Estimating the time complexity of QEvaF for web service oriented grid based system

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Abstract- Deployment of web service in grid based system can enhance the service quality of overall execution against different massive level of consumers. However, complexity of quality estimation of such execution is an important concern. As such, a prototype quality evaluation framework is designed which can be deployed to estimate the effectiveness of executing web service oriented grid based system. We called it as QEvaF (Prototype Quality Evaluation Framework). In this paper, an architecture of web service deployment in grid based system is discussed. An algorithm for the QEvaF is developed and the time complexity of its operation is discussed. It is observed that the problem of quality estimation of web service oriented grid based system against different increased stresses of users can be solved in polynomial time complexity. From the overall assessment and comparative evaluation, it can be concluded that the QEvaF is effective for estimating the quality aspects of such deployment.

Keywords- web service; grid based system; time complexity; quality of service.

I. Introduction

Over the past decades, the deployment of distributed computing is growing gradually, where the interconnections among diverse systems and sub systems are provided for executing computational logic. The deployment of such system primarily required at the environment of industry, laboratory, academics, government, embedded real time system and centers of computing [1]. The facts and advantages behind such interest of deployment is to have high performance computing, efficiency, tightly-coupled services, availability, lower mean time to repair and better reliability [2][3]. In such scenario, the grid based system can play a vital role for deploying distributed service. It provides a platform for integration of computing and resources distributed over different nodes. The grid based systems connect the geographically isolated distributed services into a single node over networks [4]. The grid computing can be defined as a collective set of computing systems situated over dispersed locations that can be utilized to execute a particular specific job [5]. Each computing system can be termed as servicing node. Over such network, each node is responsible for executing a specific application or business logic (BL). Usually, such grid based system is deployed over mesh like network where the resources can be shared. However, the application services of such nodes in grid based system can be interconnected through the principles of Service Oriented Architecture (SOA). The SOA provides the principles of service discovery, service integration and service consumption. On the contrary, the Web Service (WS) technology that follows the SOA principles provides the software integration features through web protocols, mainly Hyper Text Transfer Protocol (HTTP) and Extensible Markup Language (XML) [8][10].

II. Quality aspects of WS oriented grid based system

Among the research community, the evaluation of quality aspects for service execution through WS oriented grid based system is getting comparatively higher priority. However, quality aspects against different load of users are another concern that needs to be evaluated through proper standards. In that case, the system testing can play a vital role. The experience and observation of load testing can impute greater impact on the quality evaluation. A WS is basically deployed for executing BL. Each BL can contain specific set of instruction. The instructions such as processing and generating data with database engine, serialization and de serialization of SOAP messages, security aspects and operations, data authentication and organizational operations can be executed. On the contrary, the grid computing and grid service mimics the distributed service or computing that can share service or resource over network based protocol. The service node in grid based system can be configured or developed for specific tasks or the task may be replicated among multiple grid nodes. One of the major concerns in grid based system is the execution and evaluation of quality against different load of users. The way the grid node can be utilized for service execution with rapid growth of request from end user is another quality factors for organization. The system metrics such as response time, throughput and HTTP fault count observation for reliability estimation is getting comparatively greater importance from the perspective of industries, software practitioners and researchers. From end user's perspective, the response time of a WS oriented grid based system depicts the delay of a round trip from the submission of HTTP request to the processing and delivering of response to end user [6][7]. On the contrary, the throughput of a system depicts the number of data bytes that are processed for the submitted HTTP request as received in server side [6][8]. The HTTP fault count is observed to evaluate the reliability and mean fault count during execution of the service. The reliability of WS oriented grid based system is the probability that the system will deliver relevant information without fail [9][10]. For estimating the strong reliability of the system, the HTTP fault count records against different stress of users can be evaluated and measured accordingly.

However, the quality evaluation against different load of users over such system needs a proper methodology or framework that one can be deployed for estimation of quality of WS oriented grid based system. Among the research community, very few studies are carried out which primarily highlight the quality evaluation framework for WS oriented grid based system.

