2. Application Servers (a.k.a. TP Monitors)

CSE 593 Transaction Processing

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Outline

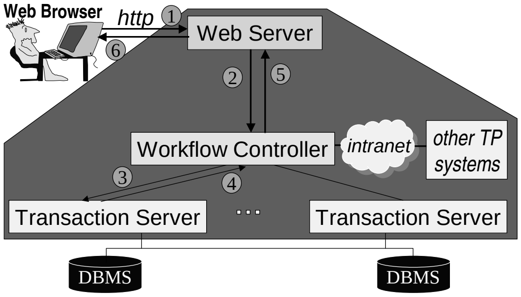
1. Introduction
2. Two-Tier vs. Three-Tier
3. Presentation Servers
4. Web Servers
5. Transaction Bracketing
6. Processes and Threads

2.1 Introduction

- A request is a message that describes a unit of work for the system to execute
- An application server coordinates the flow of requests between message sources (displays, applications, etc.) and application programs that run requests as transactions.
- Basic control flow:
  - Translate the display input (form/menu selection, etc.) into a standard-format request.
  - Send the request to the appropriate server based on the transaction type in the request header
  - Start the transaction
  - Invoke the transaction type's application program
  - Commit and send the transaction's output to the display

Application Server Architecture

- App server should make the previous control flow scale up
- Bold lines carry request messages

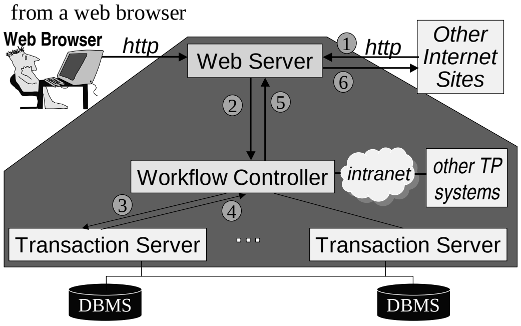


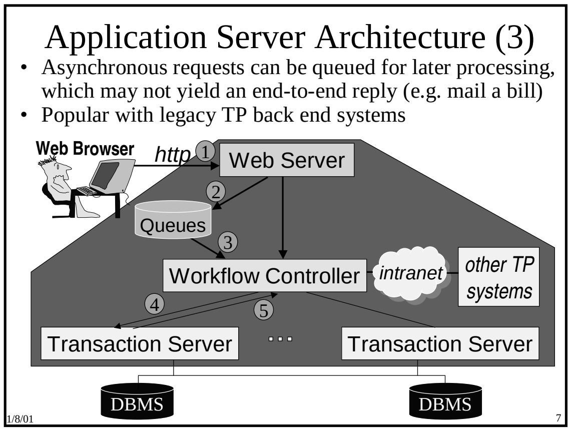
Application Server Components

- Web Browser
  - A smart device, with forms, menus, input validation
- Web server
  - Performs front-end work, e.g., security, data caching, ….
  - "Calls" the web page associated with the URL, which in turn calls a workflow controller
- Workflow controller
  - Calls Start, Commit, and Abort
  - App logic that transforms request (automatic loan payment, money transfer) into calls on basic objects (loan, account). Sometimes called *business rules*.
- Transaction server
  - Business objects (customer, account, loan, teller)
- DBMS – Database Management System

Application Server Architecture (2)

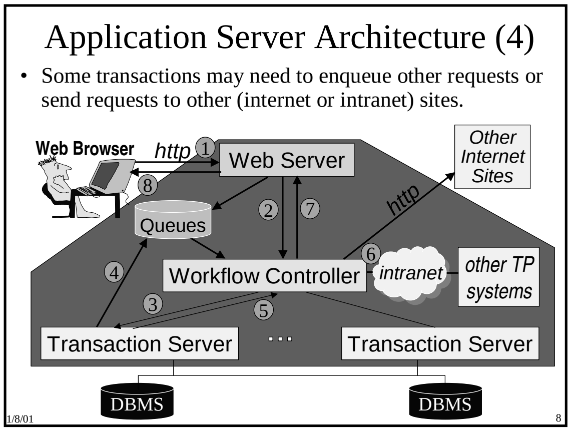
- Some requests are received from other sites, rather than from a web browser





