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Chapter 15 – Web Services Coordination and Transactions

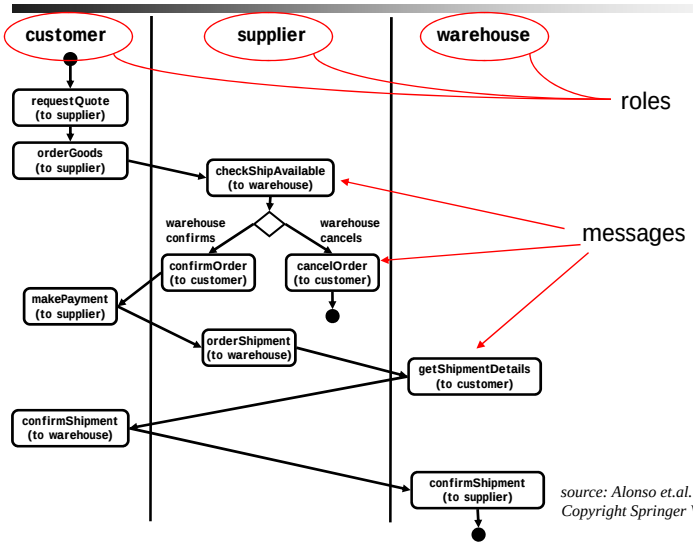
Coordination - Motivation

- Interactions are typically more complex than simple invocations
- Need to coordinate (sets of) activities or applications
  - Distributed
  - Running on different platforms using local coordinators
- Examples
  - Reach consistent agreement on the outcome of distributed transactions
    - Atomic transactions, 2PC
  - Coordinate auctioning activities
    - involves seller, auctioneer, buyers
  - Interactions between a customer and a supplier for ordering a product
    - request order, order goods, make payment

Conversations and Coordination Protocols

- Interactions form a ***conversation***
  - sequences of operations (message exchanges)
    - maintain context information across invocations
- Interactions adhere to a ***coordination protocol***
  - specifies a set of correct/accepted conversations
  - *vertical* protocols: specific to business area (e.g., product ordering protocol)
  - *horizontal* protocols: define common infrastructure (e.g., transactions)
- Different ways of modeling conversations
  - state machines
  - sequence diagrams
  - activity diagrams
- Middleware support can be provided, with various degrees of automation
  - conversation controllers
  - generic protocol handlers

Modeling Protocols - Activity Diagrams



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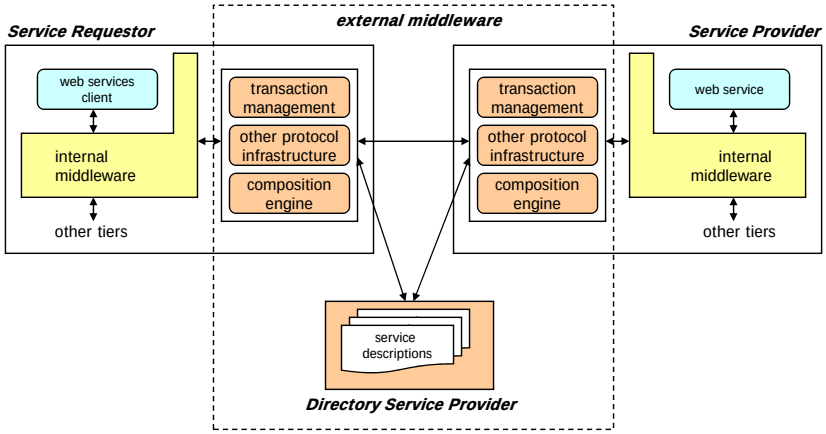
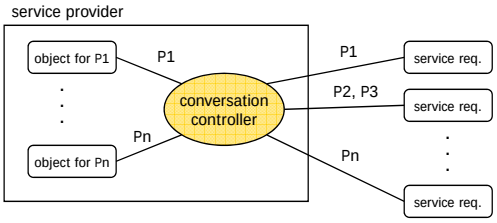
External Web Services Architecture



