3GPP TSG RAN#101
Bangalore, India – September 11th – 15th, 2023

RP-232325
Agenda Item 8A.2.13.6

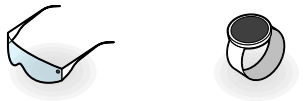
rev. of RWS-230111

[RAN1-led] Device collaborative Tx and Rx

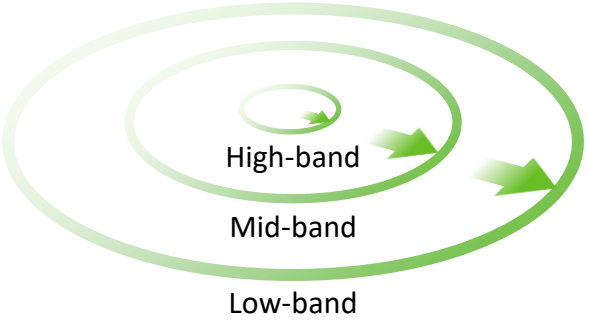
MediaTek Inc.

Motivation
Personal Area Network

- Issue 1: Device form-factor restrictions
  - Bottleneck of MIMO gain, due to physical limitations in the number of feasible Tx and Rx antennas



- Issue 2: Worse propagation/coverage properties in higher frequencies
  - Limit maximizing MIMO gain even in case more device antennas are feasible



- More and more users carry a multiplicity of devices
  - incl. smartphones, tablet, wearables, etc. – a trend we expect will strengthen (e.g. XR, new form-factors)
    - These devices often operate "together" e.g. via BT tethering (voice calls, remote phone camera shutter etc.)
  - Such personal network of devices open some opportunity for greater collaboration that can address Issues 1 and 2.

The collective PHY capability of devices in close proximity can offer much greater performance than with a device alone.

Motivation
UE Collaboration at Lower Layers

- **UE aggregation at PDCP layer** has been studied in R18 where the UE is connected to the network via direct path and via another UE using a non-standardized UE-UE interconnection as shown below [*RP-223501*].

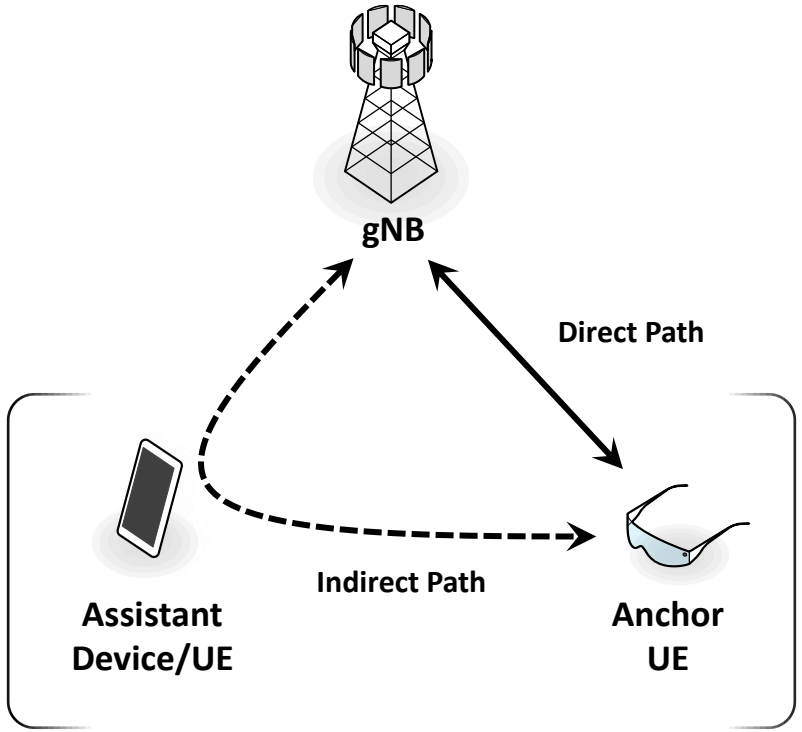
> *This multi-path relay solution can also be utilized to for UE aggregation where a UE is connected to the network via direct path and via another UE using a non-standardized UE-UE interconnection. UE aggregation aims to provide applications requiring high UL bitrates on 5G terminals, in cases when normal UEs are too limited by UL UE transmission power to achieve required bitrate, especially at the edge of a cell. Additionally, UE aggregation can improve the reliability, stability and reduce delay of services as well, that is, if the channel condition of a terminal is deteriorating, another terminal can be used to make up for the traffic performance unsteadiness caused by channel condition variation.*

