

# Running Out of Integers

**The Impending Scarcity of IP Addresses  
and What To Do About It**

Ben Edelman

May 8, 2009

# Plan

- What IPs are and how they're used
- Scarcity
- Possible alternatives
  - Adding digits
  - Sharing addresses
- Market for transferring IPs
  - Objectives
  - Basic approach
  - Restrictions

# Checking Your IP Address

The screenshot shows the Windows Network Connections window. The left sidebar is expanded to show the details of the 'Local Area Connection'. The IP address '199.94.11.10' is highlighted with a red box. The status is 'Connected, Firewalled' and it is 'Manually Configured'.

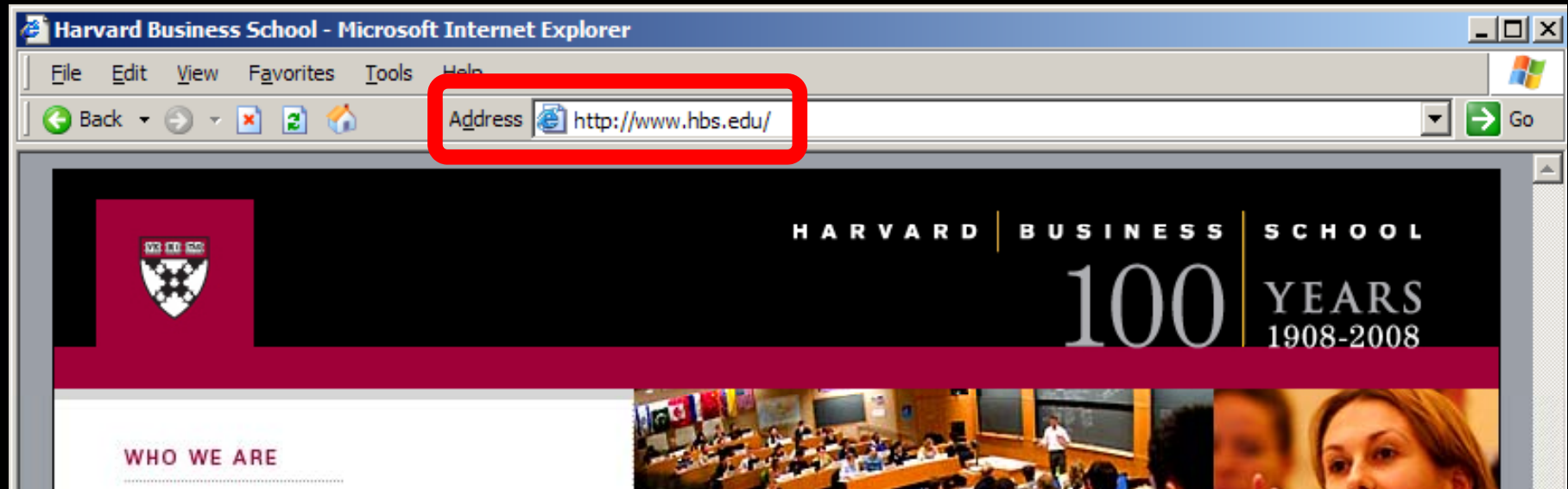
Name	Type	Status
<b>LAN or High-Speed Internet</b>		
1394 Connection	LAN or High-Speed Inter...	Connected, Firewalled
Local Area Connection	LAN or High-Speed Inter...	Connected, Firewalled

