DisCarte

A Disjunctive Internet Cartographer

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Based on: "DisCarte: A Disjunctive Internet Cartographer"
by R. Sherwood, A. Bernder and N. Spring, SIGCOMM 08

Network Topology Discovery

Goal:

Infer the structure of a network.
Necessary, because the structure is mostly unknown/unpublished.

More accurate and complete topologies benefit, for example:

- network diagnostics, overlay construction or measurement

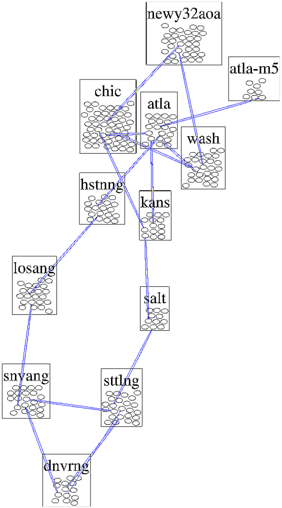
Tools:

- Rocketfuel
- Passenger
- Paris traceroute

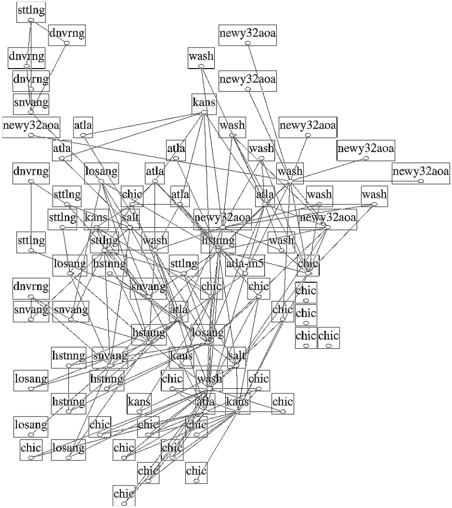
They are based on traceroutes and direct probing.

An Example: The Topology of the Abilene Network

Reality:



Rocketfuel:



DisCarte: a Network Topology Inference Tool

DisCarte uses *disjunctive logic programming (DLP)* to combine

- conventional traceroutes,
- the IP *Record Route Option (RR)* and
- observed engineering practices.

As result a topology is generated, that

- is more accurate/complete and
- contains fewer errors.

Content

Problems of current techniques and an introduction of RR

How can RR be used to improve topologies?

Disjunctive Logic Programming (DLP)

How DLP is used by DisCarte

Results

Outline

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Problems of Traceroute-based Techniques

Problems:

- mid-measurement path instabilities (e.g. due to load-balancing)
- anonymous routers, that don't send ICMP answers to packets with expired TTL
- hidden routers, that don't alter the TTL of forwarded packets
- routers that ignore packets addressed directly to them (direct probing)

Consequences:

- false links
- missed routers
- unresolved aliases

Improvement: RR as Independent Source of Information

What is RR?

- packet-option of the IP-protocol
- allows to track the path of a packet
- forwarding routers record their address in the packet-header (address of the outgoing interface)

Problems:

- limited header size allows only 9 entries
- IP options are rarely used and may cause unexpected behaviour (e.g. broken load-balancing or useless firewall responses)

An Example for an IP Header with RR

<table>
<tr><th>0</th><th>4</th><th>8</th><th>12</th><th>16</th><th>20</th><th>24</th><th>28 31</th></tr>
<tr><td>Version</td><td>IHL</td><td colspan="2">TOS</td><td colspan="4">Total Length</td></tr>
<tr><td colspan="4">Identification</td><td>Flags</td><td colspan="3">Fragment Offset</td></tr>
<tr><td colspan="2">TTL</td><td colspan="2">Protocol (IP)</td><td colspan="4">Header Checksum</td></tr>
<tr><td colspan="8">Source Address</td></tr>
<tr><td colspan="8">Destination Address</td></tr>
<tr><td colspan="2">7 (= RR)</td><td colspan="2">40 (= Length)</td><td colspan="2">24 (= Pointer)</td><td colspan="2">(unused)</td></tr>
<tr><td colspan="8">Address 1</td></tr>
<tr><td colspan="8">Address 2</td></tr>
<tr><td colspan="8">Address 3</td></tr>
<tr><td colspan="8">Address 4</td></tr>
<tr><td colspan="8">Address 5</td></tr>
<tr><td colspan="8">(empty)</td></tr>
<tr><td colspan="8">(empty)</td></tr>
<tr><td colspan="8">(empty)</td></tr>
<tr><td colspan="8">(empty)</td></tr>
</table>

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Use of RR information

RR should enhance information of traceroutes
⇒ RR and traceroute information have to be merged

Address Alignment:

Every router found by traceroute has to be associated with one or more IPs found by RR.

