Enabling Agents to Dynamically Select Protocols for Interactions

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Abstract

The work achieved in multi-agent interactions design mostly relates to protocols definition, specification, etc. In this paper we tackle a new problem, the dynamic selection of interaction protocols. Generally the protocols and the roles agents play in protocol based interactions are imposed upon the system at design time. This selection mode severely limits the system’s openness, the dynamic behaviours agents can exhibit, the integration of new protocols, etc. To address this issue, we developed a method which enables agents to select protocols themselves at runtime when they need to interact with one another. Regarding the conditions which hold in the MAS agents can either jointly perform the selection or individually. We define the concepts and algorithms which enable agents to perform this dynamic selection. We also describe the mechanisms which help agents anticipate interaction inconsistencies.

1 Introduction

Generally, the interaction protocols which support agents collaborative tasks’ execution are imposed upon multi-agent systems (MAS) at design time. This static protocols selection severely limits the system’s openness, the dynamic behaviours agents can exhibit, the integration of new protocols, etc. For example, consider a collaborative task which can be executed following varied methods either by means of a Request protocol [5] (an identified agent exhibiting specific skills is requested to perform the task) or a Contract Net protocol (CNP) [6] (a competition holds between some identified agents in order to find out the best one to perform the task). Since the MAS is open and CNP looks for the best contractor, it will undoubtedly be preferred to Request for such a task in absence of constraints such as execution delay. Thus, selecting Request at design-time prevents the initiator agent from benefiting a better processing of this task. Moreover, the set of protocols used in multi-agent interactions is increasingly enlarging, and a static protocol selection will only consider the protocols the designer knows even if these agents have the capacity of interpreting and executing other protocols unknown at design time. To overcome this limitation, we should enable agents to dynamically select protocols in order to interact.

As yet, there have been some efforts [1, 4] to enable agents to dynamically select the roles they play during interactions using Markov Decision Processes, planning or even probabilistic approaches. However, they don’t suit protocol based coordination mechanisms. Indeed, as protocols are partially sorted sequences of pre-formatted messages exchange, selecting them to execute a task requires that their descriptions match that of the collaborative task. The solutions proposed so far do not explicitly focus on protocols and do not check such compliance either. To address this void, we developed a method which enables agents to dynamically select protocols and roles in order to interact. Our method puts the usual assumptions about multi-agent interactions a step further. First, we consider that some interaction protocols can be known only at runtime. Thus, starting from a minimal version, agents interaction models can grow up by integrating these protocols from safe and authenticated libraries of interaction protocols when needed. Second, we consider that agents may have different designers, therefore they may encompass different protocols specification formalisms. Furthermore, an interaction protocol is a triple \( \{R, M, \Omega\} \) where \( R \) is a set of interacting roles which can be of two types: initiator and participant. An initiator role is the unique role in charge of starting the protocol whereas a participant role is any role taking part in the protocol. Consequently, an initiator agent will be any agent playing the initiator role in an interaction while a participant agent will be any agent taking up a participant role. In addition, protocols used in MAS can be classified\(^1\) in three categories: (1) 1-1 protocols, which are protocols made of

\(^1\) A complex protocol can be a combination of these basic categories.
two roles (initiator and participant) both of them having only one instance (ex Request); (2) 1-1 \( N \) protocols, again protocols made of two roles with several instances of the participant (ex CNP); (3) 1-N protocols, which are protocols with several distinct participant roles each of them having only one instance (ex an auction protocol with one buyer, one seller and one manager). Subsequently, we define the dynamic protocols selection process for each of these categories.

