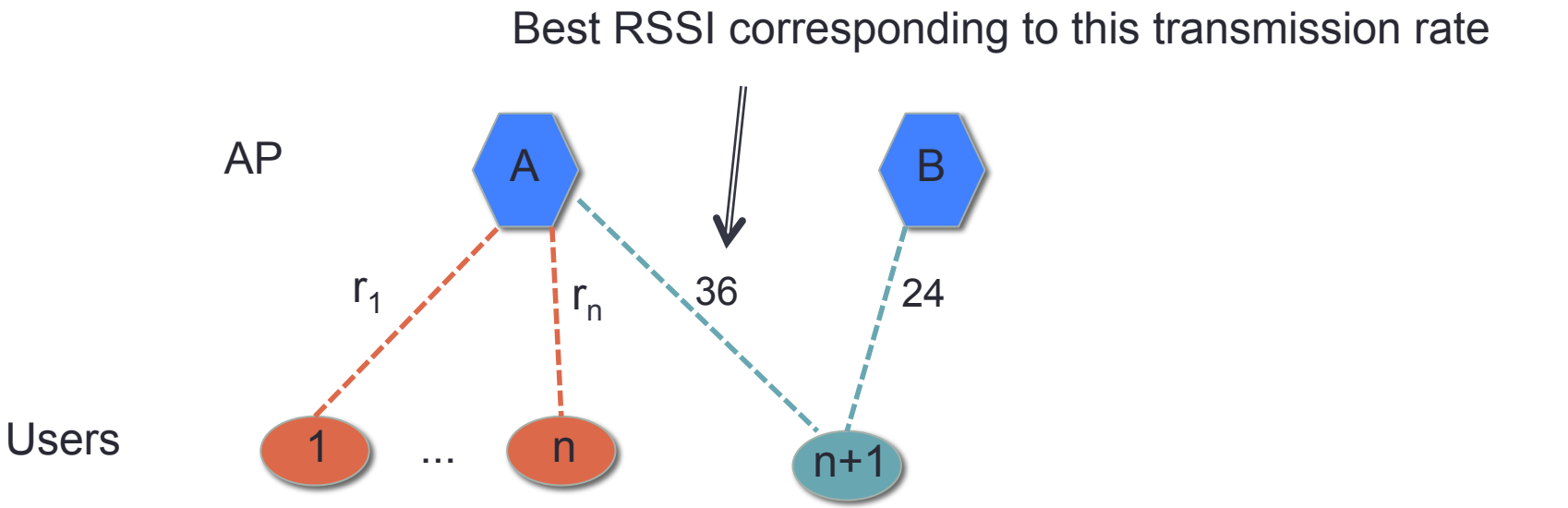
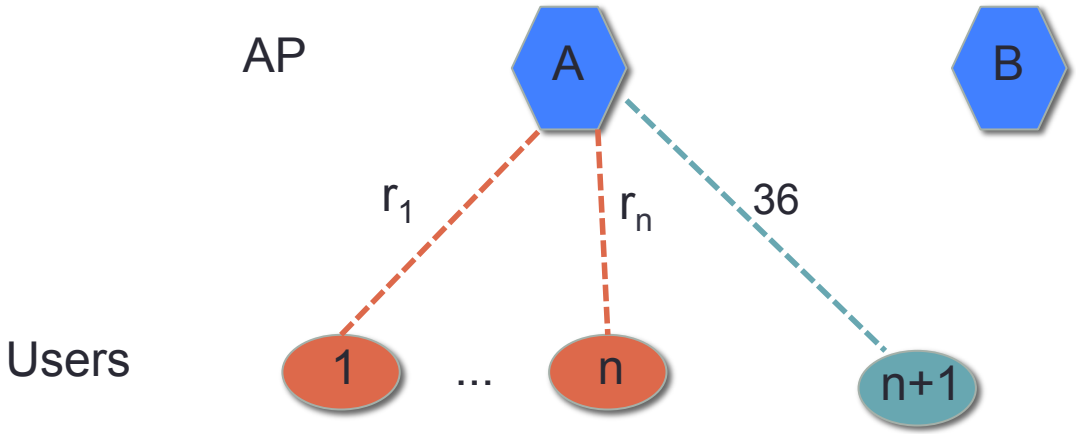


