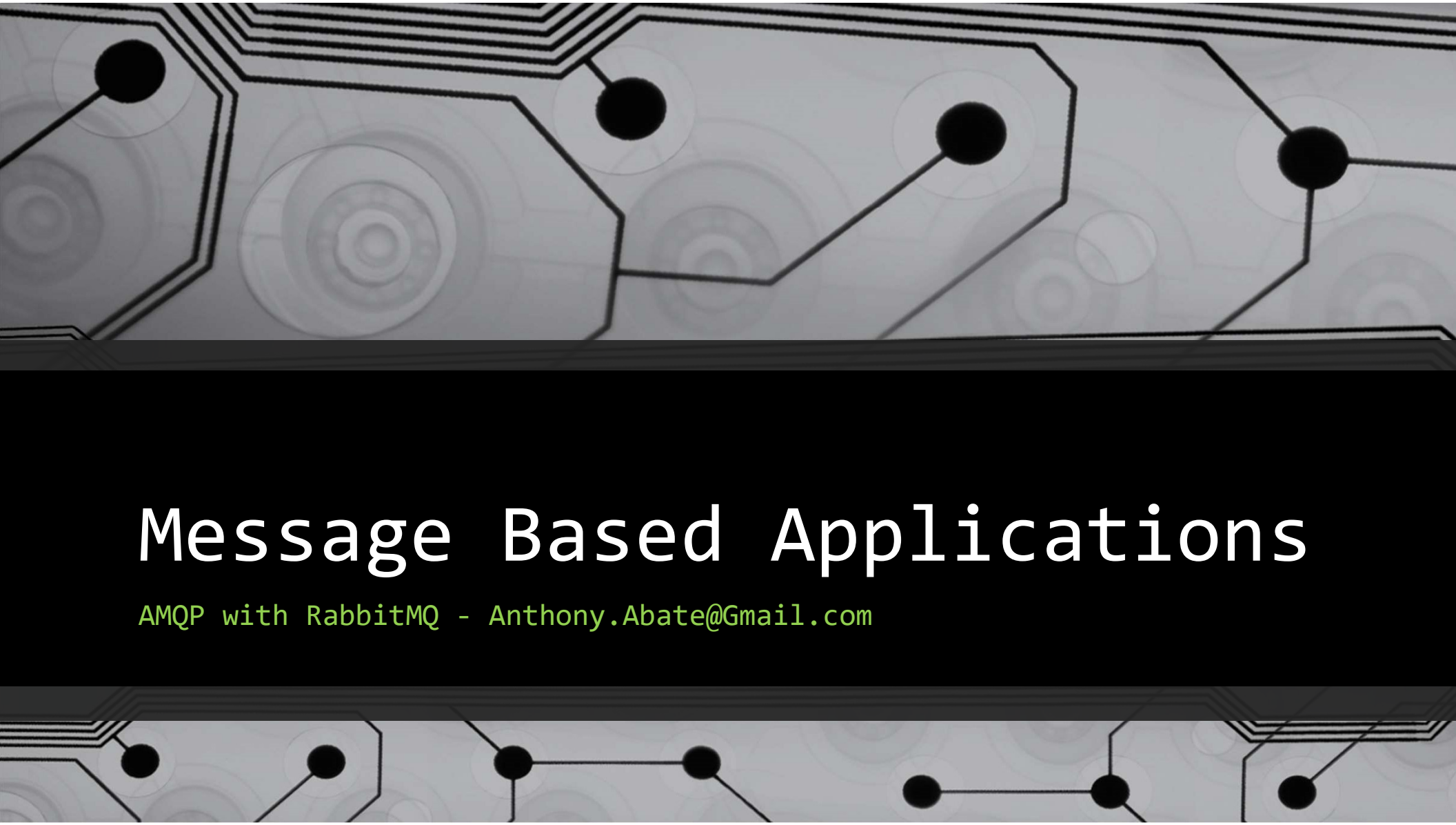

Message Based Applications

AMQP with RabbitMQ - Anthony.Abate@Gmail.com

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Overview

- Why Messaging?
- Why Advanced Message Queuing Protocol (AMQP)?
- Why RabbitMQ?
- AMQP Basics
  - Publishing / Exchanges
  - Subscribing / Queues
- Advanced Topics
  - Message Patterns
  - Error Handling
  - Anti-Patterns
  - Distributed Setups

Abridged Evolution of Application Architectures

- Single Stand Alone Application
  - One process / Multiple Threads
- 2 Tier (Application + Database)
  - Could span Multiple Process
  - Simple Distributed Applications
- 3+ Tier (Applications Layers + Services + Storage)
  - Many disconnected services
  - Many Interdependencies
  - Client resources: threads or tasks to make each call
- Cloud Based Applications
  - Better suited for messaging

Why Messaging?

- Loosely coupled architecture
  - The messaging infrastructure handles routing, duplication, and queuing
  - Allows for publishers to have zero knowledge about subscribers
  - Clients can subscribe to any event
- Scalable and Performance
  - Your application will become 'Event' based with callbacks from the Broker indicating a message is ready for processing
  - Different parts of the app can be tuned accordingly
- Transfer of Responsibility
  - Can 'Fire and Forget' - when the message has been transferred
  - Guarantees no lost message and eventual delivery (no guarantees on processing)

Messaging sounds useful, so Why AMQP?

- There are numerous MQ Technologies out there:
  - TIBCO, JMS, MQ-Series, MSMQ, Zero-MQ, etc
- Open standard application layer protocol for message-oriented middleware
  - Queuing
  - Routing
    - Point-to-Point
    - Publish-and-Subscribe
  - Reliability
  - Security
  - Extendable

Why RabbitMQ?

- RabbitMQ is an implementation of AMQP with extensions written in Erlang
- Many official and unofficial clients
  - .Net, Java, Erlang, Python, Etc
- Extensions / RabbitMQ Specific
  - High Availably Nodes / Clustering
  - Confirmation Mode
  - Message TTL
  - Dead Letter Exchanges

Erlang

- Erlang is a general-purpose concurrent, garbage-collected programming language and runtime system
- Developed in 1986 by Ericsson and open sourced in 1998.
- It was designed to support distributed, fault-tolerant, soft-real-time, non-stop applications.
- Supports hot swapping - code can be changed without stopping a system!
- Designed for concurrency!
- Internally, processes communicate using message passing instead of shared variables, which removes the need for locks.

Message Architecture Planning

- Before you start, plan out the message workflow end to end
- What to send?
  - The message types must be defined
- How much to send?
- Who needs to know?
  - Potential clients and queues should be identified
- How fast can messages be processed?
  - RabbitMQ is fast, but if you produce more than you consume, you will run out of memory
- Before any messages can be published, the Broker objects must be created.

What makes a good message?

- Independent unit of work
  - An order for a Customer X is independent of an order for Customer Y
- Self Contained
  - Should include as much info required to process that can always remain true
  - Avoid extra data lookups when processing
- Avoid relying on the order of delivery if possible
  - If order is important, then try to group them logically
  - Order 1 for Customer X must be processed before Order 2
  - Customer Y's orders have no relevance Customer X

