

15-496 : A Hand-on Introduction to Wireless Networks

Lecture 13: Self-managing Wireless LANs

Peter Steenkiste
 Departments of Computer Science and
 Electrical and Computer Engineering
 Spring Semester 2008
<http://www.cs.cmu.edu/~prs/wireless08/>

Peter A. Steenkiste, CMCL, CMU

1

Outline

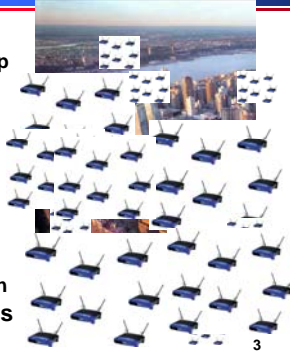
- Chaotic wireless networks
- Channel selection
- Rate selection
- Transmit power selection

Peter A. Steenkiste, CMCL, CMU

2

Chaotic Wireless Networks

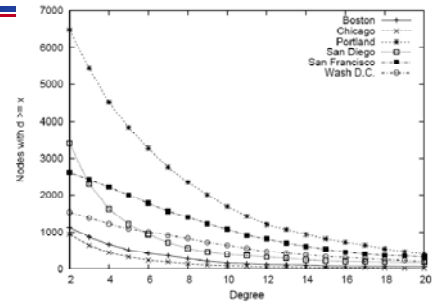
- **Unplanned:**
 - » Independent users set up APs
 - » Spontaneous
 - » Variable densities
 - » Other wireless devices
 - **Unmanaged:**
 - » Configuring is a pain
 - » ESSID, channel, placement, power
 - » Use default configuration
- **“Chaotic”** Deployments



Peter A. Steenkiste, CMCL, CMU

3

Example Degree Distribution



Degree of node = number of access points within range
 Place Lab data set - www.placelab.org/

Peter A. Steenkiste, CMCL, CMU

4

Project Roadmap

- Pervasive wireless through self-optimization
- What can we do with today's commercial hardware?
 - » Automatically tune 802.11 parameters to optimize network performance
 - » E.g.: channel, transmit power, transmit rate
- Leverage emerging wireless technologies
 - » Tomorrow's commercial hardware
 - » Software defined radios, smart antennas
- Optimize use of the scarce wireless spectrum
 - » Dynamic spectrum sharing

Peter A. Steenkiste, CMCL, CMU

5

Channel Selection

- Carefully place access points
 - » Avoid shadows
- Assign channels to minimize interference
 - » E.g. using graph coloring
 - » Also consider load balancing across Aps
- Continuously monitor performance and adjust placement and channel assignments
 - » Also user complaints



Peter A. Steenkiste, CMCL, CMU

Does this Approach Work for Chaotic Deployments?

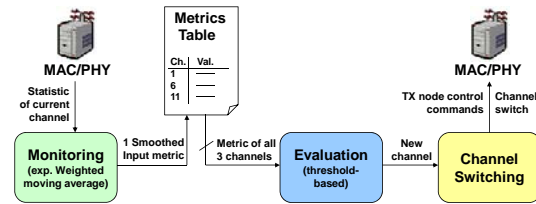
- **No!**
- **Placement is uncoordinated and tends to be based on convenience**
 - › Put AP close to DSL or cable modem
- **No centralized control to assign channels to APs in different homes**
 - › Each user is independent
 - › Competition rather than coordination
 - › Many APs also use the default settings
- **Traffic in residential areas is very bursty**
 - › Most of the time, nobody is home

