National University of Science and Technology POLITEHNICA Bucharest
Faculty of Electronics, Telecommunications and Information Technology

REPORT

on the PhD thesis
„Enhancing Localization Accuracy in Industrial Wearables with LoRaWAN"
developed by Ms. Eng. ***Ekaterina SVERTOKA***

The undersigned, Alexandru Marțian, associate professor at the Telecommunications Department, Faculty of Electronics, Telecommunications and Information Technology, National University of Science and Technology POLITEHNICA Bucharest, appointed by the Decision of the Director of the Council of University Doctoral Studies (CSUD) no. 29/26.03.2024 (Judgment of CSUD no. 11/26.03.2024), member of the commission established for the examination and public defense of the PhD thesis developed by Ms. Eng. ***Ekaterina Svertoka*** in order to confer the title of doctor, proceeded to analyze the work "*Enhancing Localization Accuracy in Industrial Wearables with LoRaWAN*" and reached the following conclusions.

1. Considerations regarding the topic of the PhD thesis

The topic of this thesis is located in a field of particular interest in the conditions of the increase in the number of workplace accidents in recent years. In this context, the use of industrial wearables was seen as a possible solution for increasing the degree of safety at work.

The author made a review of the current stage of development of industrial wearables, focusing on aspects related to their localization, one of the essential problems in this field.

One of the most common solutions in Internet of Things (IoT) networks and particularly in the case of industrial wearables is LoRaWAN technology. The integration of theoretical and practical research trajectories prompted towards the exploration regarding the potential use of LoRaWAN for localizing wearables in hazardous workplace environments. This field was underexplored due to the inherent limitations of LoRaWAN, initially not designed for localization purposes and constrained by narrow bandwidth, suggesting potential accuracy issues. However, certain features were appealing for localization via low-power devices, suggesting the feasibility of enhancing precision through additional preprocessing or postprocessing methods while conserving energy. This approach could offer society a cost-effective, energy-efficient, and wide-reaching solution, ensuring adequate positioning accuracy for wearables, particularly in workplace safety scenarios.

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2. Considerations regarding the structure and content of the thesis

The work elaborated by Ms. Eng. Ekaterina Svertoka, having a volume of about 124 pages, is structured in 6 chapters, accompanied by a bibliography, list of tables, list of figures and list of acronyms.

In the first chapter, Introduction, the research field, purpose, motivation, as well as the objectives and content of the doctoral thesis are presented.

Chapter 2, *Technological State-of-the-Art*, focuses on the Industrial Internet of Things (IIoT) paradigm and the integration of wearables within it. This section provides a thorough examination of wearable technology, encompassing both general wearables and those designed for industrial applications. Topics covered include the various types of wearables, their applications across different sectors, their purposes, market trends, and the impact of the pandemic. Furthermore, this chapter explores the most hazardous industries globally, identifies the sources of danger within them, and explores the potential for mitigating these risks through wearable technology. Additionally, it discusses state-of-the-art wearables in data collection, transmission, and localization, concluding with an overview of the primary research gaps and challenges. Finally, the chapter narrows down the research direction to focus on localization through industrial wearable devices and selects LoRaWAN for further analysis in this context.

In Chapter 3, *LoRaWAN Technology Analysis*, the rationale for choosing LoRaWAN for the localization-focused study is examined, along with an exploration of its structure and architecture. Initial forecasts regarding the expected localization accuracy are made. Furthermore, this chapter offers theoretical and simulation-driven analyses of LoRaWAN network coverage, crucial for anticipating signal levels at specific distances. Discrepancies identified between theoretical and simulation outcomes emphasize the importance of practical evaluations to corroborate theoretical forecasts and enhance coverage estimations.

Chapter 4, *Experimental analysis of LoRaWAN-based localization*, focuses on the practical evaluations discussed earlier, continuing the exploration of the second research question. It delves into the potential of utilizing LoRaWAN for localization, utilizing datasets gathered from Brno University of Technology, Czech Republic, and University Politehnica of Bucharest, Romania. The chapter details the measurement campaigns conducted, assesses and analyzes the datasets, asserts the accuracy of LoRaWAN-based localization across various environments and conditions, and explores opportunities to enhance precision by adjusting measurement campaign parameters.

