



Bluetooth – Longer Range, Higher Speed and Increased Capacity

Kai Ren, Senior Developer Relations Manager, Bluetooth SIG



微信



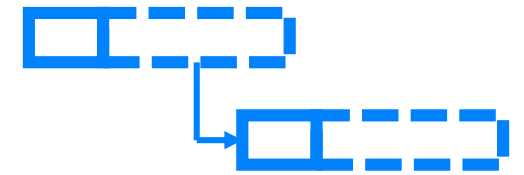
The Features Introduced in Bluetooth Low Energy of Bluetooth Core Specification v5.0



High Speed



Long Range



**Advertising
Extension**

The image features a solid blue background with a diagonal line running from the top-left to the bottom-right. On the left side, there is a large, hollow, light-blue triangle pointing to the right. On the right side, there is a smaller, solid, dark-blue triangle pointing to the left. In the center, the words "High Speed" are written in a bold, white, sans-serif font.

High Speed



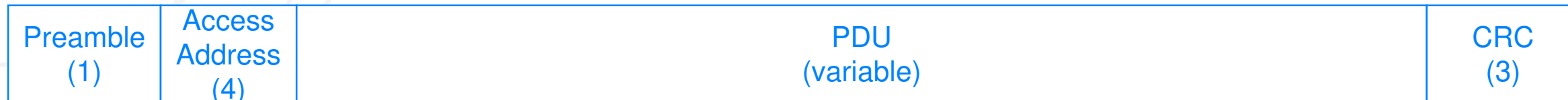
Packet Format For LE Uncoded PHYs

* Without Constant Tone Extension

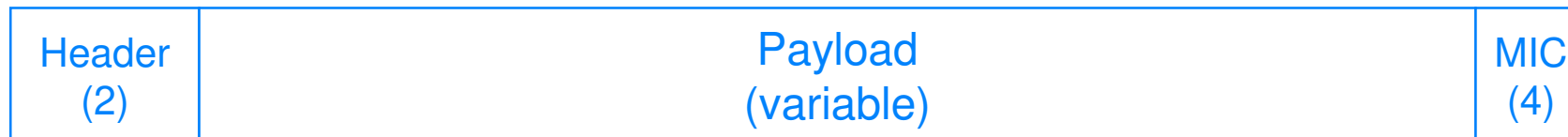
Preamble (1 or 2)	Access Address (4)	PDU (variable)	CRC (3)
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PDU



Link Layer





L2CAP

Preamble (1)	Access Address (4)	PDU (variable)	CRC (3)
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Link Layer

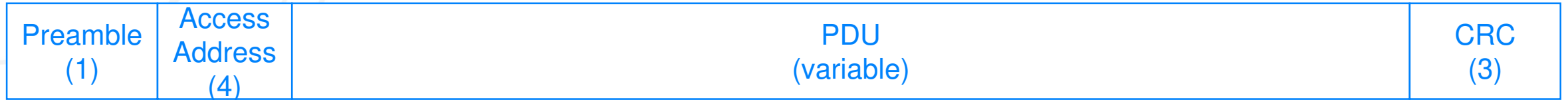
Header (2)	Payload (variable)	MIC (4)
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L2CAP

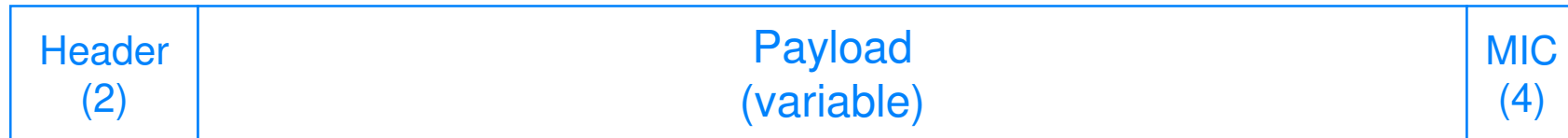
Len (2)	Channel ID (2)	Information Payload (variable)
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ATT



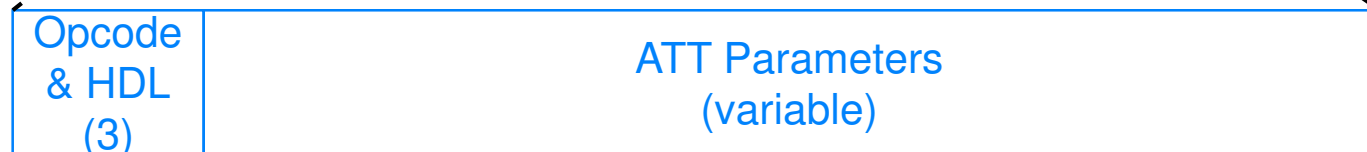
Link Layer



L2CAP

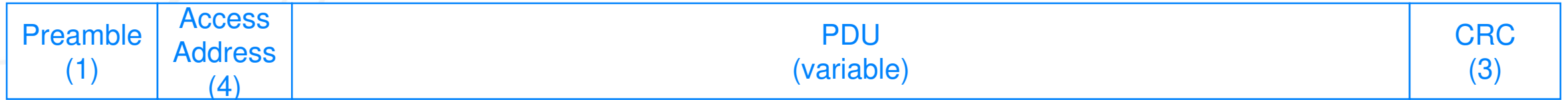


ATT

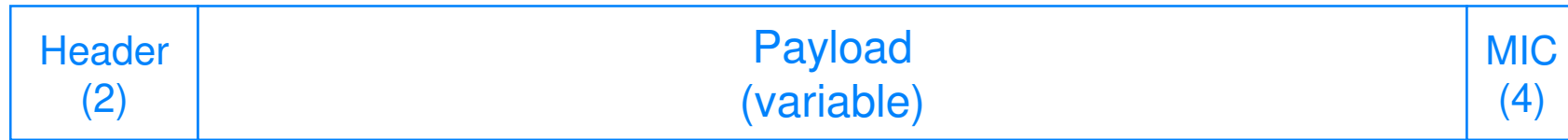




ATT



Link Layer



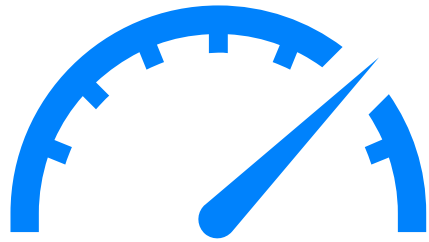
L2CAP



ATT



Bluetooth Core Specification v4.0/4.1



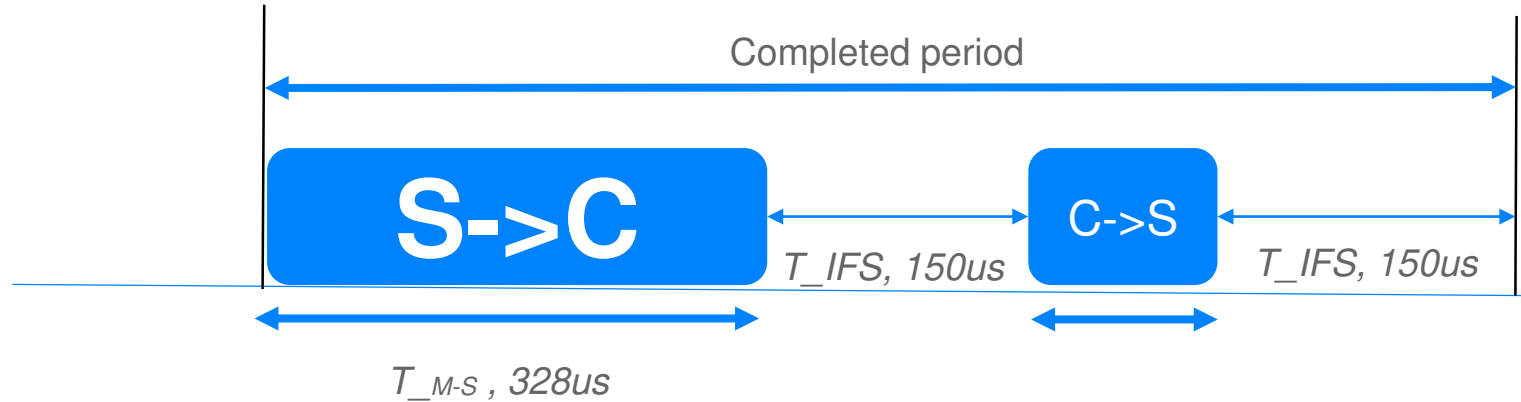
1 Mega symbols/sec

1 symbol -> 1 us

1 bit = 1 symbol

1 bit -> 1 us

Bluetooth Core Specification v4.0/4.1

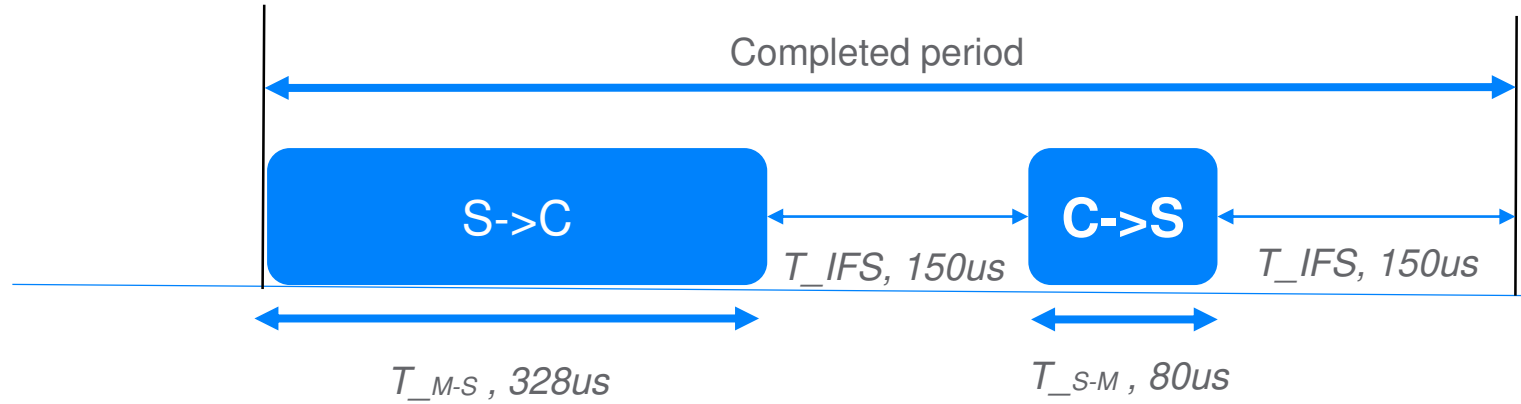


S – GATT Server
C – GATT Client

Handle Value Notification, Maximum length, 41 Bytes = 328 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 20)	MIC (4)	CRC (3)
-----------------	-----------------------	------------------	------------------	--------------------	---------------------	-----------------------------	------------	------------

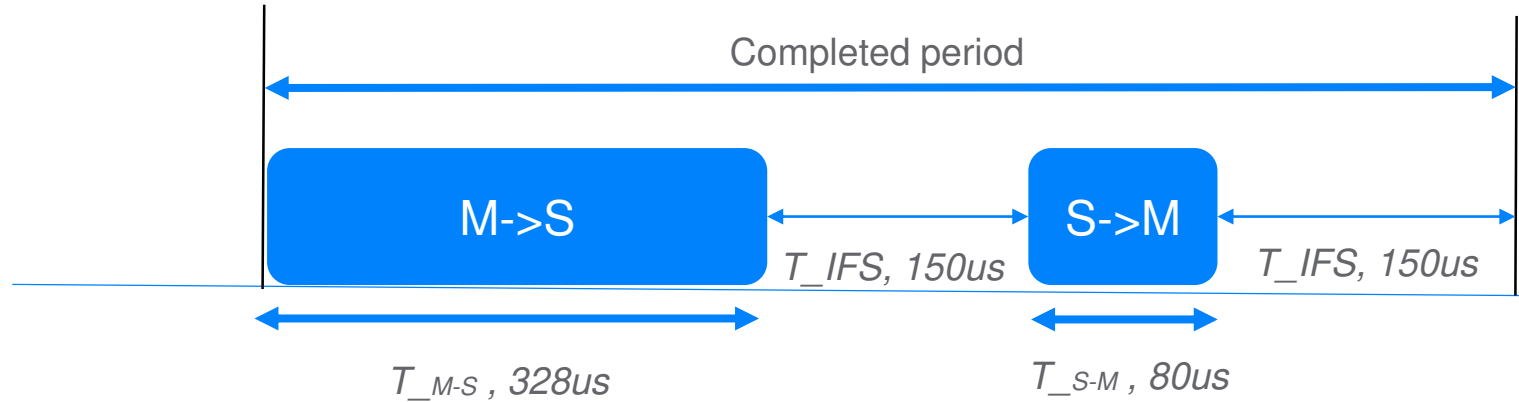
Bluetooth Core Specification v4.0/4.1



LL Data PDU, empty unit, 10 bytes = 80 bit

Preamble (1)	Access Address (4)	LL Header (2)	CRC (3)
-----------------	--------------------------	---------------------	------------

