Chapter 3.

System Design

3.1. System Software Architecture

The system software block diagram in our design is illustrated in Figure 3.1. The system software architecture is divided into two parts according to their processing units. One is the MIPS CPU which is in charge of control-plan tasks like system configuration, maintenance of various tables, IPv4 address pool, TCP/IPv4 protocol stack, a portion of TCP/IPv6 protocol stack (Neighbor Solicitation and Neighbor Advertisement), and DNS-ALG. The other is FACEU CPU which is responsible for data-plan tasks such as filtering, scheduling, forwarding, and header translation.

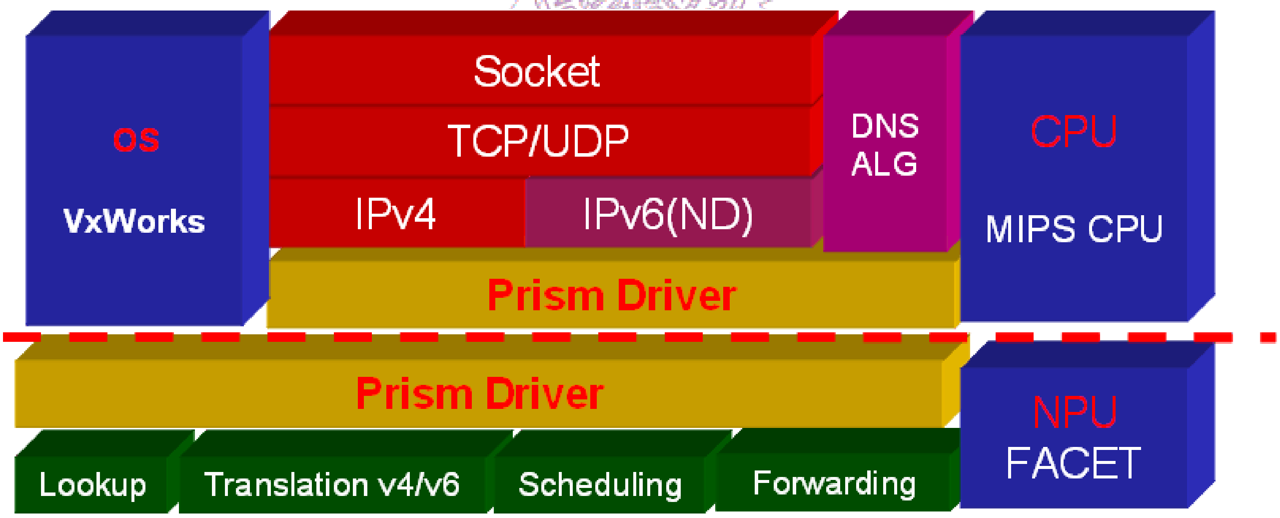

Figure 3.1 System Software Block Diagram

The MIPS CPU and FACET CPU use an interface called Prism Driver [33] to communicate to each other. The Prism Driver prepares a set of four queues in the main memory for the communication between the MIPS and FACET. For those need to be dealt with by the MIPS CPU, the FACET CPU puts the control-plan packets into a shared memory. At the same time, the FACET sets the queuing information for these enqueued packets. The MIPS takes a sequential and periodical way to pool the shared memory to see if anything requiring control-plan service inside the queue, the operating system may process these packets. We will leave the detail of Prism Driver in the end of this chapter.

The embedded operating system supporting to the MIPS CPU in Vitesse IQ2000 is VxWorks. While the VxWorks doesn't supply the functionality of TCP/IPv6 protocol stack, it cannot make the NAT-PT implementation easy. That is because the process of Layer 2 address resolution in IPv6 domain needs some function of IPv6 called Neighbor Discovery [35] to get the destination MAC address for delivering the packets. As a result, we have to additionally implement these required functionalities for making up the deficiency of VxWorks. Making the NAT-PT system be able to send Neighbor Solicitation and reply Neighbor Advertisement is enough for our design being workable. This implementation will be described in chapter 4.

