Efficient Resource Utilization Scheme on the basis of Precoding and Cooperative Transmission in Downlink

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Purpose:

Recommend an efficient resource utilization scheme for 802.16j

Introduction

- OFDMA subcarrier allocation algorithms are different for the uplink and downlink [1].
- In the downlink, the pilots are allocated before data subchannels and there is no mechanism to associate pilots with data subchannels.
- This allocation algorithm forbids simultaneous BS/RSs transmissions, which will cause the wrong channel estimation at SSs [2], and thus results in low resource utilization efficiency [3].
- We recommend efficient resource utilization scheme through joint precoding and cooperative transmission by BS/RS in downlink.

Illustrations of Pilot Collision Problem

- During concurrent transmissions of multiple BS/RSs, some SSs will hear multiple pilots and estimate a sum of the channel rather than the true data channel response, as is shown in Fig.1 and Fig.2.
- This problem is named as pilot collision problem, which will greatly reduce the performance of the involved SSs.

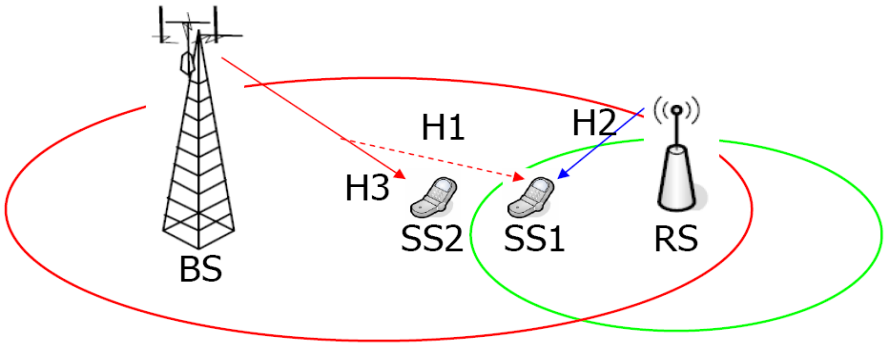


Fig. 1

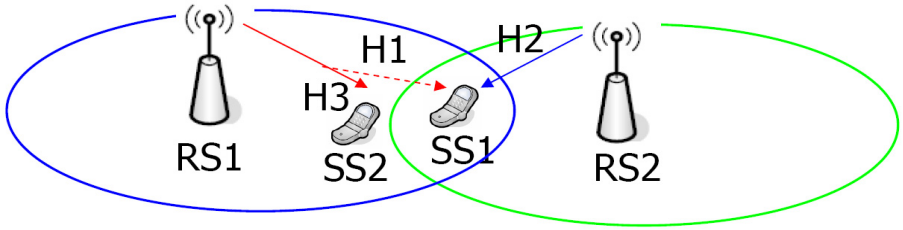


Fig. 2

Inefficient Resource Utilization Under Pilot Collision Problem

- Pilot collision problem is an obstacle to effective resource utilization because it forbids the simultaneous transmissions of multiple BS/RSs in the same OFDM symbol, for example, as indicated in [3].
- The resource can not be efficiently shared and utilized among BS/RSs until the pilot collision problem can be appropriately solved without changing the SS/MS.

