NTN Architecture for PPDR in 5G-Advanced

Benjamin Barth, Roshith Sebastian, Tomaso de Cola
Institude of Communications and Navigation
German Aerospace Center (DLR)
Oberpfaffenhofen, Germany
{Benjamin.Barth; Roshith.Sebastian; Tomaso.deCola}@dlr.de

Alessandro Guidotti
Electrical, Electronic, and Information Engineering
National Inter-University Consortium for Telecommunications
(CNIT), Bologna, Italy
a.guidotti@unibo.it

This work has been published by IEEE: B. Barth, R. Sebastian, T. De Cola and A. Guidotti, "NTN Architecture for PPDR in 5G-Advanced," 2024 IEEE Future Networks World Forum (FNWF), Dubai, United Arab Emirates, 2024, pp. 351-356, doi: 10.1109/FNWF63303.2024.11028781.

Abstract—Satellites have been included in 3GPP as non-terrestrial networks (NTN) in release 17 which holds a strong potential for public protection and disaster relief (PPDR) due to their inherited resilience to terrestrial disaster event. Hence, we investigated on the possible architecture options to provide Mission Critical (MC) services to first responders via NTN based on service flows and requirements. Considering 5G-Advanced NTN setups including Integrated Access Backhaul (IAB) and multi-connectivity. NTN can be fundamental complement for both the first responders and the users in the area. While a transparent setup with a full gNB on-board the satellites seem to be the fitting and future-proof solution, ATSSS-like multi-connectivity can further increase resilience, robustness and complement capacity during the development of a disaster event and the nominal work of PPDR organisations.

Keywords—PPDR, NTN, 5G-Advanced, Architecture

I. Introduction

The advent of Low Earth Orbit (LEO) mega-constellations and the standardisation of NTNs in 3GPP release 17 with a transparent payload and in release 18 as regenerative hold a strong potential for PPDR communication. Satellite communication provides additional resilience in disaster cases, hence, have been considered since a long time for disaster event communications in case terrestrial infrastructure is damaged. NTNs have inherently a big coverage area and can reach users in remote locations or those that have been affected by a disaster event and since main parts of the infrastructure is in space, this part is not affected by terrestrial events. Therefore, NTNs as complement to terrestrial infrastructure is increasing strongly available, reliability and overall system capacity. Considering NTNs as 3GPP system we are investigating on this for PPDR use cases in and present options for the architecture.

PPDR communications itself has gained more attention these days due to the fact that lack of communication during these situations can cause loss of lives. 3GPP has standardized Mission Critical (MC) communications which is an enabler for PPDR communications. The initial works in the application domain started in release 13, by standardizing Mission Critical Push to Talk (MCPTT) in 2016, although the enablers for the technology like Group Communication System Enablers (GCSE), D2D Proximity Based Services (ProSe) was standardized prior to release 13. Release 14 saw enhancements to MCPTT, and the introduction of MCData, MCVideo and a general framework which facilitates standardizing additional MC Services. With the introduction of 5G in release 15, there were further studies on interconnection between 3GPP defined MC systems, interworking between the 3GPP defined MC system and legacy systems such as TETRA or P25, for voice and short data service, MC service requirements for railway and maritime industries [1]. As part of release 16, MC services were extended to address a wider business sector than the initial rather narrow public security and civil defence services for which they had originally been developed. The motivation behind this approach is that if similar standards can be deployed at a wider scale, this would enhance the reliability of the services and reduce the deployment costs [2]. In the next release, release 17, these technologies were extended even further for better interoperability. In release 18, MC gateway UE was introduced that enables MC service access for a MC service user residing on non-3GPP capable devices and for devices which cannot host MC service clients. The 5GS capabilities were also integrated into MC services which enriched ad hoc communication, group communication, relaying techniques to ensure connectivity to remote MC service UE(s) and Railway functionalities. While the plan is to continue developing enhancements to some of the existing specifications in release 19, other aspects like application layer support for AI/ML, satellite connectivity, may also be included due to the high interest in these areas [3].

