Coordinated configuration of wireless networks: A win-win approach based on bargaining

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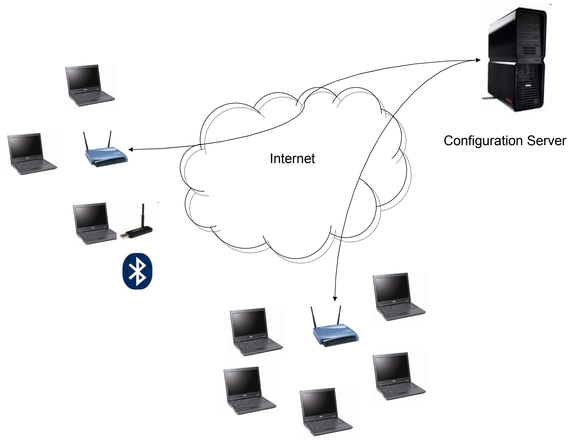
Problem

- Plummeting costs of wireless devices resulted in dense deployments
  - -Apartment buildings, Enterprise deployments
- Heterogeneous devices using the same unlicensed spectrum
  - -802.11abg
  - -Bluetooth
  - -ZigBee
- Possible uncoordinated configurations
  - -Default – Poor performance
  - -Myopic – High Interference
- Need for alternative, informed, socially responsible configuration



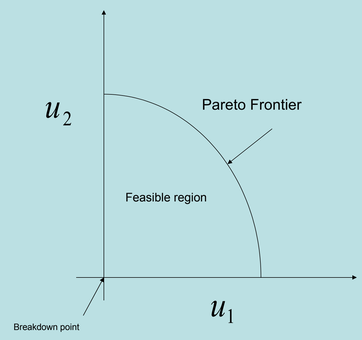
Proposed solution

- Cooperative Approach
  - -Devices contact a central **Configuration Server**
  - -Devices choose a performance function
    - •Performance function should be flexible (802.11 devices expect high bandwidth and use high transmit power, and Bluetooth devices require low bandwidth and have lower power limitation)
  - -**Configuration Server** computes optimal configuration and commands the devices
  - -Devices set tx-power, Frequency

Formulation

- Pareto Optimality
  - -Definition: At the Pareto optimal configuration, any unilateral change to the configuration of a WLAN will hurt the performance of one or more other WLANS
  - -Breakdown point: If a optimal configuration cannot be found, the WLANs revert back to the default configurations
- Fairness properties

  (Not easily captured for wlans – depends on neighborhood of each node)
  - -Symmetry – Equal gains to all participating entities
  - -Universal Improvement – No participating entity should observe a decrease in performance



$$\text{maximize} \quad \prod_{i=1}^{n} u_i$$
$$\text{subject to} \quad u_i \geq u_i^*$$

Where,

u_i is performance function of i^{th} player

u_i^* is the value of the performance function at the breakdown point

The optimization problem for WLANs can be written as

$$\text{maximize } U = \prod_{i=1}^{n} T_i$$
$$\text{subject to } T_i \geq T_{\min}$$
$$0 \leq P_i \leq P_{\max}$$
$$0 \leq C_i \leq C_{\max}$$

Where,

T_i is the throughput between i^{th} AP-client pair

P_i is the Transmit power of the i^{th} AP-client pair

C_i is the CCA threshold of the i^{th} AP-client pair

and throughput depends on

$$SINR_i = \frac{G_{ii} P_i}{\sigma^2 + \sum_{j \neq i} G_{ij} P_j}$$

Where,

$i, j = 1, \ldots, n$

G_{ij} is the path loss between i^{th} AP and jth client

σ is the thermal noise

C_i is the CCA threshold of the i^{th} AP-client pair

The neighborhood set N_i

Starvation conditions due to CSMA

Simulation Results

- Win-win situation: Significant improvement in aggregate throughput without any AP sacrificing its performance
  - -Pareto optimal solution favors low powers and high carrier sense threshold
- Aggregate throughput improvement is lesser in dense topologies and levels off when nodes are far apart
- Performance at Pareto optimal solution is a function of utility function. Poor choice of utility function will result in poor throughputs. Utility functions can be designed to meet the requirements of the individual.

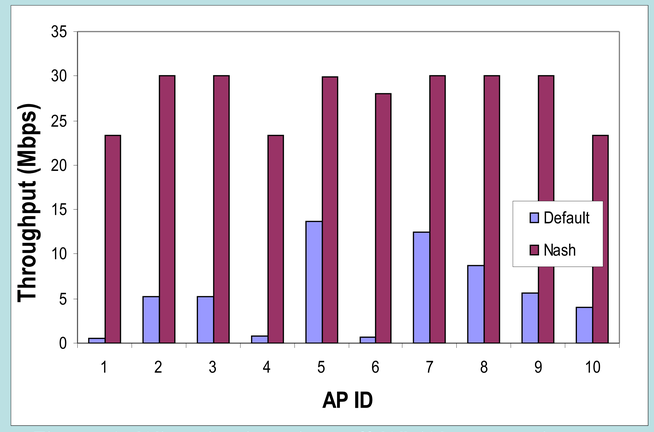


Figure 1: Win-win situation: all WLANs see an increase in throughput

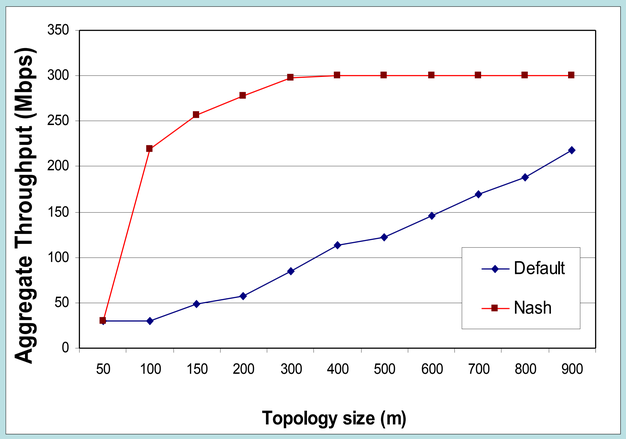


Figure 2: Aggregate throughput depends on density of deployment

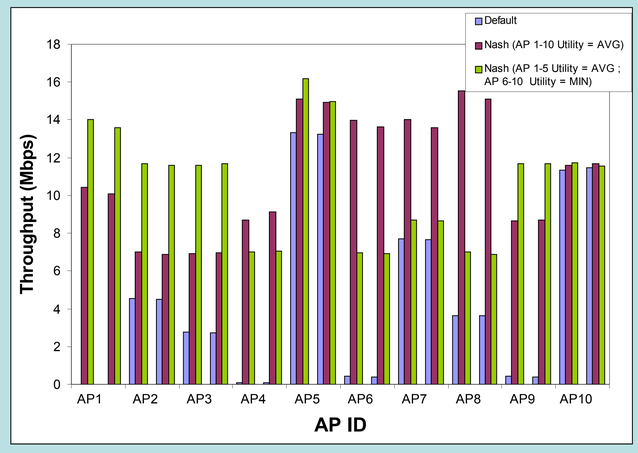


Figure 3:Throughput at Pareto Optimal configuration depends on choice of utility function