# Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

**Submission Title:** [ Anti-blocking Mechanism by Relay]
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**Re:** []
**Abstract:** [In order to avoid blocking in line-of-sight, anti-blocking mechanism via relay is proposed.]
**Purpose:** [To be considered in IEEE 802.15.3c standard]

# Contents

# Comments about blocking (#483)

- When blocking happens during the communication between source and destination device, the beam forming functionality doesn't seem to be enough to recover the connection. Even though there are lots of multi-paths, the path loss attenuation would be too severe because of the characteristics of 60 GHz frequency band. Moreover, the performance pretty much depends on the environment such as the material reflecting signals and etc. So, we need the alternatives for this beam forming problem.
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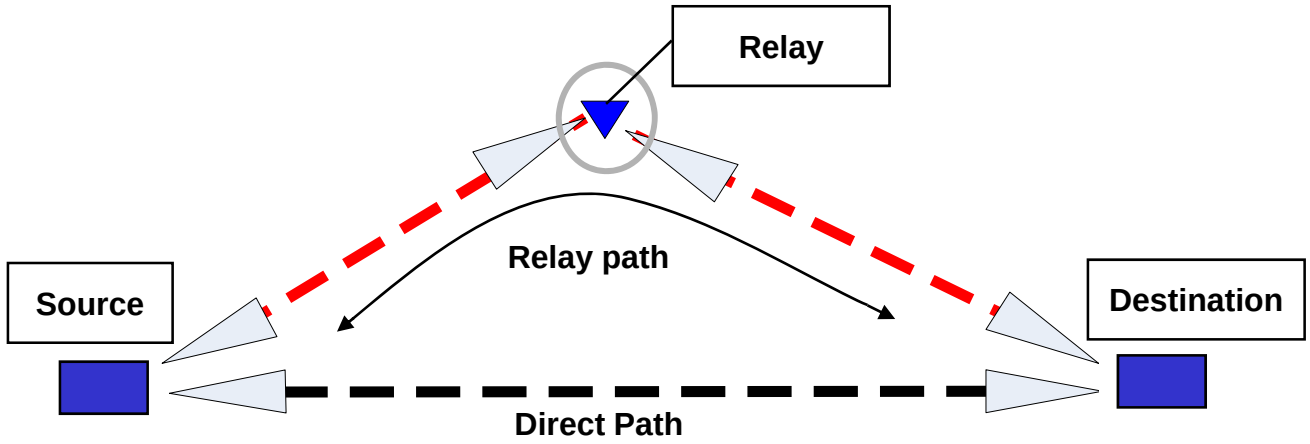
# Introduction

- 60GHz Characteristics
  - High directivity
  - High path loss in indoor environment
  - Sudden level fluctuation caused by human movements
- Considering these, the existing beam switching (steering) can be used. However, it has still troubles maintaining rates because of huge channel gain loss by obstacles (e.g human movements) or by reflection on material.
- Relaying
  - Can help to prevent the outage of systems by obstacles.
  - Can maintain the required data rates when the direct link is not enough.

