Agenda

The course is on Mobile Computing

Mobile computing: anytime, anywhere computing

Agenda: Introduction to mobile computing

- Books and references.
- What is mobile computing?
  - Characteristics of enabling technologies.
  - System related issues.
- Its relation with distributed computing.
- Cellular architecture.

Books & references

1. Theodore S. Rappaport: Wireless communications: principles and practice, Pearson.
2. C. Y. Lee: Mobile communication engineering: theory and applications, Tata McGraw Hill.
3. Charles Perkins: Ad hoc Networking, John Wiley.
4. P. Bellavist and A. Corradi : Handbook of Mobile Middleware, Auerbach.
5. Jie Wu: Handbook of Algorithmic Aspects of Sensors, Ad Hock Wireless and Peer-to-Peer Networks, Auerbach.
6. Research Papers.
7. Other resources on Internet.

Marks Distribution

Evaluation

Mid term exams	20
End term exam	30
Project	40-45
Assignment	5-10

Minor tweaking may be done to increase assignment and reduce project weightages if needed. Lecture attendance is important.

Important dates

Schedule

TA will post assignments and grade them.
Assignments will not be graded if you fail to give demos in allotted time slots.
The project ideas (some topics) will be posted by Jan 25th.
Project presentations starting from April 2nd.

Introduction

Requirements and features

- Ability to work from a **non-fixed location**.
- Basic requirements are:
  - **Portability**.
  - **Wireless network**.

Introduction

Portability related issues

- **Scarcity resource**:
  - Low power CPU
  - Limited memory
  - Low batter life
- **Less reliable**:
  - Lost or physical damaged.
  - Administered by novice users.

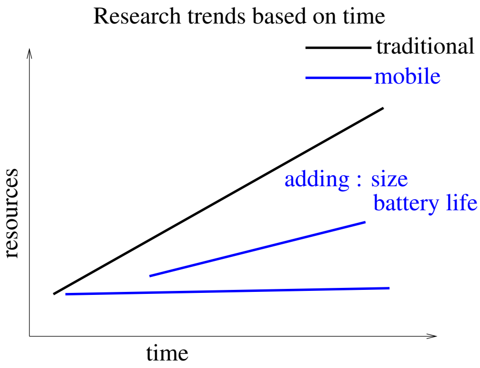
Introduction

Network related issues

- **Low bandwidth** and **high error rates**
- Frequent network **outage**
  - Disconnection due to limited coverage
  - Voluntary disconnection for saving battery.
- **Single hop connectivity** and asymmetry in connection.
- **High tariff**.

Introduction

System related issues



Introduction

Heterogeneity & variability

- Location becomes non-static.
- Connectivity becomes variable.
- Bandwidth becomes variable.
- Device interface becomes variable.
- Environment related influence increases.
- Security and vulnerability increases.

Introduction

Consequences

- Must deal with resources variation.
- Must support heterogeneity.
- Must adapt to environmental condition.
- Must handle intermittent connectivity.
- Must handle mobility across domains.
- Must handle scalability.

Mobile versus distributed computing

Distributed systems

- No resource scarcity.
- All computers have comparable resources.
- Symmetry in computation.
- All computers have fixed location.
- Failure model is simple.

Mobile distributed systems

- Suffer from resource scarcity.
- Location search is required.
- Involuntary disconnection is not necessarily failure.
- Asymmetry in computation as end nodes are resource poor.

Radio connectivity

Coverage & capacity

- Increasing coverage is the main focus of radio systems.
- But spectrum for private communication is limited (25MHz).
- Typically about 30KHz required for voice communication.
- So, even with a high power antenna mounted on a large tower can support just about 25MHz/30KHz = 833
- How to increase both capacity & coverage?

