Overlapping BSS Analysis of Channel Requirements

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Abstract

Using empirical propagation formula, the number of overlapping networks is estimated for various residential scenarios.

The resulting OBSS situation is evaluated and the probabilities of finding clear or single channels is calculated for each OBSS scenario.

Propagation Formula

Indoor propagation loss formula (11n) *, F in MHz, d in feet

For d<16.5ft

Lp = – 38 + 20 log *F* + 20 log *d* + *Wall/Floor loss* *Free Space*

For d>16.5ft

Lp = – 38 + 20 log *F* + 20 log *16.5* + *35* log *(d/16.5)* + *Wall/Floor Loss*

Std. Dev 3-4dB

Wall Losses, 5GHz	Interior drywall	3dB
	Firewall	10dB
	Exterior wood and stucco	12dB
Floor Losses, 5GHz	Wooden Beam and flooring	5dB
	Firewall	10dB

*Erceg et al (2004) as per 11n, Channel Model B – Residential

NOTE: "Indoor Propagation Empirical Formula with Testing in a typical Californian Home", Graham Smith 2004

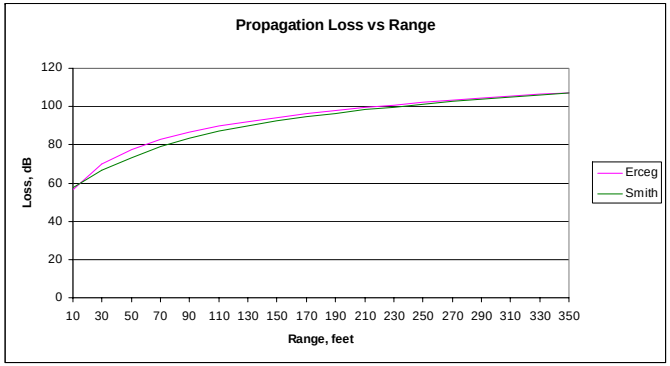
For d<35ft

Lp = – 38 + 20 log *F* + 20 log *d* + *Wall/Floor loss* *Free Space*

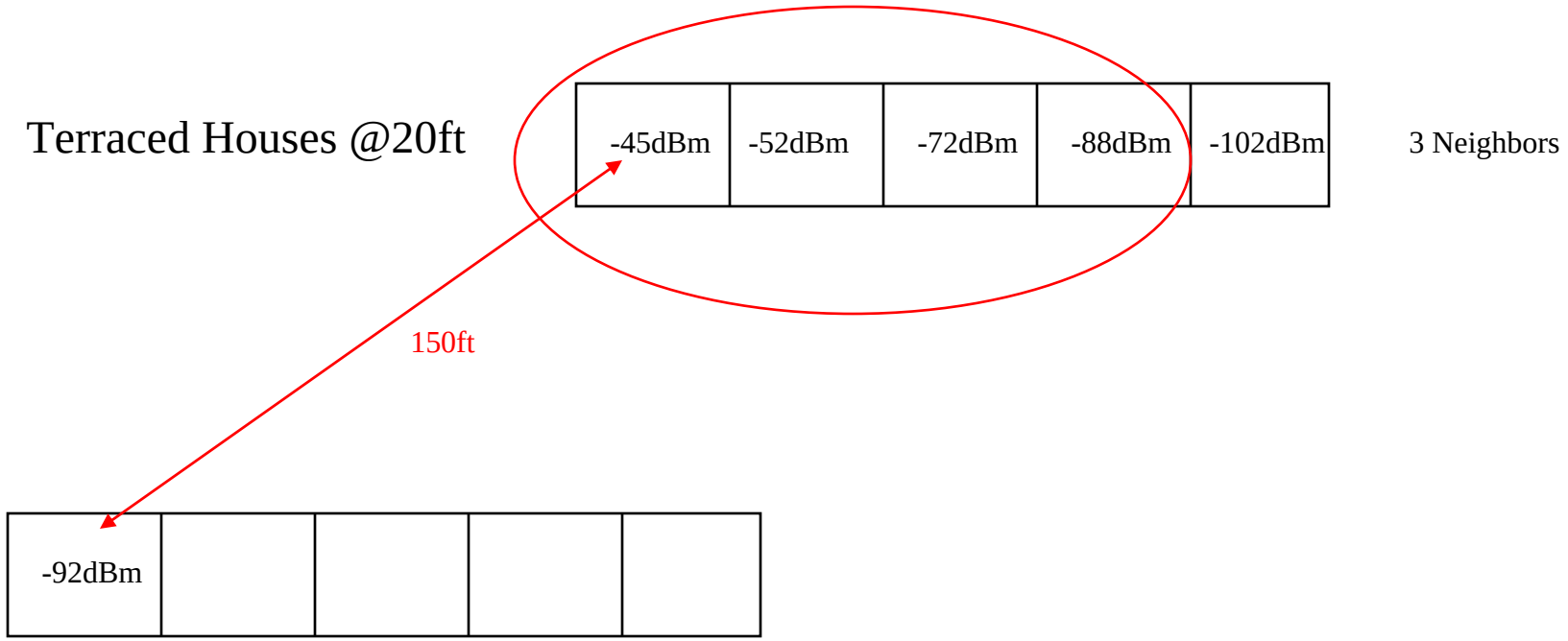
For d>35ft

Lp = – 69 + 20 log *F* + 40 log *d* + *Wall/Floor Loss*

Measured std dev of error = 4.5dB



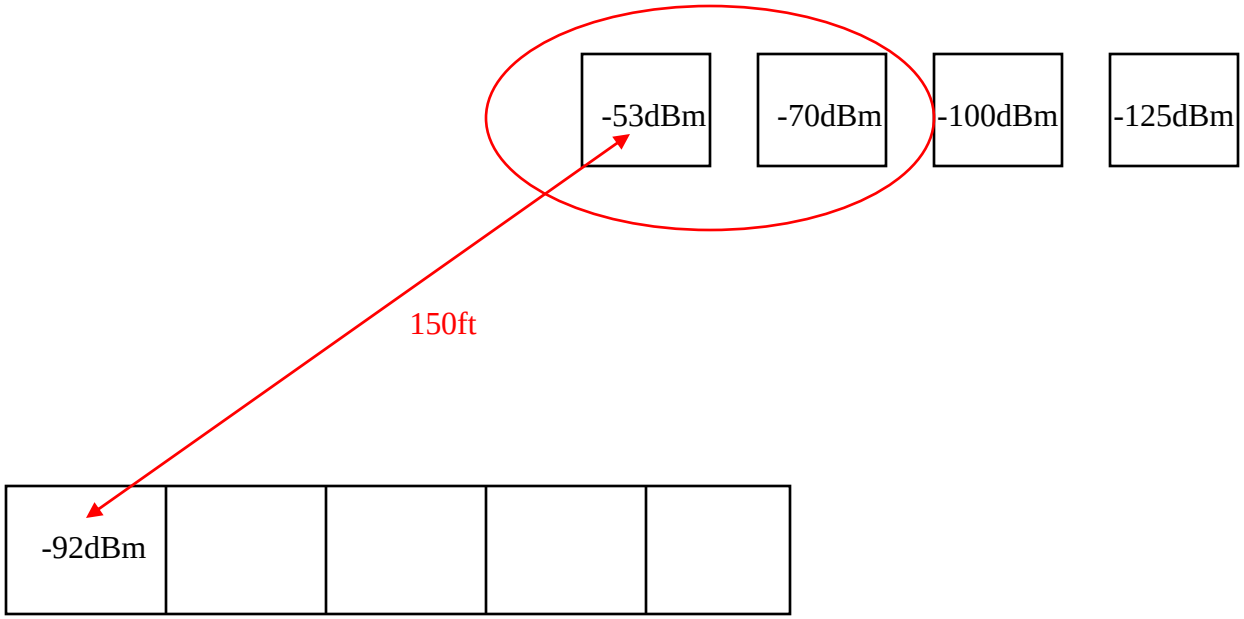
Terraced/Town Houses



Neighbors 3 houses down, and opposite houses within 150 feet have potential to overlap

Note: No internal wall losses, external wall loss only.

Detached Houses



Neighbors 1 house down, and opposite houses within 150 feet have potential to overlap

