Relational Database Similarity Detection via Network Traffic Analysis

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Research objective

Present and evaluate methods for measuring similarities between complex software systems where there is no access to the internal structure of the system , such as access to the source code or even compiled server binaries.

Similarity Detection

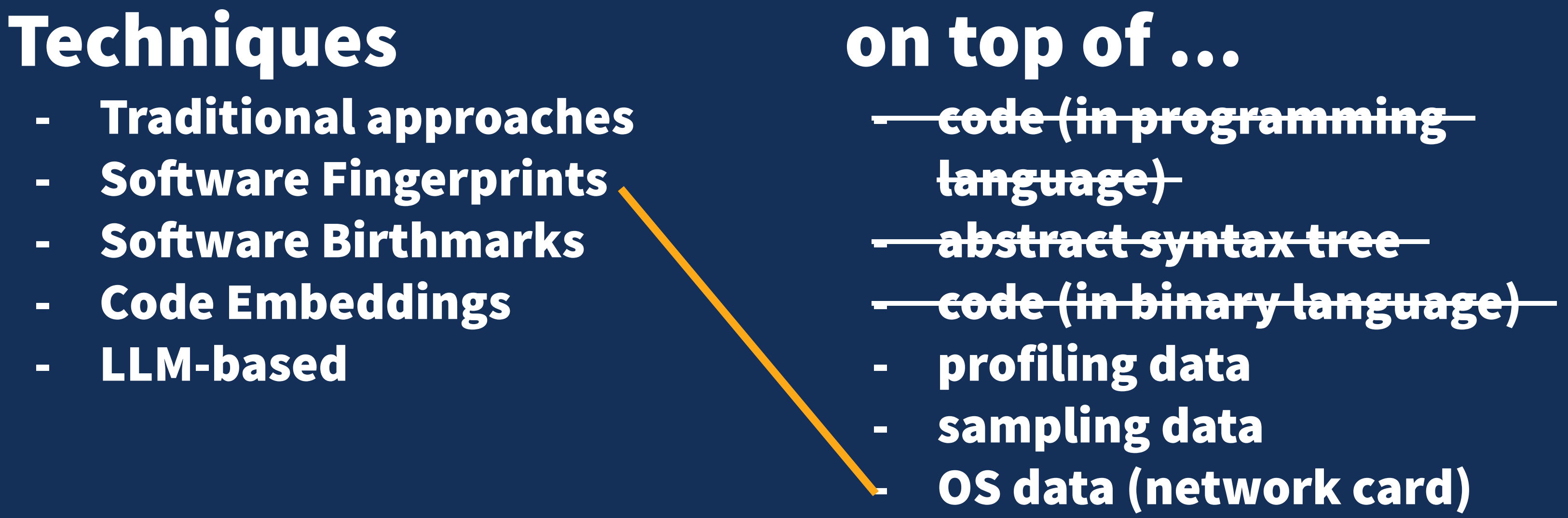
Techniques

- Traditional approaches
- Software Fingerprints
- Software Birthmarks
- Code Embeddings
- LLM-based

on top of ...

- code (in programming language)
- abstract syntax tree
- code (in binary language)
- profiling data
- sampling data
- OS data

Similarity Detection
(via Network Traffic Analysis)



