Wireless Relays for Broadband Access

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Outline

- Background
- Concept of Relaying
- Multihop Relaying for WiMAX Networks
  - Topology
  - Radio Interface and Frame Structure
  - Path Management and Routing
  - Radio Resource Management
- Impact on Network Planning
- Example of Deployment Cost Analysis
- Conclusions and Issues

Background

- The broadband market includes two segments
  - Wire-line : DSL and FTTH;
  - Wireless : HSPA, WiMAX (UMB), 3G (LTE)

- Overall broadband market shows that wireless broadband system will grow significantly
  - 17% (69M / 407M, 2008)

  => 48% (568M / 1.175B, 2012)

- The rate of growth will slow down as soon as markets reach their saturation points
  - Due to the number of wired access available

Background

- Some first tier European mobile operator suggests that operational expenditure (OPEX) will increase if the cell exploited its maximum capacity
  - 19% (over all cost) to 80% for delivering a bit to end user
- More issues
  - Next-Generation Mobile Networks (NGMN) are limited range to higher operation frequency
    - Coverage[1GHz] = 4 * Coverage[2GHz] = 10 Coverage[3GHz]
  - Data rate decreased if the distance from a BS to increases
  - Quality of end-user experience depends on where the terminal is located in a cell
- Total cost of ownership (TCO) increases dramatically

Background

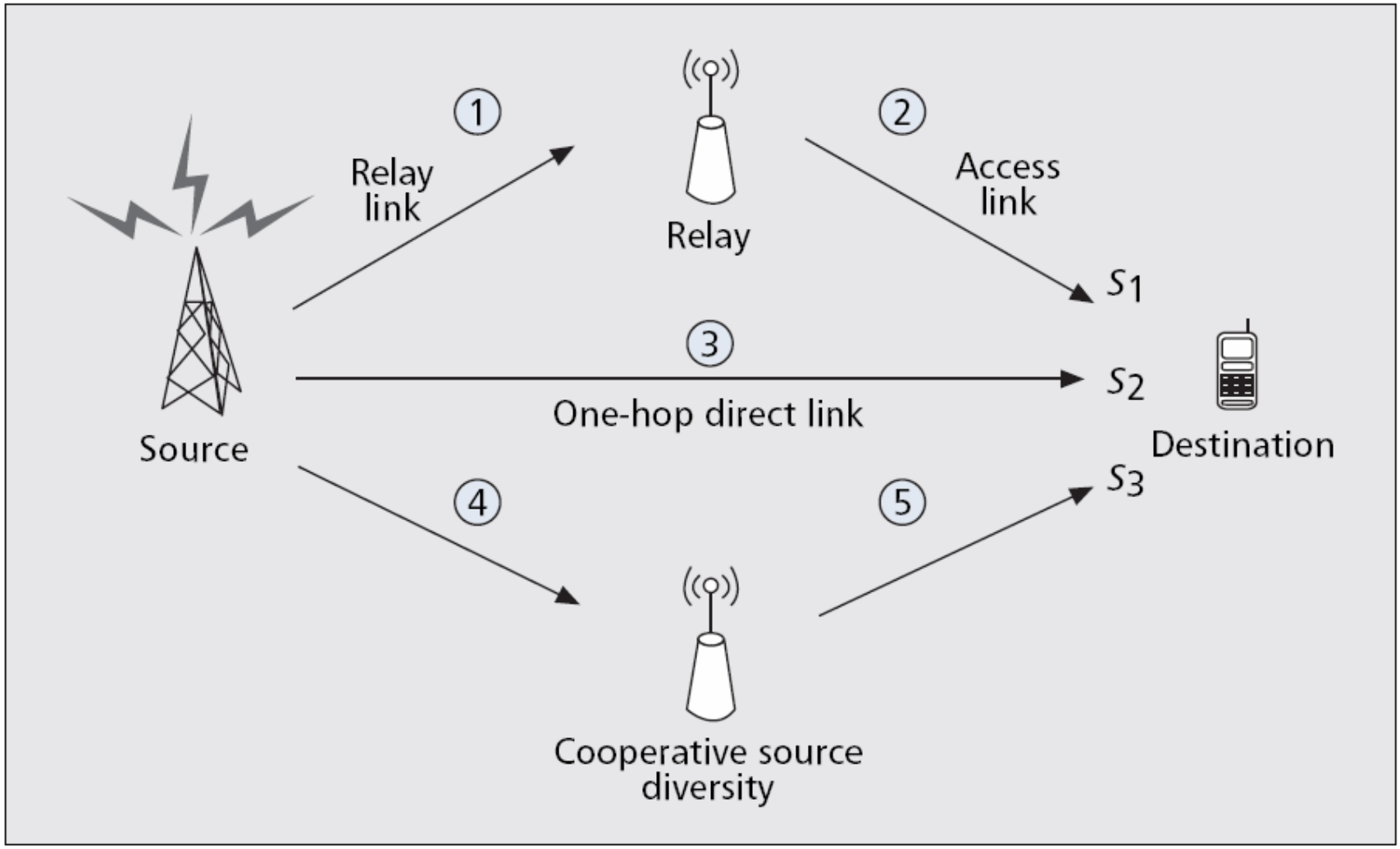
- Deployment concept based on layer 2 relay nodes appears to be the promising solution
  - Low-cost for both short-range and wide-area

- Reasons
  - Do not need a wired background access
  - Reducing deployment costs
    - Capital expenditures (CAPEX)
    - Operating expenditures (OPEX)
  - Offering high flexibility in placing relays
  - Allowing fast network rollout
  - Adaptive traffic capacity engineering

Concept of Relaying

- The relay system consists
  - Three-node relay model
    - One source
      - e.g. mobile multi-hop relay-base station (MMR-BS)
    - One relay
      - e.g. fixed relay station (FRS), nomadic relay station (NRS) or mobile relay station (MRS)
    - One destination
      - e.g. mobile station (MS), or user-terminal (UT)
  - Two kinds of links
    - Relay link
      - Physical channel between source node and the relay
    - Access link
      - Physical channel between relay and the destination

