Deep dive into the PostgreSQL Frontend/Backend protocol

Xavier Fischer
Swiss PGDay 2026

Who is using **psql**?

How on Earth is this possible?

you type a query text, and…

```
dvdrental=# select * from actor limit 10;
 actor_id | first_name |  last_name   |        last_update
----------+------------+--------------+----------------------------
        1 | Penelope   | Guiness      | 2013-05-26 14:47:57.62
        2 | Nick       | Wahlberg     | 2013-05-26 14:47:57.62
        3 | Ed         | Chase        |                      :57.62
        4 | Jennifer   | Davis        |                      :57.62
        5 | Johnny     | Lollobrigida |                      :57.62
        6 | Bette      | Nicholson    |                      :57.62
```

… you get data back !!

psql does NOT know beforehand

- if the query syntax is OK
- how many columns the results will have
- the name, type for each column value

```
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----------+------------+---------------+------------------------
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        6 | Bette      | Nicholson     | 2013-05-26 14:47:57.62
```

This is handled by libpq (the “**connector**”) after exchanging several messages with PostgreSQL

Who am I

Xavier Fischer

- Principal Software Engineer at EDB since 2023
- Working on EDB .NET Connector
- 20+ years of experience in .NET / database development
- Hailing in Aix-en-Provence, France

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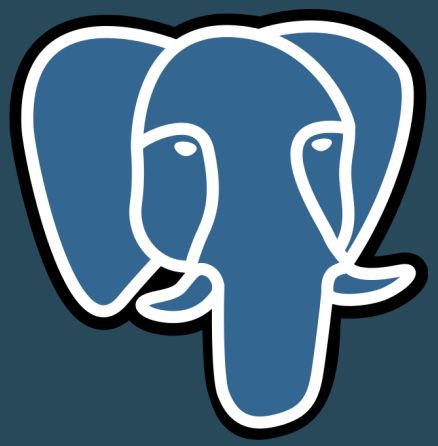
What is a **connector**?

it's a **database driver**

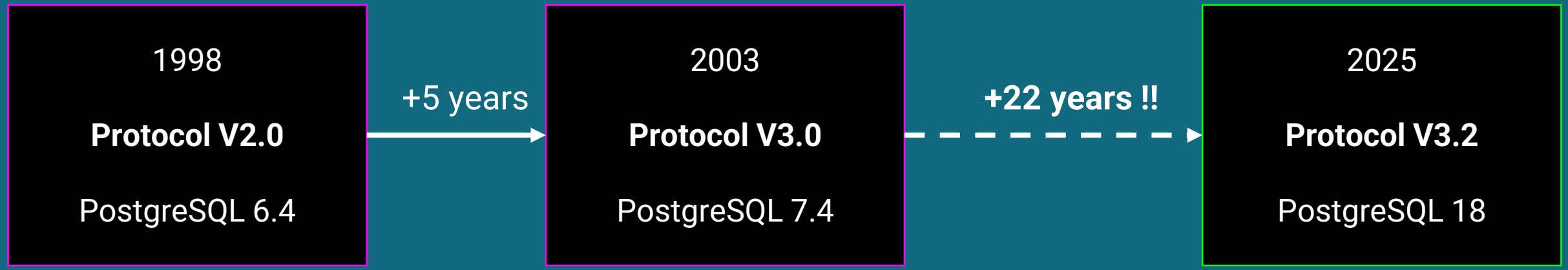
available in **your programming language**
will **translate** calls to database language using
the **wire protocol**
aka the Frontend/Backend protocol

what's the **wire protocol**?

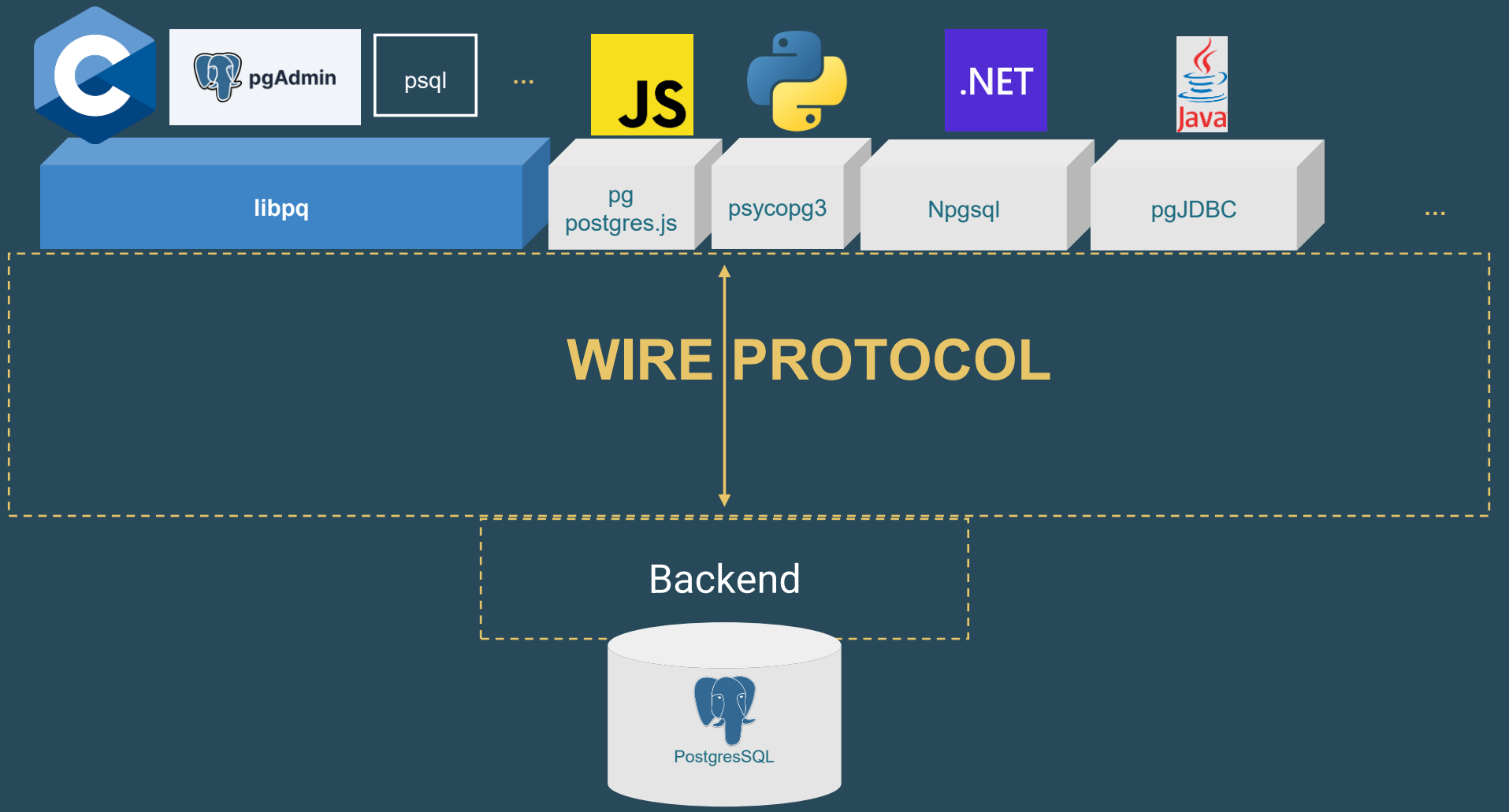
It’s the PostgreSQL **message-based** protocol between **frontends and backends** (clients, servers, poolers, tools, ...) over TCP/IP or Unix sockets



Protocol history



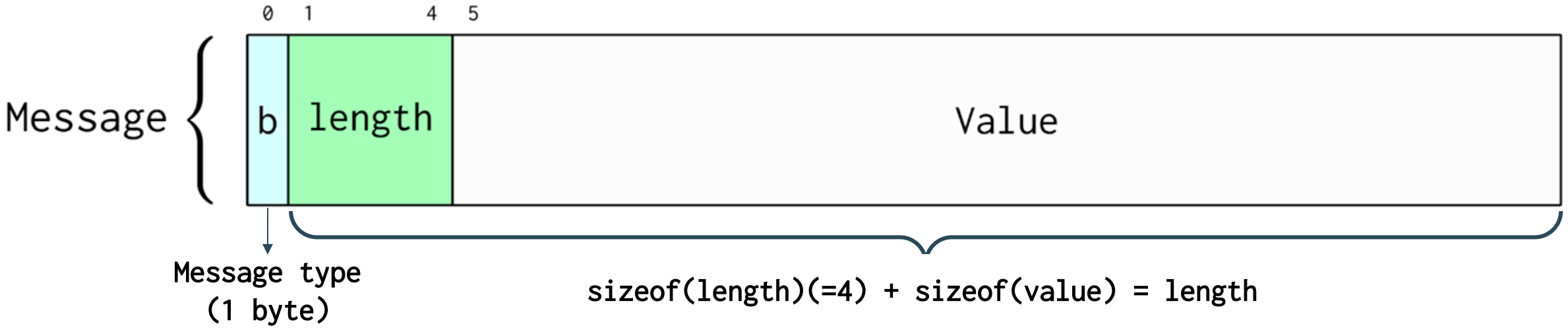
Postgres Connector landscape



protocol messages

Protocol message format 101

Messages are usually Type-Length-Value (TLV)



=> If a new protocol is released, unknown messages can be skipped easily

Protocol conversation 101

TCP or Unix socket connection

Encryption channel

SCRAM

Direct

Password

GSSAPI

...

