CCCI Metrics for the Measurement of Quality of e-Service

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Abstract

The growing development in web-based trust and reputation systems in the 21st century will have powerful social and economic impact on all business entities, and will make transparent quality assessment and customer assurance realities in the distributed web-based service oriented environments. The growth in web-based trust and reputation systems will be the foundation for web intelligence in the future.

Trust and Reputation systems help capture business intelligence through establishing customer relationships, learning consumer behaviour, capturing market reaction on products and services, disseminating customer feedback, buyers' opinions and end-user recommendations, and revealing dishonest services, unfair trading, biased assessment, discriminatory actions, fraudulent behaviours, and un-true advertising. The continuing development of these technologies will help in the improvement of professional business behaviour, sales, reputation of sellers, providers, products and services.

In this paper, we present a new methodology known as CCCI (Correlation, Commitment, Clarity, and Influence) for trustworthiness measure that is used in the Trust and Reputation System. The methodology is based on determining the correlation between the originally committed services and the services actually delivered by a Trusted Agent in a business interaction over the service oriented networks to determine the trustworthiness of the Trusted Agent.

1. Introduction

Trustworthiness measure is defined as the measure of the trust level or the trustworthiness value of Trusted Agent after a service interaction. Trustworthiness measure is unidirectional from the Trusting Agent to the Trusted Agent. The measurement is made using a correlation metric. We correlate the actual service delivered by the Trusted Agent with the originally committed service. Terms and Conditions of the agreement between the Trusted Agent and Trusting Agent serve as criteria or benchmarks when carrying out the correlation. The clarity of the criteria (or terms and conditions) is very important in avoiding disputes involving trustworthiness measurement. The weight of each criterion influences the decision making process and affects trustworthiness values.

The proposed CCCI metrics provide the trusting agent with the intelligence that can enable him to assign a trustworthiness value to another agent after interacting with him/her. The trusting agent can make use of the assigned trustworthiness value as a means to decide whether or not to interact with the other trusted agent in the future.

2. Trustworthiness in Literature

There are different proposals for trustworthiness rating systems. A Bayesian Network based model for determining trust has been proposed [7], where each root node has two values 'satisfying', denoted by 0, and 'unsatisfying', denoted by 1. The use of a decision function for determining trustworthiness has been proposed [2], where 'trust' is represented by 1 and 'mistrust' is represented by -1. A trust metric based on a number of parameters which include the amount of agent satisfaction and credibility of agent feedback has been proposed [8]. Normalized, local trust values, i.e. trust values between 0 and

1, have been proposed [6]. A system where the trustworthiness of an agent is the expectation of the cooperativeness modelled as a probability of the agent has been proposed [9].

A trustworthiness scale of −1 to 4 is proposed [4]. Four different levels of trustworthiness ratings: 'Very Trustworthy', 'Trustworthy', 'Untrustworthy' and 'Very Untrustworthy' have been proposed [1]. A non-numeric rating expressed using stars with each additional star denoting a higher rating is proposed [5]. The highest possible rating in their proposed method is 5 stars and the lowest possible rating is 1 star. However, there is a lack of semantic explanation of the different trustworthiness levels and a lack of coverage of all possible trustworthiness levels. For example, if 1 to 5 stars denote positive trust, how is negative trust to be denoted? There is also a lack of precise meaning and clear definition for a given trustworthiness level.

In existing literature, there has been no clear distinction made between the concepts of trust, trust value and trustworthiness. Many researchers have studied aspects of trust and trustworthiness. However, no clear semantics or definitions have been provided for these concepts. There has also been no description of how to determine the trustworthiness level of unknown persons or agents. Moreover, there is a lack of a trustworthiness scale that can adequately represent the trust levels. For example, a system with three levels such as good, average, and poor is better than a system with two levels; good and poor. This is especially important in open and often anonymous, virtual collaborative environments such as Service-oriented networks.

3. Trustworthiness Defined

Definition: Trustworthiness is defined as an estimate of the level of trust that the Trusting Agent has in the Trusted Agent. The Trustworthiness scale system provides the reference standard for trustworthiness measurement and trustworthiness prediction.

It quantifies the trust values and rates the trust in service-oriented networks.

The terms 'an estimate', 'the level of trust', 'a scale system', 'trustworthiness measure', 'trustworthiness prediction', 'quantifies the trust values', 'rates the Trust' are essential when defining trust. These six terms are important concepts in the definition of Trustworthiness. These terms are explained below in the context of the definition of trustworthiness.

