

LA-UR- 09-07791

Approved for public release;
distribution is unlimited.

Title: Bandwidth Provisioning in Infrastructure-based Wireless Networks Employing Directional Antennas

Author(s): Shiva Kasiviswanthan: CCS-3, Z# 209013
Bo Zhao: Pennsylvania State University
Sudarshan Vasudevan: University of Massachusetts
Amherst
Bhuvan Urgaonkar: Pennsylvania State University

Intended for: 11th International Conference on Distributed Computing and Networking



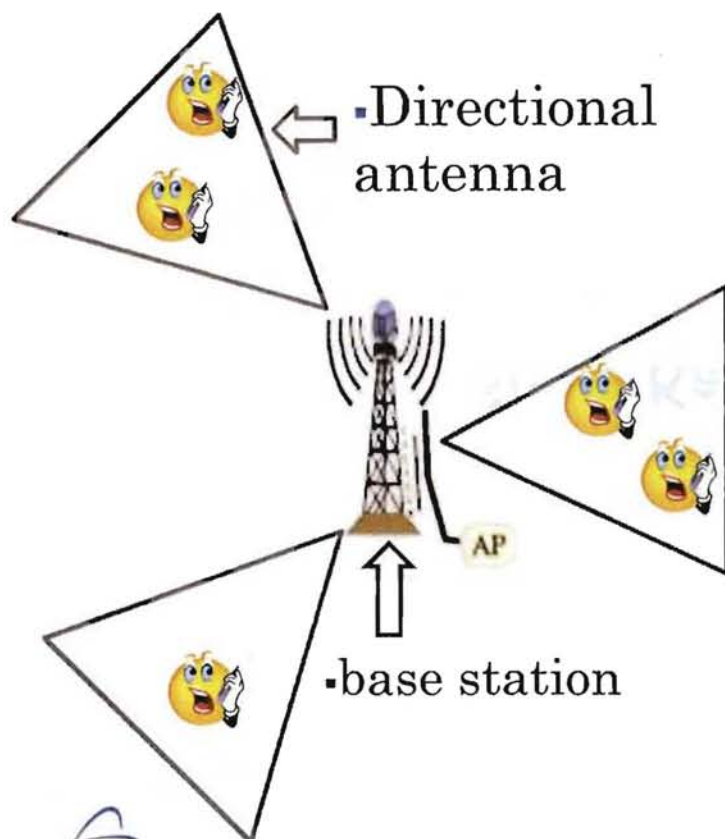
Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

Bandwidth Provisioning in Infrastructure-based Wireless Networks Employing Directional Antennas

