5G-STARDUST: The Potentials of 5G-Advanced from the Sky

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***Abstract*—5G-STARDUST is a recently kicked-off project coming from Stream A of the first SNS call and hence addressing the evolutionary path of 5G (i.e. 5G-Advanced) to prove its benefits in the context of integrated NTN and terrestrial infrastructures. In this perspective, the project will address the potentials offered by regenerative satellite payloads and their operations' optimisation from a radio interface and networking functions standpoint to meet key performance requirements. This paper illustrates the main objectives of the project and provides a first overview of the some of the main use cases being currently addressed prior to the definition of the system architecture.**

Keywords—Non-terrestrial Networks, 5G-Advanced, SNS, Network Integration

I. Introduction

The next generation of cellular systems (6G) [1] is expected to revolutionize the current structure of telecommunication network as well as to reshape the entire digital life with profound implications on industry and society by leveraging on the advances currently brought by 5G. Amongst the many expectations coming from 6G deployment with respect to extreme low latency requirements, ultra broadband, and massive machine type communications, additional items stem from the conception of digital twin [2] and metaverse [3] as well as from the exploitation of Terahertz frequency band. An important key item, however, will still be ubiquitous connectivity to be achieved by a set of possible technologies in a such way that the overlaying network architecture would polymorphically adapt its functionalities according to data-driven paradigms so as to enable effective utilisation of very diverse services. Moreover, the need for more pervasive content distribution even in areas with poor or unavailable telecommunication infrastructures has lead to the necessity of re-inventing the classical data communication model in order to *connect the unconnected*. To this end, the integration of satellite systems and broadly speaking of *non-terrestrial network (NTN)* (also including HAPs, drones, and other air-/space-borne assets) will be pivotal for achieving these goals.

Differently from 5G systems, which have embraced from a standardisation standpoint NTN technologies only at a late stage (and whose specification is still ongoing), the inclusion of NTN in the 6G ecosystem is seen as of primary importance from the very early conception of 6G. In other words, the baseline network architecture will intrinsically build on a few communication technologies, also including NTN [4]. As such, NTN is expected to play a central role as it will be providing *connectivity from the sky* [5], hence supporting a new connectivity model where advanced routing concepts, sophisticated QoS management frameworks, and overall harmonised network management approaches will be necessary [6].

This paper will review some of the most interesting research directions [7] currently being explored in the context of the 5G-STARDUST project, aimed at proving the potentials of converged TN-NTN networks building on 5G-Advanced technology and hence paving the way towards 6G development.

Accordingly, the remainder of the paper is structured as follows. Section II will shortly introduce the project objectives and the overall methodology to reach them, while Section III will outline the main scenarios under consideration. Finally, considerations about the next steps to carried out in the project and preliminary notes about the network architecture will be drawn in Section IV.

II. 5G-STARDUST: A Primer

5G-STARDUST[1] is the project selected for funding from the first **HE SNS call within Stream A-01-02** *"Ubiquitous Radio Access"*. The project full title is *"Satellite and Terrestrial Access for Distributed, Ubiquitous, and Smart Telecommunications"* and its main mission is to design, develop and demonstrate a deeper integration of TN and NTN. In more detail, the project will deliver a fully integrated 5G-NTN autonomous system with novel self-adapting end-to-end connectivity models for enabling ubiquitous radio access. To reach these ambitious target, the project consortium coordinated by the German Aerospace Center (DLR) and supported by ten organisations operating in the field of terrestrial and satellite communications at industry and research level have defined a consistent work-plan tailored around the following key objectives:

- To define an integrated terrestrial-satellite network building on 5G-compliant regenerative satellite payloads, enabling cost-effective connectivity in un(der)served areas.
- To ensure a more efficient user connectivity concept by providing geographic coverage according to user-centric approaches (i.e. cell-free strategies).
- To define a self-organised end-to-end network architecture able to adapt to diverse verticals' requirements

[1] More info at the project website: https://www.5g-stardust.eu/

and to time-varying network operations (e.g., data traffic loads and topology changes).

- To provide end-to-end network flexibility by means of data driven AI-based multi-connectivity and resource allocation strategies.
- To guarantee cost reduction and capability to scale up the integration of satellite with terrestrial infrastructures to efficiently manage the deployment and operation of massive capacity networks.

In more detail, the 5G-STARDUST evolves the concept of current satellite systems so as to consider the potential of regenerative payloads, in the overall framework of *5G-Advanced*, hence aligning to Rel. 18 and 19 of 3GPP standardisation framework. In particular, standalone satellite systems are being considered, possibly interconnected through the terrestrial infrastructure(Fig. 1 but not in the form of multi-layer networks, which is instead of the object of 6G-related activities. Last but not the least, regenerative payloads are intended to offer not just packet-level processing functionalities, but in general also the potential of a **full-gNB onboard satellites** also complemented by an additional UPF (User Plane Function) module to enable advanced higher layer protocol stack mechanisms (e.g., in-space edge computing).

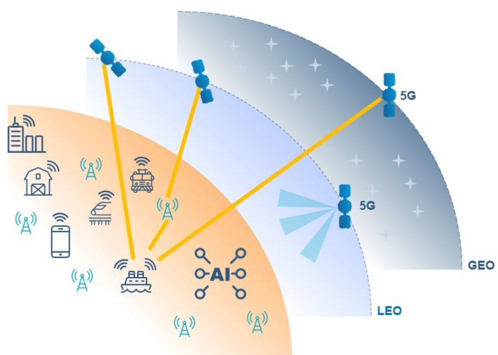

Fig. 1. 5G-STARDUST: Reference Scenario

III. Reference Scenario and Use-Cases

In order to support the value of the aforementioned network concept, a number of scenarios and corresponding use-cases are being analysed and consolidated, in terms of 1) *dual connectivity* and 2) *architecture and service distribution*. As to the former, it is about the actual coexistence of terrestrial and non-terrestrial infrastructure, whereby the opportunity of alternately or simultaneously exploiting them is an added value. On the other hand, the latter builds on the concept of service-based architecture pushed forward since the initial conception of 5G, whereby new use cases targeting the convergence between terrestrial and non-terrestrial network architectures are identified. More specifically, the tentative list of use-cases currently being analysed:

1) Dual Connectivity:
   a) Maritime, railway, airway neutral host-cell;
   b) Residential broadband;
2) Architecture and Service Distribution Scenario:
   a) V2X autonomous/remote driving;
   b) PPDR (Broadband Public Protection and Disaster Relief;
   c) Global Private Network.

IV. Conclusions

This paper introduced the framework of the 5G-STARDUST project, by highlighting in particular the overall vision and the main objectives tailored to the general mission of the satellite community to achieve integration between non-terrestrial and 5G-terrestrial technologies. In this respect, important challenges have been identified, that the project work plan will address towards the final demonstration of the activity aimed at demonstrating the advantages coming the support of regenerative satellites, possibly onboard implementing a gNB.

The very next steps of the activity will be about the finalisation of the scenario and the definition of the system architecture, whose preliminary indications will be available in Q3 of year 2023.

Acknowledgment

5G-STARDUST project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101096573.

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