# IPv6 101

Addressing Fundamentals and Basic Configuration

**SomNOG Capacity Building Series - SomNOG × ISOC Somalia Chapter**

Saturday, August 1, 2026

4:00 – 6:00 PM (EAT)

Virtual (Zoom)

*Facilitated by Mohamed Ali Ahmed (Bile)*

# Agenda

| | | |
|---|---|---|
| 1 | **Welcome and Introduction** | 5 min |
| 2 | **IPv4 Exhaustion and Its Implications** | 10 min |
| 3 | **IPv6 Address Basics** | 20 min |
| 4 | **IPv6 Address Types** | 20 min |
| 5 | **Address Planning** | 25 min |
| 6 | **Lab: Basic Configuration (Hands-On)** | 25 min |
| 7 | **Q&A and Wrap-Up** | 10 min |

WHERE WE STAND

# IPv6 Adoption: World, Africa, and Somalia

*IPv6-capable and IPv6-preferred traffic, by region (APNIC Labs measurement)*

| Region | IPv6 Capable | IPv6 Preferred |
|---|---|---|
| World | 42.11% | 39.90% |
| Africa | 6.14% | 5.95% |
| Eastern Africa | 4.38% | 4.32% |

**≈0%**

measured IPv6 capability across Somalia's domestic ISPs

Starlink (satellite) measures 22.92% — foreign infrastructure, not domestic deployment.

WHERE WE STAND

# AFRINIC: The Road to IPv4 Exhaustion

*Live from AFRINIC's public statistics portal (stats.afrinic.net), snapshot at time of this training*

**93.49%**
of AFRINIC's IPv4 pool is exhausted

**651,008**
/32 addresses left before total exhaustion

**2,588**
total members (+3% this year)

1. **IPv4 allocations to date:**
   438,025 /24 blocks allocated · 2,543 /24 blocks still available

2. **ASN allocations to date:**
   2,763 ASNs allocated · 1,159 ASNs still available

***At the current pace, AFRINIC's remaining IPv4 pool will not last — IPv6 is not optional, it's the only sustainable path forward.***

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# IPv4 Exhaustion

and Its Implications for African Networks

# Global IPv4 Address Distribution Is Unbalanced

*IPv4 addresses available per person, by region*

IPV4 EXHAUSTION

# IPv4 Pool Depletion Timeline

| IANA | APNIC | RIPE NCC | LACNIC | ARIN | AFRINIC |
|---|---|---|---|---|---|
| 3 Feb 2011 | 19 Apr 2011 | 14 Sep 2012 | 10 Jun 2014 | 24 Sep 2015 | 2017 |

*AFRINIC — Africa's registry — was the last to exhaust its IPv4 pool, in 2017.*

# Exhaustion Drives Up Address Costs & NATs

**$50**
per IPv4 address

*leads to more*

**NAT**

1. **Network complexity**
   More moving parts to design, operate, and troubleshoot.
2. **Increased OPEX**
   More equipment and engineering time to keep translation running.
3. **Breaks end-to-end connectivity**
   Devices behind NAT are no longer directly reachable.
4. **Cripples innovation**
   Peer-to-peer, IoT, and new protocols struggle behind layers of NAT.

# Implications for Africa

1. African networks are deprived of the IPv4 needed to ease a transition to IPv6.

2. Operators are effectively forced to deploy greenfield IPv6.

3. Reliance on NAT increases across the continent's networks.

# How Will You Deal with IPv4 Exhaustion?

### Deploy IPv6

The forward-looking, scalable path — and the focus of this training.

### Deploy NAT on Steroids

Buys time, but adds cost, complexity, and breaks end-to-end reachability.

### Wait and See

Not a strategy — the IPv4 pool is already gone in every region, including Africa.

