



The Untold Tale of Database Communication Protocol Vulnerabilities

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Agenda

- A Brief History of Database Security Threats
- Introduction to Database Communication Protocols (and their problems)
- Detailed Walk Through of Vulnerabilities
- Mitigation Techniques

A Brief History of Database Security Threats

- Infrastructure Attacks

- Targets generic network stack vulnerabilities or common services on a server
- Unrelated to the role of the server as a DB server
- Not DB vendor specific
- Proactive mitigation using network FW
- Reactive mitigation using IDS / IPS

A Brief History of Database Security Threats

- Privilege Abuse Using SQL Queries
 - Compromised credentials
 - Excessive privileges
 - Inherent to database servers
 - Not DB vendor specific
 - Proactive mitigation using internal access controls

A Brief History of Database Security Threats

- SQL Level Vulnerabilities
 - Buffer overflow
 - xp_SetSQLSecurity, xp_sprintf, pwdencrypt (MS SQL)
 - Pwdencrypt (MS SQL)
 - CREATE DATABASE LINK (Oracle)
 - SQL Injection
 - driload.validate_stmt, dbms_metadata.get_ddl (Oracle)
 - Privilege elevation
 - OpenRowset (MS SQL)
 - Modify Data via Inline View (Oracle)

A Brief History of Database Security Threats

- Vendor Specific
- Proactive Mitigation
 - DB configuration
 - Access control
- Reactive Mitigation
 - Patching

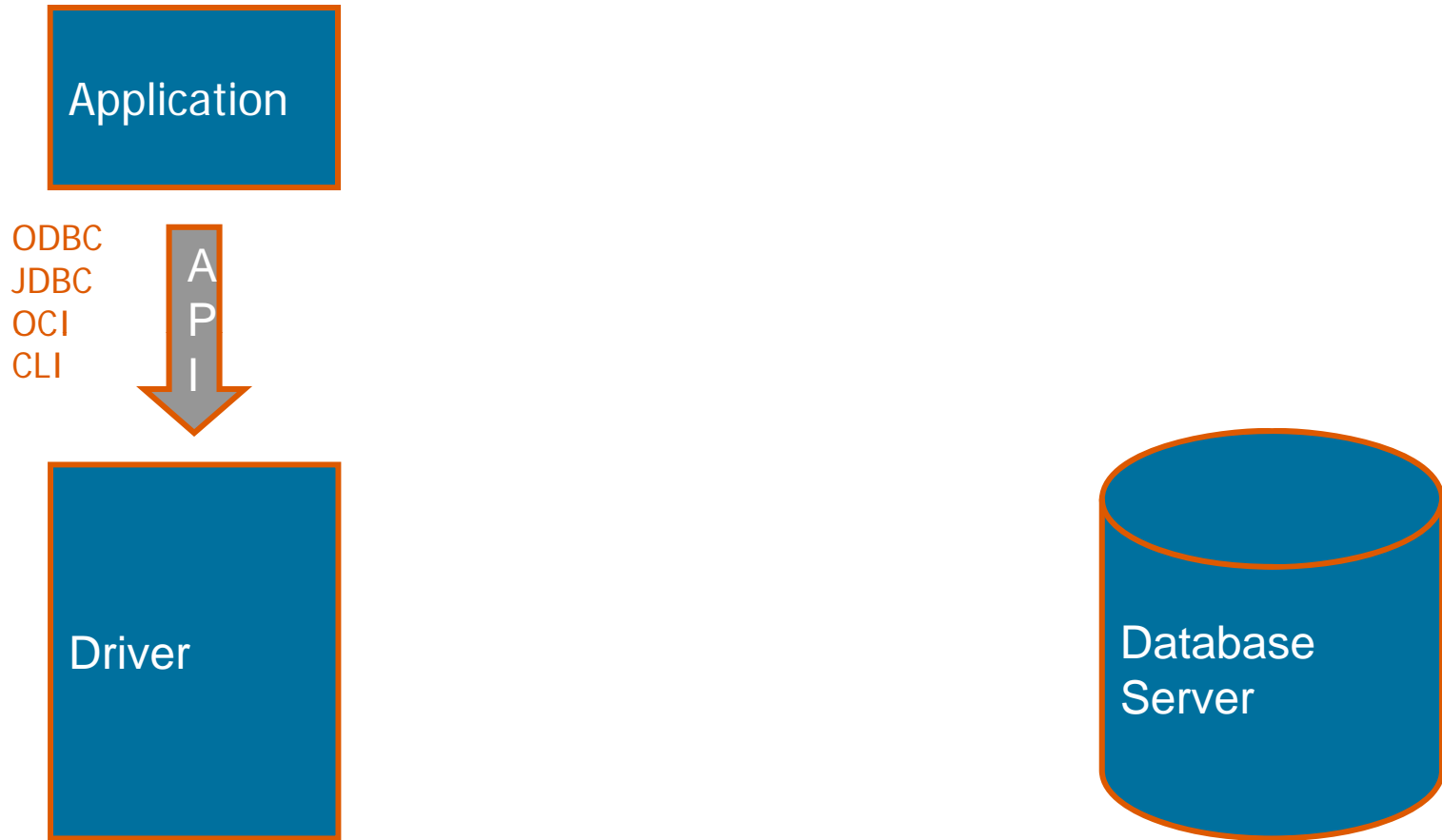
A Brief History of Database Security Threats

