Chapter 1: Green Radio Technology

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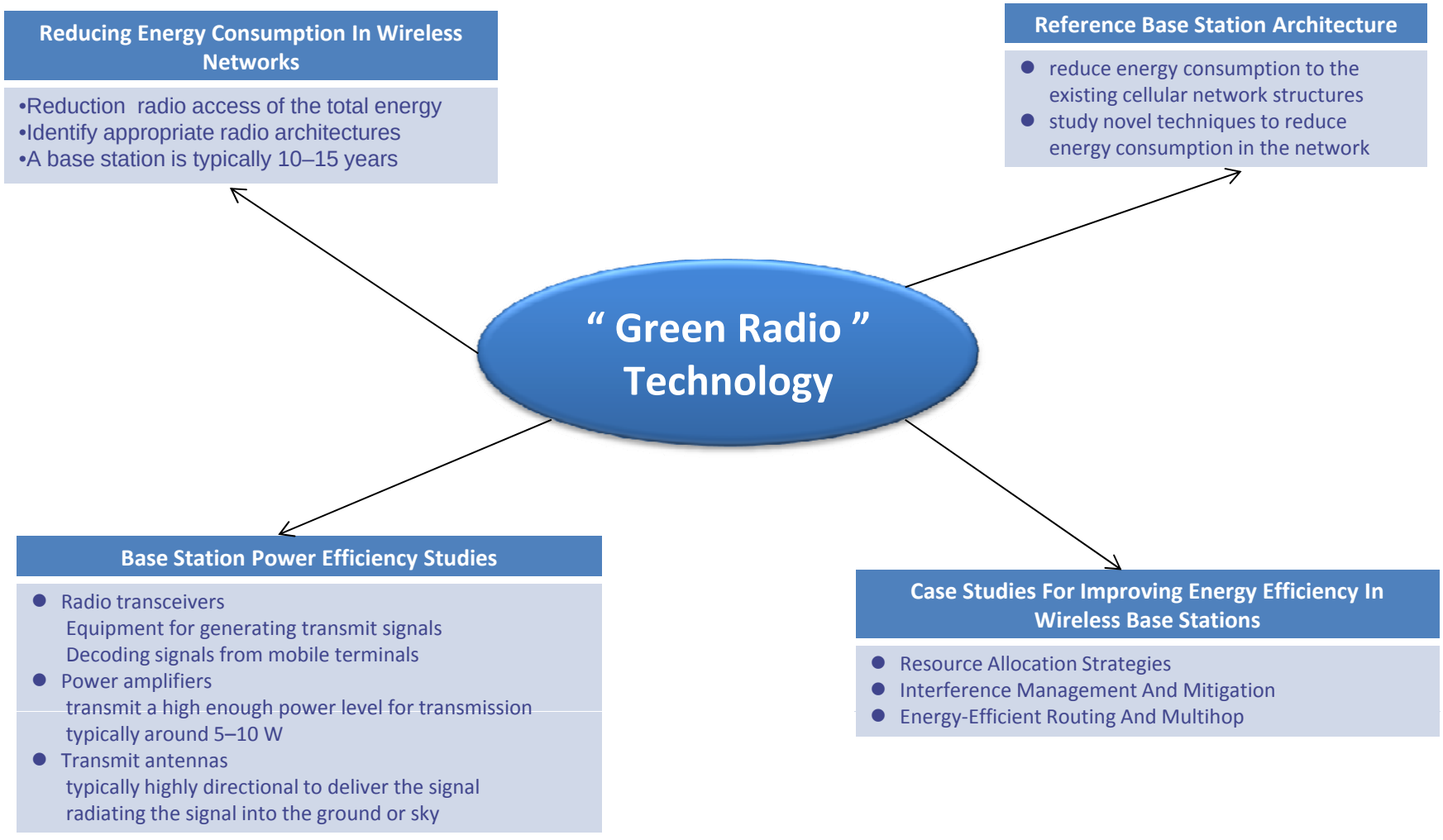
Outline

1. Introduction
2. Reducing Energy Consumption In Wireless Networks
3. Base Station Power Efficiency Studies
4. Reference Base Station Architecture
5. Case Studies For Improving Energy Efficiency In Wireless Base Stations
   - 5.1 Resource Allocation Strategies
   - 5.2 Interference Management And Mitigation
   - 5.3 Energy-Efficient Routing And Multihop
6. Conclusion

Technical roadmap for "Green Radio" Technology A taxonomy graph



Abstract

- Manufacturers and network operators has shown that current wireless networks are not very energy efficient, particularly the base stations by which terminals access services from the network.
  - The Mobile Virtual Centre of Excellence (VCE) Green Radio project was established in 2009 to establish how significant energy savings may be obtained in future wireless systems.
  - Describes some of the most promising research directions in reducing the energy consumption of future base stations.

Outline

1. Introduction

- Move to higher-data-rate mobile broadband in the number of mobile subscribers and the increasing contribution of information technology to the overall energy consumption of the world, there is a need on environmental grounds to reduce the energy requirements of radio access networks.

Example to united Kingdom may consume

- A typical mobile phone network in the United Kingdom may consume approximately 40 ~ 50 MW, even excluding the power consumed by users' handsets.

- MW is MegaWatt.

