On the Effectiveness of Distributed Worm Monitoring

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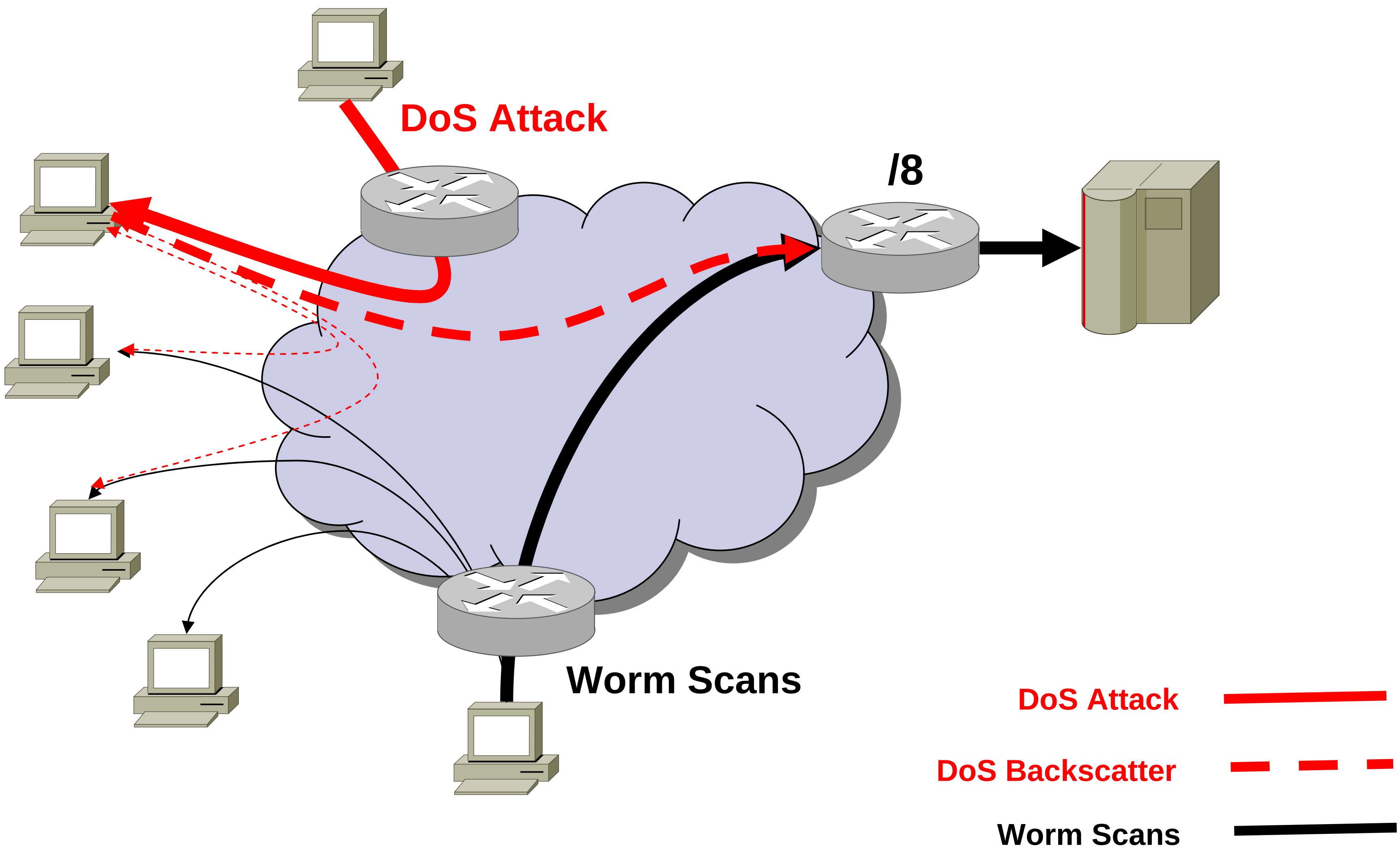
Monitoring Internet Threats

- Threat monitoring techniques:
  - Intrusion detection systems monitoring active networks
  - Monitoring routable unused IP space [Moore et al, 2002]
- Monitoring unused address space is attractive
  - No legitimate traffic
  - Forensic analysis and early warning
- CAIDA deployed the first /8 telescope