- Database Communication Protocol Vulnerabilities
 - First peeks on 2000
 - A major surge during 2006
 - Oracle (~20)
 - DB2 (~10)
 - Informix (~10)
 - MS SQL (<5)
 - Database vendor specific

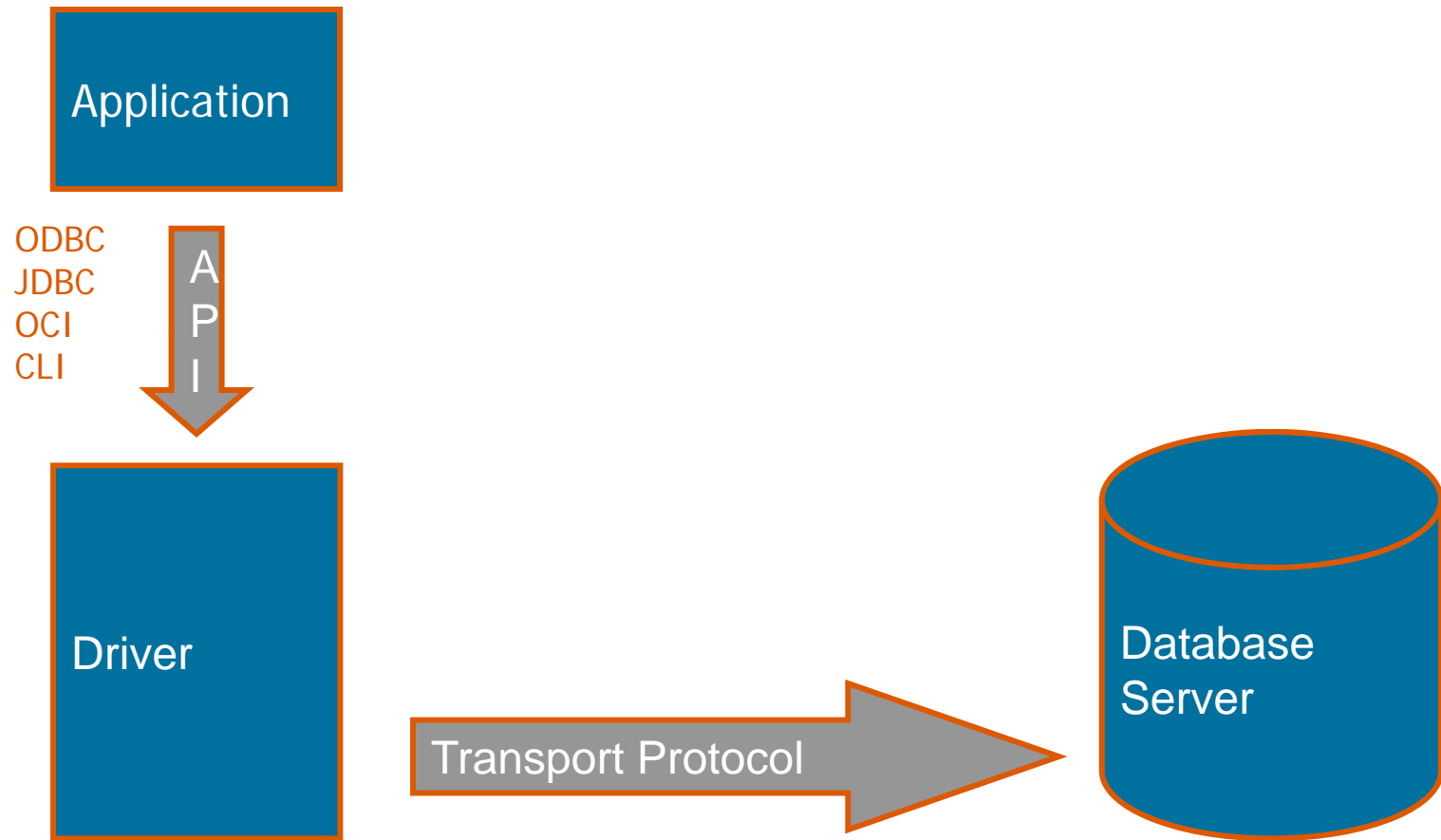
Database Communication Protocols Introduction