Detached Houses

12 Potential APs in range

Town Houses - Dense

Bleiswijk, The Netherlands

150 ft

25 Potential APs in range

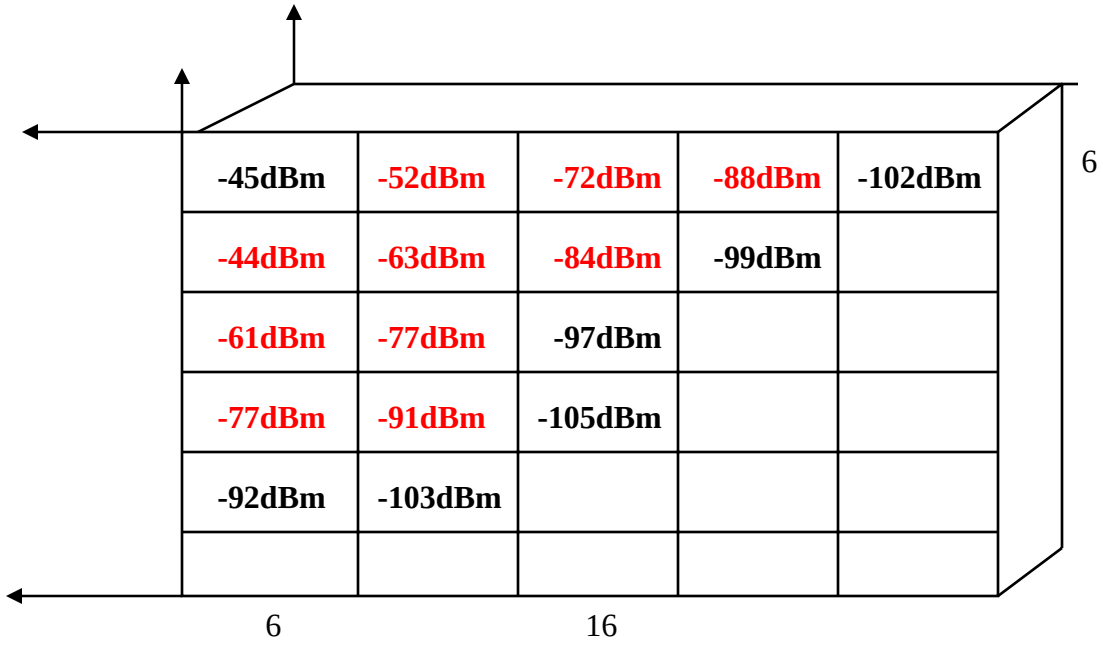
Terraced Houses

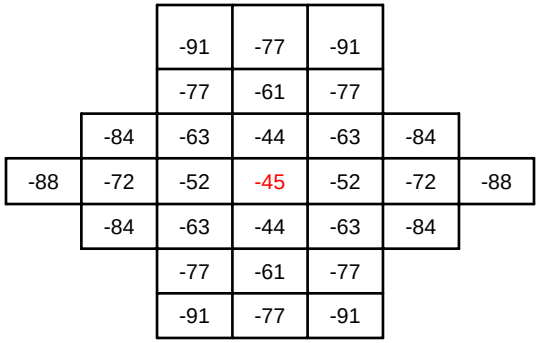
Leigh Park, Havant, England

150 ft.

16 Potential APs in range

Apartment Block Single Layout

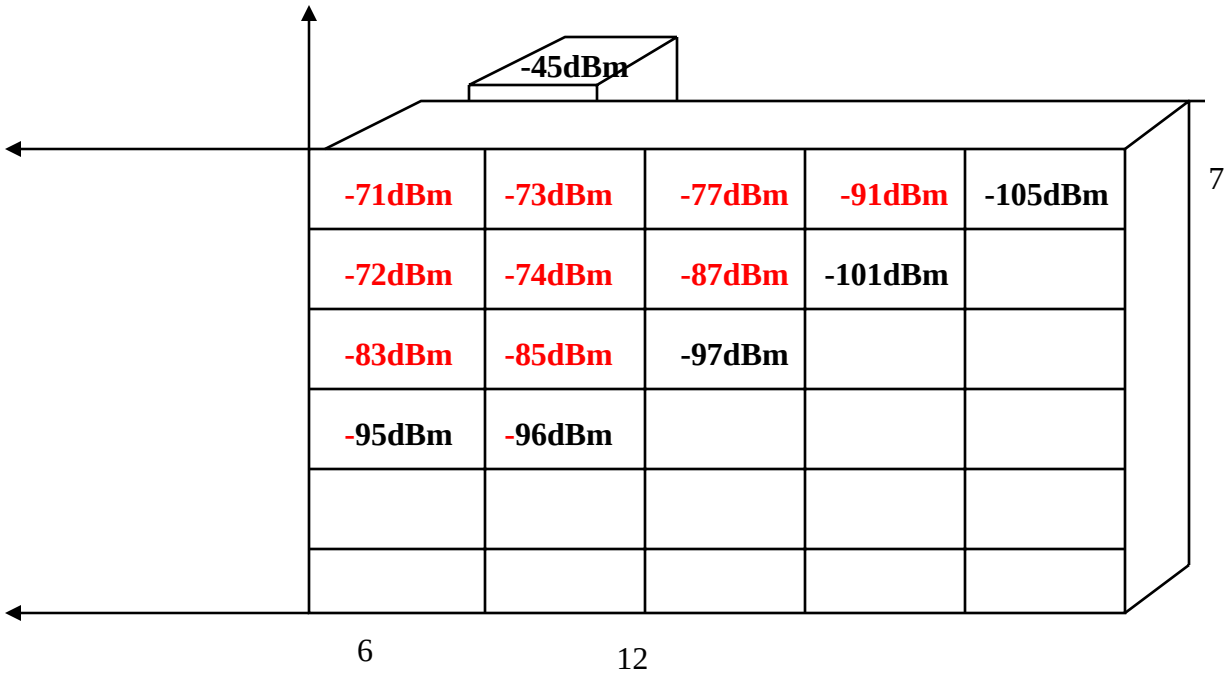




Total within range = 28

Each Apartment
20 x 35 feet
about 700 square feet

Apartment Block – Double Layout



Apartments across the corridor

Total within range = 28 + 25 = 53

Summary

- **Examples used show maximum potential number of APs within range**
  - Detached Houses 12
  - Terraced Houses 16
  - Townhouses 25
  - Single Layout Apartments 28
  - Double Layer Apartments 53

