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Wireless Mobile Computing Model Based on BDI and Memory Evolution Mechanism

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Abstract
With the advances in hardware performance and related technologies of embedded mobile devices such as PDA and smart phones, on the one hand these devices can make effective use of the advanced Agent technology, upgrade theirs technology, but intelligent business software in domestic market for embedded mobile device is rare, and the application is not ideal; on the other hand, the large number of embedded mobile devices in our country, and a huge mobile business application prospects, although there have been business applications system for embedded mobile devices on the market system, but the applications use more commonly information query and browsing of WAP technology.We propose a multi-Agent computing model, which is efficient from experiment point of view. Fist, Agent technology is introduced, and combining BDI (Brief Desire Intention) model and memory evolution mechanism in the model, which is consist of wireless mobile computing physical architecture model and agent mental state model. Second, on and basis of that the basic mental state update, learning and decision-making are achieved by JADE multi-Agent platform. Finally, the experiment is carried out for the migration of Agent, and the experimental result shows that the model is valid.

Key words: Multi-Agent computing model, Wireless mobile computing, Agent model, Migration of Agent

1. INTRODUCTION

At present, business application has two forms, one is the traditional electronic business based on PC, the other is embedded mobile business based on mobile devices, the former achieves more functions, but the PC position must be fixed, the latter is easy to use, but limited resources, with the increase of embedded mobile devices and the popularity of mobile business applications, a new development opportunities and tremendous opportunities for development of intelligent application software on embedded mobile devices is appear as well. Therefore, how to use the intelligent software of the business application on the embedded mobile device has become a research hotspot(Picco, 2001), technology and solution suitable for embedded mobile devices are widely concerned by Agent.

From the research results of applying Agent to business application, foreign study focuses on building the Agent system platform, such as University of Michigan on AuctionBot system, allowing users to establish a negotiation model, and setting the bidder according to their own preferences, then Agent can negotiate according to the negotiation strategy; argainFinder system developed by Andersen consulting company can query the price of a commodity in the nine shops at the same time, and offer the best business name, URL for users; the Kasbah system designed by MIT Media Lab can send the sale Agent to replace the user automatic negotiation in the process of commodity transaction, and reached a consensus on the price set by the user between the highest and the lowest price; Adaptive Artifical Agent system proposed by Oliver et al can make Agent be autonomously learning better negotiation strategy and use it as the basis for the next negotiation in order to search out the best strategy. Although those Agent system have their own advantages, but there are mainly two issues: one is that negotiation mechanism can't be modified and improved through Agent learning, the other is that there are no different evaluation methods for different negotiation issues.

Domestic Agent model research and application is mainly aimed at the traditional field of electronic business, namely electronic business for PCs, which have stronger computing ability, richer resources, more stable network connection environment. However, the research and application of Agent model for embedded mobile devices with limited computing power and poor network connection environment is less. Although the wireless computing model from domestic universities and scientific research institutions is fully functional, it is too complex, it is not easy to implement in the middle low end embedded mobile devices with limited computing power. How to build a suitable wireless mobile computing model for embedded mobile communication device, and on the basis of that achieving better automatic business negotiation function has an important significance, therefore the model established should have an intelligent Agent structure with automatic reasoning and learning ability, on the one hand, in recent years Agent structure based on BDI model has also an extensive research on intelligent Agent structure, the main reasons are as follows (Pan and wang, 2011): intention can help clear the abstract of Agent intention, knowledge and commitment; able to analyze and design multi Agent system more naturally; help to describe and explain the complex behavior Agent-based system; contribute to the realization of knowledge and behavior reasoning for other Agent. In a word, the Agent structure based on BDI model improves the ability of Agent to respond to environmental changes in dynamic environment. On the other hand, the memory mechanism can remember the successful experience and help to improve the learning ability of Agent in the intelligent Agent structure.

In summary, in this paper, we put forward a kind of wireless mobile computing model WMCMAME (Wireless Mobile Compute Model based on Agent Memory Evolution) for embedded mobile devices, which combines intelligent BDI model(Shi and Xu, 2009; Kang and Shi, 1999; Raphael and Deloach,2000; Sakellariou and Kefalas, 2008; Huber, 1999) with memory evolution mechanism(Chen and Yao, 2013; Ho and Tay, 2007; Michalski, 2000), the next section will introduce detailed the design process of the model, and analyze the relative experiment.

