International Journal of Modern Engineering Research (IJMER)

www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-1237-1243 ISSN: 2249-6645

Fuzzy Inference System Based Reputation Model for Grid Computing

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***Abstract*: Development of grid computing enforces the implementations of economic and efficient models, though the assumptions are there that both transaction parties are honest and trustworthy. In reality there is serious information asymmetry between transacting entities . Introducing trust and reputation can solve this problem to a great extent though the issue which is related with reputation and trust is it's imprecise nature which makes it difficult to be determined by precise conventional mathematics. In this paper we focus on a Fuzzy Inference System based Reputation model that will provide an previous experience based custom rule-setting to determine reputation for a transacting party. Malicious recommendations in indirect trust transmission has been also removed and punished in this model . The design and simulation of the controller is done using GRIDSIM and the simulation results are presented to demonstrate the efficiency of the Fuzzy Inference System Based Reputation Model (FISRM). The experimental results on different type of fraudulent users shows it's stability and steady performance over the conventional Reputation Based Allocation Model(RBAM).**

Keywords: Fuzzy Inference System; Mamdani Type Fuzzy inference; Global Information Service

I. Introduction

A grid computing system is an open, dynamic and competitive service oriented field . Due to its openness, resource management and their safety is one of the prime concern in grid . There are good number of service providers present in grid network which offers various competitive services and there are plenty of buyers to pay for that. But resource which are offered by several resource providers are not always trustworthy, and may be a huge number of them providing non-efficient and non-authorized resources with a huge amount of cost to make profit. And situation becomes more grave when the consumer deal with the transacting party who is entirely unknown to it.

Openness, dynamic nature and easy to get high computing services in less cost features of Grid computing comes under the cost of its serious information asymmetry. The primitive unit in Grid is a node or a system capable of computation along with some computer resources like memory(main and auxiliary), CPU units, printer etc. connected to each other by LAN or MAN or wireless network. Therefore, a Grid node or system can play at a time dual nature like resource provider and resource consumer. A grid network consists of grid nodes could be huge and overlaid over several states as well as several countries. So it's difficult for each resource provider and consumer to know each other at the first hand, resource node completely masters their own information. The available information is only a description of the resource node. Due to the serious information asymmetry, resource nodes may carry out dishonest transaction and in order to pursue maximum benefit and attract more customer to buy their merchandise. Since it is unrealistic to expect that all transacting parties are honest to behave proper measurements should be taken to stop fraudulent practice.

Introduction of trust and reputation model solves the issues of security in resource transactions in Grid network up to a great extent. The trust and reputation mentioned here is about the behavioral trust. Trust is often classified two categories: Identity trust and Behavioral trust. Identity trust is static. Once the identity is identified, the behaviors of the entities are not getting monitored any more even though they might do something harmful, whereas behavior trust is dynamic trustworthiness. Behavior trust is based on transactions between entities in the past time. If the entities do something wrong or harmful, it's behavioral trust value will get dropped and it'll help the other resources to decide that whether they still want to do any more transaction with the same entity or not .

Many trust models based on behavior trust had been proposed already. In the trust model proposed by Alfarez Abdur Raheman and Stephen Hailers, trust is divided into Direct Trust and Recommend Trust [1]. Literature [2] proposed a trust and reputation-based resource selection in grid computing, amended the reputation of resource provider based on trust factors to select the trustworthy transaction participators. Literature [3] examined the role of reputation in grid environments, introducing reputation and trust avoided the potential risk of opportunistic behavior of service providers or users who opportunistically exploit the information gap between providers and consumers on the quality of services. Therefore reputation mechanism can provide reference for resource node selecting transaction participators and resource node transact with trust. But trust is a subjective and inaccurate value which is decided by the Grid entity, it is difficult to describe with accurate probability distribution. Few behavior trust models based on fuzzy logic in Grid are proposed [4] [5] [6]. But the fixed weighted fuzzy comprehensive evaluation in [4] is not suited;

