Domain Name System ▶0

This diagram is a model of the Domain Name System (DNS), a system vital to the smooth operation of the Internet. The goal of the diagram is to explain what DNS is, how it works, and how it's governed. The diagram knits together many facts about DNS in hopes of presenting a comprehensive picture of the system and the context in which it operates.

Concept Map

A concept map is a web of terms. Verbs connect nouns to form propositions. Groups of propositions form larger structures. Examples and details accompany most terms. More important terms receive visual emphasis; less important terms, details, and examples are in gray. Terms related to names and addresses (the heart of DNS) are in blue. Terms followed by a number link to terms preceded by the same number.

Begin reading anywhere you like or from the top or from the word "people." ▶1

8 **standards organizations** include · rely on

ISoc members form · originally chartered · charters

Internet Society (ISoc) is a professional membership society with more than 150 organizations and 11,000 individual members from over 182 countries.

IETF sponsors

Internet Engineering Task Force (IETF) is a voluntary, non-commercial organization comprised of individuals concerned with the evolution of the architecture and operation of the Internet. ▶16

working groups are managed by · write

IESG decisions can be appealed to · approves

Internet Engineering Steering Group (IESG)

11 **IAB** provides advice to

Internet Architecture Board (IAB)

IANA functions were moved to

Internet Assigned Numbers Authority (IANA) originally handled many of the functions that are now ICANN's responsibility. ICANN hired many of IANA's staff.

10 **RFCs** specify rules for assignments made by · related to DNS include

Requests for Comments (RFCs) document technical and organizational aspects of the Internet.

- **RFC 779** "Internet Name Domains," outlined the problem, 9/81
- **RFC 819** "The Domain Naming Convention for Internet User Applications," 8/82, first defined ... **DNS** ▶0
- **RFC 881** "The Domain Names Plan and Schedule," 11/83, updated by RFC 897
- **RFC 882** "Domain Names - Concepts And Facilities," 11/83, updated by RFC 1034
- **RFC 883** "Domain Names - Implementation And Specification," 11/83, updated by RFC 1035
- **RFC 973** "Domain System Changes and Observations," 1/86
- **RFC 974** "Mail Routing And The Domain System," 1/86, ... authored by ▶33
- **RFC 1034** "Domain Names - Concepts And Facilities," 11/87
- **RFC 1035** "Domain Names - Implementation And Specification," 11/87, defines many ... **record types** ▶25
- **RFC 1591** "Domain Name System Structure and Delegation," 3/94
- **RFC 1886** "DNS Extensions to support IP version 6," 12/95
- **RFC 2065** "Domain Name System Security Extensions," 1/97, see also RFC 2136, 2137, 2535, 3007, 3008
- **RFC 2870** "Root Name Server Operational Requirements," 6/00, defines the role of ... **Root Server Operators** ▶22
- **RFC 2916** "E.164 Number and DNS," 9/00, ... authored by ▶31
- **RFC 2929** "Domain Name System (DNS) IANA Considerations," 9/00
- **RFC 3071** "Reflections on the DNS, RFC 1591, and Categories of Domains" 2/01, ... authored by ▶32
- **RFC 3363** "Representing IPv6 Addresses in the DNS, 8/02, see also RFC 3364 ... authored by ▶30
- **RFC 3467** "Role of the Domain Name System (DNS), 2/03, ... authored by ▶32
- **RFC 3490** "Internationalizing Domain Names in Applications (IDNA)," 3/03, ... authors include ▶31

implementors include

Implementors write software based on standards—that is, they implement the standards. Other implementors include Cisco and Microsoft as well as smaller firms such as Men & Mice.

ISC implements standards defined in · maintains

Internet Software Consortium (ISC) is a non-profit corporation that develops and maintains reference implementations of core Internet protocols—and makes them available for free. ▶23

BIND is used by most ... **name servers** ▶21

Berkeley Internet Name Domain (BIND): name server, resolver library, and tools.

United States government

runs at the pleasure of · charters

Congress votes funds for

The US House of Representatives has a Committee on Commerce, and the US Senate has a Committee on Commerce, Science, and Transportation, which has a Sub-Committee on Commerce. These committees oversee the Department of Commerce (DoC).

9 **Department of Commerce (DoC)** includes

Congress has given DoC primary responsibility for managing Internet related issues. The President of the United States nominates the Secretary of the DoC who must then be confirmed by the Senate. ▶34

National Telecommunications and Information Administration (NTIA) enters into

NTIA is run by an Administrator who reports to the Secretary of the DoC. NTIA has direct responsibility for working with ICANN.

