Tutorial at VLDB 2001
(Rome, Italy, September 11-14, 2001)

Managing Business Processes Via Workflow Technology

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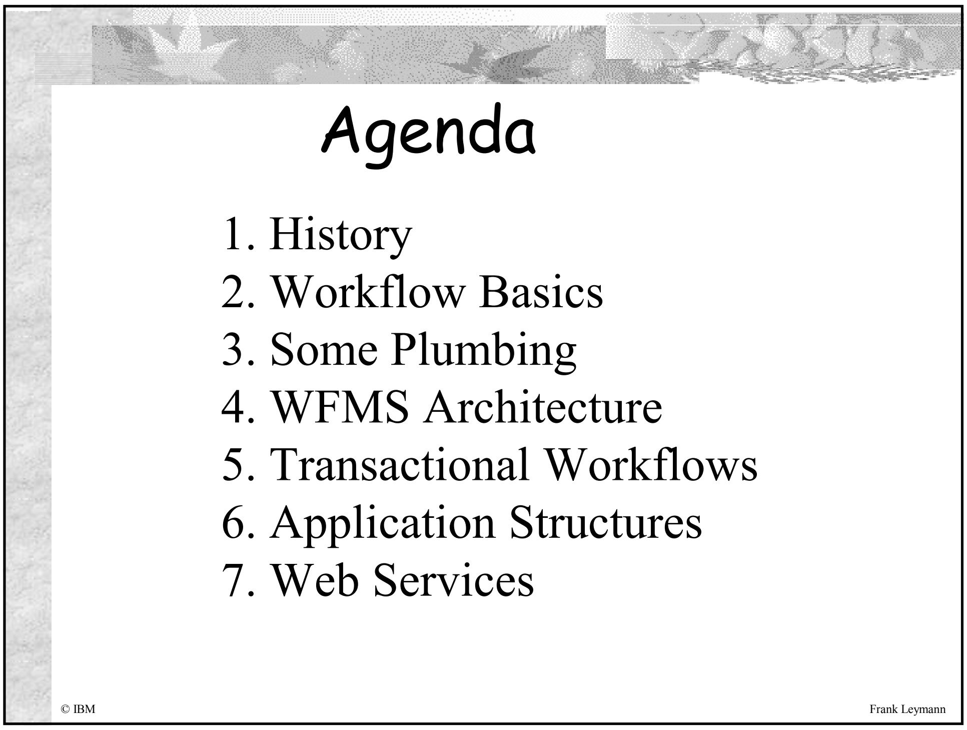

Agenda

1. History
2. Workflow Basics
3. Some Plumbing
4. WFMS Architecture
5. Transactional Workflows
6. Application Structures
7. Web Services

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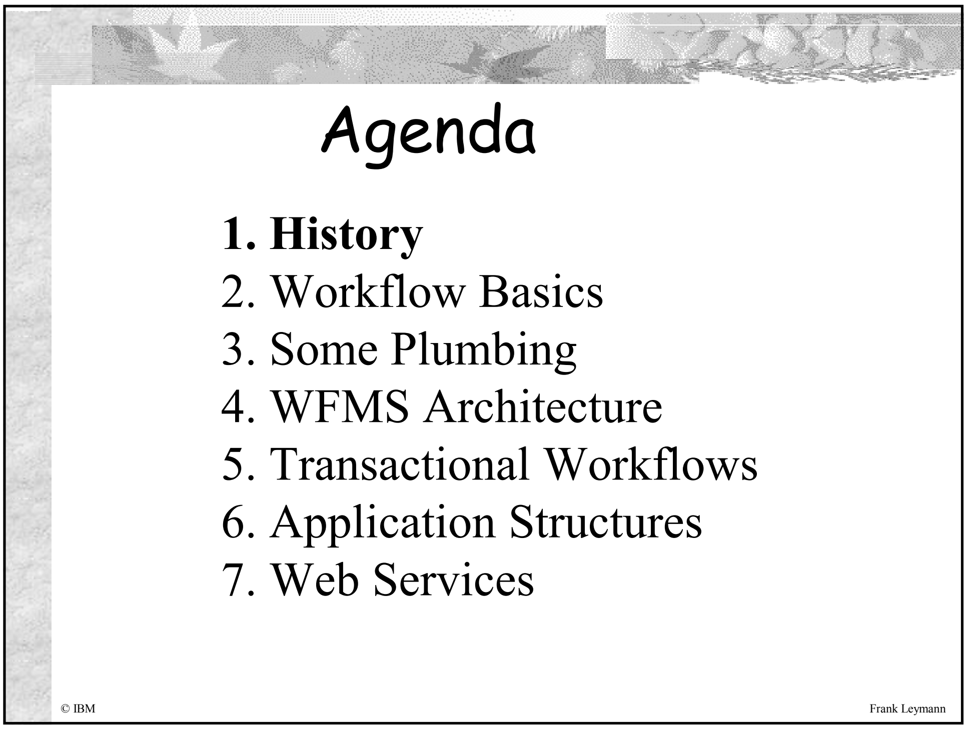

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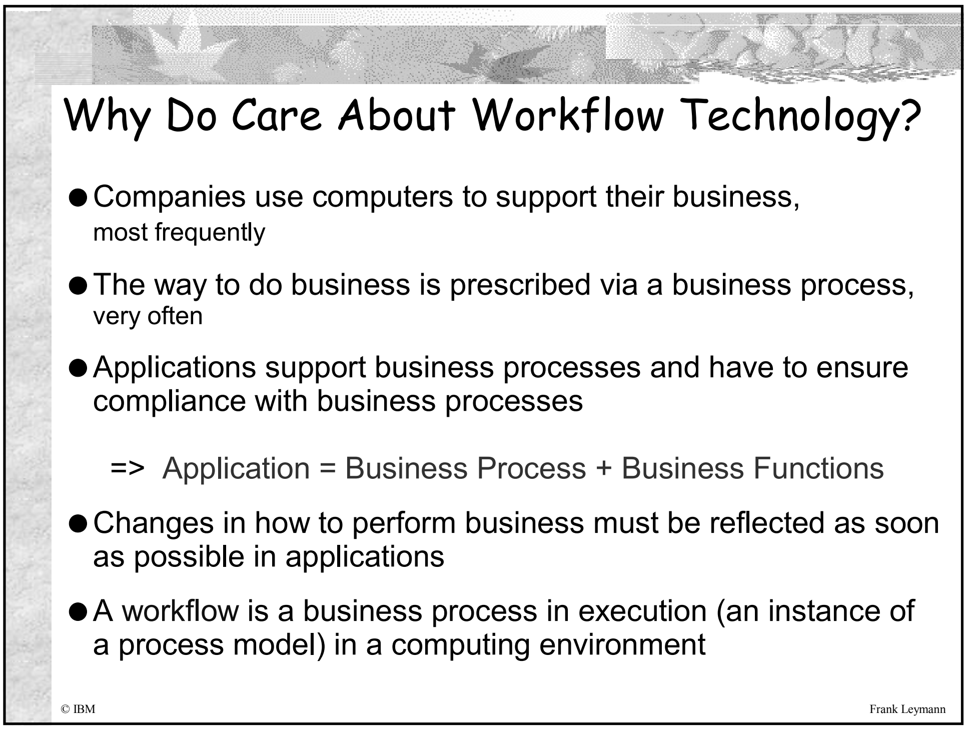

Why Do Care About Workflow Technology?

- Companies use computers to support their business, most frequently
- The way to do business is prescribed via a business process, very often
- Applications support business processes and have to ensure compliance with business processes

  => Application = Business Process + Business Functions

- Changes in how to perform business must be reflected as soon as possible in applications
- A workflow is a business process in execution (an instance of a process model) in a computing environment

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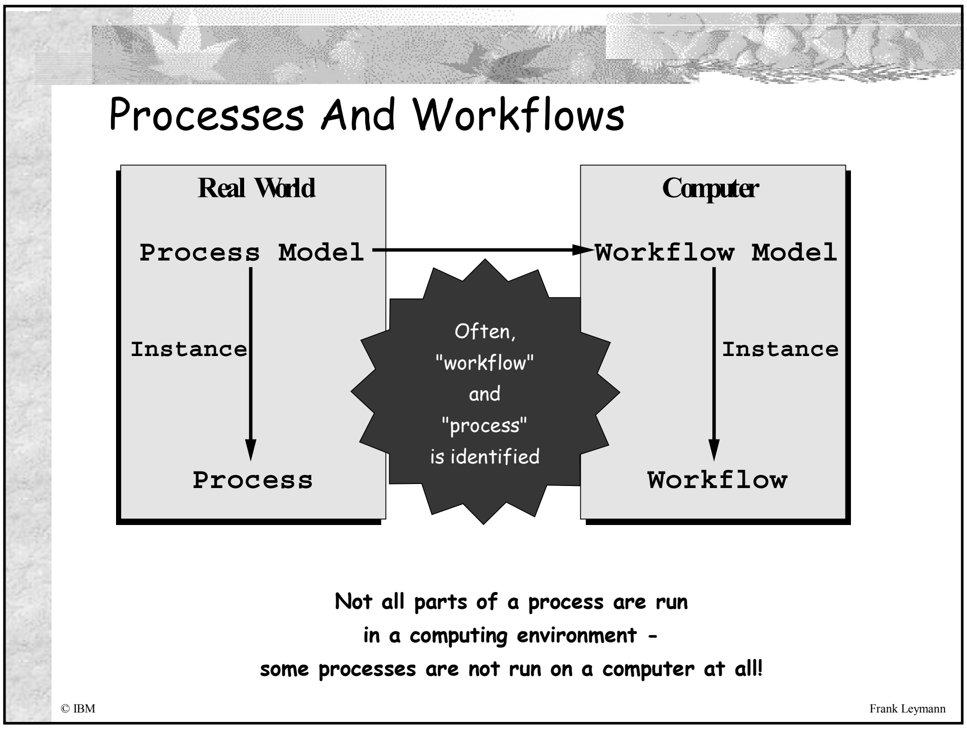

Processes And Workflows

Real World

Process Model

Instance

Process

Computer

Workflow Model

Instance

Workflow

Often, "workflow" and "process" is identified

Not all parts of a process are run in a computing environment - some processes are not run on a computer at all!