  A year ➔ 40 ~ 50 x 1000 x 24 x 365

  $= 3.504 \times 10^8 \sim 4.38 \times 10^8$ KWh

  (The average electricity was $1.8 ~ 2.4 of Taiwan)

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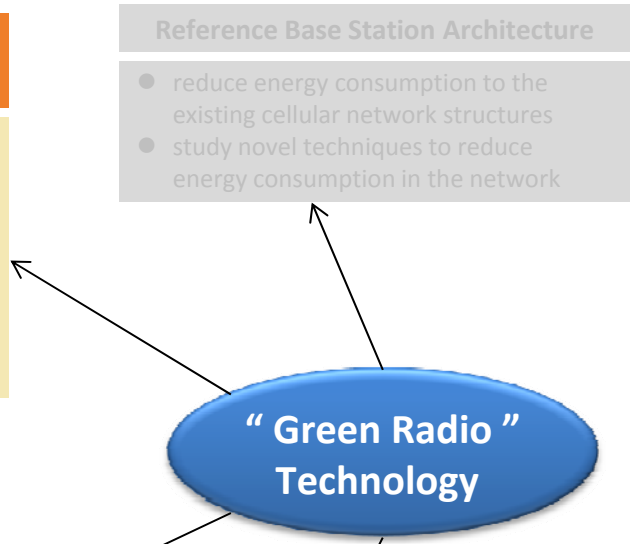
Reducing Energy Consumption In Wireless Networks

- Reduction radio access of the total energy
- Identify appropriate radio architectures
- A base station is typically 10–15 years



Reference Base Station Architecture

- reduce energy consumption to the existing cellular network structures
- study novel techniques to reduce energy consumption in the network

Base Station Power Efficiency Studies

- Radio transceivers
  Equipment for generating transmit signals
  Decoding signals from mobile terminals
- Power amplifiers
  transmit a high enough power level for transmission
  typically around 5–10 W
- Transmit antennas
  typically highly directional to deliver the signal
  radiating the signal into the ground or sky

Case Studies For Improving Energy Efficiency In Wireless Base Stations

- Resource Allocation Strategies
- Interference Management And Mitigation
- Energy-Efficient Routing And Multihop

2. Reducing Energy Consumption In Wireless Networks

- The typical power consumption of different elements of a current wireless network is shown in Fig. 1a.
  - These results clearly show that reducing the power consumption of the base station or access point has to be an important element of this research program.
- Studies have indicated that the mobile handset power drain per subscriber is much lower than the base station component, Fig. 1b.
  - The Green Radio project will mainly focus on base station design issues.

Fig. 1a. *Power consumption of a typical wireless cellular network (source: Vodafone)*

