Managing Chaotic Wireless Networks

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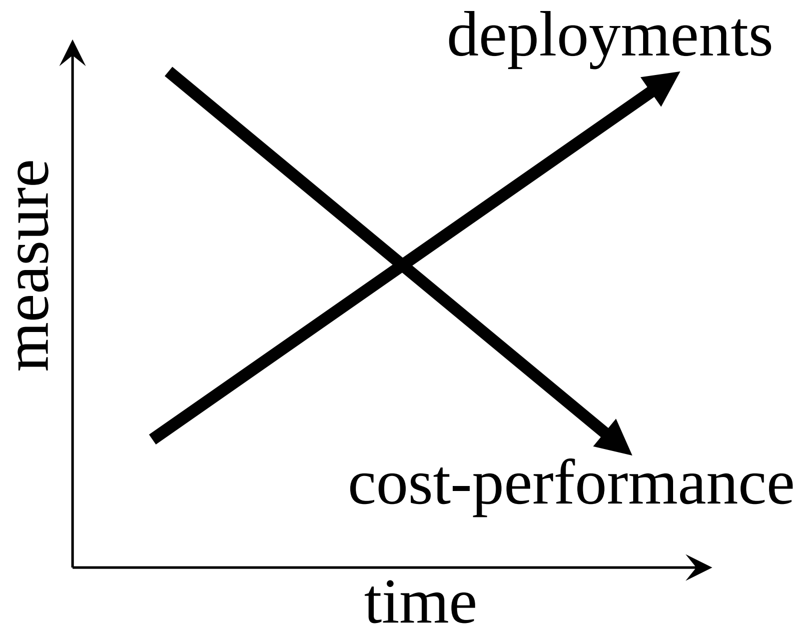
Credits

- UW/CSE wireless group
  - John Zahorjan, Maya Rodrig, Charlie Reis, Ratul Mahajan, Ed Lazowska
- Intel Research Seattle
  - Yatin Chawathe, Mike Chen, Brian Noble, Anthony Nicholson
- CMU
  - Srini Seshan et. al. for “Chaotic” wireless

Context: WiFi boom



- Advantages: minimal infrastructure, mobility
- Technologies: 802.11 a/b/g/n, and more
- Deployments: hotspots, home networks

Chaotic Wireless Networks

Two consequences of growth:

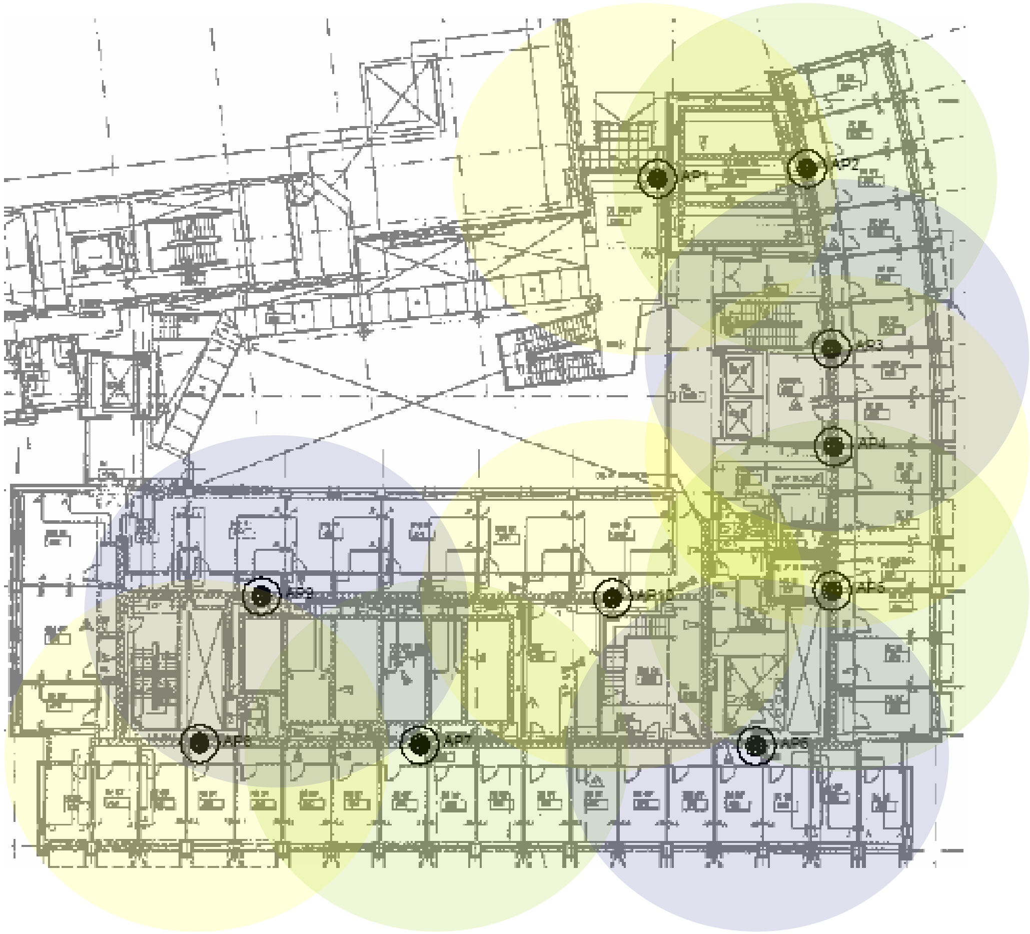
1. Overlapping (dense) deployments
   - Compete for spectrum
   - Seen in urban areas today
2. That are independently managed
   - Limited visibility into the operation of others
   - Focus on their own goals; no central planning

