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May 10, 2026

Reviewer's opinion
on Ph.D. dissertation authored by
Cezary Adamczyk
entitled:
Conflict Mitigation in Open Radio Access Networks

1. Problem and its impact

The most important problem discussed in the dissertation is the issue of detecting and resolving control conflicts in Open Radio Access Network (O-RAN) networks caused by the simultaneous operation of multiple optimization applications (xApps and rApps) in a multi-vendor environment. The author correctly observes that the openness and programmability of the O-RAN architecture, while being its major advantage, also significantly increase the probability of conflicting control decisions that may negatively affect network performance, stability, and reliability. This research problem is clearly formulated in Chapter 1.1 through the dissertation thesis stated as: *"Conflict mitigation mechanisms can significantly improve the performance, stability, and reliability of O-RAN networks operating with conflicting applications."*

In my opinion, the considered problem is undoubtedly scientific in nature, as it concerns a novel and still insufficiently explored area related to intelligent control coordination in modern radio access networks. The dissertation identifies an important research gap, namely the lack of universal and O-RAN-compliant methods for Conflict Detection and Resolution (CD&R), and subsequently proposes original solutions including a procedural Conflict Mitigation Framework (CMF), rule-based methods, and Artificial Intelligence (AI) or Machine Learning (ML)-driven mechanisms based on Reinforcement Learning (RL). The presented thesis constitutes a coherent foundation for the entire research process and is systematically verified through both simulation-based and hardware-based evaluations.

The discussed problem also has substantial practical importance. O-RAN is currently one of the key directions in the evolution of fifth-generation (5G) and future sixth-generation (6G) networks, where interoperability between software components from multiple vendors becomes a critical operational requirement. Without effective Conflict Mitigation (ConMit) mechanisms, network operators may face instability of network behavior, degradation of Quality of Service, and inefficient utilization of radio resources. An important strength of the dissertation is that the proposed solutions were not limited to theoretical analysis only, but were additionally implemented and validated in a real O-RAN Open Test and Integration Center (OTIC) laboratory environment compliant with O-RAN Alliance standards, which significantly increases the practical value and credibility of the presented research.

2. Contribution

The main and original contribution of the dissertation is the development of a comprehensive approach to CD&R in O-RAN architectures, covering conceptual, algorithmic, and implementation-related

aspects. In particular, the most significant achievement of the author is the design and implementation of the proprietary CMF, which constitutes a universal and O-RAN-compliant solution enabling the integration of various CD&R methods for xApps and rApps. The author summarized the individual contributions in detail in Table 1.1 presented in Chapter 1.3 of the dissertation.

In my opinion, the dissertation is especially valuable due to the combination of several complementary research elements: identification and categorization of conflicts in O-RAN, development of a dedicated simulation environment for conflict analysis, definition of evaluation methodologies for conflict resolution algorithms, and implementation of both rule-based and AI/ML-driven approaches based on RL. An important strength of the dissertation is also the validation of the proposed methods not only in simulation scenarios but additionally in a real O-RAN OTIC laboratory compliant with O-RAN Alliance standards. Consequently, the proposed solutions demonstrate not only scientific value but also considerable practical applicability.

In my assessment, the author correctly identifies the key contributions of the dissertation. Particularly important is the fact that the proposed solutions address an actual gap in current O-RAN specifications, which recognize the need for ConMit mechanisms but do not define detailed implementation methods. It is also worth noting that the research results have been partially disseminated through the author's scientific publications, which additionally confirms the relevance and importance of the undertaken research topic.

It is also worth emphasizing that the scientific contribution presented in the dissertation is confirmed not only by the thesis itself, but also by the author's publication record directly related to the research topic. This record includes publications [1]–[7], among them two articles published in the renowned journals *IEEE Communications Magazine* and *IEEE Journal on Selected Areas in Communications*, three presentations delivered at international conferences, including two workshop papers presented within *IEEE INFOCOM*, as well as a preprint and an article published in *Telecommunication Review* (in Polish: *Przegląd Telekomunikacyjny*). The dissemination of the research results through recognized international publication venues, together with the citations already received by these works, objectively demonstrates that the solutions proposed by the author have gained recognition within the research community focused on O-RAN networks and intelligent RAN control.

3. Correctness

The research results and conclusions presented in the dissertation should be considered credible and properly justified. The dissertation has been prepared in a systematic and consistent manner – the author begins with a broad review of the literature and O-RAN standards, subsequently identifies existing research gaps, proposes original solutions, and finally performs a multi-stage evaluation of the developed methods. The structure of the dissertation is logical, and the individual stages of the research naturally follow from the previously defined problems and research hypotheses.

Particular recognition should be given to the correctness and completeness of the adopted research methodology. The author did not limit the work to conceptual considerations only, but additionally developed a proprietary simulation environment enabling controlled experiments in representative O-RAN scenarios. Another important strength of the dissertation is the use of clearly defined evaluation metrics together with comparisons against baseline solutions. This allowed for a reliable assessment of both rule-based ConMit methods and the AI/ML-driven approach based on RL.

In my opinion, one of the most valuable aspects of the dissertation is the validation of the proposed solutions not only through simulations but also in a real OTIC laboratory environment using O-RAN Alliance-compliant hardware and software. Such experimental verification significantly increases the

credibility of the obtained results and confirms the practical feasibility of the proposed CMF. The proposed methods were evaluated in realistic network operation scenarios, which constitutes an important added value of the dissertation.

The editorial and visual quality of the dissertation also deserves high recognition. The thesis has been prepared very carefully, maintaining a coherent structure, consistent terminology, and high-quality figures, diagrams, and tables that significantly improve the readability of the presented concepts and research results. In particular, the clarity of the illustrations describing the O-RAN architecture and the information flows within the proposed ConMit mechanisms should be positively acknowledged.

