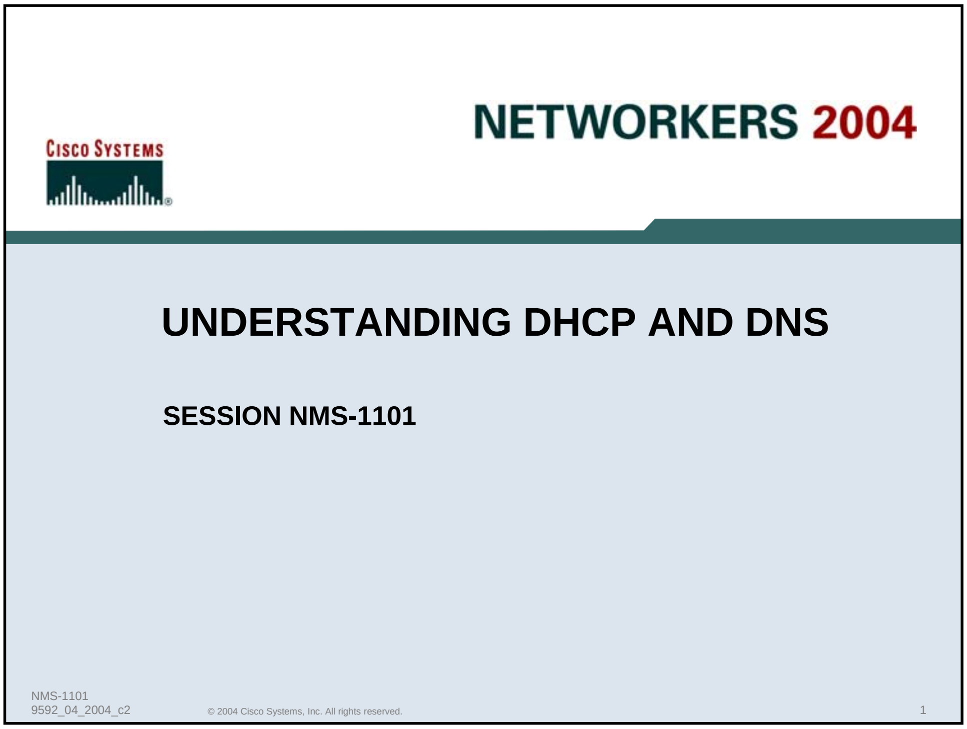
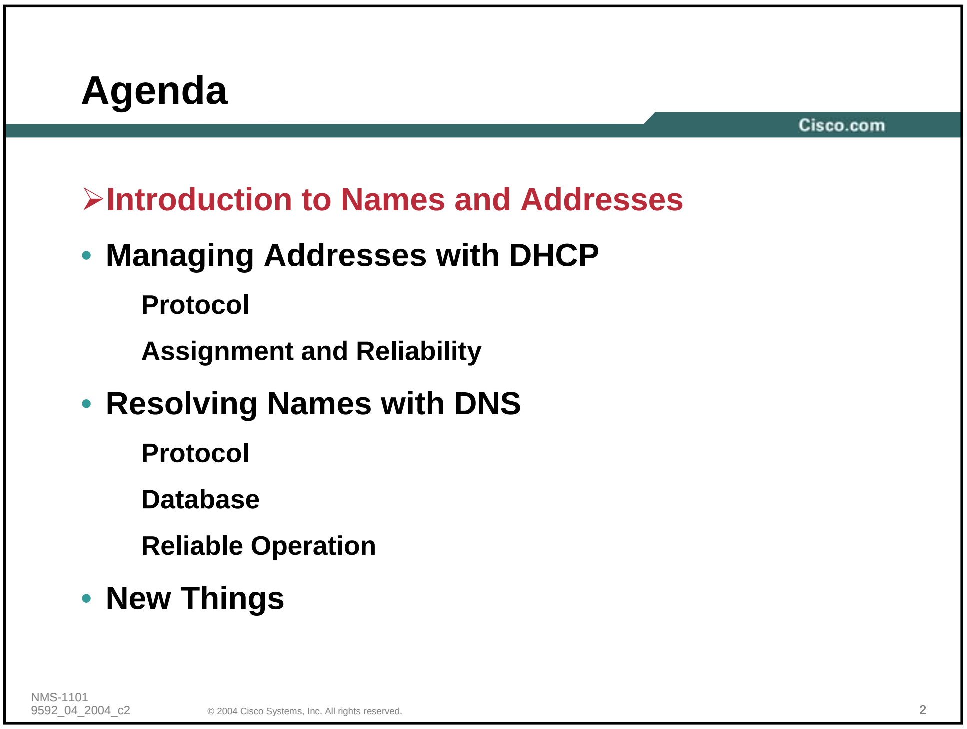


CISCO SYSTEMS

NETWORKERS 2004

# UNDERSTANDING DHCP AND DNS

SESSION NMS-1101

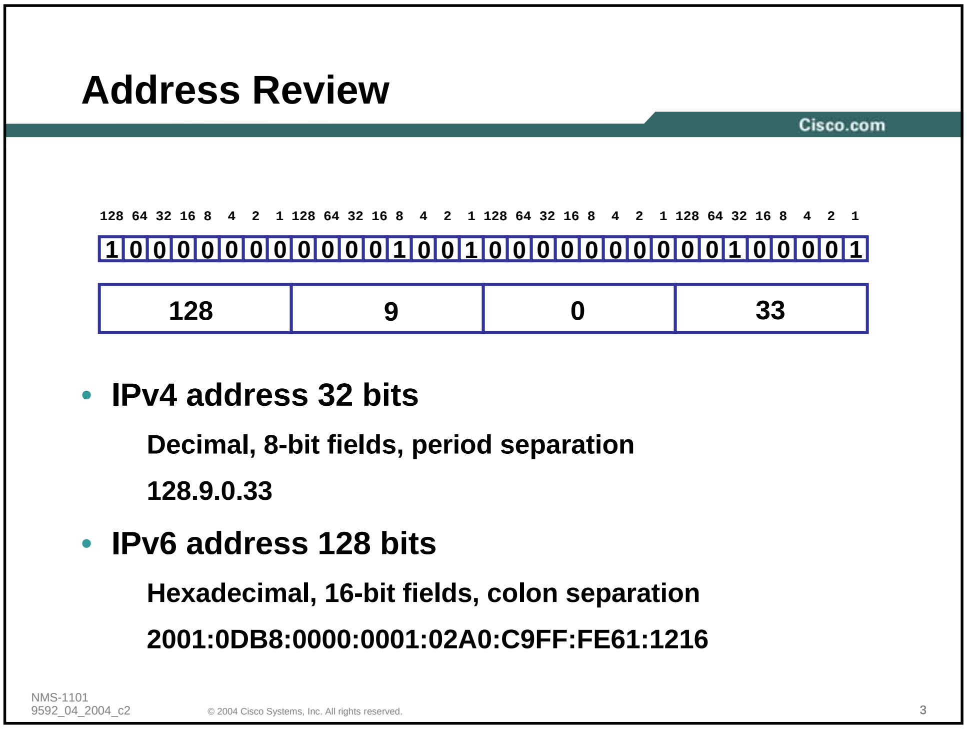


## Agenda

Cisco.com

➢Introduction to Names and Addresses

- Managing Addresses with DHCP
  - Protocol
  - Assignment and Reliability
- Resolving Names with DNS
  - Protocol
  - Database
  - Reliable Operation
- New Things

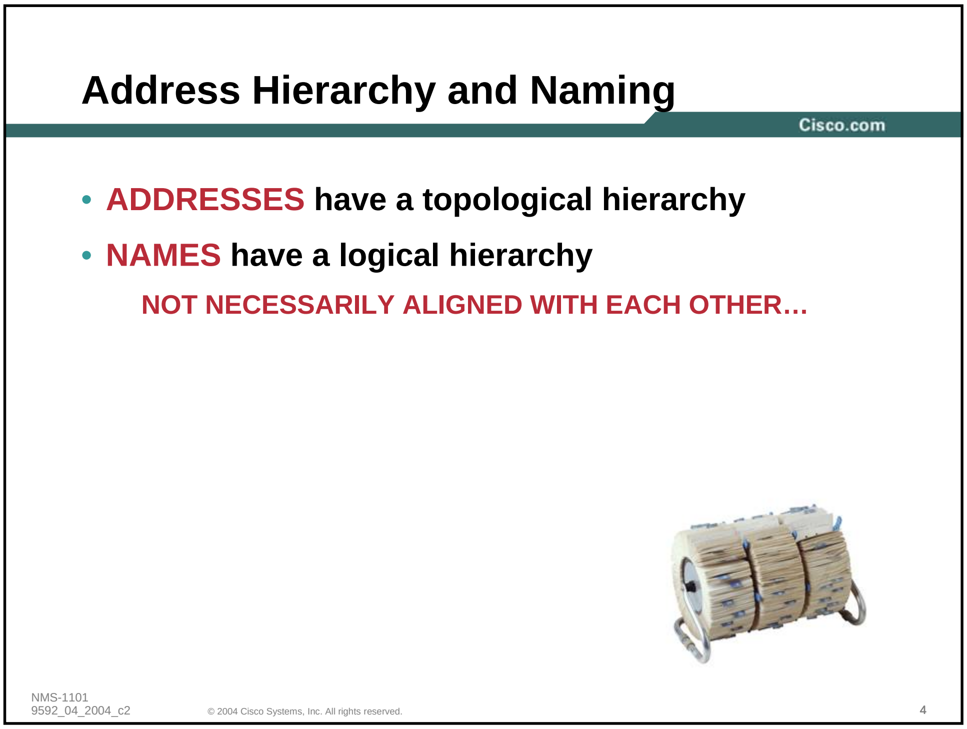


# Address Review

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |

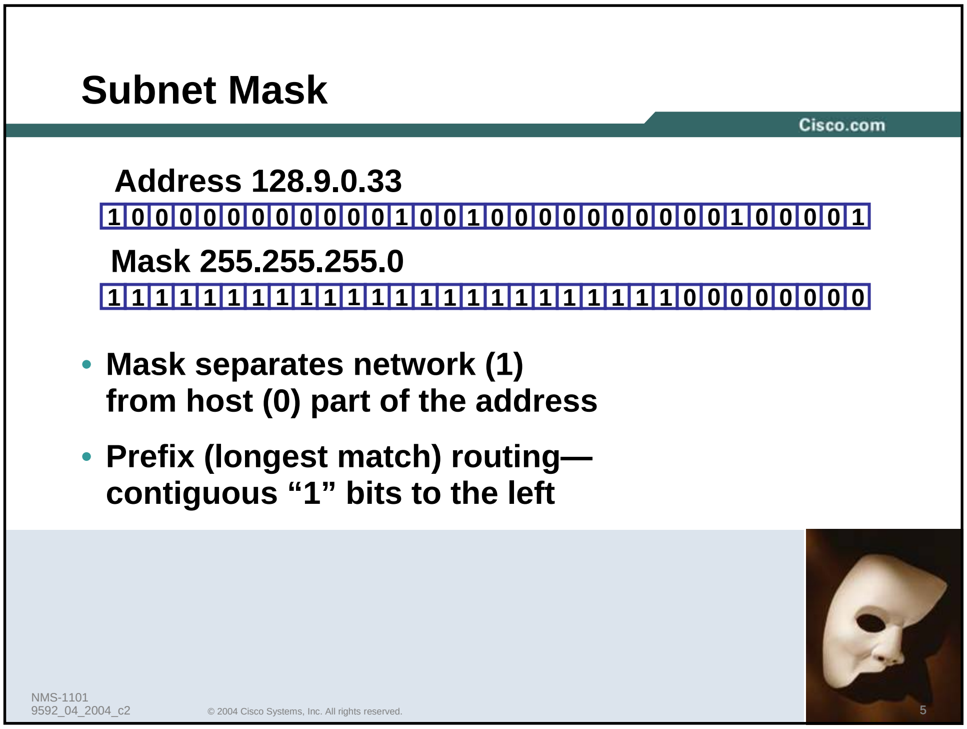
| | | | |
|---|---|---|---|
| 128 | 9 | 0 | 33 |

- IPv4 address 32 bits
  - Decimal, 8-bit fields, period separation
  - 128.9.0.33
- IPv6 address 128 bits
  - Hexadecimal, 16-bit fields, colon separation
  - 2001:0DB8:0000:0001:02A0:C9FF:FE61:1216



# Address Hierarchy and Naming

- ADDRESSES have a topological hierarchy
- NAMES have a logical hierarchy
  - NOT NECESSARILY ALIGNED WITH EACH OTHER…



# Subnet Mask

Cisco.com

Address 128.9.0.33

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |

Mask 255.255.255.0

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

- Mask separates network (1) from host (0) part of the address
- Prefix (longest match) routing—contiguous “1” bits to the left

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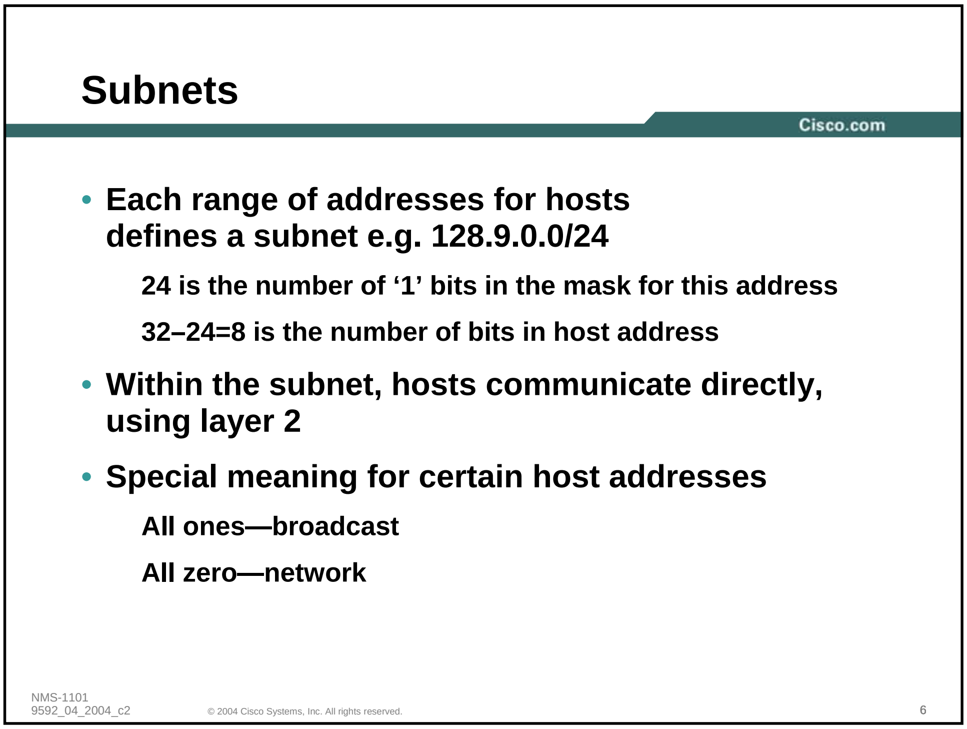

# Subnets

Cisco.com

- Each range of addresses for hosts defines a subnet e.g. 128.9.0.0/24
  - 24 is the number of ‘1’ bits in the mask for this address
  - 32–24=8 is the number of bits in host address
- Within the subnet, hosts communicate directly, using layer 2
- Special meaning for certain host addresses
  - All ones—broadcast
  - All zero—network

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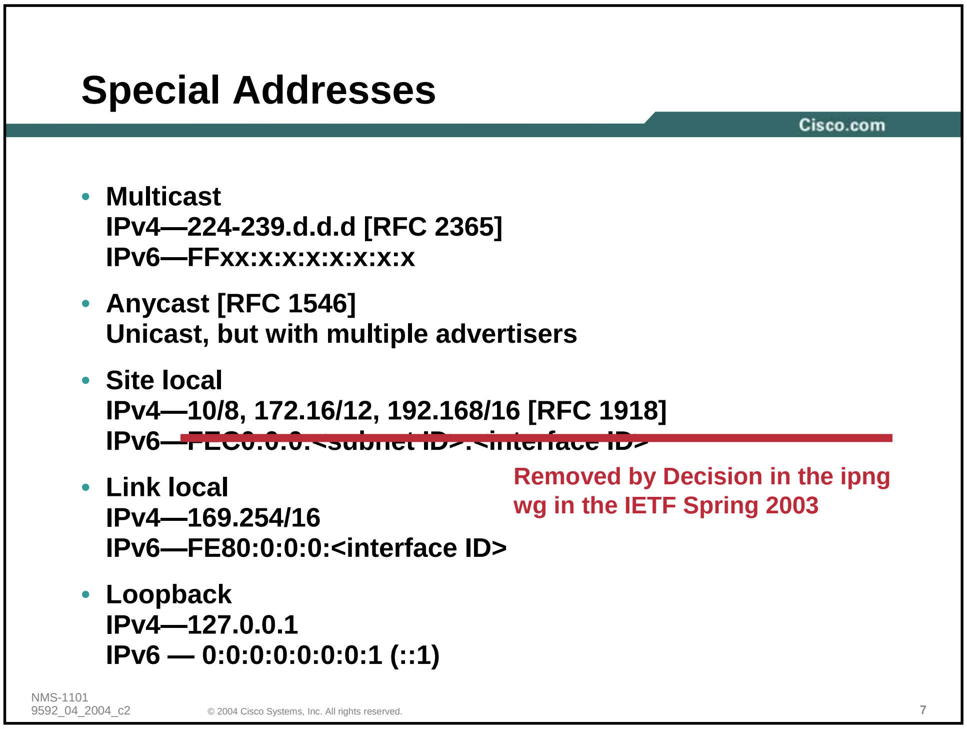
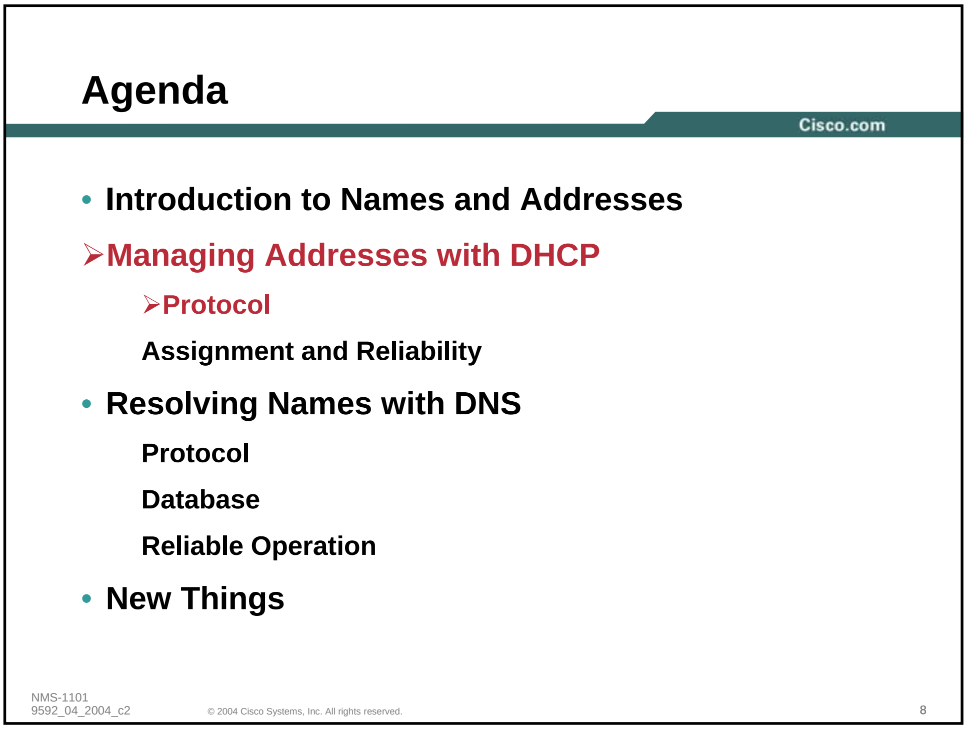


## Special Addresses

Cisco.com

- Multicast
  IPv4—224-239.d.d.d [RFC 2365]
  IPv6—FFxx:x:x:x:x:x:x:x
- Anycast [RFC 1546]
  Unicast, but with multiple advertisers
- Site local
  IPv4—10/8, 172.16/12, 192.168/16 [RFC 1918]
  IPv6—~~FEC0:0:0:<subnet ID>:<interface ID>~~
- Link local
  IPv4—169.254/16
  IPv6—FE80:0:0:0:<interface ID>
- Loopback
  IPv4—127.0.0.1
  IPv6 — 0:0:0:0:0:0:0:1 (::1)

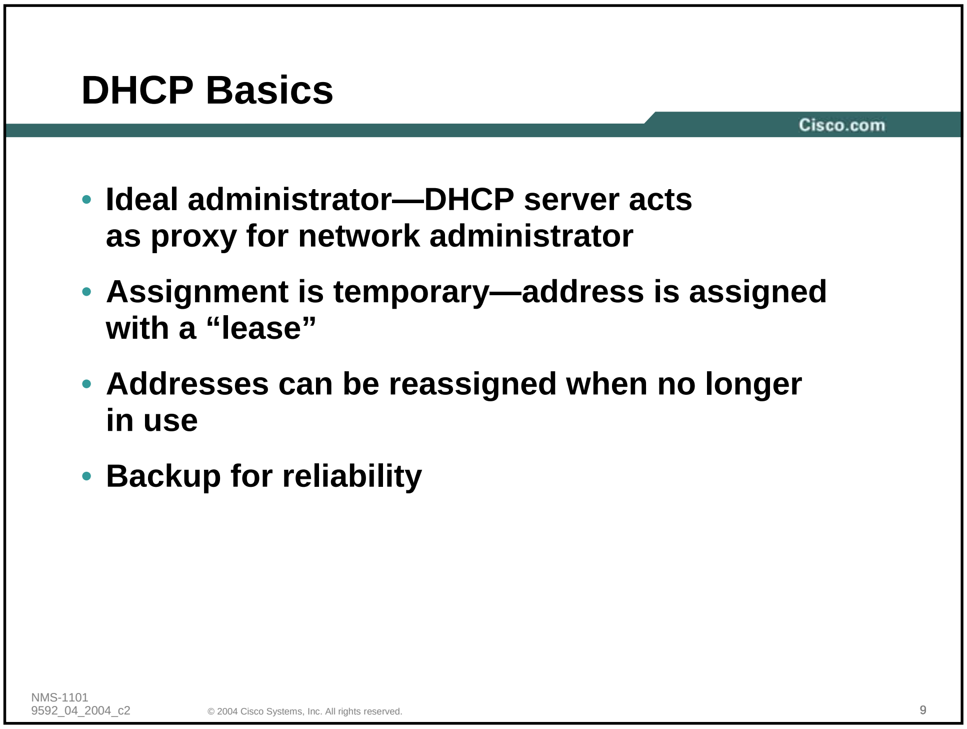
Removed by Decision in the ipng wg in the IETF Spring 2003



