Firewalls

Linux System Administration
Fall 2026

The purpose of Firewalls

- Control packet processing
  - Input - packets destined for a local address
  - Output - packets with source a local address
  - Forward - packets with source and destination that are not local
- Enforce connectivity policy

Defense in Depth

- Filter at the router
  - Limit access to DMZ and LAN
- Filter at each machine
  - Limit DMZ machine functionality
  - Trust devices on the LAN

Security is hard

- Don't write firewall rules if you don't know what you are doing
  - Don't assume that after this class, you can write firewall rules!!!
- Be paranoid
  - Don't trust the network

Linux Firewalls

- `ipchains`
  - The original 1990s (stateless)
- `iptables`
  - Mainstay of most firewalls (1998-2022)
- `nftables`
  - new hotness (2014-)
- `netfilter`
  - Kernel module that implements packet filtering

Wrappers around iptables/nftables

- `firewalld` Redhat
- `ufw` uncomplicated firewall Debian
- `shorewall` simplified rule generator
- `fail2ban` dynamic blocking
- `pf` popular BSD firewall

Testing firewalls

- `ping` & `traceroute` basic connectivity
- `nmap` network scanner
  - scan for TCP on 100.64.42.0/24
    `nmap -sS 100.64.42.0/24`
  - fast scan all ports on 100.64.42.3
    `nmap -T4 -n -Pn 100.64.42.3`
- ***It matters where you run the test from***

nmap -n -sS -sU 100.64.42.0/24

Nmap scan report for 100.64.42.1
Host is up (0.040s latency).
Not shown: 1997 closed ports

PORT	STATE	SERVICE
22/tcp	open	ssh
67/udp	open|filtered	dhcps
123/udp	open|filtered	ntp

Nmap scan report for 100.64.42.2
Host is up (0.037s latency).
Not shown: 1997 closed ports

PORT	STATE	SERVICE
22/tcp	open	ssh
111/tcp	open	rpcbind
111/udp	open	rpcbind

Nmap scan report for 100.64.42.3
Host is up (0.040s latency).
Not shown: 1995 closed ports

PORT	STATE	SERVICE
22/tcp	open	ssh
80/tcp	open	http
111/tcp	open	rpcbind
68/udp	open|filtered	dhcpc
111/udp	open	rpcbind

Nmap scan report for 100.64.42.4
Host is up (0.034s latency).
Not shown: 1996 closed ports

PORT	STATE	SERVICE
22/tcp	open	ssh
80/tcp	open	http
111/tcp	open	rpcbind
111/udp	open	rpcbind

Nmap scan report for 100.64.42.6
Host is up (0.037s latency).
Not shown: 1994 closed ports

PORT	STATE	SERVICE
22/tcp	open	ssh
53/tcp	open	domain
111/tcp	open	rpcbind
53/udp	open	domain
68/udp	open|filtered	dhcpc
111/udp	open	rpcbind

Stateless vs. Statefull

- Stateless
  - Packets define what is allowed
  - Simplifies work for developers and improves performance
- Statefull (connection tracking)
  - Decision may depend on previous packets
  - Greatly simplifies writing firewall for user
    - Allow out what was allowed in
    - Absolutely required for complex protocols like ftp

