IPv4 Address Allocation and Evolution of BGP Routing Tables

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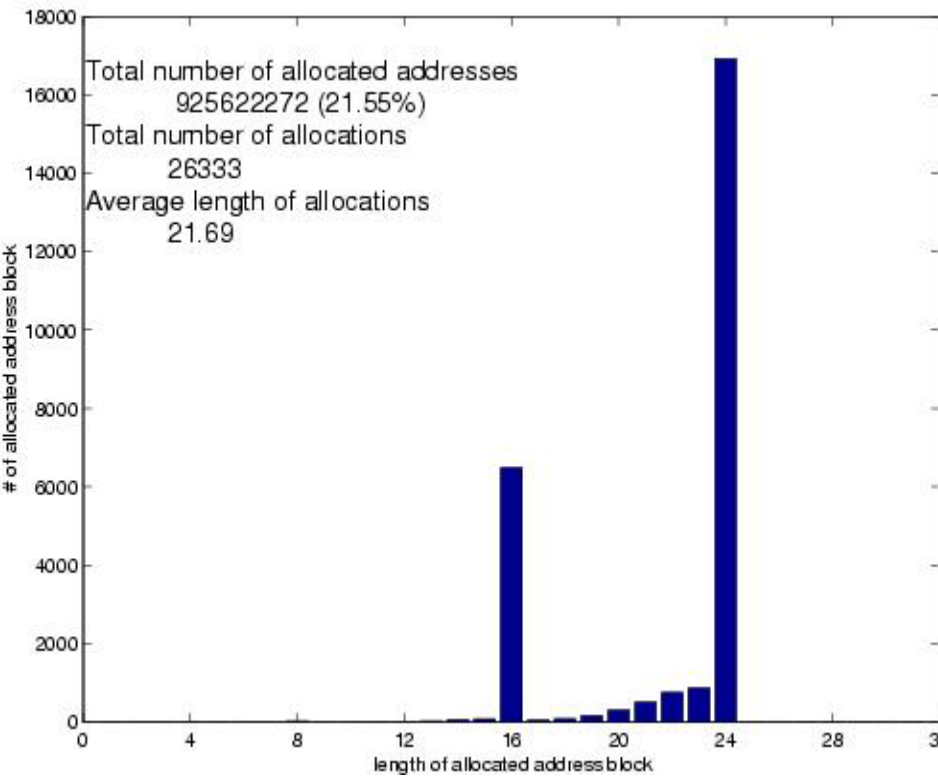 - Lixia Zhang, lixia@cs.ucla.edu

Overview

- IP address blocks allocated by the regional registries: the distribution of prefix lengths over time

- Do prefixes show up in the routing as allocated?
    - Using the last 4 years as a case study

- The evolution of the routing table over the last 4 years
    - Appearance and disappearance of prefixes
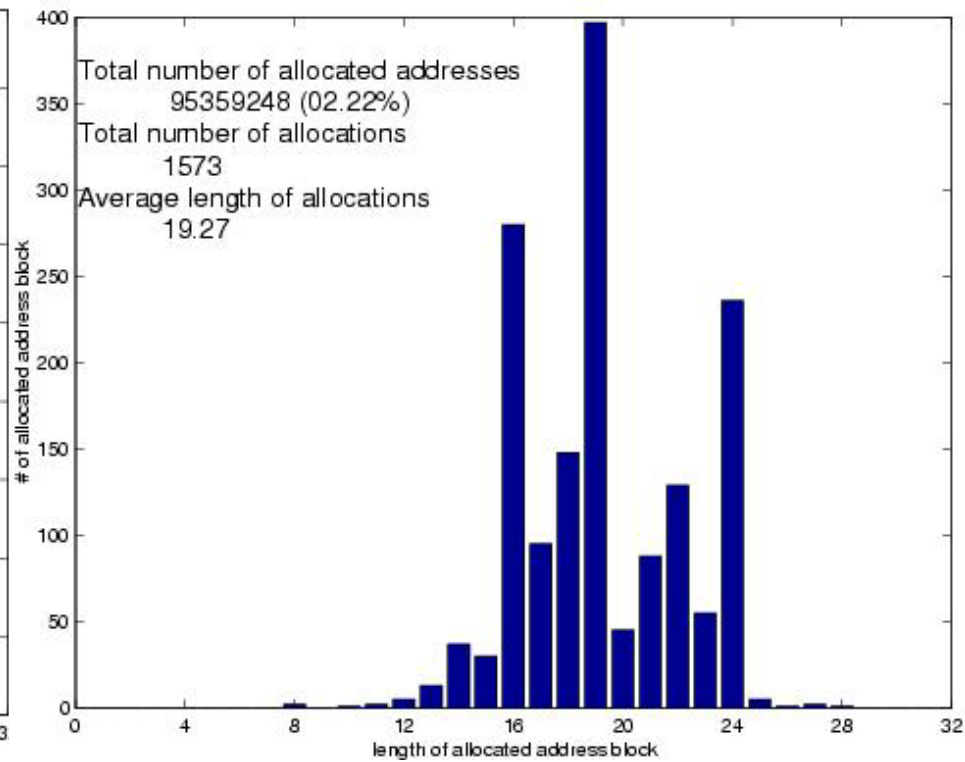   - Study done for allocations and assignments

IPv4 Address Allocation

- In hierarchy fashion
  - Four regional Internet Registries (RIR)
  - ISP, Large enterprises
  - End-Users
- Policy changes
  - Classless Inter-domain Routing (CIDR) (1994-1995)
  - Default allocation size from /19 to /20 (2000)