Bluetooth Core Specification v4.0/4.1



Handle Value Notification, Maximum length, 41 Bytes = 328 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 20)	MIC (4)	CRC (3)
-----------------	--------------------------	---------------------	---------------------	-----------------------	------------------------	-------------------------------------	------------	------------

$$\text{Throughput} = \frac{\text{Attribute Value}}{T_{M-S} + T_{IFS} + T_{S-M} + T_{IFS}} = \frac{20 \times 8 \text{ bit}}{(328 + 150 + 80 + 150)us} = 226\text{kbps}$$

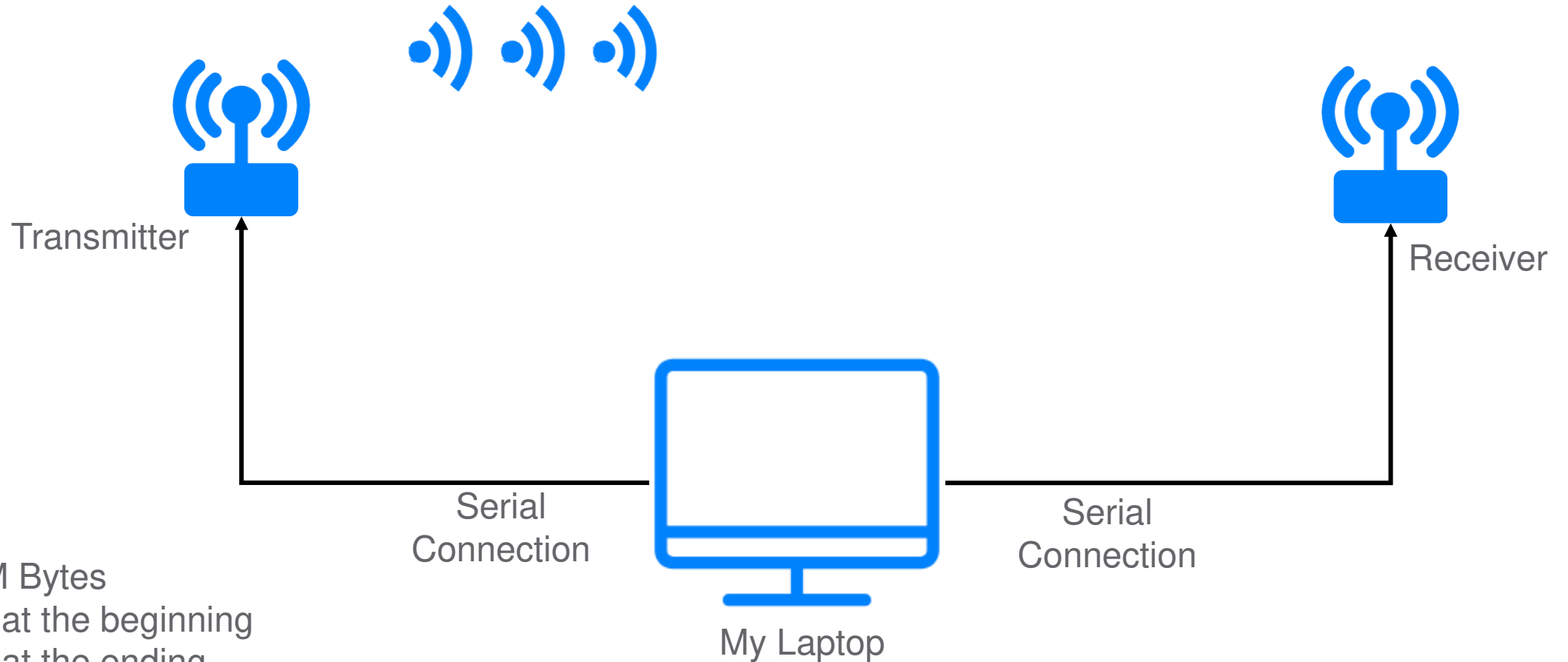
#BluetoothAsia2019#



Demo

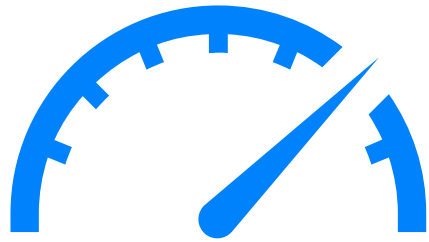
探索、创新、开拓

Setup



- Transmit 1M Bytes
- RTC stamp at the beginning
- RTC stamp at the ending
- $1M \times 8\text{bit} / (\text{ending_stamp} - \text{beginning_stamp})$

Bluetooth Core Specification v4.2



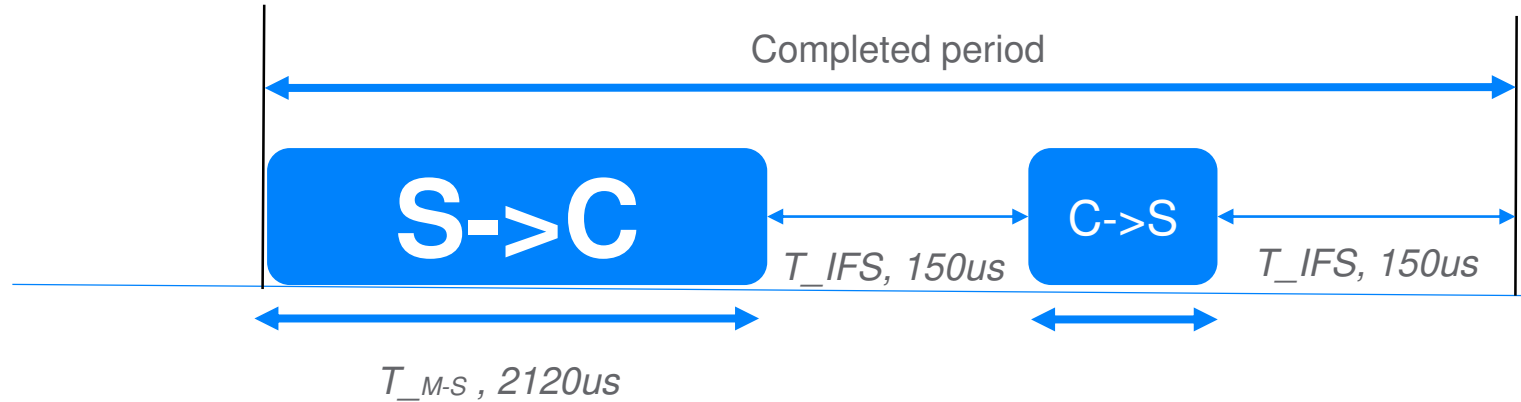
1 Mega symbols/sec

1 symbol -> 1 us

1 bit = 1 symbol

1 bit -> 1 us

Bluetooth Core Specification v4.2

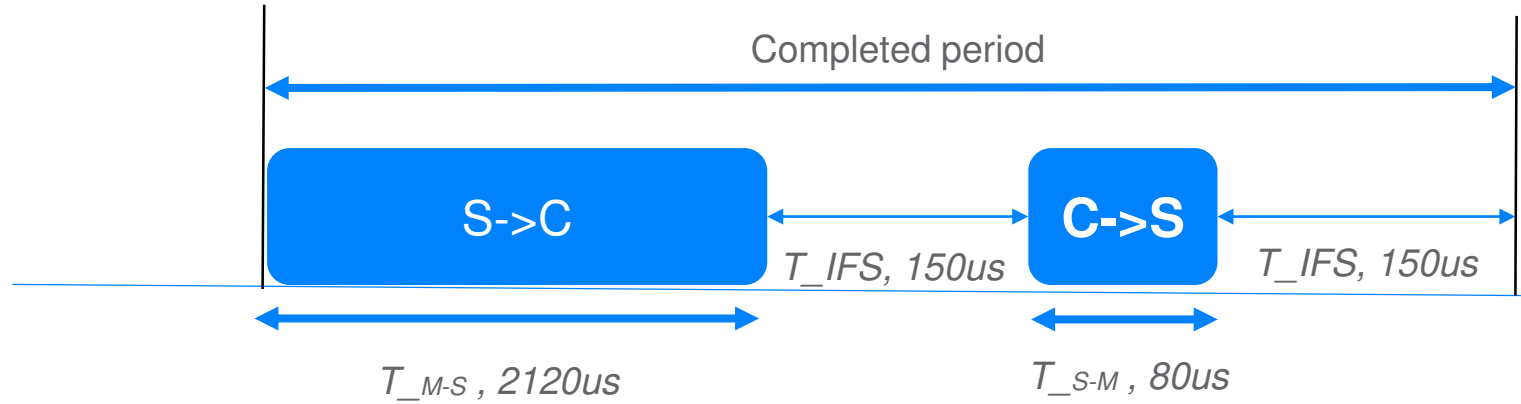


S – GATT Server
C – GATT Client

Handle Value Notification, Maximum length, 265 Bytes = 2120 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 244)	MIC (4)	CRC (3)
-----------------	-----------------------	------------------	------------------	--------------------	---------------------	------------------------------	------------	------------

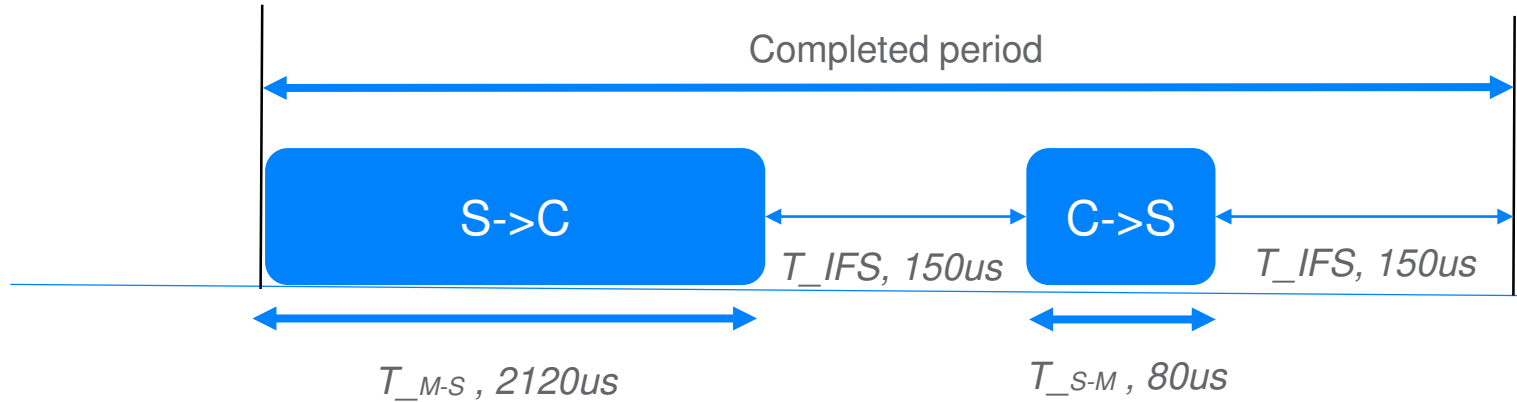
Bluetooth Core Specification v4.2



LL Data PDU, empty unit, 10 bytes = 80 bit

Preamble (1)	Access Address (4)	LL Header (2)	CRC (3)
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Bluetooth Core Specification v4.2



