CHAPTER 3

THE PROPOSED RESOURCE BROKER ARCHITECTURES

3.1 INTRODUCTION

The proposed broker architectures such as Single Broker Architecture, Multi-Broker Architecture and Hierarchical Broker Architecture are discussed in this chapter. Features and problems of each of the architectures are also discussed here.

3.2 SINGLE BROKER ARCHITECTURE

Single Broker Architecture proposed initially advocates the presence of single broker per domain. All entities (RPs and consumers) are associated with this broker. There is a possibility of heavy traffic at the broker’s site with the broker being heavily loaded since all the resource requests and feedbacks in a domain are processed only through that broker. Single broker architecture also may result in single point failure.

3.3 MULTI-BROKER ARCHITECTURE

In order to alleviate these problems, the grid framework is modified to a Multi-Broker Architecture. In this proposed architecture, each domain is associated with multiple brokers, and each of the entities (RPs and consumers) is associated with more than one broker as shown in Figure 3.1. The brokers maintain a database of all the consumers and RPs associated with
them, thereby alleviating the need for the entities duplicating information about each other at their sites. This leads to a robust architecture with a centralized resource selection process for every consumer request, based on the information and feedback gathered by the broker from various sources.

Figure 3.1 Multi-Broker Architecture

In the proposed architecture, it is mandated that every domain should have multiple brokers and information about every entity should be available with at least two brokers. Advantages are twofold: This avoids accumulation of too many requests at any broker site, leading to easing of network traffic at the broker site. Sensitive information such as transaction details and the trust-indices of RPs, consumers and other brokers are maintained at each of the brokers’ site leading to possibilities of hacking. This means loss of precious data. This may be avoided by designing for reliability through redundancy.
However, the presence of multiple brokers raises other issues such as distribution of entities among brokers and maintenance of consistency of information about entities at different brokers. Failing to deal with these issues will negate the advantages of having multiple brokers. The following simulation assumes uniform distribution of entities among the brokers. However, this need not be the case always. The consumers and RPs are considered separately for distribution among the brokers. The algorithm for this distribution is as follows.

i. Let there be $d$ domains ($D_0, D_1, \ldots, D_{d-1}$), $n$ brokers ($B_0, B_1, \ldots, B_{n-1}$) and $k$ entities ($x_0, x_1, \ldots, x_{k-1}$), $n$ brokers be distributed across $d$ domains with $n/d$ brokers per domain. Redundancy factor ($r_f$) determines the number of brokers associated with each entity. For an RP, $r_f$ is based on the criticality of resource type and its functional value is calculated thus. Consumers are assumed to have an $r_f$ of 2. Consumer’s information also must be available with at least any two brokers.

For each domain ($D_i$) do

{} For each broker ($B_j$) within each domain ($D_i$) do
{} For each entity ($x_k$) within domain ($D_i$) do
{} If an entity $x_k$ is an RP,

Then redundancy factor ($r_f$) = function of the value of criticality of resource type

Else if (the entity is a consumer) $r_f = 2$

Associate $x_k$ with $B_p, B_{j+1}, \ldots B_{j+r_f-1}.$

$j = (j + r_f) \mod (n / d)$

The algorithm distributes entities optimally. When each RP is associated with more than one broker ($=r_f$), each of these $r_f$ brokers is required to maintain all the information about the RP. This includes the RP’s ID, type
of resource provided, time up to which it shall be active, criticality factor of the resource, and cost per hour for using the resource and finally the trust-indices for the resource computed based upon the feedback obtained from the consumers who have earlier had transactions with the RP. The RP should also provide information on the details of infrastructure (I-index) and policy (P-index) during the time of publishing the resources at the broker-site. I-index is based on the bandwidth, the system-capability, failover process (whether provided or not), business continuity and disaster recovery (whether BC/DR is available or not) and adherence to infrastructure standards (yes or no). P-index includes the information security practices certified by International Standards authorities such as BITS, ISO 270001, etc, the presence of and adherence to policies on warranty, payment and delivery. These details are consolidated as the presence-index of the RP that indicates the presence of the RP in the grid-industry. Since the parameters of presence-index are authenticated by third party, the initial trust-index of a RP is assigned by the associated brokers based on this presence-index.