III. Related Work

In the year 2004, Shirasuna et al. had introduced a novel framework for evaluating the responses of grid services and to estimate the security and performance aspects of service execution in such platform [26]. The capability and scalability issues as faced by service execution were discussed with measures. However, the authors had not introduced the proper algorithm and measures that can be followed for such deployment.

In the year 2006, Saddik had developed a framework for evaluating a service oriented nodal service that can estimate the performance metrics of WS over network based systems [21]. A novel framework was introduced that can identify the limitation of service execution in network based protocol.

In the year 2011, Kalita et al. had developed a framework for identifying the quality aspects against different load of users [14]. The algorithm for testing such service was discussed. However, the methodology of time complexity against load of user execution was not evaluated.

In the same year, Misra et al. had introduced a novel framework for evaluation of software quality measure [23]. A test methodology was developed to study the applicability of the framework by using theoretical and empirical measure.

In the year 2012, Kalita et al. had introduced a novel methodology for estimating the quality ratio of performance metrics against various test cases and environmental set up [13]. The proposed framework was able to highlight the importance of system metrics and their correlation for enhancing the quality of service execution. However, no proper strategy was developed for identifying the failure records and reliability measures against growth of users.

In the year 2014, Medhi et al. had discussed the quality aspects and their importance in service execution over network based protocol [15]. A performance model and evaluation strategy was developed and implemented with an experimental arrangement. In this study, emphasize was given over execution of service with database oriented system. However, no proper time complexity estimation of service execution was discussed.

In the year 2014, Rahmani et al. had introduced a novel framework for software architecture development [17]. The study was carried out over service execution for delivering service response to end users. The importance of evaluating system metrics for reliability estimation was discussed. However, the time complexity estimation of proposed framework was not evaluated.

In the year 2015, Bezboruah et al. had introduced a novel framework for estimating the quality measures of cluster based and non cluster based web servers [24]. The test of normality was observed against the recorded system metrics. However, the time complexity evaluation of the proposed framework was not carried out.

In the year 2015, Singh et al. had discussed a novel framework for estimating the quality metrics for sensor based service execution [7]. The study was carried out by using a test bed environment.

In the year 2016, Ba et al. had discussed the quality aspects for optimization of service execution in distributed server machines [22]. The time complexity evaluation of the service execution is estimated to be efficient while managing the different load of users. However, the proposed framework had not highlighted the key system metrics that are observed to be important from the perspective of end users.

In the year 2017, Dobravec had carried out a study to develop a framework that can facilitate the process of testing the service execution, comparing and evaluating the results against the usage of the system metrics [25]. The time complexity indicators were discussed to measure the behavior of system in real environment.

In the year 2018, Yamada et al. had introduced a novel framework for analyzing the aggregation of WS execution and its scalability in grid based system [27]. A validity model was developed to establish the applicability of the framework.

This study is novel from the previous work as emphasize is given over developing an algorithm and evaluating the time complexity of execution for estimating the quality aspects of WS oriented grid based system against different load of users.

IV. Architecture and system model for WS oriented grid based system

The architecture and the system model for deployment of WS oriented grid based system are shown in Fig. 1. The multi WS (M_{WS}) is deployed which can fetch the record from database engine. Medhi et al. and Bora et al. had discussed about the flexibility and efficiency of deploying multi service multi function WS in system rather than single service single function WS [8][15]. They observed that the performance can be increased by segregation of functionality among WSs. As such, in this study, we propose to deploy M_{WS} in grid based system. However, the inclusion of load balancing server as middle tier among end users and grid nodes can play a vital role in such system. Alternatively, the action node in such system will be the users, load balancing server machine and grid based servers with M_{WS} functionalities. The user accesses the common graphical user interface (GUI) of the service running in the grid nodes and submits the request to load balancing server. The GUI is usually provided by the middle tier load balancing web server. The middle tier after receiving the request, identifies the grid node which is comparatively low in load. As such, the middle tier decides and sends the request to specific grid node. For instance, it can be stated that if grid node A is low in load, the request from end user will be redirected to A for necessary processing in server side, otherwise if A is busy with heavy load, then the request will be redirected to grid node B. However, the end user will not realize about which grid node is executing from behind.

