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Agenda Item: 5

RWS-230006

# Fast Beam Management and Capacity Enhancement for Release 19

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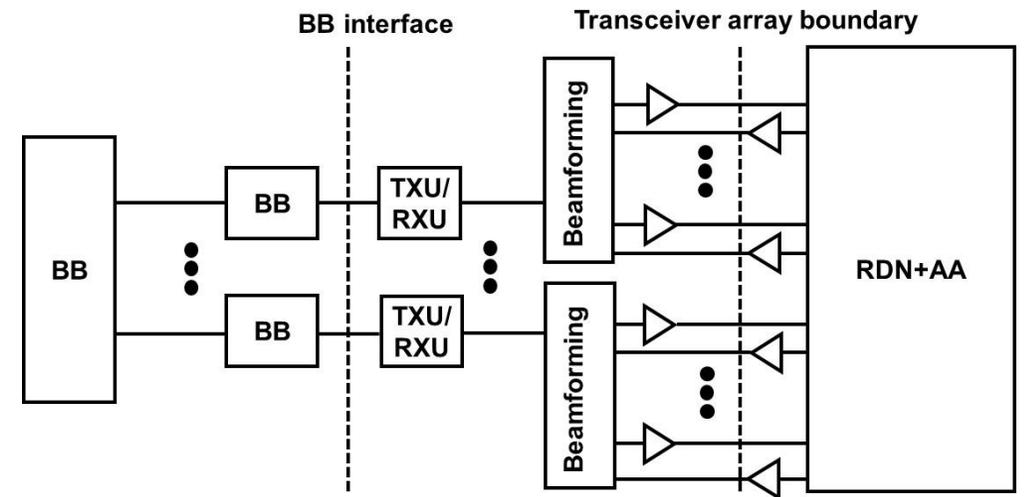


# Outline

- **Fast beam management (BM) enhancements**
  - Motivations
  - New antenna architecture for fast BM
  - Beam acquisition procedure
  - Performance benefits
- **Capacity enhancements**
  - Motivations
  - Cooperative MIMO w/ non-ideal backhaul
  - MIMO transmission schemes for XR and URLLC

# Fast BM Enhancements: Motivations

- Better utilization of spectrum with higher frequency is critical, including FR2 and high-middle band
  - Larger number of narrow beams are required to combat higher propagation loss and provide sufficient coverage at higher frequency.
  - Hybrid beamforming with small number of digital chains and corresponding BM procedure (beam sweeping through P1, P2, and P3, and reporting) is slow with high overhead and results in frequent beam failure events.
  - Enhancements in R17/18 on beam indication does not solve the fundamental issue. What AI/ML-based algorithm can do is also limited.

