Comparative Analysis of Fog and Cloud Computing in IOT based on Power Consumption Factor

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Abstract: ***As technology is increasing day by day the use of internet and internet based devices are continuously increasing in huge number. Internet of thing (IOT) is very fast growing system which will get higher priority in some years. As IOT devices provide comfort, security, safety, ease in work, it is a widely used system. The IOT systems are continuously adopted by people everywhere like in smart home, smart Hospital, Smart Card and many more. In our technological world is also very necessary to optimize the use of resources which are used in such systems. IOT devices works on fog computing and also on cloud computing. Cloud Computing is conventional system and fog is an emerging Technology. In this paper we have focused on power consumption in completing task by IOT , we have compare and analyse power consumption by fog based IOT and conventional cloud computing based IOT. We model the fog computing paradigm by mathematically characterizing the fog computing network in terms of power consumption and evaluating its performance for an environment with high number of Internet-connected devices. A case study is performed with traffic generated from the 100 highest populated cities being served by eight geographically distributed DCs. Results show that the power consumption of fog computing consumes lesser amount power as compared to cloud computing while processing internet of thing based applications. It is also evaluated that the overall power consumption is calculated to be 41.3% less in fog computing.***

IndexTerms - Cloud computing, Fog computing, Internet of Things (IOT), Power Consumption, Network Congestion.

I. INTRODUCTION

Recent advancements in computer technologies have led to the conceptualization, development, and implementation of cloud computing systems. From its inception, cloud computing has gained widespread popularity due to its applicability in diverse, widespread domains. Cloud computing systems are generally based on data centric networks (DCNs), which are treated as the sole, monopolized hubs responsible for computation and storage. For contemporary cloud-based systems, all service requests and resource demands are analyzed and processed within the data centers (DCs) [7]. Another emerging technology , Fog computing is a geographically distributed computing architecture with a resource pool consists of one or more ubiquitously connected heterogeneous devices (including edge devices) at the edge of network and not exclusively seamlessly backed by cloud services, to collaboratively provide elastic computation, storage and communication (and many other new services and tasks) in isolated environments to a large scale of clients in proximity[1].In this work, we analyze the suitability of a recent computing paradigm – fog computing to serve the demands of applications in the context of IOT.

II. SIMULATION SETUP

Network Topology-The setup consist of Terminal Nodes N, Fog Instances F and the cloud data centers DC. For our analysis we have consider 100 cities across the world [6] which are highly populated and having people using internet service accordingly [3]. Fig. 1 shows the complete setup of FIs and DCs in which FIs and corresponding DCs are placed on coordinate system. The termina nodes form a virtual cluster (VC) within a particular city.

Terminal Nodes-In the system all terminal node is consider as a variable having range [10000,100000]. The number of TNs in each of the 100 cities is taken as proportional to the population of Internet users of the city. The TNs send their data through access point provided in each city. All TNs of a city are consider to send their data to a single Fog Instance.

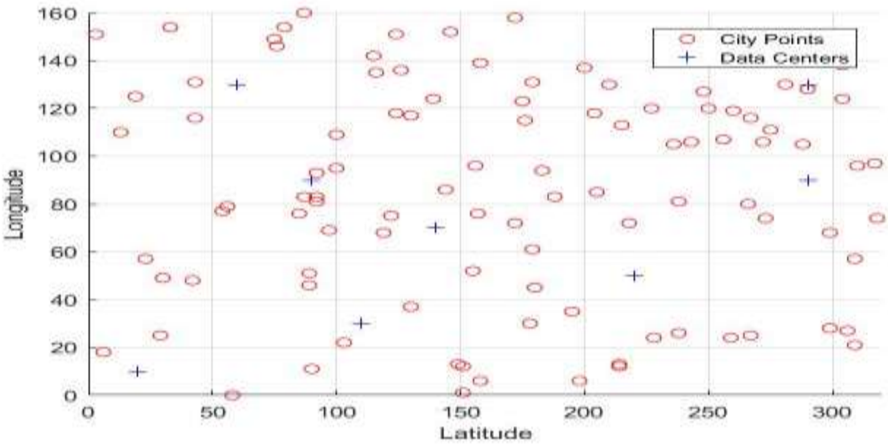

Fig. 1: Global Position of Data Centers and Fog Instances

Data Centers-For this research purpose we have considered 8 DCs present globally. The locations of DCs are determined by clustering of the city population. Euclidian distance between DCs is taken here for measuring distance. On the basis of network traffic processing every DC is assumed to accommodate varied number of IT components within the discrete set {16000, 32000, 64000 and 128000}.

Power Consumption-According to our research, power consumption calculation is core objective. To calculate overall power consumption of the system it is mandatory to calculate power consumption by every devices of the system like network, storage , computation process and data migration.Power Consumption by every component is shown below in table 1.

