Practical Distributed Channel Assignment in Home Wi-Fi networks

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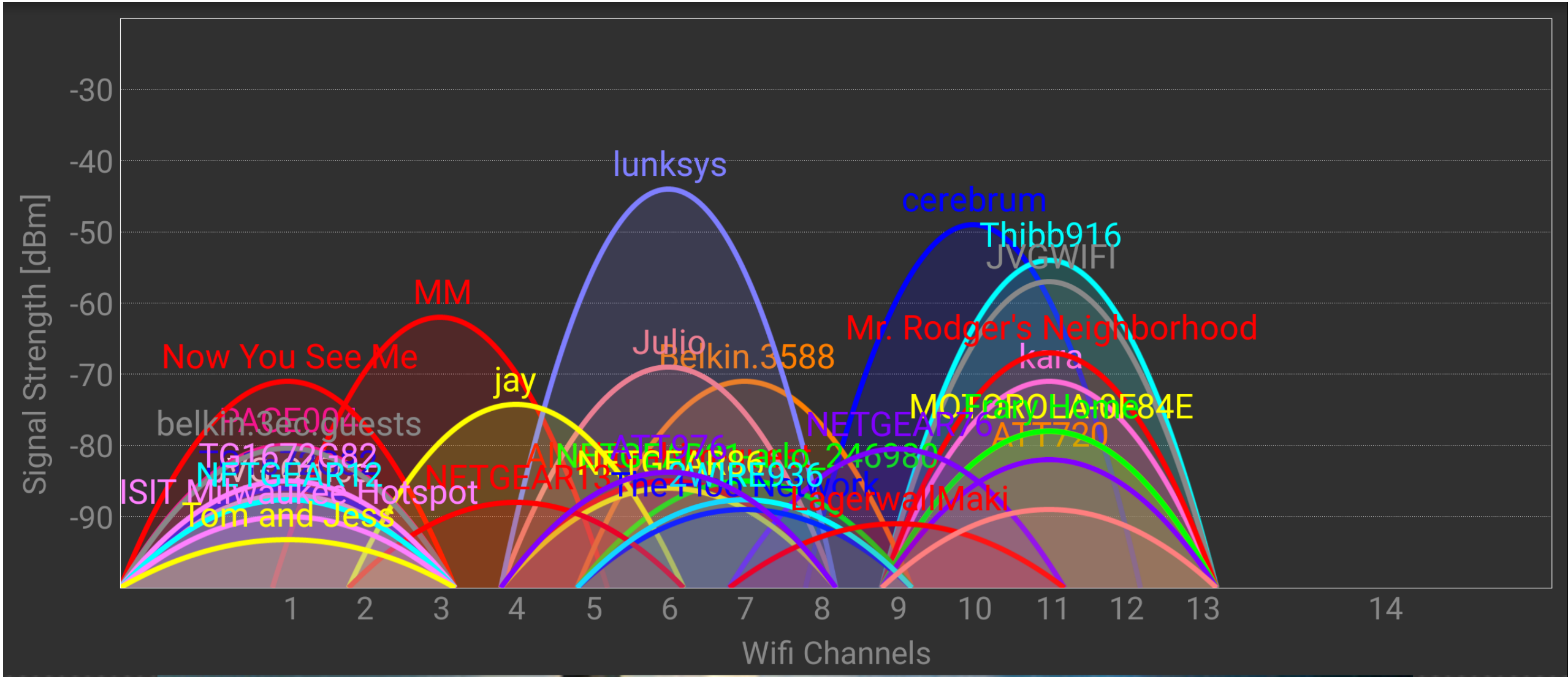
Keywords

- Cooperative networks
- Home Wi-fi networks
- Self-organizing networks (SON)
- Smart cities, homes
- Wireless Local Area Networks (LAN)

