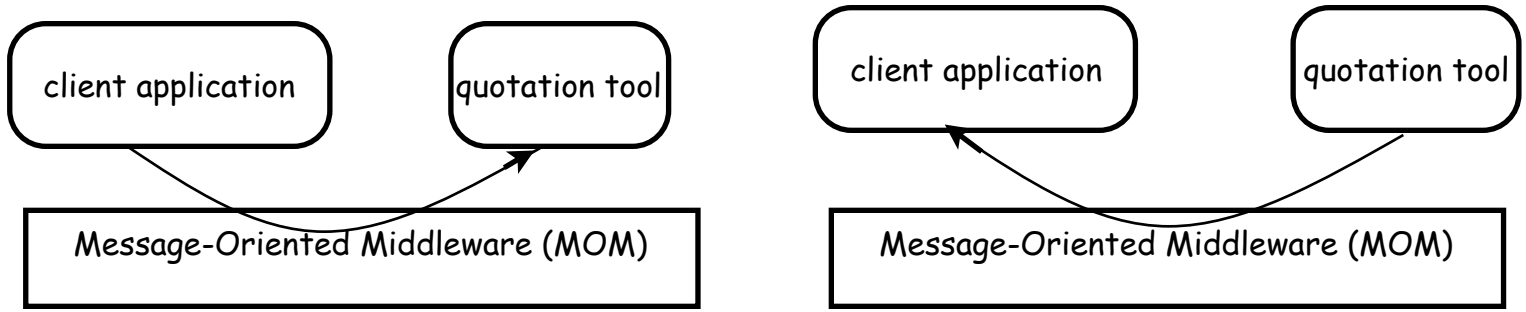
Message Oriented Systems

- MOM
  - [ACKM04] Section 2.5
  - [BN97] Ch 4
- Message Brokers, EAI, Workflow
  - [ACKM04] Ch 3

Async RPC as two messages

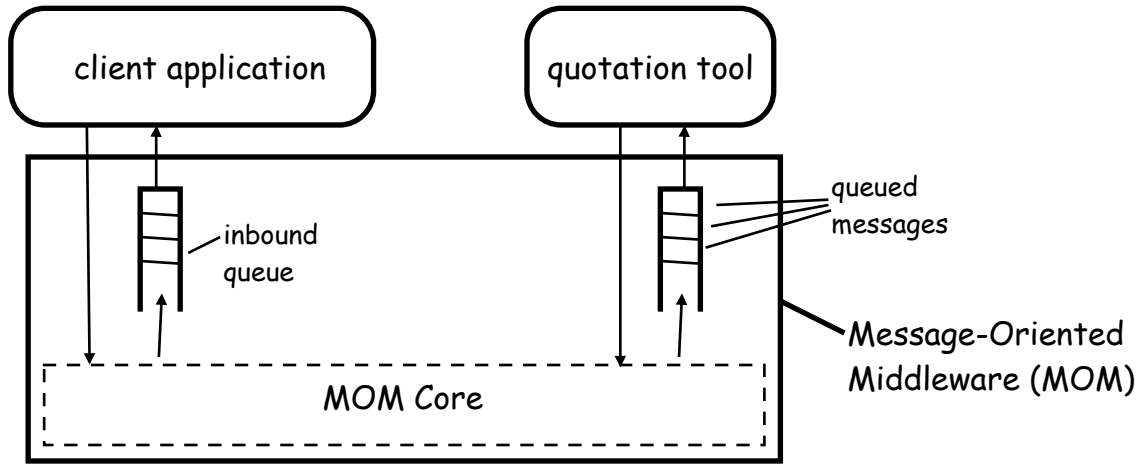
```
Message : quoteRequest {
 QuoteReferenceNumber: 325
 Customer: Acme,INC
 Item:#115 (Ball-point pen, blue)
 Quantity: 1200
 RequestedDeliveryDate: Mar 16,2003
 DeliveryAddress: Palo Alto, CA
}
```

```
Message: quote {
 QuoteReferenceNumber: 325
 ExpectedDeliveryDate: Mar 12, 2003
 Price:1200$
}
```



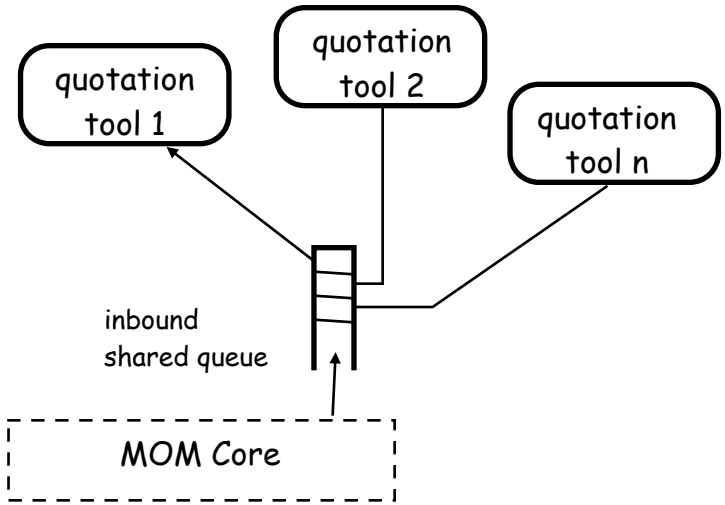
(a) (b)