Gain:

- path instabilities can be recognized
- anonymous and hidden routers can be found
- aliases can be resolved

Observed RR types

Problem:

Not all routers comply with the specification
⇒ different implementations complicate the *Address Alignment*

Observed implementation types:

Departing: RR entry with the address of the outgoing interface when the packet is forwarded

MPLS: like Departing, no RR entry when packet arrives over an MPLS-enables interface

NotImpl: router ignores the RR option

Arriving: RR entry when packet arrives

Lazy: like Departing, but TTL is not decremented

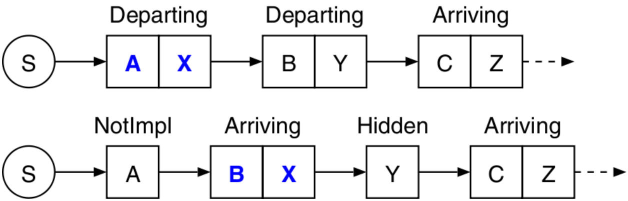
Mixed: like Departing if the packet is forwarded, RR entry with incoming interface if TTL is expired

Address Alignment

Assignment based on a single RR entry is usually ambiguous.

Example:

Probe ttl	ICMP source IP	RR Array
1	A	-
2	B	X
3	C	X, Y, Z



Several assignments are possible. Multiple traces have to be taken into account.

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Use of DLP in DisCarte

Address Alignment:

given:	information (facts): traceroutes and RR-paths number of possible RR implementations
wanted:	consistent assignment of implementation types and associated IP-addresses to each router

DLP

Solution of a logic program:

- *DLP-Solver* tries to find an assignment (solution) for variables, so that the statement holds true
- Solutions are usually not distinct
- strong/weak constraints narrow/sort the solutionspace

A DLP program consist of:

Facts:	given logical statements
Rules:	combination of facts, rules and variables with logical operators

Rules in a DLP:

$\text{fact}_0 \Rightarrow \text{rule}_1 \vee \cdots \vee \text{rule}_n$

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Example: a Rule used in DisCarte

$$\begin{aligned}
probePair(X, Y, \delta), & \\
\delta = 1 & \quad \Rightarrow \\
transition(X, Y, Departing, Departing) & \quad or \\
transition(X, Y, Arriving, Arriving) & \quad or \\
transition(X, Y, Departing, NotImpl) & \quad or \\
transition(X, Y, NotImpl, Arriving) & \quad or \\
transition(X, Y, NotImpl, Hidden, Departing) & \quad or \\
transition(X, Y, NotImpl, Hidden, NotImpl) & \quad or
\end{aligned}$$

Solutions & Observed Engineering Practices

one strong constraint:

All interfaces (aliases) of a router have to have the same RR type.

weak constraints:

1. no self-loops
2. IP-addresses of a link differ only in one bit
3. information gained by direct probing is probably correct
4. there are few hidden routers
5. there are few routers that do not implement RR

The solution with the lowest costs is probably the closest to reality.

