Edge Computing in IoT: Preliminary Results on Modeling and Performance Analysis

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***Abstract*—Edge computing, the subsidiary model of Cloud computing, is aiming to push computational resources closer to the edge of network. Its objectives are to improve network latency and ensure efficiency of performed tasks. However Internet of Things (IoT) devices usually are of limited processing power or/and connecting to network episodically, mostly due to power saving necessity and mobility. Thus in the paper investigation of the performance of edge computing for IoT is presented. Multiple simulations by *EdgeNetworkCloudSim* of different topologies, their parameters, together with considered IoT device primary limitations, are carried out. Simulation results confirm the specificity of edge computations for IoT and gives some practical insights.**

***Index Terms*—Edge Computing; Cloud Computing; Internet of Things.**

I. Introduction

Classic Cloud computing network structure no more satisfy current demands of services, since it has high computational and network requirements and because of its centralized arrangement. Each year increasing number of IoT devices [1], [2] lead to network clog up. To overcome this issue, together with increasing amount and overall computational power of edge devices, often tasks are pushed to edge of the network [3], [4]. Such decentralization greatly impacts on overall latency, mobility of the systems improvement, as well as grants larger data to be processed. To acknowledge main parameters of network topology, modeling and performance analysis is performed.

Most simulations of Edge network are performed on model with wired devices having high resources. Network topologies investigated in this paper are tuned to represent realistic IoT devices. In addition, novelty is provided by carrying out two performance analysis cases of Edge network: high throughput (wired) and low throughput (IoT). To realize full potential of Internet of Things research of possible application for blockchain [5], bioinformatics [6], [7], [8] and intelligent algorithms [9], [10], [11] environments are considered. The carried out simulation and investigation researches main parameters in Edge computing structure to achieve improvement of network utilization and reduce latency.

In this paper we present overview of related work, discuss preparation of data and parameters for simulation, report on performed simulations over different network parameters and topologies. Results of simulations are evaluated in terms of overall service time, success and failure rates.

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II. Related work

Developers of *EdgeNetworkCloudSim* simulation tool performed study [12] on high throughput Edge network, performed improvements to “CloudSim” framework [13] by reorganizing algorithms and results to evaluate service times and failures, opposing to energy consumption, that is more reliable measurement for Cloud computing. Furthermore, introduced customization of data centers and service chains allows to evaluate its orchestration. Experimental investigation is performed on network topology consisting of 13 nodes and 15 edges, evaluating only service times. Additionally, comparison of results of doubling bandwidth and delays is performed.

Related investigation is performed by simulating intelligent surveillance system [14], [15], where “iFogSim” toolkit is used. Comparison between Cloud and Edge-Fog computing is performed in terms of average control loop latency, execution time. Five different physical network topology configurations are evaluated, revealing 15% energy and 25 s execution time optimization by pushing surveillance system controls to Edge rather than performing computations in Cloud.

Edge computing integration together with blockchain research [16] outlines possibility to use peer-to-peer distributed blockchain technique beyond transactions verification. Three tier model is used for research, which reveals bottleneck in load that can be processed in real time.

For smart city and fourth industrial revolution applications [17], “iSapiens” [18] Edge Computing based platform is proposed. Main advantages of platform is complete network virtualization, layered structure, followed by anomaly detection and aggregation agents, complete obscure heterogeneity of physical devices. Closed source is main disadvantage in

