Front. Electr. Electron. Eng. China (2006) 4: 396–399
DOI 10.1007/s11460-006-0076-2

RESEARCH ARTICLE

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Implementation and design of a communication system of an agent-based automated substation

Abstract A substation system requires that communication be transmitted reliably, accurately and in real-time. Aimed at solving problems, e.g., flow confliction and sensitive data transmission, a model of the communication system of an agent-based automated substation is introduced. The running principle is discussed in detail and each type of agent is discussed further. At the end, the realization of the agent system applied to the substation is presented. The outcome shows that the communication system of an agent-based automated substation improves the accuracy and reliability of the data transfer and presents it in real-time.

Keywords data transfer, substation automation, agent system, communication system

1 Introduction

Along with the development of computer and communication technology, especially network application, the Ethernet technique is being introduced into automated substation systems, which forms a distributed pattern of an automated substation based on a control network. The communication of this type has time limitation and the data to be transferred differ in its sensitivity. The system should also meet the need for efficiency in communication [1]. There are problems, e.g., transmission conflict and the transmission of sensitive data during network transmission service that need to be addressed. There is also a need to improve the reliability and validity of the data transmission in real-time. According to the present development trend of computer networks, improving quality and, building up the flexibility of a network transmission and guaranteeing good service has became the primary aim. The different kinds of expert systems and AI technologies adopt an object-oriented method to the substation automatic system in order to advance its automation capability [2–4]. For its characteristics, an agent can be used to construct a communication software that can process and transmit data immediately, flexibly, and independently. Therefore, it makes not only practical sense but also provides theoretical value to take the research on an agent, and the development of an Internet work communication system if it is introduced into the computer network communication system. The substation is an important part of the electric system. The application of an agent in the substation makes good sense when trying to improve the reliability and validity of an Internet communication in real-time.

Aimed at solving the problems in communicating transmission, this paper has brought forward a model of an agent-based substation automation system.

Translated from *Transaction of North China Electric Power University,* 2005, 32(6): 68–71 (in Chinese)

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2 The model of an agent-based automated substation system

2.1 System structure

In order to accomplish the three main functions of measuring, controlling and protecting, the IEC TC57 logically divides the automated substation system into three layers: the substation layer, the interval layer and the process layer [1].

The agent-based substation communication system is composed of a Host-Agent, a Sub-Agent and a Manage-Agent (see Fig. 1).

Host-Agent: receives the information coming from the

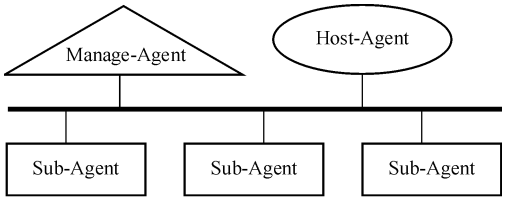

Fig. 1 The structure of an agent-based substation system

interval layer and sends a corresponding data in response.

Sub-Agent: transmits the collected relay data to the host station, which is in charge of failed information management and receives the control information from it.

Management-Agent: registers and administers relevant information about the starting and suspending operation to each Host-Agent and Sub-Agent station and manages the agent itself.

2.2 System operation mechanism

The system is presented in distributing types. If an individual Sub-Agent fails to run, the communication between other Sub-Agents and the Host-Agent will not be affected. The whole purpose of the system is to prevent and avoid the occurrence of flow conflict during the transmission process, and make sure that sensitive data will be transmitted effectively and reliably. Each agent in the system makes its own decision for this purpose.

When the Host-Agent needs some Sub-Agents to upload data, the Host-Agent will determine whether they are sensitive or not based on the information stored in it.

If the data are found to be sensitive, the Host-Agent will initiate an action based on the net state in the knowledge-base. If the rules show that the net is overloading and some information are being lost because of the confliction, then the Host-Agent will ask the Manage-Agent to block some of the Sub-Agents which are transmitting non-sensitive data in order to make sure that the transmission of sensitive data would get enough bandwidth so that flow confliction will not occur and the sensitive data will be transmitted reliably and effectively until the transmission is finished. It still is the Host-Agent that calls the Manage-Agent to evoke the blocked Sub-Agents to go on transmitting.

If the data are non-sensitive, the Host-Agent will send out a request to the Sub-Agent directly. The Sub-Agent decides whether to respond to the Host-Agent based on its own state and the state of the net and decide on a proper tactic according to its target to avoid flow confliction and make sure that the sensitive data will be transmitted reliably in real-time.

If the Sub-Agent is in a running state and the network state is fine, the Sub-Agent will connect the Host-Agent, choose UDP as the transmission protocol and prepare to send the corresponding data. At the same time, the Sub-Agent "tells" the Host-Agent about its chosen protocol so that the Host-Agent will select the same protocol.

If the Sub-Agent is in a running state but the network state is ordinary. This kind of states indicates that flow confliction might occur, some data packets might be lost or the message might be delayed and not arrive at the given destination in time. In this condition, the Sub-Agent will choose TCP, which has a reliable transmission. Although some messages have been lost because of a few conflicts, the overtime-retransmission will offer a reliable data transmission service.