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- Software Birthmarks
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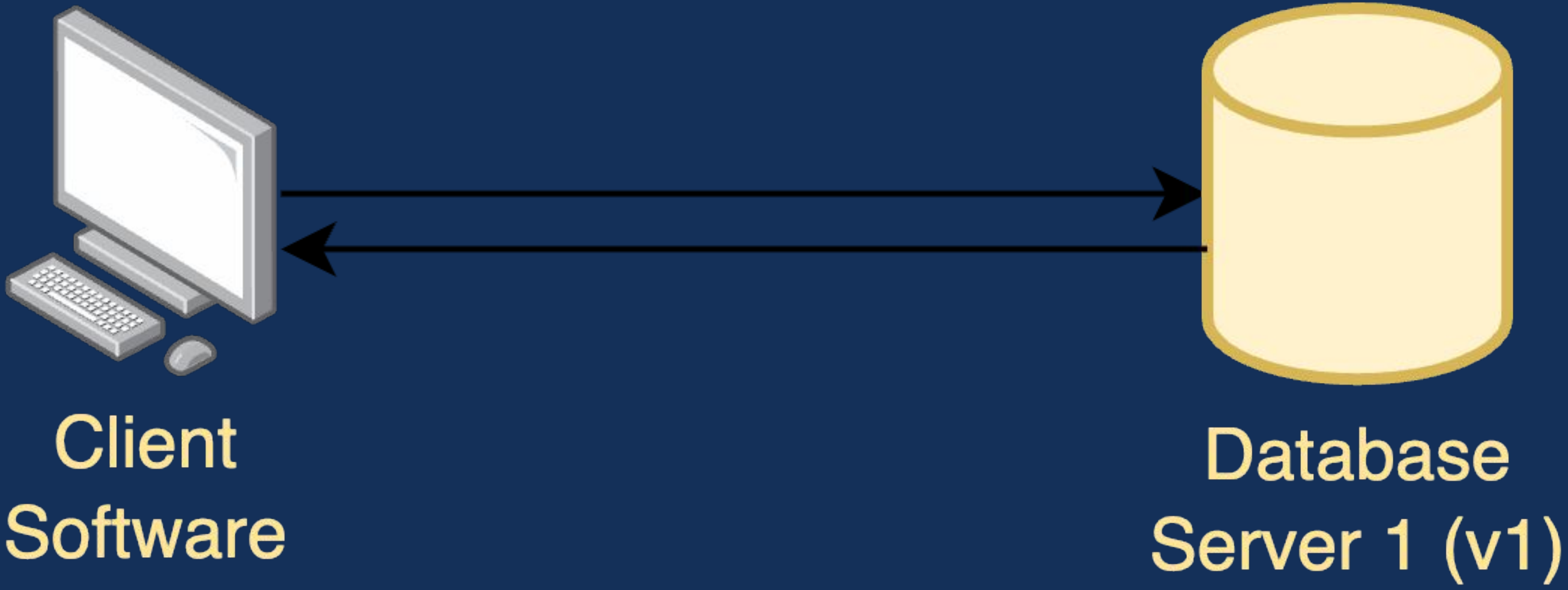
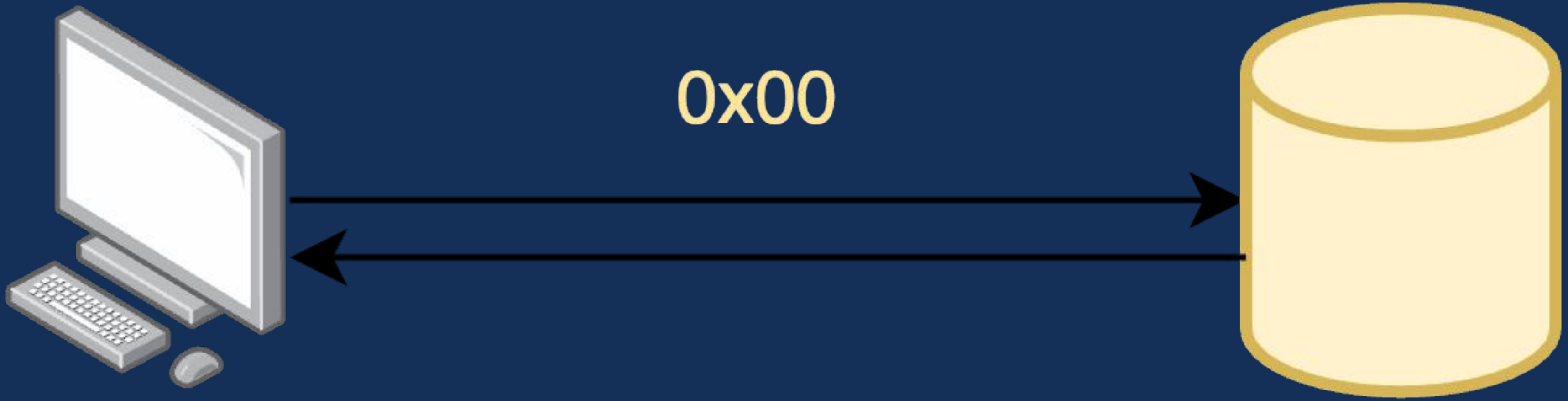
on top of …

- ~~code (in programming language)~~
- ~~abstract syntax tree~~
- ~~code (in binary language)~~
- profiling data
- sampling data
- OS data (network card)

