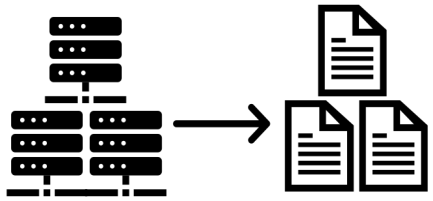
μSlope: High Compression and Fast Search on Semi-Structured Logs

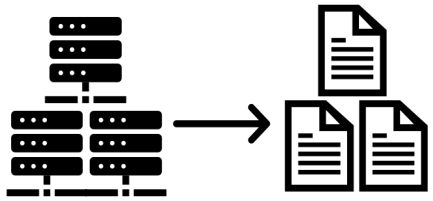
Rui Wang, Devin Gibson, Kirk Rodrigues, Yu Luo,
Yun Zhang, Kaibo Wang, Yupeng Fu, Ting Chen, Ding Yuan

YScope Uber University of Toronto



Software systems

Logs



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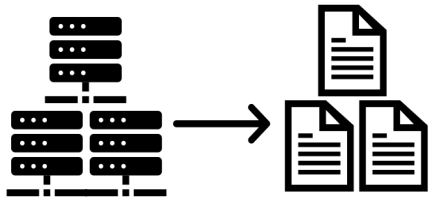
- Error detection
- Performance debugging
- Operation management
- Usage analysis
- Security



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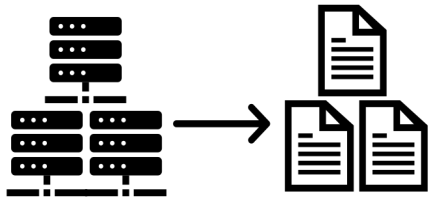
Unstructured log



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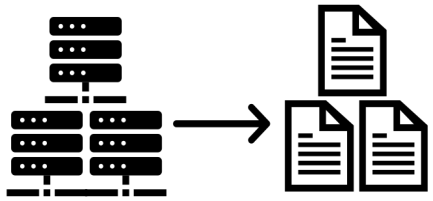
Semi-structured log



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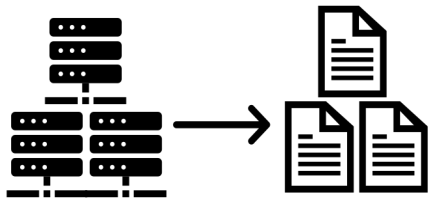

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Semi-structured log

$0.0125 per GB per month
1 PB logs result in annual storage cost at $35,019,817

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- ✗ Sparse table
- ✗ Predefined schema for each field
- ✗ Polymorphism limitation

Limitations of systems with native JSON support

- E.g. BSON from MongoDB, jsonb from PostgreSQL, and OSON from Oracle

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\x02                       // 0x02 = value type String
hello\x00                  // key name
\x06\x00\x00\x00world\x00  // size of value (6 bytes), value
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BSON

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splunk> elastic

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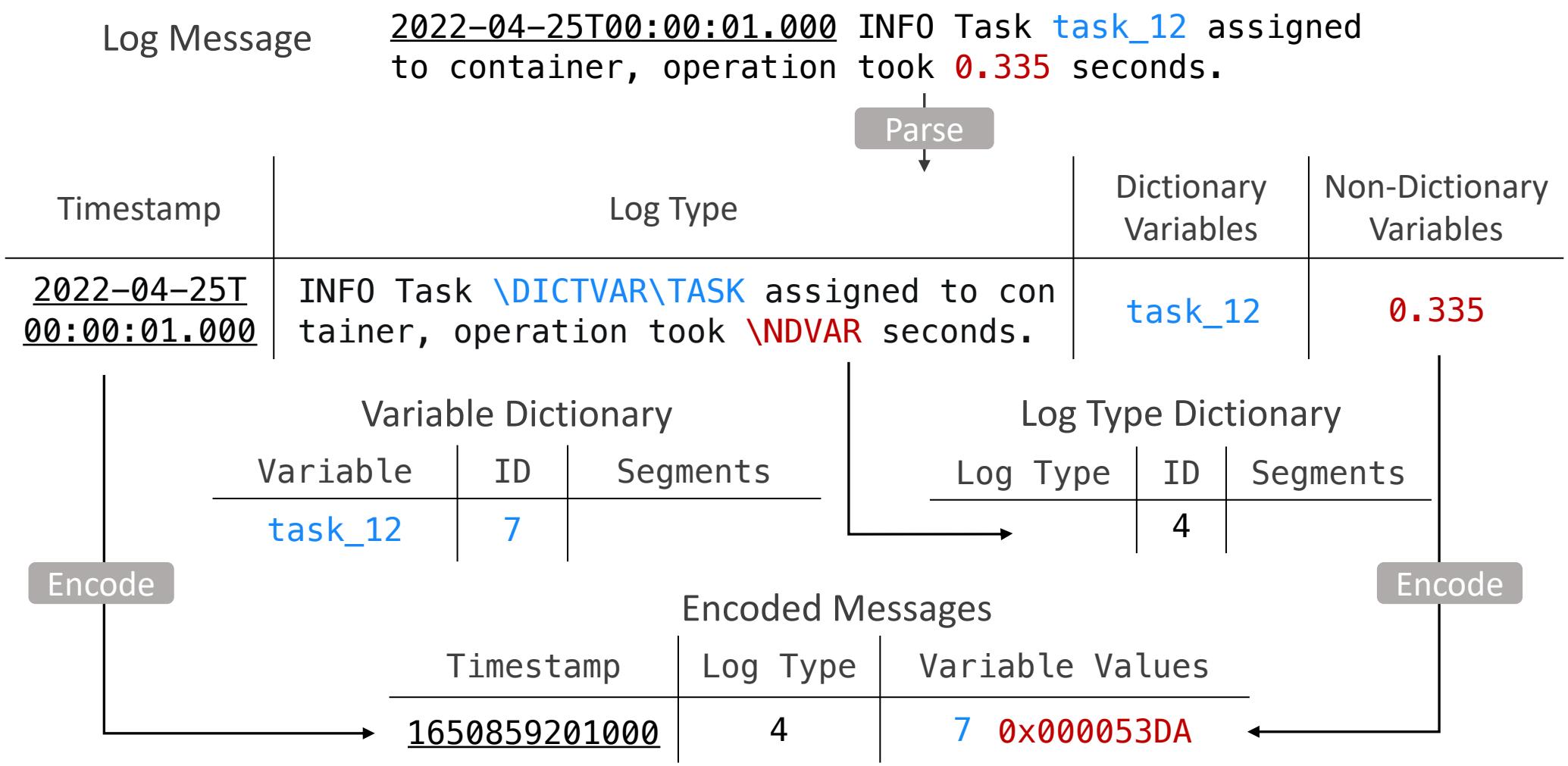
❌ Low compression ratio

❌ Low ingestion speed

❌ High resource usage

CLP[1]: Deisgned for *unstructured* logs



1. Kirk Rodrigues, Yu Luo, and Ding Yuan. “CLP: Efficient and Scalable Search on Compressed Text Logs”. In: 15th USENIX Symposium on Operating Systems Design and Implementation. OSDI ’21. USENIX, 2021, pp. 183–198.

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Log Message

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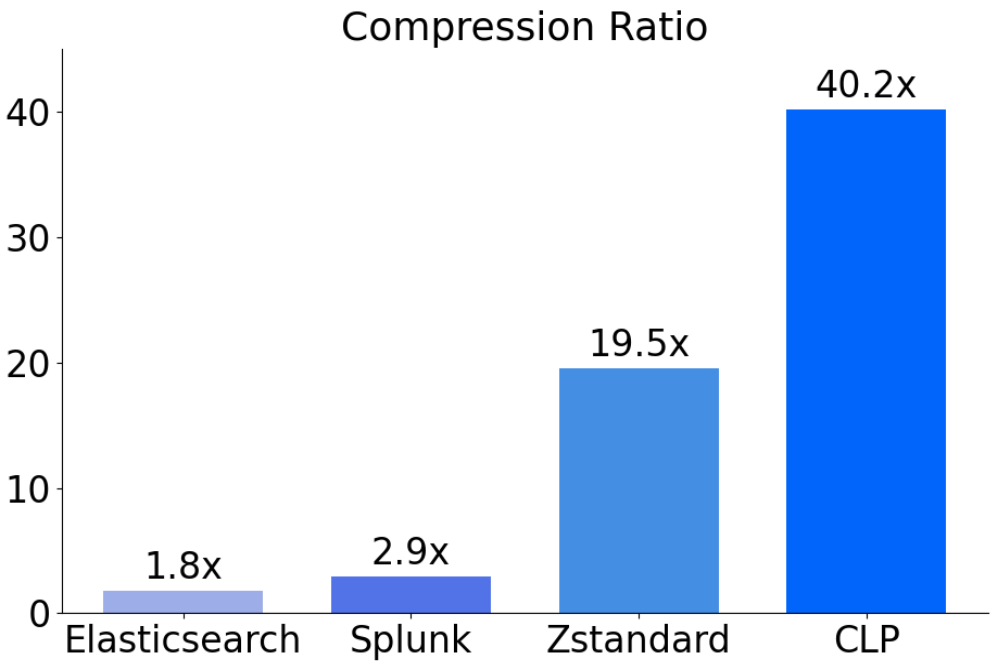