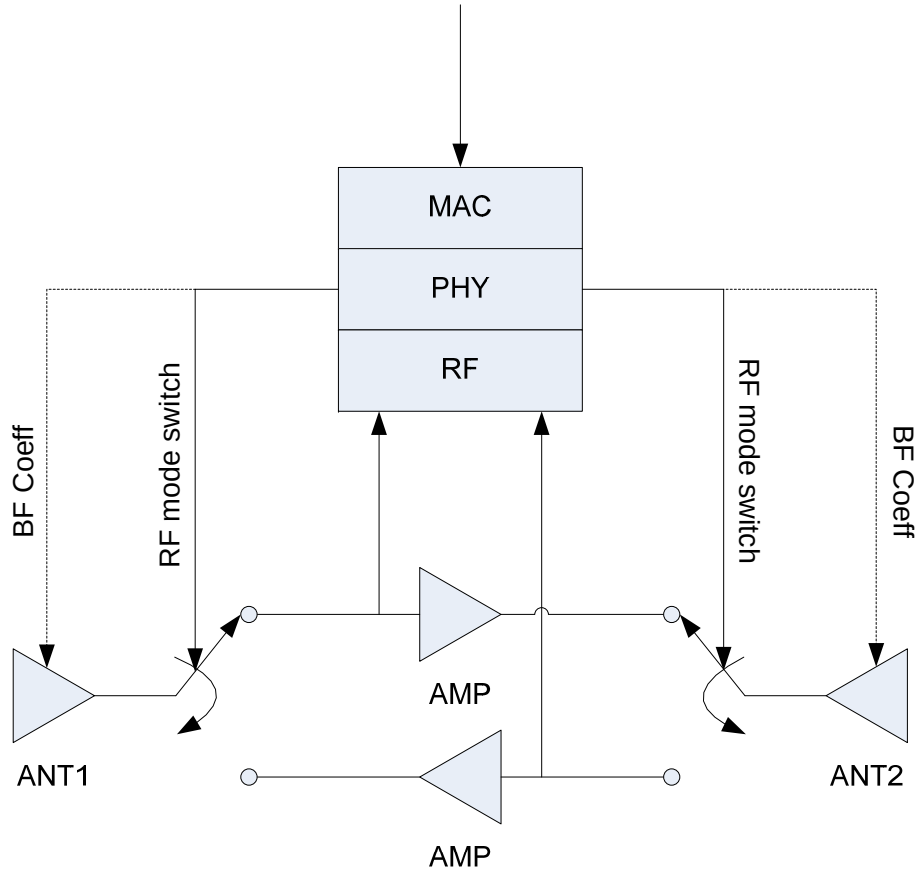
# Introduction (cont'd)




[Configuration of a pair of devices and a relay]

- Requirements of relaying
  - Amplify and forward (AF) on RF level
  - Have at least two antennas for receiving signal and at the same time, sending it
  - Switch the mode of two antennas, (Rx->Tx and Tx->Rx)
  - Support point-to-point communication
  - Beam forming capability is preferable.

# Relay Capable Device



# Setup Procedures for Relay Operation

- Relay Capability Identification
- Relay Device Selection
- Relay Association

# Relay Capability Identification (1)

- Capability Information Element Format

| octets: 1 | 3 | 5 | 4 |
|---|---|---|---|
| Relay Capa. | Beam forming Capa. | DEV Capa. | PNC Capa. |

| Bits:b7-b3 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|
| Reserved | A/C power mode | Relay Des-mode | Relay supportable | Relay capable |

# Relay Capability Identification (2)

- A source needs to identify a relay and to know whether or not destination supports relay operation.
- This is accomplished by DEVs reporting their relay capability in the association process and then PNC broadcasts in the beacon.

# Relay Device Selection

- If source finds multiple relay devices, it selects one more qualified to be its relay, based on the relay selection criteria which is much like PNC selection.

| Order | Information | Note |
|---|---|---|
| 1 | PNC Des-mode = 1 and Relay Des-mode = 1 | PNC Des-mode=1 and Relay Des-mode=1 is preferred |
| 2 | Relay Des-mode = 1 | Relay Des-mode=1 is preferred |
| 3 | A/C Power mode = 1 | A/C Power mode=1 is preferred |
| 4 | DEV address | Higher value is preferred |

