Interactive Collector Engine

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Route collectors (RCs) are devices which collects BGP routing data from co-operating ASes.

A route collector
- Maintains a routing table (RIB) with the best routes received
- Dumps the content of the RIB and received UPDATEs periodically
BGP route collector projects

University of Oregon Route Views Project
Route Views was originally conceived as a tool for Internet operators to obtain real-time information about the global routing system from the perspectives of several different backbones and locations around the Internet. It collects BGP packets since 1997, in MRT format since 1997
http://www.routeviews.org

RIPE NCC Routing Information Service (RIS)
The RIPE NCC collects and stores Internet routing data from several locations around the globe, using RIS. It collects BGP packets in MRT format since 1999
https://www.ripe.net/analyse/internet-measurements/routing-information-service-ris

Packet Clearing House (PCH)
PCH is the international organization responsible for providing operational support and security to critical Internet infrastructure, including Internet exchange points and the core of the domain name system. It operates route collectors at more than 100 IXPs around the world and its data is made available in MRT format since 2011
https://www.pch.net/resources/Raw_Routing_Data

Isolario
Isolario is a route collecting project which provides inter-domain real-time monitoring services to its participants. It collects BGP packets in MRT format since 2013
https://www.isolario.it
Real-time requirements

Off-line analysis of data . . .

Route collectors were originally conceived as a tool for network administrators to obtain information about the Internet inter-domain routing status.

. . . vs real-time monitoring

Depending on the application, some information must be obtained on-the-fly, i.e. without the delay caused by storing the data.

Example

Check the routes a feeder is using to reach a given portion of IP space.

Check MRT data?

- RIB snapshots are available every 2-8 hours
- Update messages are available every 5-15 minutes
Real-time requirements

Is it possible to perform real-time queries on the RC RIB?

Current situation
Typically RCs run general-purpose routing software, e.g. Quagga

Cons
- The collection process is affected by the queries because most RC software is **single-threaded**
- Overhead in terms of CPU and memory usage due to BGP specs (e.g. BGP decision process)
Example with Quagga

- $t = 0$ Feeder $F_1$ starts a RIB transfer (ends $t = 35$, $\sim 580k$ prefixes)
- $t = 45$ Feeder $F_2$ starts another RIB transfer
- $t = 60$ ten $F_1$ full table read operations are issued sequentially

Data collection is delayed of about 20 seconds

After the read requests, packets arrives with higher rate
ICE: an Interactive Collector Engine

- Each BGP session is handled by a dedicated set of threads
- Each service request is handled by a dedicated thread
- Readers and writers sync on the RIB according to the classic readers-writers paradigm
RIB implementation: Patricia Trie

- Each node represents a subnet
- Each subnet has associated a set of path attributes, one for each feeder that announced the subnet

Readers and Writers

- Writer: feeder thread
- Reader: request thread

Writers/Readers can \textit{W\_lock}/\textit{R\_lock} both the whole trie \textbf{and} single nodes
RIB implementation: Patricia Trie

Writer

1. Checks if the node is present (R_lock RIB)
2. If not, inserts new node (W_lock RIB)
3. Inserts/updates the path attribute (W_lock node)

Reader

1. Checks if the node is present (R_lock RIB)
2. If yes, reads the node (R_lock node)
Test: delay in storing BGP packets

- $t = 0$ Feeder $F_1$ starts a RIB transfer
- $t \sim 40$ Feeder $F_2$ starts a RIB transfer
- $t \sim 41$ Multiple $F_1$ full table read operations are issued simultaneously

Thanks to the scheduler activity (and the multi-threaded design) ICE is able to write incoming packets while readers are reading.
Test: delay in storing BGP packets

- $t = 0$ Feeder $F_1$ starts a RIB transfer
- $t \approx 40$ Feeder $F_2$ starts a RIB transfer
- $t \approx 41$ Multiple $F_1$ full table read operations are issued simultaneously

Thanks to the scheduler activity (and the multi-threaded design) ICE is able to write incoming packets while readers are reading.
Test: delay in reading the RIB

<table>
<thead>
<tr>
<th># of readers</th>
<th>Before $F_2$ RIB transfer</th>
<th>During $F_2$ RIB transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 core</td>
<td>8 cores</td>
</tr>
<tr>
<td></td>
<td>$\mu$</td>
<td>$\sigma$</td>
</tr>
<tr>
<td>1</td>
<td>2.12</td>
<td>0.07</td>
</tr>
<tr>
<td>2</td>
<td>2.15</td>
<td>0.10</td>
</tr>
<tr>
<td>4</td>
<td>2.32</td>
<td>0.15</td>
</tr>
<tr>
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<td>0.06</td>
</tr>
</tbody>
</table>

- Similar to the previous test, but from the reader side
- How much time a reader takes to retrieve the full routing table of $F_1$ before and during $F_2$ table transfer?
- $\mu$ and $\sigma$ are respectively the average time and the standard deviation

The time the second set of readers takes to retrieve $F_1$ table is very close to the time taken by the first set, confirming that multiple readers can proceed in parallel with $F_2$
Test: delay in reading the RIB

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- Similar to the previous test, but from the reader side
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What about memory?

