Your Q is my Q

Message Queue Security

G. Geshev

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Introduction

Georgi Geshev

- Security Researcher at MWR Labs
- Research Interests
  - Vulnerability Development
  - IPv6 Network Reconnaissance
  - Message Queues

Agenda

- MQ Concepts
- Attack Surface
- Case Studies
- Attack Scenarios
- Common Issues
- MQ Hardening

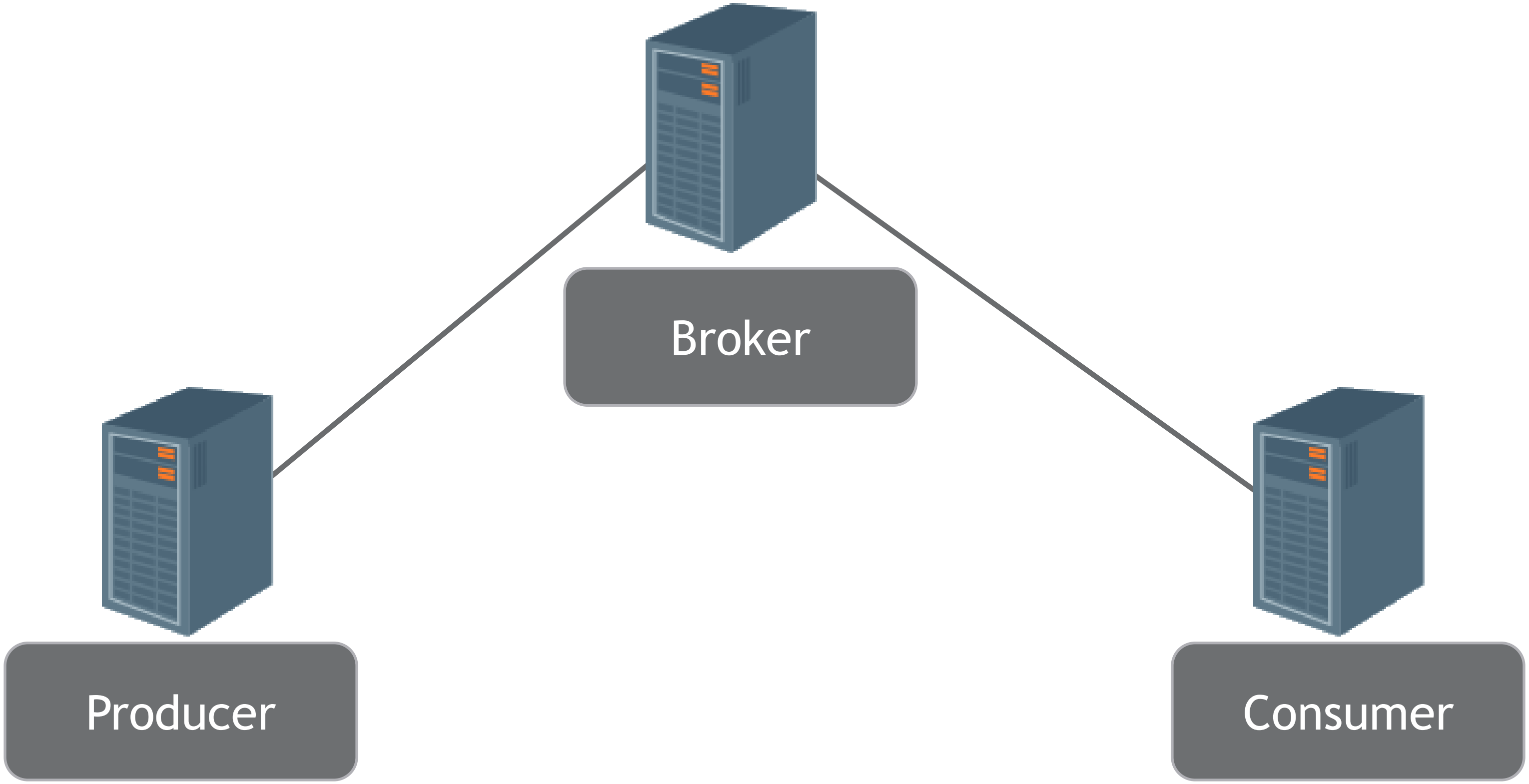
Disclaimer

- This is **not** a talk on new classes of bugs, i.e. none of the vulnerabilities are MQ specific.
- This **is** a talk on problems found to be common across some popular MQ implementations.

MQ Concepts

- Message-oriented Middleware (MOM)
  - Asynchronous Message Exchange
  - Decoupling
    - Space, Time and Synchronization Decoupling
  - Publish & Subscribe
    - Publishers Create Messages
    - Subscribers Consume Messages
    - Topic, Content and Type Based Subscriptions

