Teaching Learning Based Optimization (TLBO) for energy efficiency in Fog Computing

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Abstract: **Fog Computing is eminent to ensure quality of service in handling huge volume and variety of data and to display output, or for closed loop process control. It comprises of fog devices to manage huge data transmission but results in high energy consumption, end-to end-delay, latency. In this paper, an energy model for fog computing environment has been proposed and implemented based on teacher student learning model called Teaching Learning Based Optimization (TLBO) to improve the responsiveness of the fog network in terms of energy optimization. The results show the effectiveness of TLBO in choosing the shortest path with least energy consumption.**

Indexed Terms: **learning model, energy consumption, caching, Energy utilization, energy model.**

I. INTRODUCTION

Fog computing also called fogging is an architecture based on edge devices to perform substantial amount of computation, storage, communication locally as well as over the internet [1],[7]. The Fog nodes (or edge nodes) in Fog Computing are responsible for providing sensor input, display output, or for closed loop process control. These devices also employ smaller Edge Clouds or Cloudlets at the Edge or nearer to the Edge rather than employing centralized Clouds in a large data center (figure 1).

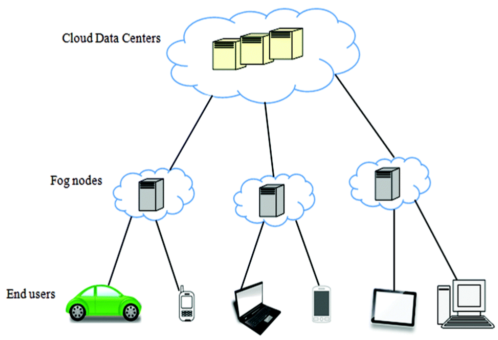

FIGURE 1: FOG NODES DEPLOYED IN CLOUD

A. Need of Fog Computing

- **To bring data in vicinity to its Owner or User:** The data retrieval time will be reduced if it is available at nearby locations of its owner or user.
- **To improve support for Internet Intelligence and data mobility:** As data is available at multiple edge points, the control to data access is important. But high data availability will provide more benefits to the users in terms of more services t its doorstep.
- **Numerous verticals are ready to be accepted:** Many organizations already accept the term mist. Many different types of services typically provide rich content for the end user. Also contains IT shops, providers, and artist.

B. Challenges in Fog Computing:

Various issues in Fog computing are discussed further:

- **Limited capabilities of Fog devices:** The hardware of fog devices have limited capacity in terms of computational and memory energy. Thus, the resources remain overutilized in fog environment [10].
- **High expectation of end users:** The user always expect a smooth reception of the data (video, Audio, Data) being streamed.
- **High inter-device communication:** The communication among physical devices is ever increasing resulting in upward trend in waiting and response times.
- **High energy utilization:** The energy or power requirement of fog devices is a big challenge. The energy utilization is required to be optimized using heuristic and metaheuristic techniques. This is also reduce the response time and improve throughput [7].

In this paper, an efficient energy model for fog computing is proposed and its results are compared with existing state-of-the art model (Cache in Mobile) [2] on the basis of end to end delays, energy consumption and throughput.

II. PRESENT WORK

The performance of edge infrastructure in fog computing can be enhanced by “caching” [3]. Caching is a technique which helps to increase responsiveness in network. The fog applications are highly time sensitive and demand a high degree of Quality of Service (QoS) specification to meet customer quality of experiences[9], [12], [13]. The resource manager needs to consider residual energy, current payload, and schedule and response time between resources for optimizing the fog infrastructure. Also, in the current scenario, the enterprise systems should work with multiple network protocols, multiple data formats, and exchange standards. The system should be able to work with the heterogeneous arrangement of devices which may have different levels of energies and constraints. Then it also needs to work with multiple sensing technologies whose output may be analog in nature or it may require modulator boosters, repeaters for signal conditioning and propagation.

The scope of research work is to overcome the issues in fog computing related to energy consumption with help of caching. The main aim of this work is to enhance and modify the state of art algorithm proposed in [2] and to optimize the energy consumption[8].

