Jian-wen XU, Kaoru OTA, Mian-xiong DONG, An-feng LIU, Qiang LI, 2018. SIoTFog: Byzantine-resilient IoT fog networking. *Frontiers of Information Technology & Electronic Engineering*, 19(12):1546-1557. https://doi.org/10.1631/FITEE.1800519

SIoTFog: Byzantine-resilient IoT fog networking

Key words: Byzantine fault tolerance; Fog computing; Resource allocation; Internet of Things (IoT)

Corresponding author: Mian-xiong DONG
E-mail: mxdong@mmm.muroran-it.ac.jp
Mian-xiong DONG, http://orcid.org/0000-0002-2788-3451

Motivations

1. We used to regard fog computing as an extension of cloud computing, but it is now becoming an ideal solution to transmit and process large-scale geo-distributed big data.

2. Byzantine faults can be very common in the distributed systems, such as fog networks.

3. A good fault tolerance performance can greatly tolerate the interruption of retransmissions in network communications and reduce extra energy consumption and time costs.

Main ideas

1. We aimed to propose solutions on the issue of Byzantine fault tolerance in providing fog services in IoT applications.

2. Taking the mobility of IoT devices into account, the relationship between replicas and primary devices can change while the entire network is running.

3. Therefore, we needed a dynamic resource allocation strategy to solve the BFT in fog computing.

Methods

1. Based on the non-recursive breadth-first search (BFS) method, we first designed a BFT fog networking algorithm to implement BFT fast networking.

2. To achieve Byzantine faults tolerance in this fast-built fog network, we designed a one phase minimum distance (OPMD) algorithm and a two-phase shortest path (TPSP) algorithm to set nearby fog nodes as replicas while allocating computing resources.

Major results

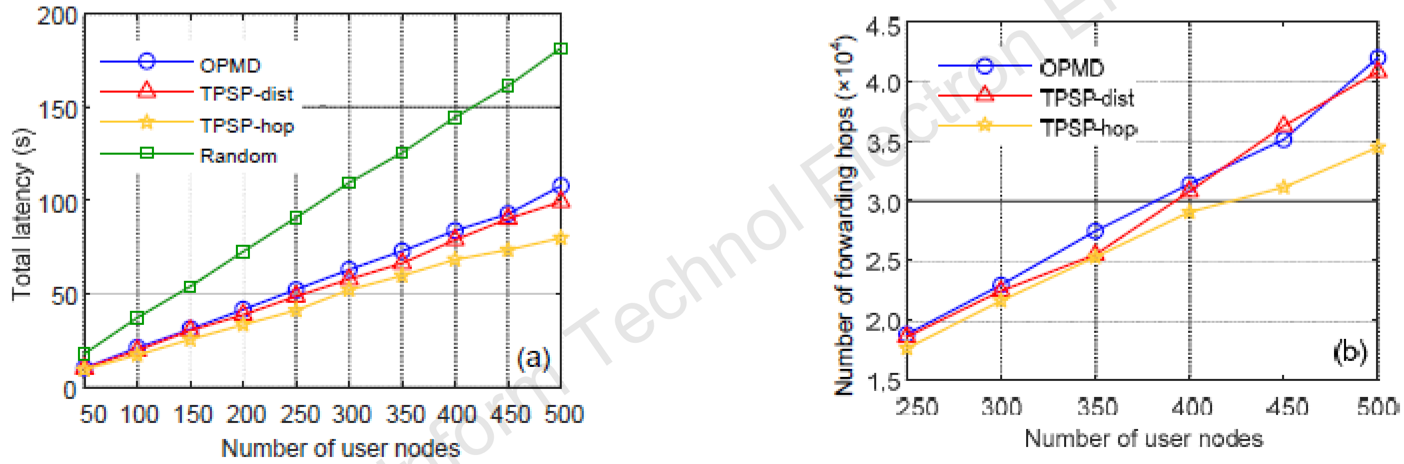

Fig. 3 Simulation results in the case of a single Byzantine fault: (a) total latency; (b) number of forwarding hops in transmission

