An Automatic Carrier Planning Scheme in Analog Train Transport Network

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Abstract

ATTN (Analog Train Transport Network) is a brand-new network architecture that is completely different from TCP/IP-based Internet in terms of information transmission. Based on the principle of ATTN and the data traffic of network, this paper presents an automatic carrier planning scheme which involves three aspects: number of carriers, carrier routes and carrier scheduling time. The automatic carrier planning scheme is implemented on the ATTN simulation platform. The simulation results show that the scheme makes a great performance improvement in data throughput and data retention.

Keywords

Analog Train Transport Network; Carrier Route; Automatic Planning.

1. Introduction

The TCP/IP-based Internet has become an increasingly significant infrastructure in our society since it was built more than 40 years ago. With the rapid development of cloud computing, the Internet of things and wireless communication applications, the network load has grown rapidly [1].

The point-to-point communication mode of TCP/IP architecture leads the network traffic to converge on the backbone network, which causes a substantial increase of data traffic in backbone network to be much faster than that by Moore's law [2-3]. This affects the scalability of the Internet and makes the global optimization of network much more difficult as well. Meanwhile, terminals of the Internet of things such as sensors and RFID (Radio Frequency Identification) are so constantly added that the dynamic nature of the network node is continuously enhanced. As a result, data transmission path has been frequently changed, which seriously damages the fixed terminal design and the continuity of upper application services [4]. All these reasons lead to the de-cline of communication efficiency.

In this case, research on future network though innovative method-starting from scratch without any restrictions of existing network has become the consensus on the design of future network system. In [5], Zainab R. Zaidi et al. explored a new integrated architecture based RAN and BCG2 for future mobile network. The architecture improved the service continuity and gained opportunistic RAN sharing function. Another research was presented in [6], where authors elaborated a next generation network architecture where an identity management system was designed to enhance the performance in security, user data privacy and usability.

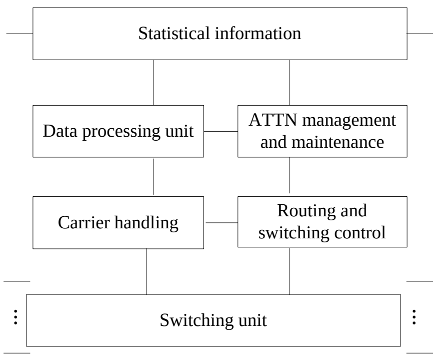
ATTN is a brand-new network architecture based on the principle of train transmission of public transportation system. Up to now, a simulation platform of ATTN has been built [7-8]. Besides, a node-based admission control mechanism in ATTN has been introduced to improve throughput [9]. Nevertheless, the mechanism fails to dynamically plan carrier routes, so it is not optimal to communication efficiency. This paper presents an automatic carrier planning scheme to

obtain optimal throughput in ATTN. The carrier automatic planning scheme is implemented on the ATTN simulation platform. Simulation results show that the scheme makes a great performance improvement in data throughput and data retention in network.

2. ATTN Introduction

2.1 Structure of ATTN

In ATTN, the data transmission and switching unit is called "carrier", which can simultaneously carry numerous data (for instance, hundreds or thousands of IP packets) with different types of protocol data units such as IPv4 packet, IPv6 packet, ATTN custom data unit (hereinafter referred to as ATTN unit), etc. Due to the different positions on a carrier route, ATTN nodes may be divided into three types: source node, intermediate node and destination node. Fixed routing and regular switching is adopted for a given carrier in an ATTN. The carrier in an ATTN runs along a fixed route. The intermediate nodes along the route reserve resources for the carrier in terms of the scheduling time, and release the corresponding resources after its switching [4].



