Further Clarifications on Open Items of Option 2 in Relay Frame Structure and Performance Comparison between Two Options

Document Number:
IEEE C80216m-08_1358
Date Submitted:
2008-10-31
Source:
Ki-Dong Lee, Li-Hsiang Sun, Sang Kim
LG Electronics, San Diego, USA E-mail: kidonglee@lge.com
Dongguk Lim, Jong Young Han, Aeran Youn, Jin Sam Kwak
LG Electronics, Anyang, Korea

Venue:
SDD, in response to Call for Comments/Contributions (IEEE 802.16 #57 Kobe, Japan)
Re:
IEEE 802.16m-08/040: Call for Comments and Contributions on Project 802.16m System Description Document (SDD), Target topic: “SDD Session 56 Cleanup, Call for PHY details”.
Base Contribution:
C80216m-08_1106, C80216m-08_1226, 058r1 (Intel)
Purpose:
For discussion about the above mentioned contribution on throughput comparison of Relay Frame Structure options in 16m SDD
Notice:

Release:

Patent Policy:

Contents

- Further Clarifications
- Performance Comparison

Further Clarifications on Open Items of Option 2 in Relay Frame Structure

LG Electronics

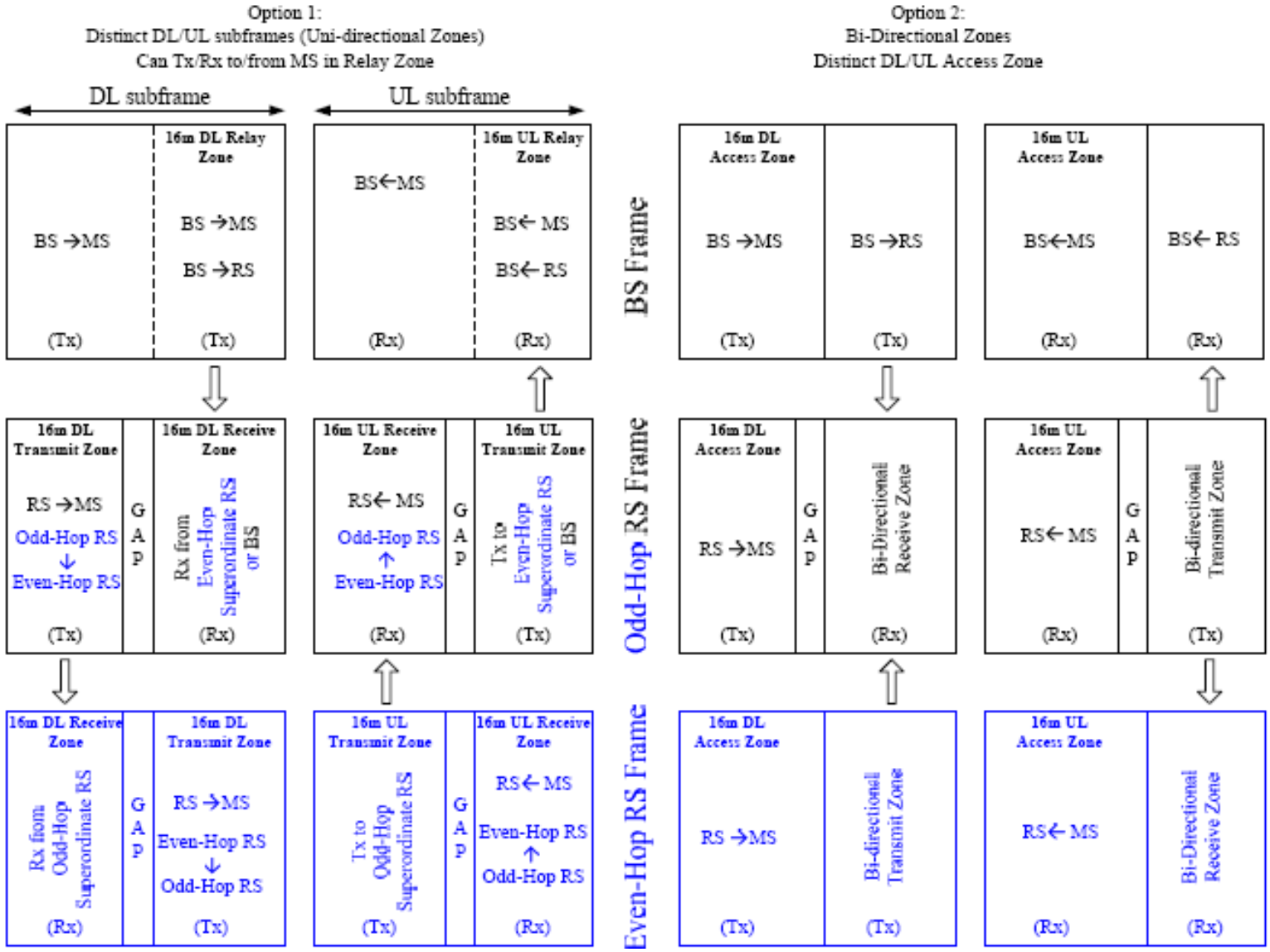
Outline

- Quick Summary from #57 Meeting, Kobe, Japan
  - Two major Options for 16m relay FS are deferred to
  - Open items for Options 1 and 2 were requested for further clarifications
- Clarifications of Open Items in Option 2
