Research question, hypothesis and refined design

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Domain and scope of research - ACM 2012

A:**Computer systems organization → Real-time systems → Real-time system architecture**
(Tošić, Vičič & Mrissa, 2019; Castellano, Esposito & Risso, 2019; Rocha & Brandão, 2019; Guerrero, Lera & Juiz, 2019)

B:**Theory of computation → Design and analysis of algorithms → Distributed algorithms → Self-organization**
(Li et al., 2014; Castellano, Salimitari, Chatterjee & Fallah, 2020; Oróstica & Núñez, 2019; Qin et al., 2017; Gulati & Kaur, 2020; Mondal & Tsourdos, 2020; Shi & Yang, 2018)

C:**Computer systems organization → Architectures → Distributed architectures**
(Tapas et al. 2020; Abdelwahab et al., 2015)

D:**Computing methodologies → Distributed computing methodologies → Distributed algorithms → Self-organization**
(Bof, Carli & Schenato, 2017; Raghav et al., 2020; Whittaker et al., 2020; Zhang et al., 2020; Fortino, et al., 2020)

E:**Information systems → Information systems applications → Computing platforms**
(Fortino et al. 2020; Al-Doghman, Brookes & Chaczko, 2018)

Domain:

Internet of Things architecture

Scope:

Distributed consensus algorithms

Gaps in the literature and research question

Consensus algorithms, when adopted for Internet of Things (IoT), provide mechanism for balanced decision making on the edge nodes, and avoiding loosing data from IoT devices in the presence of a number of malfunctioning processes (Li et al. 2014). Tošić et al. (2019) proposed decentralized self-balancing architecture that implements consensus algorithm with an aim to improve usage of all IoT devices on the network, and resilience to disconnection while providing increased privacy and security. In their work, authors focused on small number of devices and missed the opportunity to test their architecture with different consensus algorithms against multiple use cases. Li et al. (2014) designed a distributed consensus algorithm with the goal of improving decision making at the edge nodes of IoT, with a focus on global consensus of multiple services. As per authors' suggestion, more focus should be given to research on collaborative methods for the realization of information exchange and resource allocation in IoT environment. Similar attempt to develop Distributed Resource AssiGnment and OrchestratioN (DRAGON) algorithm is presented in the paper authored by Castellano, et al. (2019). Authors tested proposed algorithm within the scope of two use cases focusing on its convergence and performance properties. Gulati & Kaur (2020) present different approach with implementing Weighted Voting Game (WVG) model for conflict resolution in argumentation enabled social IoT networks. Authors simulated and evaluated proposed model's performance within one use case scenario. Additionally, authors notice that implementing model in multi-agent environment to enable agreement among conflicting agents is very promising future work. Meritocratic mechanism is the base for Fortino, et al. (2020) the Friendship and Group Formation (FGF) algorithm designed with organization and improvement of IoT objects collaboration in mind. Authors of the paper could extend the research by implementing additional use cases with multiple agents cooperating. Oróstica & Núñez (2019) discussed distributed multi-cast algorithm for robust average consensus over internet of things environments. Proposed algorithm was tested and compared with Push-Sum-Based algorithm introduced by Bof et al. (2017) that implemented asynchronous communication between the nodes on the network. Oróstica & Núñez mentioned that their algorithm outperformed Bof et al. algorithm, but missed the opportunity to compare it with additional consensus algorithms. It worth mentioning work of Cui, Yang & Liu (2020) on positive edge consensus of nodal networks, where authors presented consensus algorithm addressing the issue of consensus in complex networks. It is not directly related to IoT environments but has a potential as "computationally cheaper especially for large-scale systems." Rocha & Brandão (2019) proposed scalable architecture for discovering and managing group of IoT devices. Whereas their model is successful, it does not take into account impact of devices' energy consumption, or increase in number of nodes connected. Salimitari, Chatterjee & Fallah (2020) compared multiple blockchain based consensus methods that can be applied to IoT networks. They did not achieve implementation satisfying all challenges listed in the paper. Qin, et al. (2017) present a survey advances in consensus of Multi-Agent Systems (MAS), but as they pointed out "survey is far from an exhaustive literature review and there may still be some important results missing in the review due to space limitation." Al-Doghman, Brookes & Chaczko (2018) introduced consensus techniques that provide a complete information about network status by implementing one case study using the consensus aggregation within Fog environments. Abdelwahab et al. (2015) developed algorithms for sensing resource discovery in IoT with their main focus on gossip policy. Paper did not discuss implementation of other communication protocols (e.g., asymmetric, or coordinated broadcast). Mondal & Tsourdos (2020) discussed the optimal topology problem and way of solving it using Genetic Algorithm (GA) technique to achieve optimal adjacency matrix. Authors came to conclusion that their research can be extended by including more agents in the experimental network (by changing the dimension of adjacency matrix). Raghav et al. (2020) proposed proof of elapsed work and luck (PoEWAL) consensus algorithm for satisfying security requirements (e.g., integrity, authentication, and availability) on IoT devices. Although PoEWAL was compared with other consensus algorithms in terms of consensus time, energy consumption, and network latency authors missed the opportunity to make it more complete by not including scalability, computing requirements and decentralization features. Similarly, Whittaker et al. (2020) compared multiple consensus protocols (e.g., Paxos, Matchmaker Paxos and Raft), and applied them to IoT universe, focusing on applying proactive reconfiguration in elastic systems.