Rather than explicitly indicating the protocols and the roles to use for all the agents which will execute the desired interaction, we suggest that agents programmers simply mention the collaborative task’s description in the initiator agent’s source code. As soon as an agent locates such a description, it identifies some potential participant agents and thereafter fires the dynamic protocol selection process taking up the initiator role. We assume that the MAS is provided with potential participant agents identification procedures. Agents can dynamically select protocols in two possible ways. First, the initiator agent and all the potential participant agents collectively select a protocol and assign roles to each agent inside this protocol. This is the joint protocol selection method which assumes that agents trust one another and that they don’t dread publishing their knowledge and preferences. On the other hand, agents can individually select protocols and roles and start the desired interaction. This is the individual protocol selection method which assumes that agents do not trust one another and/or the system is heterogeneous (several sub systems with different protocol formalisms are plugged together). In this method, as the selected roles may mismatch, agents should anticipate errors in order to guarantee consistent messages exchange. We focus on wrong message structure error which indicates that something is wrong in the message structure (performative, content, language, ontology, etc.) and wrong message content error which indicates that the message’s content doesn’t match the expected content pattern. We argue that our method introduces more flexibility in protocols execution, fosters agents autonomy, favours their dynamic behaviours and suits MAS’ openness. In this paper we describe both methods and detail their principles, concepts and algorithms. We exemplify them towards a web documents filtering MAS composed of (1) query agents representing the queries users formulate, (2) document agents representing the documents retrieved from the web, (3) and rule agents corresponding to any linguistic rule invoked to compute documents attributes (author(s), content, language, etc.).

The paper is organised as follows. Section 2 formally defines the protocols selection problem. Sections 3 and 4 detail our methods. Section 5 discusses some related work and section 6 draws some conclusions.

2 Problem Description

Our purpose in this research, is to ease protocols definition, implementation and use. Thus, we claim to free agents programmers from hard coding the protocols and the exact roles to use every time their agents have to execute a collaborative task. Rather, they should only mention in the initiator agent’s source code the description of the collaborative task to execute. Then, once an agent comes across such a description, it will launch the dynamic selection process implicating potential participant agents. Concretely, given a collaborative task \( t_j \) which is to be executed by a set \( A = \{a_1,a_2,\ldots,a_k\} \) of agents, the selection problem is stated as how an agent can select a protocol and a role inside this protocol to execute \( t_j \)? It consists in finding out a protocol \( p \) and the roles \( r_1,r_2,\ldots,r_p \) each \( a_i \) should be enacting in this protocol in order to get \( t_j \) executed. We assume that each agent is provided with an interaction model \( I = \{r_1,r_2,\ldots,r_n\} \) containing some configured protocols \( (p_1,\ldots,p_m) \) some of which can be introduced at runtime and for each protocol \( p_i \) a set of roles \( \{r_1,r_2,\ldots,r_k\} \) this agent can play during interactions based on \( p_i \).

In the following two sections, we elaborate on our solution to the selection problem.

3 Joint Protocol Selection

Once an agent locates the description of a collaborative task, it finds out a set of protocols needed to execute this task which it refines to a sub set of protocols whose initiator roles are configured inside its interaction model. Moving from collaborative tasks models to protocols’ requires the agents to analyse both models and detect their adequacy. In this paper we assume that agents are able to examine tasks and protocols models and relate the first ones to the second ones. After moving from task to protocols the initiator agent should identify all the potential participant agents for the determined protocols. Both steps provide the initiator agent with a sparse matrix: potential participants linked to protocols. These potential participant agents are thus contacted whether at the same time or one after the other and are required to validate a protocol. To contrast the messages exchanged during the joint selection and those exchanged during normal interactions, we proposed some performatives which we informally describe here bellow:

- **call-for-collaboration** the sender of this performative invites the receiver to take part in a protocol described in the content field.
- **unable-to-select** the sender of this performative informs the receiver that it cannot play a participant role in the related protocol. The in-reply-to and reply-with fields help relate this message to a prior
call-for-collaboration. The reasons why an agent may reply this performative, though identified as a potential participant for the protocol, are (1) its autonomy since it may not want to execute this protocol at this moment and (2) some errors in some fields.