Shiva Kasiviswanathan, CCS-3
Los Alamos National Laboratory

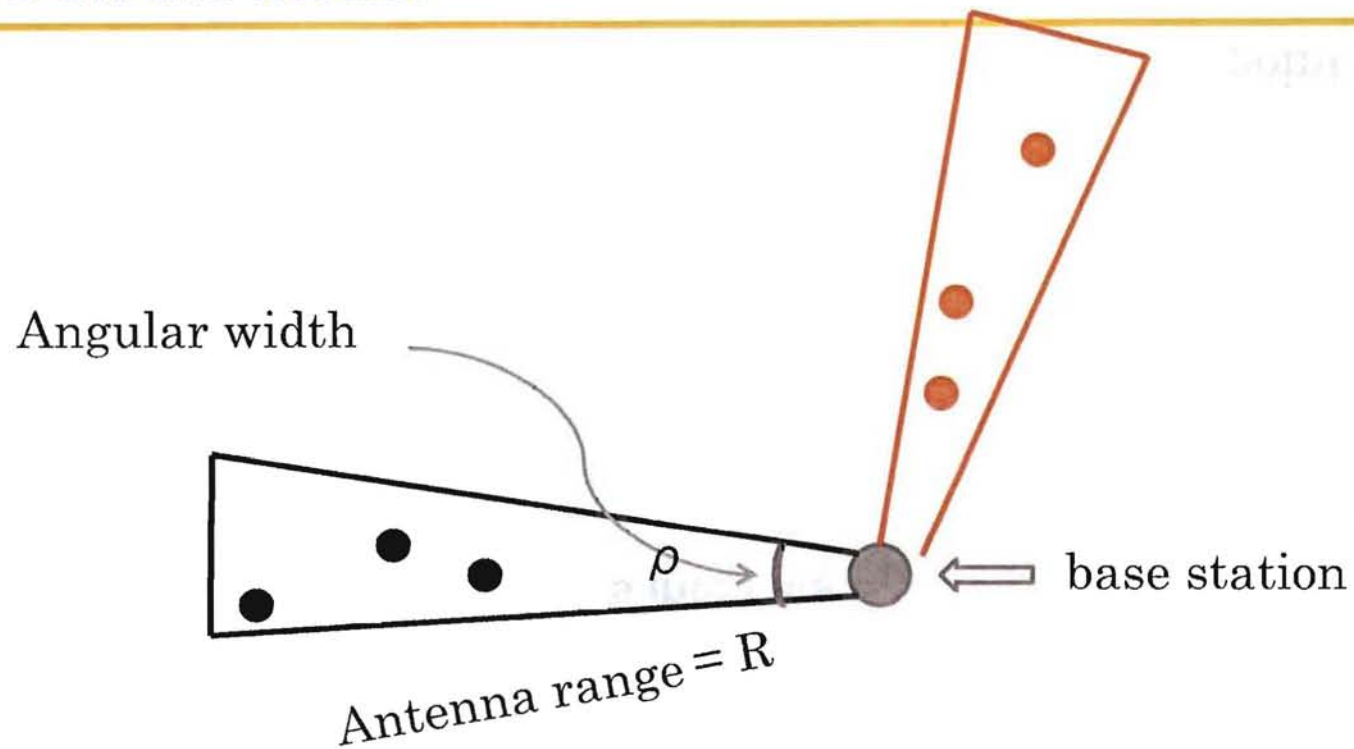
Joint work with
Bo Zhao, Penn State University
Sudarshan Vasudevan, Univ of Massachusetts
Bhuvan Urgaonkar, Penn State University

Directional Antenna



- **Transmits a narrow beam**
- **Leads to:**
 - Lower interference
 - Higher throughput
 - Energy efficiency
- **Customers (cellular, 802.11)**
- **Positions known and fixed**
- **Bandwidth demand**

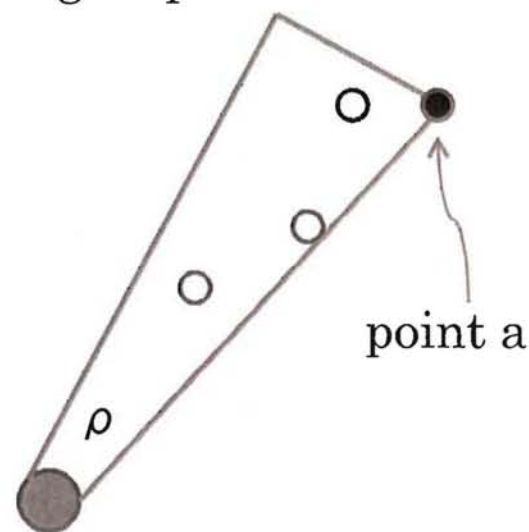
More on the Model



ANTENNA COVERING PROBLEM

- **Input:** set of customer position and demand, and no of antennas k
Each antennas has a capacity (we assume it to be same for all antennas)
- **Output:** partition of customers into sets $S_1, \dots, S_K$
 - $\forall i, S_i \subseteq R(a)$, for some point a (feasibility of a set)

$R(a)$ = set of customers in a sector starting at point “a” with angle ρ



Subscriber-Centric Model

Aim: To divide the bandwidth “fairly” among subscribers

Settings: Universities, offices, etc

Notion of Fairness: Max-Min Fairness

Max-min Fairness is defined via a type of equilibrium

Defn: Given two vectors, $X = (x_1, \dots, x_k)$ and $Y = (y_1, \dots, y_k)$, each in non-decreasing order, we say that X lexicographically dominates Y if $X = Y$, or there exists some index p such that $x_p > y_p$ and $x_q = y_q$ for all $q < p$.

