Chapter 3

A Reputation-Based Partner Selection Model (RBPS model)

As trust is a critical factor in collaborative supply chain environment, this study develops a model, that propagates the objective and subjective testimonies of potential partners from third parties by using distributed approach, to select parties with high level of initial trust to be collaborative partners. The reputation system and referral networks were adopted in the proposed reputation-based partner selection model (RBPS model) for selecting a partner with excellent behavior in competence, consistent performance, and goodwill. The RBPS model will be elaborated in the next sections.

3.1 Overview

RBPS model

Josang and Ismail (2002) depicted that there were two fundamental aspects to consider for deriving the score in the form of reputation or trust: (1) propagation mechanism that enabled entities to obtain the needed information, (2) reputation engine that calculated the value of user reputation rating. For selecting the partner with high initial trust score, we developed the RBPS model (see Fig. 3.1), based on the concept that Josang proposed, that performs partner selection in two phases: discovery phase and selection phase.

During the discovery phase, the request enterprise (as a trustor) issues specific requirements to the parties who were selected from either an internal database of the trustor or Internet; furthermore, the parties (as partner candidates), with willingness and required competence, respond by providing specific information to the trustor regarding potential collaboration. Finally, a list of partner candidates was emerged.

The trustor selects a partner from among numerous partner candidates (as trustee) using a reputation and referral system during the selection phase. The selection phase includes three steps: namely, (1)

testimony definition step, (2) testimony propagation step and (3) testimony aggregation step. First, during the testimony definition step, the required information elements (i.e. ratings, past history and performance etc.) are defined. The testimonies are obtained from raters with previous experience of interacting with the trustees, and contain not only the subjective perceptions from raters, but also the objective data. Second, during the testimony propagation step, the trustor requests testimonies of trustees from trusted neighbors. If the neighbor is a rater, he returns the testimonies to the trustor. Meanwhile, neighbor with no previous contact with the trustee may return the referral to the trustor and recommend others who may be able to provide the testimonies. Subsequently, for distinguishing the power of testimonies that raters provided, the trustor constructs a referral networks containing all related members and calculated the weight of them.

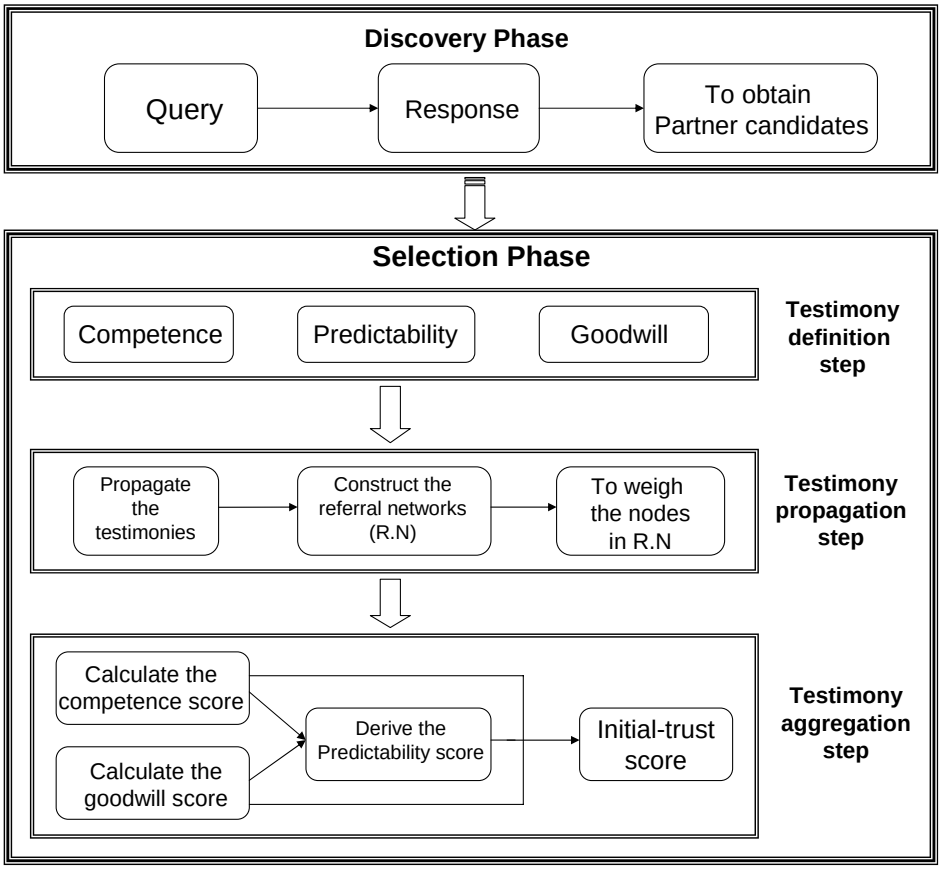

Fig. 3.1 The reputation-based partner selection model (RBPS model)

Finally, during the testimony aggregation step, the trustor calculates the initial trust scores by using the gathered testimonies and weighted raters. The trustor calculated the competence initial trust score via objective testimonies; meanwhile, he computed the goodwill initial trust score by using subjective testimonies. Subsequently, the trustor derived the variation of history performance from the objective and subjective testimonies, and then obtained the predictability initial trust score. Finally, the trustor aggregated the scores of three trust types into the initial-trust score of each trustee.

Partner Selection Lifecycle

Figure 3.2 demonstrates the lifecycle of partner selection in RBPS model. Firstly, during the discovery phase, the trustor enterprise obtains a list of partner candidates with willingness to collaborate and self-claimed capability. Secondly, during the selection phase, the trustor enterprise derives the testimonies for evaluating the trustees from raters by asking the friends and friends' friends; subsequently, the raters are weighed to measure the level of trustworthiness of testimonies.

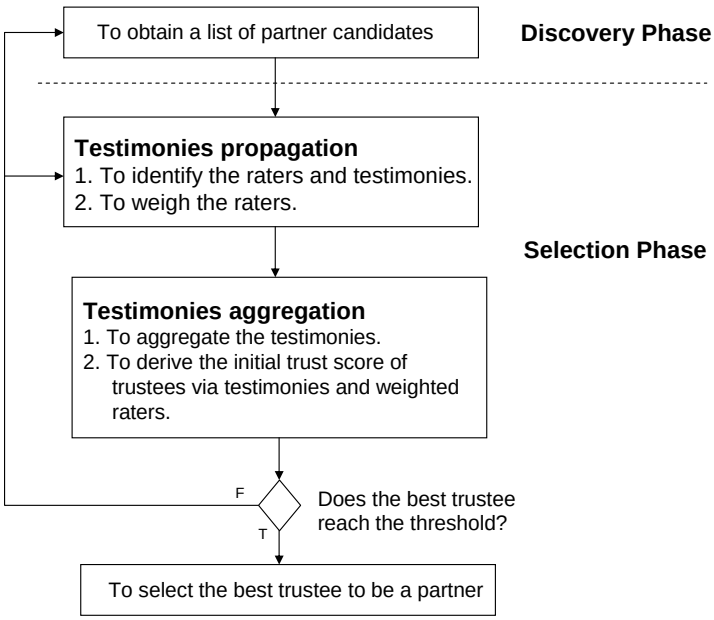

Fig. 3.2 Partner selection lifecycle

Thirdly, the aggregated testimonies are transformed into initial trust

score to identify the most reputable trustee, and then the trustee with highest trust score will to be a partner. If the initial trust score of best trustee can not reach the threshold, the process of selection returns to the discovery phase for identifying another suitable candidates or to the testimonies propagation step for searching another raters and testimonies. The details of partner selection of RBPS are described in the later sections.

3.2 Assumption

The assumptions of the RBPS model are listed as following:

- Hartono and Holsapple (2004) proposed five phases to construct collaboration. This study assumed that one party has recognized new business opportunities in the first phase, and the RBPS model focuses on searching for suitable partners to take advantage of the opportunities in the second phase.
- The relationships among the participants in the RBPS model are projected-based and temporary to explore short-term opportunities.
- The partner selection in the RBPS model focuses on the source of testimonies and the weights of raters, not focuses on the weights of criteria; that is, the weights of three trust types (such as competence, goodwill and predictability) and objective and subjective criteria have to be computed via other methods like AHP.
- The partner selection in RBPS not focuses on a specific industry, and it can be widely adopted in the collaborative fields such as manufacturing, software development and product design etc.
- The RBPS model defines three trust types and related criteria to evaluate the partner candidates, but not defines the operational definition of criteria.
- The RBPS model focuses on the partner selection in B2B, not in B2C or C2C fields, for the participants have to share sensitive information and jointly developed the project.
- The RBPS model explores the trust of the initial relationships in new and temporary organizations, not in the long-term

relationships.