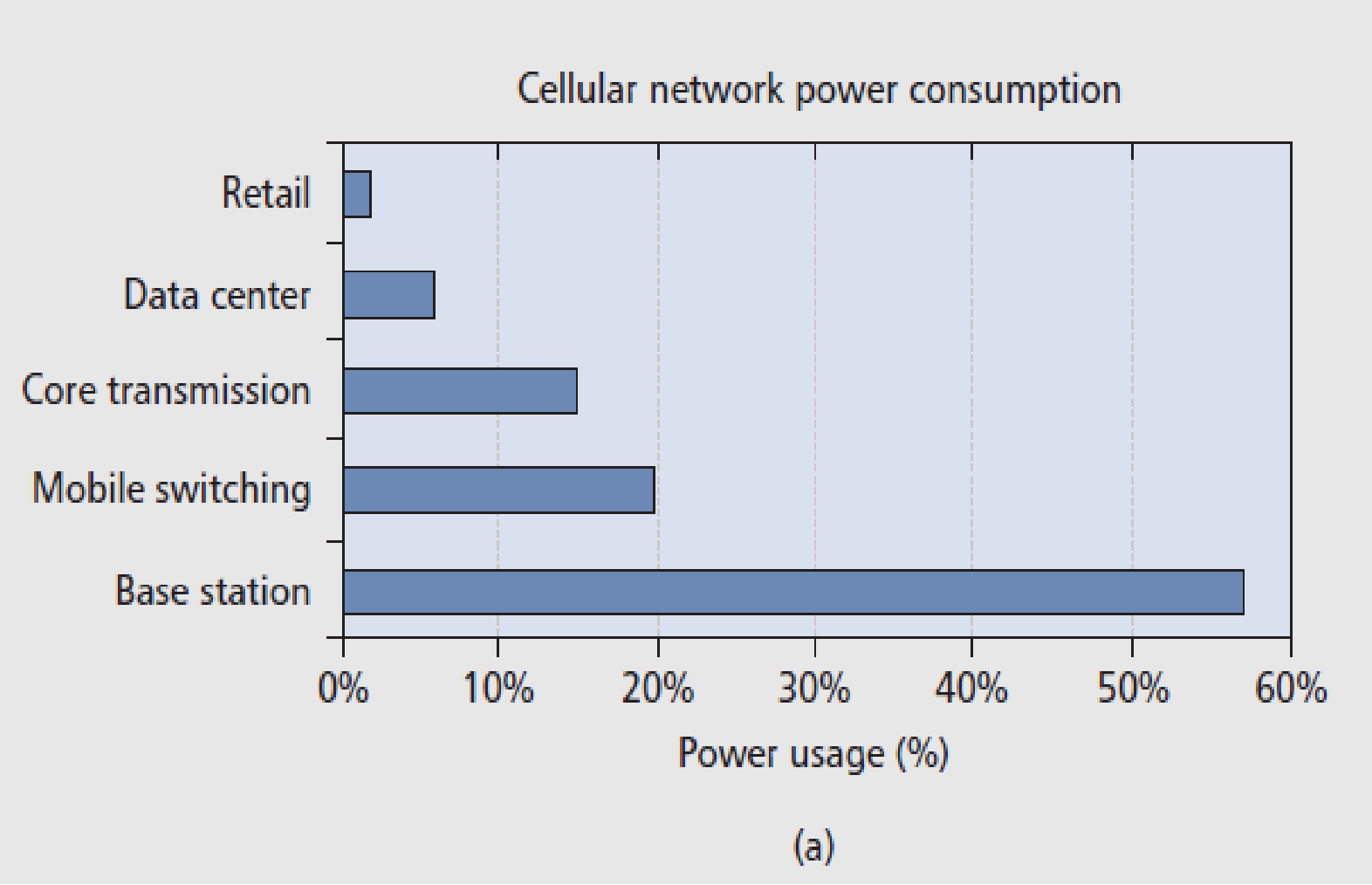
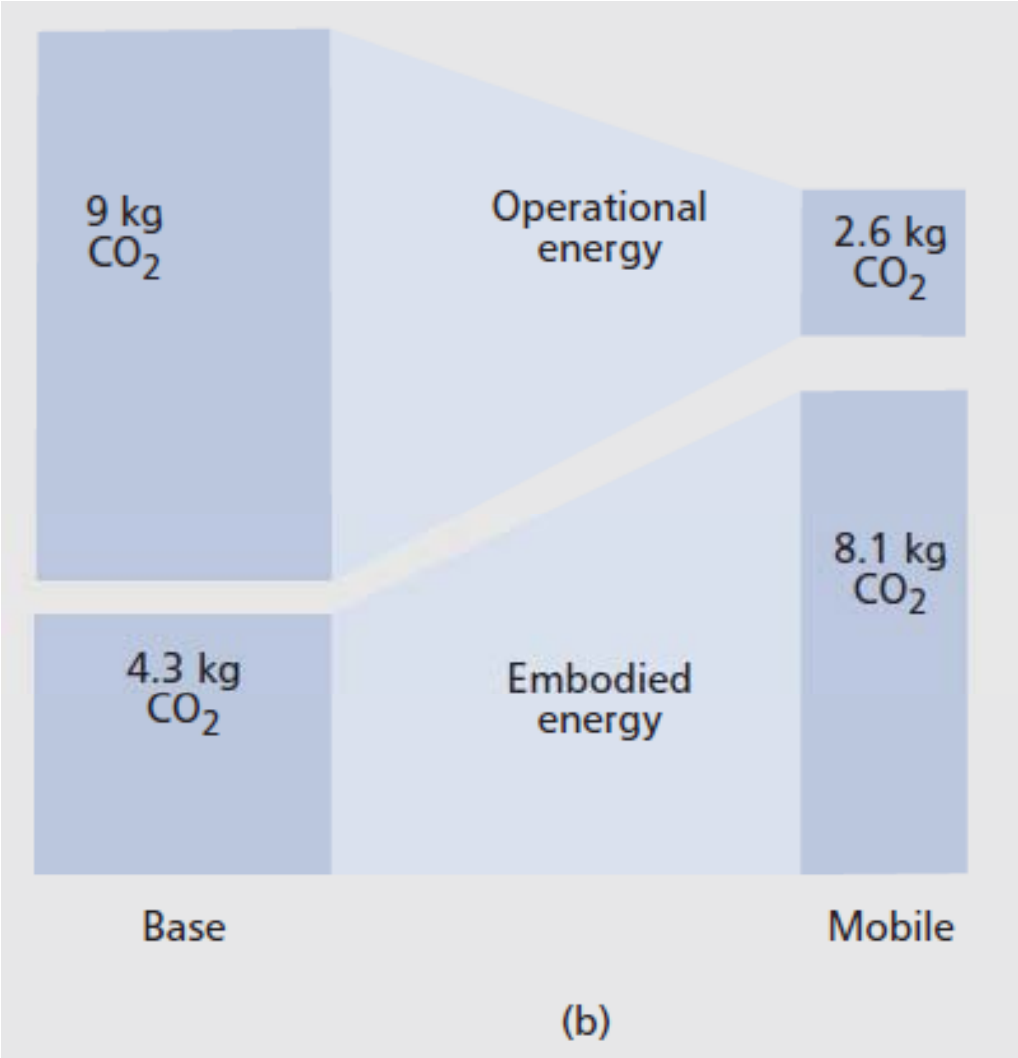


Fig. 1b. CO2 emissions per subscriber per year as derived for the base station and mobile handset



