SQL Injection Isn't Dead

Smuggling Queries at the Protocol Level

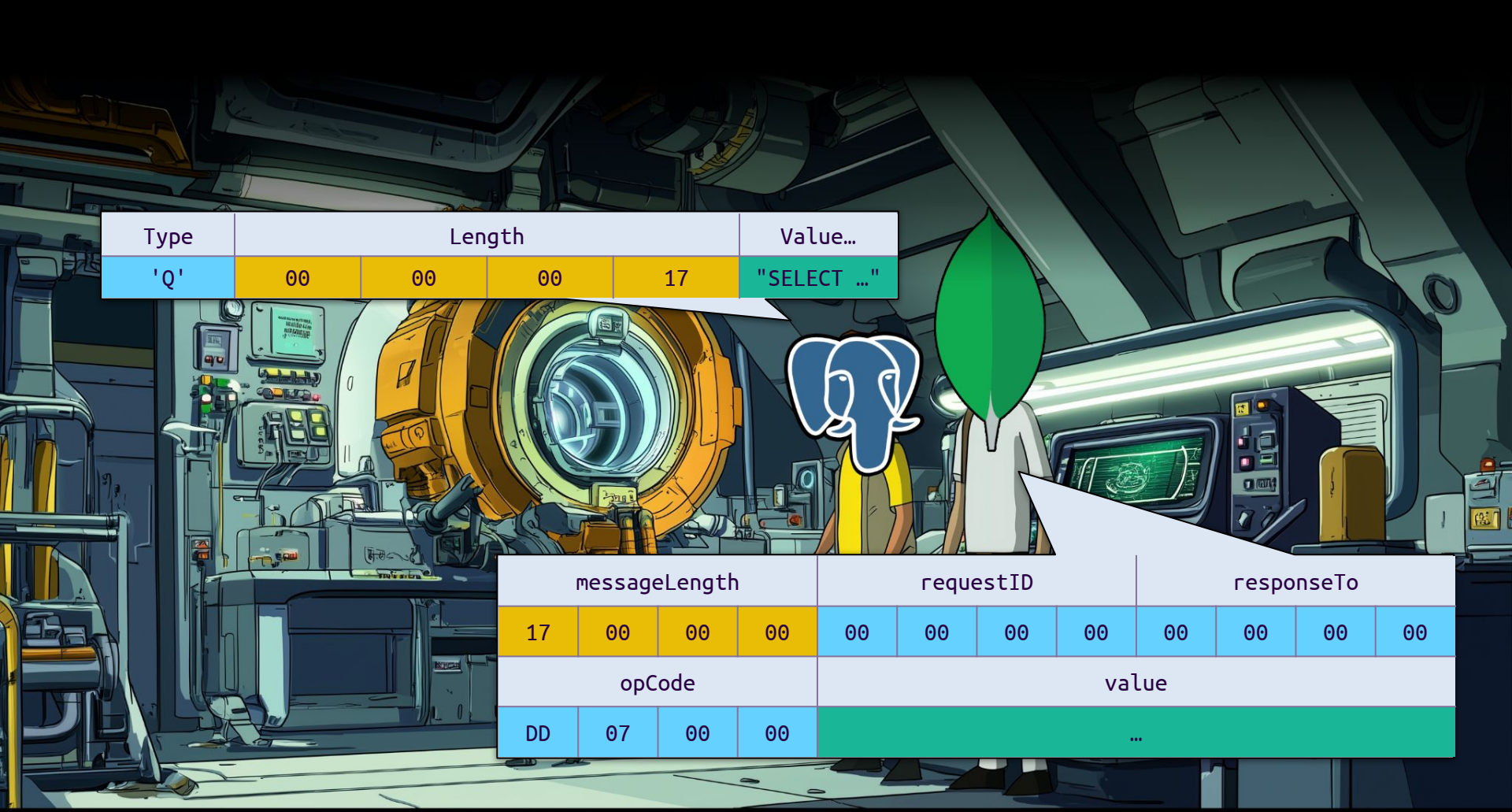
Paul Gerste – DEF CON 32 – August 10, 2024

sonar

SQL INJECTION LOWER DECKS

sonar


HGETALL user:1
SELECT * FROM users WHERE id=1
db.users.find({
id: 1,
})
MySQL

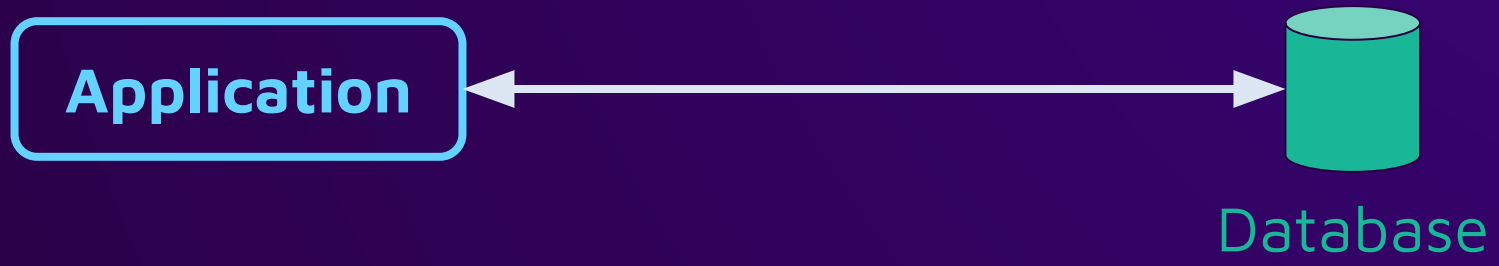

Type
Length
Value…
'Q'
00
00
00
17
"SELECT …"
messageLength
requestID
responseTo
17
00
00
00
00
00
00
00
00
00
00
00
opCode
value
DD
07
00
00
…

Teaser

```go
func getUser(w http.ResponseWriter, req *http.Request) (user User) {
    body, _ := io.ReadAll(req.Body)
    id := string(body)
    db.QueryRow("SELECT * FROM users WHERE id=$1", id).Scan(&user)
    // ...
}
```


sonar

Teaser



Teaser

SELECT * FROM speakers

```
    name     |       role        | company | team
-------------+-------------------+---------+------
Paul Gerste | Vuln Researcher |  Sonar  | R&D

(1 row)
```

SELECT * FROM speakers INNER JOIN companies

name	role	company	team
Paul Gerste	Vuln Researcher	Sonar	R&D

logo	name	description
	Sonar	The home of Clean Code

(1 row)

sonar

Outline

- The Idea
- Attacking Database Wire Protocols
  - PostgreSQL
  - MongoDB
- Real-World Applicability
- Future Research
- Takeaways

sonar

The Idea

Request smuggling, but for binary protocols

sonar

Prior Art

- James Kettle: HTTP Desync Attacks
  - Cause disagreement over the end of HTTP requests
- Example root causes:
  - Text parsing: `chunked` vs. `[\t]chunked`
  - Logical: `Content-Length` vs. `Transfer-Encoding`
- What about other protocols?

sonar

What About Binary Protocols?

