Communication and Coordination of the Group Decision Support System of Water Resources Based on the Dynamic Contract Net Protocol

Jia Zhao [1,2] , Huibing Wang [1], Xuewen Wu [1], Yejun Xu [3], Fengzhou Wang [1], *Lizhong Xu [1]

1 College of Computer and Information, Hohai University, Nanjing, China
2 *School of Information Engineering*, Nanchang Institute of Technology, Nanchang, China
3 *School of Business*, Hohai University, Nanjing, China
*. tel: 0791-82080251, fax: 0791-88126661, e-mail: lzhxu@hhu.edu.cn, zhaojia925@163.com

Abstract **— As a complex system, water management system based on Multi-Agent technology is a typical group decision-making system. How to transform the complex interaction into a simple orderly interaction to achieve effective communication and coordination is one of the key issues for building the water management system based on multi-Agent technology. This paper puts forward the communication and coordination mechanism based on dynamic contract net protocol, establishes a Multi-Agent interaction and behavior model, and designs simulation experiments to exemplify the effectiveness of the models and its algorithm.**

Keywords - dynamic contract net protocol; multi-Agent technology; inter-basin water transfer system; group communication and coordination

I. INTRODUCTION

Inter-basin water transfer system is a complex system combined with natural and artificial systems. It is a complex water resource system, aiming to achieve multi and trans-regional water resource allocation in a wide range of space and time scales. And it is also a typical group decision-making system and has made abundant achievements based on CAS Research on complex water resource system. How to effectively coordinate the behavior of various management agents to solve all kinds of conflicts and contradictions; how to adapt to the random temporal and spatial distribution characteristics of water resources, achieve optimal scheduling and controlling trans- regionally on a large scale, make scientific decision-making, and enable it to realize mutual operation goal, have become the key to inter-basin water transfer management decision making [1].

Since the1970s, many scholars and institutes have conducted numerous researches and made great achievements about water resources allocation based on the multi-object optimization. Cohon made a significant study of water resources' multi-objective problems [2]; Watkins proposed a sustainable water resources planning model with uncertainty, establishing the representative joint scheduling model of water resources; Whipple proposed that the development, configuration and management of water resources have entered a new period characterized with communication and cooperation[3]. Ioslovish believed that the power of market mechanism to achieve effective allocation of various water resources has been widely studied, and the price mechanism is the focus of current research and application. Tisdell studied the environmental impact of Border River on Queensland in Australia. He came to the conclusion that the water rights trading has the potential to increase the contradiction between the water and the natural flow regime need, because production water concentrates on high profits to grow crops, while water market has may limit the efficiency of water policy to recover from the natural flow regime. Therefore, it is necessary to keep a balance of production need water and environment demand water. Jerson made a discussion on water allocation mechanism in view of the fact that the economical use of water has exceeded its water capacity in arid regions, and proposed the water allocation principle of cost opportunity to satisfy various demands of different users [4-8].

At home, researchers in this field have carried out numerous studies on water resources allocation and optimization since the 1990s. For example, Wang Huimin raised the SNWDP supply chain operation management and water resources allocation based on complex adaptive system and management paradigm system[9-11]; Ma Zhenli established the basic management model system and made a detailed analysis of the simulated water transfer system of SNWDP[12]; Wang Hao, Qin Dayong have put forward the conception of water resources allocation on the basis of all attributes functions[13]; Li Chenming proposed the simulated model of trans-basin water diversion based on multi-agent, and carried out the simulation model of the water diversion, adopting complex adaptive system as the scientific basis [14-16].

Most of the research results mentioned above focus on the theoretical framework of qualitative analysis, fail to break away essentially from the traditional multi-target engineering optimization system and to substitute game theory for the traditional balance theory. Theoretical analysis of the allocation and management of water resources, and the substitution of "communication and cooperation" for "technical and economic optimization" have become a trend[8], but there is still a lack of effective communication mechanism, therefore, the majority of group decision making is conducted without communication, and its advantages have not been given full play. Thus, to study on communication and coordination mechanism to meet the complexity of water resources allocation and management has become the key to the research on the new theory of water resources allocation and scheduling decisions which takes the principle of communication and cooperation as the basis.

In the light of the communication and coordination problems in the inter-basin water transfer group decision-making system, on the basis of multi-Agent-based inter-basin water transfer group decision support system model, this paper has proposed the communication and coordination mechanism based on dynamic contract net protocol, established a Multi-Agent interaction and behavior model, and designed simulation experiments to exemplify the effectiveness of the models and its algorithm.

II. INTER-BASIN WATER TRANSFER GROUP DECISION SUPPORT SYSTEM BASED ON MULTI-AGENT

Inter-basin water resources planning, allocation, management and scheduling involve different levels of decision makers, including the state, province, region, city and county etc. Many departments and units need to participate in decision-making, and each decision maker is relatively autonomous, therefore, inter-basin water resources planning, allocation, management and scheduling problem, is a typical group decision-making problem which is highly complex characterized with multi-stages, multi-levels, multi-objectives, and multi-decision makers[17].

This paper establishes a structure model about Inter-basin water transfer group decision support system based on mutil-Agent. This system is composed of the coordinators, experts and policymakers such as the view of Fig. 1.

