NFQL: A Tool for Querying Network Flow Records

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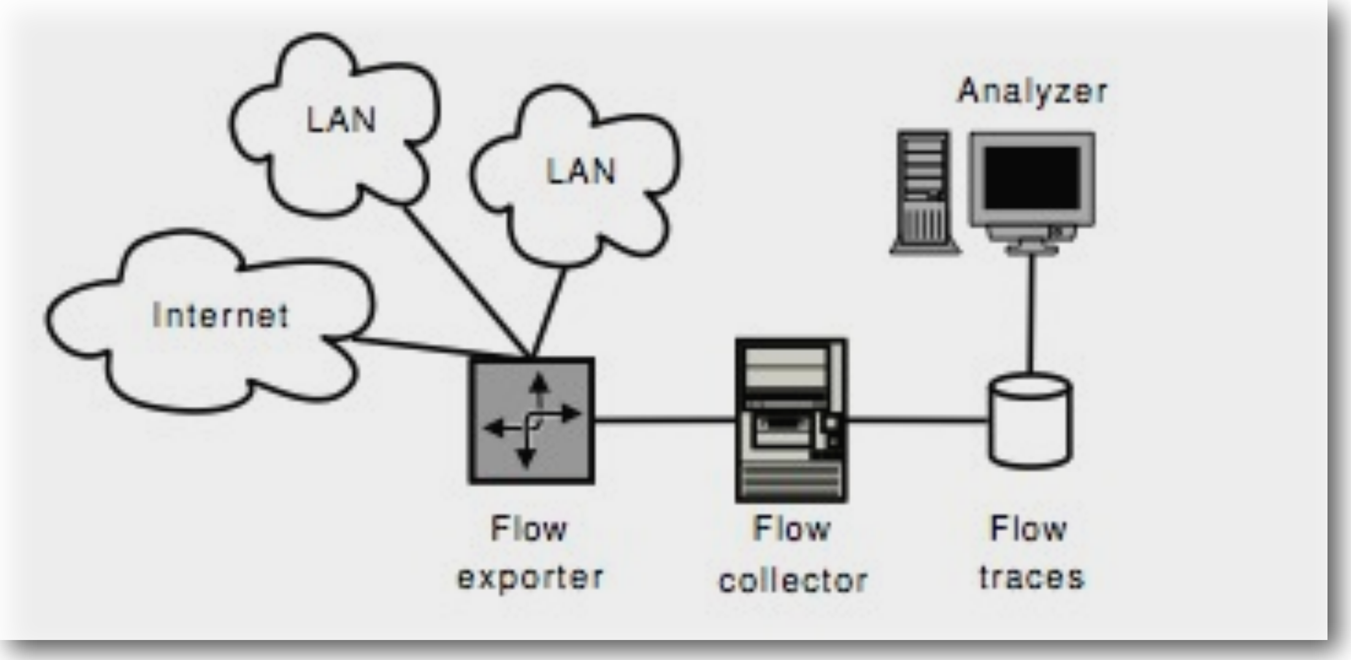
Overview

- Motivation
- Related Work
- Flow Query Language: NFQL
- Implementation: `nfql`
- Performance Evaluations
- Conclusions

Motivation

- IP traffic flow



A set of IP packets passing an observation point in the network during a certain time interval. All packets belonging to a particular flow have a set of common properties [RFC 3917].

Flow analysis use cases:

- Survey on detection of intrusion attacks [1].
- Survey on behavior analysis of Internet backbone traffic [2].

- Flow export protocols
  - Cisco NetFlow [RFC 3954]
  - IETF IPFIX [RFC 5101]

version	features
v1,{2,3,4}	original format with several internal releases
v5	CIDR, AS support and flow sequence numbers
v{6,7,8}	router-based aggregation support
v9	template-based with IPv6, and MPLS support
IPFIX	universal standard, transport-protocol agnostic

- Understanding intricate traffic patterns require sophisticated flow analysis tools
- Current tools **fail** to deliver owing to their simplistic language designs.

