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A Multi-Agent Environment as a Management Tool for Database Communication Channels

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Abstract- In this paper, we propose a model based on an ensemble of interacting rational agents and multi-agent environment, which dynamically optimizes system performance. This model is used to reduce the speed of user interaction with a database is the bandwidth of communication channels. Simulation experiments have confirmed this concept.

Keywords**:** rational agents, multi-agent environment, database, communication channels

1. Introduction

Notion of a rational agent (RA) is widely used (see fundamental papers Wooldridge M., 2001, Burmeister B. et al., 1998, comprehensive book Bradshaw, J. M., 1997 and many recent works). But usually there are no precise definitions of RA, they are mimicked by fuzzy descriptions and advertisement claims. Here is proposed a formalization of this notion based on system of interacting flexible probabilistic automata. This model is applied to deal with communication channels in very dynamic data stream system.

One of main problems for data bases (DB) is performance of queries. It becomes crucial for very large data bases (VLDB). We concentrate here on communication problems user ↔ system (CPUS). This problem is actual both for Internet and Intranet transactions.

Let there is a channel between the control system of DB (CSDB) and the set of users. Each user can make unpredictable queries in unpredictable moments. Volume of transferred data can vary from kilobytes to terabytes and more. They can both get and send big data.

Usually users are transferring data and queries through access points (AP). Capacity of each point is limited and is shared between attached users. Thus more users and more "thick" queries mean more delays and even DoS hazards.

Usually this problem is solved merely by brute force (see Fig. 1). Capacity and speed of an AP can be increased using more effective internal software system or more expensive hardware. Locations or users can be re-attached to other access point if it is physically possible. The whole system can be enriched also by adding new access points or activating reserve AP for some locations. Reattachment or reallocation usually is what a system administrator is responsible on. When characteristics of data streams are changing very fast a sysadmin personally can "collapse".

Many papers (for example Alexandrov A. et al 2014, Kumar K. A. et al 2014) discuss various aspects how to accelerate work and increase the reliability of VLDB. Majority of them do not consider CPUS (e.g. Ward P.G.D. et al 2014, includes many references). Some include them into consideration only partially (e.g., Binnig C. et al 2014).