Available monitoring tools



Available monitoring tools

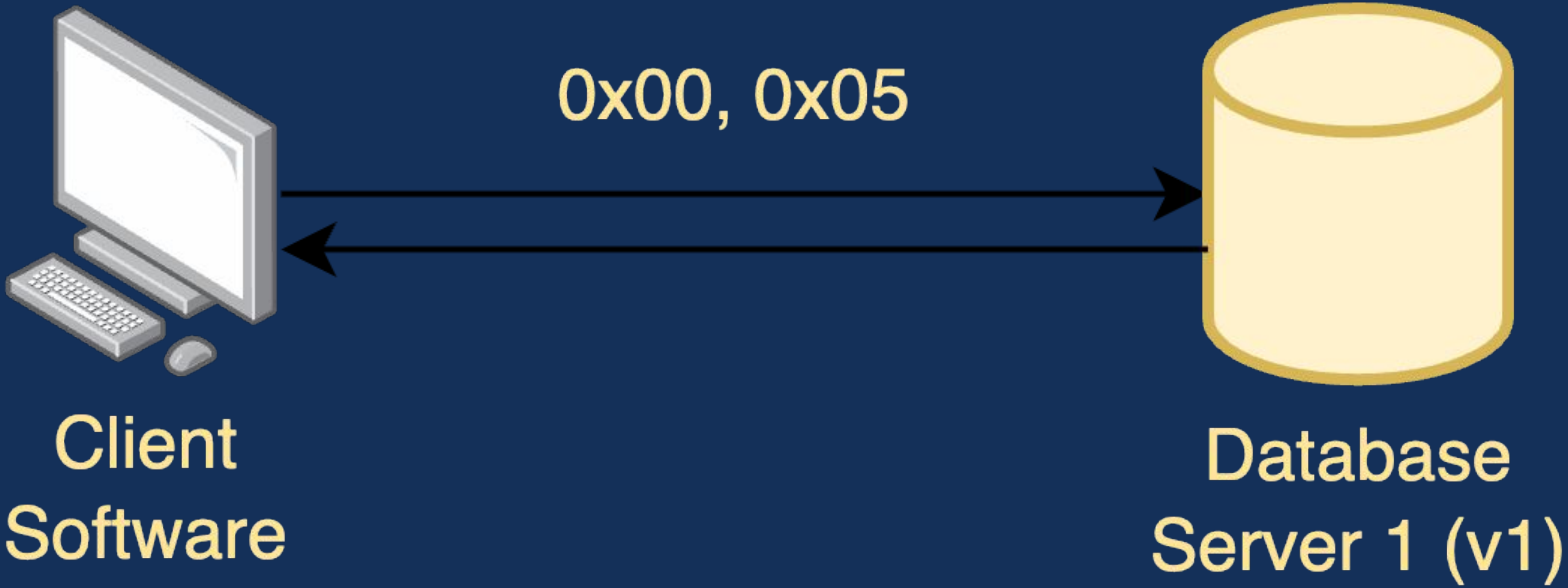


0x00

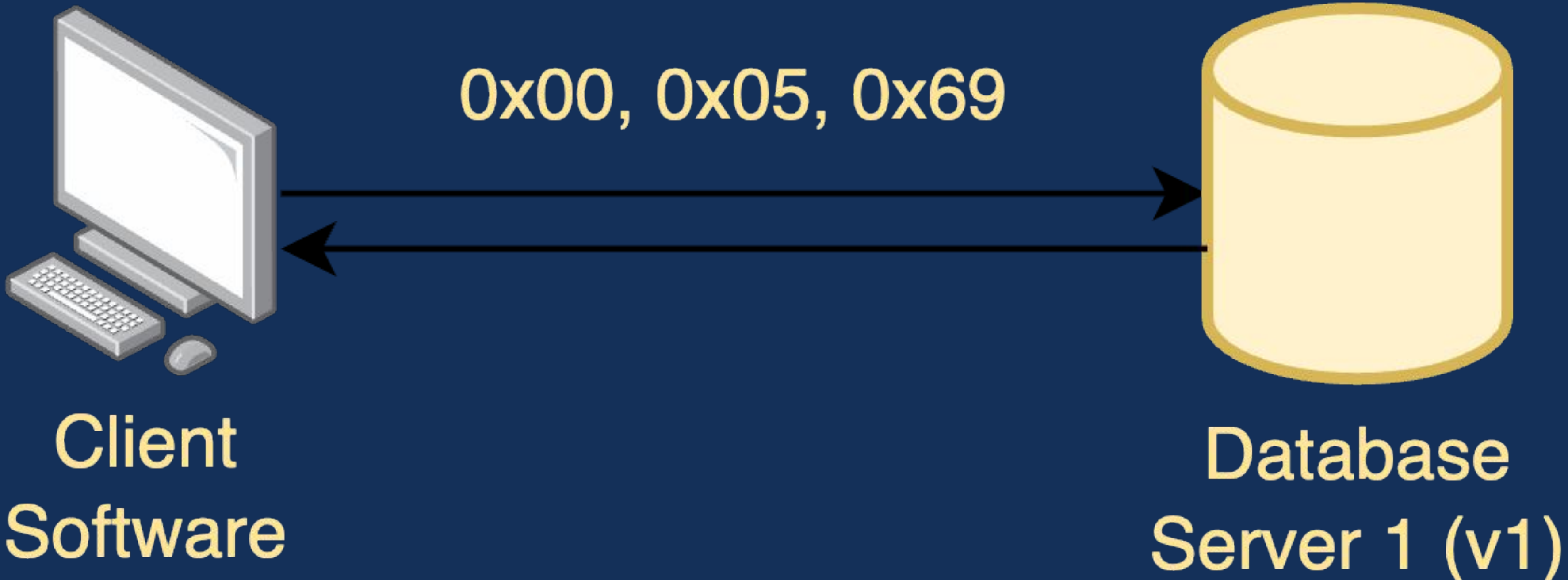
Client
Software

Database
Server 1 (v1)