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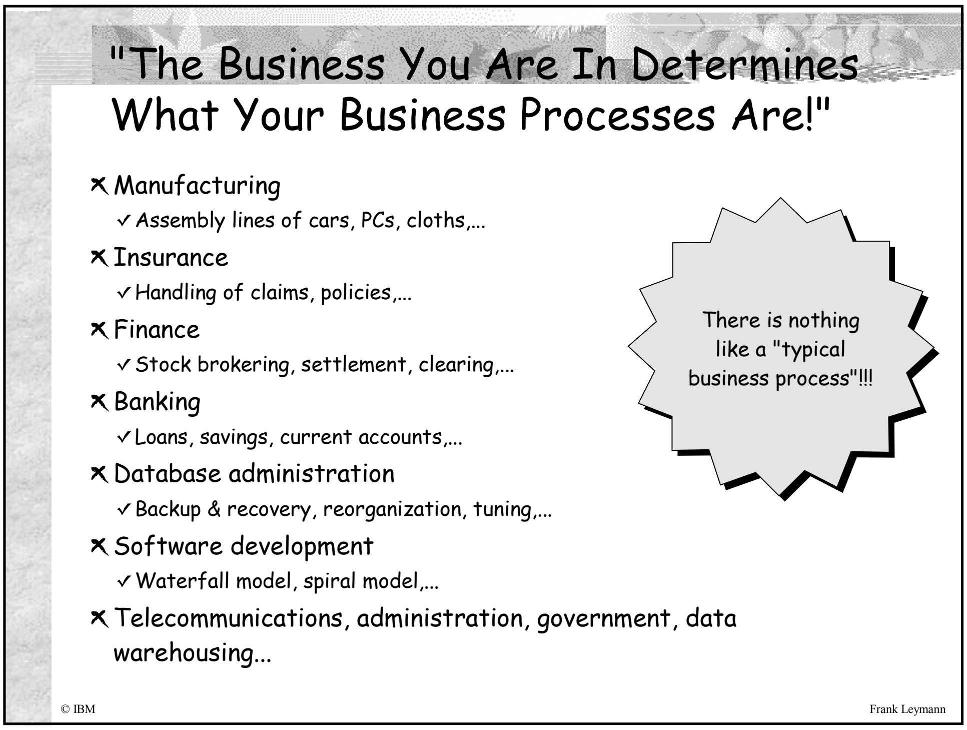

"The Business You Are In Determines What Your Business Processes Are!"

- Manufacturing
  - ✓ Assembly lines of cars, PCs, cloths,...
- Insurance
  - ✓ Handling of claims, policies,...
- Finance
  - ✓ Stock brokering, settlement, clearing,...
- Banking
  - ✓ Loans, savings, current accounts,...
- Database administration
  - ✓ Backup & recovery, reorganization, tuning,...
- Software development
  - ✓ Waterfall model, spiral model,...
- Telecommunications, administration, government, data warehousing...

There is nothing like a "typical business process"!!!

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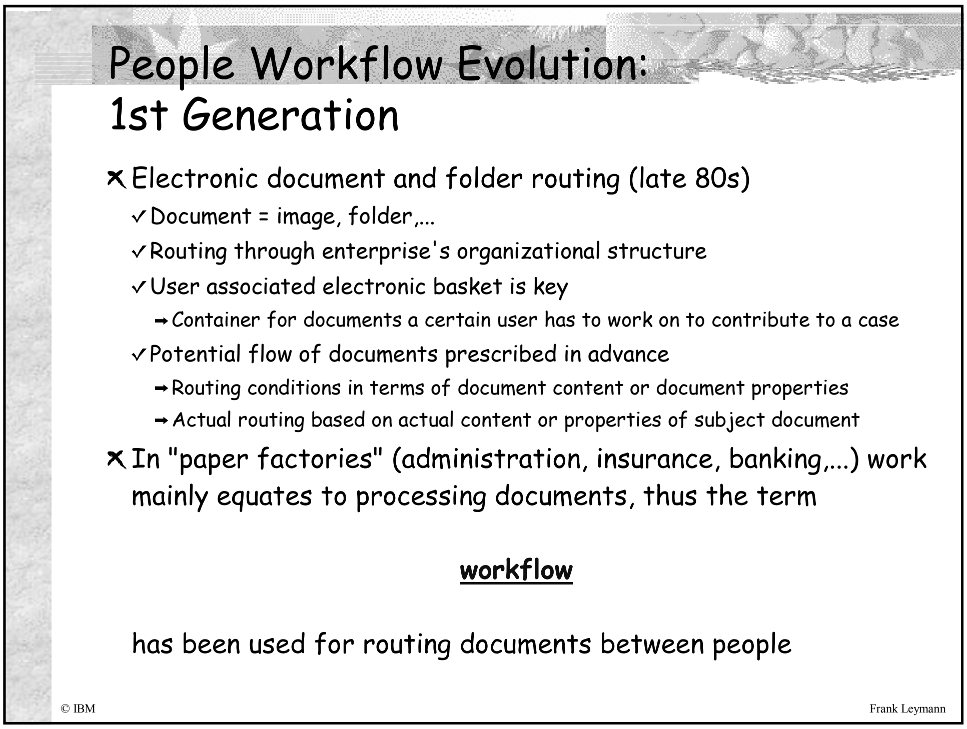

People Workflow Evolution: 1st Generation

- Electronic document and folder routing (late 80s)
  - ✓ Document = image, folder,...
  - ✓ Routing through enterprise's organizational structure
  - ✓ User associated electronic basket is key
    - → Container for documents a certain user has to work on to contribute to a case
  - ✓ Potential flow of documents prescribed in advance
    - → Routing conditions in terms of document content or document properties
    - → Actual routing based on actual content or properties of subject document
- In "paper factories" (administration, insurance, banking,...) work mainly equates to processing documents, thus the term

workflow

has been used for routing documents between people

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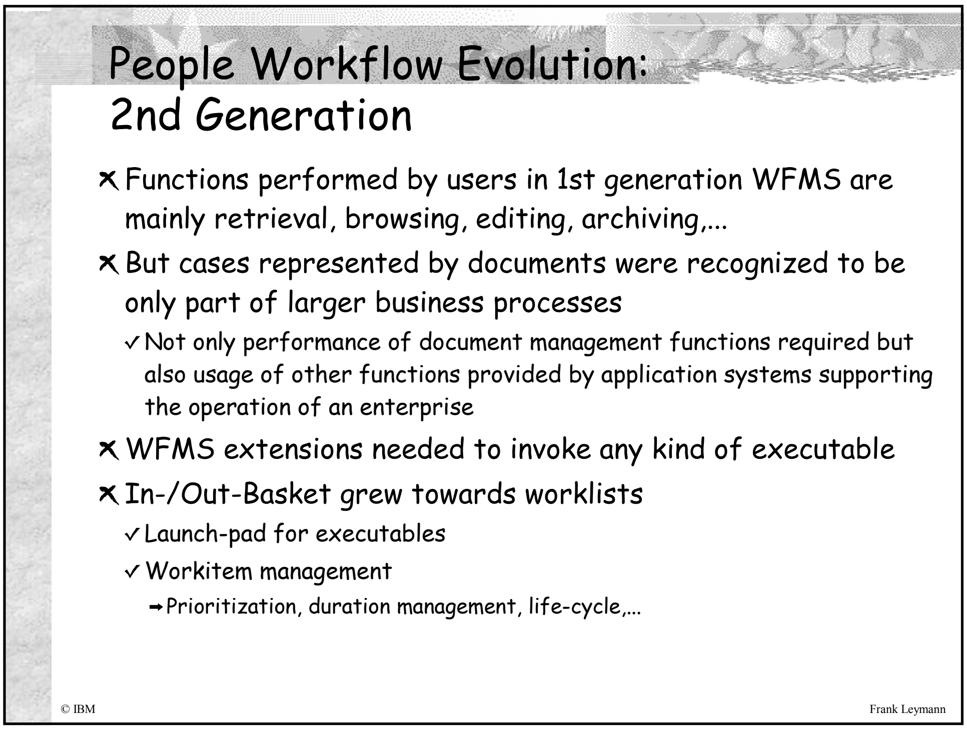

People Workflow Evolution: 2nd Generation

- Functions performed by users in 1st generation WFMS are mainly retrieval, browsing, editing, archiving,...
- But cases represented by documents were recognized to be only part of larger business processes
  - Not only performance of document management functions required but also usage of other functions provided by application systems supporting the operation of an enterprise
- WFMS extensions needed to invoke any kind of executable
- In-/Out-Basket grew towards worklists
  - Launch-pad for executables
  - Workitem management
    - Prioritization, duration management, life-cycle,...

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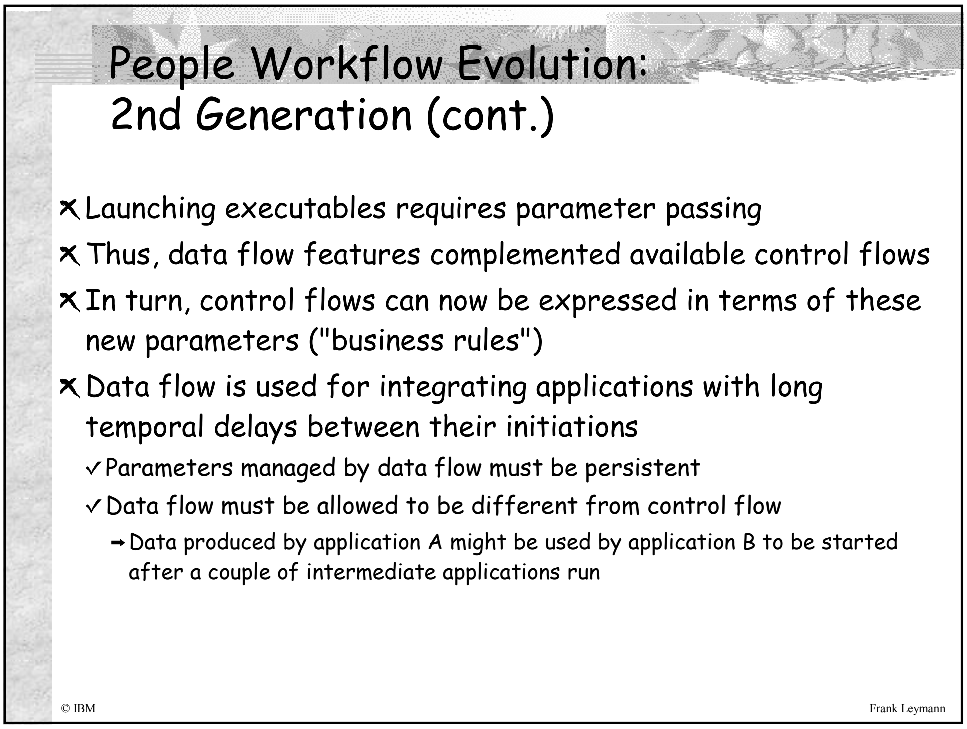

People Workflow Evolution: 2nd Generation (cont.)