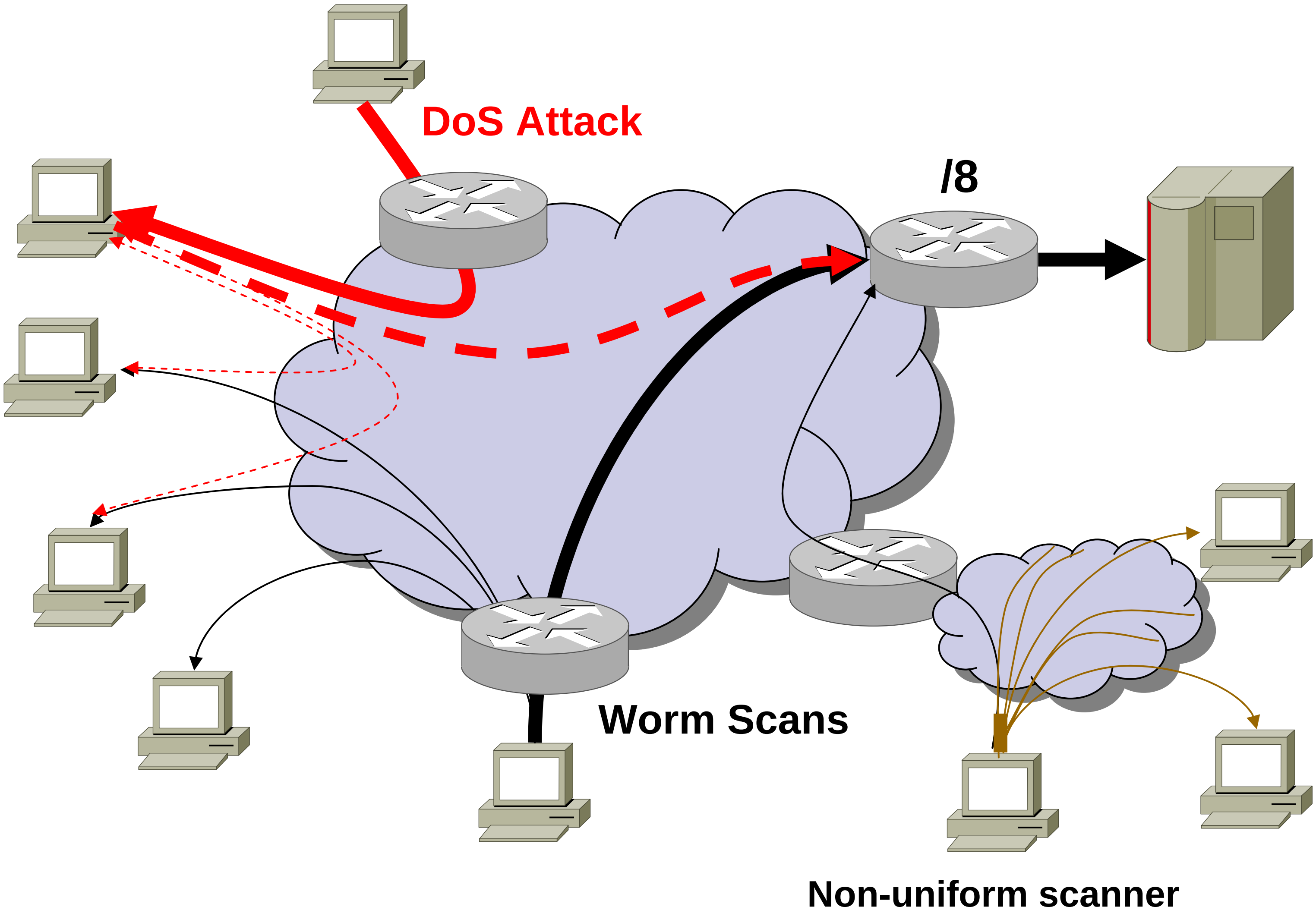
Single Monitor Case



Size Matters!

- Size of the monitor is an important factor in providing an accurate view of a worm breakout [Moore et al, 2002]
- But there are several other factors yet to be explored

Single monitor view is too limited



Goals

- Provide a model to evaluate the performance of distributed monitoring systems in terms of:
  - Number of monitors?
  - Sizes of monitors and the overall IP space requirements?
- Provide guidelines for better design and monitor deployment practices.