  - **Disclaimer**: This clarification part is based on contents of the former contribution C80216m-08_1106 and C80216m-08_926 since most of our positions remain the same

Relay FS Options

- C80216m-003r4
  - Three options for 16m relay frame structure (FS) were introduced and discussed during #56 meeting
  - Option 1: Uni-directional
  - Option 2: Bi-directional

Relay FS: Option 1 and Option 2

- 

Open Items for Option 2

- C80216m-08_848r2 (Relay AHG report #56, Denver)
- 1. How would you do distributed scheduling
- 2. Control signaling
- 3. How would you do Power control
- 4. Need to investigate Interference DL to UL
- 5. Latency
- 6. Subchannelization scheme (DL/UL compatible)
- 7. Synchronization

Clarification on “Distributed scheduling” and on “Control signaling”

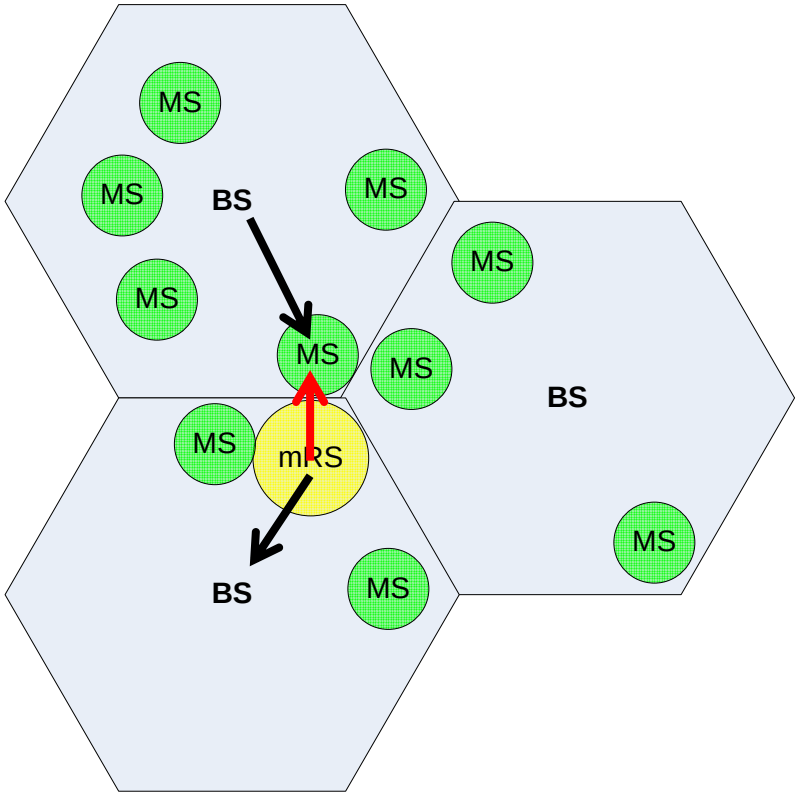
- “coordination” by superordinate node

Clarification on “Power control”

- Simultaneous transmission to both superordinate and subordinate nodes, which have different distances from the transmitter node: this is not a new problem since this is often the case in typical DL transmission where one transmitter and multiple receiver nodes are existent.
- The intermediate station receiving from both superordinate and subordinate nodes simultaneously should feedback channel condition on the respective relay links to the transmitter nodes.