# Quick Check

**Which Regional Internet Registry (RIR) was the last to exhaust its IPv4 address pool?**

**A.** ARIN

**B.** RIPE NCC

**C.** AFRINIC

**D.** APNIC

# Answer

**Which Regional Internet Registry (RIR) was the last to exhaust its IPv4 address pool?**

**A.** ARIN

**B.** RIPE NCC

**C. AFRINIC ✓ Correct**

**D.** APNIC

# Quick Check

## What is a common consequence of IPv4 exhaustion for network operators?

**A.** Increased reliance on NAT

**B.** Larger IPv4 allocations from RIRs

**C.** Elimination of the need for routing

**D.** Guaranteed public IPv4 addresses for all new customers

# Answer

## What is a common consequence of IPv4 exhaustion for network operators?

**A. Increased reliance on NAT ✓ Correct**

**B.** Larger IPv4 allocations from RIRs

**C.** Elimination of the need for routing

**D.** Guaranteed public IPv4 addresses for all new customers

02

# IPv6 Address Basics

Notation, Format, and Shortening Rules

# IPv4 vs. IPv6: The Network Layer

| Layer | IPv4 | IPv6 |
|---|---|---|
| Application | DNS, HTTP, IMAP, SMTP, POP, NFS | DNS, HTTP, IMAP, SMTP, POP, NFS |
| Transport | TCP, UDP | TCP, UDP |
| Network | ICMP, IGMP, IPSec, NAT, OSPF, IS-IS, mob. IP | ICMPv6, MLD, IPSec, ND, OSPFv3, IS-IS, mob. IP |
| Data Link | Ethernet et al, NBMA, ATM, 3GPP | Ethernet et al, NBMA, ATM, 3GPP |

*Same layers, same job — IPv6 mainly changes what happens at the network layer (bigger addresses, no more NAT-by-necessity, and a new neighbor discovery model).*

# Writing an IPv6 Address

128 bits, written as 32 hexadecimal digits (nibbles), in 8 groups of 4:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| hhhh | hhhh | hhhh | hhhh | hhhh | hhhh | hhhh | hhhh/n |

**h** = a hex digit (0–9, a–f)  **n** = prefix length (decimal)

**Full address example:**

```
2001:4290:0010:0249:bae8:56ff:fe4a:ecfe
```

# Two Rules for Shortening Addresses

### 1. Zero Suppression

Strip off all leading zeroes within each 16-bit group.

e.g. 0249 → 249

### 2. Zero Compression

Replace one contiguous run of all-zero groups with a double colon ( :: ).

Only one :: is allowed per address.

# Shortening in Practice

Original address:

`2001:0000:0000:0249:0000:0000:0000:ecfe`

### ✓ Correct

2001::249:0:0:0:ecfe

Compress the first zero-run, suppress the rest.

### ✓ Correct

2001:0:0:249::ecfe

Suppress the first zero-run, compress the last.

### ✗ Wrong

2001::249::ecfe

Two :: compressions used — the address becomes ambiguous.