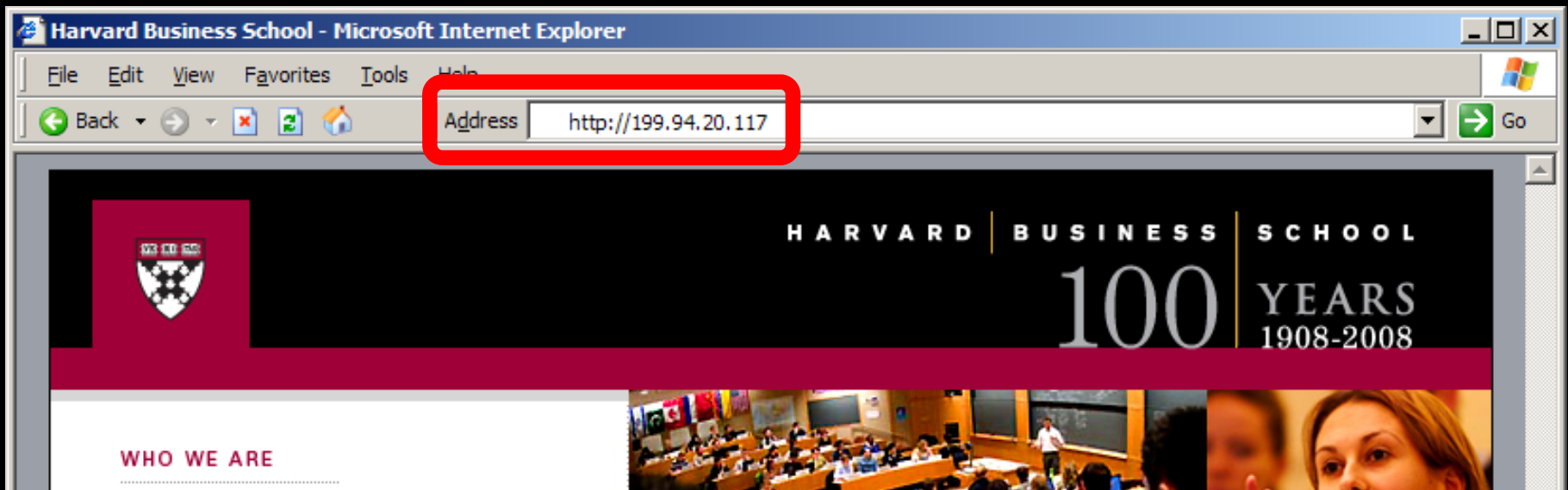
Local Area Connection
LAN or High-Speed Internet
Connected, Firewalled
Broadcom NetXtreme 57xx Gigabit Controller
<b>IP Address: 199.94.11.10</b>
Subnet Mask: 255.255.252.0
Manually Configured

```
C:\WINDOWS
C:\>ipconfi
Windows IP
Ethernet ad
Con
IP
Sub
Defa
C:\>
```

