

Drink. Water Eng. Sci. Discuss., author comment AC1
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Reply on RC1

Marius Møller Rokstad and Karel van Laarhoven

Author comment on "Technical note: Graph-theory-based heuristics to aid in the implementation of optimized drinking water network sectorization" by Marius Møller Rokstad and Karel van Laarhoven, Drink. Water Eng. Sci. Discuss.,
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Dear Referee,

Thank you for taking the time to read our manuscript, and thank you for your thorough and constructive comments. We appreciate the effort you have put into this, and believe your comments will contribute to improve the quality of our manuscript. Please find answers to your comments and questions below. *Your comments are written in Italic text*, while our responses are provided using normal formatting.

RC1-C01: *The DWDS sectorization problem is not well defined, this should be corrected by adding an appropriate problem statement. The same applies to the optimization problem formulation. Instead, the authors go straight into the presentation of the solution method based on EA and Graph Theory, which makes things hard to follow.*

Response from authors: We propose to expand on the problem statement in the introduction by adding the following to the statements in alinea 3 of the introduction: "The key challenge of network sectorization lies in finding ways to efficiently divide the network is as many DMAs as possible with as few changes (which are costly) to the network as possible. This essentially is a version of the (np-hard) minimal k-cut problem (Kim et al. 2011)." and then to also reemphasize the problem statement in the lead of the bullet list in 2.1 that describes the layout of the optimization approach: "The white boxes in Figure 1 illustrate a basic way in which an EA can be applied to find solutions to the sectorization problem, i.e. to find ways to divide the network into subnetworks with as few boundaries between them as possible: "

RC1-C02: *Literature review is missing important recent publications on the topic of DWDS sectorization. This is not the first paper on this topic nor the one that makes use of Graph Theory. Recent Vasilic et al (2020) paper can be used as a good starting point for improved literature review as it contains relevant references. Authors are encouraged to use the improved review to better position their approach within the existing body of literature. This will also help better justify the novelty of the proposed method.*

Response from authors: This is a valid point. We will expand on the literature in the introduction, by including references to literature both pertaining to the different motivations for pressure management and novel techniques for optimization of sectorization solutions. Some preliminary suggested literature to include may be:

- Alvisi, S. A (2015) New Procedure for Optimal Design of District Metered Areas Based on the Multilevel Balancing and Refinement Algorithm. *Water Resources Management*, **29**, 4397–4409. doi:10.1007/s11269-015-1066-z.
- Brentan, B.; Campbell, E.; Goulart, T.; Manzi, D.; Meirelles, G.; Herrera, M.; Izquierdo, J.; Luvizotto, E. (2018) Social Network Community Detection and Hybrid Optimization for Dividing Water Supply into District Metered Areas. *Journal of Water Resources Planning and Management*, **144**. doi:10.1061/(ASCE)WR.1943-5452.0000924.
- Ciaponi, C.; Murari, E.; Todeschini, S. (2016) Modularity-Based Procedure for Partitioning Water Distribution Systems into Independent Districts. *Water Resources Management*, **30**, 2021–2036. doi:10.1007/s11269-016-1266-1.
- Diao, K., Y. Zhou, and W. Rauch. (2013). Automated creation of district metered area boundaries in water distribution systems. *Journal of Water Resources Planning and Management*. **139** (2): 184–190. [https://doi.org/10.1061/\(ASCE\)WR.1943-5452.0000247](https://doi.org/10.1061/(ASCE)WR.1943-5452.0000247).
- Diao, K.; Fu, G.; Farmani, R.; Guidolin, M.; Butler, D. (2016) Twin-Hierarchy Decomposition for Optimal Design of Water Distribution Systems. *Journal of Water Resources Planning and Management*, **142**. doi:10.1061/(ASCE)WR.1943-5452.0000597.
- Hajebi, S., E. Roshani, N. Cardozo, S. Barrett, A. Clarke, and S. Clarke. (2016). Water distribution network sectorisation using graph theory and many-objective optimization. *Journal of Hydroinformatics* **18** (1): 77–95. <https://doi.org/10.2166/hydro.2015.144>.
- Laucelli, D.B.; Simone, A.; Berardi, L.; Giustolisi, O. (2017) Optimal Design of District Metering Areas for the Reduction of Leakages. *Journal of Water Resources Planning and Management* **143**, doi:10.1061/(ASCE)WR.1943-5452.0000768
- Liu, J.; Han, R. (2018) Spectral Clustering and Multicriteria Decision for Design of District Metered Areas. *Journal of Water Resources Planning and Management*, **144**. doi:10.1061/(ASCE)WR.1943-5452.0000916.
- di Nardo, A.; di Natale, M.; Santonastaso, G.F.; Tzatchkov, V.G.; Alcocer-Yamanaka, V.H. (2014) Water Network Sectorization Based on Graph Theory and Energy Performance Indices. *Journal of Water Resources Planning and Management*, **140**, 620–629. doi:10.1061/(ASCE)WR.1943-5452.0000364.
- Vasilic, Ž.; Stanic, M.; Kapelan, Z.; Prodanovic, D.; Babic, B. (2020) Uniformity and Heuristics-Based DeNSE Method for Sectorization of Water Distribution Networks. *Journal of Water Resources Planning and Management* **146** (3). DOI:10.1061/(ASCE)WR.1943-5452.0001163
- Zhang, Q.; Wu, Z.Y.; Zhao, M.; Qi, J.; Huang, Y.; Zhao, H. (2016) Leakage Zone Identification in Large-Scale Water Distribution Systems Using Multiclass Support Vector Machines. *Journal of Water Resources Planning and Management*, **142**. doi:10.1061/(ASCE)WR.1943-5452.0000661.
- Zhang, Q.; Wu Zheng, Y.; Zhao, M.; Qi, J.; Huang, Y.; Zhao, H. (2017) Automatic Partitioning of Water Distribution Networks Using Multiscale Community Detection and Multiobjective Optimization. *Journal of Water Resources Planning and Management*, **143** (9). doi:10.1061/(ASCE)WR.1943-5452.0000819.