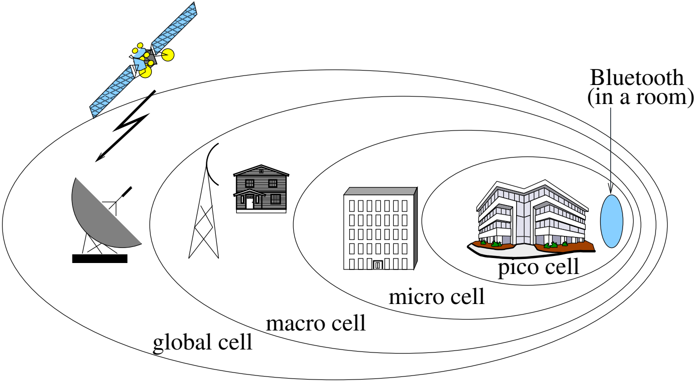
Radio connectivity

Coverage & capacity

- **Solution**: reuse frequencies, but without interferences.
  - **spectral congestion** can be eliminated by developing an architecture which allows **spatial multiplexing**.

Radio connectivity

Spatial multiplexing of radio frequency



Cellular architecture

Frequency reuse

- Turning point in frequency reuse based wireless communication.
- Allows spatial multiplexing which not only eliminates **interferences** but also provide **uninterrupted coverage**.
- Uses partitioning of coverage area into small **cells** each serviced by one transceiver.

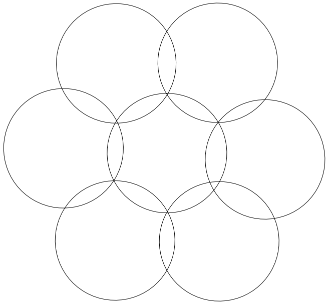
Cellular architecture

Frequency reuse

- Could be viewed as equivalent to marking out counties in a district by using colors.
- A subtle difference exists between map coloring and spatial multiplexing of spectrum:
  - To avoid co-channel and adjacent channel interferences while planning frequency reuse.
- Frequency reuse plan, thus, needs an engineering solution.

Cellular architecture

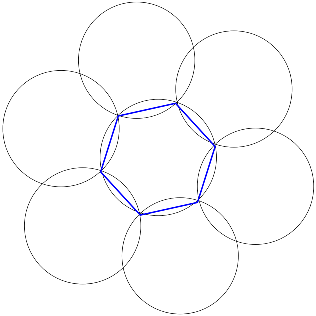
Frequency reuse



- Geometrically coverage area of an antenna represents a circle.
- Continuous coverage is provided by packing it with equal sized circles such that
  - No uncovered gaps should exist.
  - Circles overlap minimally.

Cellular architecture

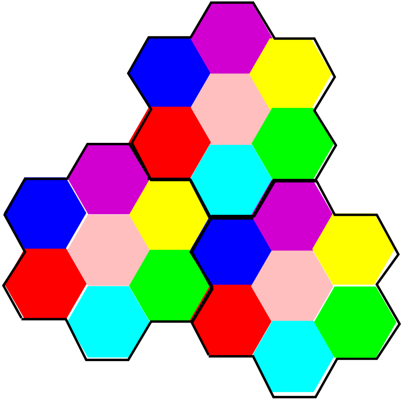
Frequency reuse



- Common chords of overlapping circles define a hexagonal areas.
- The collection of hexagons packs the service area.

Frequency planning

Capacity enhancement



Frequency planning

Capacity enhancement

- The bunch of channels allocated to one cell is different from the bunch assigned geographically adjacent cells.
  - C: total number of duplex channels
  - C_x: number allocated to a cell x
  - N: number of cells among which C channels equally divided
  - I.e., $C = N \times C_x$.
- The group of N cells is called a **cluster**.
  - R_c: number of replicated clusters in a system.
  - The **system capacity**: $K = R_c \times C$.
- So, the size of a cluster determines system capacity.

Frequency planning

Effects of capacity enhancement

- Suppose cluster is replicated 4 times.
- Effective frequency allocation: 25MHz$\times$4=100MHz.
- Suppose we use a cluster size of 7, then each cell of a cluster:
  - Gets a spectrum of 25MHz/7 = 3.57MHz.
  - Can support 3.57MHz/30kHz = 119 users.
- The number of users in each cluster = 119$\times$7 = 833.
- With 4 clusters the total number of users = 3332.

