Chapter 9

Smart Buildings and Cities

Greta Vallero[a] *and Periklis Chatzimisios*[b]

[a]*Politecnico di Torino, Turin, Italy*
[b]*International Hellenic University, Greece*

Contributors of this chapter: Agnieszka Czapiewska, Andres Navarro Cadavid, Enis Kočan, Fernando Velez, Hamid Taramit, Luis Orozco, Piotr Rajchowski, Daniele Medda, Gianluca Antonio Rizzo, Abdul Saboor, Valentina Timcenko, and Athanasios Iossifides.

This chapter focuses on the theme of Smart Buildings and Cities. As explored in [1], how very high-rate communications and ultra-dense wireless networks can enable future smart environments is investigated. A particular emphasis is placed on the deployment of small cells to enhance coverage, capacity, and energy efficiency – foundational capabilities for next-generation services across various verticals, including massive Internet of Things (IoT), automotive, healthcare, Industry 4.0, and urban infrastructure. Envisioning Sixth Generation (6G)-era smart ecosystems, the enabling technologies considered include carrier aggregation, intelligent reflecting surfaces, wireless power transfer, and integrated terrestrial, airborne, and satellite networks. In this context, several key challenges must be addressed to unlock the full potential of smart city infrastructures:

- **Spectrum management:** Future networks must support highly dynamic environments, requiring efficient spectrum sharing algorithms, seamless HandOvers (HOs) in dense deployments, robust support for variable data traffic, and collaborative resource allocation across heterogeneous Base Stations (BSs) and Access Points (APs).
- **Energy efficiency**: Addressing the growing volume of traffic and increasing demand for connectivity, while accounting for the environmental impact and

Smart Radio Communications: Intelligence-Enabling Radio Communications for Seamless Inclusive Interactions, 427–436

Copyright © 2027 by Greta Vallero and Periklis Chatzimisios. Published by Emerald Publishing Limited. This work is published under the Creative Commons Attribution (CC BY 4.0) licence. Anyone may reproduce, distribute, translate and create derivative works of this work (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this licence may be seen at http://creativecommons.org/licences/by/4.0/legalcode
doi:10.1108/978-1-80686-849-020261009

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

lifetime of IoT devices, is essential. This requires particular attention to the energy efficiency of communication systems.

- **Security and privacy**: Ultra-dense and IoT-rich environments increase the surface area for cyber threats. Ensuring secure and privacy-preserving communication is crucial, particularly in mission-critical applications such as transportation, healthcare, and public safety.
- **Interoperability**: Next-generation smart cities will operate across a diverse mix of legacy and emerging technologies. Seamless interoperability and coexistence across platforms are essential to ensure continuity, scalability, and backward compatibility.
- **Advanced radio resource management:** Emerging cellular and non-cellular architectures – such as cell-free massive MIMO (mMIMO) and Uncrewed Aerial Vehicle (UAV)-assisted communication – require novel techniques to enhance capacity, coverage, and resilience under highly variable user and traffic conditions.
- **Support for emerging applications:** forward-looking use cases such as Visible Light Communications (VLC) for urban infrastructure, autonomous transportation, and remote healthcare delivery are also investigated, each with stringent Quality of Service (QoS)/Quality of Experience (QoE) requirements.
- **Smart buildings and cities as enablers:** These environments aim to enhance the quality of life and operational efficiency across various sectors, including education, mobility, utilities, and entertainment. They require integrated solutions for the planning, deployment, monitoring, and maintenance of interconnected systems. Key use cases include:
  - *Massive IoT*: High-density, low-power sensors and actuators.
  - *Connected vehicles*: Ultra-reliable, low-latency Vehicle-to-Any (V2X) communication.
  - *Smart healthcare*: Real-time diagnostics and telemedicine.
  - *Industry 4.0*: Intelligent, sensor-rich automation and production.
  - *Urban infrastructure*: Smart metering, public safety, and energy-aware street lighting.
- **AI for spectrum and network management:** Finally, Artificial Intelligence (AI), particularly Deep Reinforcement Learning (DRL), plays a pivotal role in automating resource management. AI-driven techniques improve:
  - *Spectral efficiency*: Maximising throughput under limited spectrum.
  - *Power efficiency*: Reducing energy consumption via intelligent control.
  - *Network convergence*: Harmonising the operation of diverse technologies.
- Applications of AI include dynamic spectrum allocation, access control, and transmit power regulation. These approaches enable networks to self-optimise in real-time, adapting to environmental and traffic variations while ensuring user-centric service delivery.