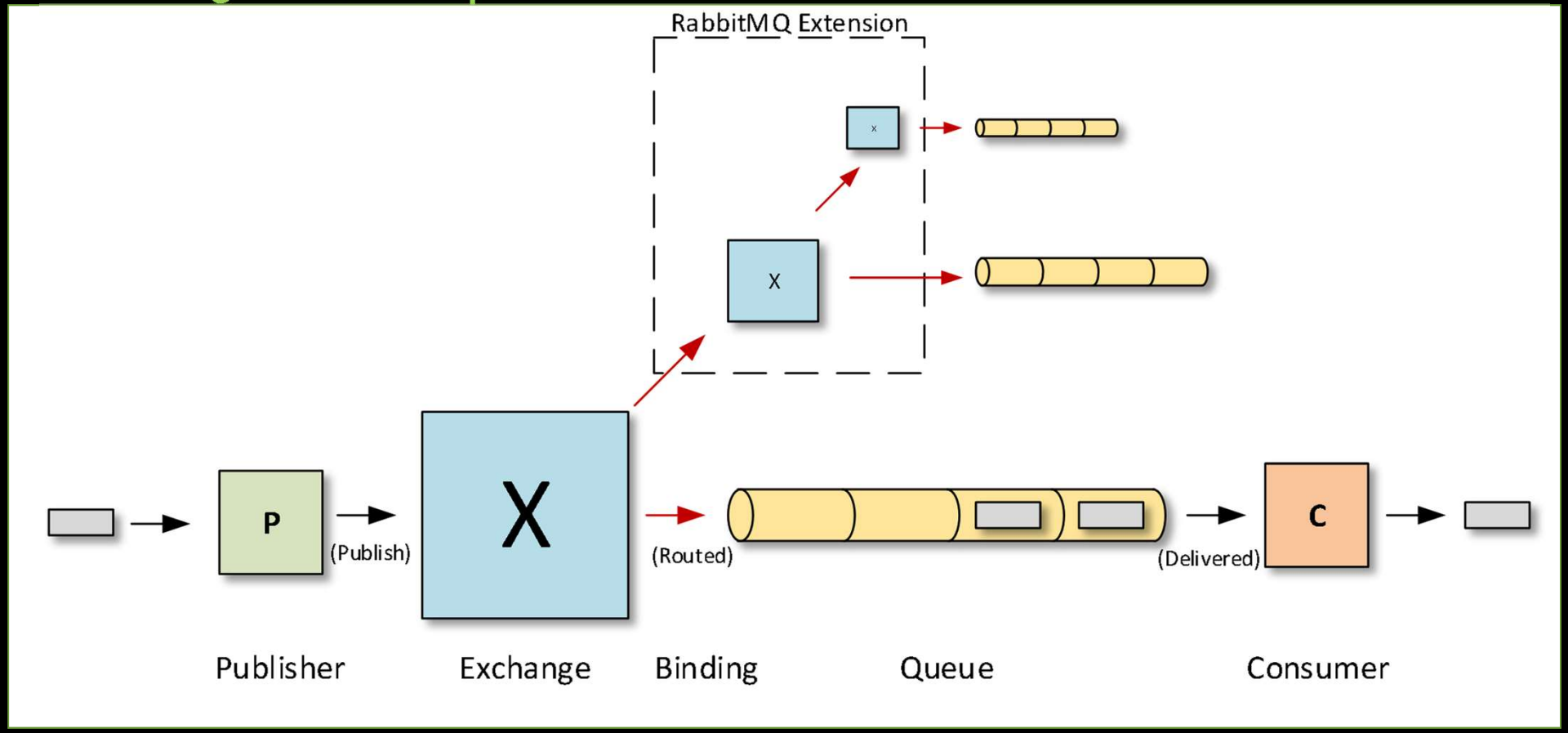
Idempotency

- Ability to process the same message more than once with no adverse side effects
- Expect to see messages more than once, that is by design
- Should design your messages and handlers to process the same message twice
- Scenarios
  - If there is a failure by a consumer, or connection interruption, the broker will decided to resend any unack'd messages
  - If a message is rejected by a particular client with requeue=true
  - If there is a failure in a RabbitMQ node, any unack'd messages will be resent

AMQP Concepts

- Connection
- Messages
- Publishing
- Exchange
  - Bindings
- Queue
  - Bindings
  - Consumer

AMQP Concepts



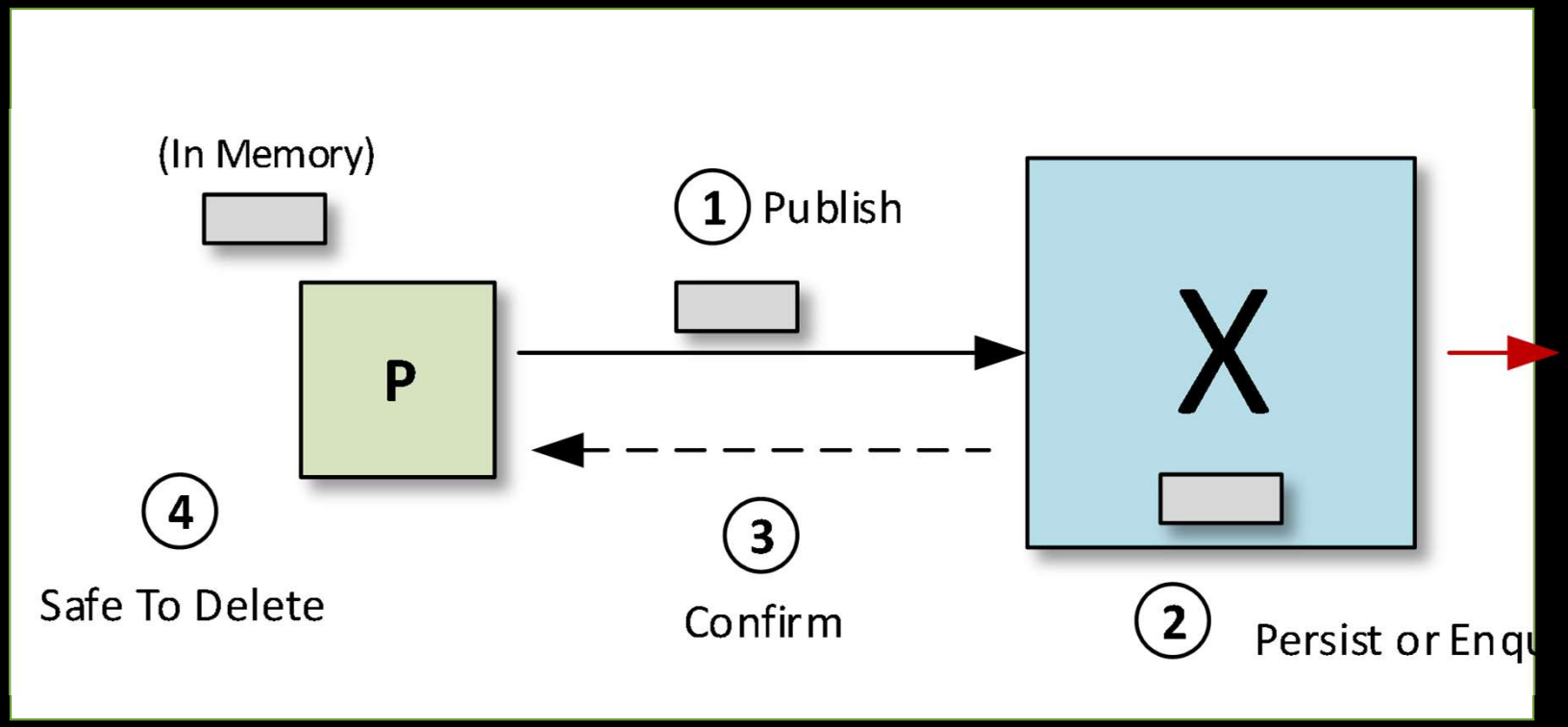
AMQP Client

- 1. Publish Messages
- 2. Consume Messages
  - Get
  - Consumer
- 3. Management
  - Declare Broker Objects (Queues, Exchanges)
  - Configure Broker Objects (Bindings)