Handling of Large Networks

problem:

- large networks produce a lot of measurement data
- number of possible RR assignment grows exponentially
- the solution space becomes to large to be handled (effectively)

solution:

- divide & conquer
- compute small parts of the network and merge the solutions
- conflicts may occur and have to be solved

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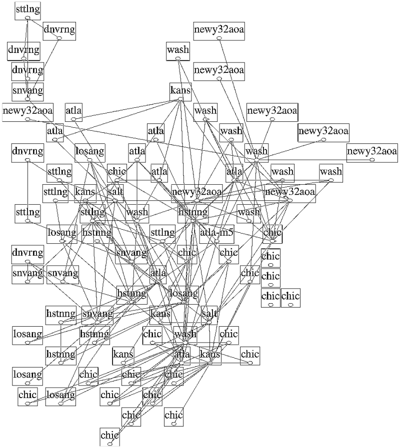
Validating DisCarte

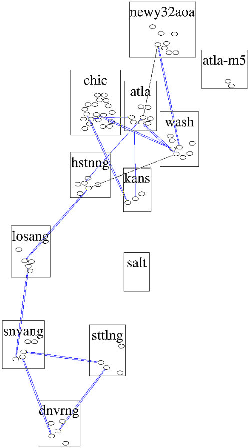
Comparison of Results generated by DisCarte, Passenger and Rocketfuel:

- DisCarte inferred no false links
- RR resolved aliases, that have been missed by direct probing techniques
- no addresses were wrongly aliased by DisCarte

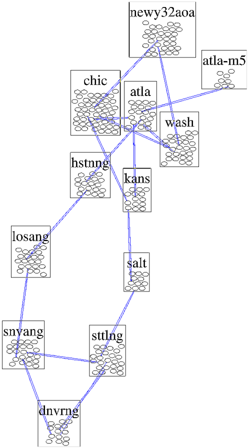
The Abilene Topology



Rocketfuel

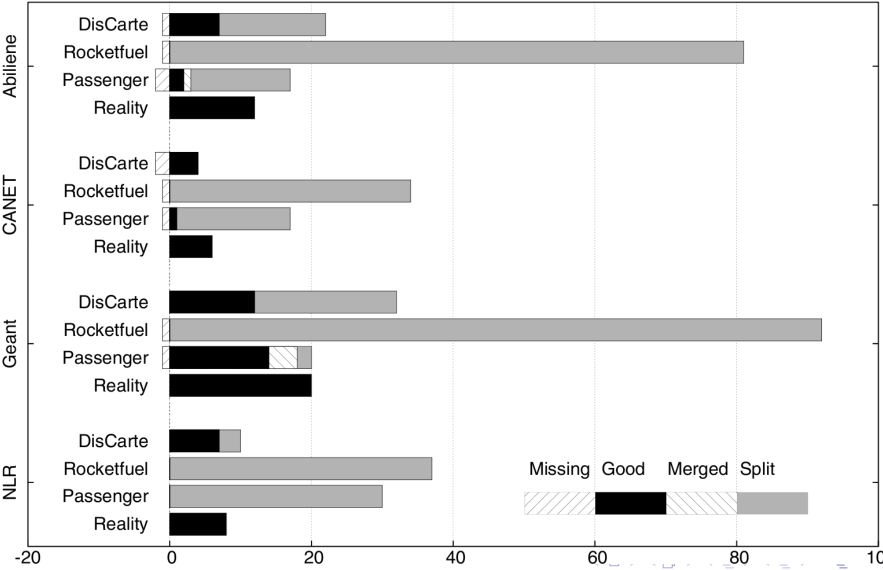


DisCarte



Reality

Comparison with other Tools



Conclusion

The use of RR allows:

- alias resolution without direct probing
- discovery of hidden and anonymous routers
- recognition of load-balancing and path instabilities

In addition it has been shown with DisCarte, that:

- DLP is flexible enough to cope with the task of Address Aligning
- the process can be scaled to larger networks

The quality and accuracy of the inferred topologies could be increased significantly.

Bibliography

- Rob Sherwood, Adam Bender, Neil Spring: *DisCarte: A Disjunctive Internet Cartographer*; ACM SIGCOMM 2008.
- Rob Sherwood, Neil Spring: *Touring the Internet in a TCP Sidecar*; ACM 2006.
- B. Augustin, et al.: *Avoiding traceroute anomalies with Paris traceroute*; ICM 2006.
- N. Spring, R. Mahajan, D. Wetherall: *Measuring ISP topologies with Rocketfuel*; ACM 2002.
- J. Postel, editor. Internet protocol: IETF RFC-791 `http://tools.ietf.org/html/rfc791`; 1981.