Cooperative Relay Protocol for 802.16j

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Technical proposal to IEEE 802.16j

Cooperative Relay Protocol

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Outline

- **Objective**
- **Military/Government requirements**
- **Main features**
  1. Cooperative Relay Group
  2. Relay Aware Engine
  3. Cooperative Discovery
  4. Cooperative Resource Allocation
  5. Cooperative Power Saving
  6. Mobile Handling
- **Summary**

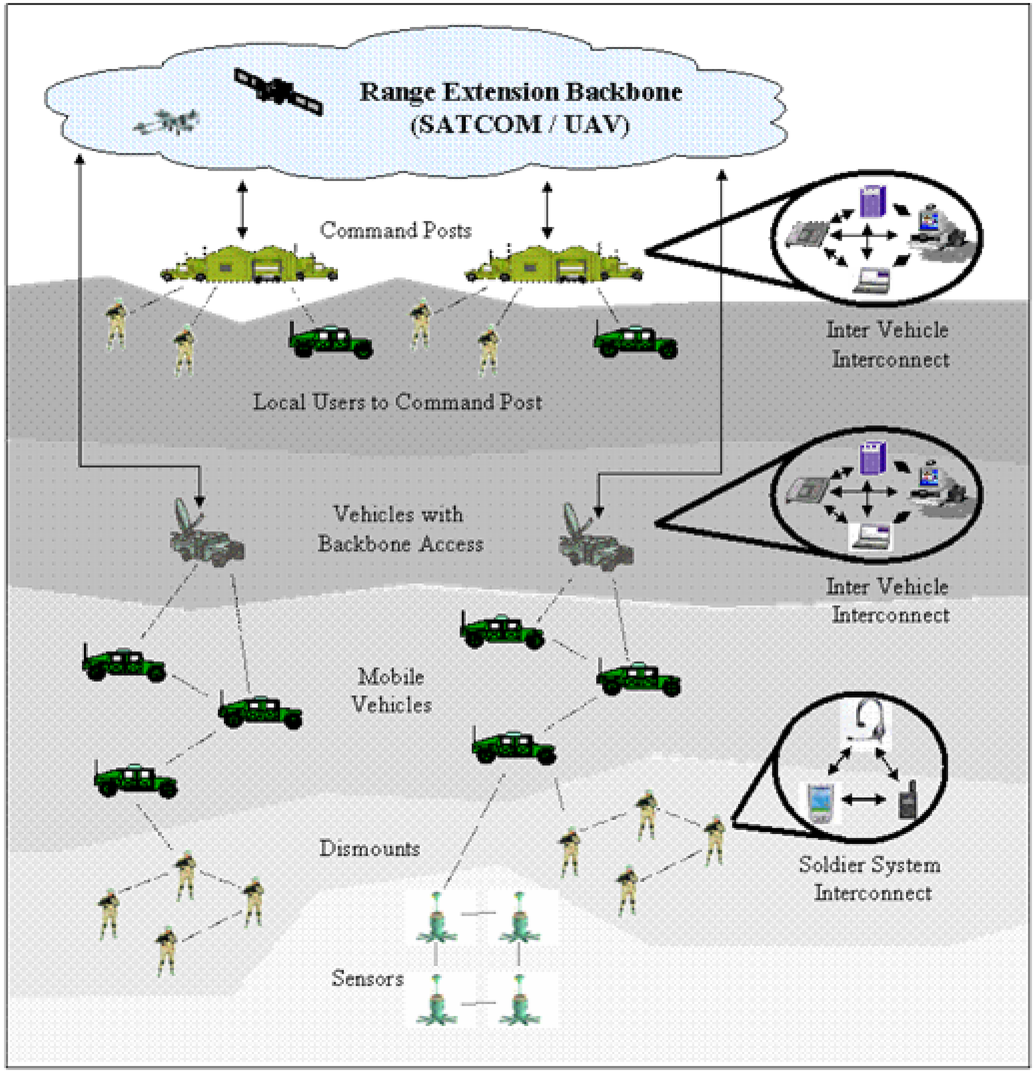
Objective

- Our proposal provides solutions (in MAC enhancements, dynamic resource allocation, and cross-layer optimization) to support Mobile Multihop Relay for 802.16j
  - Also needs to meet military/government requirements

Military/Government Requirements

- The majority is 2 hops from the BS with a small number being 3 hops
- Support BS/relay mobility
  - Support coordination among BSs
- Support handoff with relay
- Distributed scheduling for resource allocation for relays
- Security/Survivability and QOS (for different applications)
- Support multicast traffic
- Consider the device willingness to relay
- Compensate for variable radio link capacity
- Minimize battery power consumption
- Role switching between relay and BS
  - MS communicates with MS via relay (cross communication)
- Priority and preemption

ARMY Usage Scenario for 802.16e/j*



- **BS/relay mobility, mobile multi-hop relaying, and security are unique requirements for the military to deploy 802.16e**

*D. J. Shyy and S. Duffalo (W302), "Military usage scenario for 802.16 MMR," C80216mmr-05_030, Nov. 2005.