Here’s the thing – about Wi-Fi

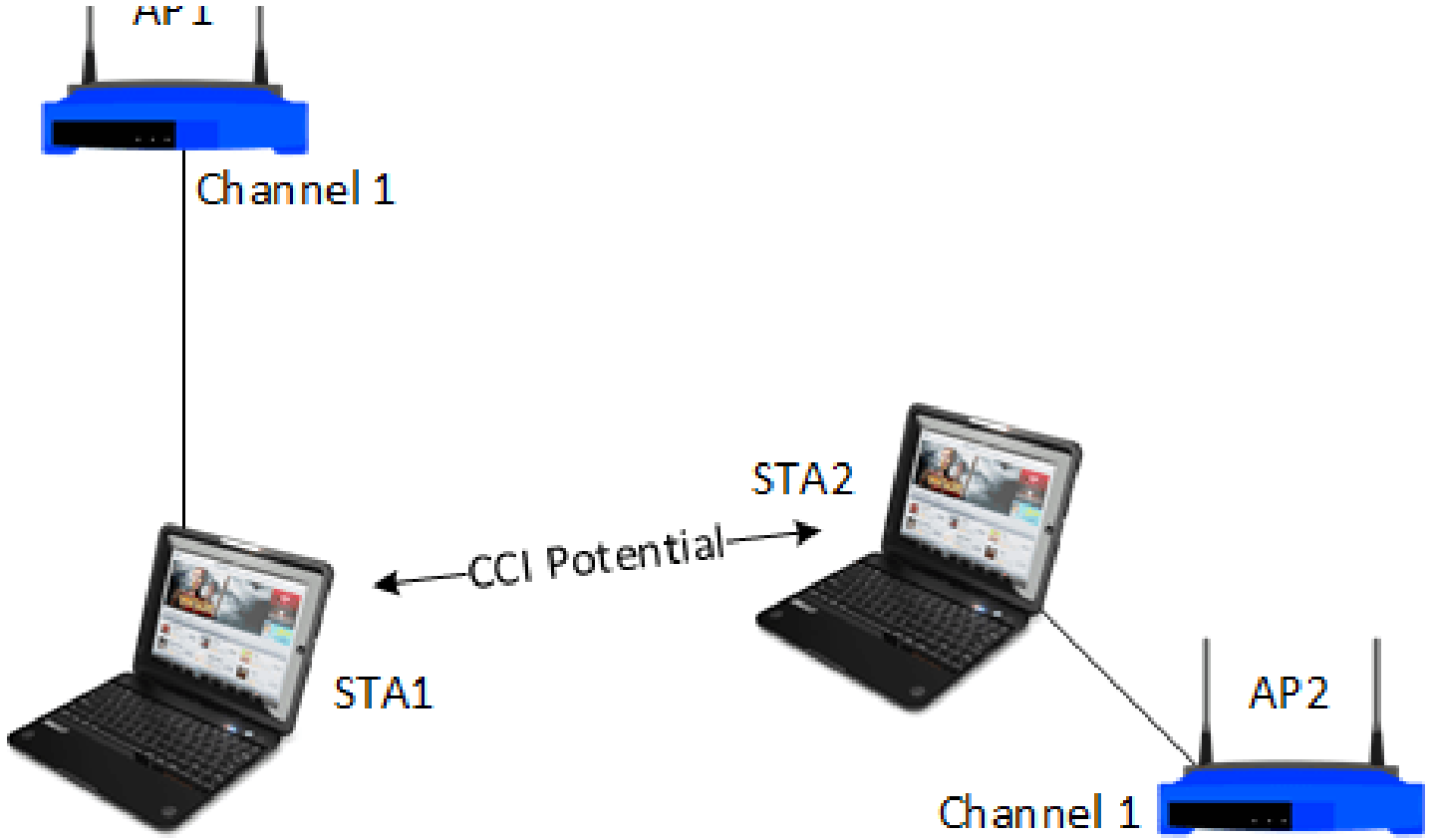
- IEEE 802.11 (AKA Wi-Fi) extremely popular technology
- Provides a comfortable way to connect devices
  - Residential Wi-Fi
  - Practical way to access internet
- But,
  - Dense deployments cause performance issues due to interference and contention
  - Maintaining high Quality of Service (QoS) becomes a problem

Screenshot from Wi-Fi spectrum analyser app



What’s Contention?

- A way to share a broadcast medium
- Wi-Fi uses CSMA/CA
- Participating nodes compete for channel access
  - Based on exponential backoff timers and listening to wireless medium
- More (active) neighboring nodes -> increased latency + increased risk of collisions -> worse performance

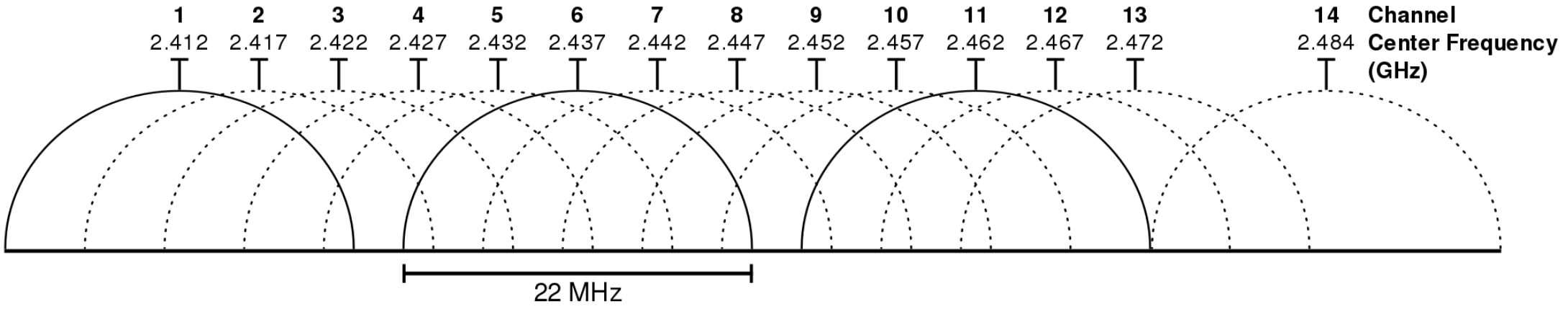


Co-channel interference (CCI)

