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Modeling and Analysis of Combat Command Network Based on Theory of Complex Networks

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Abstract. The war system is a typical complex giant system, under the conditions of information warfare system compared with the previous war system, the scale is greater, the relationship is more complex. How to describe the complex relationship of the network in the information system is the core and key of the complex system modeling. In this paper, we use the theory and method of complex network to study the modeling and analysis of combat system network. Topology model. As an example, the construction process of the model is demonstrated, and the rationality of the abstract model is proved.

Introduction

Modern warfare is the system and the system of confrontation, is a kind of overall combat effectiveness is greater than the sum of the part of the combat style, pay more attention to the combat system of information exchange between entities. By using the theory and method of complex network, the war complex system analysis, each subsystem, operational entities abstracted as nodes in the network, as long as between the subsystems and the operational entities "connections", no matter how this relationship, the relationship between characteristics of how and how they can be abstracted as a a network side, so it will be difficult to analyze the relationship between complex warfare system clearly more difficult expression is simplified into a network model, has brought great convenience to our study of complex warfare system. From the point of view of system modeling, it is a new method and an effective method to study the war system and to model the war system with complex network theory.

Multi Level Cross layer Combat Network Construction Method

The future joint operation is based on the effect of the rapid operation, this joint operation requires the operational forces around the operational intentions in accordance with the operational situation of both sides of the enemy to adjust operational action, rapid decision-making. Therefore, command and control to rely on network information system can be directly linked to the important and key nodes. To strengthen the horizontal connection between units quickly integrated joint operations, vertical multistage cross layer link to strengthen the combat command and control flexibility, reflects the sensitivity to the emergency, major unexpected events, the future combat network should be a large number of transverse connection and a small amount of longitudinal connected network.

Lateral Connection Method. Nodes in the same layer of nodes belonging to the same operational group are interconnected by probability Psc (the Psc of each layer can be different). Secondly, the nodes of different nodes in the same layer nodes are interconnected by probabilistic Pdc.

Longitudinal Connection Method. On the basis of the horizontal connection network, for the first j=1,...... I L-2, the node layer, with probability Pec turn on the j+2 layer to the L layer are all descendants of the node priority connection, the connection probability is d/N (D is connected descendant node degree); with probability 1-Pec turn on the j+2 layer to the L layer are all descendants of the node random connection, the connection probability is 1/N. Fig. 1 is a multi-level cross layer cooperative control network generated by this algorithm.

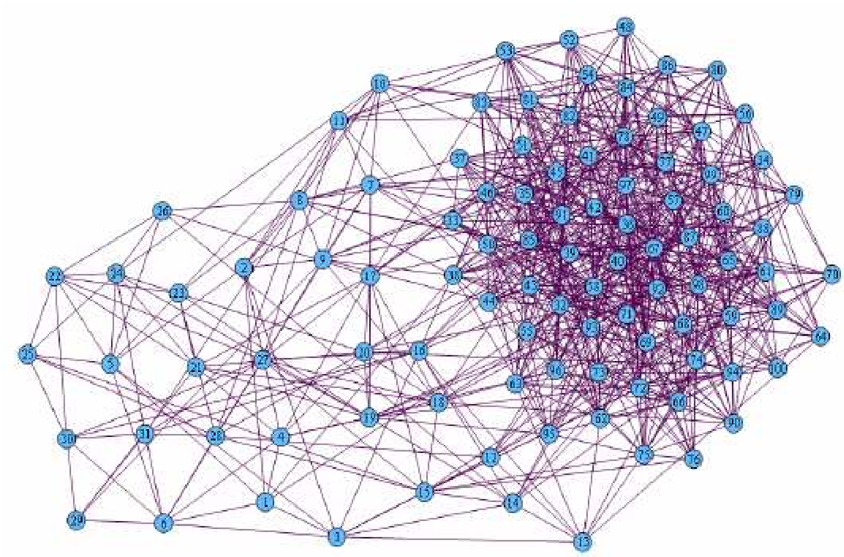

Figure 1. Multilevel cross layer cooperative control network: the total number of nodes in the network N=100, the command layer Level=5 within the group connection probability Psc=0.80, the probability of Pdc=0.2 outside the group, the probability of cross connection Pec=0.60

Combat Charge Network Construction Example

With an accused node Nc=3, sensor node Ns=3, attack node Nf =8 attack network, for example, as shown in fig. 2. The process of generating network topology model is analyzed. It is assumed that the processing time of each node is 1, and the information transmission delay on each edge is also 1.