Military Usage Scenario for 802.16j*

Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Contribution on 802.16j (Mobile Multihop Relay) Military Usage Models**
Date Submitted	**2006-06-15**
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Unique Requirements extracted from the Military Usage model

- Antenna height is lower than that for commercial deployment
- Relay can be carried by HUMMV, UAV or Soldier (manpack)
- Relay has size, weight and power limitation
- Battery power efficiency is important
- Multiple routes between source and destination to increase the network reliability
- MS can communicate with another MS via RS

*C802.16j-06/042, July 2006.

Main Features

- Cooperative Relay Group (CRG) is treated as a remote sector
  - A remote sector is a sector that is not co-located with the BS
  - Low-complexity relays
- Relay Aware Engine to Perform Cross-Layer Optimization
  - A software engine to make decisions on optimal values of different parameters at different sublayers
  - Antenna, radio and channel configurations agnostic

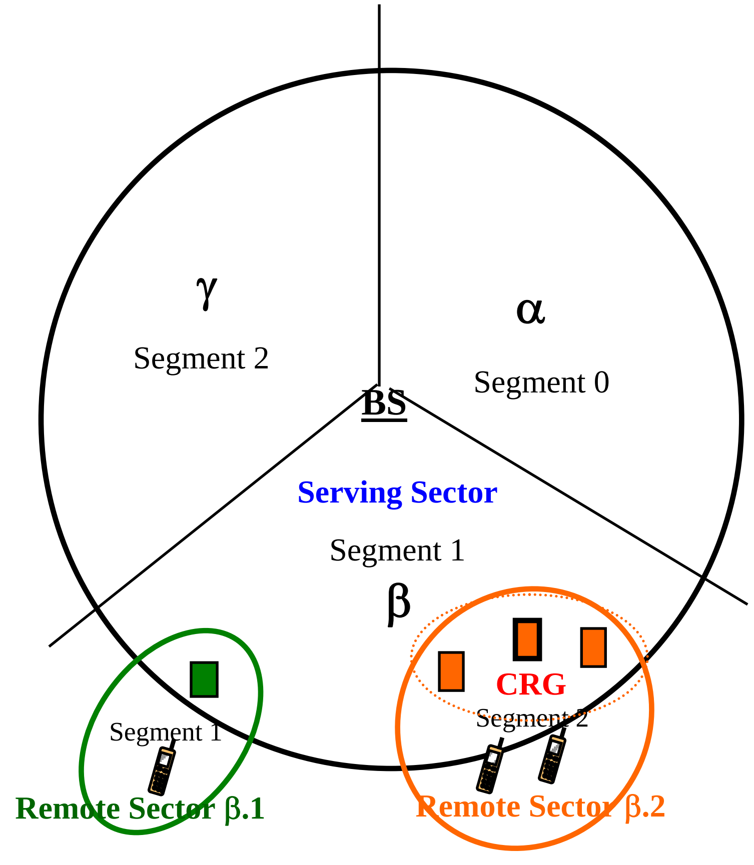
Main Features (Cont’d)

- Cooperative Discovery
  - Combing the discovery from multiple layers to improve the efficiency by using ONE protocol to perform multiple discovery tasks, and to speed up the session setup time and save battery power
- Cooperative Resource Allocation
  - Resource for relay station (RS) is both time and frequency
- Cooperative Power Saving
  - Cooperation is the only way to maximize the battery life for the whole network
- Cooperative Cross Communication
  - Cooperation between MMR-BS and RSs to minimize the overhead and delay for data transmission