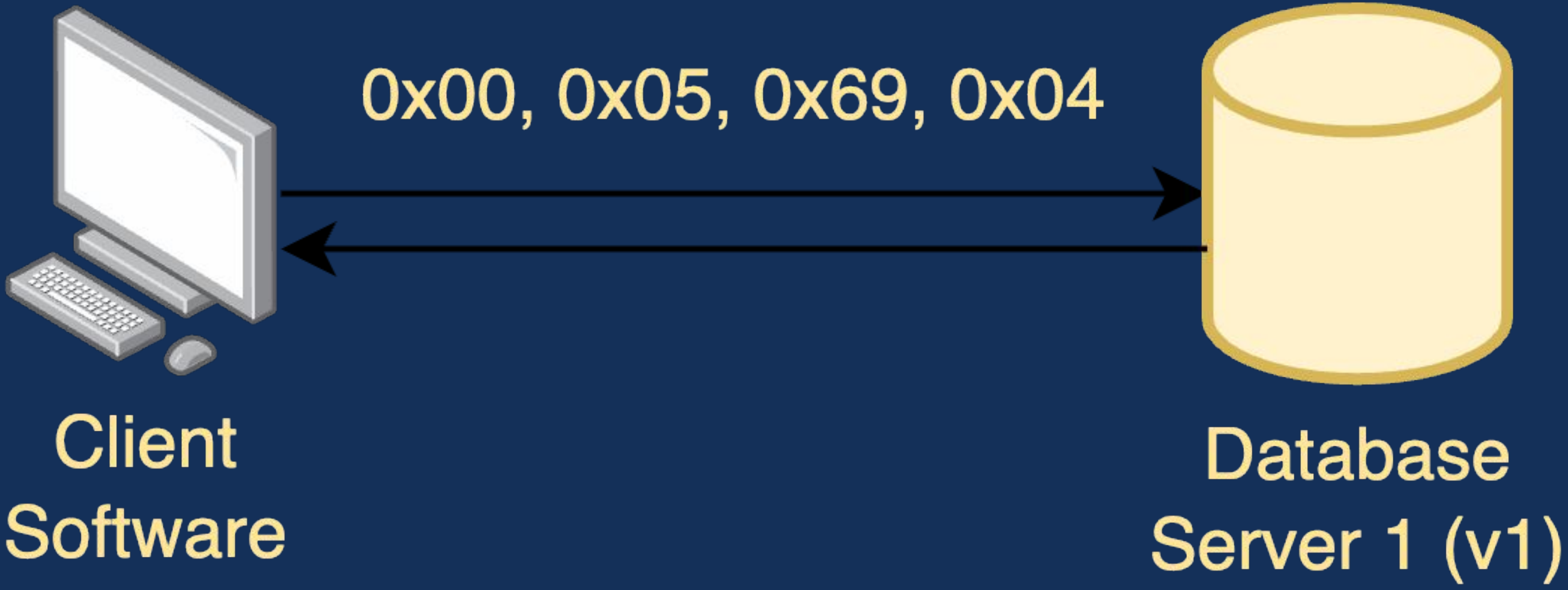
Available monitoring tools



Available monitoring tools



Available monitoring tools



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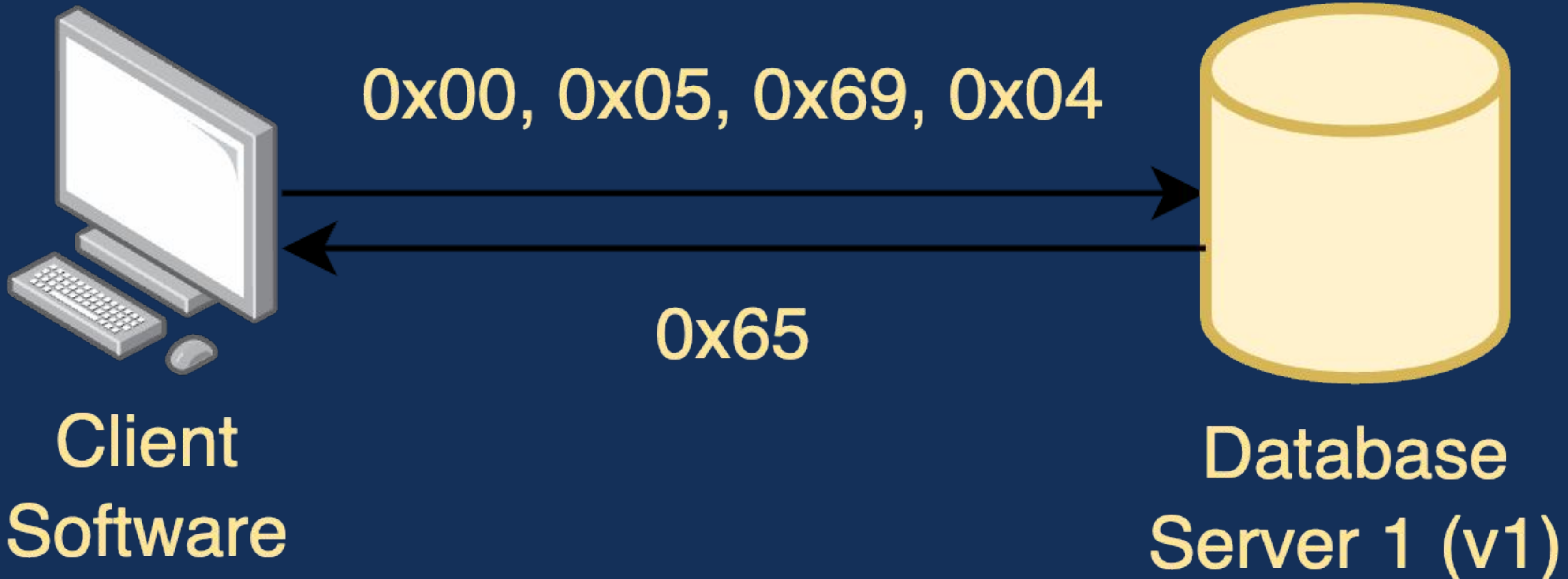
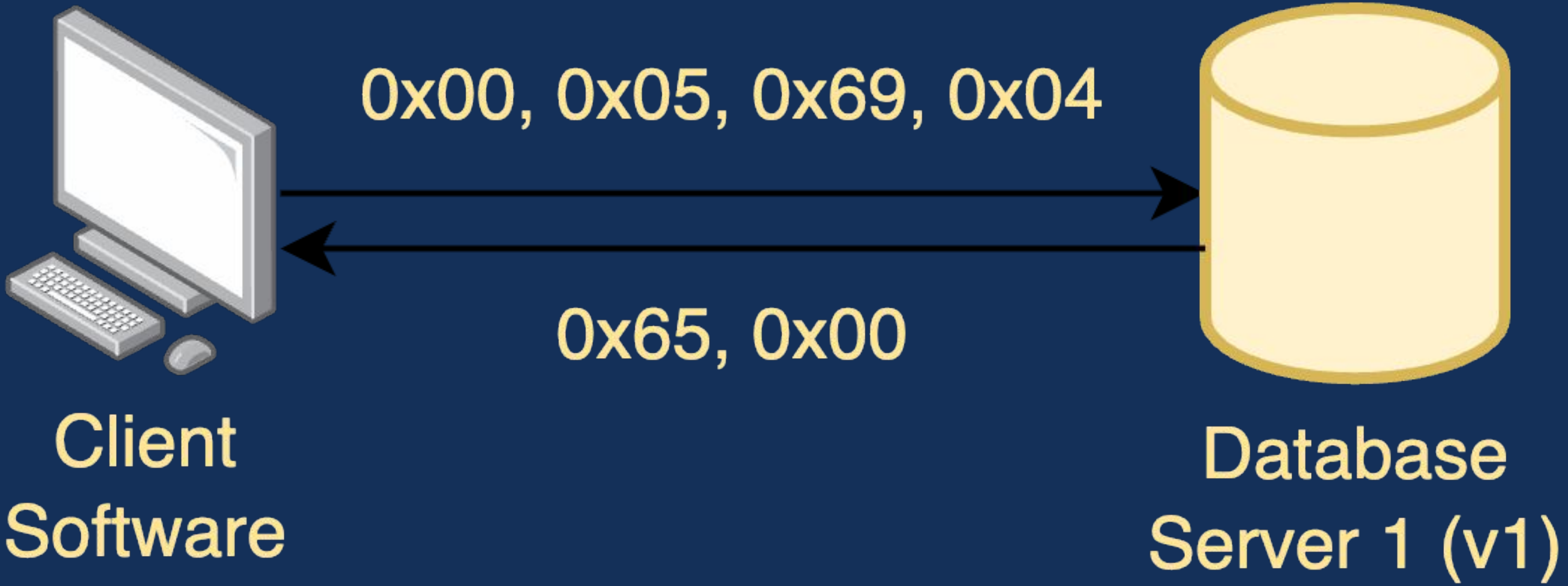
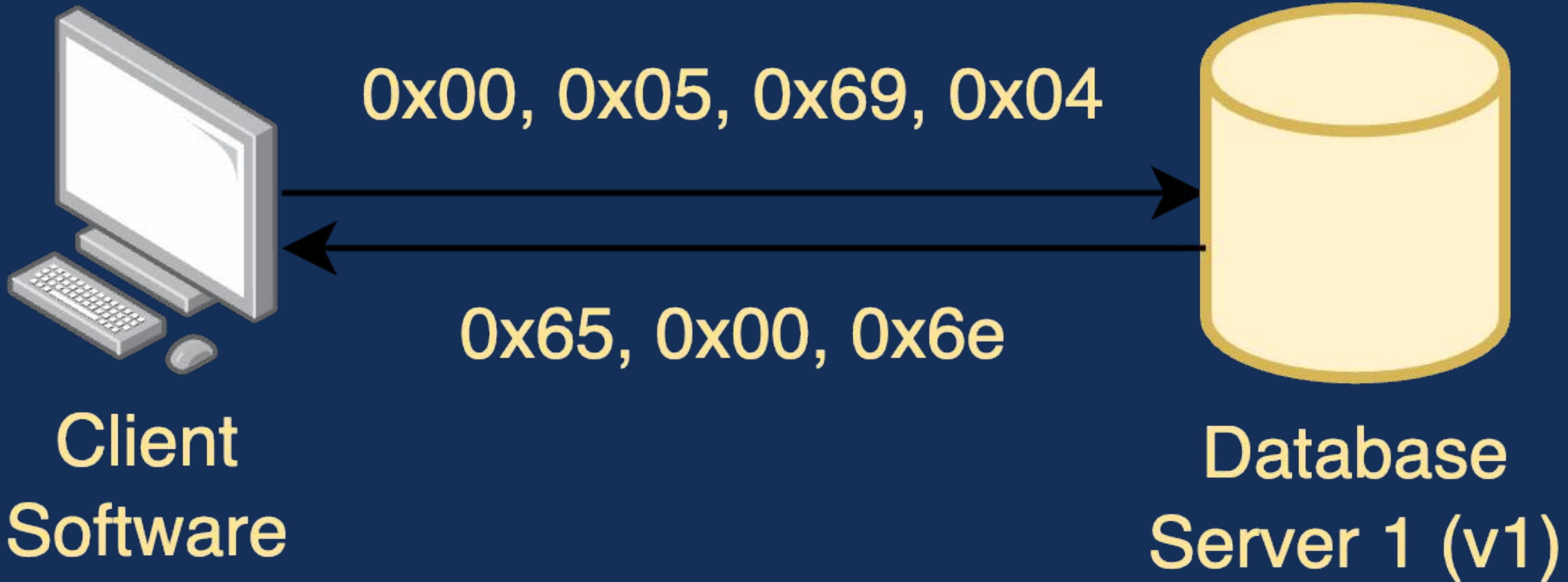