The brokers shall offer membership for an RP if and only if the trust-index of that RP is greater than or equal to its own trust-index. Otherwise, membership is disallowed, irrespective of any business profit. This is done by the broker in order to maintain its (own) trust-worthiness in the industry. The trustworthiness of a broker is directly a function of the trustworthiness of all the RPs attached to the broker. The broker’s trust-index is computed as the average of the trust-indices of the RPs associated with the broker. Initially, the trust-index of a broker is assigned by a standard forum such as the Global Grid Forum (GGF), based on the presence-index of the broker similar to the RP and the trust-indices of the RPs associated with the broker. The trust-index of a broker is updated after the completion of each transaction and is maintained by a standard forum. This trust-index may be published for the benefit of the consumer community (who wishes to
approach brokers for membership and resources) and the RPs (who wish to approach the brokers for membership). The brokers are also obliged to maintain information about each of the consumers attached to them. This includes the ID and the trust-index of the consumer. The broker may publish invitations for new RP with the identified faulty RP due to less trustworthy leaving the scene, leading to business opportunity for a new RP.

Each broker is also required to maintain information such as the number of RPs and the consumers associated with it and the trust-indices of other brokers. The list of brokers associated with each entity should also be maintained at the corresponding broker’s site.

3.3.1 Working Principle of the Architecture

When a consumer requires a specific type of resource, it sends its resource-request to the broker with the least queue-length for the requested resource type, operating in the same domain as the consumer. The broker examines the trust-index of the consumer to ensure its trust-worthiness before proceeding with the request. If the consumer is trustworthy, the broker starts the process of selection of a suitable RP, else penalizes the consumer’s request. In its request, the consumer specifies its constraints on the type of the requested resource, the cost and the schedule. This cost reflects the criticality and QoS expected by the requested resource. If the consumer expects timeliness and good QoS, the budget for the resource would be suitably high. The broker examines the trust-indices of all the RPs who could provide the requested resource as per the consumer’s constraint from among those who are associated with it. It also delegated the request to other brokers on the same domain, and at other brokers in other domains to select the trustworthy RP for the consumer’s request. Only the top T brokers, whose average trust-index is greater than the threshold, are chosen to avoid traffic congestion for
delegation of consumer’s request. Threshold value is chosen based on the criticality of the resource type.

Each of these brokers (T brokers) selects a RP having the highest trust-index among all the RPs that best satisfy the consumer’s constraints and recommends this RP to the requesting broker, as its choice. The broker (who is associated with the consumer) examines the suitability of all the RPs nominated to serve the request and selects all RPs whose trust-indices is above the seventy-fifth percentile from among the chosen set. This ensures that only the RPs with acceptable trust-values are considered for servicing the client request. From this set, the one with the least number of transactions to process is selected for this instance of the client request. If more than one RP falls into this category, the one among them with the best trust-index is selected. In the case of more than one RP complying with these selection criteria, the RP that has a more direct relationship with the broker is selected. For example, if RP₁ and RP₂ satisfy the consumer constraints and have the least number of transactions to process, have the same trust-index, broker B₁ chooses RP₁, assuming that B₁ has a more direct relationship with RP₁ than RP₂ which is associated with another broker. If RP₁ and RP₂ satisfy consumer’s constraints and have the same number of transactions to process the same highest trust-index and both are directly related to broker B₁, the one projecting the least cost is chosen. Thus, the process of electing a suitable RP for a transaction involves a hierarchical priority based selection procedure, considering the consumer’s constraints, the trust-indices of the brokers and the RPs, queue length at the RPs, the nature of association with the broker initiating the transaction and finally the cost of transactions. Thus, in the event of a new RP joining the grid circuit, with an initial trust-index equal to or greater than the seventy-fifth percentile, there is a high probability that it may be given a chance to process the latest transaction, by virtue of having the least number of transactions to process. Thus, this schema avoids starvation
of new RP, while still using a fair selection process. There is a chance of such new RP getting elected by the associated broker for a consumer’s request if highly trustworthy RPs are currently busy and unable to satisfy the schedule of the request. And anyway trust-index of the new RP is greater than / equal to the trust-index of the associated broker and definitely greater than the trust indices of the untrustworthy RP due to past untrustworthy transactions. Once chosen, the broker intimates the selected RP about the details of the consumer’s request. The consumer is also notified of the selection.

