SMART AGENT-BASED FRAMEWORK FOR MULTIPLE SIMULTANEOUS BILATERAL NEGOTIATIONS TO SUPPORT BUSINESS PROCESSES

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Abstract

This paper introduces an innovative agent-based intelligent framework aimed at modelling and facilitating simultaneous and parallel negotiations among organisations operating within the same industrial sector. The challenge lies in capturing the dynamic nature of the environment, where negotiations involving multiple attributes and participants are competing for a diverse array of resources. The quest for enhanced competitiveness has prompted companies to establish specialised business units to navigate the pursuit of new partnerships, necessitating seamless interoperability.

However, the current state of Enterprise Interoperability is susceptible to the disruptive influence of external factors, making it vulnerable to fragmentation. To adapt to necessary changes, continual adjustments must be made, albeit at the risk of introducing conflicts with existing concepts, potentially jeopardising interoperability with partner organisations or necessitating widespread modifications. In response, this paper proposes a collaborative framework to facilitate negotiations aimed at enhancing interoperability among organisations operating within the same industrial domain, leveraging a model-driven, cloud-based infrastructure and services.

The objective of this study is to provide assistance to autonomous microgrids that lack the capacity to secure large contracts independently. Addressing interoperability challenges, the paper advocates negotiation activities as a fundamental solution. Negotiation serves as a means for all microgrids within the collaborative network to reach mutually acceptable resolutions. The paper presents a negotiation approach wherein intelligent agents assess and modify offers and counteroffers, supported by a communication protocol among these agents.

Keywords: *Automated Negotiation, microgrid, smart agents, dynamic environment, Network Enterprises, Virtual Enterprise.*

1. Introduction

Enterprises are forging specialised business units to seek and align with optimal partners and suppliers, ensuring their solutions resonate with strategic objectives. In a landscape marked by evolving solutions, platforms, trends, standards, and regulations, this pursuit demands continual updates to solutions, interfaces, methods, and quality standards. The ability of enterprises to seamlessly exchange information, internally among departments or externally with external parties, defines Enterprise Interoperability (EI). While large enterprises establish market standards and influence their supply chains accordingly, Small and Medium Enterprises (SMEs) face greater vulnerability to environmental fluctuations, necessitating constant adaptation for interoperability within their ecosystems. Sustainable EI (SEI) entails maintaining interoperability throughout the lifecycle of enterprise systems and applications, requiring continual maintenance and adaptation to evolving conditions and partners.

Recent advancements in information technology have given rise to virtual organisations, exemplified by the concept of Virtual Enterprises (VEs) or Networks of Enterprises. These alliances, formed by independent companies, pool skills and resources to enhance profitability, facilitated by computer networks. In this context, the paper aims to develop a conceptual framework and associated informational infrastructure to support collaboration activities, particularly negotiations, within Network Enterprises.

The concept of Virtual Enterprise (VE) or Network of Enterprises has emerged to identify situations wherein multiple independent companies collaborate to establish a virtual organisation, aiming to enhance profitability. Defined by Camarinha-Matos, „a Virtual Enterprise (VE) is a temporary alliance of enterprises that come together to share skills and resources, facilitated by computer networks”[1].

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[1] L.M. Camarinha-Matos, H. Afsarmanesh, *Collaborative Networked Organizations*, Kluwer Academic Publisher Boston, 2024.

Focusing on the intersection of communication technologies and industrial relationships, the paper delineates two main directions: leveraging the Internet and Informatics for interpersonal communication and envisioning efficient coordination of information technologies to streamline activities. In this respect, the objective of the paper aligns with the continual pursuit of enhancing profitability through fostering collaborative endeavors. The paper underscores the importance of supporting SMEs in virtual alliances, enabling them to subcontract tasks and negotiate within inter-organizational alliances.

