Structural Transitivity of Trust in Academic Social Networks Using Agent-Based Simulation

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Abstract. Research interest in social networks area can be explained mainly because this type of network: (i) promotes the interpersonal relationship; (ii) has a natural tendency for knowledge emergence; (iii) generates large volumes of information. This interest is reinforced due to the fact that since the 90's Web Social Networks, e.g. Facebook or Orkut, have millions of users around the world. Our proposal in this paper is to analyze the physical structure of three computer networks topologies - centralized, decentralized and distributed – in a real academic social network, the Lattes Curriculum. The main question is how the network structure could influence the flow of the trust transitivity between the members of the network. Firstly, we conducted a survey with researchers about their trust in Lattes Curriculum and later we developed an agent-based model and simulated it to analyze the resulting data.

Keywords: Agent-Based Simulation, Trust, Transitivity, Academic Networks.

1 Introduction

In the Information and Communication Technologies (ICT) field the study of trust has become a topic of increasing interest because most of its developments involve interactions among several autonomous partners for the achievement of the expected outcomes. Therefore, such outcomes depend on the execution of tasks by several autonomous entities that need to perform them in a robust/deterministic (safe) way. Thus, the entities involved in the development (human or artificial) have to cooperate and solve conflicts towards the goal achievement, which together with the knowledge sharing and management, need to increase the importance of trust [6]. Therefore, in a scenario in which we do not know exactly with whom (or what) we are interacting, it is important to define trust metrics in order to help in the decision making process about cooperation. Several researchers attempted to escalate trust by creating degrees of mutual trust. However, trust is a subjective function related to the personals' beliefs about itself, the environment, and so on, requiring further depth studies about its transitivity in a network [6].

Transitivity is especially important as in an open net we have to interact with new or unknown agents, and it is not possible to count on our personal experience and evaluation, or on some authority's guarantees, or on the explicit recommendation of another agent. However, there is a network of trust or distrust relations/links; if we might know and exploit this information we can *derive* our trust from the other trust relations. It is a real collective capital: if I know that Y trusts Z, I might trust Z, and so on (see later for the conditions). Moreover, recommendations and explicit reputation presuppose a trust in the source (recommender, evaluator): it is precisely this trust in Y (source) that creates my trust in Z.

Recently, the large-scale use of social networks has also promoted an increase in available human interaction data, (a capital to be exploited) which consequently stimulated an increased in the number of studies associated to this area despite some studies date back to 1950's [16, 29]. A type of such network is the Academic Social Network that keeps records of interactions and collaborations among academic researchers. We consider its main aspect, the social capital that is kept undiscovered in the represented relationships and the possible high relevance that it may have on the academic context. Being aware of this unexplored area, some researchers have performed some quantitative studies on this type of network, in which concepts of Social Network Analysis are used to identify the centrality, density or clustering of the network and to understand the levels of cooperation and collaboration among researchers [20]. The few studies that deal with the trust aspect consider it from the data integrity point of view. Hence, the study of trust and its transitivity among researchers is an incipient research topic that has not yet been comprehensively examined in this domain [1,13, 14, 17, 27].

In the literature there are three topologies for computer networks: centralized, decentralized and distributed [3]. For each type there is a different relationship between its members. These types of topologies are applied in social networks and the most common is the decentralized structure. Exchanges in social networks can occur in two different ways: the positive (where A exchanges information with B, and B exchanges with A, i.e., zero sum), and the negative (where A exchanges with B, but B does not necessarily exchange with A). The negative one is the most common in this domain [9].

Since the 80's social networks structure is a subject that many authors have studied analyzing the power and dependency between the members of this type of network. Cook et al. (1983) [11] present a theoretical and experimental analysis performed with laboratory experiments and computational simulations. Their conclusion is that centralized models, where one of its members is central, are models where the power is centralized but are more susceptible to problems if the central member has some problem. In distributed networks, where all members are connected to all other members, the power is also distributed. However, these two cases are not the common formation in reality. Decentralized networks are the most common and they studied where power is concentrated in this kind of network. In their experiments members known as "intermediaries" are those who have more power, because they are the link between agents in the center and in the peripherals places. The authors highlight that for each "information exchange", the conditions and values chosen for each member are different.

