cuPHY Features Overview

Table of contents

cuPHY Features Overview

This section provides an overview of supported features in cuPHY.

Supported Features

Aerial CUDA-Accelerated RAN Layer 1

Aerial CUDA-Accelerated RAN adheres to 3GPP Release 15 standard specifications to deliver the necessary Layer 1 capabilities for a gNB.

3GPP Release 15

Aerail cuPHY adheres to 3GPP Release 15 standard specifications to deliver the following capabilities for gNB Layer 1.

Overall PHY capabilities include:

- Error detection on the transport channel and indication to higher layers
- FEC encoding/decoding of the transport channel
- Hybrid ARQ soft-combining
- Rate matching of the coded transport channel to physical channels
- Mapping of the coded transport channel onto physical channels
- Power weighting of physical channels
- Modulation and demodulation of physical channels including:
    - Frequency and time synchronization
    - Radio characteristics measurements and indication to higher layers
    - Multiple Input Multiple Output (MIMO) antenna processing
    - Transmit Diversity (TX diversity)

- Digital and Analog Beamforming
- RF processing

PHY FH Interface

Aerial CUDA-Accelerated RAN PHY Overall Capabilities

Features	Configuration	Supported
Standard support	3GPP 5G NR Rel 15	P
Duplexing Mode	TDD	Y
Nawrrow Bandwidth (MHz)	30MHz, 40 MHz, 50MHz, 80 MHz	P
Channel Bandwidth (MHz)	100 MHz	Y
Subcarrier Spacing (kHz)	30khz	Y
Maximum Number of Subcarriers (Max number of RBs x Num of Subcarriers per RB) = 273 x 12	3276	Y
Downlink Waveform	CP-OFDM	Y
Uplink Waveform	CP-OFDM	Y
	DFT-s-OFDM (for data and control)	Y
	Configurable to DFT-s-OFDM (for data & Control)	Y
Number of Downlink SU-MIMO layers	Up to 4	Y
Number of Uplink SU-MIMO layers	1, 2	Y
Number of Tx physical antennas	1	N
	2	Y
	4	Y
	8	N
	32	Y
	64	Y

Number of Rx physical antennas	1	N
	2	Y
	4	Y
	8	N
	32	Y
	64	Y
Slot format	DDDSUUDDDD S = 6:4:4 (DL: G: UL)	Y
Carrier Aggregation	Configurable component carriers	Y
Configurable BW Parts	Up to 4	Y
BBU-RRU split option	7.1	Y
	7.2	Y
	8	N
Maximum Downlink throughput per user (Mbps) 4T4R configuration	1870	Y
Maximum Uplink throughput per user (Mbps) 4T4R configuration	467	Y

TS 38.211 Numerologies, Physical Resources, Modulation, Sequence, Signal Generation

Aerial CUDA-Accelerated RAN PHY Numerologies

Feature	Configuration	Supported
Numerologies Normal CP	μ=0 SCS=15kHz, 14symbol/slot, 10slot/frame, 1slot/subframe, Normal CP	N
	μ=1 SCS=30kHz, 14symbol/slot, 20slot/frame, 2slot/subframe, Normal CP	Y
	μ=2 SCS=60kHz, 14symbol/slot, 40slot/frame, 4slot/subframe, Normal CP	N

	μ=3 SCS=120kHz, 14symbol/slot, 80slot/frame, 8slot/subframe, Normal CP	N
	μ=4 SCS=240kHz, 14symbol/slot, 160slot/frame, 16slot/subframe, Normal CP	N
Numerologies Extended CP	μ=2 SCS=60kHz, 12symbol/slot, 40slot/frame, 4slot/subframe, Extended CP	N

Aerial CUDA-Accelerated RAN Overall PHY Physical Resources

Feature	**Supported**
Antenna Ports	Y
Resource Grid	Y
Resource Elements	Y
Resource Block	Y
Resource Block - Common Resource Block(CRB)	Y
Resource Block - Physical Resource Block(PRB)	Y
Resource Block - Virtual Resource Block (VRB)	Y
Bandwidth Part (BWP) Dynamically adapt the carrier bandwidth and numerology in which a UE operates A bandwidth part is a subset of contiguous common resource blocks for a given numerology μi in bandwidth part i on a given carrier. A UE can be configured with up to four bandwidth parts in UL and DL	Y

Aerial CUDA-Accelerated RAN PHY Physical Resources – BWP

Feature	**Supported**
Bandwidth Part (BWP) Dynamically adapt the carrier bandwidth and numerology in which a UE operates A bandwidth part is a subset of contiguous common resource blocks for a given numerology μi in bandwidth part i on a given carrier A UE can be **configured** with up to **four** bandwidth parts in **both** UL and DL	Y

Default Aerial CUDA-Accelerated RAN startup configuration to not use BWP, can be enabled to support BWP on a per carrier basis (while cell OOS)	N
Default Aerial CUDA-Accelerated RAN startup configuration to not use BWP, can be enabled to support BWP on a per carrier basis at startup	N

Aerial CUDA-Accelerated RAN Overall Carrier Aggregation

Feature	Description	Supported (emulated)
Carrier Aggregation	Transmissions in multiple cells can be aggregated to support inter-band and intra-band configurations	Y
100MHz	Up to 2 cells aggregation(1CC,2CC)	Y
	Up to 4 cells aggregation(1CC,2CC,3CC, 4CC)	Y
Narrowband Carrier Aggregation (ZMhz)	Configurable upto 4 component carriers	Y

Aerial CUDA-Accelerated RAN PHY Modulation Mapper

Modulation Scheme	Supported
Pi/2 BPSK	Y
BPSK	Y
QPSK	Y
16QAM	Y
64QAM	Y
256QAM	Y

Aerial CUDA-Accelerated RAN PHY Sequence Generation

Feature	Description	Supported
Sequence Generation	Pseudo-random sequence generation Generic pseudo-random sequences are defined by a length-31 Gold	Y

	sequence	
	Low-PAPR sequence generation type 1	Y
	Low-PAPR sequence generation type 2	Y

