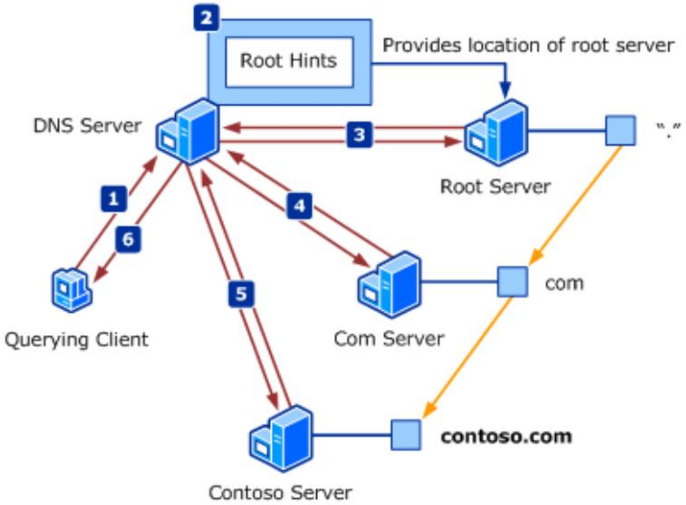
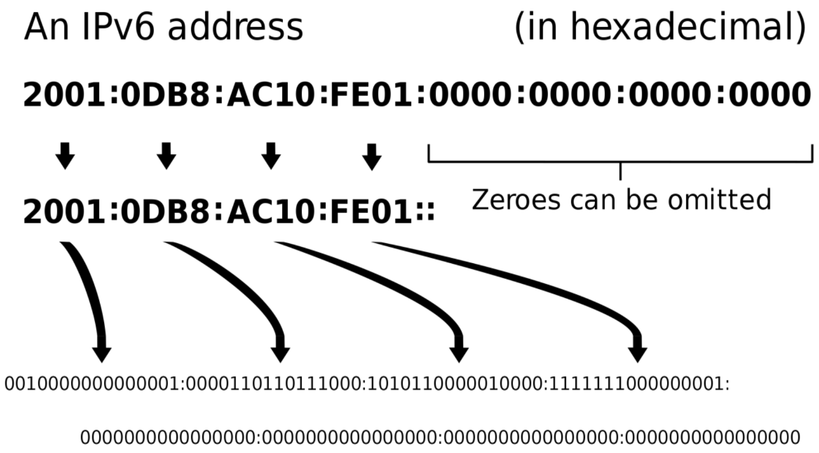
Domain Name System.

IPv6

Lecture 4





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Domain Name System

DNS structure

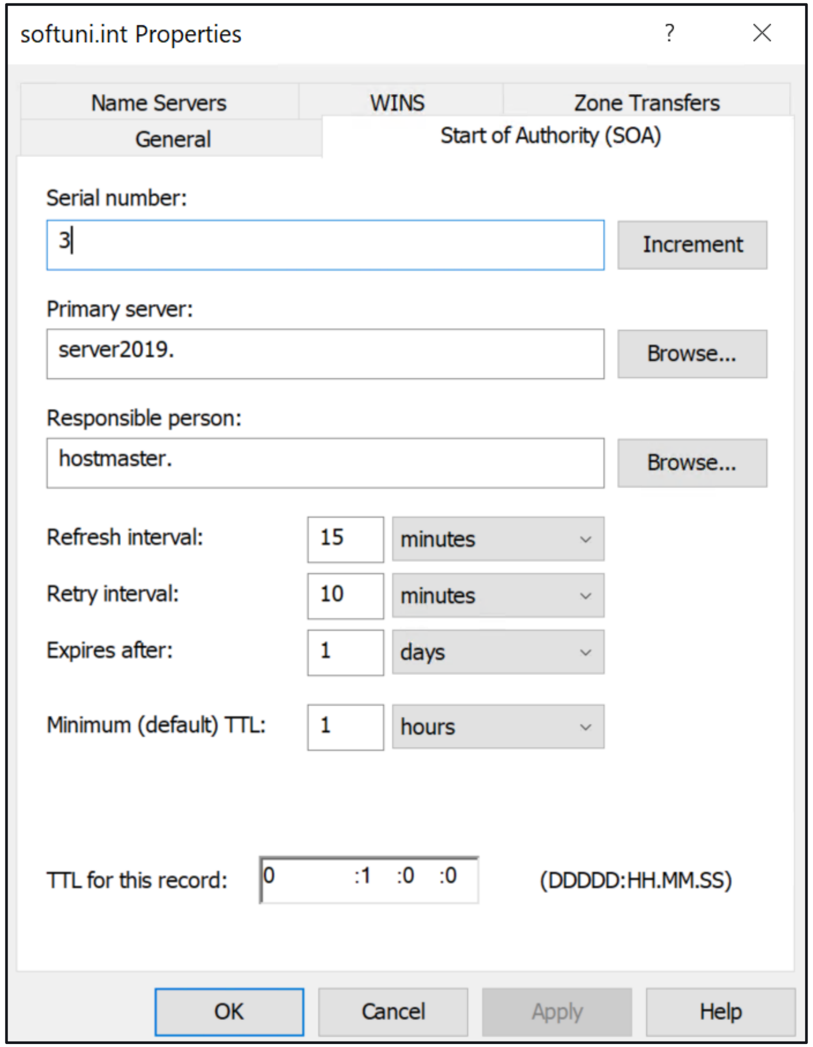
- DNS is hierarchical and distributed system
- At the top there is the root domain or "."
    - One level below are the TLD (top level domains, i.e. ".com")
        - One level below are the second level domains, i.e. "yahoo"
            - Possible third level domains, etc.
- DNS Zone – part of the DNS namespace, managed by specific organization

Resource records (in a DNS zone)

- Common resource records and their purposes:
  - A record: a name which points to a IPv4 address
  - AAAA record: a name which points to a IPv6 address
  - CNAME record (alias): a name which points to another name
    (Canonical Name)
  - MX record: shows who is the mail server for that domain
    (Mail EXchanger)
  - TXT record: text entry, usually used for domain verification and anti-spam
    (TeXT)
  - NS record: shows which are the name servers for the zone
    (Name Server)
  - SOA record: contains administrative information about the zone
    (Start Of Authority)

Start of Authority (SOA) record

- SOA specifies authoritative about the DNS zone
  - Serial number – incremented each time there is a change in the zone
  - Primary server – who stores the primary zone file
  - Refresh and retry intervals – when the secondary DNS will query the primary for changes
  - TTL – how long the data should be kept in the clients’ cache



Serial number: 3

Primary server: server2019.

Responsible person: hostmaster.

