Linux Kernel Networking

Rami Rosen

ramirose@gmail.com

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Disclaimer

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Warning

- This lecture will deal with design functional

description side by side with many implementation details;

some knowledge of “C” is preferred.

General

- The Linux networking kernel code (including network device drivers) is a large part of the Linux kernel code.
- **Scope**: We will not deal with wireless, IPv6, and multicasting.
  - Also not with user space routing daemons/apps, and with security attacks (like DoS, spoofing, etc.) .
- Understanding a packet walkthrough in the kernel is a key to understanding kernel networking. Understanding it is a must if

  we want to understand Netfilter or IPSec internals, and more.
- There is a 10 pages Linux kernel networking walkthrouh document

General - Contd.

- Though it deals with 2.4.20 Linux kernel, most of it is relevant.
- This lecture will concentrate on this walkthrough (design and implementation details).
- References to code in this lecture are based on linux-2.6.23-rc2.
- There was some serious cleanup in 2.6.23

Hierarchy of networking layers

- The layers that we will deal with (based on the 7 layers model) are:

Transport Layer (L4) (udp,tcp...)

Network Layer (L3) (ip)

Link Layer (L2) (ethernet)

Networking Data Structures

- The two most important structures of linux kernel network layer are:
  - sk_buff (defined in *include/linux/skbuff.h*)
  - netdevice (defined in *include/linux/netdevice.h*)
- It is better to know a bit about them before delving into the walkthrough code.

SK_BUFF

- sk_buff represents data and headers.
- sk_buff API (examples)
  - sk_buff allocation is done with *alloc_skb()* or *dev_alloc_skb();* drivers use *dev_alloc_skb();*. (free by *kfree_skb()* and *dev_kfree_skb()*.
- *unsigned char* data* : points to the current header.
- *skb_pull(int len)* – removes data from the start of a buffer by advancing data to data+len and by decreasing len.
- Almost always sk_buff instances appear as “skb” in the kernel code.

SK_BUFF - contd

- sk_buff includes 3 unions; each corresponds to a kernel network layer:
- **transport_header** (previously called h) – for layer 4, the transport layer (can include tcp header or udp header or icmp header, and more)
- **network_header** – (previously called nh) for layer 3, the network layer (can include ip header or ipv6 header or arp header).
- **mac_header** – (previously called mac) for layer 2, the link layer.
- skb_network_header(skb), skb_transport_header(skb) and skb_mac_header(skb) return pointer to the header.

SK_BUFF - contd.

- **struct dst_entry *dst** – the route for this sk_buff; this route is determined by the routing subsystem.
  - It has 2 important function pointers:
    - *int (*input)(struct sk_buff*);*
    - *int (*output)(struct sk_buff*);*

int (*input)(struct sk_buff *);
int (*output)(struct net *net, struct sock *sk, struct sk_buff *skb);

- ***input()*** can be assigned to one of the following : ip_local_deliver, ip_forward, ip_mr_input, ip_error or dst_discard_in.
- **output()** can be assigned to one of the following :ip_output, ip_mc_output, ip_rt_bug, or dst_discard_out.
  - we will deal more with dst when talking about routing.

SK_BUFF - contd.

- In the usual case, there is only one dst_entry for every skb.
- When using IPSec, there is a linked list of dst_entries and only the last one is for routing; all other dst_entries are for IPSec transformers ; these other dst_entries have the DST_NOHASH flag set.
- **tstamp** (of type ktime_t) : time stamp of receiving the packet.
  - *net_enable_timestamp()* must be called in order to get values.

net_device

- net_device represents a network interface card.
- There are cases when we work with virtual devices.
  - For example, bonding (setting the same IP for two or more NICs, for load balancing and for high availability.)
  - Many times this is implemented using the private data of the device (the **void *priv** member of net_device);
  - In OpenSolaris there is a special pseudo driver called “vnic” which enables bandwidth allocation (project CrossBow).
- Important members:

net_device - contd

- **unsigned int mtu** – Maximum Transmission Unit: the maximum size of frame the device can handle.
- Each protocol has mtu of its own; the default is **1500** for Ethernet.
- you can change the mtu with ifconfig; for example,like this:
  - *ifconfig eth0 mtu 1400*
  - You cannot of course, change it to values higher than 1500 on 10Mb/s network:
  - *ifconfig eth0 mtu 1501* will give:
  - *SIOCSIFMTU: Invalid argument*

net_device - contd

- **unsigned int flags -** (which you see or set using ifconfig utility): for example, RUNNING or NOARP.
- **unsigned char dev_addr[MAX_ADDR_LEN]** : the MAC address of the device (6 bytes).
- **int (*hard_start_xmit)(struct sk_buff *skb,**

  struct net_device *dev);
  - a pointer to the device transmit method.
- **int promiscuity;** (a counter of the times a NIC is told to set to work in promiscuous mode; used to enable more than one sniffing client.)

net_device - contd

- You are likely to encounter macros starting with IN_DEV like:

IN_DEV_FORWARD() or IN_DEV_RX_REDIRECTS(). How are the related to net_device ? How are these macros implemented ?

