Course Name:	MCAN Laboratory	Semester:	VI
Date of Performance:	13 / 01 / 2025	Batch No.:	B - 2
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Experiment No: 1
Title: Program on cellular concept

Aim and Objective of the Experiment:

Write a program to solve the following problems on cell size and system capacity.

1. Consider a single high-power transmitter that can support 40 voice channels over an area of 140 km² with the available spectrum. If this area is equally divided into seven smaller areas (cells), each supported by lower power transmitters so that each cell supports 30% of the channels, determine
   (a) coverage area of each cell
   (b) Total number of voice channels available in cellular system.

2. a) Assume a cellular system of 32 cells with a cell radius of 1.6 km, a total spectrum allocation that supports 336 traffic channels, and a reuse pattern of 7. Calculate the total service area covered with this configuration, the number of channels per cell, and a total system capacity. Assume regular hexagonal cellular topology.
   b) Let the cell size be reduced to the extent that the same area as covered in Part (a) with 128 cells. Find the radius of the new cell, and new system capacity.

COs to be achieved:

CO1: Understand the cellular concept and multiple access techniques.

Books / Journals / Websites Referred:

Tools required:

C/C++/Python IDE/compiler

Theory:

Cellular Concept

The cellular concept is the basis of mobile communication systems, which divides a geographical area into smaller regions called **cells**. Each cell is served by a base station, and this structure allows efficient use of the radio frequency spectrum.

Key Principles:

1. **Cell Design:**
    - The area is divided into hexagonal cells to ensure maximum coverage without overlapping or gaps. Hexagons are used because they cover the area efficiently with fewer cells compared to circular shapes.
2. **Frequency Reuse:**
    - Each cell is assigned a group of frequencies that differ from neighboring cells to avoid interference. These frequencies can be reused in non-adjacent cells, increasing the system's capacity.
    - Example: If cells A and C are far apart, they can reuse the same frequency.
3. **Handoff Mechanism:**
    - As a user moves from one cell to another, the system transfers the call to the next cell's base station without interruption. This process is called **handoff** or **handover**.
4. **Reducing Interference:**
    - Proper cell design and frequency reuse reduce **co-channel interference** and **adjacent channel interference**, ensuring efficient communication.

Multiple Access Techniques

In cellular systems, multiple users need to access the network simultaneously. To achieve this, several multiple access techniques are used.

1. Frequency Division Multiple Access (FDMA):

- **Principle:** The available frequency spectrum is divided into individual frequency channels, and each user is assigned a unique frequency band.
- **Features:**
    - Each user uses the entire bandwidth of their channel during the call.
    - Suitable for analog systems like 1G.

2. Time Division Multiple Access (TDMA):

- **Principle:** The available frequency band is divided into time slots, and each user is assigned a specific time slot to transmit data.
- **Features:**
    - Multiple users share the same frequency but at different times.
    - Used in systems like 2G (e.g., GSM).

3. Code Division Multiple Access (CDMA):

- **Principle:** All users share the same frequency band simultaneously, but unique codes are assigned to differentiate users.
- **Features:**
  - Based on spread-spectrum technology.
  - Provides high capacity and robust performance against interference.
  - Used in systems like 3G.

4. Orthogonal Frequency Division Multiple Access (OFDMA):

- **Principle:** Divides the frequency band into multiple orthogonal subcarriers, and each user is allocated a subset of these subcarriers.
- **Features:**
  - Efficient use of spectrum.
  - Used in modern systems like 4G (e.g., LTE) and 5G.

5. Spatial Division Multiple Access (SDMA):

- **Principle:** Users are separated by their spatial location using beamforming and advanced antenna technologies.
- **Features:**
  - Used in conjunction with other techniques (e.g., MIMO in 5G).
  - Increases capacity by reusing the same frequency in different spatial directions.

Implementation details:

1. **Enlist all the Steps followed and various options explored.**
   - **Input Handling**:
     The program accepts inputs from the user for each parameter (e.g., total area, number of cells, etc.).
     The user can input "n/a" if they don't have a value for a particular parameter.

   - **Program Workflow**:
     The user selects which question they want to solve (Question 1 or Question 2) or exits the program.
     Based on the choice, the program asks for relevant inputs and calculates the required values.

   - **Options Explored**:
     a. For **Question 1**, it calculates:
        - Coverage area per cell.