2. Wireless Mobile Compute Model based on Agent Memory Evolution (WMCMAME)

The WMCMAME consists of two parts, one part is the wireless mobile computing environment model (Wireless Mobile Compute Environment Model, WMCEM), which mainly consider the overall system architecture of embedded mobile communication equipment in wireless environment, the other part is the agent model for embedded mobile communication equipment (Wireless Mobile Embedded Agent Model, WMEAM). This paper focuses on the intelligent agent (Agent) model, which is the core part of the WMCMAME model.

2.1. Wireless Mobile Compute Environment Model (WMCEM)

The WMCEM designed is as shown in Figure 1, the model includes registration server, data server, intermediate server, application server, and clients such as smart phones, notebooks and PCs. The registration server is mainly responsible for the registration Agent information and provide services; the data server mainly stores service data corresponding to the seller's product information; the intermediary server mainly provides Agent negotiation and trading places; the application server is the other server with Agent services, can be registered to the registration server, and join the system to form business Agent alliance.

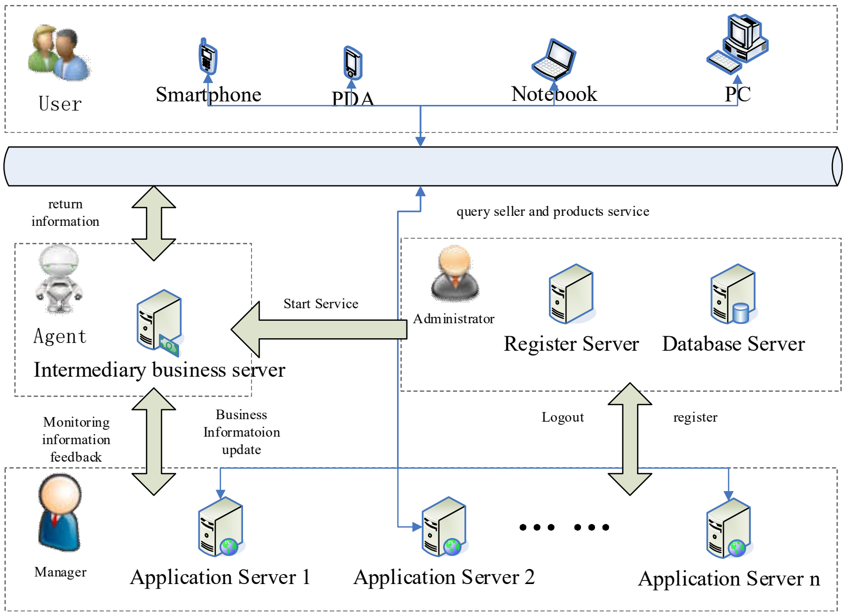

Figure 1. Wireless Mobile Compute Environment Model

2.2 Intelligent Agent Model

In Figure 1 the Agent is supported by wireless mobile embedded Agent model, namely according to the requirements of embedded applications of mobile devices, and combining with the characteristics of BDI Agent structure and the characteristics of information processing, an improved Agent model that is called WMEAM is proposed in this paper, the model extends belief, desire and intention, increases environment, perception, memory state set, matching, search, decision, target and processes etc, in order to achieve real-time interaction with the external environment. The model is mainly involved in Agent (WMEAM Agent) logical basis, mental state, belief modification, goal planning, learning and decision mechanisms, the schematic principle of mental state is shown in Figure 2, the details are as follows.

