IP ADDRESS MANAGEMENT

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IP ADDRESS MANAGEMENT

Principles and Practice

Timothy Rooney

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In memory of my father, Patrick Rooney

CONTENTS

PREFACE

The practice of IP address management (IPAM) entails the application of network management disciplines to Internet Protocol (IP) address space and associated network services, namely Dynamic Host Configuration Protocol (DHCP) and Domain Name System (DNS). The linkages among an IP address plan and configurations of DHCP and DNS servers are inseparable. A change of an IP address affects DNS information and perhaps DHCP as well. These services provide the foundation for today's converged services IP networks, which offer ad hoc anytime, anyplace communications.

If end-user devices such as laptops or voice-over IP (VoIP) phones cannot obtain an IP address via DHCP, they will be rendered unproductive and users will call the help desk. Likewise, if DNS is improperly configured, application navigation by name, phone number, or web address will likewise impair productivity and induce help desk calls.

Effective IPAM practice is a key ingredient in an enterprise or service-provider IP network management strategy. As such, IPAM addresses configuration, change control, auditing, reporting, monitoring, trouble resolution, and related functions as applied to the three foundational IPAM technologies

1. **IP Address Subnetting and Tracking (IPv4/IPv6 Addressing):** Maintenance of a cohesive IP address plan that promotes route summarization, maintains accurate IP address inventory, and provides an automated individual IP address assignment and tracking mechanism. This tracking of individual IP address assignments on each subnet includes those assigned by hard-coding, for example, routers or servers, and others assigned dynamically, for example, laptops and VoIP phones.
2. **DHCP:** Automated IP address and parameter assignment relevant to location and device type. This requires tracking address assignments configured on devices and setting aside dynamically allocated address pools. These address pools can be configured on DHCP servers in order to enable devices to request an IP address, and receive a location-relevant address in reply.
3. **DNS:** Lookup or resolution of hostnames, for example, www entries to IP addresses. This third key aspect of IP address management deals with simplifying IP communications for humans through the use of names, not IP addresses, to establish IP communications. After all, the mapped IP addresses must be consistent with the IP address plan.

The technologies comprising these three core functions are discussed in the first three parts of this book. The practice of IPAM in the fourth part* explains their interrelationships and practices for managing them cohesively. Most IP networks are constantly changing, with the daily demands of the business new stores are opened, offices are closed or moved, companies are acquired, and new devices and device types need IP addresses. These and other changes impacting the IP network can have major repercussions on the existing IP address plan. As the number of users and IP addresses increases, along with the number of subnets or sites, the task of tracking and managing IP address allocations, individual assignments, and associated DNS and DHCP server configurations grows in complexity.

The most common method for performing IPAM functions today entails the use of spreadsheets to track IP addresses, and text editors or Microsoft Windows to configure DHCP and DNS services. As such, IPAM concepts will be demonstrated throughout the book using sample spreadsheet data and configuration file examples as applied to a fictitious organization called IPAM Worldwide, Inc. The intent is to link the technology and configuration details to a real-world example.

CONVENTIONS

This book is typeset in 10-point Times Roman font. *Times Italic* font is used for terms introduced for the first time or to provide emphasis.

To differentiate prose from example configuration information within a DHCP or DNS server, for example, the Courier font in the following manner:

`Courier plain` font: Used to denote keywords or literal text within a configuration file or screen.

`Courier italic` font: Used to denote a parameter name that in practice is substituted for a value reflecting the denoted data element or type.

ORGANIZATION

The book is organized into four parts. The first three parts of the book focuses on each of the three core IPAM aspects, respectively: IP addressing and management, DHCP, and DNS. Part IV then integrates these three core components, describing management techniques and practice.

Part I: IP Addressing. Part I provides a detailed overview of IPv4, IPv6, and IP allocation and subnetting techniques.

Chapter 1: The Internet Protocol. Chapter 1 covers IP (IPv4) from a review of the IP header to classful, classless, and private IP addressing and discusses evolution of Internet

* In actuality, several constituent IPAM practices are discussed in respective technology chapters, though they are summarized in the context of overall practices in Part IV.

Protocol and the development of network address translation and private addressing as key technologies in preserving global IP address space.

*Chapter 2: Internet Protocol Version 6 (IPv6).*Chapter 2 describes the IPv6 header and IPv6 addressing, including address notation, structure, and current IANA allocations. This includes a detailed discussion of each address allocation by type (i.e., reserved, global unicast, unique local unicast, link local, and multicast). Special use addresses, including the solicited node address and the node information query address are also described. The chapter continues with a discussion of the modified EUI-64 algorithm and address autoconfiguration, then concludes with a discussion of reserved subnet anycast addresses and addresses required of IPv6 hosts.

