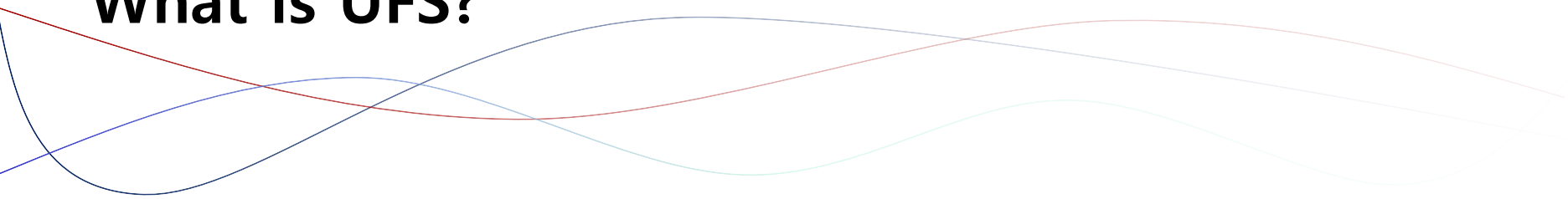
CONFIDENTIAL

UFS Overview

Aug. 21, 2015

Mobile AE

What is UFS?

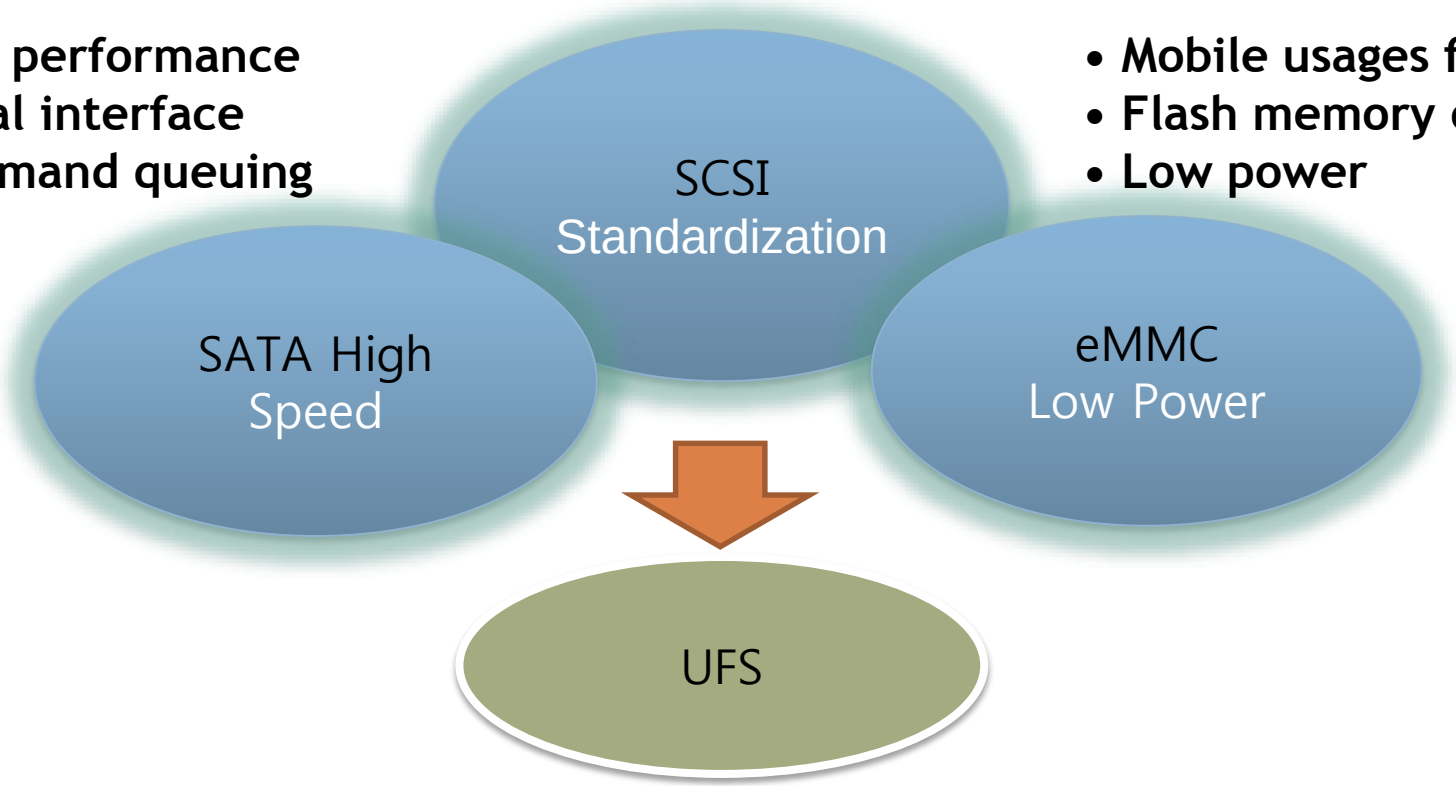


What is UFS?

UFS ???

• **Universal Flash Storage (UFS)** is a common flash storage specification for digital cameras, mobile phones and consumer electronic devices. This could bring higher data transfer speed and increased reliability in flash memory storage

- **High performance**
- **Serial interface**
- **Command queuing**

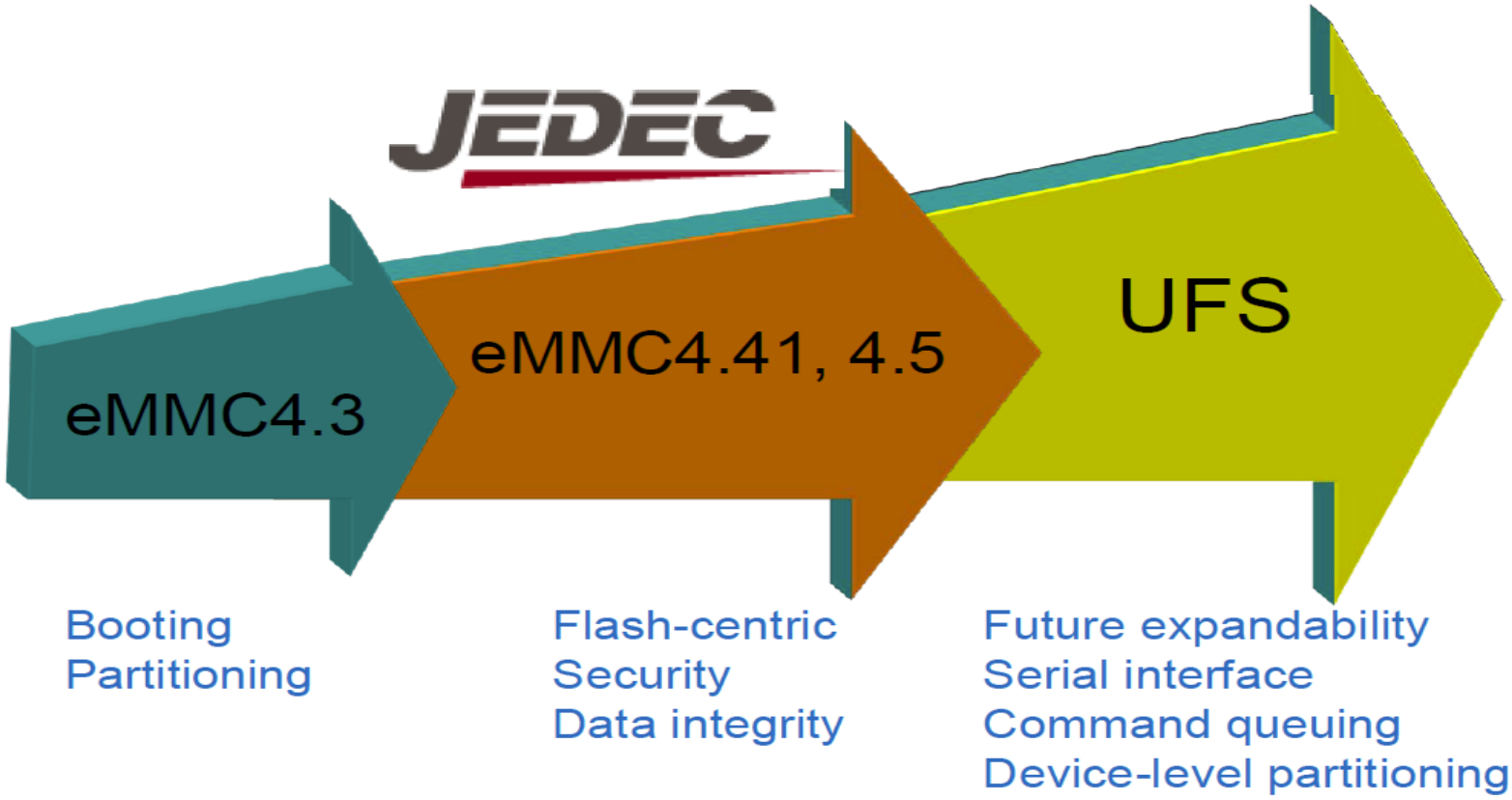


- **Mobile usages friendly**
- **Flash memory oriented**
- **Low power**

What is UFS?

UFS ???

- JEDEC defines UFS as the next generation mobile storage spec



What is UFS?

UFS vs eMMC

Multiple Partitions	Boot / RPMB	Enhanced /Extended	Parallel Interface	
Erase (Purge)	Reliable Write	PON	SDR/DDR	Packed
Write Protection	Cache	BKOPs	HS200	State Transition
Context ID & Data Tag	Sleep &Reset	Dynamic Capacity	Sync	

Good Features, But e.MMC today command-response based architecture is limiting
- Designed for Single-thread computing model
- Increasing bus frequency will not further improve BW

SCSI architecture model[SAM], a Multi-threaded computing operation model
→
Re-Use Standard SCSI commands

Async & Queue
Serial Interface
Stateless

Low-Power Serial Interface
Multi-Task,
Async & Queuing
Command Prioritization,
Out-of-order execution

Universal Flash Storage[UFS]

What is UFS?

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Context ID & Data Tag	Sleep &Reset	Dynamic Capacity

SCSI architecture model[SAM],

a Multi-threaded computing operation model,

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Multi-Task,
Async & Queuing
Command Prioritization,
Out-of-order execution

Value-added Point

eMMC functions

SCSI SAM-5 & UPIU Format

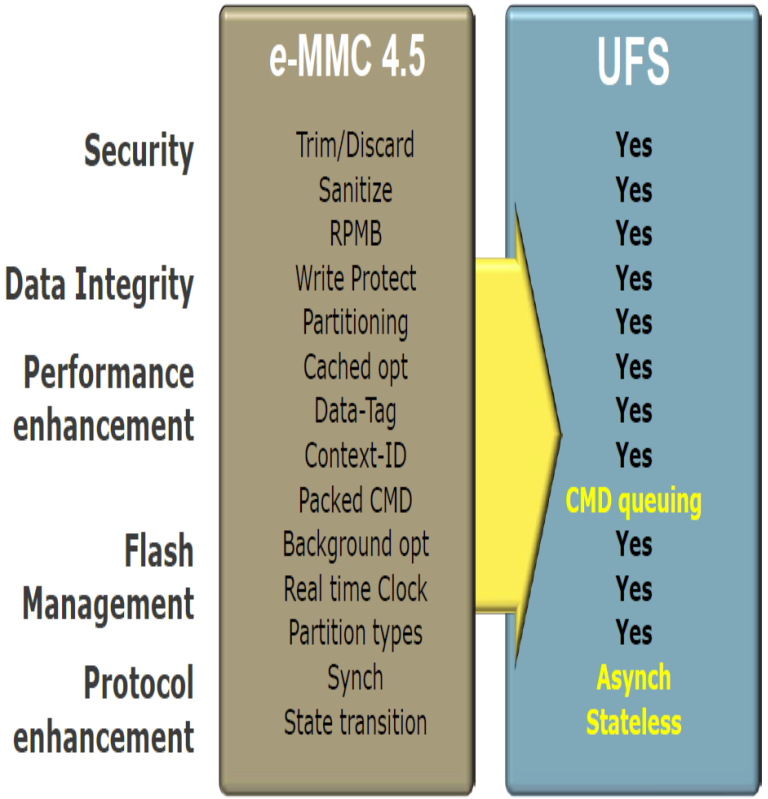
주) SCSI : **layered communication architecture. Client-server model**

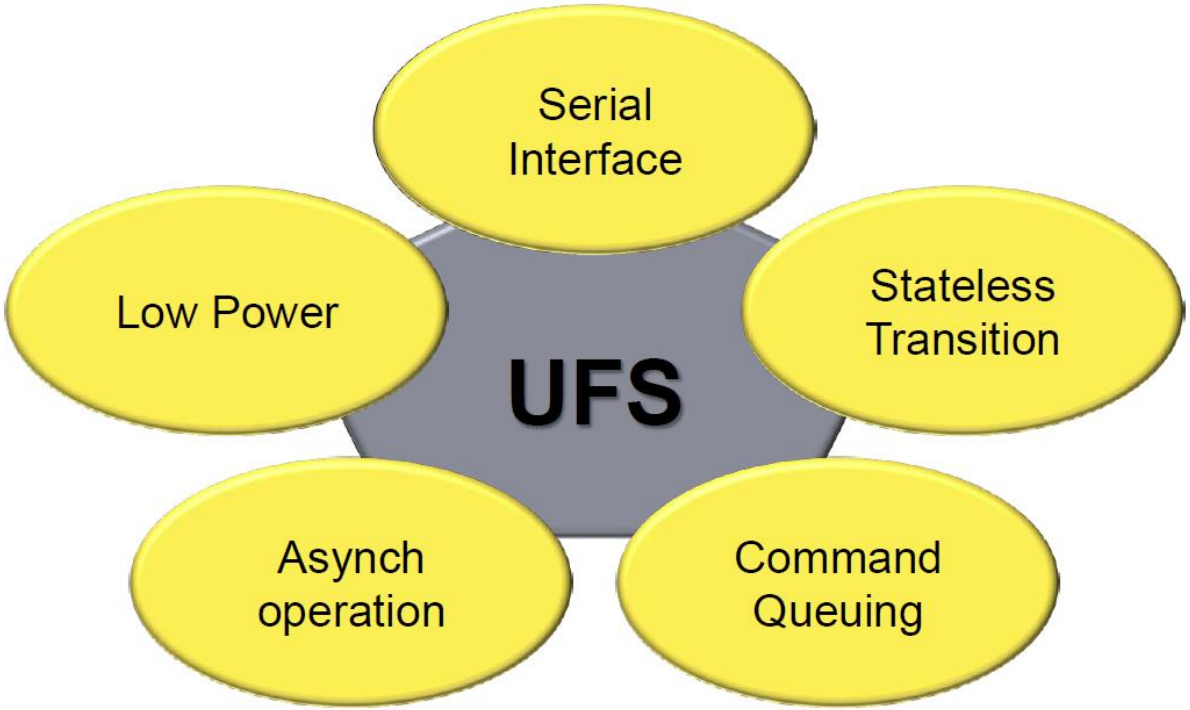
Layered Protocol(UniPro)
+ Serial interface(M-PHY)

Universal Flash Storage[UFS]

What is UFS?

UFS Merits

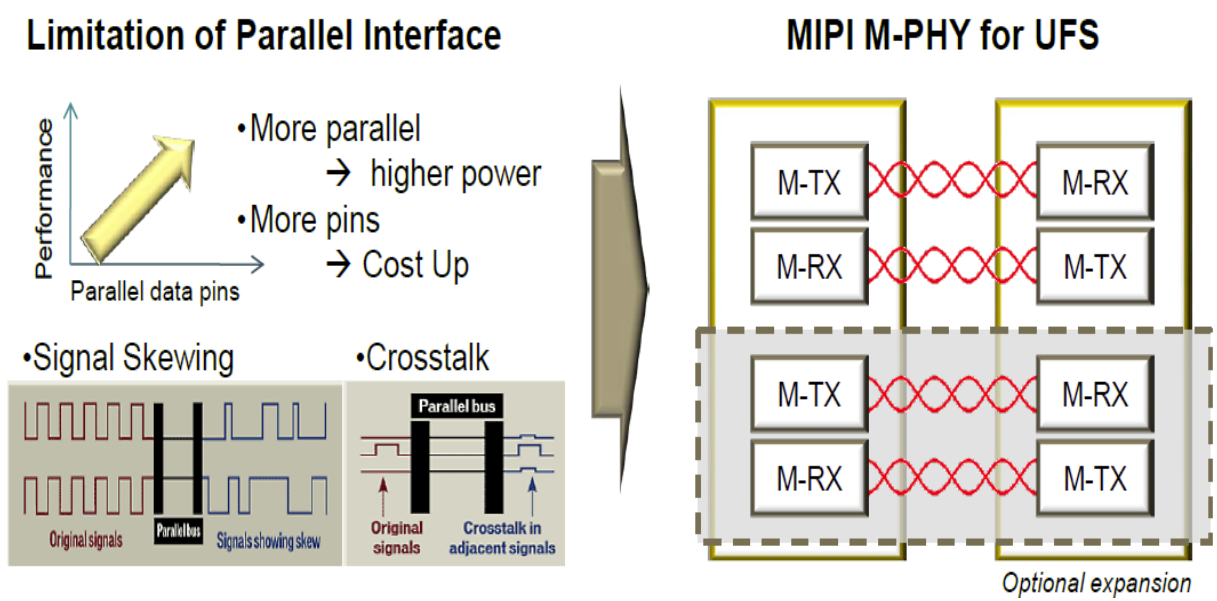




* CMD queuing is supported from eMMC5.1

Serial Interface

- **the demand for speed and cost has led to parallel communication links becoming deprecated in favor of serial links.**
- **Speed:**
  - Clock skew reduces the speed of every link.
  - Crosstalk creates interference between the parallel lines,
- **Cost: The decreasing cost of integrated circuits**



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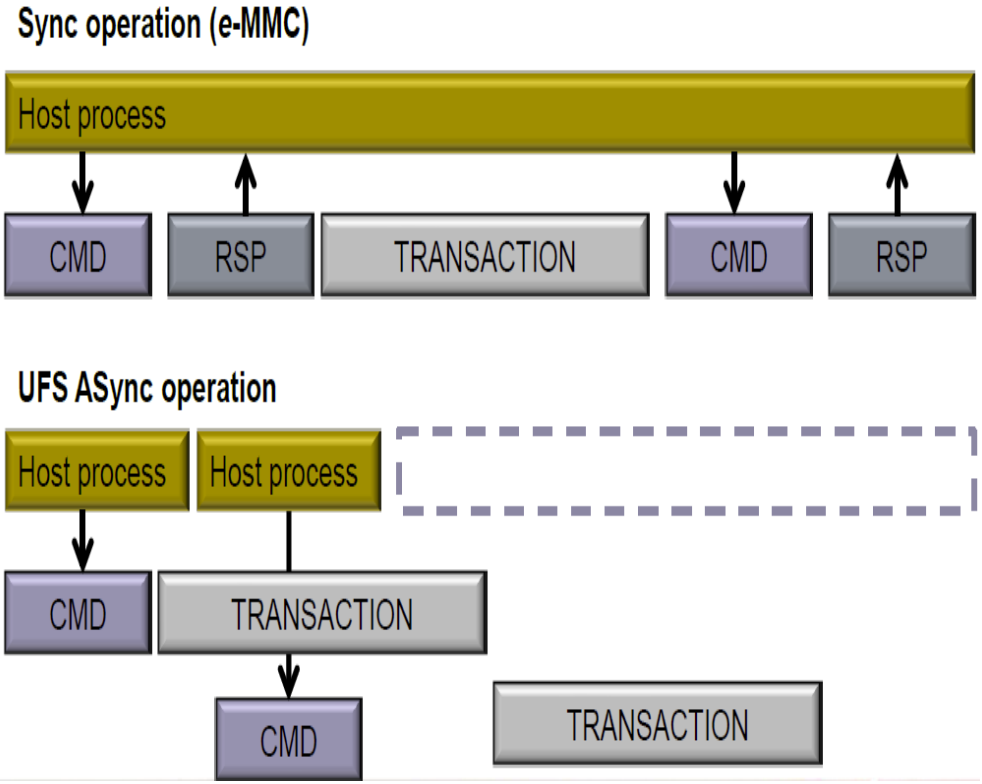
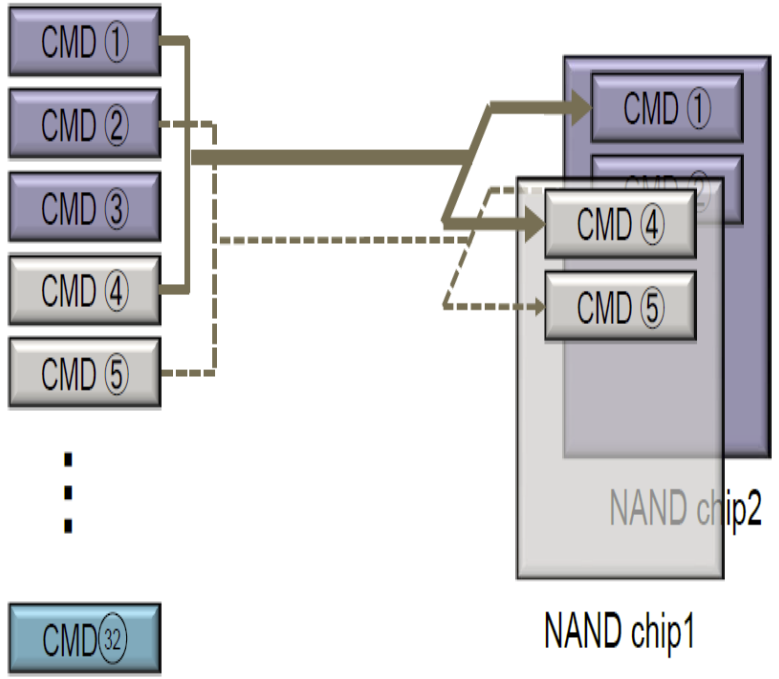
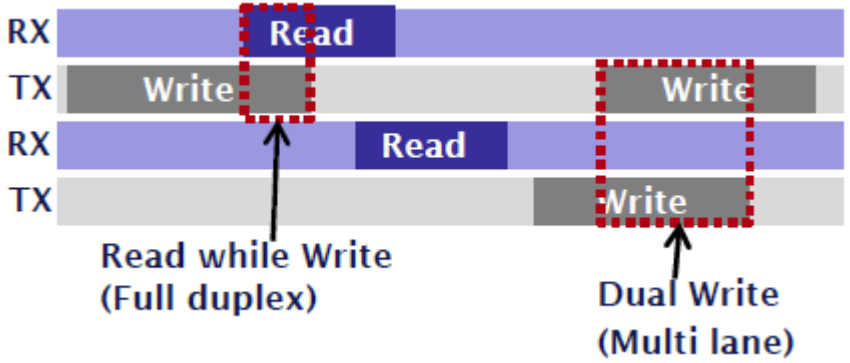
What is UFS?