Refresh interval: 15 minutes

Retry interval: 10 minutes

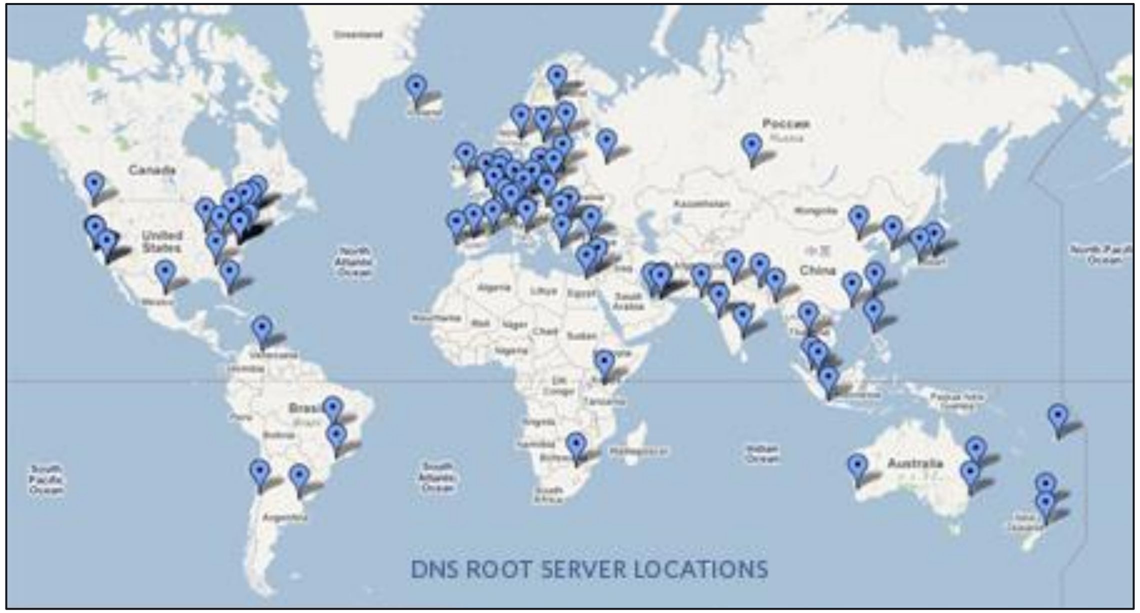
Expires after: 1 days

Minimum (default) TTL: 1 hours

TTL for this record: 0 :1 :0 :0 (DDDDD:HH.MM.SS)

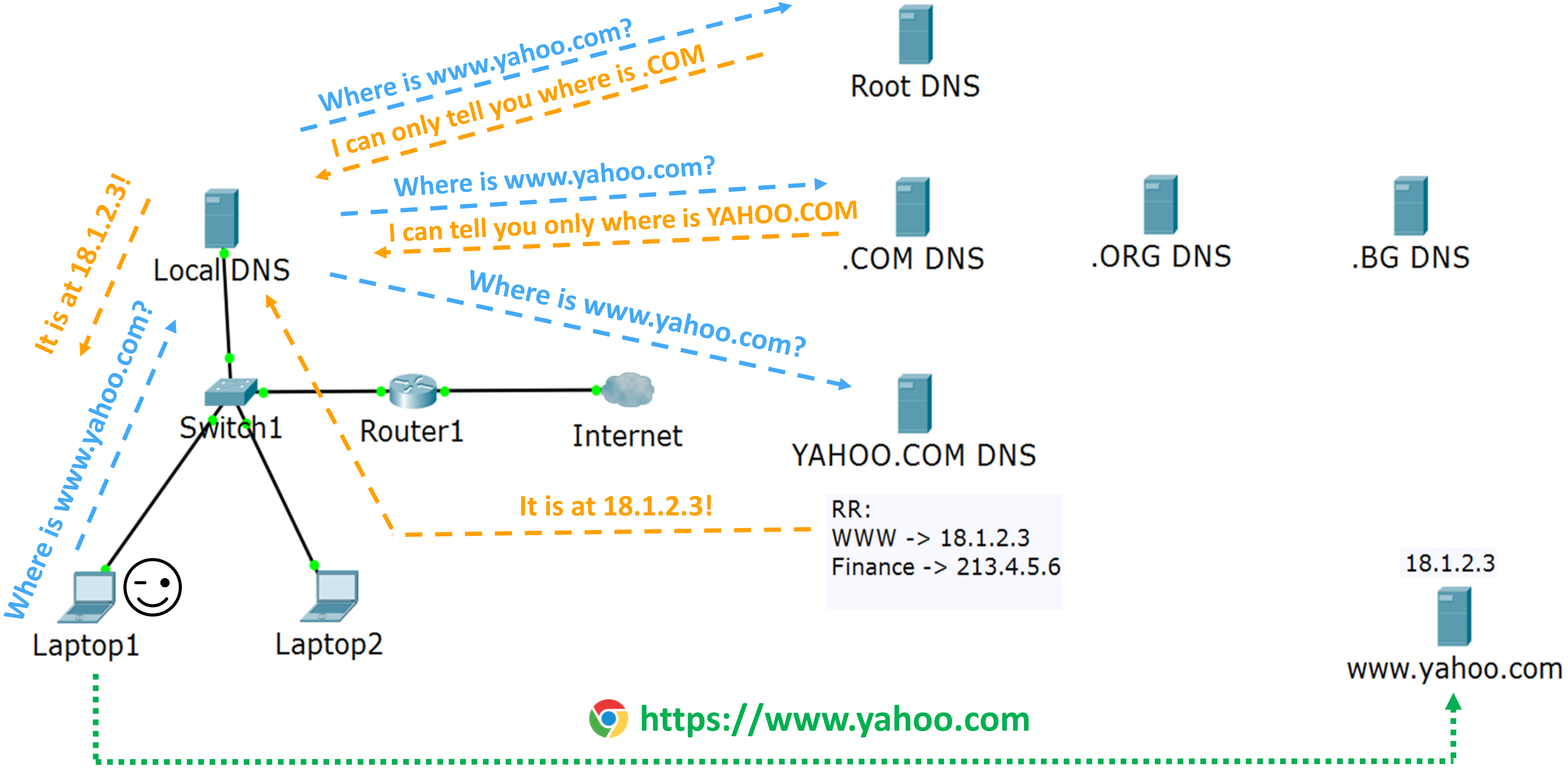
Root Hints

- The authoritative name servers for the “root” zone
- There are 13 named authorities, globally distributed
- They provide just a reference for the top-level domains (TLD)