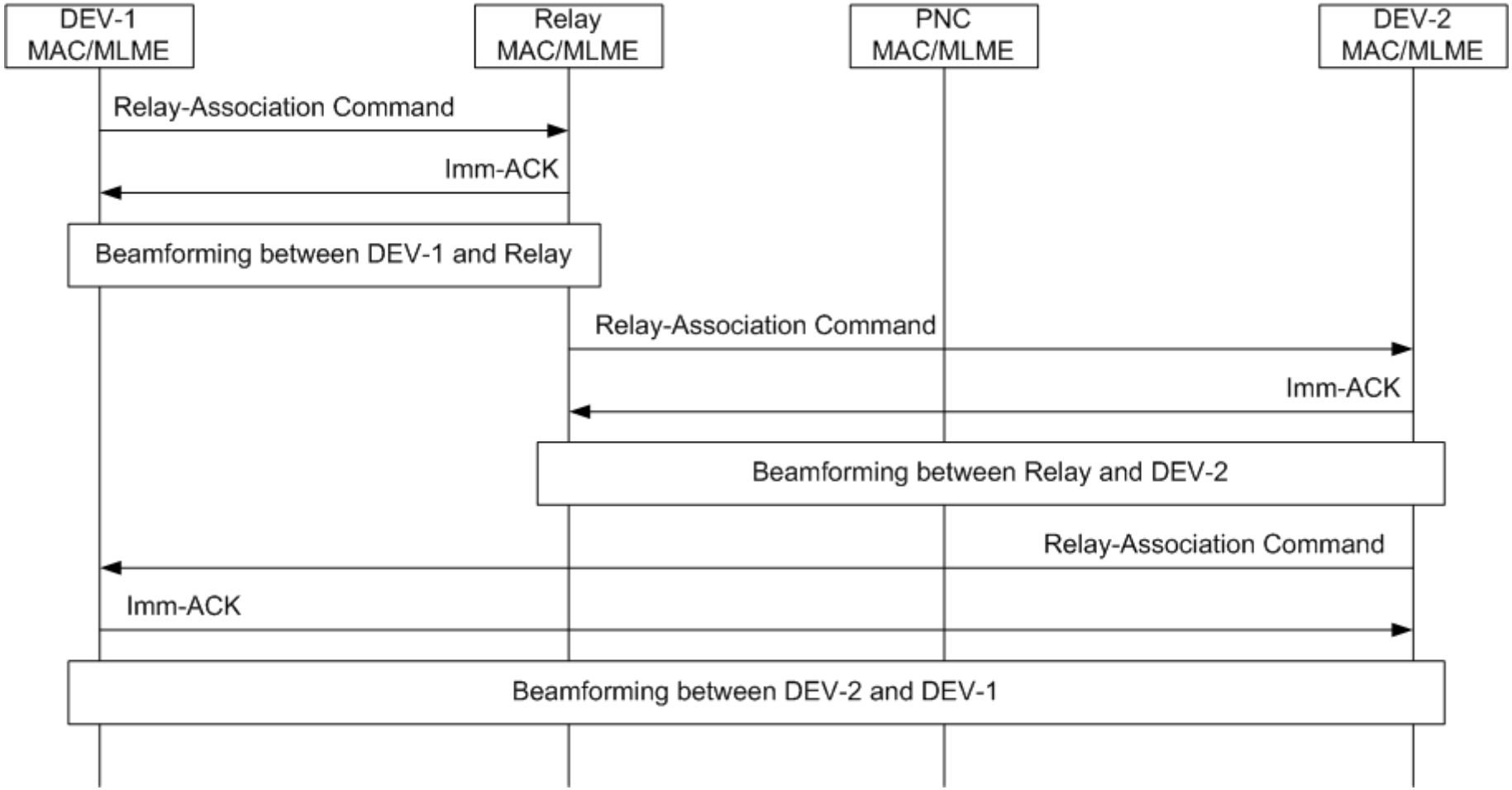
# Relay Association (1)

- Identify three DEVs (source, destination, and relay) and do beamforming between each pair

- Relay Association command frame

| Octets: 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 |
|---|---|---|---|---|---|---|---|
| Third Target DEVID | Second Target DEVID | First Target DEVID | Link Count | Duration | Transaction code | Length | Command type |

# Relay Association (2)



# CTA Request & Allocation

- CTA for Relay
  - CTA for three DEVs involved in Relay association
  - In views of source and destination device, identical with general CTA
  - In views of relay device, all it has to do is
    - to listen to beacon from PNC
    - to check the SrcID and the DestID in the channel time allocation block
    - If the SrcID and the DestID are corresponding to those devices associated with the Relay device, the Relay device may use the CTA for relay operation.