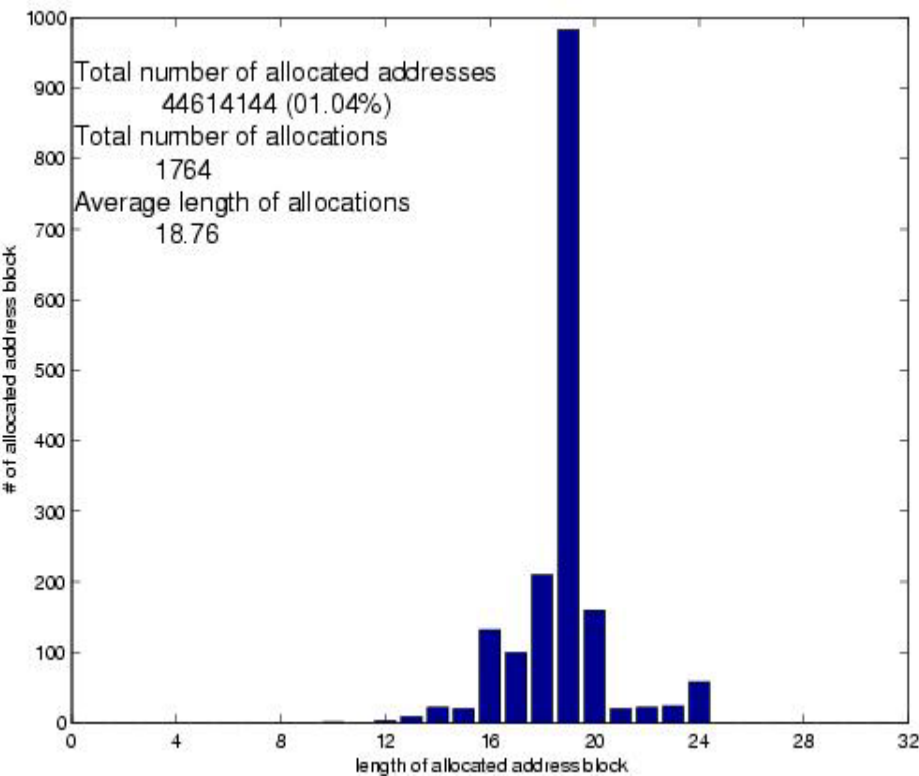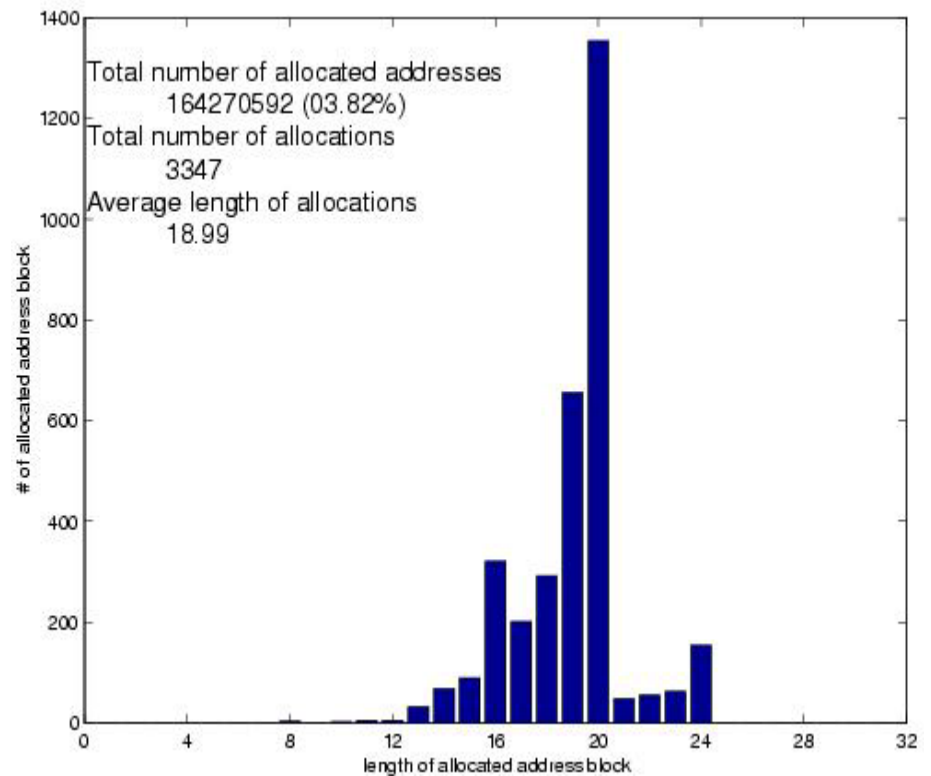# Distribution of Address Allocation (before and after CIDR deployed)

Total number of allocated addresses
925622272 (21.55%)
Total number of allocations
26333
Average length of allocations
21.69

Total number of allocated addresses
95359248 (02.22%)
Total number of allocations
1573
Average length of allocations
19.27

1993

1996

Distribution of Address Allocation (before and after "/19 to /20")

Total number of allocated addresses
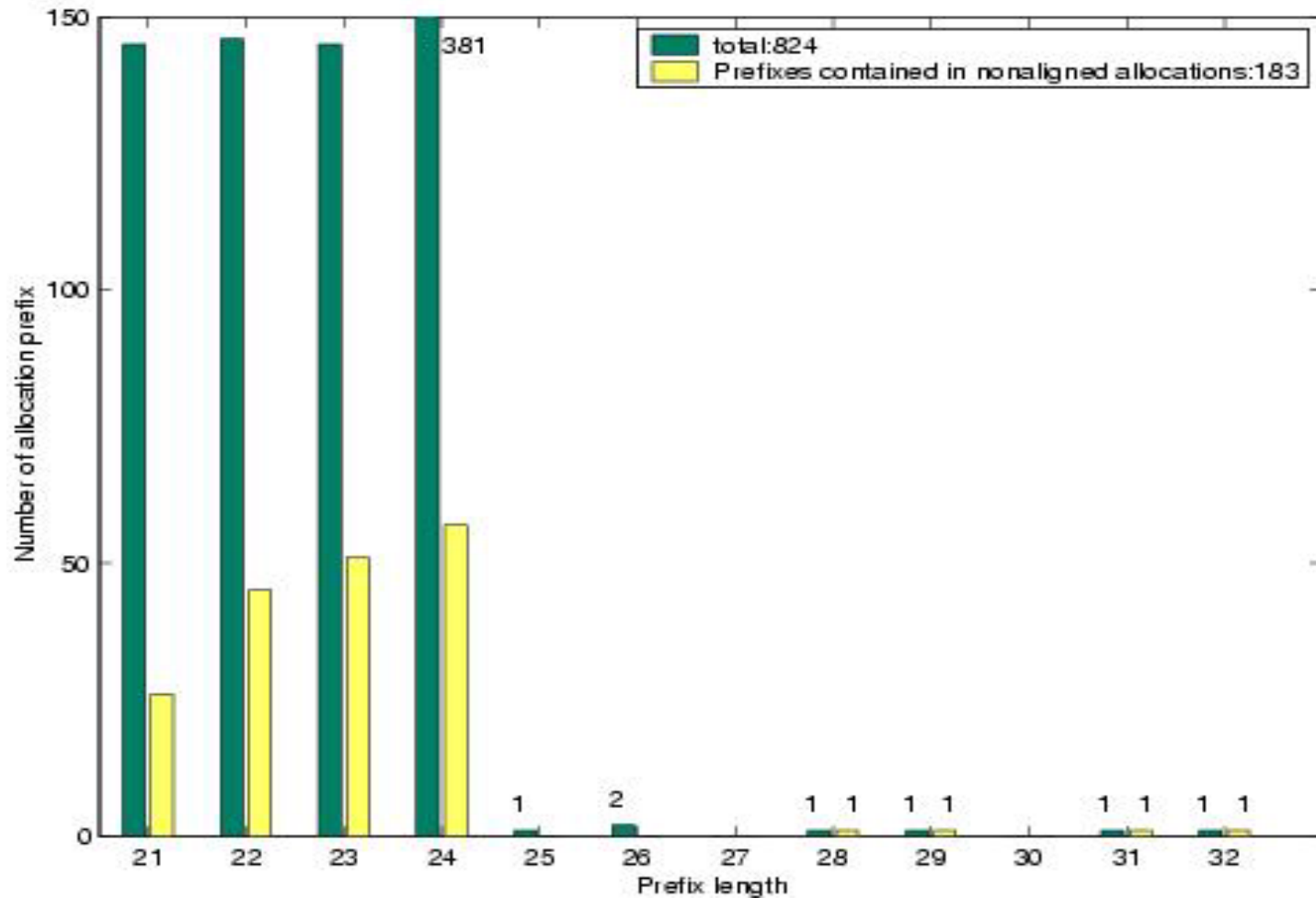44614144 (01.04%)
Total number of allocations
1764
Average length of allocations
18.76

Total number of allocated addresses
164270592 (03.82%)
Total number of allocations
3347
Average length of allocations
18.99