- **void *ip_ptr**: IPv4 specific data. This pointer is assigned to a pointer to in_device in *inetdev_init()* (*net/ipv4/devinet.c*)

net_device - Contd.

- struct in_device have a member named cnf (instance of ipv4_devconf). Setting */proc/sys/net/ipv4/conf/all/forwarding*

  eventually sets the forwarding member of in_device to 1.

  The same is true to accept_redirects and send_redirects; both

  are also members of cnf (ipv4_devconf).
- In most distros, */proc/sys/net/ipv4/conf/all/forwarding=0*
- *But probably this is not so on your ADSL router.*

network interface drivers

- Most of the nics are PCI devices; there are also some USB network devices.
- The drivers for network PCI devices use the generic PCI calls, like *pci_register_driver()* and *pci_enable_device().*
- For more info on nic drives see the article "**Writing Network Device Driver for Linux**" (link no. 9 in links) and chap17 in **ldd3**.
- There are two modes in which a NIC can receive a packet.
  - The traditional way is interrupt-driven : each received packet is an asynchronous event which causes an interrupt.

NAPI

- NAPI (new API).
  - The NIC works in polling mode.
  - In order that the nic will work in polling mode it should be built with a proper flag.
  - Most of the new drivers support this feature.
  - When working with NAPI and when there is a very high load,

    packets are lost; but this occurs before they are fed into the network stack. (in the non-NAPI driver they pass into the stack)
  - in Solaris, polling is built into the kernel (no need to build drivers in any special way).

User Space Tools

- iputils (including ping, arping, and more)
- net-tools (ifconfig, netstat, , route, arp and more)
- IPROUTE2 (ip command with many options)
  - Uses rtnetlink API.
  - Has much wider functionalities; for example, you can create tunnels with “ip” command.
  - Note: no need for “-n” flag when using IPROUTE2 (because it does not work with DNS).

Routing Subsystem

- The routing table and the routing cache enable us to find the net device and the address of the host to which a packet will be sent.
- Reading entries in the routing table is done by calling *fib_lookup(const struct flowi *flp, struct fib_result *res)*
- FIB is the “Forwarding Information Base”.
- There are two routing tables by default: (non Policy Routing case)
  - local FIB table (*ip_fib_local_table* ; ID 255).
  - main FIB table (*ip_fib_main_table* ; ID 254)
  - *See : include/net/ip_fib.h.*

Routing Subsystem - contd.

- Routes can be added into the main routing table in one of 3 ways:
  - By sys admin command (route add/ip route).
  - By routing daemons.
  - As a result of ICMP (REDIRECT).
- A routing table is implemented by struct fib_table.

Routing Tables

- *fib_lookup()* first searches the local FIB table (ip_fib_local_table).
- In case it does not find an entry, it looks in the main FIB table (ip_fib_main_table).
- Why is it in this order ?
- There is one routing cache, regardless of how many routing tables there are.
- You can see the routing cache by running *"route -C".*
- Alternatively, you can see it by : "*cat /proc/net/rt_cache*".
  - con: this way, the addresses are in hex format

Routing Cache

- The routing cache is built of **rtable** elements:
- struct rtable (see: */include/net/route.h*)

```
{
union {
        struct dst_entry dst;
        } u;
...
}
```

Routing Cache - contd

- The **dst_entry** is the protocol-independent part.
  - Thus, for example, we have a dst_entry member (also called dst) in rt6_info in ipv6. (*include/net/ip6_fib.h*)
- The key for a lookup operation in the routing cache is an IP address (whereas in the routing table the key is a subnet).
- Inserting elements into the routing cache by : *rt_intern_hash()*
- There is an alternate mechanism for route cache lookup, called **fib_trie**, which is inside the kernel tree (*net/ipv4/fib_trie.c)*

Routing Cache - contd

- It is based on extending the lookup key.
- You should set: CONFIG_IP_FIB_TRIE (=y)
  - (instead of CONFIG_IP_FIB_HASH)
- By Robert Olsson et al (see links).

Creating a Routing Cache Entry

- Allocation of **rtable** instance (rth) is done by: *dst_alloc()*.
  - dst_alloc() in fact creates and returns a pointer to dst_entry and we cast it to rtable *(net/core/dst.c).*
- Setting input and output methods of dst:
  - (rth->u.dst.input and rth->u.dst.input)
- Setting the flowi member of dst (rth->fl)
  - Next time there is a lookup in the cache,for example , *ip_route_input()*, we will compare against rth->fl.

Routing Cache - Contd.

- A garbage collection call which delete eligible entries from the routing cache.
- Which entries are not eligible ?

Policy Routing (multiple tables)

- Generic routing uses destination-address based decisions.
- There are cases when the destination-address is not the sole parameter to decide which route to give; Policy Routing comes to enable this.

Policy Routing (multiple tables)-contd.