Related Work

- Simple traffic analysis tools
    - ntop, FlowScan, NfSen, Stager

- Popular NetFlow analysis tools
    - `flow-tools`: supports NetFlow v5
    - `nfdump`: supports NetFlow v9

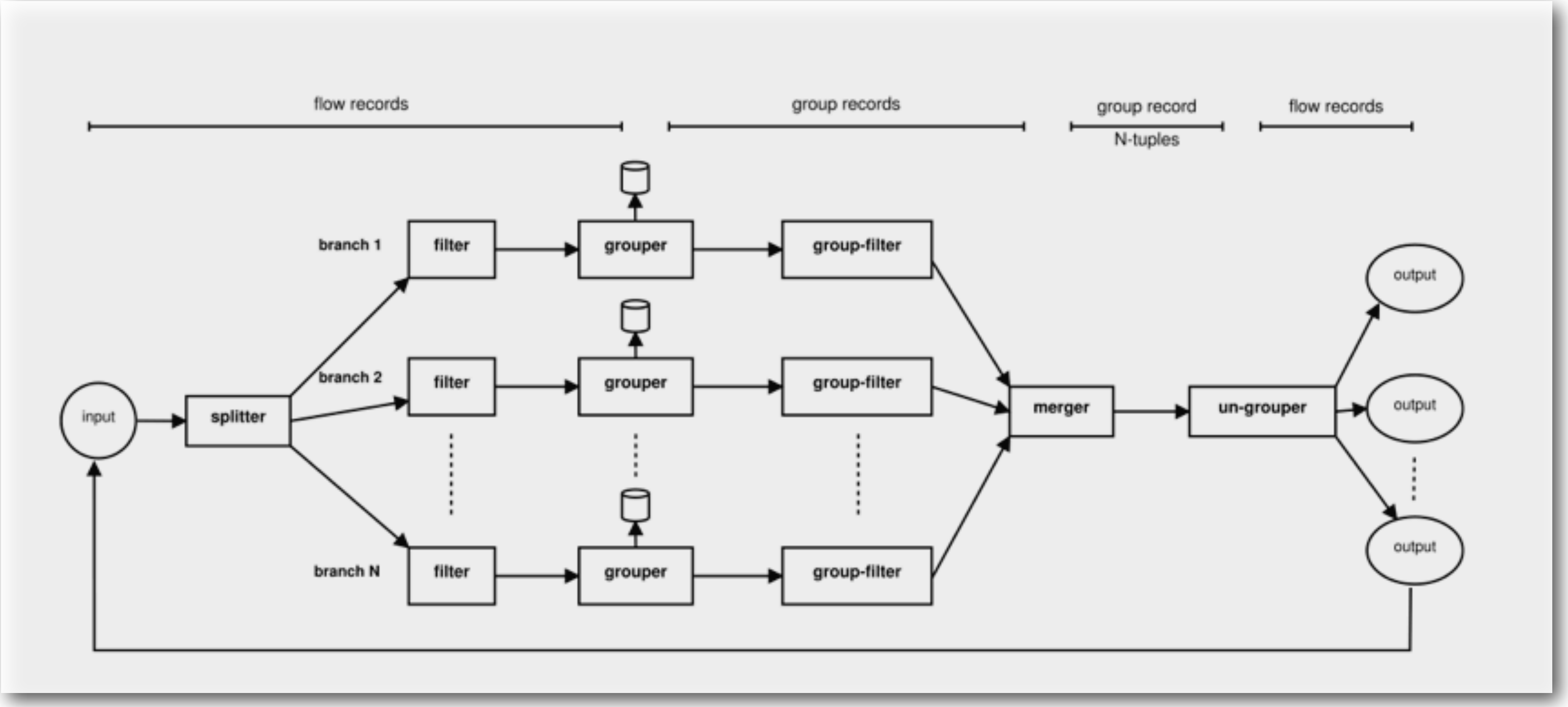
Limited to only absolute comparison of flow-keys

- Popular IPFIX analysis tools
    - `SiLK`

- Grouping and merging can only be performed on = operator.
- Cannot ungroup the flows once grouped.
- Stringent requirements on organization of input flows.