Async Command & Command Queuing





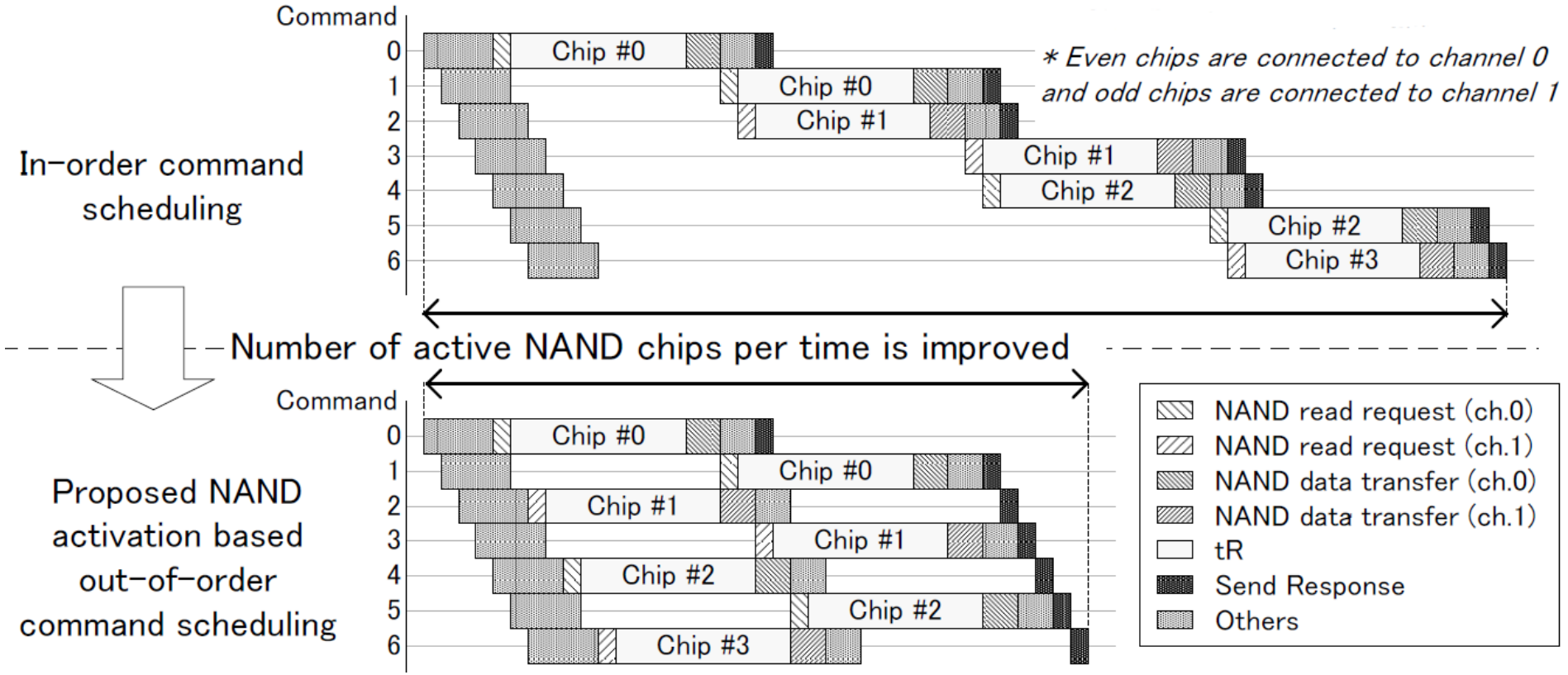


- Set it and forget it
- Optimal for multi processing
- Support multiple CMD queuing Maximize parallel programming
- Better throughput through better NAND utilization

Async Command & Command Queuing

Re-Ordering.

- **Command queue execution sequence can be changed by considering NAND interleaving**
- **Number of active NAND chips per time is improved.**
- **Suitable for UFS because UFS protocol is a multi-thread, asynchronous protocol**

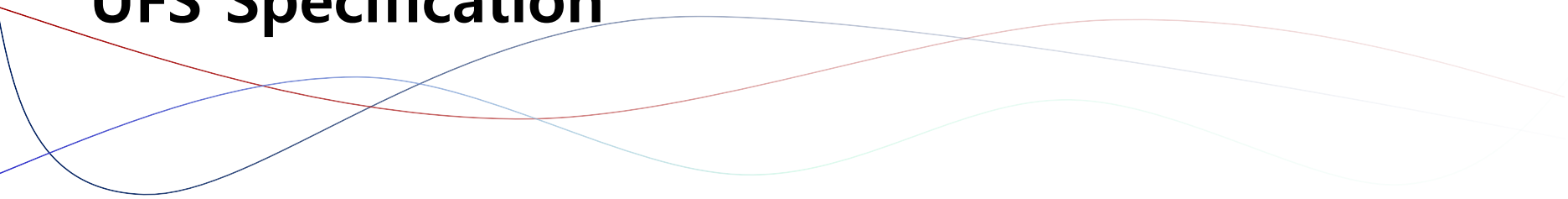


eMMC vs UFS

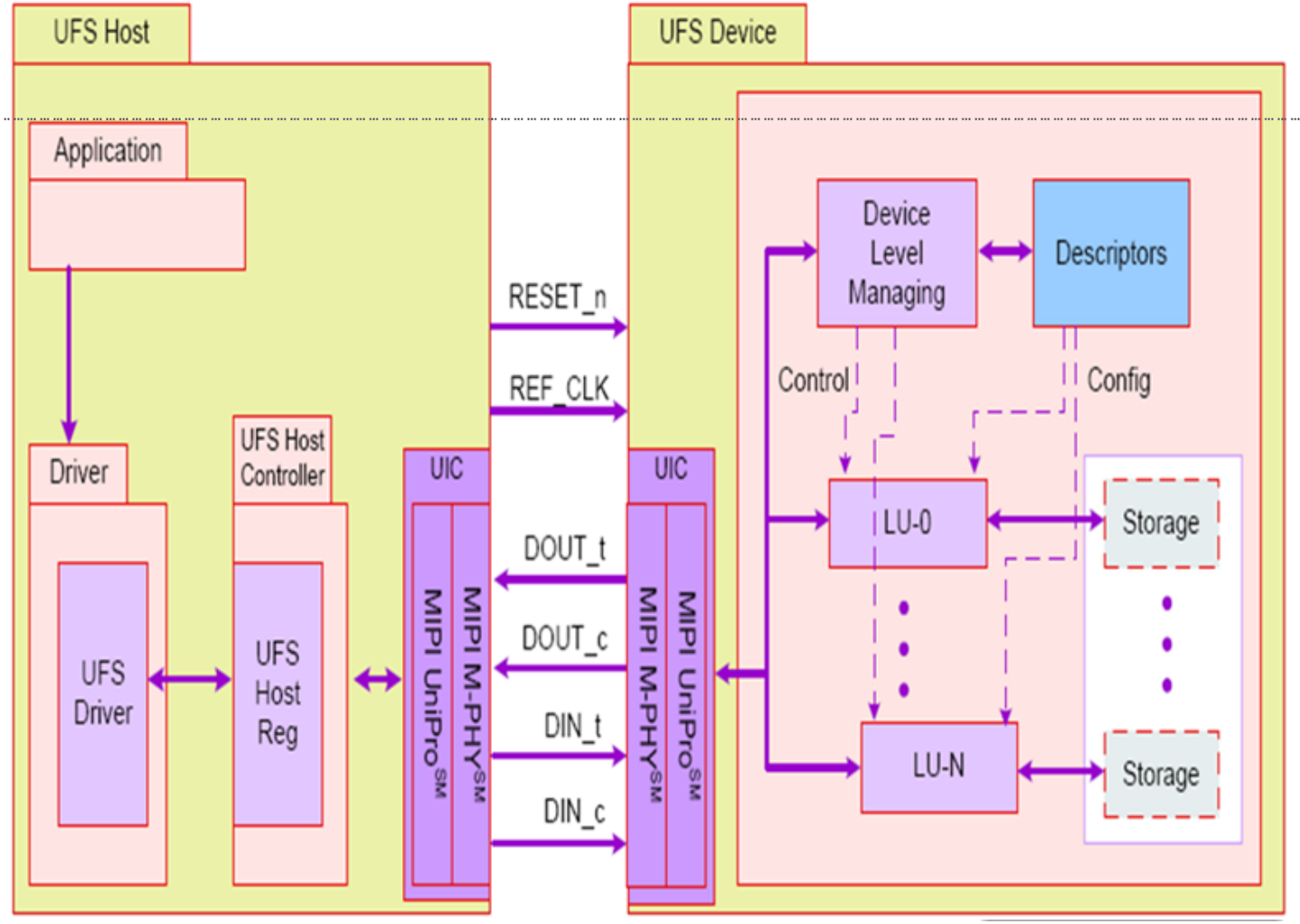
- **UFS has better features than eMMC**

Items	eMMC	UFS
Transfer scheme	Sync	Async
Command Queue	No(Yes for eMMC5.1) Packed Commands	Yes 32-Queue Depths
State	State Transition	Stateless
Interface	Parallel/Half-Duplex	Serial / Full-Duplex
Priority	No	SCSI Command Priority Higher-Priority LU
Abort Scheme	HPI	Task Management Scheme
Features	Legacy eMMC Functions	Same with eMMC
Command Set	Legacy eMMC Commands	SCSI Commands
Partitions	Boot/RPMB/User Area	8-LU(including Boot)/ RPMB

UFS Specification



UFS Architecture



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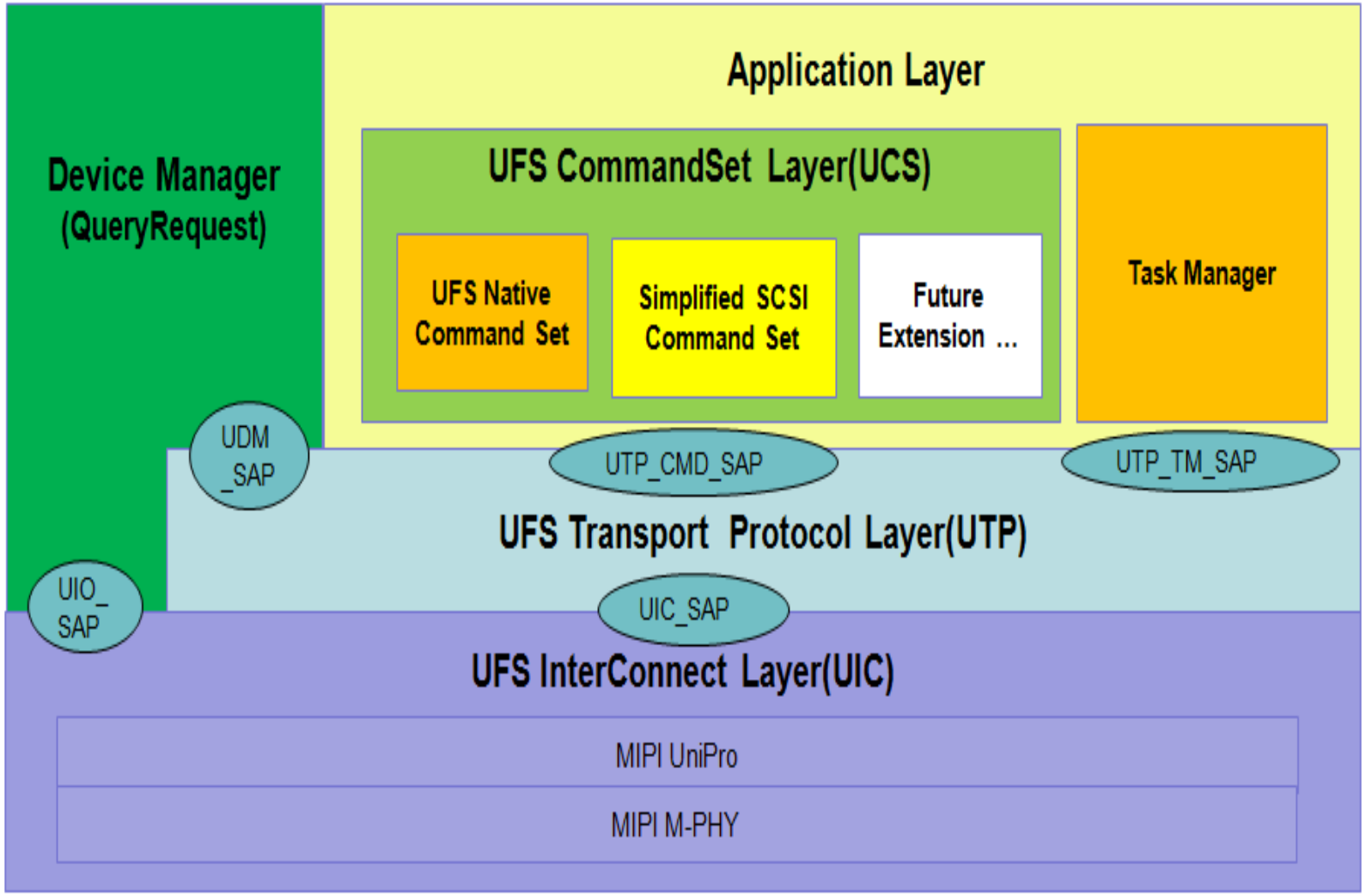
UFS Protocol Layer



UFS Architecture

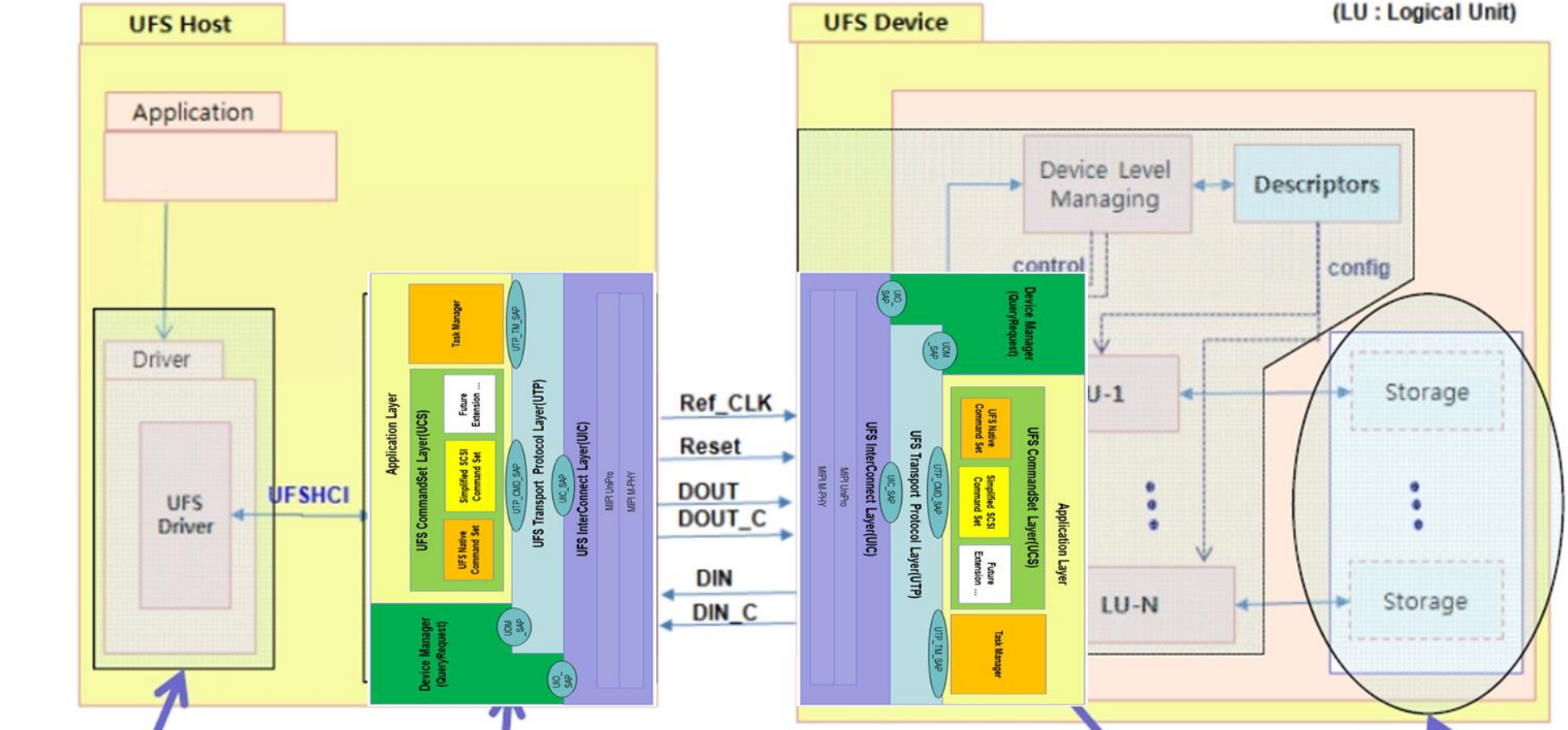


Figure 2-4 — UFS System Model

UFS Specification

M-PHY

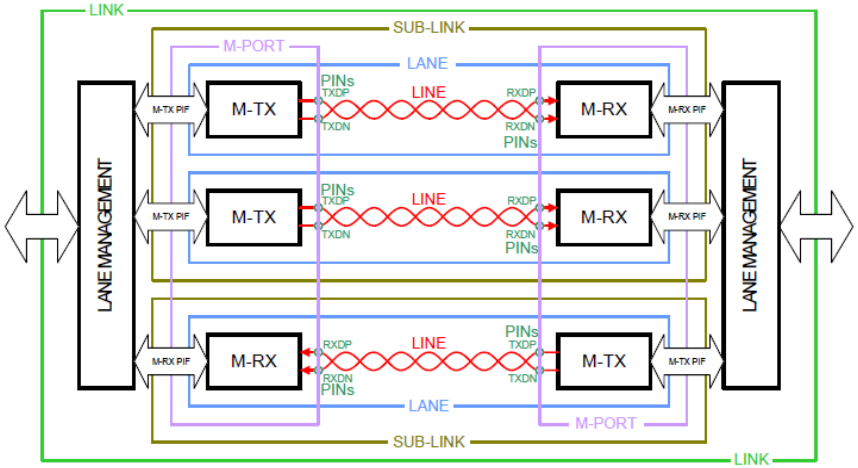
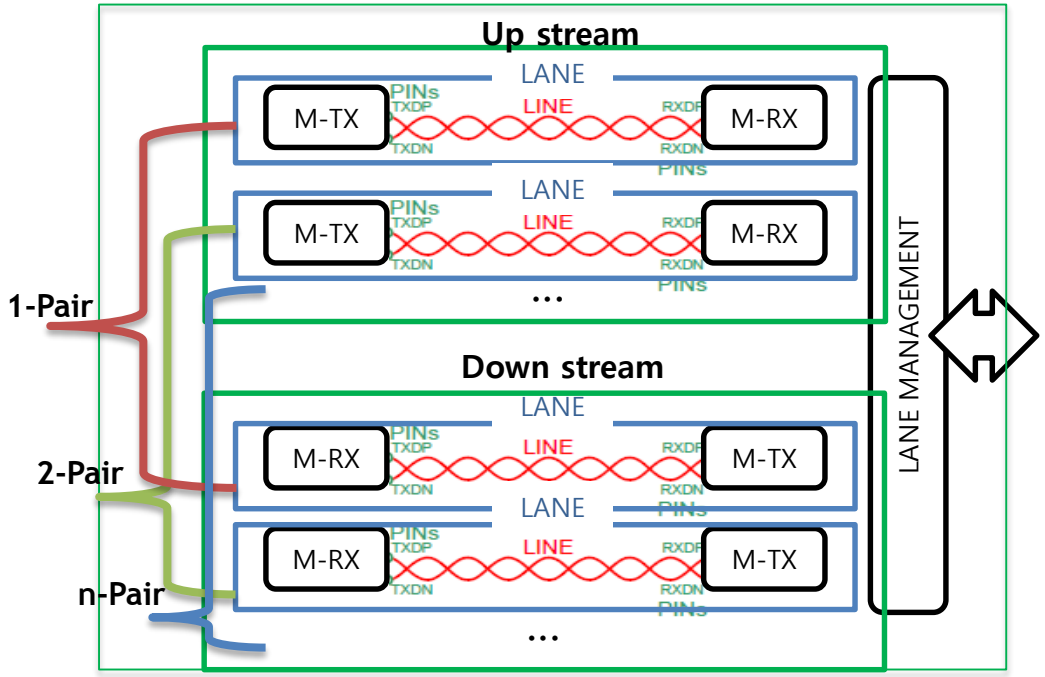