- The RBPS model adopts the distributed approach of reputation system that each participant records the opinion about each experience with other parties, and provides this information on request from relying parties.
- The measurements of ratings and reputation scores in the RBPS model utilize the objective measure that the rater adopts the objective assessment to trustee under formal criteria, and subjective measures that the rater rates the trustee based on subjective judgment.
- The subjective ratings of goodwill indicators, such as non-opportunistic behavior (OB), affective feeling (AF) etc., of trustee enterprise are rated by the committee of the rater enterprise, not by the individuals.
- In this study, we assume that the quality of the testimonies provided from the raters is guaranteed, and these testimonies is rated objectively and not amended by unrelated people.
- In this study, we assume that the raters provide the testimonies with willingness due to the social relationships in the referral networks. Additionally, the trustee also wills to returns the authorized message when the raters ask for the authorization.

3.3 Discovery Phase

The discovery phase aims to identify partner candidates who are willing and capable collaborators. Figure 3.3 shows the process for obtaining the partner candidates, and we will introduce the process as following.

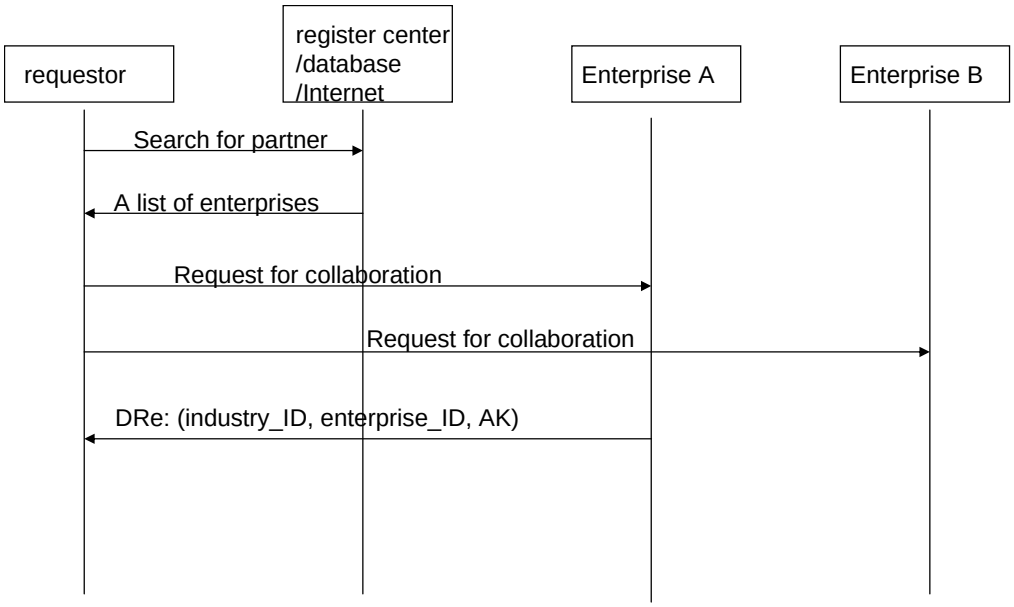

Fig. 3.3 The process of the discovery phase

Query

The trustor begins searching for potential partners from the internal database, Internet search engine, or associated register center where enterprises register their information (e.g. such as, name, address, web site, core competence etc.). After obtaining a list of enterprises, the trustor then issues a request to the enterprises (e.g. such as, enterprises A and B) for collaboration.

Response

Willing enterprises with specific required capabilities then return messages as follows:

$$D\,\mathrm{Re} = (industry\_ID, enterprise\_ID, AK)$$

'Industry_ID' indicates the identification of a specific industry, such as construction, transportation, health etc., to which the partner candidates belong. The North American Industry Classification System (NAICS) defines codes for a variety of North American industries

(NAICS, 2002). For example, agriculture was coded as ‘11’, while manufacturing was coded as ’31-33’. This study uses message elements such as ‘industry_ID’ and ‘enterprise_ID’ to narrow down the searching scope and reduce searching cost during the selection phase.

The message element “AK” contains one of the duplicated symmetric keys generated by a specific algorithm from partner candidates. While one of the duplicated keys transmits to the trustor, the other one is temporarily stored by the partner candidates. The mechanisms to utilize the symmetric keys will be introduced in the next phase.

To obtain partner candidates

After all willing enterprises response their messages, the trustor enterprise gathers a list of partner candidates and their related profiles. Next, the trustor has to select a collaborative partner among these partner candidates in the next selection phase.

3.4 Selection Phase

The Figure 3.4 demonstrates that the selection phase contains three steps. First, during the testimony definition step, the measured indicators of three trust types, as competence, goodwill and predictability, to evaluate trustees were defined. Second, in the testimony propagation step, the trustor identifies the raters who can provide the testimonies about the trustees based on reputation system and referral networks. Finally, in the testimony aggregation step, the testimonies about trustees were obtained, and the ratings and transaction history were calculated into initial trust scores for each trustee.

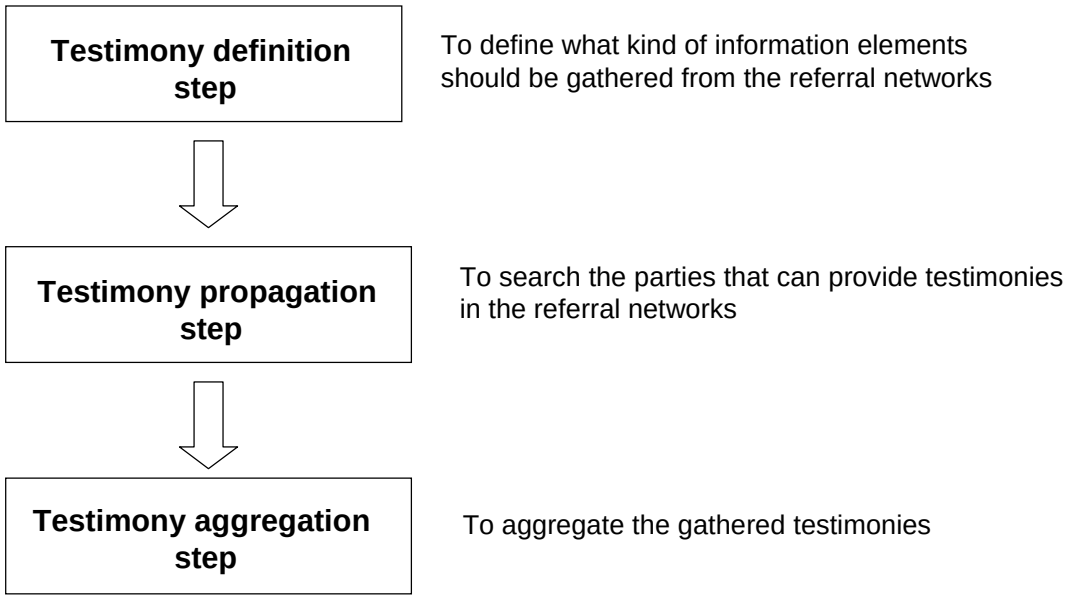

Fig. 3.4 Three steps to select trusted partner

3.4.1 Testimony Definition Step

Josang (2007) depicted that the first fundamental question in the research agenda for trust and reputation system was 'what information elements are most suitable for deriving measures of trust and reputation in a given application'. However, the reputation system for partner selection in the collaborative supply chain is not similar with the reputation system in C2C or B2C environment that simply depends on the subjective perception of raters like binary rating such as trust / not trust , or discrete rating like 'very trust', 'trustworthy', 'untrustworthy', and 'very untrustworthy'. Actually, the reputation system not only based on the subjective ratings by the end user, but also with the objective view of performance history (Kalepu, Krishnaswamy and Loke, 2004).

The testimonies of reputation system about potential trusted partners in B2B environment have to consider the elements such as skill, technical knowledge, abilities, consistent behavior, care, concern, honesty, and benevolence etc. Hence, the definitions of trust types for evaluating trading partners proposed by Ratnasingam (2005) were adopt. It identifies three types of inter-organizational trust: competence, predictability, and

goodwill trust (see Fig. 3.5). The measurement of three trust types will be introduced later.

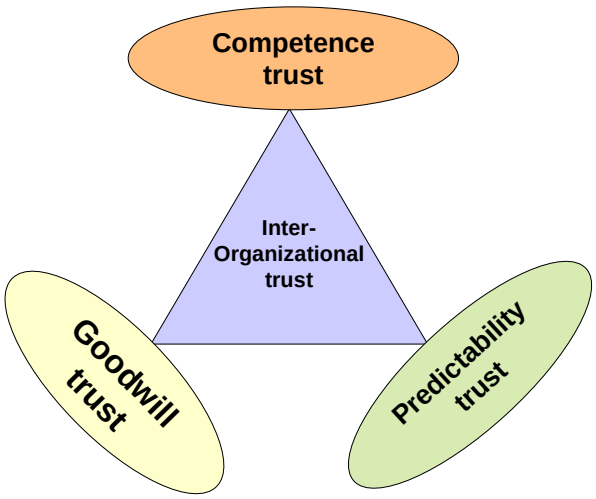

Fig. 3.5 Three types of inter-organizational trust

3.4.1.1 Competence Trust

The competence trust was derived from a capability process of the trading partner and determines the ability, skills, competence, and technical knowledge of the trading partner. The measurement in the RBPS model is based on the concept 'conformance', and it was adopted by Kalepu (2004) to calculate the difference between projected/agreed level and actual performance level for measuring the quality of service (QoS) in the Web Service arena.

