Where did all those IPv6 addresses go?

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It seems rather odd…

- To be considering address capacity issues in a technology that is really only ramping up.
- 128 bits allows an awesomely large pool of unique values

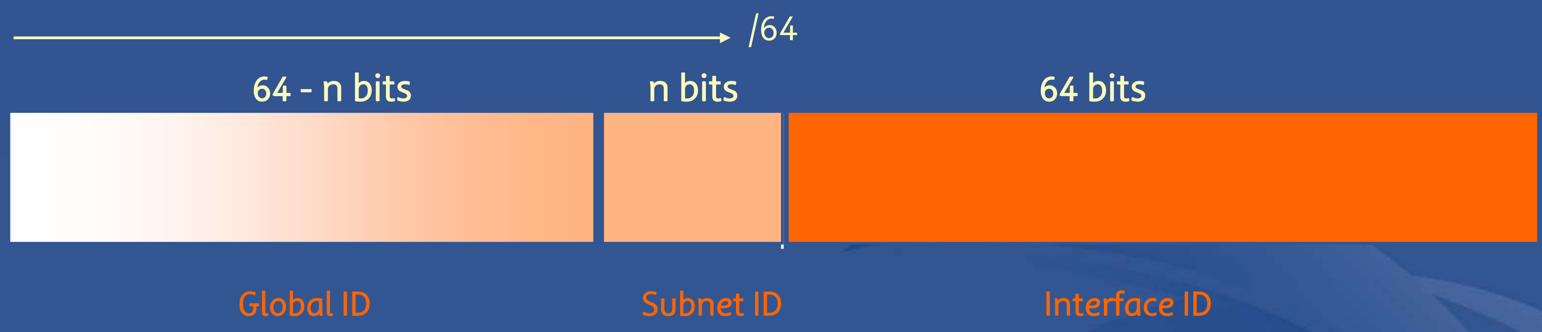
  "If the earth were made entirely out of 1 cubic millimetre grains of sand, then you could give a unique address to each grain in 300 million planets the size of the earth" -- Wikipedia

- This is a highly speculative exercise….

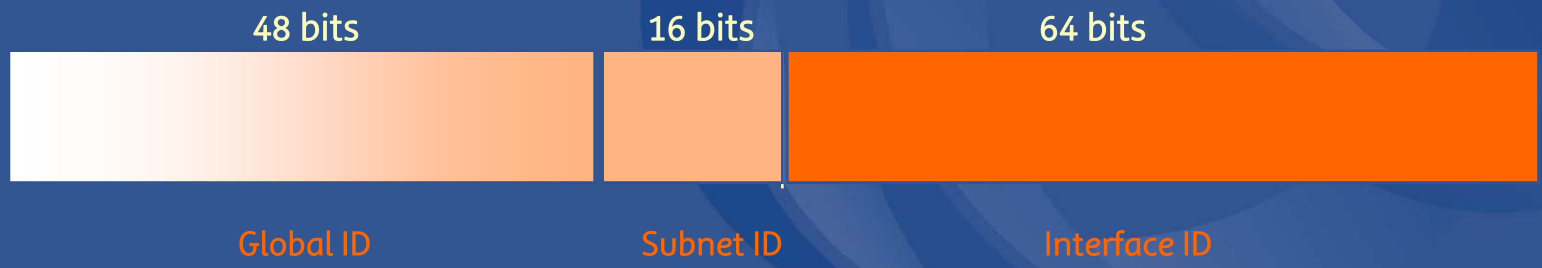
Asia Pacific Network Information Centre

APNIC

IETF IPv6 Address Structure



RIR IPv6 Address Structure



Current Address Allocation Policies

- RIR to ISP(LIR):
  - Initial allocation: /32 (minimum)
  - Subsequent allocation : /32 (minimum)
- ISP(LIR) to customer:
  - Only 1 interface ever: /128
  - Only 1 subnet ever: /64
  - Everything else: /48 (minimum)
- ISP(LIR) to each POP:
  - /48

