Towards B2B Automation Via Coalition Formation Among Service Agents

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Abstract. The modeling and enactment of business processes is being recognized as key to modern information management. However, current approaches are inadequate for adoption in open, dynamic environments such as the Internet. These approaches take a logically centralized view of processes instead of treating the individual business entities (realized via services) as peers. Also, the efforts are directed towards the low-level implementation issues of the composite services, rather than towards the interactions between the businesses - a higher level of abstraction appropriate for open systems. Consequently, existing approaches fail to adequately accommodate the autonomy, heterogeneity, and dynamism of the business partners in a process. Our research focus is to facilitate the enactment of Internet-based workflows by addressing the limitations in the current approaches and standardization efforts towards the coordination and composition of Web services. We focus on the coordination protocols (business protocols), which model the intractions between various (simple or composite) Web services, and propose a multiagent approach for enacting the corresponding business processes. We show that such a mechanism meets the fundamental requirements of businesses for Internet-based business collaborations.

1 Introduction

There is a fundamental shift in the way enterprises conduct their businesses today. Traditional integrated enterprises with centralized control are giving way to loosely-coupled networks of applications owned and managed by diverse business partners that interact via standard protocols. A standards-based approach helps reduce both development and maintenance costs for integrated systems. Web services simplify the interoperability problem between systems by presenting an application integration mechanism based on standard Internet protocols and languages. In the long term, Web services could become the basis for a seamless and almost completely automated infrastructure for electronic commerce and wide-area, cross-enterprise application integration [1].

Our vision for B2B automation [2, 12] is that complex projects involving multiple services to be performed by multiple enterprises will be accomplished by the formation of dynamic alliances among the best businesses available at the time of project execution without any human intervention. Individual businesses will focus only on their core competencies, thereby reducing their costs and time-to-market, while also increasing their flexibility and market access, and improving efficiency for their customers. These businesses will rely on other businesses for handling complex projects successfully. These projects or customer requests will typically be represented as business protocols using some standard business process specification language, which identifies the activities along with the order of their execution to satisfy the business process. So, whenever a customer submits a new request, the potential business partners that can handle individual activities in the corresponding business process will coordinate their actions and form coalitions on-the-fly to handle the request. There will be no long-term commitments on the part of the business owners that come together to handle a project; these coalitions will be temporary and exist only for the duration of the project. The rewards generated out of performing the request will be mutually distributed between the coalition members.

There are many algorithmically complex issues that need to be addressed before B2B automation is feasible. The businesses are selfishly interested in maximizing their individual profits, but they have to cooperate with each other as without each other's help they would not be able to successfully perform any project, and thus generate no revenue for themselves. Under such circumstances, how do the businesses determine a project's actual worth for them? Therefore, how do they decide which projects to participate in? Businesses vary in many significant ways like the quality of service they provide, the share of the total reward that they demand, etc. How do the businesses select their partners for a particular project, such that the required quality standards for the project are met without adversely affecting their profit margins? How should the businesses distribute the revenue accrued among themselves?

We propose a multiagent approach to address the research issues mentioned above. Our approach is based on a programming model where agents represent the various businesses. These agents, by nature, are autonomous and preserve the interests of their owners during the negotiations (business interactions) with other agents (business partners). These agents selfishly try to maximize the benefits of their owners by applying their local policies and preferences while respecting the pre-defined negotiation protocols (business protocols) during agent interactions. The negotiation process is fully distributed, asynchronous, and flexible to adapt to the continuously changing business environment commonly observed in electronic commerce.

The organization of the rest of the paper is as follows. The following section presents a sampling of the related research work conducted by other researchers in this area. Section 3 provides further details about our programming model and our negotiation mechanism, comprising of a negotiation protocol and a candidate agent strategy. We also present our views on potential opportunities of incorporating our research work on multiagent systems into service-oriented computing in this section. Finally, we conclude and discuss future research directions in section 4.

2 Related Work

Business process [1] management has been an active research area for many years. Initiatives such as RosettaNet and ebXML have defined many standards that facilitate dynamic and flexible trading relationships between businesses over the Internet. RosettaNet starts with a business model that describe how business partners interact to accomplish various tasks, and re-engineers it to produce partner roles that dictate how individual partners have to interact in the form on Partner Interface Process (PIP) specifications. ebXML also allows trading partners to publish information about their business processes, including the roles they assume in the exchanges, using Collaboration Protocol Profiles (CPP). The complete business protocols in ebXML are derived by aggregating the individual partners' Collaboration Protocol Agreements (CPA). With the advent of Web services, the vision of B2B integration and automation seems increasingly close to realization. The concept of composing Web services to handle complex applications, including business-to-business (B2B) collaborations, is gaining increasingly widespread acceptance [1, 3]. Web service composition approaches based on process flows (WS-BPEL, WS-Choreography, etc.), semantic service description (OWL-S), process algebra, petri-nets, model-checking, finite-state automata, etc. have been proposed in the recent past [11, 6].