- However, **UE aggregation at PDCP Layer is far from enough**

- **UE collaboration at lower layers** can provide benefits over PDCP aggregation, including lower resource consumption, higher throughput, higher reliability, and lower latency.

Target Scenario
General

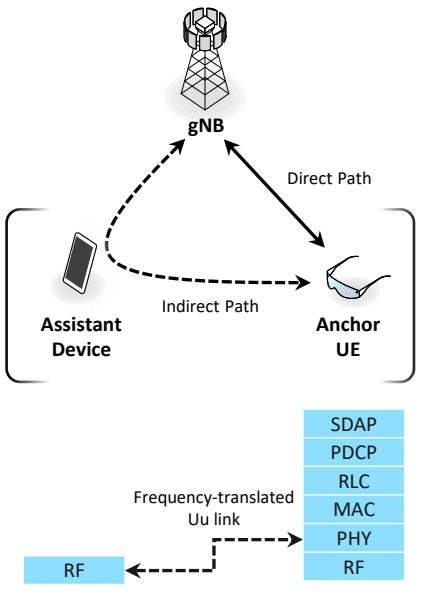
- NR should support means for low-layer collaboration between an anchor UE and an assistant device/UE to achieve high reliability/throughput, where
  - Anchor UE: typ. form-factor constrained e.g., XR glasses
  - Assistant device/UE: e.g., smartphone, CPE
- The anchor UE and assistant device/UE are assumed to be in close proximity (e.g. ≤10 meters) of each other
- Use cases
  - Path combining: Use both direct and indirect paths for data transfer to achieve high throughput (via higher rank)/reliability
  - Path switching: Use either direct path or indirect path for data transfer to achieve improved reliability or power saving