Address Efficiency – HD=0.8

Prefix	/48 count	end-site count
/32	65,536	7,132
/31	131,072	12,417
/30	262,144	21,619
/29	524,288	37,641
/28	1,048,576	65,536
/27	2,097,152	114,105
/26	4,194,304	198,668
/25	8,388,608	345,901
/24	16,777,216	602,249
/23	33,554,432	1,048,576
/22	67,108,864	1,825,677
/21	134,217,728	3,178,688
/20	268,435,456	5,534,417
/19	536,870,912	9,635,980
/18	1,073,741,824	16,777,216

Google ("subscribers millions")

- Broadband
  - 150 million total globally
    - 85 million DSL Globally
      - 12 million in US today
      - 58 million in US in 2008
- Cellular
  - Cingular: 50 million
  - Verizon: 43 million
  - Korea: 37 million
  - Russia: 20 million
  - Asia: 560 million
    - China: 580 million subscribers by 2009

Squeezing in Bigger Numbers for Longer Timeframes

- The demand - global populations:
  - Households, Workplaces, Devices, Manufacturers, Public agencies
  - Thousands of service enterprises serving millions of end sites in commodity communications services
  - Addressing technology to last for decades
  - Total end-site populations of tens of billions of end sites

  i.e. the total is order (10^{11}) ?

- The supply – inter-domain routing
  - We really may be stuck with BGP
  - Approx 200,000 routing (RIB) entries today
  - A billion routing (RIB) entries looks a little too optimistic

  i.e. a total entry count is order(10^7)

- The shoe horn
  - Aggregation and hierarchies in the address plan

Putting it together

- Aggregation and hierarchies are not highly efficient addressing structures
- The addressing plan needs to accommodate both large and small
- The addressing plan needs to be simple

16 bit subnets + HD = 0.8 + global populations + 60 years =?

HD Ratio for Bigger Networks

Prefix	/48 count	end-site count
/21	134,217,728	3,178,688
/20	268,435,456	5,534,417
/19	536,870,912	9,635,980
/18	1,073,741,824	16,777,216
/17	2,147,483,648	29,210,830
/16	4,294,967,296	50,859,008
/15	8,589,934,592	88,550,677
/14	17,179,869,184	154,175,683
/13	34,359,738,368	268,435,456
/12	68,719,476,736	467,373,275
/11	137,438,953,472	813,744,135
/10	274,877,906,944	1,416,810,831
/9	549,755,813,888	2,466,810,934
/8	1,099,511,627,776	4,294,967,296
/7	2,199,023,255,552	7,477,972,398
/6	4,398,046,511,104	13,019,906,166
/5	8,796,093,022,208	22,668,973,294
/4	17,592,186,044,416	39,468,974,941
/3	35,184,372,088,832	68,719,476,736
/2	70,368,744,177,664	119,647,558,364
/1	140,737,488,355,328	208,318,498,661

Multiplying it out

A possible consumption total:

a simple address plan (/48s)

x aggregation factor (HD = 0.8)

x global populations (10**11)

x 60 years time frame

= 50 billion – 200 billion

= /1 -- /4 range

RFC 3177 (Sept 2001) estimated 178 billion global IDs with a higher HD ratio. The total “comfortable” address capacity was a /3.

Is this enough of a margin?

/4 consumption

- A total of 1/16 of the of the available IPv6 address space

/1 consumption

- A total of 1/2 of the available IPv6 address space

Factors / Uncertainties:

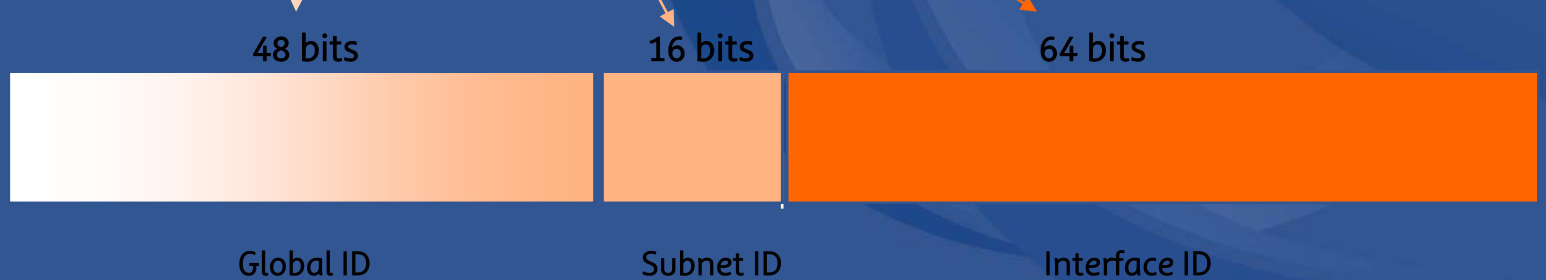
- Time period estimates (decades vs centuries)
- Consumption models (recyclable vs one-time manufacture)
- Network models (single domain vs overlays)
- Network Service models (value-add-service vs commodity distribution)
- Device service models (discrete devices vs ubiquitous embedding)
- Population counts (human populations vs device populations)
- Address Distribution models (cohesive uniform policies vs diverse supply streams)
- Overall utilization efficiency models (aggregated commodity supply chains vs specialized markets)

If this is looking slightly uncomfortable…

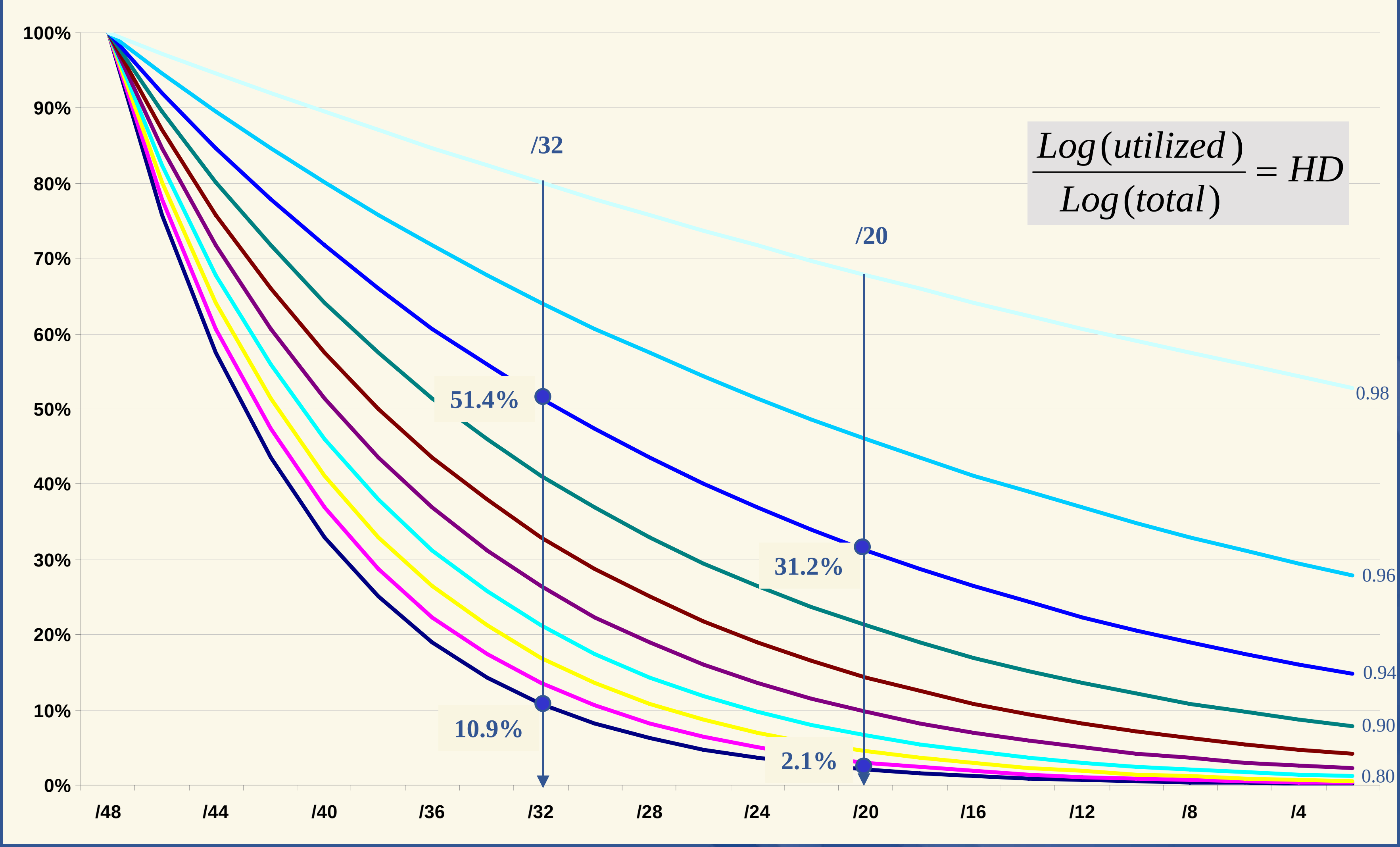
then we need to re-look at the basic assumptions to see where there may be some room to shift the allocation and/or architectural parameters to obtain some additional expansion space