The term 'an estimate' refers to trustworthiness which gives a measure of the level or the degree of trust. An estimate is the result of a tentative measure. The term 'the level of trust' determines the amount of trust that the Trusting Agent has in the Trusted Agent. It can be represented numerically or non-numerically. The level of trust represented by the Trustworthiness is unidirectional from the Trusting Agent to the Trusted Agent and it depends on the context and time.

'A scale system' is defined as a measurement system which can be used to determine the level of trust. The scale system can have either numeric measures or non-numeric measures. We define the numeric measure of a trust level as an assessment of a trust relationship expressed in terms of an integer or a real number. We define the non-numeric measure of a trust level as a valuation of a trust level expressed neither in terms of an integer nor in terms of real numbers, but as lexicons such as Very Trustworthy or Untrustworthy.

'Trustworthiness Measure' is defined as an estimate of the level of trust or the trustworthiness value assigned to the Trusted Agent AFTER a business service interaction over the distributed Service-oriented environment.

'Trustworthiness Prediction' is defined as the initial trust value assigned to the Trusted Agent BEFORE a business service interaction over the distributed Service-oriented environment.

Trustworthiness is a measure that determines the amount of trust that the Trusting Agent has in the Trusted Agent. It provides a 7-level trustworthiness scale system and helps to quantify the trust

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values. *Quantify,* here, means to calculate the trust value in order to determine the corresponding trustworthiness levels.

Trustworthiness helps in the rating of trust by numerically quantifying the trust values and qualifying the trust levels non-numerically. Here, the term *qualify* means to give a specific meaning to the level that is derived.

4. Seven Trustworthiness Levels and Star Ratings

The Trustworthiness Scale is an ordinal scale with seven discrete levels and corresponding semantics (linguistic definitions). In order to help explain the significance of each of the trustworthiness levels we map the approximate ranges on a user defined interval scale to the levels on the ordinal scale. The levels are -1, 0, 1, 2, 3, 4, 5 and the corresponding linguistic definitions are 'Unknown Agent', 'Very Untrustworthy', 'Untrustworthy', 'Partially Trustworthy', 'Largely Trustworthy', 'Trustworthy', and 'Very Trustworthy' respectively. The seven levels of trustworthiness defined are shown in the table below:

Trustworthiness Level	Semantics (Linguistic Definitions)	Trustworthiness Value (User defined)	Visual Representation (Star Rating System)
Level -1	Unknown Agent	$x = -1$	Not displayed
Level 0	Very Untrustworthy	$x = 0$	Not displayed
Level 1	Untrustworthy	$0 < x \leq 1$	From ⭐ to ⭐
Level 2	Partially Trustworthy	$1 < x \leq 2$	From ⭐⭐ to ⭐⭐
Level 3	Largely Trustworthy	$2 < x \leq 3$	From ⭐⭐⭐ to ⭐⭐⭐
Level 4	Trustworthy	$3 < x \leq 4$	From ⭐⭐⭐⭐ to ⭐⭐⭐⭐
Level 5	Very Trustworthy	$4 < x \leq 5$	From ⭐⭐⭐⭐⭐ to ⭐⭐⭐⭐⭐

Table 1. Seven levels of trustworthiness and a corresponding visual representation

5. Issues

In distributed service-oriented environments, how can we shape the world of e-business by building trust and establishing trust? How can we help organizations improve customer service, business value and consumer confidence? How can we help to provide quality assessment and assurance for the customer in the networked economy?

6. Trustworthiness Measure

The primary measure for the quality of service in service oriented network environments is that the delivered service fulfils its commitment and delivery according to the mutual agreement.

Trustworthiness implies the quality of service. The purpose of trustworthiness measure is to record the loyalty and honesty of Trusted Agents, such as business partners, service providers, or consumers, etc in heterogeneous and sometime anonymous service networks, for future

reference of Trusting Agents or others who might query them about some service they do not know or have no experience with. Thus help trusted business transaction, e-service, virtual collaboration help business improve their service and keep the service oriented network safe and trustworthy. This in turn, helps provide transparency and harmony to the distributed heterogeneous, anonymous, pseudo-anonymous, and non-anonymous service network.

7. Correlation Methodology

Trustworthiness measure is made through the correlation between what was committed and what has actually been delivered. We must use the following:

1. $Corr_{service}$

2. $Commit_{criterion}$
3. $Clear_{criterion}$ and
4. $Inf_{criterion}$.