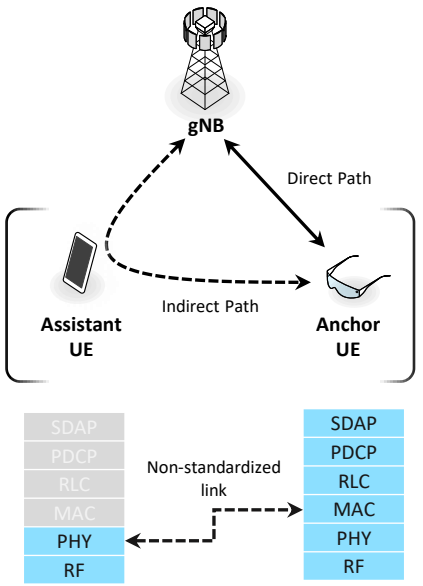
Rel-19 UE Collaboration

Potential Solutions with Initial Evaluation

Use Case		Mechanism	Physical Layer Aspect	Protocol Stack	Gain
UE collaboration at lower layers	**A-1**: Path combining	**Transparent scheme (assistant "device" is transparent to the gNB)** • Assistant device acts as an external antenna panel wirelessly connected to the anchor UE • Uu link for UE-device interconnection based on L1 amplify-and-forward with frequency translation (L1 FT-Fwd) • Anchor UE controls assistant device via control info. which is based on gNB control info. **Non-transparent scheme (assistant "UE" is non-transparent to the gNB)** • Assistant UE provides complete physical layer functions, including baseband and RF • Non-standardized UE-UE interconnection, e.g., WiFi or BT • gNB directly controls the assistant UE	**Transparent scheme** • gNB schedules resources and transmits/receives data to/from the Anchor UE with upgraded capability to cover also assistant device capability. • Anchor UE performs joint DL/UL Rx/Tx from/to direct link and indirect link with two different frequency bands **Non-transparent scheme** • Both group scheduling and UE-specific scheduling seem to be required • gNB transmits/receives the same data (data duplication) or different data (data split) on the same resources or different resources to/from the Anchor UE and the Assistant UE	**Transparent scheme** • Combining and switching (across 2 bands) at PHY layer • Data processing (SDAP, PDCP, RLC, MAC, PHY) is performed at anchor UE as legacy (no impact on protocol stack) **Non-transparent scheme** • Combining and switching at MAC layer • Data processing of the higher layer (SDAP, PDCP, RLC, MAC) is performed at anchor UE • NOTE: inter-UE coord required at network side (SA2 work expected)	Mean UPT increase: • DL: 37% [1] • UL: >59% [2], 51%[1] RU reduction: • 49%~55% [2] Successful packages increase: • 43% [2]
	A-2: Path switching		**Transparent scheme** • gNB schedules resources and transmits/receives data to/from anchor UE • Anchor UE performs DL/UL Rx/Tx from/to direct link OR indirect link with two different frequency bands at any one time **Non-transparent scheme** • No group scheduling needed (compared to Path Combining case)		Mean UPT increase: DL: 14%,UL:28%[1]



Transparent scheme



Non-transparent scheme

NOTE

1. The UPT gain comes from dynamic low layer aggregation/switch, including reduced resource utilization, increased antenna capability, HARQ combining, better diversity and avoid unnecessary HARQ re-transmission etc.
2. For A-1 and A-2, the data can be split/switched dynamically and efficiently according to instant channel conditions and available physical resources for each UE (e.g., time/ frequency resources or rank or power).

Work Scope

Objectives

- Study the use cases and evaluate the performance benefits for UE collaboration at lower layers [RAN1]
  - The application scenario consists of an anchor UE and an assistant device/UE
  - The anchor UE and the assistant device/UE are assumed to be in close proximity (e.g. ≤10 meters)
  - Use cases are defined as:
    - Path combining and path switching
  - Performance metrics at least including reliability, spectrum efficiency, data rate, power consumption and hardware requirements etc.

- Study candidate solutions to enable UE collaboration at lower layers [RAN1, RAN2, RAN4]
  - Identify necessary functions/signaling for different use cases of UE collaboration at lower layers [RAN1, RAN2]
    - For transparent scheme (assistant device is transparent to the gNB), this should include the necessary control information from gNB/anchor UE to support UE-device interconnection based on L1 amplify-and-forward with frequency translation
    - For non-transparent scheme (assistant UE is non-transparent to the gNB) , this should include scheduling enhancement for different use cases of UE collaboration, e.g., group scheduling for coordinated transmission to allow multiple UEs to transmit same TB on the same resources, assuming non-standardized UE-UE interconnection
  - Study the feasibility of and impact on RF requirements considering L1 amplify-and-forward with frequency translation [RAN4]