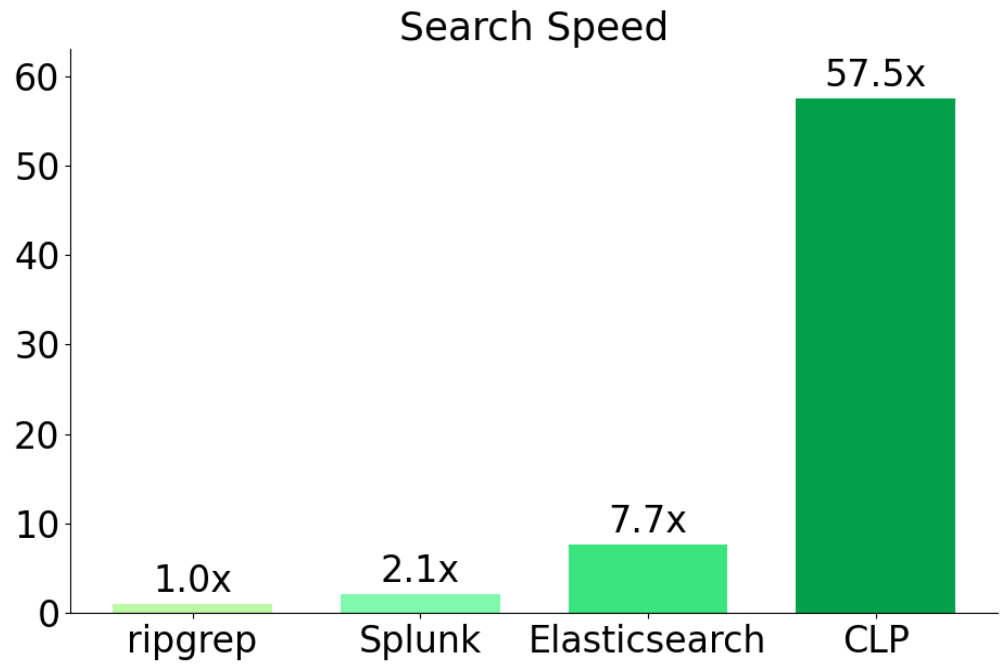

Timestamp	Log Type	Variable Values
1650859201000	4	7 0x000053DA

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Challenges of using CLP with semi-structured logs

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Search taking lot of time using clg binary #154

Closed **bb-rajakarthik** opened this issue on Aug 29, 2023 · 4 comments

bb-rajakarthik commented on Aug 29, 2023

Bug

We are using CLP for compressing logs generated by our Kubernetes cluster which are in JSON format. A sample log is given below:


```
{
"log_time": "2023-08-29T13:55:09.477456Z",
"stream": "stdout",
"time": "2023-08-29T13:55:09.477456564Z",
"@timestamp": "2023-08-29T19:25:09.477+05:30",
"@Version": "1",
"message": " Method: POST;Root=1-64edf8bd-5c762a676349ee71616bb687 , Request Body : {"orders":
[{"order_type":"normal","external_reference_id":"69426","items":
[{"offset_in_minutes":"721","quantity":"1","external_product_id":"225090"}]}]}",
"level": "INFO",
"level_value": 20000,
"request_id": "6f3f3651-a22b-42a0-b5fe-412d2167c5ca",
"kubernetes_docker_id": "caa9102a169a1495e5790cb2c17cb21d0a279ffc50d802d413938870ba59c7c0",
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Challenges of using CLP with semi-structured logs

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ID	Variable Value
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NOT, OR operators and numeric comparison ?

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- ❌ Incompatible query interface
- ❌ Poor query performance

NOT, OR operators and numeric comparison ?

μSlope: High compression and *index-less* search

- Automatic schema inference
- Queries on different fields connected by logical operators
- High compression ratio and fast search

Semi-structured **logs** are highly repetitive.

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Key takeaways

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- 29% of the queries can be completed only by querying the schema structure.

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Find more details in the paper!

Schema Tree and Schema Map

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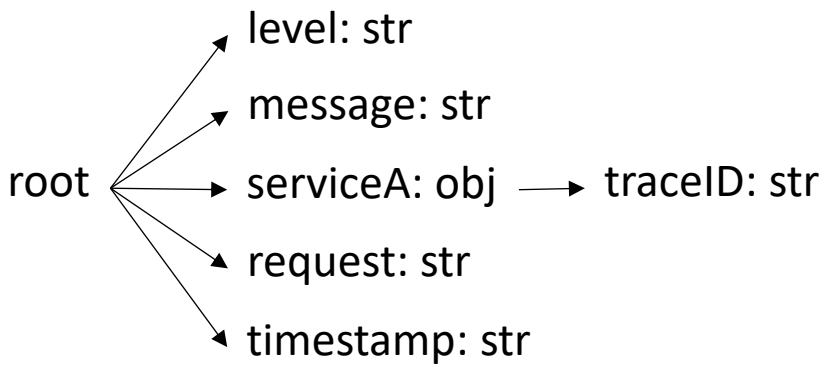

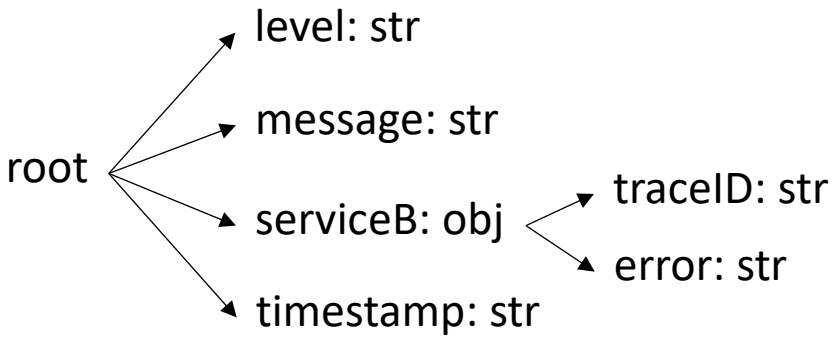


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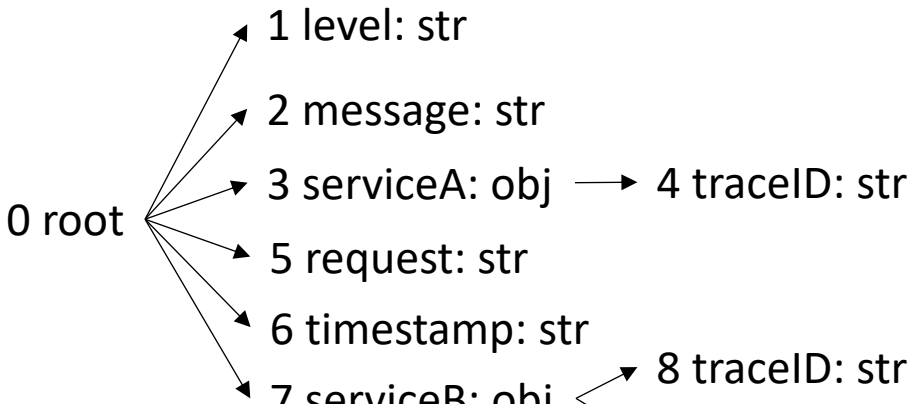
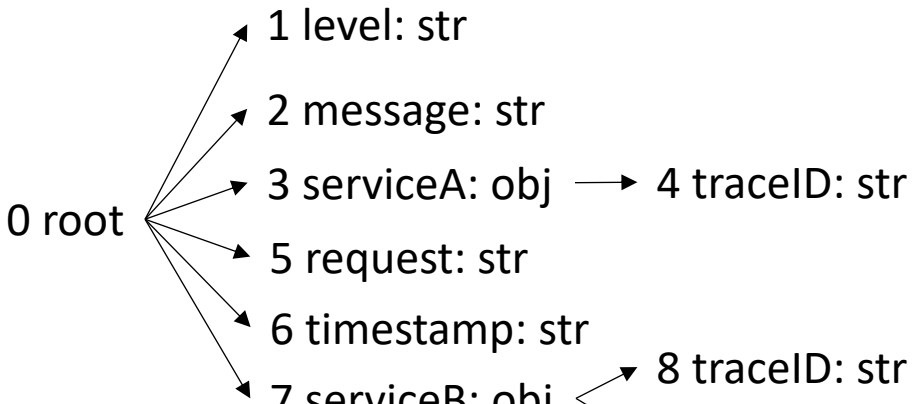


Merged Parsed Tree (MPT)