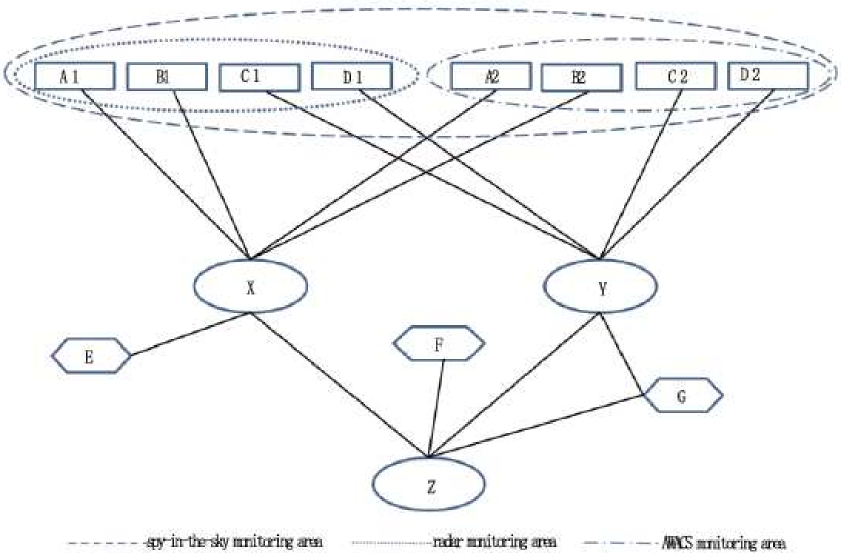

Figure 2. Example of a joint attack network(A: Infantry fighting vehicle; B: Tank; C:Fighter;D:hongz;E:Rada; F:Reconnaissance satellite; G:AWACS;X:Ground command post; Y: Air command post; Z: Unified conmmnd)

Topological Model Abstraction

Definition of Attacks on the Network Node Abstract. Joint command: {1, the joint command post, C, {2, 3, 3, 5, 6}, {2, 3, 5, 6}, 1}; ground command: {2, the ground command center, C, 3, {1, 4, 7, 8, 9, 10}, {1, 4, 7. 8, 9, 10}, 1}; abncp: {3, abncp, C, {1, 3, 5, 11, 12, 13, 14}, {1, 5, 11, 12, 13, 14}, 1};Rada: {4, rada, S, 3, {2}, {2}, 100, 0.6}；Early warning airplane: {5, early warning airplane, S, 3, {1, 3}, {1, 3}, 100, 0.8}；Reconnaissance satellite: {6, Reconnaissance satellite, S, 3, {1}, {1}, 200, 0.7}； Infantry fighting vehicle1: {7, Infantry fighting vehicle1, F, 4, {2}, {2}, 100, 0.9}； Infantry fighting vehicle2: {8, Infantry fighting vehicle2, F, 4, {2}, {2}, 100, 0.9}; Tank1: {9, tank1, F, 4, {2}, {2}, 100, 0.9}; Tank2: {10, tank2, F, 4, {2}, {2}, 100, 0.9}; Fighter1: {11, Fighter1, F, 4, {3}, {3}, 100, 0.8}; Fighter2: {12, Fighter2, F, 4, {3}, {3}, 100, 0.8}; Bomber1: {13, Bomber1, F, 4, {3}, {3}, 100, 0.8}; Bomber2: {14, Bomber2, F, 4, {3}, {3}, 100, 0.8}.