stop-selection the sender of this performative asks the receiver to stop the selection process this message is linked to.

ready-to-select the sender of this performative notifies the receiver of the participant roles it can be enacting regarding the protocol description it received. All the participant roles in any protocol compatible with the current one can be listed. This grouping not only reveals by order of preference the roles the sender commits in playing but it also avoid going back and forth about protocols sharing the same background. Roles of protocols are compatible when they can execute safe interactions albeit the difference in their respective specifications. As an example the initiator role of CNP can interact with either the participant role of CNP or that of Iterated CNP (ICNP [5]). While the initiator of ICNP can’t interact with the participant of CNP because of the probable iterations.

notify-assignment the sender of this performative informs the receiver about the role the latter has been assigned to in the jointly selected protocol. The assigned role is one among those the receiver priorly committed in playing.

Whatever protocol category the selection is concerned with, we can describe the joint selection messages exchange sequence as follows:

1. the initiator agent sends a call-for-collaboration encapsulating a protocol’s description.
2. Each participant agent can reply with an unable-to-select driving the initiator agent to stop the selection process between both agents by sending a stop-selection.
3. Each participant agent can also reply with a ready-to-select. In this case, the initiator agent parses the participant’s proposals and adopts one of them sending a notify-assignment or reject all the proposals sending a stop-selection.

In the remainder of this section we detail the joint selection method for each class of protocol.

3.1 Inside the Joint Protocol Selection

3.1.1 1-1 Protocols

In the dynamic 1-1 protocols selection, the aim of the initiator agent is to early find out a solution, a couple \((a_i, p_j)\) where \(a_i\) is one of the potential participant agents formerly identified and \(p_j\) one of the 1-1 protocols determined for the current task. In the midst of the solution search is the matrix’s exploration. Hence, it behaves the initiator agent to explore the matrix traversing protocols or potential participants agents. In the protocol-oriented exploration, the initiator selects a protocol and iterates through the set of agents which it identified for this protocol and retains one that fits the protocol. As soon as an agent is determined the selection process successfully completes. Otherwise, the iteration proceeds until there is no more protocol to select. Analogously, in the agent-oriented exploration the initiator selects an agent and delves into its protocols’ set looking for one they can execute together. Whatever exploration the initiator adopts, it should overcome the matrix sparsity by selecting as next element (protocol or agent) the one holding the least sparse vector.

Consider, by way of illustration, a query agent \(q_1\) which is requested to execute a task \(t_1\): “find out a document exhibiting the following characteristics: [language=‘English’, content=’plain/text’]”. Protocols and potential participant agents identifications for \(t_1\) lead to the matrix given in table 1 where a cross in a cell \([i,c]\) indicates that the agent at column \(c\) can play a participant role in the protocol at line \(i\). This matrix reveals that \(q_1\) has identified IPS (an Incremental Problem Solving protocol where a problem submitter -initiator- and its solver -the participant- progressively find out a solution to a given problem) and Request. A diagrammatic representation of IPS is given in figure 1.

| IPS   | \(d_1\) | \(d_2\) | \(d_3\) | \(d_4\) | \(d_5\) | \(d_6\) | \(d_7\) |
|-------|--------|--------|--------|--------|--------|--------|--------|
| Request | \(x\) | \(x\) | \(x\) | \(x\) | \(x\) |        |        |

