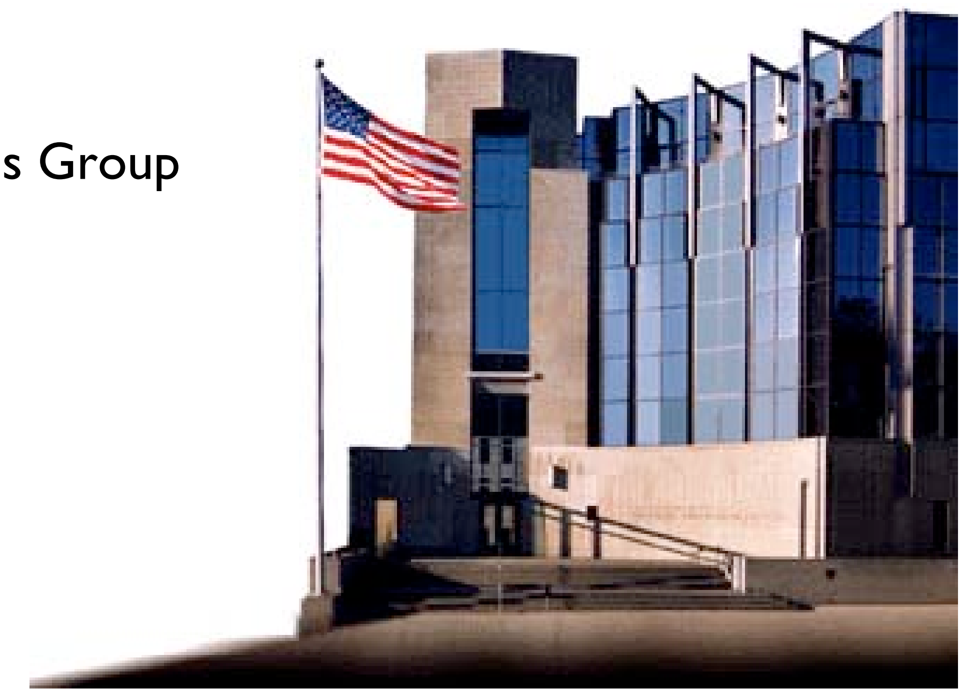
Carnegie Mellon
Software Engineering Institute

CERT
Situational
Awareness

Preparing RIR Allocation Data for Network Security Analysis Tasks

Brian Trammell <bht@cert.org>

for NANOG 31, San Francisco, May 23-25, 2004



CERT® Network Situational Awareness Group
Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213-3890

The CERT Network Situational Awareness Group is part of the Software Engineering Institute. The Software Engineering Institute is sponsored by the U.S. Department of Defense.

Background

- Actors in incident and traffic analysis data are expressed by IP address.
- Analysis operations categorize events at higher levels of abstraction:
  - by location
  - by organization
  - by network
- Correlation of incident and traffic analysis data with regional registry allocation data bridges the gap.

Requirements

- Group addresses into CIDR blocks.
- Provide network names, country codes, and POC handles for each block.
- Provide a tree view of IPv4 address space.
  - allows association of an address with a network at any level of allocation or assignment
  - we are not yet interested in IPv6 because we receive no incident or traffic data from IPv6 networks.
- Run periodically, require little operational support.
  - used for batch analysis
  - e.g., RIPE database mirror would be overkill

Data Sources

- Data from three RIRs:
  - ARIN (bulk data by request)
  - RIPE (publicly-available ripe.db.inetnum)
  - APNIC (publicly-available apnic.db.inetnum)
- 2,061,995 ranges (2,123,270 CIDR blocks) from these three sources (as of May 5, 2004)
- What about LACNIC?
  - LACNIC data omitted from counts pending bulk data request.

