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Reviewer's opinion
on Ph.D. dissertation authored by
Saif Sabeeh (M.Sc.)
entitled:
Radio resource management for C-V2X communication systems

1. Problem and its impact

The dissertation considers the scheduling and allocating of radio resources for C-V2X technologies to support highly reliable and error-free transmissions. Concretely, the candidate investigates two modes of transmission of C-V2X communications in centralized and decentralized resource allocation in both LTE (Long Term Evolution) and 5G-NR (5G New Radio) technologies. Centralized and decentralized resource allocation are the typical models considered in the standards, and, specifically, LTE considers the Mode 3 and the Mode 4 for centralized and decentralized allocation, respectively, whereas the 5G-NR defined Mode 2 and Mode 1 for centralized and decentralized resource allocation, respectively.

The problems posed in the dissertation are scientific and have been considered in the scientific literature since 15 years ago. The scientific community has partially solved the issues, and the results have been standardized by mainly 3GPP SDO (Standardisation and Development Organization). However, several aspects require a more profound analysis because the market poses higher requirements to the radio resources. In this context, the dissemination is located, and the solutions proposed by the candidate should be understood.

The dissertation has a clear theoretical component with mathematical analysis and simulations provided to validate the results. However, the proposed solutions have a clear, practical aspect, and it is entirely credible that some could be implemented in vehicular communications.
Other proposals are no longer applicable because they have been solved in new releases of mobile networks. Even if the work is focused on both LTE and 5G-NR technologies, the major part of the contributions and results are focused on LTE networks. This fact is understandable since LTE technology is much more consolidated and, especially, it was much more consolidated when the candidate started the research some years ago. This provokes that some of the proposed solutions are not actually applicable in LTE since LTE will not be further changed, and the 5G has solved some of the issues: for example, the issue of fast resource reselection (fast connection recovery in 5G NR).

Briefly, the issues exposed in the dissertation have a high impact on technology, especially in mobile networks, and bring light to many of the problems of vehicular communications and the instability of the radio spectrum.

2. Contribution

The author has not provided one clear thesis in the work, and the work is a recompilation of research papers on the field of vehicular communications in mobile networks. The positive point is that all the different issues and solutions provided in the different parts of the work are closely related, so, in its entirety, the dissertation is comprehensive and presents several contributions to managing radio resources.
The main contributions are next described:

- The author has proposed a new procedure for selecting radio resources focused on the improvement of the broadcast messages' reliability;
- The author has proposed a method for fast reselection of resources when reserved radio resources are lost;
- The author has proposed a new algorithm for resource congestion control;
- The author has proposed an algorithm for sharing radio resources on a highway.

The presented contributions have been previously presented in five published papers, one of them in Electronics journal (Impact Factor = 2.690) and four in international conferences: three papers have been presented in the IEEE International Symposium on Personal and Indoor Mobile Radio Conference (three different years) and one in a Workshop of the Vehicular Technology Conference. Moreover, two other papers in top journals (IEEE Access IF = 4.340, and IEEE Communications Letters IF = 3.436) have been submitted and are currently under review. All the papers have been published at the international level and at good-quality conferences. The IEEE journals, where the work is submitted, have a high impact factor, and the acceptance of these papers would confirm the impact of the research in international ambits.

3. Correctness

The mathematical models developed by the candidate are appropriate and flawless (as far as I could check). Highly interesting is the model of the Broadcast Collision Zone presented in Section 6 jointly to the analysis of Resource Blocks used and free during communication (as well in Section 6).

As far as simulations are concerned, the work seems to be correct in all the simulation analysis provided by the candidate; however, sometimes a reader may have the impression that there is an abuse of simulations for obtaining results. Sometimes, it would be better to understand deeper the simulation model more so one may expect the final results and may provide a discussion on the anomalies (from the expected results to the final results).
For example, in section 3, the candidate proposes a simulation scenario where many parameters are constant (Table 3.3), and only some are variable (the density of automobiles on the road). The student assumes Poisson arrival model for CAM messages. In my opinion, the simulation could be simplified to M/D/1/K queuing model, which is confirmed by the shape of the results (Figures 3.7, 3.8 and 3.9). The candidate aims to consider many factors in the simulations, so he uses a complete simulation tool, which includes propagation, packet arrival model, packet exchange and others. However, a prior analysis of the work done in the simulation could provide a better understanding of the results. For example, Figure 3.9 (S-SPS) does not follow the trend of M/D/1/K model in some points (α=0.5 and α=0.6), so the author should have analyzed the confidence intervals that, regretfully, have been avoided in the Figure. The lack of confidence intervals is not easy to understand especially considering that the simulations were repeated several times, as shown in Figure 3.10.