NFQL (Network Flow Query Language)

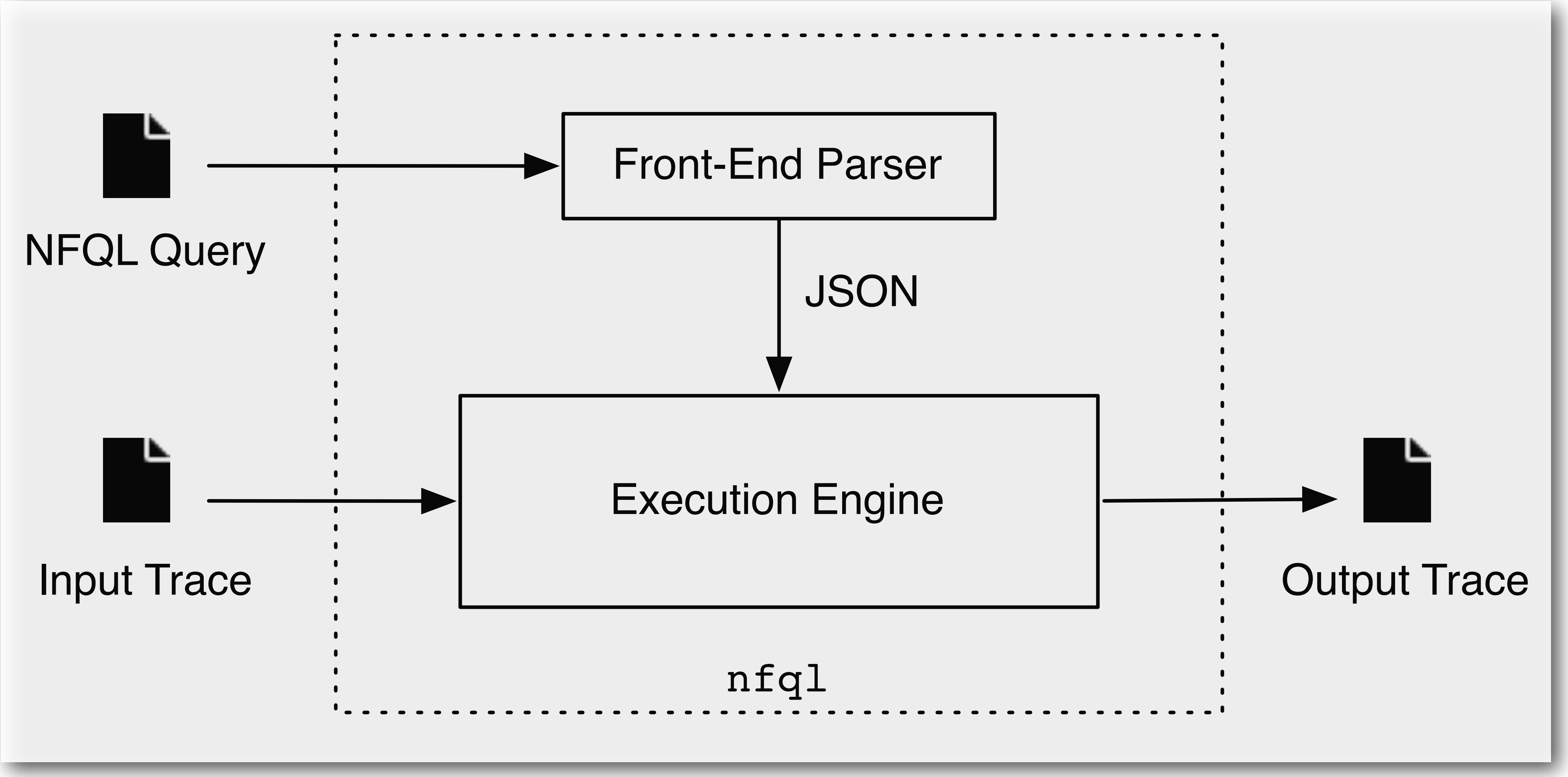
The expressiveness of the language can be seen from [4], where NFQL queries are used to identify application signatures.