Clarification on “Interference DL to UL” (1/2)

- **Case 1**: Both Options 1 and 2 have the same level of interference. When mRS transmits, it doesn’t matter whether the direction is UL or DL.
- If the signal for MS in DL (from serving BS or RS) is weaker than the interference from mRS in the neighboring cell, the MS should be attached to the mRS instead of the BS/RS.

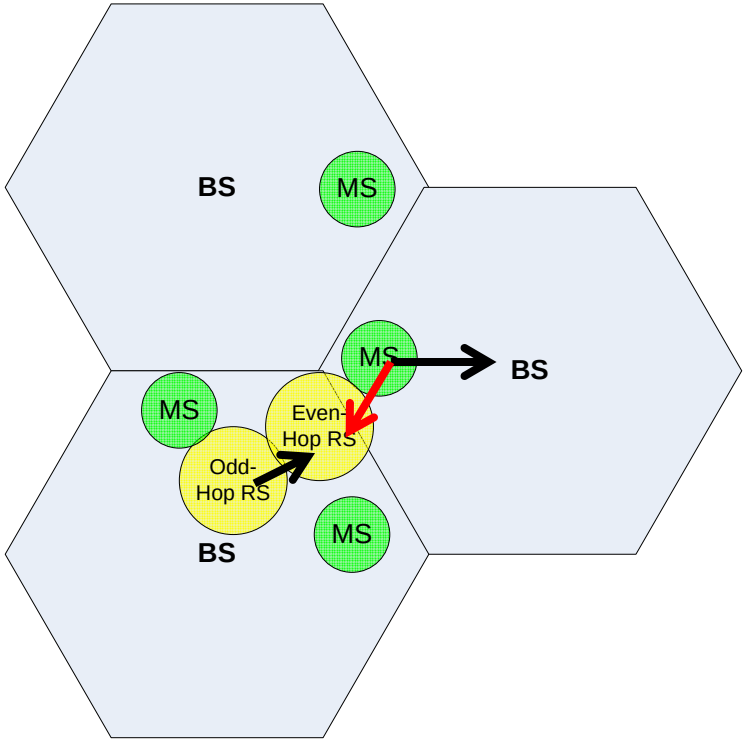


Interference

Communication

Clarification on “Interference DL to UL” (2/2)

- **Case 2**: Consider a case that the MS is so close to the mRS in the neighboring cell that the interference from the mRS is too strong. In this case, the MS can be attached to the mRS (in the neighboring cell) instead of being attached to the serving BS/RS.
- If mRS2 transmits at a weaker DL pilot power than the serving BS, the MS can be attached to the BS. mRS2 is very close to MS. In this case, the “*MS will transmit at a higher Tx power level so that the mRS2 can hardly listen to another RS*”. This is the same for Option 1, where the only difference is “*MS will transmit at a higher Tx power level so that the mRS2 can hardly listen to another MS*”.



Clarification on “Latency”

- Latency comparison example:
  - Setups:
    - 5 subframes for DL : 3 subframes for UL
    - Legacy zones come first, followed by 16m zones
  - Result:
    - The latency in Option 2 is smaller than that of Option 1.

<source: IEEE C802.16m_08-926, LGE>

	# hop	Option 1		Option 2	
		Access/Relay	**Relay/Access**	**MS use access zone**	**MS use Bi-D zone**
DL	2	2-frame(8-subframe)	2-frame(10-subframe)	2-frame(8-subframe)	1-frame(4-subframe)
	3	3-frame(17-subframe)	3-frame(17-subframe)	2-frame(8-subframe)	2-frame(8-subframe)
	4	4-frame(24-subframe)	4-frame(26-subframe)	3-frame(16-subframe)	2-frame(12-subframe)
UL	2	2-frame(10-subframe)	2-frame(10-subframe)	2-frame(10-subframe)	2-frame(10-subframe)
	3	3-frame(17-subframe)	3-frame(17-subframe)	2-frame(10-subframe)	2-frame(10-subframe)
	4	4-frame(26-subframe)	4-frame(26-subframe)	3-frame(18-subframe)	3-frame(18-subframe)

Clarification on “Subchannelization”

- In sect. 11.5.1.2 and 11.6.1.2 in SDD (r4), the LLRU can be used for both UL and DL.
- “coordination”: e.g., odd hop RS’s use the same hopping pattern and even hop RS’s use the same pattern, respectively.