From communications perspective, in disaster scenarios there is the high risk for the sudden unavailability of the terrestrial infrastructure (entirely or in partitions) for a limited period of time, whereby backup connectivity access has to be provided by means of NTN. As a matter of fact, the availability of satellite links is pivotal for the success of rescue operations as well as general communication means between the affected areas and decision centres (civil protection authorities, data processing centres, etc.). Traffic demands of the general public strongly increase at such events which should not prevent communications of the involved organisations. Upon progressive restoration of the terrestrial infrastructure, the satellite connectivity will be in turn used in conjunction with the terrestrial one. On the other hand, more public safety operations in remote areas (e.g., poorly connected environments) may still require the use of satellite networks due to the limited coverage offered by the existing terrestrial infrastructure or their restricted capacity, which may not be sufficient to provide broadband connectivity to all users.

The sudden and high demand of capacity combined with priority needs for first responder critical communications leads to challenging spectrum demands for a relatively short period of time. As such, the ITU recommends in [4] a dynamic spectrum allocation and basically adds (if still available) extra channels of public networks to the PPDR network. In some countries, first responder organizations for their operations have dedicated frequency bands for 4G/5G systems. It is envisaged that these frequencies are used to deploy temporary setups for responding the disaster situation or permanently in areas of high risk such as nuclear plants. This leads to a variety of communication services options for first responders (dedicated networks combined with public networks and satellite) which can be temporary in tactical bubbles or permanently.

A. Scenario

According to the description provided in the previous section, two main sub-scenarios can be identified which benefit from the provision of NTN services:

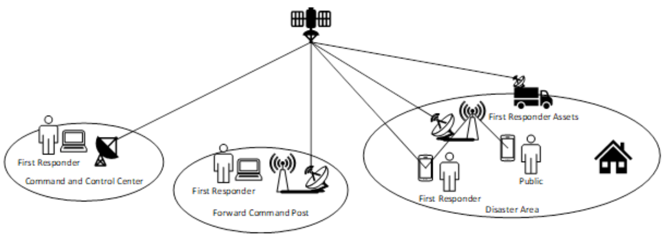

Figure 1: PPDR scenario during a disaster event

- Response to a disaster event (natural or man-made), subdivided into consecutive increments of connectivity (illustrated in Figure 1). First responders need to communicate in three different zones: the command and control centre (CCC), the forward command post (FCP) with the incident commander, and the actual disaster area. In the first increment, the terrestrial connectivity is completely disrupted or at least end-to-end connectivity cannot be established because the overall local network is partitioned. In such a case, the availability of connectivity means (e.g., satellite-based) will be fundamental in order to a) allow rich content information exchange between first responders, b) share of information and collaborative frameworks between first responder teams positioned in far areas though part of the same incident areas, and c) general data connectivity between the affected population and other parties. To support rescue groups the provision of indoor communication is required where possible. Applications of involved organisations in this scenario include push-to-talk (PTT) for voice communication, video transmission, and other mission-critical data such as positions, pictures, alerts etc. Different types of UEs are considered in this scenario: first responder handhelds, backhaul links to forward command posts, vehicular communication such as fire trucks and aerial communication such as helicopters and drones. In this case, it is conceivable to establish direct access between UEs and satellites in Frequency Range 1 (FR1), or alternatively use backhaul connectivity over Frequency Range 2 (FR2) offering higher bandwidth but demand the use of directive antennas. The use of integrated access backhaul (IAB) in conjunction with a terrestrial base station is needed for indoor and off-network communication. Support from regenerative satellite payload provides additional resilience and may further improve data connectivity especially in terms of reduced latency. Given the high traffic demand that may arise from the general public during emergencies, utilizing a regenerative satellite can help mitigate the risk of having the feeder link act as a bottleneck, which could impede proper communication. From terrestrial side 5G RAN can be used as part of the existing, not damaged base stations or by deploying dedicated transportable units. Then, upon partial or total restoration of the terrestrial infrastructure connectivity, the capacity joint offered by satellite and terrestrial networks will be shared across subscribers by means of optimised traffic sharing and load balancing solutions.
- Nominal public safety operations in underserved areas, where command & control (C2C) of medical services, police, or fire-brigades' operations may require complementing the scarce terrestrial infrastructure capacity with that possibly offered by satellite links. In such a case, depending on the traffic demands, network saturation conditions, and overall location of users (some users may be located in sub-areas with decent terrestrial connectivity, other in sub-areas with harsher connectivity conditions), part of the traffic could be offloaded to the satellite network. Hence, also this scenario may benefit from a dual- or multi-connectivity solution, although the availability of more network resources would be used to allocate user traffic to either of the available networks. As such, the overall connectivity concept will be pretty much oriented to service distribution through a heterogeneous network architecture.

