Q-Contract Net: A negotiation protocol to enable quality-based negotiation in Digital Business Ecosystems

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***Abstract*— The Digital Business Ecosystem (DBE) is the result of the co-evolution of the Business Ecosystem and the Digital Ecosystem. There are numerous approaches and enabling technologies which are used in modeling open business marketplaces and, due to the similarities between the Digital Business environments, they can also help to enable the Digital Business Ecosystem but with some limitations. The complete lifecycle of the DBE can be decomposed into the following phases: formation, evolution and dissipation. In this work, our main focus is on the importance of negotiation in the DBE formation phase and especially on the structure of Contract Net Protocol. We will present an extension to the primitive Contract Net Protocol and name it Contract Net with Quality Protocol (CNQP or Q-Contract Net) to facilitate the negotiation process by adding the quality evaluation steps during the negotiation phase of the DBE formation.**

Index Terms — CNP, Quality, Digital Business Ecosystem, Trust.

I. INTRODUCTION

The Digital Business Ecosystem is considered as the result of the co-evolution of the Business Ecosystem and the Digital Ecosystem [2]. A Business Ecosystem is defined as an economic community [1], whereas a Digital Ecosystem is a self-organizing digital infrastructure used by the networked organizations [2]. There are some good approaches used to model electronic marketplaces which have features similar to the Digital Business Ecosystem. The DBE project [2] is considered to be one of the great contributions made to promoting the vision of the Digital Business Ecosystem. Based on the agent technology, Electronic Institutions [4] [5] [6] are used to model such business scenarios which facilitate heterogeneity, autonomy and a cooperative environment. This environment is governed by a set of norms that constitute the Electronic Institution. Another multi-agent system called the Contractual Agent Societies [7] [16] is similar in many aspects to the Electronic Institutions. Both of these approaches use a set of norms to coordinate social activities. All these and other approaches which are used to model the dynamic electronic marketplaces have concepts which approximate those of the Digital Business Ecosystem.

The Digital Business Ecosystem goes through different phases during its lifecycle during which a number of activities take place. One important phase of the DBE lifecycle is the DBE formation phase. This phase plays an important role in the success or failure of the overall Ecosystem or in any transaction among the entities of the Ecosystem. The most important activity in the formation phase is the Negotiation. The process of negotiation has been formalized by different models. The most interesting and easy to implement protocol used to facilitated negotiation is the Contract Net Protocol [10]. In Contract Net Protocol, the negotiation process is decomposed into a number of steps with a comprehensive description of each step, message format etc. FIPA (Foundation for Intelligent Physical Agents) [11] further extended the CNP with minor modifications. There are a few other extensions of CNP which are discussed in the following sections.

The focus of this work is on the negotiation process during the formation of a Digital Business Ecosystem and mainly on Contract Net Protocol.

We propose an extension of the CNP with the addition of the quality evaluation step during the negotiation process. This will facilitate the Digital Business Ecosystem formation phase which will reduce the associated risk in the transactions and boost the performance of the transactions in the DBE.

In Section II, we will focus on the concept of DBE and some related approaches in enabling such electronic marketplaces. An overview of the DBE lifecycle is presented in Section III. In Section IV, we discuss the DBE formation phase and highlight the importance of the negotiation process. We will present our proposed Contract Net with Quality Protocol (CNQP) and discuss the negotiation trade-off due to the introduction of the quality evaluation steps. In this paper we make use of the acronyms 'CNQP' and 'Q-Contract Net' interchangeably in order to refer to Contract Net with Quality Protocol.