Handle Value Notification, Maximum length, 265 Bytes = 2120 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 244)	MIC (4)	CRC (3)
-----------------	-----------------------	------------------	------------------	--------------------	---------------------	--------------------------------------	------------	------------

$$\text{Throughput} = \frac{\text{Attribute Value}}{T_{M-S} + T_{IFS} + T_{S-M} + T_{IFS}} = \frac{244 \times 8 \text{ bit}}{(2120 + 150 + 80 + 150)\mu s} = 781 \text{ kbps}$$

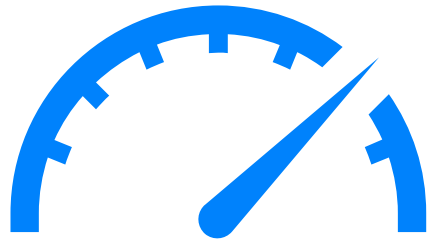
#BluetoothAsia2019#



Demo

探索、创新、开拓

Bluetooth Core Specification v5.0, 2M Uncoded PHY



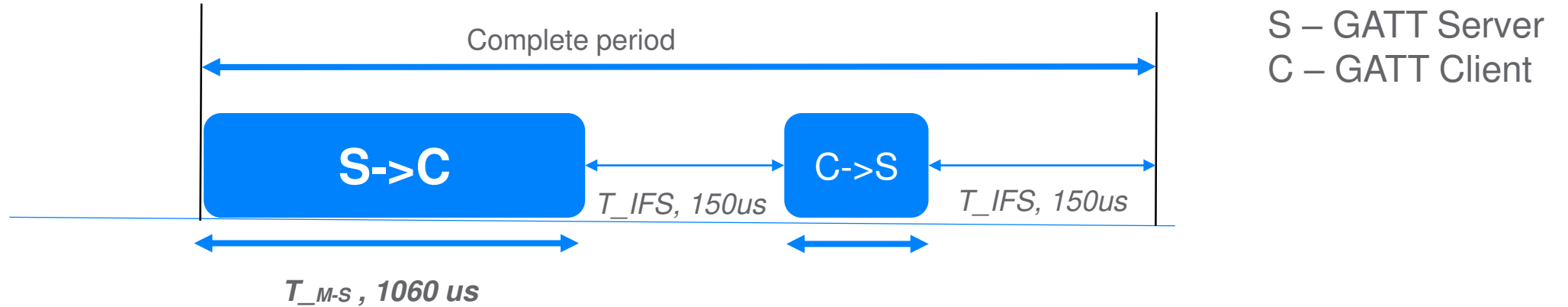
2 Mega symbols/sec

1 symbol -> 0.5 us

1 bit = 1 symbol

1 bit -> 0.5 us

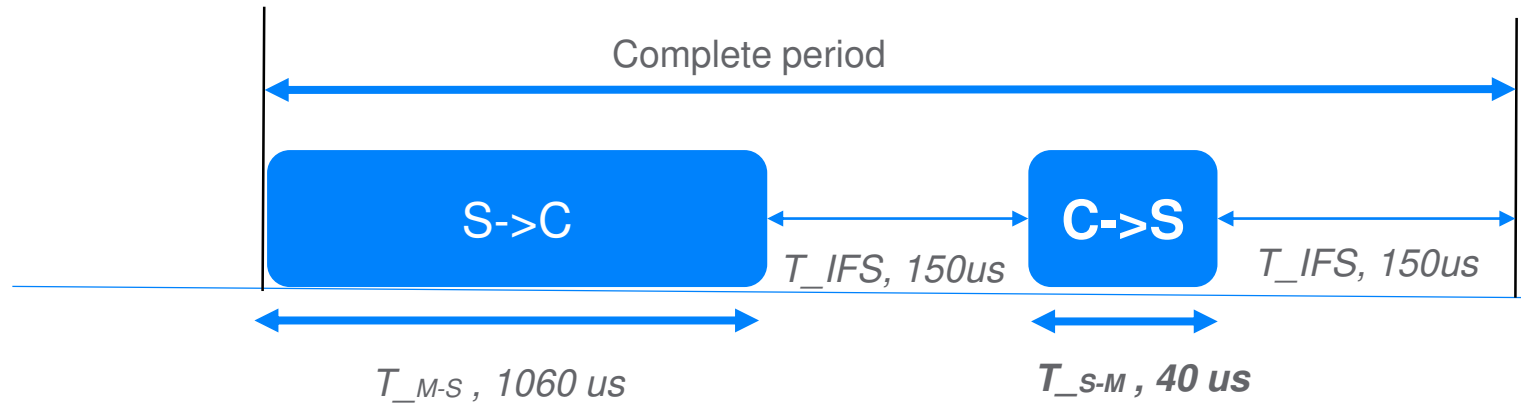
Bluetooth Core Specification v5.0, 2M Uncoded PHY



Handle Value Notification, Maximum length, 265 Bytes = 2120 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 244)	MIC (4)	CRC (3)
-----------------	--------------------------	---------------------	---------------------	-----------------------	------------------------	------------------------------	------------	------------

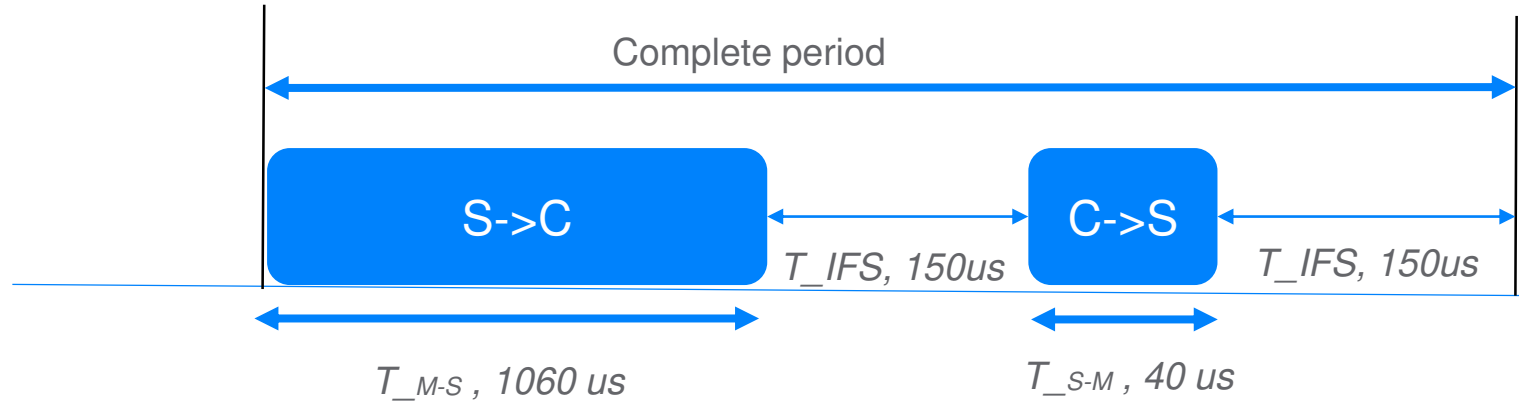
Bluetooth Core Specification v5.0, 2M Uncoded PHY



LL Data PDU, empty unit, 10 bytes = 80 bit

Preamble (1)	Access Address (4)	LL Header (2)	CRC (3)
-----------------	--------------------------	---------------------	------------

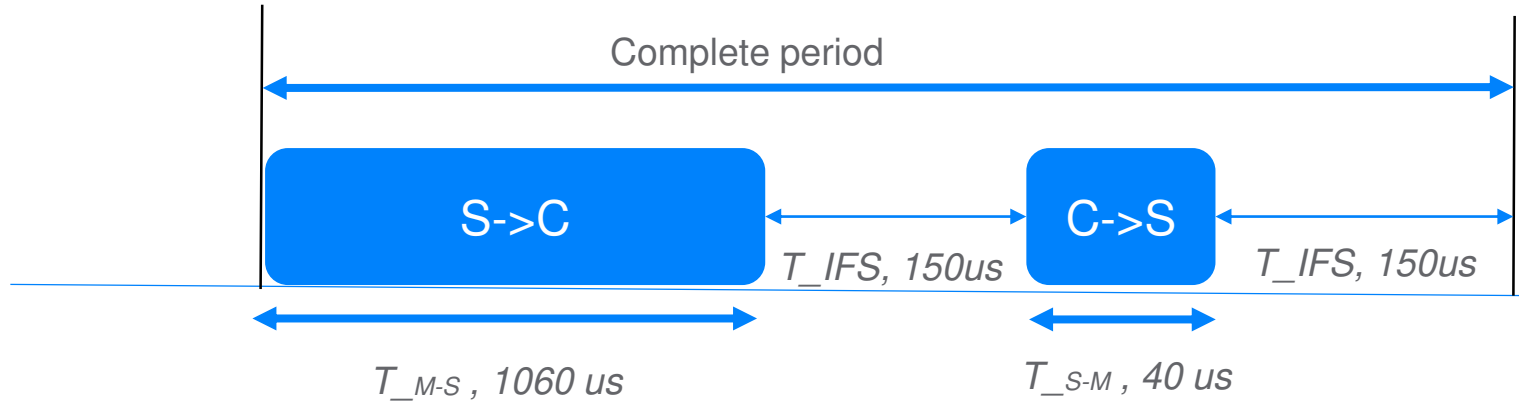
Bluetooth Core Specification v5.0, 2M Uncoded PHY



Handle Value Notification, Maximum length, 265 Bytes = 2120 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 244)	MIC (4)	CRC (3)
-----------------	--------------------------	---------------------	---------------------	-----------------------	------------------------	--------------------------------------	------------	------------

Bluetooth Core Specification v5.0, 2M Uncoded PHY



Handle Value Notification, Maximum length, 265 Bytes = 2120 bits

Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	Attribute Value (0 ~ 244)	MIC (4)	CRC (3)
-----------------	--------------------------	---------------------	---------------------	-----------------------	------------------------	--------------------------------------	------------	------------

$$\text{Throughput} = \frac{\text{Attribute Value}}{T_{M-S} + T_{IFS} + T_{S-M} + T_{IFS}} = \frac{244 \times 8 \text{ bit}}{(1060 + 150 + 40 + 150)us} = 1.39Mbps$$

#BluetoothAsia2019#



Demo

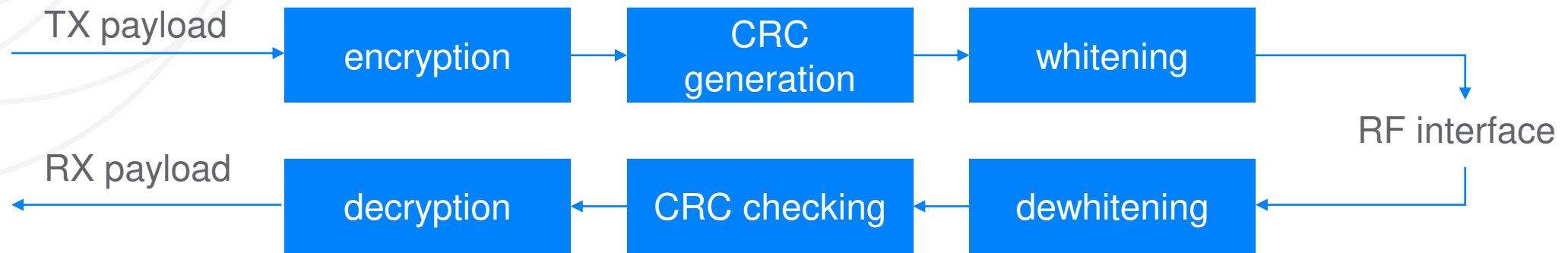
探索、创新、开拓

The background is a solid blue color with a diagonal line from the top-left to the bottom-right. On the left side, there is a large, hollow, light-blue triangle pointing right. On the right side, there are two overlapping, solid, dark-blue triangles pointing left.

