Design Feasibility and Link Budget Assessment of Aerial 5G IoT and eMBB Connectivity

Jyrki T. J. Penttinen
Alphacore Inc.
Tempe, Arizona, USA
jyrki.penttinen@alphacoreinc.com

***Abstract*—Uncrewed Aerial Vehicles (UAVs) equipped with radios can establish rapid, ad-hoc connectivity in areas where terrestrial infrastructure is unavailable or compromised. Leveraging the virtualized architecture of fifth generation (5G) mobile networks, both base station and required minimal core functions can be hosted aloft, enabling agile IoT or eMBB centric private networks for emergency response, expeditionary, military operations, and consumer events. This study evaluates the technical feasibility of UAV-mounted 5G Non-Public Network assembled from commercial off-the-shelf components, comparing the physical radio layer performance of IoT and evolved mobile broadband use cases. Candidate 3GPP architectural options are reviewed, and radio link budget calculations quantify physical layer performance in open and rural environments for a single-UAV. The obtained results highlight the trade-off between frequency band, UAV-altitude, and the resulting radio coverage and data rate, providing design guidance for lightweight, energy-efficient aerial 5G systems.**

Keywords—aerial 5G network; uncrewed aerial vehicle (UAV); non-public network (NPN); link-budget analysis; emergency communications; ad-hoc radio access network (RAN); drone-mounted IoT and eMBB radio service.

I. INTRODUCTION

Apart from their commercial use, cellular systems can be deployed also as complementing ad-hoc networks, e.g. in emergency solutions after a natural disaster that has damaged telecommunications infrastructure, or in other scenarios where non-permanent augmented capacity and radio coverage are desired. A 5G private network model through temporally deployed base stations can provide a suitable platform for data transfer and signaling in such situations, enabling enhanced situation awareness also for, e.g., defense groups.

However, in temporal ad-hoc use cases, 5G users may be highly mobile, so deploying terrestrial trailer-mounted radio base stations may not suffice, as the varying link conditions alter quality and can result in uncertainties, resulting in radio network outages when users are on the move. An aerial ad-hoc 5G network that follows the underlying users can provide an important opportunity to overcome these challenges.

3GPP is developing the Internet of Things (IoT) concept further in 5G as a logical continuum from the 4G era. 5G IoT in 3GPP is realized through legacy LTE-based NB-IoT / LTE-M seamlessly attached to the 5G core and, from Release 17 onward, through 5G New Radio (NR) RedCap, a native, reduced-bandwidth flavor of NR, and evolves further as of Release 18 [1]. Combining these two concepts, non-public network (NPN) and IoT, enables a novel means to develop and provide low-power, low-data rate services in very large areas.

This paper presents a feasibility study of a UAV-based 5G radio network that can be used in various Line of Sight (LOS) scenarios through 5G NPN. Section II discusses the state-of-the art of UAV-assisted wireless communication, current gaps and novelty of this work. Section III presents IoT and eMBB, and Section IV discusses 3GPP-defined 5G NPN. Section V describes a 5G-UAV concept and discusses UAV-mounted equipment, presenting an example of a feasible set. Section VI describes physical radio aspects, and Section VII presents the results obtained for validation of radio network performance applying adequate radio propagation modeling for aerial network, comparing 5G eMBB and IoT use cases that represent two "extremes" in terms of achievable 3D-network coverage areas. Finally, Section VIII summarizes the findings, and Section IX presents the plan for further research.

II. UAV-ASSISTED NETWORKING

Evolution

The 3GPP technical specifications are maturing and global deployments are expanding. The GSM Association (GSMA) estimates that the adaption for 5G will surpass that of 4G in 2028, whereas the earlier networks, 2G and 3G, keep losing their customers; in fact, many of these networks have already been decommissioned [2]. The current 5G system architecture models enable various deployment options and variations for tailored solutions. Examples of these facilitators include non-public networks (NPN), non-terrestrial networks (NTN), Open RAN, and massive machine type communications (mMTC) of which IoT is part of.

While 5G matures, there are already concrete efforts to develop systems beyond 5G (B5G), paving the way for 6G [3]. The first commercial 6G networks can be expected to be available as of 2030 [4]. The 6G is anticipated to be particularly attractive for connected UAVs due to significant improvements, including ubiquitous 3D connectivity on the ground and in the air [5].

