Research on Agent Communication Model and Its Application in Electric System

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Abstract: It is important of Agent communication for the reality of coordination, cooperation and consistency in multi-Agent system. In this paper, an architecture of Agent communication is given. In order to decrease the working capacity to maintain the communication protocol, using the KQML as the basic Agent communication language, the paper proposes an Agent communication model based on dynamic modification to communication protocol where a new protocol is added or modified without changing the protocol software's source code. Based on study of the multi-Agent technology and electric system structure characteristics, the paper presents the layered software architecture of electric system and implementation model. Furthermore, according to the difficulty to debug of the communication protocol in actual electric system, the proposed Agent communication model can be used for decreasing the working capacity to maintain the system's communication protocols, and the results show that the model enhances the system's adaptability and stability.

Key-Words: Agent, Multi-Agent system, Agent communication language, KQML, Protocol rule database, Protocol Agent

1 Introduction

With the rise of the computer network as a popular computation technology, the distributed computation undergoes from the file-shared, distributed object technology and latterly to the Agent technology. Being a branch of the artificial intelligence and distributed technology, the Agent technology seizes close attention recently which hopes to realize the ideal pattern: the disperse-equal and cooperative computation. And the main way of the technique is that it gives the system a modularity design and builds the Agent category according with the construction and function. In the recent years, many researchers have already studied and developed the Agent technology.

It has been accepted definition that an Agent is an autonomous entity that runs in a dynamic environment . Generally, an Agent has the four basic properties[1]: autonomy, reactivity, interaction and sociality. Multi-Agent system (MAS) is an intelligent open distributed system which consists of several computational Agents. It aims to transform large and complicated tasks to small ones that can communicate and cooperate with each other[2~4]. And the communication is the base of the cooperation in MAS. So the study of Agent communication is always the popular topic in the MAS research. Agent communication means that in order to implement the self goal, Agent must collaborate and be cognitive of the environment through exchanging information and transporting orders.

In paper [5], the communication in MAS be classified as three types: communication directly, strong signal communication and black communication. Paper [6] thought that the communication can be classified as below: no communication, primitive passing, message passing based on the computer, plan passing, blackboard, communication based on speech act theory, Agent communication language (ACL). Agents communicating with each other must based on a certain language or protocol. Many Agent communication languages were introduced in [7] [8] [9]. In order to make such system work more intelligently, artificial intelligence (AI) technologies especially intelligent Agent[10~14] are desired. Agent-based approaches in application development seem to meet the requirements of adaptability, scalability, decentralization, and flexibility imposed by complex software systems [15]. And some other role approaches for agents have been proposed and implemented in paper [16], [17], each one with its own characteristics and applicability. Mobile Agent (MA) is a recently

developed computing paradigm that combines intelligent agent and distributed computing technologies. Mobile agents are programs, which can autonomously migrate from one host to another during their execution[18~20].

The structure of this paper is as follows: In Section 2, we present the conceptions about the Agent, multi-Agent system and necessary functions in MAS. In section 3, we give the Agent conversation policy and Agent communication mechanism. Then, the paper introduce the ACL and KQML. In Section 4, based on KQML, we present the general architecture of Agent communcation. Furthermore, an Agent communication model based on dynamic modification protocol is proposed. In section 5, firstly we present the layered software architecture of electric system. Secondly, we give an implementation model based on multi-Agent technology. Thirdly, we give a framework of protocol interface according to the electric system protocol characteristics. Then, a detail design of protocol rule database and protocol Agent is given using the model which is mentioned in section 4. Finally, the paper give an example of KQML message. Section 6 briefly concludes this paper and outline the future work.

2 Agent Technology and Multi-Agent System

2.1 Agent's Conception

There is no universally accepted definition of the term Agent. However, in this paper, Agent is defined as a computer system that is situated in some environment, and that is capable of autonomous action in this particular environment in order to meet its designed objectives [21].