Chaotic = overlapping + independent

Claim for chaotic environments:

- Today's 802.11 designs won't fare well
- There's an opportunity to do much better

A single 802.11 network architecture



CSE Allen Center, 3rd floor

10 802.11b/g APs per floor, managed as a whole:

- Channels 1, 6, 11
- 20/30 mW power
- Omni-directional antennas

Site surveys, sparse deployments, and decoupling are the basis for good coverage and performance.

Adverse interactions across networks

- 802.11 won’t degrade gracefully in chaotic environments
  - Ideally CSMA/CA would provide reasonable sharing …

- Default channel assignments
  - Crowding, non-orthogonal effects
- Static power management
  - Wastefully high, leads to interference
- Rate diversity
  - High rate transmissions beat out by low rates
- Hidden terminals and capture
  - Poor access from some locations
- Other unlicensed band transmissions
  - Don’t argue with a phone/microwave …

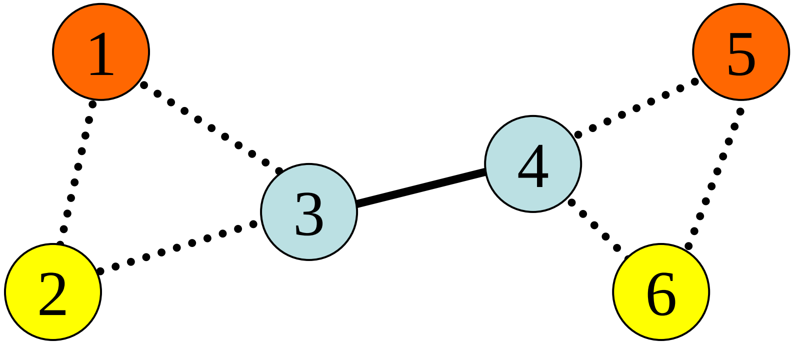
- Problems increase with density, load and heterogeneity

A Band-aid: Dynamic tuning

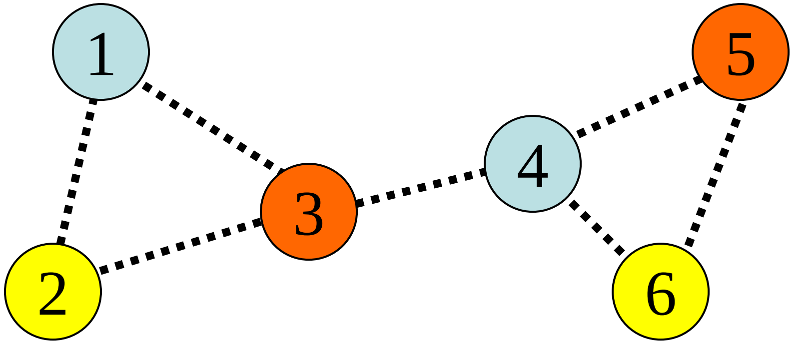
- One possible fix: dynamic parameter tuning
  - Each network measures environment and chooses the channel/power/routes that works best for it
- Claim: dynamic tuning isn't enough
  - Adaptation is necessary but not sufficient
  - There are opportunities to do much better

Pitfalls (1) – you can get stuck

- Top: AP conflict on channel 1 (middle two blue nodes) can't be resolved by individual tuning