Conversation Controller

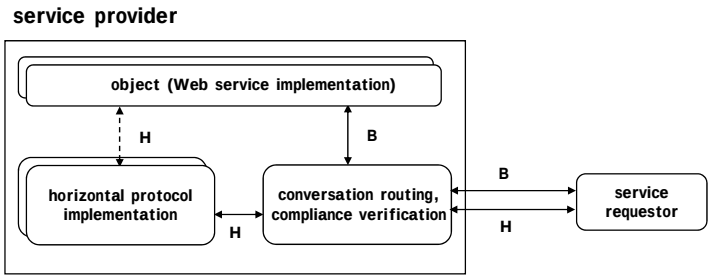
- Performs *conversation routing*
  - dispatch message to the appropriate "internal object"
    - one object for each instance of a conversation (e.g., an ordering session)
  - involves message correlation (conversation identifier), management of conversation context
    - example: session id
- Verifies *protocol compliance*
  - understand definition of the protocol (-> standardization of protocol descriptions)
  - check if all messages adhere to the protocol definition
- Can be implemented as a component of a SOAP router



Generic Protocol Handlers

- Module that implements a specific coordination protocol
  - includes protocol-specific logic
  - processes and generates messages in accordance with the protocol rules
- Mostly applicable to horizontal protocols
  - example: transactions
- Forms of protocol execution support
  - handler realizes complete support, no intervention from the web service
    - Example: reliable messaging
  - handler and web service jointly realize the support
    - Example: atomic, distributed TAs
      - infrastructure coordinates sending/receiving prepare/commit/abort messages
      - web services decide over commit/abort, implement operations

Implementing Horizontal Protocols



B: conversation compliant with a business protocol
H: conversation compliant with an horizontal protocol

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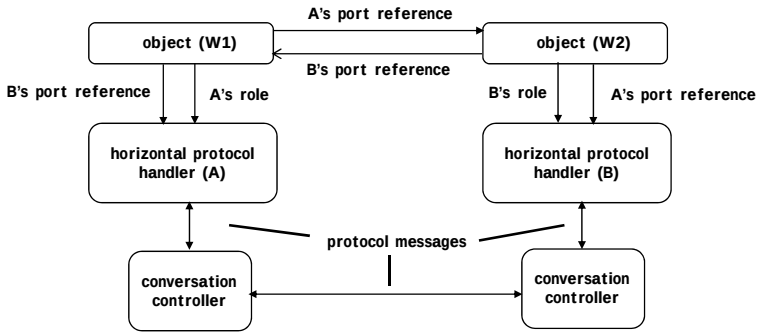
Communicating Roles and Port References



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Standardization

- Coordination infrastructure support for web services needs to be based on standards for
  1) generating and transporting unique conversation identifiers in SOAP headers
     - needed to map messages to conversations, and eventually to the objects handling them
  2) a framework and a set of (meta-) protocols for agreeing on which protocol is to be executed on how it is coordinated
  3) horizontal protocols
     - to separate horizontal protocol implementation from the inidividual web services
  4) protocol languages
     - to allow for protocol verification
- Web Services Coordination (WS-Coordination) Specification
  - standardizes 1), 2)
- Web Services Atomic Transaction (WS-AtomicTransaction) Specification
  - uses WS-Coordination framework to define coordination type for Atomic Transactions (i.e., it standardizes 3) for atomic TAs)
- Web Services Business Activity Framework (WS-BusinessActivity) Specification
  - same for (long-running) business transactions
- Standardized by the OASIS WS-TX technical committee
  - initial proposals by BEA, IBM, IONA, Microsoft