In the course of the research on Agent, the different researchers endowed Agent with different construction, context and capability in their own system. Here we consider that the Agent has four essential characteristics as follows:

Autonomy: Agent controls its action and internal state by itself when they are in motion on some degree and it does not need man or other mechanics' direct control.

Reactivity: Agent could comprehend the circumstance and draw a real time reaction when there is some change in the circumstance.

Interaction: Agent is able to interact with other Agent in order to accomplish and solve a task through a special protocol.

Sociality: Agent is in a social environment which consists of many Agents. It can cooperate, negotiate or compete with other Agents by using Agent language.

2.2 Multi-Agent System

Agent is defined as software or an entity, which possesses a certain special function, but a single Agent could not solve the complicated and distributed problem in reality. Therefore, one applied system usually is composed of many Agent, these Agent not only have their own action goal and problem solving ability, but also have the cooperation ability for common goal through a certain organization strategy and protocol. In other words, multi-Agent system (MAS) consists of many self-determinative or semi-determinative Agents, each Agent performs its own function, and can communicate with other Agents to accomplish the solution of whole task through cooperation. Therefore, MAS should have the following properties:

Distribution: The application domain geographically and logically distributed entities, data, or information are identifiable. The distributed entities that have to make decisions or distributed knowledge bases which have been developed independent of each other have to be integrated.

Complexity: The overall problem usually be separated into a series of problem-solving entities.

Flexible: There is no a prior assignment of tasks to problem solvers and there are no fixed problem-solving processes.

Dynamic environments: problem-solving entities need to responsive and adaptive on environments.

Openness: In these settings, a large number of travel users with differing interests interact with each other.

2.3 The Agent Necessary Functions in MAS

According to these properties, the intelligent Agent is widely used in distributed calculation environment, and multi-Agent can complete a certain more complicated mission together through coordinative calculation. In software technique, people use Agent model controlling and coordinating the data sharing and information communicating during the cooperative work, in order to conquer the not-communality or delay of the data processing. Each Agent is consisted in general Agent kernel and many function modules. Usually think that the Agent includes several parts as these: the Belief being used for defining its own knowledge; the Capabilities being used for describing its data dealing

capacity; the Choice being used for describing the activity for a group of Agent; the Commitment being used for describing the communication between this Agent and others. Basing on this architecture, the intelligence Agent primarily has five functions:

(1) Collect and save information: Collect and save the information environment.

(2) Establish the knowledge library: Explain, classify and assign the from the information establish the knowledge library at the same time.

(3) Pre-conception planning for information: Deal some simple affair and emergency or short term targets fast or in real time. It also can make pre-conception planning for the information.

(4) Coordination and cooperation: Coordinate the cooperative activity and mutual effect between itself and other Agents or Agent organizations through the cooperation and coordination module. Carry on undertaking task, assigning task, dispatching task, and dispelling the resource conflict among Agents through consultative way and negotiations for user, Agent and Agent organizations.

(5) Exchange information and modify knowledge library: Exchange information with environment, human-machine interactive interface or other Agents through transferring problem-solvers and concomitantly or parallel executing the task or activity which has been planned before, synthesizing the executive result and submitting it to the coordinator. Modify the belief space and the relevant content of knowledge library.

The Multi-Agent system is a great complicated and coupled system that is laxly composed by many problem-solvers which is distributed on the network; these problem-solvers solve the complicated problem through interacting each other [22, 23], which single Agent cannot solve with its own capacity and knowledge. Multi-Agent System has a typical property besides the properties that a single Agent has: each Agent in the system has a limited information resource and capacity of problem-solving, knowledge and data are scattered, the control is distributed, and it lacks the overall point of view for realizing cooperation.

The research about Multi-Agent system mainly focuses on coordination for the intelligence activity among a group of autonomous intelligence Agents. To the Multi-Agent System, the coordination is a very important process of knowledge, planning, different skills and the Agent's itself activity [24,25]. Such as how to coordinate their knowledge, targets, skills, and planning activity for uniting them together, adopting an identical activity or solving the complicated problem are the main research contents. In multi-Agent System, Agents maybe generally have one target or quite a few interactive targets.