Chapter 3: IP Address Allocation. Chapter 3 discusses techniques for IP block allocation for IPv4 and IPv6 address spaces. This includes coverage of best-fit hierarchical address allocation logic and examples, as well as sparse and random allocation approaches for IPv6. This chapter also discusses unique local address space as well as the role of Internet Registries. Block allocation is an important function of IP address management and it lays the groundwork for configuration of DHCP and DNS services.

Part II: DHCP. Part II provides an overview of DHCP for IPv4 and IPv6 and covers applications that rely on DHCP, DHCP server deployment strategies and DHCP and relevant network access security.

Chapter 4: Dynamic Host Configuration Protocol. Chapter 4 describes the DHCP protocol, including a discussion of protocol states, message formats, options, and examples. A table of standard option parameters with descriptions of each is provided.

Chapter 5: DHCP for IPv6 (DHCPv6). Chapter 5 covers the DHCPv6 protocol, including a comparison with DHCP(v4), message formats, options, and examples. A table of DHCPv6 option parameters is provided.

Chapter 6: DHCP Applications. Building on the previous two technology-based chapters, Chapter 6 highlights the end-user utility of DHCP in describing key applications that rely on DHCP, including VoIP device provisioning, broadband access provisioning, PXE client initialization, and lease limiting.

Chapter 7: DHCP Server Deployment Strategies. DHCP server deployment considerations are covered in Chapter 7, in terms of trading off server sizing, quantities, and locations. DHCP deployment options regarding distributed versus centralized approaches will be discussed, as will redundant DHCP configurations.

Chapter 8: DHCP and Network Access Security. Chapter 8 covers DHCP security considerations as well as discussion of network access security, of which DHCP is a component. A DHCP captive portal configuration example is described as is a summary of related network access control (NAC) approaches, including DHCP-based approaches, switch-based, Cisco NAC, and Microsoft NAP approaches.

Part III: DNS. Part III describes the DNS protocol, DNS applications, deployment strategies and associated configurations, and security, including the security of DNS servers and configurations and DNSSEC.

Chapter 9: The Domain Name System (DNS) Protocol. The opening chapter of Part III, provides a DNS overview, including a discussion of DNS concepts, message details, and protocol extensions. Covered DNS concepts include the basic resolution

process, the domain tree for forward and reverse domains, root hints, local-host domains, and resolver configuration. Message details include the encoding of DNS messages, including the DNS header, label formatting, and an overview of International domain names. DNS Update message formatting is also discussed as is EDNS0.

Chapter 10: DNS Applications and Resource Records. Chapter 10 builds on the material in Chapter 9 to describe key applications, which rely on DNS, including name resolution, services location, ENUM, antispam techniques via black/white listing, SPF, Sender ID, and DKIM. Discussion of applications support is presented in the context of associated resource records.

Chapter 11: DNS Server Deployment Strategies. DNS server deployment strategies and trade-offs are covered in Chapter 11. DNS server deployment scenarios include external DNS, Internet caching, hidden masters/slaves, multimaster, views, forwarding, internal roots, and anycast.

Chapter 12: Securing DNS (Part I). Chapter 12 is the first of two chapters on DNS security. This chapter covers a variety of topics related to DNS security, other than DNSSEC (DNS security extensions), which is covered in its own chapter. Known DNS vulnerabilities are presented first, followed by mitigation approaches for each.

Chapter 13: Securing DNS (Part II): DNSSEC—Chapter 13 covers DNSSEC in detail. The process of creating keys, signing zones, securely resolving names, and rolling keys is discussed, along with an example configuration.

Part IV: IPAM Integration. Part IV brings together the prior three parts, discussing techniques for cohesively managing IP address space, including impacts to DHCP and DNS.

Chapter 14: IP Address Management Practices. In Chapter 14, everyday IP address management functions are described, including IP address allocation and assignment, renumbering, moves, splits, joins, DHCP and DNS server configuration, inventory assurance, fault management, performance monitoring, and disaster recovery. This chapter is framed around the FCAPS network management model, emphasizing the necessity of a disciplined "network management" approach to IPAM.

Chapter 15: IPv6 Deployment and IPv4 Coexistence. The implementation of IPv6 within an IPv4 network will drive a lengthy coexistence of IPv4 and IPv6 protocols. Chapter 15 provides details on coexistence strategies, grouped into sections on dual stack, tunneling approaches, and translation techniques. Coverage includes 6to4, ISATAP, 6over4, Teredo, DSTM, and tunnel broker tunneling approaches and NAPT-PT, SOCKS, TRT, ALG, and bump-in-the-stack or API translation approaches. The chapter concludes with some basic migration scenarios.

Norristown, Pennsylvania TIMOTHY ROONEY
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T. R.