Systematic relay station identification allocation and relay path configuration mechanism for 802.16j (Multi-hop relay)

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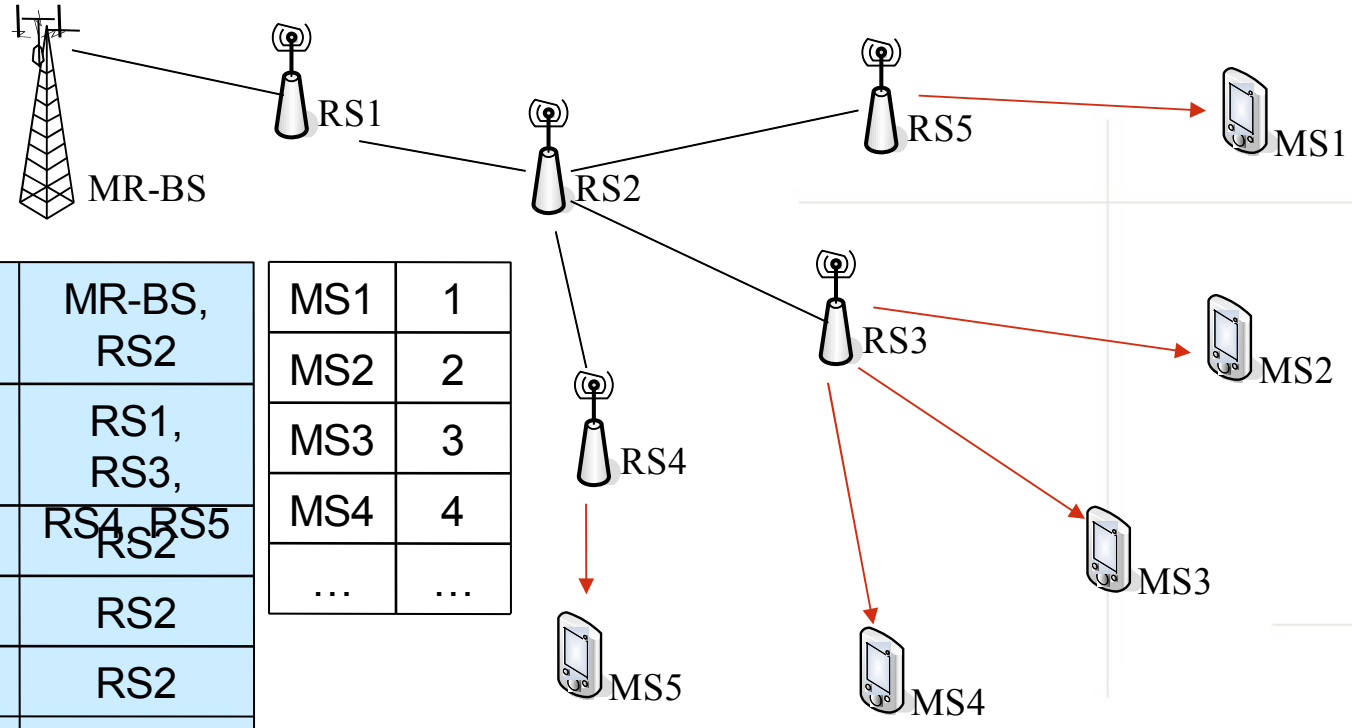
CID Allocation with Multi-hop Relays

- Two tables for SS and RS ID allocation
- Additional fields are required to store the MR topology