Simple Query
Extended Query

Replication

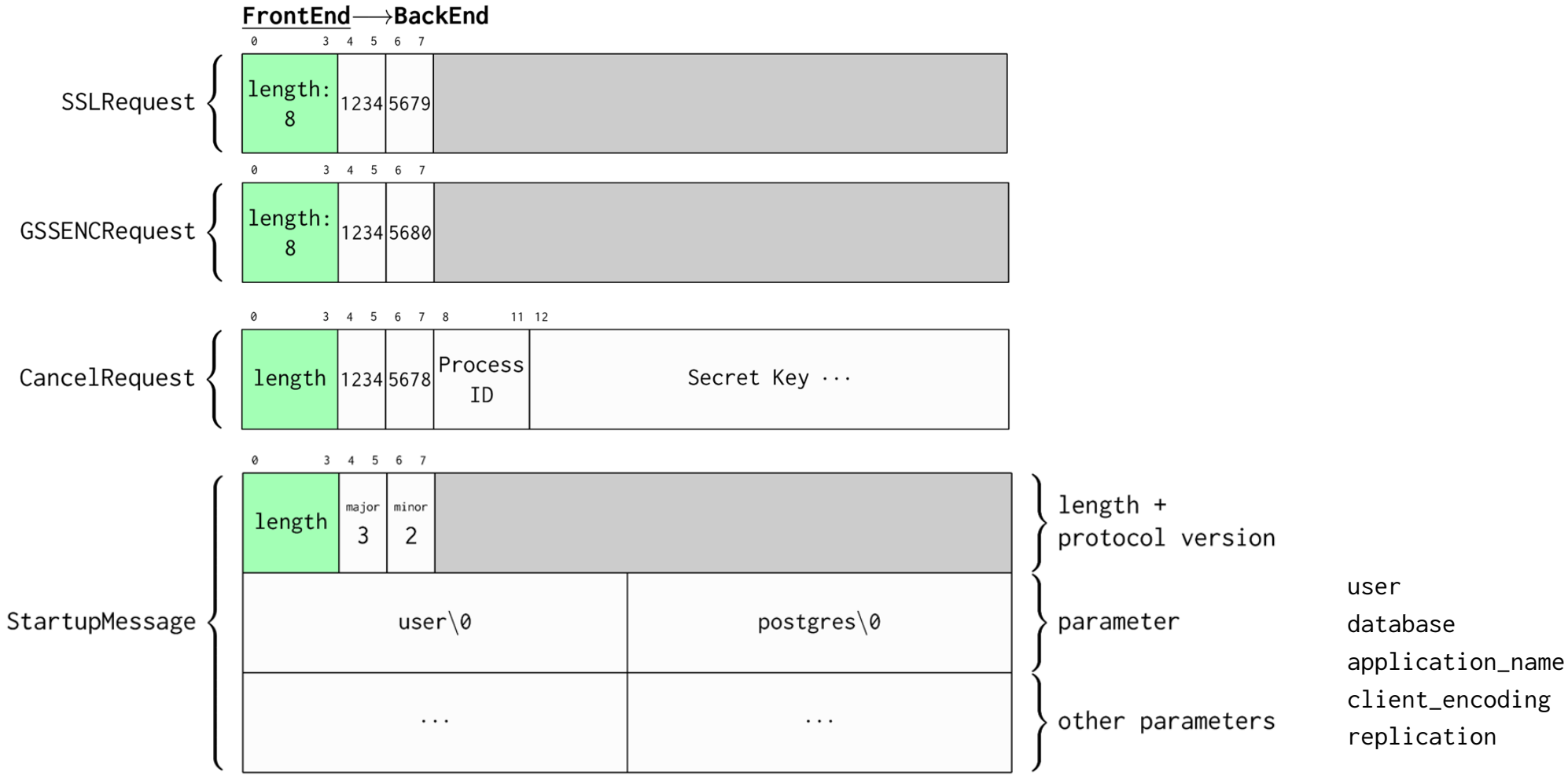
Copy

Listen/Notify

Free resources

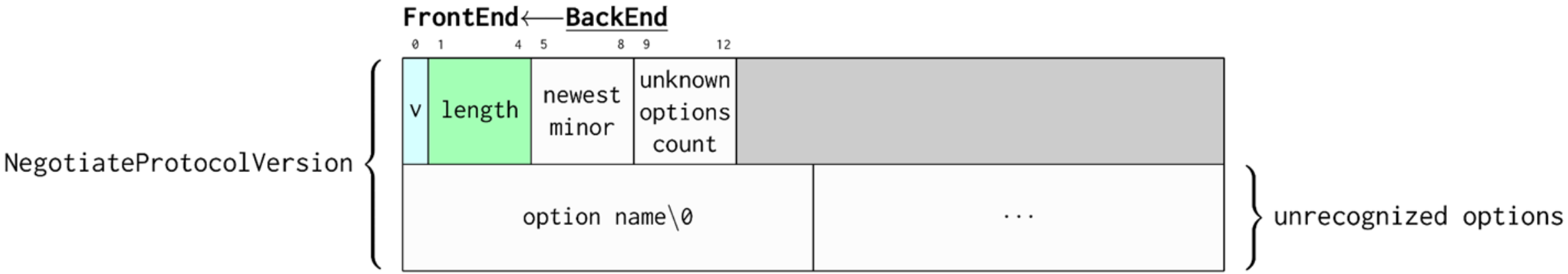
Startup Message

First message sent from the frontend is one of those



Startup Message

When backend doesn't support minor protocol version



Frontend should close the connection if it does not support this minor version.
With PG18 and V3.2 this could happen if frontend expects V3.2 and server only has V3.0

The frontend can usually continue if it can live without the unsupported options or stick to server version

Authentication

Method picked in pg_hba.conf, backend sends the Authentication* “challenge” message

- Messages exchanged vary for each method
- Final step: backend sends `Error` or `AuthenticationOk`

PG18 introduced OAUTH, deprecated MD5

SCRAM and OAUTH are recommended since PG18

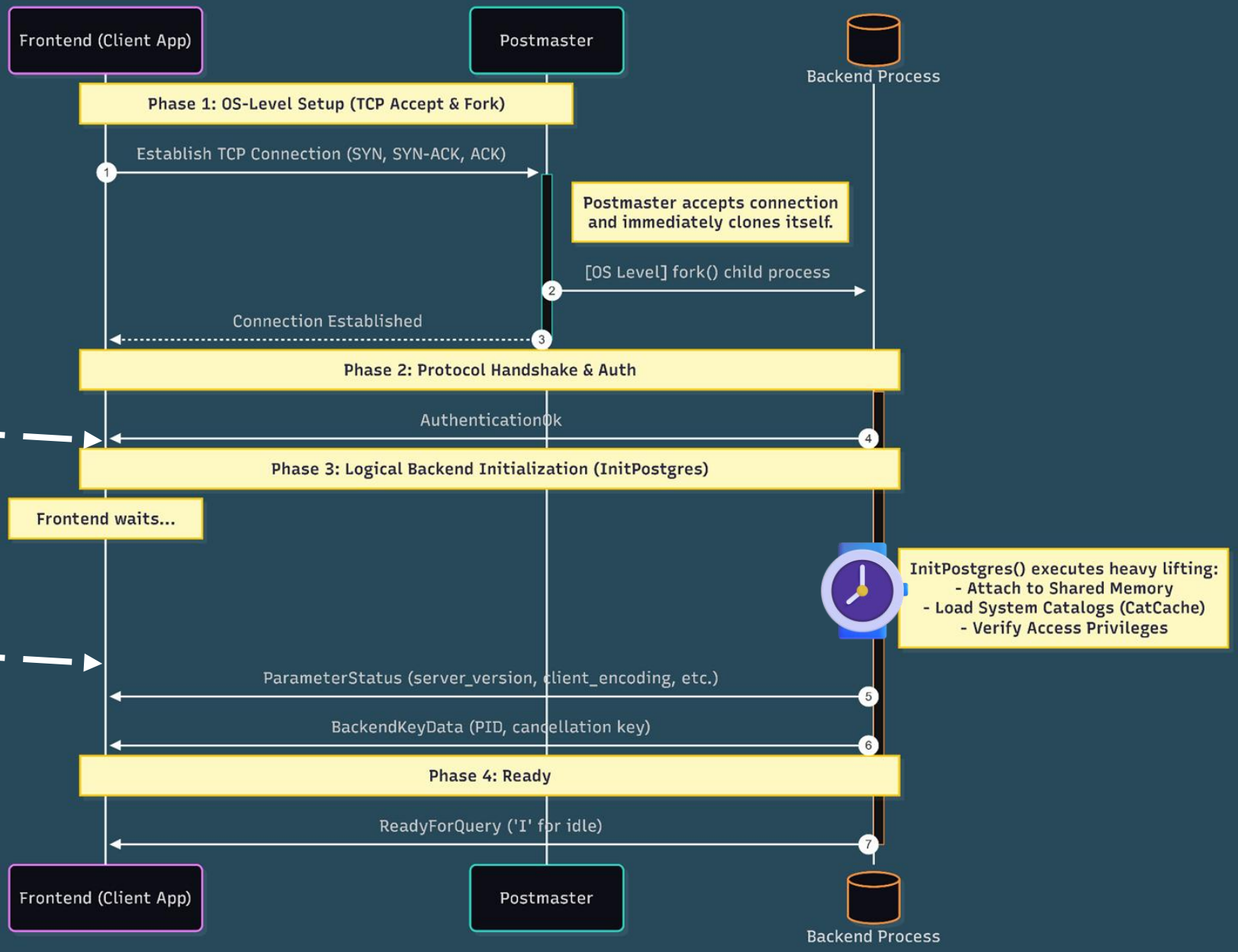
you’re (nearly) in!

how is the **backend** process **created**?

Backend spawn

You are here

We are going there

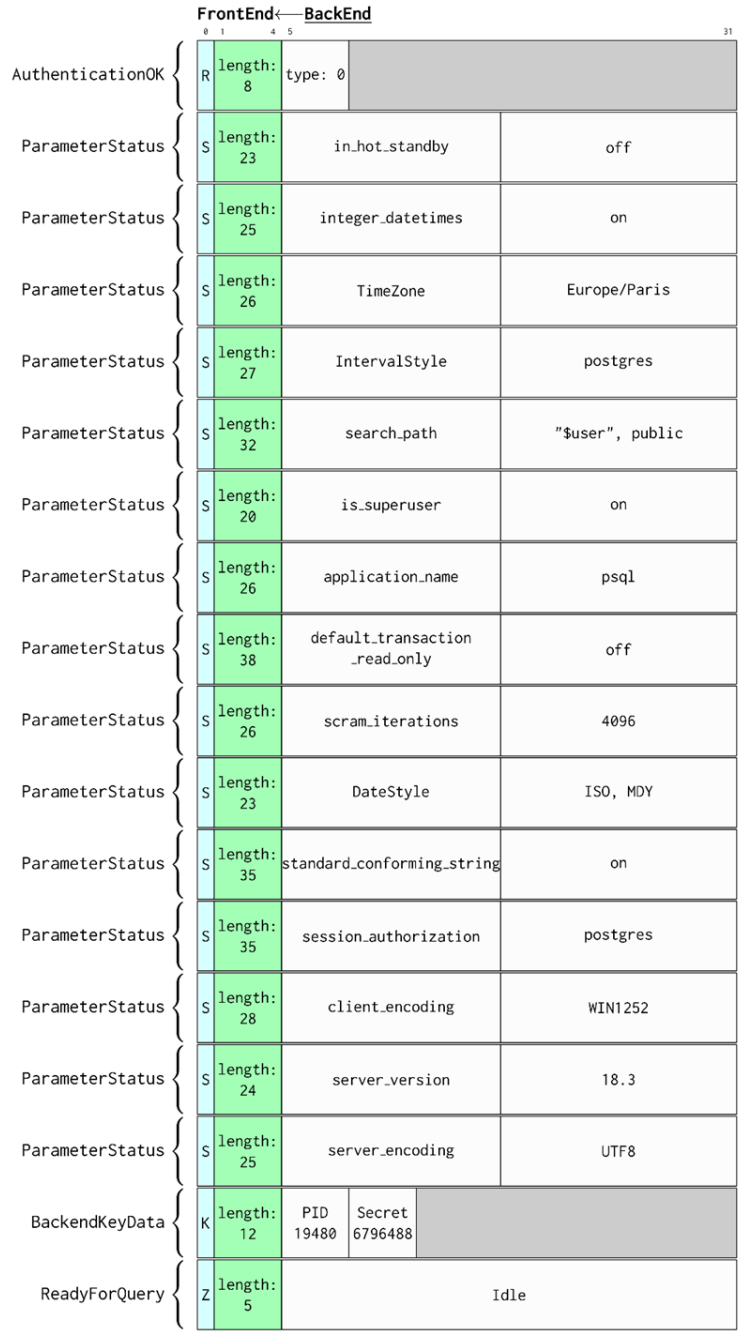


Server parameters

- ParameterStatus (a lot)
- Backend Key Data: PID + key

  (needed by CancelRequest on a fresh new connection)

- **ReadyForQuery (🎉)**



Simple query explained

```
dvdrental=# select * from actor limit 10;
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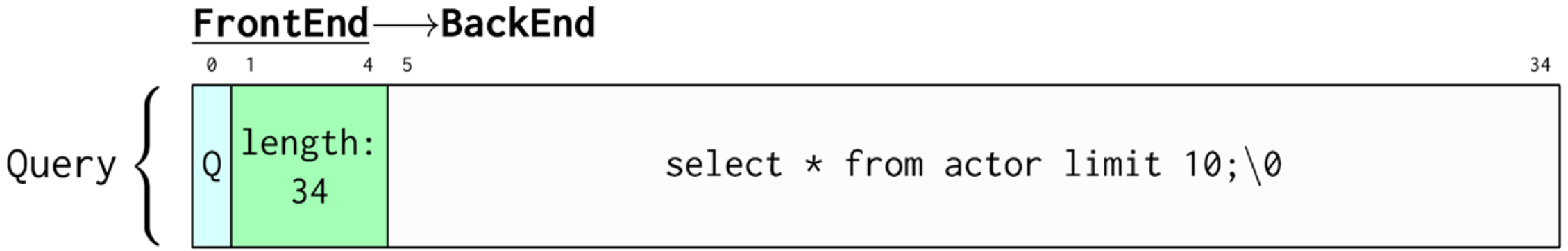
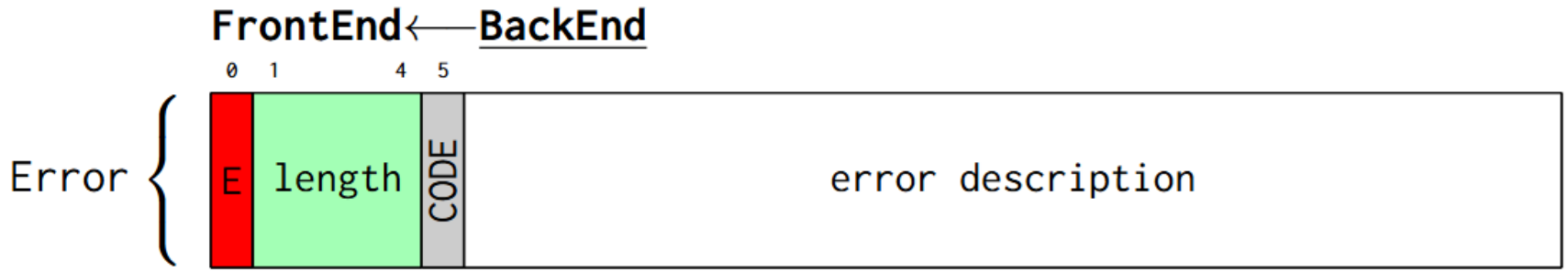
```