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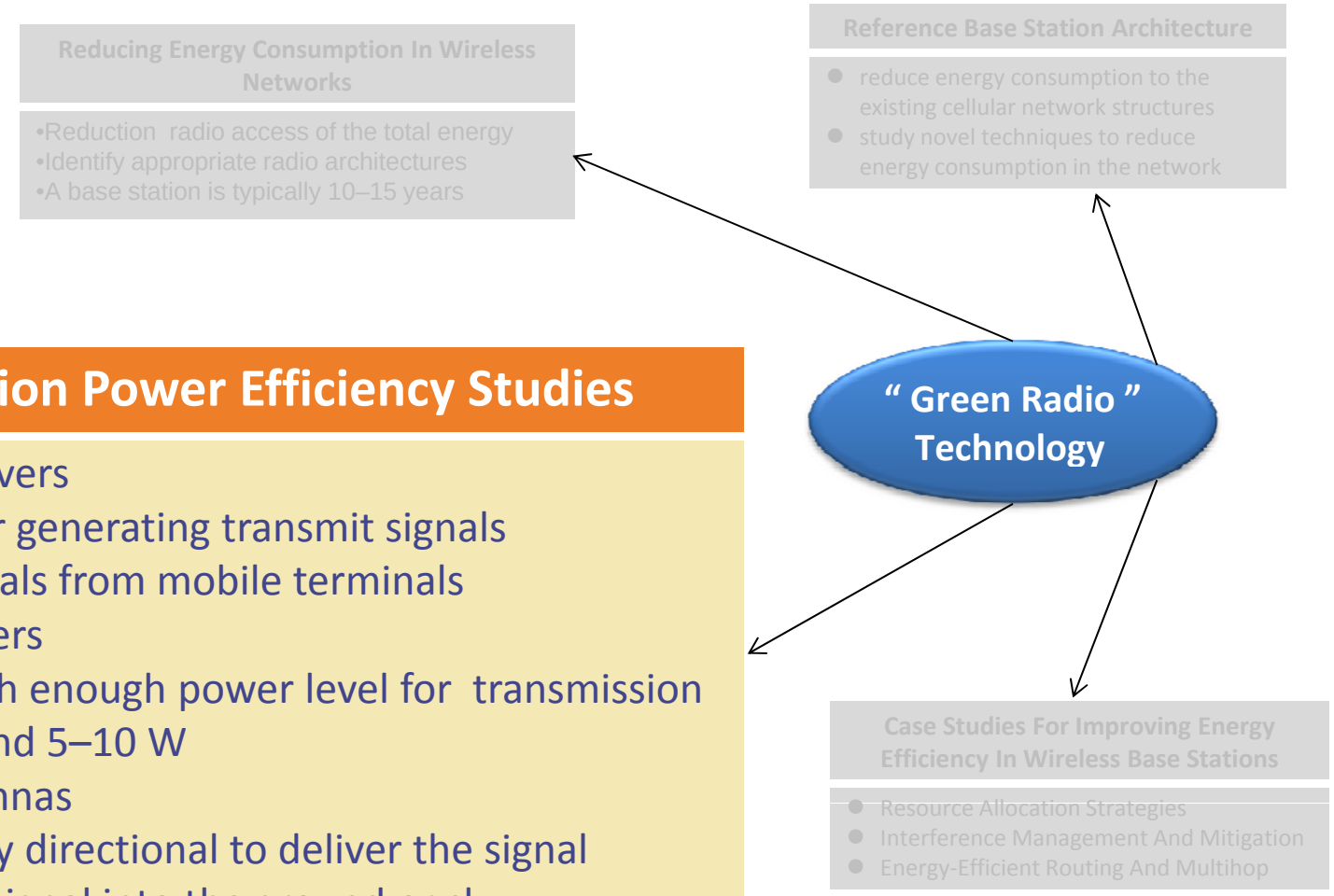

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3. Component of Base Station

- Radio transceivers:
  - The equipment for generating transmit signals to and decoding signals from mobile terminals.
- Power amplifiers:
  - These devices amplify the transmit signals from the transceiver to a high enough power level for transmission, typically around 5–10 W.
- Transmit antennas:
  - The antennas are responsible for physically radiating the signals, and are typically highly directional to deliver the signal to users without radiating the signal into the ground or sky.

Base Station Power Efficiency Studies

- Base stations also contain other ancillary equipment, providing facilities such as connection to the service provider's network and climate control.
- A major opportunity to achieve the power reduction targets of the program lies in developing techniques to improve the efficiency of base station hardware.