Proposed Architecture

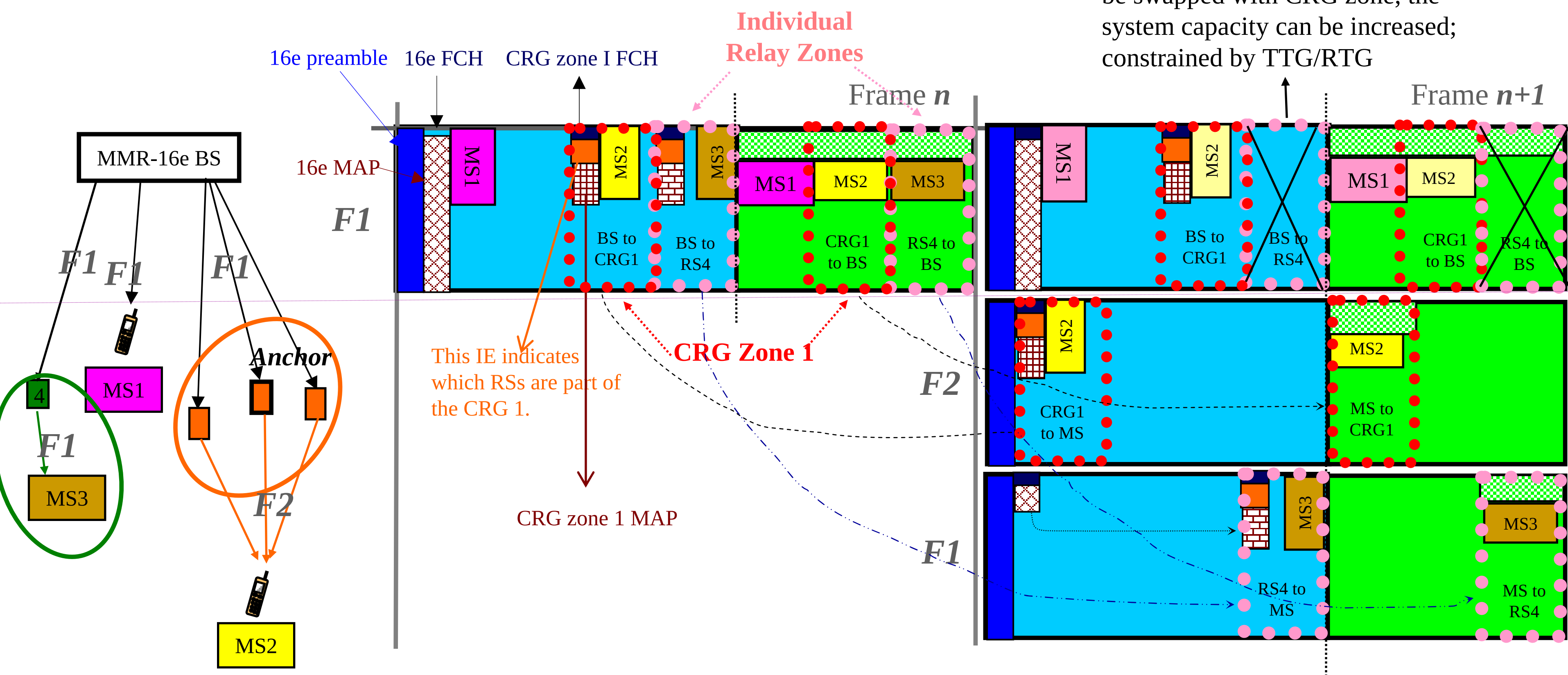
- Main Principle: Treat RS or a group of (single-antenna) RSs as one of the (remote) sectors of the BS
  - The cooperative relay group (CRG) forms cooperative (virtual) MIMO
  - The serving sector is in charge of the resource allocation of the CRG

- A RS or a CRG transmits its own cell ID to become one of the (remote) sectors.
  - All the RSs in the CRG send out the same cell ID
  - A CRG transmits its own preamble and FCH
    - However, the creation of preamble and FCH could be done at the BS



Proposed Frame Structure

• If the Individual Zone location can be swapped with CRG zone, the system capacity can be increased; constrained by TTG/RTG



Both FREQUENCY and TIME Allocations

DL Subframe

UL Subframe

Dedicated UL management channels

• 16e MAP contains both 16e allocations and the boundaries of relay zones.

• The relay zone preamble is re-generated by the RS. The serving sector informs the RS what preamble to create via the management channel (similar to CQI channel). The relay zone has its own FCH and MAP. The relay zone MAP contains the allocations within the relay zone.

• ***Multiple relay zones are allowed***. Each CRG or relay has its own zone.

• The Segment used between BS and RSs can be ***different*** from the Segment used between RSs and mobiles.