Long Range

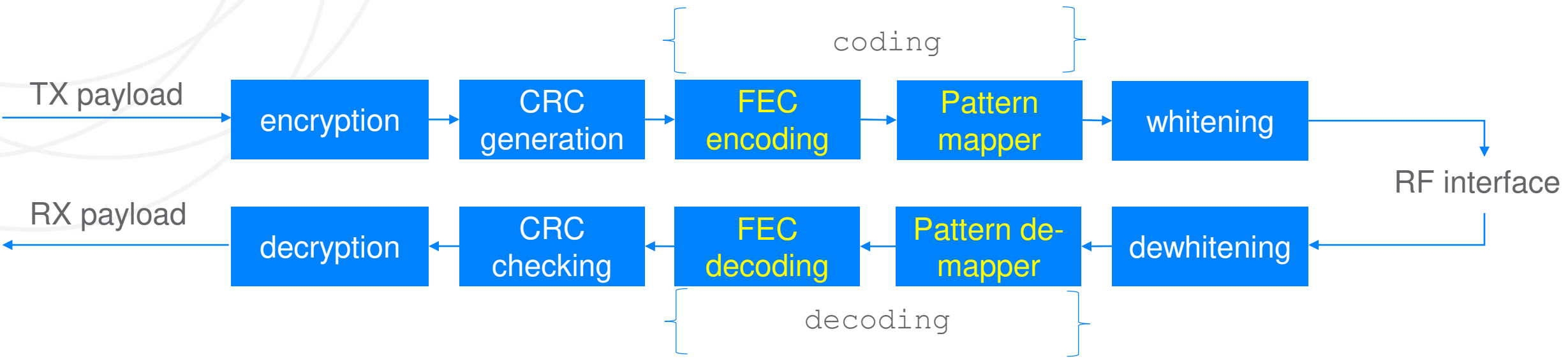


LE Uncoded 1M or 2M Bit Stream Processing



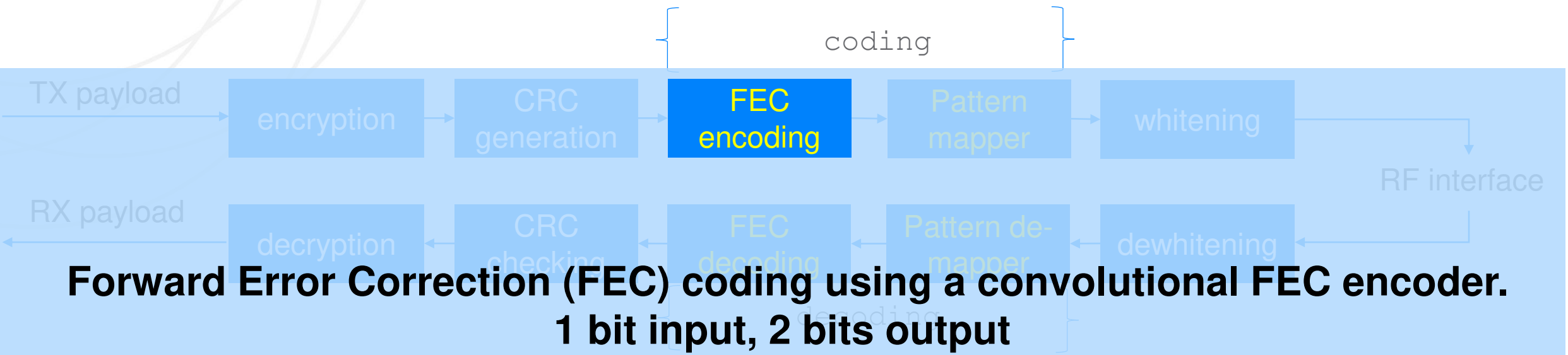
Note: LE 1M and LE 2M are collectively known as the “**LE Uncoded**” PHYs

LE Coded Bit Stream Processing

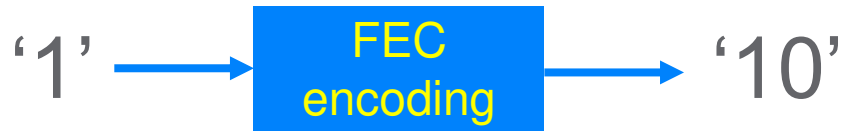
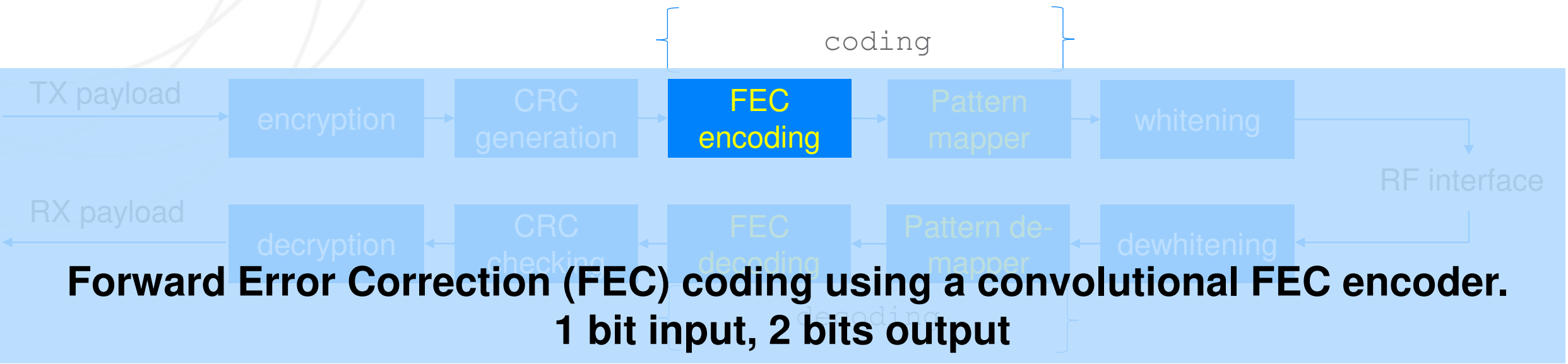