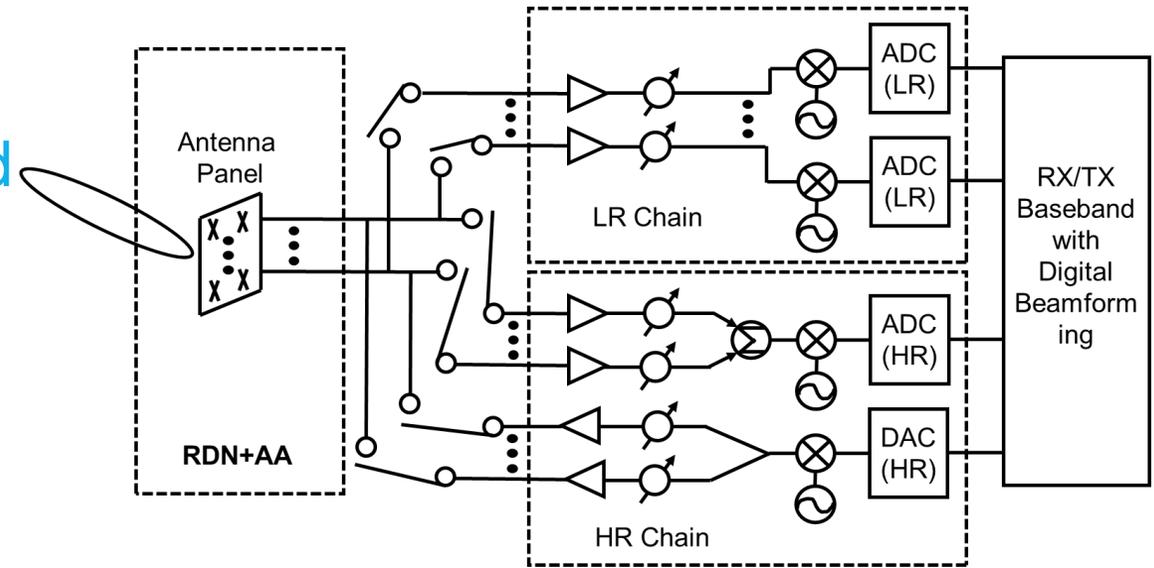


Conventional hybrid beamforming architecture

BB: baseband  
RDN: radio-distribution network  
AA: adaptive antenna

# Fast BM Enhancements: New Antenna Architecture

- A new antenna architecture with two parts is proposed to take advantage of analog/hybrid antenna architecture and the all-digital antenna architecture for very fast BM:
  - A low-resolution digital array only for the receiver **adds to** an analog/hybrid array with a small number of high-resolution digital chains for both transmitter and receiver. The two arrays can share antenna panels.

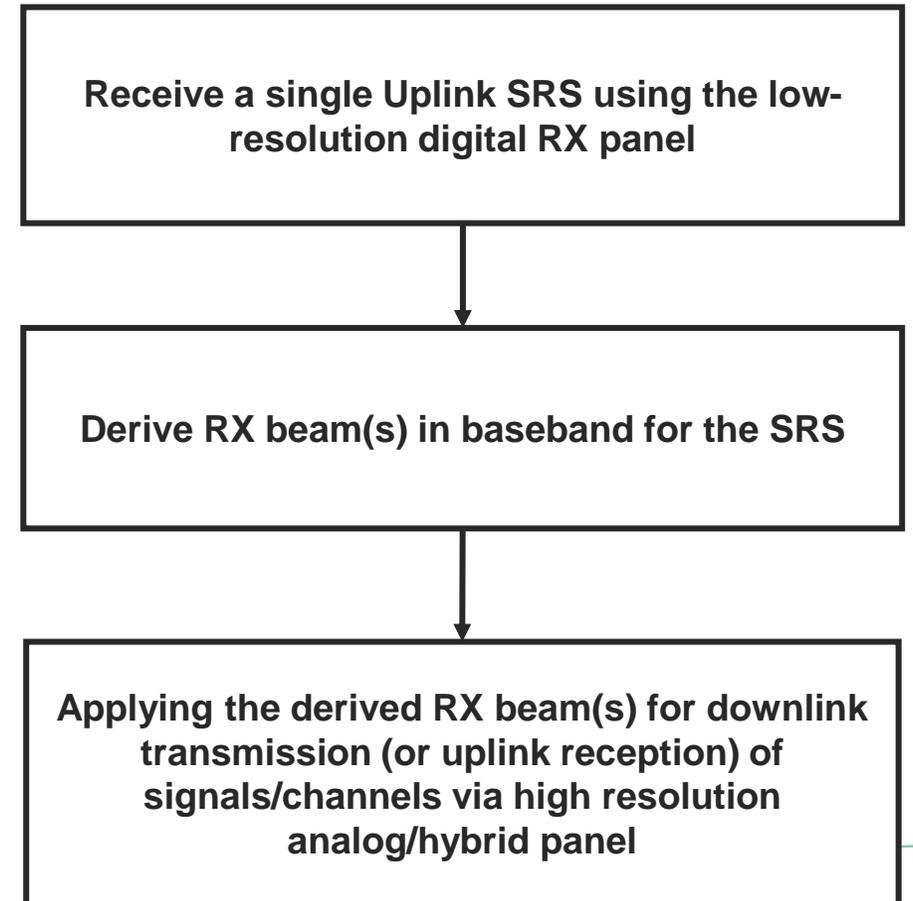


LR all digital array and analog/hybrid array share antenna panels

LR: low-resolution  
HR: high-resolution  
RDN: radio distribution network  
AA: adaptive antenna