Low Complexity Relay

- The relay performs
  - Full baseband decoding including channel coding
  - Frequency translation for better frequency reuse
  - Time shift of the relay zones when necessary (the time shift has been predicted by the BS, so no change on the relay zone MAP)
    - Simple to configure
    - Less power consumption
    - Low complexity

Cooperative Relay Group

Cooperative Relay Group

- In CRG, multiple RSs coordinate their transmissions so that cooperative parallel transmissions can be established between multiple cooperative MIMO capable nodes and destination node.
  - CRG shares the same preamble, FCH, and MAPs
  - Cooperative MIMO is a cross-layer technique
  - Cooperative MIMO improves capacity and range

- A RS can be discovered when joining the network through a) network entry or b) peer neighbor discovery
  - The CRG capability is detected at this stage
  - The peer neighbor discovery is discussed in later slides

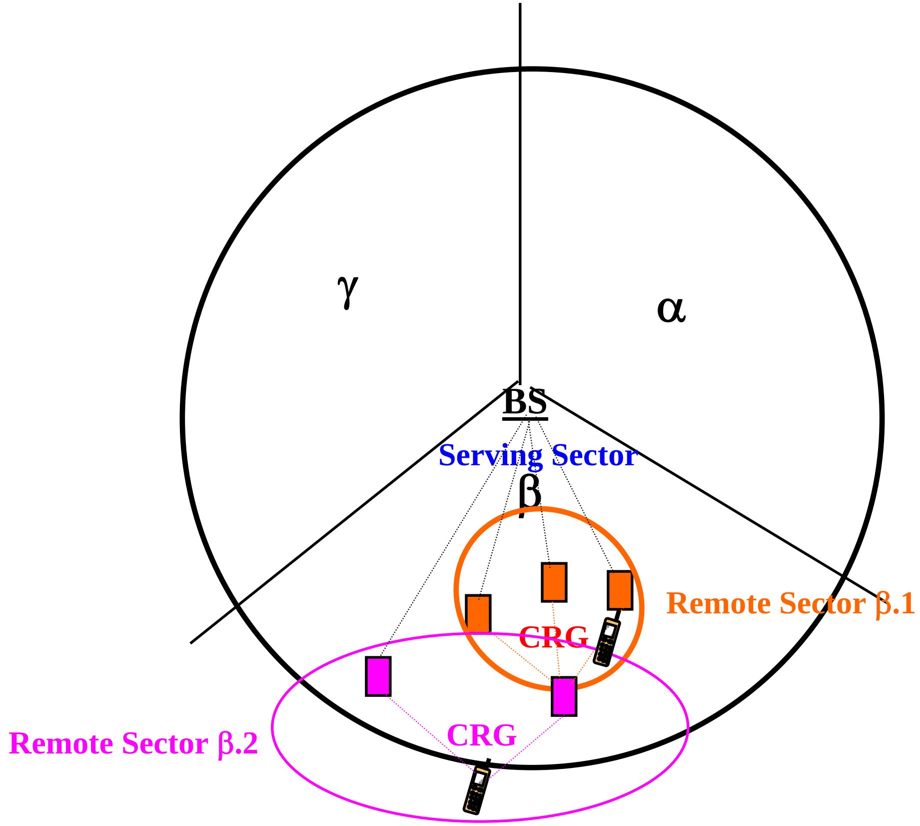
Cooperative Relay Group (Cont’d)

- Forming of the CRG is done when the BS builds the routing table (to forward the data from BS to mobiles)
  - Assign a group of (cooperative) RSs to serve certain mobiles
  - CRG consists of 2 or more RSs
    - Recommended size for CRG: 2 – 4
  - The number of CRGs per sector is recommended to be 1 or 2
    - Balance between performance enhancement and overhead

- The members in the CRG can be added or deleted on any frame
  - An IE in the relay MAP indicates which RSs should be grouped as a CRG
  - The formation of CRG can be based on many different factors; for example, <u>proximity of the RSs</u>, coverage, performance (QoS), security, load balancing, and battery power conservation
  - A RS CANNOT belong to more than one CRG

Multihop Extension

- The CRG concept can be extended to more than 2 hops



Communication Between Serving Sector, CRG, and Mobile

- For Relay DL (serving sector to CRG), the serving sector broadcasts the messages to all the RSs in the CRG
  - All the RSs in the CRG are in the same multicast group
- For Access DL (CRG to the mobile), the CRG uses MIMO technique to send the message to the mobile
  - The forming of MIMO pattern at different members of CRG is determined by the serving BS