## Agenda

Cisco.com

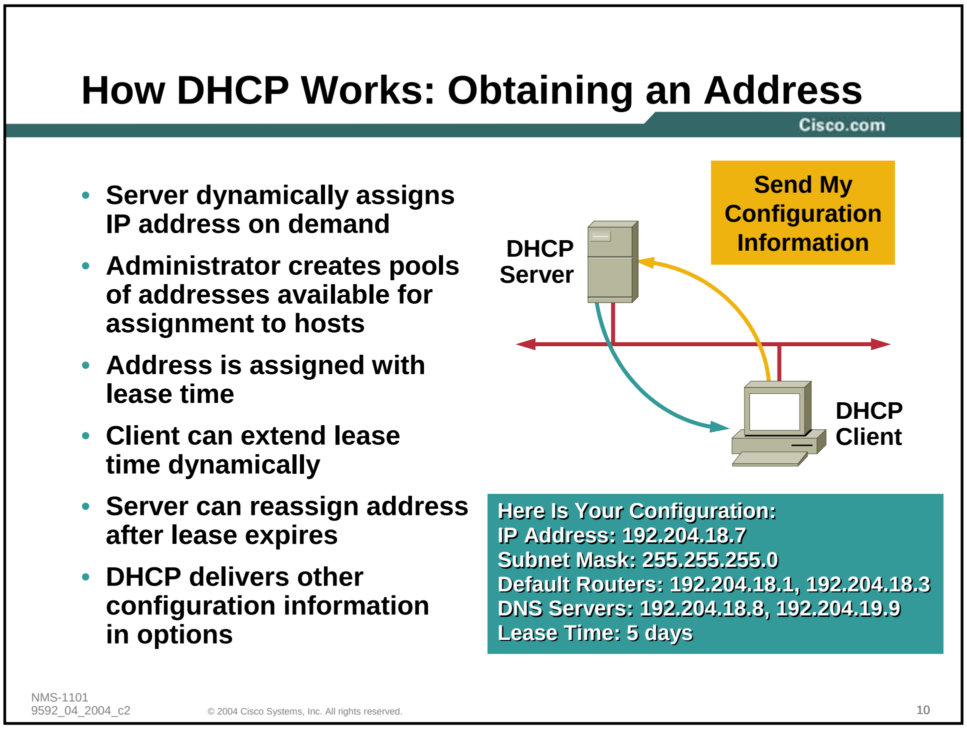
- Introduction to Names and Addresses
- ➢Managing Addresses with DHCP
  - ➢Protocol
  - Assignment and Reliability
- Resolving Names with DNS
  - Protocol
  - Database
  - Reliable Operation
- New Things



## DHCP Basics

Cisco.com

- Ideal administrator—DHCP server acts as proxy for network administrator
- Assignment is temporary—address is assigned with a “lease”
- Addresses can be reassigned when no longer in use
- Backup for reliability



## How DHCP Works: Obtaining an Address

Cisco.com

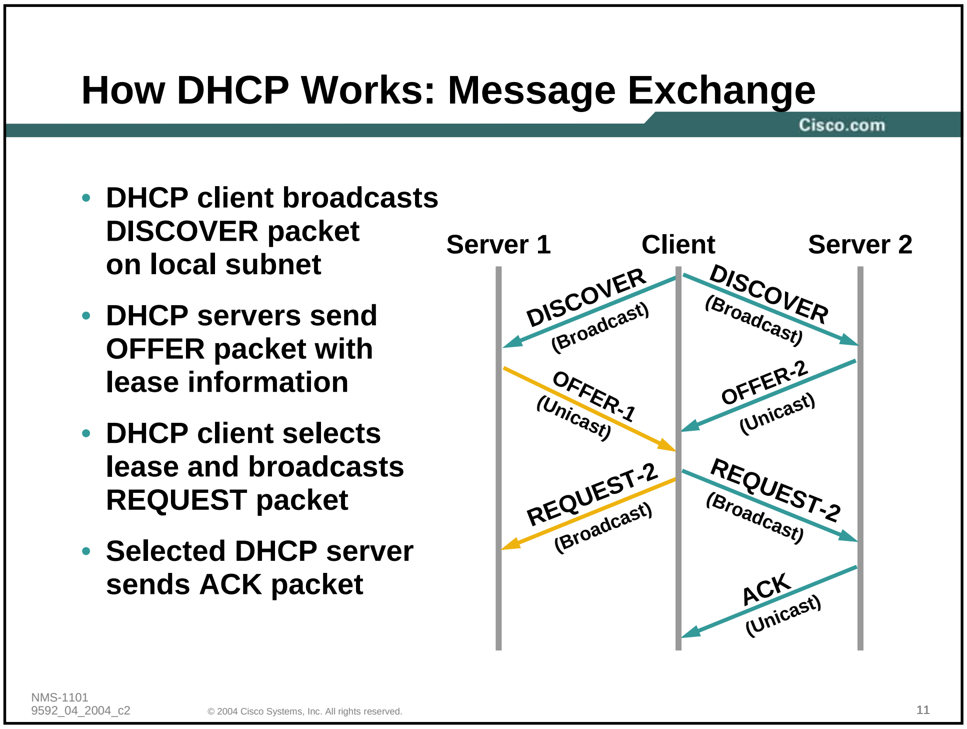
- Server dynamically assigns IP address on demand
- Administrator creates pools of addresses available for assignment to hosts
- Address is assigned with lease time
- Client can extend lease time dynamically
- Server can reassign address after lease expires
- DHCP delivers other configuration information in options

Send My Configuration Information

DHCP Server

DHCP Client

Here Is Your Configuration:
IP Address: 192.204.18.7
Subnet Mask: 255.255.255.0
Default Routers: 192.204.18.1, 192.204.18.3
DNS Servers: 192.204.18.8, 192.204.19.9
Lease Time: 5 days



## How DHCP Works: Message Exchange

Cisco.com

- DHCP client broadcasts DISCOVER packet on local subnet
- DHCP servers send OFFER packet with lease information
- DHCP client selects lease and broadcasts REQUEST packet
- Selected DHCP server sends ACK packet

Server 1

Client

Server 2

DISCOVER (Broadcast)

DISCOVER (Broadcast)

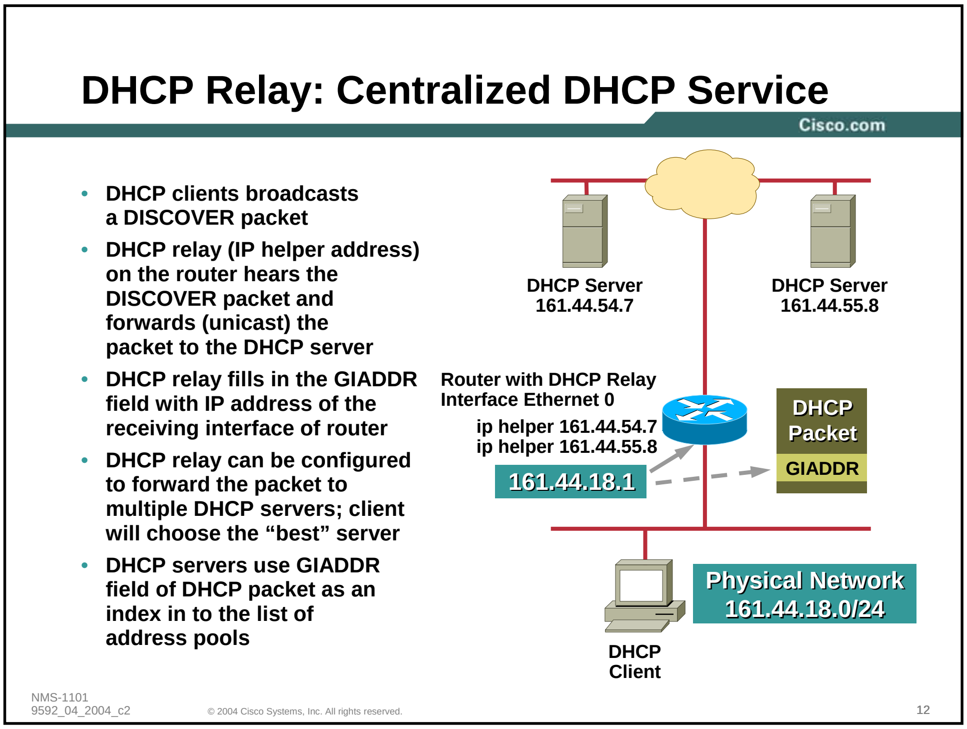
OFFER-1 (Unicast)

OFFER-2 (Unicast)

REQUEST-2 (Broadcast)

REQUEST-2 (Broadcast)

ACK (Unicast)



## DHCP Relay: Centralized DHCP Service

Cisco.com

- DHCP clients broadcasts a DISCOVER packet
- DHCP relay (IP helper address) on the router hears the DISCOVER packet and forwards (unicast) the packet to the DHCP server
- DHCP relay fills in the GIADDR field with IP address of the receiving interface of router
- DHCP relay can be configured to forward the packet to multiple DHCP servers; client will choose the "best" server
- DHCP servers use GIADDR field of DHCP packet as an index in to the list of address pools

DHCP Server
161.44.54.7

DHCP Server
161.44.55.8

Router with DHCP Relay
Interface Ethernet 0
ip helper 161.44.54.7
ip helper 161.44.55.8

161.44.18.1

DHCP Packet

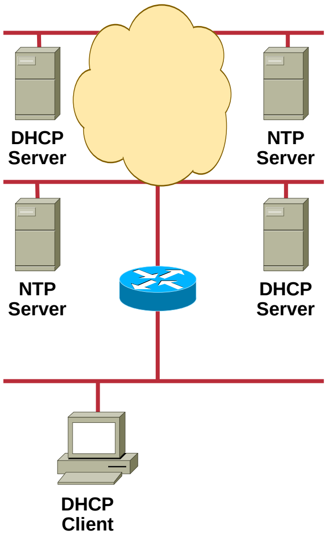
GIADDR

Physical Network
161.44.18.0/24

DHCP Client

## DHCP Options for Applications

- Options are registered with IANA
- Time, NIS, TCP, and IP parameters… [RFC 2131]
- Service Location Protocol (SLP) [RFC 2610]
- Novell directory services [RFC 2241]



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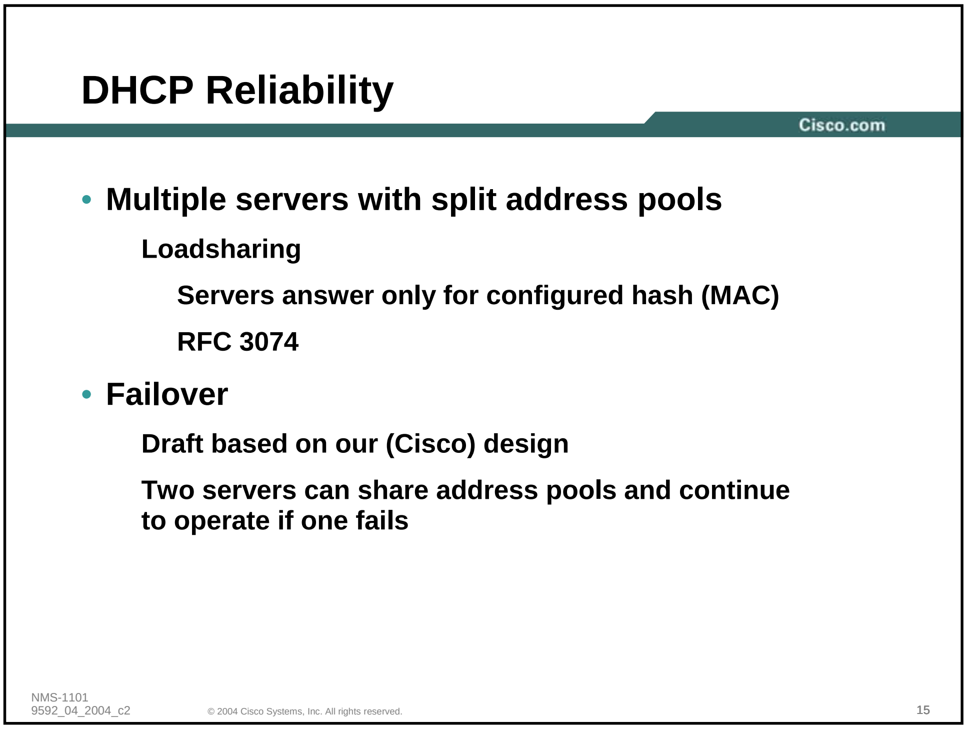
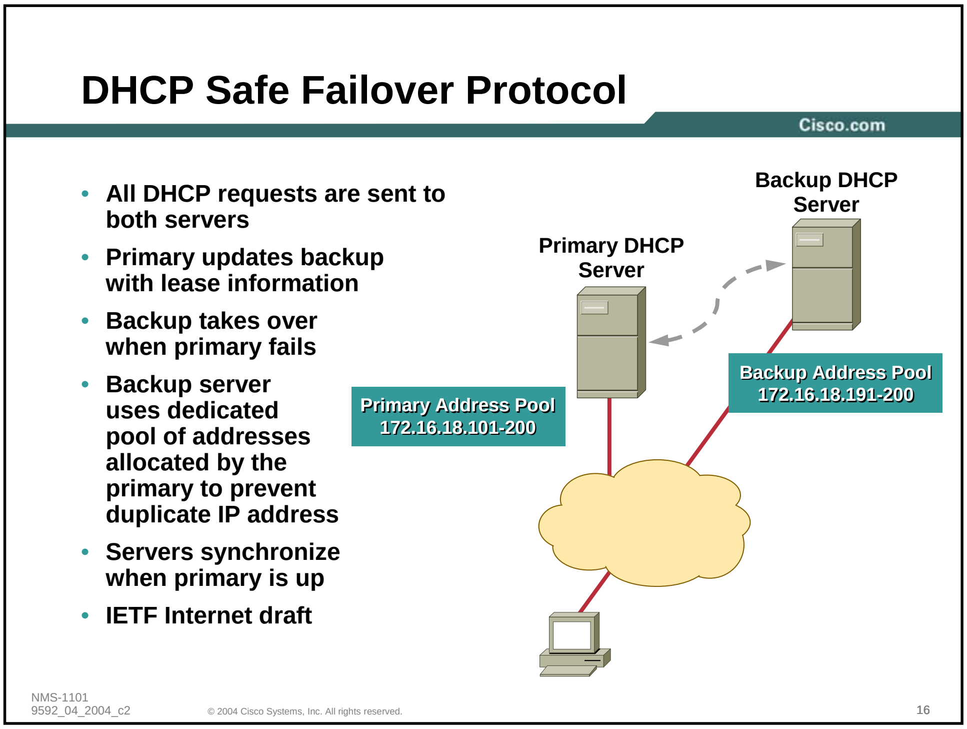


## DHCP Reliability

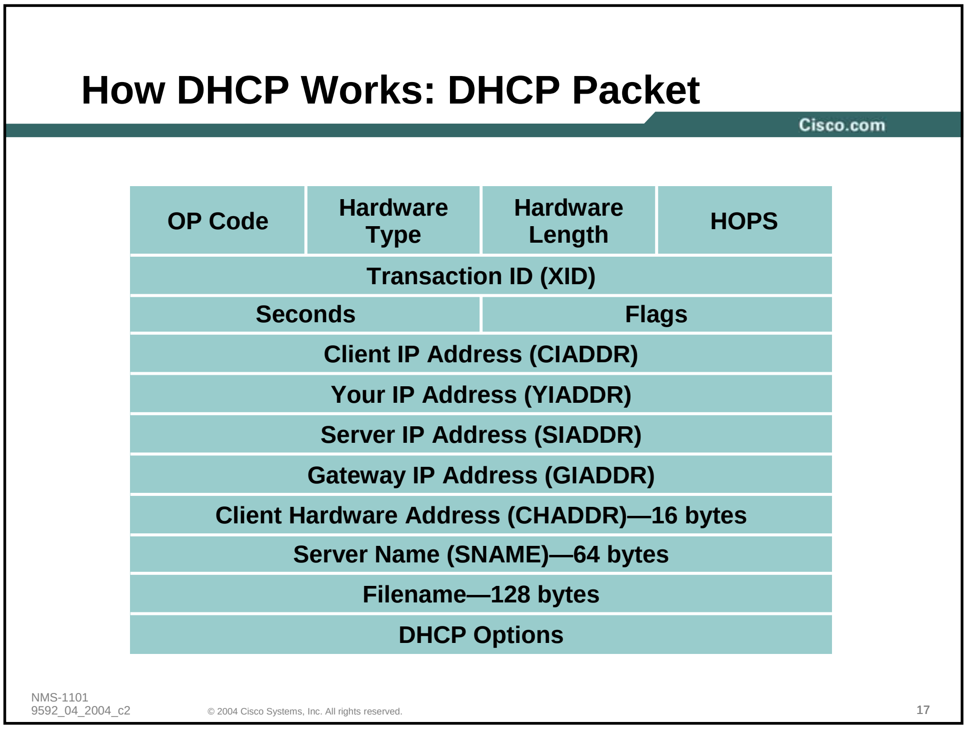
- Multiple servers with split address pools
  - Loadsharing
    - Servers answer only for configured hash (MAC)
    - RFC 3074
- Failover
  - Draft based on our (Cisco) design
  - Two servers can share address pools and continue to operate if one fails



## DHCP Safe Failover Protocol

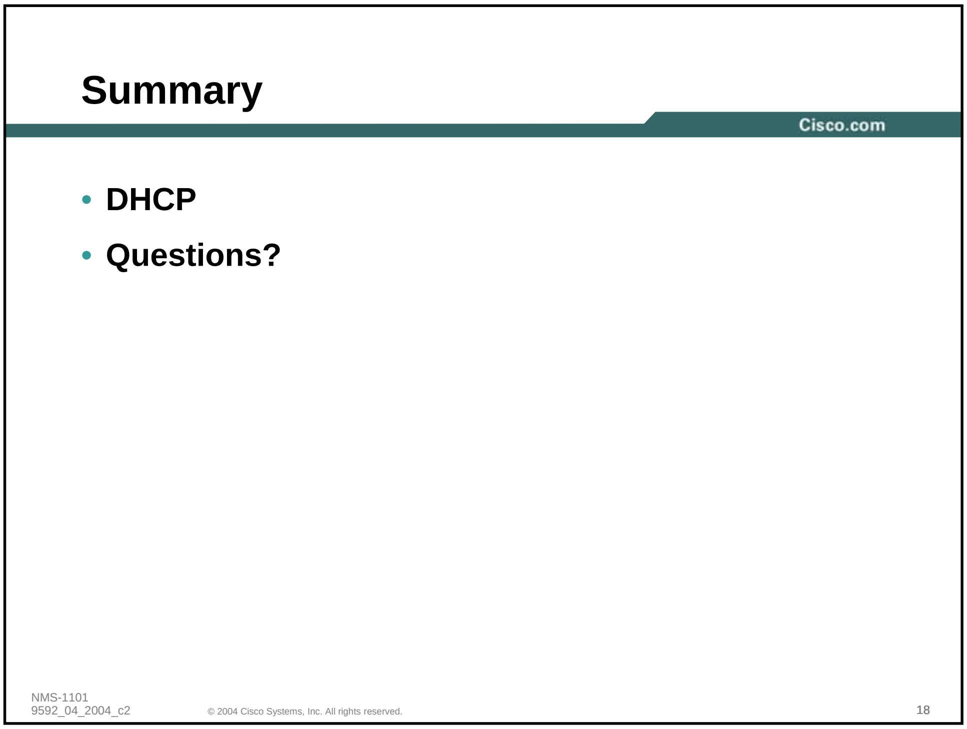
- All DHCP requests are sent to both servers
- Primary updates backup with lease information
- Backup takes over when primary fails
- Backup server uses dedicated pool of addresses allocated by the primary to prevent duplicate IP address
- Servers synchronize when primary is up
- IETF Internet draft

Backup DHCP Server
Primary DHCP Server
Backup Address Pool 172.16.18.191-200
Primary Address Pool 172.16.18.101-200