It is these four key metrics that form the CCCI trustworthiness measure methodology. In the following section we define all the possible levels and values of $Commit_{criterion}$, $Clear_{criterion}$ and $Inf_{criterion}$. Using the values of $Commit_{criterion}$, $Clear_{criterion}$ and $Inf_{criterion}$ assigned to all criteria in the interaction we determine the value of $Corr_{service}$.

8. Fulfilment of a Commitment

8.1 Definition

The fulfilment of each commitment is defined as a measure of how much of the Trusted Agent's commitment to each criterion (i.e. the original commitment set out in the service agreement) has been fulfilled by the service delivered.

The fulfilment of each commitment is represented by $Commit_{criterion\ c}$.

8.2 Levels of Commit $_{criterion}$ and Values

We define 7 levels of $Commit_{criterion\ c}$ from -1 to 5. Each of these seven levels corresponds to a different degree or extent to which the Trusted Agent fulfils its commitments.

The corresponding semantic definitions or linguistic descriptions of the levels are 'none or ignore', 'nothing is delivered', 'barely delivered any commitment', 'partially delivered all the commitment', 'largely delivered all the commitment', 'delivered all the commitment' and 'fully delivered all the commitment' respectively.

9. Clarity of each Criterion

9.1 Definition

The clarity of each commitment is defined as a measure of how clearly the criteria or terms and conditions have been laid out in the service agreement. The clarity of each commitment is represented by $Clear_{criterion\ c}$.

9.2 Levels of Clear $_{criterion}$ and Values

We propose seven different levels and values for Clear $_{criterion}$, to represent how clearly the criteria are defined in an interaction.

It is expressed on a scale of -1 to 5, and the corresponding linguistic definitions of the levels are 'none or ignore', 'not clear', 'barely clear', 'partially clear', 'largely clear', 'clear' and 'very clear' respectively.

10. Influence of each criterion

10.1 Definition

The Influence of each criterion is defined as a measure of how important of the criteria or terms and conditions when deciding the trustworthiness of the Trusted Agent.

The influence each commitment is represented by $Inf_{criterion\ c}$.

10.2 Levels of Inf $_{criterion}$ and Values

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There are seven different levels of $Inf_{criterion}$ with seven corresponding semantic definitions.

The levels are expressed on a scale of -1 to 5, and the corresponding linguistic descriptions of the levels are 'none or ignore', 'unimportant', 'barely important', 'partially important', 'largely important', 'important' and 'very important' respectively.

11. Correlation with Mutually Agreed Service

11.1 Definition

The correlation with mutually agreed service is defined as a measure of how much the Trusted Agent deliver his commitment set out in the terms and conditions of the service agreement.

The correlation of mutually agreed service is represented by $Corr_{service\ s}$.

The contribution of the 'c^{th}' criterion to the overall value of $Corr_{service}$ can be represented as:

$$f(Commit_{criterion\ c}, Clear_{criterion\ c}, Inf_{criterion\ c})$$
$$= Commit_{criterion\ c} * Clear_{criterion\ c} * Inf_{criterion\ c}$$

Therefore we can express $Corr_{service}$ as:

$$Corr_{service} = \sum_{c=1}^{N} f(Commit_{criterion\ c}, Clear_{criterion\ c}, Inf_{criterion\ c})$$

...............(1)

$$= \sum_{c=1}^{N} (Commit_{criterion\ c} * Clear_{criterion\ c} * Inf_{criterion\ c})$$

11.2 Maximum and Relative Values of $Corr_{services}$

We can define the maximum possible correlation value (Max $Corr_{service}$) for an interaction as a numeric value that quantifies the maximum possible concurrence between what the Trusted Agent committed to deliver and what it actually delivered in its interaction with the Trusting Agent. Alternatively, it is the correlation value for an interaction when the service of the Trusted Agent is equivalent to the expected service.

We define relative correlation value (Rel $Corr_{service}$) as a numeric value that quantifies the degree of concurrence between the correlation value for an interaction and the maximum possible correlation value for the interaction.

For N criteria, the maximum and relative values of $Corr_{service\ s}$ are as shown in the table below:

The maximum value of $Corr_{service\ s}$	Max $Corr_{service\ s}$	sum of (Max $Commit_{criterion\ c}$ x $Clear_{criterion\ c}$ x $Inf_{criterion\ c}$) over all N criteria
The relative value of $Corr_{service\ s}$	Rel $Corr_{service\ s}$	$Corr_{service\ s}$ / Max $Corr_{service\ s}$

Table 2. The maximum and relative values of $Corr_{service\ s}$

12. Trustworthiness Values

$Corr_{service}$ provide a framework for determining the trustworthiness of a Trusted Agent once the Trusting Agent has determined the criteria on which he/she is going to assign trustworthiness to the Trusted Agent.