Whitmeyer (1999) [28] presents a different type of network, called "interest-network structures". In this model in addition to the physical structure an interest variable is associated with the agents. This interest variable indicates the interest of the agent to exchange information with others (using 1-exchange rule[1]). The author considers that the interests are more important to define dependence and power than the physical structure. However, the physical structure restricts the relationships. For instance, in a scenario where an agent has great interest in other and they are not connected the exchange information will not happen.

In the work of Mizrucchi (2006) [24], a revision about social network and how the physical structures may influence the forms of interaction is presented. This author divides networks in hierarchical (centralized) and non-hierarchical (distributed, where everybody can exchange information). However, there is the "subgroups", with subnets (in fact, decentralized networks). He treats about rational choice theory, where the network members must do the choice that brings the best result (such as an utility function). However, people do not always do rational choices. Often, friendship, emotions, loyalty, etc., can influence the exchanges.

The goal of this paper is to analyze *how the physical structure of networks (based in the three topologies - centralized, decentralized and distributed) can influence in the trust transitivity* in an academic social network. We have used in our research the Lattes curriculum. Lattes curriculum is a public available database from Brazilian researchers. In fact, in our project, the main goal is to identify how the structure of the network could help (or not) the academic information exchange between Brazilian researchers.

Many authors affirm that the structure of the social network cannot define the power of each member [8, 9, 14]. This is due to the fact that the structure is just a basic condition to the existence of interactions, i.e., if X has something needed by other members, but not other member can access it or know that, X has not real power over the others. Connection is a necessary but not sufficient condition for power. Therefore, if X potentially might be able to impose something to the others, to obtain from them what it wants, but it is not connected, it cannot access them, it cannot send or receive from them, because it is a "missing channel" and it is actually impotent (isolated). Vice versa X is connected to Y but has nothing good or bad for Y, and has no power over him for exchange, cooperation, threat, ..

Considering these facts, it is clear that it is impossible to measure the network power based solely in the number of connections.

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[1] Markovsky et al. (1988) [22] defined the metric "1-exchange rule", where each member chooses just one other member to exchange information per round, independent of the total number of members. The choice could be a utility function or randomly.

For that reason the focus of this paper is not to find/define the network power. The main idea is *to analyze the physical structure and how it could influence the "flow" of the trust transitivity between the members of the network*.

This paper is structured in 5 sections. In sections 2 and 3, we present the two basis subjects of this research: network structures and trust transitivity in social networks. In section 4, we present the proposed model and our preliminary results and section 5 concludes the paper.

2 Structure of Networks and Metrics to Social Networks

According to Baran (1964) [3] there are three topologies for computer networks: centralized, decentralized and distributed (Figure 1). Baran's research originated from security problems in computer networks during the Cold War. His ideas of topology for networks are still actual nowadays and can be applied to social networks. The centralized networks, also called Star, are the most vulnerable because they have a central node which if is destroyed the entire network is lost. Distributed networks, called Mesh or Grids, are least vulnerable due to their high level of redundancy, where all nodes are interconnected (a relation n:n). However, the vast majority of computer networks is decentralized, namely hierarchical networks, forming small centralized networks (subnets). They are less vulnerable that centralized networks but there are some nodes that can cripple the communications. The structure complexity of these topologies can be defined as: the simplest level (centralized), intermediate level (decentralized) and more complex (distributed). In Narayanan et al (2013) [25], a special type of decentralized network is presented, called Federated Networks. This network has a decentralized topology, forming small centralized networks, but closed, where only members can access the subnets. In our project, we will work with the three first types.