OFDM Baseband Signal Generation (UL DFT-S-OFDM)

Feature	Configuration	Supported
Signal generation for all channels except PRACH & RIM-RS		RU support expected
PRACH		RU support expected
RIM-RS		RU support expected
Uplink waveform Support concurrent UE configuration to use CP-OFDM or DFT-S-OFDM on same cell.	DFT-S-OFDM for UL. Some specific parameters: • Support for PUSCH and for PUCCH format 3 • Support 0.5 pi-BPSK for Modulation • Support DMRS group hopping • Support DMRS sequence hopping	Y

TS 38.211 Channels

Aerial CUDA-Accelerated RAN Physical Overall Channels and Reference Signals

Category	L1 requirement	Supported
Downlink Channels (TX)	PDSCH processing	Y
	PDCCH processing	Y

	PBCH processing	Y
Downlink signals (TX)	DMRS for PDSCH	Y
	DMRS for PDCCH	Y
	DMRS for PBCH	Y
	PSS, SSS	Y
	CSI-RS, TRS	Y
	PT-RS	N
Downlink Physical Resources	Antenna ports starting with 1000 for PDSCH	Y
	Antenna ports starting with 2000 for PDCCH	Y
	Antenna ports starting with 3000 for channel-state information reference signals	Y
	Antenna ports starting with 4000 for SS/PBCH block transmission	Y
Uplink Channels (RX)	PUSCH processing	Y
	PUCCH processing	Y
	PRACH processing	Y
Uplink signals (RX)	DMRS for PUSCH	Y
	DMRS for PUCCH	Y
	SRS	Y
	PT-RS	N
Uplink physical Resources	Antenna ports starting with 0 for PUSCH and associated demodulation reference signals	Y
	Antenna ports starting with 1000 for SRS	Y
	Antenna ports starting with 2000 for PUCCH	Y
	Antenna port 4000 for PRACH	Y

Aerial CUDA-Accelerated RAN Overall Channel - PUSCH (Physical Uplink Shared Channel)

Features	Configuration	Supported
Number of codewords	1	Y
Scrambling		Y
Modulation schemes	Pi/2-BPSK	Y
	QPSK	Y
	16 QAM	Y
	64 QAM	Y
	256 QAM	Y
PUSCH transform precoding mode	Disable	Y
	Enable	Y
Precoding	Implemented in UE for UL	Y
HARQ process	Number of HARQ process = 1	Y
HARQ process	Maximum number of HARQ process is 16	Y
Mapping to virtual resource blocks		Y
VRB to PRB mapping Type	Non-interleaved	Y
	Interleaved	N
Transmission Mode	SU-MIMO up to 4 layers	Y
	MU-MIMO 2 up to 4 layers	Y
	MU-MIMO up to 8 layers	P
PUSCH DMRS CDM group without data	PUSCH DMRS CDM group without data 1	Y
	PUSCH DMRS CDM group without data 2	Y
PUSCH users per TTI	16	Y
Uplink algorithm	UL HARQ control	Y

	UL Channel Estimation LS	Y
	MRC, MMSE for equalizer	Y
	IRC, MMSE for equalizer	Y
	Frequency Offset Correction	Y
Rate Matching	I_LBRM = 1 (Limited Buffer Rate Matching)	Y
	I_LBRM = 0 (Limited Buffer Rate Matching)	Y

Aerial CUDA-Accelerated RAN Overall Channel - PUCCH (Physical Uplink Control Channel

Format	Configuration	Supported
Format	0	Y
	1	Y
	2	Y
	3	Y
	4	N
UCI sched coding, AFC, DFT (Format 1)		N
Modulation schemes	Pi/2-BPSK, BPSK, QPSK	Y
Scheduling Request SR	Support needed	Y
Group hopping	neither	Y
	disable	Y
	enable	Y
Sequence cyclic shift	Zadoff-Chu sequence	Y
Intra-slot Frequency hopping/second hop PRB	Support	Y
Inter-slot Frequency hopping/second hop PRB	Support	Y
PUCCH over multiple slots	Number of slots - 2,4,8	N
Frequency Offset Correction	PUCCH format 1, 3	N

Multi-UE support	24 UEs / TTI	Y
PUCCH UCI HARQ-ACK Polar	codeblock CB size < 359, liftsize = 8	Y

1-Capabilities-TSx211-6-3-3] Aerial CUDA-Accelerated RAN Overall Channel - PRACH(PHY Random Access Channel)

Feature	Configuration	Supported
Format	A1	N
	A2	N
	A3	N
	B1	N
	B2	N
	B3	N
	B4	Y
	C0	N
	C2	N
	0	N
	1	N
	2	N
	3	N
Subcarrier Spacing (kHz)	1.25	N
	5	N
	15	N
	30	Y
Sequence cyclic shift	Zadoff-Chu sequence	Y
Preamble length	839	N
	139	Y
Number of PRACH occasions per TTI	4 FDM	Y

Contention based Random Access	Configurable non-contention based Random Access	N

Aerial CUDA-Accelerated RAN Overall PHY - UL Reference Signals

	Configuration	Supported
PUSCH		
PUSCH DMRS sequence generation when transform precoding is disabled		Y
PUSCH DMRS sequence generation when transform precoding is enabled	Neither group, nor sequence hopping is enabled	Y
	Group hopping is enabled and sequence hopping is disabled	Y
	Sequence hopping is enabled and group hopping is disabled	Y
Demodulation reference signal for PUSCH Mapping to physical resources	DM-RS configuration type 1	Y
	DM-RS configuration type 2	N
	UL-DMRS-max-len=1	Y
	UL-DMRS-max-len=2	Y
	UL-DMRS-add-pos=0	Y
	UL-DMRS-add-pos=1	Y
	UL-DMRS-add-pos=2	Y
	UL-DMRS-add-pos=3	Y
Phase-tracking reference signals for PUSCH Sequence generation	transform precoding is not enabled	N
	transform precoding is enabled	N
Phase-tracking reference signals for PUSCH Mapping to physical resources	transform precoding is disabled	N
	transform precoding is enabled	N
PUCCH		