- **Number of Channels**
  - 2.4GHz 20MHz 3
  - 5GHz 20 MHz 24 USA, 19 Europe
    40MHz 11 USA, 9 Europe

Probability of Sharing

- **At first sight, one may assume that:**
  - 28 overlapping APs, 19 channels, must share with at least 1
- **In fact, this is not correct, there is channel re-use within the 28 overlapping APs**

- **Analysis - example**
  - Assume all 28 channels are selected at random
  - Calculate probability that the QAP can find
    - A clear channel
    - Either a clear or a single channel

Probability of Sharing – Free Channel

- **IF *N* Channels,**
  - probability of selecting one channel = *1/N*
  - Probability of not selecting one channel = *1 – 1/N*
  - In *n* selections, probability of not selecting one channel *p0 = (1-1/N)^n*
  - Probability that one particular channel is selected
    - *P1 = 1- p0 = 1-(1-1/N)^n*

As there are N channels, the probability that any one channel is selected is therefore

- ***(P1)^N = (1-(1-1/N)^n)^N***

Or probability that there is at least one channel not used is

- *1-(P1)^N = 1-**(1-(1-1/N)^n)^N***

Probability of Sharing Zero or One Channel

- **IF *N* Channels, *n* selections**
  - Probability of not selecting one channel
    - *p0 = (1-1/N)^n* *Binomial distribution*
  - Probability of selecting one particular channel just once
    - *p1 = n/N (1 – 1/N)^(n-1)* *Binomial distribution*
  - Probability of selecting one channel at least 2 times = *1 – p0 – p1*
  - Probability selecting any channel at least 2 times
    - *(1 – p0 – p1)^N*
  - Probability that any channel is selected never or only once, or **Probability that Shares with zero or one AP**
    - ***1 - (1 – p0 – p1)^N***
  - Probability that must share with 1 channel
    - *(1 - (1 – p0 – p1)^N) – (1-(P1)^N)*

Probability of Sharing

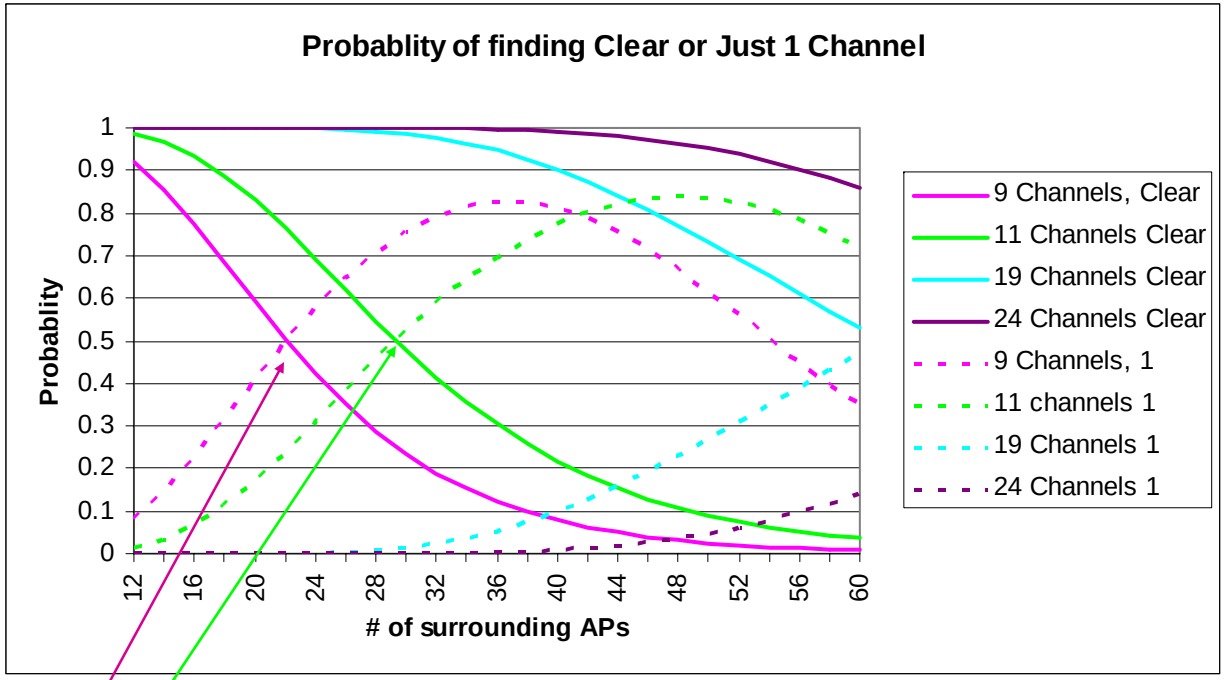
Based on a QAP AP surrounded by OBSS Channels that have been randomly selected, i.e. not selected by any Channel Selection process