Assumptions and Anomalies

- Early in the effort, we assumed that…
  - the allocation tree is strictly a tree.
  - the registries agree on all allocations.
  - allocations and assignments are universally done in terms of CIDR blocks.
  - supplementary information (e.g., modification dates) are stored in a universally uniform format.
- >99.3% of ranges conform to these assumptions

Transformations

- Our tool chain ("AddrTree") was designed to process allocation data from the RIRs for use in categorizing actors in incident and traffic data.
- AddrTree performs the following transformations:
  - Normalization of modification dates.
  - Elimination of redirect records.
  - Resolution of conflicts between regional registries.
  - Arrangement of allocations and assignments into a single tree structure.
  - Detection of anomalies in address ranges:
    - "Erosions" – off-by-one errors in allocation range ends.
    - "Inversions" – violations of tree hierarchy.
  - Splitting of allocation ranges into CIDR blocks.

Step 1: Parsing and Stripping

- Extracts essential information from registry text databases and transforms it into a compact, line-oriented text format
- Normalizes modification dates to ISO8601
  - Two-digit years (2,566)
  - YYYYDDMM date format (7)
    - only unambiguous instances of this anomaly can be detected.
  - Dates beyond end of month (4)
- Eliminates non-network (redirect) records (1,692)

Step 2: Merging

- Merges allocations between two registries into a single tree
  - Applied in stages to build a “world” allocation tree
- Detects and resolves conflicts between registries
  - most of these are early registrations
  - first by national affiliation (2,580)
    - the RIR with responsibility for the network’s country is probably more correct
  - then by registry seniority (3)
    - arbitrary, but avoids human intervention

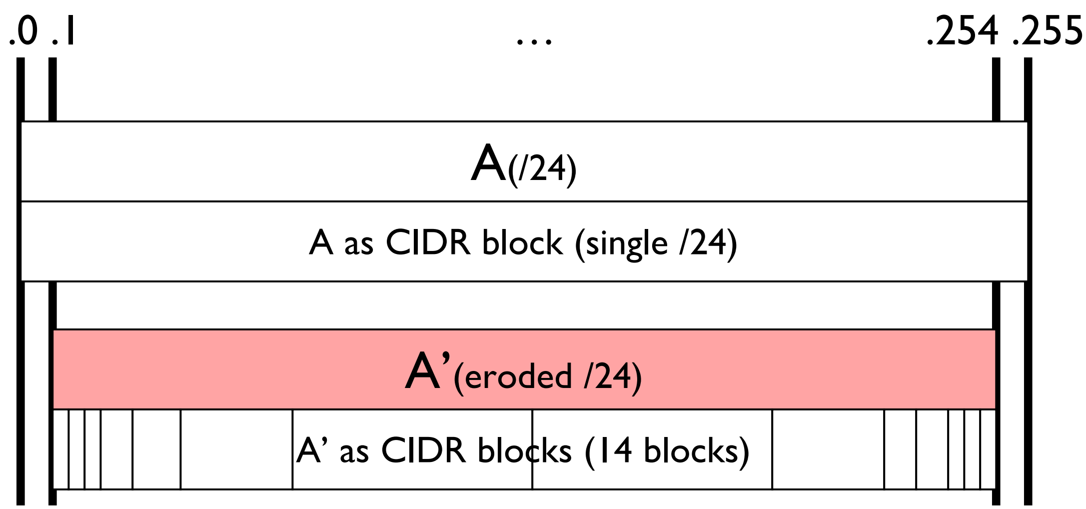
Step 3: Stacking and Splitting

- Range “erosions” are corrected before stacking.
- Stacking notes each record’s depth in the tree – necessary to maintain hierarchy of ranges after each range is split into CIDR blocks.
- Range “inversions” are detected during stacking.
- Each range record is replaced with one range per CIDR block covered by the record.
  - Growth in number of records is small.
  - > 99.98% of allocation ranges are a single block wide.