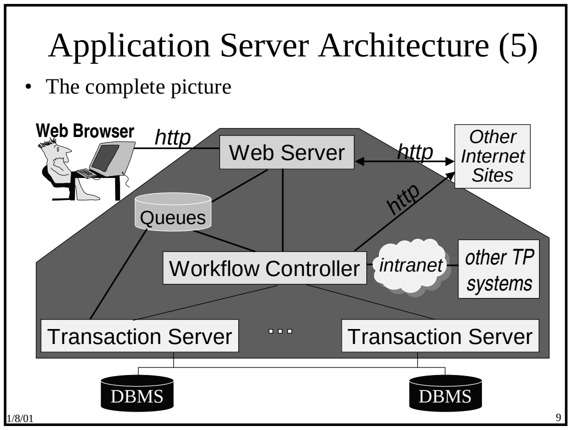
Application Server Architecture (3)

- Asynchronous requests can be queued for later processing, which may not yield an end-to-end reply (e.g. mail a bill)
- Popular with legacy TP back end systems



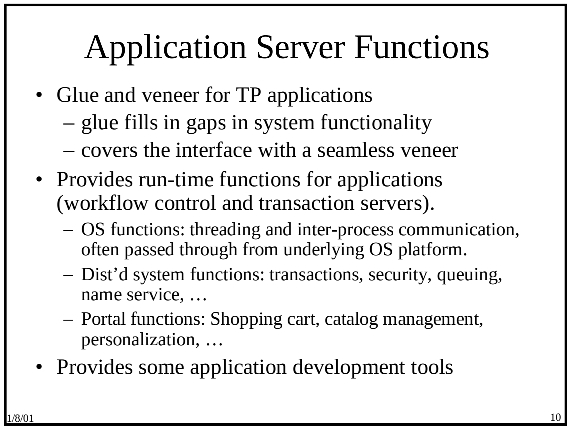
Application Server Architecture (4)

- Some transactions may need to enqueue other requests or send requests to other (internet or intranet) sites.



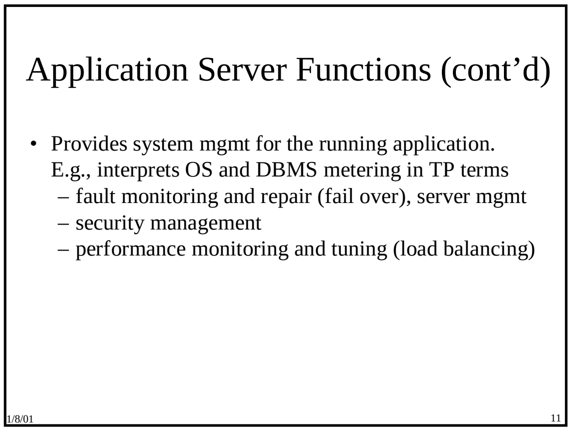
Application Server Architecture (5)

- The complete picture



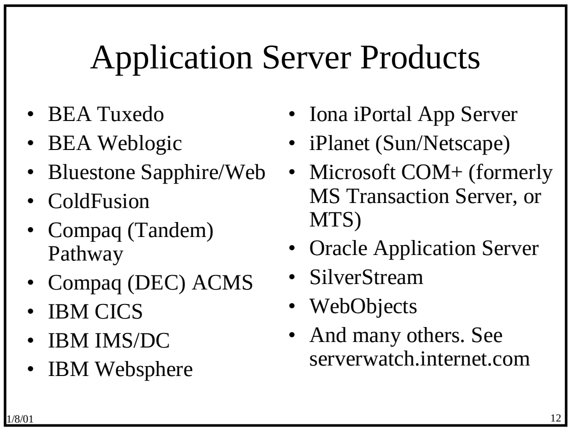
Application Server Functions

- Glue and veneer for TP applications
  - glue fills in gaps in system functionality
  - covers the interface with a seamless veneer
- Provides run-time functions for applications (workflow control and transaction servers).
  - OS functions: threading and inter-process communication, often passed through from underlying OS platform.
  - Dist’d system functions: transactions, security, queuing, name service, …
  - Portal functions: Shopping cart, catalog management, personalization, …
- Provides some application development tools