# Fast BM Enhancements: Beam Acquisition Procedure

- Beam acquisition is performed using the low-resolution digital array by receiving signal and deriving the best beam(s) at baseband **without beam sweeping**
- Acquired beam(s) are then applied for data/control channel/signal reception and transmission (using analog/hybrid array) assuming beam correspondence
- Very fast beam acquisition and recovery can be achieved



# Fast BM Enhancements: Performance Benefits

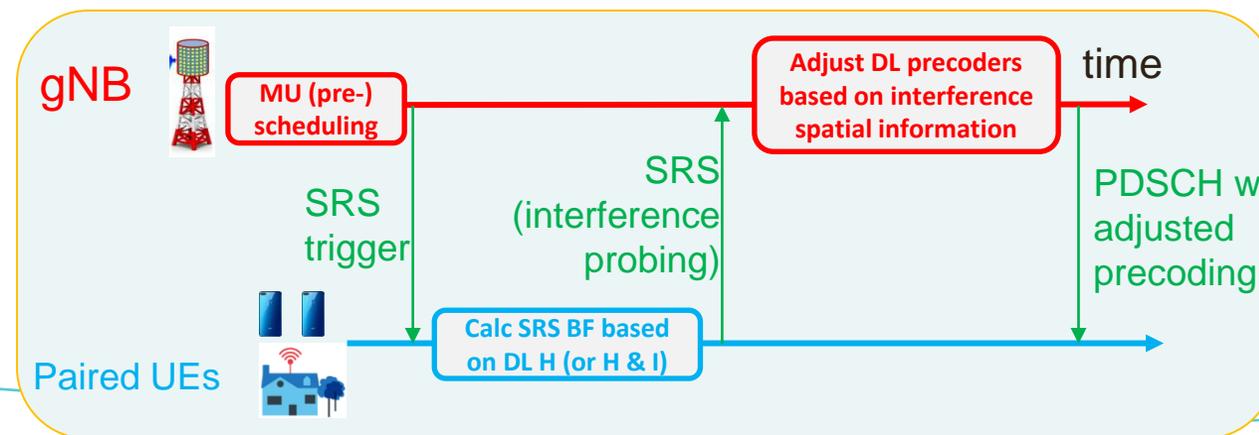
- **Very fast (one-step) beam acquisition**
  - Beam acquisition is performed through baseband processing in a single step
  - Acquired beam(s) are applied for data/control channel reception and transmission assuming beam correspondence
  - No beam sweeping/reporting steps (P1/P2/P3), removes the largest portion of BM latency and leads to much faster beam acquisition and recovery
- **Good tradeoff between fast BM, cost, and power consumption**
  - Only beam acquisition is performed via digital array, low resolution ADC can be used to reduce cost and power consumption significantly
  - No need of all digital array (or array with high number of digital chains) for beamformed transmission
- **Moderate standards impacts**
  - Current beam/TCI indication framework can be largely reused with some simplification and modification

# Capacity Enhancements: Motivations

- **Areas demand higher efficiency / more capacity**
  - XR and multi-modality services:
    - Emerging applications: Edge computing immersive XR, digital twins, metaverse, tele-inspection, etc.
    - RAN status: Little enhancement for XR capacity; Only several XR devices per cell per 100 MHz BW
  - URLLC w/ higher data rate:
    - Emerging applications: Smart factories, automatic guided vehicles (AGV), IIoT, emergency response, etc.
    - RAN status: Mainly focused on low SE/capacity scenarios; not suitable for high SE/capacity requirements
  - Cell-edge:
    - Emerging applications require more uniform, cell-center-like user experience in the entire network
    - Still need significant improvement on cell-edge performance despite of existing MIMO/M-TRP schemes
  - And more: Network enabled robotics and autonomous agents/systems, distributed AI...
- **MIMO enhancements for things beyond eMBB/data channel**
  - Existing MIMO schemes are designed for eMBB/data channel without considering the uniqueness of services such as XR, URLLC, etc.
  - MIMO should be considered as the top candidate for meeting the SE/capacity requirements for applications beyond eMBB/data channel
- **Candidate solutions**
  - Cooperative MIMO w/ non-ideal backhaul
  - MIMO transmission schemes for URLLC and XR traffics