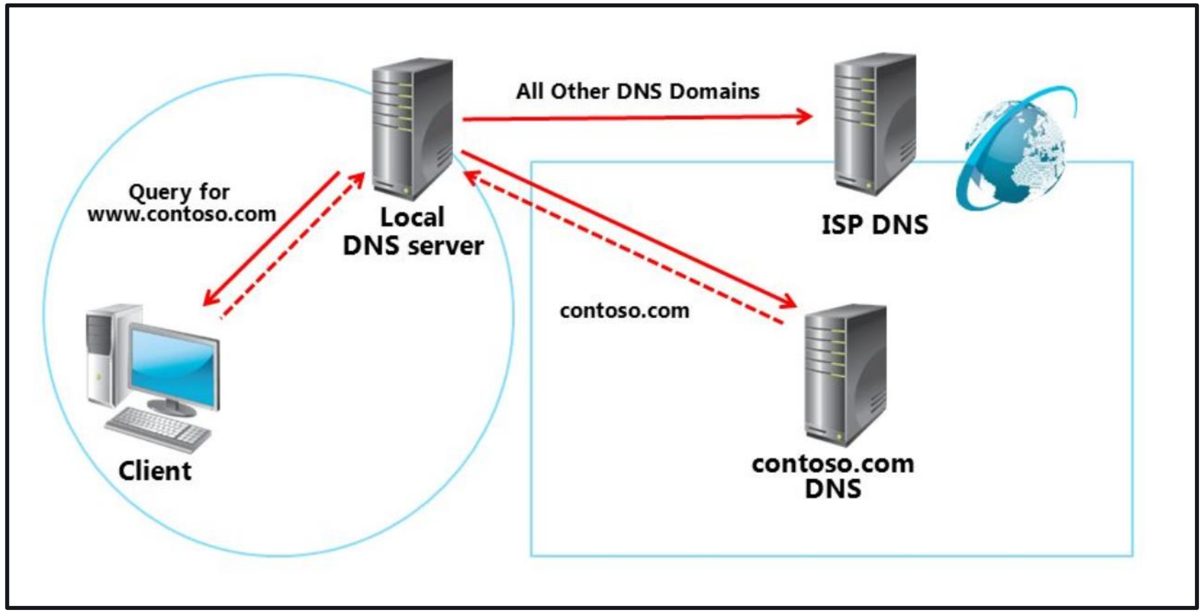
DNS ROOT SERVER LOCATIONS

DNS query process



DNS forwarder and conditional forwarder

- A local DNS server only knows about its local zones and records
- If a client asks for an external zone/record, the local DNS should ask someone else



- If we have multiple local DNS zones, hosted on different servers, we can use conditional forwarders

DNS end to end process

- First, the client checks its local cache
- If the entry is not in the cache, the client makes a query to the first DNS server(s) in its local configuration
  - The client will query alternative (second) DNS server only if the first one is not reachable (and not if it receives a negative answer)
- The DNS server checks its local cache
- If the entry is not in the cache, the DNS server queries a forwarder
- If no forwarder available, the DNS server uses the Root Hints

Windows client local DNS cache

- Resolved DNS queries stay in the local cache for a time period determined by the zone TTL value on the server
- The **hosts** file
  - Alternative name resolution mechanism
  - Usually located in %systemroot%\system32\drivers\etc folder
  - Not distributed and scalable but can serve as a backup DNS method
  - It has higher priority than DNS resolution
  - The content of the hosts file is constantly copied in the DNS cache

Windows client local DNS cache (2)

- **ipconfig /displaydns**
  - shows the local DNS cache of a Windows computer
- **ipconfig /flushdns**
  - deletes the local DNS cache of a Windows computer
- Remember – the hosts file content is constantly copied in this cache

Recursive and iterative queries

- Recursive query - the DNS server must respond with either
  - the requested resource

    OR
  - Error message (not found)
- Iterative query - the DNS server responds with the best answer it can give

The NSLOOKUP command

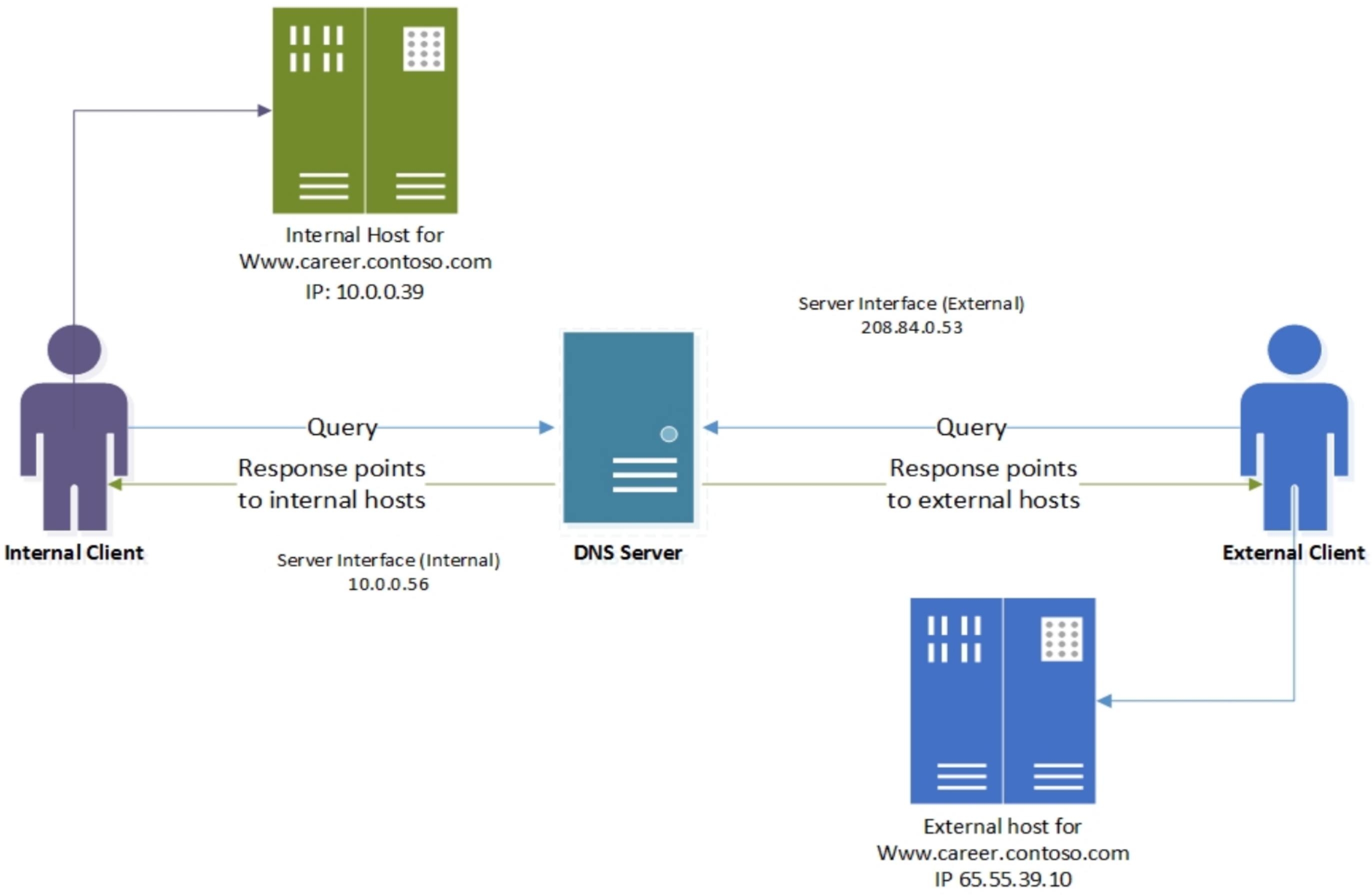
- To check a DNS resolution, one can use **ping** or **nslookup**
  - ping - intuitive to use but can have older and inaccurate info the purpose of ping is not to troubleshoot DNS
  - **nslookup** - useful tool designed for troubleshooting DNS
- Demo: how to use **nslookup** on Windows