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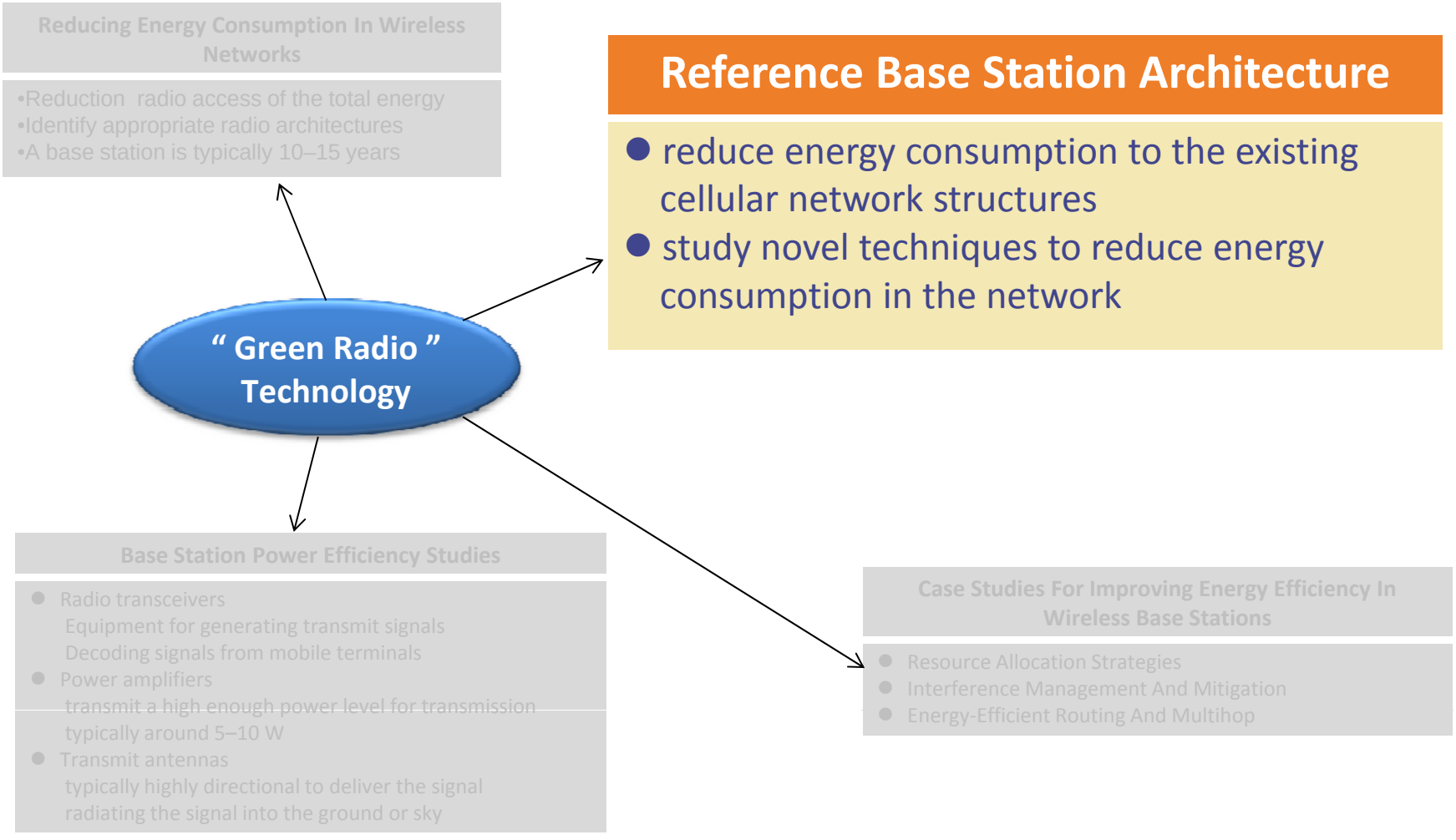
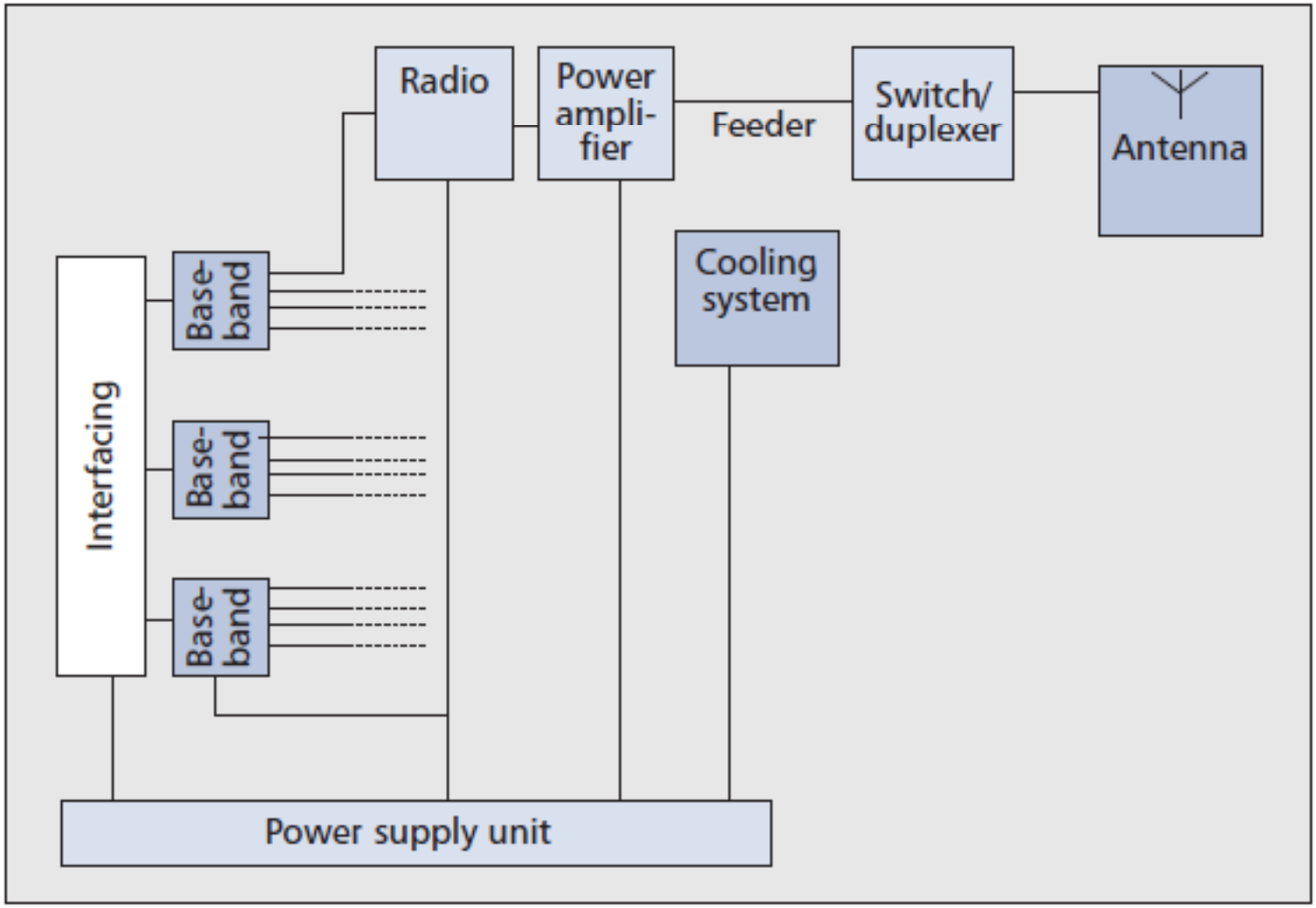