Outline

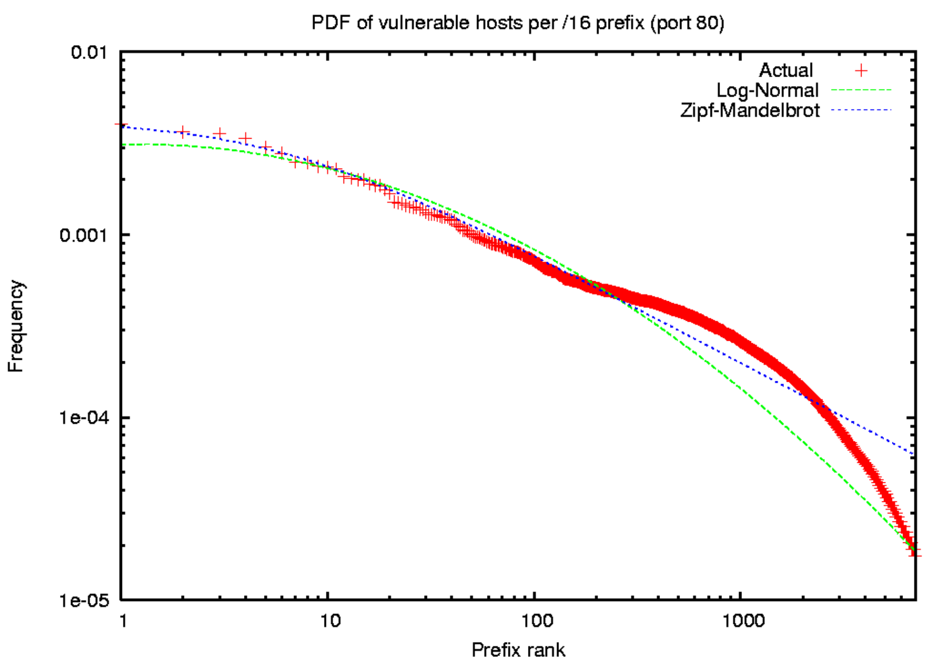
- Problem and Motivation
- A Worm Propagation Model
  - Population Distribution
  - Extended worm model
- Distributed Worm Monitoring
  - Distributed Telescope Model
  - Design parameters
- Summary

Why another worm model?

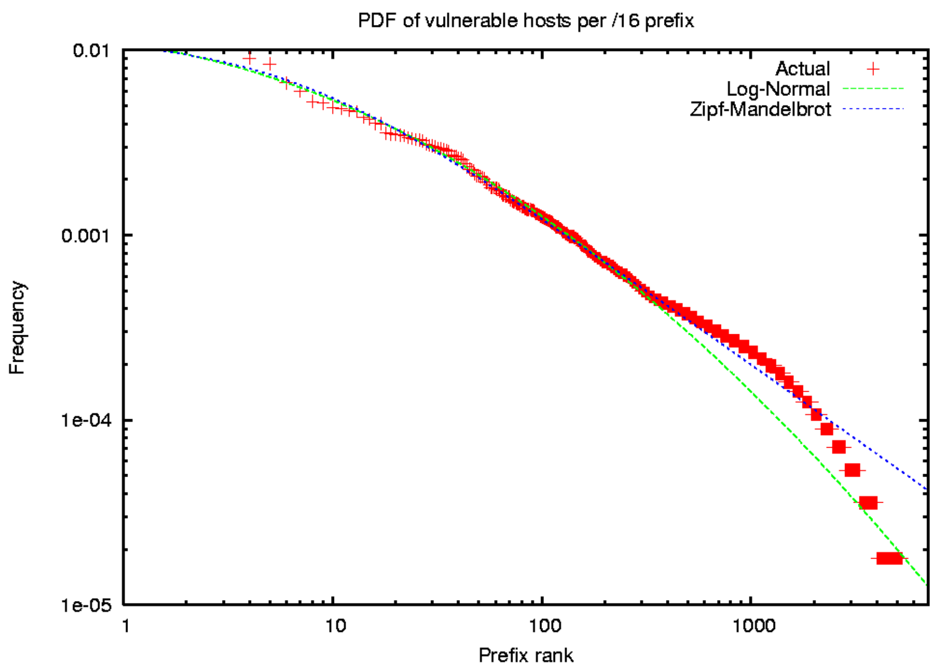
- Previous worm models assumed that the vulnerable population is uniformly distributed over the whole IP space.

- Sources of non-uniformity in population distribution
  - Un-allocated address space
  - Highly-clustered allocated space
  - Usage of the allocated space

Population distribution



DShield dataset



CAIDA's dataset (Witty Worm)

The distribution of Vulnerable population over the IP space is far from uniform
Best fits a Log-normal distribution