NFQL processing pipeline [3]

- Features
  - Filter flows.
  - Combine flows into groups.
  - Aggregate flows on flow-keys as one grouped flow aggregate.
  - Invoke Allen interval algebra on flows.
  - Merge grouped flows.
  - Apply absolute or relative filters when grouping or merging.
  - Unfold grouped flows back into individual flows.

`nfql` Tool



`nfql` architecture

- Execution engine is written in C
- Parser is written in Python
- The input and output traces are in NetFlow v5 format.

- JSON intermediate format
  - Each pipeline stage of the JSON query is a DNF expression.
  - JSON query can disable the pipeline stages at RUNTIME.
  - Execution engine uses `json-c` to parse the JSON query.

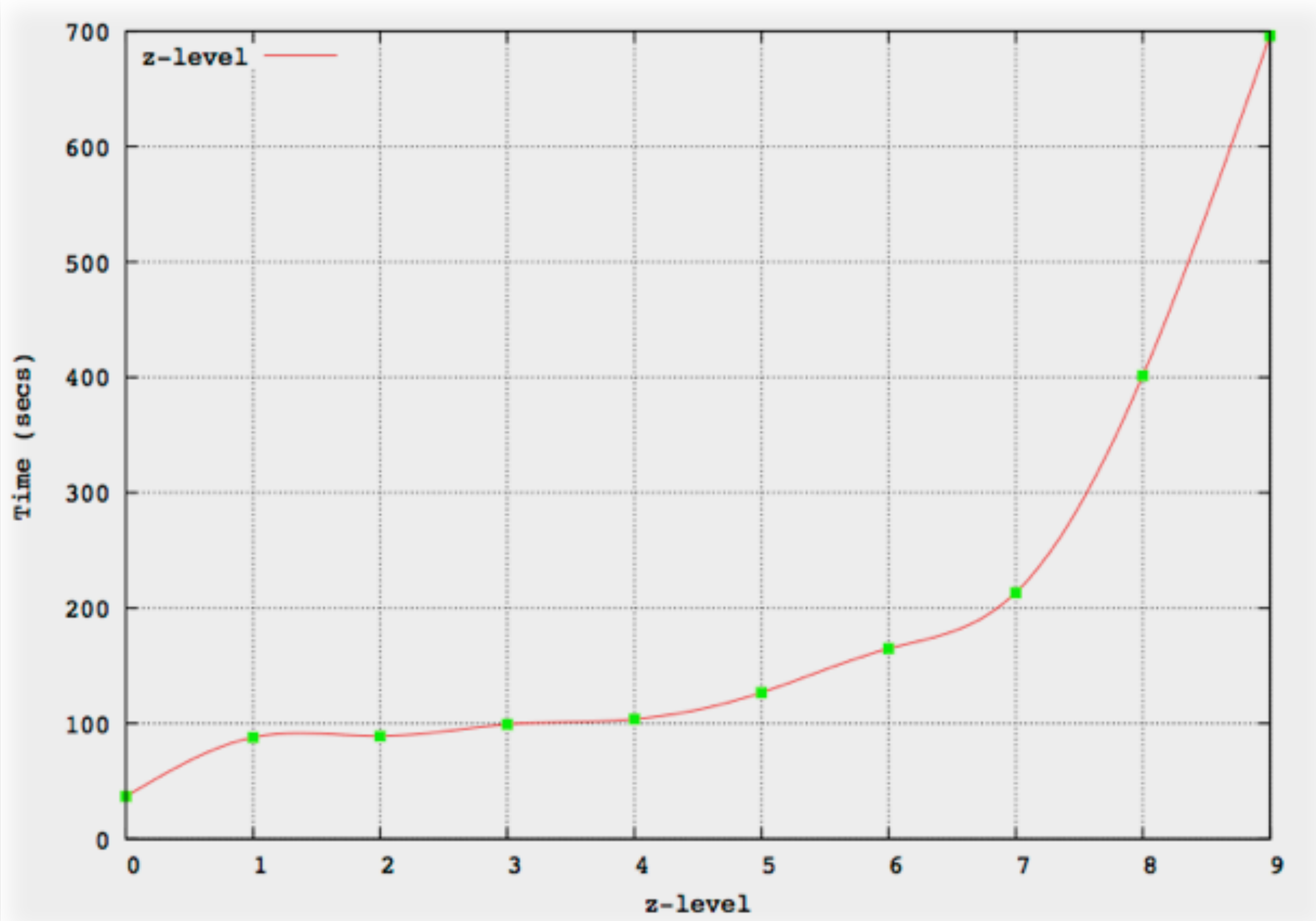
`nfql` Tool

- Execution workflow
  - A custom C library has been written to read/write traces in `flow-tools` format
  - Flows are read in memory and indexed to allow retrieval in $O(1)$ time.
  - Each branch is run in separate thread.

- Performance optimizations
  - No splitter: Using indexes to reference flows in each branch.
  - Inline filter: Flows are filtered as soon as they are read in memory.
  - Faster grouper lookups: Sort on group keys and perform a nested binary search.