- Two STAs connected to different APs are within transmission range of each other
- Can have normal contetion or…
- Collisions can occur if using same channel
- Hidden terminal problem
- E.g. Transmission from STA2 > AP2 can collide with transmissions AP1 > STA1
  - Will cause errors and retransmission

Adjacent interference

- Happens whenever overlapping channels are involved
  - Causes corrupt data and retransmissions
    - 2.4 GHz Wi-Fi has 14 channels
  - Only 11 of those channels are commonly used
  - Only 3 of which are non-overlapping (1, 6 and 11)

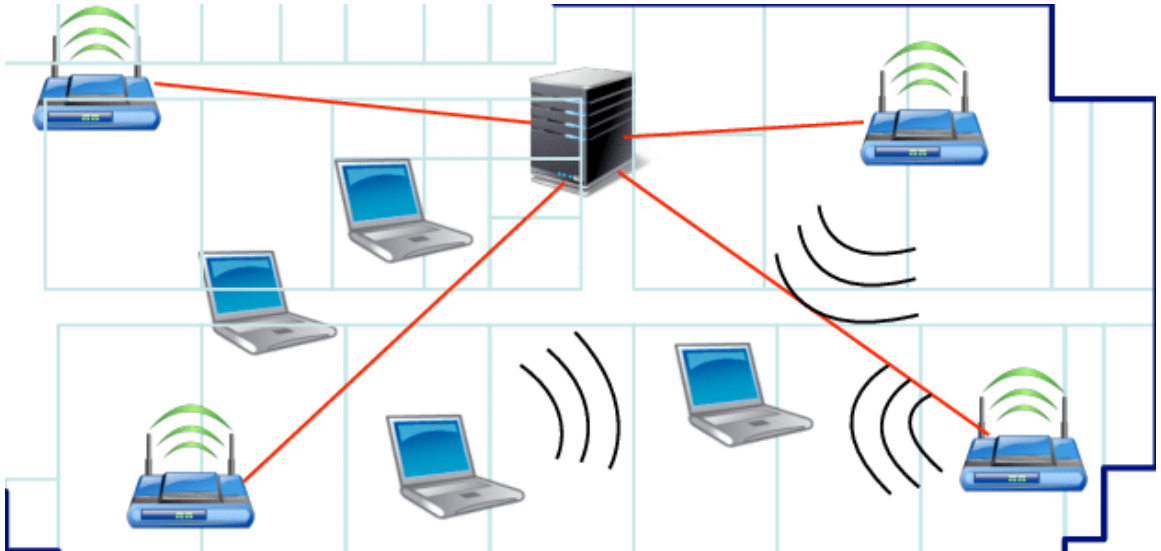


How do we reduce contention and interference in dense Wi-Fi deployment?

- We need to be able to assign channels intelligently
  - E.g. based on observations of channel load
  - Try to limit overlapping channels

How do we do this?

- Has been solved for enterprise!
  - Using centralized controllers
  - Manages channel assignment of all APs in a domain
  - Based on load and avoiding of overlapping channels
  - But,
    - Requires ability to properly plan out the Wi-Fi deployment
    - Single administrative domain



How do we do this for Residential/Home Wi-fi deployments?

- Typical situation: Multiple autononomous APs (e.g. one in each home)
  - Centralized controller impractical
  - Users have lack of technical skills
- Recently manufacturers implemented AP self-optimization
  - Mostly only during setup or reset of AP
  - Limited to local observations within AP
- What's the solution?

Goal of the paper

- Showcase/present **a distributed radio channel assignment scheme**
  - Implemented using the **ResFi** platform
  - Neighboring Wi-Fi APs cooperate to negotiate channel selection, using information about:
    - Own network load
    - Network load of neighbouring ResFi APs
    - Network load of neighbouring non-ResFi APs
- Demonstrator

