



## Improving Mobile Grid Performance Using Fuzzy Job Replica Count Determiner

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### Abstract

*Grid computing is a term referring to the combination of computer resources from multiple administrative domains to reach a common computational platform. Mobile Computing is a Generic word that introduces using of movable, handheld devices with wireless communication, for processing data. Mobile Computing focused on providing access to data, information, services and communications anywhere and anytime with all significances. Mobile grids simultaneously are related with traditional grids and mobile computing technologies. This kind of grids inherits all bequests of traditional grid computing and has the trait that supports mobile users and devices in a wireless, Transparent, secure and efficient way. In this paper we suggest a job replica count determiner based on fuzzy inference system to improve mobile grid performance. Simulation results shows that our approach improve parameters like system throughput and network traffic, though job failure rate remains in same condition and mean response time become worse.*

**Keywords:** Mobile Grid, Fuzzy Inference System, Job Replication

### 1. Introduction

Grid computing is a term referring to the combination of computer resources from multiple administrative domains to reach a common computational platform. The grid can be thought of as a distributed system with non-interactive workloads that involve a large number of files. What distinguishes grid computing from conventional high performance computing systems such as cluster computing is that grids tend to be more loosely coupled, heterogeneous, and geographically dispersed [1].

Mobile Computing is a Generic word that introduces using of movable, handheld devices with wireless communication, for processing data. This devices includes Notebooks with Local Area Networks (LAN) for communication, Mobile Cell Phones and Personal Digital Assistants (PDAs) with Bluetooth or Infrared communication media [2][3].

Mobile Computing focused on providing access to data, information, services and communications anywhere and anytime with all significances, but technical approaches to achieve this purpose aren't always simple. In fact mobile computing needs design and implement communication infrastructures and making changes in computer networks, operating systems and applications[2][3].

Devices movement is a limiting factor in mobile computing network that have to be considered in design of communication foundations and each infrastructures based on mobile grid computing [4].

Mobile grids simultaneously are related with traditional grids and mobile computing technologies. This kind of grids inherits all bequests of traditional grid computing and has the trait that supports mobile users and devices in a wireless, Transparent, secure and efficient way [2][4].

Mobile grids are capable of extend to provide infrastructures for Ad-hoc networks and self-configuring grid systems of mobile devices that joint with wireless communications and with arbitrary and erratic topologies [5].

With extending grid computing to mobile devices and composing traditional grids with mobile computing, Grid structure has been changed significantly and encountered with new challenges [2].

These changes derived from the nature of small mobile devices, their limited facilities, also mobility and transportation of these devices [4]. So it is necessary to extend new infrastructures to provide utilization of grid services for mobile devices and getting these devices to processing grid jobs [6][8]. New designed structure includes interfaces needed for mobile devices communications.

One of important challenges opposite to mobile grid is resource allocation [2]. There are new difficulties with resource allocation in mobile grids in comparison with resource allocation in traditional grids like device migration, battery power limitation and low processing facilities [5]. This new problems make the complicated resource allocation issues more and more complicated.

Therefore fault-tolerance parameter in resource allocation likewise performance have own importance, unlike traditional grids that fault-tolerance have lower importance than performance in resource allocation [4][6].

But improving one of fault-tolerance or performance in resource allocation of mobile grids, make another parameter deteriorated. Therefore implementing approaches to resource allocation that improves both parameters are too difficult.

The most important challenge apposite to resource allocation in mobile grids is device migration. As described before, because of device mobility there is probability for each mobile device to leave the current proxy. This situation named device migration. Device migration is one of important reasons of job failure in mobile grids. Because the resource (device) that allocated to a job can't return results if it migrated and the job will be failed and have to be rescheduled [4].

## 2. Related works

In [2], composition of traditional grids and mobile devices are suggested and challenges are described. Also [5] suggests an approach to utilizing Agents to provide grid services for mobile devices. Litkeet al. in [4], have dissected changes and challenges of resource management in mobile grid environment.

Birjeet al. in [7], have suggested an approach to resource allocation using Agents. Also Choi et al. in [6], have described an approach for resource allocation based linear regression. This reference uses Bayesian probability to calculate probability of remaining a device in current proxy based on distinct movement pattern.