Problem: Obtain a max-min fair allocation of the bandwidth

Provider-Centric Model

Aim: To maximize the profit of the provider

Settings: Commercial where subscribers are willing to pay for their bandwidth

Each subscriber has a demand

Let d_i be the demand of the i^{th} subscriber

Also, each subscriber pays $C \times d_i$ if his demand is satisfied, and 0 otherwise

We need to respect the capacity constraint of each antenna

Problem: Maximize the revenue of the provider

Our Results

- **Subscriber-centric Model:**

- Dynamic Programming based algorithm
- Simplest implementation $O(n^4k)$ time, where $n=\#$ subscribers and $k=\#$ antennas

- **Provider-centric Model:**

- NP-hard (simple reduction from bin-packing)
- 2-approx algorithm based on greedy packing

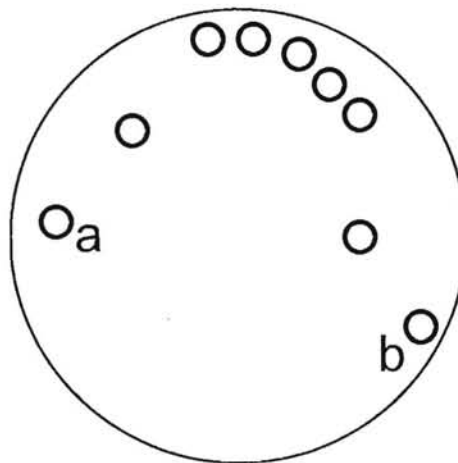
Subscriber-Centric Model



- Antenna 1
- Antenna 2

Dynamic Programming

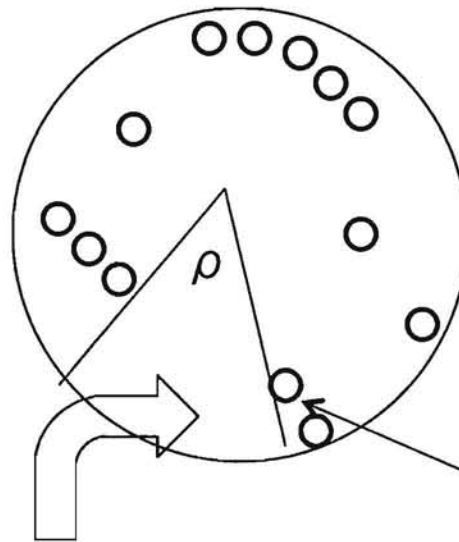
- For each pair of subscribers (a,b) look at allocating t ($1 \leq t \leq k$) antennas to all subscribers between a and b (say in the clock-wise direction)



- Pick the fairest vector with k antennas given by the dynamic programming

Provider-Centric Model

- NP-hard, so we use a greedy heuristic
- Find a sector (angular width ρ) with least demand concentration



Assume subscriber i has demand d_i

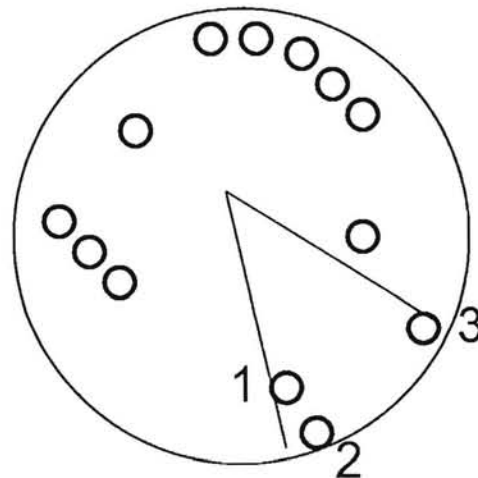
denote this as subscriber 1

sector with least demand concentration

Greedy Algorithm

Order the customers start from customer 1 in a cyclic manner

Start greedy packing from customer 1



Close an antenna if

- 1) Sum of demands already assigned to antenna exceeds antennas capacity
- 2) Antenna reaches its angular width of ρ

Bin-packing style analysis gives an approximation factor of 2

Practical Considerations

Channel assignment problem: 802.11 has 11 overlapping channels, but only 3 non-interfering channels

