Mobile Agent-based Applications : a Survey

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Summary
A mobile agent is a computer entity capable of reasoning, use the network infrastructure to run in another remote site, search and gather the results, cooperate with other sites and return to his home site after completing the assigned tasks. Mobile Agent based applications research activities are increased and are applied in a wide range domain areas : network management, electronic commerce, energy efficiency and metering; Wireless Multimedia Sensors, grid computing and grid services, distributed data mining, multimedia, human tracking, security, affective computing, climate environment and weather, e-learning, location, recommendation and semantic web services. In this paper, a survey of mobile agent based applications on above domains areas and implementation platforms are presented. The major function which mobile agents are better adapted for these domain areas are described.

Key words:
Mobile agent, network management, e-commerce, energy efficiency and metering; Wireless Multimedia Sensors, grid computing and grid services, distributed data mining, multimedia.

1. Introduction

In general, an agent is an autonomous entity that performs one or several tasks in order to achieve some goals. In the domain of networking, an agent can run even if the user disconnects from the network. Some agents run on dedicated servers, others work on standard platforms. Many examples of agent systems exist, and they have attracted considerable attention on the World Wide Web ("WWW"). As explained in detail Nwana [1] in his paper, an agent might well be summarized as: any relatively autonomous entity able to perform actions in an environment perceived by him. Note that it is a computer entity whose nature can be physical or software. This could be likened to a "robot". The usual appellations of agents are : softbots, taskbots, knowbot, etc.

Nwana [1] use a set of criteria used to classify agents. These criteria emerged seven types of agents:

- Collaborative
- Interface,
- Mobile
- Information
- Reactive
- Hybrid
- Intelligent.

Initially agents were used in personal computers in most environments, networks and homogeneous closed Unix platforms. Their behaviours were limited and all tasks that should be achieved must be predetermined. In recent years, technology has made these agents jump to other types of agents called: Mobile Agents. They were so named because it can move from one computer to another through the network.

Mobile agents represent a class of agents whose main functions are their transmission capabilities between nodes on the same network or different networks, in addition to the inherited capabilities of stationary agents. They represent the basic design agent information management. Mobile agents represent a direct extension of the client-server approach. In the client-server paradigm [2], the communication entities have a role well defined and fixed. The server offers a set of services and the client uses these services. This implies a dependency of client on services provided by the server. The mechanism of transmission that occurs between a client and a server is performed by a message. With this method it is necessary to the programmer to program the server address and to provide synchronization between the two entities. The system RPC (Remote Procedure Call) (Figure 1) was developed by Sun Microsystems Inc. [3] to simplify the operating of client-server by simplifying the programming. The services introduced allow the customer to feel like making a local application. These services are represented by stubs. The location of the server, triggering the transport service and results are handled in a transparent manner to the client.

However, a fundamental problem exists with the approach client/server with regard to the management of distributed information. If the server does not provide the exact service that the customer needs, for example the server only provides low levels, then the client must continually poll the server. This can lead to increased waiting times. In summary the RPC approach: Uses

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bandwidth network for each message; Requires maintaining communication with the network with a specific service for the duration of communication. Other client/server architecture are CORBA (Common Object Broker Architecture) [4] who wants to make the paradigm client/server accessible by adopting the object-oriented principles (reuse of object, inheritance and the encapsulation, ...) and the Distributed Computing Environment RPC (Open Software Foundation, 1992), which provides equipment and security and authentication interface using threads instead of sockets to achieve a higher level of abstraction.

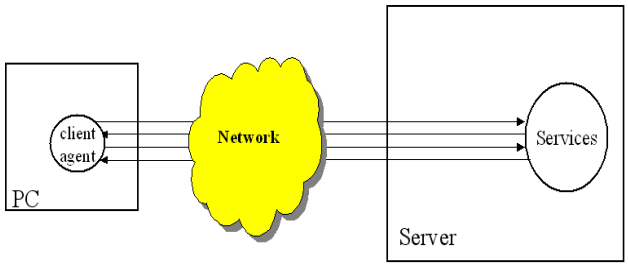

Figure 1 – RPC paradigm

The mobile agent paradigm can overcome some problems encountered in client-server approach. In particular, mobility is the most important feature of mobile agent for the following reasons [5]:

Efficiency: If an agent moves through the network to the node where resources reside, then the resulting traffic is reduced since it can pre-process data locally and decide what are the most important information to transfer. It is a crucial aspect for users who are connected by a link of lower bandwidth.

Persistence: When a mobile agent is launched, it is no longer connected to its creator node, and will not be affected if this node fails.

Peer to Peer Communication (Peer-to-peer): A failure in the paradigm case of client / server is the inability of servers to communicate. Mobile agents are considered peer entities and, as such, can act as either client or server is like.

