#BluetoothAsia2019#

BluetoothAsia
探索、创新、开拓

Bluetooth – Longer Range, Higher Speed and Increased Capacity

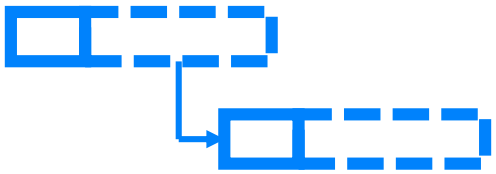
Kai Ren, Senior Developer Relations Manager, Bluetooth SIG

微信

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

High Speed

Long Range



Advertising Extension

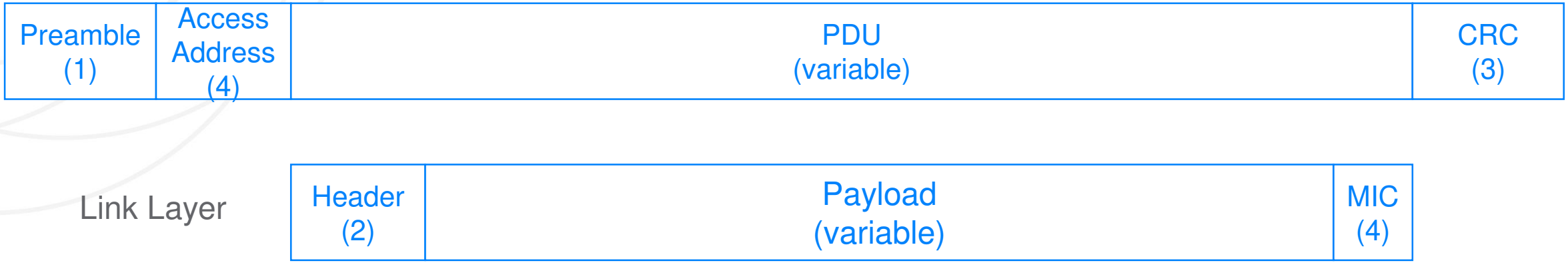
High Speed

Packet Format For LE Uncoded PHYs

* Without Constant Tone Extension

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

PDU

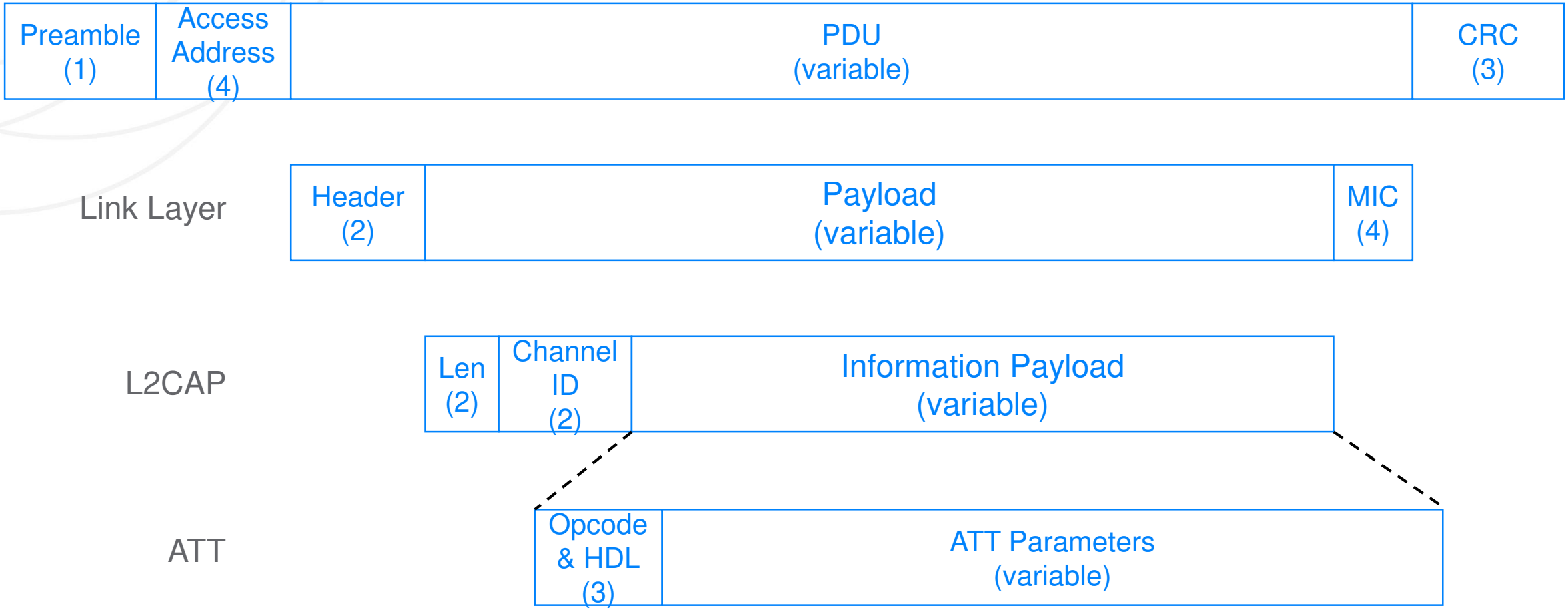

Preamble
(1)
Access
Address
(4)
PDU
(variable)
CRC
(3)
Link Layer
Header
(2)
Payload
(variable)
MIC
(4)

L2CAP

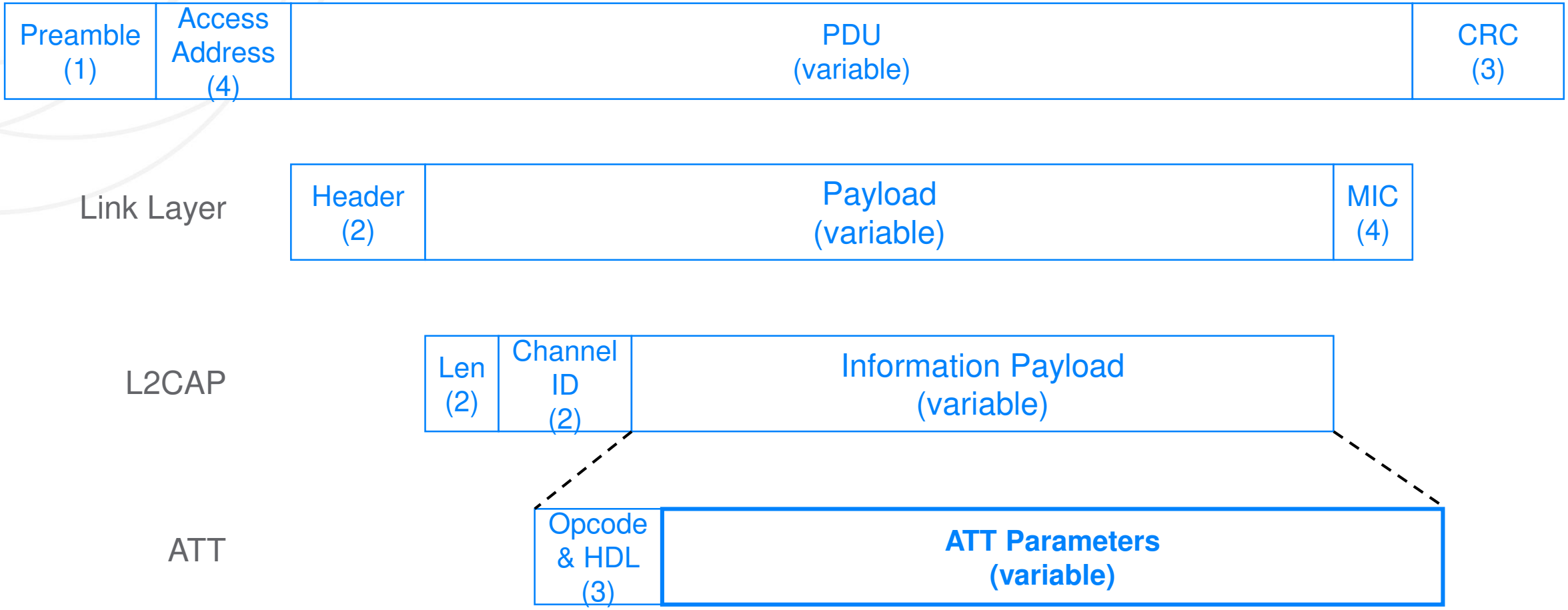
Link Layer

L2CAP

ATT


Preamble (1)
Access Address (4)
PDU (variable)
CRC (3)
Link Layer
Header (2)
Payload (variable)
MIC (4)
L2CAP
Len (2)
Channel ID (2)
Information Payload (variable)
ATT
Opcode & HDL (3)
ATT Parameters (variable)

ATT


Preamble (1)
Access Address (4)
PDU (variable)
CRC (3)
Link Layer
Header (2)
Payload (variable)
MIC (4)
L2CAP
Len (2)
Channel ID (2)
Information Payload (variable)
ATT
Opcode & HDL (3)
ATT Parameters (variable)

Bluetooth Core Specification v4.0/4.1

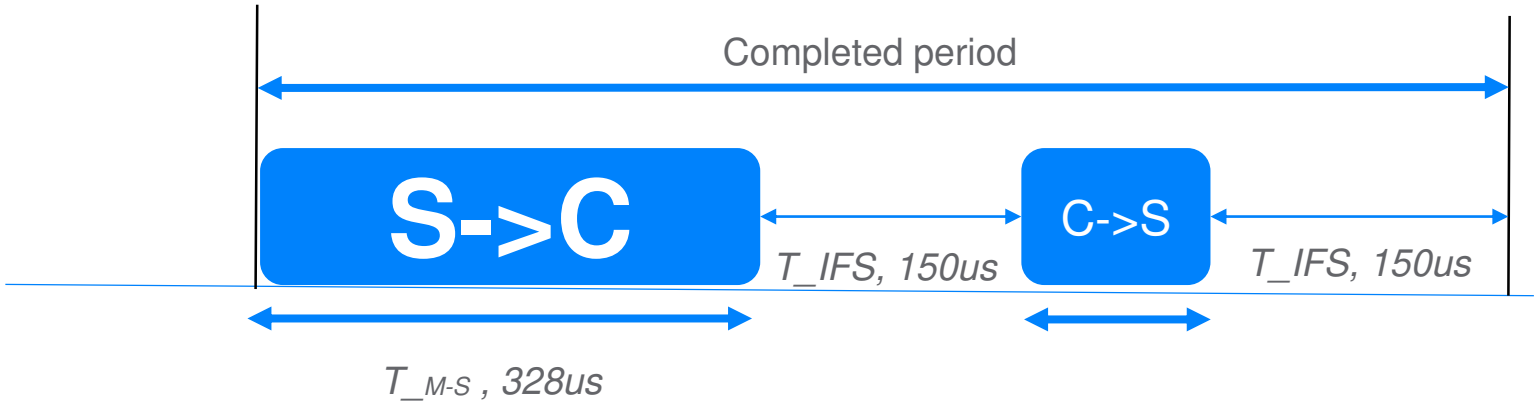
1 Mega symbols/sec

1 symbol -> 1 us

1 bit = 1 symbol

1 bit -> 1 us

Bluetooth Core Specification v4.0/4.1

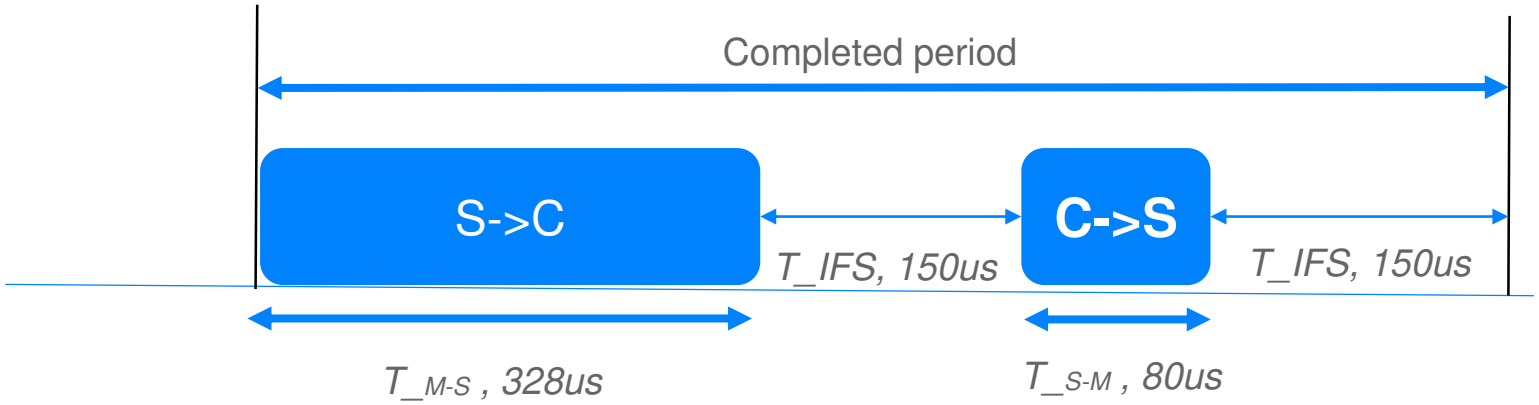


S – GATT Server
C – GATT Client

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)

