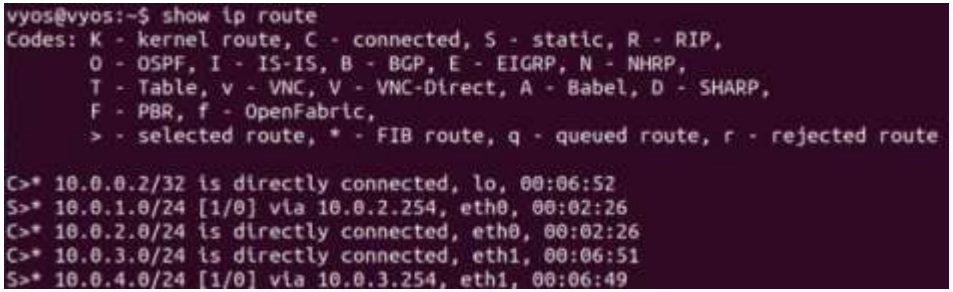
Static and Default Routes

- Categories of routing table entries
  - Directly connected
  - Paths to remote networks
  - Host routes
  - Default route
- Directly connected routes
  - IP network/subnet for each active interface
- Static routes
  - Added manually by administrator
- Default route
  - Static route used if no other match
  - 0.0.0.0/0 or ::/0

Routing Tables and Path Selection

- Protocol
  - Source of the route
- Destination
  - Network/host address and prefix
- Interface
  - Outgoing interface
- Gateway/next hop
  - Address of next router along the path



Routing Table Example

Router B Routing Table		
Network	Interface	Source
10.0.1.0/24	G0	Static
10.0.2.0/24	G0	Connected
10.0.3.0/24	G1	Connected
10.0.4.0/24	G1	Static

Router A Routing Table		
Network	Interface	Source
10.0.1.0/24	G0	Connected
10.0.2.0/24	G1	Connected
10.0.3.0/24	G1	Static
10.0.4.0/24	G1	Static

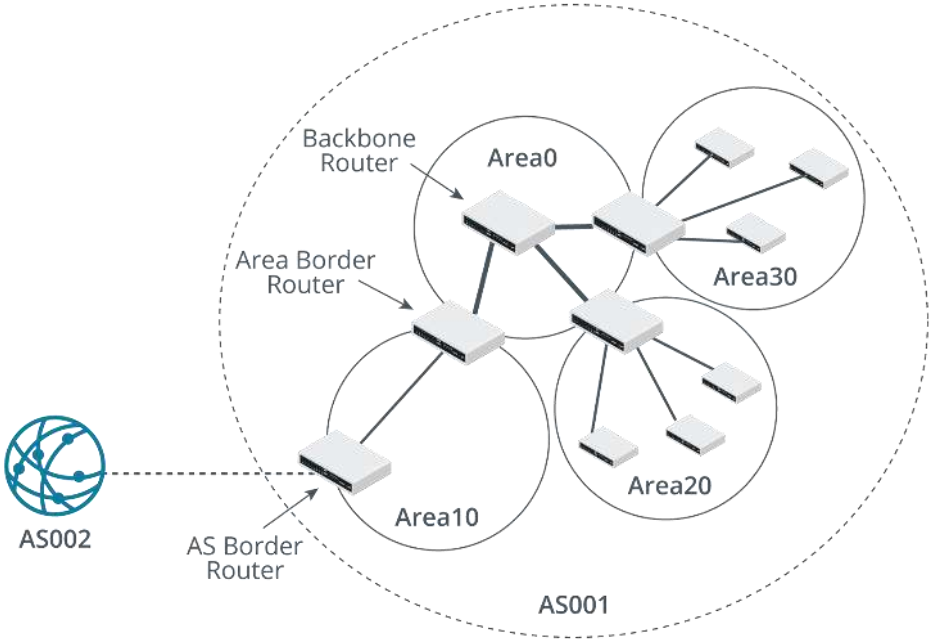
Router C Routing Table		
Network	Interface	Source
0.0.0.0/0	G0	Static
10.0.3.0/24	G0	Connected
10.0.4.0/24	G1	Connected

Dynamic Routing Protocols

- Build routing information base
- Share information with other routers (learned routes)
- Topology and metrics
  - Distance vector versus link state
  - Metrics assess similar routes for use of least-cost path in IP routing table
  - Algorithm determines nature of metrics
- Convergence
  - All routers agree on network topology

Open Shortest Path First

- Link state interior gateway protocol suited to complex private networks
- Group related networks by area hierarchy
- Supports classless addressing
- Runs over IP directly (protocol number 89) using multicasts



Border Gateway Protocol

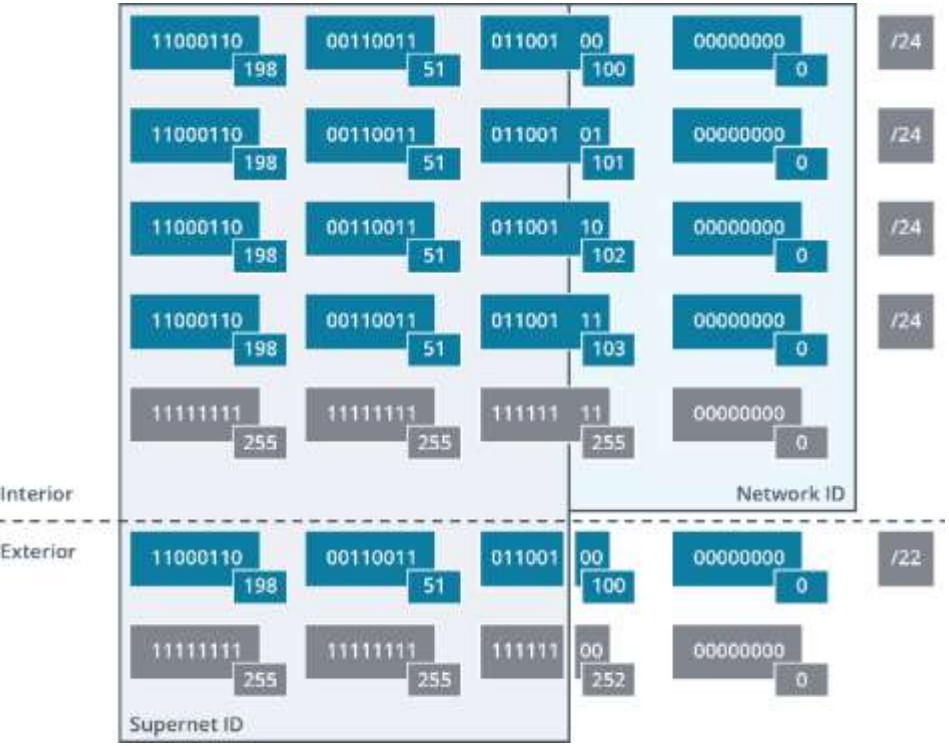
- Classed as hybrid or path vector
- Usually deployed as an Exterior Gateway Protocol
- Supports routing on the Internet
  - Autonomous Systems (ASes) hide internal network complexity from Internet routers
  - Autonomous System Number (ASN)
  - BGP routers exchange AS path data between Autonomous Systems
- Supports classless addressing
- Runs over TCP on port 179