The red and yellow lines represent the simulation results of different standards when choosing suitable neighbor fog nodes, as shown in step 5 of Algorithm 3. The yellow line considering the number of forwarding hops shows less total latency than the red one, which illustrates that the time cost of L_{trans} takes up a larger proportion than that of L_{prop}. References to color refer to the online version of this figure

Major results

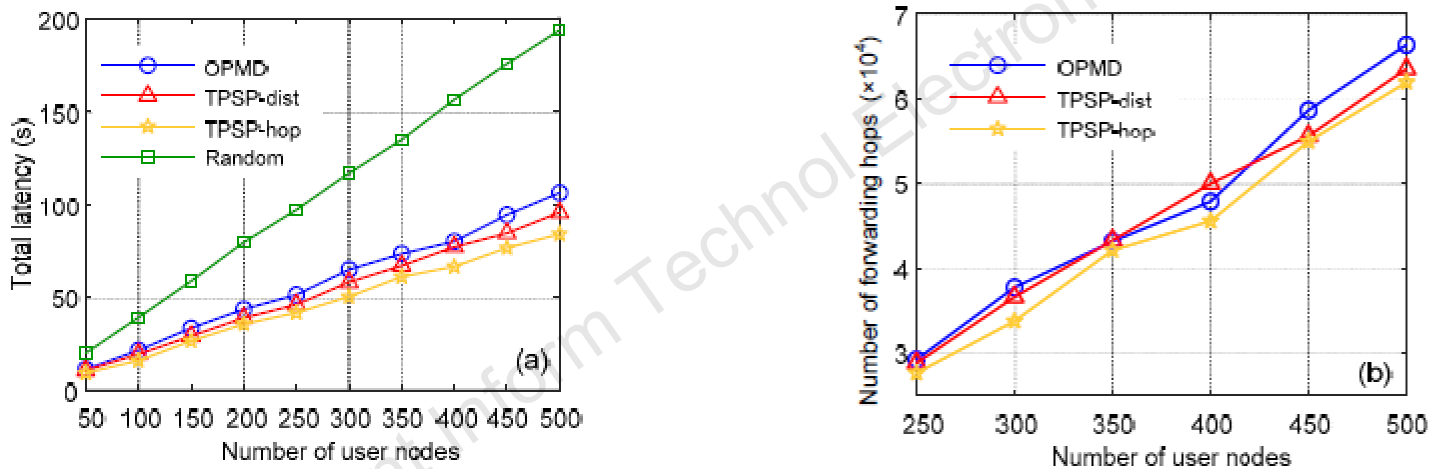

Fig. 4 Simulation results in the case of multiple Byzantine faults: (a) total latency; (b) number of total forwarding hops in transmission