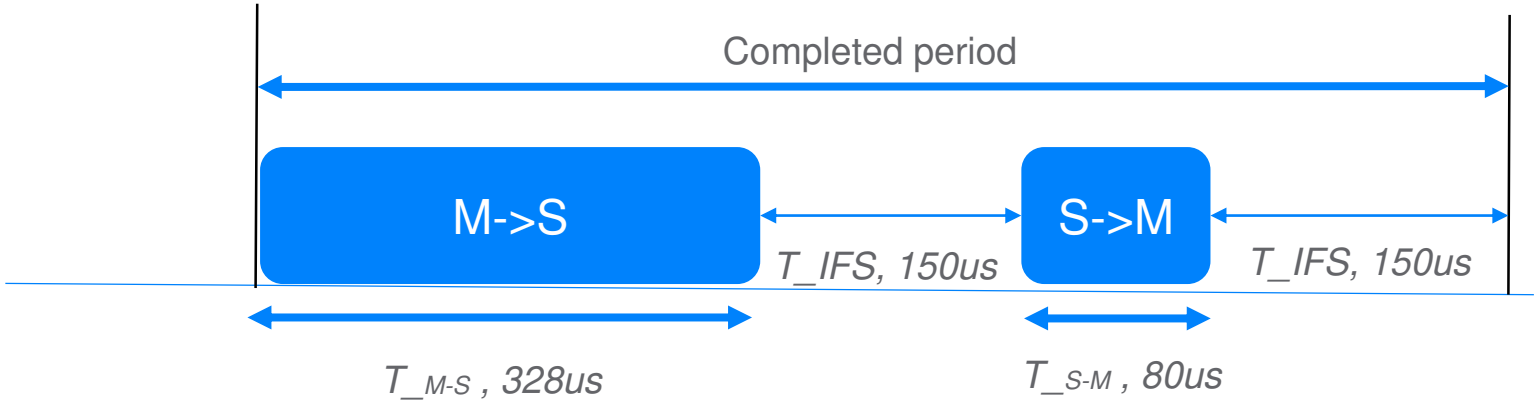
Bluetooth Core Specification v4.0/4.1



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



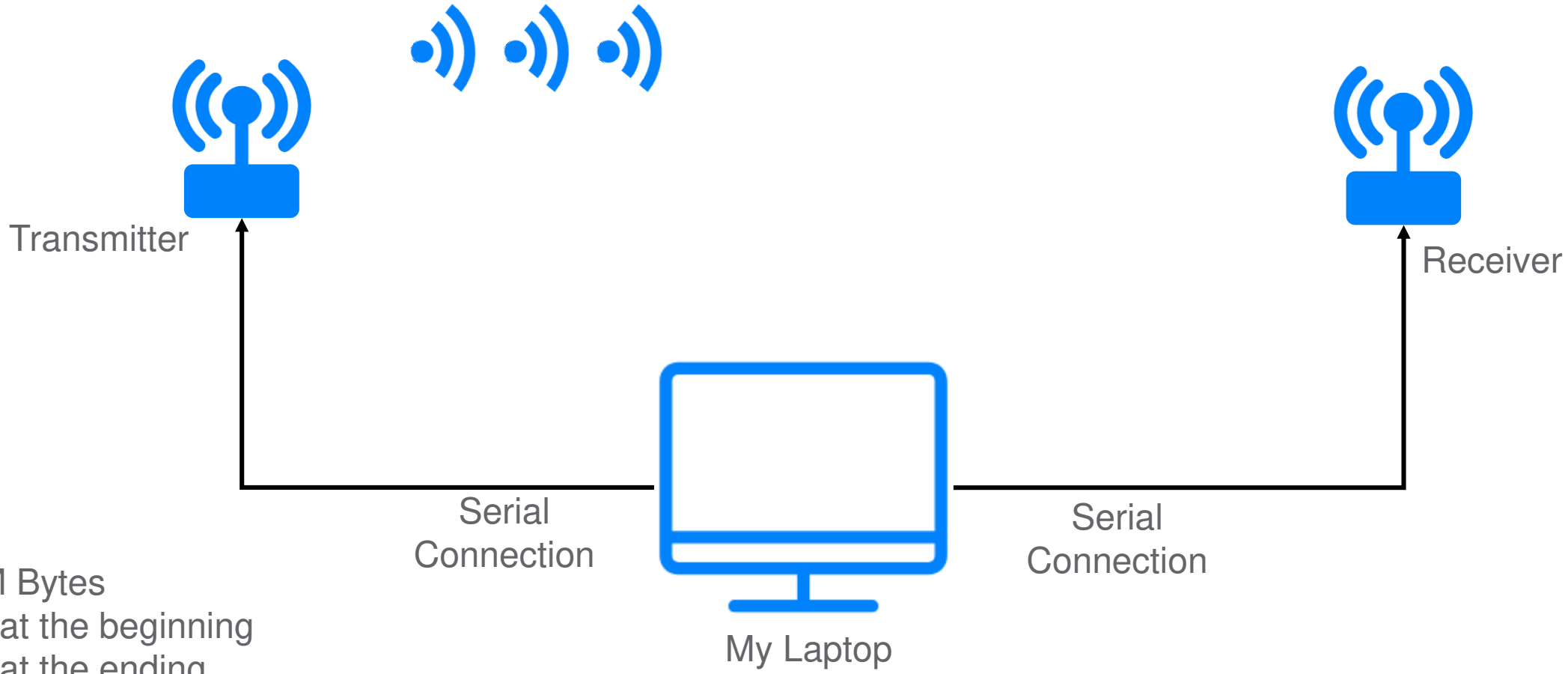
Handle Value Notification, Maximum length, 41 Bytes = 328 bits

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)

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


Demo

Setup



- Transmit 1M Bytes
- RTC stamp at the beginning
- RTC stamp at the ending
- 1M x 8bit / (ending_stamp – beginning_stamp)

Bluetooth Core Specification v4.2

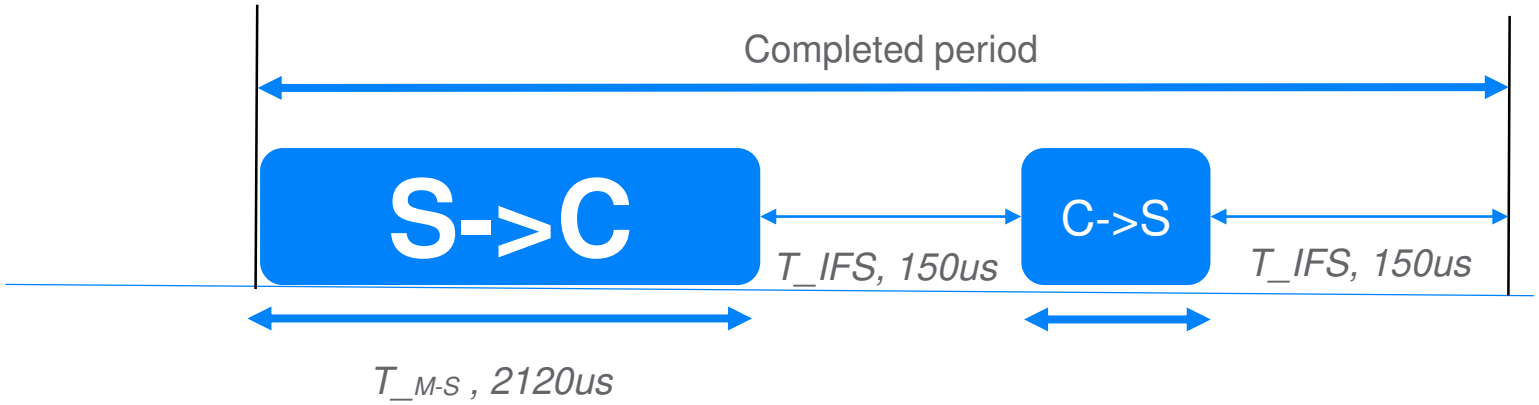
1 Mega symbols/sec

1 symbol -> 1 us

1 bit = 1 symbol

1 bit -> 1 us

Bluetooth Core Specification v4.2

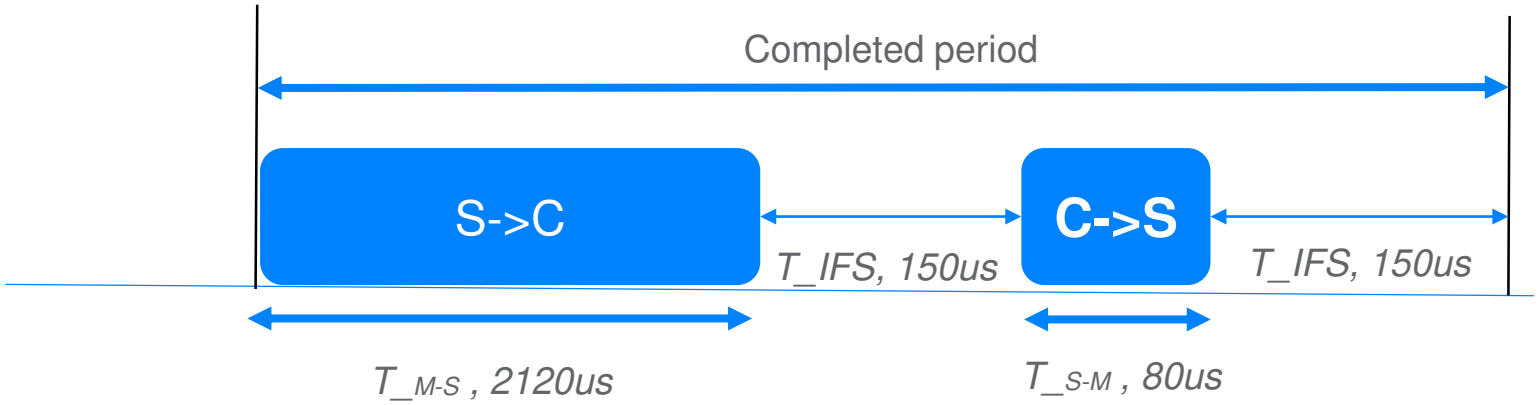


S – GATT Server
C – GATT Client

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)

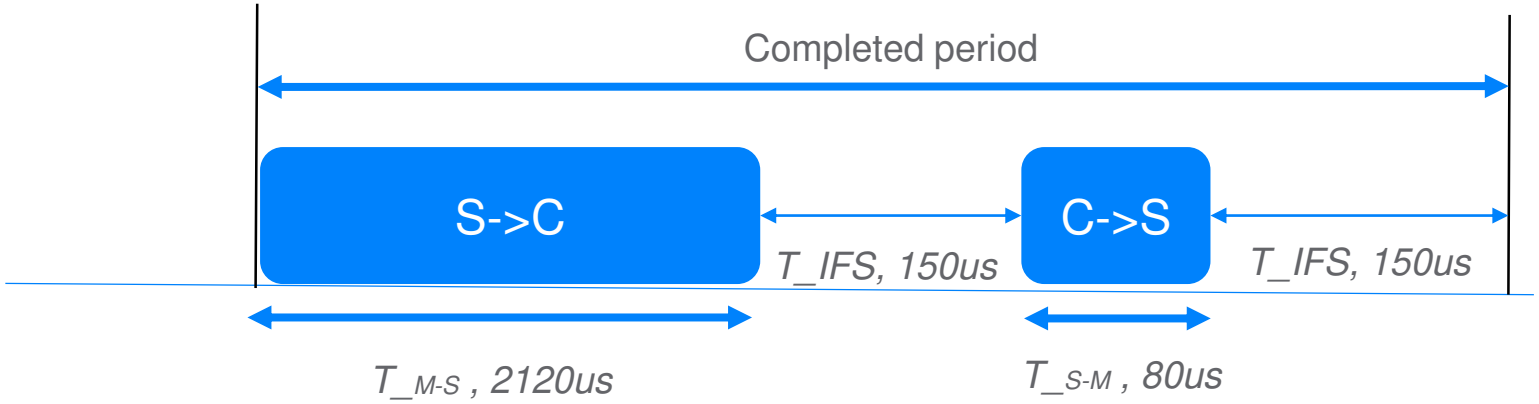
Bluetooth Core Specification v4.2



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

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

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)