Reference

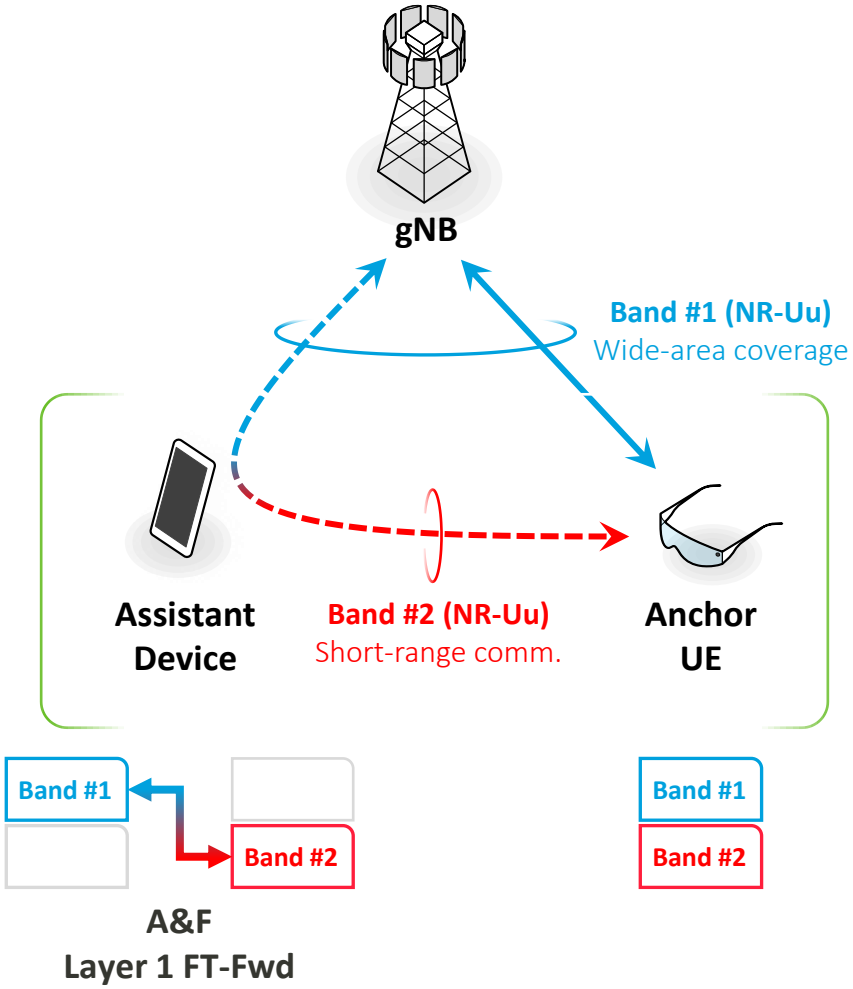
1. RWS-230111, Device Collaborative Tx and Rx, MediaTek, RAN R19 workshop. Taipei, June 15-16, 2023.
2. RWS-230288, Views on user virtualization and collaboration in Rel-19, ZTE. RAN R19 workshop. Taipei, June 15-16, 2023.
3. RWS-230425, Study on UE collaboration in R19, CMCC. RAN R19 workshop. Taipei, June 15-16, 2023.
4. RWS-230418, NR MIMO Enhancement in Rel-19, CMCC. RAN R19 workshop. Taipei, June 15-16, 2023.
5. RWS-230067, UE aggregation enhancement in Rel-19, VIVO. RAN R19 workshop. Taipei, June 15-16, 2023.
6. RWS-230232, Views on Rel-19 MIMO evolution. RAN R19 workshop. Taipei, June 15-16, 2023.