Three-node relay network and cooperative relaying

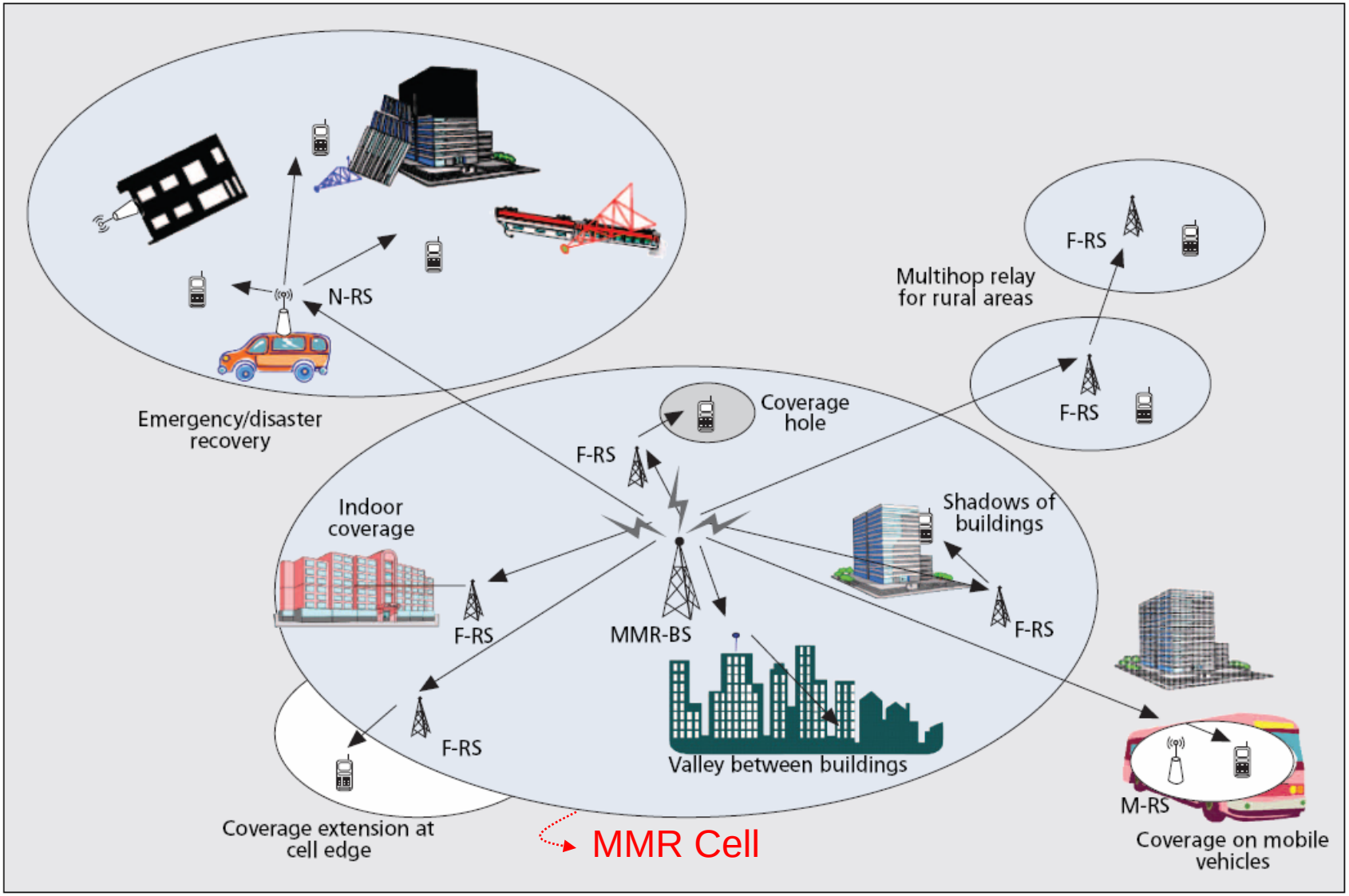


Concept of Relaying

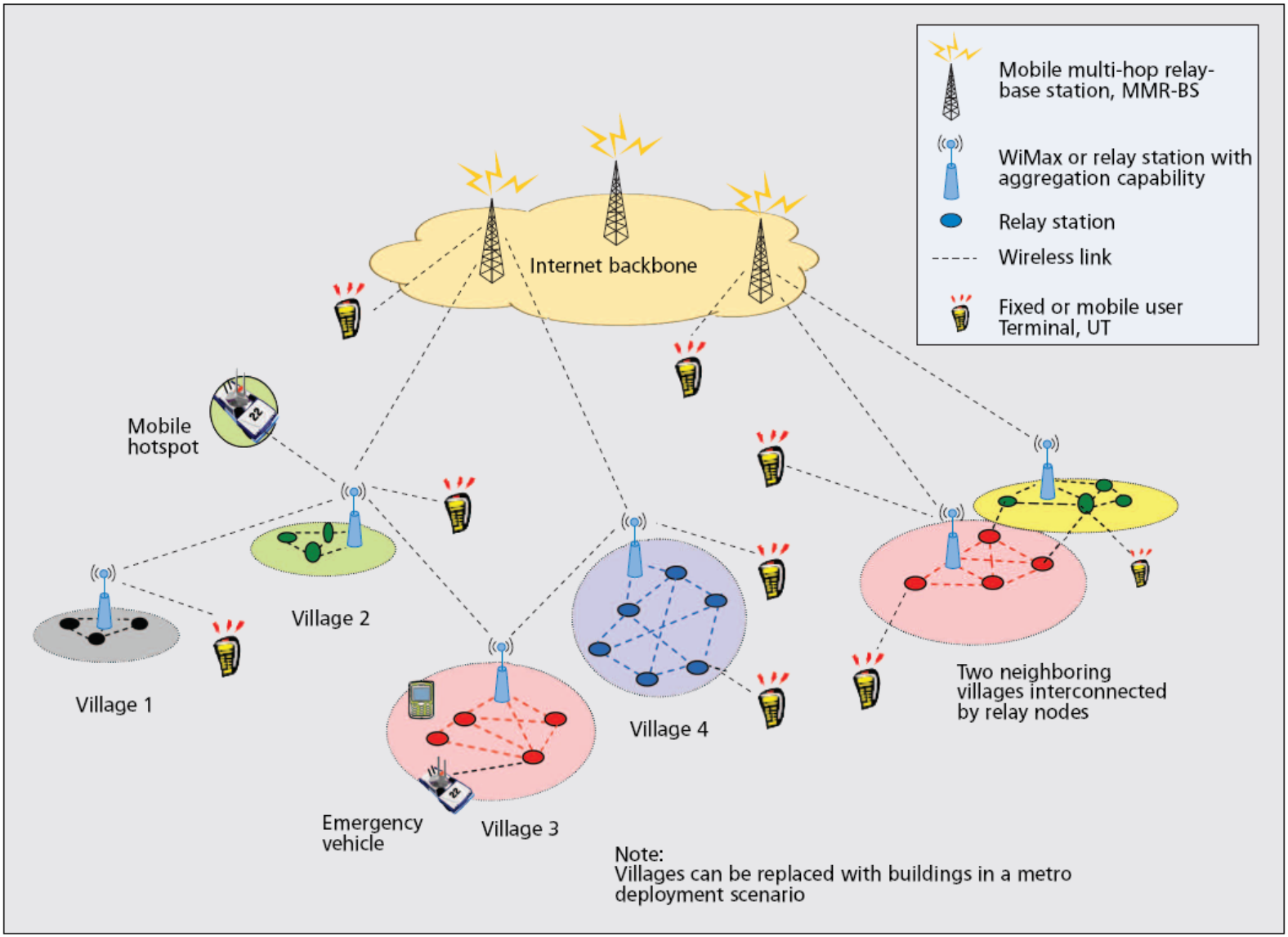
- The relay normally works in half-duplex mode
  - Station does not receive and transmit using the same channel at the same time
- All data communications may occur between MMR-BS and UTs directly , or through one or more RSs
- Downlink and uplink communications between MMR-BS and UTs can be symmetric or asymmetric

- The relay may operate in three schemes
  - Amplifying and forwarding (AF)
    - Analog repeater
  - Decoding an forwarding (DF)
    - Digital repeater
  - Estimating and forwarding (EF)
    - Hybrid solution