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


Demo

Bluetooth Core Specification v5.0, 2M Uncoded PHY

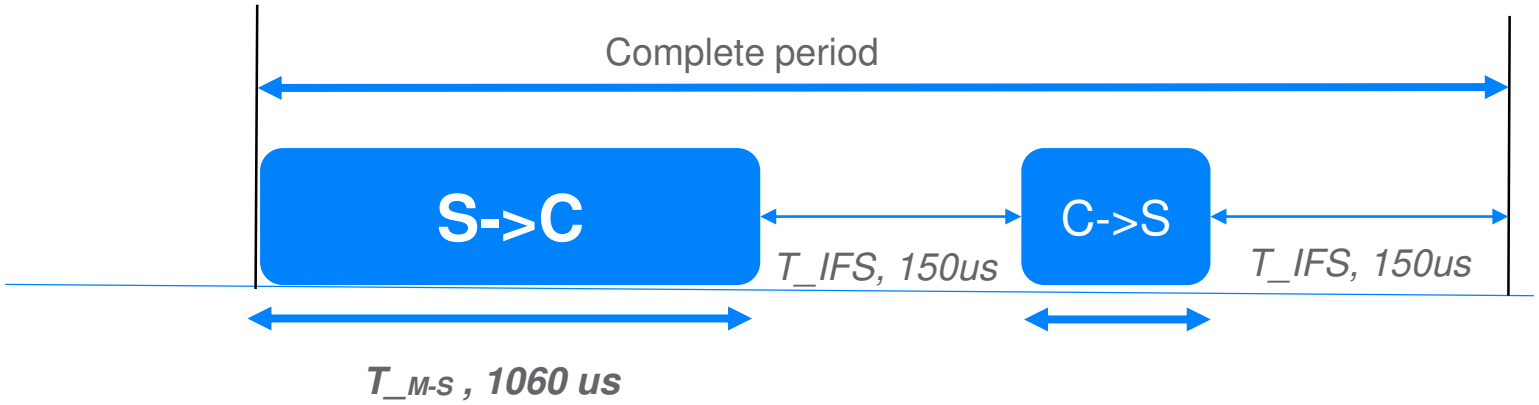
2 Mega symbols/sec

1 symbol -> 0.5 us

1 bit = 1 symbol

1 bit -> 0.5 us

Bluetooth Core Specification v5.0, 2M Uncoded PHY

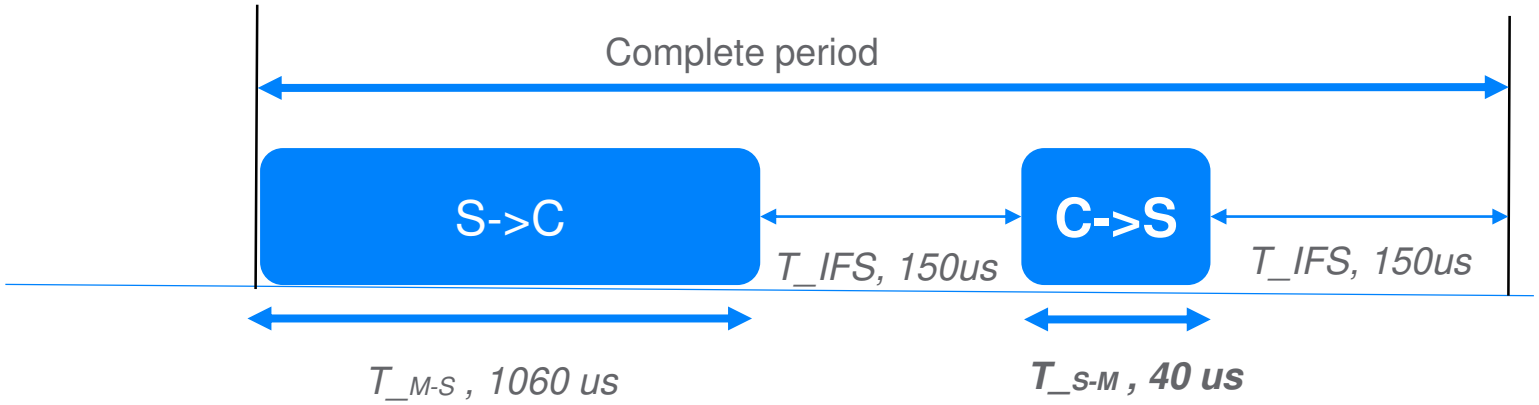


S – GATT Server
C – GATT Client

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)

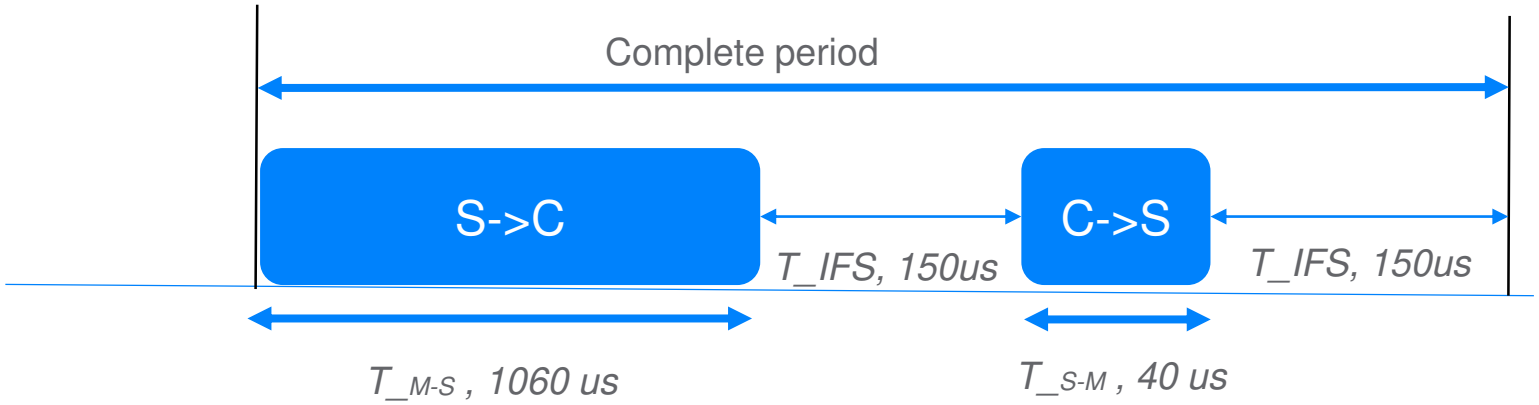
Bluetooth Core Specification v5.0, 2M Uncoded PHY



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

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

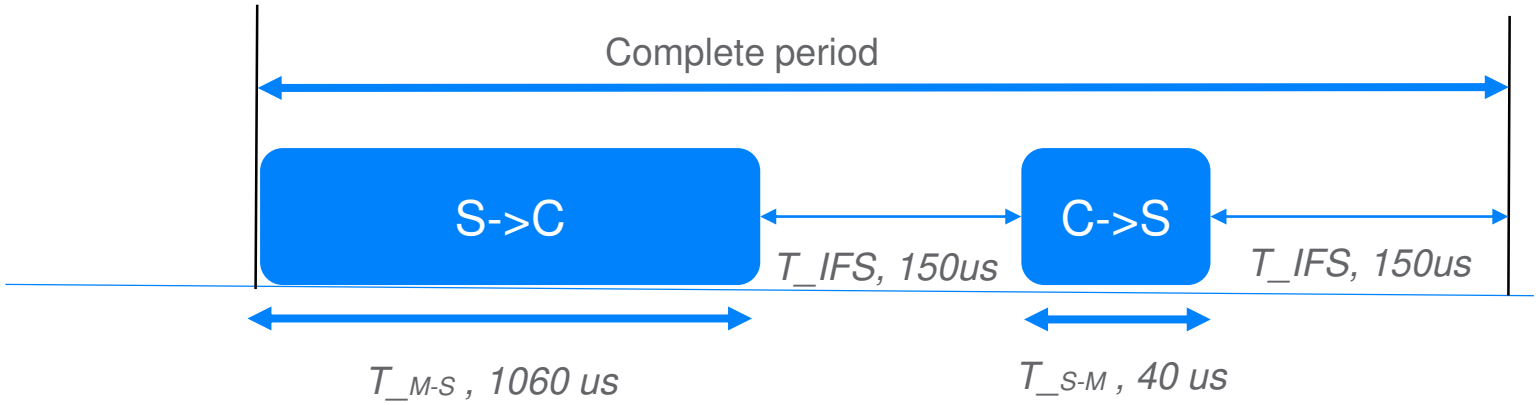
Bluetooth Core Specification v5.0, 2M Uncoded PHY



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

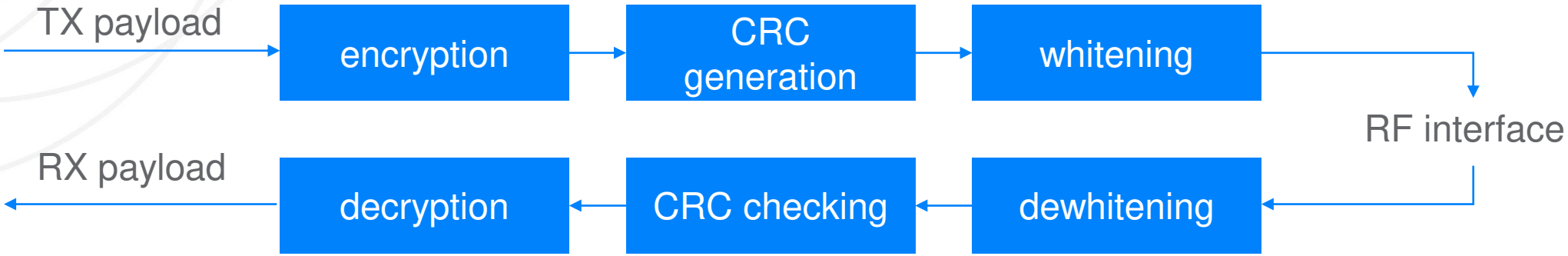
Preamble (1)	Access Address (4)	LL Header (2)	L2CAP Len (2)	L2CAP Ch ID (2)	Opcode & HDL (3)	**Attribute Value (0 ~ 244)**	MIC (4)	CRC (3)