Available monitoring tools



Available monitoring tools



0x00, 0x05, 0x69, 0x04

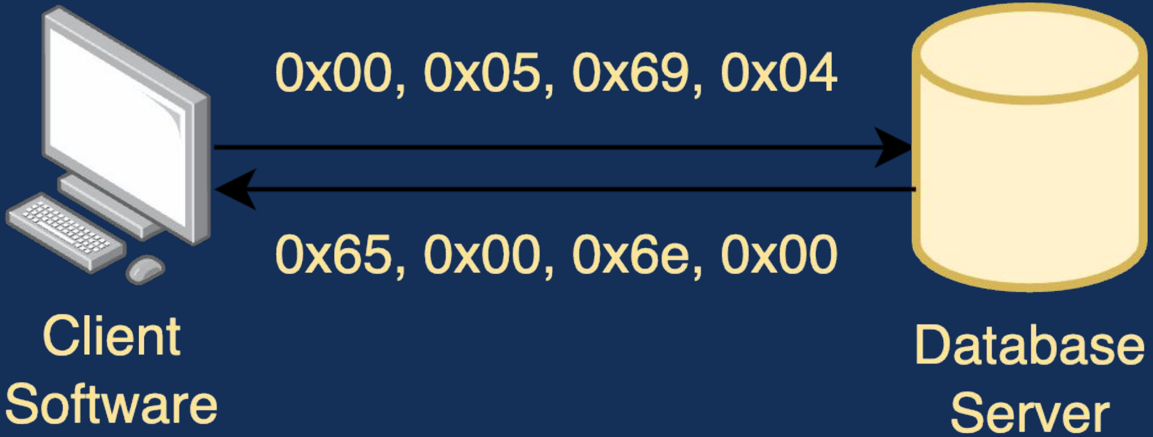
0x65, 0x00, 0x6e

Client Software

Database Server 1 (v1)