System design

The maximum number of calls/hour/cell is decided on the basis of traffic conditions in each cell.

System design

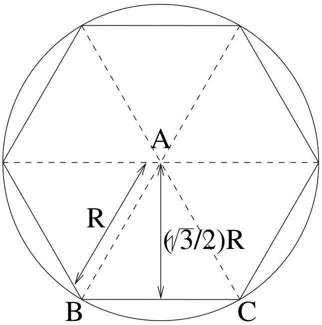
The maximum number of calls/hour/cell is decided on the basis of traffic conditions in each cell.

Example

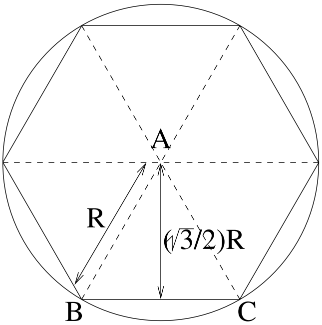
Let Q denote the number of calls per hour during busy period. Let the values of Q for 10 cells be 2000, 3000, 500, 1000, 1200, 1800, 2500, 2800, 900. Assume 60% of the car phones will be used during this period, and one call is made per phone.

- Total number of calls per hour $\sum_i Q_i = 17200$.
- Since 60% of car phones are used, system can handle $= 17200/0.6 = 28667$.

Geometry of cell

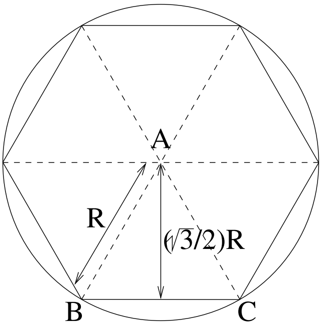


Geometry of cell



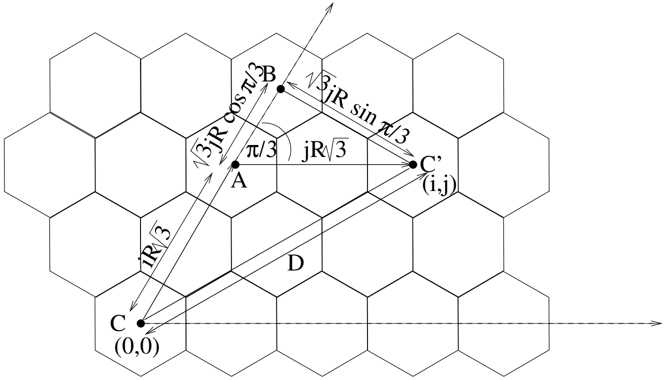
Area of the triangle = $(\sqrt{3}/4)R^2$.

Geometry of cell

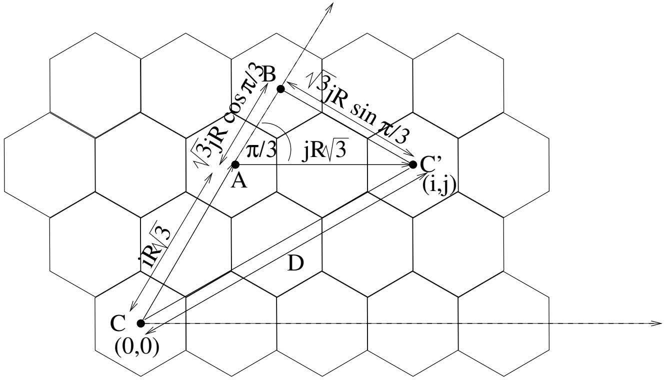


Area of the hexagon = 6$(\sqrt{3}/4)R^2$.