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


Demo

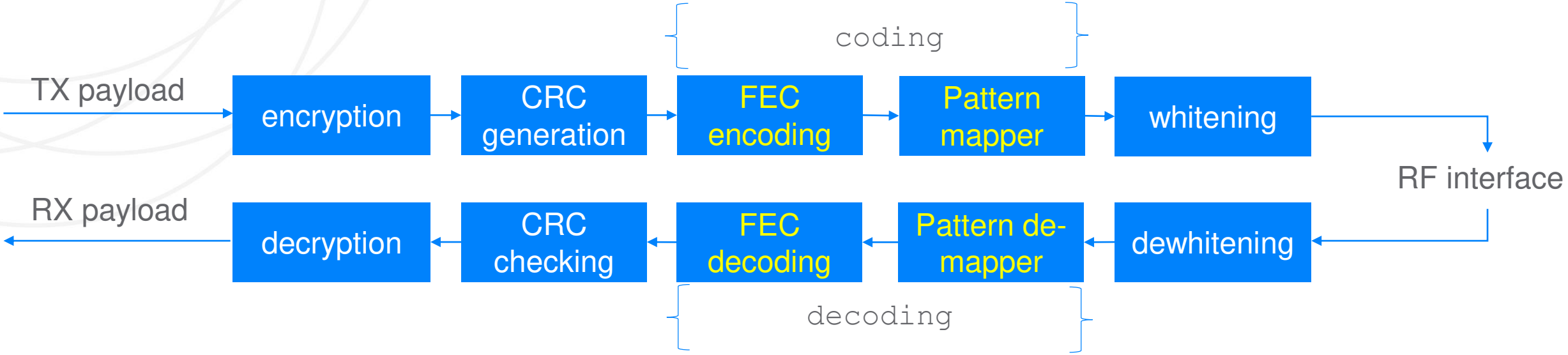
Long Range

LE Uncoded 1M or 2M Bit Stream Processing

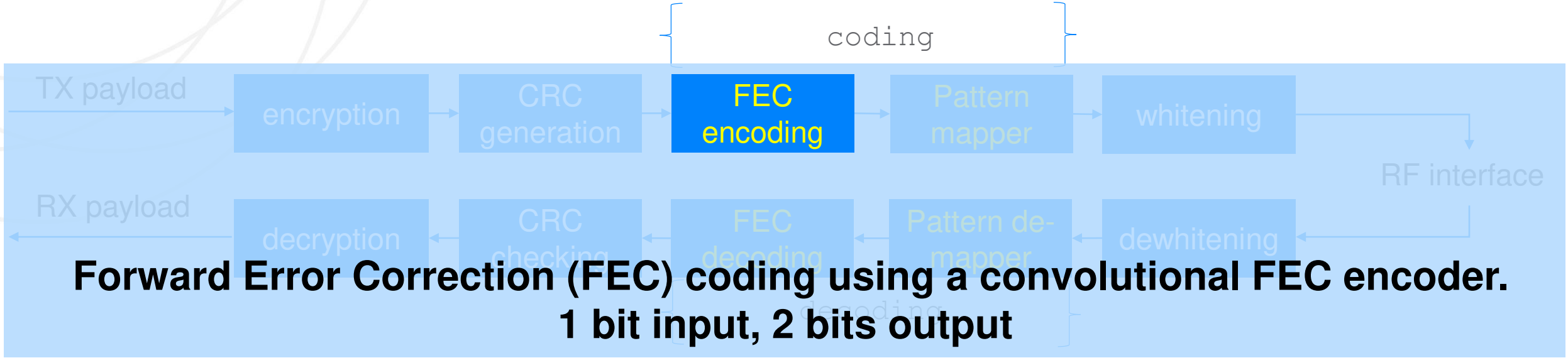


Note: LE 1M and LE 2M are collectively known as the "**LE Uncoded**" PHYs

LE Coded Bit Stream Processing

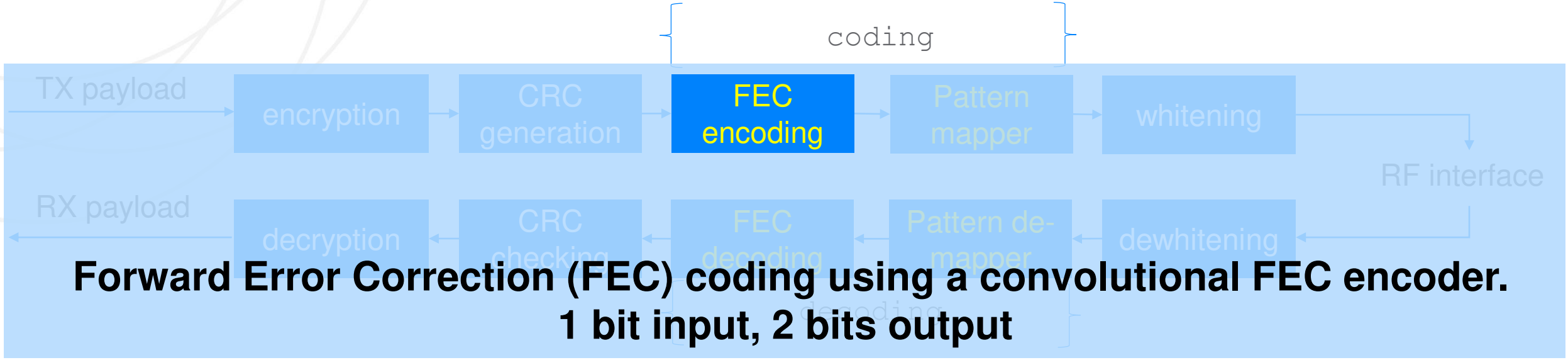


Forward Error Correction, FEC



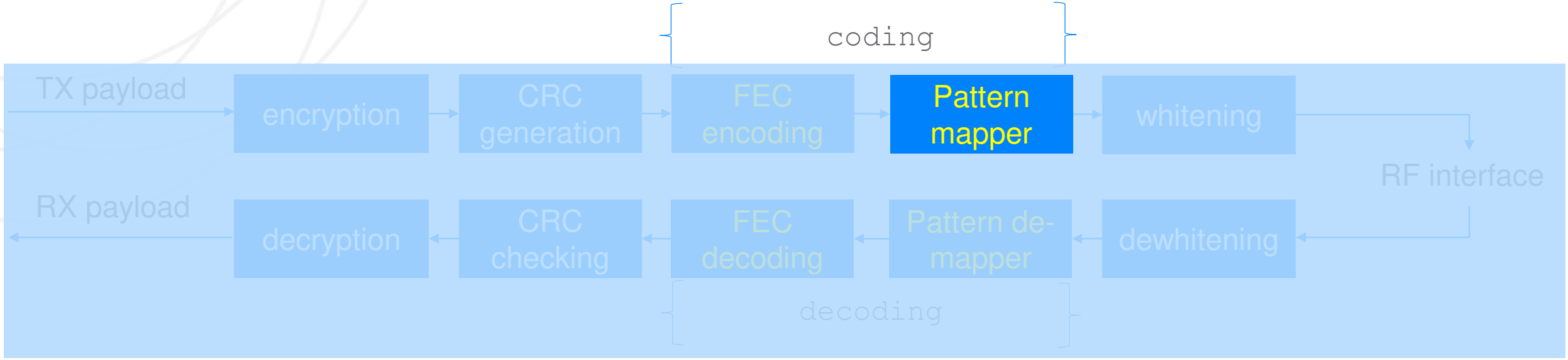
Forward Error Correction (FEC) coding using a convolutional FEC encoder.
1 bit input, 2 bits output

Forward Error Correction, FEC



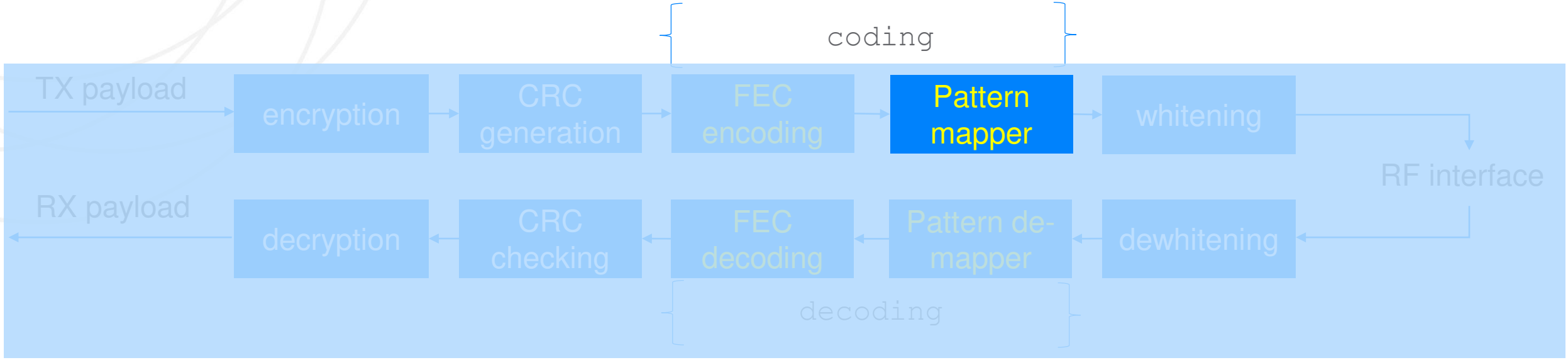
Forward Error Correction (FEC) coding using a convolutional FEC encoder.
1 bit input, 2 bits output

Patter Mapper

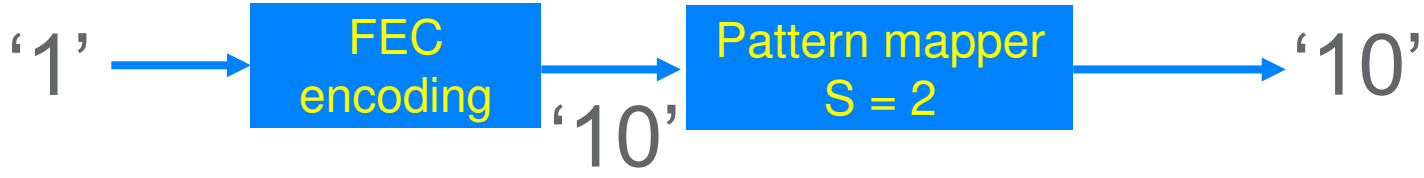


Input Bit from FEC	Output (S=2)	Output (S=8)
0	0	0011
1	1	1100

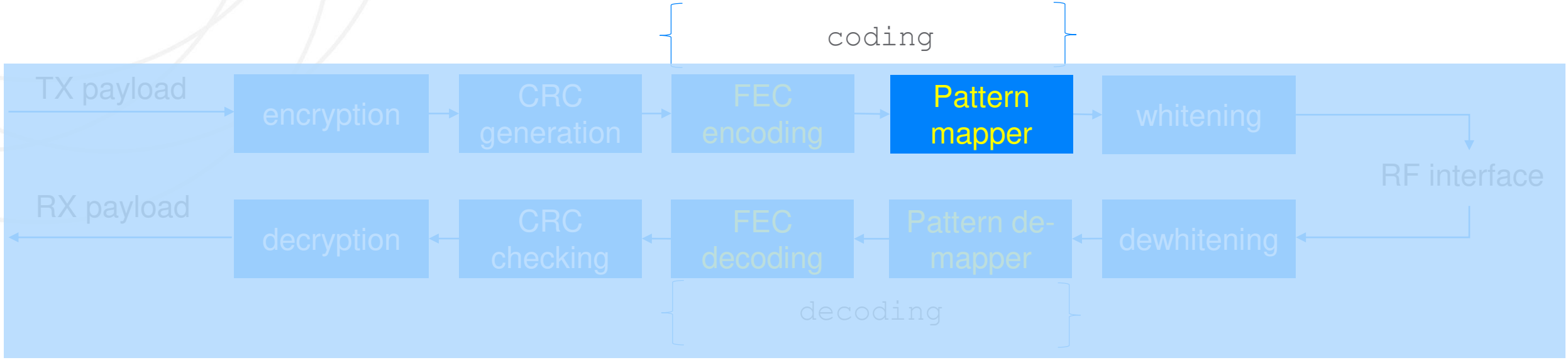
Patter Mapper



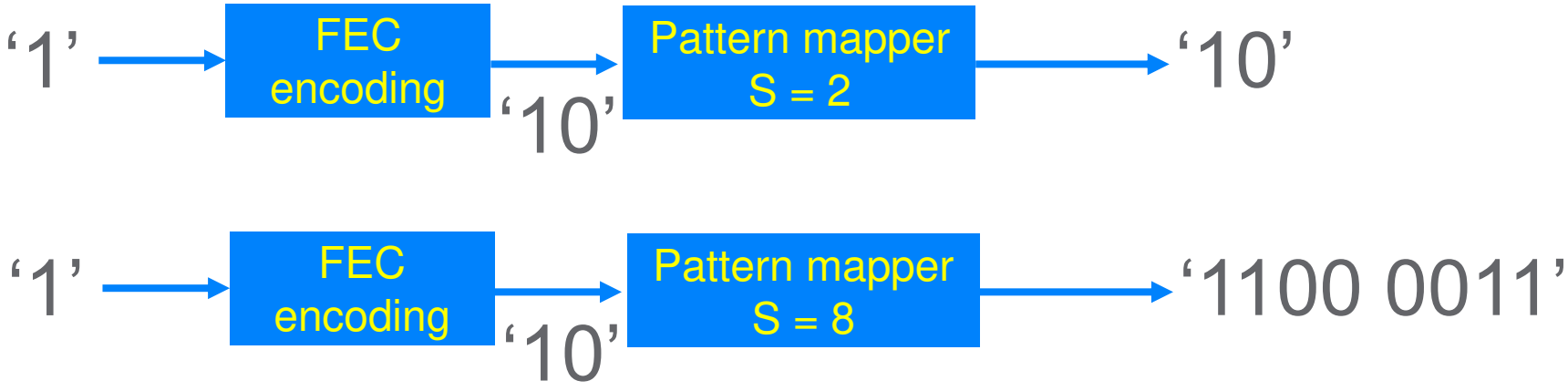
Input Bit from FEC	Output (S=2)	Output (S=8)
0	0	0011
1	1	1100



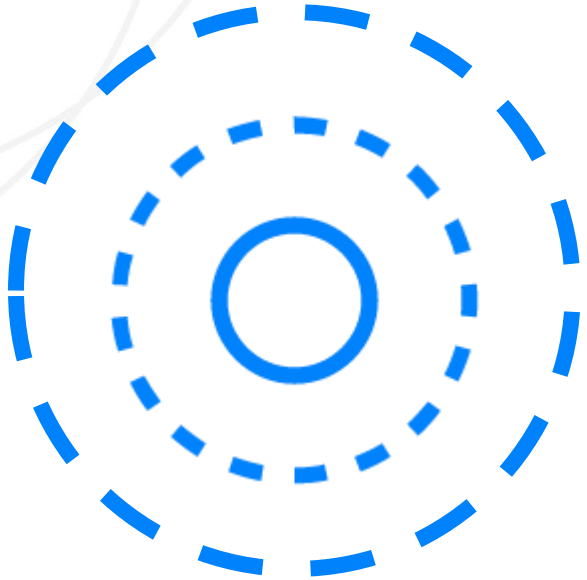
Patter Mapper



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

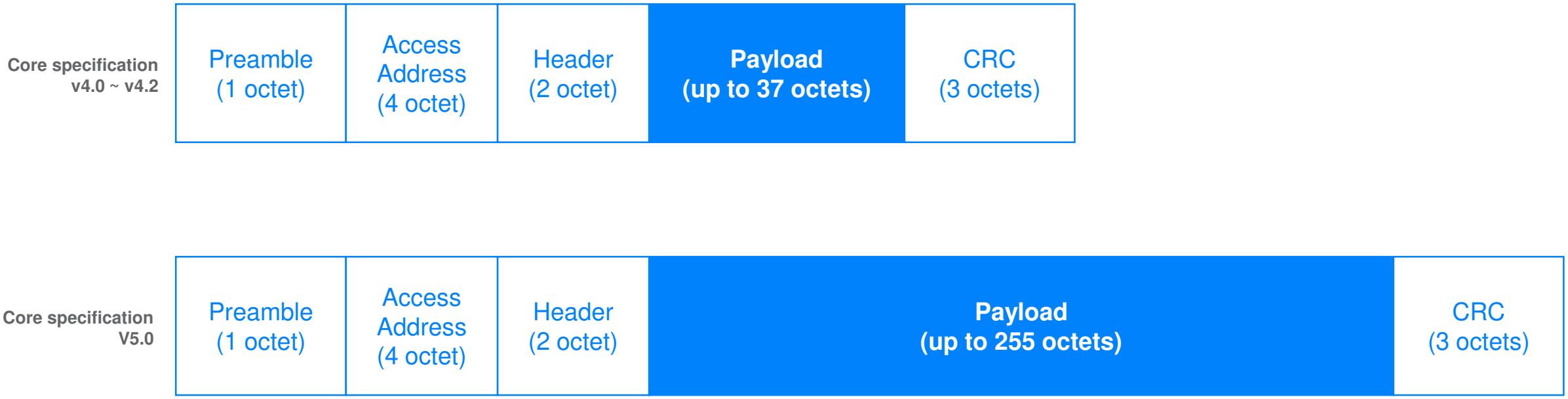
- S=2
  - 2 symbols for 1 data bit, 500kbps
  - 5dB sensitivity increasing
- S=8
  - 8 symbols for 1 data bit, 125kbps
  - 12dB sensitivity increasing