- Launching executables requires parameter passing
- Thus, data flow features complemented available control flows
- In turn, control flows can now be expressed in terms of these new parameters ("business rules")
- Data flow is used for integrating applications with long temporal delays between their initiations
  - Parameters managed by data flow must be persistent
  - Data flow must be allowed to be different from control flow
    - Data produced by application A might be used by application B to be started after a couple of intermediate applications run

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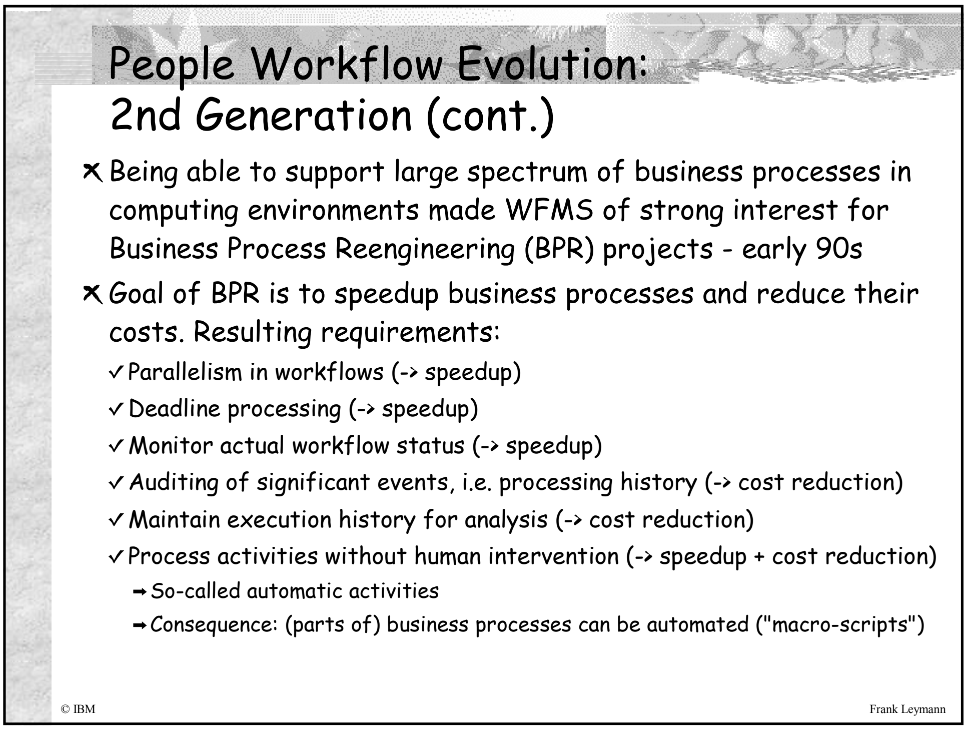

People Workflow Evolution: 2nd Generation (cont.)

- Being able to support large spectrum of business processes in computing environments made WFMS of strong interest for Business Process Reengineering (BPR) projects - early 90s
- Goal of BPR is to speedup business processes and reduce their costs. Resulting requirements:
  - Parallelism in workflows (-> speedup)
  - Deadline processing (-> speedup)
  - Monitor actual workflow status (-> speedup)
  - Auditing of significant events, i.e. processing history (-> cost reduction)
  - Maintain execution history for analysis (-> cost reduction)
  - Process activities without human intervention (-> speedup + cost reduction)
    - So-called automatic activities
    - Consequence: (parts of) business processes can be automated ("macro-scripts")

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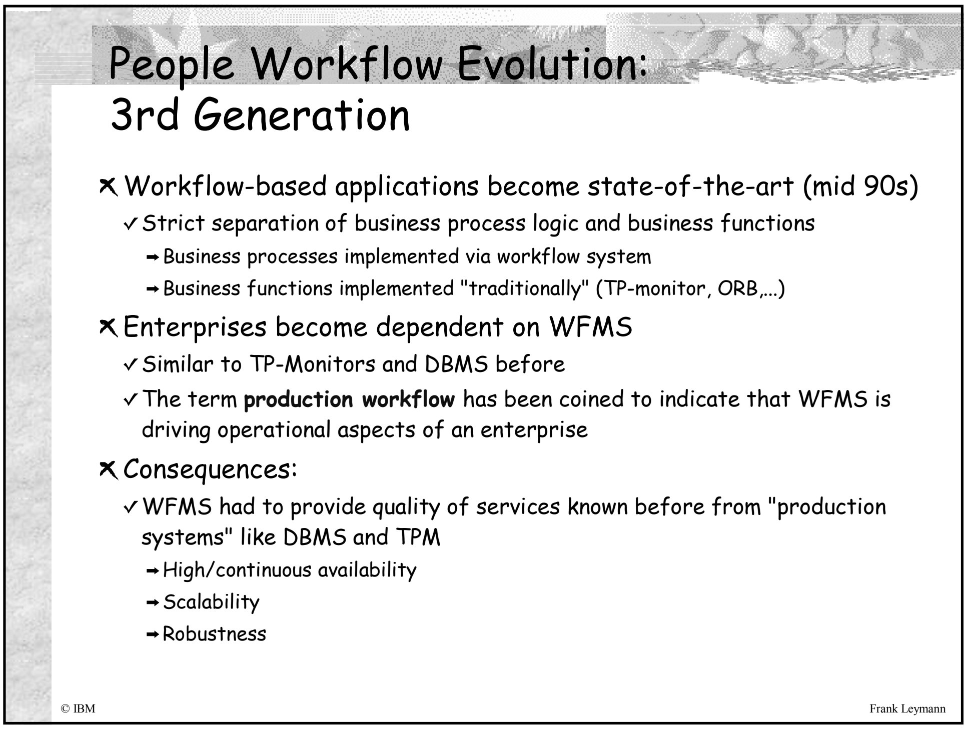

People Workflow Evolution: 3rd Generation

- Workflow-based applications become state-of-the-art (mid 90s)
  - Strict separation of business process logic and business functions
    - Business processes implemented via workflow system
    - Business functions implemented "traditionally" (TP-monitor, ORB,...)
- Enterprises become dependent on WFMS
  - Similar to TP-Monitors and DBMS before
  - The term **production workflow** has been coined to indicate that WFMS is driving operational aspects of an enterprise
- Consequences:
  - WFMS had to provide quality of services known before from "production systems" like DBMS and TPM
    - High/continuous availability
    - Scalability
    - Robustness

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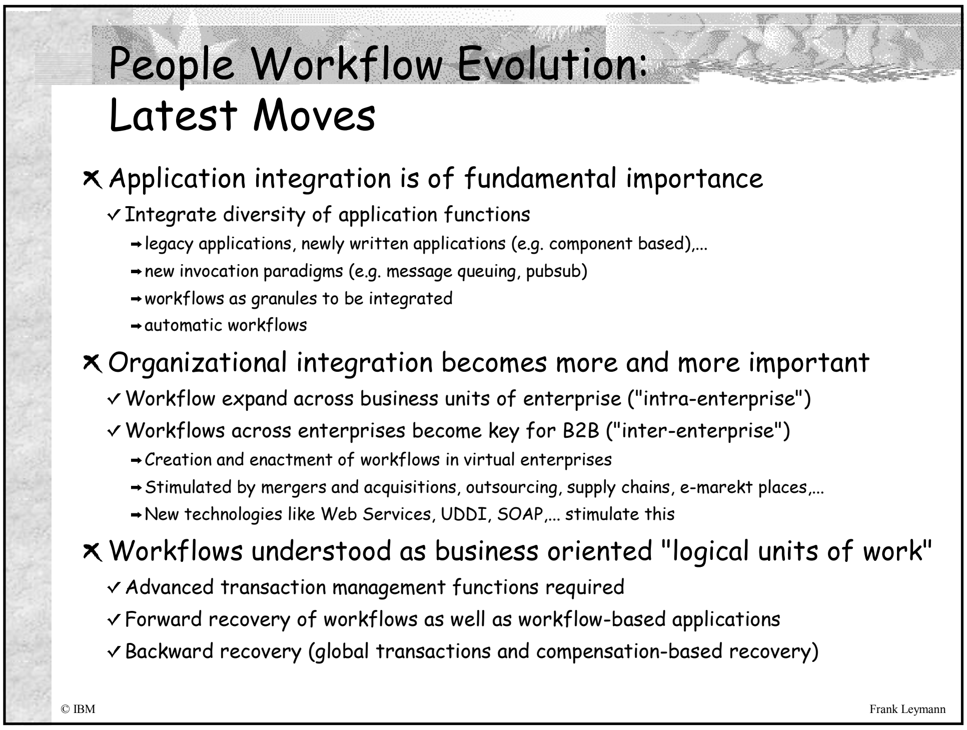

People Workflow Evolution: Latest Moves

- Application integration is of fundamental importance
  - Integrate diversity of application functions
    - legacy applications, newly written applications (e.g. component based),...
    - new invocation paradigms (e.g. message queuing, pubsub)
    - workflows as granules to be integrated
    - automatic workflows
- Organizational integration becomes more and more important
  - Workflow expand across business units of enterprise ("intra-enterprise")
  - Workflows across enterprises become key for B2B ("inter-enterprise")
    - Creation and enactment of workflows in virtual enterprises
    - Stimulated by mergers and acquisitions, outsourcing, supply chains, e-marekt places,...
    - New technologies like Web Services, UDDI, SOAP,... stimulate this
- Workflows understood as business oriented "logical units of work"
  - Advanced transaction management functions required
  - Forward recovery of workflows as well as workflow-based applications
  - Backward recovery (global transactions and compensation-based recovery)