Demodulation reference signal for PUCCH format 1	no intra-slot frequency hopping	Y
	intra-slot frequency hopping enabled	Y
Demodulation reference signal for PUCCH format 2		Y
Demodulation reference signal for PUCCH format 3 Format 4 not supported	No additional DM-RS, No hopping	Y
	No Additional DM-RS, hopping	Y
	Additional DM-RS, No hopping	Y
	Additional DM-RS, hopping	Y
SRS		
Sounding reference signal resource	Antenna ports=1, 1OFDM symbols	Y
	Antenna ports=1, 2OFDM symbols	Y
	Antenna ports=1, 4OFDM symbols	Y
	Antenna ports=2, 1OFDM symbpls	Y
	Antenna ports=2, 2OFDM symbols	Y
	Antenna ports=2, 4OFDM symbols	Y
	Antenna ports=4, 1OFDM symbpls	Y
	Antenna ports=4, 2OFDM symbols	Y
	Antenna ports=4, 4OFDM symbols	Y
Sounding reference signal Sequence generation	KTC=2	Y

	KTC=4	Y
	KTC=8	Y
Sounding reference signal Mapping to physical resources	CSRS=0~63	Y
Sounding reference signal slot configuration	Indicated by higher layer parameter SRS-Config	Y
PTRS		
PTRS Support	Support	N

Aerial CUDA-Accelerated RAN Overall Channel - PDSCH(PHY DL Shared Channel)

Feature	Configuration	Supported
Scrambling		Y
Modulation schemes	QPSK	Y
	16 QAM	Y
	64 QAM	Y
	256 QAM	Y
Transmission Mode	4T4R SU-MIMO up to 4 layers	Y
	32T32R SU-MIMO up to 8 layers	P
	64T64R SU-MIMO up to 16 layers	P
Number of codewords	1	Y
	2	N
Number of antenna ports	1000 - 1011	Y
Number of physical antennas	4	Y
	32	P
	64	P
Beam Forming weights computation	BF m2	N
Precoding	non-codebook	Y

	pre-coding weight	N
	Type I Single-Panel Codebook	N
	Type I Multi-Panel Codebook	N
	Type II Codebook	N
	Type II Port Selection Codebook	N
PDSCH mapping type	Type A	Y
	Type B	Y
Resource allocation type	Type 0	Y
	Type 1	Y
VRB to PRB mapping Type	Non-interleaved	Y
	Interleaved	N
PDSCH DMRS CDM groups without data	1	Y
	2	Y
	3	N/A
Number PDSCH users per TTI	16	Y
Power Control	PDSCH	Y
	DMRS - PDSCH	Y

Aerial CUDA-Accelerated RAN Overall Channel - PDCCH (Physical DL Control Channel)

Feature	Configuration	Supported
Scrambling	Up to 2 codewords	N
CORESET	Normal	Y
	RMSI CORESET	Y
SSB - RMSI CORESET multiplexing pattern	Pattern 1	Y
Aggregation Level	1	Y

	2	Y
	4	Y
	8	Y
	16	Y
Modulation schemes	QPSK	Y
Layer mapping	Supported	Y
Antenna port mapping	Supported	Y
Mapping to virtual resource blocks	Supported	Y
Mapping from virtual to physical resource blocks	Non-interleaved VRB-to-PRB mapping	Y
Polar code	Block length up to 128 bits	Y
DMRS (Demodulation Reference Signal)	m-sequence	Y
CCE To REG Mapping Type	Non-interleaved	Y
	Interleaved	Y
Number OFDM symbol of CORESET	1	Y
	2	Y
	3	Y
Power Control	PDCCH	Y
	DMRS-PDCCH	Y
DCI format	0_0	NA
	0_1	NA
	1_0	NA
	1_1	NA
	2_x	NA
Precoding	Precoding Matrix Idx based precoding in the DU	Y

Aerial CUDA-Accelerated RAN Overall Channel - PBCH (Physical Broadcast Channel)

	Configuration	cuBB Tested
Precoding		Y
Scrambling	SS/PBCH block index Lmax=4	N
	SS/PBCH block index Lmax=8	N
	SS/PBCH block index Lmax=64	N
Modulation schemes	QPSK	Y
Mapping to Physical Resources		Y
DMRS Support	Support	Y
DMRS config type	Type 1	Y
	Type 2	N
DMRS type A Pos	Pos2	Y
	Pos3	Y
DMRS max length	1	Y
	2	Y
DMRS Additional Position	Pos0	Y
	Pos1	Y
	Pos2	Y
	Pos3	Y

Aerial CUDA-Accelerated RAN Overall - PHY DL Reference Signals

Feature	Configuration	Supported
PDSCH		
Demodulation reference signals for PDSCH Sequence generation		Y
Demodulation reference signals for PDSCH Mapping to physical resources	DM-RS configuration type 1	Y
	DM-RS configuration type 2	N
	DL-DMRS-max-len=1	Y

	DL-DMRS-max-len=2	Y
	DL-DMRS-add-pos=0	Y
	DL-DMRS-add-pos=1	Y
	DL-DMRS-add-pos=2	Y
	DL-DMRS-add-pos=3	Y
Phase-tracking reference signals (PTRS) for PDSCH Mapping to physical resources	LPT-RS=1	N
	LPT-RS=2	N
	LPT-RS=4	N
PDCCH		
Demodulation reference signals for PDCCH Sequence generation		Y
Demodulation reference signals for PDCCH Mapping to physical resources		Y
PBCH		
Demodulation reference signals for PBCH Sequence generation		Y
Demodulation reference signals for PBCH Mapping to physical resources		Y
CSI reference signals		
CSI reference signals	Zero-power	Y
	non-zero-power	Y
CSI reference signals Sequence generation	nID equals the higher-layer parameter ScramblingID	Y
CSI reference signals Mapping to physical resources	Row 1: 1 port, Density = 3, CDMtype = No CDM	Y
	Row 2: 1 port, Density = 1, 0.5, CDMtype = No CDM	Y
	Row 3: 2 port, Density = 1, 0.5, CDMtype = FD-CDM2	Y