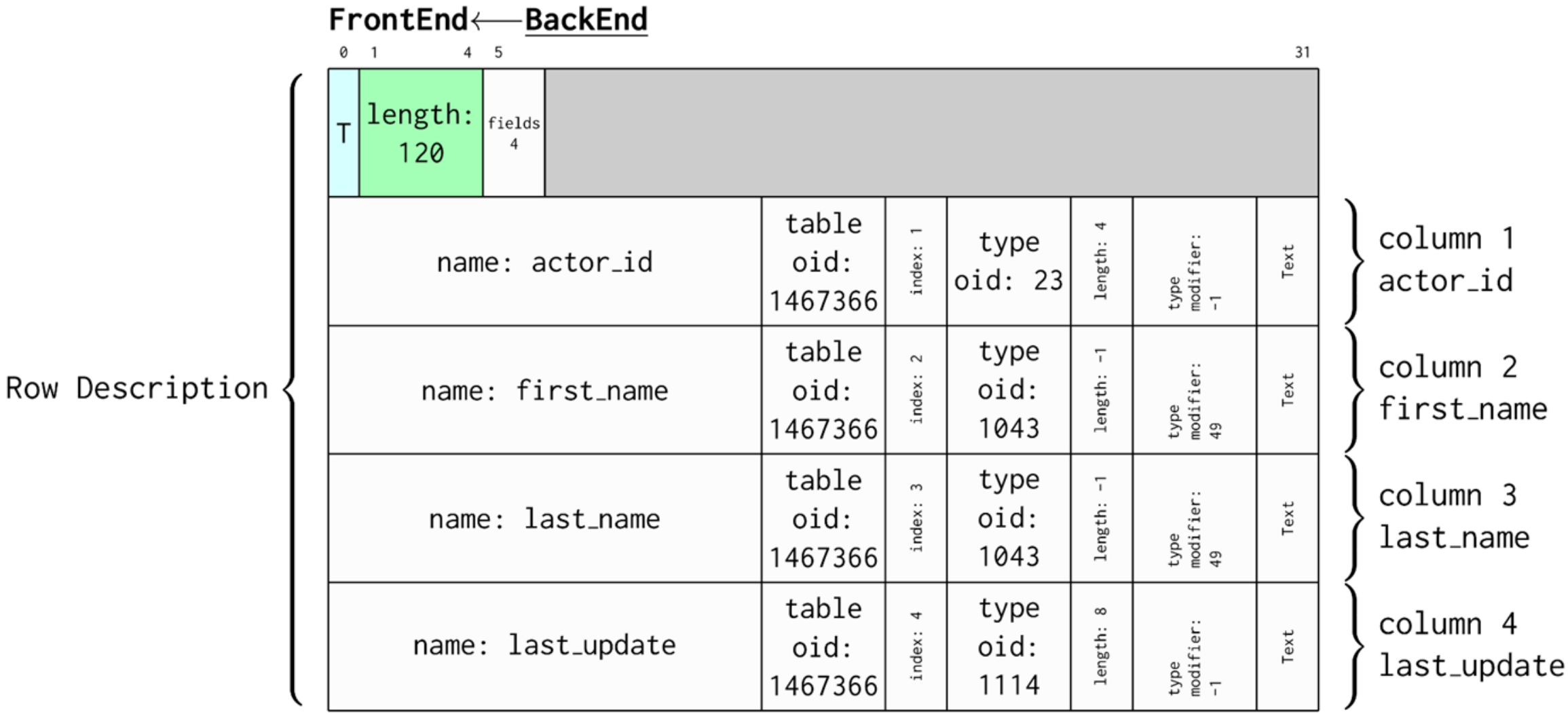
Simple query explained: >Q



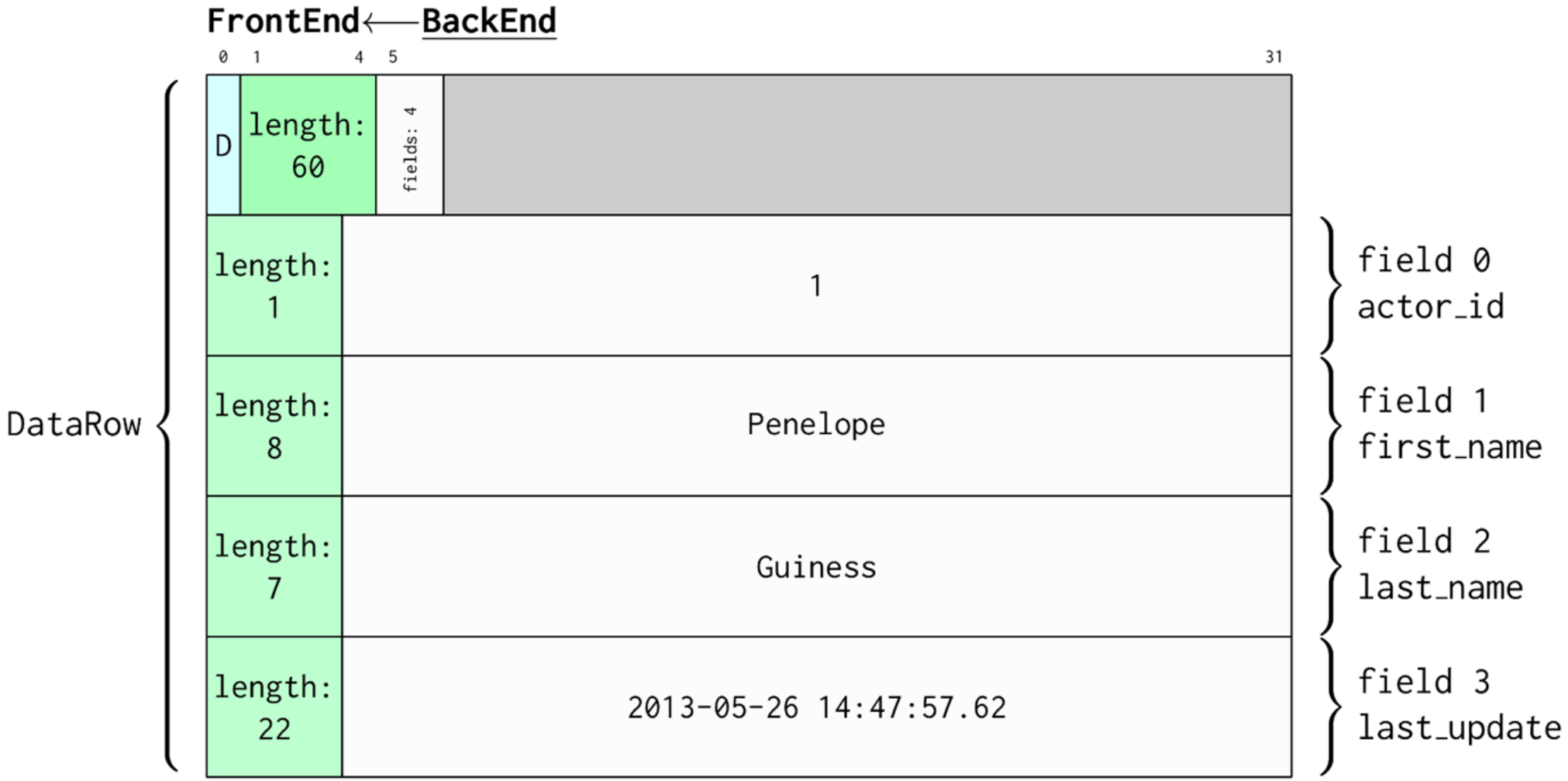
Things can go wrong



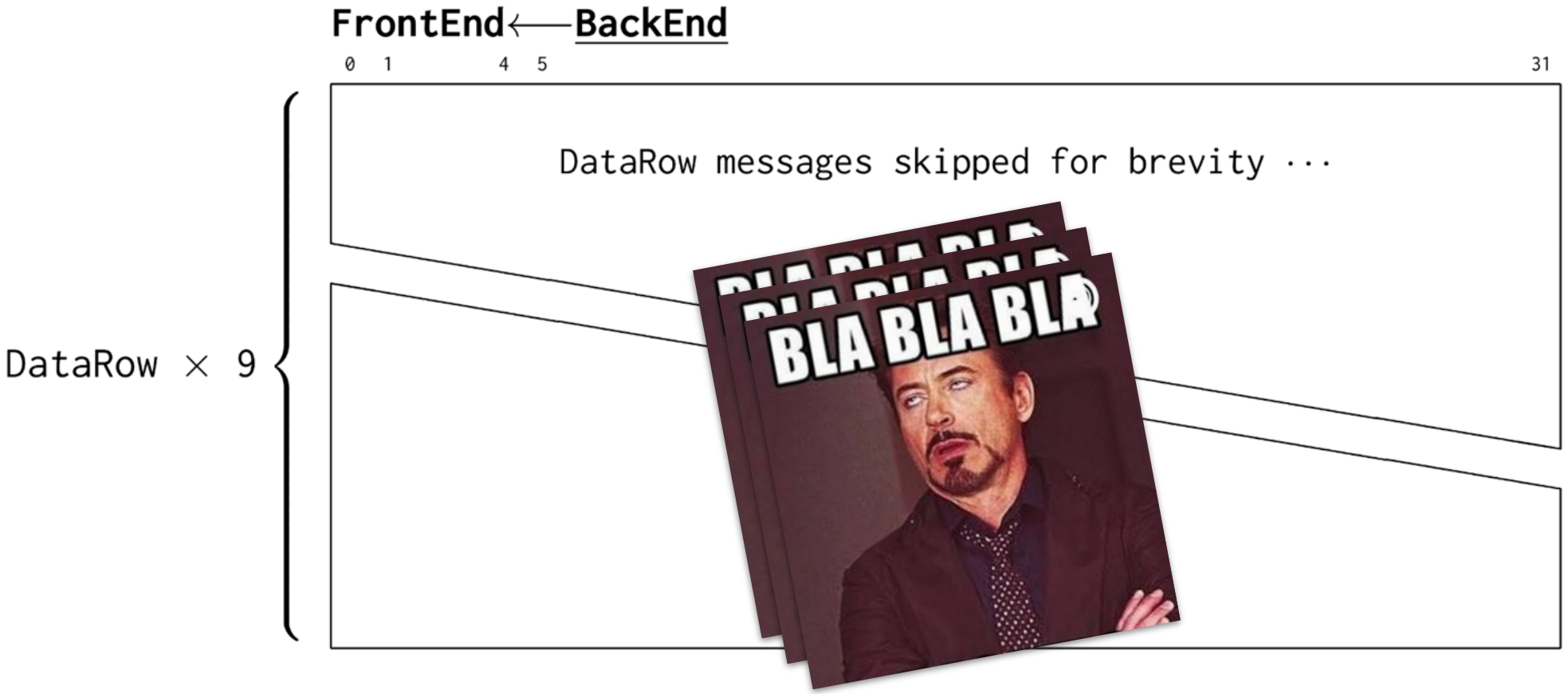
Simple query explained: >Q <T



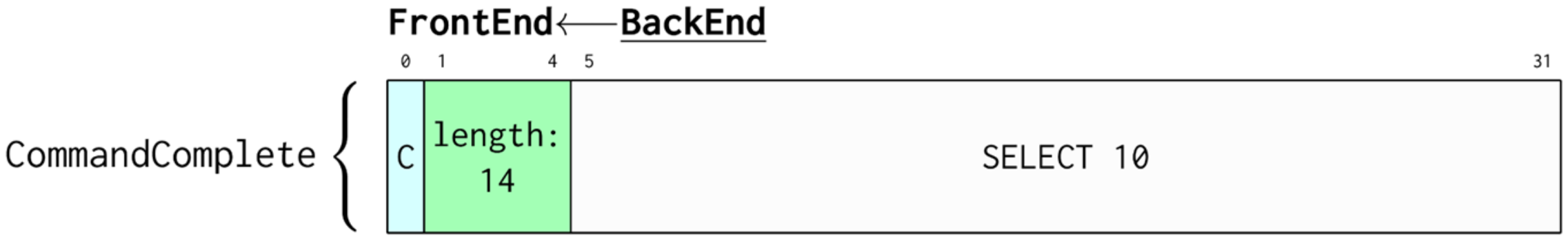
Simple query explained: >Q <T/D



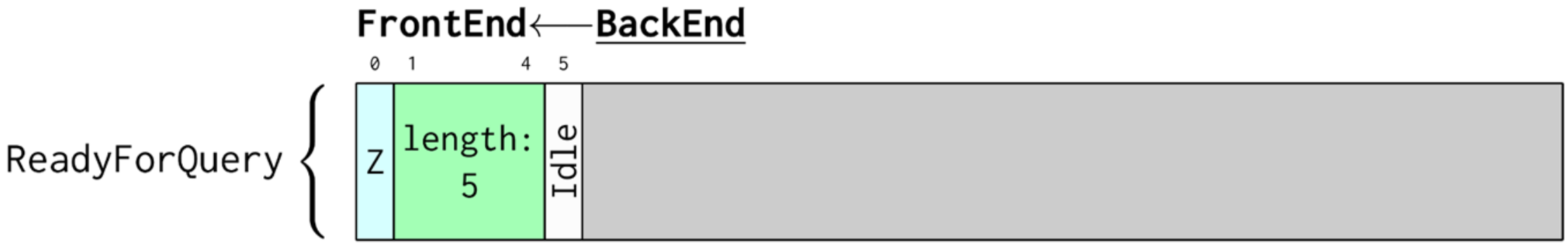
Simple query explained: `>Q <T/D/……`



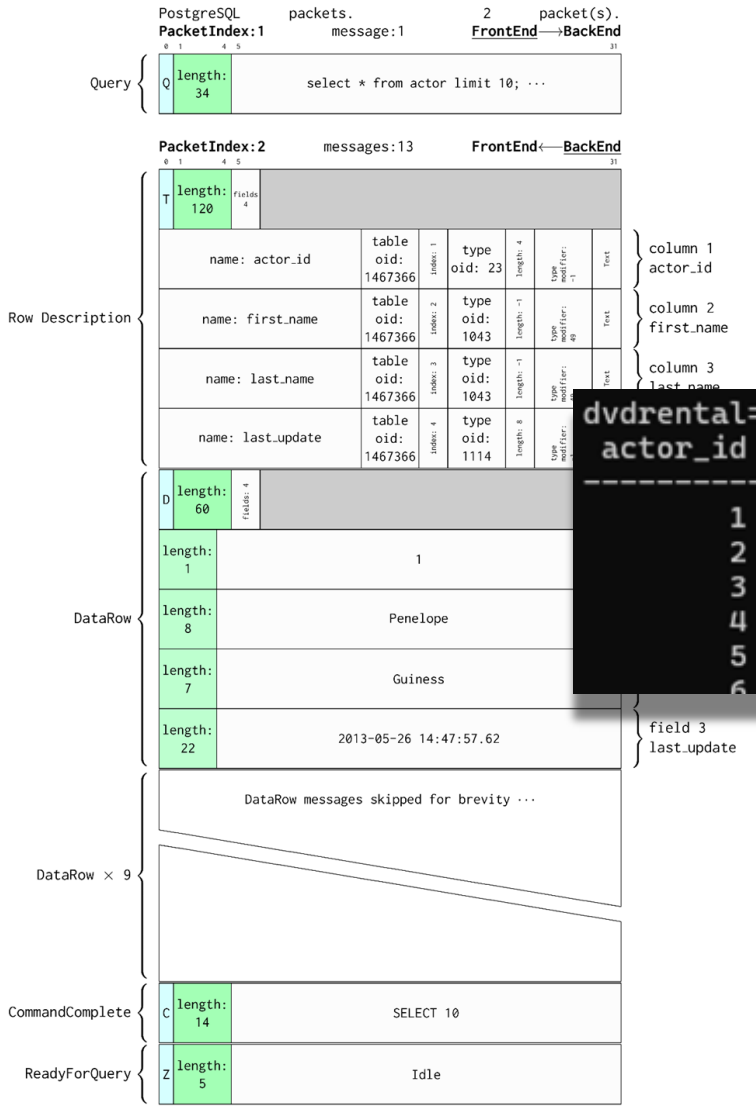
Simple query explained: >Q <T/D/D/D/D/D/D/D/D/D/C



Simple query explained: `>Q <T/D/D/D/D/D/D/D/D/D/C/Z`



Simple query explained: >Q <T/D/D/D/D/D/D/D/D/D/C/Z

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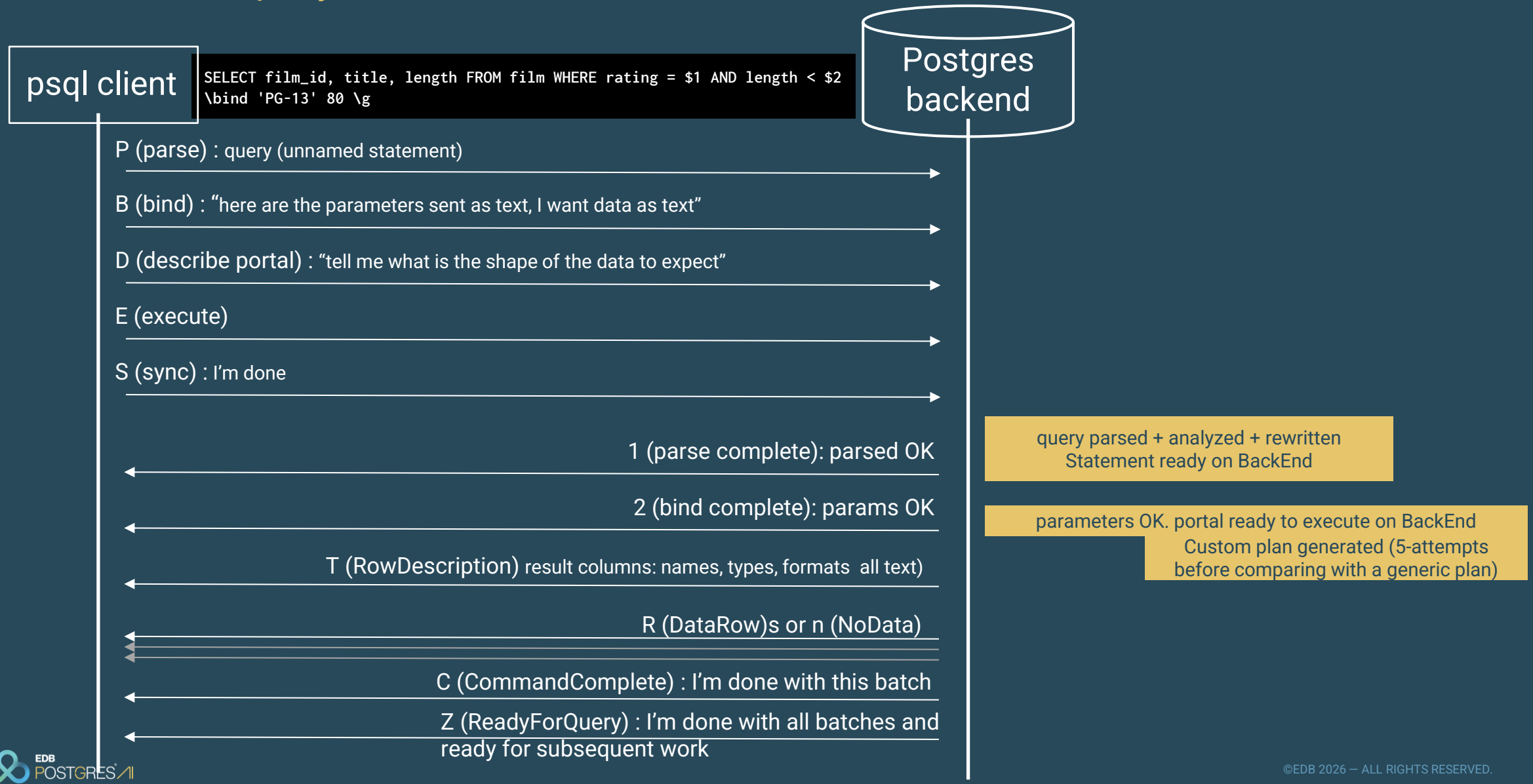
```

extended query

Extended query: simple example

parameterized query

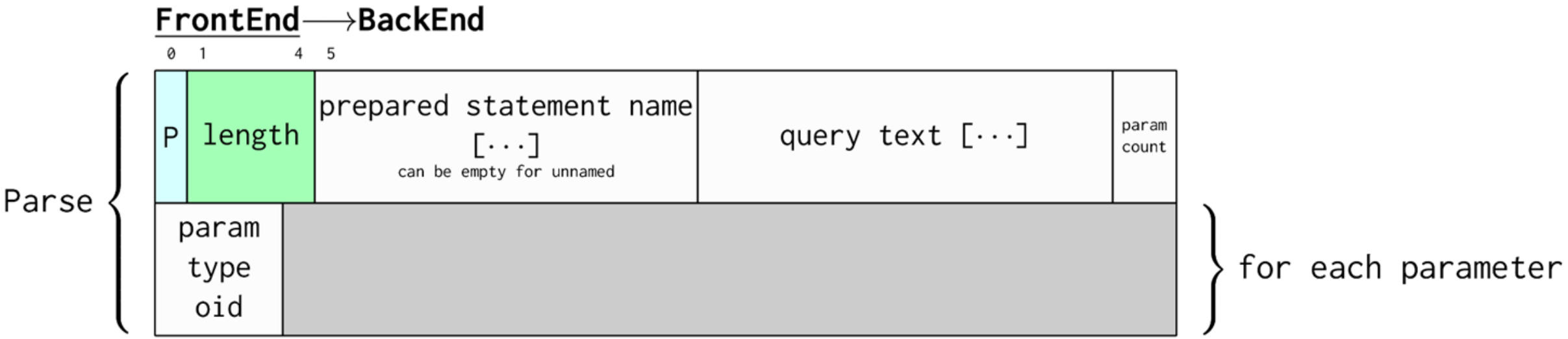


Statements / portals