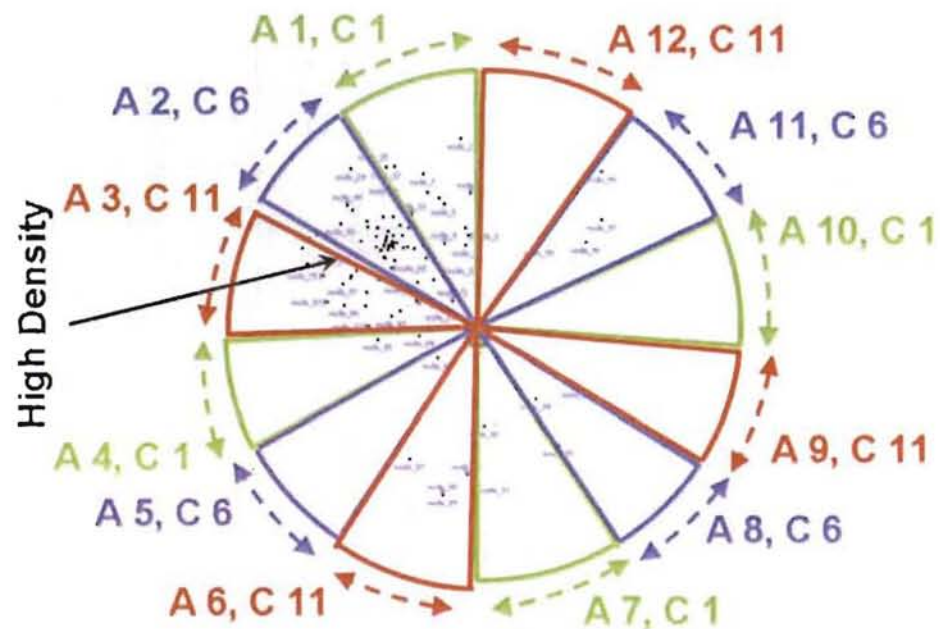
Solution: We use the above algorithms to assign antennas, and then use a round-robin scheme to assign channels to antennas

Multiple access point problem: Above algorithms assume single access point, what happens if there are more.

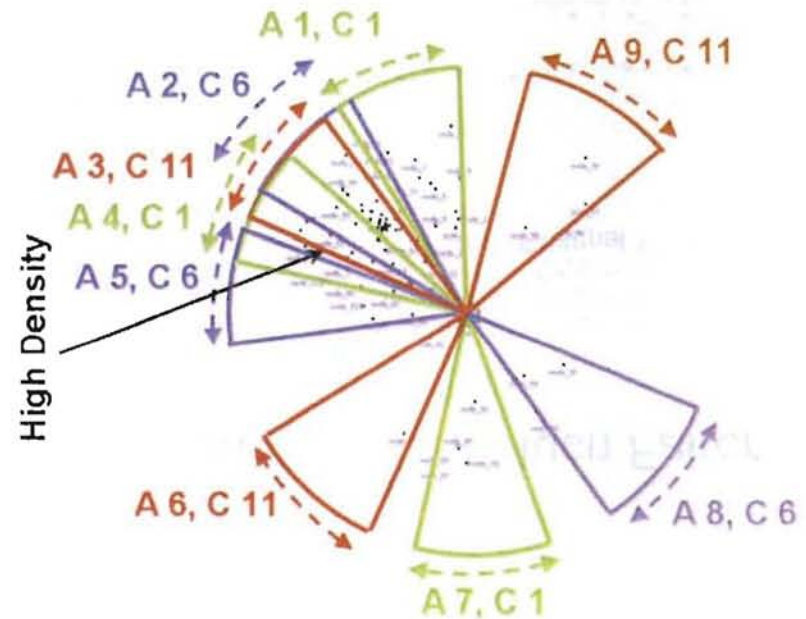
Solution: We develop heuristics which are generalizations of the above algorithms to handle the case of multiple access points

Experimental Evaluation

Subscriber-Centric Model (using OPNET simulator)