Message Oriented Middleware



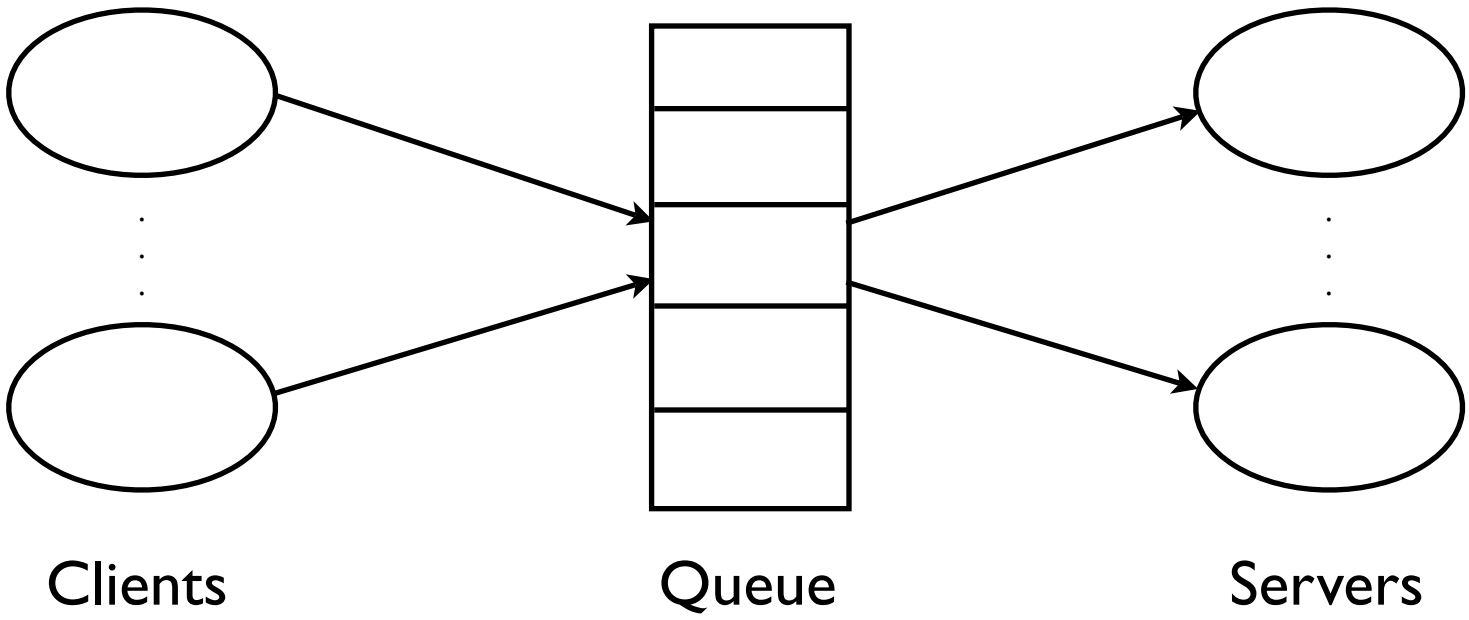
MOM routes messages and maintains input queues

Multiple Servers



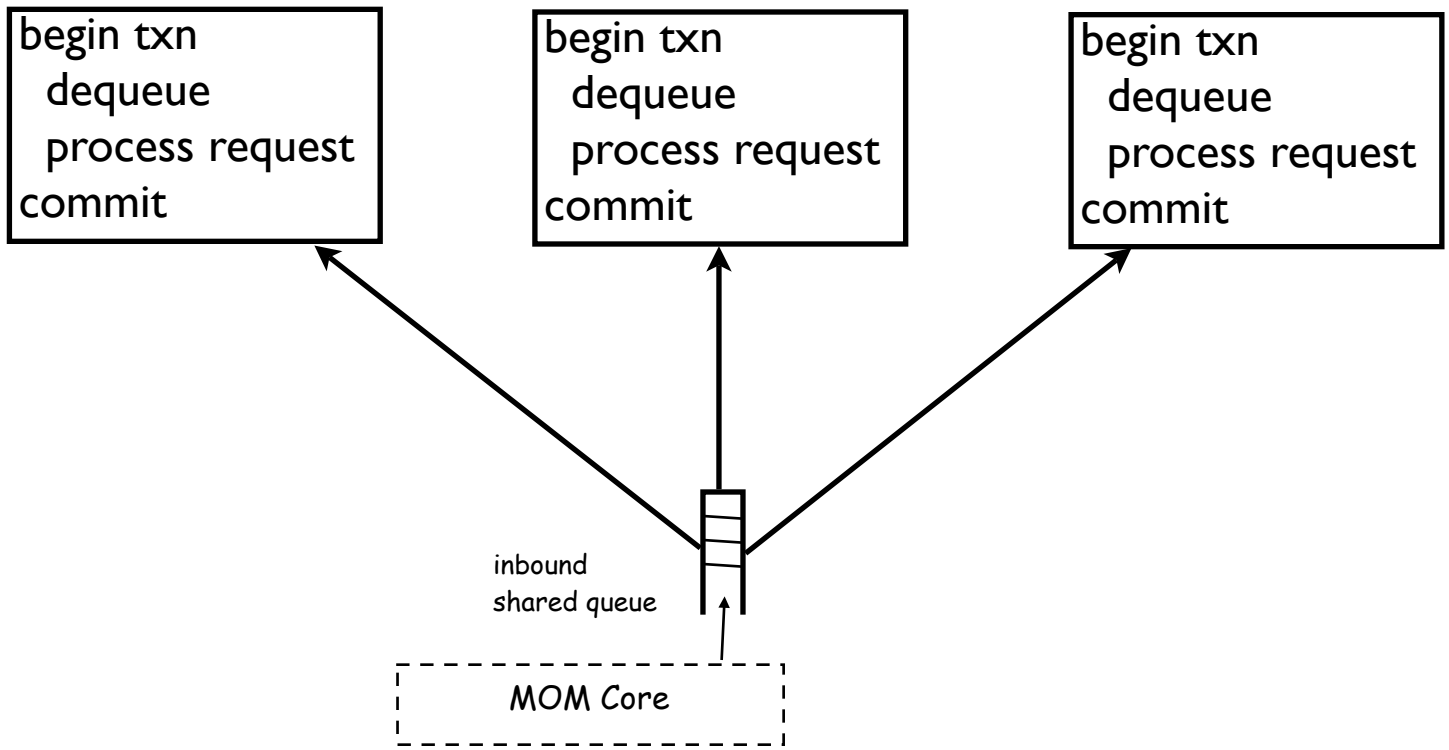
Queue can act as worklist for multiple server processes

Multiple Clients and Servers



- Queue can be output for multiple clients
- Load balancing on *both* sides of queue