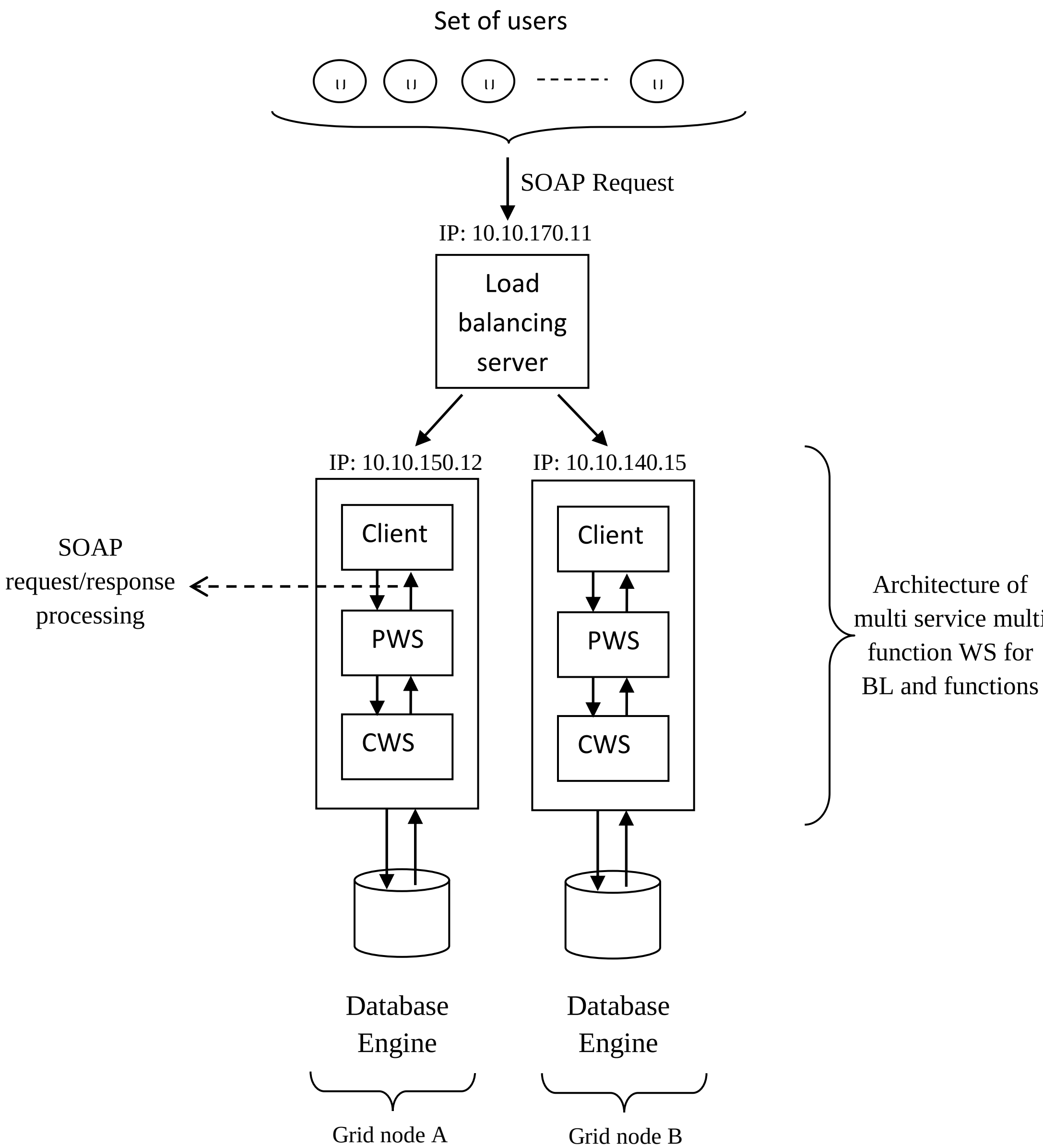

Fig. 1. System model for deployment of WS oriented grid based system

The particular grid node will send the response to middle tier load balancing server and the middle tier server will give response to end user. The role of WS such as parent, consumer and child is distributed among Parent WS(PWS), client and Child WS (CWS). The client, PWS and CWS will execute necessary BL and function for server side processing as per request received from the end users through load balancing server. The WSs are solely responsible for database query execution and report generation. The SOAP request and response methodology can help communication for messaging among WSs.

V. Mathematical model for WS oriented grid based system

The deployment and connectivity among different services of the WS oriented grid based system can be observed through mathematical model. The optimization of service against load can be evaluated to identify the limitation of such execution.

A. Network model and notation the system

The interconnection of WS oriented grid based system is represented by an undirected graph G(V, E). Here, V represents the set of service as nodes and E represents the edges or the communication among them. The $VU \subseteq V$ is the set of users of specific node. Each VU is assigned the task of service execution instructions and functions F, i.e. |VU| = F. A user is represented by $q \subseteq VU$. The web server that executes the WS is represented by $V_{WS} \subseteq V$ with the set of web server in the grid based system is represented by $| V_{WS} | = N$. The specific WS oriented grid node is represented by $V_{WS}^{j} \in V_{WS}$.

The edges or the communication among users and grid nodes are represented by $E_{VU} \subseteq E$. Each consumer of the service $q \subseteq VU$ has an edge $(q, V_{WS}L) \in E_{VU}$. The edge connects the user to the load balancing server $V_{WS}L$. The load balancing server $V_{WS}L$ has connection with all grid nodes V_{WS}^{j}. That is, the edge connects the $V_{WS}L$ to the WS oriented grid node V_{WS} $(V_{WS}L , V_{WS}^{j}) \in E_{VU}$.