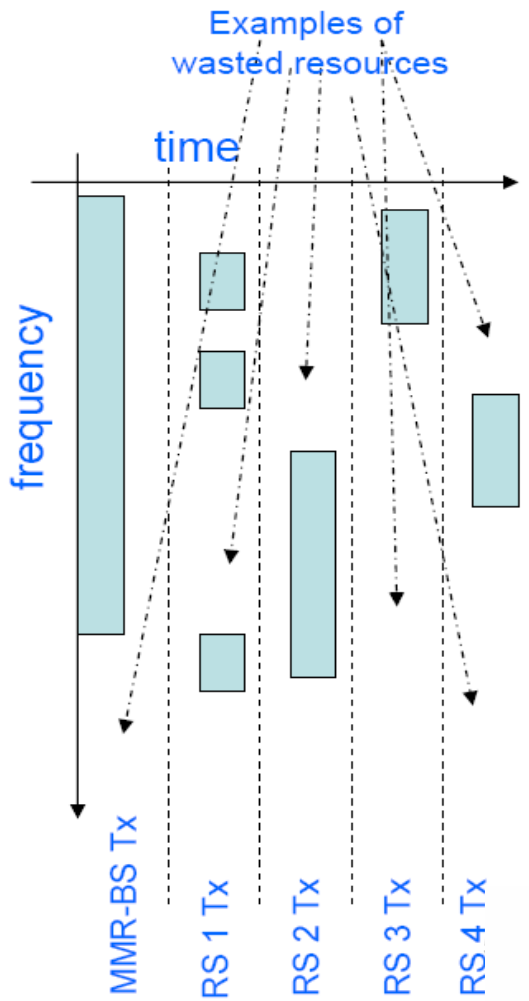


Fig. 3 **(From reference [3])**

Cooperative Transmission

- To solve the pilot collision problem, BS and RSs can cooperatively transmit data and pilots to SSs with properly designed precoding.
- By combining with appropriate scheduling, effective resource utilization can be achieved.

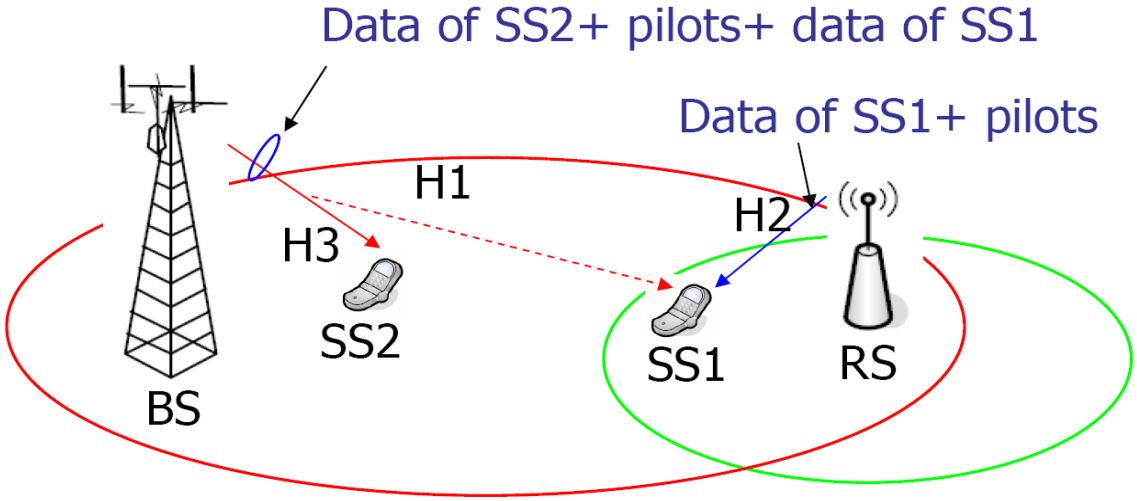


Fig. 4

Joint Pilot and Data Precoding

- No need of channel response
  - Only (coarse) SNRs from MS/SS to BS/RS are needed
    - E.g. in Fig.4, the SNRs from SS1 to BS and RS are needed.
  - The SNR information is used to adjust the transmission power of BS and RS during the cooperative transmission

	Pilot	Data
BS	$W_{BM}^{P}(n)\cdot P$	$W_{BM}^{D}(n)\cdot D_{BM}$
RS	$W_{RM}^{P}(n)\cdot P$	$W_{RM}^{D}(n)\cdot D_{RM}$

Precoding

- $W_{BM}^{P}(n)$ BS to MS weight on subcarrier n for Pilot
- $W_{BM}^{D}(n)$ BS to MS weight on subcarrier n for Data
- $W_{RM}^{P}(n)$ RS to MS weight on subcarrier n for Pilot
- $W_{RM}^{D}(n)$ RS to MS weight on subcarrier n for Data
- P, D Pilot signal and Data signal

Joint Pilot and Data Precoding

- For simultaneous transmission

Example1

Pilot	Data ϕ_1	Data ϕ_2
P	D_1	D_2
P	D_1	0

➢BS to SS2 and RS to SS1 transmissions can happen in one OFDM symbol simultaneously without causing SS1 to suffer from pilot collision.

