CSCM 23 Designing in Trust, Understanding and Negotiation

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OFFICE HOUR: TUESDAY 2-4PM

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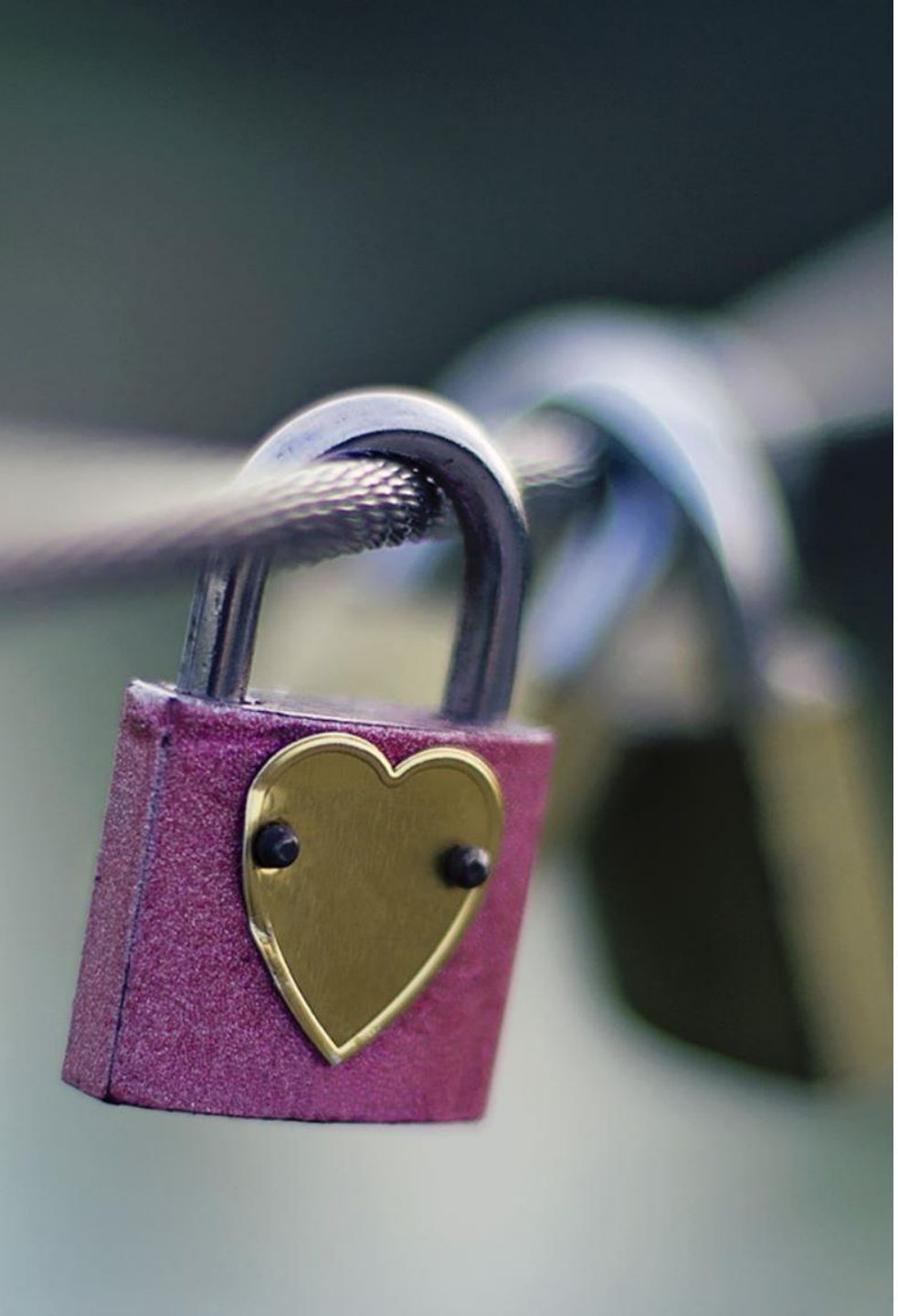


In the lectures

- Why study trust?
- What is trust?
- The factors impacting trust
- The characteristics of trust
- Trust modeling
  - Cognitive model
  - Computational model (soft security)
  - The application of trustworthiness
- Challenges

Why study trust?

- "*Trust and trustworthiness are necessary in our everyday life. It is part of the glue that holds our society together*". (Luhmann 1979)
- Created and supported by a legal framework
- In digital world, e.g., distributed systems, e-commerce
  - The legal framework is hard to enforce on a global level
  - Trust between interacting digital entities
  - A special issue beyond system security and personal privacy

Do you trust me?

What is trust?

- "Build a trustworthy system" – what is trust?
- Trust has traditionally been difficult to define and measure (Rousseau et al. 1998)
  - "A confusing potpourri" (Shapiro 1987)
  - "A conceptual confusion" (Lewis and Weigert 1985)
  - "A conceptual morass" (Barber 1983)
- Trust is becoming more and more important, but we still cannot really define what it exactly is.

From Cambridge dictionary

Verb (trust is a behavior)

- To believe that someone is good and honest and will not harm you, or that something is safe and reliable (✓)
- To hope and expect that something is true

Noun (trust is a property)

- The belief that you can trust someone or something (✓)
- A legal arrangement in which a person or organization controls property and/or money for another person or organization
- An organization that controls property and/or money for another person
- Used in the name of some banks (e.g., Morgan Guaranty Trust)

From literatures

- A state involving confident positive expectations about another's motives with respect to oneself in situations entailing risk (Boon and Holmes, 1991)
  - A trust relationship involves at least two entities: a trustor and a trustee, reliant on each other for mutual benefit
  - Trust involves uncertainty and risk
  - The trustor has faith in the trustee's honesty and benevolence, and believes that the trustee will not betray his/her risk-assuming behavior

From literatures

- Trust (or, symmetrically, distrust) is a particular level of the subjective probability with which an agent will perform a particular action, both before [we] can monitor such action (or independently of his capacity of ever to be able to monitor it) and in a context in which it affects [our] own action (Gambetta 1990).
- The willingness of a party to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party (Mayer, Davis, and Schoorman 1995).
- Trust is a qualified belief by a trustor with respect to the competence, honesty, security and dependability of a trustee within a special context (Grandison and Sloman 2000).

Trust is subjective and context dependent

From literatures

- On-line System: On-line trust is an attitude of confident expectation in an online situation of risk that one's vulnerabilities will not be exploited (Corritore, Kracher, and Wiedenbeck, 2003)
- Multi Agent System: In a multi-agent system, trust is a subjective expectation an agent has about another agent's future behavior (Mui, 2003).
- Software Engineering: From a software engineering point of view, trust is accepted dependability (Avizienis, Laprie, Randell, and Landwehr, 2004).
- Ad-Hoc Networks: For an ad hoc network, trust could be defined as the reliability, timeliness, and integrity of message delivery to a node's intended next-hop (Liu, Joy, and Thompson, 2004).

Finally……

A system is trusted if and only if its users trust it.

Group discussion

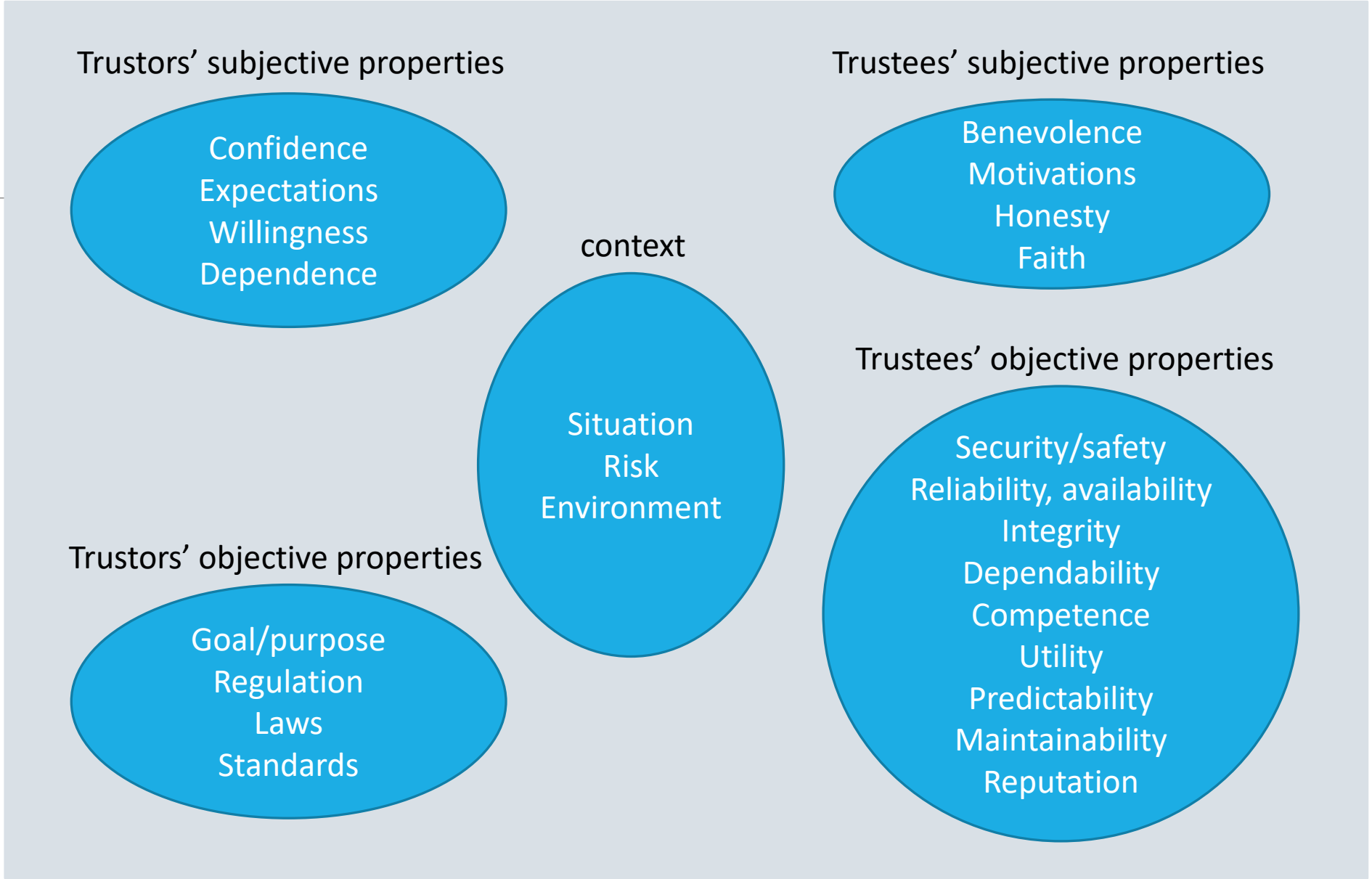
Consider the following two scenarios

1. You are going to buy masks from Amazon, how do you choose a seller? What are the factors impacting your decision?

2. Suppose you have a malfunctioning air-conditioner in your rented apartment. However, after repeated calls to the landlord, it has not been fixed. You are going to investigate your legal rights in this situation by visiting a legal advice Web site for which you have seen an advertisement in the local newspaper. After you explore the Web site to find the relevant information, how do you decide whether to follow the advice found from the Web stie? What are the factors impacting your decision?