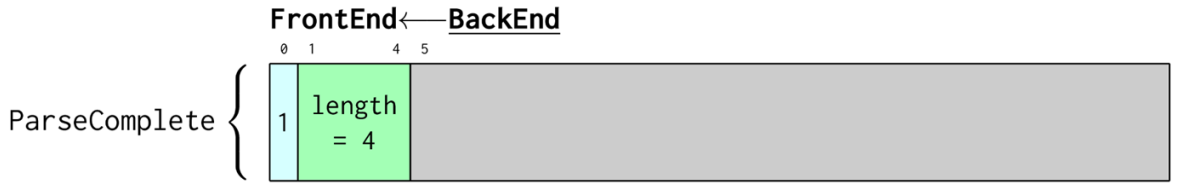
- **Statement** is created with Parse. It’s a reusable parameterized query “template”
  => kip parsing stage.
- **Portals** are created with Bind. It’s statements with parameters, planned and ready to be executed.

Parse → statement → Bind → portal → Execute (all or fetch)

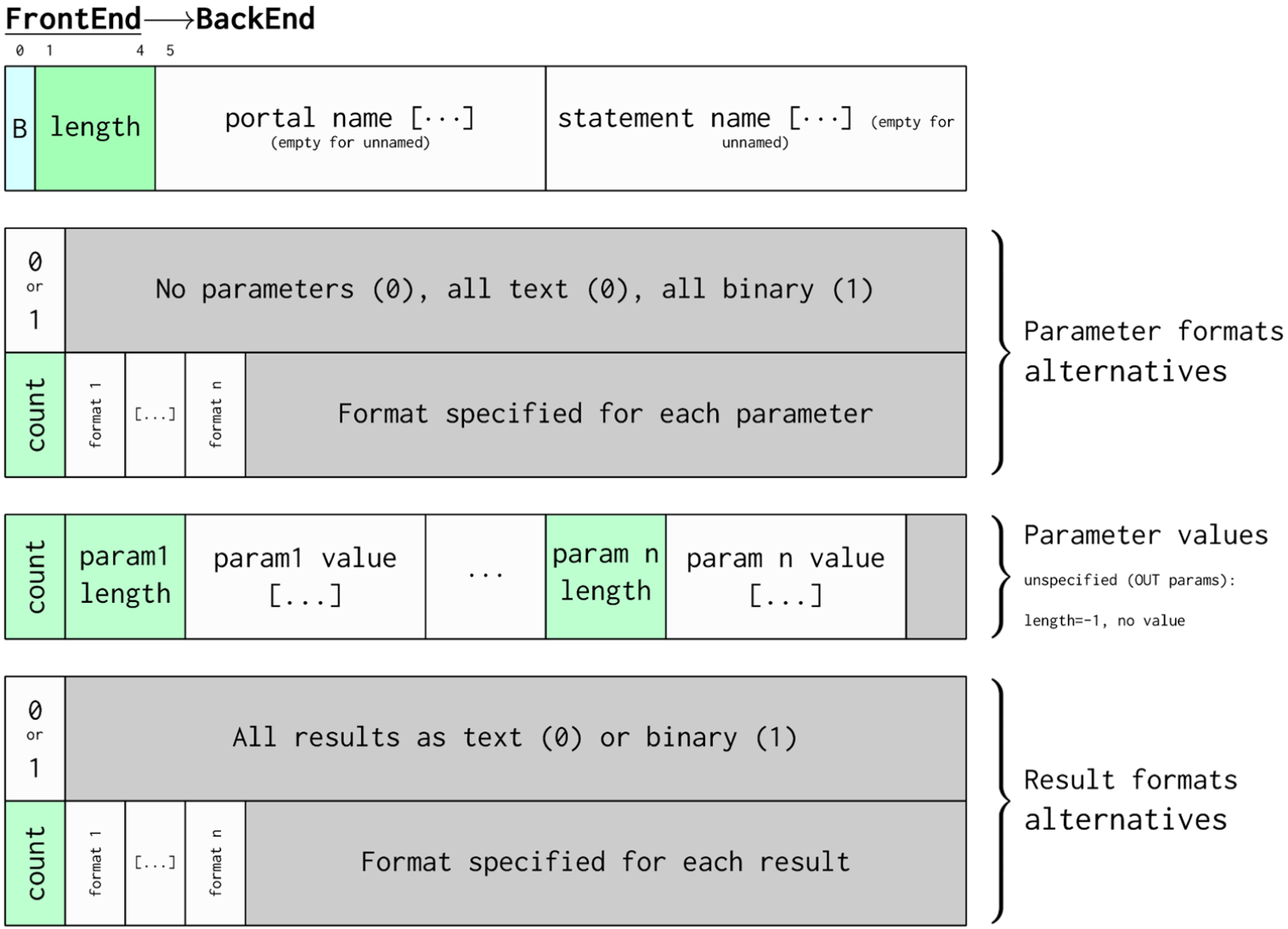
Extended query explained: Parse



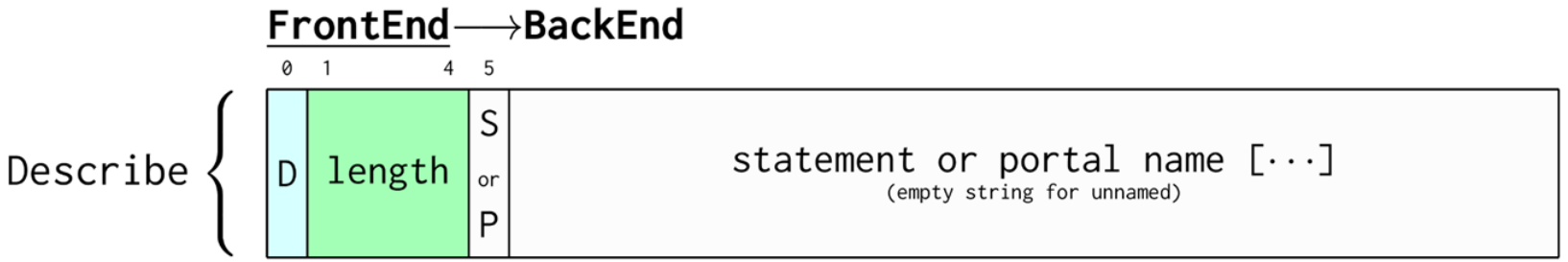
=> Parse complete expected



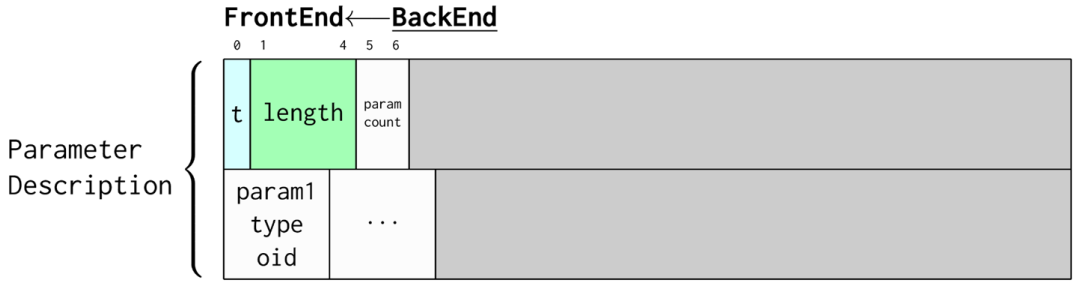
Extended query explained: Bind



Extended query explained: `Describe (statement/portal)`



=> Statement variant returns ParameterDescription, usually called before Bind



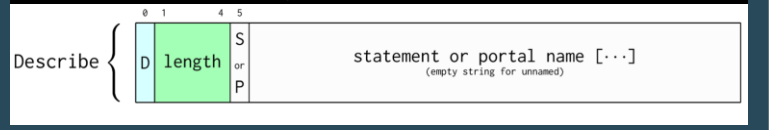
=> both variants return RowDescription

Extended query : prepared statement

Named statement
(in psql since PG18)

