Enhancing Digital Business Ecosystem Trust and Reputation with Centrality Measures

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***Abstract*— Digital Business Ecosystem (DBE) is a decentralised environment where very small enterprises (VSEs) and small to medium sized enterprises (SMEs) interoperate by establishing collaborations with each other. Collaborations play a major role in the development of DBEs where it is often difficult to select partners, as they are most likely strangers. Even though trust forms the basis for collaboration decisions, trust and reputation information may not be available for each participant. Recommendations from other participants are therefore necessary to help with the selection process. Given the nature of DBEs, social network centrality measures that can influence power and control in the network need to be considered for DBE trust and reputation. A number of social network centralities, which influence reputation in social graphs have been studied in the past. This paper investigates an unexploited centrality measure, betweenness centrality, as a metric to be considered for trust and reputation.**

Keywords: Digital Business Ecosystem, trust, reputation, centrality measures, social network analysis

I INTRODUCTION

The adoption of new forms of e-business for small and medium enterprise (SME) has been identified as a key priority for fostering innovation and competitiveness [37]. A Digital Business Ecosystem (DBE) is an environment where very small enterprises (VSEs) and small to medium sized enterprises (SMEs) can interoperate. The aim of the Digital Business Ecosystem is to support its participants to co-evolve in a competitive but at the same time collaborative environment [27]. Collaboration ensures that the entire Digital Business Ecosystem's market value is increased to be able to compete against bigger competitors [23].

The Digital Business Ecosystem vision presents unique challenges that are difficult to manage as it employs a decentralised model that is open to a diverse range of participants across many locations. It is apparent that peer-to-peer (P2P) implementations lend themselves naturally to digital ecosystem architectures [19]. Interactions in a Digital Business Ecosystem can be modeled by a multi-agent peer-to-peer network where agents represent VSEs and SMEs that interact with each other. The network of agents can be viewed as a social graph where the agents are the nodes and the relationships are the edges.

As collaborations play a major role in the development of Digital Business Ecosystems, the selection of partners who are strangers at the time is difficult. Since trust forms the basis of all human interaction, collaboration and society [6], agents can decide to collaborate based on the trust they have in each other. The more trustworthy a partner is, the higher its reputation is likely to be in its community. Participants with higher reputation are more likely to be selected, leading to further business and more profit. Modeling, computing and analyzing trust and reputation for Digital Business Ecosystems is a challenging issue as participants leave and join the network continuously. Social network analysis is a rich model in conceptualization and investigation. It provides a powerful set of concepts and methods for designing, modeling and analyzing complex situations [26]. The motivation for this paper is to discover social network metrics that can be used to assist with trust and reputation for Digital Business Ecosystem.

Next, section 2 provides a motivating example to give background on a Digital Business Ecosystem. Section 3 gives background on Digital Business Ecosystem trust and reputation. In section 4, the Digital Business Ecosystem is defined in terms of a social graph, and the properties that influence social graphs with regards to trust and reputation are discussed. Section 5 identifies how closeness and betweenness can influence trust and reputation and proposes a framework for Digital Business Ecosystem trust and reputation systems. Section 6 concludes the paper.

I. MOTIVATING EXAMPLE

Consider the Digital Business Ecosystem social network graph in Figure 1. It consists of nodes representing very small enterprises (VSE) such as builders and plumbers, and medium sized enterprises (SMEs) such as suppliers, collaborating with each other. The connectivity of nodes indicated by the social graph is generally not defined by geography or proximity, but by information sharing and transactions between nodes.