Reuse distance

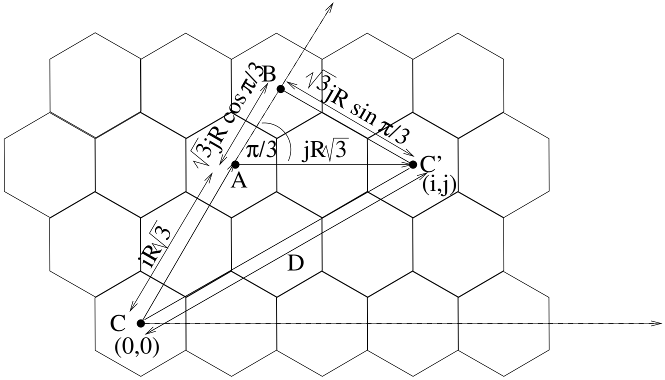


Reuse distance



Axes at 60° to each other.

Reuse distance



Coordinates are represented by integers.

Reuse distance

Computation

$$
\begin{aligned}
D^2 &= (\sqrt{3}iR + \sqrt{3}jr\cos\pi/3)^2 + (\sqrt{3}jR\sin\pi/3)^2\\
&= R^2(3i^2 + 6ij\cos\pi/3 + 3j^2\cos^2\pi/3 + 3j^2\sin^2\pi/3)\\
&= R^2(3i^2 + 3ij + 3j^2)\\
&= 3R^2(i^2 + ij + j^2)
\end{aligned}
$$

Reuse distance

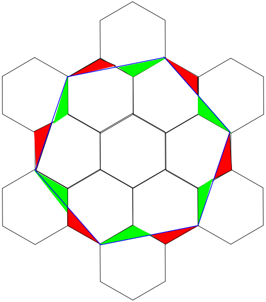
Cells per cluster

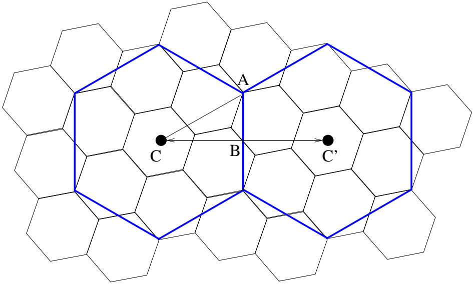
- The number of cells N per cluster can be found by finding proportion of the cell area to the cluster area.
- The area of a cluster can be found by analyzing the cell geometry.

Reuse distance

Cells per cluster

C and C' are co-channel cells.





Reuse distance

Cells per cluster

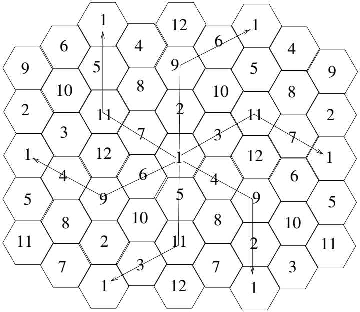
- The area of a cluster hexagon $= 6\frac{D^2/3}{4\sqrt{3}}$.
- The area of one cell $= 6R^2\sqrt{3}/4$.
- The number of cells per cluster is given by ratio of two areas.

$$N = \left(\frac{D^2}{12\sqrt{3}}\right) / \left(\frac{R^2\sqrt{3}}{4}\right) = \left(\frac{D}{R\sqrt{3}}\right)^2$$

$$= \frac{3R^2(i^2 + ij + j^2)}{3R^2} = i^2 + ij + j^2$$

Reuse distance

Cells per cluster



- For example, if (2, 2) is the closest co-channel cell of a cell at position (0, 0), then
  - The cluster size is $N = 2^2 + 2.2 + 2^2 = 12$.