3.2. DNS-ALG

Most type of services can be transparently translated by NAT-PT functionality operated by lower layer processor except for those who embed IP information in their payload part by upper layer processor. The DNS packet is one of those who need to be modified in payload. During the IPv6 migration, we should define both types of DNS packets for supporting the IPv4 and IPv6 address domains with "A" and "AAAA" records respectively.

In terms of DNS-ALG which is accomplished at the upper layer processor named MIPS CPU in our design, there are two main operations while receiving DNS query/reply ether from IPv4 or IPv6 address domain. First, while the UDP packets of port 53 being snooped by NAT-PT at lower layer processor, they will be sent to DNS-ALG across the Prism Driver at upper layer processor for DNS record translation. DNS-ALG translates the “A” record DNS query/reply into “AAAA” record query/reply from IPv4 address domain to IPv6 address domain and vice versa. Second, the operation of address allocation including available IPv4 address popping from IPv4 address pool and IPv4-IPv6 mapping table maintaining should be done whenever an “AAAA” record DNS reply packet from IPv6 address domain arrive the NAT-PT gateway. That is, when NAT-PT gateway receives the “AAAA” record DNS reply, the DNS-ALG allocates an available IPv4 address from address pool to the IPv6 address answered from the IPv6 DNS server and adds a mapping entry of this pair of IPv4 and IPv6 address into the IPv4-IPv6 address mapping table for the continued header translation and session establishment initiated from IPv4 to IPv6 address domain.

3.3. Data Flow of NAT-PT with DNS-ALG

In fact, the data flow of NAT-PT with DNS-ALG in our design based on network processor platform is similar to the description in RFC 2765 and RFC 2766. The main difference between the standard and our design is that the data flow in our design is divided into control-plane and data-plane since we implement this NAT-PT system in a network processor-based platform. As a result, we can use the outstanding properties of hardware-assisted platform to optimize our system design. We are now detail describing the data flow in our design as below. To keep an important aspect in mind that there are two special mapping tables between physical address and IP address will be pre-constructed during the system initialization process which is described in next chapter. Therefore, the NAT-PT device can simply ignore the process of address resolution when receiving either an ARP Request [36] from IPv4 side or a Neighbor Solicitation from IPv6 side.

3.4.1. Data Flow of IPv4 to IPv6

Figure 3.2 represents the data flow while an IPv4 host wants establish a connection with an IPv6 host across the network processor-based NAT-PT gateway. The following steps give the detail depictions.

1. The IPv4 user sends an “A” record DNS query to IPv4 DNS server for resolving the domain name of the IPv6 host into the corresponding IPv6 address.
2. Certainly, the IPv4 DNS server has no answer to this “A” record DNS query and forwards this query to the IPv6 DNS server which is predefined in the IPv4 DNS server for advanced resolving. This forwarded query is intercepted by the middle NAT-PT gateway.
3. The FACET receives this DNS query from PIM A.
4. The FACET translates the IPv4 header into an equivalent IPv6 header using the SIIT algorithm defined in RFC 2765 with a predefined address mapping of IPv6 DNS server in main memory for correctly exchanging the destination address in IPv4 header into corresponding IPv6 address and appending a predefined IPv6 Prefix to the original source address into a mapped IPv6 address.
5. After the layer 3 translation at data-plane, the translated packet is sent to the DNS-ALG at control-plane across the Prism Driver for DNS record translation.
6. DNS-ALG translates the “A” record into “AAAA” record and then transfers the translated IPv6 DNS query to out from POM B.
7. The NAT-PT gateway forwards the translated DNS query to IPv6 DNS server for resolving the hostname into a corresponding IPv6 address.
8. After this resolving process, the IPv6 DNS server replies an “AAAA” record DNS reply with the IPv6 address of the IPv6 host to the IPv4 DNS server. This DNS reply

is intercepted by the middle NAT-PT gateway.