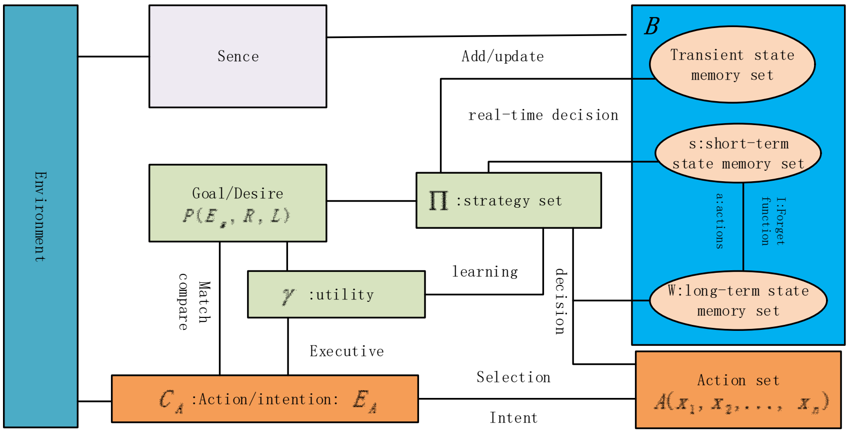

Figure 2. WMEAM Schematic diagram of mental state

(1) The Logical Basis of WMEAM Agent

Logic can be used to describe the Agent mental state and conduct action reasoning, which is the advanced stage of research Agent. Based on the dynamic description logic (DDL) proposed in literature (Kim, 2007), combining ontology description with production rules, the embedded Agent structure model is used to describe the Agent mental state and behavior action.

Definition 1: concept is defined as follows:

①Full concept $\top$ and empty concept $\bot$ are atomic concepts;

②If C, D are atomic concept, $\sqcup$, $\sqcap$, $\neg$, $\exists$, $\forall$ are concept operators, then $\neg C$, C$\sqcup$D, C$\sqcap$D are concepts;

③If R is an any relation, C is an any concept, then $\exists R.C, \forall R.C$ are concepts.

Definition 2: action is defined as follows:

② If $A_1, A_2, \ldots$ are atomic action, $x_1, x_2, \ldots, x_n$ are object variables, then $A_n(x_1, x_2, \ldots, x_n)$ is an action;

②If $\alpha, \beta, \gamma, \ldots$ are action, symbol ; indicates synthesis, symbol ? indicates test, symbol * indicates repeat, symbol $\cup$ indicates intersection, they are used as the action connectors, $\alpha;\beta, \alpha\cup\beta, \gamma^*, \gamma?$ are all actions.

Definition 3: the formula is defined as follows:

①If individual constant elements are represented by $a, b, \ldots$, the individual variables are represented by $x, y, \ldots$, C is concept, R is a relation, α is an action, then C (a), R (a, b), C (x), R (x, y),[α],C (a) are basic formulas.

②If basic formulas are represented by $\phi, \psi, \ldots$, the formula operator are represented by $\neg, \wedge, \rightarrow, \forall$, then $\neg\phi, \phi\wedge\psi, \phi\rightarrow\psi, \forall x\phi$ are formulas.

Note: the definition of concept, action and formula is according to literature (Kim, 2007) and the basic description logic definition, and here the semantic description is need no longer.

(2)Mental State of and its representation of WMEAM Agent

At present, the BDI model with strong theoretical foundation is widely used. The behavior of agents in BDI model is determined by belief, desire and intention. This model can be used to greatly explain the behavior of agents in static environment, but be lack of effective support for action reasoning and learning decision in dynamic environment. On the basis of the BDI model, this paper takes into account the effect of the Agent action on the overall goal and the accumulation of experience in the environment.

Definition 4: mental state of WMEAM Agent is a quadruple M=($B, A, \prod, G$), where B is Agent itself state belief set; A is atomic action set of Agent; $\prod$ is strategy set of Agent, G is goal set completed by Agent.

Belief is the most basic component of the Agent mental component, representing the knowledge of the environment and Agent itself, including knowledge of truth in specific fields, facts, data, concepts and relationships between them. Here only refers to the state related belief, namely state belief. From the memory point of view, belief is also the memory of Agent's knowledge of the environment and its own state. In order to adapt to the embedded device, the state belief set in the large-scale knowledge base is reduced to the long-term memory state belief set and the current memory (also known as short-term memory) state belief set. The current memory state mainly refers to a belief in a problem domain, is formula set reflecting the current Agent state, such as atomic concept and the relationship assertion formula, and is directly related to the current state of the Agent and the current problem domain. Long-term memory state belief is the belief that the current memory state is processed by memory.

Definition 5: Agent state belief is descripted as a quadruple $\mathrm{B} = (W, s, I, f)$, where:

①W is the possible state belief space of Agent, that is, the reduced long-term memory state belief set;

②S is state belief set which is directly related to the current environmental information for Agent, which is the reduced short-term memory state belief set;

③I is the memory mapping function, $s \xrightarrow{I} W$, namely transform s into W;

④f is a forgetting control function, which produces a forgetting factor, and determines s belief is whether or not forgotten.

Action represents Agent behavior ability. Action belongs to the category of belief in nature, the action here also refers to the action belief. The implementation of the action will lead to Agent state changes, therefore, the action can also be seen as a state transition relationship, such as $u \xrightarrow{\alpha} v$,where u and v is Agent state, α is action.