For these reasons, combining the grid resource oversupply situation and subjective and imprecise nature of Behavioral Trust, this paper proposes a Fuzzy Inference System based Reputation model (FISRM) for resource allocation in grid computing. This model based on user defined fuzzy inference rules enables grid node to decide a resource provider's trust and reputation value and secure a transaction between two unknown participator. After transaction a entity is asked to provide feedback on a resource provider for future reference and false recommendations are removed and punished in this model. Trust is an entity's belief in another entity's capabilities, honesty and reliability based on its own direct experiences within a specific context at a given time; Reputation can be obtained by fuzzy derivation and combination of recommendation trust.

II. FUZZY LOGIC IN TRUST DOMAIN

With fuzzy logic trust can partially belong to a set and this is represented by the set membership [7].

Let $X=\{x_0, x_1, \ldots, x_{n-1}\}$ be the problem domain that trust manage will be researched in x_i (i=1,....,n) denote the entity in Grid. The definition of fuzzy set is :

A fuzzy set is any set that allows its members to have different grade of membership (membership function) in the interval between [0,1].

Definition: Let X be the domain, and let x be the element of the set X, ∀x ∈X and the mapping is as :

$$X \rightarrow [0,1], x \rightarrow \mu_A(x) \in [0,1]$$

The fuzzy set A in X is expressed as a set of ordered pair

$$A = \{(x|\mu_A(x))\}, \forall x \in X$$

$\mu_A(x)$ is the membership function of fuzzy set A, which describes the membership of the element x of the base set X in the fuzzy set A. The grade of membership $\mu_A(x_0)$ of a membership function $\mu_A(x)$ describes for the special element $x=x_0$, to which grade it belongs to the fuzzy set A. This value is in the unit interval [0, 1].

In Grid, the grade of trust can be described by membership degree of different fuzzy sets in X which denote different trust levels. M different fuzzy sets T_i (i =1, 2, ..., M), which are in the set of all fuzzy sets in X can be used to denote M different trust levels. For example, when M=6, seven fuzzy sets T_i (i =1, 2, ..., 7), can be used to denote ix different trust levels in Grid. The trust level of T_i (i =1, 2, ..., 7), is defined as follows:

T_1 denotes the "very low" fuzzy set;
T_2 denotes the "low" fuzzy set;
T_3 denotes the "mid low" fuzzy set;
T_4 denotes the "mid " fuzzy set;
T_5 denotes the "mid high" fuzzy set;
T_6 denotes the "high" fuzzy set;
T_7 denotes the "very high" fuzzy set;

The membership function of x to fuzzy set T_i denoted as $T_i(x)$. To a concrete x_i, the membership degree is $T_j(x_i)$, which can be marked as T_{ii}. Trust vector of x_i is :
denoted as $T_i(x)$. To a concrete x_i, the membership degree is $T_j(x_i)$, which can be marked as T_{ij}. Trust vector of x_i is :
$V = \{v_1, v_2, \ldots, v_7\}, v_j\ (i = 1, \ldots, 7)$, v_j denotes the membership degree of x_i to T_j. But x_i can simultaneously belong to another fuzzy set T_k, such that $T_k(x_i)$ characterizes the grade of membership of x_i to T_k.

III. THE OVERVIEW OF FISRM

Introduction of trust and reputation mechanism into grid network protects the resource consumer by saving them the fraudulent resource providers . Trust and reputation reflects a grid node's past behavior as well as its future expected performance . A task node periodically collects the information about all registered resource nodes and their reputation information from concerned Grid Information Service (GIS). When a resource register itself for the first time the local GIS assigns it a neutral trust value which just above from the par. Later according to its performance, efficiency and consistency increase its own trust and reputation value which make it more acceptable than other nodes. In this model Grid Information Service plays a very important role, the dependency of resources on the Local GIS make the entire network more scalable compared to earlier models because the complexity of the computation of trust and reputation reduced to O(n) from $O(n^2)$. In this paper, we pay more attention to the task and reputation of resources node, because the task node has less information but takes larger risk at the same time in transaction process and its trust and reputation have a comparatively small impact to results of the transaction, contrary to the resource node.