Transactional Queueing



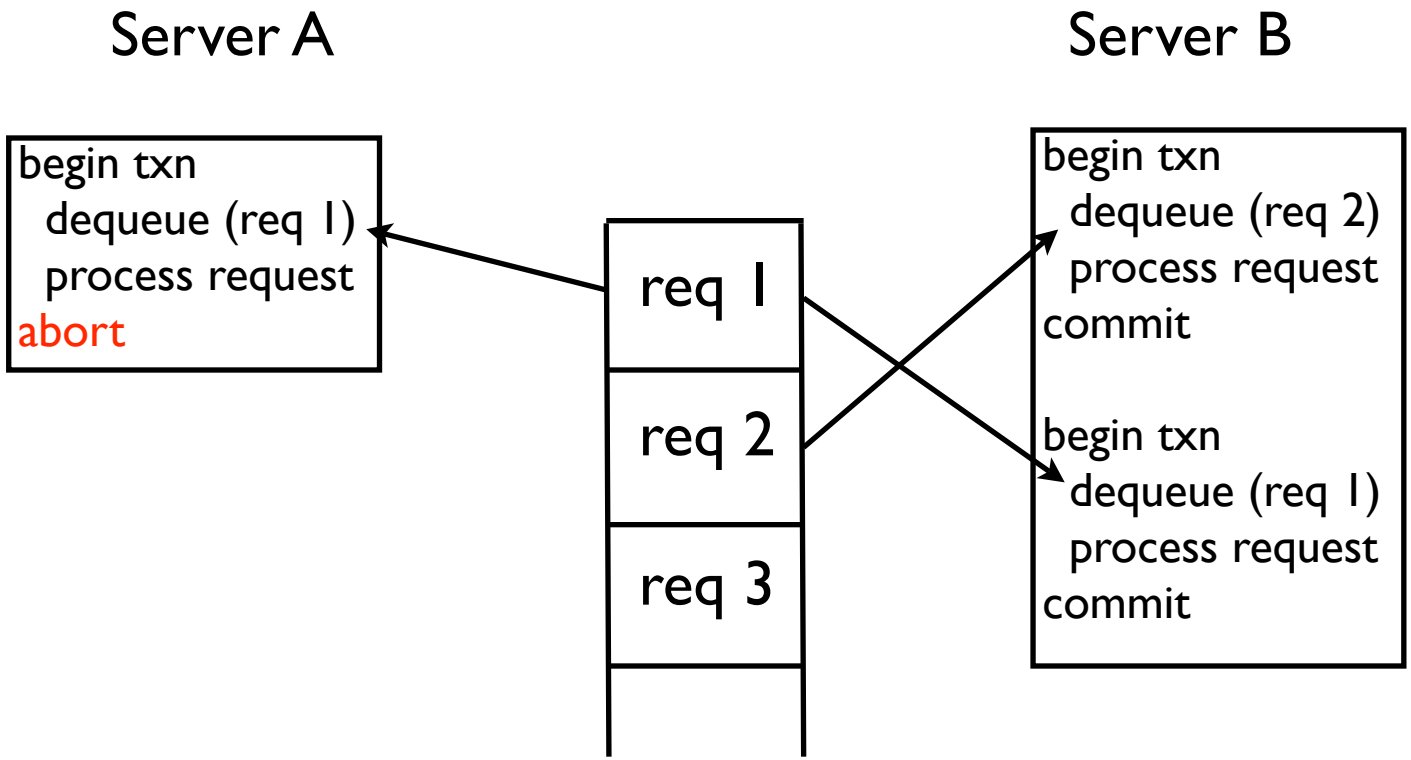
Failure of server process does not drop request

But FIFO or request priority may be affected

Transactional Server

- Careful here:
  - Everything the server does that affects permanent state must commit/abort as part of the *same* transaction as the dequeue operation
  - So in general transactional MOM requires distributed txns, 2PC just like TP monitor

Service Ordering



- Server A fails/aborts after dequeue of req 1 (by server A) and req 2 (by server B)
- No message lost, but service *not* FIFO

Queue is not just a Relation

Suppose a DEQUEUE(Q) operation is the SQL

```
DELETE FROM Q WHERE Q.pri = (SELECT MAX(pri) FROM Q)
```

Then the sequence

DEQUEUE(Q1)	
	DEQUEUE(Q2)
DEQUEUE(Q2)	
	DEQUEUE(Q1)
COMMIT	
	COMMIT

is NOT SERIALIZABLE (second dequeue in each queue is a dirty read).

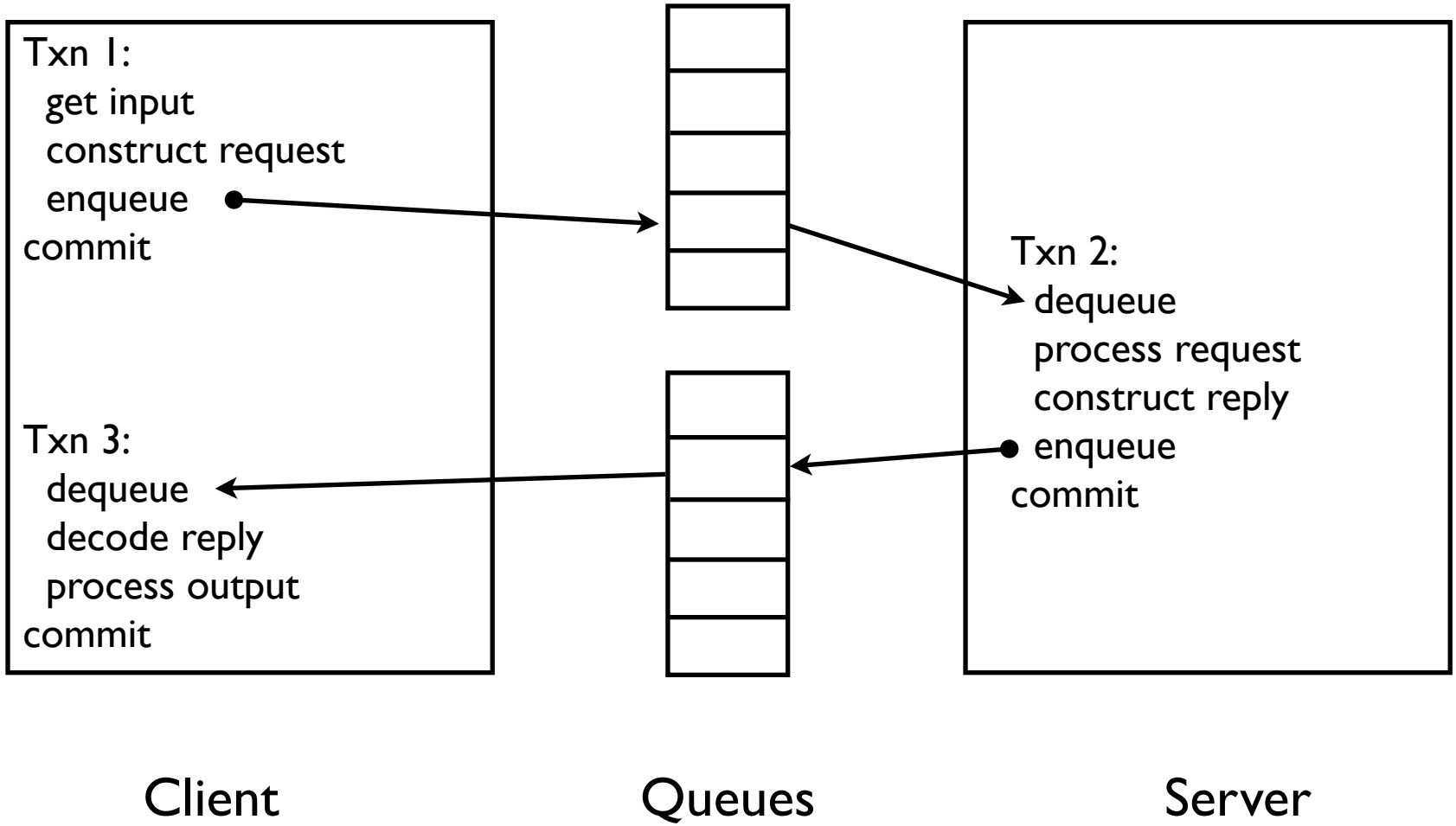
This pair of transactions is a DEADLOCK!

