Experimenting with Localization Management Functions in 5G Core Networks

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ABSTRACT

Localization has achieved great attention in 5G networks, pushed by standardization. However, experimentation in 5G networks lacks the integration of network function modules designed for localization. We present our implementation of the 5G Localization Management Function. It complies with the 3GPP standard and OpenAirInterface, the most advanced framework that implements a full 5G-New Radio stack. We show that we are able to extend the functionality of OpenAirInterface, enabling location services. Finally, we demonstrate that the tool's performance satisfies the 5G Key Performance Indicators required by 3GPP for localization.

CCS CONCEPTS

• **Networks → Mobile networks**; *Location based services*; • **Computer systems organization** → Cellular architectures.

KEYWORDS

5G Localization, 5G Core Network, Network Functions

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1 INTRODUCTION

Motivation. Although cellular localization has been under standardization for more than a decade, only recently it is targeting very high location accuracy and low latency with Release 16 and beyond of the 3rd Generation Partnership Project (3GPP). Initially, 3GPP (on 3G and early 4G devices) mainly relied on Global Positioning System (GPS) as the primary positioning method to meet the User Equipment (UE) Federal Communication Commission (FCC) emergency call positioning requirements in adequate deployments. Since then, localization has evolved to support emerging commercial applications through 3GPP specifications that leverage the much higher accuracy that could be achieved with more recent cellular network generations. In particular, three trends have emerged: (i) network densification, resulting in smaller absolute errors in the distance estimates, (ii) wider bandwidth of transmission for higher data rate, resulting in more accurate time of flight for distance estimation, and (iii) larger number of antennas to transmit to multiple users resulting in more accurate angle measurements. 3GPP location specifications allow targeting new use cases e.g., autonomous vehicles and the Internet of Things (IoT), all with critical requirements for localization accuracy and reliability guaranteed by the 5G specifications [5].

Since Release 16, 3GPP has proposed to use network functions to operate with position measurements between the 5GC and the User Equipment (UE). The targets vary by *positioning service level*, ranging from 95 % percentile accuracy in the order of decimeters and latency of 15 ms for applications such as augmented reality, to accuracy of 10 m, and latency of 1 s for less stringent applications [1].

Contribution. Despite such considerable industry interest, there are no existing experimental studies on the impact of integrating localization services in 5GC by characterizing their performances. We believe this study will enable a plethora of network location-based applications and analytics. We provide implementation details and a study based on the current 3GPP standards, in terms of latency and system scalability, two required 5G Key Performance Indicators (KPIs).

2 LMF IN 5GC

3GPP defines the Location Management Function (LMF) as the critical enabler for localization purposes. The most advanced framework that implements a full 5G-New Radio stack open-source implementation of the 5GC is Open Air Interface (OAI)[1]. The message bus between the 5GC components is a service-based interface (SBI) that employs RESTful API principles over HTTP/2, and it is implemented with the C++ *pistache* framework[2]. The only connection between the 5GC and LMF occurs via the Access and Mobility Management Function (AMF) module via an SBI called Nlmf [2]. We fully integrate our LMF module implementation into the 5GC OAI dockerized environment, ensuring full compliance with 3GPP and OAI standards.

In our emulation scenario, AMF acts as a gateway between a Location Service (LCS) requesting the localization service and LMF implementing a trilateration algorithm in C++ and used in Microsoft localization competitions. [6]. Its applicability to 5G networks can be in contexts wherein the NG-RAN computes the distances using Multi-RTT (round trip time), which is mapped to estimated distances. Two reference signals (RSs) are used to compute multi-RTT in the 3GPP standards, that is, the downlink positioning reference signal (DL-PRS) and Uplink sounding reference signals (UL-SRS). However, our LMF implementation is flexible, and other algorithms can be integrated in the future.

3 DEMONSTRATION

We describe the demo settings and sketch the experimental results we can obtain.

Testbed. We demo our testbed comprising the 5GC with the new LMF integration and the LCS requesting the location service reported in the previous section.

Performances. The localization functions can be characterized using specific 5G KPIs [4]. The *latency* describes the time elapsed between the event that triggers the request of the position-related data and their availability at the positioning system interface; *system scalability* specifies the number of UEs for which the positioning system can calculate position-related data in a given time unit and at a given update rate. Furthermore, we set two parameters for each user: the Inter-Packet Gap (IPG) and the Quality of Service (QoS), to differentiate user behavior and obtain different latency measurements for users assigned to different positioning service levels.

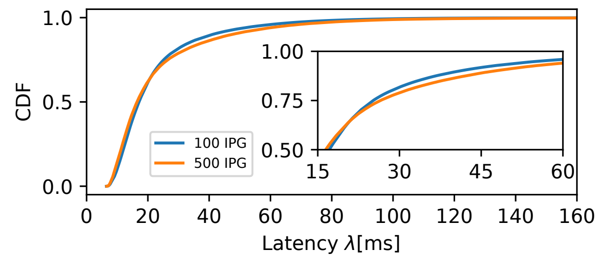

Figure 1: CDF of the latency λ for different IPG values.

Evaluation. The demo shows LMF performance following the KPIs and network constraints described. In particular, our emulation results are obtained by characterizing a time series of users connected to a real gNB. Such trace-driven analysis grounds on a LTE dataset with traffic allocations from multiple base stations in Madrid, Spain [3]. Our demonstration focuses on five request patterns differentiated by IPG and QoS for each user, where the best IPG localization service is 100 ms, the worst is 500 ms, and user latency is also affected by a *QoS mechanism that prioritizes users requiring better positioning service levels.* In the experiment, the latency difference between the two QoS classes is 10 ms.

The median latency is below 15 ms, which is within the standard's requirements for stringent latencies (see Figure 1). The IPG has no significant effect on latency. The latency displayed is for privileged QoS, but the emulation also included unprivileged users.

4 CONCLUSION

In this demo, we enable location services by extending OAI in a 3GPP compliant fashion. Then, we showcase with trace-driven emulation that current state-of-the-art 5G localization techniques achieve KPIs aligned with 3GPP specifications.

REFERENCES

[1] 2022. TS 22.261, Service requirements for the 5G system. In *3rd Generation Partnership Project, Release 18.*
[2] 2022. TS 29572, 5G System; Location Management Services. In *3rd Generation Partnership Project, Release 17.*
[3] Giulia Attanasio and et al. 2021. Characterizing RNTI Allocation and Management in Mobile Networks. In *Proc. of ACM/IEEE MSWiM.* 189–197.
[4] Stefania Bartoletti and et al. 2018. 5G localization and context-awareness. In *5G Italy White Book: From Research to Market.* National, Inter-Univ. Consortium for Telecommunications, 167–187.
[5] Stefania Bartoletti and et al. 2021. Location-based Analytics in 5G and Beyond. *IEEE Communications Magazine* 59, 7 (2021), 38–43.
[6] Maurizio Rea and et al. 2019. Time-of-flight wireless indoor navigation system for industrial environment. In *Proc. of ACM WiNTECH.* 37–44.

[1]Open Air Interface: https://openairinterface.org/
[2]Pistache Framework: https://github.com/pistacheio/pistache