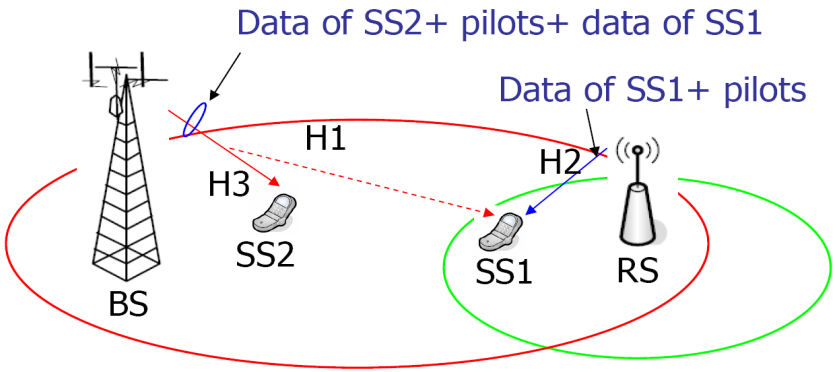
➢The unusable spare resource caused by pilot collision problem can be avoided.

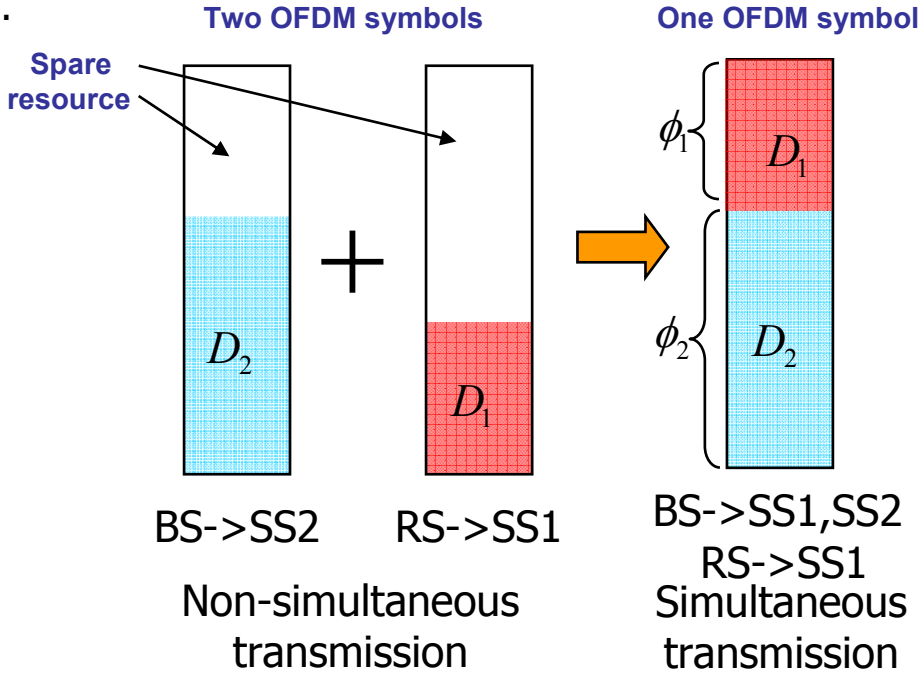
Example2

Pilot	Data ϕ_1	Data ϕ_2
$P/\sqrt{2}$	$D_1/\sqrt{2}$	$D_2/\sqrt{2}$
$P/\sqrt{2}$	$D_1/\sqrt{2}$	0

➢The transmission power of BS and RS can be adjusted in cooperative transmission.

➢For example, if we schedule a SS2 near BS, the total transmission power of BS and RS can be reduced on the premise of satisfying the performance requirement of SS2.