DoC also includes a Technology Administration run by the Under-Secretary for Technology. The Technology Administration includes the National Institute of Standards and Technology which provides technical advice to NTIA.

Memos of Understanding (MoUs) establish a relationship with

The first MoU between NTIA and ICANN was signed on November 25, 1998. Since then, there have been 5 amendments to the original agreement. The latest amendment was signed in September 30, 2002 and extends the agreement for one year.

3 ICANN

has instituted the · per its by-laws, enters into agreements which create · through its by-laws creates a set of · has entered into · has NO agreements covering the operation of · should charter · should pay

a board of directors governs

15 Voting Directors
Chosen by:
- 12 ▶ 8 Nominating Committee
- 13 ▶ 2 Address Supporting Organization
- 13 ▶ 2 Country-Code Supporting Organization
- 13 ▶ 2 Generic Names Supporting Organization
- 1 President of ICANN (serves *ex officio*)

6 Non-Voting Liaisons
Chosen by:
- 14 ▶ 1 At-Large Advisory Committee
- 15 ▶ 1 Governmental Advisory Committee
- 16 ▶ 1 Internet Engineering Task Force (IETF)
- 17 ▶ 1 Root Server System Advisory Committee
- 18 ▶ 1 Security and Stability Advisory Committee
- 19 ▶ 1 Technical Liaison Group

Internet Corporation for Assigned Names and Numbers (ICANN) is a California non-profit corporation. It resides in Marina del Rey and has a staff of 24 and an FY03 budget of about $7,000,000. It coordinates, at the overall level, the Internet's systems of unique identifiers and ensures the stable and secure operation of those systems. Specifically, it:
1. Coordinates the allocation and assignment of the three sets of unique identifiers for the Internet, which are
   a. Domain names (forming a system referred to as DNS) ▶5
   b. Internet protocol (IP) addresses ▶6 and autonomous system (AS) numbers
   c. Protocol port and parameter numbers.
2. Coordinates the operation and evolution of the DNS root name servers.
3. Coordinates policy development related to these technical functions.

Sponsorship and Registry Agreements empower

Supporting Organizations ▶13
- **Address Supporting Organization (ASO)** is made up of members from
- **Country-Code Supporting Organization (ccSO)** will be made up of members from
- **Generic Names Supporting Organization (gNSO)** includes members from

Advisory Committees
- At-Large Advisory Committee ▶14
- Executive Search Committee
- Governmental Advisory Committee ▶15
- Root Server System Advisory Committee ▶17 drawn from ... **Operators** ▶22
- Security and Stability Advisory Committee ▶18

Other Committees and Task Forces
- Internationalized Domain Names (IDN) Committee
- New TLD Evaluation Process Planning Task Force
- Nominating Committee ▶12
- Technical Liaison Group

Regional Internet Registries (RIRs) allocate blocks of IP addresses to
RIRs are non-profit organizations that manage, distribute and register public numeric Internet address spaces and related resources within their respective regions.
- American Registry for Internet Numbers, Ltd. (ARIN)
- Asia Pacific Network Information Centre (APNIC)
- Latin America Caribbean IP Address Registry (LACNIC)
- Réseaux Internet Protocol Européens Network Coordination Centre (RIPE NCC)
ICANN has begun the process of accepting other RIRs
- African IP Address Registry (AfriNIC)

Regional TLD Organizations
- AFTLD, Africa
- APTLD, Asia and Pacific
- CENTR, Europe
- LACTLD, Latin America and Caribbean
- NATLD, North America

Uniform Domain-Name Dispute-Resolution Policy (UDRP)
All registrars in the .biz, .com, .info, .name, .net, and .org TLDs, as well as some in ccTLDs, have agreed to follow the UDRP. Under the policy, most types of trademark-based domain-name disputes must be resolved by agreement, court action, or arbitration before a registrar will cancel, suspend, or transfer a domain name.

Internet Service Providers (ISPs) resell ... **IP addresses** ▶6
ISPs can join their RIR and participate in policy making.

Technical Liaison Group Organizations ▶19
- ETSI (European Telecommunications Standards Institute)
- IAB (Internet Architecture Board) ▶11
- ITU (International Telecommunications Union)
- W3C (World Wide Web Consortium)

4 registry operators run

manage

ICANN has not established formal relationships with all registry operators. Therefore, not all are chartered, nor do all pay. ▶20

A registry operator's primary responsibility is running the registry database. Each top-level domain (TLD) must have one registry operator and one registry database. Registry operators may manage more than one TLD. For example, VeriSign manages both the .com and .net TLDs.

