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DESIGN OF HIGH THROUGHPUT AND HIGH SPEED HYPERCUT PACKET CLASSIFICATION

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ABSTRACT

Packet classification is the critical task in networking and it is used by network processor present in router to classify the packets according to the header field values. Packet classification is the process of matching packet header values to the rule header values. The packet is processed according to the matched rule. The contribution of this paper is "Pipelined packet classification" architecture using hyper cut algorithm. This architecture is based on building the decision tree. The pipelined architecture for packet classification reduces the critical delay and gives high throughput of 3.98 Gbps.

Keywords: Packet classification,high throughput,high speed, parallel and pipeline processing

I. INTRODUCTION

The usage of the internet grows for every year, because of the easy access of the internet through 'smart phones', 'note books' and 'net books'. Packets are processed through the network processor, which are responsible to convert the packets into fragments, reassembling the converted fragments, encryption and packet classification. Due to incremented line rates, pressure is creating on network processor. There are two ways to minimize the pressure. One is to insert more processing cores but it increases power consumption and clock speed, so it has created difficulty in fabrication due to physical constraint in the silicon, so there is a need to get optimized solution for relieving the pressure on network processor.

"The process of matching the incoming packets with the rules, in an network router is called Packet classification. All the packets which are matched to the same rule are processed in homogeneous manner [1]". The application of the packet classification includes' Intrusion detection',' firewalls' and 'monitoring architectures'. Due to greater evolution of internet services, the packet classification becomes difficult task. The design of any algorithm will depends on performance parameters like speed, throughput, low area etc. In this paper, different algorithms used for packet classification are also discussed with respect to performance parameters like 'time complexity', 'speed complexity', memory usage, throughput and efficiency. The basic algorithms like 'Linear search' [2],' hierarchical trie' [3], 'set pruning trie' [4] etc are failed to meet the performance requirement. So hypercut packet classification algorithm will give the better performance like 'high speed' and 'high throughput', because of its high throughput, more packets can be processed per second, it reduces the time. The rest of the paper is organized as follows. Section II explains related work in packet classification. Section III explains the overview of packet classification. Section IV explains pipelined hyper cut packet classification. Srction V explains comparison of performance parameters for parallel hyper cut packet classification[5], and pipelined hyper cut packet classification. Section VI concludes the paper.

II. RELATED WORK

In packet classification several algorithms are present starting with linear search algorithm, in which packets are searched sequentially until the matched rule is found. It takes the total time of O(N), where N is the number of rules. The decision tree based algorithms are proposed. In which the set of rules are divided until the linear search is possible on the rules. In which space decomposition is used. Space decomposition is the process of building the decision tree. The space decomposition starts from root node, rules are divided into child nodes and these child nodes contains not more than the threshold value. The separate rules are stored in leaf node. If there are L leaf nodes, then the average height of decision tree is O(log L). So searching time is decreased from O(N) to O(log L).

Hicut[6]: In this decomposition space is divided equally until the small subspace is present. The root node covers all searching rules. Hicut selects one dimension to cut the rules. The rules present in root node are divided into separate child nodes. If the rules cannot be covered by only one subspace then rule replication is required. So it increases the space and it is only used for one dimension. Parallel hyper cut algorithm: It is used for multi dimensional packet classification. It has lower tree height as compared to hicut algorithm. Rule replication is absent in this algorithm, but it requires larger critical delay so that speed is reduced.

The proposed pipelined hyper cut packet classification uses pipeline approach to classify the packets, so that critical delay is reduced and speed is increased

III. OVERVIEW OF PACKET CLASSIFICATION

A packet is a 'formatted unit of data' which is carried by 'packet switched network'. When the data is formatted to packet, the bandwidth associated with the communication channel reduces". Packet mainly consists of three

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parts. They are 'packet header', 'payload' and 'trailer', which is shown in fig 7. The maximum size possible for the packet is 64535 bytes, and minimum size is 20 bytes. The size of header and trailer for IPv4 are fixed and which are 20 bytes and 32 bits respectively. The size of payload varies from 0 bytes to 64,511 bytes. The fig 1 shows the 'format of packet'.

Header (20 bytes)	Payload(Variable in size)	Trailer(32 bits)

Fig 1. Format of packet

Header: Header is a portion of the 'IP' packet, and it contains the destination address information. The header of the packet has five fields which are "source IP address (size 32 bit), Destination IP address (size 32 bit), source port number (16 bit), destination port number(16 bit),protocol(size 8 bit)", and also it contains packet number and synchronization bits.