If the Sub-Agent is running and the network state is bad. The bad state will show that some data packets have been lost and some messages have been delayed for flow confliction. In this case, the Sub-Agent needs to respond to the Host-Agent a moment later until the right opportunity. If the state remains in a bad state within the time limit of a permitted transmission, the Sub-Agent will then transmit the higher priority-ranked data by reducing the traffic.

During running time, the Manage-Agent will start a Host-Agent and a Sub-Agent according to the request of the Host-Agent, and at the same time, record the state of each agent. The Manage-Agent will also block some Sub-Agent if the Host-Agent would request to do so.

The Host-Agent acts as an information sponsor all the time during network communications of the substation. The connection it sponsors is not completely blind but has its own "thinking" and "deciding" behavior. It will create or suspend a correspondence with a certain substation according to the permissive condition of practical situations. As Sub-Agents need to finish uploading information and each kind of information has a different time limit and quality, by taking the actual network state into account, the Host-Agent should be capable of selecting a proper strategy to reach the requirement respectively: by reducing the amount of traffic or by delaying connections or by switching communication protocol.

3 The structure of an individual agent in the substation system

The Host-Agent and the Sub-Agent are the principal parts in the communication system and take on the primary task. Whether data can be transmitted reliably, effectively and on time depends on their performance to a great extent. They are intelligent agents who can study themselves, so they are designed as an inserted-piece style. The Manage-Agent, as its function is relatively simple, is designed as a reactive style.

3.1 The inner structure of the Host (Sub)-Agent

Figure 2 shows the inner structure of the Host (Sub)-Agent.

1) Special-field-knowledge-module
2) Decision-tactic-module

3) Arithmetic-module
4) Arithmetic-base- maintenance
5) Knowledge-base-maintenance
6) Fact-base-maintenance

Sensor-machine: to perceive the environment. It is a functional module for the Host(Sub)-Agent to sense changes in net capability. The Sensor-machine senses the state of the current network by using a ping command every second.

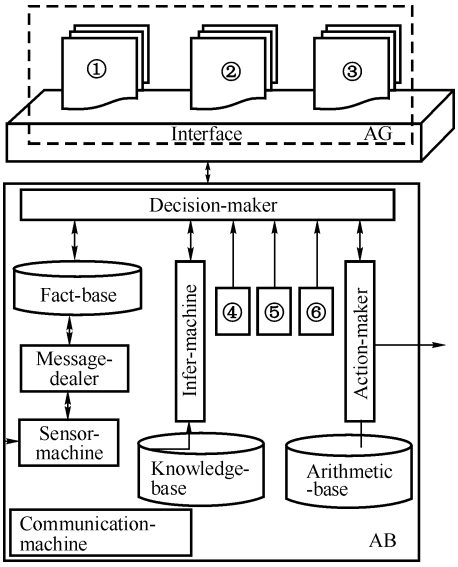

Fig. 2 The inner structure of Host (Sub)-Agent

Communication-machine: an interface inside and outside of the system to be able to communicate with each other. The data between the Host and the Sub-station are transmitted directly through it.

Decision-maker: to coordinate the running of the agents.

Action-maker: to regulate the size of the sending (receiving) buffer, which improves the data sending (receiving) speed based on the net state provided by decision-maker.

Special-field-knowledge-module: to store all the special knowledge needed during the process of agent running, for example, rules of relay protection, the state of the data transmission on the net, e.g., good or bad, time limitation and so on.

Decision-tactic-module: to decide which state the agent should run into and which module should be called. This module makes the decision with the help of the Infer-machine, the Knowledge-base and the Fact-base.

3.2 The inner structure of the Manage-Agent

The Manage-Agent is responsible for recording each agent's individual information, which is expected to be simple and responds quickly. Therefore, its design should be a type of reactive structure agent. The internal structure is shown in Fig. 3.

The functions of the sensor-machine, the action-maker, the message-dealer, and the fact-base of the Manage-Agent are the same as those of a communication agent. The information on each communications agent is recorded in a registering table, e.g., the agent's name, address, function and running status.

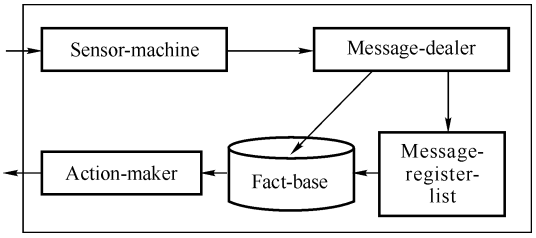

Fig. 3 The inner structure of the Manage-Agent

4 Implementation of each agent

Both the Host- and Sub-Agent are intelligent agents that can function on their own, and they have the same model pattern, so an intelligent agent for communication (ComAgent class) is designed and defined, while the Manage-Agent is defined as Manage-Agent class.