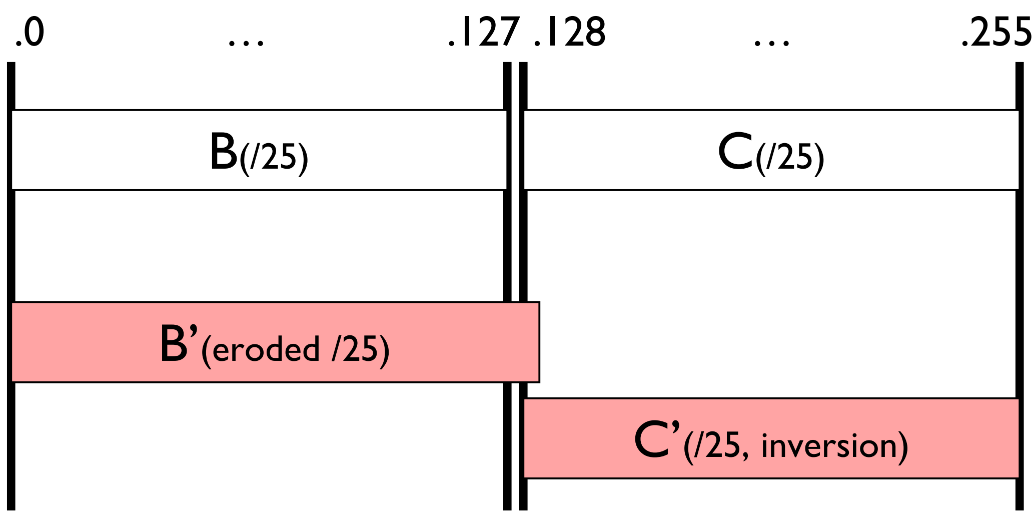
Range “Erosion”

- Off-by-one errors at start or end of a probable single CIDR block range
  - Missing network/broadcast address (“inner erosion”)
    - e.g., 10.2.3.0/24 as 10.2.3.1 - 10.2.3.254
  - End of range non-inclusive (“outer erosion”)
    - e.g., 10.2.3.0/25 as 10.2.3.0 - 10.2.3.128
- Inner erosions break CIDR block splitting.
  - 10.2.3.0/24 vs. 10.2.3.1/32, 10.2.3.2/31, 10.2.3.4/30, 10.2.3.8/29, 10.2.3.16/28, 10.2.3.32/27, 10.2.3.64/26, 10.2.3.128/26, 10.2.3.192/27, 10.2.3.224/28, 10.2.3.240/29, 10.2.3.248/30, 10.2.3.252/31, 10.2.3.254/32
- Outer erosions may cause inversions.