- Number of channels per cell.
- Total number of channels in the cellular system.

b. For **Question 2**, it calculates:
Total service area for a given number of cells and radius.
Number of channels per cell.
Total system capacity.
If the number of cells increases, it calculates:
   - New cell radius using the scaling formula.
   - New system capacity based on the updated number of cells.

2. Explain your program logic and methods used.

- **Functions for Modular Code**:
  `calculate_question_1()`: Handles all calculations related to Question 1, such as dividing the area and computing the total channels.
  `calculate_question_2()`: Performs computations for hexagonal cellular topology, including reduced cell size.
  Each function works independently and prints results only for what can be calculated based on available inputs.

- **Input Validation**:
  `get_input()`:
  - Ensures that users provide valid numeric inputs.
  - Accepts "n/a" for missing parameters, returning `None`.

- **Mathematical Operations**:
  - **Hexagonal Area**: Used standard geometry for hexagonal cells.
  - **Channel and Capacity Calculations**: Used basic arithmetic for determining total channels and system capacity.

- **Dynamic Adjustments**:
  The program recalculates values like radius and capacity dynamically when new conditions are introduced, such as an increased number of cells.

- **User-Friendly Interface**:
  Clear prompts and error-handling to guide the user through the calculations.
  Results are formatted for readability with appropriate units (e.g., km^2, channels).

C/C++/Python Code implemented:

```
import math

def get_input(prompt, dtype=float):
    while True:
        user_input = input(prompt).strip()
        if user_input.lower() == "n/a":
            return None
        try:
            return dtype(user_input)
        except ValueError:
            print("Invalid input.")

def calculate_question_1():
    print("\nQuestion 1: Single high-power transmitter")
    total_area = get_input("Enter the total coverage area (in km^2): ")
    total_channels = get_input("Enter the total number of voice channels: ")
    num_cells = get_input("Enter the number of cells: ")
    percentage_channels_per_cell = get_input("Enter the percentage of channels per cell (e.g., 30 for 30%): ")

    if total_area and num_cells:
        area_per_cell = total_area / num_cells
        print(f"Coverage area of each cell: {area_per_cell:.2f} km^2")
    else:
        print("Insufficient data to calculate the coverage area per cell.")

    if total_channels and percentage_channels_per_cell:
        channels_per_cell = (percentage_channels_per_cell / 100) * total_channels
        total_system_channels = channels_per_cell * num_cells if num_cells else None

        print(f"Number of channels per cell: {channels_per_cell:.2f}")
        if total_system_channels:
            print(f"Total number of voice channels in the cellular system: {total_system_channels:.2f}")
    else:
        print("Insufficient data to calculate the total number of voice channels.")

def calculate_question_2():
    print("\nQuestion 2: Cellular system with regular hexagonal topology")
    num_cells = get_input("Enter the number of cells: ")
```

```
    cell_radius = get_input("Enter the radius of each cell (in km): ")
    total_channels = get_input("Enter the total number of traffic channels: ")
    reuse_pattern = get_input("Enter the reuse pattern (e.g., 7): ")

    if num_cells and cell_radius:
        # Calculate the total service area for hexagonal cells
        area_per_cell = (3 * math.sqrt(3) * cell_radius ** 2) / 2
        total_service_area = area_per_cell * num_cells
        print(f"Total service area covered: {total_service_area:.2f} km^2")
    else:
        print("Insufficient data to calculate the total service area.")

    if total_channels and reuse_pattern:
        channels_per_cell = total_channels / reuse_pattern
        system_capacity = channels_per_cell * num_cells if num_cells else None

        print(f"Number of channels per cell: {channels_per_cell:.2f}")
        if system_capacity:
            print(f"Total system capacity: {system_capacity:.2f}")
    else:
        print("Insufficient data to calculate channels per cell or system
capacity.")

    # Part (b): Reduced cell size
    new_num_cells = get_input("Enter the new number of cells (e.g., 128): ")
    if new_num_cells and num_cells and cell_radius:
        new_cell_radius = cell_radius * math.sqrt(num_cells / new_num_cells)
        new_area_per_cell = (3 * math.sqrt(3) * new_cell_radius ** 2) / 2
        new_total_service_area = new_area_per_cell * new_num_cells
        print(f"New cell radius: {new_cell_radius:.2f} km")

        if total_channels and reuse_pattern:
            new_channels_per_cell = total_channels / reuse_pattern
            new_system_capacity = new_channels_per_cell * new_num_cells

            print(f"New system capacity: {new_system_capacity:.2f}")
    else:
        print("Insufficient data to calculate new cell radius or system
capacity.")

def main():
    print("Welcome to the Cellular System Calculator")
    while True:
        print("\nSelect the question to solve:")
```

```python
        print("1. Question 1: Single high-power transmitter")
        print("2. Question 2: Cellular system with hexagonal topology")
        print("3. Exit")

        choice = input("Enter your choice (1/2/3): ").strip()
        if choice == "1":
            calculate_question_1()
        elif choice == "2":
            calculate_question_2()
        elif choice == "3":
            break
        else:
            print("Invalid choice. Please select 1, 2, or 3.")

if __name__ == "__main__":
    main()
```