# Quick Check

**Shorten this address correctly: 2001:0db8:0000:0000:0000:ff00:0042:8329**

**A.** 2001:db8::ff00:42:8329

**B.** 2001:0db8::ff00:42:8329

**C.** 2001:db8:0:0:0:ff00:42:8329

**D.** 2001:db8::ff00::42:8329

# Answer

**Shorten this address correctly: 2001:0db8:0000:0000:0000:ff00:0042:8329**

**A. 2001:db8::ff00:42:8329 ✓ Correct**

**B.** 2001:0db8::ff00:42:8329

**C.** 2001:db8:0:0:0:ff00:42:8329

**D.** 2001:db8::ff00::42:8329

# Quick Check

**Shorten the loopback address: 0000:0000:0000:0000:0000:0000:0000:0001**

**A.** 0:0:0:0:0:0:0:1

**B.** ::1

**C.** ::0:1

**D.** 0::1

# Answer

**Shorten the loopback address: 0000:0000:0000:0000:0000:0000:0000:0001**

- **A.** 0:0:0:0:0:0:0:1
- **B.** **::1 ✓ Correct**
- **C.** ::0:1
- **D.** 0::1

# Quick Check

**Which shortened form is INVALID for 2001:0db8:0000:0000:0000:0000:1428:57ab?**

**A.** 2001:db8::1428:57ab

**B.** 2001:0db8:0:0:0:0:1428:57ab

**C.** 2001::db8::1428:57ab

**D.** 2001:db8:0:0:0:0:1428:57ab

# Answer

**Which shortened form is INVALID for 2001:0db8:0000:0000:0000:0000:1428:57ab?**

**A.** 2001:db8::1428:57ab

**B.** 2001:0db8:0:0:0:0:1428:57ab

**C. 2001::db8::1428:57ab ✓ Correct**

**D.** 2001:db8:0:0:0:0:1428:57ab

*Invalid — it uses two "::" compressions in one address, which makes the number of suppressed groups ambiguous. Only one "::" is ever allowed.*

# Quick Check

**Shorten 2001:0000:0000:0234:0000:0000:0000:5678 — there are two runs of all-zero groups. Which one should you compress?**

**A.** 2001::234:0:0:0:5678

**B.** 2001:0:0:234::5678

**C.** 2001::234::5678

**D.** 2001:0:0:0234:0:0:0:5678

# Answer

**Shorten 2001:0000:0000:0234:0000:0000:0000:5678 — there are two runs of all-zero groups. Which one should you compress?**

**A.** 2001::234:0:0:0:5678

**B. 2001:0:0:234::5678 ✓ Correct**

**C.** 2001::234::5678

**D.** 2001:0:0:0234:0:0:0:5678

*Compress the longer zero-run (three groups after "0234"), not the shorter one (two groups before it) — always compress the longest run.*

03

# IPv6 Address Types

Unicast, Multicast, Anycast, and Scope

# Three Types of IPv6 Addresses

### Unicast

One-to-one

Delivered to a single, specific interface.

### Multicast

One-to-many

Delivered to every interface in a group.

### Anycast

One-to-nearest

Delivered to the topologically closest interface sharing the address.

***There is no broadcast address (or concept) in IPv6.***

# Address Scope: How Far Is an Address Valid?

## Global Scope

Unique and reachable across the entire Internet — like a public IPv4 address.

## Link-Local Scope

Valid only on the local link (the segment behind one router interface).

*Within a given scope, an address uniquely identifies one interface.*

# Global Unicast Addresses (GUA)

Range: 2000::/3 — the routable, public address space of IPv6.

| | | | |
|---|---|---|---|
| 001 | Global Routing Prefix (n bits) | Subnet ID | Interface ID (64 bits) |

**network** (n bits, assigned by your RIR / upstream) **host** (always 64 bits)

**Example:**

`2001:4290:0010:0249:bae8:56ff:fe4a:ecfe`

# Link-Local Addresses (LLA) & Scope IDs

| 1111111010 (fe80::/10) | 0 (54 bits) | Interface ID (64 bits) |
| --- | --- | --- |

`fe80::bae8:56ff:fe4a:ecfe`

A host can have the same link-local address on more than one interface, so the OS needs to know **which interface** to use. That's the job of the zone ID:

### macOS

fe80::bae8:56ff:fe4a:ecfe%en0

### Windows

fe80::bae8:56ff:fe4a:ecfe%10

# Unique Local Addresses (ULA)

Range: fc00::/7 — private address space, IPv6's equivalent of RFC 1918.

| 1111110 | L | 0 (56 bits) | Interface ID (64 bits) |
|---|---|---|---|

**L = 0**

Unassigned (reserved for future use).

**L = 1 → fd00::/8**

Free-use, self-assigned space — generate it yourself, no registry needed.