3 Agent Communication

An Agent has the four basic properties and can complete some simple tasks in this particular environment. But it can not know all information about the environment and world knowledge. Communication between Agents can help Agent to enhance the ability to exchange information with the outsides. It is very important[26] of communication for the reality of coordination, cooperation and consistency, in MAS Agent communication means that in order to implement the self goal, Agent must collaborate and be cognitive of the environment through exchanging information and transporting orders. During the upper process all contacts must obey the conversation policy.

3.1 Agent Conversation Policy

Conversation policy (CP) is a set of rule sets which is abided by Agents during they are exchanging the information that can change agent's current desire and state. It is the fundamental for Agent communication. State Change Diagram and Finite State Machine can be used to figure the CP.

Communication is an action happened between two or more agents. It is not a simple process just like sending a request or receiving a message. The generation and implement of communication rely on the credit to other agents which is similar, obey the same CP and have the same idea with the agent sender. So we must select an effective and flexible communication mechanism for the implement of Semiautonomous agent communication model.

3.2 Agent Communication Mechanism

The communication in MAS can be classified as below [6]:

(1) No Communication; Primitive Passing;
(2) Message Passing based on the computer;
(3) Plan Passing;
(4) Blackboard;
(5) Agent Communication Language (ACL).

There is another classification only three types [27]: Communication directly; Strong Signal Communication and Blackboard communication. Communication directly means agent send message to receiver directly, peer to peer, the other agents cannot receive this message in the system. Strong

signal communication refers that Agent broadcast the message to the open system or environment. The distance of the communication is longer, the intension of this Signal is more week. The reaction is more strongly which is near the sent source of the message. So there exists random for the transport object. Blackboard mode share a public area which is used to exchange information. Any Agent can read, write information freely in the area. It is compliant with publication of the common information. Such as the information about environment altering, the overall goal etc. Blackboard mode is effective, accurate, flexible.

3.3 ACL and KQML

Agent Communication Language is a communication mechanism in Agent based system. DARPA KSE(Knowledge Sharing Effort) group developed protocols for exchange of represented knowledge among autonomous information system from 1990. The principle result of this effort is KQML (Knowledge Query and Manipulation Language) [7]. Another research group in Europe FIFA announced an new Agent communication language FIPA-ACL in 1997. At present, KQML and FIPA-ACL have been accepted widely as the two main ACL standards. They are both based on the speech-act theory. In this paper, the Agent communication model, which is proposed, is based on the KQML. Therefore, here we introduce the KQML.

KQML is a language and protocol for the exchange of information and knowledge between Agents, through message types that express an attitude regarding the actual expression being exchanged. In addition, the more advanced model can been established based on KQML's performative ,for example, contract nets. Furthermore, KQML can provide an architecture of knowledge sharing system. The standard KQML is based on Lisp language.

The expression of KQML message is shown as follows:

```
( performative
      : sender       <word>
      : receiver     <word>
      : in_reply_to <word>
      : reply_with  <word>
      : language     <word>
      : ontology     <word>
      : content      <expression>
)
```

KQML and table 2 gives the reserved parameter keyword KQML.

From table 2, a KQML message includes conceptually the following three logical layer:

(1) Communication layer: describes the bottom lager communication parameter, for example, : sender, :receiver and :reply with.

(2) Message layer: defines the communication performative, knowledge representation language (: language) and using ontology (: ontology).

(3) Content layer: includes the actual communication message content (: content).