Example of Usage Scenarios



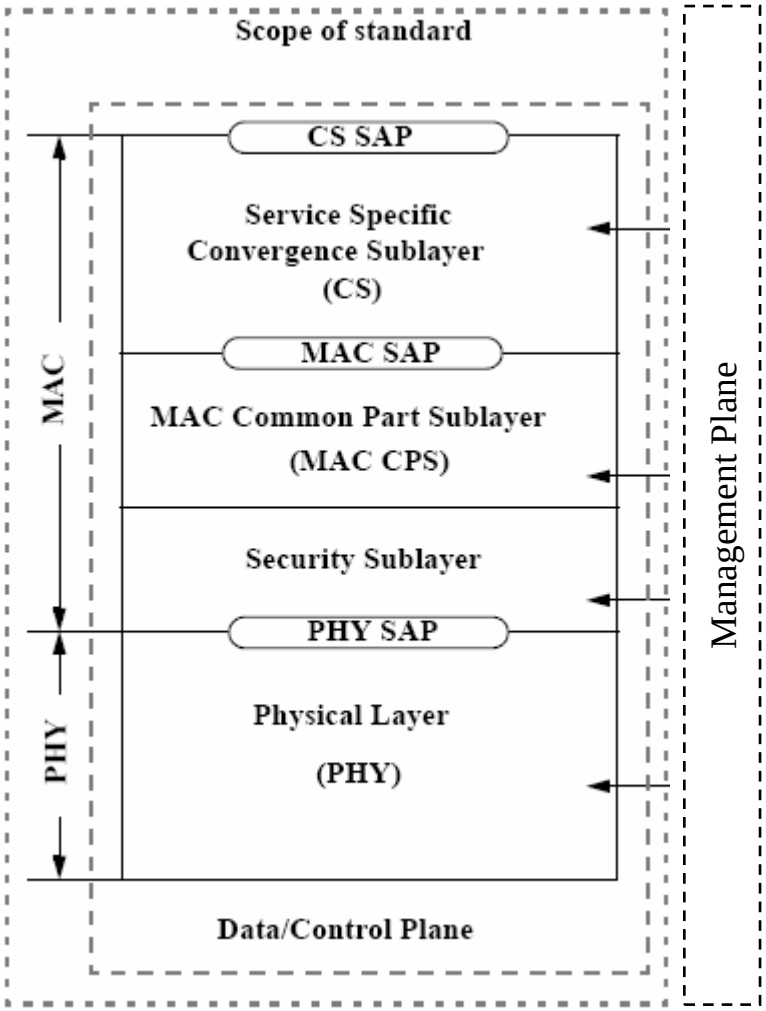
A Use Case Scenario of Rural Deployment



Multihop Relaying for WiMAX Networks

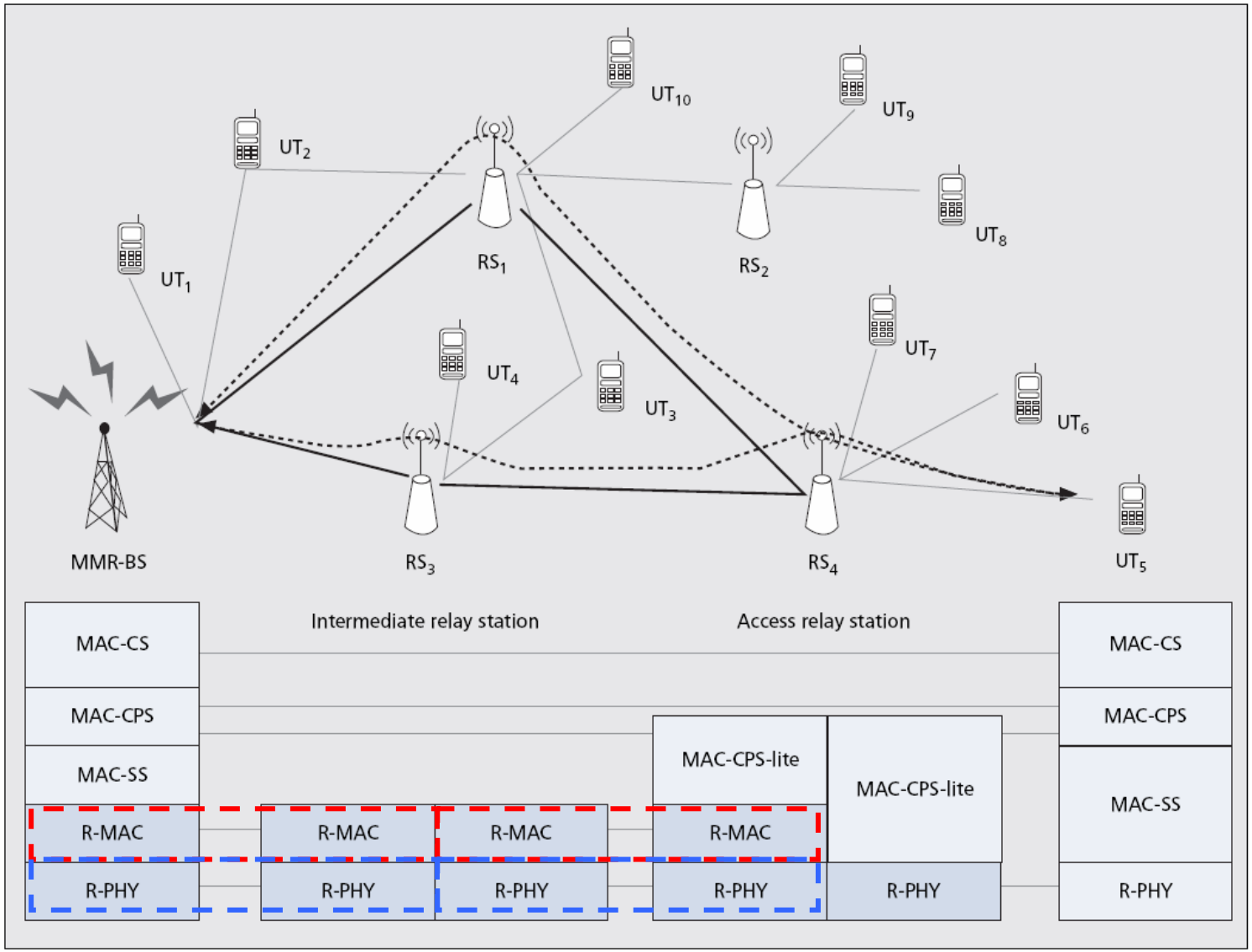
- Overview of IEEE 802.16j system
  - Propagation condition
    - Line of sight (LOS) and non-line of sight (NLOS)
  - Duplex mode
    - TDD or FDD
  - Relaying method
    - In-band or out-of-band relaying
  - Resource allocation
    - Centralized or distributed control
  - Security model
    - Centralized or distributed model
  - Data forwarding
    - Tunnel and non-tunnel mode
  - HARQ
    - End-to-end and hop-by-hop HARQ
  - ARQ
    - End-to-end, two segments, or hop-by-hop ARQ
  - Usage scenarios
    - RS can be own by operator or the customer
  - RS types
    - FRS
      - Improve coverage capacity or per user throughput
    - NRS
      - Temporarily to provide additional coverage or capacity
    - MRS
      - Can be mounted on a vehicle and connected to an MMR-BS or RS via mobile link

Reference Model

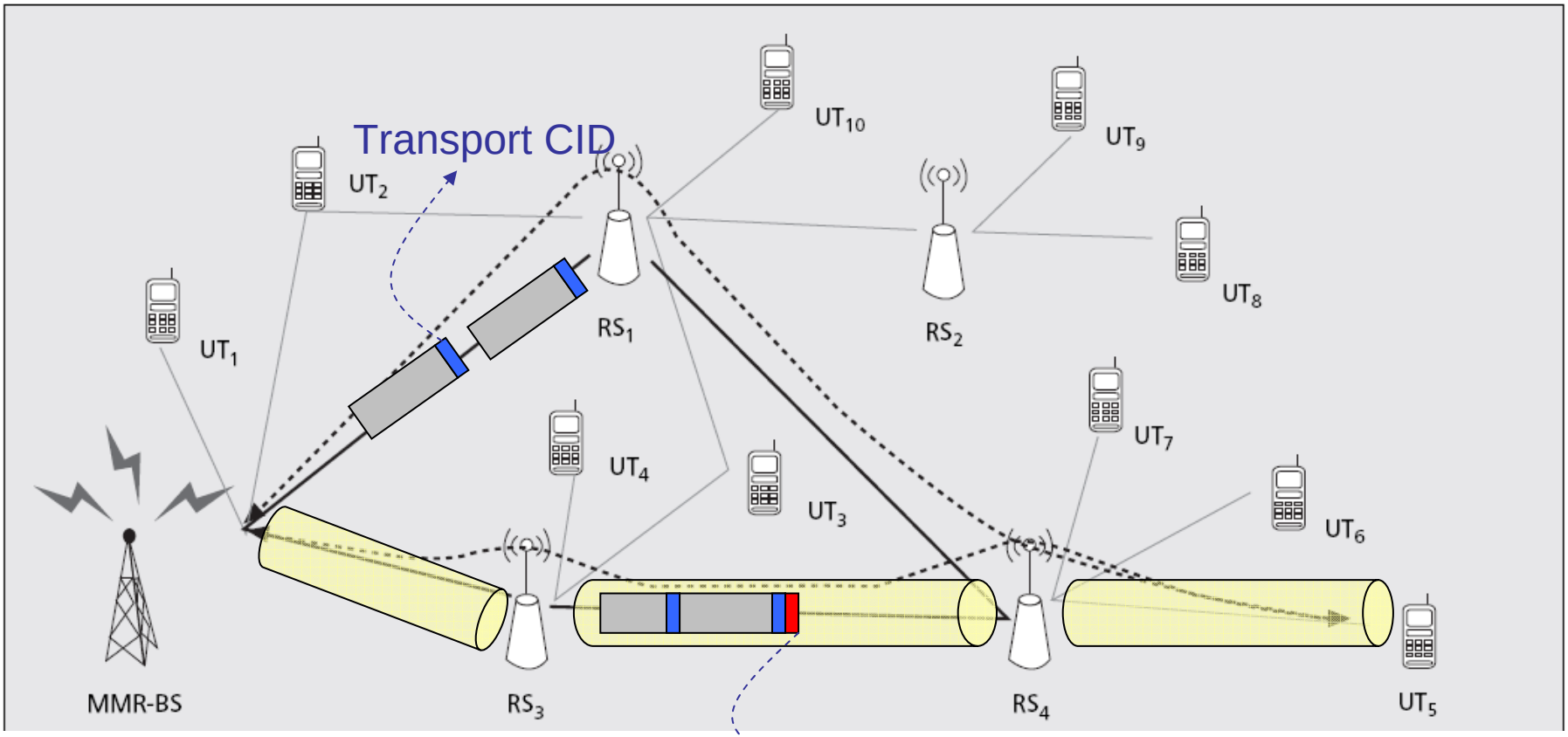


- Service Specific Convergence Sublayer (CS)
  - Mapping upper-layer data into MAC SDUs
  - Upper-layer data traffic classifications
  - Payload header suppression (PHS) - optional
- MAC Common Part Sublayer (CPS)
  - System access control
  - MAC PDU encoding and decoding
  - Bandwidth management
  - QoS provision
- Security Sublayer (SS)
  - Authentication
  - Security key exchange
  - Encryption