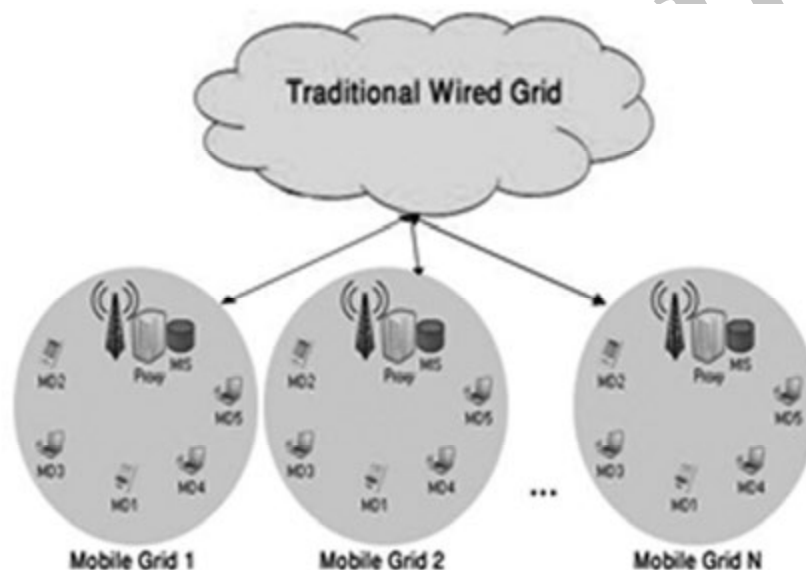
Park et al. in [8] use an algorithmic approach to make decision about partnership of a mobile device in processing scheduled job. Also this reference suggests a Job-Proxy

that interacts with processor device instead of user submitted the job when the communication is disjoint. This reference decides about device participation in job processing without considering device situation (either connected or disconnected).

In [9], an approach suggested for saving battery power in video stream processing and improving reliability of resource allocation in mobile grids. Also Huang et al. in [10] have suggested power saving via scheduler in mobile grids.

### 3. Mobile grid structure and architecture

Figure 1 presents mobile grid environment schema that can apply to our work. A traditional wired grid and several mobile grid network are interconnected. There is a proxy for each mobile grid that manages mobile devices. Also there is a mobile information server (MIS) that stores mobile devices information and managed with proxy.



*Figure 1. Mobile grid computing environment*

Figure 2 presents mobile grid architecture and part of this architecture that effected with our work. In this architecture QoS manager in both proxy and mobile device side, manage the quality of provided services and reliability of the mobile grid.

Security manager performs matching grid operation with security rules issue. Also communication manager manages the efficient connection between proxy and mobile devices.

Job monitor in proxy side monitors the job execution and commit. Device monitor collects, manages and monitors mobile devices information.

Job scheduler schedules the submitted jobs based on specific policies and resource allocation manager is responsible for allocating devices to scheduled jobs. Job executer in mobile device side executes the workloads and its operation monitors with job monitor. Location recognizer recognizes current location of job frequently. And capacity manager is responsible for reporting utilization of mobile device to proxy.

Job replication manager in proxy side manages different replicas of submitted job. We have affected this part to determine number of job replicas based on mobile grid current condition (number of mobile devices and mobile devices specifications).