Rel Corr$_{service}$ (defined in the previous section) shows the extent to which the Trusted Agent abides by what it had initially agreed to do and hence denotes the extent to which the Trusted Agent can be relied upon to perform a given action. Since trustworthiness denotes the amount of trust that can be reposed in the Trusted Agent, Rel Corr$_{service}$ can be used to denote the trustworthiness of the Trusted Agent.

12.1 Derivation

In our method, trustworthiness has to be expressed on the scale of -1 to 5. A trustworthiness value of '-1' denotes that the Trusting Agent is new to the network. In order to express trustworthiness in the range 0 to 5 we need to multiply Rel Corr$_{service}$ by a factor of '5'.

$$\text{Trustworthiness} = 5 * (\text{Rel Corr}_{service})$$
$$= 5 * ((\text{Corr}_{behaviour}) / (\text{Max Corr}_{behaviour}))$$

$$\dots (2)$$

Where,

$$\text{Corr}_{service} = (\text{Commit}_{space} * \text{Inf}_{space} * \text{Clear}_{space}) + (\text{Commit}_{days} * \text{Inf}_{days} * \text{Clear}_{days})$$

$$\dots\dots\dots(3)$$

$$\text{Max Corr}_{service} =$$

$$(\text{Max Commit}_{space} * \text{Inf}_{space} * \text{Clear}_{space}) +$$

$$(\text{Max Commit}_{days} * \text{Inf}_{days} * \text{Clear}_{days})$$

$$\dots\dots\dots..(4)$$

Therefore, expressing Trustworthiness (T) in terms of Commit criterion c, Clear criterion c , Inf criterion c we get the following equation:

$$T = 5 * \frac{\left(\sum_{c=1} \text{Commit}_{criterion\ c} * \text{Clear}_{criterion\ c} * \text{Inf}_{criterion\ c} \right)}{\sum_{c=1}^{N} \text{Max Commit}_{criterion\ c} * \text{Clear}_{criterion\ c} * \text{Inf}_{criterion\ c}}$$

$$\dots\dots\dots\dots(5)$$

Since the value of Max Commit$_{criterion\ c}$ is 5, we can write the equation above as:

$$T = 5 * \frac{\left(\sum_{c=1}^{N} \text{Commit}_{criterion\ c} * \text{Clear}_{criterion\ c} * \text{Inf}_{criterion\ c} \right)}{\sum_{c=1}^{N} 5 * \text{Clear}_{criterion\ c} * \text{Inf}_{criterion\ c}}$$

$$\dots\dots(6)$$

The trustworthiness value that we obtain using Equation 5 or 6 will be a real number in the range [0-5].

Note that Equations 5 or 6 is useful for rating services in a service-oriented network where a centralized trustworthiness system can take input from both parties involved in an interaction in order to determine the quality of service. This means that if the Trusted Agent did not agree with the Trusting Agent about the clarity of a criterion in the original agreement for an interaction, then that criterion would not be taken into account by the trustworthiness system when evaluating the trustworthiness of the Trusted Agent. Similarly, if the Trusted Agent felt that the importance of the criterion was not made clear to him prior to the interaction, that particular criterion would not be used for trustworthiness measure.

In a distributed peer-to-peer environment, where the peers maintain their own trust repositories for their own use, a modified version of equation 7 could be used. This is because the clarity of a given criterion would need to be determined from a Trusting Peer's perspective only. Therefore, if the Trusting Peer felt that all criteria had been conveyed very clearly to the Trusted Peer, then equation 6 could be written as follows:

$$T = 5 * \frac{\sum_{c=1}^{N} \text{Commit}_{\text{criterion c}} * \text{Inf}_{\text{criterion c}}}{\sum_{c=1}^{N} 5 * \text{Inf}_{\text{criterion c}}}$$

………………………..(7)

12.2 An Example

Let us consider the example of two logistics companies West Warehouse and East Logistics in an interaction where East Logistics is the Trusting Agent and West Warehouse is the Trusted Agent. West Warehouse enters into an agreement with East Logistics by which West Warehouse will provide a service as described by the table below

Context	Terms & Conditions	
Warehouse Space Booking	1	Space: Provide 6000 sq ft
	2	Days: Provide for 2 months