While 6G is still under development, the current 5G systems outperform the previous generations, and can be tailored to provide radio service also beyond traditional terrestrial base stations through service-based architecture (SBA) and service-based interfaces (SBI) that handle specific needs of varying use cases and dynamically provide optimal sets of required and available resources to different usage types through network functions virtualization (NFV). The key benefit of 5G is its capability to run network functions

(NF) on commercial off-the-shelf (COTS) hardware. This evolution makes 5G a suitable candidate also for UAV-type networking, e.g., through non-public network models as they can form an architectural base for isolation (with augmented security) or interconnection / roaming (providing wider connectivity) network segment. A mobile network operator (MNO) or network slice (NS) provider can set up NSs, that can be used for deploying UAV-networks, too.

5G systems can be optimized further through Open RAN (Radio Access Network) concept. Examples of the efforts driving Open RAN include Open RAN Alliance's O-RAN [6] and Telecom Infra Project's TIP [7]. Via Open RAN, vendor-specific internal RAN interfaces are opened so that an extended number of stakeholders can provide select RAN protocol layers independently, increasing efficiency and reducing costs [8], and it can be used also in UAV-based networking [9].

State of the Art and Challenges

The mobile networks' radio coverage extension mounting a base station or repeater on aerial vehicle has been studied from several points of view, such as how to maximize the radio coverage by optimal UAV positioning [10] and how to enable group handover for drone base stations [11]. The scenarios behind these considerations relate to the massive machine-type communications, increased use of data services, and commercial needs for respective coverage and capacity extension to facilitate adequate data rates and quality of service (QoS) for the subscribers.

An example of current UAV-based networking is AT&T's 5G Cell on Wings (CoW), a drone-mounted cellular 4G or 5G base station that temporarily extends the respective radio coverage to improve network performance and provide connectivity, e.g., during disasters and large events [12].

Nevertheless, the available studies are not necessarily conclusive in terms of the tradeoffs of the UAV altitude and deployed frequency bands [13]. Furthermore, the adaptation of optimal architectural models of UAV-networking for isolated cases can benefit from further studies [14].

Novelty of this Work

This research 1) presents a concept based on 3GPP-defined NPN-architecture and available COTS components to provide aerial IoT and data services to a variety of use cases and 2) evaluates the performance of such a solution comparing UAV-mounted 5G gNB performance of eMBB and mMTC.

This initial design considers a single UAV that provides local communication to the UEs underneath, paving the way for the forthcoming work that will consider the formation of a multi-UAV-based 5G RAN service and automized location functions through advanced sensing and artificial intelligence.

III. IoT vs. eMBB

The 5G eMBB and IoT (mMTC) represent opposites in terms of many aspects, like data rates, power consumption and number of simultaneously communicating devices. These elements dictate also the achievable radio coverage area size. For example, IoT has been optimized for bandwidth given that IoT payloads are small, and narrow band lowers the thermal noise floor. IoT relies on robust modulation schemes and HARQ repetition balancing throughput and coverage. Also, battery-driven IoT modules stay below 1 W to meet license and life constraints (e.g., NB-IoT Class 3 and Class 5 use 23 dBm and 20 dBm, respectively), and IoT sensors may be often in basements and metal cabinets increasing fading margin.

Table 1. Comparison of key aspects of 5G eMBB and IoT

Link budget term	eMBB	IoT
Channel bandwidth B	20 – 400 MHz	180 kHz – 20 MHz
SNR (BLER<10%)	8 – 15 dB (64 / 256 QAM)	-13 – -3 dB (BPSK / QPSK, heavy coding, repetitions)
Fade/penetr. margin	3 – 5 dB	10 – 15 dB
Device TX power	23 dBm (smartphone)	14 – 23 dBm (sensor)
Data rate target	10 Mb/s – 1 Gb/s	50 b/s – 1 Mb/s

IV. Aerial Private Network Considerations

For the architectural modeling of 5G-based UAV network, the following technical specifications form the base: 1) 3GPP TS 23.501 (System Architecture for the 5G System) defines high-level architecture for both SNPNs and PNI-NPNs [15]; 2) 3GPP TS 23.548 (5G System Enhancements for NPN) explores enhancements specific to NPNs (e.g., management, registration, selection) [16]; and 3) 3GPP TS 22.261 (Service Requirements for 5G System) covers typical service-level requirements relevant to NPNs including verticals, e.g., public safety [17] stating also that 5G is expected to support various enhanced UAV scenarios for applications and scenarios for low altitude UAVs in commercial and government sectors.