```
SELECT film_id, title, length FROM film WHERE rating
= $1 AND length < $2
\parse film_search
```

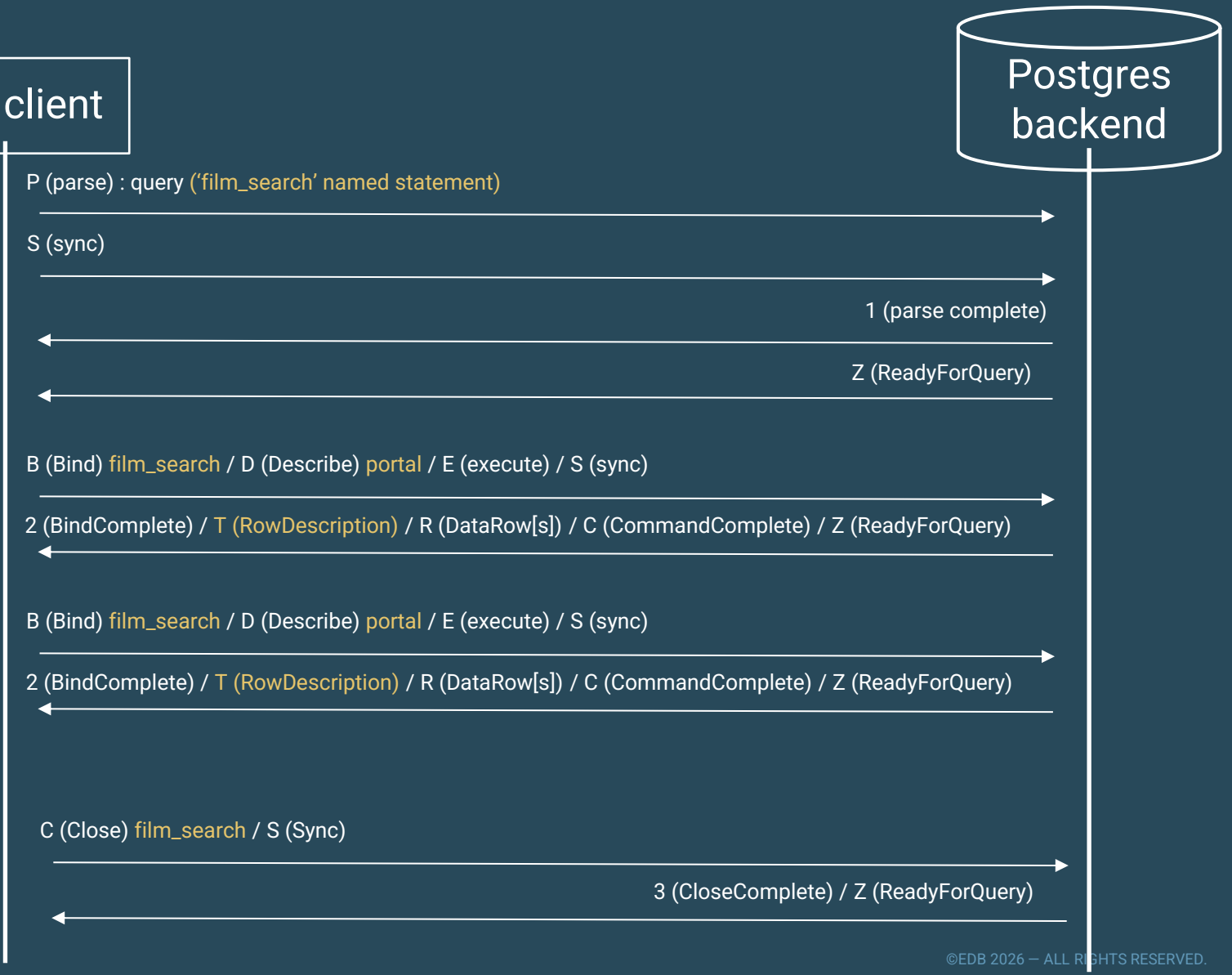
```
\bind_named film_search 'PG-13' 80
EXECUTE film_search;
```




```
\bind_named film_search 'PG-13' 120
EXECUTE film_search;
```

...