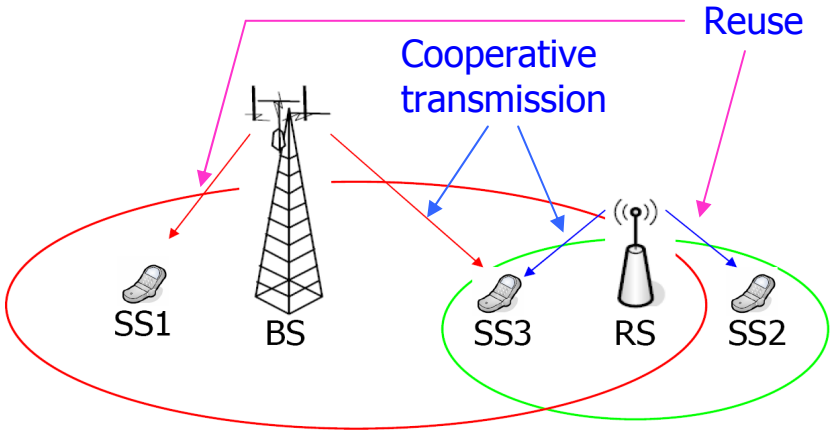




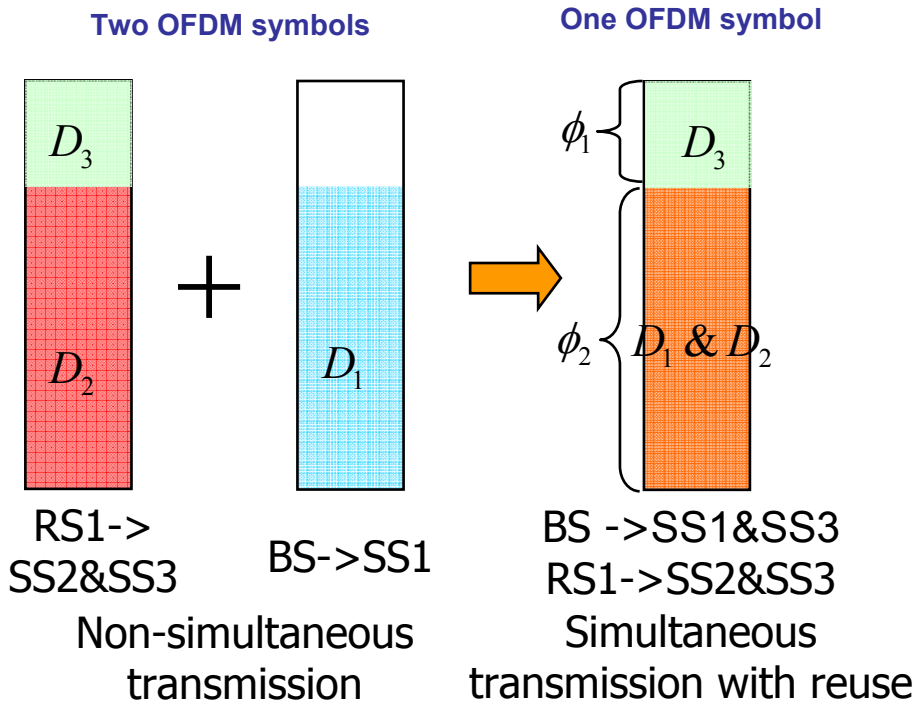
Joint Pilot and Data Precoding

- For resource reuse

	Pilot	Data ϕ_1	ϕ_2
Example	P	D_3	D_1
	P	D_3	D_2



➢During the transmission of RS to SS2 and SS3, BS to SS1 transmission can be scheduled at the same time if SS1 is out of the RS coverage.
➢Through the cooperative transmission by BS and RS to SS3, SS3 will not suffer from the pilot collision problem caused by the simultaneous BS and RS transmission.
➢The transmission power of BS and RS can be adjusted in cooperative transmission by scheduling proper SSs.



Efficient Resource Utilization

- Cooperative transmission and joint precoding enable resource reuse and avoid the unusable spare resource caused by pilot collision problem, and therefore can achieve high efficiency of resource utilization by combining with proper scheduling.
- Two examples are shown in the following slides.
  - Coverage extension: Coverage hole
  - Throughput enhancement: Manhattan model
- Frame structure in [4] is used for illustrations.