ADV Extension

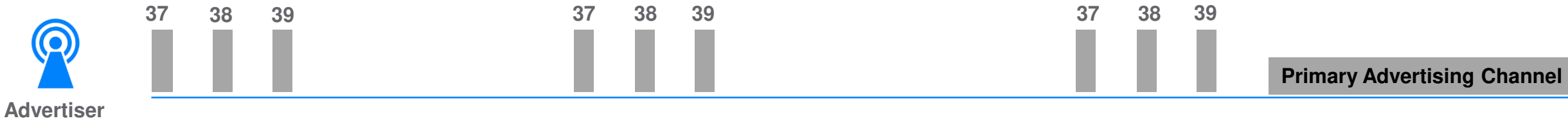
Advertising Payload

Core specification v4.0 ~ v4.2

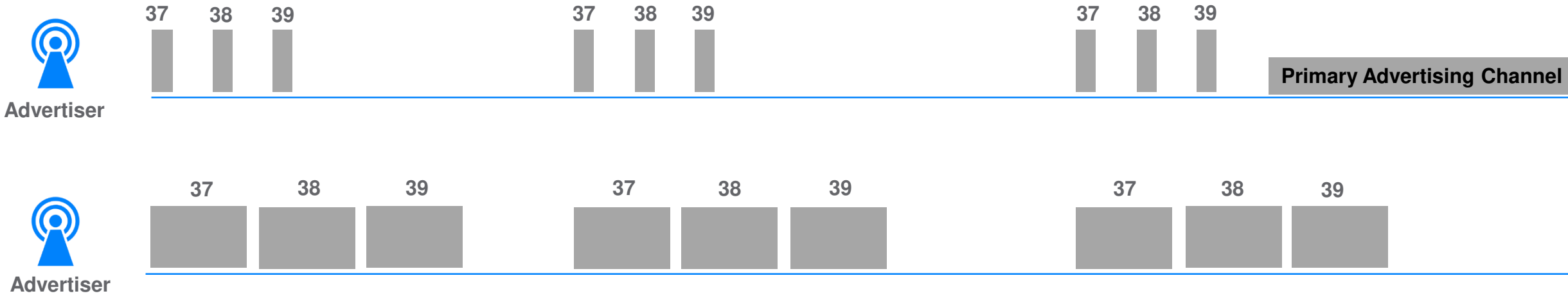
Longer Advertising Payload



Legacy Advertising

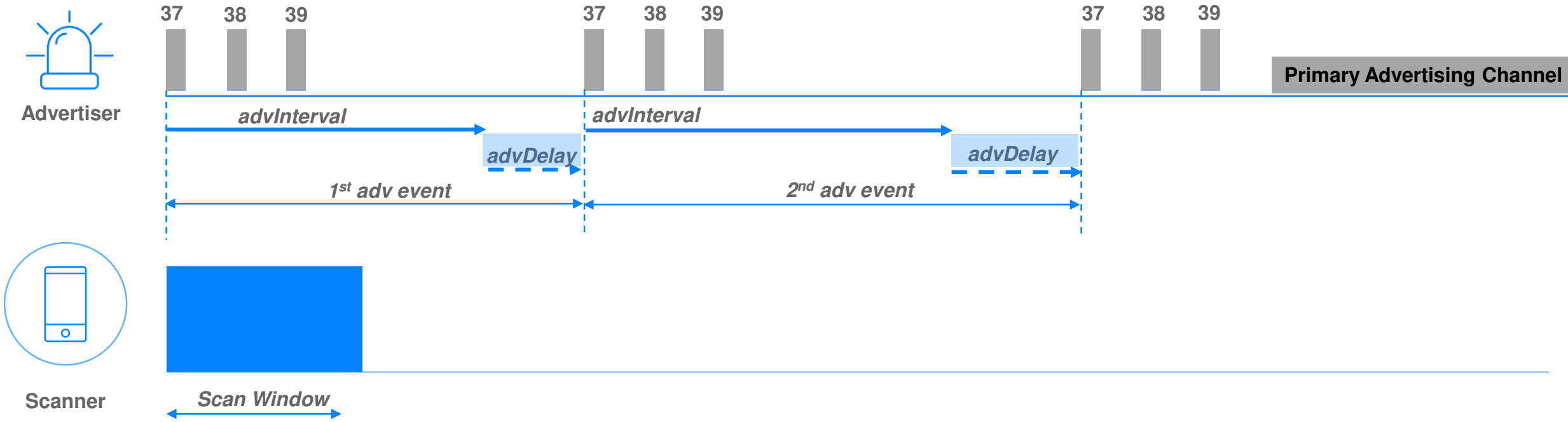


Longer Payload over Legacy Advertising

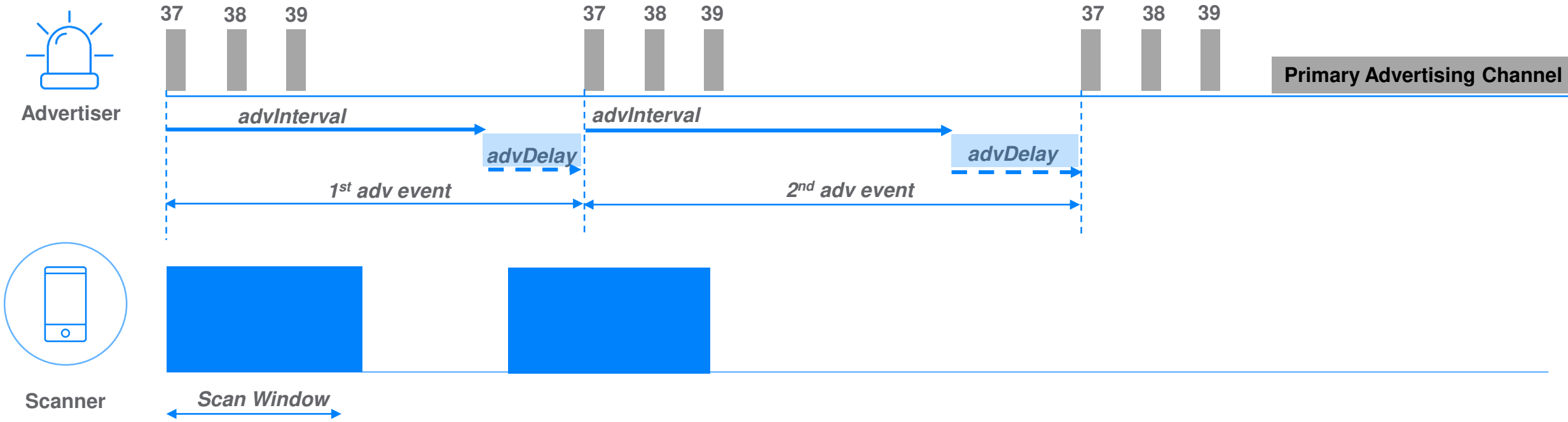


Offload Advertising Payload

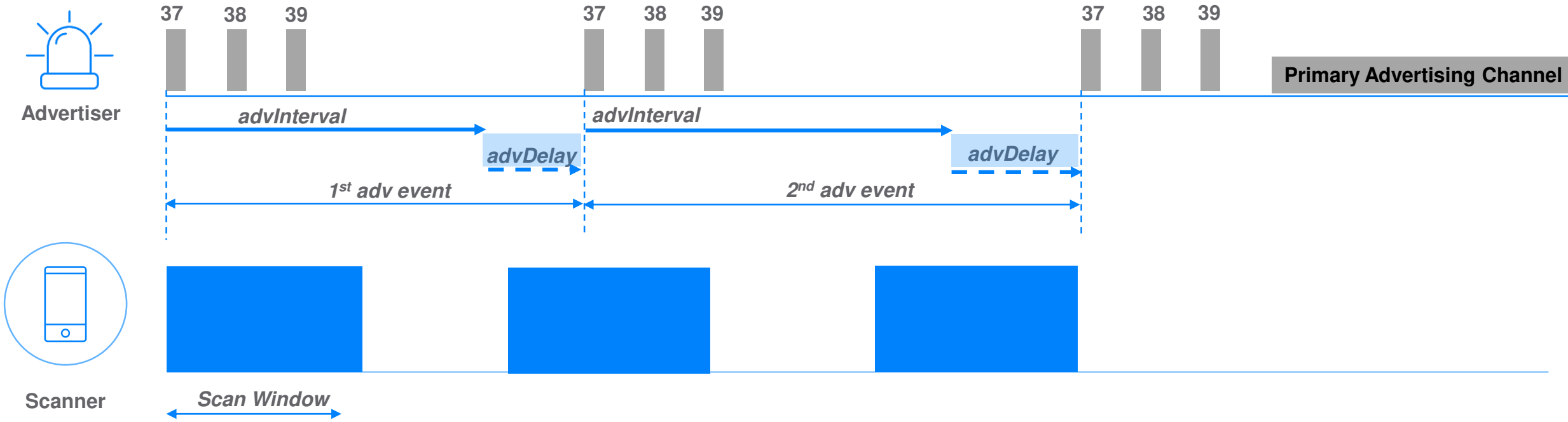
Legacy Advertising



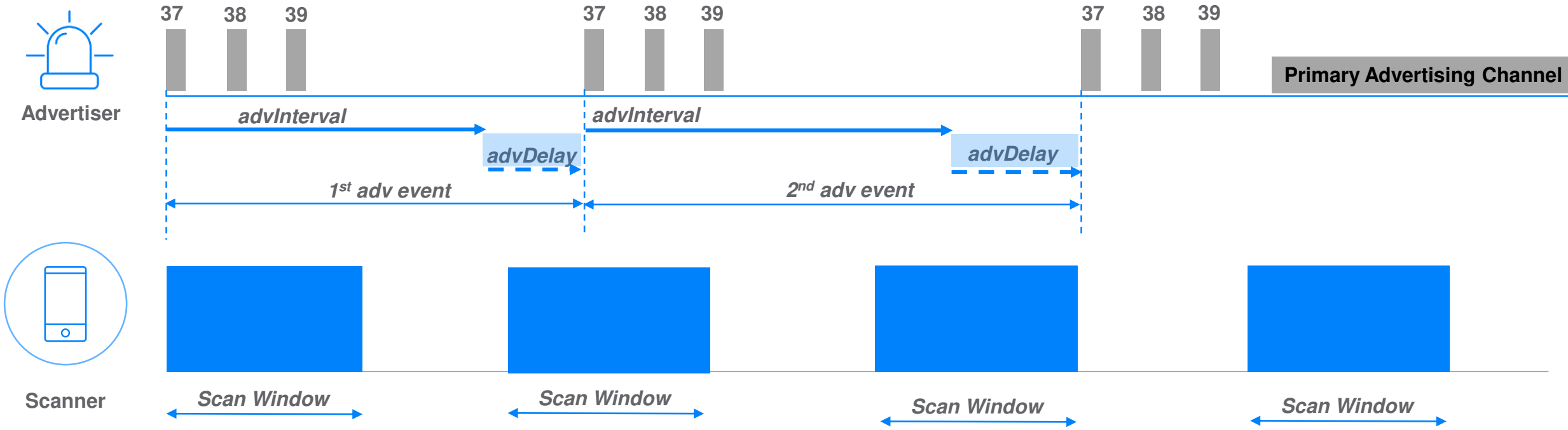
Legacy Advertising



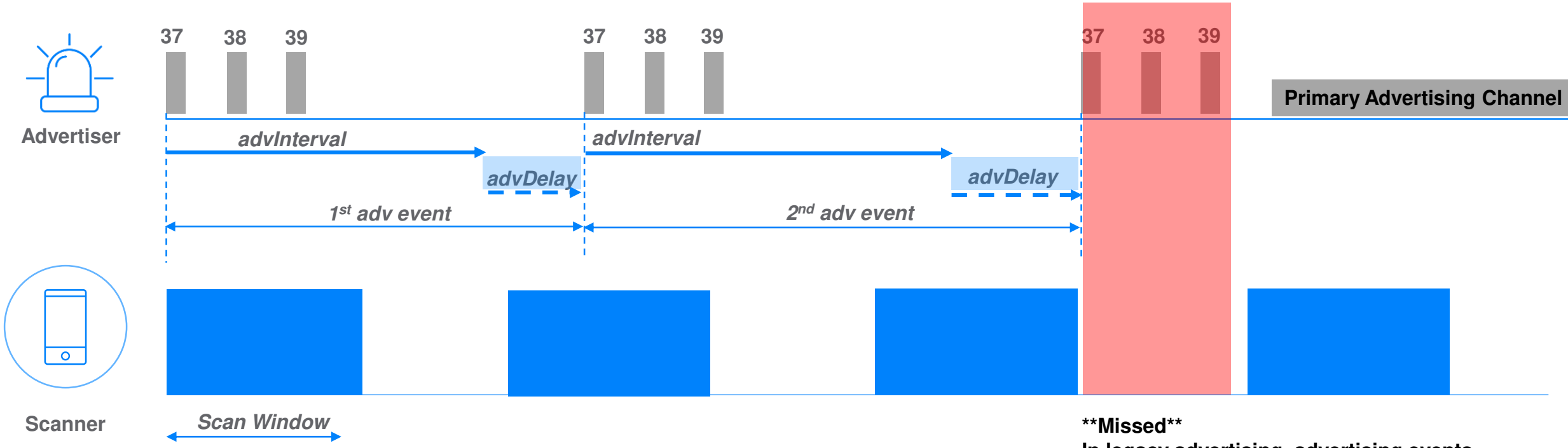
Legacy Advertising



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

37 38 39