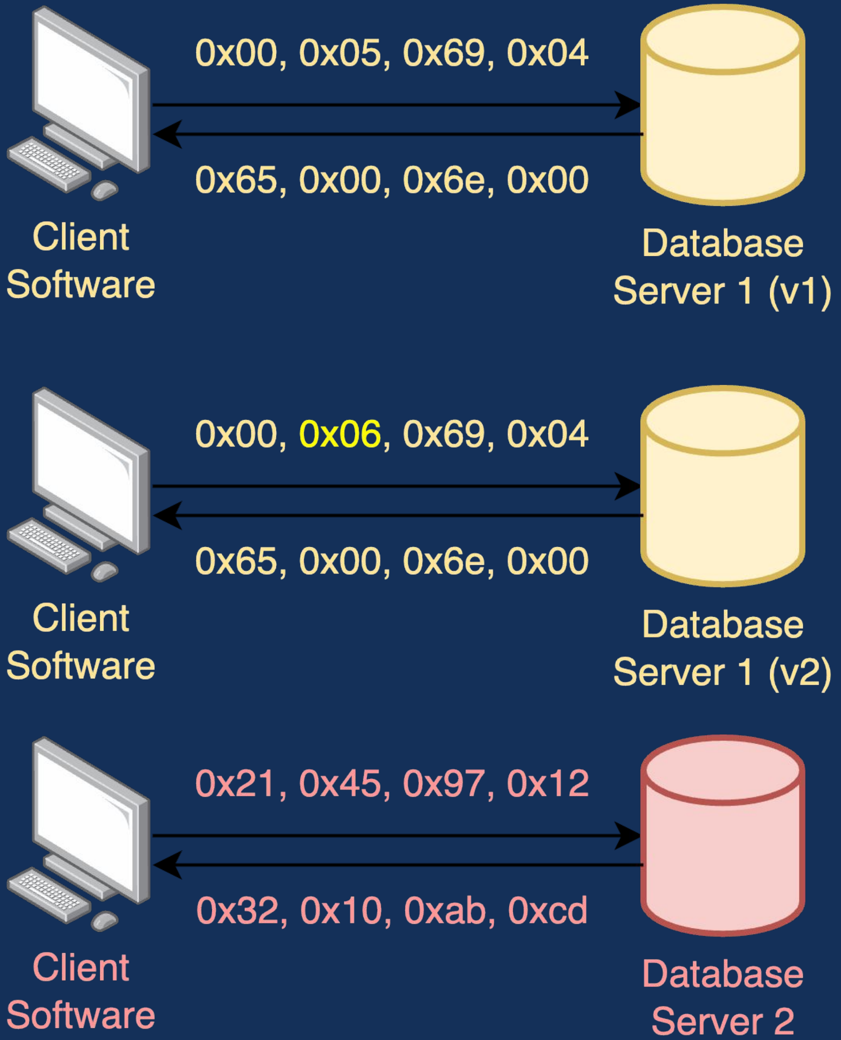
Hypothesis

Similar software systems will exhibit comparable communication patterns at application layer, while different systems will show distinct ones.



Research scope

Similar database engines will exhibit comparable communication patterns, while different engines will show distinct patterns.



Analysed software

3 database types (MySQL, PostgreSQL, SQL Server)
20 major versions
2 deployments (official Docker images, Google Cloud SQL)

31 unique databases configurations

Corpus

Several (tens) MB of data of intercepted database traffic, capturing the interaction between **clients** and **database engines** , during regular interactions (simple interactions, sysbench, custom benchmarks).