With only a single queue, second server would block behind first.

Transactional RPC

- Want a recoverable RPC
- Client and/or server may fail and be recovered
- State of RPC can be recovered from the durable transactional queues

Multi-Transaction RPC



Idea: suppose client or server fails; on recovery, can we recover the state of current RPC?

Server Recovery

- Server dequeues some inputs, does some processing, enqueues some outputs
- Suppose all processing reads/writes data under control of Txn 2 -- thus either commits or aborts along with dequeue and enqueue
- We are done!

Client Recovery

- Client may read inputs and produce outputs that are not undoable
  - read from terminal, print boarding pass, dispense $20 bills, ...
- So client maintains log on persistent storage
  - as in 2PC resource managers, log contains read results or intentions to write
  - crash recovery restores state from log
  - continue operation with minimal loss of data

Client Recovery

Assume: client runs one txn at a time.

On recovery: 4 possible states of current txn:

A: Txn 1 did not commit
Client should resubmit request if possible

B: Txn 2 did not commit
Client should wait

C: Txn 3 did not commit
Client should restart txn 3

D: Txn 3 committed
No client action required

Client Recovery

- GUID for each transaction
  - known to both client and queue mgr
- Client logs GUID of each enqueued request and each dequeued reply just before commit of its txn
- Queue mgr retains GUID of last enqueued request and dequeued reply committed by client

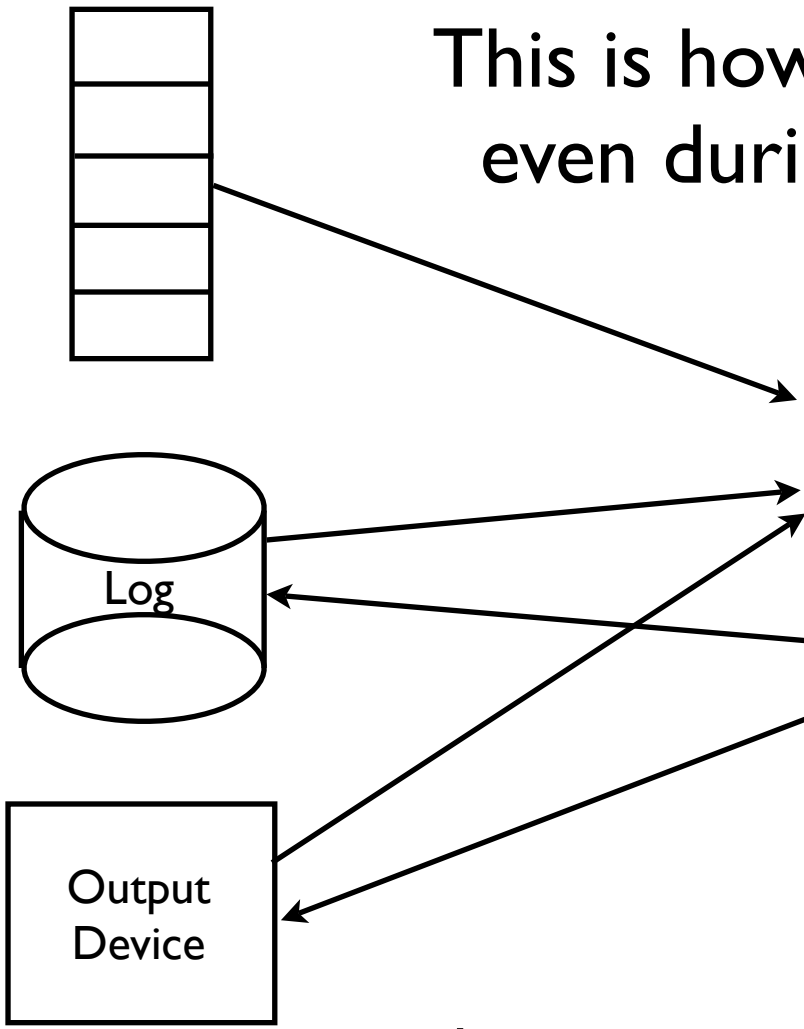
Client Recovery

- On recovery, client compares GUIDs in its own log with GUIDs provided by queue mgr
  - enqueue mismatch => state A
    - resubmit request using data from log
  - dequeue match => state D
    - do nothing
  - reply queue not empty => state C
    - retry -- see below
  - else
    - wait for reply message

Recovering from state C

- We don't know how far client got in previous run ...
- Might have done something that cannot be undone/redone
  - print boarding pass
  - dispense cash
- How do we handle this? Two ways:
  - device state
  - idempotency

Recovering Using Device State



This is how to run T3 so it works properly even during recovery ...

1. start transaction T3
2. dequeue reply
3. earlier logged device state different from current state => ask operator
4. write current device state to log
5. perform operation on device
6. commit

Assumption: every operation changes state of device!

Idempotency

- Idempotent => no harm if done twice
  - e.g. "move robot arm to this position"
- Sometimes a small tweak makes an operation idempotent:
  - send message "You just bought 100 shares of IBM" is not idempotent, but
  - send message "your request number 1234 to buy 100 shares of IBM has executed" is idempotent!

Queue Manager Summary

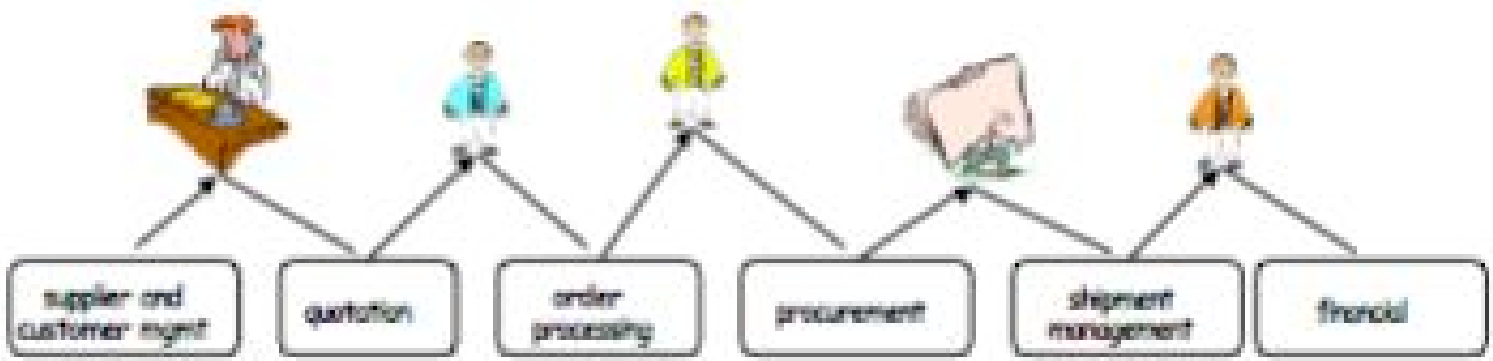
- Queue "DDL"
  - create/destroy/alter queue
- Queue operations
  - enqueue
  - dequeue (blocking/nonblocking, priority/FIFO)
  - enumerate
- Nontransactional queue operations