The conformance of competence trust was measured under the objective and quantitative information provided by the raters had transacted with the trustees. The transaction histories, recorded in the internal database of ERP, CRM or KM system, include contracts that the raters signed with partners and actual performance that the partners fulfill the contract. Figure 3.6 shows the example of constructs and indicators to evaluate competence trust; accordingly, the indicators measured in the competence trust have to be quantitative and could be arranged in the contract.

Construct	Indicators
Quality	Quality
	Order fill rate
Delivery	Average production time
	Order fulfill lead time
Cost	Unit cost
	Discount

Fig. 3.6 The example of indicators of competence trust

3.4.1.2 Goodwill Trust

The goodwill trust of trading partner emphasizes beliefs as care, concern, honesty, benevolence, and permits other partners to further invest in their trading relationships.

To measure goodwill trust is not an easy work, because it is a social behavior with complex constructs and there are various definitions proposed by literatures. Saunders (2004) demonstrated that the coding scheme of trust dimensions include competence, predictability, benevolence, integrity, and openness etc.; actually, it is consistent with three types of trust, as competence, goodwill and predictability trust, that Ratnasingam (2005) proposed.

Table 3.1 shows the definition of dimension abut goodwill trust adapted from Saunders (2004). The constructs of goodwill trust contain benevolence, integrity, and openness. Furthermore, the indicators are identified like: non-opportunistic behavior (OB), affective feeling (AF), responsibility (RE), ethical behavior (EB), information sharing (IS), habituation (HA), and learn/information processing abilities (LIP). All indicators are rated by raters after each collaborative occurrence and each indicator is rated as [-1, 1].

Table 3.1 The constructs and indicators of goodwill trust

construct	indicator	description
Benevolence	the extent to which a trustee is believed to want to do good to the trustor, aside from an egocentric profit motive.	
	Non-Opportunistic Behavior (OB)	Rooted in the transaction cost theory, it measures the degree of non-opportunistic behavior about the trustee
	Affective Feeling (AF)	It measures the affective feelings of trustee lead to the willingness of acting in the best interest of the trustor.
integrity	The trustor's perception that the trustee adheres to a set of principles that the trustor finds acceptable.	
	Responsibility (RE)	It measures the perception of a trustee's intention to perform in line with integrity, responsibility, and dependability.
	Ethical Behavior (EB)	It measures the awareness and acceptance of ethical norms and behaviors about the trustee.
openness	The other party is willing to share information about its business.	
	Information Sharing (IS)	It measures the degree of information sharing about the trustee using information technology.
	Habituation (HA)	It measures the degree that the trustor depends on the trustee and becomes a habit and behaviors are institutionalized
	Learn and Information Processing abilities (LIP)	It measures the trustee's ability to process information or to communicate affect trust

Additionally, the lower rating of a specific indicator reflects the subjective perception that the rater is not satisfied with the trading partner.

3.4.1.3 Predictability Trust

The predictability trust is derived from the consistent behavior of trading partners and it implies that trading partners are dependable and can follow through on promises. Additionally, predictability is an extension of competence due to a series of positive, consistent, reliable

behaviors makes a trading partner predictable and trustworthy (Ratnasingam, 2001).

After collecting the testimonies from the raters in the next testimony propagation step, we calculate the variation of performance of objective testimonies as reputation score of competence trust; meanwhile, the variation of performance of subjective testimonies as reputation score of goodwill trust was calculated by trustor. Subsequently, we aggregate these variations into the predictability trust score; that is, the more fluctuation in the performance of competence and goodwill, the less the predictability trust score.

3.4.2 Testimony Propagation Step

During the testimony definition step, the measured indicators and means for evaluating the trustees were defined. The next question emerges: how to obtain these testimonies. During the testimony propagation step, the required testimonies were obtained from third parties who had collaborated with the trustees based on the concept namely social networks or referral networks.

Figure 3.7 describes the process to obtain the identified parties and the testimonies. First, the trustor searches the raters for obtaining the objective and subjective testimonies by asking his friends and friends of friends. Second, the process of testimonies propagation was finished, and the trustor constructs the referral networks for identifying the parties and their relationships. Third, the related parties need to be weighed for distinguishing the power of the testimonies that the raters provided.

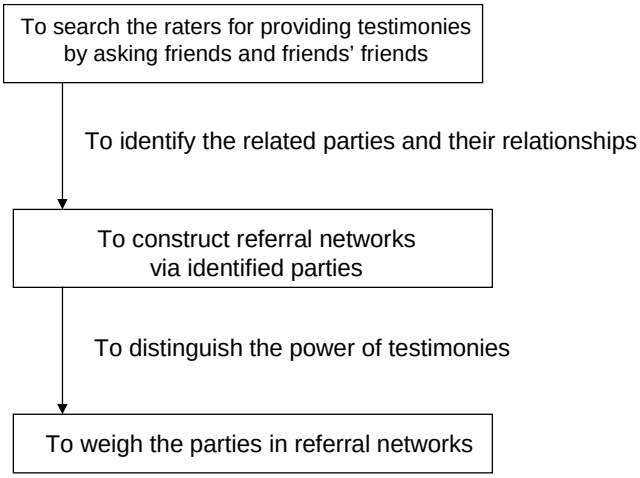

Fig. 3.7 The process to obtain the parties and testimonies

The concept of multi-agents was adopted to archive the RBPS model due to the complexity and complication of the process for propagating and aggregating these testimonies. Specific agents were defined as servants to serve for his host (enterprise), and the roles of the agents were defined as:

- Trustor agent: The trustor agent serves for the trustor enterprise, and his jobs are to issue the request message, to aggregate testimonies, to construct referral networks, to weigh the nodes as agents, to decrypt the testimonies came from the rater agent, and to rank the trustees for selecting the best one.
- Recommender agent: The recommender agent serves for the enterprise who does not know the trustees. His jobs are to search for the internal database of his host when he receives the request message from trustor agent. If he did not contact the trustees before, he can recommend others, who are trusted and had interacted with him, to trustor agent.
- Rater agent: If the recommender agent found he had contacted the trustees before, he became a rater agent. The jobs of the rater agent are to deliver the request message to trustees, to encrypt the testimonies and reply to the trustor agent.
- Trustee agent: The trustee agent serves for the trustees. His jobs

are to reply the authorization to the rater agent.

In the later sub-section, the process of propagation and construction of referral networks will be introduced.

3.4.2.1 Propagate the Testimonies

Like social behavior of human beings, the trustor starts to identify the raters of trustees from his friends (neighbors). The neighbor may be a rater who had contacted with the trustee, or a recommender who does not know the trustee. The Figure 3.8 illustrates the process for propagating the testimonies. In the beginning, the trustor AG_1 issues the message *Req* to his trusted friend AG_2 for requesting the testimonies of trustee AG_4. The AG_2 does not recognize the AG_4; he then returns a message *Recom_rep* and recommends AG_3 to AG_1. Meanwhile, the AG_2 sends a message *Notify_next_recom* that notifies AG_3 about the propagation events AG_1 initiates. The AG_3 is willing to provide the associated information to AG_1 due to the social behavior that the recommendation was recommended by his friend AG_2.

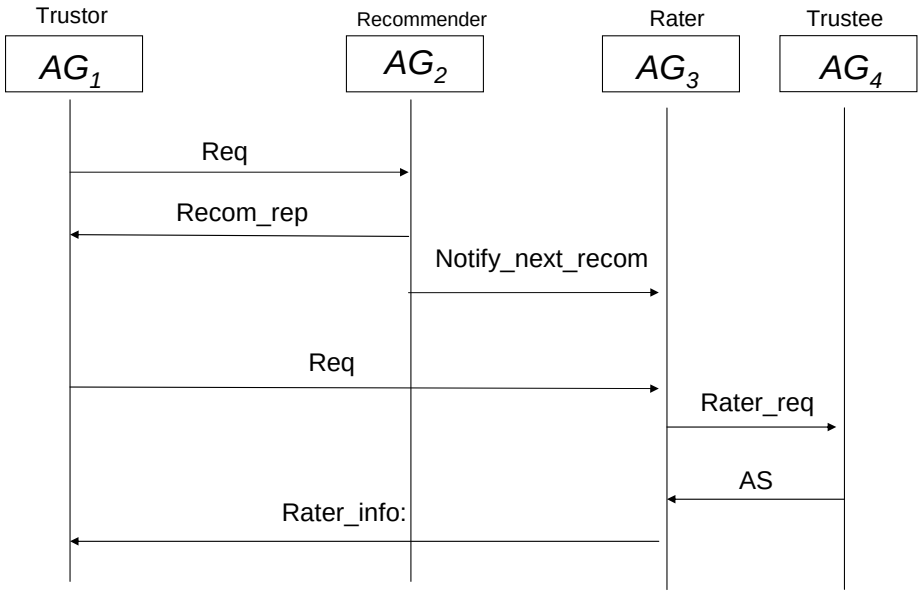

Fig. 3.8 The process of testimony propagation

After receiving messages from AG_2, the AG_1 issues a message *Req*

to AG_3. Because AG_3 knows the trustee AG_4, the AG_3 issues a message *Rater_req* to AG_4 for authorization. However, the AG_4 already knows AG_1 during the discovery phase, he returns a message *AS*, that contains authorized ID and a symmetric key, the same as the key transmitted to AG_1 in the discovery phase, to AG_1. Finally, the AG_3 encrypts the objective and subjective testimonies using the symmetric key and returns the message *Rater_info* to AG_1.