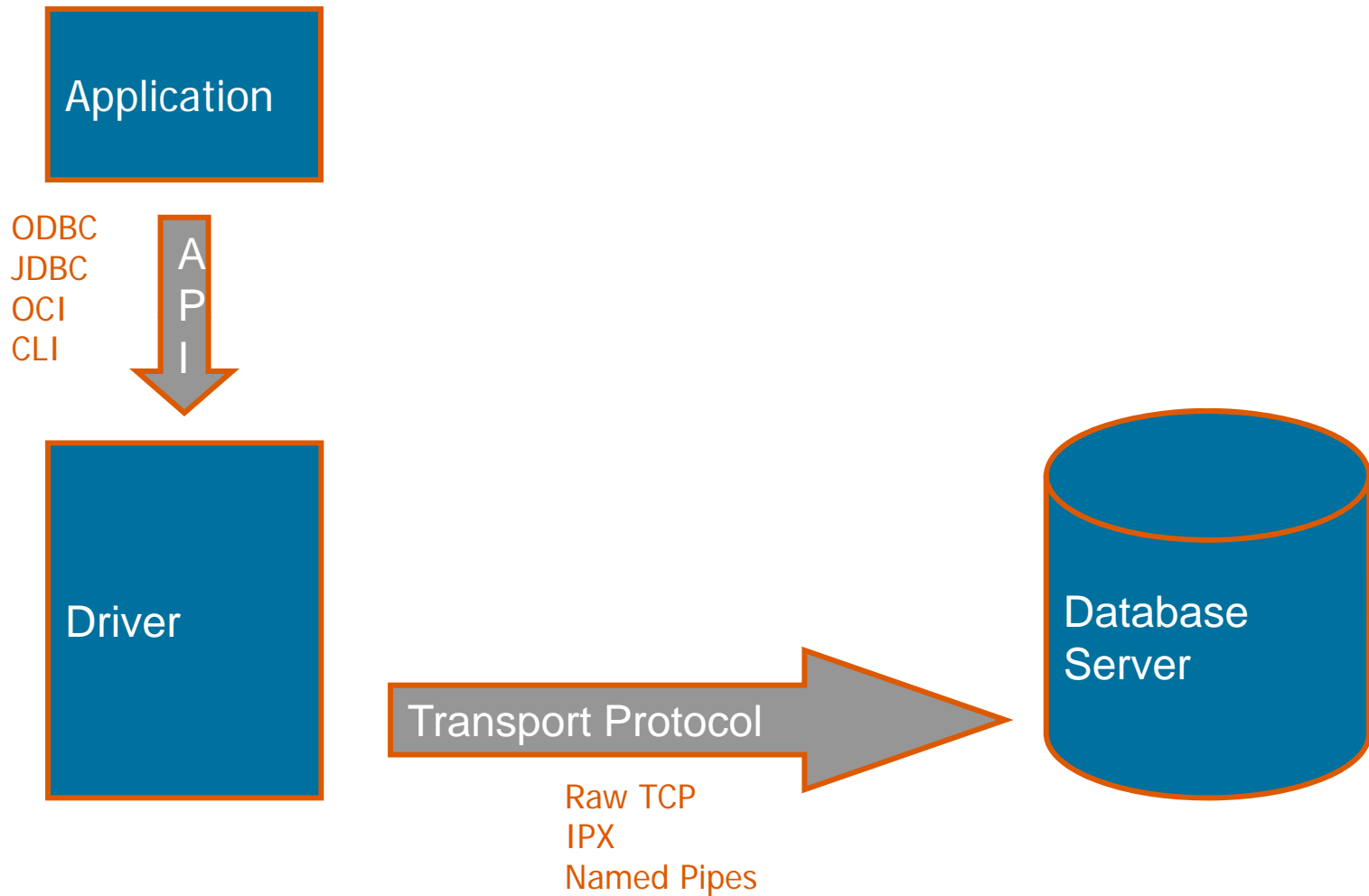
Database Communication Protocols Introduction



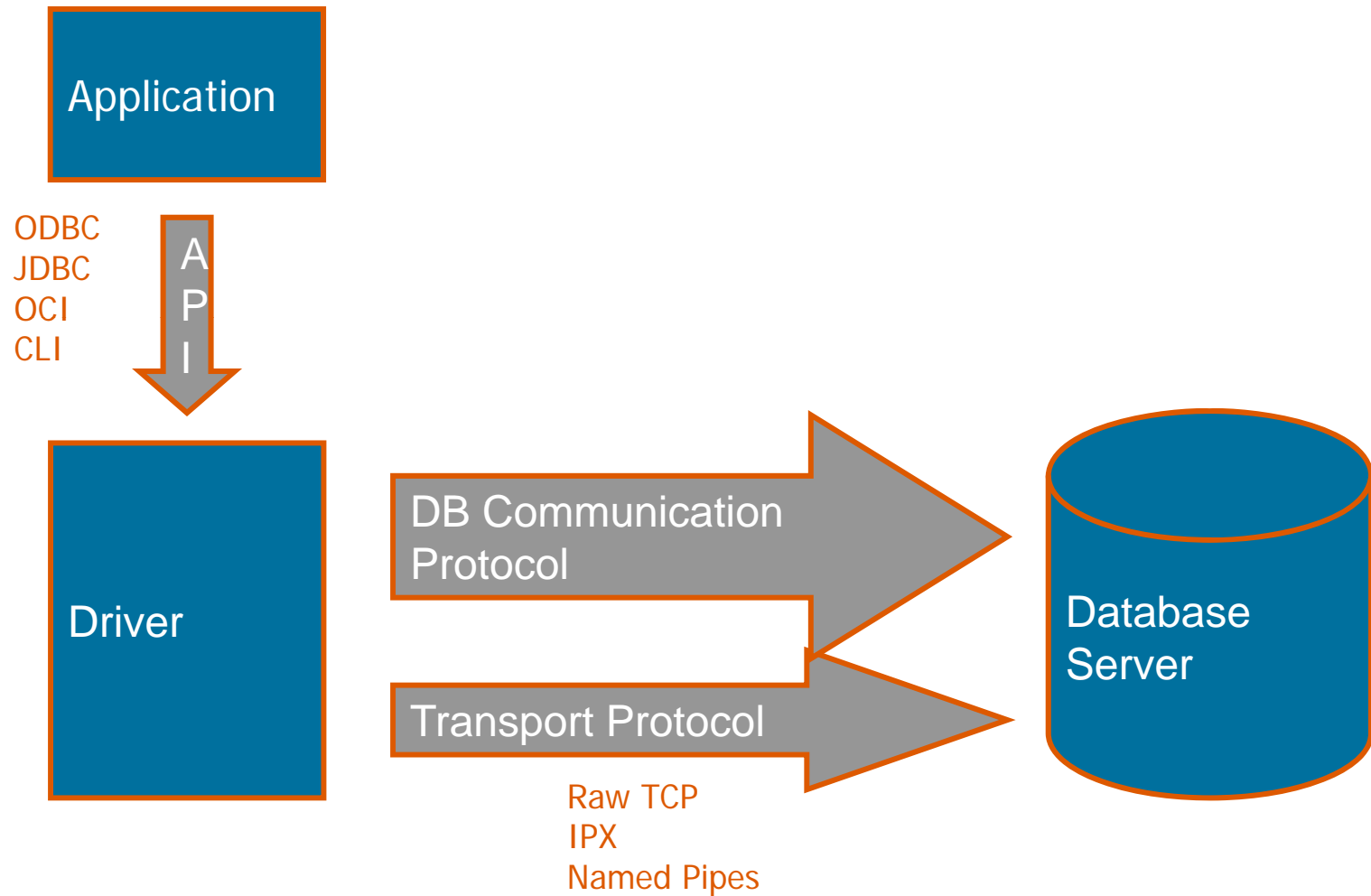
Database Communication Protocols Introduction