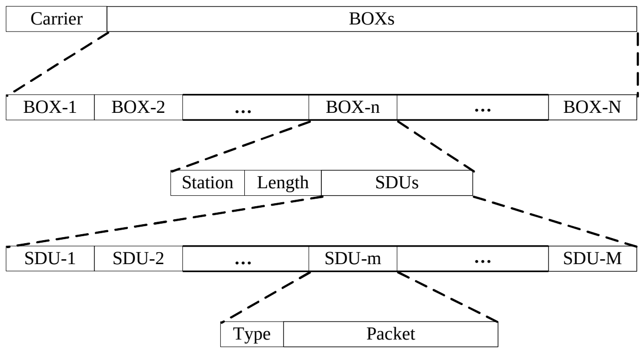


Fig. 1 Function modules of nodes Fig. 2 Structure of carrier

As shown in Fig. 1, the functions of node mainly include six parts: data processing unit, ATTN management and maintenance unit, carrier processing unit, routing and switching control unit, statistical unit and switching unit. These units conduct data assembling and data transmitting to a specified location, and also provide a certain identification and security mechanism. In Fig. 2, the structure of a carrier includes the fields of Carrier, BOXs, SDU, Station, Length, Packet and Type. The "Carrier" is used for the identification of carrier, and the "Station" is used for the address identification of ATTN nodes which may support SDU uploading and downloading. The "Length" is defined as the length of BOXs in byte. The "Packet" is used for data load, and the "Type" marks the type of packet [7-8].

2.2 Transport process

The transport process was introduced in detail in [10], and here it is just outlined. Management center calculates carrier routes and timely sends the route information to the corresponding nodes. Each node assembles ATTN data or IP packets needed to be sent. Packets heading to different destinations are put into different buffer queues. Then the packets, on the basis of carrier routes, are uploaded to the corresponding carrier. As an example, Fig. 3 shows a route.

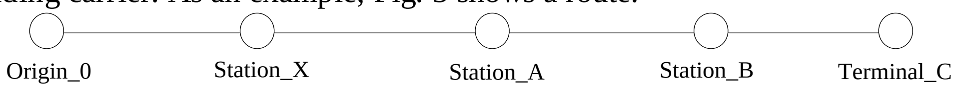


Fig. 3 Carrier route

Firstly, origin node reserves resources, and the data packets heading to node A, node B or node C, are assembled into a carrier which is sent to station X named a straight-through node not supporting packet uploading and downloading. Then the carrier is send to station A. Station A and station B are intermediate nodes where packets destinated to them are downloaded and packets to their downstream nodes are uploaded upon receiving the carrier. Subsequently, the carrier is sent to the downstream node. When the carrier arrives at terminal C, all packets are downloaded and even forwarded further to IP networks. So far, the transport process ends.

3. Automatic carrier planning scheme

3.1 Scheme principle

As for the configuration of ATTN carrier in the scheme, there are three specific aspects to be taken into consideration:

(1)Number of carriers: how many reasonable carries are determined. In this scheme, the number of required compartments is taken into account in the case of full load of carriers. Therefore, it is able to calculate the average number of required compartments in the relatively stable environment of network, and the number of carrier can be controlled according to the number of compartments.

(2)Carrier routes: how to exactly determine the carrier route can greatly improve the performance of whole network. Given current outgoing data traffic, each carrier is allowed to select route with maximum transport amount. After configuring a carrier's route, the outgoing data matrix is then updated. Subsequently, the next carrier's route is configured on the basis of the updated data matrix [2]. Therefore, it ensures that each node is at least on one carrier route.

(3)Scheduling time of carriers: how to exactly determine the scheduling time of a carrier can further enhance throughput of network and reduce retention amount of packets at nodes. For a real train network, it is necessary for passengers to arrive at the train station in advance and to wait for the scheduled train. The passengers are assembled up to a certain number, which can ensure the railway transport volume. So does ATTN, in order to ensure that a carrier loads enough packets to be transmitted at the scheduled departure time, packets are assembled at nodes and it is necessary to specify a scheduling time table for each carrier.

3.2 Scheme description

(1) Number of carriers

Let M_{usable} denotes the number of available compartments for the whole network. It is calculated by the Equ.(1). After configuring a carrier's route, the number of compartments is updated by deducting the correspond value. The configuring process of carriers ends until $M_{\text{usable}} \le 0$. As shown in Equ.(1), it is quite clear that the number of available compartments is the value of the amount of network packets divided by the size of each compartment. So the number of carriers can be controlled in a reasonable value.

$$M_{\text{usable}} \approx \frac{N_{\text{total}}}{L_{\text{box}}} \tag{1}$$

where N_{total} is the outgoing data amount of the whole network and L_{box} is the capacity of a compartment.