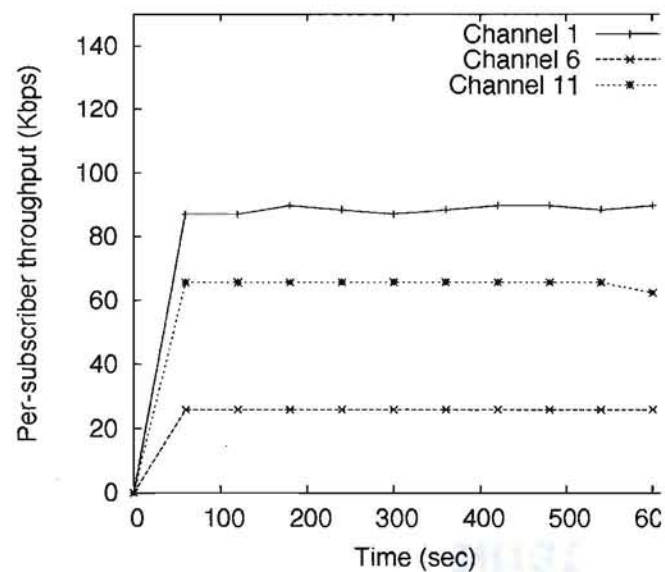
Baseline, non-uniform distribution



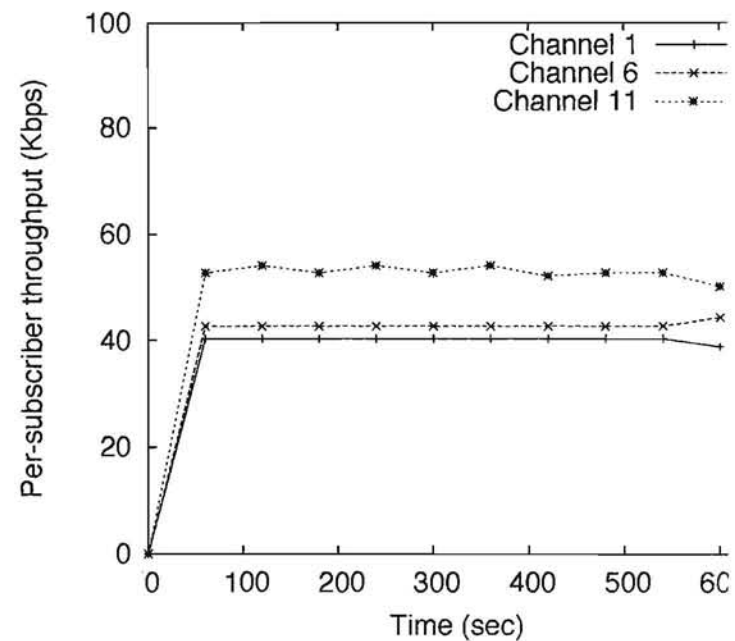
Our allocation, non-uniform distribution