Forward and reverse DNS zones

- Forward lookup zone: Name → IP address
- Reverse lookup zone: IP address → Name
- A reverse DNS zone:
    - Can be used for antispam mechanism, logs from applications
    - Require to be created from your ISP (because it manages your IP addresses)

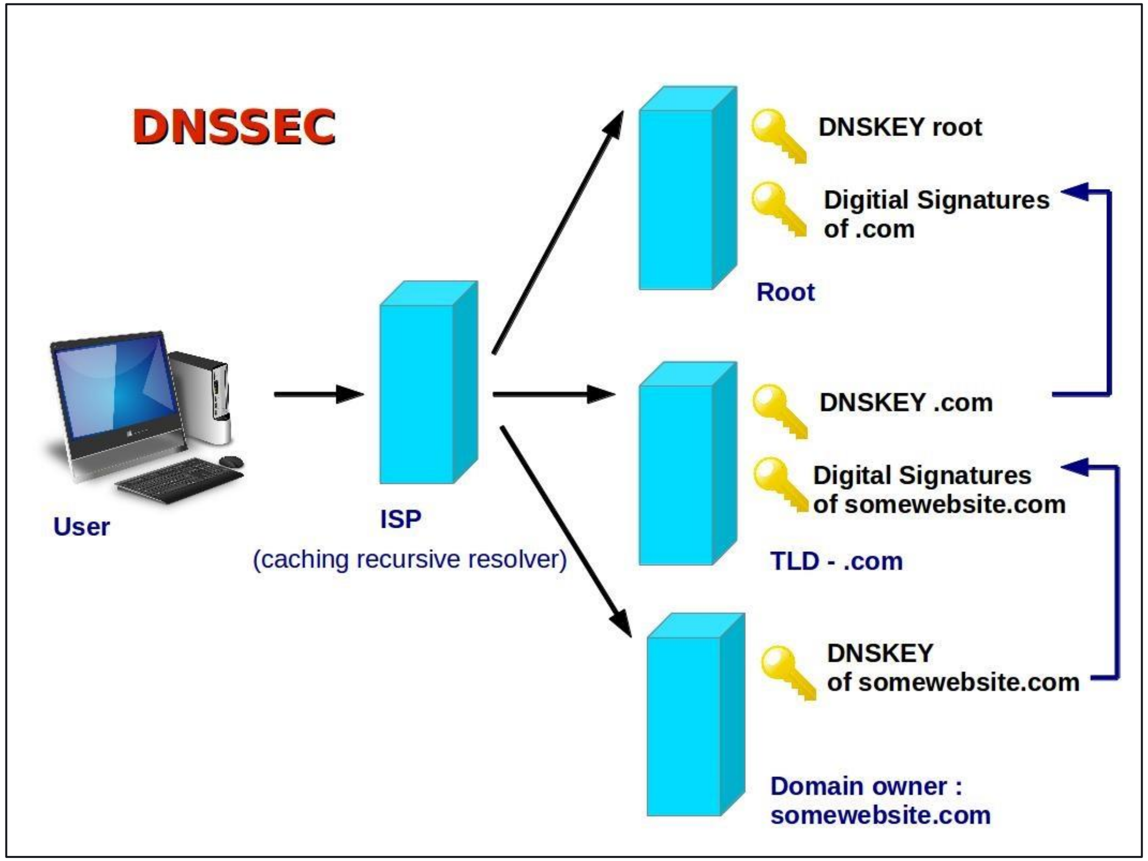
Split-Brain DNS

- Can provide different information depending on the client’s location
- May increase performance and security



DNSSEC (Domain Name System Security Extensions)

- DNS is insecure protocol by design
- When enabled, non-authoritative DNS servers can validate the responses from other DNS servers
- DNSSEC uses public key cryptography to digitally sign authoritative zone data
- …but it is not very popular for different reasons – it is complicated, expensive, incomplete and may create problems like DDoS attacks


DNSSEC
DNSKEY root
Digitial Signatures of .com
Root
DNSKEY .com
Digital Signatures of somewebsite.com
TLD - .com
DNSKEY of somewebsite.com
Domain owner : somewebsite.com
User
ISP
(caching recursive resolver)