- What are message boundaries here?
- Delimiters
  - E.g., null-terminated strings
- Length fields
  - E.g., Type-Length-Value (TLV) protocols

sonar

Binary Protocols: Desync

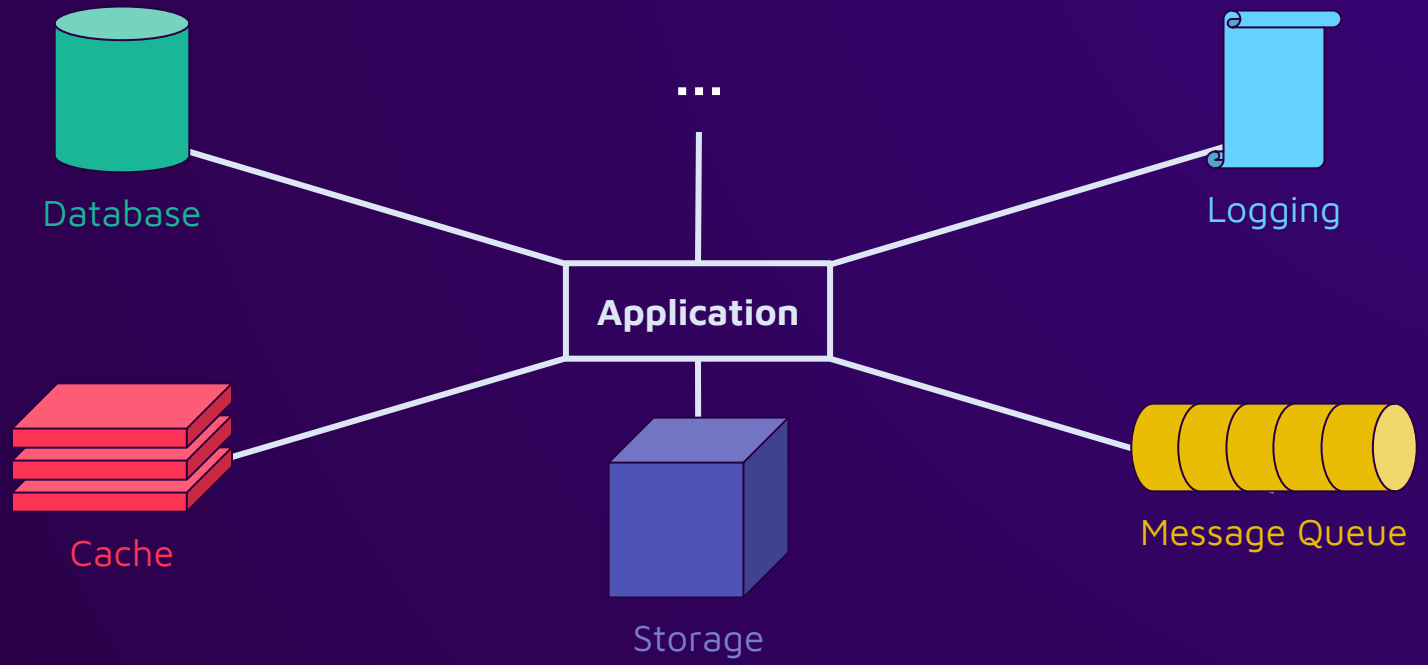
- Delimiters
  - Insert delimiters into values

Binary Protocols: Desync

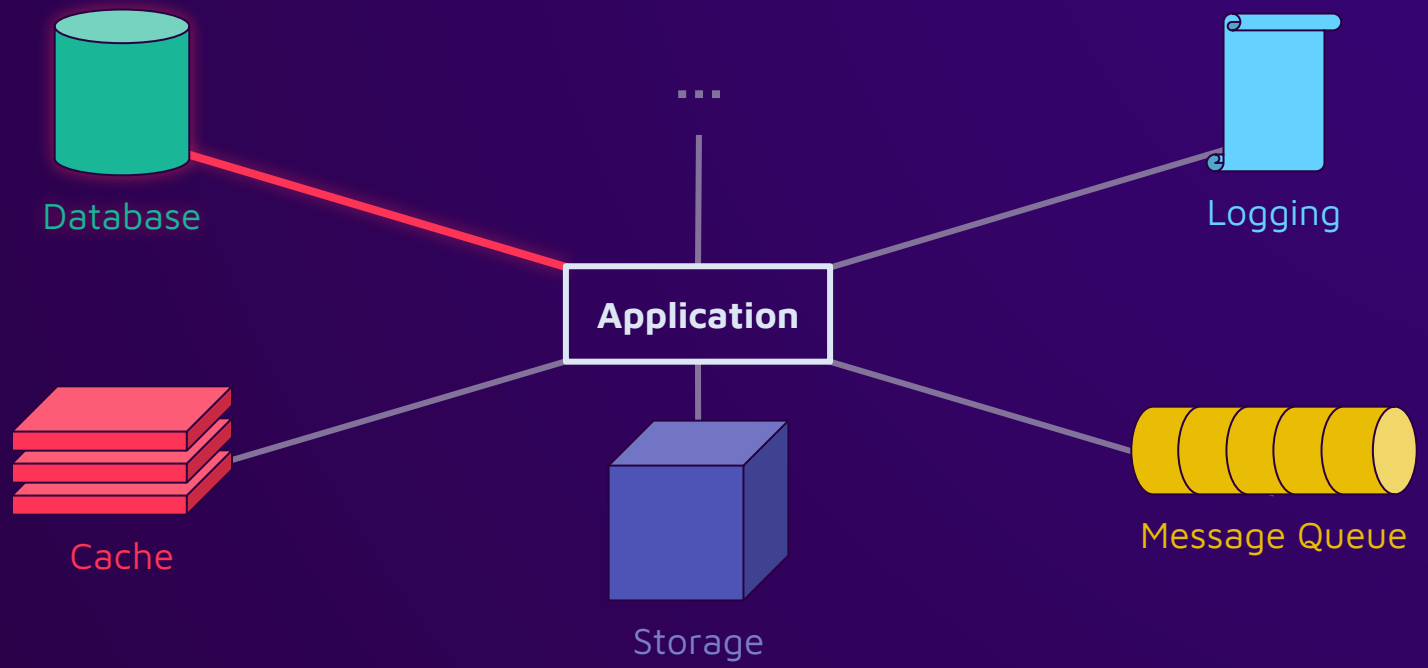
- Delimiters
  - Insert delimiters into values
- Length fields
  - 🤔
  - Endianness issues?
  - Overflows?

sonar

Binary Protocols: Landscape



Binary Protocols: Landscape



Why **Database** Wire Protocols?