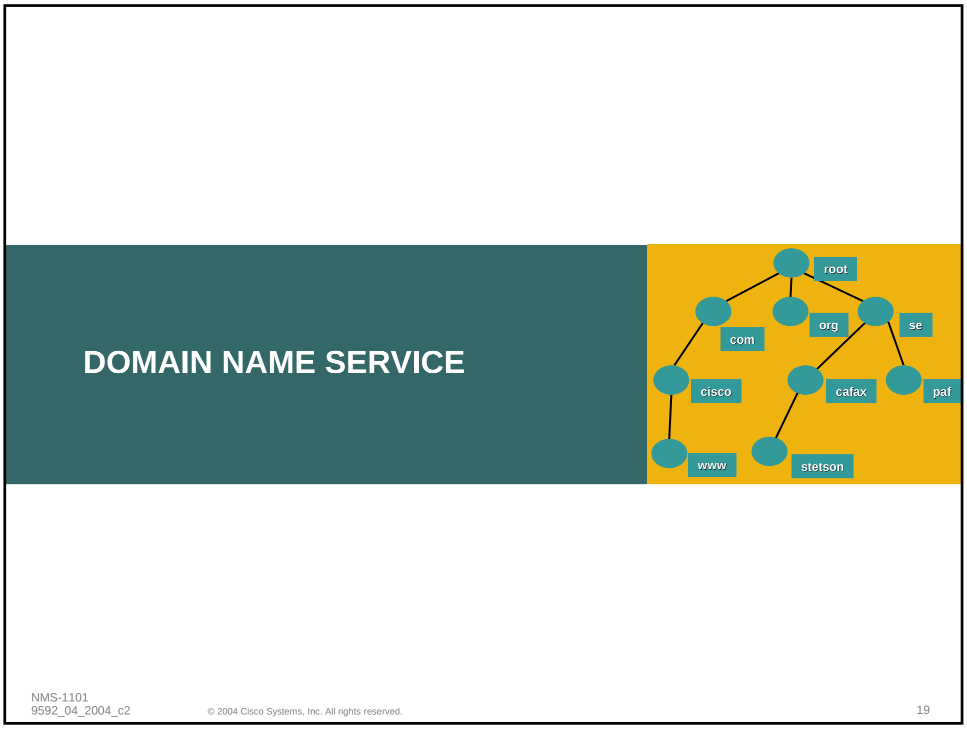
# How DHCP Works: DHCP Packet

| OP Code | Hardware Type | Hardware Length | HOPS |
|---|---|---|---|
| Transaction ID (XID) | | | |
| Seconds | | Flags | |
| Client IP Address (CIADDR) | | | |
| Your IP Address (YIADDR) | | | |
| Server IP Address (SIADDR) | | | |
| Gateway IP Address (GIADDR) | | | |
| Client Hardware Address (CHADDR)—16 bytes | | | |
| Server Name (SNAME)—64 bytes | | | |
| Filename—128 bytes | | | |
| DHCP Options | | | |

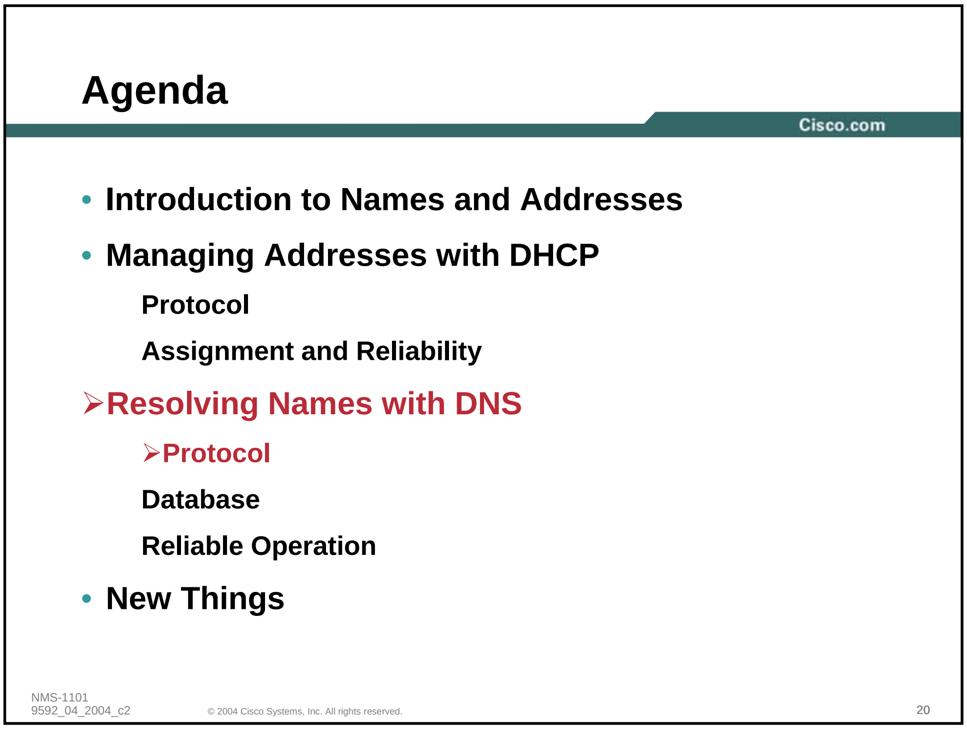


# Summary

- DHCP
- Questions?



# DOMAIN NAME SERVICE



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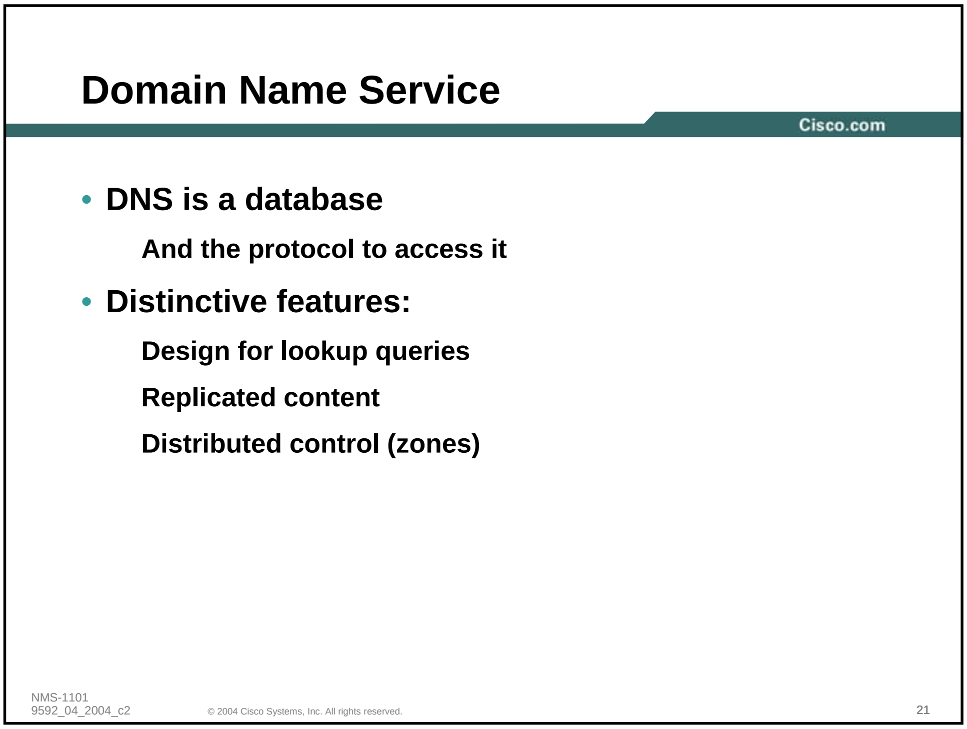


## Domain Name Service

Cisco.com

- DNS is a database

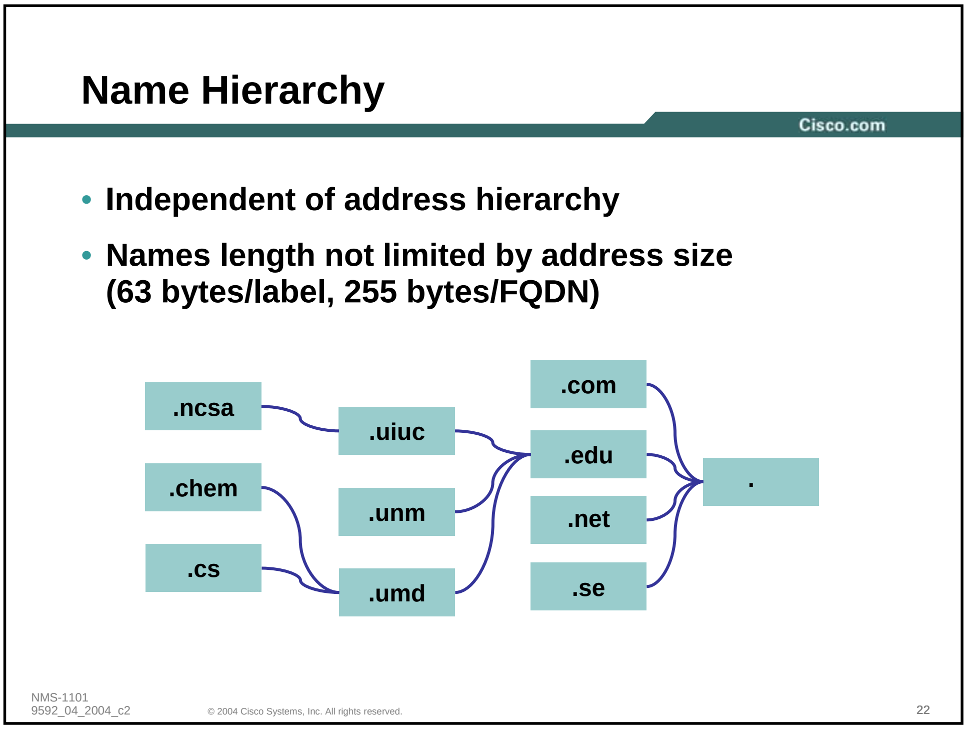
  And the protocol to access it

- Distinctive features:

  Design for lookup queries

  Replicated content

  Distributed control (zones)



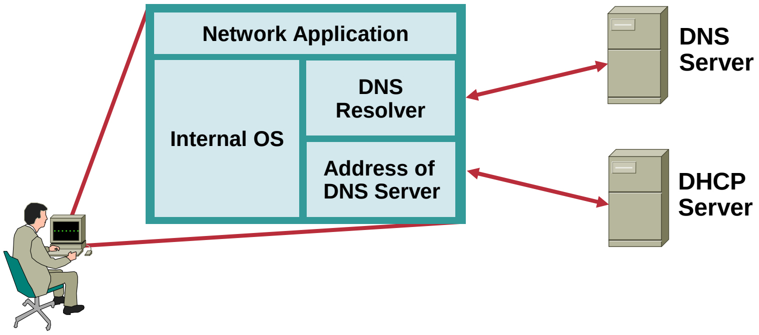
## Name Hierarchy

Cisco.com

- Independent of address hierarchy
- Names length not limited by address size (63 bytes/label, 255 bytes/FQDN)

# DNS Servers and Resolvers

Cisco.com



- Application connects by name, the application gets the address from the resolver
- Most applications use addresses in the order provided by the resolver

# TCP and UDP Ports

Cisco.com

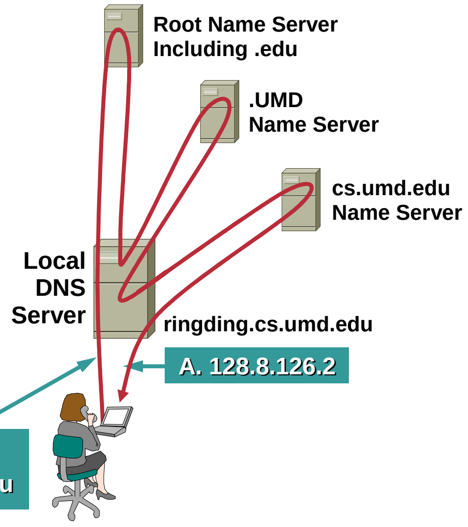
- Port 53 for both TCP and UDP
- UDP for queries if small enough
- TCP for zone transfer
- Server can use source port of 53 when “forwarding”

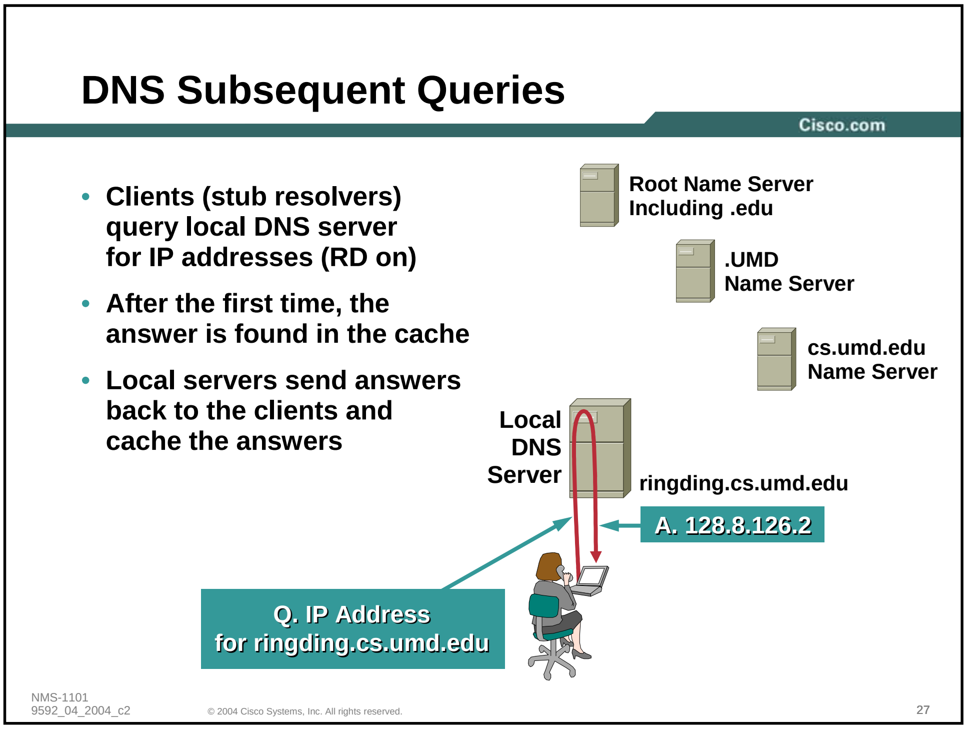
## Redirection and Recursion

- **Redirection:**
  **“Take your question down the hall”**
- **Recursion:**
  **“I’ll get back to you”**
- **Resolver sets Recursion Desired (RD), server responds with Recursion Available (RA) through bits in the DNS header**

## DNS First Query

- Clients (stub resolvers) query local DNS server for IP addresses (RD on)
- Local server queries (RD off) the root name server and follows referrals until it finds a server that has the answer
- Local servers send answers back to the clients and cache the answers





## DNS Subsequent Queries

Cisco.com

- Clients (stub resolvers) query local DNS server for IP addresses (RD on)
- After the first time, the answer is found in the cache
- Local servers send answers back to the clients and cache the answers

Root Name Server
Including .edu

.UMD
Name Server

cs.umd.edu
Name Server

Local
DNS
Server

ringding.cs.umd.edu

A. 128.8.126.2

Q. IP Address
for ringding.cs.umd.edu

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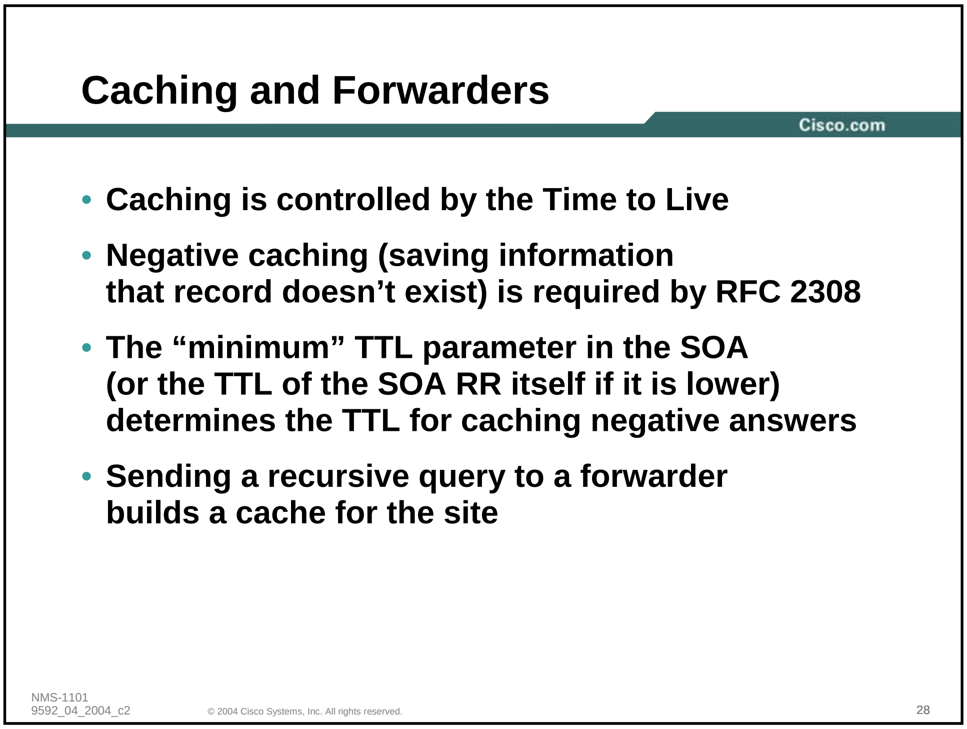

## Caching and Forwarders

Cisco.com

- Caching is controlled by the Time to Live
- Negative caching (saving information that record doesn't exist) is required by RFC 2308
- The "minimum" TTL parameter in the SOA (or the TTL of the SOA RR itself if it is lower) determines the TTL for caching negative answers
- Sending a recursive query to a forwarder builds a cache for the site

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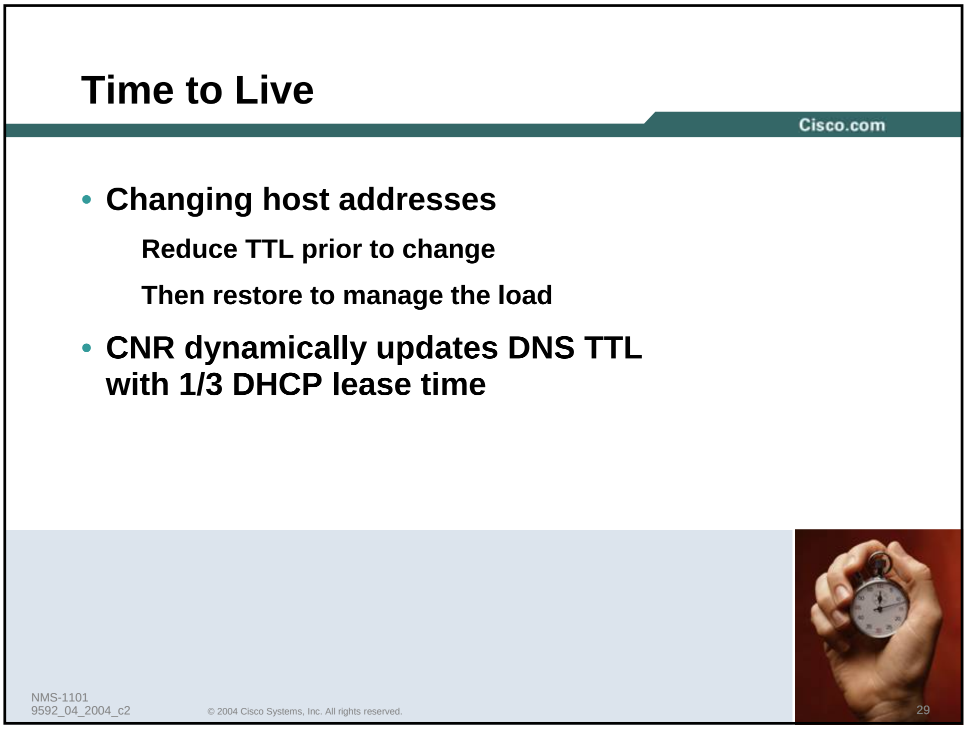
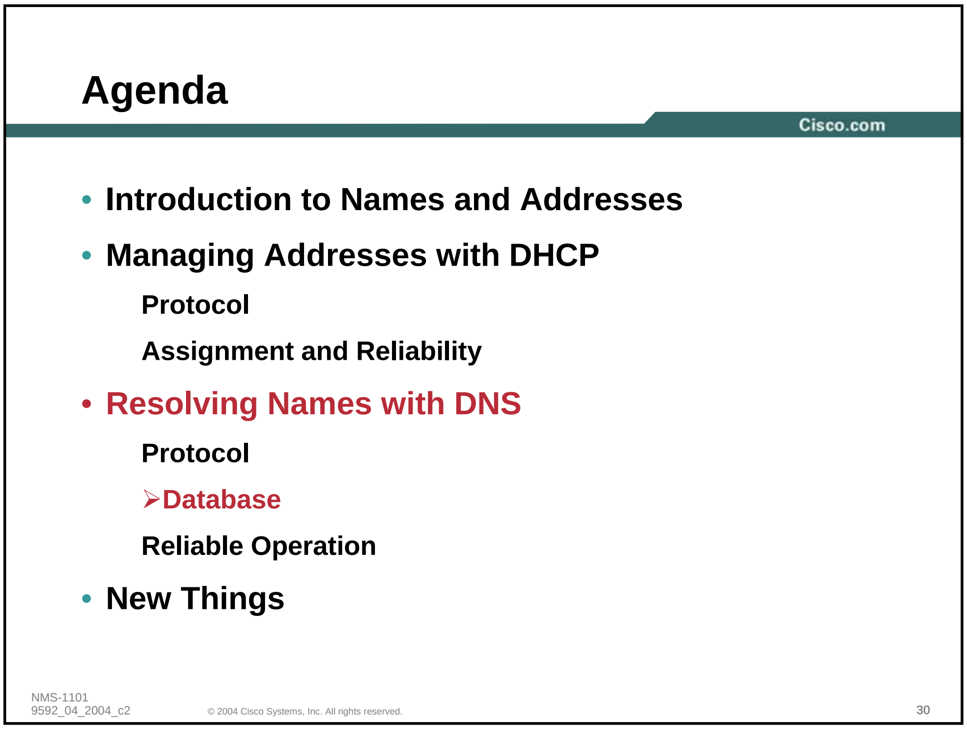


## Time to Live

- Changing host addresses
  - Reduce TTL prior to change
  - Then restore to manage the load
- CNR dynamically updates DNS TTL with 1/3 DHCP lease time