The 3GPP architectural models allow private network realizations through standalone non-public network (SNPN) and different variants of public network integrated non-public network (PNI-NPN) as presented in Table 2. Although 3GPP designed these models for terrestrial networking, their principles can be extended to serve also in aerial networks.

SNPN is self-contained and independently operated from public networks. It is adequate for rapid deployment for on-demand aerial networks with no dependency on commercial MNO infrastructure. It is a match for UAV-based temporal networks serving field units. PNI-NPN, in turn, is an NPN deployed with integration into a public mobile network, and it may share infrastructure (e.g., RAN or core network). The variants of PNI-NPN include RAN-sharing with network slicing, core network sharing; and UEs with public and private subscriptions (PLMN/NSI selection).

Table 2 summarizes the 3GPP-defined NPN types and presents their key benefits related to their applicability for forming UAV-based network services.

Table 2. Private network types in UAV-based deployments

Variant	Assessment
SNPN (fully standalone)	Best for autonomous, localized, quick-to-deploy networks (no MNO dependency)
PNI-NPN with RAN sharing	Enables UAVs to share ground RAN where available, while maintaining separate core
PNI-NPN with core sharing	UAV-based NPN reuses public 5G core network, allowing leaner deployment
UE route selection via PLMN/NSI selection	UEs served by UAVs can select between private and public network profiles

V. 5G-CAPABLE UAV REALIZATION

Architecture

The system considered in this study is based on minimal viable 5G SNPN architecture and a single UAV equipped with a 5G gNB enabling local connectivity to the UEs underneath.

Figure 1 presents the UAV-based SNPN realization in this study. UAV (or set of UAVs) houses radio functions, whereas the essential core network (CN) network functions (NFs) of gNBs can be on the same UAVs, separate UAVs, or ground station. This model can be extended to cover additional UAVs and respective gNBs that are interconnected (e.g., through PC5 link) forming a 5G RAN drone swarm.

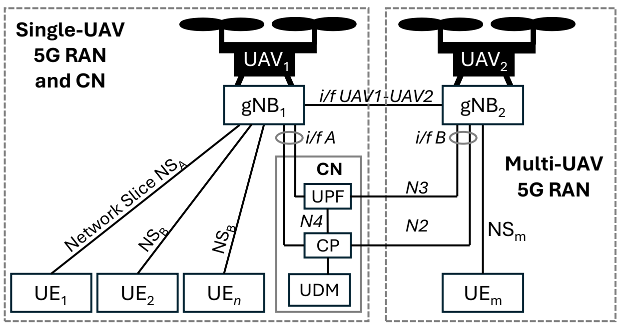

Figure 1. UAV-based, isolated SNPN realization; this feasibility study considers radio performance of a single 5G-UAV scenario

Equipment Considerations

To deploy a 5G SNPN UAV gNB, the UAV can host a basic integrated gNB (e.g., Amarisoft / Parallel Wireless). The basic location management is assumed to be manual and GPS-assisted, but automated methods can also be developed based on UE signals and using basic RF heuristics (e.g., received signal strength indicator weighting) to position the UAV(s) according to user density. Basing the solution on commercial off-the-shelf (COTS) devices, Table 3 presents a set of candidate elements for simplified functional architecture.

Table 3. Simplified functional architecture of aerial 5G system

Layer	Function	Realization
Radio Access	gNB (5G standalone) with full UE-to-UE routing support	Lightweight COTS integrated into small cell
Control Plane (CP)	Lightweight distributed UAV logic (also swarm consensus)	Simple microcontroller and onboard logic
Backhaul	None (fully isolated); direct local P2P 5G	PC5 direct-mode or local user plane function (UPF)
Intelligence	Initially manual; advanced version has UE-following	Position, RSSI-based positioning heuristics
UE Signaling	Simple beaconing uplink from UEs, e.g., by synchronization signal blocks (SSBs)	Existing 5G UE support
Swarm Comms	When more than one UAV, 5G-based mesh between UAVs	5G PC5 (5G Sidelink)

Table 4 presents examples of UAV-mounted equipment. For advanced alignment of the UAVs and UEs, downward-facing cameras can be considered for UE clustering estimation (COTS-based image processing) and barometers for altitude stabilization. Based on the selected options, the total UAV payload (essential RAN components) is approximately 2.5–3.0 kg, which is feasible for medium-class UAVs (e.g., DJI Matrice 300 RTK [18] or similar custom UAVs).