```
\close_prepared film_search
```



EDB POSTGRES AI

Extended query : cursors/portals

Producer/Consumer with slow consumer

psql client

Postgres backend

P (parse) 'film_search' / D (Describe) S 'film_search' / S (Sync)

1 (ParseComplete) / t (ParameterDescription) / D (RowDescription) / Z

B (Bind) values + film_search + **film_portal** / E (execute) film_portal 100 rows / S (sync)

2 (BindComplete) / R (100 DataRow[s]) / s (PortalSuspended) / Z (ReadyForQuery)

Slow processing…

E (execute) film_portal 100 rows / S (sync)

R (100 DataRow[s]) / s (PortalSuspended) / Z (ReadyForQuery)

…

…

R (20 DataRow[s]) / C (CommandComplete)

END

C (Close) film_portal / S (sync)

3 (CloseComplete) / Z (ReadyForQuery)

220 rows in total

Extended query / wrap up

Pros

- Prevents SQL injection
- Binary data support
- Plan reuse with prepared statements
- Many ways to improve performance

Cons

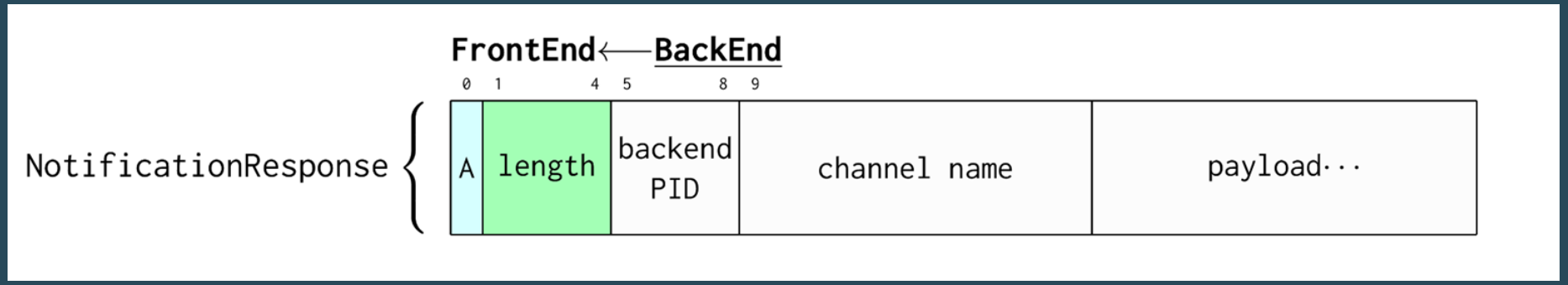
- Slower for one-off queries
- Single statement only

server-pushed messages

Listen / notify

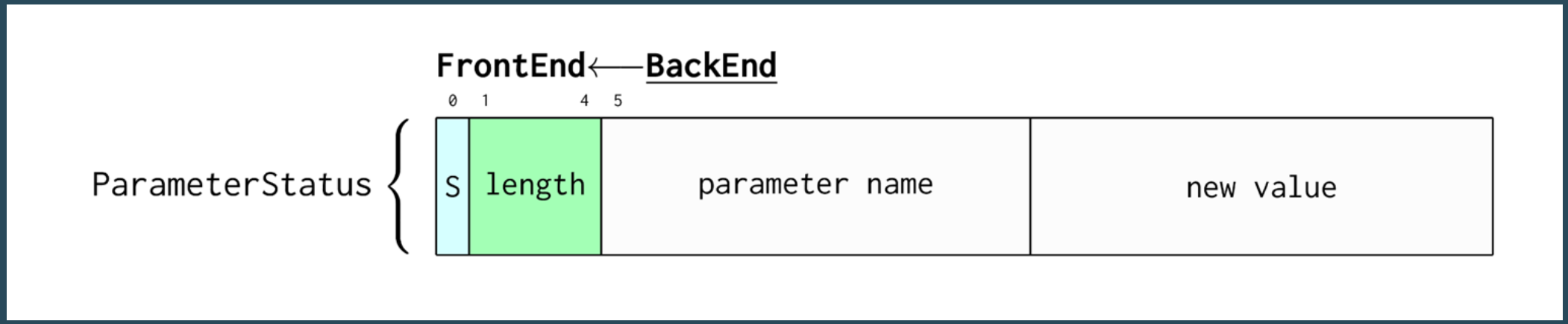
Subscription model

- Any frontend subscribes via simple query *LISTEN <channel name>*
- Any backend can *NOTIFY <channel name> payload*
- Listeners receive a NotificationResponse message when connection is idle



GUC changes

- Notifies frontends when any GUC sent after Startup changes
- Backend sends *ParameterStatus* message before the next *ReadyForQuery* for each changed GUC
- Needed for drivers to interpret wire data correctly and consistently



copy

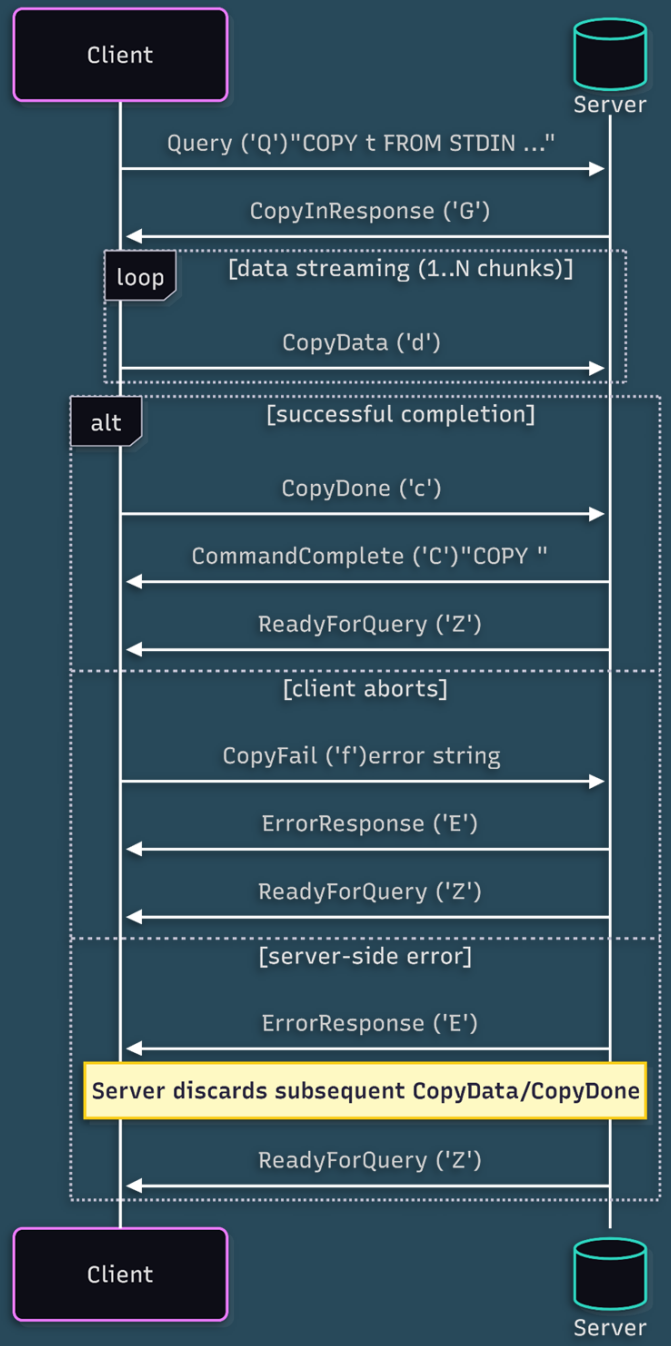
Bulk import/export

Copy is a sub protocol

Formats

- Text (default)
- CSV
- Binary (10-100x faster than INSERTs)

Used by shp2pgsql, pg_dump, pglogical



replication

Replication

Initiated with the **`replication`** parameter in the Startup packet.

It's a special mode of the protocol with its own grammar (IDENTIFY_SYSTEM, START_REPLICATION…)

- **`replication=true`** physical replication
- **`replication=<database>`** logical replication

Replication

Physical replication works only with same:

- server major version
- Same on-disk binary format

Logical replication is “cross platform”

- Does not replicate DDL (functions, procedures, catalog)

Replication

Great talks from PG Conf EU 2023

“The journey towards active-active replication in PostgreSQL” by Jonathan S. Katz

https://www.postgresql.eu/events/pgconfeu2023/schedule/session/4783-the-journey-towards-active-active-replication-in-postgresql/

performance

Performance considerations : connections

Connections are expensive (5 to 10MB, 5-50ms to open)

- use pooling (implemented in some drivers, or with pgBouncer, pgPool, …)

Performance considerations : queries

Repetitive parameterized queries benefit from prepared statements

- use binary format
- 5-exections_trap: make sure data is well distributed with param variation; Postgres may switch to a generic plan whose selectivity assumptions are wrong for skewed data

Performance considerations : quick-wins

Avoid N+1 problem (fetch N rows, then perform a query per row)

- Postgres will do it better than you!

Avoid unnecessary roundtrips

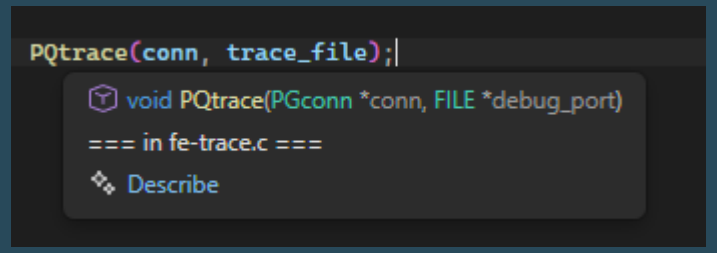
- Use batches (INSERT, arrays)

Trust Postgres, trust the drivers, measure, and read the docs!

diagnosing

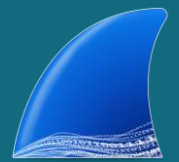
libpq has PQtrace()

If you use/wrap libpq, you can activate protocol tracing (improved in PG14)



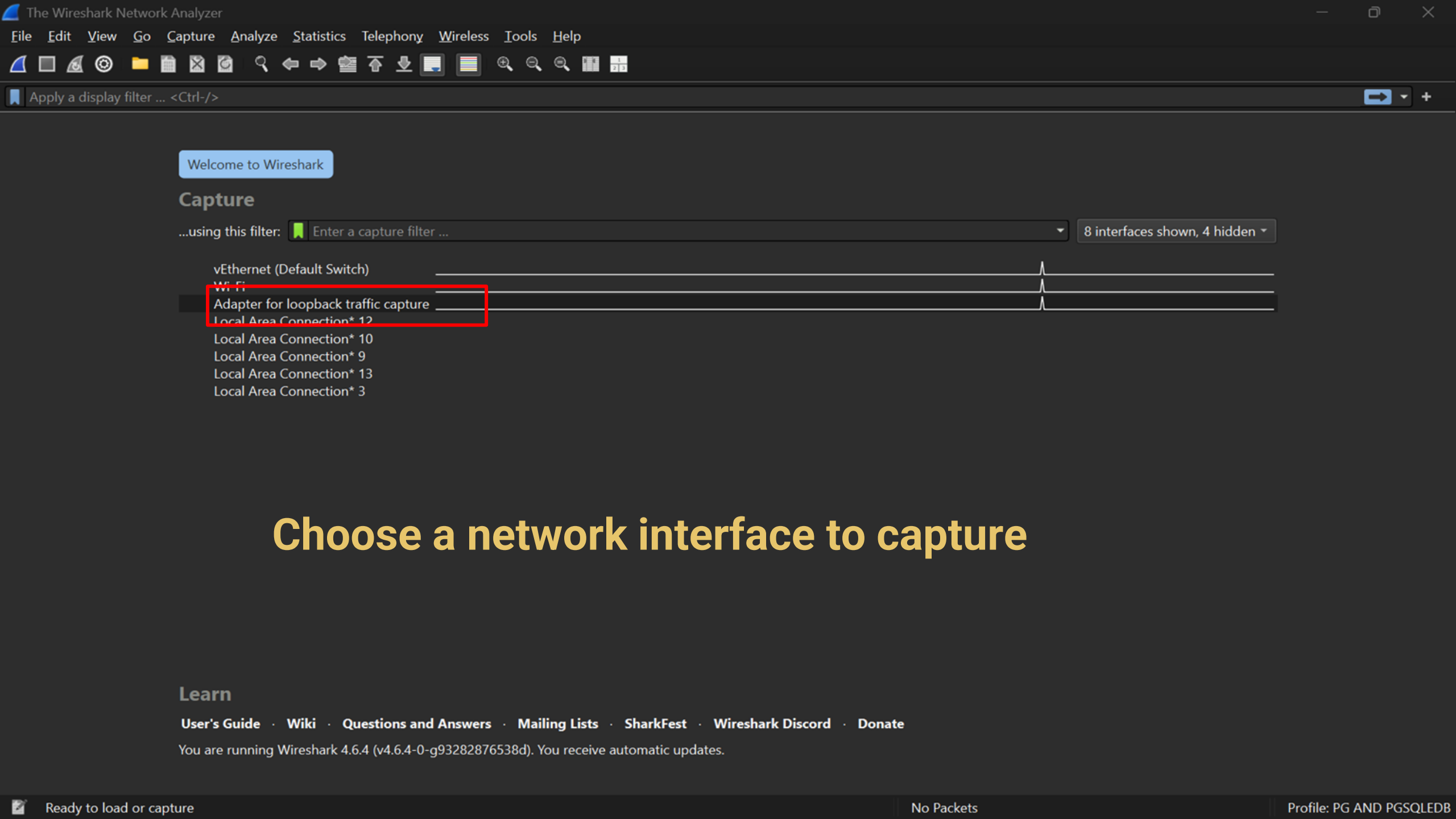

```
F             33            Query           "select * from actor limit 10"
B             120           RowDescription  4 "actor_id" 1467366 1 23 4 -1 0 "first_name" 1467366 2 1043 65535 49
0 "last_name" 1467366 3 1043 65535 49 0 "last_update" 1467366 4 1114 8 -1 0
B             60            DataRow         4 1 '1' 8 'Penelope' 7 'Guiness' 22 '2013-05-26 14:47:57.62'
B             57            DataRow         4 1 '2' 4 'Nick' 8 'Wahlberg' 22 '2013-05-26 14:47:57.62'
B             52            DataRow         4 1 '3' 2 'Ed' 5 'Chase' 22 '2013-05-26 14:47:57.62'
B             58            DataRow         4 1 '4' 8 'Jennifer' 5 'Davis' 22 '2013-05-26 14:47:57.62'
B             63            DataRow         4 1 '5' 6 'Johnny' 12 'Lollobrigida' 22 '2013-05-26 14:47:57.62'
B             59            DataRow         4 1 '6' 5 'Bette' 9 'Nicholson' 22 '2013-05-26 14:47:57.62'
B             56            DataRow         4 1 '7' 5 'Grace' 6 'Mostel' 22 '2013-05-26 14:47:57.62'
B             61            DataRow         4 1 '8' 7 'Matthew' 9 'Johansson' 22 '2013-05-26 14:47:57.62'
B             53            DataRow         4 1 '9' 3 'Joe' 5 'Swank' 22 '2013-05-26 14:47:57.62'
B             60            DataRow         4 2 '10' 9 'Christian' 5 'Gable' 22 '2013-05-26 14:47:57.62'
B             14            CommandComplete              "SELECT 10"
B             5             ReadyForQuery   I
F             59            Parse           "actor_by_id" "select * from actor where actor_id  = $1" 0
F             4             Sync
B             4             ParseComplete
B             5             ReadyForQuery   I
F             30            Bind            "" "actor_by_id" 0 1 1 '1' 1 1
F             6             Describe        P ""
F             9             Execute         "" 0
F             4             Sync
B             4             BindComplete
B             120           RowDescription  4 "actor_id" 1467366 1 23 4 -1 1 "first_name" 1467366 2 1043 65535 49
1 "last_name" 1467366 3 1043 65535 49 1 "last_update" 1467366 4 1114 8 -1 1
B             49            DataRow         4 4 '\x00\x00\x00\x01' 8 'Penelope' 7 'Guiness' 8
'\x00\x01\x80\x9e\xe2\xf57 '
```

diagnosing issues with wireshark



wireshark allows to trace network messages

wireshark dissectors allows presenting the messages in a **understandable way** for a given **protocol**

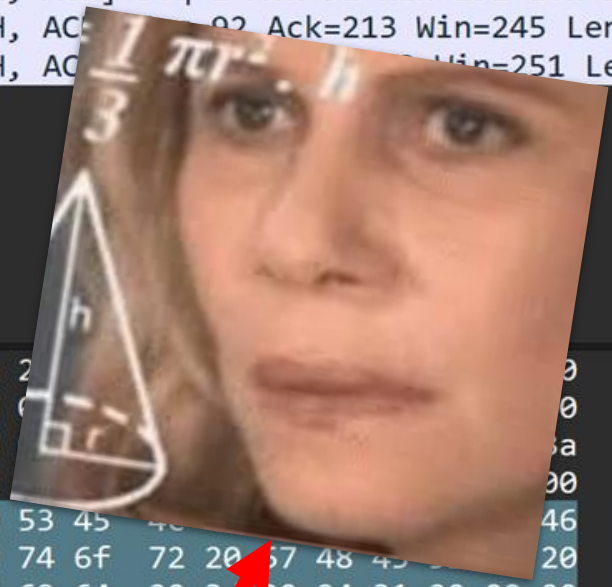

The Wireshark Network Analyzer
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Welcome to Wireshark
Capture
...using this filter: Enter a capture filter ...
8 interfaces shown, 4 hidden
vEthernet (Default Switch)
Adapter for loopback traffic capture
Local Area Connection* 10
Local Area Connection* 9
Local Area Connection* 13
Local Area Connection* 3
Choose a network interface to capture
Learn
User's Guide · Wiki · Questions and Answers · Mailing Lists · SharkFest · Wireshark Discord · Donate
You are running Wireshark 4.6.4 (v4.6.4-0-g93282876538d). You receive automatic updates.
Ready to load or capture
No Packets
Profile: PG AND PGSQLEDB

extendedquery.pcapng

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

tcp.port==5434

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	::1	::1	TCP	155	63342 → 5434 [PSH, ACK] Seq=1 Ack=1 Win=246 Len=91
2	0.000690100	::1	::1	TCP	276	5434 → 63342 [PSH, ACK] Seq=1 Ack=92 Win=251 Len=212
3	3.838513300	::1	::1	TCP	155	63342 → 5434 [PSH, AC 92 Ack=213 Win=245 Len=91
4	3.839248200	::1	::1	TCP	273	5434 → 63342 [PSH, AC Win=251 Len=209



- Frame 1: Packet, 155 bytes on wire (1240 bits), 155 b
- Null/Loopback
- Internet Protocol Version 6, Src: ::1, Dst: ::1
- Transmission Control Protocol, Src Port: 63342, Dst F
- Data (91 bytes)
  - Data: 500000003000053454c454354202a2046524f4d2061637
  - [Length: 91]