Are there similar factors impacting your decisions?

Factors impacting trust



The characteristics of trust

- Trust is directed
- Trust is subjective
- Trust is context-dependent
- Trust is measurable
- Trust depends on history
- Trust is dynamic
- Trust is conditionally transferable
- Trust can be a composite property

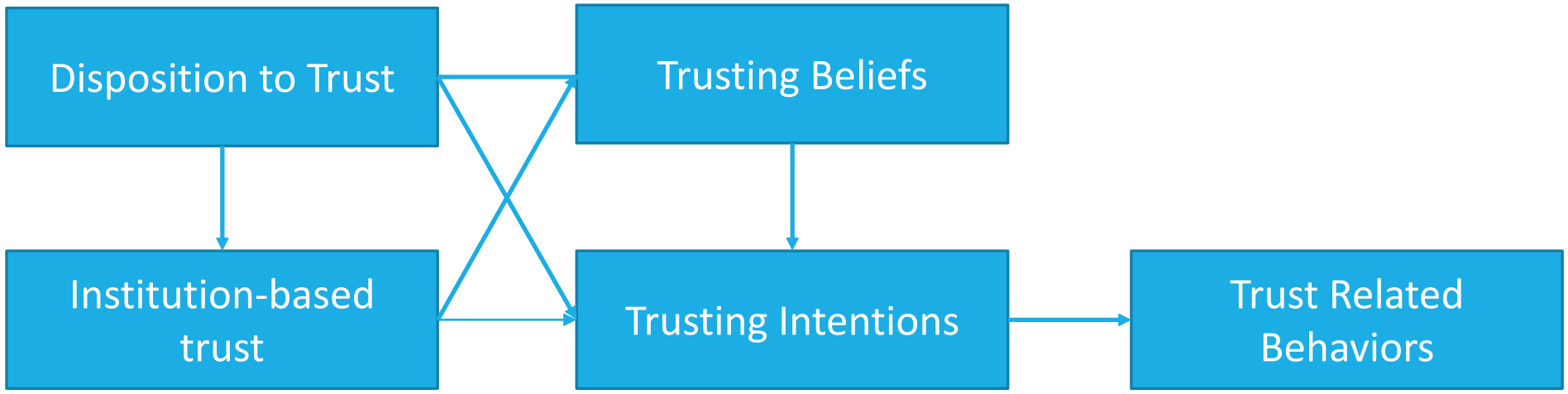
Trust modelling

- What is a trust model?
  - The method to specify, evaluate and set up trust relationships amongst entities for calculating trust is referred as the trust model.
  - Trust modelling is the technical approach used to represent trust for the purpose of digital processing
- Categories
  - Cognitive trust models
    - Conceptualize trust based on user studies through a psychological or sociological approach
    - Prove the complicated relationships among trust and other multiple factors in different facets.
  - Computational trust models
    - Modelling trust in a digital way
    - Focuses on concrete solutions in special systems.

Cognitive trust models

A cognitive trust model

- McKnight, Choudhury, and Kacmar (2002), an initial trust model that explain and predict customer's trust towards an e-vender in an e-commerce context.
- Initial trust refers to trust in an unfamiliar trustee, a relationship in which the actors do not yet have credible, meaningful information about each other



Trusting beliefs

- The confident trustor perception that the trustee has attributes that are beneficial to the trustor
  - Competence: ability of the trustee doing what the trustor needs
  - Benevolence: trustee caring and motivation to act in the trustor's interests
  - Integrity: trustee honesty and promise keeping
  - Others: predictability, openness, carefulness, attraction

Institution-based trust

- The belief that need structural conditions are present to enhance the probability of achieving a successful outcome in an endeavor
  - Coming from sociology – the structures that make an environment feel trustworthy
  - Procedures and structures of security and protection
- Two dimensions:
  - Structural assurance
    - Guarantees, regulations, promises, legal recourse, other procedures are in place to promote success
  - Situational normality
    - The situation is normal or favorable

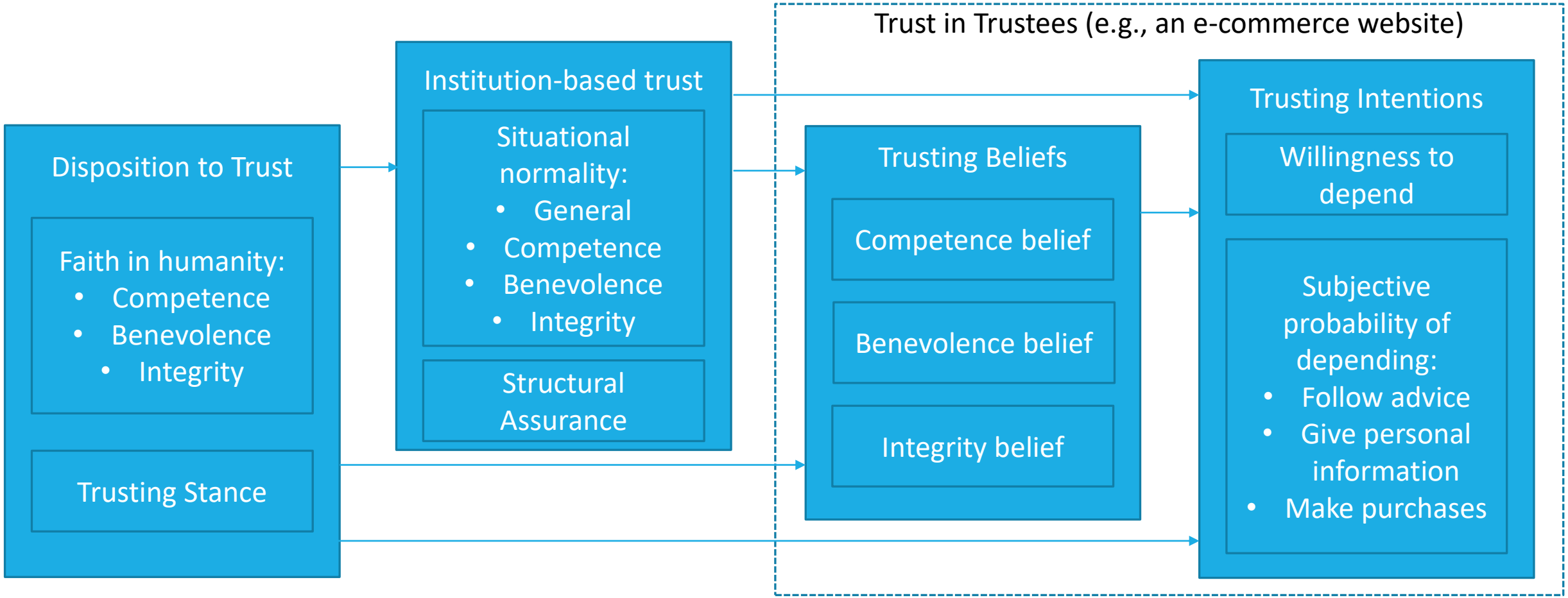
Disposition to trust

- The extent to which a person displays a tendency to be willing to depend on others across a broad spectrum of situations and persons
- Two subconstructs
  - Faith in humanity: one assumes others are usually upright, well meaning, and dependable, decomposed into faith in general others' integrity, competence, and benevolence
  - Trusting stance: regardless of what one believes about peoples' attributes, one assumes better outcomes result form dealing with people as though they are well meaning and reliable
- Trust-building strategies may be different for individuals with low versus high disposition to trust.

Trusting intensions and behavior

- Trusting intentions: intention to engage in trust-related behaviors
  - The trustor is securely willing to depend, or intends to depend on the trustee
    - Willingness to depend
    - Subjective probability of depending
- Trust-related behavior: actions that demonstrate make one vulnerable to others, or increase one's risk, e.g., sharing personal information, making a purchase, or acting on information recommended.

Relationships among trust constructs



Group exercise

1. You are going to buy masks from Amazon, how do you choose a seller? 2. Suppose you have a malfunctioning air-conditioner in your rented apartment. However, after repeated calls to the landlord, it has not been fixed. You are going to investigate your legal rights in this situation by visiting a legal advice Web site for which you have seen an advertisement in the local newspaper. After you explore the Web site to find the relevant information, how do you decide whether to follow the advice found from the Web stie?

For the above two scenarios, how is initial trust formed based on this model?

Problems with cognitive trust models

- The trust models generated based on this approach are generally linguistic or graphic. They do not quantify trust for machine processing purposes.
- The achieved results could only help people understanding trust more precisely in order to work out a design guideline or an organizational policy towards a trustworthy digital system or a trustworthy user interface.
- However, the psychological and sociological study results could further play as practical foundations of computational trust – modelling trust for a digital processing purpose.