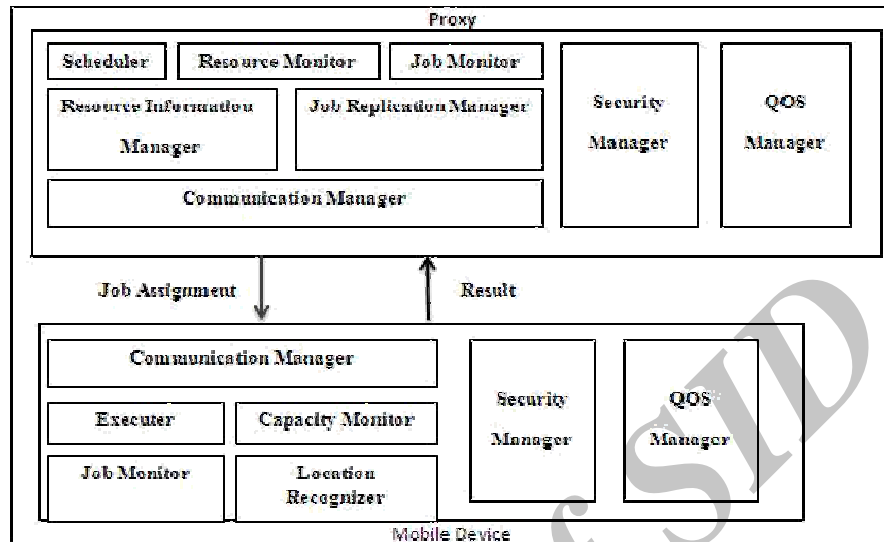


Figure 2. Mobile grid architecture

## 4. Proposed Method

### 4.1 Background

Fuzzy logic [11] is a tool to deal with uncertain, imprecise, or qualitative decision-making problems. Unlike in Boolean logic, where an element  $x$  either belongs or does not belong to a set  $A$ , in fuzzy logic the membership of  $x$  in  $A$  has a degree value in a continuous interval between 0 and 1. Fuzzy sets are defined by membership functions that map set elements into the interval  $[0, 1]$  (set elements membership degree).

One of the most important applications of fuzzy logic is the design of fuzzy rule-based systems. These systems use “if-then” rules (fuzzy rules) whose antecedents and consequents use fuzzy-logic statements to represent the knowledge or control strategies of the system. A fuzzy model is a qualitative model constructed from a set of fuzzy rules to describe the relationship between system input and output [12].

The process of applying fuzzy rules on the system is called inference mechanism. Because fuzzy rules describe the relationship between system variables in fuzzy values, two functions are necessary for translating between numeric values and fuzzy values. The process of translating input values into one or more fuzzy sets is called fuzzification.

Defuzzification is the inverse transformation which derives a single numeric value that best represents the inferred fuzzy values of the output variables.

### 4.2 Job replica count determiner based on fuzzy inference system

As already mentioned, the proposed job replica determiner is based on fuzzy logic. This type of controller has been chosen because of the uncertainty of the process, the small number of information available, the easiness of implementation and the small time necessary to put it in operation. The design of the controller is depicted in Figure 3.

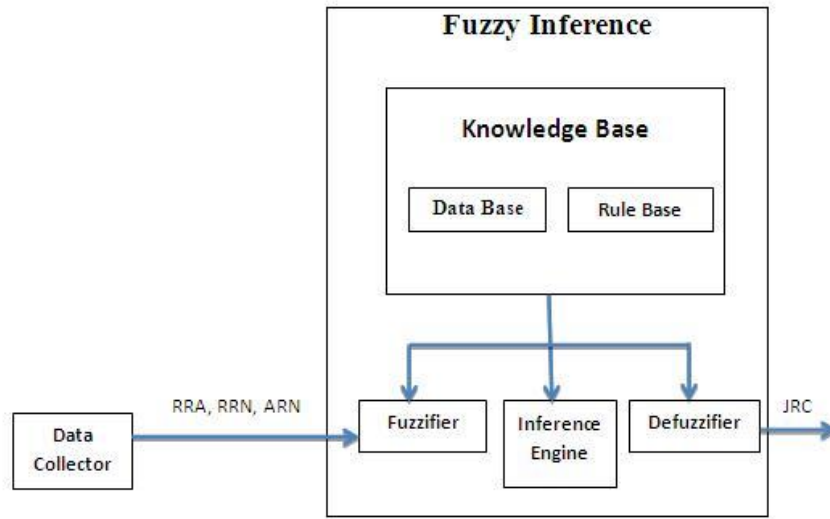


Figure 3. Fuzzy inference system for job replica count determiner

Data collector in figure 3 is in charge of periodically handling measurements about fuzzy inference system input variables like Available Resource Number (ARN), Resources (mobile devices) Rank Average (RRA) and Required Resource Number (RRN) for specific job to process it.

Available resource number and resources rank average comes from proxy side resource monitor showed in figure 2. Resources rank evaluate base on equation (1) for each resource then average of all resources rank is use to determine the job replica count[6].

$$R = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon \quad (1)$$

Where  $R$  is resource rank for a specific mobile device,  $x_1, x_2$  and  $x_3$  are the value of  $B_i, M_i$  and  $P_i$  that calculate based on equation (2), (4) and (5) respectively. Finally  $\beta_0, \beta_1, \beta_2$  and  $\beta_3$  are the regression coefficient and  $\varepsilon$  is the error rate[6]. Subsequently  $B_i, M_i$  and  $P_i$  parameters calculation will be described.