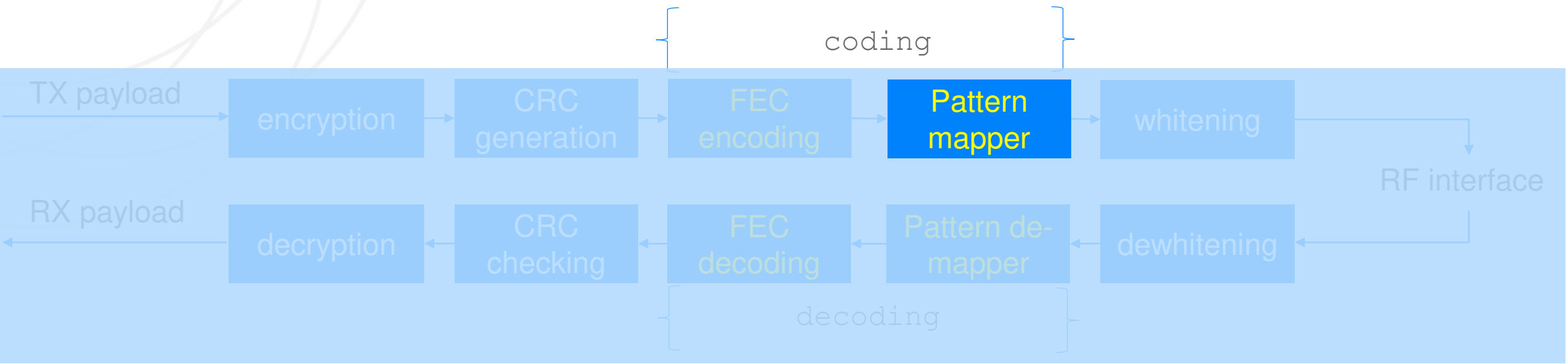
Forward Error Correction, FEC



Forward Error Correction, FEC

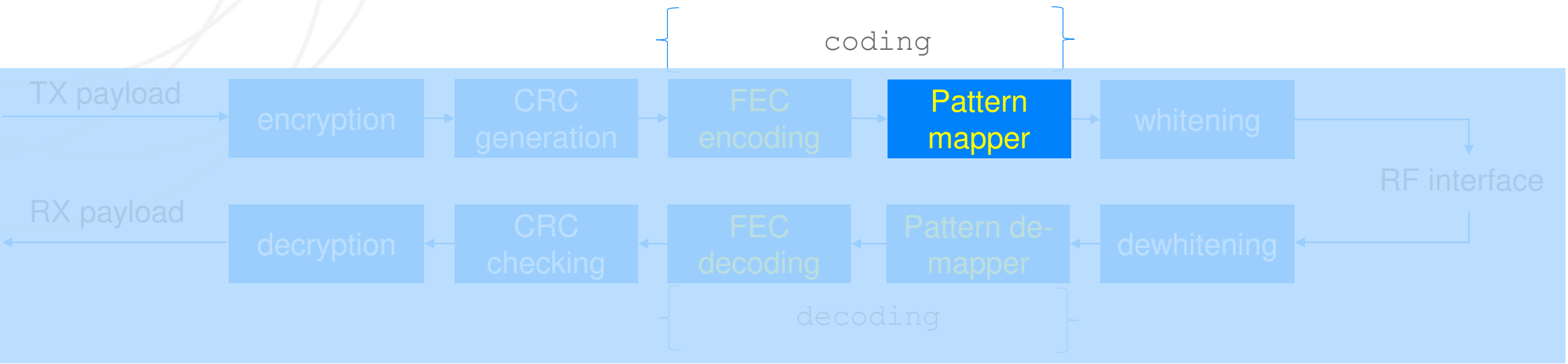


Patter Mapper

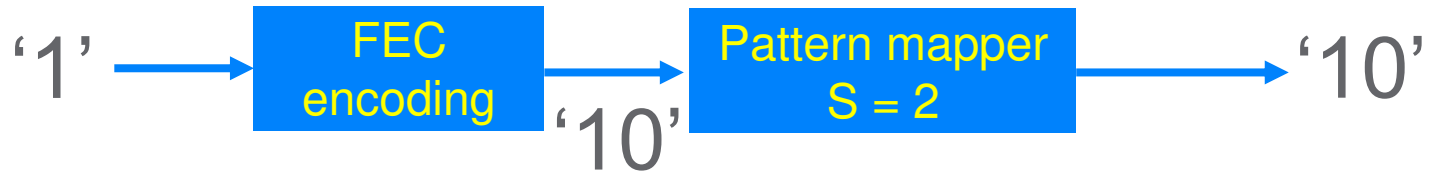


Input Bit from FEC	Output (S=2)	Output (S=8)
0	0	0011
1	1	1100

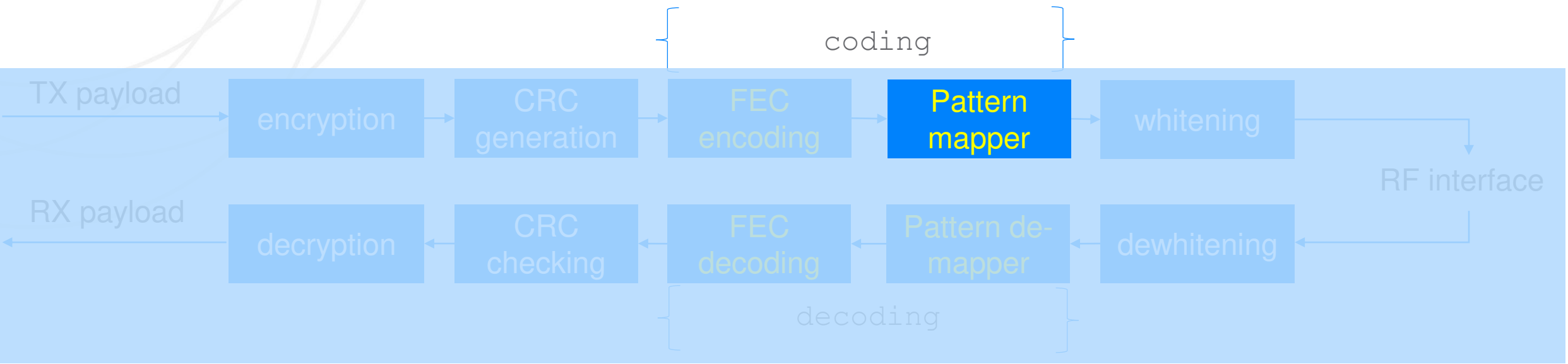
Patter Mapper



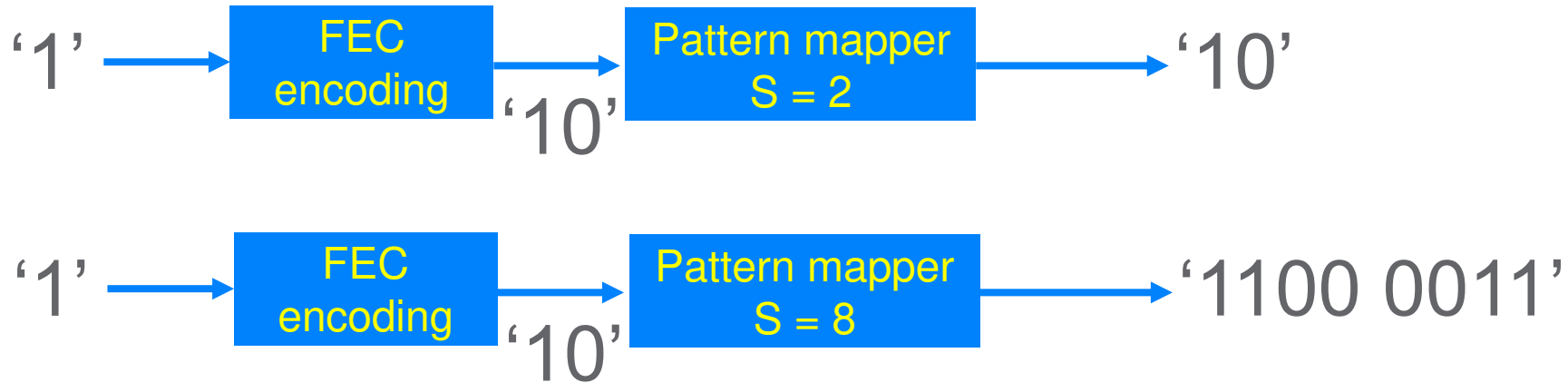
Input Bit from FEC	Output (S=2)	Output (S=8)
0	0	0011
1	1	1100



Patter Mapper

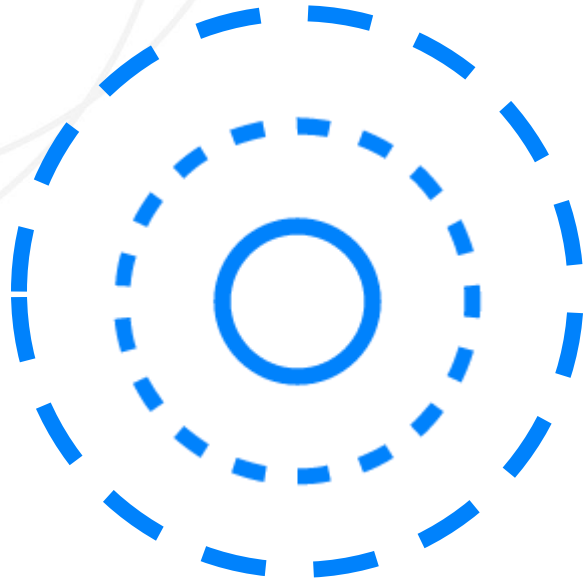


Input Bit from FEC	Output (S=2)	Output (S=8)
0	0	0011
1	1	1100





Long Range



Long Range

Physical layer

- 1M symbol/sec modulation

Coding Schemes

- $S=2$
 - 2 symbols for 1 data bit, 500kbps
 - 5dB sensitivity increasing
- $S=8$
 - 8 symbols for 1 data bit, 125kbps
 - 12dB sensitivity increasing