The activities summarised in this chapter contributes to building the technical foundation for resilient, secure, sustainable, and intelligent communication infrastructures tailored to the evolving needs of smart buildings and cities. The following sections present advances in: (i) sensing and connectivity,

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

(ii) network densification and mobility, and (iii) sustainability, resilience, and security, each tackling different aspects of the complex smart city landscape.

9.1. Connectivity and Sensing in Smart Environments

Smart buildings and cities rely on robust sensing and connectivity infrastructures to enable real-time monitoring, automation, and informed decision-making. This section explores key technologies, including massive IoT deployments, Wireless Local Area Network (WLAN) band management and indoor localisation, which collectively enable reliable data acquisition and communication in complex urban and indoor environments.

Wireless Sensor Networks (WSNs) are extensively used for monitoring complex systems in industrial and commercial environments due to their flexibility, programmability, and cost-effective deployment. However, ensuring their performance, reliability, and security requires effective monitoring solutions, particularly in dense, interference-prone WSN environments, such as smart city infrastructure. Consequently, new measuring devices and transmission technologies have been developed to facilitate data transfer from multiple locations to the network management centre. Nevertheless, there is still a demand for devices that function as data concentrators, integrating various transmission technologies and protocols into a single unit. These devices should enable communication between different transmission methods and utilise edge computing to support the management centre by prioritising and merging data. Such a device should also include a decision-making algorithm to choose the optimal radio interface for each specific transmission.

Focusing on power grid monitoring, the works in [2, 3] address this need by presenting measurements of Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), Signal to Interference plus Noise Ratio (SINR), Receiver Signal Strength Indicator (RSSI), Modulation and Coding Scheme (MCS), and Channel Quality Indicator (CQI), which serve to develop an algorithm for evaluating the success probability of packet transmission under current propagation conditions. Notably, the measurements are taken with the commercially available Quectel RM500Q-GL radio module, making the proposed algorithm straightforward to implement in the target device. In addition, these works contribute a data concentration unit capable of interfacing with various systems, including Advanced Metering Infrastructure, Supervisory Control and Data Acquisition (SCADA), Home Area Network, and IoT, demonstrating a practical integration of multi-network communication within smart infrastructures.

Although these efforts focus on optimising data acquisition and transmission, effective network monitoring remains equally crucial. In this regard, the work in [4–6] addresses the challenge of determining the optimal number and placement of sniffers to ensure complete monitoring coverage in multi-hop, multi-channel WSNs. It introduces a passive sniffing-based approach that leverages a distributed network of sniffers to capture real-time packet transmissions across multiple channels. Modelling the WSN as a connectivity graph, the sniffer placement problem is formulated as a coverage maximisation task, with performance metrics

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

such as the aggregate Packet Delivery Ratio (PDR) between sniffers and network nodes, guiding the deployment strategy. The results show that approximately 10 sniffers are sufficient to detect 90% of packet transmissions in a 50-node network spread over a 2 × 2 km outdoor area, highlighting the method's efficiency in scalable deployments.

Beyond monitoring, managing channel access in high-density IoT environments presents further challenges. To address this, Institute of Electrical and Electronics Engineers (IEEE) 802.11ah (Wireless Fidelity (Wi-Fi) HaLow) stands out as a promising solution because it operates in the sub-1 GHz band, providing long-range coverage and low power consumption. A key feature of the standard is the Restricted Access Window (RAW) mechanism, which allocates channel access to device groups in scheduled time slots. However, the standard does not offer guidance on configuring these slots under dynamic network conditions. To fill this gap, the work in [7, 8] proposes the load-aware channel allocation algorithm, which adaptively determines RAW slot lengths based on the number of contending devices, traffic load, and spatial distribution. By modelling channel dynamics with a two-level renewal process, this approach enhances channel utilisation and data freshness while reducing retransmissions. These qualities make it especially suitable for time-sensitive communication in smart urban environments.