Queue Manager Summary

- Persistent sessions
  - associate queues with clients
  - persistent state aids client recovery
- Queue forwarding/routing
  - enqueue at one site
  - queue mgr transactionally forwards messages to remote queue(s) in priority or FIFO order
  - dequeue at remote site

Workflow

- A Supply Chain ...



- This is really a *sequence* of atomic transactions

Workflow

- Why do things this way? Lots of reasons ...
  - Availability
    - need all the resources at once
  - Resource contention
    - hold only the subset of resources you needed *now* => better throughput
  - Legacy systems
    - may not have distributed commit

ACID Properties?

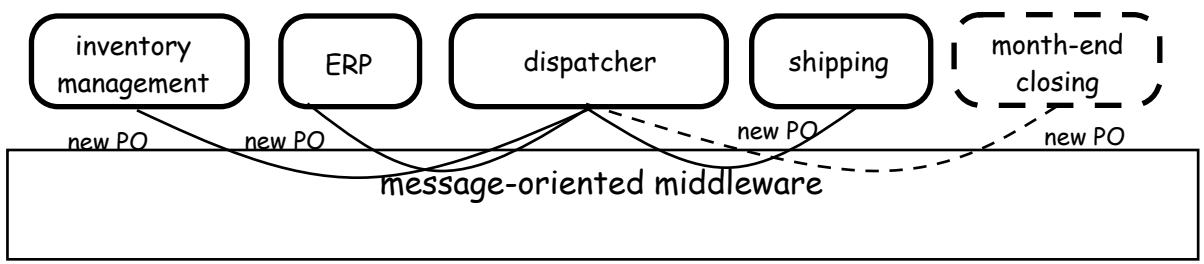
- Clearly fails Isolation
  - other txns can read state between committed steps
  - e.g. transfer funds by withdraw and deposit as separate txns
  - can view this as expanding set of "consistent" states
  - highly application dependent

ACID Properties?

- Atomicity?
  - not in short term -- same argument as for isolation!
  - long term -- to roll back a sequence of transactions, execute a *compensating transaction* for each committed step
  - but this is not always possible
    - S1 makes deposit to bank acct
    - S2 makes withdrawal
    - Later we try to compensate for S1's deposit and find insufficient funds ...

EAI

- Despite weak transactional semantics, workflow extremely useful for integration of legacy applications: Enterprise Application Integration (EAI)

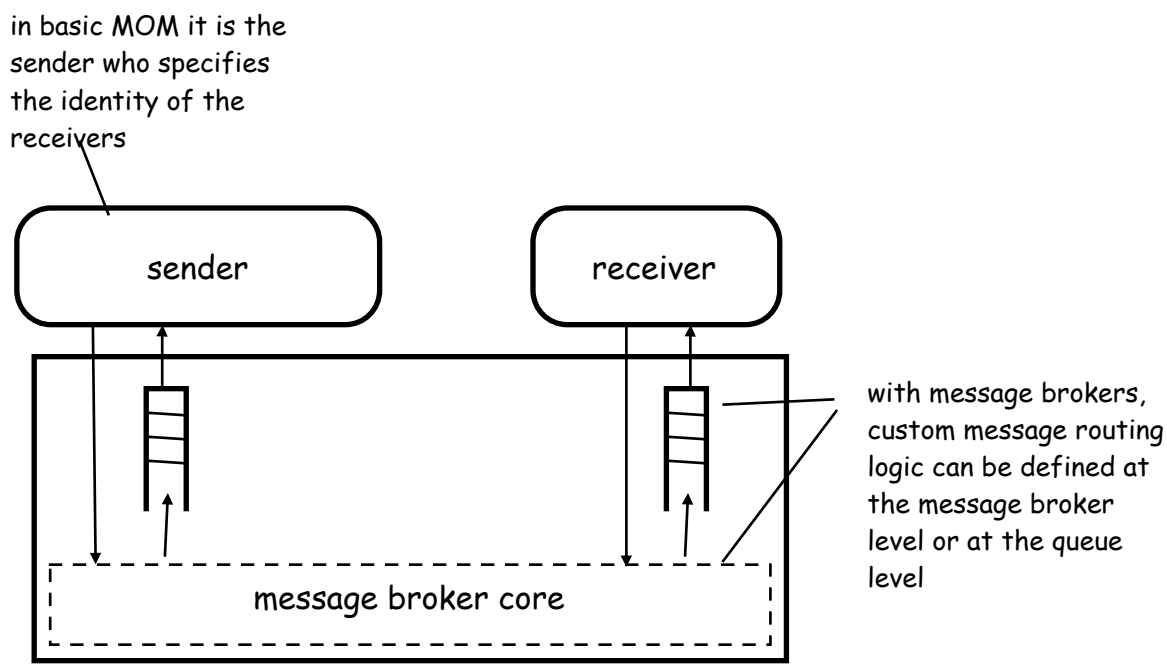


Of course they all run independent transactions!

How add new apps without modifying the existing ones?

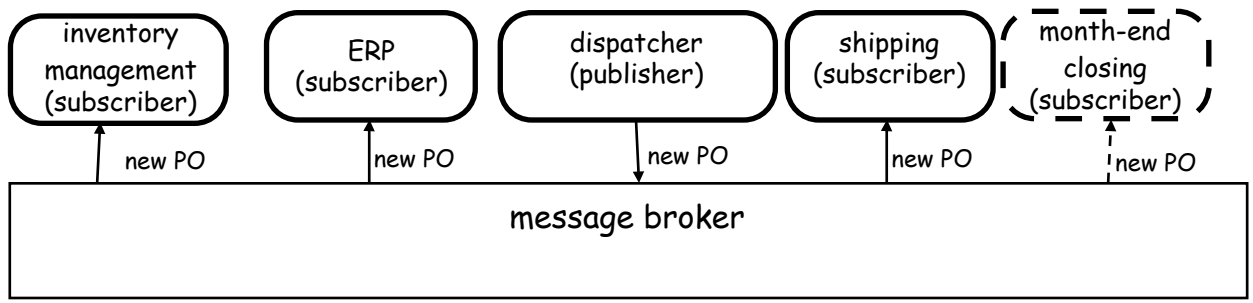
Message Broker -- Routing

- Message broker determines destinations
  - based on sender identity, message type, message content
- Senders do not specify or know who the receivers are!