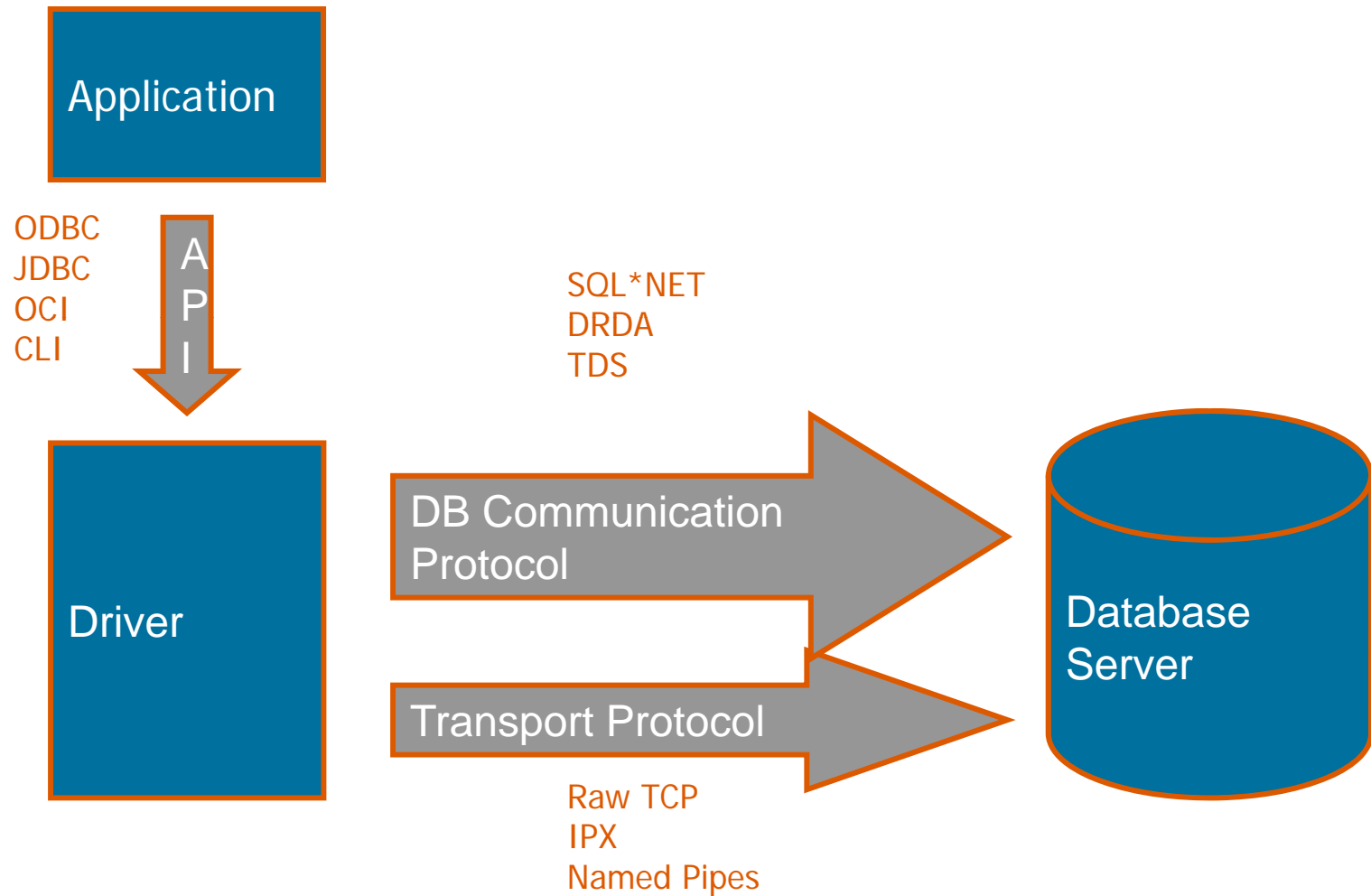
Database Communication Protocols Introduction