It can be stated that each user is connected to all WS oriented grid based system via $V_{WS}L$. $E_S \subseteq E$ is the set of edge among segregated WS. As per the study of Medhi et al. and Bora et al., it is concluded that the role of WS segregation can enhance the performance of a system [8][15]. As such, M_{WS} is deployed in grid based node. However, $(i,j) \in E$ represents the edge between load balancer server i and specific WS oriented grid based system j. As such, the WS oriented grid based system and load balancer is interconnected.

The delay in between user $q \subseteq VU$ and the load balancing server $i \in V_{WS}L$ is represented by d_{qi}, and the delay between the load balancing server $i \in V_{WS}L$ and WS oriented grid system $j \in V_{WS}$ is represented by d_{ij}. The delay of processing data in M_{WS} is represented by d_3. Md_1 and Md_2 represent the maximum value of d_{qi} over $(q, i) \in E$ and d_{ij} over $(i,j) \in E$. Md_3 represents the maximum value of M_{WS} response for d_{Es} over E_S. The maximum load of users that can be processed by specific grid node $V_{WS}^{j} \in V_{WS}$ at a time is denoted by Max_j. The binary decision variable B_{xy}, C_j and WS_{xy} is deployed. The B_{xy} is set to 1 if grid servers or the execution service x and y are in use, and 0 in other cases. C_j identifies the used grid server $j \in V_{WS}$. We set $C_j = 1$, if server j is used, and 0 otherwise. The WS_{xy} identifies the set of WS in the specific grid node.

B. Optimization of Service

The optimization of the service depends upon how the load is distributed among WS oriented grid based system. The proposed service execution methodology aims to minimize the maximum delay time of service execution and providing response to end users when the data processing time of each nodes are given. The maximum delay of service execution can be represented by $MD_{time} = 2 \times Md_1 \times Md_2 \times Md_3$.