Negotiation plays a pivotal role in these alliances, serving as a means for achieving common agreements to support collaborations. By exemplifying negotiation processes within scenarios involving microgrids—autonomous entities managing contracts, programs, and resources—the paper introduces a smart framework for coordinating simultaneous negotiations in dynamic environments.

These scenarios underscore the flexibility required to support negotiation processes while respecting the autonomy of partners. The collaborative infrastructure must enable minimal exchange of information, ensuring that each participant retains decision-making power over its contracts, resources, and clients. Ultimately, the objective is to foster cooperation among competing entities within virtual alliances, enhancing responsiveness to market demands while maintaining individual autonomy.

The following sections describe the challenge of automated negotiations, the collaborative microgrid architecture, the coordination components that manage different negotiations, the description of the negotiation process among autonomous microgrids and the final considerations of this paper.

2. The Challenge of Automated Negotiations

In simple terms, negotiation is a discussion between two or more participants trying to find a solution to a problem. This interpersonal or intergroup process can occur at both the individual level and the level of an industrial organisation or even internationally (diplomatic). Therefore, we will identify several characteristics of the negotiation process that are common across most research domains. To distinguish between the mechanisms that drive negotiation and aspects that are not directly related to negotiation but influence the process, we will present a synthetic view of negotiation, structured into three categories of dimensions:

- the participant involved in the negotiation;
- the context in which the negotiation takes place;
- the mechanism that drives the negotiation.

Regarding the participant in a negotiation, in most disciplines studying negotiation mechanisms (excluding computer science), the participant is usually human. In this section, we will detail two aspects of the participant in a negotiation:

- the individual dimension, which describes the human aspects of the participant;
- the social dimension, which characterises the possible roles in a negotiation.

We have proposed this division with the aim of distinguishing between the characteristics of participant behavior that may influence the negotiation process and the possible constraints imposed by the negotiation process.

In daily negotiations, the success of any transaction depends heavily on the human factor, on the players negotiating these transactions. The participants are unique individuals with different personalities and motivations, exhibiting distinct behaviors shaped by their own emotions and psychology. A different perspective can be found in books that make a clear distinction between the mind of the participant - responsible for developing negotiation strategies and reasoning mechanisms - and the heart of the participant, which characterises the emotional, psychological, and intuitive aspects of negotiation[2] [Thompson, 2020].

Another approach emphasises that skilled negotiators can learn to manipulate their own emotions and those expressed by other participants very effectively. Thus, two different negotiations can be identified: one with one's own emotions and another with the person on the other side of the table[3] [Gray, 2007]. Therefore, they are free to respond constructively to their adversaries. This means that the best negotiators seek, and probably succeed in finding, certain expressions of the emotional behaviors of other participants, which recur with a certain regularity. By identifying these regularities, attached to the individual dimension of the different participants, negotiators can refine their own behavior based on the behaviors of others.

[2] L.L. Thompson, *The Mind and Heart of the Negotiator*, 7th ed., Northwestern University, Publisher Pearson, 2020.
[3] B. Gray, *Negotiating With Your Nemesis*, 2007, *https://doi.org/10.1111/j.1571-9979.2003.tb00789.x*.

2.1. The negotiation participant

During a negotiation, the rhythmicity of certain actions by the participants is linked to the values attached to the social dimension that identifies the roles participants play in the negotiation process.

Multiple roles are proposed in negotiation studies. Considering that, most often, the characteristics of these roles do not have the same dimensions, we have structured the proposed roles based on three aspects: i) the goals participants try to achieve, where the roles are: seller and buyer; ii) the involvement of the participant in the negotiation process, where the roles are: initiator and guest; iii) the power of the participants over the negotiation process execution, where the roles are: mediator and active participant.