II. PPDR Service Flows

The response to a disaster is from network perspective more challenging and the main case for NTN systems. As such in the following we focusing on this case and present a possible service flow for a disaster event considering 5G-NTN MC services.

A. Pre-conditions

- First responder organization has a subscription with terrestrial and non-terrestrial operators to provide 5G network service.
- Terrestrial infrastructure is damaged and (partially) not available.
- User have either a UE that supports direct connection to satellite or is connected by a base station backhauled by satellite, e.g., at FCPs.
- The FCP is based in a safe zone away from operation on the field.

B. Service Flows

- First responders communicate in the field, FCP and CCCs via MC services (MC-PTT, MC-data and MC-video communication). This includes group communication and the related synchronisation and prioritisation requirements
- Communication is backhauled through NTN access for forward command posts.
- First responders have priority access to TN and NTN resources compared to public. (priority access to IAB+ resource pre-emption possible)
- First responder operation is deployed inside a building with no line of site visibility to satellite; communication to control centre is hopped UE to UE back to NTN back to command centre (IAB)
- Optionally: warning information is broadcasted to public UEs in FR1 while the terrestrial network is down on a private PPDR PLMN
- First responder operation communication switch to TN (MCPTT seamless handover from NTN to TN)

C. Post-conditions

- Communication service for first responder organisation is setup. Afterwards communications to and for the general public can be provided, prioritizing the first responder communication to no block their task.

- After the event, the terrestrial infrastructure is successively restored until normal operations can continue as in pre-incident conditions. NTN solutions support during this time by providing additional capacity.

III. Services and Requirements

The PPDR use case is a challenging and complex environment with a multitude of critical services and requirements. In particular, 3GPP defines mission critical as “quality or characteristic of a communication activity, application, service or device, that requires low setup and transfer latency, high availability and reliability, ability to handle large numbers of users and devices, strong security and priority and pre-emption handling. [5]”. The MC services include three types each with different traffic structure:

- MC-PTT, i.e., voice transmission
- MC-Data
- MC-Video

In general, MC services, include point-to-point and multi-point communication and are bi-directional, i.e., they make use of the forward and the return link. Furthermore, it is real-time and non-real and can be all, intermittent and continuous traffic, periodic and aperiodic. Furthermore, positioning service are required.

The PPDR use case includes a variety of actors using different devices such first responders in the field using handhelds, command posts provide backhauled access points for computers and handhelds, and vessels like trucks and helicopters. For example, [5] mentions as a requirement real time communication with helicopters and aircrafts. Drones are used as well as IoT devices such as wearables and other sensors. Consequently, also the size, weight and power consumptions are varying as well as the mobility pattern.

Existing service requirements for this use case are for example collected in 3GPP TS 22.280 [5] and related documents. TS 22.179 [6] covers the requirements for MCPTT, TS 22.281 [7] for MC video and TS 22.282 [8] for MC data, respectively. The following covers the requirements of first responder organizations, it does not include needs for the communication of and to the general public, e.g. such required for alerting.

- The NTN RAN shall back-up terrestrial infrastructure during disaster events
- The NTN RAN shall cover white spots of terrestrial networks
- The NTN system shall support Mission Critical Services
- The NTN system shall support highly mobile environments (e.g. helicopters)
- The NTN system shall be able to support private networks
- Communication of first responder organization shall be prioritized and pre-emption shall be supported
- The system shall support MC-PTT, MC-Data and MC-Video
- The UE shall be able to perform group calls (36 to 150 simultaneous MC-PTT Group Calls shall be supported per incident)
- Group calls shall be synchronized
- Voice and video transmission shall be synchronized
- Communication shall be protected
- User speeds of 450 km/h (160 km/h for video) shall be supported
- User altitudes of 15.000 ft shall to be supported
- The NTN system shall be able to setup connections fast (1 second for immediate data communication and 3 seconds for normal ones)

For a general MC system, the KPIs in Table 1 have been identified which should also be supported by an NTN system.