Figure 1 M-PHY Lane Example



M-PHY Lane In UFS

Each 1LANE

PWM-G0 ~ PWM-G7 (Normal Speed) HS-G1 ~ HS-G3(High Speed)
PWM G1 : 3 ~ 9Mbps
HS-G1 : (1.25Gbps or 1.45Gbps)
optional : HS-G2(2.5Gbps or 2.9Gbps) HG-G3(5Gbps or 5.8Gbps)
HS-Mode : A/B → for EMI Mitigation

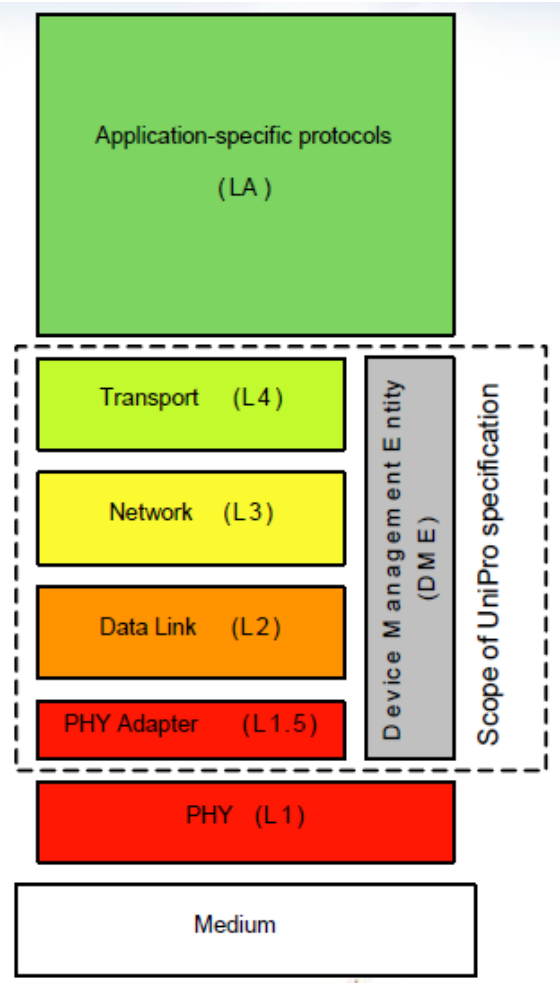
TYPE I : PWM Signaling → **in UFS 1.0**
TYPE II : system Clock Reference(NRZ Signaling)

2.9Gbps(HS-G2) & 1.45Gbps(HS-G1) In UFS 1.0(currently)

- Extensible by lane increase in pairs
- Each lane's speed is 2.9Gbps(HS-G2).
  So, ideal bi-directional speed is double of this.
- Interface of card type UFS is same as M-PHY of embedded UFS. So, host side implementations (HW, SW) have no difference.

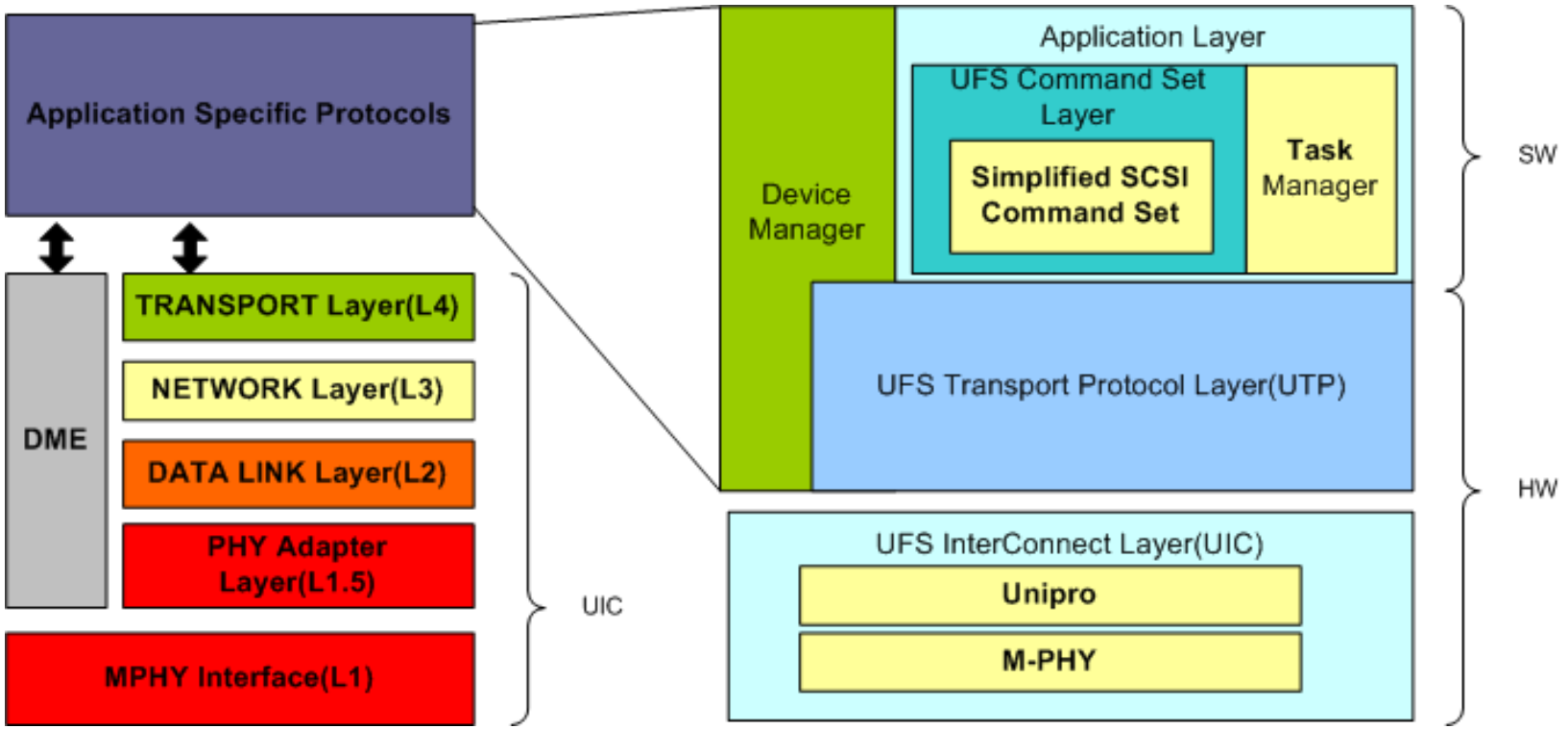
UNIPRO

- UniPro = Unified Protocol
- Optimized
  - ❖ For mobile use cases & multiple applications
  - ❖ Low power & small battery-powered systems
- Enables minimized/extendable implementations
- Reliability with error detection and correction via retransmission simplifies protocol design
- Optimally uses MIPI's PHY technologies
  - ❖ Allows aggressive power optimization
  - ❖ Allows for bandwidth scaling options
- Formal UniPro SDL model available
- UniPro testing specification available

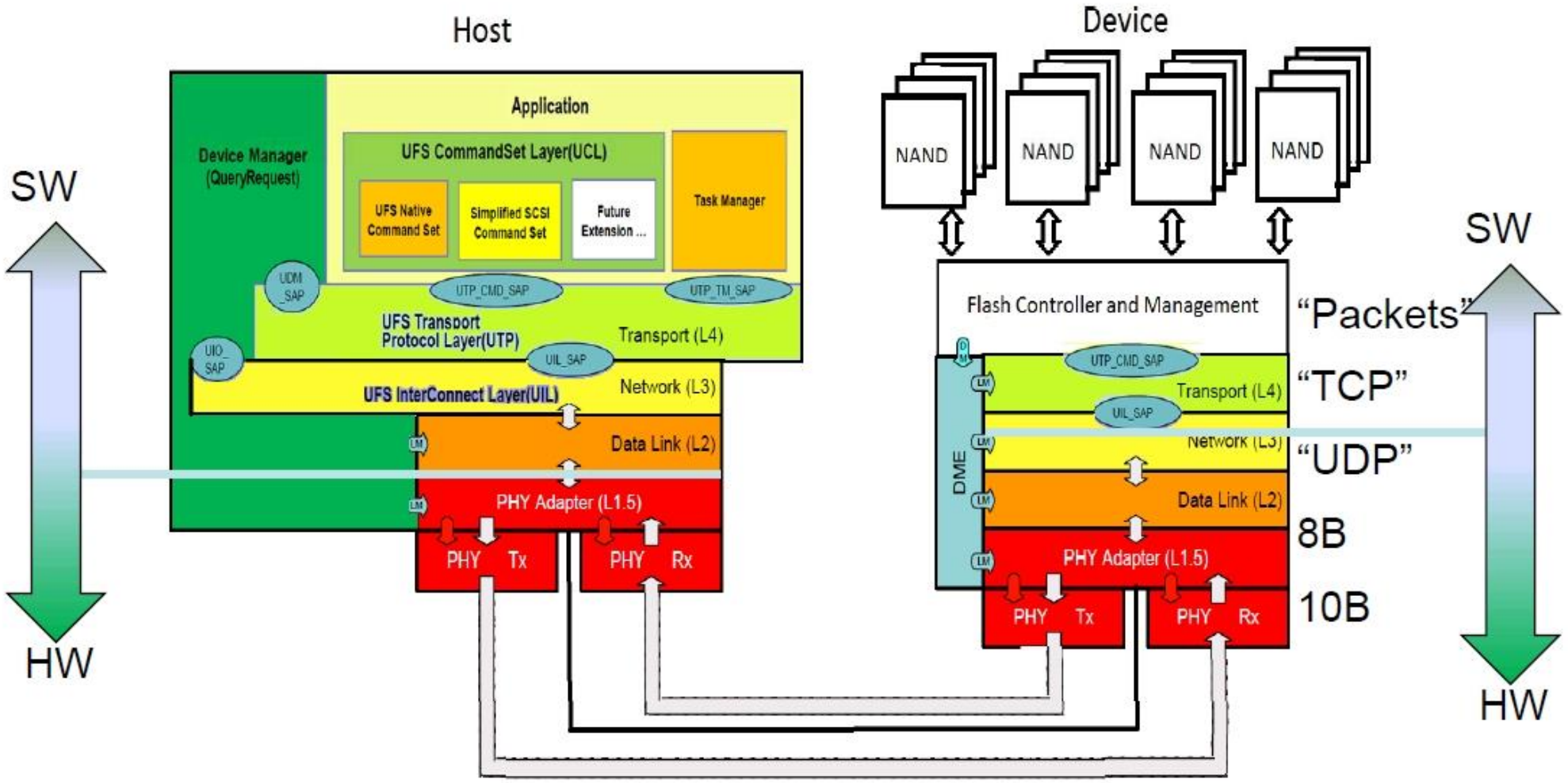


UTP

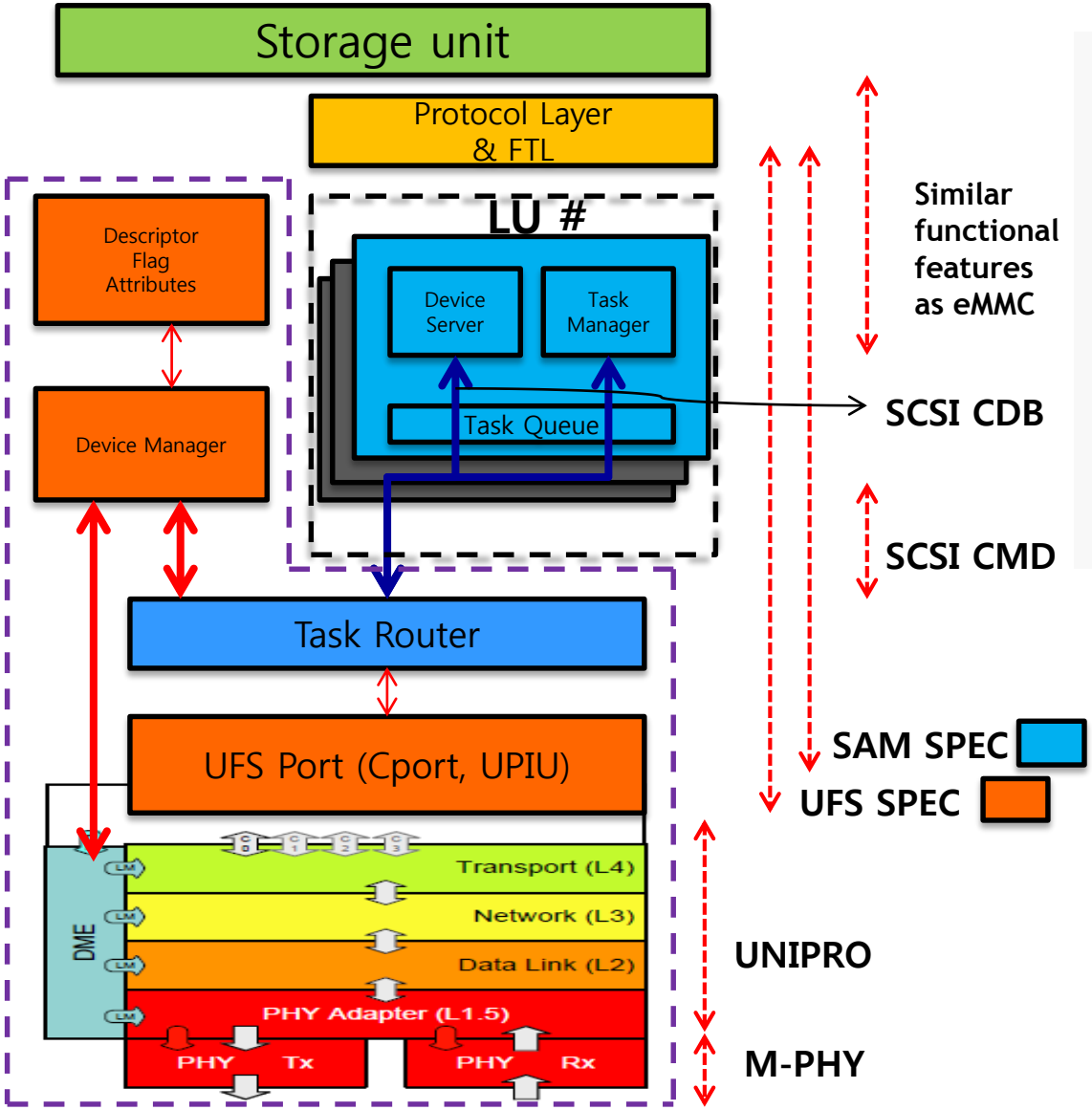
- ✓ highest HW Layer
- ✓ SLOT : HW Resource for Command Acceptance
- ✓ 32 CMD Slots, 8 Task Slot, 1 Query Slot → Each Slot has it's own DESC.(Description of operation)

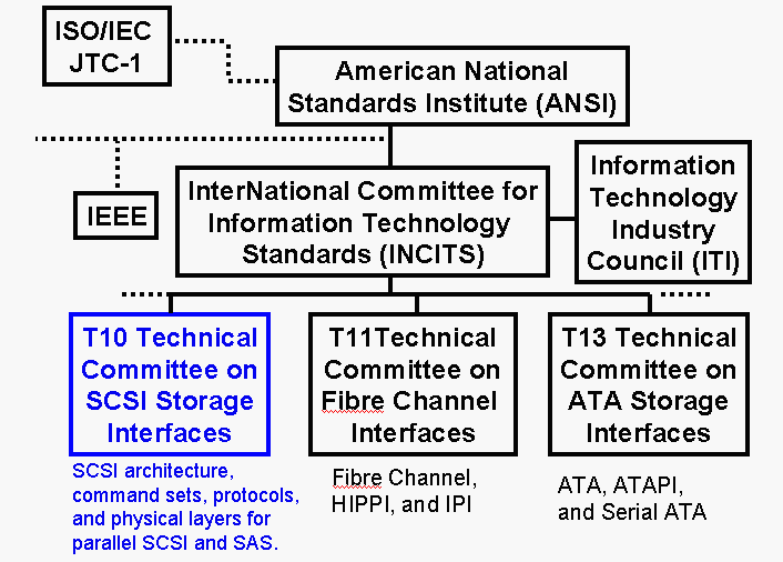


Hardware vs. Software



Standardization





JEDEC

mipi® alliance

Normative Reference

- UFS HCI Version 2.0

[MIPI-M-PHY], *MIPI Alliance Specification for M-PHY℠, Version 3.0*

[MIPI-UniPro], *MIPI Alliance Specification for Unified Protocol (UniPro℠), Version 1.6*

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[SBC], *INCITS T10 draft standard: SCSI Block Commands – 3 (SBC–3), Revision 24,* 05 August 2010

[UFS], JEDEC JESD220B, *Universal Flash Storage (UFS), Version 2.0*

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- UFS Device Version 2.0

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[SPC], *INCITS T10 draft standard: SCSI Primary Commands – 4 (SPC-4), Revision 27,* 11 October 2010

[SBC], *INCITS T10 draft standard: SCSI Block Commands – 3 (SBC–3), Revision 24,* 05 August 2010

UFS UPIU

General UPIU Format			
0 Transaction Type	1 Flags	2 LUN	3 Task Tag
4 Reserved / Command Set Type	5 Query Function / Task Manag. Function	6 Response	7 Status
8 Total EHS Length	9 Device Information	10 (MSB) / 11 (LSB) Data Segment Length	
12	13	14	15
16	Transaction Specific Fields		19
20			23
24			27
28			31
k	k+1	k+2	k+3
Extra Header Segment (EHS) 1			
...			
j	j+1	j+2	j+3
Extra Header Segment (EHS) N			
Header E2ECRC (omit if HD=0)			
Data Segment			
Data E2ECRC (omit if DD=0)			

Table 10-3: General format of the UFS Protocol Information Unit

Basic Head format

Initiator UPIU	Target UPIU
NOP Out	NOP In
Command, Data Out	Ready to Transfer, Response
Command	Data In, Response
Task Management Request	Task Management Response
Query Request	Query Response

Table 10-9: UPIU associated to a single task

Different information included depend on "Transaction Type"

UFS Specification

General UPIU Format

0 Transaction Type	1 Flags	2 LUN	3 Task Tag
4 Reserved / Command Set Type	5 Query Function / Task Manag. Function	6 Response	7 Status
8 Total EHS Length	9 Device Information	10 (MSB) / 11 (LSB) Data Segment Length	
12	13	14	15
16	Transaction Specific Fields		19
20			23
24			27
28			31
k	k+1	k+2	k+3
Extra Header Segment (EHS) 1			
...			
j	j+1	j+2	j+3
Extra Header Segment (EHS) N			

Basic UPIU Header Format

Transaction Type	Flags	LUN	Task Tag
Reserved / Command Set Type	Query Function, Task Manag. Function	Response	Status
Total EHS Length	Device Information	Data Segment Length	