- Applicability
  - Almost every web app has a database
- Severity
  - Interesting data (e.g., PII)
  - Relevant data (e.g., for authentication)
- Exploitability
  - Most queries contain some user input

sonar

Attacking Database Wire Protocols

sonar

High-Level Protocol Comparison

- PostgreSQL
- MySQL
- Redis
- MongoDB

High-Level Protocol Comparison

- **PostgreSQL**
- MySQL
- Redis
- MongoDB

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

sonar

High-Level Protocol Comparison

- PostgreSQL

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

- **MySQL**

Length			Sequence	Value…
00	00	17	00	"SELECT …"

- Redis
- MongoDB

sonar

High-Level Protocol Comparison

- PostgreSQL
- MySQL
- **Redis**
- MongoDB

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

Length			Sequence	Value…
00	00	17	00	"SELECT …"

Type	Length	Delimiter	Value…	Delimiter
'+'	"17"	\r\n	"GET …"	\r\n

sonar

High-Level Protocol Comparison

- PostgreSQL
- MySQL
- Redis
- **MongoDB**

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

Length			Sequence	Value…
00	00	17	00	"SELECT …"

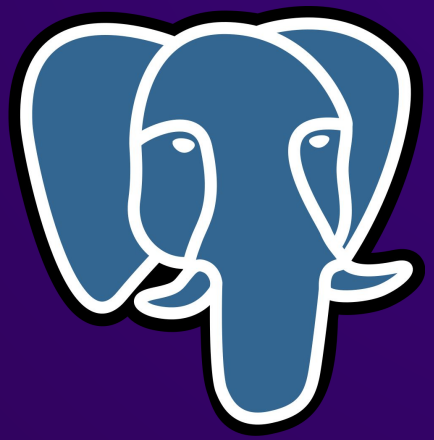
Type	Length	Delimiter	Value…	Delimiter
'+'	"17"	\r\n	"GET …"	\r\n

messageLength				requestID				responseTo			
17	00	00	00	00	00	00	00	00	00	00	00
opCode				value							
DD	07	00	00	…							

sonar

Case Study:

PostgreSQL



sonar

PostgreSQL Wire Protocol

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

- Type: 1-byte identifier
- Length: 4-byte integer
- Value

sonar

PostgreSQL Wire Protocol

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

- Type: 1-byte identifier
- Length: 4-byte integer
- Value

Max value: $2^{32}-1$

sonar

PostgreSQL Wire Protocol

Type	Length				Value…
'Q'	00	00	00	17	"SELECT …"

- Type: 1-byte identifier
- Length: 4-byte integer
- Value

Max value: $2^{32}-1$

sonar

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

Write message type

sonar

The Bug: pgx

```
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

Save size offset

sonar

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

Build the rest

sonar

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

Write size

sonar

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

The message buffer

sonar

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

Buffer length (int)

sonar

The Bug: pgx