Table 1: Quality of Service Requirements identified

Throughput	End-to-end Latency	User service packet error rate
500Mbps [9]	300ms	10^{-6} [10]

IV. Architecture Options

The first option on the architecture for NTN inclusion is the selection of the orbit since different characteristics apply for different orbits. Typically, they are classified by Geostationary, Medium and Low Earth Orbits (GEO, MEO, LEO). While GEOs have high coverage already by a single satellite, they introduce high latency (RTT approx. $0.5s$). LEOs on the other hand offer lower latency but multiple satellites (constellation) are required to provide broader coverage. For the sake of completeness, also HAPS/LAPS are included in NTNs providing a rapid deployable extension, but it is out of scope for our investigations.

Looking at the requirements, it should be noted that an end-to-end latency of 300ms is not achievable with classical (GEO) lower altitudes have to be used to meet the requirements or requirements have to be relaxed for GEO case. It is basically a trade-off of service availability and latency. However, LEO satellites are moving with increasing and the decreasing elevation angle, i.e. in varying distance to the UE making it especially challenging to meet synchronisation requirements.

On the other hand, aerial communication requirements on altitude can be met. Satellite are the technical solution already today to provide broadband connectivity to commercial airplanes.

On spectrum side, there are two radio frequency bands for 5G NR namely, FR1 and FR2. FR1 ranges from 410 MHz to 7125 MHz [11] while FR2 offers a wider range from 24.25 GHz to 71 GHz [12]. FR1 and FR2 have frequencies that can be used by both TN and NTN. As mentioned FR1 could be used also for direct connectivity to UEs, but for FR2 directive antennas are required, therefore also higher system capacity can be achieved which is needed to meet the throughput requirements.

Besides the general satellite considerations, several architectural options exist on the 3GPP implementation outlined in the following.

A. Transparent and Regernative

Depending on the complexity and cost of the NTN payloads, various architecture options can support PPDR scenarios with different performance in terms of, e.g., on-board computation, latency, and link budget.

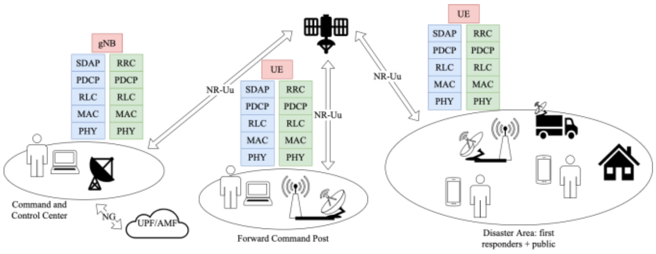

Figure 2. Transparent payload PPDR architecture and protocol stacks (UP in blue and CP in green).

Notably, the lowest on-board complexity is obtained with a transparent payload. In that case, shown in Figure 2, the NTN node only implements frequency conversion, filtering, and amplification, acting as an air-/space-borne RF repeater forwarding the radio protocols received by the UEs to the gNB and *vice versa*. The gNB serving the on-ground first responders and FCPs is conceptually located at the NTN gateway (GW) of the CCC. As per 3GPP specifications, all control (CP) and user plane (UP) protocols are terminated at the on-ground gNB and, thus, both the feeder and the user service links shall be implemented by means of the NR-Uu Air Interface. The gNB at the CCC is then connected to the UP Function (UPF) and the Access and Mobility Management Function (AMF) in the 5G Core network (5GC) by means of the terrestrial NG Air Interface. This option provides the lowest complexity and cost of the payload, at the expense of larger latencies and lower link budget, due to the absence of on-board computations and longer propagation delays within the network. Please note that, within 3GPP, the combination of gNB, NTN payload, and GW is usually referred to as Satellite Access Node (SAN).