Extended Worm Propagation Model

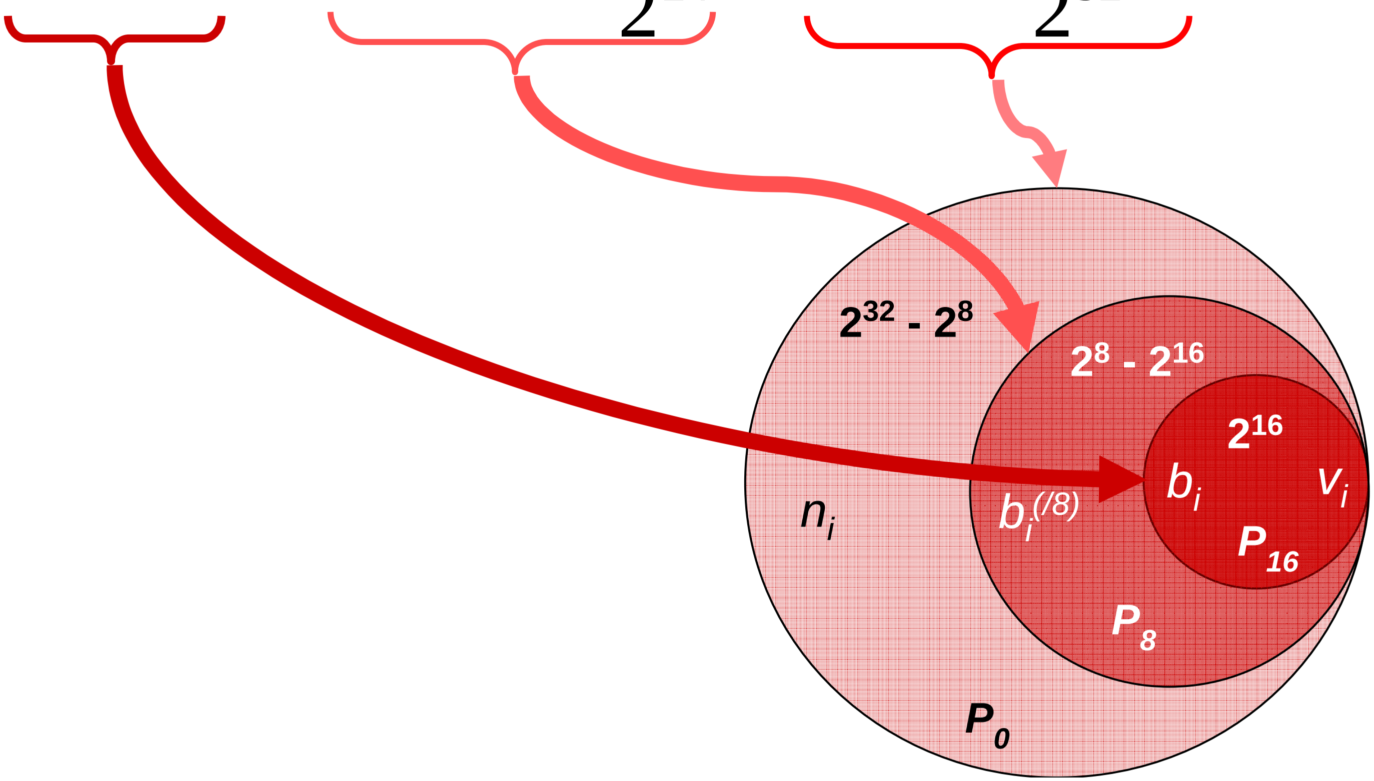
- Worm propagation models must incorporate population density distribution.

- Especially Non-uniform scanning worms:
  - Probability of scanning a host depends on its location relative to the infected scanner

Non-uniform worm propagation model

- Expected number of scans per /16 subnet

$$k_i^j = p_{16}\, s\, b_i^j + p_8\, s\, b_i^{(/8)} \frac{2^{16}}{2^{24}} + p_0\, s\, n_i \frac{2^{16}}{2^{32}}$$



Non-uniform worm propagation model

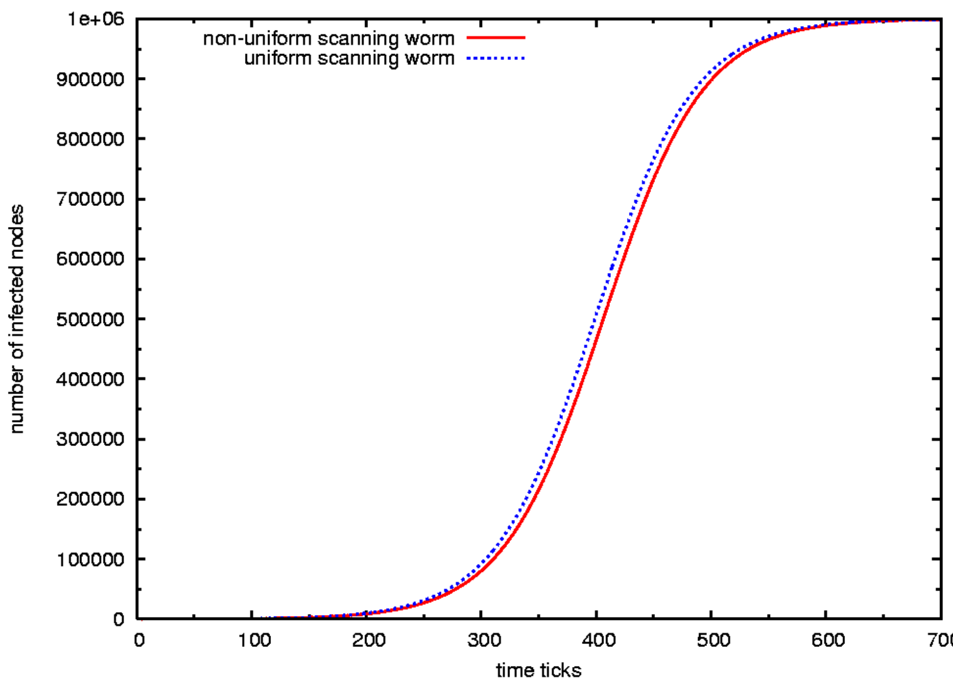
- The expected number of infected hosts per /16 subnet (AAWP Model [*Chen et al,2003*])