Fault tolerance: If the client/server, the transaction state is generally divided between the client and server. In case one server is down, the client can resume the situation and resynchronize with the server because the network connection is lost. However, since the mobile agent need not keep the connection permanently, in case of network failure it will continue to run in the node.

In mobile computing, an application is built with a combination of stationary objects and moving objects, or agents (Figure 2). When necessary, agents can move toward stationary or agents to other agents to increase the communication speed.

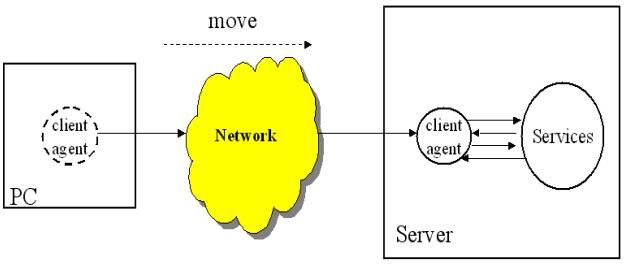

Figure 2 – Mobile agents paradigm

The agent approach:

- use a bandwidth of the network where the agent is mobile,
- allow agents to continue to run after leaving a node, even if they lose connection with the node where they were created,
- reduces traffic in the network thereby increasing the communication speed,
- parallel distributed applications: An agent can move on to other machines when necessary and can delegate tasks to other mobile agents in order to achieve real parallel applications,
- reliability: mobility and autonomy allow the agent to move from one point to another in the network and provide services and meet predefined goals without intervention.

In this paper, we present mobile agent applications classified by type of application domain. Different implementation, platform or frameworks are also presented. We also discuss whether mobile agents used and in which application mobile agents are more benefits.

2. Mobile agents based applications

In this section is presented the mobile agent applications in different domains such as network management, electronic commerce, energy efficiency and metering; Wireless Multimedia Sensors, grid computing and grid services, distributed data mining, multimedia, human tracking, security, affective computing, climate environment and weather, e-learning, location, recommendation and semantic web services.

2.1 Network management

For over ten years, researches are carried out to introduce mobile agents into network intelligent alarm management. They also study using mobile agents to reduce the bandwidth. In order to reduce the bandwidth used in network management, Outtagarts et al. [6] propose a solution which is based on mobile agent paradigm instead client-server paradigm based in SNMP protocol. The reducing of network bandwidth occupation with mobile agents is more interested, when network administrators have more than one node to manage. The authors demonstrate the benefits of mobile agent by studying the performances of the two paradigms. The figure 3 shows the comparison results of client-server and mobile agent performances. The authors demonstrate theoretically and experimentally that the bandwidth is more saved with mobile agent than with client-server when administrators have to manage multiple network nodes (Figure 4).

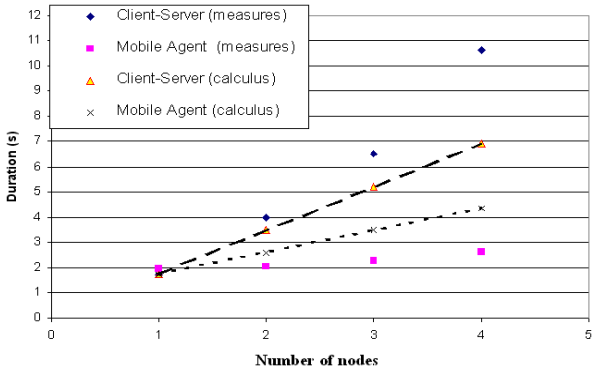

Figure 3 – Performances comparison between client-server and mobile applications [6]

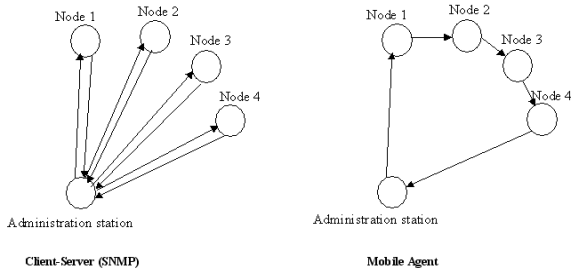

Figure 4 –client-server and mobile agent application in network management [6]

Manvi et al. [7] use mobile agent to find multiple QoS paths and select a best path among them to increase call success ratio and network bandwidth. The scheme is simulated in various network scenarios to verify performance. The mobile agent based on-demand quality of service is compared with RSVP-based QoS routing using an internet routing protocol.