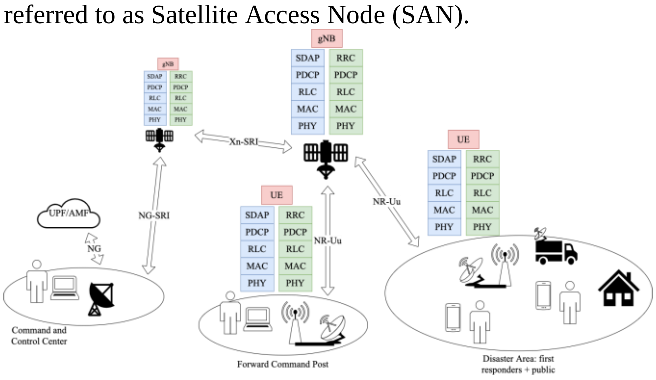

Figure 3. Regenerative payload PPDR architecture and protocol stacks (UP in blue and CP in green): full gNB on-board and ISLs.

Since Rel. 18-19, regenerative payloads have been introduced in 3GPP NTN specifications. In general, a regenerative NTN payload in the SAN allows to move the entire protocol stack of the gNB on-board, or just part of if functional split is implemented. The exploitation of regenerative payloads also allows the introduction of Inter-Satellite Links (ISLs), operating in RF or optical frequency bands, which can be either 3GPP or non-3GPP defined. Today, ISLs constitute a pre-requisite for satellite constellations as, without ISLs, a huge number of gateways would be required to manage the system, leading to unfeasible costs and complexity. In addition, regenerative payloads also allow to lower the required bandwidth for in-space routing, which might be required in the PPDR scenario in case the NTN payload is not in the visibility of both the CCC and the FCP. Another potential application for regenerative payloads is related to their support for direct UE-to-UE connectivity for users served by the same satellite, i.e., without letting the traffic flow through the GW; this feature might ease the coordination both among the first responders in the disaster area and between them and the FCP close to the disaster area. Figure 3 depicts the architecture and protocol stacks assuming a full gNB on-board; it can be noticed that now only the user service link requires a NR-Uu interface, while the NG interface on the feeder link can be supported by means of any Satellite Radio Interface (SRI). With a full gNB on-board, all protocols up to the Service Data Adaptation Protocol (SDAP) on the UP and the Radio Resource Control (RRC) on the CP are terminated on-board, thus allowing to (massively) reduce the overall latency; moreover, the link budget is improved thanks to signal regeneration and other advanced signal processing techniques that can be supported, e.g., user-centric and digital beamforming. In case multi-hop communications are needed between the disaster area and the CCC, adaptive routing schemes are implemented on-board and the ISLs shall support the logical Xn interface, as shown in Figure 3; it shall be noticed that the connection to the AMF/UPF in the 5GC is still passing through the GW, but no gNB is located at its premises. This solution is on the conceptual opposite of the transparent payload, as it provides the lowest latency and the most advanced computational capabilities on-board. Considering even a UPF on-board would also enable edge computing services in space offering low latency applications for PPDR. Clearly, these advantages come at the expense of an increased operational cost.

B. Functional Split

When functional split is implemented, many different options are possible depending on the type of split and the network elements carrying the different parts of the gNB (i.e., on-ground or on-board). Due to space limitations, it is not possible to address all of them here and we only focus on option 2 (RRC/PDCP split, please refer to Figure 3), which is the only one, for the moment being, completely 3GPP-compliant, [13]. In Figure 4 we show the PPDR scenario with split option 2. This solution allows scalable network implementations based on Network Function Virtualization (NFV) and Software Defined Network (SDN) principles, aimed at tailoring the system to the requested use cases and vertical services in addition to a more efficient network management. However, it shall also be mentioned that the overall system cost and complexity are increased. Moreover, two disadvantages arise: i) the RLC and PDCP layer processing might involve links with delays above 10 ms, depending on the NTN system, and thus the RLC would acknowledge packets and then forward them to the PDCP for decryption and reordering with more than a 10 ms latency, which would make the split not feasible; and ii) the split requires additional encoding and decoding on the F1 interface, thus requiring more processing time and, ultimately, increasing the latency. In addition, the F1 interface is a persistent one, meaning that it cannot be deleted and re-established without dropping all the UEs currently served, something that is not possible in a PPDR scenario in particular. As such, smart implementations of the F1 interface are required. Finally, it is worthwhile noticing that no ISLs are currently foreseen by the specifications between multiple gNB-DUs: one gNB-DU can be connected to its corresponding CU only.

