Katarzyna Kosek-Szott, Prof. AGH
AGH University
Institute of Telecommunications
katarzyna.kosek-szott@agh.edu.pl

26th January, 2023

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 focuses on radio resource management for cellular-vehicle-to-everything (C-V2X) communication support in long term evolution (LTE) and new radio (NR) networks. In my opinion this is timely an important research area. The proposed solutions may be potentially interesting from a practical point of view.

The most important problems discussed in the dissertation are:

- decentralized and centralized resource allocation,
- congestion control,
- spectrum partitioning

in 4G/5G cellular networks.

2. Contribution proposed

The Ph.D. candidate (Saif Sabeeh) proved the thesis that the performance of C-V2X communication systems may be improved by implementing novel mechanisms for resource scheduling, congestion control, and spectrum partitioning. He has focused both on decentralized and centralized resource management.

The following novel solutions were proposed in the dissertation to improve the performance of C-V2X communication:

- ERRA (estimation and reservation resource allocation) and E-ERRA (extension of ERRA) algorithms for autonomous resource allocation (described in Chapter 3). ERRA is intended to decrease the number of collisions and increase the number of successful transmissions using (i) the estimation of the available resource locations for the intended transmissions and (ii) resource reservation. The algorithm operates based on a random counter. E-ERRA extends ERRA to allow re-using of the dropped resource pre-allocations, which is a useful feature.
- S-SPS (sensing-based semi-persistent scheduling) with AM (adaptive modulation) and S-SPS with AMCD (adaptive modulation and collision detection) algorithms (described in Chapter 4). These algorithms were proposed to solve the problems with resource re-selection observed for S-SPS and to avoid channel overloading. Both algorithms are based on the channel busyness ratio (CBR) and the probability of resource re-selection.
- TPC-DCC (transmission power control-decentralized congestion control) method applied to S-SPS and E-ERRA to improve congestion control (described in Chapter 5).

- Centralized resource allocation and cooperation among roadside units (RSUs) for bandwidth repartitioning in C-V2X Mode 3 (described in Chapter 6). The operation of the proposed mechanisms is based on a reselection counter and is managed by a cellular station (either eNB in 4G or gNB in 5G). They are intended to reduce collisions and improve frequency reuse.
- C-ERRA (centralized EERA) and PTR (partial time reuse) intended for better resource partitioning and allocation supervised by a NR base station (gNB) (described in Chapter 7). The proposed mechanisms help to maximise frequency reuse distances and minimize latency of resource selection in gNBs.

The proposed modifications to the standard solutions are solid and well presented in the dissertation. All proposed algorithms exceeded the baselines, as shown in Chapters 3-7. The presented simulation results were gathered for multiple simulation scenarios, which shows the potential of the proposed solutions in a broad scope.

The Ph.D. candidate has published several articles describing research conducted during his doctoral studies. Three papers were presented during the IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) conference. One other paper was presented during the International Workshop on Intelligent Communication Network Technologies (ICNET). Additionally, two papers appeared in international journals: one in MDPI Electronics, and one in IEEE Access. According to Google Scholar, Saif Sabeeh currently has 33 citations.

Critical comments to the description of the proposed solutions are the following:

- The selection procedure of the random counter (RC) range used in the sensing-based semi-persistent scheduling (S-SPS) (described on pages 49-50) is unclear. What is the motivation? How were the ranges chosen?
- The description of the ERRA algorithm, given on page 52, is unclear. The following should be better explained:
    - "UE*i* keeps all packet locations that that have the same RC value" – why?
    - "The estimated location of the resource is evoked from $List_A$ when RC_i reaches 5" – why 5?
    - In Fig. 3.2 $List_A$ and $List_B$ are not shown, which complicates its analysis.
    - Fig. 3.2 is not clear and rather poorly described, e.g., why the resource of E1 was cancelled, what is the meaning of the green and red arrows?
    - What is the cost of the overhead introduced by the ERRA algorithm?
    - What does it mean that the "*new RC should be compatible with other RC packet values*"?
- Equation 3.12 does not include $RS_{collided}$, and RS_{total}, as suggested by its description.
- The abbreviation RC is used twice (to indicate a *random counter* and a *reselection counter*), which is a little bit misleading, see e.g., Section 3.2 and Section 6.1.
- "*The same packet size, the same number of resource blocks in each subchannel, the same broadcast power*" is assumed, e.g., in Section 6.3.2, which is a significant simplification. The Ph.D. candidate writes that "*the analysis shown in the following can be also extended to other resource configurations*" but he does not explain how.
- On page 53 there is a sentence "*In this section, we suggest that the RC does not generate in an entirely random way like S-SPS.*" What does it mean?
- On page 135 it is written "*C-list and E-list are the queues arranged in time. The vehicle of the first resource address in the queue will use the next one, and so on.*" What does it mean?