# Data exchange in CTA

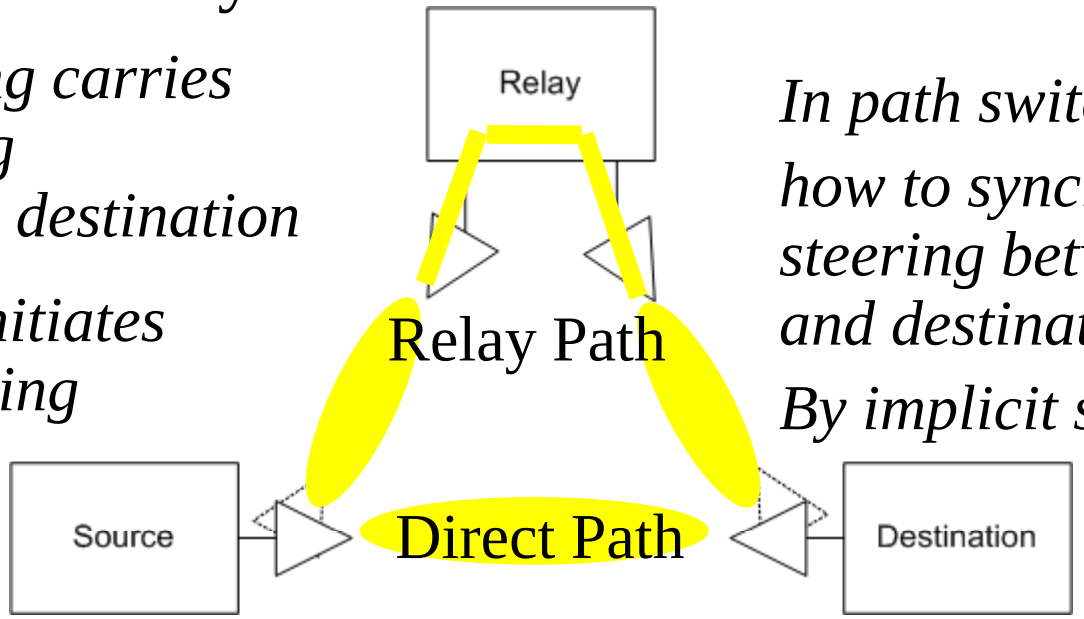
- Path Switching
- Decision on path switching
- Data exchange rule
- RF mode switching

# Implicit Signaling for Path Switching (1)

- Path Switching
  - From Direct Path to Relay Path
  - From Relay Path to Direct Path

*Path switching carries beam steering at source and destination*

*Just source initiates a path switching*



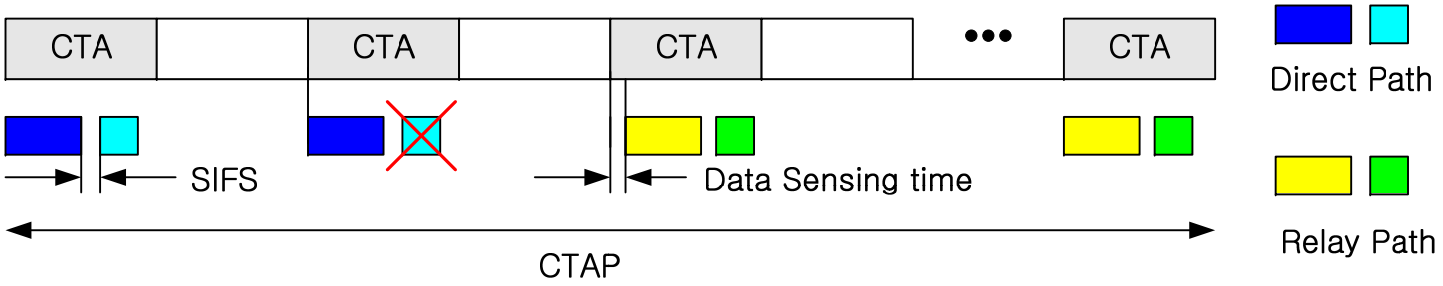

*In path switching,*

*how to synchronize beam steering between source and destination?*

*By implicit signaling*

# Implicit Signaling for Path Switching (2)

- Data Sensing Time
  - The source shall start to transmit data at the beginning of CTA
  - However, if path switching occurs, the source shall defer transmitting data during data sensing time in order to implicitly signal a path switching
  - The destination shall do beam steering into other path if there is no data from the source during the data sensing time in the CTA