Example of Network Topology and Protocol Stacks



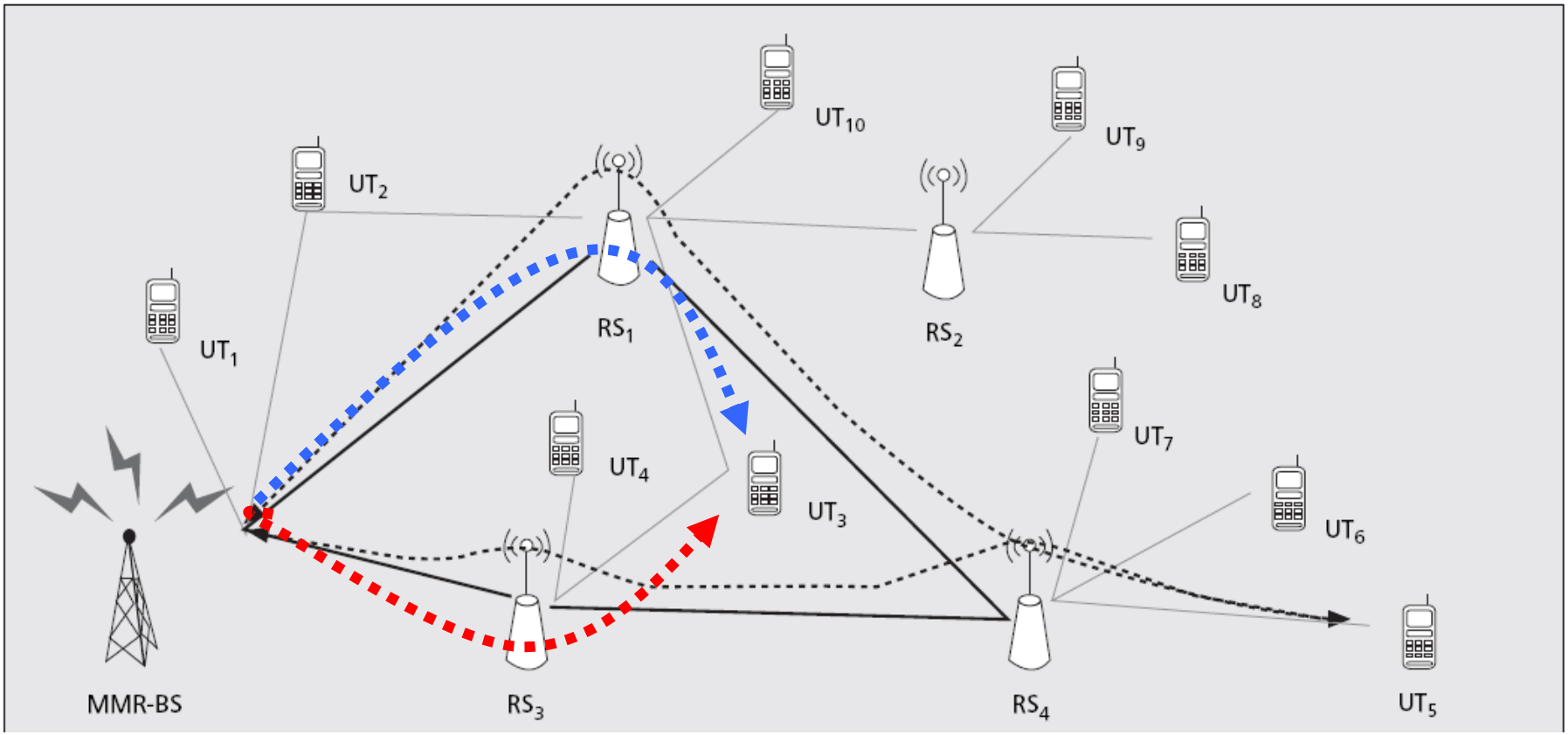
Data Forwarding - Tunnel



Tunnel

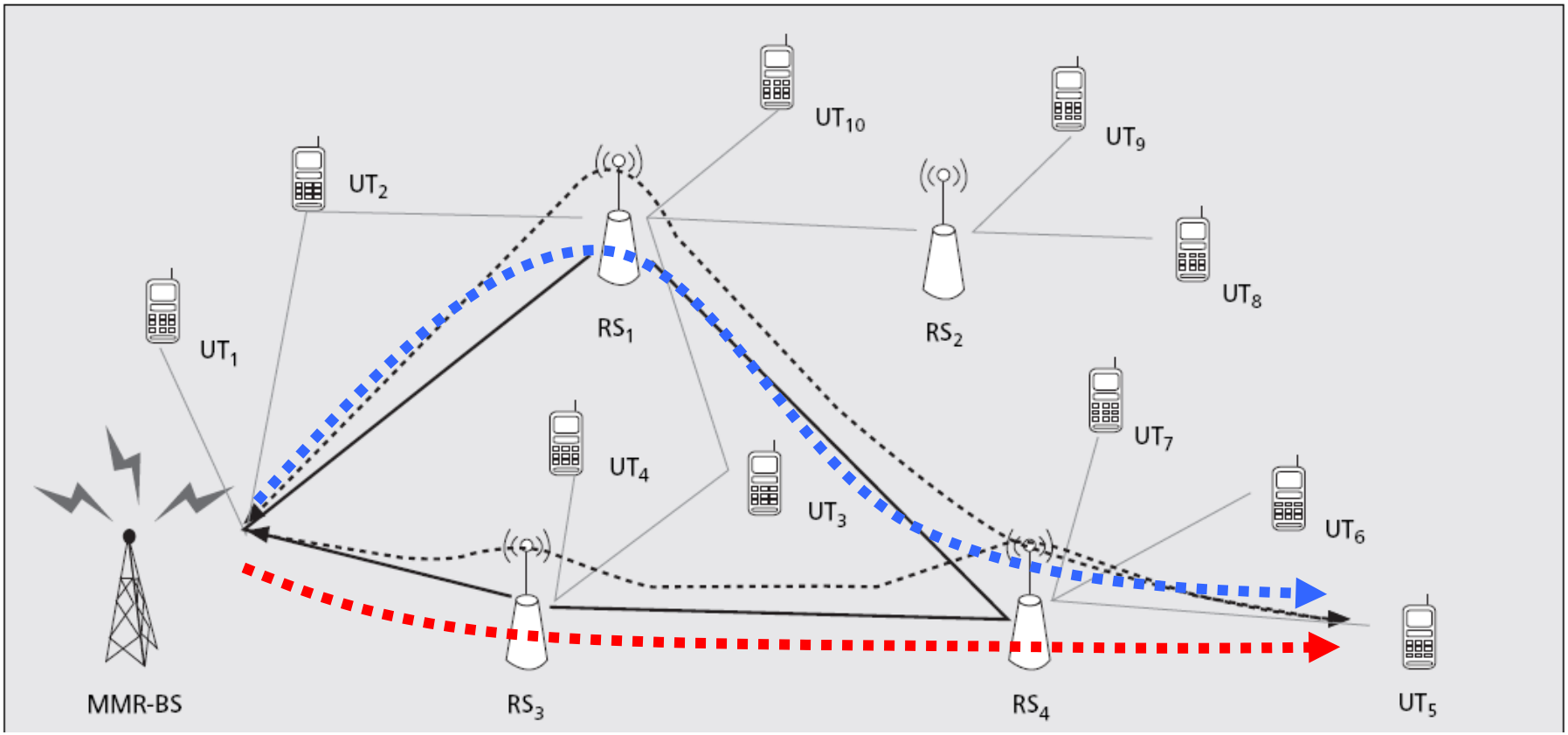
[Issue] Overhead vs efficiency

Data Forwarding - Routing



[Issue] Route Decision

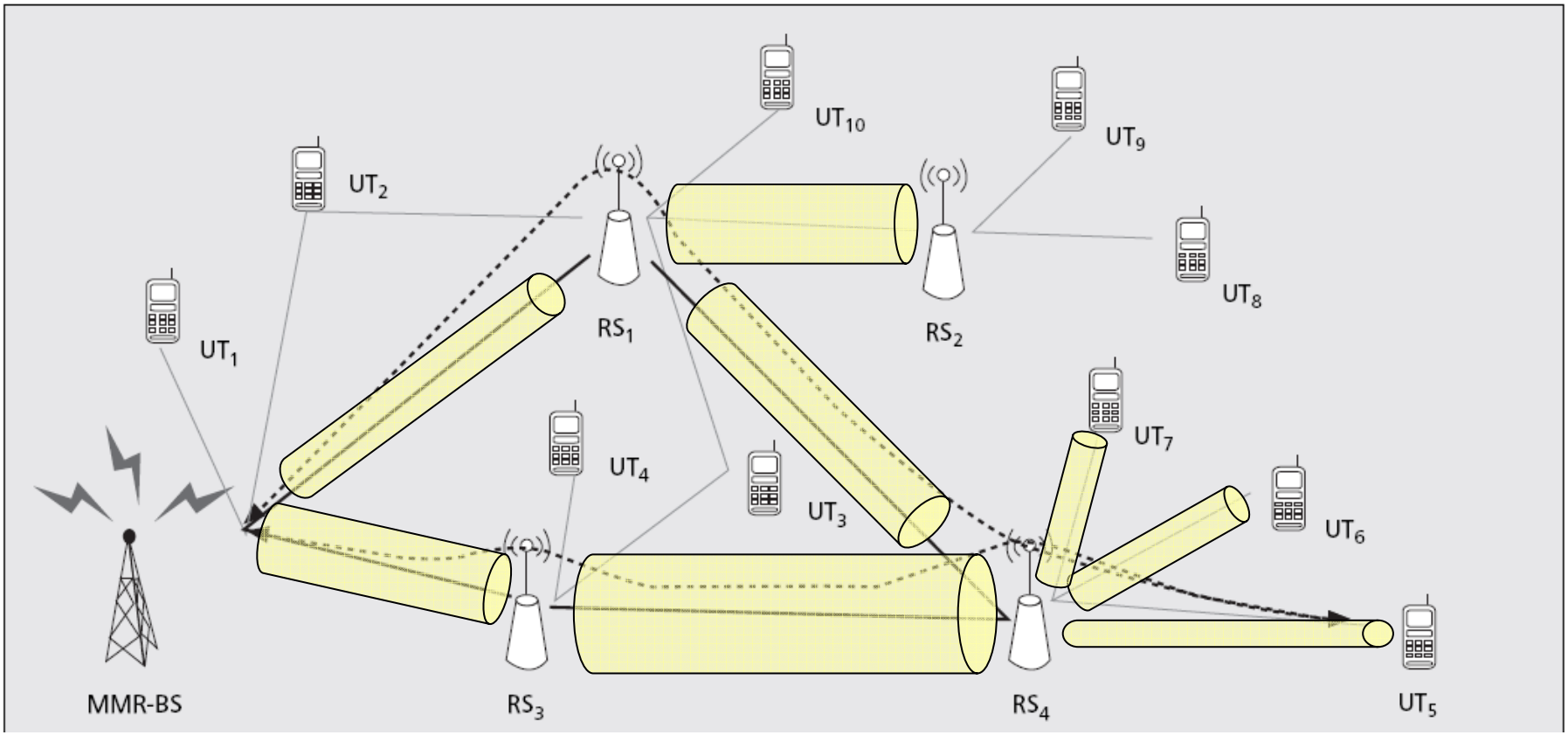
Data Forwarding – Load Balance



[Issue] Dynamic Routing Algorithm