nftables vs. iptables

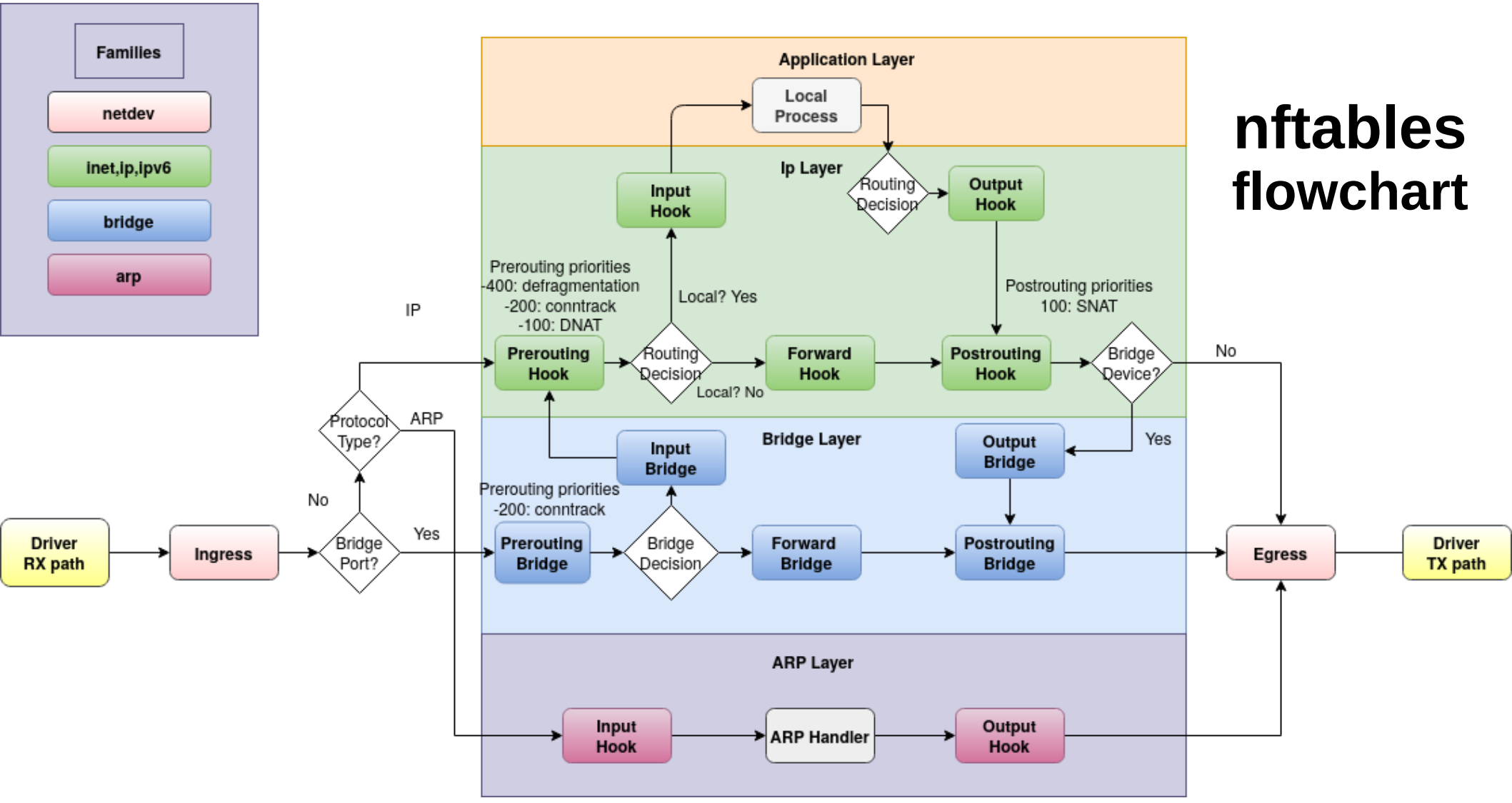
- Same team of developers
  - Same kernel module (netfilter)
  - Same terminology
- New syntax in nftables
  - More flexible rules
- No default chains in nftables
  - Improves performance and scalability
- Comprehensive types in nftables
  - Includes ARP, IPv6, ethernet

`iptables` terminology

- `table` container for chains
  - Predefined names `filter`, `nat`, `mangle`, `raw`
- `chain` list of rules executed in sequence
  - `filter` table has `INPUT`, `OUTPUT` and `FORWARD`
  - `nat` table has `PREROUTING, POSTROUTING` and `OUTPUT`
  - Default action is called policy
- `rule` defined action
  - Actions are `ACCEPT`, `DROP`, `QUEUE` or `RETURN`

`nftables` terminology

- `table` container for chains
- `chain` list of rules
  - `type` filter, route or nat
  - `hook` where this chain fits
  - `priority` used to order chains
  - `policy` default action
- `rule` defined action


Families
netdev
inet,ip,ipv6
bridge
arp
Application Layer
Local Process
Ip Layer
Routing Decision
Output Hook
Input Hook
Prerouting priorities
-400: defragmentation
-200: conntrack
-100: DNAT
Local? Yes
Postrouting priorities
100: SNAT
IP
Prerouting Hook
Routing Decision
Local? No
Forward Hook
Postrouting Hook
Bridge Device?
No
Yes
Bridge Layer
Input Bridge
Output Bridge
Protocol Type?
ARP
No
Prerouting priorities
-200: conntrack
Driver RX path
Ingress
Bridge Port?
Yes
Prerouting Bridge
Bridge Decision
Forward Bridge
Postrouting Bridge
Egress
Driver TX path
ARP Layer
Input Hook
ARP Handler
Output Hook
nftables
flowchart