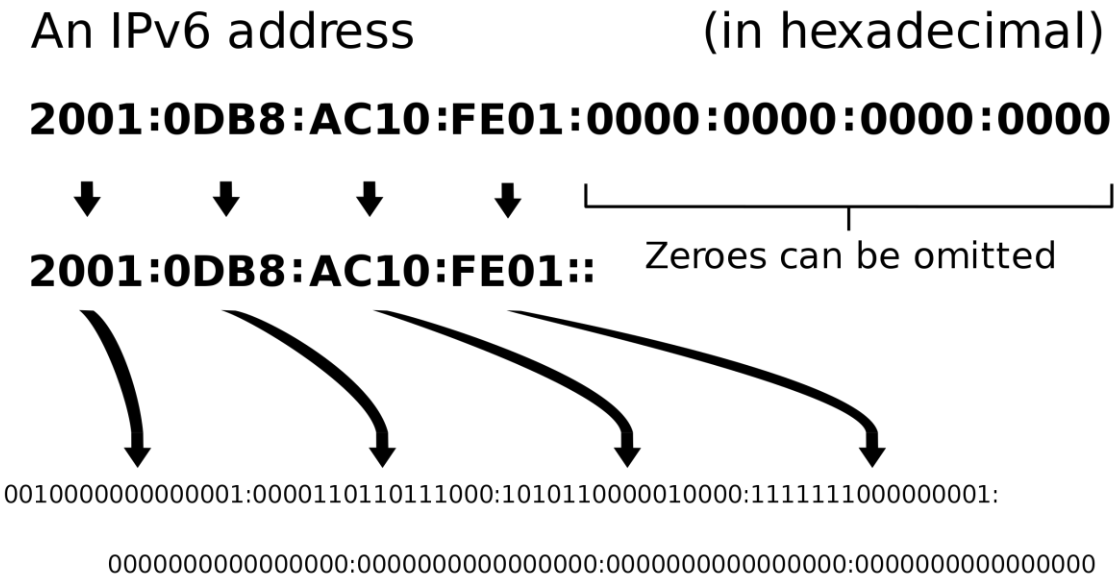
DoT and DoH (DNS over TLS and DNS Over HTTPS)

- Another attempts to implement security in the DNS protocol
- DoH is a proposed standard, published October 2018
- Some common usage scenarios:
  - Use DoH within an application - some browsers have a built-in DoH support and can thus bypass the OS's DNS functionality
  - Install DoH proxy – the client uses the traditional (port 53) DNS to query in the local DNS (central or local proxy)
  - Installing a DoH resolving plugin for the operating system

IPv6

IPv6 introduction

- Larger address space (128 bits rather than 32) or 2^{128}
- Simplified header format
- Improved quality of service and security



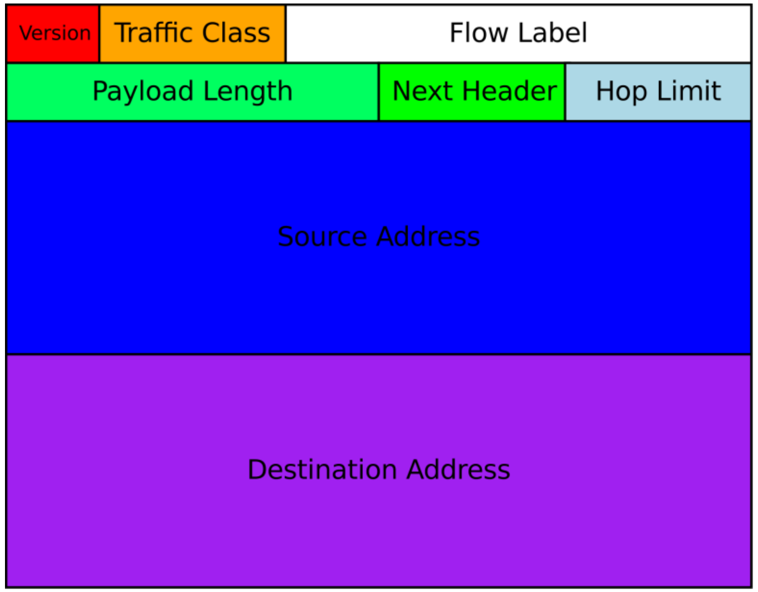
An IPv6 address (in hexadecimal)

2001:0DB8:AC10:FE01:0000:0000:0000:0000

2001:0DB8:AC10:FE01:: Zeroes can be omitted

0010000000000001:0000110110111000:1010110000010000:1111111000000001:

0000000000000000:0000000000000000:0000000000000000:0000000000000000



Version | Traffic Class | Flow Label

Payload Length | Next Header | Hop Limit

Source Address

Destination Address

How big is the IPv6 address space?

- 2^{128} is like $3.4×10^{38}$, which is: 340,282,366,920,938,463,463,374,607,431,768,211,456
- It is 10 million trillion times the total number of grains of sand on all the beaches in the world
- We can assign IPv6 address to every atom on the surface of the Earth, and still have enough addresses left to do another 100+ earths

IPv6 address format

- IPv6 address is represented as eight groups of four hexadecimal digits
- Example:

  2001:0db8:0000:0000:0000:ff00:0042:8132

- Each of this groups has 16 bits and is separated from the others with ":"

IPv4 vs IPv6

- Much (much…) larger address space in IPv6
- A lot of the IP concepts and upper layer protocols remain the same or similar
- In the OSI model, only L3 is different
- No broadcast, no subnetting and no NAT in IPv6!

Abbreviations

- One option - remove the long string with zeros (allowed only once)
  - Original: 2041:0000:140F:0000:0000:0000:875B:031B
  - Short: 2041:0000:140F::875B:031B
- Another option - replace four zeros with one
  - Short: 2041:0000:140F::875B:031B
  - Shorter: 2041:0:140F::875B:031B
- Also, another leading zero can be removed: 031B --> 31B
- The result from the above options:
  2041:0000:140F:0000:0000:0000:875B:031B --> **2041:0:140F::875B:31B**

Abbreviations – other examples

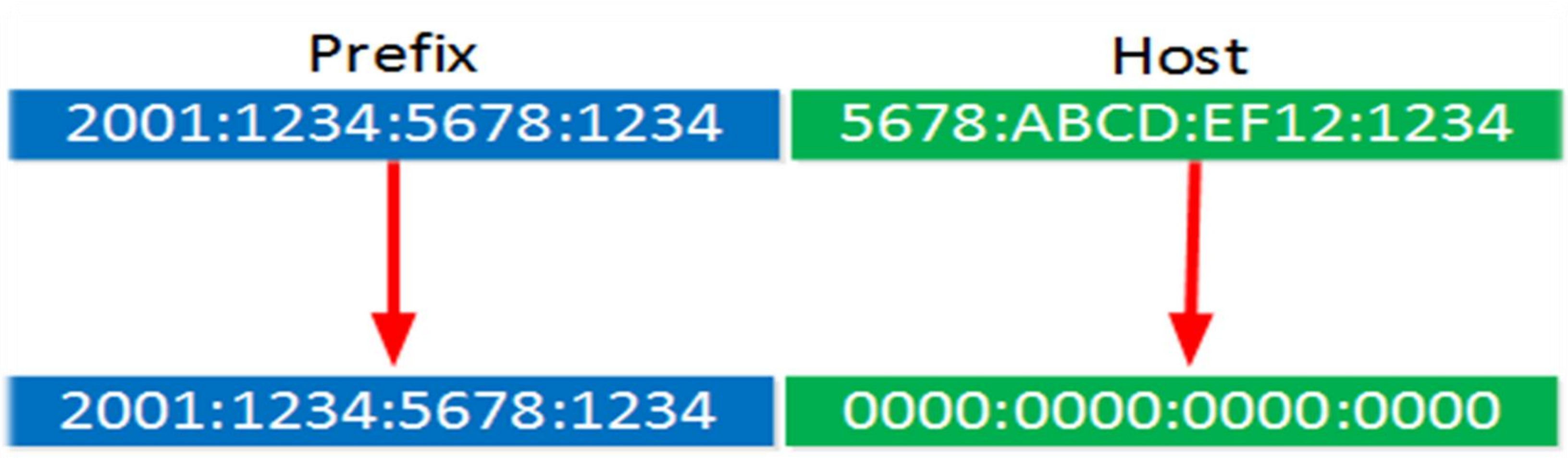
- FF02:0000:0000:0000:0000:0000:0000:0001
  - FF02:0:0:0:0:0:0:1
  - FF02::0:0:0:1
  - FF02:0:0::1
  - FF02::1
- 1234:0000:0000:5678:0000:0000:4321:001
  - 1234::5678:0:0:4321:1
  - 1234:0:0:5678::4321:1
- 0000:0000:0000:0000:0000:0000:0000:0001 (the loopback address)
  - ::1