A. Logical Structure Of FISRM

The Logical structure of FISRM is shown in Figure 1. The module definition of FISRM is introduced in section B. Grid resource allocation workflow based FISRM has been in section D.

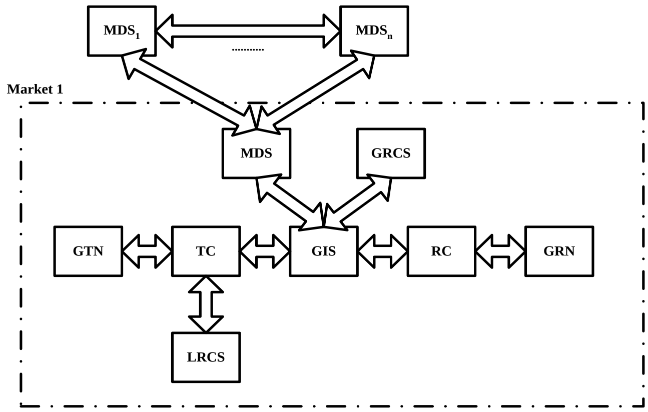

Fig. 1. Logical Structure Of FISRM

B. Related Definitions

Market in grid network is a platform for transaction between a resource and a task. Without existence of market a task cannot assign it's tasks to a proper resource. Transaction manager is significantly responsible for maintaining the benefits of transaction participators, making market resources to achieve balance of supply and demand, contacting with other grid resource markets and sharing grid resources.

But in this paper our motive is not to describe the role of transaction manager, it's beyond the scope of this paper. We mainly focused on the behavior of the following components of market in grid network including GIS(Global Information Service), TCS(Trust Computation Server), RCS or CCS(Reputation Computation Server or Credibility Computation Server).Apart from them, other components are as follows:

Grid Resource Nodes(GRN): grid node gains benefit through selling resource and permitting others to use its resource, which is recorded as resource node.

Grid Task Nodes(GTN): grid node gets the service through paying for the resource, which is recorded as task node. It also keeps its own record of the ratio of successful and failed transactions for each resource node.

Task collector(TC): collect the request information of gird task nodes and submit it to the GIS.

Resource collector(RC): collect the request information of gird resource provider and submit it to the GIS.

Grid Information Servers(GIS): The primary task of GIS is to keep records of all available resource nodes and task nodes in a single market in a grid network. Task nodes which are interested to consume a resource should register itself with GIS and wait for the periodic updates of the resource nodes with their reputation values, then a task node decide whether it will perform transaction with the resource node or not. Along with that GIS is also responsible for to assign reputation values for newly registered resource and to keep track of the information about ratio of total transaction a resource node participated and the number of successful transaction irrespective of any task node. After the completion of each transaction task node calculate the trust value of the resource node and send it as a feedback to the GIS for future reference.

Market Directory Servers(MDS): Record the grid resource market directory information. It can map to other resource market information servers through the directory, query the information of other resource market members, including the registration information, the transaction record, reputation information and so on.

Trust Computation Server(TCS): Compute the trust value of the resource node after the completion of a transaction on behalf of a task node and after defuzzification send it to task node.

Reputation Computation Server(RCS): Check the credibility of the node giving feedback on different node and punish it if any discrepancy happened and reward the node which is performing consistently in a honest and efficient approach.

Reputation: Grid node's reputation is the expectation of future transaction behavior which is based on the observation of transaction behavior from other resource nodes during a given period.

Local Reputation Value: Grid node j's local reputation value LR_{ij} is the expectation of i to j's future transaction behavior based on the transaction history and the evaluation of transaction history by i .

Global Reputation Value: Resource node j's global reputation value R_j is the credibility which is got by integrating the evaluation given by other resource nodes which have transactions with node j.