Payload: It contains the actual data that is transmitted between the two nodes, and it is variable in size from 0 bytes to 64,511 bytes.

Trailer: It is used to inform to destination device about the completion of transmission of the packet.

A. Packet classification:

'Packet classification' is the task of deciding which rule(s) from the rule set, are matched to the packet depending on its header information. If packet is matched to multiple rules, then the rule with highest priority is taken. Packet classification is required to sort the packets depending on the services they require such as mail service, facebook service, you tube and it also deny the unsecured data.'Packet classification' [7], is shown in fig 2, here incoming packet is given to the forwarding engine. The forwarding engine contains the rule sets and every incoming packet is matched to the rule sets which are present in 'forwarding engine' and according to the matched rule, packet classification can be carried.

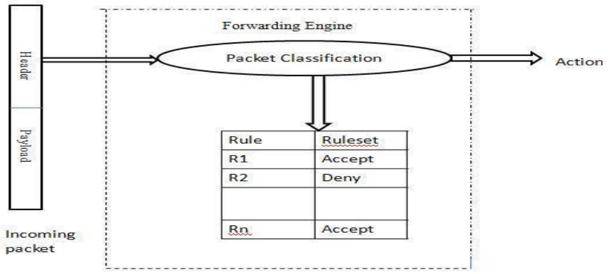

Fig 2. Packet classification engine

IV. PIPELINED HYPER CUT PACKET CLASSIFICATION

A. The architecture of pipelined packet classification using hyper cut algorithm

The architecture of pipelined packet is shown in fig 3. Here the incoming packets are stored in the packet buffers A and B. The "memory" of the packet classification architecture contains the tree structure. The rulesets are present in memory. The tree structure is used to match the incoming packets to the rules present in memory. The architecture of pipelined packet classification contains eight packet classification engines. The incoming packets from the buffer A are given to the packet classification engines 11,12,13 and 14. The incoming packets from packet buffer B are given to the packet classification engines 21,22,23 and 24.Here the incoming packets from packet buffer A and B are given simultaneously to the packet classification engines, so that eight packet classification engines are working simultaneously, processing two packets at a time. Here the packet classification engines 11,12,13 and 14 are produce the packet classification engines output as match, nomatch and rule id signals for the packet buffer A. The packet classification engines 21,22,23 and 24 are produce the packet classification engines output as match, nomatch and rule id signals for the packet buffer B. The two sorter blocks are used to output the two matching rules simultaneously. If the incoming packet is matched to more than one rule, then the rule with highest priority is taken as matched rule.

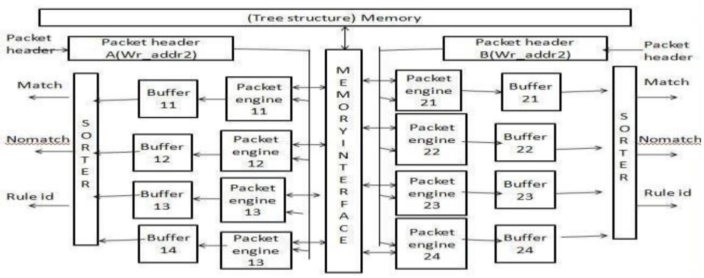

Fig 3. The architecture for pipelined hyper cut packet classification

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The rule set header values are shown in the table 1. This ruleset contains seven rules. These ruleset is used for authentication of the packets. In the table S.IP denotes source IP address of rule header, D.IP denotes destination IP address of rule header, S.P denotes source port number of rule header, D.P denotes destination port number of rule header, Protocol denotes the protocol field of rule header.