II. BUSINESS ECOSYSTEMS

The term "Ecosystem" is generally defined as a network of interdependent entities. It is seen as an environment where

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species depend on each other for their survival and prosperity. James F. Moore [1] first introduced the concept of a Business Ecosystem in his famous work published in 1996, where he defined a Business Ecosystem as an economic community comprised of organizations and individuals in different roles including suppliers, consumers, competitors and various stakeholders. According to Moore [1], the capabilities and roles of the organisms in the Business Ecosystem can co-evolve and can be standardized. Another familiar term is "Digital Ecosystem" which, as defined in the DBE project [2], is a "self-organizing digital infrastructure aimed at creating a digital environment for networked organizations that supports the cooperation, the knowledge sharing, the development of open and adaptive technologies and evolutionary business models". The DBE project [2] defines a Digital Business Ecosystem as the co-evolution of the Business Ecosystem and Digital Ecosystem. The continuous adoption of Internet Technologies by the DBE has given tremendous advantages and flexibility to the Business Ecosystem, but at the same time, has raised many important issues and challenges. Since DBE itself is a result of the adoption and evolutionary stages like e-commerce and e-business, it depends greatly on ICT, which leads to challenges in the formation of such Business Ecosystems.

The DBE project [2] is considered to have made a great contribution to promoting the vision of Digital Business Ecosystems. The DBE project [2] describes the six stages of the introduction of ICT and Internet technologies in the leveraging of the Digital Ecosystem. The digital network, in its initial stage of moving towards an ecosystem, made use of simple message exchanges using emails and related simple message-passing mechanisms. This stage significantly assisted the Digital Ecosystem to organize and synchronize the tasks among its elements (organisms). As the adoption of Internet technologies gained momentum, new concepts like e-commerce and e-businesses emerged, creating more opportunities and challenges for the digital environment. Organizations became networked and eventually an ecosystem of digital businesses (analogous to species or organisms in an ecosystem) emerged. Businesses started implementing open standards, shared knowledge and information, and conflict resolution mechanisms. Regulatory schemes in this open business environment forced businesses to cooperate and compete in new dimensions.

The initial benefit of the Digital Ecosystem was seen to be an open, distributed environment where the organisms of the ecosystem could share and gain access to information from any domain. The discovery and mapping of information sources remained as interesting issues due to the dynamic nature of such sources.

In order to model and enable Digital Business Ecosystems and such electronic marketplaces, different approaches and platforms were introduced like the one by Bhaskaran et al. [3]. This platform was basically introduced for B2B e-Commerce and the requirements needed for such a platform were proposed. The platform is based on a framework of software design patterns. These design patterns are basically used for collaborative business processes and to integrate trading partner systems. Bhaskaran et al [3] propose that the supply chain business processes of the participants are the key to the success or failure of the markets. The key requirements for the proposed platform include integrated user experience, a common security mechanism and business process integration mechanism, common messaging infrastructure, solution management and monitoring. In their work [3], they also consider some non-functional requirements like performance, scalability, reliability, availability and extensibility as being part of the platform. In the following sections, we will discuss some approaches that are used to enable electronic marketplaces and which share similarities with the Digital Business Ecosystem.

III. DIGITAL BUSINESS ECOSYSTEM'S LIFECYCLE

Like Electronic Institutions, Contractual Agent Societies and Virtual Enterprises, the Digital Business Ecosystem also has different phases in its life cycle. Starting from formation to evolution and then dissipation, all these phases closely follow the approaches to all the concepts discussed above.

Formation: The Digital Business Ecosystem formation is the most crucial phase of its lifecycle. In the digital environment, businesses search for business opportunities and different services and components during this phase. Searching for partners normally depends on the level of skill and knowledge, or it may be on the availability of the partners or resources. This phase also provides opportunities to perform complex tasks through collaboration among agents, which is not achievable by a single business entity. This collaboration depends on the trust that entities have in their counterparts. To achieve this collaborative task execution, a proper negotiation mechanism helps with contract establishment.

Evolution: This phase is also referred to as DBE operation or execution. During the evolution, the activities and transactions of entities occur which are governed by a different set of norms or business rules. Adoption in a dynamic environment is a challenging part of this phase where the entities are facilitated while at the same time tackling the undesired behaviors of the entities, which can affect the initial objective of the contract. Conflict resolution and deadlock handling mechanisms work actively to maintain the Business Ecosystems integrity.