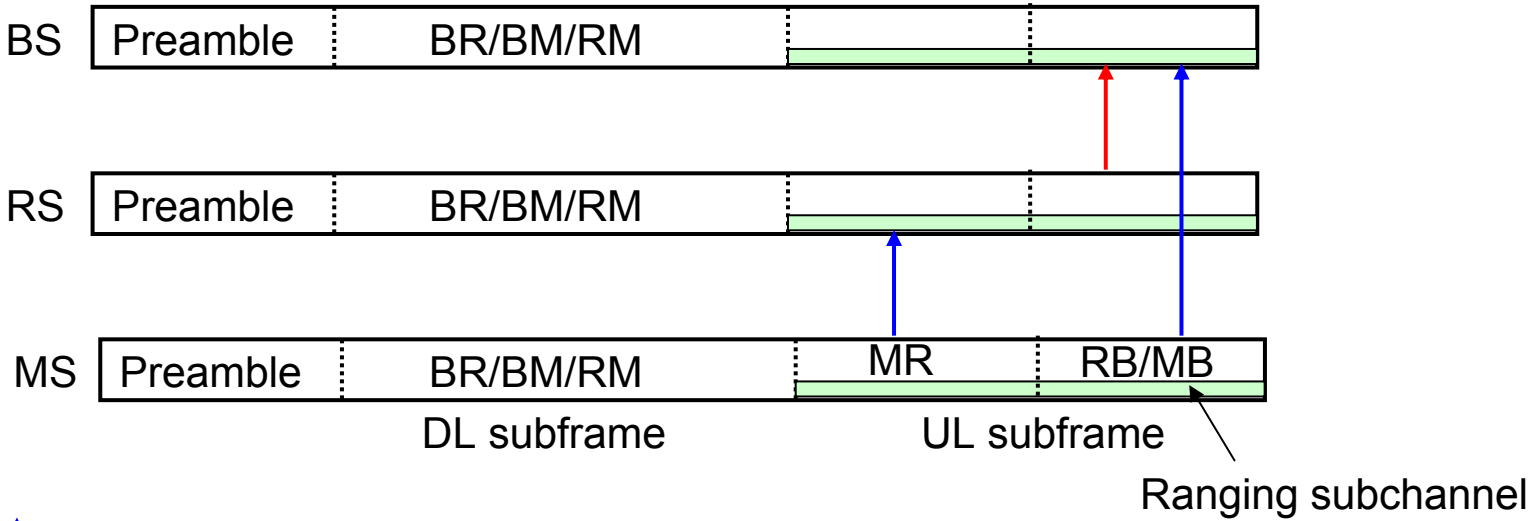
Efficient Resource Utilization

- Classify MS
  - Divide MSs into different categories according to their SNRs to BS and RSs under different BS/RSs transmission scenarios.
  - Purpose
    - Classify MSs into multiple groups with different FRF (Frequency Reuse Factor) for scheduling and resource reuse.
  - Method
    - 1)Generally, BS has the SNRs of MSs for AMC, power control or handover, etc. These SNRs can be used directly.
    - 2)The required SNR information can also be obtained from ranging
      - See the example in the next slide.

Proposal on how to divide MSs into different categories

- BS decides the category of MS on the basis of the measured and reported SNR of MS.

