

# 6G Vehicular-Aware RAN Strategies for Urban Air Mobility Communications

Alex Piccioni<sup>\*†</sup>, Andrea Marotta<sup>\*†</sup>, Claudia Rinaldi<sup>†</sup>, Graziano Battisti<sup>\*†</sup>,  
Dajana Cassioli<sup>\*†</sup>, and Fabio Graziosi<sup>\*†</sup>

<sup>\*</sup>Department of Information Engineering, Computer Science and Mathematics, University of L'Aquila, L'Aquila, ITALY

{alex.piccioni, andrea.marotta, graziano.battisti, dajana.cassioli, fabio.graziosi}@univaq.it

<sup>†</sup>CNIT, University of L'Aquila Research Unit, L'Aquila, ITALY, claudia.rinaldi@univaq.it

**Abstract**—Urban Air Mobility (UAM) is envisioned as a key component of next-generation transportation systems, requiring highly reliable, low-latency, and high-throughput wireless connectivity to ensure safe and efficient aerial operations. Leveraging existing terrestrial mobile networks represents a cost-effective and scalable solution to support these demanding communication needs, offering flexible infrastructure, wide coverage, and seamless integration with future 6G technologies. This paper investigates the feasibility and advantages of employing mobile networks for UAM connectivity, with a particular focus on RAN-level optimization through vehicular-traffic awareness. By integrating information about planned trajectories and urban vehicle traffic conditions into the radio access decision process, the proposed approach aims to enhance link reliability and improve overall spectral efficiency, demonstrating the potential of mobile networks as a reliable enabler for large-scale and performance-critical UAM deployments.

**Index Terms**—Urban Air Mobility (UAM), Advanced Air Mobility (AAM), 6G, Radio Access Network (RAN).

## I. INTRODUCTION

The rapid evolution of urban transportation systems is witnessing a paradigm shift toward three-dimensional mobility solutions, with Urban Air Mobility (UAM) emerging as a transformative technology to address the increasing congestion in metropolitan areas [1]. As cities worldwide grapple with traffic saturation and environmental concerns, UAM promises to revolutionize passenger and cargo transportation through electric Vertical Take-Off and Landing (eVTOL) aircraft operating at low altitudes [2]. However, the successful deployment of UAM systems relies on robust, reliable, and high-performance wireless communication infrastructure capable of supporting both Command and Control (C2) and non-C2 services with stringent quality-of-service requirements [3].

While various communication technologies have been proposed for UAM connectivity, including satellite-based Non-Terrestrial Networks (NTNs) and dedicated aviation systems,

This work is partially supported by the European Union under the Italian National Recovery and Resilience Plan (NRRP) of NextGenerationEU, through National Innovation Ecosystem (ECS00000041 - VITALITY - CUP E13C22001060006); and Mission 4, Component 2, Investment 1.3, CUP D93C22000910001, CUP E83C22004640001, and CUP F83C22001690001 partnership on “Telecommunications of the Future” (PE00000001 - program “RESTART”); and Investment 1.1, Call for tender No. 1409 of 14.09.2022 of the Italian Ministry of University and Research (MUR), Project Title UPWARD CUP E53D230144900001 - Grant Assignment Decree No. 1383 of 1.9.2023.

terrestrial mobile networks present unique advantages in terms of deployment readiness, cost-effectiveness, and technological maturity. The evolution toward 6G networks introduces unprecedented capabilities that align seamlessly with UAM requirements. Furthermore, the widespread deployment of mobile infrastructure in urban environments provides an existing foundation that can be enhanced rather than replaced, significantly accelerating UAM integration timelines [4].

A critical challenge in utilizing terrestrial networks for UAM lies in the dynamic and heterogeneous nature of the communication environment, which must accommodate both aerial and ground users. In urban areas, the trajectories, the density, and the spatial distribution of UAM vehicles vary according to the underlying ground traffic flows and airspace regulations. These factors directly influence the 3D coverage requirements and interference conditions experienced by aerial users, particularly when operating near densely populated or high-mobility regions [5]. Traditional Radio Access Network (RAN) architectures, primarily optimized for two-dimensional terrestrial coverage, lack the contextual awareness needed to adapt dynamically to the movement patterns and spatial concentration of UAM traffic [6].