Dissipation: After the achievement of the initial objectives as per contract, the Temporary Business Ecosystem is dissipated to provide the chance for the entities to participate in other activities. In this phase, all the information regarding the activities that have occurred, along with the information about the behaviors of the entities, is stored for future transactions. The payoffs according to the contact are distributed among participating entities. The Dissipation of Business Ecosystems may occur for any of several reasons, such as the successful completion of tasks, the changed market demands, loss of contract validity or severe types of disasters occurring during the transaction.

In the following section, we will focus on the Digital Business Ecosystem formation and discuss the importance of the negotiation and other challenges in this phase.

IV. Digital Business Ecosystem formation

As discussed above, this phase is of great importance and plays a crucial part in a successful transaction. During this phase, business entities try to find business opportunities in a competitive environment. During this competition phase, several issues arise that need to be addressed such as the identification of malicious entities, entities with fewer or no previous transaction histories etc. On the other hand, in the case of complex task execution when collaborative efforts are needed, searching for qualified partners is also a challenge. An optimized negotiation mechanism can help to establish lucrative contracts during this phase.

A. The Negotiation Process

Let us examine more closely some of the systems in use which are better at facilitating the negotiation process. Most of these systems are based on the Multi-agent approach like auctioning [5] and some of the most interesting ones using Electronic Institutions. The main focus of Electronic Institutions [6] [8] is on defining a certain set of norms, which normally governs the entire environment. It can be seen as associations of intelligent, autonomous and heterogeneous agents, which play different roles in the environment and fulfill their individual or common goals. Electronic Institutions are also used to enable Digital Business Ecosystems [5] and Virtual Enterprises lifecycle [9].

The importance of negotiation can be seen in different concepts and approaches as in [7] that used the standard Contract Net Protocol in modeling the marketplace in Contractual Agent Societies [16]. The Contract Net Protocol first introduced by Reid G. Smith [10] was designed for communication and control in distributed problem solving to facilitate cooperative task execution. Further details and issues will be discussed in the next section.

B. The Contract Net Protocol (CNP)

Contract Net Protocol is a high level communication protocol, which was initially used for communication among the nodes in a distributed problem solver. It facilitates cooperative task execution and control in a distributed environment. The contract net is described as "The collection of nodes [10]".

One of the main issues in the negotiation process is how to share a task among the nodes, which have processing ability. This problem is referred to as the connection problem. It is considered as a great challenge in distributed problem solving in terms of the performance. Generally, there are two aspects to the connection problem: how to allocate the resources, and who the possible contractors will be.

Contract Net Protocol describes the message format, which is used for communication among the nodes. There can be different types of messages, which are associated with the nature of the task which is being negotiated. Along with the messages, it also introduces a Common Internode language for the communication and interpretation of these messages.

The Contract Net Protocol divides the negotiation process into a sequence of steps. After the task has been decided, the first message that is sent by the task announcer (manager) contains all the necessary information in the messages slot with proper encoding. This message is received by other nodes (which may be arbitrary or focused nodes) and they start processing this announcement. Table 1 shows each step with the identification of the processing node and action taken by the nodes.

TABLE 1
Description of Negotiation steps through Contract Net Protocol

Steps	Description of Steps	Processing Node
1	Task Identification	Manager
2	Task Announcement	Manager
3	Task Announcement Processing (Evaluation)	Contractor
4	Bidding	Contractor
5	Bid Processing (Bid Evaluation)	Manager
6	Awarding Contract	Manager
7	Contract Processing	Contractor
8	Termination	Contractor/ Manager

Table 1 sets out the sequence of steps taken during the Negotiation process. It can also be considered as a sequence of activities because it has several more steps similar to primitive CNP [10] in which more than one activity is considered as a single step. We also consider the Task Identification, Awarding Contracts and Termination of the contract as separate steps.