ADV_EXT_IND ADV_EXT_IND ADV_EXT_IND

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

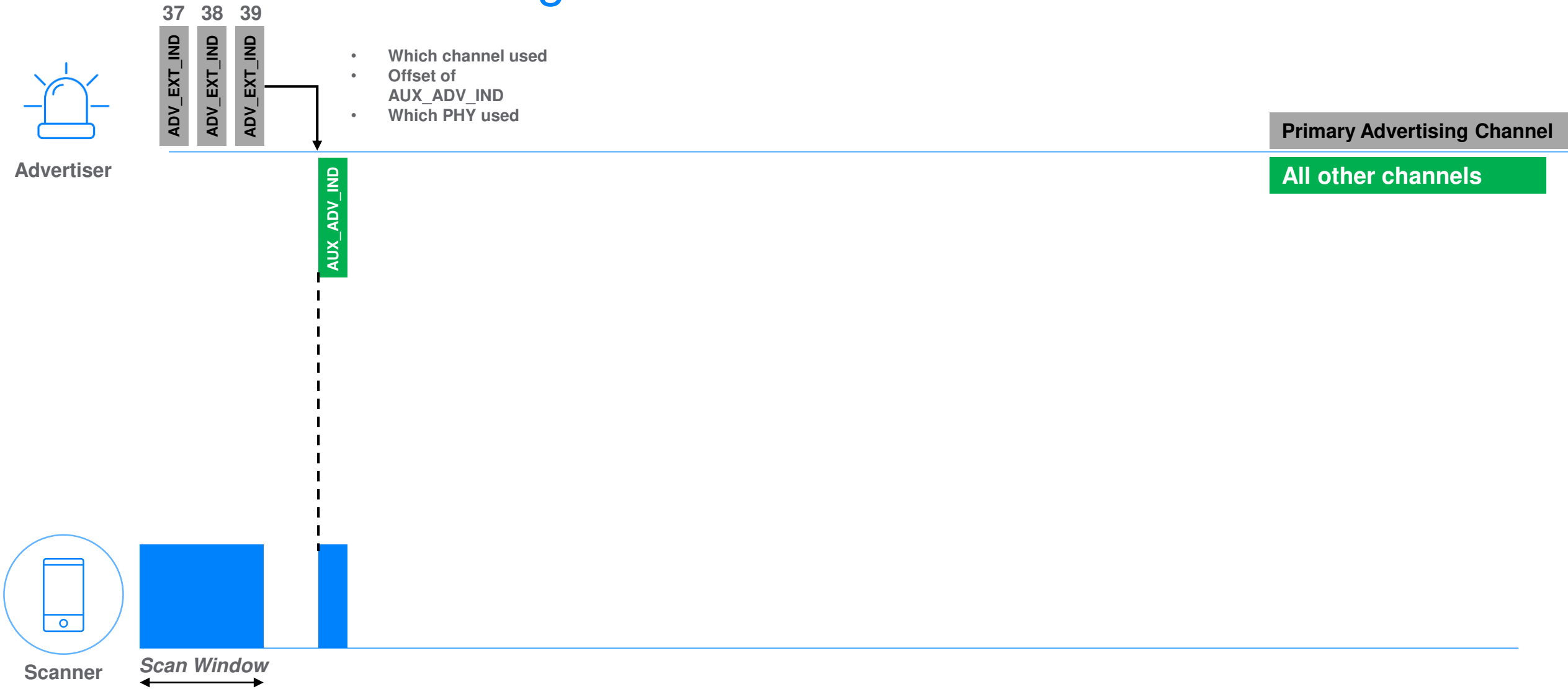
Primary Advertising Channel

All other channels

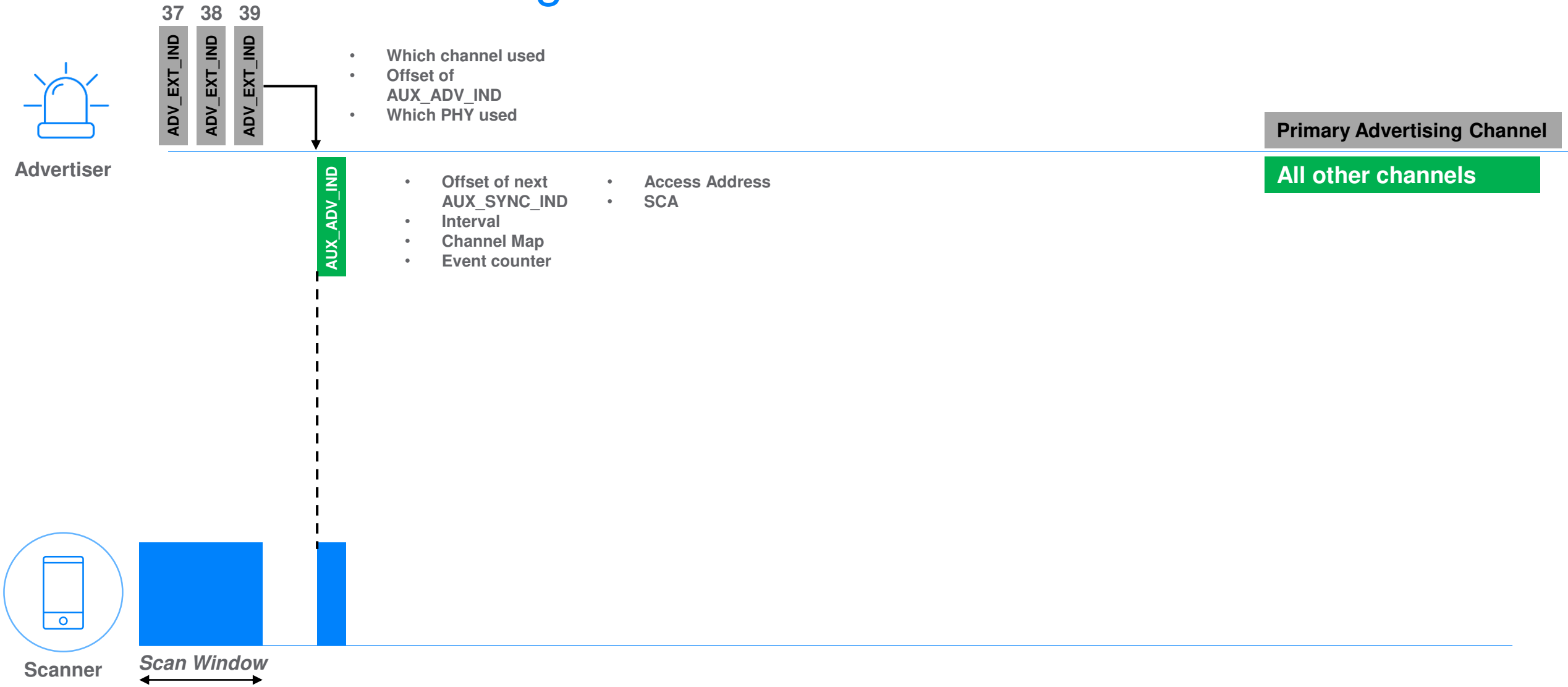
Scanner

Scan Window

Periodical Advertising



Periodical Advertising



Periodical Advertising

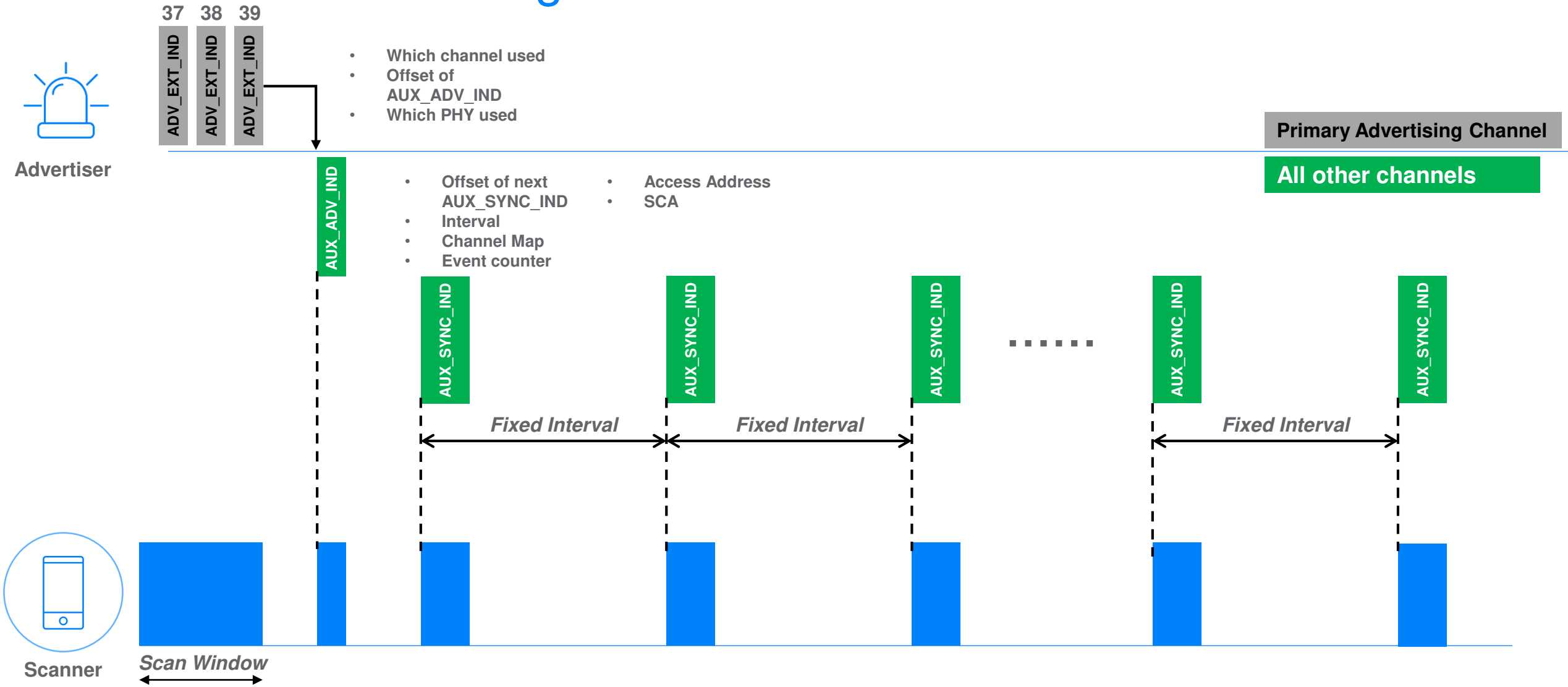
Periodical Advertising

Periodical Advertising

Periodical Advertising

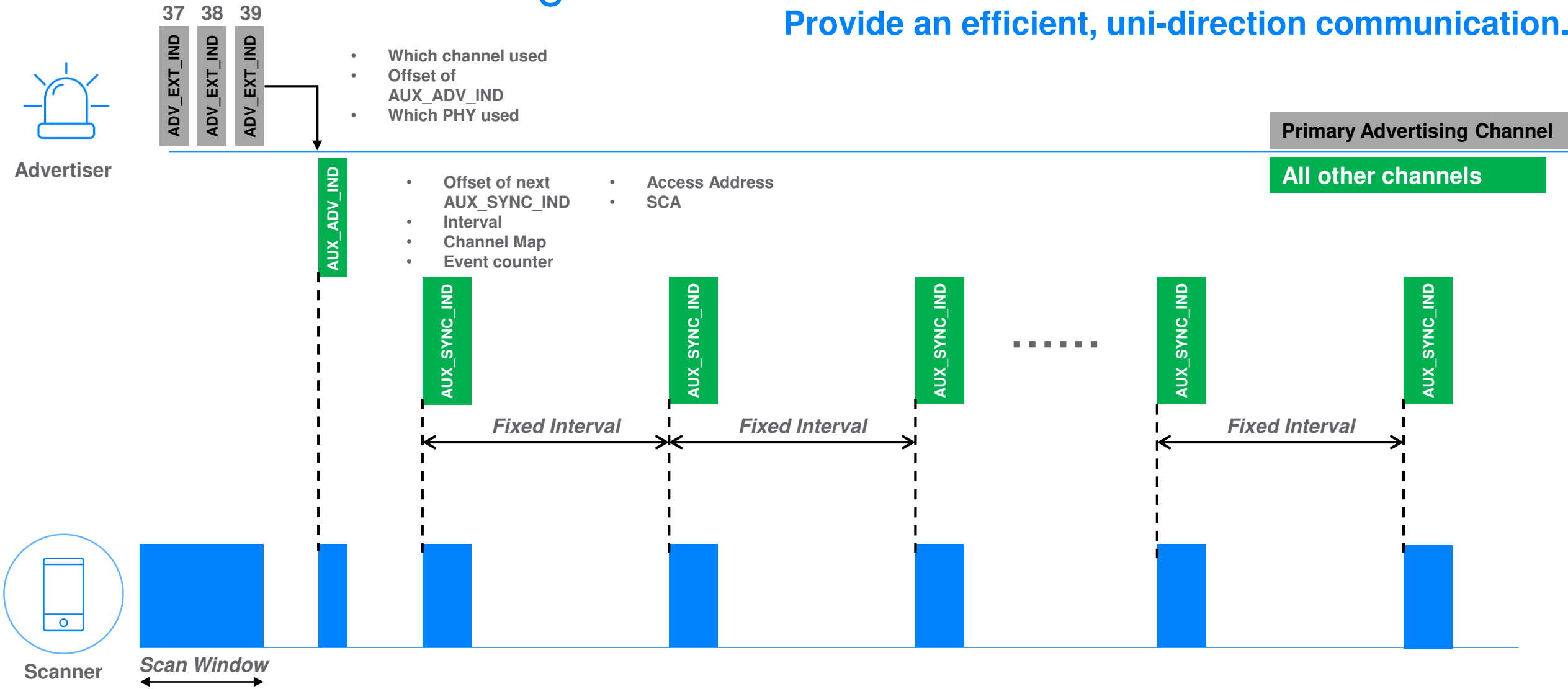
Periodical Advertising

Periodical Advertising



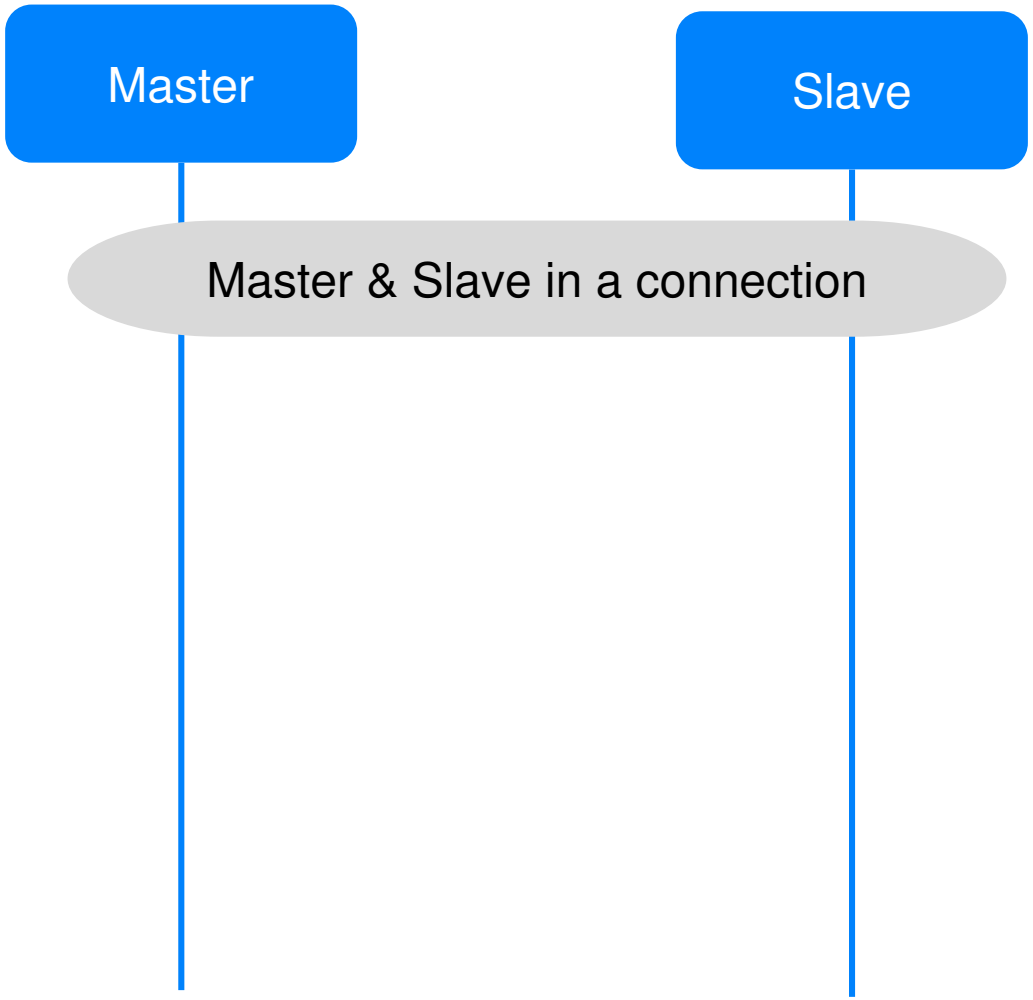
Periodical Advertising

Provide an efficient, uni-direction communication.