Clarification on “Synchronization”

- Problem or Example: Simultaneous reception from two neighboring nodes
- Comment: if there is centralized synchronization (e.g., by BS), then there are no concerns about synchronization at simultaneous reception from parent and child.
- RS can use superordinate node’s signal arrival time to adjust subordinate delay (timing advance).

Performance Comparison

Outline

- Throughput
- HARQ latency

Throughput Comparison for 16m Relay Frame Structure Options

This part is based on C80216m-08_1126.

LG Electronics

Outline

- Throughput, in terms of what?
  - A single-hop network and a multi-hop network have different meaning of “throughput” in terms of the actual average throughput the users can experience.
  - A tree network and a mesh network have different level of asymmetry between UL and DL.
  - In tree networks, each node (e.g., RS) still has the traffic asymmetry that the two end nodes (e.g., BS and MS) have.
    - As far as the asymmetry comes, the throughput in nature has an important bottleneck, which needs to be considered to examine the throughput performance of a given FS.

Adaptation Capability for Traffic Asymmetry (1/2)

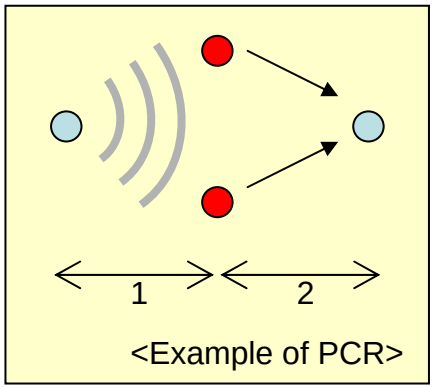
- Asymmetry b/w Traffic Volume Demands in UL and DL
- Why is “Adaptation Capability” important?
  - Traffic asymmetry between UL and DL is an inherent characteristic of a tree network (whether multihop or not).
  - With a limited number of subframes in a single radio frame for DL-A, DL-R, UL-A, and UL-R zones, the actually experienced level of throughput is completely upper-bounded by the one (either UL or DL) that is saturated first.
    - This is the same problem even when both UL and DL are saturated/overloaded because the utility (value of resource utilization) still falls into a non-optimal situation.

Adaptation Capability for Traffic Asymmetry (2/2)

- Comparison
  - Option 1:
    - No substantial adaptation capability but changing the number of subframes for each zone
  - Option 2:
    - Better adaptation capability through bidirectional zones

Capability of Cooperative Diversity (1/4)

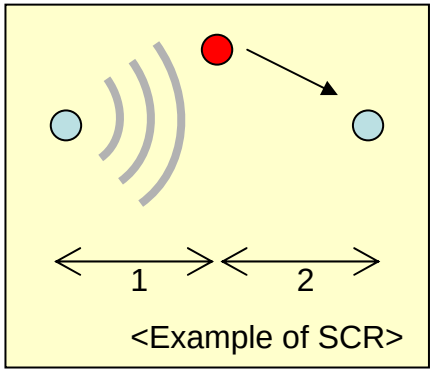
- Parallel Cooperative Relaying (PCR)
  - min. # (required) RS's = 2
  - What if # RS's <2, no PCR gain
    - In Option 1, no SCR gain, either
  - Probability perspective:
    - Pr{# RS's >= 2} = 1 - Pr{# RS's =1} - Pr{# RS's =0}
    - Example (Poisson): $\Pr\{PCR\} = 1 - \exp(-\lambda) - \lambda \exp(-\lambda)$