C. Reputation Value Computation

This procedure starts from the time a node in grid network register itself for the first time in GIS. In this paper we have assumed that initially GIS assign every node a initial reputation value of 0.6. If it seems to naive to assign a value in such manner , GIS can conduct some initial test procedure to decide appropriate reputation value what should be suited it better.

Reputation value of a node in grid network get decided through a two-fold system. First after completion of a transaction consumer decide the reputation of the provider and later in GIS based on the feedback submitted by the consumer, reputation of both consumer and provider got affected globally.

Local reputation computation depends on the following three metrics,

Capability: Capability of a grid node indicates the capability of this node to accomplish a task submitted by a task node successfully. The ratio of total transactions it has participated to the number of transactions it had accomplished successfully has been taken here as a node's capability.

$$C_j = \frac{n_{tj}}{n_{sj}} \qquad (1)$$

For a node j, (j = 1,...,n) it's capability C_j is the ratio of total transactions it participated n_{tj} to the number of successful transaction n_{sj}.

Reliability: Reliability feature of a grid node prevent a fraudulent node to practice slow poisoning or frog-boiling frauds. It reflect that how spontaneous a node is by measuring it's activity coefficient. Here is an empirical formula to measure it

$$R_j = e^{\left(\frac{n_{tj}}{n_t} - .8\right)} \qquad (2)$$

Here n_t is the total number of system transactions between all nodes in a grid market. 0.8 is a upper threshold value which indicates that for a node, it's not possible to participate in more than 80% transactions.

User-Satisfaction: User satisfaction is the measurement of the satisfaction of a node with another node based on the status of the transaction as well as the previous transactions happened between them.

$$U_{ji} = \frac{n_{s_{ji}}}{n_{t_{ji}}} \qquad (3)$$

For a node j, (j = 1,...,n) $n_{s_{ji}}$ is the number of successful transaction between node i and node j and $n_{t_{ji}}$ is the number of total transaction between them.

Now using the above mentioned metrics as input parameters for fuzzy inference system, Trust Computation Server calculates the trust value of the grid node which has provided the resource.

Initially the reputation value of a newly registered resource node, a node receive from GIS is 0.6 which just above the bottom watermark 0.5 for a node to decide to take part in a transaction. Later the value get changed based on its consistency and honesty in feedback to other resources. Values of capability, reliability and user-satisfaction are though in the interval between [0,1], to decide that which trust level they come under fuzzification is required using different membership functions, one for each of capability, reliability and user-satisfaction. The range of values for different trust levels for the membership functions are shown in Table 1. Users can set their customized value range based on their past experience and expert knowledge.

Trust-level	Very Low	Low	Mid-low	Mid	Mid-high	High	Very High
Capability	(0.0, 0.1)	(0.0, 0.15, 0.2)	(0.15, 0.3, 0.4)	(0.3, 0.45, 0.6)	(0.4, 0.55, 0.7)	(0.6, 0.8, 0.9)	(0.85, 1.0)
Reliability	(0.0, 0.2)	(0.1, 0.25, 0.4)	(0.3, 0.4, 0.5)	(.45, 0.5, 0.6)	(0.55, 0.65, 0.8)	(0.7, 0.8, 1.0)	(0.95, 1.0)

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User-satisfaction	(0.0, 0.1)	(0.0, 0.15 ,0.2)	(0.15,0.3, 0.4)	(0.3, 0.45, 0.6)	(0.4, 0.55, 0.7)	(0.6, 0.8, 0.9)	(0.85, 1.0)

Table 1. Range Of Different Trust Levels

The fuzzy inference system we have used here is Mamdani type. The Mamdani-type fuzzy inference process [8] is performed in four steps:

1. Fuzzification of the input variables
2. Rule evaluation (inference)
3. Aggregation of the rule outputs (composition)
4. Defuzzification

We examine a simple two-input one-output problem that includes three rules:

Rule: 1 IF x is A_1 OR y is B_1 THEN z is C_1
Rule: 2 IF x is A_2 AND y is B_2 THEN z is C_2
Rule: 3 IF x is A_3 THEN z is C_3

The behavior of fuzzy system is studied through the rule viewer and surface viewer which are simulated in Matlab. Figure 2 shows the trust model, having three input parameters and one output. The fuzzy inference used is depicted in Figure 3. shows the rule viewer of various rules taken into the consideration. The rule viewer gives the graphical representation of rule base designed.