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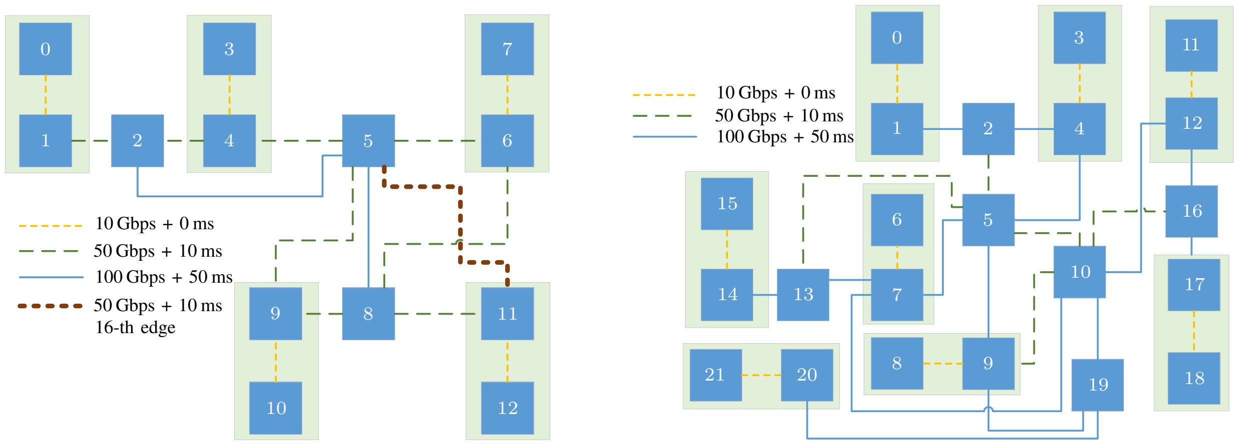

(a) 13 nodes 15/16 edges

(b) 22 nodes 27 edges

Fig. 1. Investigated network topologies

terms of security, as well as platform flexibility to adapt it for beyond smart city applications.

Consequently, main objectives of this paper are:

1) assure that *EdgeNetworkCloudSim* tool is suitable to simulate Edge computing network and control varied parameters;
2) simulate high and low throughput Edge computing network with uttermost environment to detect bottlenecks;
3) reveal which network parameters plays the most important role in terms of success to failure rate and service time.

III. Simulation

This section describes simulation environment and varied parameters of *EdgeNetworkCloudSim* software to evaluate different scenarios.

A. Environment

Simulation tool is implemented in Java environment, simulation is executed in Java virtual machine console, which guarantee simulation is not parent machine parameters dependent and can be run in any operating system. In this particular case, Ubuntu linux 16.10 x64 operating system is used. Results are saved to text files, which are analysed with Matlab environment.

B. Parameters

Edge network topology is defined by Boston university Representative Internet Topology Generator (BRITE) structure [19]. Graphical user interface is provided for this particular tool. Table I represents parameters defining topology. *EdgeNetworkCloudSim* simulation tool considers network delay and maximum bandwidth.

Additionally, each device is described by its resource parameters, main of which are: MIPS (million instructions per second), RAM (capacity of random access memory), bandwidth and file size it capable to address.

For simulations services with 1 GB data chunk size are designed: access to database, direct stream and web query.

As a result, such values are gathered by simulation tool: time consumed for each service, success/failure state with reason of failure, data route, and resources utilized.

Fig. 1 illustrates topologies modeled to perform wired simulation. Structure in Fig. 1a represents 15 and 16 edges, since the only difference is additional (red thick dashed line) path between nodes 5 and 11, however this additional path changes whole topology and its results. Structure in Fig. 1b represents more complex topology with 22 nodes and 27 edges. Each topology legend shows link bandwidth and delay.

Simulation of IoT case is performed on same topologies, in exclusion where Edge device 0, linked to node 1 has wireless connection, complying IEEE 802.11g specification: average 100 ms delay and 54 Mbps bandwidth.

Additionally, to find which network parameter has greater impact on overall performance – bandwidth or delay, simulations for each topology where bandwidth or delay is doubled to base value are performed.

Three different machine parameters, described in Table II are selected to perform simulation, where resources are selected averagely between regular PC and IoT device.

TABLE I
BRITE generated parameters for network topology depiction

Type	Parameters	Units
Nodes	NodeID	–
Edges	EdgeID	–
	Source_NodeID	–
	Destination_NodeID	–
	Delay	ms
	NetworkCapacity	kBps

TABLE II
Machine parameters used in simulation

Name	MIPS	RAM, MB	BW, kBps	FileSize, MB
M1	2000	512	1024	1024
M2	1000	128	1024	128
M3	100	16	512	64

IV. Results

Investigation of simulation results was performed in order to reveal difference on success/failure cases over topologies and different network parameters.