Peter A. Stenikite, CMCL, CMU

7

Algorithm - Node Functionality

Operating channel is switched as soon as threshold is crossed by channel metric

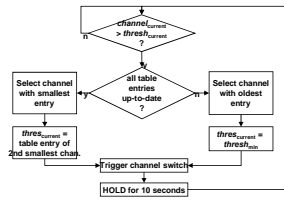


Peter A. Stenikite, CMCL, CMU

8

"Chaotic" Channel Selection

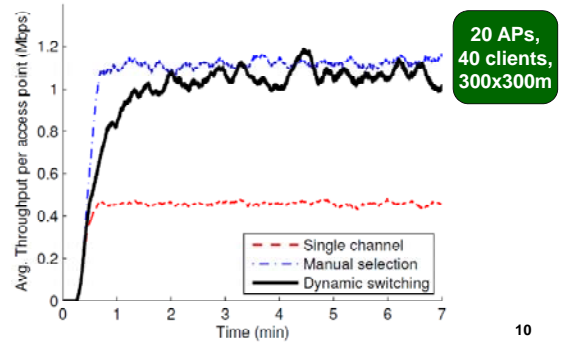
- Each base station selects channel independently
- If load high, pick new channel based on history information
- If history information is stale, pick a new channel randomly
- Stations work completely independently
- There is some advantage if APs exchange hints about their channel switching plans
 - › Especially if the channel switching cost is high



Peter A. Stenikite, CMCL, CMU

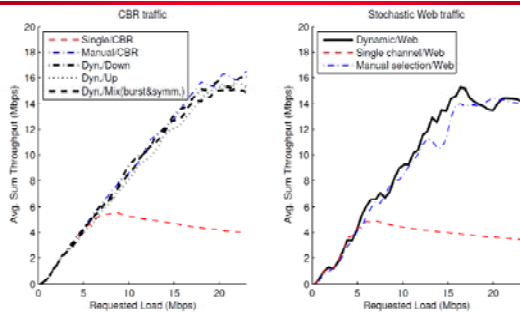
9

Evaluation - Low density Scenario



10

Evaluation - Constant and Web traffic profile

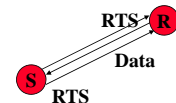
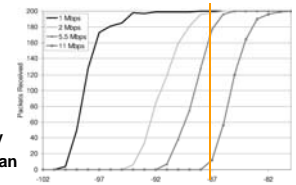


Peter A. Stenikite, CMCL, CMU

11

Transmit Rate Selection

- Want to pick rate that provides best throughput
 - › Needs to be adaptive
- Most techniques rely on trial and error
 - › Packet success rate history
 - › Can be slow to adapt and can fail (e.g. hidden terminal)
- Other techniques leverage probing and/or channel reciprocity
 - › E.g. use RTS/CTS to learn channel quality
 - › Introduces overhead



Peter A. Stenikite, CMCL, CMU

12

Automatic Rate Selection

- Best transmit rate depends on the SINR
 - › Signal to noise and interference ratio
- Can be estimated on 802.11 cards based on RSSI
 - › Can measure received signal strength using RSSI
 - › Can exchange information about transmit power, noise, etc.

Peter A. Stenikite, CMCL, CMU

Charm: Channel-Aware Rate Selection

- Leverage channel reciprocity: overhear packets sent by destination to learn about channel conditions
 - › Build history of path loss for channel
- When transmitting packet, use path loss history to "predict" path loss
- Many practical challenges
 - › RSSI versus RSS
 - › Noise in RSSI measurements
 - › Calibration of measurements

Peter A. Stenikite, CMCL, CMU

Charm Performance

- Charm performs better in both static and dynamic scenarios

Peter A. Stenikite, CMCL, CMU

Hidden Terminal?

- AMRR and ONOE sensitive to hidden terminals

Peter A. Stenikite, CMCL, CMU

Transmit Power Selection

- Interference is a big problem in wireless networks
 - › Can prevent transmitters from sending (carrier sense)
 - › Can prevent receivers from decoding message (collision)
- How can we reduce the interference a wireless node creates for other nodes?
- Transmit power control!
- But how?

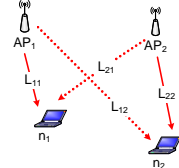
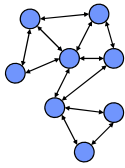
Peter A. Stenikite, CMCL, CMU

Minimizing the Effect of Interference

- Simple idea: reduce transmit power to minimum needed to reach destination
 - › Based on SINR
- Does not work: interference is not constant but affected by transmit power control of other nodes
 - › Also: reducing transmit power makes receiver more susceptible to interference
- Simple experiment: if all nodes cut transmit power in half, SINR stays the same
 - › Assuming noise is not a concern (very common)