Once the trust evaluation is accomplished by Trust computation server, it defuzzify back it in the range [0,1]. Defuzzification is the reverse process of fuzzification. Trust and reputation calculated by TCS is a "fuzzy" result, described

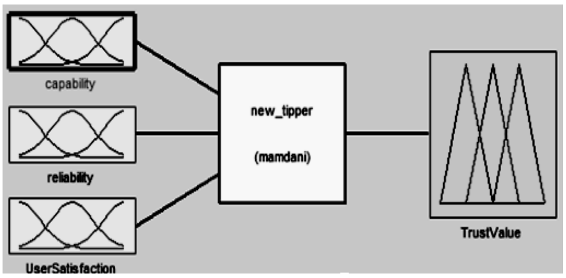

Fig. 2 Trust Model based on Mamdani-type Fuzzy Inference

in terms of fuzzy member sets. Defuzzification would transform this result into a single number indicating the trust level of an entity. This may be necessary if we wish to output a real number to the user. An average of maxima method or a centroid method [8] can be used to do this work. We have used centroid method in our work.

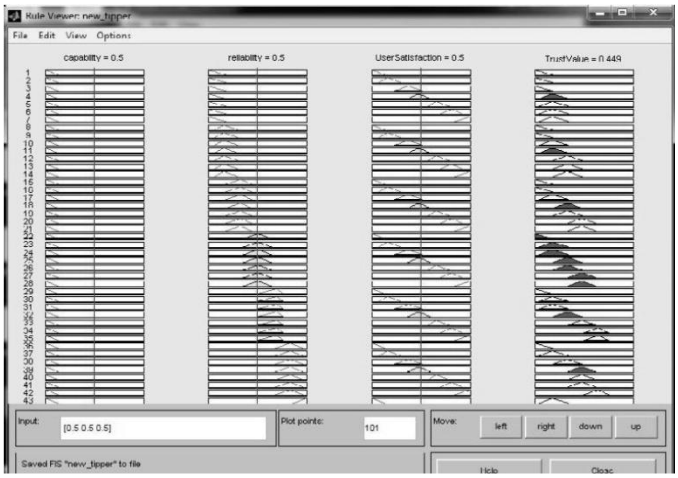

Fig. 3 A sketch map of Mamdani-type Fuzzy Inference

After the computation of local reputation, task node sends the reputation information to GIS for future reference. In GIS for security purpose and to prevent foul practice the reputation value sent by has been checked using some firsthand rules.

Because of the self-interest of the many and varied organizations in the Grid, there will be some unfair ratings for strategic lying and collusion amongst agents in the all ratings from entities in the Grid. To remove false reputation recommendation, local reputation value checked against the node's global reputation value. If the deviation is more than some user defined value $\pm\sigma$ then it will be discarded and the reputation value of the feed backing resource will be defamed by the given empirical formula:

$$R_i = R_i(1 - e^{-0.5})\ j = 1,2,\dots,n \qquad (4)$$

Global reputation value of a grid node is the mean value of the feedback received for that node. A node constantly performing with a steady efficiency is rewarded by this model after a short interval of 5 to 10 feedbacks by the following empirical formula:

$$R_j = R_j(1 + e^{-0.3})\ j = 1,2,\dots,n \qquad (5)$$

D. ResourceAllocation Based On FISRM

Resource allocation based on FISRM has been shown using a flowchart in Figure 4.