Table 4. Examples of 5G RAN key equipment per UAV

Component	Description	Example	Weight
Integrated 5G Small Cell	Embedded gNB; RU (SA mode)	Amarisoft Callbox Mini / Baicells Nova430	400–800g
Lightweight Compute Module	For basic UAV / swarm logic	Raspberry Pi CM4 or Jetson Nano	100–200g
Simple Mesh Swarm Radio	IEEE 802.11s Wi-Fi 6 / V2V PC5	Compex WLE900VX / 5G module	50–100g
Battery Pack	Standard UAV LiPo	6S 22000 mAh	1.5–2.0 kg
Positioning Sensors	GPS, IMU	COTS GPS + Pixhawk FC	<100g

One of the key challenges of UAV-based networking is the limitations of power supply, which represents the major weight of the payload. As an example, the above-mentioned DJI Matrice 300 RTK supports up to 55 minutes operational time [18]. For the operational power of the UAVs and 5G RAN components, this feasibility study assumes ideal power management, but in practice (for a more detailed future assessment considering drone swarm), one of the potentially feasible approaches can be a hybrid model that is selected with tethered UAVs (permanent anchor nodes with gNBs) and rotating UAVs (fly, recharge, rotate).

Complementary power sources can be, e.g., solar panels (small flexible panels on UAV structure extending flight by 10-20%), hydrogen fuel cells (2-3× endurance of lithium polymer, LiPo), or tethered power supply forming wired UAVs with unlimited power (feasible for anchor UAVs [19]).

VI. PHYSICAL RADIO INTERFACE

This feasibility study considers theoretical coverage limits of a single UAV applying relevant propagation loss models, with the aim to provide optimal 5G RAN quality and performance as a function of UAV altitude (and later, inter-UAV distance) in rural and open areas, and the following parameters: 1) Frequency band f = low (1 GHz), mid (3.5 and 6 GHz) and high (24 and 28 GHz); 2) UAV altitude h_{gNB} = 50m, 100m,…, 400m; 3) UE type = pedestrian; 4) Power = P_{UE} +23 dBm, P_{gNB} +23 dBm; 5) UAV antenna type = omni-directional (0 dBi gain, uniform, ideal radiation pattern). The key results include achievable cell size and respective data rate estimate for both eMBB and IoT use cases.

The starting point of the study was to consider a single UAV that houses 5G SNPN equipment needed to form basic radio access for the UE-UAV_{gNB}-UE communications.

In rural and open-space areas, for the line of sight (LOS) scenarios, the free space path loss L_{FSPL} (in dB) can be estimated by applying the ITU-R P.525 model (within version 12 of ITU-R P.1411) that assumes minimal obstructions [20]. The LOS path loss equation is:

$$L_{FSPL} = 20\log_{10} f + 20\log_{10} d + 92.45 \quad (1)$$

In this equation, f is the frequency in GHz and d is the distance in kilometers between UAV_{gNB} and UE.

For the feasibility study presented in this paper, Figure 2 depicts the principle of the UAV setup.

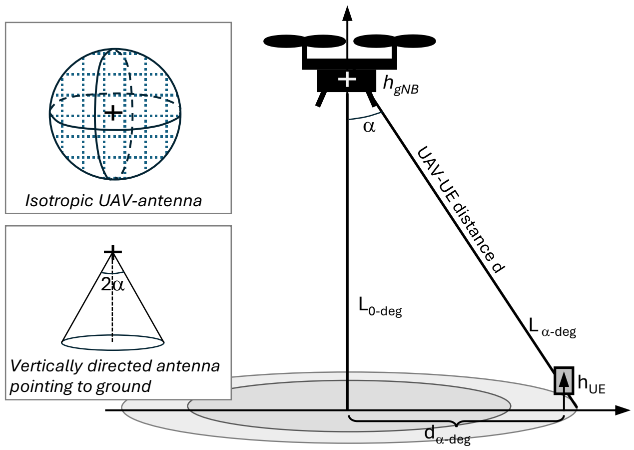

Figure 2. Principle of (theoretic) radiation patterns and respective radio coverage formation assumed in this study

For baseline and comparative reference, this study is based on a theoretical omnidirectional UAV-mounted antenna type with 0 dBi gain. In practical realization, if relying on a passive antenna solution, a directive antenna is needed to optimize the radio coverage minimizing the interference; an example of this is a cone-shaped vertical radiation pattern as depicted in Figure 2. In practical deployments, an adaptive MIMO antenna provides augmented performance, capacity, and interference mitigation, although the drawback is the increased complexity and power consumption. This is especially valid in multi-UAV gNB scenarios, for which adequate radio network planning is important, including appropriate antenna and cell dimensioning.