Table 1 The reserved performative of KQML

Function	Communication performative
Discourse	ask-if, ask-all, ask-one, stream-all, tell, untell, deny, insert, uninsert, delete-one, delete-all, undelete, achieve, unachieved, advertise, unadvertised, subscribe
Intervention and mechanics	error, sorry, stand by, ready, next, rest, discard
Facilitation and networking	register, forward, broadcast, transport-address, broker-one broker-all, recommend-one, recommend-all, recruit-one, recruit-all

Table 2 The reserved parameter keyword KQML

The reserved parameter keyword	explanation of the keyword
:sender	actual message sender
:receiver	actual message receiver
:from	represent starting-point in communication
:to	represent end point in communication
:in-reply-to	response previous message identifier
:in-reply-with	response current message identifier
:language	language name used in content parameter
:ontology	terminological definition set name
:content	actual message content

4 An Agent Communication Model

4.1 the General Architecture of Agent Communication

A KQML message is called a performative where the message is intended to perform some action by virtue of being sent. The general architecture of Agent Communication includes the following components shown in Fig. 1: interpreter, communication interface(CI) and knowledge database(KDB). There are some reserved performative sets in KDB. Every Agent needs a KQML's interpreter to interpret and carry out some basic operations. However, the reserved KQML performative in KDB is limited and not satisfied with all applications. So we must extent the performative sets that is supported by the KQML.

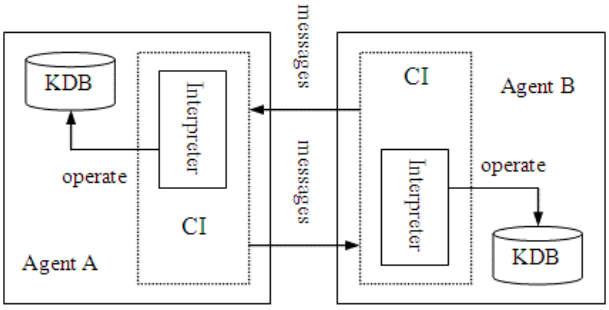

Fig. 1 The general architecture of Agent communication

4.2 An Agent Communication Model based on Dynamic Modification Protocol

In MAS, the communication protocols need frequently to be modified and added in order to carry out the different transmission services. In actual application, it must spend a lot of time in changing the protocol software's source code to maintain the communication protocol. Therefore, it decreases the system's adaptability and stability.

Communication language and protocol are the basis to exchange information and knowledge effectively among Agents. KQML is a widely used communication language, which defines the representation style of message and mode of work and supports the knowledge sharing among run-time Agents. A KQML-based communication model is proposed where Agent can add new protocol or modify protocol without any modification of the protocol software's source code. The working capacity to maintain the communication protocol can be decreased, thus the adaptability and stability are enhanced.

A communication protocol is considered that it is consists of some CFSM (Communication Finite State Machines) [28] and messages which are exchanged by FIFO (first-in-first-out) queue. Therefore, it can be looked upon as a series of received and dispatched message sequences. Essentially, Agent communication is a state transfer mode where messages are mapped into Agent's state transfer relationship.

Assuming an expression of a state transfer process is defined as follows:

Tk(Ink, Prock, Rek)

Where Ink is a message, which comes from the other Agent. Prock is a process according to the Ink. Rek is a message responsing to the Prock.