(1) The coordination group. In each layer there are administrative jurisdictions of units and inter-administrative units as well. Because of the difference of local interests, it is difficult to form satisfactory solutions through mere negotiation and coordination. The superior departments are supposed to be responsible for the disagreements between the regional units, thus a coordination group can be established in this layer. The group can be composed of representatives from the superior departments and of experts who are not members of the coordination group. The coordination group manages the target system, examines feasible solutions, coordinate conflicts of different departments under the jurisdiction of this layer. Constrained by the goal system of this layer; taking the interest distributions between different groups into consideration, it will aim to bring about the consensus of the decision-making groups within the compass of this layer.

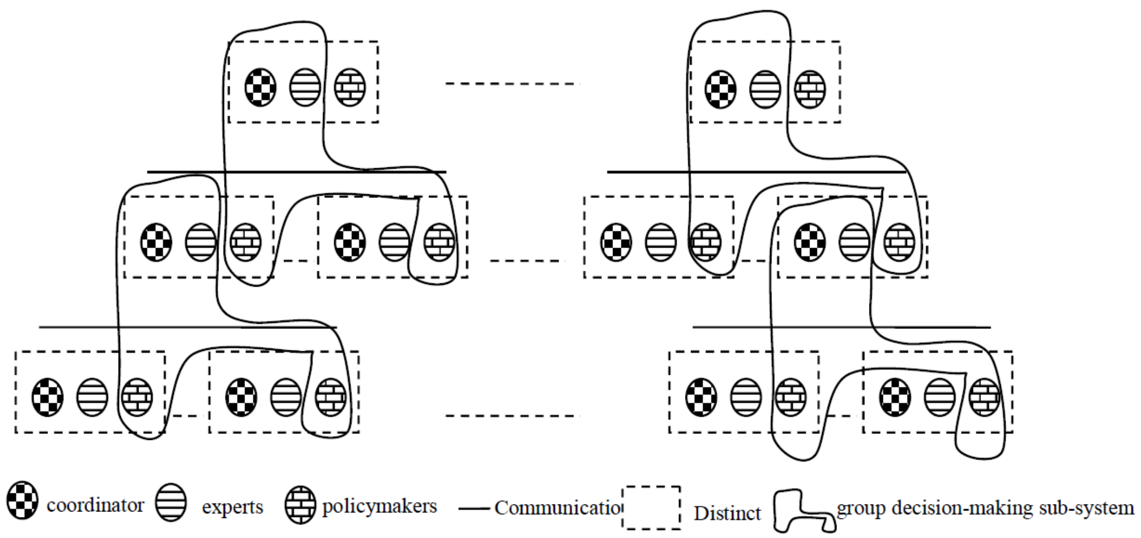

Fig. 1 : The topology structure of coordination mutil-levels dynamic group decision-making system

(2) The panel of experts. The expert panel is responsible for working out the goal, target constraints group and possible solutions on the basis of the upper-layer policy constraints and the configuration constraints of this layer. The water resource allocation involves ecological, social, economic and other factors; therefore, it will be more reliable and scientific if the panel is composed of experts from various fields. The expert panel accepts the direction of coordination group,

to whom it is supposed to illustrate the reasonableness of objectives and constraints, scheme and planning.

(3) The decision making group. It is composed of representatives of jurisdiction by each layer and a certain proportion of experts. Its role is to analyze the possible solutions according to the target system, forming a satisfactory solution set. Eventually the coordination group will bring about unanimous agreement by group voting.

The coordination group will take responsibility for the interaction between the adjacent layers. If the present layer is unable to achieve the basic goal, or based on the cost analysis, and the upper index constraints, it fails to achieve the basic utility of this layer, it will submit feedback to the upper layer. The upper coordination group will make rational analysis of the feedback, adopt reasonable suggestions and ignore the unreasonable part. Then it will set new goals, plan and constraints in the layer, implement decision process again, and transmit the result to the lower layer.

III. COMMUNICATION AND COORDINATION OF THE INTER-BASIN WATER TRANSFER SYSTEM BASED ON DYNAMIC CONTRACT NET PROTOCOL

A. Entity of the inter-basin water transfer management system

Based on CAS theory, inter-basin water transfer management system can be regarded as a cooperative symbiosis network system composed by a variety of relatively independent autonomous entity. Management of the network system includes the whole process from supply chain to demand chain, that is, the whole parts are thought of as being made up of different entities which play appropriate roles of different levels, representing the water supply, water demand complex activities, drainage, quality protection, tariff management, etc. Through the negotiation and compromise between the entities and the environment, and the entities themselves, the whole process can be in symbiotic cooperation.

The operation of the entire system can be viewed as an aggregate made up of the water supply, water demand, water usage, etc. gathered together by the so-called adhesion. The smaller, lower-level entity, under certain conditions, may be gathered into a larger, higher-level multi-agent aggregate through negotiation and compromise. This aggregate can act as a single entity on this level as, for example, the water supply entity can be a multi-agent aggregate formed by the upstream and downstream water supply, water rights allocation, running water engineering facilities and the main sewage treatment, etc.