	Row 4: 4 port, Density = 1, CDMtype = FD-CDM2	Y
	Row 5: 4 port, Density = 1, CDMtype = FD-CDM2	Y
	Row 6: 8 port, Density = 1, CDMtype = FD-CDM2	Y
	Row 7: 8 port, Density = 1, CDMtype = FD-CDM2	Y
	Row 8: 8 port, Density = 1, CDMtype = CDM4 (FD2, TD2)	Y
	Row 9: 12 port, Density = 1, CDMtype = FD-CDM2	N
	Row 10: 12 port, Density = 1, CDMtype = CDM4 (FD2, TD2)	N
	Row 11: 16 port, Density = 1, 0.5, CDMtype = FD-CDM2	N
	Row 12: 16 port, Density = 1, 0.5, CDMtype = CDM4 (FD2, TD2)	N
	Row 13: 24 port, Density = 1, 0.5, CDMtype = FD-CDM2	N
	Row 14: 24 port, Density = 1, 0.5, CDMtype = CDM4(FD2, TD2)	N
	Row 15: 24 port, Density = 1, 0.5, CDMtype = CDM8(FD2, TD4)	N
	Row 16: 32 port, Density = 1, 0.5, CDMtype = FD-CDM2	N
	Row 17: 32 port, Density = 1, 0.5, CDMtype = CDM4(FD2, TD2)	N
	Row 18: 32 port, Density = 1, 0.5, CDMtype = CDM8(FD2, TD4)	N
RIM		

RIM reference signal General	The first RIM-RS type can be used to convey information	N
	The second RIM-RS type depends on configuration only	N
RIM reference signal Sequence generation		N
RIM reference signal Mapping to physical resources		N
RIM reference signal RIM-RS configuration	Enough Indication is disabled	N
	Enough Indication is enabled	N
Positioning Reference		
Positioning reference signal Sequence generation		N
Positioning reference signal Mapping to physical resources	LPRS = 2, Kcomb = 2	N
	LPRS = 4, Kcomb = 2	N
	LPRS = 6, Kcomb = 2	N
	LPRS = 12, Kcomb = 2	N
	LPRS = 4, Kcomb = 4	N
	LPRS = 12, Kcomb = 4	N
	LPRS = 6, Kcomb = 6	N
	LPRS = 12, Kcomb = 6	N
	LPRS = 12, Kcomb = 12	N
Synchronization signals		
SSB numerology	30 kHz	Y
SSB precoding	supported	Y
SSB burst set configuration	2 SS blocks w/ single SSB burst set	Y

Synchronization signal generation	PSS generation and mapping to physical resources	Y
	SSS generation and mapping to physical resources	Y
SS/PBCH block	Mapping of PSS within an SS/PBCH block	Y
	Mapping of SSS within an SS/PBCH block	Y
	Mapping of PBCH and DM-RS within an SS/PBCH block	Y
	Time-frequency structure and time location of an SS/PBCH block	Y

TS 38.212 Multiplexing and Channel Coding

Aerial CUDA-Accelerated RAN Overall Multiplexing and Channel Coding

Feature	Configuration	Supported
General Procedures	CRC calculation All CRC len supported (6, 11, 16, 24)	Y
	Code block segmentation and code block CRC attachment • Polar coding • Low density parity check coding	Y
Transport to physical channel mapping - UL	UL-SCH -> PUSCH	Y
	RACH -> PRACH	Y
	UCI -> PUCCH,PUSCH	Y
Transport to physical channel mapping - DL	DL-SCH -> PDSCH	Y

	BCH -> PBCH	Y
	PCH -> PDSCH	Y
	DCI -> PDCCH	Y
Channel coding schemes	Polar coding	Y
	Low density parity check coding (LDPC)	Y
	Channel coding of small block lengths	Y
Rate matching	Rate matching for Polar code	Y
	Rate matching for LDPC code	Y
	Rate matching for channel coding of small block lengths	Y
Code block concatenation	sequentially concatenating the rate matching outputs for the different code blocks • LDPC • Polar Coding	Y
uplink transport channels and control information	Random access channel	Y
	Uplink shared channel • LDPC graph selection • Rate Matching • Code block concatenation • Data & Control Mulitiplexing	Y
	Uplink control information • Uplink control information on PUCCH • Uplink control information on PUSCH	Y
downlink transport channels and control information	Broadcast channel	Y
	Downlink shared channel and paging channel	Y
	Downlink control information	Y

	• DCI formats • CRC attachment • Channel coding	
UCI multiplexing on PUCCH	support muxing mode as per 38.212 - 6.3.1.1	Y

TS 38.213 Physical Layer Procedures for Control

Aerial CUDA-Accelerated RAN Overall - PHY Control Procedures

UE procedures (Not applicable to base station)

Category	L1 requirement	Supported
Synchronization procedures	Cell search	NA
	Transmission timing adjustments	NA
	Timing for secondary cell activation / deactivation	NA
Radio link monitoring	SSB based	NA
	CSI-RS based	NA
Link recovery procedures	radio link failure	NA
	beam failure recovery	NA
Uplink power control	Physical uplink shared channel	NA
	Physical uplink control channel	NA
	Sounding reference signal	NA
	Physical random access channel	NA
	Power ramping counter suspention	NA
	Dual connectivity	NA
	Power headroom report	NA

PHY RACH

Category	L1 requirement	Supported
	Type-1 random access procedure	Y
	Type-2 random access procedure	N

UE procedures (Not applicable to base station)

Category	L1 requirement	Supported
HARQ-ACK codebook determination	CBG-based HARQ-ACK codebook determination	NA
	Type-1 HARQ-ACK codebook determination in physical uplink control channel	NA
	Type-1 HARQ-ACK codebook determination in physical uplink shared channel	NA
	Type-2 HARQ-ACK codebook determination in physical uplink control channel	NA
	Type-2 HARQ-ACK codebook determination in physical uplink shared channel	NA
	Type-3 HARQ-ACK codebook determination	NA

