A short survey of quantitative and qualitative trust management methodologies

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Introduction

- Trust management is turning out to be essential for new ubiquitous computing paradigms ranging from agents to SOA.
- This short survey gives methodologies that are used for trust management, and range from
  - quantitative ones (Bayesian statistics based ones, Dempster Schaffer based ones, game-theoretic based ones) to
  - qualitative ones (qualitative assessment dynamics - QAD).

Introduction

- The survey presents the basic principles of each methodology, its shortcomings and its advantages.
- It all started actually with imprecise (wrong?) understanding of trust phenomenon – the initial solutions were actually security related.
- Roughly a decade ago the core of trust phenomenon started to be addressed.
- The need for a new perspective in IT?

What is trust?

- Defining trust first:
  - Trust is assured reliance on the character, ability, strength, or truth of someone or something (Merriam-Webster dictionary).
  - **Trust is an assessment that is driven by experience, shared through a network of people interactions and continually remade each time the system is used (prof. D. Denning in 1993).**

First efforts were about security

- In the nineties first trust management related solutions were about security.
  - W3C: Platform for Internet Content Selection (PICS), which was about access control (web-sites filtering).
  - AT&T: PolicyMaker, which was about bounding access rights to the owner of a public key, whose identity was bound to this key through a certificate (similar was IBM's Trust Establishment Module that enabled trusting relationships between unknown entities by using PKI).

Quantitative methodologies

- Commercially deployed approaches.
  - As to trust management, businesses today mostly use reputation systems, which are a kind of socially derived trust estimate systems.
  - These systems collect positive and negative responses, and present the difference in absolute terms or in relative terms (eBay, Amazon).

Quantitative methodologies

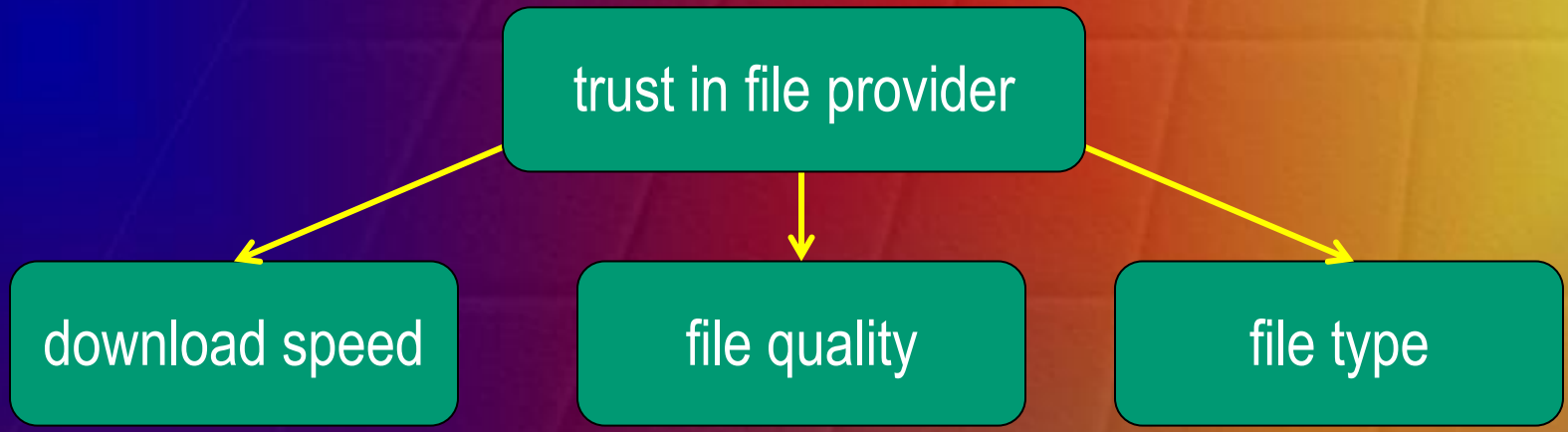
- Commercially deployed approaches.
  - Pro: easy to understand (in principle) and easy to implement.
  - Contra: aggregated values prevent pondering, more sophisitcated analysis is hard to implement, temporal dynamics can not be applied applied for estimates, the reference is very broad (a problem of context), …, last but not least, they are dealing with a derivative of trust, not trust.