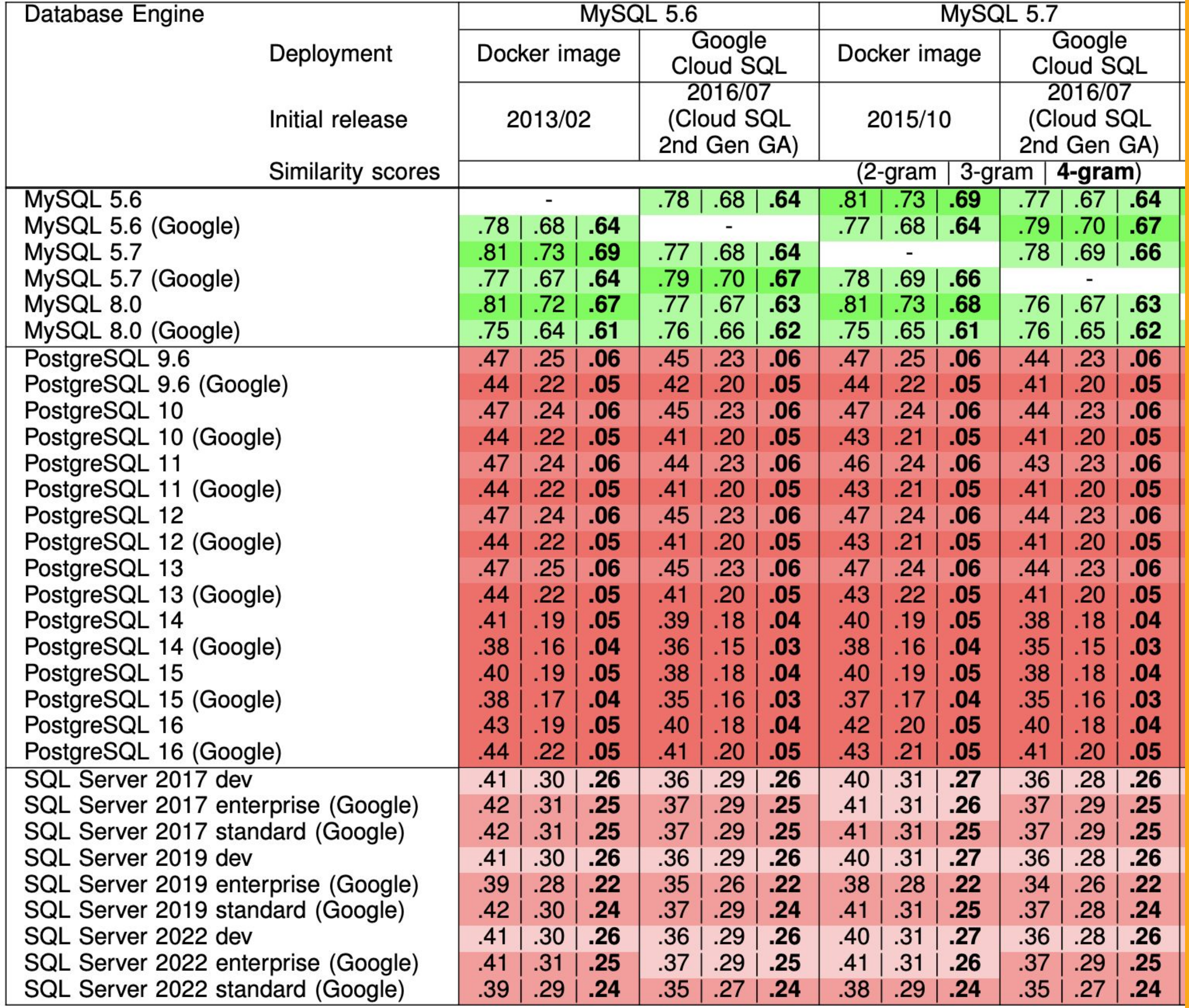
Similarity Score Function

4-grams : sequential word combinations

TF-IDF : word importance score

cosine distance : vector angle difference

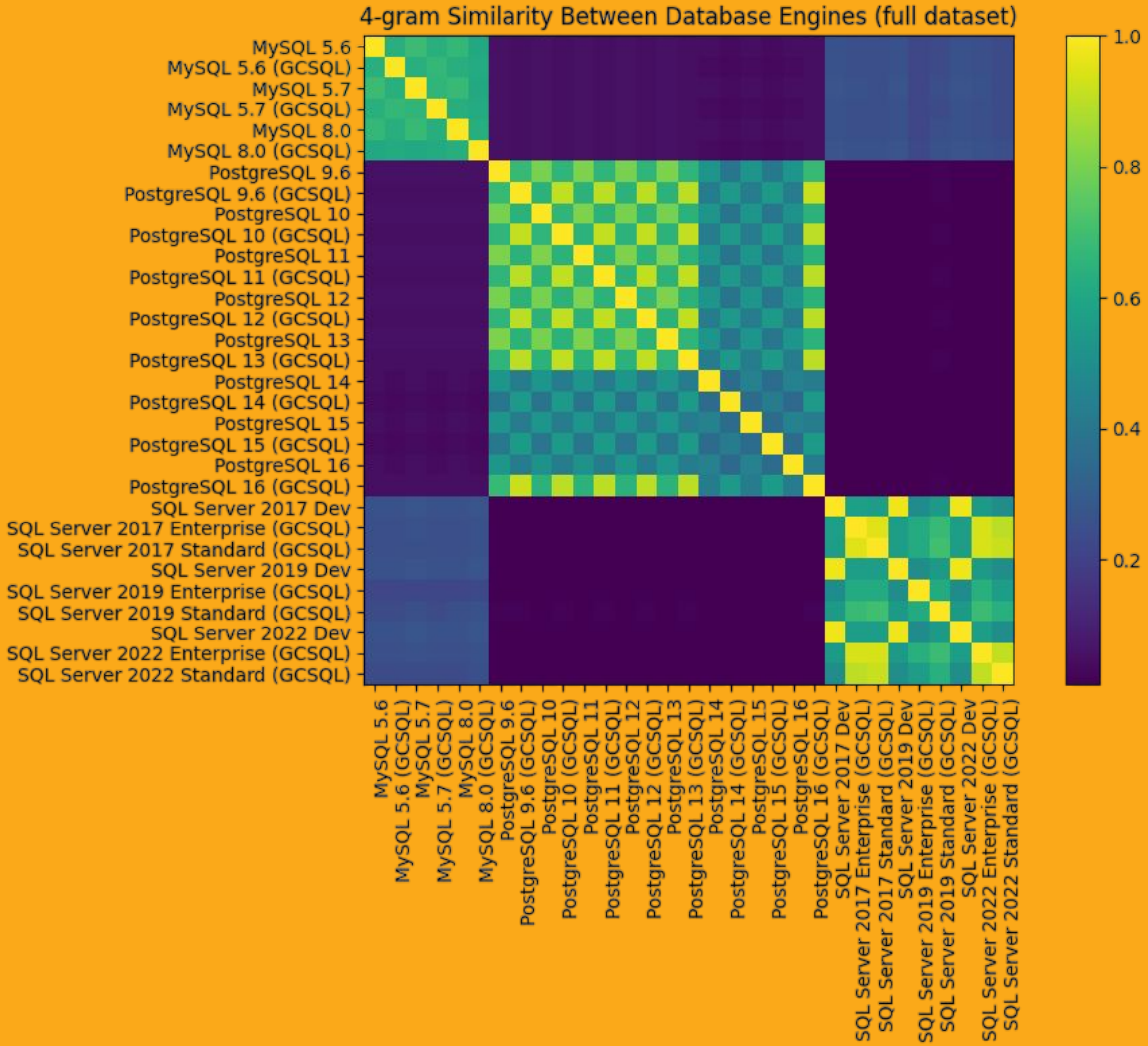
MySQL v. other engines



Database Engine	MySQL 5.6						MySQL 5.7					
Deployment	Docker image			Google Cloud SQL			Docker image			Google Cloud SQL		
Initial release	2013/02			2016/07 (Cloud SQL 2nd Gen GA)			2015/10			2016/07 (Cloud SQL 2nd Gen GA)		
Similarity scores							(2-gram	3-gram	**4-gram**)			
MySQL 5.6	-			.78	.68	**.64**	.81	.73	**.69**	.77	.67	**.64**
MySQL 5.6 (Google)	.78	.68	**.64**	-			.77	.68	**.64**	.79	.70	**.67**
MySQL 5.7	.81	.73	**.69**	.77	.68	**.64**	-			.78	.69	**.66**
MySQL 5.7 (Google)	.77	.67	**.64**	.79	.70	**.67**	.78	.69	**.66**	-		
MySQL 8.0	.81	.72	**.67**	.77	.67	**.63**	.81	.73	**.68**	.76	.67	**.63**
MySQL 8.0 (Google)	.75	.64	**.61**	.76	.66	**.62**	.75	.65	**.61**	.76	.65	**.62**
PostgreSQL 9.6	.47	.25	**.06**	.45	.23	**.06**	.47	.25	**.06**	.44	.23	**.06**
PostgreSQL 9.6 (Google)	.44	.22	**.05**	.42	.20	**.05**	.44	.22	**.05**	.41	.20	**.05**
PostgreSQL 10	.47	.24	**.06**	.45	.23	**.06**	.47	.24	**.06**	.44	.23	**.06**
PostgreSQL 10 (Google)	.44	.22	**.05**	.41	.20	**.05**	.43	.21	**.05**	.41	.20	**.05**
PostgreSQL 11	.47	.24	**.06**	.44	.23	**.06**	.46	.24	**.06**	.43	.23	**.06**
PostgreSQL 11 (Google)	.44	.22	**.05**	.41	.20	**.05**	.43	.21	**.05**	.41	.20	**.05**
PostgreSQL 12	.47	.24	**.06**	.45	.23	**.06**	.47	.24	**.06**	.44	.23	**.06**
PostgreSQL 12 (Google)	.44	.22	**.05**	.41	.20	**.05**	.43	.21	**.05**	.41	.20	**.05**
PostgreSQL 13	.47	.25	**.06**	.45	.23	**.06**	.47	.24	**.06**	.44	.23	**.06**
PostgreSQL 13 (Google)	.44	.22	**.05**	.41	.20	**.05**	.43	.22	**.05**	.41	.20	**.05**
PostgreSQL 14	.41	.19	**.05**	.39	.18	**.04**	.40	.19	**.05**	.38	.18	**.04**
PostgreSQL 14 (Google)	.38	.16	**.04**	.36	.15	**.03**	.38	.16	**.04**	.35	.15	**.03**
PostgreSQL 15	.40	.19	**.05**	.38	.18	**.04**	.40	.19	**.05**	.38	.18	**.04**