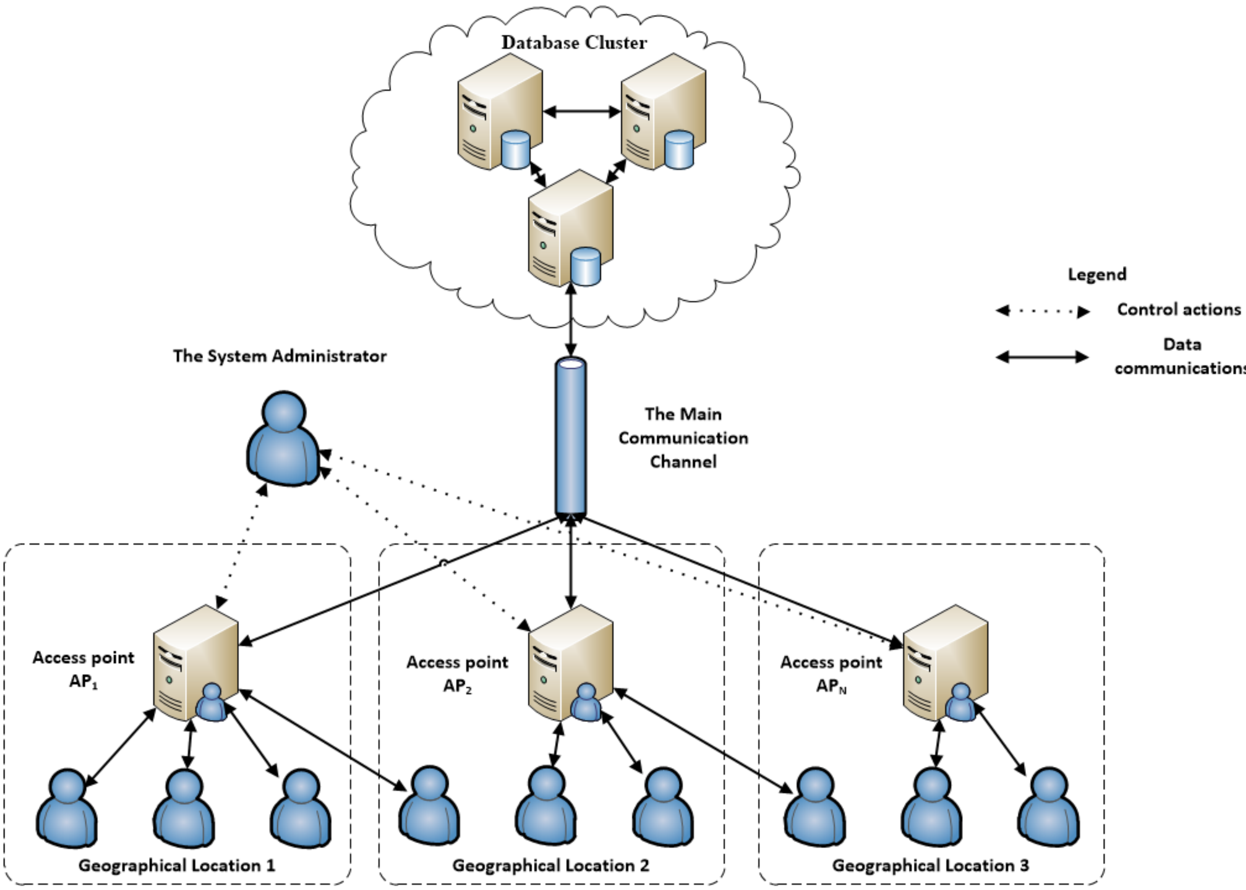

Fig. 1. Communication problems and its standard decision

2. A system of rational agents and a multi-agent environment

An active element is considered here as a probabilistic automaton. This automaton by itself is not RA. It becomes RA inside a system of automata and communication channels and in an environment. Thus a key notion here is a system in which active elements behave "intellectually" and become RA.

Thus our agents are not narrow agents but merely broad agents (Barnard et al, 2003). They have no explicitly stated goal except of its "surrogate": to keep the feeling of agent as high as possible. Secondly, they are indirect, some of them are facilitating and some are initiating. Moreover a role of an agent can be changed dynamically. Typically if its feeling is tolerable it behaves as facilitating, if it becomes too low, it turns into initiating. Direct actions are left to service programs of the access points or of the central cluster.

Thus out automata are collective internal rational agents. Their behavior does not fit any of Barnard−Symon paradigms. Our *ant colony* paradigm is slightly close to emergent one from one hand and to synergetic concepts from other hand. Our agents have *indisputable precisely stated common values based on vital characteristics of a real system and simple common interaction protocol.* This unity allows them to act locally synergetic and globally flexible like ants. There is no need of "central government" in this case.

2. 1. Flexible Probabilistic Automaton

A Moore automaton can be defined as a pair of the alphabet A and of the transition function: Φ(a,b): A→A. As usually in theoretical works our input, output alphabets and set of states are the same. This simplification is not essential. A probabilistic automaton replaces transition function by three dimensional array of probabilities P[A,A,A]. Its elements are real numbers from [0,1]. They are understood as probabilities of transfer into the state *c* having the current state *a* and the input symbol *b*.

Our point and innovation is the new variable x interpreted as the *feeling* of the automaton. Furthermore we combine feeling variable with the concept of flexible probabilistic automaton with P varying. P and x are called the *internal characteristics* of an automaton. This can be formalized as follows.

Definition of a flexible probabilistic automaton. There is a function array f[A,A,A]: R*[0,1]→[0,1]. When our automaton is in the state a and has input symbol b and transfers into state c with feeling x the corresponding probability is changed into f[a,b,c](x,P[a,b,c]).

Example. Extremely simplified control automaton for DB communications.

Let we have two access points sending at each time moment their states to the terminal point. Let there are only four states: almost free, normal, working hard, overloaded. Output of our automaton is the decision where to send a query. Query itself is not processed anyway. Feeling x_i at the moment i is computed as **if** $T–t<0$ **then** $0.9x_{i–1}$ **else** $x_{i–1}+(1–x_{i–1})/10$ **fi**, where T is the presupposed standard time of query processing, t is the processing time of the previous query.

Then if our query is sent to more busy access point our probability to send a new query to the same point is diminished. For example if our favorite access point is overloaded and other is free then new probability to send to the same point is $\boldsymbol{P}–(1–x)$ and to other is $(1–\boldsymbol{P})+(1–x)$.

Rationality is defined in (Russell 2014) "relative to the agent's ultimate goals. These are expressed mathematically by a performance measure U on sequences of environment states. Let $V(f,\mathbf{E},U)$ denote the expected value according to U obtained by an agent function f in environment class $\mathbf{E}$, where (for now) we will assume a probability distribution over elements of $\mathbf{E}$. Then a perfectly rational agent is defined by an agent function f_{opt} such that

$$f_{\text{opt}} = \text{argmax}_f V(f,\mathbf{E},U)$$

This is just a fancy way of saying that the best agent does the best it can. The point is that perfectly rational behavior is a well-defined function of the *task environment* fixed by **E** and U."