RC1-C03: *Two real case studies are used to illustrate the methodology (The Hague and Trondheim). However, neither is well described in terms of the current situation/issues nor the corresponding sectorization motivation/goals. Instead, the authors dive straight into presenting results. The reader needs to understand first why the sectorization is needed (in both towns), i.e. what is hoped to be achieved with it. This can then be used to assess the success of sectorization.*

Response from authors: To introduce the motivation behind the case study of The Hague, the following is added at the start of section 2.3.2: " The performance of this approach was tested within the context of a case study involving the optimization of a real DWDS: the network of the city of The Hague, in the supply area of the Dutch water utility Dunea. At the moment of writing, The Hague's network is strongly meshed and has no

DMAs implemented, other than one pilot DMA that separates ~2000 customers from the other ~48000. Dunea seeks to implement a DMA structure in The Hague as a part of their effort to better monitor the flow of their water supply. "

To introduce the motivation behind the case study in Trondheim, it is suggested to add the following explanation from L110 (section 2.2) of the original manuscript "The need to check whether a particular solution for sectorization of the drinking water network will be in violation of the performance requirements set by the utility or legislation has been limiting Trondheim municipality's capacity to optimize their sectorization with respect to pressure management, as the number of hydraulic simulations and computational time would be impractically high, thus making it virtually impossible for the utility to identify a globally effective solution for pressure management."

RC1-C04: *There is no discussion section in the technical note. Yes, the space available is limited but it would be good to, briefly, discuss the pros and cons, especially the limitations of proposed sectorization methodology.*

Response from authors: One possible drawback of the approaches is added to the conclusions section, in relation to future work (see response to the final comment). In addition to mentioning this potential drawback, we also suggest adding a concluding remark about the strengths of what has been actually achieved, namely "computationally quick ways of solving sectorization problems, while at the same time considering specific practical constraints" in the conclusion.

RC1-C05: *The methodology proposed is not compared to any of the existing sectorization methods. This should be ideally done to support various claims made (see e.g. two claims made in the last paragraph of the Conclusions section). Otherwise, these claims need to be toned down.*

Response from authors: We agree. As a comparison to other methods is not our intention, we tone down the claims to better match our goal: to provide additional approaches rather than replace other ones: " The shortest path Algorithm presented in section 2.2 can be used as a pre-processing step that ultimately excludes pipes as viable locations for pressure control zone boundaries, with practical requirements and regulations in mind. This provides an approach to use EA for optimizing the design of pressure reduction zones - while guaranteeing acceptable performance under a multitude of possible failure scenarios - in a way that is computationally feasible. The hybrid variator presented in section 2.3 can be used (sparingly) in addition to other variators to add a local search component to the search behaviour that contributes to finding stronger solutions more quickly with EA (as shown in figure 13). The variator can be used more rigorously to find even stronger solutions at the cost of substantial computational time (as shown in figure 14). As a result, the variator can be a valuable additional asset when applying EA in the water utility practice to optimize the design of DMAs. "

RC1-C06: *The conclusions section should also mention some future work.*

Response from authors: We have added the following section to the conclusions: " The shortest path algorithm presented in section 2.2 essentially constitutes a search space reduction with a specific DMA functionality in mind and the hybrid variator presented in section 2.3 essentially constitutes a greedy optimization step towards a specific DMA property. Although the initial results look promising and are able to provide results that are suitable for the water utility practice, both approaches increase the risk for the optimization to get stuck in local optima (i.e. to arrive at solutions that are 'very good' but not 'the best achievable'). Future work should focus on further elucidating this potential trade-off. "