Table 3. Example of the Criteria in an interaction

Criterion c	Commit$_{\text{criterion c}}$		Inf $_{\text{criterion c}}$	Clear $_{\text{criterion c}}$	Corr $_{\text{service}}$	
	Actual	Max	Actual	Actual	Actual	Max
Space	4	5	5	5	100	125
Days	3	5	4	5	60	100
				Total	160	225

Table 4. Example of the different values of metrics

The above table shows the actual values for Commit $_{\text{criterion c}}$, Inf $_{\text{criterion c}}$ and Clear $_{\text{criterion c}}$ for each criterion. The table also shows the maximum possible scores for Commit $_{\text{criterion c}}$ and Corr $_{\text{service s}}$.

From the table we conclude that in this case:

Rel Corr$_{\text{service}}$ = Corr$_{\text{service}}$ / Max Corr$_{\text{service}}$ = 160/225

Therefore,

Trustworthiness = 5 * Rel Corr$_{\text{service}}$ = 3.5 (approximately)

This value of Trustworthiness corresponds to Trustworthiness Level 4 on our ordinal scale of Trustworthiness. According to the semantics for this level, the Trusted Agent (in this case, West Warehouse) is largely trustworthy.

13. Conclusions

It is envisioned by Bakos and Dellarocas (2002) that a substantial fraction of economic transactions are likely to render online trust and reputation systems into powerful quality assurance institutions in the social, economic and perhaps political environments. Such a technology trend deserves careful study and attention that will promote honest trade without requiring the threat of litigation.

The proposed CCCI methodology is an advanced trustworthiness measurement methodology that provides four metrics, and defines the maximum possible correlation value for a business service interaction

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Corr$_{service}$, and the maximum possible values of **Commit**$_{criteria\ c}$, **Clear**$_{criteria\ c}$ and **Inf**$_{criteria\ c}$. The relative correlation value is determined by the ratio of the correlation value and the maximum possible correlation value against trustworthiness scale, the user defined trustworthiness value in the range -1 to 5, the trustworthiness value is obtained by multiplying the relative correlation value by a factor of 5.

It is important to have a more sophisticated trust and reputation assessment method that provides complete and adequate information about business entities and the quality of products and services to the consumers and end users. Such a method will result in a positive impact in the networked economy.

14. References

[1] Abdul-Rahman, A. & Hailes, S., (2003), '*Relying on Trust to Find Reliable Information*', Available: http://www.cs.ucl.ac.uk/staff/F.AbdulRahman /docs/dwacos99.pdf (7/08/2003).

[2] Aberer, K. & Despotovic, Z., (2003), '*Managing Trust in a Peer-2-Peer Information System*', Available: http://citeseer.nj.nec.com/aberer01managing. html (11/9/2003).

[3] Bakos, Y. & Dellarocas, C., (2002) 'Cooperation without Enforcement?-A comparative Analysis of Litigation and n-line Reputation as Quality Assurance Mechanism'. *Proceedings of the 2*rd *International Conference on Information Systems (ICIS 2002),* Barcelona, Spain.

[4] Chen, R. & Yeager, W., (2003), '*Poblano: A distributed Trust Model for Peer-to-Peer Networks*', Available: http://www.jxta.org/docs/trust.pdf (20/9/2003).

[5] Cornelli, F., Damiani, E., Vimercati, S., De Capitani di Vimercati, Paraboschi, S. & Samarati, P., (2003), '*Choosing Reputable Servents in a P2P Network*', Available: http://citeseer.nj.nec.com/cache/papers/cs/2 6951/http:zSzzSzseclab.crema.unimi.itzSzPap erszSzwww02.pdf/choosing-reputable-servents-in.pdf (20/9/2003).

[6] Kamvar, Sepandar, D., Schlosser, M.T. & Garcia-Molina, H., (2003), '*The EigenRep Algorithm for Reputation Management in P2P Networks*', Available: http://citeseer.nj.nec.com/kamvar03eigentrus t.html (11/9/2003).

[7] Wang, Y., '*Bayesian Network -Based Trust Model in Peer-to-Peer Networks*'9

[8] Xiong, L. & Liu, L., (2003), '*A Reputation-Based Trust Model for Peer-to-Peer eCommerce Communities*', Available: http://citeseer.nj.nec.com/xiong03reputation based.html (9/10/2003).

[9] Yu, B. & Singh, M. P., (2002), 'Distributed Reputation Management for Electronic Commerce', *Journal of Computational Intelligence*, vol. 18, no. 4, pp. 535-549.