Transaction Type Bits

7	6	5	4	3	2	1	0
HD	DD	Transaction Code					

Device Server

Task Manager

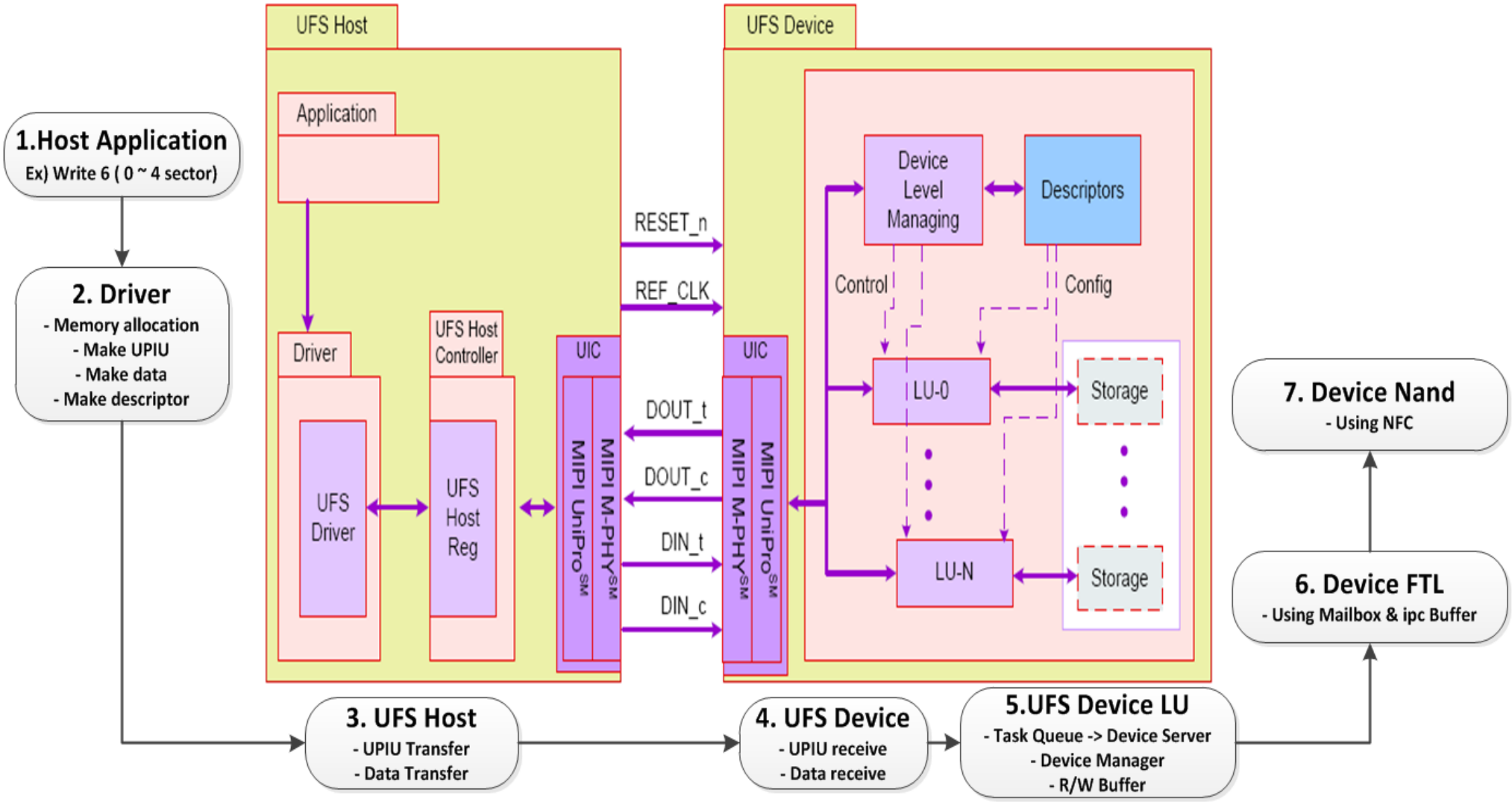
Device Manager

Initiator To Target	Transaction Code	Target to Initiator	Transaction Code
NOP OUT	00 0000b	NOP IN	10 0000b
COMMAND	00 0001b	RESPONSE	10 0001b
DATA OUT	00 0010b	DATA IN	10 0010b
TASK MANAGEMENT REQUEST	00 0100b	TASK MANAGEMENT RESPONSE	10 0100b
Reserved	01 0001b	READY TO TRANSFER	11 0001b
QUERY REQUEST	01 0110b	QUERY RESPONSE	11 0110b
Reserved	01 1111b	REJECT UPIU	11 1111b
Reserved	Others	Reserved	Others

UFS UPIU Transaction Type

Initiator To Target	Transaction Code	Target to Initiator	Transaction Code
NOP OUT	00 0000b	NOP IN	10 0000b
COMMAND	00 0001b	RESPONSE	10 0001b
DATA OUT	00 0010b	DATA IN	10 0010b
TASK MANAGEMENT REQUEST	00 0100b	TASK MANAGEMENT RESPONSE	10 0100b
Reserved	01 0001b	READY TO TRANSFER	11 0001b
QUERY REQUEST	01 0110b	QUERY RESPONSE	11 0110b
Reserved	01 1111b	REJECT UPIU	11 1111b

Command Flow



Command Flow

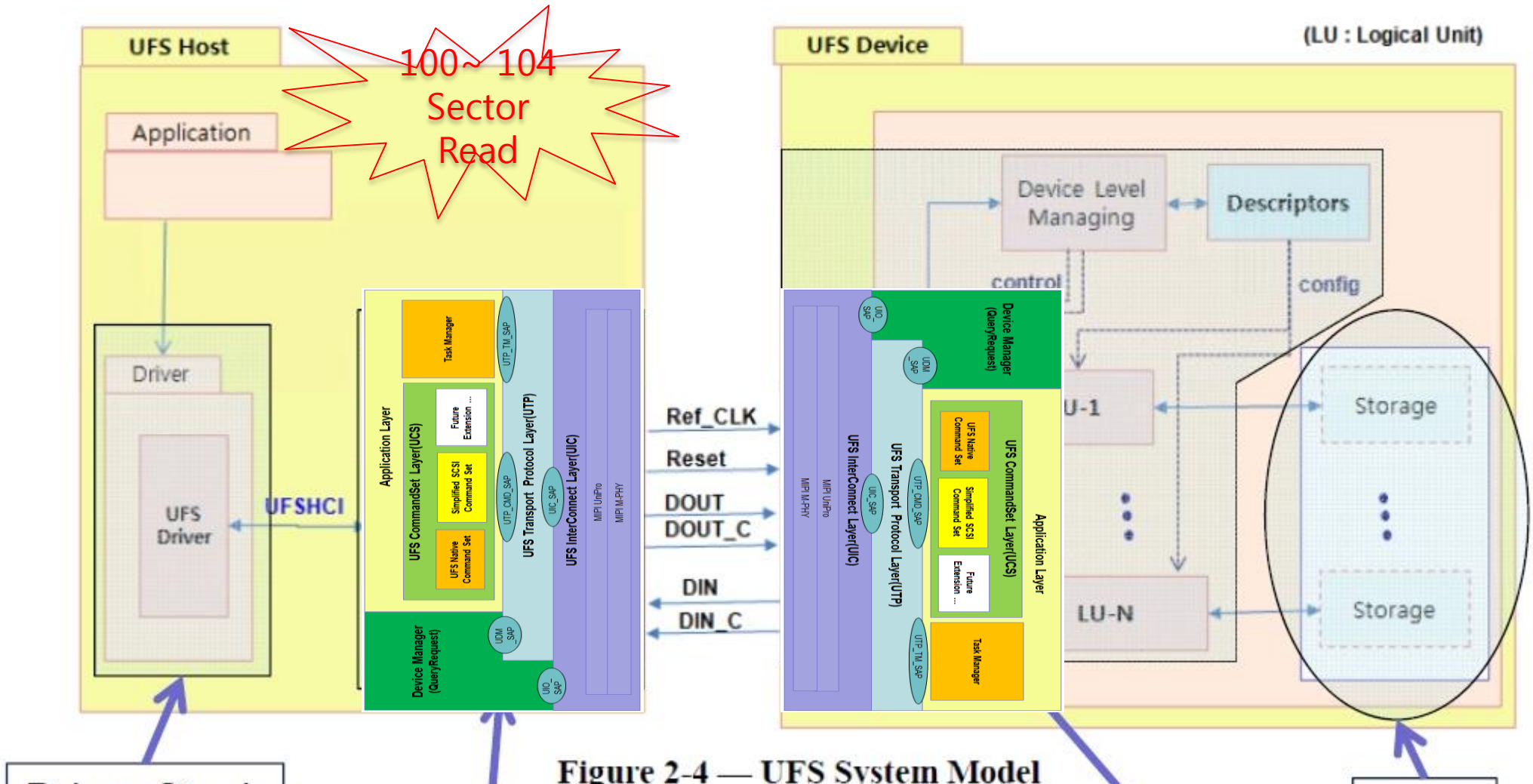
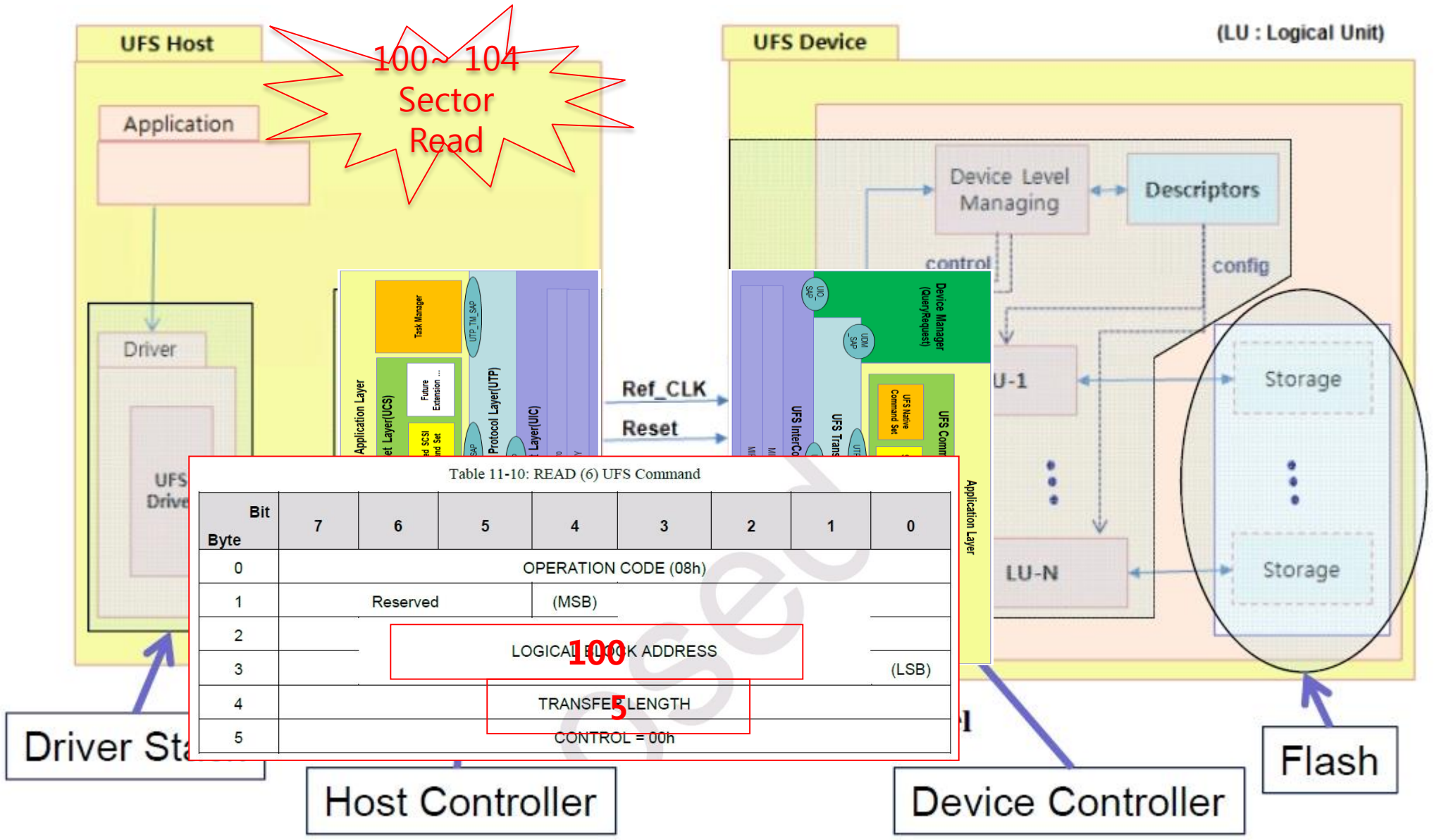


Figure 2-4 — UFS System Model

Command Flow



Command Flow

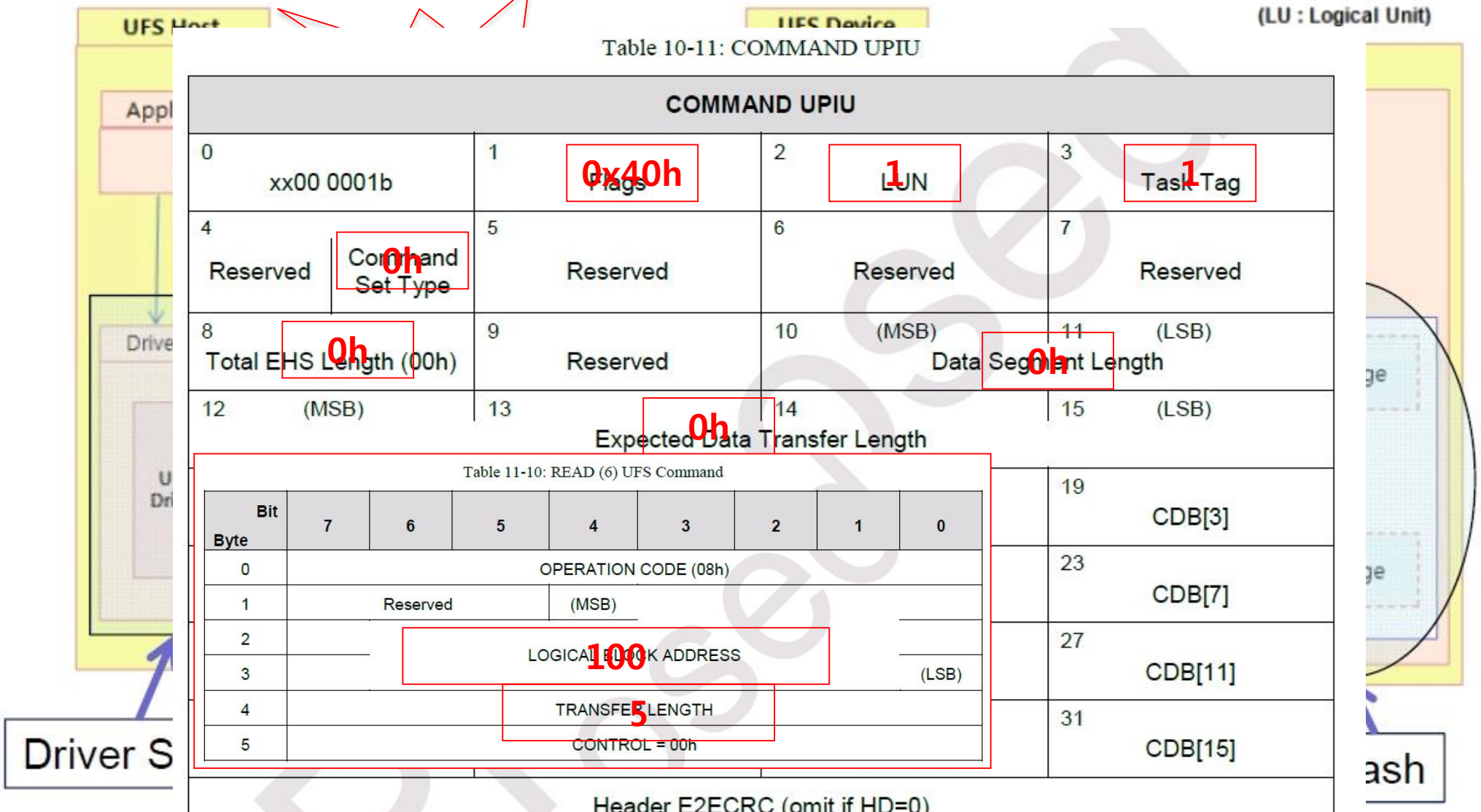


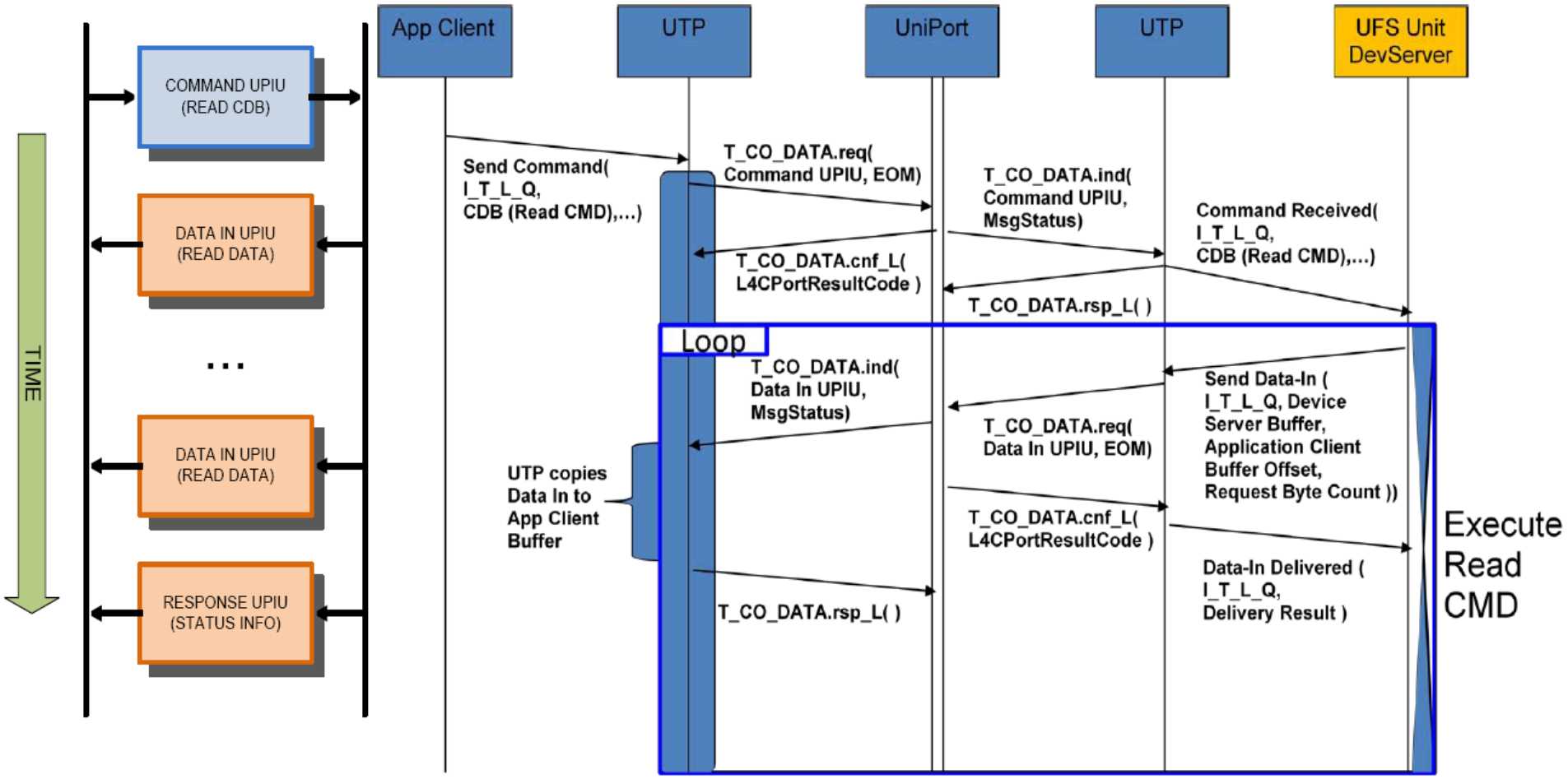
Table 10-11: COMMAND UPIU

COMMAND UPIU			
0 xx00 0001b	1 Flags 0x40h	2 LUN 1	3 Task Tag 1
4 Reserved	Command Set Type 0h	5 Reserved	6 Reserved	7 Reserved
8 Total EHS Length (00h) 0h	9 Reserved	10 (MSB) Data Segment Length 0h	11 (LSB)
12 (MSB)	13	14	15 (LSB)
Expected Data Transfer Length 0h			
			19 CDB[3]
			23 CDB[7]
			27 CDB[11]
			31 CDB[15]
Header E2ECRC (omit if HD=0)			

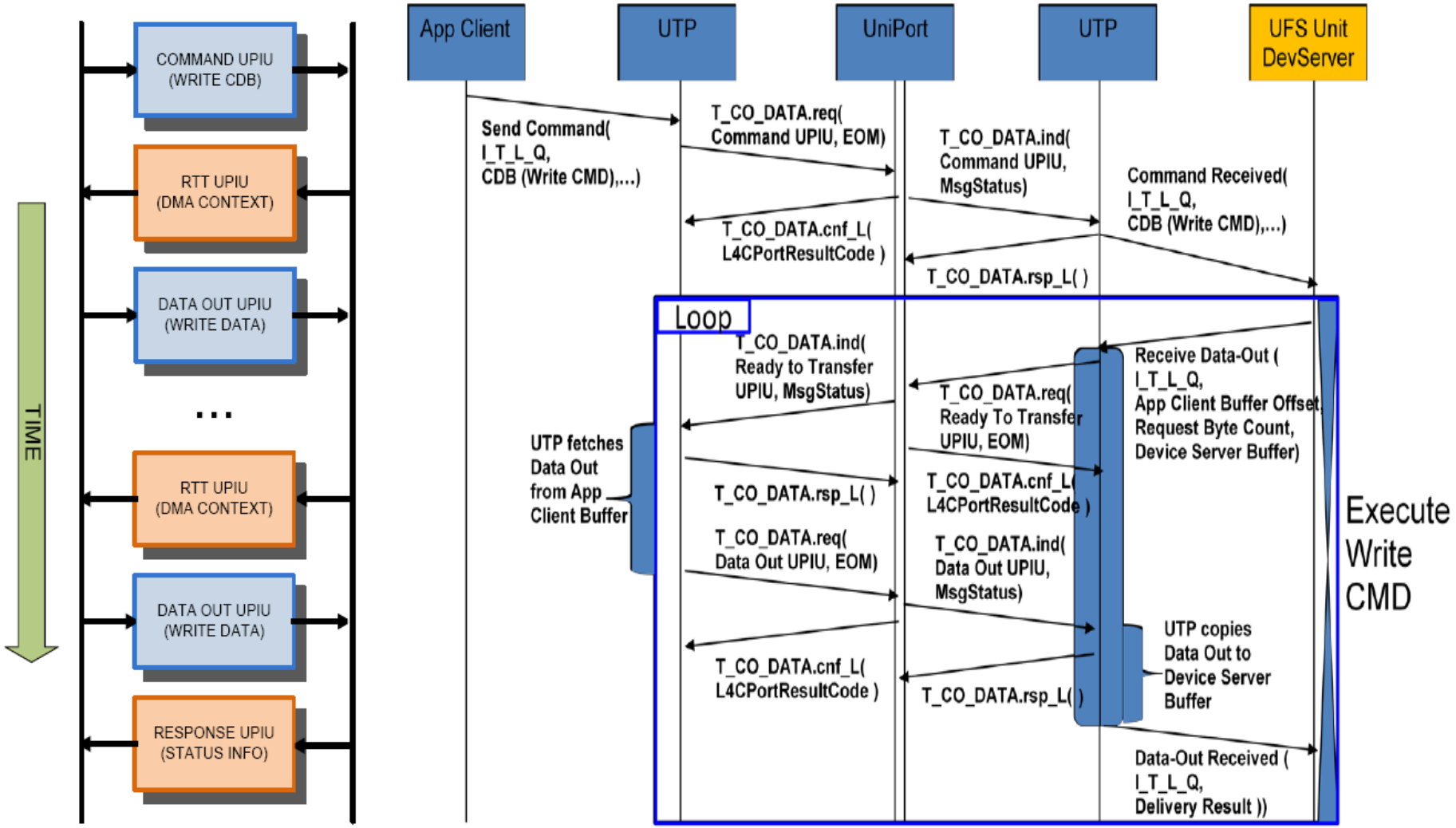
Table 11-10: READ (6) UFS Command

Byte \ Bit	7	6	5	4	3	2	1	0
0	OPERATION CODE (08h)							
1	Reserved			(MSB)				
2	LOGICAL BLOCK ADDRESS 100							
3								(LSB)
4	TRANSFER LENGTH 5							
5	CONTROL = 00h							

