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Computation of Trust

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Abstract

Trust, a multi-faceted and context dependent subjective factor, is gaining prominence in the computer world for the virtue of shielding applications from deceptions. Numerous applications online and offline rely on trust-reputation system as a means for the propagation of trust. Trust which is determined as encompassment of personal experiences and reputation is propagated across the participants in an application through transitivity. Difference in the nature of applications and context dependency of trust make it impossible to have a universal trust propagation scheme. The dimension of challenges in establishing transitivity of trust remains unexplored. This paper discusses the changing face of trust determination based on the computational models. It structures the transitive propagation of bi-directional trust, explores the challenges of transitivity in unidirectional trust and proposes a solution for the same. Prominent applications are discussed and classified along the lines of trust propagation.

Keywords: Ecommerce, trust, reputation, reputation systems, trust propagation and transitive trust.

Introduction

With every advancement in the E-world, the life of people becomes easier and cozy. The world is so addicted to doing things over the internet, making it the most happening place. People collaborate passionately in trading communities, social networking sites or dynamic scientific communities in their own interest and risks. Trust, subjective probability with which an entity performs a particular action in a context, is quintessential for the beneficial interaction of people both in the real and virtual world. The brick and mortar presence guaranteed in the real world interactions gives it an edge over the e-world in determination of trust. For instance, a buyer in the real world accepts a product by virtue of the touch and feel which is deprived for an online buyer. And cyber world has proved not to be immune to deceptions and hence it is in its own interest to provide users a trustworthy collaborating environment. The initial step towards this venture is to allow a user to rate a service provider after each transaction. Thus, a service provider is bestowed with an aggregated rating which stands as a testimony for its good/bad behavior. The scheme performs well if all the raters are sincere and honest. This is not the case always, people with malicious interest flood the network with unfair ratings to draw personal benefits out of it. This paved way to the development of numerous sophisticated trust propagation mechanism. Each of them proposes a computational model of trust depending upon the context. Trust is multifaceted of which the predominant faces of trust are direct trust and indirect trust. And whatever be the face of trust, it is context dependent. Taking an instance from e-learning environments, an entity Alice may be competent in Artificial Intelligence but need not be generous to help slow learners. Here, the contents posted by Alice could be trusted but one should rely on her to clear doubts. This gives rise to two aspects of trust; trust-on-user, trust-on-context. A lot more colors have been added to the context of trust by the wide variety of applications ranging from social networking to distributed computing. At this juncture, it is important to note that in the context of collaboration of people, collaboration of peer to peer system is gaining immense significance and hence distributed computing. The structuring and classification of trust enables its better computation in different environments. In the light of the study done, we highlight that the knowledge of different faces of trust, computational models of trust proposed so far and the cognizance about the applications that use trust are very much significant to explore the higher realms of security. The contribution of the work in this paper are outlined as follows 1) Analysis of trust in different contexts 2)Categorization of trust based on computational model- trust propagation- and application 3)Exploration of trust propagation and challenges 4) Enhancement of transitive trust propagation to accommodate unidirectional trust based application. Outline of the paper is as follows; Section 2 describes the computation methodologies of trust computational Models and Section 3 explains the trust propagation, challenges and solution. Application models and their Categorization is presented in Section 4. With Section 5 paper concludes.

Changing Faces of trust Computation

Trust and Reputation

Trust is the estimation of probable behavior of a partnerentity, called as truster, in the future. The computation takes into account both personal experiences and recommendations from third parties. This facilitates trustees, those who seek the trust of an entity, to choose a trustworthy partner for interaction. Trustworthiness is highly context dependent Entities that cast recommendation about a target entity to trustees, are termed as recommenders whose honesty should be under strict checkup. Attackers use this role perfectly to subvert the system by inducing wrong recommendations. The aggregate of recommendations gathered forms the reputation of an entity. The induction of reputation in trust calculation is to facilitate trustees to choose a rightful partner in the absence of personal experience. On the other hand, entities will not interact with a new truster with zero or low trust value apparently because of the lack of interactions. This circumstance is termed as cold start problem. A solution for which is assigning a minimal trust value to the new comers which in turn would help the whitewashing attackers. Whitewashing is a technique used by the attackers where they vanish from the scenario once enough benefits are gained and reappear in a new identity. Hence the allotment of anacceptable trust value to cater new comers would be similar to opening a hole to patch up another. Trust and reputation along with the applications that use them have evolved along the time. In the light of this, we present different perspectives to trust and its computational models.

Types of trust

Decision trust–The extent to which a trustee wills to depend on a truster in a particular context, in spite of the awareness about the possibility of negative consequences. Considering this as an evidence for the general trusting attitude of a trustee, it is also named as '*dispositional trust'*.

Reliability trust/ interpersonal trust - The subjective probability by which a trustee expects that the truster behaves in a given context on which its welfare depends. It has two different variations based on the type of estimation. If the trust is determined relying on the personal experiences alone it is called as *direct trust*. The absence of personal interactions would result in soliciting recommendations. And the trust build on peer recommendations, called as *indirect trust*, banks on trust propagation.

Computational methods [7]

Reputation systems determine the trust of an entity based on the feedbacks given by the entities that have partnered with it. These feedbacks are in the form of ratings or reviews are collected, aggregated and disseminated to the public to enable decision making purposes. The aggregation method vary among the reputation systems. Here is an attempt to list the major methodologies followed-

- Simple summation or average of ratings: The simplest of the methods followed works with binary ratings, where a '1' indicates a positive feedback and a '0' stands for a negative feedback. The number of positive and negative ratings are enumerated. And in simple summation technique the count of

negative ratings is subtracted from that of the positive ratings (e.g., eBay). Another way is to take the average of the counts (e.g., Epinions and Amazon).

- Bayesian systems: Ratings towards an entity are fit in to a probability density function (PDFs) mostly the Beta Reputation System. The expectation of the distribution stands for the reputation of the corresponding entity.
- Fuzzy models: A rule based system following the approach of learning theory. Functions are used to describe to what degree an entity can be described as trustworthy or not. It translates the human expert's knowledge to some rules. Consider a situation, where A wants to buy laptops. She seeks recommendations from her acquaintances and B provides the same. The decision to take B's opinion into account depends on different aspects; 1)B's interest in laptops 2) B's recent purchase which should is at most a few weeks ago 3) Trust of A on B. An instance of rule goes like this, IF the rating is provided recently, and the similarity between the witness and the truster is high, and the witness is confident in providing ratings, THEN the rating's weight is very high.
- Flow models: Reputation is a measure of flow of data. It increase with incoming flow and decreases with outgoing flow. (e.g., Google's Page Rank, Advogato). For instance, Page Rank of a web page increases when there are many hyperlinks to that page and the same reduces when many hyperlinks are from this page.

Trustpropagation

Transitivity of trust

Considering every new transaction sets a path, a directed path from service requester to service provider, between the partnering entities, which essentially stands an evidence for acquaintance' service trust encompassing personal experience and recommendations. Every further transactions strengthens / lightens the trust value. In the absence of an established path when an entity wants to check how far the complementing entity can be relied on, it traverses trusted paths to the 'stranger' entity through its acquaintances. This act could be termed as gathering recommendations. An aggregate of these recommendations is taken to make a decision of whether to build a new path or not. It is comprehensible that all the transactions put together form a directed graph. In the light of this, we explain trust propagation. *The act of passing trust value on an acquaintance entity to an entity which seeks it for building an indirect trust on the former*. Recommender entities that contribute their trust values to trustee are awarded a 'recommender trust' value according to their loyalty. An entity would wisely choose its recommenders based on the recommender trust value. If no recommenders are there for a stranger entity it would garner recommendations from its acquaintances on the basis of their service trust. Trust propagation is explained further in the plot of file sharing systems. Consider a file downloader entity 'A' which needs to collaborate with another entity 'C'. Suppose that A does not have any previous experience with 'C'. Hence there

arise a need to find a trusted path from A to C. ie 'A' finds an entity 'B' such that 'A' has direct trust on 'B' and 'B has the same on 'C'. 'B' was an uploader of 'A' and downloader of C and thus 'A' trusts 'C' through 'B'. Figure 1 depicts transitive propagation of trust.

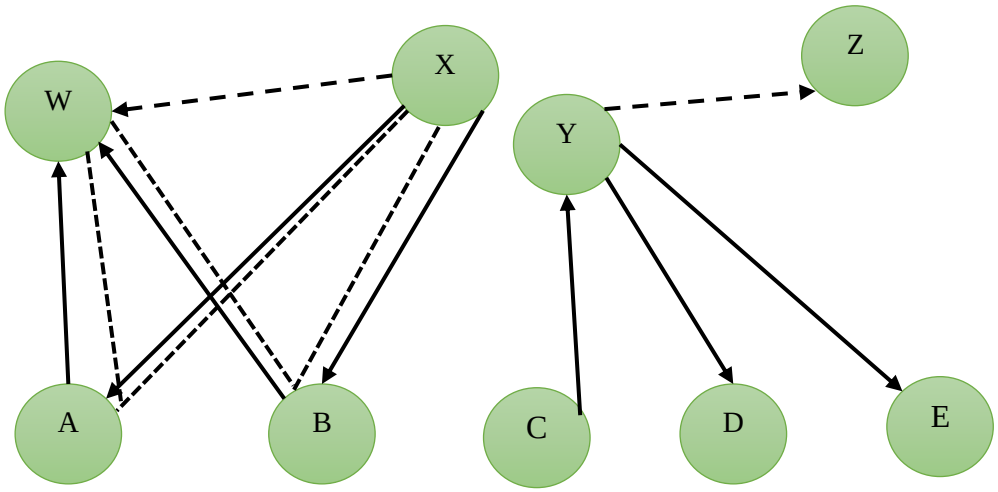

Figure 1: Trust Propagation

Table 1: Symbols used in Fig.1 and their meaning

Symbols	**Meaning**
X	Entity present in a transaction
⟶	Acquaintanceship. Arrow head points to the provider and tail beholds the requester
- - →	Would be acquaintanceship. Arrow head points to the provider which is a stranger and tail beholds the requester.
------	Trust propagation path that is traversed to establish a transaction. If such a path is non-genuine or absent would be acquaintanceship is discarded. Transaction would not happen.

In Fig.1 '*X*' has been provided service by '*B*' and '*A*'. They in turn have acquaintance with '*W*'. Now, '*X*' needs a service from '*W*', which is a stranger. '*X*' tries to find a trusted path. It has two paths – one through '*A*' and other through '*B*'. ie '*A*' and '*B*' share their experience with '*W*' as recommendation to '*X*'. The decision of '*X*' to convert the possibility to an acquaintance depends on the 'recommender trust' of '*A*' and '*B*' as well as the reputation- collective reputation- of '*W*'. Taking into consideration '*Y*' and '*Z*'. '*Y*' needs a service from '*Z*' but there is no trusted

path between them and hence no recommenders. At this juncture, '*Y*' can either discard '*Z*' or take a chance based on its necessity.

Challenges In Transitive Trust

Propagation of trust through transitivity is enabled only when transactions are bidirectional iewhen entities act as service providers and service requesters at different contexts. According to the scenario, only a service provider can give recommendation, which it gives only when the 'target entity' is an acquaintance, implying that the service provider has been facilitated by the target. The challenge comes in certain applications that sticks to unidirectional transaction. For instance, in product rating sites, a transaction is, 'rater rating product'. It is apparent that a rater never takes the role of a product and vice versa. Hence, trust propagation using the established transitivity without any modification is worthless. Figure. 2 depicts trust propagation in a unidirectional transaction.

In Fig.2 '*W*', '*X*', '*Y*' and '*Z*' are servers or service providers. '*A1*', '*A2*', '*A3*', '*A4*' and '*A5*' are clients or service requesters. Symbols have the same meaning as in Table 1. A_is provide service and there is absolutely no interaction among them. Consider '*X'* which seeks reputation of '*A2*', a stranger. Before making the choice, '*X*' has to pool the reputation of the same. '*A1*' is an acquaintance of '*X*'. '*A1*' and '*A2*' are acquaintances of '*Y*'. Here we exploit the commonalities of '*A1*' and '*A2*', acquaintanceship with '*Y*', to give it a shade of relationship. '*A1*' being an acquaintance of '*X*' is made responsible to be a recommender of '*A2*' to '*X*'. '*A1*' cannot recommend in its capacity as it has no interaction with '*A2*'. Now, the recommendation of on '*A2*' is gathered from '*Y*' and '*A1*' bears the propagation ie recommendation from '*Y*' is garnered through '*A1*'. We bank on the trustworthiness that '*A1*' has on '*Y*' in its capacity to provide service.

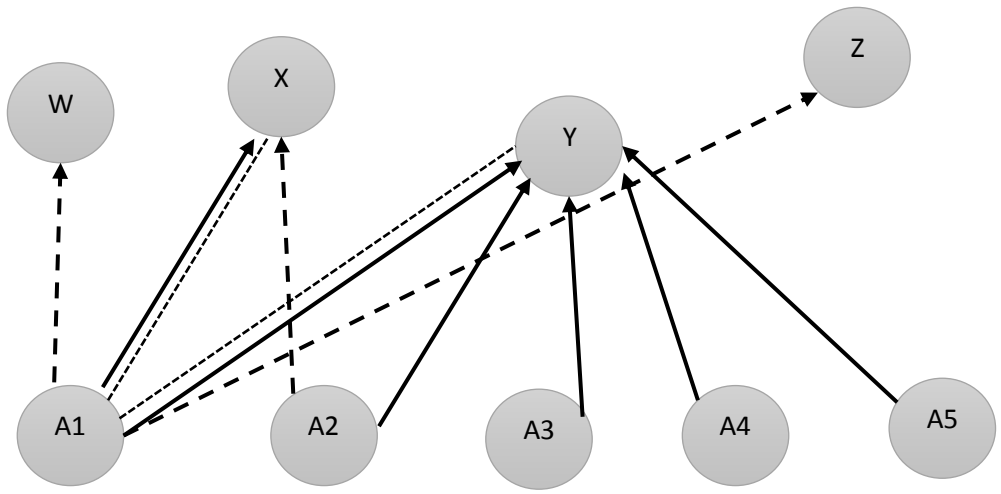

Figure 2: Trust propagation in unidirectional transaction

The significance of developing a modified trust propagation mechanism comes in applications like product rating. Here, providers are raters and clients are products.

Service is rating and it is available without any requesting. Apparently, a rater never assumes the role of a product, there is a clear division between the actions performed by each of them. Trust propagation presented in Fig.2 could be directly applied to this scenario.

Trust and Its Applications

Trust is a subjective factor which is built with the bricks of past. It was adopted as a new member of the security pillars with the realization that the existing security measures are futile against 'deceptions' in virtual environment. There are numerous applications that rely on trust-reputation systems of which a few quintessential ones are discussed here.

Application Models

Collaboration network

Information sharing over the web forms the basis of many ethnic communities. They collaborate in the account of education, business and even significant scientific research. It is quite understandable that parties in the interaction does not treat every peer equal. And also they have a varying taste of interaction. Some of the entities stay active in the network by giving and taking but certain others stay aloof. By and large, it is a moving crowd and very few remain stay alive throughout. For instance, in scientific research communities, there would be people falling into categories listed here [colon]

- People who gets updated by participating passively in forums and provide nothing.
- People who gets updated, participate actively in forums to help others and provide nothing significant to research.
- People who gets updated, participate actively in forums to help others and contribute something to research.
- People who contribute best findings but refrain them from helping others.

This categorization of people throw light into one fact. There is hardly any person who is trusted across the situation, the very reason being the nature of humans. A person belonging to the last category could be highly trusted for the content posted by her. But it will be a 'false positive' when the same person is relied upon in discussion forums by virtue of her findings.The fact that trust is context dependent finds strength here.

Distributed Computing

Distribution of resources for security purposes and distribution of computationfor better performance have become a norm in the recent past. To meet the growing needs of people organizations resort to distributed computing. And the induction of trust is

to tackle the wide avenue for manipulation. The participant nodes generally donothave any problems except for the hardware faults that result in unavailability of systems. This is the case when the environment is devoid of adversaries which is almost impossible in real world scenario.A node under the control of an adversary would be available but would have corrupt resources. Hence it becomes very important to evaluate the trustworthiness- the extent to which the resources/ computing provided is correct- of an entity along with availability.Trust, in this scenario, is mostly bidirectional.

Ecommerce

The absence of interpersonal trust in online trading makes it vulnerable to delusion. Buyers and Sellers conduct trade through e-meetings where Buyer is deprived of examining the product. Considering the wide avenue for manipulation that an e-market is prone to, it is not advisable for the entities to trust each other blindly. Hence reputation systems are used as a means to propagate trust. After every transaction the participating entities rate each other. The cumulative ratings show the overall trustworthiness of an entity in the online environment.

Product Rating

An important dimension in Ecommerce- 'product rating'- propagates the trustworthiness of products sold online. With the advent of Ecommerce consumers are vested with infinite choice of products. The vastness of trade arena opens ample possibilities for malicious people to deceive gullible laymen. This poses a threat to the existence of business by destroying the trust of people on online business. Hence, it is in the interest of sustainable business that product rating system has evolved. Every person is allowed to cast ones opinion soon after the purchase of a product. The collective opinions form the reputation of a product thus helping laymen to choose a product from infinite possibilities.

Categorization of Application Models

Application models presented in section 4.1 are classified on the basis of the trust propagation (unidirectional / bi-directional) along withexamples.

Table 2: Application Models and Trust Propagation

Application Model	Type of Trust Propagation	Example
Collaboration Network	Bi-directional	Epinions
Distributed Computing	Bi-directional	Gnutella
Ecommerce	Bi-directional	eBay
Product Rating	Unidirectional	Amazon

Conclusion

The paper elaborates the significance of establishing trust as an additional layer of security to guard applications / systems/ people from deception.Trust being multi-

faceted, the different perspectives to trust is discussed. There exist numerous computational models of trust of which the major ones are presented.Trust, encompasses personal experiences combined with reputation garnered andevolves with interactions. Garnering reputation banks on the transitive nature of trust which works efficiently for applications generating mutual trust. An enhancement to the existing scheme is required to build transitivity in unidirectional trust based environment. Transitive trust propagation in bi-directional trust system has been structured. Challenges in establishing transitivity in unidirectional environment is explored and an efficient solution has been proposed by an enhancement in the structured model. A few important applications among the wide variety of application model that rely on trust-reputation system to propagate trust online have been discussed. With the insight that classification of applications based on the nature of trust propagation (unidirectional/ bidirectional) would help in computation of trust, a categorization of these models based on the trust propagation scheme is presented.

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