Database Communication Protocols Introduction



Database Communication Protocols Introduction



Database Communication Protocols

Introduction

- SQL language is standard, so are some of the APIs. However,
- No standard exists for the following tasks:
 - Creating client session
 - Conveying commands from client to server
 - Conveying data and status from server to client
 - Implementing cursor commands and prepared statements
- Vendors are filling the gap with proprietary technology:
 - Messages
 - Sequences
 - Semantics

Database Communication Protocols

Introduction

Oracle	SQL*NET (AKA Net8, Net9)
IBM	DRDA (replacement of DB2RA)
Sybase	TDS 5 (extending TDS 4.2)
MS SQL	TDS 7 & 8 (extending TDS 4.2)

Database Communication Protocols

Maximum Complexity

- Multiple layers
 - TDS: 2 layers (~10, ~100)
 - DRDA, SQL*NET: 3 layers
 - Sometimes there is redundancy between layers (size fields, offsets, termination tokens)
 - Each layer is handled independently

Database Communication Protocols

Maximum Complexity

- Microsoft TDS
- Hello Message

00000000		12	01	00	34	00	00	00	00	00	00	15	00	06	01	00	1b
00000010		00	01	02	00	1c	00	0c	03	00	28	00	04	ff	08	00	01
00000020		55	00	00	00	4d	53	53	51	4c	53	65	72	76	65	72	00
00000030		a8	07	00	00												

Database Communication Protocols

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00000020		55	00	00	00	4d	53	53	51	4c	53	65	72	76	65	72	00
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Database Communication Protocols

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00000020		55	00	00	00	4d	53	53	51	4c	53	65	72	76	65	72	00
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Database Communication Protocols

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00000020		55	00	00	00	4d	53	53	51	4c	53	65	72	76	65	72	00
00000030		a8	07	00	00												

Database Communication Protocols

Maximum Complexity

- Long history of backwards compatibility
 - Oracle 8 through Oracle 10g
 - TDS 4.2 through TDS 9
 - TDS 5 duplicate set of commands
- Data representation
 - Try to bridge different client and server environments
 - Fixed for lower layer, negotiable for other layers (Endianness, String representation, etc.)
 - DRDA uses 8 different code pages for protocol messages
 - Oracle has 3 different data representations for numeric message fields
 - Oracle **can** eliminate multiple network transmissions of identical values

Database Communication Protocols

Minimum Scrutiny

- Vendors are (almost) exclusive producers of basic client software
 - Some exceptions like DataDirect's drivers and FreeTDS implement subsets of the protocols
- Server side protocol implementation is not tested against spec but against client implementation
 - Driver developers are not always aware of the full capabilities of the protocol
- Probably few out-of-spec testing.
 - Especially for backwards compatible code
- Spec is not open for public review
 - DRDA is an exception

Database Communication Protocols Bring in the Vulnerabilities!

- Analysis of protocols is required for network based database security gateways
- Simple analysis can be done using a network sniffer

Database Communication Protocols Bring in the Vulnerabilities!

- Vulnerability research of connection establishment can be done using simple tools like *netcat*
- Deeper analysis of the protocol and vulnerability research into other parts of it requires a different tool
 - Changing selectively parts of messages within an existing connection
 - Injecting messages into existing connection
 - Removing messages from a connection

▪ Introducing: **TCPirate**

Database Communication Protocols

TCPirate

- Interactive TCP Proxy
- Record messages in both directions
- Messages can be trapped
 - Inspect message
 - Make controlled changes to the message before letting it go
 - Replace the message with a message from a file
 - Drop the message
- Spontaneously inject messages into a connection

Vulnerability Details Classification

- Message Structure Tampering
- Field Size Tampering
- Field Content Manipulation
- Message Sequence Tampering

Vulnerability Details

Message Structure Tampering

- Message fields are explicitly declared (e.g. DRDA, Some Oracle Messages, Informix)
- Three main techniques
 - Removing fields from a message
 - Adding fields to a message or duplicating fields in a message
 - Combining fields in an unexpected manner

Vulnerability Details

Message Structure Tampering

- BID 19586, Denial of Service vulnerability patched by IBM
- Fields in DRDA messages are explicitly declared
- RDBNAM field (code 0x2110) can be omitted from connection request message
- Server becomes unstable upon connection