One of the most significant example of mobile agents applications is the management of commercial telecommunication networks. Currently if an optical cable in the WAN is accidentally cut, the time required to locate the problem may extend ridiculous because of the slow response of the network itself Thanh [8]. Alarms will be sent to all systems attached to this network and data protection can be lost. In addition, these alarms can trigger other alarms and alerts that will spread across the network. This "stream" of alarms due to a single event can take a very long time before fixing the problem and we imagine the financial loss and information that may caused. Agents can change this scenario by instant recognition of the place of the network cut. Also, by using algorithms that can detect secondary alarms caused by the cut, we can eliminate redundant alarms. Research is conducted to introduce mobile agents in products that support event correlation to help stop the alarm in heterogeneous networks Thanh [8]. Based on mobile agent, a routing algorithm with multiple constraints is proposed by CHEN et al. [9] for ad doc network . In the their work, the authors use mobile agents to collect information of all mobile nodes in order to reduces the network delay and the overhead of control messages for routing. They said that their algorithm has lower probability of link failure because it selects links with large link expiration time during route creating phase. Yamaha et al. [10] were interested on flexible peer-to-peer networking technology for information sharing on the Internet (*MiNet*). *MiNet* enables users to share information based on mobile agents (Figure 5), can construct ad-hoc peer-to-peer networks by encapsulating information and sending it as mobile agents. The mobile agents *MiNet* beyond firewalls, proxies, and NATs in LANs. The mobile agent can migrate via HTTP protocols.

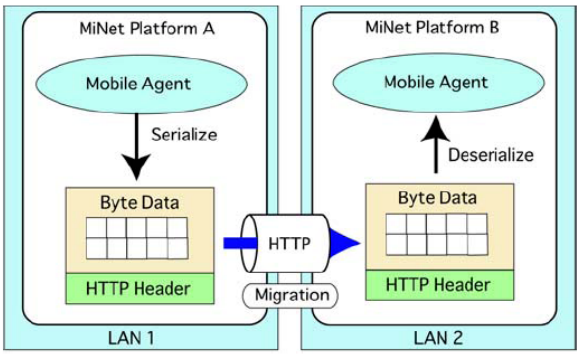

Figure 5 - A Migration of MiNet agent [10]

2.2 Electronic commerce

The commercial activity is a significant part of the network infrastructure allowing an open market of the services. Al-Jaljouli et al [11] have implemented mobile agent in e-commerce to search and to filter information of interest from electronic markets. They describe also robust security techniques that ensure a sound security of information gathered throughout agent's itinerary against various security attacks, as well as truncation attacks. The figure 6 describes the sequence of processes carried out during the agent's lifetime. The authors utilize two co-operating agents where the initial verification terms are securely stored within a secondary agent (SA) that resides at the initiator and cooperates with a major agent (MA) that traverses the Internet.

Nipur et al. [12] propose a fault tolerant comparison internet shopping system BestDeal. The author have conducted the simulation by launching nine shopping mobile agents where each has to visit five supplier sites to get the best deal for different products. Performance is measured in terms of execution steps as well as execution time of the simulation. The mobile agent survives even if failure rate is more than 80% however for higher failure rate performance degraded significantly. Li et al. [13] have studied mobile agent oriented M-commerce platform. The design and implementation of a mobile agent platform for M-commerce applications is discussed in this paper. According to the authors, the advantage of adopting mobile agents for M-commerce is to scale up to large, dynamic world market places distributed over the Internet and to ease the access and participation of mobile users.

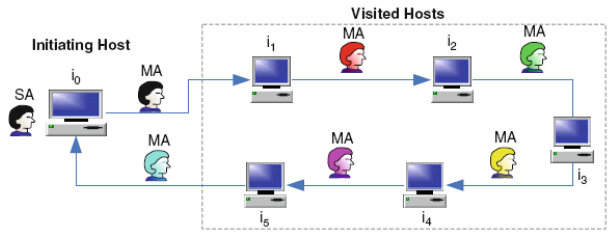

Figure 6 – System architecture [11]

2.3 Wireless Multimedia Sensors

Several works [14], [15], [16], [17], [18], [19], [20], [21] have been done in wireless multimedia sensors using mobile agent. Shen et al. [14] analyze the strengths and weaknesses of mobile agent based middleware. They have proposed mobile agent based publish/subscribe middleware, which improves the efficiency of transmitting agent by using the publish/subscribe mechanism to build interest route. The experiment results show that their proposal is more effective of agent's transmission and it can improve the reliability of the entire application. Tu et al. [16] have focused on modeling and designing two mobile agent methods in wireless sensor networks : Static Mobile Agent Planning and Dynamic Mobile agent Planning. Three metrics (energy consumption, network lifetime, and the number of hops) are used in the simulation to quantitatively measure the performance of different itinerary planning methods. Simulation results show that "Dynamic Mobile agent Planning" has overall advantages in terms of energy consumption, network lifetime, and the number of hops. Chen et al. [17], [18] have studied image processing applications over wireless sensor networks, where multiple hops may exist between target source nodes, and the sensory data packets may not be aggregated efficiently. The authors [18] have proposed in his paper an architecture mobile agent based for Wireless Multimedia Sensors Network. The simulation shows that with their architecture they obtained better performance than client/server communications in terms of energy consumption and the packet delivery ratio.