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Computational Trust Models

The definition of trust in computational trust

"Trust is the subjective probability by which an individual, A, expects that another individual, B, performs a given action on which its welfare depends"

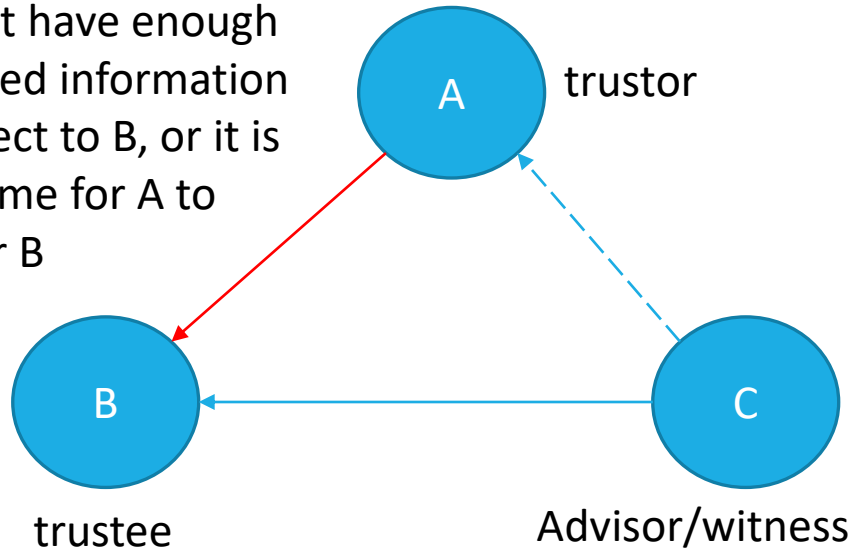
– D. Gambetta, 1990.

Computational trust models

- Trust is influenced by
  - The trustor's past experiences
  - Recommendations (e.g., public evidences with respect to the trustee, a group of entities' evidence on the trustee)
  - Context (e.g. ontology, time, etc.).
- A singular trust value or level calculated by taking into account the previous behavior of the trustee
- Use the term trust and reputation interchangeably
- Computational trust models play the role of self-regulating in digital worlds – soft security.

A simplified view

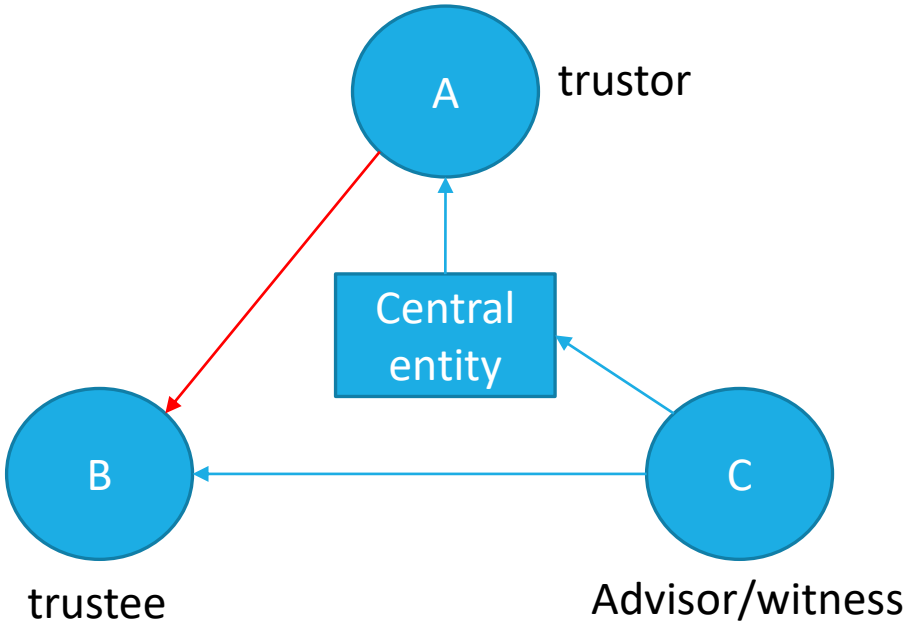
A does not have enough trust related information with respect to B, or it is the first time for A to encounter B

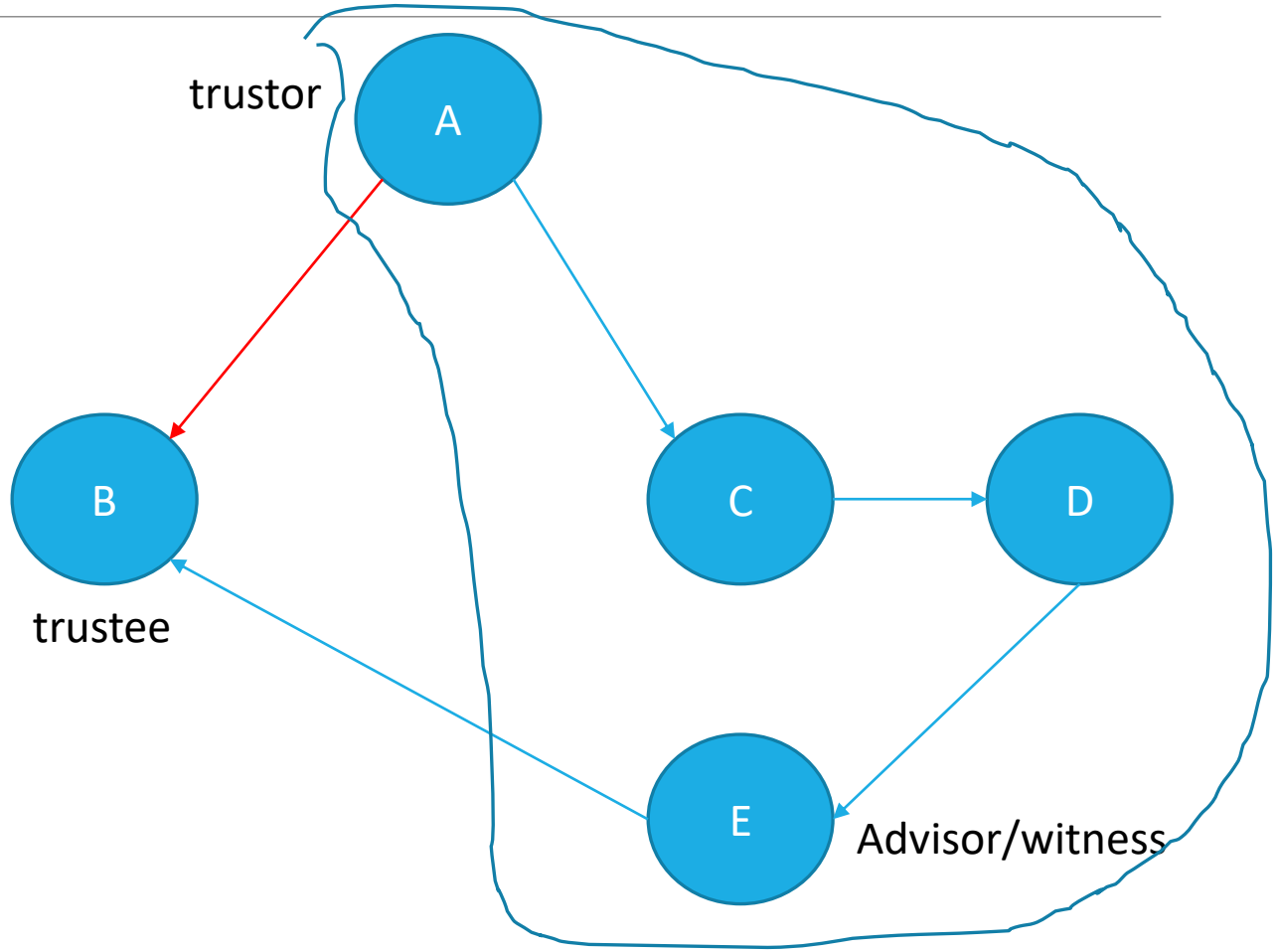


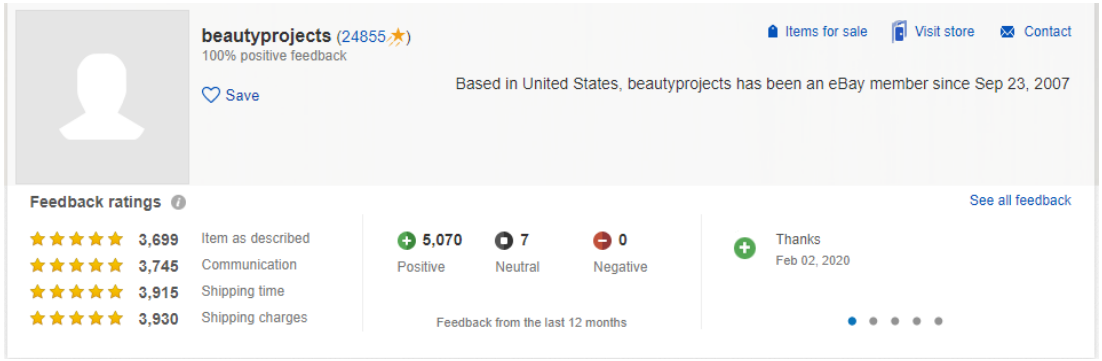
- A: trustor; B: trustee. A is evaluating B's trustworthiness/reputation
- C: advisor/witness
- Information we have:
  - The trust related information between A and B
  - The trust related information between C and B
  - The trust related information provided by C to A
  - Other information (ontology, time, etc.)
- Goal:
  - $M(all\ information) = Trustworthiness\ [A \rightarrow B]$
- Basic problems
  - How to find C
  - What will M be like?
    - What information will be included (usually in numerical ratings)

How to find ‘C’