ADV Extension

Advertising Payload

Core specification
v4.0 ~ v4.2

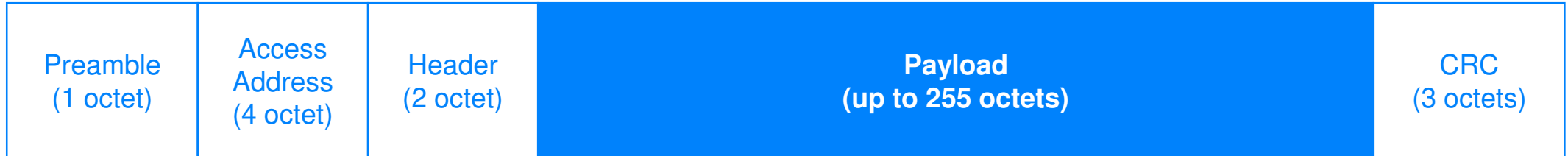


Longer Advertising Payload

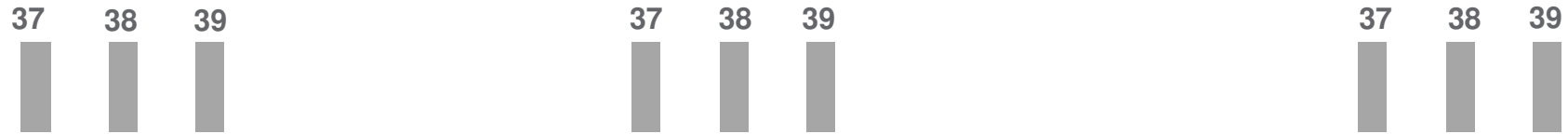
Core specification
v4.0 ~ v4.2



Core specification
V5.0



Legacy Advertising



Primary Advertising Channel

Longer Payload over Legacy Advertising

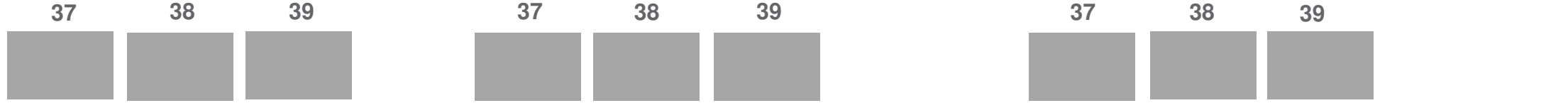


Offload Advertising Payload

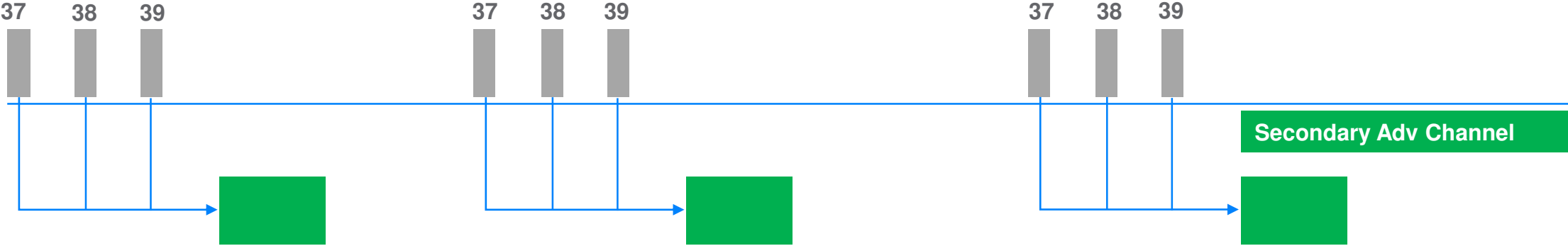

Advertiser



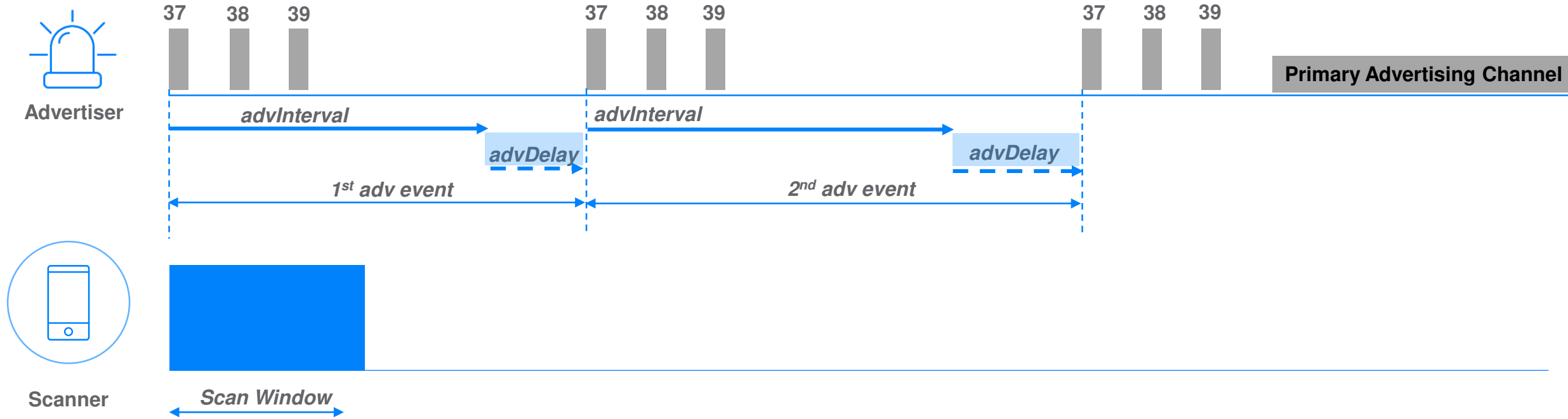

Advertiser



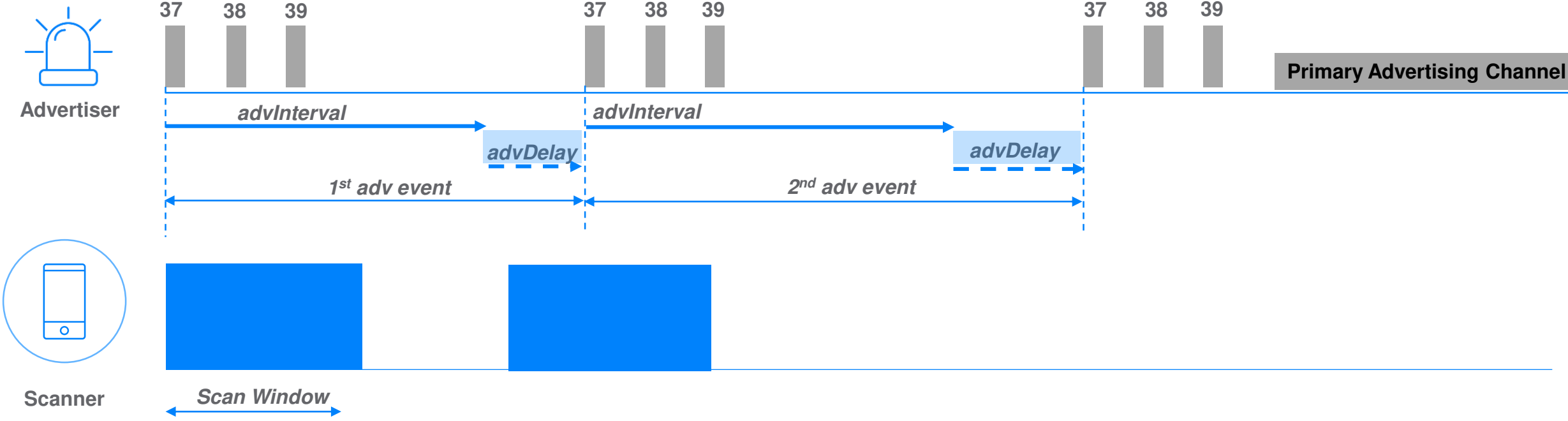

Advertiser



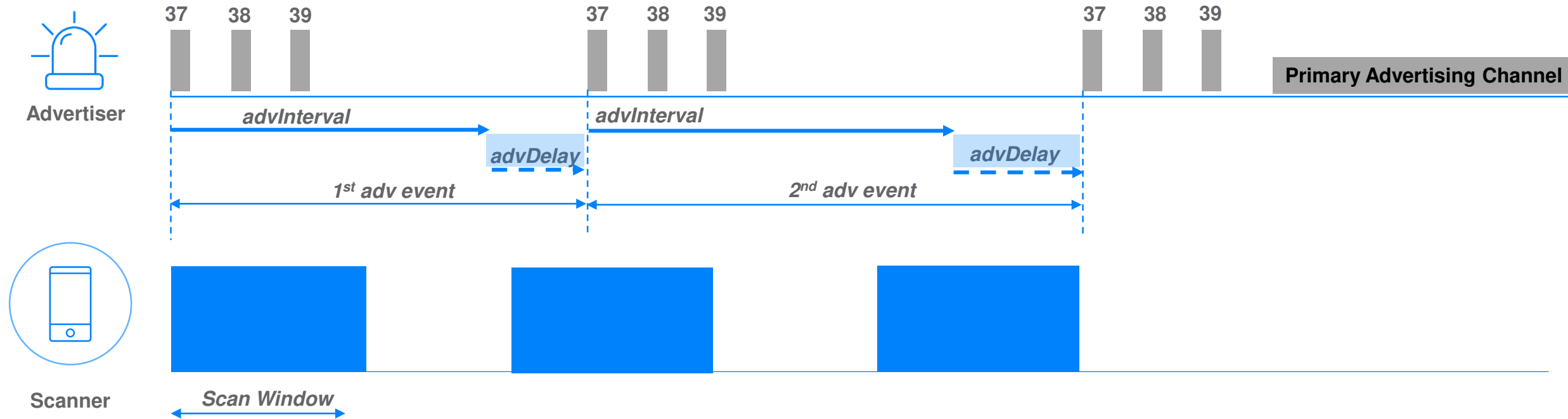
Legacy Advertising



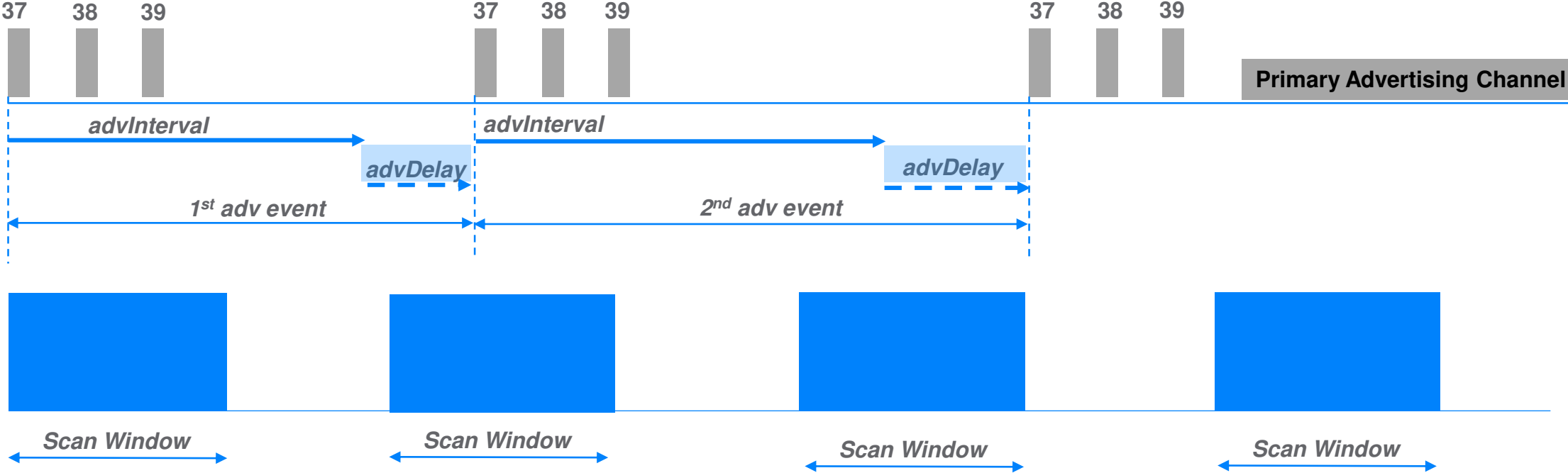
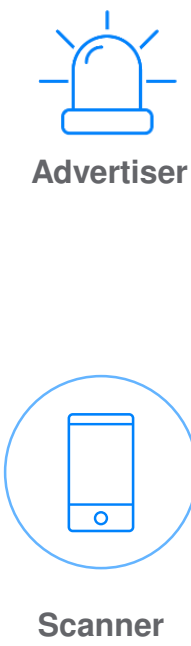
Legacy Advertising



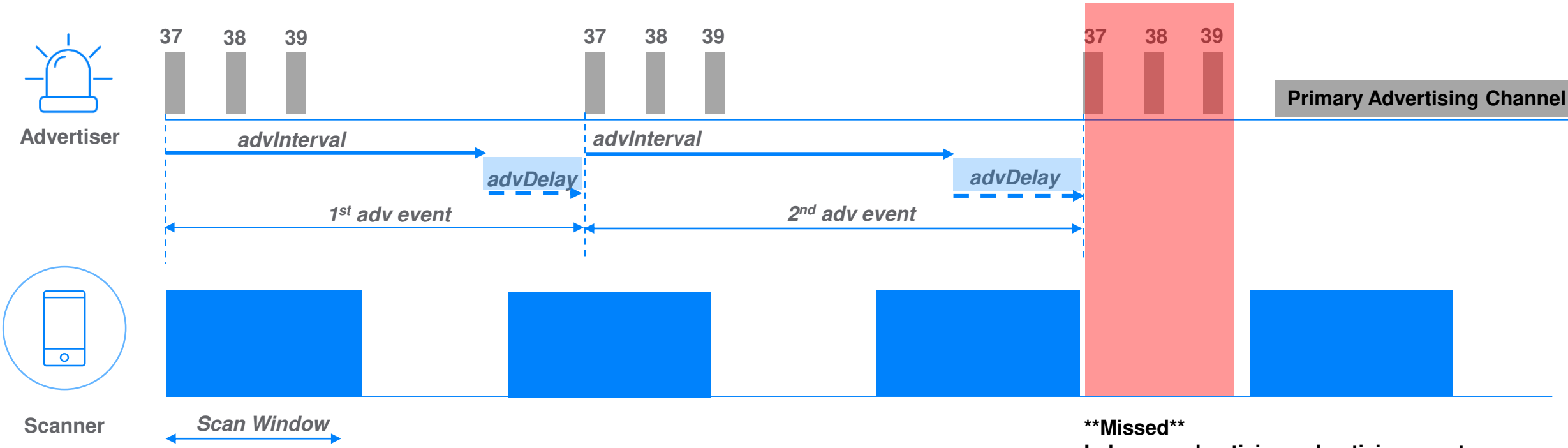
Legacy Advertising



Legacy Advertising



Legacy Advertising

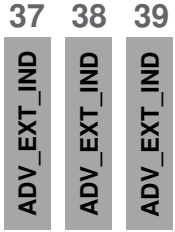


****Missed****
In legacy advertising, advertising events have a random delay to prevent persistent collisions
It is hard for a scanner to follow the advertiser.

Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

All other channels



Scanner



Scan Window

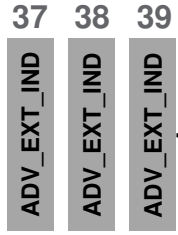
Periodical Advertising



Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used



- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA

Primary Advertising Channel

All other channels



Scanner

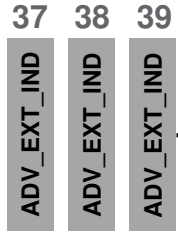


Scan Window

Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

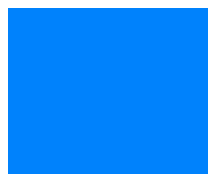
All other channels



- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA



Scanner



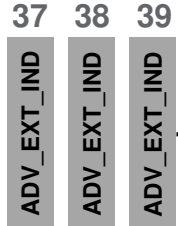
Scan Window



Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

All other channels

AUX_ADV_IND

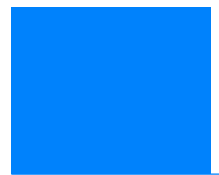
- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA

AUX_SYNC_IND

AUX_SYNC_IND



Scanner

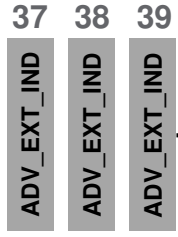


Scan Window

Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

All other channels

AUX_ADV_IND

- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA

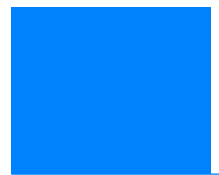
AUX_SYNC_IND

AUX_SYNC_IND

AUX_SYNC_IND



Scanner

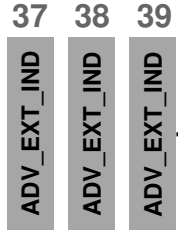


Scan Window

Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

All other channels

AUX_ADV_IND

- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA

AUX_SYNC_IND

AUX_SYNC_IND

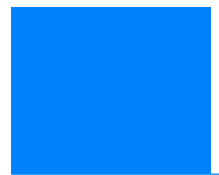
AUX_SYNC_IND

...

AUX_SYNC_IND



Scanner

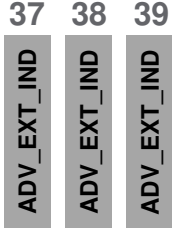


Scan Window

Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

All other channels

AUX_ADV_IND

- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA

AUX_SYNC_IND

AUX_SYNC_IND

AUX_SYNC_IND

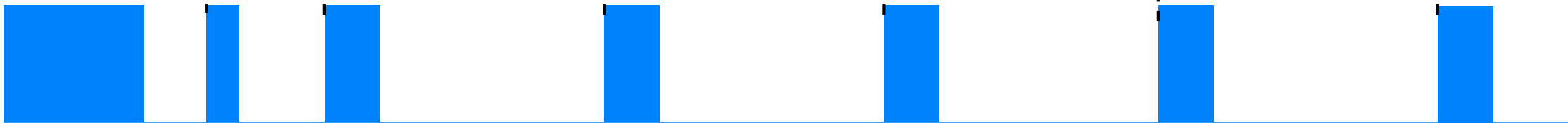
...

AUX_SYNC_IND

AUX_SYNC_IND



Scanner

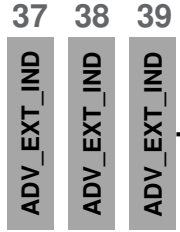


Scan Window

Periodical Advertising



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used

Primary Advertising Channel

All other channels

AUX_ADV_IND

- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA

AUX_SYNC_IND

AUX_SYNC_IND

AUX_SYNC_IND

...

AUX_SYNC_IND

AUX_SYNC_IND

Fixed Interval

Fixed Interval

Fixed Interval



Scanner



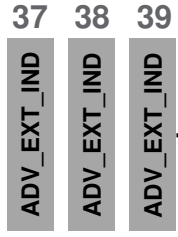
Scan Window

Periodical Advertising

Provide an efficient, uni-direction communication.



Advertiser



- Which channel used
- Offset of AUX_ADV_IND
- Which PHY used



- Offset of next AUX_SYNC_IND
- Interval
- Channel Map
- Event counter
- Access Address
- SCA



...