Recent advances in flexible radio access architectures opens the possibility of incorporating vehicular traffic information, such as predefined aerial corridors and expected vehicle density, into the network planning and control process. By modeling the RAN according to known UAM trajectories, the network can proactively adapt coverage zones, beam orientations, and handover configurations to ensure seamless and reliable aerial connectivity [7].

The integration of vehicular-traffic awareness into RAN operations represents a novel cross-layer design principle that leverages the predictable and regulated nature of UAM mobility. Unlike terrestrial traffic, UAM trajectories are typically predefined and constrained by flight corridors, enabling the RAN to anticipate connectivity demands. Embedding such information into the radio access design allows the network to reduce coverage overlap and ensure continuous service availability across flight paths [8].

This paper presents a comprehensive framework for vehicular-traffic-aware RAN strategies designed to support UAM communications in 6G networks. We propose a mod-

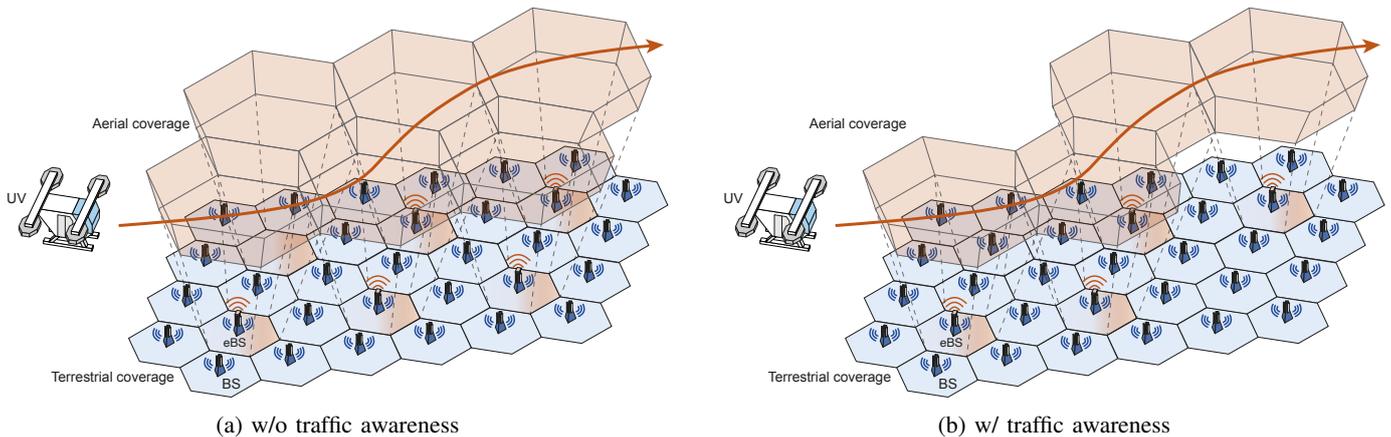


Fig. 1: Reference scenario with and without vehicular traffic awareness.

eling approach that integrates information about UAM routes and vehicle distribution into the RAN configuration process, enabling adaptive coverage and resource allocation according to spatial mobility patterns. The analysis focuses on evaluating how trajectory-aware network planning can enhance coverage continuity, reduce interference, and improve link reliability for aerial users, demonstrating the potential of mobile networks as a reliable enabler for scalable and safe UAM deployments.

## II. SYSTEM ARCHITECTURE

We consider a future 6G network enhanced to provide aerial connectivity for UAM vehicles (UVs). We assume a set of Base Stations (BSs) deployed according to a hexagonal cellular layout to ensure terrestrial coverage across a square urban region of side  $L$ . Let  $\mathcal{B} = \{b_1, \dots, b_{N_b}\}$  denote the set of terrestrial BSs. A subset of these sites is upgraded to support UV connectivity. The upgraded nodes are referred to as enhanced BSs (eBSs). The eBSs employ upward-tilted or multi-beam antennas capable of providing directional coverage toward the altitude range where UVs operate (typically 150–300 m). The generic UV  $u_i \in \mathcal{U} = \{u_1, \dots, u_{N_u}\}$  communicates with the eBS  $b_j$  using Orthogonal Frequency-Division Multiple Access (OFDMA). A set of Physical Resource Blocks (PRBs) (i.e., the minimum physical resource assigned to the UVs) is dynamically assigned according to the selected scheduling strategy [9].