Where's the Wriggle Room?

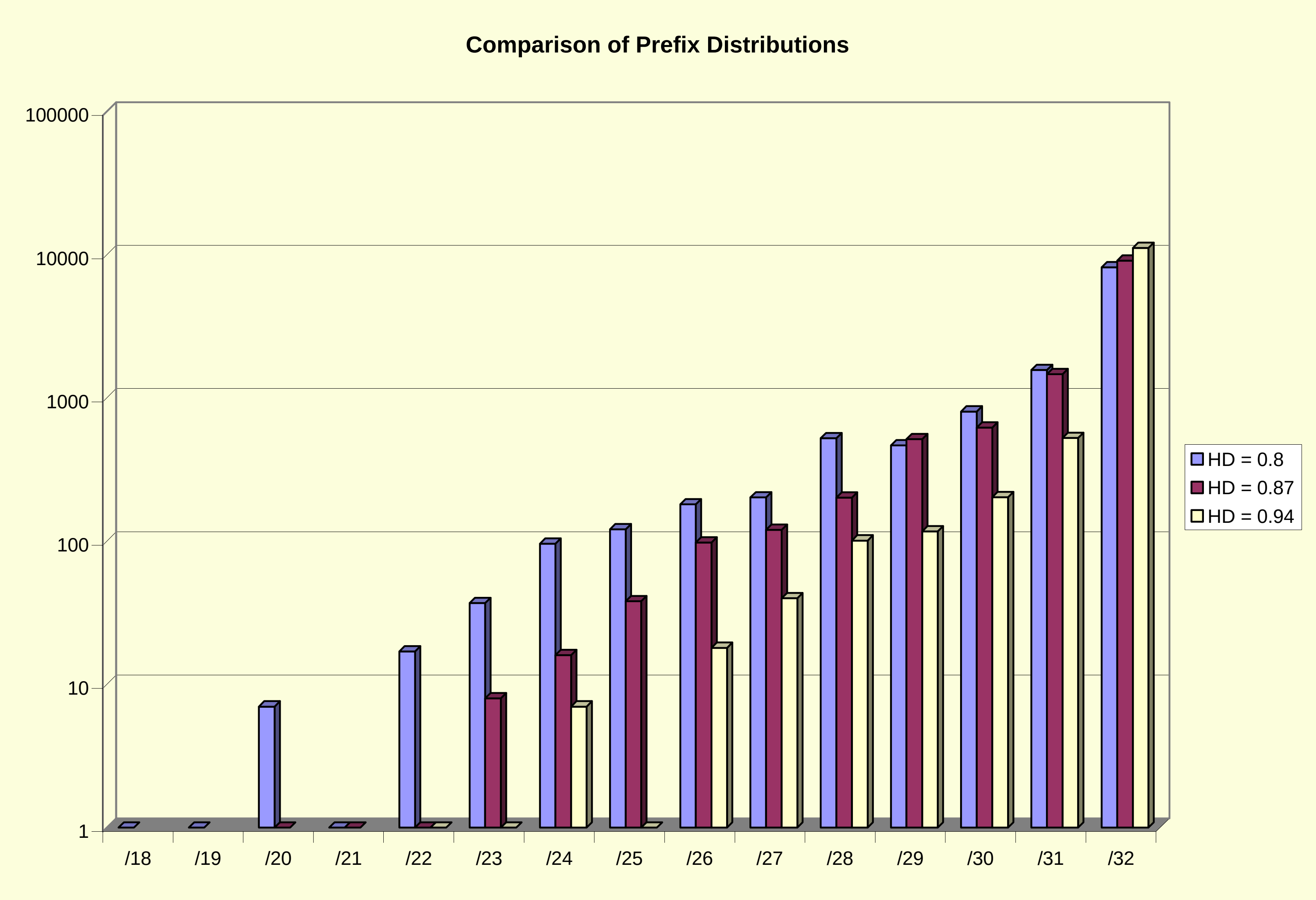
- IPv6 Allocation Policies
  - The HD-Ratio target for address utilization
  - The subnet field size used for end-site allocation
- IPv6 Address Architecture
  - 64 bit Interface ID