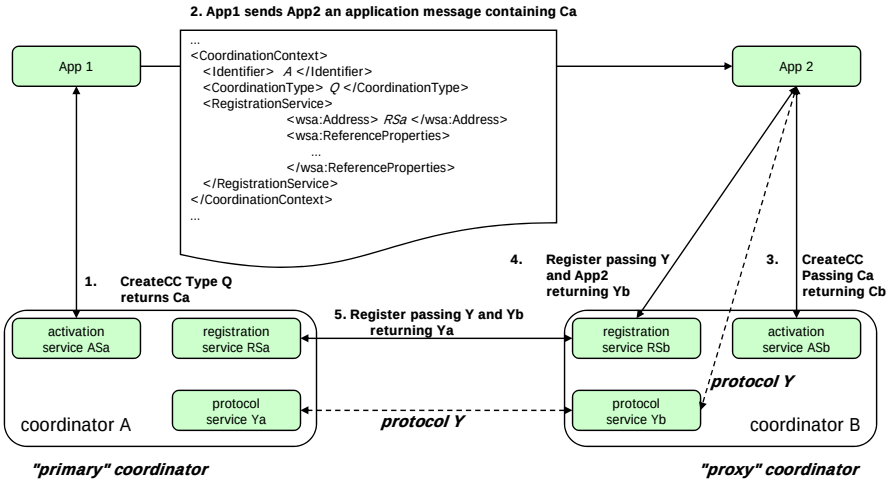
WS-Coordination

- Basic entities are **coordinators** and **participants** that wish to be coordinated
  - central coordination: all participants talk to a single coordinator
  - distributed coordination
    - each (or multiple) participant talks to its own coordinator
    - coordinators are chained together (subordinate coordinators act as participants)
- Abstractions to describe the interactions between coordinator and participants
  - coordination protocol
    - set of rules governing the conversation
      - example: 2PC
  - coordination type
    - set of logically related protocols
      - example: atomic transactions (completion, 2PC, volatile 2PC)
    - instance of a coordination type may involve several instances of the coordination protocols
- Coordination context
  - used to exchange coordination information among different parties
    - contains coordination type, identifier of the coordination type instance
    - placed within messages exchanged between parties (SOAP header)

Coordinator/Participant Interactions

- Coordination service (coordinator) consists of
  - **Activation** service (generic)
    - Used by a participant to create coordination context (initiate instance of protocol type)
    - WS Interfaces: ActivationCoordinator, ActivationRequester
  - **Registration** service (generic)
    - Enable application to register for coordination protocols
      - provide endpoint information, role
    - WS Interfaces: RegistrationCoordinator, RegistrationRequester
  - (set of) **coordination protocols** (protocol-specific)
    - Specific to coordination type
- Extensibility
  - Publication of new coordination protocols
  - Definition of extension elements that can be added to protocols and messages