2.4 Energy efficiency and metering

In the context of energy metering and control, different work have been done using mobile agent paradigm [22], [23], [24], [25], [26]. Arai et al. [22], [23] have applied mobile agent technology for controlling power of distributed generations in an isolated micro grid. In their solutions, the mobile agent has three role : acquire operation data and equipment parameters from all the distributed power, determine the output power order for each power source and distribute the output power order to all the power sources. Chang et al. [24] propose an approach based on mobile agent for adapting knowledge retrieving in the context of mobile grid. The proposed approach is also based on resource estimation models, time estimation model and energy consumption model. Using this approach the authors evaluate resource of mobile grid including computing power bandwidth and energy consumption to determine the place of mining. Suriyakala et al. [25] have developed a multi-agent system to enable the function beyond the capabilities of any singular mobile agent in the system which perform particular task. Using the multi-agent system, the authors demonstrate that the load balancing and delay in propagation time was reduced.

2.5 Grid computing and grid services

Mobile agent technology has been used by Aversa et al. [27] to develop agent based Grid services. The service are delivered using a standard interface which is compliant with the common services. Agents use the

ACL (Agent Communication Language) message to migrate in Jade platform [28]. In order to enter the Grid node, the agent must be transmitted as a SOAP message. The agent can migrate from the Grid node the any nodes outside the Grid by the http default transmission protocol used by Jade (Figure 7). Tong et al. [29] propose a prototype system, the Geographic Information Grid System (GIGS) based on mobile agent. This system provide services and improve sharing distributed resources. In the context of grid architecture [30], [31], Wang et al. [30] present a knowledge grid architecture based on mobile agent in order to implement knowledge grid services. An other architecture is proposed by Tveit [31] to enables routing and handling of FIPA ACL messages.

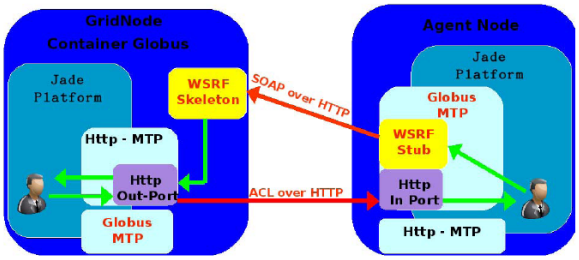

Figure 7 - Agent migration to a Grid Node [27]

2.6 Distributed data mining

Distributed data mining is a complex system which is related on the distribution of resources over the network as well as data mining processes. Moemeng et al. [32] have survey the integration of multi-agent system and distributed data mining. As open issues and trends, the authors provide perspectives on Research, on software engineering, on Systems and on Users. Hou [33] has studied a distributed data mining structure in e-commerce environment based on Web services and mobile agent. In this context of data in heterogeneous environment, mobile agents can resolve problems of integration and communication. Yubao et al. [34] present a study of mobile agent technology and its application in distributed data mining. Kulkarni et al. [35] propose a method that explores the capabilities of mobile agents an algorithm that better suits the Distributed Data Mining applications. The authors present a performance analysis and comparison with the existing such method.

2.7 Multimedia

Recently Picard [36], [37] have study in his thesis the search of images in distributed databases using multi-agent systems. The mobile agents roam in the network to search relevant images and mark the relevant path in order to guide to the interesting sites. His strategy is based on the behavior of ants and their marking of the environment by using pheromones. The author re-use the marks done during previews session in new research sessions. This learning during different session allows agents to find more easily the sites containing the relevant images. Haider et al. [38] present a solution based on Mobile Agent and introduces the concept of Middleware for dynamically discovered, location dependent multimedia services for mobile devices. Mobile Agents perform tasks on behalf of mobile device over a fixed. The action performed by the mobile agent are : configuration and reconfiguration, communication, downloading multimedia to mobile device and Quality of service handling.

2.8 Human Tracking

To enhance video monitoring system in the automatic human tracking system, Kakiuchi et al. [39] introduce mobile agent paradigm. The mobile agent utilize the algorithm of determination of neighbor video cameras to pursue the human efficiently. Actually, since e-learning systems don't consider the emotional intelligence in the context of instruction, Wang et al. [46] construct an emotional intelligent e-learning system based on mobile. the emotion of a student is recognized by facial expression captured by a camera. The get the student's learning psychology by analyzing the facial expression of students using two-dimension model to describe a student's emotion.

2.9 Others applications

Mobile agents been have applied in several other domain such as security [40], [41], [42], [43], [44], [45] especially in intrusion detection [40], [41], [45], affective computing [46], climate environment and weather [47], e-learning [48], location [49], recommendation [50], [51], semantic web services [52].