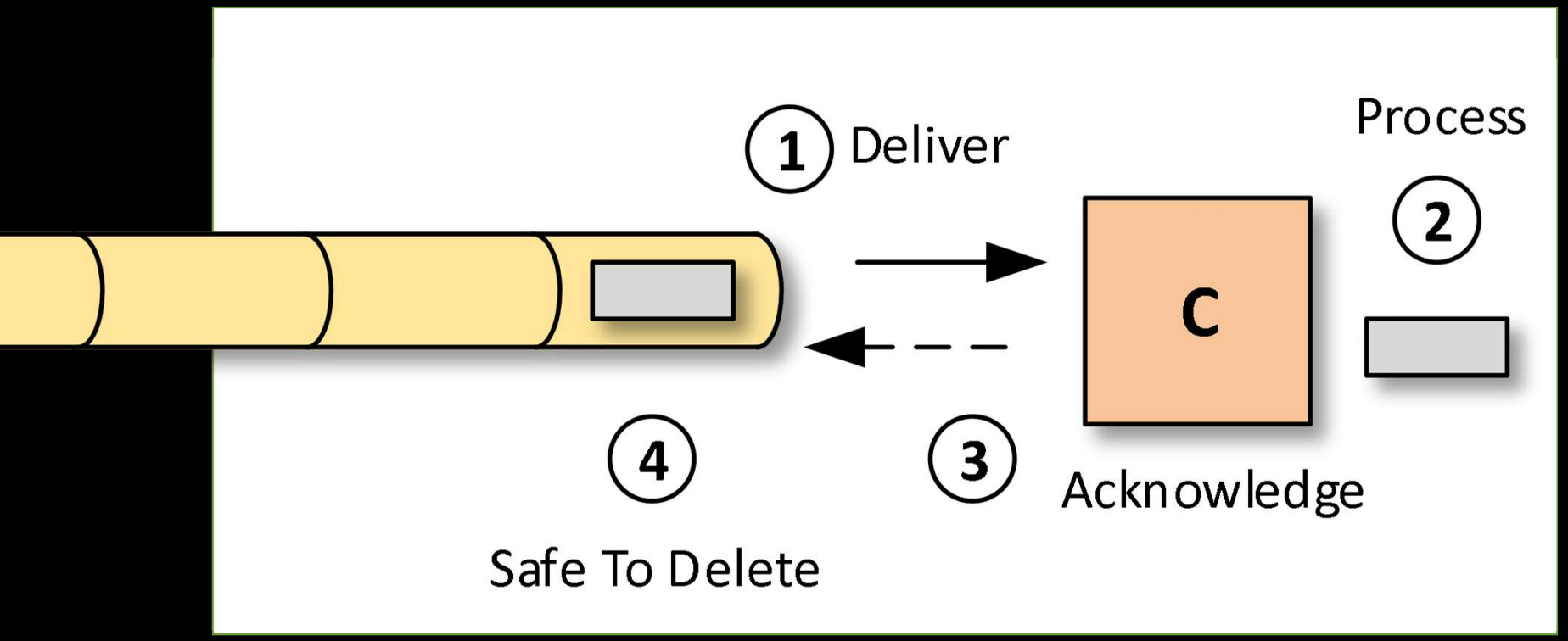
AMQP Client

- User
  - Authentication
  - Server side authorization
  - security on exchanges / queues
- Connection
  - Heartbeat
- Channel (aka Model)
  - Multiple per connection
  - Should use 1 per thread
  - Model has Actions (Publish/Get/Consume)

Transfer of Responsibility (Publisher)



Transfer of Responsibility (Consumer)



Message Publishing

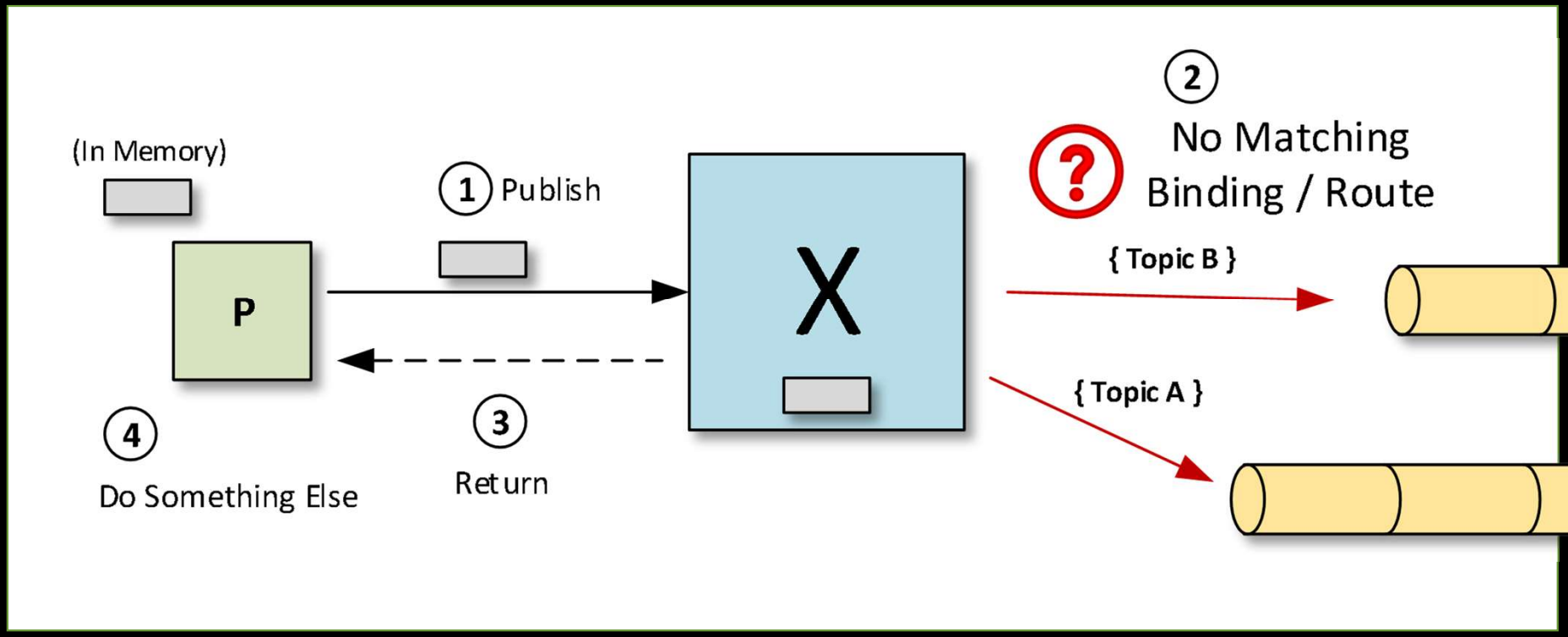
- Byte[] – Payload
  - Up to application to decide what you put in and how
  - Unless using a framework (SpringAMQP)
- Routing Key / Topic
  - If unspecified, “” is used

- Try not to think about the queue when publishing
- It is possible that no one could be listening for your message

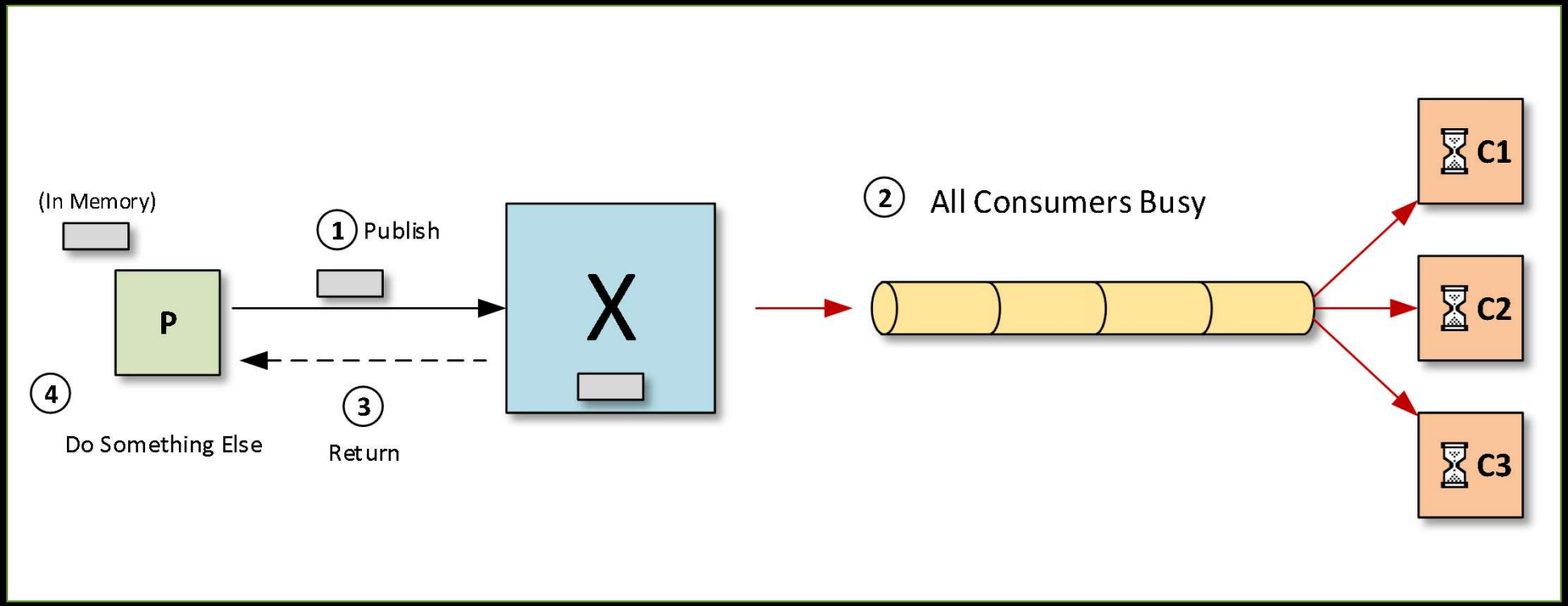
Message Publishing - Flags

- Flags
  - Immediate – requires an idle consumer
  - Mandatory – requires a valid queue to hold the message
- Delivery Mode
  - Persistent – message will be stored to disk (if possible)
  - Transient – message will only be in memory (faster)