  - Faster merger matches: Sort on merger keys to skip iterator permutations.

Filter (worst case)	$O(n)$ *where* n=num(flows)
Grouper (average case)	$O(n \times lg(k)) + O(p \times n \times lg(n))$ *where* k=num(unique(flows)), p=num(terms)
Grouper aggregations (worst case)	$O(n)$
Group Filter (worst case)	$O(g)$ *where* g=num(groups)
Merger (worst case)	$O(g\hat{}m)$ *where* m=num(branches)
Ungrouper (worst case)	$O(g)$

nfql Tool



Adaptable compression levels

- Output traces are compressed using `zlib` library. `nfdump` uses `lzo` compression

- Compression level is configurable at RUNTIME. `nfql` uses `ZLIB_LEVEL 5` by default

- Each compression level adds its own performance overhead when writing output traces to files.

- Additional Features
  - Each pipeline stage results can be written out as `flow-tools` files.
  - Capability to read multiple input traces from `stdin`: `$ flow-cat $TRACES | nfql $QUERY -`

Demo

Thread A

```
branch A {

  filter f1 {
    dstport=80
    protocol=TCP
  }

  grouper g1 {
    srcaddr = srcaddr
    dstaddr = dstaddr
    aggregation {
      sum(dPkts)
      sum(dOctets)
    }
  }

  groupfilter gf1 {
     dPkts > 200
   }
}
```

```
merger M {
  A.srcaddr = B.dstaddr
  A.dstaddr = B.srcaddr
}
```

```
ungrouper U {

}
```