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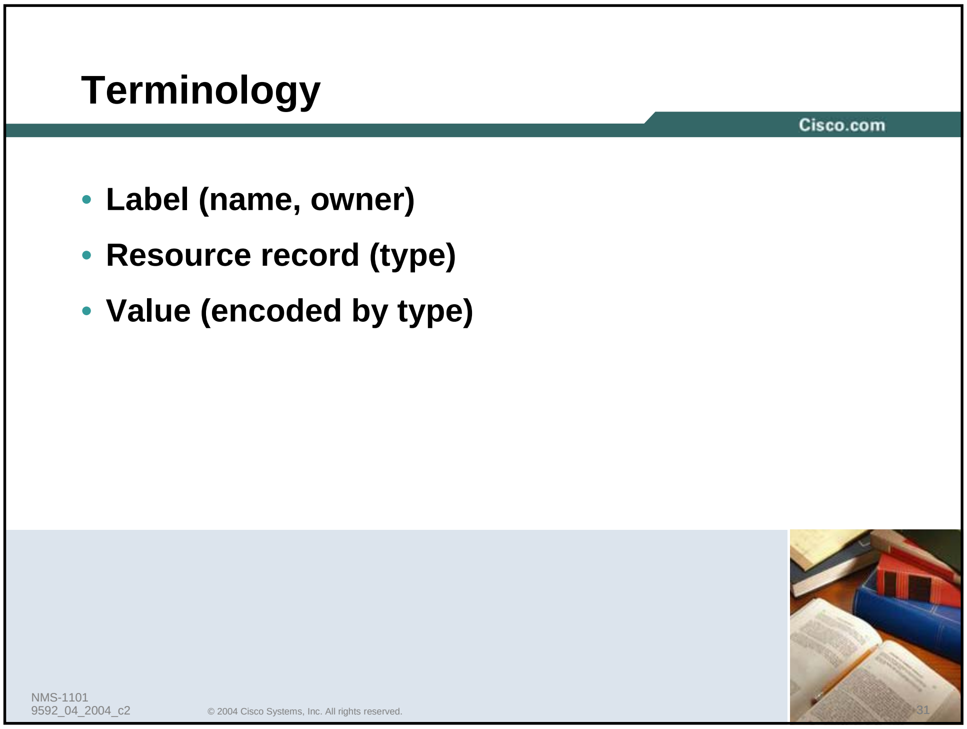
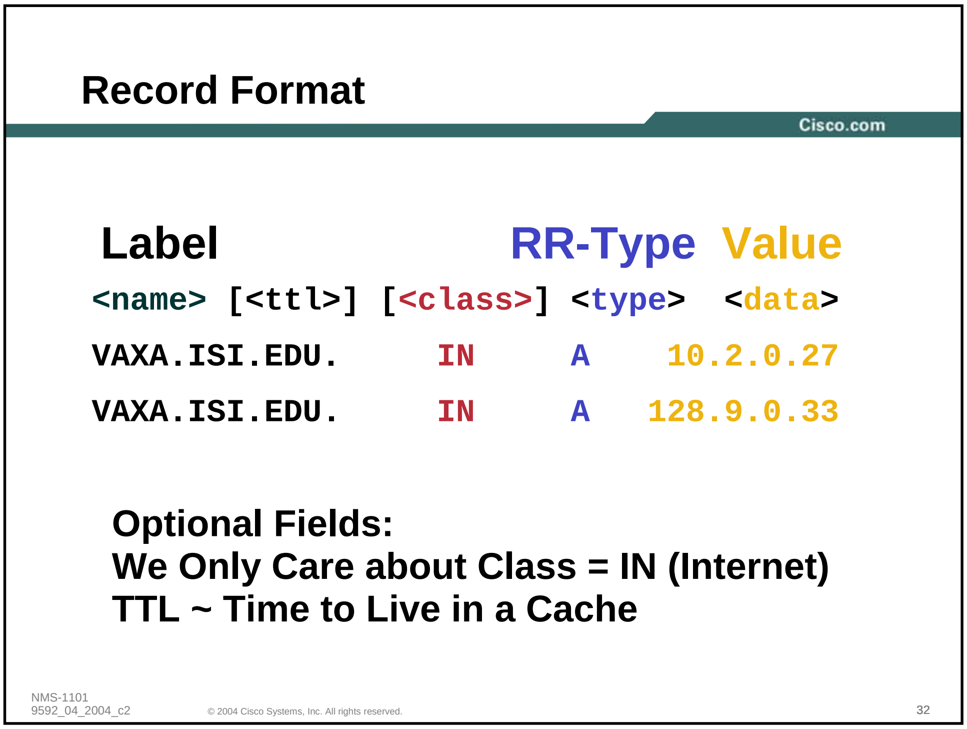


## Terminology

- Label (name, owner)
- Resource record (type)
- Value (encoded by type)

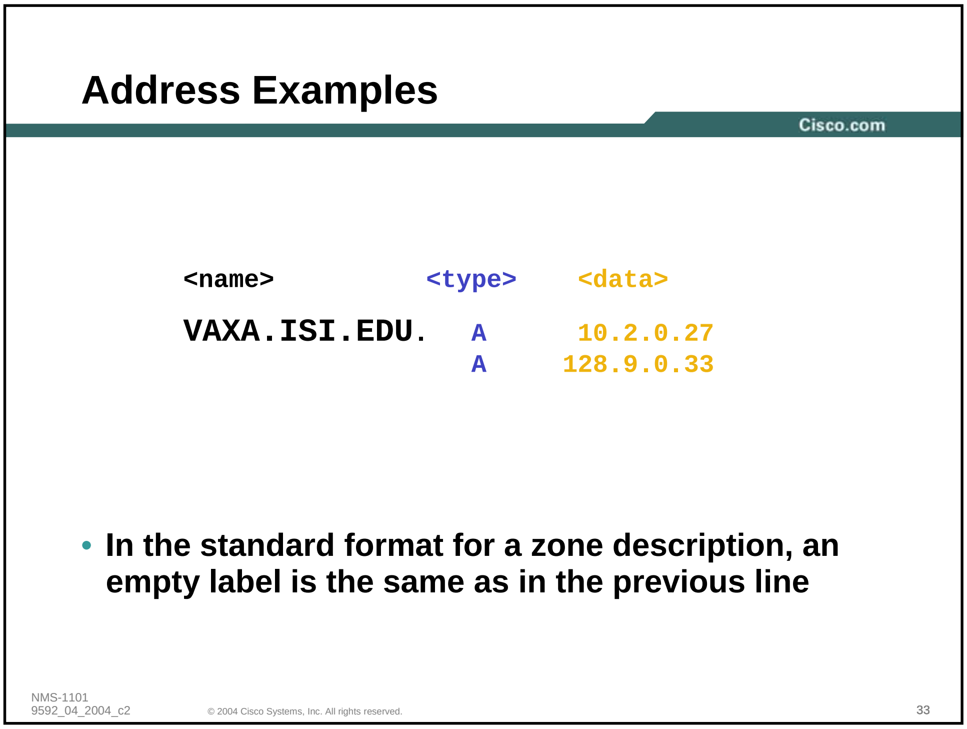


## Record Format

**Label** **RR-Type** **Value**

```
<name> [<ttl>] [<class>] <type>  <data>
VAXA.ISI.EDU.      IN      A     10.2.0.27
VAXA.ISI.EDU.      IN      A    128.9.0.33
```

**Optional Fields:**
**We Only Care about Class = IN (Internet)**
**TTL ~ Time to Live in a Cache**

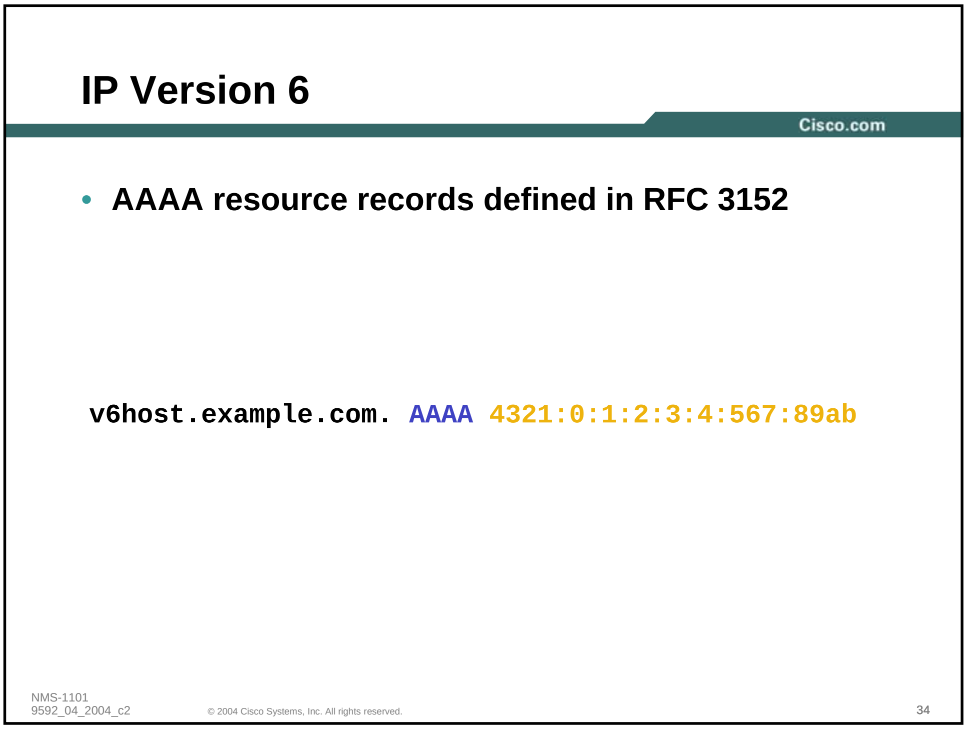


## Address Examples

```
<name>          <type>    <data>

VAXA.ISI.EDU.      A      10.2.0.27
                   A     128.9.0.33
```

- In the standard format for a zone description, an empty label is the same as in the previous line



## IP Version 6

- AAAA resource records defined in RFC 3152

```
v6host.example.com. AAAA 4321:0:1:2:3:4:567:89ab
```

## Address and Canonical Name

- A (address) resource record (RR)

  The value is a 32-bit IPv4 address

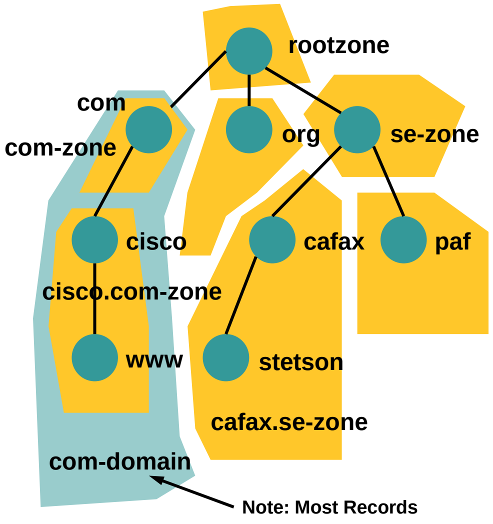
- CNAME

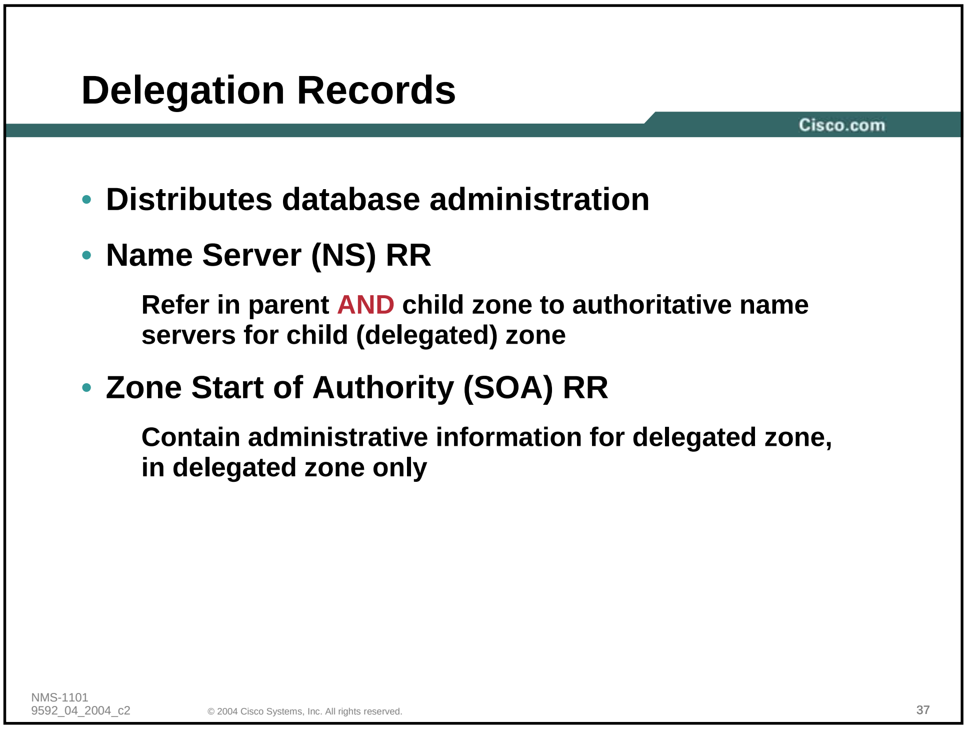
  The value is the name of a label

  The value of a canonical name is not allowed to be the label of an CNAME record—but multiple levels of reference happen anyway

## Delegation Zone

- Hierarchical name space
- Each node in the tree represents a domain/subdomain
- Some subdomains are defined as zones
- Each zone has a “primary” name server responsible for all lower nodes, but delegation is to all authoritative name servers
- Resource Records (RR) can, but don’t have to, be defined for each node





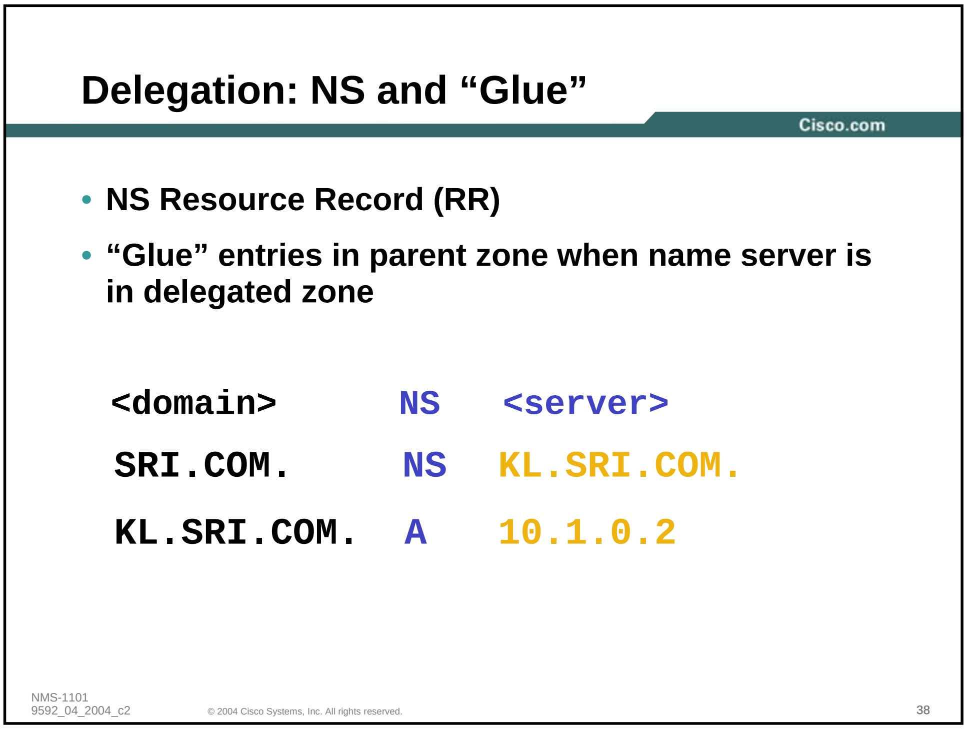
## Delegation Records

- Distributes database administration
- Name Server (NS) RR

  Refer in parent AND child zone to authoritative name servers for child (delegated) zone

- Zone Start of Authority (SOA) RR

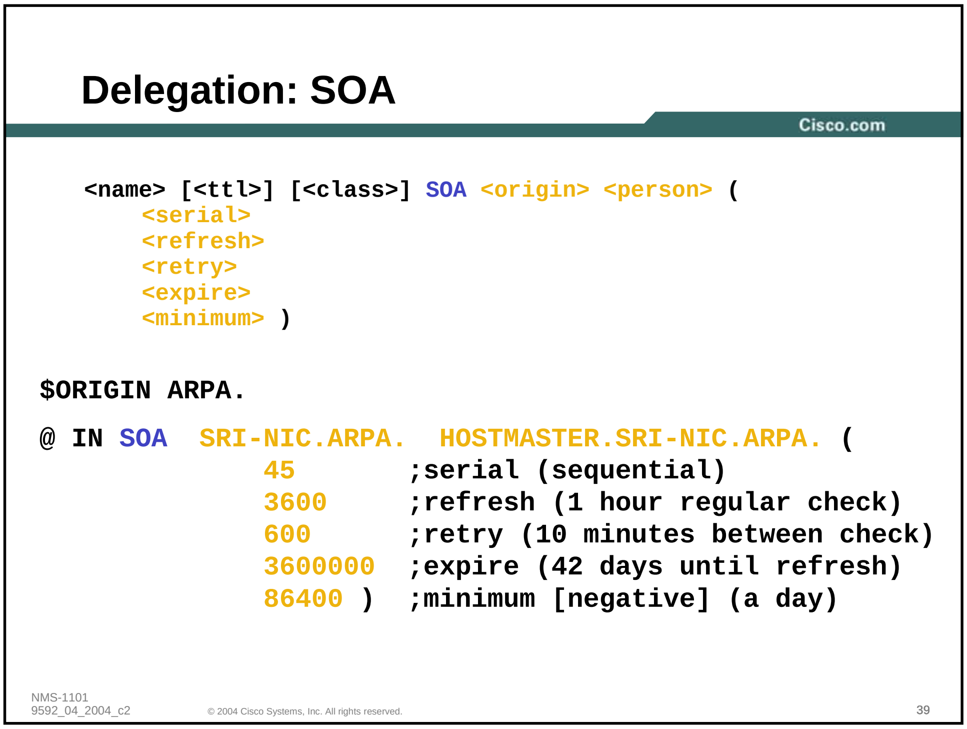
  Contain administrative information for delegated zone, in delegated zone only



## Delegation: NS and “Glue”

- NS Resource Record (RR)
- “Glue” entries in parent zone when name server is in delegated zone

```
<domain>       NS    <server>
SRI.COM.       NS   KL.SRI.COM.
KL.SRI.COM.    A    10.1.0.2
```



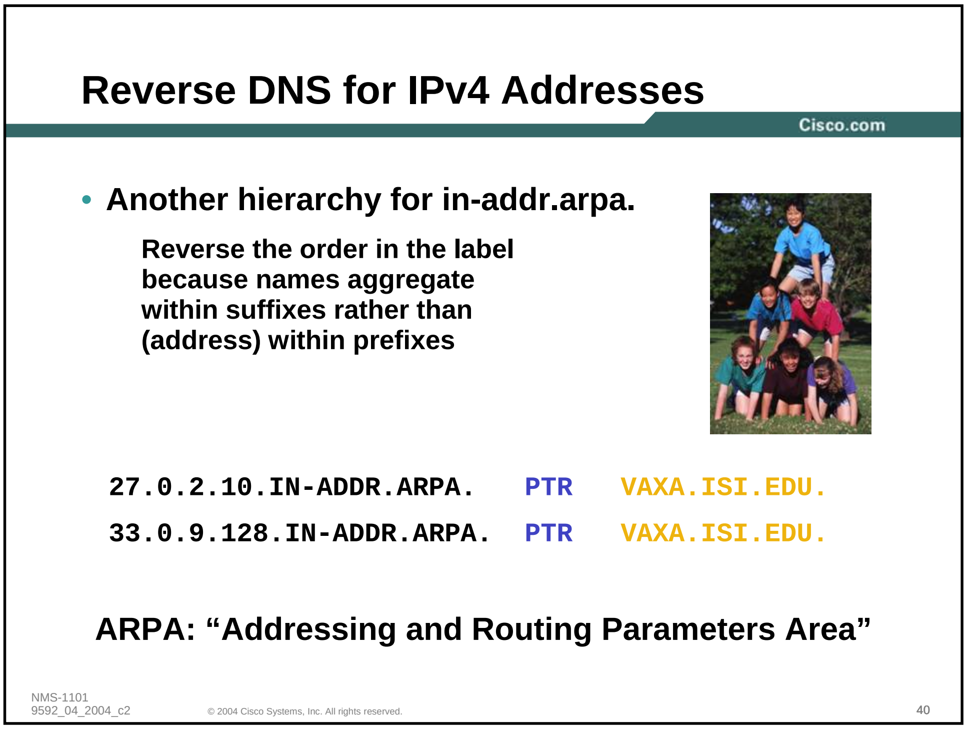
## Delegation: SOA

Cisco.com

```
<name> [<ttl>] [<class>] SOA <origin> <person> (
    <serial>
    <refresh>
    <retry>
    <expire>
    <minimum> )
```

```
$ORIGIN ARPA.

@ IN SOA  SRI-NIC.ARPA.  HOSTMASTER.SRI-NIC.ARPA. (
              45        ;serial (sequential)
              3600      ;refresh (1 hour regular check)
              600       ;retry (10 minutes between check)
              3600000   ;expire (42 days until refresh)
              86400 )   ;minimum [negative] (a day)
```



## Reverse DNS for IPv4 Addresses

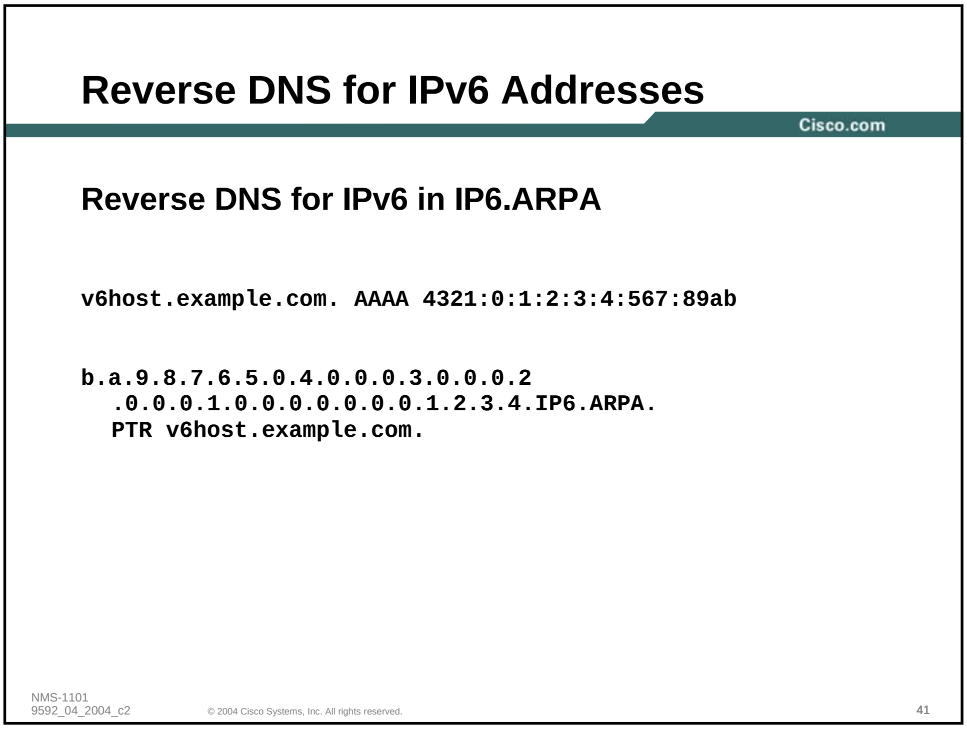
Cisco.com

- Another hierarchy for in-addr.arpa.