Application Server Functions (cont’d)

- Provides system mgmt for the running application. E.g., interprets OS and DBMS metering in TP terms
  - fault monitoring and repair (fail over), server mgmt
  - security management
  - performance monitoring and tuning (load balancing)

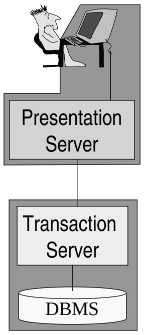


Application Server Products

- BEA Tuxedo
- BEA Weblogic
- Bluestone Sapphire/Web
- ColdFusion
- Compaq (Tandem) Pathway
- Compaq (DEC) ACMS
- IBM CICS
- IBM IMS/DC
- IBM Websphere
- Iona iPortal App Server
- iPlanet (Sun/Netscape)
- Microsoft COM+ (formerly MS Transaction Server, or MTS)
- Oracle Application Server
- SilverStream
- WebObjects
- And many others. See serverwatch.internet.com

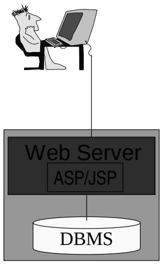
2.2 Two-Tier vs. Three-Tier

- Before the web, most small-to-medium scale apps were implemented in 2 tiers
- 2-tier on a LAN
  - Connect PCs directly to transaction servers
  - Server system includes transaction server app and DBMS
- Presentation server is usually a 4GL on a PC: Visual Basic, PowerBuilder, Delphi, … (RAD = rapid app development)



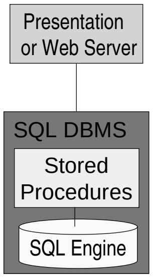
Two-Tier for the Web

- Presentation server ⇒ Web server
  - In essence, the web browser is a device
- Web server invokes a web page that has embedded script (Active Server Page (ASP) / Java Server Page (JSP))
  - Page (file) extension tells the web server to run the ASP interpreter
  - Script can include DBMS calls and can run as a transaction



Two-Tier is Enabled by DBMS Stored Procedures

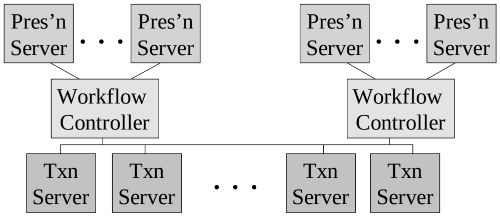
- Stored procedure – An application procedure that runs inside the DBMS
  - Often in a proprietary language, such as PL/SQL (Oracle), T-SQL (MS, Sybase)
  - Moving toward standard languages, such as Java
- Implement transaction server as stored procedures
- Use DBMS client-server protocol
- No application server
  - Just a 4GL plus DBMS
  - Hence, sometimes called "TP lite"



Scalability Problem of Two-Tier

- 2-tier is feasible, but does not
  - match OO application designs, which are inherently 3-tier
  - scale as well as 3-tier due to session management
- Session - shared state between communicating parties
  - Entails a memory cost and a setup (processing) cost
- Sessions reduce amount of per-request context passing (comm addr's, authenticated user/device)
  - Standard DB APIs (ODBC and OLE DB) work this way
  - Hence, in 2-tier, N clients and M servers ⇒ N× M sessions
- Example -10^5 presentation servers and 100 servers
  ⇒ 10^5 presentation sessions per server ⇒ 10^7 sessions overall
- Now guess why http has no sessions.