Quantitative methodologies

- Bayes theorem based approaches.
  - Naïve trust management [Wang, 2003] - the posterior probability of a hypothesis *H* after observing datum *D* is given by *P*(*H* | *D*) = *P*(*D* | *H*) * *P*(*H*) / *P*(*D*), where *P*(*H*) is the prior probability of hypothesis *H* before datum *D* is observed, *P*(*D*|*H*) is the probability that *D* will be observed when *H* is true, while *P*(*D*) is the unconditional probability of datum *D*.

Quantitative methodologies

- Bayes theorem based approaches.
  - Naïve trust management example – P2P:



  - Every agent developes a Bayesian net for each file provider – this network has a root node *T* (*T*=1 satisfying, *T*=0 unsatisfying).

Quantitative methodologies

- Bayes theorem based approaches.
  - Naïve trust management example – P2P:
  - The percentage of satisfying interactions is given by

$$p(T=1) = m / n,$$

where m is the number of satisfying interactions, and n the number of total interactions.

  - As expected: $p(T=1) + p(T=0) = 1$

Quantitative methodologies

- Naïve trust management example–P2P:
  - Let $p(FT=\text{“}music\text{”} \mid T=1)$ denote the conditional probability that measures the probability that the file involved is music, given that interaction is satisfying.
  - Let $p(FT=\text{“}music\text{”}, T=1) = m_1/n$ be the prob. that interactions are satisfying and files involved are music files (m_1 is the num. of satisfying interact. when music is involved).
  - In line with a definition of cond. probability:

$$p(FT=\text{“}music\text{”} \mid T=1) = p(FT=\text{“}music\text{”}, T=1)/p(T=1)$$

Quantitative methodologies

- Naïve trust management (Bayes):
  - Pro: in principle understandable (at least to those with a knowledge of advanced mathematics), easy to measure.
  - Contra: for many users too advanced mathematics is needed for proper interpretation, …, and last but not least, it is about probability, not trust itself.

Quantitative methodologies

- Dempster - Schafer ToE [Schafer,1976]:
  - ToE bisis is a set of possible states, called a *frame of discernment* Θ.
  - Within Θ, exactly one state is assumed to be true at any time -- if a frame of discernment is given by atomic states x_1 and x_2, and a compound state $x_3=\{x_1, x_2\}$, this means that $\Theta = \{x_1, x_2, \{x_1, x_2\}\}$.
  - In case of trust, $\Theta = \{T, \neg T\}$ (T means target is trustworthy, while $\neg T$ means target is untrustworthy).

Quantitative methodologies

- Dempster - Schafer ToE [Schafer,1976]:
  - A *basic probability assignment* (*bpa*) is a function m: $2^{\Theta} \rightarrow [0,1]$, where $m(\varnothing) = 0$, and

$$\sum_{A \subseteq \Theta} m(A) = 1$$

(the latter condition for the above frame of discernment means that $m(\{T\}) + m(\{\neg T\}) + m(\{T, \neg T\}) = 1$).

Quantitative methodologies

- Dempster - Schafer ToE [Schafer,1976]:
  - Now for a subset $A \subseteq \Theta$, the belief function *bel*(*A*) is defined as the sum of the beliefs committed to the possibilities in *A*, e.g. if *A* = {*T*, ¬*T*}, then *bel*(*A*) = *m*({*T*}) + *m*({¬*T*}) + *m*({*T*, ¬*T*}).
  - For one-element sets (in our case {*T*} and {¬*T*}), *bel* and *m* are equal. For example, assume that *m*({*T*}) = 0.7, *m*({¬*T*}) = 0, and *m*({*T*, ¬*T*}) = 0.3. Then *bel*({*T*}) = *m*({*T*}) = 0.7, and *bel*({¬*T*}) = *m*({¬*T*}) = 0.

Quantitative methodologies

- Subjective algebra [Jøsang, 2001].
  - This algebra preserves mathematically sound basis (i.e., ToE), and enhances it by introducing trust related operators:
    - equivalents to traditional logical operators and
    - new ones like recommendation and consensus.
  - An opinion ω modeled with a triplet (*b, d, u*), where *e*ach of these elements gets its continuous values from the closed interval [0, 1], such that $b + d + u = 1$.
  - PS: Note relation to $A = \{T, \neg T\}$, $bel(\{T\})$ and $bel(\{\neg T\})$ on the previous slide.