  Reverse the order in the label because names aggregate within suffixes rather than (address) within prefixes

```
27.0.2.10.IN-ADDR.ARPA.    PTR   VAXA.ISI.EDU.
33.0.9.128.IN-ADDR.ARPA.   PTR   VAXA.ISI.EDU.
```

ARPA: “Addressing and Routing Parameters Area”

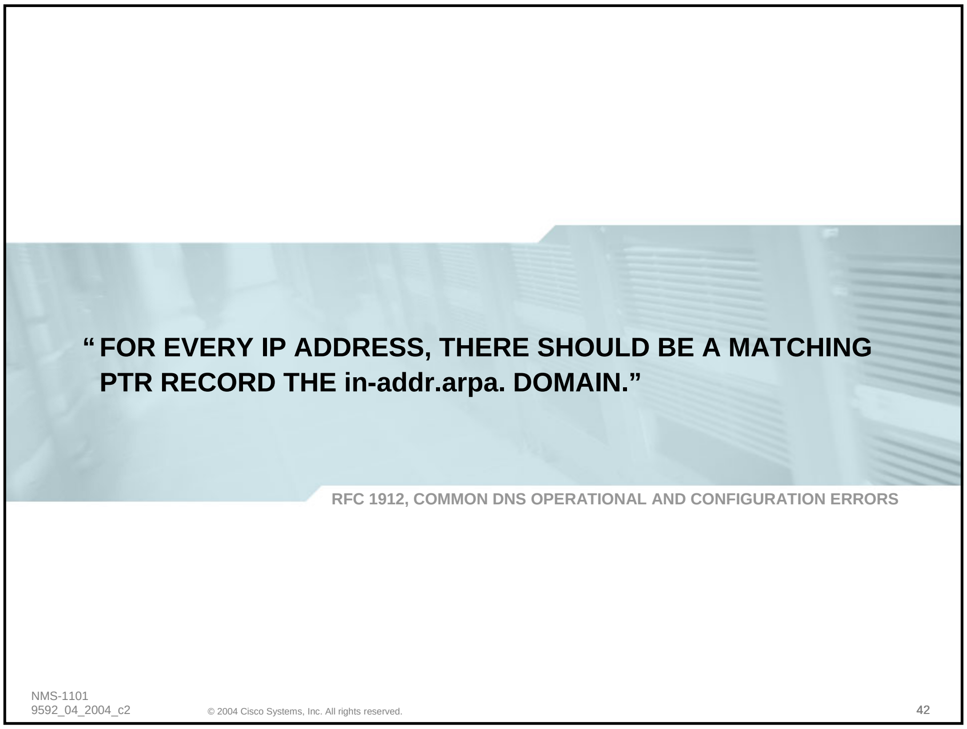


## Reverse DNS for IPv6 Addresses

### Reverse DNS for IPv6 in IP6.ARPA

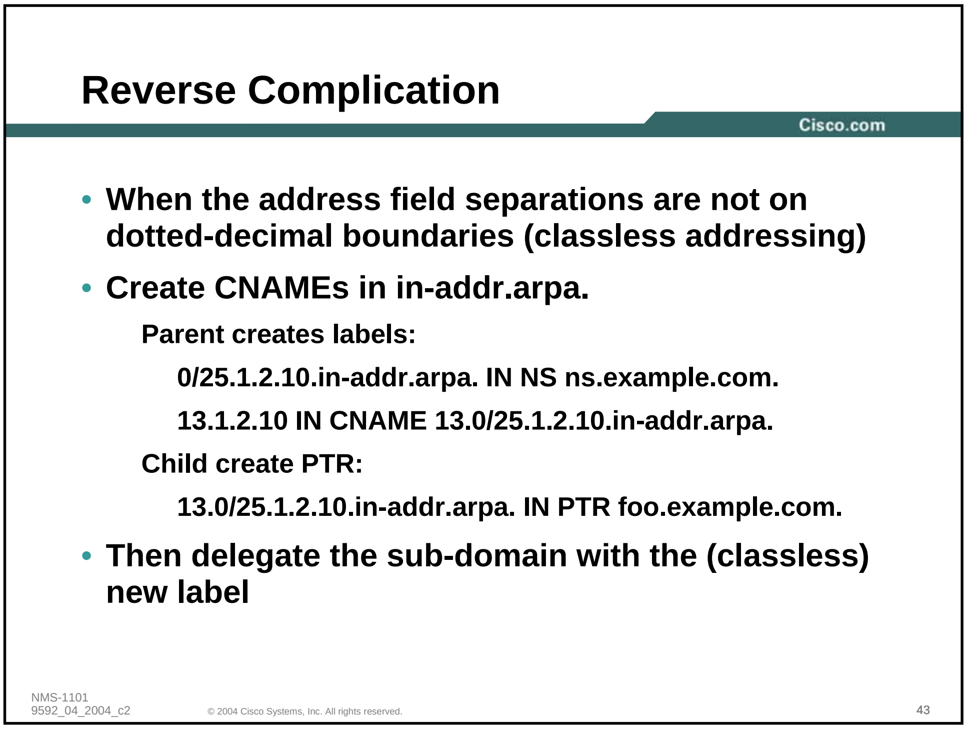
```
v6host.example.com. AAAA 4321:0:1:2:3:4:567:89ab


b.a.9.8.7.6.5.0.4.0.0.0.3.0.0.0.2
  .0.0.0.1.0.0.0.0.0.0.0.0.1.2.3.4.IP6.ARPA.
  PTR v6host.example.com.
```



“ FOR EVERY IP ADDRESS, THERE SHOULD BE A MATCHING PTR RECORD THE in-addr.arpa. DOMAIN.”

RFC 1912, COMMON DNS OPERATIONAL AND CONFIGURATION ERRORS



## Reverse Complication

Cisco.com

- When the address field separations are not on dotted-decimal boundaries (classless addressing)
- Create CNAMEs in in-addr.arpa.

  Parent creates labels:

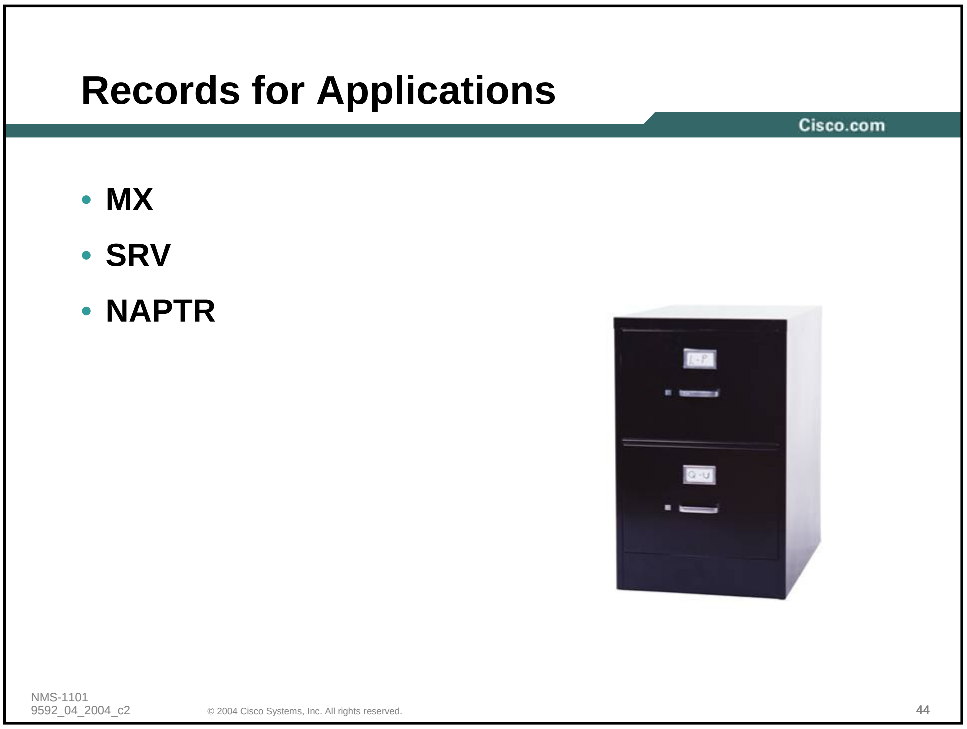
  0/25.1.2.10.in-addr.arpa. IN NS ns.example.com.

  13.1.2.10 IN CNAME 13.0/25.1.2.10.in-addr.arpa.

  Child create PTR:

  13.0/25.1.2.10.in-addr.arpa. IN PTR foo.example.com.

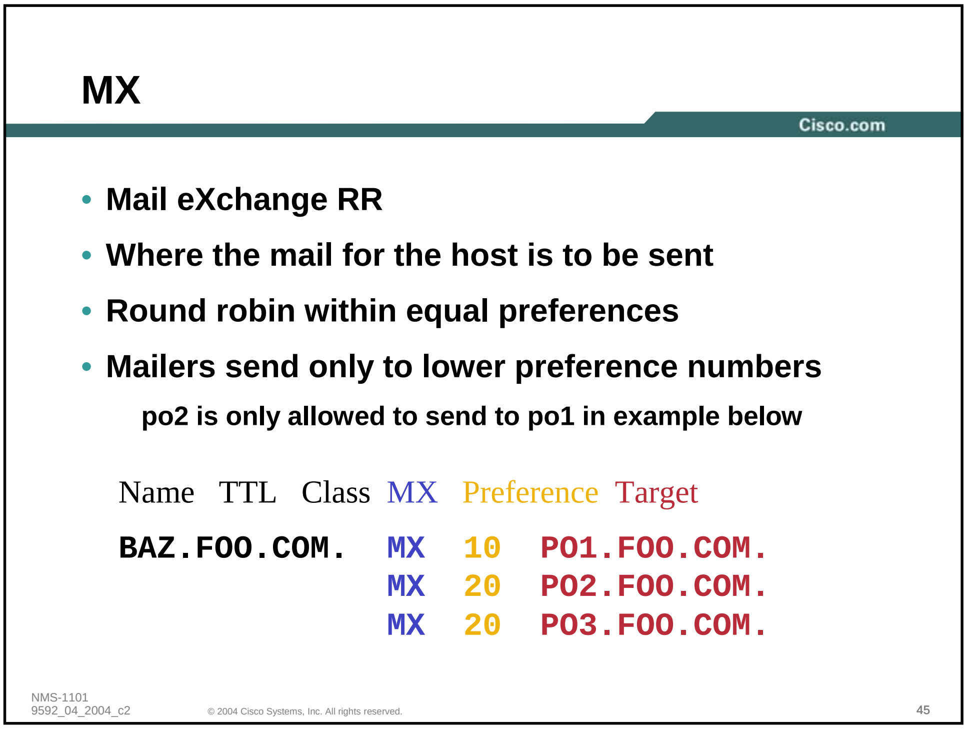
- Then delegate the sub-domain with the (classless) new label



## Records for Applications

Cisco.com

- MX
- SRV
- NAPTR



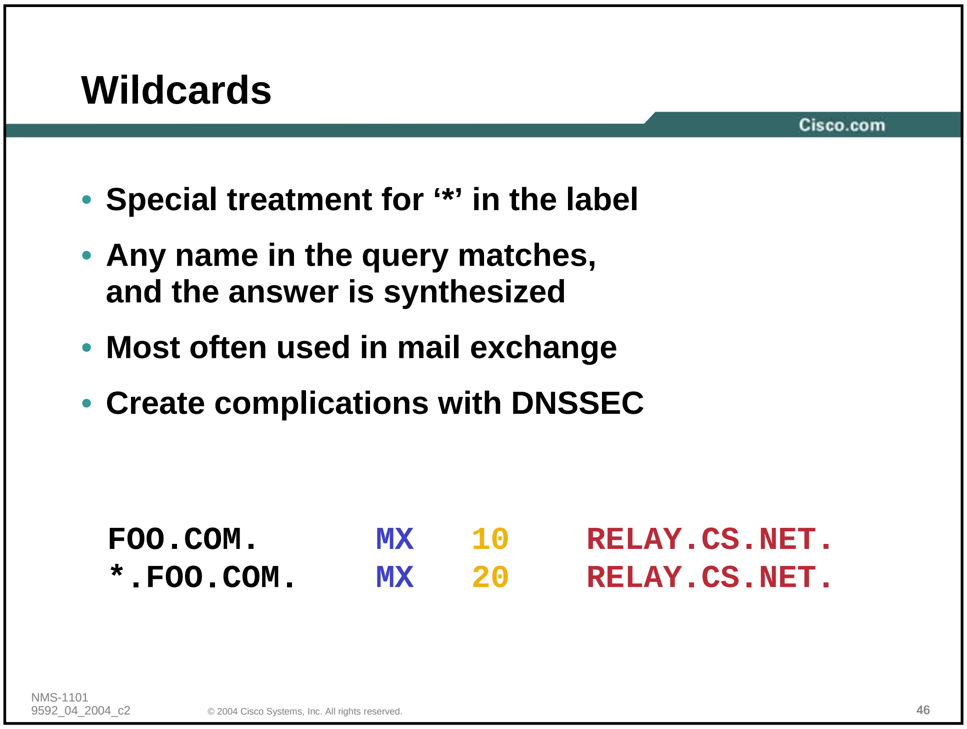
## MX

Cisco.com

- Mail eXchange RR
- Where the mail for the host is to be sent
- Round robin within equal preferences
- Mailers send only to lower preference numbers

  po2 is only allowed to send to po1 in example below

```
Name   TTL   Class  MX   Preference  Target
BAZ.FOO.COM.        MX   10   PO1.FOO.COM.
                    MX   20   PO2.FOO.COM.
                    MX   20   PO3.FOO.COM.
```

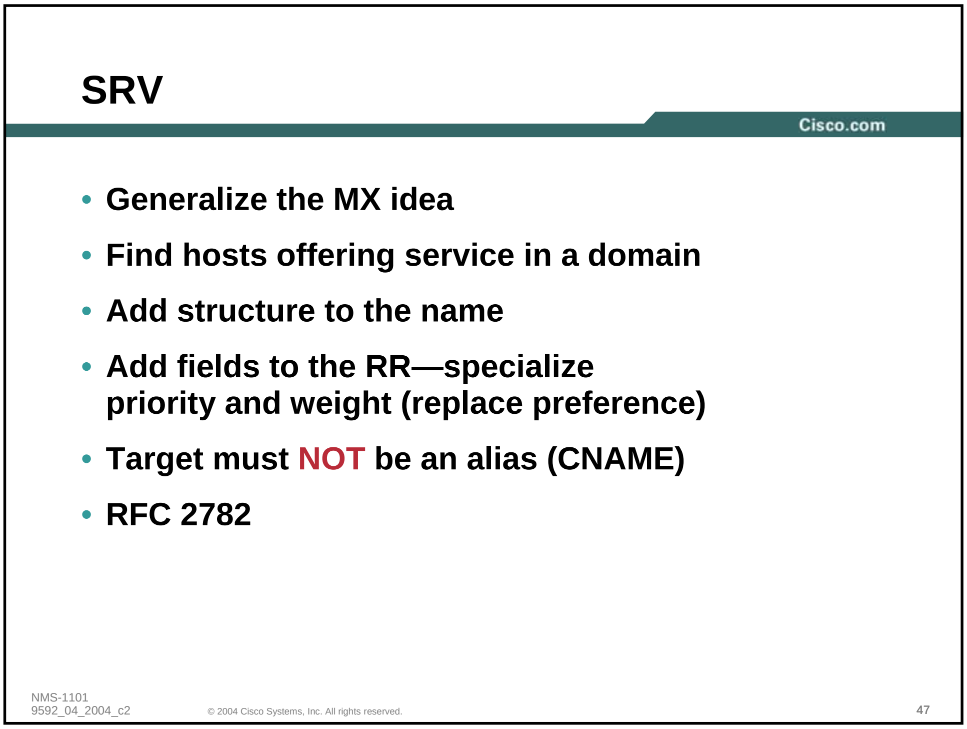


## Wildcards

Cisco.com

- Special treatment for '*' in the label
- Any name in the query matches, and the answer is synthesized
- Most often used in mail exchange
- Create complications with DNSSEC

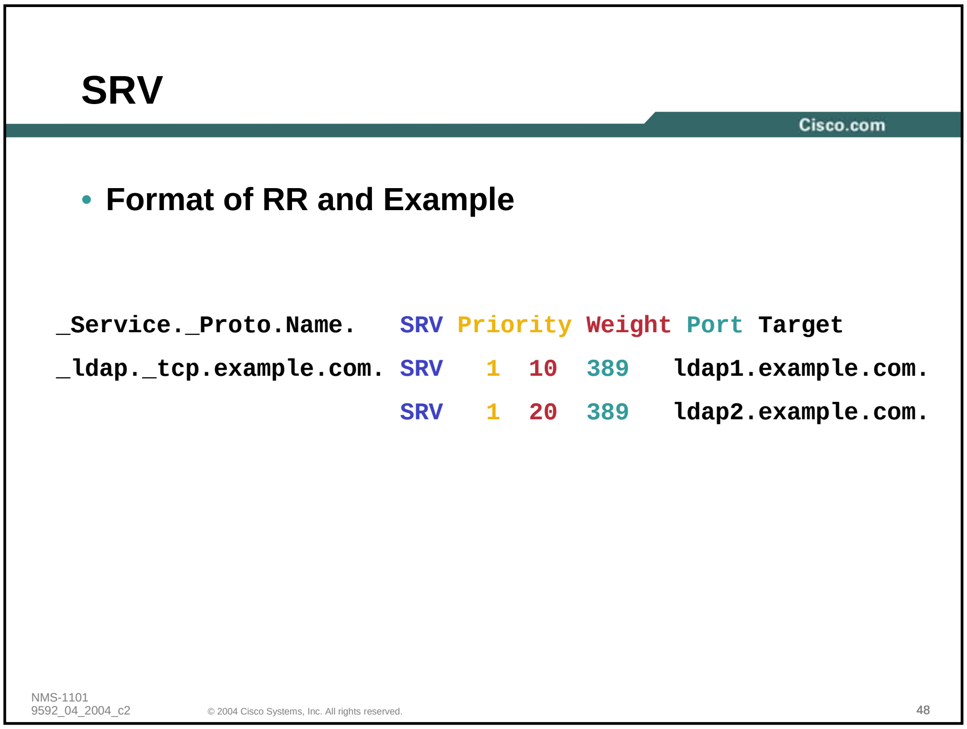
```
FOO.COM.       MX    10     RELAY.CS.NET.
*.FOO.COM.     MX    20     RELAY.CS.NET.
```



## SRV

Cisco.com

- Generalize the MX idea
- Find hosts offering service in a domain
- Add structure to the name
- Add fields to the RR—specialize priority and weight (replace preference)
- Target must NOT be an alias (CNAME)
- RFC 2782



## SRV

Cisco.com

- Format of RR and Example

```
_Service._Proto.Name.   SRV Priority Weight Port Target
_ldap._tcp.example.com. SRV    1   10   389    ldap1.example.com.
                        SRV    1   20   389    ldap2.example.com.
```

## NAPTR

- Naming Authority PoinTeR
- Universal resource identifier
- Regular expressions
- Replacement strings
- RFC 2915
- Used for example in ENUM