Ultimately, accurate indoor and outdoor localisation is crucial for delivering context-sensitive services in smart cities. With the growth of Fifth Generation (5G)-NR Stand Alone networks, both public and private, new opportunities emerge for realistic performance evaluations. Although many studies investigate User Equipment (UE) positioning, they often lack real-world validation due to the absence of transmitted Positioning Reference Signals (PRS) in commercial networks. The work in [9, 10] overcomes this limitation by utilising the periodically transmitted Primary Synchronisation Signal (PSS) in commercial 5G networks for localisation. Using a flexible Software-Defined Radio (SDR)-based testbed, the authors show how small movements, such as a 30 m indoor shift, can greatly reduce positioning accuracy because of changes in the radio channel, especially increased multipath. The Root Mean Square Error (RMSE) increases from 146 m outdoors to 273 m in deep indoor environments, highlighting the importance of considering propagation conditions in practical localisation systems.

9.2. Network Densification and Mobility Support

To meet the growing traffic demands and mobility needs of smart urban systems, flexible and densely deployed networks are essential. This section addresses the challenges and solutions related to Radio Access Network (RAN) densification, the heterogeneity of IoT aggregator nodes, and the use of mobile BSs installed on vehicles to extend coverage and responsiveness.

A cornerstone of dense deployments is the use of high-throughput wireless technologies. The upcoming IEEE 802.11be standard aims to deliver extremely high data rates, supporting next-generation use cases, particularly in densely populated scenarios. Among its features, Multi-Link Operation (MLO) stands out as the most impactful. This mechanism enables Multi-Link Devices (MLDs) to transmit

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

simultaneously across multiple frequency bands (2.4 GHz, 5 GHz, and 6 GHz), unlocking data rates up to 40 Gbps and significantly reducing latency. However, the coexistence of MLDs with legacy devices in current and future WLAN deployments remains an open challenge. To address this, [11, 12] investigate band management policies in a three-band densely populated WLAN, assessing different access and data transfer strategies for MLDs. The results underscore the importance of intelligent band allocation, as various strategies yield trade-offs between throughput and access delay. Carefully distributing legacy devices across frequency bands can enhance fairness and efficiency in heterogeneous deployments.

While [11] focuses on device-level improvements in Wi-Fi networks, broader performance considerations at the cellular level are examined in [13, 14], which evaluate ultra-dense RAN scenarios. These studies compare the 2.6 GHz, 3.5 GHz, and 5.62 GHz frequency bands using a two-slope Path Loss (PL) model, which is better suited for urban environments, to analyse metrics such as packet loss ratio, average delay, and goodput. The findings highlight how increasing the number of users affects performance, particularly under small cell radii. While Long Term Evolution (LTE) suffers from faster performance degradation, 5G New Radio (NR) sustains higher user densities and better maintains service quality. Notably, a packet loss ratio threshold of 2% emerges as a practical bound, with delays consistently below the 150 ms QoS threshold. These results validate 5G NR as the more resilient option for future ultra-dense deployments.

Beyond performance metrics, deployment cost and architectural decisions also play a central role. To this end, [15, 16] explore the cost/revenue trade-offs of deploying 5G NR small cells in the sub-6 GHz band using functional splits 6 and 7.2. Through simulation of video and video plus best-effort traffic, the studies find that split 6 provides the highest profitability due to its lower front-haul requirements. In contrast, split 7.2 becomes viable only for smaller cells or with adequate fibre infrastructure. Furthermore, the choice of frequency band influences deployment density and user capacity, with 2.6 GHz favouring short-range, high-throughput scenarios, and 5.62 GHz excelling at longer-range deployments. These insights underscore how flexible architectures can align economic viability with technical performance. To support efficient network design, optimisation tools are also being integrated into radio planning processes. The work in [17] introduces MiniZinc, a solver-independent modelling language for linear integer programming and constraint satisfaction problems, as a backend for radio access optimisation. Combined with a professional coverage simulation tool, MiniZinc is used to reconfigure BSs in underperforming areas by tuning azimuth, tilt, and transmission power based on real-world constraints such as population density, coverage gaps and interference levels. Although computationally demanding, this approach offers a flexible and modular framework for tailoring RAN design to evolving demands across different radio technologies.