Downlink communications (i.e., from eBS to UV) do not introduce significant interference to aerial or satellite systems. On the contrary, uplink communication (i.e., from UV to eBS) constitutes a major challenge, since UVs may generate strong interference at ground level, degrading terrestrial user performance. Thus, dedicated uplink interference-mitigation policies are required to guarantee coexistence between aerial and terrestrial users. An additional challenge arises from the frequency reuse structure of terrestrial networks. Traditional deployments rely on aggressive reuse across adjacent cells to improve spectral efficiency, where UV uplink signals can propagate over longer distances due to channels dominated by Line of Sight (LOS), increasing inter-cell interference.

Considering these architectural constraints, the placement and selection of eBSs play a central role in guaranteeing robust aerial coverage. In this work, two complementary planning strategies are considered, the homogeneous coverage deployment (Fig. 1a) and the vehicular traffic-aware approach (Fig. 1b).

### A. Homogeneous Aerial Coverage

In this configuration, a subset of BSs is upgraded according to a regular, coverage-oriented pattern. Specifically, eBSs are placed on a hexagonal aerial grid with an increased Inter-Site Distance (ISD) compared to terrestrial deployments. Since upward-tilted and multi-beam antennas can illuminate large aerial regions at higher altitudes, upgrading spatially spaced BSs already provides continuous coverage to UVs flying across the urban area. This strategy offers homogeneous coverage across large areas, but does not exploit information on UV corridor to efficiently provide aerial connectivity.

### B. Vehicular-Traffic-Aware Coverage

The second strategy leverages the predictable and regulated nature of UAM mobility. The eBS selection is restricted to BSs positioned along regulated UAM routes and flight corridors, ensuring that aerial coverage is strengthened precisely along the UV trajectories. Since UV trajectories are known a priori and constrained by airspace rules, this targeted deployment ensures that network upgrades are concentrated where aerial connectivity is required. As a result, the vehicular-traffic-aware approach reduces unnecessary BS upgrades, improves link continuity along operational routes, and enhances spectral efficiency by focusing upward-oriented beams precisely along the expected UV distribution.

## III. TRAFFIC-AWARE RAN OPTIMIZATION

We assume a 6G terrestrial network where a set of  $N_b$  BSs provides downlink connectivity to a fleet of  $N_u$  UVs, where each user corresponds to one aerial vehicle. A subset of BSs is upgraded to support aerial coverage through upward-tilted antennas. Radio access follows an OFDMA structure where

radio resources are partitioned into  $K$  PRBs. Let  $\zeta_{ij}$  denote the number of PRBs assigned by the generic BS  $b_j$  to the  $i$ -th UV  $u_i$  within a Transmission Time Interval (TTI), with  $\zeta_{ij} \in [0, K]$ .

Each vehicle associates with the BS providing the highest Signal-to-Noise Ratio (SNR). Denoting by  $\gamma_{ij}$  the SNR experienced by  $u_i$  from  $b_j$ , the transmission parameters are selected through the 3GPP Modulation and Coding Scheme (MCS) [10]. For each MCS index  $m$ , the Block Error Rate (BLER) can be expressed as a function of the SNR, i.e.,  $P_{\text{BL},ij}^m = f(\gamma_{ij})$ . Thus, the selected MCS  $\bar{m}$  is the highest index satisfying the constraint  $P_{\text{BL},ij}^{\bar{m}} \leq T_{\text{BLER}}$ , where  $P_{\text{BL},ij}^{\bar{m}}$  is the actual BLER experienced by  $u_i$  and  $T_{\text{BLER}}$  denotes the target BLER threshold. The corresponding spectral efficiency  $\varepsilon_{ij}$  results from the MCS selection and determines the achievable rate per PRB, allowing the downlink throughput of vehicle  $u_i$  connected to  $b_j$  to be written as:

$$S_{ij} = \zeta_{ij} \varepsilon_{ij} (1 - P_{\text{BL},ij}^{\bar{m}}). \quad (1)$$