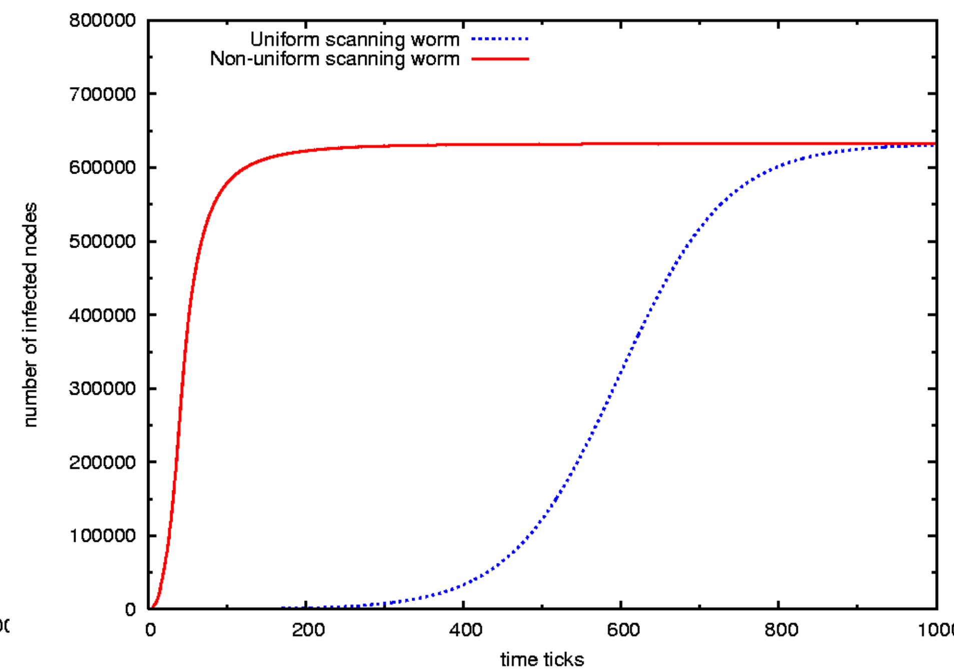
$$b_{i+1}^{j} = b_i^{j} + \underbrace{(v_i - b_i^{j})}_{\text{Vulnerable non- infected hosts}} \left[1 - \left(1 - \frac{1}{2^{16}} \right)^{k_i^{j}} \right]$$

- The expected total infection

$$n_{i+1} = \sum_{j=1}^{2^{16}} b_i^{j}$$

Impact of population distribution





Number of Infected hosts vs time, for a Nimda-like worm

s= 100 scans/time tick, $P_{16}= 0.5$, $P_8=0.25$, $P_0 = 0.25$

$N= 10^6$ hosts uniformly distributed Over the IP space

N= 620,000 hosts extracted from DShield data set

Outline

- Problem and Motivation
- Better Worm Model
  - Population Distribution
  - Extended worm model
- Distributed Worm Monitoring
  - Distributed monitoring system model
  - Design parameters
- Summary