First parameter that is required to evaluate resource rank is  $B_i$  that indicates remaining battery power of specific mobile device. For mobile device  $i$ , let  $B_{i_c}$  be the current amount of battery before a job is assigned. And let  $B_i$  be the amount of battery after a job is processed.  $B_i$  is calculated using equation (2):

$$B_i = B_{i_c} - (J_f - J_s) * B_{i_p} - B_{i_t} \quad (2)$$

Where  $B_{i_p}$  refers to the amount of battery that spends in time unit, and  $B_{i_t}$  refers to the amount of battery to communicate.  $J_s$  and  $J_f$  is the start and completion time of job[6].

Second parameter that is required to evaluate resource rank is  $M_i$  that indicates probability of mobile device  $i$  keeps staying in a mobile grid network.  $M_i$  is calculated using equation (3), Bayes formula. If mobile user moves out current mobile grid,  $M_i$  is 0.

$$M_i = P(a|b) = \frac{P(a)P(b|a)}{P(b)} \quad (3)$$

$P(a|b)$  is the probability that the mobile device keeps staying in the mobile grid network even through a mobile device moves.  $a$  is the event that a mobile device is located in the mobile grid network and  $b$  is the event that a mobile device moves [6].

$P(a)$  can rewrite as  $P(a|h_r)$ , that is probability of sojourn of a mobile device in the mobile grid network according to stored movement pattern ( $h_r$ ), and  $P(b)$  can rewrite as  $P(h_r|b)$  that is probability following the pattern  $h_r$  when a mobile device moves. Therefore equation (3) can be changed to equation (4) [6].

$$M_i = \frac{\frac{P(a)P(h_r|a)}{P(h_r)}P(b|a)}{\frac{P(h_r)P(b|h_r)}{P(b)}} \quad (4)$$

Where

$$P(a) = P(a|h_r) = \frac{P(a)P(h_r|a)}{P(h_r)}$$

$$P(b) = P(h_r|b) = \frac{P(h_r)P(b|h_r)}{P(b)}$$

Last parameter required to evaluate resource rank is  $P_i$  that indicates mobile device performance information. For a mobile device  $i$ , performance information  $P_i$  is calculated using equation (5).  $C_{i\_CPU}$ ,  $C_{i\_MEM}$  and  $C_{i\_STR}$  are the value of CPU, memory and storage and  $U_{i\_cpu}$ ,  $U_{i\_mem}$  and  $U_{i\_str}$  are the utilization ratio of each element [6].

$$P_i = \frac{1}{U_{i\_cpu}} C_{i\_CPU} * \frac{1}{U_{i\_mem}} C_{i\_MEM} * \frac{1}{U_{i\_str}} C_{i\_STR} \quad (5)$$

Another part of fuzzy job replica count determiner is fuzzifier. This part fuzzifies input and output variables using membership functions. In this paper we use triangular membership function for input variables because of decreasing job replica count determination process time. Equation (6) presents triangular membership function.

$$f(x; a, b, c) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ \frac{c-x}{c-b}, & b \leq x \leq c \\ 0, & x \geq c \end{cases} \quad (6)$$

Also Gaussian membership functions used for output variable Job Replica Count (JRC) to increase uncertainty. Equation (7) presents Gaussian membership function.

$$f(x; \sigma, c) = e^{\frac{-(x-c)^2}{2\sigma^2}} \quad (7)$$

Inference engine is other part of fuzzy job replica count determiner. This part determines the job replica count based on fuzzy rules in rule base and input variables. At last defuzzifier change the fuzzy number that shows job replica count to ordinary number.

## 5. Simulation results

Suggested approach to determine job replica count is simulated using OMNeT++ discrete event simulator for network systems [14]. Simulation scenarios are as below:

- Simulation No.1: Number of grid cluster is 3; mean number of mobile devices for each cluster is 6, 8, 12 mobile devices respectively.
- Simulation No.2: Number of grid cluster is 3; mean number of mobile devices for each cluster is 8, 8, 10 mobile devices respectively.
- Simulation No.3: Number of grid cluster is 3; mean number of mobile devices for all clusters is 9 mobile devices.

First analyzed parameter is mean response time that is presented in figure (4) and figure (5). Figure (4) represents mean response time based on suggested approach in this research and figure (5) represents mean response time based on suggested approach in [6]. Simulation results show that compared to Choi et al. suggested approach in [6] this parameter gets a little worse. Also simulations shows that mean response time increases with increase in job number but after a threshold it remain constant. In the other hand balancing number of machines in grid clusters causes better results for response time.