Registry operators must provide public access to a database of the domain names and related contact information in their TLD—the Whois database. They must also provide access to the zone data file—the domain/name servers information for all names in their TLD. They should also periodically deposit registration data into escrow with an approved escrow operator.

2 registrars pay

may contract with third-party · may themselves be

Registrars exist primarily to lease domain names. In many cases, registry operators also act as registrars. The unrestricted generic top-level domains (gTLDs) now have many registrars. ICANN has accredited 167 registrars for the gTLDs. Registrars pay ICANN $5000 per year to be accredited.

Registrars set rates and terms for leasing names. Rates generally vary from $10 to $35 per year for gTLDs Some country-code top-level domains (ccTLDs) are much higher, e.g. Speednames is asking 375 euros for a one year lease of a .gl name. However, .ar offers free registration. Terms are generally 1 to 2 years though some registrars offer terms up to 10 years, a limit imposed by ICANN.

7 registry databases populate

A registry database contains a record for each domain name registered in its TLD. For each name, the database also records:
- the names and IP addresses of the name servers that are authoritative for this domain
- registrant of the name
- registrant's contact information
- technical contact
- technical contact's contact information

ICANN, not the registry operator, retains rights to the information in the registry databases.

Name Registration Process

The name registration process is the method by which people lease a unique domain name within a particular TLD.

1 people

can also directly access · who are US citizens may elect some elements of the · register names with · register names in · pay · remember · lease unique · (often without realizing) rely on

People rely on DNS in many ways. Some of the most common are:
- addressing an email
- entering a URL into a browser
- clicking on a link in which a URL is embedded
- using FTP to transfer a file

One person or organization may register many names. Domain names, once registered, may be sold to others. Registrations may also be transferred from one registry to another by their holders.

At the time of registration, people must enter the IP addresses of the name servers that will be authoritative for their domain name. (They can later change those addresses.) The domain name must also be added to their authoritative servers.

top-level domains (TLDs)

are of two types · contain

A TLD is a unique string of letters designating a top-level branch of a hierarchical name space. The domain names under that branch are unique; that is, each can be registered to only one person or organization. Some TLDs have restrictions on who can register a domain name; others do not.

Today, there are 258 active TLDs. 15 are gTLDs; 243 are ccTLDs. ICANN can create new TLDs and direct VeriSign/NSI to change the root zone file, but only after the approval of the US Department of Commerce.

In 2003, operators of registries larger than 50,000 names will pay ICANN:

VeriSign	.com	$115,000
VeriSign	.net	$115,000
Afilias	.info	$115,000
PIR	.org	$115,000
NeuLevel	.biz	$92,000
GNR	.name	$92,000
RegistryPro	.pro	$92,000
total		$736,000

generic (gTLDs) and

names registered	**Original gTLDs, most introduced in 1984**	*Restrictions*	*Operator or sponsor*
5	.arpa	for Internet infrastructure (1982)	IANA under the guidance of IAB
23,239,000	.com	unrestricted	VeriSign Global Registry Services
18,224	.edu	for US higher-educational institutions	Educause
unavailable	.gov	for US government organizations	US General Services Administration (recently opened to state governments)
30	.int	for treaty organizations (1988)	IANA .int Domain Registry
3,990,000	.net	unrestricted	VeriSign Global Registry Services
unavailable	.mil	for US military organizations	US DoD Network Information Center
2,637,000	.org	unrestricted	Public Interest Registry
	New gTLDs, approved in November, 2000		
2700	.aero	for air-transport industry	Société Internationale de Télécommunications Aéronautiques (SITA)
837,000	.biz	for businesses	NeuLevel, Inc.
2289	.coop	for cooperative associations	Dot Cooperation LLC
1,029,000	.info	unrestricted	Afilias Limited
530	.museum	for museums	Museum Domain Management Association
87,000	.name	for individuals	Global Name Registry
-	.pro	for credentialed professionals	RegistryPro
total: 31,819,000			

country code (ccTLDs) are

ccTLDs are two letter designators for countries, territories, and geographic regions. Originally Jon Postel advised that IANA should not be in the business of determining what is or is not a country and adopted the ISO 3166 standard as a basis for ccTLDs. Some appear to have never been sponsored and some have changed. Also, the former Soviet Union (.su) ccTLD is still active. Recently, ICANN gave IANA authority to delegated the .eu domain (for European Union); .eu is not yet active.

