COMP9334: Capacity Planning of Computer Systems and Networks

Optimisation – Part 3

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Integer Programming - What have you seen?

- A recurrent theme is to use integer programming to make *binary decisions*

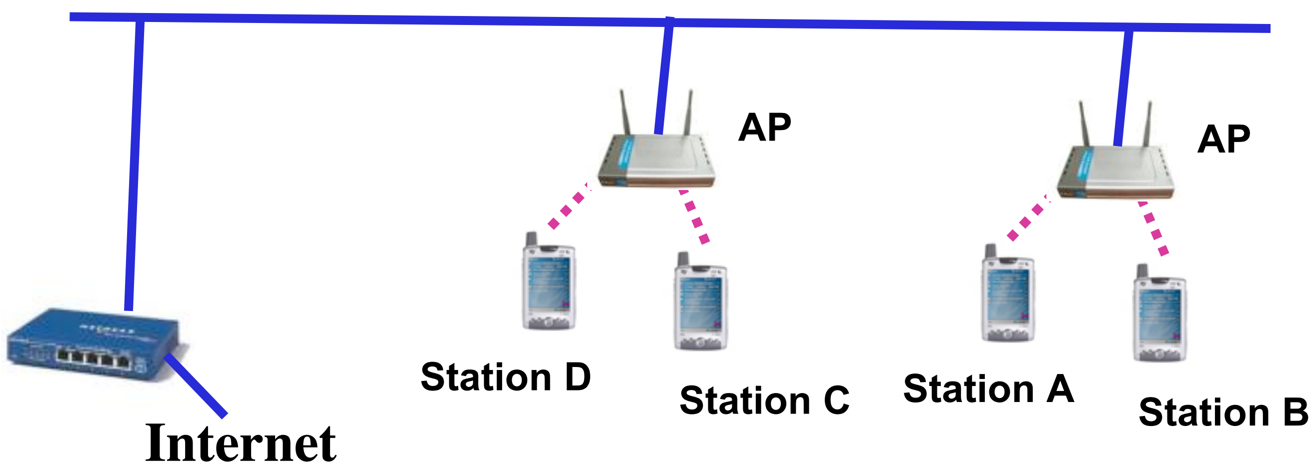
- Examples of binary decisions
  - Week 10: Grid computing problem
    - Choose a particular grid computing company or not
  - Week 11: Routing of flows
    - Should the flow be routed on a link or not?

This week's lecture

- Integer programming for placement problem
  - Example: There are a number of potential places that I can put certain devices, what are the best places to put them?
- We will study a placement problem in wireless networks
  - Placement of wireless access points
- For the revision problem, we will look at the controller placement problem for software-defined networking

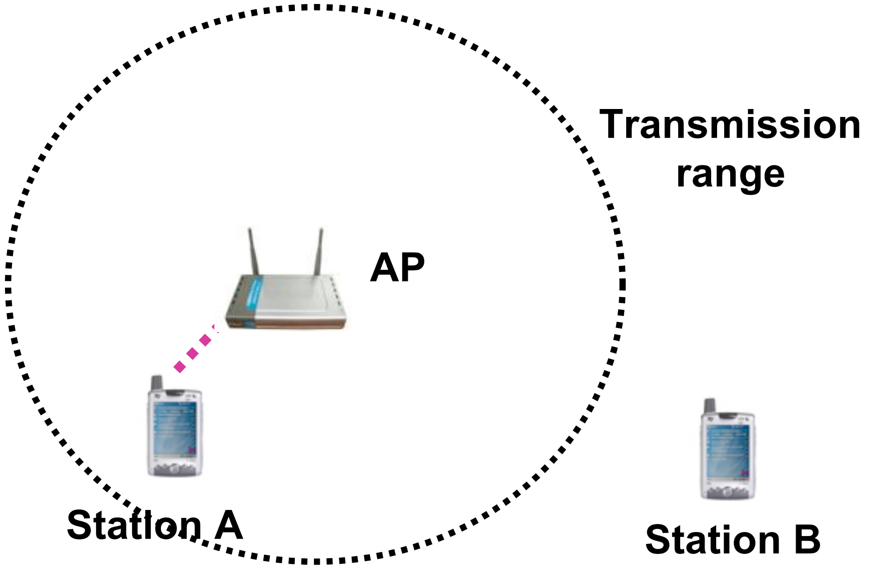
Wireless Local Area Networks

- Commonly known as Wireless LAN, WiFi etc.
- Formal standards in IEEE 802.11, IEEE 802.11a/b/g/n/ac
- Infrastructure mode: Wireless Access Points (APs) and Wireless stations