Edge Abstraction. Joint command post and ground command post: {1, CC, 14, {1, 2}, {1, 2}, 1};Joint command post and air command post: {2, CC, 14, {1, 3}, {1, 3}, 1};Joint command and reconnaissance satellites: {3, CS, 14, {1, 6}, {1, 6}, 1};Joint command post and AWACS: {4, CS, 14, {1, 5}, {1, 5}, 1};Ground command and radar: {5, CS, 14, {2, 4}, {2, 4}, 1};Ground command and infantry fighting vehicle1:{6, CF, 14, {2, 7}, {2, 1}, 7};Ground command and infantry fighting vehicle2:{7, CF, 14, {2, 8}, {2, 1}, 8};Ground command post with tank 1:{8, CF, 14, {2, 9}, {2, 9}, 1};Ground command post with tank 2:{9, CF, 14, {2, 10}, {2, 10}, 1};Air command and early warning aircraft: {10, CS, 14, {3, 5}, {3, 5}, 1};Air command post and fighter 1:{11, CS, 14, {3, 11}, {3, 11}, 1};Air command post and fighter 2:{12, CS, 14, {3, 12}, {3, 12}, 1};Air command post and bomber 1:{13, CF, 14, {3, 13}, {3, 13}, 1};Air command post and bomber 2:{14, CF, 14, {3, 14}, {3, 14}, 1}.

Topology Model Matrix. By the connection between the nodes, the topology model matrix is shown in fig. 3. The processing time of each node is the same as that of 1, according to the Dijikstra algorithm on the graph topology model matrix 3 shortest distance matrix between the nodes, the network information transmission between nodes each attack delay matrix, the results are shown in Fig.4.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	1	1	0	1	1	0	0	0	0	0	0	0	0
2	1	0	0	1	0	0	1	1	1	1	0	0	0	0
3	1	0	0	0	1	0	0	0	0	0	1	1	1	1
4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	1	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	1	0	0	0	0	0	0	0	0	0	0	0	0
8	0	1	0	0	0	0	0	0	0	0	0	0	0	0
9	0	1	0	0	0	0	0	0	0	0	0	0	0	0
10	0	1	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0	0	0	0	0	0
12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
13	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Figure 3. Topological matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	1	1	3	1	1	3	3	3	3	3	3	3	3
2	1	0	3	1	3	3	1	1	1	1	5	5	5	5
3	1	3	0	5	1	3	5	5	5	5	1	1	1	1
4	3	1	5	0	5	5	3	3	3	3	7	7	7	7
5	1	3	1	5	0	3	5	5	5	5	3	3	3	3
6	1	3	3	5	3	0	5	5	5	5	5	5	5	5
7	3	1	5	3	5	5	0	3	3	3	7	7	7	7
8	3	1	3	3	5	5	3	0	3	3	7	7	7	7
9	3	1	3	3	5	5	3	3	0	3	7	7	7	7
10	3	1	3	3	5	5	3	3	3	0	7	7	7	7
11	3	5	1	7	3	5	7	7	7	7	0	3	3	3
12	3	5	1	7	3	5	7	7	7	7	3	0	3	3
13	3	5	1	7	3	5	7	7	7	7	3	3	0	3
14	3	5	1	7	3	5	7	7	7	7	3	3	3	0

Figure 4. Network information transmission delay matrix

Topological Model Analysis

Information Flow Delay.

Table 1 information flow delay

Node	Rada	Reconnaissance satellite	AWACS
Infantry1	3	5	5
Infantry2	3	5	5
Tank 1	3	5	5
Tank 2	3	5	5
Fighter 1	7	5	3
Fighter 2	7	5	3
Bomber1	7	5	3
Bomber2	7	5	3

The information flow delay of the whole network is 3×8+5×12+7×4/24=4.667.

Cooperative Delay.

Table 2 Cooperative delay

Node	Infantry 1	Infantry 2	Tank 1	Tank 2	Fighter 1	Fighter 2	Bomber 1	Bomber 2
Infantry 1	0	3	3	3	7	7	7	7
Infantry 2	3	0	3	3	7	7	7	7
Tank 1	3	3	0	3	7	7	7	7
Tank 2	3	3	3	0	7	7	7	7
Fighter 1	7	7	7	7	0	3	3	3
Fighter 2	7	7	7	7	3	0	3	3
Bomber 1	7	7	7	7	3	3	0	3
Bomber 2	7	7	7	7	3	3	3	0

The cooperative delay of the whole network is (3×12+ 7×16)/28=5.286.