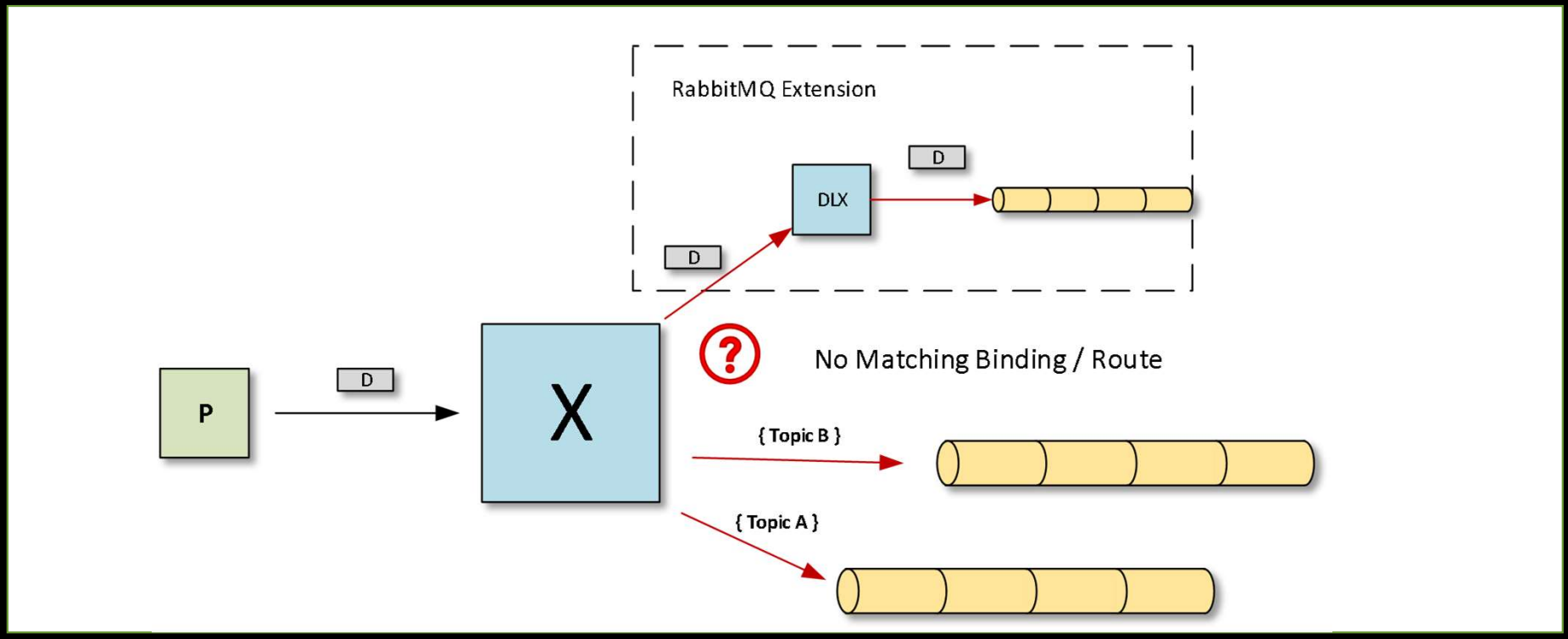
Mandatory Mode



Mandatory Mode



Dead Letter Exchange



Message Publishing – Headers / Properties

- Headers
  - Well known properties
  - Custom user data
- Used by RabbitMQ
  - user_id – use for authentication if enabled
  - expiration - TTL for message
- priority - not enforced by AMQP
- reply_to - should be set if publisher needs a reply

Message Publishing – Headers / Properties

- timestamp
- Type Specifiers
  - content_type
  - content_encoding
  - type
- Identifiers
  - app_id
  - cluster_id
  - correlation_id
  - message_id – client specified / server generates sequence number per consumer which is different

Payload – Byte[]

- If you are using the RabbitMQ client by itself, you will need a pattern for interpreting the message payload
  - Serializing the messages
  - Binary / Xml Serialization
  - Custom Payloads
  - Versioning

Routing Key / Topic

- Aside from actual Payload, this is the single most important message property
- Determines where message is sent based on bindings
- Much more efficient than sending messages that a client can't process

- I prefer 1 topic per message type and perhaps include a version #
  - Application.MessageTypeA.V1
  - Application.MessageTypeB.V1

- (Alternatively could use a header – ContentType + Content Encoding)

Publish Modes

- Standard Mode – no guarantees
- Transaction Mode (Tx)
  - Not the same as ACID / Database transaction
  - Reduces throughput by ~250 times
  - Its there because its in the AMQP standard, but not recommended by RabbitMQ
- Confirmation Mode
  - Serves the same purpose as Tx Mode, just faster (its an RMQ extension)
  - Broker will send a confirmation to the publisher indicating it success 'owns' the messages
  - Can be configured to group together Acks (ie if received N then all before have been received - Exactly like TCP Ack's)

Publish Callbacks (Client Events)

- Basic.Ack – Message Confirmed
  - Client is no longer responsible for it
- Basic.Return – Message could not be confirmed:
  - Immediate Flag
  - Mandatory Flag
- Basic.Nack
  - Rare, problem with broker and client needs to resend

AMQP Concepts

- Connection -
- Messages -
- Publishing -
- Exchange
  - Bindings
- Queue
  - Bindings
  - Consumer

Exchanges

- These are where you publish
- Even if you don’t specify one, it is going to the ‘default exchange’
- Types
  - Fanout – sends out all messages
  - Direct - sends out specific messages
  - Topic – uses topic patterns
  - Header – inspects headers
- Durability

Fanout & Direct - Exchange

- Faster – But you may not care
- Fanout
  - Can not specify topic
  - you get everything
- Direct
  - Must specify every topic you want
  - Potentially a lot of maintenance

Topic Exchanges

- Very Flexibile!
- Allows wild cards in bindings
  - # = all topics
  - Namespace.Class.*
  - Namespace.*.Method
- Can represent Fanout and Direct
  - binding with '#' = fanout
  - binding with 'Topic' = direct
- Because of its more generality, I always use topic

Header Exchange

- May be useful if you have a lot of custom headers
- Only inspects the string properties of header
- Harder to check multiple headers with complex conditions
- Can not fully represent a topic exchange
- Slowest

Bindings – Exchange -> Exchange

- Exchanges can be bound to each other (RabbitMQ)
  - Same rules for binding queues apply to exchanges
- These allow for federation / scaling of messages publication
  - Can be used for distributed setups

Bindings – Exchange -> Queue

- Without bindings, no messages go into a queue
- Depending on the exchange type, different options exist
  - Routing key
    - (Topic / Direct – implied # for fanout)
  - Header

Durability

- Remember Message Delivery Mode? – Transient or Persistent
- A persistent message will only be saved to disk if the Exchange / Queue they pass through are durable
- If the message is transient it will not be stored even if the Exchange / Queue is durable they are (for speed)

Queues

- A client Gets / Consumes messages from a Queue
- Application named or broker named (random)
- Shared vs Exclusive
- Durability

Message Retrieval

- Now that my message is in the queue, How do I get it out?
- You need to know the queue name
- Get Operation
  - Takes a single message
- Consumer (RECOMMENDED)
  - Put the client channel into consumer mode

Acknowledgements

- Used to indicate message processed successfully by client
- AutoAck is used, broker assumes success when it has been delivered to subscriber
- Outstanding Unacked messages tracked by broker
  - Used in QoS
- Can Ack the highest number and perform a batch Ack
- Message will not be redelivered if it is rejected