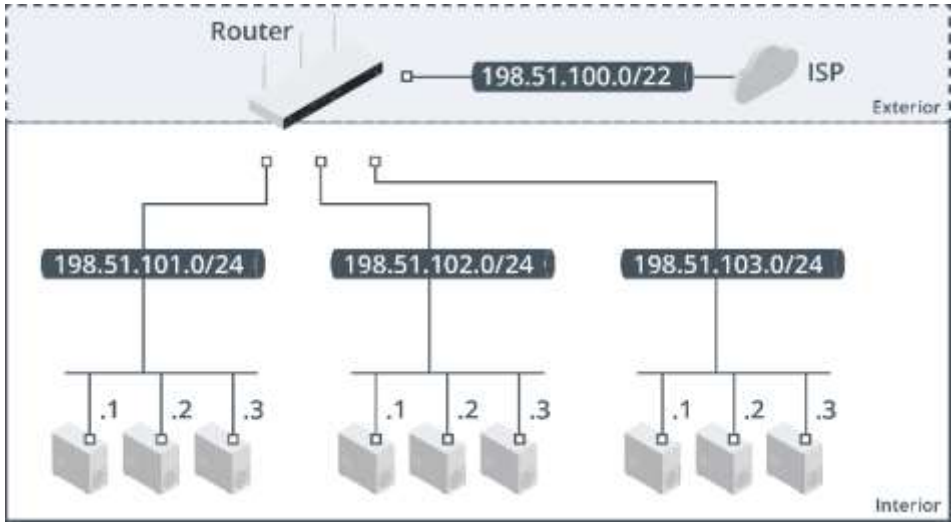
Administrative Distance

Source	AD
Local interface/Directly connected	0
Static route	1
BGP	20
EIGRP	90
OSPF	110
RIP	120
Unknown	255

- Longer prefixes preferred for path selection
- Protocols add one route per destination prefix to global IP routing table
- Routing protocol uses metric to determine least-cost path
- Router uses administrative distance to prefer paths to same destination learned by different protocols

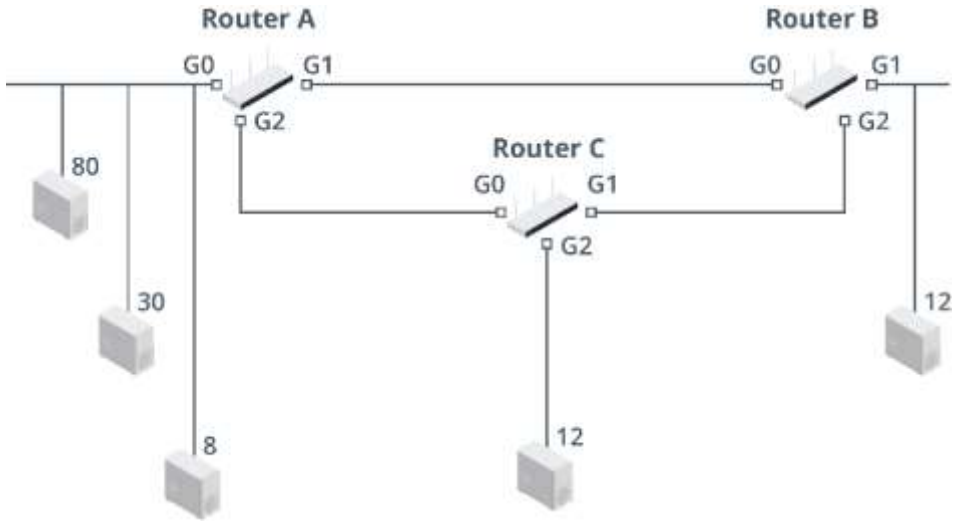
Classless Inter-Domain Routing





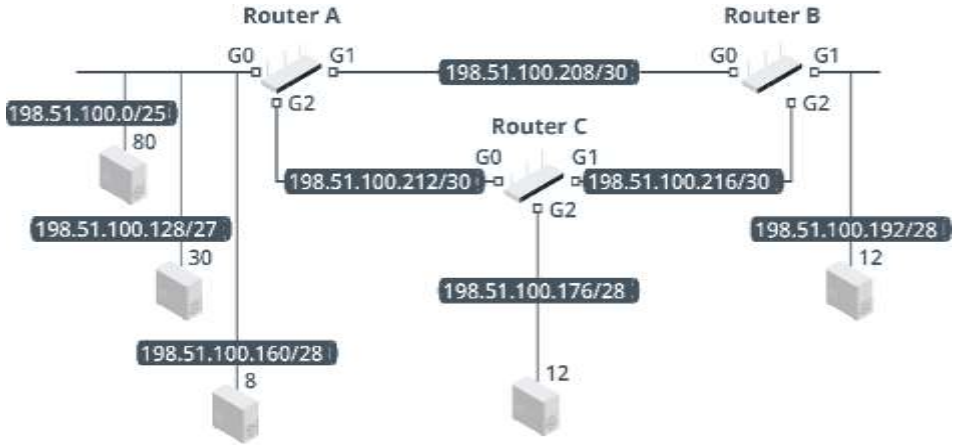
Variable Length Subnet Masks

- Use address space in IPv4 network more efficiently
- Rather than use the same mask for all subnets, use different mask lengths according to host numbers per subnet