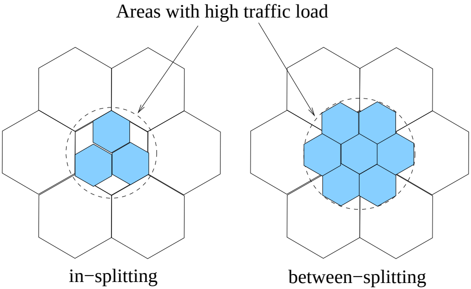
Splitting & sectoring

Increasing capacity

- Increased reuse of frequency increases chance of interference.
- How to keep interference low and increase the capacity?
- Service area has been planned and infrastructure is in place, any incremental change is difficult to execute.
- To address this two simple ideas
  1. Cell splitting
  2. Cell sectoring

Splitting & sectoring

Cell splitting



- Creates smaller cells from standard cells.
- Spatial multiplexing with micro cells.
- Smaller cells are placed in or between large cells.
- For example, two possible splitting

Splitting & sectoring

Cell splitting

- Increase in co-channel interference.
- The number of clusters also increases in the coverage area.
- The transmission power of micro cells must be reduced to avoid the co-channel interference.
- For example, let the transmit power of the base station in the original cell be P_{t1} and that of micro-cell be P_{t2}.
- The received power P_r at cell boundaries of the two cells are:

$$P_r[\text{original cell}] \propto P_{t1} R^{-n}$$
$$P_r[\text{micro-cell}] \propto P_{t2} (R/2)^{-n}$$

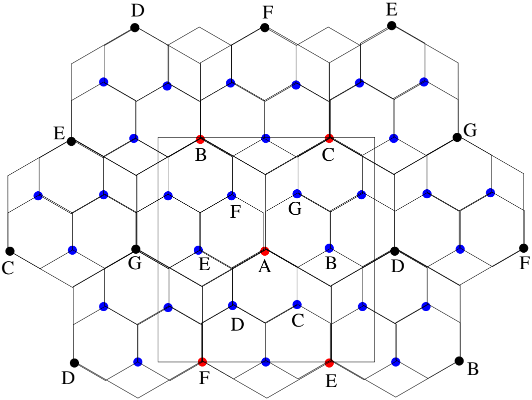
Splitting & sectoring

Effect of splitting

- The ratio of transmit powers of a micro-cell versus a normal cell is 1:16 when path loss exponent is 4.
- It is not necessary to split all the cells.
- Sometimes it becomes difficult to exactly identify the coverage area that would require cell splitting.
- So in practice different cell sizes may co-exist.
- Therefore, a careful fine-tuning of power outputs by transceivers is needed to keep co-channel intereference at minimum level.
- The channel assignment becomes quite complicated.

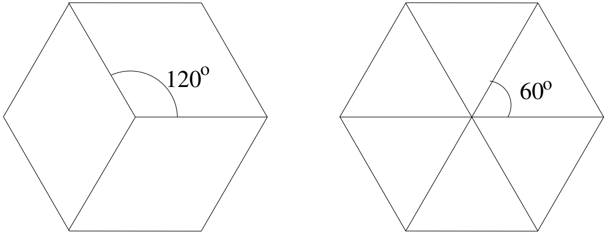
Splitting & sectoring

Example for splitting



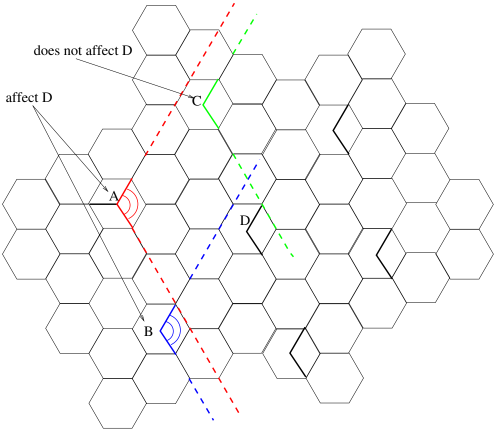
Splitting & sectoring

Cell sectoring



Splitting & sectoring

Cell sectoring



Summary

- We learnt about mobile computing as new paradigm of distributed computing.
- It differs significantly from conventional distributed computing in two important respect.
  1. Allows some of the participating nodes of a computation to move while maintaining active network connectivities.
  2. The computation load between static and mobile participating nodes is not balanced.
- We also discussed about cellular architecture which is the key networking technology for communication with mobile nodes.