References to color refer to the online version of this figure

Major results

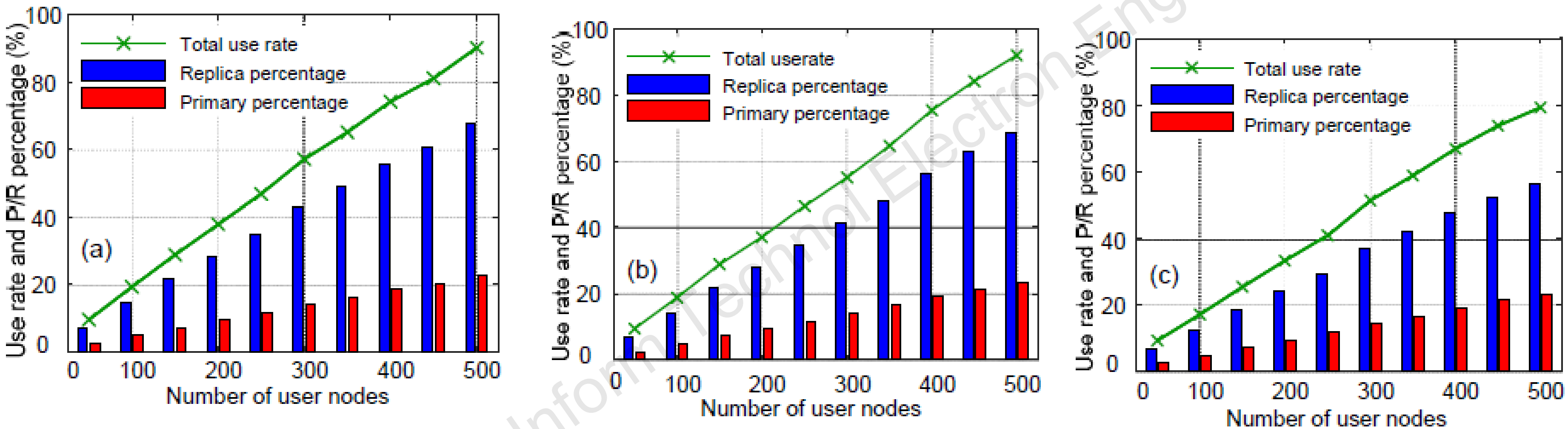

Fig. 5 Device use rates and percentage of the primary devices and replicas in the case of a single Byzantine fault: (a) OPMD; (b) TPSP-dist; (c) TPSP-hop

Green broken line stands for the actual occupancy rates, which are the average of 10 time slots. The blue and red bars are the average percentages of workload capacity occupied by the replicas and primary devices, respectively. References to color refer to the online version of this figure

Major results

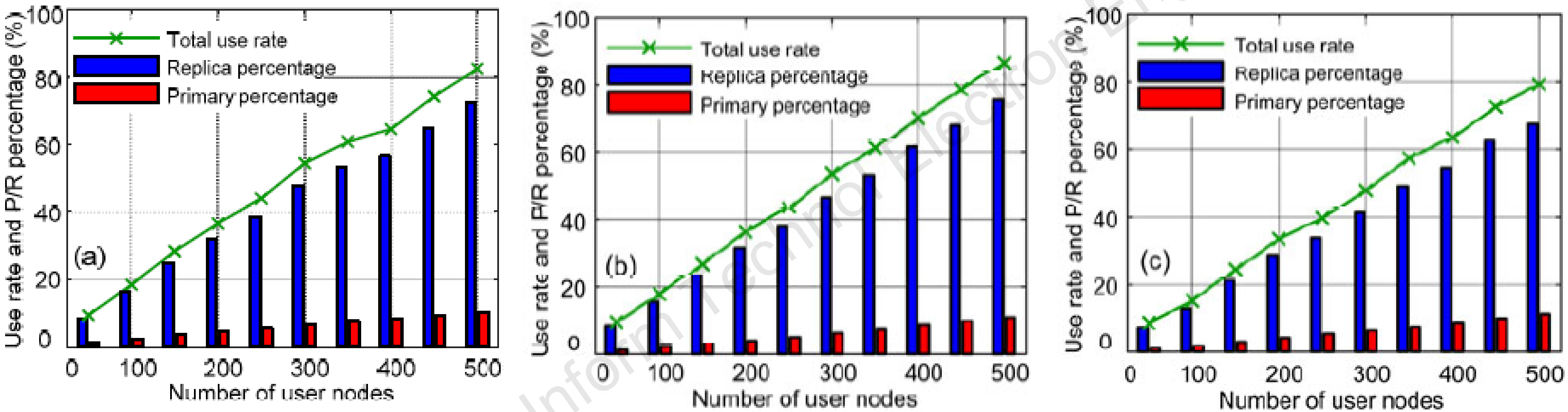

Fig. 6 Device use rates and percentage of the primary devices and replicas in the case of multiple Byzantine faults: (a) OPMD; (b) TPSP-dist; (c) TPSP-hop

The green broken line stands for the actual occupancy rates, which are the average of 10 time slots. The blue and red bars are the average percentages of workload capacity occupied by the replicas and primary devices, respectively. References to color refer to the online version of this figure

Conclusions

1. We have designed a three-tiered heterogeneous IoT fog network model which consists of routers as fog nodes to provide fog service to IoT users.

2. We have proposed a fog networking method based on breath-first search and two BFT resource allocation strategies to distribute workload capacities of the fog nodes to users upon request.

3. We have considered both a single Byzantine fault and multiple faults in simulations. Results showed that our proposed strategies can build an efficient and reliable fog network when faced with Byzantine faults.