Quantitative methodologies

- Subjective algebra [Jøsang, 2001].

$$b(x) = \sum_{y \subseteq x} m(y), \qquad d(x) = \sum_{x \cap y = \emptyset} m(y), \qquad x, y \in 2^{\Theta}$$

Let A and B be two agents where $\omega_B^A = \{b_B^A, d_B^A, u_B^A\}$ is A's opinion about B's recommendations, and let p be a binary statement, where $\omega_p^B = \{b_p^B, d_p^B, u_p^B\}$ is B's opinion about p expressed in a recommendation to A. Then A's opinion based on B's recommendation is defined by

$$\omega_p^{AB} = \omega_B^A \otimes \omega_p^B = \{b_p^{AB}, d_p^{AB}, u_p^{AB}\},$$

where

$$b_p^{AB} = b_B^A b_{p'}^B, \quad d_p^{AB} = b_B^A d_{p'}^B, \quad u_p^{AB} = d_B^A + u_B^A + b_B^A u_p^B$$

Quantitative methodologies

- ToE & Subjective algebra.
  - Pro: formally sound, open to (for) introduction of operators for close modeling (of trust?).
  - Contra: requires knowledge and understanding of very sophisticated maths, no experimental findings (mostly theoretical studies), …, and it makes trust and probabiltiy sematically equal.

Quantitative methodologies

- Game-theoretic approaches [Tennenholz, 2008, Harish et al, 2007].
  - A game consists of a set of players, a set of actions that are realizations of certain strategies available to the players, and a set of payoffs for each strategy.

Let N be the set of players in the game, A the set of action profiles, A_i the set of actions available to player i, and u_i player i's utility function. Then a profile $a \in A$ is a Nash equilibrium (NE) if

$$\forall i \in N: a_i \in br_i(a_{-i}),$$

where $br_i(a_{-i})$ for $i \in N, a_{-i} \in A_{-i}$ denotes the set of best responses of i to a_{-i}:

$$\arg\max_{a_i \in A_i} \{u_i(a_i, a_{-i})\}$$

Quantitative methodologies

- Game-theoretic approaches [Tennenholz, 2008, Harish et al, 2007].
  - Nash equilibrium - it represents action(s) that no other agent would prefer to deviate from, assuming that other agents also stick to it.
  - The well-known Prisoner's dilemma:

		prisoner B	
		confesses	does not confess
prisoner A	confesses	5 yrs for A, 5 yrs for B	0 yrs for A, 12 yrs for B
	does not confess	12 yrs for A, 0 yrs for B	1 yr for A, 1 yr for B

Quantitative methodologies

- Game-theoretic approaches [Tennenholz, 2008, Harish et al, 2007].
  - Pro: attractive to achieve rationally optimal solutions, intellectually intriguing.
  - Contra: assumption of rational players *ON BOTH SIDES*, require understanding of sophisticated logic, …, trust is limited to trust in other entity being able and willing to play in line with game-theoretic principles, *ASSUMPTION OF EXISTING PREFERENCES, ASSUMPTION OF TRANSITIVITY OF PREFERENCE RELATION.*