3. Implementation and platforms

Several platforms that implement the mobile agents have emerged since the 1990s. Some of them are no longer maintained or disappeared and others continued to be used in various research laboratories and even in some commercial products.

3.1 Voyager

Voyager [53] is a Java platform that provides flexibility using traditional techniques and distributed computing based on mobile agents in order to create network applications for a range of equipment from

computers to consumer devices. It includes various models of mobile computing: client / server, peer-based and agent-based. Voyager contains features or functions that can be found in other ORBs (Object Request Broker) and platforms based agents, include CORBA, RMI [54], Aglets [55] and JADE [28].

3.2 TACOMA

TACOMA (Tromosø And Cornell Moving Agents) [56] is a joint project being developed by the University of Tromosø and Cornell University and is primarily to provide a support system for farm workers. TACOMA considers agents, stationary or mobile, as units of computing system. The agents which are mobile operate stateless mode and each agent has three of memory mechanisms. When an agent moves between sites, the status information is stored within a data file called DATA, and the agent code itself is stored in a data file called CODE. At the receiving site, the agent code is extracted from the data file of CODE and executed the agent using the file data for its data and information on the status of the agent.

When an agent wants to move to a new site, an entry is added to the data directory called HOST tell him where to move. It is a mechanism predetermined movement but the authors want to remove the directory HOST by implementing a mechanism that partially automates the process of transfer.

3.3 PIAX

PIAX (P2P Interactive Agent eXtensions) [57] is an open source framework that integrates mobile agents paradigm and P2P structured overlay network. Using P2P and mobile agent advantages, PIAX allows to build a scalable and efficient federated system in a large-scale distributed environment (e.g., pervasive environment, cloud environment) where various kinds of data and processes are located in each device.

3.4 Trinity mobile agent framework

Trinity [58] is mobile agent based framework which allows to create for wide range of mobile agent types. It allows rapid development of non-complex agents.

3.5 JADE

JADE (Java Agent DEvelopment Framework) [28] is a java software Framework. JADE allow implementation of multi-agent systems which complies with the FIPA specifications [59]. The agent platform can be distributed across machines where the configuration is performed via a remote GUI. Several international projects, from different financing European frameworks (IST, ACTS, …), have been based on JADE. Among these project we can find [28]: TeSCHet, MicroGrid, E-Commerce Agent Platform (E-CAP), IM@GINE IT.

3.6 Secure Mobile Agent Rapid Development

SMARD [60] is a development environment oriented programming of on mobile agents based applications. Programmers can design, build and launch mobile agents using a graphical interface. The developed applications can be run on JADE platforms [28].

3.7 Float's Mobile Agent

FMA [61] is a free mobile agent platform which provide phone editing tool allowing users to easily manage all of the personal data stored in their phones, via a number of different connections methods. FMA also allows management of Phonebook (SIM and memory), SMS, Profiles, and Files stored on the phone.

3.8 Sensorware

Sensorware [62] is an implementation of mobile agent environment for wireless sensor network. SensorWare's scripting language is based on Tcl [63], and Scripts can move their code and data from node to node, autonomously. The distributed algorithms are realized as control scripts that are autonomously replicated or migrated in the "proper" sensor.

3.9 MAF

Mobile Agent Framework (MAF) [64] is a based Python research prototype which provide a set of primitives to facilitate the development of distributed mobile agent. MAF should provide a mechanism to be able to incorporate and integrate effortlessly with a variety of "foreign agents" written in other languages such as C and C++.

3.10 TAgent

Travel Agent (TAgent) [65] is a Java based platform which allows to develop Mobile Agent. These Mobile Agent can act on behalf of their owner without the requirement for the user to interact. TAgent provide an easy service extending, an easy Agent development platform and a secure design of the agents. TAgent is compliant with MASIF Standard of OMG [66].

4. Conclusion

In this paper, a survey of mobile agents based applications in different domain areas and implementation platforms have been presented. Research on mobile agents have started for over a decade in general and in the fields of network management and electronic commerce in particular. With the development of new networks, the increasing of networks bandwidth and innovation in cloud computing in recent years, there has been an upsurge in the use of mobile agents in different research areas described above. The major functions which mobile agents are better adapted are : gathering, filtering, sharing, monitoring, recommending, comparing information, guiding Web surfers, email filtering, auto responders and negotiating. The table 1 shows the functions which can be performed by mobile agents in different applications domains. In this table, we find that functions such as gathering, sharing, filtering, monitoring, comparing information and at the end, the negotiation between mobile agents or between an agent and a network node have a greater need to be used throughout the application areas listed above.