# Cooperative MIMO w/ non-ideal backhaul (1/2)

- Downlink interference avoidance via SRS utilizing DL/UL reciprocity
  1. Precoded SRS associated w/ MU scheduling is used at the network to cooperatively probe downlink interference conditions
  2. Downlink precoding for inter-/intra-cell interference avoidance based on step 1
- Distributed operation across gNBs/TRPs without channel information exchange, well suit for non-ideal backhaul
  - Network only needs to coordinate resources for SRS interference probing and PDSCH transmission in a semi-static manner
  - **No** scheduling / channel / interference information exchange needed among gNBs



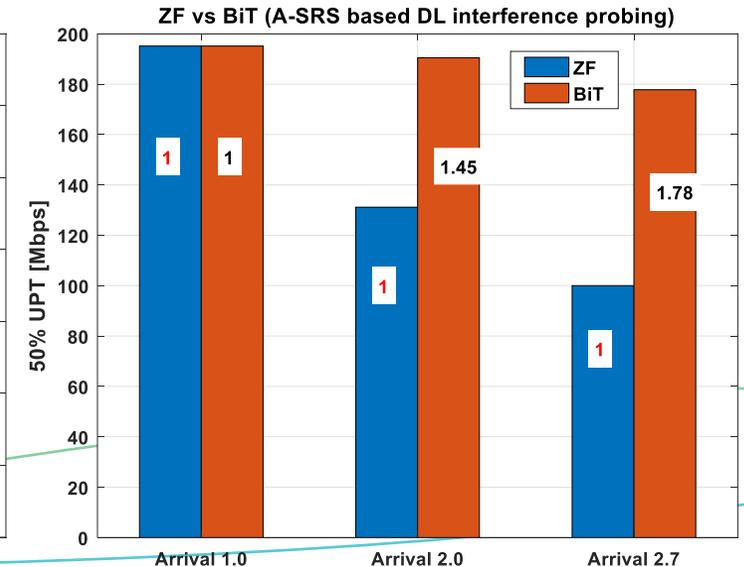
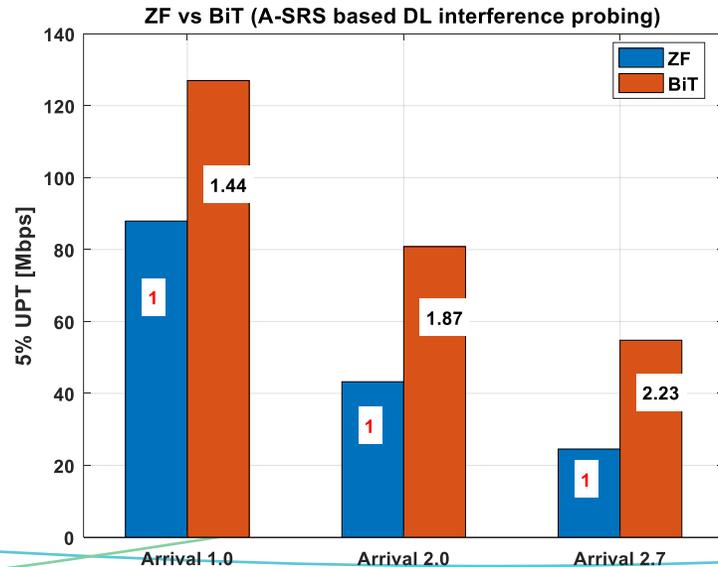
# Cooperative MIMO w/ non-ideal backhaul (2/2)

- Substantial capacity gain (up to over 50%) observed for XR and FTP traffics
  - A specific implementation of Cooperative MIMO precoding via Bi-Directional Training (BiT)