Seller/Buyer: The seller is the one who possesses an object or a service and tries to sell it. The buyer has a complementary goal; they are seeking a specific object or service to purchase. We can observe that the two roles are linked not only by the notion of goal but, especially, by the typical negotiation scenario where one party requests something and the other is willing to offer it;

Initiator-Guest: Another possible scenario may involve negotiation being initiated because the parties want to create something new that neither can do alone. In this second scenario, the difference between goals is not as visible to make a clear separation between the seller and the buyer. In this case, a more precise distinction between participants can be made at the level of the actions taken to initiate the negotiation process. The initiator is the one who starts the negotiation, and the guest is the participant proposed to enter into this process;

Mediator and Active Participant: A common characteristic of the participants, with the roles presented above, is that they have the capacity and decision-making power over the negotiation. Active participants are those who decide the final outcome of the negotiation and, at the same time, are the direct beneficiaries of the outcome.

A distinct role, from those presented before, is the mediator role. Mediators, or intermediaries, are neutral individuals who help a group negotiate more effectively. Mediators can be internal or external (*i.e.*, coming from an organisation with no interest in the current negotiation). In both cases, they must be accepted by all members of the group involved in the negotiation.

Taking into account more precise and detailed scenarios, roles can complement each other: a seller can become an initiator or guest in a negotiation, while the buyer can also initiate a negotiation or be invited. A participant's behavior in a negotiation is framed within certain limits according to the values attached to the two dimensions - individual and social. Thus, these two dimensions delimit a space within which the participant can negotiate in their own way. The conduct of a negotiation depends not only on the involved participants but also on the context in which the negotiation takes place, bringing new dimensions.

2.2. The negotiation context

The concept of context, its structuring, and characteristics are the subject of many studies. In the following, we will attempt to propose a new way of structuring the context, by listing certain dimensions of the environment and constraints that can influence the negotiator's behavior or the conduct of the negotiation process. According to our study, the dimensions of context that have a significant influence on the negotiation process are: culture, power, and time. Culture is always an important dimension in a negotiation. A more precise case is the diplomatic negotiation of a conflict where culture plays a central role in influencing the negotiation process.

The notion of culture is often associated with national cultures. However, culture is much more complex, encompassing the beliefs, attitudes, and behaviors of various groups. At the same time, culture differentiates individuals based on their religious or ideological beliefs, professions, educational backgrounds, age, or gender (male/female).

Given these cultural variables that have significant variations across different cultures, theories of negotiation and conflict resolution attempt to develop general hypotheses about how a particular person or group, regardless of their cultural background, may behave in negotiations.

Therefore, we can say that cultural attitudes and behaviors can influence the conduct of a negotiation across multiple dimensions[4] [Moor et Woodrow, 2004]:

- the execution of negotiation stages;
- negotiation strategies and tactics;

[4] C. Moor, P. Woodrow, *Mapping Cultures-Strategies For Effective Intercultural Negotiations*, 2004, *https://mediate.com/mapping-cultures-strategies-for-effective-intercultural-negotiations/*.

- the role, relationships, and trust between negotiation participants;
- orientation towards profit or success.

While national or cultural approaches to negotiation are difficult to characterise, generalisations are frequently described. These generalisations are presented by various negotiation studies as a kind of guide for participants to integrate the negotiation process into a much broader context. Thus, the cultural dimension manifests in language patterns, behavior, and activities and provides norms for acceptable interactions and communication patterns used in a negotiation process.

In general, power can encompass everything that establishes and maintains the authority relationship between two or more individuals. Thus, power covers all social relationships and the most subtle influences through which one person can have authority over others.

Kenneth Ewart Boulding[5] [Boulding, 1990] proposes three types of power: integrative power, coercive power, and power of change.

- integrative power is defined by the ability to obtain from others what we need and want concretely.
- at the opposite pole, coercive power is defined by the ability to obtain something without regard for others.
- different from the other two cases, where power is associated with a single entity, the power of change is seen as an equitable relationship between multiple parties. The power of change is a concept similar to negotiation: "I want you to do something, and to convince you to do it, I offer you something you need."

