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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 10 (7): 1388-1394, 2011
ISSN 1812-5638 / DOI: 10.3923/itj.2011.1388.1394

Agent-based Topology Discovery for Tactical Internet

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Abstract: Tactical internet is one of top priorities of army in digitizing the battlespace. There are more different architectures of tactical internet because of more different network equipments which bring a lot of difficult to discovery topology in tactical internet. To realize topology discovery on tactical internet which own special architecture and communication model because of the router-switch which was the unique key equipment of tactical internet made by special institute, a distributed topology discovery method was proposed based on Agent. It depended on cooperation of two topology discoveries: topology discovery in management domain and topology discovery in whole network. Through rational assigning tasks of the two topology discoveries, occupation of radio bandwidth on topology discovery would be reduced more largely. Collecting topology data in time and using radio bandwidth more rational would be realized by adjusting process priority of topology discovery in whole network with manual regulation and self-adaptation regulation. Then two algorithms of topology discovery in management domain and in whole network firstly were presented. The data saving structure of topology discovery in management domain was designed in detail and these data would be sent to network management centre from Agent.

Key words: Tactical internet, topology discovery, distributed network management, agent, discovery in management domain, self-adaptation regulation

INTRODUCTION

The tactical internet is defined as an assemblage of interconnected radio stations and hardware and software of the computer which takes a hierarchical structure of brigade, battalion, company and chariot, providing a communication network platform for composition of brigades (including the unit below brigade) and digitalized combat troops to meet the demands of future wars (Zheng *et al*., 2002).

Tactical internet includes the access network of field regional network, broadband communication network, ultra short wave communication network, short wave communication network and field army LAN, among which the access network of platoon regional network is used to access the command posts of brigade and battalion to the platoon regional network, applied typically to position battles and peacetime training. Distributing in a variety of battle shelters, the platoon regional network refers to a mini-type regional network aiming at the information exchange between computers and other equipment in the chariot. Therefore, wireless communication is the primary communication mode in actual combat (Wang and Hou, 2003).

Due to the tree structure of tactical troop's configuration together with its higher level's leadership on the lower level, wireless communication model can also be presented in the tree structure, indicated in Fig. 1.

Including two aspects, the generalized topology discovery firstly refers to detecting and displaying the linking relationship of network equipment and secondly determining the type of the detected network equipment. There have been a lot of researches on network topology discovery (Covindan and Tangmunarunkit, 2000; Yong *et al*., 2008; Shen *et al*., 2007; Bitam and Batouche, 2008; Jun-Jun *et al*., 2008; Shaikh *et al*., 2002; Yan-Tao *et al*., 2009; Hong-Jian, 2007; Xia *et al*., 2010; Zhou *et al*., 2009; Suo-Fa and Jian, 2007), with SNMP, ARP, ICMP, RIP, DNS and OSPF etc. being the network protocols. However, it is rare to see in the aforementioned research the algorithms of topology discovery in view of characteristics of tactical internet, such as the need to consider narrower wireless bandwidth in topology discovery and collecting the linking information of co-channel radio (Shuaib and Brooks, 2004). Through the analysis of tactical internet communication model and router-switch made by a special institute, a topology discovery method based on Agent was proposed for tactical internet controlled by distributed network management system as well as its related algorithms. The method would try to reduced more largely occupation of radio bandwidth, improved the real-time and efficiency in topology discovery.