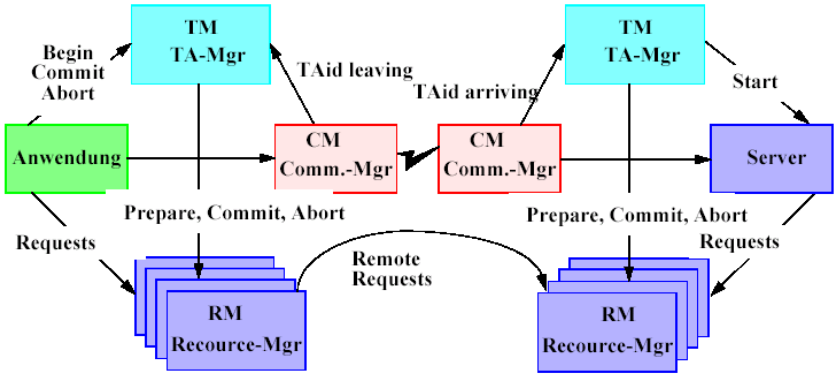
Distributed Coordination - Interactions



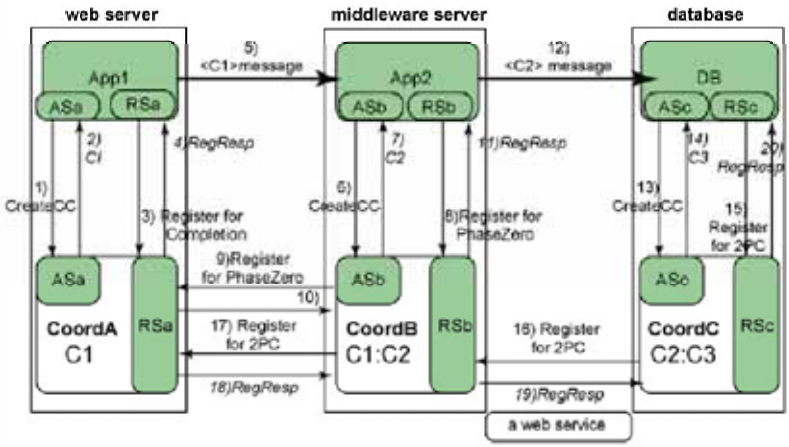
WS Atomic Transactions

- Atomic Transactions (TA) coordination type
  - Defines type-specific commit protocols
    - Completion: A participant (app creating the TA) registers so that it can tell the coordinator when/how to complete the TA (commit/abort)
    - 2PC: a resource manager (RM) registers for this protocol to be included in the commit/abort decision
      - Hierarchical 2PC (local coordinators can be interposed as subordinate coordinators)
    - Two variants of 2PC
      - volatile 2PC: a participant wants to be notified by the coordinator just before the 2PC begins
        - Example: participant caches, needs to communicate changes on cached data to DBMS before TA commits
      - durable 2PC: a participant (e.g., DBMS) manages durable resources
  - Completion must be registered with the root coordinator
  - Participants can register for more than one protocol
  - Extension elements
    - Example: communicate isolation levels

X/Open DTP revisited ...



AT WS-Coordination Flow



AT WS-Coordination Flow (cont.)

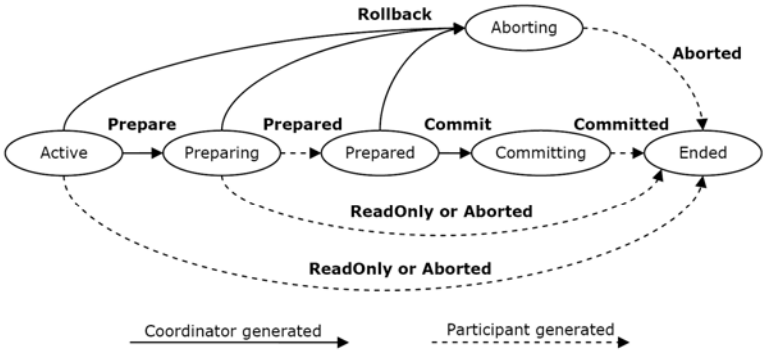
- App1:
  - sends a CreateCoordinationContext message (1) to its local coordinator's Activation service ASa
    - create an atomic transaction T1
    - gets back in a CreateCoordinationContextResponse message (2) a CoordinationContext C1 containing the transaction identifier T1, the atomic transaction coordination type and CoordA's registration address RSa
  - sends a Register message (3) to RSa to register for the Completion protocol
    - gets back a RegisterResponse message (4), exchanging protocol service addresses for the coordinator and participant sides of the two-way protocol
  - sends an application message to App2 (5)
    - propagating the CoordinationContext C1 as a header in the message.
- App2:
  - decides to interpose local coordinator CoordB in front of CoordA
    - acts as a proxy to CoordA for App2
    - CoordA is the superior and CoordB is the subordinate
  - does this by sending a CreateCoordinationContext message (6) to the Activation service of CoordB (ASb) with C1 as input
    - getting back (7) a new CoordinationContext C2 that contains the same transaction identifier (T1) and coordination type, but has CoordB's registration address RSb.
  - registers with CoordB for the PhaseZero (volatile 2PC) protocol (8 and 11)
    - CoordB registers with CoordA for the PhaseZero protocol (9 and 10)
  - sends a message to DB (12), propagating CoordinationContext C2

AT WS-Coordination Flow (cont.)