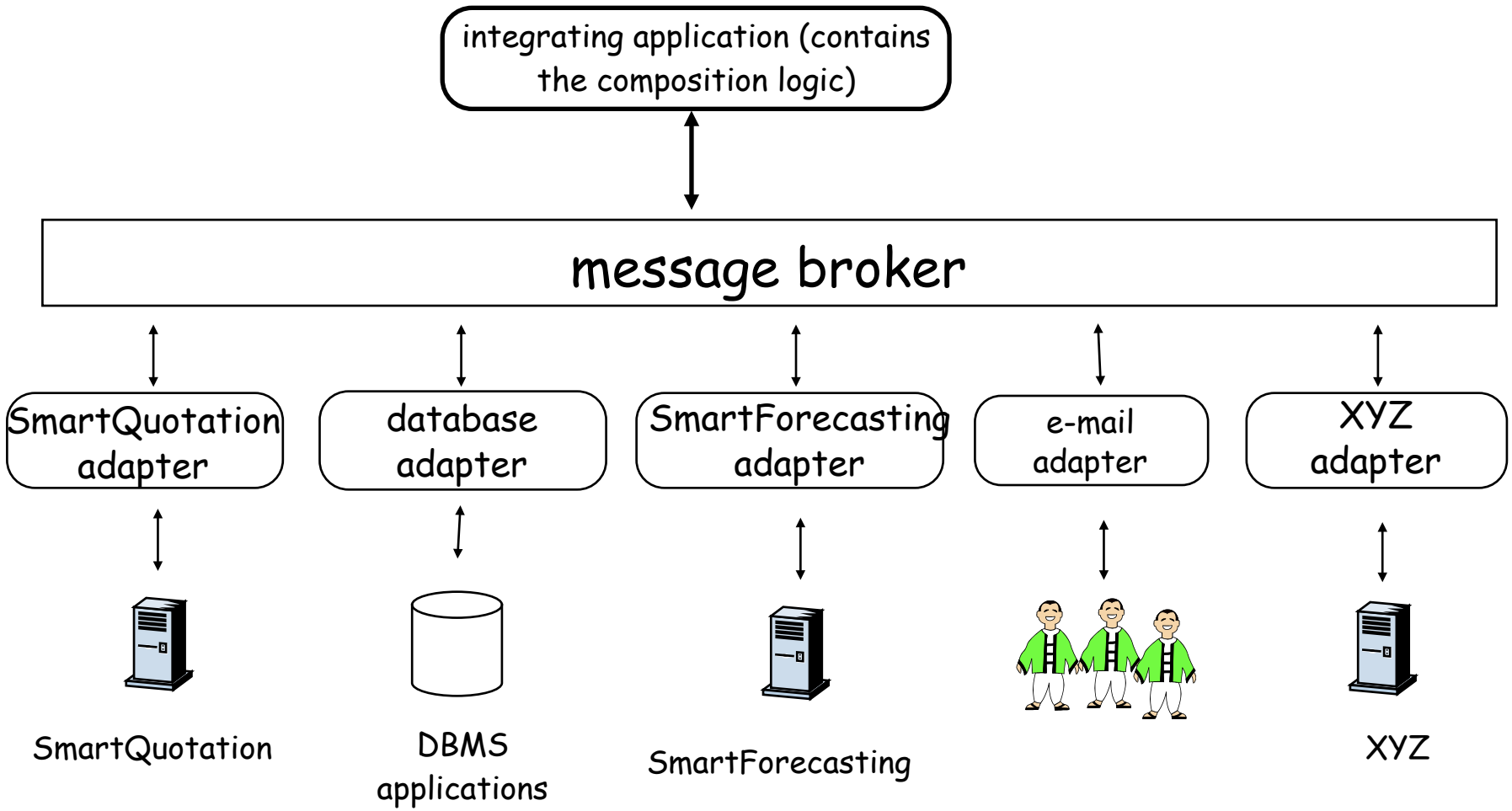
EAI Using Message Broker

- Add new application by altering routing specification in Message Broker ...