Vulnerability Details

Message Structure Tampering

■ Original Message

00000000	00	b4	d0	41	00	01	00	ae	10	41	00	6e	11	5e	84	82
00000010	f2	82	97	4b	85	a7	85	40	40	40	40	40	40	40	40	40
00000020	40	40	f0	f5	c6	f8	f0	f5	f5	f4	f0	f0	f0	e6	00	c5
00000030	00	c2	00	c3	00	d6	00	c8	00	d6	00	d9	00	e3	00	00
00000040	00	00	00	00	00	00	00	00	00	00	00	00	00	60	f0	f0
00000050	f0	f1	c1	d4	c9	c3	c8	c1	c9	40	40	40	40	40	40	40
00000060	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
00000070	c3	e3	d6	c4	c2	40	40	40	00	18	14	04	14	03	00	07
00000080	24	07	00	07	14	74	00	05	24	0f	00	07	14	40	00	07
00000090	00	0b	11	47	d8	c4	c2	f2	61	d5	e3	00	0d	11	6d	c5
000000A0	c4	e5	c9	c3	c5	60	c1	d4	00	0c	11	5a	e2	d8	d3	f0
000000B0	f8	f0	f1	f5	00	4a	d0	01	00	02	00	44	10	6d	00	06
000000C0	11	a2	00	09	00	16	21	10	e2	c1	d4	d7	d3	c5	40	40
000000D0	40	40	40	40	40	40	40	40	40	40	00	24	11	dc	5c	17
000000E0	36	09	dd	e8	92	88	f4	e3	79	b0	57	9d	05	36	e1	26
000000F0	f6	ce	a9	90	e7	8d	86	09	e8	36	d0	95	e0	32		

Vulnerability Details

Message Structure Tampering

Original Message

00000000	00	b4	d0	41	00	01	00	ae	10	41	00	6e	11	5e	84	82
00000010	f2	82	97	4b	85	a7	85	40	40	40	40	40	40	40	40	40
00000020	40	40	f0	f5	c6	f8	f0	f5	f5	f4	f0	f0	f0	e6	00	c5
00000030	00	c2	00	c3	00	d6	00	c8	00	d6	00	d9	00	e3	00	00
00000040	00	00	00	00	00	00	00	00	00	00	00	00	00	60	f0	f0
00000050	f0	f1	c1	d4	c9	c3	c8	c1	c9	40	40	40	40	40	40	40
00000060	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
00000070	c3	e3	d6	c4	c2	40	40	40	00	18	14	04	14	03	00	07
00000080	24	07	00	07	14	74	00	05	24	0f	00	07	14	40	00	07
00000090	00	0b	11	47	d8	c4	c2	f2	61	d5	e3	00	0d	11	6d	c5
000000A0	c4	e5	c9	c3	c5	60	c1	d4	00	0c	11	5a	e2	d8	d3	f0
000000B0	f8	f0	f1	f5	00	4a	d0	01	00	02	00	44	10	6d	00	06
000000C0	11	a2	00	09	00	16	21	10	e2	c1	d4	d7	d3	c5	40	40
000000D0	40	40	40	40	40	40	40	40	40	40	00	24	11	dc	5c	17
000000E0	36	09	dd	e8	92	88	f4	e3	79	b0	57	9d	05	36	e1	26
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Vulnerability Details

Message Structure Tampering

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00000010	f2	82	97	4b	85	a7	85	40	40	40	40	40	40	40	40	40
00000020	40	40	f0	f5	c6	f8	f0	f5	f5	f4	f0	f0	f0	e6	00	c5
00000030	00	c2	00	c3	00	d6	00	c8	00	d6	00	d9	00	e3	00	00
00000040	00	00	00	00	00	00	00	00	00	00	00	00	00	60	f0	f0
00000050	f0	f1	c1	d4	c9	c3	c8	c1	c9	40	40	40	40	40	40	40
00000060	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
00000070	c3	e3	d6	c4	c2	40	40	40	00	18	14	04	14	03	00	07
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000000B0	f8	f0	f1	f5	00	4a	d0	01	00	02	00	44	10	6d	00	06
000000C0	11	a2	00	09	00	16	21	10	e2	c1	d4	d7	d3	c5	40	40
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Vulnerability Details

Message Structure Tampering

- Tampered Message

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00000010	f2	82	97	4b	85	a7	85	40	40	40	40	40	40	40	40	40
00000020	40	40	f0	f5	c6	f8	f0	f5	f5	f4	f0	f0	f0	e6	00	c5
00000030	00	c2	00	c3	00	d6	00	c8	00	d6	00	d9	00	e3	00	00
00000040	00	00	00	00	00	00	00	00	00	00	00	00	00	60	f0	f0
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00000060	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
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000000A0	c4	e5	c9	c3	c5	60	c1	d4	00	0c	11	5a	e2	d8	d3	f0
000000B0	f8	f0	f1	f5	00	34	d0	01	00	02	00	2e	10	6d	00	06
000000C0	11	a2	00	09	00	24	11	Dc	5c	17	36	09	Dd	E8	92	88
000000D0	F4	E3	79	B0	57	9d	05	36	E1	26	F6	Ce	A9	90	E7	8d
000000E0	86	09	E8	36	D0	95	E0	32								
000000F0																

Vulnerability Details

Field Size Manipulation

- Field size is explicitly declared using another dedicated field
- Mostly used for buffer overflow attacks
 - The length indicator field is capable of expressing larger data sizes than actually supported by server
- Example 1:
 - BID 18428, Buffer overflow vulnerability in DB2 connection request
 - A field called MGRLVLLS is extended to include more than 400 bytes
 - Unauthenticated denial of service and possible execution of arbitrary code
 - Affects all platforms including OS/390!