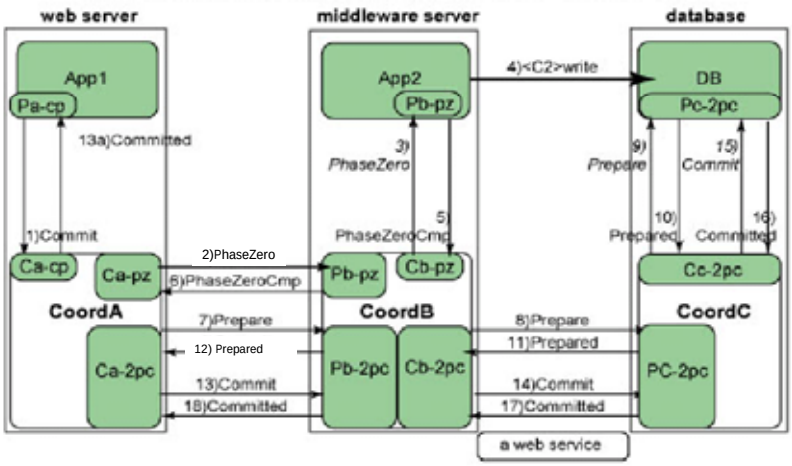
- DB:
  - decides to interpose its local coordinator CoordC by sending a CreateCoordinationContext message (13), further extending the superior-subordinate chain
    - gets back (14) a new CoordinationContext C3 that contains the same transaction identifier (T1) and coordination type, but CoordC's Registration service address RSc
  - registers with CoordC for the 2PC protocol because it is a resource manager (15 and 20)
  - causes CoordC to register with CoordB for the 2PC protocol (16 and 19)
  - causes CoordB to register with CoordA for the 2PC protocol (17 and 18)

AT – 2PC Protocol

- Two-way protocol
  - Exchange of messages between coordinator and participant
- State Diagram
  - State reflects common knowledge of both parties



AT Coordination Protocol Flows



AT Coordination Protocol Flows (cont.)

- App1:
  - tries to commit the transaction using the Completion protocol (1)
- CoordA executes prepare-phase of **Volatile 2PC protocol**
  - has 1 participant registered for PhaseZero (CoordB), sends a Prepare message (2) to CoordB's PhaseZero Participant protocol service Pb-pz
  - CoordB relays Prepare message to App2 (3)
  - App2 sends its cached updates to DB
    - application message (4) propagates the CoordinationContext C2
    - sends a Prepared message (5) to CoordB
- CoordA executes prepare-phase of **durable 2PC protocol**
  - sends a Prepare message (7) to CoordB's 2PC Participant protocol service Pb-2pc
  - CoordB sends Prepare message (8) to CoordC's 2PC Participant protocol service Pc-2pc
  - CoordC tells DB to Prepare (9)
- CoordA commits
  - sends Commit message (13) to CoordB
    - Committed notification to App1 (13a) can also be sent
  - CoordB sends Commit message (14) to CoordC
  - CoordC tells DB to commit T1
    - DB receives the Commit message (15) and commits
  - Committed message returns (16, 17 and 18)

WS-BA – Business Activities Framework

- Characteristics (see discussion in chapter on WfMS)
  - Usually long-running
    - Responding to a request may take a long time
  - May consume lots of resources, perform a lot of work
    - Early commit of atomic subactivities/transactions
    - Forward recovery, compensation
- Goal: define protocols that "wrap" proptietary business activity mechanisms to achieve interoperability
- Design points
  - State transitions need to be reliably recorded
  - All request messages are acknowledged
    - Detect problems early
  - Response to a request is a separate operation
    - Not the output of the request
    - Avoid problems with timeouts of message I/O implementations

Compensation

- An action used to logically undo the effects of another action is called compensation action
  - Extends to real world actions
    - drilling a hole: throw away part
  - Semantic Recovery: Recovery schema based on compensation
  - Compensation very likely one of today's most frequently exploited techniques in transaction processing
- Compensation action is often dependent on context
  - E.g. writing an offer and sending it via mail to a customer
    - If letter is still in outbasket, simply remove it from outbasket
    - If letter is already received by the customer, write and send a countermanding letter
- Compensation often cannot recreate the same state that existed before the proper action had been performed
  - E.g. canceling a flight might cost a cancellation fee
    - Even more complicated, the cancellation fee might depend on the point in time, i.e. it is higher the later the cancellation is requested
- Compensation action may fail!