1. Varying the HD Ratio



Comparison of prefix size distributions from V6 registry simulations



Observations

- **80% of all allocations are /31, /32 for HD ratio of 0.8 or higher**
  - Changing the HD ratio will not impact most allocations in a steady state registry function
- **Only 2% of all allocations are larger than a /27**
  - For these larger allocations the target efficiency is lifted from 4% to 25% by changing the HD Ratio from 0.8 to 0.94
- **Total 3 year address consumption is reduced by a factor of 10 in changing the HD ratio from 0.8 to 0.94**

What is a "good" HD Ratio to use?

- Consider **what is common practice** in today's network in terms of internal architecture
  - APNIC is conducting a survey of ISPs in the region on network structure and internal levels of address hierarchy and will present the findings at APNIC 20
- Define a **common 'baseline' efficiency level** rather than an average attainable level
  - What value would be readily achievable by large and small networks without resorting to renumbering or unacceptable internal route fragmentation?
- Consider overall **longer term objectives**
  - Anticipated address pool lifetime
  - Anticipated impact on the routing space

2. The Subnet Identifier field

- RFC 3177: The subnet field

  Recommendation

  - **/48** in the general case, except for very large subscribers
  - **/64** when it is known that one and only one subnet is needed by design
  - **/128** when it is absolutely known that one and only one device is connecting

  Motivation

  - reduce evaluation and record-keeping workload in the address distribution function
  - ease of renumbering the provider prefix
  - ease of multi-homing
  - end-site growth
  - allows end-sites to maintain a single reverse mapping domain
  - Allows sites to maintain a common reverse mapping zone for multiple prefixes
  - Conformity with site-local structure (now unique locals)

Alternatives for subnetting

- Consider /56 SOHO default size
  - Maintain /128 and /64 allocation points, and /48 for compound enterprise end-sites
  - Processing and record-keeping overheads are a consideration here
  - End-site growth models for SOHO are not looking at extensive subnetting of a single provider realm
  - Renumbering workload is unaltered
  - Multi-homing is not looking at prefix rewriting
  - Fixed points maintains reverse mapping zone functions

  - Allow for overall 6 – 7 bits of reduced total address consumption

Alternatives for subnetting

- Consider variable length subnetting
  - Allows for greater end-site address utilization efficiencies
  - Implies higher cost for evaluation and record keeping functions
  - Implies tradeoff between utilization efficiency and growth overheads
  - Likely strong pressure to simplify the process by adopting the maximal value of the range

3. The Interface Identifier

- This identifier is now well embedded in the address architecture for V6
- Considerations for change here have extensive implications in terms of overlayed services of auto-configuration and discovery functions

Where's the Wriggle Room?

The HD ratio

- If using HD = 0.8 consumes 1 block of address space
- Using HD = 0.87 consumes 1/2 as much space
- Using HD = 0.94 consumes 1/10 as much space
- i.e. moving to a higher HD ratio will recover 3 bits here

The subnet field

- /56 SOHO default subnet size may alter cumulative total by 6 - 7 bits

/10 -- /17 range total

Is this sufficient margin for error / uncertainty in the initial assumptions about the deployment lifetime for IPv6?