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6G NON-TERRESTRIAL NETWORKS FOR THE FULL INTEGRATION OF NTN COMPONENTS INTO THE FUTURE 6G INFRASTRUCTURE

Enablers for E2E integration in 6G-NTN

Reliable Positioning

Positioning objectives

UE positioning is integral for 6G NTN operations, gaining prominence with 3GPP Rel.17's introduction [1]. NTN, pivotal for emergency services, explores explicit positioning via single or multiple LEO satellites in scenarios with weak or unavailable GNSS signals. Various methods, including TOA, TDOA, RTT, two-way TOA, and FDOA based on delay and Doppler measurements, are discussed. Method choice hinges on system requirements and available resources. For instance, TOA and RTT need high bandwidth for resolution, RTT requires bidirectional signaling, and TDOA has a trade-off with DOP [2]. This paper explores positioning techniques in 6G NTN, focusing on LEO satellite constellations in diverse configurations and deployments to propose suitable NTN positioning methods.

[1] Technical Specification Group Services and System Aspects; Location Services (LCS); Service description; Stage 1," 3GPP TS 22.071, version 17.0.0.J.
[2] M. L. Psiaki, "Navigation using carrier Doppler shift from a LEO constellation: TRANSIT on steroids," Navig. J. Inst. Navig., vol. 68, no. 3, pp. 621 – 641, Sep. 2021.

State of the art for positioning

NR-positioning involves two key processes: measurement and position estimation based on these measurements. The positioning procedures in 5G-NR are categorized as UEassisted, UE-based, and Network-based, offering flexibility in implementation. In terms of measurements, 5G provides timing measurements (DL-RSTD, UL-RTOA, Rx-Tx time difference) and receive-power measurements (DL PRS-RSRP, UL SRSRSRP, AoA, Zenith-AoA, SSB, and CSI-RS). Numerous 3GPP evaluation studies on these schemes are documented in 3GPP 38.855 [3] and 38.859 [4], providing valuable insights into their performance in the context of NR-positioning. The following highlights the main challenges in LEO-NTN based positioning:

- LEO-NTN's single-satellite positioning for communication faces challenges: UEs lack simultaneous coverage, and continuous tracking of a single satellite may not meet latency and accuracy requirements due to channel decorrelation and limited visibility. Time-variability of UE-clock error adds complexity.
- Atmospheric errors in NTN positioning, including ionospheric and tropospheric delays, present unique challenges. Effectively addressing these is crucial for enhanced accuracy. However, using differencing methods (single/double/triple) for mitigation comes with trade-offs like increased signal processing, overhead, latency, and time-to-first-fix.
- Multipath detection is a significant challenge for reliable UE positioning accuracy, especially in environments where Line-of-Sight (LOS) path detection is crucial, particularly with differencing methods.
- Application-specific positioning in NTN is envisioned as an integral component of 6G, providing customizable positioning solutions based on UE-application demands. This design allows efficient trade-off management among accuracy, signallingoverhead, processing, latency, time-to-first-fix, and reliability.

[3] 3GPP TR 38.855, "Study on NR positioning support (Release 16)," Mar. 2019.
[4] 3GPP TR 38.859, "Study on expanded and improved NR positioning support (Release 18)," Dec. 2022.

First results

The results for all the considered scenarios are summarized in Table 1. Four base stations (Tx) are considered around a receiver (Rx), each transmitting 5 ms of signal from the BS to the receiver. Two different frequency bands are considered FR1, FR2 and for each sub-carrier spacing . We consider in this first simulations, the size of forwarded signal for PRS positioning is comb N= 12.

2D estimated position accuracy in terms of Root Mean Square Error in meters is illustarated in Table 1.

FR Band (GHz)	Sub-spacing (KHz)	RMSE (m)
FR1 (5)	15	5.34
	60	2.04
FR2 (78)	60	1.92
	240	0.68

Table 1: Positioning and accuracy results

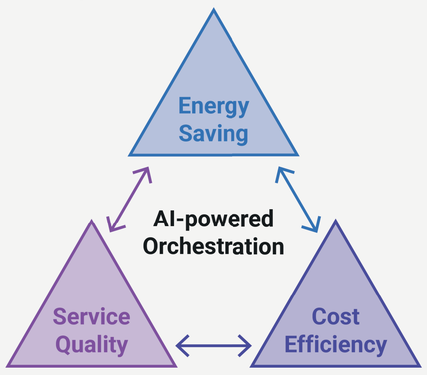
By comparing the results among the different considered scenarios, we have observed the following:

- The best positioning accuracy was achieved in FR2 with highestfrequency of operation (i.e., 78 GHz) and with the highest subcarrier spacing (i.e., 240 kHz).
- The achievable positioning accuracy is indeed below 1m. However, using FR1 and sub-carrier spacing between 15 kHz and 60 kHz, the accuracy is above 1 m and below 6 m.