As of March 15, 2003, ICANN reports that 19,855,021 domain names have been registered in all ccTLDs. 36 ccTLDs have registered more than 50,000 names; they account for 96.8% (19,222,804 names). See list at right for detailed figures.

20 Only 10 ccTLD registries have signed sponsorship agreements with ICANN: .af, .au, .bi, .jp, .ke, .la, .mw, .sd, .tw, .uz ▶27

Fee apportionment and legal jurisdiction are issues creating controversy and inhibiting adoption of sponsorship agreements. In the meantime, the sponsors already in place continue to operate without agreements, and some make voluntary contributions in lieu of paying fees.

By convention, www.nic.foo is the URL for the registry for foo where foo is any TLD—though there are exceptions.

5 domain names

for example, · can be called in

www.example.com

sub-domain is part of ...... **domain** is part of .... **top-level domain**

resolves to

Some ccTLDs have restrictive policies at the second level. In that case, registrations are at the third level, e.g., example.co.uk.

A domain may represent a single computer or a network of com-puters. Sub-domains can be appended for each computer on a network or for each new network.

When a change is made in a local network the local organization responsible for the network needs to update its name server only. An organization may delegate responsibility for segments of the network (sub-domains). Thus, the work of registering changes can be distributed among many organizations.

Domain names were historically restricted to a subset of ASCII: 10 figures, 26 letters (with no cases), and the hyphen. Only letters may begin a name; names may not end in a hyphen. New names must be from 3 to 63 characters long. (Many two-letter names already exist.)

Typically, one domain name points to one IP address. However, one domain name can point to several IP addresses. Pointing to multiple IP addresses allows geographic distribution improving performance and balancing load—which can be important for high-traffic sites. (The number of IP addresses to which a single domain name points faces a practical limit: the amount of data that fits in a single 512-octet packet.)

input into · **the DNS look-up process** · return

The DNS look-up process is detail-ed in the blue box to the right.

The DNS was designed to return unique IP addresses in response to domain name queries from com-puter applications. Uniqueness was one of the its design objec-tives, and preservation of unique-ness has been a criterion used to assess proposals for change.

input into · **the DNS reverse look-up process** · return

The DNS reverse look-up process links IP addresses to their primary domain names. It's useful for individuals and required by some software applications such as some email servers. However, some machines with a single IP address can host multiple domains; a reverse look-up will return only the primary domain name.

DNS Look-up Process

The DNS look-up process is a method of finding the IP addresses that correspond with domain names. It involves searching a hierarchical, distributed database.

a client, e.g., a browser

first checks · **a cache** · may contain · or may contain an error record, e.g., "not found" · or, if no record is found,

Actually, clients generally rely on an operating system (OS) to provide a resource called a stub **resolver** ▶24 which keeps a list of recently visited sites and their IP addresses (a cache) and talks to the local DNS server. (Stub resolvers are contrasted with full or iterative resolvers.)

The OS finds a local server by:
1) reading IP addresses explicitly entered during configuration or
2) receiving IP addresses along with its own IP address via Dynamic Host Configuration Protocol (DHCP)

checks · 1 or more

The OS can be configured to query alternate local DNS servers, if it does not receive an answer. Or it can be configured to simultaneously query multiple local DNS servers.

For example, a query might begin with this local name server: pdevine.com 63.193.117.11 and proceed as follows

The root servers are operated voluntarily, without charge and without external subsidy, and in the absence of any formal, external monitoring.

a local 21 **name server**

first checks · **its cache** · may contain · or may contain an error record · or may contain a record that · or may contain a record that · or, if no record is found,

Local name servers provide a resource called a full **resolver** ▶24 which handles queries from stub resolvers, manages its own cache, and itself queries a series of other name servers until it resolves a name (finds its associated IP address or finds none exists) and reports the results to the stub resolver.

Caching records minimizes look-up time and reduces load on the DNS servers. Records do not remain indefinitely in a cache. Each record comes with a time-to-live value (TTL) specified by the originating server. The TTL defines how long the record is valid and may be set to anything from 0 seconds to several days. Typically, it's set for 24 hours.

24 **A resolver** is an agent that runs locally to a machine needing to access a TCP/IP network.

The resolver's role is to look-up DNS information for applications running on the machine. It takes a domain name and a **DNS resource record type** ▶25 as parameters. The query type identifies what information about the domain is being requested.