<Example of PCR>

- Single Cooperative Relaying (SCR)
  - min. # (required) RS's = 1
  - What if # RS's <2, still SCR gain (if >= 1)
  - Probability perspective:
    - Pr{# RS's >= 1} = 1 - Pr{# RS's =0}
    - Example (Poisson): $\Pr\{SCR\} = 1 - \exp(-\lambda)$

$$= \Pr\{PCR\} + \lambda \exp(-\lambda)$$



<Example of SCR>

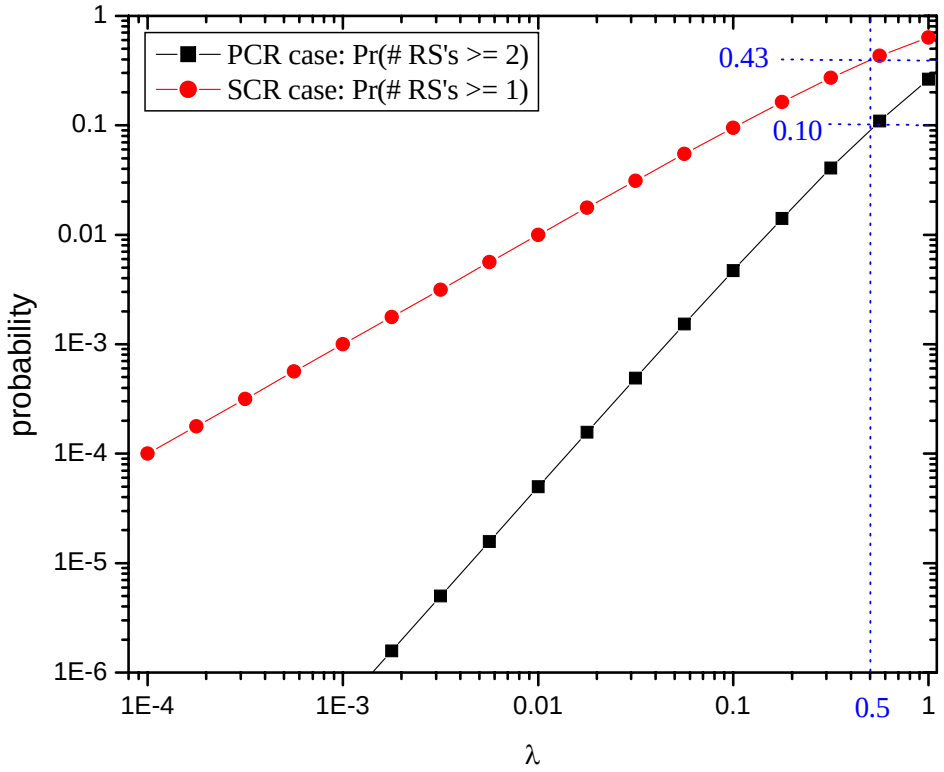
Capability of Cooperative Diversity (2/4)

- Comparison of Probability
  - Probability for having min. # required RS(s): for PCR (>1), for SCR (>0)
  - Option 1: PCR gain with low probability, no SCR gain at all times
    - The even-numbered are transmitting while the odd-numbered are receiving: grandparent cannot hear grandchild (both in Tx)
  - Option 2: PCR gain with low probability, SCR gains with higher probability

# RS's that can hear from MS	Option 1	Option 2
0	No PCR gain No SCR gain	No PCR gain No SCR gain
1	No PCR gain No SCR gain	No PCR gain with SCR gain
2 or more	possible PCR gain No SCR gain	possible PCR gain with SCR gain