AMQP Concepts (Recap)

- Connection
- Messages
- Publishing
- Exchange
  - Bindings
- Queue
  - Bindings
  - Consumer

Broker Infrastructure

- Now you understand the purpose of Exchange, Bindings, Queues
- When to define them?
  - Clients can create them on demand, but how will another client know about it?
  - Where will the client know where to publish?
- Static
  - Parts of the infrastructure should always exist and no client should create them (think of a database table)
  - These are the ‘starting points’ for your client to either broadcast its existence to the world, or start publishing to.
  - Manage these object them as you would table schemas and roll out changes carefully
- Dynamic
  - Some parts can be declared at runtime
  - Implicitly dynamic (publishers)

Declaration

- Declaring Exchanges and Queues
  - Always succeeds
  - Idempotent operation
    - Except when configuration is different
  - Some feel its ok to always ‘declare’, but I think could get into problems
- Passive Declaration
  - Will fail if it doesn’t exist
- Declaring returns meta data
    - Message Count
    - Consumer Count
    - Randomized Name (if left blank)

Infrastructure

- Static
  - Exchanges
  - Work Queues
- Dynamic
  - Publishers
  - Observers

Advanced Topics

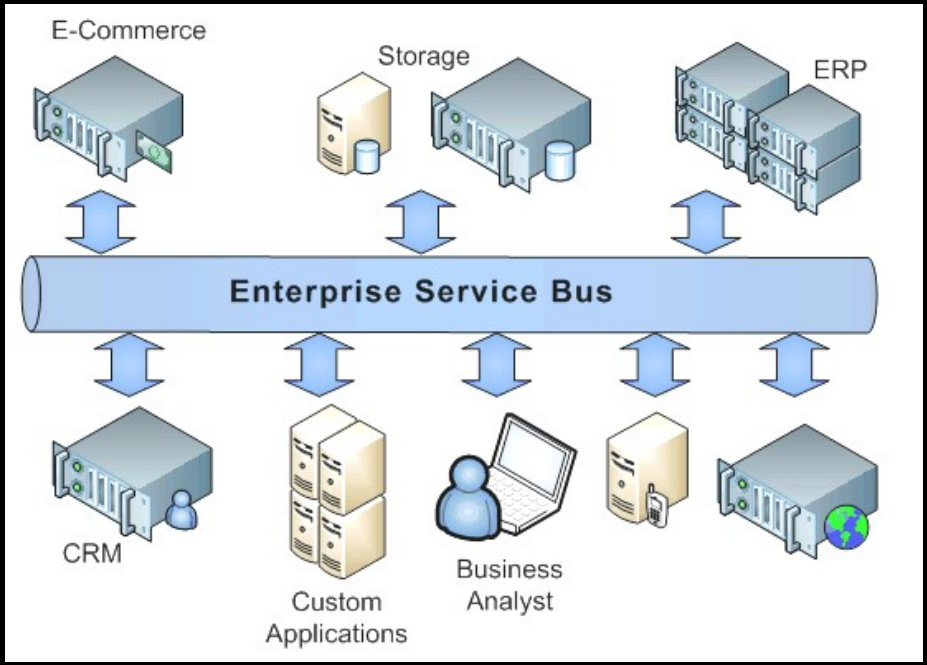
- Message Expiration / Auto Delete
- Error Handling
- Usage Patterns

Message Patterns

- 1 - Publisher – N Subscribers
  - Handled through configuration transparent to publisher
- Work Queue / Load Balanced
  - Need to process ‘every’ messages
  - as fast as possible
  - Can be done in parallel
  - Order not important
- Observer
  - Just want to be able to ‘peek’ be notified of what is going
  - No business processes based off the events
  - Logging is a simple example

Enterprise Service Bus

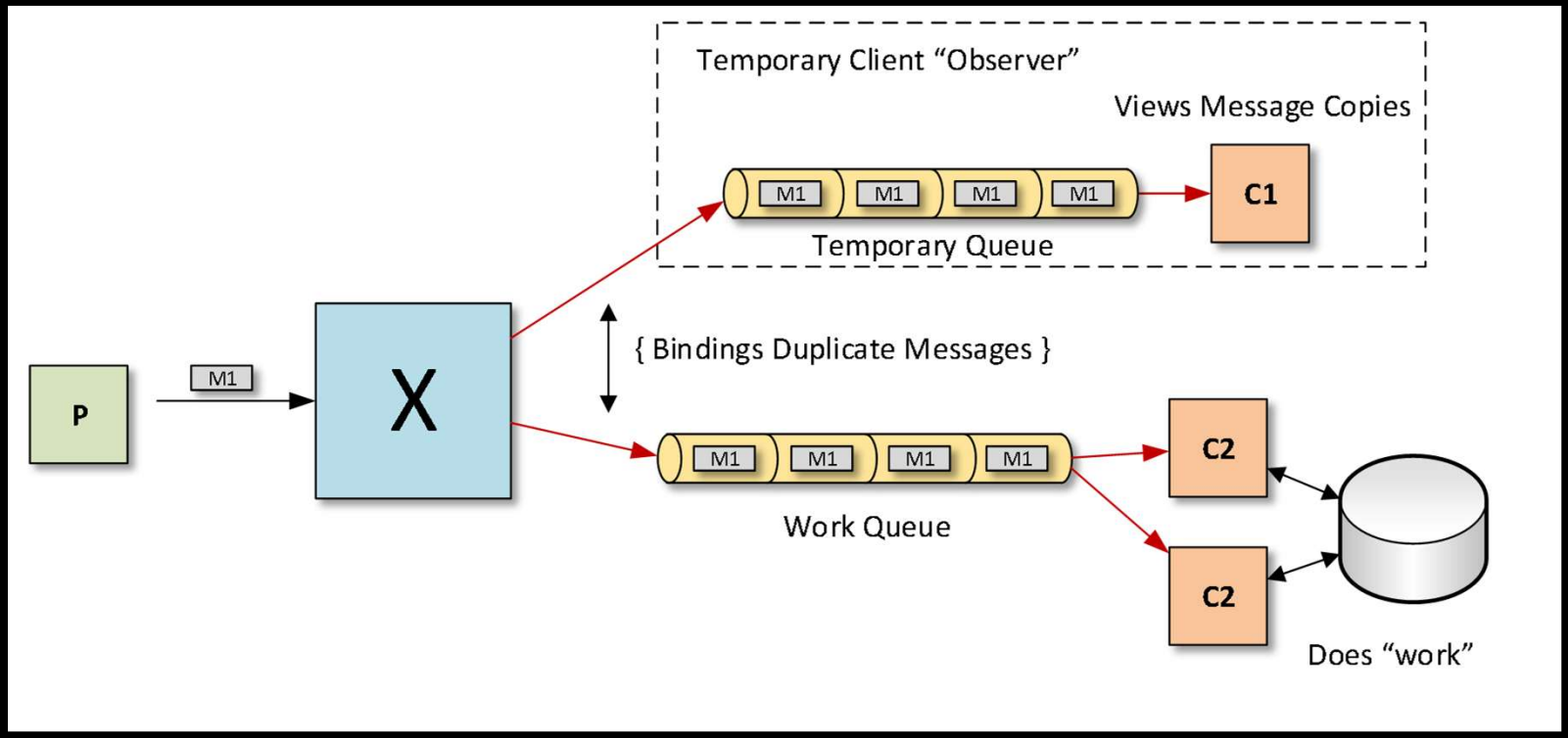
Common Pattern Allow for Many Pub / Subs



Observer

- Client wants to see current events (doesn't care about past events)
- Queue - used by one consumer
  - Temporary – Name assigned by Broker
  - Exclusive – Don't want anyone else taking messages
  - Non-Durable – who cares if the messages are lost?
  - Auto ack mode -there is no real work
  - Auto-Delete – Remove the queue when client disconnects
- A new one will be created next time client
- Messages dropped when client is not listening