Inner Erosion Example



Outer Erosion Example



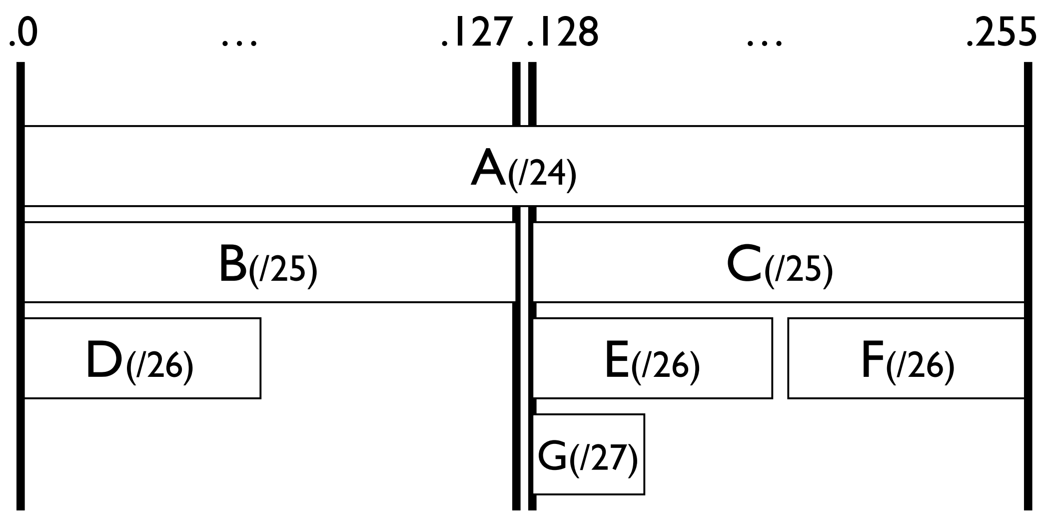
Erosion Statistics

- 6,404 range erosions detected:
  - 71.0% (4,547) are inner erosions.
  - 21.9% (1,400) are outer erosions.
    - 93% (1,302) of these are at end of range.
  - 7.1% (457) are "shifted" records (both outer and inner erosions).
- 98.9% on /24 blocks and smaller
- Erosions not detected on blocks smaller than /28.
  - Erosions on tiny blocks more likely to be false positives.

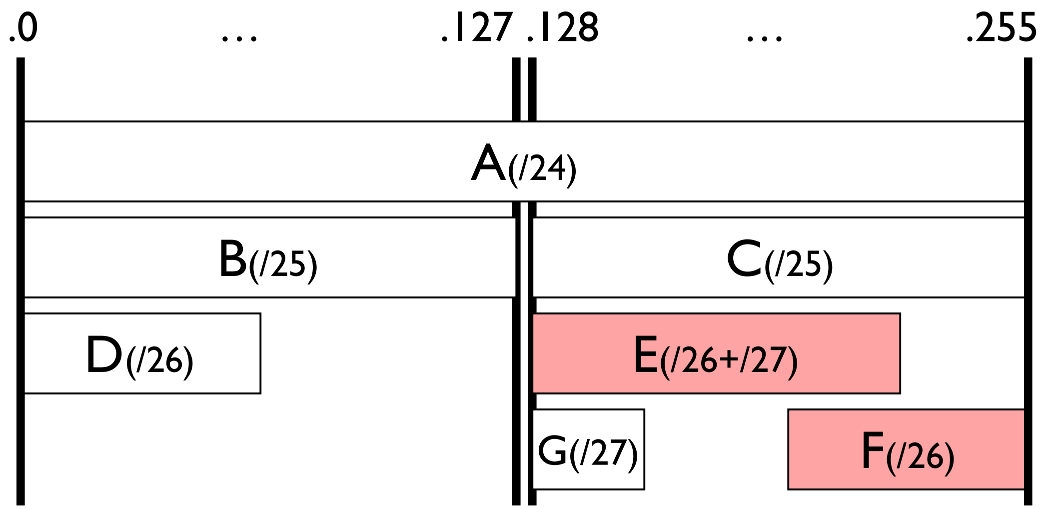
Range “Inversion”

- An inverted range is one which does not fit cleanly into the tree.
- May indicate errors in allocation ranges, or stale allocation records
- Difficult (if possible) to know which range in an inversion is correct
- Inversion correction is an area for future work.
  - Current procedure arbitrarily drops the second range.

Normal Allocation Tree



Inverted Allocation Tree



Inversion Statistics

- 745 range inversions detected:
  - typographical errors
    - e.g., 10.2.3.120 - 10.2.4.127 collides with 10.2.3.128-10.2.4.135; both are probably /29s, though it's not clear which /29s they should be.
  - simple overlap (possible stale records?)
  - outer erosions on tiny blocks
    - these are not fixed during erosion correction because of the higher risk of false positives on smaller blocks.
- Counts by type not available because inversion categorization is not yet automated.

Anomaly Logging

- Anomalies are logged during detection
  - for tuning of anomaly detection and correction techniques.
  - for transformation into a useful format for automated submission to the registries.

Future Work

- Inversion categorization
- Inversion correction
- Use of context to minimize false erosion detection
  - Allows erosion correction on tiny blocks
- Erosion detection on multiple-block ranges
- Automated anomaly submission to RIRs

For More Information

- http://aircert.sourceforge.net/addrtree

Appendix: AddrTree workflow