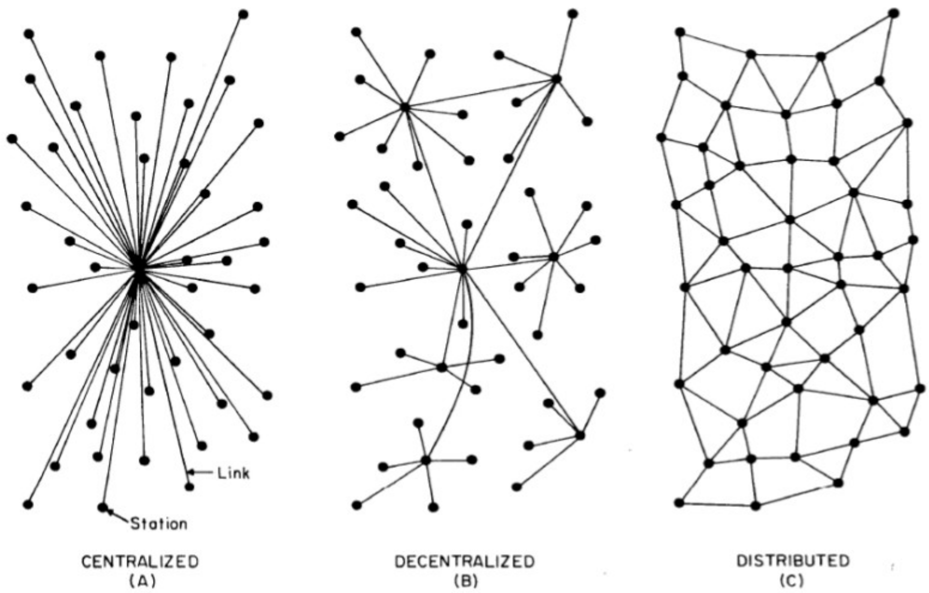

Figure 1: Types of Networks [3]

There are many metrics to analyze social networks such as degree centrality, density, clustering coefficient, giant coefficient, closeness centrality, betweenness centrality, diameter, and so on [15, 20, 23]. In our work three metrics are important to explain the network structure:

a) degree centrality (dc): when a node has many connections it is considered important. On the contrary, if the node does not have any connection it is considered irrelevant. This degree represents the relational activity of each node. The equation (1) presents the calculus of degree centrality to n_i node.

$$dc(n_i) = \sum_{k=1}^{N} e(n_i, n_k) \tag{1}$$

b) density (d): it is based in the degree centrality. The number of connections of each node is divided by the total number of connections of the network. The equation (2) presents the calculus of density to the whole network G.

$$d(G) = \frac{\sum_{i=1}^{N} dc(n_i)}{N(N-1)} \tag{2}$$

c) clustering coefficient (cc): represents the number of connections between the neighbors of a node divided by the total number of connections of the network.

In this way, considering the network structure, we can define:

if d (P) = 1 → distributed network

$\exists$ dc(n_i) = N and $\forall$ d(n_j) = 1, and j ≠ i → centralized network

$\exists$ cc(n_i) and $\forall$ dc(n_j) => 3[2], and j ≠ i → decentralized network with subnet

Otherwise → generic decentralized network (with any formation).

3 Trust and Transitivity in Social Networks

In social networks trust has been analyzed as it is an aspect that greatly influences the process of interaction among their members. There are works that deal with the transitivity of trust. The main idea is: if X trusts Y and Y trusts Z, then X trusts Z. In fact, this is not necessarily true. Trust carries not only a degree but it is related to a content, where the agent has performance and result, and is relative to certain attribute (qualities or defect) a for that "task/good". This scenario interferes with transitivity [9]. For this transition to be true the trust relation T between X and Y and between Y and Z must have specific subjective attributes in a given domain and this rarely happens [5, 6, 7, 8, 9]. In other terms transitivity is "content and context dependent".