MQ Concepts

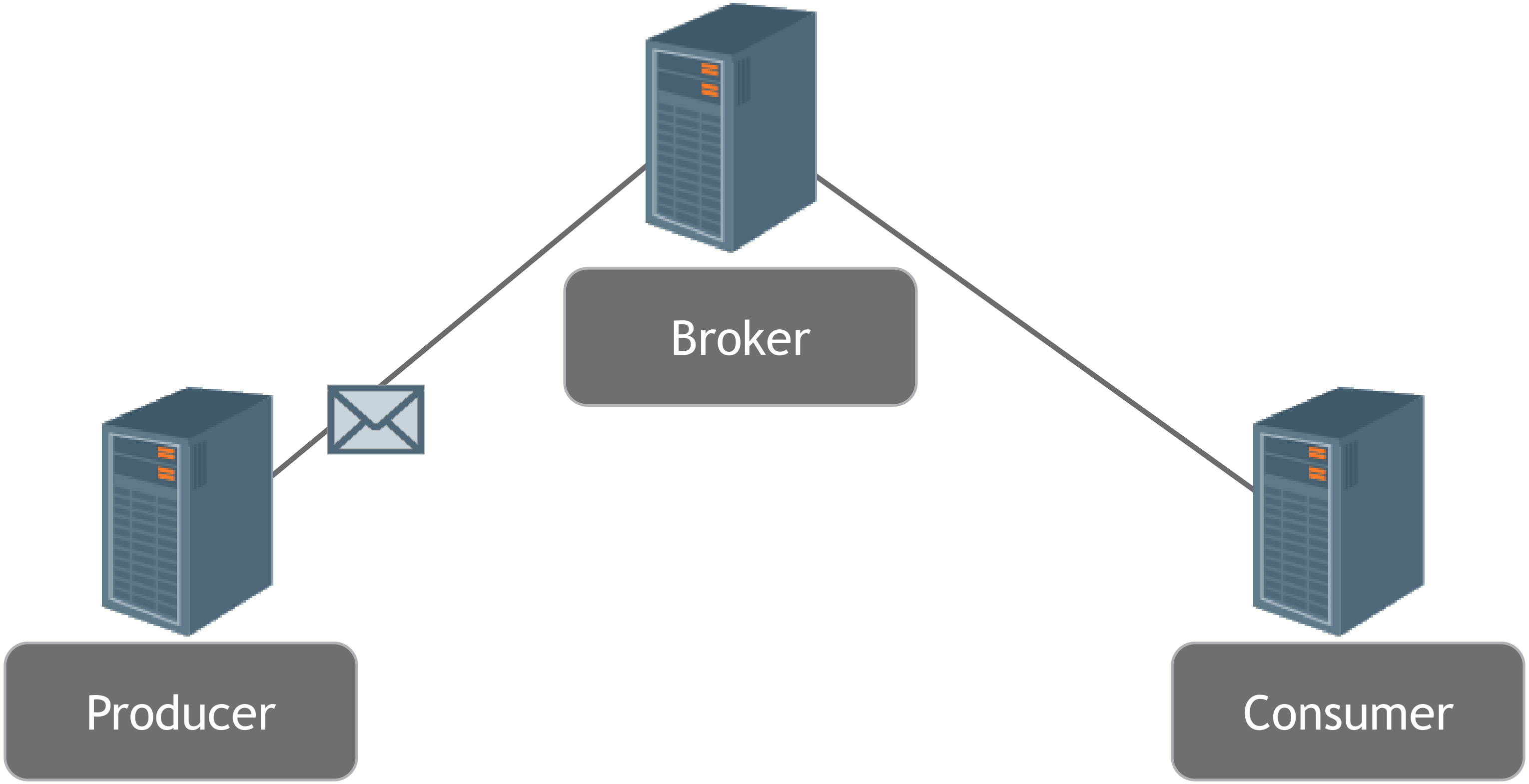


Broker

Producer

Consumer

MQ Concepts



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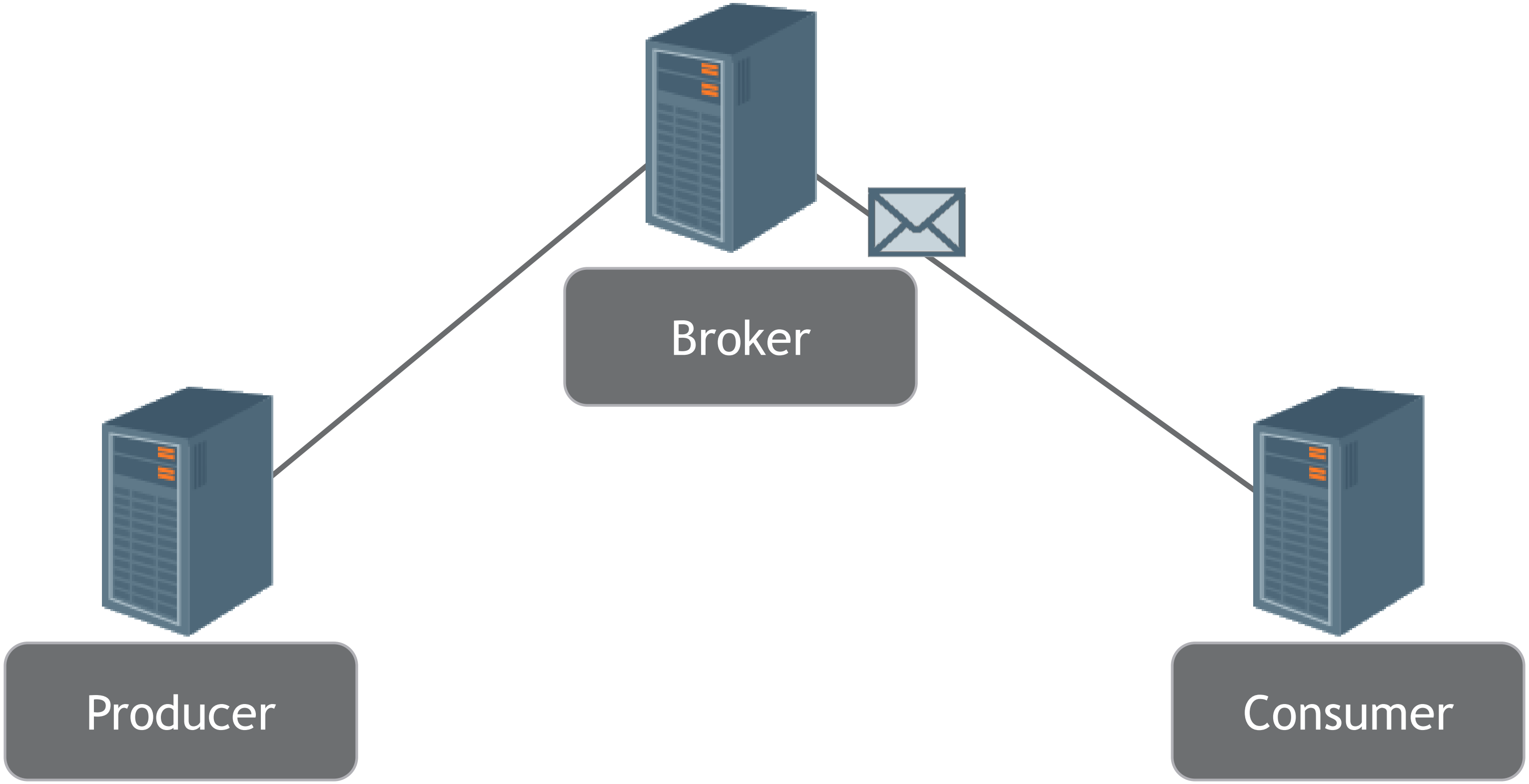

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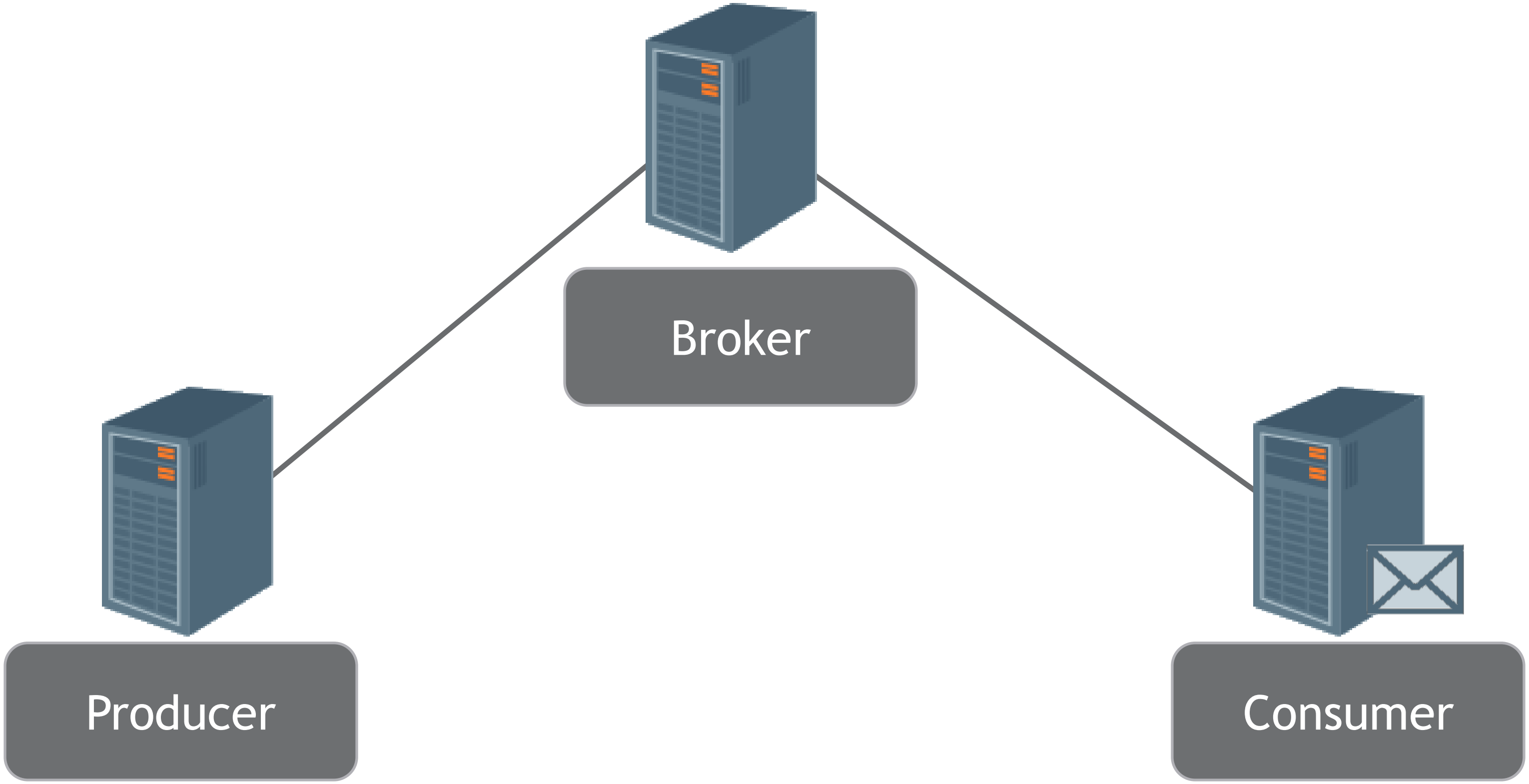