In the traditional reputation system, the problem of fake rating occurred while the agents did not know the trustee but return testimonies due to the competition or contend relationship for business. In this study, the proposed mechanism about "symmetric key" can mitigate the fake rating problem; simultaneously, the sensitive transaction records and subjective ratings about the trustees were secured due to the data were encrypted during the transmission from rater agent to trustor agent. When the trustor agent receives the message that is encrypted by symmetric key from the rater agent, he may decrypt the message using the key he received in the discovery phase.

To avoid the situation that the recommendation becomes to circles (e.g., 'A' recommends 'B' and 'B' recommends 'A'), the trustor agent has to define the depth of searching in the referral networks before the process of propagation.

Messages for Propagation

The messages transmitted in the propagation step demonstrate the semantics that the participants communicate each other. Table 3.2 illustrates the parameters of messages that the issuer transmits to the receiver. The messages contain parameters as:

- The message *Req* contains the ID of issuer, the industry_ID that the issuer belongs to, the trustee's name, and the indicator *Ind* to evaluate the trustees.

Table 3.2 The description of messages

Issuer	Message	Receiver	Parameters
Trustor agent	*Req*	Recommender agent	Trustor, industry_ID, trustee_ID, Ind
			Ind = (Comp, Gw)
			Comp = (comp_ind1, comp_ind2, ..)
			Gw = (gw_OB, gw_AF, gw_RE, gw_EB, gw_IS, gw_HA, gw_LIP)
Recommender agent	*Recom_rep*	Trustor agent	Recommender, next_recommender, int_num
	Notify_next_recom	Rater agent	Recommender, trustor
	Recom_H	Trustor agent	Recommender, helpless
Rater agent	*Rater_req*	Trustee agent	trustor
	Rater_info	Trustor agent	Rater, trustee, Testimony
			Testimony = (Test_comp, Test_gw)
	Rater_U	Trustor agent	Rater, trustee, un-authorized
Teustee agent	*AS*	Rater agent	Authorized_ID, symmetric key
	AS_U	Rater agent	Un-authorized

- The message *Recom_rep* contains the recommender's ID, and next_recommender denotes the agent that the recommender recommends. The *int_num* indicates the number of times of interactions that the recommender collaborates with the next recommender.
- The message *Notify_next_recom* contains the ID of the recommender and the trustor.
- If the recommender does not recognize the trustee and have no any information about next recommender, he returns the *Recom_H* that implies he can not provide any help in this propagation event.
- The message *Rater_req*, contains the ID of trustor, was issued to the trustee for requesting permission when the rater receives the message *Req* from the trustor.
- The message *Rater_info*, contains objective and subjective testimonies about the trustee, was issued to the trustor while the

rater receives the authorization message *AS* that contains the identification of authorization and symmetric key.

- If the rater agent received the message *AS_U* from the trustee agent that the trustee does not want to participate in this propagation event, he replies message *Rater_U* to the trustor agent.

When the recommender or rater receives the request *Req* from the trustor, he returns the messages *Recom_rep, Recom_H, Rater_info*, or *Rater_U* to the trustor. The rule to select the messages is represented as follows:

If the recommender knows the trustee
then
if the recommender get the permission from the trustee
then return Rater_info
else return Rater_U
else
if the recommender knows others to recommend
then return Recom_rep
else return recom_h

3.4.2.2 To Construct the Referral Networks

After the process of propagation, the trustor constructs the referral networks. Figure 3.9 demonstrates the referral networks. Like social behavior of human beings, the trustor A1 searches for the trustee A12 to obtain the testimonies of trustee via friends or friends of friends (as recommenders, e.g. such as, A2, A3, A4 and A5). The A1 issues the request to his neighbors and obtains the associated information, in the form of testimonies or referral, from raters or recommenders. The trustor A1 receives testimonies while the recommender is a rater; on the other hand, the A1 receives referrals while the recommender with no previous interaction history with the trustee.

Referral networks resemble social networks containing nodes, edges, as well as relationship degree and strength. The relationship strength in

the proposed method describes the number of times of interaction between two adjacent nodes. That is, the more frequent interactions between two nodes make the one knows more about the other. Additionally, if the one knows more about the counterpart, the probability that they will collaborate for the next time will be high. For example, the edge, between A1 and A2 is marked as 3, indicates that A1 had interacted with A2 for 3 times.

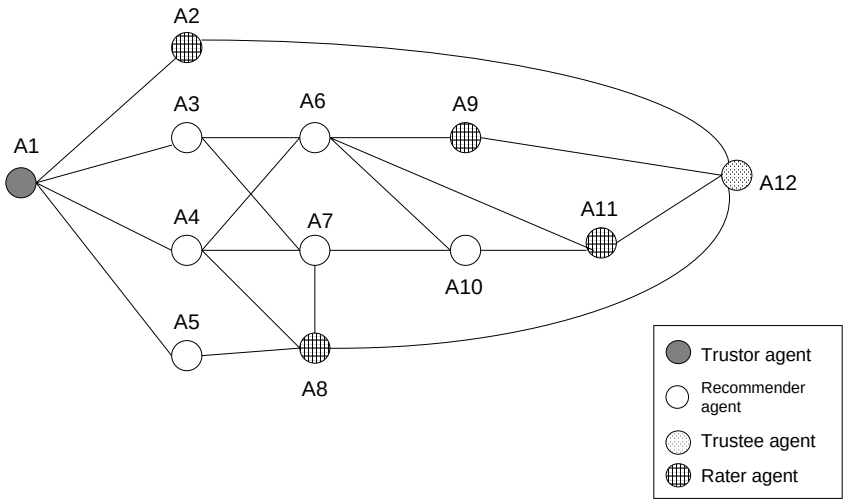

Fig. 3.9 The referral networks

The relationship degree indicates the distance between two nodes. For example, the degree of A1 and A6 is two via A3, and the degree of A4 and A11 is three via A7 and A10. Therefore, the trustor has to set the searching depth to propagate the testimonies that may limit the scope of the referral networks for abbreviating the propagation event.

3.4.2.3 Weighting the Nodes

Josang and Pope (2005) demonstrated how trust was weakened or diluted through transitivity. Accordingly, this study adopts the method of Yu and Singh (2003) to weigh the referral networks. Each node and edge in the referral networks was weighted.

The nodes are weighted as follows:

- The weight of the root A1 in referral networks (as W_{A1}) is set to 1.
- The adjacent nodes (as A1-A2) have *n* interactions.

- The threshold is set to θ.
- The weight of the edge between A1 and A2 (as $W_{A1\text{-}A2}$) is n/θ.
- The weight of A2 (as W_{A2}) is the product of W_{A1} and $W_{A1\text{-}A2}$ (as 1 * n/θ).

The weight of nodes with multiple referrals from other recommenders is defined as follows (see Fig. 3.10):

- The weight of A_m is W_{Am}.
- The weight of A_n is W_{An}.
- The node A_p, an adjacent node of A_m and A_n, has weight W_{Ap}.
- A_p and A_m have *m* interactions.
- A_p and A_n have *n* interactions.
- W_{Ap} is obtained as: $W_{Ap} = W_{Am} \times \frac{m}{\theta} + W_{An} \times \frac{n}{\theta}$

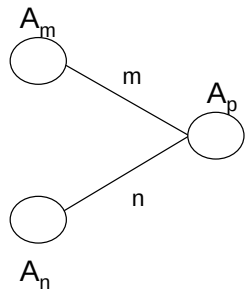

Fig. 3.10 Multiple referrals to one node

For example, the weighted referral network with nodes A1, A3, A4, A6, and A7 was shown as Figure 3.11, with θ= 5.

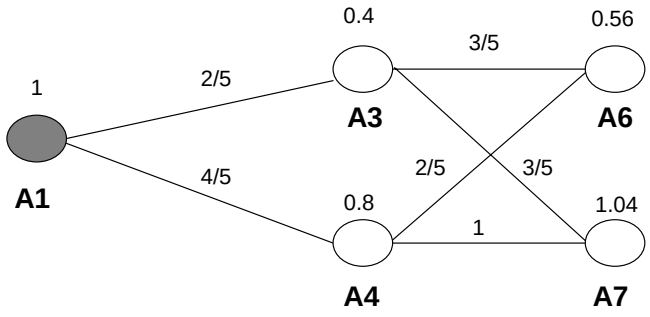

Fig. 3.11 An example of weighted referral networks

From the weighted referral graph, we can observe that the nodes close to the root or with multiple referrals from others are weighted more than others. Intuitively, this phenomenon matches the social behavior of human beings that we have more trustworthiness to the friends with closer relationships or with multiple recommendations from others.