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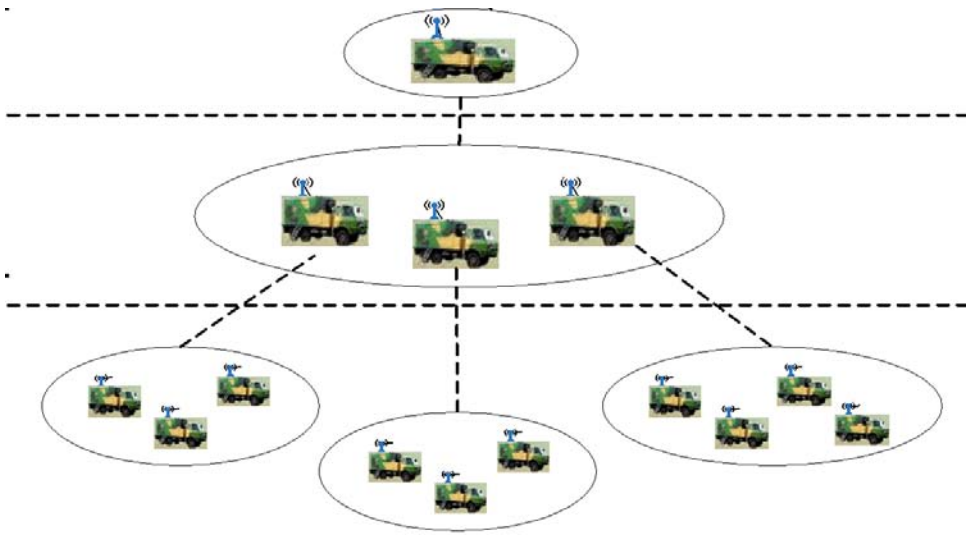

Fig. 1: Wireless communication model of tactical internet

ROUTER-SWITCH AND TACTICAL INTERNET COMMUNICATION MODEL

As the key equipment of tactical internet and a self-developed one, the router-switch has several ports classified into two types, the network port and COM. The network port connects the Ethernet equipment such as command computer, weapon control computer, navigation computer, real-time data transmission equipment etc. with a speed of 1000 M while the COM is used to connect radio and other COM equipment. The connect equipments of router-switch is indicated in Fig. 2. The network port and COM can be disposed as different network addresses and through either one of them the management of router-switch is accomplished. Besides, over the radio the router-switch is linked to other router-switch for communication which is set in every chariot composing LAN inside chariot.

Taking router-switch as the core node, chariot as the carrier, wireless as the main means of communication, the configuration of tactical internet is in the form of a hierarchical tree structure composed of multiple- chariot regional network. With the capability of routing and transmitting data between different network segments, the router-switch can achieve reliable communication of the data in whole network. Figure 3 indicates the tactical internet communication model based on router-switch.

As a result of the radio being the primary means for communication, the bandwidth is narrow. In order to ensure the communication for actual combat, there shall

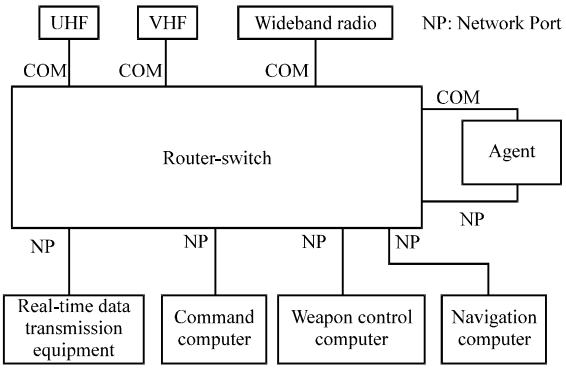

Fig. 2: Connect equipment of the router-switch

be a great bandwidth limitation to auxiliary functionalities just like network management and topology discovery.

SOLUTION TO THE DISTRIBUTED TOPOLOGY DISCOVERY

An analysis of the solution: The network management of tactical internet includes two classifications, centralized management and distributed management, in which distributed management overcomes many shortcomings of the centralized management, enhancing largely the reliability and expansibility of the system (Kakakhel and Anjum, 2008). Considering the narrowness of radio band, the design of the topology discovery aims at a high efficiency by decreasing requests from the radio network as well as reducing the bandwidth utilization of