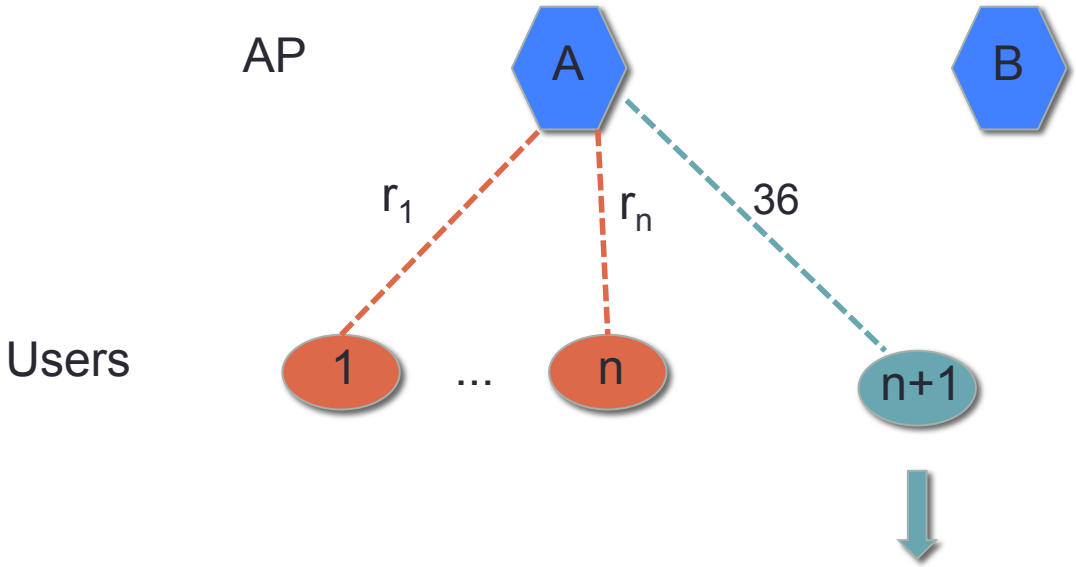
A new user arrives
It has 2 possible choices for AP selection