Strategy is an optional action sequence for Agent, among them, the strategy rules are on behalf of the experience of Agent, they can be generated by planning tools.

Definition 6: the description of an atomic action of Agent like $A(x_1, x_2, ..., x_n) = P(C_A, E_A, \gamma)$. Where A is action name, $x_1, x_2, ..., x_n$ are object variables involving the action, C_A is action precondition set, E_A is result set of executing action, γ is the implementation of the utility assessment after executing action, i.e. an immediate reward (short-term returns)of system feedback after executing action, that is the assessment after the action interaction, and on behalf of the action priority.

Definition 7: $\prod$ is defined as the strategy set of Agent, A is the action set of Agent, G is the goal set of Agent, $\pi_i \in \prod$, $g_i \in G$, $\alpha_i \in A$, u is state variables, $B(u)$ is state formula, then $\pi_i ::= \alpha_1; \alpha_2; ...; \alpha_n$, $[\alpha_n]B(u) \Rightarrow g_i$. The goal is what Agent wants to accomplish, namely the state of Agent after executing a series of actions.

Definition 8: a goal of Agent is descripted as $G(x_1, x_2, ..., x_n) = P(E_g, R, L)$. Where, G is goal description name, $x_1, x_2, ..., x_n$ are relevant object variables achieving the goal, Eg is the state set realizing the goal, R is utility evaluation to achieve the goal, L is the goal level indicating whether can be further decomposed, if a goal is not decomposable, it represents the base goal accomplished by Agent.

Definition 9: $g_1, g_2, ..., g_n \Rightarrow g_L$ is goal derivation formula, u is a state variable, $B(u)$ is state formula, α_i is an atomic action, if $[\alpha_i]B(u) \Rightarrow g_i$, then gL is a long-term goal or a general goal, $g_1, g_2, ..., g_n$ are decomposable sub goal or a short-term goal, and it can also be a base goal.

(3)Belief revision

With the change of Agent operation and environment, Agent itself state belief will change, that is belief change. The belief change of WMEAM Agent is mainly due to the state change caused by the action taken according to the goal. This paper illustrates the method of belief revision. For example, if B is a description of formula set of the current memory state belief, the action is executed, the formula set of current memory state beliefs will change, the results state formula set PE after executing action will be added to B, and removes the state belief formulas set that disappear after executing the action (B-PA).

In order to meet emergency requirements, some action of Agent will lead to the change directly state, for example, encountered a serious error to enforce the initialization operation, regardless of Agent at this time in what state will forced to change its state to the specified belief state. Such as definition 5, WMEAM Agent memory can be processed and forgotten, can also lead to state change, that will make the current memory state belief under the action of I memory mapping function evolves into a long-term memory state beliefs and are stored. The current memory state, that is, short-term memory state will be constantly updated by forgetting control.

(4)Learning and decision-making

Learning is the process by which the agent interacts with the environment and constantly accumulates experience in order to improve the ability to reach the goal. The learning also enables the agent to make more reasonable and efficient action decisions. For random events, WMEAM Agent makes learning and action decision combining the thought of reinforcement learning and memory evolution model(Zhang and Li, 2009). Referring to the three stage memory evolution model(Medin et al.,1999), the information processing of WMEAM Agent can be divided into three stages, namely, the instantaneous memory stage, the short-term memory stage and the long-term memory stage. Instantaneous memory plays the role of filter and data initialization in the whole learning process of Agent, in this stage, Agent will classify the information from the external environment, preprocess and format conversion. For limited thinking, perception, decision-making ability of Agent, this stage can effectively reduce the computational burden. Short-term memory plays an important role in in Agent learning and decision-making, it can make real-time decision in order to make quick response through the limited memory beliefs and combining with environmental real-time feedback and short-term goals. In this stage, information processing is similar to human intuition or subconscious reaction, it makes Agent have the ability to respond. In the process of real time decision-making, the method of maximizing returns can be used, such as random strategy or learning automata. Long-term memory mainly deals with short-term memory beliefs, such as classification, formatting, reasoning and so on, and use larger memory space to store, in this phase, the Agent combines long-term goals with delay assessments to make action delay decisions. In the case of making delay decision, the method of delay reward maximization is adopted, such as time difference method or Q learning(Lian et al.,2009). Finally, integrating the delay decision based the long-term memory and the real time decision based on the short-term memory, the Agent action decision is made. The learning and decision-making mechanism play a good role for the WMEAM Agent in the case of uncertain knowledge.