The consumer utilizes the resources of the RP and at the end of the transaction, provides a feedback to the broker. This feedback includes the consumer’s ID, RP’s ID, the resource type, the satisfaction-index and the date of transaction. The satisfaction-index indicates the level of satisfaction achieved by the consumer on the resource provided by the RP. A value between -1 and 1 is used, with 1.0 indicating 100% satisfaction and -1.0 indicating the lowest satisfaction. The broker, who is associated with the RP, also generates its feedback on the resources provided by the RP after the completion of each transaction. The feedback provided by the broker is considered to be more reliable compared to the consumer’s feedback since the broker is assumed to be a centralized more-trustworthy entity than the individual consumer who may tend to be malicious or partial. When the consumer’s feedback deviates from the broker’s feedback by more than the threshold (a value of 5% is assumed here), it is discounted as false feedback and only the broker’s feedback is used for the computation of trust-index of the RP. Otherwise, the feedback on the transaction is consolidated based on the broker’s and the consumer’s feedbacks. The rationale behind using 5% as a threshold for the deviation between consumer’s and broker’s feedback is to allow for the genuine differences in feedback given by lenient and strict consumers for similar resources, and for possibility of an otherwise trustworthy RP providing degraded resource due to overload or due to any other
extraneous factors. Allowing a usual maximum of 2.5% deviation to accommodate the difference between lenient and strict feedback and an additional maximum degradation of 2.5% to allow for an RP providing degraded resource due to overload, infrastructure failure, etc., thus makes the total allowable deviation due to non-malicious reasons to 5%.

This feedback information is propagated to all the brokers associated with the RP. These, along with the cost of that transaction form the transaction information for that transaction and are maintained at the associated brokers’ sites. The cost of the transaction is computed at the broker’s site based on the cost per hour for the usage of that resource (maintained at the broker’s site) and duration of utilization. The trust-index of the RP is updated by aggregating the satisfaction-index and the cost of the present transaction with that of the past transactions. The details of computing and updating the trust-indices of RP are explained in chapter 4. The trust-index of the consumer is updated at the associated broker’s site based on whether the consumer provided the feedback on the utilized resources and whether it honored its commitment on payment. The trust-index of the broker associated with the selected RP is also updated and maintained by the standard forum, after each transaction. The computations of trust-indices of consumer and broker are also discussed in chapter 4.

3.4 MULTI-BROKER ARCHITECTURE WITHOUT DELEGATION

In most of the trust-based systems, intermediaries known as brokers are responsible for the selection of RPs for consumer requests. In such models, the intermediaries gain monetary benefit for each of the transactions made through them. This may lead to favoritism and bias in the selection of suitable RP. The earlier architecture discussed by Sungkeun et al (2005) insist on multiple brokers in each domain. In the earlier Multi-Broker Architecture,
the consumer’s request is not only processed by the associated broker but also
delegated to other brokers in the same domain as well as other brokers in
other domain in order to select the best trustworthy RP for the consumer’s
request discussed in the earlier architecture. If a broker associated with the
consumer and the selected RP are different, the brokerage charge of that
resource will be shared among them. A broker may choose an RP against a
consumer’s request from its own members though a more suitable
‘trustworthy’ RP may exist with another broker.

