UnChannelize the Channels in WLANs

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**Unbalanced Traffic Distribution**

- AP usage in WLANs tends to be unbalanced
- User population served by APs fluctuates considerably

**Limitations of Fixed Channels**

- Limit Network Capacity
  - # of neighboring APs is small
- Cause Interferences
  - # of neighboring APs is large
- Deteriorate Per-client Fairness
Dynamic Channelization Structure

• The key idea
  – Dynamically create suitable # of channels
    • Accommodate # of neighboring APs
  – Adaptively adjust channel bandwidth
    • Consider user/traffic distribution
Case Study

- Total **80 MHz Spectrum**
  - Fixed Channels: 4, 20 MHz
  - Dynamic Channels: 10, 20, 40 MHz

<table>
<thead>
<tr>
<th></th>
<th>Total used spectrum</th>
<th>Per-client Fairness (Jain’s fairness index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>80MHz</td>
<td>0.58</td>
</tr>
<tr>
<td>Dynamic</td>
<td>80MHz</td>
<td><strong>0.97</strong></td>
</tr>
</tbody>
</table>

**Dynamic channels improve per-client fairness!**
Case Study • Total 80 MHz Spectrum
– Fixed Channels: 4, 20 MHz
– Dynamic Channels: 10, 20, 40 MHz

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<th>Total used spectrum</th>
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<tbody>
<tr>
<td>Fixed</td>
<td>60MHz</td>
<td>0.82</td>
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<td>80MHz</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Dynamic channels improve network capacity!
Dynamic Channel Allocation Algorithms

Assumptions:

- Assume central controller
  - Aruba, Cisco, Symbol
- AP reports traffic/user to the central controller
  - 802.11k/802.11i
- The central controller controls freq-bandwidth setting of any AP in WLAN
- Hardware support

Problem:

- Maximize throughput with per-client fairness constraints by allocating non-overlapping channels of variable bandwidth to neighboring APs in WLAN
- NP-hard problem!

Solution:

- Integer Linear Program (ILP)
- Linear Program
- Heuristic algorithm: GreedyRaising

“Load-aware channel-width assignment in WLANs”, Microsoft Research, Technique report, MSR-TR-2007-79
Simulation Study in Small Scale Offices

- WLAN deployment in a Microsoft building
- 5 days trace of client location and activities
Throughput & Fairness in Small Scale Office

Qualnet Settings:

- 80MHz spectrum
- 1 MHz to 1.2 Mbps
- 5, 10, 20, 40 MHz
- Reconfigure overhead: 50us

Dynamic channelization significantly improves throughput and fairness!
Simulation Study in Large Scale Offices

Qualnet Settings:
- IBM trace data 50 APs
- 1000m x 1000m flat
- 80MHz spectrum
- Reconfigure overhead: 50us
- 1 MHz -> 1.2 Mbps

Dynamic channels significantly improve system throughput and reduce interferences!

![Graph showing throughput and collisions per client vs. average number of interfering APs]
Conclusions

• Dynamic channelization significantly improves system throughput and fairness

• Ongoing work
  – Extensive studies driven by real-world traces
  – Experimental testbed
  – Distributed version of the GreedyRaising channel allocation algorithm
Shall we UnChannelize the Channels?

QUESTION?
Per-client Fairness Definition

• Measured by Jain’s fairness index

\[ \frac{(\sum C_i)^2}{N \cdot \sum C_i^2} \]

• For client \( i \) associated with AP (Alice), \( C_i \) is defined as: Bandwidth\(_{Alice} \)/ n\(_{Alice}\)

**Intuition**: ensure every client receives similar fraction of available spectrum
Fluctuations in User Distribution

- User population varies with time
- User distribution varies with AP location
Limitations of Fixed Channels with Unbalanced Traffic Distribution

- AP usages in WLANs are extremely unbalanced
  - Some become hotspot
  - Some remain unused
- User populations served by APs fluctuate considerably

1. Limit Network Capacity

Fixed channel structure wastes the spectrum!
Limitations of Fixed Channels with Unbalanced Traffic Distribution

1. **Limit Network Capacity**
   
   # of neighboring APs is small

2. **Cause Interferences**
   
   # of neighboring APs is large

Fixed channels cannot handle dynamics in # of neighboring APs!
Limitations of Fixed Channels with Unbalanced Traffic Distribution

1. **Limit Network Capacity**
   
   # of neighboring APs is small

2. **Cause Interferences**
   
   # of neighboring APs is large

3. **Deteriorate Per-client Fairness**

   Client receives different service depending on its location!
Dynamic Channel Allocation Algorithm

Assumptions:

• Centralized WLAN
• AP reports traffic/user to central controller
• Hardware support
  – Frequency, bandwidth, power

Greedy Algorithm:

• Packing route
  – Generate (fi, bi) if allocation is feasible
1. Start with a feasible allocation
  – Di/\sum(Dj) * Total_Spectrum
2. Follow a sequence of APs, try to raise bandwidth
3. Iterate 2, still program terminates
Actions

• Work with Vendors, and encourage them to improve the PLL accuracy, and allows software to control the bandwidth.
• Adjust bandwidth facilitate the handoff process, the same transmission power, the longer handoff range
• Why researchers propose overlapped channels? Because there is no enough channel. What if we have enough? What if we can balance the load using bandwidth?
• Associate to the best AP? No need association control
• Hidden terminal problems, totally out of picture in wireless LANs
• Start the measurements