Normalize the Weighted Nodes

The weights of the rater agents were obtained in the referral networks that will be calculated during the testimony aggregation step. However, the weights of all rater agents have to be normalized and ranged as [0, 1] for calculating the initial trust of the trustees. The normalized weight of rater agents is determined as:

- The weights of the rater R_i for a specific trustee AT_j are expressed as $wr_{AT_j}^{R_i}$.
- The maximum weights for all raters of trustee AT_j are:

$$wr_{AT_j}^{\max} = \max(wr_{AT_j}^{R_i}), \quad i = 1,2,...r$$

- The maximum weights for all raters of all trustees are derived as:

$$wr^{Max} = \max(wr_{AT_j}^{\max}), \quad j = 1,2,...k$$

- The normalized weights of R_i are obtained by Eqn. (1).

$$Nwr_{AT_j}^{R_i} = \frac{wr_{AT_j}^{R_i}}{wr^{Max}}, \quad i = 1,2,...r, \quad j = 1,2,...k \tag{1}$$

3.4.3 Testimony Aggregation Step

During the testimony aggregation step, the objective and subjective testimonies were calculated into the initial trust scores of competence and goodwill; meanwhile, the variations of performance of objective and subjective testimonies were lead to the predictability trust score. Finally, trust scores of three trust types were then aggregated into the level of

initial trust for evaluating the trustees (see Fig. 3.12). The process and equations to aggregate the testimonies were introduced later.

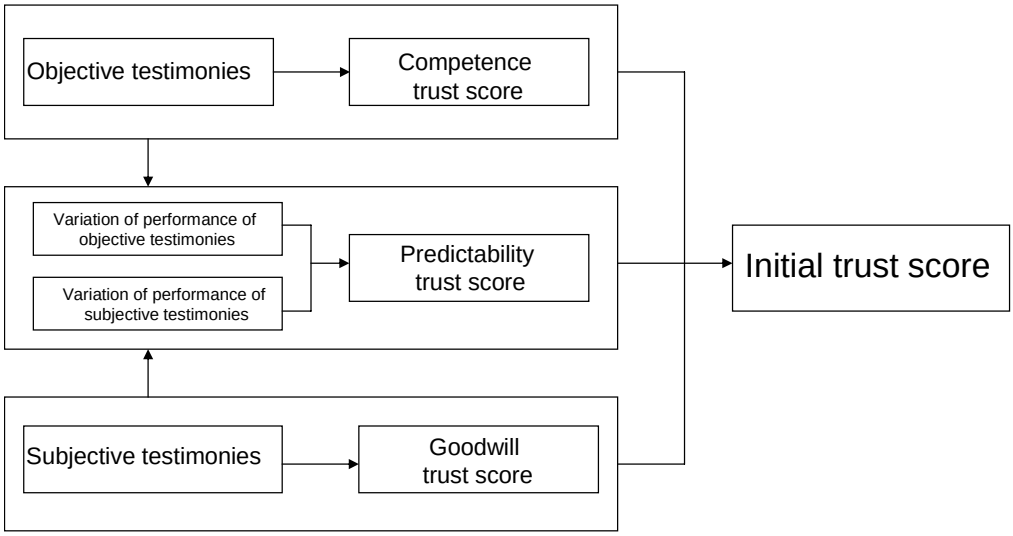

Fig. 3.12 To aggregate the initial trust score

Notation List

For explaining the mathematical equations of the RBPS model in the remainder of this study, the notations and descriptions were listed as Table 3.3:

Table 3.3 The notation list

Notation	Description
R_i	The i_{th} rater of the specific trustee.
AT_j	The j_{th} trustee who was evaluated by the trustor.
Ind_s	The specific indicators s that were used to evaluate the trustee in order to aggregate the competence trust.
$CI^t_{R_i}(Ind_s)$	The contract value of a specific indicator Ind_s that was occurred in the t_{th} interaction for specific rater R_i.
$PI^t_{R_i}(Ind_s)$	The actual performance value of a specific indicator Ind_s in the t_{th} interaction that was recorded by the rater R_i.

$D_{R_i}^t(Ind_s)$	The conformance of a specific indicator Ind_s in the t_{th} interaction that was recorded by the rater R_i.
$ND_{R_i}^t(Ind_s)$	The normalized conformance of $D_{R_i}^t(Ind_s)$ that was ranged as [0, 1].
$TND_{R_i}^t(Ind_s)$	The normalized conformance $ND_{R_i}^t(Ind_s)$ that was calculated by time decay factor λ in the t_{th} interaction.
$\overline{Ind}_s^{R_i}$	The arithmetic mean of specific indicator Ind_s for R_i across all interactions.
Z^{R_i}	The competence reputation of the trustee rated by R_i that is obtained as the sum of the weighted $\overline{Ind}_s^{R_i}$.
$Comp_{AT_j}$	The competence initial trust of a specific trustee AT_j
ind_p	The p_{th} indicators that were used to evaluate the trustee's *goodwill* trust.
$FGI_{R_i}^t(ind_p)$	The rating scores, rated by the rater R_i across all interactions, of a specific indicator Ind_p that the unfair ratings or extreme values were filtered out.
$TFGI_{R_i}^t(ind_p)$	The $FGI_{R_i}^t(ind_p)$ is calculated by the time decay factor λ in the t_{th} interaction.
$\overline{G}_{R_i}^t$	The sum of all weighted goodwill indicators for rater R_i.
$T_{R_i}^t$	The goodwill reputation that was calculated by the rater R_i in the t_{th} interaction, and it is ranged as [-1, 1].
$TT_{R_i}^t$	The transferred value of the $T_{R_i}^t$, and it is ranged as [0, 1].
$\overline{T}^{R_i}$	The arithmetic mean of the goodwill reputation for R_i across all interactions.
GW_{AT_j}	The goodwill initial trust of a specific trustee AT_j.
$Var(Ind_s)$	The variance of specific indicator Ind_s that was calculated based on the competence testimonies.
$\Pr ed\_Comp_{AT_j}$	The variance of the competence initial trust.

Var^{R_i}	The variance of the goodwill reputation for a specific rater R_i based on the goodwill testimonies.
$\Pr ed\_GW_{AT_j}$	The variance of the goodwill initial trust.
$\Pr ed_{AT_j}$	The predictability initial trust of a specific trustee AT_j.
$dt_{AT_j}(\alpha)$	The initial trust that the trustor evaluates a specific trustee AT_j in a new business opportunity α.

3.4.3.1 To Aggregate the Initial Trust of Competence

In this study, the competence initial trust is derived from the conformance of objective data. The conformance measures the difference of each indicator between the value of contract, signed by the rater and trustee before each transaction, and the value of actual performance that the trustee fulfilled the contract after each transaction. The conformance was then normalized and dealt with time decay factor. Subsequently, the normalized conformance was obtained to yield the competence reputation that leads to the derivation of competence initial trust. Competence initial trust is obtained as follows:

To obtain the objective testimonies

A set $Con_{AT_j}^{R_i}$ denotes the contract signed by the rater R_i and the trustee AT_j before each interaction, and contains sub-sets $C_{R_i}^t$ as contract values across *n* interactions.

$$Con_{AT_j}^{R_i} = \{C_{R_i}^t\}, t = 1,2,3,...n$$

The sub-set $C_{R_i}^t$ contains the values of a specific indicator Ind_s (e.g. such as, quality, order fill rate, or unit cost, etc.) at the t_{th} interaction and the term is marked as $C_{R_i}^t(Ind_s)$.

$$C_{R_i}^t = \{C_{R_i}^t(Ind_s)\}, s = 1,2,3,.....f$$

A set $Per_{AT_j}^{R_i}$ indicates the actual performance of trustee AT_j in fulfilling the contract with rater R_i following each business interaction, and contains sub-sets $P_{R_i}^t$ as the performance values across *n* interactions.

$$Per_{AT_j}^{R_i} = \{P_{R_i}^t\}, t = 1,2,3,...n$$

A sub-set $P_{R_i}^t$ contains the performance value of Ind_s at t_{th} interaction, and is denoted as $P_{R_i}^t(Ind_s)$.

$$P_{R_i}^t = \{P_{R_i}^t(Ind_s)\}, \quad s = 1,2...f$$

Conformance

The term $D_{R_i}^t(Ind_s)$ represents the conformance of an indicator Ind_s recorded by R_I in the t_{th} interaction. Indeed, the conformance is calculated by the trustor. If the trustee fulfills the contract, $D_{R_i}^t(Ind_s)$ is zero; otherwise, $D_{R_i}^t(Ind_s)$ is the absolute value of difference between $C_{R_i}^t(Ind_s)$ and $P_{R_i}^t(Ind_s)$ (see Eqn. (2)).

$$D_{R_i}^t(Ind_s) = \left| C_{R_i}^t(Ind_s) - P_{R_i}^t(Ind_s) \right|,$$

Where the trustee does not fulfill the contract

$$D_{R_i}^t(Ind_s) = 0,$$

Where the trustee fulfills the contract. (2)

Normalized conformance

Owing to the indicators being measured using different metrics (for example, date and ratio), the conformance of specific indicators must be normalized. The trustor identifies the maximum value $D_{Ind_s}^{\max}$ of the conformance of Ind_s for all raters and across all interactions. The normalized value $ND_{R_i}^t(Ind_s)$ of the conformance of Ind_s is thus obtained via Eqn. (3).