IPv6 address types

- Unicast - a packet is delivered to one interface
  - Global
  - Reserved
  - Link local (something like APIPA in IPv4)
  - Site local (something like the RFC 1918 private addresses in IPv4, deprecated)
- Multicast - a packet is delivered to multiple interfaces
- Anycast - a packet is delivered to the nearest of multiple interfaces (as defined by the routing protocols in use)

*no more Broadcast in IPv6

IPv6 prefixes



Prefix	Host
2001:1234:5678:1234	5678:ABCD:EF12:1234
2001:1234:5678:1234	0000:0000:0000:0000

2001:1234:5678:1234:0000:0000:0000:0000/64

2001:1234:5678:1234::/64

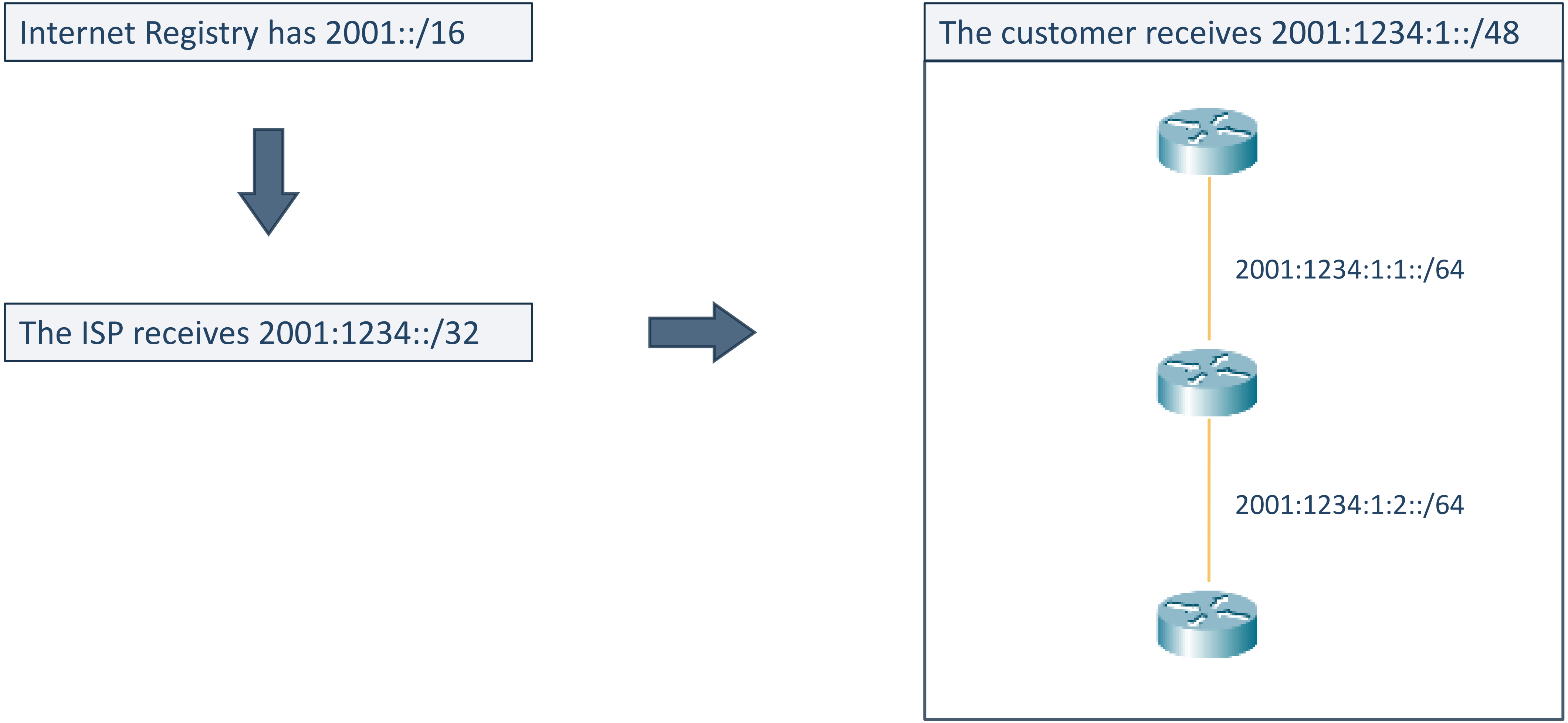
IPv6 global unicast

Network prefix	Interface ID (host)
64 bits	64 bits

Global prefix	Subnet ID	Interface ID (host)
48 bits	16 bits	64 bits
Public/Internet	Customer’s subnets	Interface

- ISP allocates to the customer /48
- The customer allocates /64 to each interface while having 2^{16} (65536) subnets

IPv6 global unicast - example



Internet Registry has 2001::/16

The ISP receives 2001:1234::/32

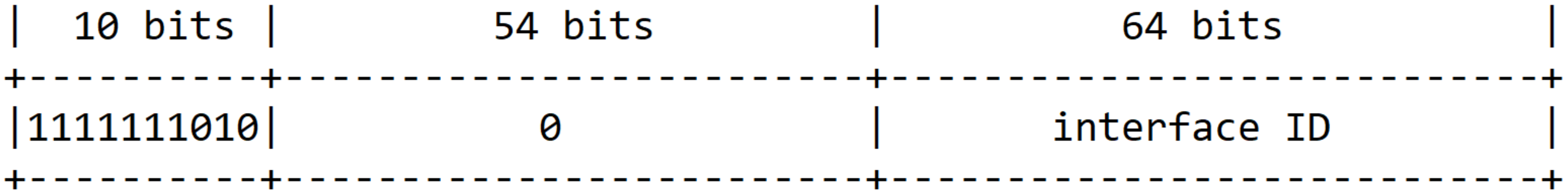
The customer receives 2001:1234:1::/48

2001:1234:1:1::/64

2001:1234:1:2::/64

IPv6 scopes (Unicast)

- Link-local (similar to APIPA in IPv4)
  - Prefix is FE80::/10…(or FE80::/64?)