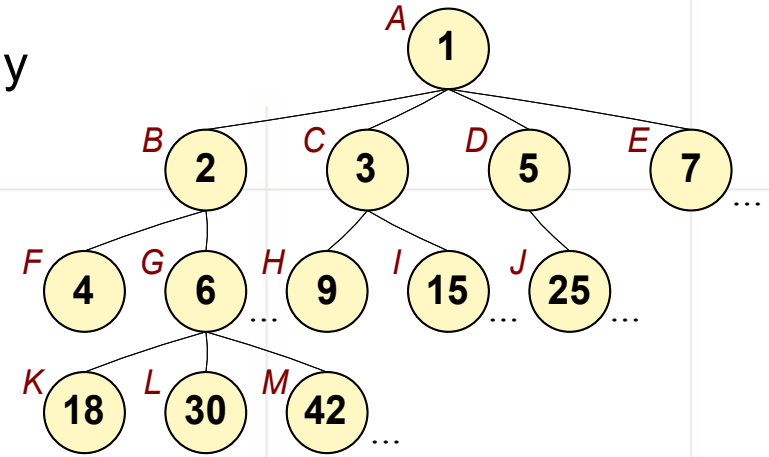


RS1	1001	MR-BS, RS2
RS2	1002	RS1, RS3, RS4, RS5
RS3	1003	RS2
RS4	1004	RS2
RS5	1005	RS2
…	…	…

MS1	1
MS2	2
MS3	3
MS4	4
…	…

Systematic CID Allocation

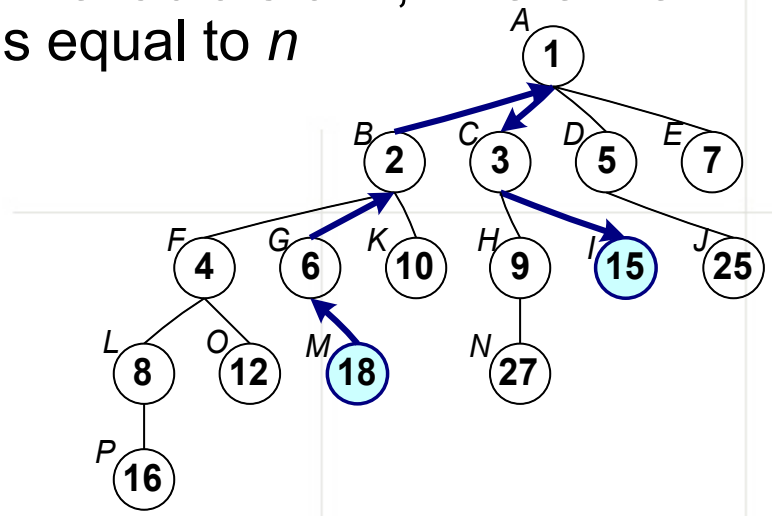
- The proposed systematic CID allocation mechanism
  - Make CIDs of RSs represent the topology of multi-hop relay (MR) network
  - The MR-BS could easily tell the topology of network by CIDs of RSs
- Prime-based CID allocation
  - For RSs associating to MR-BS
    - Allocates all prime numbers in the ascending order
      - E.g., RS E has the CID of 7



  - For RSs associating to another RS with CID *n*
    - Allocates addresses as *n* multiplied by a prime number starting from the largest prime factor of *n*
      - E.g., RS K is the first RS associates to RS G (CID=6)
        The largest prime factor of 6 is 3, so the MR-BS assigns 6*3=18 to RS K.

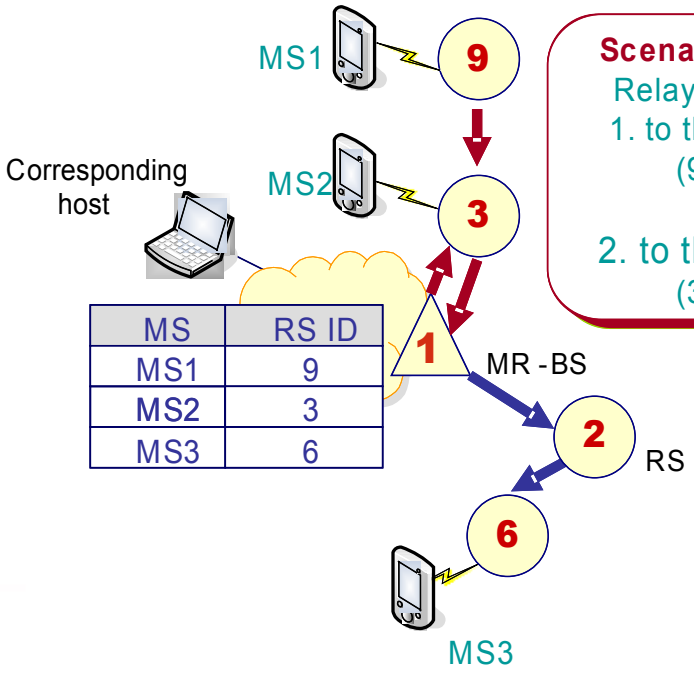
Systematic Relaying

- Define: Prime factorization sequence of an integer *n*
  - An ascending ordered set of all prime factors of *n*, where the product of all elements in the set is equal to *n*
  - Noted as ***pfSeq(n)***
  - E.g., pfSeq(54)= (2, 3, 3, 3)
- Relay path
  - The source RS to the MR-BS
    - send to the parent link directly
    - E.g., 18, 6, 2, 1
  - The MR-BS to the destination RS (CID=*n*, *pfSeq(n)*=(p_0, p_1, p_2, …, p_m))
    - Path is $\left(\prod_{i=0}^{i_1} p_i, \prod_{i=0}^{i_2} p_i, \ldots, \prod_{i=0}^{i_m} p_i \right)$
    - E.g., pfSeq(15)=(3,5), path=(1*3, 1*3*5)=(3, 15)



Systematic Relaying

- Prime-based Relaying
  - Intra-MR relaying
  - Inter-MR relaying



Scenario 1: Connection MS1 → MS2

Relay path: (9, 3, 1, 3)

1. to the MR-BS

   (9, 3, 1): continuously to parent node until reaching the MR-BS

2. to the RS3

   (3): pfSeq(3) = (3), and the path is (self*3)=(3)

Scenario 2:

Connection CH→MS3

finds destination at RS6

Relay path is (2, 6)