Thread B

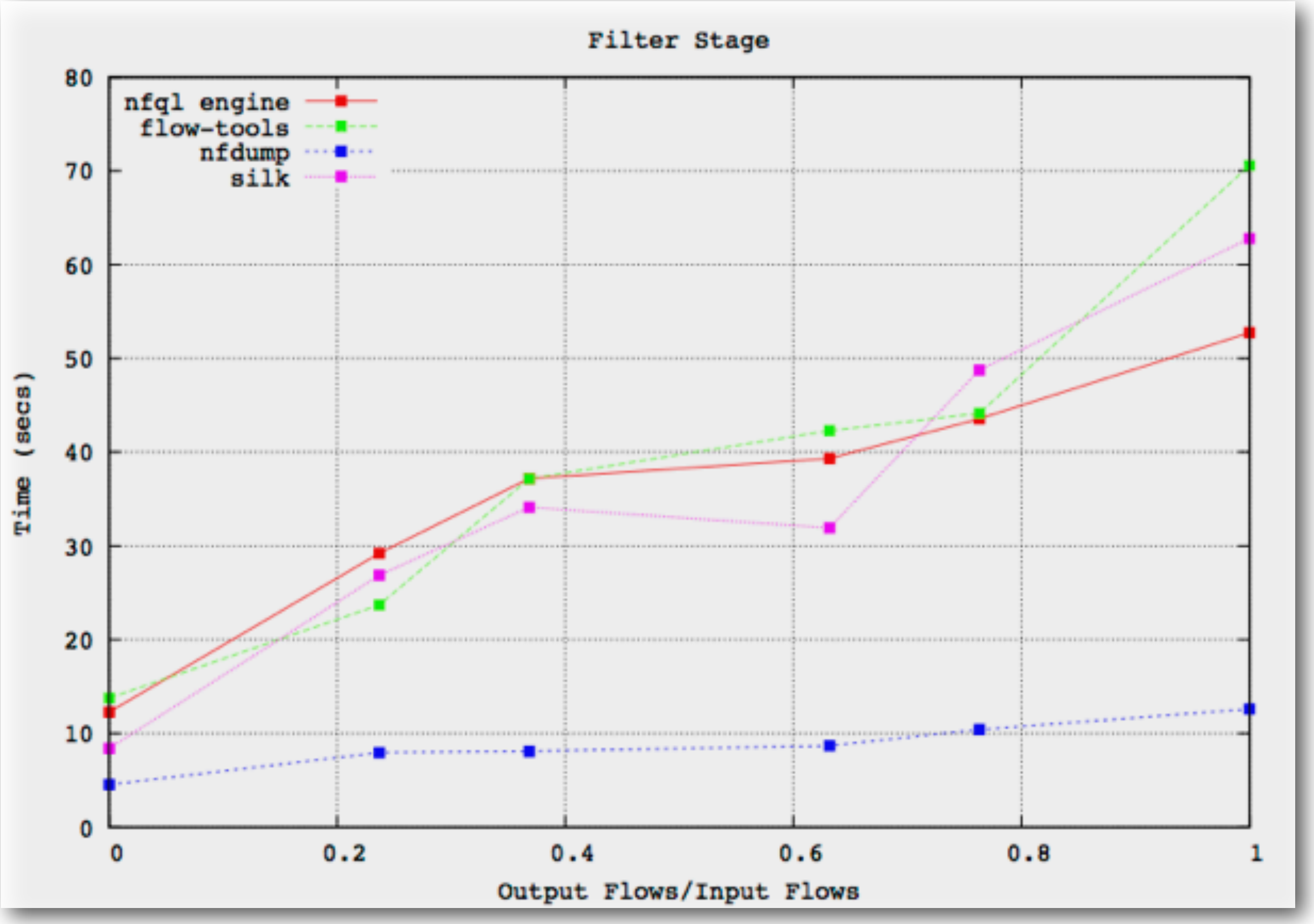
```
branch B {

  filter f1 {
    srcport=80
    protocol=TCP
  }

  grouper g1 {
    srcaddr = srcaddr
    dstaddr = dstaddr
    aggregation {
      sum(dPkts)
      sum(dOctets)
    }
  }

  groupfilter gf1 {
     dPkts > 200
   }
}
```

Performance Evaluations



- Used first 20M flows from Trace 7 in the SimpleWeb repository [5].
- Input trace was compressed at `ZLIB_LEVEL 5`.
- Ran on a machine with 24 cores, 2.5 GHz clock speed and 18 MiB of physical memory.
- `nfdump` uses `lzo` compression to trade output trace size with RUNTIME speed.

- Stressing the rest of the pipeline stages (please refer to the paper)
  - `flow-tools` and `nfdump` do not have the equivalent functionality to participate.
  - `nfql` and `SiLK` are compared in the Grouper, Group Filter and Merger stages.
  - `SiLK` does not have equivalent Ungrouper functionality.

Conclusion

- NFQL' richer language capabilities allow sophisticated flow queries.
- `nfql` can process such complex queries in minutes.
- `nfql` has comparable execution times when processing real-world traces.
- `nfql` has expanded the scope of current flow-processing tools.
- Evaluation queries developed as part of this research can become input towards a generic benchmarking suite for flow-processing tools

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