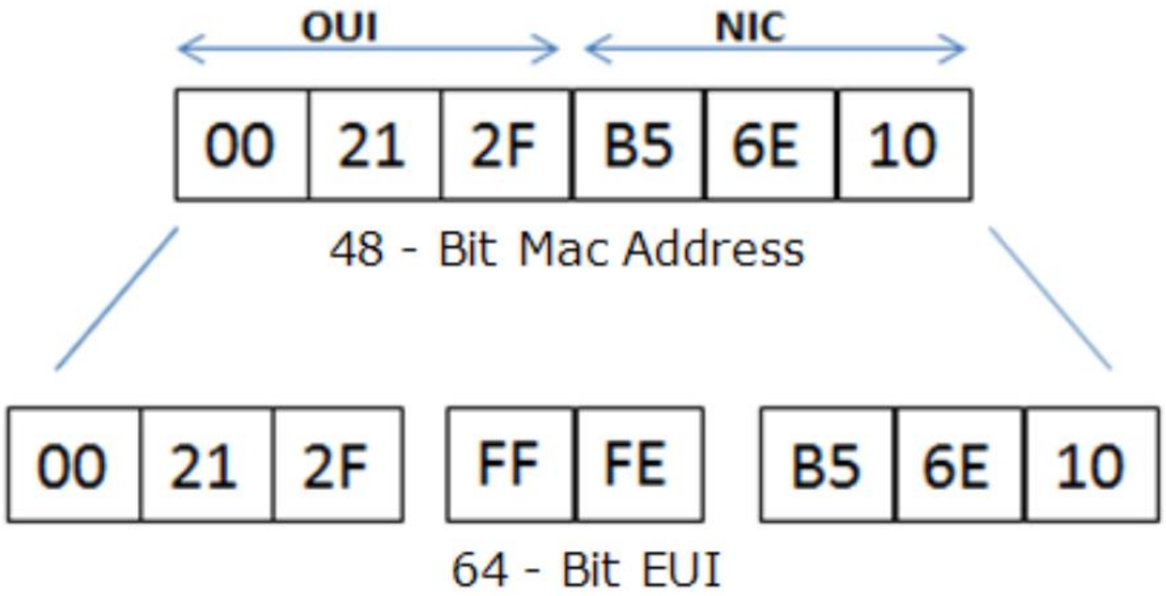
```
|  10 bits |           54 bits           |           64 bits            |
+----------+-----------------------------+------------------------------+
|1111111010|              0              |         interface ID         |
+----------+-----------------------------+------------------------------+
```

- Global (similar to IPv4 public addresses)
  - Typical prefix is 2000::/3

::1/128 - the loopback address is a unicast localhost address

IPv6 EUI-64 bit address

- EUI: Extended Unique Identifier
- One option to auto-assign the second 64 bits to a link-local address using the MAC address of the interface