VII. Results

Using ITU-R P.1411, Figure 3 presents the path loss UE-UAV at a distance *d* from UAV's location for isotropic UAV TX antenna at 100m altitude (earth curvature limit 35 km).

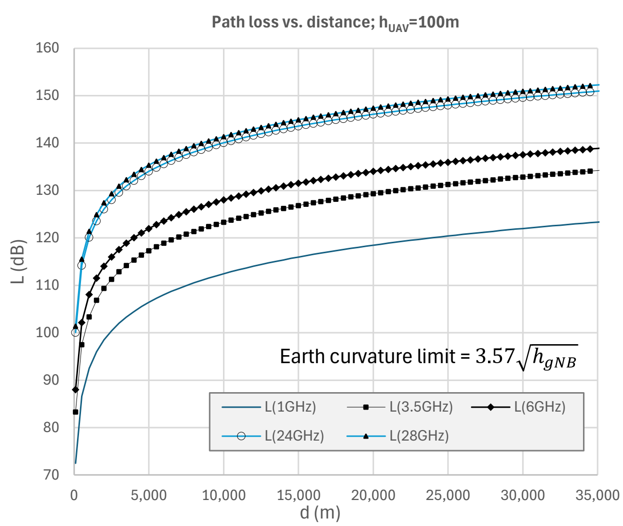

Figure 3. Path loss of UAV-UE as a function of the UE's distance from UAV's vertical reference location (UAV altitude is 100m)

Figure 4 summarizes the estimated path loss values L (dB) directly beneath (α=0º) and off the vertical location of the UAV (α=30º) in open and rural areas.

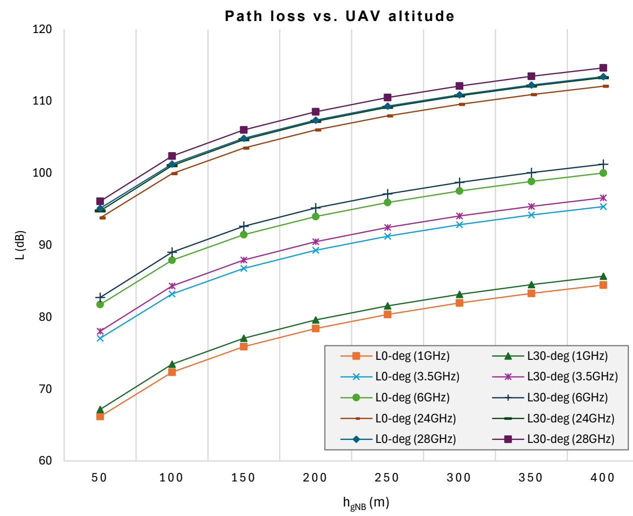

Figure 4. Path loss prediction, 1GHz – 28GHz, for UAV altitudes of 50m – 400m

Scenario: eMBB

Table 5 presents key eMBB radio budget items, and Table 6 presents an example of the radio link budget when the UAV altitude is 400 m and the UE is located underneath.

Table 5. Applied radio link budget items, eMBB scenario

Parameter	Value	Notes
gNB transmitter power P_{TX}	+23 dBm	Typical small-cell power limit, applicable to a UAV-mounted gNB
TX antenna gain G_{TX}	0 dBi	Isotropic (no beamforming)
UE antenna gain G_{RX}	0 dBi	Smartphone baseline
Fade margin *M*	3 dB	Covers body loss, ageing, fading
UE noise figure *NF*	7 dB	5G NR handset typical
Thermal noise density	–174 dBm/Hz	$N_o=kT=1.38\times10^{-23}$ J/K · 290K

Table 6. Example of the radio link budget for d=400m

Link budget, h_{UAV}=400m, α=0º	1 GHz	3.5 GHz	6 GHz	24 GHz	28 GHz
Path loss PL, dB at (2km)	84.5	95.4	100.1	112.1	113.4
Tx power (gNB), dBm	23.0	23.0	23.0	23.0	23.0
Tx antenna gain, dB	0.0	0.0	0.0	0.0	0.0
UE antenna gain, dBi	0.0	0.0	0.0	0.0	0.0
Implementation/fade margin, dB	3.0	3.0	3.0	3.0	3.0
UE noise figure NF, dB	7.0	7.0	7.0	7.0	7.0
Thermal noise density, dBm/Hz	-174.0	-174.0	-174.0	-174.0	-174.0
Channel bandwidth, MHz	20	100	100	400	400
Received power Prx, dBm	-61.5	-72.4	-77.1	-89.1	-90.4
Noise floor N, dB	-94.0	-87.0	-87.0	-81.0	-81.0
Operational SNR after margin, dB	29.5	11.6	6.9	-11.1	-12.5
Spectral efficiency SE	5.88	2.38	1.54	0.06	0.05
Data rate, Mb/s	**117.6**	**237.5**	**154.4**	**25.8**	**19.1**