- Adding a routing table : by adding a line to: */etc/iproute2/rt_tables.*
  - For example: add the line “252 my_rt_table”.
  - There can be up to 255 routing tables.
- Policy routing should be enabled when building the kernel (CONFIG_IP_MULTIPLE_TABLES should be set.)
- Example of adding a route in this table:
- > ip route add default via 192.168.0.1 table my_rt_table
- Show the table by:
  - ip route show table my_rt_table

Policy Routing (multiple tables)-contd.

- You can add a rule to the **routing policy database (*RPDB*)** by "*ip rule add* ..."
  - The rule can be based on input interface, TOS, fwmark (from netfilter).
- *ip rule list* – show all rules.

Policy Routing: add/delete a rule - example

- *ip rule add tos 0x04 table 252*
  - This will cause packets with tos=0x08 (in the iphdr)

    to be routed by looking into the table we added (252)
  - So the default gw for these type of packets will be 192.168.0.1
  - ***ip rule show*** will give*:*
  - 32765: from all tos reliability lookup my_rt_table
  - ...

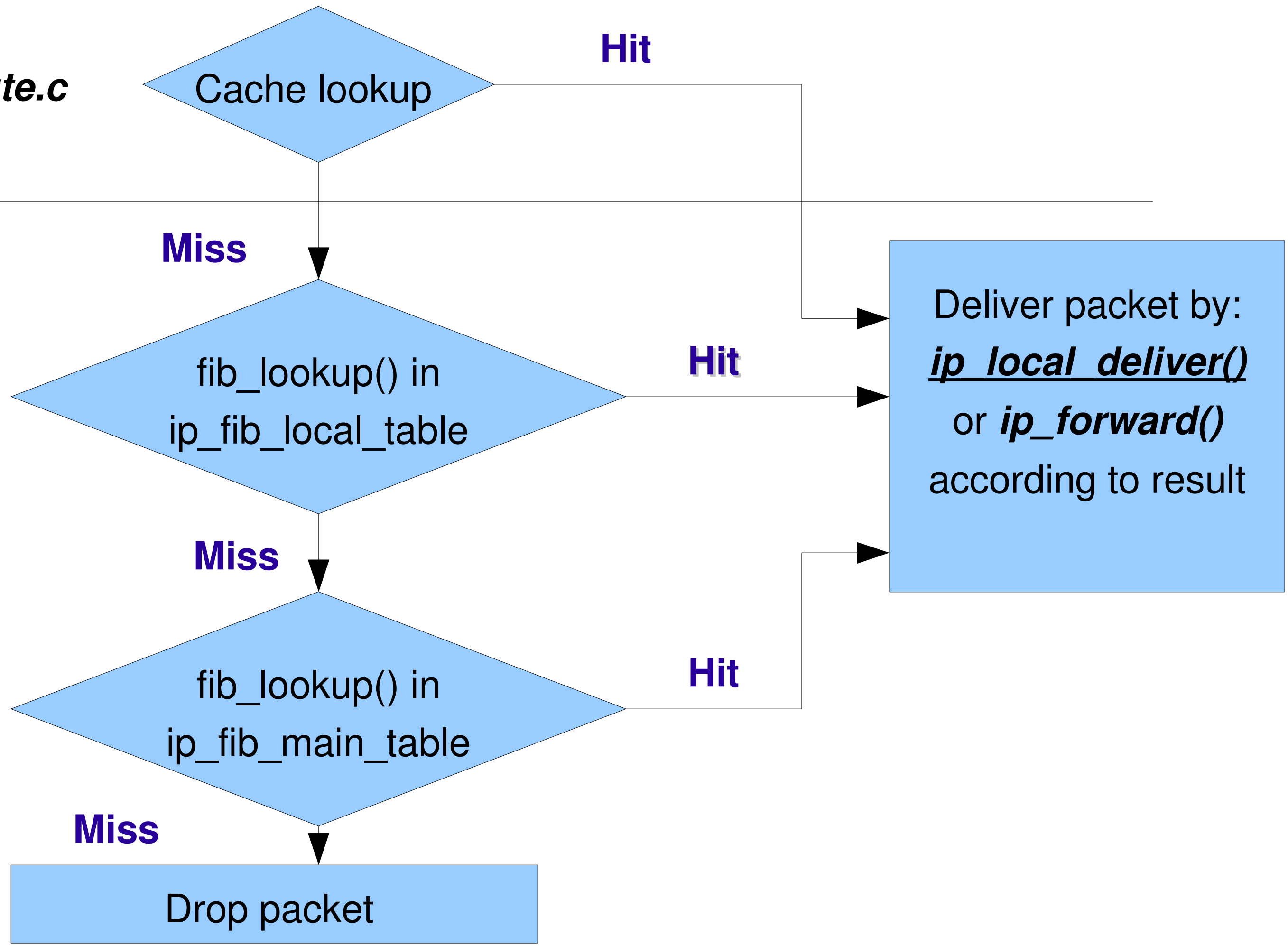
Policy Routing: add/delete a rule - example