Is it a good choice?: toy example



The highest RSSI is with AP A.
It decides to associate to AP A

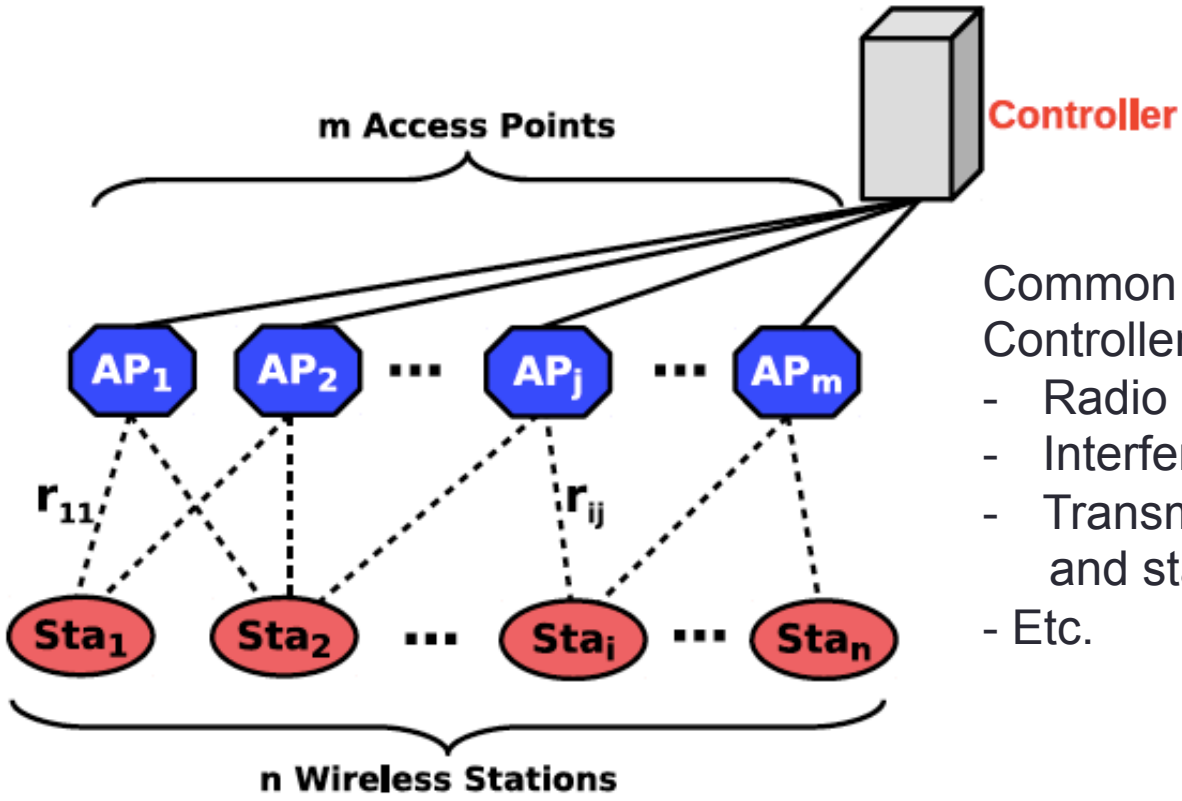
Is it a good choice?: toy example



The achieved throughput is shared with the other users << 36
and very likely << 24

Can we provide a better association?

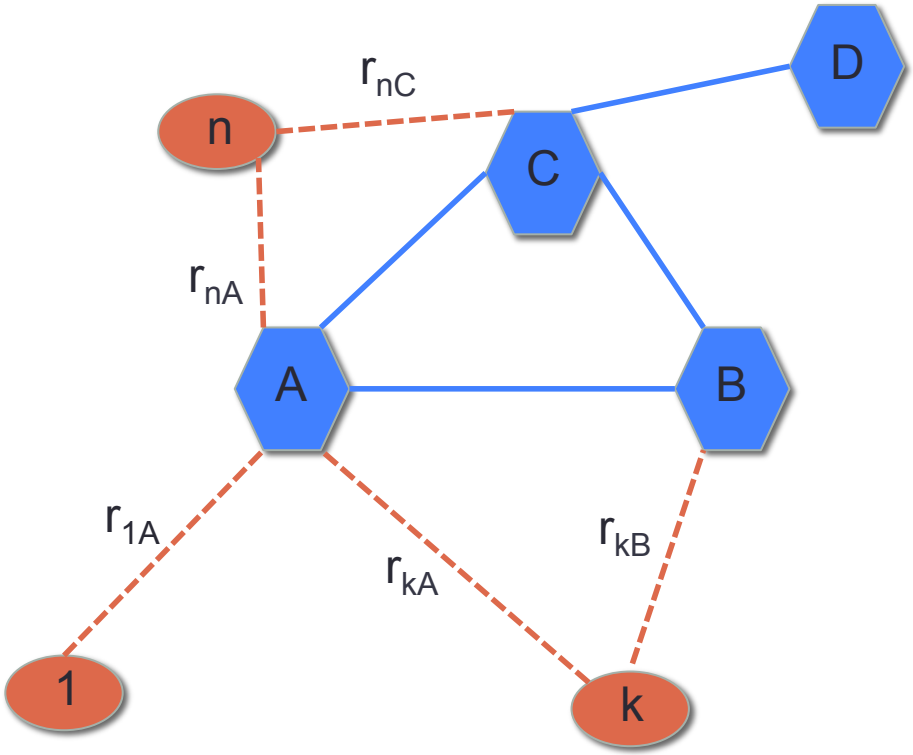
Central management



Common approach
Controller can collect:
- Radio channels used by APs
- Interfering APs
- Transmission rates between APs and stations / users
- Etc.