```
0000  18 00 00 00 60 0e 2                                  ····`·$· ·o·····
0010  00 00 00 00 00 00 (                                  ···· ···· ····
0020  00 00 00 00 00 00                                    ···· ···· ····n·:
0030  95 4e 6a 46 14 62                                    ·NjF·bR· P·····
0040  50 00 00 00 30 00 53 45                              P···0·SE LECT * F
0050  52 4f 4d 20 61 63 74 6f  72 20                       ROM acto r WHERE
0060  61 63 74 6f 72 5f 69 64  20 3                       actor_id  = $1 ··
0070  00 42 00 00 00 13 00 00  00                          ·B····· ····
0080  31 00 01 00 00 44 00 00  00 06 50 00 45 00 00 00    1····D·· ··P·E···
0090  09 00 00 00 00 00 53 00  00 00 04                   ·····S· ···
```

Those a raw packets, undissected

Data (data.data), 91 bytes

Packets: 4 · Displayed: 4 (100.0%)

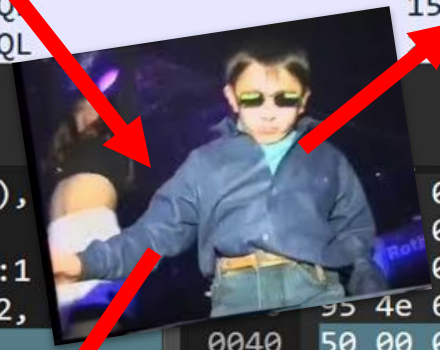
Profile: No Reassembly

extendedquery.pcapng

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

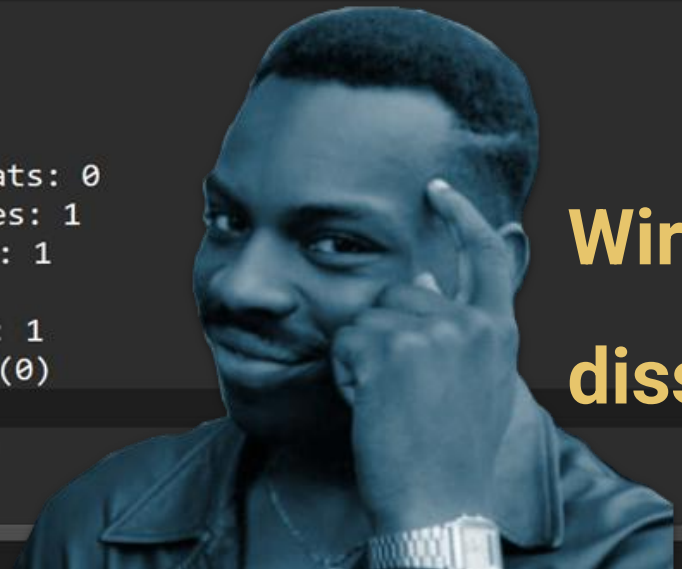
pgsql

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000…	63342	5434	PGSQL	155	>P/B/D/E/S
2	0.000…	5434	63342	PGSQL	276	<1/2/T/D/C/Z
3	3.838…	63342	5434	PGSQ	155	>P/B/D/E/S
4	3.839…	5434	63342	PGSQL	3	<1/2/T/D/C/Z



- Frame 1: Packet, 155 bytes on wire (1240 bits),
- Null/Loopback
- Internet Protocol Version 6, Src: ::1, Dst: ::1
- Transmission Control Protocol, Src Port: 63342,
- PostgreSQL
  - Type: Parse
  - Length: 48
  - Statement:
  - Query: SELECT * FROM actor WHERE actor_id = $1
  - Parameters: 0
- PostgreSQL
  - Type: Bind
  - Length: 19
  - Portal:
  - Statement:
  - Parameter formats: 0
  - Parameter values: 1
    - Column length: 1
    - Data: 31
  - Result formats: 1
    - Format: Text (0)
- PostgreSQL
  - Type: Describe
  - Length: 6
  - Portal:

```
                                00 00 60 0e 24 a6  00 6f 06 80 00 00 00 00    ····`·$· ·o····· 
                                00 00 00 00 00 00  00 00 00 01 00 00 00 00    ···••••• ••••••••
                                00 00 00 00 00 00  00 00 00 01 f7 6e 15 3a    ···••••• ••••••n:
                                95 4e 6a 46 14 62  52 a3 50 18 00 f6 84 0f 00 00    ·NjF·bR· P·····
0040  50 00 00 00 30 00 53 45  4c 45 43 54 20 2a 20 46    P···0·SE LECT * F
0050  52 4f 4d 20 61 63 74 6f  72 20 57 48 45 52 45 20    ROM acto r WHERE 
0060  61 63 74 6f 72 5f 69 64  20 3d 20 24 31 20 00 00    actor_id  = $1 ··
0070  00 42 00 00 00 13 00 00  00 00 00 01 00 00 00 01    ·B····· ••••••••
0080  31 00 01 00 00 44 00 00  00 06 50 00 45 00 00 00    1····D·· ··P·E···
0090  09 00 00 00 00 00 53 00  00 00 04                   ·····S· ···
```



Wireshark has a built in PostgreSQL dissector

PostgreSQL (pgsql), 49 bytes

Packets: 4 · Displayed: 4 (100.0%)

Profile: PG AND PGSQLEDB

extendedquery.pcapng

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

pgsql

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000…	63342	5434	PGSQL	155	>P/B/D/E/S
2	0.000…	5434	63342	PGSQL	276	<1/2/T/D/C/Z
3	3.838…	63342	5434	PGSQ	155	>P/B/D/E/S
4	3.839…	5434	63342	PGSQL	3	<1/2/T/D/C/Z

- Frame 1: Packet, 155 bytes on wire (1240 bits),
- Null/Loopback
- Internet Protocol Version 6, Src: ::1, Dst: ::1
- Transmission Control Protocol, Src Port: 63342,
- PostgreSQL
  - Type: Parse
  - Length: 48
  - Statement:
  - Query: SELECT * FROM actor WHERE actor_id = $1
  - Parameters: 0
- PostgreSQL
  - Type: Bind
  - Length: 19
  - Portal:
  - Statement:
  - Parameter formats:
  - Parameter values: 1
    - Column length: 1
    - Data: 31
  - Result formats: 1
    - Format: Text (0)
- PostgreSQL
  - Type: Describe
  - Length: 6
  - Portal:

```
0000  00 00 60 0e 24 a6 00 6f 80 00 00 00 00   ··`·$··o·····
0010  00 00 00 00 00 00 00 00 00 01 00 00 00 00 ··············
0020  00 00 00 00 00 00 00 00 00 01 7f 6e 15 3a ···········n·:
0030  95 4e 6a 46 14 62 52 a3 50 18 00 f6 84 01 00 00 ·NjF·bR·P·····
0040  50 00 00 00 30 00 53 45 4c 45 43 54 20 2a 20 46 P···0·SE LECT * F
0050  52 4f 4d 20 61 63 74 6f 72 20 57 48 45 52 45 20 ROM acto r WHERE
0060  61 63 74 6f 72 5f 69 64 20 3d 20 24 31 20 00 00 actor_id = $1 ··
0070  00 42 00 00 00 13 00 00 00 00 00 00 00 01 00 01 ·B··· ··· ·····
0080  31 00 01 00 00 44 00 00 00 06 53 00 00 00 04 00 1····D···· ····S····
0090  00 00 00 00                                     ····
```

But, still, your brain has to process a lot

PostgreSQL (pgsql), 49 bytes

Packets: 4 · Displayed: 4 (100.0%)

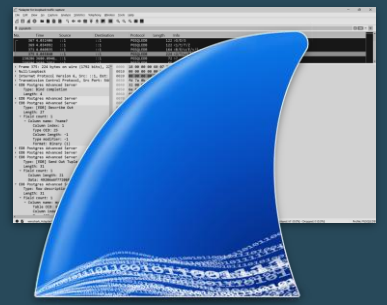
Profile: PG AND PGSQLEDB

here comes

pg_protoexport

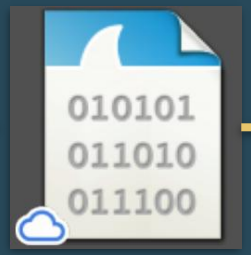
an open source tool do **document** the **protocol**