In these scenarios, the channel bandwidth is 20 MHz (1 GHz), 100 MHz (3.5/6 GHz), or 400 MHz (24/28 GHz). In these calculations, spectral efficiency model is η(bps/Hz) = $0.6\cdot\log_2(1+SNR)$. The assumption for the 0.6 factor is due to scheduler, modulator and coding inefficiencies that lower the theoretic capacity of Shannon limit. The received power is $P_{RX} = P_{TX} + G_{TX} + G_{RX} - L$, and the noise floor is $N = -174 + 10\log_{10}B + NF$. The operational signal to noise ratio (SNR) after margin is $\text{SNR} = P_{RX} - N - M$. The spectral efficiency $SE = 0.6{\cdot}\log_2(1+10^{\text{SNR}/10})$, and the data rate is $R = SE \times B$.

Figure 5 and Figure 6 summarize the impact of h_{UAV} (50 m–400 m) on the received single user data rate considering the space below the UAV and surrounding region.

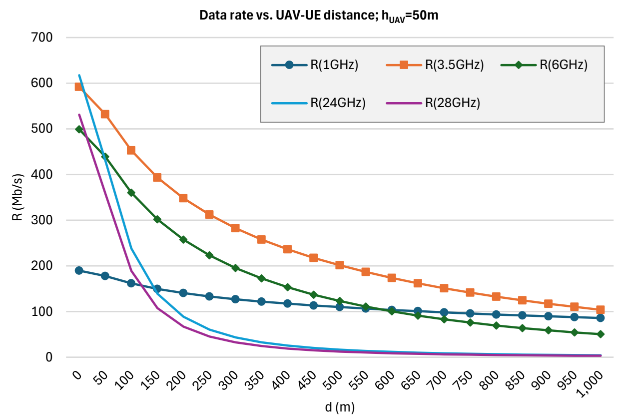

Figure 5. Data rate for UAV-mounted 5G gNB at 50 m altitude

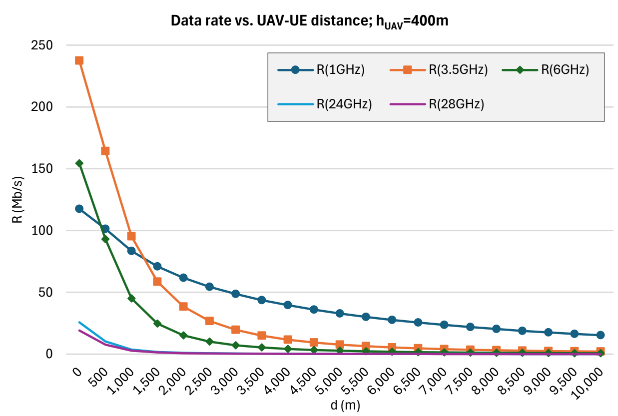

Figure 6. Data rate for UAV-mounted 5G gNB at 400 m altitude

As can be seen, high-band (24 GHz and 28 GHz) provides the highest rates when the distance between UAV_{gNB} and UE is relatively short, but the rate lowers drastically as the distance between UAV and UE increases over a few hundred meters due to the strong attenuation of this band. As can be expected, the mid-band (3.5 GHz and 6 GHz) performs more constantly at short distances and nearby regions.

Taking a closer look at the short distance (5–200 m) between the UAV and UE, Figure 7 shows more detailed behavior. As can be seen, high-band outperforms the other bands up to about 50 m distances providing 1–2 Gb/s data rates, but afterwards, mid-band provides the highest rate (250-500 Mb/s). The heavy attenuation of the high-band makes also the low-band data outperform it beyond 150–200 m distance.

Figure 7 shows that for a critical mission in open and rural areas; if the key requirement is fast data connectivity and high capacity, e.g. for high-definition video contents, high-band provides the most performant service up to about 100 m.