During the first step, the task is decided along with the target recipient (broadcast, focused addressed or point-to-point) and the type of message. Then the task is announced by sending this message to the appropriate Contractors. The Contractors then process this announcement and can refuse or bid on this offer before the deadline. The Manager, on the other hand, will receive refusals or bids and will start to process (evaluate) these bids. The successful Contractors will receive a reward message and are allowed to execute the contract. During the contract execution, an intermediate report can be sent to the Manager if needed. The contract at this stage can be terminated due to any of several reasons, either by the Manager or, at the completion of the successful contract, executed by the Contractor. The final report is then sent to the Manager. Here, we have given a brief overview of the negotiation steps, but several issues will emerge during these steps.

The FIPA (Foundation for Intelligent Physical Agents) [11] introduced Contract Net with Interaction Protocol (CNIP) with a minor modification by adding rejection and confirmation communicative acts. Fig. 1 shows the sequence of steps in the FIPA Contract Net Protocol [11].

Some important extensions of the CNP can be found in works such as:

- Constraint-based Contract Net Protocol [12]
- Contract Net with Confirmation Protocol (CNCP) with threshold plus DoA [13]
- Competitive Contract Net Protocol with decommitment [14].

In order to achieve a successful contract execution, we must be sure about the quality of the participating contractors (participants) and the manager (initiator). The importance of quality in the negotiation phase can be seen in several approaches such as the introduction of Q-negotiation Algorithm [9]. The Q-negotiation protocol [9] is used for the electronic marketplace in modeling Virtual Enterprises.

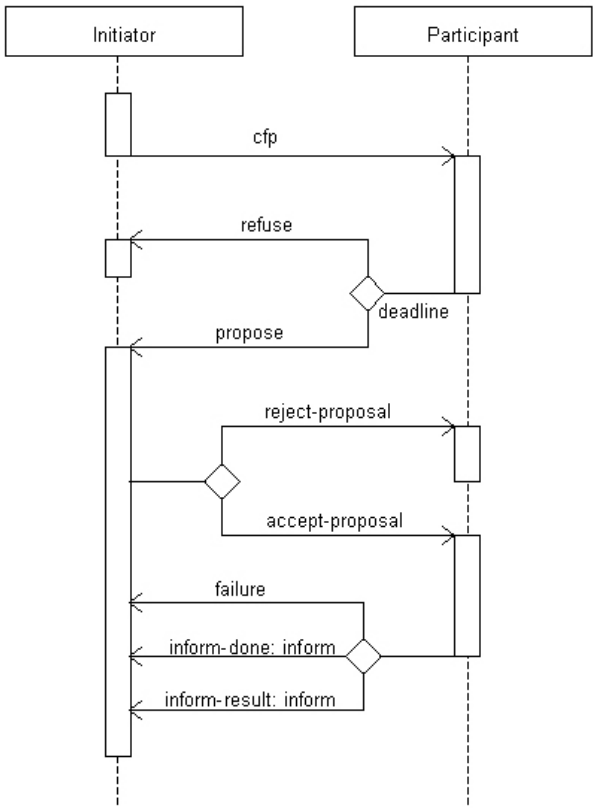

Fig. 1. FIPA Contract Net Protocol sequence diagram

We will frequently use certain terms during the discussion which we consider to be synonymous such as Entities for Business Entities and Nodes, initiator for manager and announcer, announcement for cfp and participant for contractor. Some of them are used by FIPA instead of the terms used in primitive CNP.

V. CONTRACT NET WITH QUALITY (CNQP)

One of the main reasons for using Contract Net Protocol for the negotiation process in Digital Business Ecosystems formation is that CNP is lightweight compared with the normative form of negotiation as in Electronic Institutions.