In time, participants who do not successfully exchange information become less strongly connected, and those who contribute achieve stronger connections. This leads to a small-world network topology where node position in the network plays a major role in the economic growth of the node. Small-networks have many strongly connected clusters or communities, see labels **x** – **z** in Figure 1, with a few connections between these communities. These networks have

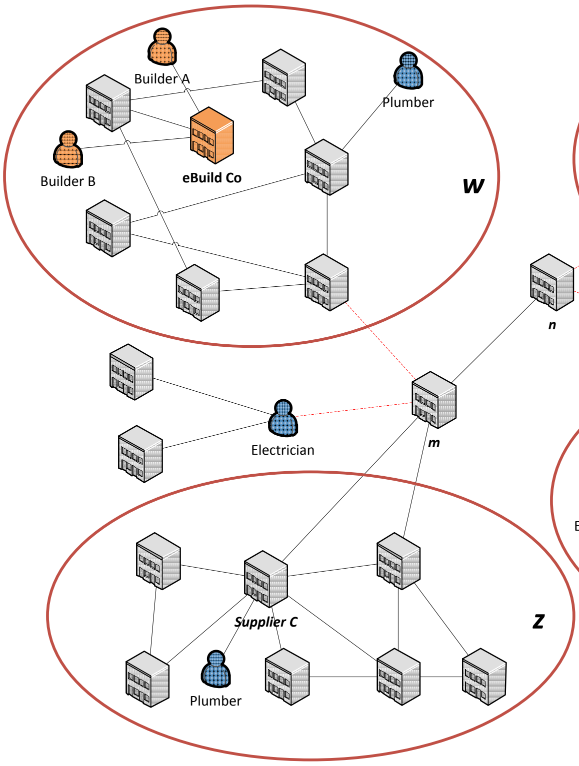

Figure 1. Digital Business Ecosystem

very high clustering coefficient and small characteristic path lengths [26].

For any node seeking to form collaborations, there is the problem of choosing a partner. Partnering with any available VSE or SME is not feasible as their reliability is not known beforehand. By making use of recommendations from others, better partners can be selected. Such recommendations are highly influenced by the extent of overlap of social relations between VSEs or SME. There is generally a tendency for nodes to ask recommendations from partners that are close to them in the network space. For example, if my partners have had good experiences with a specific SME, my perceived value of that SME increases. The network of immediate contacts is thus an important source of information about possible future contacts. Also, the number of indirect links between two VSEs may have an effect on the probability that they will form a direct link or partnership in the future. In Digital Business Ecosystems no central party can dominate because this would provide a significant barrier to the growth and sustainability of the environment. If a node such as eBuild Co would like to become a strong competitor in the environment, they need to collaborate with those who have the strongest ties in the network in order to be successful. eBuild Co will thus have to determine the reputation of other nodes by sourcing recommendations before making a decision to collaborate with them. If eBuild Co knew that the most trusted and effective community was, for example, community **x** they would try to become part of this community. This can only be made possible if a node in the Digital Business Ecosystem, positioned in between the two communities could introduce eBuild Co to this group. It is thus important for eBuild Co to determine who these brokers are as they play an important role in fostering growth and innovation.

Next, trust and reputation features of Digital Business Ecosystem systems are described.

II. DIGITAL BUSINESS ECOSYSTEM TRUSTAND REPUTATION

A Digital Business Ecosystem can be represented as society of autonomous agents conforming to a peer-to-peer network architecture [19] [23]. These autonomous agents compete and collaborate with each other to benefit themselves and the communities they inhabit. The location of a specific member of a community within a Digital Business Ecosystem social network can be used to infer some properties about their reputation. Organisations that are effective and highly regarded by most members of the Digital Business Ecosystem tend to be highly connected nodes in the social network graph. Such information could be used by the reputation mechanism of agents instead of having to use the ratings issued by each participant.

It is necessary to clearly distinguish between the notions of trust and reputation for Digital Business Ecosystems. Reputation is generally computed over a period of time, whereas trust is based on a personal bias before taking a decision to interact with another person.

Literature defines trust as the extent to which one party is willing to depend on something or somebody in a given situation with a feeling of relative security, even though negative consequences are possible [6] [21]. If the agent of Builder A has trust in the agent of eBuild Co, it is confident that the agent will behave in a particular way. Trust is subjectively formed [19] and cannot be assumed to be mutual. The trust value used by the agent represents the confidence the agent has in the expected behaviour of another.