Fixed Interval

Fixed Interval

Fixed Interval

Primary Advertising Channel

All other channels



Scanner

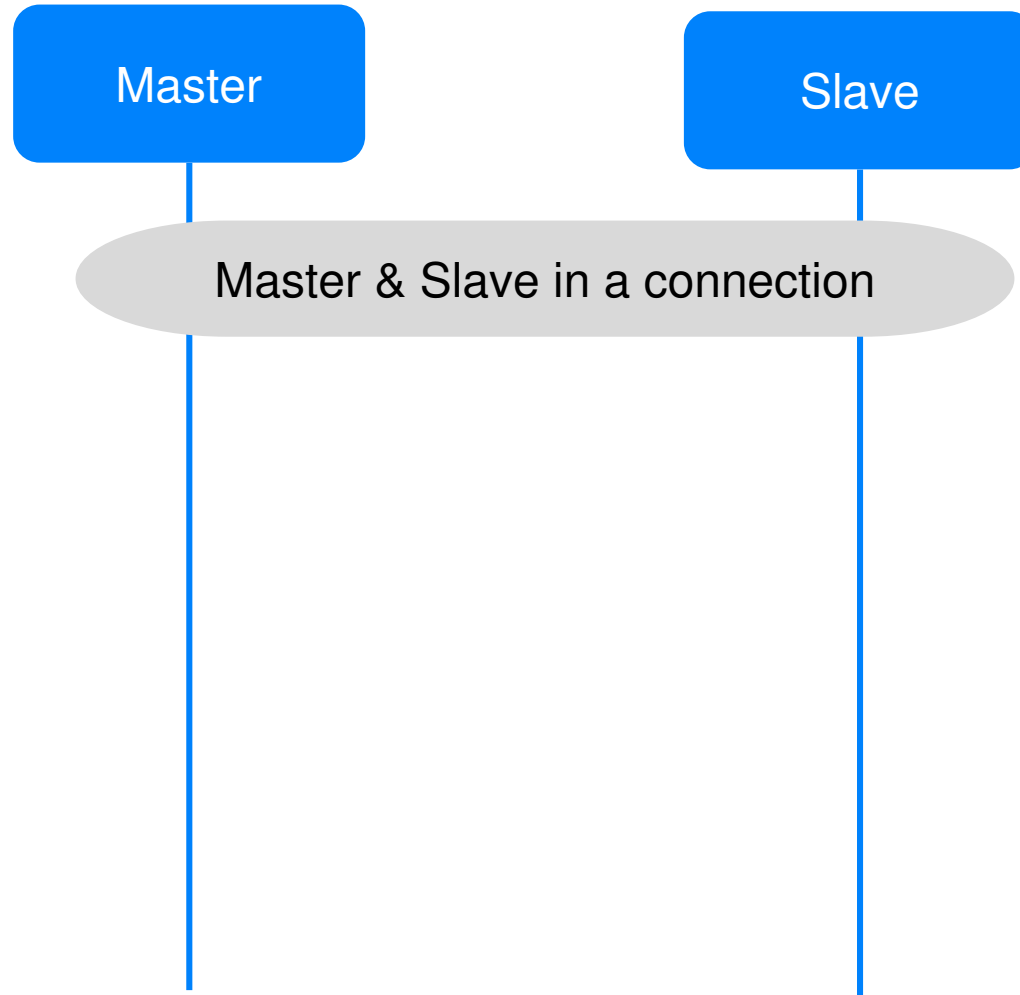
Scan Window

The background is a solid blue color with several geometric shapes. A large, light blue triangle is positioned on the left side, pointing towards the center. Another large, dark blue triangle is on the right side, pointing towards the center. A smaller, dark blue triangle is located at the bottom right corner. The text is centered in the middle of the slide.

PHY Update Procedure

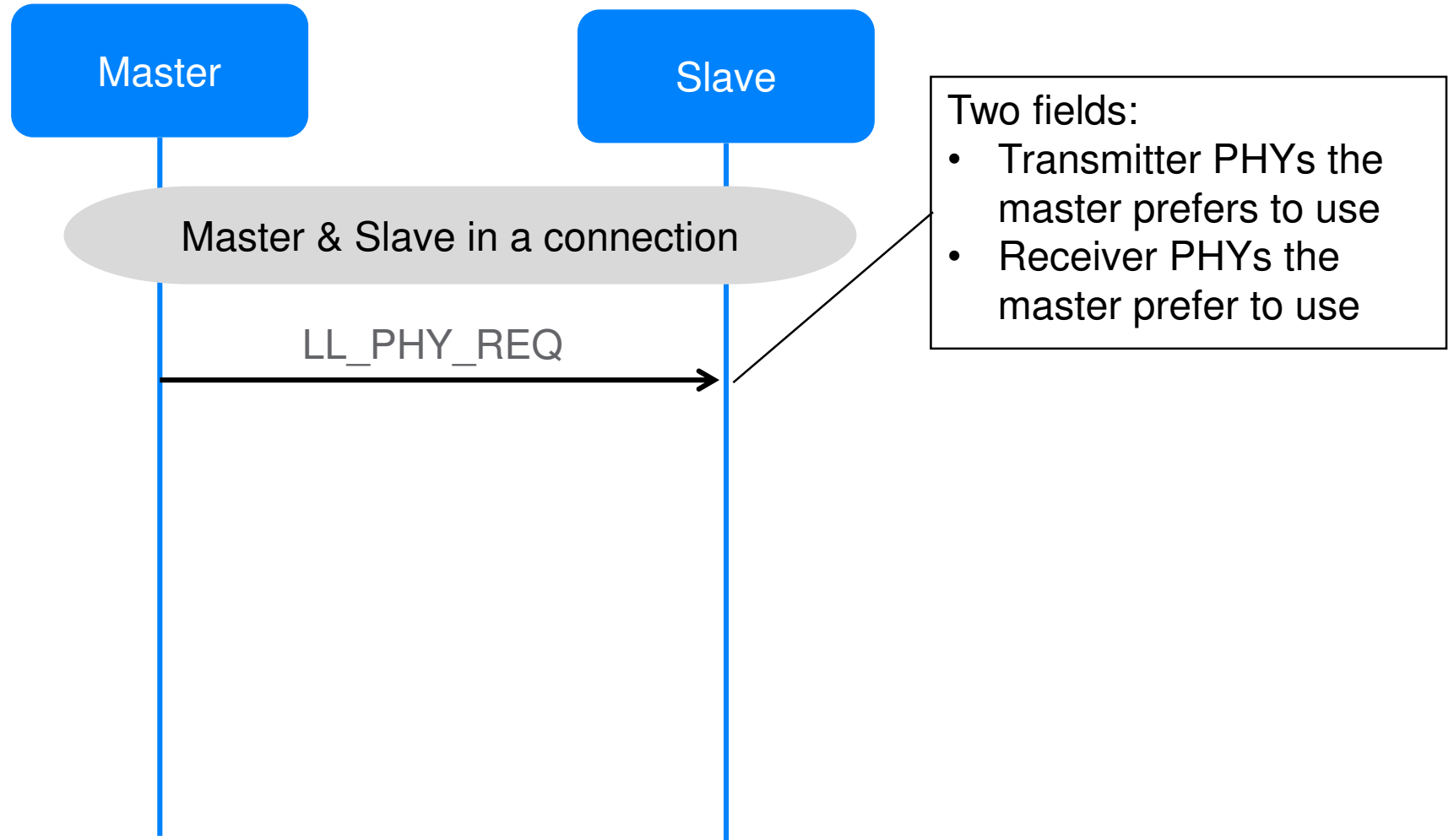


Master Initial





Master Initial

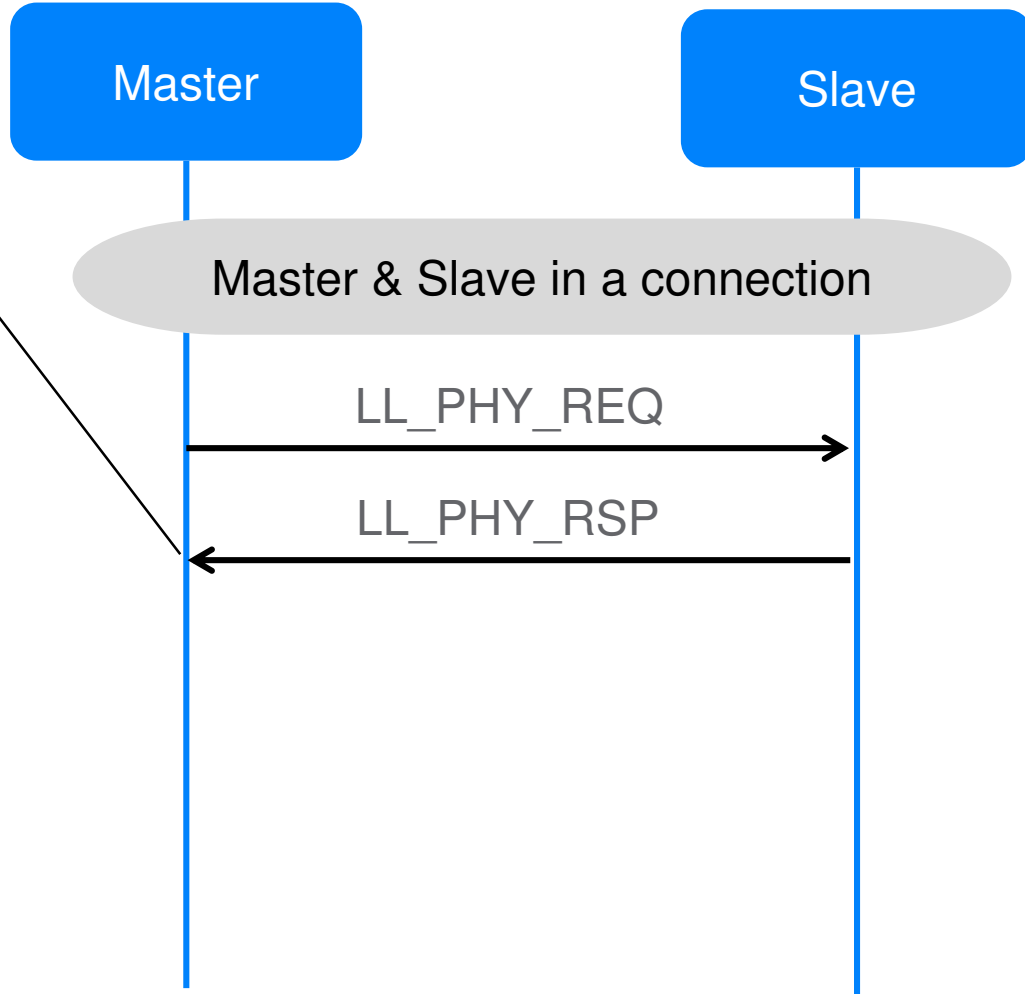




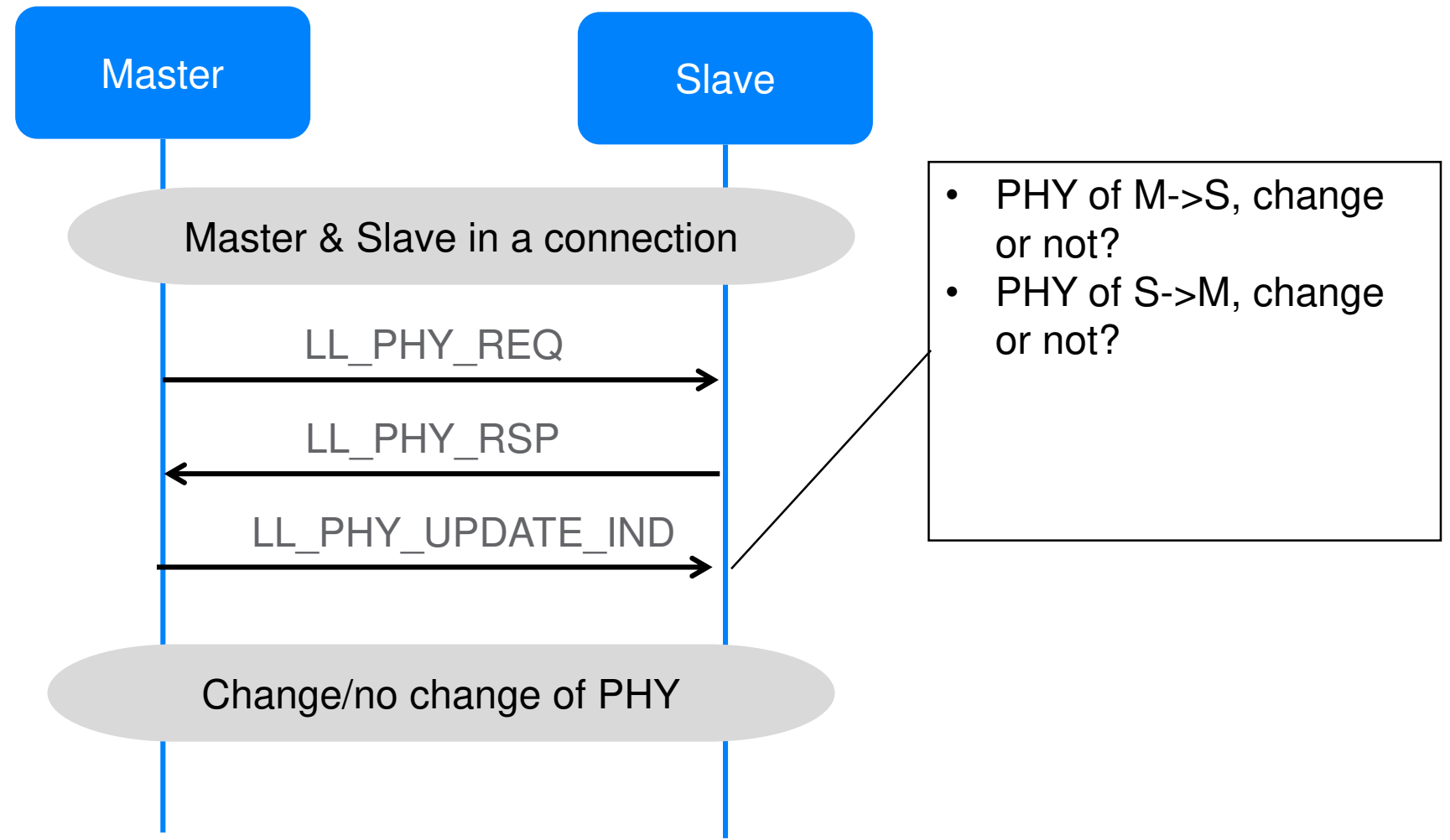
Master Initial

Two fields indicated by slaver:

- Transmitter PHYs the slave prefers to use
- Receiver PHYs the slave prefer to use

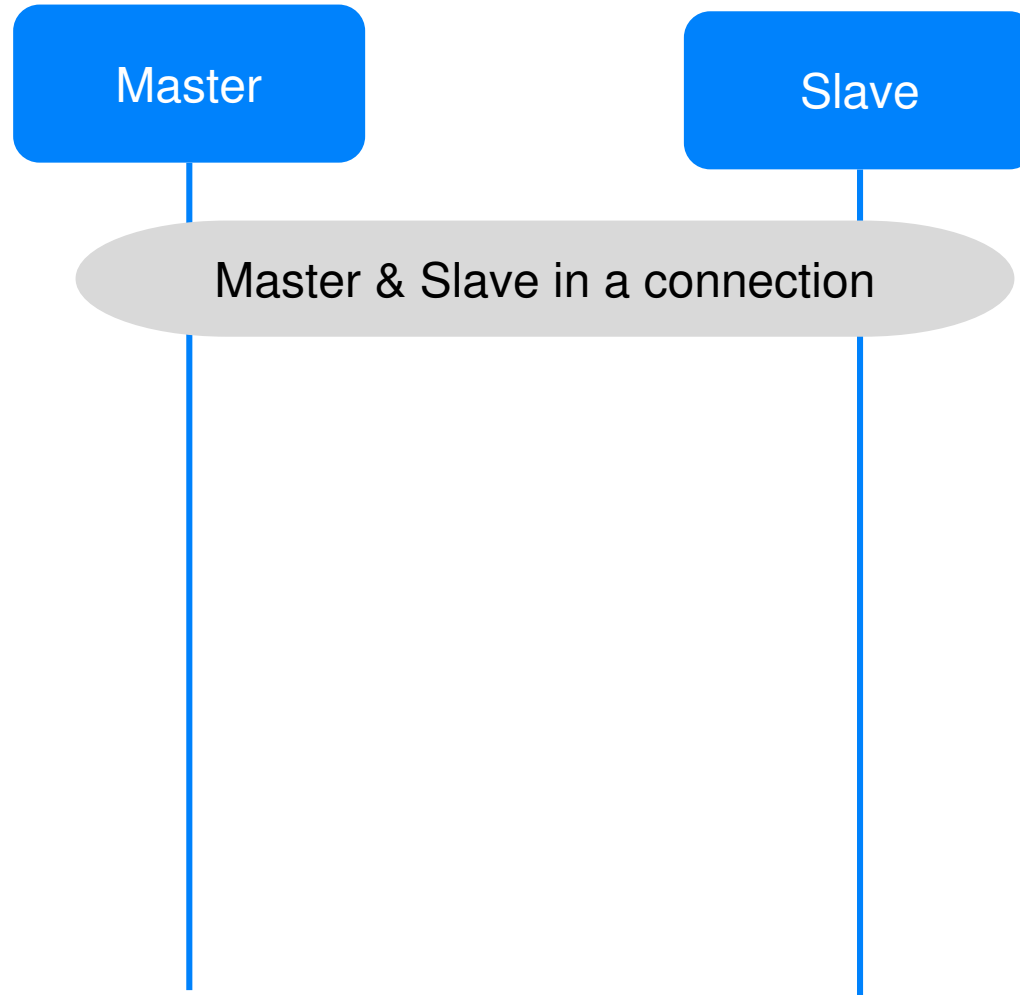


Master Initial





Slave Initial

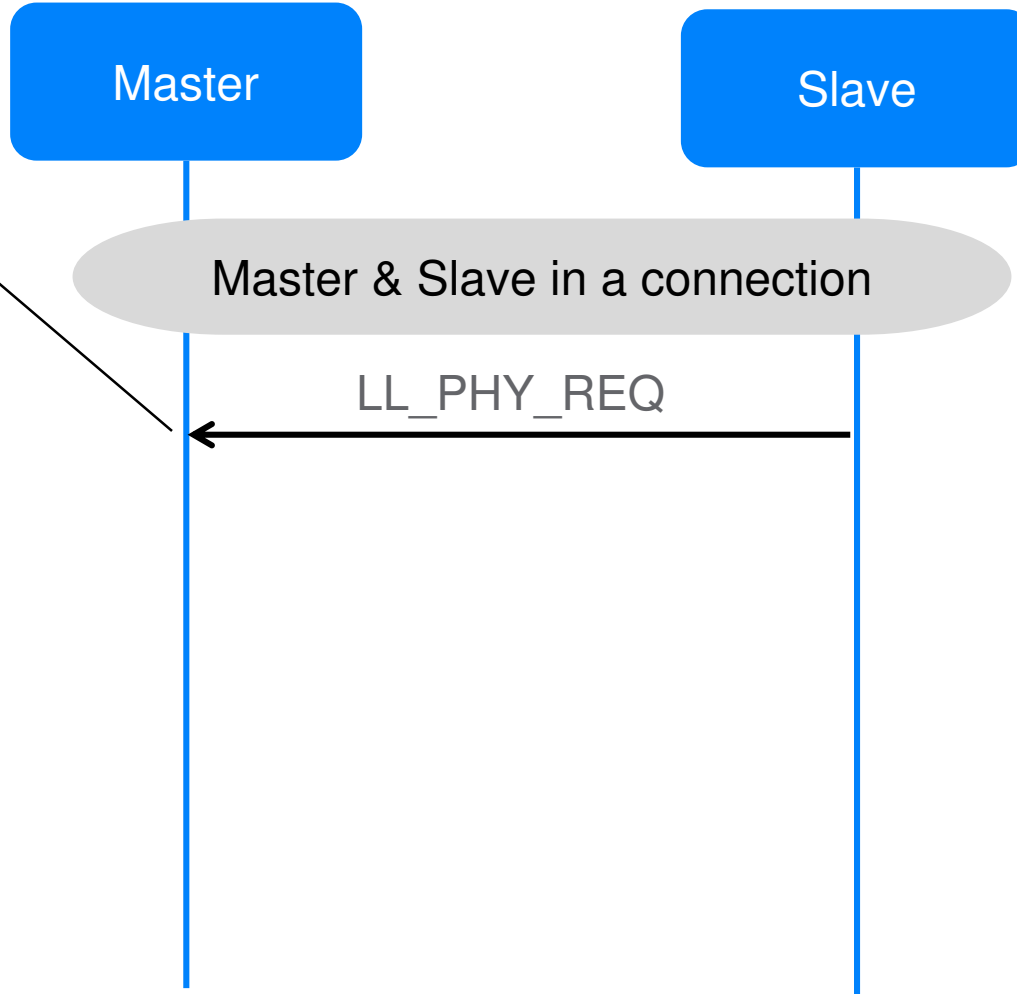




Slave Initial

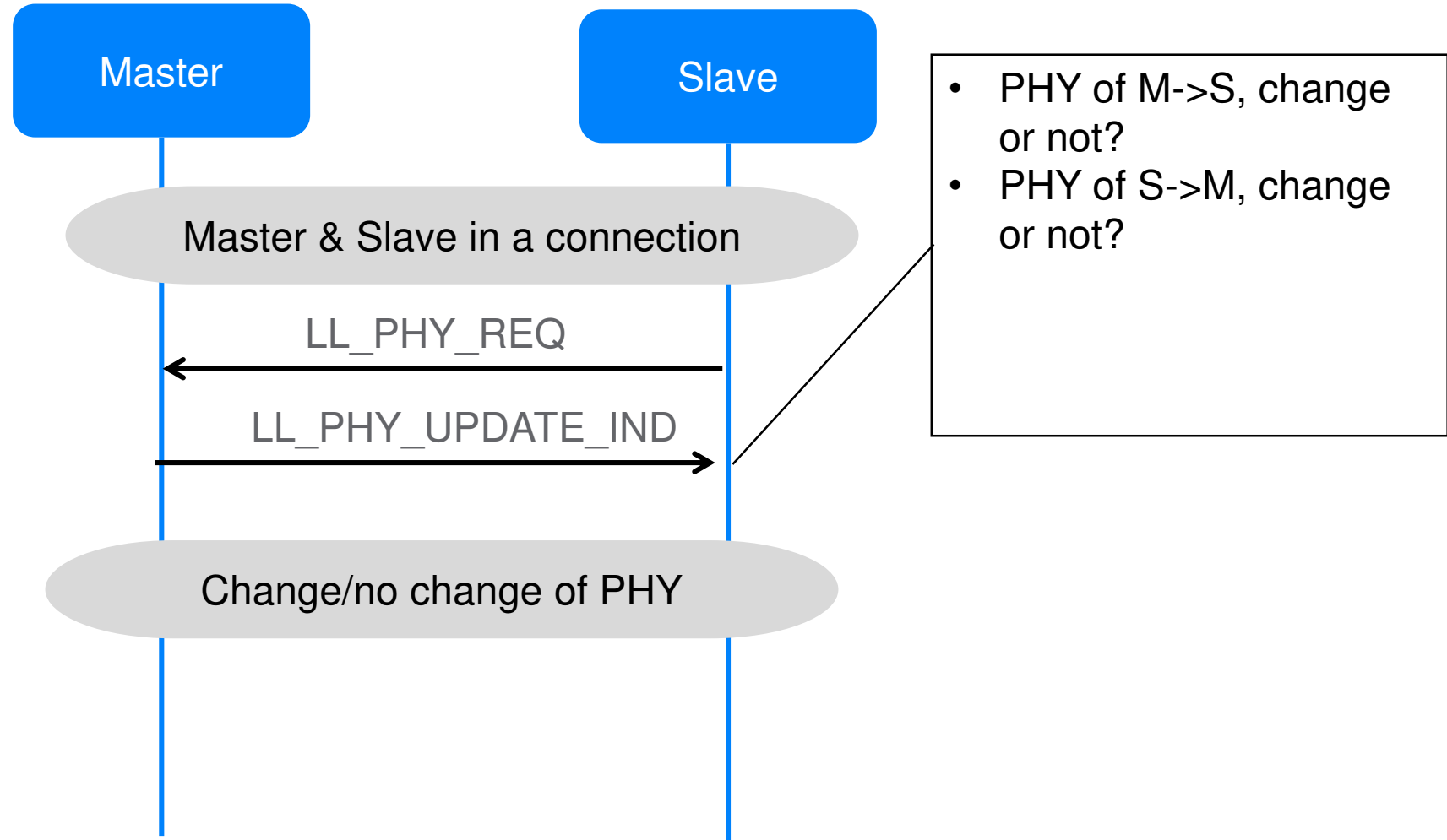
Two fields:

- Transmitter PHYs the slave prefers to use
- Receiver PHYs the slave prefer to use





Slave Initial





Thank you