(2) Carrier route

A matrix as shown in Equ.(2) is defined for the statistics of the amount of data between nodes and can be used for determination of carrier route.

$$A = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{ccccc} 0 & 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0 & \gamma_{01} & \gamma_{02} & \gamma_{03} & \gamma_{04} \\ \gamma_{10} & 0 & \gamma_{12} & \gamma_{13} & \gamma_{14} \\ \gamma_{20} & \gamma_{21} & 0 & \gamma_{23} & \gamma_{24} \\ \gamma_{30} & \gamma_{31} & \gamma_{32} & 0 & \gamma_{34} \\ \gamma_{40} & \gamma_{41} & \gamma_{42} & \gamma_{43} & 0 \end{bmatrix} \end{array} \tag{2}$$

where γ_{ij} is the amount of packets from the i th node to the j th node. Matrix A is generated in terms of the statistics of average outgoing data amount of each node at every ten cycles. To determine a carrier route, the node with the maximum $\sum_j \gamma_{\text{ij}}$ is selected as an origin node, where $\sum_j \gamma_{\text{ij}}$ is the sum of outgoing packets from the i th node to the other nodes. After determining the original node, a node with the maximum γ_{j} by Equ.(3) and being adjacent to the previous node is chosen as the next node of the route. Afterwards, the Equ.(3) is reused, and the process of seeking subsequent nodes continues until there is no adjacent node. Finally, the matrix A and M_{usable} are updated in terms of the outgoing data amount of each node in the carrier. In this way, the configuration of a carrier route is well done. Then the configuration process is repeated, and a new carrier route is to be configured. This process continues until the number of carries reaches the upper limit. According to statistics of the configured carries, it is known that whether there are some nodes not being in any carrier routes. If such type of nodes exist, it is necessary to configure a carrier route following the above steps. Otherwise, the process of carrier configuration ends [9, 11].

$$\gamma_j = \sum_i \gamma_{ij} \tag{3}$$

where γ_j is the sum of outgoing data amount from upstream nodes of node j along all carrier routes. Matrix A is updated by subtracting the estimated amount of corresponding node data from the amount of each node outgoing data. The formula of outgoing data estimated amount is shown in Equ.(4).

$$\gamma'_{ij} = \begin{cases} \dfrac{\lambda'_{i,j}}{\lambda'_{1,j} + \lambda'_{2,j} + \dots \lambda'_{j-1,j}} * \gamma_j & \gamma_j \le 1M \\ \dfrac{\lambda'_{i,j}}{\lambda'_{1,j} + \lambda'_{2,j} + \dots \lambda'_{j-1,j}} * 1 & \gamma_j > 1M \end{cases} \tag{4}$$

where γ'_{ij} is the estimated amount of outgoing data from node i to node j, and $\lambda'_{i,j}$ is the arrival rate from node i to node j. The subscript 1 stands for the first node rather than for node 1. The estimated amount of transmitted data is confirmed by the formula. The surplus value of estimated outgoing data amount is obtained by subtracting the estimated amount of transmitted data from the outgoing data amount in the corresponding position of matrix. So, a new route can be configured again in terms of the new outgoing data matrix.

(3) Carrier scheduling time

A threshold δ is set for selection of a carrier's scheduling time. The carrier is sent when the outgoing data amount of origin node is equal to a specified threshold. This sending time is set as the departure time of the carrier in the origin node. After being sent, the carrier runs along the planed route. The residence time of carrier in intermediate nodes is set 2s to upload or download data. After 2s, the carrier moves away from the station. The calculation formula of carrier threshold δ is shown in Equ.(5).

$$\delta = \sum_j \gamma'_{ij} \tag{5}$$

where δ is specified threshold of the carrier, and $\sum_j \gamma'_{ij}$ is the sum of estimated amount of transmitted data from origin node i to other nodes in the carrier's route.