Although current approaches provide the foundation for managing cross-enterprise business processes, there are several issues that still need to be addressed. One, the development of composite Web services still largely requires time-consuming hand-coding, which entails a considerable amount of low-level programming. Since a composite service's components can be heterogeneous, distributed, and autonomous, service composition requires a high-level approach. Two, the number of services to be composed can be large and continuously changing. Consequently, approaches that require the selection and binding of component services at service definition time are inappropriate. Three, although the components that contribute to a composite service can be distributed, existing techniques usually employ a central control point. In a B2B environment, no business would allow being dictated to by others in any way. Also, businesses would want to apply their local policies and preferences while interacting. Therefore, there is a pressing need for novel mechanisms with completely decentralized execution of services, where the confidentiality, autonomy, and heterogeneity of the businesses are preserved. Four, the current standards and tools are about how a process or composed service is implemented; what we need is a declarative approach with protocols that specify *what* action should be performed, rather than *how* it should be performed. The focus should be more on the interactions between the business parties, rather than the composition per se. Five, workflow management systems today typically assume that the participants in the workflow are cooperative. However, this does not hold true for e-businesses. We need systems that are robust to manipulation by the participants. Our approach towards B2B integration addresses all these issues.

[1] We use the terms business process and workflow interchangeably in the document

3 Multiagent Solution for Dynamic Coalition Formation

Coalition formation has been studied by social scientists, economists, game-theorists, and multiagent researchers for decades [4]. While game-theorists and social scientists have provided us with various solution concepts for establishing stable coalitions (coalitions where no participant has any incentive for defecting), multiagent researchers focus on devising computationally tractable solutions for forming stable coalitions. Our research contribution to date has been the design of a negotiation mechanism for multiagent systems that allows selfish agents to pursue their agenda and maximize their profits, and yet the resultant coalition is stable and performs admirably to the empirically tested optimal solution. The negotiation mechanism comprises of a negotiation protocol, which is akin to a business protocol in service-oriented applications, and an agent strategy, which dictates how individual businesses interact in the negotiation process. We now provide some further insights into our research work.

3.1 Coalition Formation Problem in Multiagent Systems

The coalition formation process in multiagent systems involves the following steps:

1. Agents determine their values for all coalitions that they can participate in, i.e. all businesses determine their rewards from participating in the various projects with all combinations of potential partners.
2. Agents rank and select their preferred coalitions and generate the coalition structure for the system, i.e. all businesses determine their preferences for the projects and business partners, and this information is aggregated in a distributed fashion via message exchanges to determine their assignments.
3. Coalition members internally resolve the task distribution issues in the coalitions, i.e. once the business partners for a particular project are decided, the individual businesses negotiate over the roles that they will play in the business process.
4. Coalition members internally distribute the generated revenue such that the coalition is stable.

Ideally, we would want to arrive at a coalition configuration that is optimal (social welfare maximizing solution), stable (Nash equilibrium [7] or any other game-theoretic solution stability concept [4]) and fair (each agent is satisfied with its share of the reward). However, the computational complexity required for such solutions is exponential [8]. All the steps described above are interdependent, and require a combinatorial search. The fact that systems of our interest are open and dynamic add to the uncertainty and further exacerbate the problem. Therefore, considering the computational limitations, the best that we can do is use heuristics for addressing the above research issues and devise solutions that compromise on some of the ideal properties. We focus on solutions that guarantee stability because it is important for the business partners engaging in electronic commerce to know that they cannot better their current profits in the current business environment. We present a solution [2] that has its roots in human psychology and behavioral sciences [10]. Our empirical results show that the heuristics also lead to solutions that are very close to the optimal solution.