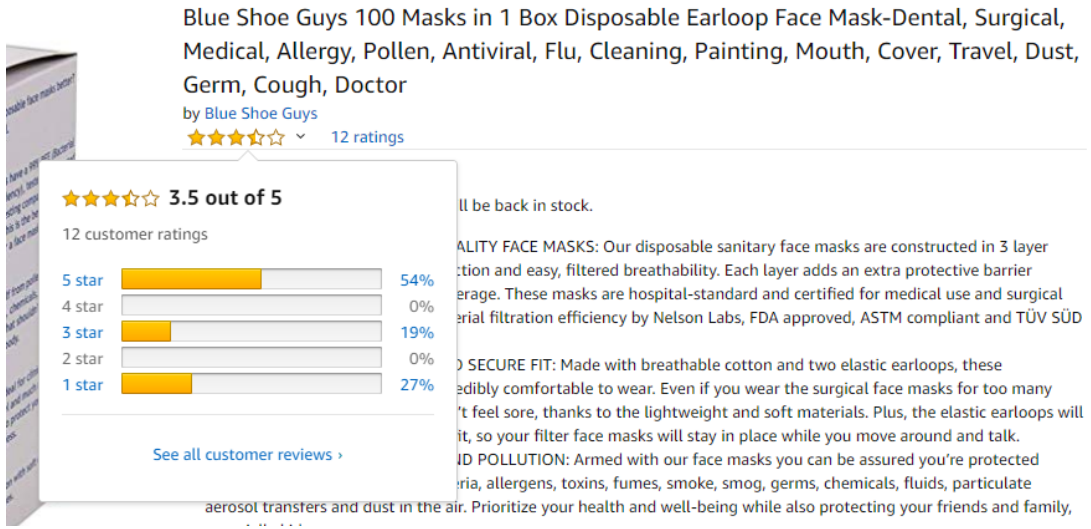
- Centralized
- Distributed





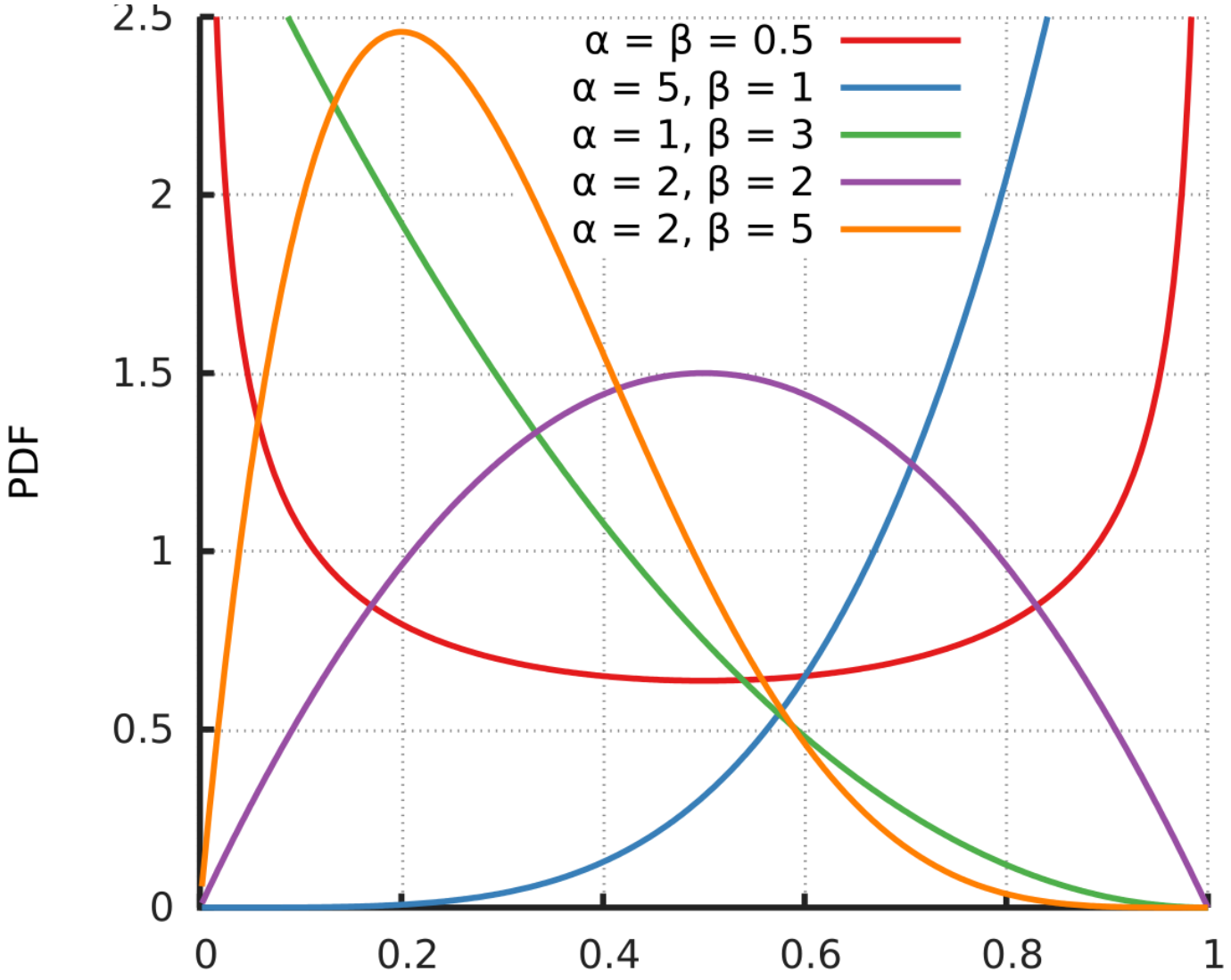


- eBay
- The simplistic aggregation of ratings can be unreliable, particularly when some buyers do not return ratings



- Amazon
- Problems:
  - 12 ratings, 3.5/5 vs. 120 ratings, 3.45/5
  - Recent ratings & History ratings

What will 'M' be like: Online reputation models

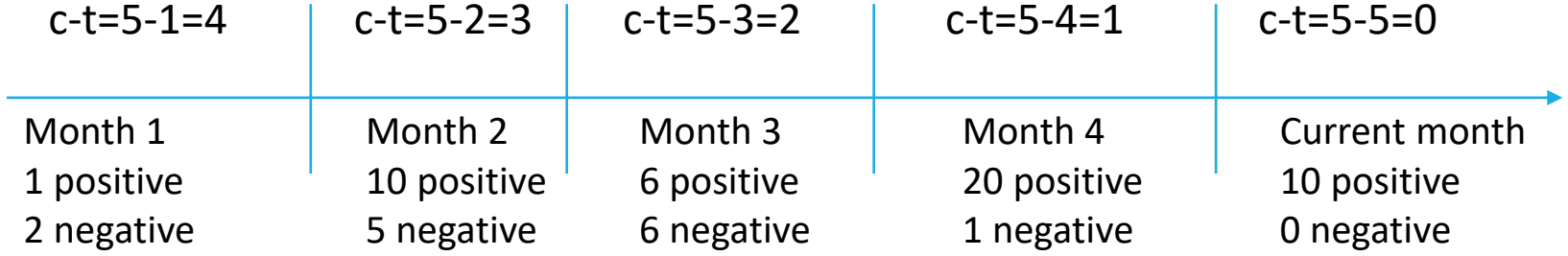


Beta reputation system: Basic form

- Consider *M* as Beta distribution: Beta(p|α,β)
- α = accumulated number of postive ratings + 1
- β = accumulated number of negative ratings + 1
- $reputation = E[postive\ ratings] = \frac{\alpha}{\alpha+\beta}$
- Example: A trustee receives 10 positive ratings and 5 negative ratings in total, the reputation of the trustee
  - $repuation = \frac{10+1}{(10+1)+(5+1)}$=0.65
- Question: why
  - α = accumulated number of postive ratings + 1
  - β = accumulated number of negative ratings + 1

Beta reputation system: Forgetting factor

- $\alpha = \sum_{t \in T} \lambda^{c-t} \times (accumulated\ number\ of\ postive\ ratings\ in\ timeframe\ t) + 1$
- $\beta = \sum_{t \in T} \lambda^{c-t} \times (accumulated\ number\ of\ negative\ ratings\ in\ timeframe\ t) + 1$
- Where λ is the forgetting factor, in $[0,1]$, c = current time
- $reputation = \frac{\alpha}{\alpha+\beta}$
- Example:



$\alpha = \lambda^4 \times 1 + \lambda^3 \times 10 + \lambda^2 \times 6 + \lambda^1 \times 20 + \lambda^0 \times 10+1$

$\beta = \lambda^4 \times 2 + \lambda^3 \times 5 + \lambda^2 \times 6 + \lambda^1 \times 1 + \lambda^0 \times 0+1$

If λ=0.9, what is the reputation?