Adding this more economic aspect to power - beyond authority - we can view power as a measure of the relationship between the parties involved in a negotiation. Thus, in a negotiation, power becomes a relative power used by negotiators to establish the extent of the dependency of the relationships that existed before the negotiation, the relationships revealed during the negotiation, and the relationships desired at the end of the negotiation.

Parties can evaluate their power, in relation to another party, by comparing their capabilities in terms of human and material resources available, necessary qualifications and knowledge, possible sanctions and reprisals, and also organisational authorities. These different aspects help a participant in a negotiation to find out if their relationship with the other party is based on independence, dependence, or interdependence and, often, to determine if one negotiator or another is motivated to share the gain, take it, or offer it.

According to Kersten[6] [Kersten *et al.*, 2002], there are two different time orientations: monochronic and polychronic. Monochronic time orientations are linear, sequential, and assume a focus on one thing. Polychronic time orientations assume the simultaneous existence of multiple things and the involvement of multiple people.

From a negotiation perspective, the differences between the two cultural time orientations are as follows:

- for polychronic cultures, the time required for a negotiation is elastic and more important than the entire schedule, communication involves a large flow of information without all being relevant;
- for monochronic cultures, the negotiation schedule is fixed and communication is based on relevant and sequentially launched information.

Another approach that views time as a variable in the negotiation process is also divided into two dimensions, depending on the negotiation stage in which time is considered: the beginning of the negotiation or the end of the negotiation.

At the beginning of the negotiation, time is a synchronisation variable. Negotiation works in the same way; if synchronisation is not chosen well, negotiations will not reach any result. This applies in particular to mediation negotiation, where the mediator must negotiate with the parties only when they are ready to participate, in order to facilitate reaching a consensus.

At the end of the negotiation, time is a variable that affects the conduct of the negotiation. Time can also be the subject of negotiation - parties may negotiate when the negotiation should stop - or it is only a variable that characterises, for each party, the urgency of reaching a result.

Thus, time can influence not only the outcome of a negotiation but also how this outcome is achieved.

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[5] K.E. Boulding, *Three Faces of Power*, Publisher SAGE, 1990, p. 264.

[6] G. Kersten, S.T. Köszegi, R. Vetschera, *The Effects of Culture in Anonymous Negotiations*, Experiments in Four Countries, in J.F. Nunamaker & R.H. Jr. Sprague (eds.), Proceedings of the 35th Hawaii International Conference on System Sciences (pp. 1-36), IEEE Computer Society Press, 2002, *http://hdl.handle.net/20.500.12708/66000*.

2.3. The negotiation mechanism

All the dimensions detailed so far impose constraints on the dynamics of the process without presenting the means used to characterise and drive the negotiation process. In the following, we will present the stages of a negotiation and the main dimensions that characterise the mechanisms used during the negotiation process.

A negotiation process usually consists of two main stages:

- pre-negotiation (or negotiation planning) - refers to the discussions that precede formal negotiations and often includes procedural questions: who will be involved? where and when will the negotiations take place? how will they be structured? what will be the subject of negotiation? The answers to these questions will be values for the dimensions defined above, such as participant or time. Before answering other questions, new dimensions and possible values must be defined;
- negotiation - refers to interactions regarding the exchange of proposals and counter-proposals formulated based on negotiation strategies.

Considering the division of the negotiation process into these two stages, three main dimensions must be taken into account:

- manipulated information, the relative dimension of the data defining the framework and content of the negotiation;
- negotiation protocols, the relative dimension of the messages (language, content, sequences, number of participants) exchanged between participants;
- reasoning or negotiation strategies, the relative dimension of modelling the reasoning of the participants involved in negotiation that they use to achieve their objectives.

In the early stages of negotiation planning, negotiators need to determine their goals, foresee what they want to achieve, and prepare for the negotiation process. Depending on their goals, the parties will gather comprehensive lists of all information and data that help them define what is being negotiated and how it is being negotiated.