  ENUM is mapping from E.164 number to URLs

## Agenda

- Introduction to Names and Addresses
- Managing Addresses with DHCP

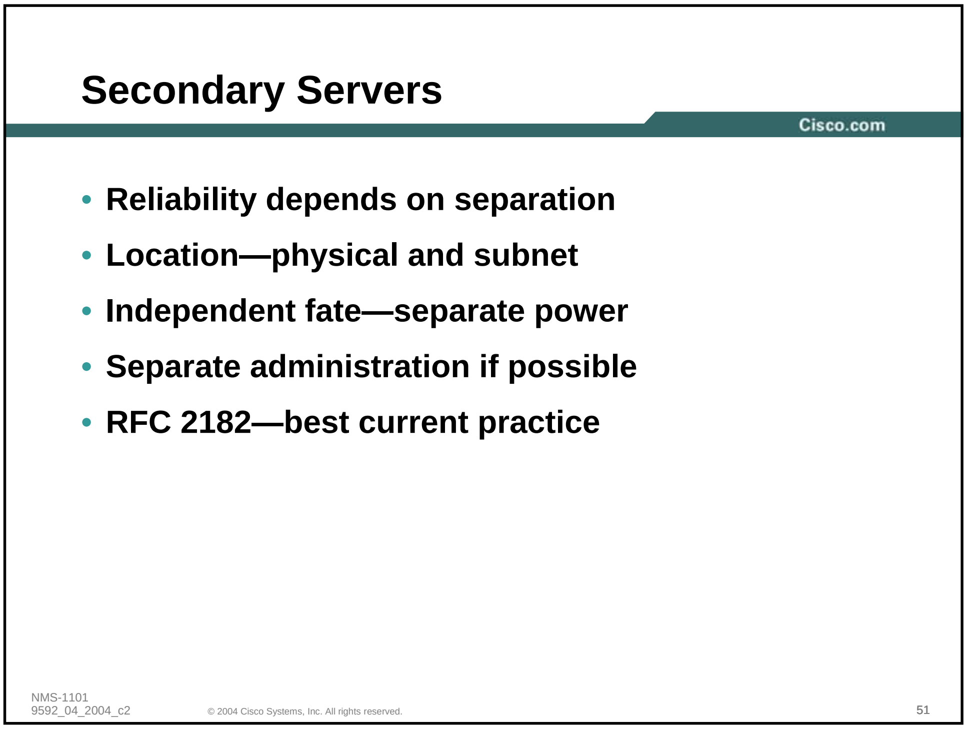
  Protocol

  Assignment and Reliability
- Resolving Names with DNS

  Protocol

  Database

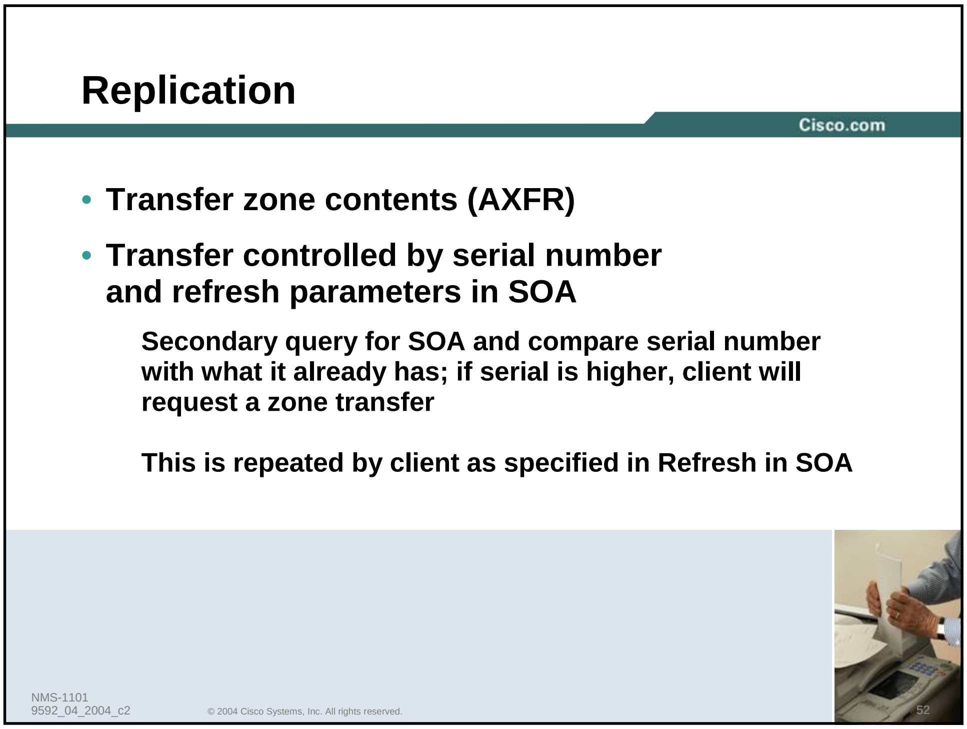
  ➢Reliable Operation
- New Things



## Secondary Servers

Cisco.com

- Reliability depends on separation
- Location—physical and subnet
- Independent fate—separate power
- Separate administration if possible
- RFC 2182—best current practice



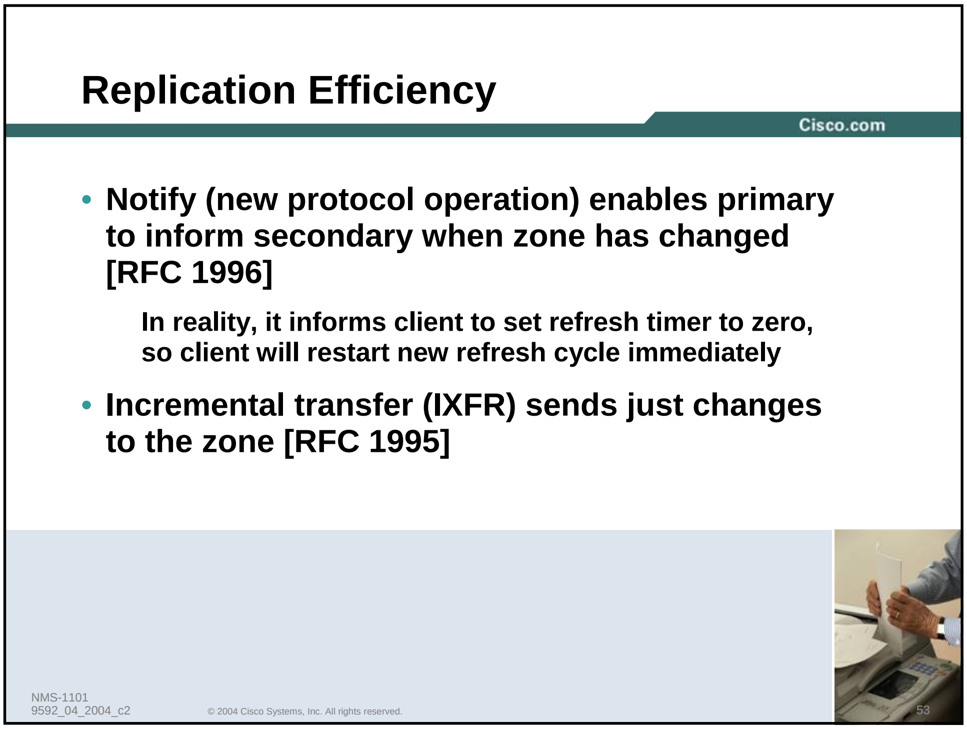
## Replication

Cisco.com

- Transfer zone contents (AXFR)
- Transfer controlled by serial number and refresh parameters in SOA

  Secondary query for SOA and compare serial number with what it already has; if serial is higher, client will request a zone transfer

  This is repeated by client as specified in Refresh in SOA



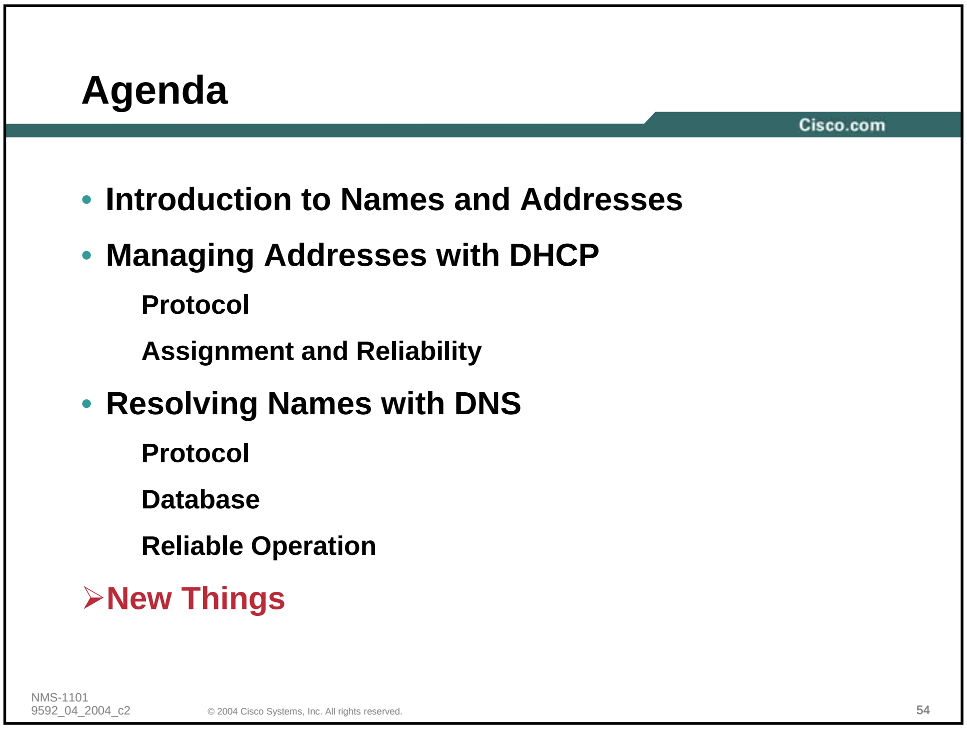
## Replication Efficiency

Cisco.com

- Notify (new protocol operation) enables primary to inform secondary when zone has changed [RFC 1996]

  In reality, it informs client to set refresh timer to zero, so client will restart new refresh cycle immediately

- Incremental transfer (IXFR) sends just changes to the zone [RFC 1995]



## Agenda

Cisco.com

- Introduction to Names and Addresses
- Managing Addresses with DHCP

  Protocol

  Assignment and Reliability

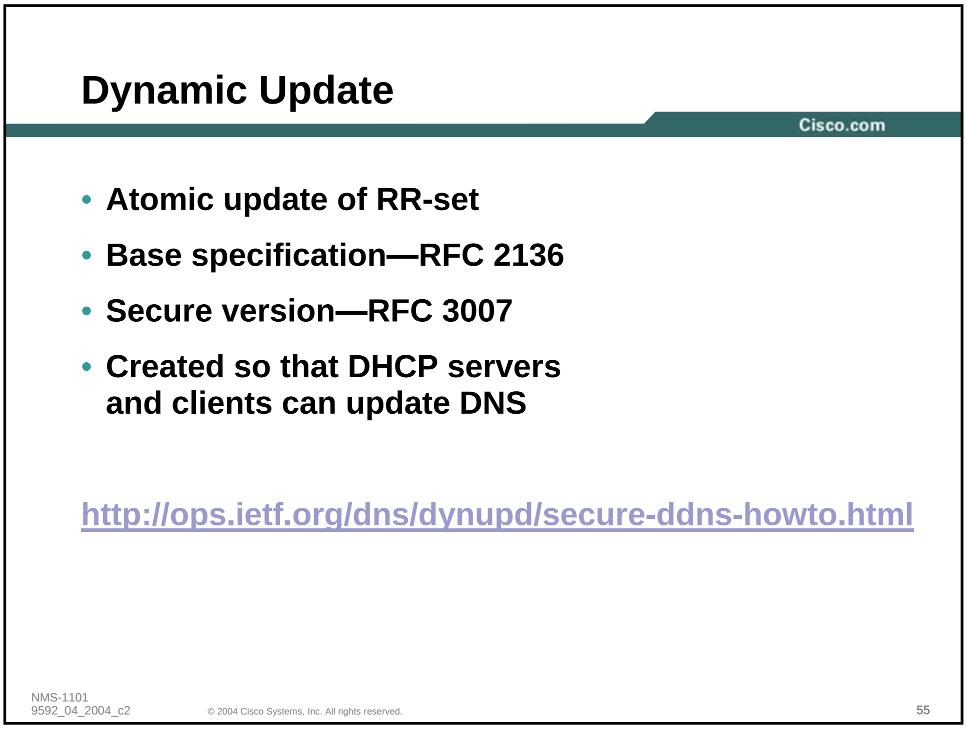
- Resolving Names with DNS

  Protocol

  Database

  Reliable Operation

➢New Things



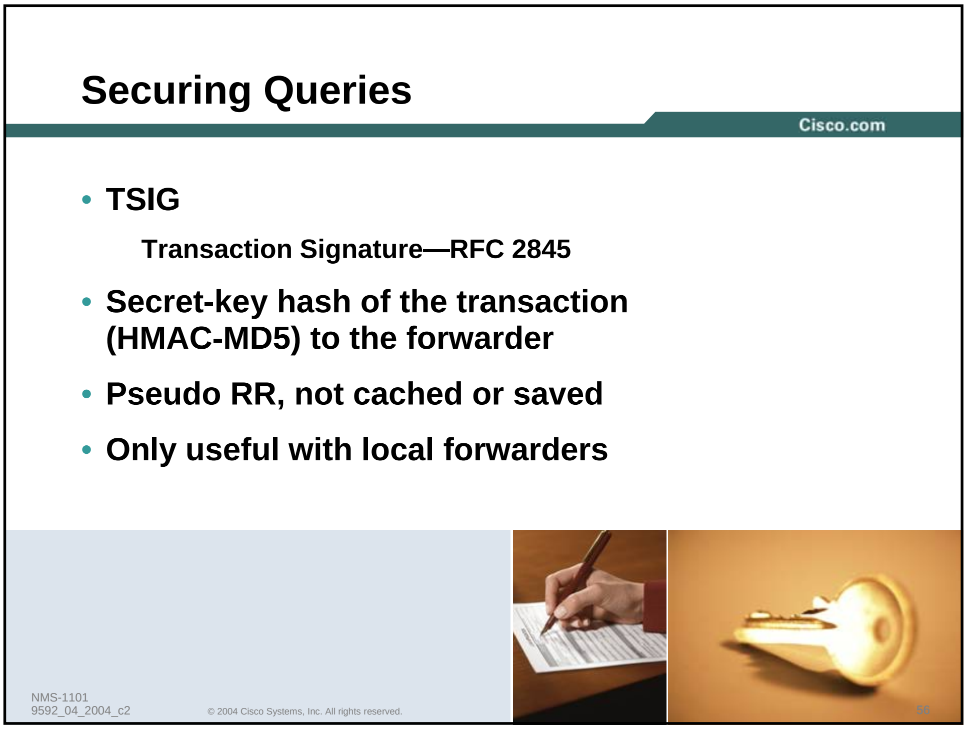
## Dynamic Update

Cisco.com

- Atomic update of RR-set
- Base specification—RFC 2136
- Secure version—RFC 3007
- Created so that DHCP servers and clients can update DNS

http://ops.ietf.org/dns/dynupd/secure-ddns-howto.html

NMS-1101
9592_04_2004_c2



## Securing Queries

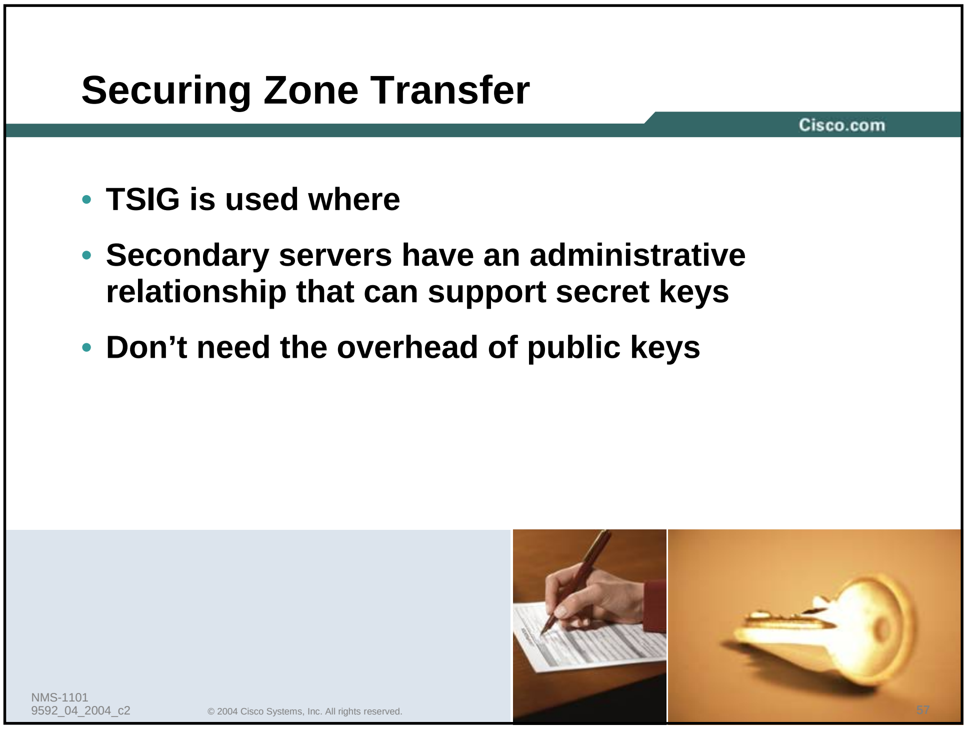
Cisco.com

- TSIG

  Transaction Signature—RFC 2845

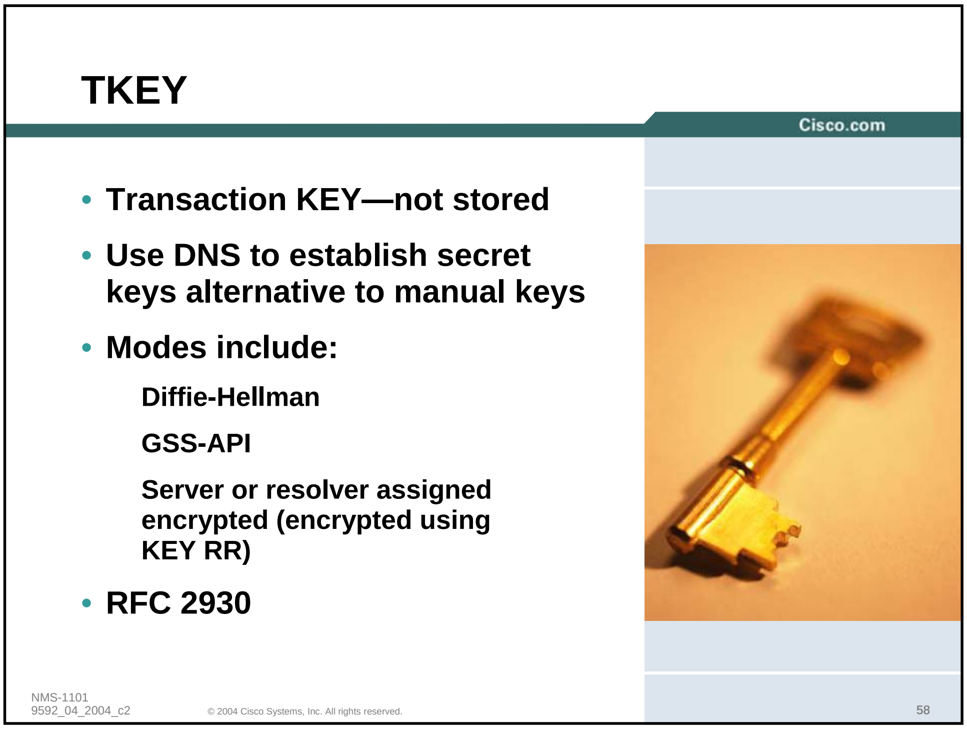
- Secret-key hash of the transaction (HMAC-MD5) to the forwarder
- Pseudo RR, not cached or saved
- Only useful with local forwarders

NMS-1101
9592_04_2004_c2



## Securing Zone Transfer

- TSIG is used where
- Secondary servers have an administrative relationship that can support secret keys
- Don’t need the overhead of public keys



## TKEY

- Transaction KEY—not stored
- Use DNS to establish secret keys alternative to manual keys
- Modes include:
  - Diffie-Hellman
  - GSS-API
  - Server or resolver assigned encrypted (encrypted using KEY RR)
- RFC 2930

## SIG(0)

Cisco.com

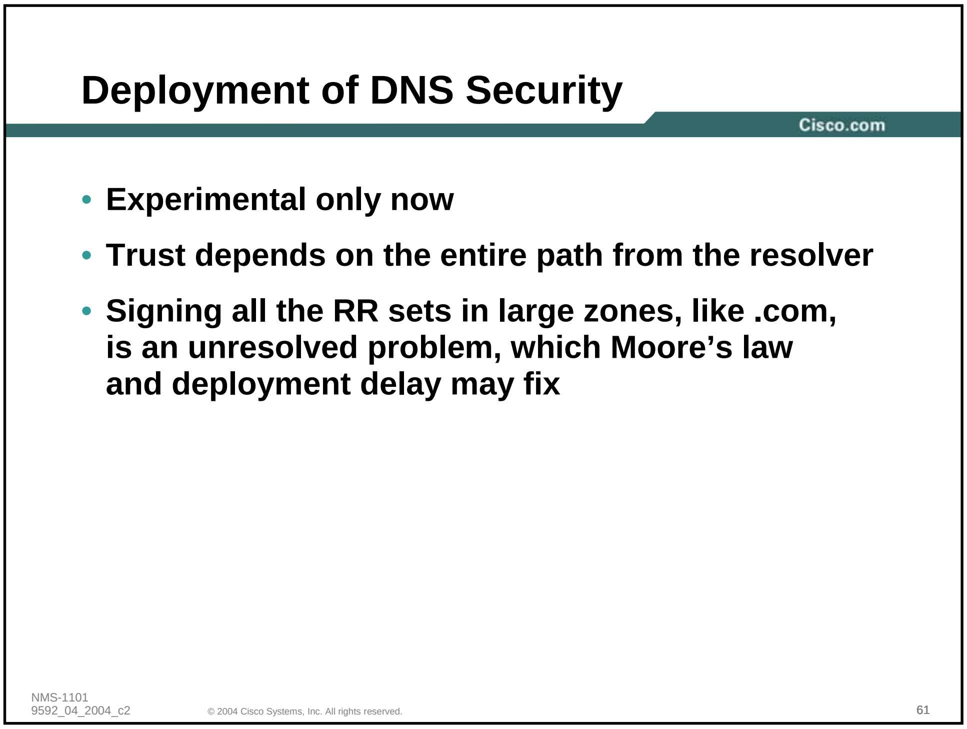
- Use DNS for client to authenticate to server
- Authenticates the transaction
- Public KEY in DNS
- Private key in client
- RFC 2931