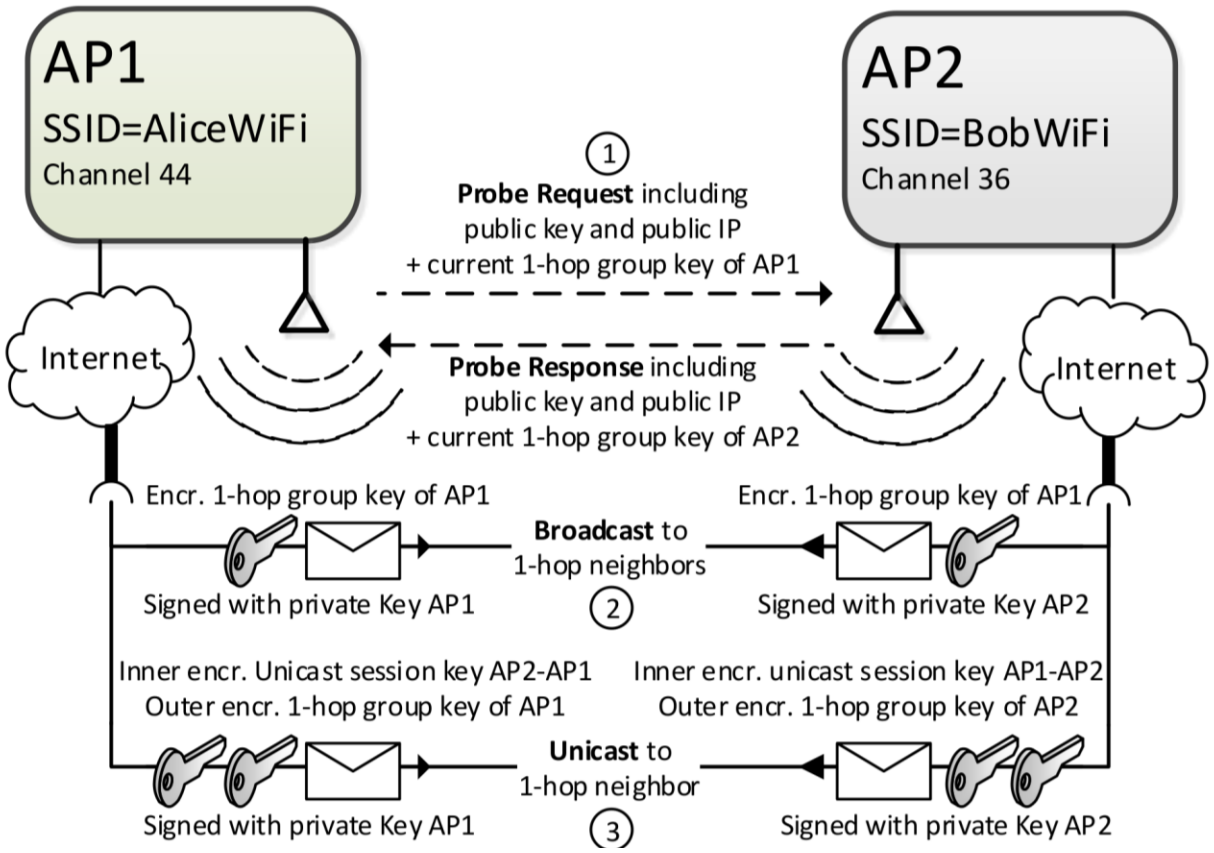
What is ResFi?

- https://github.com/resfi/resfi
- ResFi: A Secure Framework for Self Organized Radio Resource Management in Residential WiFi Networks
  - http://www.tkn.tu-berlin.de/fileadmin/fg112/Papers/2016/zehl16resfi.pdf
- Enables residential Wi-Fi APs to detect neighboring APs and **build secured side-channels over the internet** to each other
- Used to perform **distributed radio resource management (RRM)**

How does ResFi work?

1. Broadcast probe request during AP boot with IEV containing ResFi “contact data”
2. ResFi APs within coverage respond with probe response containing own “contact data”
3. After having completed active scan, new AP establishes secure, point-to-point channel to RRMUs of all discovered ResFi APs over the internet, using received “contact data”
4. Discovered APs does the same in the reverse direction

- Contact data?
  - Globaly routable IP-address and port number to APs RRMU
  - Public cryptography key for RRMU