4. Reference Base Station Architecture

- The target system for the base station efficiency analysis is the LTE system with support for four transmit antennas.
  - This system can exploit the space domain to achieve high data throughputs through multiple input multiple output (MIMO) techniques.
- Base station Architecture show in Fig. 2.

Architecture	
Power supply unit	Power amplifier
Interfacing	Feeder
Base-band	Cooling system
Radio	Switch/duplexer
Antenna	

Fig. 2. Reference base station architecture for a system per sector



The target system for the base station efficiency analysis

- Pursuing energy reduction from two different perspectives.
  - The first is to examine alternatives to the existing cellular network structures to reduce energy consumption.
  - The second approach, is to study novel techniques that can be used in base stations or handsets to reduce energy consumption in the network.

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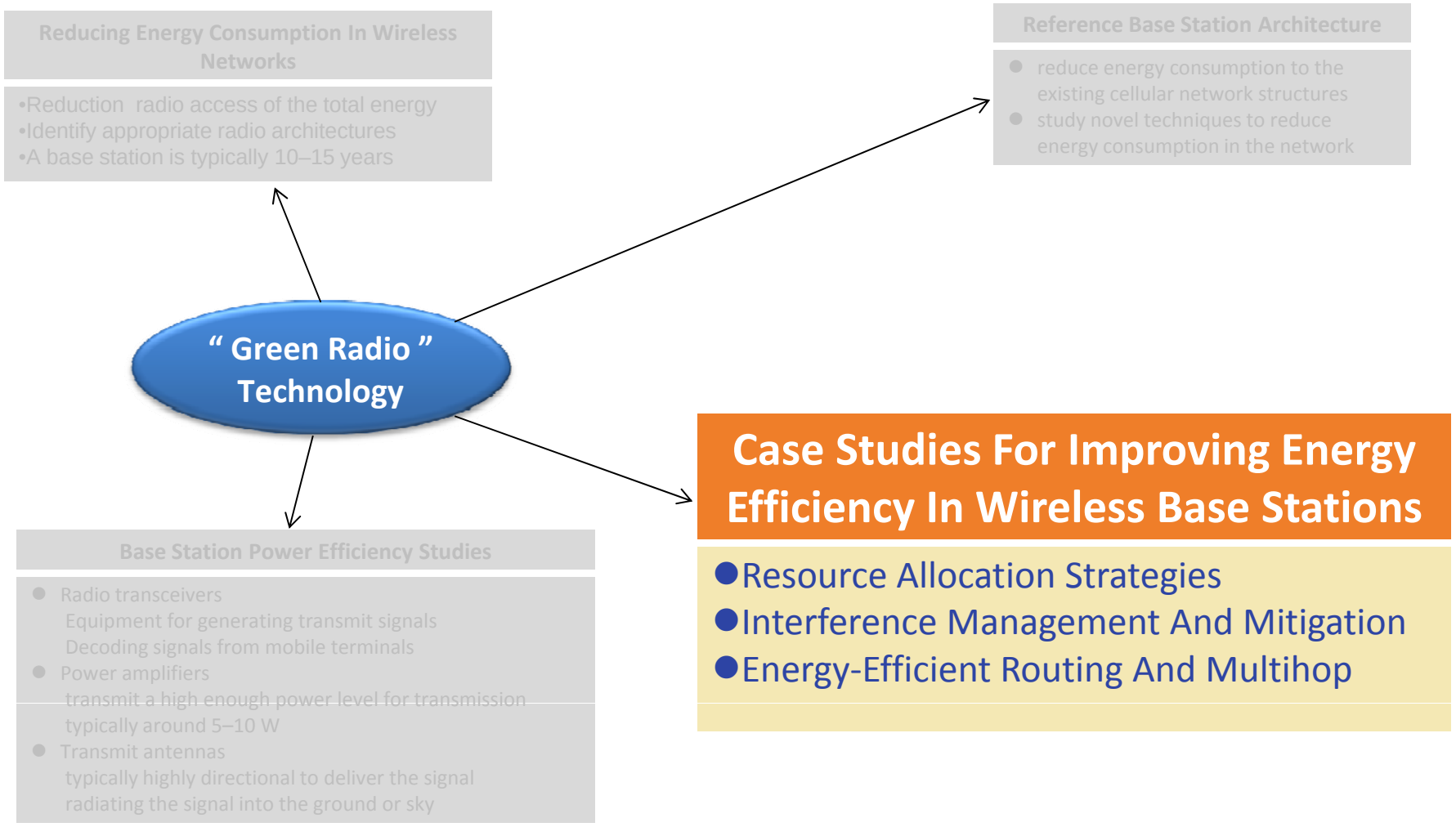