MQ Protocols

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    - AMQP (Advanced Message Queuing Protocol)
    - MQTT (MQ Telemetry Transport)
    - OpenWire

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    - AMQP (Advanced Message Queuing Protocol)
    - MQTT (MQ Telemetry Transport)
    - OpenWire
  - ASCII Protocols:
    - STOMP (Streaming Text Oriented Messaging Protocol)
    - XMPP

MQ Security

- Transport over SSL/TLS
- Authentication and Authorisation Mechanisms:
  - Certificates, Kerberos, LDAP, etc.
- Persistent Storage
  - SQL Databases
  - File Based Databases
- Redundant Brokers
  - Clustering
  - Broker Networks

Misconfigurations

- Default Administrative Credentials
- Management Interfaces Exposed
  - Java Management Extension (JMX)
  - Java Remote Method Invocation (RMI)
  - Java Debug Wire Protocol (JDWP)
- Default Queues
  - Anonymous Access
    - Publish
    - Subscribe

Demo

- ActiveMQ 5.6.0
  - Debian 7.5.0
  - Ubuntu 14.04.1
- Default Configuration
- Java Management Extension (JMX)
  - Custom script to identify RMI service endpoint via JMX.
  - RMI Registry endpoint is only locally exposed.*
  - Port forwarding to access the RMI service.
  - Deploying and executing a JAR payload.

Case Studies

- Sending Serialised Objects
- Sending System Commands
- Rendering Untrusted Messages in Administrative or Monitoring Consoles
    - Cross-Site Scripting
- Inserting Unsanitised Messages in Databases
    - SQL Injection

Attack Scenarios

- Attacker’s Perspective
  - Anonymous
  - Client
  - Broker

- Attacks
  - Man-in-the-Middle
  - Authentication Bypasses
  - Implementation Specific
  - DoS

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Bug Hunting

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- Source Code Audit
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- Fuzzing
  - Stateless
    - Radamsa
  - Stateful
    - MITM Fuzzing
  - Patching

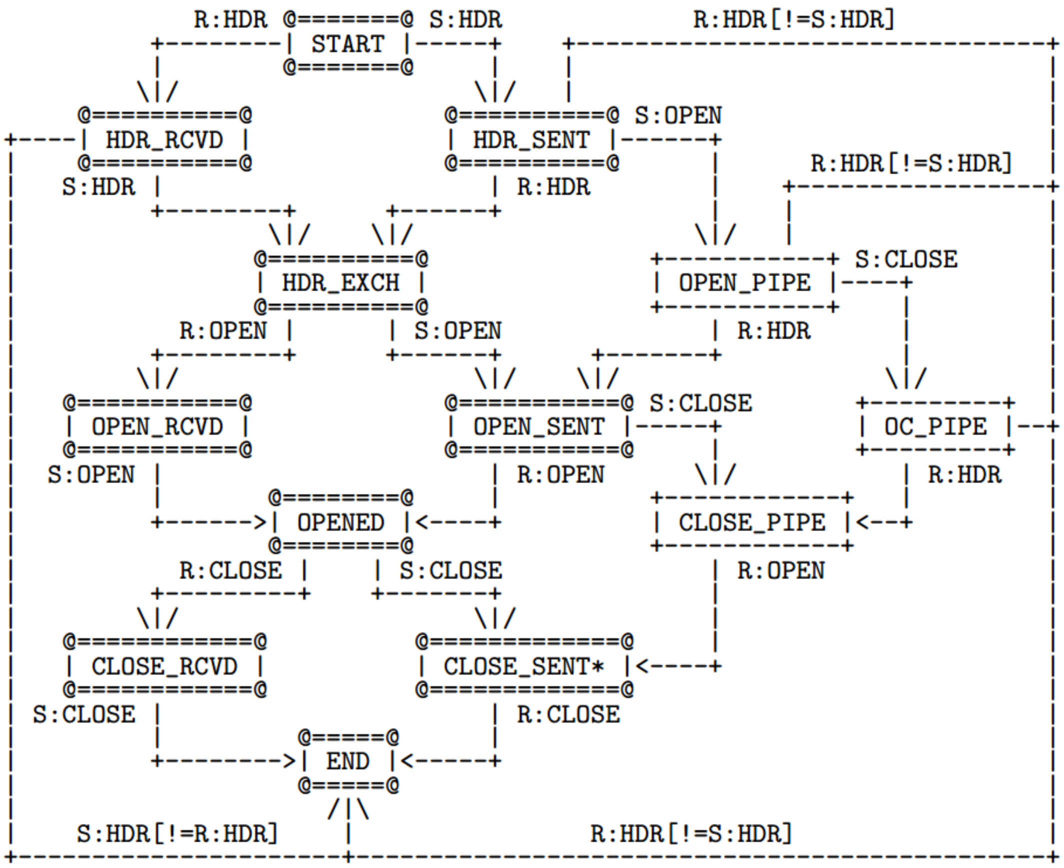
- Traffic Generation
  - Unit Tests
  - Performance Harness Tools
  - Code Samples

Bug Hunting

- Source Code Audit
  - Pattern Based
- Fuzzing
  - Stateless
    - Radamsa
  - Stateful
    - MITM Fuzzing
  - Patching
- Outdated Libraries
  - e.g. Vulnerable XStream in ActiveMQ < 5.10.0

- Traffic Generation
  - Unit Tests
  - Performance Harness Tools
  - Code Samples