I have not identified any major methodological or technical flaws that would undermine the correctness of the presented results. Certain limitations of the dissertation stem naturally from the complexity of the considered O-RAN environment and from the necessity to evaluate the proposed methods using representative rather than exhaustive deployment scenarios. These limitations, however, should not be regarded as significant weaknesses of the dissertation, but rather as typical constraints of research involving complex networked systems and, at the same time, as indications of promising directions for future work.

One aspect that could be further expanded concerns the scalability and operational overhead of the proposed CMF presented in Chapters 5 and 6. While the author convincingly demonstrates the effectiveness of the proposed methods in representative simulation and hardware-based scenarios, the dissertation provides less detailed discussion regarding the impact of increasing numbers of simultaneously operating xApps, larger network deployments, and highly dynamic environments on the latency and computational complexity of the proposed ConMit mechanisms. In particular, a more extensive analysis of the processing overhead introduced by the AI/ML-based methods in the context of Near-Real Time RAN Intelligent Controller (Near-RT RIC) timing constraints would further strengthen the practical evaluation of the proposed solution. Nevertheless, this observation should be treated as a suggestion for future extension rather than a weakness undermining the correctness or usefulness of the presented research.

Another natural direction for further development concerns a more formal analysis of the RL methods presented in Chapter 6, especially with regard to stability, convergence properties, and robustness of the learned control policy under substantially different network conditions. It would also be interesting to compare the proposed solution with more recent AI-native approaches, such as multi-agent RL or graph-based coordination methods. These remarks do not diminish the scientific value of the dissertation, but rather demonstrate that the presented research opens broad and promising opportunities for further scientific development.

4. Knowledge of the candidate

The dissertation contains extensive tutorial-like and survey-oriented sections that confirm the candidate's broad knowledge in the **Information and Communication Technology** (ICT) discipline, particularly in the areas of modern radio networks, O-RAN architecture, network control systems, and artificial intelligence methods applied in telecommunications. In this context, Chapters 2 and 3 are especially important. Chapter 2 ("Intelligence in RAN") provides a structured and comprehensive overview of the evolution of RAN towards O-RAN, the architecture of RICs, the operation of xApps and rApps, and AI/ML methods used in modern radio access networks. Chapter 3 ("Conflict management in O-RAN") presents an extensive review of the problem of control conflicts in O-RAN, covering architectural and procedural aspects as well as an analysis of existing solutions proposed in the literature and O-RAN Alliance specifications.

The quality of these chapters deserves positive recognition. The author does not merely summarize existing solutions, but additionally provides critical analysis, identifies limitations of current standards, and consistently builds the motivation for the proposed research contributions. These chapters are characterized by a high substantive level and may serve as valuable introductory material for researchers entering the field of O-RAN and intelligent radio network control. In particular, the relationships between the O-RAN architecture, RIC functionalities, and the problem of control conflicts between xApps and rApps are presented in a very clear and well-structured manner.

I also assess the selection and completeness of the references very positively. The bibliography includes both classical works related to Self-Organizing Network (SON) and RAN evolution, as well as current O-RAN Alliance and Third Generation Partnership Project (3GPP) standardization documents together with recent scientific publications concerning ConMit AI/ML methods in O-RAN. This demonstrates the candidate's very good understanding of the current state of the art and the ability to critically analyze contemporary scientific literature. It is also worth emphasizing that the dissertation refers to very recent sources, including publications and technical reports from 2023–2025, which is particularly important in such a rapidly evolving research field.

Overall, the dissertation confirms that the candidate possesses not only specialized expertise directly related to O-RAN and intelligent radio network control, but also a broad understanding of topics belonging to the **Information and Communication Technology** discipline, including telecommunication system architectures, 5G/6G networks, distributed systems, ML, and the design and evaluation of complex ICT systems.

5. Conclusion

Taking into account what I have presented above and the requirements imposed by Article 187 of the Act of 20 July 2018 – Law on Higher Education and Science (Journal of Laws of 2018, item 1668, as amended), my evaluation of the dissertation according to the three basic criteria is the following:

A. Does the dissertation present an original solution to a scientific problem? (the selected option is marked with **X**)

[X]	[ ]	[ ]	[ ]	[ ]
Definitely YES	*Rather yes*	*Hard to say*	*Rather no*	*Definitely NO*

B. After reading the dissertation, would you agree that the candidate has general theoretical knowledge and understanding of the discipline of **Information and Communication Technology**, and particularly the area of **advanced O-RAN architectures, conflict management in O-RAN systems, and intelligent control mechanisms for next-generation mobile networks**?

[X]	[ ]	[ ]	[ ]	[ ]
Definitely YES	*Rather yes*	*Hard to say*	*Rather no*	*Definitely NO*

C. Does the dissertation support the claim that the candidate is able to conduct scientific work?

[X]	[ ]	[ ]	[ ]	[ ]
Definitely YES	*Rather yes*	*Hard to say*	*Rather no*	*Definitely NO*

Moreover, taking into account the novelty, originality, and practical relevance of the research topic, the comprehensive scope of the conducted studies, the high scientific and editorial quality of the dissertation, the implementation and validation of the proposed solutions both in simulation and real O-RAN OTIC environments, as well as the strong publication record directly related to the dissertation

topic, including publications in highly recognized IEEE journals and international conferences, **I recommend distinguishing the Ph.D. dissertation** for its quality and contribution to the discipline of Information and Communication Technology.

płk dr hab. inż. Jan KELNER, prof. WAT

Signature