# Domain Name – www.hbs.edu



# IP Address - 199.94.20.117



Search ARIN WHOIS for: 140.247.21.21

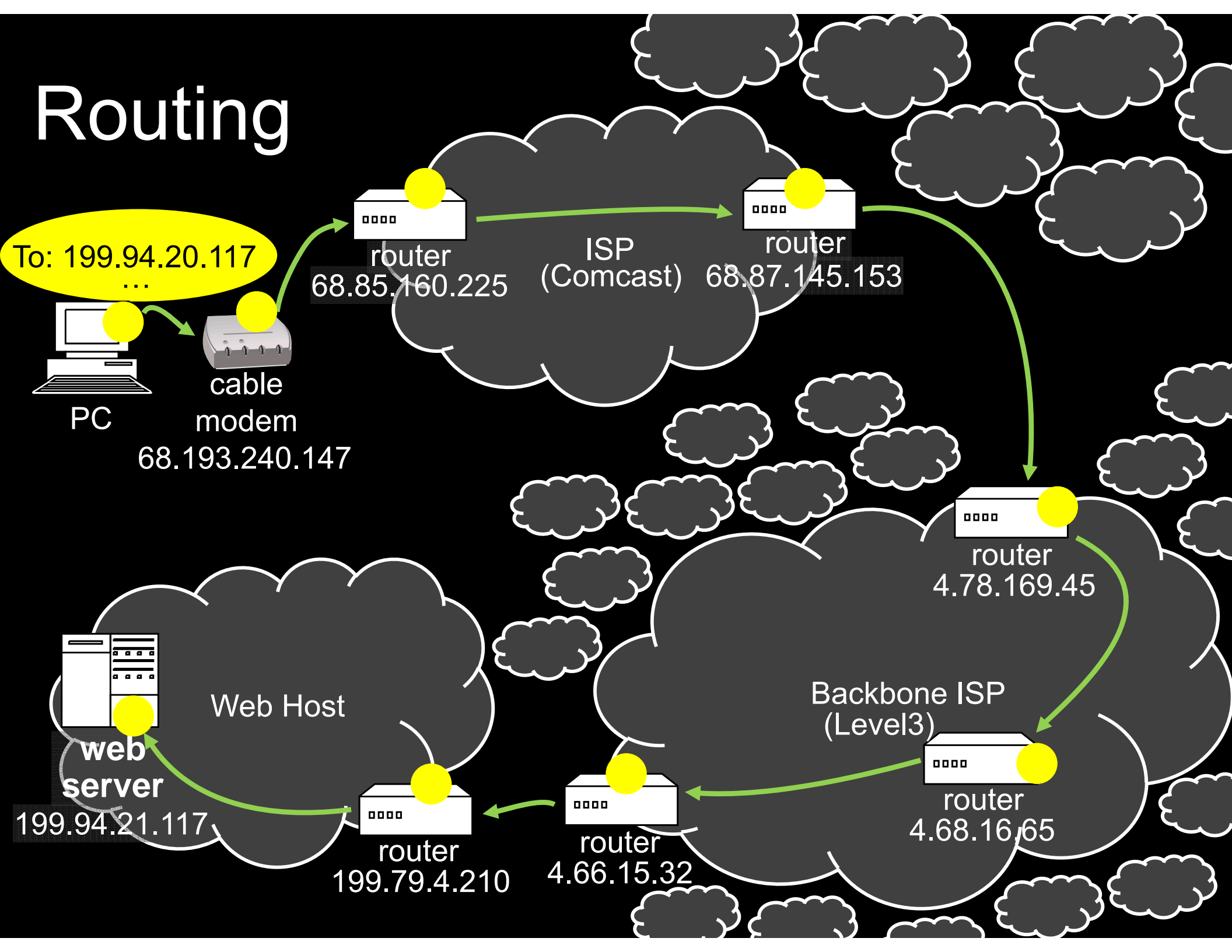
140.247.21.21 Submit Query

OrgName: Harvard University
OrgID: HARVAR
Address: UIS Network Operations Center
Address: Jay Tumas - Network Operations Manager
Address: 60 Oxford Street
Address: Suite 132
City: Cambridge
StateProv: MA
PostalCode: 02138
Country: US

NetRange: 140.247.0.0 - 140.247.255.255
CIDR: 140.247.0.0/16
NetName: HARVARD-COLL
NetHandle: NET-140-247-0-0-1
Parent: NET-140-0-0-0-0
NetType: Direct Assignment
NameServer: CNRDNS1.FAS.HARVARD.EDU
NameServer: CNRDNS2.FAS.HARVARD.EDU
Comment:
RegDate: 1992-09-18
Updated: 2006-08-21

RAbuseHandle: FNO1-ARIN
RAbuseName: FAS Network Operations
RAbusePhone: +1-617-495-1262
RAbuseEmail: netmanager@fas.harvard.edu

# Routing



# Widener Call Number Locations

WID-LC D 4 West

WID-LC E 1 East

WID-LC F 1 East

...

WID-LC G\*–GV Pusey 3

WID-LC H\*, HA Pusey 3

WID-LC HB\*–HX Pusey 2

WID-LC J–JZ D East

...