Use a Middle Tier to Reduce the Number of Sessions



- Partition presentation servers across workflow controllers
  - Each workflow controller still connects to all transaction servers but there are much fewer workflow controllers than presentation servers

Session Example (cont'd)

- Recall 10^5 presentation servers and 100 servers
  ⇒ 10^5 presentation sessions (PS) per server
  ⇒ 10^7 sessions overall
- Now, add 100 workflow controllers (WFC)
  - Partitions the set of presentation devices (10^3 PS's per WFC)
  - So each WFC has 10^3 PS's and 10^2 server sessions
  - 100 WFC × ($10^3 + 10^2$) = 110,000 sessions
- Each transaction server has 100 WFC sessions
  - 100 TS × 100 WFC-sessions/TS = 10,000 sessions
    ⇒ 120,000 sessions overall (= .012 × 10^7)

Two-Tier vs. Three Tier Other Issues

- In early 90’s people argued whether 2-Tier was enough
  - Scalability was the decisive factor, but there were other issues
- Database Servers
  - Nonstandard stored procedure language, usually less expressive with weaker development tools and it’s another language to learn
  - Limited interoperability of cross-server calls
  - Limited interoperability of distributed transactions
- TP monitors
  - more system complexity

How the Web Changed Things

- Presentation server ⇒ Web server
- All requests have to pass through a Web server
  - Each Web server needs sessions to all DB servers
  - At least one DB session per active Web server
  - So session reduction by workflow control is still useful
- Workflow control layer is still useful for other request mgmt functions …
  - Calling Start, Commit, and Abort
  - Encapsulating business rules that transform each request into calls on basic objects

2.3 Web Servers

- Presentation independence - application is independent of the display device used
  - Today, this is via http and html
  - In the past, it was via a display controller or middle-tier minicomputer whose presentation functions insulated the rest of the back-end system from different device types
- Web server performs presentation functions:
  - Gathering input
  - Validating input
  - DB caching
  - Authentication
- They also do some basic request routing
  - Constructing requests
  - Invoking applications
- Examples - IIS (MS), Apache, Netscape Server

Gathering Input

- Gathering input - Select transaction type (menu item, etc.), and fill in a form (request’s parameters)
- 30 year evolution of presentation devices
  - Teletype, character-at-a-time terminal (async), block-mode terminal (IBM 3270), PC, web browser
  - Specialized devices - ATMs, bar code readers, gas pumps, robots, credit card authorization, cash registers, ticket printers, etc.
- Presentation tool to design and render screens
  - Forms manager - WYSIWYG form editor, compile form, execute it (with record defn binding to programming language)
  - RAD tool - ActiveX controls accessed from Visual Basic (VB), PowerBuilder, Delphi, etc.
  - Now HTML forms, and XML with XSLT

Caching

- Every process-to-process call has a cost
  - Adds to response time and consumes resources
- Use a DB cache to avoid calling workflow controller or DB system
  - Some dynamically generated pages need not be refreshed frequently
  - E.g., popular catalog items, sale items, cover page at an auction site, recent news, etc.
  - Also, data required for input validation info

Input Validation

- Validate input against <u>locally</u> <u>cached</u> tables
  - E.g., product types, department numbers
- Avoids wasting communications and server resources for obvious input errors
  - Fewer round-trips to the DBMS
  - And faster feedback to the end user
- “Cache” is part of the web page
  - List boxes, script
  - Cache size is a factor (it affects page access time)

Constructing Requests

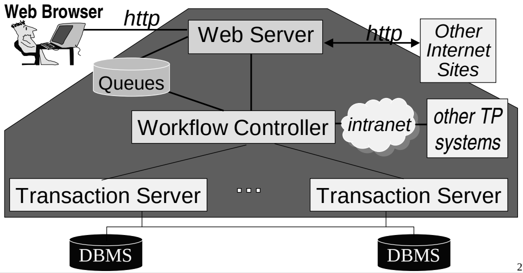
- A request includes
  - User id – for authorization and personalization
  - Device id – where to send a reply
  - Device type - what message types can it understand?
  - ObjectID – in a OO setting
  - Request type – name of transaction type requested
  - Request-specific parameters
- In http, can be a combination of http header elements and method parameters.
- It’s helpful if each request includes a request id
  - to ask later about status,
  - to cancel a request, or
  - to allow an asynchronous reply