## Securing Zone Contents

Cisco.com

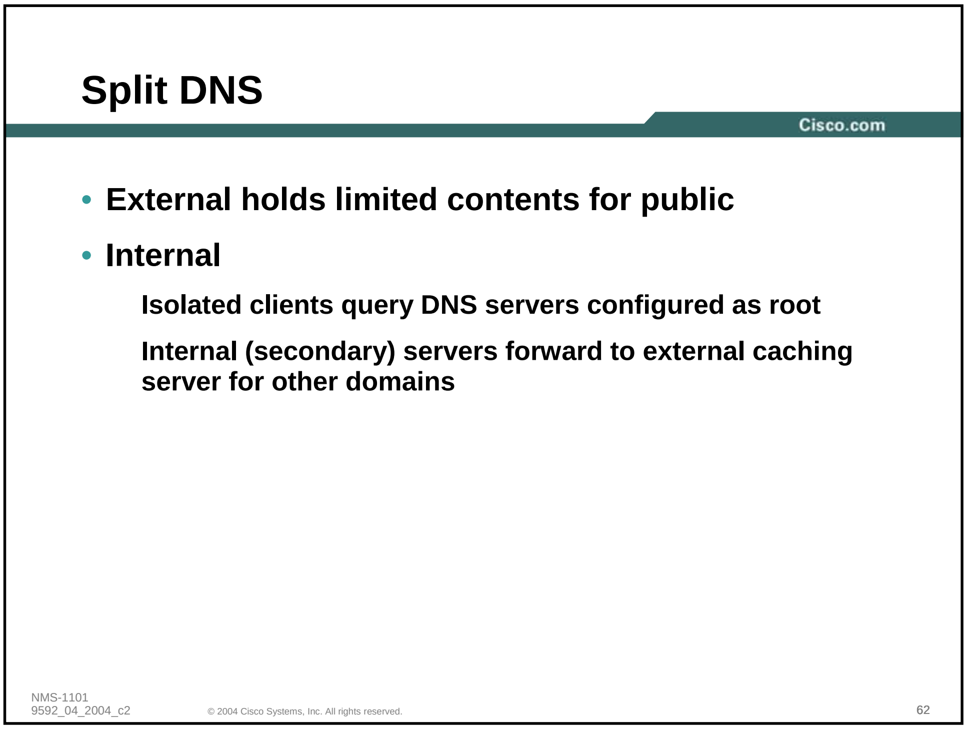
- DNS security
  - DNSKEY ~~Key~~ RR—distributes public keys for records
  - RRSIG ~~SIG~~ RR—authenticates (signs) one RR set
  - NSEC ~~NXT~~ RR—“next” record enables authentication of non existence
- DS RR—delegation signer~key in parent with which the child zone is signed
- RFC 2535—being revised

draft-ietf-dnsext-dnssec-records



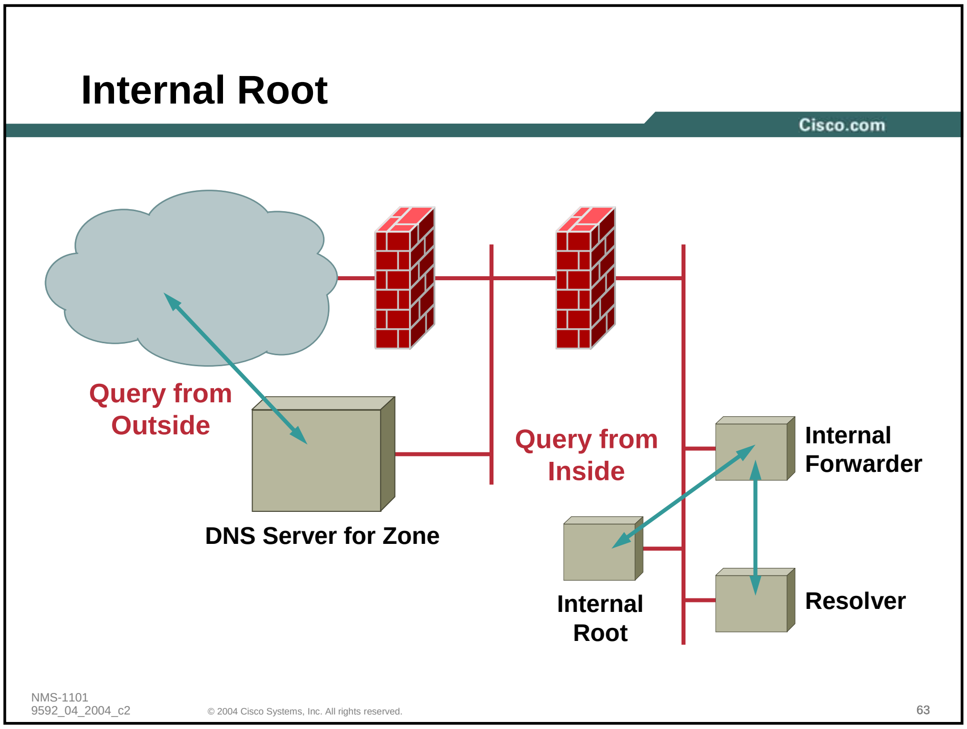
## Deployment of DNS Security

- Experimental only now
- Trust depends on the entire path from the resolver
- Signing all the RR sets in large zones, like .com, is an unresolved problem, which Moore’s law and deployment delay may fix



## Split DNS

- External holds limited contents for public
- Internal
  - Isolated clients query DNS servers configured as root
  - Internal (secondary) servers forward to external caching server for other domains



## Internal Root

Cisco.com

Query from Outside

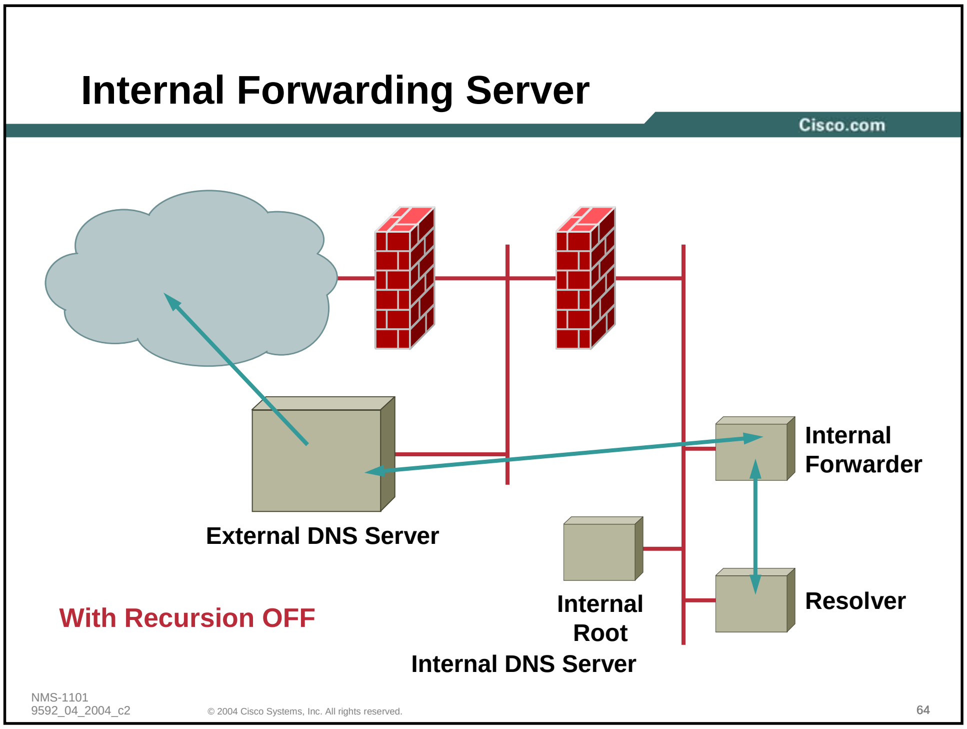
DNS Server for Zone

Query from Inside

Internal Forwarder

Internal Root

Resolver



## Internal Forwarding Server

Cisco.com

Internal Forwarder

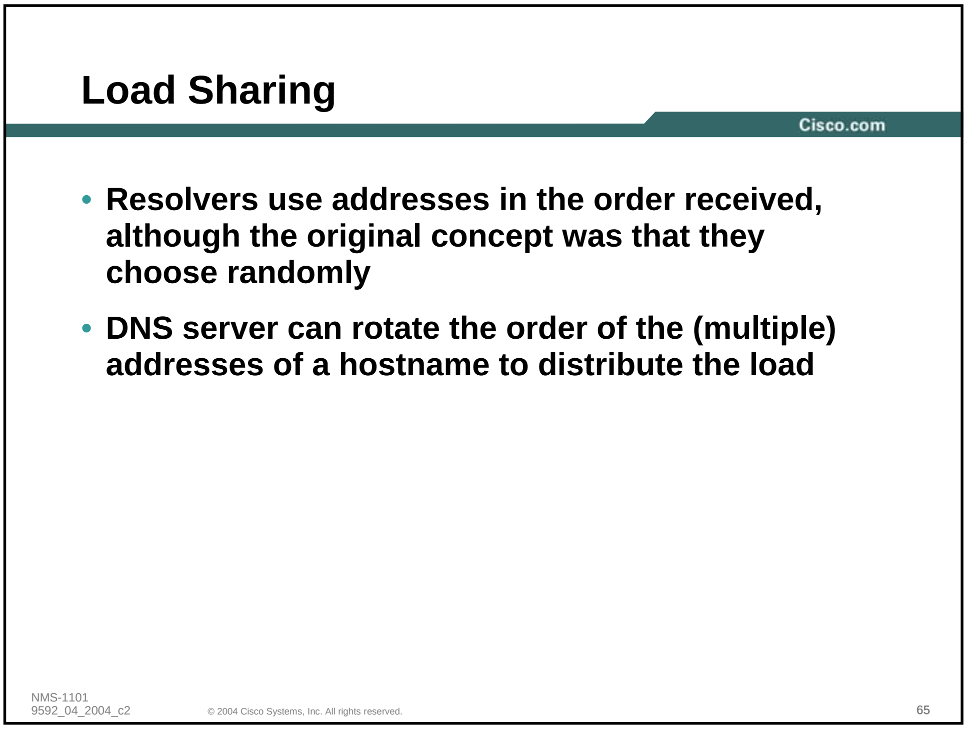
External DNS Server

Resolver

With Recursion OFF

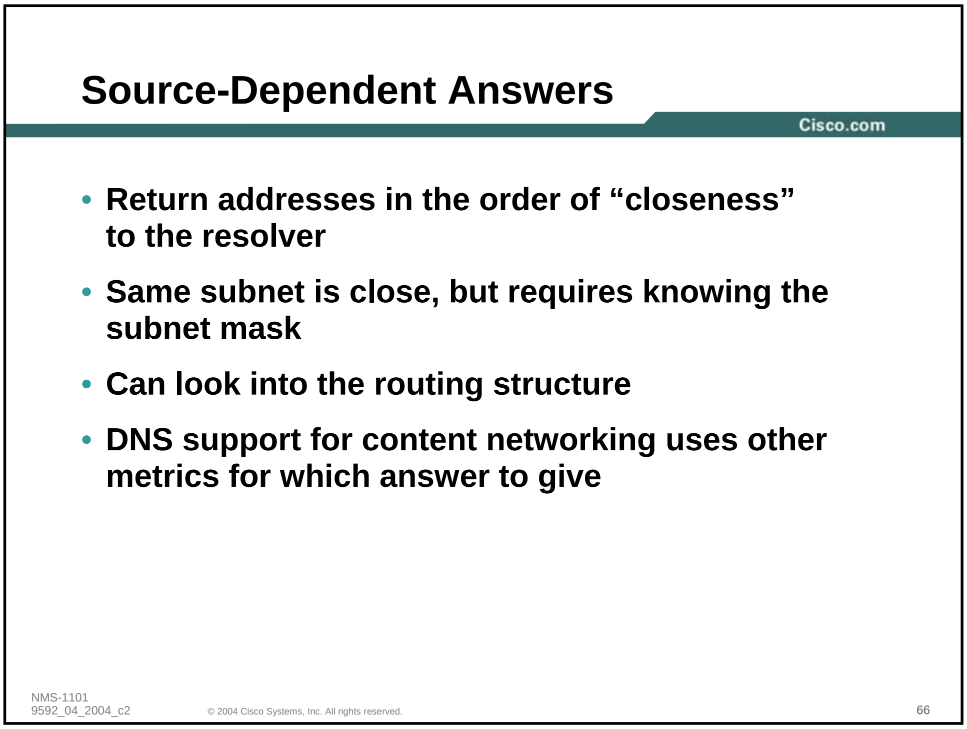
Internal Root

Internal DNS Server



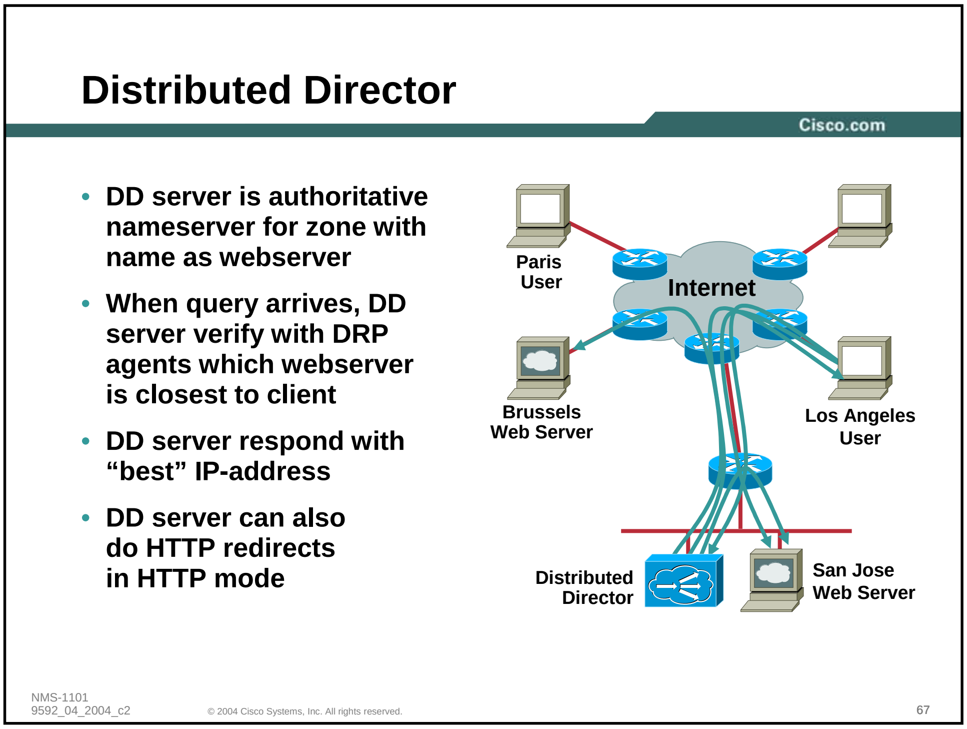
## Load Sharing

- Resolvers use addresses in the order received, although the original concept was that they choose randomly
- DNS server can rotate the order of the (multiple) addresses of a hostname to distribute the load



## Source-Dependent Answers

- Return addresses in the order of “closeness” to the resolver
- Same subnet is close, but requires knowing the subnet mask
- Can look into the routing structure
- DNS support for content networking uses other metrics for which answer to give



## Distributed Director

Cisco.com

- DD server is authoritative nameserver for zone with name as webserver
- When query arrives, DD server verify with DRP agents which webserver is closest to client
- DD server respond with “best” IP-address
- DD server can also do HTTP redirects in HTTP mode

Paris User

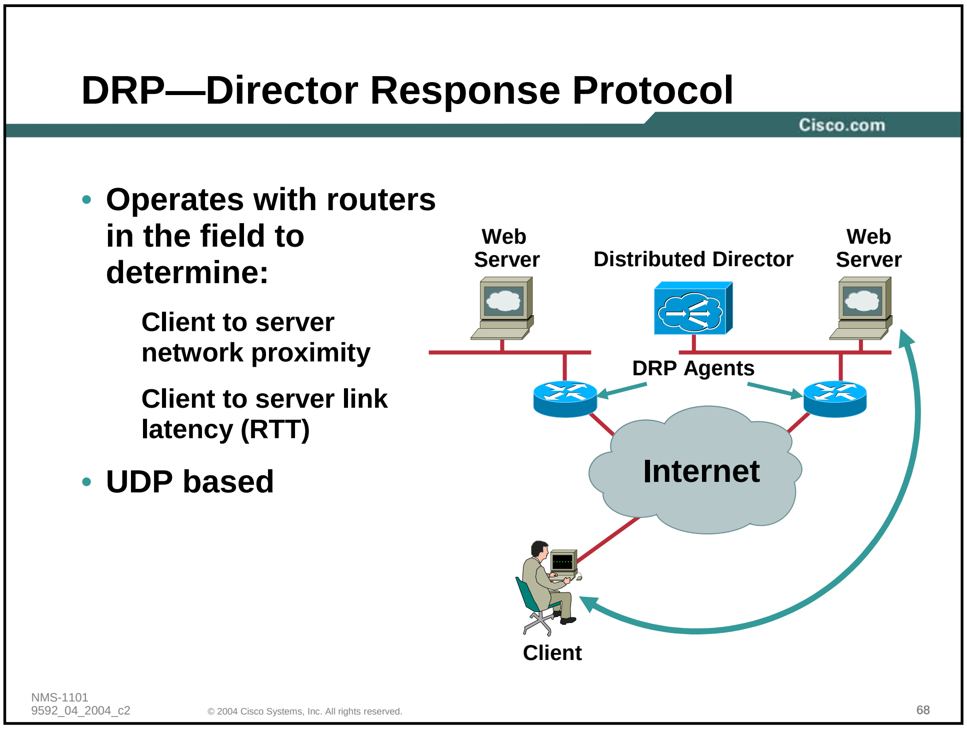
Internet

Brussels Web Server

Los Angeles User

Distributed Director

San Jose Web Server



## DRP—Director Response Protocol

Cisco.com

- Operates with routers in the field to determine:

  Client to server network proximity

  Client to server link latency (RTT)
- UDP based

Web Server

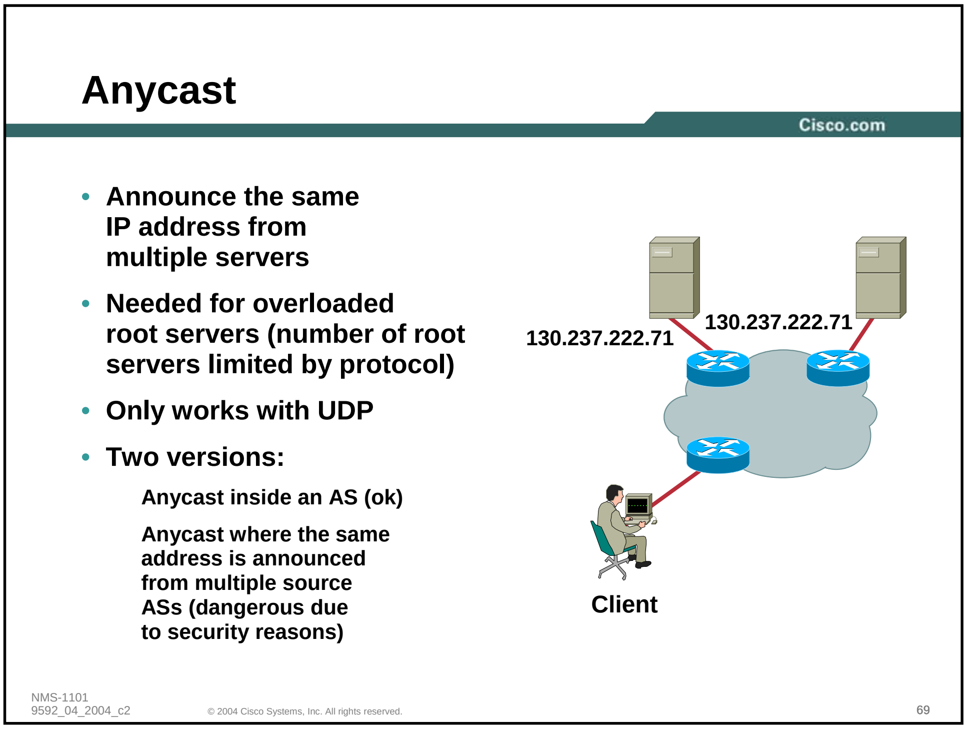
Distributed Director

Web Server

DRP Agents

Internet

Client

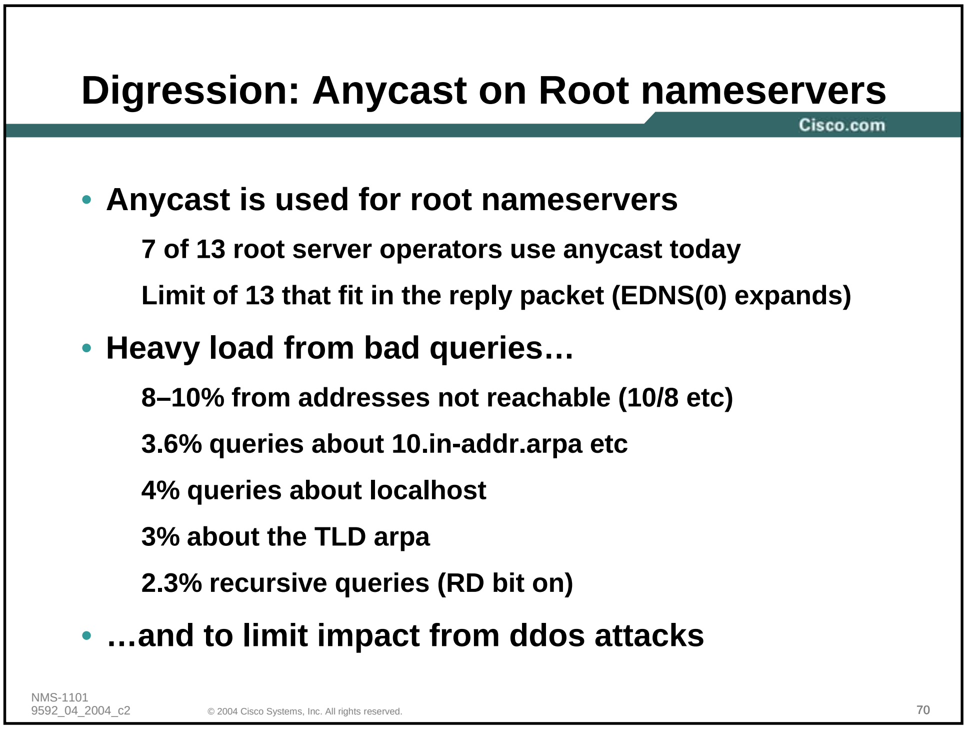


## Anycast

Cisco.com

- Announce the same IP address from multiple servers
- Needed for overloaded root servers (number of root servers limited by protocol)
- Only works with UDP
- Two versions:
  - Anycast inside an AS (ok)
  - Anycast where the same address is announced from multiple source ASs (dangerous due to security reasons)