AMQP State Machine

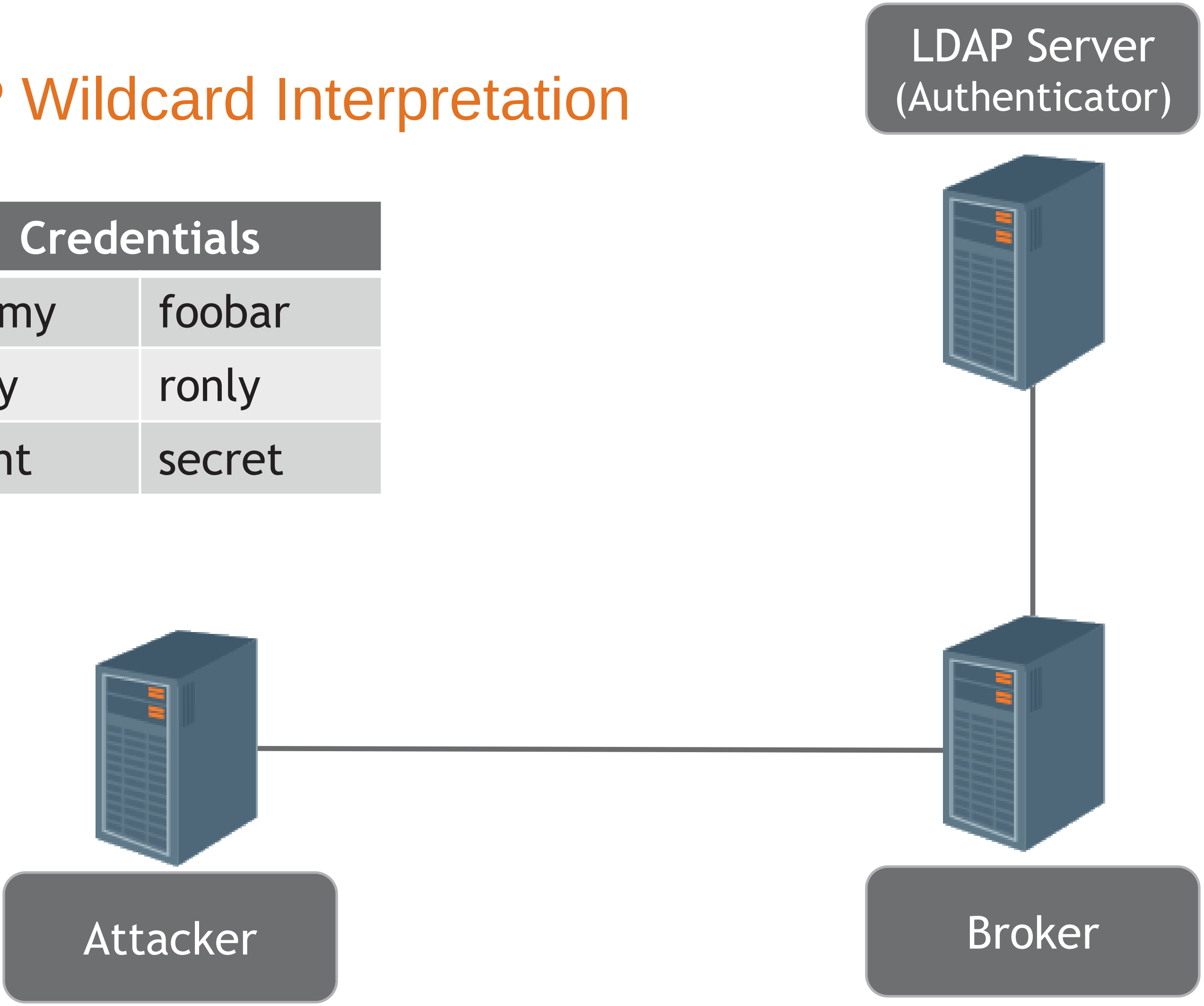


```
             R:HDR @=======@ S:HDR             R:HDR[!=S:HDR]
          +--------| START |-----+    +--------------------------------+
          |        @=======@     |    |                                |
         \|/                    \|/   |                                |
     @==========@             @==========@ S:OPEN                      |
+----| HDR_RCVD |             | HDR_SENT |------+                      |
|    @==========@             @==========@      |      R:HDR[!=S:HDR]  |
|   S:HDR |                      | R:HDR        |    +-----------------+
|         +--------+      +------+              |    |                 |
|                 \|/    \|/                   \|/   |                 |
|                @==========@               +-----------+ S:CLOSE      |
|                | HDR_EXCH |               | OPEN_PIPE |----+         |
|                @==========@               +-----------+    |         |
|           R:OPEN |      | S:OPEN              | R:HDR      |         |
|         +--------+      +------+      +-------+            |         |
|        \|/                    \|/    \|/                  \|/        |
|   @===========@             @===========@ S:CLOSE       +---------+  |
|   | OPEN_RCVD |             | OPEN_SENT |-----+         | OC_PIPE |--+
|   @===========@             @===========@     |         +---------+  |
|  S:OPEN |                      | R:OPEN      \|/           | R:HDR   |
|         |       @========@     |          +------------+   |         |
|         +------->| OPENED |<----+          | CLOSE_PIPE |<--+         |
|                 @========@                +------------+             |
|           R:CLOSE |    | S:CLOSE              | R:OPEN               |
|         +---------+    +-------+              |                      |
|        \|/                    \|/             |                      |
|   @============@          @=============@     |                      |
|   | CLOSE_RCVD |          | CLOSE_SENT* |<----+                      |
|   @============@          @=============@                            |
| S:CLOSE |                      | R:CLOSE                             |
|         |         @=====@      |                                     |
|         +--------->| END |<-----+                                     |
|                   @=====@                                            |
|                     /|\                                              |
|    S:HDR[!=R:HDR]    |                R:HDR[!=S:HDR]                 |
+----------------------+-----------------------------------------------+
```

```
R:<CTRL> = Received <CTRL>
S:<CTRL> = Sent <CTRL>
* Also could be DISCARDING if an error condition
  triggered the CLOSE
```

LDAP Wildcard Interpretation

Credentials	
tommy	foobar
ronly	ronly
client	secret



LDAP Server (Authenticator)

Attacker

Broker

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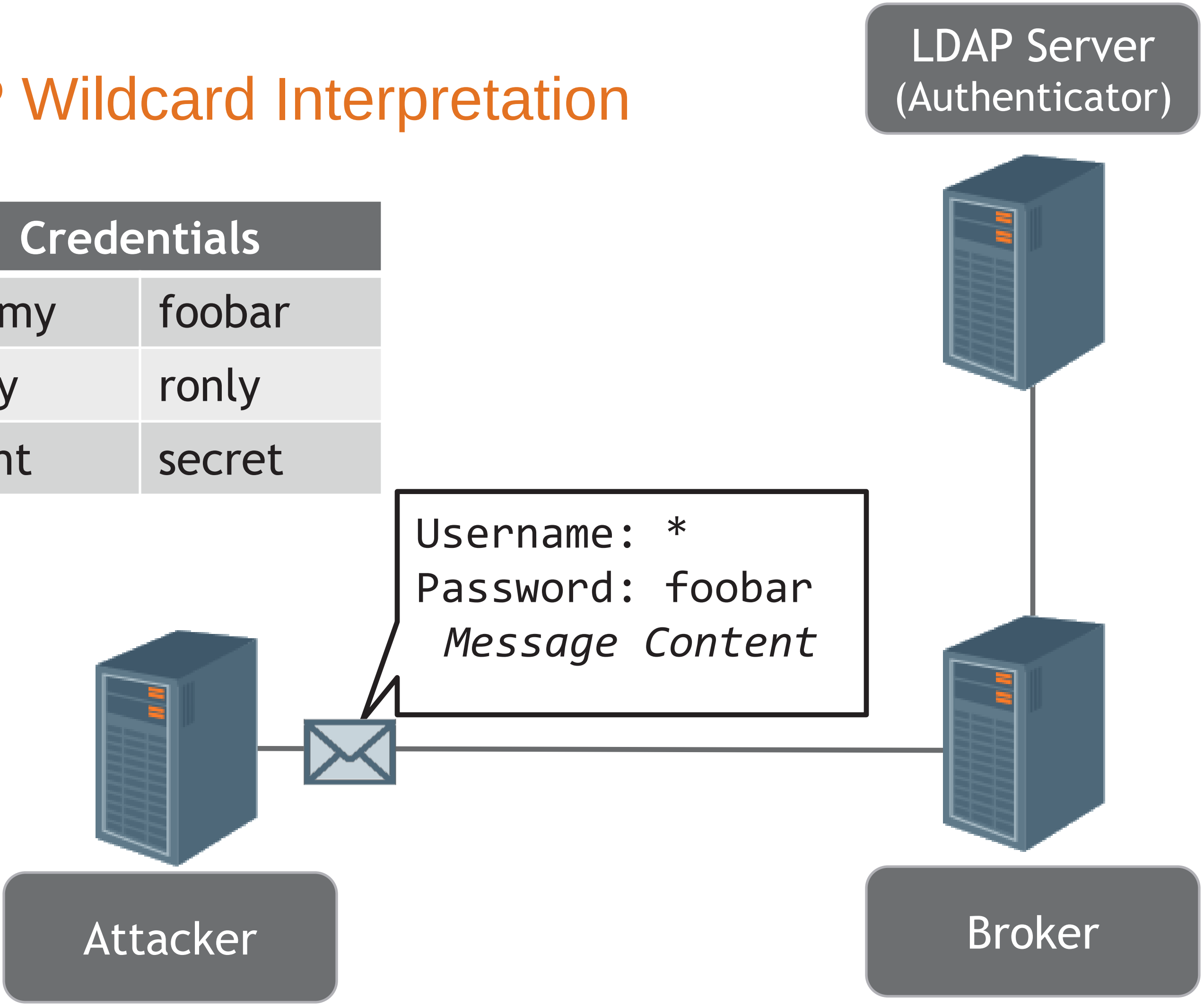

```
Username: *
Password: foobar
```