Intelligence Reliability. Set the network time delay threshold to 5. Step 1: reliable factor chariot (1 - (1 - 0.7) (1 - 0.6)) / 5 =0.176; reliable factor: 0.75 / 2 infantry and 5 =0.14 tanks: 1; reliability factor (1 - (1 - 0.7) (1 - 0.6)) / 5 =0.176 tanks; reliability factor 2: 0.75 / 5 =0.14;Reliable factor fighter 1: 0.75 / 5 =0.14; reliability factor Fighter 2: (1 - (1 - 0.7) (1 - 0.8)) / 5 =0.188; 1 of the bombers reliable factor: 0.75 / 5 =0.14; reliable factor 2: bombers (1 - (1 - 0.7) (1 - 0.8)) / 5 =0.188; the whole network information reliability value is 0.161.

Combat Effectiveness. The combat effectiveness of infantry fighting vehicles 1: 100 x 0.176 x 0.9 =15.84; 2 infantry combat effectiveness: 100 x 0.14 x 0.9 =12.6; combat effectiveness 1 tanks: 100 x 0.176 x 0.9 =15.84; combat effectiveness 2 tanks: 100 x 0.14 x 0.9 =12.6; 1 fighter combat effectiveness: 100 * 0.14 * 0.8=11.2; the 2 fighter attack aircraft combat effectiveness: 100 x 0.176 x 0.9 =15.84; 1 bomber combat effectiveness: 100 x 0.14 x 0.8 =11.2; 2 bomber combat effectiveness: 100 x 0.188 x 0.8 =15.04; the combat effectiveness of the whole network is 109.36.

Alleged Node Importance. Only the importance of the accused node is calculated, and the results are shown in table 3.

Table 3 the importance of the accused node

Ground command post	Node importance	Node degree
Accused node	7 /104	6
Air command post	7 /108	6
Joint command post	7 /162	4

It can be seen from table 3, the ground command center node important degree is the highest, followed by the air command, and finally the joint command post, in the combat system in the ground command center is the most important, the need to focus on the protection and special protection. Although the ground command and the air command and the node degree is 6, but the importance of the ground command center is greater than the air command, because the cohesion depends on two factors: the node degree (under the same conditions, if the node degree is large, the number of nodes and edges in the network in the future node contraction is less, the network cohesion degree is bigger, the more important the node); node location in the network (if the node is in the shortest path in a lot of important position between pairs of nodes are through the node, then when the shrink can greatly reduce the average network distance, thus get the condensation degree of a larger network). According to the analysis results of an important node of Figure 2 we optimize the reconnaissance satellite data provided by the link joint command post transfer to the ground command center, and in the air between the command and the ground command established duplex information channel, the data link between the AWACS and joint command post to cancel, so keep in the total system the cost remains unchanged, the evaluation index of the network are improved, the results are shown in table 4. The information flow delay of the whole network is as follows: 4. The cooperation delay of the whole network is as follows: 4.143; The reliable information of the whole network is 0.19, and the efficiency of the whole network is as follows: (130.4).

Table 4 Changes of indexes before and after optimization

evaluating indicator	Information flow delay	Operational coordination delay	Information reliability	Network combat effectiveness
Before optimization	4.667	5.286	0.161	109.36
After optimization	4	4.143	0.19	130.4

Conclusion

This paper is based on the complex network theory, adopts the method of modeling and simulation, with the war under the condition of information environment is the premise of operation system and associated real yuan yuan between the abstract, construct a multi-level cross layer charge network model, obtained the expected results. Using complex network theory and method to guide the informationization operation under the condition of modeling is still in the initial stage in China, coupled with high technology constantly in the war and the application of the new operation theories appear constantly affect changes in the pattern of war, the combat system field there are many key and difficult to study etc..

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