# Generating an Interface ID — EUI-64

1. **Start with the 48-bit MAC address**
   00 90 27 17 FC 0F

2. **Split it and insert FFFE in the middle**
   00 90 27  FF FE  17 FC 0F

3. **Flip the U/L bit (7th bit of the first byte)**
   00 → 02

4. **Result: your 64-bit Interface ID**
   02 90 27 FF FE 17 FC 0F

# Well-Known and Multicast Addresses

## Well-Known Addresses

| | |
|---|---|
| :: | Unspecified address — never used as a destination |
| ::/0 | Represents all IPv6 addresses |
| ::1 | Loopback — never forwarded off the node |

## Multicast Basics

1. **ff00::/8**
   The entire multicast address range
2. **FF02::1**
   All nodes on the local link
3. **FF02::2**
   All routers on the local link

*Every unicast/anycast address also has a matching Solicited-Node Multicast Address, built from its last 24 bits — used so neighbor discovery doesn't have to interrupt every host on the link.*

# Quick Check

**Which of the following does NOT exist as an address type in IPv6?**

**A.** Unicast

**B.** Anycast

**C.** Broadcast

**D.** Multicast

# Answer

**Which of the following does NOT exist as an address type in IPv6?**

**A.** Unicast

**B.** Anycast

**C. Broadcast ✓ Correct**

**D.** Multicast

# Quick Check

**What is the prefix range for Unique Local Addresses (ULA)?**

**A.** 2000::/3

**B.** fe80::/10

**C.** fc00::/7

**D.** ff00::/8

# Answer

**What is the prefix range for Unique Local Addresses (ULA)?**

**A.** 2000::/3

**B.** fe80::/10

**C. fc00::/7 ✓ Correct**

**D.** ff00::/8

04

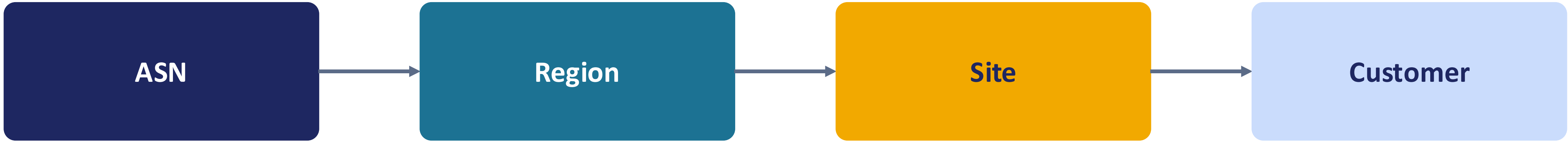
# Address Planning

For ISPs, Campuses, and Enterprises

# Forget Your IPv4 Subnetting Habits

1. You subnet IPv6 for routing and security — not to conserve space.
2. There's no VLSM in IPv6 — use the same prefix length on every LAN.
3. Only the number of subnets matters — host counts don't.
4. You'll rarely, if ever, need to expand a /64 subnet.

# Model Your Network as a Hierarchy




*Same pattern, different labels: a university becomes Campus → Building → Department, and an enterprise becomes Branch → Function (Data/Voice/Video) → Business Unit.*

# Calculating the Bits You Need

| Number of Entities | Bits Required |
|---|---|
| 16 | 4 |
| 256 | 8 |
| 4,096 | 12 |
| 65,536 | 16 |
| 1,048,576 | 20 |
| 16,777,216 | 24 |
| 268,435,456 | 28 |
| 4,294,967,296 | 32 |

# Choosing Your End-Network Prefix Size

| | | | | |
|---|---|---|---|---|
| /64 | /60 | /56 | /52 | /48 |

Whatever you choose, keep it nibble-aligned (a multiple of 4 bits) — it keeps the resulting address ranges clean and easy to read, instead of splitting in the middle of a hex digit.

***Don't worry about running out: 2000::/3 alone holds roughly 35 trillion /48 blocks.***

# Worked Example

An ISP operates in **10 cities**. Its largest city has **50 PoPs**, and the largest PoP serves **2,700 clients**. Each customer gets a /48. How much space should it request from AFRINIC?

| Level | Description | Count | Bits |
|---|---|---|---|
| 1 | Cities | 10 | 4 |
| 2 | PoPs in largest city | 50 | 8 |
| 3 | Clients in largest PoP | 2,700 | 12 |
| 4 | End-network size | /48 | — |

48 – 12 – 8 – 4

Request

**/24**

# PI or PA Space? A Quick Decision Guide

## Provider-Independent (PI)

Choose PI if you already hold IPv4 PI space, or if you multihome across ISPs and announce the same prefix from more than one site.