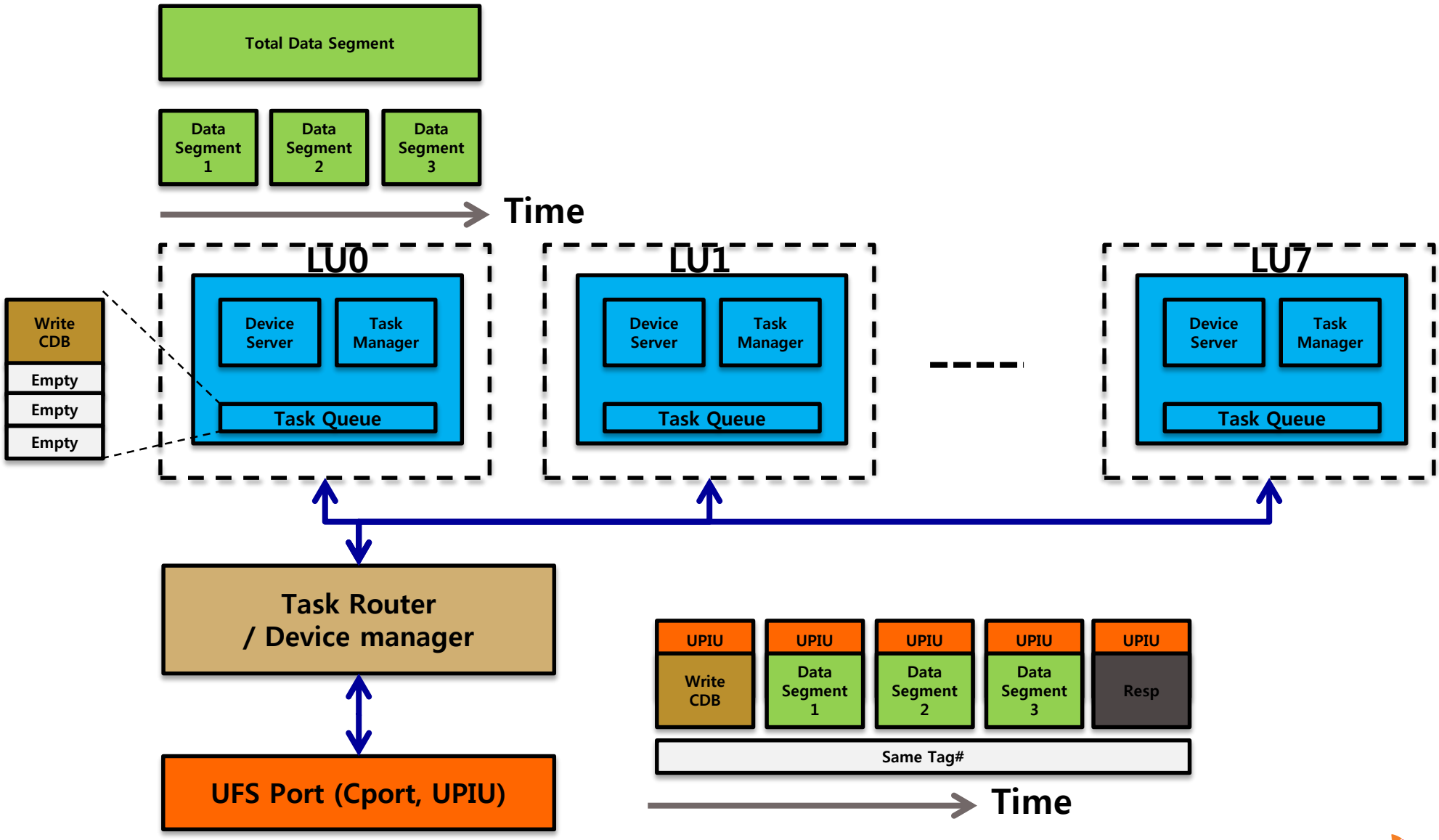
Read Operation Flow



Write Operation Flow



UFS Specification



SCSI Command

✓ Scsi Command Set supported by UFS is based on UFS native commands and Scsi primary commands spec(SPC-4/SBC-3).

Commands (CDB Size)	Description	DATA IN UPIU	DATA OUT UPIU
TEST UNIT READ(6)	Test if device is ready (not for a self-test)	X	X
Inquiry(6)	Report device information - type, manufacture, etc	a single Data In UPIU(36byte)	X
Request Sense(6)	Report sense data - current status of device	a single Data In UPIU(18byte)	X
Read Capacity(10)	Report medium capacity and block size can be issued per Logical Unit	a single Data in UPIU(8byte)	X
Start Stop Unit(6)	Change power condition or load or eject medium	X	X
Read(10)	Transfer data from medium to host	a series of Data In UPIU's	X
Write(10)	Transfer data from host to medium	Ready To Transfer UPIU	a Data OUT UPIU per RTT
Read Buffer(10)	Read microcode and other data and tunneling	a series of Data In UPIU's	X
Write Buffer(10)	Transfer microcode and other data and tunnelling	Ready To Transfer UPIU	a Data OUT UPIU per RTT
Mode Select(10)	Set parameter , modes, etc	Ready To Transfer UPIU	a Data OUT UPIU per RTT
Mode Sense(10)	Report parameters and other device Information - geometry, other	a series of Data In UPIU's	X
Report LUNS(12)	Report the accessible logical unit inventory	one or more Data IN UPIU's (Most likely one data in UPIU) (8byte+8*n) (n = LUN)	X
Verify(10)	Verify medium data is same as transferred data To determine if specific LBA's are accessible	X	X
Format Unit(6)	Format medium into logical blocks, manage medium and defects	Ready To Transfer UPIU	a Data Out UPIU containing the unmber of bytes
Send Diagnostic(6)	Perform diagnostic operations on LU or device	Ready To Transfer UPIU	a Data Out UPIU containing the unmber of bytes
Synchronize Cache(10)	Recording most recent device data to medium	X	X

SCSI Command & Operation

✓ Scsi commands operation by Command Flag Type

• No Data (Test Unit Ready, Start Stop Unit, Verify)

• Data from Device (Inquiry, Read6, Request Sense, Read Capacity, Mode Sense, Report LUN)

• Data to Device (Write6, Mode Select, Unmap, Format Unit)

HOST

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (00h)							
1	Reserved (00h)							
2								
3								
4								
5	Control (00h)							

Device

Response UPIU				
xx10 0001b		Flags	LUN	Task Tag
Reserved	Command Set Type	Reserved	Response	SCSI Status
Total EHS Length		Device Information	Data Segment Length	
Residual Transfer Count				
Reserved				
Reserved				
Reserved				
Reserved				
Header E2ECRC (omit if HD=0)				
Sense Data Length			Sense Data[0]	Sense Data[1]
...		...	...	...
Sense Data[14]		Sense Data[15]	Sense Data[16]	Sense Data[17]
Data E2ECRC (omit if DD=0)				

✓ **Response :** target successs, fail, vandor specific

✓ **SCSI Status :** GOOD, CHECK CONDITION BUSY Etc...

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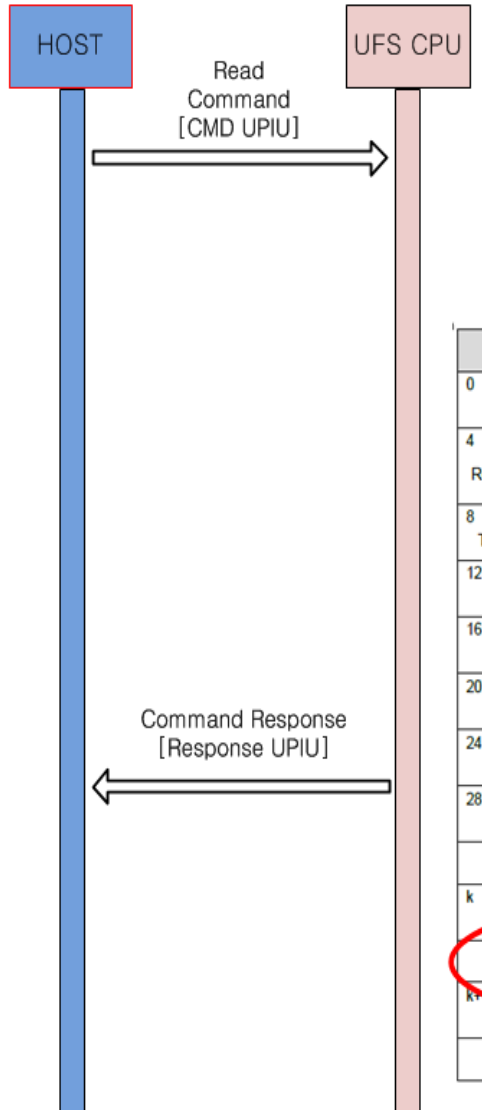
SCSI Command & Operation (TUR)

Basic UPIU Header Format				
Transaction Type		Flags	LUN	Task Tag
Reserved	Command Set Type	Query Function, Task Manag. Function	Response	Status
Total EHS Length		Device Information	Data Segment Length	

Byte \ Bit	7	6	5	4	3	2	1	0
0	OPERATION CODE (00h)							
1	Reserved							
2	Reserved							
3	Reserved							
4	Reserved							
5	CONTROL = 00h							



1. Indicating Interrupt
2. Read Command UPIU From Descriptor Buffer
   1) Transaction Type : Identify UPIU
   2) LUN : Routing to Task Queue in LU
   3) Operation Code : Identify Command Type
3. Processing Test Unit Read Command
4. Response (Make Response UPIU & Descriptor)

RESPONSE UPIU			
0 xx10 0001b	1 Flags	2 LUN	3 Task Tag
4 Reserved / Command Set Type	5 Reserved	6 Response	7 Status
8 Total EHS Length (00h)	9 Device Information	10 (MSB) / 11 (LSB) Data Segment Length	
12 (MSB) / 13 / 14 / 15 (LSB) Residual Transfer Count			
16 / 17 / 18 / 19 Reserved			
20 / 21 / 22 / 23 Reserved			
24 / 25 / 26 / 27 Reserved			
28 / 29 / 30 / 31 Reserved			
Header E2ECRC (omit if HD=0)			
k (MSB) / k+1 (LSB) Sense Data Length		k+2 Sense Data[0]	k+3 Sense Data[1]
...	...	...	...
k+16 Sense Data[14]	k+17 Sense Data[15]	k+18 Sense Data[16]	k+19 Sense Data[17]
Data E2ECRC (omit if DD=0)			

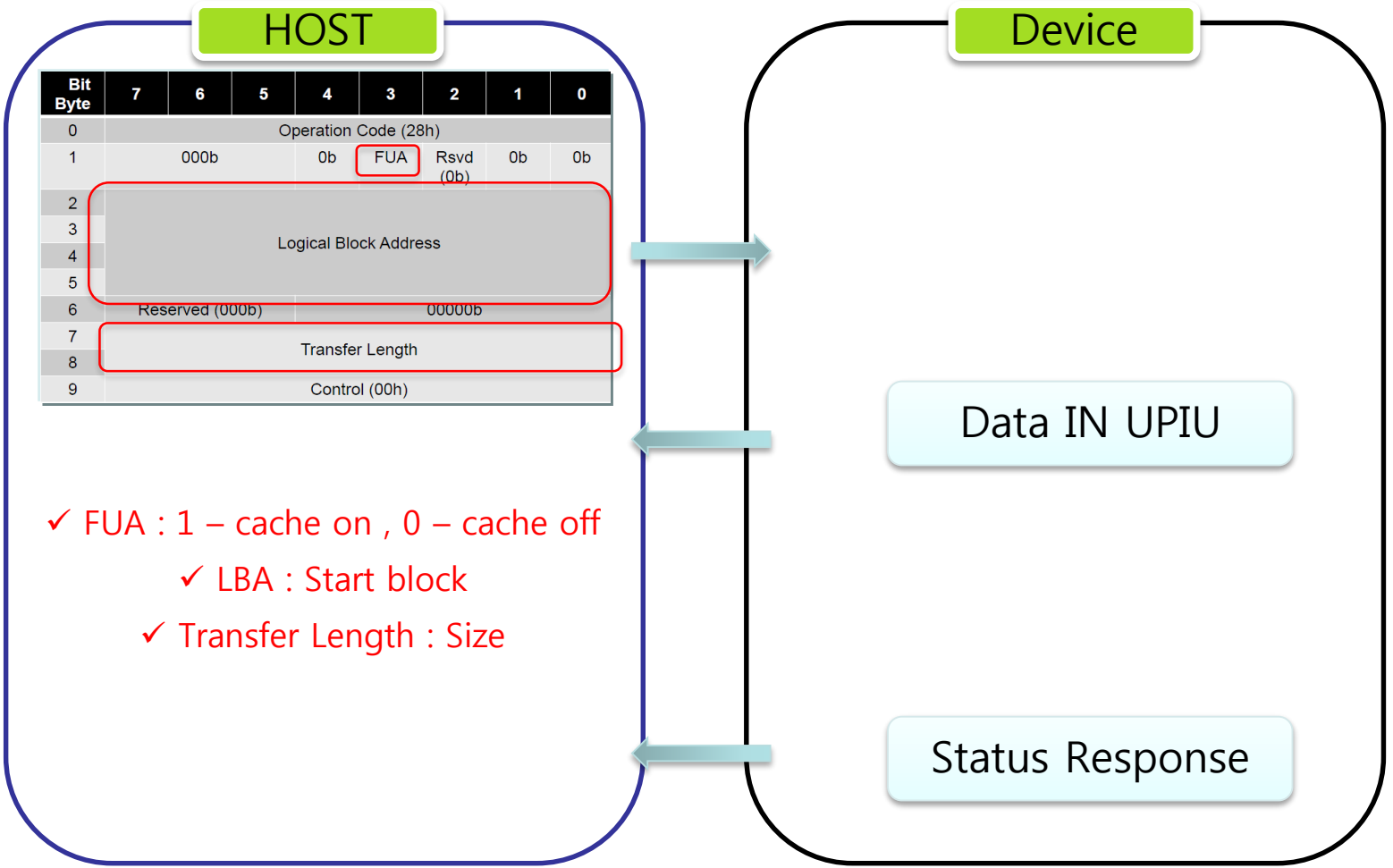
SCSI Command & Operation

✓ Scsi commands operation by Command Flag Type

• No Data (Test Unit Ready, Start Stop Unit, Verify)

• Data from Device (Inquiry, Read6, Request Sense, Read Capacity, Mode Sense, Report LUN)

• Data to Device (Write6, Mode Select, Unmap, Format Unit)



SCSI Command & Operation

✓ Scsi commands operation by Command Flag Type

- No Data (Test Unit Ready, Start Stop Unit, Verify)
- Data from Device (Inquiry, Read6, Request Sense, Read Capacity, Mode Sense, Report LUN)
- Data to Device (Write6, Mode Select, Unmap, Format Unit)

HOST

Bit Byte	7	6	5	4	3	2	1	0
0	Operation Code (2Ah)							
1	000b			0b	FUA	Rsvd (0b)	0b	0b
2	Logical Block Address							
3								
4								
5								
6	Reserved (000b)			00000b				
7	Transfer Length							
8								
9	Control (00h)							

Data OUT UPIU

✓ LBA : Start block

✓ Transfer Length: Size

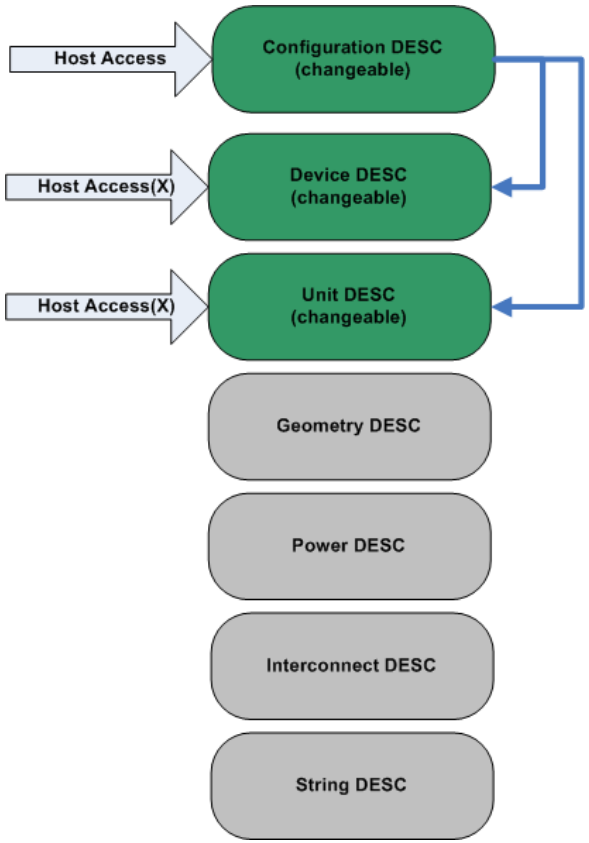
Device

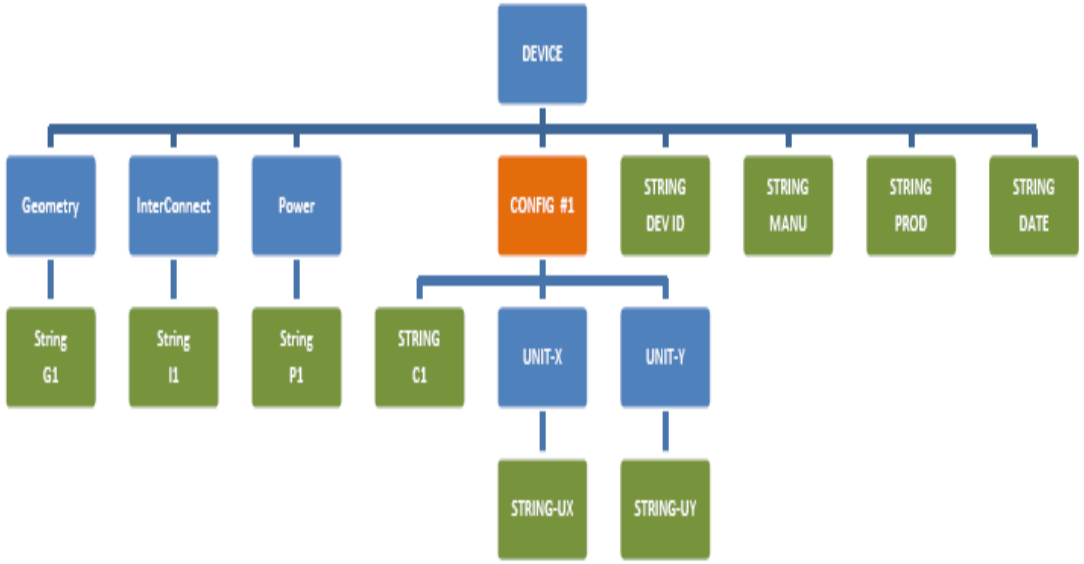
Ready To Transfer UPIU			
xx11 0001b	Flags	LUN	Task Tag
Reserved	Reserved	Reserved	Status
Total EHS Length	Reserved	Data Segment Length	
Data Buffer Offset			
Data Transfer Count			
Reserved			
Reserved			
Reserved			
Header E2ECRC (omit if HD=0)			

Status Response

Descriptor & Attribute

- ✓ Descriptor : General Configuration for Device-level
- ✓ Attribute : Frequently Configurable Range Value
- ✓ Flag : Frequently Configurable BOOL Value





