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# SwarmDAG: A Partition Tolerant Distributed Ledger Protocol for Swarm Robotics: Open Review

Authors: Jason A. Tran, [†] Gowri Sankar Ramachandran,[‡] Palash M. Shah,[§] Claudiu B. Danilov,[¶] Rodolfo A. Santiago,[††] Bhaskar Krishnamachari[‡‡]

Reviewers: Reviewer A, Reviewer B

**Abstract.** The final version of the paper "SwarmDAG: A Partition Tolerant Distributed Ledger Protocol for Swarm Robotics" can be found in Ledger Vol. 4, S1 (2019) 25-31, DOI 10.5915/LEDGER.2019.174. There were two reviewers involved in the review process, none of whom have requested to waive their anonymity at present, and are thus listed as A and B. After initial review (1A), the editors requested the authors to respond to the reviewer concerns and make revisions (1B), which were carried out by the authors, completing the peer-review process.

## 1A. Review

### Reviewer A:

The paper proposes a method that allows to maintain blockchain technology on a swarm of robots that may not be sufficiently connected at all times. The key contribution is the proposal of a protocol that the authors call 'swarmDAG' that facilitates the operation of a distributed ledger. The authors adopt the Extended Virtual Synchrony method. This allows network partitions to continue updating their progress. They address the problem of conflicting

[†] J. A. Tran (jasontra@usc.edu) is a doctoral student in the Ming Hsieh Department of Electrical Engineering at the University of Southern California, Los Angeles, CA, USA.
[‡] G. S. Ramachandran (gsramach@usc.edu) is a post-doctoral researcher in the Center for Cyber-Physical Systems and Internet of Things at the University of Southern California, Los Angeles, CA, USA.
[§] P. M. Shah (palashms@usc.edu) is a master's student in the Ming Hsieh Department of Electrical Engineering at the University of Southern California, Los Angeles, CA, USA.
[¶] C. B. Danilov (Claudiu.B.Danilov@boeing.com) is a researcher with the Networks & Cyber Systems group at Boeing Research and Technology, Huntington Beach, CA, USA.
[††] R. A. Santiago (Rodolfo.A.Santiago@boeing.com) is a researcher with the Networks & Cyber Systems group at Boeing Research and Technology, Seattle, WA, USA.
[‡‡] B. Krishnamachari (bkrishna@usc.edu) is a full professor of the Ming Hsieh Department of Electrical Engineering at the University of Southern California, Los Angeles, CA, USA.

information when separate partitions merge through a novel ledger structure based on a directed acyclic graph.

The authors describe the proposed protocol and list the assumptions. There are a few figures that illustrate the concept; more example with robots in motion would help strengthen the idea.

The paper is well written and structured. Although it is clearly at a premature stage (no empirical results nor theoretical proofs), it is relevant to this community and provides an interesting basis for discussion at an intimate conference such as BROS.

**Reviewer B:**

This paper presents SwarmDAG, a distributed ledger that integrates mechanisms to cope with partition tolerance and ensure eventual consistency.

The paper is central to the topic of the symposium. The paper is well-written and easy to follow.

I enjoyed reading this paper as I share with the authors an ongoing interest in partition-tolerant distributed data structures. I think that this work is a good discussion point for the symposium.

The main limitation of this paper is the extremely preliminary state at which it actually is. The authors do not seem to have implemented their approach, and the paper seems to describe a design proposal more than an actual system.

## 1B. Authors' Response

**Reviewer A:**

The paper proposes a method that allows to maintain blockchain technology on a swarm of robots that may not be sufficiently connected at all times. The key contribution is the proposal of a protocol that the authors call 'swarmDAG' that facilitates the operation of a distributed ledger. The authors adopt the Extended Virtual Synchrony method. This allows network partitions to continue updating their progress. They address the problem of conflicting information when separate partitions merge through a novel ledger structure based on a directed acyclic graph.

The authors describe the proposed protocol and list the assumptions. There are a few figures that illustrate the concept; more example with robots in motion would help strengthen the idea.

The paper is well written and structured. Although it is clearly at a premature stage (no empirical results nor theoretical proofs), it is relevant to this community and provides an interesting basis for discussion at an intimate conference such as BROS.

- The authors thank Reviewer A for the feedback and agree that this work is relevant to the community and will spark interesting discussions at BROS. This paper presents



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the conceptual design of SwarmDAG, a distributed ledger protocol which aims to address the problem of network partitions in robotic swarms. The work presented is ongoing and the implementation of SwarmDAG is currently in progress which will be open sourced when complete. For portability and ease of reproducing the implementation, we are implementing our system components using Docker containers and focusing on compatibility for Raspberry Pis (ARM), which is commonly used in robots in the research community. The underlying blockchain toolkit in our current implementation is Tendermint, and to test for design correctness in the face of partitions, we are utilizing Blockade (`https://github.com/worstcase/blockade`) to emulate network partitions. To implement the Membership Management Service (MMS) as detailed in the paper, we are using the libp2p network stack (`https://libp2p.io/`) to facilitate peer-to-peer communication via gossip messages. In future work, we will present empirical results of the SwarmDAG implementation.

- In addition to the implementation, we will present a formal proof of SwarmDAG's partition tolerance in future work. Because the implementation is currently in progress, we do not have the current capability of illustrating SwarmDAG using moving robots. We intend to run SwarmDAG on our in-house Intelligent Robotic Internet of Things TeStbed (IRIS - `https://github.com/ANRGUSC/iris-testbed/`) built by the authors in previous work to illustrate the effectiveness of SwarmDAG in a real swarm of robots.

**Reviewer B:**

This paper presents SwarmDAG, a distributed ledger that integrates mechanisms to cope with partition tolerance and ensure eventual consistency.

The paper is central to the topic of the symposium. The paper is well-written and easy to follow.

I enjoyed reading this paper as I share with the authors an ongoing interest in partition-tolerant distributed data structures. I think that this work is a good discussion point for the symposium.

The main limitation of this paper is the extremely preliminary state at which it actually is. The authors do not seem to have implemented their approach, and the paper seems to describe a design proposal more than an actual system.

- The authors appreciate the positive feedback from Reviewer B, and agree the work is at an extremely preliminary state. Due to the page limit of this venue, we were unable to fit the additional progress of the ongoing work presented in this paper. We currently have an implementation of SwarmDAG in progress, which we will open source upon completion. We also intend to present the progress of this implementation at BROS. To facilitate ease of reproducibility and portability, we are implementing SwarmDAG using Docker containers and focusing on compatibility with Raspberry Pis, a computing platform widely used by robots in



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the research community. The underlying blockchain toolkit used is Tendermint, and the Blockade tool is being used to emulate network partitions for testing SwarmDAG for partition tolerance. To implement the Membership Management Service (MMS) as detailed in the paper, we are using the libp2p network stack for peer-to-peer gossip messaging. In future work, we will present more details of the implementation as well as empirical results.





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