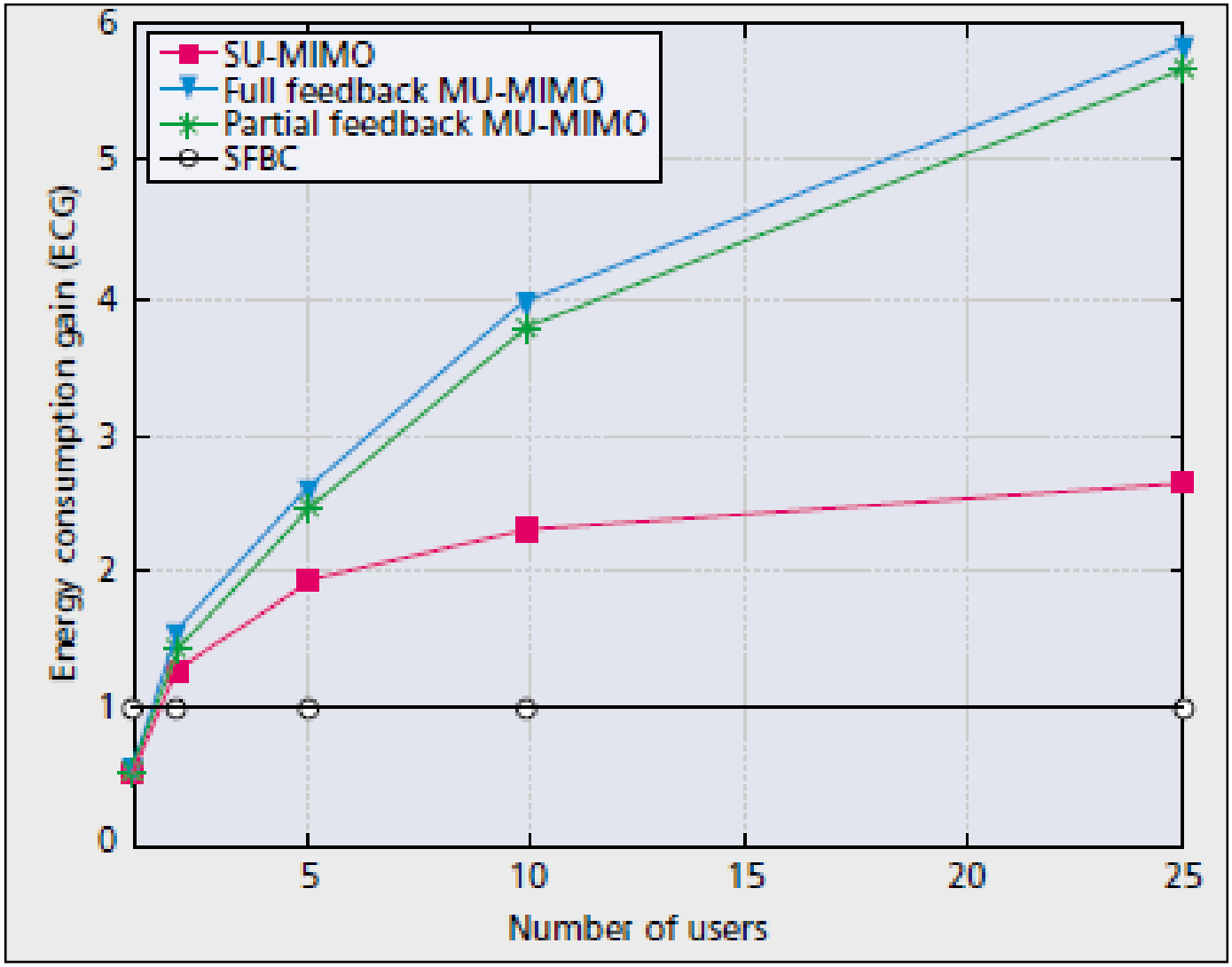
5.1 Resource Allocation Strategies

- RF amplifiers were identified as a key contributor to the overall energy consumption of a typical base station.
- This chapter use the term resource allocation to describe how the base station transmitter make the decision of how and when to transmit data to different users on the downlink (base-mobile link) within the cell it is serving.

Resource allocation techniques

- Make the most efficient use of the RF amplifier.
- Energy reductions could lead to further energy savings through switching off transceiver equipment and base station cooling.
- Shown in peak hours, 90 percent of the data traffic is carried by only 40 percent of the cells in the network.