## Provider-Aggregatable (PA)

Choose PA if you don't hold IPv4 PI space and either single-home, or multihome without announcing identical prefixes from multiple sites.

# Implementation Best Practices

1. **Use /64 for every multi-host LAN subnet.**
2. **Reserve /64 (or /128 for loopbacks) for infrastructure — inter-router links and loopback addresses.**
3. **Assign sub-prefixes sequentially or by bisection — pick one strategy and stay consistent.**

# Point-to-Point Links: Why Consider /127?

### Traditional: /64 or /126

Works, but leaves room for two routers to loop packets back and forth ('ping-pong') and for neighbor-exhaustion attacks against the large address space.

### Recommended: /127

Only two usable addresses on the link — eliminates forwarding loops on point-to-point links and closes off neighbor-exhaustion attacks.

# Quick Check

## What is a valid reason for subnetting in IPv6?

**A.** To conserve address space

**B.** Subnetting enables us to create address hierarchies to optimize route aggregation.

**C.** To avoid needing a routing protocol

**D.** To reduce the total number of usable addresses

# Answer

## What is a valid reason for subnetting in IPv6?

**A.** To conserve address space

**B. Subnetting enables us to create address hierarchies to optimize route aggregation. ✓ Correct**

**C.** To avoid needing a routing protocol

**D.** To reduce the total number of usable addresses

# Quick Check

## Which statement(s) concerning minimum RIR allocations are correct?

*Select all that apply.*

**A.** As an enterprise network, minimum is /48

**B.** As an ISP, minimum is /32

**C.** As an enterprise network, minimum is /32

**D.** As an ISP, minimum is /48

# Answer

## Which statement(s) concerning minimum RIR allocations are correct?

*Select all that apply.*

**A. As an enterprise network, minimum is /48 ✓ Correct**

**B. As an ISP, minimum is /32 ✓ Correct**

**C.** As an enterprise network, minimum is /32

**D.** As an ISP, minimum is /48

*Reference: LIRs / ISPs → minimum /32. End sites, enterprises, universities → minimum /48.*

# Quick Check

**What block size will an RIR give an ISP without an address plan?**

**A.** /48

**B.** /32

**C.** /29

**D.** /24

# Answer

**What block size will an RIR give an ISP without an address plan?**

**A.** /48

**B. /32 ✓ Correct**

**C.** /29

**D.** /24

# Quick Check

**A housing project has 7 villages, each with 15 blocks, each block with 75 apartments. Every apartment gets a /60. What size block should the project request from its RIR?**

**A.** /48

**B.** /44

**C.** /40

**D.** /36

# Answer

**A housing project has 7 villages, each with 15 blocks, each block with 75 apartments. Every apartment gets a /60. What size block should the project request from its RIR?**

**A.** /48

**B. /44 ✓ Correct**

**C.** /40

**D.** /36

*7 villages → 4 bits, 15 blocks → 4 bits, 75 apartments → 8 bits = 16 bits total. 60 − 16 = /44.*

# Quick Check

## Which are valid reasons for subnetting in IPv6?

*Select all that apply.*

**A.** Make it easier to aggregate routing

**B.** Separate communications and enforce security

**C.** Conserve address space

**D.** Increase the number of usable host bits

# Answer

## Which are valid reasons for subnetting in IPv6?

*Select all that apply.*

**A. Make it easier to aggregate routing ✓ Correct**

**B. Separate communications and enforce security ✓ Correct**

**C.** Conserve address space

**D.** Increase the number of usable host bits

# Quick Check

**What block size will an RIR give a university without an address plan?**

**A.** /32

**B.** /48

**C.** /56

**D.** /64

# Answer

**What block size will an RIR give a university without an address plan?**

**A.** /32

**B. /48 ✓ Correct**

**C.** /56

**D.** /64

# Next Up: Hands-On Lab

Basic Configuration — hosts and routers

# Questions?



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