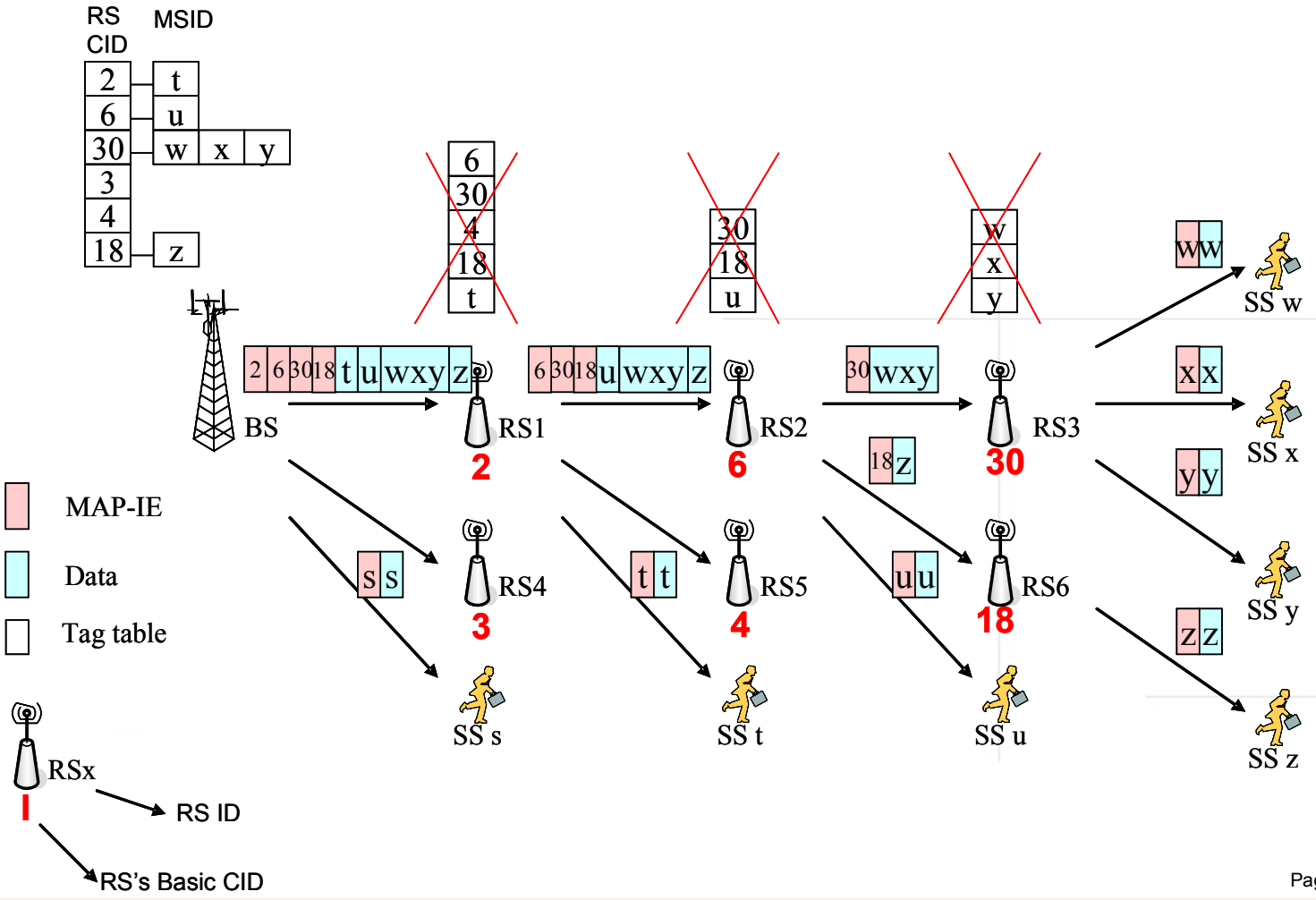
1. to the RS 6

   pfSeq(6)=(2, 3)

   path=(self*2, self*2*3)

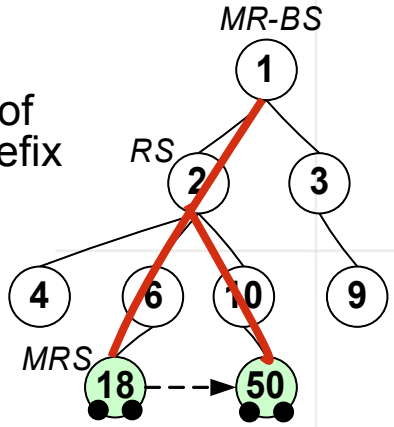
   = (1*2, 1*2*3) = (2, 6)

Implementation Example
(Relay path oriented relay scheme)



Mobility Support

- The proposed prime-based CID allocation could help to quickly find the anchor RS (Least Common Ancestor, LCA) for mobile RS (MRS)
  - The anchor RS can help to buffer and forward data traffic
    - Release the buffering loads at the MR-BS
    - Easily combine with the buffering mechanism for HARQ
  - The relay path is not required to be re-established
    - For distributed resource management (under MR-BS's control), bandwidth reservation is only required to be set up along the new segment from the anchor RS and the new RS
- LCA determination
  - By computing **seqGCD(serving RS, target RS)**:
    - The product of the prime factors in the longest common prefix of pfSeq(serving RS) and pfSeq(target RS), or 1 if no common prefix
    - E.g., seqGCD(6, 10)=2
      - pfSeq(6)=(2, 3)
      - pfSeq(10)=(2, 5)
      - The longest common sequence is (2)