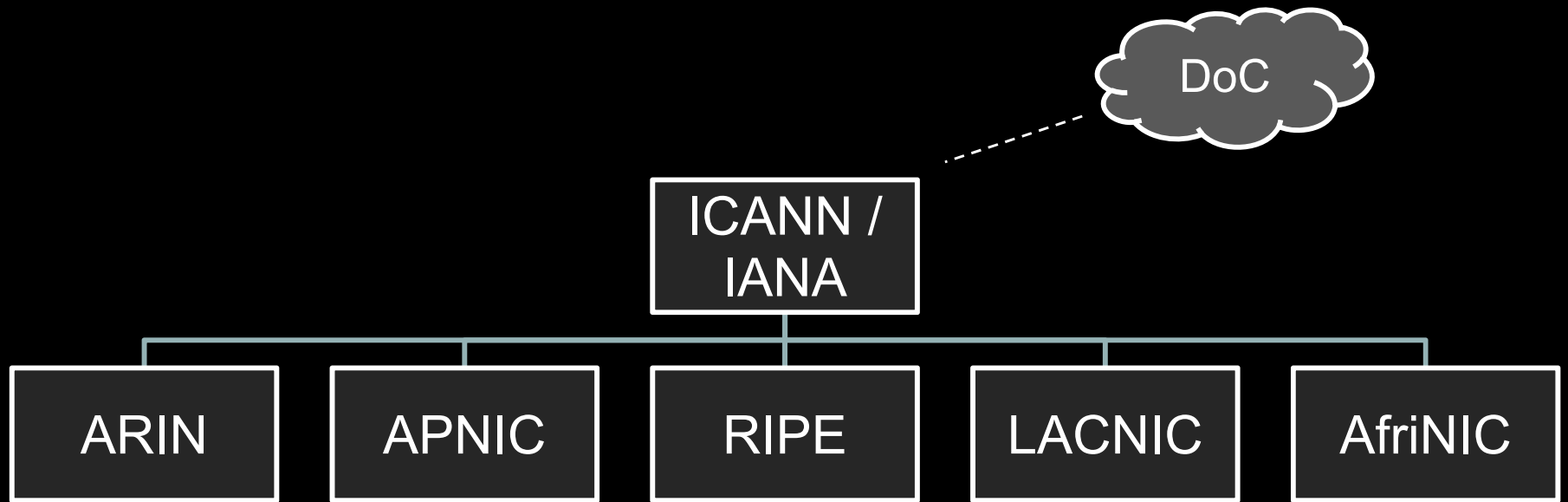
} two location entries

more compact alternative

WID-LC G Pusey 2

WID-LC H Pusey 3

# Address Assignment Structure





# ARIN Fees

<b>Size</b>	<b>Fee</b>	<b>Total Allocation Block Size</b>
X-small	\$1,250/year	blocks smaller than a /20 ( $<2^{12}$ addresses)
Small	\$2,250/year	blocks from a /20 to a /19 in size
Medium	\$4,500/year	blocks larger than a /19, up to and including a /16
Large	\$9,000/year	blocks larger than a /16, up to and including a /14
X-large	\$18,000/year	blocks larger than a /14 ( $>2^{18}$ addresses)

