From Concept to Reality: 5G Positioning with Open-Source Implementation of UL-TDoA in OpenAirInterface

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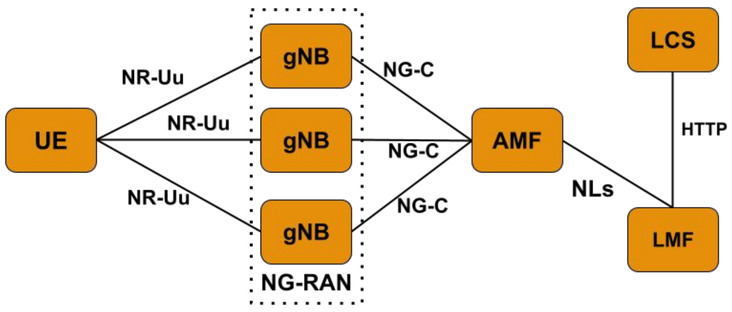
Introduction to 5G UL-TDoA Positioning

- 5G New Radio (NR) improves positioning accuracy, particularly indoors and in urban areas.
- While GPS and Wi-Fi face limitations in accuracy and latency
- UpLink Time Difference of Arrival (UL TDoA), is a positioning method defined by 3GPP that offers high-precision location tracking in 5G networks.

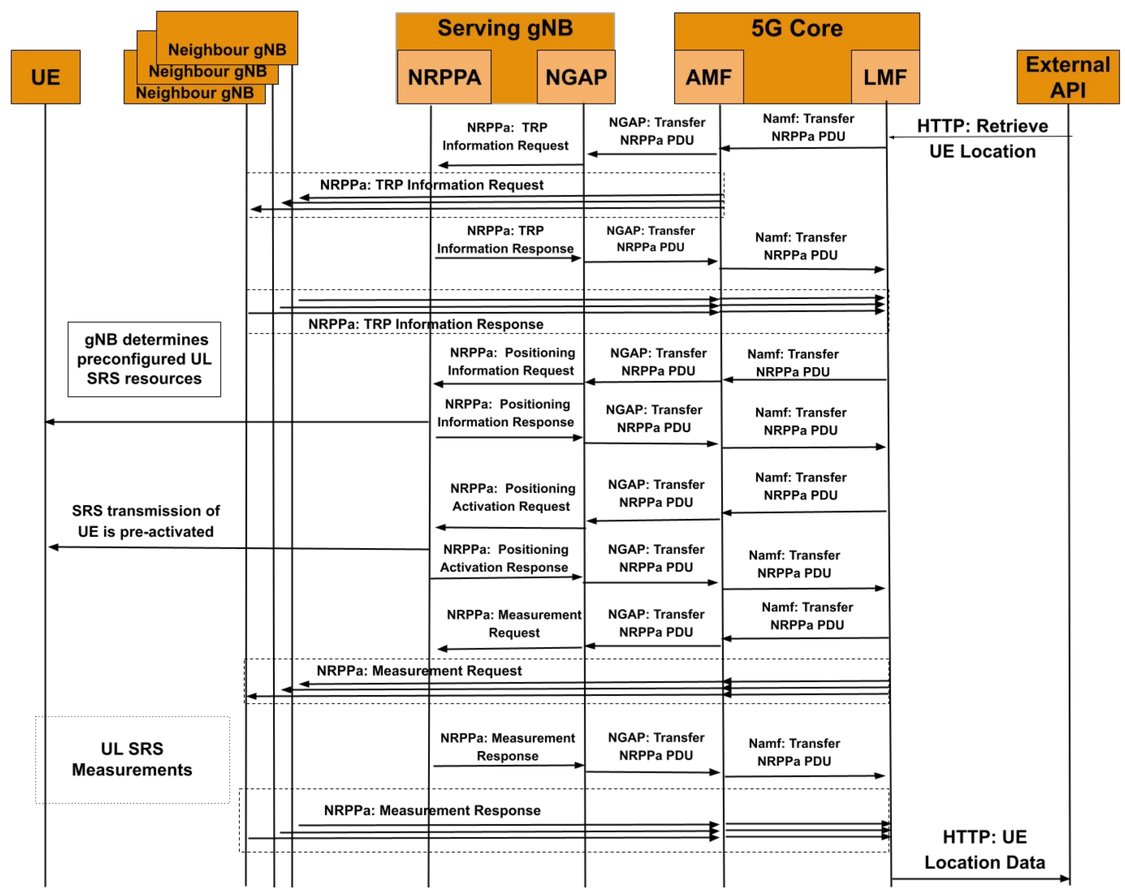


3GPP UE Positioning Architecture

- UE transmits UL Sounding Reference Signals (SRS) to gNBs
- Multiple ToAs are estimated by peak detection from Channel Impulse Responses and sent to Location Management Function (LMF) over New Radio Positioning Protocol (NRPPA)
- Tight synchronization between gNBs with known coordinates
- TDoA extracted from ToAs to resolves UE-gNB ref time issue
- Solving the nonlinear system of position equations between UE and gNBs to estimate the UEs coordinates on LMF
- Return the position estimation to a Location Service (LCS) API