Agent communication process is based on a

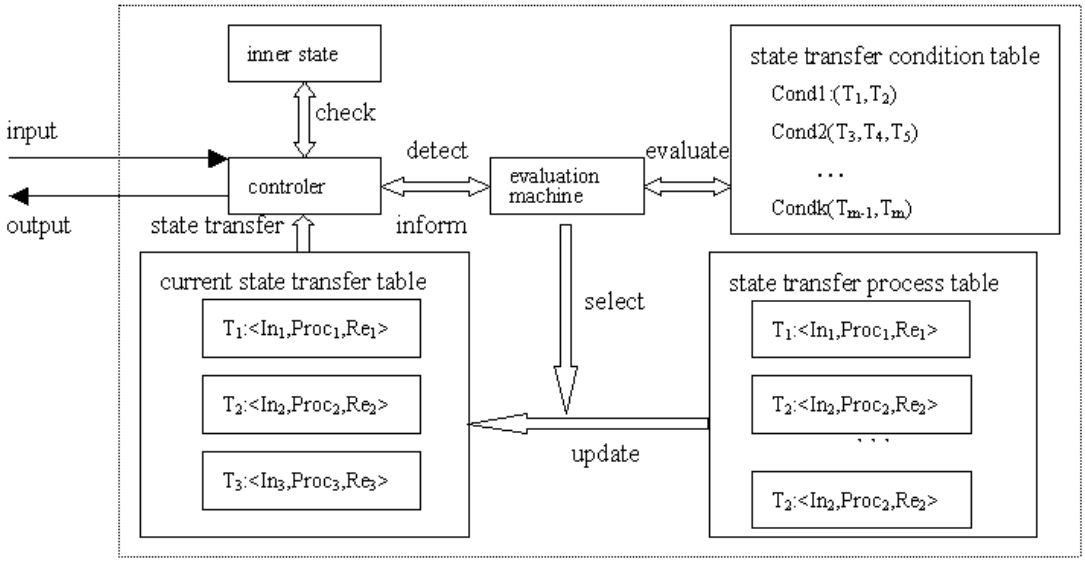

Fig. 2 The inner protocol interface of Agent

standard communication protocol, could be regarded as Agent's state transfer process. Therefore, a standard communication protocol can be mapped into state transfer rule database which is made up of the state transfer condition table and state transfer process table. In real application, we can modify the state transfer condition table and state transfer process table when an Agent communication protocol needs to be added. The inner communication protocol interface of Agent is shown in Fig. 2 which is composed of five elements, which are controller, evaluation machine, state transfer condition table, state transfer process table and current state transfer process table. Their working processes include three steps shown as follows:

Step 1: Controller checks the current state then informs the evaluation machine.

Step 2: Evaluation machine selects a process of the state transfer according to the current state and state transfer condition.

Step 3: Controller triggers off a process of the state transfer according to imported messages and the current state transfer process.

We only modify the Agent state transfer condition table and state transfer process table when the communication need to been modified and added. The contents of the two tables which is related to Agent domain knowledge and communication protocol specification are discussed detailedly in the next section.

5 Application of Agent Communication Model in Electric System

5.1 The Layered Software Architecture of Electric System

According to the complex distributed structure of electric system, in this subsection, we present the layered software architecture of electric system. In next subsection, implementation of the electric system based on multi-Agent is proposed. According to the electric system module function, the software architecture includes three layers (see Fig. 3):