Taking the Eastern Route of the South–North Water Transfer Project as an example, the aggregates can be divided into three categories:

(1) Southern Water Agent aggregate represents the interests of diversion areas. Interest demands and the various contradictions in the southern individual entities will all be reflected by the southern water Agent aggregates. Agents in this area, though with polymorphic locations and capacity, they are in the scheduling supply chain, whose most fundamental purpose is to optimally schedule the water and get the best profits. Southern Water Agent aggregate can make gains due to providing water resources, but also must face various issues of shipping, drainage, ecology and management due to the outflow of water.

(2) North Water Demand Agent aggregate represents the water demanding Agents. The aggregate includes different types of user Agent, different water sources and administrative departments Agent. They are on the chain of water demand; and its function is to use water rationally, to boost the stable development of local economy and ecology. Northern Water Demand Agent aggregate need to pay for the transferred water resources, but also is responsible for the rational allocation and scheduling program. The scheduling and use of each water resource by various agents within the aggregate will leave different impacts on the local economy, society and ecology. Different areas in the northern region also have different demands for water and interests, but conflicts can also be reflected comprehensively by the northern Agent aggregate.

(3) Coordination and management aggregate. The above two aggregates shoulder the responsibility of overall coordination of the conflicts between the demand and supply.

For multi-level inter-basin water transfer management system, the above-mentioned three types of aggregates exist in each layer.

B. Multi-Agent interaction model based on dynamic network contract

The traditional relationship between water supply and demand is mainly regulated administratively. To establish a new relationship under market economy system, a series of new highly adaptive behavioral rules should be developed for reflecting the respective interests of water supply and water demand. The Agents interact in accordance with behavioral rules; react with each other and improve their behavior through learning or experience, thus improving the behavior of the whole system. In the water resources system, it is unrealistic to assume that there is a universal decision-making center to deal with problems caused by collaboration and interaction within all agents. Meanwhile, the centralized management will be restricted by solving techniques and can not find a solution to the potential conflict caused by the distribution and autonomy of each Agent. Strict global regulation is very difficult, except in emergent flood relief.

As for the water allocation scheme, many contradictions are bound to bring about the difficulty of coordination. Therefore, this paper decomposes water resources allocation scheme, enabling decision-makers at every level to seek consensus on the program, and on this basis, gradually the overall configuration will be completed, and eventually it will be possible to form a globally satisfactory configuration. According to this concept, this paper introduces contract net protocol mechanism, and modifies it to establish a mechanism for multi-Agent communication and coordination.

In 1980, Smith proposed a contract net protocol (CNP) in distributed problem solving. This paper, based on CNP and combined with the limits of diversion management organizational structure, responsibilities, communication and coordination properties, modifies CNP and changes the way of tender to tender negotiation. It designs a series of interactive collaboration rules of assignments, role allocation and commitment for supply and demand in the North and South aggregates. The improved dynamic contract net protocol and interaction rules are as follows:

Manager Agent (MA) (borne by the coordinator of Layer K; the coordinator agent represents the coordinator's intentions, and acts according to the coordinator's behavioral strategy) is responsible for decomposition of the task, monitoring its implementation, and works out the processing operation results; Execution agents (Demand agent and Supply agent) are responsible for the execution of the task.

The procedures are listed as following:

(1) Initialization. In the system, all agents report to MA about their supply and demand preferences. Based on the preferences and requirement of high aggregate, MA makes overall planning of this layer.

(2) Invitation of tender. According to the overall planning requirements, MA makes classification of water demand information and sends tender notices to the supply and demand Agent aggregates, covering water quality, price, and the latest time for scheduling and deadline for bid. MA invites bid according to the following rules:

$$\text{Bel (MA, Cap(B,T))} \wedge \text{Bel (MA,(Trust(B,T)} \geq \text{T0)|Des(MA,S3)} \rightarrow \text{Int (MA,a1)} \tag{1}$$

If T is a configuration, the Cap (B, T) indicates that B has the ability to accomplish the task of T, including the trust degree of scheduling ability to complete T on the basis of T constraints and the trust degree of decomposing of configuration task T; Bel (MA, Trust (B, T) ≥ T0) indicates that MA believes that B has exceeded the lowest bidding trust T0; Des (MA, S3) indicates that MA has the intention of transferring to state S3.

$$\text{Bel(B,Int(MA,a1))} \wedge \text{Bel(B, Cap(B,T))} \wedge \text{Bel(B, Do-Well(B, T)} > \text{W0)|Des(B,S3} \rightarrow \text{Int(B, b2)}$$

3) Tender. After receiving the bidding information, the supply and demand agents will participate in the tender according to the contract rules and its intention. The tender will be sent to the North and South MA respectively, North MA is responsible for bid evaluation. Bidding rules are listed as following:

$$\text{Bel (B, Int (MA, A1)) is a Bel (B, Cap (B, T)) is a Bel (B, Do-Well (B, T)} > \text{W0) |Des (B, S3, Int (B, B2)} \tag{2}$$

Bel (B, Int (MA, A1)) indicates that Agent B has received the tender notice from MA; Bel (B, Cap (B, T)) indicates that Agent B knows that it has the ability to complete this task T; Bel (B, Do-Well (B, T) > W0) shows that B's robustness is beyond the expectation W0; Bel (B, Do-Well (B, T) > W0) says that B has the intention of transferring to state S3; Int (B, B2) shows that Agent B will take action B2, b2=Bid (B, A, T), that is, B has submitted a bid to A for task T.