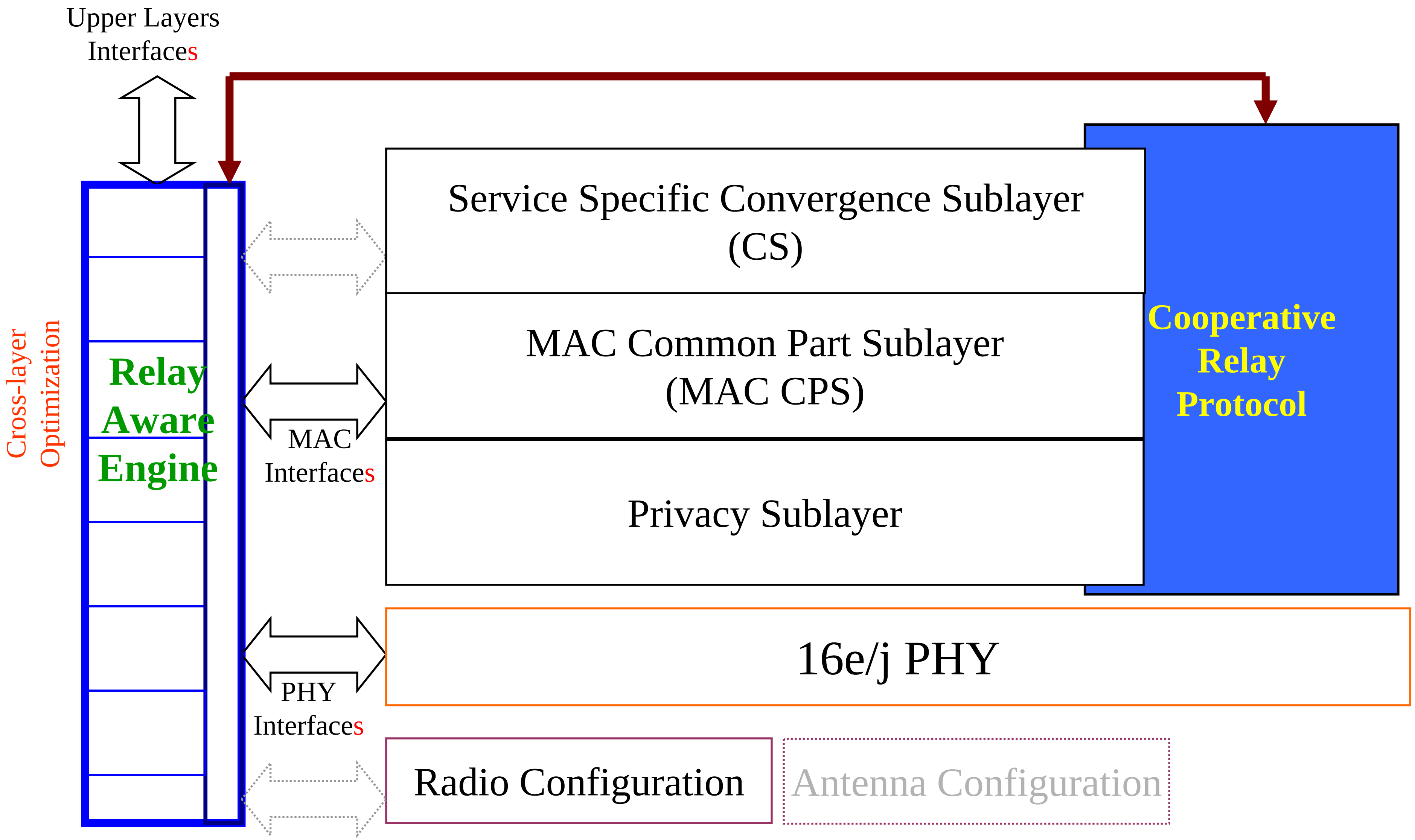
- For Access UL (mobile to the CRG), the mobile sends the message to the anchor RS in the CRG
  - The anchor RS passes the data to the serving sector
  - Periodically, all RSs in the CRG measures the signal quality from the mobile. The signal quality report is sent back to the serving sector such that the serving sector determines who the anchor RS is for the mobile.
- For Relay UL (CRG to the serving sector)
  - Each RS in the CRG is able to send its own message to the serving sector
    - Dedicated management channels are used for the RSs to communicate with the serving sector for management purpose
  - The BS measures the signal quality from the RSs. The signal quality is one of the factors for the BS to determine if the formation of a new CRG or change to the existing CRG are needed. The BS uses Relay MAP IE to inform the RSs about this decision.