# Decision on Path Switching

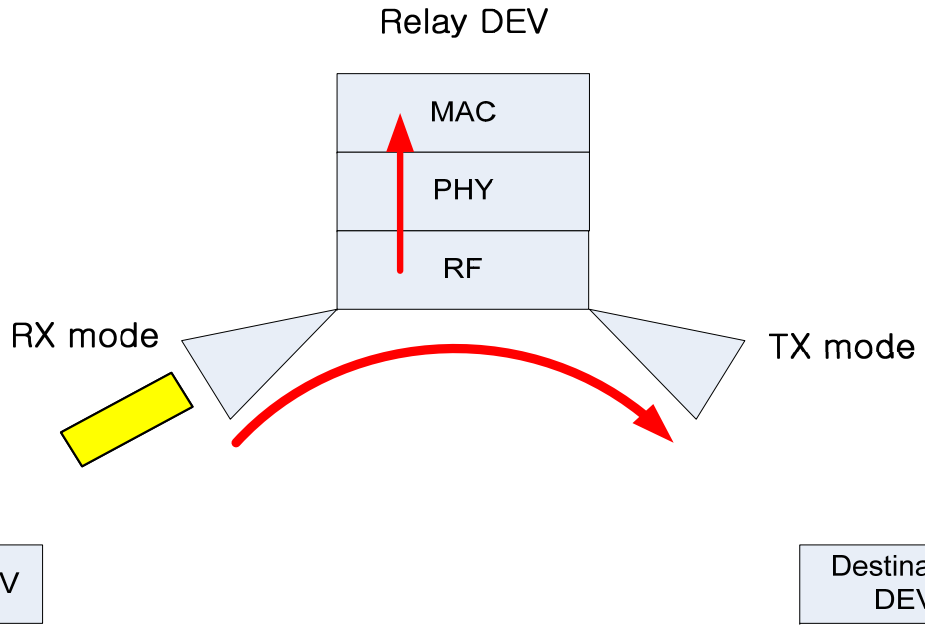
- There are three methods to decide whether the path used in current CTA is available or not.
  - First, if source didn't receive ACK frame, the path is considered as blocked.
  - Second, whether the path used is blocked or not is determined by channel status information. If the chosen channel status information is lower than the predefined threshold, the source may change the path to the other path. The channel status information can be obtained by using channel probing.
  - Third, if ACK policy is delayed ACK or block ACK, the ratio between total number of subframes and the number of subframes requesting retransmission or frame error rate may be used as decision metrics
- Those methods may be used simultaneously for path change decision.

# Data Exchange Rule

- The data exchange within one CTA shall be done only through one path.
- When the DEVs try to exchange data in CTA for the first time after association with Relay, the source shall send its first data through the direct path.
- The source shall change the path and transmit data to the other path for data exchange in the next CTA when it didn't receive ACK frame in current CTA. In this case, the currently remaining CTA is no longer used for data exchange.
- In case of path switching, the source shall transmit data to the other path after waiting for at least data sensing time in the next CTA.
- The destination shall listen for data sensing time whenever the CTA starts. If there's no data during data sensing time at the start of the CTA, the destination immediately change the path to receive data.

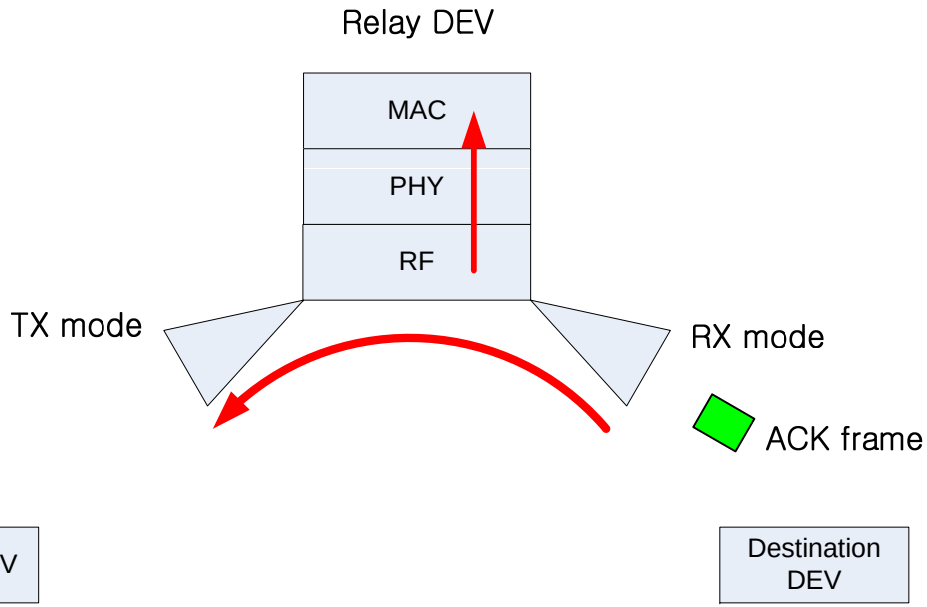
# RF mode switching of Relay (1)

- According to the ACK Policy, the time the relay needs to receive ACK can be changed. So, the relay should have the method for predicting the transmission direction of next data before data reach the relay.
- In order to do that, the relay shall decode the relayed frame to identify ACK policy from frame header as well as amplify and forwards it simultaneously. The relay shall switch the mode of each antenna based on the information extracted from frame header.