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Descriptor

Table 10-31: Read descriptor

Transaction Specific Fields for READ DESCRIPTOR OPCODE			
12	13	14	15
01h	DESCRIPTOR IDN	INDEX	SELECTOR
16	17	18 (MSB) / 19 (LSB)	
Reserved	Reserved	LENGTH	
20	21	22	23
Reserved			
24	25	26	27
Reserved			

DEVICE DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	bDevice
03h	bDeviceClass
04h	bDeviceSubClass
05h	bProtocol
06h	bNumberLU
07h	bNumberWLU
08h	bBootEnable
09h	bDescrAccessEn
0Ah	bInitPowerMode
0Bh	bHighPriorityLUN
0Ch	bSecureRemovalType
0Dh	bSecurityLU
0Eh	Reserved
0Fh	bInitActiveICCLevel
10h	wSpecVersion
12h	wManufactureDate
14h	iManufacturerName
15h	iProductName
16h	iSerialNumber
17h	iOemID
18h	wManufacturerID
1Ah	bUD0BaseOffset
1Bh	bUDConfigPLength
1Ch	bDeviceRTTCap
1Dh	wPeriodicRTCUpdate

Configuration Descriptor	
00h	bLength
01h	bDescriptorType
02h	bNumberLU
03h	bBootEnable
04h	bDescrAccessEn
05h	bInitPowerMode
06h	bHighPriorityLUN
07h	bSecureRemovalType
08h	bInitActiveICCLevel
09h	wPeriodicRTCUpdate
0Bh:0Fh	Reserved

Unit Descriptor	
00h	bLUEnable
01h	bBootLunID
02h	bLUWriteProtect
03h	bMemoryType
04h	dNumAllocUnits
08h	bDataReliability
09h	bLogicalBlockSize
0Ah	bProvisioningType
0Bh	wContextCapabilities
0Dh:0Fh	Reserved

UNIT DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	bUnitIndex
03h	bLUEnable
04h	bBootLunID
05h	bLUWriteProtect
06h	bLUQueueDepth
07h	Reserved
08h	bMemoryType
09h	bDataReliability
0Ah	bLogicalBlockSize
0Bh	qLogicalBlockCount
13h	dEraseBlockSize
17h	bProvisioningType
18h: 1Fh	qPhyMemResourceCount
20h	wContextCapabilities
21h	bLargeUnitSize_M1

GEOMETRY DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	bMediaTechnology
03h	Reserved
04h	qTotalRawDeviceCapacity
0Ch	Reserved
0Dh	dSegmentSize
11h	bAllocationUnitSize
12h	bMinAddrBlockSize
13h	bOptimalReadBlockSize
14h	bOptimalWriteBlockSize
15h	bMaxInBufferSize
16h	bMaxOutBufferSize
17h	bRPMB_ReadWriteSize
18h	Reserved
19h	bDataOrdering
1Ah	Reserved
1Bh	bMaxContextIDNumber
1Ch	bSysDataTagUnitSize
1Dh	bSysDataTagResSize
1Eh	bSupportedSecRTypes
1Fh	wSupportedMemoryTypes
20h	dSystemCodeMaxNAllocU
24h	dSystemCodeCapAdjFac
26h	dNonPersistMaxNAllocU
2Ah	dNonPersistCapAdjFac
2Ch	dEnhanced1MaxNAllocU
30h	dEnhanced1CapAdjFac
32h	dEnhanced2MaxNAllocU
36h	dEnhanced2CapAdjFac
38h	dEnhanced3MaxNAllocU
3Ch	dEnhanced3CapAdjFac
3Eh	dEnhanced4MaxNAllocU
42h	dEnhanced4CapAdjFac

RPMB UNIT DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	bUnitIndex
03h	bLUEnable
04h	bBootLunID
05h	bLUWriteProtect
06h	bLUQueueDepth
07h	Reserved
08h	bMemoryType
09h	Reserved
0Ah	bLogicalBlockSize
0Bh	qLogicalBlockCount
13h	dEraseBlockSize
17h	bProvisioningType
18h: 1Fh	qPhyMemResourceCount
20h: 21h	Reserved

POWER DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	wActiveICCLevelsVCC(15:0)
22h	wActiveICCLevelsVCCQ(15:0)
42h	wActiveICCLevelsVCCQ2(15:0)

INTERCONNECT DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	bcdUniproVersion
04h	bcdMphyVersion

MANUFACTURER NAME STRING	
00h	bLength
01h	bDescriptorType
02h	UC[0]
04h	-
LENGTH-2	UC[(LENGTH-2)÷2-1]

PRODUCT NAME STRING DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	UC[0]
04h	-
LENGTH-2	UC[(LENGTH-2)÷2-1]

OEM ID STRING DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	UC[0]
04h	-
LENGTH-2	UC[(LENGTH-2)÷2-1]

SERIAL NUMBER STRING DESCRIPTOR	
00h	bLength
01h	bDescriptorType
02h	UC[0]
04h	-
LENGTH-2	UC[(LENGTH-2)÷2-1]

Attribute & Flag

Table 10-33: Read Attribute

Transaction Specific Fields for READ ATTRIBUTE OPCODE			
12 03h	13 ATTRIBUTE IDN	14 INDEX	15 SELECTOR
16 Reserved	17 Reserved	18 Reserved	19 Reserved
20	21	22 Reserved	23
24	25	26 Reserved	27

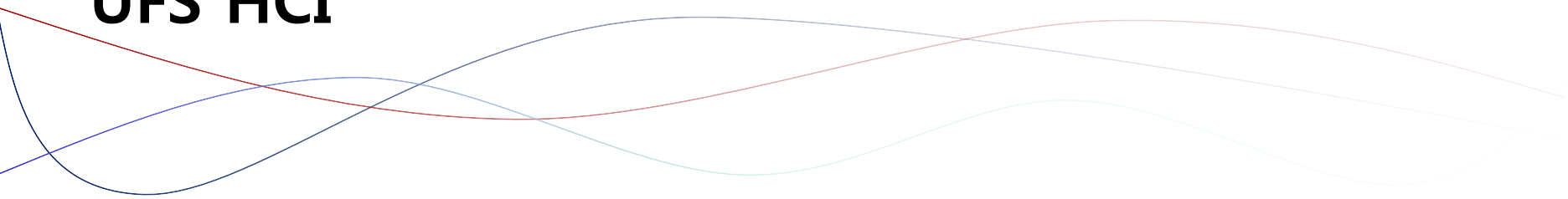
Attributes	
00h	bBootLunEn
01h	Reserved
02h	bCurrentPowerMode
03h	bActiveICCLevel
04h	bOutOfOrderDataEn
05h	bBackgroundOpStatus
06h	bPurgeStatus
07h	bMaxDataInSize
08h	bMaxDataOutSize
09h	dDynCapNeeded
0Ah	bRefClkFreq
0Bh	bConfigDescrLock
0Ch	bMaxNumOfRTT
0Dh	bExceptionEventControl
0Eh	bExceptionEventStatus
0Fh	dSecondsPassed
10h	wContextConf
11h	dCorrPrgBlkNum

Flag	
00h	Reserved
01h	fDeviceInit
02h	fPermanentWPEn
03h	fPowerOnWPEn
04h	fBackgroundOpsEn
05h	Reserved
06h	fPurgeEnable
07h	Reserved
08h	fPhyResourceRemoval
09h	fBusyRTC

Table 10-35: Read Flag

Transaction Specific Fields for READ FLAG OPCODE			
12 05h	13 FLAG IDN	14 INDEX	15 SELECTOR
16 Reserved	17 Reserved	18 Reserved	19 Reserved
20	21	22 Reserved	23
24	25	26 Reserved	27

UFS HCI



HOST Controller Interface

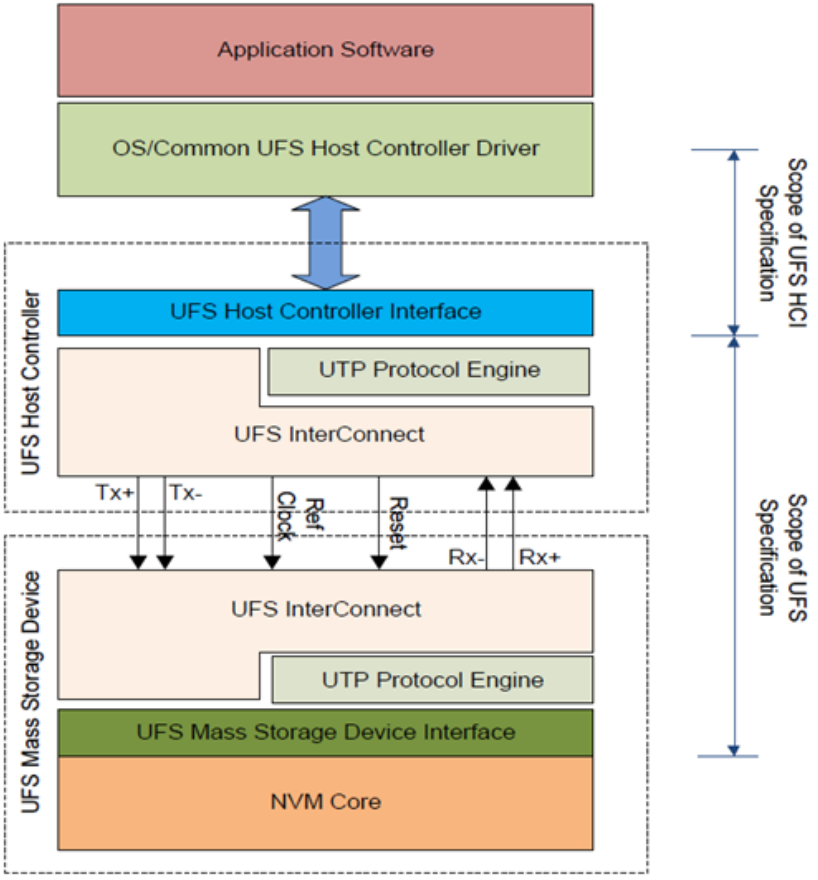


Figure 1 — UFS Architecture Overview

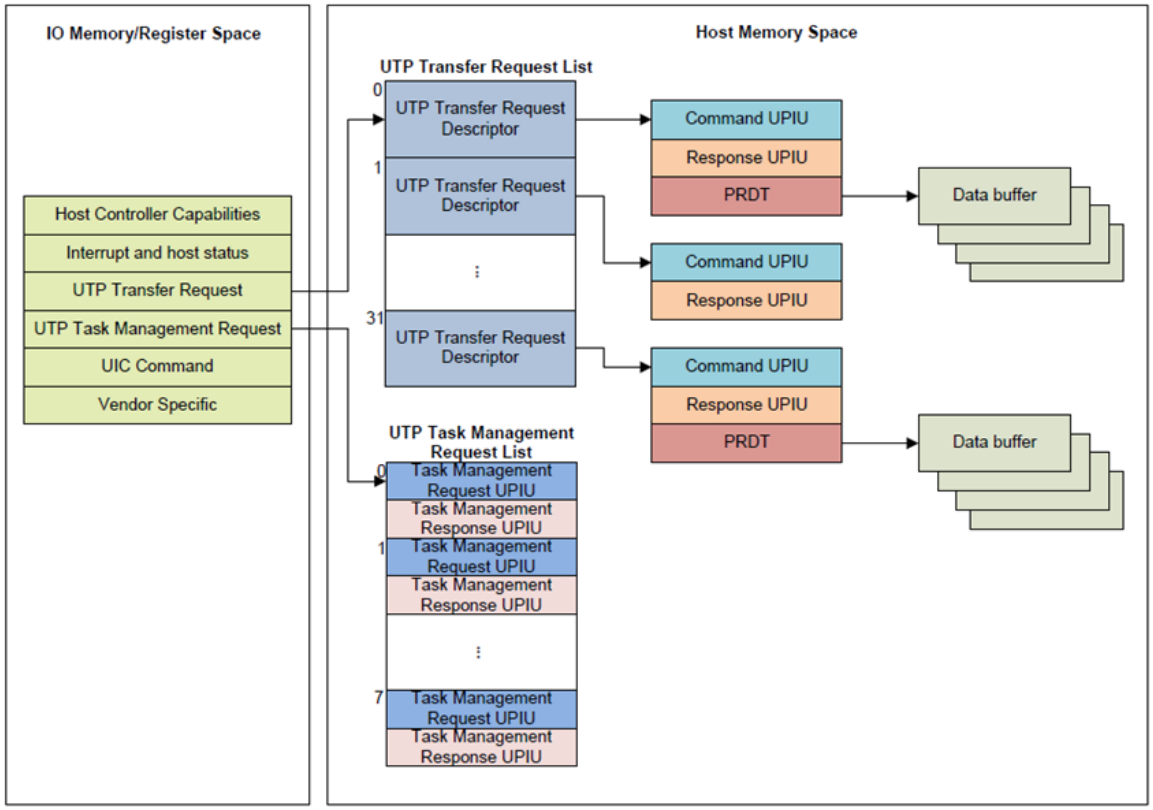


Figure 2 — General architecture of UFS Host Controller Interface.

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HCI Register

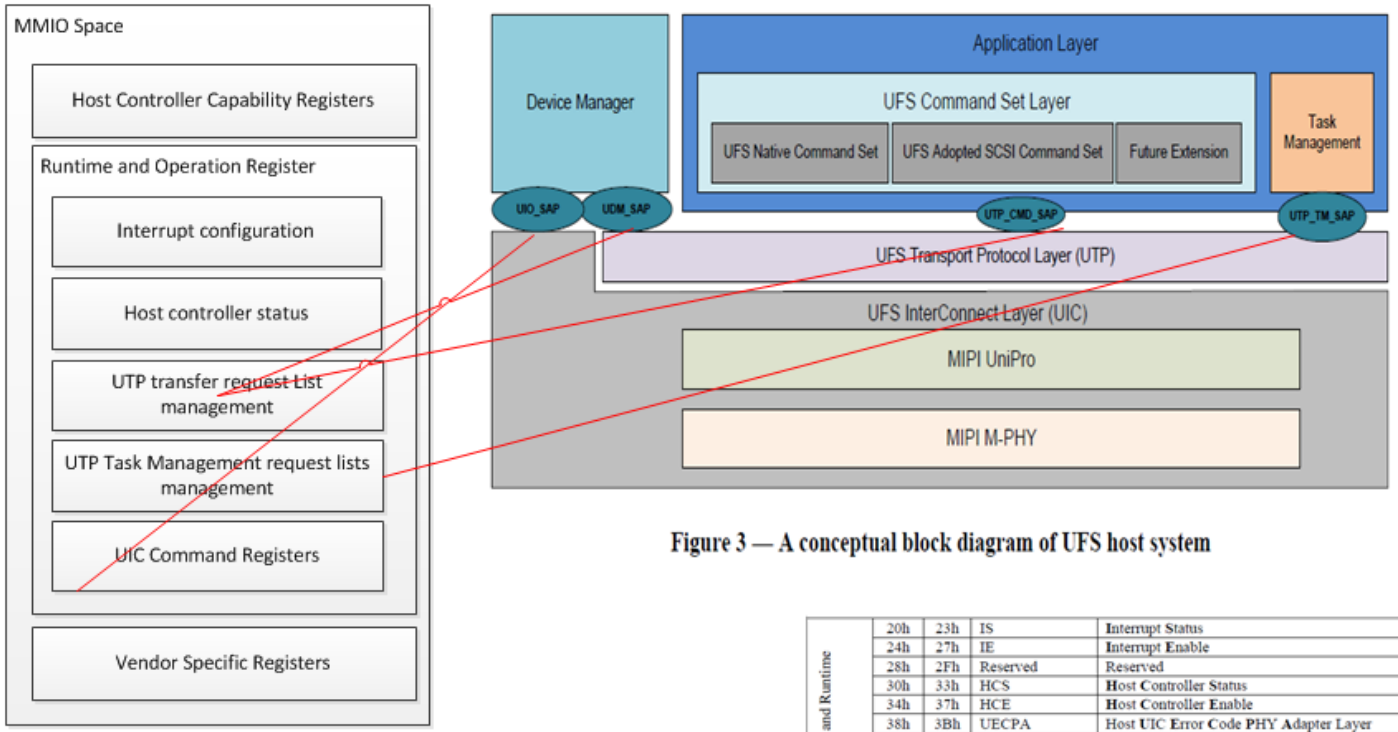

Figure 3 — A conceptual block diagram of UFS host system

	Start	End	Symbol	Description
Host Capabilities	00h	03h	CAP	Host Controller Capabilities
	04h	07h	Reserved	Reserved
	08h	0Bh	VER	UFS Version
	0Ch	0Fh	Reserved	Reserved
	10h	13h	HCDDID	Host Controller Identification Descriptor – Device ID and Device Class
	14h	17h	HCPMID	Host Controller Identification Descriptor – Product ID and Manufacturer ID
	18h	1Bh	AHIT	Auto-Hibernate Idle Timer
	1Ch	1Fh	Reserved	Reserved

Operation and Runtime	20h	23h	IS	Interrupt Status
	24h	27h	IE	Interrupt Enable
	28h	2Fh	Reserved	Reserved
	30h	33h	HCS	Host Controller Status
	34h	37h	HCE	Host Controller Enable
	38h	3Bh	UECPA	Host UIC Error Code PHY Adapter Layer
	3Ch	3Fh	UECDL	Host UIC Error Code Data Link Layer
	40h	43h	UECN	Host UIC Error Code Network Layer
	44h	47h	UECT	Host UIC Error Code Transport Layer
	48h	4Bh	UECDME	Host UIC Error Code DME
	4Ch	4Fh	UTRIACR	UTP Transfer Request Interrupt Aggregation Control Register

UTP Task Managemeng	70h	73h	UTMRLBA	UTP Task Management Request List Base Address
	74h	77h	UTMRLBAU	UTP Task Management Request List Base Address Upper 32-Bits
	78h	7Bh	UTMRLDBR	UTP Task Management Request List Door Bell Register
	7Ch	7Fh	UTMRLCLR	UTP Task Management Request List CLear Register
	80h	83h	UTMRLRSR	UTP Task Management Run-Stop Register
	84h	8Fh	Reserved	Reserved

UTP Transfer	50h	53h	UTRLBA	UTP Transfer Request List Base Address
	54h	57h	UTRLBAU	UTP Transfer Request List Base Address Upper 32-Bits
	58h	5Bh	UTRLDBR	UTP Transfer Request List Door Bell Register
	5Ch	5Fh	UTRLCLR	UTP Transfer Request List CLear Register
	60h	64h	UTRLRSR	UTP Transfer Request Run-Stop Register
	68h	6Fh	Reserved	Reserved

UIC Command	90h	93h	UICCMD	UIC Command Register
	94h	97h	UCMDARG1	UIC Command Argument 1
	98h	9Bh	UCMDARG2	UIC Command Argument 2
	9Ch	9Fh	UCMDARG3	UIC Command Argument 3
	A0h	AFh	Reserved	Reserved

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UTP Transfer Request

1. SetCommand Type
2. Data Direction
3. Interrupt
4. Initialize OCS with 0xF
5. Set UTP Command Descriptor Base Address
6. Set Response Offset & Length
7. Set PRDT Offset & Length
8. Check UTP Transfer Request List Run Stop Register
9. Set UTP Transfer Request Interrupt Aggregation Control Register to 1
10. Set Counter and Timer Reset bit to 1
11. Interrupt aggregation counter threshold
12. Interrupt aggregation timer threshold
13. Set Doorbell register(UTRLDBR) to 1

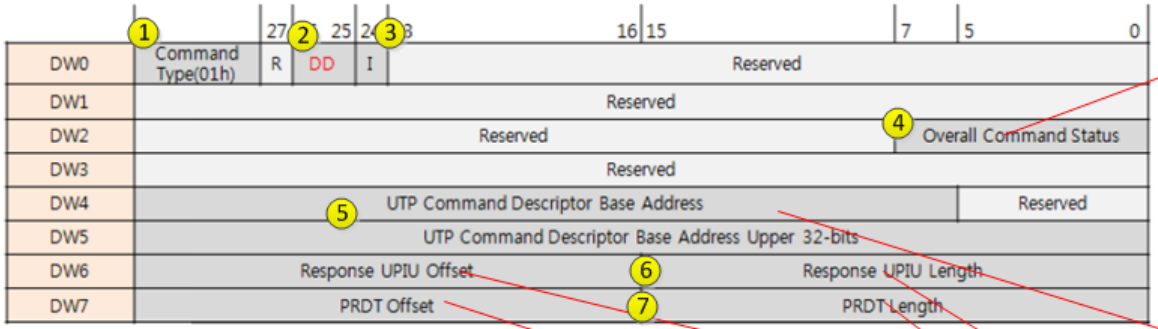

Figure 4 — UTP Transfer Request Descriptor

Value	Description
00h	SUCCESS
01h	INVALID_COMMAND_TABLE_ATTRIBUTES
02h	INVALID_PRDT_ATTRIBUTES
03h	MISMATCH_DATA_BUFFER_SIZE
04h	MISMATCH_RESPONSE_UPIU_SIZE
05h	COMMUNICATION_FAILURE within UIC layers
06h	ABORTED
07h	FATAL ERROR within host controller that is not covered by the error conditions described above in this table.
08h-0Eh	Reserved
0Fh	INVALID_OCS_VALUE
10h-FFh	Reserved