- Delete a rule *: ip rule del tos 0x04 table 252*

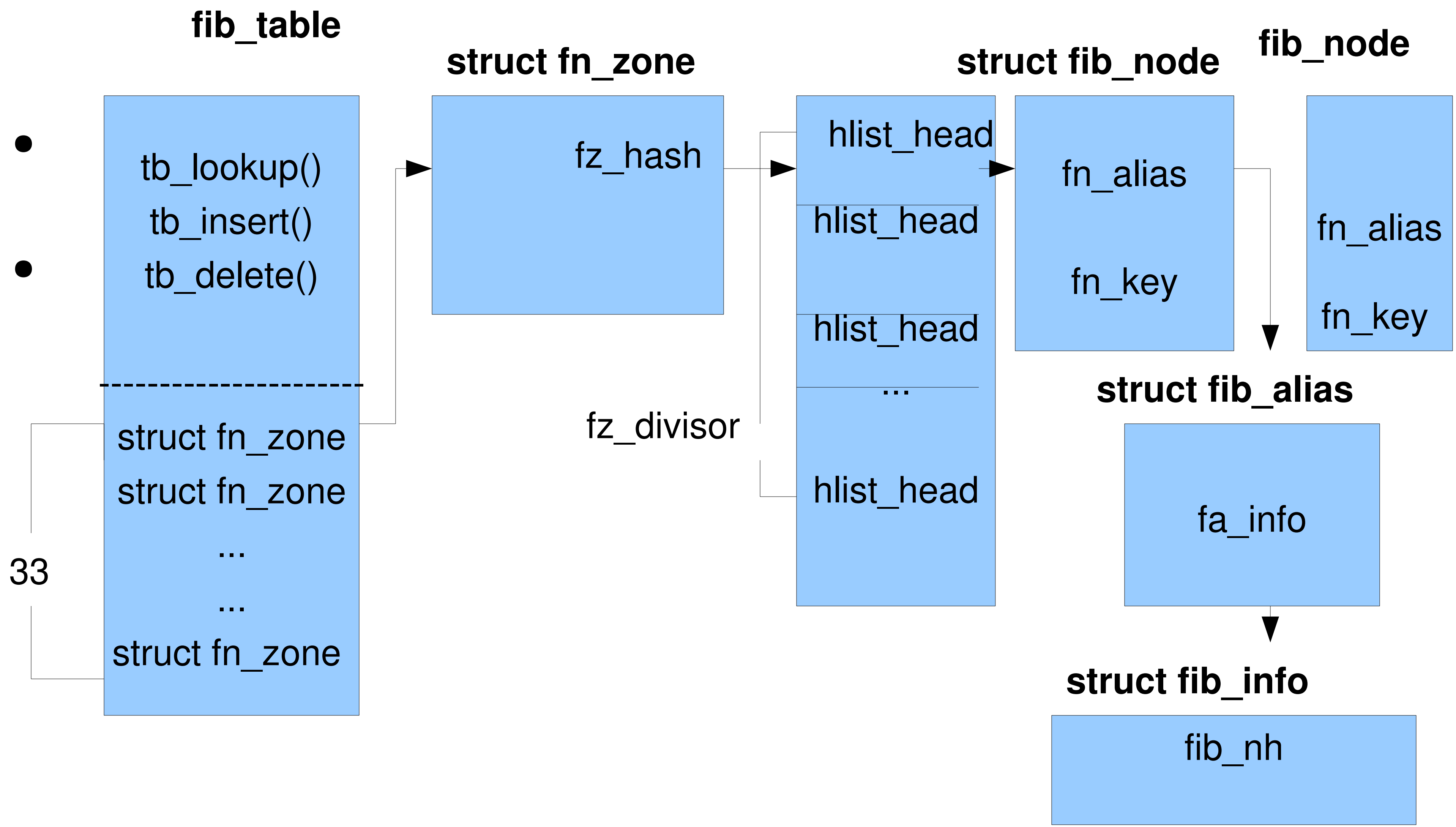
Routing Lookup

ip_route_input() in: net/ipv4/route.c

ip_route_input_slow()
in: net/ipv4/route.c



Routing Table Diagram



Routing Tables

- Breaking the fib_table into multiple data structures gives flexibility and enables fine grained and high level of sharing.
  - Suppose that we 10 routes to 10 different networks have the same next hop gw.
  - We can have one fib_info which will be shared by 10 fib_aliases.
  - fz_divisor is the number of buckets

Routing Tables - contd

- Each ***fib_ node*** element represents a unique subnet.
  - The ***fn_key*** member of fib_ node is the subnet (32 bit)

Routing Tables - contd

- Suppose that a device goes down or enabled.
- We need to disable/enable all routes which use this device.
- But how can we know which routes use this device ?
- In order to know it efficiently, there is the **fib_info_devhash** table.
- This table is indexed by the device identifier.
- See *fib_sync_down()* and *fib_sync_up()* in

  net/ipv4/fib_semantics.c

Routing Table lookup algorithm

- **LPM (Longest Prefix Match)** is the lookup algorithm.
- The route with the longest netmask is the one chosen.
- Netmask 0, which is the shortest netmask, is for the default gateway.
  - What happens when there are multiple entries with netmask=0?
  - *fib_lookup()* returns the **first entry it finds** in the fib table where netmask length is 0.