The probabilities of the QAP finding a spare channel are:

Virtually 100%

Channels	Overlaps	Prob of free CH	Prob of 1 CH	
11	12	0.985304	0.999998	Detached Houses
9	12	0.918673	0.999783	
11	16	0.932774	0.999897	Attached Houses
9	16	0.773003	0.995807	
24	25	0.999961	1.000000	Town Houses
19	25	0.996622	1.000000	
11	25	0.655343	0.986316	
9	25	0.385248	0.889470	
24	28	0.999831	1.000000	Apartments Single layout
19	28	0.991103	1.000000	
11	28	0.546388	0.965416	
9	28	0.287475	0.805464	
24	53	0.929850	0.999963	Apartments double layout
19	53	0.671791	0.992046	
11	53	0.068191	0.364102	
9	53	0.017369	0.125825	

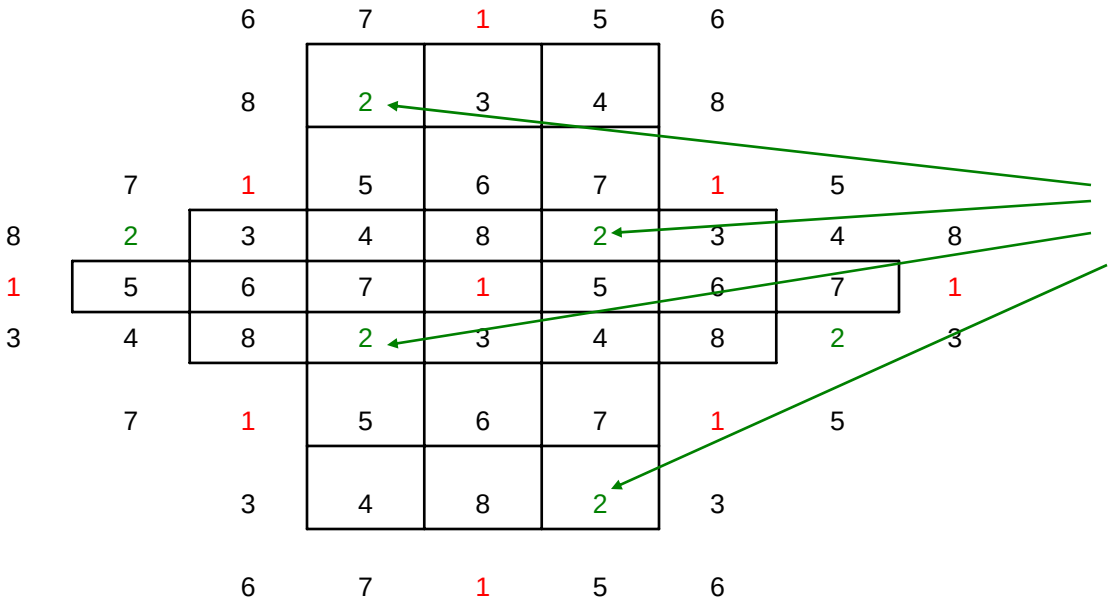
Probability of finding 1 or 0 Channels



For 9 Channels, with up to 22 surrounding APs, guaranteed to find either clear channel or to share with just 1
For 11 channels up to 29 APs
For 19 Channels >60 APs
For 24 Channels >60 APs

Minimum number of Channels Apartments single layout

In fact, if one applied standard channel re-use to the Apartment single layout, 28 overlapping APs, only 8 channels are actually required.



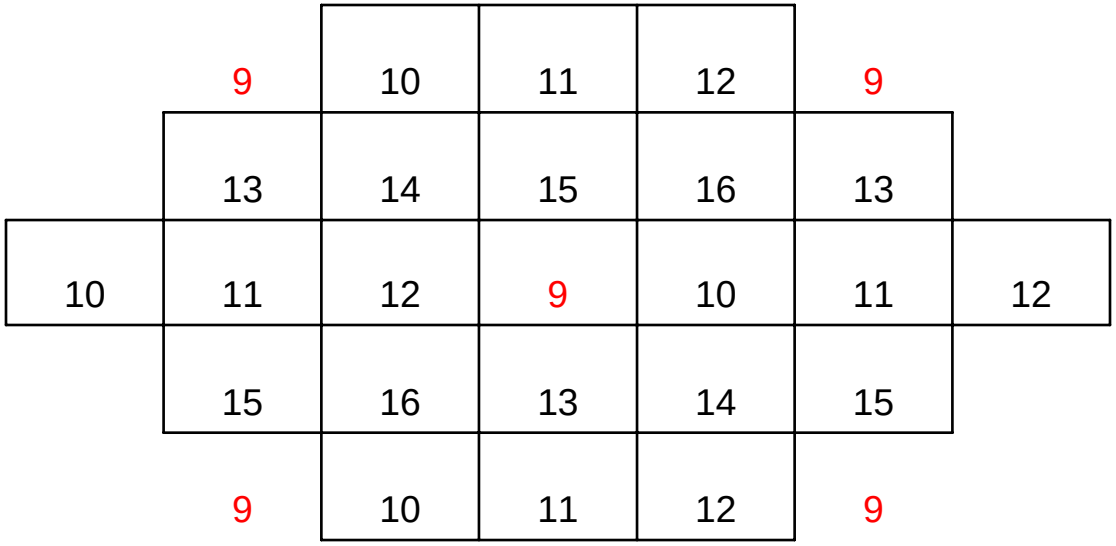
24 overlapping APs
But channel re-use is extensive