We cannot expect that our agents do the best. It suffices that they make sufficiently good decision in majority of cases and avoid crash. Therefore we decided (Nepejvoda Hatkevich Tsvetkov 2014) to define *good behavior* as such which will reach to the given time T a given relative performance $0<\varepsilon<1$ with probability >0.5.

If this condition is achieved then system of automata described below can be optimized into a system of deterministic automata. But in our case this optimization is inacceptable because properties of queries and data streams of VLDB could change in drastic manner and in unpredictable moment.

2. 2. Flexible System of Finite Automata as Rational Agents

Automata become true RA inside a system. Here we describe our representation of RA system, structure of interconnections and some aspects of automata interaction.

Environment S is a compact subset of Euclidean finite dimensional space. Environment states are points of S. Automata cannot access S directly. They use analog inputs.

An analog input E is a pair of an alphabet A_E and a collection L_a ($a\in A_E$) of subcompacts of S such that , and there is only a finite set of boundary points of their intersections not belonging to the interior of some L_a. The device E yields a if $x\in L_a$.

Our demands on intersections take into account the necessary and unavoidable error arising during measurements and representation of real numbers. Overlaying of two domains is a subset where we cannot decide precisely where our state is. Modeling of measurement errors by probabilities and random values is too rough. This is a reason why our analog inputs are indeterministic ones.

Our notion is a generalization of step functions to multi-dimensional domains and constructive mathematics.

Input device with inputs A_i, $i\in[1:n]$ is a deterministic automaton without memory over direct product of A_i (encoding device).

Structure of RAs is an oriented graph with four types of vertices: input, encoding, RA, output. Each input vertex is accompanied by the analog input, each output does by output device, RA does by probabilistic automata. All initial vertices are input ones; the single final vertex is output. Encodings and inputs have one arc from. RAs have one arc into starting in encoding or input.

Thus different RAs can interact only through encodings which serves as extra feature of encapsulation and information security. Cascades of encodings are allowed because often they are more efficient and secure than single which is functionally equivalent.

Now we are ready to give the **definition of a system of the rational agents**.

System of RAs is a structure of RAs together with state transition function t:S□N□S where N is a discrete timeline, feeling function for each agent and evaluation function $G(x,p,t)$ where x is a state of environment, p is an output result and t is time.

Thus we replace measure of Russell by evaluation and optimality by feasibility.

3. Multi-agent environment for a database communication channels

The structure of VLDB commutations through RAs (Rational Agents Data Base, RADB) is displayed on Fig.2.