```
{
    "level": "warn",
    "message": "Could not fetch cell for flow 1.",
    "serviceA": {
        "traceID": "abc"
    },
    "request": "1_vehicle_compliance",
    "timestamp": "2022-04-14T07:58:02.368Z"
}

{
    "level": "error",
    "message": "Error handling inbound request.",
    "serviceB": {
        "traceID": "xyz",
        "error": "application_error"
    },
    "timestamp": "2022-04-14T07:58:02.372Z"
}
```

Schema Tree and Schema Map



Merged Parsed Tree (MPT)

Node IDs	Schema ID

Schema Map

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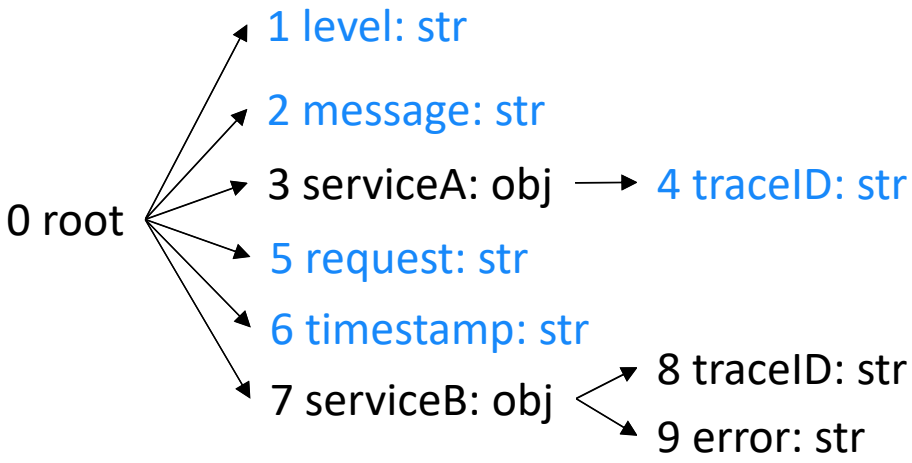
Schema Tree and Schema Map



Merged Parsed Tree (MPT)

Node IDs	Schema ID
1 2 4 5 6	0

Schema Map

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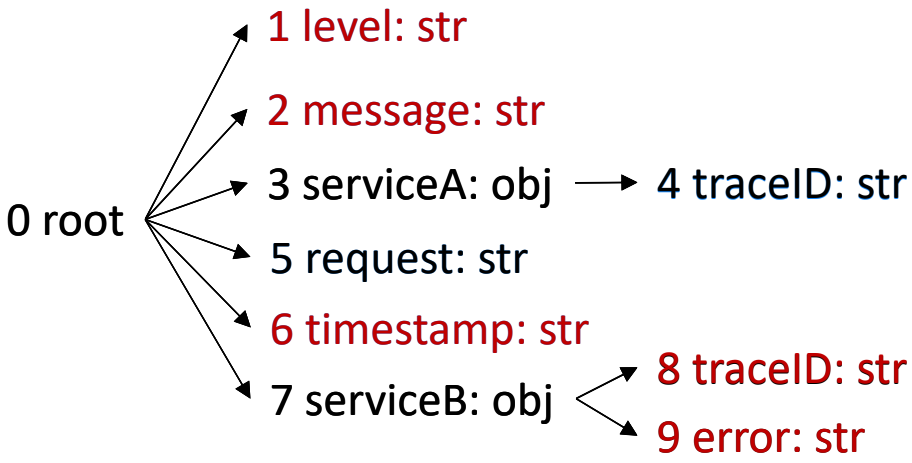
Schema Tree and Schema Map



Merged Parsed Tree (MPT)

Node IDs	Schema ID
1 2 4 5 6	0
1 2 6 8 9	1

Schema Map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    "message": "Could not fetch cell for flow 1.",
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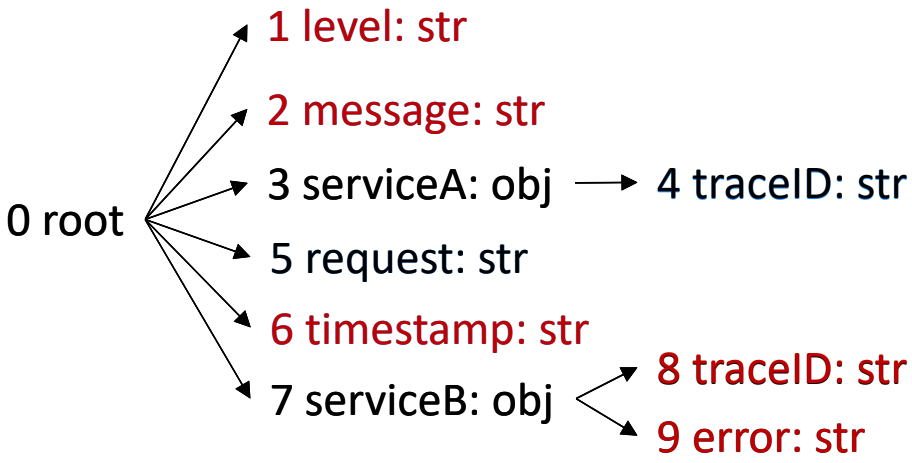
Schema Tree and Schema Map



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        "error": "application_error"
    },
    "timestamp": "2022-04-14T07:58:02.372Z"
}
```


- MPT and Schema Map takes up less than 0.001% of the total compressed data size

Data encoding and storage

Data encoding and storage

- Log records are stored in tables partitioned by schemas.

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    "timestamp": "…368Z"
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```

```
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    },
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}
```

Node ID	1	2	4	5	6
Encoded Vars	warn	Could not…	abc	1_vehicle_compliance	…368Z

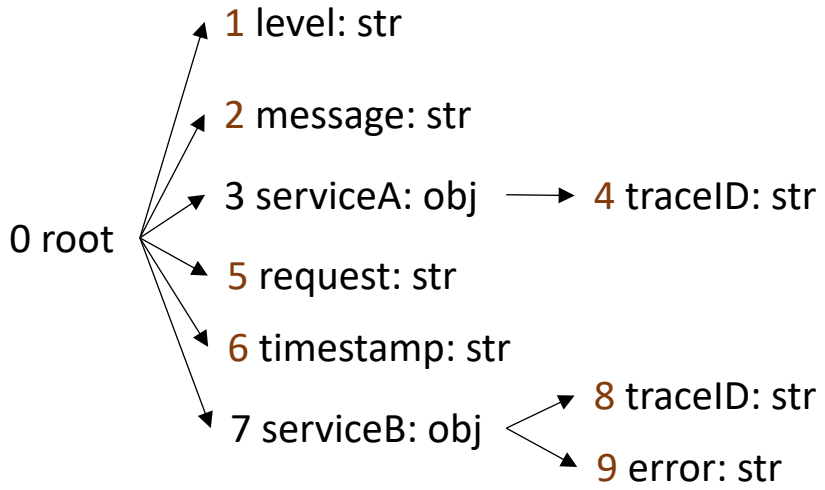
schema[0] Encoded Record Table

Node ID	1	2	6	8	9
Encoded Vars	error	Error…	xyz	application_error	…372Z

schema[1] Encoded Record Table

Node IDs	Schema ID
1 2 4 5 6	0
1 2 6 8 9	1

Schema Map



Merged Parsed Tree

Data encoding and storage

ID	Variable Value
V0	warn
V1	abc
V2	1_vehicle_compliance
V3	error
V4	xyz
V5	application_error

Variable Dictionary

Node IDs	Schema ID
1 2 4 5 6	0
1 2 6 8 9	1

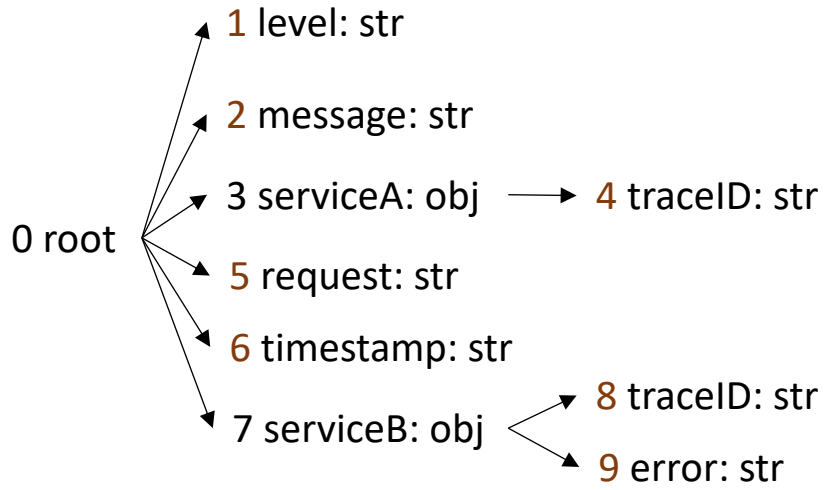
Schema Map

Node ID	1	2	4	5	6
Encoded Vars	V0	Could not…	V1	V2	…368Z

schema[0] Encoded Record Table

Node ID	1	2	6	8	9
Encoded Vars	V3	Error…	V4	V5	…372Z

schema[1] Encoded Record Table



Merged Parsed Tree

Data encoding and storage

ID	Variable Value
V0	warn
V1	abc
V2	1_vehicle_compliance
V3	error
V4	xyz
V5	application_error

Variable Dictionary

ID	Log Type
L0	Could not fetch cell for flow \INT.
L1	Error handling inbound request.