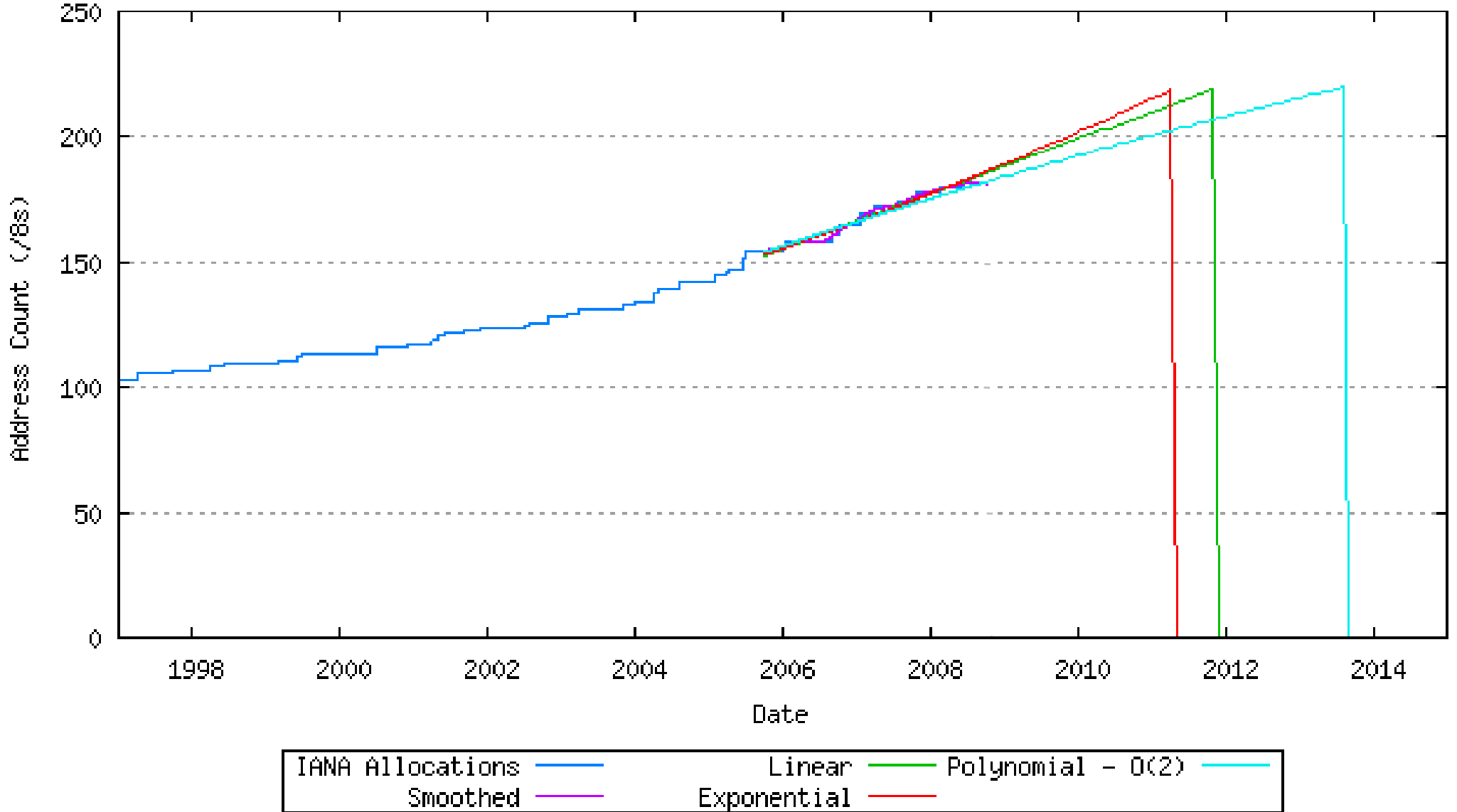
# The Structure of IPv4 Addresses

199.94.20.117

$\underbrace{11000111}_8$   $\underbrace{01011110}_8$   $\underbrace{00010100}_8$   $\underbrace{01110101}_8$