As the traditional Ethernet adopts a CSMA/CD protocol, which is a non-determinism communication way and unsustainable to priority transmission, its quality becomes low when the load is very heavy and it can't guarantee that data will be transmitted reliably and validly in real-time. To solve the data flow conflict and sensitive data transfer problems during transmission, scholars at home and abroad had put forward many possible solutions that can avoid these problems [2–4], but nearly all of the suggested ways involve altering the protocol and are not flexible enough for common use. In this paper, the model adopts a TCP/IP combined with IEC 60870-5-103 [5].

This paper realizes an agent-based substation system by virtue of data of relay protection during communication failure between the Manage-Agent in the substation layer and the IEDs.

4.1 Class of intelligent agent for communication

```
//Agent Type Definition: Sub-Agent and Host-Agent
//Agent State Tag Definition: static, running and blockedf
//Define Class: AgentBase
// Define Class: AgentGene
//Implementation of the function for data base maintenances, take Knowledge-base for example
addKnow(RuleBase rb, Rule rule){
int len=rb.size();
rb.add(len,fact);}// add new knowledge
public void addKnow(RuleBase rb,Rule r){
```

```
rb.removeElement(r);}    //delete outdated knowledge
//realizing the function of //inference, using the in-
fer-once function
infer(Vector ruleList,Vector factList,
                    String[] result){
String[] f=new String[FactList.size()];
String infr= " ";
Int num=inferonce(ruleList,f);
If(num>=0){
Infr=((Rule)
ruleList.elementAt(num)).consequent;
result[0]=infr;
}                              //after the first infer, go
                                    //on next infering
int i=1;
while(num!=–1){
        String midi=infr;
        String m[]=new String[1]; //use the outcome of
                        // last inference as the premise
                        //of current inference.
m[0]=midi;
    num=inferonce(ruleList,m)     //inference
          ……
    }
}
```

4.2 Manage-Agent class

The definition of Manage-Agent as follows:

```
ManageAgent{
……
Vector          AregList=new          Vector();
                    //Message-Registe-List
Initialize(){};
Process(){
stopped=false;
msg=new AgentMessage("regiseter", i d, host
                                port, desc)
AgentEvent e=new AgentEvent(this, msg);
Register(e);                  //add host information to
                              //Message-Regist-List
Stop(){…  stopped=true;  …
}              //end the running of Manage-Agent
void run(){
runnit=new Thread(HostAgent);
runniest.start();
runnit=new Thread(LocalAgent);
runniest.start();
}              //start running of the Host-Agent
               //and Sub-Agent.
```

5 Analysis of the system instance running

As the Host-Agent and the Sub-Agent uses their flexibility and intelligent characteristics fully, they have succeeded in distributing the net load logically. They adapt to the current condition and the demands of transmission, so given the same condition, data and net load, the agent-based system and the conventional system have different response time and rates of data packets lost. The agent has the ability to react and a level of intelligence, so that the system then can adjust its transmission strategy according to the changes of a dynamic environment: to increase the size of the receiving (sending) buffer when the net load is light to improve throughput and reduce the response time; to block services of low priority when the load is heavy to guarantee the transmission of sensitive data in real-time; to decrease data traffic and change protocol to guarantee the reliability of non-sensitive data transmission and reduce the delay. The flexibility prevents and avoids the occurrence of flow confliction effectively, and minimizes the possibility of information loss.

On the whole, the outcome shows that the agent-based substation network transmission system is more flexible and intelligent than the traditional one. It cannot only prevent and avoid flow confliction from arising, but can also guarantee the transmission of sensitive data in real-time even if data confliction exists. It improves reliability, validity of the Ethernet transmission and be more real-time.

6 Conclusions

In the wake of the development of net technology, the amount of data being transmitted is increasing rapidly, and data flow problems and data loss will have a serious effect on the application system, especially on the one with a high demand for quality and speed. With desirable characteristics such as flexibility, intelligence and so on, a software agent can be applied to solve the problems that exist in a distributed system or a dynamic environment. The agent will prevent and avoid data flow problems, and guarantee a reliable transmission of sensitive data on time, and improve the quality of the data transmission: reliability, validity and real-time transmission. On the condition that the hardware has been developed up to a certain grade, using an agent, an advanced method, to construct communication software is a significant work that is worth trying.

References

1. Sun Jun-ping, Sheng Wang-xing, Wang Sun-an, Research on the new generation of communication system of substation automation, China Electric Engineering Transaction, 2003, 23 (3): 16–19, 145 (in Chinese)
2. Shi Zhong-zhi, Intelligence body and its application, Beijing Technology University Express, Beijing: 2000: 20–45
3. Court R., Real-time Ethernet, Computer Communication, 1992, 15(3): 198–201
4. Venlcatramani C., Chiueh T., Supporting real-time traffic on Ethernet, Proc. of Real-time System Symposium, 1994: 282–286
5. Jacobson V., Congestion avoidance and control, IEEE/ACM Transaction Networking, 1998, 6(3): 314–329