25 **DNS Resource Record Types**

A	Address. See RFC 1035 *Maps a name to an IP address.*
AAAA	IPv6 address. See RFC 1886.
AFSDB	AFS Data Base location. See RFC 1183.
CNAME	Canonical Name. See RFC 1035.
HINFO	Host Information. See RFC 1035.
ISDN	ISDN. See RFC 1183.
KEY	Public key. See RFC 2065.
KX	Key Exchanger. See RFC 2230.
LOC	Location. See RFC 1876.
MB	Mailbox. See RFC 1035.
MG	See RFC 1035.
MINFO	See RFC 1035.
MR	See RFC 1035.
MX	Mail Exchanger. See RFC 1035. *Identifies which hosts will accept mail for a given domain.*
NAPTR	See RFC 3403.
NULL	See RFC 1035.
NS	Name Server. See RFC 1035. *Points to the authoritative name server for a sub-domain.*
NSAP	Network service access point. See RFC 1348, 1637, 1706.
NXT	Next. See RFC 2065.
PTR	Pointer. See RFC 1035. *Used during reverse lookup.*
PX	Pointer to X.400/RFC822 information. See RFC 1664.
RP	Responsible Person. See RFC 1183.
RT	Route Through. See RFC 1183.
SIG	Cryptographic signature. See RFC 2065.
SOA	Start Of Authority. See RFC 1035.
SRV	Server. See RFC 2052.
TXT	Text. See RFC 1035.
WKS	Well-Known Service. See RFC 1035.
X25	X25. See RFC 1183

checks · 1 of 13 worldwide ▶26

The local name server should randomly select root servers and track response times. Then it should choose the one responding most quickly and ask for an NS record. ▶25

a root 21 **name server**

checks · **its records** · or, if a record is found, it · if no record is found, returns an error

A current version of this information (which is needed to initialize the cache of all Internet domain name servers) is available at ftp://ftp.rs.internic.net/domain/named.root from InterNIC which is operated by ICANN under a trademark license from US DoC.

Root name servers:	*IP address:*	22 *Root Server Operators:*	*Located in:*		
A.ROOT-SERVERS.NET.	198.41.0.4	VeriSign/Network Solutions, Inc (NSI)	Herndon, VA	USA	Authoritative
B.ROOT-SERVERS.NET.	128.9.0.107	Information Sciences Institute, USC	Marina Del Rey, CA	USA	*Mirrored*
C.ROOT-SERVERS.NET.	192.33.4.12	PSINet	Herndon, VA	USA	
D.ROOT-SERVERS.NET.	128.8.10.90	University of Maryland	College Park, MD	USA	
E.ROOT-SERVERS.NET.	192.203.230.10	NASA	Mountain View, CA	USA	
F.ROOT-SERVERS.NET.	192.5.5.241	23 Internet Software Consortium (ISC)	Palo Alto and SF, CA	USA	
G.ROOT-SERVERS.NET.	192.112.36.4	Defense Information Systems Agency	Vienna, VA	USA	
H.ROOT-SERVERS.NET.	128.63.2.53	Army Research Laboratory	Aberdeen, MD	USA	
I.ROOT-SERVERS.NET.	192.36.148.17	NORDUNet	Stockholm	Sweden	
J.ROOT-SERVERS.NET.	192.58.128.30	VeriSign/Network Solutions, Inc (TBD)	Herndon, VA	USA	
K.ROOT-SERVERS.NET.	193.0.14.129	RIPE-NCC	London	UK	
L.ROOT-SERVERS.NET.	198.32.64.12	ICANN (TBD)	Marina Del Rey, CA	USA	
M.ROOT-SERVERS.NET.	202.12.27.33	WIDE	Tokyo	Japan	

26 The current number of root servers is limited to 13 as that is the maximum number of name servers and their address records that fit in one 512-octet answer for a SOA record. The original 512 restriction was put in place to reduce the probability of fragmentation of DNS responses.

points to · 1 of 719 worldwide

The root name server returns a list of up to 13 TLD name servers—today, the number returned is between 2 to 10 depending on the TLD. The local name server picks one to query and asks for an NS record. ▶25

gTLD name servers for .com:

A.GTLD-SERVERS.NET.	192.5.6.30	Authoritative
B.GTLD-SERVERS.NET.	192.33.14.30	*Mirrored*
C.GTLD-SERVERS.NET.	192.26.92.30	
D.GTLD-SERVERS.NET.	192.31.80.30	
E was not returned		
F.GTLD-SERVERS.NET.	192.35.51.30	
G.GTLD-SERVERS.NET.	192.42.93.30	
H.GTLD-SERVERS.NET.	192.54.112.30	
I.GTLD-SERVERS.NET.	192.43.172.30	
J.GTLD-SERVERS.NET.	192.48.79.30	
K was not returned		
L.GTLD-SERVERS.NET.	192.41.162.30	
M was not returned		

a TLD 21 **name server**

checks · **its records** · or, if a record is found, it · if no record is found, returns an error

points to · 1 of 10,000s worldwide

The TLD name server returns a list of (at least 2) domain name servers with authoritative information on the requested domain. The local name server picks one to query and asks for an A record. ▶25

the 2 domain name servers for example.com:

a.iana-servers.net	192.0.34.43
b.iana-servers.net	193.0.0.236

a domain 21 **name server**

checks · **its records** · or may contain a record that · or may contain · if no record is found, returns an error

points to · or returns

The domain name servers for example.com contain a record for the www sub-domain and return the name and IP address to the local name server which returns the record to the stub resolver that originated the query.

a sub-domain 21 **name server**

checks · **its records, etc.**

The domain name servers may point to sub-domain name servers which may point to still lower-level name servers until the full name is resolved. This ability to point lower allows the delegation and distribution of responsibility for sub-domain names within large organizations.

may also functions as

Often a user's local name server performs two functions:
1) it provides a full resolver for local clients trying to find Internet hosts outside its local network, and
2) it acts as an authoritative name server to the outside world for queries about the local network.
You can think of the server as having two components: one for inbound queries about local hosts and one for outbound queries about remote hosts. Depending on the implementation, these functions may be performed by the same program, BIND being the most common, or they could be performed by separate programs on one machine or by separate machines altogether.

0 DNS relies on links

to find

By separating the name of a domain from the IP address to which it corresponds, the Domain Name System (DNS) enables people to easily move the contents of a domain from one machine to another—without changing the configuration of the network. Likewise an IP address may be transferred from one machine to another, allowing devices to be serviced or upgraded.

A name system is a combination of:
a) an object space (things named)
b) the name space applied to it
c) the rules governing assignment of names to objects
d) files recording the assignments
e) administrative processes applying the rules and maintaining the files

In the DNS, those are:
a) IP addresses (representing computing devices) ▶6
b) domain names ▶5
c) rules defined in the RFCs ▶10
d) registry databases ▶7
e) processes defined by DoC, ▶9 ICANN, ▶3 registry operators, ▶4 registrars, ▶2 and the standards organizations. ▶8

6 IP addresses

for example, · identify

IP addresses are also called IP numbers.

Each device on a network must have an IP address in order to communicate with the network, but the IP address need not be associated with a domain. Conversely, one IP address can be associated with several domain names. In this way, a single server can host many domains, as is often the case with ISPs.

192.0.34.166

IP addresses are typically written as 4 numbers separated by dots. Each number is in a range from 0 to 255. Thus a full address is 32 bits. These are IPv4 addresses. In some places, IPv6 has been deployed. IPv6 addresses are 128 bits written using hexadecimal strings, e.g., 1080:0:0:0:8:800:200C:417A.