# RF mode switching of Relay (2)

- If the relay receives ACK frame, RF mode is switched right after the relaying.



# Conclusion

- Advantages of introduced anti-blocking mechanism based on ACK via Relay
  - When data blockage of LOS occurs, data exchange can be done by detour path via relay device in an amplify and forward manner.
  - Simple blocking avoidance mechanism (blocking detection and detour)
  - A complement to beam forming technology

# BACKUP SLIDES

# Relay Capability Identification(1-1)

- Relay Capability bit field
  - The Relay Capable Bit shall be set to one if the DEV is capable of being a Relay in the piconet. Otherwise, the Relay Capable Bit shall be set to zero.
  - The Relay Supportable Bit shall be set to one if the DEV is able to transmit/receive data via a Relay in the piconet. Otherwise, the Relay Supportable Bit shall be set to zero.
  - The Relay Des-Mode bit is the desired mode of the DEV. This bit shall be set to one if it is desired that the DEV be the Relay of the piconet and the Relay Capable bit is set to one. Otherwise, this bit shall be set to zero.
  - The A/C Power Mode bit shall be set to one if the DEV detects the presence of A/C power. Otherwise the A/C Power Mode bit shall be set to zero.

# Relay Association (1-1)

| Octets: 1 | 1 | 1 | 1 | 2 | 1 | 2 | 2 |
|---|---|---|---|---|---|---|---|
| Third Target DEVID | Second Target DEVID | First Target DEVID | Link Count | Duration | Transaction code | Length | Command type |

- The Transaction code field is unique identifier assigned by a DEV which is initiating a relay operation. This field is used to identify unique relay set composed of destination DEV, source DEV and relay DEV with the same code.
- The Duration field defines the maximum total time that the DEV sending this command can spend performing beam forming with the target device.
- The Link count field identifies the links for relay operation.
- The First Target DEVID field indicates the DEVID that corresponds to the target DEVID of the first link for relay association.
- The Second Target DEVID field indicates the DEVID that corresponds to the target DEVID of the second link for relay association.
- The Third Target DEVID field indicates the DEVID that corresponds to the target DEVID of the third link for relay association.

# Data Exchange Rule

- The data exchange within one Relay CTA shall be done only through one path. In other words, if the source DEV needs to or wants to change the path, the source shall start to transmit data to the other path in the next relay CTA.
- When the DEVs try to exchange data in Relay CTA for the first time after association with Relay DEV, the source DEV shall send its data through the direct path.
- The source DEV shall change the path and transmit data to the other path for data exchange in the next Relay CTA when it didn't receive ACK frame in current Relay CTA. In this case, the currently remaining Relay CTA is no longer used for data exchange.
- The source DEV may transmit data to the other path for data exchange when it decided to change the path intentionally according to channel status for instance.
- In both cases of path changes described above, the source DEV shall transmit data to the other path after waiting for at least data sensing time plus path switching time in the next Relay CTA in order for the destination DEV to change to the other path as well.
- The destination DEV shall listen for data sensing time whenever the Relay CTA starts. If there's no data during data sensing time at the start of the Relay CTA, the destination DEV shall change the path to receive data at once.

# Path Change

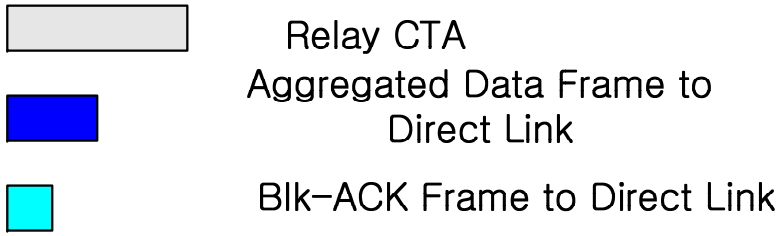
- If the path used is blocked or the source DEV decides to change the path based on channel status, the path shall be changed to the other path.
- This path switching shall start at the next allocated Relay CTA and then data exchange shall start the next relay CTA.
- The source DEV shall transmit data after the predefined data sensing time plus path switching time, in order to avoid the case that destination DEV does not receive data due to its path switch later than that of source DEV.