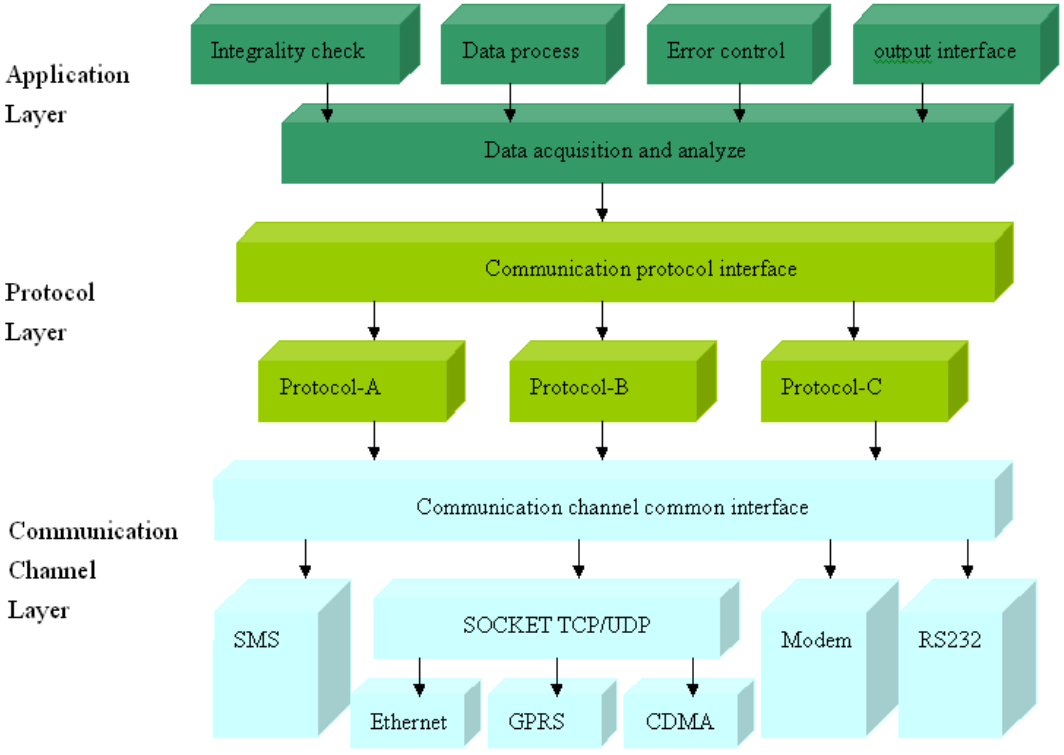

Fig. 3 The layered software architecture of electric system

communication channel layer, protocol layer and application layer. These layer function are shown as follows:

Communication channel layer: Implement to communicate in bottom layer communication, such as GPRS, CDMA, modem mode and etc. and give an unified I/O communication interface to upper layer.

Protocol layer: resolves the problem of external communication protocol interface, implement to

communicate among the Agents, offers to an unified protocol process interface to upper layer.

Application layer: includes some applications, for example, integrality check, data process, error control and etc. and give an unified output interface.

5.2 Implementation Model based on Multi-Agent

etc. In this subsection, we present an implementation model based on multi-Agent which is shown in Fig.4 . The model shows the following type Agents.

(1) Monitor Agent: Carry on undertaking some tasks, for example, system program start and stop, monitor to the other Agents state, allocation resource and load balancing in the whole system.

(2) AQ (acquisition) Agent: Is the one of the system's core business modules. It carries out data

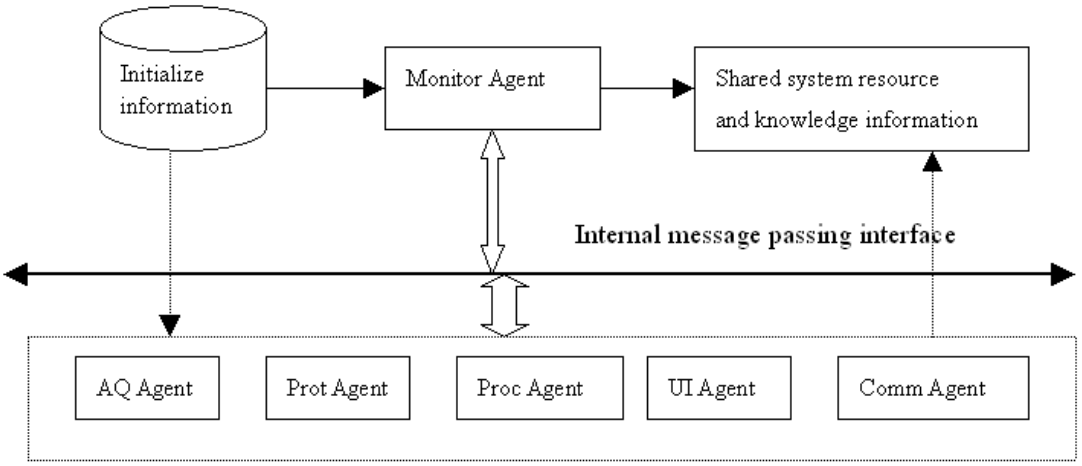

Fig. 4 Implementation model based on Multi-Agent

Recently, with the rapid development of MAS, the multi-Agent technology is widely used in many applied fields, such as traffic control system[29], electric system[30], decision support system[31], and

acquisition and steering command.