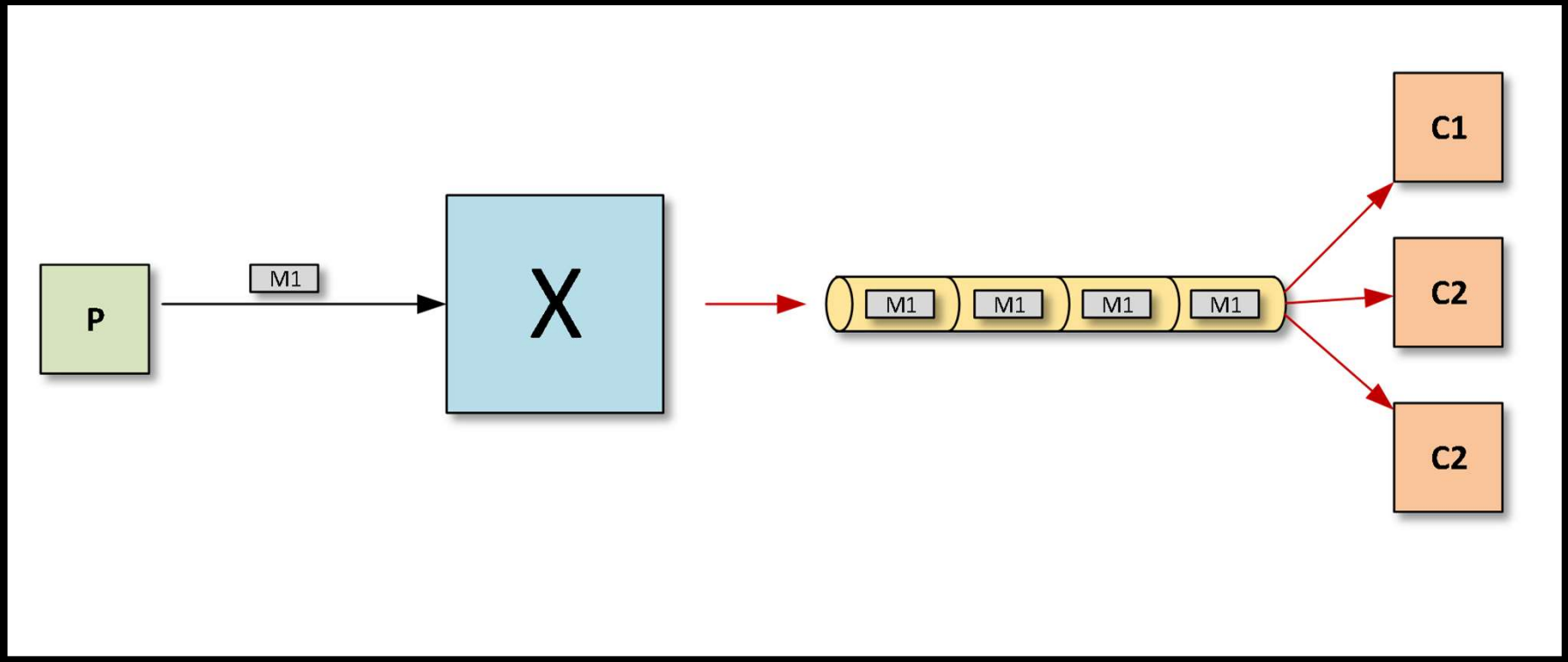
Observer


Temporary Client "Observer"
Views Message Copies
M1
M1
M1
M1
C1
Temporary Queue
{ Bindings Duplicate Messages }
P
M1
X
M1
M1
M1
M1
C2
C2
Work Queue
Does "work"

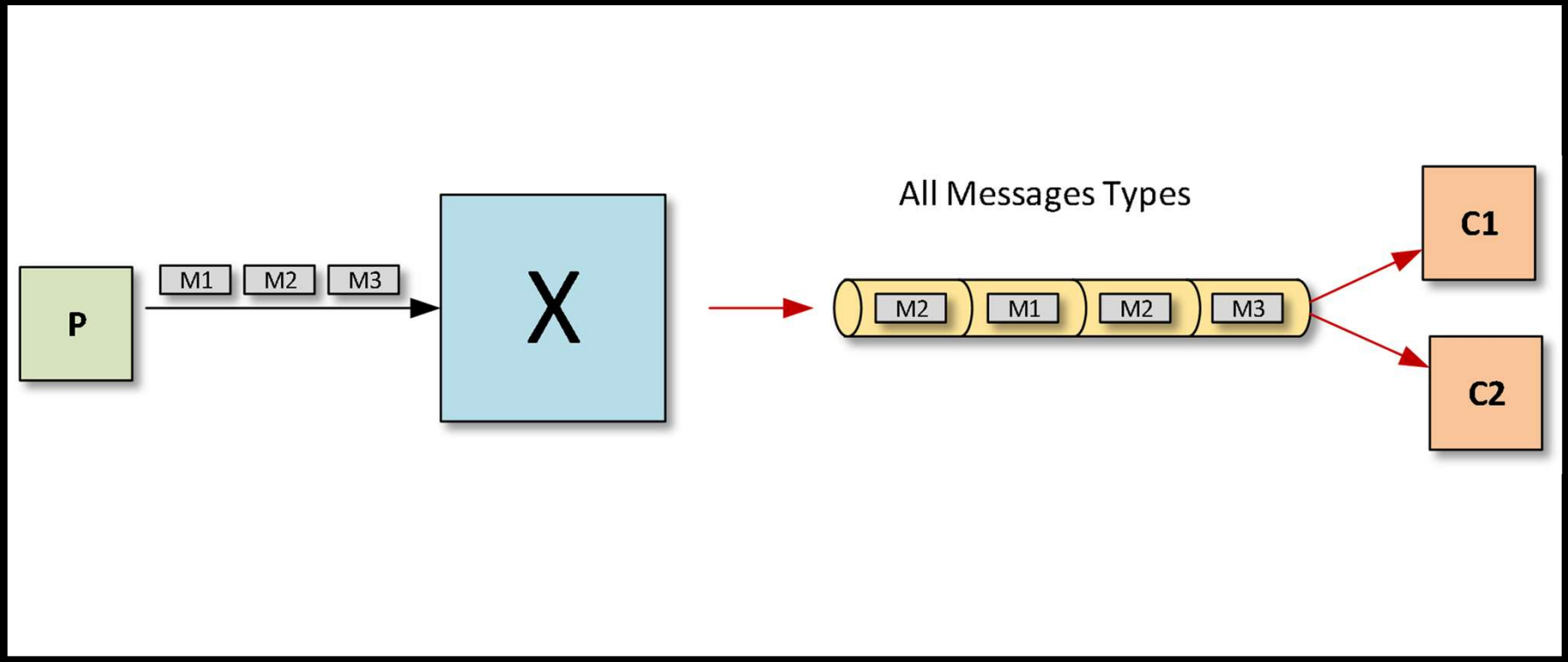
Work Queue

- Queue - used by multiple consumer
  - Permanent Name – Defined by application
  - Shared – needs to be for load balance
  - Durable – who cares if the messages are lost?
  - Manual Ack - only when successfully processed
  - No-Auto-Delete – Remove the queue when client disconnects
- Messages will persist between client connects and disconnects regardless if anyone is listening