4. Illustration

Fig. 4 shows an example of outgoing data amount matrix. According to the procedure above, the configuration process of automatic carrier planning scheme is as follow. Fig. 5 is the network topology and Fig. 6 is the arrival rate matrix.

	0	1	2	3	4
0	0	787188	2361564	1049584	2886356
1	3411148	0	2099168	655990	2230366
2	3411148	2361564	0	3017554	1574376
3	2755158	1180782	1049584	0	1443178
4	2361564	918386	2623960	1311980	0

Fig. 4 Outgoing data amount matrix

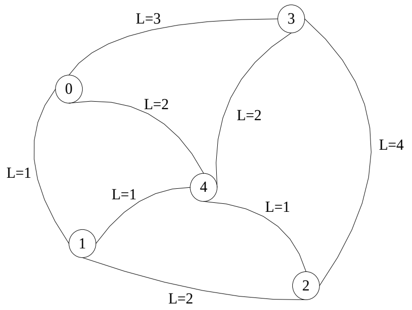


Fig. 5 Network topology

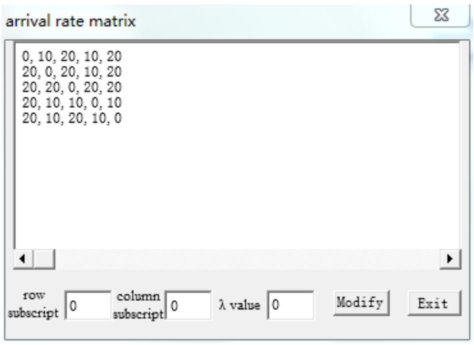


Fig. 6 Arrival rate matrix

The outgoing data amount matrix is updated automatically in the program, and available compartment M_{usable} is obtained by Equ. (1). Here M_{usable} is 38 by calculation. Firstly, all nodes are put into set $V_1()$, namely $\{0,1,2,3,4\}$. Then the node with the maximum data amount is chosen as the route's origin node. By the statistics of the outgoing data amount in $\{0,1,2,3,4\}$, it can be found that the data amount to node 2 is the maximum, so node 2 is chosen as the origin node. Next, the adjacent nodes of node 2 are put into set $V_2()$ where the nodes that have been chosen are removed. So $V_2()$ is $\{1,3,4\}$. By Equ. (3), the sum of outgoing data amount form previous node to all nodes in the set is calculated, and node 3 with the maximum sum of outgoing data amount is chosen as the next node. Next, the adjacent nodes of node 3 are put into the set $V_3()$, namely $\{0,4\}$. By Equ.(3), the sum of outgoing data amount form previous node to all nodes in the set is is calculated, and the node 0 with the maximum sum of outgoing data amount is chosen as the next node. The adjacent nodes of node 0 are put into set $V_4()$, namely $\{1,4\}$. By Equ.(3), the sum of outgoing data amount form previous node to all nodes in the set is calculated, and the node 4 with the maximum sum of outgoing data amount is chosen as the next node. The adjacent nodes of node 4 are put into the set $V_5()$, namely $\{1\}$. By Equ.(3), the sum of outgoing data amount form previous node to all nodes in the set is calculated, and the node 1 with the maximum sum of outgoing data amount is chosen as the next node. So far, the configuration of a carrier route finishes, and the route is 2-3-0-4-1.The route configuration process is expressed by traversal tree, as shown in Fig. 7, and the nodes with underline represent the nodes that are removed. After the determination of a carrier route, the estimated amount of each node outgoing data is calculated by Equ.(4), meanwhile outgoing data amount matrix A is updated.