Table 1 : Mobile agent functions in different application areas

	Gt	Fl	Sh	Mn	CI	Gws	Ef	N
NM	X	X	X	X	X			X
EC	X	X	X	X	X			
EMM	X	X	X	X	X			
WMS	X	X	X	X	X			X
GCnDS	X	X	X	X	X	X		X
DDM	X	X	X	X	X		X	X
MM	X	X	X		X			X
HT	X	X	X	X	X			X
S	X	X	X	X	X		X	X
R	X	X	X	X	X	X	X	X
SWS	X	X	X	X	X	X	X	X

NM : Network Management
EC : Electronic Commerce
EEM : Energy Efficiency and Metering
WMS : Wireless Multimedia Sensors
GCnDS : Grid Computing and Grid Services
DDM : Distributed Data Mining,
MM : Multimedia
HT : Human Tracking
S : Security
R : Recommendation
SWS : Semantic Web Services.

Gt : Gathering
Fl : Filtering
Sh : Sharing
Mn : Monitoring
CI : Comparing Information
Gws : Guiding eb surfer
Ef : Email filtring
R: Responding
N : Negotiating

New platforms for mobile agents have emerged in recent years, such as: Float's Mobile Agent, Piax, Trinity mobile agent framework, JADE and Sensorware. The platforms Voyager and TACOMA existed in the 90s. There was also a decrease of research activities in the 2000s with the disappearance of platforms such as ARA, Concordia and Mole or maintenance stopping of platforms such as Aglet [55]. The table 2 below highlights the programming language and the supported operating system for each platform.

Table 2 – Mobile agent platforms characteristics

Mobile agent systems	Programming language	Operating system
Voyager	Java .NET, C++	Unix, Windows
TACOMA	C, Tcl/Tk, Perl, Python, and Scheme	Unix
PIAX	Java	All (with JRE)
Trinity	.NET	Windows
JADE	Java	All (with JRE)
SMARD	Java	All (with JRE)
Float	Borland Delphi	Windows
SensorWare	TCL/TK	Unix
MAF	Python	Unix
TAgent	Java	All (with JRE)
Aglet	Java	All (with JRE)

5. Future works

Future work plans mainly concern social energy management. The mobile agents share and compare the data collected in home energy metering sensors with others in an online community. The mobile agent can then alert the user of over consumption of each household appliances and solutions for reducing energy consumption in connection with the use of the green community.

References

[1] H. S. Nwana, Software Agents: An Overview, Knowledge Engineering Review, Vol. 11, No 3, 1996, pp.1-40.

[2] P. E. Renaud, Introduction To Client/Server Systems: A Practical Guide For Systems Professionals, Wiley & Sons, 1993.

[3] Bloomer, J. - Power Programming with RPC, O'Reilly and Associates, 1992.

[4] W Sadiq, F. Cummins, Developing Business System with CORBA, Cambridge University Press, 1998, 234p.

[5] J. Dale, A Mobile Agent Architecture to Support Distributed Resource Information Management, thesis, University of Southampton, 1998, 86p.

[6] Outtagarts, A., Kadoch, M.: Client-Server and Mobile Agent: Performances Comparative Study in the Management of MIBs. Proceedings of the First International Workshop on Mobile Agents for Telecommunication Applications (1999) 69–81.

[7] S.S. Manvi and P. Venkataram, Mobile agent based approach for QoS routing, IET Commun., 2007, pp. 430-439

[8] Do, van Thanh: Using Mobile Agents in Telecommunications, Proceedings of the International Workshop for Internet Bots: Systems and Applications (INBOSA'2001), to be held in conjunction with DEXA/EC-WEB/DAWAK'2001, Munich, Germany, September 3-7, 2001

[9] W. Chen, Y. Zhang, A Multi-constrained Routing Algorithm based on Mobile Agent for MANET Networks, IEEE Computer Society, 2009, pp. 16-19.

[10] T. Yamaya1, T. Shintani1, T. Ozono1, Y. Hiraoka1,H. Hattori1, T. Ito1, N. Fukuta2, and K. Umemura, MiNet: Building Ad-Hoc Peer-to-Peer Networks for Information Sharing Based on Mobile Agents, International conference on practical aspects of knowledge management N°5, Vienna, Austria, 2004,vol.3336,pp.59-70

[11] R. Al-Jaljouli, J. Abawajy, Agents Based e-Commerce and Securing Exchanged Information, Pervasive Computing, Springer London, ISBN: 978-1-84882-598-7, 2009, pp. 383-404.

[12] H. P. Nipur, K. Garg, A Fault Tolerant Comparison Internet Shopping System: BestDeal by using Mobile Agent, International Conference on Information Management and Engineering, 2009, pp. 541-544

[13] X. Li, G. Autran, Implementing an Mobile Agent Platform for M-commerce, 33rd Annual IEEE International Computer Software and Applications Conference, 2009, p. 50-45.