However, static densification strategies, even when optimised, face scalability limitations due to their high Capital Expenditure (CAPEX) and Operational Expenditures (OPEX). In response, next-generation RAN concepts are increasingly embracing mobility and adaptability. Movable infrastructure, such as BSs mounted on drones or vehicles, offers on-demand coverage with reduced reliance

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

on permanent installations. In this context, [18, 19] address one of the key challenges for UAV-based networks: accurately modelling the probability of Line-of-Sight (LoS) in complex Three-dimensional (3D) urban environments. The authors propose a flexible 3D city simulator that estimates the probability of LoS based on UAV and user heights, elevation angles and city structure. The results demonstrate that no single UAV position guarantees optimal coverage across all scenarios, emphasising the need for adaptive and real-time optimisation strategies. This framework represents a significant step towards realistic planning of UAV-enabled communication networks, where performance depends on both spatial positioning and environmental constraints. Building upon the concept of mobility, the work in [20, 21] explores the deployment of Next Generation Node Bs (gNBs) on ground vehicles. Enabled by advances in smart vehicle technologies, these mobile BSs can dynamically adapt to variations in spatial and temporal user demand. The study introduces a stochastic geometry-based analytical model to optimise deployment and resource allocation in scenarios where traffic patterns are periodic and location-dependent, such as urban day/night cycles or rural events. The proposed framework not only supports efficient infrastructure reuse but also minimises interference and improves cost-effectiveness. Validation in realistic deployment scenarios confirms the potential of mobile infrastructure to supplement static networks, enabling a more responsive and efficient wireless system for future smart cities.

9.3. Sustainability, Resilience, and Security

As smart cities scale, ensuring sustainable operation, system resilience, and data security becomes increasingly crucial. This section explores cutting-edge approaches to improving energy efficiency through updated power consumption models, preserving hardware reliability with intelligent RAN management, enhancing resilience via microgrid integration and securing vehicular networks against cyber threats.

The communication and networking community has long recognised the urgent need to reduce the power requirements of RANs [22, 23]. In response, significant efforts have been devoted to designing RAN management strategies that enable a more sustainable and energy-efficient evolution of mobile networks. A key element in this process is the accurate assessment of BS power consumption, which guides operators in optimising resource allocation. However, many of the models historically adopted in the literature are becoming obsolete, as they are unable to reflect the rapid technological advancements in BS hardware. To address this gap, the work in [24] introduces a new data-driven and explainable model for BS power consumption. This model leverages sector- and frequency-specific power demand, traffic volume, Uplink (UL)/Downlink (DL) load, radiated power and cable losses to estimate power usage with high accuracy. Notably, a linear regression approach is preferred due to its strong performance compared to Multilayer Perceptrons (MLPs) and Recurrent Neural Networks (RNNs), as well as its simplicity, explainability, and suitability for convex optimisation.

Building on the foundation of energy-aware modelling, a complementary line of research focuses on managing energy at runtime through intelligent RAN

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

resource allocation. Beyond hardware efficiency and optimal site placement, sustainable RAN design increasingly incorporates mechanisms such as local renewable energy harvesting [25–29] and BS sleep modes [30]. While these techniques can yield notable energy savings, they also raise concerns regarding hardware reliability. Specifically, frequent transitions between power states can stress electronic components, potentially increasing failure rates, even if sleep periods generally lower device temperatures and thus reduce failures according to the Arrhenius law [31]. The study in [32] addresses this trade-off by incorporating the BS failure rate into the RAN management framework. By employing AI-based traffic forecasting, the proposed strategy dynamically adjusts the network configuration to minimise both energy consumption and component failures simultaneously. Results demonstrate energy savings of up to 40% and a 24% reduction in BS failure rate compared to conventional methods. This work reframes energy optimisation through a resilience lens, a lens that becomes even more critical in future network scenarios where service continuity must be guaranteed even during energy disruptions.

Indeed, while the integration of renewable energy sources has emerged as a promising path for sustainable RAN operation, it introduces new vulnerabilities, particularly in terms of power continuity. In the event of grid outages, BSs typically rely on battery backups. However, the densification of mobile networks has significantly increased the number of BSs, making widespread battery deployment costly and maintenance-intensive. In response, the works in [33, 34] propose organising BSs into microgrids, enabling them to collectively manage locally harvested renewable energy. This architecture reduces dependence on batteries while increasing resilience to grid outages. The results show that microgrids can boost managed traffic by up to 300%, with smaller photovoltaic systems (under 6 kWp) achieving performance comparable to much larger installations when used in a coordinated microgrid setting. Moreover, the system's effectiveness is largely unaffected by the specific traffic profiles of the involved BSs or the duration of power grid outages, further highlighting its practicality.