A global knowledge on the network allows the use of optimization tools

What is the problem?



Inputs:
- AP conflict graph
- Possible transmission rates between users and APs

Output:
- User association with the best performance

Network performance:
- Overall network throughput
- Delay
- User fairness
- Etc.

Challenge: predicting the network performance for a given association
➔ realistic models of the channel sharing

One solution

- User throughput prediction

$$d_{ij} = \frac{1}{\sum_{k=1}^{n} \frac{x_{kj}}{r_{kj}}}$$

- Overall throughput AND throughput fairness optimization

$$\max \sum_{i=1}^{n} \log \left(\sum_{j=1}^{m} d_{ij} x_{ij} \right)$$

Assumptions:
- Orthogonal channels
- Downlink traffic
- Saturating flows
- Fair AP service between users
- Identical frame size

Another solution

- User throughput prediction

$$d_{ij}^{*} = \frac{1}{\sum_{i'=1}^{n} x_{i'j}} \cdot \frac{1}{\sum_{k=1}^{m} \left(\frac{s_{kj}}{\sum_{i'=1}^{n} x_{i'k}} \cdot \sum_{i'=1}^{n} \frac{x_{i'k}}{r_{i'k}} \right)}$$

- Overall throughput AND throughput fairness optimization

$$\max \sum_{i=1}^{n} \log \left(\sum_{j=1}^{m} d_{ij}^{*} x_{ij} \right)$$

Assumptions:

- ~~Orthogonal channels~~
  - Fair channel access between APs in conflict
- Downlink traffic
- Saturating flows
- Fair AP service between users
- Identical frame size

And yet another solution

Assumptions:

- ~~Orthogonal channels~~
  - Fair channel access between APs in conflict
- Downlink traffic
- ~~Saturating flows~~
- ~~Fair AP service between users~~
  - Same success probability in the same channel
- Identical frame size

- Busy time fraction prediction
  - Based on ugly formulas, like this...

$$Pr\left(\bigcap_{l\in I} A_l\right) = \frac{\prod_{l\in I}\left(Pr\left(\bigcup_{l'\in I'\cup\{l\}} A_{l'}\right) - Pr\left(\bigcup_{l'\in I'} A_{l'}\right)\right)}{\left(1-Pr\left(\bigcup_{l'\in I'} A_{l'}\right)\right)^{|I|-1}}$$

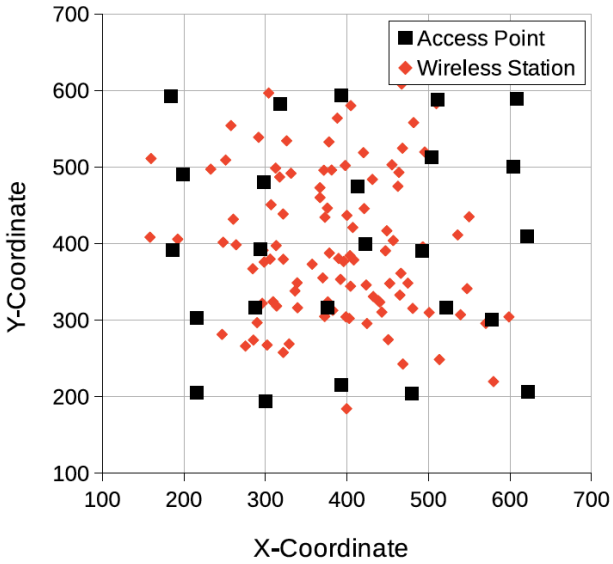
Too long to explain...