III. METHODOLOGY

The proposed network for energy model is shown in Figure 2. The algorithm uses the concept of teacher student learning model for iteratively searching best cache that can increase the overall responsiveness in the fog network. It consists five layers and each layer has unique specifications. The layers are- Persistent Storage, Temporal Cache, Temporal Storage, Optimization Layer, Fog Device Layer and Client Layer. Every layer is described below.

- **Layer 1:** This layer represents the original data location. It consists of server farms [4]. Server farms have backup servers (SO1, SO2 ..,)which can take the place of primary servers with primary Cache(PC). The fog device(fd) may try to retrieve data or send for persistent storage.
- **Layer 2:** The second layer is created for doing temporal storage [5]. It is also called as interim storage to act as primary cache. It is also called as internal cache, level 1 cache, for cluster of servers in data farm. The primary cache (PC) has a data which represents most frequently used data for the clients.
- **Layer 3:** As the network size increases and also the span of fog devices increases. The primary cache may further be divided into secondary caches (CS1, CS2). So that, there is little jitter/delay
- **Layer 4:** This layer consists of routing servers that have inbuilt resource monitoring (G1, G2) and optimization algorithms for guiding the fog device clients.
- **Layer 5**: Fog computing is an architecture that uses one or more collaborative end-user client's devices (C1, C2, C3) to carry out a huge amount of storage rather than stored on primarily in cloud data centers. Gateway is a computer program and a link between two computer programs that allow each other to share information and bypass certain protocols on a host computer.

Teaching Learning Based Optimization(TLBO) [6] has been implemented to identifying the routing path/lines for improving Fog network. TLBO is to find an optimal value to make the response fast for edges of cloud network. The following block diagram shows the working flow of an algorithm. The optimal solution is to the generate a finest Teacher-Student team, in terma of maximum score. The best team will be evaluated on the basis of highest cumulated score 'X' which is computed as in equation (1).

$$X = \frac{\exp(C_{score} - P_{score})}{Total\ score} \qquad \ldots\ldots\ldots\ldots (1)$$

Where C_{score} is current score and P_{score} is previous score

As the iterations continue, and it work till the condition is fulfilled that is, when the highest probabilities of enhancement have been exhausted, and maximum marks have been attained. TLBO consist of two phases:

- **Teacher phase:** This is the first phase which is similar to the education from the teacher. It is due to the teacher's efforts the mean class score will increase. The probability of optimal results depends on this phase.
- **Learning phase:** This phase refers to the learning earned by the students for enhancement. During each iteration in this phase, a neighbor is selected on the basis of slight change to current output value. The subsequent selected neighbor is the following 'cache server' in the designated fog network. After selecting the next neighbor, the coordinates of the next neighbor solution are decided to change which refers to the fog cache. Then, the algorithm is continued and iterations are done to reduce the 'maximum marks' in order to achieve the optimal score. The score continues to improve with the iterations.

IV. RESULTS

Teaching-Learning Based Optimization (TLBO) algorithm has been implemented. The purpose of implementation of TLBO is to find an optimal value as per following conditions to make the response fast. There are number of links and that are marked for a particular route. Arbitrarily three links (link 1, link 2, link 3) has been selected to compile results and analyse the energy utilized at a particular path from client to the cloud server. The path for Link 1 comprised of C_1(client), f_{d1} (fog device), G_1 (resource monitoring layer), C_{S2} (temporal storage), PC (primary Cache or memory) and S_{O4} (persistent server storage); Link 2 initiated from client C_2 and follows path through, f_{d1}, G_1. C_{S2}, PC, S_{O4} (Figure 2) and Link 3 is setup through C_3, f_{d3}, G_2,, S_{O4}.

Figure 3 represents the working of along with a small code snippet for identification of the routing path/Lines for improving Fog and network. Table 1 shows the average energy consumption at the three links-Link1, Link2 and Link3. The energy consumed at link 2 using path C_2, fd1, G_1, CS_2, PC and SO_4 has been presented in Table2 and Table 4 presents energy utilized at Link 3 through path C_3, fd_3, G_2, SO_4. The energy consumed across three links has b een analyzed thoroughly and presented in figure 4. It has depicted that link 3 utilized minimum or energy during all five iterations. The purpose of putting additional edge network i.e. the Fog Computing network is to have better managed network.