130.237.222.71
130.237.222.71
Client



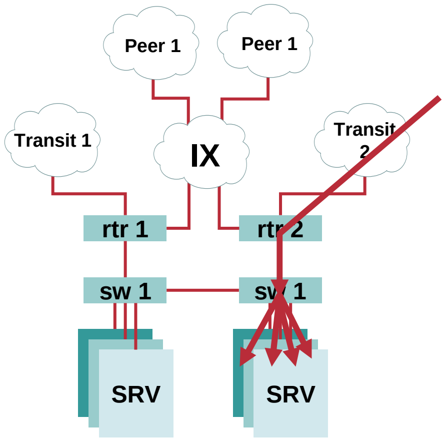
## Digression: Anycast on Root nameservers

Cisco.com

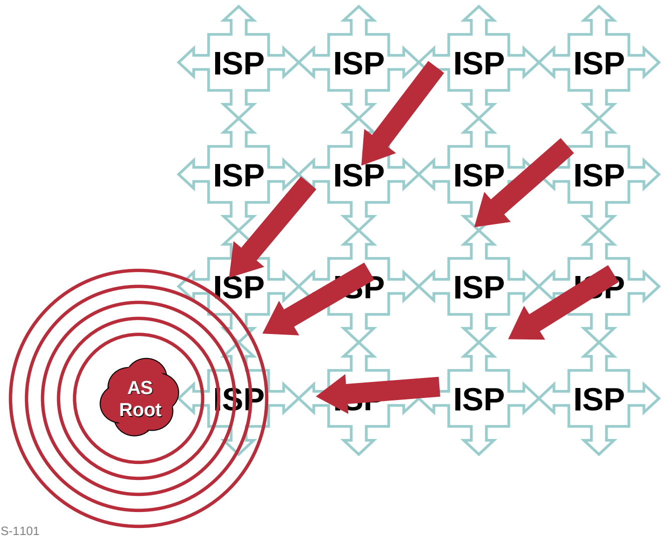
- Anycast is used for root nameservers
  - 7 of 13 root server operators use anycast today
  - Limit of 13 that fit in the reply packet (EDNS(0) expands)
- Heavy load from bad queries…
  - 8–10% from addresses not reachable (10/8 etc)
  - 3.6% queries about 10.in-addr.arpa etc
  - 4% queries about localhost
  - 3% about the TLD arpa
  - 2.3% recursive queries (RD bit on)
- …and to limit impact from ddos attacks

## Load Sharing Locally

- Multiple hosts behind a content switch to make a “big” root nameserver

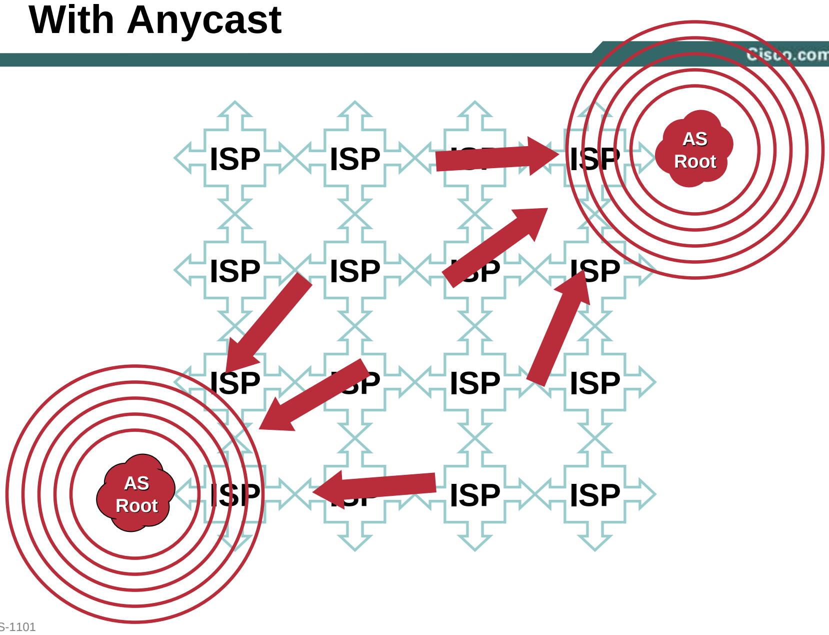


## DDOS Attack Scenario



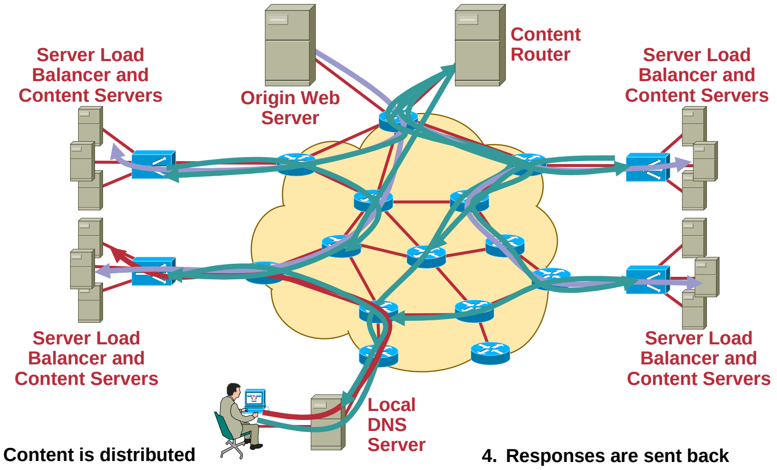
# With Anycast

Cisco.com



# Boomerang

Cisco.com



1. Content is distributed
2. Client query content router via local DNS Server
3. Content servers are told to respond to DNS query
4. Responses are sent back
5. First response arriving is closest
6. Client connect to that IP address

## Summary

Cisco.com

- Addresses can be allocated automatically
- DNS can support more than just name to address lookup

## Associated Sessions

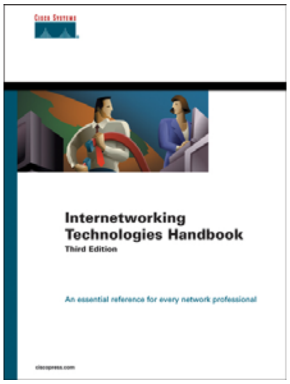
Cisco.com

- NMS-2101—DNS Deployment and Operation

## Recommended Reading

### IP Addressing Fundamentals

ISBN: 1587050676



Internetworking Technologies Handbook
Third Edition

An essential reference for every network professional

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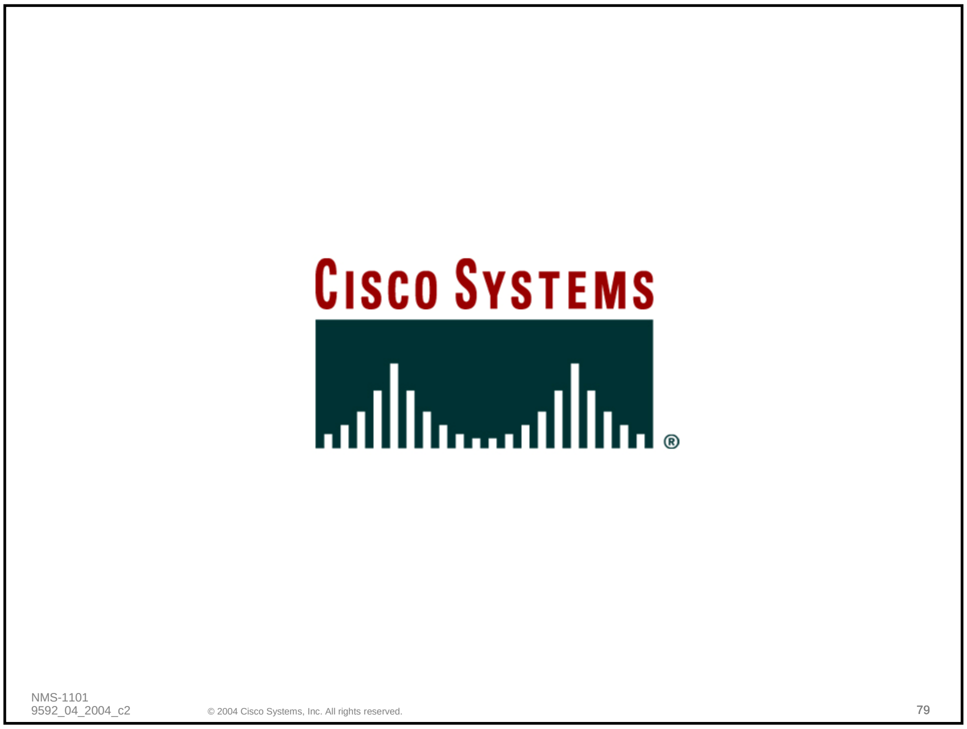
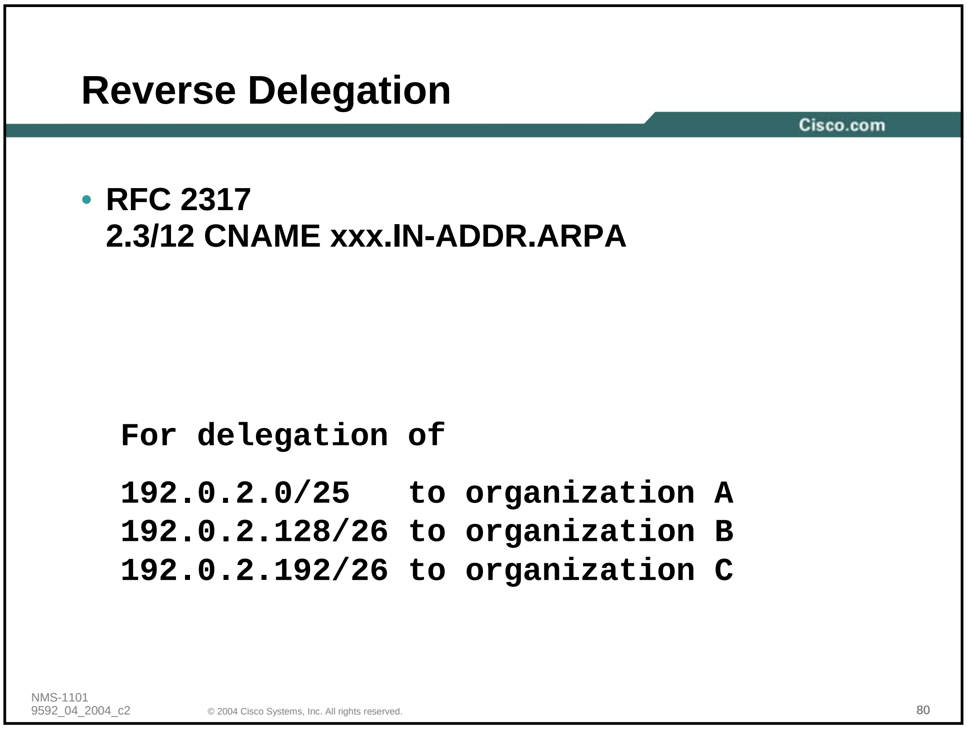
**WHY:** Win fabulous prizes! Give us your feedback!

**WHERE:** Go to the Internet stations located throughout the Convention Center

**HOW:** Winners will be posted on the onsite Networkers Website; four winners per day



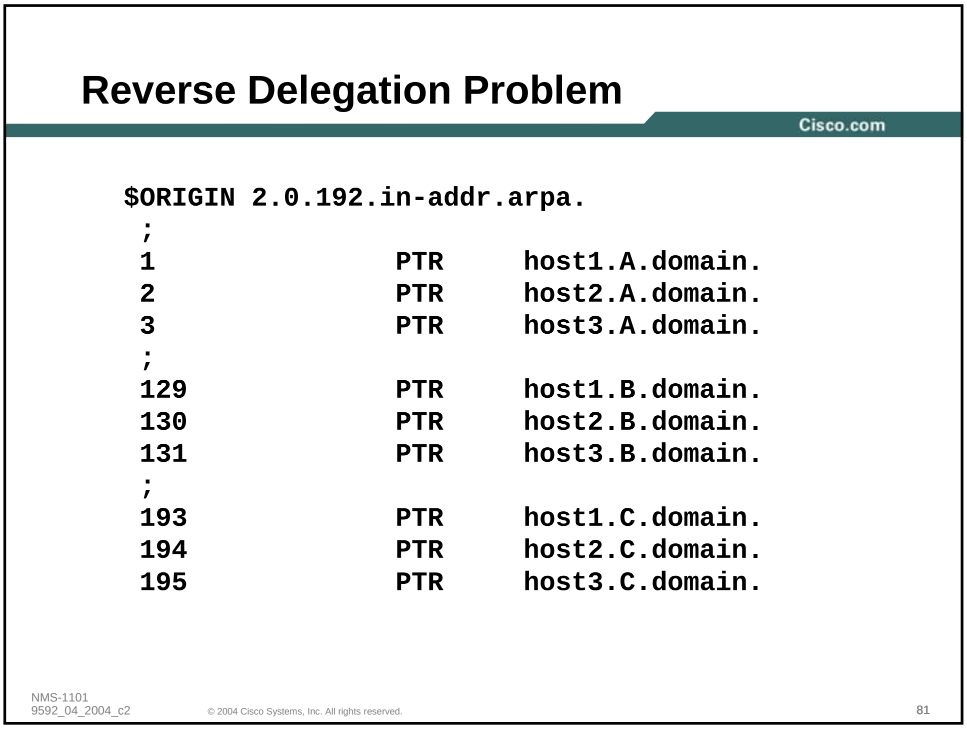


## Reverse Delegation

- RFC 2317
  2.3/12 CNAME xxx.IN-ADDR.ARPA

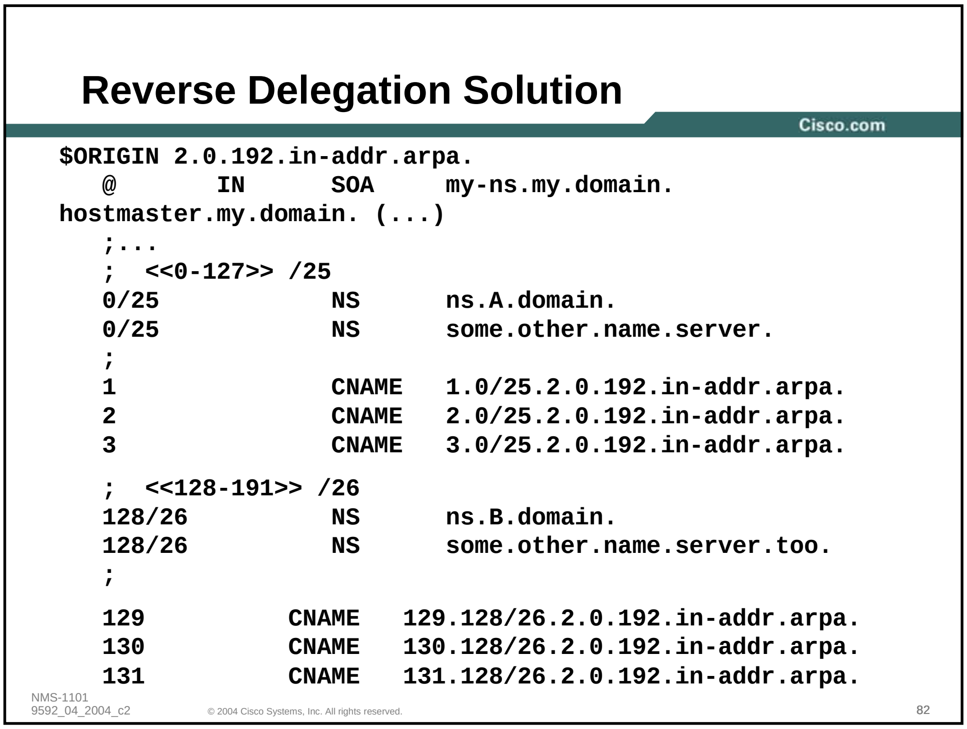
```
For delegation of

192.0.2.0/25   to organization A
192.0.2.128/26 to organization B
192.0.2.192/26 to organization C
```



## Reverse Delegation Problem

```
$ORIGIN 2.0.192.in-addr.arpa.
 ;
 1               PTR     host1.A.domain.
 2               PTR     host2.A.domain.
 3               PTR     host3.A.domain.
 ;
 129             PTR     host1.B.domain.
 130             PTR     host2.B.domain.
 131             PTR     host3.B.domain.
 ;
 193             PTR     host1.C.domain.
 194             PTR     host2.C.domain.
 195             PTR     host3.C.domain.
```

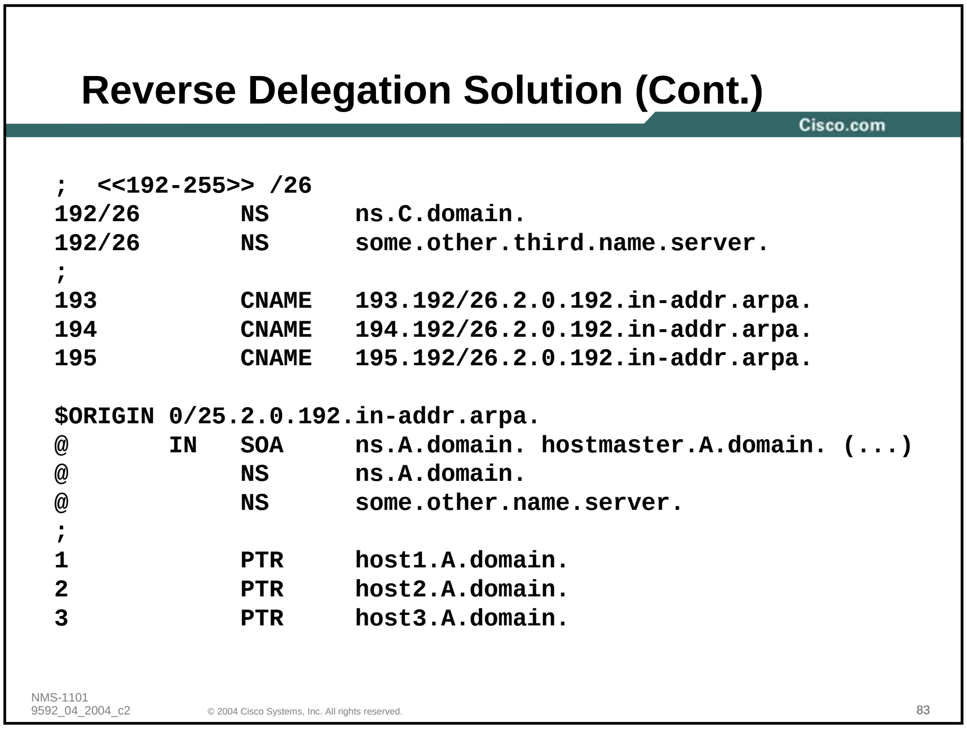


## Reverse Delegation Solution

```
$ORIGIN 2.0.192.in-addr.arpa.
   @       IN      SOA     my-ns.my.domain.
hostmaster.my.domain. (...)
   ;...
   ;  <<0-127>> /25
   0/25            NS      ns.A.domain.
   0/25            NS      some.other.name.server.
   ;
   1               CNAME   1.0/25.2.0.192.in-addr.arpa.
   2               CNAME   2.0/25.2.0.192.in-addr.arpa.
   3               CNAME   3.0/25.2.0.192.in-addr.arpa.

   ;  <<128-191>> /26
   128/26          NS      ns.B.domain.
   128/26          NS      some.other.name.server.too.
   ;

   129          CNAME   129.128/26.2.0.192.in-addr.arpa.
   130          CNAME   130.128/26.2.0.192.in-addr.arpa.
   131          CNAME   131.128/26.2.0.192.in-addr.arpa.
```



## Reverse Delegation Solution (Cont.)

```
;  <<192-255>> /26
192/26       NS      ns.C.domain.
192/26       NS      some.other.third.name.server.
;
193          CNAME   193.192/26.2.0.192.in-addr.arpa.
194          CNAME   194.192/26.2.0.192.in-addr.arpa.
195          CNAME   195.192/26.2.0.192.in-addr.arpa.

$ORIGIN 0/25.2.0.192.in-addr.arpa.
@       IN   SOA     ns.A.domain. hostmaster.A.domain. (...)
@            NS      ns.A.domain.
@            NS      some.other.name.server.
;
1            PTR     host1.A.domain.
2            PTR     host2.A.domain.
3            PTR     host3.A.domain.
```