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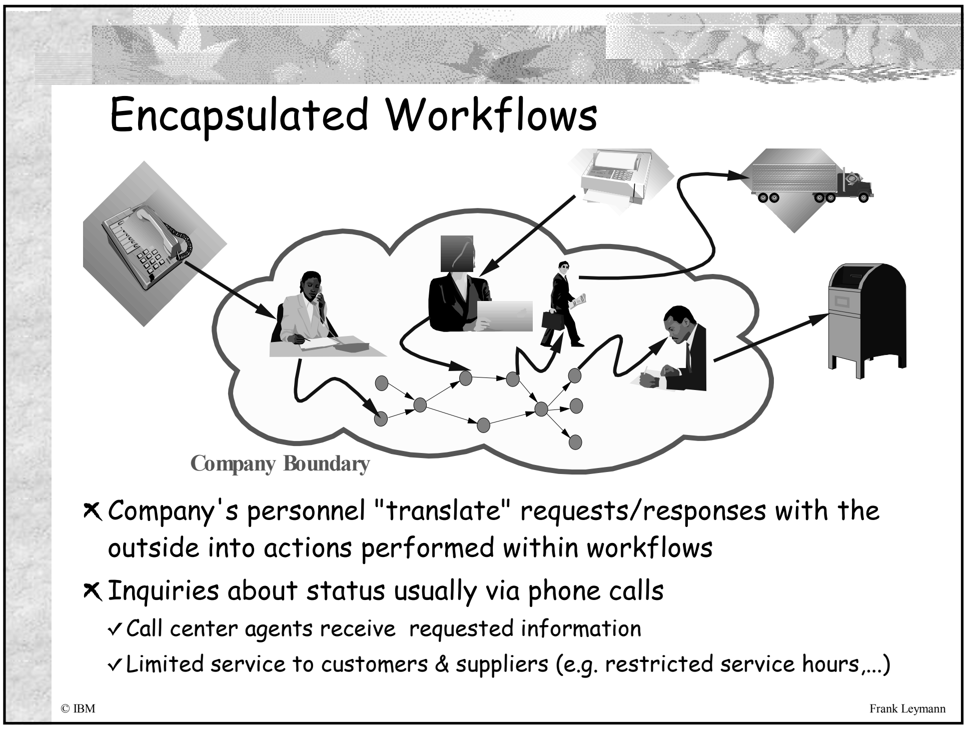

Encapsulated Workflows

- Company's personnel "translate" requests/responses with the outside into actions performed within workflows
- Inquiries about status usually via phone calls
  - Call center agents receive requested information
  - Limited service to customers & suppliers (e.g. restricted service hours,...)

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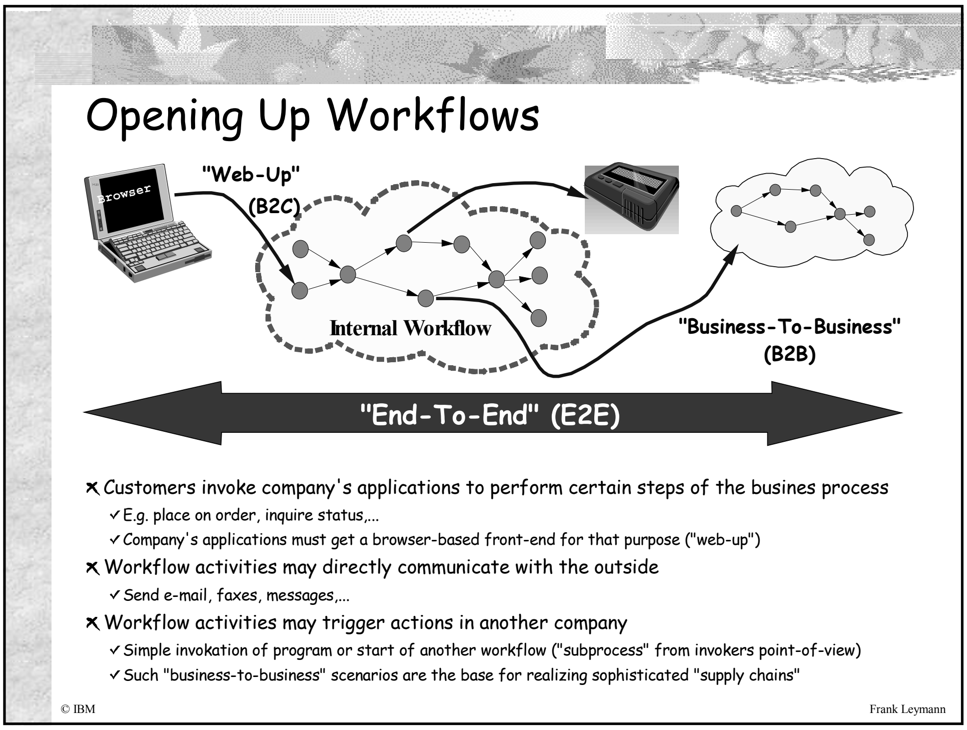

Opening Up Workflows

- Customers invoke company's applications to perform certain steps of the busines process
  - ✓ E.g. place on order, inquire status,...
  - ✓ Company's applications must get a browser-based front-end for that purpose ("web-up")
- Workflow activities may directly communicate with the outside
  - ✓ Send e-mail, faxes, messages,...
- Workflow activities may trigger actions in another company
  - ✓ Simple invokation of program or start of another workflow ("subprocess" from invokers point-of-view)
  - ✓ Such "business-to-business" scenarios are the base for realizing sophisticated "supply chains"

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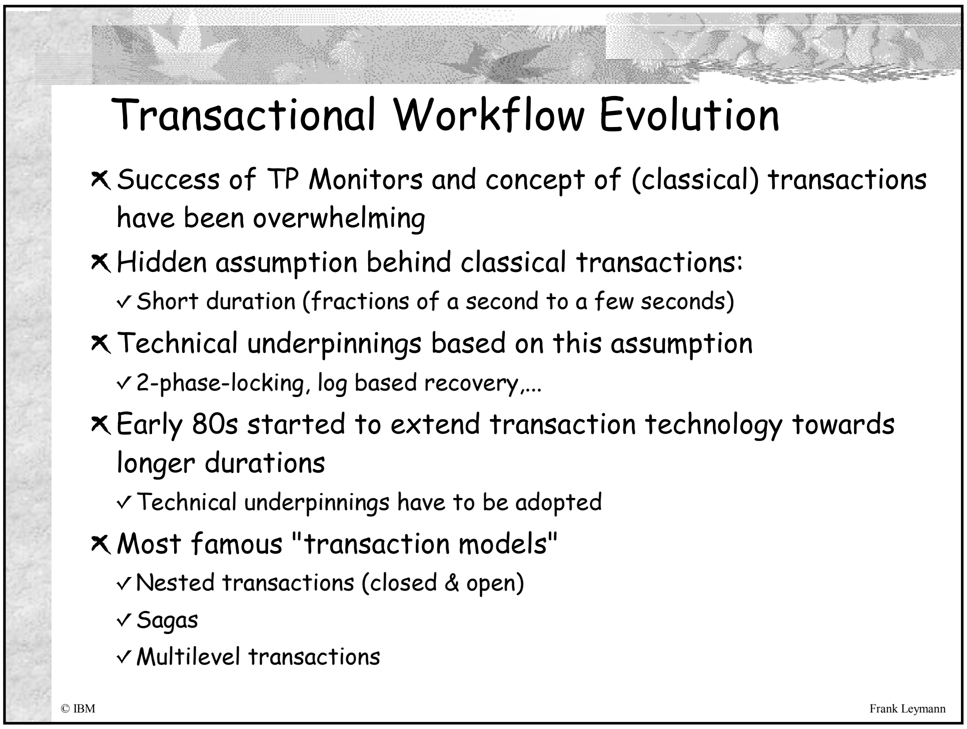

Transactional Workflow Evolution

- Success of TP Monitors and concept of (classical) transactions have been overwhelming
- Hidden assumption behind classical transactions:
  - ✓ Short duration (fractions of a second to a few seconds)
- Technical underpinnings based on this assumption
  - ✓ 2-phase-locking, log based recovery,...
- Early 80s started to extend transaction technology towards longer durations
  - ✓ Technical underpinnings have to be adopted
- Most famous "transaction models"
  - ✓ Nested transactions (closed & open)
  - ✓ Sagas
  - ✓ Multilevel transactions

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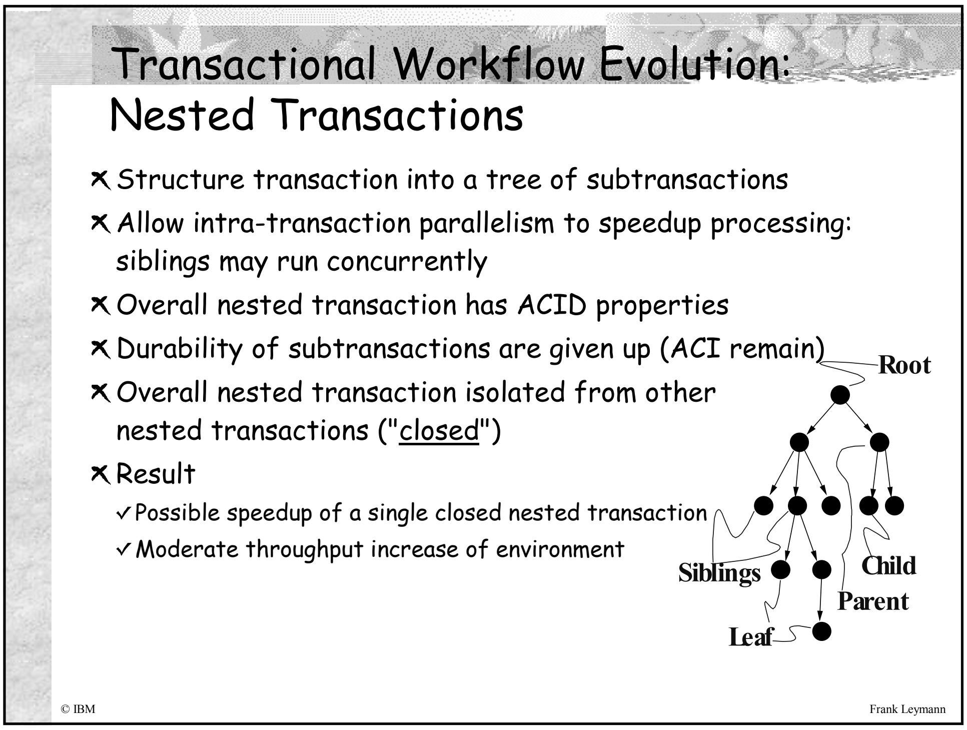