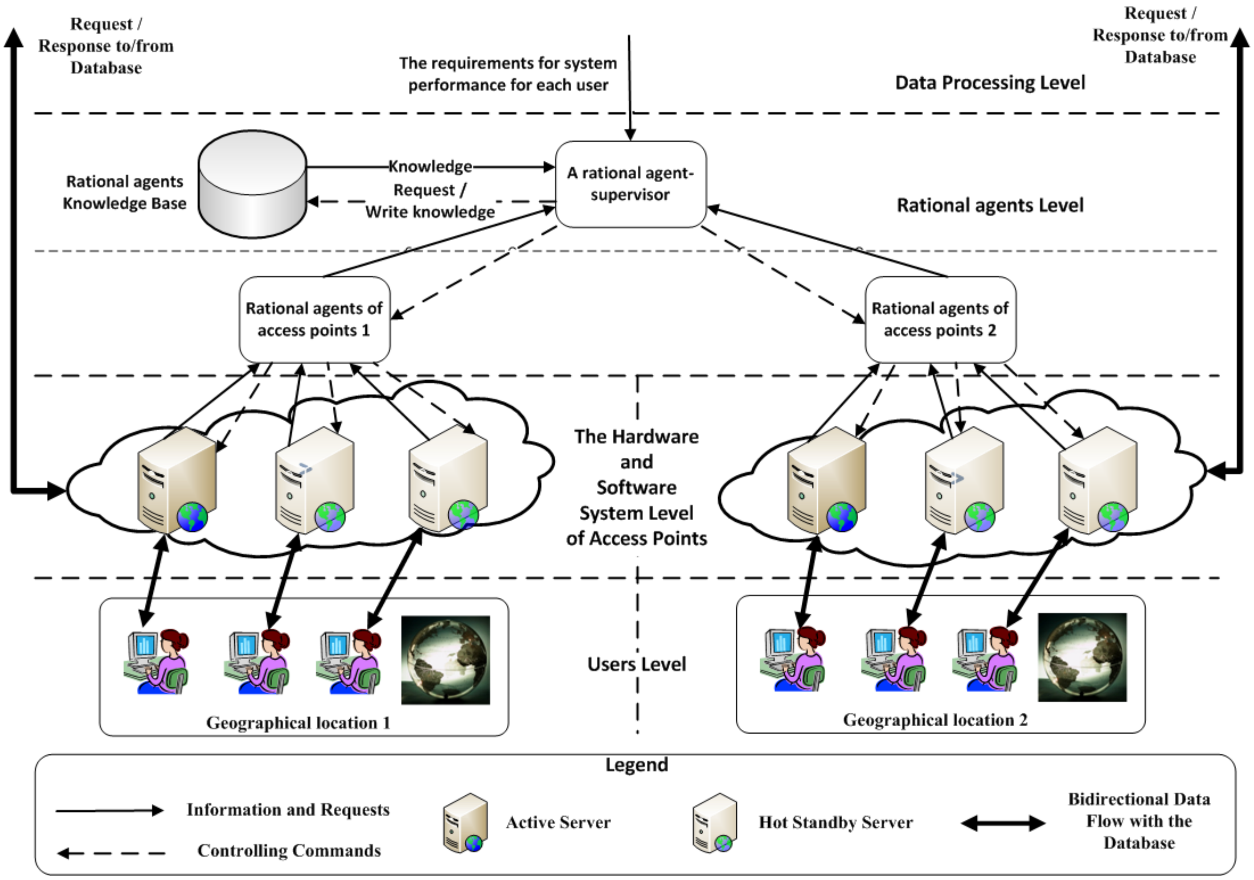

Fig. 2. Model of multi-agent environment to control the communication channels

To implement system of RAs we use the model of Nepejvoda N.N., Frolova M., Tsvetkov A. (2014).

Data Processing Level evaluates the maximum response time for each user. This time is used in main switch functions throughout the system. Rational agent-supervisor transfers for each RA of the access points.

If RA for some access point detects that too much response times are close to it initiates one of the following actions:

- To activate one of Hot Standby Servers and to inform the Rational agent-supervisor;

- If there are no more Hot Standby Servers to inform the Rational agent-supervisor that Red Alert occurs and to await commands from the Rational agent-supervisor.

If a Red Alert occured or too much Hot Standby Servers activations for some Access Point are demanded then the Rational agent-supervisor performs the following:

- Searches Rational agents Knowledge Base to find previous successful solutions of likewise problems. They can be for example: to attach some users to other access point; to inform the sysadmins on DoS accident and to advice to increase capacity of an access point or to insert a new access point;
- If there are no adequate precedents in the Knowledge Base then the Rational agent-supervisor finds the least loaded access point and tries to redirect users through RAs of access points. The time of the accident and re-direction resulted are recorded. If an accident is solved then this record is added to the Rational agents Knowledge Base;
- If there detected a regularity of some accidents in the Rational agents Knowledge Base (now that there is approximately the same time of accidents) then the Rational agent-supervisor advices to RA of this access points to make preventive actions and could re-configure the environment before a probable accident.

There are some additional actions also:

- If an RA cannot process all signals it can clone itself and to produce a subordinate RA;
- If it becomes nearly idle it can eliminate subordinates;
- If both generation and elimination of a subordinate proved to be successful this is recorded in the Rational agents Knowledge Base to open the possibility for RAs to make these action preventively.

UML-diagram of a model system of RAs and data base is presented on Fig. 3.