Sagas – Transactions and Compensation

- Sagas support specification of compensation actions in advance and run them automatically on abort
  - Sequence of (Sub-)Transaction/compensating action pairs
  - DBMS guarantees LIFO execution of compensation actions during abort/rollback of Saga
  - ACID for each sub-TA

Definition:

A Saga is a sequence [(T1,C1),..., (Tn,Cn)] having the following properties:

1. T1,...,Tn and C1,...,Cn are two sets of transactions, such that Ci is the compensation function for Ti,
2. [(T1,C1),..., (Tn,Cn)] is executed as one of the following sequences:
   i. [T1,...,Tn], if all Ti committed, or
   ii. [T1,...,Ti, Ci-1,..., C1] if Ti aborts and T1,...,Ti-1 committed before.

Business Activities Model

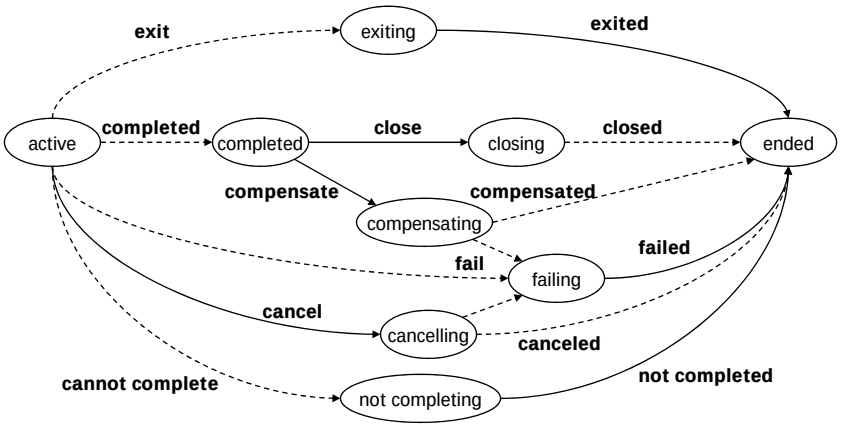
- Application is partitioned into business activity scopes
  - carries out business tasks using web services (participants)
  - mutually agreed outcome of all participants
- Participants registered with a coordinator of a BA
  - notify the coordinator about (successful) completion
  - may be asked by the coordinator to cancel an active task or to compensate a completed task
  - may indicate that it
    - cannot complete the task (and has cancelled it)
    - is leaving (exit) the BA (and has cancelled it)
    - has failed (during regular activities, when compensating or cancelling the task)
      - state of work is undetermined!
- Scopes may be arbitrarily nested

Business Activity (cont.)

- Business Activity (BA) coordination types
  - AtomicOutcome: coordinator directs all participants to either close or compensate
  - MixedOutcome: coordinator may direct some participants to close, others to compensate
- BA protocol types
  - BusinessAgreementWithParticipantCompletion protocol
    - participant must know when it has completed all the work for a business activity
  - BusinessAgreementWithCoordinatorCompletion protocol
    - participant relies on coordinator to tell it when it has received all requests for work in the business activity

Business Agreement Protocol

- BusinessAgreementWithParticipantCompletion – State Diagram



Summary

- Coordination protocols
  - protocol defines set of correct conversations (WS message exchanges)
    - involves multiple partners, roles implemented as web services
  - vertical vs. horizontal protocols
  - different modeling approaches (e.g., activity diagrams)
- Infrastructure
  - conversation controller for internal routing based on conversation identifier
  - generic protocol handlers for horizontal protocols
- Coordination protocol infrastructure
  - WS-Coordination as a framework for supporting coordination protocols
  - central vs. distributed coordination
- WS-Transaction
  - based on WS-Coordination infrastructure
  - atomic transactions vs. business activities