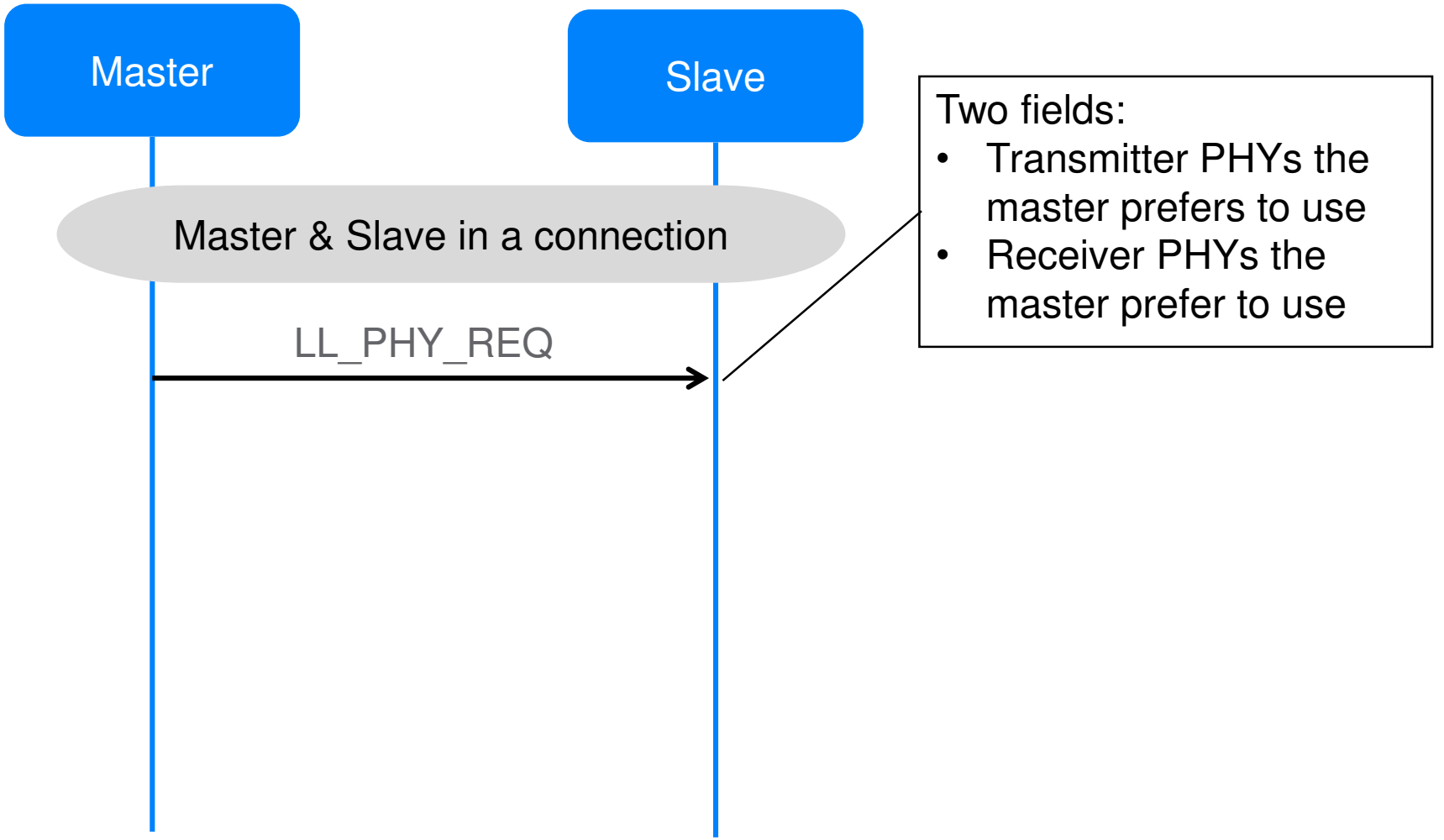


PHY Update Procedure

Master Initial



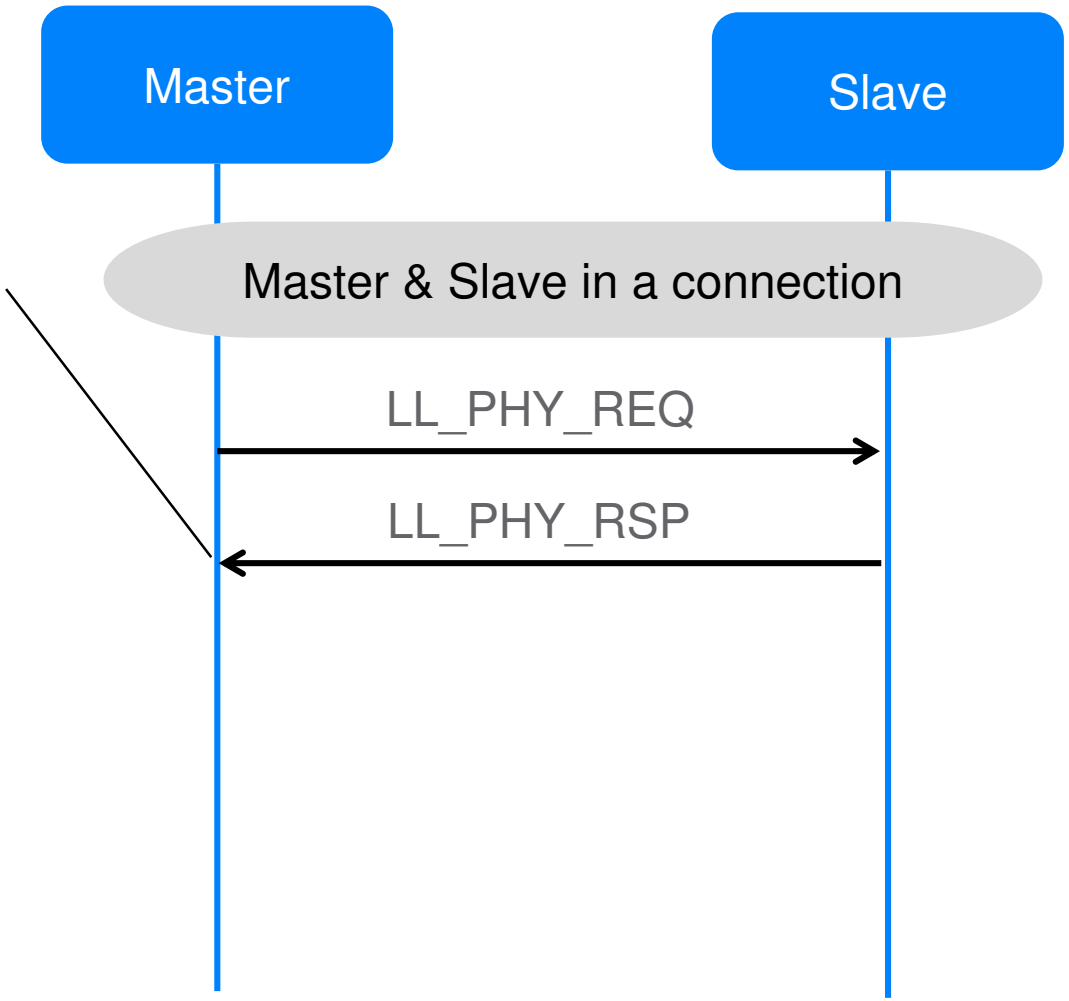
Master Initial



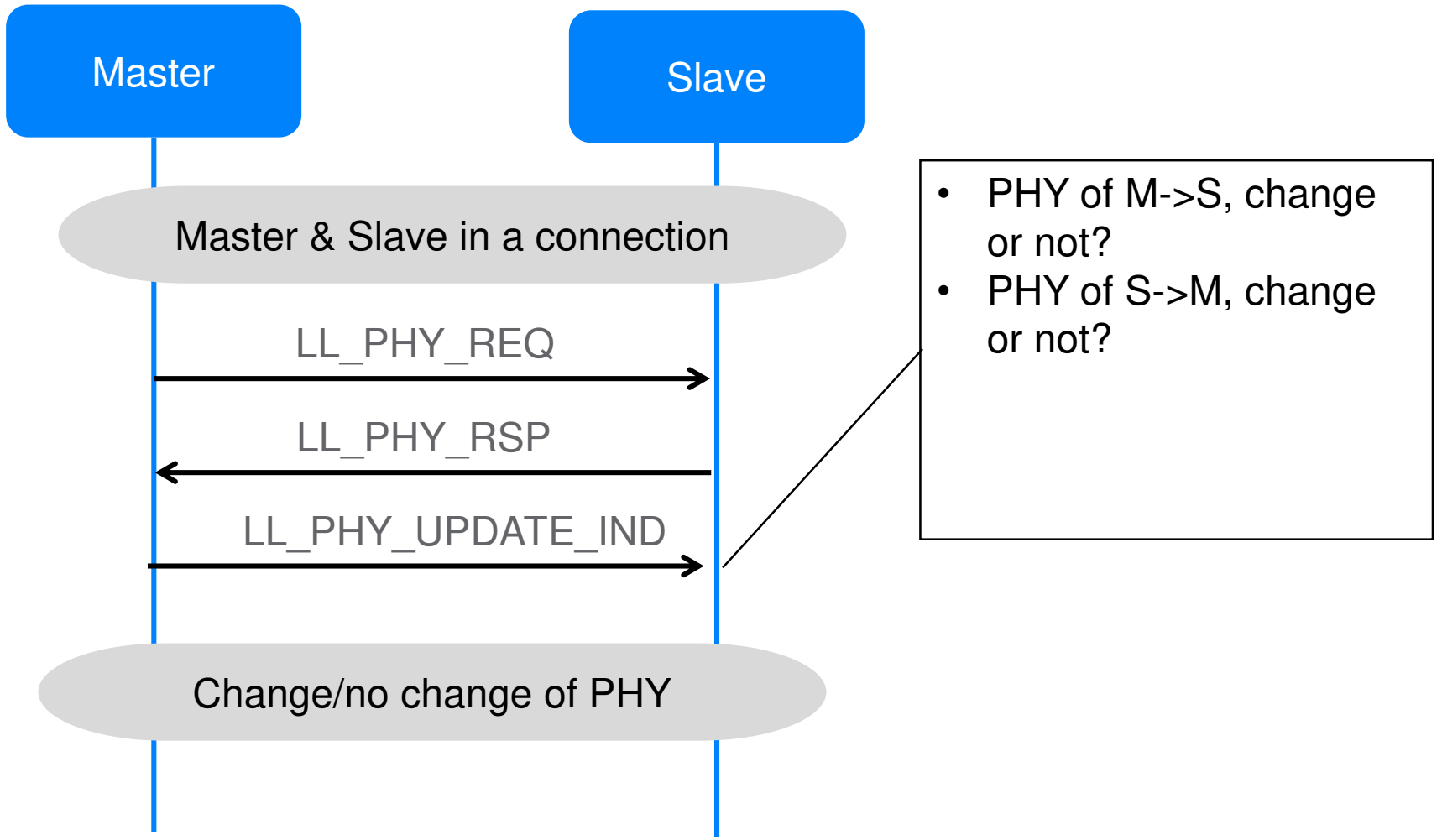
Master Initial

Two fields indicated by slaver:

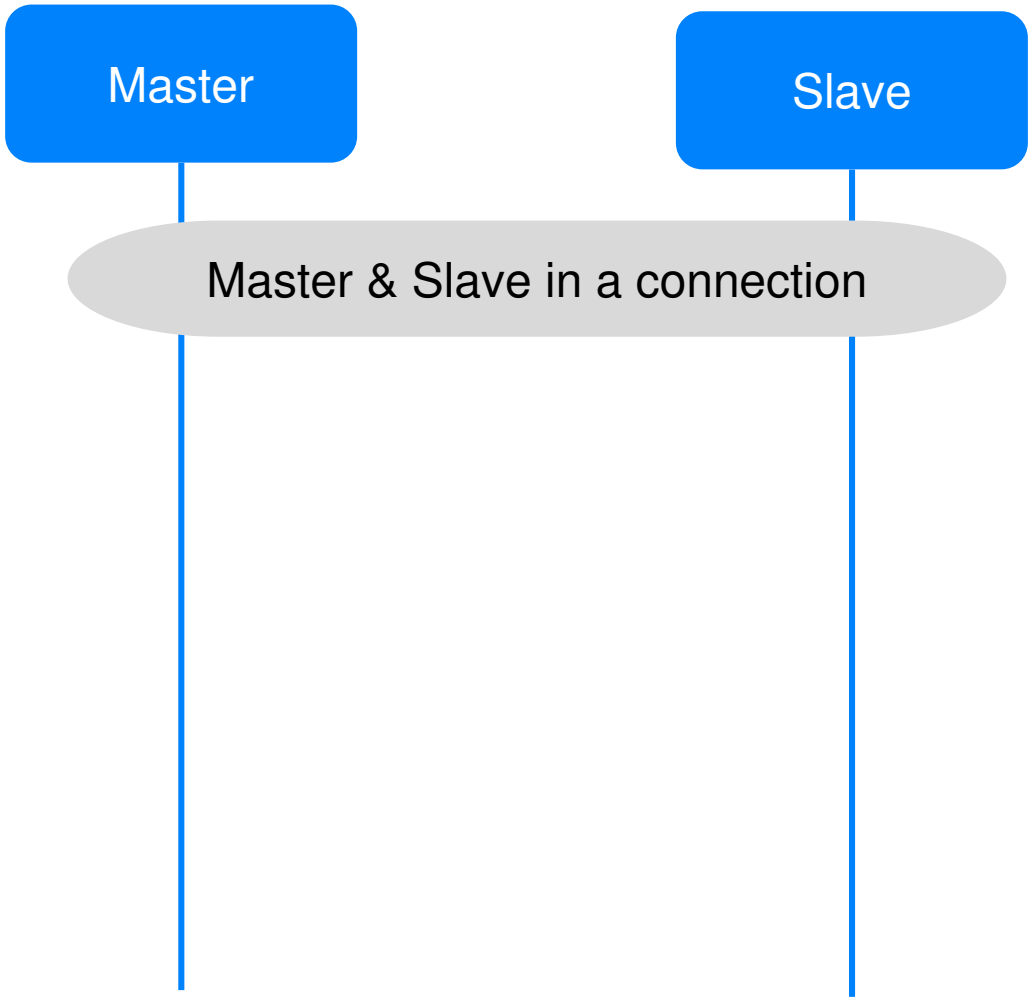
- Transmitter PHYs the slave prefers to use