To assess the communication delay experienced by aerial vehicles, we adopt the 3GPP latency model, which decomposes the total latency at radio level as follows:

$$t_{ij} = t_{\text{proc}}^{\text{eBS}} + t_{\text{FA}} + t_{w,ij} + t_{\text{TTI}} + t_{\text{proc}}^{\text{UV}}. \quad (2)$$

Processing delays  $t_{\text{proc}}^{\text{eBS}}$  and  $t_{\text{proc}}^{\text{UV}}$  correspond to the time required by the BS and the UV to encode, decode, and prepare data for transmission and reception. In line with 3GPP guidelines, they are both set equal to one TTI. The frame-alignment delay  $t_{\text{FA}}$  captures the waiting time required for synchronizing packet arrival with the start of the next TTI and is modeled as a uniform random variable over the time interval  $[0, \text{TTI}]$  [11]. The term  $t_{\text{TTI}}$  corresponds to the data transmission time, equal to one TTI.

The queuing component  $t_{w,ij}$  depends on the amount of data awaiting transmission. Assuming the FTP Model 3 for downlink traffic, we can model the UV traffic as a Poisson arrival process with rate  $\lambda_i$  and packets of fixed size  $q$ . Thus, the requested data rate can be expressed as  $R_{ij}^{\text{req}} = \lambda_i q$ , and the resulting queuing delay can be expressed as:

$$t_{w,ij} = \left\lceil \frac{R_{ij}^{\text{req}} / \varepsilon_{ij}}{\zeta_{ij}} \right\rceil \cdot \text{TTI}, \quad (3)$$

where the ratio indicates the number of consecutive TTIs needed to transmit the buffered traffic. Moreover, if no PRBs are assigned during the current TTI, the UV is assumed to be granted at least the minimum PRB allocation observed at the serving base station in the next interval.

#### IV. PERFORMANCE EVALUATION

The proposed vehicular-traffic-aware RAN optimization framework has been evaluated through a dedicated system-level simulator developed in MATLAB, designed to reproduce 6G terrestrial connectivity for aerial vehicles. The simulator emulates downlink radio mechanisms, including resource scheduling and channel-dependent performance, thus enabling

TABLE I: Simulation parameters.

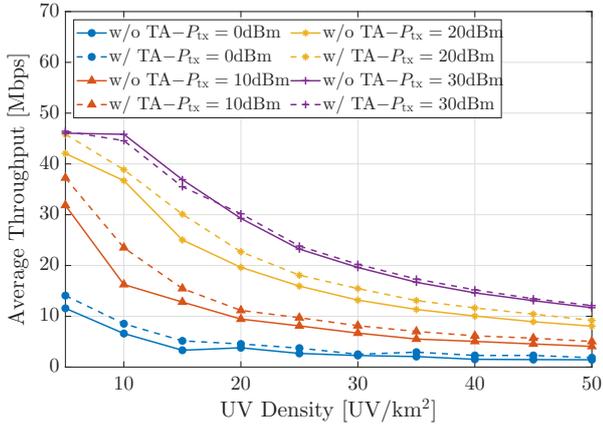
Parameter / Description	Value
Scenario length, $L$	3 km
ISD w/ and w/o TA	{500, 1000} m
Bandwidth, $B_w$	100 MHz
Carrier frequency, $F_c$	3.7 GHz
Numerology, $\mu$	1
Number of PRBs per eBS, $K$	250
UV population, $N_v$	[5 – 50] UV/km <sup>2</sup>
eBS transmitted power, $P_{\text{tx}}$	[0 – 30] dBm
Traffic model	FTP Model 3 $\lambda = 15000$ pkt/s, $q = 3$ kb/pkt
Target BLER, $T_{\text{BLER}}$	$10^{-4}$
UV altitude, $h_u$	[150 – 300] m
BS altitude, $h_b$	25 m
Noise spectral density, $N_0$	−174 dB/Hz

an accurate assessment of throughput and latency under realistic propagation and allocation conditions. Two configurations have been analyzed: without vehicular Traffic Awareness (TA), where eBS are deployed at a larger ISD to provide altitude-oriented coverage, and with TA, where only the BSs intersecting predefined aerial routes are upgraded. These strategies also affect the UV spatial distribution: in the w/o TA case, UV are uniformly positioned according to a Poisson Point Process (PPP), whereas in the TA scenario they are uniformly distributed along fixed trajectories.