Log Type Dictionary

Node IDs	Schema ID
1 2 4 5 6	0
1 2 6 8 9	1

Schema Map

Node ID	1	2		4	5	6
Encoded Vars	V0	L0	1	V1	V2	…368Z

schema[0] Encoded Record Table

Node ID	1	2		6	8	9
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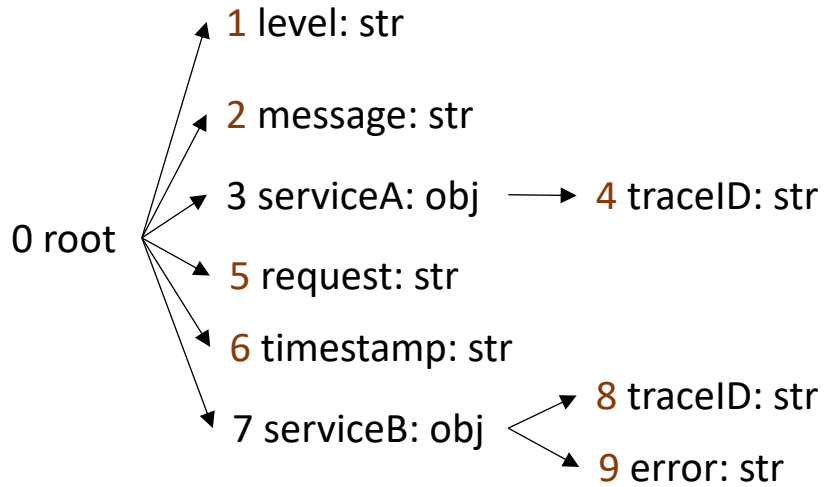
schema[1] Encoded Record Table



Merged Parsed Tree

Data encoding and storage

ID	Variable Value
V0	warn
V1	abc
V2	1_vehicle_compliance
V3	error
V4	xyz
V5	application_error

Variable Dictionary

ID	Log Type
L0	Could not fetch cell for flow \INT.
L1	Error handling inbound request.

Log Type Dictionary

ID	Format
T0	yyyy-MM-dd'T'HH:mm:ss'.'SSS'Z'

Timestamp Dictionary

Node IDs	Schema ID
1 2 4 5 6	0
1 2 6 8 9	1

Schema Map

Node ID	1	2		4	5	6	
Encoded Vars	V0	L0	1	V1	V2	T0	…368

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Node ID	1	2		6	8	9	
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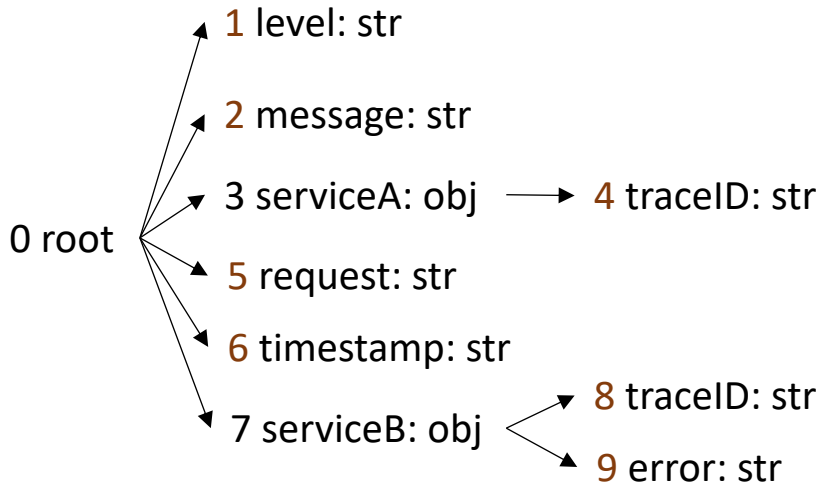
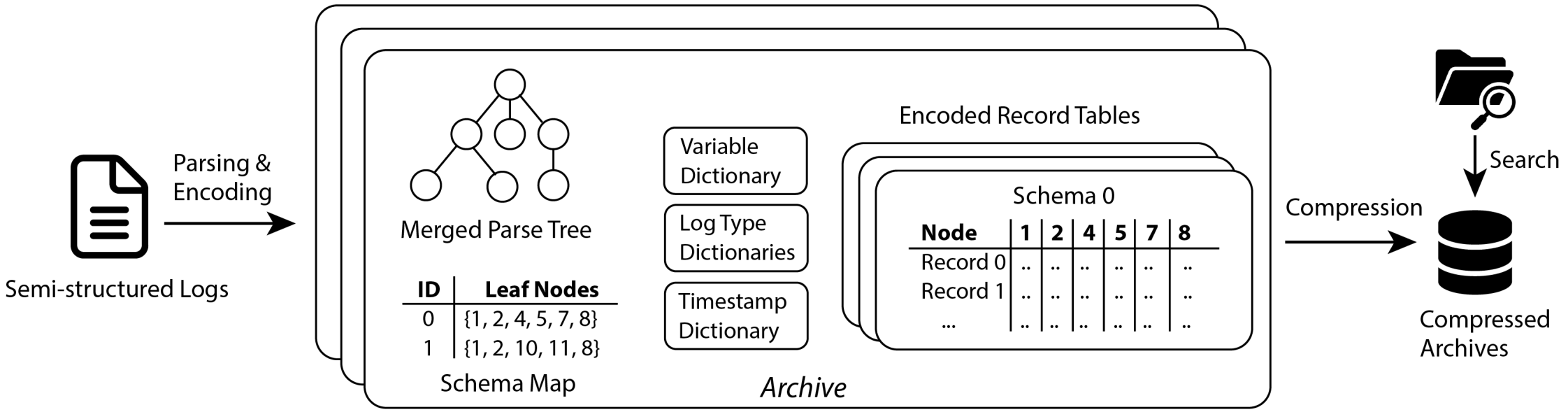
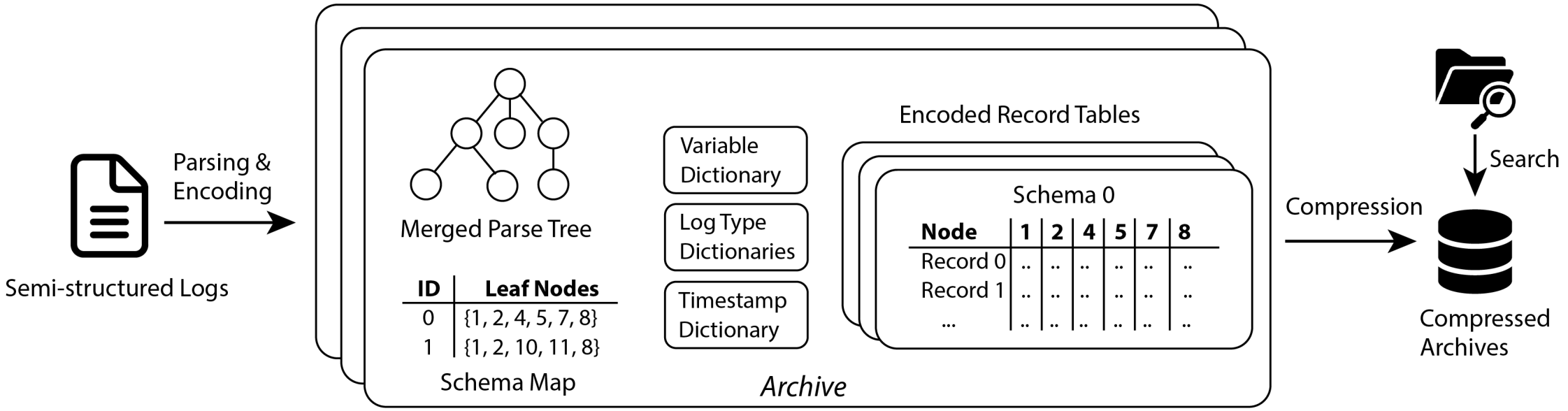