We propose an extension of the FIPA Contract Net Protocol by introducing quality evaluation steps during the negotiation process and call it Contract Net with Quality Protocol (CNQP). Since we are modeling the negotiation process for the Digital Business Ecosystem formation, we need a very solid and straightforward mechanism to elicit the most committed contracts. Any kind of failure will definitely affect the entire life cycle of the Digital Business Ecosystem. Furthermore, it is very difficult to deal with unexpected scenarios during the Evolution phase (execution) of the Business Ecosystem. Although it is very difficult to handle and guarantee the future of the Digital Business Ecosystem by taking appropriate measures during the formation phase, nevertheless a major supportive decision for the success of the DBE can be taken during the formation phase. As discussed in the previous sections, the negotiation process plays an important role in filtering and scaling the participants in any business transaction. In CNP and in its extension, a general processing and evaluation of Task Announcement and Bids during the Bid Processing is carried out. In the case of processing Task Announcement, the participant checks for eligibility specifications, which include ensuring the participant's eligibility to meet all the conditions expressed in the specification. Task ranking, which is a task-specific operation, is also part of processing the announcements. This can be considered as a general evaluation of the announcement, which compares the task specification with the capability of the participant itself. But an important issue which arises here and which must be addressed is the evaluation of the quality and eligibility of the initiator by the participants. This is very important and can easily be seen in real world business transactions where businesses engage in contracts only with those business initiators who have a satisfactory history of a similar type of transaction. The quality of the initiator, eligibility, resources, and the faith in the initiator in distributing the payoffs in accordance with the initial contracts during the negotiation process, are all very important doubts which arise in the mind of the participant when a proposal is announced.

During the bid processing stage, the initiator (manager) maintains a rank-ordered list of bids that have been received for the task. The bids are ranked by their level of satisfaction, which is normally the closest to the eligibility criteria or task-specific requirements. But the main issue here is to evaluate the actual eligibility of the participants that includes the previous transaction history, the most recent level of quality of the participant, available resources for task execution etc. The quality factor here plays an important role in the success of the future transaction and selection of the appropriate participant. According to the specification of CNP [10], announcements cannot always be in the form of broadcasting to all the available participants, but can be directed towards a particular set of participants; this is known as focused addressing. This focused addressing can be towards a sub-set of the participants or can be in the form of point-to-point communication. But this is possible only when the nature of the participants is known a priori. Still, due to dynamic business environments such as digital business ecosystems or electronic marketplaces, the quality

of the participants frequently varies. These frequent changes can affect either the entire, or some aspects of, the quality of the participant. In this case, even a focused addressing mechanism can face problems in the future during the execution of the contracts. There should be a quality evaluation mechanism during the bid processing phase, in addition to the normal processing of the bids regardless of the type of communication - that is, whether it is a broadcast or focused addressing. Fig. 3 shows the introduction of quality evaluation phases in the CNP sequence diagram.

A. CNQP Negotiation Trade-offs

The introduction of the quality evaluation phases during the negotiation process using Contract Net protocol will also produce a few challenges. The main issue is the effect of these new phases on the overall efficiency of the negotiation process. Fig. 2 shows the time acquired during the negotiation process during each stage of negotiation in the primitive CNP. There are several activities going on during each of the mentioned time slices or stages of negotiation. We have named these time slices t1, t2, t3, t4, t5 and t6.

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Note: At this point in our discussion, we are not considering the iterations during the negotiation process in particular during the stages of announcement processing, bidding and bid processing, but rather a one-cycle flow for the simplicity of the scenario.