Table 1. matrix for task \(t_1\)
A solution to the dynamic \(1-N\) Protocols selection problem is a couple \((\mathcal{A}, p_j)\) where \(\mathcal{A}\) is the set of participant agents and \(p_j\) the protocol to use. For this category of protocols the matrix is explored only in a protocol-oriented way since all the identified agents for a protocol are contacted at the same time. Once all the contacted agents have replied, the initiator agent should select a common protocol for the agents (generally for a part of them) which replied a ready-to-select. We devised several strategies to perform this selection but here we only describe one, the largest set’s strategy, which looks for the role most agents selected. If there exists a role \(r_j\) that all the agents pointed out, then this one is selected for all the agents which replied a ready-to-select. Otherwise, we look for a role that will involve the largest set of agents. Therefore, we construct an array where each index \(i\) contains a collection of all the roles which exactly \(i\) agents candidated for. As we didn’t succeed in finding out a role for all the \(n\) agents which sent a ready-to-select, the highest index in this array points to a collection of roles that exactly \(n - 1\) agents candidated for. We traverse the array from the highest index down to the lowest. While exploring index \(k\), if the collection of roles is not empty, we represent for each role \(r_i\) the set \(e_i\) of agents which candidated for it.

1. If all the \(e_i\) are equal, then we randomly select a \(r_p\) and adopts its corresponding \(e_p\) as the participant agents’ set. The solution is then \(e_p\) and the relevant protocol \(r_p\) belongs to.

2. Otherwise:
   (a) For each \(e_i\), we compute the difference with the union of all the sets except \(e_i\):
      \[
      dif_i = (e_i - \bigcup_{j \neq i} e_j).
      \]
      Then, we select the largest \(dif_i\).
   (b) If no decision could be made, we save all the \(e_i\) (only for the highest index) and proceed on our iteration.

After a solution has been found for an index \(k\), we check whether some sets have not been saved for a higher index. If no sets were found the final solution is the one at hand. Otherwise, we select from the latters the set whose intersection with the currently selected set is the largest. If no solution has been found we iterate through the selection process changing protocols.

3.1.3 \(1-N\) Protocols

A solution to the dynamic \(1-N\) Protocols selection problem is a triple \((\mathcal{A}, p_j, m)\) where \(\mathcal{A}\) is the set of participant agents, \(p_j\) the protocol to use and \(m\) an associative array mapping each agent to the role(s) it will play in the protocol. Here again, the matrix is explored only in a protocol-oriented way. The initiator agent \(a_i\) waits for all the participants’ replies and gathers the ready-to-select messages. The roles are clustered following the protocols they belong to and the protocols which have not been identified by the initiator agent are eliminated. For each protocol \(p\), \(a_i\) maps each role \(r_j\) to a set of agents which candidated for it:

\[
\text{candidates}(r_j) = \bigcup_k \{a_k\}.
\]

If \(\text{candidates}(r_j) = \emptyset\), the protocol \(r_j\) belongs to is no more considered in the selection process. Moreover, as there exists several participant roles in \(1-N\) protocols, some of them may receive their first message from other participant roles. Thus, we introduce a new relation, \(father\): given two roles \(r_1\) and \(r_2\) of a \(1-N\) protocol, \(r_1 = father(r_2)\) if \(r_2\) is the sender of the \(r_1^{'s}\) first message.

For each protocol retained after the candidates sets construction, the initiator agent constructs a tree \(t\) wherein nodes are the roles of the protocol. A node \(r_m\) is child of another node \(r_n\) if \(r_n = father(r_m)\). \(t\) is traversed in a breadth-first way and for each node \(r_j\) of \(t\) an agent \(a_j\) is assigned to \(r_j\) from candidates\((r_j)\). Assigning a role to an agent can be performed by any known resource allocation algorithm (ex election). This assignment is achieved for all the trees and the initiator agent uses a strategy to select one of the totally assigned trees. An improvement during the roles assignment is to avoid situations where the
same agent plays several roles in a protocol. Thus, when candidates is a singleton, its only one agent is removed from all other candidates sets it appears in when these are not singletons. As well, while exploring \( t \), once a role has been assigned to an agent we should remove this agent from all the candidates sets it appears in provided these are not singletons. The singleton criterion may guide a tree selection strategy.