Qualitative methodologies

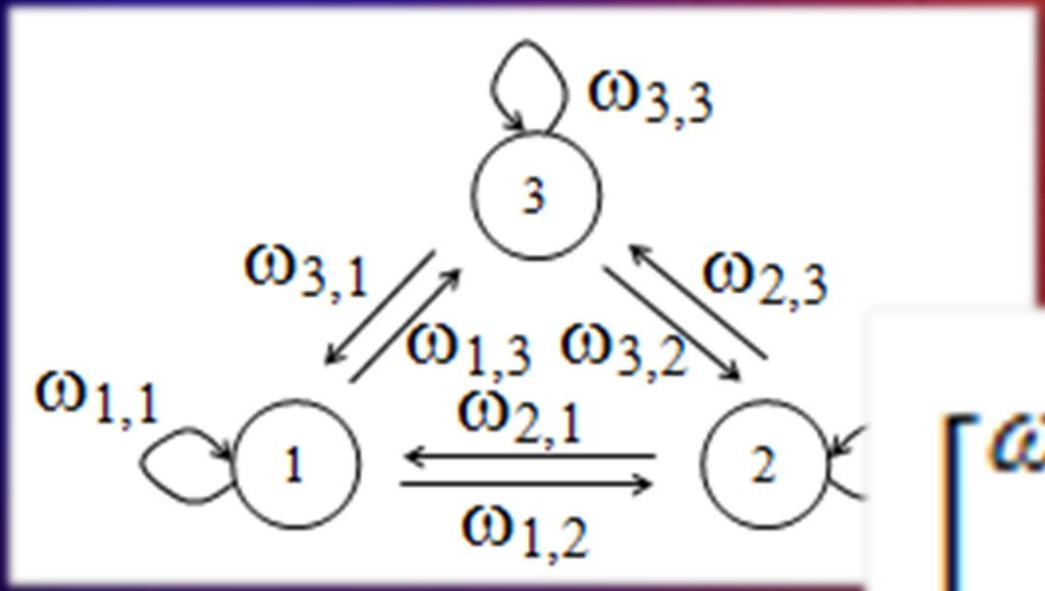
- Qualitative assessment dynamics – QAD [Trček, 2008] – the basic tenets:
  - Agents are not (always) rational.
  - Even if they are rational they (may) have problems with (the basic and advanced) probability calculus.
  - In case of trust, there may exist no preference(s); but, when there exists a preference, it is not necessarily transitive.
  - Aristoteles: How many teeth do women have? ➔ *GO MEASSURING AND COUNTING*.

Qualitative methodologies

- Qualitative assessment dynamics – QAD:
  - Trust is a weighted relation between two entities, where these entities can be atomic or compound.
  - In case of QAD (qualitative algebra), this weight is a qualitative value from an ordinal scale: totally trusted, partially trusted, undecided, partially mistrusted, totally mistrusted.

Qualitative methodologies

- Qualitative assessment dynamics – QAD.



$$\begin{bmatrix} \omega_{1,1} & \cdots & \omega_{1,n} \\ \vdots & \ddots & \vdots \\ \omega_{n,1} & \cdots & \omega_{n,n} \end{bmatrix}$$

Qualitative methodologies

- QAD - the defined operators.
  - Extreme-optimistic assessment operator, which results in the most positive assessment value among existing community values in a certain context; it is denoted by "⇑".
  - Extreme-pessimistic assessment operator, which results in the most negative assessment value among existing community values in a certain context; it is denoted by "⇓".
  - Moderate optimistic assessment operator, which means the expressed assessment is "strengthened" to the next higher level, narrowing the gap towards the aggregated assessment of the rest of community if this is more optimistic than the agent's trust is (the value changes one level upwards); it is denoted by "↑".
  - Moderate pessimistic assessment operator, which means the expressed assessment is "weakened" to the next lower level, narrowing the gap towards the aggregated assessment of the rest of community if this is more pessimistic than the agent's trust is (the value changes one level downwards); it is denoted by symbol "↓".
  - Centralistic consensus–seeker assessment operator, which results in a "towards zero rounded average" value by considering existing community values in a certain context; it is denoted by "⇝".
  - Non-centralistic consensus-seeker assessment operator, which results in a value, which is (contrary to the previous operator) "average rounded away from the 0 value"; it is denoted by the "↔".
  - Self-confident assessment operator, which results in the same value after changes are calculated; it is denoted by "⊙".
  - Assessment-hoping operator, which results in a value that is changing through time on an unidentifiable basis, and can be seen as a random process; it is denoted by "↕".

Qualitative methodologies

- Qualitative assessment dynamics.
  - Pro: It complements existing quantitative methodologies by addressing points, not addressed by them, it is intuitive, practical experiments show it has a potential to well complement users' cognitive models for trust management in pervasive computing.
  - Contra: operators are yet to be verified, large sample experiments (population projections) are yet to be done. Other issues?

Conclusions = References

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Conclusions = References

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Conclusions = References

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