While energy resilience is a major concern, another critical aspect of smart infrastructure is security, particularly in the context of Vehicular *ad hoc* Networks (VANETs) and V2X communication. These systems, which enable real-time interactions between vehicles (Vehicle-to-Pedestrians (V2P)), infrastructure (V2I), and pedestrians (V2P), are central to intelligent traffic management and urban mobility. However, their dynamic and decentralised nature makes them highly vulnerable to cyberattacks. Malicious actors can exploit vulnerabilities at various layers, including physical (jamming), network (packet drops and routing manipulation), and application (false alerts and identity spoofing), thereby degrading reliability and causing operational failures. The works in [35, 36] focus on identifying and analysing such threats in NR-V2X highway scenarios. Through realistic simulations, the authors model attack behaviours by varying vehicle positioning, transmission parameters, and attacker strategies. The study reveals that network performance, particularly throughput, is highly sensitive to changes in data rate under malicious activity. Importantly, detecting these disruptions requires a substantial increase in the monitored data rate, providing key insights into designing robust detection and mitigation strategies for future vehicular communication systems.

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

9.4. Future Directions and Conclusions

This chapter has outlined some key research directions and technological enablers for Smart Buildings and Cities. The pivotal role of ultra-dense networks, small cells, and very high-rate communications in addressing the stringent requirements of emerging innovative environments is emphasised. Within this context, spectrum management, energy efficiency, security, interoperability and advanced radio resource management have proven essential for building scalable, resilient and efficient networks capable of supporting diverse use cases, including massive IoT, automotive, healthcare, Industry 4.0, and smart city applications.

Effective monitoring, optimised placement of WSN sniffers, and efficient IoT channel access, as well as localisation services, benefit from context-aware algorithms and edge intelligence. To meet the needs of next-generation networks, technologies such as multi-link WLAN devices, ultra-dense 5G deployments, cost-optimised small cell architectures, and dynamic, mobile BSs have emerged as key enablers of reliable and adaptable connectivity. At the same time, as networks evolve to meet demands for high data rates and ultra-low latency in dense, heterogeneous environments, their sustainability and resilience must be addressed. Solutions such as intelligent sleep strategies, microgrid integration, and enhanced security protocols for dynamic vehicular networks can mitigate internal failures, power outages, and cyber threats while supporting long-term operational sustainability.

Looking at future research directions, the penetration of AI in mobile networks is expected to increase exponentially, driven by the demand for real-time decision making, predictive network management, and automation. This shift will require widespread and distributed sensing, with large-scale data collection across the network. Yet, AI-driven functions must be tailored to operate within the limitations of resource-constrained devices. This necessitates the development of lightweight, efficient models and decentralised intelligence that can power advanced management strategies. Such capabilities will be critical to ensuring the energy efficiency, adaptability, and resilience of future communication infrastructures in smart environments.

References

[1] F. J. Velez, P. Chatzimisios, L. Orozco-Barbosa, and G. Villemaud, "Challenges and achievements in VT4," INTERACT Cost Action CA20120, Dubrovnik, Croatia, Tech. Rep. TD(23)04058, 2023.

[2] R. Burczyk, A. Czapiewska, M. Gajewska, and S. Gajewski, "Lte performance estimation based on indicators measured by the radio module," INTERACT Cost Action CA20120, Lisbon, Portugal, Tech. Rep. TD(24)07052, 2024.

[3] R. Burczyk, A. Czapiewska, M. Gajewska, and S. Gajewski, "LTE and NB-IOT performance estimation based on indicators measured by the radio module," *Electronics*, vol. 11, no. 18, p. 2892, 2022.

[4] J. Crnogorac, J. Crnogorac, E. Kočan, M. Pejanović-Djurišić, and M. Vučinić, "Monitoring dense multi-channel multi-hop wireless sensor networks," INTERACT Cost Action CA20120, Valencia, Spain, Tech. Rep. TD(22)03020, 2022.