If, instead, the main requirement is a large coverage area (e.g., over 10 km), and the UAV operation is possible at high altitude (e.g., 400m), low-band is adequate selection as Figure 6 indicates. Should there be limitations for the UAV altitude, such as nearby airports or other restricted areas, mid-band (particularly 3.5 GHz) provides the most adequate balance for h_{UAV} and performance, as can be seen in Figure 5.

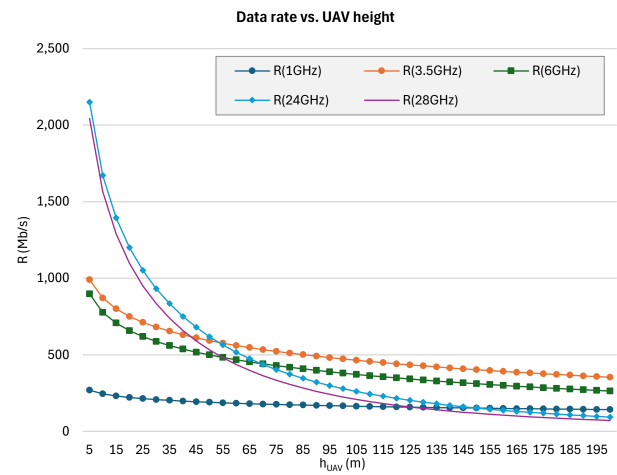

Figure 7. Data rate behavior when the distance between the UAV and UE is short (5-200m)

Scenario: IoT

Table 7 presents key radio budget items for the IoT scenario comparing NB-IoT class CE0 and CE2, LTE-M, and RedCap. In all these cases, the gNB transmitter power is 23 dBm, TX and RX antenna gains are 0 dBi, and RX noise figure is 7 dB (typical low-cost IoT modem). Again, the free-space path loss model is used in these calculations. Receiver sensitivity is driven by bandwidth, i.e., noise floor plus the required SNR for the lowest modulation / coding of each profile. Path-loss budget is the maximum loss the link can tolerate after allocating the fade / implementation margin. Converting that budget to free-space distance shows the theoretical cell radius; real-world coverage will be smaller due to UAV altitude (earth curvature), foliage, buildings and interference.

Table 7. Applied radio link budget items, IoT scenario

Link budget	**NB-IoT$_{\text{CE0}}$**	**NB-IoT$_{\text{CE2}}$**	**LTE-M**	**Red Cap**
Channel bandwidth, MHz	0.18	0.18	1.40	5.00
Thermal noise floor, dBm	-114.4	-114.4	-105.5	-100.0
Impl. / fade margin, dB	8.0	14.0	8.0	5.0
Required SNR / E_b/N_o	-5.0	-13.0	-7.0	-3.0
RX sensitivity, dBm	-119.4	-127.4	-112.5	-103.0
Peak data rate, b/s	25k	50-100	1M	150M
Path loss budget, dB	**134.4**	**136.4**	**127.5**	**121.0**
Distance (1GHz), km	>>35	>>35	>>35	~25
Distance (3.5GHz), km	~35	>35	~15	~7

The presented SNR / (E_b/N_o) values are for the lowest-order modulation / coding in each profile (reference sensitivity) as per the UE RF specifications [21] [22], and the RX sensitivity is N + Required SNR (cross-checked with the specifications for minimum guaranteed UE sensitivity).

As can be seen, NB-IoT can reach the radio horizon even with only 23 dBm EIRP; coverage is limited by geometry, not RF. LTE-M at 1 GHz still covers tens of kilometers, whereas at 3.5 GHz it shrinks to about 15 km LOS. NR RedCap offers the highest data rates but requires roughly 10 dB more SNR than NB-IoT, confining its cell to single-digit-kilometer radii at 3.5 GHz. These tables can be used directly to size UAV altitude, antenna gain, or additional power needed for a given IoT service profile. Compared with the broadband case (for which MCL is 95–105 dB), IoT enjoys tens of dB link budget head-room mainly from the narrow bandwidth and low SNR requirement. Thus, all the presented IoT cases outperform the radio coverage of the eMBB case.

VIII. Summary

This feasibility study focuses on a single UAV-mounted 5G gNB that provides isolated wireless coverage in open and rural areas and serves as a complementing communications method for underlying UEs. The study shows that a COTS-based realization for deploying a UAV-based gNB is feasible selecting a drone that supports the required payload. The cost of drone and COTS-based 5G components, e.g., relying on Open RAN, can be adequate compared to the benefits such as solution provides over terrestrial trailer-mounted solution.