Routing Table lookup - contd.

- It may be that this is not the best choice default gateway.
- So in case that netmask is 0 (prefixlen of the fib_result returned from fib_look is 0) we call *fib_select_default()*.
- *fib_select_default()* will select the route with the lowest priority

  (metric) (by comparing to *fib_priority* values of all default gateways).

Receiving a packet

- When working in interrupt-driven model, the nic registers an interrupt handler with the IRQ with which the device works by calling *request_irq()*.
- This interrupt handler will be called when a frame is received
- The same interrupt handler will be called when transmission of a frame is finished and under other conditions. (depends on the NIC; sometimes, the interrupt handler will be called when there is some error).

Receiving a packet - contd

- Typically in the handler, we allocate sk_buff by calling *dev_alloc_skb()* ; also *eth_type_trans()* is called; among other things it advances the data pointer of the sk_buff to point to the IP header ; this is done by calling *skb_pull(skb, ETH_HLEN).*
- See : *net/ethernet/eth.c*
  - ETH_HLEN is 14, the size of ethernet header.

Receiving a packet - contd

- The handler for receiving a packet is *ip_rcv()*. (*net/ipv4/ip_input.c*)
- Handler for the protocols are registered at init phase.
  - Likewise, *arp_rcv()* is the handler for ARP packets.
- First, *ip_rcv()* performs some sanity checks. For example:

  if (iph->ihl < 5 || iph->version != 4)

  goto inhdr_error;

  - *iph* is the ip header ; iph->ihl is the ip header length (4 bits).
  - The ip header must be at least 20 bytes.
  - It can be up to 60 bytes (when we use ip options)

Receiving a packet - contd

- Then it calls *ip_rcv_finish*(), by:

  NF_HOOK(PF_INET, NF_IP_PRE_ROUTING, skb, dev, NULL,
  ip_rcv_finish);

- This division of methods into two stages (where the second has the same name with the suffix finish or slow, is typical for networking kernel code.)
- In many cases the second method has a “slow” suffix instead of “finish”; this usually happens when the first method looks in some cache and the second method performs a lookup in a table, which is slower.

Receiving a packet - contd

- *ip_rcv_finish()* implementation:

```
if (skb->dst == NULL) {
  int err = ip_route_input(skb, iph->daddr, iph->saddr, iph->tos,
                           skb->dev);
...
}
...
return dst_input(skb);
```

Receiving a packet - contd

- *ip_route_input()*:

  First performs a lookup in the routing cache to see if there is a match. If there is **no match (cache miss),** calls *ip_route_input_slow()* to perform a lookup in the routing table. (This lookup is done by calling *fib_lookup()*).

- *fib_lookup(const struct flowi *flp, struct fib_result *res)*

  The results are kept in fib_result.

- *ip_route_input()* returns 0 upon successful lookup. (also when there is a cache miss but a successful lookup in the routing table.)

Receiving a packet - contd

According to the results of *fib_lookup()*, we know if the frame is for **local delivery** or for **forwarding** or to be **dropped.**

- If the frame is for local delivery , we will set the input() function pointer of the route to *ip_local_deliver()*:

  rth->u.dst.input= ip_local_deliver;

- If the frame is to be forwarded, we will set the input() function pointer to *ip_forward()*:

  rth->u.dst.input = ip_forward;

Local Delivery

- Prototype:

  *ip_local_deliver(struct sk_buff *skb) (net/ipv4/ip_input.c).*

  - calls NF_HOOK(PF_INET, NF_IP_LOCAL_IN, skb, skb->dev, NULL,ip_local_deliver_finish);

- Delivers the packet to the higher protocol layers according to its type.

Forwarding

- Prototype:
  - *int ip_forward(struct sk_buff *skb)*
    - *(net/ipv4/ip_forward.c)*
  - *decreases the ttl in the ip header*
  - *If the ttl is <=1* , the methods send ICMP message *(ICMP_TIME_EXCEEDED)* and drops the packet.
  - Calls *NF_HOOK(PF_INET,NF_IP_FORWARD, skb, skb->dev, rt->u.dst.dev, ip_forward_finish);*

Forwarding- Contd

- *ip_forward_finish():* sends the packet out by calling *dst_output(skb)*.
- *dst_output(skb)* is just a wrapper, which calls

skb->dst->output(skb). (see *include/net/dst.h*)

Sending a Packet

- Handling of sending a packet is done by ***ip_route_output_key().***
- We need to perform routing lookup also in the case of transmission.
- In case of a cache miss, we calls *ip_route_output_slow()*, which looks in the routing table (by calling *fib_lookup()*, as also is done in ***ip_route_input_slow*****()**.)
- If the packet is for a remote host, we set dst->output to *ip_output()*

Sending a Packet-contd

- *ip_output()* will call *ip_finish_output()*
  - This is the NF_IP_POST_ROUTING point.
- *ip_finish_output()* will eventually send the packet from a neighbor by:
  - *dst->neighbour->output(skb)*
  - *arp_bind_neighbour()* sees to it that the L2 address of the next hop will be known*. (net/ipv4/arp.c)*

Sending a Packet - Contd.