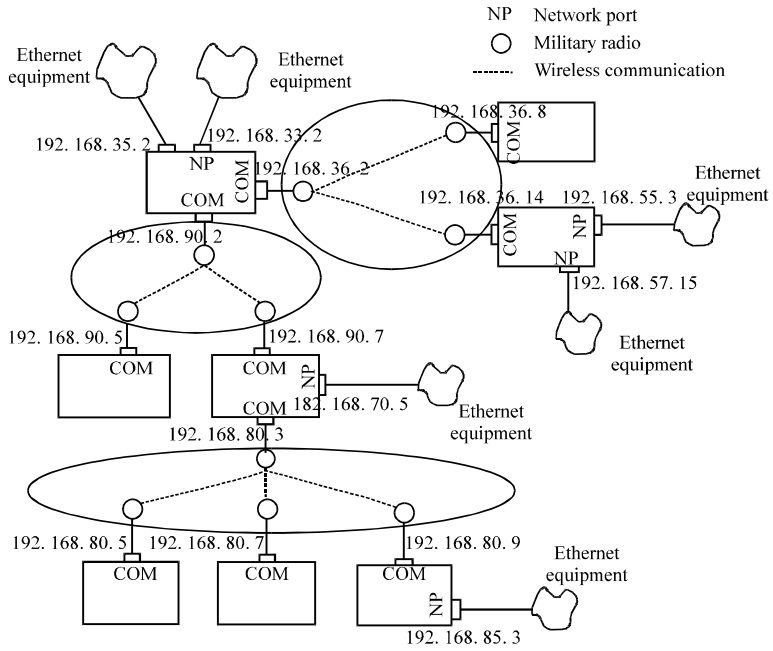

Fig. 3: Model of tactical internet communication based on router-switch

theses requests. So in this study, the topology discovery was separated into two parts: the topology discovery in management domain and the topology discovery in whole network.

During the process of this topology discovery, the deployment of network management agent which is settled in a special PC connecting router-switch through network port, is accomplished by taking chariot as the basic unit. With network inside chariot being the management domain, agents can intercommunicate and coordinate with each other. The management of router-switch and most its work is done by the agent through SNMP protocol.

The private MIB information of the router-switch: MIB is categorized as standard and private MIB. Because of the peculiarity of its hardware, the router-switch fails to support well the standard MIB, so the private MIB becomes the main means of management.

In private MIB of a router-switch, element relevant to topology discovery are comprised in four parts, i.e., ESG (Equipment System Group), EI3G (Ethernet IP information Interface Group), ENI2G (Extended Network Information Interface Group) and SRTG (System Routing Table Group) (Table 1).

The value of sysAgentIP in ESG provides IP addresses for the communication between the external and local agents. And through the value of ipEthernetAddr from EI3G and that of endIPaddr from ENI2G, all port IP addresses of router-switch are available. Furthermore, by reading the gateway address from SRTG, the interface IP address and Ethernet address from other router-switch connected to the aforementioned one can be obtained.

The topology discovery in management domain: Depended on Table 1, the topology discovery in management domain just is a unique limited topology discovery, whole completed by agent (Alicia Tang and Kuna, 2003; Nehra *et al*., 2007). The discovery result will be offered to other agents when necessary and is normally saved in the form of Table 1. The items of Table 1 include equipment unit number, unit type, unit IP address, connection equipment IP address, connection equipment type and subnet addresses.

Table 1 not only saves the connected relation between the router-switch and other equipments but also saves the type of connected equipments and the relevant information of some radio subnet.

Since the topology discovery in basic management domain can be realized only through the Ethernet by the agent, not using wireless communication of radio network, it will no be influenced by bandwidth. By setting time for the recycling collection (it was set as 5 sec in this study), the topology discovery in management domain could run and the data was updated uninterruptedly. In this way, the topology discovery can complete most of the work in the local management domain with a good effect in both

Table 1: Object relevant to topology discovery in the private MIB

Group	Object	Type	Remark
ESG (Equipment System Group)	sysAgent IP (OID:1.3.6.1.4.1.600.1.1.3.0)	IP Address	IP Address of agent settled in chariot
EI3G (Ethernet IP Information Interface Group)	ipEtherNetNo	Integer8	Equipment unit number
(OID prefix: 1.3.6.1.4.1.600.1.2.2)	ipEthernetAddr	IP Address	IP Address
	ipEthernetMask	Integer8	Subnet mask
ENI2G (Extended Network Information Interface Group)	enddevUnit	Integer8	Equipment unit number
(OID prefix:1.3.6.1.4.1.600.1.3.2)	endIPAddr	IP Address	IP Address
	endEthernetMask	Integer8	Subnet mask
SRTG (System Routing Table Group)	routeIndexNo	Integer8	index
(OID prefix:1.3.6.1.4.1.600.1.5.2)	routeSrGatewayAddr	IP Address	IP Address of gateway
	routeEthernetMask	Integer8	Subnet mask