Critical comments to the simulations performed are the following:

- It is not clear to me how many simulation runs were performed (cf. Chapters 3-7). Statistical analysis of the results is also missing.
- The selected values of different system parameters should be better motivated, e.g., the road length, simulation time.
- What does it mean that the "*std. dev.*" was 3 for LOS and 4 for NLOS (cf. Table 3.1)?
- In Table 4.1 the information about the simulation time is missing. It is also not clear why MCS = 8 and 14 were selected in this test.
- In Table 5.2 there is a reference to Figures 8 and 9 instead of Figures 5.6 and 5.7, respectively. The motivation of the selected numbers of vehicles is also missing.
- Why have the proposed algorithms not been compared with other algorithms proposed in the literature?

Other comments:

- I regret that the Ph.D. candidate did not comment (in Chapters 3-7) what is the relationship between the presented state-of-the-art solutions and his own ideas. In most cases, the short descriptions of the available articles (given in Chapters 3-7) are in my opinion insufficient. For example, on page 85 it is written that "[...] our work proposes a new algorithm to assign CBF to each level, compared to the solutions presented in the literature such as [37] and [114]" but the comparison with the state-of-the-art solutions is not given in the following figures, showing the gathered simulation results.
- I regret that the code of the implemented simulators is not available online, which would allow for its broader verification.

The above-mentioned comments should be considered as minor. My overall evaluation of the dissertation is very positive.

3. Correctness

In my opinion, the arguments presented in the dissertation are solid and correct. However, I recommend that the minor comments, presented in Section 2, are answered during the public defence. I believe this will even better prove the validity of the presented results.

4. Knowledge of the candidate

The main area covered in the dissertation is radiocommunication (mostly 4G/5G communication systems and networks). In Chapter 2, the Ph.D. candidate adequately described the background of vehicular communications, including the IEEE 802.11p amendment, LTE-V2X, and NR-V2X. Additionally, in Chapters 3-7 he has correctly listed and described the state-of-the-art solutions to the problems raised in the dissertation. The Bibliography Section includes 138 items.

5. Other remarks

The dissertation is neat and well formatted. The available list of used abbreviations is very helpful.

There are several minor editorial and grammatical errors in the dissertation. They are the following:

- On page 22, the number of a referred figure is missing.
- Some acronyms are explained more than once, e.g., OFDM.

- Citation numbers are missing on page 32 and 83.
- A citation is missing to the distribute congestion control (DCC) given on page 67.
- Several figures are of poor quality.
- In Fig. 2.6
  - There is an error in the legend, both types of blocks are named "*Slots/RBs not available for SL communication.*"
  - The source of this figure is missing.
  - There is an arrow on top of the figure with no explanation of what it represents.
  - When describing this figure, the Ph.D. candidate refers to colours, which are missing in the figure.
- In Fig. 2.7
  - A legend is missing that would explain the meaning of TB, SR, DCI.
  - The source of this figure is missing.
  - TB2 is missing in Fig. 2.7a.
  - T8 is missing in Fig. 2.7b.
- In Fig. 5.9 there is "*in Scenario 3*" and should be "in Scenario 4".
- Some abbreviations are missing in the List of Abbreviations, e.g., ERRA, RC, S-SPS.
- Not always there is a space between the numerical value and unit symbol.

6. Conclusion

Considering 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)[1], 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 radiocommunication?

[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, given the number of published scientific papers (both in international journals and at international conferences), which confirm the high quality of the research conducted by the Ph.D. candidate, I recommend **distinguishing** the dissertation for its quality.

Ha-Holt

Signature

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