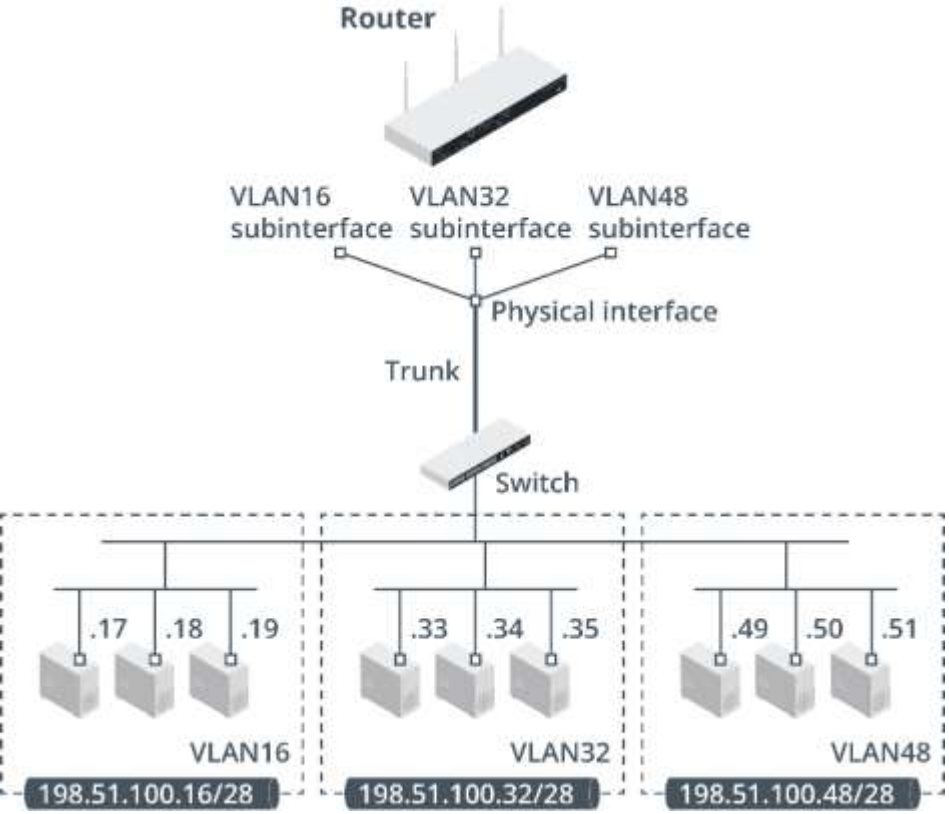


VLSM Design

Office/Subnet	Required Number of IP Addresses	Mask Bits	Actual Number of IP Addresses	Prefix
Main Office 1 (Router A)	80	7	126	/25
Main Office 2 (Router A)	30	5	30	/27
Main Office 3 (Router A)	8	4	14	/28
Branch Office (Router B)	12	4	14	/28
Branch Office (Router C)	12	4	14	/28
Router A – Router B	2	2	2	/30
Router A – Router C	2	2	2	/30
Router B – Router C	2	2	2	/30



Internal Routers



- Implement subnets and internal borders/areas
- Subinterfaces
  - Split single physical connection to per-VLAN subinterfaces
- Layer 3 switches
  - Hardware optimized to forward between VLANs

tracert and traceroute

- traceroute
  - UDP probes to identify each hop in a path
  - Increments TTL with each iteration
  - Outputs number of hops, the IP address of the ingress interface of the router or host, and time taken in milliseconds (ms)
- tracert
  - Windows
  - Uses ICMP

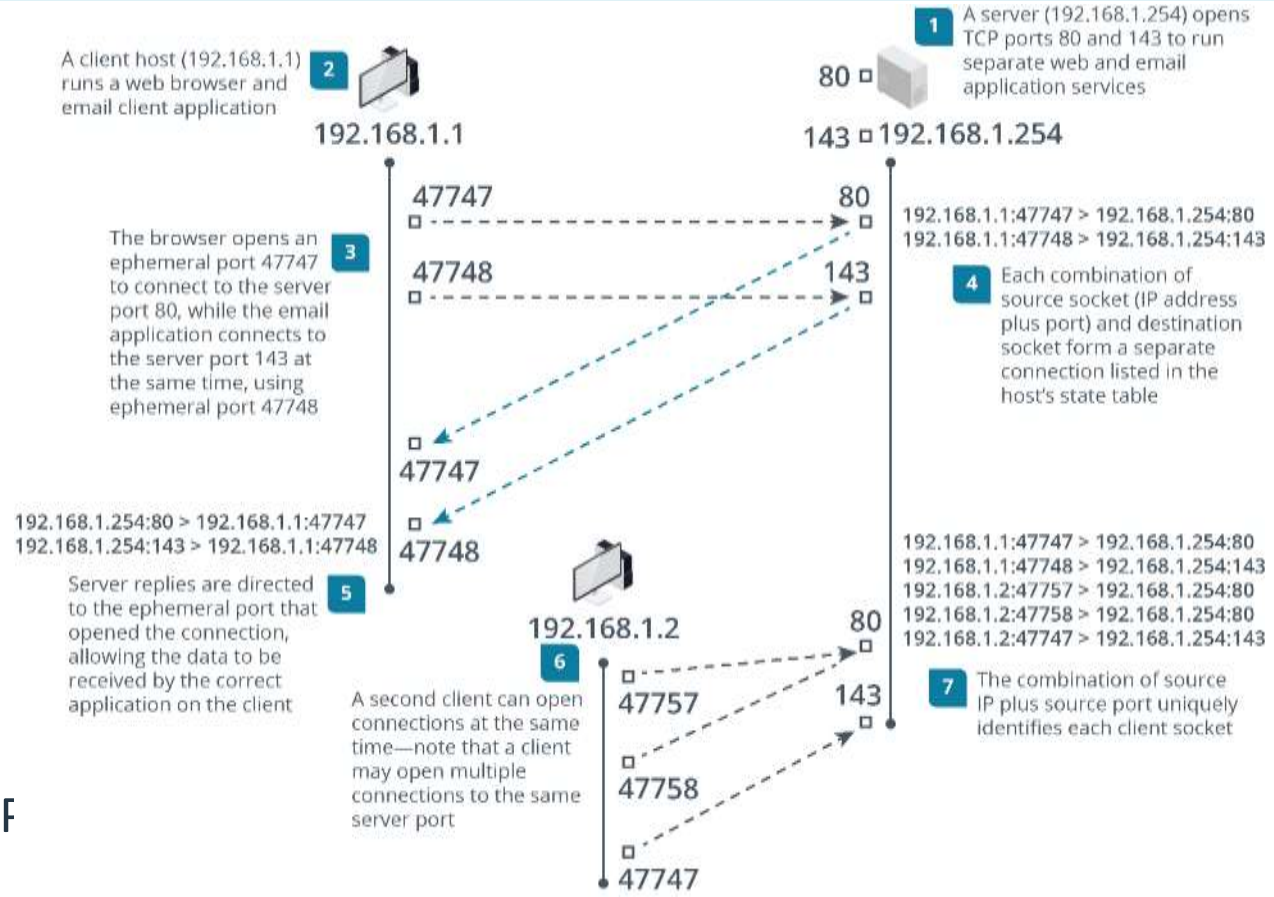
```
PS C:\Windows\system32> tracert 203.0.113.33

Tracing route to 203.0.113.33 over a maximum of 30 hops

  1    <1 ms    <1 ms    <1 ms  10.1.24.254
  2    <1 ms    <1 ms    <1 ms  10.1.128.253
  3     1 ms     *        1 ms  198.51.100.30
  4     1 ms     1 ms     1 ms  198.51.100.253
  5     2 ms     2 ms     1 ms  203.0.113.33

Trace complete.
```