3.2 Solution Approach

As mentioned earlier, we adopt a negotiation based approach for the dynamic coalition formation problem. Our mechanism comprises of a simple, unbiased negotiation protocol to form coalitions, and a candidate strategy for the agents that allows them to bargain over their payoff based on their negotiating power within coalitions. The negotiation protocol allows the agents to concurrently negotiate in all the different coalitions that it can potentially participate in. The choice of the coalitions to participate in is left with the agents. Our candidate stategy presents a heuristic that performs creditably in our experiments. The negotiation protocol facilitates the agents to come to a concensus, agreeing to participate in one of the coalitions which yields them the maximum profit after splitting the associated reward satisfactorily. Unlike some of the other work in this area, we do not assume a pre-decided coalition configuration [13] and/or payoff distribution [9, 5], or truthful, cooperative agents [9] in our research; our mechanism facilitates the agents to determine the best coalition and payoff for themselves via negotiations with other agents over a period of time. A heuristic for distributing the revenue among selfish agents is described in our candidate strategy for the agents. It is based on the issuance of threats and counter-threats such that agents eventually reach an equilibrium state where they cannot do any better than what they currently get. Our test results show that the strategy is stable and it also allows the agents to maximize their benefits in proportion to their negotiating power. Hence, it is reasonable to assume that the agents will use the suggested strategy in lieu of searching for others.

4 Conclusions and Future Work

In this paper, we present a novel mechanism to address the B2B integration problem in service-oriented applications by adopting a multiagent approach. We discuss the limitations of current approaches, which are mostly based on Web service composition, for application integration in open, dynamic environments, and discuss how we plan to address them in our work. We summarize some of the salient features of our solution. One, it provides the companies complete autonomy over its participation and provisioning of services for the projects. Two, it safeguards the confidentiality and vested interests of the companies as it is based on a peer-to-peer model and there is no central authority to monitor the negotiations. Three, it navigates the interactions towards a deal that all

[2] We skip most of the details due to space constraints. We have submitted a paper describing these details at the Autonomous Agents and Multi Agent Systems (AAMAS) 2007 conference.

participants prefer, if there exists one; otherwise it results in a conflict deal where nobody makes any profit - a situation that rational agents would want to avoid. Four, it allows businesses to be adaptive and take advantage of new opportunities that might arise in dynamic market environments like the Internet by allowing dynamic selection of business partners at runtime. Five, it adheres to the business protocols like PIP specifications in RosettaNet or CPPs in ebXML, thereby facilitating the migration from the existing, tried and tested solutions to the new multiagent solution with Web services. We expect to see widespread adoption of this methodology in the near future.

Our current contributions are only to the field of multiagent systems, where we have devised our negotiation mechanism for open, dynamic, fully distributed environments. Our next goal is to build a prototype system for B2B integration based on these principles. Our current solution only handles simple, sequential workflows. We would like to build on it to support more complex workflows with exception and fault handling capabilities. We hope that our research ideas would eventually lead to standards upon maturity.

References

1. Gustavo Alonso, Fabio Casati, Harumi Kuno, and Vijay Machiraju. *Web Services: Concepts, Architectures and Applications*. Springer-Verlag, 2003.
2. Hrishikesh Goradia and José M. Vidal. Multiagent workflow enactment using adaptive pricing mechanisms. In *AAAI Planning and Scheduling for Web Services Workshop*, 2005.
3. Richard Hull and Jianwen Su. Tools for Composite Web Services: A Short Overview. In *ACM SIGMOD Record*, 34(2), June 2005.
4. James P. Kahan and Amnon Rapoport. *Theories of coalition formation*. L. Erlbaum Associates, 1984.
5. Sarit Kraus, Onn Shehory, and Gilad Taase. Coalition formation with uncertain heterogeneous information. In *Proceedings of the Second International Joint Conference on Autonomous Agents and MultiAgent Systems*, pages 1–8. ACM, 2003.
6. Nikola Milanovic and Miroslaw Malek. Current solutions for Web service composition. *IEEE Internet Computing*, 8(6):51–59, November/December 2004.
7. John F. Nash. The bargaining problem. *Econometrica*, 18:155–162, 1950.
8. Tuomas Sandholm, Kate Larson, Martin Anderson, Onn Shehory, and Fernando Tohmé. Coalition structure generation with worst case guarantees. *Artificial Intelligence*, 111(1-2):209–238, 1999.
9. Onn Shehory and Sarit Kraus. Methods for task allocation via agent coalition formation. *Artificial Intelligence*, 101(1-2):165–200, May 1998.
10. Samuel S. Komorita. An equal excess model for coalition formation. *Behavioral Science*, 24(6):369–381, November 1979.
11. Biplav Srivastava and Jana Koehler. Web Service Composition - Current Solutions and Open Problems. In *AAAI Planning and Scheduling for Web Services Workshop*, 2003.
12. José M. Vidal, Paul Buhler, and Christian Stahl. Multiagent systems with workflows. *IEEE Internet Computing*, 8(1):76–82, January/February 2004.
13. Gilad Zlotkin and Jeffrey S. Rosenschein. Coalition, cryptography, and stability: Mechanisms for coalition formation in task oriented domains. In *National Conference on Artificial Intelligence*, pages 432–437, 1994.