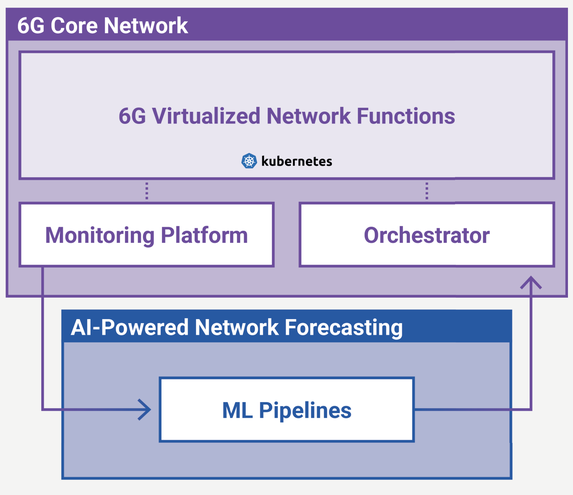
Dynamic Orchestration and Autonomous Monitoring

ML for VNF orchestration

- **A virtualized and cloud native architectures for the 6G core network** capable to cope with ad-hoc satellite constellations of 6G through a dynamic orchestration of the service-based architecture.
- In TN/NTN scenarios, the orchestrator leverages insights from the **AI management platform to dynamically adjust resources**, ensuring that sufficient resources are allocated to meet each user's specific requirements.
- **Pre-emptive resource allocation** to mitigate costs and prevent waste of energy associated with overprovisioning while simultaneously avoiding degradation of service quality due to under provisioning.



- Machine Learning **multivariate forecasting** algorithms to predict the virtual resource utilization of each network function.
- Continuous interaction with the monitoring component and the orchestrator to enable proactive resource allocation and optimization.
- **Dynamic autoscaling** of logical resources on the shared physical set of resources.
- Machine Learning Function Orchestrator (**MLFO**) to handle the ML workflows execution on a cloud-native distributed environment and schedule the training and inference of ML models.
- MLOps pipelines for **continuous and energy efficient** ML models training and optimization.



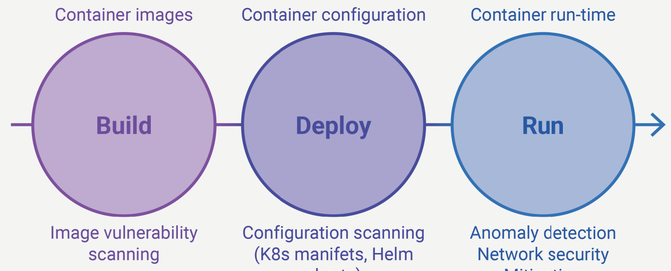
Cyber Security

Context and technical problem

Security of cloud computing infrastructures

It is a de facto standard to deploy complex applications of micro-services. Kubernetes is an open-source orchestration engine of containers on clusters of servers. It's very flexible but with some drawbacks:

- Security risks induced by virtualization
- Security to rethink compared to traditional deployments (mental model)
- Security configurations complex and difficult to implement correctly
- Little visibility on what is implemented



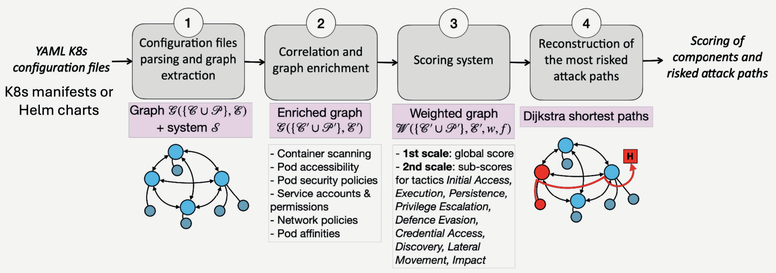
Technical solution

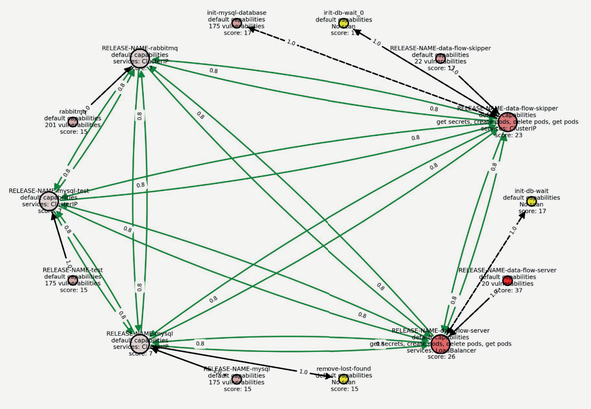
Building a microservice deployment model using a topological graph $\mathcal{G}(\mathcal{N},\mathcal{E})$ and assessing its security

- Nodes ($\mathcal{N}$): pods (or deployments) and containers
- Edges ($\mathcal{E}$): relations between nodes

4-stages algorithmic approach

A. Blaise and F. Rebecchi, "Stay at the Helm: secure Kubernetes deployments via graph generation and attack reconstruction," 2022 IEEE 15th International Conference on Cloud Computing (CLOUD), Barcelona, Spain, 2022



Illustrative example — bitnami/spring-cloud-data-flow

1. **Initial access**: pod accessible from the outside (LoadBalancer service)
2. **Execution**: container cannot be scanned – may contain critical severity vulnerabilities
3. **Impact**: service account can create new pods/workloads
4. **Lateral movement**: no firewall rules – can potentially access every other resource of the cluster