(5)Goal programming

WMEAM Agent uses the goal driven mechanism and apply the planning tree to program goal. Agent exchanges constantly with external environment in order to produce new goal gL, if the gL is not a base goal, it can be further decomposed, and ultimately make the short-term goal gn become base goal g that can be completed by Agent, such as the definition 8. Generally the base goal is achieved by presetting action series of Agent system, namely Agent predefined strategy. Agent can also achieve short-term goals or long-term goals through learning strategies from the process of interaction with the external environment.

WMEAM Agent uses the planning tree to decompose and organize goal. In the planning tree, the root node is the long-term goal, the leaf node is the base goal, and the other nodes are the short-term goal. The implementation of each short-term goal will evaluate its utility, and ultimately achieve accumulated overall utility of the long-term goal. Finally, the learning and decision-making of Agent is realized by the utility of the goal.

2.3. Experiment and analysis

In order to construct the experimental environment of wireless mobile computing environment model, 4 HP Proliant DL60 Gen9 servers (CPU Intel Xeon E5-2603v3, 6 core 1.6GHz, sharing the 3 level cache memory 15MB, 4GB (1x4GB) DDR4-2133MHz) are used as business intermediary server, register server, database server and application server. XiaoMi smartphone (CPU Mi5 Qualcomm snapdragon 820 2.15GHz; Adreno graphics processor 530 624MHz; 3GB RAM LPDDR4 1866MHz; body storage 64GB) is used as embedded handheld devices. HP (CPU Intel core i5-6300HQ 4 core 4 thread; RAM 8GB (2x4GB) DDR4-2133MHz; hard disk storage 1T+128G SSD; graphics GTX960 2G) is used the notebook computer. Lenovo (CPU Intel core I5-650 2 core 4 thread; RAM 8GB (2x4GB) DDR4-2133MHz; hard disk storage 1T) is used as PC. Install Windows Server 2008 R2 operating system and JADE4.0 multi Agent system on each server, and installing custom JADE-LEAP systems on Android6.0 systems on embedded handheld devices. Install the Windows 10 operating system and the JADE4.0 multi Agent system on the notebook computer and the PC.

In the experiment, we design a WMEAM Agent super class, which has the basic properties of AID, AgentState, Role, Goal, etc., and AID is Agent identification, inherited from JADE Agent; AgentState represents the current state of WMEAM Agent, including creation, activity, hang, waiting, delete, transfer; Role represents the role of WMEAM Agent; Goal represents the goal of WMEAM Agent. WMEAM Agent super class has some method, including setup (), destroy (), takedown (), move (), execute (), wait (), wakeup (), resume (), suspend (), and so on, which are inherited from JADE Agent. The design of other Agent classes are inherited from the Agent super class, these categories include embedded Agent class, belief class, event class, GUI class, strategy class, goal class. Embedded Agent class includes object, ontology, belief, behavior set and other attributes and actions to reflect the specific behavior and status of Agent. Belief class indicates Agent long-term memory state and short-term memory state; event class is responsible for the management of BDI events and common events. GUI class for the embedded Agent interface class, mainly is responsible for displaying the user interface Agent. The strategy class is responsible for managing the Agent strategy. The goal class is responsible for the decomposition, synthesis and utility evaluation of Agent goal. In the experiment we also design two modes of WMEAM Agent used to start and run Agent, one is a stand-alone mode: the Agent container will complete launch on the device; the other is the split mode, the Agent container will be divided into foreground and foreground, The foreground is running on the device and the background is running on the server host. In order to improve the Agent performance of the embedded mobile devices, split mode is used in the embedded devices with limited storage and computation capacity.