In order to resolve this, the Multi-Broker Architecture is
implemented without delegating the consumers’ requests to other brokers in
this thesis. Resource selection is done here not only based on trust but also the
matched policy constraints. This model also helps to reduce the broker’s
workload. The consumer’s feedback is evaluated by the broker for
genuineness. By doing so, the trust-index of RP is safe-guarded against
dishonest feedbacks given by the consumer. An appropriate true consumer’s
feedback is predicted according to the broker’s feedback even with false
feedback of consumer. The trust-index of consumer is updated based on its
genuineness in each transaction. Deregistration of RP either voluntarily or
forcibly also has been dealt here. All these concepts are explained in the
following sections.

This architecture is implemented with an unequal, non-uniform
distribution of entities. The entities are free to attach themselves to any of the
brokers present in their domain.

3.4.1 Need for Predicted Feedback

Our architecture, apart from being a consumer-friendly one, also
protects RP from malicious behavior of consumers. Consumers are known to
intrude onto the resources, misuse the resources (by attaching viruses, worms, etc.) or provide false feedback to degrade RP. Of these, the false feedback problem is the most dangerous one, as it is the most difficult to detect immediately. Hence, the feedback submitted by the consumer at the end of each transaction must be verified for genuineness, and only truthful feedbacks should contribute to the updates of the RP’s trust (trust-index). When a dishonest feedback is identified for a particular transaction, a simple method is proposed to predict an appropriate true consumer’s feedback.

3.4.2 Registration of RP to Brokers

The RPs are free to attach themselves to any of the brokers present in the same domain. There are no conditions or rules imposed on the RPs for the selection of brokers. This selection is not forced by any external factors but may be governed by internal factors such as the RP’s impression on the broker based on the broker’s reputation in the market and its present trust-index which is average of the trust-indices of all the entities attached to the broker. When an RP selects a particular broker, it sends a request to that broker along with all of its details such as RP’s ID, type of resources provided, criticality factor of each resource, and cost per hour for using each of the resources and the policy-constraints required for utilizing the resource from the consumer side. The RP also provides details of infrastructure (I-index) and policy (P-index) during the time of publishing and registering its resources at the broker-site as explained earlier. These details are consolidated as the presence-index of the RP. The following steps are carried out once the broker receives a request.

- The initial trust-index of RP is computed based on its presence-index.
The broker shall offer membership for an RP if and only if the trust-index of that RP is greater than or equal to its own trust-index. Otherwise, membership is disallowed, irrespective of any business profit. This is done in order to maintain its trustworthiness in the industry, since the trustworthiness of a broker is a direct function of the trustworthiness of all the entities associated with the broker.

Since the parameters of presence-index are authenticated by third party, the trust-index computation may be further fine-tuned.

Once the RP associates itself with a broker, the database at the broker’s site would be updated with the details of the RP.

If the RP is allowed to be associated, the trust-index of broker is recomputed at the standard forum’s sites as explained below.

### 3.4.3 Publishing of Brokers

In the proposed model, whenever a broker has to join a grid network, it publishes itself in the domain where it is present currently, to ensure knowledge of its existence. These brokers are included in the domain at the time of creation of brokers through publishing.

Initially, the trust-index of a broker is assigned by a standard forum such as the GGF based on its presence-index similar to the RP’s presence-index. This trust-index along with broker-ID and its facilities are published at a common site for the benefit of the consumer community (who wishes to approach brokers for membership and requests for resource) and the RPs (who wish to approach the brokers for membership and offers of resources).
The broker’s trust-index is updated after every registration of RP and deregistration of RP (as explained in section 3.4.2, 3.4.4 and 3.4.5), or every time the trust-index of an RP associated with this broker is updated. Trust-index of a broker is computed as the average of trust-indices of RP which belong to that broker.

3.4.4 Deregistration of RP by choice

Once the RP registers with a broker, it services requests, only of those consumers who approach the broker directly associated with the RP. The broker chooses the best RP for the consumer, hence there can be a scenario where any of the RP remains idle for a long time since the trust or requirement constraints of the consumers approaching the broker did not match those of the RP or even if there is a match, it is not ranked as the best RP and hence not chosen. These RPs are then free to dissociate themselves from this broker and once again approach another broker for registration, as explained in section 3.4.2. To deregister, the RP sends a request to the broker for deregistration. The broker then looks at the history of transactions and current trust-index of that RP. It either allows or disallows the RP to deregister. Lower the trust-index, longer the RP would remain idle.