Memory consumption
- ICE uses $\sim 82.4$MB per feeder, $\sim 100$ feeders on a standard machine
- This means that in scenarios where the feeders are near to a thousand (e.g. route collecting, route servers) at least ten machines are needed

How to reduce memory consumption?
Repetitiveness of BGP data

- The memory usage is mainly caused by the PATH_ATTRIBUTEs.
- Is that possible to compress them? Are they repetitive?

We analysed BGP data collected by Route Views, RIS and Isolario route collectors:
- March 2nd, 2016
- February 2nd, 2016
- March 2nd, 2015
- March 2nd, 2006 (only Route Views and RIS)

We consider only full feeders data

We computed an uniqueness index \( u - index \) for each attribute.

Given a full feeder RIB and an attribute \( A \), the \( u - index \) is the ratio between the different values assumed by \( A \) and the number of occurrences of \( A \).
Attributes are more repetitive in IPv4 scenarios than IPv6
- Only about one every five ASes appears in IPv6 routes
- an AS announces on average two subnets vs ten in the IPv4 case
- `NEXT_HOP` is the most repetitive (of course)
Data can be compressed!

Requirements for the compression algorithm
- Lossless
- Adaptive
- Random access at record level

Compression algorithms categories
- Entropy encoding
- Dictionary encoding

Recurring patterns are substituted with fixed-size indexes
One dictionary per feeder
- The dictionary is kept in memory
- The decompressor does not need to rebuild the dictionary (small compression variant applied here)
Results

<table>
<thead>
<tr>
<th>Memory usage (GB)</th>
<th># of IPv4 full routing tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 2 4 8 16 32 64</td>
</tr>
<tr>
<td>1</td>
<td>without LZW* with LZW*</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Compression saves up to 30% of memory, i.e. 57.5MB per feeder

Route processing time increases from 12\(\mu\)s-20\(\mu\)s to 30\(\mu\)s-64\(\mu\)s

Amount of time it takes a complete feeder table transfer
Isolario is a route collector project which offers real-time monitoring services to its participants. Services obtain the real-time inter-domain status of a feeder by querying ICE. Evolution is obtained with subsequent UPDATE messages.
## Conclusion

### Interactive Collector Engine

- We proposed a multi-threaded collector engine which takes care of memory consumption
- This is **not** a complete BGP daemon like Quagga or Bird
- It is designed to support real-time access to the routing table and simultaneous collection of data

### Future

- Add support for ADD_PATH and BMP
- Route Server? (Add BGP decision process, import/export policies)
- Use as a basic brick to implement a real-time looking glass on IXPs?
- Suggestions?

ICE is open-source and written in C++
- It can be downloaded from [isolario.it](http://isolario.it) (Tools section)
Usage/Demo

Config file

- Usual parameters (listening IP/port, MRT output folder, ...)
- CLI parameters (text and raw channel)

Interface

- **Text channel:**
  - Accepts textual commands, answer with textual output

- **Raw channel**
  - Transfer of raw BGP data
  - An API is provided to interact with this channel
Usage/Demo (cont.)

Install

- Download package from Isolario (www.isolario.it, Tools section)
- configure [--enable-lzw] && make && make install

Executables

- ICE
- ICE_client (a tool to ease the interaction with the TEXT channel)
- ICE_raw_client (a tool exploiting some RAW channel API)
Each full feeder uses on average a number of distinctive AS paths which is much smaller than the average size of the full table.

Almost every full feeder uses the same **number** of distinctive AS paths.

The number of distinctive AS paths is about 1.5 times the number of ASes.
### Tuning the index size $N$

<table>
<thead>
<tr>
<th>Dictionary Size</th>
<th>Data Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dict=2B</td>
<td>0 B</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>2GB</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>4GB</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>6GB</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>8GB</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>10GB</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>12GB</td>
</tr>
<tr>
<td>Dict=2B</td>
<td>14GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>0 B</td>
</tr>
<tr>
<td>No LZW*</td>
<td>2GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>4GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>6GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>8GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>10GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>12GB</td>
</tr>
<tr>
<td>No LZW*</td>
<td>14GB</td>
</tr>
</tbody>
</table>

- $N = 4B$ best compression but too large dictionary
- $N = 2B$ data is still fairly compressed