UCI reporting on PUSCH

Category	L1 Requirement	Supported
Short block codes for UCI	Input: 1 - 11 bits output 32 bits	Y
Multiplexing of coded UCI bits to PUSCH	CSI part 1, support maximum 48 bit	Y
	CSI part 1 and CSI part 2, support maximum 48 bit	Y
	Decoding UCI on PUSCH with PUSCH data (UCI-ON-PUSCH	N

	scaling) 0.5/0.65/0.8/1	
	Decoding UCI on PUSCH without PUSCH data (UCI-ON-PUSCH scaling) 0.5/0.65/0.8/1	N
	HARQ information length maximum 128	Y
	Semi-static offset	N
	Dynamic offset	N

UCI Reporting on PUCCH

Category	L1 Requirement	Supported
UCI reporting on PUCCH	PUCCH Resource Sets before RRC connection establishment	N
	PUCCH Resource Sets for RRC connected UE	N
	UE procedure for reporting multiple UCI types	N
	PUCCH repetition procedure	N

UE Procedures (Not applicable to base station)

Category	L1 Requirement	Supported
UE procedure for determining physical downlink control channel assignment	Type0-PDCCH common search space	NA
	Type0A-PDCCH common search space	NA
	Type1-PDCCH common search space	NA
	Type2-PDCCH common search space	NA
	Type3-PDCCH common search space	NA

	UE-specific search space	NA

UE Procedure for Receiving Control Information

Category	L1 Requirement	Supported
PDCCH validation for DL SPS and UL grant Type 2		NA
PDCCH validation for DL SPS and UL grant Type 2		NA
PDCCH monitoring indication and dormancy/non-dormancy behaviour for SCells		NA
Search space set group switching		NA
HARQ-ACK information for PUSCH transmissions		NA

UE-Group Common Signaling

Category	L1 Requirement	Supported
UE-group common signalling	Slot configuration	N
	UE procedure for determining slot format	N
	Interrupted transmission indication	N

	Cancellation indication	N
	Group TPC commands for PUCCH/PUSCH	N
	SRS switching	N

Bandwidth Part Operation

Category	L1 Requirement	Supported
BWP	Configurable upto 4	Y
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 15} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 15} kHz for frequency bands operated with shared spectrum channel access	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {15, 30} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 15} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 30} kHz for frequency bands with minimum channel bandwidth 5 MHz or 10 MHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 30} kHz for frequency bands operated with shared spectrum channel access	N

	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 15} kHz for frequency bands with minimum channel bandwidth 40MHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {30, 30} kHz for frequency bands with minimum channel bandwidth 40MHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {120, 60} kHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {120, 120} kHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {240, 60} kHz	N
	Set of resource blocks and slot symbols of CORESET for Type0-PDCCH search space set when {SS/PBCH block, PDCCH} SCS is {240, 120} kHz	N
	Parameters for PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET Multiplexing pattern 1 and FR1	N
	Parameters for PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET Multiplexing pattern 1 and FR2	N
	PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET Multiplexing pattern 2 and {SS/PBCH block, PDCCH} SCS {120, 60} kHz	N
	PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block andCORESET Multiplexing pattern 2 and {SS/PBCH block, PDCCH} SCS {240, 120} kHz	N
	PDCCH monitoring occasions for Type0-PDCCH CSS set - SS/PBCH block and CORESET Multiplexing pattern 3 and {SS/PBCH block, PDCCH} SCS {120, 120} kHz	N

Integrated access-backhaul operation		N
Dual active protocol stack based handover		N

TS 38.214 Physical Layer Procedures for Data

Aerial CUDA-Accelerated RAN Overall PHY Data Procedures

Category	L1 Requirement	Supported
UL PUSCH Procedures		
Transmission Scheme	Codebook-based	Y
	Non-codebook-based	Y
Resource allocation	Type 0	Y
	Type 1	Y
Modulation order, redundancy version and transport block size determination		Y
Code block group based PUSCH transmission		N
MCS Table	Table64QAM	Y
	Table256QAM	Y
	Table64QAMLowSE	Y
PUSCH mapping type	Type A	Y
	Type B	Y
CBG retranmission bitmap	Enable	N
	Disable	Y

FH Interfaces

Aerial CUDA-Accelerated RAN Overall 4T4R L1 - L2 Layer Interface Based on SCF FAPI

Feature	Configuration (10.02)	Supported (Emulated)
SCF control interface must support the following messages		
Config.request	4T4R	Y
Config.response	4T4R	Y
Start.request	4T4R	Y
Stop.request	4T4R	Y
Stop.indication	4T4R	Y
Error.indication	4T4R	Y
Param.request (cap query)	4T4R	Y
Param.response	4T4R	Y
SCF data interface includes the following messages		
DL_TTI.request	4T4R	Y
UL_TTI.request	4T4R	Y
UL_DCI.request	4T4R	Y
SLOT errors	4T4R	Y
TX_Data.request	4T4R	Y
Rx_Data.indication	4T4R	Y
CRC.indication	4T4R	Y
UCI.indication	4T4R	Y
SRS.indication	4T4R	Y
RACH.indication	4T4R	Y

Aerial CUDA-Accelerated RAN Overall PHY FH Interface

Feature	Description	Supported

IOT Profiles	**Simultaneous** support of TDD profile(s) and TDD pattern on single GPU • NR TDD IOT Profile 1: NR-TDD-FR1-CAT-A-NoBF • NR TDD IOT Profile 2: NR-TDD-FR1-CAT-A-DBF	Y
O-RAN CUS plane features with fronthaul 7.2-x split: [10][11]	**Simultanous** O-RU category support on same GPU/DU • CAT-A (precoding supported for PDCSH) • CAT-B	Y
Beamforming	• Predefined beamID based beamforming	Y
IQ compression & bit-width	**Simultaneous support for** • Static-bit-width Fixed point IQ (14 bit) • BFP IQ Compression (9 bit)	Y
O-DU timing	• Defined transport delay method	Y
Synchronization	• G8275.1 (full timing support) • LLS-C3 with PTP + SyncE	Y
Transport features	• eCPRI • Application layer fragmentation • QoS over fronthaul	Y
Section types	• Section Type 1 (DL/UL channels) • Section Type 3 (PRACH) • Multiple sections within a single C-plane message	Y
Digital power scaling	• UL gain correction	Y