# Data exchange through the relay path

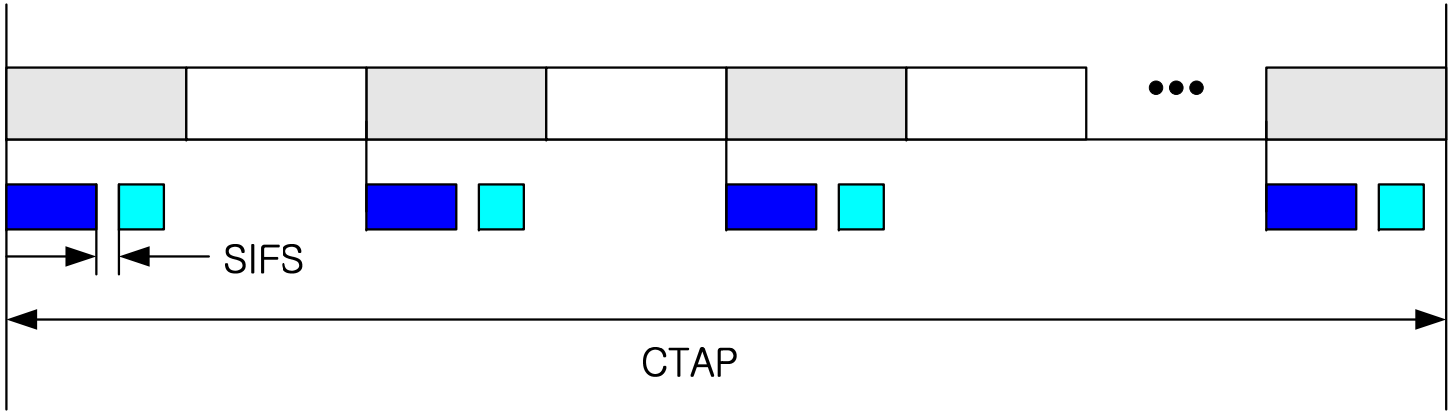
- The source DEV and destination DEV exchange data with the relay path since the direct path is blocked.
- In the Relay CTA, the source DEV shall always start to transmit data. And the source DEV transmits a data frame after data sensing time plus path switching time at the beginning of the next relay CTA toward the optimum direction found in the beam forming step in order to transmit through the relay path.
- In the similar manner, the destination DEV also changes the path after data sensing time toward the optimum direction found in the beam forming step in order to receive through the relay path.