In the flow chart terms are used like n(F) means no. of feedbacks and LR means local reputation and GR means global reputation.

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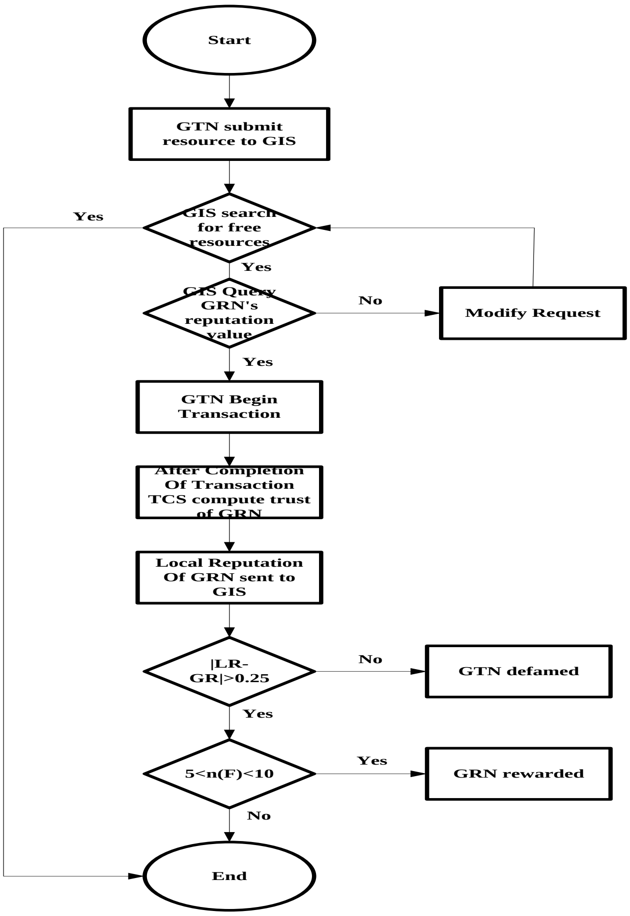

Fig. 4 Resource Allocation Based On FISRM

IV. Experiments And Simulation Results

To check that the model we have implemented is working efficiently or not we carry out a number of experiments. Before stating about them, to check the trend of trust transfer between Capability, Reliability and User-satisfaction, we have simulated the corresponding surface viewer of these parameters in Matlab and depicted here in Figure 5.

Experiment environment is set in GridSim by doing a series of changes to make suitable for FISRM model. GridSim is a discrete event simulation toolkit based on java and its main object is to study effective methods of resource allocation based on computational economy model by simulating the grid environment.

In our experiment we have set a grid network of 30 grid nodes and each node has their own tasks and resource. The constraint is no node can submit their task to their own resource and has to register their resources in GIS. By this constraint each node is able to play the roles of both resource provider and task node. In grid market resource nodes can be divided in two categories:

Good Node: Nodes which performs with consistency and honesty.

Malicious Node: Nodes which are notorious to do foul practice.

But the malicious node definition is really broad category to realize. Literature [9] describe a more specific sub category of them.

Slander nodes: These malicious nodes of this type provide unauthentic resource and false negative evaluation when resource node is asked to feedback other nodes transaction evaluation.

Collusive fraud nodes: These malicious nodes of this type collude with each other and provide authentic resources and good feedbacks for inside members, but provide unauthentic resources and incorrect evaluation for external nodes.