	• DL reference level adjustment	
Rx window monitoring,	Counters like • Data received too early • Data received too late • Data received on-time	Y
Scale	Support for upto 8 peak - 16 avg 100Mhz carriers	Y

Measurements

Aerial CUDA-Accelerated RAN Overall PHY Measurements 4T4R

Measurements	Cfg Supported	Supported cuBB Tested
PUSCH measurements		
RSS	4T4R	Y
RSRP	4T4R	Y
Pn+I pre-eq (Noise+Interference power)	4T4R	Y
Pn+I post-eq (Noise+Interference power)	4T4R	Y
SINR pre-eq	4T4R	Y
SINR post-eq	4T4R	Y
Timing Advance	4T4R	Y
PUCCH measurements		
PUCCH Format 0	4T4R	Y
PF0 RSS	4T4R	Y
PF0 RSRP	4T4R	Y
PF0 Pn+i	4T4R	Y
PF0 timing advance	4T4R	Y
PUCCH Format 1	4T4R	Y

PF1 RSS	4T4R	Y
PF1 RSRP	4T4R	Y
PF1 Pn+i	4T4R	Y
PF1 timing advance	4T4R	Y
PUCCH Format 2	4T4R	Y
PF2 RSS	4T4R	Y
PF2 RSRP	4T4R	Y
PF2 Pn+i	4T4R	Y
PF2 timing advance	4T4R	Y
PUCCH Format 3	4T4R	Y
PF3 RSS	4T4R	Y
PF3 RSRP	4T4R	Y
PF3 Pn+i	4T4R	Y
PF3 timing advance	4T4R	Y
PUCCH Format 4	4T4R	N
PF4 RSS	4T4R	N
PF4 RSRP	4T4R	N
PF4 Pn+i	4T4R	N
PF4 timing advance	4T4R	N
PRACH measurements		
Pn+i (Noise+Interference power)	4T4R	Y
Preamble signal strength	4T4R	Y
SRS measurements		
SNR	4T4R	Y
Received signal strength	4T4R	Y
Timing advance	4T4R	Y
All channels measurements		

Both pre-equalization and post-equalization across all channels should be configurable and supported	4T4R	N

TS 38.104 (base station radio Tx and Rx) Base Station (BS) Radio Transmission and Reception

Aerial CUDA-Accelerated RAN Overall PHY Performance Conformance

Feature	Configuration	Supported
PUSCH		
PUSCH with transform precoding disabled	4T4R	Y
PUSCH with transform precoding enabled	4T4R	Y
UCI multiplexed on PUSCH	4T4R	Y
PUCCH		
DTX to ACK probability	4T4R	N
Performance requirements for PUCCH format 0	4T4R	N
Performance requirements for PUCCH format 1	4T4R	N
Performance requirements for PUCCH format 2	4T4R	N
Performance requirements for PUCCH format 3	4T4R	N
Performance requirements for PUCCH format 4	4T4R	N
Performance requirements for multi-slot PUCCH	4T4R	N
PRACH		
Performance requirements for PRACH	PRACH False alarm probability	N

	PRACH detection requirements	N

Aerial CUDA-Accelerated RAN Features for 5G gNB

The 5G gNB capabilities, procedures, and interfaces have dependencies on Aerial CUDA-Accelerated RAN PHY Layer. The purpose of this section is to ensure that the Aerial CUDA-Accelerated RAN provides support for gNB capabilities, procedures, and interfaces.

Highlights

- PUCCH Format 1 I+N and SINR, DTX for UCI on PUSCH
- Predefined BeamId support
- Foxconn O-RU support
- Cell life cycle management
- 4T4R TDD 7 beam support
- 8-port CSI-RS
- Dynamic OAM supporting out-of-service updates:
    1. Dest MAC and VLAN ID
    2. exponent_dl
    3. dl_iq_data_fmt
    4. ul_iq_data_fmt
    5. exponent_ul
    6. max_amp_ul
    7. section_3_time_offset
    8. pusch_prb_stride

9. prach_prb_stride
10. fh_len_range
11. lower_guard_bw
12. gps_alpha (Shared across cells)
13. gps_beta (Shared across cells)
14. prachRootSequenceIndex
15. prachZeroCorrConf
16. numPrachFdOccasions
17. restrictedSetConfig
18. prachConfigIndex
19. K1

- Fronthaul Extension to 50km
- Simultaneous fronthaul ports for higher fronthaul bandwidth
- Multiple BandWidth Part (BWP) support
- 4T4R TDD bandwidth 10MHz, 30MHz, 40MHz, 50MHz and 80MHz
- Carrier aggregation:
    1. 100MHz + 80MHz
    2. 100MHz + 40MHz
    3. 80MHz + 40MHz
    4. 100MHz + 80MHz + 40MHz

- L1 startup time within 30sec
- Support for multiple L2 on a single converged card
- Cell-Id starts from 0 for all pods

Capabilities

Homogeneous Cell Lifecycle Mgmt - Cell State Mgmt (IS/OOS)

Feature	Supported
Ability to support cell activation and de-activation. This is commonly refered to as taking a carrier OOS (Out of Service) and bringing it to IS (In Service) states	Y

Procedures

Aerial CUDA-Accelerated RAN Overall Beam and Carrier Mobility

Feature	Configuration	Supported
Inter-gNB Handover	UE moves from 1 gNB to another gNB • UL RRC transfer • UE Context Modification Request/Response • UE Context Release • Serving and Target gNB cells can support different frequencies	N
Intra-DU Handover	Cell-level Mobility - UE establishes new connection to new carrier (inter-cell) supported by UE context modification procedure • UE Context Modification Request/Response • UE Context Release • Serving and Target Cells can support different frequencies	N