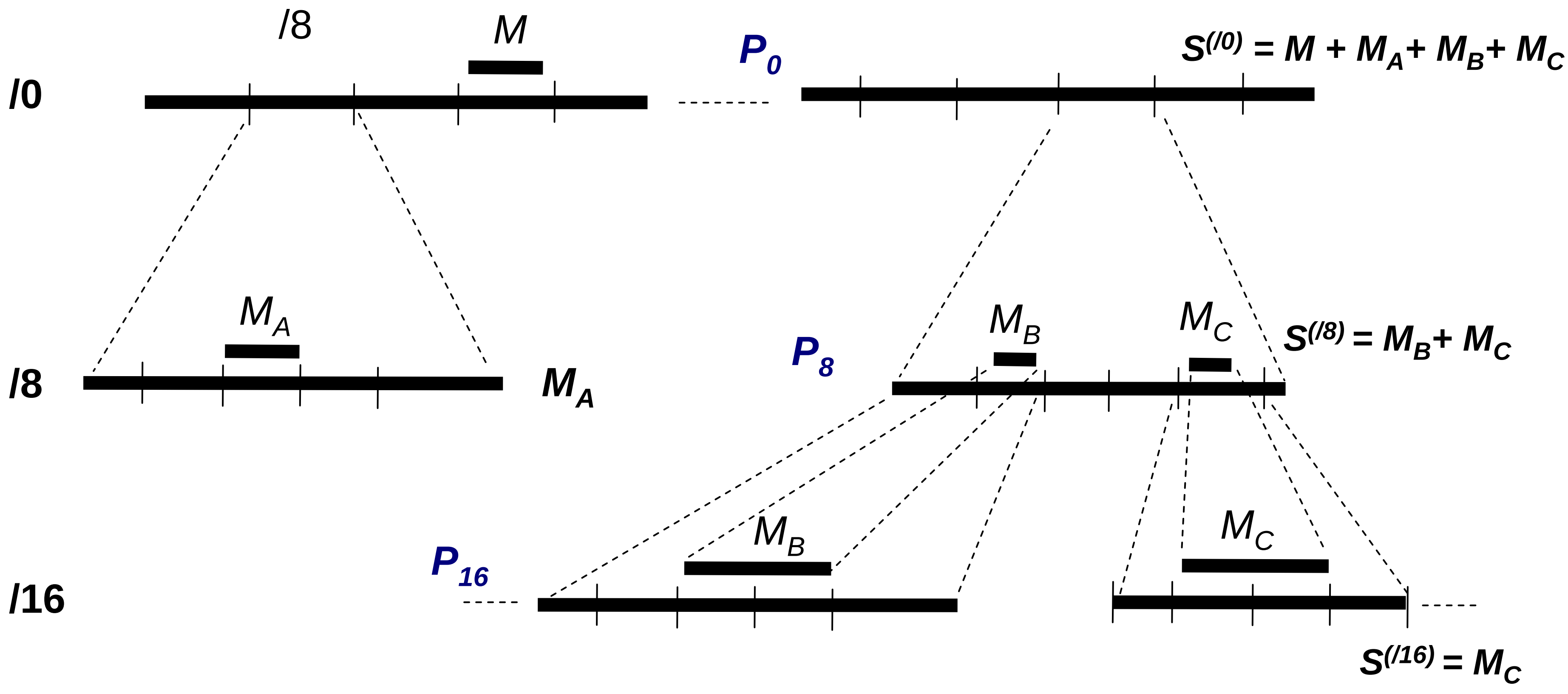
Using the Model--- Distributed Monitoring:

- What do we want to evaluate?
  - System detection time: the time it takes the monitoring system to detect (with particular confidence) a new scanner.

Assumptions

- Single scan detection
- Information sharing and aggregation infrastructure among all monitors.

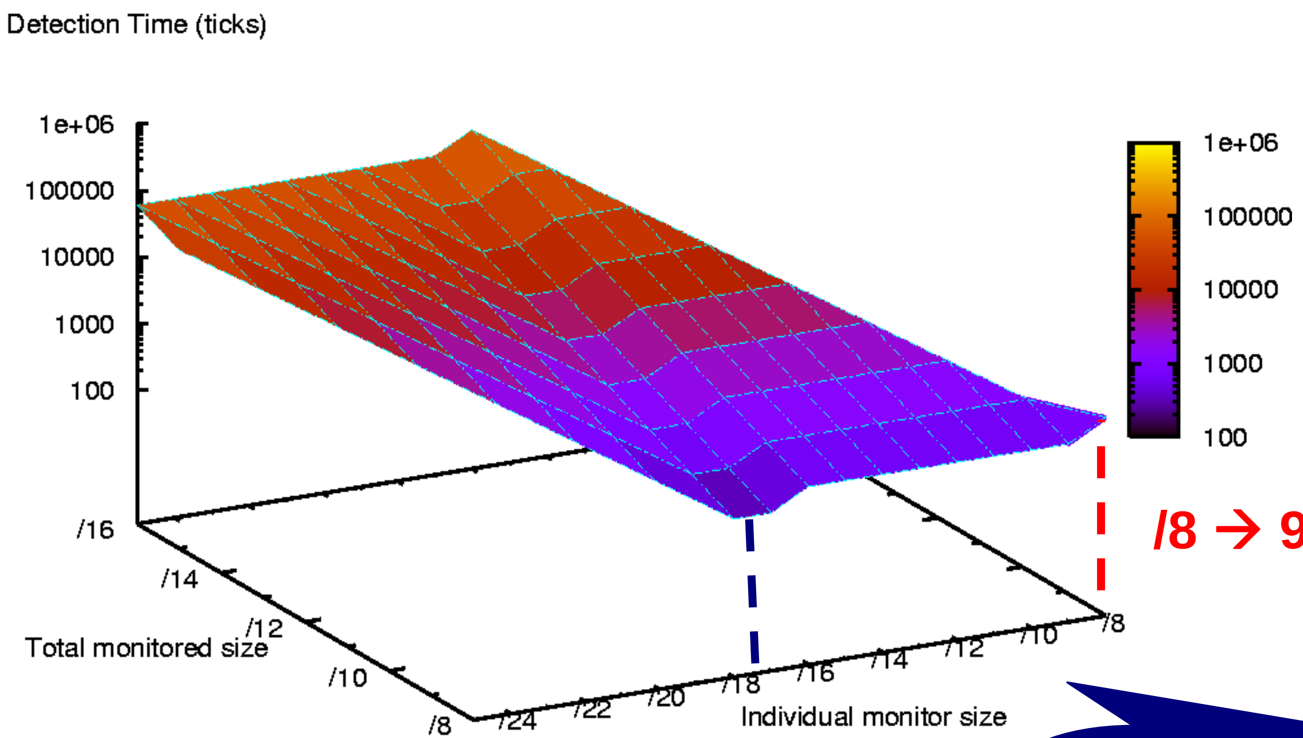
Monitors Logical Hierarchy



Evaluation

- Nimda-like scanner
- Three Monitor deployment scenarios:
  - Random monitor deployment
  - Full knowledge of population distribution
  - Partial population knowledge

