

Performance Evaluation of Mobile Agent Network

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Abstract. The paper deals with performance evaluation of a mobile agent network that includes a multi-agent system and a set of processing nodes connected by a communication network where it resides and operates. A mobile agent network is described as a queuing system where an agent represents an information unit to be served. Agent hosting, execution and migration are defined as stochastic processes. Simulation-based method for evaluation of performance is proposed.

1. Introduction

Agent paradigm is a promising choice for network-centric applications, especially for Internet applications and services, because it is intrinsically communication and co-operation oriented [1, 2]. Agent concepts and mobile software agents have become a part of the system and service architecture of the next generation networks. Application areas include the use of the agents in operation and management of networks, systems and services. It is where agent's mobility offers important advantages because of the network load reduction, increased asynchrony between the communicating entities and higher concurrency. Global end-to-end interactions, typical for a client-server paradigm, are replaced by local interactions in a server, visited by a mobile agent. Consequently, the need for long reliable connections is reduced, bandwidth requirements are lower and repeated interactions less frequent.

This paper elaborates performance issues of a mobile agent network [3]. It consists of a multi-agent system and its agents co-operate and communicate in a network that allows agent mobility. A mobile agent network is described as a queuing system where an agent represents an information unit to be served. Network flows of agents as well as the parameters defining agent hosting, execution and migration are introduced.

The paper is organised as follows: Mobile agent network is defined in Section 2; Performance evaluation model is presented in Section 3; Simulation based performance evaluation is elaborated in Section 4, while Section 5 concludes the presentation.

2. Mobile Agent Network

A mobile agent network is represented by the following triple:

$\{A, S, N\}$

where

A - a multi-agent system consisting of co-operating and communicating mobile agents,

S - a set of processing nodes in which the agents perform services,
 N - a network that connects processing nodes and allows agent mobility.

A mobile agent represents a user in a network. It can migrate autonomously from node to node, to perform some processing on behalf of a user. An agent is defined by the triple:

$$agent_k = \{name_k, address_k, service_k\},$$

where $name_k$ represents a unique agent identification, $address_k$ its location and $service_k$ functionality it provides. Each node, S_i , is characterised by a set of services, s_i , it supports. For $agent_k$ hosted by the node S_i or directed towards it $address_k = S_i$ and $service_k \in s_i$.

The users interact with the mobile agent network by requesting the services (Figure 1). S_i node collects the requests from its users and activates the agents. Having completed the service, the agent returns the response to the user. Requests and responses form an input flow, G_i , and output flow, R_i respectively. Agent migration is defined by the flows between the network nodes, X_{ij} and X_{ji} . The agents accepted for execution at S_i node represent its internal flow, L_i . The processing nodes are single servers. Processing intensity of S_i node is denoted by B_i .

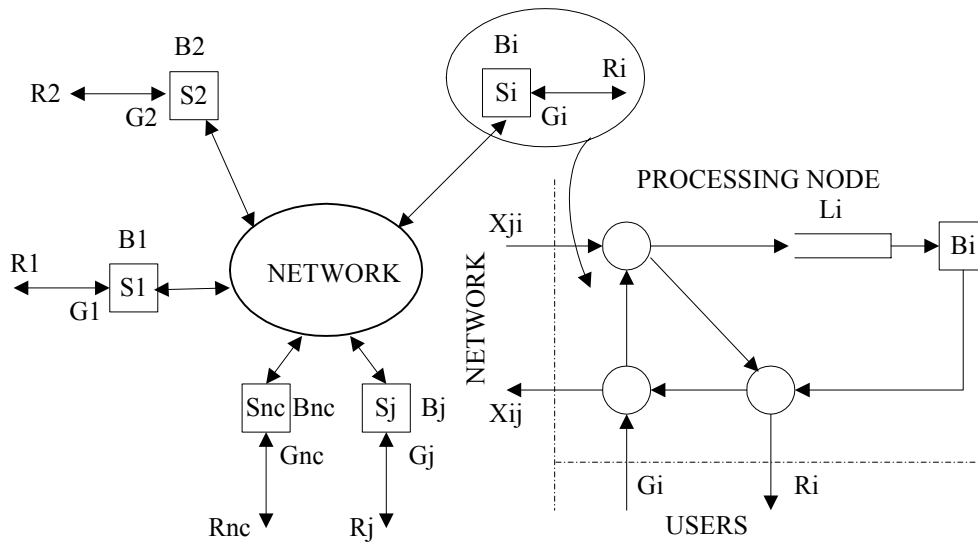


Figure 1 – Mobile agent network and agent flows

This basic model has been enhanced in order to include the features important for using the agents in operation and management of networks, systems and services. Actually, an agent can be used for several tasks that can be fulfilled in a single migration path, or for a single task to be performed at several nodes. Because of this, the concept of monolithic service is refined. Elementary services, similar to elementary tasks used in distributed parallel processing in telecommunications [4], are introduced in the following way:

- A service, $service_k$, provided by $agent_k$ is composed of n_k elementary services, es_{jk} .
- All elementary services are the same with respect to serving time which equals Δt .
- Having completed elementary service, es_{jk} , $agent_k$ continues on the same node or moves to another one in order to perform next elementary service, es_{j+1k} .
- After completing the last elementary service $agent_k$ migrates to the originating node.