Beam Mobility	UE establishes data path to new beam within carrier coverage (intra-cell)	N
Mobility at low speeds	Aerial CUDA-Accelerated RAN shall support pedestrian mobility by modeling the 3GPP channels and 38.104 requirements	N
Mobility at vehicular speeds	Aerial CUDA-Accelerated RAN shall support mobility at high vehicular speeds - upto 70mph (Doppler Shift = 400Hz)	N

UL Power Control

Feature	Description	Supported
Single UE Power Control	BS initiated power control for single UEs	Y
UE Group Power Control	BS initiated power control for UE groups	Y

Carrier Aggregation

Feature	Description	Supported
Carrier Aggregation	Transmissions in multiple cells can be aggregated to support **inter-band and intra-band configurations**	Y
100MHz	Up to 2 cells aggregation(1CC,2CC) intra-band contiguous	Y
	Up to 2 cells aggregation(1CC,2CC) intra-band non-contiguous	Y
	Up to 4 cells aggregation(1CC,2CC,3CC,4CC) inter-band non contiguous	Y
Narrowband Carrier Aggregation (ZMhz)	Configurable upto 4 component carriers	Y

Interfaces

gNB Interfaces

Interface	Supported
NG Interface (TS 38.410)	Y
Xn interface (TS 38.420)	N
F1 interface (TS 38.470)	N
E1 interface (TS 38.460)	N
Front Haul interface - ORAN 7.2 Split (CUS version 3)	Y
E2 interface	N
O1 interface	N

Network, Services, and KPIs

This section includes E2E integration configuration and KPIs for appropriate NEs across 5G RAN, CN, and 5G infrastructure.

Highlights

- 4 Peak Cells validated in K1RF and eCPRI setup. 8 Average cells (50% traffic) also validated in eCPRI setup
- 4 DL Layers and 2 UL Layers supported in 4T4R configuration
- 6 UE/TTI Supported
- Simultaneous Front Haul capability. Multi L2 also validated with each L2 supporting different cells.
- 1 Cell OTA verified

E2E Summary

- 8 Cells in E2E configuration (CN + RAN + UE-EM) via eCPRI connection to test equipment

  (Achieving aggregate DL throughput of 4.2Gbps which is 530MBps per cell)

- 4 Peak Cells in E2E configuration (CN + RAN + UE-EM) via RF cabled connection to O-RU

(Achieving aggregate DL throughput of 5.6Gbps and UL throughput of 800Mbps)

- 3 Peak Cell in E2E configuration (CN + RAN + UE-EM) via eCPRI connection to test equipment

  (Achieving aggreagte DL throughput of 4.2Gbps)

- 1 Peak Cell in E2E configuration (CN + RAN + UE-EM) via RF cable connection to O-RU

  (Achieving DL throughput of 1.3Gbps and UL throughput of 100Mbps)

- Simultaneous Front Haul capability (8 peak cells)

  (4 Peak cells per Front Haul port)

- 1 Cell OTA in E2E configuration (CN + RAN + CUE) via OTA connection to UE device

  (Achieving DL throughput of 871Mbps and UL throughput of 99Mbps)

- 1 Cell OTA in E2E configuration (CN + RAN + CUE) via OTA connection to UE devices

  (Achieving 8 CUEs connected for greater than 8 hours)

4T4R EA Overall Configuration and KPIs

Feature	Configuration	Supported
Release 15 SA	TDD 7.2 CatA	Y
Subcarrier spacing (SCS)	30kHz	Y
sub-6 frequency spectrum	n78 Germany (3700 - 3800 MHz)	Y
sub-6 frequency spectrum	n48 US CBRS (3550 - 3700 MHz)	Y
sub-6 frequency spectrum	N79	N
Channel bandwidth	100 Mhz	Y
MIMO Layers support	DL : 4 layer UL : 2 layer	Y
100MHz cells per GPU [AX800]	Up to 4 peak cells Up to 8	Y

	average cells (50%)	
100MHz cells per GPU [GH200]	Up to 10 peak cells Up to 20 average cells (50%)	Y
Peak throughput per cell	DL : 1.38 Gbps per cell UL : 210 Mbps per cell	Y
Number of RRC Connected UEs per cell	100	Y
Number of active data transmitting UEs per cell	256	N
Number of UEs/TTI	DL : 16 UE/TTI UL : 16 UE/TTI	Y
Frame structure and slot format	DDDSUUDDDD S = 6:4:4 (DL: G: UL)	Y
	DSUUUDSUUU	N
	DDDSU	Y
User plane latency (RRC connected mode)	10ms one way for DL and UL	Y
Synchronization and Timing support	IEEE 1588v2 PTP / SyncE ORAN LLS-C3	Y
MTU size	1500 bytes	Y
Modulation	256 QAM DL 256 QAM UL	Y
Soak Testing	8 hours	Y

Aerial CUDA-Accelerated RAN Overall ORU Ecosystem

ORU	Configuration	Freq Band	Supported
Foxconn RPQN-7801E	4T4R	3.7GHz - 3.8GHz (indoors)	Y
Fujitsu TA08029-B059	4T4R	3.6GHz - 3.7GHz	Y
Foxconn RP0N-7800	4T4R	3.7GHz - 3.8GHz (outdoors)	N
Fujitsu MU-MIMO	32T32R	3.7GHz - 3.8GHz	N

Foxconn RPQN-4800E	4T4R	CBRS 3.55GHz - 3.7GHz, indoor	N

Aerial CUDA-Accelerated RAN Overall UE Ecosystem

UE	Configuration
Camera FourFaith Camera F-SC241-216-5G	SU-MIMO 4DL, 1UL
Camera FourFaith Camera F-SC241-216-5G (EU)	SU-MIMO 4DL, 2UL
Handset OnePlus Nord 5G AC2003 EU/UK Model	SU-MIMO 4DL, 1UL
Handset Oppo Reno 5G	SU-MIMO 4DL, 1UL
Handset Samsung S22	SU-MIMO 4DL, 1UL
Handset Samsung S23	SU-MIMO 4DL, 1UL