Missing Route Issues

- Use ping and traceroute/tracert to identify where network path fails
- Check routing table
  - Missing static route
  - Dynamic protocol failure
- Device configuration review

Transport Layer Ports and Connections

- Identify individual applications as port numbers
- Socket
  - Source IP plus port bound to software process
- Connection
  - Client IP and port connected to server IP and port



Transmission Control Protocol

- Connection-oriented, guaranteed delivery
- Segments with header fields to track sequence and acknowledgements

TCP Handshake and Teardown

```
Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.

C:\Users\administrator>netstat -ano

Active Connections

  Proto  Local Address          Foreign Address        State           PID
  TCP    0.0.0.0:135            0.0.0.0:0              LISTENING       652
  TCP    0.0.0.0:445            0.0.0.0:0              LISTENING       4
  TCP    0.0.0.0:5985           0.0.0.0:0              LISTENING       4
  TCP    0.0.0.0:47001          0.0.0.0:0              LISTENING       4
  TCP    0.0.0.0:49664          0.0.0.0:0              LISTENING       428
  TCP    0.0.0.0:49665          0.0.0.0:0              LISTENING       912
  TCP    0.0.0.0:49666          0.0.0.0:0              LISTENING       864
  TCP    0.0.0.0:49669          0.0.0.0:0              LISTENING       1996
  TCP    0.0.0.0:49670          0.0.0.0:0              LISTENING       524
  TCP    0.0.0.0:49703          0.0.0.0:0              LISTENING       516
  TCP    0.0.0.0:49706          0.0.0.0:0              LISTENING       524
  TCP    10.1.0.100:139         0.0.0.0:0              LISTENING       4
  TCP    10.1.0.100:49764       10.1.0.192:3000        ESTABLISHED     4280
  TCP    [::]:135               [::]:0                 LISTENING       652
  TCP    [::]:445               [::]:0                 LISTENING       4
  TCP    [::]:5985              [::]:0                 LISTENING       4
  TCP    [::]:47001             [::]:0                 LISTENING       4
```

- Three-way handshake
  - Client SYN
  - Server SYN/ACK
  - Client ACK

User Datagram Protocol

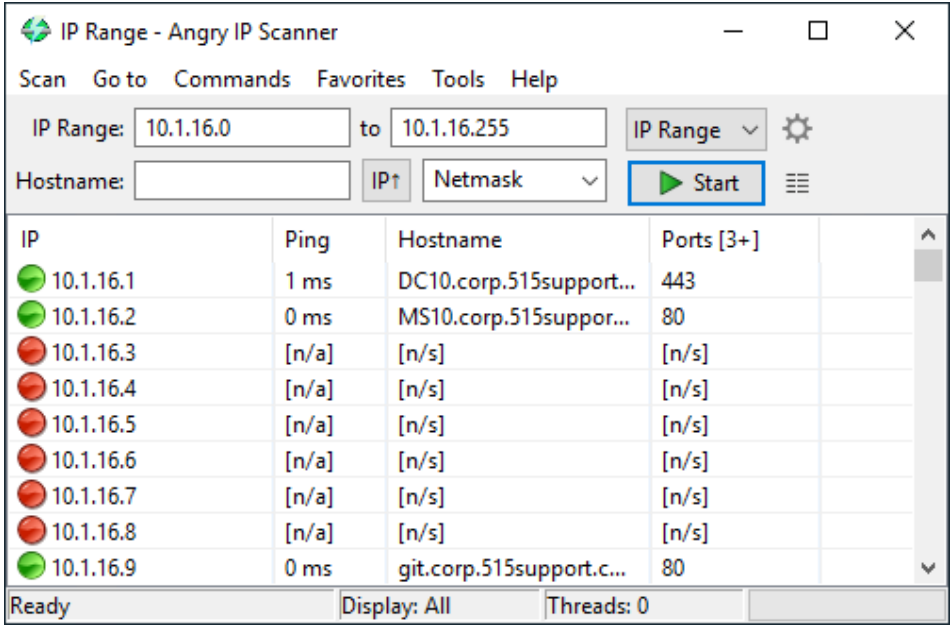
- Connectionless, non-guaranteed communication
- Fewer header fields required
- Used by protocols that can tolerate lost or out-of-order packets