Authentication

- Authentication - determining the identity of a user and/or display device
  - Client system (e.g., PC) may do authentication, but the server usually does it too (doesn’t trust clients)
  - Encrypt the wire to avoid wiretapping and spoofing (on the Web, use https = http over secure socket layer)
- Geographical entitlement - check that a particular *device* is allowed access (e.g., security trading room)
- Need system mgmt functions to create accounts, initialize passwords, bracket hours of access (simplify it using a role abstraction … more later)
- Major activity in TP application development

Application Invocation

- Request arrives as an http message.
- Needs to call a program, to perform the request



How to Call a Program

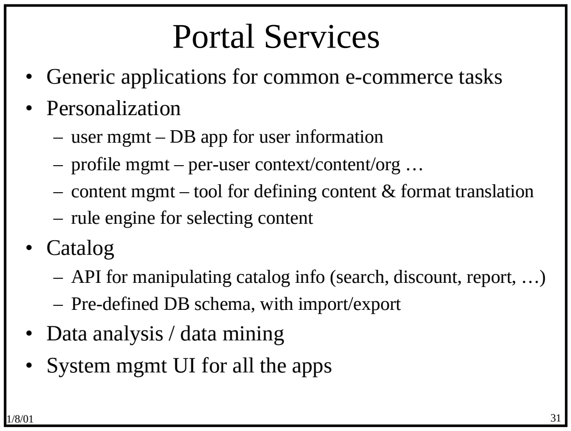
- Common Gateway Interface
  - Write a script, store it as a file in cgi-bin
  - Web server creates a process to execute the request S..L..O..W
- ISAPI (Microsoft) and NSAPI (Netscape)
  - Web server calls an in-proc .dll instead of creating a process
  - More complex programming model, but much faster
  - Microsoft’s web server (IIS) caches the .dll
- Active Server Pages (and Java Server Pages)
  - Offers the performance of ISAPI with programmability of CGI

Load Balancing

- Enable scale out at all levels of the system, so you can just add more server boxes to handle more load.
- There are two related issues
  - Spreading the load evenly
  - Routing the work to the correct server
- To simplify this problem
  - Ensure all web servers are identical (no server-specific state) ⇒ don’t retain client state on web servers (hard to avoid …)
  - Randomly assign requests to servers (e.g., use an IP sprayer)
  - Avoid sending requests to a failed server
- We’ll deal with more complex scenarios later

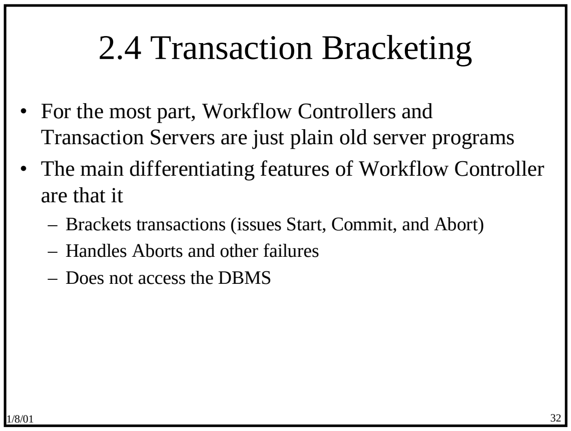
Other Presentation Functions

- Logging
  - Record all messages sent and received by a web server
  - Useful for auditing and error analysis
- System management
  - Expose presentation and web components as meaningful concepts (e.g., named devices instead of IP addresses)