3.4.5 Forced Deregistration of RP

When an RP continuously provides poor resource service or behaves viciously, it obtains a continuous set of low feedbacks from broker as well as from the consumers and hence its trust-index decreases. The net effect of an RP behaving viciously results in lowering of broker’s trust-index. Hence, if an RP misbehaves for certain period and its trust-index reduces to less than a minimum threshold (which is set by the associated broker), the
broker forces the RP to deregister i.e. dissociate itself from the broker. However, the RP may approach any other broker for registration.

3.4.6 Registration of Consumers under Brokers

Similar to the RP, consumers are allowed to be associated with any of the interested brokers. The brokers are obliged to maintain information about each of the consumers associated with them. This includes the ID, either the behavior of providing feedback is genuine or not, the number of genuine feedbacks, non-genuine feedbacks, and total number of transactions performed till now and finally the trust-index of the consumer. Initially, the consumer is assigned with a median trust-index value of 0.5 and updated later based on its performance after the completion of transactions based on the genuineness of feedback about RP’s resource.

In order to check the genuineness of the consumer’s feedback about the RP’s resource after the completion of transactions, the consumer is instructed to perform transactions with the pre-evaluating set (as explained in chapter 4) along with the registration. Then, the consumer is instructed by the broker to perform transactions with the newly formed pre-evaluating set periodically based on its current trust-index to maintain its adaptability. The new pre-evaluating set is formed with the recent twenty transactions performed by the consumer. The consumer’s feedbacks along with the corresponding broker’s feedbacks for this new pre-evaluating set are used in the procedure given in chapter 4. For example, if the consumer’s trust-index is 0.7, then it is sufficient if the new pre-evaluation set is formed after seventy transitions. The new pre-evaluation set is formed with the last twenty transactions among those seventy transitions.
3.4.7 Workflow of the Architecture

When a consumer sends a request to a broker, it specifies the required parameters such as the consumer-id, type of resource required, budget allotted for the resource, deadline and its required policy constraints. This budget reflects the criticality and quality of service expected by the requested resource as discussed above.

3.4.7.1 Integrating reputation and policy

Policy is a subject relating to third party accreditations that an entity has acquired. In this policy-based system, a consumer concludes on the worthiness of an RP purely based on its credentials acquired from standard organizations (such as signed certificates from Certification Authorities). Different weights are assigned to each of the policies depending on the third party that provided the accreditations.

Reputation-based system has been favored for peer-to-peer sort of environment, whereas the policy-based system is well suited for structured organizational environment. But, for a distributed grid environment, a mixed approach is required. For example, the consumer might be interested in knowing whether an RP has the information security practices certified by international standards authorities such as BITS, ISO 270001 but also has high reputation due to past transactions with other consumers. In addition, an RP might be interested in protecting its resources depending on the cost of that resource.

As stated above, there are two ways to check the genuineness (trust-index) of an RP, based on its reputation and by verifying its policies. Selection of a suitable RP for a consumer request based on a suitable
combination of both these factors is considered in this thesis. The consumer requests include certain policy requirements that the RP should possess. Considering the RP’s point of view, when an RP associates itself with a broker, it specifies a set of policy requirements that the consumer should possess to utilize its resources. Policies are well suited to specify access control conditions that are eventually meant to yield a Boolean decision (the requested resource is either granted or denied). The broker processing the consumer request tries to find an RP that not only matches the consumer's constraints with good trust-index for providing trustworthy resource but also the one with matched policy requirements of both consumer and RP. Thus, runtime failure due to policy mismatch is avoided. The broker allots an RP only to those consumers who satisfy both the trust-index and policy requirements.