Often, negotiators exchange and/or negotiate the list of issues to be discussed beforehand. Consultation between negotiators, prior to the actual negotiation, allows them to agree on lists of information that define the subject of negotiation by attributes to be discussed, as well as other negotiation characteristics such as the negotiation venue, time and duration of the session, the parties involved in the negotiation, and the techniques to follow if the negotiation fails. As emphasised above, the purpose of the negotiation planning phase is not to attempt to solve the problem but to obtain information that will allow for a clearer picture of the true issues to be negotiated. This picture forms the basis for choosing the strategy to be used in negotiation by each involved party.

The object of negotiation contains the attributes that one of the participants wants to negotiate. In some cases, only one attribute is negotiated (for example, price), but in other cases, multiple attributes need to be negotiated, such as the time required to fulfil an order, the quality of the products, etc. Before starting the negotiation, a participant not only specifies the attributes of the object but also tries to be very precise in depicting these measurable objectives. By setting possible values for the attributes to be negotiated, a participant identifies a set of negotiation objects rather than just one object. Depending on the values set for attributes, the set includes: i) at most one object - the best possible outcome, ii) at least one object - the least acceptable outcome, iii) a target object - a fixed result.

After deciding on the object of negotiation, negotiators must prioritise their goals and evaluate possible differences between them. Negotiators need to understand what their goals and positions are and must identify the desires and fears underlying these goals. They also need to identify which are the most important questions and whether the different attributes they negotiate on are related or independent.

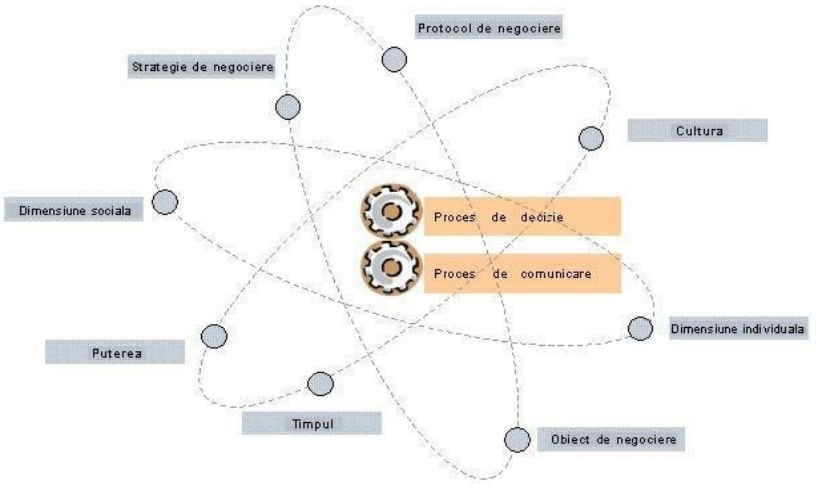
Because negotiation objects typically involve more than one attribute, it is useful for negotiators to anticipate different ways to classify attributes. Thus, they can identify the attributes they consider most important to be more flexible in negotiating the attributes they consider less important.

Thus, analysing values for this dimension provides participants with a better understanding of the dynamics and development of the negotiation and allows them to predict the best negotiation strategies that can be employed immediately.

Through this interdisciplinary study, according to the three considered directions (negotiation participant, negotiation context, and negotiation mechanisms), we can discern several common characteristics and

dimensions of negotiation. Also, this approach clearly identifies two distinct processes that form the negotiation process (Figure 1): the decision-making process and the communication process.