1999   2001

Allocated Blocks Over Time

Allocation Time (Notes: 93 includes all allocated before 93 and 02 is only until Apr. 02)
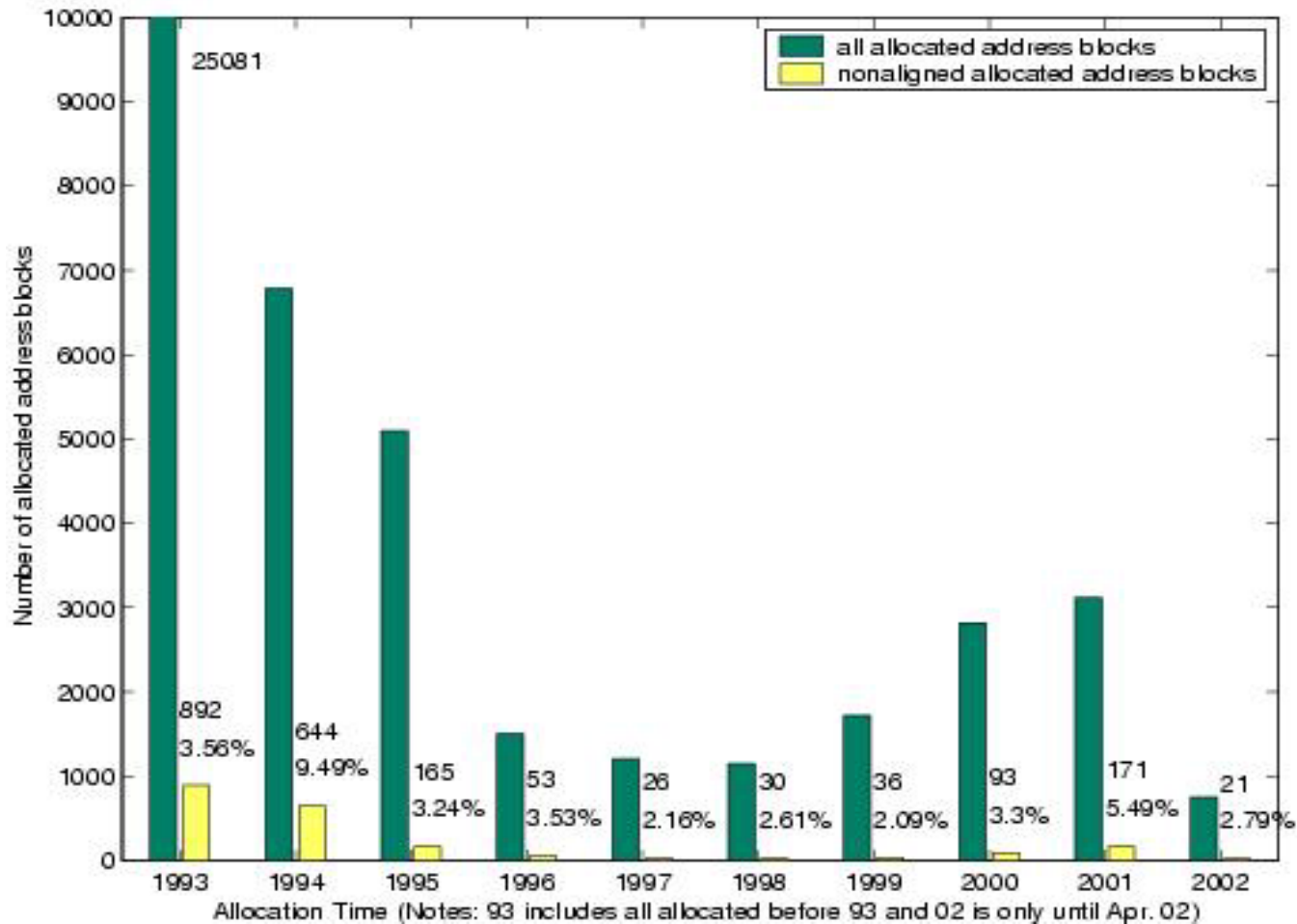
# Small Allocated Blocks (01/01/1998-04/30/2002)