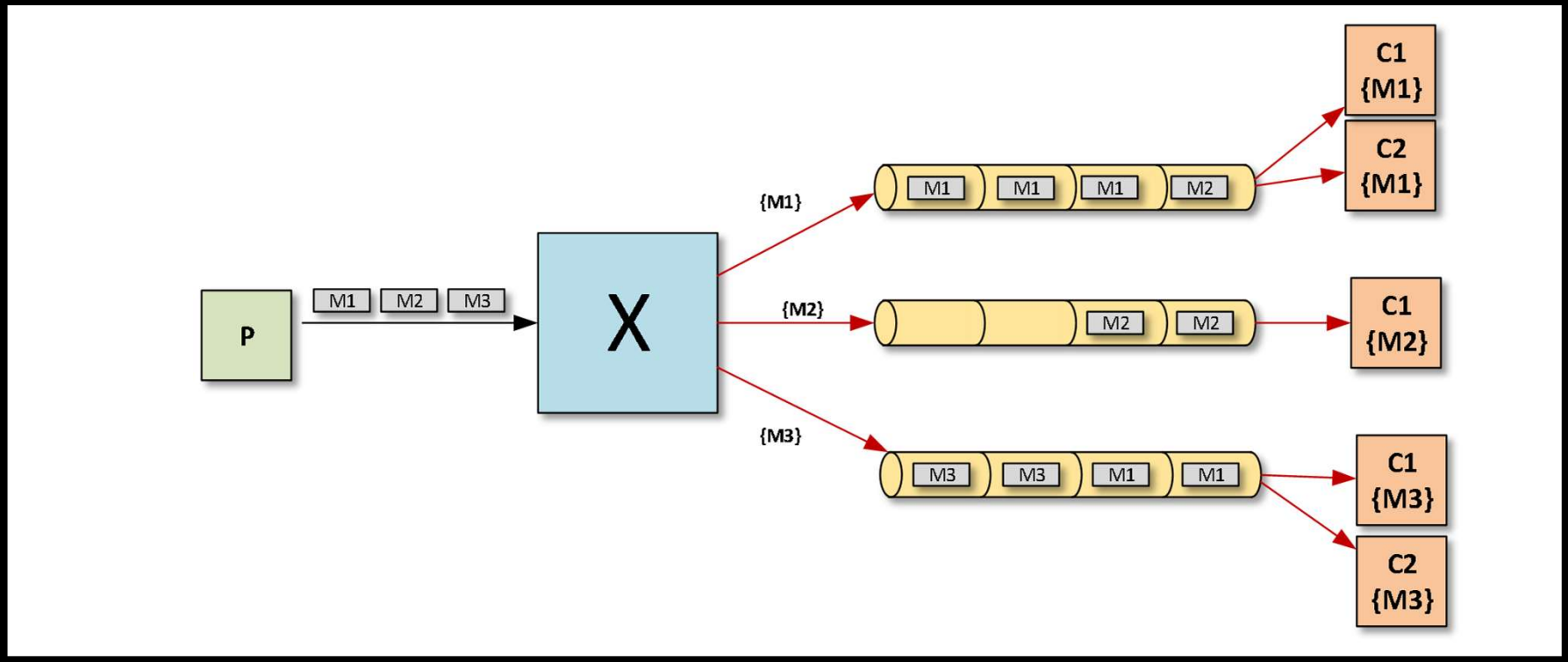
Work Queue (Load Balancing)



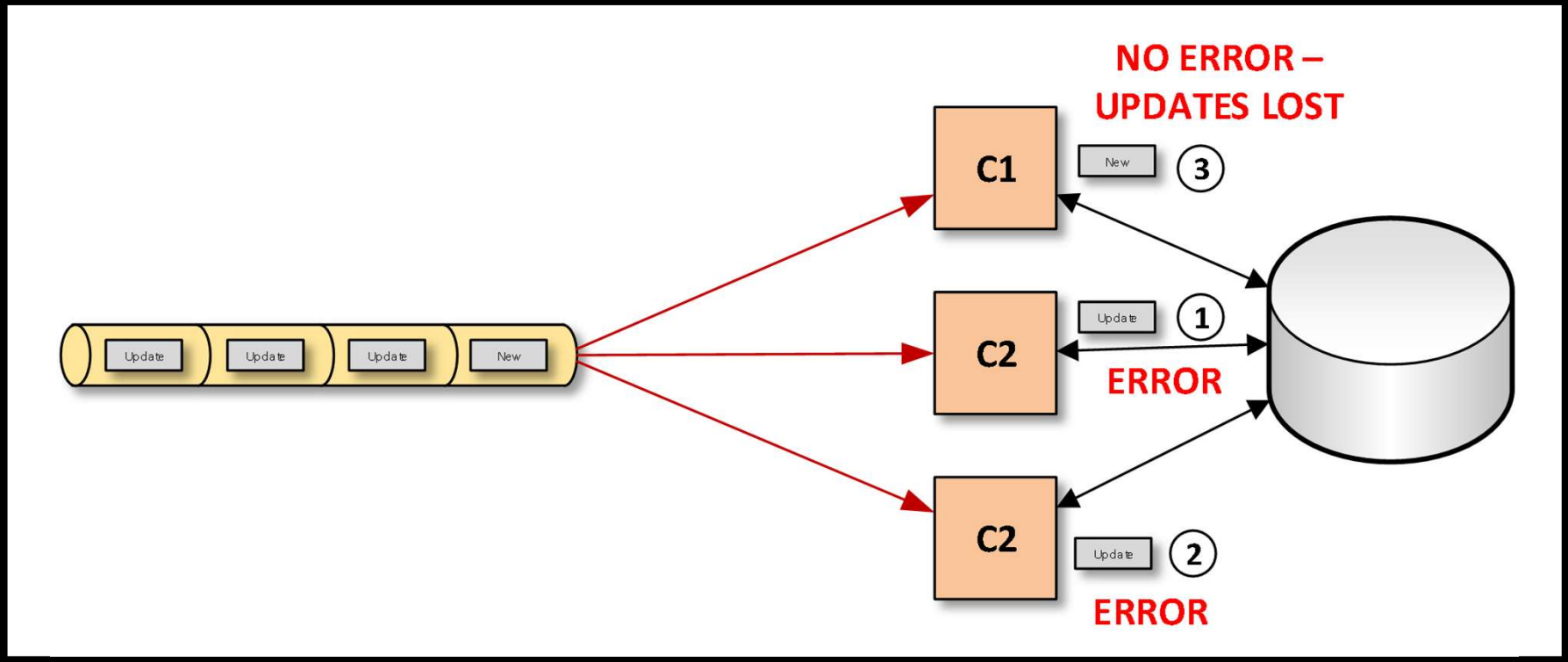
Work Queue (Anti-Pattern)