# Data Exchange with Blk-ACK (1)

Case 1. Blk-ACK with Aggregation – no error

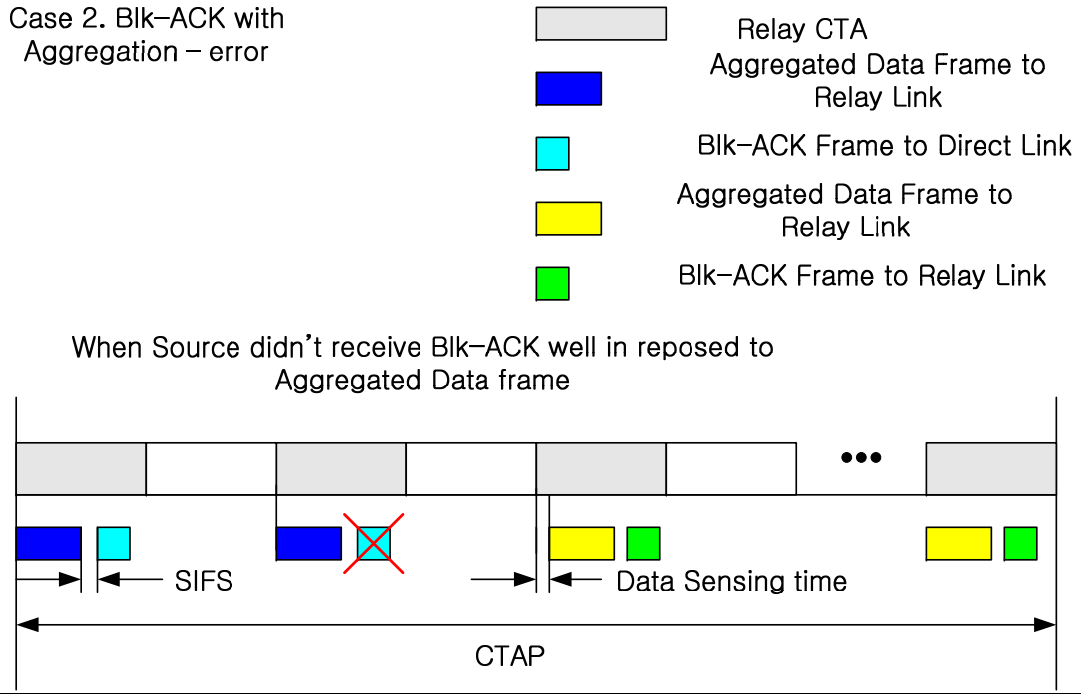



When Source received Blk-ACK well in reposed to Aggregated Data frame



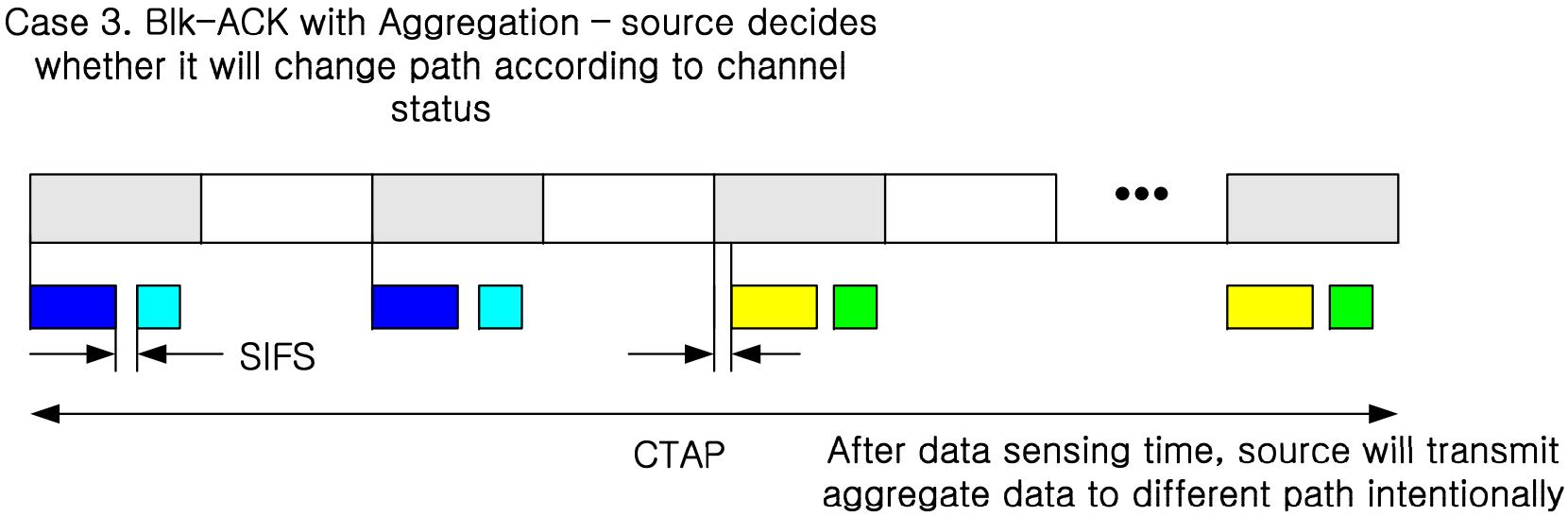
# Data Exchange with Block ACK (2)

- In case that ACK is not received,
  - Source DEV considers the path used blocked and change to the other path. And it transmits data in the next relay CTA after data sensing time.
  - Destination DEV recognizes the path blocked because data is not received at the next time slot of present CTA. So, it immediately switch to the other path and receive data again.



# Data Exchange with Block ACK (3)

- In case ACK is received but channel status is not good,
  - Source DEV considers the path used blocked. Therefore, it operates the same as case 2.
  - Same to case 2, destination DEV recognizes the path blocked because data is not received at the next time slot of present CTA. So, it immediately switch to the other path and receive data again.



# Recovery of Blocked Path

- Source and destination DEV check periodically whether the blocked path is available or not. This checking can be done by exchanging blocked path recovery command frame.
- If source DEV receives the blocked path recovery response command frame with availability field set to 1, it considers the path recovered. And then the source and destination DEV move to the recovered path at the next allocated relay CTA.
- This command frame can be exchanged in CAP or CTA, directionally.