From allocation to routing table: many questions

- How long after allocation does it take for prefixes to appear in the global routing table?
  - How many prefixes have never appeared ?
- How do the prefixes appear?
  - As allocated?
  - Aggregated?
  - Fragmented?
- What's the impact of changing default allocation size from /19 to /20?
- Our study period: 1/1/98 -- 4/30/02
  - total allocated prefixes: 9,554
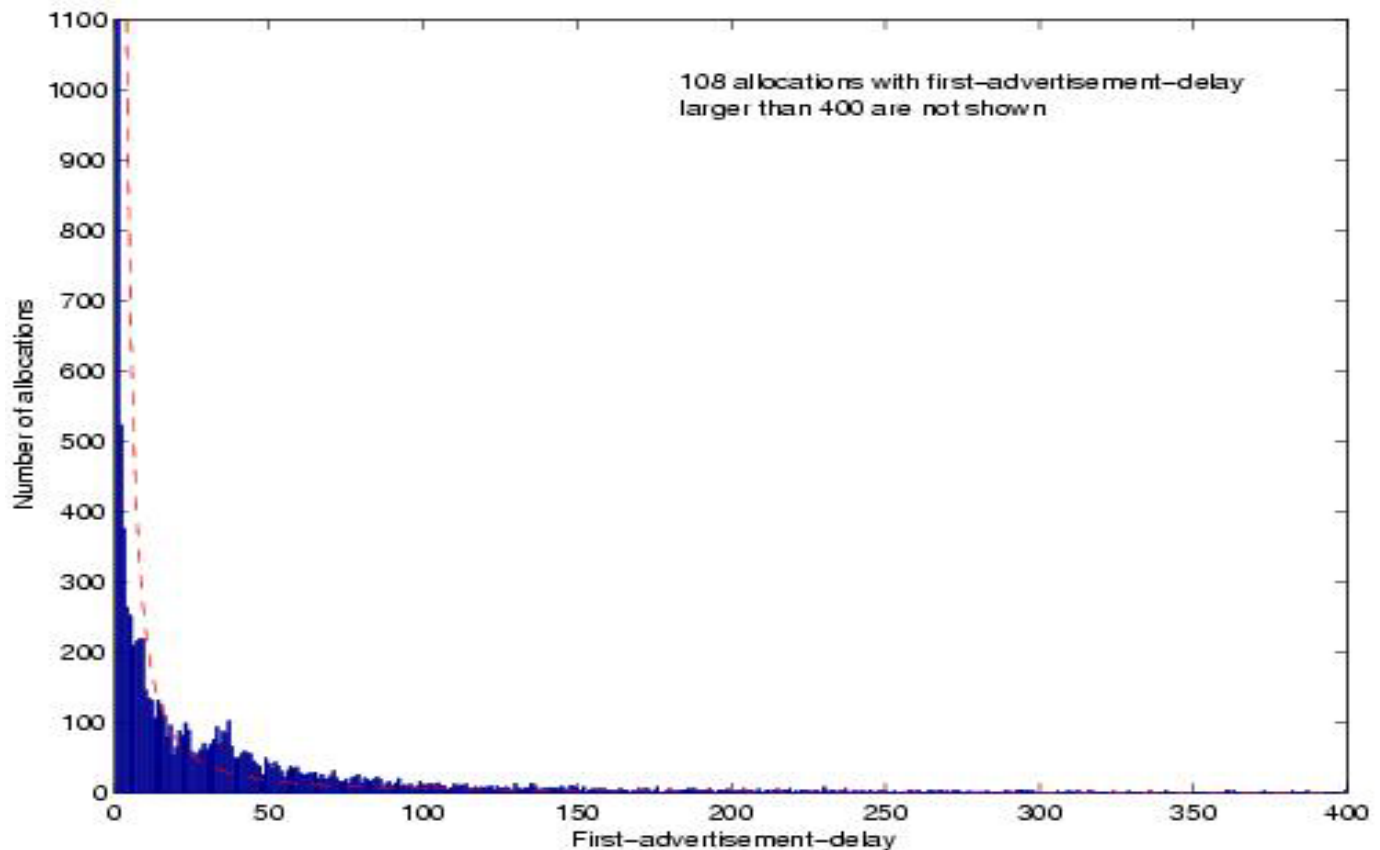
Do All the Allocated Prefixes Appear?
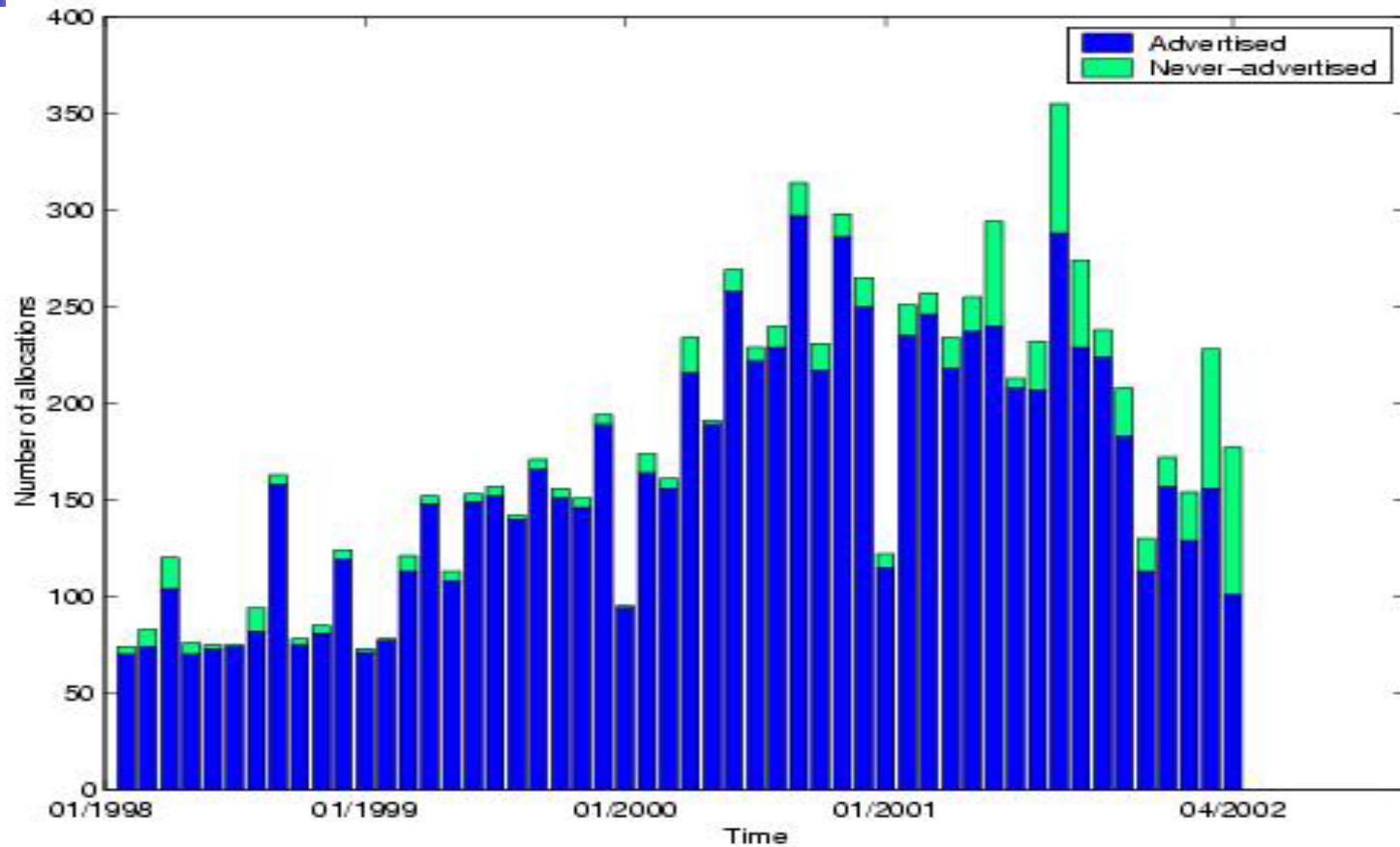
For disappeared prefixes:
How long had they been advertised?

4 years
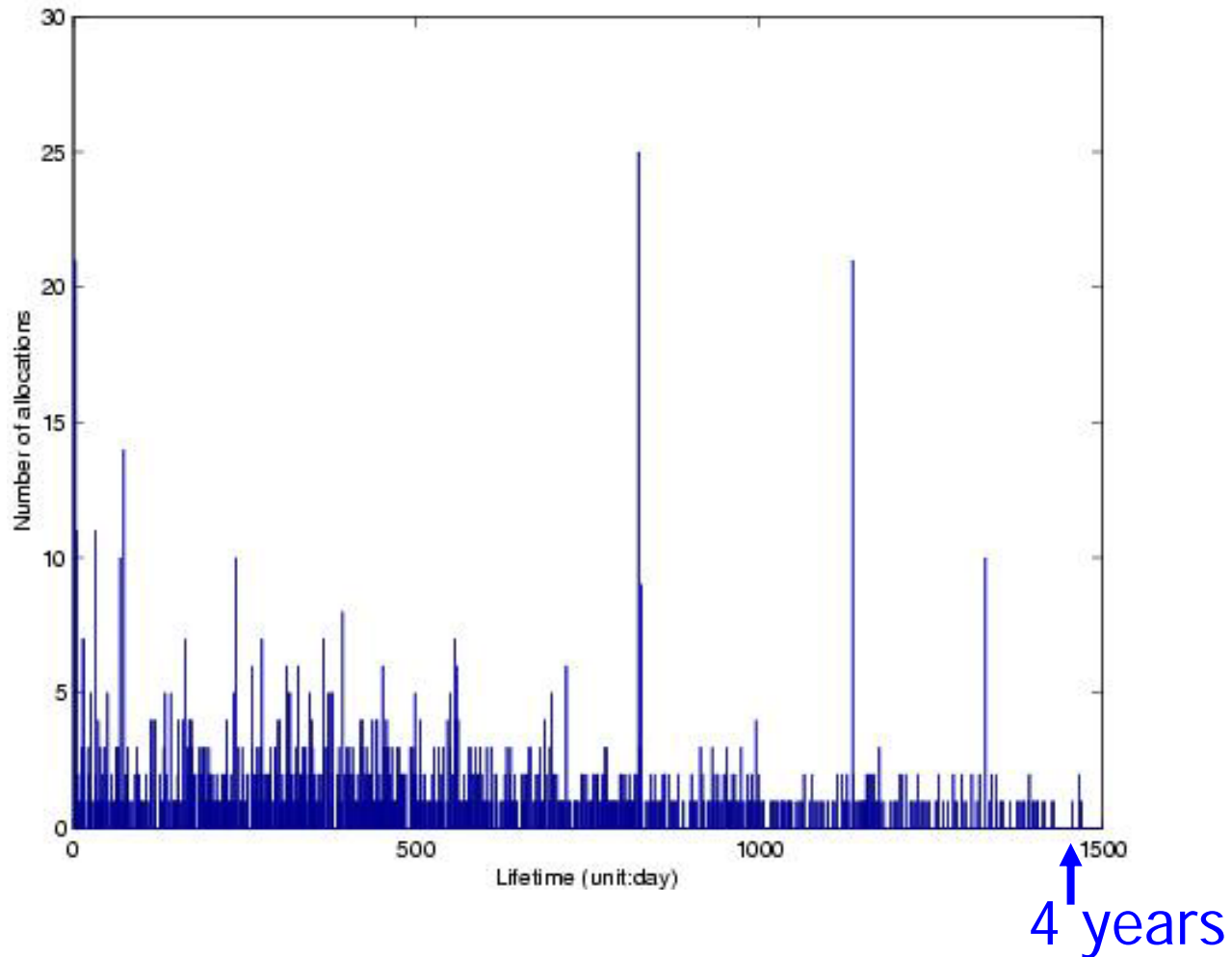
First-Advertised-Delay

The interval between allocation time and the first time the block appears in the routing table