$$D_{Ind_s}^{\max} = \max(D_{R_i}^t(Ind_s)),\ \ i = 1,2...r, t = 1,2...n, s = 1,2...f$$

$$ND_{R_i}^t(Ind_s) = \frac{D_{R_i}^t(Ind_s)}{D_{Ind_s}^{\max}},\ \ i = 1,2....r, t = 1,2,...n, s = 1,2...f \qquad (3)$$

Time decay

Trustee behavior may change over time. The time decay factor λ is thus considered and older testimonies are assigned less weight than more recent feedback. The normalized conformance $ND_{R_i}^t(Ind_s)$ produced by a time decay factor λ for a specific indicator Ind_s and a specific rater R_i at the t_{th} interaction, and the term $TND_{R_i}^t(Ind_s)$ is obtained using Eqn. (4). The t_r represents the time of the t_{th} interaction, and t_c represents current time.

$$TND_{R_i}^t(Ind_s) = \lambda^{t_r - t_c} \times ND_{R_i}^t(Ind_s),\ \ where\ \ 0 < \lambda \le 1 \qquad (4)$$

Derive the competence reputation and initial trust

The $\overline{Ind}_s^{R_i}$ denotes an arithmetic mean of a specific indicator Ind_s for R_i across all interactions (see Eqn. (5)).

$$\overline{Ind}_s^{R_i} = \frac{\sum_{t=1}^{n}(1 - TND_{R_i}^t(Ind_s))}{n},\ \ t = 1,2...n \qquad (5)$$

The competence reputation Z^{R_i} of the trustee rated by specific rater R_i is obtained as the sum of the weighted $\overline{Ind}_s^{R_i}$ (see Eqn. (6)).

$$Z^{R_i} = \sum_{s=1}^{f} W_s \times \overline{Ind}_s^{R_i},\ \ s = 1,2,.....f,\ \ where\ \ \sum_{s=1}^{f} W_s = 1 \qquad (6)$$

The competence initial trust $Comp_{AT_j}$ for the trustee AT_j interacting with rater R_i is obtained using Eqn. (7). The $Nwr_{AT_j}^{R_i}$ was obtained using Eqn. (1) and the Z^{R_i} was obtained via Eqn. (6).

$$Comp_{AT_j} = \frac{\sum_{i=1}^{r} Nwr_{AT_j}^{R_i} \times Z_{AT_j}^{R_i}}{\sum_{i=1}^{r} Nwr_{AT_j}^{R_i}}, \quad i = 1,2....r, \quad j = 1,2...k \qquad (7)$$

3.4.3.2 To Aggregate the Initial Trust of Goodwill

One obstacle to implement a collaborative supply chain environment is the lack of goodwill among participants in sharing sensitive information. The process to derive goodwill initial trust was described as: First, the subjective ratings of goodwill indicators are collected and the testimonies are then processed by filtering out unfair ratings of extremely high or low and dealing with time decay. Subsequently, the subjective ratings are transformed into goodwill reputation scores that can be used to derive goodwill trust. Goodwill trust is obtained via the following process:

The subjective testimonies

The set $AG_{AT_j}^{R_i}$ contains sub-sets $G_{R_i}^t$ that represent the subjective ratings supplied by rater R_i to trustee AT_j across *n* interactions.

$$AG_{AT_j}^{R_i} = \{G_{R_i}^t\}, \quad t = 1,2....n$$

The sub-set $G_{R_i}^t$ contains the values of goodwill indicators $GI_{R_i}^t(ind_p)$, which are rated as [-1, 1] at the t_{th} interaction. The set *GInd* includes the goodwill indicators previously mentioned during the testimony definition step.

$$G_{R_i}^t = \{GI_{R_i}^t(ind_p)\}, \quad p = 1,2,...7, \quad ind_p \in GInd$$

where

$$GInd = \{OB, AF, RE, EB, IS, HA, LIP\}$$

Filter out unfair ratings

Because of social relationships such as competition or collusion

between raters and trustees, goodwill rating scores may be unfairly high or low. The rating values of a specific indicator (e.g. such as, information sharing, IS) for all raters and interactions are assumed to be random variables represented in the form of a statistical distribution (e.g. such as, normal distribution). That is, the p values of the left and right tails of the distribution are defined and unfair or extreme values are screened out. Additionally, the set FH_{ind_p} contains $FGI^t_{R_i}(ind_p)$ that filtering out unfair ratings or extreme values.

$$FH_{ind_p} = \{FGI^t_{R_i}(ind_p)\}, \quad t = 1,2,...n, \quad i = 1,2,...r$$

Time decay

As competence trust, time decay factor was adopted to derive goodwill trust. While $FGI^t_{R_i}(ind_p)$ represented the indicator value after screening out the unfair rating of extreme value, the $TFGI^t_{R_i}(ind_p)$ is obtained using Eqn. (8).

$$TFGI^t_{R_i}(ind_p) = \lambda^{t_r - t_c} \times FGI^t_{R_i}(ind_p), \quad where \quad 0 < \lambda \le 1 \tag{8}$$

The $\overline{G}^t_{R_i}$ represents the sum of all weighted goodwill indicators for rater R_i, and is obtained using Eqn. (9).

$$\begin{aligned} &\overline{G}^t_{R_i} = \sum_{p=1}^{7} W_{ind_p} \times TFGI^t_{R_i}(ind_p), \quad p = 1,2,...7, \\ &where \quad \sum_{p=1}^{7} W_{ind_p} = 1 \end{aligned} \tag{9}$$

Changeful goodwill reputation

The definition of trust proposed by Yu and Singh (2000) was adopted, namely that reputation should be difficult to build up, but easy to destroy. The goodwill reputation rated by R_i at the t_{th} interaction is defined as $T^t_{R_i}$ that $-1 < T^t_{R_i} < 1$ and $T^0_{R_i} = 0$. Goodwill reputation during the next time period is derived based on the goodwill performance during the current period. Table 3.4 lists the change in goodwill reputation. The term $\overline{G}^{t-1}_{R_i}$ is initially set to zero; additionally, the α represents positive evidence and the β represents negative evidence. Thus $\alpha \ge 0$ and $\beta \le 0$.

If the trustee behaves well during the current time period, they will gain only a small score during the subsequent. On the other hand, if the trustee behaves poorly during the current time period, their reputation score will reduce markedly during the subsequent time period. This scheme may reward trustees who behave well and punish the one who betray their partner. The value of goodwill reputation T_{R_i} is then transferred as [0, 1] and represented as:

$$TT_{R_i}^t = \frac{T_{R_i}^t + 1}{2}$$

Table 3.4 The goodwill reputation over time periods

$\overline{G}_{R_i}^t$ \ $\overline{G}_{R_i}^{t+1}$	≥ 0	<0
>0	$T_{R_i}^{t+1} = \overline{G}_{R_i}^t + \alpha(1 - \overline{G}_{R_i}^t)$	$T_{R_i}^{t+1} = (\overline{G}_{R_i}^t + \beta)/(1 - \min\{\lvert\overline{G}_{R_i}^t\rvert, \lvert\beta\rvert\})$
<0	$T_{R_i}^{t+1} = (\overline{G}_{R_i}^t + \alpha)/(1 - \min\{\lvert\overline{G}_{R_i}^t\rvert, \lvert\alpha\rvert\})$	$T_{R_i}^{t+1} = \overline{G}_{R_i}^t + \beta(1 + \overline{G}_{R_i}^t)$
=0	If $\overline{G}_{R_i}^{t+1} = 1$, then $T_{R_i}^{t+1} = 1$, else $T_{R_i}^{t+1} = \alpha$	If $\overline{G}_{R_i}^{t+1} = -1$, then $T_{R_i}^{t+1} = -1$, else $T_{R_i}^{t+1} = \beta$

Derive goodwill initial trust

The arithmetic mean of goodwill reputation for R_i across n interactions can be obtained via Eqn. (10) (as $\overline{T}^{R_i}$).

$$\overline{T}^{R_i} = \frac{\sum_{t=1}^{n} TT_{R_i}^t}{n}, \quad t = 1,2...n \tag{10}$$

Finally, the goodwill initial trust GW_{AT_j} for trustee AT_j is obtained by Eqn. (11). The $Nwr_{AT_j}^{R_i}$ is obtained by Eqn. (1) and $\overline{T}^{R_i}$ is obtained by Eqn. (10).

$$GW_{AT_j} = \frac{\sum_{i=1}^{r} Nwr_{AT_j}^{R_i} \times \overline{T}_{AT_j}^{R}}{\sum_{i=1}^{r} Nwr_{AT_j}^{R_i}}, \quad i = 1,2...r, j = 1,2...k \qquad (11)$$

3.4.3.3 To derive the predictability Initial Trust

Predictability trust implies consistent behavior of trading partner and indicates partner reliability. This study thus defines predictability trust as being derived from the predictability of competence and goodwill. The competence predictability is derived from variance of competence reputation, and goodwill predictability is derived from variance of goodwill reputation. The ultimate aim of this method is to identify a collaborative partner with high initial trust of competence and goodwill and low variance of performance.