Another minor remark is that, in Sections 3 and 4 of the Thesis, the author does not discuss the simulation results in depth, and he just describes the figures without trying to understand the causes that explain the results. This is much improved in the next Sections, and, e.g., in Sections 5 and 6, the author provides very serious discussions on the results.

In conclusion, the dissertation is correct, and the conclusions are valid under light of the results presented in the Thesis.

4. Knowledge of the candidate

The dissertation contains eight chapters:

- Chapter 1 presents the work and the main contributions of the Thesis;
- Chapter 2 is a deep analysis of the State of the Art on Vehicular communications and mobile networks;
- Chapter 3 analyses the sensing-based access to the resources (packet collisions when more than one user tried to access the channel) and proposes small innovations for improving radio resource allocation;
- Chapter 4 analyses the problem of resource reselection in LTE networks and proposes how sensing-based semi-persistent scheduling could be improved by introducing algorithms for collision detection and adaptation through adaptive modulation;
- Chapter 5 faces up the problem of resource congestion control and proposes to introduce a variable threshold for the received signal that may adapt to the state of the network;
- Chapter 6 considers the signaling overhead created by the resource allocation processes. The candidate proposes to reduce the signaling by controlling the resource allocation requests. This solution can be done only in centralized resource allocation;
- Chapter 7 is complementary to the previous chapter and discusses the problem of latency in the resource allocation processes, and, similarly, as in chapter 6, the author proposes an improvement for 5G-NR Mode 1. This chapter is dedicated to the 5G;
- Chapter 8 concludes the work and presents several issues that should be solved in the future to make vehicular communications more reliable regardless of the radio technology (mobile networking or WiFi).

The author has gone more deeply into the literature on several aspects of Telecommunications, from 5G networking, through the Vehicular communications standards to radio resource allocation. Section 2 (Background in Vehicular communications) is very interesting. In that section, the candidate explains in detail all the issues related to vehicular communications with many references. The language of how the author presents the details and the reasoning throughout all the chapter shows a high knowledge of the candidate in the field of vehicular communications and mobile networks.

The author has cited 138 references, and almost all of them are crucial for achieving results. The list of references is complete, and all references are necessary for the discussion.

Regretfully not all of the references are publicly available: sometimes, the candidate uses information from Technical Reports from the 3GPP SDO instead of Technical Specifications (which are publicly available). This makes that sometimes the reasoning is hard to understand. For example, the formula (3.10) that has been extracted from TR 36.885 is challenging to understand (TR 36.885 is not publicly

available) and raises the question: is the parameter 'α' introduced by the candidate or is a parameter from the Technical Report? Furthermore, what exactly does this parameter mean in a formula that provides the distance between cars?

5. Other remarks[1]

Not Applicable.

6. Conclusion

Taking into account what I have presented above and the requirements imposed by Article 13 of *the Act of 14 March 2003 of the Polish Parliament on the Academic Degrees and the Academic Title* (with amendments)[2], 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 Radiocommunications?

[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 variety of the proposed solutions in the theme of the Thesis and their deep analysis (especially through simulations), I **recommend to distinguish** the dissertation for its quality[3]. In fact, the proposed algorithms show that the candidate has reached a very high knowledge of the radio part of mobile networks and is capable of proposing different technological solutions for improving the performance of the radio network. In addition, the candidate has shown capabilities for mathematically describing algorithms and has constructed an advanced (and quite complete) simulation tool based on State-of-the-Art libraries.

Jordi Longay Batalla

Signature

[1] Optional

[2] http://www.nauka.gov.pl/g2/oryginal/2013_05/b26ba540a5785d48bee41aec63403b2c.pdf

[3] Obviously, this sentence is optional.