Radio Resource Management – Centralized Control

MMR-BS broadcast MAPs to all the RS in the MMR cell

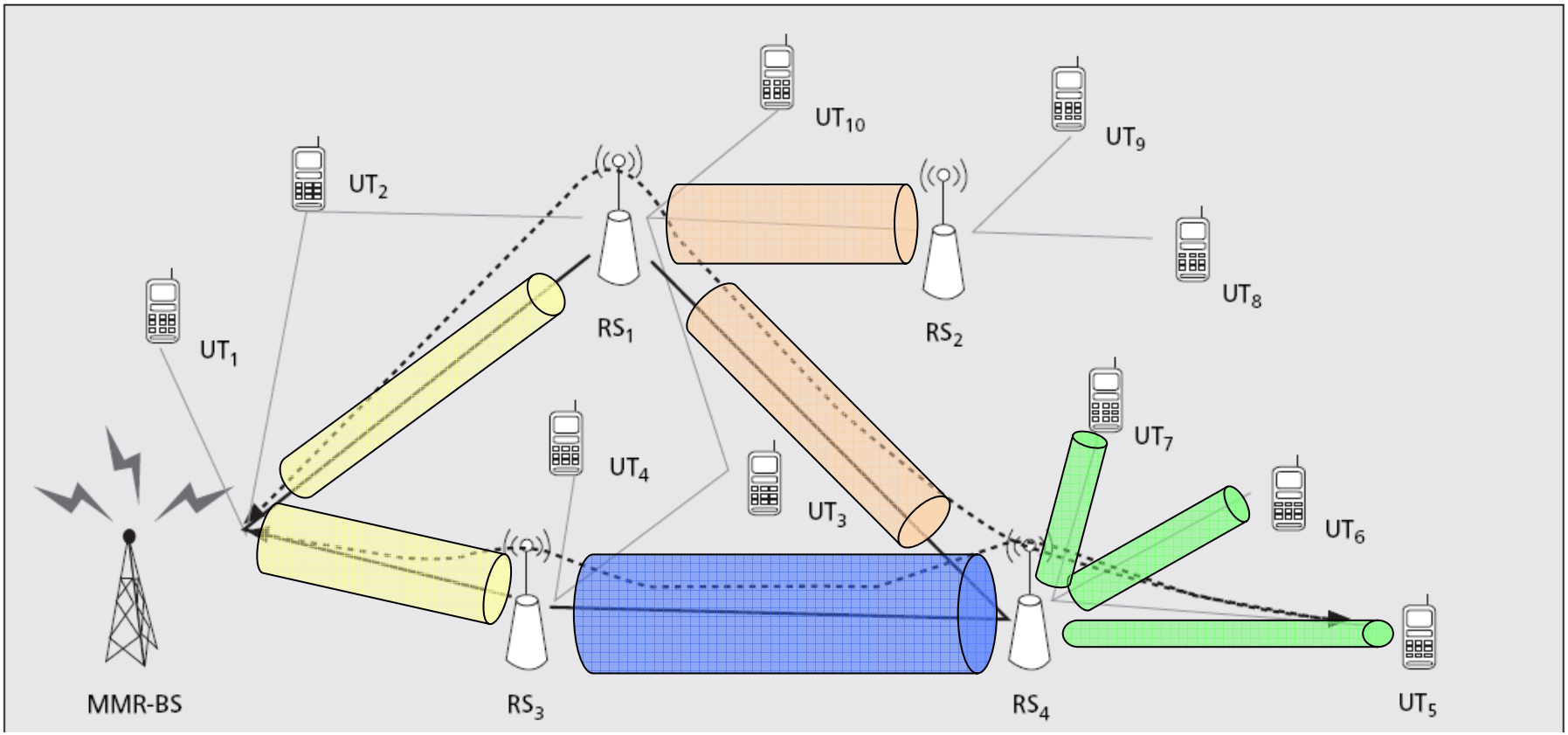


Radio Resource

[Issue] Scheduling Algorithm

Radio Resource Management – Distributed Control

MMR-BS and RSs broadcast MAPs to its sub-ordinate stations

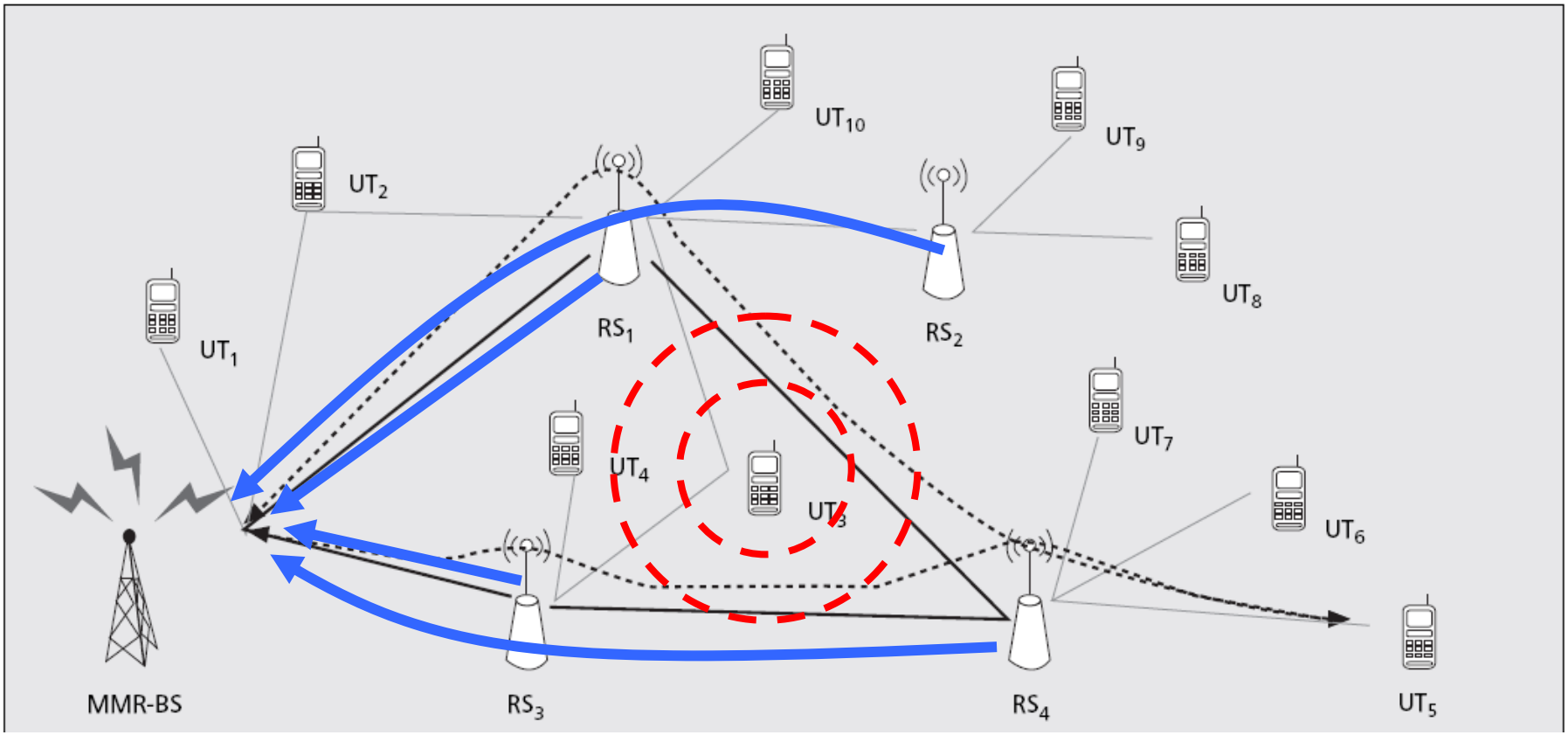