Transactional Workflow Evolution: Nested Transactions

- Structure transaction into a tree of subtransactions
- Allow intra-transaction parallelism to speedup processing: siblings may run concurrently
- Overall nested transaction has ACID properties
- Durability of subtransactions are given up (ACI remain)
- Overall nested transaction isolated from other nested transactions ("<u>closed</u>")
- Result
  - ✓ Possible speedup of a single closed nested transaction
  - ✓ Moderate throughput increase of environment

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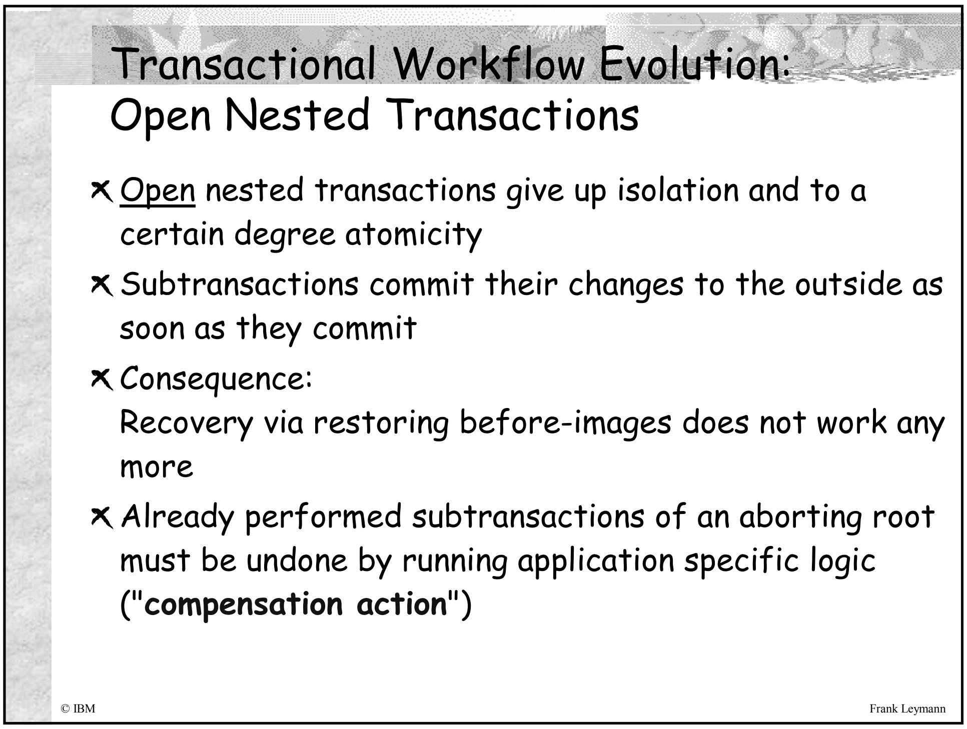

Transactional Workflow Evolution: Open Nested Transactions

- <u>Open</u> nested transactions give up isolation and to a certain degree atomicity
- Subtransactions commit their changes to the outside as soon as they commit
- Consequence:
  Recovery via restoring before-images does not work any more
- Already performed subtransactions of an aborting root must be undone by running application specific logic ("**compensation action**")

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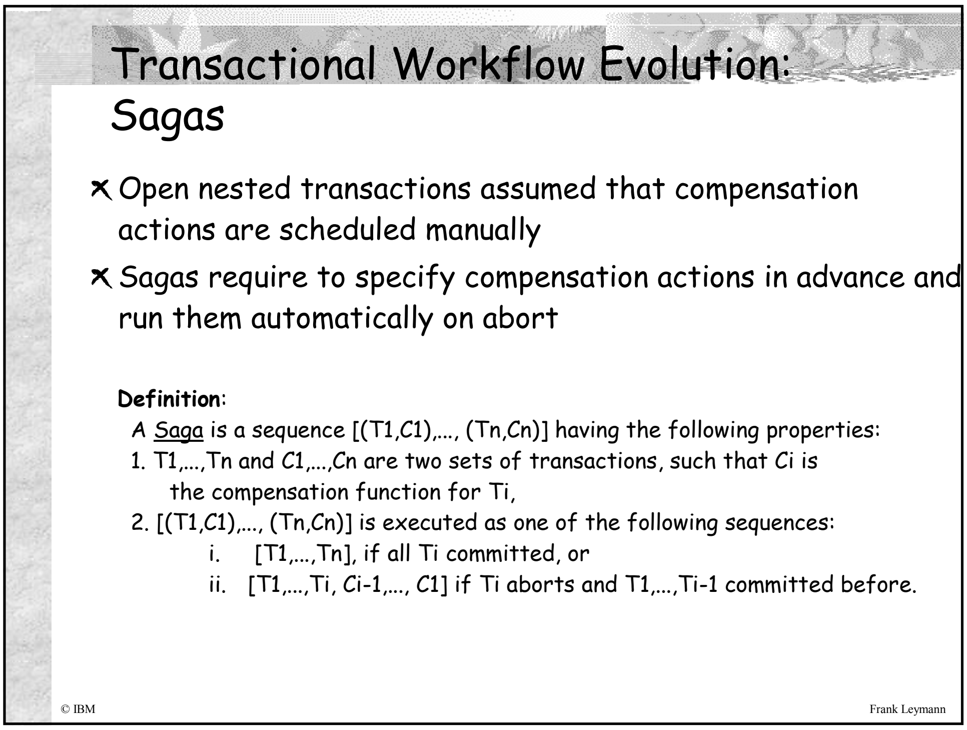

Transactional Workflow Evolution: Sagas

- Open nested transactions assumed that compensation actions are scheduled manually
- Sagas require to specify compensation actions in advance and run them automatically on abort

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.

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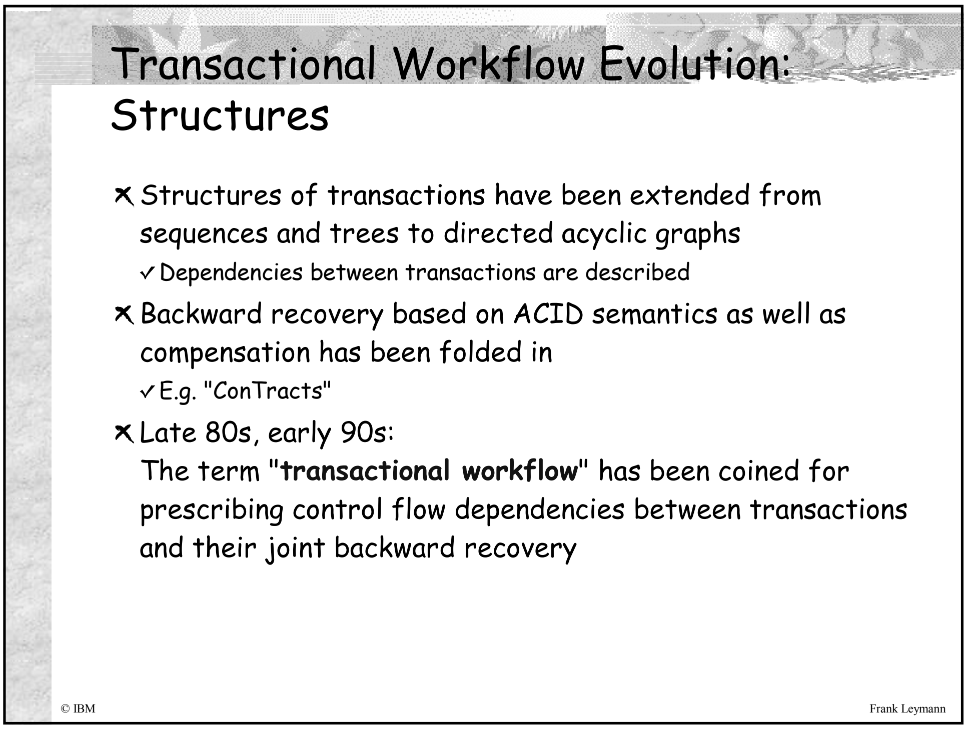

Transactional Workflow Evolution: Structures

- Structures of transactions have been extended from sequences and trees to directed acyclic graphs
  - ✓ Dependencies between transactions are described
- Backward recovery based on ACID semantics as well as compensation has been folded in
  - ✓ E.g. "ConTracts"
- Late 80s, early 90s:
  The term "**transactional workflow**" has been coined for prescribing control flow dependencies between transactions and their joint backward recovery

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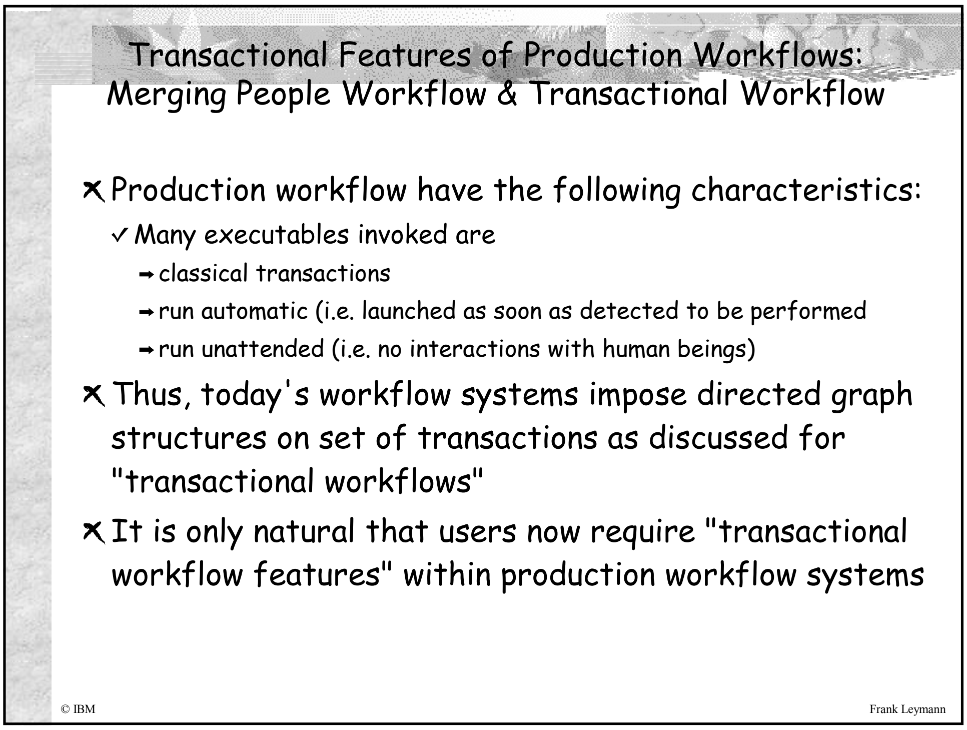