Fairness Comparison

Baseline Case

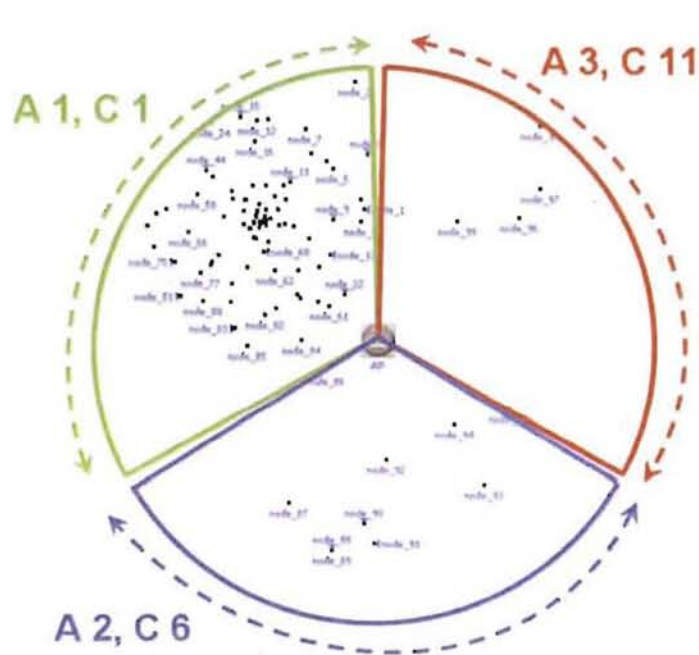


Our Solution, Much Fairer

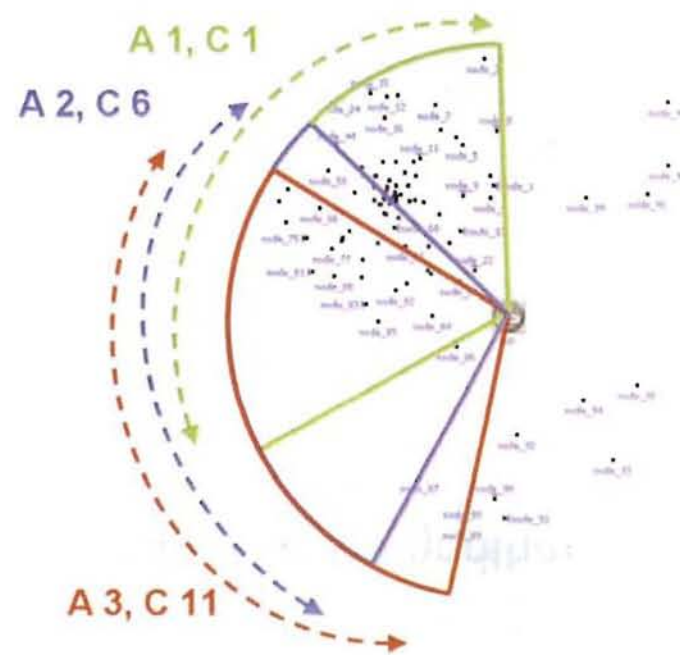


Experimental Evaluation

Provider-Centric Model (using OPNET simulator)