→  $2^{32}$  possible addresses

# IANA Allocations - Projections

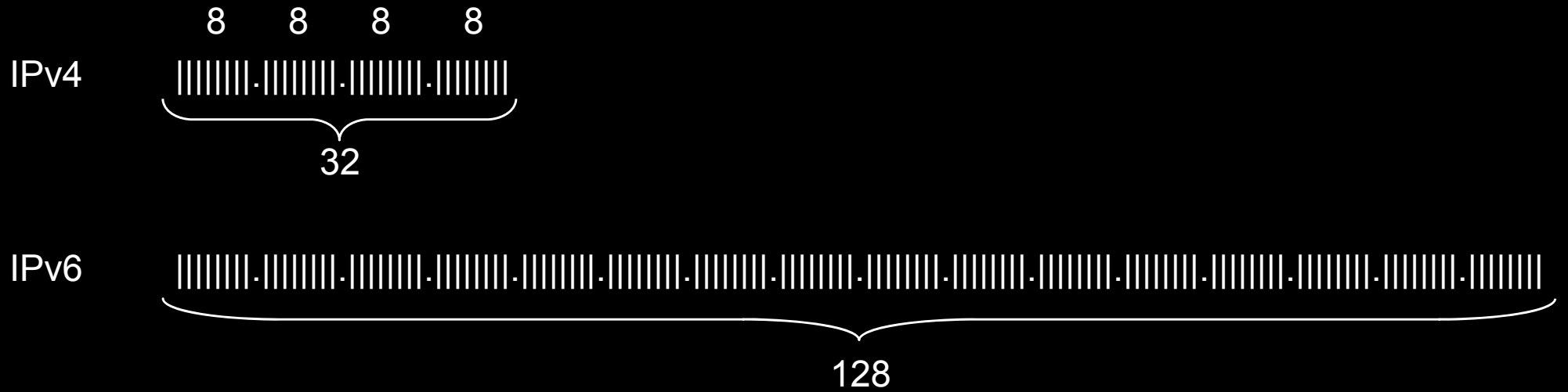


Source: Geoff Huston

# “Add another digit”

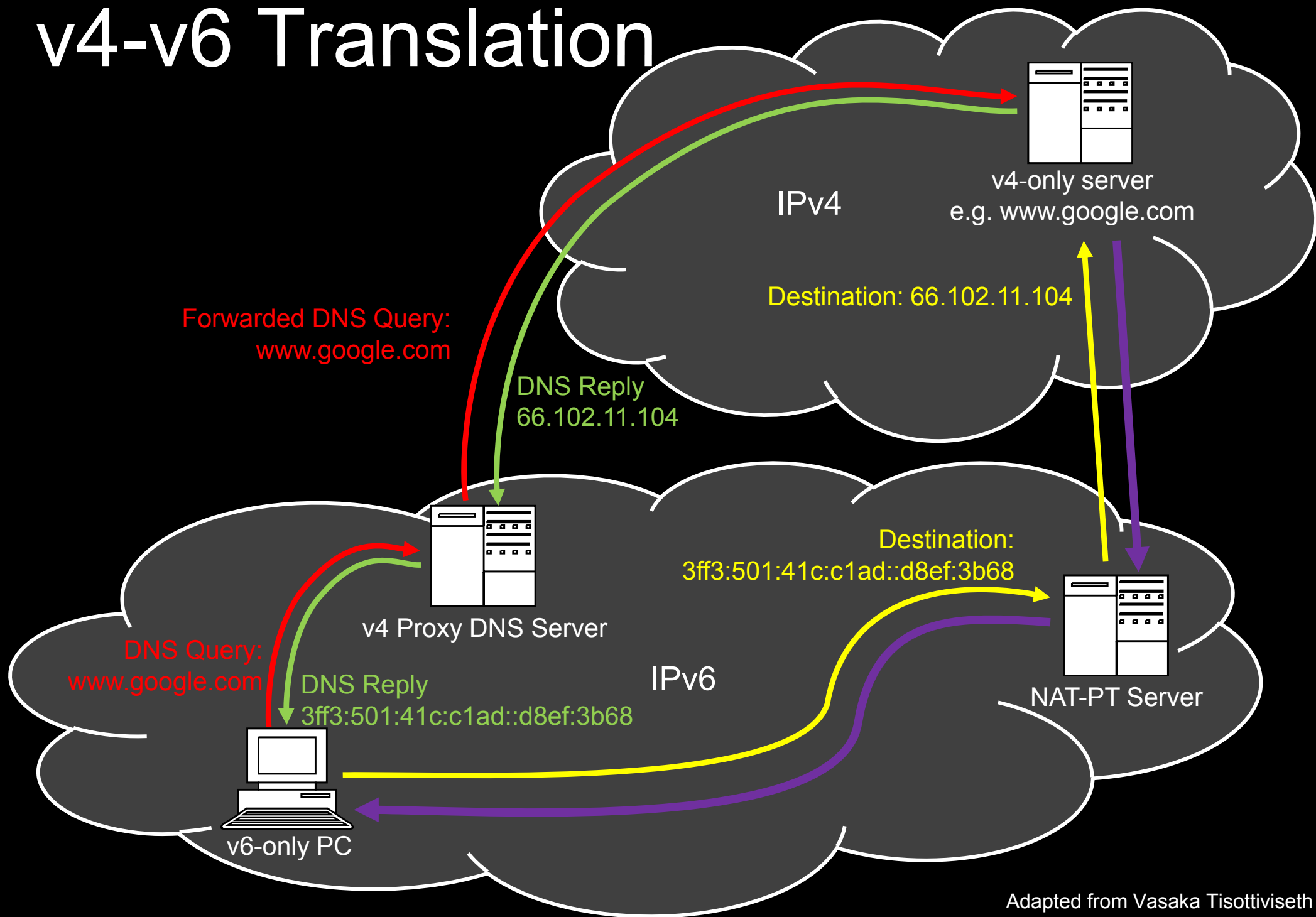
- License plates
- Phone numbers

# IPv6



$$2^{128} \approx 3.4 \times 10^{38}$$

# v4-v6 Translation



# Costs to IPv6 Transition

- Forwards compatibility
- Backwards compatibility
- Renumbering
  - Hard-coded IPs
- Software upgrades
  - Commercial
  - Internal
- Hardware upgrades
  - Printers, firewalls, routers
- Training