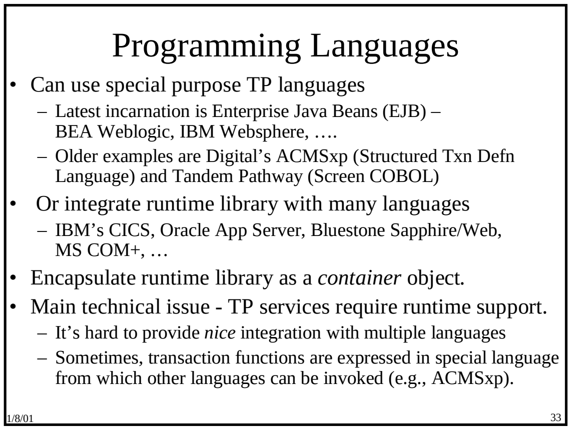
Portal Services

- Generic applications for common e-commerce tasks
- Personalization
  - user mgmt – DB app for user information
  - profile mgmt – per-user context/content/org …
  - content mgmt – tool for defining content & format translation
  - rule engine for selecting content
- Catalog
  - API for manipulating catalog info (search, discount, report, …)
  - Pre-defined DB schema, with import/export
- Data analysis / data mining
- System mgmt UI for all the apps



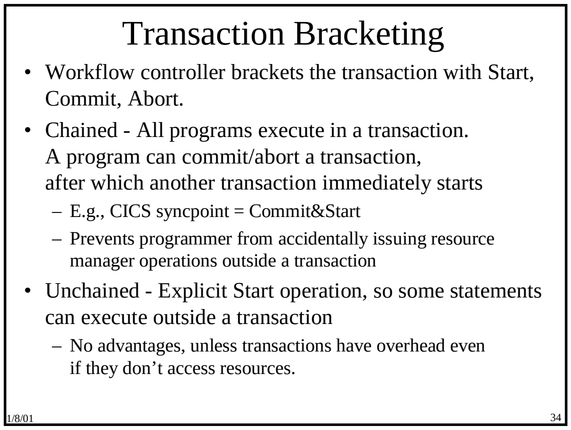
2.4 Transaction Bracketing

- For the most part, Workflow Controllers and Transaction Servers are just plain old server programs
- The main differentiating features of Workflow Controller are that it
  - Brackets transactions (issues Start, Commit, and Abort)
  - Handles Aborts and other failures
  - Does not access the DBMS



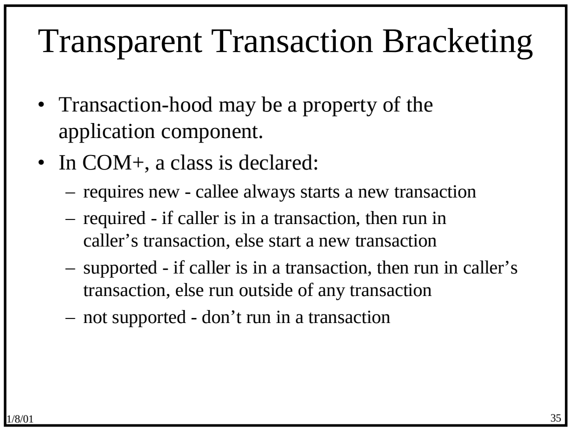
Programming Languages

- Can use special purpose TP languages
  - Latest incarnation is Enterprise Java Beans (EJB) – BEA Weblogic, IBM Websphere, ….
  - Older examples are Digital’s ACMSxp (Structured Txn Defn Language) and Tandem Pathway (Screen COBOL)
- Or integrate runtime library with many languages
  - IBM’s CICS, Oracle App Server, Bluestone Sapphire/Web, MS COM+, …
- Encapsulate runtime library as a *container* object.
- Main technical issue - TP services require runtime support.
  - It’s hard to provide *nice* integration with multiple languages
  - Sometimes, transaction functions are expressed in special language from which other languages can be invoked (e.g., ACMSxp).