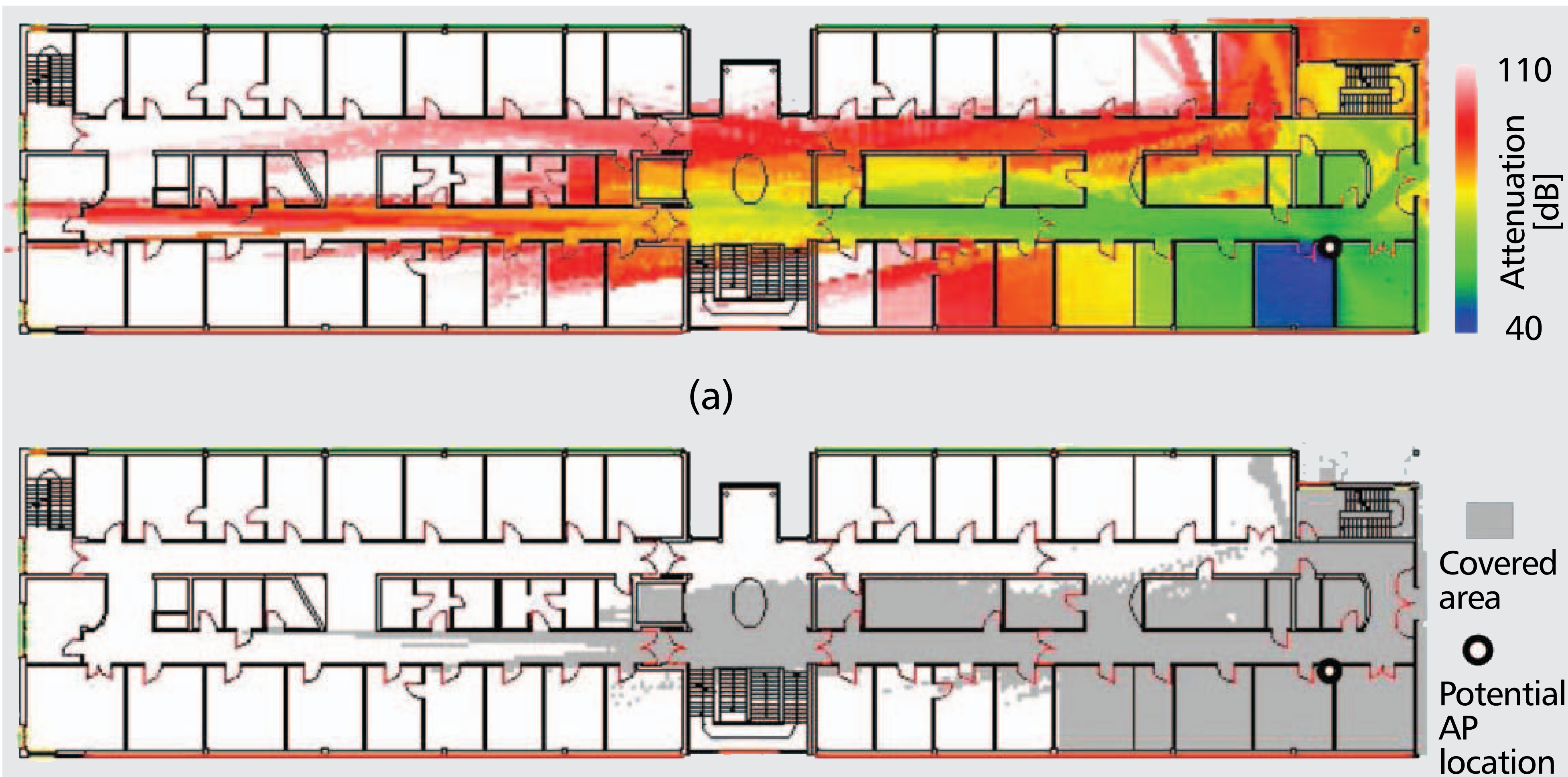
Wireless Access Point Coverage

- Due to radio propagation loss and mandated limit on transmission power, wireless access points have only limited coverage
- For example, a Cisco Aironet access point has a coverage of 304m when operating outdoor at 11 Mbps
- Ideal coverage area is a circle. In the picture below, Station A can talk to the access point but not Station B