(4) Assessment. MA will choose the best partners from the tenders, based on complementary water demand time level. If the bids can not meet the expectation, water demand Agent will make adjustment and send tender again. The evaluation score is calculated according to the following formula:

$$\text{Score (a, T)} = (\alpha \text{ *commited\_fa+ } \beta \text{ *trust\_fa+ } \gamma \text{ *rlation\_fa+ } \delta \text{ *active, fa)} \tag{3}$$

In the formula, α, β, γ, δ are weighted factors, and $\alpha+\beta+\gamma+\delta=1$, commited_fa, trust_fa, relation_fa, active_fa indicate the commitment factor, trust factor, cooperation frequency factor and active factor.

The Best contractor (a, T) meets the following conditions:

IFF a ∈ {ai}, Score (a, T) =max (Score (AI, T)) ^ (Score (a, T) >S0)

Select the contractor, and then delegate the task. MA's rebidding rules are as following:

$$\text{Bel (MA, Int (B, R1)} \vee \text{Bel (MA, Lose (B, T)) |Des (MA, S9)} \rightarrow \text{Int (MA, A9)} \tag{4}$$

Bel (MA, Int (B, R1) indicates that MA has received the information that all the agents refuse to tender; Lose (B, T) indicates that Agent B has been considered as a failed bid; Bel (MA, Lose (B, T)) shows that MA has already known that all the bidders give up; (MA, S9) indicates that MA has the intention of transferring to the state of inviting bidding again; Int (MA, A9) shows a new plan and new bid (A9)will be made.

(5) Execution of the task.

The interactive UML sequence diagram of the above mentioned three types of aggregates is shown in Fig. 2. For multi-level inter-basin water transfer management system, each layer is taking the following interaction sequence:

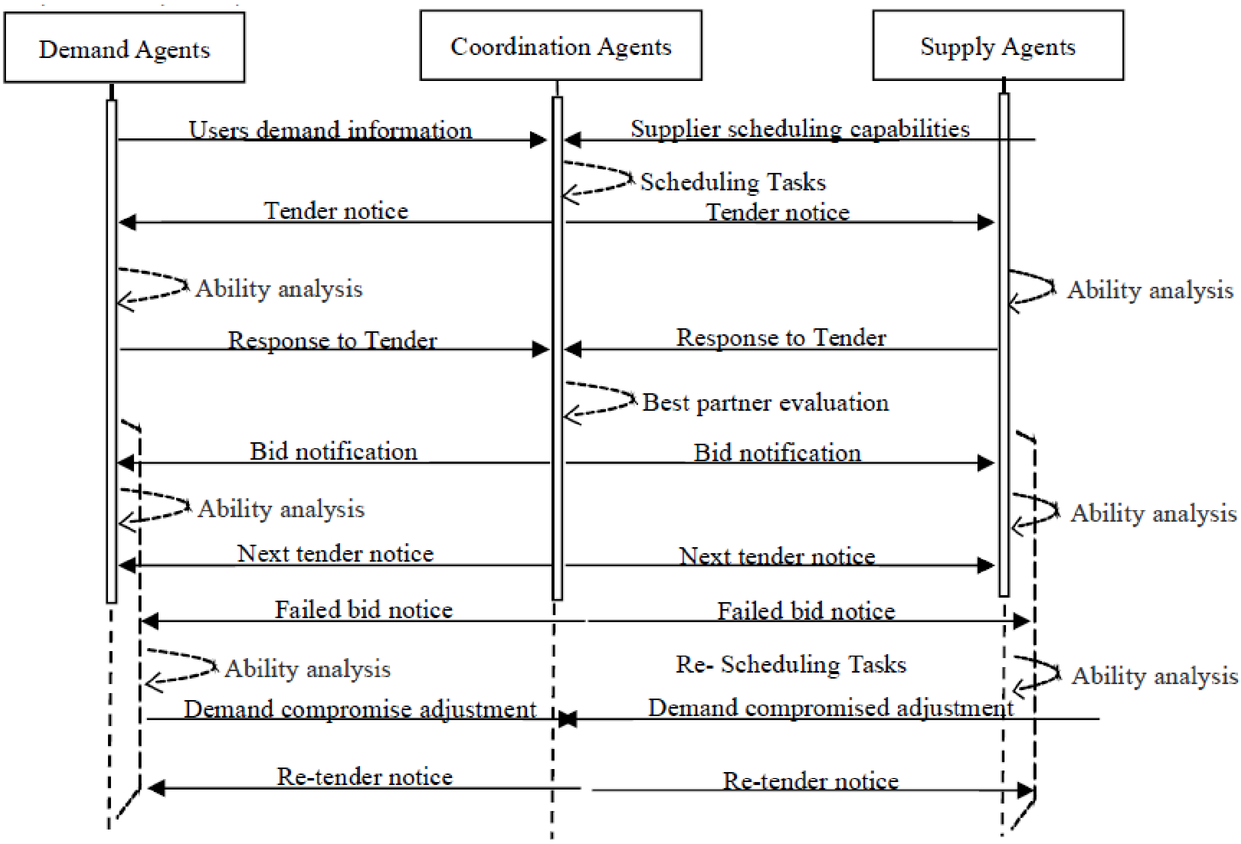

Fig. 2：interactive UML sequence diagram of the above mentioned three types of aggregates