### 3.2 Beyond the joint protocol selection

The joint protocol selection mechanism does not apply to all interaction contexts. One evident issue is that generic protocols are thought to be invariably specified in the MAS. However, the only one aspect that remains invariant in generic protocols’ specification is the description of exchanged messages which is imposed by communication languages (KQML, FIPA ACL) and embedded in the protocols’ specification. Hence, there is no guarantee for generic protocols to be specified in a unique formalism and agents might fail to interpret some of the formalisms used to specify generic protocols in the MAS. Particularly, plugging heterogeneous sub-systems together in a MAS increases the risk for multiple generic protocols specification formalisms. The joint protocol selection then falls short in a MAS where generic protocols are specified in several formalisms and agents are unable to interpret all those formalisms. In addition, there are also situations where agents do not always trust one another. Then, basing protocols selection on specifications exchange becomes unsafe.

To address these drawbacks, we developed an individual protocol selection method.

### 4 Individual Protocol Selection

This selection form is carried out concomitantly to the targeted interaction. Likewise the joint protocol selection form, the initiator agent is in charge of starting the selection process when it locates a collaborative task’s description. It finds out some protocols which comply with the task’s descriptions and wherein it can play an initiator role. The initiator agent may adopt a static behaviour during this selection by choosing a protocol among the candidates. In this case, the strategy it adopts is required to be fair. It may also be given the possibility to exhibit dynamic behaviours by changing protocols in order to address occurring inconsistencies. In this paper we consider the first case.

The initiator agent sends the initial message \( m_0 \) of the selected protocol \( p_i \) to one or several potential participant agents. \( m_0 \) actually denotes a need for a new interaction and any agent which receives it selects a participant role \( r_j \) which starts with \( m_0 \)'s reception. Hence, each participant agent \( a_j \) constructs the collection of candidate roles \( r_j \) which we refer to in the remainder of this section as \( \text{collection}(a_j, t_k) \). The roles are then selected from \( \text{collection}(a_j, t_k) \) and instantiated so that the interaction can take place. The individual protocol selection, although more sophisticated and powerful, can lead to interaction inconsistencies. Indeed, as individually selected roles may mismatch, the exchanged messages’ content or structure (performative, ontology, language, etc.) may be wrong.

Thus, we provide agents with techniques to anticipate such errors by checking incoming messages over structure and content compliance. When \( \text{collection}(a_j, t_k) \) is a singleton, the only one role is instantiated in order to interact. If any error occurs during the interaction no recovery would have been possible. Dynamically selecting protocols is more appealing when the \( \text{collection}(a_j, t_k) \) contains several roles.

In this case we explore \( \text{collection}(a_j, t_k) \) either sequentially or in parallel. In this paper, we only describe individual 1-1 protocols selection since the selection mechanism is quite similar for the other two types of protocols and only some extensions are required to fit the specificity of these protocols.

#### 4.1 Sequential Roles Instantiation

In the purpose of starting an interaction or replacing a failing role during an interaction, a participant agent randomly (or using another strategy we’ll define later) selects roles from the collection one after the other until there is no available role to select or the interaction eventually safely ends up. Once selected, roles are removed from the collection in order to avoid selecting them anew during the same interaction. When a message is wrong the participant agent must recover from this error by replacing the failing role. The recovery process lies on the interaction’s journal where agents log the executed methods and the related events (input: events which fired the method, and output: events generated by the method’s execution). Each method and its events form a record. The following four steps define the error recovery process:

1. If an agent detects an error, it notifies its interlocutor;
2. \( a_j \) then purges \( \text{collection}(a_j, t_k) \) and selects another role;
3. \( a_j \) computes the point where the interaction should continue at in the newly selected role and notifies the initiator;
4. Both agents update their journals by erasing the wrong records and the interaction proceeds.