Example, Ch 2 can be used 4 times
Within the 28 OBSS

Minimum number of Channels Apartments double layout

16 Channels required in all
With 53 overlapping APs

8 Channels as per single layout plus another 8 for the opposite apartments



OBSS at 2.4GHz

A quick check to see if OBSS solution for QAPs at 2.4GHz is practical

Channels	Overlaps	Prob of free CH	Prob of 0 or 1 CH	Scenario
3	12	0.022944	0.153279	Detached Houses
3	16	0.004560	0.040545	Terraced Houses

Clearly NO

OBSS solution must include use of 5GHz band

20/40MHz Operation

20/40 BSS Operation*

Co-Existence with neighboring BSSs is managed through a number of mechanisms, including:

- Overlapping BSS scanning and careful channel selection on initial BSS setup to avoid channels already in use by other BSSs.
- Changing channels or operating width after BSS setup if a new BSS is detected operating on the secondary channel

Also

- 40MHz Intolerance bit can be set by any STA, (7.3.2.61)
- 20/40 Intolerant Channel Report Element (7.3.2.59)
- Overlapping BSS Scan Parameters element (7.3.2.60)

In high OBSS conditions, networks will fall back to 20MHz operation, (and if not, we could/should make them)

We could ignore the 11/12 channel conditions (only significant for double apartments with 53 overlapping APs)

* Reference: "Next Generation Wireless LANS: Throughput, Robustness and Reliability in 802.11n", Eldad Perahia and Robert Stacey, Cambridge University Press 2008.

Channel Selection

- **Proposed Channel Selection as follows, "OSQAP" (ref 08/0457r04, and 08/1260r01):**
  - Is there a QAP on the channel?
    - If no QAP, set CHP = 1
    - If just one QAP with CHP = 1 and QLoad is acceptable, then SELECT
    - If two QAPs with CHP=1, DO NOT SELECT
    - QAP with CHP = 0, then DO NOT SELECT

Analysis with All APs using Channel Selection

- Previous analysis is where all APs have selected channels at random. The new QAP then scans to find the clear channel.
- What happens if ALL APs scan to find a clear channel?
- A program was written to analyze this

AP Channel Selection Analysis Program

- **Set up an Apartment block:**
  - Number of Apartments per floor
  - Number of floors
- **Select number of Channels**
- **Randomly select an Apartment**
- **Scan the surrounding apartments in range**
  - Select a channel, in turn, starting at channel 1
    - Count how many surrounding apartments are using that channel
  - If not in use in surrounding apartments, assign that channel to that apartment
  - If no spare channel, select channel with the least usage
- **Do this many times to ensure that all apartments get assigned**
- **Repeat the whole procedure many times to investigate the variations and distributions**

AP Channel Selection Analysis Program

- **Condition**
  - Modeled on Single layout Apartment block
  - Modeled on the 28 overlapping apartments pattern as per Slide 6
- **INPUTS**
  - Number of Apartments per Floor
  - Number of Floors
  - Number of Channels
  - Number of random selections of apartments
    Note: selections >> number of apartments to ensure all apartments are assigned
  - Number of Trials
- **OUTPUTS (per Trial)**
  - Maximum Number of Channels assigned
  - Number of apartments that are sharing with at least one other
  - Number of sharing apartments for each case of sharing
    - i.e. 1, 2 or more
  - Array of apartments and assigned channels