Table:1. Power Consumption by Components

Components	Power Consumption
1 Gbps Router	20W
10Gbps Router	40W
3-layer switch	350W
Storage component	600W
computing devices within single FI	3.7 W total
DC Range	{9.7,19.4,38.7,77.4}MW

III. MODELING THE PERFORMANCE MATRICES

Power Consumption

The total power consumption is divided into three broad categories for application requests which are served by the fog computing tier without inference of the cloud framework, and into four broad categories for requests which are required to be served by the cloud computing tier. Following is the list of factors which are responsible for power consumption during big data handling using the fog computing framework.

1) **Data forwarding:** While forwarding of data packets, the overall power consumed due to reception of the byte-stream, initial processing required for routing, and subsequent transmission of the same, is categorized as power consumption due to data forwarding. Power consumption due to data forwarding ($\Psi_{df}^{fog}(t)$) at time t is computed as:

$$\Psi_{df}^{fog}(t) = (\Upsilon_{eg} + \Upsilon_{fi})[\ \sum_{i=1}^{V}\{P_r^{v_i}(t) - Q_r^{v_i}(t) + P_s^{v_i}(t) - Q_s^{v_i}(t)\}\sum_{v_i,e,f} X_{v_i,e,f}^{fog}(t)\ ] \quad (1)$$

$$= (\Upsilon_{eg} + \Upsilon_{fi})[\ \sum_{v_i,e,f}\{P_r^{v_i}(t) - Q_r^{v_i}(t) + P_s^{v_i}(t) - Q_s^{v_i}(t)\} X_{v_i,e,f}^{fog}(t)\ ]$$

where $\Upsilon_{eg}\, and\, \Upsilon_{fi}$ represent the amount of energy required per second (power) to forward unit byte of data by the edge gateways and the fog instances, respectively. Similarly, for core cloud computing module forwarding of the data packets($\Psi_{df}^{cld}(t)$) at time t is expressed as:

$$\Psi_{df}^{cld}(t) = (\Upsilon_{eg} + \Upsilon_{fi})[\ \sum_{i=1}^{V}\{Q_r^{v_i}(t) + Q_s^{v_i}(t)\}\sum_{v_i,e,f} X_{v_i,e,f}^{fog}(t)\ ] + \Upsilon_{cl}[\ \sum_{i=1}^{V}\{Q_r^{v_i}(t) + Q_s^{v_i}(t)\}\sum_{f,g,c,d} X_{f,g,c,d}^{cld}(t)\ ] \quad (2)$$

$$= \sum_{i=1}^{V}\{Q_r^{v_i}(t) + Q_s^{v_i}(t)\}[\ (\Upsilon_{eg} + \Upsilon_{fi})\sum_{v_i,e,f} X_{v_i,e,f}^{fog}(t) + \Upsilon_{cl}\sum_{f,g,c,d} X_{f,g,c,d}^{cld}(t)\ ]$$

Where Υ_{cl} is the power required to forward unit byte of data by a cloud gateway.

2) **Computation:** The power consumption due to computation also occur at both fog tier and cloud tier. Let τ denote the time-to-live for every data packet after which it is removed from the temporary fog storage. Therefore, at time t, the computational power consumption at the fog layer ($\Psi_{cp}^{fog}(t)$) depends on the data stored within the FIs from time (t- τ) till the present time-slot.

($\Psi_{cp}^{fog}(t)$) is mathematically expressed as:

$$\Psi_{cp}^{fog}(t)=\beta^{fog}\sum_{j=t-\tau}^{t}\Phi_{j}^{fog}\sum_{i=1}^{V}\{P_{s}^{v_i}(j)-\Phi_{s}^{v_i}(j)\} \quad \textbf{(3)}$$

where β^{fog} is the average per byte computational power consumption. Φ_{j}^{fog} is the weight-factor associated with the data-set which is required for analysis. The expression $\{P_{s}^{v_i}(j)-\Phi_{s}^{v_i}(j)\}$ indicates the cumulative amount of data which is stored at time t within the temporary fog storage units, for analysis and computation.At time instant t, the power consumption at the cloud computing framework due to computation and analysis, $\Psi_{cp}^{cld}(t)$, is dependent on the cumulative amount of data which stored within the DCs, starting from the very beginning, i.e., t = 0. ($\Psi_{cp}^{cld}(t)$) is computed as:

$$\Psi_{cp}^{cld}(t)=\beta^{cld}\sum_{j=0}^{t}\Phi_{j}^{cld}\sum_{i=1}^{V}\Phi_{s}^{v_i}(j) \quad \textbf{(4)}$$

where β^{cld} is the mean computational power required to process unit byte at the cloud-end, and $\sum_{i=1}^{V}\Phi_{s}^{v_i}(j)$ is the total data aggregated within a DC for process and computation, with $\Psi_{j}^{cld}\in[0,1]$.