Table 1. The rulesets containing seven rules

RuleID	S. IP	D. IP	S. Port	D. Port	Protocol	Action
R_1	0000	0101	30-80	0-65535	UDP	ACT_1
R_2	111*	1***	0-2000	10-10	UDP	ACT_2
R_3	1***	101*	60-80	0-65535	TCP	ACT_3
R_4	101*	0***	0-65535	960-990	TCP	ACT_4
R_5	00**	101*	0-65535	800-811	TCP	ACT_5
R_6	000*	0111	30-80	0-65535	UDP	ACT_6
R_7	000*	0110	30-80	0-65535	UDP	ACT_7

The flow chart for the tree structure is shown in fig 4 as

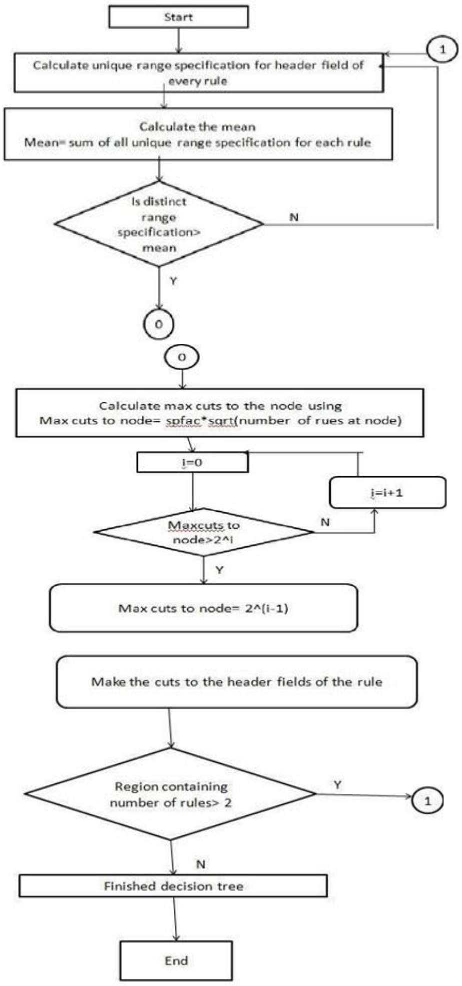

Fig 4. The flowchart for building the decision tree

The steps for building the decision tree is shown in the flowchart. The tree structure for the rulesets shown in table ar1e constructed according to the flowchart shown in fig 4. From the table 1 , it is observed as the distinct range specification for source IP address has 6, destination IP address has 6, source port number has 4, destination port number has 4 and protocol field has 2. The mean is obtained as (6+6+4+4+2)/5=4.4. The distinct range specification for source and destination IP address field has range specification as 6, it is more than 4.4, so it is considered for cutting.

The number of cuts performed to the fields are obtained using this equation as max number of cuts to the field<= spfac* sqrt(number of rules), here the value of spfac is 3, because if the spfac value is less than two then maximum two regions are created and the memory used to store all the rules is less,but the time needed to traverse the entire memory is more . If the spfac value is more than two then number of regions created more, but the time needed to traverse the tree is less. Max cuts to the field is<= 3*sqrt(7)= 7.9, which should be the power of two. So

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maximum four cuts can be performed to the header fields. After cutting, the tree structure is obtained as shown in fig 5.

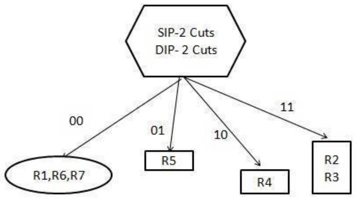


Fig 5. The tree structure obtained after cutting the root node

The region having more than two rule is considered for cutting. Here the first region of the tree contains three rules, which is more than two so it is considered for cutting. Next three rule header fields of R1,R6 and R7 are considered for cutting. The distinct range specification for source IP address has 2, destination IP address has 3, Source port number has 1, destination port number has 1 and protocol number has 1. The mean is calculated as (3+2+1+1+1)/5=1.6, the distinct range specification for source and destination field is greater than mean, so these two fields are considered for cutting.

The number of cuts performed to the fields are obtained using this equation as Max cuts to the field is<= 3*sqrt(3)= 5.9, which should be the power of two. So maximum four cuts can be performed to the header fields. After cutting, the tree structure is obtained as shown in fig 6 as

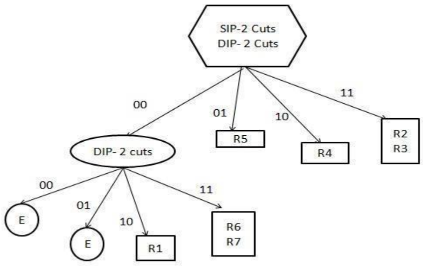


Fig 6. The finished tree structure

The regions obtained after cutting the internal node are shown in the fig 13. Here all the regions contains less than two rules. Now the cutting process is complete. Procedure for matching the incoming packets to the tree structure is shown as first the MSB bits of both source and destination IP address fields are considered to traverse the tree next the two MSB bits of destination IP addresses are considered for traversing. The regions for traversing is shown in Table 2 as