Appendix

Transparent Scheme
Layer-1 based antenna capability aggregation

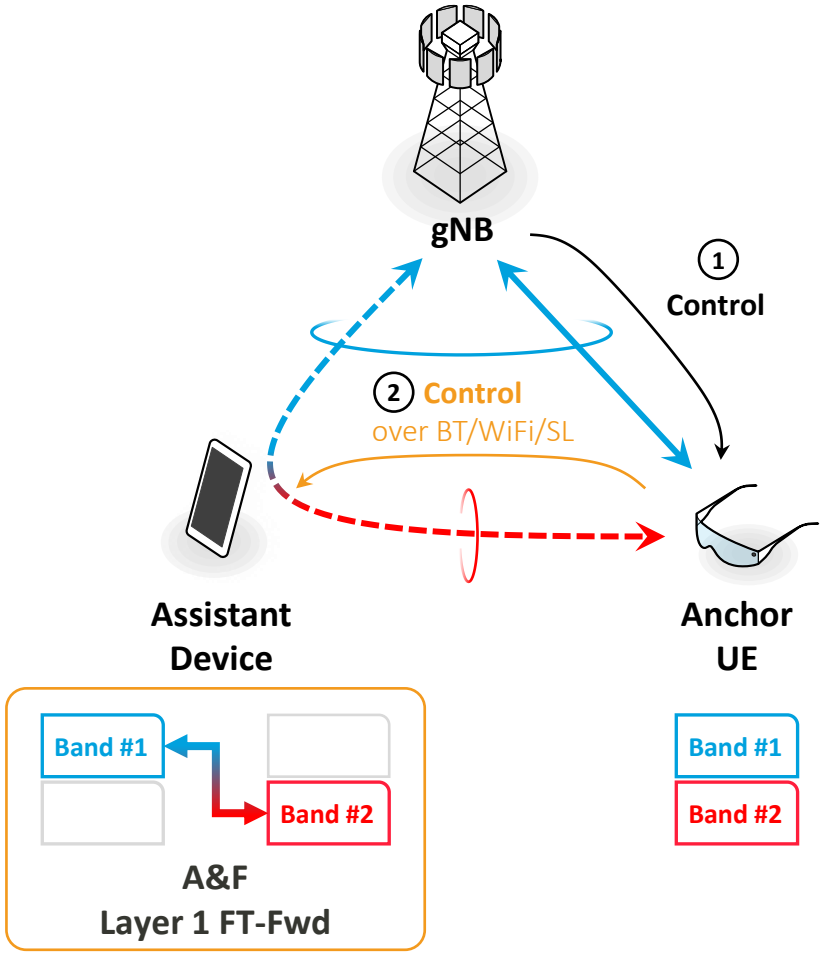
- Assistant device acts as an **external antenna panel** wirelessly connected to anchor UE
  - Performs **amplify-and-forward with frequency translation** (*Layer-1 FT-Fwd*) between Bands #1 and #2 with ~zero latency
    - Band #1: e.g., wide area coverage for gNB deployment, e.g., low-band or mid-band (2.5 or 3.5 GHz)
    - Band #2 e.g., limited geographical coverage, e.g., mid-band (4.7 or 6 GHz)
  - Transparent to the gNB (when operating as such device)
  - gNB can be informed by the anchor UE of the intention to use the "remote panel"
  - Anchor UE still controls the Layer-1 FT-Fwd behavior based on configuration from the gNB (See this slide for control)

- The gNB/Anchor UE performs data transfer:
  - **On a direct path** <> directly to/from gNB on Band #1; and
  - **On an indirect path** <> indirectly to/from gNB via the collaborative device with A&F and Layer-1 FT-Fwd between Bands #1 and #2
  - See this slide for possible operating schemes