Proposed Text

[Add the following text into section 6.3.1.3]

6.3.1.3.1 Addressing Scheme for Relaying

In the procedure of the network entry and initialization for a new RS, the temporary associated RS for initialization could be determined after the ranging of the new RS. At this time, the MR-BS shall assign CIDs (i.e., basic CID, primary CID, secondary CID) to the new RS by performing the prime-based identification allocation mechanism for the rest of initialization procedure. However, according to the topology configuration, the preceding RS of the new RS may differ from temporary associated RS for initialization, so the RS topology establishment procedure shall be proceeded in order to determine the actual selected preceding RS for the new RS. Thereafter, the MR-BS should assign a new CID to the new RS if required. Figure 6.3.1.3.X depicts the corresponding CID allocation message flows after the completion of RS network entry procedure.

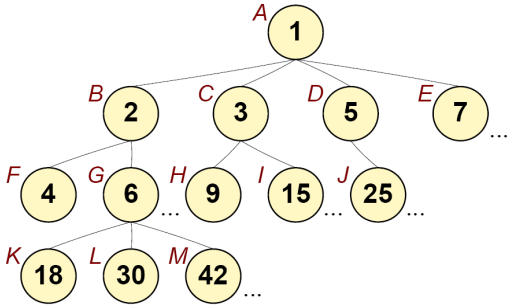


Figure 6.3.1.3.XX: An example of prime-based CID allocation tree

…

Proposed Text

[Add the following text into section 6.3.25]

6.3.25.1 Relaying Path Management and Routing

Each RS shall be able to serve all MSs and SSs that associate with it to relay traffic from the source RS (RSs) to the destination RS (RSr). If a RSs does not know which RSr is the access RS of the destination SS (or MS), it could ask the MR-BS if necessary. The MR-BS shall be capable to be aware of the access RS of the destination SS and configure a relay path to the RSr along the branches of the CID allocation tree. Assume the CID of RSr is n, we define prime factor sequence of n, denoted as pfSeq(n), …

There are two types of relay path configuration as follows:

- Relaying type 1: Intra-MR relaying: the source station and destination station are in the same MR network.

- Relaying type 2: Inter-MR relaying: the source station and destination station are in the different MR network.

…

6.3.25.1.1 Relaying type 1: Intra-MR relaying

When the source and destination nodes are both in the same MR network, the RSs needs to relay traffic to the RSr. First of all, the RSs shall relay traffic to the MR-BS by sending traffic to its parent RS. Each RS simply relay traffic destined to the MR-BS to its parent RS. Upon receiving the traffic from the RSs, the MR-BS also checks the RSr for the destination node, and relay traffic to the RSr as illustrated in Figure 6.3.25.1.Y.

…

6.3.25.1.2 Relaying type 2: Inter-MR relaying

This type of relaying defines relaying procedure when a source or a destination is not in the same MR network as the MR-BS.

…

Proposed Text

[Add the following text into section 6.3.22.4]

6.3.22.4 Mobile Relay Station Handover

6.3.22.4.1 Mobile Relay Station Handover using Prime Addressing Mechanism

Since prime-based identification allocation mechanism can enable MR-BS to efficiently find out the anchor RS (i.e., the LCA RS) of two subordinate nodes by GCD method, it can benefit the procedure of Mobile Relay Station (MRS) handover. Figure 6.3.22.4.X describes the procedures when MRS handovers between RSs.

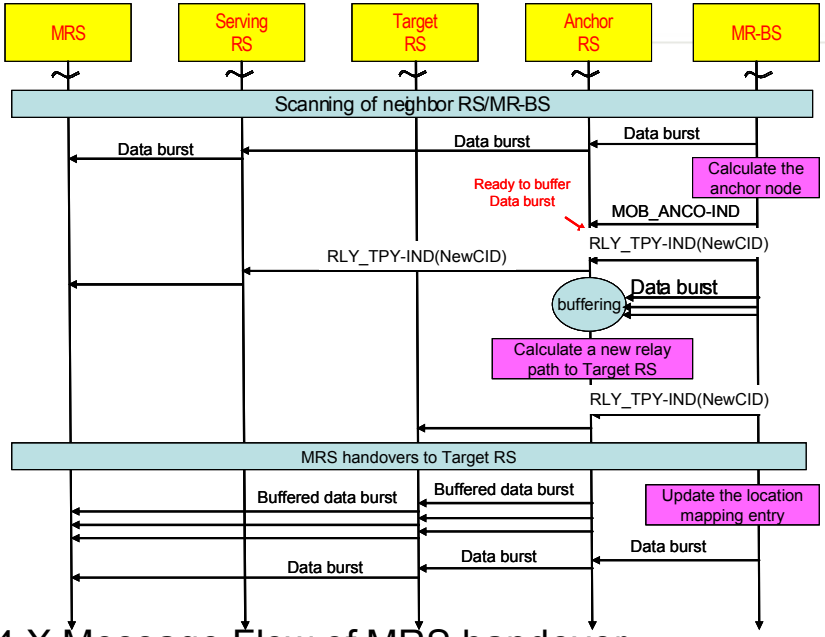


Figure 6.3.22.4.X Message Flow of MRS handover

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Proposed Text

[Add the following text into sub-clause of section 6.3.2.3]

- **Relaying mode RS topology indication (*RLY_TPY-IND*) message**

  An MR-BS shall transmit a RLY_TPY-IND message for indicating what the suitable preceding RS is and indicating the CID for new RS, and then trigger the network re-entry. A RLY_TPY-IND message may also be transmitted to the selected preceding RS for the notification that a new RS with CID descending from this preceding RS.