Radio Resource

[Issue] Scheduling Algorithm

Radio Resource Management – Network Entry/Re-entry

Measurement report

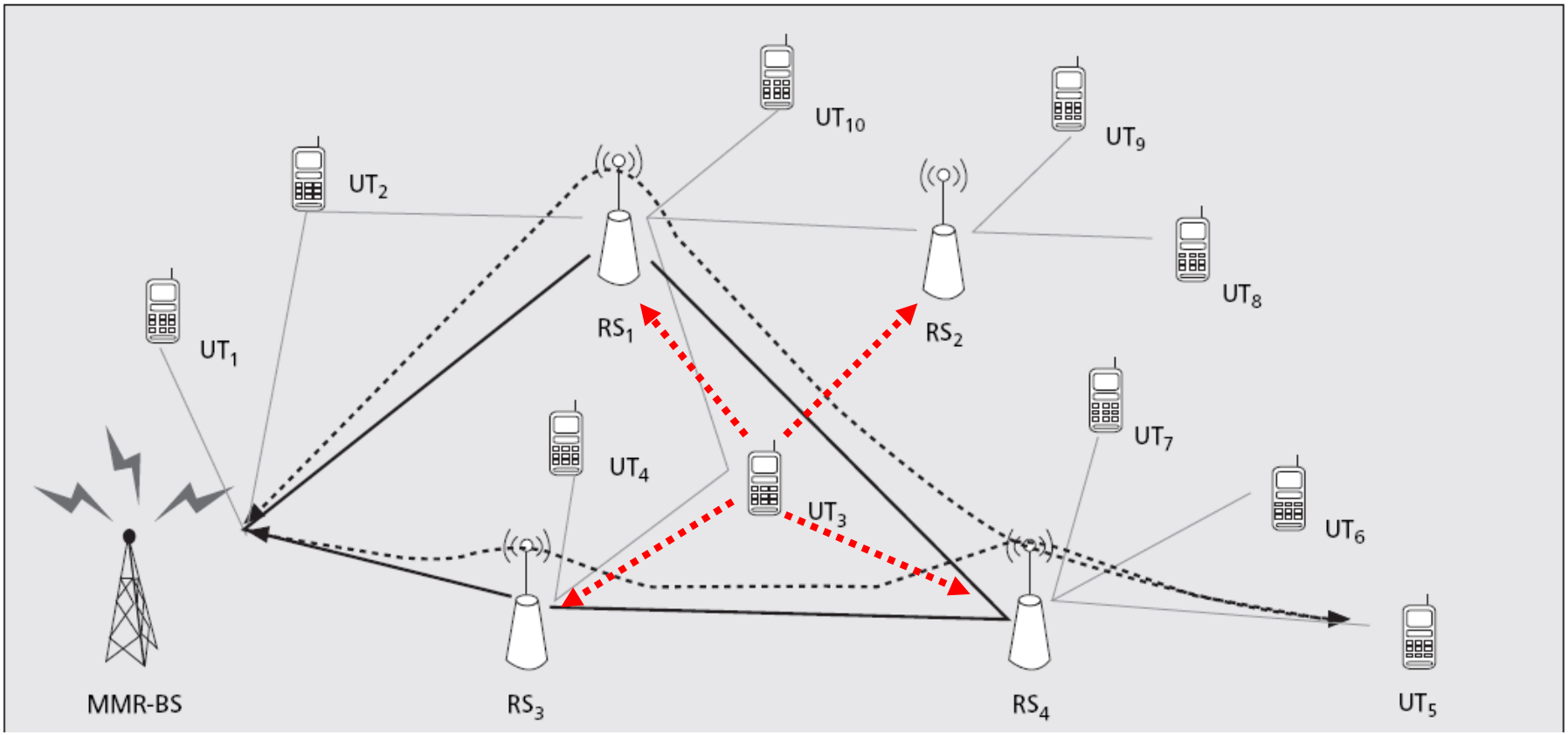


Report Path

[Issue] Network entry and report

Radio Resource Management – Handover Control

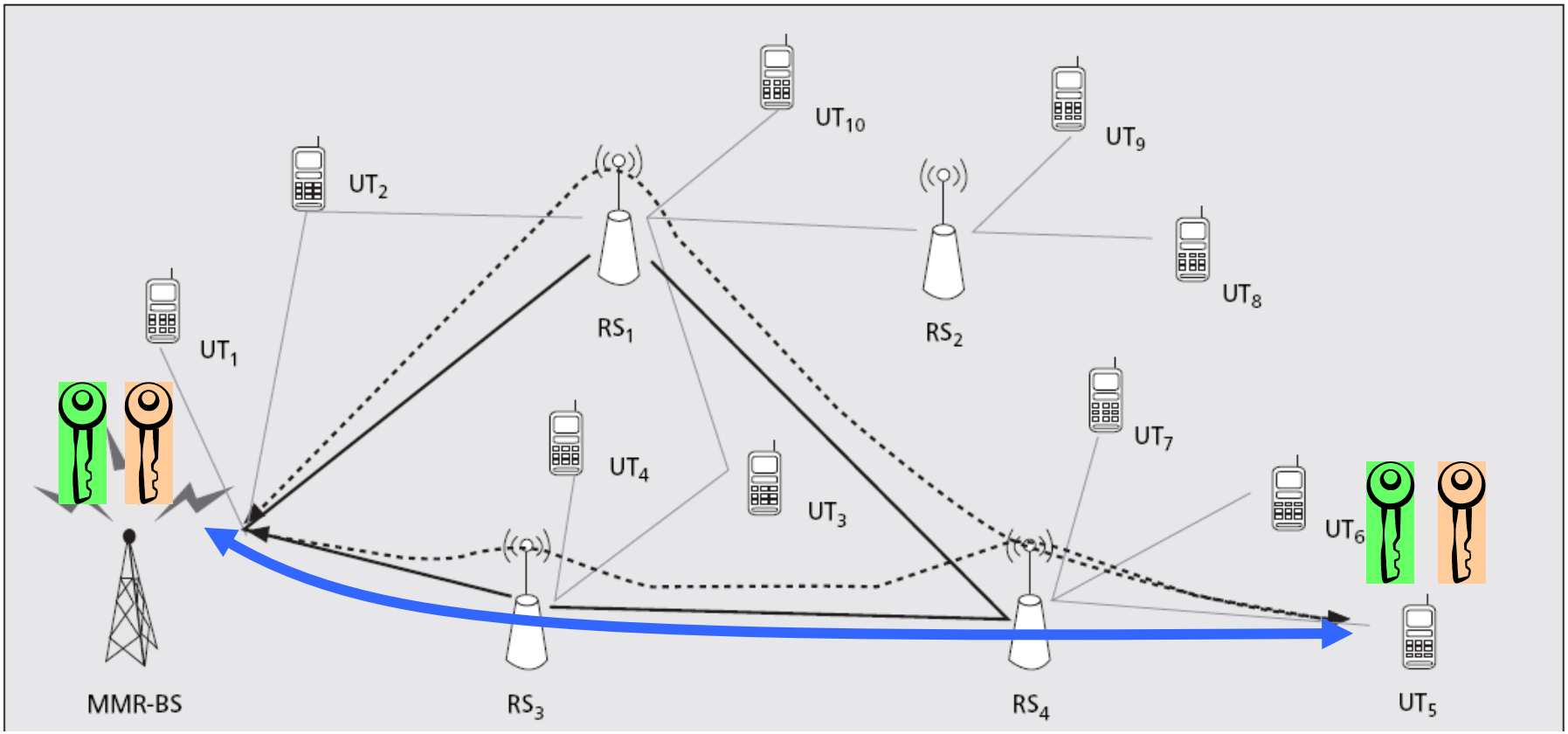
Handover decision : RSSI, radio resource, routing, etc….