Fig. 3. *Simulated ECG of various MIMO schemes, relative to SFBC all at 3 b/s/Hz spectral efficiency*



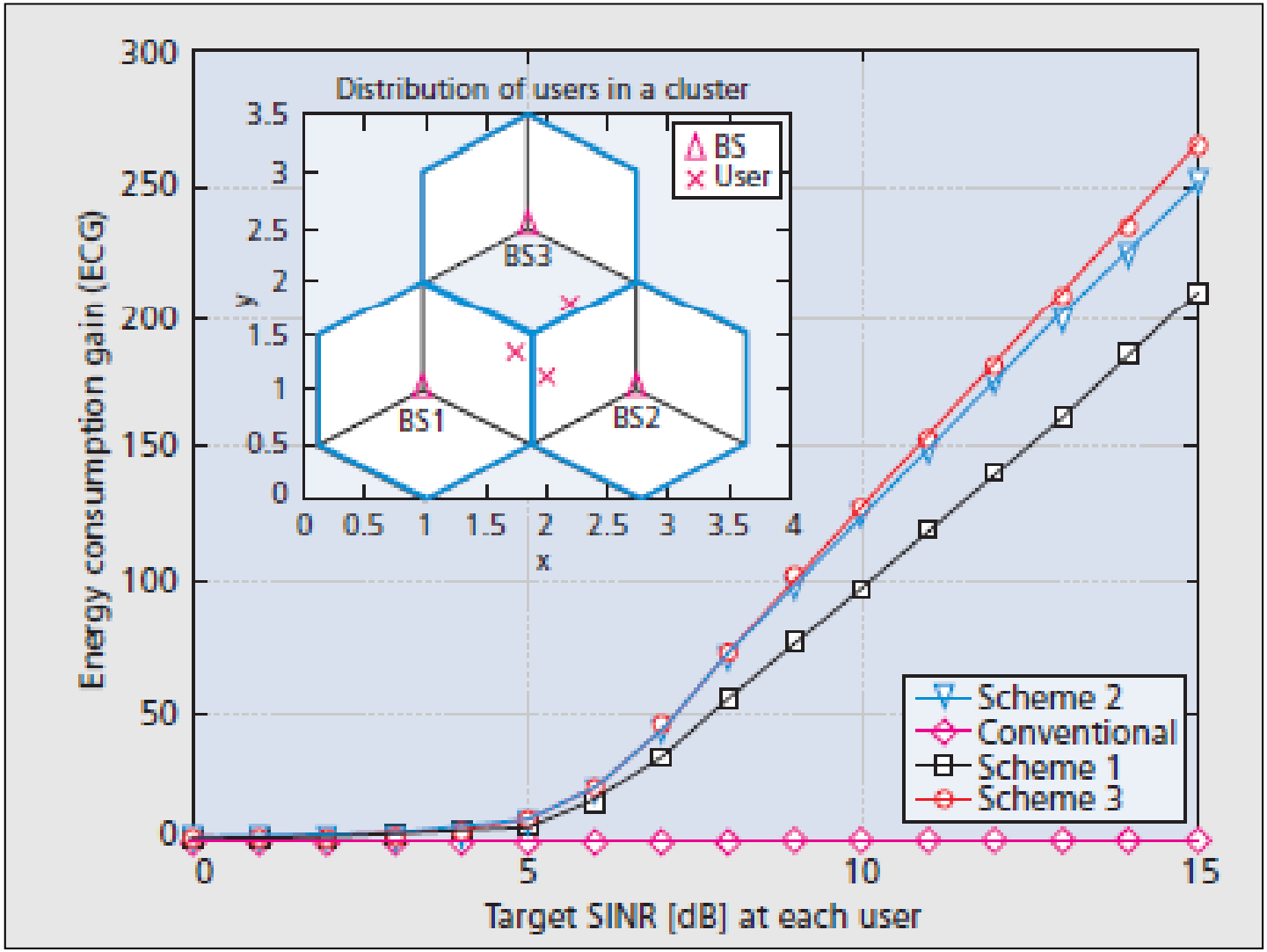
5.2 Interference Management And Mitigation

- The impact of interference is more severe as users move closer to the boundary region between two cells, leading to significant SINR and hence data rate reduction.
- Most existing interference cancellation schemes have been designed to increase the spectral efficiency and data rate, while overlooking energy efficiency.

Four different schemes

- Scheme 1 : the user is served by the base station providing the highest SINR while other base stations avoid transmitting signal energy toward that user.
- Scheme 2 : all users are served by multiple base stations using multiple antenna beam forming and coherent user-end combining.
- Scheme 3 : Users are allocated to one or more base stations based on their position.

Fig. 4. *performance comparison of three schemes, plotting ECG vs SNR.*



Result for Interference Management And Mitigation

- These three schemes are compared in terms of ECG vs. SINR against the conventional no cooperative case in Fig. 4 for a cluster of three cells with one user per cell.
- The picture show that all three schemes significantly outperform the conventional system at high SINR, with schemes 2 and 3 outperforming scheme 1.

5.3 Energy-Efficient Routing And Multihop

- Use relays to exchange information between a base station and a mobile terminal may be an efficient way to improve base station energy efficiency.
- This is because the transmission distance can be reduced, increasing data rates or permitting reductions in transmission energy.

Important future target for the work in area.

- One important future target for the work in this area is to be able to compare the energy efficiency of relay techniques with the use of femtocells.
- Relays provide a connection to the Internet through the nearest wireless base station.
- Conversely, femtocells are small low-powerbase stations installed in the home or office that use a wired Internet connection to provide service.

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- The result has described the approach being taken in the Mobile project to study novel approaches to reducing the energy consumption of wireless links, particularly in improving the design and operation of wireless base stations.
- Proper modeling of the energy consumption of base stations has been shown to be an important issue when trying to obtain a clear view of how different radio technologies can reduce energy consumption.

Homework#1

1) Please show some case studies of improving energy efficiency in wireless base stations.

2) Please provide possible schemes of interference management and mitigation for the base station.

3) Please provide some perspectives of energy reduction for the base station efficiency.