The participant role replacement during error recovery can require the initiator agent to roll some actions back in order to synchronise with the newly instantiated role. To purge \( \text{collection}(a_j, t_k), a_j; \)
1. Removes from \(\text{collection}(a_j, t_k)\) all the roles whose description, from the beginning of the role to the point the error occurs at, does not match the journal;

2. If the message structure is wrong and the error has been detected by the initiator agent, removes from \(\text{collection}(a_j, t_k)\) the roles that generated the wrong message. If the error has been detected by \(a_j\) itself, it removes from \(\text{collection}(a_j, t_k)\) the roles that can’t receive the claimed erroneous message;

3. If the message content is wrong and if the error was detected by the participant agent, removes from \(\text{collection}(a_j, t_k)\) the roles that do not receive the same message structure at the point the error occurs at and adds \(\text{collection}(a_j, t_k)\) the roles that use the same method as the one causing the error. If the error was detected by the participant agent, removes from \(\text{collection}(a_j, t_k)\) the roles that do not receive the same message content at the point the error occurred at.

Since it’s no use checking the content when the message structure is wrong, structure compliance is checked prior to content’s. When a role does not comply with the current execution, it is removed from \(\text{collection}(a_j, t_k)\). Roles removal actually consists in marking them so that they can no more be instantiated in the current interaction. Then, from the updated \(\text{collection}(a_j, t_k)\), \(a_j\) selects a new role following the strategy described hereby:

1. If the message content is wrong: (a) for each role of \(\text{collection}(a_j, t_k)\), construct the set of messages (generated or received) at the point the error occurred at; (b) withdraw from these sets the message that caused the error; (c) compare these sub sets and select the weakest one; Then the role the selected sub set originates from is instantiated. The weakest messages sub set is the one containing the higher number of weak messages. Weak messages are those which lead to interaction termination: these messages are potentially weaker than those which continue the interaction. The reason why we prefer the weakest messages sub set is that we wish to avoid producing another message than the “structurally” correct one we generated priorly. When there are several sub sets candidate for selection or when there are none, a role is randomly selected.

2. If the message structure is wrong: randomly select a role in the \(\text{collection}(a_j, t_k)\).

Once a new role has been selected, the participant agent might expect to continue its execution from the point the error occurred at. However, doing so can bring inconsistencies in the interaction execution because the roles, though enacted by the same agent, do not necessarily use the same methods. These inconsistencies could be avoided by looking for methods of the new role which follow the same sequence order as in the journal from the starting point. This set of methods won’t be re-executed. We represent the methods of the new role as nodes of a directed graph wherein an edge \(m_i m_j\) means that method \(m_j\) can be executed immediately after \(m_i\) completes and the conditions for its execution hold. Algorithm 1 achieves this computation and returns the recovery points for both the initiator and the participant. In this algorithm, \(i\) is the number of the latest message the initiator should be considering it has sent to the participant and \(j\) the point where the participant is to start executing its new role from. The third event type considered in the journal (data value change in addition to message emission and reception) accounts for the difference between \(i\) and \(j\). Once the initiator receives \(i\) it looks for the record in its journal representing the \(i^{th}\) message it sent to the participant. All the records following this one will be erased from the journal. The participant also updates its journal in quite the same way basing on \(j\).

Suppose \(c_1\) wants to identify the language its document is written in; this task (\(t_2\)) requires an interaction with a rule agent. We assume \(c_1\) finds out a protocol which starts with an ask-one emission and expects a tell. Consider \(c_1\) contacted a rule agent \(c_2\) whose interaction model is partially depicted in figure 2. In this figure, for example the given portion of \(c_1\) can be interpreted as: \(r_1\) receives an ask-one and can reply an insert or a sorry. \(\text{collection}(c_1, t_2) = \{r_1, r_2, r_3, r_4\}\).