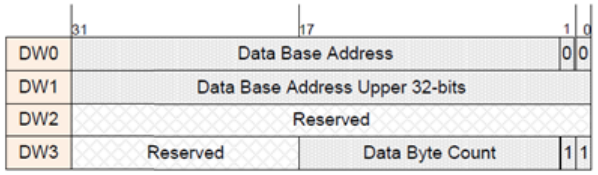

Figure 6 — Data structure for Physical Region Description Table

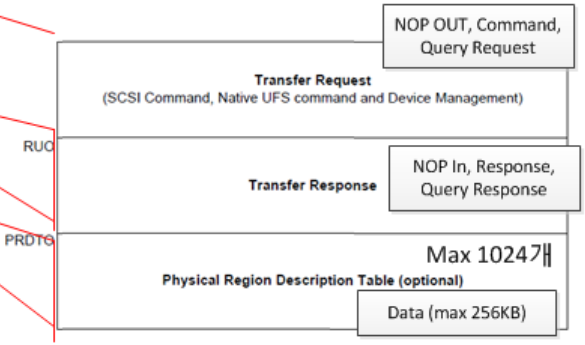

Figure 5 — UTP Command Descriptor (UCD)

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UTP Transfer Request Completion

UTP Transfer Request Completion

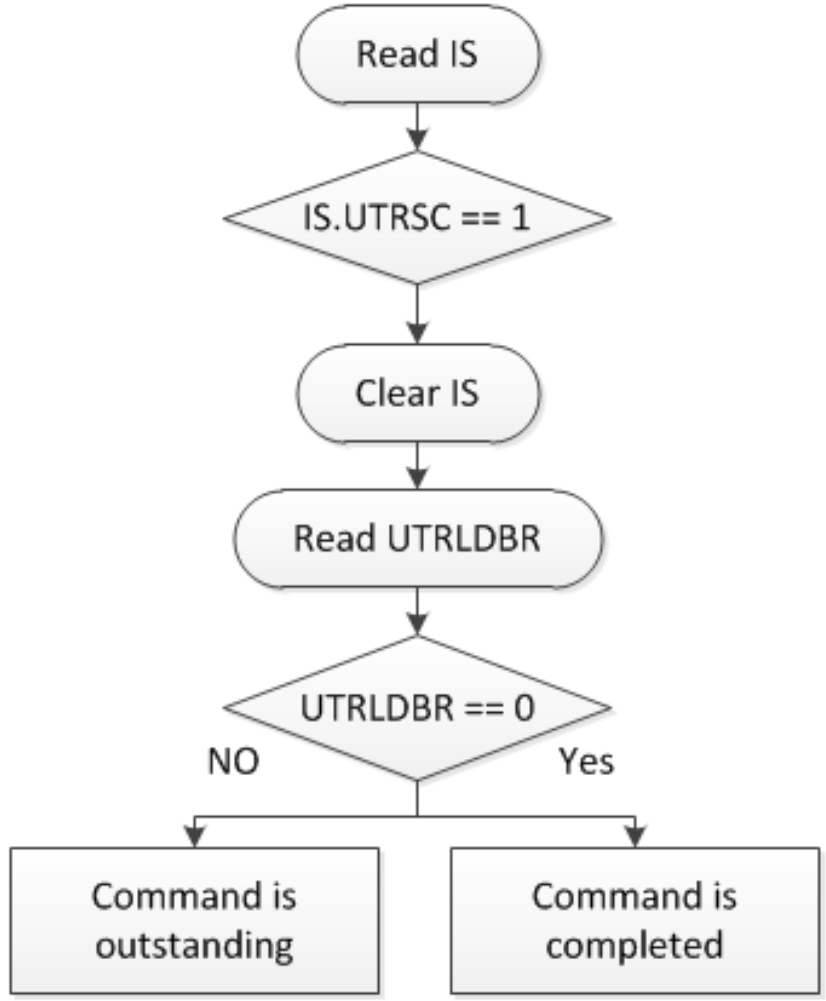
If Regular Command(UTRD.I == 0)

1) Check IA interrupt counter
2) If Counter is 0, IA Timer is running

Four conditions which make IS.UTRCS is set

1) UTRD.I == 1
2) When Counter reach Interrupt threshold(IACTH) value
3) Timeout occurs (IATOVAL)
4) When OCS value is not SUCCESS

If IE.UTRCE is set, Interrupt is disabled



Host Controller link startup

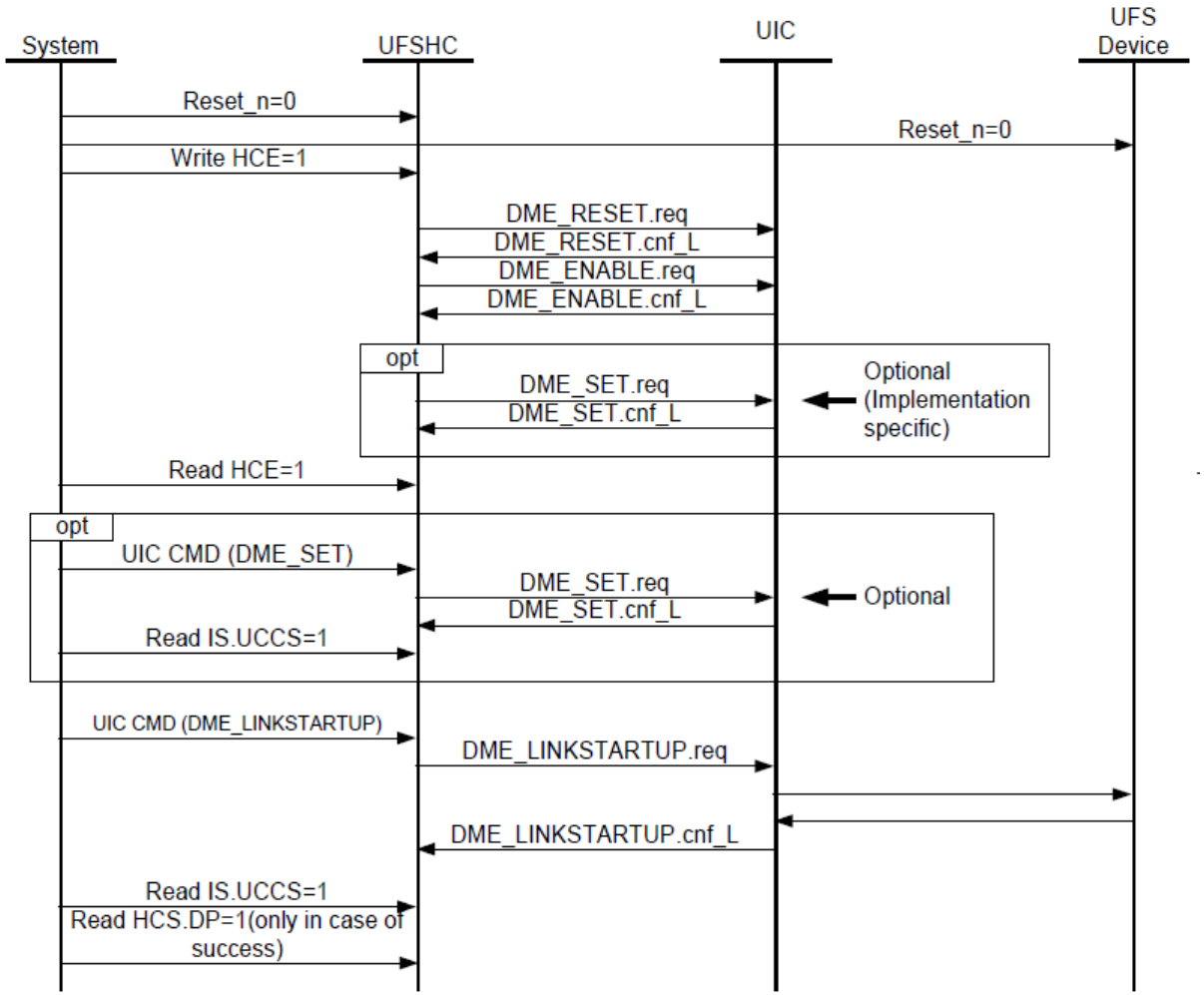


Figure 8 — Host controller link startup sequence

Host Power Mode Change

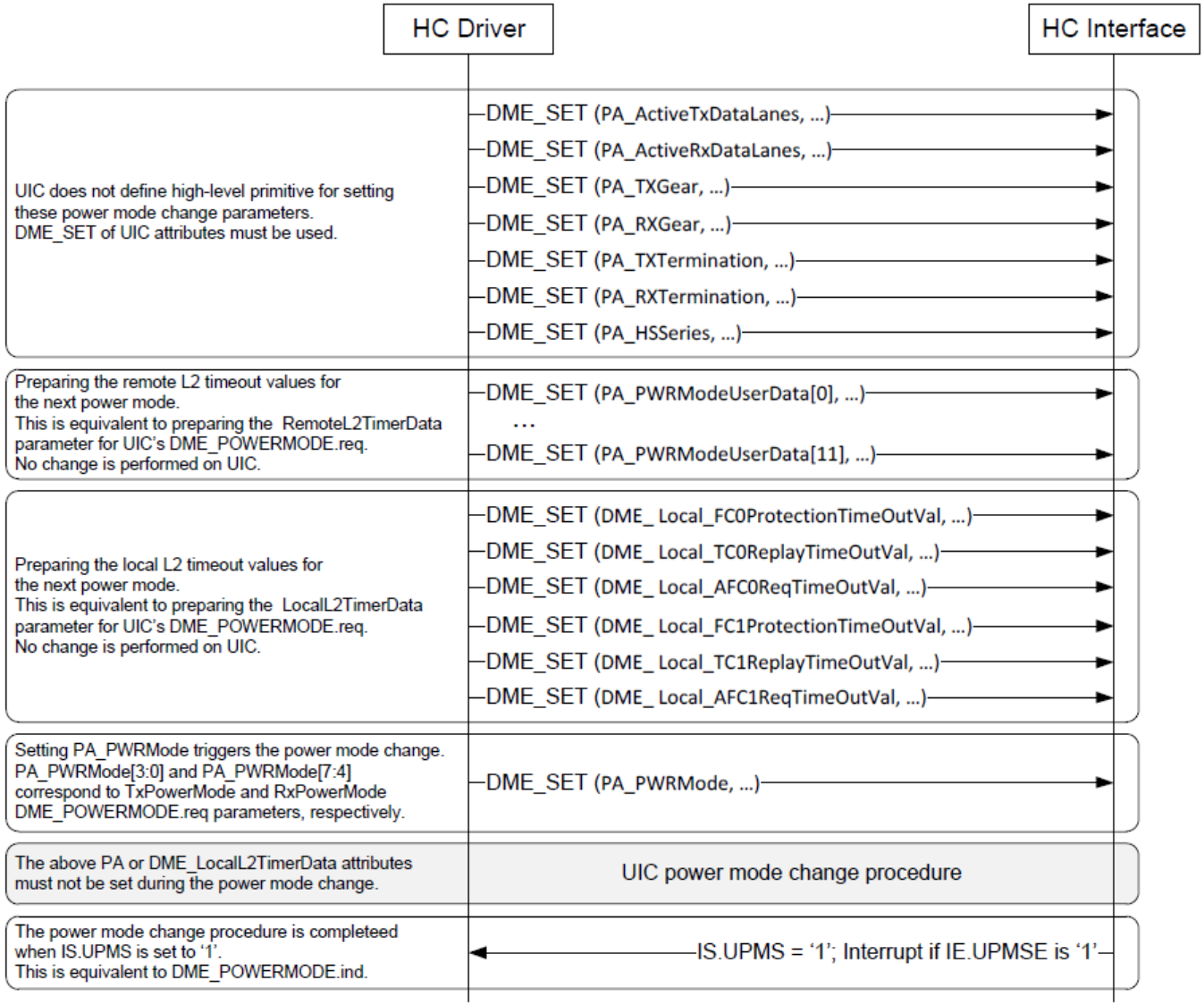
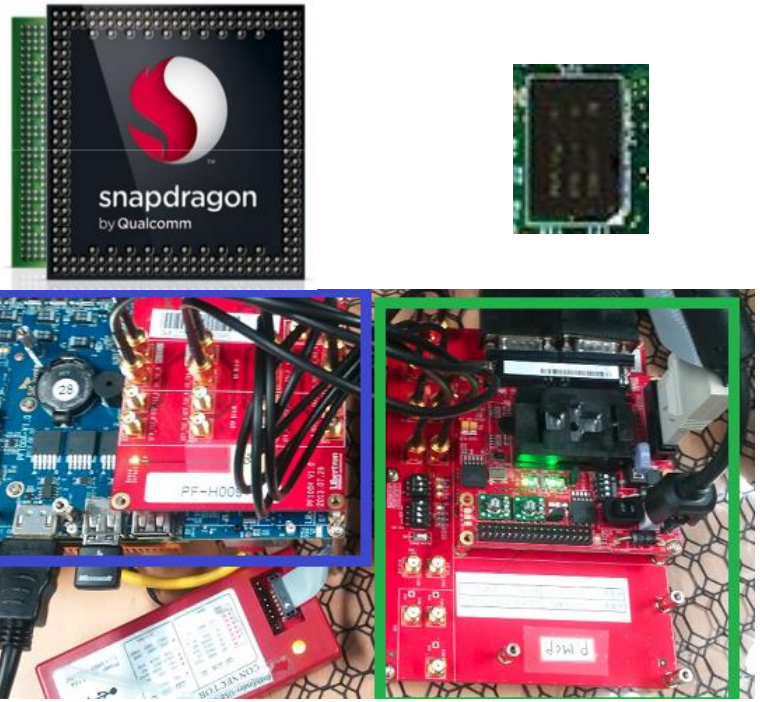


Figure 9 — UIC Power mode change

UFS Host & Device System



TEST Implementation

- ✓ Device driver and AUTO TEST application have been developed on PC based HOST environment
  - ✓ HOST(AP) / device firmware implemented
  - ✓ Technical understanding of AP side will be helpful for co-work with AP vendors
  - ✓ Simplicity and easy debugging are most important factor of AUTO TEST application

7.12.1 Test Case Id: UFS_Read6_01

If this test case is used to BOOT well-known logical unit, WRITE command may not be issued from host because WRITE command is not supported on BOOT well-known logical unit. Data comparison may not be processed.

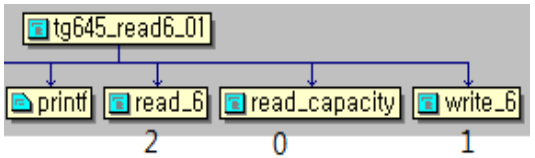
Ref. specs Section	UFS : Section 11.3.5
Test Purpose	To Verify the READ (6) command reads 256 blocks of data when TRANSFER LENGTH = 00h.
Test Procedure	**[Precondition]:** 1. Issue READ CAPACITY (10) command and verify LU has more than or equal to 256 Logical blocks **[Main]:** 1. Issue WRITE (6) command. 2. Issue READ (6) command. 3. Verify the Expected Output. **[Cleanup]:** None
Input parameter values	**WRITE (6)** LBA = 00h, TRANSFER LENGTH = 00h, CONTROL = 00h. Any Data can be written. **READ (6)** LBA = 00h, TRANSFER LENGTH = 00h, CONTROL = 00h.
Expected Output	1. The READ (6) command response shall be: Response: Target Success; Status: GOOD; Sense Key: -; Additional Sense Code: - 2. Compare data buffers of WRITE (6) and READ (6) commands. Data shall be same.

```
[TG645],Read6,1
[Cmd],Read_Capacity10,LUN,0,LOGICAL_BLOCK_ADDRESS,0x0,CONTROL,0x0
[Cmd],Write6,LUN,0x0,LOGICAL_BLOCK_ADDRESS,0x0,TRANSFER_LENGTH,0x00,CONTROL,0x0
[Cmd],Read6,LUN,0x0,LOGICAL_BLOCK_ADDRESS,0x0,TRANSFER_LENGTH,0x00,CONTROL,0x0
```

```
./auto_test input/Read6_01.csv
```

Tg645_read6.c

```
include <stdio.h>
include <string.h>
include "ufs_blk_ioctl.h"
include "hw_ufs_test.h"
include "test_main.h"
include "tg645.h"
BUF_FILE_NAME
tg645_read6_01
tg645_read6_02
tg645_read6_03
tg645_read6
```




```
Command #2 : Final Result...OK!
```

```
[root@ufs auto_test_1]# find . -name "*.[chS]" | xargs wc -l
   74 ./Source/Pathfinder_Linux_Drv_V01/inc/common/common.h
  296 ./Source/Pathfinder_Linux_Drv_V01/inc/common/ufs_AdaptationLayer.h
62956 total
```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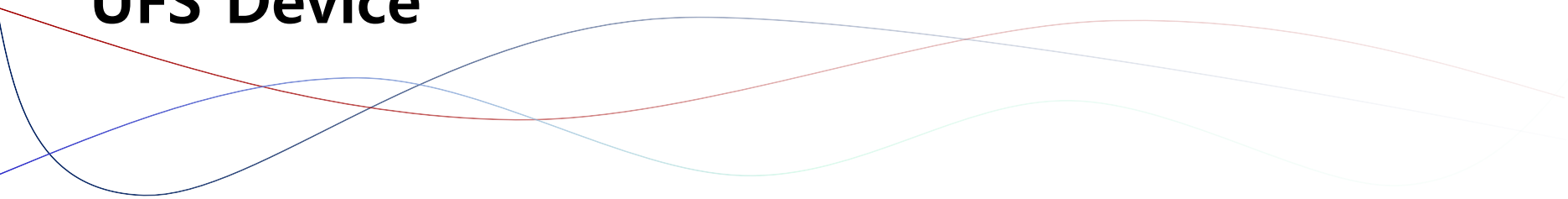
UFS Device



HOST & Device E2E Interface

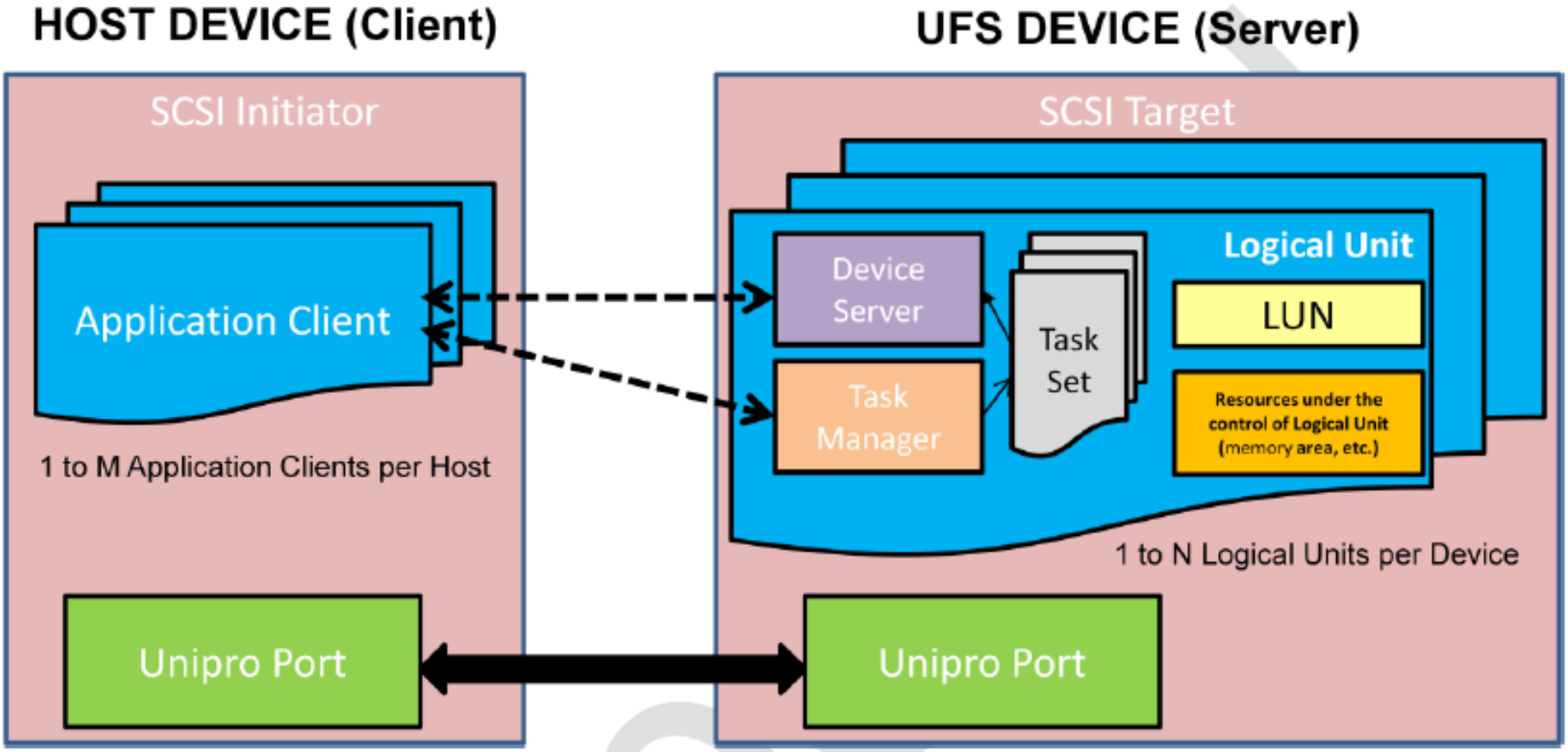
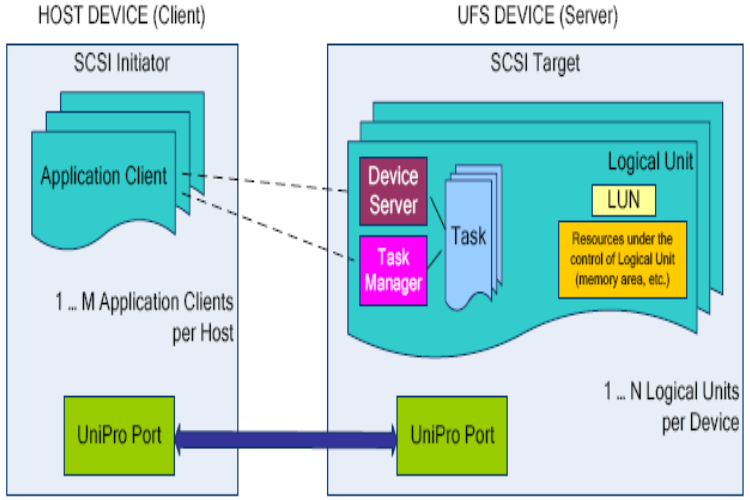