Collaboration Steps in Fig. 2 are illustrated as following:

(1) Manager of the layer (MA, the coordinator) discomposes task, makes planning and forms a set of tasks according to information of the Agents' ability;

(2) MA issues a tender notice to all Agents;

(3) The water supply Agent proposes a feasible scheduling scheme according to the planning;

(4) The north user group aggregate submits the requirements to the north MA.

(5) MA makes analysis of the best sequence of cooperation based on supply and demand ability;

(6) If the optimal task subset exists, it will be taken as the core, and send the bid winning notice to the supply and demand party;

(7) If MA cannot find a satisfying scheduling scheme, it will send notice of failure to inform all supply and demand agents, and send the re-planning notice as well; After receiving the notice, north and south agent aggregate will re-analyze the task, expand capacity analysis range and bidding scope, define some administrative mandatory terms, impel inactive agents to adjust capacity and make compromise ability, to achieve the goal of supply regulating demand, communication and coordination. Based on the adjustment of supply and demand side, and the results of the previous round of bidding, MA will make new plan for the next round;

(8) If there is winning bid, MA will take the task set as the core, and make plan for the next round of bidding;

(9) If all the tasks have been decomposed and formed satisfactory contract for all, the bidding will be ended;

(10) Centered on the best solution set and contract net, the southern water agent is responsible for task

scheduling, and the MA of each layer will do inspection and evaluation.

C. Agent behavior design based on dynamic contract net protocol

The key to realize the contract net protocol is how the Agent acts in accordance with the agreement, generally using automatic state machine to represent Agent behavior. Dynamic contract net protocol implementation can be described as M:

M= (K, Σ, F, S0, Z) (5)

K is the state set; sigma represents event message set; f is the state transition function; f: K × Σ K→S0 is the initial state; Z represents end state set, S0 □ K, Z □ K.

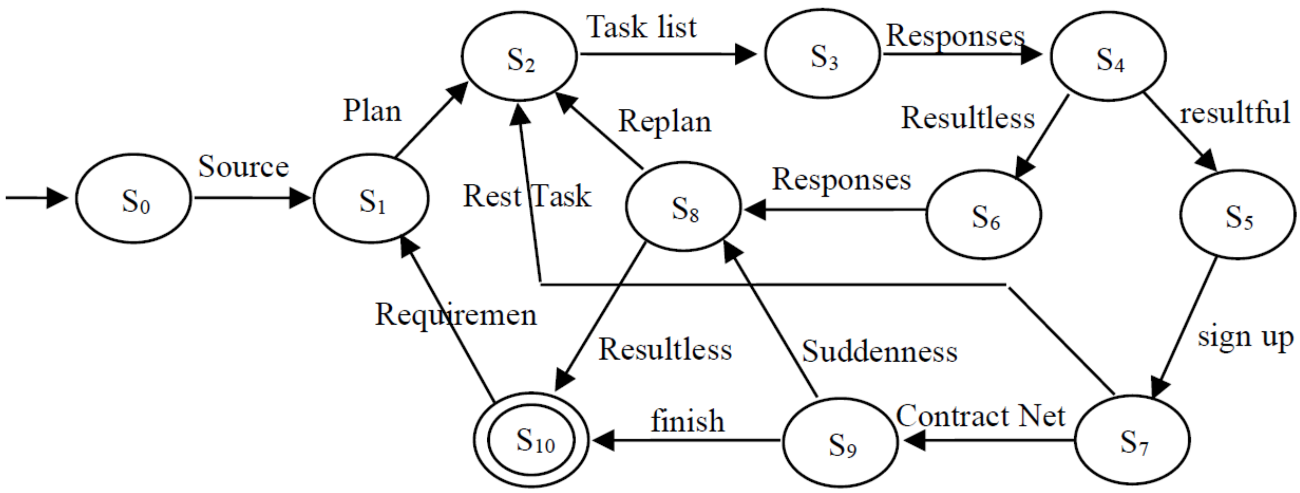

Fig. 3 State Automata Model

State automata model is shown in Fig. 3. State automata mainly centers on a bidding activity of a certain layer based management agent (MA) function and the effect of the contract net protocol automatic state machine design. Among them, the initial state is S0; S1 is planning state; S2 is the state of task decomposition; S3 is tender state; S4 indicates condition assessment scheme; S5 the state of winning bid; S6 is the state of failed bid; S7 is contract state; S8 is the state of re- planning, S9 is the state of organization and implementation; S10 indicates the contract net assessment state, terminal state. The machine sets up 10 kinds of state, respectively, as the initial state of S0, ending the state of S10, the other for the intermediate state. The initial state is initiated by arbitrary aggregates of Agent. The end state occurs under the completion of the execution of the contract or when it is impossible to form a complete planning as a result of significant differences. The intermediate state characterizes the interaction, communication and compromise, etc.