Evaluation (Random monitor placement)



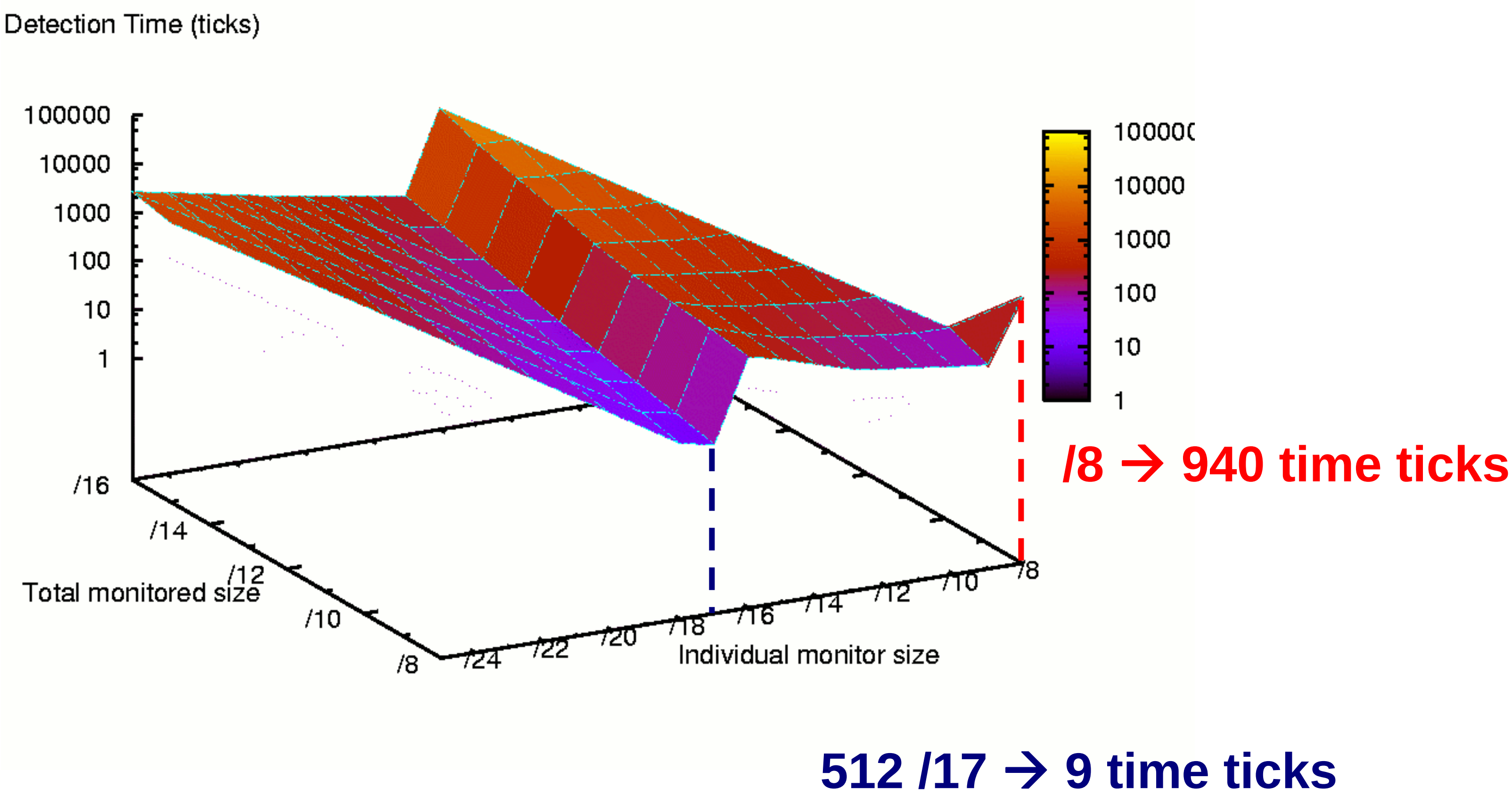
/8 → 940 time ticks

512 /17 → 230 time ticks

with only 40 hosts per /16, 7100 more scans will cause infecting 2 victims before being detected