9. The FACET receives this resolved DNS reply from PIM B.
10. The FACET translates the IPv6 header into relative IPv4 header using SIIT algorithm. After layer 3 translation at data-plane, the translated DNS reply is sent to the DNS-ALG at control-plan process via Prism Driver for DNS record translation and address allocation
11. DNS-ALG allocates a free IPv4 address for resolved IPv6 address of IPv6 user into the IPv4-IPv6 address mapping table.
12. DNS-ALG translates the "AAAA" record into "A" record and then transfers the translated IPv4 DNS reply out from POM A.
13. The NAT-PT gateway forwards the translated DNS reply to IPv4 DNS server for complete the previously DNS query for resolving the hostname of IPv6 host.
14. The IPv4 DNS server sends the DNS reply with the resolved IPv4 address to the IPv4 host for communication.
15. The IPv4 host broadcasts an ARP request for resolving the physical address of the IPv6 host and intercepted by the middle NAT-PT gateway.
16. The FACET receives the ARP request from PIM A.
17. The FACET searches the IPv6-MAC address mapping table for corresponding physical address of that IPv6 host.
18. The FACET translates the ARP quest into corresponding ARP reply with searched physical address of IPv6 user and transfers to out from POM A.
19. The NAT-PT gateway replies an ARP reply with the corresponding physical address of the IPv6 user from the pre-constructed IPv6-Mac address mapping table in main memory to IPv4 user.
20. IPv4 host sends the connection packets to the IPv6 host and intercepted by the middle NAT-PT gateway.

21. The FACET receives the connection packets from PIM A.
22. The FACET performs the header translation from IPv4 to IPv6 on the connection packets.
23. After being translated from IPv4 to IPv6 packets, the FACET CPU transfers them to POM B.
24. The NAT-PT gateway forwards connection packets to the IPv6 user for completing the session establishment.