If (consumer’s request constraints match RP’s resource constraints)
If (consumer’s policy-constraints match RP’s policy-constraints)
    Broker allots the RP to the consumer with the highest trust-index.
Else
    Consumer is free to approach another broker
End if
Else
    Consumer is free to approach another broker
End if

Once an appropriate trustworthy, policy-matched RP is selected by a broker for the consumer’s request, it is notified to both consumer and RP. Then, an actual transaction is performed. After the completion of transaction, the feedback about the RP’s resource is obtained from the consumer as well as from the associated broker as explained earlier. The trust values of
consumers, RP and brokers are updated based on their performance in the actual transaction.

3.5 HIERARCHICAL BROKER ARCHITECTURE

The issues of biasness of brokers are resolved further by the proposed Hierarchical Broker Architecture. For the simulation purpose, only three levels (or tiers) are considered in this architecture. Here, the Regional Resource Administrators (RRA), resource brokers and the RPs are arranged into three-tiers. RRAs derive their compensation from registration, renewal, and audit charges paid by broker community, not from individual transactions. RRAs serve the consumer community in an ‘unbiased’ and ‘trustworthy’ manner. In this model, the trust-indices of each of the entities are computed based on the feedback provided by other entities after each transaction. These feedbacks are evaluated by RRA for genuineness. By doing so, the trust-index of RP is safeguarded against dishonest feedbacks. These trust-indices of brokers, consumers and RP are updated dynamically, to ensure trustworthy resources and to quicken the selection of ‘suitable’ RP. This implementation, not only supports a choice of RP based on trust-index but also on policy-match. Thereby the consumer is free from runtime failure as the policies have been matched with.

In the proposed Hierarchical Broker Architecture framework, also called Hierarchical Three-tier Architecture, the RRA, brokers and the RP are organized at different tiers as shown in Figure 3.2. Just as RPs are associated with brokers, brokers seek membership from multiple RRA in this Hierarchical Broker Architecture, discussed below.
3.5.1 Motivation for Identifying Genuine Feedbacks

The proposed architecture, apart from being a consumer-friendly one, protects RP from malicious feedbacks. False feedback problem is the most dangerous one, as it is the most difficult to detect immediately. In this model, after the completion of each transaction, feedback about the RP’s resource is collected from the concerned consumer as well as from the recommended broker since it continuously monitors the execution on the resource. These feedbacks must be verified for genuineness by the associated RRA, as its feedback as reference by comparing them against the feedbacks generated by consumer / broker for the reference set. And only those feedbacks which are determined to be truthful should contribute to the updates of the RP’s trust (trust-index). When feedbacks from malicious natured entities are identified, a genuine feedback is generated by the RRA itself about the RP’s resource. RRA need not generate feedback if transaction
involves any of the genuine entities with true feedbacks, thus maintaining fewer loads.

3.5.2 Association of RP with Brokers

The brokers publish their availability as intermediaries to the public, through advertisement along with special features such as resource-efficiency, service-levels, affiliation to various RRAs, etc. The RP are free to associate with any of the interested brokers. The registration of RP to brokers is done as discussed earlier in Multi-Broker Architecture without delegation. The broker’s trust-index is computed as the average of the trust-indices of the RP that belong to the broker. Initially, the trust-index of a broker is assigned by an associated RRA, based on the presence-index (similar to the RP’s presence-index in the grid environment) of the broker and the trust-indices of the RP associated with the broker.

3.5.3 Registration of Consumers under RRA

Similar to the RP, consumers are allowed to be associated with any of the interested RRA. The RRAs are also obliged to maintain information about each of the consumers associated with them. This includes the ID, either the behavior is genuine or not, the number of genuine feedbacks, non-genuine feedbacks, and total number of transactions performed till now and finally the trust-index of the consumer. Initially, the consumer is assigned with a median trust-index value of 0.5 and updated later based on its performance after the completion of each of the transactions.