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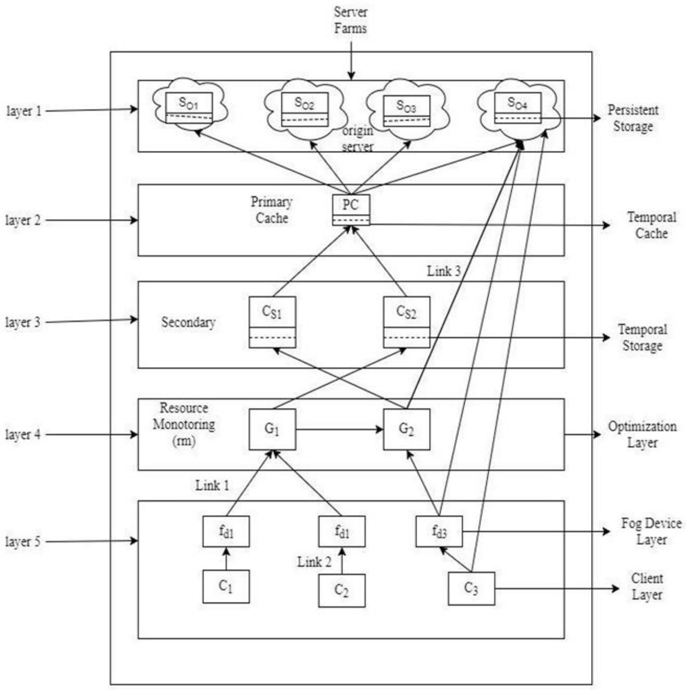