[14] Z. Shen, R. LI, J. Luo, Mobile Agent Based Middleware using Publish/Subscribe Mechanism in Wireless Sensor Networks, International Conference on Communication Software and Networks, 2009, pp. 111-115.

[15] Z. Tu, Q. Wang, Y. Shen, Optimal Mobile Agent Routing with Fusion Cost in Wireless Sensor Network, I2MTC - International Instrumentation and Measurement, 2009, 5p.

[16] Y. Xu, H. Qi, Modeling of Agent Migration for Collaborative and Distributed Processing, IEEE, 2006, pp. 825-830

[17] L. Tong, Q. Zhao, and S. Adireddy, Sensor Network with Mobile Agents, International. Symposium Military Communications, 2003, 6p.

[18] M. Chen, T. Kwon*, Y. Yuan, Victor C.M. Leung, Mobile Agent Based Wireless Sensor Networks, Journal of Computers, Vol. 1, No. 1, 2006, pp. 14-21.

[19] Min Chen,1 Taekyoung Kwon, Y. Yuan, Y. Choi, Victor C. M. Leung, Mobile Agent-Based Directed Diffusion inWireless Sensor Networks, EURASIP Journal on Advances in Signal Processing, 2007, 13p.

[20] M. Chen, S. Gonzalez, Victor C. M. Leung, Applications and Design Issues for Mobile agents in Wireless Sensor Network, IEEE Wireless Communications, 2007, pp. 20-26.

[21] D. Massaguer, C.-L. Fok, N. Venkatasubramanian, G.-C. Roman, C. Lu, "Exploring Sensor Networks using Mobile Agents", In Proceedings of Fifth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2006), Future University-Hakodate, Japan, 2006, pp. 323-325.

[22] J. Arai, S. Yamazaki, M. Ishikawa, T. Ito, Study on a new power control of distributed generation in an isolated microgrid IEEE PES General Meeting, Calgary, Canada, July 26-30, 2009, 6p.

[23] J. Arai, S. Yamazaki, M. Ishikawa, T. Ito Application of Mobile Agent Technology to Power Generation Control in Microgrid Power System Asia-Pacific Power and Energy Engineering Conference, 2009, 5p.

[24] Y.-S. Chang, P.-C. Shih, Y.-C. Luo, Adaptive Knowledge Retrieving on Mobile Grid, Eighth International Conference on Intelligent Systems Design and Applications, 2008, 6p.

[25] C.D.Suriyakala, P.E. Sankaranarayanan, Smart Multiagent Architecture for Congestion Control to Access Remote Energy Meters, International Conference on Computational Intelligence and Multimedia Applications 2007; 5p.

[26] M. Genoese, F. Sensfuß, A. Weidlich, D. Möst, O. Rentz; Development of an agent-based model to analyse the effect of renewable energy on electricity markets, 19th International Conference Informatics for Environmental Protection, 2005; 5p.

[27] R. Aversa, B. Di Martino, S. Venticinque, Integration of Mobile Agents technology and Globus for assisted design and automated development of Grid Services, International Conference on Computational Science and Engineering, 2009, 8p.

[28] JAva Platform DEvelopment Framework (JADE), http://jade.tilab.com/

[29] Qiang Tong, Zhidong Shen, Research of Mobile Agent Technology for GIS Grid, Ninth International Conference on Hybrid Intelligent Systems, 2009, 5p.

[30] Gang Wang, Tao Wen, Quan Guo, Xuebin Ma, A Knowledge Grid Architecture Based on Mobile Agent, Proceedings of the Second International, Conference on Semantics, Knowledge, and Grid, 2006, 4p.

[31] A. Tveit. jfipa – an Architecture for Agent-based Grid Computing, Proceedings of the Symposium of AI and Grid Computing, AISB Convention, 2002.

[32] C. Moemeng, V. Gorodetsky, Z. Zuo, Y. Yang, C. Zhang, Agent-Based Distributed Data Mining: A Survey, L. Cao (ed.), Data Mining and Multiagent Integration, Springer Science + Business Media, LLC 2009, 12p.

[33] J. Hou, Research on Distributed Data Mining in E-commerce Environment Based onWeb Services and Mobile Agent, International Conference on Computational Intelligence and Natural Computing, 2009, 3p.

[34] M. Yubao, D. Renyuan, Mobile Agent technology and Its Application in Distributed Data Mining, First International Workshop on Database Technology and Applications; 2009, 5p.

[35] U.P. Kulkarni, P.D. Desai, Tanveer Ahmed, J.V. Vadavi, A.R.Yardi, Mobile Agent Based Distributed Data Mining, International Conference on Computational Intelligence and Multimedia Applications, 2007, 7p.