Moreover there should be an effect of convergent or divergent attitudes/evaluation from different agents/sources. Not only my trust in Y (as evaluator) and Y's trust in Z can determine my trust in Z; but if also W and Q trust Z? Or if Y trusts Z but W and Q do not trust Z? Doesn't this affect my derived trust in Z? This is an important factor in a "network" of trust with many possible trust links on Z.

Liu et al. (2011) [21] present how to calculate the transitivity of trust based on four parameters: trust, social relations, recommendation rules and preferences similarity. This work presents some formalizations for the four parameters, defining principles and properties. A very important property is that the transitivity has a "decay", i.e., if A trusts B and B trusts C, and if A trusts C, the value of the last trust will be smaller that the trust value of B and C.

According to Noble et al. (2004) [26], the network topology can influence knowledge transmission. They conclude that in symmetrical networks the transitivity is higher. However, in real social networks this type of distribution is not realistic.

In the work of Josang et al. (2006) [18], a quantitative formalization of forms to interrelation between A and B with C is done. There are three different formalizations: Dependent Opinions (A and B have the same beliefs about C); Independent Opinions (A and B have different beliefs about C) and Partially Dependent (A and B have similar beliefs about C, but not identical).

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2 According to Barabasi and Albert (1999), 3 links is a typical number of connections to large networks. In fact, they identified a typical interval [2.1, 4] and they used 3 connections, because it is the average of this interval. They also defined this type of network as "scale-free" [4].

4 Proposed Model

In our project we try to identify how the structure of the social networks can influence the trust transitivity. To achieve that we have defined some steps:

• Step 1: Define a survey to capture the trust in the Lattes Curriculum and apply it to researchers in different knowledge areas;

• Step 2: Analyze the survey data and define "Trust Types", i.e., divide the researchers according to their trust (they trust more in one or other type of information in Lattes);

• Step 3: Verify if co-authors or co-organizers have influence in the trust, to analyze the "weight" of transitivity in the trust;

• Step 4: Develop a computational simulation to the trust types using the parameters obtained from the real data. For example, if 20% of the researchers think that "formation" influences the interaction, 20% of the agents will be implemented using this influence.

• Step 5: Analyze real and simulated data

Until now we have concluded the steps 1, 2 and 3, and the first proposed model with preliminary results.

4.1 Lattes Curriculum: the Academic Network in Brazil

The Lattes Platform (lattes.cnpq.br) is an information system developed and maintained by CNPq (National Council for Scientific and Technological Research). The main idea is to manage the science, technology and innovation in Brazil [10]. The first version was released on August 1999, with the initial version of the Lattes Curriculum. Recently, the Lattes Platform was cited as an example of complete database with highly qualified information in Nature [19].

This platform is composed by the integration of four separate systems: Lattes curriculum, which records the academic life of the researchers; research groups directory, which maintains information about the research groups in the country; institutions directory, which stores information on research institutes, universities, etc; and financial/promotion management system, which manages the requests of financial/support to researchers [2]. In our work, we have interest is Lattes curriculum. This is structured hierarchically in the following topics [12]:

• General Data and Formation: data identification, addresses, academic formation, research areas;

• Bibliographic Production: all publications of the researcher as papers in journals and/or conferences and books;

• Students Oriented: guidance and supervision (completed or in progress);

• Projects: projects of the researcher, with a abstract and members;

• Technical Production: software, products, technical reports;

• Events: information related to events that the researcher organized or participated;

4.2 Lattes Survey

The goal of this survey was to determine how the information provided by the researchers can influence the decision-making for new activities and/or to find works by the researcher, based on Lattes information trust.

We defined quantitative questions (with the possibility of qualitative information). For all questions, the parameters are: strongly influence, more than the average influence, little influence,very little influence and no influence.