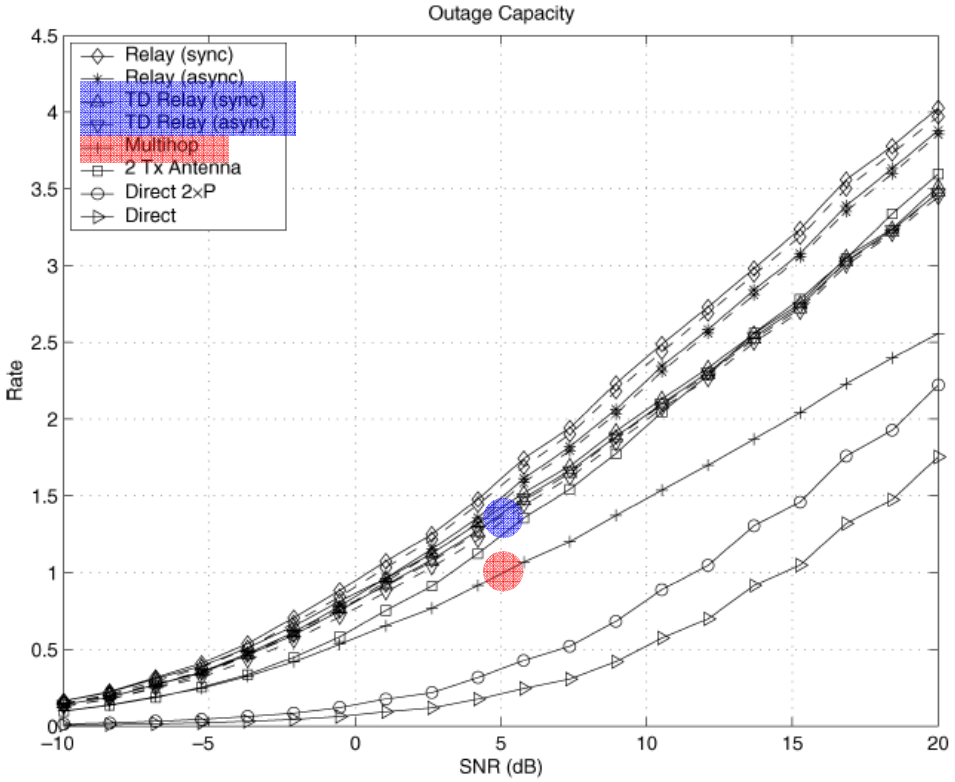
Capability of Cooperative Diversity (3/4)

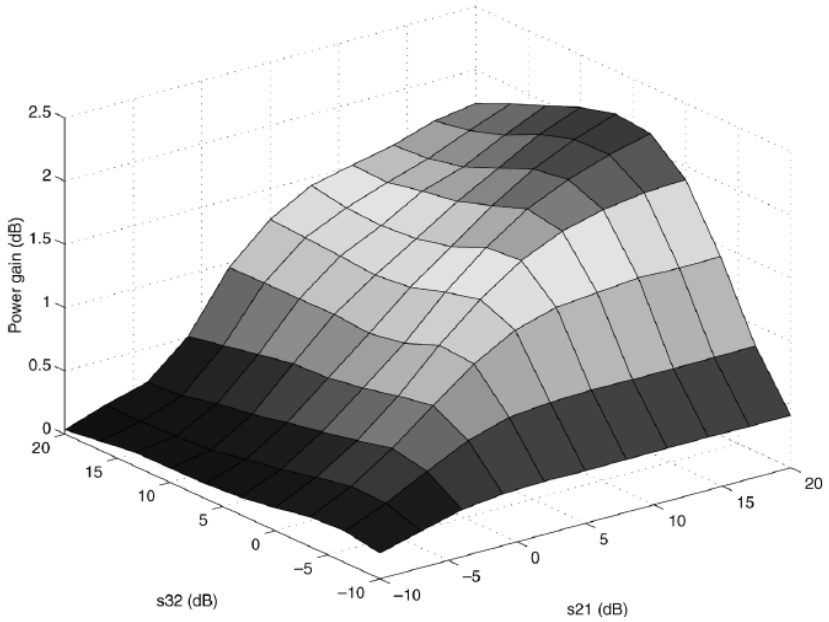
- Toy example for Probability Comparison: PCR and SCR cases
  - Setup:
    - BS coverage radius: 2km; RS coverage radius: 0.5km
    - # RS's in BS coverage area (near cell boundary): 8
    - Binomial approximation (N=8, p=1/16); Poisson approximation (λ=N*p=1/2)
  - Result:



Capability of Cooperative Diversity (4/4)

- How much is SCR gain?
  - 30% in rate; 1.2dB in power





<Source: "Capacity Bounds and Power Allocation for Wireless Relay Channels," *IEEE Trans Info. Theory*, Vol. 51, No. 6, June 2005>

Comparison: Different Types of Cooperative Relaying (CR) in Option 1 and Option 2

- PCR: (not always possible for both UL and DL in both Options)
  - (to achieve PCR gain, two parallel RS's must be able to decode)
  - if parent schedules, it requires significant control signaling overhead b/w two parallel RS's for synchronized resource assignment (in both UL and DL);
  - if grandparent schedules, no extra overhead
- DL SCR: (possible in both Options but requires more control overhead than UL SCR)
  - if grandparent schedules, the MS must know where grandparent and parent will send (extra overhead: need to know where to hear from grandparent)
  - if parent schedules, the MS must know where grandparent and parent will send (extra overhead: where to hear from grandparent)
- UL SCR: (not possible in Option 1)
  - when parent signals resource assignment to MS, grandparent can also hear without additional signaling overhead
- Summary:
  - For UL CR, only Option 2 with SCR is feasible