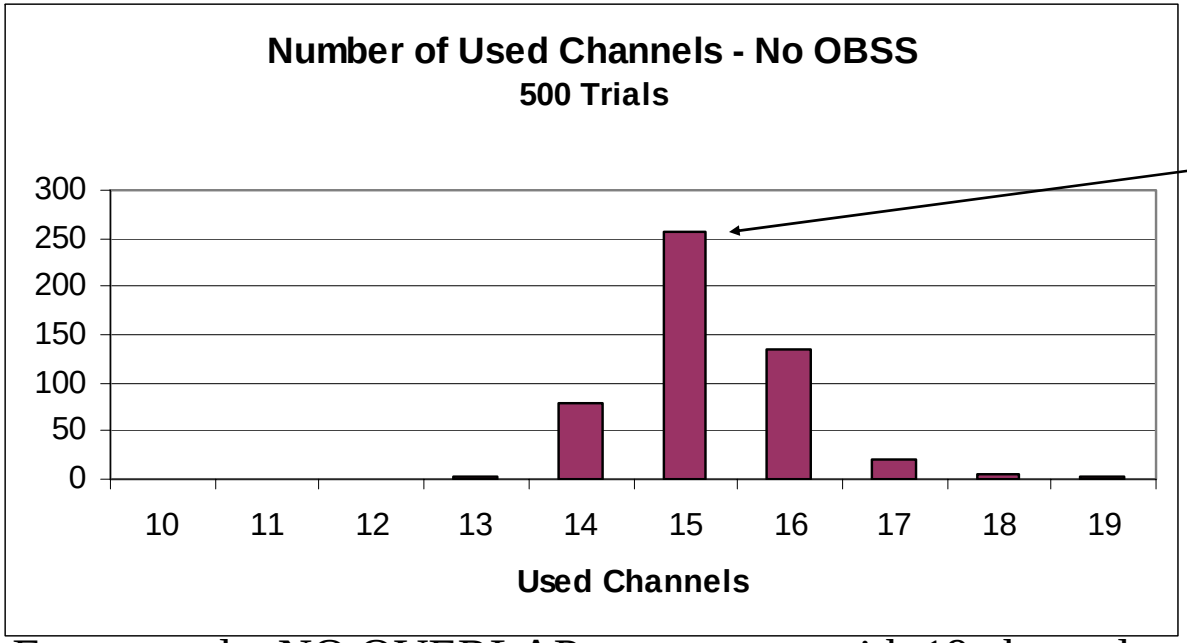
AP Channel Selection Analysis Program

- **Infinite number of possible inputs, for example:**
  - Can set number of random selections of apartments so as to **partially populate apartment block with APs**
  - Can vary the apartment block size
  - Can vary the number of channels so as to see effect of reduced available channels, i.e. radar protection
  - Can carry out many trials to see the distribution
- **Relatively easy to change the scanning area to different models, e.g.**
  - Double apartment block (might do this later)
  - Townhouses
- **Just a couple of meaningful results given in this presentation**
- **Program not perfect in that as a new APs is introduced, if it shares, then the existing AP should be able to search again (this would happen in practice)**

Results of Channel Selection Analysis - 1

Results are shown for the case of an Apartment Block of 10 Floors of 10 Apartments per floor. Each apartment has **28** other apartments within range (see slide 9)

Program run 500 times with 24 Channels,
Graph shows how many Channels were actually used, with NO overlap



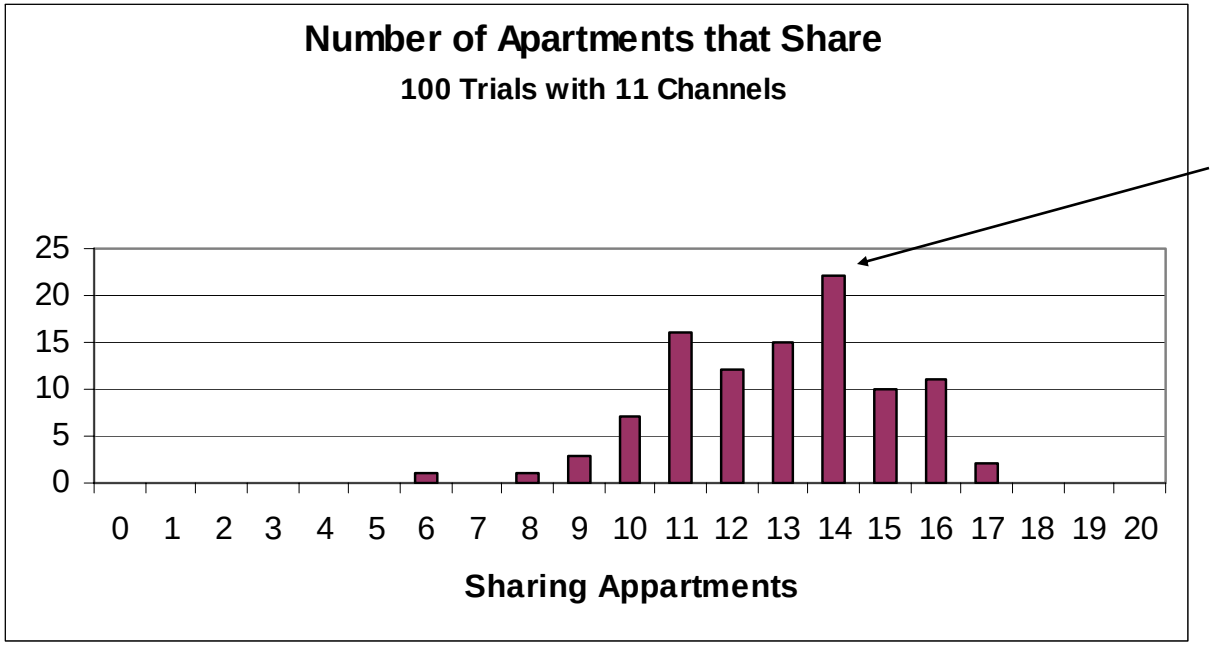
Over 500 trials,
256 cases
where only 15 channels
were assigned