3) Storage: The power consumption due to storage, similar to the computational power consumption, depends on the number of bytes of data which is stored in the database for processing and analysis. The mathematical expression for the storage power consumption at time t for the fog tier ($\Psi_{st}^{fog}(t)$) is given by:

$$\Psi_{st}^{fog}(t)=\alpha^{fog}\sum_{j=0}^{t}\Phi_{j}^{fog}\sum_{i=1}^{V}\{P_{s}^{v_i}(j)-\Phi_{s}^{v_i}(j)\} \quad \textbf{(5)}$$

Similarly, for the cloud computing tier, the storage power consumption ($\Psi_{st}^{cld}(t)$) is computed as:

$$\Psi_{st}^{cld}(t)=\alpha^{cld}\sum_{j=0}^{t}\sum_{i=1}^{V}\Phi_{s}^{v_i}(j) \quad \textbf{(6)}$$

where α^{cld} and α^{fog} represent the per byte per unit time energy consumption to storage data within the databases in the fog tier and the cloud DC, respectively.

4) Data migration: The power consumption due to data migration is only associated with the cloud computing layer.. At time t, the overall migration cost ($\Psi_{mg}^{cld}(t)$) within the cloud computing framework is given by:

$$\Psi_{mg}^{cld}(t)=\begin{cases}\sum_{c\in D}\sum_{d\in D}\eta_{cd}\sum_{j=0}^{t-1}\Phi_{j}^{cld}\sum_{i=1}^{V}\Phi_{s}^{v_i}(j), if\ A_t\neq A_{t-1}\\ 0, otherwise\end{cases} \quad \textbf{(7)}$$

where η_{cd} is the per byte power consumption for cost migration of data from DC c to DC d, c,d$\in$ D. A_t denotes the aggregator DC at time-slot t. Therefore, at time t, the overall power consumption for applications which are served by the fog computing tier, Ψ^{fog} is computed as:

$$\Psi^{fog}(t)=\Psi_{df}^{fog}(t)+\Psi_{cp}^{fog}(t)+\Psi_{st}^{fog}(t) \quad \textbf{(8)}$$

Whereas, for application seeking intervention of the core cloud computing, the cumulative power consumption at time t is calculated as:

$$\Psi^{cld}(t)=\Psi_{df}^{cld}(t)+\Psi_{cp}^{cld}(t)+\Psi_{st}^{cld}(t)+\Psi_{mg}^{cld}(t) \quad \textbf{(9)}$$

IV. RESULT

The power consumption for fog based IoT and cloud based IoT is considered in this section. The collective effect of data forwarding , computation and data storage is analyzed. We define the ratio of the total bytes transmitted to the fog computing tier to the number of bytes referred to the cloud computing core as the cloud transmission ratio, mathematically represented by the variable θ. With the change in the magnitude of θ, within the range [0.05,0.75], we plot the power consumption for both fog computing and the conventional cloud computing architectures, and observe the change in the corresponding consumptions.. In fig. 2, the power consumption is shown against the number of terminal nodes (TNs).We can observe here two things : First, as the number of terminal nodes increase the power consumption is significantly increasing and second, the power consumption in fog computing is always less as compared to cloud computing. It is extracted that for $\theta=75$, the overall power consumption is calculated to be 41.3% less in fog computing.

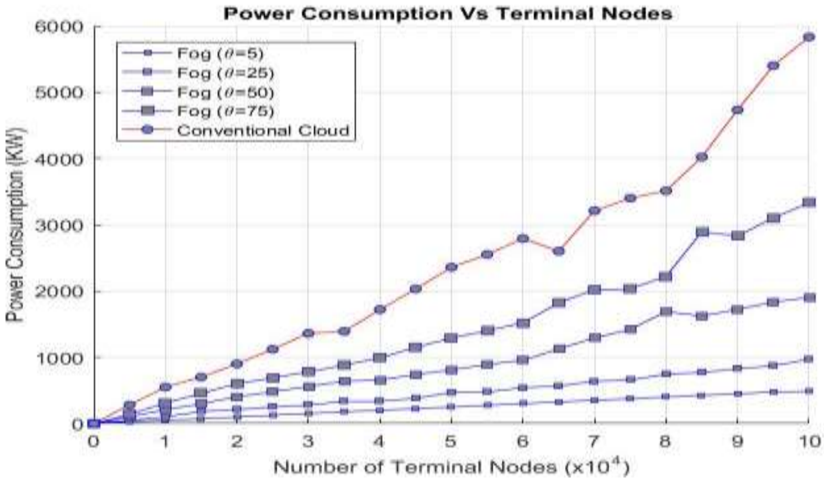

Fig.2: Overall power consumption vs. No. of TNs

V .Conclusion and Future scope:

The work focuses on analyzing the suitability of fog computing within the framework of IoT. The goal of this paper is to develop a mathematical model of fog computing and assess its applicability in the context of IOT where it is pivotal to meet the low consumption of power while running the system. The work further performs a comparative performance evaluation of cloud computing with that of fog computing with high number of Internet-connected devices. Results clearly depict the enhanced performance of fog computing both in terms of power consumption. We eventually justify fog paradigm as an improved computing platform that can support IOT better compared to the existing cloud computing paradigm. In the future, we plan to extend this work by proposing a working fog computing prototype to support real-time implementation.

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