Message Content

LDAP Wildcard Interpretation

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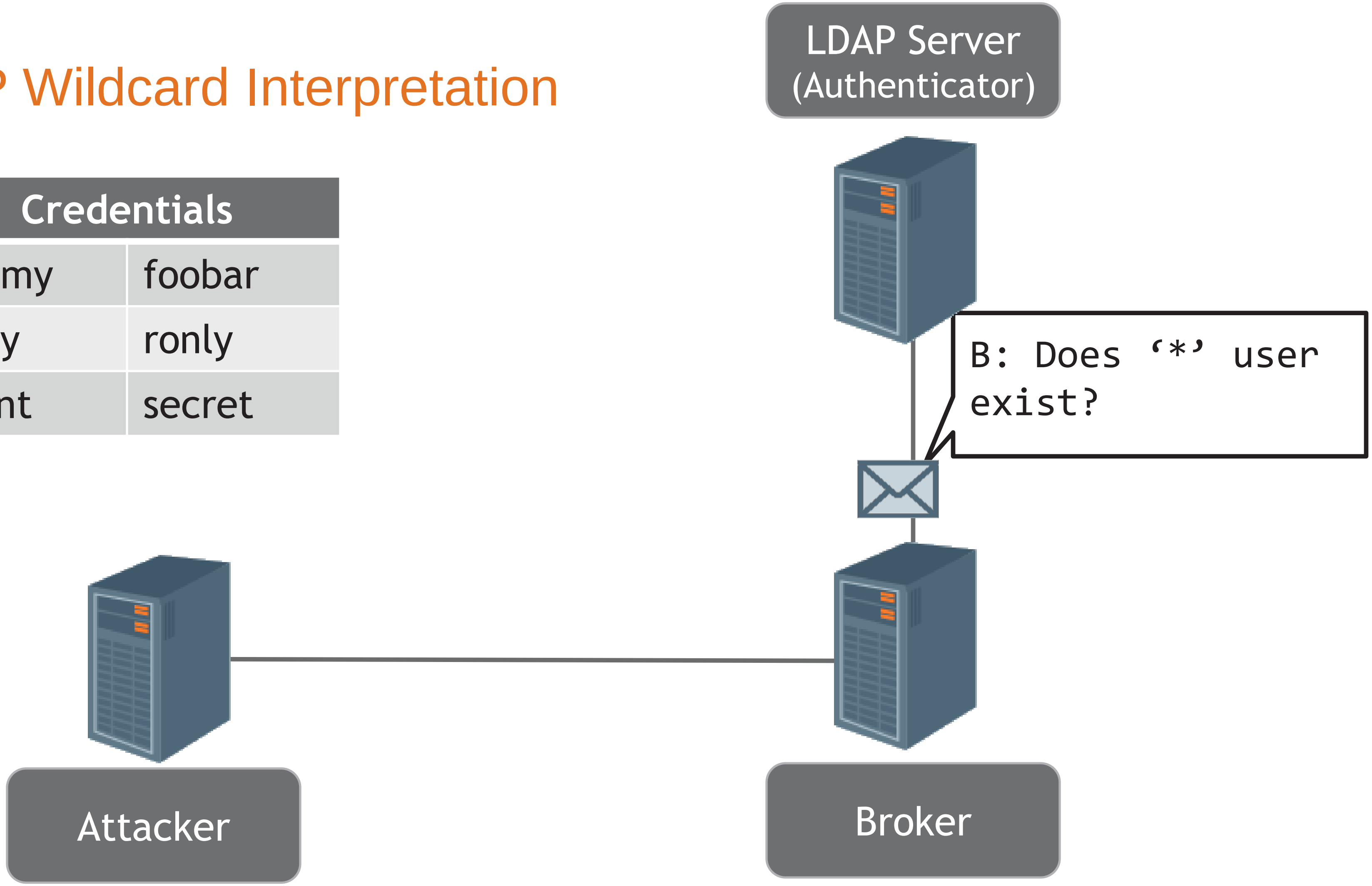

LDAP Server (Authenticator)

B: Does ‘*’ user exist?

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Broker

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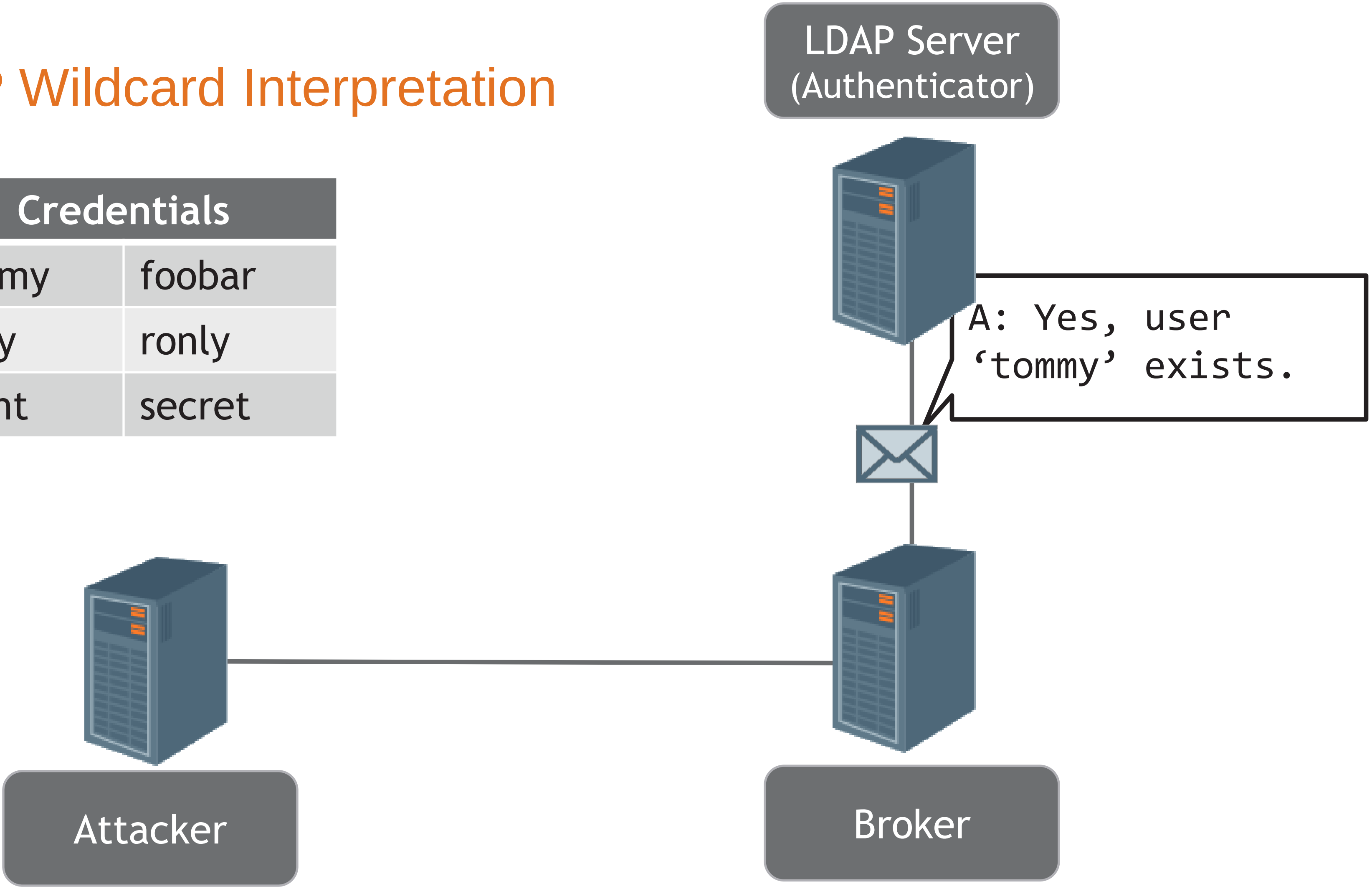