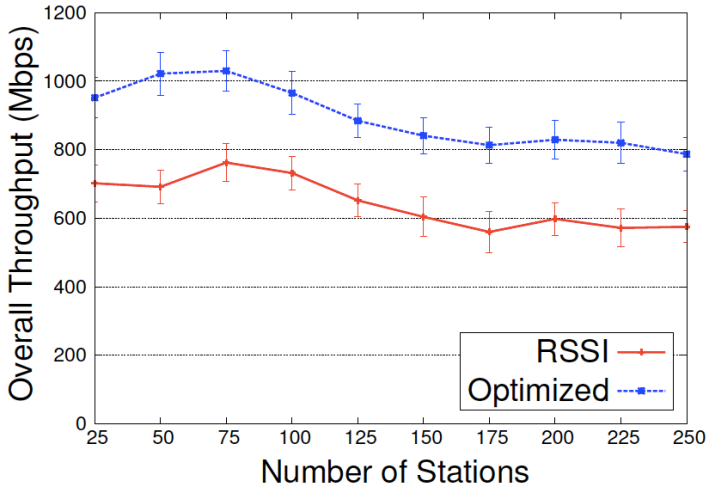
Heuristic & Evaluation

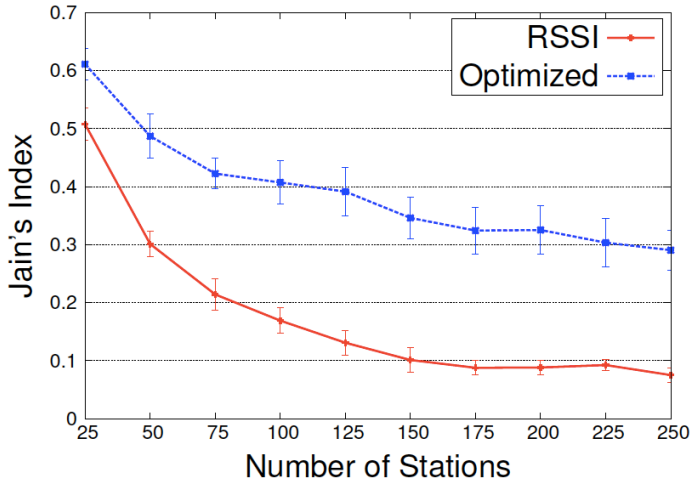
- An iterative heuristic based on local search
  - Advantages
    - Simple
    - Can be stopped at any time with a feasible solution
      - Computation time can be considered
  - Initial state: RSSI association

- An evaluation on a network simulator
  - More realistic than classical evaluations of the objective functions
  - How is the proposed model resilient against realistic parameters not considered in the modelling step?
    - *e.g.* downlink traffic, no frame collision, identical packet size

Simulation results (with ns-3)