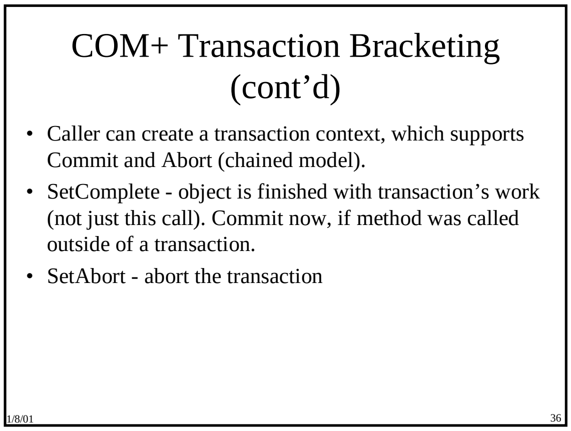
Transaction Bracketing

- Workflow controller brackets the transaction with Start, Commit, Abort.
- Chained - All programs execute in a transaction.
  A program can commit/abort a transaction,
  after which another transaction immediately starts
  - E.g., CICS syncpoint = Commit&Start
  - Prevents programmer from accidentally issuing resource manager operations outside a transaction
- Unchained - Explicit Start operation, so some statements can execute outside a transaction
  - No advantages, unless transactions have overhead even if they don’t access resources.



Transparent Transaction Bracketing

- Transaction-hood may be a property of the application component.
- In COM+, a class is declared:
  - requires new - callee always starts a new transaction
  - required - if caller is in a transaction, then run in caller’s transaction, else start a new transaction
  - supported - if caller is in a transaction, then run in caller’s transaction, else run outside of any transaction
  - not supported - don’t run in a transaction



COM+ Transaction Bracketing (cont’d)

- Caller can create a transaction context, which supports Commit and Abort (chained model).
- SetComplete - object is finished with transaction’s work (not just this call). Commit now, if method was called outside of a transaction.
- SetAbort - abort the transaction

Enterprise Java Beans

- A Java API for Application Services
- For the most part, implements COM+ technology in Java. Came later, so there are some additions.
- EJB Transaction functions taken from COM+
  - RequiresNew, Required, NotSupported, Supports
- EJB adds
  - Mandatory – If caller is in a transaction, then run the callee in that transaction, else raise an exception
  - Never – If caller is in a transaction, then raise an exception
- Some other EJB features at the end of this chapter.

Nested Transaction Calls

- What does Start do, when executed within a txn?
  1. it starts an independent transaction, or
  2. it does nothing, or
  3. it increments a nested transaction count (which is decremented by each commit and abort), or
  4. it starts a sub-transaction
- If (1), then be careful not to start a transaction from within a transaction
  - E.g., only start transaction in workflow control, not in a transaction server
  - (3) avoids this problem

Exception Handling

- Workflow control brackets the transaction, so it must say what to do if the transaction aborts
- An exception handler must know what state information is available
  - cause of the abort, e.g., a status variable
  - possibly program exception separate from abort reason
  - for system failures, application must save state in stable storage; note that none of the aborted txn's state will be available
- Chained model - exception handler starts a new txn
- COM+ - component returns a failure hresult

Integrity of Request after Abort

- To permit request retries, it's useful if **`get-request`** runs inside the request's transaction:

```
Start;
  get-request;
     . . .
Commit;
```

- If the transaction aborts, then **`get-request`** is undone, so the request becomes available for the next **`get-request`**.
- In the RPC or "push model," make the "catch-the-call" operation explicit, so it can be undone. Possibly hidden in the dispatch mechanism. Often requires a queue manager.

Savepoints

- Savepoint - a point in a program where an application saves all its recoverable state
- Can restore a savepoint within the transaction that issued the savepoint. (It's a partial rollback.)
- Usually supported by SQL DBMSs, since it helps them support atomic SQL statements.

```
Start;
get-request;
Savepoint("B"); . . .;
if (error) {Restore("B"); …; Commit;}
. . .;
Commit;
```

Savepoints (cont'd)

- Savepoints are not recoverable. If the system fails or the transaction aborts, the txn is completely undone.
- Persistent savepoints have appeared in the research literature, but aren't supported commercially. There are formidable technical difficulties.