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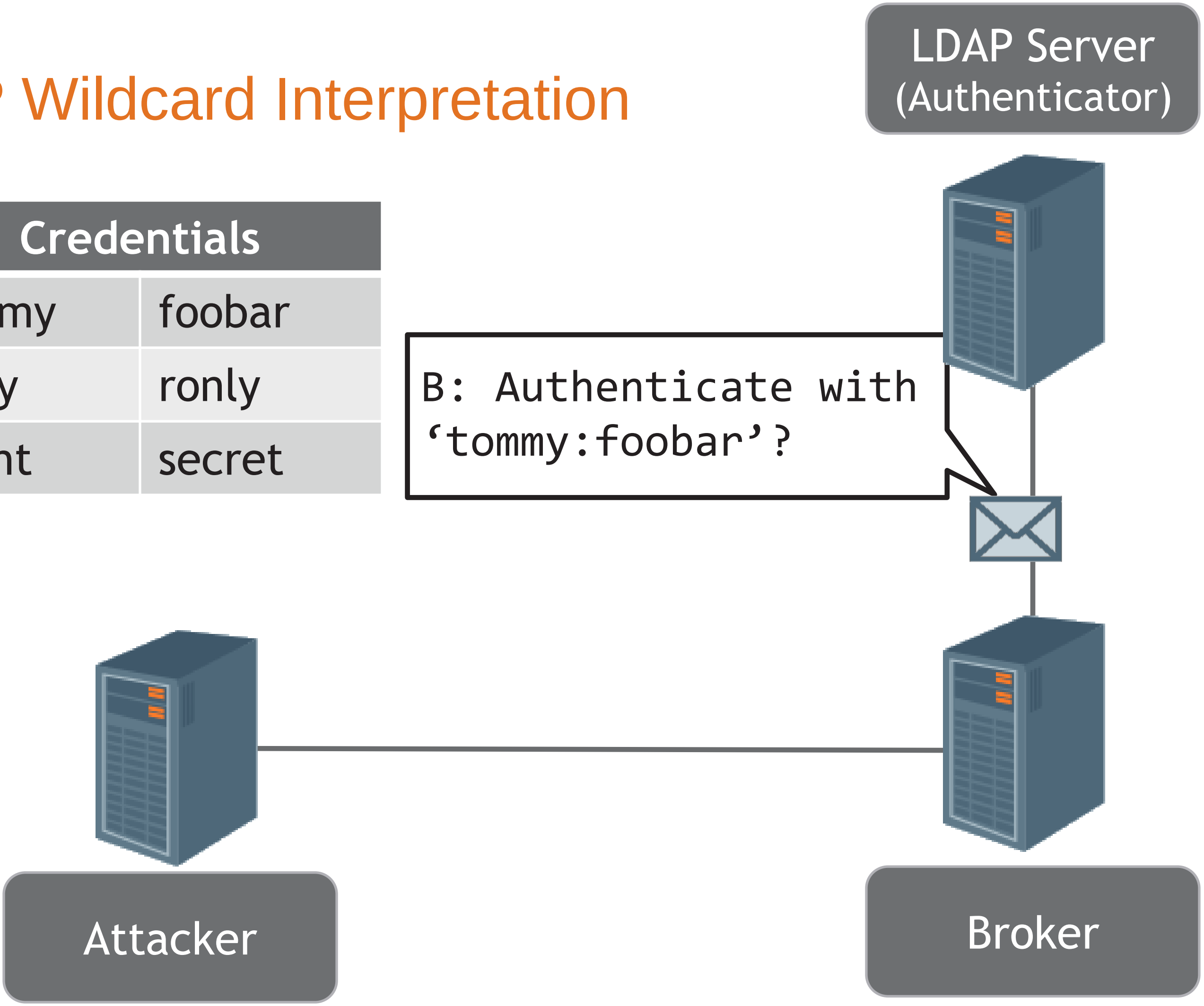

B: Authenticate with ‘tommy:foobar’?