A. Investigation procedure

To bring out success and failure ratios, Internet and IoT cases are investigated separately. Success rate is calculated as follows:

$$\widehat{E_\mathrm{S}}(\mathcal{T},\mathcal{P}) = \frac{E_\mathrm{S}(\mathcal{T},\mathcal{P})}{E_\mathrm{T}(\mathcal{T},\mathcal{P})} \times 100\%\,, \tag{1}$$

accordingly, failure rate:

$$\widehat{E_\mathrm{F}}(\mathcal{T},\mathcal{P}) = \frac{E_\mathrm{F}(\mathcal{T},\mathcal{P})}{E_\mathrm{T}(\mathcal{T},\mathcal{P})} \times 100\%\,; \tag{2}$$

here E_S, E_F and E_T are number of success, failure and total events, correspondingly. $\mathcal{T} \in \{A, B, C\}$, $\mathcal{P} \in \{P_0, P_\mathrm{D}, P_\mathrm{B}\}$, where A, B and C denotes different network configurations, P_0 denotes base network parameters, correspondingly P_D and P_B network parameters with double delay and double bandwidth to the base.

Network parameters influence on success and failure cases are expressed by status differences:

$$\Delta\widehat{E_\mathrm{S}}(\mathcal{T},\mathcal{P}) = \widehat{E_\mathrm{S}^\mathrm{IoT}}(\mathcal{T},\mathcal{P}) - \widehat{E_\mathrm{S}^\mathrm{Int}}(\mathcal{T},\mathcal{P})\,, \tag{3}$$

and

$$\Delta\widehat{E_\mathrm{F}}(\mathcal{T},\mathcal{P}) = \widehat{E_\mathrm{F}^\mathrm{IoT}}(\mathcal{T},\mathcal{P}) - \widehat{E_\mathrm{F}^\mathrm{Int}}(\mathcal{T},\mathcal{P})\,. \tag{4}$$

To guarantee trustworthiness of results, each simulation is repeated 3 times, ensuring no error is introduced by random generated initial variables in simulation software internally.

B. Performance analysis

Three different network topologies are denoted as follows:

- Network A – network topology with 13 nodes and 15 edges;
- Network B – network topology with 13 nodes and 16 edges;
- Network C – network topology with 22 nodes and 27 edges.

Success and failure rates presented in Fig. 2 simulated in Internet and IoT environments shows that:

- relative success numbers for Internet and IoT edge scenarios are varying depending on network type and parameters, but are not too far apart;
- contrary, relative failure numbers for Internet and IoT edge scenarios indicate more occasional issues in IoT edge cases.

Integral picture given in Fig. 3 shows differences for considered Internet and IoT edge scenarios measured by success and failure numbers reveals that:

1) in a majority of cases (6 from 9), increase of the number of failure states was followed by the decrease of success states number, while once the opposite happened;
2) Network A for an increase of bandwidth and delay responded by the increase of failures and decrease of success;
3) Network B was less effected by the increase of delay than bandwidth;
4) for the Network C increase of the bandwidth was positive, while increase of the delay was mostly harmful comparing to other networks.