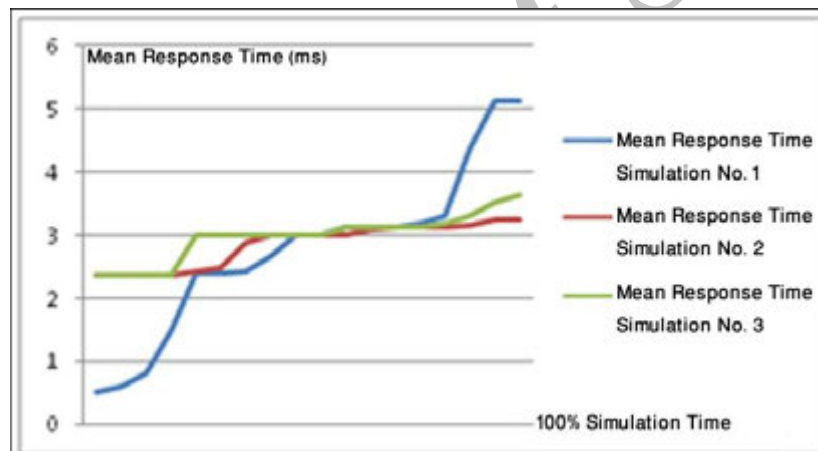


Figure 4. Mean response time based on suggested approach in this paper

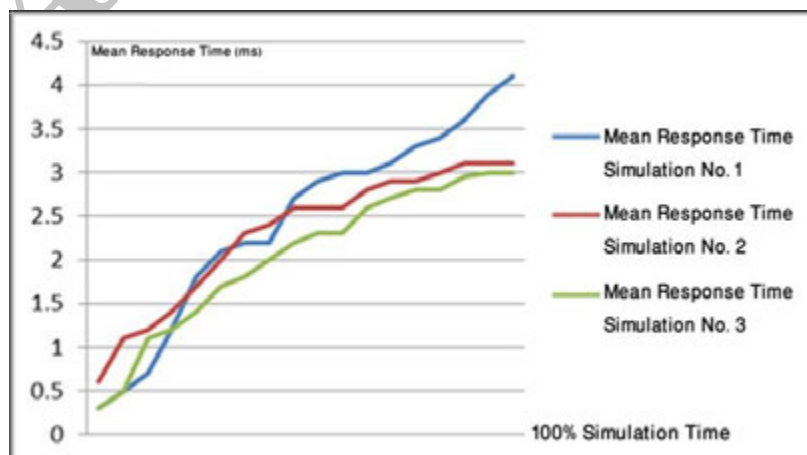


Figure 5. Mean response time based on suggested approach

Second analyzed parameter is system throughput that presented in figure (6) and figure (7). Simulations shows that this parameter becomes better compared to suggested approach in [6] because of accurate number of job replicas that decrease resources utilization for each individual job and increase resources efficiency. Also like previous parameter balancing number of resources in grid clusters causes better results for throughput.