Reputation is an objective measure assigned to an agent, representing the collective evaluation from a group of agents that have interacted with it. The reputation of Supplier A is based on all past actions with the agents that it has interacted with and associated ratings [19]. An agent with a good reputation will be trusted more by other agents, than one with a bad reputation. This implies that trust can be built through reputation.

The interactions between Digital Business Ecosystem participants can be recorded by a graph, where an arc in the graph corresponds to an interaction between the participants who are nodes of the graph. Such a graph can be called a social network as it simply encodes interactions among all participants. If a network graph is directed, an edge from Builder A to Builder B implies that Builder A recommends Builder B. Intuitively, network graph centrality measures are established over aspects such as trust transitivity, where it is more likely that individuals will interact with friends of friends than with unknown parties. Also, individuals are more inclined to trust someone who is trusted by some of their trusted friends. Important questions that arise are - where is the graph stored? How is the trust computation done? How can the trust metric be used to help making decisions?

In order to evaluate a Digital Business Ecosystems participant's trustworthiness, an agent needs to rely on the judgments of other peers who have already interacted with them and shared their impression. These impressions are expressed as trust metrics. Trust metrics are divided into those with global and those with local scope [31].

Global trust metrics take into account all members of the social network and their relationships. A global trust rank is computed based on the opinion of all nodes in the network. A disadvantage is that the entire graph must be known and stored and the computation may be expensive.

On the other hand, when computing trust and reputation in the local community or neighbourhood, only the local graph needs to be explored. These *local* trust metrics are subjective as they are personalized and their computation scales well. Local trust metrics operate on partial trust graph information defined by personalized webs of trust where only neighbour links and their direct links are explored to a set of nodes reachable through these relationships. Merging these local trust web graphs gives the global trust graph.

The nature of Digital Business Ecosystems, therefore dictate that local trust metrics should be preferred because of its decentralised peer-to-peer architecture. A Digital Business Ecosystem agent forms a subjective opinion on participants it interacts with based on the computation it performs.

Approaches to trust and reputation computation are generally classified as centralised or decentralised [31]. More recently, hybrid approaches [34] accommodate the difficulties of decentralised reputation systems.

Centralised: Centralised trust and reputation systems are found in e-commerce applications, for example, eBay [8]. Here, a central entity is responsible for collecting ratings from all parties involved in an interaction. The reputation of users is public and global and is computed by the system. The advantage is that there is less communication required between users.

Decentralised: In decentralised trust and reputation systems, agents represent users or organisations. There is no central party for agents to share their ratings with each other and no global or public reputation exists [8]. For example, when Builder A wants to find out the reputation of Builder B, it's agent has to ask other agents for their ratings about Builder B, including those of Builder A's friends or the friends of friends. This implies a large volume of communication between agents. These ratings are then combined by the agent of Builder A to determine the reputation of Builder B.

Hybrid: Recent work introduced a super-agent based mechanism [34], inspired from super-peer networks, for reputation management to solve the inefficiency problem of a decentralised trust and reputation systems. Now, an agent with poor capabilities will not be able to cause system blockages as in a true decentralised approach. Super-agents collect and store feedback about services, build reputation of services, and share reputation information with other agents. A super-agent can form communities based on its interests and judging criteria. A community-based reputation for services, found on the collective opinion of its community members can be developed, and shared with the community members.

Even though centralised methods are simpler and more efficient to use they may not be well-suited to Digital Business Ecosystems. As participants are autonomous in Digital Business Ecosystems, their agents need to follow a decentralised approach where they can decide how to weigh ratings provided by other agents based on how much they are trusted, thereby ensuring personalized reputation. However, for Digital Business Ecosystems this approach represents some difficulties such as how to find reputation information. In a centralised system, the central entity in charge stores the reputation graph and related information. In a decentralised P2P network the answer is not clear-cut. The agent may not know which other agents have interacted with this agent for whom they are trying to build reputation. Also, agents are not always available at all times. If they are offline, their ratings about other agents are not available at the time of request. Also, the Digital Business Ecosystem illustrated in Figure 1 is typically a small-world network that has a few strongly connected communities, with a few connections between communities. Very often, participants of these communities are not sophisticated and do not have the ability to support and manage a reputation system. A super-agent approach to trust and reputation may therefore ideally be suited to Digital Business Ecosystems environments.