(2) Design of protocol automatic state machine algorithm based on contract net for Management Agent (MA).

In the algorithm, we first define two data structures. One is the state transition structure, and the other is the message Call Back function table structure. When managers Agent into the next state, need to take "enter" action to do the work, the allocation of resources, establish the message buffer and initializing the user interface, and then continue to receive messages and processing. The message is processed by the message Call Back mechanism. Be processed in all news, managers Agent will leave the current state, the release of resources, and notify the other Agent.

The steps of the algorithm are illustrated as following:

Step 1: Initial state transition table and message processing table;

Step 2: Check whether the current status is invalid state or not. If it is, switch to the end;

Step 3: Cycling Ma's processing state table. Obtain the position of the current status of the process table and a corresponding message processing table;

Step 4: Cycling message processing table until the status of invalid message. If the corresponding message processing function is received, use it; otherwise, ignore this message processing;

IV. DYNAMIC CONTRACT NET COMMUNICATION AND COORDINATION

In order to verify the algorithm of communication and coordination, this paper employs Java programming technology combined with Swarm algorithm platform to make a simulation experiment. The simulation design takes a water supply area (Southern aggregates) and a water demand area (Northern aggregates) of Shandong province, which is on the eastern route of SNWD as research subjects. The experimental assumptions and indicators of sustainable development of water resources can be found in ref. [18]. The internal structure and model of aggregate Agent have referred to ASPEN model, a Microscopic simulation model of economy developed by Sandia laboratory of US; this paper designs a simulated model system such as Fig. 4.

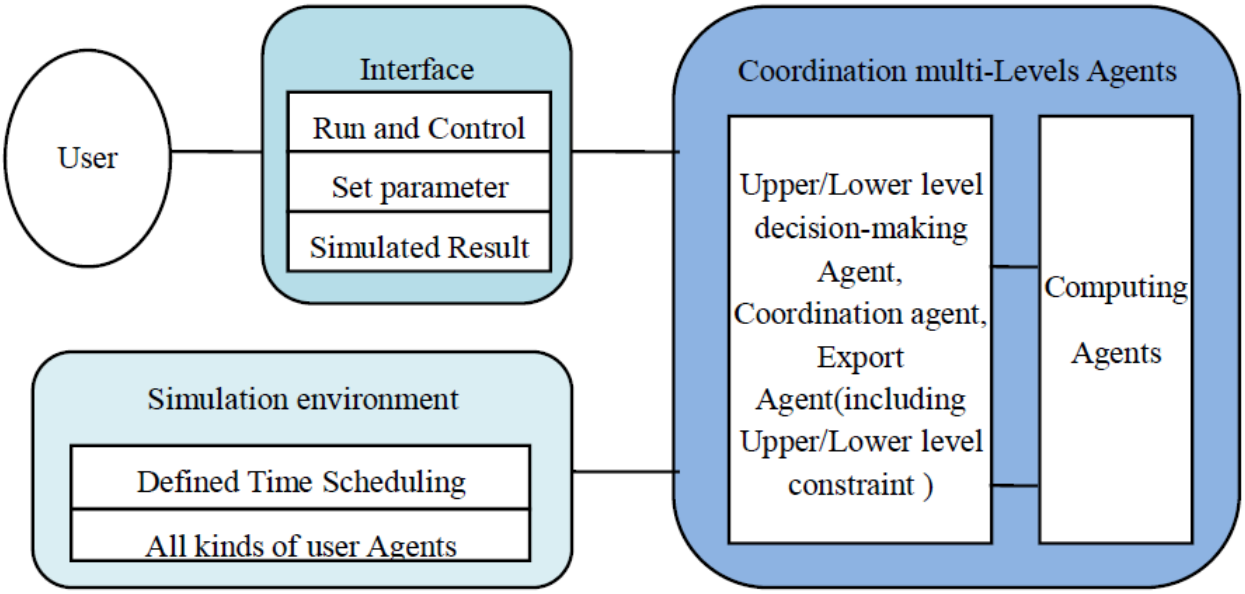

Fig. 4 The Structure of Mutil-Agent Simulation System

The simulated environment of this model designs 600 user agents in water demand area. Agents are composed by resident agent, enterprise agent, government agent, environment agents (including water, ecological, economic and social environment agents, etc.). Different users have different requirements for water quality and price. One management agent is mainly responsible for receiving the user agent's task and selecting contract bid. Ten water supply aggregates agent from the upstream supply chain, are responsible for the formulation and participation in the tender; one environment Agent and government Agent aim to handle government guidance prices and regulate the current water resources situation.

The simulation data used in this paper are taken from the bibliographies based on Shandong Province, Jiangsu Province and Anhui Province. In addition, the simulation experiments carried out take use of the simulation data as well [19-22].

Among them, P1, P2 are decision makers, distributing along water transfer line from south to north; P0 acts as coordinator. Specific data can refer to table I-IV; according to statistics, the regional dispatch ability can be listed as: the water flow rate to P1 area is 450 m3/s; the water flow rate out of P1 region is 350 m3/s; the flow rate into P2 zone is 275 m3/s; the flow rate out of P2 a 250 m3/s.