- Receiver PHYs the slave prefer to use



Master Initial

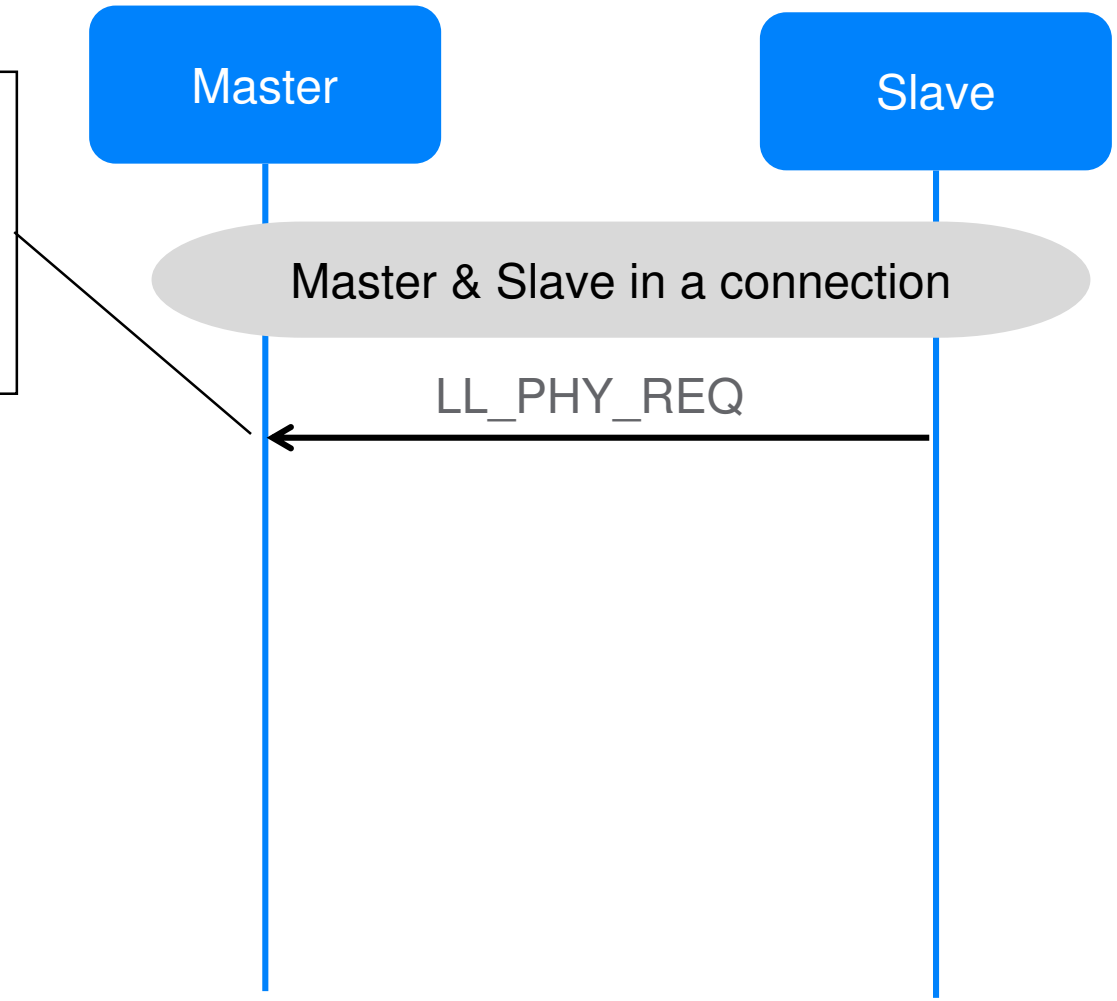


Slave Initial

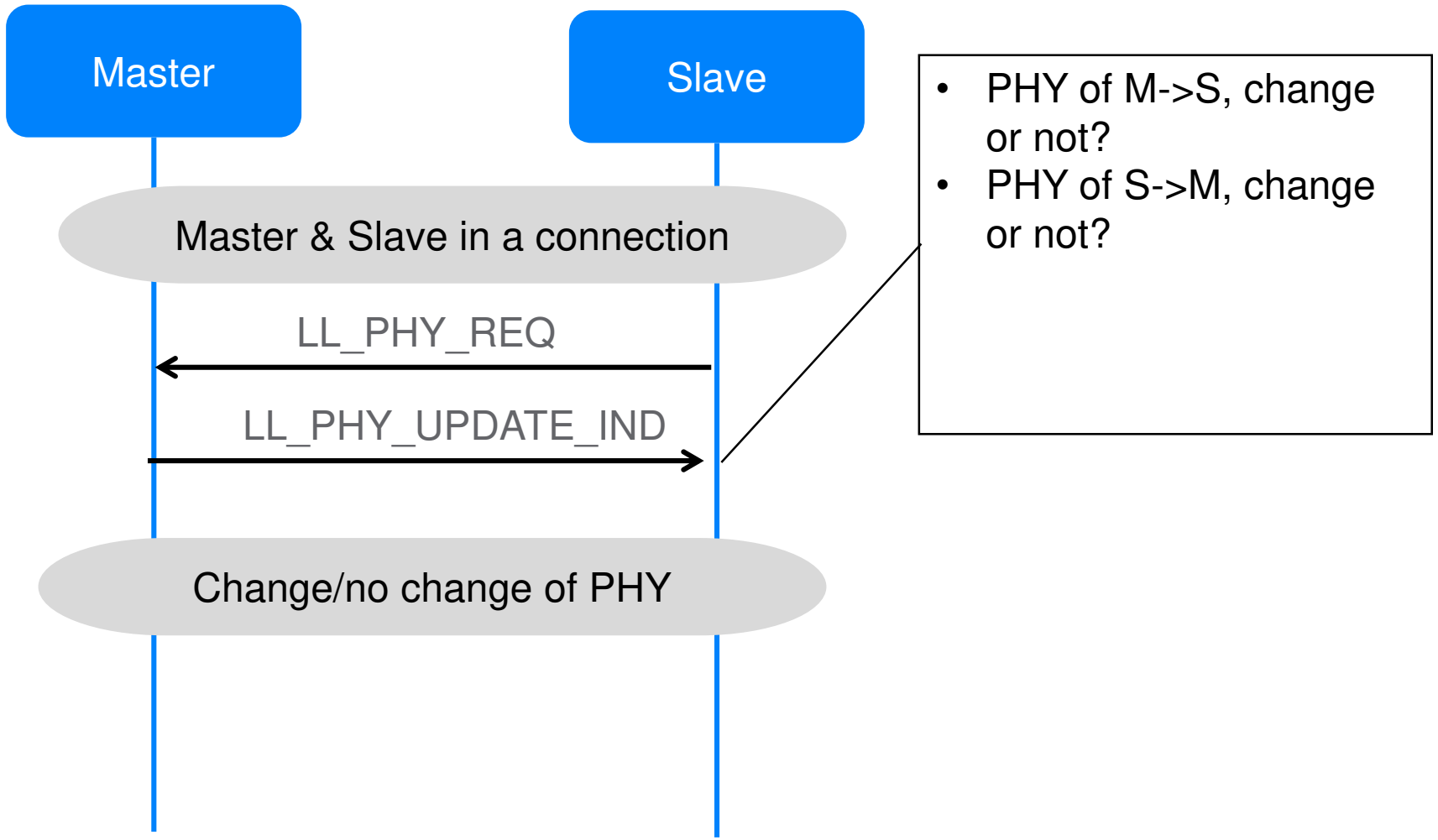


Slave Initial

Two fields:
- Transmitter PHYs the slave prefers to use
- Receiver PHYs the slave prefer to use



Slave Initial



#BluetoothAsia2019#

BluetoothAsia
探索、创新、开拓

Thank you