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

[5] J. Crnogorac, J. Crnogorac, M. Vučinić, E. Kočan, and T. Watteyne, "Dense multi-channel sniffing in large IOT networks," *IEEE Access*, vol. 10, pp. 105101–105110, 2022.

[6] J. Kovač, J. Crnogorac, E. Kočan, and M. Vučinić, "Sniffing multi-hop multi-channel wireless sensor networks," in 2020 28th Telecommunications Forum (TELFOR), IEEE, 2020, pp. 1–4.

[7] H. Taramit, L. O. Barbosa, A. Haqiq, J. J. C. Escoto, and J. Gomez, "Load-aware channel allocation for Rayleigh fading Wi-Fi HaLow networks," INTERACT Cost Action CA20120, Barcelona, Spain, Tech. Rep. TD(23)05023, 2023.

[8] H. Taramit, L. Orozco-Barbosa, A. Haqiq, J. J. C. Escoto, and J. Gomez, "Load-aware channel allocation for IEEE 802.11ah-based networks," *IEEE Access*, vol. 11, pp. 24484–24496, 2023.

[9] P. Rajchowski, L. M. Correia, and K. K. Cwalina, "Experimental analysis of 5G-NR based positioning in outdoor and indoor environments," INTERACT Cost Action CA20120, Lisbon, Portugal, Tech. Rep. TD(24)07007, 2024.

[10] P. Rajchowski, L. M. Correia, and K. K. Cwalina, "Experimental analysis of 5G-NR based positioning in outdoor and indoor environments," in 2024 4th URSI Atlantic Radio Science Meeting (AT-RASC), IEEE, 2024, pp. 1–4.

[11] D. Medda, A. Iossifides, and P. Chatzimisios, "Study of band allocation policies in IEEE 802.11be networks with devices of different capabilities," INTERACT Cost Action CA20120, Barcelona, Spain, Tech. Rep. TD(23)05048, 2023.

[12] D. Medda, A. Iossifides, and P. Chatzimisios, "Study of band allocation policies in IEEE 802.11be networks with devices of different capabilities," in *ICC 2023-IEEE International Conference on Communications*. IEEE, 2023, pp. 3205–3209.

[13] R. R. Paulo and F. J. Velez, "Impact of the two-slope path loss model in the service quality of 4G and 5G small cells," INTERACT Cost Action CA20120, Barcelona, Spain, Tech. Rep. TD(23)05078, 2023.

[14] R. R. Paulo and F. J. Velez, "Impact of the two-slope path loss model in the service quality of 4G and 5G small cells," in 2022 IEEE Conference on Standards for Communications and Networking (CSCN), IEEE, 2022, pp. 1–6.

[15] B. Khan, N. Nidhi, R. R. Paulo, A. Mihovska, and F. J. Velez, "Cost revenue trade-off for the 5G NR small cell network in the sub-6 GHz operating band," INTERACT Cost Action CA20120, Dubrovnik, Croatia, Tech. Rep. TD(23)04042, 2023.

[16] B. Khan, N. Nidhi, R. R. Paulo, A. Mihovska, and F. J. Velez, "Cost revenue trade-off for the 5G NR small cell network in the sub-6 GHz operating band," in *2022 25th International Symposium on Wireless Personal Multimedia Communications (WPMC)*, IEEE, 2022, pp. 64–69.

[17] A. Navarro, L. Vargas, and C. Amu, "5G optimization model formal description using MiniZinc," INTERACT Cost Action CA20120, Barcelona, Spain, Tech. Rep. TD(23)05003, 2023.

[18] A. Saboor, E. Vinogradov, Z. Cui, and S. Pollin, "Probability of line of sight evaluation in urban environments using 3D simulator," INTERACT Cost Action CA20120, Valencia, Spain, Tech. Rep. TD(22)03046, 2022.

[19] A. Saboor, E. Vinogradov, Z. Cui, and S. Pollin, "Probability of line of sight evaluation in urban environments using 3D simulator," in 2023 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), IEEE, 2023, pp. 135–140.

[20] G. Rizzo, "Mobile networks on the move: Optimizing moving base stations dynamics in urban scenarios," INTERACT Cost Action CA20120, Espoo, Finland, Tech. Rep. TD(24)08010, 2024.