App	PDB	Bit rate	Fps	Capacity					
				[DDDUU]			[DDDSU]		
				ZF	BiT	BiT Gain	ZF	BiT	BiT Gain
AR/VR	10 ms	45Mbps	60	8	13.1	64.8%	12.2	16.9	38.5%
		30 Mbps	60	13.7	19.9	45.3%	21.7	25.8	18.9%
CG	15 ms	45Mbps	60	12.7	16.9	33.1%	17.4	21.7	24.7%
		30 Mbps	60	21.5	25.6	19.1%	27.1	30.1	11.1%

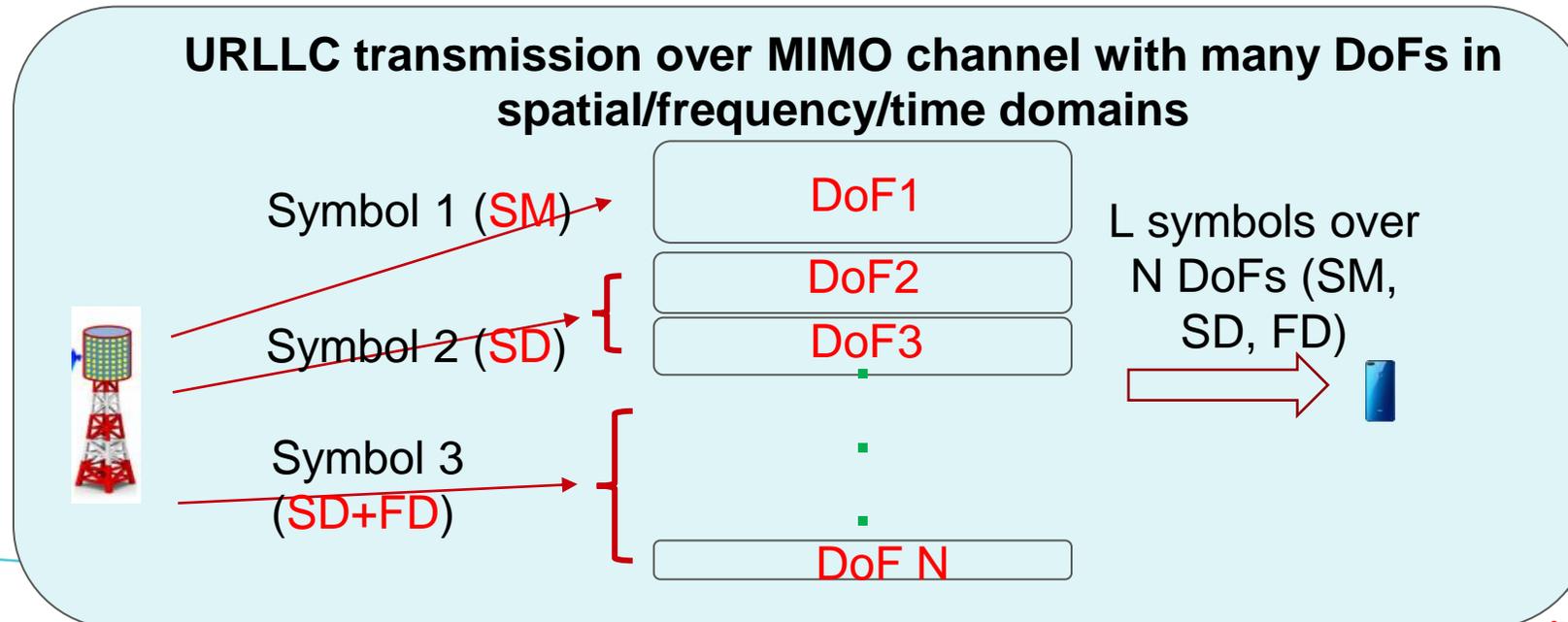
- XR Capacity Comparison of between ZF and BiT
- TR 38.835: Study on XR enhancements for NR

- FTP Traffic Performance Comparison between ZF and BiT
  - In the bars, the value “1” is for the baseline and the other value (such as “1.46”) is relative to the baseline)
- R1-2108794, Enhancements on SRS flexibility, coverage and capacity, Futurewei, 3GPP TSG RAN WG1 Meeting #106bis-e