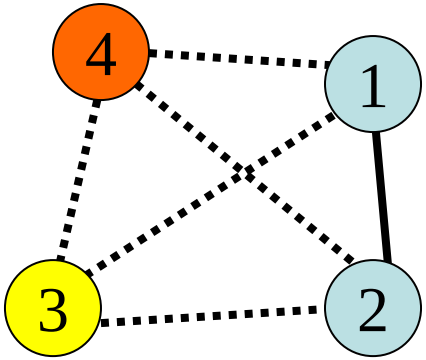


- Bottom: but a solution needs only a simple switch between two adjacent nodes



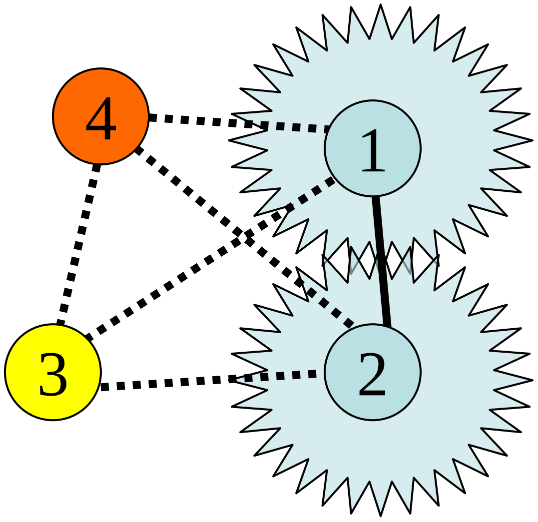
Pitfalls (2) – lack of stability

- To avoid getting stuck, need to perturb the system, changing channels even without immediate gain
- Q: What happens to in the configuration below?
- A: Four APs dance around three channels
- Tradeoff between stability and convergence



Pitfalls (3) – power escalation

- Suppose APs adjust their transmit power (between min and max) based on delivery to their clients
- What will the APs on channel 1 do?
  - Higher power increases delivery/rate and interference
  - Potential tragedy of the commons (lose/lose)



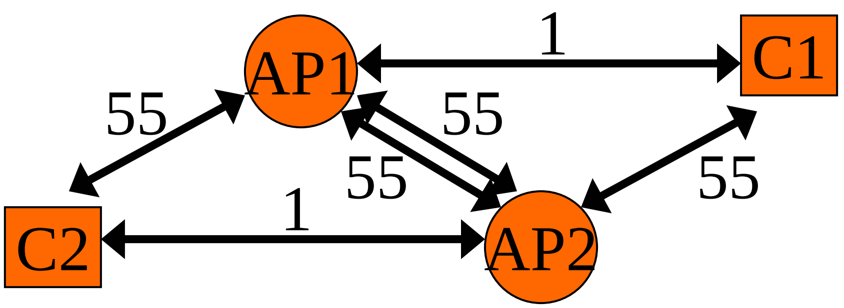
Opportunities for Coordination

- Suppose we go beyond dynamic tuning …
  - Coordination = actively exchange information and make joint decisions (for selfish gain), rather than merely try to avoid each other

- Claim: coordination beats tuning
  - Improves outcome for pitfalls
  - Enables new beneficial scenarios

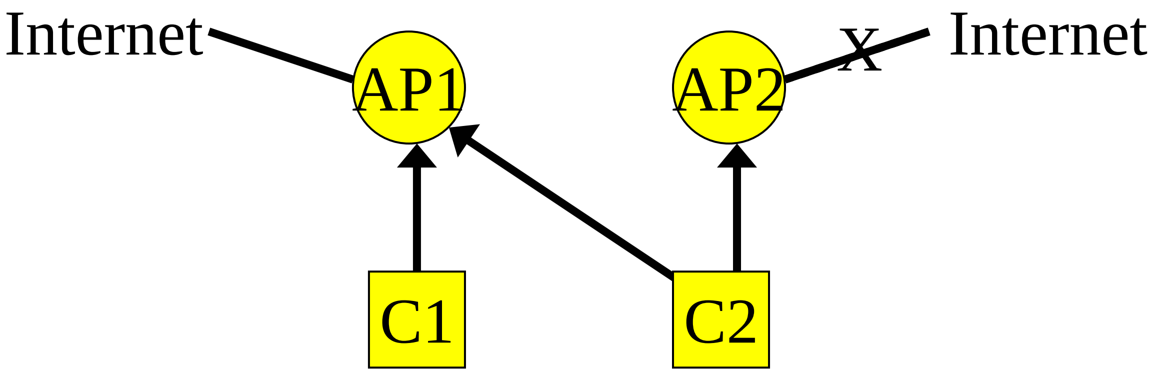
Relaying for coverage/performance

- Relaying can leave both networks better off
  - Use of better links allows higher rates,
  - i.e., one transmission per packet at 1 Mbps vs. two transmissions per packet, each at 55Mbps



Backup for reliability/performance

- Use neighbor AP for backup Internet access
  - Or always use neighbor's surplus for performance
  - Need to consider AUP issues



Goal: Wireless internetworking

- Wireless Internet = architecture that coordinates multiple individual wireless networks for better coverage, performance and reliability
  - Predictably allocate wireless and access bandwidths
  - Leave individual networks better off than before

- Architectural roles:
  - Effectively allocate underlying resource
  - Allow new applications to flourish
  - IP does both; 802.11 does neither …

Research agenda

- How does wireless work in practice?
  - Predict what will happen for a given choice of channel/power/routes and protocols
- What information is exchanged where?
  - Need to find small regions with tight coupling
- How do we make this win-win?
  - Choices that benefit all players
- How do we foster a grassroots effort?
  - Deployment incentives

Questions?

Aside: WiFi vs Cellular data

- WiFi
  - Local = high bandwidth, inexpensive
  - Many islands of coverage
- Cellular data
  - Wide-area = low bandwidth, expensive
  - Build-out for good coverage “away from home”

- So concentrate on WiFi here
  - Potential for combining the best of both worlds