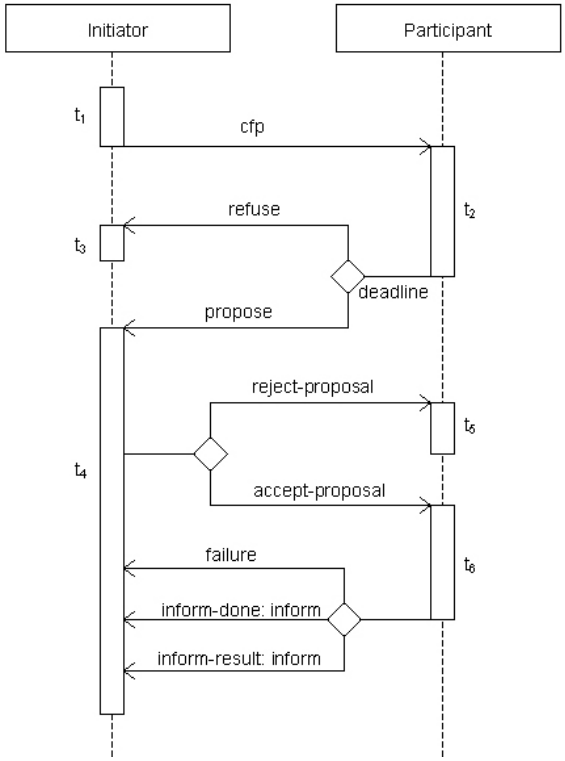

Fig. 2. FIPA Contract Net Protocol time slices

The introduction of quality evaluation phases during the negotiation process can be seen in Fig. 3. We have decomposed the time slice t2 into two distinct parts t2 and tq1 according to the nature of the activity being carried out during these stages. During the time t2, the normal announcement processing will occur as in the primitive form of CNP, but the new time slice called tq1 will deal with the evaluation of the quality of the announcer. The Bid processing stage of negotiation is named t4 (Fig 2), and in our extension (Fig. 3) we have decomposed this stage into two distinct time t4 and tq2 slices according to the nature of the activities being carried out during these stages. During the new time slice tq2, the initiator will perform the quality evaluation and time slice t4 is the same as in primitive CNP during which bid processing will take place. We can see in Fig 3. that, as a result of decomposing t4, we have separated it from the final stage and named it t7, which are considered as one in Fig. 2.

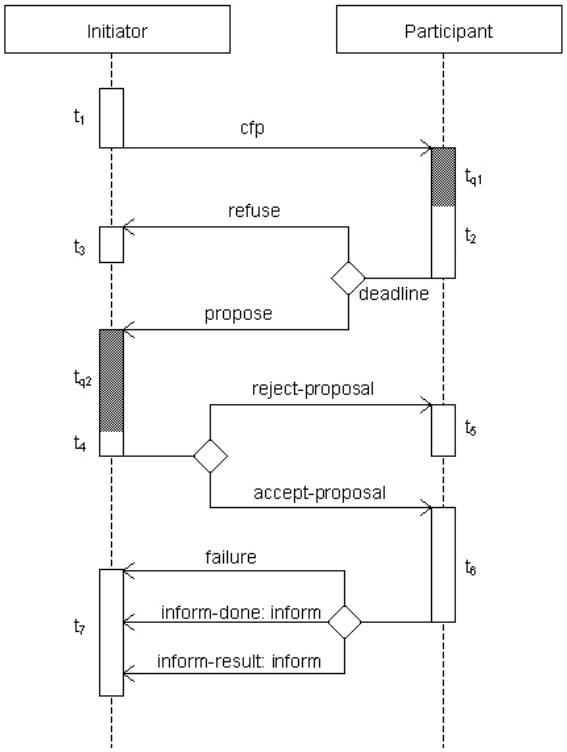

Fig. 3. Contract Net with Quality Protocol sequence Diagram with time slices

The description of each time slot, along with the activities performed during each time slice and the nodes involved in the processing, is shown in Table 2. These are the major activities during each time slot but there are also other minor activities during each time slice.

$$T_p = t_1 + t_2 + t_3 + t_4 + t_5 + t_6 \quad (1)$$

$$T_q = t_{q1} + t_{q2} \quad (2)$$

$$T_Q = T_p + T_q \quad (3)$$

In equation (1), Tp represents the sum of all the time intervals in primitive CNP i.e. t1, t2, t3, t4, t5 and t6 during the negotiation process. Tq in equation (2) represents the sum of the added time for quality evaluation during negotiation. TQ in equation (3) shows the sum of the two sets of time slices Tp and Tq, which is the overall time taken for negotiation with CNQP.