Indication

[Issue] Handover decision

Security Management – Centralized Model



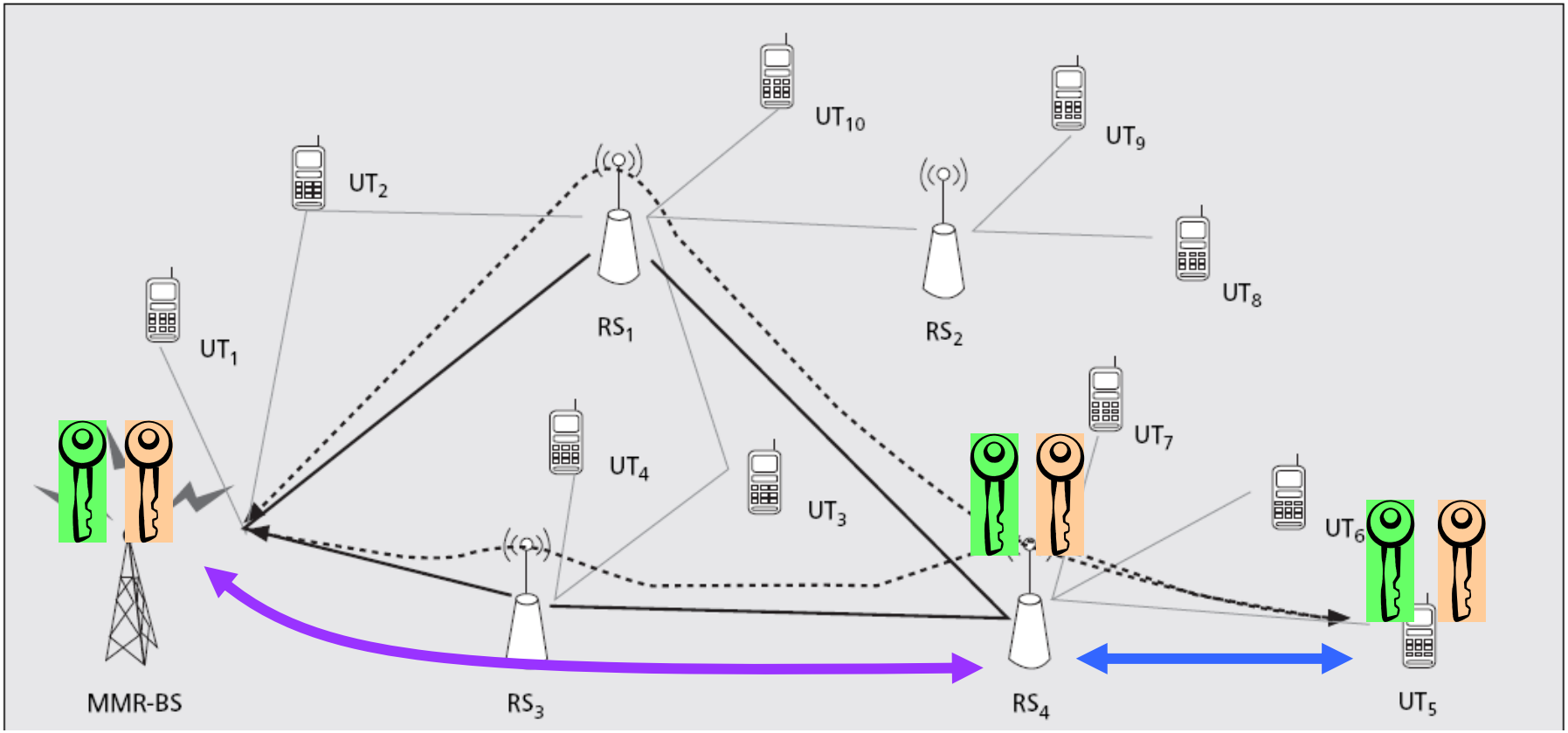
Master Key

Traffic Key

Security Association

[Issue] Computation Complexity

Security Management – Distributed Model



Master Key

Traffic Key

Security Association

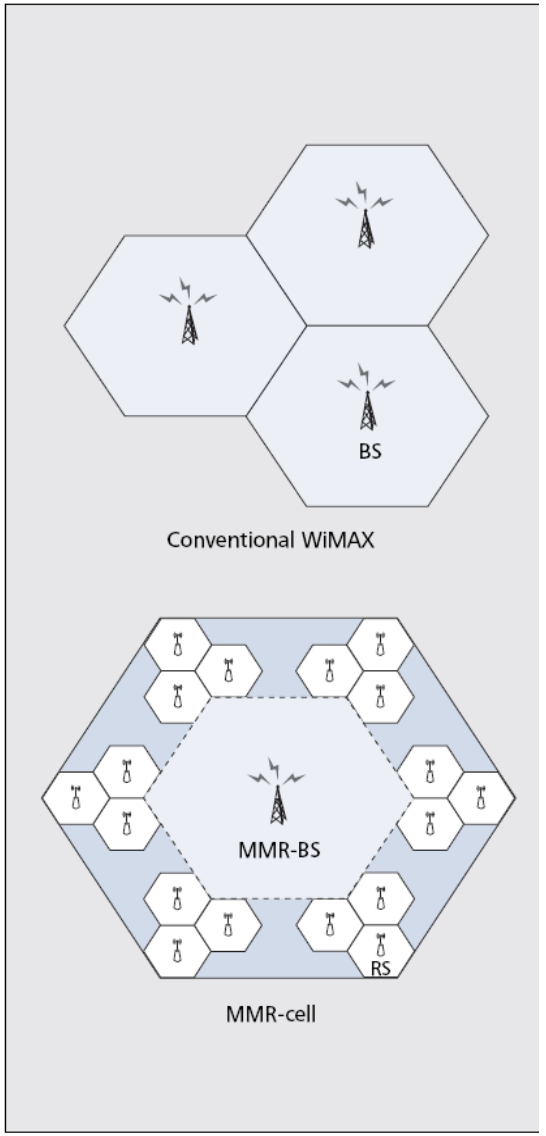
[Issue] Mutual Authentication and Key Management