Advertisement modes

- Allocated prefixes announced in routing tables in seven modes
  - Identical
  - Fragmented
  - Aggregated (encouraged by CIDR)
  - Identical + Fragmented
  - Identical + Aggregated
  - Fragmented + Aggregated
  - Identical + Fragmented + Aggregated

Example

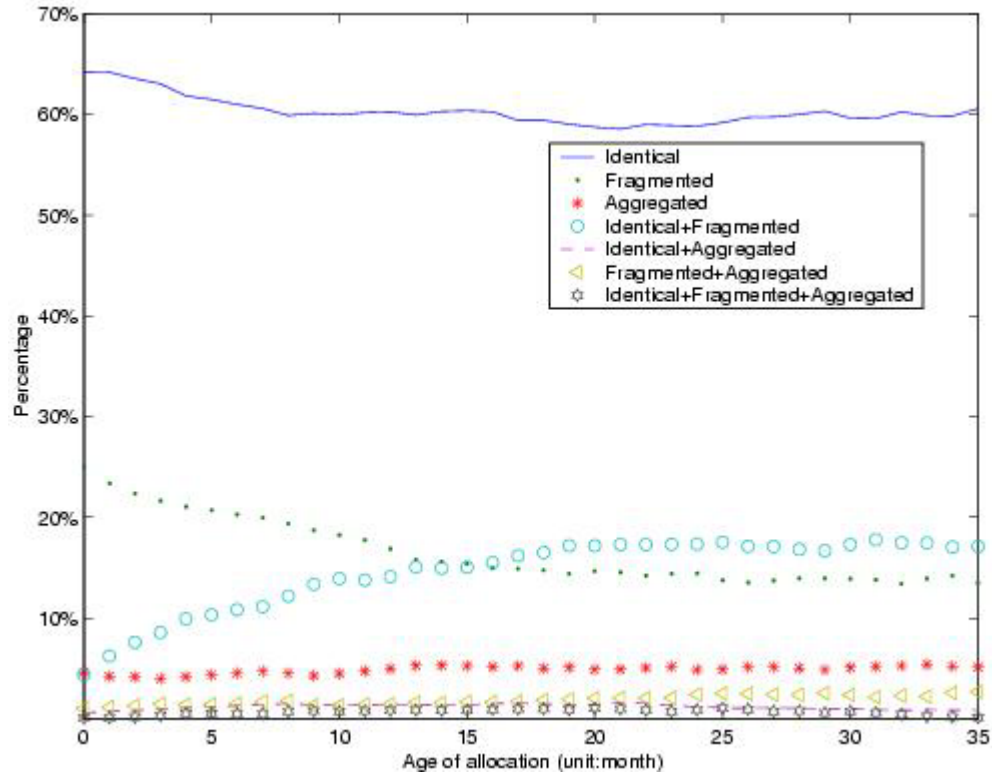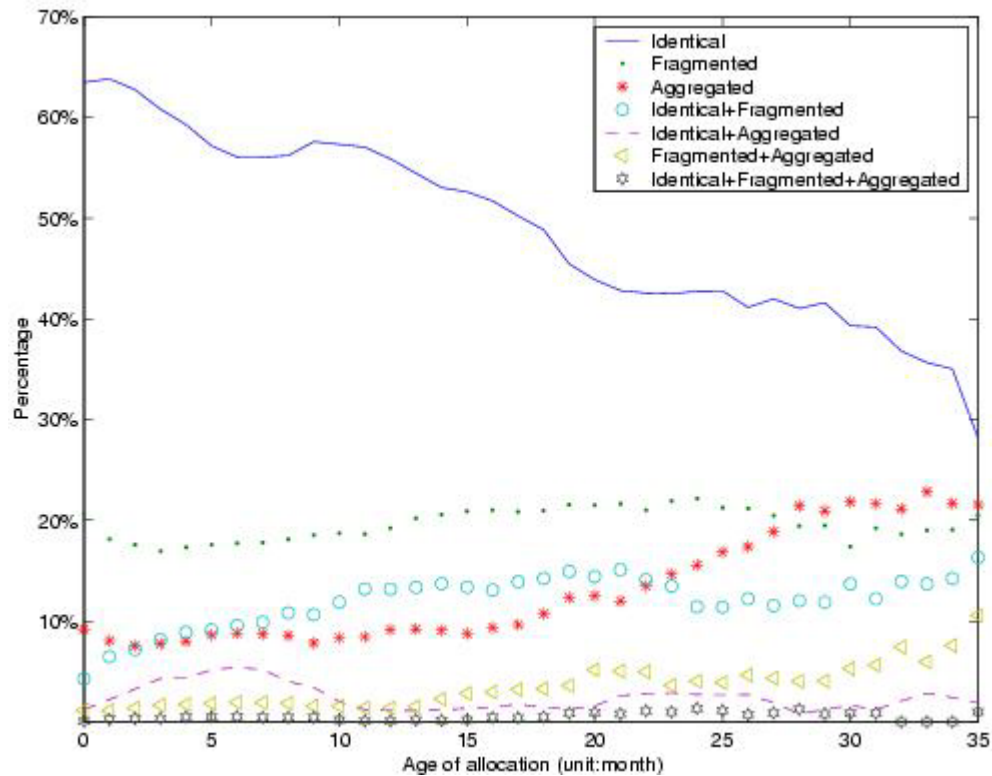|	Allocated blocks		Routing prefix
•Identical	1.1.0.0/16	→	1.1.0.0/16
•Fragmented	1.1.0.0/16	→	1.1.1.0/24 1.1.2.0/24
•Aggregated	1.0.0.0/16 1.1.0.0/16	→	1.2.0.0/15