DoC estimates \$25 billion over 25 years

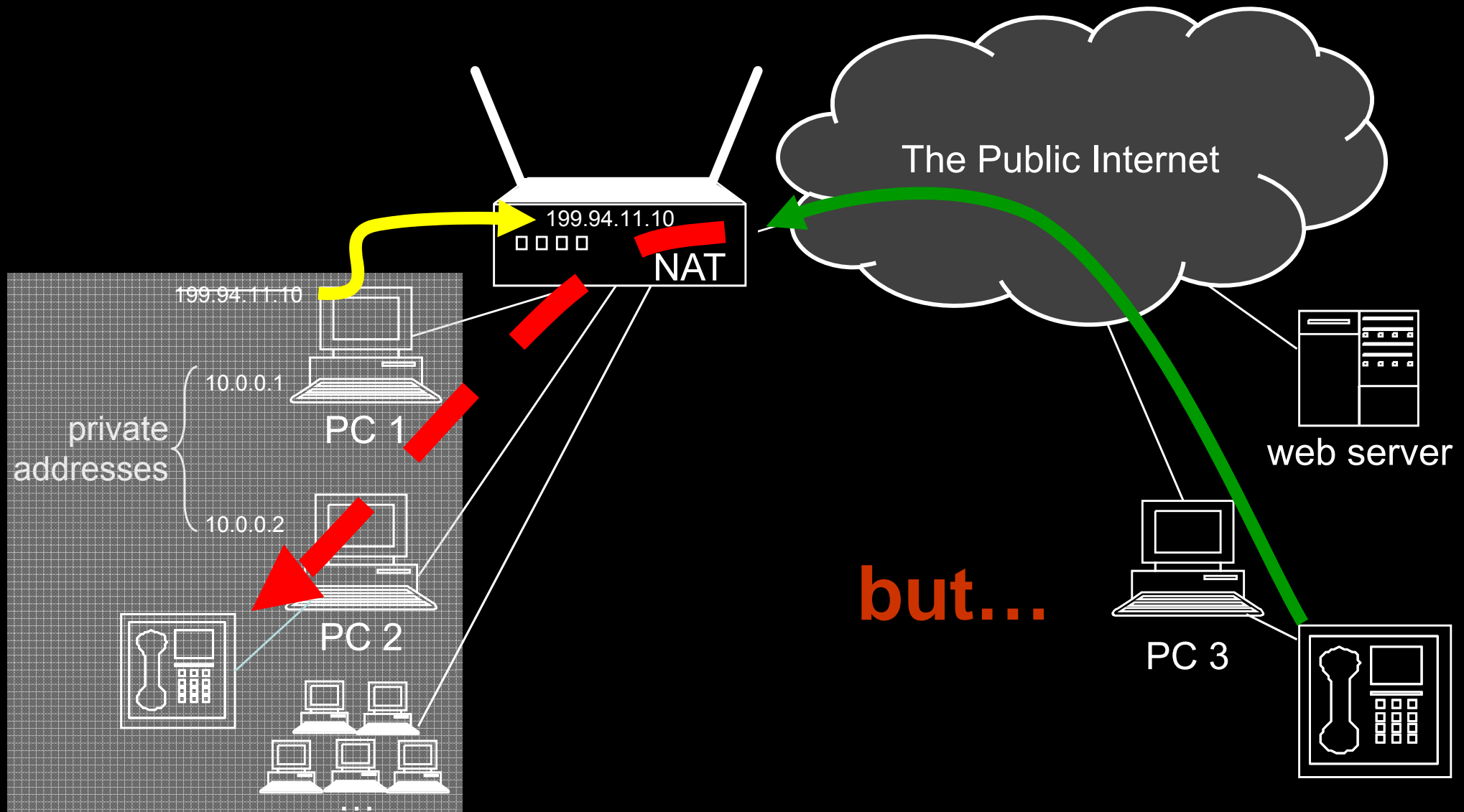
# IPv6 Detriments

- IPv4 works
- IPv4 addresses are still easy & cheap to get
- Everyone else runs IPv4
- IPv6 transition is expensive and complicated



# Sharing IPv4 Addresses

## Network Address Translation



# NAT Complexity

The image displays two overlapping windows illustrating NAT configuration. The background window is the D-Link DI-614+ Enhanced 2.4GHz Wireless Router configuration page, accessed via Microsoft Internet Explorer at the address `http://192.168.0.1/adv_virtual.html`. The page shows the 'Advanced' tab selected, with the 'Virtual Server' section highlighted by a red rounded rectangle. This section includes radio buttons for 'Enabled' and 'Disabled', a 'Name' text field with a 'Clear' button, 'Private IP', 'Protocol Type' (set to 'TCP'), 'Private Port', and 'Public Port' text fields. Below these are 'Schedule' options: 'Always' and 'From time' (with dropdowns for hours, minutes, AM/PM, and days).

The foreground window is a 'Settings' dialog box, with the 'Network Options' tab selected and highlighted by a red rounded rectangle. It features a 'Listening Port' section with a text field containing '32459' and a 'Random port' button. Below this is a checkbox for 'Randomize port each time Utorrent starts'.

# Inhibiting IPv4 Transfers

“Number resources are non-transferable and are not assignable to any other organization ...

“[N]umber resources are assigned to an organization for its exclusive use for the purpose stated in the request, provided the terms of the Registration Services Agreement continue to be met and the stated purpose for the number resources remains the same. ...

“ARIN will consider requests for the transfer of number resources only upon receipt of evidence that the new entity has acquired the assets which had, as of the date of the acquisition ..., justified the current entity's use of the number resource.”

-ARIN Number Resource Policy Manual  
Section 8.1-2

# Sources of IPv4 Addresses

- Legacy operators
- Bankrupt / defunct networks
- Networks substituting out of IPv4