TABLE I.REGIONAL AVAILABLE WATER RESOURCES UNIT：100 MILLION M3

-----	1	2	3	4	5	6	7	8	9	10	11	12
P1	5.60	5.77	6.04	6.05	6.70	7.10	6.59	6.76	7.29	6.74	6.54	6.10
P2	2.29	2.49	2.55	2.70	2.34	2.36	2.40	2.91	2.30	2.45	1.98	1.70
downstream	3.60	3.95	3.30	3.65	4.25	4.20	4.15	4.20	3.45	3.45	3.40	3.10

TABLE II. REGIONAL WATER DEMAND UNIT：100 MILLION M3

-----	1	2	3	4	5	6	7	8	9	10	11	12
P1Min	3.12	4.20	6.94	6.92	3.61	4.71	5.10	4.02	4.56	6.37	5.50	4.10
P1Max	3.80	4.93	7.67	7.73	4.90	5.19	5.78	4.80	5.11	6.92	6.00	4.87
P2Min	2.78	2.89	4.80	2.88	4.35	4.77	4.80	2.36	3.21	4.14	3.07	3.18
P2Max	3.10	3.77	5.14	3.23	4.92	5.38	5.61	3.05	4.30	4.96	3.84	4.00

TABLE III. THE DISTRIBUTION OF WATER USERS IN P1 AREA

period	Life（%）			Agriculture（%）			Industrial（%）			Ecosystem（%）		
	1	2	3	1	2	3	1	2	3	1	2	3
1	2	15	8	10	8	2	10	20	10	3	12	0
2	2	16	7	10	8	2	9	21	9	3	12	1
3	1	12	2	18	10	1	9	22	8	3	12	2
4	1	11	2	17	11	1	10	21	9	4	11	2
5	1	15	3	11	11	1	11	21	8	3	11	3
6	2	16	3	9	9	1	11	22	10	3	10	2
7	1	11	2	17	12	1	9	22	8	3	13	1
8	1	10	1	18	12	1	11	20	10	4	11	1
9	1	16	2	10	13	1	11	20	8	3	12	2
10	2	16	3	8	10	1	11	22	10	3	10	2
11	1	15	9	10	8	2	10	20	10	3	10	2
12	1	15	10	9	7	3	11	19	11	2	11	1

TABLE IV.THE DISTRIBUTION OF WATER USERS IN P2 AREA

period	Life（%）			Agriculture（%）			Industrial（%）			Ecosystem（%）		
	1	2	3	1	2	3	1	2	3	1	2	3
1	1	14	2	16	8	4	9	20	14	2	9	1
2	2	12	2	17	8	3	10	21	14	2	8	0
3	1	14	1	16	9	4	9	20	15	1	7	2
4	0	12	1	18	16	5	12	21	11	0	2	1
5	0	8	1	18	21	4	13	21	11	0	1	1
6	0	2	1	18	26	6	12	20	11	1	1	1
7	0	3	1	17	24	8	11	20	11	1	2	1
8	1	13	2	17	14	5	12	21	11	0	2	1
9	0	3	1	18	25	6	12	20	10	1	2	1
10	1	15	2	15	8	3	10	21	14	2	6	2
11	1	12	3	15	10	2	11	20	15	4	4	2
12	2	11	4	16	8	3	10	18	15	4	5	3

One environment Agent and one government Agent consist of the government guidance price and the current situation of water resources. The initial price is 1.2CNY per ton, and simulation years are 360 steps (about 10 years).

The refresh frequency is 1, namely to refresh once after each simulation cycle. After initiating the simulation experiment system, each agent will act and interact according to the set schedule in advance（referring to table IV,V）. Then observe the changes of water resources system in the Southern and Northern supply and demand aggregates through the computer observation window. The experimental results will be shown in Fig. 5~ Fig. 8.

Fig.5 showcases the evolution trend of the government guidance price and market negotiation price. It can be seen from the chart that due to the development of economy, and the shortage of water resources, government designated price of water goes upward on the whole. With the progress of the simulation, industry, agriculture, management, government and other types of agent can interact and learn from each other and make behavioral adjustment respectively according to their demand and supply. The government guidance price fluctuates slightly and goes up steadily. Contract Price of Water fluctuates dominantly around the government guidance price, which can reflect timely and accurately of the supply and demand situation in the market economy, up to the operation and management concept of eastern route of SNWD.