In the following section, social network centrality metrics is described in the context of Digital Business Ecosystem trust and reputation systems.

III. TRUST AND REPUTATION USING SOCIAL NETWORK ANALYSIS

The underlying idea of deriving a participant node's reputation from a social network topology is that reputable members in a social network tend to be highly connected powerful people who are experts or people who share valuable resources easily. Such measures can be determined by social network analysis that is a technique used to study social graphs to analyse the patterns, behaviours and interactions of communication in social groups [26]. Key players in a social network can be identified as well as groups in large and complex social networks. Groups represent clusters in the social graph consisting of nodes that are more central, nodes that are peripheral, and nodes that lie in between all these nodes [26]. One of the main social network analysis measures is centrality which is used to define the actor's position relative to the other actors in his or her social graph [26].

Many reputation systems are based on network graph centrality measures. An example of a well-known network graph-based reputation system is PageRank [33]. The PageRank algorithm uses hyper-links as a sign that one web page recommends another web page. PageRank can also be used to indicate the number of times a random surfer visits a web page, thereby reflecting the popularity and reputation of a web page. A drawback of PageRank as a reputation measure is that all outgoing links from a node are considered equally and not whether the interaction was a good or bad experience [35]. In order to address this problem the TrustRank [33] algorithm was defined.

The focus of the discussion is on the local and decentralised characteristics of social network graphs, to accommodate the nature of Digital Business Ecosystem trust and reputation systems. Next, the social network perspective used in social network analysis is described. The role and effect of centrality measures on trust and reputation is then analyzed.

A. Network perspective

Network perspective of social network analysis is achieved from two perspectives, a socio-centric perspective and an egocentric perspective.

1) Socio-centric Perspective

A socio-centric perspective analyses a complete and bounded social graph from a global perspective [7]. Figure 1 gives the socio-centric view of the Digital Business Ecosystem social graph. Here, trust metrics take into account all the peers as well as the trust links that connect them [31]. This means that each node only consider the global reputation of nodes calculated via a centralised reputation manager that can view the entire network. As mentioned, this is process intensive as the complete social graph, which may change continuously, needs to be considered. The centralised and global approach limits the personalised property of trust as a nodes trust would only be considered from a single third party perspective and not personally [14]. Due to these facts this approach would therefore not be useful in Digital Business Ecosystem trust and reputation systems.

2) Egocentric Perspective

An egocentric perspective analyses only the ego network of a node which consists of the node (actor), its friends (alters) and all the connections between them [7]. The ego neighborhood is the collection of ego and all nodes with which ego has a connection at some path length. In social network analysis, this includes only ego and actors that are directly adjacent and all of the ties among all of the actors to whom ego has a direct connection [31]. If one considers eBuild Co as an ego in Figure 1, then community ***w*** would be the neighbourhood to be considered.

Performing trust and reputation computations from this perspective is less process intensive as each node such as eBuild Co only maintains trust and reputation for its own locally stored ego network. It is natural to use an egocentric perspective in peer-to-peer networks due the decentralised nature of these networks.

Next, social network centrality measures for Digital Business Ecosystem trust and reputation are discussed.