Example: local access to ssh server

- Accept only TCP/IP connections on port 22 from LAN and DMZ
- Allow any outgoing connections
- iptables
  - ```
    iptables -A INPUT -p tcp --dport 22 -s 100.64.42.0/24 -j ACCEPT
    iptables -A INPUT -p tcp --dport 22 -s 10.21.32.0/24  -j ACCEPT
    iptables -P INPUT DROP
    iptables -P OUTPUT ACCEPT
    ```
- nftables
  - ```
    nft -i
    table ip saclass {
      chain incoming {
        type filter hook input priority 0; policy drop;
        ip saddr {100.64.42.0/24,10.21.32.0/24} tcp dport 22 accept
      }
    }
    # No output chain - defaults to accept
    ```

Understanding iptables/nftables

- Packets mapped to table & chains based on source/dest
  - filter input, output, forward, etc
- Rules in chain are executed in order
  - check for match of address, port, etc
    - action taken if match
  - rest of rules are not evaluated
    - except if the action was `jump`
- You have to allow replies to establish a connection

tables

- The table select the packet family
- `iptables` predefines `filter`, `nat`, `mangle`, `raw`
- `nftables` user defined `table` *`family`* `name`
  - `ip` IPv4
  - `ip6` IPv6
  - `inet` Internet (IPv4 or IPv6)
  - `arp` IPv4 ARP
  - `bridge` bridge (ethernet)
  - Example: `nft add table ip saclass`

base chains

- `iptables` predefined `filter` chains `INPUT`, `OUTPUT` and `FORWARD`
  - Policy set by `iptables -P chain action`
    Example: `iptables -P INPUT DROP`
- `nftables` user defined `table chain name`
  - `type` chain type `filter`, `nat`, `route`
  - `hook` where it fits `input`, `forward`, `output`, `prerouting`, `postrouting`
  - `priority` order of chains (low to high) numeric or by name
  - `policy` default action `accept` or `drop`
  - Example: Incoming packet filter drop except what is allowed

```
nft add chain saclass incoming
   '{type filter hook input priority 0; policy drop;}'
```

rules

- Rules are executed in order
- Execution stops when a rule matches and action is taken
  - iptables actions are `ACCEPT`, `DROP`, `REJECT`
  - nftables actions are `accept`, `drop`, `reject`
- Example: Allow incoming to port 22 (ssh)
  - iptables
    `iptables -A INPUT` **`-p tcp --dport 22 -j ACCEPT`**
  - nftables
    `nft add rule saclass incoming` **`tcp dport 22 accept`**
- All the conditions in the rule must match

iptables

- `-F` flush (clear)
- `-A` append rule
- `-I` insert rule
- `-D` delete rule
- `-N` new chain
- `-P` set policy

- Set rules on boot
  - Redhat
    - `/etc/sysconfig/iptables`
  - Debian
    - `/etc/iptables/rules.v4`
- Show rules
  - `iptables -nvL`

Example /etc/sysconfig/iptables

```
#iptables for dundermifflin web server
*filter
# Default drop INPUT, accept FORWARD and OUTPUT
:INPUT   DROP   [0:0]
:FORWARD ACCEPT [0:0]
:OUTPUT  ACCEPT [0:0]
# Allow established or related connections
-A INPUT -m conntrack --ctstate ESTABLISHED,RELATED -j ACCEPT
# Allow selected icmp traffic
-A INPUT -p icmp --icmp-type echo-request            -j ACCEPT
-A INPUT -p icmp --icmp-type echo-reply              -j ACCEPT
-A INPUT -p icmp --icmp-type time-exceeded           -j ACCEPT
-A INPUT -p icmp --icmp-type destination-unreachable -j ACCEPT
-A INPUT -p icmp                                     -j DROP
# Allow any inbound http
-A INPUT -p tcp --dport 80  -j ACCEPT
# Permit selected inbound ssh
-A INPUT -p tcp -s 198.18.0.0/16 --dport 22 -j ACCEPT
-A INPUT -p tcp -s 100.64.0.0/16 --dport 22 -j ACCEPT
-A INPUT -p tcp -s 10.21.32.0/24 --dport 22 -j ACCEPT
# Deny outbound to facebook
-A OUTPUT -d 157.240.28.35 -j DROP
COMMIT
```