Transactional Features of Production Workflows: Merging People Workflow & Transactional Workflow

- Production workflow have the following characteristics:
  - ✓ Many executables invoked are
    - ➡ classical transactions
    - ➡ run automatic (i.e. launched as soon as detected to be performed
    - ➡ run unattended (i.e. no interactions with human beings)
- Thus, today's workflow systems impose directed graph structures on set of transactions as discussed for "transactional workflows"
- It is only natural that users now require "transactional workflow features" within production workflow systems

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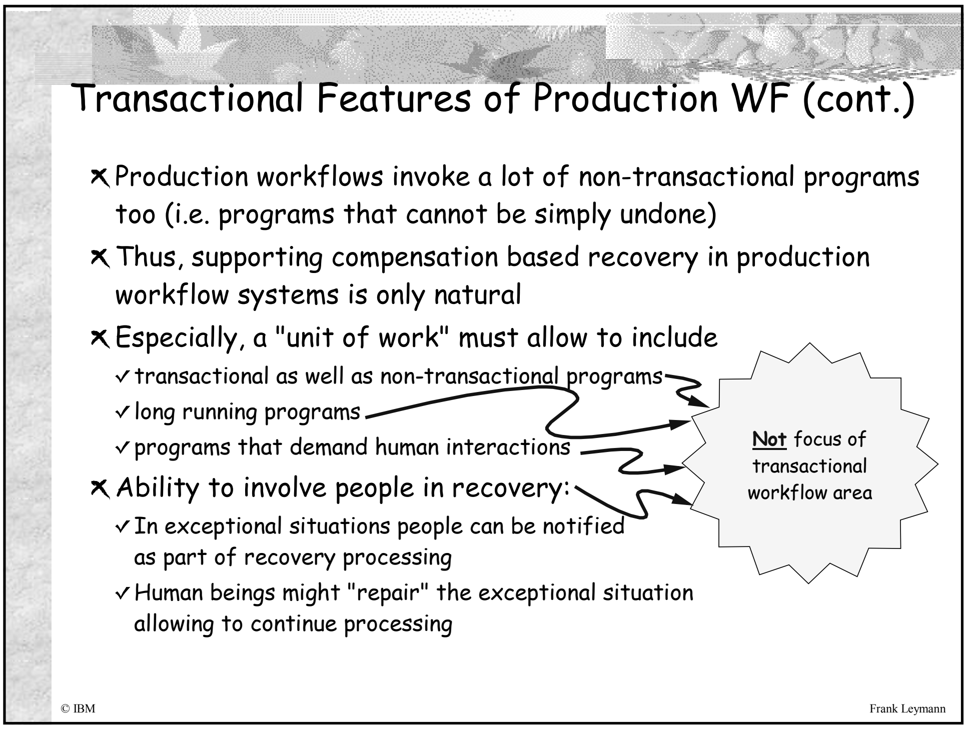

Transactional Features of Production WF (cont.)

- Production workflows invoke a lot of non-transactional programs too (i.e. programs that cannot be simply undone)
- Thus, supporting compensation based recovery in production workflow systems is only natural
- Especially, a "unit of work" must allow to include
  - ✓ transactional as well as non-transactional programs
  - ✓ long running programs
  - ✓ programs that demand human interactions
- Ability to involve people in recovery:
  - ✓ In exceptional situations people can be notified as part of recovery processing
  - ✓ Human beings might "repair" the exceptional situation allowing to continue processing

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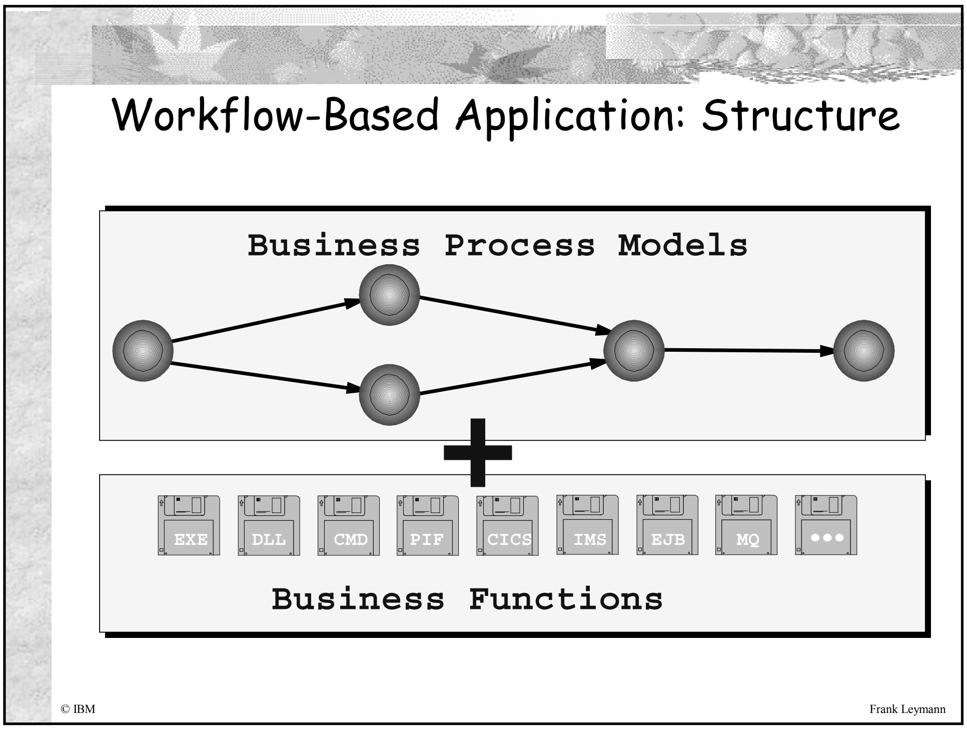

Workflow-Based Application: Structure

Business Process Models

+

EXE DLL CMD PIF CICS IMS EJB MQ •••

Business Functions

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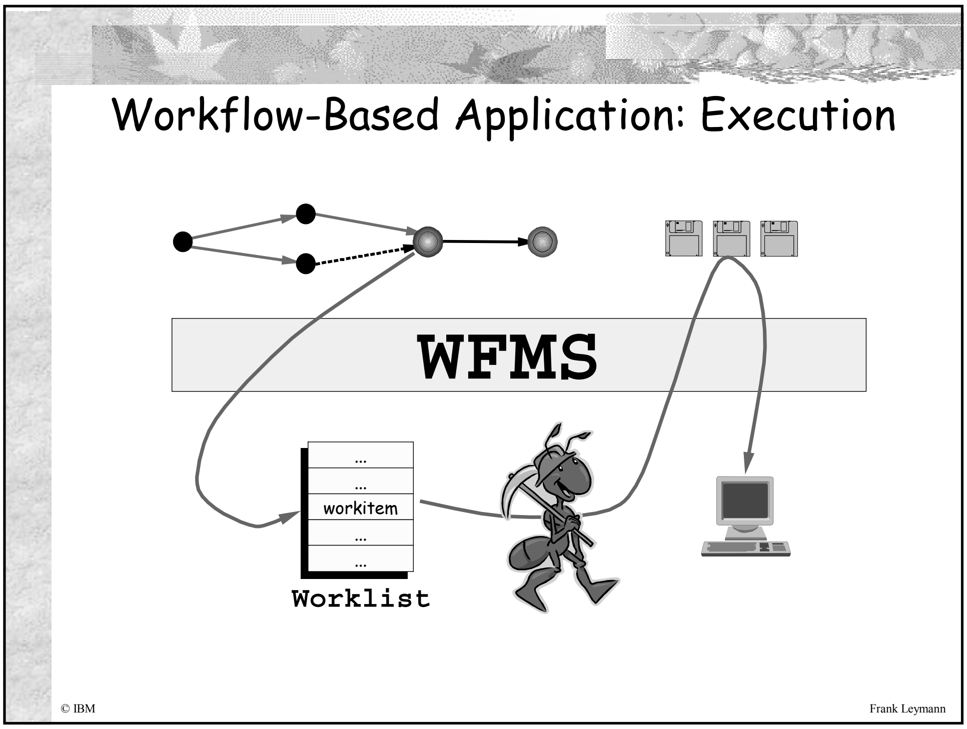

Workflow-Based Application: Execution

WFMS

...

...

workitem

...

...

Worklist

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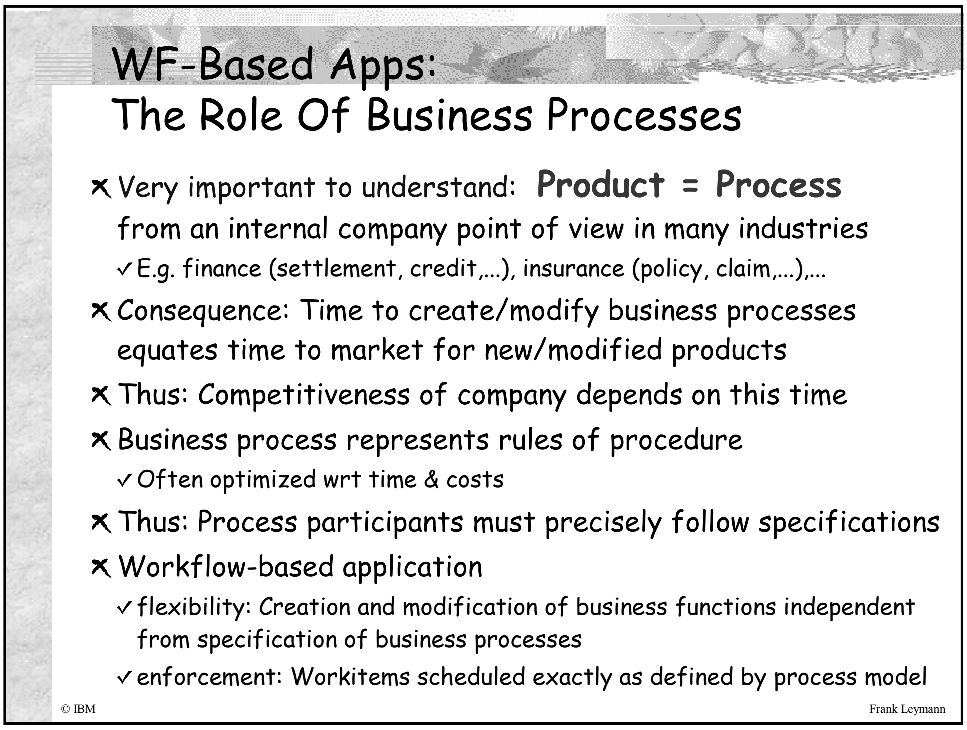