B. Social network centrality for trust and reputation

Centrality measures give the relative importance of a node within the graph [7]. In social networks, trust and reputation is computed by considering the strength of the relationship between two nodes defined by direct trust, and the further influence of other relationships defined by indirect trust. In direct trust, local social network centralities to be considered are degree centrality and tie strength. These metrics can affect the availability and accuracy of recommendation information provided to and about the node. Indirect trust on the other hand is a result of the transitive property and propagation of trust which can be influenced by a number of centrality measures such as shortest path, density and clustering coefficient. Short paths and dense clusters can lead to more accurate, reliable, and trustworthy indirect trust values and recommendations.

Direct and indirect trust, as well as the centrality measures that influence these trust values, are discussed next.

Direct Trust

Direct trust exists between two nodes that have a trust relationship established; this is sometimes referred to as individual trust [25] [17]. Consider the case of just two nodes as in Figure 2. A Builder and eBuild Co, taken from Figure 1, is labeled *A* and *B* respectively. There are always three elements that form trust regardless of which definition is used, namely, the *trustor, trustee,* and the *state of trust* [9] [1]. If *B* is the trustor and *A* the trustee, $T_{b\text{-}a}$ is the state of trust. Trust is subjective meaning that *B* will not necessarily trust *A* to the same extent that *A* will trust *B* and vice versa. This implies that trust is *asymmetric* [14]. The direct trust value can evolve over time as the two companies collaborate more often thereby potentially forming a stronger trust relationship. In figure 2, each node has a single incoming and outgoing link. Trust and reputation computation may be very different for nodes with many links, than with nodes with few links.

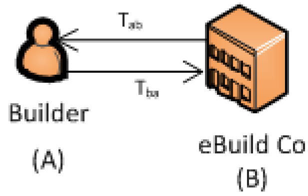

Figure 2. Direct trust relationship

Social network metrics to be considered next are degree, density and tie strength. Both can be used in ego neighborhoods such as community ***w*** in Figure 1.

1) Degree

The degree centrality of a node is defined as the total number of connections the node has [2] [18]. In a directed graph there are two degrees namely outdegree and indegree. Outdegree is the number of connections a node has to other nodes, i.e. the number of nodes that can be reached from a node in one hop [4]. In Figure 2, both nodes have an indegree and outdegree of 1.

The effect of degree on trust is that it can be seen as a parameter which defines the extent to which a node would convey information about another node to the trustor [1]. A node that is reliable will have a higher outdegree than a node who is less reliable [1]. Indegree is the extent to which a node receives information about another node from the other nodes. Therefore, node with both high indegree and outdegree are well connected and could therefore play an important role in the computation of trust and reputation.

2) Tie Strength

In social network analysis, tie strengths are classified as either strong ties or weak ties and it refers to the strength of the relationship. A strong tie represents a strong trust relationship between two nodes and a weak tie represents a lower trust relationship between two nodes. The weight which is used to measure the strength of ties is the weight of the edges connecting nodes. Weak ties will have a weight relatively smaller than the weights of the connections a node regularly maintains, and the opposite is true for strong ties [18]. A node with many strong ties will be more trusted than a node with many weak ties.

Indirect Trust

Now consider the case where the social network graph grows and more nodes are linked together. Another Builder, shown as *C* establishes a relationship with B. There is direct trust between these two nodes. If *A* would like to collaborate with *C* it may ask *B* for a recommendation of *C.* The transitivity property of trust and the network topology identifying paths can be used to assist *A* in its decision whether it should trust *C.* Because of the number of links, trust is propagated through the network [14] [17] [22]. Transitive trust implies that if A trusts B and B trusts C then it is inferred that A can trust C to some degree [24].

The trust established from transitive trust is known as indirect trust as it is determined by recommendations [31].

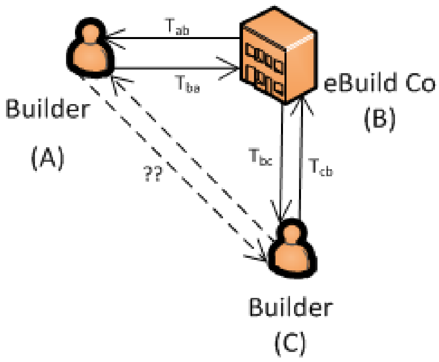

Figure 3. Indirect trust relationship

The reputation of *B* will influence *A's* decisions on how much trust to place in *C.* If there were many nodes linked to both *A* and *C, A* would have had to aggregate all the recommendations received on *C* using an algorithm. Important centrality metrics that have an effect on this situation is shortest path, network density and clustering coefficient.