# IPv4 Market Design Questions

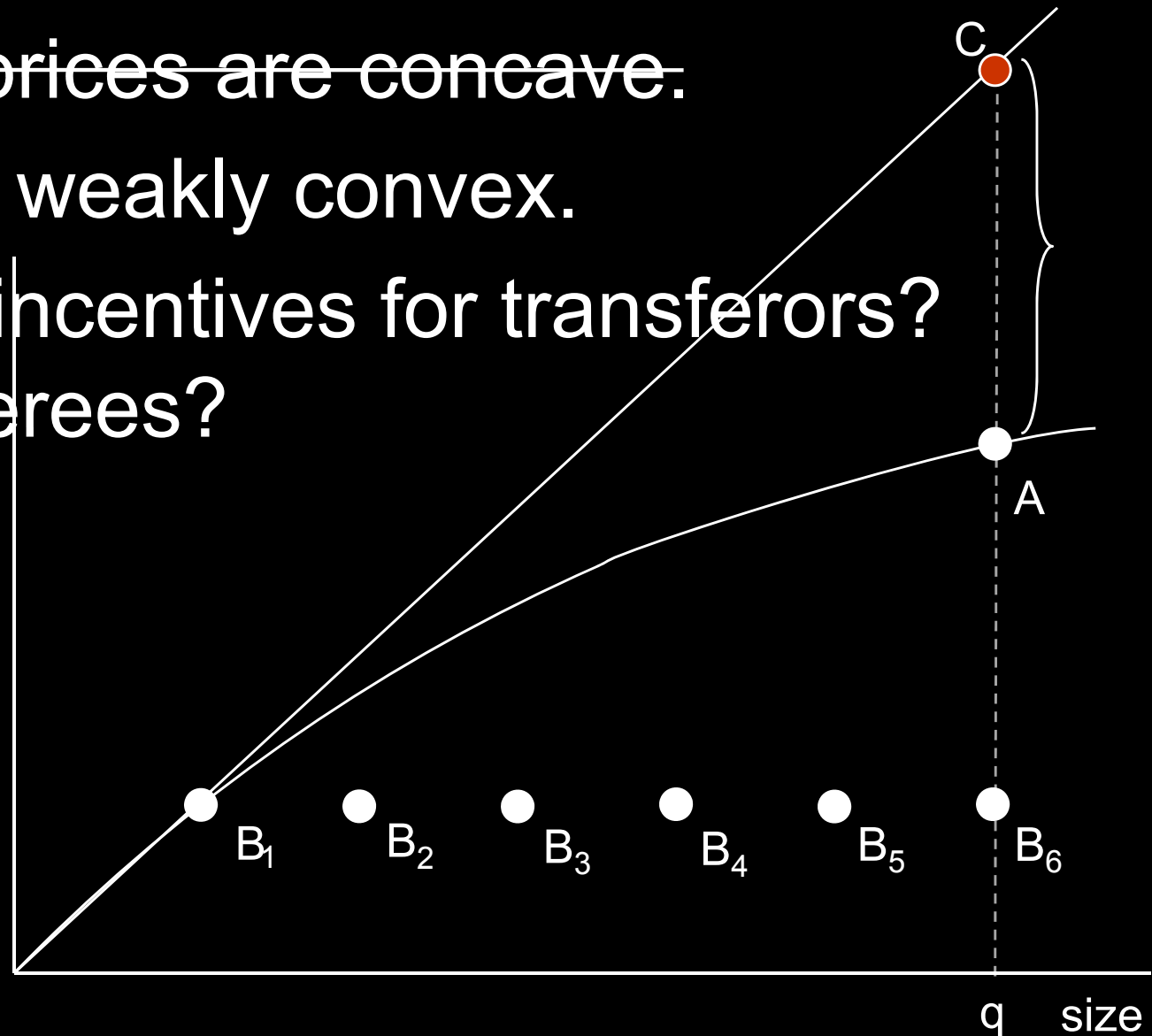
- Allow paid transfers at all?
- Block size?
- Speculators?
  - “Need” requirement?
  - Minimum holding period?
- Inter-region transfers?
- Effect on IPv6 transition?
- Likely prices?

# Subdivision and Full-Fill

- Subdivision by transferors
    - Could prohibit, limit, or allow
  - Full-fill rule for transferees
- Which side to regulate? Or both?

# Full-Fill plus Unlimited Subdivision

- ~~Suppose prices are concave.~~
- Prices are weakly convex.
- Resulting<sup>p</sup> incentives for transferors?  
For transferees?





# Political Economy of IPv4 Markets

- Tech-savvy network engineers
- Multiple regions with independent RIRs
- Networks vary dramatically
  - size, wealth, purpose

# Alternatives

- Unrestricted markets
- RIR as warehouse, sole buyer, sole seller
  - At what price?

# Research questions

- In a v4 market, what rules are appropriate?
- Likely prices in a v4 market? As a function of market rules?
- Effect of v4 market on v6 transition?
- Unpriced resources more generally
  - Addresses
  - Routing slots
  - Email, web browsing, end-user bandwidth, etc.