```go
func (src *Bind) Encode(dst []byte) []byte {
    dst = append(dst, 'B')
    sp := len(dst)
    // …
    pgio.SetInt32(dst[sp:], int32(len(dst[sp:])))
    return dst
}
```

Truncate to int32

sonar

Message Size Overflow

Message 1					
Type	Length				Value
'Q'	00	00	00	08	"AAAA"

Size: 8 = 0x00000008

4 bytes length + 4 bytes data

Payload: "A" * 4

Message Size Overflow

Message 1					
Type	Length				Value
'Q'	FF	FF	FF	FF	"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA…"

Size: 2^{32}-1 = 0xFFFFFFFF

4 bytes length + 2^{32}-5 bytes data

Payload: "A" * (2**32 - 5)

sonar

Message Size Overflow

Message 1						?			
Type	Length				Value	?	?		
'Q'	00	00	00	04	""	'A'	'A'	'A'	

Size: $2^{32}+4$ = 0x100000004

4 bytes length + 2^{32} bytes data

Payload: "A" * (2**32)

sonar

Message Size Overflow

Message 1						Injected Message			
Type	Length				Value	Type	Length		
'Q'	00	00	00	04	""	'Q'	00	00	

Size: 2^{32}+4 = 0x100000004

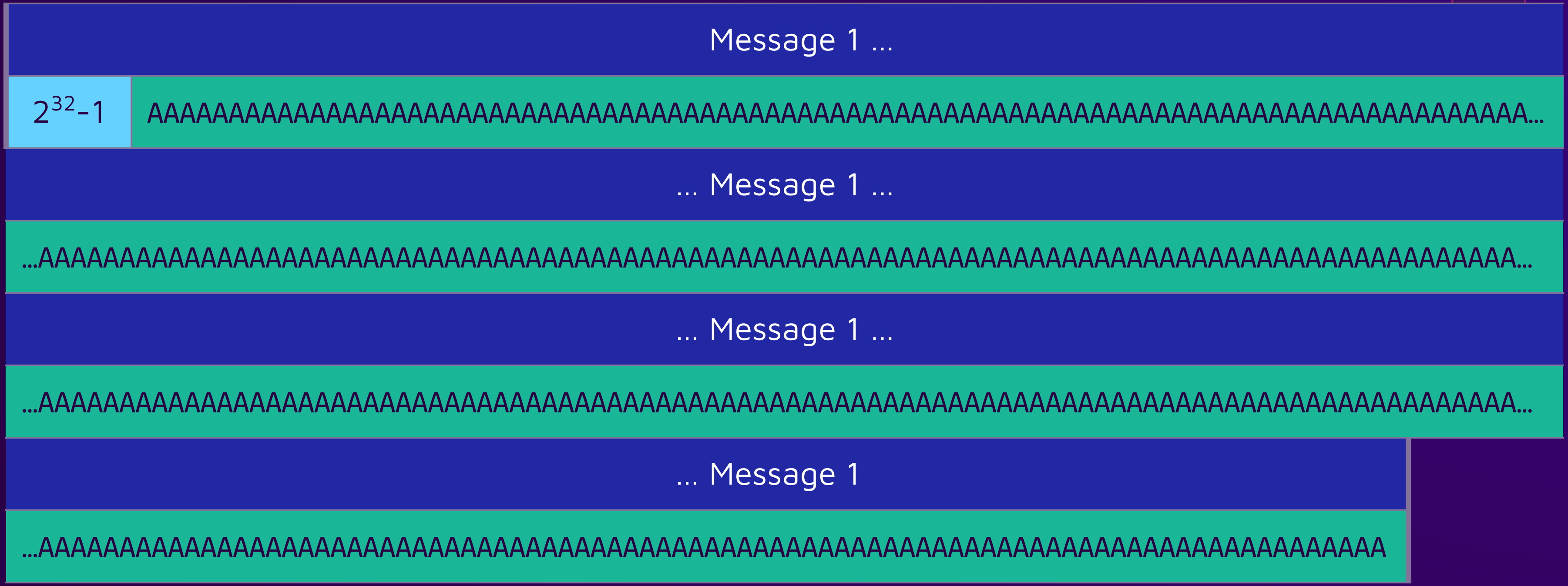
4 bytes length + 2^{32} bytes data

Payload: fakeMsg + "A" * (2**32 - len(fakeMsg))

Message Size Overflow - Zoomed Out

Message 1	
8	AAAA

Message Size Overflow - Zoomed Out



Message 1 ...

$2^{32}-1$ AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

... Message 1 ...

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

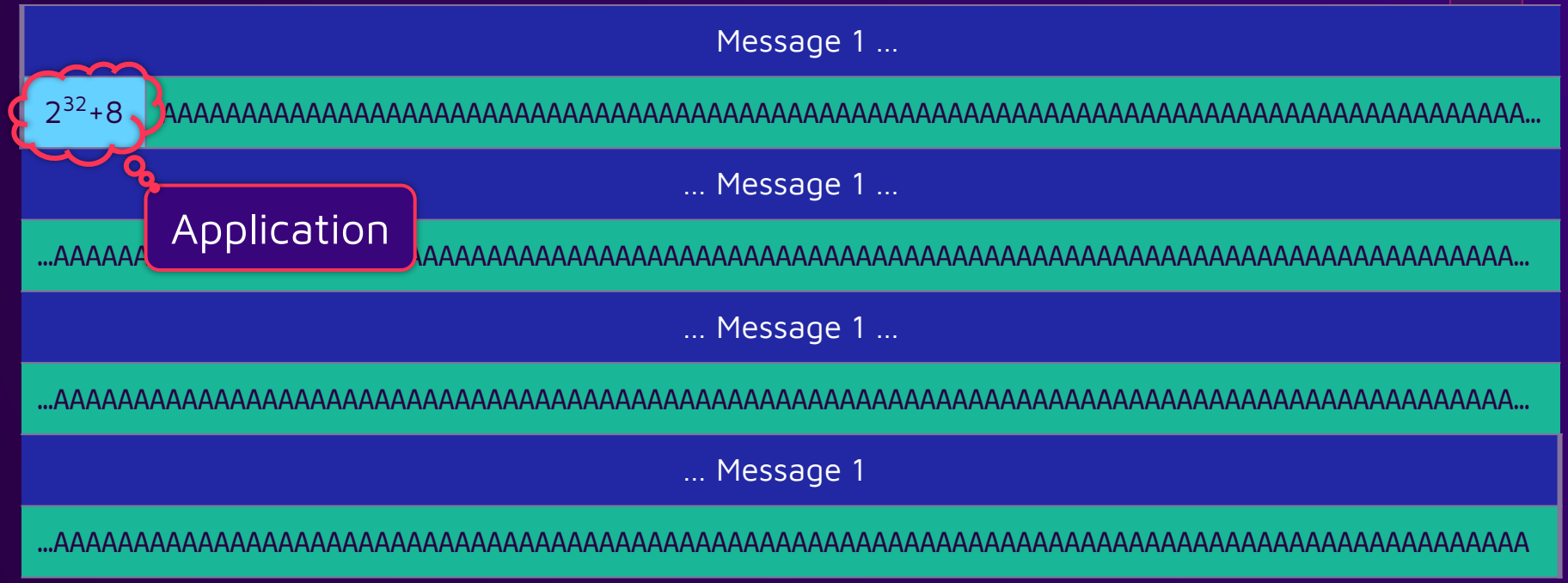
... Message 1 ...

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

... Message 1

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Message Size Overflow - Zoomed Out



Message Size Overflow - Zoomed Out

Message 1 | Garbage ...

8 | AAAA | AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

... Garbage ...

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

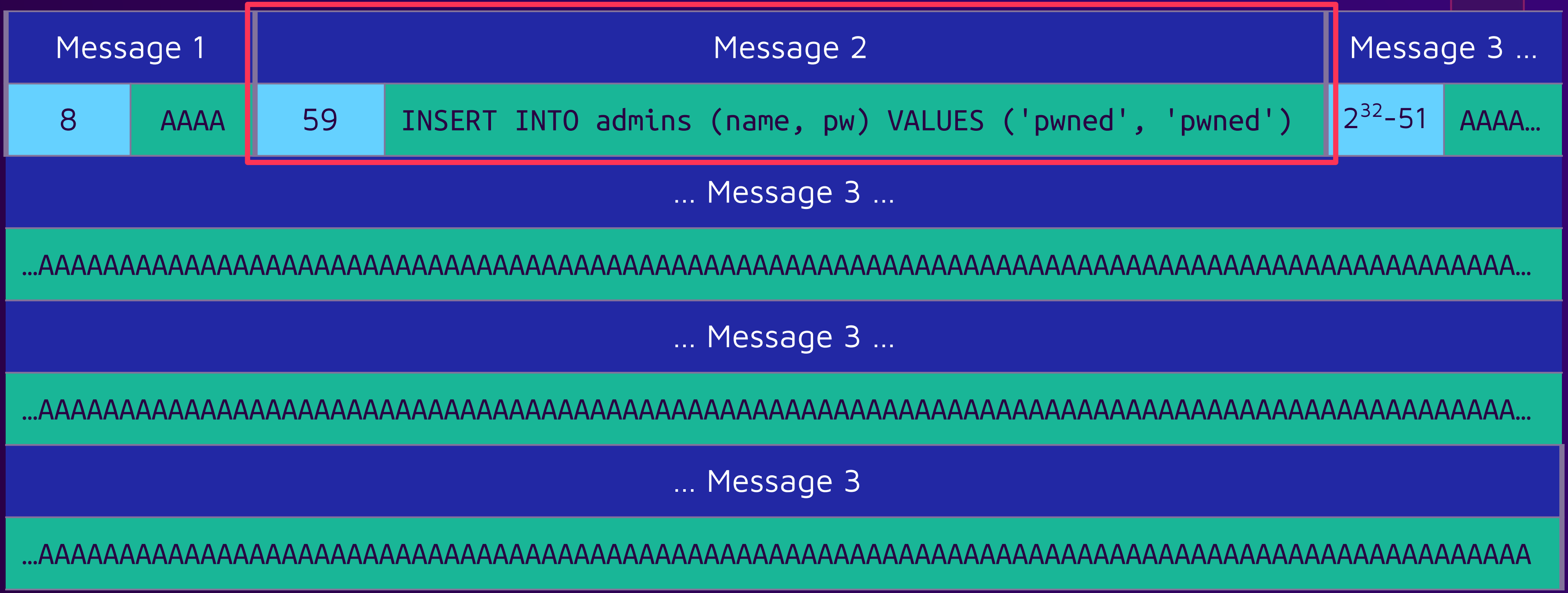
... Garbage ...

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

... Garbage

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Message Size Overflow - Zoomed Out



Message 1

8 AAAA

Message 2

59 `INSERT INTO admins (name, pw) VALUES ('pwned', 'pwned')`

Message 3 ...

$2^{32}-51$ AAAA...

... Message 3 ...

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

... Message 3 ...

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA...

... Message 3

...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Impact

- Inject entire SQL statements
  - Not limited to UNION, subqueries, etc.
  - Like stacked queries
- Read/write/delete all data in the DB
- Direct exfiltration is inconvenient
  - Application only processes the first DB response

sonar

How does it look in the real world?

How does it look in the real world?