Peter A. Stenikite, CMCL, CMU

Automatic Power Control: Concepts



- Any transmission creates interference on all links
 - › Must consider pair-wise interference between all links
- Captured in conflict graph:
 - › Nodes are wireless links – edge if simultaneous transmission not possible
- Concurrent transmission is possible if

$$SINR_1 + SINR_2 \geq 2 * SINR_{threshold}$$

Peter A. Stoenkita, CMCL, CMU

19

Power Control Algorithm

- Create conflict graph and iteratively remove edges by adjusting transmit power for pairs of nodes
 - › Transmit power is per destination!
 - › Simple, greedy approach
 - › Converges when no more edges can be removed
- Must also adjust “Clear Channel Assessment” threshold
 - › Done in a separate phase using variant of existing algorithm
 - › Otherwise we run the risk of getting significant problems with hidden or exposed node terminals
- Centralized algorithm is pretty simple

Peter A. Stoenkita, CMCL, CMU

20

20

Distributed Power Control

- Nodes exchange information about transmit power they use and RSS observed from neighboring nodes.
 - › Stored in header of packets
- Each node builds local conflict graph and adjusts its transmit power to destinations to minimize edges
 - › Also executed CCA threshold
- This is a continuous process
 - › Can adapt to dynamic environments on relatively slow time scales (seconds)
 - › Adjustment of transmit power and CCA threshold ends up being interleaved

Peter A. Stoenkita, CMCL, CMU

21

21

Many Practical Challenges

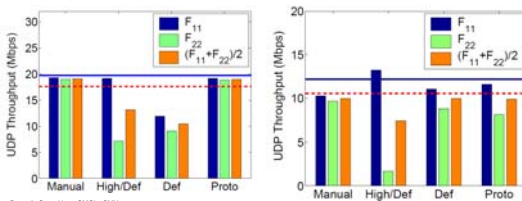
- Calibration of transmit power, CCA, RSSI readings
 - › Cards from multiple vendors may use different scales
 - › There can be offsets between multiple cards from the same vendor
 - › It is possible to have drift over time
- Noise on RSSI readings
 - › Need to filter out noise and (legitimate) rapid variations in transmit power
- Sensitivity of various controls
 - › An 8 bit register does not mean that you have 256 meaningful values
- Optimization based on neighbor’s neighbors

Peter A. Stoenkita, CMCL, CMU

22

UDP Throughput

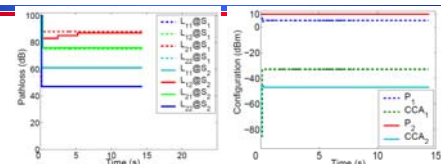
- 36Mbps: F_{11} interferes with F_{22} using default txpower
 - Concurrent transmission possible by reducing F_{11} 's txpower
 - Not fair even with default low CCA
- 48Mbps: no concurrent transmission
 - fairness of the protocol is slightly worse because of relatively high CCA
 - fairness can be achieved by reducing F_{11} 's txpower



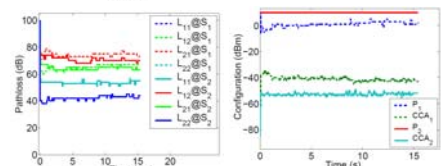
Peter A. Stoenkita, CMCL, CMU

Protocol Stability

Our approach



Moving average



Peter A. Stoenkita, CMCL, CMU

24

TCP & Mobility

- Both directions are important in TCP performance
 - » otherwise ACKs are not protected
- When a client moves away from AP, recovery is slow
 - » periodically set CCA thresholds to low level

Data Rate	Pwr Ctl	LT1(%)	LT2(%)
36	BI	94.6	90.7
	Uni	96.3	8.6
48	BI	91.7	87.7
	Uni	90.6	85.6

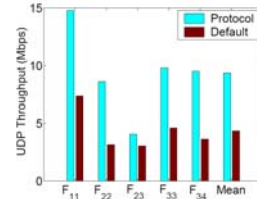
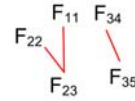
Movement	Without Low CCA (seconds)	With Low CCA (seconds)
R_1 away from S_1	15.5	1.2
R_1 to S_1	0.8	0.7

Peter A. Stenikate, CMCL, CMU

25

Experiment with 8 nodes

- F_{11} interferes with F_{23} , but not with F_{22}
- pair-wise assumption inaccurate on F_{34}
- default behavior is better than expected



Peter A. Stenikate, CMCL, CMU

26