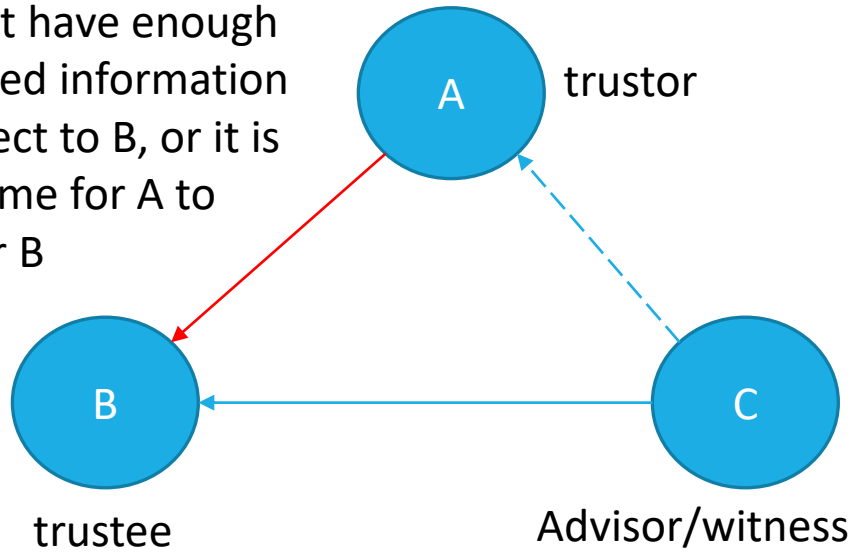
Group exercise

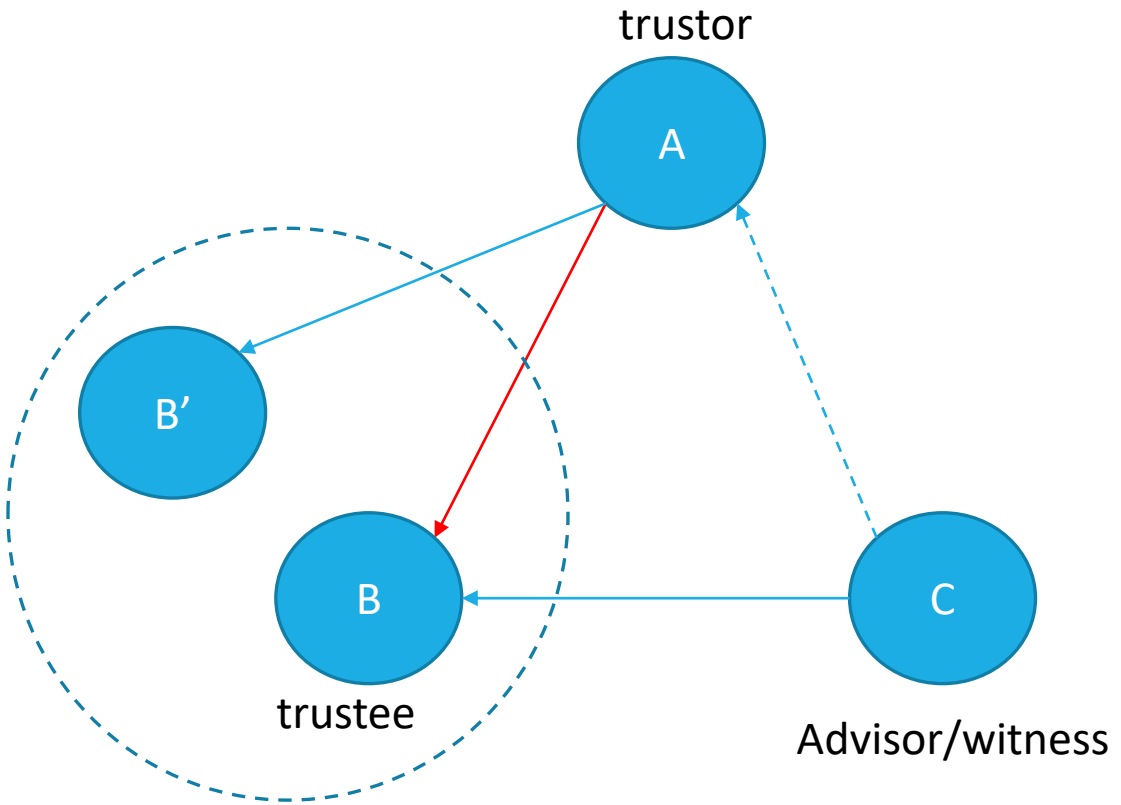
Suppose you are evaluating the reputations of two professors as supervisors. Professor A has supervised three students, the ratings from the students are positive (10 years ago), negative (5 year ago), positive (1 year ago). Professor B does not have experiences in supervising students and did not receive any rating.

1. What are the reputations of the two professors by using eBay model and BRS (assume the forgetting factor λ as 0.9)?
2. Which processor will you choose as supervisor based on the trust values?
3. Optional question: What are the problems with respect to eBay model and BRS?
4. Optional question: How will you change the scheme of ratings to adapt to Amazon model?

A more complicated view

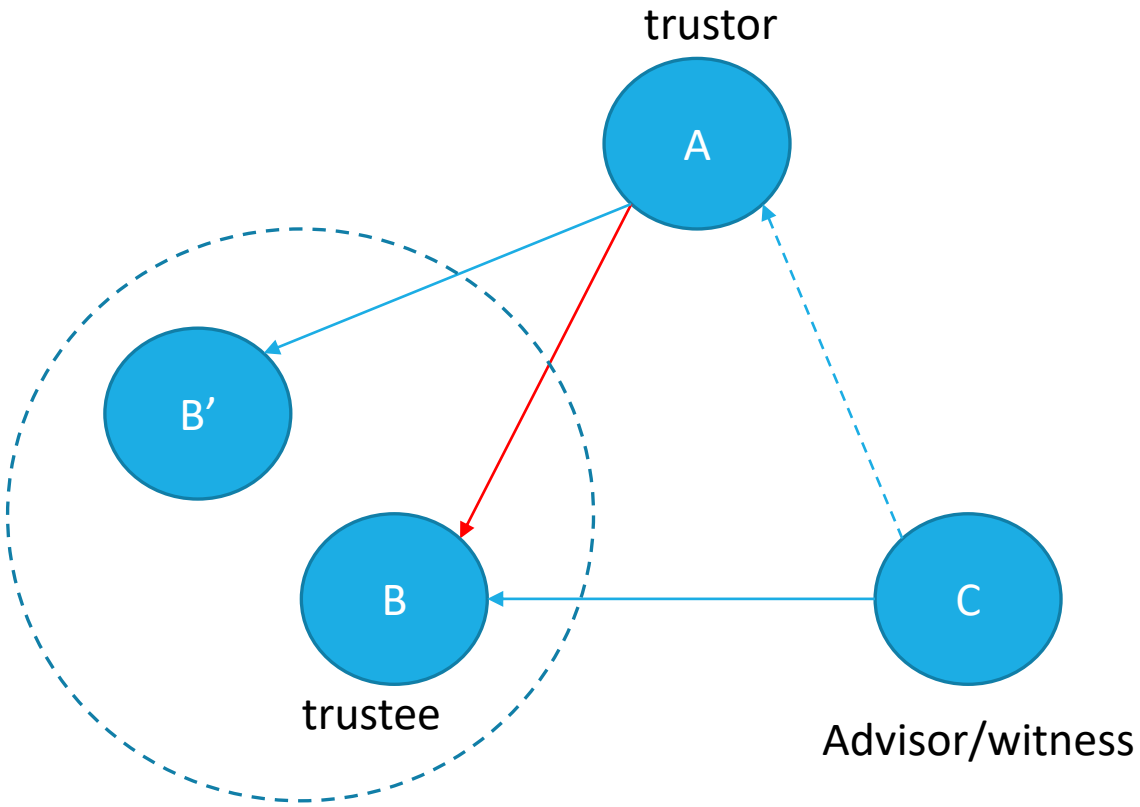
A does not have enough trust related information with respect to B, or it is the first time for A to encounter B



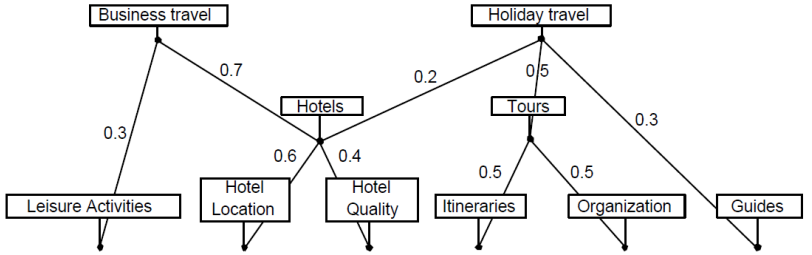


A more complicated view

- Information we have:
  - The trust related information
    - between A and B
    - Between A and B’
    - Between C and B
    - Provided by C to A
  - The group information for
    - B and B’



Regret trust model



Consider the following scenario

- Travelers
  - Travel regularly either for business for holiday
  - Buy trips from travel agencies
- Travel agencies
  - Provide travelers with packages
  - Affiliated with a tour operator providing facilities included in package
- Tour operator
  - Provide to the affiliated agencies hotels, tours, leisure activities and guides
- Travel
  - Hotel location, hotel quality, leisure activities, tour itineraries, tours organization, guides

What is a traveler's trustworthiness for a travel agency?

- Traveler->Travel agency (business trip)
- Traveler->Travel agency (holiday trip)
- Individual dimension
  - A reputation at time *t* from traveler *a*'s point of view for travel agency *b* for a particular aspect, e.g., hotel quality
- Social dimension
  - The reputation of the group that a travel agency belongs to.
  - The travel agencies affiliated by the same tour operator are considered as one group.
- Ontology dimension
  - The reputation combing reputations on different aspects

Regret trust model

- Individual dimension

$R_{a\to b}(subject) = \sum \rho(t,t_i)W_i$, where $\rho(t,t_i) = \frac{f(t_i,t)}{\sum f(t_j,t)}, f(t_i,t) = \frac{t_i}{t}, W_i \in [-1,1]$

a is the trustor, *b* is the trustee, W_i is the rating given by *a* for one subject (i.e., a dimension, e.g., hotel location) to *b* at time *i,* e.g., $W_{January\ 1st,2020} = 0.7$ for subject 'hotel location'

- Social dimension

$R_{a\to B}(subject) = \sum_{b_i \in B} \omega^{ab_i} \times R_{a\to b_i}(subject), where\ \sum_{b_i \in B} \omega^{ab_i} = 1$

$R_{A\to b}(subject) = \sum_{a_i \in A} \omega^{a_i b} \times R_{a_i\to b}(subject), where\ \sum_{a_i \in A} \omega^{a_i b} = 1$

$R_{A\to B}(subject) = \sum_{a_i \in A} \omega^{a_i B} \times R_{a_i\to B}(subject), where\ \sum_{a_i \in A} \omega^{a_i B} = 1$

$SR_{a\to b}(subject) = \zeta_{ab} \times R_{a\to b}(subject) + \zeta_{aB} \times R_{a\to B}(subject) + \zeta_{Ab} \times R_{A\to b}(subject) + \zeta_{AB} \times R_{A\to B}(subject)$, where

$\zeta_{ab} + \zeta_{aB} + \zeta_{Ab} + \zeta_{AB} = 1$

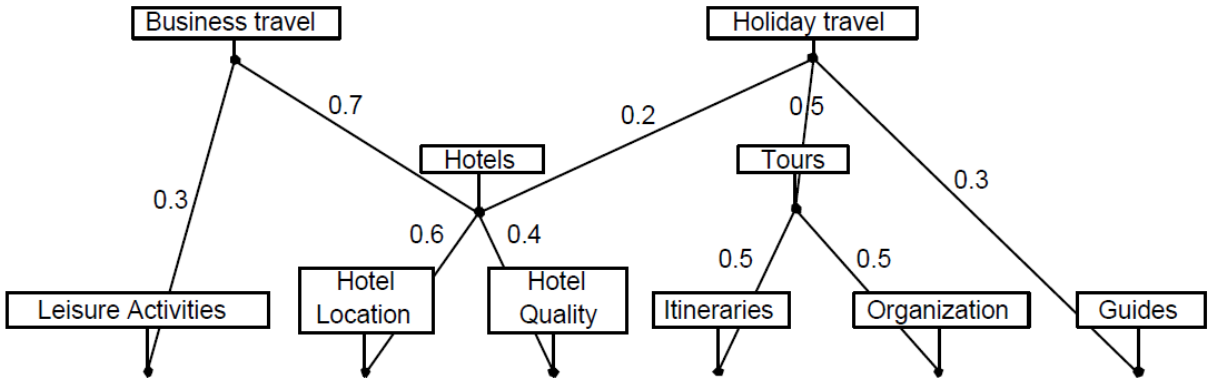
Regret trust model

- Ontological dimension (trustworthiness)

$OR_{a\to b}(i) = \sum_{j\in children(i)} w_{ij} \times OR_{a\to b}(j)$, where w_{ij} is the weight between node *i* and *j*