```
id := "5831bfeb"

conn.QueryRow("SELECT * FROM users WHERE id = $1", id)
```

Type	Length				Value
'Q'	00	00	00	2e	SELECT * FROM users WHERE id = '5831bfeb'\x00

How does it look in the real world?

```
id := strings.Repeat("A", 1<<32)

conn.QueryRow("SELECT * FROM users WHERE id = $1", id)
```

Type	Length				Value	
'Q'	00	00	00	26	SELECT * FROM users WHERE id = 'AAAAAAAAAAAAAAAA…	

0x26 = 38

sonar

How does it look in the real world?

```
id := strings.Repeat("A", 1<<32)

conn.QueryRow("SELECT * FROM users WHERE id = $1", id)
```

Type	Length				Value	Type	Length
'Q'	00	00	00	29	SELECT * FROM users WHERE id = 'A	'Q'	00

How to know this offset?

sonar

Crafting a Payload

- Offset depends on the query
  - Where is the injection point?
  - How long is the query?
- Calculate the offset when query is known
- What if it's not?

Crafting a Payload

- Naïve solution: Try all the offsets!
  - Need to send 4GB for each try
  - Takes time, creates noise
  - Risk of DoS
- Can we make it more reliable?

sonar

Crafting a Payload: NOP Sled

- Idea: NOP sled
  - Use a lot of small messages
  - Hit start of a message → success
  - Hit something else → connection closed

sonar

Crafting a Payload: NOP Sled

Smallest possible message

Type	Length			
'Q'	00	00	00	04

Crafting a Payload: NOP Sled

Type	Length				Type	Length				Type	Length			
'Q'	00	00	00	04	'Q'	00	00	00	04	'Q'	00	00	00	04

…

…

Type	Length				Type	Length				Value
'Q'	00	00	00	04	'Q'	00	00	00	3B	INSERT INTO admins VALUES …

Crafting a Payload: NOP Sled

Type	Length				Type	Length				Type	Length				...
'Q'	00	00	00	04	'Q'	00	00	00	04	'Q'	00	00	00	04	

Crafting a Payload: NOP Sled

Pad	Type	Length				Type	Length				Type	Length			
A	'Q'	00	00	00	04	'Q'	00	00	00	04	'Q'	00	00	00	04

Crafting a Payload: NOP Sled

Pad		Type	Length				Type	Length				Type	Length		
A	A	'Q'	00	00	00	04	'Q'	00	00	00	04	'Q'	00	00	00

Crafting a Payload: NOP Sled

Pad			Type	Length				Type	Length				Type	Lengt		
A	A	A	'Q'	00	00	00	04	'Q'	00	00	00	04	'Q'	00	00	

Crafting a Payload: NOP Sled

Pad				Type	Length				Type	Length				Type	
A	A	A	A	'Q'	00	00	00	04	'Q'	00	00	00	04	'Q'	00

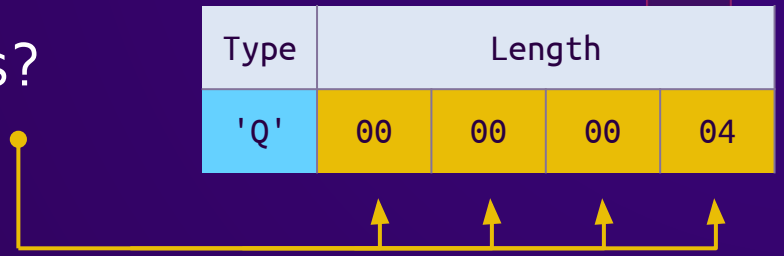
Crafting a Payload: NOP Sled

- Success after ≤5 attempts!
  - 20% chance of success
  - Attack is repeatable, just change the offset
- Still have to send 5 x 4 GB in the worst case
  - Can we make it even better?

sonar

Crafting a Payload: Trampolines

- Can length bytes be valid types?



Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	'Q'	'Q'	'Q'	'Q'
	?	?	?	?

sonar

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?

Q	Q	Q	Q	Q	S	S	S	S	S	B	B	B	B	B	E	E	E	E	E	Z	Z	Z	Z	Z	…	Q	?	?	?	?	Q	?	?	?	?	Q	?	?

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?

Q	Q	Q	Q	Q	S	S	S	S	S	B	B	B	B	B	E	E	E	E	E	Z	Z	Z	Z	Z	…	Q	?	?	?	?	Q	?	?	?	?	Q	?	?

Crafting a Payload: Trampolines

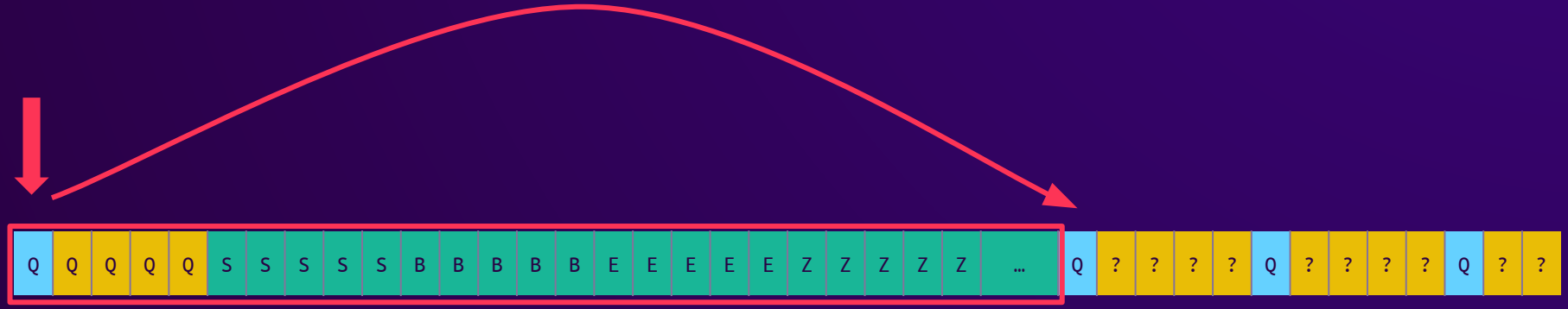
- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