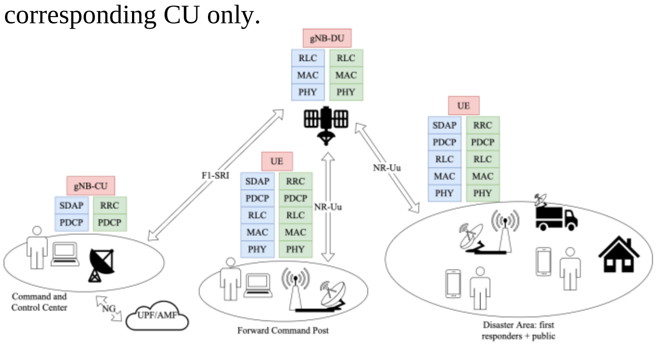

Figure 4. Regenerative payload PPDR architecture and protocol stacks (UP in blue and CP in green): split option 2.

C. Integrated Access Backhaul

UEs can connect directly to terrestrial and NTNs accessing the gNBs or, alternatively, indirectly, by an gNB which is connected via IAB. An IAB node is a network element introduced in Rel. 16 specifications to provide flexible and scalable multi-hop backhauling solutions for ultra-dense scenarios, while minimising the impact on the core network [14],[15]. The use of IAB enables a seamless integration of UEs with NTN without any modifications which makes it easier to use the existing devices for PPDR communications. Thus, all the access related protocols (i.e., up to RLC) were retained in the IAB protocol stack. It is also possible to have an indoor IAB node to which all devices in the building can connect ensuring easy connectivity.

The use of IAB for indirect communication necessitates two elements namely, IAB donor and IAB node. An IAB-Donor acts as a gNB and it is connected to the 5GC through the NG Air Interface as shown in Figure 5, it includes a CU (CP and UP) that interacts with the 5GC and then one or more DUs that manage other IAB nodes in a hierarchical structure. The DU of each IAB-node or IAB-Donor can either provide backhaul connectivity to other child IAB-nodes (through the corresponding Mobile Termination, MT) or indirect connectivity to UEs. The F1 interface supports the multi-hop backhaul between the IAB-node DU and the IAB-Donor CU, while communications on the upper layers (PDCP and above) are established between the IAB-Donor CU and the UE.

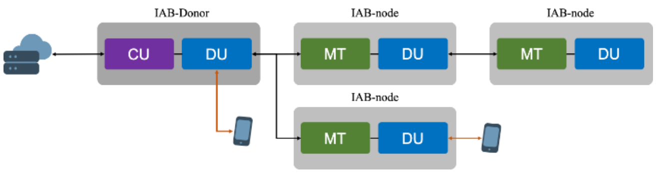

Figure 5: Indirect connectivity using IAB

Based on the above observations, and considering both transparent and regenerative payloads, there are several implementations of IAB-based NTN networks. When assuming a transparent NTN payload, there are two possible applications: i) the NTN payload connects the IAB-Donor and its child IAB-nodes; and ii) the NTN payload connects the 5GC and one or more IAB-Donors. The main benefit of the former case is that the NTN payload can provide direct connectivity to the UEs and provide backhaul connectivity between the IAB-Donor and the IAB nodes. In the second approach, both the feeder and the user links should implement the NG Air interface to support the connectivity between the IAB-Donor and the UPF on the UP and the AMF on CP, respectively. Hence, it is not flexible to provide direct access for UEs but only the backhaul connectivity is possible.

When considering regenerative NTN payloads, either an IAB-node or an IAB-Donor can be implemented on-board; moreover, if functional split is implemented at the IAB-Donor, it is also possible to only implement the IAB-Donor DU on the payload, while leaving the CU on-ground. In this configuration, the communications between the IAB Donor DU and CU on the CP/UP shall be supported through the F1-C/F1-U interfaces. For PPDR scenarios, taking into consideration the services and requirements mentioned in IV, the architecture with the full IAB-Donor implemented on-board is promising. The architecture with CP and UP protocol stacks is shown in Figure 6.