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**Algorithm 1 recovery points computation**

Input: \(\text{Journal} \equiv \text{the participant’s journal}\)

Input: \(\text{Graph} \equiv \text{the new role’s methods graph}\)

Result: Initiator and participant recovery points

```
1. \(\text{stop} \leftarrow \text{false}\), \(i \leftarrow 1\), \(j \leftarrow 1\).
2. \(\text{mth}_\text{journal} \leftarrow \text{read}_\text{init}(\text{journal});\)
3. \(\text{mth}_\text{graph} \leftarrow \text{get}_\text{init}(\text{node}(\text{graph});\)
4. \(\text{if} \) \(\text{mth}_\text{journal} \neq \text{mth}_\text{graph} \) \(\text{then}\)
5. \(\text{stop} \leftarrow \text{true};\)
6. \(\text{end if}\)
7. \(\text{while} \) \(\text{stop} = \text{false} \) \(\text{do}\)
8. \(\text{mth}_\text{journal} \leftarrow \text{Succ}(\text{mth}_\text{journal});\)
9. \(\text{if} \) \(\text{mth}_\text{journal} = \text{null} \) \(\text{then} \)
10. \(\text{stop} \leftarrow \text{true};\)
11. \(\text{else} \) \(\text{if} \) \(\text{mth}_\text{journal} \in \text{follow}(\text{mth}_\text{graph}) \) \(\text{then}\)
12. \(\text{mth}_\text{graph} \leftarrow \text{mth}_\text{journal};\)
13. \(\text{if} \) \(\text{Input is Message} \) \(\text{then}\)
14. \(\text{\(i \leftarrow i+1\);}\)
15. \(\text{end if}\)
16. \(\text{else} \)
17. \(\text{stop} \leftarrow \text{true};\)
18. \(\text{end if}\)
19. \(\text{end while}\)
20. \(\text{Initiator recovery point:} \ i;\)
21. \(\text{Participant recovery point:} \ j;\)
```
Whatever role $c_1$ selects, if it replies a *sorry* the interaction will end up, may be prematurely -the first message has not been validated yet. To get sure it’s not so $c_1$ issues a warning: "*May be premature interaction termination!*". $c_1$ tries to select another role and the interaction proceeds or definitely stops.

If $c_1$ selected $r_x$ and sent a *tell* whose content is wrong $d_1$ notifies $c_1$ a *wrong message content* error. $c_1$ then stops $r_x$, purges its *collection*($a_j$, $t_k$) by removing $r_1$ (since it cannot generate a *tell* at the error location), selects $r_3$ because it corresponds to the weakest sub set and computes the recovery points: $i = j = \text{Rec}_1$. $c_1$ updates its journal and replies anew to the *ask-one*.

In order to avoid inconsistencies at the end of interactions, we require both agents to explicitly notify each other the protocol’s termination. Instead of selecting roles on the basis of messages they can generate, it sounds to select them on the basis of messages they really generated. This is possible only if all candidates roles are instantiated at the same time. This parallel roles instantiation is only known from the participant agent; the initiator agent still has the perception of a sequential roles instantiation.

### 4.2 Mixed Roles Instantiation

All the roles $a_j$ identified in *collection*($a_j$, $t_k$) are instantiated at the same time. They handle the received message and generate their reply messages which are stored in a *control zone* ($C_z$). $C_z$ also contain the messages which are destined to currently activated roles. The roles are then deactivated. Only one message $m_k$ is selected from $C_z$ and sent to the initiator. This selection can be performed following several strategies. For example, the participant agent can randomly select a message among those which don’t shorten the interaction. Therefore, if an *insert*, a *sorry*, an *error* and a *tell* are generated in reply to an *ask-one*, *insert* and *tell* will be preferred to *sorry* and *error*, and the random selection will be performed between the first two messages. After a message $m_k$ has been selected, all the roles which generated a message of the same structure and content are activated. In this instantiation mode, when an error occurs, the participant agent recovers from it by stopping the wrong roles and by reactivating one or several other roles. Thus, if an error occurs on $m_k$:

1. All the activated roles are stopped;
2. If the message structure is wrong: all the $m_k$ as well as the messages having the same structure are removed from $C_z$ and their roles are stopped. The participant selects another message $m_k'$ following the same principle as $m_k$’s selection.
3. If the message content is wrong: all the $m_k$ messages as well as those having the same content pattern are removed from $C_z$ and their roles are stopped. The participant selects another message $m_k'$ having the same structure but a different content pattern.