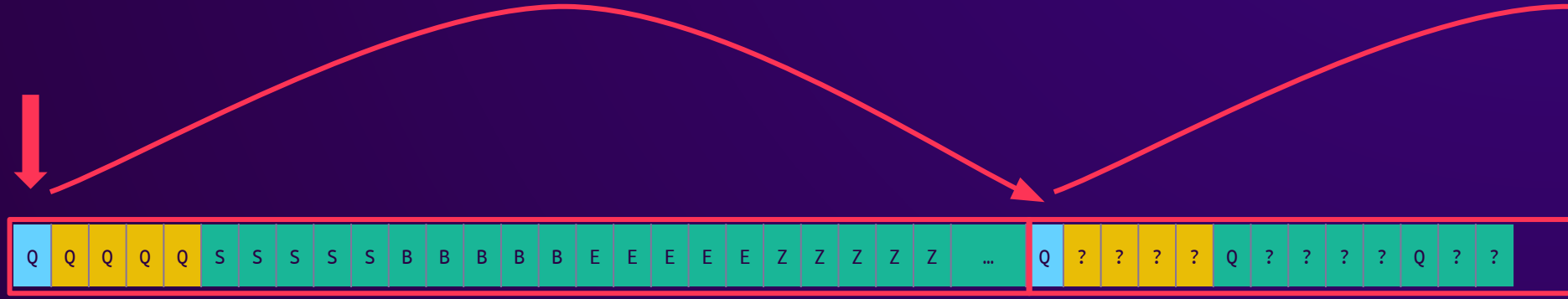
Type	Length			
'Q'	51	51	51	51
	?	?	?	?



Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?



Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?

Q	Q	Q	Q	Q	S	S	S	S	S	B	B	B	B	B	E	E	E	E	E	Z	Z	Z	Z	Z	…	Q	?	?	?	?	Q	?	?	?	?	Q	?	?

Crafting a Payload: Trampolines

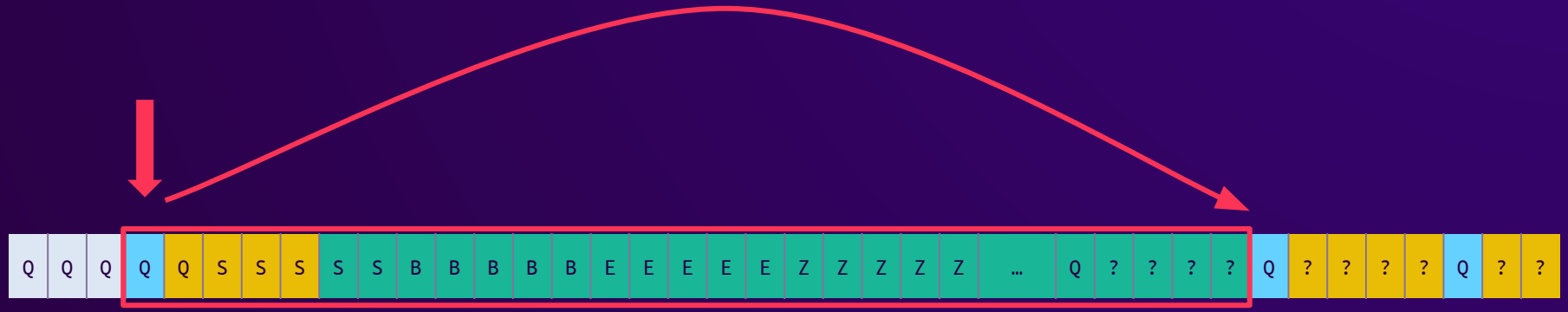
- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

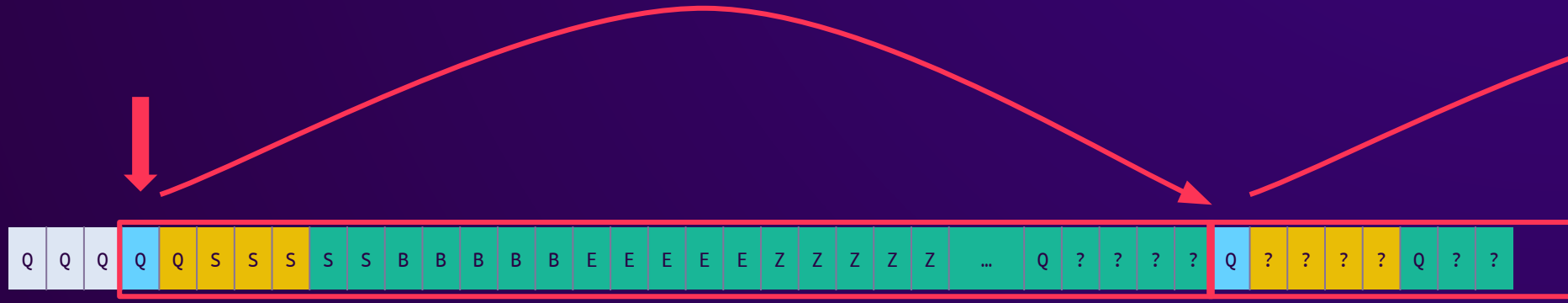
Type	Length			
'Q'	51	51	51	51
	?	?	?	?



Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?



sonar

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!

Type	Length			
'Q'	51	51	51	51
	?	?	?	?

sonar

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!
- Max. logical size: `0x3fffffff`
  - First size byte cannot be > `0x3f`

Type	Length			
'Q'	51	51	51	51
✅	❌	✅	✅	✅

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!
- Max. logical size: `0x3fffffff`
  - First size byte cannot be > `0x3f`

Type	Length			
3f	3f	3f	3f	3f
?	?	?	?	?

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!
- Max. logical size: `0x3fffffff`
  - First size byte cannot be > `0x3f`
- No valid message type ≤ `0x3f`

Type	Length			
3f	3f	3f	3f	3f
❌	✅	✅	✅	✅

sonar

Crafting a Payload: Trampolines

- Can length bytes be valid types?
  - Trampolines!
- Max. logical size: `0x3fffffff`
  - First size byte cannot be > `0x3f`
- No valid message type ≤ `0x3f`
- Solution: alternating pattern

Type	Length			
'Q'	00	'Q'	00	'Q'
✅	❌	✅	❌	✅

Crafting a Payload: Trampolines

- Every **2nd** byte is a valid type
  - Hit a valid type byte → success
  - Hit other bytes → connection closed
- Success after ≤2 attempts!
  - 50% chance of success
  - Attack is repeatable, just change the offset

Type	Length			
'Q'	00	'Q'	00	'Q'
✅	❌	✅	❌	✅

sonar

Vulnerable Libraries

Language	Library	Vulnerable?	Exploitable?	Fixed Versions
Go	pgx	✅	✅	4.18.2, 5.5.4
	pg	✅	✅	none
	pgdriver	✅	✅	none
	pq	✅	✅	none
C#/.NET	Npgsql	✅	✅	4.0.14, 4.1.13, 5.0.18, 6.0.11, 7.0.7, 8.0.3
Java	pgjdbc	❌	❌	-
	pgjdbc-ng	✅	❌	-
	r2dbc-postgresql	✅	❌	-
JS/TS	pg	✅	❌	-
	pg-promise	❌	❌	-
	pogi	✅	❌	-
	postgres	✅	❌	-
	@vercel/postgres	✅	❌	-

sonar

Disclosure Timeline

- Sent advisories in February 2024
- `pgx` fixed in March
- `Npgsql` fixed in May
- `pg` and `pgdriver` maintainer initially responded but then stopped
- `pq` maintainers never responded to issue/PR

sonar

Exploitable Applications

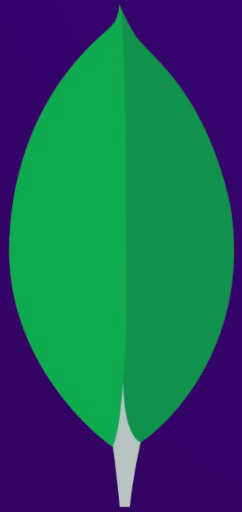
Demo: Harbor

- Container registry
  - CNCF Graduate project
  - Part of VMware Tanzu Kubernetes
- Default configuration was vulnerable
- No authentication required
- Fixed in 2.11.0 by updating pgx [1]

[1] https://github.com/goharbor/harbor/pull/20139

Case Study:

MongoDB



sonar

MongoDB Wire Protocol

messageLength				requestID				responseTo			
17	00	00	00	00	00	00	00	00	00	00	00
opCode				value							
DD	07	00	00	…							

- 4-byte length field
- Queries are BSON documents
  - Hierarchical objects
  - Serialized to TLV sections

The Bug: mongodb