Advertisement Mode for Allocated Prefixes (/16)
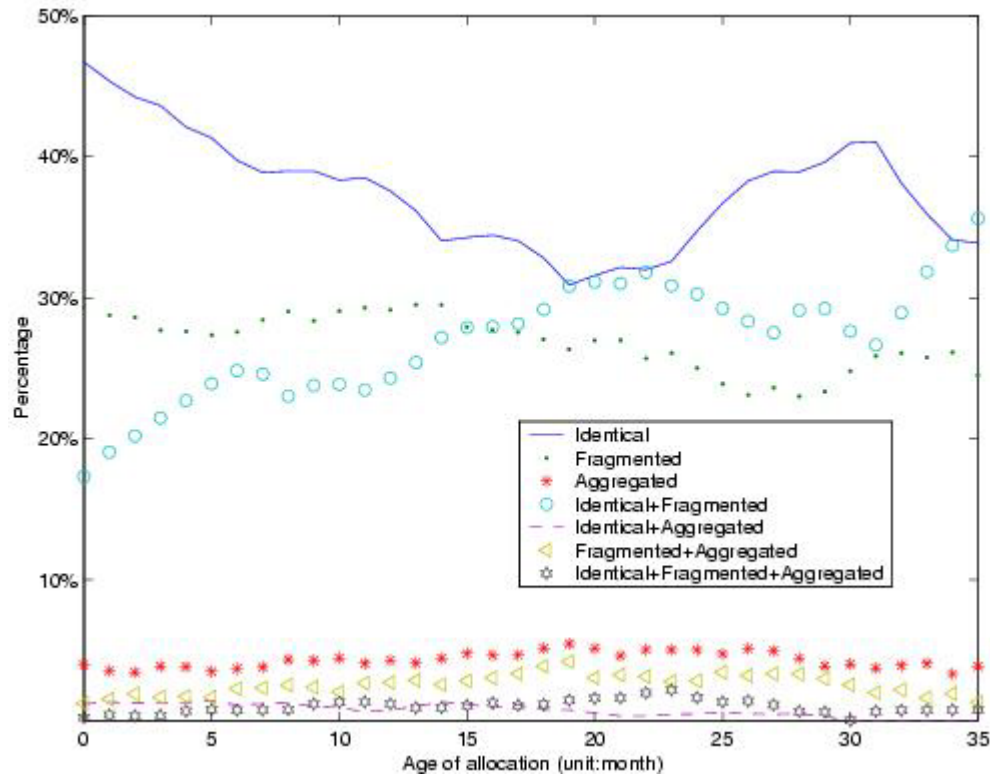
Advertisement Mode for Allocated Prefixes (/19)

Advertisement Mode for Allocated Prefixes (/20)

Advertisement Mode for Allocated Prefixes (all)
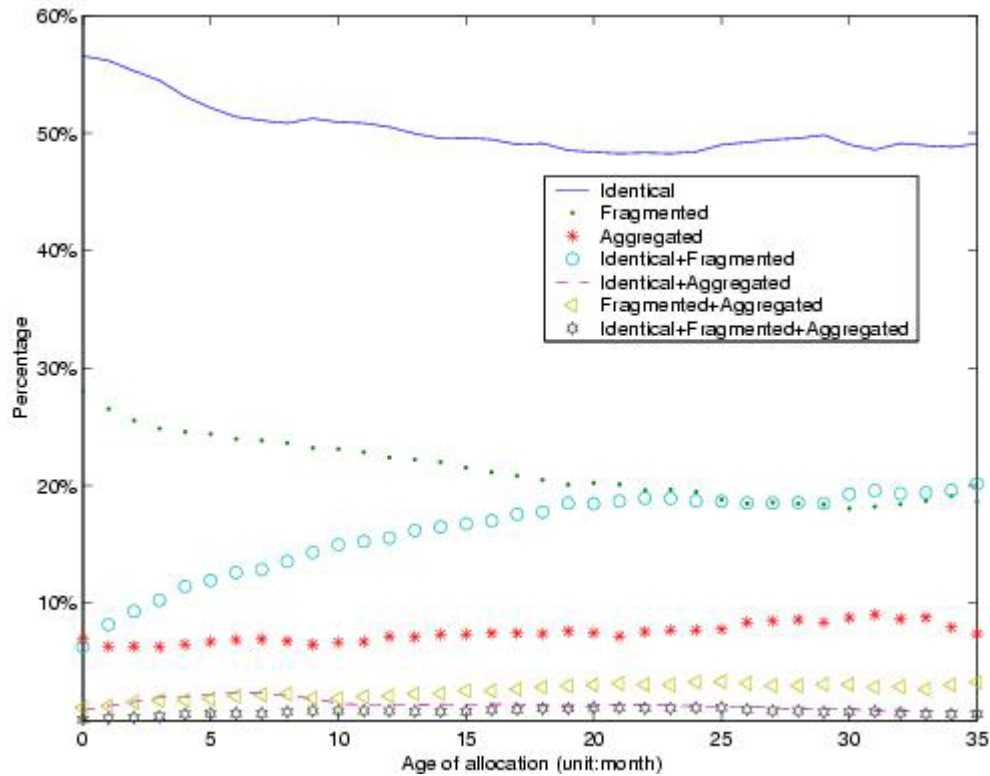
Announced Allocations that are Aggregated into Shorter Prefixes
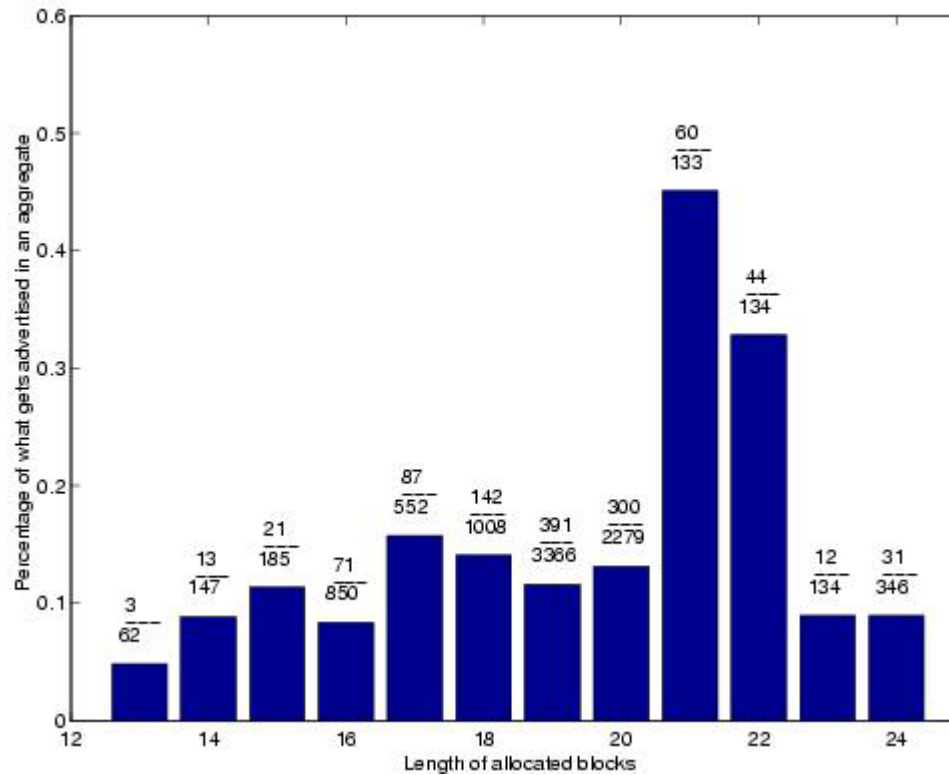
Dynamic Properties of Allocations

		/16	/19	/20	All
Number of allocations		828	3242	2293	8644
first-advertisement-delay (day)		32	48	50	44
Percentage of dead allocations		10%	19%	17%	17%
Average lifetime (day)		416	663	320	515
Persistence	Day	93%	91%	89%	91%
	Month	97%	98%	100%	98%