Table 2 The regions for rules

Region	Rules	Region	Rules
44(0111)		34(1111)	R2
43(0110)		33(1110)	R2
42(0101)	R5	32(1101)	R2,R3
41(0100)		31(1100)	R2
14(0011)	R6,R7	24(1011)	R4
13(0010)	R1	23(1010)	R4
12(0001)		22(1001)	R4
11(0000)		21(1000)	R4

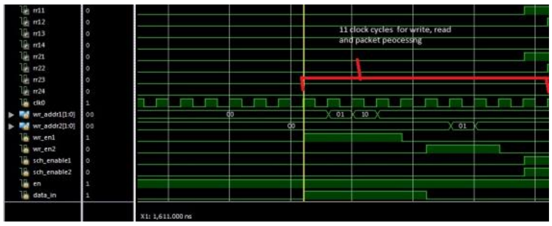
The matching of incoming packets to the rule id's takes 16 clock cycles. In the first 4 cycles the four incoming packets are stored in memory. In 5th cycle, the incoming packets for the buffer B are enabled. In next 3 clock cycles three incoming packets are stored in memory. In 9th clock cycle, the process of storing in the buffer is finished. In 10th clock cycle, the selection of buffer location to read the incoming packets are takes place. It takes 7 clock cycles to process the packets and produce the result.

V EXPERIMENTAL RESULTS

The simulation results for the pipeline packet classification architecture is shown in the fig 7 and fig 8.. Here 11 clock cycles are needed to write, read and to process the incoming packets, next four clock cycles are needed to produce the packet classification outputs. The critical delay for this packet classification is 11 clock cycles. The performance parameter are compared with respect to the parallel packet classification[5] using hyper cut algorithm is given in table2.

A. Comparison of performance parameters

The performance parameters like frequency of operation, throughput, minimum clock period, the critical path delay and number of slice registers are compared in the table 3. The frequency of operation for parallel packet classification[5], is less as compared to parallel and pipelined packet classification architecture. The throughput for parallel and pipelined architecture is high compared to parallel packet classification architecture. The critical path delay in parallel and pipelines packet classification is reduced as compared to parallel packet classification. The number of slice registers required for parallel and pipelined architecture is more compared to parallel packet classification architecture. It shows that the speed, throughput and frequency of operation are more in parallel and pipeline packet classification, but the area is increased in parallel and pipelined architecture because of insertion of buffers.



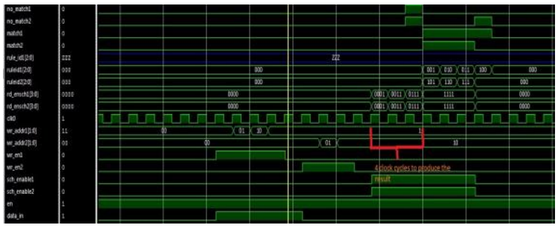


Fig 7. The simulation results for write operation in pipelined packet classification architecture

Fig 8. The simulation results for write operation in pipelined packet classification architecture

Table 3. The comparison of performance parameters

Parameter	Parallel packet classification	Parallel and pipelined packet classification
Frequency(Mhz)	251.825	474.15
Throughput(Gbps)	2.12	3.98
Min clock period(ns)	3.971	2.109
Critical path delay(no of clock cycles)	15	11
No of slice registers	124	164

VI CONCLUSION

There are various algorithms for packet classification based on performance parameters like time complexity, space complexity etc. available in the literature. In all algorithms, there is an enhanced research on reducing area, increasing speed and throughput. In this thesis, the proposed parallel and pipelined design made an attempt to enhance the performance and to reduce the critical path delay at the cost of little increase in area and propagation delay..

There is the need of modification in the way that the rule is stored in the leaf node of decision tree and to fetch the information needed to match the incoming packets to the rule. There are some modifications, like node merging; pushing common rule upset and rule overlap are possible in order to reduce the memory consumption.

Further work is needed to increase the performance and reduce the area and power. It is also possible to design modified hypercut algorithm using node merging, pushing common rule upset and rule overlap to reduce the number of memory accesses and to reduce the memory storage of rule sets. This can be considered as future work.

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