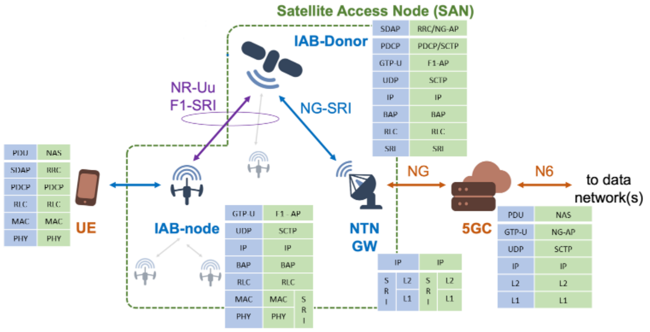

Figure 6: Full IAB node on payload with Protocol Stacks. (UP in blue and CP in green)

In this scenario, SRIs can support both the BAP and RLC communications between the IAB-Donor and the IAB-nodes on the user link and the NG interface on the feeder link. All layers and interfaces carried over SRI shall be not impacted by the NTN links, apart from the possible need to extend the timers of specific procedures to accommodate the extended latencies. The UP and CP protocol stacks in this scenario are also shown in Figure 6.

It is worthwhile mentioning that, recently, an increasing interest has been dedicated to Wireless Access Backhaul (WAB) nodes, [16]. These newly introduced relay nodes are aimed at allowing Mobile Edge Computing (MEC) on-board and to support Vehicle Mounted Relay (VMR) services. A WAB node encompasses a full gNB and a MT unit; the former serves the users, while the latter is exploited for the backhaul connectivity. In TR 38.799, it is clarified that the NR-Uu interface between the served users and the WAB-gNB cannot be an NTN link, thus indicating that WAB-NTN solutions are only possible for backhaul (i.e., WAB on-board a moving platform and NTN node(s) providing backhaul connectivity to the core network).

D. Multi-Connectivity

For PPDR scenarios, the ideal solution would be to connect to one multiple TNs and an NTNs simultaneously for maximum resilience and increased throughput. Hence, multi-connectivity is a complementary option that can be used for PPDR communication supporting a) the seamless switchover in case of damaged infrastructure and the switch back while restoring and b) the complementary use of different systems providing additional capacity. Several options for multi-connectivity on various layers have been summarized in [17] while our focus is on an Access Traffic Splitting and

Switching (ATSSS)-like approach connecting a 5G-NTN system with a 5G TN system but also between two NTNs. ATSSS builts on Multi-Path (MP)TCP and MPQUIC and allows also for proper mitigation of current equipment. But it needs to be mentioned that this 3GPP specification is supporting only a single 5G connection and a non-3GPP connection which means that an extension of the standard is required for this. The architecture with MC established with TN and NTN is shown in Figure 7.

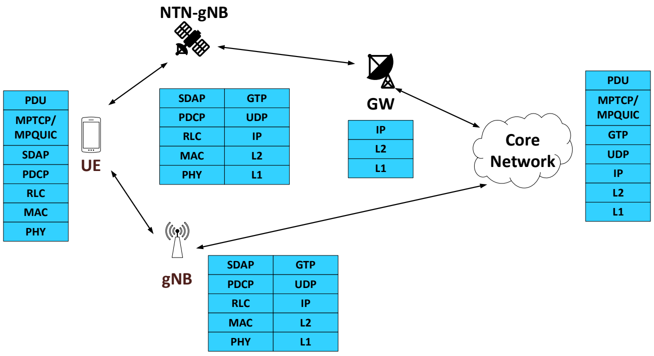

Figure 7: Multi-Connectivity including the protocol stack (UP)

The diagram also shows the protocol stacks on considering full gNB in space but also transparent setups are possible.
Interesting for PPDR and the challenging requirements is the case of connecting a UE to both frequencies in FR1 and FR2, e.g. a FR1 NTN and a FR2 NTN further increasing resilience and robustness.
Finally, it is worthwhile highlighting that all functions that are specified for a UE can be also used for the MT of an IAB, i.e., the IAB-MT can access the node exploiting Multi-Connectivity principles and architectures. In this context, the possibility of multi-radio dual connectivity approach would be also appealing, because of the possibility for a UE to connect simultaneously through two separated RANs, though with some technical challenges.