The results show that in aerial eMBB scenarios, the 5G frequency band selection plays a key role, so it is important to evaluate the requirements and respective tradeoffs of bands, UAV altitude, and expected capacity and data rate figures, whereas IoT service can be realized easily for very large areas.

IX. Future Research

The next step in this study will cover 5G-UAV RAN performance evaluation in expanded terrain types, including low- and high-rise urban topologies, applying up-to-date radio propagation models. The future study also considers extended UAV-based RAN network formation through a drone swarm and will evaluate feasible methods for inter-connected gNBs, including AI-assisted coordination. Future research also considers ways to deploy automated positioning functions for the 5G-UAV network with the underneath UEs for which AI may provide feasible means also in presence of interferences, through advanced sensing techniques.

X. Acknowledgement

I gratefully acknowledge the feedback of Professors M. Reisslein, G. Trichopoulos, S. Zeinolabedinzadeh, and A. Alkhateeb of Arizona State University on this work.

References

[1] 3GPP, "3GPP TR 38.865: Study on further NR RedCap UE complexity reduction," 2022.

[2] GSMA, "Mobile economy report 2025," GSMA Intelligence, London, UK, 2025.

[3] J. Penttinen, "On 6G visions and requirements," *Journal of ICT Standardization,* vol. 9, no. 3, pp. 311-325, 2021.

[4] P. Jain, "3GPP SA 6G planning and progress," 3GPP, 2024.

[5] G. Wikstrom and S. Thorson, "Explore the impact of 6G," Ericsson, 19 December 2024. [Online]. Available: https://www.ericsson.com/en/blog/2024/12/explore-the-impact-of-6g-top-use-cases-you-need-to-know.

[6] O-RAN Alliance, "Who we are," [Online]. Available: https://www.o-ran.org/who-we-are.

[7] Telecom Infra Project, "How TIP Works," [Online]. Available: https://telecominfraproject.com/how-we-work/.

[8] Ericsson, "Industrializing Open RAN," [Online]. Available: https://www.ericsson.com/en/openness-innovation/open-ran-explained.

[9] M. Mushi, Y. Liu and S. Sreenivasa et al, "Open RAN testbeds with controlled air mobility," *Computer Communications,* vol. 228, 2024.

[10] M. M. F. A. M. Saym, "Coverage maximization by optimal positioning and transmission planning for UAV-assisted wireless communications," in *International Conference on Science & Contemporary Technologies (ICSCT)*, Dhaka, Bangladesh, 2021.

[11] G. K. E. O. H. Y. Y. Aydin, "Group handover for drone base stations," *IEEE Internet of Things Journal,* vol. 8, no. 18, pp. 13876-13887, 2021.

[12] S. Howe, "AT&T's flying COW transmits 5G network by tethered drone," Commercial UAV News, 29 June 2022. [Online]. Available: https://www.commercialuavnews.com/public-safety/at-t-s-flying-cow-transmits-5g-network-by-tethered-drone.

[13] N. Tafintsev, A. Chiumento and O. Vikhrova et al, "Utilization of UAVs as flying base stations in urban environments," in *15th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, 2023.

[14] P. Valente, A. Teixeira and M. Luis et al, "Easy to deploy UAV-based non-public open-source 5G network," in *15th International Conf. on Network of the Future*, 2024.

[15] 3GPP, "System architecture for the 5G System (5GS)," [Online]. Available: https://www.3gpp.org/DynaReport/23501.htm.

[16] 3GPP, "5G System Enhancements for Edge Computing; Stage 2," [Online]. Available: https://www.3gpp.org/DynaReport/23548.htm.

[17] 3GPP, "Service requirements for the 5G system," [Online]. Available: https://www.3gpp.org/DynaReport/22261.htm.

[18] DJI, "Support for Matrice 300 RTK," [Online]. Available: https://www.dji.com/support/product/matrice-300.

[19] "Drone power feed through ground tethering," [Online]. Available: https://yle.fi/a/74-20156841.

[20] ITU, "Recommendation P.1411-12 (08/2023)," ITU-R, August 2023. [Online]. Available: https://www.itu.int/rec/R-REC-P.1411-12-202308-I/en.

[21] 3GPP, "TS 36.141: E-UTRA; Base Station conformance testing.," 2025.

[22] 3GPP, "TS 36.101: E-UTRA; User Equipment radio transmission and reception," 2025.