(3) Prot (protocol) Agent: Implements to transfer communication protocol in different communication protocol rule database and adapts to

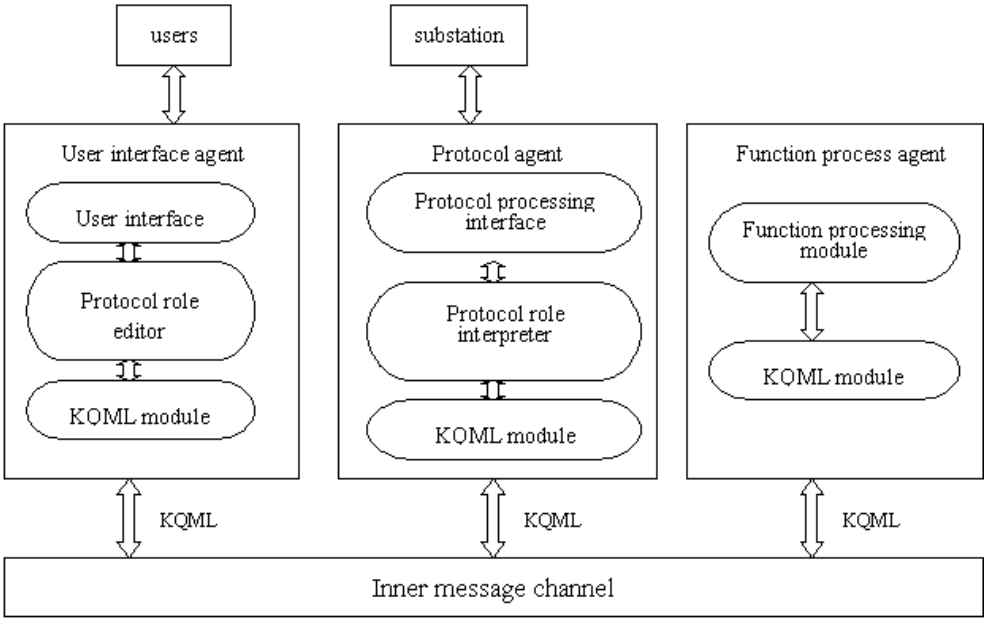

Fig. 5 Framework of system protocol interface

all kinds of the terminal station.

(4) Poc (process) Agent: Is also the one of the system's core business modules. It's main function is to write in the original database according to the different applications.

(5) UI (User Interface)Agent: is a intelligent interface to uses and can maintain the protocol rule database, query the system working state and etc.

(6) Comm (Communication) Agent: implement to communicate in all kinds of Agent.

All Agents communicate with each other using socket communication mode in internal message passing interface. The implementation results show that this model enhances the system's adaptability and stability.

5.3 Framework of Protocol Interface

At present there are many different standard protocols in the actual electric system and it is very difficult to realize and debug the communication protocols. According to the electric system protocol characteristics, the communication model, as mentioned in section 4, is used in the system and it decreases the working capacity to maintain the communication protocol and enhances the system's adaptability and stability. In the system, an interface is given by which the users input some protocols parameters and rules. Then, these parameters and rules are transferred into communication protocol rules that the protocol process Agent can comprehend. Since the communication protocol rules associated with protocol processing processes. When the system need to added or modified the communication protocols, we only modify the communication protocol rule base and need not to change the protocol processing programming codes.

Generally, an electric system includes control station (master station) and some contained stations (substations) and the architecture of control station interface is more complex than contained station. Here, we take the design for control station interface as an example.

The Fig. 5 shows a framework of system protocol interface, which mainly includes three Agent modules: user interface Agent, protocol Agent, business processing Agent and Agents communicate with each other using knowledge query and KQML by inner message channel. The Agent module's function are shown as follows:

(1) User interface Agent: Carries out mapping protocols into communication protocol rule base and communicating with protocol Agent by KQML module.

(2) Protocol Agent: Protocol rule interpreter carries out mapping the communication protocol rules into the state transfer rules, communicating with substations according to the inner state transfer rules and sending some information to business processing Agent by KQML module.