Figure 2: Network Layout for proposed energy model

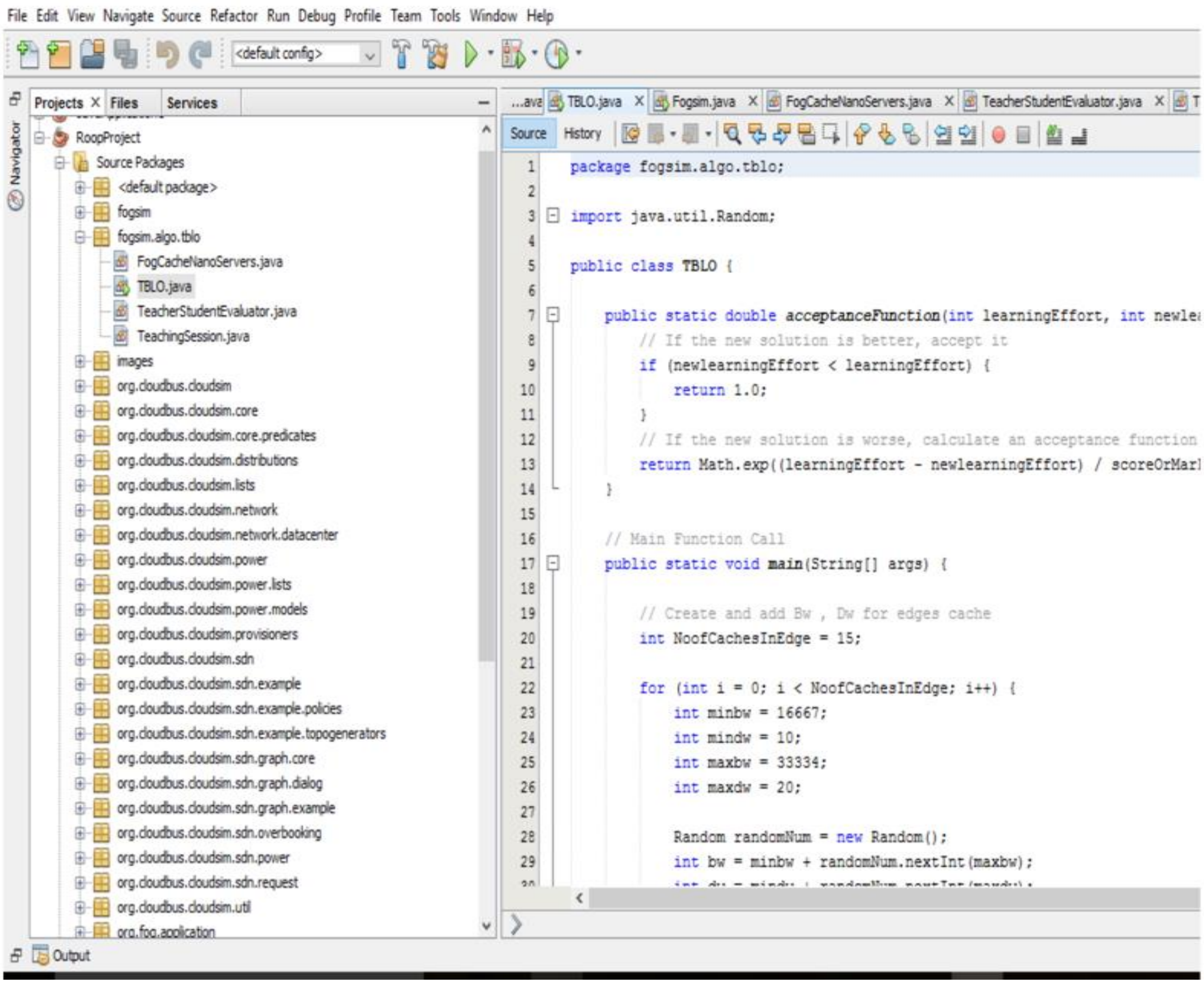

Figure 3: Screenshot of implementation of proposed model

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TABLE 1: ENERGY UTILIZED AT LINK 1 (THROUGH PATH-C_1, F_{D1}, G_1, C_{S2}, PC, S_{O4})

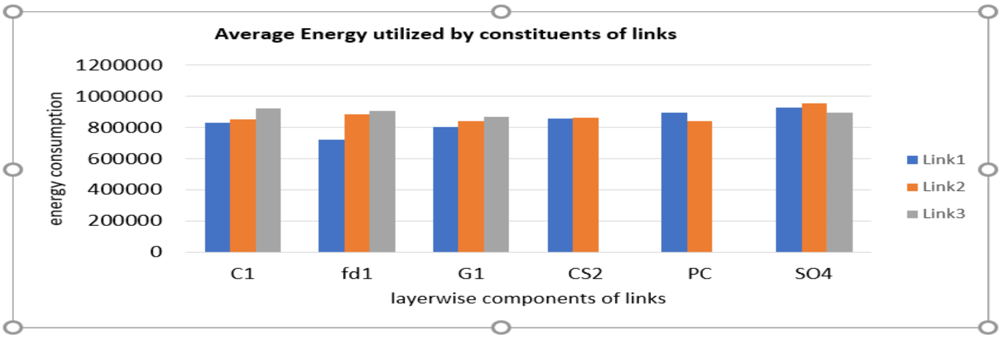
LINK 1	Location						
Iterations	C_1	f_{d1}	G_1	C_{S2}	PC	S_{O4}	Total
Iteration 1	746301.8	796301.8	734332.9	754332.9	907660.2	906301.8	4845231
Iteration 2	846504.8	226504.7	844432.9	844432.9	927660.2	926504.7	4616040
Iteration 3	816301.8	896301.6	771332.8	879632.8	867650.1	896301.6	5127521
Iteration 4	855301.8	885901.8	834933	904933	897560.1	955301.8	5333931
Iteration 5	876903.7	816303.7	844635.7	914635.7	877662.3	946303.7	5276445
Average	828262.8	724262.7	805933.5	859593.4	895638.6	926142.7	**5039834**

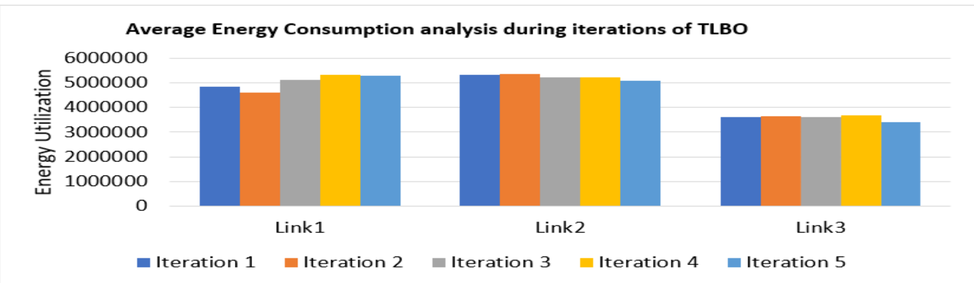
TABLE 2: ENERGY UTILIZED AT LINK 2 (THROUGH PATH-C2, FD1, G1, CS2, PC, SO4)

