Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 109C (2017) 632–639

Procedia Computer Science

www.elsevier.com/locate/procedia

The 8th International Conference on Ambient Systems, Networks and Technologies (ANT 2017)

Reasoning about Trust and Time in a System of Agents

Nagat Drawel[a], Jamal Bentahar[a,*], Elhadi Shakshuki[b]

[a]*Concordia University, 1515 Ste-Catherine Street West, Montreal H3G 2W1, Canada*
[b]*Acadia University, 15 University Avenue, Wolfville B4P 2R6, Canada*

Abstract

The study of trust in Multi-Agent Systems (MASs) has been an area of interest for many researchers over the last years. This is due to the fact that trust is the basis for agent communication wherein entities have to operate in a dynamic and uncertain environment. Several approaches have been proposed to define logical semantics for trust in MASs. However, these approaches are limited to reason about trust based on the sole agents' mental states. Therefore, this paper considers trust from a high-level abstraction based on the social correct behaviors of agents. Specifically, we propose a logical framework that allows us to reason about unconditional trust and time. In particular, we introduce a new logical language called Trust Computation Tree logic (TCTL) that extends the Computation Tree Logic (CTL) with a new modality to represent trust. We describe the semantics by extending the interpreted systems formalism and consider a set of reasoning rules along with proofs to support our logic. Finally, we evaluate our approach using a real-life case study in the e-business domain to explain our proposed logic in a practical application.

Peer-review under responsibility of the Conference Program Chairs.

Keywords: Multi-Agent Systems (MASs), trust, temporal logic.

1. Introduction

1.1. Context

A multi-agent system is a set of autonomous entities, which interact in dynamic and uncertain environments in order to achieve their goals[1]. Such systems have been rapidly adopted in a large number of critical applications such as commercial, industrial, governmental and health-care systems[2,3,4,5]. Although this adoption has the advantages of solving complex problems that an individual agent cannot handle alone, and building efficient and effective MASs, it raises, however, a number of challenges related to their present and future behaviors. Nevertheless, in open MASs, entities can join and leave the interactions at any time. This means that MASs will actually provide no guarantee about the behavior of their agents which makes the concept of trust of particular importance for regulating the relationships and interactions among these agents.

Trust has been an essential research topic in several disciplines for many years. Each of these disciplines gives different definitions for trust[6,7,8,9]. For instance, in the field of distributed computing, trust is used mainly to regulate the

* Corresponding author. Tel.: +1 514 848 2424; fax: +1 514 848 3171.
E-mail address: bentahar@ciise.concordia.ca (Jamal Bentahar).

Peer-review under responsibility of the Conference Program Chairs.
10.1016/j.procs.2017.05.369

relationship between service providers and customers[9,10]. In social science disciplines, trust is seen as a relationship between individuals in social settings[8] (e.g, trust is used to control relationships between truster and trustee to ensure that the trustee will perform a certain action).

In the context of MASs, the most widely used definition is the one proposed by Castelfranchi and Falcone (abbreviated as C&F)[11], where trust is basically defined as a mental state of one agent (the truster) towards another agent (the trustee) in which the truster's goals and beliefs are reflected in some internal properties of the trustee. They studied the trust concept in a cognitive perspective that emphasizes the importance of the goal component. Such component allows us to distinguish trust from mere thinking and foreseeing[12]. Indeed, by emphasizing the agent's goal, C&F rely on the internal structures of agents for the fulfillment of their own goals. Since these systems involve autonomous entities that keep their structure private, it seems impossible to know which agent's goals they refer to. To cope with this limitation, we take in this research a new approach towards social perspectives of trust where the trust parties do not have intuition for cognitive goals. Instead, we define trust from a high-level abstraction without having to depend on individual agent's internal mental states.

Trust in multi agent systems has been analyzed in different aspects. The major studies focused on two main approaches: the quantitative approach and the logical approach. The quantitative direction treats trust as a numerical measure that is calculated based on feedback, user ratings, and agent monitoring[13,14,15]. Such approaches represent and quantify the strength level in which an agent trusts another party. Specifically, the higher an agent trusts another agent, the more likely the later would be chosen as an interaction partner. Trust was first introduced as a measurable notation of an entity in[16]. Following this work, a number of computational models have been proposed in the MASs literature (see for instance[17]). On the other hand, the logical approach mainly focuses on defining semantic structures for trust. Several logical frameworks have been proposed to describe the static and dynamic properties of trust. Such approaches provide a formal semantic to reason about trust properties in various applications such as security protocols, information sources, and recommendation systems. Moreover, in terms of expensiveness, some of these studies adopted combining logics[18,19], while others extended standard logics of action and belief, or enriched temporal logics with a new modality for trust[20,12,21].

1.2. Motivation

Our motivation behind introducing TCTL logic is to capture the trust relationships among interacting parties from social perspectives. Reasoning about trust from a high level abstraction is relatively rare in the literature. Most of the existing approaches considered a mental agent concept that depends on the capability of interacting agents. Since these agents are autonomous and heterogeneous, such mental concepts cannot make those agents abide by the language semantics whenever they interact. Thus, the need for a logical language that can provide a certain level of abstraction with the ability to express the trust properties is particularly important. Although the concept of trust in our work originates mainly from the work proposed by Singh[21] where a neighborhood semantics is being used, our proposal, however, formalizes trust by extending the standard Computation Tree Logic (CTL)[22], where trust is a modal operator with grounded and intuitive semantics. We introduce a new accessibility relation which is needed to define the semantics of the trust modal operator. This accessibility relation is defined so that it captures the intuition of trust while being easily computable. The concept of trust in our work has been defined as a direct unconditional relation from one agent in the system, the truster, towards another agent, the trustee. Specifically, the truster considers the trustee as a trustworthy agent when the truster chooses to reach his goal through the task performed by the trustee if there is a possibility of satisfying the trust content. For example, the customer trusts that the merchant will deliver the requested items if for the customer there is a way that the merchant will deliver the item.

The contributions of this work are threefold. First, we introduce a logical language named Trust Computation Tree Logic (TCTL), which extends CTL[22] logic with a trust operator to represent and reason about the properties that an agent requires to be achieved by the trusted agent. The introduction of the new logic is motivated by the fact that the needed modality for trust cannot be expressed using current temporal logics such as LTL[23] and CTL. Next, to capture the trust relationships between the interacting parties, we extend the original interpreted systems[24] by defining the trust accessibility relation. To the best of our knowledge, our work is the first initiative that gives formal and computational definitions of the unconditional trust accessibility relation between interacting agents in MASs. Thereafter, we consider a set of reasoning postulates along with proofs to support our logic. Finally, we evaluate