Common TCP and UDP Ports

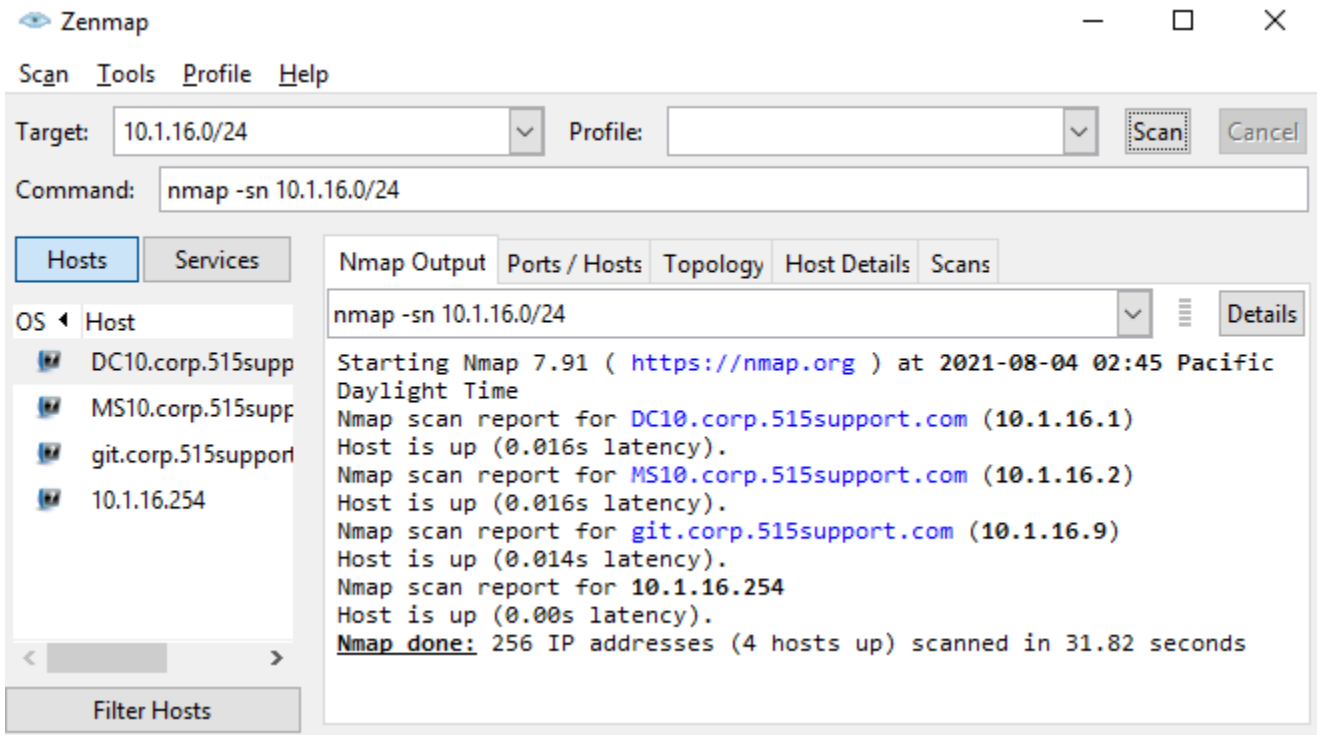
TCP/UDP/53 DNS	UDP/123 NTP	UDP/67 DHCP-Server	UDP/68 DHCP-Client	UDP/546 DHCPv6-Client	UDP/547 DHCPv6-Server	TCP/80 HTTPS
TCP/25 SMTP	TCP/587 SMTPS	TCP/110 POP	TCP/995 POP3S	TCP/143 IMAP	TCP/993 IMAPS	TCP/443 HTTPS
UDP/5004 RTP	UDP/5005 RTCP	TCP/UDP/5060 SIP	TCP/UDP/5061 SIPS	TCP/1433 MS-SQL	TCP/1521 SQL*net	TCP/3306 MySQL
TCP/20 FTP-Data	TCP/21 FTP-Control	TCP/22 SSH/SFTP	TCP/23 Telnet	UDP/69 TFTP	TCP/3389 RDP	
UDP/514 Syslog	UDP/161 SNMP	UDP/162 SNMP-Trap	TCP/UDP/389 LDAP	TCP/636 LDAPS		TCP/445 SMB over TCP/IP

IP Scanners

- Perform host and topology discovery to maximize network visibility
  - Standalone tools
  - IP Address Management (IPAM)
- Determining “up” status
  - ping, arp, traceroute
  - Simple Network Management Protocol (SNMP)
  - Query DHCP/DNS



Nmap


Zenmap
Scan Tools Profile Help
Target: 10.1.16.0/24
Profile:
Scan
Cancel
Command: nmap -sn 10.1.16.0/24
Hosts
Services
OS Host
DC10.corp.515supp
MS10.corp.515supp
git.corp.515support
10.1.16.254
Filter Hosts
Nmap Output
Ports / Hosts
Topology
Host Details
Scans
nmap -sn 10.1.16.0/24
Details
Starting Nmap 7.91 (https://nmap.org) at 2021-08-04 02:45 Pacific Daylight Time
Nmap scan report for DC10.corp.515support.com (10.1.16.1)
Host is up (0.016s latency).
Nmap scan report for MS10.corp.515support.com (10.1.16.2)
Host is up (0.016s latency).
Nmap scan report for git.corp.515support.com (10.1.16.9)
Host is up (0.014s latency).
Nmap scan report for 10.1.16.254
Host is up (0.00s latency).
Nmap done: 256 IP addresses (4 hosts up) scanned in 31.82 seconds