3) Shortest Path

When indirect trust is computed, a number of paths may be found linking two nodes. The shortest path between two nodes in a social graph is defined as the geodesic distance between these nodes according to the unit length of the edges [2]. The unit of length is the weight of an edge. This weight is not necessarily a distance measure but can also be, for example, the trust level of the relationship [17]. In terms of the transitive trust property and trust propagation, the shorter the path between two nodes, the more trustworthy the indirect trust value will be [14] [17]. This is due to the fact that a node will trust its direct contacts more but the further away the nodes get, the trust value of these nodes will be less, leading to a less trustworthy recommendation. To be able to find a short path to other nodes the complete social network must be known. This measure is global and cannot be applied to a locally stored social network graph of an ego neighborhood.

4) Density

Density is the number of connections a node has, divided by the number of possible connections [4]. Densely clustered networks are more likely to lead to strong trust and a shared identity [5] [16] [28]. This leads to a sense of community where these nodes can collaborate and cooperate by ensuring a self-enforcing informal governance [12] [28]. In a dense network, agents are likely to receive good recommendations from a larger number of other agents [30]. Considering figure 1, community ***x*** has a high density and community ***z*** has a low density. This means that in community ***x*** organisations have formed a strong community where they have high trust and reputation established due to the alliances and collaborations that are continuously formed. Because density requires knowledge of the full network, it cannot be applied to a locally stored social network graph of an ego neighborhood.

5) Clustering Coefficient

A node's clustering coefficient can be defined as the proportion of alters that are themselves directly connected [18] [28]. This metric therefore quantifies how close the node's graph is to becoming a cluster or, in social networking terms, a clique [2]. This can be used in ego neighborhoods such as community ***w*** or ***x*** in Figure 1, to determine the strongest community.

As organisations collaborate with other organisations, they form stronger trust relationships and clusters tend to form, as shown in Figure 1 [28]. Clustering increases the transmission efficiency in the network by giving nodes the ability to assess all the information received. [28]. If nodes are clustered in trust groups then this would improve the quality of recommendations [11]. Clustering can form strong trusted communities where the organisations in these communities are collaborating to enhance their organisations and in-turn the entire community. With this in mind, the reputation of these organisations can be very accurate and reliable.

The social measures discussed so far have been used in trust and reputation systems. There are more social network centrality measures that have not been exploited for trust and computation, which are discussed next.

IV. INVESTIGATING UNEXPLOITED SOCIAL METRIC CENTRALITIES

Social network centrality measures indicate how communication happens within a social network. It identifies nodes that are in central positions within a social network. If a node with high centrality must pass ratings and recommendations to others, there exists a risk that the node can compromise the information and behave opportunistically [10]. To gain more power in a Digital Business Ecosystem, a node may fail to pass along all important information to nodes that are dependent on this information. The node may believe that it would be worth his while to risk his position of power. If other nodes should find this out, the node will in time lose his position in the network. The node's centrality therefore will decline. There are two such centrality measures to be considered namely closeness centrality and betweenness centrality. Consider Figure 4 from [26]. Node **p** has the best closeness, whereas node **h** has the best betweenness.