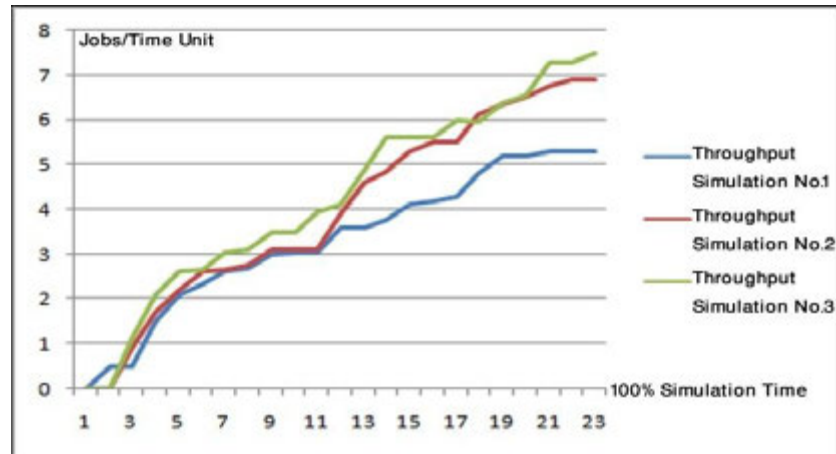


Figure 6. System throughput based on suggested approach in this paper

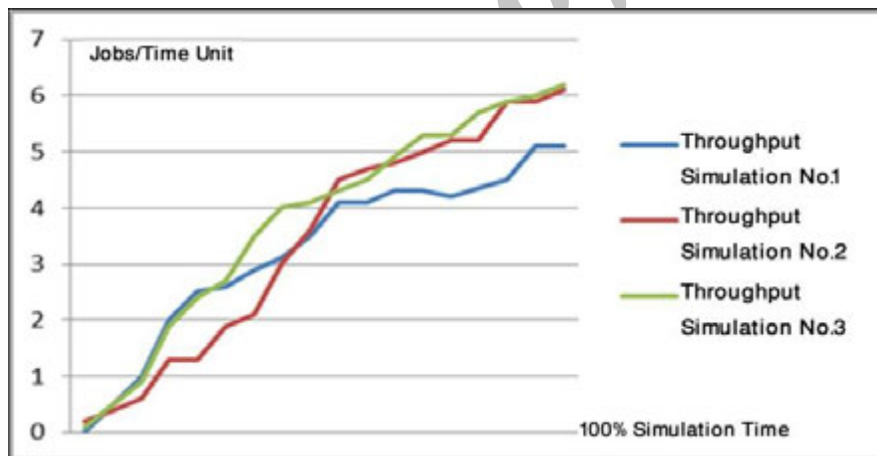
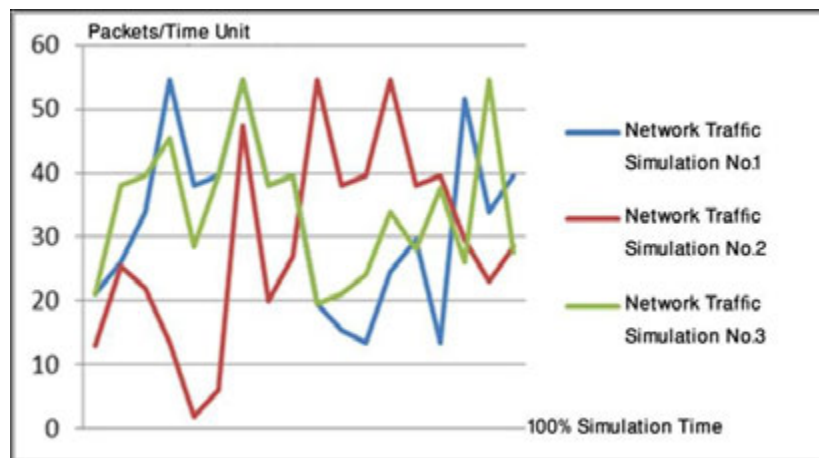
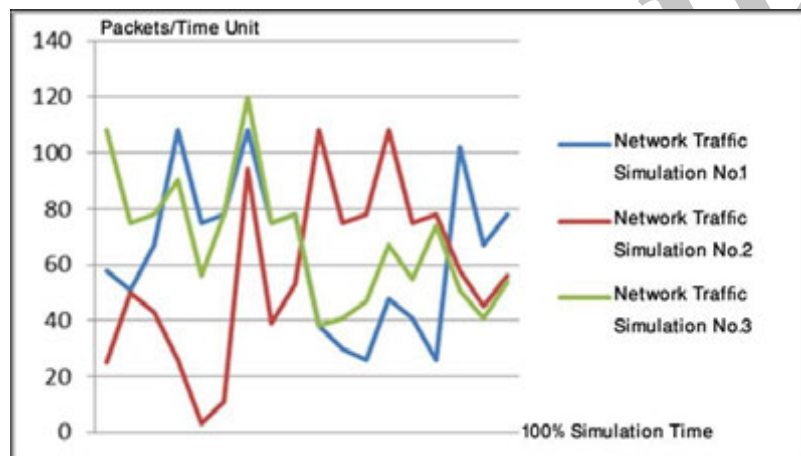


Figure 7. System throughput based on suggested approach

Another analyzed parameter is network traffic that presented in figure (8) and figure (9). Figure (8) represents network traffic based on suggested approach in this paper and figure (9) represents network traffic based on suggested approach in [6]. Because less job replica produce less network traffic hence network traffic gets better compared to suggested approach in [6]. Simulation results show that having fuzzy job replica count determiner, network traffic approximately dropped by half compared to suggested approach in [6].