A. Experiment 1: Growth of reputation values of resource nodes with the increase of transaction

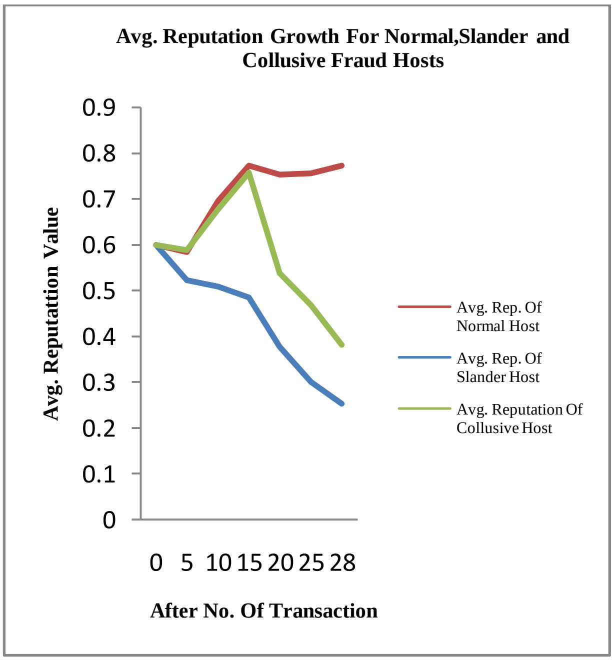

Fig. 6 Avg. Reputation Growth For Normal, Slander and Collusive Fraud Hosts

Figure 6 shows that growth of reputation values of normal nodes or good nodes are steady after the first transactions. The dip in first five transaction is due to the initial assignment of reputation value of 0.5. After 5 to 7 transactions it adjusts it's reputation value to it's true reputation value what it deserves. Slander hosts are started to dip from very beginning itself due to their malicious activity, results shows that it can detect the maliciousness efficiently and in a short frame of time window. Collusive nodes are hide themselves in a crafty manner but still in this model they are getting detected after a short interval with respect to other models.

B. Experperminet 2: Trend of average successful transactions with the increase of transaction

Figure 7 shows that the average number of successful transactions are steadily increasing from the very beginning as expected. The curves for the successful transactions for slander and collusive nodes are expected as well and they are consistent to their characteristics.

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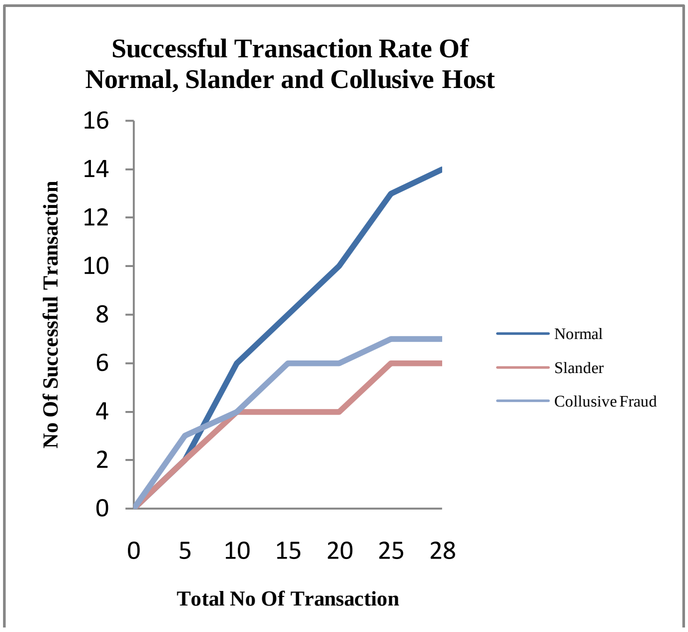
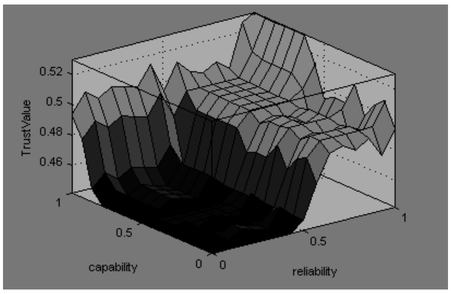
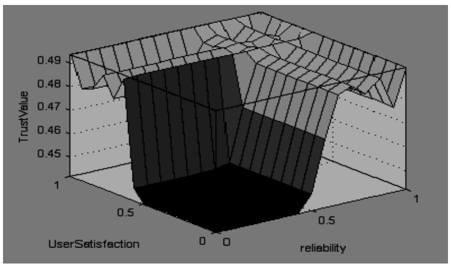