Impact on Network Planning

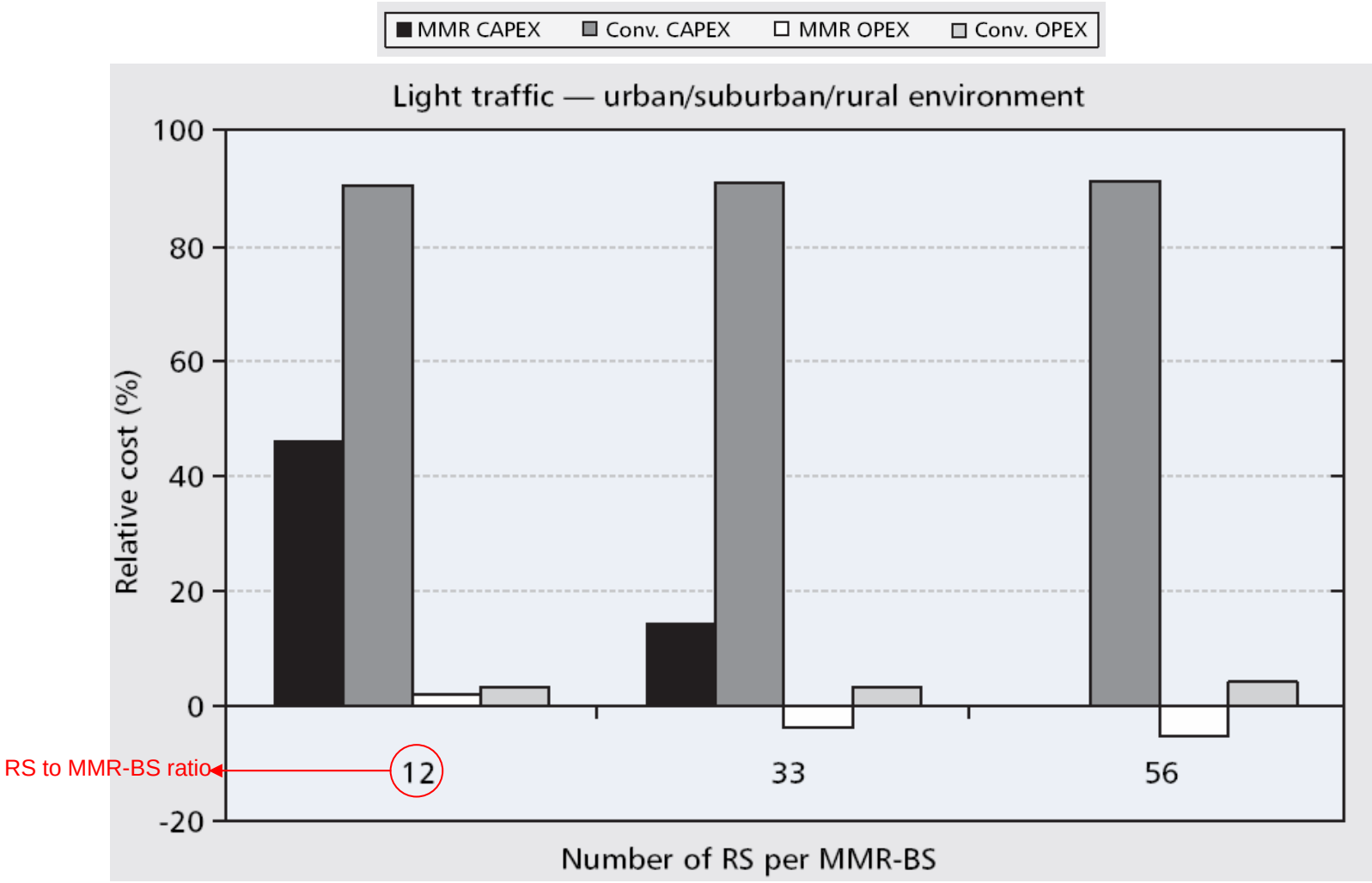
- The network planning process consists of the following phases
  - Pre-planning
    - Criteria for deploying wireless relays are agreed on with customers
    - Encompass the definition of traffic, service, network topology and deployment scenarios, and coverage
  - Planning
    - Calculate coverage range and estimate of the number of MMR-cells based on average SINR distribution
  - Detailed planning
    - Make use of a tool for combined coverage and capacity computation
  - Acceptance and Optimization
    - Additional MMR parameters are set and fine-tuned based on service and network performance measurements

Example of Deployment Cost Analysis

- This study discusses the relative CAPEX and OPEX of an MMR approach vs. conventional WiMAX deployment at 3.5 GHz
  - Scenario
    - Urban environment with heavy traffic
    - Urban, suburban, rural environment with light traffic
  - Spectral efficiency
    - 5 b/s/Hz for WiMAX BS and MMR-BS
    - 2 b/s/Hz for RS
  - CAPEX consists of site acquisition and construction costs per cell, wired backhaul costs and station costs

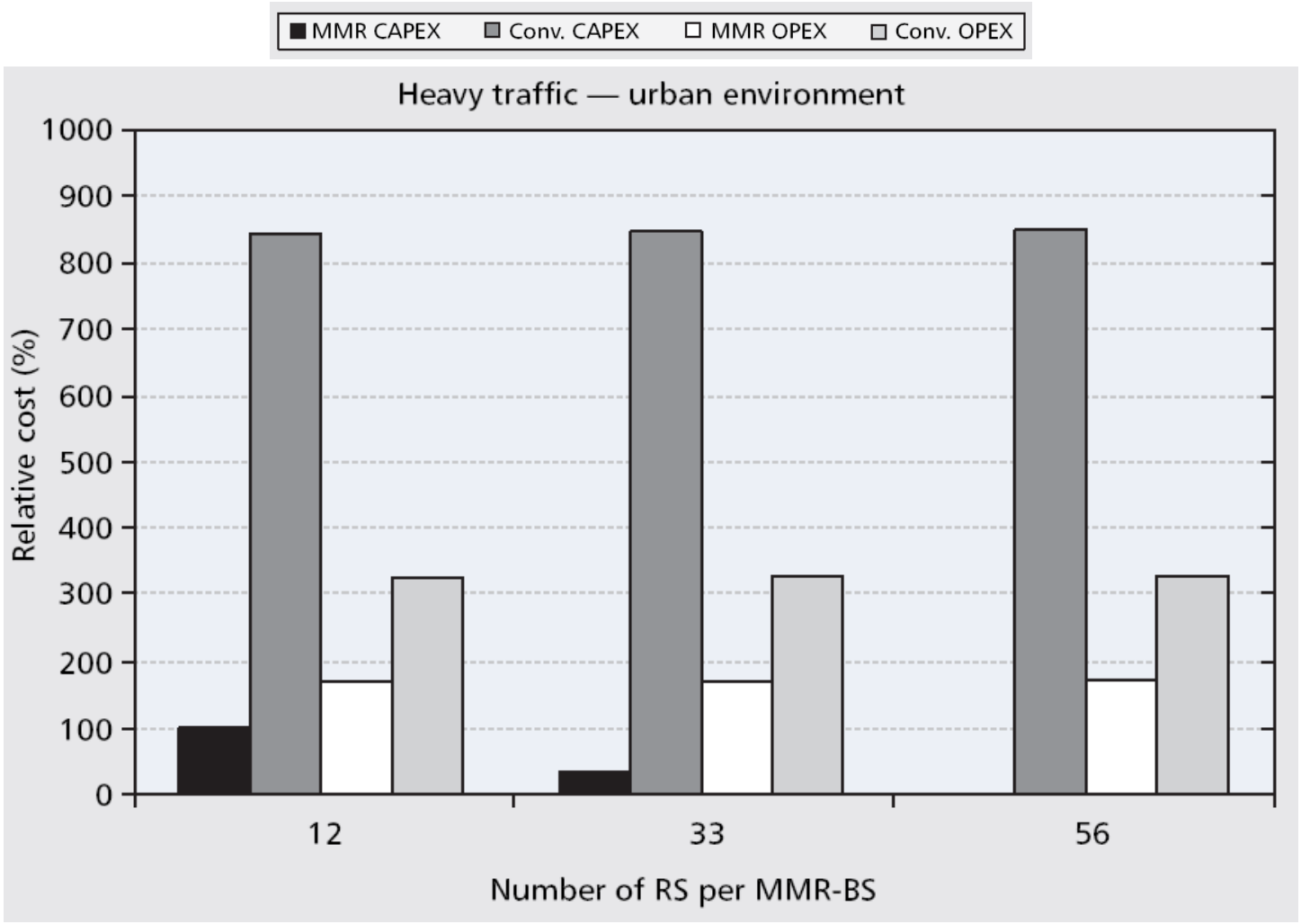


Light Traffic – urban/suburban/rural environment



Normalize and relative to the MMR CAPEX (56)

Heavy Traffic – urban environment



Normalize and relative to the MMR CAPEX (56)

Conclusions

- Relay technology has been receiving much attention due to its
  - Simplicity
  - Flexibility
  - Speed of deployment
  - Cost effectiveness

- Some keys of advantages of relays are:
  - No backhaul required
  - Flexibility in locating relays
  - Decrease transmit power and interference
  - Mobile relays enable s fast network rollout

Disadvantages and Issues

- Disadvantages
  - Increased use of radio resources in in-band relay and need for multiple transceivers in out-of-band relay
  - Relays introduce additional delays

- Issues
  - Data forwarding
    - QoS based tunnel, radio specified tunnel, or non-tunnel, etc.
  - Routing algorithm
    - Load balance, QoS, etc
  - Radio resource management
    - Centralized/Distributed control, etc.
  - Handover
    - Decision, measurement report, etc.
  - Security