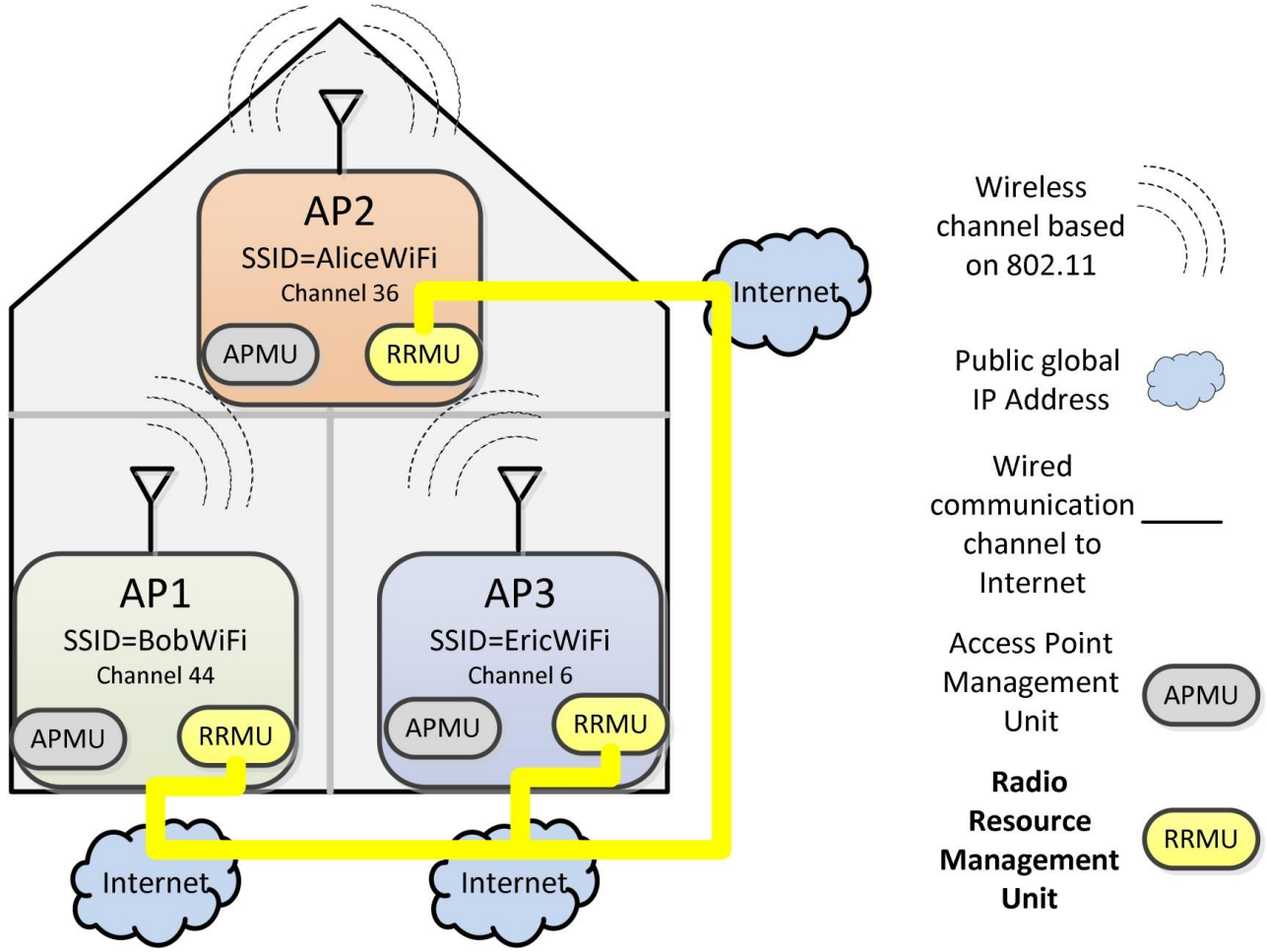


RRMU=radio resource management unit

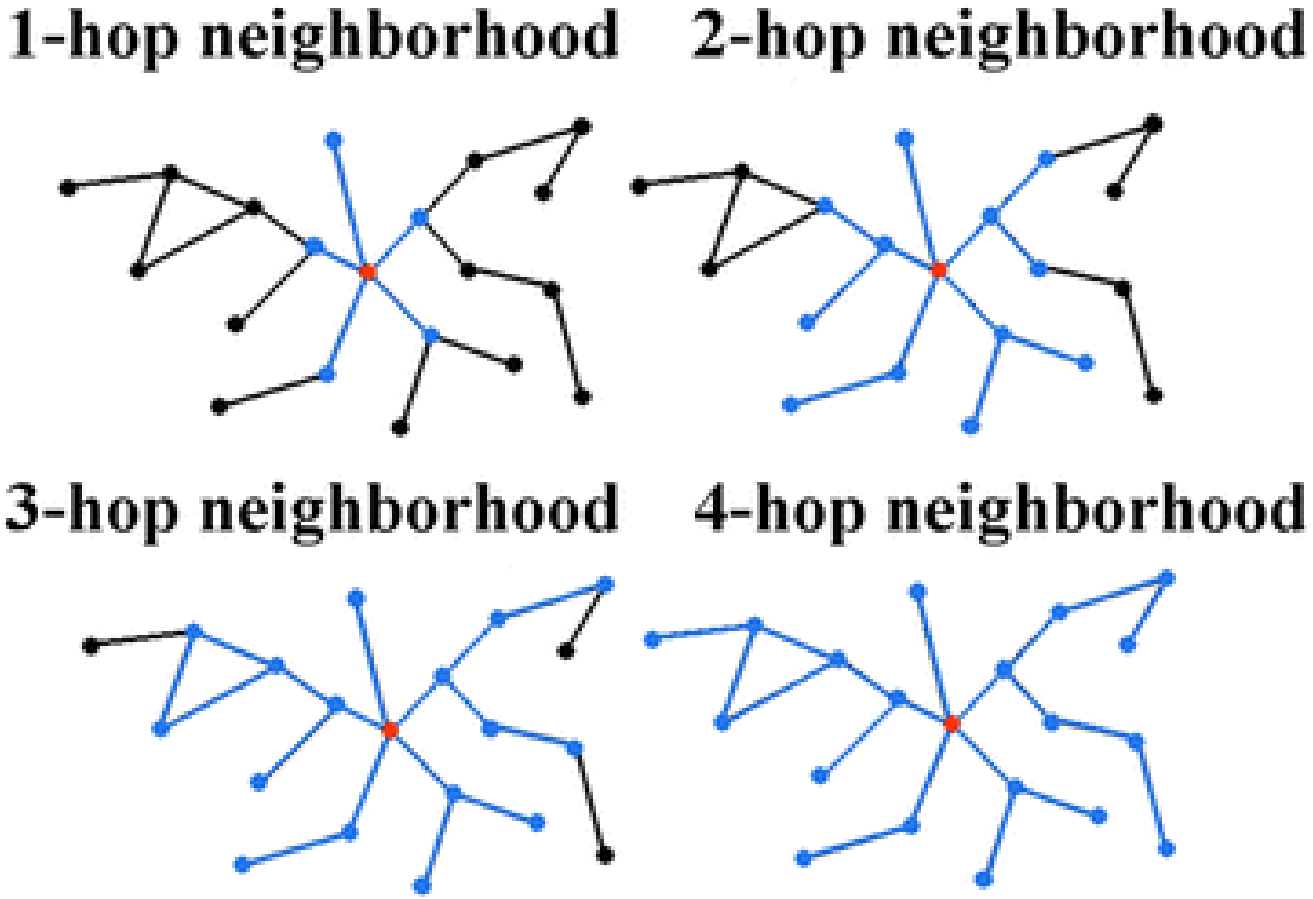
The end result

Each ResFi APs RRMU is connected to its neighbors via secured point-to-point channels over the internet