Figure 2 gives the example of a migration matrix for five agents in a network of four nodes. Each row k corresponds to an agent and describes its migration path. Column j defines the node where elementary service es_{jk} is handled. For instance, $agent_3$ with five elementary services starts at S_2 node. The first two elementary services are served at this

node and the agent is transferred to S_4 node where next two elementary services are completed. The last elementary service is accomplished at S_2 node.

Agents $k = 1, \dots, 5$	$\begin{array}{cccccc} 1 & 2 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & & & \\ 2 & 2 & 4 & 4 & 2 & \\ 3 & 3 & 3 & & & \\ 1 & 1 & & & & \end{array}$	Nodes $i = 1, \dots, 4$
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Figure 2 – Migration path matrix

3. Performance Evaluation

A mobile agent network is described as a queuing system where the agents represent information units to be served. The nodes represent the servers capable of hosting and executing the agents. The actions performed during agent migration and execution are defined by the parameters shown in Figure 3. Agent migration from S_i to S_j , is described by agent transfer time:

$$T_{ij} = t_{pi} + t_{ij} + t_{aj}$$

where

t_{pi} - agent preparation time needed for agent serialization and other operations related to agent migration,

t_{ij} - agent communication time needed for agent transfer from S_i to S_j ,

t_{aj} - agent activation time that includes agent reception, de-serialisation and restart.

Agent handling at the elementary service level at S_j is described by holding time:

$$t_{aj} = t_{wj} + t_{sj}$$

where

t_{wj} - waiting time, i.e. the time an agent spends in the S_j queue expecting elementary service execution,

t_{sj} - serving time, i.e. the time needed for elementary service execution at S_j . Serving time is fixed and equals Δt .

All parameters are expressed in discrete time units, Δt .

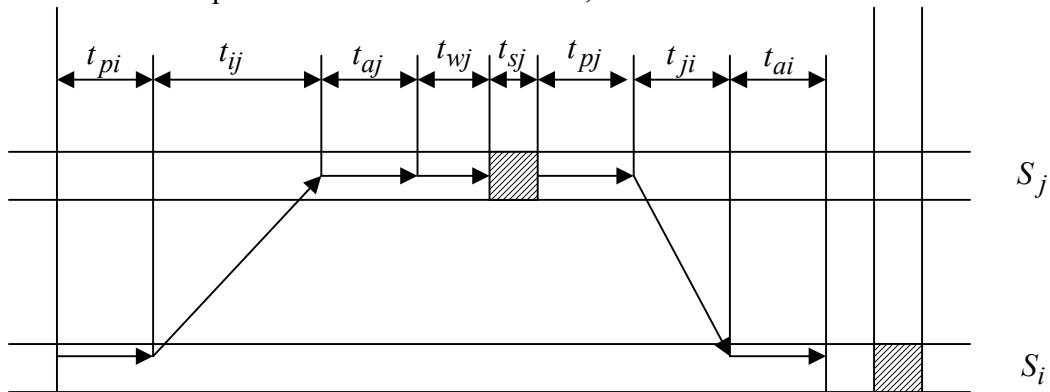


Figure 3 – Agent transfer and holding time

User requests are random events as well as activation of the agents capable of handling the services. Agent execution proceeded by its migration from its originating to destination node, and response to a user, are also stochastic processes. The reasons for migrating an agent and the decisions where to transfer it are excluded from performance analysis. They are influenced by basic properties of an agent, such as reactivity (the agent's response to the

influence from environment), pro-activity (the agent's initiative and goal-orientation), intelligence (reasoning/ learning of an agent) or autonomy (the agent follows the goal without interaction from the environment). Agent migration feature is defined as follows:

- An agent $agent_k$ handles ns_k elementary services es_{jk} , where ns_k represents random variable bounded by NS ,
- After completing the elementary service, es_{jk} , at S_i node, the node for hosting $agent_k$ and serving next elementary service, es_{j+1k} , is selected randomly.