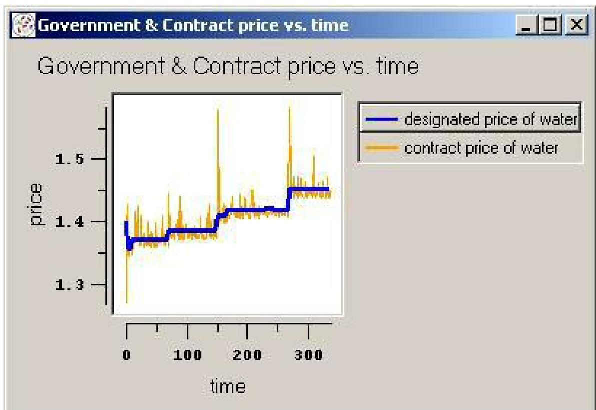

Fig. 5: evolution trends of government guidance price and the market price

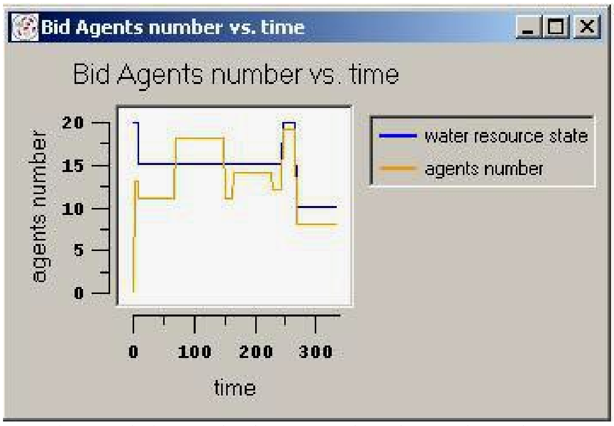

Fig. 6 evolution trends of water supply and water demand zone

But in the 160 and 270 steps, the curve of contract net transferring water price mutates and there emerge two "noise points" as well, which reflects the tense contradiction between supply and demand, thereby causing the price leap. In the noise point position, it is necessary for the government to implement macroeconomic regulation and control.

Fig. 6 shows the evolution trend of water supply and water demand zone. When the amplitude of water resource state curves at 20:00, indicating that the current water demand in the South and the North side is in rich phase; When the curve amplitude stays at 15:00, indicating that water demand in the north is in the period of water shortage, while the South is rich in water resources; when the curve amplitude stays at 10:00, indicating that the South and the North are both in the period of water shortage. As can be seen from the number of Agent curve, when the North and the South are in water-rich period, each supply Agent shows more enthusiasm for tender, and a larger number of Agents participate in bidding; and when the north experiences the period of water shortage, due to the lack of water resources, there are less agents to bid, so the number of Agent participating in the tender can also reflect the condition of water resources. Fig. 7 indicates that, with the economic development, there is an overall upward trend of market demand and supply, and the market supply fluctuates around the market demand, which is consistent with the law of the development of market economy.

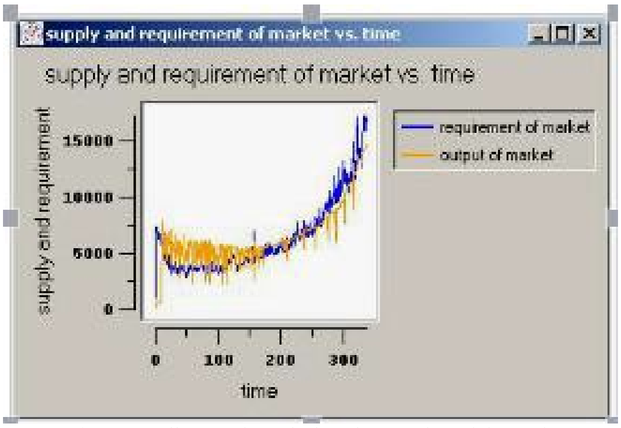

Fig. 7 overall upward trend of market supply and demand

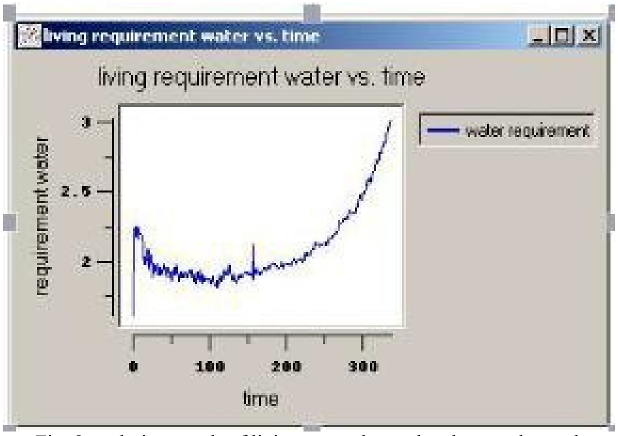

Fig. 8 evolution trends of living water demand and water demand

Fig. 8 showcases the evolution trend of the city water demand and domestic water demand. With the improvement of people's living standard, water requirement per capita index will show a moderately uptrend, which corresponds to the analysis provided by Ref [20].

V. CONCLUSION

In light of the communication and coordination problems in the inter-basin water transfer group decision-making system, on the basis of multi-Agent-based inter-basin water transfer group decision support system model, this paper has proposed the communication and coordination mechanism based on dynamic contract net protocol, established a Multi-Agent interaction and behavior model, and designed simulation experiments to exemplify the effectiveness of the models and its algorithm. Experimental results show that the use of communication and coordination mechanism based on dynamic contract net protocol can better solve the problems in complex system group decision-making, such as group communication, coordination and multi-objective optimization, etc. And meanwhile, it can provide a feasible mechanism and method to solve the configuration issues of limited resources in complex system group decision-making process when meeting conflicting situations.

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