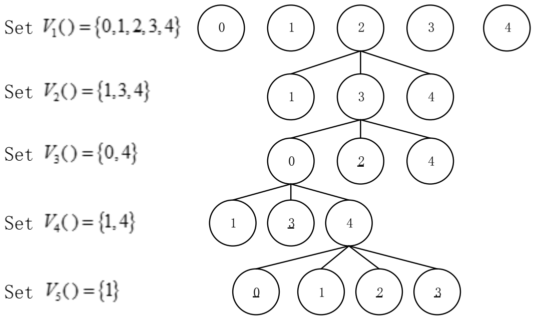


Fig. 7 Generated tree

	0	1	2	3	4
0	0	590391	2361564	1049584	2492762
1	3411148	0	2099168	655990	2230366
2	2230366	1705574	0	1574376	1180782
3	2230366	983985	1049584	0	983985
4	2164767	918386	2623960	1311980	0

Fig. 8 Updated outgoing data matrix

According to Equ.(4), the estimated amount of outgoing data from node 2 to node 3 is 1049584B, the estimated amount of outgoing data from node 2 to node 0 is 524792B, the estimated amount of outgoing data from node 2 to node 4 is 393594B, the estimated amount of outgoing data from node 2 to node 1 is 393594B, the estimated amount of outgoing data from node 3 to node 0 is 524792B, the estimated amount of outgoing data from node 3 to node 4 is 327995B, the estimated amount of outgoing data from node 3 to node 1 is 327995B, the estimated amount of outgoing data from node 0 to node 4 is 393594B, the estimated amount of outgoing data from node 0 to node 4 is 393594B, the estimated amount of outgoing data from node 0 to node 1 is196797B, and the estimated amount of outgoing data from node 4 to node 1 is196797B. After counting the estimated amount of outgoing data, the new outgoing data amount matrix is obtained by subtracting the estimated amount from the corresponding amount of outgoing data in existing matrix. Then the next carrier route can be configured in terms of the new outgoing data amount matrix, and the available compartment M_{usable} is updated. As seen from the configuration route, the route generates 4 compartments, so the available compartment M_{usable} should subtract 4. After being updated, the available compartment M_{usable} is 34. Finally, the generated carrier route is 2-3-0-4-1. The carrier threshold δ is calculated on the basis of the generated carrier route. According to Equ.(5) and the amount of outgoing data from node 2 to other nodes, the node 2 carrier threshold δ is 2361564B. The program in ATTN network simulation platform can automatically count the time when the data amount of origin node 2 is equal to the carrier threshold δ, and the time serves as the sending time of the carrier. After being updated, the outgoing data amount matrix is shown in Fig. 8. After that, by reusing the updated outgoing data amount matrix A and M_{usable}, the process above is repeated to configure more carries routes until the number of carriers reach the upper limit [11-13].

5. Simulation and analysis

Fig. 9 and Fig. 10 are the automatic planning interface diagram on the simulation platform. Fig. 9 is the interface diagram before the automatic carrier planning scheme is conducted, and Fig. 10 is the interface diagram after the automatic carrier planning scheme is done. As seen from Fig. 10, the carrier best route is 2-3-0-4-1.