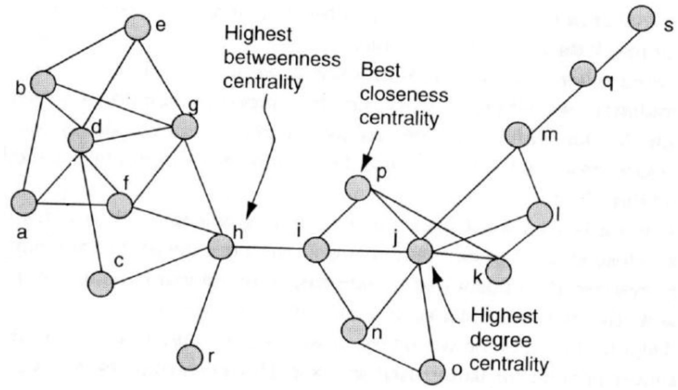

Figure 4. Centrality measures

Not many trust and reputation systems specifically consider these measures in their computations. Their effect on trust and reputation is now discussed.

A. Closeness Centrality

Freeman identified the closeness centrality as the total distance to or from all other nodes, where distance refers to the number of links along the shortest path [26]. Since closeness measures the distance to all other nodes, then the shorter this distance is, the more central the node is [29].

If nodes are central but have low trust, information should rather flow through nodes with higher trust but with less centrality. This could lead to information taking longer and less efficient routes in the network [10]. Therefore, as a node's trust gets lower, so will the nodes closeness centrality, because the node will be bypassed so that a more trusted node can be used to transmit the information. Closeness is related to shortest path in the sense that if a node is closer to you, the indirect trust values might be more accurate and reliable [29]. Unfortunately, closeness centrality is uninformative in an ego neighborhood network because of the limitation on network size.

B. Betweenness Centrality

Betweenness centrality is the measurement of the extent to which a node falls along a number of shortest paths connecting other pairs of nodes [3] [18] [7] [29]. Figure 4 clearly indicates that node **h** is such a node. A node will have a high betweenness value based on the extent to which it exists on the short paths between all other pairs of nodes, meaning that the node will have control over these paths [3]. High betweenness nodes thus have the ability to facilitate interactions and control information between unconnected nodes [7].

Nodes with high betweenness values essentially act as "brokers" or "bridges". This is due to the fact that there are no other short paths that can bypass this node with a high betweenness [3]. Therefore nodes with high betweenness values are very important within the network as the loss of these nodes can disrupt the structure of the network [29]. Should a node with a high betweenness value in the Digital Business Ecosystem social network no longer be in existence, this would impact a significant number of organisations negatively. The positions of nodes *m* and *n* in Figure 1 clearly illustrate this. Should node *m* or *n* fail, there would be no path by which companies in the different clusters could connect with each other. This indicates how important these nodes are in establishing and maintaining a robust network structure.

An interesting feature of betweenness is that it can be used in both sociocentric and egocentric networks [7]. This means that regardless of how the network and the trust relationships are viewed, i.e. globally or locally, the betweenness value of a node can always be determined.

The presence of bridges in the social network of Digital Business Ecosystem present more business opportunities to ensure that the Digital Business Ecosystem grows and evolves to become more competitive. The question is what is the effect of these central positions on trust and reputation? Betweenness centrality has been addressed in the analysis of various topics, such as transportation, social networks, and biological networks, but to the best of the knowledge of the researchers, no real work has specifically addressed betweenness centrality with reputation except for the work of Delaviz, Andrade and Pouwelse [36]. They use the betweenness centrality of nodes in the BarterCast reputation mechanism that is used by a Bittorent-based file-sharing client Tribler to compute reputation not from the perspective of a node, but from the perspective of the node with the highest betweenness centrality.

The researchers believe that betweenness centrality is an unexploited social network analysis measure that indicates the importance of a node in a network where reputation mechanisms should treat such nodes differently because of the central role that they can play.

The next section describes a basic trust and reputation framework, taking into account the nature of Digital Business Ecosystems.

