Design and Implementation of Hardware Search Algorithm Based on FPGA

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Abstract

In the design of the switch, the search algorithm is one of the most critical core modules. There are many traditional table entry search methods, mainly: linear search method, binary tree search method, hash table search, etc. These search methods are software search methods based on SRAM, and the common feature is slow search speed. The linear lookup table method needs to traverse all entries in the table; the binary tree search method needs to traverse most nodes in the tree, and the search speed is greatly affected by the depth of the tree; the hash table search method is relatively fast, but with the network speed requirement As it gets higher and higher, hash search still cannot meet the demand for extremely fast search. This text designs and realizes a kind of hardware search algorithm, utilizes the characteristic of FPGA to process the data in parallel, speed up the data search ability greatly, further shorten the switch forwarding delay.

Keywords

Field Programmable Gate Array; Media Access Control Address; TCAM.

1. Introduction

Since the 1980s, with the application of computer technology on trains, the technology of Train Communication Network (TCN), which connects various on-board communication devices, has developed vigorously. With the continuous improvement of train speeds, the real-time and accuracy of the data it needs to transmit have increased significantly. Traditional fieldbus technology has been difficult to meet its development needs. For example, while maintaining high-speed operation, high-speed railways are inseparable from frequent data exchanges between vehicles and vehicles. This requires that the train communication network must have a relatively large bandwidth, and at the same time, the data processing should be as fast as possible; and similar The traditional fieldbus bandwidth of WTB and MVB is only 1.5Mbps. When faced with so much information to be transmitted, the data transmission bandwidth is obviously insufficient. Therefore, in the train network, the network equipment responsible for data forwarding and switching is particularly important, and the search algorithm of the switch is one of the core modules of a switch. This paper designs an FPGA-based TCAM implementation. The search cycle of this algorithm is much shorter than that of software search algorithms, and it is suitable for large-capacity network equipment search.

2. Introduction to TCAM and its FPGA implementation

2.1. TCAM Introduction

The hardware search algorithm is mainly based on Ternary Content Addressable Memory (TCAM). TCAM has a parallel and fully connected structure, and the matching result can be obtained in one clock cycle. TCAM is developed from Content Addressable Memory (CAM). Compared with CAM, TCAM can not only store "0" or "1", but also store "X" for fuzzy matching.
The matching range is wider and the matching efficiency is higher. TCAM table entries are stored in the form of <address, mask>, which makes it possible to store keyword table entries of any length, so it is very suitable for the realization of the switch's secondary lookup table. Due to the parallel search, the search speed of TCAM is very suitable for the longest matching search, and the table search rate of TCAM is much faster than that based on ASIC design, which can reach 125MSPS.

The TCAM table look-up rate is fast and easy to implement. Similar to RAM, TCAM stores entries in an array. The width of each entry is called the word width, and the number of entries in the TCAM is called the depth of the TCAM. Word width and depth can characterize the capacity of TCAM. When searching for the TCAM module, req_valid indicates the start of the search, and the keyword to be searched is directly sent through req_key. TCAM determines whether the keyword is equal to the entry. If it is equal, the keyword matches the entry. The signal res_valid is high and res_addr is Output the address of the item.

2.2. Implementation in FPGA

TCAM saves keyword masks so that it can save keyword entries of any length. Therefore, using TCAM is very suitable for searching for the longest prefix. In this design, since the MAC addresses of terminal devices in the ECN network are similar. Therefore, the 48-bit MAC address is set as an 8-bit keyword through the mask, and the key is entered into the table entry for search. If a unique match is found, the address is entered as the RAM address, and the data corresponding to the address Read out, the data returned at this time is 64 bits in total. Not only need to include the MAC address, but also need to include data such as the paired port number, port priority, etc., so the data format of the lookup table in the memory is:

<table>
<thead>
<tr>
<th>Port_id</th>
<th>reserve</th>
<th>Port_prio</th>
<th>Dest_mac</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 bits</td>
<td>9 bits</td>
<td>3 bits</td>
<td>48 bits</td>
</tr>
</tbody>
</table>

It is defined as follows:
Port_id: the port number corresponding to the physical address.
Reserve: Does not represent any information.
Port_prio: The priority of the port, with a total of eight levels, ranging from 0 to 7.
Dest_mac: 48bit physical address.

2.3. Learning and searching of address table

When a data frame arrives at the switch, the switch will first read the destination MAC address and source MAC address of the frame, and mark the entry port number of the MAC address. The switch will search based on the source MAC address in the lookup table constructed with RAM. If it matches an item in the table, the source MAC will be discarded. If it does not match, the port record does not exist in the table. At this time, the lookup table will learn the port record, and write the source MAC into the lookup table in the form of MAC address + port number. This is the learning function of the switch.

At the same time, the switch will retrieve the table entry again according to the destination MAC address of the frame. At this time, which table entry is the same as the MAC address will be retrieved. If it matches, the port number of the entry will be read as the destination of the data frame. Port, the switch will forward according to this port.
2.4. The workflow of the TCAM algorithm

The TCAM algorithm search process is as follows:

Step 1: Extract the information that needs to be searched, and sort it into the same format as the table items stored in TCAM through the mask, and call this sorted data as a key.

Step 2: Compare the key with the table item bit by bit. If there is a matching entry, the address where the entry is located is output, and this output is called an index. Since TCAM is a parallel search algorithm, the result can be obtained in only one cycle, which greatly shortens the search time.

Step 3: Input Index as the address of RAM to get the required search information from RAM. This information is called Data.

Step 4: Return Data to the module that initiated the search, and then complete a search.

3. Functional simulation

3.1. Learning simulation of lookup table

As shown in the figure, in the learning process, make port 0 correspond to the MAC address DA02_0304_0506 and store it in the starting address of the memory; make port 3 correspond to the MAC address DA02_0304_0507 and store it in the memory address 1; make port 1 correspond to the MAC address DA02_0304_0508 and store it in address 2 of the memory; finally, port 2 is corresponding to the MAC address DA02_0304_0509 and stored in address 3 of the memory; in this way, the destination address and the port number are corresponding to the memory.

3.2. Find process simulation

As shown in the figure, in the search process, when the input MAC address is DA02_0304_0508, the output memory address is 02, and the output port number is 1; when the input MAC address is DA02_0304_0509, the output memory address is 03, and the output The port number is 02. The output result is the same as the learned information, and the search is completed after only one cycle, indicating the correctness of the design.
4. Conclusion

For the Ethernet switch, the main job is to search for the MAC address according to the destination MAC address in the received data frame, and forward the data frame to the corresponding port. The search efficiency of the MAC address table directly affects the performance of the switch. TCAM algorithm can realize high-efficiency storage and search, and with the characteristics of FPGA parallel processing, the performance of the switch is further improved.

References