- If the packet is for the local machine:
  - *dst->output = ip_output*
  - *dst->input   = ip_local_deliver*
  - *ip_output()* will send the packet on the loopback device,
  - Then we will go into *ip_rcv()* and *ip_rcv_finish()*, but this time dst is NOT null; so we will end in *ip_local_deliver()*.
- See: *net/ipv4/route.c*

Multipath routing

- This feature enables the administrator to set multiple next hops for a destination.
- To enable multipath routing, CONFIG_IP_ROUTE_MULTIPATH should be set when building the kernel.
- There was also an option for multipath caching: (by setting CONFIG_IP_ROUTE_MULTIPATH_CACHED).
- It was experimental and removed in 2.6.23 - See links (6).

mc - root@rr:/proc/net/stat

```
Linux Kernel v2.6.21-rc7 Configuration

                         Networking options
  Arrow keys navigate the menu.  <Enter> selects submenus --->.  Highlighted letters are
  hotkeys.  Pressing <Y> includes, <N> excludes, <M> modularizes features.  Press
  <Esc><Esc> to exit, <?> for Help, </> for Search.  Legend: [*] built-in  [ ] excluded
  <M> module  < > module capable

        [ ] Network packet debugging
        <*> Packet socket
        [*]   Packet socket: mmapped IO
        <*> Unix domain sockets
        <*> Transformation user configuration interface
        [ ] Transformation sub policy support (EXPERIMENTAL)
        [ ] Transformation migrate database (EXPERIMENTAL)
        <M> PF_KEY sockets
        [ ]   PF_KEY MIGRATE (EXPERIMENTAL)
        [*] TCP/IP networking
        [*]   IP: multicasting
        [*]   IP: advanced router
                Choose IP: FIB lookup algorithm (choose FIB_HASH if unsure) (FIB_HASH)
        [*]   IP: policy routing
        [*]   IP: equal cost multipath
        [*]     IP: equal cost multipath with caching support (EXPERIMENTAL)
        <M>       MULTIPATH: round robin algorithm
        < >       MULTIPATH: random algorithm (NEW)
        < >       MULTIPATH: weighted random algorithm (NEW)
        < >       MULTIPATH: interface round robin algorithm (NEW)
        v(+)

                  <Select>    < Exit >    < Help >
```

Netfilter

- Netfilter is the kernel layer to support applying iptables rultes.
  - It enables:
    - Filtering
    - Changing packets (masquerading)
    - Connection Tracking

Netfilter rule - example

- Short example:
- Applying the following iptables rule:
  - iptables -A INPUT -p udp --dport 9999 -j DROP
- This is NF_IP_LOCAL_IN rule;
- The packet will go to:
- *ip_rcv()*
- and then: *ip_rcv_finish()*
- And then *ip_local_deliver()*

Netfilter rule - example (contd)

- but it will **NOT** proceed to *ip_local_deliver_finish()* as in the usual case, without this rule.
- As a result of applying this rule it reaches *nf_hook_slow()* with verdict == NF_DROP (calls *skb_free()* to free the packet)
- See */net/netfilter/core.c.*

ICMP redirect message

- ICMP protocol is used to notify about problems.
- A REDIRECT message is sent in case the route

  is suboptimal (inefficient).
- There are in fact 4 types of REDIRECT
- Only one is used :
  - Redirect Host (ICMP_REDIR_HOST)
- See **RFC 1812 (Requirements for IP Version 4 Routers).**

ICMP redirect message - contd.

- To support sending ICMP redirects, the machine should be configured to send redirect messages.
  - ***/proc/sys/net/ipv4/conf/all/send_redirects*** should be 1.
- In order that the other side will receive redirects, we should set

  /proc/sys/net/ipv4/conf/all/accept_redirects to 1.

ICMP redirect message - contd.

- Example:
- Add a suboptimal route on 192.168.0.31:
- route add -net 192.168.0.10 netmask 255.255.255.255 gw 192.168.0.121
- Running now “route” on 192.168.0.31 will show a new entry:

Destination	**Gateway**	Genmask	Flags	Metric	Ref	Use	Iface
192.168.0.10	**192.168.0.121**	255.255.255.255	UGH	0	0	0	eth0

ICMP redirect message - contd.