Used for communication between RRMUs



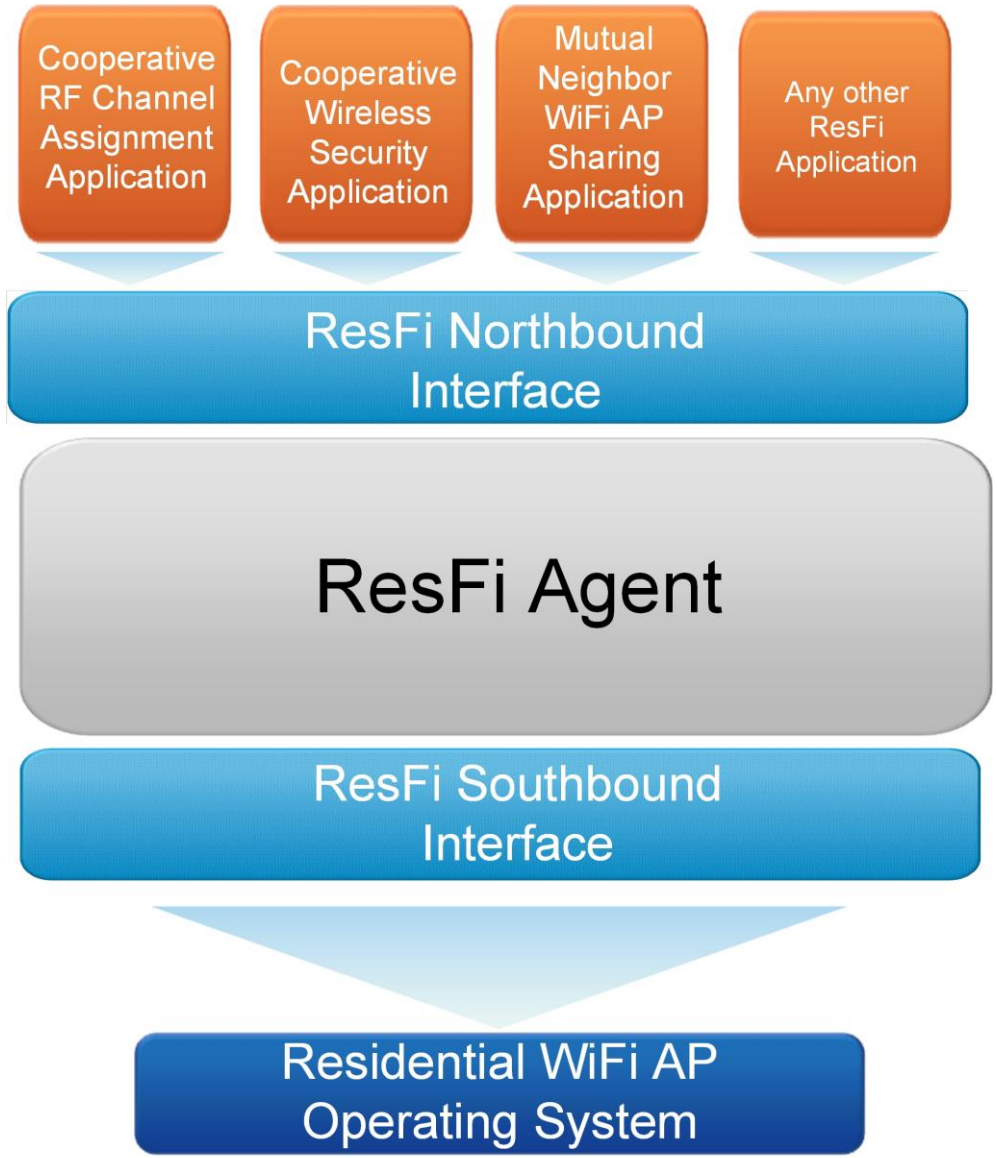
ResFi - forwarding



- Each RRMU can act as forwarder
  - Extend secure connectivity to N-hop neighborhood
  - RRM performs best when done on a cluster of APs larger than 1-hop neighborhood