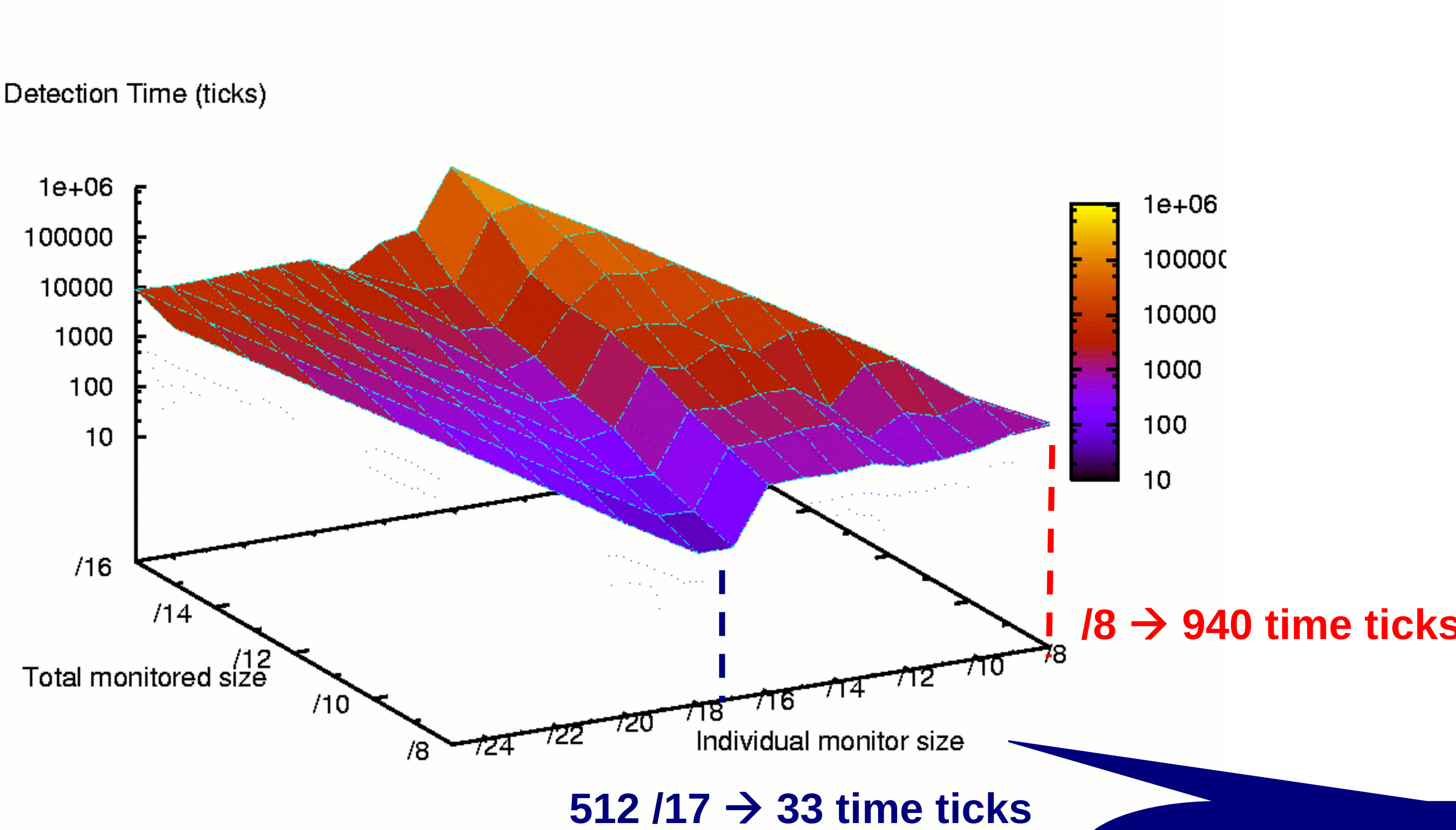
Random Monitor placement
P_r= 0.999, s= 10 scans/time tick
Nimda-like scanning

Evaluation (Full vulnerable distribution knowledge)



Monitors deployed in top populated prefixes

Evaluation (Partial Knowledge)



Monitors deployed randomly over the 5000 most populated /16 prefixes (contain 90% of the vulnerable population)

Example: 512 monitors with 2048 IP addresses/monitor → 160 time ticks

Practical Considerations

- Monitors will be deployed at different administrative domains.
- How many domains are needed to deploy these 512 monitors?
- Mapping the monitors to AS space, only 130 AS's among the top address space owners are required to achieve detection time of 160 time ticks

Summary

- Population distribution has a profound impact on worm propagation speed.
- Distributed Monitoring provides an improved detection time (three times faster than a single monitor of equivalent size).
- Even partial knowledge of the population distribution can improve detection time by roughly 30 times.
- Effective distributed monitoring is possible with cooperation among top address space owners.

Questions?