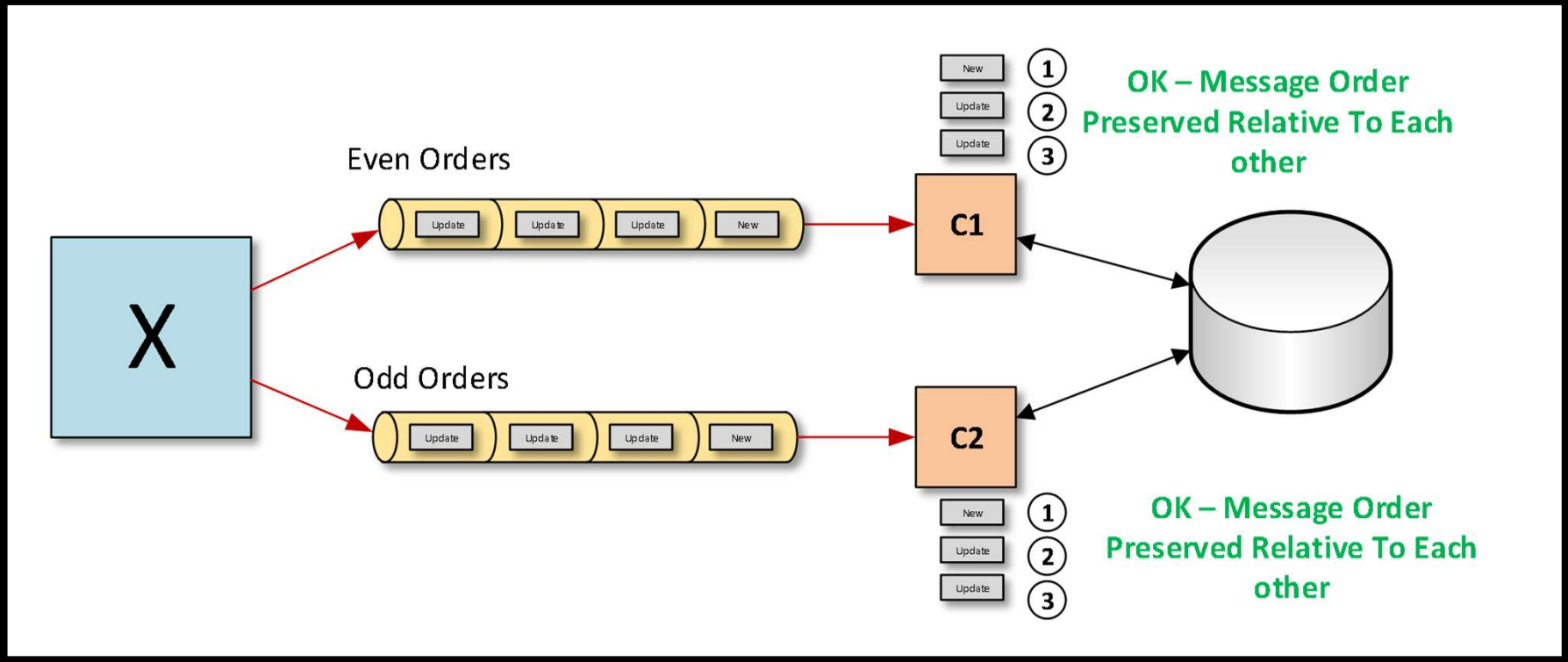
Work Queue (Anti-Pattern) - Solution



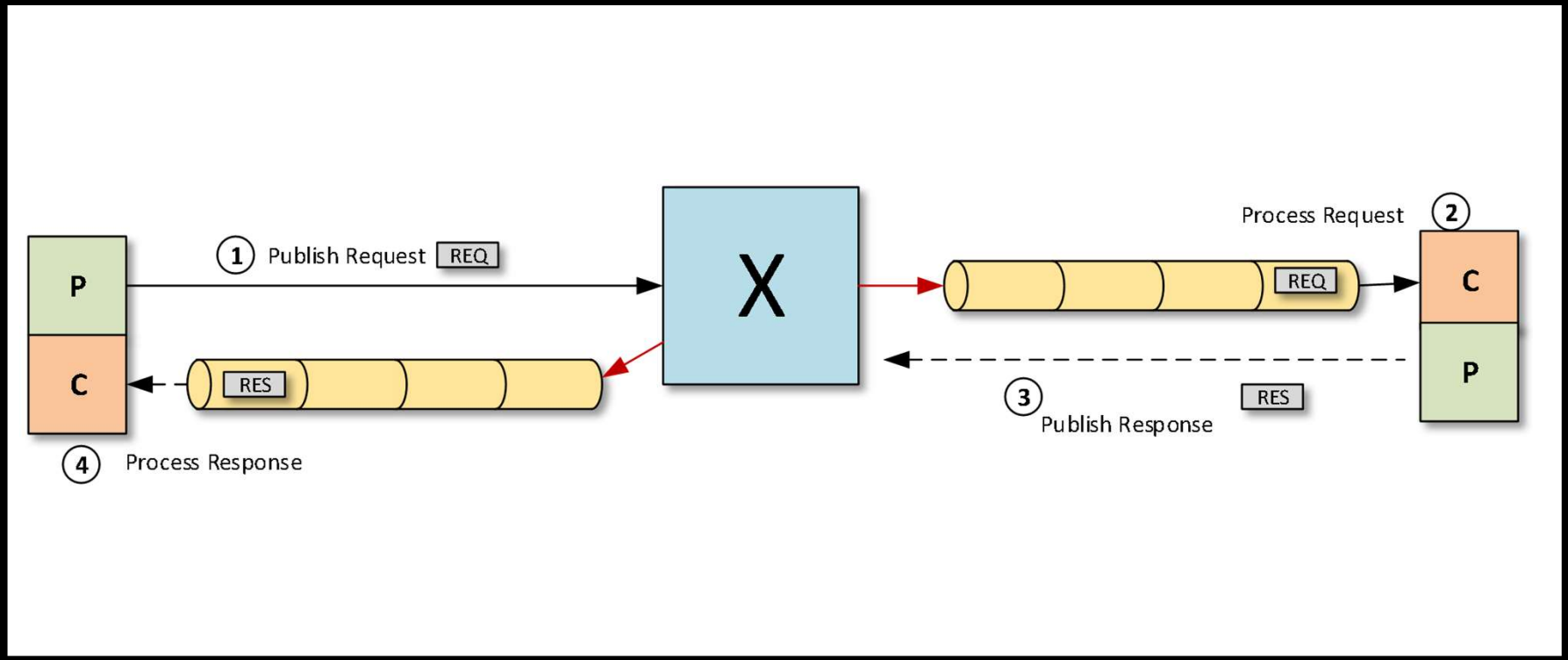
Work Queue (Anti-Pattern)
Message Order Dependency



Work Queue (Anti-Pattern) - Solution



Request - Response



Time To Live / Auto Delete

- Messages, Queues, Exchanges can all be cleaned up automatically
  - Useful or dynamically created resources not static infrastructure
- Message TTL
  - Can be set per Message
  - Can be set per Queue
  - Message cannot exceed queue's TTL
- Auto Delete
  - Queues can auto-delete after last client disconnects
  - Exchanges can auto-delete after last queue is deleted / unbound
  - Only takes after at least 1 connected

Other Client Events (Connection / Channel)

- I suggest subscribing to ALL events on the channel and connection
- Flow Control – Can kick in if the high/low watermarks are hit for memory
- Basic.RecoverOk
- ModelShutdown
- CallbackException

Error Handling

- When using acknowledgements
  - Bad messages can hold up the queue and/or create infinite loops
  - Must ack it with a 'Reject'
- Basic.Reject(Requeue=False)
  - Message is dropped
- Basic.Reject(Requeue=True)
  - put back in the queue(in the same spot) and it will be reprocessed again
  - If the same error happens again, it will reprocess this message indefinitely
- There is a 'Redelivery' flag but No Redelivery Count

No Redelivery Count

- The redelivery flag will be set regardless if the a client rejects it explicitly or it was dropped due to disconnection
- Some errors are transient (remote server busy) and might not occur the 2nd time
- You can not make this determination based on a single flag. A count of redelivery attempts could help your error handling logic determine when its time to ‘Reject’

Pattern for Error Handling

```
try {
        ProcessMessage
} catch(TransientException) {

        If (msg.Redelivery = false) {
                Reject(msg, requeue = true)  // Perhaps the error wont occur next time?
        } else {
                Reject(msg, requeue = false) // Possibly 2nd time
        }
} catch(FatalException) {
        Reject(msg, requeue = false)
}
```

Dead Letter Exchange

- Configured per queue
- Tells queue where to resend message if it has been ‘Rejected’ by a client
- Expired Messages also sent
- This is much better safer than acking and republishing in client code as it is all handled and guaranteed by the broker
- Message sent unaltered to DLX.
  - Don’t forget to create a queue
- Optional Dead Letter Topic
  - Sets an additional property on the message

QoS Settings

- Global vs Local
  - Can be set per connection
  - Or set for all consumers
- Prefetch
  - Reduces the amount of network round trips
  - By default it is unlimited will send as many messages to a client as it has memory
  - Undesirable for round-robin / load balancing between long processes

More Messaging Anti-Patterns

- Basic.Get
- Ack / Republish Bad Messages
- Excessive RPC

Basic.Get

- Requires Polling / Busy Loop
- Wastes a thread
  - While(true) {
    - Var msg = channel.get();
    - Sleep(100);
  - }
- Only 1 Message at a time
- Doesn't Take advantage of AMQP 'Consumers'
  - Doesn't tie into QoS
  - Not Truly Asynchronous / Event Based
  - Always Use Consumers

Remote Procedure Calls

- It is somewhat cool that you can use RabbitMQ and wire up WCF or Java RPC calls
  - var message = client.Method(parameter);
- Use it with restraint. It can easily get out of hand
- Not obvious code being used is queue / dequeue messages
- Not really designing a message based application

More Advanced Topics

- Protocol / Message Versioning
- High Availability
- Distributed Systems

Multi-Version Protocols

- A large real-time system may be need to run with no down time
- Need to deploy updates and changes to messages definitions
- If using Topic or Header exchanges, this can be done as follows

High-Availability / Mirrored Clusters (Single Node)

- RabbitMQ supports built in clustering
- Building / Joining nodes to clusters will increase fault tolerance
- Messages will be can replicated to N out of M nodes in cluster
- Warning! – AMQP does not spec says nothing about clusters!
  - If the node a client connects to fails, it is up to the client to reconnect to another node!
  - Either let all clients know about all nodes
  - Or, use a hardware based solution (better for transparency)
- RabbitMQ Must be the same version for all nodes

Distributed RabbitMQ (Multiple Nodes)

- Can be used between versions of RabbitMQ

- Shovel Plugin
  - Copies ‘ALL’ messages from 1 exchange to a remote exchange
    - Creates a local queue

- Federation
  - Optimized to only send messages to remote exchanges for relevant queues

RabbitMQ over the internet Example

- Local RabbitMQ
- Federated
- Cloud RabbitMQ