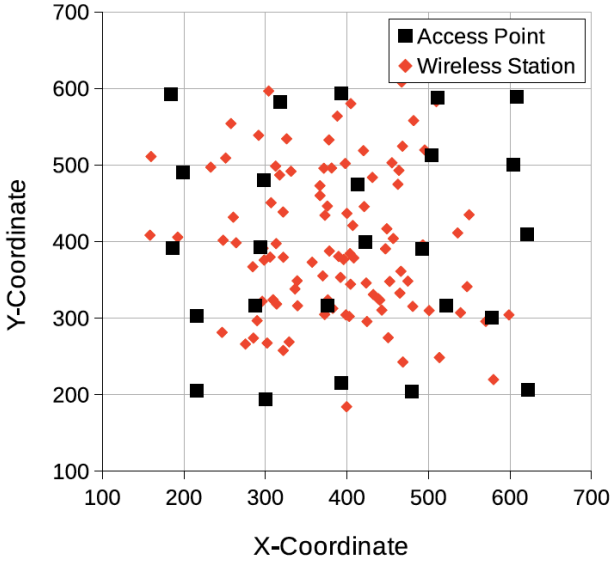


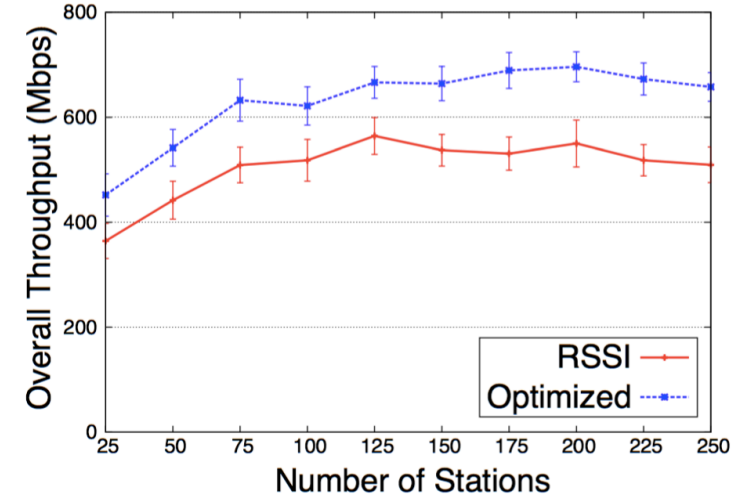


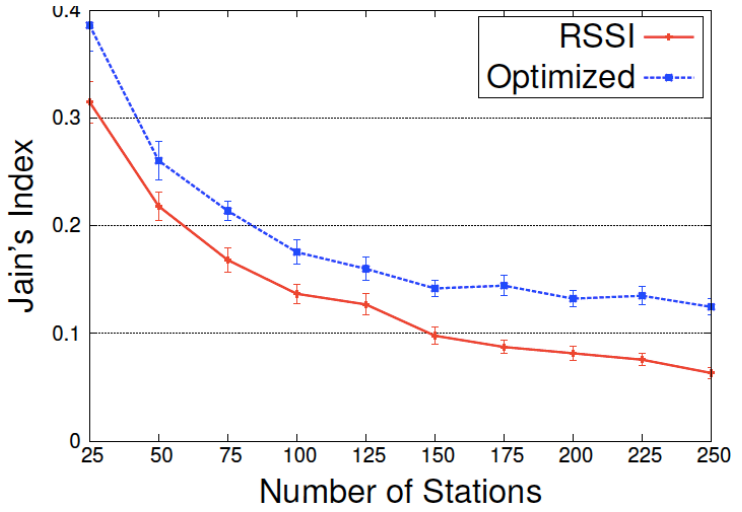


8 orthogonal channels
Downlink saturated UDP traffic

Simulation results (with ns-3)





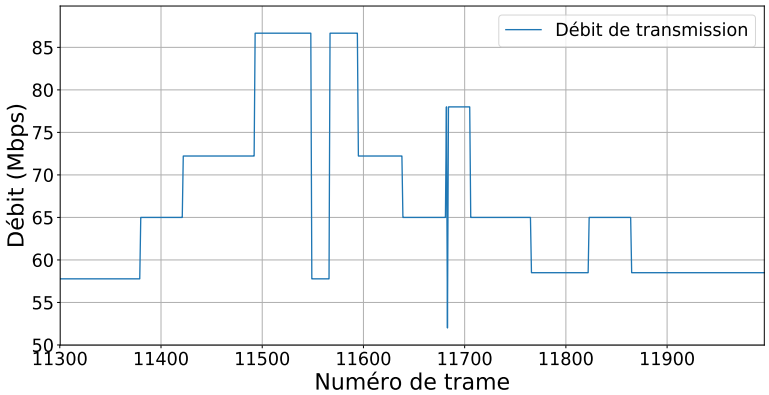


8 orthogonal channels
Downlink TCP traffic

Conclusion

- Key step
  - Modelling part
  - Very difficult in Wi-Fi networks
  - Trade-off between details consideration and simplicity of use
- Difficulties
  - What do the real Wi-Fi products do in respect to the standard?
  - Some impacting parts are not standardized
    - e.g. transmission rate control algorithm

Evolution of the transmission rate of Intel Wi-Fi cards



Still a large number of fantastic problems with Wi-Fi!

- Many new features
  - How does it work, what are the performances and which algorithms?
  - Examples: association algorithms, transmission rate algorithms
- Many new different contexts (UAVs, IoT, 5G, etc.)
  - How to adapt it to these contexts and to leverage it in these contexts?
  - Examples: controlled mobility of UAVs based on Wi-Fi communication performance
- Energy consumption
  - How is the energy consumed and how much? Which energy efficient solutions?
  - Examples: how to use Wi-Fi in heterogeneous wireless networks
- And many other problems... Contact me if you are interested!

Thank you
Questions?