How many routing prefixes are fragmented from the allocated prefixes?
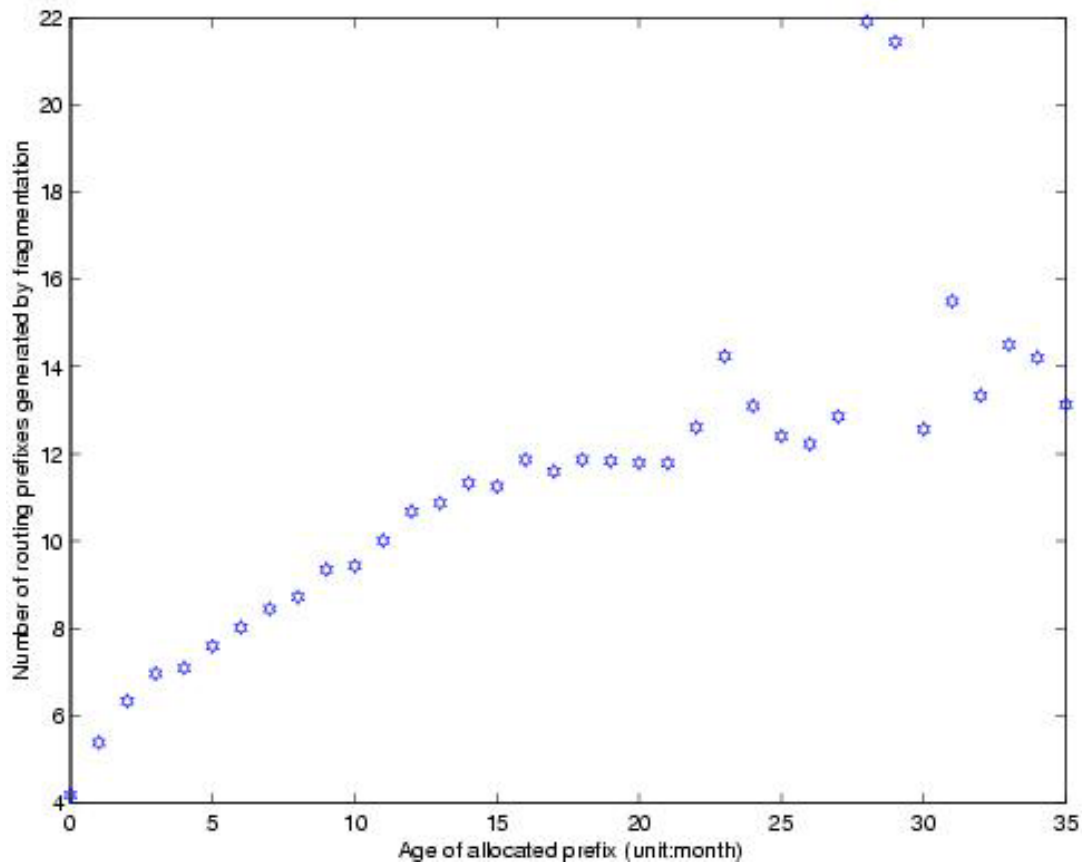
Degree of Aggregation

Allocated blocks   Routing prefix

- Degree = 1   1.1.0.0/16 ⟶ 1.0.0.0/15

- Degree = 2   1.1.0.0/16 ⟶ 1.0.0.0/14

Degree of Aggregation for /21 and /22
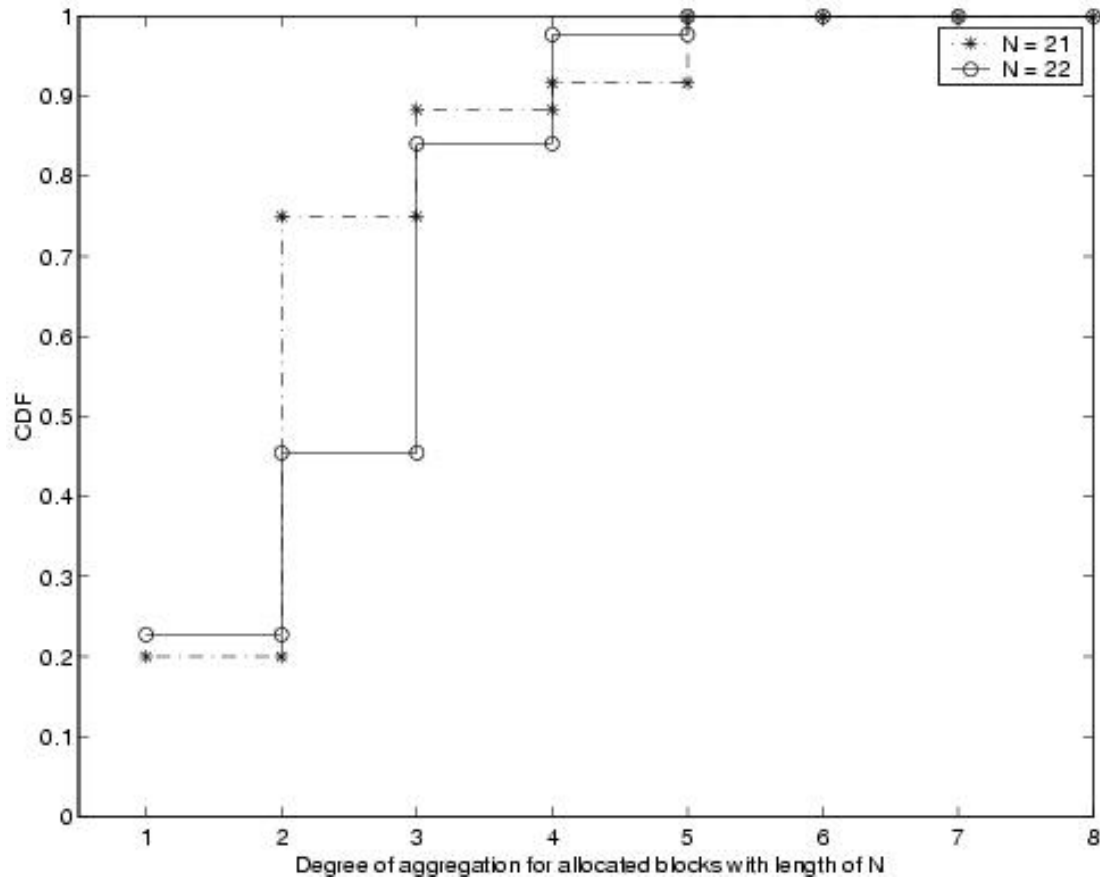
Changes in the Global Routing Table

- Comparing the routing table entries between 1 Jan. 1998 – 31 Dec. 2001
  - How many new prefixes added?
  - How many old prefixes disappeared?
- How much has the size of consumed address space change?
  - An IP address is consumed if it is contained in existing routing prefixes
  - Example
    - |208.51.113.254|3549|3.0.0.0/8|3549 1239 80|IGP|208.51.113.254|0|0|3549:2023 3549:30840|NAG||
    - Address Range 3.0.0.0 – 3.255.255.255; Size 2 ^ (32 – 8)