$OR_{a\to b}(i) = SR_{a\to b}(j)\ when\ j\ is\ an\ atomic\ aspect.$

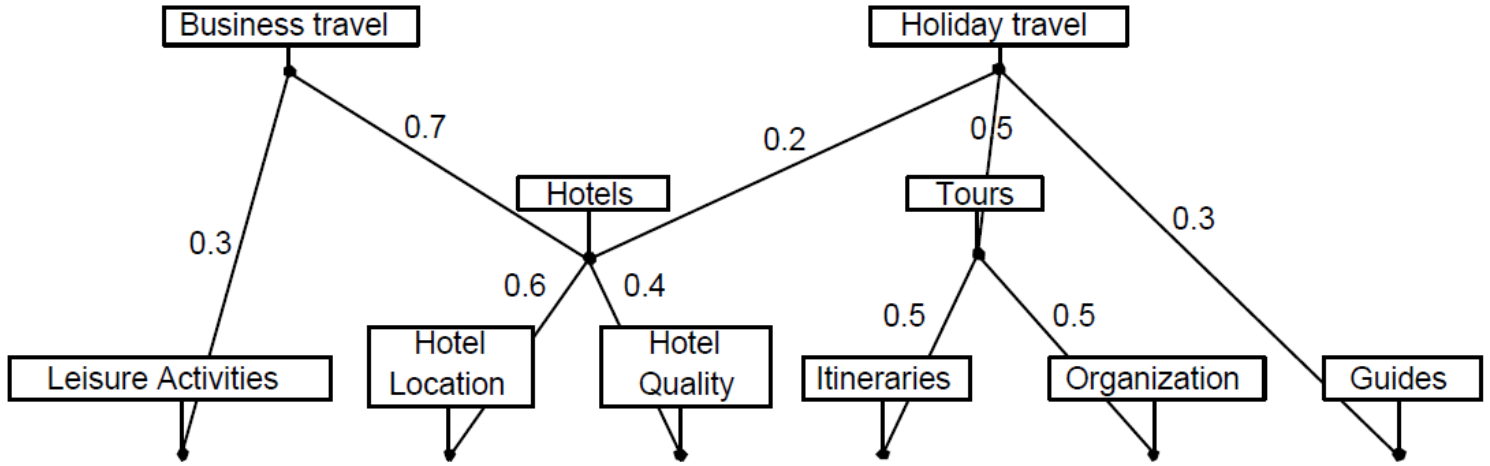
For example,



$OR_{a\to b}(business\ travle) = \sum_{j\in children(business\ travle)} w_{ij} \times OR_{a\to b}(j) = 0.3 \times OR_{a\to b}(leisure\ activities) + 0.7 \times OR_{a\to b}(hotels) = 0.3 \times SR_{a\to b}(leisure\ activities) + 0.7 \times \left(0.6 \times SR_{a\to b}(hotel\ location) + 0.4 \times SR_{a\to b}(hotel\ quality)\right)$

Optional Exercise

- Refer back to the scenario of traveler and travel agencies, suppose there are 5 travelers, 4 travel agencies and 2 tour operators, named as Op1 and Op2. Op1 is affiliated to travel agency 1&2 and Op 2 to travel agency 3&4. Op1 and Op2 provide different qualities of the facilities (i.e., leisure activities, hotel location, hotel quality, itineraries, organization, guides). The ontological information is:

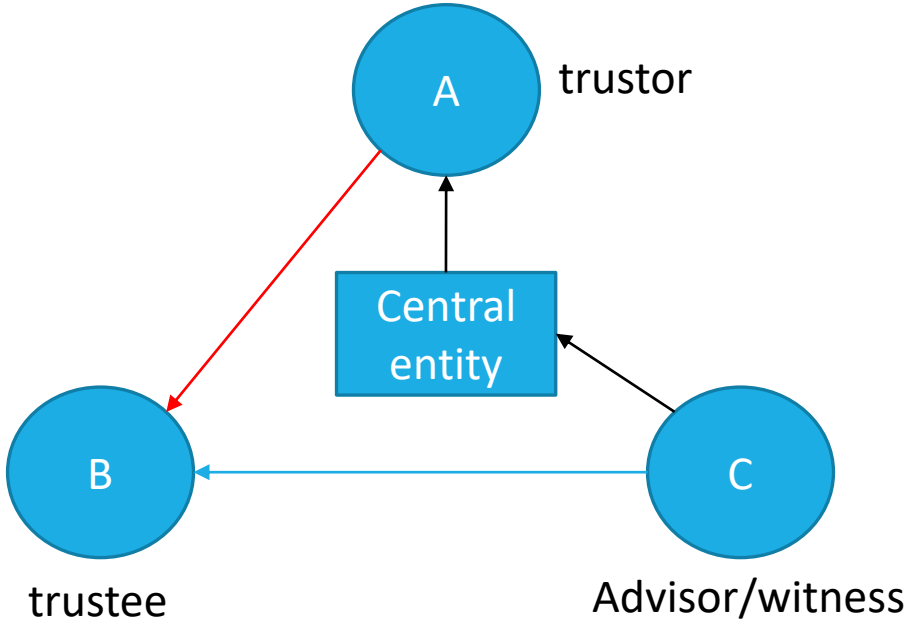


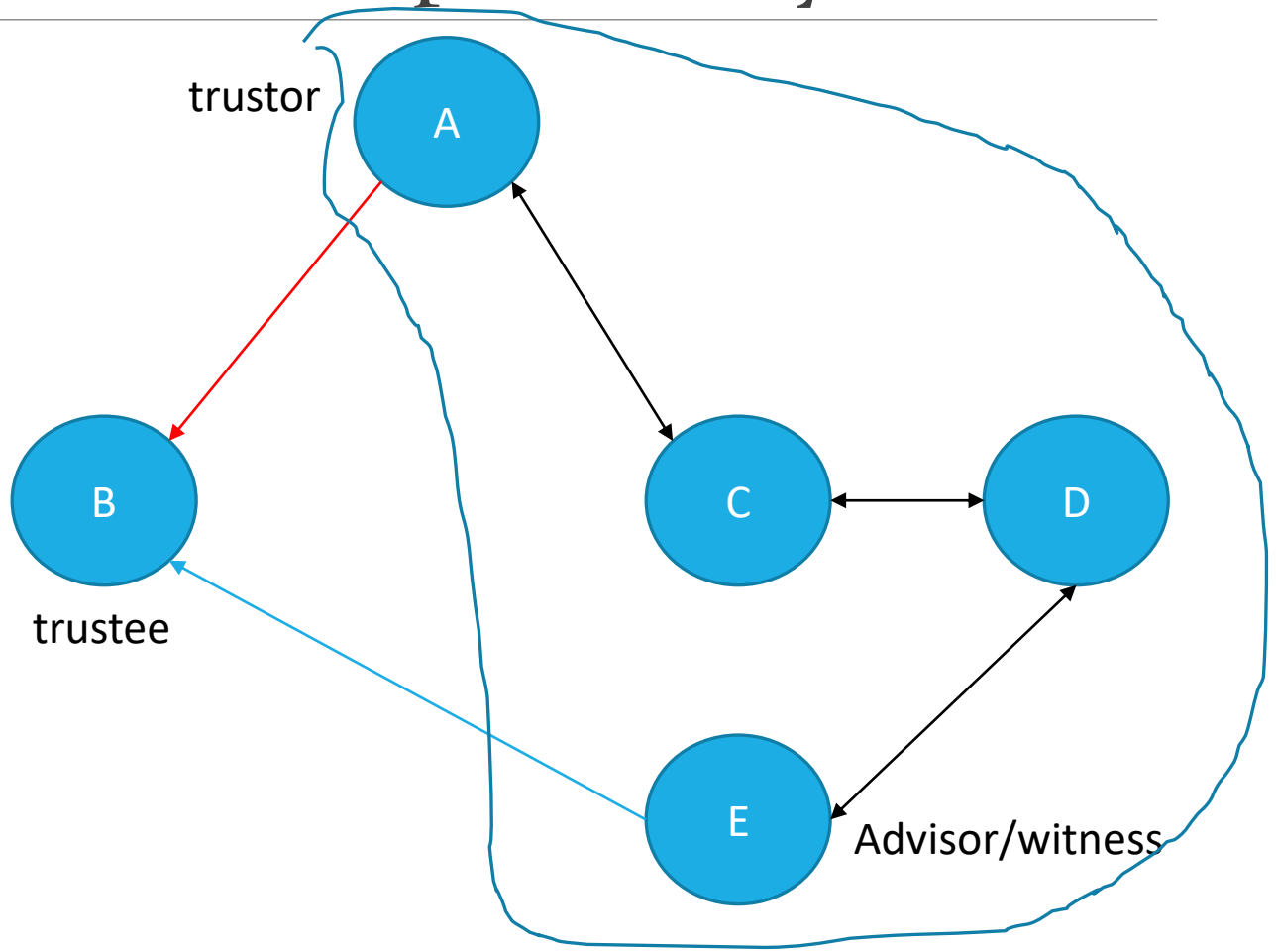
- What is the trustworthiness of an agency from a traveler's point of view with respect to business travel/holiday travel (you can assume the ratings and parameters by yourself)?