Implementations of 3GPP Procedures for UL-TDoA Positioning in OAI

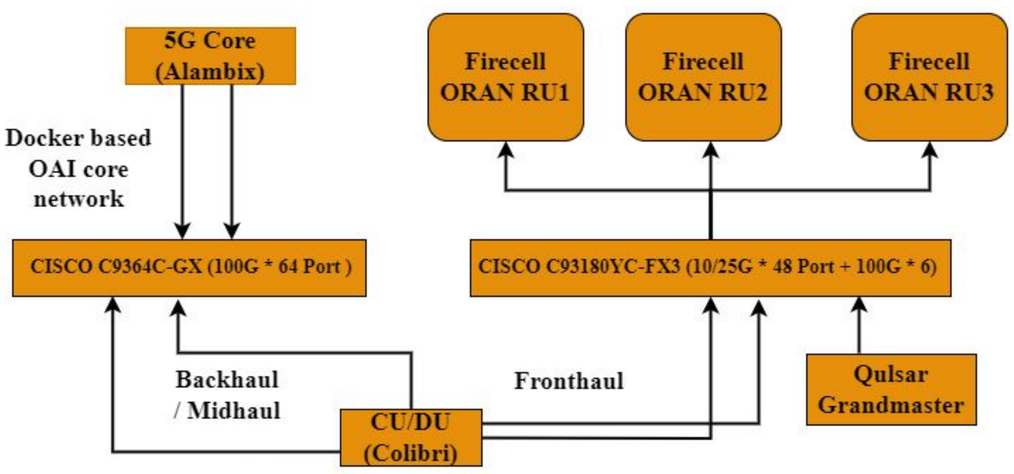
- **Contributions to OAI 5G RAN:**
  - Integration of NRPPa functionalities
  - Monolithic: Full support for UL-TDoA
  - Split Mode: Partial support for UL-TDoA
  - ToA estimation on OAI gNB
  - SRS generation and channel estimation
  - Interpolation and oversampling
  - NRPPa PDU Transfer between AMF-gNB
- **Contributions to OAI 5G CORE LMF:**
  - Implementation of LMF procedures
  - Integration of NRPPa functionalities
  - Integration of Algorithm for Geoloc
  - Framework to integrate user-defined Positioning Algorithm
  - NRPPa PDU transfer between AMF-LMF
- **Contributions to OAI 5G CORE AMF:**
  - NRPPa PDU Transfer protocol AMF-LMF
  - NRPPa PDU Transfer Protocol AMF-gNB



Live Demo: O-RAN BASED TESTBED AT EURECOM

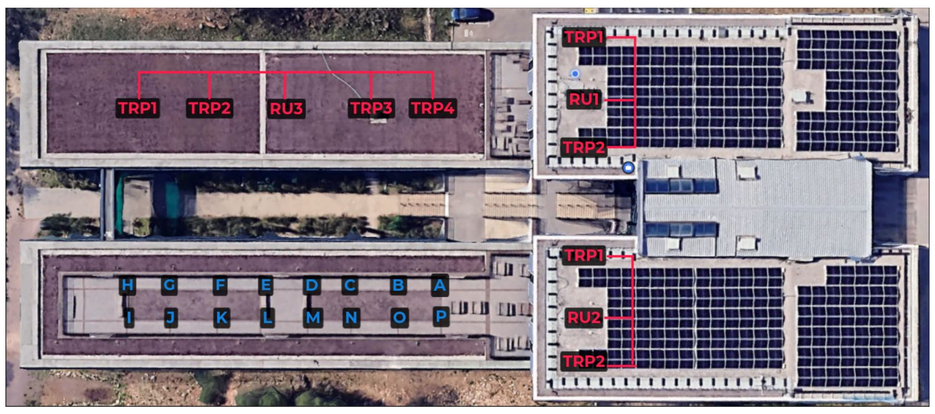
- The Firecell positioning testbed at EURECOM is designed for real-world validation of the UL-TDoA implementations.
- This testbed is equipped with Firecell Radio Units (RUs).
- It follows the O-RAN architecture to evaluate the accuracy and efficiency of 5G positioning in urban and indoor environments.

Logical Architecture of EURECOM Testbed



Ground Truth Measurements

- Measuring distance from test points A-P to all antennas
- Taking TRP1 on RU3 as reference (x=0, y=0)
- Solving the system of equations for all test points in cartesian coordinate



Firecell Low Power O-RAN RU

NR Radio Specification	
Band	n77
Occupied Bandwidth(max)	100MHz
Duplex Mode	TDD
Sub Carrier Spacing	30KHz
MIMO	4T4R
RF Output Power per port	250mWatt/ 24dBm
Antennas	Internal/External
Connectivity Specification	
Physical	10G Base-T over SFP 1G Base-T over Ethernet
Interface Protocol	ORAN Split 7-2 CAT-A
Time and Synchronization	IEEE 1588v2, ITU T G.8275.1
Environmental Specification	
Powering	PoE ++ Type 3 IEEE802.3bt
Dimension (mm)	250mm x 213.5mm x 92.1
Weight	<4Kg
Operating Temperature	-5 to 40C / -40 to 55C
Environmental	IP31/ IP65
Mounting Style	Wall/ Pole / Ceiling

Evaluation and Preliminary Results

- Mean Absolute Error results from RU3 with 4 distributed antennas.

Point	Error (m)	Point	Error (m)
A	4.7766	I	3.0248
B	4.6982	J	2.3258
C	0.8191	K	3.3805
D	1.3082	L	3.2353
E	2.3743	M	0.3461
F	2.0003	N	4.8525
G	2.2792	O	5.4106
H	3.3180	P	4.1295