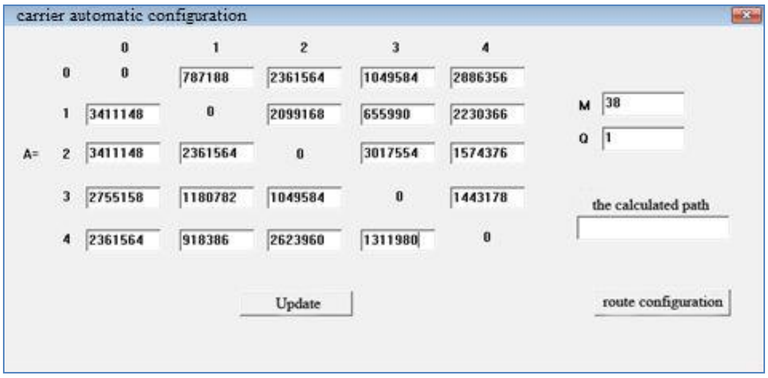


Fig. 9 Automatic scheme interface before configuration

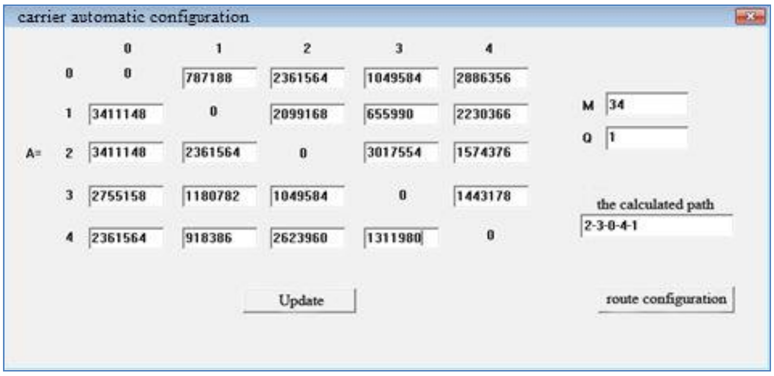


Fig. 10 Automatic scheme interface after configuration

To validate feasibility and superiority of the scheme, this paper mainly verifies two performance indexes: throughput and retention amount of the entire network. Fig. 11 and Fig. 12 shows the throughput and the retention amount between the existing scheme and the automatic planning scheme, respectively. The two charts below are in five cycles.

Obviously, Fig. 11 shows that the throughput of automatic planning scheme greatly exceeds that of the existing scheme. From Fig. 12, it is clear that the retention amount of the existing carrier configuration scheme is two times more than that of the automatic carrier planning scheme. After the first cycle, the retention amount for the automatic planning scheme changes very little, but the retention amount for the existing configuration scheme grows linearly. From the results, it can be observed that the automatic planning scheme outperforms the exiting scheme. To sum up, through the analysis of throughput and retention amount, the network performance has been greatly improved by using the automatic carrier planning scheme, which also verifies the feasibility and effectiveness of the scheme.

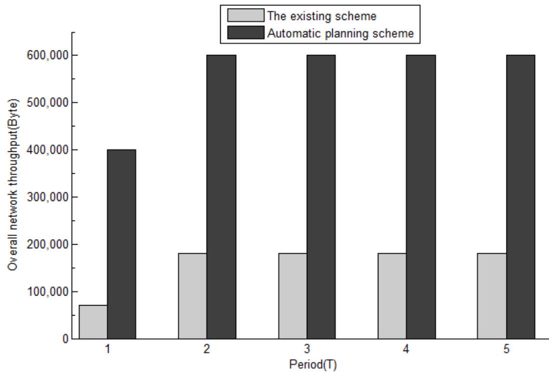


Fig. 11 Throughput

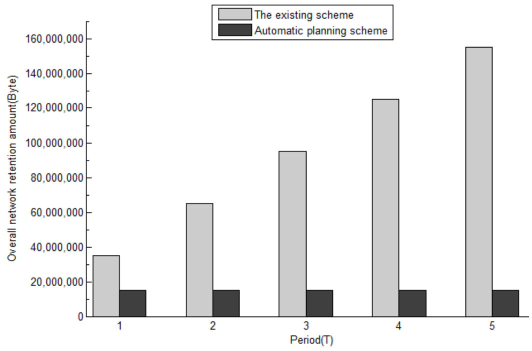


Fig. 12 Retention amount

6. Conclusion

In this paper, an automatic carrier planning scheme is presented based on the whole network data amount. The scheme mainly takes into considerations three aspects: number of carriers, carrier's routes and carrier's scheduling time. First the paper introduces the characteristics of TCP/IP-based Internet and the research status of ATTN. Then the scheme principle, design process and illustration are described respectively. Finally the scheme is implemented on the ATTN simulation platform. The simulation results show that the automatic carrier planning scheme can greatly improve network performance in data throughput and data retention in networks.

Acknowledgements

This work is supported by 2015 University Innovation Team Construction Plan Funding Project of Chongqing, Natural Science Foundation Project of CQ CSTC under Grant No.2011BB2144, Research Program of Chongqing Education Committee of China under Grant No. 133044 and 2012-GX-130. Corresponding author email: luoqiang314@163.com. This paper is organized as follows. Section 2 gives a sketch of structure and transport process of ATTN, and Section 3 describes the automatic carrier planning scheme in detail followed by an illustration in Section 4. Then Section 5 shows simulation results. Finally, Section 6 concludes the paper.

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