In order to check the genuineness of the consumer’s feedback about the RP’s resource after the completion of transactions, the consumer is instructed by the associated RRA to perform transactions with the reference
set as part of registration process. The RRA keeps its feedbacks as reference about the entities’ resources in reference set to check the genuineness of the consumer’s feedback. Then, the RRA performs transactions along with the consumer periodically, based on consumer’s current trust-index to adaptively construct the new reference set. The new reference set is formed with the recent transactions performed by the consumer. The consumer’s feedbacks along with the corresponding RRA’s feedbacks for this new reference set are used. For example, if the consumer’s trust-index is 0.7, then it is sufficient if the new reference set is formed only after seventy transitions. That new reference set is formed with the last twenty transactions among those seventy transitions. If the trust-index is less than or equal to 0.5, then the new reference set is formed with the immediate next twenty transactions to check its genuineness of the feedback.

3.5.4 Association of Brokers with RRA

Initially, each RRA fixes its objectives by analyzing the demands in the society. Each RRA publishes its availability, objectives and special features through advertisements to the public. Each of the brokers may register under any of the RRA. RRAs confirm the registration of brokers based on the broker’s trust-index in addition to its resource service functionalities. If a broker’s trust-index is above a threshold (chosen by the corresponding RRA), the RRA shall offer membership for a broker. Similar to consumers, brokers are also instructed to transact with reference set to check the genuineness of the broker’s feedback about the completed transactions, using RRA’s feedbacks about the reference set as reference. In order to maintain adaptiveness for checking the genuineness of the brokers’ feedback, RRA periodically forms the new reference set similar to consumers. Each of the RRA requires maintaining information such as broker’s ID, list of resources provided by that broker along with the corresponding highest trust-
indices, the genuine or false behavior, the number of genuine feedbacks, non-genuine feedbacks, and total number of transactions performed till now, for each type of resources. RRAs normally serve the consumer community in a manner similar to the DNS service. RRAs derive remuneration from the registration, renewal, and audit charges paid by the broker community, not from the individual transactions. This eliminates the problem of biasness in the selection of suitable RP through brokers. The RRA periodically audit the trustworthiness of the brokers on processes and procedures for the maintenance of RP associated with them. This ensures the maintenance of QoS and trustworthiness of brokers and RPs under RRA. Every broker needs to be registered with at least one RRA to be able to bag resource-contracts for its RP.

3.5.5 Working Principle of the Architecture

When a consumer requires a specific type of resource, it sends its resource-request to any of the associated RRA that it may be interested in. In its request, the consumer specifies its constraints on the type of the requested resource, the cost, the schedule and the required policy constraints.

The RRA examines the trust-indices of all its associated brokers who could provide the requested resource as per the consumer’s constraint. To avoid traffic congestion, only the top T brokers, whose trust-indices are greater than the threshold-index, are chosen for the delegation of the consumer’s request. To avoid broker-starvation, the RRA may also decide on random selection of T brokers from among the brokers attached to it. A RRA computes the threshold-index as a function of budget of the consumer’s request, since the budget only reflects the QoS expected by the consumer. Here, RRA will choose the best trustworthy RP under multiple brokers compared to Multi-Broker Architecture.
3.5.5.1 Integration of reputation with policy

Reputation-based trustworthy resource selection alone is not sufficient. The consumer requests include certain policy requirements that the RP should possess. Considering the RP’s point of view, when an RP associates itself with a broker, it specifies a set of policy requirements that the consumer should possess to utilize its resources. The broker processing the consumer request tries to find an RP that not only matches the consumer's constraints with good trust-index for providing trustworthy resource but also the one with matched policy requirements of both consumer and RP. The broker nominates an RP who satisfies both the trust-index and policy requirements of the consumer’s request to the associated RRA.