```rust
async fn write_to<T: AsyncWrite + Send + Unpin>(&self, mut writer: T) -> Result<()> {
    let sections = self.get_sections_bytes();
    let total_length = Header::LENGTH
        + std::mem::size_of::<u32>()
        + sections.len()
        + /* ... */;
    let header = Header {
        length: total_length as i32,
        // ...
    };
    header.write_to(&mut writer).await?;
    writer.write_u32_le(self.flags.bits()).await?;
    writer.write_all(&sections).await?;
    // ...
}
```

The Bug: mongodb

```rust
async fn write_to<T: AsyncWrite + Send + Unpin>(&self, mut writer: T) -> Result<()> {
    let sections = self.get_sections_bytes();
    let total_length = Header::LENGTH
        + std::mem::size_of::<u32>()
        + sections.len()
        + /* ... */;
    let header = Header {
        length: total_length as i32,
        // ...
    };
    header.write_to(&mut writer).await?;
    writer.write_u32_le(self.flags.bits()).await?;
    writer.write_all(&sections).await?;
    // ...
}
```

Get content bytes

The Bug: mongodb

```rust
async fn write_to<T: AsyncWrite + Send + Unpin>(&self, mut writer: T) -> Result<()> {
    let sections = self.get_sections_bytes();
    let total_length = Header::LENGTH
        + std::mem::size_of::<u32>()
        + sections.len()
        + /* ... */;
    let header = Header {
        length: total_length as i32,
        // ...
    };
    header.write_to(&mut writer).await?;
    writer.write_u32_le(self.flags.bits()).await?;
    writer.write_all(&sections).await?;
    // ...
}
```

Calculate message size (usize)

The Bug: mongodb

```rust
async fn write_to<T: AsyncWrite + Send + Unpin>(&self, mut writer: T) -> Result<()> {
    let sections = self.get_sections_bytes();
    let total_length = Header::LENGTH
        + std::mem::size_of::<u32>()
        + sections.len()
        + /* ... */;
    let header = Header {
        length: total_length as i32,
        // ...
    };
    header.write_to(&mut writer).await?;
    writer.write_u32_le(self.flags.bits()).await?;
    writer.write_all(&sections).await?;
    // ...
}
```

Truncate to i32

Crafting a Payload

- Avoid bad bytes
  - Payload must be valid UTF-8
- Problem:
  - Message type (`dd 07`) is already invalid
  - Size fields can become invalid

sonar

Crafting a Payload

- Avoid bad bytes
  - Payload must be valid UTF-8
- Problem:
  - Message type (`dd 07`) is already invalid
  - Size fields can become invalid
- Solution:
  - Use metadata to create those bytes!

sonar

Crafting a Payload

Query:

```
{
  title: "The Wrath of Khan",
  genre: "SciFi",
  description: "...",
}
```

BSON Document:

```
4800 0000 0274 6974  6c65 0012 0000 0054   H....title.....T
6865 2057 7261 7468  206f 6620 4b68 616e   he Wrath of Khan
0002 6765 6e72 6500  0600 0000 5363 6946   ..genre.....SciF
6900 0264 6573 6372  6970 7469 6f6e 0004   i..description..
0000 002e 2e2e 0000                        ........
```

Length Type Key Value Other

Crafting a Payload

Query:

```
{
  title: "A" * (0x7dd - 1),
  genre: "SciFi",
  description: "...",
}
```

BSON Document:

```
1308 0000 0274 6974  6c65 00dd 0700 0054   H....title.....A
4141 4141 4141     ...    4141 4141 4141   AAAAA  ... AAAAA
0002 6765 6e72 6500  0600 0000 5363 6946   ..genre.....SciF
6900 0264 6573 6372  6970 7469 6f6e 0004   i..description..
0000 002e 2e2e 0000                        ........
```

Length Type Key Value Other

sonar

Vulnerable Libraries

Language	Library	Vulnerable?	Exploitable?	Fixed Version
Rust	`mongodb`	✅	✅	2.8.2
Python	`pymongo`	❌	❌	-
Go	`mongo`	❌	❌	-
Java	`mongo-java-driver`	❌	❌	-
JavaScript	`mongodb`	❌	❌	-

- Sent advisory in February 2024
- `mongodb` fixed in March

sonar

Real-World Applicability

sonar

Constraints

How Web Apps Handle Large Payloads

- Aren't apps limiting input sizes?
- Common protections:
  - Default body size limits
  - Maximum JSON/form decode sizes
  - Size-limiting reverse proxies
  - ... and more

sonar

How Web Apps Handle Large Payloads

- Potential bypasses
  - Unprotected endpoints
  - Compression
  - WebSockets
  - Alternate body types
  - Server-side creation

sonar

How Web Apps Handle Large Payloads

- Potential bypasses
  - **Unprotected endpoints**
  - Compression
  - WebSockets
  - Alternate body types
  - Server-side creation

- Some have no default limits
- Some explicitly disable limits
  - Harbor

sonar

How Web Apps Handle Large Payloads

- Potential bypasses
  - Unprotected endpoints
  - **Compression**
  - WebSockets
  - Alternate body types
  - Server-side creation

- Some enforce size limits **before** decompression
  - Nginx
  - Fastify

sonar

How Web Apps Handle Large Payloads

- Potential bypasses
  - Unprotected endpoints
  - Compression
  - **WebSockets**
  - Alternate body types
  - Server-side creation

- Compression support
- Large message size
- Many filters don't apply

sonar

How Web Apps Handle Large Payloads

- Potential bypasses
  - Unprotected endpoints
  - Compression
  - WebSockets
  - **Alternate body types**
  - Server-side creation

- Some filters don't apply
- E.g., multipart forms

sonar

How Web Apps Handle Large Payloads

- Potential bypasses
  - Unprotected endpoints
  - Compression
  - WebSockets
  - Alternate body types
  - **Server-side creation**

- Create strings on the server side
  - SSRF, templates, i18n, etc.
- Can depend on business logic

sonar

Language Comparison

- How well do languages handle big payloads?
  - How big can strings/buffers be?
- Are integer overflows silent?

Language Comparison: Large Payloads

Language	Max. String Size	Max. Buffer Size
Go	$> 2^{32}$	$> 2^{32}$
Java	$2^{31}-1$	$2^{31}-1$
C#	$2^{31}-1$	$> 2^{32}$
JS	$2^{29}-24$ *	$> 2^{32}$ *
Python	$> 2^{32}$	$> 2^{32}$
Rust	$> 2^{32}$	$> 2^{32}$

Only considering 64-bit versions.

* Depends on the implementation

sonar

Language Comparison: Integer Overflows

Language	Silent Addition Overflow?	Silent Serialization Overflow?
Go	Yes	N/A *
Java	Yes	N/A *
C#	Yes	N/A *
JS	No	Depends on impl.
Python	No	No
Rust	In release builds	N/A *

* Type system prevents overflows. Devs have to check for overflows, leading to bugs

sonar

Real-World Applicability

- Can I send large payloads?
  - A lot of times, yes!
- Can integers silently overflow/truncate?
  - In many languages, yes!
- Can I exploit real-world apps with this?
  - Absolutely!

sonar

Future Research

sonar

Safety First: No DoS Please!

Do not send large payloads to third-party systems!

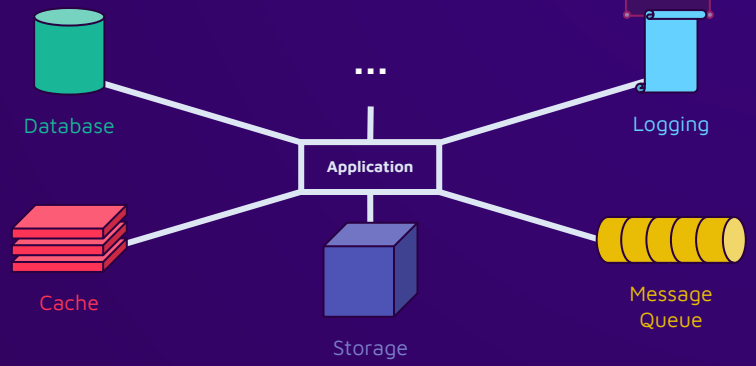
Non-Invasive Detection

- White-box tests are harmless
  - Just set up your own test environment
- How to test this black-box?
  - Sending large payloads risks DoS
- More research and tools needed!
  - Can we safely detect vulnerable libraries?
  - Build tools to test this safely

sonar

Research More!

- More protocols
  - Other databases
  - Caches, message queues, ...
- Find more desync techniques
  - What about delimiters?
- More "large payload" methods
  - New ways to bypass limits
  - Generic server-side creation techniques



Research More!

- All this was about **4-byte** length fields
- What about 2-byte fields?
  - Much easier to exploit (65KB vs. 4GB)
  - More to come in the future 👀

sonar

Conclusion

sonar

Takeaways

- Integer overflows are still relevant in memory-safe languages
- Sending large amounts of data is feasible
- SQL injection isn't dead
  - If you can't hack it, just go a level deeper!

sonar

Thank you!

@Sonar_Research

@SonarResearch@infosec.exchange

https://sonarsource.com

@pspaul95

@pspaul@infosec.exchange

sonar