The qualitative information could be written in a field “Justification”, if the researchers would like to express better their ideas. This survey was developed to Web platform. In this way, researchers could access it remotely via the following address:

http://diana.c3.furg.br/index.php?Itemid=1982&option=questionario&id_site_componente=3090.

This link was sent to several mail lists, nationwide, for researchers from various fields of knowledge. Table 1 presents the questions' survey which were based in the main topics of Lattes curriculum.

Table 1: Questions Survey about Lattes Curriculum

Q1: Do the formation (university/institute, research area) of the researcher influence your interaction with he/she?
Q2: Do the places where the researcher work(ed) influence your interaction with he/she?
Q3: Do the research areas of the researcher influence your interaction with he/she?
Q4: Do the researcher projects (in progress or completed) influence your interaction with he/she?
Q5: Do the researcher H-index, or the citations total in databases (Web of Science or SCOPUS), or the impact factor of the papers influence your interaction with he/she?
Q6: Do the publishers that the research have papers/chapters influence your interaction with he/she?
Q7: Do the technical production of researcher, as software, courses, technical reports influence your interaction with he/she?
Q8: Relating to all types of productions, do the co-authors of them influence your interaction with he/she??
Q9: Do the quantity of organized events by the researcher influence your interaction with he/she?
Q10: Do the co-organizers of events influence your interaction with he/she?
Q11: Do the researcher quantity of students oriented influence your interaction with he/she?
Q12: Do the researcher skills to organize events influence his/her skills to: a) manage projects? b) write academic or technical papers?

c) student oriented?
Q13: Do the researcher skills to write academic or technical papers influence his/her skills to: a) manage projects? b) organize events? c) student oriented?
Q14: Do the researcher formation and his/her professional performance influence his/her skills to: a) manage projects? b) organize events? c) student oriented? d) write academic or technical papers?

The survey was made available for two weeks and 94 researchers answered it. These researchers are from all areas of knowledge. The majority of researchers detailed their answers in justification field (qualitative responses) and presented “the reasons” for the quantitative choices helping us to better understand all the process.

Table 2 presents the consolidated data to all answers with the percentage of each item in each question. We can observe that some questions produce contradictory answers between the researchers. For example, question 2 has a percentage indicating little influence and more than the average near each other, related to the places where the researcher works. In some questions, as question 13-c, the most of researchers think that write papers influences in the student oriented.

The evaluation of Brazilian research has a quantitative role as researchers' work. However, to the same researchers, the questions that cover publications are not as important for interaction/trust to themselves, as presented by questions 5, 6 and 7.

Considering the trust of Lattes information, and the claim not of an empty "trust" but "trust for", with a content, an aboutness, the transitive relation between co-authors and co-organizers was not confirmed. According to the answers was not possible to conclude that the researchers believe that papers co-authorship indicates that a researcher is trustful to interact as well as to events co-organization. For both cases, several open answers highlights that a very large number of co-authors or co-organizers indicates that some people do not really participate in the processes, i.e., they just put their name in these activities. Specifically related to events, most answers were not positive and show that there are two "profiles" in academic: the scientific/technological and administrative. Organizition of events is considered an administrative activity.

Taking in consideration the main topics we can conclude that the most of researches have trust *for*:

TRUST-FOR formation
TRUST-FOR research areas
TRUST-FOR projects
TRUST-FOR students oriented

And, taking into account the questions 12, 13 and 14, the researchers have trust transitivity between the following topics:

TRUST-FOR events → to manage projects
TRUST-FOR events → to orientate students
TRUST-FOR production → to manage projects
TRUST-FOR production → to orientate students
TRUST-FOR formation → to manage projects
TRUST-FOR formation →to orientate students
TRUST-FOR formation → to increase the production

The relations described above means, for example, that if the researcher has trust in other to organize an event, he/she believes that it could manage projects in a good way (transitivity between different topics/activities).