[21] L. Finarelli, F. Dressler, M. A. Marsan, and G. Rizzo, "Mobile networks on the move: Optimizing moving base stations dynamics in urban scenarios," in 2024 IEEE Vehicular Networking Conference (VNC), May 2024, pp. 101–104. Available as TD-25-10022.

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C

[22] M. Deruyck, W. Joseph, and L. Martens, "Power consumption model for macrocell and microcell base stations," *Transactions on Emerging Telecommunications Technologies*, vol. 25, no. 3, pp. 320–333, 2014.
[23] J. Wu, Y. Zhang, M. Zukerman, and E. K. -N. Yung, "Energy-efficient base-stations sleep-mode techniques in green cellular networks: A survey," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 2, pp. 803–826, 2015.
[24] G. Vallero, G. Perin, M. Meo, M. S. Garino, S. D'Elia, and D. Vaccarono, "A new explainable power demand model for 4G LTE and 5G NR base stations," INTERACT Cost Action CA20120, Dublin, Ireland, Tech. Rep. TD(25)10042, 2025.
[25] W. Tan, S. Li, and M. Zhou, "Spectral and energy efficiency for uplink massive MIMO systems with mixed-ADC architecture," *Physical Communication*, vol. 50, p. 101516, 2022.
[26] A. Salh, L. Audah, Q. Abdullah, Ö. Aydoğdu, M. A. Alhartomi, S. H. Alsamhi, F. A. Almalki, and N. S. M. Shah, "Low computational complexity for optimizing energy efficiency in mm-wave hybrid precoding system for 5G," *IEEE Access*, vol. 10, pp. 4714–4727, 2021.
[27] G. Castellanos, S. De Gheselle, L. Martens, N. Kuster, W. Joseph, M. Deruyck, and S. Kuehn, "Multi-objective optimisation of human exposure for various 5G network topologies in Switzerland," *Computer Networks*, vol. 216, p. 109255, 2022.
[28] S. Alotaibi, "Key challenges of mobility management and handover process in 5G HetNets," *International Journal of Computer Science & Network Security*, vol. 22, no. 4, pp. 139–146, 2022.
[29] H. Chen, Y. Li, J. L. Rebelatto, B. F. Uchoa-Filho, and B. Vucetic, "Harvest-then-cooperate: Wireless-powered cooperative communications," *IEEE Transactions on Signal Processing*, vol. 63, no. 7, pp. 1700–1711, 2015.
[30] Y. Ramamoorthi and A. Kumar, "Resource allocation for comp in cellular networks with base station sleeping," *IEEE Access*, vol. 6, pp. 12620–12633, 2017.
[31] S. Arrhenius, "On the reaction velocity of the inversion of cane sugar by acids," Zeitschrift für Physikalische Chemie, vol. 4, no. 1, pp. 226–248, 1889.
[32] G. Vallero and M. Meo, "Energy consumption and fatigue-aware management in radio access networks," INTERACT Cost Action CA20120, Linz, Austria, Tech. Rep. TD(24)09001, 2024.
[33] G. Vallero and M. Meo, "Microgrid for radio access network resilience," INTERACT Cost Action CA20120, Espoo, Finland, Tech. Rep. TD(24)08046, 2024.
[34] G. Vallero and M. Meo, "Microgrid for radio access network resilience," in 2024 22nd Mediterranean Communication and Computer Networking Conference (MedComNet), IEEE, 2024, pp. 1–8.
[35] V. Timčenko, S. L. Morancho, B. Bojović, K. Koutlia, S. B. Rakas, and C. A. Haro, "Attack identification and classification in V2X scenarios," INTERACT Cost Action CA20120, Barcelona, Spain, Tech. Rep. TD(23)05020, 2023.
[36] V. Timčenko, S. B. Rakas, S. L. Morancho, B. Bojovic, K. Koutlia, and C. A. Haro, "Attack identification and classification in V2X scenarios," in *2024 23rd International Symposium INFOTEH-JAHORINA (INFOTEH)*, IEEE, 2024, pp. 1–6.

Downloaded from www.emerald.com/books/oa-edited-volume/chapter-pdf/11898985/978-1-80686-849-020261009en.pdf by Haute Ecole Specialisee de Suisse C