5G Infrastructure Integration

5G RAN Integration

Function	Features	Supported
gNB	Baseband functions for • signal processing using multiple antennas • signal processing for detecting and correcting errors in the wireless transmission • signal processing to ensure that the wireless transmission is secure • managing the wireless resources efficiently between different devices in the network	Yes
O-RU	Radio functions to convert digital information into signals that can be transmitted wirelessly, ensuring that the transmitted signals are in the right frequency bands and have the correct power levels. Includes antennas which radiate the electrical signals into radio waves	Yes
UE	End user devices such as smartphones, routers, tablets, HMDs, CPEs	Yes

5G Mobile Core (NGC) integration

Function	Features	Supported
AMF Core Access and Mobility Management Function	Connection and reachability management, mobility management, access authentication and authorization, location services	Yes
SMF Session Management Function	UE session, including IP address allocation, selection of associated UP function, control aspects of QoS, and control aspects of UP routing.	Yes
PCF Policy Control Function	Manage policy rules that other CP functions then enforce.	Yes
UDM Unified Data Management	Manage user identity, including generation of authentication credentials.	Yes
AUSF Authentication Server Function	Essentially an authentication server	Yes
UDR Unified Data Repository	Repository of subscriber information that can be used by other microservies. For example UDM	Yes
NCHF New Charging Function	Cover all the network's needs of charging and interaction with billing systems	Yes
CP - SDSF Structured Data Storage	"Helper" service used to store structured data.	Yes
CP - UDSF Unstructured Data Storage	"helper" service used to store unstructured data.	Yes

CP - NEF Network Exposure Function	Expose select capabilities to third-party services, including translation between internal and external representations for data. Could be implemented by an “API Server” in a microservices-based system.	N
CP - NRF NF Repository Function	A means to discover available services.	N
CP - NSSF Network Slicing Selector Function	A means to select a Network Slice to serve a given UE. Network slices are essentially a way to partition network resources in order to differentiate service given to different users.	N
UP - UPF User Plane Function	Forwards traffic between RAN and the Internet. In addition to packet forwarding, it is responsible for policy enforcement, lawful intercept, traffic usage reporting, and QoS policing	Y

5G NSE Overall Network Deployment Topologies

Topology	**Configuration**	**Supported**
On Prem Isolated Island	Co-located gNB + CN + MEC applications	Yes
Colocated 5G infra with low latency MEC applications + centralized 5GC	MEC applications + gNB + UPF with centralized 5G CN (CUPS support - with SBA and to minimize latency in user plane)	N
Campus Distributed MEC applications (latency tolerant)	Campus Distributed MEC applications + colocated (gNB + UPF + CN) - (Non latency sensitive applications can be distributed and leverage an existing enterprise network data stream)	N
CUPS Architecture Support		N

Aerial E2E Reference BOM and Component Manifest

5G Infra Component	HW and SW Revision Manifest	Supported
gNB	Gigabyte Edge E251-U70 Server x 1	Y
	Dell PowerEdge R750 Server	Y
	Altran L2+	N
CN	Dell PowerEdge R750 Server	Y
	Altran CN	N
FH Switch	Dell PowerSwitch S5248F-ON	Y
	Adva switch FSP 150 XG400	Y
	Spectrum switch SN3750X	N
	Ciena switch 5164	Y
	Cisco switch N9K-C93180YC-FX3S	Y
GM	QULSAR Qg 2 Multi-Sync Gatway	Y
Cables	Dell C2G 1m LC-LC 50/125 Duplex Multimode OM4 Fiber Cable - Aqua - 3ft – Optical patch cable	Y
	NVIDIA MCP1600-C001E30N DAC Cable Ethernet 100GbE QSFP28 1m	Y
	Beyondtech 5m (16ft) LC UPC to LC UPC Duplex OM3 Multimode PVC (OFNR) 2.0mm Fiber Optic Patch Cable	Y
	CableCreation 3ft Cat5/Cat6 Ethernet Cables	Y
PDUs	Tripp Lite 1.4kW Single-Phase Monitored PDU with LX Platform Interface, 120V Outlets (8 5-15R), 5-15P, 12ft Cord, 1U Rack-Mount, TAA	Y
Transceivers	Finisar SFP-to-RJ45 Transceiver	Y
	Intel Ethernet SFP+SR Optics	Y
	Dell SFP28-25G-SR Transceiver	Y
Ethernet Switch	Netgear ProSafe Plus JGS524E Rackmount	Y

Supported O-Rus

ORU	Configuration	Freq Band	Supported	New
Foxconn RPQN-7801E	4T4R	3.7GHz - 3.8GHz (indoors)	Y	
Fujitsu TA08029-B059	4T4R	3.6GHz - 3.7GHz	Y	
Foxconn RP0N-7800	4T4R	3.7GHz - 3.8GHz (outdoors)	N	New
Fujitsu MU-MIMO	32T32R	3.7GHz - 3.8GHz	N	New
Foxconn RPQN-4800E	4T4R	CBRS 3.55GHz - 3.7GHz, indoor	N	New

Supported UEs

UE	Configuration	Peak Tput	Supported
Camera FourFaith Camera F-SC241-216-5G	SU-MIMO 4DL, 1UL	DL NA UL NA	Y
Camera FourFaith Camera F-SC241-216-5G (EU)	SU-MIMO 4DL, 2UL	DL UL	Y
Handset OnePlus Nord 5G AC2003 EU/UK Model	SU-MIMO 4DL, 1UL	DL 850Mbps UL 55 Mbps	Y
Handset Oppo Reno 5G	SU-MIMO 4DL, 1UL	DL 850Mbps UL 55 Mbps	Y
Handset Samsung S22	SU-MIMO 4DL, 1UL	DL NA UL NA	Y
Handset Samsung S23	SU-MIMO 4DL, 1UL	DL NA UL NA	Y