Example: Get SNR from ranging

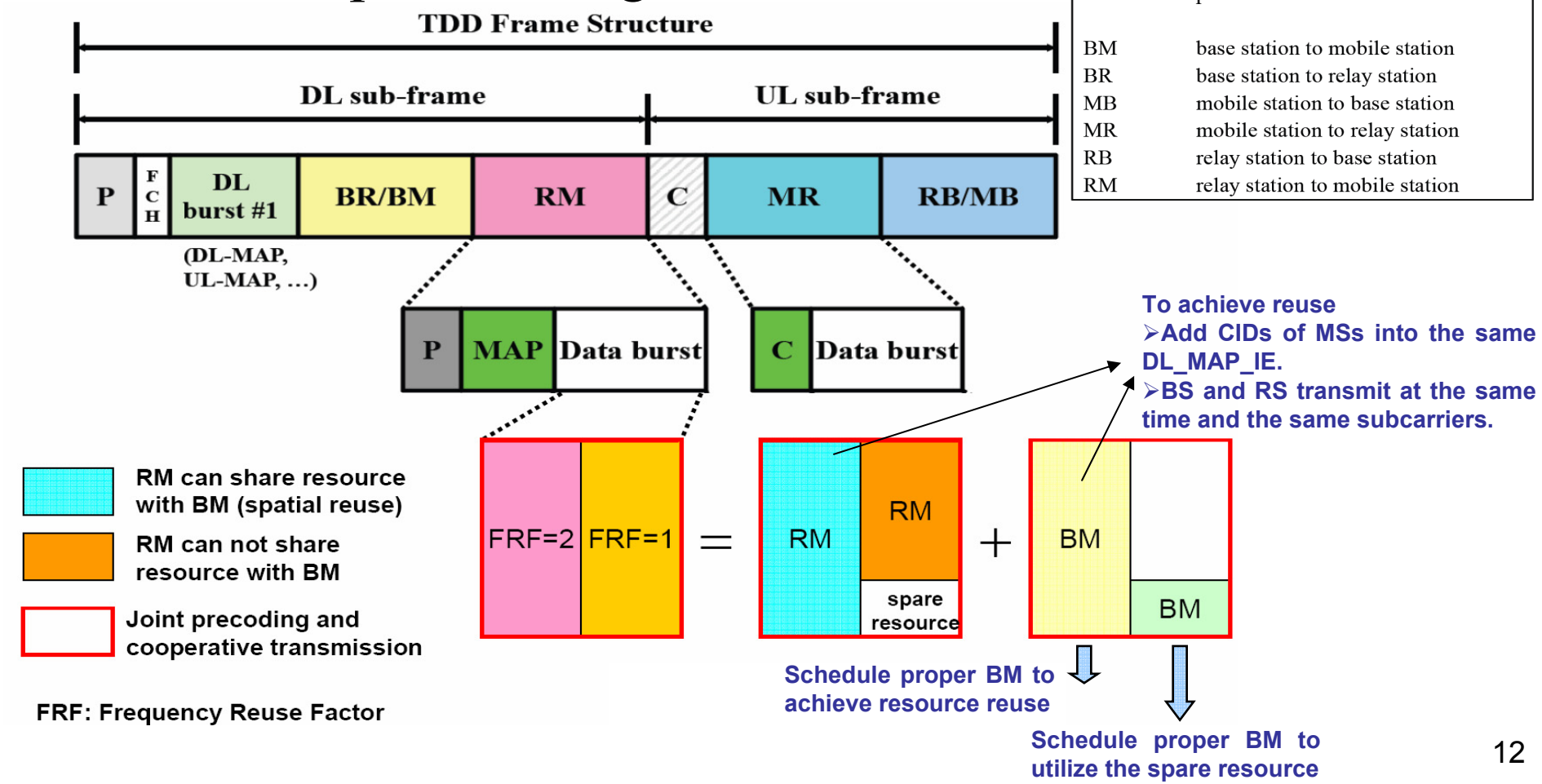


BS and RS monitor all the ranging signals to obtain the SNR of MS.

RS reports the measured results to BS.