When some roles stayed activated, they all generate their messages. If the messages have the same structure and content, all these roles remain activated. Otherwise, only one message is selected and all the roles whose message have not been selected are deactivated. If all the previously activated roles have been stopped, the participant agent reactivates the most recently deactivated role but cares about early interaction termination. When there are more than one such roles, they all are reactivated. The participant role reactivation, might require the initiator to roll some actions back to a recovery point. An algorithm similar to algorithm 1 performs the recovery points computation for both the initiator and participant. For each role the algorithm is applied, considering the roles’ current execution, and the final recovery point is the earliest.

### 5 Related Work

Protocols selection in agents interactions design is something generally done at design time. Indeed, most of the agent-oriented design methodologies (*Gaia* [7] and *MaSE* [3] to quote a few) all make designers decide which role agents should play for each single interaction. However dynamic behaviours and openness in MAS demand greater flexibility.

To date, there have been some efforts to overcome this limitation. [4] introduces more flexibility in agents’ coordination but it only applies to planning mechanisms of the individual agents. [2] also proposes a framework based on multi-agent Markov decision processes. Rather than identifying a coordination mechanism which suits best for a situation, this work deals with optimal reasoning within the context of a given coordination mechanism. [1] proposed a framework that enables autonomous agents to dynamically select the mechanism they employ in order to coordinate their inter-related activities. Using this framework, agents select their coordination mechanisms reasoning about the rewards they can obtain from collaborative tasks execution as well as the probability for these tasks to succeed.

The main requirement the selection process faces in protocol based coordination mechanisms is whether or not
there exists in the agent’s interaction model roles capable of supporting the desired interaction. To fill this void, we proposed a method to enable agents to dynamically select protocols basing on their interaction capacities.

6 Conclusion

Designing agents for open and dynamic environments is still a challenging task, especially in regard to protocol based interactions. Two main concerns arise from interactions modelling and design in such systems. First, how interactions which are based on generic protocols are configured so that consistent messages exchange can take place? Second, does it sound that designers always decide which protocols and roles to use every time an interaction is asked for? We address both issues by developing several methods. In this paper we focus on the second concern. We argued that due to openness and dynamic behaviours more flexibility is needed in protocols selection. Furthermore, in the context of complex applications demanding multi-protocols agents, moving from static to dynamic protocol selection greatly increases such systems’ efficiency and properly handles the situation tightly related to openness where all the protocols are not known at design time. Thus, we enabled agents to dynamically select protocols upon the prevailing circumstances.

One outcome of the dynamic protocol selection is that the protocols to use are no more hard-coded in all agents source code. Rather, programmers mention collaborative tasks descriptions in the initiator agent’s source code only making the latter in charge of firing the interaction. Agents are given two ways to select protocols. First, the initiator agent and all (or a part of them) the potential participant agents it identified can join together and share information and preferences about the protocols at hand in order to select a protocol and assign a role to each agent. Second, agents are given the possibility to individually select their protocols and roles anticipating errors. We focus on two types of errors: wrong message structure and wrong message content. As roles replacement are performed as soon as an anomaly is detected, we constrain actions executed during interactions to be reversible and not to render critical side effect. Furthermore, when there are several candidate protocols in the individual protocol selection, we developed two exploration mechanisms for these candidates: (1) a sequential exploration and (2) a mixed exploration modes.

Both methods have been proposed and tested in the context of a European project dedicated for information filtering. They proved their usefulness to efficiently manage the multiple interactions that take place between agents. In this paper, we don’t provide the results we obtained from the application of these methods since they need to be interpreted and compared to static selection cases. In the bar-

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