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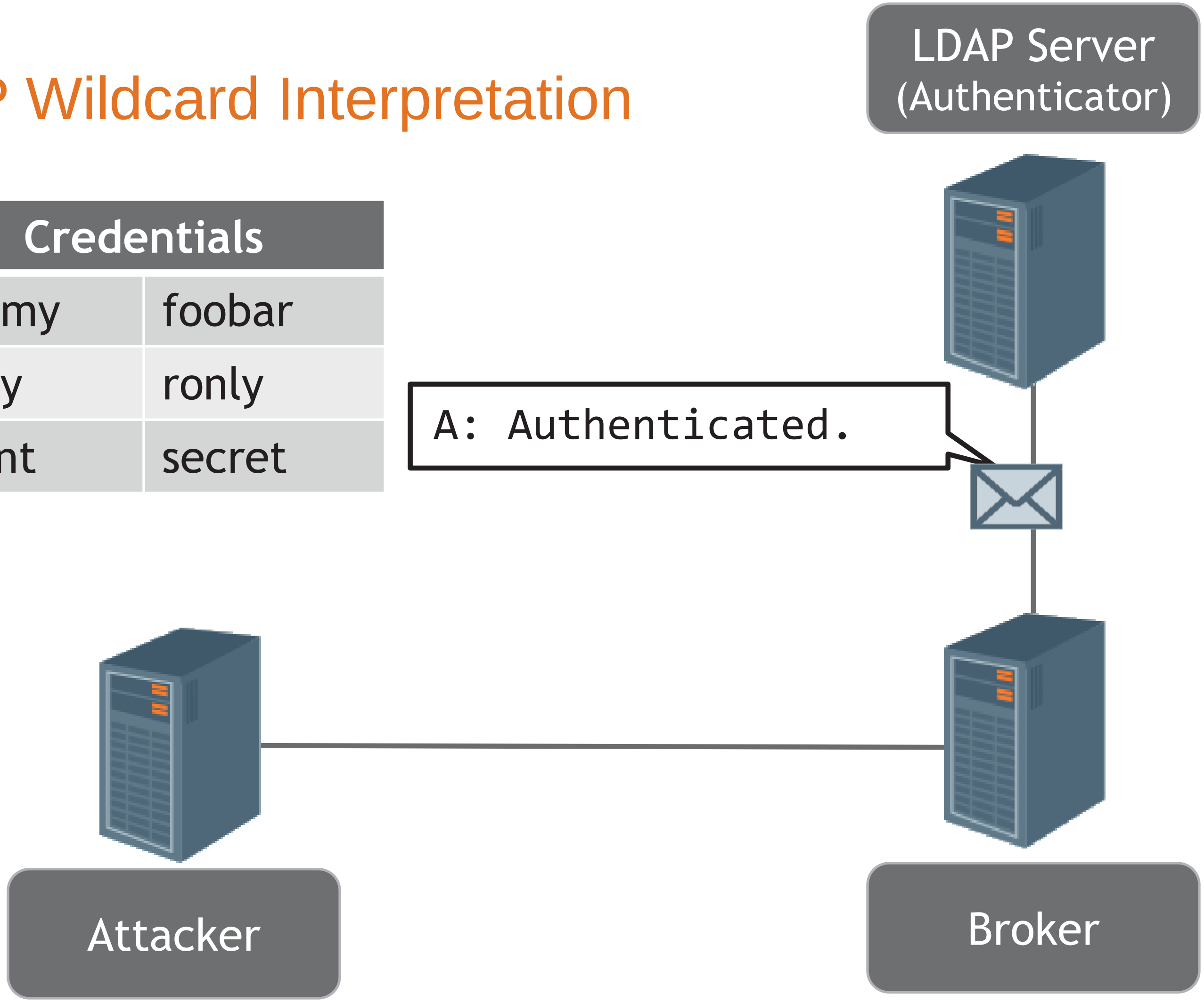
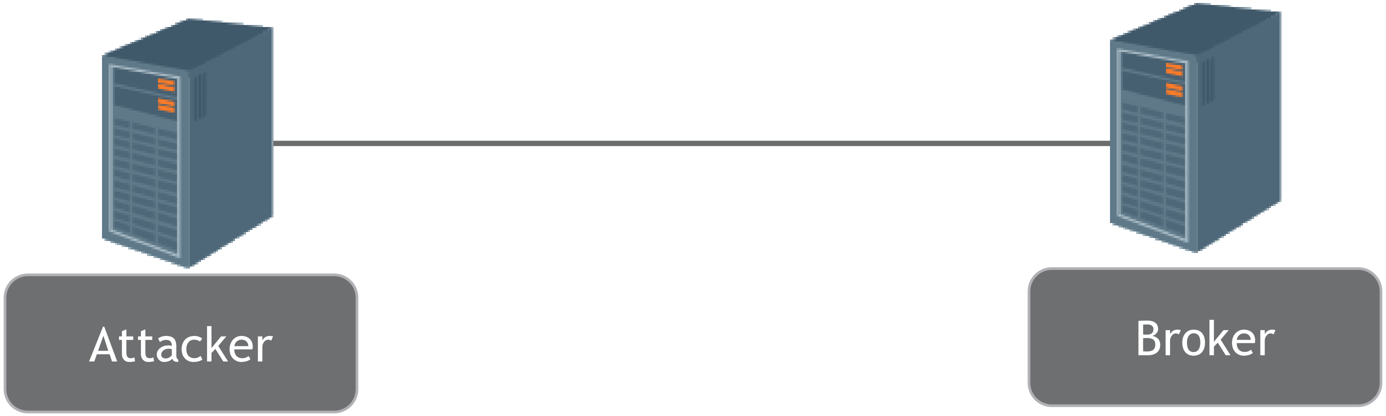


```
A: Authenticated.
```

XML External Entities Processing



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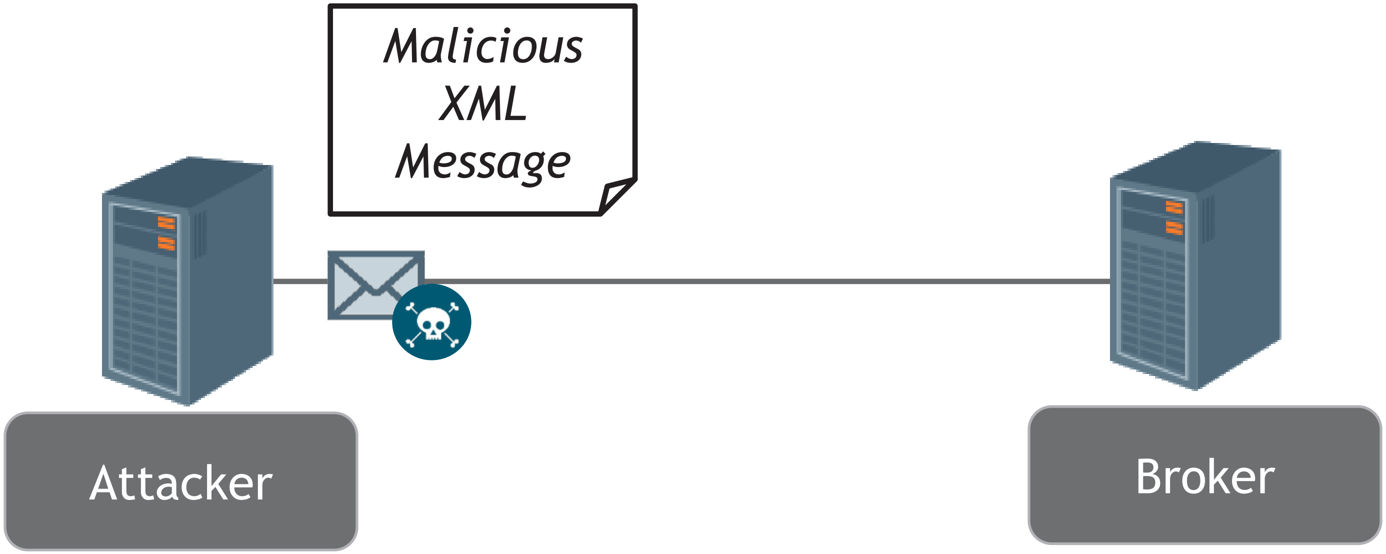

1. Adversary enqueues an XML message which contains XML external entities.

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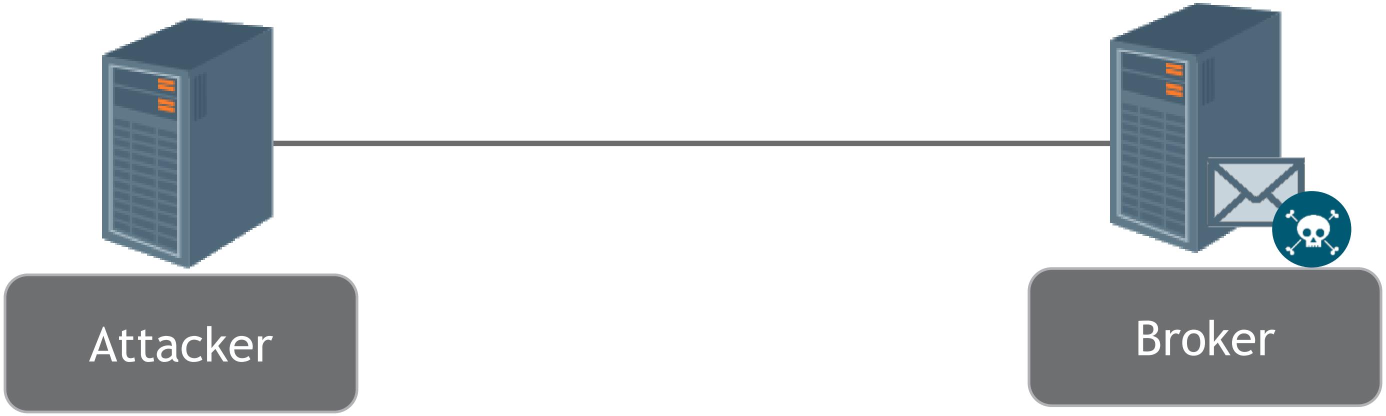