Figure 1. The structure and dimensions of a negotiation process



The decision-making process is the process through which a participant considers the identification of future proposals. This process is mainly influenced by the dimensions: strategy and negotiation object. Thus, to make an appropriate decision, the participant must be able to reason considering all these dimensions. Negotiating means making an exchange. Therefore, the exercise of negotiation involves the existence of a communication process throughout the negotiation process. This process is mainly shaped by the dimension of negotiation protocol. The choice of negotiation protocol or the definition of the different rules to be followed during the negotiation are also influenced by: the social dimension of the participant, which depending on the assigned role determines certain limits in communication, the cultural dimension that identifies norms regarding communication patterns adopted by a participant, the temporal dimension that causes the communication process to unfold according to a linear or branching scheme (*i.e.*, monochronic and polychronic), and finally, the power dimension which can reduce a negotiation to a simple exchange of orders. The two processes are not independent but interrelated. During a negotiation, participants must be able to formulate new proposals in accordance with the values of the dimensions considered in the negotiation and communicate them while respecting the rules of communication.

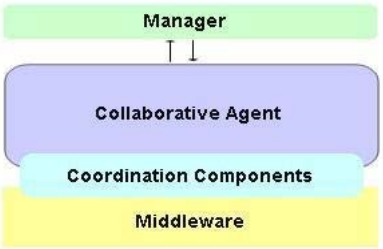
3. The Collaborative Microgrid Architecture

The primary objective of the proposed software infrastructure is to facilitate collaborative efforts within virtual microgrid enterprises (VMEs). In VMEs, partners are independent entities operating in the same sector but dispersed geographically.

Given the constraints stemming from the autonomy of VME participants, the negotiation process emerges as the primary mechanism for effectively sharing information and resources.

Figure 2 depicts the architecture of the collaborative microgrid system.

Figure 2. The architecture of the collaborative microgrid system



The proposed architecture comprises four main layers[7]: Manager, Collaborative Agent, Collaborative Coordination Components, and Middleware. The Manager layer is responsible for overseeing each organisation within the microgrid alliance. The Collaborative Agent layer aids the manager in coordinating negotiations both globally (with various participants on different tasks) and locally (with different participants on the same task), liaising with Collaborative Agents from other partners through the Middleware layer. The Coordination Components layer manages the constraints associated with coordinating multiple negotiations happening simultaneously. A Collaborative Agent is charged with managing negotiations involving its own organisation (*e.g.*, as an initiator or participant) with various microgrid alliance partners.

Each negotiation progresses through three main stages: initialization, refinement, and closure. During the initialization stage, the Negotiation Object and Negotiation Framework are defined. Past negotiation data, either locally available or provided by the negotiation infrastructure, can assist in selecting negotiation participants. In the refinement stage, participants exchange proposals on the negotiation object to address their respective constraints[8]. The manager, with support from the Collaborative Agent, may contribute to shaping and evolving negotiation frameworks and objects. Ultimately, decisions rest with the manager. For each negotiation, a Collaborative Agent oversees one or more negotiation objects, a framework, and the negotiation's status. Managers can specify global parameters such as duration, maximum message exchanges, maximum candidates considered in negotiation and contract, tactics, and protocols for Collaborative Agent interactions[9].

4. The Collaborative Coordination Components

To tackle the intricate array of negotiation scenarios within microgrid contexts, we introduce five distinct components[10]:

- subcontracting (or Contracting) handles the subcontracting of tasks by facilitating proposal exchanges among predetermined participants;
- the Block component ensures complete subcontracting of a task by a single partner;
- the Divide component oversees the dissemination of constraints across multiple slots, negotiated concurrently and stemming from the division of a single task;
- the Broker automates partner selection to initiate negotiations;
- the Transport component establishes coordination between two ongoing negotiations to synchronise on common transport arrangements for both tasks.

These components possess the capability to assess received proposals and, if deemed valid, generate new proposals based on their specific coordination constraints[11]. From our perspective, managing coordination problems between multiple negotiations can be categorised into two distinct classes of components:

- coordination components in a closed environment: These components base their actions on the ongoing negotiation and handle coordination constraints solely using information from their current negotiation graph (Subcontracting, Contracting, Block, Divide);
- coordination components in an open environment: These components also rely on ongoing negotiations but manage coordination constraints based on available information in data structures representing certain characteristics of other negotiations in the system (Broker, Transport).