2.5 Processes and Threads

- Application Server architecture is greatly affected by
  - which components share an address space
  - how many control threads per address space
- TP grew up in the days of batch processing, and reached maturity in the days of timesharing.
- TP users learned early that a process-per-user fails:
  - Too much context switching
  - Too much fixed memory overhead per process
  - Process per user per machine, when distributed
  - Some OS functions scan the list of processes
  - Load control is hard

Multithreading

- Have multiple threads of control in an address space
- Often, the Application Server implements multithreading
  - Application Server switches between threads when app calls a Application Server function that blocks
  - So the OS thinks there's just one thread
  - All app calls that can block <u>must</u> go to the Application Server, or the whole process will block
  - Possible conflict between Application Server and OS scheduling
  - Simplify the implementation by using an interpretive language (e.g. ACMSxp STDL, Tandem SCOBOL)

Multithreading (cont'd)

- Or use OS multithreading
  - No problem with blocking operations
  - Can run a process's threads on different processors (SMP)
  - Possibly more expensive to switch threads (system calls)
- Whether at the user or OS level, multithreading has
  - fewer processes
  - reduced context switching
- Disadvantages
  - Little protection between threads
  - Server failure affects many transactions

Server Pools

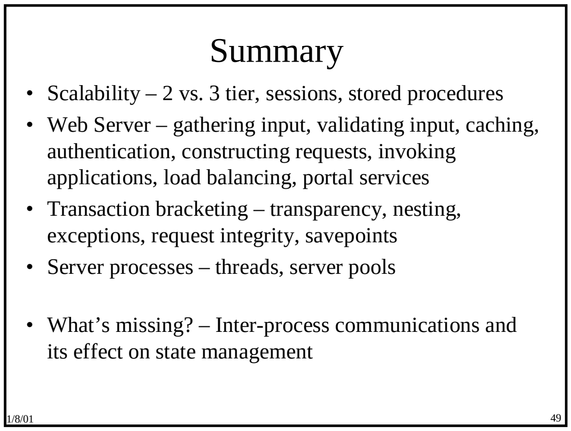
- Use a set of processes (<u>server pool</u> or <u>server class</u>) to emulate multithreading
  - Better protection and fault isolation than multithreading
  - Avoids problems of user-level multithreading - blocking operations and conflicts between scheduling levels
- How to dispatch calls?
  - Randomly select a server
  - Server class shares a dispatch queue.
    Clients enqueue, servers dequeue.
  - Use a dispatch process (adds a context switch per call)
- Number of servers is proportional to number of active transactions, so not too many processes

Mapping Servers to Processes

- Presentation/Web servers - separate processes
- Workflow controllers
  - Usually multithreaded, serving many presentation servers
  - If single-threaded, then 1 per presentation server (2-tier)
- Transaction servers
  - Multithreaded servers, or
  - Server pools
- What does all this cost?
  - 1500 - 25,000 instructions per process call, vs.
    50 instructions per local procedure call …
  - but it scales, with flexible configuration and control

OO System Abstractions

- An application executing in a thread is abstracted as an object (e.g., COM+ object, EJB Session Bean)
- Typically, lots of active objects (threads) per class
- Such objects may have volatile state
  - Global state (e.g., a catalog) ⇒ each user's request can be processed by any object
  - Per-user state (e.g., a shopping cart) ⇒ a user's calls must all go to the same object (cf. TP Communications chapter)
- EJB also offers an Entity Bean abstraction, which represents a persistent object.
  - Persistence can be managed by the class (by implementing EJB-defined functions) or its container (which maps persistent data fields to the DBMS).



Summary

- Scalability – 2 vs. 3 tier, sessions, stored procedures
- Web Server – gathering input, validating input, caching, authentication, constructing requests, invoking applications, load balancing, portal services
- Transaction bracketing – transparency, nesting, exceptions, request integrity, savepoints
- Server processes – threads, server pools

- What’s missing? – Inter-process communications and its effect on state management