Merged Parsed Tree

μSlope architecture

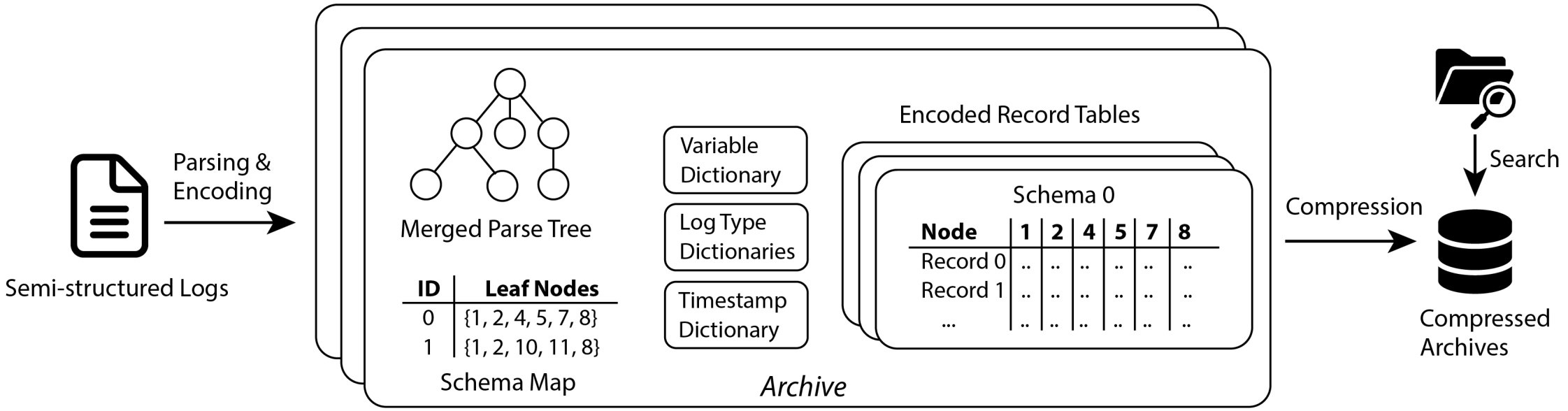


μSlope architecture



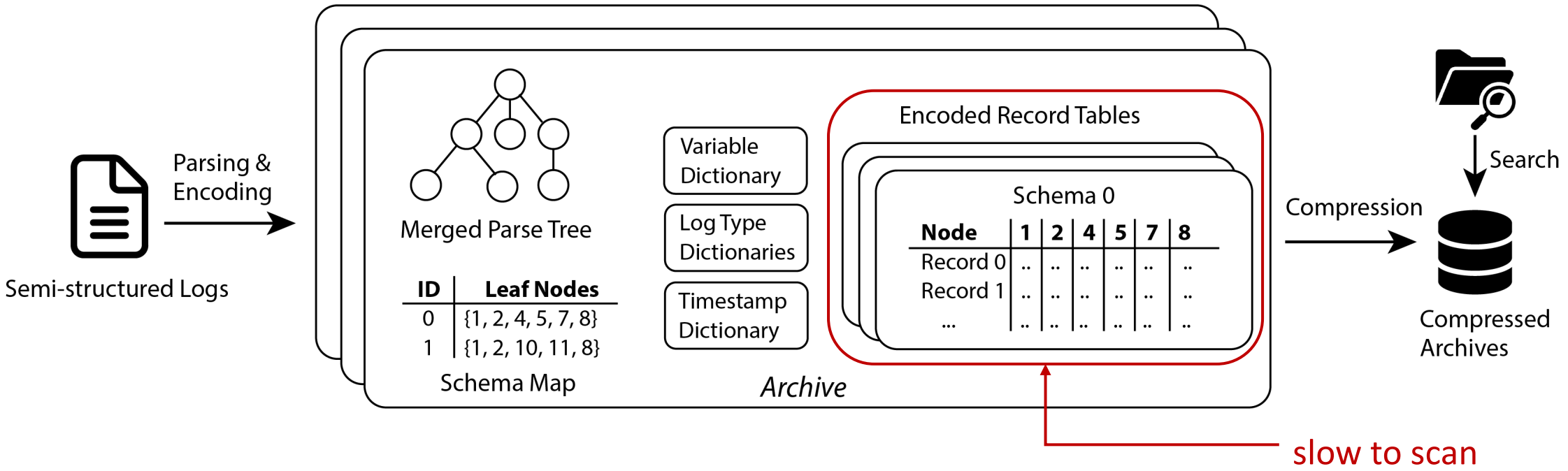
- Data is compressed into archives

μSlope architecture



- Data is compressed into archives
- Archives are independently searched and compressed

μSlope architecture



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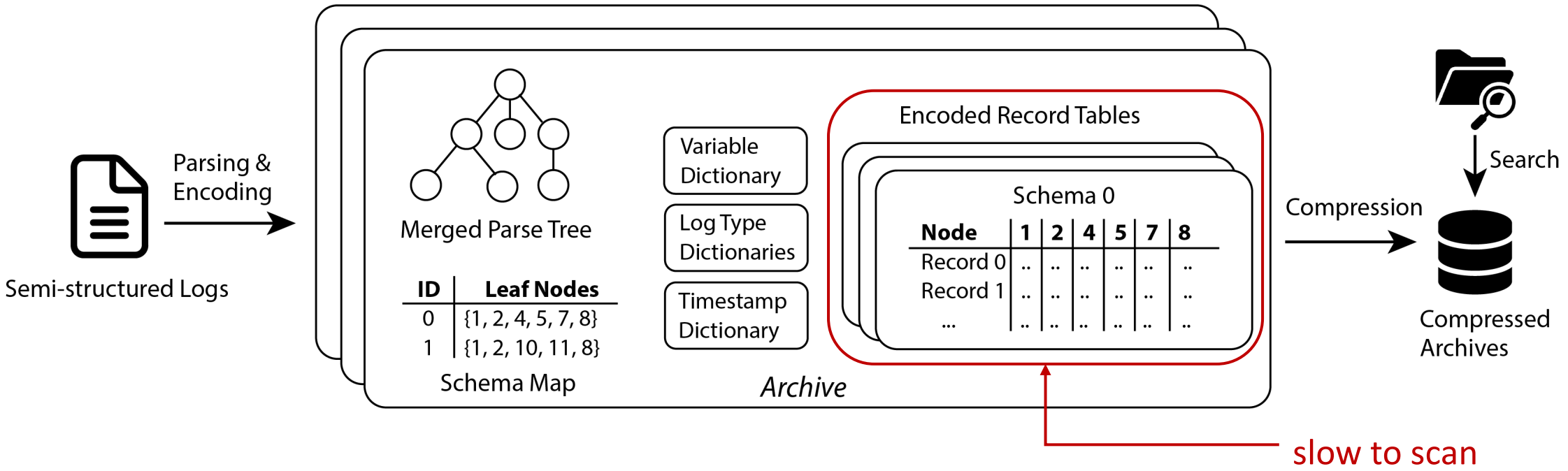
μSlope architecture



- Data is compressed into archives
- Archives are independently searched and compressed
- Schema metadata and dictionary lookup speed up search

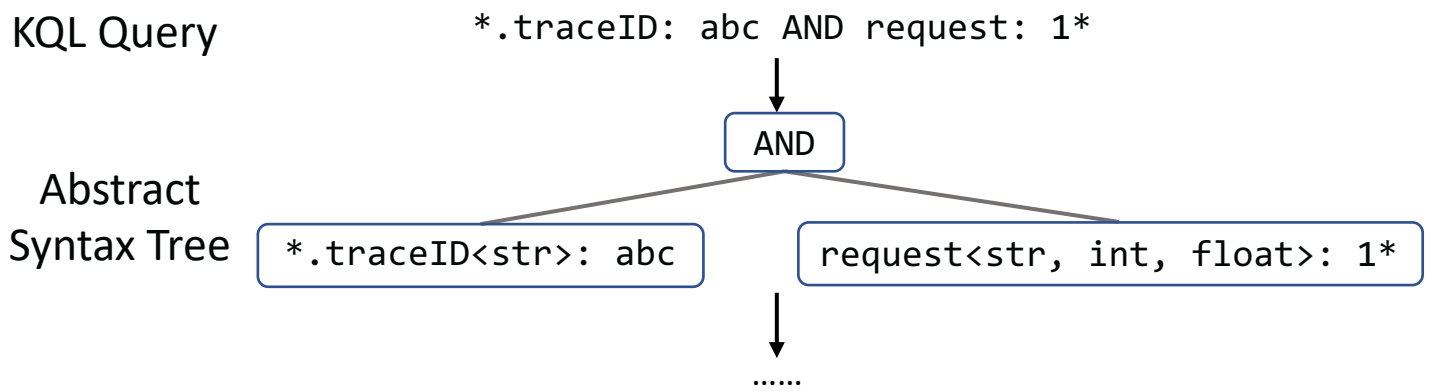
Search

Search

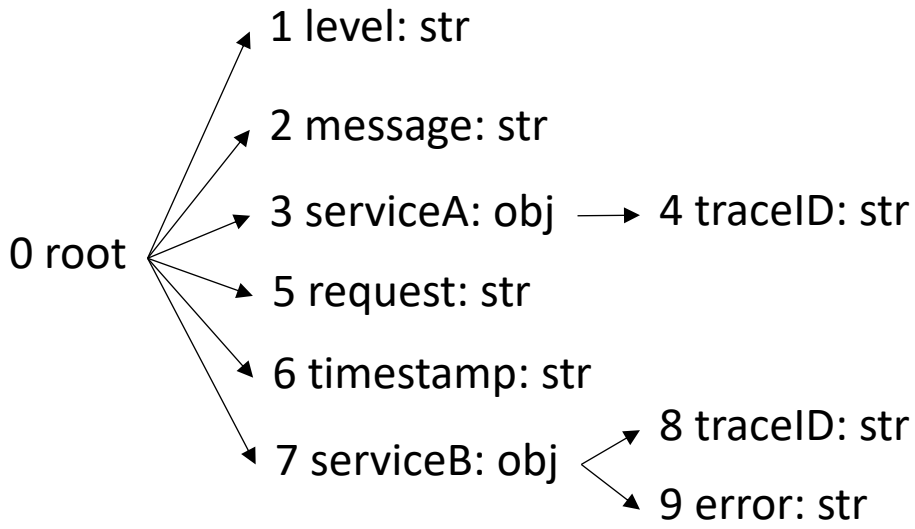
KQL Query

```
*.traceID: abc AND request: 1*
```