If (consumer’s request constraints match RP’s resource constraints)
  If (consumer’s policy-constraints match RP’s policy-constraints)
    Broker nominates the RP with the highest trust-index to the RRA
  Else
    Broker sends the failure notification to RRA
End if
Else
  Broker sends the failure notification to RRA
End if

In case of more than one RP complying with the selection criteria, the process of choosing a suitable RP for a transaction involves a hierarchical priority-based selection procedure, by considering the consumer’s constraints, the trust-index of the brokers and the RP in addition with the matched-policy constraints, queue length at the RP and finally the consolidated cost of past transactions of the RP.
Each of these T brokers selects an RP, having the highest trust-index among all the RP that best satisfy the consumer’s constraints with required policy-constraints specified in the consumer’s request and nominates those RPs to the associated RRA as its choice, along with RP’s policy-constraints required from the consumer side.

The RRA examines the suitability of all the RP nominated to serve the request and selects the one with the best trust-index with the matched consumer’s and RP’s policy-constraints. In the case of more than one RP complying with the selection criteria, similar selection procedure is adapted. The RRA intimates the selected RP about the details of the consumer’s request through the broker, who nominated this RP. The consumer is also notified of the selection.

The consumer utilizes the resource of the selected RP through their associated broker. After the completion of transaction, the feedback about the resource is received from both the consumer concerned and the associated broker by the associated RRA. The RRA will check the genuineness of the feedbacks generate the genuine feedback by itself in case of malicious feedbacks. Then update the trust-index of consumer, broker and RP based on their genuineness in the current transaction along with previous trust-index.

3.6 CONCLUSION

Thus, the working principles, flaws and advantages of the proposed architectures such as Single Broker Architecture, Multi-Broker Architecture, Multi-Broker Architecture without Delegation and Hierarchical Broker Architecture for Grid environment are discussed in this chapter briefly.
The Multi-Broker architecture supports a trust management system with multiple brokers. When a consumer sends a resource request to a broker, the broker selects the RP with the best trust-indices merely by comparing the trust-indices of eligible RP without evaluating them at the time of request. This enables the consumer to receive the response from the broker significantly quicker compared to other trust models where the trust-indices are computed at the request-time. Since the brokers have ample data to support the choice of a suitable RP, the brokers, on behalf of the consumers, handle the selection efficiently. Thus, the consumer is relieved of the risk of selecting an unsuitable RP with limited information. If an RP wishes to improve its reputation, it can get self-information from the associated brokers and may use it as a feedback to improve its resources. Thus, both the consumer and the RP are benefited through this architecture. Untrustworthy RP and consumers are penalized by this architecture. This architecture insists on multiple brokers in each domain with the entities distributed across multiple brokers as against a single broker. This introduces redundancy, thereby improving the reliability of information maintained at the broker sites. This also eases out the network traffic at each broker site, for handling the consumer’s requests and feedbacks due to the distribution of requests and feedbacks across multiple brokers.

In Multi-Broker Architecture, there is a definite possibility of the intermediaries being biased. The proposed integrated reputation and policy-based Multi-Broker Architecture without delegation ensures an unbiased selection of suitable RP for the consumer’s request, compared to the earlier Multi-Broker Architecture. The broker publishing concepts ensures that every new broker entity that enters a domain is published to provide an opportunity for entities to associate themselves with it. The proposed model gives RPs the freedom to associate themselves to any broker. The consumer’s requests are processed by the associated broker instead of delegating the request to other
brokers. This avoids the biasness in the selection of suitable trustworthy RP for processing the consumer’s requests. The dissociation of an RP from the broker had been dealt with in two specific scenarios to maintain the trust-index of brokers.

To further improve the unbiased nature of brokers, Hierarchical (Three-level) Broker Architecture (RRA, resource brokers and RP at three different levels) proposed ensures an unbiased selection of suitable RP for the consumer’s request, compared to the earlier architecture. RRAs derive their compensation from registration, renewal, and audit charges paid by broker community, not from individual transactions as in the earlier model. RRAs serve the consumer community in an ‘unbiased’ and ‘trustworthy’ manner. This implementation, not only supports a choice of RP based on trust-index but also on policy-match. Thereby the consumer is free from runtime failure as the policies have been matched with. The trust computations of different entities involved in grid system are discussed in the next chapter along with simulation and its results.