  …

- ***Mobile Anchor-node Indication* (*MOB_ANCO-IND*) *message***

  An MR-BS sends MOB_ANCO-IND to indicate the anchor RS of Serving RS and Target RS during MRS handover.

  …

Conclusion

- To jointly consider CID allocation and relay path management
  - Prime-based CID allocation mechanism
    - CIDs of RSs could represent the topology of MR network
  - Prime-based relaying
    - MR-BS could easily calculate relay path according to the CID of the access RS of the destination station
  - Mobility support
    - MR-BS could quickly locate the anchor RS to support fast handoff
      - The anchor RS helps to buffer and forward data traffic
      - Bandwidth reserved from the anchor RS to the new RS to support QoS

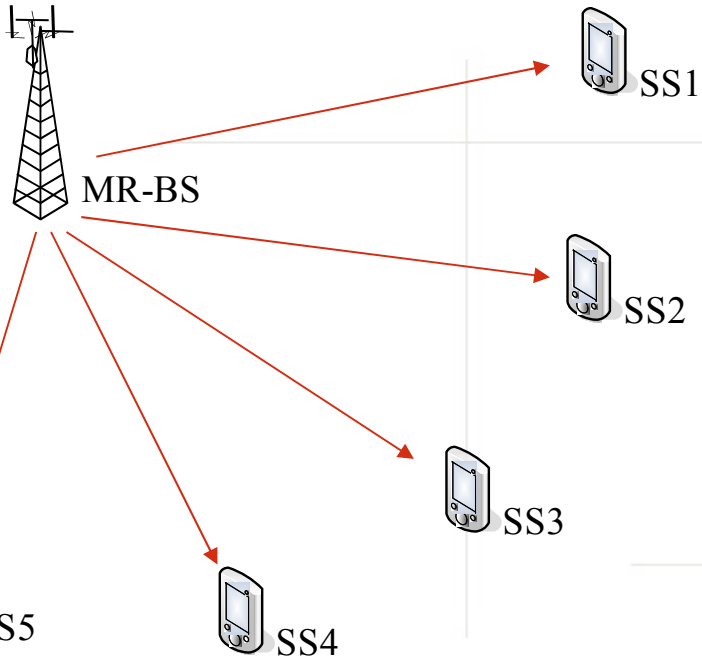
Thank You

Supplement slides

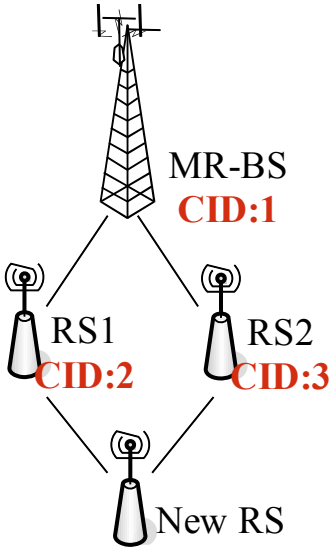
CID Allocation in 802.16e

