Scheduled Migration in Distributed Systems

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Coordination of mobile agents in distributed systems takes into account time scheduling, access to available resources, safe interaction among processes. Mobile and concurrent processes were described essentially in the π-calculus [18], a formalism working with communicating mobile processes, where the mobility is expressed by sending certain channel names as messages to other processes. The distributed π-calculus [17] is a variant of the π-calculus using explicit locations, explicit migration, replication and local communication among processes. After introducing and studying a timed extension of the distributed pi-calculus [14], we introduced a simple prototyping high-level programming language called TiMo to describe mobile agents using specific features as timed migration and timed communication in distributed networks [9]. TiMo is bridging the gap between the existing theoretical approaches and forthcoming realistic languages for bounded-time migrating agents in distributed systems. To understand the problems solved by such a language, just imagine the difficulties to find an optimal trip from Iaşi (Romania, 400km from Bucharest) to Kingston (Canada, half-way between Montreal and Toronto) according to several constraints and requirements on timing, routes, connections and price.

The standard notion of bisimilarity is extended in [5] to take into account the timed transitions and multisets of actions, and then to TiMo in [4]. Behavioural equivalences are based on the observable transitions of processes rather on their states (as in timed automata and timed Petri nets). The relationship between timed mobility in TiMo and Petri nets is presented in [10].

Several variants of TiMo were developed during the last years: a version with access permissions for mobile agents given by a type system [11], a real-time version rTiMo [1], a probabilistic extension pTiMo [15], a version perTiMo with safe access permissions [12]. Inspired by TiMo , a flexible software platform was introduced first in [7] and presented then in [8] to support the specification of agents allowing timed migration in a distributed environment.

Interesting properties of distributed networks described by TiMo refer to various time constraints over agents migration and communication, bounded liveness and optimal reachability. A verification tool called TiMo@PAT was developed by using an extensible platform for model checkers [16]. A probabilistic temporal logic called PLTM was introduced in [15] to verify properties of pTiMo processes making explicit reference to specific locations, and using temporal constraints over local clocks and multisets of actions. A formal relationship between rTiMo and timed automata allows us to use the model checking capabilities provided by the software tool Uppaal [2]. TiMo was used to describe a railway control system, and then use a new behavioural congruence over real-time systems (named strong open time-bounded bisimulation) to check which behaviours are closer to an optimal and safe behaviour [3]. In [6] it is defined a general framework for reasoning about systems specified in TiMo by using the

Event-B modelling method as the target for translating TiMo specifications. Then the Rodin platform supporting Event-B is used to verify system properties using the embedded theorem-provers and model checkers.

In [13] it was developed a new semantic model for TiMo by using rewriting logic and strategies with the aim of providing a foundation for tool support. In particular, strategies are used to capture the locally maximal concurrent step of a TiMo specification. This model is then extended with access permissions in order to develop a new semantic model for perTiMo . These semantical models are formally proved to be sound and complete with respect to the original operational semantics on which they were based.

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