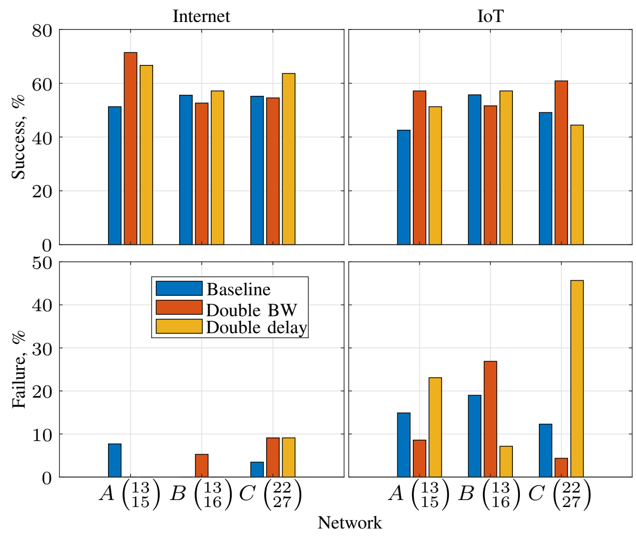

Fig. 2. Success and failure rates comparison between topologies

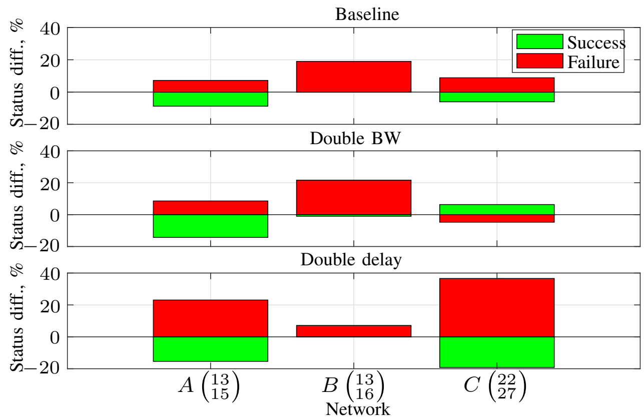

Fig. 3. Difference between success/failure status over network parameters

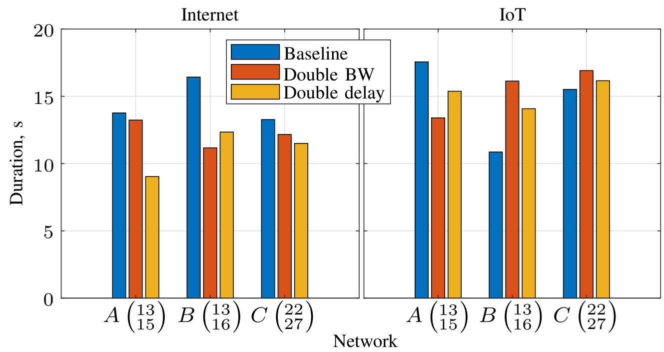

Fig. 4. Service time comparison of topologies with varied network parameters

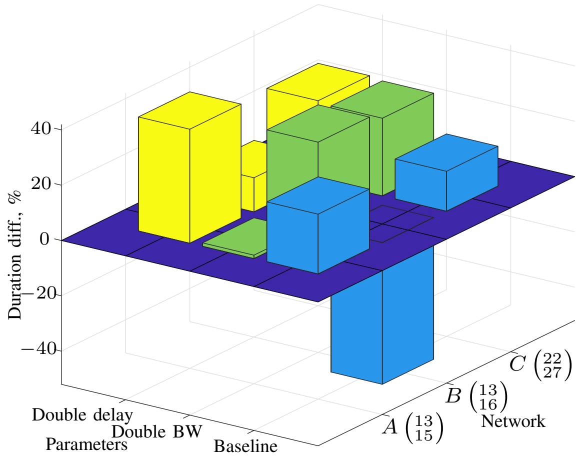

Fig. 5. Service time difference comparison over network topologies and parameters

From Fig. 4, that illustrates overall execution time in both, Internet and IoT cases, with different topologies and network parameters, becomes evident that:

- data transfer by Internet and IoT edge duration results under considered scenarios are dependent on the network topology and its parameters, thus can not be easily generalized;
- in case of Internet edge computations delays for all considered network topologies depend similarly on bandwidth and delay decrease (i.e., base configuration is the slowest, then follows configuration with increased bandwidth, and finally, the quickest configuration is with the increased delay) with the single exception: Network B processed data quicker when bandwidth was increased than when delay was increased;
- in case of IoT edge computations delays for all considered network topologies depend differently to Internet edge case;
- similarities in case of IoT edge computations delays is evident only in Networks B and C (i.e., base configuration is the quickest, then follows configuration with increased delay, and finally, the slowest configuration is with the increased bandwidth).

Fig. 5 gives integral view on all 18 simulated network topology and its parameters combinations performance in terms of processing duration relative change comparing Internet to IoT edge computations.

V. Conclusions

Simulation of modeled Edge computing networks in *EdgeNetworkCloudSim* software package was performed and performance analysis of results was carried on. The given data grounds such conclusions:

1) in 8 from 9 cases the IoT edge computations have taken longer time than Internet (common) edge computations;
2) the network topology (structure) plays a role in IoT edge computation duration however its parameters, such as bandwidth or delay, are more influential on the IoT edge performance: very different topologies like Network B and C have almost the same duration decrease when bandwidth was increased; very similar topologies like Network A and B exhibit opposite effects on the computation duration in all parameter varying cases.

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