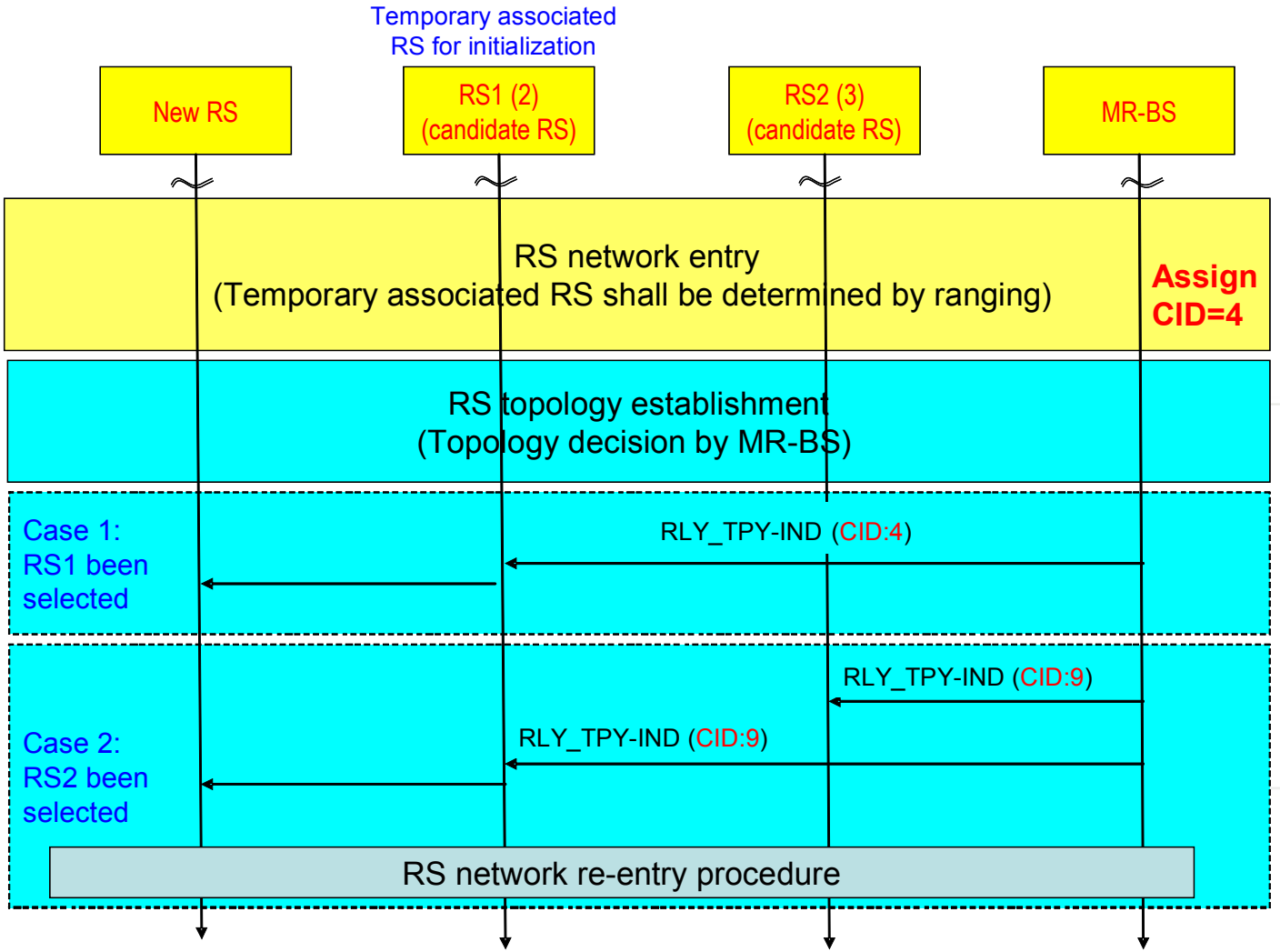
- Sequential allocation

SS1	1
SS2	2
SS3	3
SS4	4
…	…

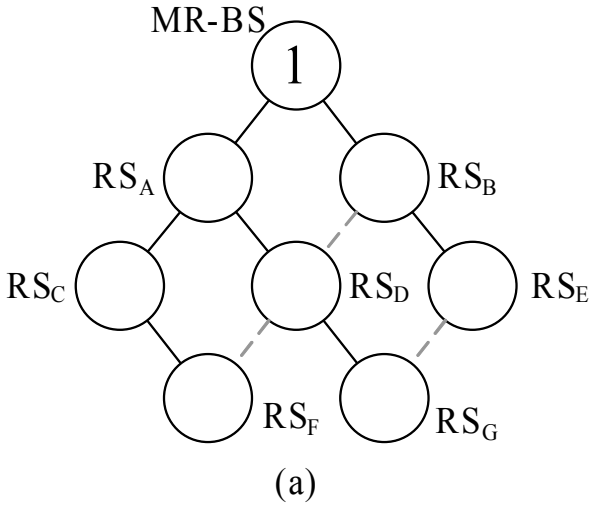


CID Allocation Message Flow

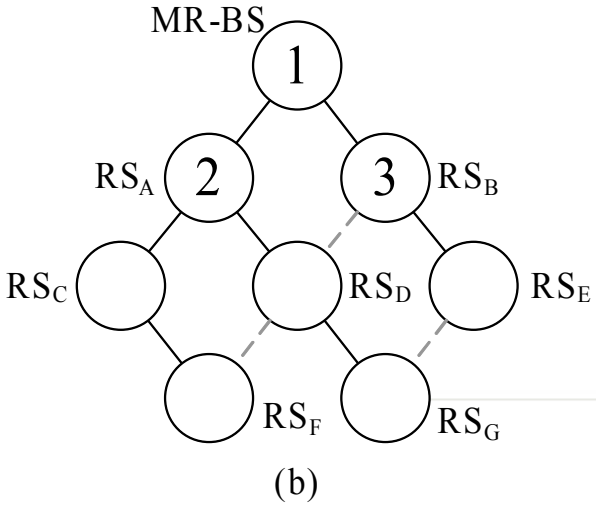




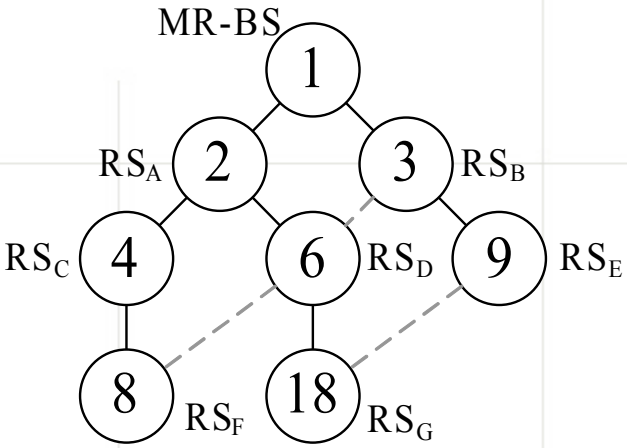
CID Allocation Example

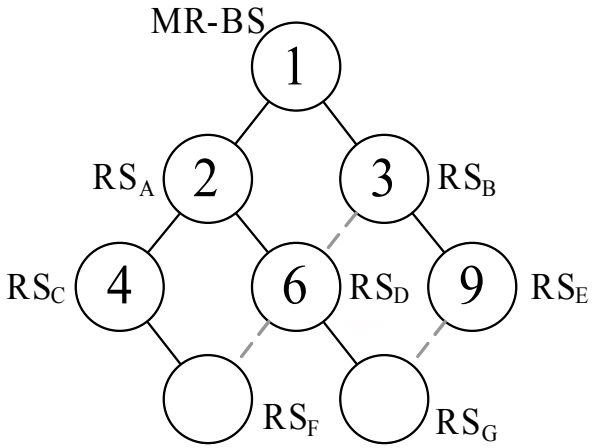


(a)

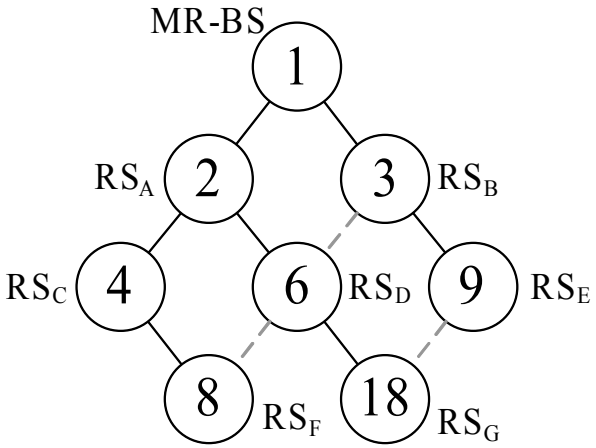


(b)



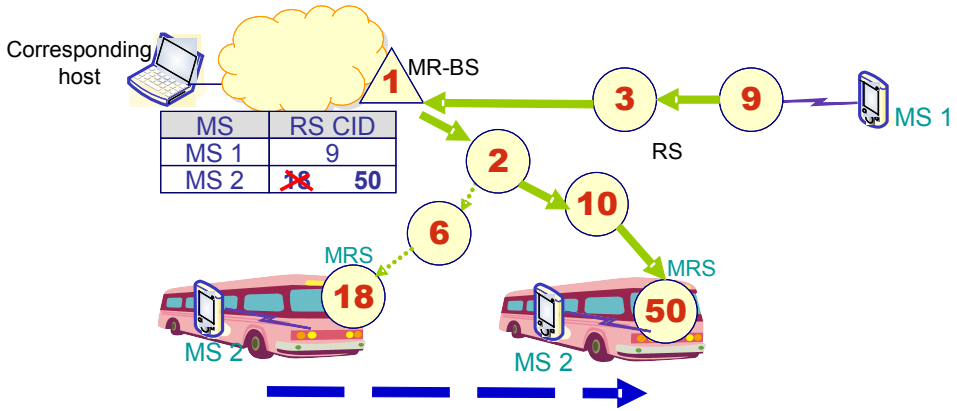


(c)



(d)