The problem of evaluating the quality of service against the load of users and to minimize the maximal delay, MD_{time} is deployed by using Integer Linear Programming (ILP) problem.

$$\min MD_{time} = 2 \times Md_1 \times Md_2 \times Md_3 \quad (1)$$

Subject to

$$d_{qi} \times B_{qi} \leq Md_1 , \forall q \subseteq VU , i \in V_{WS}L \quad (2)$$

$$d_{ij} \times B_{ij} \leq Md_2 , \forall i \in V_{WS}L , j \in V_{WS} \quad (3)$$

$$d_{Es} \times WS_{Es} \leq Md_3 , \forall E_S \subseteq E \quad (4)$$

$$\sum_{i \in V_{WS}L} B_{ij} \leq Max_j , \forall j \in V_{WS} \quad (5)$$

$$\sum_{i \in V_{WS}L} B_{ij} = 1 , \forall j \in V_{WS} \quad (6)$$

$$C_j \geq B_{ij} \; \forall i \in V_{WS}L , j \in V_{WS} \quad (7)$$

$$B_j = \{0, 1\} \forall \; j \in V_{WS} \quad (8)$$

The key objective of the optimization methodology is to minimize the processing delay after execution and allocation of users request to the specific service node which are comparatively lower in load. The evaluation of MD_{time} for service execution is given in equation (1). The minimization of MD_{time} is feasible subject to equations 2-8. Here, equations 2-4 ensures about the maximum delay between users and load balancing server, and between load balancing server and grid node, and between M_{WS}. Equation 5 ensures that no grid node server accommodates more than Max_j load of users. Equation 6 ensures that each incoming request from user to grid node through load balancing server is processed by the grid server. Equation 7 sets grid node's binary variable to 1, if specific grid node executes multi WS. Equation 8 gives the boolean decision variable for service execution.

VI. QEvaF and Time Complexity Estimation

Developing an algorithm and identifying its complexity for estimation of the quality of such deployment is an important concern. Evaluating the service against massive growth of consumers can impute greater impact over acceptance of such deployment. As such, the algorithm as an assessment framework for estimating the time complexity of quality estimation has become an important concern among researchers.

A. Algorithm and time complexity of QEvaF

The algorithm for QEvaF is shown in Fig. 2. It shows the different steps for estimating the overall quality aspects of WS oriented grid based system. The algorithm can be evaluated for the load of user N that primarily access the WS oriented grid based system all together. The user think time (UTT) is the thinking time that specific user can take in between subsequent HTTP request submission. The Ramp Up (R_{UP}) shows the total burst time of the service during which the system metrics will be recorded for estimating the system metrics. The system metrics response time (RT), throughput (THP), HTTP pass transactions (PT) and HTTP fail transaction (FT) will be recorded for evaluating the service. The fault detection rate (FDR) will be evaluated by dividing the HTTP fail transaction by total HTTP transaction. The FDR results will be used for estimating the reliability of the service. Rigorous testing through load of system generated virtual users (VU) over the system is to be applied. The population means of RT, THP and FDR is to be evaluated through 't' critical value along with confidence level 'cl' and degree of freedom 'df' [11][12][13]. As such, specific data sample is to be collected. A data sample 'C' of population 'P' can mimic different quality aspects of service execution through the paradigm of WS oriented grid based system [14][15]. As such, the QEvaF predicts the quality estimation of WS oriented grid based system based on the data sample collected through execution of load of VU with UTT during R_{UP} period. The collective set of system metrics in the data sample will be evaluated and estimated accordingly. The average evaluation of PT, FT and FDR is to be carried out to identify the mean fault count 'a' and failure rate 'b' of such execution during high load of VU. The reliability model can play a vital role for estimating the reliability aspects of a service [16]. Among the research community, many reliability models are deployed based on different methodology of evaluation [17][18][19]. However, the QEvaF is following the Non Homogeneous Poison Process (NHPP) model of Goel and Okumoto [20]. The NHPP is deployed due to its popularity and adaptability over many applications of system reliability estimation. The NHPP model predicts two metrics: mean value function m(t) and failure intensity function λ. The m(t) depicts the expected observation of failure records as observed in time t, and λ is the rate of failure during exposure period of time t. The reliability R is estimated over an execution period of calendar time for number of days, so that the WS oriented grid based system can reflect accurately about the system's usage. The reliability metric R is defined as a reliability over a exposure period 't' for a observed failure rate λ. The metric R will predict the WS oriented grid based system deliverable valid information to end users against different massive level of usage. In other cases, moderate reliability with probability of invalid information generation can be expected. The R evaluates a value which lies in the range of 0 to 1. The R metric nearer to 1 predicts strong reliability of the service execution.