Search


KQL Query
.traceID: abc AND request: 1
Abstract
Syntax Tree
AND
*.traceID<str>: abc
request<str, int, float>: 1*
……

Search



Merged Parsed Tree

Node IDs	Schema ID
1 2 4 5 6	0
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Schema Map

KQL Query

```
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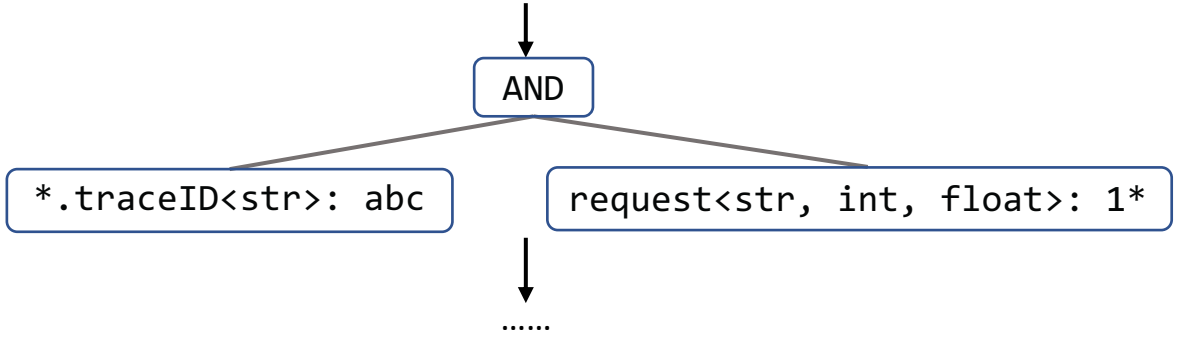
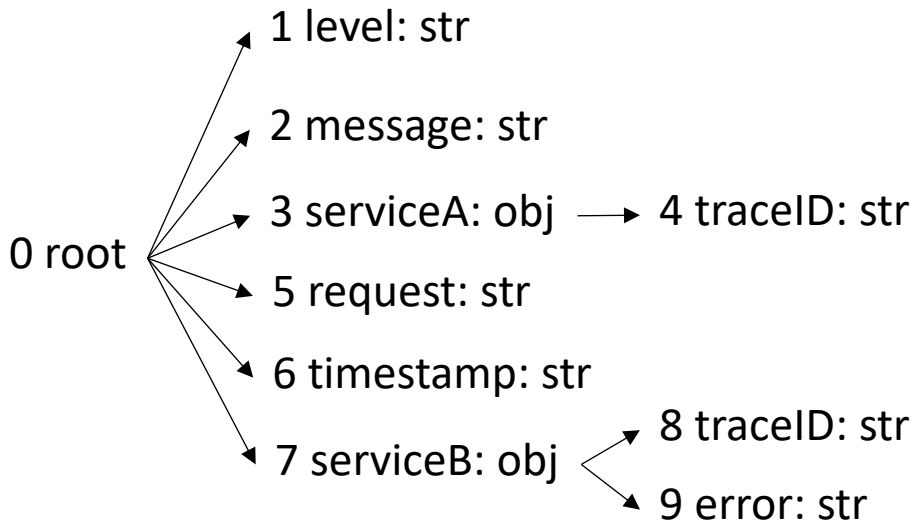
```

Abstract Syntax Tree



Search



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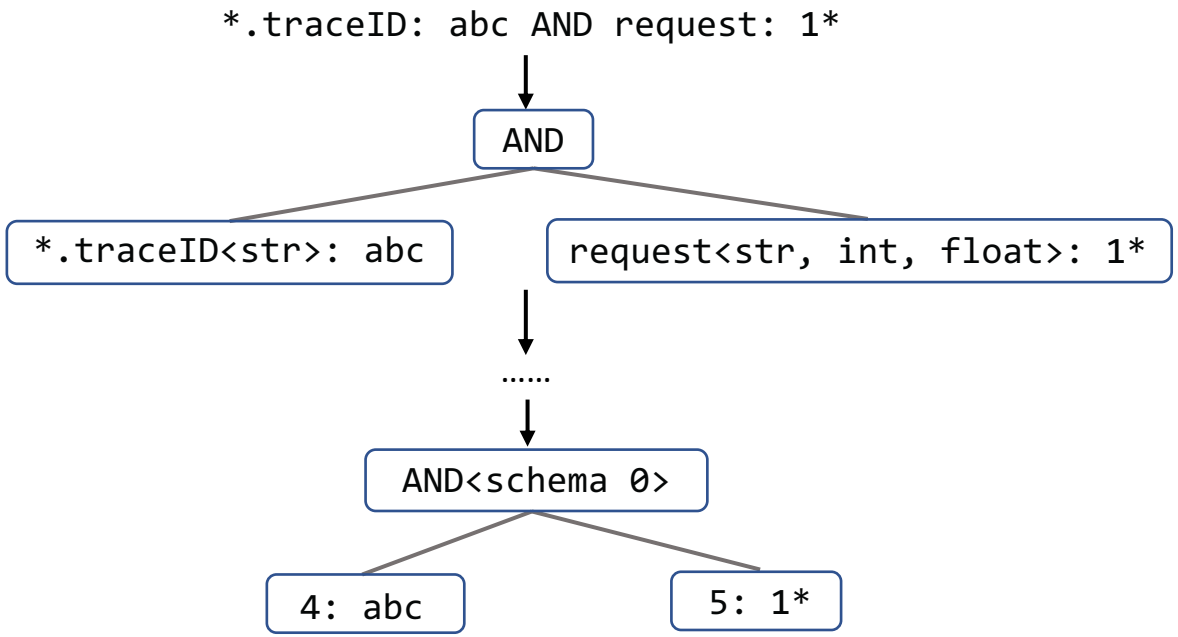
Schema Map

KQL Query

Abstract Syntax Tree

Query Plan Tree



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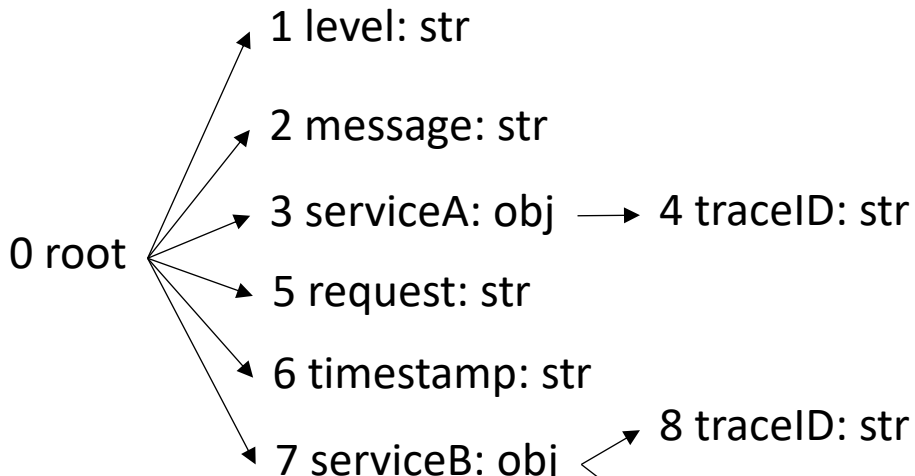

Merged Parsed Tree

Node IDs	Schema ID
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Schema Map