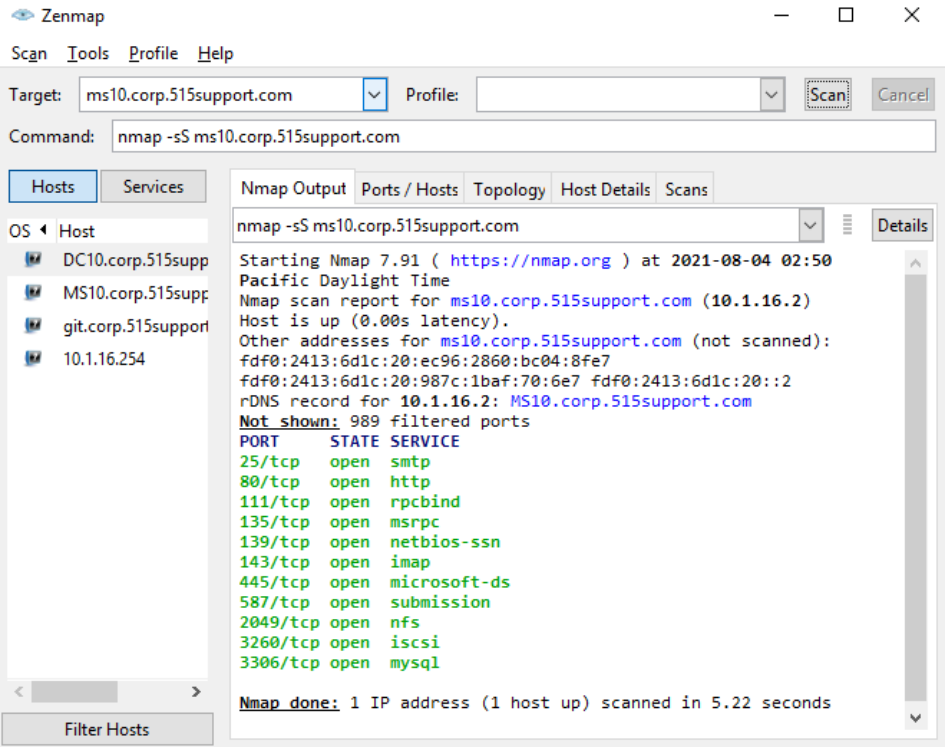
netstat

- Report local port status
  - TCP versus UDP
  - Local IP and port
  - Remote IP and port
  - State (Listening, Established, …)
- Options
  - Skip name resolution, show process, report statistics, …
  - Windows versus Linux syntax differences
  - iproute2 ss and nstat commands replace netstat

```
lamp@lamp:~$ netstat -tua
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 0.0.0.0:5000            0.0.0.0:*               LISTEN
tcp        0      0 localhost:mysql         0.0.0.0:*               LISTEN
tcp        0      0 localhost:domain        0.0.0.0:*               LISTEN
tcp        0      0 0.0.0.0:ssh             0.0.0.0:*               LISTEN
tcp        0      0 localhost:33060         0.0.0.0:*               LISTEN
tcp        0      1 172.16.0.201:52492      172.16.0.254:domain     SYN_SENT
tcp6       0      0 [::]:http               [::]:*                  LISTEN
tcp6       0      0 [::]:ssh                [::]:*                  LISTEN
udp        0      0 172.16.0.201:43367      172.16.0.254:domain     ESTABLISHED
udp        0      0 172.16.0.201:42410      172.16.0.254:domain     ESTABLISHED
udp        0      0 172.16.0.201:47084      172.16.0.254:domain     ESTABLISHED
udp        0      0 localhost:domain        0.0.0.0:*
udp        0      0 172.16.0.201:bootpc     0.0.0.0:*
```

```
lamp@lamp:~$ netstat -i
Kernel Interface table
Iface      MTU    RX-OK RX-ERR RX-DRP RX-OVR    TX-OK TX-ERR TX-DRP TX-OVR Flg
eth0      1500     4069      0      0 0          8134      0      0      0 BMRU
lo       65536     5322      0      0 0          5322      0      0      0 LRU
```