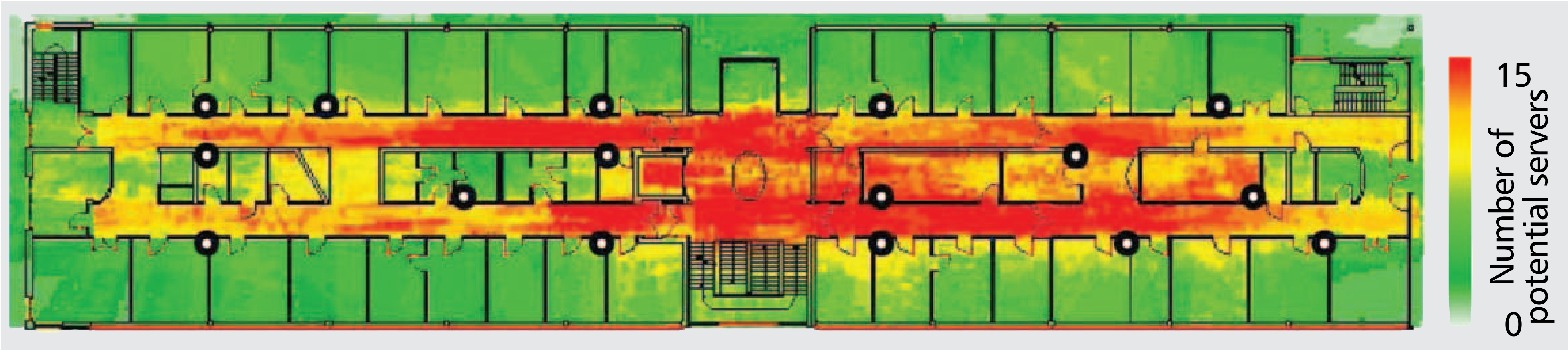
Coverage in practice

- Note: High attenuation = Poor signal = Poor coverage
- An area is covered only if the attenuation is smaller than a threshold



Covering a given area

- Multiple access points may be required to cover a given area
- Decisions to make
  - The number of access points required to cover the given area
  - The position of the access points



The coverage problem - definition

- Given
  - A number of potential access point locations $L_1, L_2, ..., L_p$
  - A number of stations $s_1, s_2, s_3, ..., s_n$
  - Binary constant δ_{ij} where