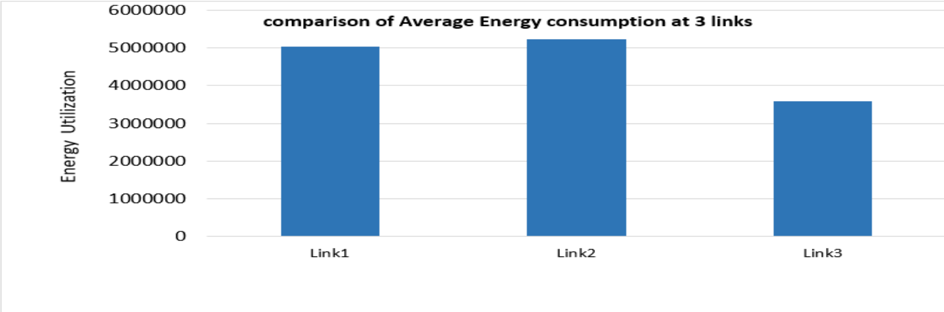
LINK 2	Location						
Iterations	C_2	f_{d1}	G_1	C_{S2}	PC	S_{O4}	Total
Iteration 1	846301.76	896301.76	834332.93	854332.89	897660.15	997660.15	5326589.64
Iteration 2	846504.76	926504.7	844432.89	944432.89	807660.17	977660.25	5347195.66
Iteration 3	836301.75	896301.62	871332.79	871632.8	767650.1	967650.1	5210869.16
Iteration 4	855301.76	885301.76	834932.96	834932.96	897560.12	897560.12	5205589.68
Iteration 5	876303.74	816303.74	814635.69	814635.69	827662.25	927664.25	5077205.36
Average	852142.75	884142.72	839933.45	863993.45	839638.56	953638.97	**5233489.9**

TABLE 3: ENERGY UTILIZED AT LINK 3 (THROUGH PATH-C3, FD3, G2, SO4)

LINK 3	Location				
Iterations	C_3	f_{d3}	G_2	S_{O4}	Total
Iteration 1	906301.76	916301.76	894332.93	896301.76	3613238.21
Iteration 2	946504.76	926504.7	864432.89	926504.7	3663947.05
Iteration 3	936301.75	896301.62	871332.79	896301.62	3600237.78
Iteration 4	955301.76	885301.76	894932.96	945301.76	3680838.24
Iteration 5	876303.74	916303.74	814635.69	816303.74	3423546.91
Average	924142.75	908142.72	867933.45	896142.72	**3596361.64**







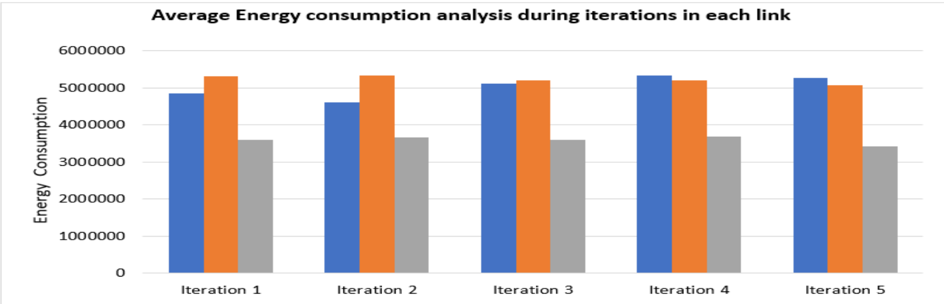


Figure 4: Energy consumption analysis across Link 1, Link 2, Link 3

V. CONCLUSION

The analysis of energy utilized by the proposed model based on TLBO has shown that energy consumption is higher in case of Link 2, this may due to fact that there is an additional overload of power consumption of cache server on this path. This cache is selected more frequently as compared to link 3 due the fact that at the link 3 the energy consumption is reduced.

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