`nft` (nftables)

- `list` show content
  - `ruleset`
  - `table`
  - `chain`
- `add` item
- `delete` item
- `flush` empty

- Set rules on boot
  - Redhat
    - `/etc/sysconfig/nftables.conf`
  - Debian
    - `/etc/nftables.conf`
- Show all rules
  - `nft list ruleset`

Example /etc/sysconfig/nftables.conf

- ```
  #!/usr/sbin/nft -f

  flush ruleset

  table ip saclass {
    chain incoming {
      type filter hook input priority 0; policy drop;
      # Allow established or related connections
      ct state related,established accept
      # Allow selected icmp traffic
      icmp type {echo-reply,destination-unreachable,echo-request,time-exceeded} accept
      # Allow any inbound http
      tcp dport 80 accept
      # Permit selected inbound ssh
      ip saddr {10.21.32.2/24,198.18.0.0/16} tcp dport 22 accept
    }
    chain outgoing {
      type filter hook output priority 0; policy drop;
      # Block facebook
      ip daddr 157.240.28.35 drop
    }
  }
  #  No forward chain which allows everything
  ```
  ```

Connection Tracking `ct`

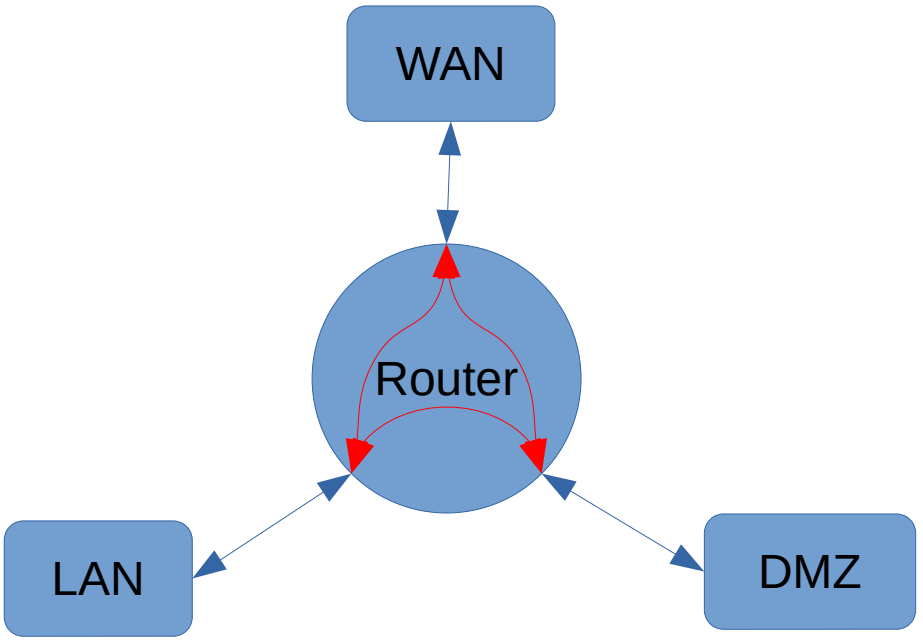
- Statefull firewall
- Allows replies to permitted connections
- Critical for complex protocols like `ftp`
- Typical usage
  - `ct state established,related accept`
  - `ct state invalid drop`

Machine A Firewall

- Inbound connections
  - ssh from LAN, DMZ, WAN and VPN
  - DHCP and NTP from LAN and DMZ
  - returns from outbound connections
- Outbound connections
  - Any except facebook

Machine A Forwarding

- Three interfaces
  - **LAN**, **DMZ**, **WAN**
- Six paths
  - **WAN** to **LAN**
  - **WAN** to **DMZ**
  - **DMZ** to **WAN**
  - **DMZ** to **LAN**
  - **LAN** to **WAN**
  - **LAN** to **DMZ**



Machine A Forward Chains

- **WAN** to **DMZ**
  - ICMP
  - UDP DNS
  - TCP ssh, http, grader
  - return packets
- **WAN** to **LAN**
  - return packets
- **LAN** to **WAN**
  - anything except facebook
- **LAN** to **DMZ**
  - anything
- **DMZ** to **WAN**
  - ICMP
  - UDP DNS
  - TCP DNS, http, https
  - return packets
- **DMZ** to **LAN**
  - ICMP
  - TCP ssh,NFS
  - return packets