Research Question:

Can implementation of Raft consensus algorithm in IoT network decrease latency on the network in the presence of malfunctioning edge nodes when compared to other leading consensus algorithms?

Hypothesis + research methods

Null hypothesis H_0: Implementation of the Raft consensus algorithm will not improve latency of the IoT network in the presence of faulty edge nodes.

Alternative hypothesis H_1: Implementation of the Raft consensus algorithm will significantly improve latency of the IoT network in the presence of faulty edge nodes.

Alternative hypothesis H_2: Implementation of the Raft consensus algorithm will increase discovery of the faulty edge nodes in the IoT network.

Research methods:

- **By type: Primary research**
  Author of this research will conduct experiment where original (non-existent) data will be collected. Different consensus algorithms will be compared on IoT network to confirm H_1 and H_2.
- **By objective: Quantitative research**
  Quantitative (numerical) data from the experiment will be collected and analysed, and provide definitive result.
- **By form: Empirical research**
  The answers will be provided by comparing quantitative data.
- **By reasoning: Deductive research**
  Author will test and confirm an existing theory.

Tasks/Objectives to test hypothesis using statistical tools

- **O1** — **Literature Review** — Review of research papers — **2 -3 weeks**
- **O2** — **Design phase** — Create use cases (network of three, five and seven edge nodes) and design experiment and data set — **1 week**

	Use Case 1	Use Case 2	Use Case 3	Use Case 4
3 nodes network	1 node failure	X	X	X
5 nodes network	1 node failure	2 node failure	3 node failure	X
7 nodes network	1 node failure	2 node failure	3 node failure	4 node failure

- **O3** — **Create an experiment** — Build network of nodes, as per use cases, with matching number of identical sensors attached to the nodes. — **2 weeks**

Client	IoT Node	Sensor	Transceiver Module
Lenoco Ideapad 530s	Raspberry Pi 3 Model B+	Arduino Nano 33 BLE Sense	REYAX RYLR896 LoRa

- **O4** — **Conduct control experiment** — **2 weeks**
  - Implement Raft algorithm and measure network latency on three, five and seven nodes IoT network.
  - Implement Paxos algorithm and measure network latency on three, five and seven nodes IoT network.
  - Implement DRAGON algorithm and measure network latency on three, five and seven nodes IoT network.
  - Implement PoEWAL algorithm and measure network latency on three, five and seven nodes IoT network.
- **O5** — **Conduct experiment** — Test algorithms performance (network latency) from control experiment in below experiments — **3 weeks**

	Experiment 1	Experiment 2	Experiment 3	Experiment 4
3 nodes network	1 node failure	X	X	X
5 nodes network	1 node failure	2 node failure	3 node failure	X
7 nodes network	1 node failure	2 node failure	3 node failure	4 node failure

- **O6** — **Results Review** — Review data collected during the experiment. Use paired-samples t-test to statistically compare performance during experiment with different conditions. — **1 week**
- **O7** — **Confirm hypothesis** — Confirm or reject hypothesis based on the data collected — **1 week**

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Dataset

Data set for this research will be gathered during the experiments. It will be the collection of message round-trip time (nanoseconds) between the edge node - Raspberry Pi 3 Model B+, and the client – Lenovo Idepad 530s. As edge nodes will be constantly fed the output of the sensors, they will update client within an identical interval.

All round-trip time data collected during control experiment will be statistically compared to algorithms performances during research experiments.