Taxonomies for trust models

- Information sources
  - Direct experiences
  - Witness information, e.g., third-party observations, reputation communication
  - Sociological information, e.g. social network
  - Prejudice, e.g., stereotyping, group
- Visibility
  - Global (Centralized)
  - Private (Distributed)
- Types of exchanged information
  - Boolean/Discrete information
  - Continuous measures

Problems with information reported by 'C'





Attacks for computational trust models

- Unfair ratings: Advisors' ratings do not reflect the actual experience
- Discrimination: A trustee provide different quality services
- Collusion: Coordinated actions among advisors
- Reputation lag: Abuse multiple entities before trustor reacts to their negative feedback
- Re-entry: Take new identity to eliminate bad behaviour history
- Sybil attack: Take on multiple identities to generate ratings
- Value imbalance exploitation: Exploit reputation from many low value services, for one high value fraud

Group discussion

For the following attacks:

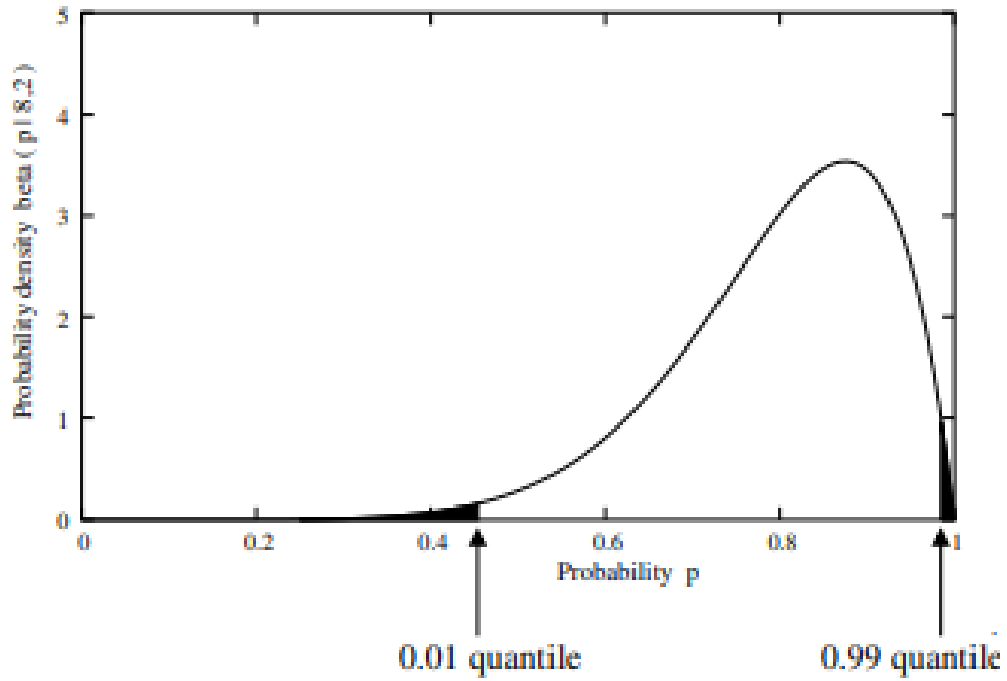
- Unfair ratings: Discrimination: Provide different quality services
- Collusion: Coordinated actions among participants
- Reputation lag :Abuse multiple entities before trustor reacts to their negative feedback
- Re-entry: Take new identity to eliminate bad behaviour history
- Sybil attack: Take on multiple identities to generate ratings
- Value imbalance exploitation: Exploit reputation from many low value services, for one high value fraud

1. Which one(s) will make the reputation estimated by Beta Reputation System (Basic form) inaccurate?

2. Which one(s) will make the reputation estimated by Beta Reputation System (with forgetting factor) inaccurate?

Iterative filtering for Beta reputation system

- Unfairly positive ratings (ballot stuffing)
- Unfairly negative ratings (bad-mouthing)



C is the set of all raters
F is the set of all assumed fair raters
Z is the target agent

$F = C$

do loop

$\rho^t(Z) := \sum_{X \in F} \rho^t(X, Z)$

$R^t(Z) := \mathrm{E}(\rho^t(Z))$

for each rater R in F

$f := \mathrm{beta}(\rho^t(R, Z))$
$l := q$ quantile of f
$u := (1-q)$ quantile of f

if $l > R^t(Z)$ or $u < R^t(Z)$
$F := F \setminus \{R\}$

loop

until F does not change

return $R^t(Z)$

Iterative filtering: example

Advisors (raters): C1, C2, C3, C4

Trustee: Z

Accumulated number of ratings provided by C1, C2, C3, and C4 at time *t* are:

$$\rho^t(\mathrm{C1},\mathrm{Z}) = \begin{bmatrix}10\\1\end{bmatrix}$$

$$\rho^t(\mathrm{C2},\mathrm{Z}) = \begin{bmatrix}10\\10\end{bmatrix}$$

$$\rho^t(\mathrm{C3},\mathrm{Z}) = \begin{bmatrix}10\\5\end{bmatrix}$$

$$\rho^t(\mathrm{C4},\mathrm{Z}) = \begin{bmatrix}1\\10\end{bmatrix}$$

Iteration 1:

F={C1, C2, C3, C4}

$\rho^t(\mathrm{Z}) = \begin{bmatrix}31\\26\end{bmatrix}$

$R^t(\mathrm{Z}) = \frac{32}{59} = 0.54$

For C1:

- $f = \mathrm{beta}(\rho^t(\mathrm{C1},\mathrm{Z})) = \mathrm{beta}(10,1)$
- $l = beta.ppf(0.01,10,1) = 0.63$
- $\mathrm{u} = beta.ppf(0.99,10,1) = 0.99$
- F = {C2, C3, C4}

For C2:

- $f = \mathrm{beta}(\rho^t(\mathrm{C2},\mathrm{Z})) = \mathrm{beta}(10,10)$
- $l = beta.ppf(0.01,10,10) = 0.25$
- $\mathrm{u} = beta.ppf(0.99,10,10) = 0.74$

For C3:

- $f = \mathrm{beta}(\rho^t(\mathrm{C3},\mathrm{Z})) = \mathrm{beta}(10,5)$
- $l = beta.ppf(0.01,10,5) = 0.37$
- $\mathrm{u} = beta.ppf(0.99,10,5) = 0.89$

For C4:

- $f = \mathrm{beta}(\rho^t(\mathrm{C4},\mathrm{Z})) = \mathrm{beta}(1,10)$
- $l = beta.ppf(0.01,1,10) = 0.001$
- $\mathrm{u} = beta.ppf(0.99,1,10) = 0.37$
- F={C2,C3}

Iteration 2:

F={C2, C3}

$\rho^t(\mathrm{Z}) = \begin{bmatrix}20\\15\end{bmatrix}$

$R^t(\mathrm{Z}) = \frac{21}{37} = 0.57$

For C2:

- $f = \mathrm{beta}(\rho^t(\mathrm{C2},\mathrm{Z})) = \mathrm{beta}(10,10)$
- $l = beta.ppf(0.01,10,10) = 0.25$
- $\mathrm{u} = beta.ppf(0.99,10,10) = 0.74$

For C3:

- $f = \mathrm{beta}(\rho^t(\mathrm{C3},\mathrm{Z})) = \mathrm{beta}(10,5)$
- $l = beta.ppf(0.01,10,5) = 0.37$
- $\mathrm{u} = beta.ppf(0.99,10,5) = 0.89$

End

Attacks for computational trust models

Malicious behaviours to manipulate reputation	Strategy	Found solution （Known Counter Measures）
Unfair ratings	Ratings do not reflect the actual experience	Yes
Discrimination	Provide different quality services	No
Collusion	Coordinated actions among participants	No
Reputation lag	Abuse multiple customers before trustor reacts to their negative feedbacks	Yes
Re-entry	Take new identity to eliminate bad behaviour history	No
Sybil attack	Take on multiple identities to generate ratings	Yes
Value imbalance exploitation	Exploit reputation from many low value services, for one high value fraud	Yes

More trust and reputation models

Side payment (Jurca and Faltings, 2003)

Eigentrust (Kamvar, Schlosser, and Molina, 2003)

BLADE (Regan, Poupart and Cohen, 2006)

Personalized approach (Zhang and Cohen, 2008)

HABIT (Teacy et.al., 2012)

Subjective grouping (Fang, Zhang and Thalmann, 2014)

COBRA (Zeynalvand, Luo, and Zhang, 2019)

Scenario for exercise

Consider the following scenario:

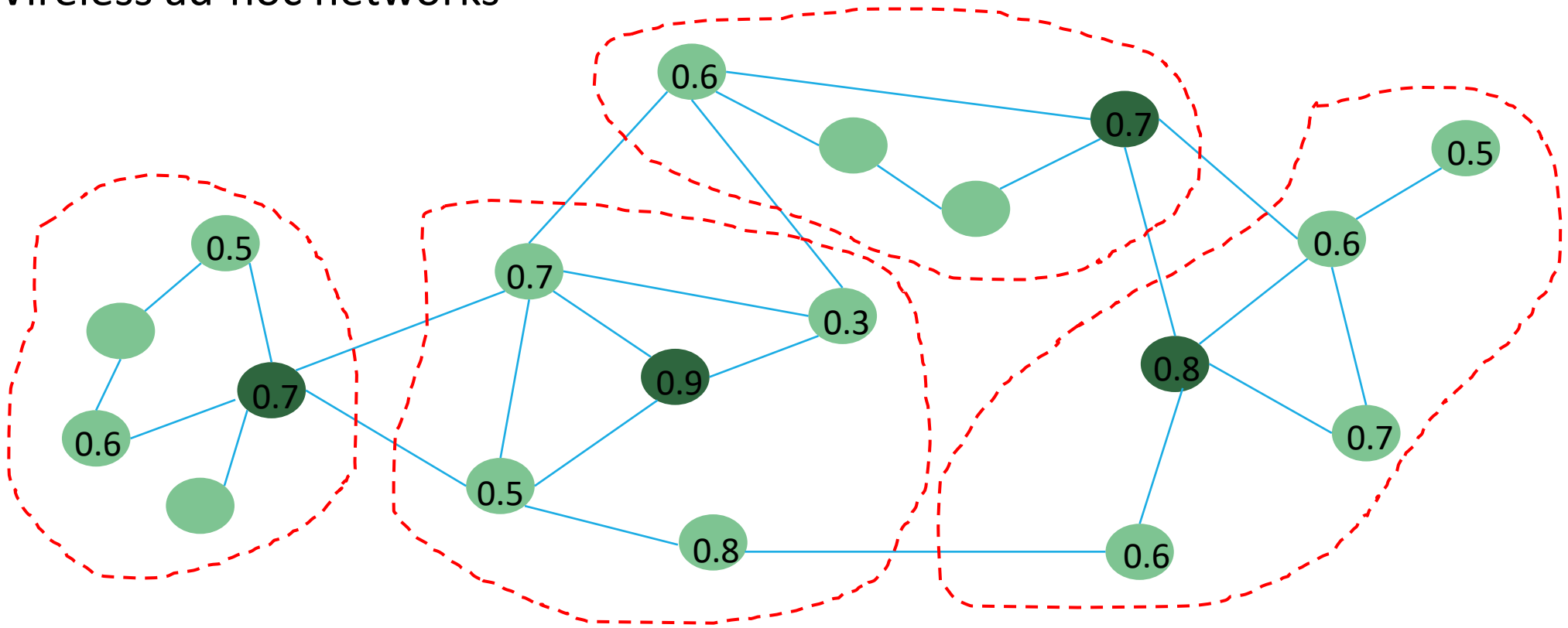
In a cognitive radio network (CRN) which includes licensed spectrum users (primary users, i.e., PUs) and unlicensed users (secondary users, i.e., SUs), SUs must opportunistically access spectrum holes, while keeping the interference the PU receivers below a prescribed level. Therefore, SUs need to obtain and analyse information from other SUs related to the spectrum bands of interest to identify the opportunities to make use of these spectrum bands. As the trustworthiness of the SUs heavily affect the decision made by the initiator SU, an SU will maintain a trust model of each of the other SUs.