Output/ program results after execution:

```
PS C:\Users\admin\OneDrive\Desktop\sem 6\mobile communication and ADHOC\codes> python -u "c:\Users\admin\OneDrive\Deskt
Welcome to the Cellular System Calculator

Select the question to solve:
1. Question 1: Single high-power transmitter
2. Question 2: Cellular system with hexagonal topology
3. Exit
Enter your choice (1/2/3): 1

Question 1: Single high-power transmitter scenario
Enter the total coverage area (in km^2): 140
Enter the total number of voice channels: 40
Enter the number of cells: 7
Enter the percentage of channels per cell (e.g., 30 for 30%): 30
Coverage area of each cell: 20.00 km^2
Number of channels per cell: 12.00
Total number of voice channels in the cellular system: 84.00

Select the question to solve:
1. Question 1: Single high-power transmitter
2. Question 2: Cellular system with hexagonal topology
3. Exit
Enter your choice (1/2/3): 2

Question 2: Cellular system with regular hexagonal topology
Enter the number of cells: 32
Enter the radius of each cell (in km): 1.6
Enter the total number of traffic channels: 336
Enter the reuse pattern (e.g., 7): 7
Total service area covered: 212.83 km^2
Number of channels per cell: 48.00
Total system capacity: 1536.00
Enter the new number of cells (e.g., 128): 128
New cell radius: 0.80 km
New system capacity: 6144.00

Select the question to solve:
1. Question 1: Single high-power transmitter
2. Question 2: Cellular system with hexagonal topology
3. Exit
Enter your choice (1/2/3): 3
Exiting the program. Goodbye!
PS C:\Users\admin\OneDrive\Desktop\sem 6\mobile communication and ADHOC\codes>
```

Post Lab Subjective/Objective type Questions:

1. **Why can the cellular topology not be formed by using ideal circular shape?**
   In theory, circular cells might seem like an ideal choice due to their symmetrical shape. However, when it comes to practical cellular network design, using circular cells leads to several challenges:
   - Coverage Overlaps and Gaps: Circular cells can't cover an area without overlapping or leaving gaps, leading to inefficiencies and potential coverage issues.
   - Tessellation: Hexagonal cells are preferred because they tessellate perfectly (fit together without gaps), ensuring uniform coverage and efficient use of frequencies.

2. **What is the significance of cell size?**
   Cell size in a cellular network is crucial for several reasons:
   - Capacity Management: Smaller cells (microcells or picocells) can handle more users in densely populated areas, improving capacity and reducing congestion.
   - Coverage Area: Larger cells cover more area, suitable for rural or low-density regions but might suffer from higher signal interference and lower capacity.
   - Power Consumption: Smaller cells require less power, allowing for efficient battery usage in mobile devices and reducing overall network costs.
   - Quality of Service: Proper cell size ensures a balance between coverage and capacity, maintaining a high quality of service.

3. **List few typical technical issues for proper design and planning of a cellular network.**
   Designing and planning a cellular network involves addressing several technical challenges:
   - Interference Management: Minimizing signal interference between adjacent cells to ensure clear communication.
   - Frequency Reuse: Strategically reusing frequencies across the network to maximize capacity without causing interference.
   - Handoff Procedures: Ensuring smooth transitions (handovers) for users moving between cells without dropping calls or data sessions.
   - Propagation Environment: Accounting for physical obstacles (buildings, trees) and terrain variations that affect signal propagation.
   - Traffic Forecasting: Predicting user density and traffic patterns to design a network that can handle peak loads efficiently.

Conclusion:

We successfully learned and implemented the concepts of cellular networks and demonstrated how to solve related problems using a flexible, user-driven program.

Signature of faculty in-charge with Date: