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Modeling "Web of Trust" with Web 2.0

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***Abstract*—"**Web of Trust" is one of the recognized goals for Web 2.0. It aims to make it possible for the people to take responsibility for what they publish on the web, including organizations, businesses and individual users. These objectives, among others, drive most of the technologies and protocols recently standardized by the governing bodies. One of the great advantages of Web infrastructure is decentralization of publication. The primary motivation behind Web 2.0 is to assist the people to add contents for Collective Intelligence (CI) while providing mechanisms to link content with people for evaluations and accountability of information. Such structure of contents will interconnect users and contents so that users can use contents to find participants and vice versa. This paper proposes conceptual information storage and linking model, based on decentralized information structure, that links contents and people together. The model uses FOAF, Atom, RDF and RDFS and can be used as a blueprint to develop Web 2.0 applications for any e-domain. However, primary target for this paper is online trust evaluation domain. The proposed model targets to assist the individuals to establish "Web of Trust" in online trust domain.

***Keywords*—**Web of Trust, Semantic Web, Electronic Social Networks, Information Management

I. Introduction

W3C's current mission is to lead the Web to its full potential by developing technologies (specifications, guidelines, software, and tools). Such technologies aim to create a forum for inspiration, information, independent thought, commerce, and collective understanding. W3C has explained its goals and operating principals in following points [1]:

A. Universal Access

W3C defined Universality as the universe of network-accessible information, available through computer, phone or television etc. Universality aims to benefit the society by enabling new innovative forms of human communication and new opportunities to share and exchange knowledge. It is W3C's primary goal to make information contribution and exchange available to all people, irrespective of their hardware, software, network infrastructure, language and geographical location. For this objective W3C aims to store and process information in text format such as XML.

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B. Semantic Web

Individuals currently share their knowledge on the Web in language intended for other users. Semantic Web aims to assist the web users to contribute information in ways that computers can understand, process and exchange. This will enable the web applications to perform tedious task of collating information from varied sources. And also assist users to find relevant information, such as, a movie review, scholarship posting for specific students, a book order, etc., quickly. The Semantic Web applications will use languages like Resource Description Framework (RDF) [1], Extensible Markup Language (XML) [2], XML Schema [3] and RDF Vocabulary Description Language 1.0: RDF Schema (RDFS) [4].

C. Web of Trust

Unlike magazines, Web is a collaborative medium that enables the individuals to contribute, access, and share contents. To further assist users to contribute more and to increase cooperation, W3C aims to develop a "Web of Trust". Initiatives like Friend of a Friend (FOAF) [5], RDF and XML signatures, etc, espouse the aim to achieve Web of Trust.

D. Interoperability

Interoperability of data not only greatly increases its exposure to general users but also impacts users' confidence. W3C is a vendor-neutral organization and promotes open (non-proprietary) computer languages and protocols to avoid market fragmentation. Examples of such languages include XML and RDF etc.

E. Decentralization

One of the great advantages of Web infrastructure is decentralization of publication. Decentralization is a principle, based on modern distributed systems, including communities and societies. Centralized systems are more prone to attacks and are not fail safe, as every message passes through a central authority that can cause bottlenecks when the traffic increases. Therefore W3C aims to promote decentralized publications, content processing and sharing. Technologies like Really Simple Syndication (RSS) [6], Atom [7], Blogs [8] and Wikis [9] are developed and proposed to support this purpose.

From the above, it is derived that the next Web ("Web 2.0") will revolve around technologies that will link the physical world with the electronic one within the social network domain so that users can be facilitated to contribute more.

W3C vision for future Web is to aim for social integration, user-contributed content, user-generated metadata, transparent business processes and decentralized and participatory products and processes [10].

Reference [11] proposed that Web 2.0 (in future) would lead to 'Internet Singularity'. Reference [12] defined it as "the idea that a deeper and tighter coupling between the online and offline worlds will accelerate science, business, society, and self-actualization." (pp. 5). He also stated, "as time goes on, the Internet's content, composition, and participants more accurately reflect the physical world" (pp. 27).

In future web systems, trust will be the main synthetic force, as it is in the present physical environment. Trust based online merchants, independent rating systems, trusted peer to peer networks and personal electronic social networks will play major role in re-shaping the way business is conducted in the e-environment. Therefore, this paper concentrates on establishing Web of Trust in the domain of trust evaluation in e-commerce by using Web 2.0 technologies.

This paper proposes a conceptual Web based model that uses FOAF, Atom, RDF and RDFS. The proposed model uses a unique blend of these technologies to assist online users to make decisions while committing electronic transactions, on the basis of initial trust evaluations contributed by individuals. A trust evaluation model proposed by Mahmood [13] is selected, as it clearly outlines the structure of metadata and provides a comprehensive mathematical model to generate the contents.

II. Trust in E-Commerce

Recently trust has been recognized as one of the main factors affecting electronic commerce. According to WISTA International E-Commerce Survey [14], trust (26%) is the most important barrier to electronic commerce in 27 surveyed countries. The survey recognized "trust as significant stumbling block in electronic commerce development, due to the fact that electronic commerce is global and its international reach means that participants must deal with unknown or anonymous individuals and companies" (pp:10). The WISTA survey also identified payment security (25%), trust in infrastructure (17%) and information privacy (15%) as the most important trust related issues for acceptance of electronic commerce. The survey established the impact of trust in electronic commerce (strongly 42%, moderately 35%).

A. Social Aspects Influencing Online E- Trust

Online initial trust establishes a connection between electronic social networks and e-commerce. For this purpose, the physical social components are identified that are present in electronic environment, and affect electronic commerce.

The two known physical social components that exist in the electronic environment and impact user's decision in committing online transaction are discussed below.

1. Trusted Referrals

Information regarding a product, physical or online business acquired from either the user's physical, or the online trusted social network impacts the user's initial and subsequent levels of trust in an online business. The impact is directly associated with the user's level of trust in the information source, in terms of source's credibility, honesty and ability. Trusted referrals [15] "are the primary means of disseminating market information when the services are particularly complex and difficult to evaluate. This implies that if one gets positive word-of-mouth referrals on e-commerce from a person with strong personal ties, the consumer may establish higher levels of initial trust in e-commerce" (pp. 538). Reference [16] defined that the user's belief on information accuracy and certainty conveyed in the information, form the level of trust in the information source.

2. Online Reputation

In the absence of trusted referral or past experience, online reputation can be one of the crucial factors for the user to establish relations with online service providers. Zacharia states "reputation is usually defined as the amount of trust inspired by a particular person in a specific setting or domain of interest" [17] (pp. 163). Online reputation regarding an e-business is built by collating the past experiences of the users who have previously interacted with the same service provider. This technique in the form of reviews, feedback and point ratings, is used by several online auction sites like eBay.com and some web retailers like Amazon.com to enhance user's level of trust on web merchants. However, in such circumstances the users' level of trust in the information source plays a decisive role.

In an empirical study by Sarah et al. [18] it was identified that most users would give high value to the previous customer endorsements, even more than third party affiliation, to judge the ability of the web merchant. In the study 80% of the respondents reacted positively to establishing trust on online merchant, due to the positive feedback from the previous customers.

Two recognized social electronic components that link together the electronic social network with the electronic commerce are trusted referrals and online reputation.

III. Initial Trust Evaluation in Electronic Commerce

Reference [14,19] proposed a mathematical model to evaluate trust in the electronic environment, which comprises of trust in the electronic transaction and the online party or e-business. The trust in online business is further subdivided into subjective probabilities consisting of trust in the business's performance and honesty. The user's perceived trust in transaction includes exchange of funds. The following figure (see Fig. 1), adopted from the selected trust evaluation model; outlines the involved dynamics of trust in an electronic transaction:

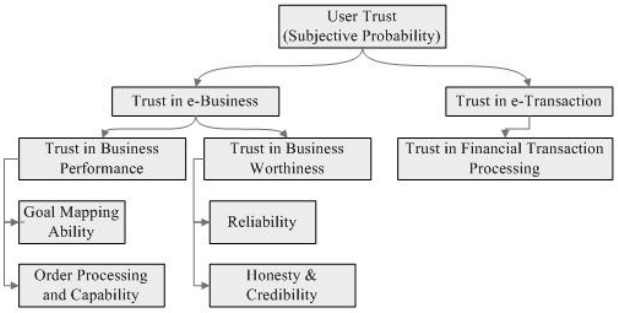

Fig. 1 Trust evaluation dynamics [14]

The author proposed to use the following mathematical equation to determine the worthiness of an electronic transaction for an online service.

$$WoI = \left(\left(\frac{w_{bp} + w_{bh}}{w_p + w_h} \right) - rw_{ui} \right) * 100 \quad (1)$$

Where

WoI = worthy of investment

w_{bp} = weighted trust in business performance

w_{bh} = weighted trust in business honesty

rw_{ui} = the ratio of weighted probability of losing uninsured investment

All the above used weighted values are computed as follows:

Weighted trust in business performance (w_{bp}) = $p_b * w_p$

Weighted trust in business honesty (w_{bh}) = $p_h * w_h$

While rw_{ui} is computed as $\frac{(1 - p_t) * f_{ui} * w_t}{m_{wt}}$

Where

p_t = subjective probability of financial transaction processing

w_t = subjective weight of financial transaction processing

m_{wt} = represents the maximum weight which can be assigned to financial transaction processing. 'm_{wt}' will always be 10

f_{ui} = fraction of uninsured investment. Which is computed as $\frac{t_i - i}{t_i}$ where t_i = total investment and i_i is insured investment amount

To compute Worthy of Investment value for each online transaction, Mahmood (ibid) proposed to use a browser plugin so that the user can enter necessary data in order.

IV. Linking Trust Evaluations with Contributors and Social Network

The trust evaluation model proposed by [14] lacks in W3C vision for Web 2.0. The conceptual web model proposed here targets to enable the online users to establish "Web of Trust" by enabling individuals to store and share subjective probabilities, weights and transaction values in such a manner that the contributed information can be validated, exchanged and processed automatically. The proposed model is divided into following main modules.

A. Social Integration

Friend of a Friend (FOAF) is a Resource Description Framework (RDF) Vocabulary. It has been utilized to store, share and represent social arrangements of the individuals, businesses and corporations. The FOAF vocabulary is identified by 'http://xmlns.com/foaf/0.1/' namespace. It enables the individuals and the organizations to participate in creating an open network of their trusted friends including both individuals and organizations.

The FOAF project looks into ways to use machine readable and parseable web pages for people, groups, companies and web applications.

B. Information Sharing

Atom Syndication Format 1.0 (Atom) has been selected for information sharing, which is an XML language used for web feeds. The two obvious choices are RSS and Atom, however Atom 1.0 is the preferred choice as it is defined within XML Namespace, it uses Atom Publishing Protocol (APP)that is IEFT draft protocol, and its syndication format is published as an IETF standard in RFC 4287 [20].

C. Representing, Linking and Exchanging Evaluations

RDF is the language of next Web, enabling Semantic Web vision, therefore user's trust evaluations, information storing, representing and sharing, will be conducted using RDF and RDFS schema. The model proposes to engineer a new RDF Scheme for this purpose. The new schema targets to use Dublin Core defined elements, IANA and W3C Standards and ISO standards. The possible use of standards include ISO8601:2004 [21] for date format, ISO639-2 [22] for language definition, DCMI Vocabulary [23] for genre of the resource, ISO4217:2001 [24] for currency code specification and IANA media types [25] for service output.

V. Linking FOAF and Trust Evaluations

The proposed model makes use of Web Feeds to exchange and share information. Web Feeds support decentralized information processing and collating architecture. As a consequence, the model uses Atom 1.0 documents as the main linking point between the contributor, contributor's social network and the contributions. The proposed Atom document structure is as follows:

A. User Contribution

Feed element provides description of the Atom document

and author's related information. The 'updated element' is used to specify the date and time for the last time the Atom document was updated. .

B. Social Representation

The 'entry element' within 'feed element' is used to represent User's each category of FOAF. Within entry, 'category element' is used to specify the type of the entry. It has 'term attribute' which specifies the type of document such as "FOAF" and 'scheme attribute' which points to namespace such as 'http://xmlns.com/foaf/0.1'. Moreover a link to FOAF document is also embedded inside the 'entry element' and 'application/rdf+xml' is assigned to 'type attribute' for the ease of processing. Besides above 'updated element' is used to specify the last update and 'published element' is used to specify the publication/creation date and time of the FOAF document.

C. Structured Trust Evaluations

'User online trust evaluation' RDF document is also linked with Atom by using 'entry element'. Within entry, 'category element' is used to specify the type of the entry such as "TrustEvals" is specified as the value of 'term attribute' and 'scheme attribute' points to "TrustEvalsSchema" document. Moreover a link to "TrustEvals" document is also embedded inside the 'entry element' and 'type attribute' is set to 'application/rdf+xml' to assist auto-processing. Similar to FOAF, 'updated element' is used to specify the last update and 'published element' is used to specify the publication/creation date and time of the corresponding "TrustEvals" document.

The Fig. 2 outlines the connections between FOAF and "TrustEvals" documents and the user through the user's Atom document.

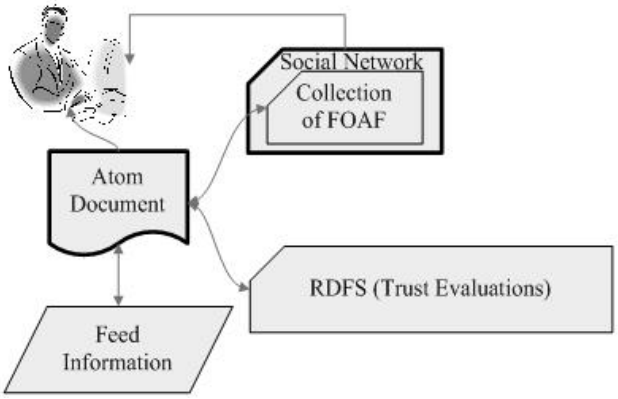

Fig. 2 Interconnecting the Atom, trust evaluations and user's other contributions

VI. Use of FOAF for Social Networking

The FOAF document is divided into Group and Person segments. The Person segment is used to provide brief information about the author and to link to author's Atom and 'TrustEvals' document. In the group segment after specifying group name and member element, the Person class of FOAF namespace is used to specify information regarding each member of the group. For each Person class, Document class is used to specify a link to "TrustEvals" and Atom documents of each member. This ensures backward linking between FOAF and Atom documents.

The figure given below (see Fig. 3) presents an example scenario where the user's FOAF document is used to connect two people. This FOAF link also enables the user to access other users' Atom and "TrustEvals" documents, where each "TrustEvals" document provides trust evaluation information on multiple e-merchants. Each Atom document is structured to refer to "TrustEvals" and multiple FOAF documents, therefore the search can be performed recursively.

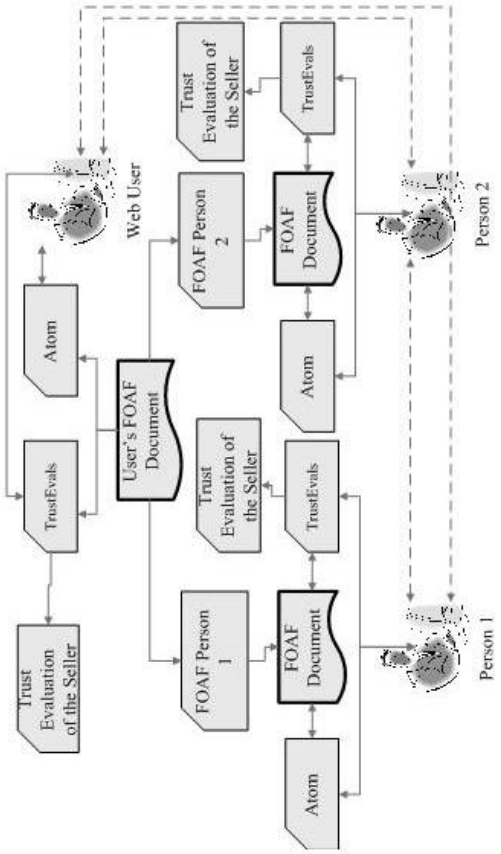

Fig. 3 Connecting trust evaluations with Atom and FOAF

VII. Encrypting Personal Contents

Web is an open place and generally users do not want to share their personal information with public e.g. a user may want to share his/her name, home page information and picture publicly, but wishes to restrict access to phone contact details to certain limited individuals. For such situations, the user can use PGP utilities like OpenPGP [26] to encrypt and sign private contents of "TrustEvals" and/or FOAF documents by using public key.

The user's private key can only decrypt contents encrypted by PGP. The user can then publish the encrypted and signed RDF GPG documents publicly, by linking them with "TrustEvals", Atom or FOAF documents with the help Web of Trust namespace [27]. This encryption and linking methods enables the user to distribute the private key to the desired individuals so that only they can decrypt the encrypted signed documents.

VIII. Feasibility of the Framework

The proposed model is based on decentralized architecture and no central server is required for participants' registration, aggregation and for processing of contributed contents. Any use of centralized server would be against the philosophy of Web 2.0 and the application would also lose the great advantage of Web's ability in enabling decentralized publication. Since the collection, linking and processing of information is completely distributed, the proposed architecture is failsafe and robust.

IX. Information Flow

The proposed model targets to achieve "Web of Trust" therefore it is recommended to implement the model as a browser plugin, to enable greater adoption and for ease of use. The conceptual diagram (see Fig. 4) outlines the sequential flow of information between the application and the user.

Only when the plugin is active, it will check for current e-merchant's trust evaluation information from the user's "TrustEvals" document. If the information is available in the user's "TrustEvals" document (step 2), then it is displayed to user (step 3i). The user then uses the displayed trust evaluations to evaluate current transaction.

In situations when there is no data on the current e-merchant in the "TrustEvals" file (step 3ii), then the user is prompted to make trust evaluations and enter the data (step 4). If the user feels confident in making evaluations and enters the trust data then the user's "TrustEvals" and Atom documents are updated (step 5). However, if the user feels confused (step 6) then a query is submitted to the user's FOAF social network (step 7). Once the search is complete, the trust evaluation data is gathered (step 8) and displayed to the user (step 9). At this point the user evaluates the collected evaluations and determines to either accept or change these before adding a new record to "TrustEvals" document (step 11).

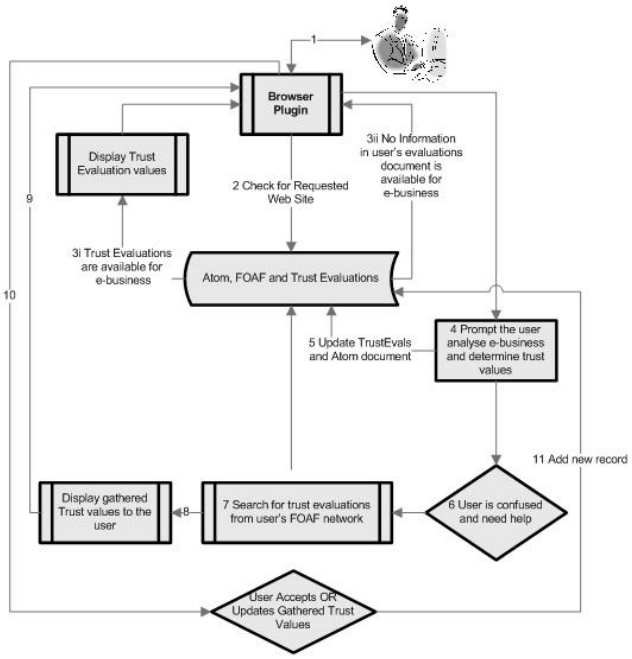

Fig. 4 User interaction and data flow

X. Conclusion

The proposed model makes use of decentralized information storage and retrieval structure, while keeping the contents and the people interlinked. The architecture uses Web 2.0 technologies such as, Atom, FOAF, RDF and RDFS for data storage, representation, processing and sharing. The model proposes to apply RDFS to engineer an online trust evaluation RDF language. The components and architecture of this model conform to Web 2.0 standards and target to assist the participants in committing online transactions by enabling the user to collate information regarding trust evaluations and contributor. The architecture establishes a strong link between the contents and people thus easing the development of open "Web of Trust" linked with participants' social network representation.

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