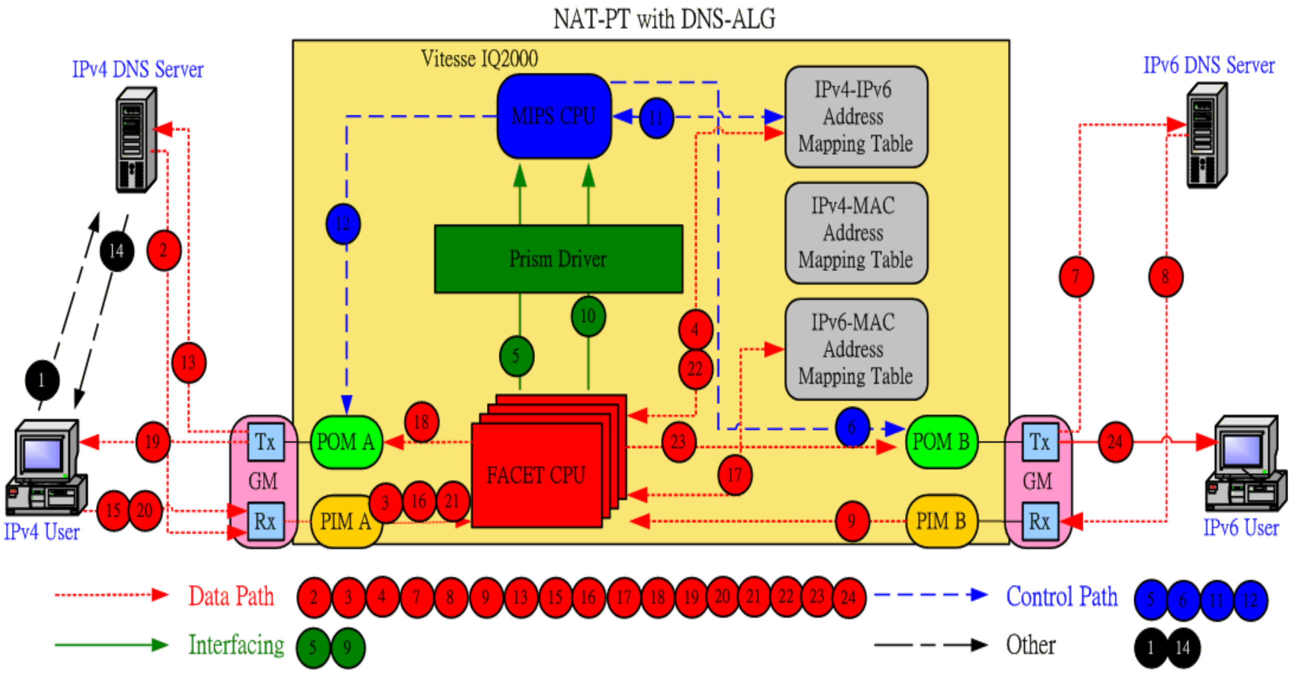

Figure 3.2 Data Flow of IPv4 to IPv6 in Chassis-Based NAT-PT

3.4.2. Data Flow of IPv6 to IPv4

Figure 3.3 represents the data flow while an IPv6 host wants establish a connection with an IPv4 host across the network processor-based NAT-PT gateway. The following steps give the detail depictions.

1. The IPv6 host sends an "AAAA" record DNS query to IPv6 DNS server for resolving the

domain name of the IPv4 host into the corresponding IPv4 address.

2. Certainly, the IPv6 DNS server has no answer to this “AAAA” record DNS query and forwards this query to the IPv4 DNS server which is predefined in the IPv6 DNS server for advanced resolving. This forwarded query is intercepted by the middle NAT-PT gateway.
3. The FACET receives this DNS query from PIM B.
4. The FACET translates the IPv6 header into an equivalent IPv4 header using the SIIT algorithm defined in RFC 2765 with a predefined address mapping of IPv6 DNS server for correctly exchanging the source address in IPv6 header into corresponding IPv4 address and removing a predefined IPv6 Prefix from the original destination address into a correct IPv4 address.
5. After the layer 3 translation at data-plan, the translated packet is sent to the DNS-ALG at control-plan across the Prism Driver for DNS record translation.
6. DNS-ALG translates the “AAAA” record into “A” record and then transfers the translated DNS query out from POM A.
7. The NAT-PT gateway forwards the translated DNS query to IPv4 DNS server for resolving the hostname into a corresponding IPv4 address.
8. After this resolving process, the IPv4 DNS server replies an “A” record DNS reply with the IPv4 address of the IPv4 host to the IPv6 DNS server. This DNS reply is intercepted by the middle NAT-PT gateway.
9. The FACET receives this resolved DNS reply from PIM A.
10. The FACET translates the IPv4 header into relative IPv6 header using SIIT algorithm.
11. After layer 3 translation at data-plan process, the translated DNS packet is sent to the DNS-ALG at control-plan process via Prism Driver for DNS record translation.
12. DNS-ALG translates the “A” record into “AAAA” record and then transfers out from POM B.
13. The NAT-PT gateway forwards the translated DNS reply to IPv6 DNS server for completing the previously DNS query of resolving the hostname of IPv4 host.
14. The IPv6 DNS server sends the DNS reply with the resolved IPv6 address to the IPv6 host for

communication.