HARQ Latency Comparison

LG Electronics

Latency Comparison of Each Relay Frame structure

■ Option 1(uni-directional)

- Access-Relay/Transmit-Receive Zone

■ Option 2 (bi-directional)

- MSs use only Access Zone for reception/transmission
- MSs can use Bi-Directional transmit/Receive Zone for reception/transmission

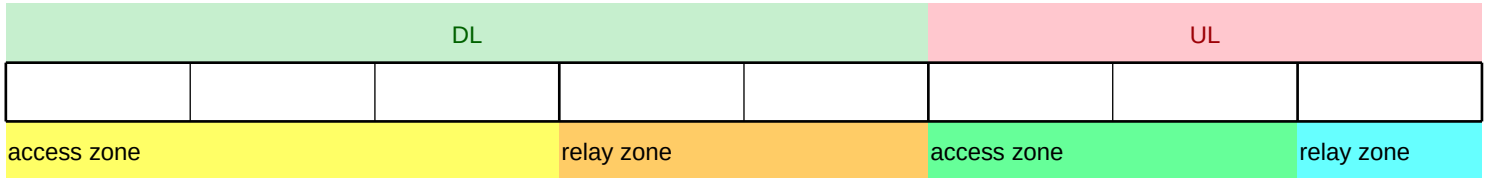
Consideration

- frame structure

  DL/UL ratio => 5: 3

  ▪ In DL, Access / Relay zone ratio => 3:2

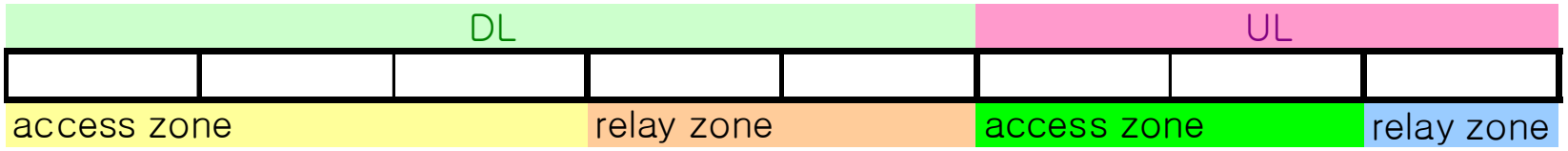
  ▪ In UL, Access / Relay zone ratio => 2:1



- number of hop : 2 and 3
- method
  - end to end (source to destination)
  - hop by hop (between BS and RS / RS and RS / RS and MS)

Some Definitions

BS frame structure



H1	data burst within first hop	A/N	Ack/Nack within first hop
H2	data burst within second hop	A/N2	Ack/Nack within second hop
H3	data burst within third hop	A/N3	Ack/Nack within third hop

Result

- DL/UL Latency based on Multi-hop Relay Frame Structures
  - Latency comparison between Option 1 and Option 2
    - Option 2 has smaller latency than Option 1.

# of hops		Option 1		Option 2			
		Access/Relay		MS use access zone		MS use Bi-D zone	
HARQ		End to end	Hop by hop	End to end	Hop by hop	End to end	Hop by hop
DL	2	3-frame (24-subframe)	1-frame (8-subframe per hop)	3-frame (24-subframe)	1-frame (8-subframe per hop)	2-frame (16-subframe)	1-frame (8-subframe per hop, last hop 7-subframe)
	3	4-frame (32-subframe)	1-frame (8-subframe)	3-frame (24-subframe)	1-frame 8-subframe per hop, last hop 6-subframe)	3-frame (24-subframe)	1-frame (8-subframe per hop, last hop 6-subframe)
UL	2	3-frame (24-subframe)	1-frame (8-subframe per hop)	3-frame (24-subframe)	1-frame (8-subframe per hop)	2-frame (16-subframe)	1-frame (8-subframe per hop)
	3	4-frame (32-subframe)	1-frame (8-subframe per hop)	3-frame (24-subframe)	1-frame (8-subframe per hop)	3-frame (24-subframe)	1-frame (8-subframe per hop)