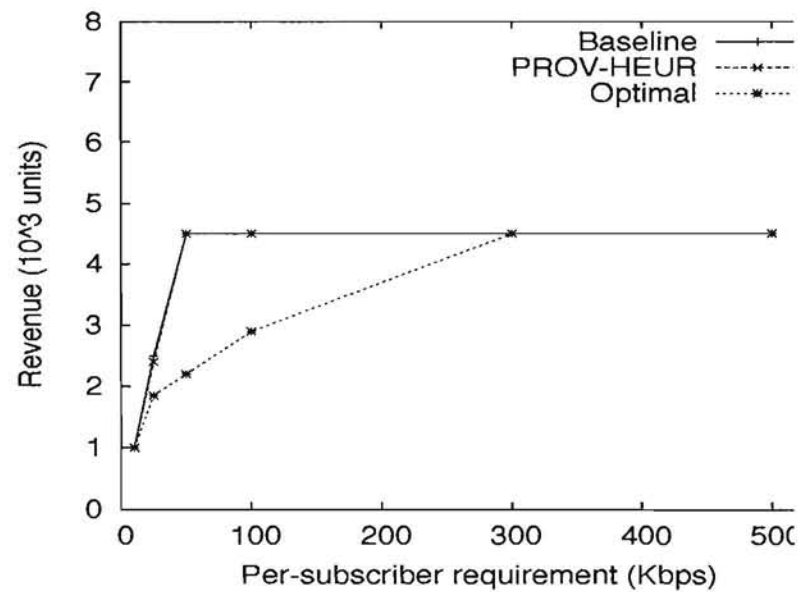
Baseline, non-uniform distribution

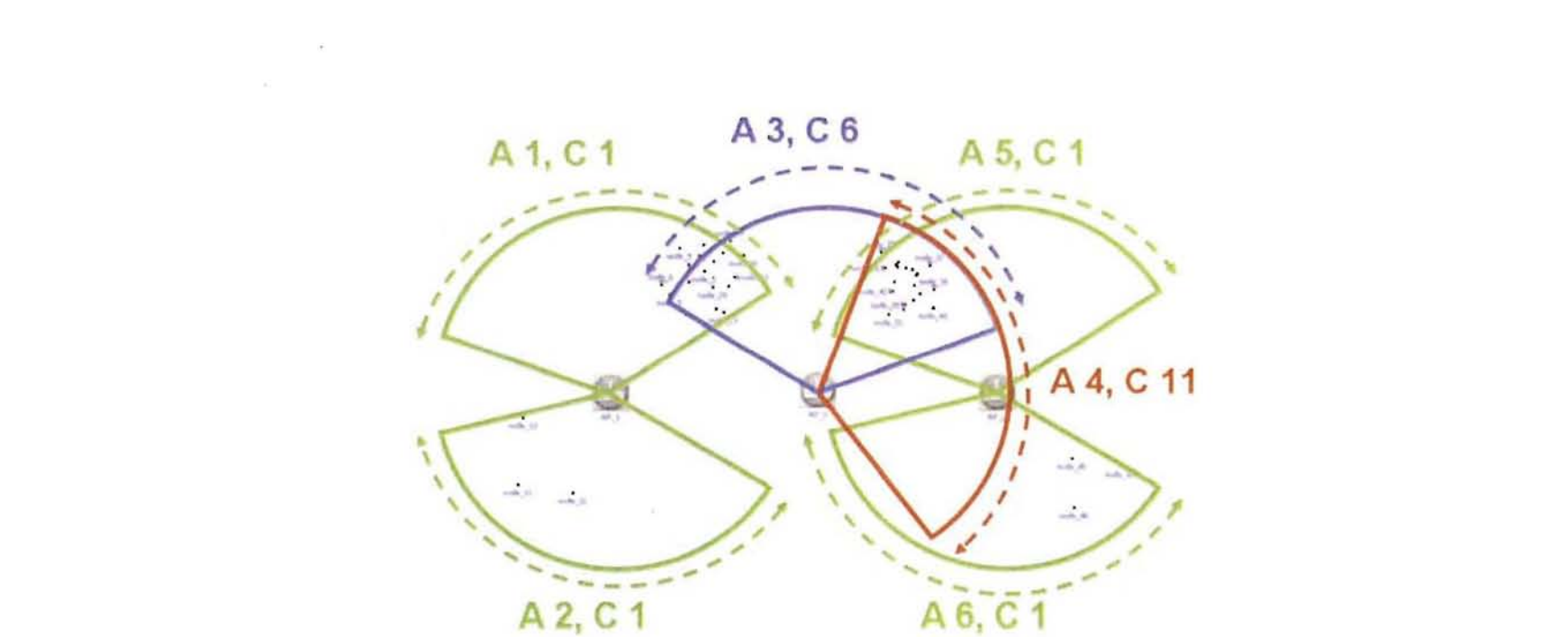


Our allocation, non-uniform distribution

Revenue Comparison

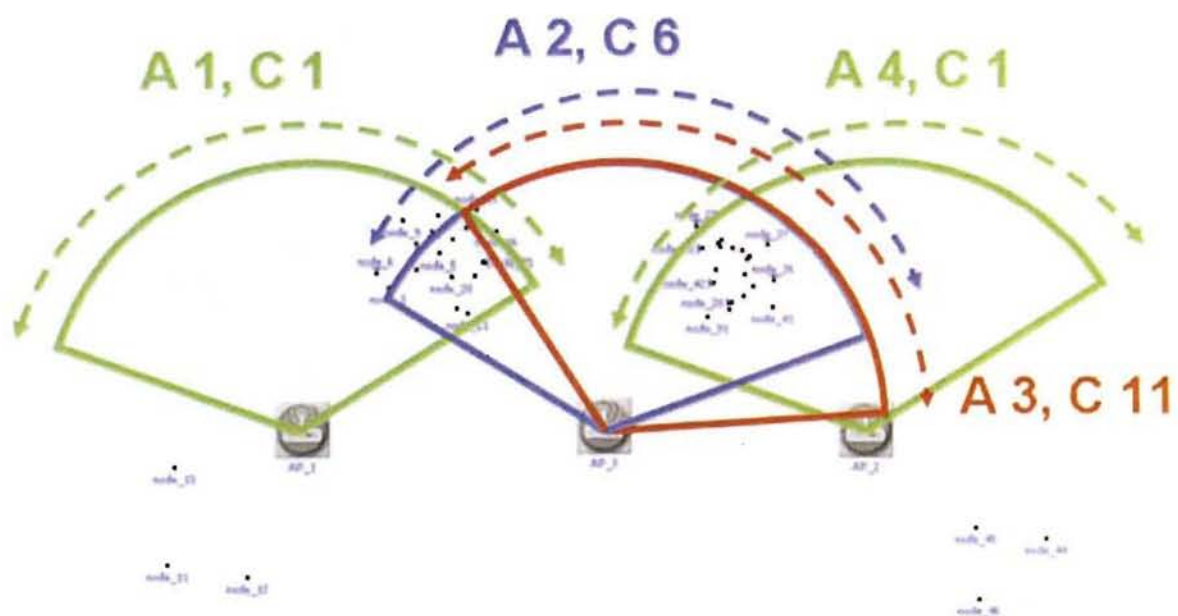
Comparing the revenue of the baseline against our algorithm





Multiple Access Point Simulation

Provider-Centric Model



Questions??