Internet resources such as

that enable

email
web browsing
file transfer

computers
handheld devices
routers

243 active ccTLDs

	.ac	Ascension Island (licensed) ▶28
	.ad	Andorra
	.ae	United Arab Emirates
	.af	**Afghanistan** ▶27
	.ag	Antigua and Barbuda
	.ai	Anguilla
	.al	Albania
	.am	Armenia
	.an	Netherlands Antilles
	.ao	Angola
	.aq	Antarctica
626,000	.ar	Argentina
	.as	American Samoa
272,000	.at	Austria
342,895	**.au**	**Australia** ▶27
	.aw	Aruba
	.az	Azerbaijan
	.ba	Bosnia and Herzegovina
	.bb	Barbados
	.bd	Bangladesh
238,000	.be	Belgium
	.bf	Burkina Faso
	.bg	Bulgaria
	.bh	Bahrain
	.bi	**Burundi** ▶27
	.bj	Benin
	.bm	Bermuda
	.bn	Brunei Darussalam
	.bo	Bolivia
427,000	.br	Brazil
	.bs	Bahamas
	.bt	Bhutan
	.bv	Bouvet Island
	.bw	Botswana
	.by	Belarus
	.bz	Belize (licensed as business) ▶28
310,000	.ca	Canada
500,000	.cc	Cocos (Keeling) Islands (licensed) ▶28
	.cd	Congo, Democratic Republic
	.cf	Central African Republic
	.cg	Congo
500,000	.ch	Switzerland
	.ci	Cote D'Ivoire (Ivory Coast)
	.ck	Cook Islands
88,819	.cl	Chile
	.cm	Cameroon
179,000	.cn	China
	.co	Colombia
	.cr	Costa Rica
	.cu	Cuba
	.cv	Cape Verde
	.cx	Christmas Island
	.cy	Cyprus
131,000	.cz	Czech Republic
6,117,000	.de	Germany
	.dj	Djibouti
428,276	.dk	Denmark
	.dm	Dominica
	.do	Dominican Republic
	.dz	Algeria
	.ec	Ecuador
	.ee	Estonia
	.eg	Egypt
	.er	Eritrea
	.es	Spain
	.et	Ethiopia
	.fi	Finland
	.fj	Fiji
	.fk	Falkland Islands (Malvinas)
	.fm	Micronesia (licensed as FM radio) ▶28
	.fo	Faroe Islands
163,000	.fr	France
	.ga	Gabon
	.gd	Grenada
	.ge	Georgia
	.gf	French Guiana
	.gg	Guernsey (Channel Island)
	.gh	Ghana
	.gi	Gibraltar
	.gl	Greenland
	.gm	Gambia
	.gn	Guinea
	.gp	Guadeloupe
	.gq	Equatorial Guinea
	.gr	Greece
	.gs	S. Georgia and S. Sandwich Islands
	.gt	Guatemala
	.gu	Guam
	.gw	Guinea-Bissau
	.gy	Guyana
64,440	.hk	Hong Kong
	.hm	Heard and McDonald Islands
	.hn	Honduras
	.hr	Croatia (Hrvatska)
	.ht	Haiti
90,000	.hu	Hungary
	.id	Indonesia
	.ie	Ireland
	.il	Israel
	.in	India
	.io	British Indian Ocean Territory
	.iq	Iraq
	.ir	Iran
	.is	Iceland
767,000	.it	Italy
	.je	Jersey (Channel Island)
	.jm	Jamaica
	.jo	Jordan
568,195	**.jp**	**Japan** ▶27
	.ke	**Kenya** ▶27
	.kg	Kyrgyzstan
	.kh	Cambodia
	.ki	Kiribati
	.km	Comoros
	.kn	Saint Kitts and Nevis
507,000	.kr	Korea (South)
	.kw	Kuwait
	.ky	Cayman Islands
	.kz	Kazakhstan
	.la	**Laos** (licensed as Los Angeles) ▶27 ▶28
	.lb	Lebanon
	.lc	Saint Lucia
	.li	Liechtenstein
	.lk	Sri Lanka
	.lr	Liberia
	.ls	Lesotho
	.lt	Lithuania
	.lu	Luxembourg
	.lv	Latvia
	.ly	Libya
	.ma	Morocco
	.mc	Monaco
	.md	Moldova (licensed for health care) ▶28
	.mg	Madagascar
	.mh	Marshall Islands
	.mk	FYROM (Macedonia)
	.ml	Mali
	.mm	Myanmar
	.mn	Mongolia
	.mo	Macau
	.mp	Northern Mariana Islands
	.mq	Martinique
	.mr	Mauritania
69,351	.ms	Montserrat
	.mt	Malta
	.mu	Mauritius
	.mv	Maldives
	.mw	**Malawi** ▶27
75,000	.mx	Mexico
	.my	Malaysia
	.mz	Mozambique
	.na	Namibia
	.nc	New Caledonia
	.ne	Niger
	.nf	Norfolk Island
	.ng	Nigeria
	.ni	Nicaragua
827,000	.nl	Netherlands
165,000	.no	Norway
	.np	Nepal
	.nr	Nauru
111,795	.nu	Niue (licensed, "now" in Swedish) ▶28
144,251	.nz	New Zealand
	.om	Oman
	.pa	Panama
	.pe	Peru
	.pf	French Polynesia
	.pg	Papua New Guinea
	.ph	Philippines
	.pk	Pakistan
175,000	.pl	Poland
	.pm	St. Pierre and Miquelon
	.pn	Pitcairn
	.pr	Puerto Rico
	.ps	Palestine
	.pt	Portugal
	.pw	Palau
	.py	Paraguay
	.qa	Qatar
	.re	Reunion
64,485	.ro	Romania
156,000	.ru	Russian Federation
	.rw	Rwanda
	.sa	Saudi Arabia
	.sb	Solomon Islands
	.sc	Seychelles
	.sd	**Sudan** ▶27
148,436	.se	Sweden
	.sg	Singapore
	.sh	St. Helena
	.si	Slovenia
	.sj	Svalbard and Jan Mayen Islands
	.sk	Slovak Republic
	.sl	Sierra Leone
	.sm	San Marino
	.sn	Senegal
	.so	Somalia
	.sr	Suriname
	.st	Sao Tome and Principe (licensed) ▶28
	.su	USSR (former)
	.sv	El Salvador
	.sy	Syria
	.sz	Swaziland
	.tc	Turks and Caicos Islands
	.td	Chad (licensed for trade domains) ▶28
	.tf	French Southern Territories
	.tg	Togo
	.th	Thailand
	.tj	Tajikistan
	.tk	Tokelau
	.tm	Turkmenistan
	.tn	Tunisia
97,335	.to	Tonga (licensed) ▶28
	.tp	East Timor
	.tr	Turkey
	.tt	Trinidad and Tobago
261,589	.tv	Tuvalu (licensed for television) ▶28
123,000	**.tw**	**Taiwan** ▶27
	.tz	Tanzania
	.ua	Ukraine
	.ug	Uganda
4,168,000	.uk	United Kingdom
	.um	US Minor Outlying Islands
529,000	.us	United States
	.uy	Uruguay
	.uz	**Uzbekistan** ▶27
	.va	Vatican City State (Holy See)
	.vc	Saint Vincent and the Grenadines
	.ve	Venezuela
	.vg	Virgin Islands (British)
	.vi	Virgin Islands (U.S.)
	.vn	Viet Nam
	.vu	Vanuatu
	.wf	Wallis and Futuna Islands
182,504	.ws	Western Samoa (licensed) ▶28
	.ye	Yemen
	.yt	Mayotte
	.yu	Yugoslavia
133,836	.za	South Africa
	.zm	Zambia
	.zw	Zimbabwe