Question:

1. Who is trustor? Who is trustee?
2. How will a trustor find advisors (centralized or distributed)?
3. What will the information reported by an advisor be like?
4. What will the trust mode built trustor be like?
5. What attacks the built trust model can resist? For the attacks that cannot be resisted, is there any possible solution?
6. Optional: how an SU will make use of the trustworthiness of other SUs to make a decision?

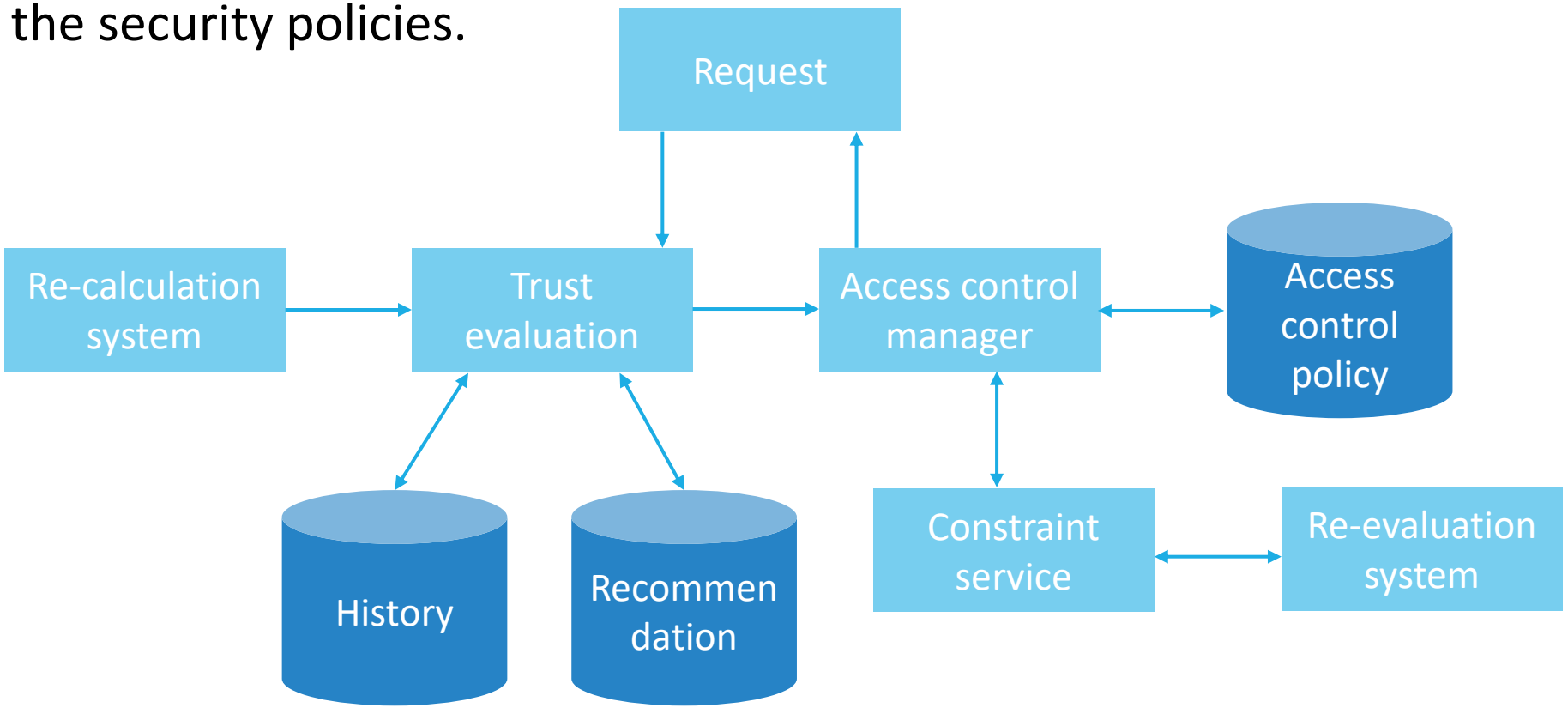
The application of trust: authentication

- Wireless ad-hoc networks

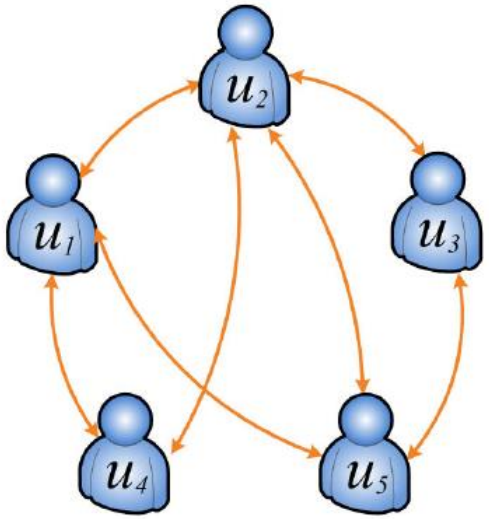


The application of trust: authorization

- Restrict unauthorised access to resources based on trust evaluation of the requesters and the security policies.



(a) Real World Social Recommendation



(b) Social Network

	v_1	v_2	v_3	v_4	v_5
u_1	1		2	3	
u_2		3			1
u_3		4		5	
u_4	5			4	
u_5		2	5		4

(c) User-Item Rating Matrix

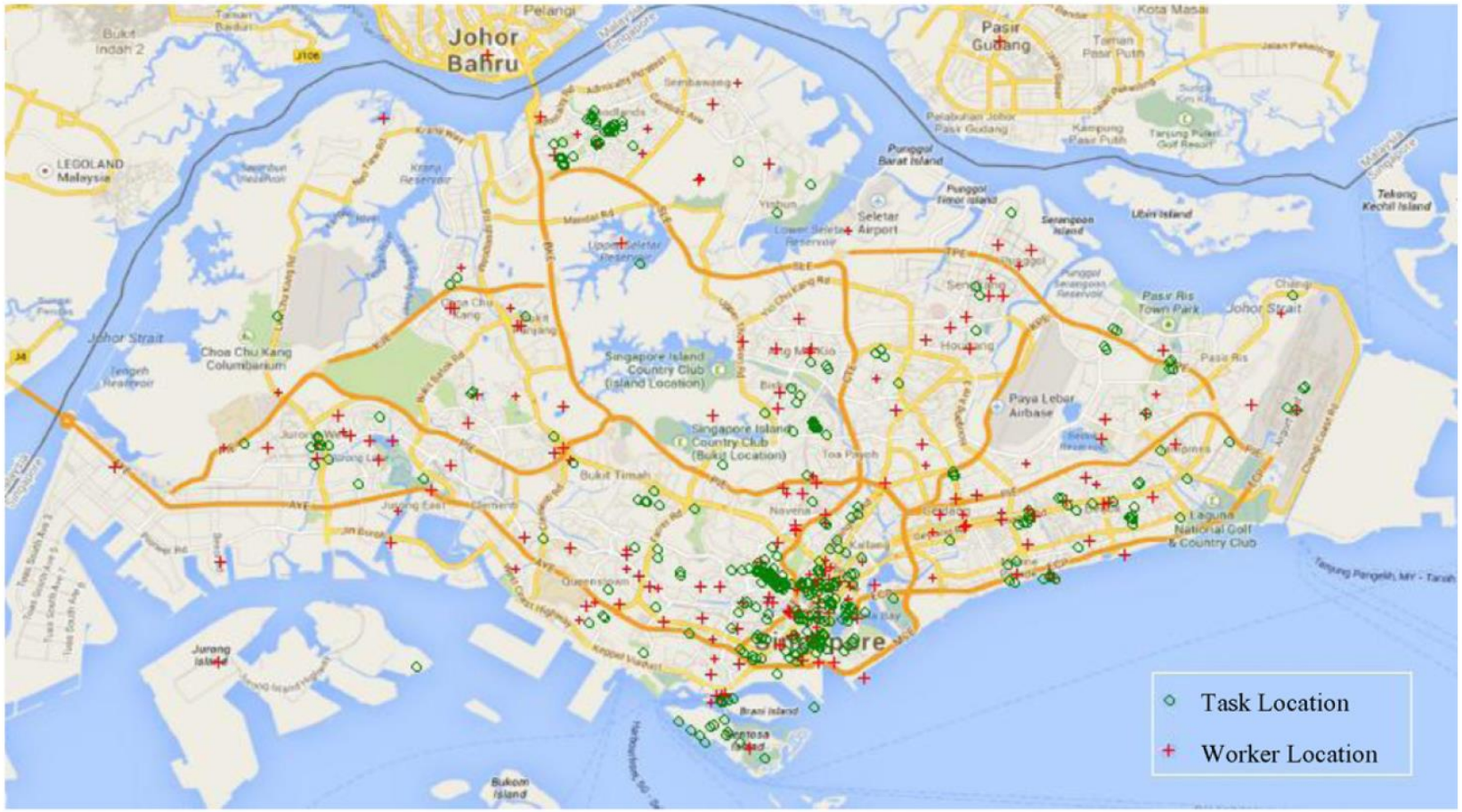
$$R = U^T \times V$$

$$\min_{U,V} \mathcal{L}_2(R, U, V) = \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{n} I_{ij} (R_{ij} - U_i^T V_j)^2$$

$$+ \quad \lambda_1 \|U\|_F^2 + \lambda_2 \|V\|_F^2. \qquad (11)$$

Trust in recommendation

Trust in Task Allocation



Maximize:

$$\sum_{j=1}^{N} c_j^{\tau^i}$$

Subject to:

$$\sum_{j=1}^{N} p_j \leq B^{\tau^i}$$

- For workers at the same distance from the location of a spatial task, the ones with higher reputation have higher credibility
- For workers with the same reputation, the ones closer to the location of a spatial task have higher credibility

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Challenges

- Refer back to “building a trustworthy system”
  - The definition of trust remains unclear
  - The factors impacting trust need more exploration
    - With new technologies, there will be new factors
  - The gap between the cognitive and computational trust models

In this lecture

- The definitions of trust and the factors impacting trust
- Cognitive trust models
- Computational trust models and attacks
- Challenges