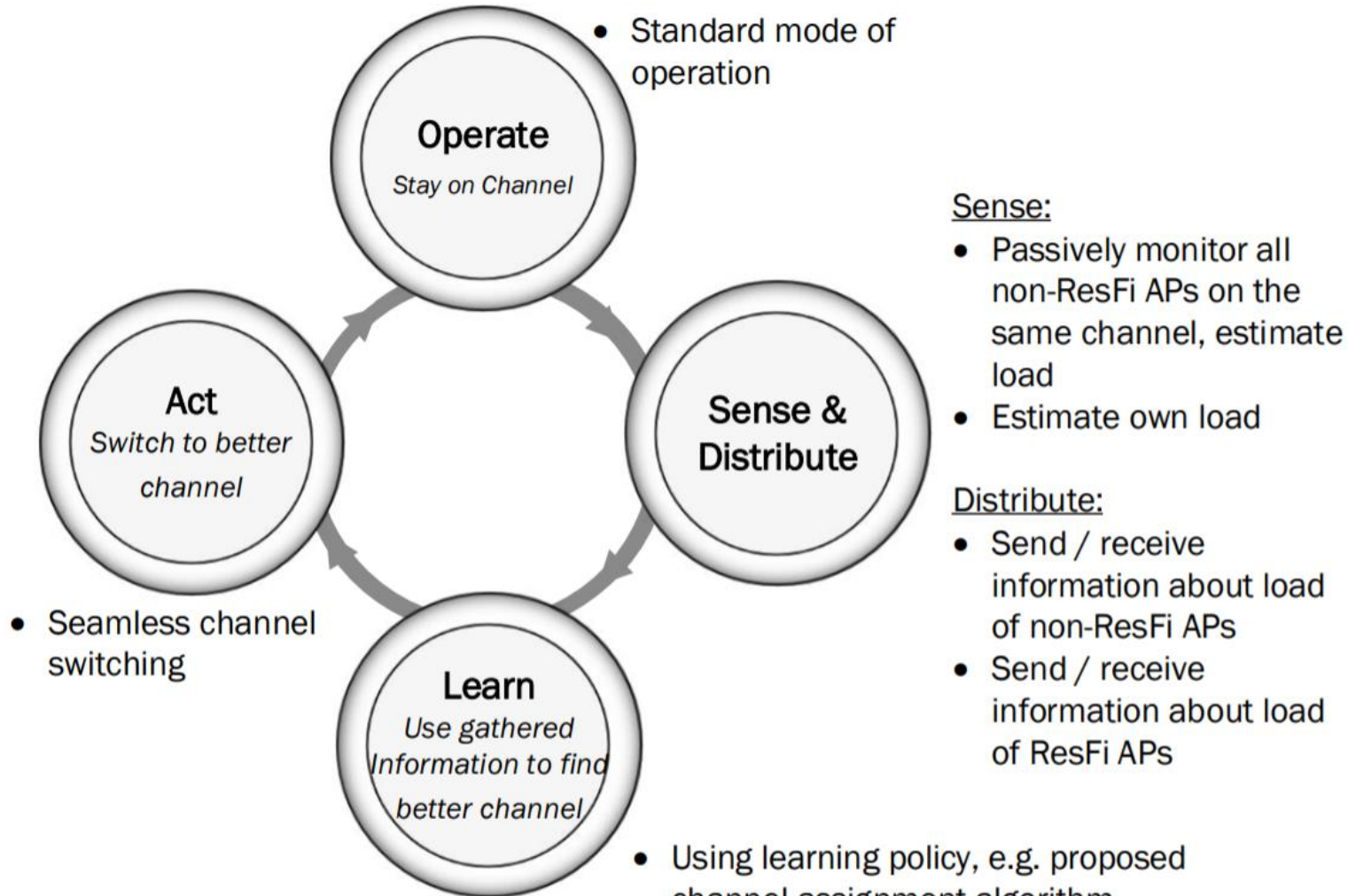
ResFi – RRM approach

- Does not feature specific RRM approach
- Is delegated to any RRM application running on top of ResFi


Cooperative RF Channel Assignment Application
Cooperative Wireless Security Application
Mutual Neighbor WiFi AP Sharing Application
Any other ResFi Application
ResFi Northbound Interface
ResFi Agent
ResFi Southbound Interface
Residential WiFi AP Operating System

The Paper's Channel assignment application

- Runs on a ResFi-enabled AP
- Every nearby ResFi AP shares info about:
  - Own load
  - Load of co-located non-ResFi APs on same channel
- 2-Hop neighbourhood
  - Migitages CCI, hidde node
- Uses info for adaptive channel assignment
  - Selects channel with minimum load
    - Reduces contention
    - Mitigates co-channel interference
- Only uses non-overlapping 2.4 Ghz channels and all available 5 GHz channels



- Standard mode of operation

Sense:

- Passively monitor all non-ResFi APs on the same channel, estimate load
- Estimate own load

Distribute:

- Send / receive information about load of non-ResFi APs
- Send / receive information about load of ResFi APs