To obtain the competence predictability

The $\overline{Ind}_s$ is an arithmetic mean of an indicator Ind_s for all raters across all interactions. Moreover, the $Var(Ind_s)$ denotes the variance of competence reputation, and the competence predictability $\Pr ed\_Comp_{AT_j}$ was the sum of weighted $Var(Ind_s)_{AT_j}$ (see Eqn. (12)).

$$\overline{Ind}_s = \frac{\sum_{i=1}^{r} \overline{Ind}_s^{R_i}}{r}, \quad i = 1,2...r$$

$$Var(Ind_s) = \frac{\sum_{i=1}^{r} (\overline{Ind}_s^{R_i} - \overline{Ind}_s)^2}{r-1}, \quad i = 1,2,....r$$

$$\Pr ed\_Comp_{AT_j} = \sum_{s=1}^{f} W_s \times Var(Ind_s)_{AT_j}, \quad s = 1,2....f, \qquad (12)$$

$$where \quad \sum_{s=1}^{f} W_s = 1$$

To obtain the goodwill predictability

The μ^{R_i} equals $\overline{T}^{R_i}$ (see Eqn. (10)), and the term Var^{R_i} indicates the variance of goodwill reputation rated by R_i. Finally, the goodwill predictability $\Pr ed\_GW_{AT_j}$ was obtained by the sum of the weighted Var^{R_i} (see Eqn. 13):

$$\mu^{R_i} = \overline{T}^{R_i}, \quad i = 1,2,...r$$

$$Var^{R_i} = \frac{\sum_{t=1}^{n} (TT_{R_i}^{t} - \mu^{R_i})^2}{n-1}, \quad t = 1,2...n$$

$$\Pr ed\_GW_{AT_j} = \sum_{i=1}^{r} Nwr_{AT_j}^{R_i} \times Var_{AT_j}^{R_i}, \quad i = 1,2,....r \tag{13}$$

Derive predictability initial trust

The predictability of competence and goodwill were aggregated to yield predictability initial trust $\Pr ed_{AT_j}$ for trustee AT_j (see Eqn. (14)).

$$\begin{aligned} &\Pr ed_{AT_j} = 1 - (W_c \times \Pr ed\_Comp_{AT_j} + W_g \times \Pr ed\_GW_{AT_j}) \\ &where \;\; W_c + W_g = 1 \end{aligned} \tag{14}$$

3.4.3.4 To Obtain the Initial Trust Score

For the trustor maybe does not know the trustees or has little information about the trustees in a new business opportunity α, the trust is derived from the testimonies obtained from referral networks. We define the initial trust as a function contains three parameters: competence, goodwill, and predictability, and it is expressed as:

Initial trust (α) = f (competence, predictability, goodwill)

The initial-trust $dt_{AT_j}(\alpha)$ was obtained by Eqn. (15). That is, the trustee with unstable performance in competence and goodwill, as low level of $\Pr ed_{AT_j}$, will obtain the low level of initial trust.

$$dt_{AT_j}(\alpha) = (W_c \times Comp_{AT_j} + W_g \times GW_{AT_j}) \times \Pr ed_{AT_j} \quad (15)$$
$$where \;\; W_c + W_g = 1$$

As aforementioned, the value of $Comp_{AT_j}$, GW_{AT_j} and $\Pr ed_{AT_j}$ are in the range of [0, 1], and we deduce that $dt_{AT_j}(\alpha)$ is also ranged as [0, 1].

Moreover, the maximum value of $dt_{AT_j}(\alpha) = 1$ occurs when the variables $Comp_{AT_j}$, GW_{AT_j} and $\Pr ed_{AT_j}$ was set to one. On the other hand, the minimum value of $dt_{AT_j}(\alpha) = 0$ occurs when the value of variables $Comp_{AT_j}$ and GW_{AT_j} equal to zero.

We may conclude that the trustee obtains extremely high initial trust when he performed consistently well with his collaborative partners, but get extremely low initial trust when he performed consistently poor with his partners. In addition, the trustee with unstable performance (e.g., high variance of competence and goodwill) will obtain the low level of derived trust.

3.4.4 Collaboration Threshold

When the trustor agent obtains the initial trust of all trustees, the question emerges: Is the trustee with highest level of initial trust qualified to collaborate with. Here, the concept of collaboration threshold was introduced for deriving the initial trust. If the score of initial trust of the best trustee reaches the collaboration threshold, collaboration occurs; else, the collaboration will not occur (see Eqn. (16)). In addition, the collaboration threshold guarantees that the trustor selects a qualified partner.

$$highest\_dt_{AT_j}(\alpha) \geq Collaboration\_threshold(\alpha) \quad (16)$$

Marsh (1994) defined the variable elements of cooperation threshold includes: (1) perceived risk, (2) importance, (3) perceived competence, and (4) situational trust. In this study, the collaboration threshold was defined before the process of partner selection, so it lacks the information of perceived competence and situational trust of trustees. Therefore, the "perceived risk" and "importance" were adopted to be the variable elements of collaboration threshold. The variable of perceived risk (as Risk (α)) and importance (as Imp (α)) are ranged as [0, 1], and the notation α denotes the new business opportunity. Thus, the collaboration threshold was determined as (see Eqn. (17)):

$$collaboration\_threshold(\alpha) = Risk(\alpha) \times \mathrm{Im}\, p(\alpha) \quad (17)$$

The Equation (17) shows that if the risk and importance of new opportunity are both equal to zero, the collaboration threshold is equal to zero. On the contrary, if the risk and importance are both equal to 1, the threshold is equal to 1. For example, the *Risk (α)* = 0.4 and *Imp (α)* = 0.8, and then the *collaboration_threshold (α)* = 0.32.

3.5 Numerical Example

For illustrating the testimony aggregation step of the RBPS model, this study makes up objective and subjective testimonies as transaction records recorded by raters for a specific trustee and calculate the initial trust; thus. First, the objective testimonies contain the contract value and performance value of indicators. Accordingly, the difference of the values of contract and performance were calculated, and the conformance and normalized conformance were obtained. Then, the scores of competence initial trust were derived. Second, the subjective testimonies contain values of goodwill indicators across all time periods. Accordingly, the changeable goodwill reputations and the score of goodwill initial trust

were derived. Third, the variance of reputation scores of competence and goodwill was obtained, and the predictability initial trust was derived. Finally, the scores derived from the initial trust of competence, predictability, and goodwill were aggregated that lead to the scores of initial trust of the trustees.

3.5.1 To Obtain Competence Initial Trust

Objective Testimony

The trustor obtained objective testimonies that include the contract testimony (CT) and performance testimony (PT) of trustees (e.g., trustee a as AT_a and trustee b as AT_b). Meanwhile, the raters (e.g., rater 1 as R_1 and rater 2 as R_2) measured the fulfillment of contracts performed by the trustee using the indicators (e.g., quality (*Qt*), order fill rate (*Ofr*), and order fulfill lead time (*Oflt*)). The trustee and the rater had an interaction history for t number of times. Table 3.5 shows the CT and PT for AT_a rated by R_1 and R_2. The term $CT_{R_1}^t$ denotes the contract testimonies recorded by R_1 at t_{th} interaction, while $PT_{R_2}^t$ represents the performance testimonies recorded by R_2 at t_{th} interaction.

Table 3.5 The raw objective testimonies

Trustee 'a' (AT_a)									
Rater	Indicators / Contract /performance	Qt	Ofr	Oflt	Rater	Indicators / Contract /performance	Qt	Ofr	Oflt
R_1	$CT_{R_1}^{t}$	0.95	0.95	10	R_2	$CT_{R_2}^{t}$	0.95	0.95	10
	$PT_{R_1}^{t}$	0.96	0.98	9		$PT_{R_2}^{t}$	0.92	0.92	8
	$CT_{R_1}^{t+1}$	0.95	0.95	10		$CT_{R_2}^{t+1}$	0.95	0.95	10
	$PT_{R_1}^{t+1}$	0.94	0.94	11		$PT_{R_2}^{t+1}$	0.94	0.94	12
	$CT_{R_1}^{t+2}$	0.95	0.95	10		$CT_{R_2}^{t+2}$	0.95	0.95	10
	$PT_{R_1}^{t+2}$	0.93	0.93	12		$PT_{R_2}^{t+2}$	0.92	0.92	14
	$CT_{R_1}^{t+3}$	0.95	0.95	10		$CT_{R_2}^{t+3}$	0.95	0.95	10
	$PT_{R_1}^{t+3}$	0.92	0.92	13		$PT_{R_2}^{t+3}$	0.9	0.9	16
	$CT_{R_1}^{t+4}$	0.95	0.95	10		$CT_{R_2}^{t+4}$	0.95	0.95	10
	$PT_{R_1}^{t+4}$	0.91	0.91	14		$PT_{R_2}^{t+4}$	0.88	0.88	18

Conformance

The trustor calculates the conformance that measures the difference between CT and PT. If the trustee fulfilled the contract, the conformance is zero; otherwise the conformance is the absolute value of the difference between CT and PT (see Table 3.6, based on Eqn. (2)).