WF-Based Apps: The Role Of Business Processes

- Very important to understand: **Product = Process** from an internal company point of view in many industries
  - ✓ E.g. finance (settlement, credit,...), insurance (policy, claim,...),...
- Consequence: Time to create/modify business processes equates time to market for new/modified products
- Thus: Competitiveness of company depends on this time
- Business process represents rules of procedure
  - ✓ Often optimized wrt time & costs
- Thus: Process participants must precisely follow specifications
- Workflow-based application
  - ✓ flexibility: Creation and modification of business functions independent from specification of business processes
  - ✓ enforcement: Workitems scheduled exactly as defined by process model

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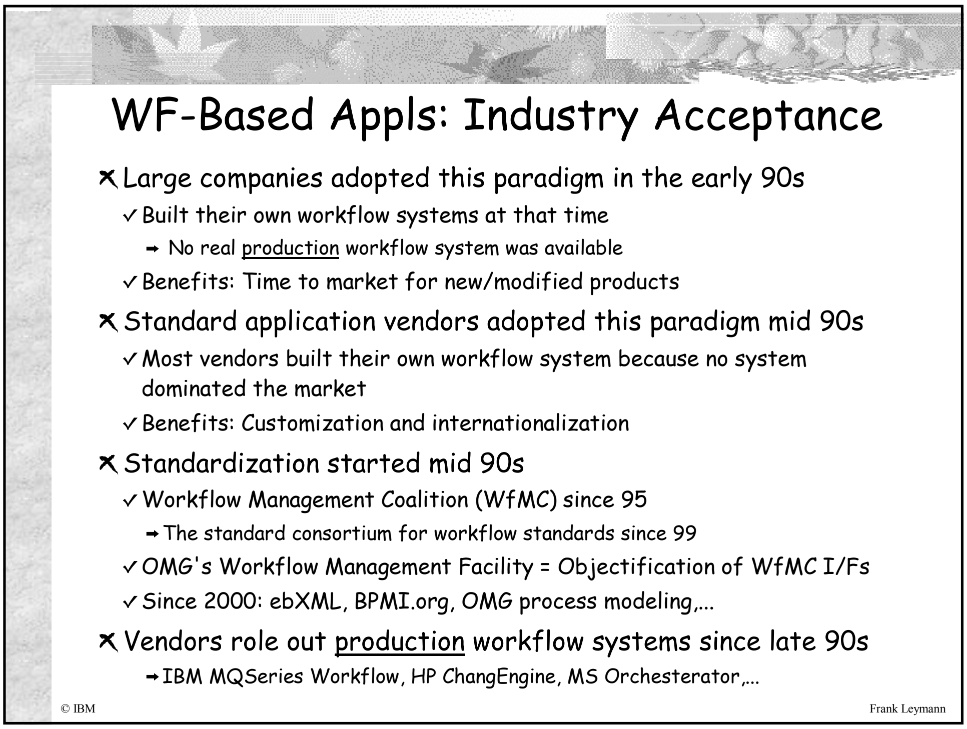

WF-Based Appls: Industry Acceptance

- Large companies adopted this paradigm in the early 90s
  - ✓ Built their own workflow systems at that time
    - ➨ No real <u>production</u> workflow system was available
  - ✓ Benefits: Time to market for new/modified products
- Standard application vendors adopted this paradigm mid 90s
  - ✓ Most vendors built their own workflow system because no system dominated the market
  - ✓ Benefits: Customization and internationalization
- Standardization started mid 90s
  - ✓ Workflow Management Coalition (WfMC) since 95
    - ➨ The standard consortium for workflow standards since 99
  - ✓ OMG's Workflow Management Facility = Objectification of WfMC I/Fs
  - ✓ Since 2000: ebXML, BPMI.org, OMG process modeling,...
- Vendors role out <u>production</u> workflow systems since late 90s
  - ➨ IBM MQSeries Workflow, HP ChangEngine, MS Orchesterator,...

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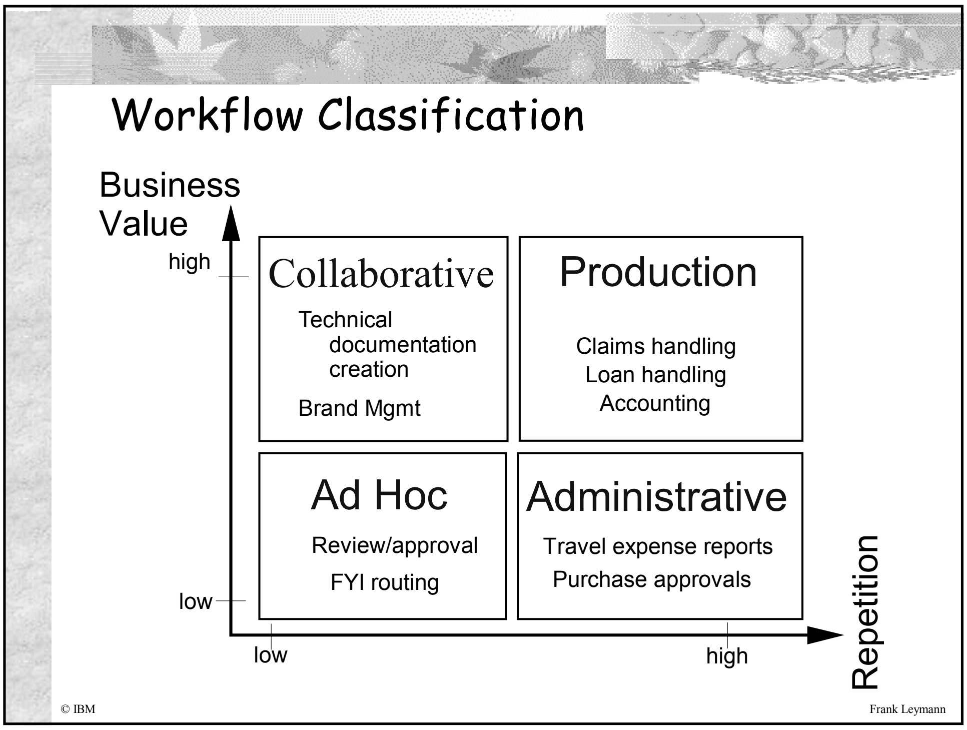

Workflow Classification

Business Value

high

low

Collaborative

Technical documentation creation

Brand Mgmt

Production

Claims handling
Loan handling
Accounting

Ad Hoc

Review/approval

FYI routing

Administrative

Travel expense reports
Purchase approvals

low

high

Repetition

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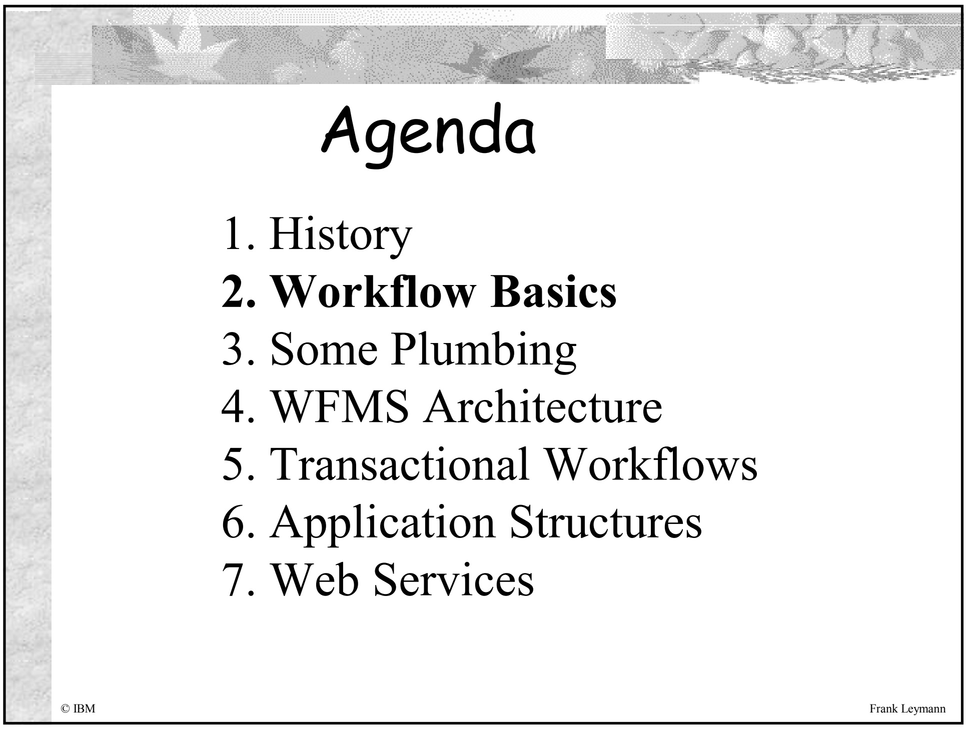

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What Are Workflows?