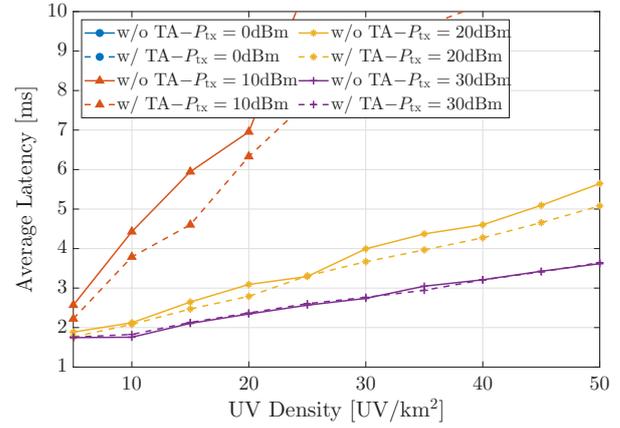
Aerial links are modeled using the 3GPP Urban Macro (UMa) channel model. Although originally developed for terrestrial scenarios, the UMa model has been shown to extend reliably to low-altitude aerial operations, making it a widely adopted reference in UAM performance evaluations [12]. Radio resource scheduling follows the Best-CQI policy, which allocates resource blocks to the vehicles experiencing the highest instantaneous channel quality. Aerial vehicles associate with the eBS providing the maximum received SNR, ensuring that each link operates under the most favorable propagation conditions. All simulation parameters, including carrier frequency, bandwidth, BS layout, and vehicle density, are summarized in Table I.

Fig. 2 exhibits the average throughput (Fig. 2a) and latency (Fig. 2b) experienced by UVs for different values of UV densities for the two considered planning strategies, i.e., without TA (w/o TA) and with Traffic Awareness (w/ TA). In particular, the simulation results show that embedding information about predefined UAM routes into the RAN configuration yields a consistent performance improvement, particularly under challenging propagation conditions. In fact, for low transmit power ( $P_{\text{tx}} = 0$  dBm), the TA strategy provides a distributed gain across all UV density values, with the average throughput increasing by up to +55% compared to the w/o TA case. A similar trend is observed for latency, with a reduction in the average latency up to −71%. This improvement stems from the concentration of aerial links along predictable corridors, which enables more efficient resource allocation and reduces interference from misaligned beams.

Conversely, when the transmit power is high ( $P_{\text{tx}} =$



(a) Average throughput vs UV density



(b) Average latency vs UV density

Fig. 2: Throughput and latency comparison between w/o and w/ TA strategies for different values of UV density.

30 dBm), both strategies exhibit comparable performance. The variations of the average throughput difference between the two cases remain within  $\pm 3\%$ – $4\%$ , suggesting that, under favorable channel conditions, the impact of vehicular-traffic awareness becomes less pronounced and requires more detailed evaluation. It is worth noticing that under poor channel conditions (i.e.,  $P_{tx} = 0$  dBm), the number of PRBs required to meet the data demand increases drastically, resulting in severe queueing and scheduling delays. As shown in Fig. 2b, this leads to average latency values that escalate by more than two orders of magnitude, and for this reason the corresponding latency curves are not visible in the plotted range.

## V. CONCLUSION

This paper investigated the use of 6G networks to provide reliable connectivity for UAM aerial vehicles through vehicular-traffic-aware RAN strategies. Two deployment options were compared: a coverage-oriented approach, where BSs are upgraded to guarantee broad aerial coverage, and a vehicular-aware strategy, where only sites intersecting predefined UAM corridors are enhanced. A system-level simulator was used to assess downlink throughput and latency under realistic deployment conditions. Results demonstrate that vehicular traffic awareness can significantly improve performance under challenging channel conditions, yielding higher throughput and lower latency compared to the baseline, while providing comparable results in favorable scenarios.