Table 3.6 The conformance of two raters

Raters	Indicators / conformance	Qt	Ofr	Oflt
R_1	D_{R1}^{t}	0	0	0
	D_{R1}^{t+1}	0.01	0.01	1
	D_{R1}^{t+2}	0.02	0.02	2
	D_{R1}^{t+3}	0.03	0.03	3
	D_{R1}^{t+4}	0.04	0.04	4
R_2	D_{R2}^{t}	0	0.95	0
	D_{R2}^{t+1}	0.01	0.01	2
	D_{R2}^{t+2}	0.03	0.03	4
	D_{R2}^{t+3}	0.05	0.05	6
	D_{R2}^{t+4}	0.07	0.07	8

Normalized Conformance

Owing to the indicators being measured by different metrics (for example, date and ratio), the conformance of a specific indicator must be normalized. Table 3.7 lists the normalized conformance ND for the indicators based on Equation (3)

Table 3.7 The normalized conformance of two raters

Raters	Indicators / Normalized conformance	Qt	Ofr	Oflt
R_1	ND_{R1}^{t}	0.00	0.00	0.00
	ND_{R1}^{t+1}	0.14	0.14	0.13
	ND_{R1}^{t+2}	0.29	0.29	0.25
	ND_{R1}^{t+3}	0.43	0.43	0.38
	ND_{R1}^{t+4}	0.57	0.57	0.50
R_2	ND_{R2}^{t}	0.00	0.00	0.00
	ND_{R2}^{t+1}	0.14	0.14	0.25
	ND_{R2}^{t+2}	0.43	0.43	0.50
	ND_{R2}^{t+3}	0.71	0.71	0.75
	ND_{R2}^{t+4}	1.00	1.00	1.00

Derive Competence Initial Trust

The term $\overline{Ind}_s^{R_i}$ denotes the arithmetic mean of indicator Ind_s about ND_{R_i} across all interactions and all raters (see Eqn. (5)). The competence reputation z^{R_i} then be obtained by Eqn. (6) (see Table 3.8).

Table 3.8 The summary of $Ind_s^{R_i}$ and z^{R_i}

	Qt	**Ofr**	**Oflt**	**notes**
$\overline{Ind}_s^{R_1}$	0.714	0.714	0.748	
Z^{R_1}	0.725			$W_s = \frac{1}{3}$
$\overline{Ind}_s^{R_2}$	0.544	0.544	0.5	
Z^{R_2}	0.528			$W_s = \frac{1}{3}$

The competence trust of AT_j (e.g., $Comp_{AT_j}$) was derived via Eqn. (7), where $Nwr_{AT_j}^{R_i}$ was obtained during the previously mentioned testimony propagation step. For the study example, the normalized weights were set as $Nwr_{AT_a}^{R_1}$ =1 and $Nwr_{AT_a}^{R_2}$ =0.5, and the competence trust of AT_a (as $Comp_{AT_a}$) was then obtained as:

$$Comp_{AT_a} = (0.725 \times 1 + 0.528 \times 0.5) / 1 + 0.5 = 0.66$$

3.5.2 To Obtain Goodwill Initial Trust

Subjective Testimony

The subjective testimonies listed in Table 3.9 include seven indicators, previously mentioned in the testimony definition step, of goodwill (as *GI*) rated by R_1 and R_2 across numerous interactions. The weights of each indicator were set to be equal, and the sum of weighted indicators for R_i over t_{th} interaction (as $\overline{G}_{R_i}^t$) was derived based on Eqn. (9).

Table 3.9 The raw subjective testimonies

Raters		**OB**	**AF**	**RE**	**EB**	**IS**	**HA**	**LIP**	$\overline{G}_{R_i}$
R_1	$GI_{R_1}^t$	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	$GI_{R_1}^{t+1}$	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	$GI_{R_1}^{t+2}$	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
	$GI_{R_1}^{t+3}$	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
	$GI_{R_1}^{t+4}$	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
R_2	$GI_{R_2}^t$	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
	$GI_{R_2}^{t+1}$	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
	$GI_{R_2}^{t+2}$	0	0	0	0	0	0	0	0
	$GI_{R_2}^{t+3}$	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	$GI_{R_2}^{t+4}$	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Changeable Goodwill Reputation

The goodwill reputation T_{R_i} can be obtained by using the rules listed in Table 3.4. The α = 0.5 and β = - 0.5. Subsequently, the T_{R_i}, ranged as [-1, 1] then be transferred into TT_{R_i} that was ranged as [0, 1]. The arithmetic mean of goodwill reputation for R_i (as $\overline{T}^{R_i}$) across all interactions can be derived by Eqn. 10 (see Table 3.10). The goodwill reputation of R_1 and R_2 is 0.555 and 0.537 respectively.

Table 3.10 The changeable goodwill reputation

Rater		**Series of Interactions**					
R_1	$\overline{G}_{R_1}$	$\overline{G}_{R_1}^{t-1}$	$\overline{G}_{R_1}^{t}$	$\overline{G}_{R_1}^{t+1}$	$\overline{G}_{R_1}^{t+2}$	$\overline{G}_{R_1}^{t+3}$	$\overline{G}_{R_1}^{t+4}$
		0	0.3	0.4	-0.2	-0.4	0.8
	T_{R_1}		$T_{R_1}^{t}$	$T_{R_1}^{t+1}$	$T_{R_1}^{t+2}$	$T_{R_1}^{t+3}$	$T_{R_1}^{t+4}$
			0.5	0.65	-0.166	-0.6	0.166
	TT_{R_1}		0.75	0.825	0.417	0.2	0.583
	$\overline{T}^{R_1}$	**0.555**					
R_2	$\overline{G}_{R_2}$	$\overline{G}_{R_2}^{t-1}$	$\overline{G}_{R_2}^{t}$	$\overline{G}_{R_2}^{t+1}$	$\overline{G}_{R_2}^{t+2}$	$\overline{G}_{R_2}^{t+3}$	$\overline{G}_{R_2}^{t+4}$
		0	-0.4	-0.2	0	0.4	0.8
	T_{R_2}		$T_{R_2}^{t}$	$T_{R_2}^{t+1}$	$T_{R_2}^{t+2}$	$T_{R_2}^{t+3}$	$T_{R_2}^{t+4}$
			-0.5	-0.7	0.375	0.5	0.7
	TT_{R_2}		0.25	0.15	0.687	0.75	0.85
	$\overline{T}^{R_2}$	**0.537**					

Derive Goodwill Initial Trust

The normalized weights of the rater R_1 $Nwr_{AT_a}^1$ =1 and R_2 $Nwr_{AT_a}^2$ =0.5, in which case the score of goodwill trust GW of AT_a is derived by Eqn (11):

$$GW_{AT_a} = (0.555 \times 1 + 0.537 \times 0.5)/1 + 0.5 = 0.549$$

3.5.3 To Obtain Predictability Initial Trust

The Competence Predictability

The terms $\overline{Ind}_s^{R_i}$ were derived by Eqn. (5) and the term $\overline{Ind}_s$ was an arithmetic mean of $\overline{Ind}_s^{R_i}$. Subsequently, the *Var(Ind$_s$)* denoted the variance of competence reputation, and the competence predictability (as *Pred_Comp*) was sum of weighted terms as *Var(Ind$_s$)* and derived by Eqn. (12) (see Table 3.11).

Table 3.11 The predictability of competence

	Qt	Ofr	Oflt
$\overline{Ind}_s^{R_1}$	0.714	0.714	0.748
$\overline{Ind}_s^{R_2}$	0.544	0.544	0.5
$\overline{Ind}_s$	0.629	0.629	0.624
$Var(Ind_s)$	0.01445	0.01445	0.0308
Pred_Comp		0.02	

The Goodwill Predictability

The goodwill reputation denoted as the term μ_{Ri}. Additionally, the variance of μ_{Ri} for a specific rater R_i across all interactions (as Var_{R_i}) was obtained. Finally, the goodwill predictability (as *Pred_GW*) was sum of the weighted terms as Var_{R_i} and derived by Eqn. (13) (see Table 3.12).

Table 3.12 To obtain the predictability of goodwill

	R_1	R_2
μ_{R_i}	0.555	0.537
Var_{R_i}	0.064	0.1
$Pred\_GW$	0.082	

Derive Predictability Initial Trust

Predictability initial trust was derived using predictability of competence and goodwill (see Table 3.11 and Table 3.12). That is, the weights of *Pred_Comp* and *Pred_GW* were set to be equal, and the predictability trust of AT_a (as $\Pr ed_{AT_a}$) was obtained by Eqn. (14).

$$\Pr ed_{AT_a} = 1 - (0.5 \times 0.02 + 0.5 \times 0.082) = 0.949$$

3.5.4 To Derive the Initial Trust Score

The initial-trust of a specific trustee AT_j for a new business opportunity α (as $dt_{AT_a}(\alpha)$) was derived by Eqn. (15). For the above example, the initial-trust of AT_a was obtained as:

$$dt_{AT_a}(\alpha)(0.5 \times 0.66 + 0.5 \times 0.549) \times 0.949 = 0.574$$

If the score of $dt_{AT_a}(\alpha)$ greater than $dt_{AT_b}(\alpha)$ and also exceeds the thresholds defined by the trustor, the trustee AT_a can be selected as a collaborative partner.