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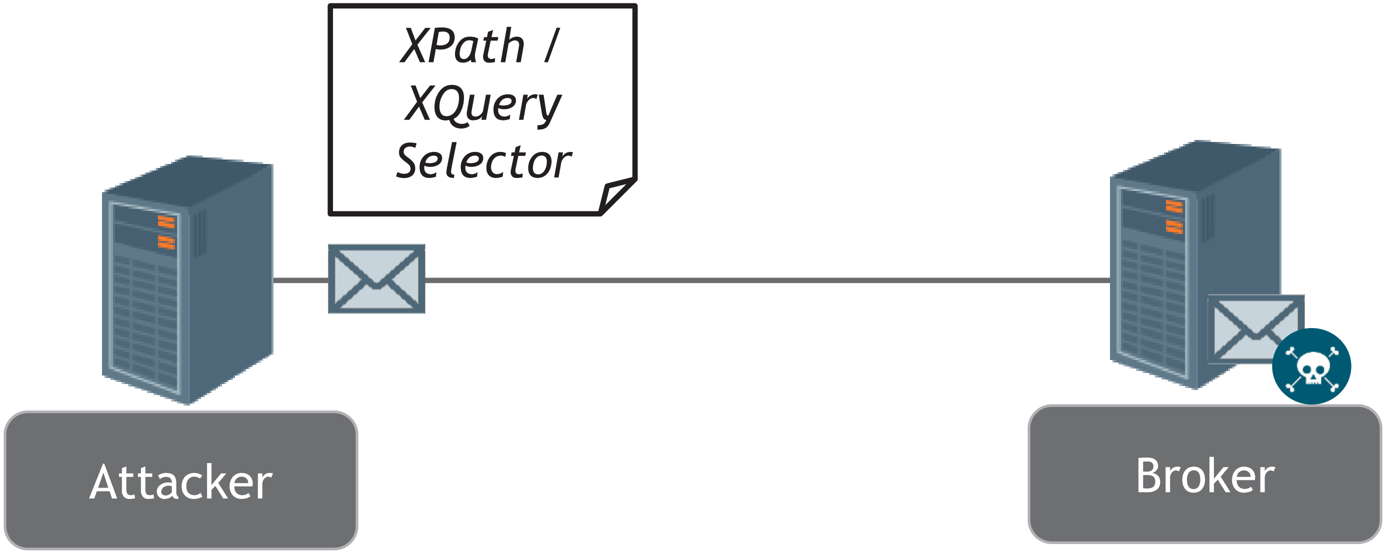

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2. Then requests dequeuing an XML message which matches a criteria expressed with XPath/XQuery based selector.

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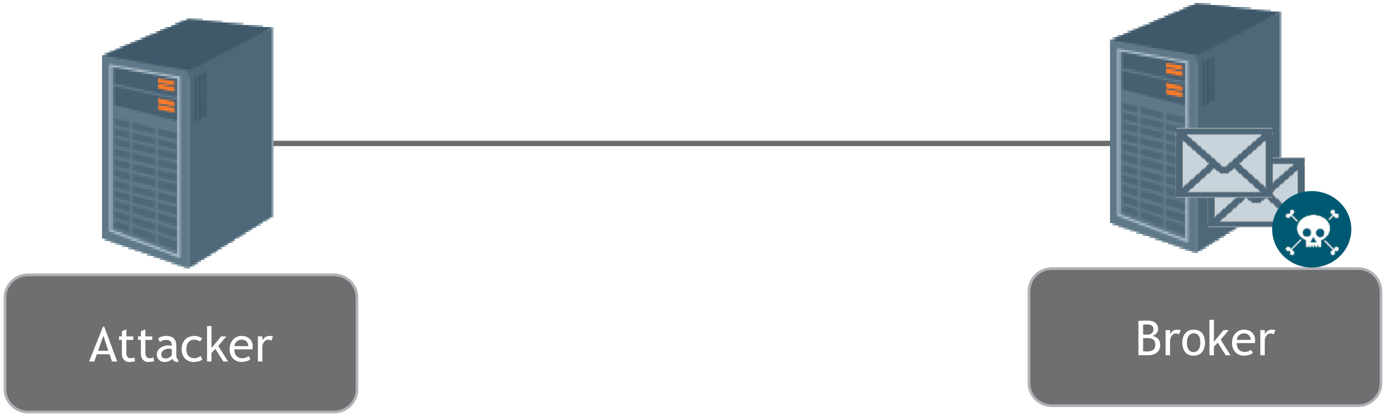

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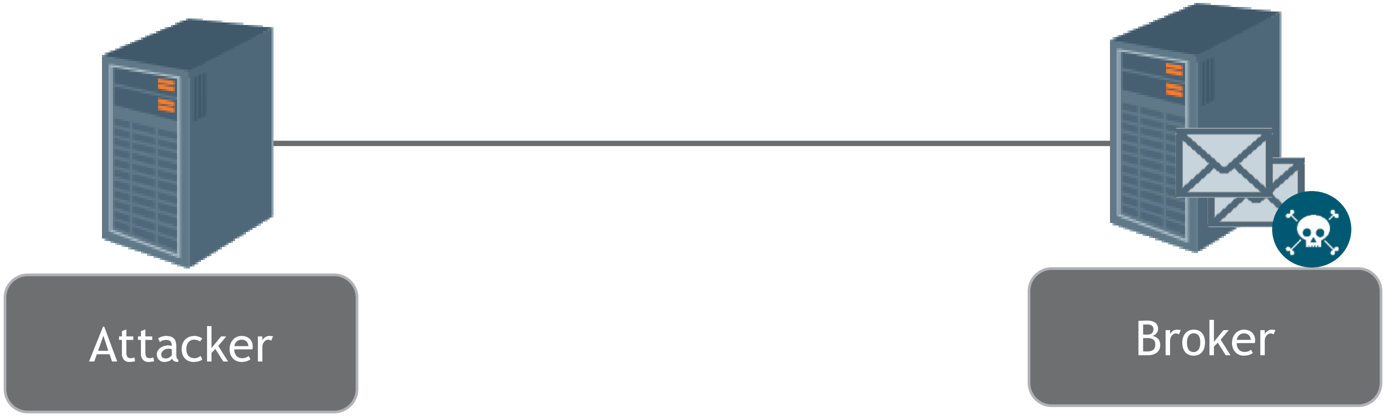

1. Adversary enqueues an XML message which contains XML external entities.
2. Then requests dequeuing an XML message which matches a criteria expressed with XPath/XQuery based selector.
3. The broker will evaluate the XPath expression and attempt to match it against the messages in the queue. This will cause the broker to resolve any external entity references.

Demo (1)

- Anonymous vs. Client / Broker
  - Authentication Bypass*

Demo (2)

- Client vs. Broker
  - XML External Entity Processing

Common Vulnerabilities

- XML External Entities Processing
  - Brokers: **6**
    - Java, Python and C++
  - Clients: 2*
- LDAP Wildcard Interpretation Bug
  - Brokers: **3**
    - Java
- Unserialisation of Untrusted Data
  - Brokers: 2*
    - Java and Python

Hardening

MQ

Applications

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- Limit the number of transport and application protocols.
  - One application protocol over one (SSL) transport.

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Applications

- Perform validation on received messages. Do not assume trusted sources.
- Enable integrity checking. Ideally, authenticated encryption.
- Whitelist objects if unserialising from messages.

Acknowledgments

- MWR Labs
- Red Hat and Apache’s Security Teams
- NoSuchCon Organisers

References

- XML Out-of-Band Data Retrieval (BlackHat Europe 2013)
  - Timur Yunusov (@a66at)
  - Alexey Osipov (@Gi_sUngiven)
- XML External Entities Out-of-Band Exploitation
  - Ivan Novikov (@d0znpp)
- Exploiting JMX RMI
  - Braden Thomas

Questions

- Feedback
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