15. The IPv6 host multicasts a Neighbor Solicitation for resolving the physical address of the IPv4 host and intercepted by the middle NAT-PT gateway.
16. The FACET receives the Neighbor Solicitation from PIM B.
17. The FACET searches the IPv4-MAC address mapping table for corresponding physical address of that IPv4 host.
18. The FACET translates the Neighbor Solicitation into a corresponding Neighbor Advertisement with searched physical address of IPv4 user and transfers out from POM B.
19. The NAT-PT gateway replies a Neighbor Advertisement with the corresponding physical address of the IPv4 user from the pre-constructed IPv4-Mac address mapping table in main memory to IPv6 user.
20. IPv6 host sends the connection packets to the IPv4 host and intercepted by the middle NAT-PT gateway.
21. The FACET receives the connection packets from PIM B.
22. FACET lookups the IPv4 address Pool to get a temporary IPv4 address and add a mapping entry into the IPv4-IPv6 address mapping table.
23. After being translated from IPv6 packets to IPv4 packets by the middle NAT-PT gateway, the FACET transfers them out from POM A.
24. The NAT-PT gateway forwards the translated connection packets to the IPv4 user for completing the session establishment.

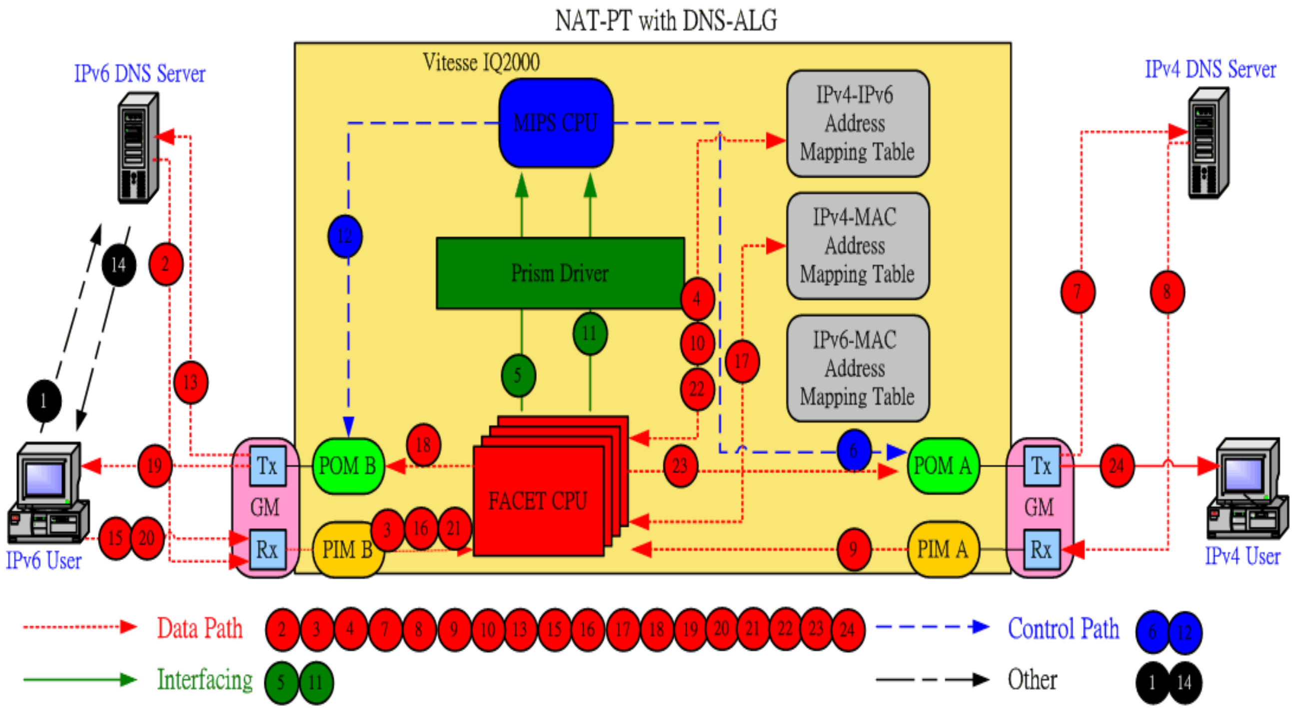

Figure 3.3 Data Flow of IPv6 to IPv4 in Chassis-Based NAT-PT