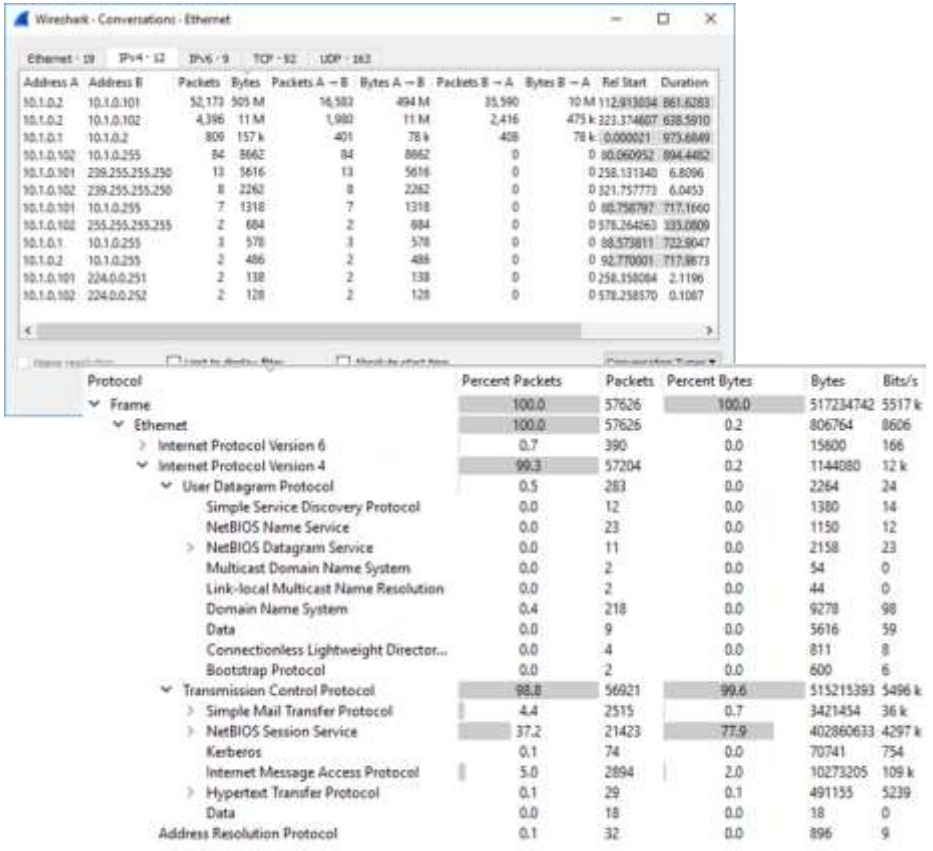
Remote Port Scanners



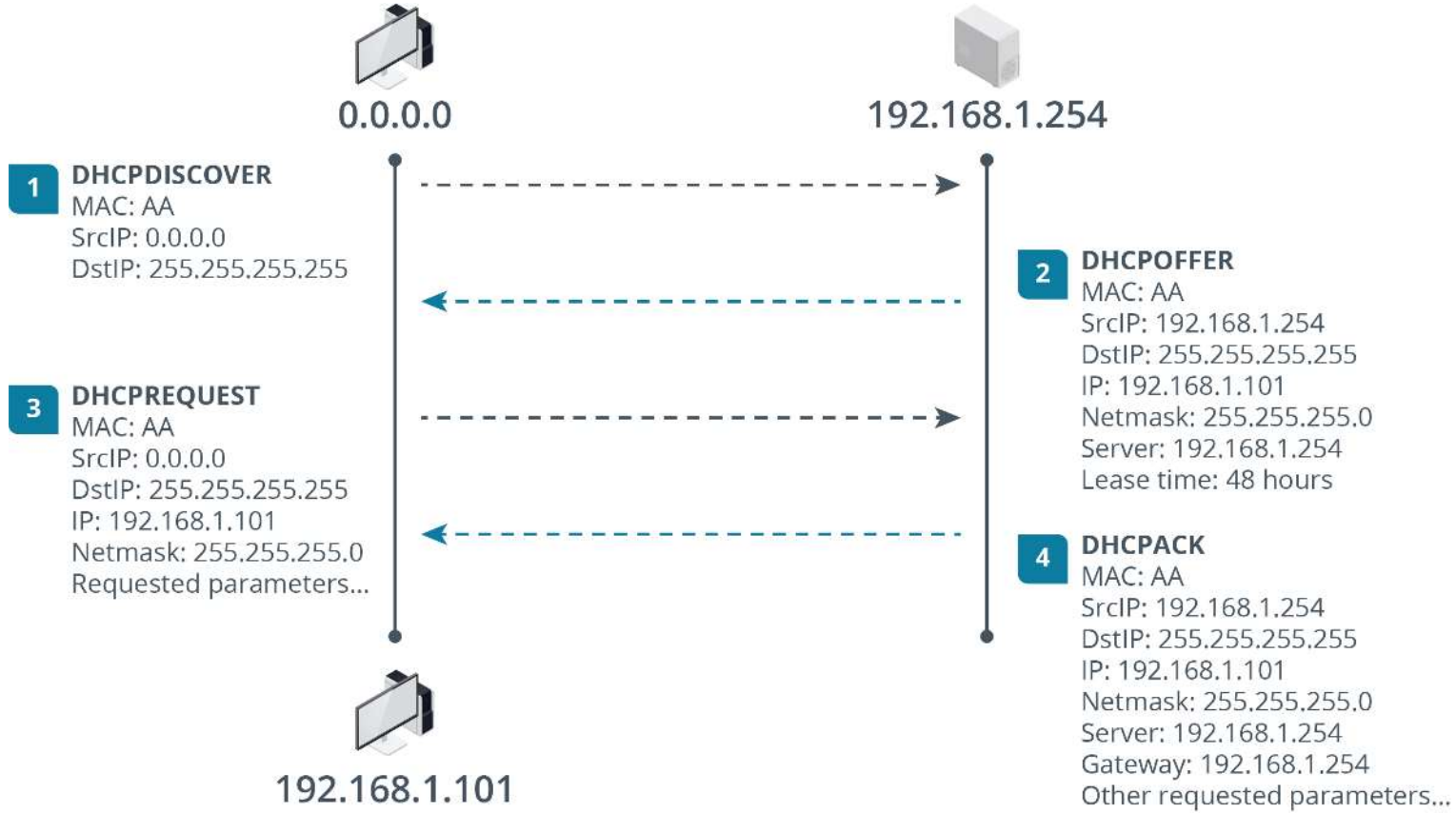
- Report port status from a remote host
- Scan types
  - Half-open, full connect, UDP, port range, …
- Host and service fingerprinting

Protocol Analyzers

- Decode frames captured by sniffer
  - Live capture or saved capture file (pcap)
  - Parse header fields to reveal packet metadata
  - Reconstruct TCP streams
- Analyze traffic statistics
  - Per-host utilization
  - Per-protocol utilization