- Send packets from 192.168.0.31 to 192.168.0.10 :
- ping 192.168.0.10 (from 192.168.0.31)
- We will see (on 192.168.0.31):
  - From 192.168.0.121: icmp_seq=2 **Redirect Host(New nexthop: 192.168.0.10)**
- now, running on 192.168.0.121:
  - route -Cn | grep .10
- shows that there is a new entry in the routing cache:
-

ICMP redirect message - contd.

- 192.168.0.31 192.168.0.10 192.168.0.10 ri 0 0 34 eth0
- The “r” in the flags column means: RTCF_DOREDIRECT.
- The 192.168.0.121 machine had sent a redirect by calling *ip_rt_send_redirect()* from *ip_forward()*.

(net/ipv4/*ip_forward.c)*

ICMP redirect message - contd.

- And on 192.168.0.31, running “route -C | grep .10” shows now a new entry in the routing cache: (in case accept_redirects=1)
- 192.168.0.31 192.168.0.10 192.168.0.10 0 0 1 eth0
- In case accept_redirects=0 (on 192.168.0.31), we will see:
- 192.168.0.31 192.168.0.10 192.168.0.121 0 0 0 eth0
- which means that the gw is still 192.168.0.121 (which is the route that we added in the beginning).

ICMP redirect message - contd.

- Adding an entry to the routing cache as a result of getting ICMP REDIRECT is done in *ip_rt_redirect(), net/ipv4/route.c.*
- The entry in the routing table is not deleted.

Neighboring Subsystem

- Most known protocol: ARP (in IPV6: ND, neighbour discovery)
- ARP table.
- Ethernet header is 14 bytes long:
  - Source mac address (6 bytes).
  - Destination mac address (6 bytes).
  - Type (2 bytes).
    - 0x0800 is the type for IP packet (ETH_P_IP)
    - 0x0806 is the type for ARP packet (ETH_P_ARP)
    - see: *include/linux/if_ether.h*

Neighboring Subsystem - contd

- When there is no entry in the ARP cache for the destination IP address of a packet, a broadcast is sent (ARP request, `ARPOP_REQUEST`: who has IP address x.y.z...). This is done by a method called *arp_solicit()*. (*net/ipv4/arp.c*)
- You can see the contents of the arp table by running:

"*cat /proc/net/arp*" or by running the "arp" from a command line .

- You can delete and add entries to the arp table; see man arp.

Bridging Subsystem

- You can define a bridge and add NICs to it ("enslaving ports") using *brctl* (from bridge-utils).
- You can have up to 1024 ports for every bridge device (BR_MAX_PORTS) .
- Example:
- *brctl addbr mybr*
- *brctl addif mybr eth0*
- *brctl show*

Bridging Subsystem - contd.

- When a NIC is configured as a bridge port, the *br_port* member of net_device is initialized.
  - (br_port is an instance of *struct net_bridge_port*).
- When we receive a frame, *netif_receive_skb()* calls *handle_bridge().*

Bridging Subsystem - contd.

- The bridging forwarding database is searched for the destination MAC address.
- In case of a hit, the frame is sent to the bridge port with *br_forward()* *(net/bridge/br_forward.c).*
- If there is a miss, the frame is flooded on all bridge ports using *br_flood()* *(net/bridge/br_forward.c).*
- Note: this is not a broadcast !
- The ebtables mechanism is the L2 parallel of L3 Netfilter.

Bridging Subsystem- contd

- Ebtables enable us to filter and mangle packets

  at the link layer (L2).

IPSec

- Works at network IP layer (L3)
- Used in many forms of secured networks like VPNs.
- Mandatory in IPv6. (not in IPv4)
- Implemented in many operating systems: Linux, Solaris, Windows, and more.
- RFC2401
- In 2.6 kernel : implemented by Dave Miller and Alexey Kuznetsov.
- Transformation bundles.
- Chain of dst entries; only the last one is for routing.

IPSec-cont.

- User space tools: http://ipsec-tools.sf.net
- Building VPN : http://www.openswan.org/ (Open Source).
- There are also non IPSec solutions for VPN
  - example: pptp
- struct xfrm_policy has the following member:
  - struct dst_entry *bundles.
  - __xfrm4_bundle_create() creates dst_entries (with the DST_NOHASH flag) see: *net/ipv4/xfrm4_policy.c*
- Transport Mode and Tunnel Mode.

IPSec-contd.

- Show the security policies:
  - *ip xfrm policy show*
- Create RSA keys:
  - *ipsec rsasigkey --verbose 2048 > keys.txt*
  - *ipsec showhostkey --left   > left.publickey*
  - *ipsec showhostkey --right > right.publickey*

IPSec-contd.

Example: Host to Host VPN (using openswan)

in */etc/ipsec.conf:*

```
conn linux-to-linux
left=192.168.0.189
leftnexthop=%direct
leftrsasigkey=0sAQPPQ...
right=192.168.0.45
rightnexthop=%direct
rightrsasigkey=0sAQNwb...
type=tunnel
 auto=start
```

IPSec-contd.