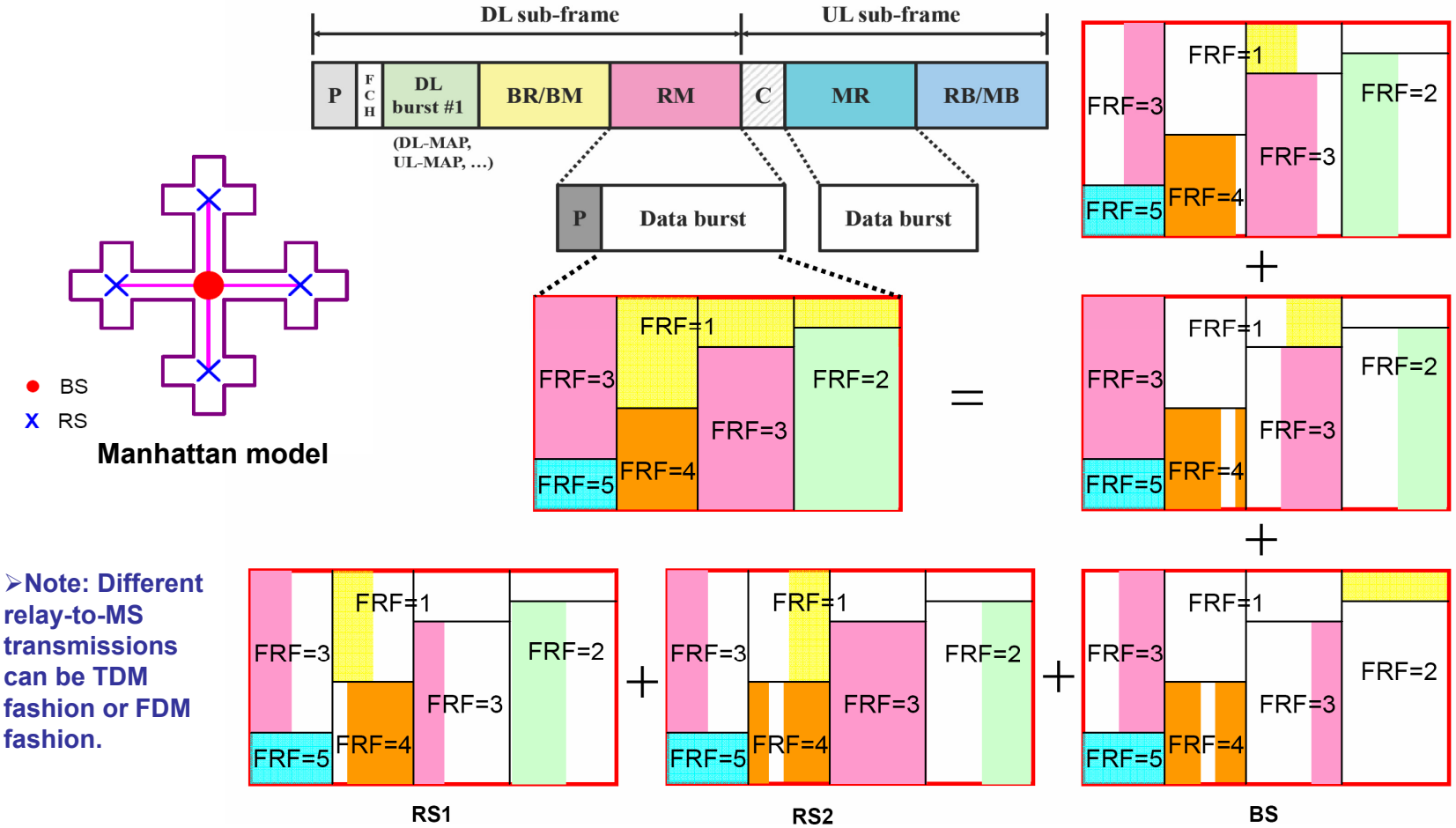
Efficient Resource Utilization

- For coverage extension
  - Example: coverage hole



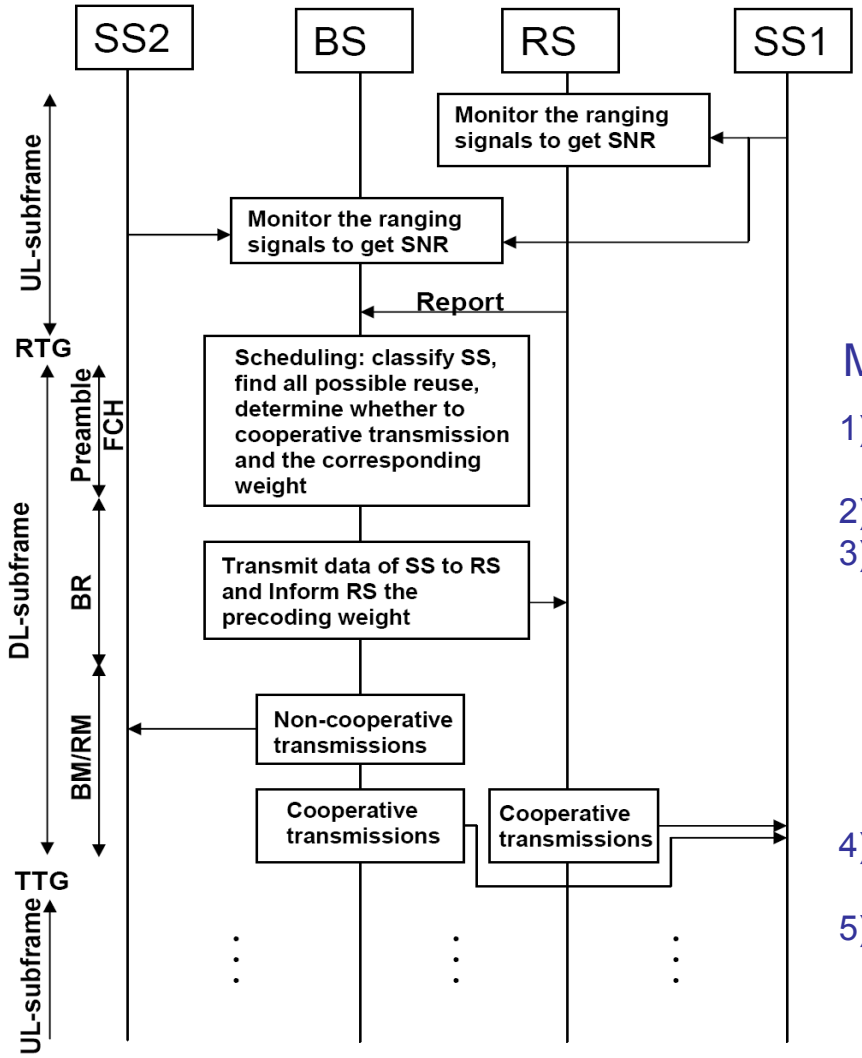
Efficient Resource Utilization

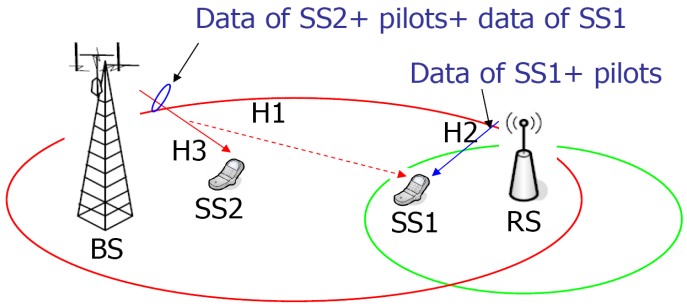
- For throughput enhancement
  - Example: Manhattan model



➢Note: Different relay-to-MS transmissions can be TDM fashion or FDM fashion.

Procedure of the Proposed Method





Main steps of proposed method

1)BS and RS monitor the ranging signals in the UL subframe to obtain the SNR of SS.

2)RS report the measured SNR to BS.

3)BS performs the scheduling according to the measured and reported SNRs. The processes at BS include: classifying the SS, finding all possible resource reuse under different BS/RS transmission scenarios, adjusting the resource allocation according the data length of SSs and determining the precoding method and weight.

4)BS transmits the data of SS to RS and informs RS of the precoding weight.

5)BS and RS perform the non-cooperative and cooperative transmissions to MSs to achieve resource reuse or avoid the unusable spare resource.

Merits of the Proposed Resource Utilization Scheme

- High efficiency of resource utilization
  - Resource reuse
  - Avoid unusable spare resource caused by pilot collision problem
- Good BER performance
  - No pilot collision
  - Spatial diversity
- Simplified RS
  - Scheduling is performed at the BS