Contrary to closed environment components, which handle coordination constraints for a single negotiation at a time, open environment components enable coordination among multiple negotiations concurrently. The novelty of this software architecture lies in its four-tier structure, each addressing a specific aspect of the negotiation process. Unlike traditional architectures that only coordinate proposal exchanges within a single negotiation, our proposed architecture facilitates complex negotiation coordination. This is achieved through the introduction of coordination components, which oversee all simultaneous negotiations involving alliance partners. These coordination components serve two main functions: mediating between the

[7] A. Creţan, C. Coutinho, B. Bratu, R. Jardim-Goncalves, *A Framework for Sustainable Interoperability of Negotiation Processes*, Paper submitted to INCOM'12 14th IFAC Symposium on Information Control Problems in Manufacturing, 2011.

[8] V. Bui, R. Kowalczyk, *On constraint-based reasoning in e-negotiation agents*, in AMEC III, LNAI 2003, pp. 31-46.

[9] P. Faratin, *Automated service negotiation between autonomous computational agent*, PhD thesis, Department of Electronic Engineering Queen Mary & West-field College, 2000.

[10] A. Creţan, C. Coutinho, B. Bratu, R. Jardim-Goncalves, *op. cit., loc. cit.*

[11] L. Vercouter, *A distributed approach to design open multi-agent system*, in 2nd Int. Workshop Engineering Societies in the Agents' World (ESAW), 2000, pp. 32-49.

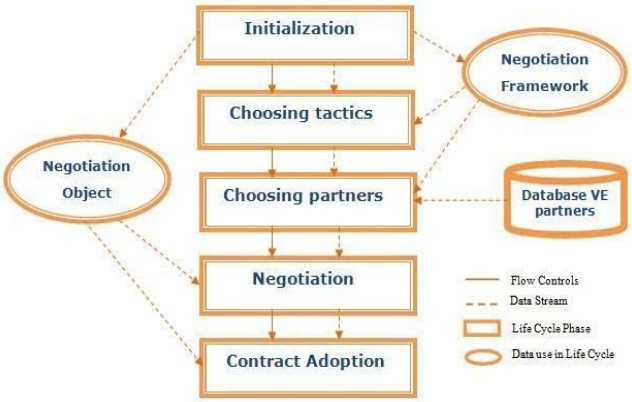
negotiation image at the Collaborative Agent level and the Middleware level, and implementing various types of behavior for specific negotiation scenarios. Hence, each component corresponds to a particular negotiation type. Therefore, this paper has developed a framework for describing negotiations within virtual microgrid enterprises. To establish a generic, non-selective, and flexible coordination framework, we first structured the negotiation process. This structure, delineated into phases specific to different negotiation stages (initialization, negotiation, contract adoption), provides a formal description of the negotiation process.

The advantage of this negotiation process structure lies in its ability to properly identify coordination elements, dependencies among ongoing negotiations within the microgrid enterprise, and modalities for managing these negotiations at the coordination component level.

5. The structure of the negotiation process within microgrid alliance

In accordance with our approach to negotiation, participants engage in proposing offers, with each participant retaining autonomy to terminate a negotiation by either accepting or rejecting an offer received. Additionally, a participant may, depending on their role, extend invitations to new participants during a negotiation. To exemplify this approach, we provide a schematic representation of the negotiation process using the negotiation and coordination mechanisms proposed in this study. The negotiation process depicted in Figure 3 is segmented into five stages: initialization, tactic selection, partner selection, negotiation, and contract adoption.

Figure 3. The structure of the negotiation process within microgrid alliance



Initialization: The Manager initiates task subcontracting, defining and conveying the properties and constraints of the negotiation object and framework to the Collaborative Agent. This process begins by instantiating the Subcontracting component, which subsequently initiates further negotiation stages based on Manager-defined constraints. It includes inviting coordination components such as Contracting, Broker, etc., and conducts negotiations concerning proposal construction and evaluation for the subcontracted task.