(3) Business processing Agent: Carries out receiving some original information data and doing some other operations (such as, writing in database).

5.4 Design of Protocol Rule Database and Protocol Agent

A standard protocol includes some definitions, for example, the communication transmission mode, data transmission frame format, link layer transmission rule, service primitive and etc. It is knowledge representation issue how to represent the protocol contents which Agents can understand. According to the electric system communication protocol characteristics and referring IEC870-5-101 protocol, we define a representation language as follows:

V is a set of variable. All variables is beginning of '?' (for example, ?X).

C is a set of constant.

F is a set of communication frame locator. For example, Frame_Byte(x) is represented the x byte in inner frame.

O is a set of operator. Besides addition, subtraction, multiplication and division, it includes some frame check algorithms (for example, CRC algorithm).

T is a set of assignment.

L is a set of logical connector, for example, '$\wedge$' and '$\vee$'.

Thus, the communication protocol contents and rules can are defined R=(V,C,F,O,T,L). The FT1.2

Table 3 FT1.2 frame format

Begin character (68H)
Length
Length
Begin character (68H)
Control domain
Address domain
Link user data
Check sum
End character (16H)

frame format, as shown in Table 3, is represented as follows:

#1: Frame_Byte(1)=0x68 ;
#2: Frame_byte(4)=0x68 ;
#3: Frame_Byte(?Data_Length+6)=0x16 ;
?Data_Length=Frame_Byte(2)+Frame_Btye(3) *256 ;
if #1 ∧ #2 ∧ #3 then Cond1 (Cond1 is represented a integral frame) ;
Protocol rule base consists of table structure of fact and table structure of role records shown as Fig.6.

Table structure of fact

Fact_id	Fact_content

Table structure of role records

Role_id	Cond_id1	Cond_id2	…	Result_id

Fig. 6 The table structure of fact and role records

Protocol Agent is designed of realization of communication protocol interface (see Fig. 5) and additional to carry out data output (for example, writing in the original database) .

5.5 An Example of KQML message

We give an example of KQML message using DL/T 634-1997 (companion standard for basic telecontrol tasks in china) which referring the IEC870-5-101.

The following is the an actual KQML message which AQ Agent informs Comm Agent to transmit a communication frame to the address (IP address): 10.191.134.8 .

```
(inform
  :sender AQ_Agent
    :content (Action:=Sent to;
                target_addr:=10.191.134.8;
                Frame_length:=13;
               Frame_packet:=688D1501001E006
                 82100B216)
      :receiver Comm_Agent )
```

5.6 Model Performance Evaluation

The model has been are successfully used for power load management in some domestic cities. The main station of the system includes the following functions: system management, resource management, application diagnosis, data handling, alarm supervision and statistics query. The application results show that the model enhances the system's adaptability and stability. To test the system's performance and efficiency in data handling and statistics query functions, we compare our proposed model with the traditional model which do not used Agent technology with the same physical design flow. The comparison result is given in Table 4.

Table 4 Comparison Result

	Traditional model	Our model
Data handling	4.7	4.1
Statistics query	16.8	9.5
Total time (ms)	21.5	13.6

From Table 4 , we can find timing path of our proposed model is shorter than the traditional model, because our proposed model fully used the multi-Agent technology for the complex and distributed system environment.

6 Conclusions

Communication is representation of Agent social property. Based on KQML, the paper proposes an Agent communication model where a new protocol is added or modified without changing the protocol software's source code. The model has been are successfully used in an actual electric system. the results show that the model enhances the system's adaptability and stability.

The Agent technique develops so fast that we even could not predict it, this technique bases on the science of computer and the science of artificial intelligence, at the same time, it is enlightened by biology, ecology, histology, the science of social behavior, anthropology, economics and the science of law, etc. The research about Agent technique have become one of the new focal points in modern science. The next step of our work is to use the model into more detailed applications. Furthermore, we will use the Agent's study mechanism for system's communication and it will further enhance the system's communication capacity.

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