- Small overhead
  - Generally, BS has the SNRs of MSs
    - If so, no overhead in the uplink
  - In the downlink, the overhead is about $K \times N$,which is much smaller than the reused resource or the unusable spare resource. (where K is the bits number for expressing the precoding weight, e.g K=3~5, and N is the number of MSs, which needs cooperative transmission, and the severing RSs of which need to change the transmission power.)
- Delay
  - Same frame relay
- No modification at SS/MS
- Can be applied to other frame structures, like [5][6].

Summary and Recommendation

- Efficient resource utilization schemes among BS and RSs are required for downlink transmissions.
- Pilot collision problem needs to be solved without changing MS/SS.
- We recommend efficient resource utilization on the basis of joint precoding and cooperative transmission at BS/RS.

References

- [1] IEEE Standard for Local and Metropolitan area networks, Part 16: Air Interference for Fixed Broadband Wireless Access Systems, IEEE 802.16-2004.
- [2] C80216mmr-05_019,PHY aspects in MMR-enabled networks, Alvarion.
- [3] C80216j-06_057, Proposal for requirement that RS transmit preamble, Intel.
- [4] C80216mmr-05_005r2, A Recommendation on PMP Mode Compatible Frame Structure, CCL/ITRI.
- [5] C802.16j-06/004r1, Recommendations on IEEE 802.16j, Alcatel.
- [6] C802.16j-06/002, Some Considerations on Mobile Multi-hop Relay Based System, Huawei.