Routing Table Size vs. Address Consumption
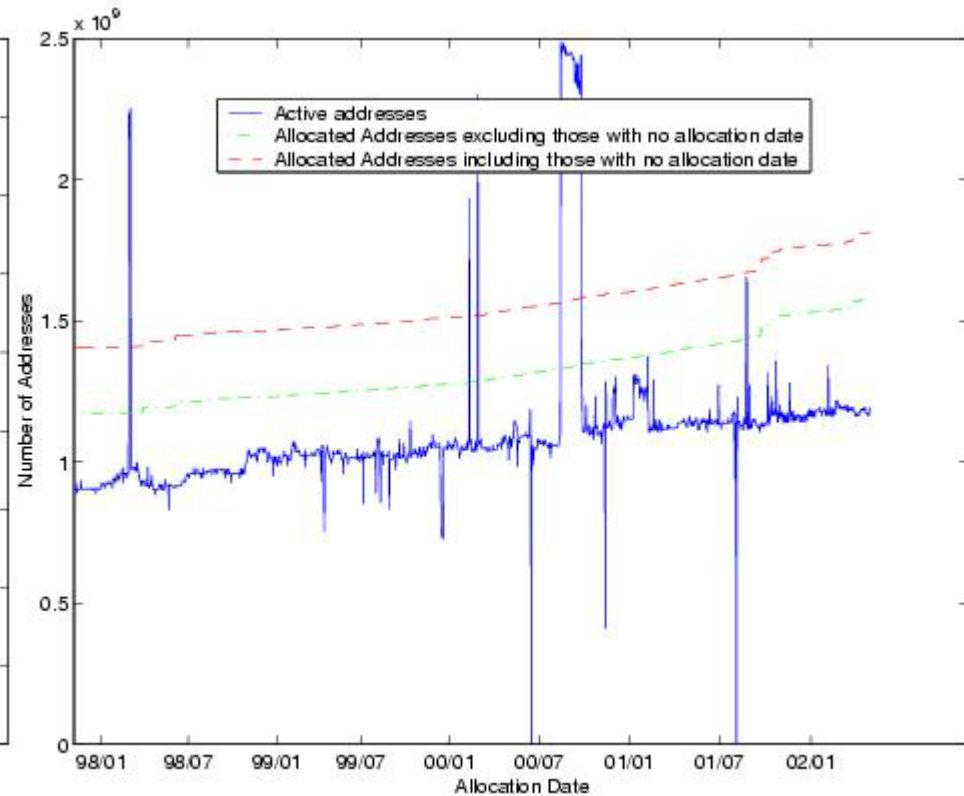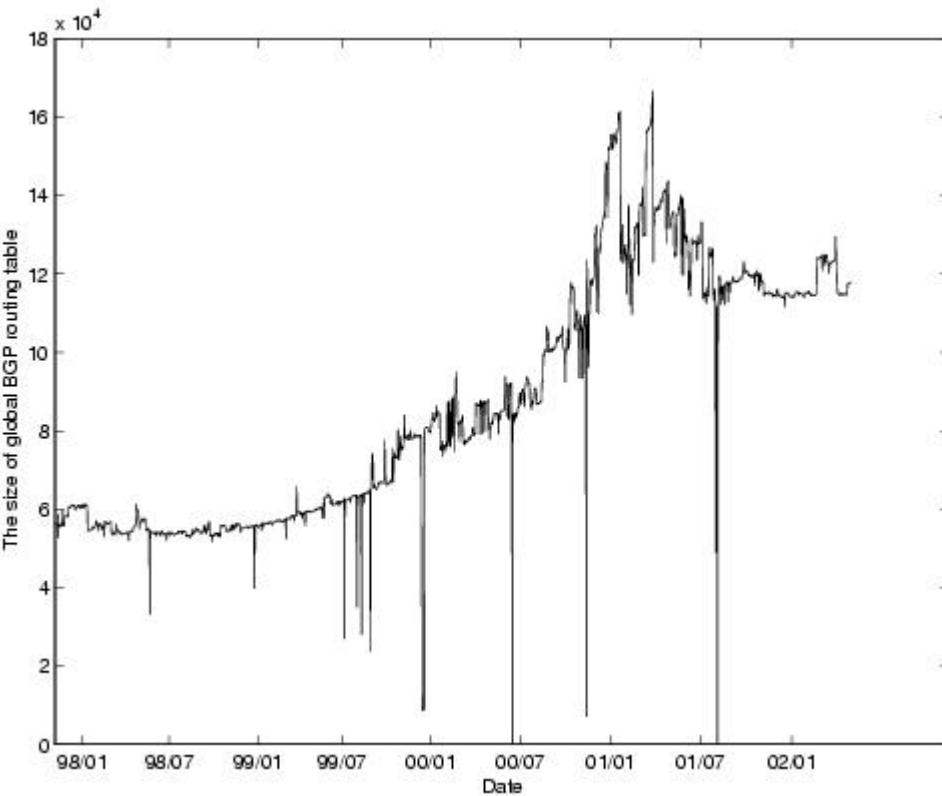
Overall Change (Jan. 98 – Jan.02)

- Routing table size: 53,929 to 114,324
  - Growth: 112%
  - Birth: 87,941 new prefixes
  - Death: 34,012 old prefixes
- Address Consumption: 921,694,960 to 1,163,961,392
  - Growth: 26.3%
  - 35416 new prefixes (40.6% of 87,941) cover existing consumed address space
  - 311 new prefixes originally existed as longer prefixes

Distribution of New Announced Prefixes (total: 87, 941)

Prefix Len	/8	/9	/10	/11	/12	/13
Number	4	4	4	5	23	57

Prefix Len	/14	/15	/16	/17	/18	/19
Number	128	249	1959	1107	1942	5694

Prefix Len	/20	/21	/22	/23	/24	/25
Number	5461	3816	6106	7635	50917	582

Prefix Len	/26	/27	/28	/29	/30	/32
Number	784	335	279	229	436	155

Distribution of Disappeared Prefixes (total:34,012)

Prefix Len	/8	/9	/10	/11	/12	/13
Number	6	1	2	4	7	8

Prefix Len	/14	/15	/16	/17	/18	/19
Number	34	55	1095	117	279	704

Prefix Len	/20	/21	/22	/23	/24	/25
Number	753	1050	1668	2635	22166	53

Prefix Len	/26	/27	/28	/29	/30	/32
Number	67	89	66	17	2832	304

Where do the new advertisements come from?

- Total number: 87,941
- Relationship with allocations
  - Fragments of larger allocations (88.4%)
  - Allocations of equal size (10.0%)
  - Aggregation of multiple smaller allocations (0.7%)
  - Others. (No matched allocation records)

Where do the new advertisements come from? (cont.)

- ## Allocation Time

Allocation Time	before 93	94	95	96	97	98
Numbers	10117	7405	7290	8139	4109	5316
Allocation Time	99	00	01	02	No Time Info	
Numbers	10670	14257	10363	3248	5659	

Table 3. Distribution of newly-appeared prefixes in terms of the time when the matched allocations are made

- ## Geographic location

Allocation Country	US	AU	FR	CA	DE
Numbers	49446	3913	3907	3264	1937

Table 4. Distribution of newly-appeared prefixes in terms of the country to which the matched allocations are made

Where the prefixes went

- Get aggregated into shorter prefixes. (the largest slice) (77.0%);
- Get further fragmented into multiple longer prefixes (1.8%);
- Fully disappear with its address space (19.1%);
- Others:
  - Its address space gets partially covered by several existing longer prefixes

Impact on Address Consumption

- Disappeared prefixes do not necessarily represent address consumption:
  - Total number of addresses covered by these prefixes: 241,051,955
  - The number of addresses that really drop off: 131,937,044

Observations

- New allocations playing a dominant role in the global routing table:
    - Out of allocations made since Jan'98, over 80% have been advertised by Apr. 2002;
    - Out of allocations made before 1996, over 60% have no longer been advertised by Apr. 2002;
- The new advertisements tend to bring in more fragments while the disappeared tend to take away fragments. What's the trend?
- /24's still make up 56.1% of the routing table, are the fastest growing prefixes by absolute count but not percentage wise.

What Next?

- What other questions should we be answering?
- Comments? Questions?