Relay Aware Engine

Relay Aware Engine

- Cross-layer optimization using measurements from different sublayers
  - Cross-layer design has been suggested in 802.16 standards and 802.16j Technical Requirements
    - H-ARQ (O4)
    - Cooperative (collaborative) MIMO
    - Cooperative relay (O11)
- Relay Aware Engine adopts open architecture design to accommodate features from different proposals seamlessly
  - Our architecture provides a common framework for integrating features from different proposals
- Interoperability with different vendors' implementations via (standardized) interfaces
- The relay aware engine is antenna, radio and channel configurations agnostic

Proposed 802.16j Relay MAC Architecture



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Relay Aware Engine (Cont’d)

- Relay Aware Engine is a piece of software that resides in both MMR-BS and RS

- The Relay Aware Engines makes an (optimal) decision on various parameters in a centralized or distributed manner
  - It is implementation preference, and will not be mandated here.

Cooperative Discovery

Cooperative Discovery Protocol

- We propose to use ONE Cooperative Discovery Protocol for peer neighbor discovery
  - It solves multiple discovery tasks to speed up the session setup time and save battery power
  - The purpose is not to discover more than one neighbor. Instead, for one neighbor, we discover multiple layers using one message

- Protocol decomposition (e.g. each layer has its own discovery procedure) is inefficient for 802.16j
  - It creates unnecessary overhead in bandwidth and delay

- The discovery result is sent back to the serving sector

High-Level Description

- **Nominal attributes at discovery**
  - Neighbor RS (local topology)
  - Cooperative MIMO capability (CRG capability)
- **Extended attributes discovery**
  - Location
  - Scheduling (resource allocation) mode
  - Operating channels and radio configuration (communication)
  - Routing protocol
  - Security policy
  - Power saving mode and battery power level
  - Cross communication capability
  - Interference profile (environment), signal to noise ratio (SNR), and signal strength measurements
  - Loading (congestion) status
  - Others

Cooperative Resource Allocation

Resource Allocation

- In the current 802.16e-2005 specifications, they allow all sectors within a cell have orthogonal subchannels assignment (e.g. with frequency reuse factor of 3)

- We extend this orthogonal concept, and propose that CRGs cooperate with the serving sector to have orthogonal allocation of subchannels in time and/or frequency.
  - The Relay link between serving sector and CRG as well as the Access link between CRG and mobiles can deploy orthogonal subchannels allocations, i.e., reuse of the segments
    - This can be achieved using PermutationBase/Cell ID, Segment, and MAP burst allocation No modification is required for the mobile operation.
      - The PermutationBase/Cell ID, Segment, and MAP burst allocation can be determined at the serving sector
  - Relay aware engine is positioned to achieve this task

Cooperative Power Saving

Power Saving

- Conservation of power consumption is crucial for battery-powered RSs
  - Bus/Ferry
  - Public safety
  - Military

- We have identify various techniques at different layers that can be used for power saving

Power Saving (Cont'd)

- Cross-layer design to achieve maximal saving on the RS power without affecting topology connectivity for the mobiles
  - Network entry
    - The power saving mode and battery power situation of a RS are discovered during RS network entry or RS peer neighbor discovery
  - Formation of CRG
    - Power saving mode and remaining battery power are criteria to determine if a RS should belong to a CRG
  - Resource allocation
    - Power-aware scheduling
      - The scheduler takes the remaining battery power into account when performing resource allocation
  - PHY modulation and coding
    - Reduce the modulation and coding scheme and allocations (data rate)
      - The result is the transmit power can be reduced
  - Routing
    - Remaining battery power level is part of the routing metric
      - Use the path with least transmit power requirement
      - Avoid using the RSs with battery power constraint for forwarding
  - Sleep
    - Choose a subset of RSs to go into sleep without affecting topology connectivity for the mobiles

Mobility Handling

Better Mobility Handling

- Periodically, all RSs in the CRG measures the signal quality from the mobile. The signal quality report is sent back to the serving sector such that the serving sector determines if a handoff is needed for the mobile.

- As long as the mobile is in connection with one of the RSs in the CRG, no handoff is needed as far as the CRG is concerned (no connection setup, and no ranging and registration as compared to independent relays scenario). However, the anchor RS for the mobile may be changed.
  - The mobile does not need to know who the anchor RS is in the CRG

Proposed Text Changes

Proposed Text Changes