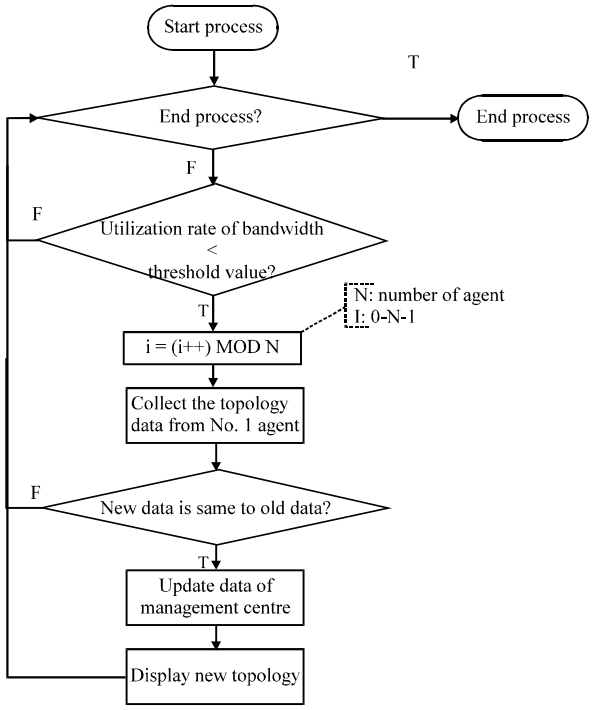

Fig. 4: Process of self-adaptation regulation

real-time and accuracy. When topology discovery in whole network is carried out, the topology discovery data can be transmitted to network management centre at one time which results in reducing the bandwidth occupation of radio network greatly and improving the discovery efficiency.

Topology discovery in whole network: Topology discovery in whole network is usually accomplished by network management centre which communicate with and collect the saved data from agents at intervals. Using these data, the topology of whole network would be produced.

Differed from topology discovery in management domain, the real time of topology discovery in whole network is not good because of the limited bandwidth of radio communication. The process priority of topology discovery in whole network is adjusted with a method, combination of manual regulation and self-adaptation regulation. At this point, when network topology structure is badly needed, the manual regulation takes the high priority and adjusts the process according to user's demands, communicating with agents in time to realize the topology discovery. Whereas when not badly needed, the self-adaptation regulation would adjust the process priority according to utilization rate of network bandwidth through the network performance management module. If the rate is greater than the threshold value, the process pauses; and if the rate is less, the process starts and circularly communicate with all the agents to collect data, update data of network management centre, display topology structure. The process of self-adaptation is elaborated in Fig. 4.

THE KEY ALGORITHM IN TOPOLOGY DISCOVERY

The algorithm of topology discovery in management domain: Based on Table 1, the topology discovery in management domain finally produces data saved in Agent. Its detailed algorithm as follows:

Step 1: Initialize the data table, the queue of gateway-subnet address, the queue of the extended network IP- subnet address and the queue of the Ethernet IP- subnet address

Step 2: Traverse SRTG, get subnet addresses corresponding to each gateway address through the gateway address and subnet mask and save them in the queue of gateway-subnet

Step 3: Traverse ENI2G, obtain subnet addresses corresponding to every IP address in the group through the IP address and subnet mask and save them in the queue of extended network IP-subnet address

Step 4: Contrast the subnet addresses of the queue of gateway-subnet address with those of the

queue of extended network IP- subnet address, fill, respectively the IP addresses and gateway addresses in respect of the same subnet address in blanks of the unit IP address and connection equipment IP address of the Table 1, together with filling in the corresponding subnet addresses as a record

Step 5: According to the value of unit IP address, attain the equipment unit number corresponding to the column record through ENI2G and fill in the corresponding blank of the data table, with COM as the unit type