Mobility Support Example

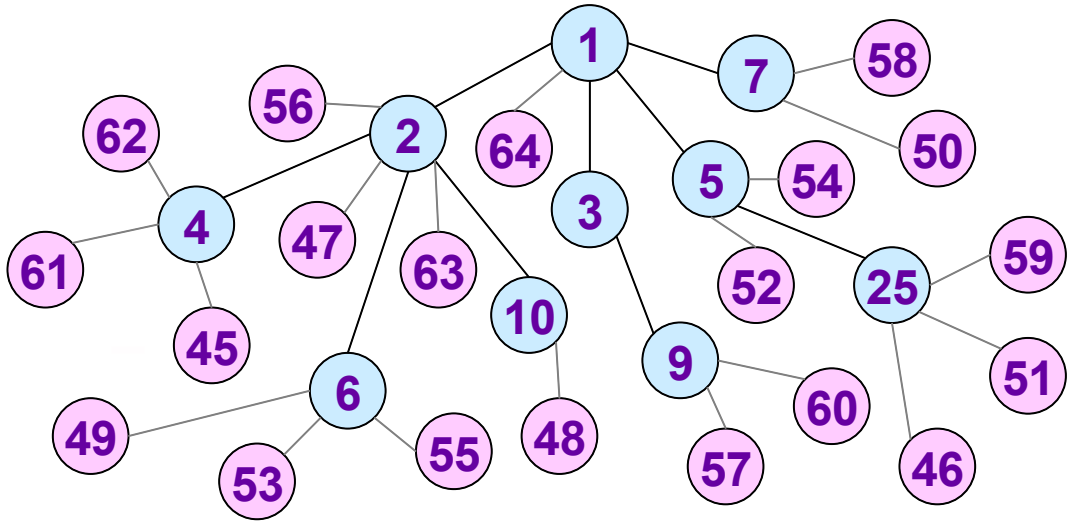


1. MRS scans neighbor RS/MR-BS, and MR-BS determines the target RS.
2. MR-BS computes the anchor RS, which is RS 2 in this example.
3. MR-BS sends *MOB_ANCO-IND* to indicate the anchor RS to make it start buffering the data traffic.
4. MR-BS sends *RLY_TPY-IND* message to pre-allocate a new CID (50) for MRS.
5. Anchor RS calculates a new relay path to the Target RS and processes the bandwidth reservation for the new path.
6. MRS handovers to Target RS (the detailed handover procedure is keeping an open issue here).
7. After MRS completes the handover to the Target RS, anchor RS forwards the buffered data traffic to Target RS.
8. MR-BS updates the location mappings entry of the new CID (50) of MRS.

CID Space Arrangement

- CID space is shared by RSs and SSs
  - Assign MSs from largest number
  - As defined in 802.16, CID has 16 bits
    - The CID space is 2^{16}
  - E.g., if CID space is 2^6

1	2	3	4	5	6	7	8	9	10	11	12	13	...	22	23	24	25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40	41	42	43	44	45	…	54	55	56	57	58	59	60	61	62	63	64



CID Space Arrangement

- An alternatives
  - Make an exclusive partition for CID space for RSs
    - Basic CID:
      - 0x0001~n: CID space for RSs
      - n+1~m: CID space for SSs and MSs
    - Primary management:
      - m+1~m+n: for RSs
      - m+n+1~2m: for SSs and MSs

CID Allocation Algorithm

- MR-BS stores the sequence of prime numbers in the range of the CID space
  - 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, …
- For the RS associates to the MR-BS
  - Directly assign the next prime number
- For the RS associates to the RS with CID *n*
  - Compute the largest prime factor *p* of n (which could be stored after first computation)
  - Compute n*p
    - Check if n*p is assigned to RS or MS
      - No: assign n*p
      - Yes: continuously try next prime number until successful
    - This information could also be kept in the ID allocation table

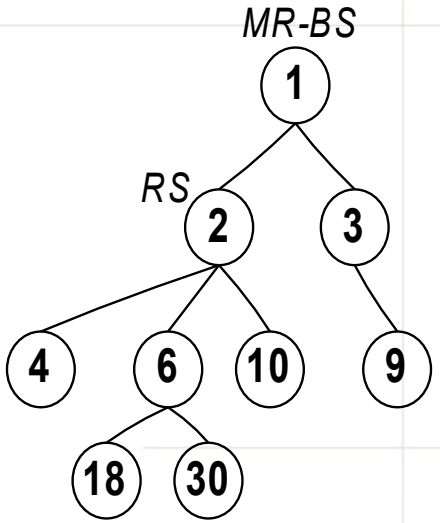
Subordinate Differentiation Algorithm

- RS computes the prime factorization of itself and destination RS
  - If the sequence of itself is the prefix of the sequence of the destination RS
    - The destination RS is its subordinate station
- For example
  - Is 30 a subordinate station of 3?
    - pfSeq(30)=(2, 3, 5), pfSeq(3)=(3)

    →no subordinate station
  - Is 30 a subordinate station of 4?
    - pfSeq(30)=(2, 3, 5), pfSeq(4)=(2, 2)

    → not subordinate station
  - Is 30 a subordinate station of 6?
    - pfSeq(30)=(2, 3, 5), pfSeq(6)=(2, 3)

    → Is subordinate station



Subordinate Differentiation Algorithm (2)

- Each RS needs to identify if the destination RS is its subordinate RS.
  - RS stores a sequence of prime numbers smaller than its own smallest prime factor
    - E.g., RS with CID 45
      - The smallest prime factor is 3
      - It stores prime numbers (2)
  - RS divides the destination CID with its own ID
    - If is not divisible: not its subordinate RS
    - If divisible
      - Divides the destination CID with all prime numbers it stores
        - If any one can divide the destination CID without remainder: not its subordinate RS
        - Else: is its subordinate RS

Subordinate Differentiation Examples

- E.g., is 30 a subordinate station of 3?
  - Prime number list of 3: (2)
  - 30%3=0
  - 30%2=0 → not subordinate station
- E.g., is 30 a subordinate station of 4?
  - Prime number list of 4: ()
  - 30%4=2 → not subordinate station
- E.g., is 30 a subordinate station of 6?
  - Prime number list of 6: ()
  - 30%6=0
  - No prime numbers in the list
  - → is subordinate station