Table 2: Perceptual of answers to each question to Survey

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
No influence	3,19	6,38	3,19	3,19	10,64	19,15	21,28	13,83	19,15	**30,85**	9,57
Very Little	4,26	8,51	3,19	4,26	15,96	25,53	14,89	15,96	22,34	24,47	8,51
Little	19,15	**32,98**	11,7	20,21	25,53	**30,85**	**39,36**	**26,6**	**34,04**	30,85	20,21
More than the ave	28,72	29,79	19,15	**26,6**	**26,6**	19,15	13,83	**27,66**	12,77	8,51	**29,79**
Strongly	**44,68**	22,34	**62,77**	**45,74**	21,28	5,32	10,64	15,96	11,7	5,32	**31,91**
Total	100	100	100	100	100	100	100	100	100	100	100
	Q12-A	Q12-B	Q12-C	Q13-A	Q13-B	Q13-C	Q14-A	Q14-B	Q14-C	Q14-D	
No influence	7,25	21,74	15,94	5,8	15,94	2,9	2,9	4,35	5,8	5,8	
Very Little	15,94	14,49	13,04	10,14	17,39	14,49	5,8	21,74	4,35	2,9	
Little	21,74	**27,54**	24,64	18,84	**40,58**	0	14,49	24,64	10,14	10,14	
More than the ave	**26,09**	10,14	**20,29**	**21,74**	7,25	21,74	26,09	17,39	18,84	21,74	
Strongly	**28,99**	**26,09**	**26,09**	**43,48**	18,84	**60,87**	**50,72**	**31,88**	**60,87**	**59,42**	
Total	100	100	100	100	100	100	100	100	100	100	

4.3 Computational Model and First Results

We designed an agent-based model in the platform NetLogo (www.netlogo.com) in order to test and to analyze the network structures in transitivity trust.

In the graphical interface of the model, the user can choose the following variables:

1. the topology of the network: centralized, distributed, decentralized nets or decentralized (as defined in section 2).
2. the number of agents: [1;500]
3. the number of neighbors: [3;100]. It is used just to decentralized nets, where the user can define the minimum number of neighbors in the subnets (in our definition in section 2, the minimum number of neighbors is 3)

Each agent has the following internal characteristics (beliefs):

1. TF – formation trust: boolean
2. TR – research trust: boolean
3. TP – project trust: boolean
4. TS – student trust: boolean
5. TE – event trust: boolean
6. TPu – publication trust: boolean
7. Collaboration: integer

Observing the survey data, the agents received in the beliefs a percentage of TRUE (strongly or more than the average influence) or FALSE (little, very little or no influence). In this way, the proportion used was:

1. TF : 75% true and 25% false
2. TR: 80% true and 20% false
3. TP : 70% true and 30% false
4. TS: 65% true and 35% false
5. TE: 20% true and 80% false
6. TPu: 45% true and 55% false

In each round, each agent chooses a topic to exchange (formation, research, project, student, events or publication) with other agent. These two choice (topic and agent) are random and based in the metric "1-exchange rule". If the value of the belief is "true" for the chosen topic, we will increment the belief "collaboration". As "collaboration" we understand that the transmission of the information, without a dependency or a real power metric.

Before to include the transitivity, we tested the following hypothesis, basing just in the physical structure of the network:

- in distributed networks, because all nodes are connected, the collaboration will be **high**.
- in centralized networks, everything depends of the central node (choosen randomly), but the collaboration will be between **high or intermediate**.
- in decentralized networks with subnets (minimum of 3 neighbors), the collaboration will be **intermediate**.
- in decentralized networks (with any formation), the collaboration will be **low**.

We used networks with 100 agents each and run it 20 times with 100 rounds each. The average values to each topic to collaborate are presented in Table 3.