Figure 7-1 UFS SCSI Domain

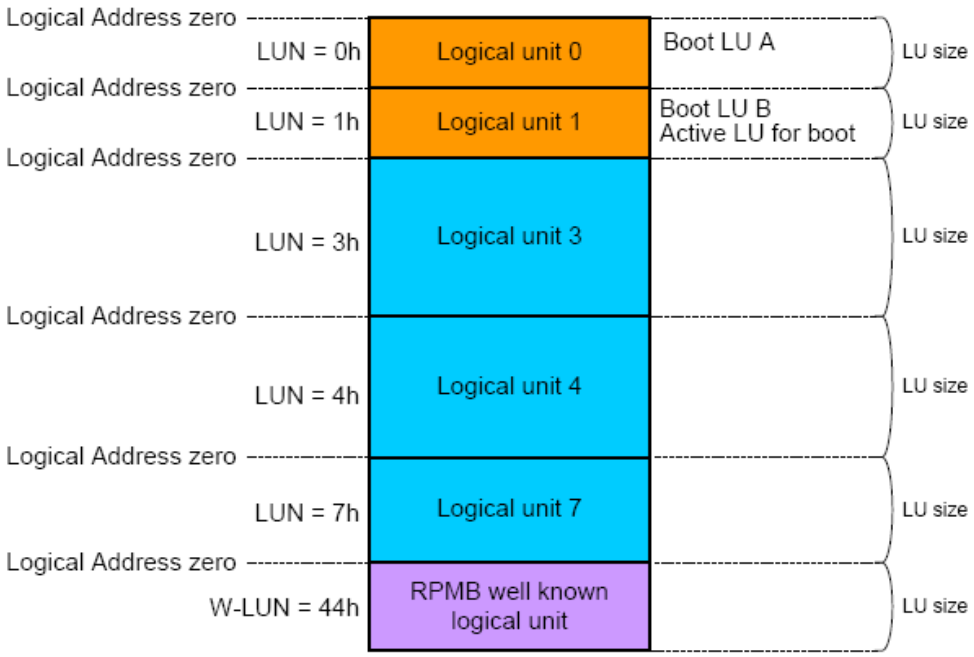
Logical Unit

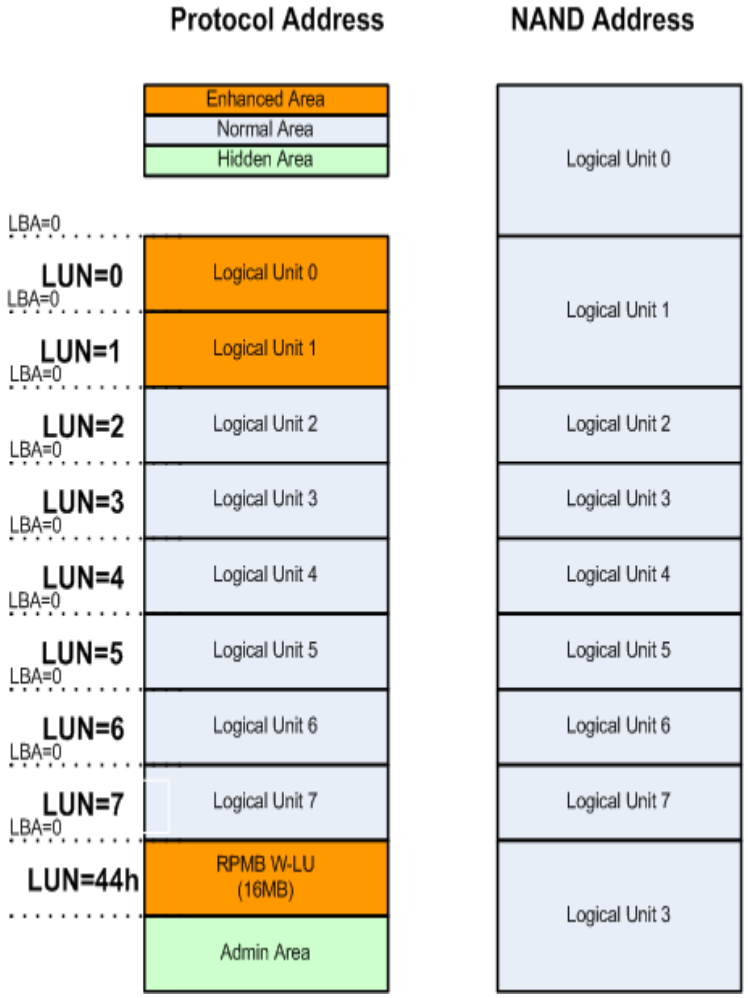
- **LU : Externally addressable, independent, processing entity.**
- **Device contains 1 or Max 8 Normal logical units & 4 Well-known LU**
- **A Logical unit contains**
  - DEVICE SERVER : Processing SCSI Commands
  - TASK MANAGER : Performs Task management Functions
  - TASK SET : A Conceptual Group of Commands



Configurable parameters		Logical Unit
Name	**Description**	
bLUEnable	Logical Unit Enable	LU 0, ..., LU 7
bBootLunID	Boot LUN ID	LU 0, ..., LU 7
bLUWriteProtect	Logical Unit Write Protect	LU 0, ..., LU 7
bMemoryType	Memory Type	LU 0, ..., LU 7
dNumAllocUnits	Number of allocation units assigned to the logical unit. The value shall be calculated considering the capacity adjustment factor of the selected memory type.	LU 0, ..., LU 7
bDataReliability	Data Reliability	LU 0, ..., LU 7
bLogicalBlockSize	Logical Block Size	LU 0, ..., LU 7
bProvisioningType	Provisioning Type	LU 0, ..., LU 7

LU Configuration





LU Configuration

8.4 UFS Descriptor

TABLE 1 Configuration Descriptor Header and Device Descriptor Configurable parameters

Offset	Size	Name	Value
00h	1	bLength	90h
01h	1	bDescriptorType	01h
02h	1	bNumberLU	00h
03h	1	bBootEnable	01h
04h	1	bDescrAccessEn	01h
05h	1	bInitPowerMode	01h
06h	1	bHighPriorityLUN	00h
07h	1	bSecureRemovalType	00h
08h	1	bInitActiveICCLevel	00h
09h	2	wPeriodicRTCUpdate	0000h
0Bh:0Fh	5	Reserved	00h

TABLE 2 Unit Descriptor Configurable parameters

Offset	Size	Name	LUN=0	LUN=1	LUN=2	LUN=3	LUN=4	LUN=5	LUN=6	LUN=7
10h +16*LUN	1	bLUEnable	01h	01h	01h	01h	01h	01h	01h	01h
11h+16*LUN	1	bBootLunID	00h	00h	01h	02h	00h	00h	00h	00h
12h+16*LUN	1	bLUWriteProtect	00h	01h	02h	00h	00h	01h	02h	00h
13h+16*LUN	1	bMemoryType	00h	00h	00h	00h	00h	00h	00h	00h
14h+16*LUN	4	dNumAllocUnits	1000h	1000h	1000h	1000h	1000h	1000h	1000h	1000h
18h+16*LUN	1	bDataReliability	00h	01h	00h	01h	00h	01h	00h	01h
19h+16*LUN	1	bLogicalBlockSize	0Ch	0Ch	0Ch	0Ch	0Ch	0Ch	0Ch	0Ch
1Ah+16*LUN	1	bProvisioningType	00h	02h	03h	00h	00h	02h	03h	00h
1Bh+16*LUN	2	wContextCapabilities	00h	01h	02h	03h	04h	05h	00h	01h
1Dh+16*LUN	3	Reserved	00h	00h	00h	00h	00h	00h	00h	00h

Higher Priority LU

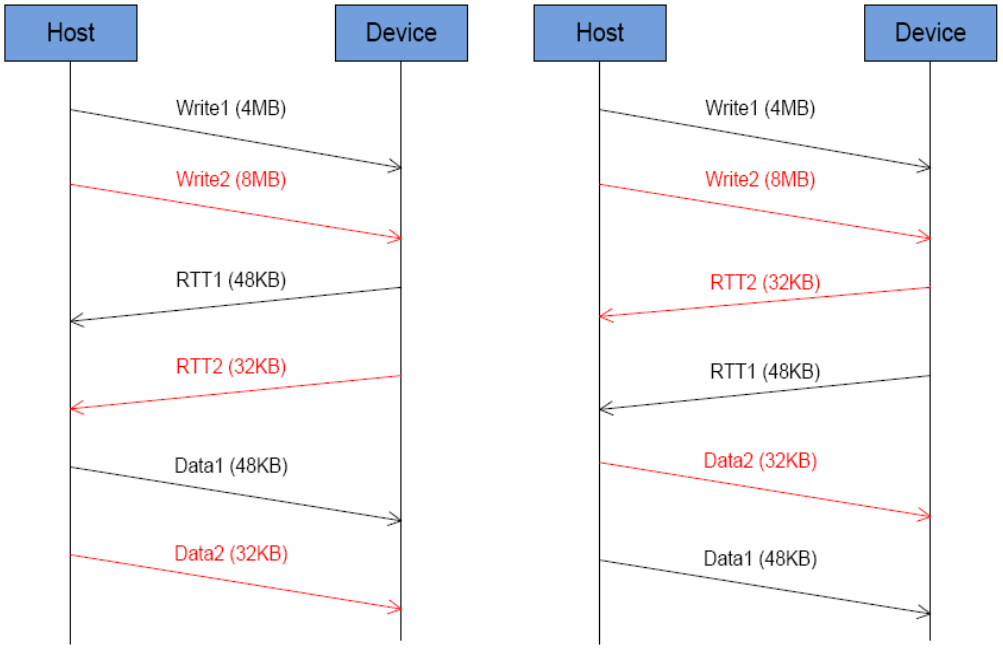


Figure 13-11: Host-Device interaction for LU with same the priority

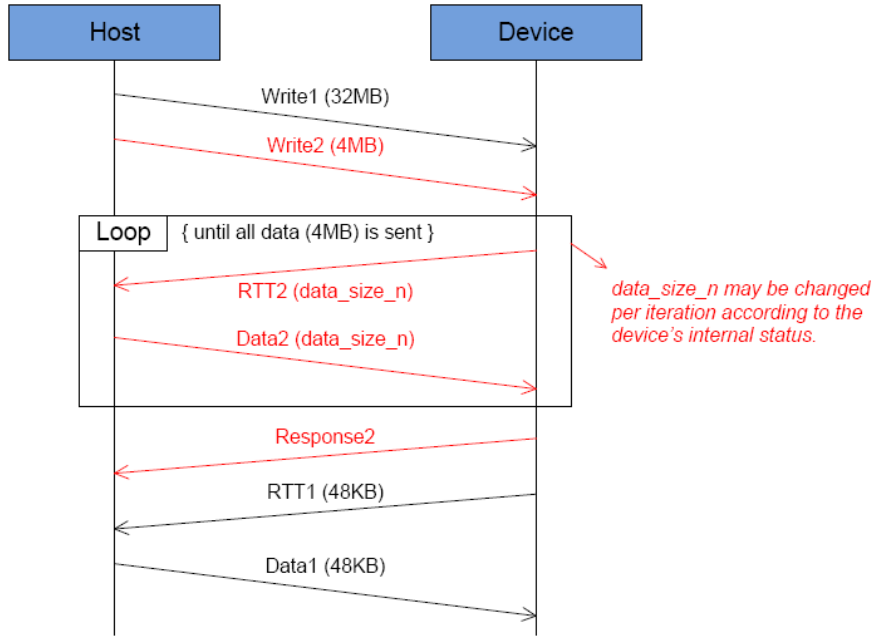
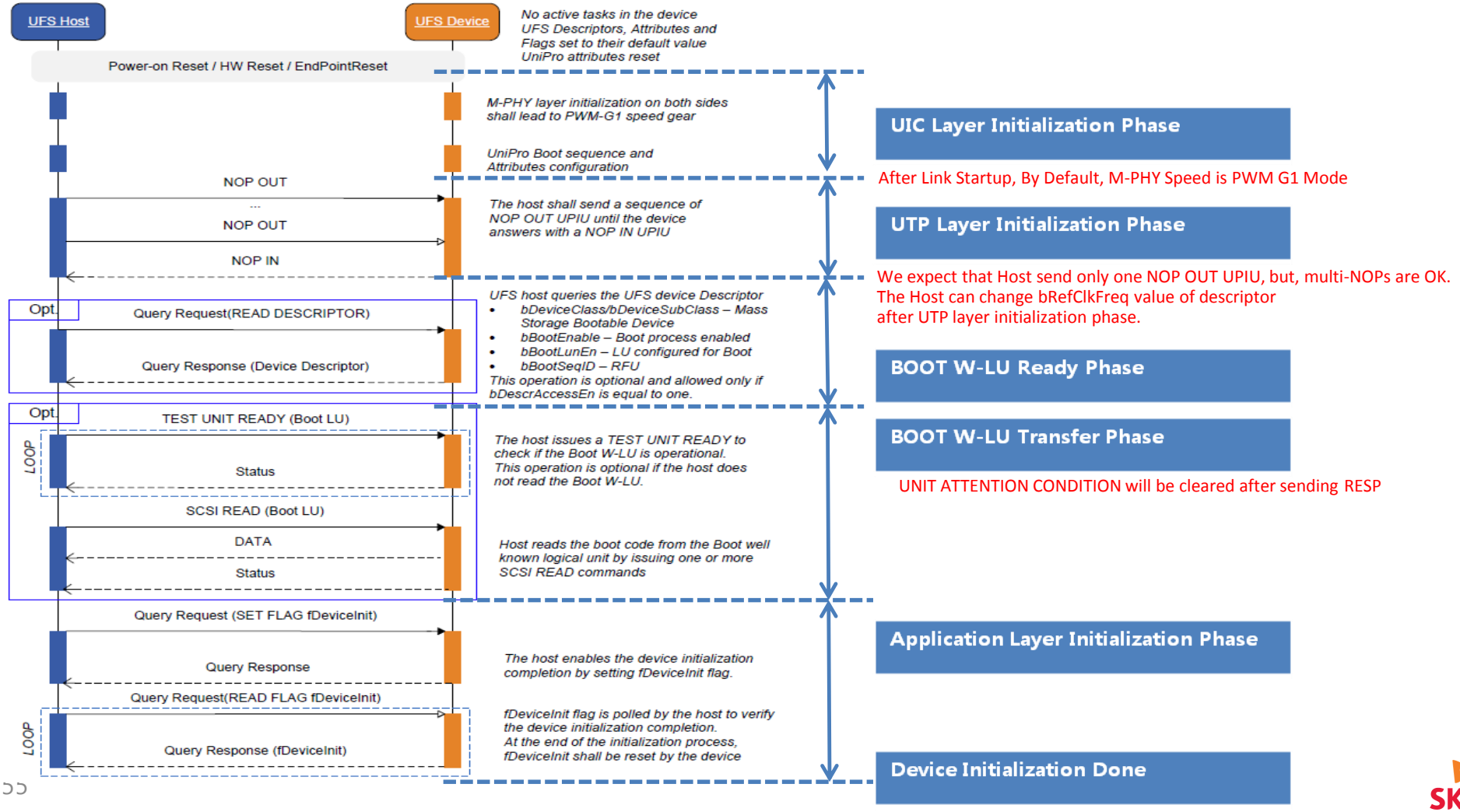


Figure 13-12: Host-Device interaction for LU with different priorities

Boot Sequence

- **UFS CMDs and Modes required by boot sequence**



SCSI Command & Operation (Unmap)

Erase operation Type

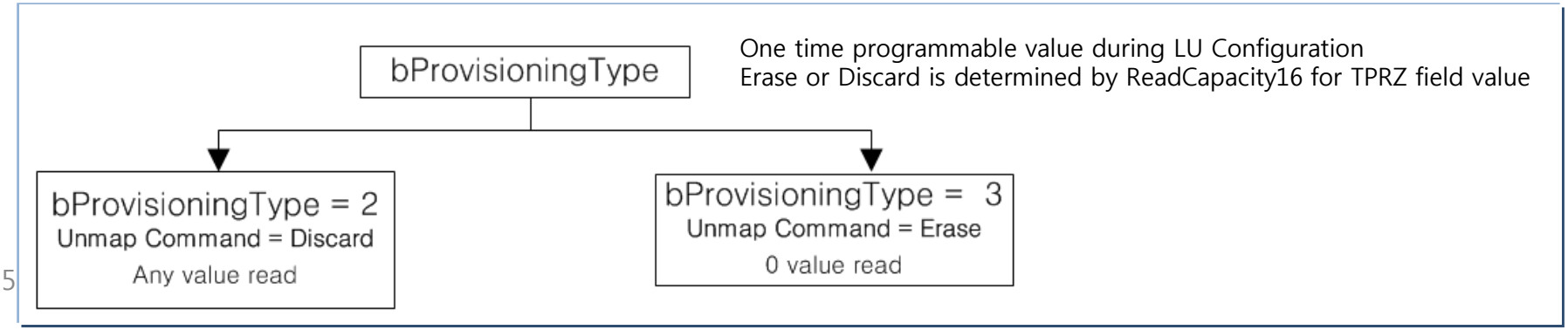
Discard	(unmap=any)
Erase	(unmap=0)
Purge	(emmc = sanitize)
Format	erase + purge

Descriptor of regarding Erase operation

bProvisioningType(OTP)	ReadCapacity16 (TPE)	ReadCapacity16 (TPRZ)
0	0	Don't care
1	Don't care	Don't care
2	1	0
3	1	1

- Erase in the multiple of dEraseBlockSize unit (bigger size than logical blocks)

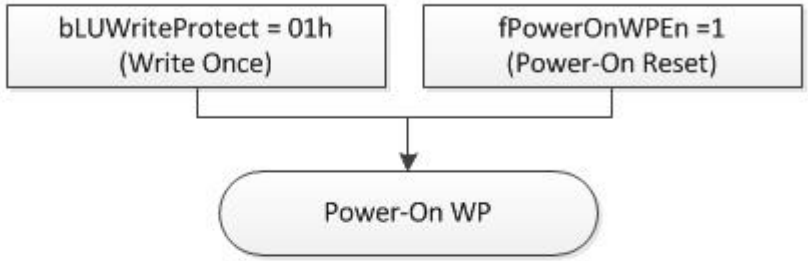
Erase or Discard

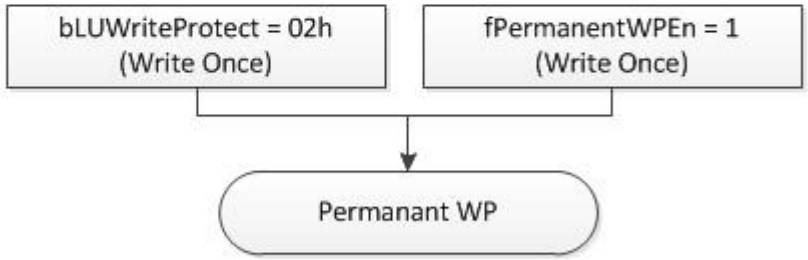


Write Protection

UNIT DESCRIPTOR					
Offset	Size	Name	MDV (1)	User Conf. (2)	Description
05h	1	bLUWriteProtect	00h	Yes	Logical Unit Write Protect 00h: LU not write protected 01h: LU write protected when fPowerOnWPEn =1 02h: LU permanently write protected when fPermanentWPEn =1 03h: Reserved (for UFS Security Extension specification) Others: Reserved

FLAGS					
IDN	Name	Type	Type (1) # Ind. (2) # Sel. (3)	Default	Description
02h	fPermanentWPEn	Read / Write once	D	0	Permanent Write Protection Enable fPermanentWPEn enables permanent write protection on all logical units configured as permanent protected; it cannot be toggled or cleared once it is set. 00h: Permanent write protection disabled
03h	fPowerOnWPEn	Read / Power on reset	D	0	Power On Write Protection Enable fPowerOnWPEn enables the write protection on all logical units configured as power on write protected. If fPowerOnWPEn is equal to one and the device receive a Query Request to clear or toggle this flag, the Query Request shall fail and Response field shall be set to "F8h" (Parameter already written). The device shall set fPowerOnWPEn to zero in the event of power cycle or hardware reset. 0b: Power on write protection disabled. 1b: Power on write protection enabled.





SK hynix

Q & A

Thanks!!!