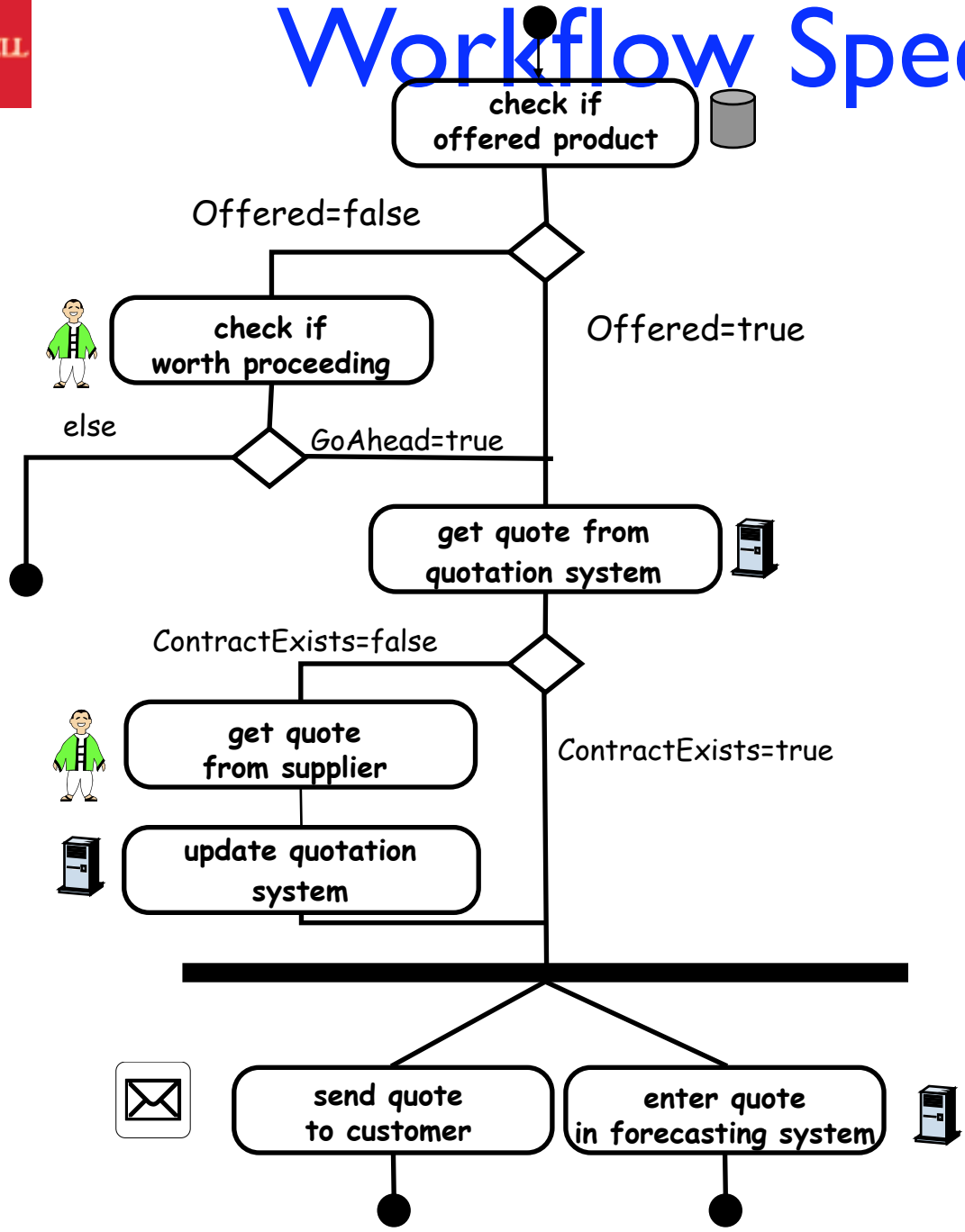


EAI Using Message Broker

- Or create new application that makes use of legacy applications

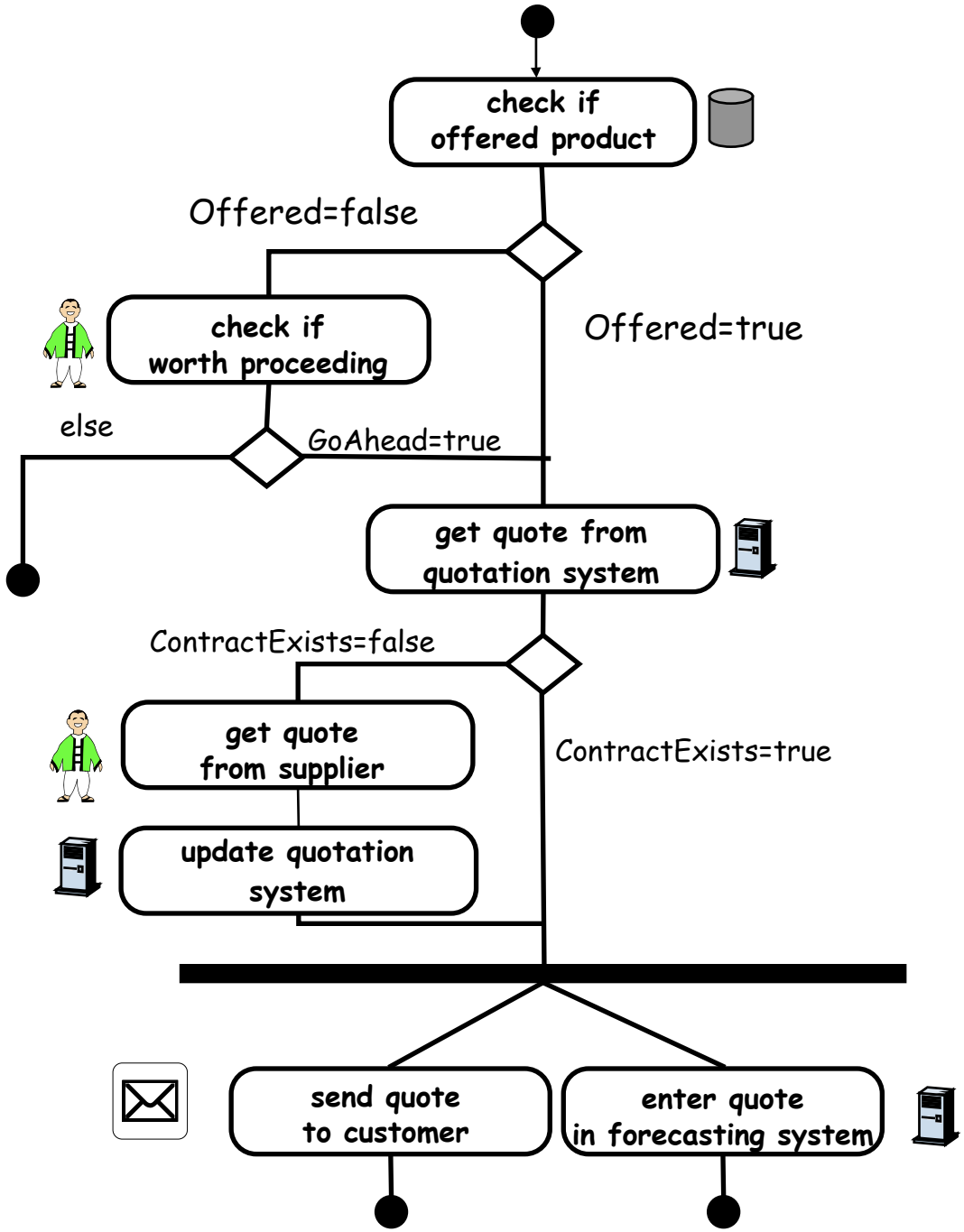


Workflow Specifications



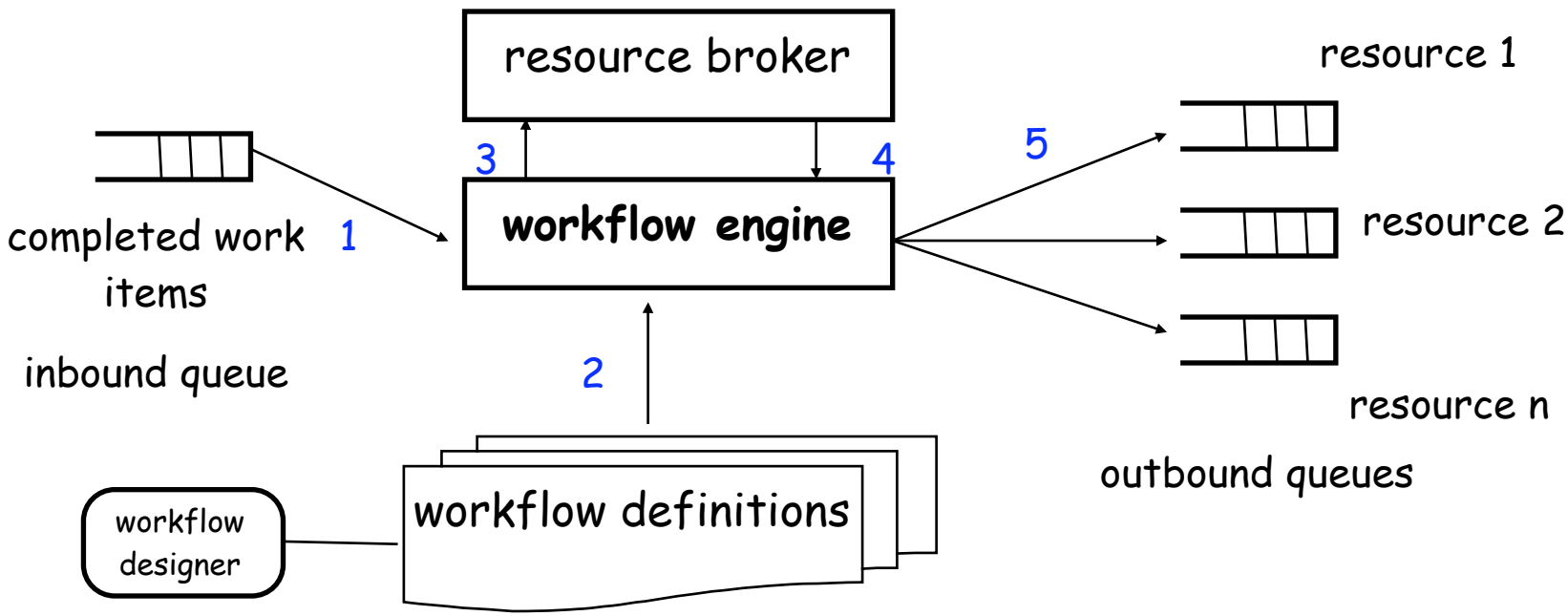
variables:
QuoteReferenceNumber: int
Customer: String
Item: String
Quantity: int
RequestedDeliveryDate: Date
DeliveryAddress: String
GoAhead: Bool
ContractExists: Bool
Offered: Bool

Workflow Definition