4. Simulation-based Evaluation

Measurement-based and analytical approach to performance evaluation are described in [5-6]. This paper presents simulation-based method which includes the following steps:

a) Specification of a mobile agent network

The set of processing nodes, S , in which the agents perform the services is defined by the number of nodes, EN , and processing intensity vector, B , describing processing speed of all nodes. Assumed is full connectivity, i.e. the network, N , does not impose any restriction on the agent mobility and allows direct transfer of the agents between any two nodes. Agent transfer times for all node pairs are assumed to be the same, $T_{ij} = T$.

b) Generation of an input agent flow

User requests form an input agent flow, consisting of the bursts of the agents. Burst interarrival time, t_a , follows exponential distribution. Agent arrival intensity, l , and mean burst interarrival time, TA , define the input agent flow generation. The number of the agents in a burst, a , is a random value, as well as the number of elementary services carried by an agent, ns_k . Uniform distribution is applied to both parameters, with BA and NES as maximum values respectively. Each burst is quantified by two global parameters: number of agents, $NoAG$, and total number of elementary services, $NoES$.

c) Selection of a migration path

Originating node is selected randomly from S , applying uniform distribution and the node where each elementary service will be accomplished. Completion of each elementary service is followed by random selection of the node for next service. This is how random walk is performed, with the length of migration path equalling to the number of nodes that each agent passes.

d) Agent execution

Load of S_i node is described by total number of elementary services submitted by all agents hosted by the node, $NoES_i$ and the length of its queue, $QUEUE_i$. A mobile agent network load is defined as follows:

$$RO = \frac{l * NES}{2 * TA * \sum_{j=1}^{EN} B_j}$$

e) Calculation of performance measure

Basic performance measures used in Figure 4 are the following ones:

TQ – Overall holding time for elementary services in a mobile agent network,

$TRIP$ – Mean agent migration time, i.e. mean time the agents spend on transfer,

RT – Mean agent response time, i.e. mean time needed to deliver the response.

Simulation results show two situations with agent transfer time 10 times higher and 10 times lower than agent serving time. Agent generator and migration path generator are two parts of the proposed methods that will be used for simulating agent traffic in a testbed for agent-based Internet services and applications.

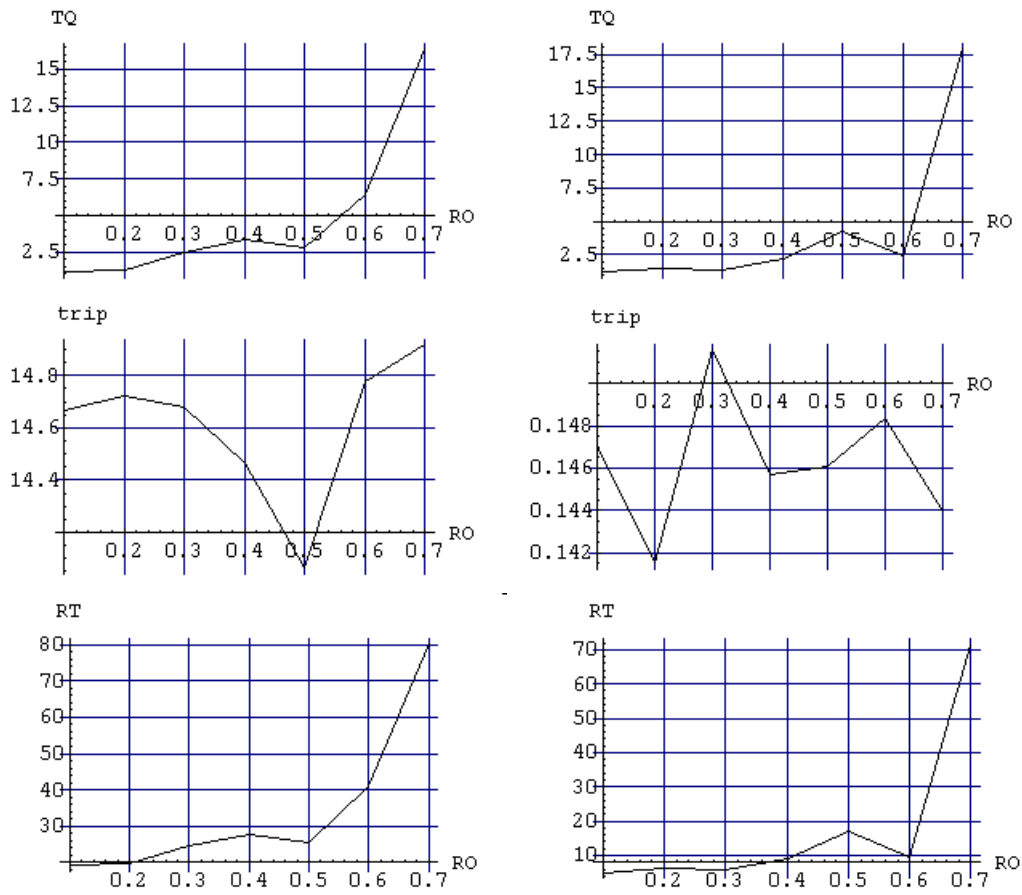


Figure 4 – Simulation results for $T = 10 \Delta t$ (left) and $T = 0,1 \Delta t$ (right)

5. Conclusion

A mobile agent network is described as a queuing system where an agent represents an information unit to be served. Agent hosting, execution and migration are defined as stochastic processes. Simulation-based method for evaluation of performance is proposed. It includes specification of a mobile agent network, generation of the input agent flow, selection of a migration path, agent execution and calculation of performance measures.

References

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