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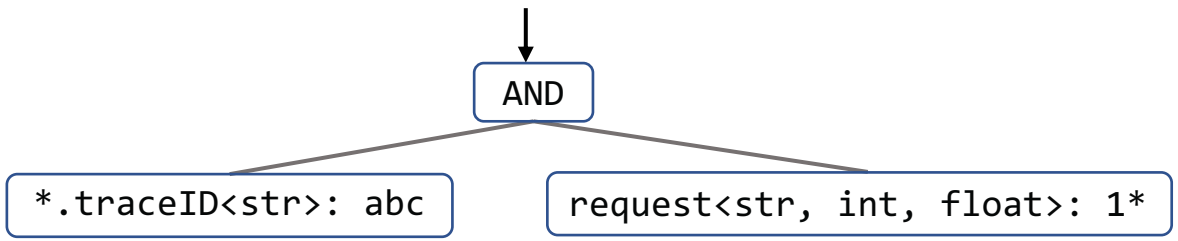

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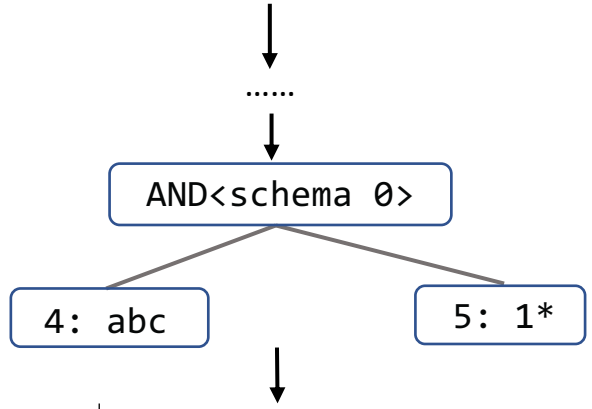
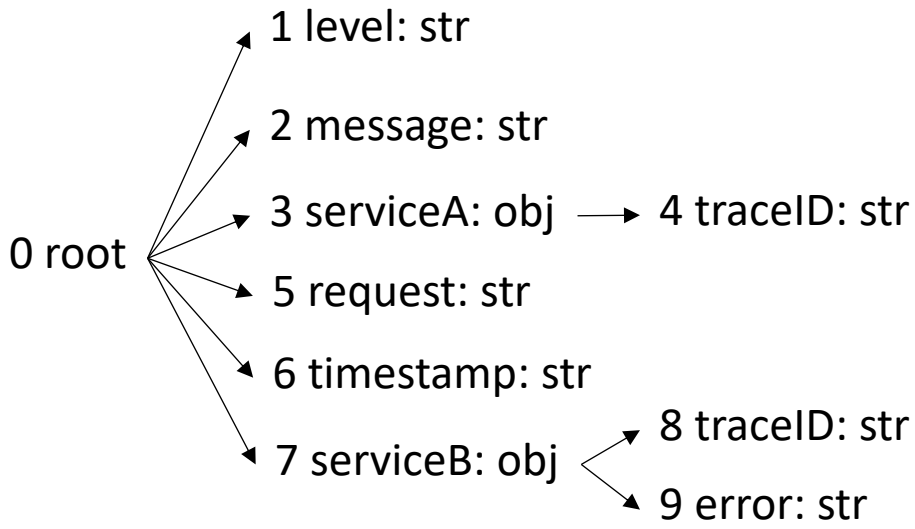


Search on Strings

ID	Variable Value
…	…
V1	abc
V2	1_vehicle_compliance
…	…

Search



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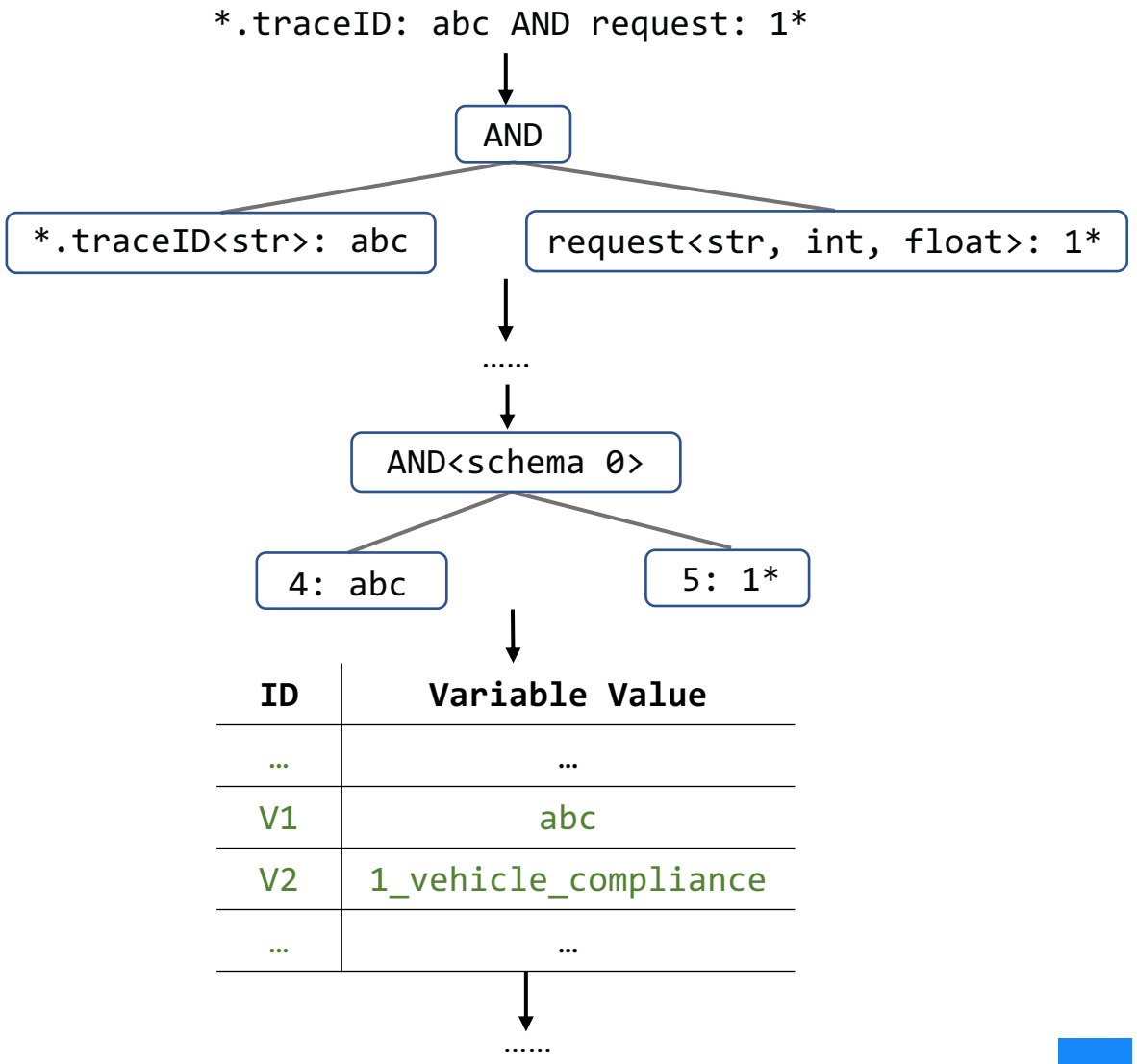

Evaluation

Evaluation

compression ratio

search performance

Evaluation

compression ratio

search performance

- In single-threaded setup and parallel setup

Evaluation

compression ratio

search performance

- In single-threaded setup and parallel setup
- 21 JSON datasets for compression
  - 16 from Uber (30.0GB to 102.9GB)
  - 5 from public software (392.8MB to 64.8GB)

	Name	Uncompressed Size	Number of Records
Uber Logs	LogA	30.0GB	22,996,492
	LogB	47.1GB	16,606,964
	LogC	60.4GB	15,306,125
	LogD	50.7GB	58,309,754
	LogE	91.8GB	22,345,071
	LogF	102.9GB	17,251,752
	LogG	30.9GB	3,046,845
	LogH	30.8GB	11,461,221
	LogI	39.7GB	27,209,375
	LogJ	36.0GB	13,605,274
	LogK	30.2GB	57,919,224
	LogL	37.1GB	45,827,554
	LogM	36.5GB	42,206,452
	LogN	38.0GB	22,307,407
	LogO	38.6GB	4,438,786
	LogP	38.3GB	34,840,347
Public Logs	Spark	2.0GB	1,011,651
	MongoDB	64.8GB	186,287,600
	CockroachDB	9.8GB	16,520,377
	elasticsearch	8.0GB	140,012,234
	PostgreSQL	392.8MB	1,000,000

Evaluation

compression ratio

search performance

- In single-threaded setup and parallel setup
- 21 JSON datasets for compression
  - 16 from Uber (30.0GB to 102.9GB)
  - 5 from public software (392.8MB to 64.8GB)
- 15 queries on 3 datasets