Vulnerability Details

Field Size Manipulation

- Example 2:
 - MSDE, Hello message
 - Abuse redundancy of size information
 - Dump internal buffers

00000000		12	01	00	34	00	00	00	00	00	00	15	00	FF	01	00	1b
00000010		00	01	02	00	1c	00	0c	03	00	28	00	04	ff	08	00	01
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Vulnerability Details

Field Size Manipulation

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00000020		55	00	00	00	4d	53	53	51	4c	53	65	72	76	65	72	00
00000030		a8	07	00	00												

Vulnerability Details

Field Content Manipulation

- Worst type of vulnerabilities
- Example 1:
 - US CERT Vulnerability Note VU#871756
 - Oracle TNS protocol fails to properly validate authentication requests
 - One of the login messages contains an SQL query that is executed under the SYS security context
 - The query is presumable hard-coded in the driver software
 - Can be exploited by simple editing of client side DLL
 - Affects all Oracle versions from 8 to 10gR2

Vulnerability Details

Field Content Manipulation

- Example 2:
 - MS SQL Server trace evasion
 - Driver does not allow for account name in login message to contain non-printable ASCII characters
 - Construct a login message that includes a valid account name preceded by NULL character
 - Authentication mechanism disregards the extra character
 - Trace mechanism tries to process it
 - Consequence: Invisible users

Vulnerability Details

Message Sequence Manipulation

- Manipulate the sequence of messages within the connection in an unexpected manner
- Two examples
 - Oracle
 - Informix
- Details cannot be disclosed as far as vulnerabilities are not patched
- Known effects
 - Unauthenticated access to server
 - Denial of service

Vulnerability Details

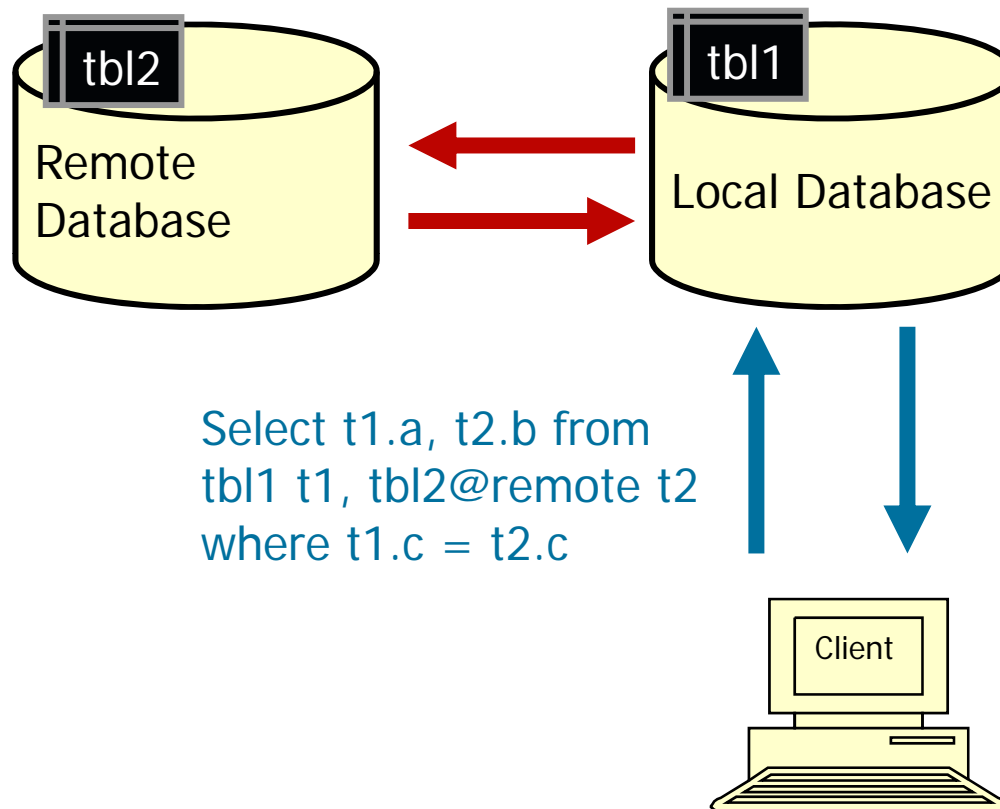
Unexpected Twist

- So far we have only considered request message manipulation (Da!)
- Should we also consider response message manipulation?
 - It does not make sense!
 - Server is not malicious so there is no danger to clients
 - Attacker does not send responses to server!

Or Does She?