Transparent Scheme
Collaborative device control

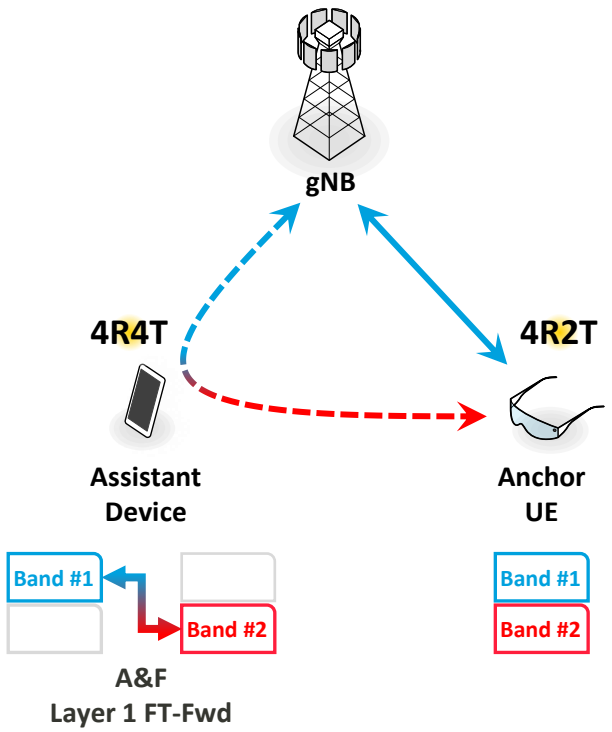
- A Control Interface between the anchor UE and the assistant device allows anchor the UE to control the **Layer-1 FT-Fwd behavior** under **constraints imposed by the gNB** (interference mitigation)
  - It operates over a paired connection (e.g., via BT, WiFi, NR Sidelink) between the anchor UE and the assistant device
  - The anchor UE provides Layer-1 FT-Fwd control information including Layer-1 FT-Fwd on/off, Band #1 configuration information, Band #2 configuration information, Tx power in Band #1, Tx power in Band #2, DL/UL split, etc.
  - The Layer-1 FT-Fwd control information is determined based on **gNB control information** (configuration/indication) including max Tx power in Band #2 (e.g. 10 dBm), candidate bands for Band #2, TDD pattern config, in order to minimize interference
  - The Layer-1 FT-Fwd control information could be specified at Stage 2 level
  - The **gNB control information** could be specified as side control information (similar to what was done for Rel-18 NCR)



Transparent Scheme

Tx/Rx schemes at the UE with aggregated antenna capability

- **Scheme #1: Path Combining**
  - Use both direct and indirect paths between gNB and anchor UE for data transfer with joint transmission/reception



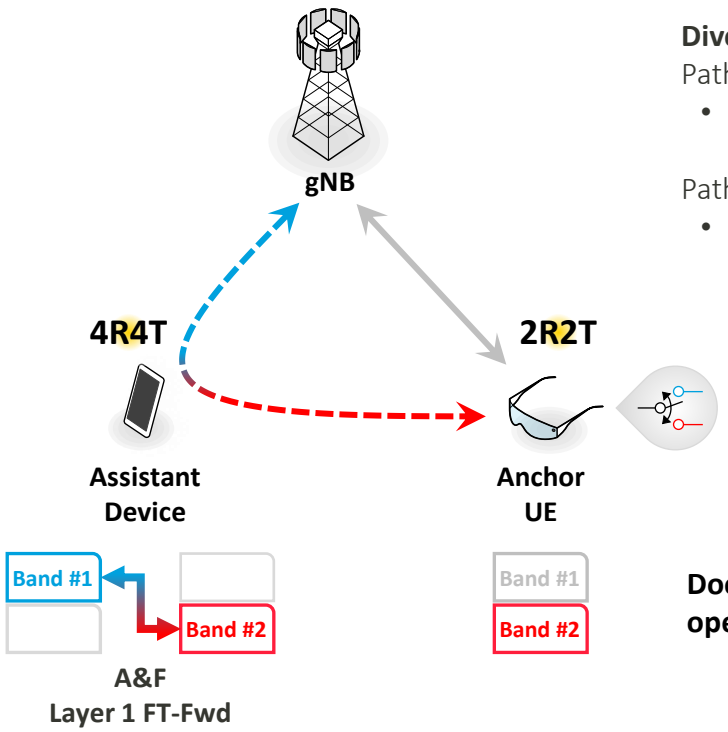
Rank Augmentation

DL: 4Rx → 4Rx + 4Rx:
- Mean DL UPT +~37%; 40% UEs with RI≥4

UL: 2Tx → 2Tx + 2Tx :
- Mean UL UPT +~51%; 90%UEs with RI>2

Requires joint Tx/Rx operation on Bands 1 and 2

- **Scheme #2: Path Selection**
  - Select either direct path or indirect path between gNB and anchor UE for data transfer at any one time



Diversity Augmentation

Path-selection:
- Mean DL UPT +~14%

Path-selection + Rx BF at UE:
- Mean DL UPT +~28%

Does not require joint Tx/Rx operation on Bands 1 and 2

UPT: User-perceived Tput