In Fig. 2, the step 1 creates a test case T_1 that contains list of instruction that all user will follow for accessing the WS oriented grid based system. The test case usually contains information about the uniform resource location (URL) of the server. Here, the URL of load balancing server will be available that will capture request from end user and will forward to

Algorithm 1: QEvaF

Global Stress level of users N, User Think Time UTT, Ramp Up R_{UP},
Response Time RT, Throughput THP, Virtual User VU, No. of data sample C,
HTTP Pass Transaction PT, HTTP Fail Transaction FT, Fault Detection Rate FDR,
Population mean of response time µRT, Population mean of throughput µTHP,
Population mean of fail transaction µFT, Standard deviation S,
Critical value $t_{(\text{confidence level cl, degree of freedom df})}$.

1. Create test case T_1 // Hold all instruction for accessing the system
2. Set UTT:= *X* Sec
   VU := N, R_{UP} = *Y* min
3. For all $VU_i \subseteq VU$, i= 1… | VU_i | ,do
   Initialize to test case i.e $VU_i[] = T_1$
   Done
4. If $VU_i \neq \emptyset$ then
   For all $C_i \subseteq C$, i= 1… | C_i |, do
   For all $R_{UPi} \subseteq R_{UP}$, i= 1… | R_{UPi} |, do
   Execute VU_i []
   $RT_i = VU_i(RT)$
   $THP_i = VU_i(THP)$
   $PT_i = VU_i(PT)$
   $FT_i = VU_i(FT)$
   $TT_i = PT_i + FT_i$
   $FDR_i = FT_i / TT_i$
   $RT[C_i] = RT_i$
   $THP[C_i] = THP_i$
   $PT[C_i] = PT_i$
   $FT[C_i] = FT_i$
   $TT[C_i] = TT_i$
   $FDR[C_i] = FDR_i$
   Done
   Done
5. For all $C_i \subseteq C$, i= 1… | C_i |, do
   $a = \sum FT[C_i] / |C_i|$
   $b = \sum FDR[C_i] / |C_i|$

   $RT = \sum RT[C_i] / |C_i|$
   $THP = \sum THP[C_i] / |C_i|$
   $FT = \sum FT[C_i] / |C_i|$
   Done
6. $\mu RT = \overline{RT} \pm t_{(cl, df)} S/\sqrt{N}$
7. $\mu THP = \overline{THP} \pm t_{(cl, df)} S/\sqrt{N}$
8. $\mu FT = \overline{FT} \pm t_{(cl, df)} S/\sqrt{N}$
9. $m(t) = a(1 - e^{-bt})$
10. $\lambda = abe^{-bt}$
11. $R = e^{-bt}$

Fig. 2 Algorithm for QEvaF

respective grid node. The time complexity (TC) for this step is $TC_1 = O(1)$ as it will be created for once for all execution.

The step 2 sets the environment variable for the test case T_1. The UTT, VU and R_{UP} can be set initially before load execution. The TC for this step is $TC_2 = O(1)$ as it will be assigned for once for all execution.

The step 3 initializes the test case T_1 to the set of VU. The initialization will be N times as it will execute for whole set of VU. As such, the TC for this step is $TC_3 = O(n)$.

The step 4 will execute for all VU. A repetitive execution for a data sample C is taken. For each repetitive execution, the system metrics will be recorded during R_{UP} of the service. As such, the TC for this step is $TC_4 = O(n+n)$ i.e $TC_4 = O(2n)$.