Dynamic Host Configuration Protocol



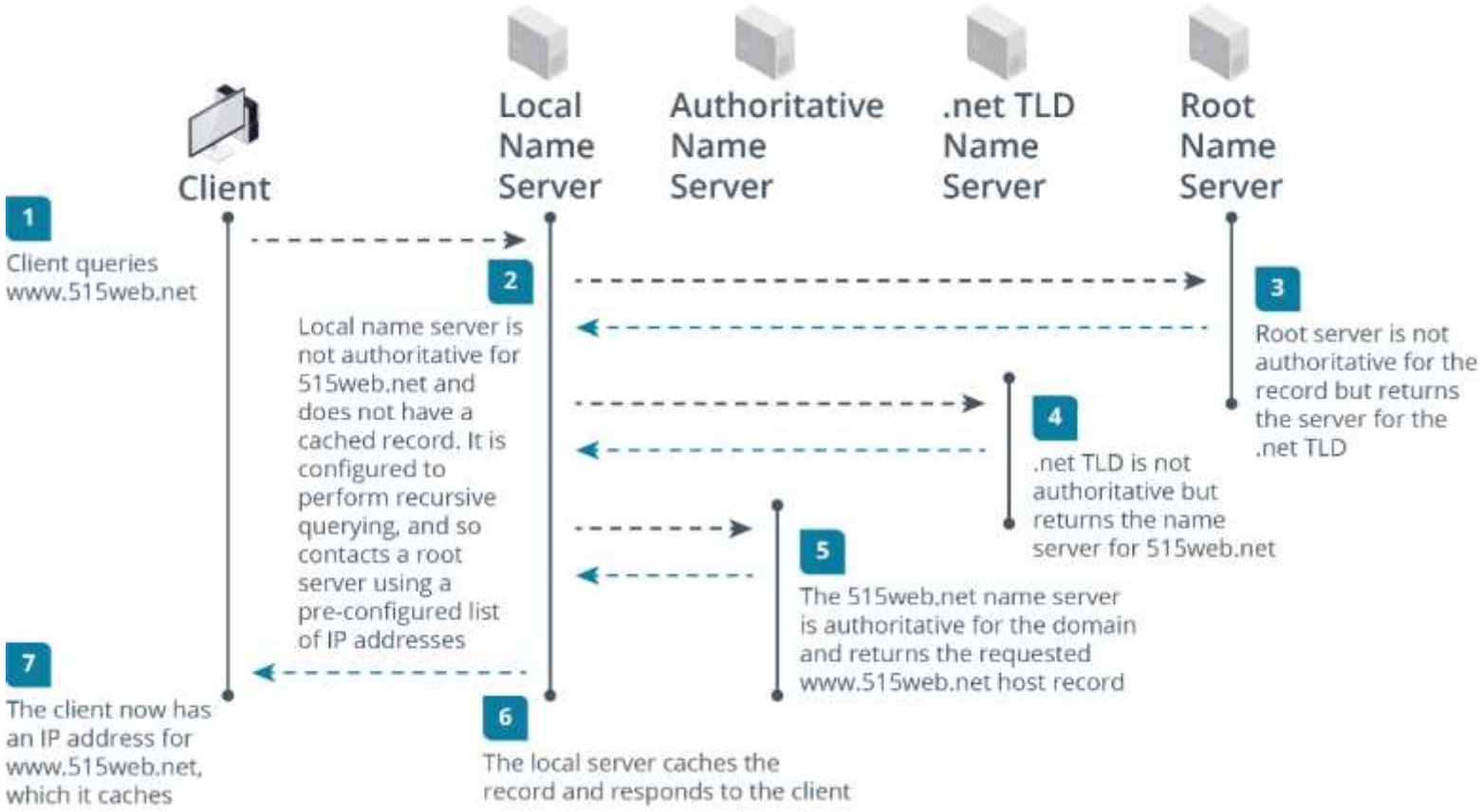
DHCP Reservations and Exclusions

- Static assignments and exclusions
  - Use IP addresses outside address pool
  - Exclude specific IP addresses from pool range
- MAC/IP reservation
  - Always allocate a device the same pre-selected IP
- Automatic allocation
  - Lease any IP address from the pool to the same client persistently

Host Names and Fully Qualified Domain Names

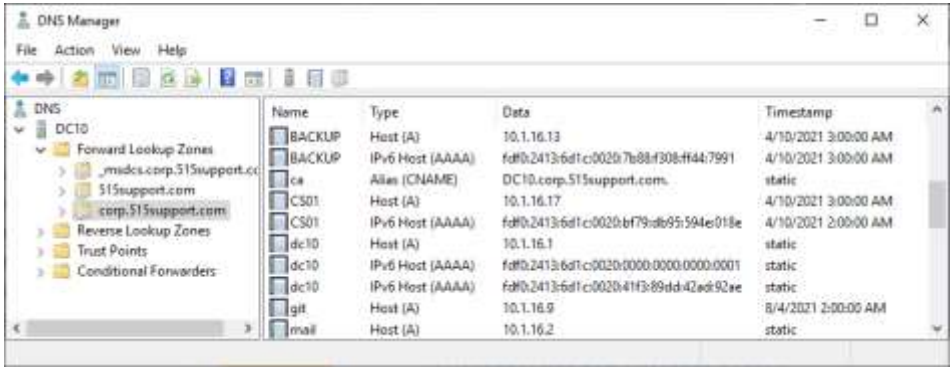
- Fully Qualified Domain Name (FQDN)
  - Host name + domain suffix
- Doman suffix
  - Domain name + Top Level Domain (TLD)
  - Subdomains
- Naming rules
  - Host name must be unique within domain
  - Labels separated by periods
  - Max length of 253 characters overall and 63 characters per label (excluding periods)

Name Resolution Using DNS



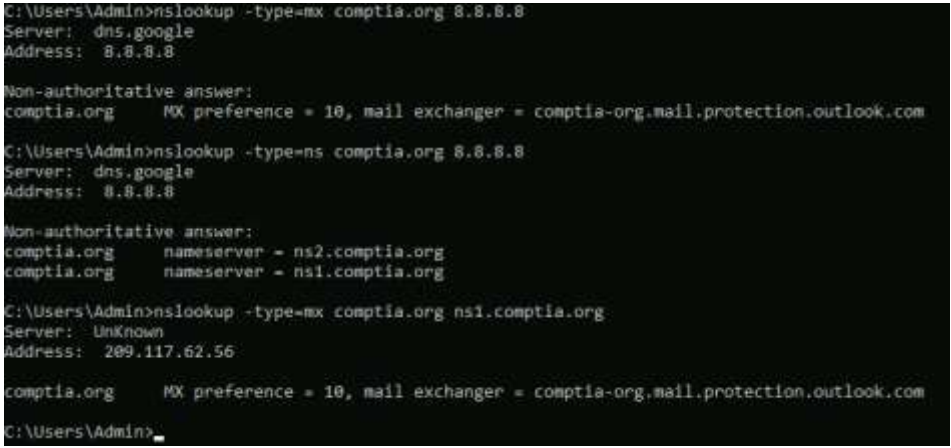
Host Address and Canonical Name Records

- IPv4 Host (A)
  - Host record to resolve a name to an IPv4 address
- IPv6 Host (AAAA)
  - Host record to resolve a name to an IPv6 address
- Canonical Name (CNAME)
  - Alternative name for a particular A or AAAA record



nslookup

- Query a name server for resource records
- nslookup –Option Host Server
- Interactive mode
- PowerShell cmdlets



dig

```
toor@LX20D:~$ dig +nocmd +noedns +noquestion 515support.com MX
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 12449
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; ANSWER SECTION:
515support.com.         6968    IN      MX      10 mail.515support.com.

;; Query time: 0 msec
;; SERVER: 127.0.0.53#53(127.0.0.53)
;; WHEN: Wed Aug 04 10:08:20 BST 2021
;; MSG SIZE  rcvd: 53

toor@LX20D:~$ dig +nocmd +noedns +noquestion mail.515support.com
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 57840
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; ANSWER SECTION:
mail.515support.com.    7029    IN      A       198.51.100.29

;; Query time: 0 msec
;; SERVER: 127.0.0.53#53(127.0.0.53)
;; WHEN: Wed Aug 04 10:08:32 BST 2021
;; MSG SIZE  rcvd: 53
```

- Domain Information Groper (dig)
- Shipped with BIND DNS server software
  - dig host
  - dig @ns1.isp.example host
  - dig @ns1.isp.example host all
  - dig @ns1.isp.example host MX
- Output parameters
  - +nocomments or +nostats