Chapter 5, *Improving LoRaWAN Localization Accuracy*, aims to explore ways to enhance the accuracy of LoRaWAN-based localization from an algorithmic perspective. Consequently, the chapter conducts a comparison of the primary machine learning approaches within the regression cluster, ultimately identifying k-Nearest Neighbors (k-NN) as the most suitable. Additionally, it introduces and evaluates several modifications based on the k-NN approach for further enhancement.

The last chapter, *Thesis Conclusions*, includes the presentation of the most significant results, personal contributions, published works and prospects for further research activity.

3. Considerations regarding the value of the thesis

As a general conclusion, it can be stated that the PhD thesis is complex and manages to deepen the subject of LoRaWAN-based localization in industrial wearables, covering all the

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necessary steps, from the basic theoretical elements, the simulation of the coverage of such a solution, the realization of campaigns measurements in different environments (indoor, outdoor, underground), up to advanced theoretical contributions, related to the optimization of some localization algorithms.

The work is based on an extremely rich bibliography, which includes 267 references and proves the effort made by the author to deepen the current state of the field. Among them are technical articles published in journals from the mainstream of publications [10, 33, 52, 59, 63, 99, 179 etc.], as well as in the volumes of recognized international conferences [17, 35, 43, 62, 86, 130, 157, etc.] and materials available online [3, 4, 6, 7, 11, 20, 38, etc.]. Also, last but not least, 6 works published by the author stand out [1, 2, 8, 16, 105, 249].

I noticed a balanced structure of the thesis: a synthesis chapter (chapter 2) in which a thorough review of the current state of research in the field of IIoT and industrial wearables is made, a predominantly theoretical chapter, dedicated to the analysis of the LoRaWAN technology (chapter 3), one mainly applied chapter, chapter 4, dedicated to the experimental analysis of LoRaWAN-based localization, and chapter 5, which includes theoretical contributions brought for improving the LoRaWAN localization accuracy. This approach highlights the training level of the PhD student, as well as the experience in using a complex of simulation and testing environments.

Following the research activity, Ms. Eng. *Svertoka* made a number of special contributions, among which I noted:

- exploration of the field of industrial wearables through a Systematic Literature Review;
- in-depth examination of the metrics and functions of wearable devices aimed at aiding enterprises in improving workplace safety;
- studies were conducted regarding the expected network coverage using well-known propagation models, like Okumura-Hata, Okumura-Hata COST 231, 3GPP Uma and 3GPP 3D Uma;
- organization of several measurement campaigns using different environments (indoor, outdoor, underground) based on which conclusions could be drawn regarding LoRaWAN-based localization accuracy and its dependence on the parameters of the measurement campaign, data processing methods, and localization approaches;
- creation of open LoRaWAN datasets collected for different environments, which could benefit a wide array of stakeholders, from researchers exploring the technology to industry leaders optimizing network deployments;
- proposed two modifications of the k-NN method for enhancing the accuracy of LoRaWAN-based localization.

Last but not least, it should be noted that the dissemination of the scientific results resulting from the research activity was achieved at a very high impact level. Thus, Miss Eng. Svertoka published a total of 8 papers in the field of her doctoral thesis, 5 of which as first author. Of these papers, 6 are indexed in the Clarivate-Web of Science database, 4 of them being published in journals from quarters Q1 or Q2. It is also worth mentioning the special interest that the scientific community has shown for the published works, which have accumulated an impressive number of over 500 citations to date.

4. Conclusion

Ms. Eng. *Ekaterina Svertoka* produced a high-level work, which covers a particularly current

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field in the context of the increasingly frequent presence of industrial wearables in different activity areas. I appreciate that it is an interesting and useful work for specialists in the field, the work bringing significant contributions, both from a theoretical point of view and from a practical one.

The thematic area addressed, the degree of complexity of the research carried out, the contributions mentioned, and the published works lead to the idea that Ms. Eng. *Svertoka* has a high-level theoretical and applied training regarding the optimization of localization in industrial wearables using LoRaWAN technology.

Based on these considerations, I appreciate that the work ***"Enhancing Localization Accuracy in Industrial Wearables with LoRaWAN"*** meets the conditions to be publicly supported and for Ms. Eng. ***Ekaterina Svertoka*** to be granted the title of Doctor of Engineering in the doctoral field of **Electronic Engineering, Telecommunications, and Information Technologies**.

17.05.2024

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