OUI NIC

00 21 2F B5 6E 10

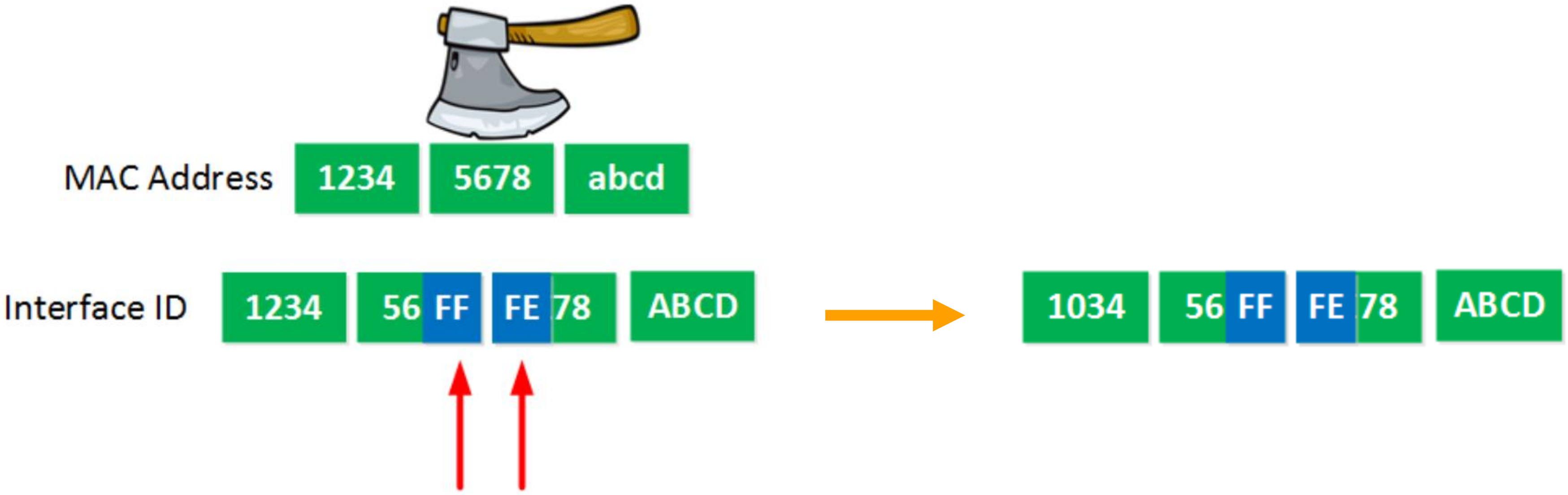
48 - Bit Mac Address

00 21 2F FF FE B5 6E 10

64 - Bit EUI

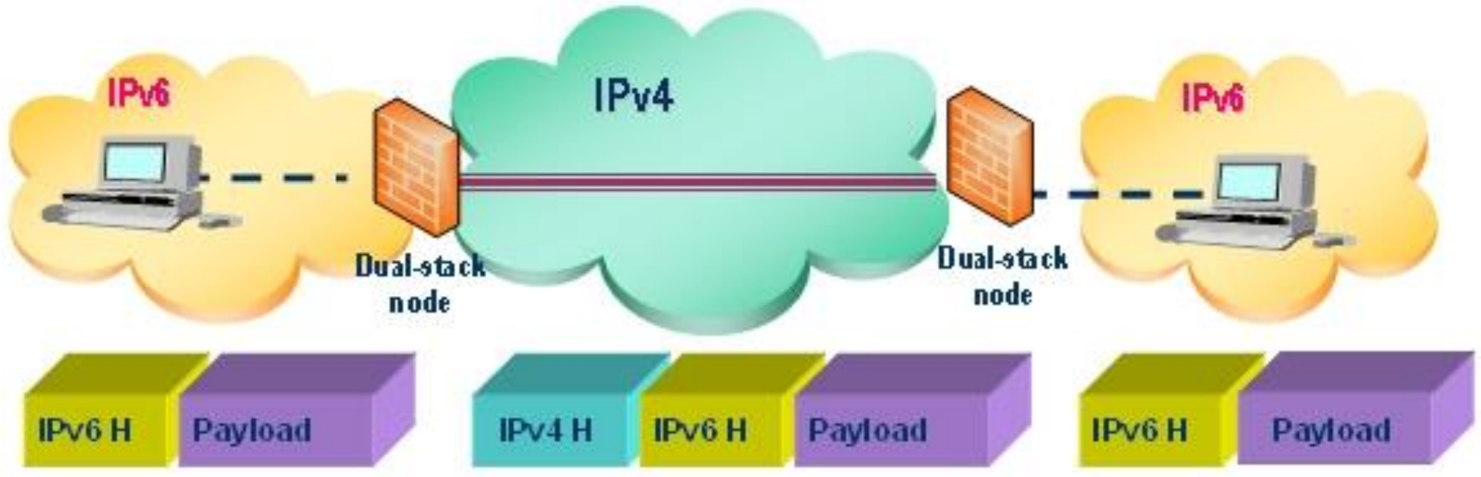
IPv6 EUI-64 bit address (2)

- How the IPv6 EUI-64 address is automatically configured:
  - ✓ Split the MAC address of the interface into two pieces
  - ✓ Insert **FFFE** between the two pieces (to achieve 64 bits)
  - ✓ Invert the 7th bit of the interface ID



IPv6 tunneling

- Encapsulates IPv6 packets in IPv4 packets for delivery across an IPv4 infrastructure
- Different methods exist – 6to4, 6rd, Teredo, ISATAP, etc.



IPv6 SLAAC

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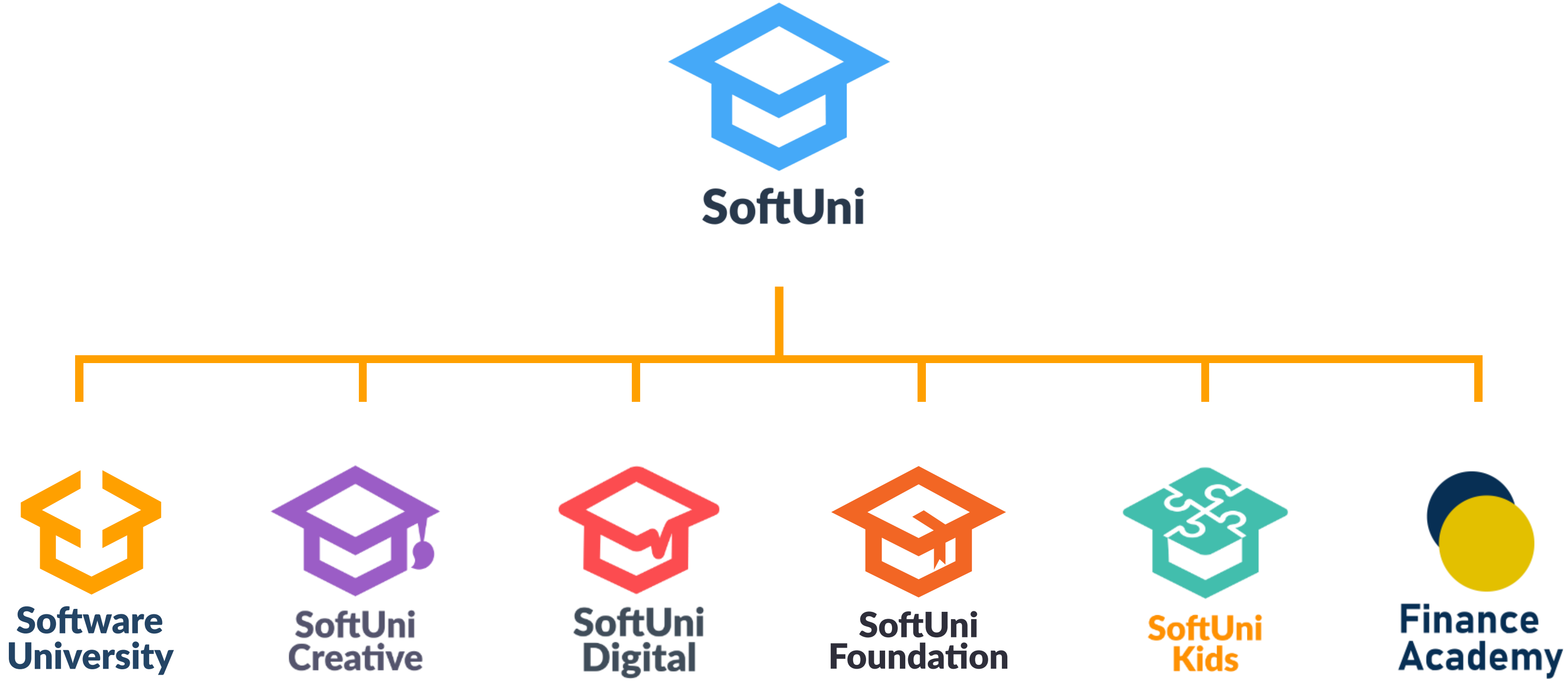
- SLAAC = StateLess Address Auto Configuration
- Designed to be fast and easy alternative to DHCPv6
- IPv6 Neighbor Discovery Protocol (NDP) is like ARP in IPv4
- With SLAAC and NDP, nodes on the network can easily autoconfigure IPv6 address from the correct subnet/prefix
- The problem: with SLAAC there is no assignment for DNS
- SLAAC and DHCPv6 can be used together:
  - the M flag (Managed) specifies if DHCPv6 is needed for IPv6 address
  - the O flag (Other) specifies if DHCPv6 is needed for DNS information

Demonstration

Summary

1. Domain Name System
2. IPv6
3. Demonstration

Questions?



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