- *service ipsec start* (to start the service)
- *ipsec verify* – Check your system to see if IPsec got installed and started correctly.
- *ipsec auto –status*
  - *If you see "IPsec SA established" , this implies success.*
- Look for errors in */var/log/secure* (fedora core) or in kernel syslog

Tips for hacking

- Documentation/networking/ip-sysctl.txt: networking kernel tunabels
- Example of reading a hex address:
- iph->daddr == 0x0A00A8C0 or

means checking if the address is 192.168.0.10 (C0=192,A8=168, 00=0,0A=10).

Tips for hacking - Contd.

- Disable ping reply:
- echo 1 >/proc/sys/net/ipv4/icmp_echo_ignore_all
- Disable arp: ***ip link set eth0 arp off*** (the NOARP flag will be set)
- Also ***ifconfig eth0 -arp*** has the same effect.
- How can you get the Path MTU to a destination (PMTU)?
  - Use tracepath (see man tracepath).
  - Tracepath is from iputils.

Tips for hacking - Contd.

- Keep iphdr struct handy (printout): (from linux/ip.h)

```
struct iphdr {

    __u8    ihl:4,
      version:4;
      __u8  tos;
      __be16        tot_len;
      __be16        id;
      __be16        frag_off;
      __u8  ttl;
      __u8  protocol;
      __sum16    check;
      __be32        saddr;
      __be32        daddr;
        /*The options start here. */

};
```

Tips for hacking - Contd.

- NIPQUAD() : macro for printing hex addresses
- CONFIG_NET_DMA is for TCP/IP offload.
- When you encounter: xfrm / CONFIG_XFRM this has to to do with IPSEC. (transformers).

New and future trends

- IO/AT.
- NetChannels (Van Jacobson and Evgeniy Polyakov).
- TCP Offloading.
- RDMA.
- Mulitqueus. : some new nics, like e1000 and IPW2200, allow two or more hardware Tx queues. There are already patches to enable this.

New and future trends - contd.

- See: “Enabling Linux Network Support of Hardware Multiqueue Devices”, OLS 2007.
- Some more info in: Documentation/networking/multiqueue.txt in recent Linux kernels.
- Devices with multiple TX/RX queues will have the NETIF_F_MULTI_QUEUE feature (include/linux/netdevice.h)
- MQ nic drivers will call *alloc_etherdev_mq()* or *alloc_netdev_mq()* instead of *alloc_etherdev()* or *alloc_netdev()*.

Links and more info

1) Linux Network Stack Walkthrough (2.4.20):

http://gicl.cs.drexel.edu/people/sevy/network/Linux_network_stack_wa

2) Understanding the Linux Kernel, Second Edition

By Daniel P. Bovet, Marco Cesati

Second Edition December 2002

chapter 18: networking.

- Understanding Linux Network Internals, Christian benvenuti

Oreilly , First Edition.

Links and more info

3) Linux Device Driver, by Jonathan Corbet, Alessandro Rubini, Greg Kroah-Hartman

   Third Edition February 2005.

   – Chapter 17, Network Drivers

4) Linux networking: (a lot of docs about specific networking topics)

   – http://linux-net.osdl.org/index.php/Main_Page

5) netdev mailing list: http://www.spinics.net/lists/netdev/

Links and more info

6) Removal of multipath routing cache from kernel code:

http://lists.openwall.net/netdev/2007/03/12/76

http://lwn.net/Articles/241465/

7) Linux Advanced Routing & Traffic Control :

http://lartc.org/

8) ebtables – a filtering tool for a bridging:

http://ebtables.sourceforge.net/

Links and more info

9) **Writing Network Device Driver for Linux**: (article)

   – http://app.linux.org.mt/article/writing-netdrivers?locale=en

Links and more info

10) Netconf – a yearly networking conference; first was in 2004.

- http://vger.kernel.org/netconf2004.html
- http://vger.kernel.org/netconf2005.html
- http://vger.kernel.org/netconf2006.html
- Next one: Linux Conf Australia, January 2008,Melbourne
- David S. Miller, James Morris , Rusty Russell , Jamal Hadi Salim ,Stephen Hemminger , Harald Welte, Hideaki YOSHIFUJI, Herbert Xu ,Thomas Graf ,Robert Olsson ,Arnaldo Carvalho de Melo and others

Links and more info

11) **Policy Routing With Linux** - Online Book Edition

   – by Matthew G. Marsh (Sams).

   – http://www.policyrouting.org/PolicyRoutingBook/

12) THRASH - A dynamic LC-trie and hash data structure:

Robert Olsson Stefan Nilsson, August 2006

http://www.csc.kth.se/~snilsson/public/papers/trash/trash.pdf

13) IPSec howto:

http://www.ipsec-howto.org/t1.html

Links and more info

14) Openswan: Building and Integrating Virtual Private Networks , by Paul Wouters, Ken Bantoft

http://www.packtpub.com/book/openswan/mid/061205jqdnh2by

publisher: Packt Publishing.