PostgreSQL 15 (Google)	.38	.17	**.04**	.35	.16	**.03**	.37	.17	**.04**	.35	.16	**.03**
PostgreSQL 16	.43	.19	**.05**	.40	.18	**.04**	.42	.20	**.05**	.40	.18	**.04**
PostgreSQL 16 (Google)	.44	.22	**.05**	.41	.20	**.05**	.43	.21	**.05**	.41	.20	**.05**
SQL Server 2017 dev	.41	.30	**.26**	.36	.29	**.26**	.40	.31	**.27**	.36	.28	**.26**
SQL Server 2017 enterprise (Google)	.42	.31	**.25**	.37	.29	**.25**	.41	.31	**.26**	.37	.29	**.25**
SQL Server 2017 standard (Google)	.42	.31	**.25**	.37	.29	**.25**	.41	.31	**.25**	.37	.29	**.25**
SQL Server 2019 dev	.41	.30	**.26**	.36	.29	**.26**	.40	.31	**.27**	.36	.28	**.26**
SQL Server 2019 enterprise (Google)	.39	.28	**.22**	.35	.26	**.22**	.38	.28	**.22**	.34	.26	**.22**
SQL Server 2019 standard (Google)	.42	.30	**.24**	.37	.29	**.24**	.41	.31	**.25**	.37	.28	**.24**
SQL Server 2022 dev	.41	.30	**.26**	.36	.29	**.26**	.40	.31	**.27**	.36	.28	**.26**
SQL Server 2022 enterprise (Google)	.41	.31	**.25**	.37	.29	**.25**	.41	.31	**.26**	.37	.29	**.25**
SQL Server 2022 standard (Google)	.39	.29	**.24**	.35	.27	**.24**	.38	.29	**.24**	.35	.27	**.24**

High similarity between different versions of the same database engine.

Low similarity when comparing different database engines.



4-gram similarity scores between various database versions

High similarity between different versions of the same database engine.

Low similarity when comparing different database engines.

Conclusions

It seems possible to distinguish between different relational database engines (e.g. MySQL, PostgreSQL, and SQL Server) and even different versions or deployment environments of the same engine, solely by examining their network traffic at application layer .

The research used n-gram analysis (specifically 4-grams) of network traffic bytes and TF-IDF analysis with cosine similarity to quantify these similarities.

Thank you!

Follow Project Martial development:

https://github.com/raresraf/project-martial