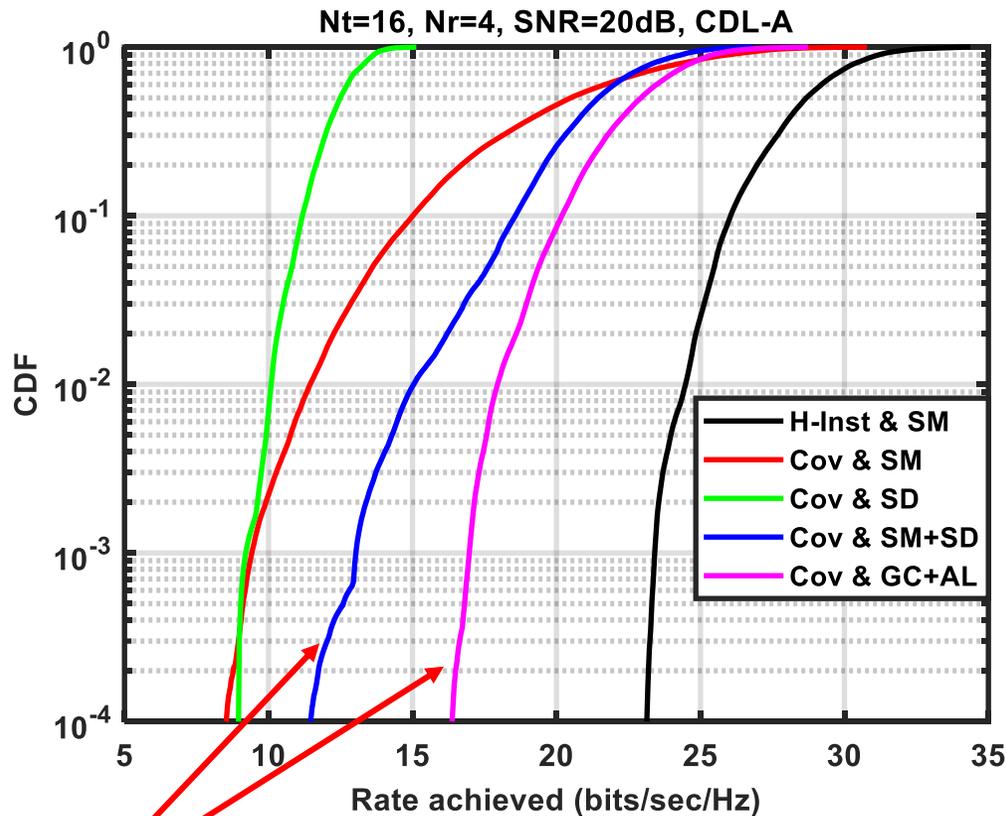
# MIMO Transmission Schemes for URLLC/XR (1/2)

- Utilize the many Degrees of Freedom (DoFs) offered by MIMO channel for URLLC/XR
  - Massive MIMO can provide many DoFs in spatial, frequency, temporal domains
- Tradeoff between capacity and reliability (via. multiplexing and diversity)
  - Adapt MIMO transmission scheme (combination of multiplexing and diversity) according to channel condition (e.g., mid/long term statistics) and traffic performance requirements (data rate and reliability)
  - Maximize data rate while satisfying reliability performance



# MIMO Transmission Schemes for URLLC/XR (2/2)

- Substantial improvement of achievable data-rate with high reliability



Joint multiplexing + diversity scheme perform the best

- **H-inst & SM**: using genie instantaneous channel matrix with spatial multiplexing (as an unachievable upper bound)
- **Cov & SM**: using channel covariance matrix with spatial multiplexing
- **Cov & SD**: using channel covariance matrix with spatial diversity
- **Cov & SM+SD**: using channel covariance matrix with joint spatial multiplexing and spatial multiplexing
- **Cov & GC+AL**: using channel covariance matrix with joint Golden Code and Alamouti Scheme (further enhanced spatial multiplexing and spatial multiplexing)

# Thank You.

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