Step 6: Traverse EI3G, acquire subnet addresses corresponding to the item record (IP address) in the group through the IP address and subnet mask and save them in the queue of the Ethernet IP-subnet address

Step 7: Contrast the subnet addresses of the queue of gateway-subnet address with those of the queue of the Ethernet IP- subnet address, fill, respectively the IP addresses and gateway addresses in respect of the same subnet address in blanks of the unit IP address and connection equipment IP address of the table, together with filling in the corresponding subnet addresses as a row record

Step 8: According to the value of unit IP address, attain the equipment numbers corresponding to the item record through ENI2G with ETHRENET as its unit type

Step 9: Send packet SNMP to all the saved addresses in the Table 1 belonging to one item-the connection equipment IP address, obtain the equipment type and fill in the corresponding blanks of Table 1

Step 10: Mark the end

Now that the agent can be connected directly to router-switch through the Giga-Ethernet and repeat the aforementioned steps to update real-time topology discovery data more effectively.

The algorithm of first-time whole network topology discovery: On account of several port IP addresses in a router-switch, the first-time discovered port IP is considered in this paper the identification IP for this router-switch. In whole network topology discovery, except the first-time discovery depending on router-switch to get the agent address, colleting and updating data in the succeeding process can be achieved by the direct communication between the network management centre and the agent, with TCP or UDP etc., The detailed algorithm is as below:

Step 1: Initialize the will-visit router-switch queue, the already-visited queue, identification queue and agent queue

Step 2: Attain the address of the local chariot and save in the agent queue

Step 3: Obtain topology discovery data in the management domain from the agent

Step 4: Check from all the record with "router-switch" as the connection equipment type and save, respectively the connection equipment IP addresses as well as the unit IP addresses in the will-visit router-switch queue and already-visited queue

Step 5: If there were not empty in the queue of the will-visit router-switch, repeat Step (5) and (10)

Step 6: Take out the initial IP address from the beginning of will-visit router-switch queue as the visiting router-switch and make the IP address as the identification IP for the visiting router-switch saving in the identification queue

Step 7: Get the agent address from the visiting router-switch record and save in the agent queue

Step 8: Obtain topology discovery data in the management domain from the agent

Step 9: Connection equipment type and save the unit IP addresses in the already-visited queue. And contrast IP addresses of connection equipment with the value of the already-visited queue to see: if there isn't any same value between the two, add the IP address of connection equipment to the will-visit router-switch queue; contrarily the value can be neglected

Step 10: If the process of visiting router-switch comes to an end, just eliminate it from the will-visit router-switch queue

Step 11: The process of first-time discovery ends and come to a recycling intercommunication process between management centre and agents illustrated by Fig. 5

The collected data through topology discovery in whole network includes the information of subnet address, through retrieval of which the IP addresses and their connected relation of military radios in the co-channel radio subnet can be attained. When a change occurs in network equipment type or connection, the agent will obtain the information and send it to network management centre for update; when there are more will-visit router-switch equipments, the aforementioned algorithm of the first-time topology discovery in whole network should be applied and a new agent should be

added to management centre; and when some agent and its relevant router-switch cannot visit the network, it will be treated as being off-line.

AN EXPERIMENT ON THE DISTRIBUTED TOPOLOGY DISCOVERY

In this experiment eight router-switch equipments consist of the experimental communication platform of tactical internet, on which the distributed topology discovery is implemented. Applying the short-wave and super short-wave radios for communication, the radio is based on TDMA protocol communication, Windows Seven being the agent's operating system. Table 2 is the data of topology discovery in management domain for some agent, with 192.168.36.1 as the identification IP address of its subordinate router-switch.