Future work will focus on validating the proposed approach in real environments, integrating measurement campaigns and testbed experimentation to capture non-ideal effects such as channel variability, antenna misalignment, and hardware impairments. Particular attention will be devoted to assessing the robustness of vehicular-traffic-aware planning under mobility uncertainties, heterogeneous urban layouts, and time-varying air-ground interference conditions. Moreover, the framework will be extended toward joint optimization of both vehicular trajectories and network traffic, enabling coordinated adaptation of flight paths and radio-resource allocation. This includes

the incorporation of traffic-aware scheduling and predictive orchestration strategies capable of reacting to congestion along UAM corridors.

## REFERENCES

- [1] A. Straubinger, R. Rothfeld, M. Shamiyeh, K.-D. Bichter, J. Kaiser, and K. O. Plötner, "An Overview of Current Research and Developments in Urban Air Mobility – Setting the Scene for UAM Introduction," *Journal of Air Transport Management*, vol. 87, p. 101852, 2020.
- [2] L. A. Garrow, B. J. German, and C. E. Leonard, "Urban Air Mobility: A Comprehensive Review and Comparative Analysis with Autonomous and Electric Ground Transportation for Informing Future Research," *Transportation Research Part C: Emerging Technologies*, vol. 132, p. 103377, 2021.
- [3] A. Baltaci, E. Dinc, M. Ozger, A. Alabbasi, C. Cavdar, and D. Schupke, "A Survey of Wireless Networks for Future Aerial Communications (FACOM)," *IEEE Communications Surveys & Tutorials*, vol. 23, no. 4, pp. 2833–2884, 2021.
- [4] W. Jiang, B. Han, M. A. Habibi, and H. D. Schotten, "The Road Towards 6G: A Comprehensive Survey," *IEEE Open Journal of the Communications Society*, vol. 2, pp. 334–366, 2021.
- [5] H. Ye, G. Y. Li, and B.-H. F. Juang, "Deep Reinforcement Learning Based Resource Allocation for V2V Communications," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 4, pp. 3163–3173, 2019.
- [6] M. Mozaffari, W. Saad, M. Bennis, Y.-H. Nam, and M. Debbah, "A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 3, pp. 2334–2360, 2019.
- [7] C. She, C. Sun, Z. Gu, Y. Li, C. Yang, H. V. Poor, and B. Vucetic, "A Tutorial on Ultrareliable and Low-Latency Communications in 6G: Integrating Domain Knowledge Into Deep Learning," *Proceedings of the IEEE*, vol. 109, no. 3, pp. 204–246, 2021.
- [8] J. Zhao, F. Gao, W. Jia, W. Yuan, and W. Jin, "Integrated Sensing and Communications for UAV Communications With Jittering Effect," *IEEE Wireless Communications Letters*, vol. 12, no. 4, pp. 758–762, 2023.
- [9] A. Mamane, M. Fattah, M. E. Ghazi, M. E. Bekkali, Y. Balboul, and S. Mazer, "Scheduling Algorithms for 5G Networks and Beyond: Classification and Survey," *IEEE Access*, vol. 10, pp. 51 643–51 661, 2022.
- [10] 3GPP, "Technical Specification Group Radio Access Network; NR; Physical Layer Procedures for Data (Release 18)," 3rd Generation Partnership Project (3GPP), Technical Specification (TS) 38.214, 07 2025, Version 18.7.0.
- [11] G. Pocovi, K. I. Pedersen, and P. Mogensen, "Joint Link Adaptation and Scheduling for 5G Ultra-Reliable Low-Latency Communications," *IEEE Access*, vol. 6, no. , pp. 28 912–28 922, 2018.
- [12] R. Amer, W. Saad, and N. Marchetti, "Mobility in the Sky: Performance and Mobility Analysis for Cellular-Connected UAVs," *IEEE Transactions on Communications*, vol. 68, no. 5, pp. 3229–3246, 2020.