V. Conclusion

We have investigated on architectures for NTN inclusion in the 3GPP MC framework for increasing resilience and providing additional capacity. Two scenarios have been identified: the disaster case and nominal operations. We have outlined the services flows and requirements for an NTN system in PPDR context and we have elaborated on several architecture options including orbits, frequencies, functional split, IAB and multi-connectivity.
In both scenarios, the availability of regenerative satellite would be an added value to have more effective data distribution between the involved parties, possibly saving some delay and better utilising the available bandwidth resources offered by the satellite feeder link, and potentially even offering processing capabilities at the edge.
In general, the service provided via NTN should be characterised by low latency and a potentially large capacity, to support both the first responders and the affected population. As such, requirements are mandating a LEO/MEO solution at higher costs since a cheaper GEO cannot meet the latency requirements. Trade-off between availability and latency requirements must be carefully performed in future works. Optionally, a two-tier satellite setup with LEO constellations possibly off-loading traffic towards a GEO one can be also envisioned, although this configuration is beyond the focus of an Advanced 5G context. Moreover, considering future setups there might even be need for Augmented Reality (AR) headsets to support the rescue operations with even stronger requirements further supporting the regenerative option as future-proof.
Taking the above aspects into account, the use of regenerative payloads with full gNB or full IAB-Donor on-board shall be prioritised. Solutions including functional split might be feasible, but the larger latencies lead to a lower prioritisation. Finally, multi-connectivity solutions are a fitting mean to boost the capacity in the disaster area, supporting the temporal development on TN fallout and restoring and further increasing resilience and robustness.

VI. Acknowledgement

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.

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

VII. References

[1] Yannick Lair and Georg Mayer, “Mission Critical Services in 3GPP2”, July 26th , 2017, available at: https://www.3gpp.org/news-events/3gpp-news/mc-services

[2] 3GPP Release 16 notes available at: https://www.3gpp.org/specifications-technologies/releases/release-16

[3] “5G Critical Communications & Application Enablement for Verticals” Jun 12,2024, https://www.3gpp.org/technologies/sa6-cc-apps

[4] ITU Report ITU-R M.2291-2, 12.2021.

[5] 3GPP TS 22.280, “Mission Critical Services Common Requirements”v18.5.0 (2023-12).

[6] 3GPP TS 22.179, “Mission Critical Push to Talk (MCPTT); Stage 1”, v18.0.0, 2023-06.

[7] 3GPP TS 22.281,”Mission Critical (MC) video”, v18.0.1, 2024-04

[8] 3GPP TS 22.282, “Mission Critical (MC) data”, 18.0.1, 2024-04

[9] TüVIT, “Study to determine the broadband frequency spectrum demand of the German public safety organisations in mobile broadband networks,” 2022.

[10] 3GPP, “ TS 23.203 (V17.2) - Policy and charging control architecture,” 2021.

[11] 3GPP TS 38.101-1 “User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone” V18.5.0, 03.2024.

[12] 3GPP TS 38.101-2 "User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone", V18.5.0, 03.2024.

[13] 3GPP TR 38.801, “Study on new radio access technology: Radio access architecture and interfaces”, v14.0.0, 2017-04.

[14] 3GPP TR 38.809, “NR; Background for integrated access and backhaul radio transmission and reception,” April 2022.

[15] 3GPP TR 38.874, “NR; Study on integrated access and backhaul,” January 2019.

[16] 3GPP TR 38.799, “Study on Additional Topological Enhancements for NR”, 1.1.0, 2024-08.

[17] C. Pupiales, et al., "Multi-Connectivity in Mobile Networks: Challenges and Benefits," in IEEE Communications Magazine, vol. 59, no. 11, pp. 116-122, Nov. 2021