Fig. 7 Avg. Successful transactions For Normal, Slander and Collusive Fraud Hosts

C. Experminet 3: Growth of Successful transaction ratio with the increase of percentage of malicious nodes

Figure 8 shows that with the increase of malicious nodes this model still provide a good performance. With the increment of collusive fraud nodes up to 50 still it gives a high successful transaction ratio around 78% which is comparatively very with respect to other models. With the presence of slander nodes also these shows a great stability with respect to earlier models. With the increment of slander nodes up to 50% still this model ensures the average amount of successful transaction ratio up to 75%.





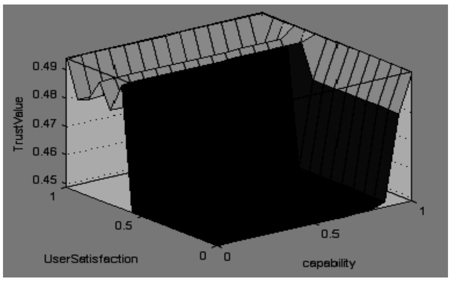


Fig. 5 A three dimensional simulative sketch map of capability, reliability, user satisfaction and Trust Value

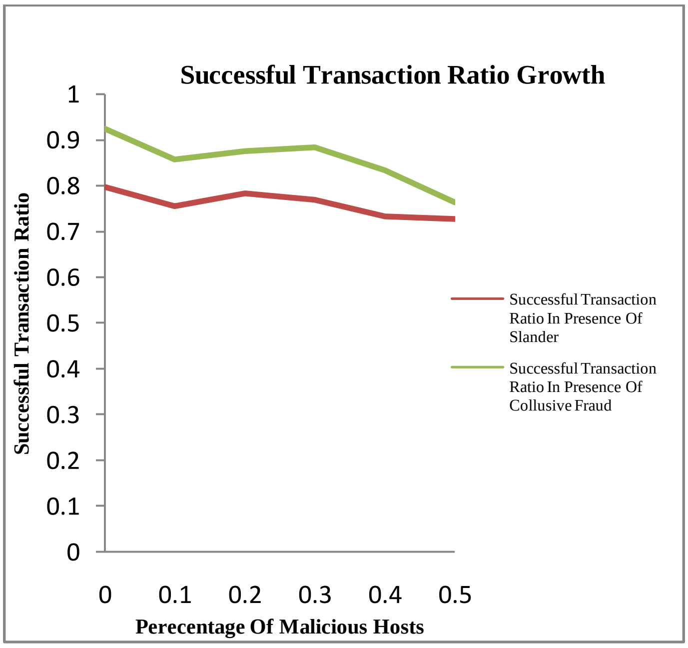


Fig. 8 Successful transactions with the increase of Malicious Hosts

V. CONCLUSIONS

This paper has implemented a reputation model based on fuzzy inference system that gives simple and but quite efficient way of ensuring security in grid network among various grid nodes. It also provides a scalable solution for the computation of reputation. After that number of inputs are three , required number of rules(7^3) are very high and it demands a high performance processor and large computation time .To avoid these problem, in future we can enhance our work in some information infusion techniques to reduce this overhead. Also in future we will try to explore Data Mining techniques of rule based classification and other artificial intelligence techniques in this field to make it more scalable and more stable with huge loads of data. Though the dependency of grid nodes on Global Information Services to get reputation information of other nodes makes it more scalable but at the same time the entire system turned into more vulnerable to system faults. We will also try to sketch new parameters to build the reputation model for intra market or grid network level to build cross platform between different security systems deployed in different grid networks.

www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-1237-1243 ISSN: 2249-6645

ACKNOWLEDGMENT

This work is supported by the Indian Institute of Technology-Roorkee (Roorkee-247667, India).

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