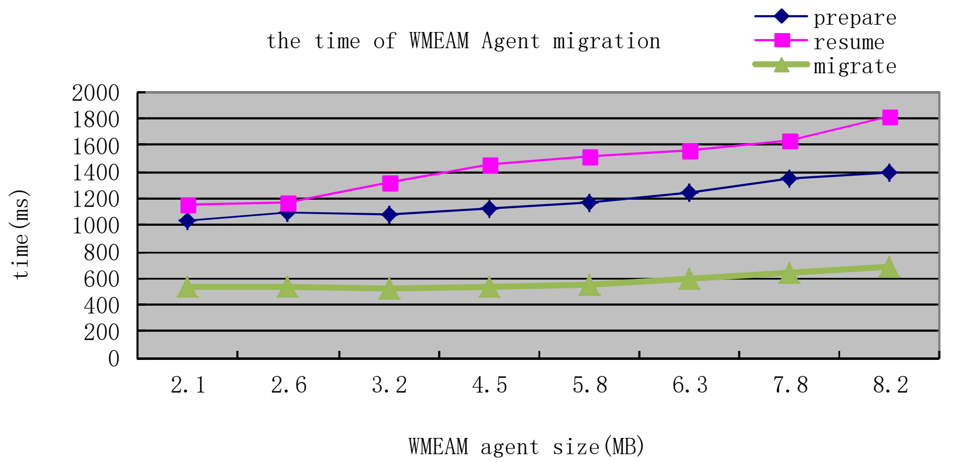

Figure 3. the time of WMEAM Agent migration

Based on the WMEAM model, we develop an online resource sharing transaction agent, which is used to demonstrate the migration of WMEAM Agent in the process of negotiation with the belief file. In the experiment, the transaction resource files were located by URI. When WMEAM Agent is migrating, they did not have to know the specific location of the resource file. WMEAM Agent migration need to carry the migration of the local belief file, marks WMEAM Agent state, and carries out serialization. Focusing on the time overhead, the experimental performance mainly consider three aspects, those are as follows: the time cost of WMEAM Agent preparation before migration, which include the time cost of receiving a migrating message, storing the agent activity state before migration, and making the local belief state (Preparation Time); the time cost of WMEAM Agent migrate to the destination in the network (Migration Time); the time cost of WMEAM Agent resume to the origin working state after it arrived at the destination (Resume Time). We create 6 WMEAM Agents to carry different size of the belief file.

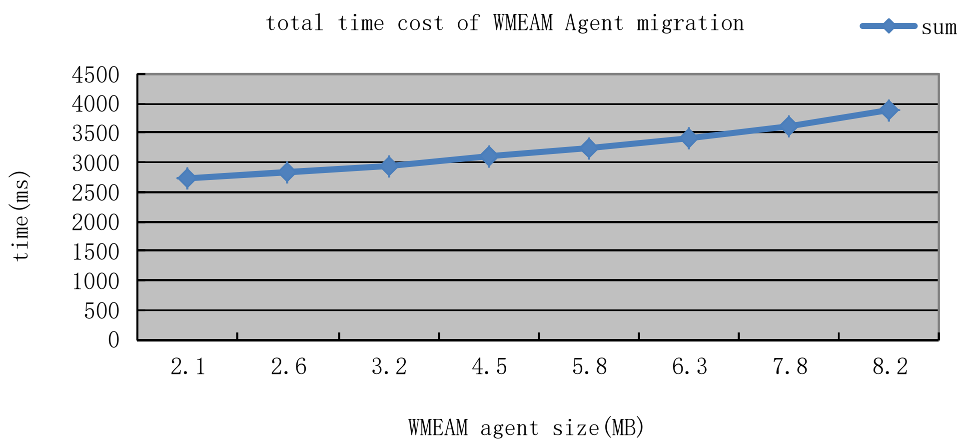

Figure 4. total time cost of WMEAM Agent migration

As shown in Figure 3, the size of the Agents (including the local belief file) from 2.1M to 8.2M growth process, the corresponding time consumption is only a slight change. During the experiment, it is found that the time of Resume Time is higher than Preparation Time, which is because when WMEAM Agent is ready to migrate, it only needs to serialize itself and save the current belief state, and when the WMEAM Agent migrated to the destination to restart, you need to rebind the library file, locate the network resource file, resume the state, which will take more time. WMEAM Agent the total time cost of migration process, as shown in Figure 4.

3. CONCLUSIONS

Focusing on mobile business application, the paper research on wireless computing model for embedded mobile devices, wireless mobile computing model for embedded mobile devices is successfully designed by using multi Agent technology and memory evolution mechanism. The belief state update, learning and decision making functions of WMEAM Agent are realized on JADE multi Agent system platform. In the WMEAM Agent migration test, aiming at embedded mobile devices, different migration patterns of custom JADE-LEAP Agent, from the operation and test results point of view, wireless computing model proposed in this paper is effective for embedded mobile devices.

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