Figure 5-6 are running interface, of which Fig. 5 is a topology structure chart based on Table 2. A variety of connected relations and type information of equipments

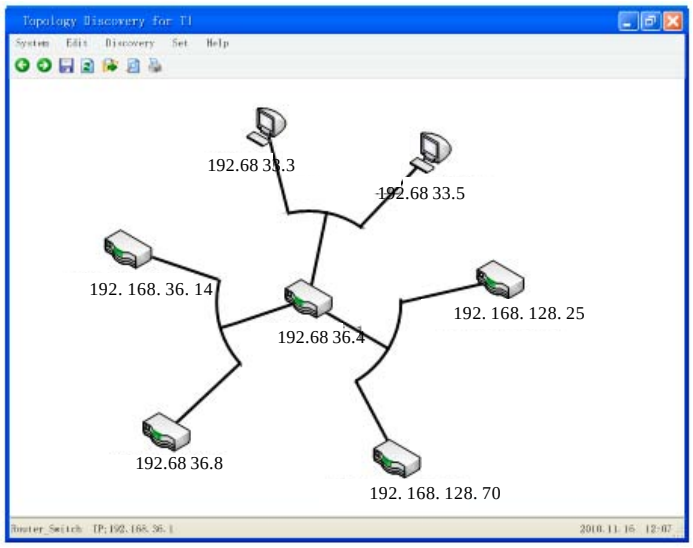

Fig. 5: The program running interface: (Fig. 1)

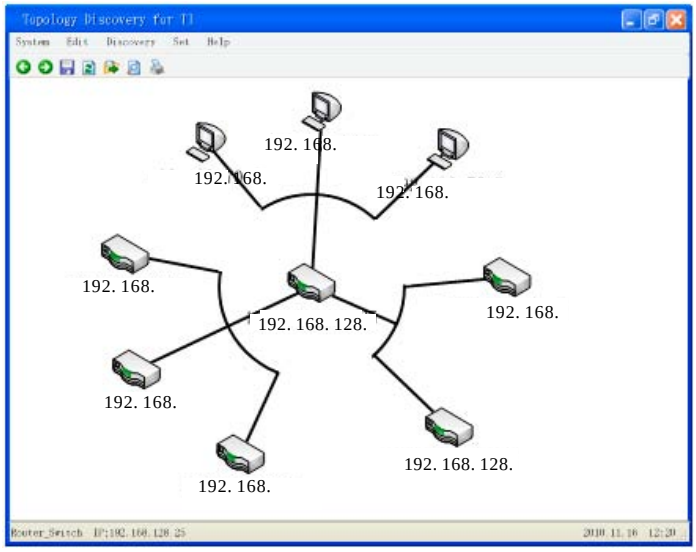

Fig. 6: The program running interface: (Fig. 2)

Table 2: Topology discovery data saved in agent

Equipment unit number	Unit type	Unit IP address	Connection equipment IP address	Connection equipment type	Subnet addresses
2	COM	192.168.36.1	192.168.36.14	RT-SW	192.168.36.0
2	COM	192.168.36.1	192.168.36.8	RT-SW	192.168.36.0
3	COM	192.168.128.2	192.168.128.25	RT-SW	192.168.128.0
3	COM	192.168.128.2	192.168.128.70	RT-SW	192.168.128.0
2	ETHERNET	192.168.33.6	192.168.33.3	PC	192.168.33.0
2	ETHERNET	192.168.33.6	192.168.33.5	PC	192.168.33.0

are presented in the two figures and equipments of the co-channel radio subnet are interconnected by diverse curves.

CONCLUSION

Through the discussion above, we can see the distributed network management system endows profound meaning for the network management of tactical internet. In the light of characteristics like the narrowness of bandwidth and instability of wireless communication, a solution to topology discovery is presented based on agent technology under the distributed network management of tactical internet. In this solution the fussy and bandwidth-utilization consuming task is assigned to the agent, minimizing largely the wireless bandwidth utilization. Meanwhile in line with the real-time information of performance management, the process priority of topology discovery is adjusted through the combination of by manual and self-adaptation regulations, ensuring the real time of collecting network topology data and rationality of bandwidth utilization. Moreover, the saving structure of discovery data is designed with a view to the information requests of topology discovery in whole network and the algorithms of topology discovery in management domain and first-time topology discovery in whole network is elaborated, respectively. In the final part of this paper we introduce the design as well as its algorithms grounded on the experiment platform for tactical internet communication developed by some military communication research institute.

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