V. A FRAMEWORK FOR DIGITAL BUSINESS ECOSYSTEM TRUST AND REPUTATION

A Digital Business Ecosystem framework for trust and reputation is now defined based on the research identified in this paper. Basic assumptions and the approach are defined. The manner in which both current and unexploited centrality measures can be used for trust and reputation is described. The Digital Business Ecosystem social graph is defined by the topology shown in Figure 1. This is the global view of the social network graph, not visible to any single node or central party. Every participant, either a VSE or SME being either a consumer or service, is represented by an agent. These agents each build a local graph of its ego neighborhood as it interacts with other agents. The agents follow a local and decentralised approach to trust and reputation. Although agents act in a decentralised way, clusters tend to form, resulting in strong trust communities.

In Digital Business Ecosystem there are nodes who are interested in building communities. They are represented by super-agents, called community managers [34], who collect and build reputation of services in their community. Such reputations are provided to any the agents of a prospective consumer of a service. In community ***x*** in Figure 1, Supplier B may be such a node. Super-agents are discovered through searches if agents of consumers want to use any services provided in community ***x***. Super-agents follow a centralized approach to reputation, thereby ensuring a hybrid approach for reputation management for a Digital Business Ecosystem.

At a community level, direct trust values between the agents of consumers and those of nodes providing services are used to determine trust. Degree and tie strength centralities are used to provide a more accurate measure of the trust in an agent of a node. The super-agent thus uses the direct trust values of agents of consumers to determine the reputation for a specific agent of a node. Between communities, super-agents may become aware of a much larger network graph requiring the use of shortest path calculations.

The trust in a community as a whole is important to consider and is determined by agents of consumer nodes. The clustering coefficient of a super-agent gives an indication of the strength of the community. Super-agents need to behave trustworthy to be able to attract more consumers to its community, thereby building a stronger community. Consumers give a weight to the super-agent's reputation information about the nodes in its community.

In these environments, super-agents exert a large amount of power and control on the flow of information in the environment. A super-agent may be a broker between agents who are in different communities. The network centrality of super-agents thus needs to be taken into account when their trust and reputation is determined. The main focus of this research is to identify how betweenness centrality can be used to enhance Digital Business Ecosystem trust and reputation. Higher betweenness centrality means a higher contribution of the node in connecting other nodes, and a higher flow that passes through it.

The following observations provide more motivation for the focus of this research:

- Super-agents with high betweenness generally regard others as more trustworthy as those who are in peripheral positions, due to their relative control over the community.
- If a super-agent has higher betweenness than others, and is highly trusted by agents of consumer nodes, it should be treated with care as not to lose its benefits.
- The power that a super-agent exerts over the environment should be carefully considered when trust and reputation is computed and used.
- A super-agent can provide reliable recommendations for a greater number of nodes, thus, enabling collaboration opportunities for highly detached nodes in the network.

To date little research has been done to determine how betweenness centrality can enhance Digital Business Ecosystem trust and reputation. Research needs to be done to evaluate the effect of betweenness when combined with trust and reputation computations. This could be valuable for Digital Business Ecosystems who follow a hybrid approach as the loss of trust in these nodes could lead to the deterioration of communities. This is of importance in Digital Business Ecosystems where nodes such as VSEs and SMEs need to survive and generate profit in a competitive environment.

There is much future research to be done. Next this research aims to focus on investigating various betweenness centrality computations to determine the best one to use for Digital Business Ecosystem trust and reputation. Simulations will be performed to experiment with betweenness centrality and its influence on trust and reputation.

VI. CONCLUSION

This paper gives a background on Digital Business Ecosystems and how trust and reputation are to be considered in conjunction with social network centrality measures. A contribution is made by the discussion of social network centrality measures in conjunction with trust and reputation. Social network centrality metrics such as degree, tie strength, shortest path, clustering coefficient, and density are identified and their effect on trust and reputation considered. Two important and popular social network centralities, not yet considered for trust and reputation are identified namely closeness and betweenness centrality. Of these, betweenness centrality is identified an unexploited measure that should be researched. Finally, a basic framework was defined that shows how social network metrics can be used to support a hybrid and local approach to Digital Business Ecosystem trust and reputation. Future research aims to investigate the effect of betweenness centrality in the formation and growth of trusted communities.

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