```
> pg_protoexport demo
```



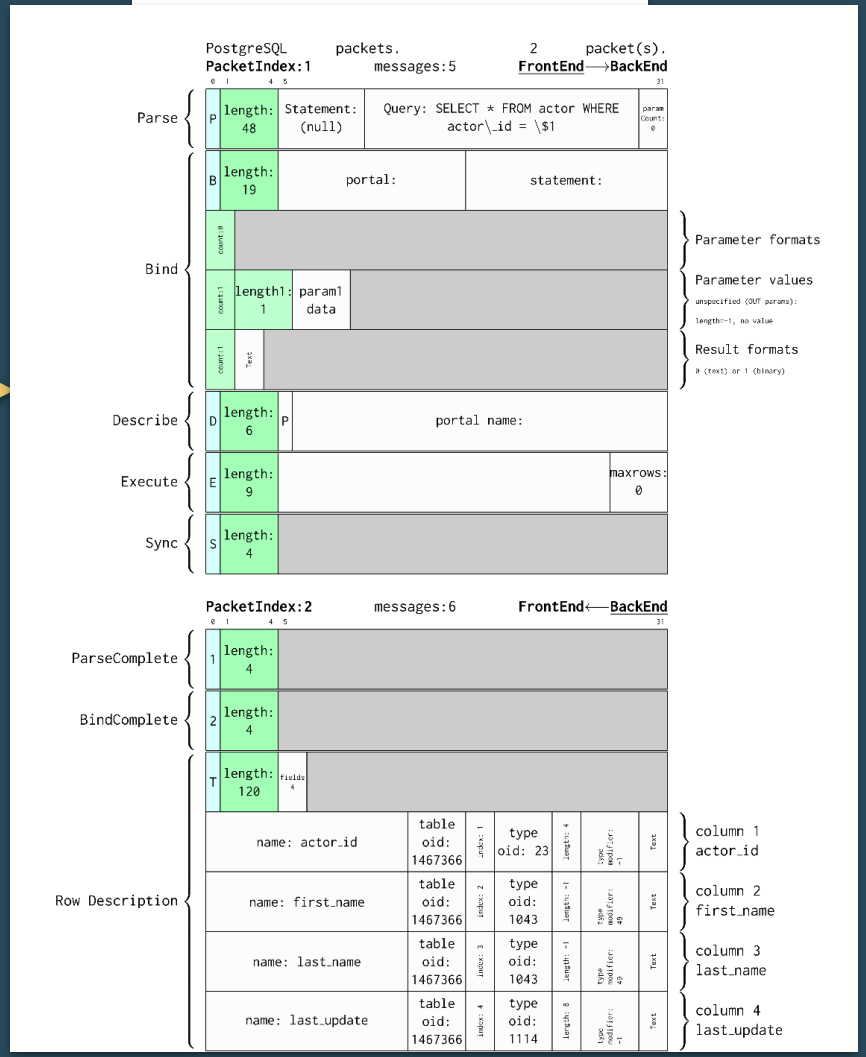
Wireshark

capture file

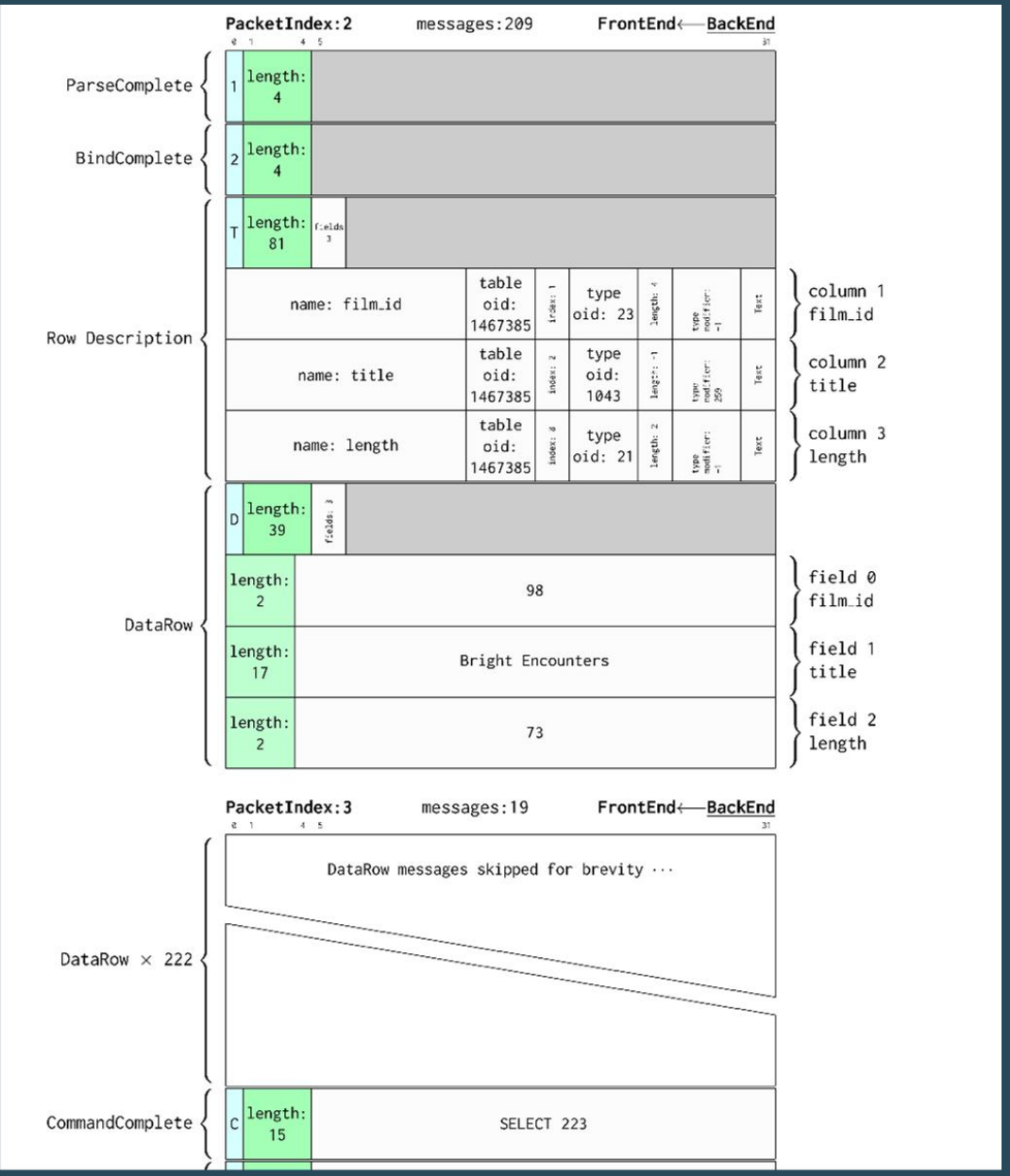


pg_protoexport

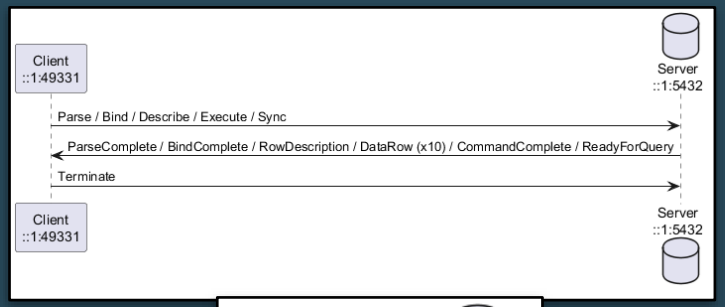
TEX

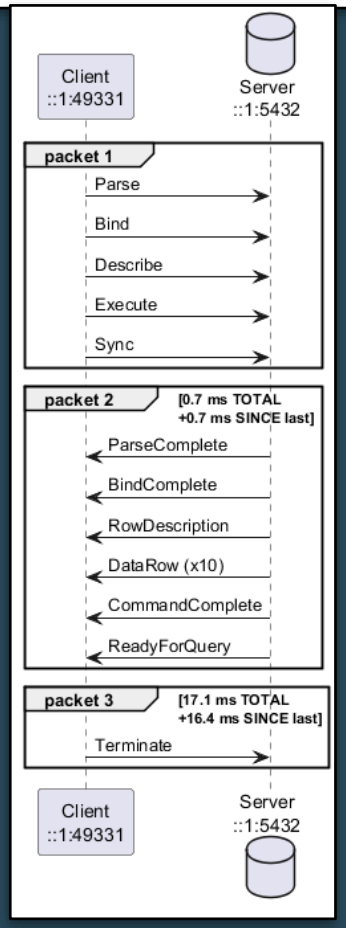


LaTeX



Mermaid/PlantUML



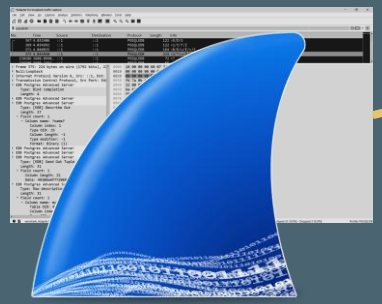


ASCII

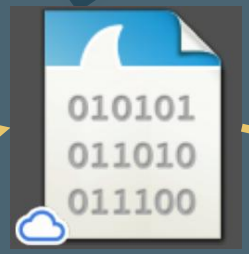
```
Packet (F)
2025-03-13T06:36:30.1436940Z    F   83  Parse   statement=, query=select oid, typname, typtype from
pg_type where typtype <> $1 limit 10;, parameter oids=[25]
2025-03-13T06:36:30.1436940Z    F   19  Bind    : formats: [], values len: [1], results format: [1]
2025-03-13T06:36:30.1436940Z    F   6   Describe    Portal: ''
2025-03-13T06:36:30.1436940Z    F   9   Execute portal='', maxrows=0
2025-03-13T06:36:30.1436940Z    F   4   Sync    SyncMessage
Packet (B)
2025-03-13T06:36:30.1444240Z    B   4   ParseComplete   ParseCompleteMessage
2025-03-13T06:36:30.1444240Z    B   4   BindComplete
2025-03-13T06:36:30.1444240Z    B   80  RowDescription  [oid: 1247, 1, 26, 4, -1, 1, typname: 1247, 2, 19,
64, -1, 1, typtype: 1247, 7, 18, 1, -1, 1]
2025-03-13T06:36:30.1444240Z    B   30  DataRow [oid:00000047, typname:pg_type, typtype:c]
2025-03-13T06:36:30.1444240Z    B   35  DataRow [oid:0000004b, typname:pg_attribute, typtype:c]
2025-03-13T06:36:30.1444240Z    B   30  DataRow [oid:00000051, typname:pg_proc, typtype:c]
2025-03-13T06:36:30.1444240Z    B   31  DataRow [oid:00000053, typname:pg_class, typtype:c]
2025-03-13T06:36:30.1444240Z    B   37  DataRow [oid:00000020, typname:pg_ddl_command, typtype:p]
2025-03-13T06:36:30.1444240Z    B   30  DataRow [oid:000002c1, typname:unknown, typtype:p]
2025-03-13T06:36:30.1444240Z    B   32  DataRow [oid:00000f40, typname:int4range, typtype:r]
2025-03-13T06:36:30.1444240Z    B   31  DataRow [oid:00000f42, typname:numrange, typtype:r]
2025-03-13T06:36:30.1444240Z    B   30  DataRow [oid:00000f44, typname:tsrange, typtype:r]
2025-03-13T06:36:30.1444240Z    B   32  DataRow [oid:00000f46, typname:tstzrange, typtype:r]
2025-03-13T06:36:30.1444240Z    B   14  CommandComplete SELECT 10
2025-03-13T06:36:30.1444240Z    B   5   ReadyForQuery   Idle
Packet (F)
2025-03-13T06:36:30.1607910Z    F   4   Terminate   TerminateMessage
```

whatever

(like, even PostgreSQL)



Wireshark



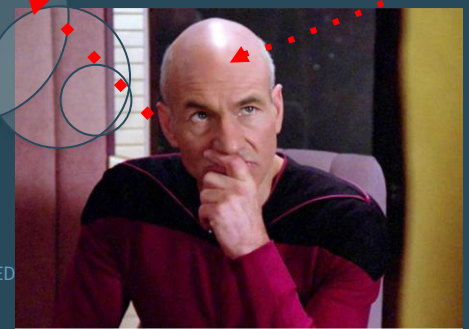
capture file

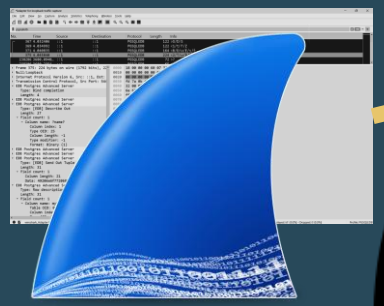
pg_protoexport

psql

whatever

(like, even PostgreSQL or spreadsheet)





Wireshark

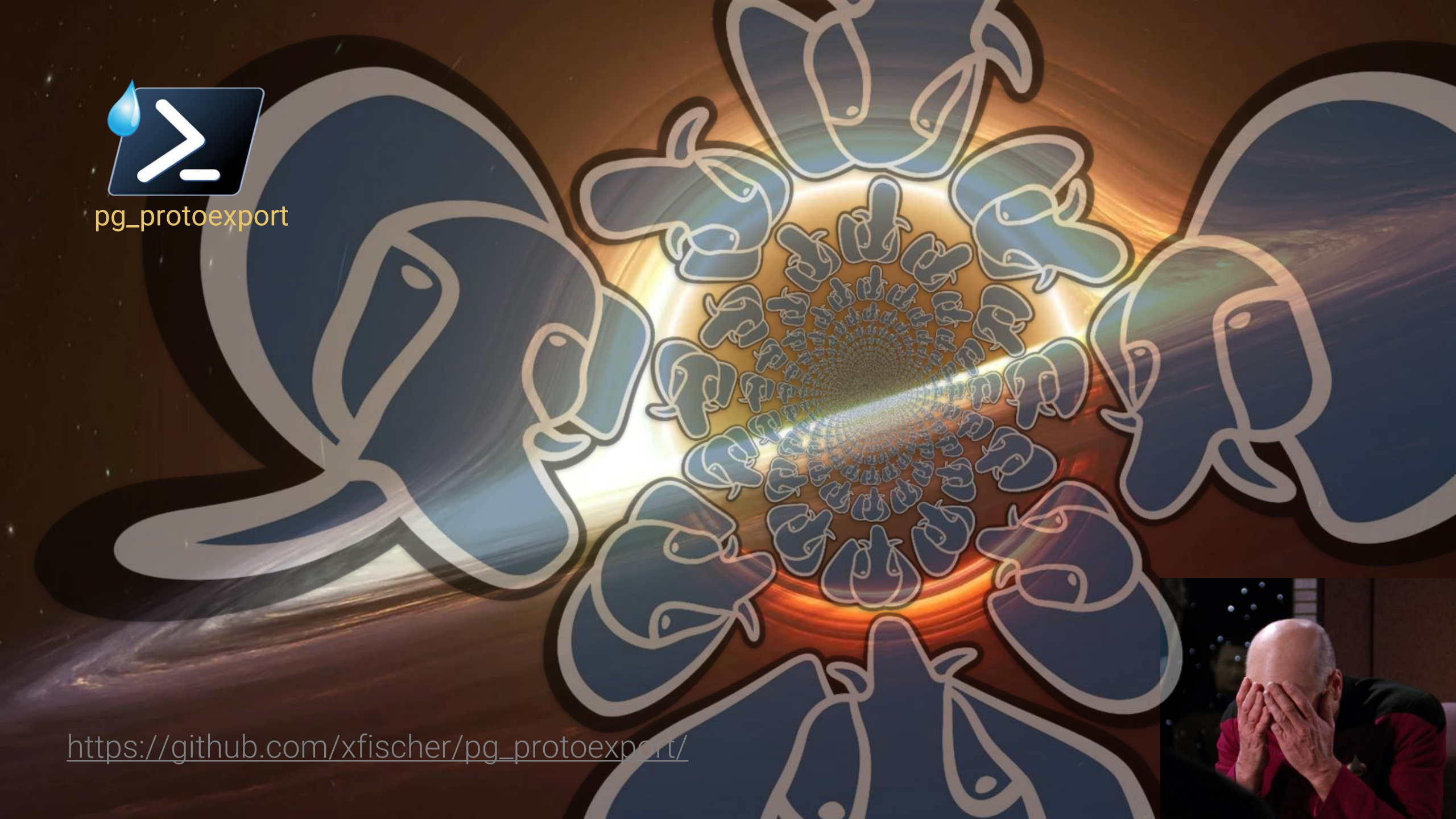
pg_protoexport

psql

whatever

PostgreSQL


WRONG HOLE!!!!


pg_protoexport
https://github.com/xfischer/pg_protoexport/

EDB POSTGRES AI