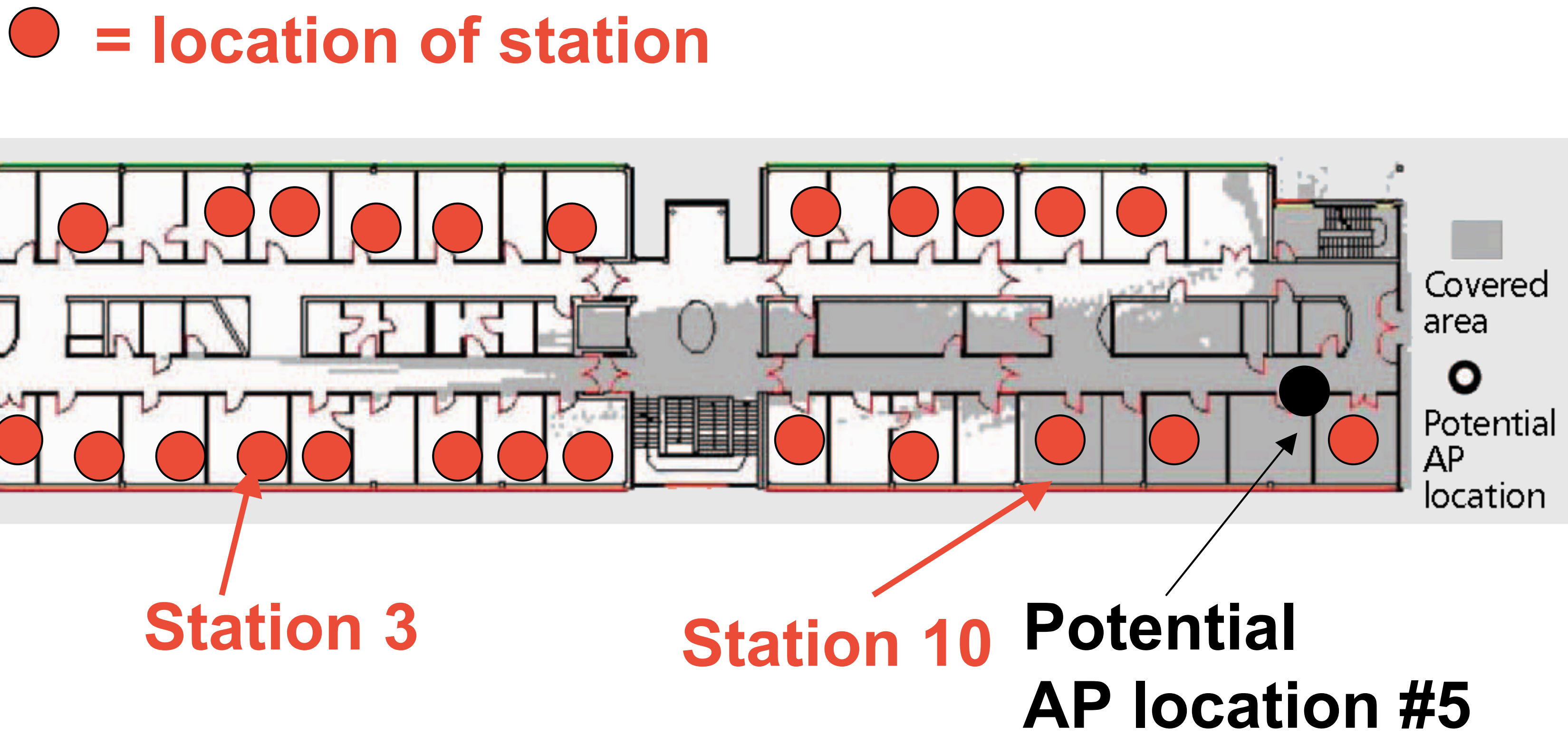
$$\delta_{ij} = \begin{cases} 1 & \text{if station } s_i \text{ is covered by an AP at location } L_j \\ 0 & \text{otherwise} \end{cases}$$

  See the next page for a graphical explanation for δ_{ij}

- Find the minimum number of access points required so that
  - All stations are covered

Explanation of δ_{ij}

- Example: $\delta_{10,5} = 1, \quad \delta_{3,5} = 0$



The coverage problem: Verbal formulation

Decision variables:

$$x_j = \begin{cases} 1 & \text{if an AP is to be installed at location } L_j \\ 0 & \text{otherwise} \end{cases}$$

Integer programming formulation:

$$\min \boxed{\text{The number of access points (An expression in } x_j\text{)}}$$

subject to

$$\boxed{\text{Each station is covered (One expression for each station, need } x_j \text{ and } \delta_{i,j}\text{)}}$$

$$x_j \in \{0, 1\}$$

The coverage problem: Formulation

Decision variables:

$$x_j = \begin{cases} 1 & \text{if an AP is to be installed at location } L_j \\ 0 & \text{otherwise} \end{cases}$$

Integer programming formulation:

$$\min \sum_{j=1}^{p} x_j$$

subject to

$$\begin{aligned} \sum_{j=1}^{p} \delta_{ij} x_j &\geq 1 \quad \forall i = 1, ..., n \\ x_j &\in \{0, 1\} \end{aligned}$$

Integer programming and optimisation: Summary

- What you have learnt
  - How to formulate integer programming problems
  - How to solve them using AMPL
  - Examples of using integer programming for network design and analysis

- There are a lot more to learn but this will give you a starting point ...

Acknowledgments

- Picture credits:
  - Andreas Eisenblätter and Hans-Florian Geerdes, ”Wireless Network Design: Solution-oriented modeling and mathematical optimization”, *IEEE Wireless Communications*, December 2006