Tactic Selection: Utilising negotiation tactics specified in the negotiation framework, coordination is broken down into various schemes. We incorporate three tactics corresponding to three coordination schemes: Block, Divide, and Transport.

Partner Selection: Two options for partner selection are considered:

- among known partners: The Manager initiating the outsourcing can set constraints on the pool of potential alliance contractors. This involves utilising job descriptions earmarked for subcontracting and accessing a database of alliance partners and/or their respective adhesion contracts;
- among unknown partners: In this scenario, the infrastructure manages the entire partner search activity through the Broker component.

Negotiation: At this juncture, during proposal exchanges, the negotiation object evolves in line with constraints set by the Manager on negotiated attributes of the subcontracting task. The ultimate aim is to construct an Instantiated Negotiation Object from the initial negotiation object specification. This instantiated object comprises attributes accepted by all partners and serves as the basis for contract establishment.

Contract Adoption: In the final negotiation phase, negotiation properties are finalised. Here, the Collaborative Agent seeks Manager validation for the negotiation outcome and communicates with agents from other partners. Depending on the responses received, the Manager may decide to either restart or suspend negotiations or proceed to the contracting phase to reach an agreement.

The negotiation process involves multiple parties engaged in bilateral negotiations, each with distinct criteria, constraints, and preferences determining their individual interests. The job under negotiation is described as a multi-attribute object, with each attribute linked to local constraints, evaluation criteria, and global constraints affecting other attributes.

6. Conclusions

Operating within a microgrid alliance entails achieving tasks that cannot be handled individually by a single microgrid for optimal alignment with customer requirements. The proposed smart agent-based framework seeks to facilitate the fulfilment of various objectives for small and medium-sized enterprises (SMEs) by facilitating collaboration among the multiple organisations gathered within a virtual enterprise. Therefore, the proposed architecture offers the following capabilities:

Defining the structure of the negotiation process: participants, interaction protocol, negotiation protocol, tactics, coordination components, negotiation object, and negotiation strategies.

Modelling all negotiations for a microgrid as a series of simultaneous bilateral negotiations that agents can manage independently.

Modelling coordination among concurrent negotiations through a set of coordination components and synchronisation mechanisms at the middleware level.

Consequently, this paper introduces an innovative agent-based smart framework that achieves the coordination of multiple simultaneous negotiations concerning a multi-attribute object among numerous participants.

A distinctive aspect of the negotiation framework presented in this study, as opposed to negotiations with fixed options (acceptance or rejection), is its ability to modify proposals by incorporating new information (such as new attributes) or adjusting the initial values of certain attributes (for example, in the case of microgrids, the price of electricity may be adjusted). Operating within the business-to-business interaction context necessitates modelling the unforeseen and dynamic aspects of this environment. An organisation may engage in multiple concurrent negotiations, each potentially resulting in the acceptance of a contract that would subsequently impact resource availability and alter the context for other ongoing negotiations.

In this study, we focus solely on interactions related to subcontracting or contracting tasks within our collaboration framework. The negotiation process may culminate in a contract, where supply schedule management and the successful completion of the contracted task become integral parts of the outsourcing process. To illustrate our approach, we have devised a hypothetical scenario involving a consortium of distributed microgrids forming a virtual enterprise. This scenario underscores a key objective related to its applicability across various industry domains.

In terms of future research directions, one avenue worth exploring is integrating the negotiation and coordination processes with contract management. This approach would enable coordination not only between negotiations and the contracts they generate but also with the execution dependencies of those contracts. Another potential avenue is the development of a tool that empowers users to define negotiation protocols based on the constrained negotiation interaction possibilities. This would entail addressing coordination challenges in negotiation protocol administration and protocol construction.

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