[36] D. Picard, Recherche d'images dans un réseau à l'aide d'un système multi-agents, Ph.D Thesis, Universit_e de Cergy-Pontoise, 2008, 167p.

[37] D. Picard, A. Revel, M. Cord, Performances of mobile-agents for interactive image retrieval, Proceedings of the 2006 IEEE/WIC/ACM International Conference on Web Intelligence, 2006, 4p.

[38] R . Haider, A. Shibli, Mobile Agent Middleware for Multimedia Services, The 9th IEEE International Conference on Advanced Communication Technology.

Phoenix Park, Korea: IEEE, Vol. 2., 2007, pp.1109-1114.
[39] H. Kakiuchi, T. Kawamura, T. Shimizu, and K. Sugahara, An Algorithm to Determine Neighbor Nodes for Automatic Human Tracking System, Proceedings of the IASTED International Conference on Parallel and Distributed Computing and Systems, 2009, 7p.
[40] H.Q. Wang, Z.Q. Wang, Q. Zhao1, G.F. Wang, R.J. Zheng, and D.X. Liu, Mobile Agents for Network Intrusion Resistance, APWeb Workshops 2006, pp. 965-970.
[41] J. Xu, Y. Li, A New Distributed Intrusion Detection Model Based on Immune Mobile Agent, Asia-Pacific Conference on Information Processing, 2009, pp. 461-464
[42] Z. Shen, Q. Tong, A Security Technology for Mobile Agent System Improved by Trusted Computing Platform, Ninth International Conference on Hybrid Intelligent Systems, 2009, pp. 46-50.
[43] F. C. You, L. F. Zhang, The Research of Digital Copyright Protecting Mechanisms Base on Mobile Agent and Digital Watermark, International Conference on New Trends in Information and Service Science, 2009, pp. 466-469.
[44] Z. Zhang, M. Yu, M; Huang, Based Mobile Agent Transaction Authentication Scheme, International Conference on Computational Intelligence and Natural Computing, 2009, pp. 445-448.
[45] N. Patil, C. Das, S. Patankar, K. Pol, Analysis of Distributed Intrusion Detection Systems using Mobile Agents, First International Conference on Emerging Trends in Engineering and Technology, 2008, pp. 1255-1260.
[46] Z. Wang, X. Qiao, Y. Xie, An Emotional Intelligent E-learning System Based on Mobile Agent Technology, International Conference on Computer Engineering and Technology, 2009, pp. 51-54.
[47] M. R. Ioan; S. L. Paula; Using Mobile Agents and Intelligent Data Analysis Techniques for ClimateEnvironment Modeling and Weather Analysis and Prediction, 10th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing, 2008, 316-319.
[48] E. McGovern, R. Collier, E. Mangina, Object Oriented vs. Agent-Based Oriented Ubiquitous Intelligent Mobile Managed e-Learning Environment, UIC 2006, pp. 1102 – 1113.
[49] Y. Liang, L.-L. Ci, Mobile Agent Technology for Geography Information System, Proceedings of the Sixth International Conference on Machine Learning and Cybernetics, Hong Kong, 2007, 1434-1438.
[50] A. Lazanas, Performing Hybrid Recommendation in Intermodal Transportation – the FTMarket System's Recommendation Module, IJCSI International Journal of Computer Science Issues, Vol. 3, 2009, pp. 24-33.
[51] T. Kowatsch, W. Maass, A. Filler, S. Janzen, Knowledge-based Bundling of Smart Products on a Mobile Recommendation Agent, 7th International Conference on Mobile Business, 2008, 181-190.
[52] I.-C. Kim, An Agent-Oriented Approach to Semantic Web Services, O. Etzion, T. Kuflik, and A. Motro , NGITS 2006, pp. 341–344.
[53] Voyager Pervasive Computing Platform, http://www.recursionsw.com/Products/voyager.html
[54] Remote Method Invocation (RMI), http://java.sun.com/javase/ technologies/core/basic/rmi/
[55] Aglets mobile agent platform, http://aglets.sourceforge.net/
[56] Tromsø And COrnell Moving Agents (TACOMA) project, http://www.tacoma.cs.uit.no/
[57] PIAX, http://www.piax.org/en/
[58] Trinity mobile agent framework, http://trinity-maf.sourceforge.net/
[59] FIPA specifications, http://www.fipa.org/
[60] SMARD, http://smard.sourceforge.net/
[61] Float's Mobile Agent, http://fma.sourceforge.net/index2.htm
[62] Sensorware, http://sensorware.sourceforge.net/
[63] Tcl/Tk Documentation, http://www.tcl.tk/doc/
[64] Mobile Agent Framework (MAF), http://maf.sourceforge.net/
[65] Travel Agent (TAgent), http://www.tagents.org/
[66] Object Management Group, http://www.omg.org/

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