The step 5 will evaluate the data sample C. It will hold number of HTTP FT and FDR. The data sample C will contain N test records. As such, the TC for this step is $TC_5 = O(n)$.

The step 6, 7 and 8 evaluates the population mean µ. It will be evaluated for once for the overall execution. The TC for step 6, 7 and 8 will be $TC_6 = TC_7 = TC_8 = O(1)$.

The step 9 will evaluate the mean fault count. It will be evaluated for once for overall execution. As such, the TC for this step is $TC_9 = O(1)$.

The step 10 will evaluate the failure rate of fault count as recorded. It will be evaluated for once for overall execution. As such, the TC for this step is $TC_{10} = O(1)$.

The step 11 will evaluate the reliability estimation. It will be also evaluated for once for overall execution. As such, the TC for this step is $TC_{11} = O(1)$.

As such, the overall TC for QEvaF is:

$$TC = TC_1 + TC_2 + TC_3 + TC_4 + TC_5 + TC_6 + TC_7 + TC_8 + TC_9 + TC_{10} + TC_{11}$$

$$= 1+ 1+ n + 2n + n +1 + 1 + 1 + 1 + 1 + 1$$

$$= 8+ 2n + n^2$$

$$= O(n^2)$$

The TC = $O(n^2)$ is observed to be polynomial. That means, number of operation for evaluating the quality depends upon the number of execution for generation of the data sample. As such, the problem of evaluating the quality of WS oriented grid based system can be solved by polynomial in time. Hence, the time complexity of QEvaF is polynomial time complexity.

VII. Comparison with existing framework and system model

Many studies had been carried out by the research community which had emphasized about the criteria that are primarily required for estimation of quality of service [7] [17] [21].

Table 1. Comparative evaluation of the proposed QEvaF with others framework

Criteria	Different evaluation methodology						
	Saddik et al. [21]	Rahmani et al. [17]	Medhi et al. [15]	Singh et al. [7]	Kalita et al. [13]	Ba et al.[22]	Proposed QEvaF
Methodology for data sample evaluation	No	No	Yes	No	Yes	No	Yes
Test bed utilization	Yes	Yes	Yes	Yes	Yes	No	Yes
Mean value observation	No	No	Yes	No	Yes	No	Yes
Failure record estimation	No	No	No	No	No	No	Yes
Mean fault count and failure rate estimation	No	No	No	No	No	No	Yes
Reliability evaluation	No	No	No	No	No	No	Yes
Observation against stress level of users	No	No	Yes	Yes	Yes	No	Yes
Population mean estimation	No	No	Yes	No	Yes	No	Yes
Observation for time complexity of assessment	No	No	No	No	No	Yes	Yes
Time complexity	Not carried out	Not carried out	Not carried out	Not carried out	Not carried out	NP Complete	Polynomial
Correlation of metrics estimation	No	No	Yes	No	Yes	No	No

As such, a comparative model is developed emphasizing the criteria to validate about the superiority of quality evaluation framework. The comparative study of evaluation for the propose QEvaF with others framework is carried out based on the model and is shown in **Table 1**. The table covers only those studies that primarily cover the deployment of service for estimation of service measures. From the table it is observed that the proposed QEvaF satisfies most of the criteria for overall estimation of service execution against massive growth of users.

To better explain the comparative results, we evaluate the percentage of satisfying the criteria against different quality evaluation framework. The percentage of satisfying criteria for different framework is shown in Fig. 3. It is observed that the evaluation framework as proposed by Saddik and Rahmani et al. have satisfied 9.09%

of total observed criteria. Whereas, the framework as proposed by Medhi et al. and kalita et al., and Singh et al and Ba et al. have