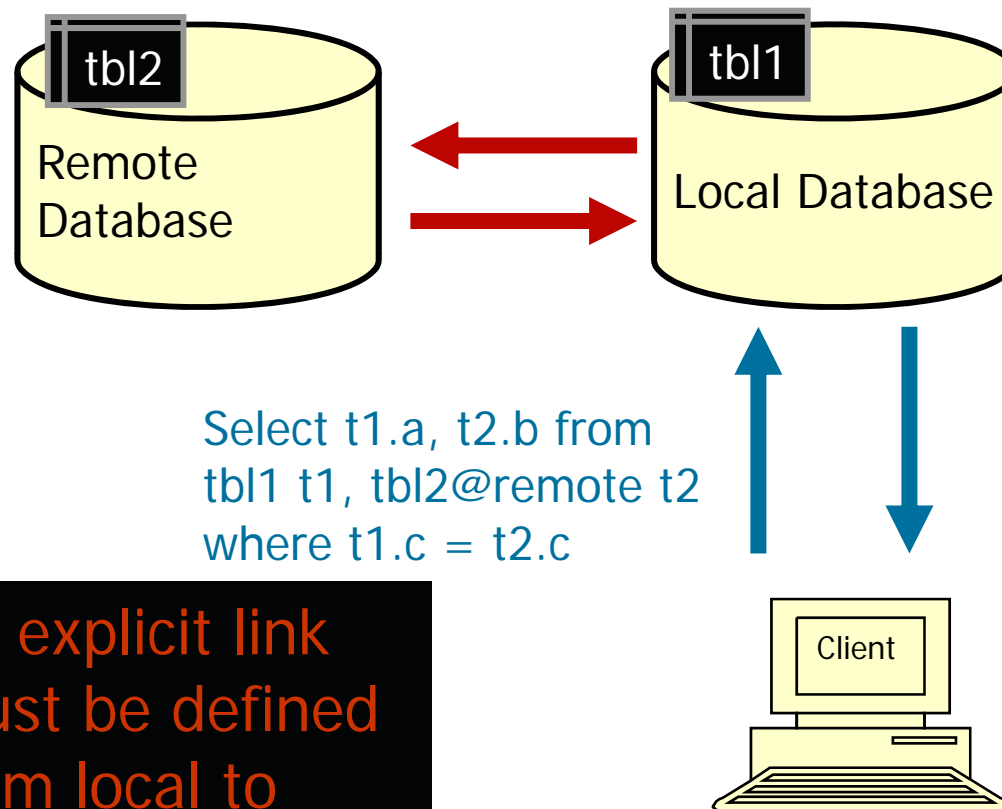
Vulnerability Details

Distributed Database



Vulnerability Details

Distributed Database



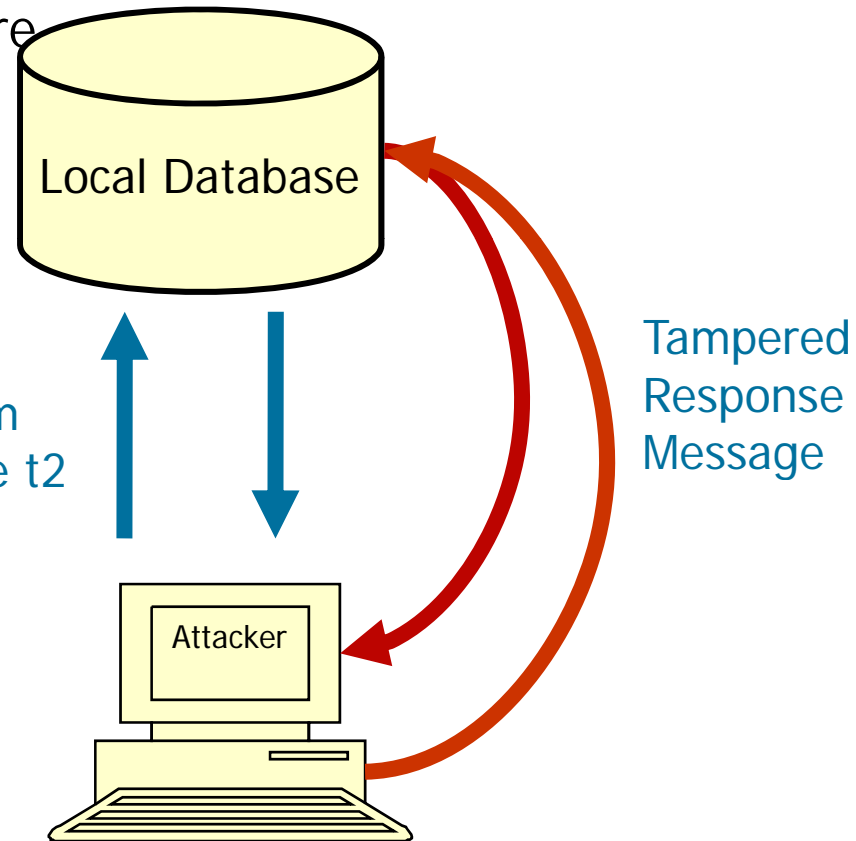
An explicit link
must be defined
from local to
remote database

Vulnerability Details

Response Tampering

- Attacker connect to server
- Defines a database link where the remote server is the attacker's machine
- Sends a distributed query

```
Select t1.a, t2.b from  
tbl1 t1, tbl2@remote t2  
where t1.c = t2.c
```



Vulnerability Details

Response Tampering

- How can an attacker define an arbitrary database link?
 - Oracle: requires CREATE DATABASE LINK privileges
 - MS SQL: OpenRowSet function
 - Informix: Set session variables
- Does it work?

Yes!!

Mitigation

- Internal server controls are useless
 - They are the ones with the vulnerability
- Patching
 - Simply not fast enough
- Reactive mitigation through IPS / IDS
 - Some vulnerabilities can be addressed using signatures or Snort-like rules

Mitigation

- Proactive mitigation with Database Security Gateway
 - Network device aware of the database communication protocol
 - Parses the data stream
 - Alert on messages that do not conform with expected client behavior
 - “Expected Client Behavior” is defined through research of vendor supplied drivers.



Thank You

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