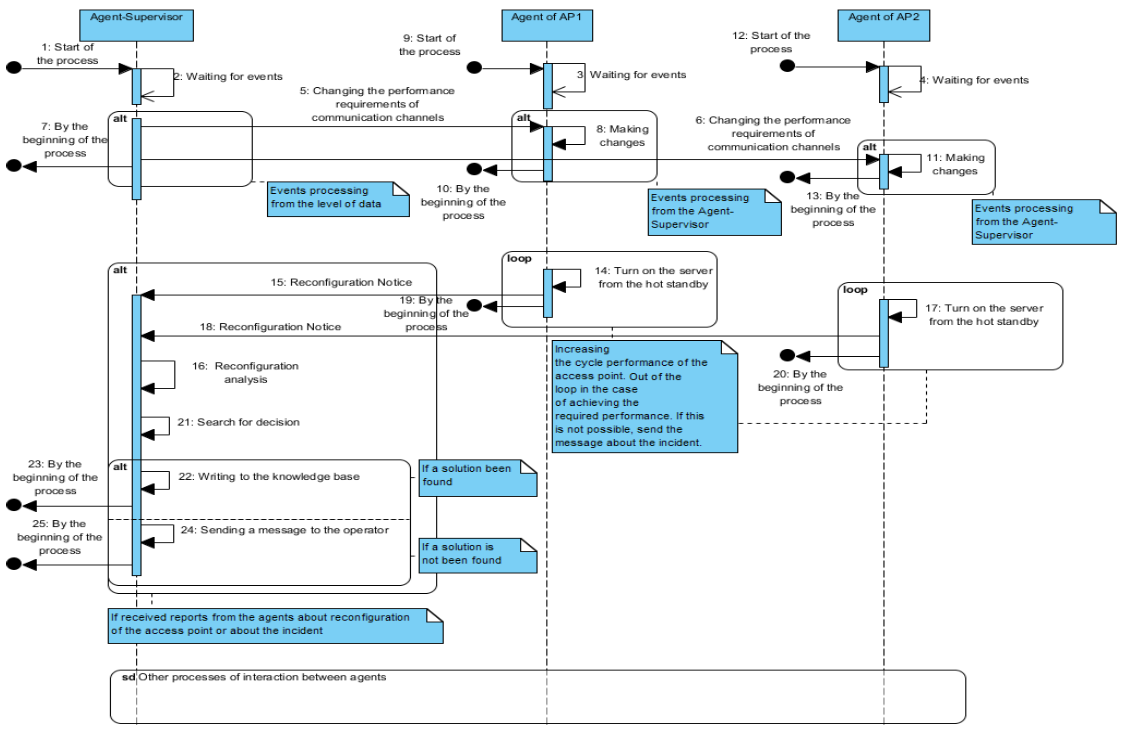

Fig. 3. UML-sequence diagram for multi-agent environment

This concept had been tested by imitation modeling. It showed that system works adequately. A part of the simulation protocol is displayed on Fig. 4.

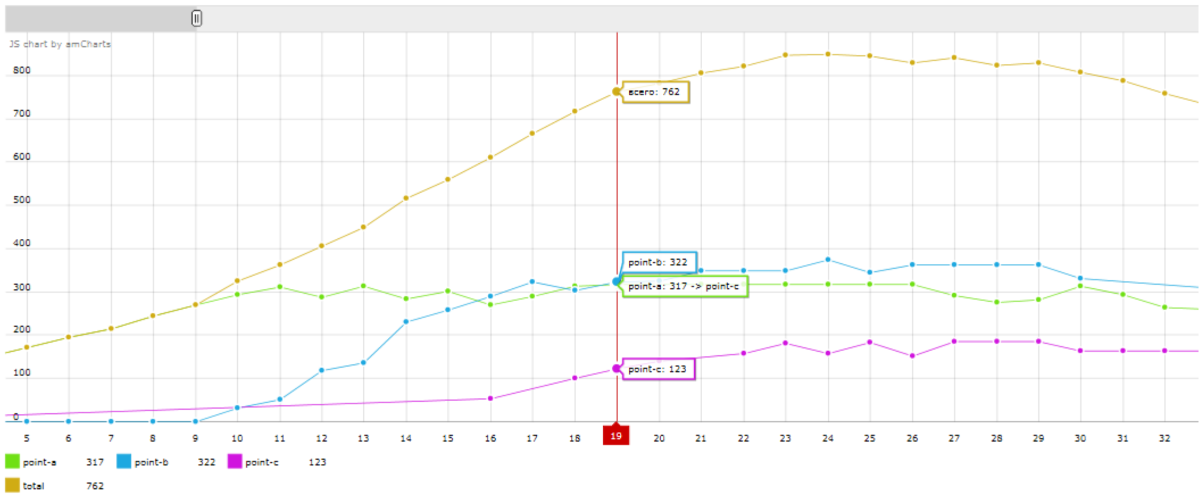

Fig. 4. The simulation modeling protocol of multi-agent environment

It can be seen on Fig. 4 that at time point «19» there occurs redirection of come users from «point-a» to «point-c».

4. Conclusion

- Rational agents in multi-agent environment can be formalized and programmed through probabilistic finite automata;
- System of RAs constructed as probabilistic finite automata can behave intellectually^ to form knowledge base ant to use it in control of system of communications for DBs;
- A model of this systems had been tested by simulation.

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