Table 3: Results to Trust in Structured Networks

Network	TF	TP	TR	TS	TE	TPu
Distributed	1241	1172	1349	1107	347	752
Centralized	1674	1643	1611	1730	32	1733
Decentralized Net	1236	1165	1326	1145	304	726
Decentralized	1220	1101	1298	981	231	699

In Table 3, the topology with higher values was Centralized. However, to TE (trust in events), the values in centralized networks was very low. It happens because the proportion of TE with true values is very low (20%), and all communication pass to central agent (randomly chosen) and each agent will have just 20% of chance to choose this central node with TE true.

To Decentralized Nets and Distributed networks, we have values very similar. It could be shown that if the node have a minimum number of connections, the collaboration will be realized (not be necessary to know all network nodes to have collaboration).

In a second step, we included in the model the transitivity. After choosing the topic to exchange and the first neighbor, the agent will choose a "neighbor of the neighbor". If the value of the belief is "true" for the chosen topic in the "second" neighbor, we will increment the belief "collaboration" (see Figure 23) .

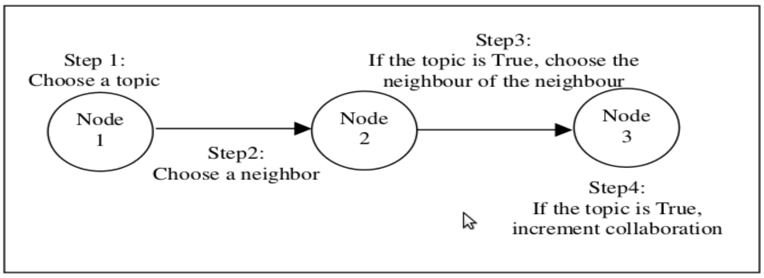

Figure 2: Steps to implement the transitivity in the model

In this second test, the proportion of trust is static, as presented above. Again, we used a network with 100 nodes each and run 20 times with 100 round each. The average values to each topic to collaborate with transitivity are presented in Table 4.

Table 4: Results to Transitivity Trust in Structured Networks

Network	TF	TP	TR	TS	TE	TPu
Distributed	901	781	1103	722	354	49

Centralized	1281	1158	1281	1095	781	31
Decentralized Net	931	801	1042	702	322	42
Decentralized	823	741	1031	681	296	32

The results of Table 4 confirm that with trust transitivity the hypothesis about the structure of the network. In centralized networks we have the higher values, after distributed and decentralized net. The lower level of exchange is in decentralized networks. The values with transitivity are lower than we have just trust (Table 3), because there is the "decay" with transitivity, according to Liu et al. (2011).

5 Conclusion

In this paper, we proposed a model to analyze the influence of the physical structure of the network to trust transitivity. Taking the trust percentage for each topic of Lattes curriculum, we have used the survey data (real data) in a static way (they do not change during all simulation). The choice for a topic and for other agent are randomly, as well as, the formation of the decentralized network (choose the neighbor).

In this first model, in generic decentralized networks, some agents could not have connection with any other agent, and this do not change during all simulation. In real life, people could "create" new connections. Is the transitivity the key to generate these new exchanges?

Besides, the perceptual of trust is static. However, these values could be increased or decreased depending on the old interactions (they have a memory). For example, if an agent interaction happens many times in a positive way with other node, could they created a loyalty?

In our first insights, we can conclude *that the physical structure of the network influence in the transitivity trust*. It can be obvious that centralized and distributed networks have the higher values of collaboration but in decentralized networks (specially with nets), the values are almost similar to distributed one. It is other important research question: does a biger degree of centrality is better to the trust transitivity? Our first results presented that, if a node has a minimum number of neighbors, the exchange will happen. However, the power of one node on the others is not simply dependent on the number of connections, and power is directly linked to trust [9], and it must be better investigated.

Another aspect that we must look for is about the comparison between "not realistic" and real-data models. According to Cointet and Roth (2007) [30], the diffusion of knowledge is slower in real-data. In this way, we will test the proposed computational model with the Lattes real-data.

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