For example, NO OVERLAP ever occurs with 19 channels,
95% probability NO OVERLAP with16 Channels

Results of Channel Selection Analysis - 2

Results are shown for the case of an Apartment Block of 10 Floors of 10 Apartments per floor. Each apartment has **28** other apartments within range (see slide 9)

Program run 100 times with 11 Channels,
Graph shows how many Channels were actually shared



Over 100 trials,
There were 22 cases
where 14 APs had to share

Over the 100 trials, there were: 810 instances of APs sharing with JUST ONE OTHER AP
12 instances of APs sharing with TWO OTHER APs

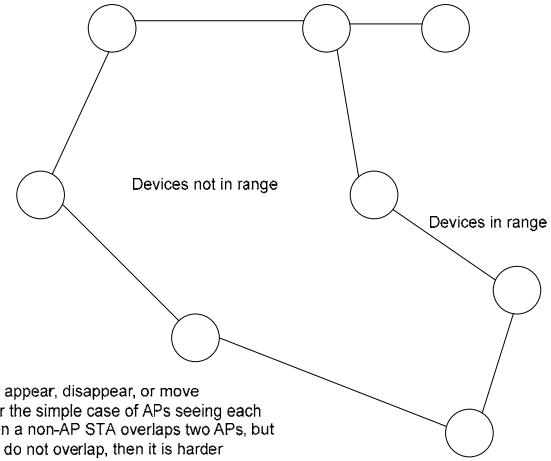
Resulting Apartment/channel Array Example - 11 Channels

2	10	4	1	8	2	4	9	8	1
1	9	7	5	6	3	10	7	2	4
5	11	2	2	4	9	11	6	2	3
8	6	3	10	7	1	8	5	10	7
7	4	1	3	8	2	4	3	1	6
2	4	1	6	11	5	3	9	11	1
5	9	8	2	4	7	6	2	2	8
10	2	7	4	9	1	8	10	5	3
6	3	5	7	10	2	4	7	6	3
4	1	11	6	3	5	9	11	1	4

15 cases of sharing with 1 other
16 APs in total

AP Chains

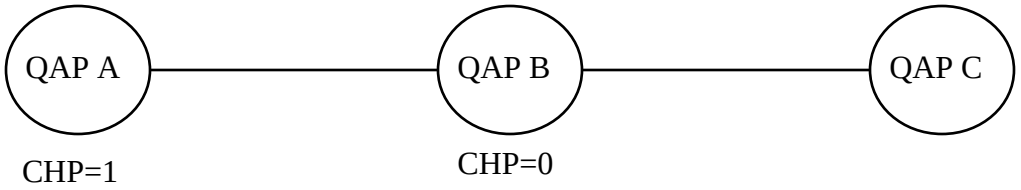
This scenario of AP Chains appears in the OBSS Requirements document 08/0944r4



Analysis shows that in most, if not all practical cases, QAP assured that **either free channel or share with 1.**

Hence, if QAP is sharing with one, that other AP, if a QAP, i.e. channel selection, is **also only sharing with one. NO CHAIN.**

ALSO, proposed channel selection in "OSQAP" guards against AP chains.



QAP C cannot share With QAP B

Summary

- **A QAP carrying out Channels Selection is virtually guaranteed to find a clear channel, or share with just one other AP**
- **40MHz channels should fall back to 20MHz in congested scenario**
  - Only apartment double layout scenario presents a ‘problem’ with 11 channels. 19/24 channels >99% probability of zero or 1 channel
- **AP Chains for QAPs will not happen**
  - Very unlikely in practice
  - OSQAP use of CHP prevents it

Conclusions

- **Tempting to declare that OBSS in practice is not a problem for 5GHz if Channels Selection is used**
- **Calculations on housing and apartment layouts show that any AP carrying out channels selection will find a clear channel, or if not, will only share with one other**
- **If all APs carried out channel selection, similar results**
- **AP chains will not be experienced in practice. Also "OSQAP" use of CHP avoids possibility of AP Chains**
- **"OSQAP" does represent a practical solution to OBSS in the 5GHz band**