The main concern with the introduction of quality evaluation stages during the negotiation process using Contract Net Protocol is the efficiency of the negotiation process. The time spent in querying the quality repository and quality management system, which we call in our work the Quality Backbone Engine (QBE), and processing the quality by the QBE, is the added time to the negotiation process. But on the other hand, the overall performance of the interactions among the entities will increase tremendously, since the QBE is capable of selecting and suggesting the most suitable entities which will reduce a lot of overhead in terms of time, resources and risk during the contract execution.

TABLE 2
TIME SCALE FOR THE NEGOTIATION PROCESS USING CONTRACT NET WITH QUALITY PROTOCOL

Time Slot	Task performed	Processing Node
t_1	• Task Identification • Message Formatting • Task Announcement	Announcer
t_{q1}	Quality Evaluation (of Announcer)	Participant
t_2	• Task Announcement Processing (Evaluation) • Bid Formatting • Bidding	Participant
t_3	Participant list updation	Announcer
t_{q2}	Quality Evaluation (of Participant)	Announcer
t_4	• Bid processing • Awarding Contract / Rejecting Proposal	Announcer
t_5	Wait for other offers	
t_6	• Contract Execution • Intermediate Reports • Final Report	Participant
	• Contract Termination	Participant/ Announcer
t_7	• Finalizing the Contract • Payoff distribution • Updating Quality Backbone Engine	Announcer

It will also help to reduce the level of uncertainty before the contract execution. It is capable of improving the confidence level among business alliances to execute complex tasks, which is one of the main objectives of our work. Our proposed CNQP will extend the primitive format of the messages with minor changes, which makes it straightforward and easy to implement. In the next section, we will discuss the different aspects of the quality being used in CNQP.

VI. QUALITY DESCRIPTION

In regards to 'quality' we do not consider only the ability of the participants to execute the contract, but we also consider different aspects, all of which act as pillars for determining the quality of a participant. Fig 4 shows the various aspects of quality. We present only a brief description of each aspect, as our main focus is on the negotiation process.

A. The Quality Aspects

- *Reliability:* We define Reliability as "the strength and ability to overcome and survive uncertain behavior and uncertain failures." The value of Reliability is based on the previous interaction.
- *Trust:* Here we make use of the term Trust as defined in [15], which states that Trust is "the belief the trusting agent has in the trusted agent's willingness and capability to deliver a mutually agreed service in a given context and in a given time slot".
- *Reputation:* We again use the definition of Reputation given by [15], which defines the Reputation of an agent as "an aggregation of the recommendations from all of the third-party recommendation agents, in response to the trusting agent's reputation query about the quality of the trusted agent."

Due to space constraints, we are able to present only the core idea of using CNP for the negotiation process in Digital Business Ecosystem formation, as our description of quality clearly defines the aspects on which business entities would be evaluated.

VII. CONCLUSIONS AND FUTURE WORK

In this work, we have discussed several of the approaches used to model the Digital Business Marketplaces. Most of the approaches are more institutionalized and provide a set of norms which help to achieve a formal environment for business activities in a digital environment. This discussion shows that these approaches have many similarities and can be helpful in enabling environments like DBE. But in modeling the DBE, they have a few limitations. In this paper, we have discussed the DBE lifecycle, i.e. its formation, evolution and dissipation and focused on the formation phase of this lifecycle. Negotiation among the entities in DBE and relative modeling approaches play an important role in the formation phase of the DBE. The success of the business transactions largely depends on well-formalized negotiation and contract assignments. The choice of CNP for the negotiation is widely used in a number of domains due to its flexibility, less complexity and ease in implementation. We

proposed an extension to the primitive CNP by adding quality evaluation steps during the negotiation to enable negotiation based on quality-based service level parameters. As pointed out and discussed in the paper, the only trade-off with the introduction of the negotiation based on quality-based service level parameters is the efficiency of the negotiation process. But, at the same time, without a proper quality evaluation mechanism, the overall performance and reliability of the negotiation and execution of the contract cannot be guaranteed. A detailed description of the actual quality evaluation mechanism during the negotiation process is not presented in this work due to space constraints.

In our future work, we intend to make use of the proposed protocol to carry out negotiation between business entities on service level parameters.

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