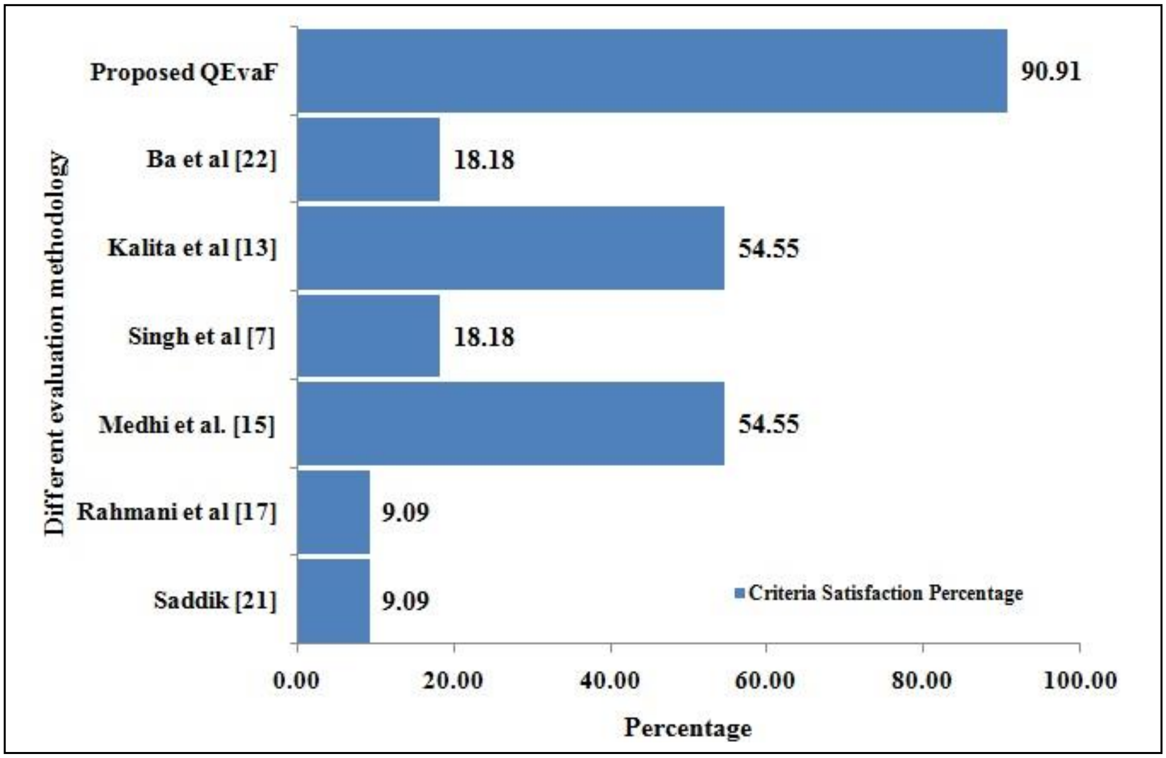

Fig. 3. Percentage of criteria satisfaction for different evaluation methodology

satisfied 54.55% and 18.18% of total observed criteria. However, the proposed QEvaF is satisfying 90.91% of total observed criteria. As such, it can be concluded that the proposed QEvaF is superior to the other evaluation framework while assessing the quality aspects of service execution. However, it can be also stated that although the QEvaF provides a guideline for evaluation and estimation of service execution in grid based system against massive users, necessary conditional logic can be developed and included for broadening the quality assessment of service execution.

VIII. Conclusion

The proposed QEvaF highlights a framework for assessment of the WS oriented grid based system against different load of users. The mathematical model of WS oriented grid based system is developed and optimization of service execution with different condition is identified. The time complexity of QEvaF is evaluated and observed to be polynomial in time complexity. The QEvaF utilizes the data sample for estimation of system metrics and reliability of the service based on fault count model. As such, the reliability estimation for WS oriented grid based system can be evaluated. The comparative study of the proposed framework with others is evaluated and observed to be better in satisfying criteria for accepting the framework. As such, the QEvaF can be deployed for identifying the quality aspects of WS oriented grid based system. Although the QEvaF highlights a guideline for proper assessment of WS oriented grid based system for different load, however, a correlation of system metrics can be find out with hypothesis of regression to identify the association among them. As part of future work, we propose to deploy the service and evaluate the performance aspects of system metrics.

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