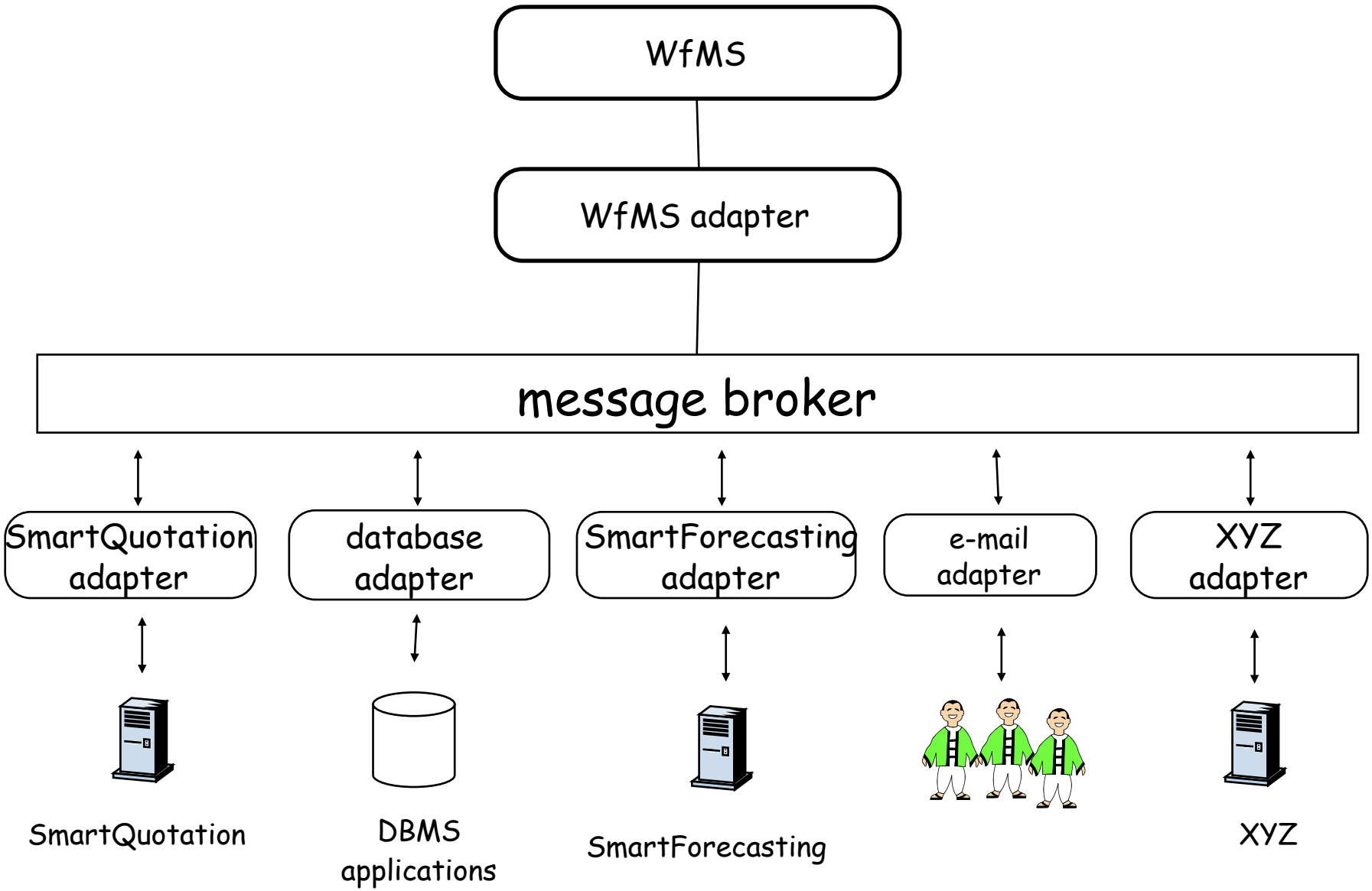


variables:
QuoteReferenceNumber: int
Customer: String
Item: String
Quantity: int
RequestedDeliveryDate: Date
DeliveryAddress: String
GoAhead: Bool
ContractExists: Bool
Offered: Bool

Workflow System



Combining ...


WfMS
WfMS adapter
message broker
SmartQuotation adapter
database adapter
SmartForecasting adapter
e-mail adapter
XYZ adapter
SmartQuotation
DBMS applications
SmartForecasting
XYZ