*Figure 8. Network traffic based on suggested approach in this paper*



*Figure 9. Network traffic based on suggested approach*

Last analyzed parameter is rejection ratio (job fail rate) that presented in figure (10) and figure (11). This parameter shows reliability for suggested approaches. Figure (10) represents rejection ratio based on suggested approach in this paper and figure (11) represents rejection ratio based on suggested approach in [6]. Despite allocation fewer resources to a specific job this parameter remains in same condition compared to suggested approach in [6]. Also like response time and throughput parameters, balancing number of resources in grid clusters causes better results.

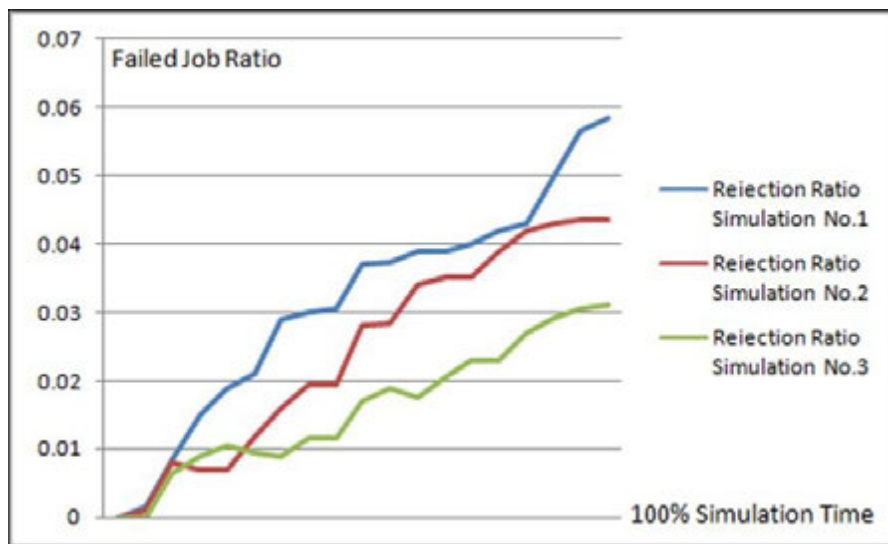


Figure 10. Rejection ratio based on suggested approach in this paper

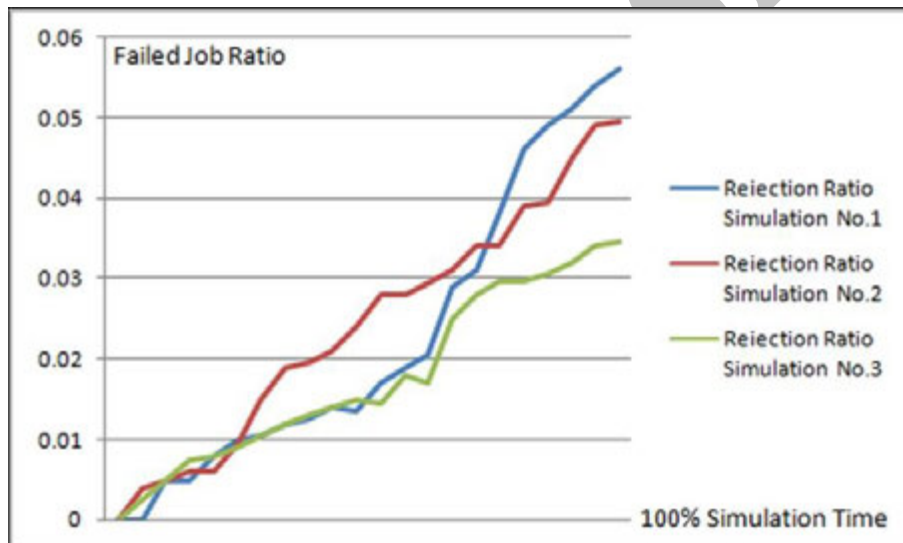


Figure 11. Rejection ratio based on suggested approach

## 6. Conclusion

In this paper we suggest an approach to determine job replica count in mobile grids based on fuzzy inference system to improve mobile grid performance.

Simulation results shows that our approach improve system throughput and network traffic, though job failure rate remains in same condition and mean response time get worse.

Also simulation results shows that balancing number of resources in grid clusters causes better results for response time, Throughput and rejection ratio.

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