No longer used
- .cs Czechoslovakia (retired in 1995)
- .gb Great Britain
- .zr Zaire (retired in 1997)

Not assigned to a sponsor
- .eh Western Sahara
- .kp North Korea

27 Countries indicated in bold have signed a ccTLD sponsorship agreement.

28 Some ccTLDs function much as gTLDs registering without restrictions; many of these are noted above as "licensed."

Selected events related to the history of DNS

1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003

- ARPANET begins.
- Steve Crocker wrote RFC1; Jon Postel began as RFC editor.
- FTP invented.
- Email invented at BBN.
- First precursor to DNS established (HOSTS.TXT file)
- ICCB formed.
- ARPANET switches to IP.
- DNS invented by Paul Mockapetris in collaboration with Jon Postel.
- IAB established; replaced ICCB (Internet Configuration Control Board).
- Information Sciences Institute (ISI) at USC given responsibility for DNS root management.
- SRI runs DNS NIC registrations.
- BIND released by UC Berkeley.
- IETF forms under IAB.
- Mail Exchanger (MX) records developed by Craig Partridge. ▶33
- RFC 1035: Domain Names Implementation and Specification published.
- IANA established (Jon Postel is Director).
- Deployment of IPv4 began.
- First ccTLD (.uk) established.
- First gTLDs established.
- .int TLD created.
- HOSTS.TXT conversion to DNS complete.
- Root server created in Stockholm; now "I."
- Web invented by a team at CERN led by Tim Berners-Lee.
- First private email carriers connected to Internet.
- ARPANET ceases to exist.
- ISOC formed; IAB becomes part of ISOC.
- National Science Foundation (NSF) creates InterNIC and grants Network Solutions, Inc., (NSI) right to manage DNS registration.
- Mosaic, first freely-available graphical web browser, invented by a team at University of Illinois.
- K root server created in London.
- M root server created in Tokyo.
- Netscape IPO heralded Internet boom.
- NSI begins fee-based registration.
- ICANN incorporated; enters agreement with US DoC.
- Multiple registrars appear.
- Jon Postel dies.
- Deployment of IPv6 began.
- VeriSign buys NSI.
- ICANN established 7 new gTLDs.

This diagram was created in conjunction with a study: "Internet Navigation and Domain Name System."

The study was run by The National Academies' Computer Science and Telecommunications Board which convened a study committee. ▶29

34 The study was sponsored by the US Department of Commerce and the National Science Foundation and mandated by the US Congress.

Hugh Dubberly and Paul Devine drafted the diagram, and the committee reviewed it. Special thanks to Juan Quiles for finding and checking facts.

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