	Name	Uncompressed Size	Number of Records
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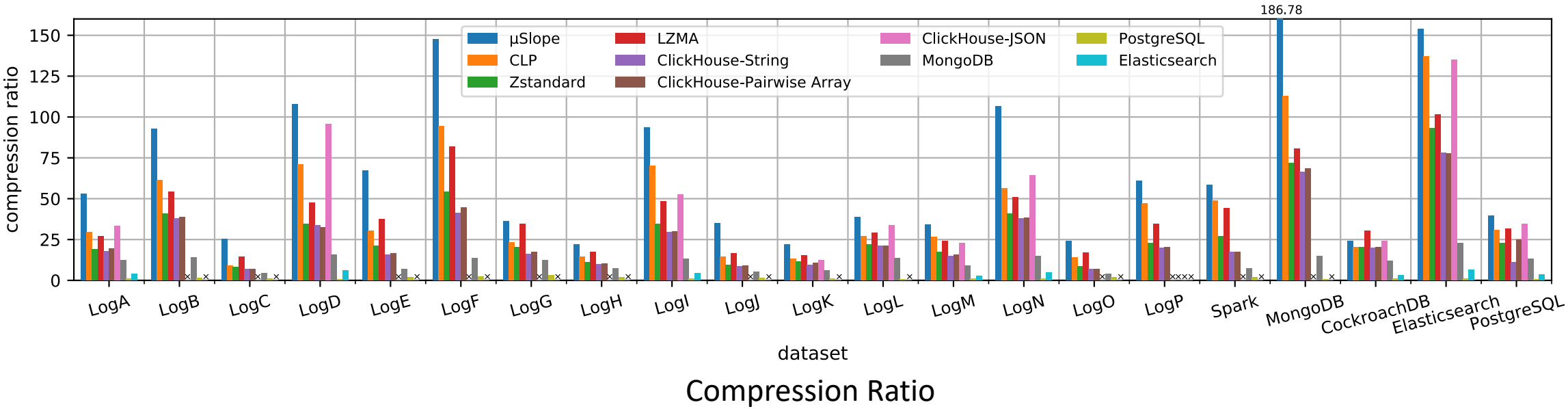
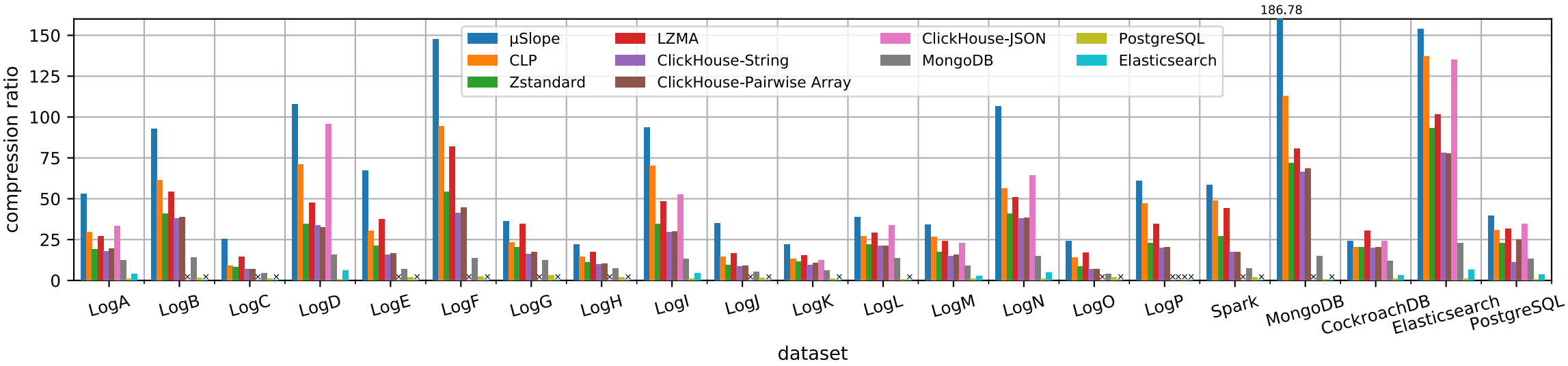
Compression performance



Compression Ratio

Compression performance



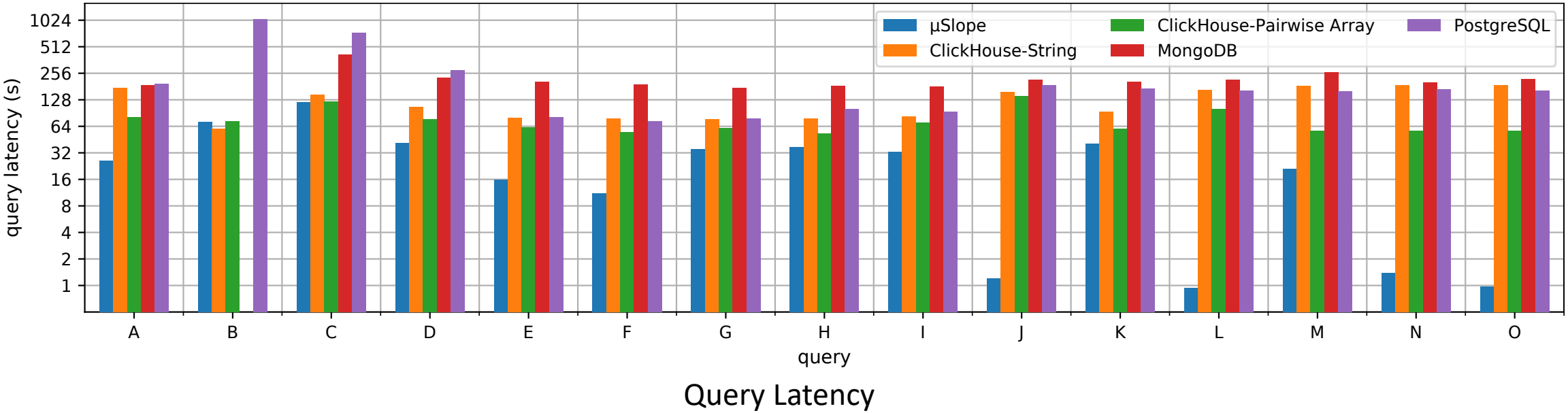
Compression Ratio

The average compression ratio of μSlope is **68.1:1**

- 1.5x of CLP's
- 1.7x of LZMA's
- 2.3x of Zstandard's
- 6.1x of MongoDB's
- 15.7x of Elasticsearch's

Query performance

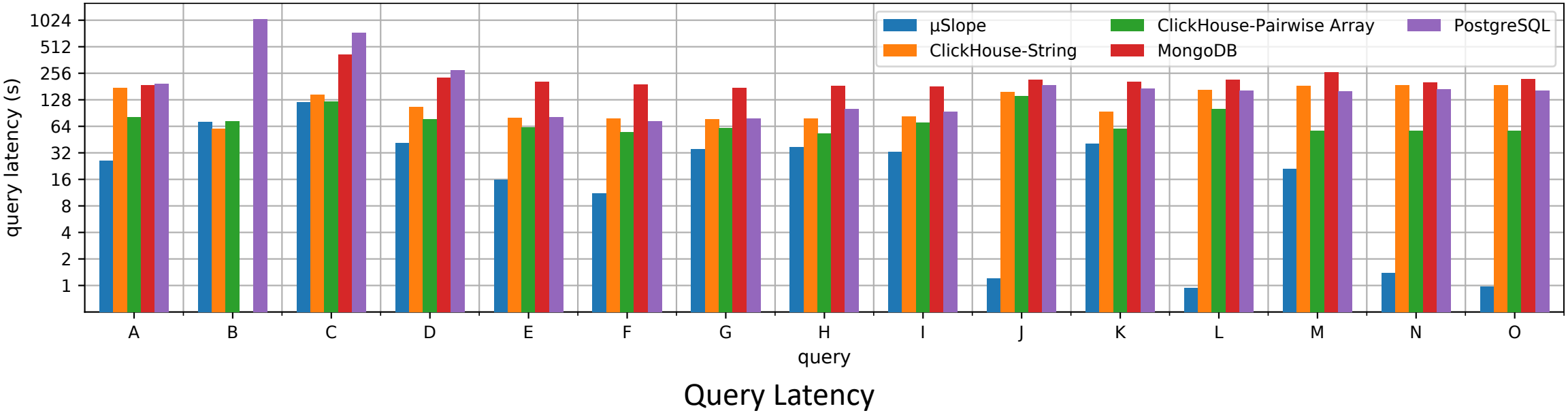
- 9 queries from Uber and 6 from public software



Query Latency

Query performance

- 9 queries from Uber and 6 from public software



Query Latency

μSlope is
- 2.5x faster than the fastest setup of ClickHouse
- 6.7x faster than MongoDB
- 8.1x faster than PostgreSQL

Conclusion

μSlope: An efficient semi-structured log management system that

- Handles dynamic schema structures
- Achieves unprecedented compression ratio
- Allows search without full decompression

- Open-sourced at *https://github.com/y-scope/clp*!
- Our email: info@yscope.com

YScope Uber UNIVERSITY OF TORONTO