- Using learning policy, e.g. proposed channel assignment algorithm

- Seamless channel switching

Channel assignment algorithm

- Input: load of all neighboring ResFi + non-ResFi Aps
  - Load: number of STA that has transmitted / received larger than thr_threshold bytes during last sample interval
- Calculate overall load for each channel
- Algorithm then chooses a channel with minimum load

Algorithm 1 Channel Assignment Algorithm (pseudo code)

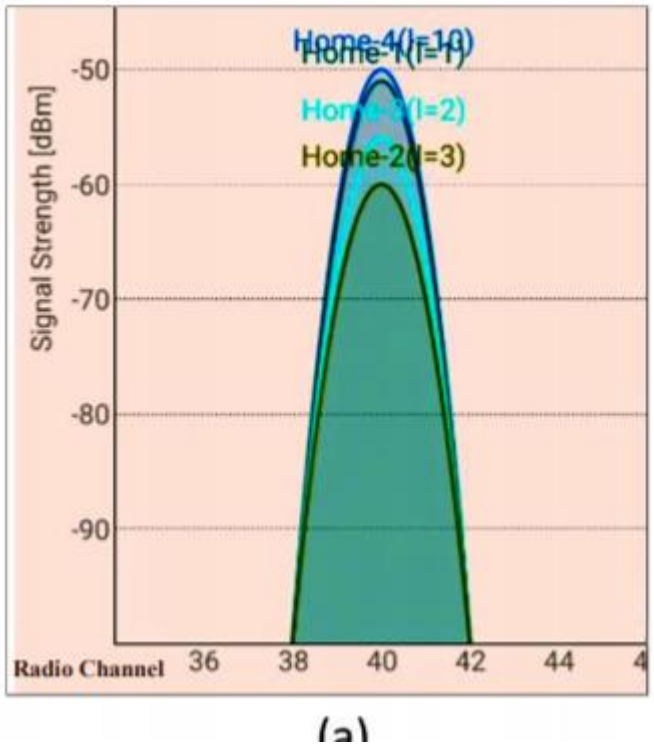
```
1:  procedure DIST_CHAN_RESFI
2:      lmax ← 0
3:      for all resfi_neighbors do ▷ Receive load information from two hop
        neighboring ResFi APs about their own load and about estimated load of
        all non ResFi APs operating on their radio channel
4:          lneigh_rf ← receive_rf_load()
5:          lneigh_nrf ← receive_nrf_load()
6:          data_fusion(lneigh_rf, lneigh_nrf)
7:      for all channels x from [1...N] do ▷ Calculate overall load for each
        available radio channel
8:          lsumcha[x] ← 0
9:          for all neighbors with channel x do
10:             lsumcha[x] ← lsumcha[x] + lneigh
11:         lsumcha[x] ← lsumcha[x] + lself
12:     bestcha ← 0
13:     leastload ← 1e9
14:     for all channels x from [1...N] do ▷ Choose radio channel with least
        load
15:         if lsumcha[x] < leastload then
16:             bestcha ← x
17:             leastload ← lsumcha[x]
18:     return bestcha
```

Demonstrator

- Four home APs running ResFi + Distributed Channel Assignment application
- APs are small form-factor linux-based PCs
  - Each given own load
- Android tablet running Wi-Fi spectrum analyser
- During demonstration:
  - Disable/enable application
  - Vary number of avilable channels
  - Vary load

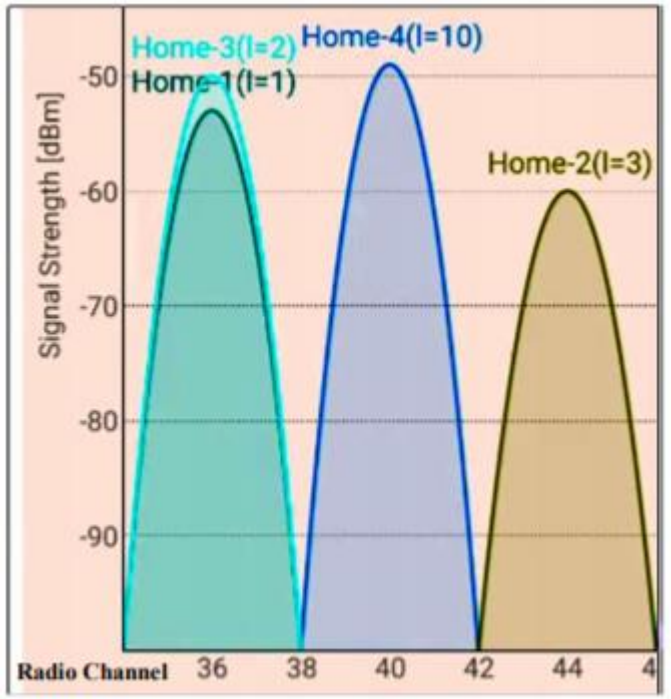
Disabled vs enabled

Application disabled



(a)

Application enabled



Thoughts on paper

+ Presents interesting solution
+ Commonly experienced problem
- Light on references
- ResFi confusion

Thanks for listening!