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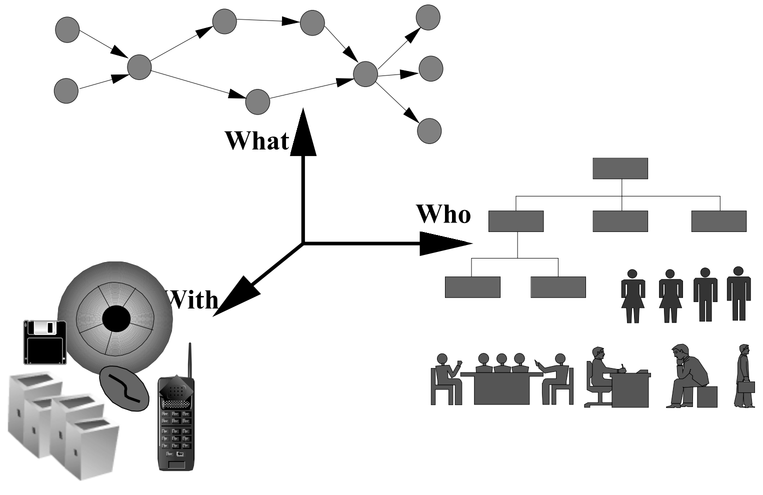
Workflows: N-Dimensional „Things“



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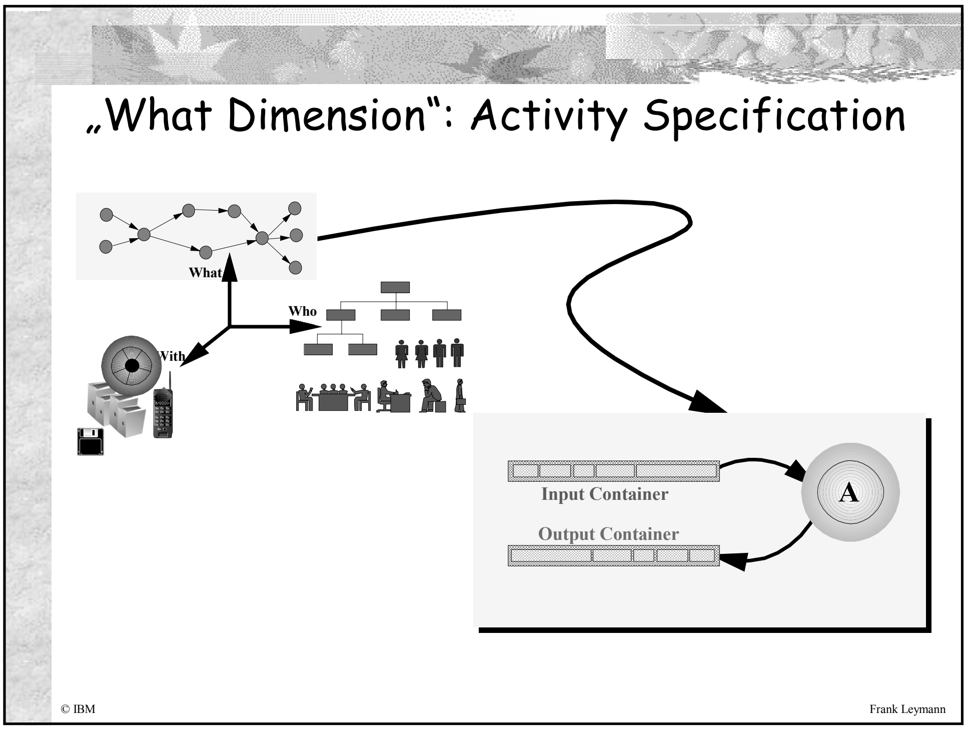

„What Dimension“: Activity Specification

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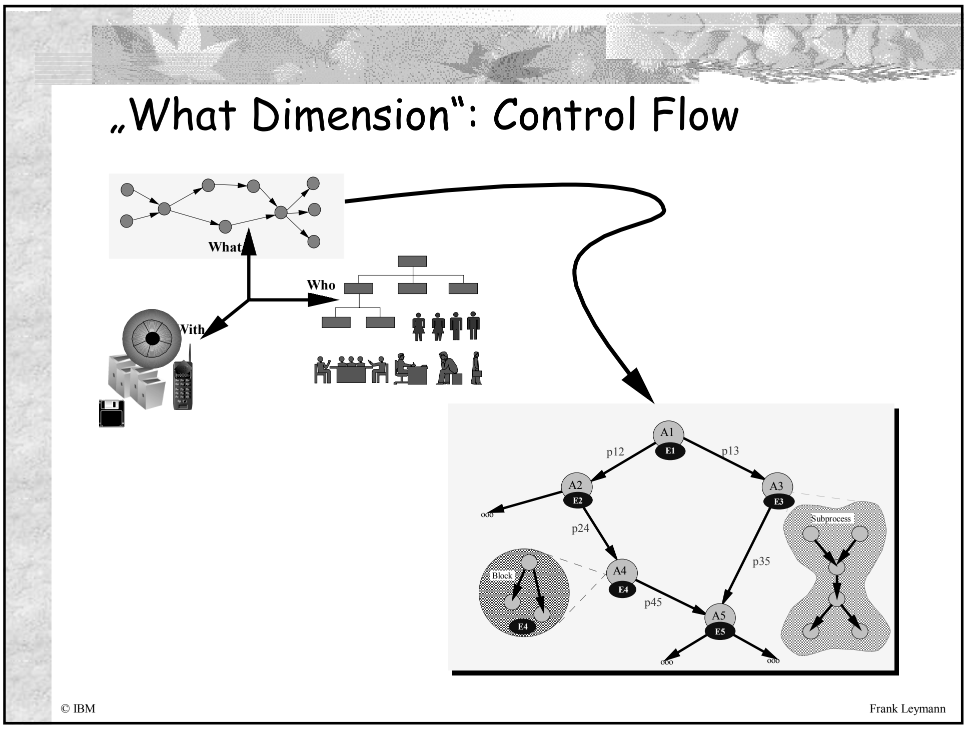

„What Dimension“: Control Flow

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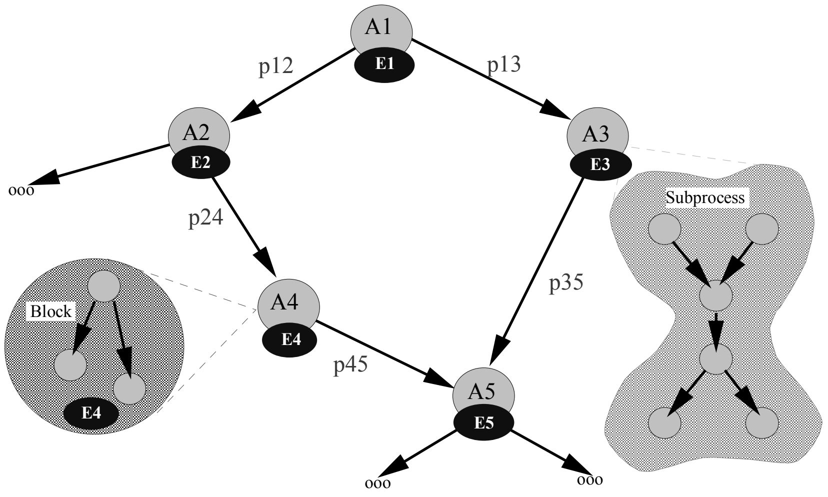
Control Flow Specification



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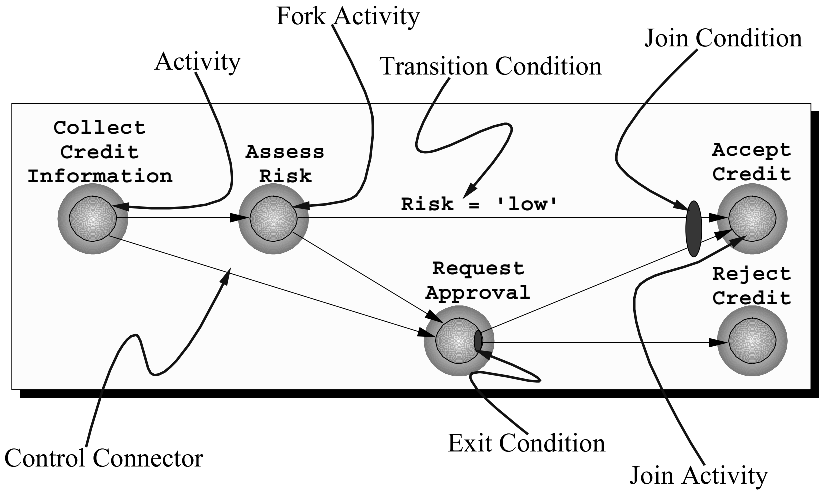
Control Flow Constructs



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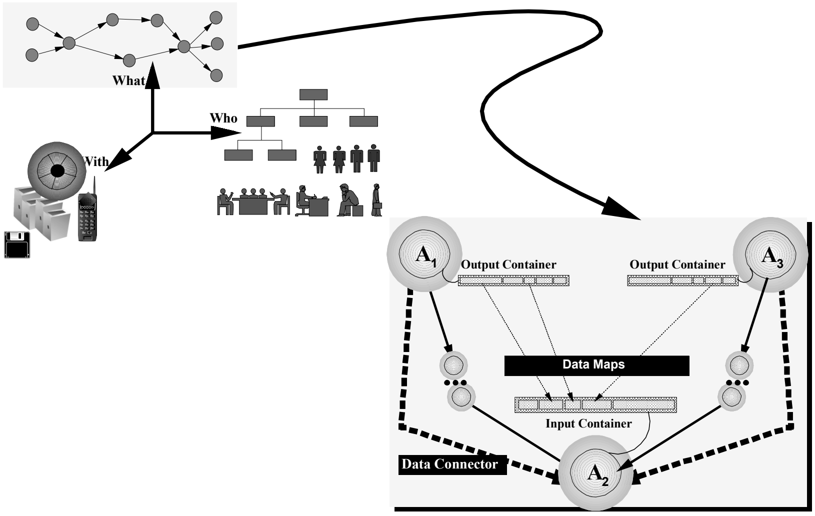
„What Dimension“: Data Flow



What

Who

With

A$_1$

Output Container

Output Container

A$_3$

Data Maps

Input Container

Data Connector

A$_2$

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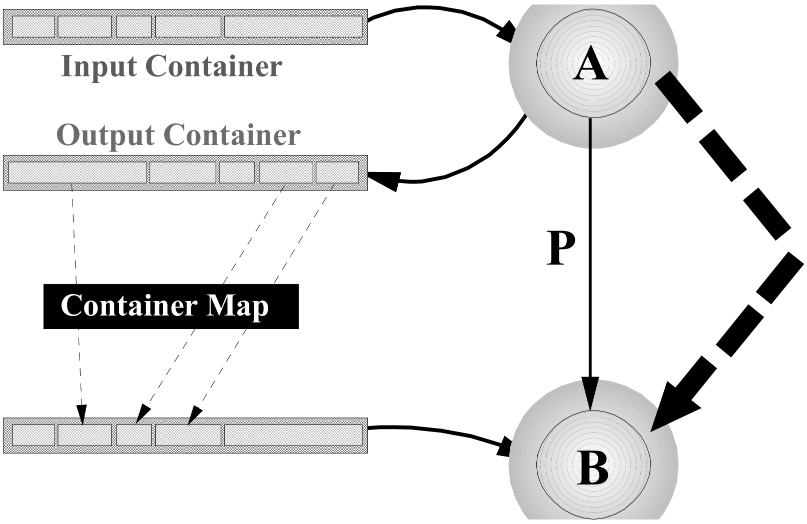
Data Flow Specification



Input Container

Output Container

Container Map

A

P

B

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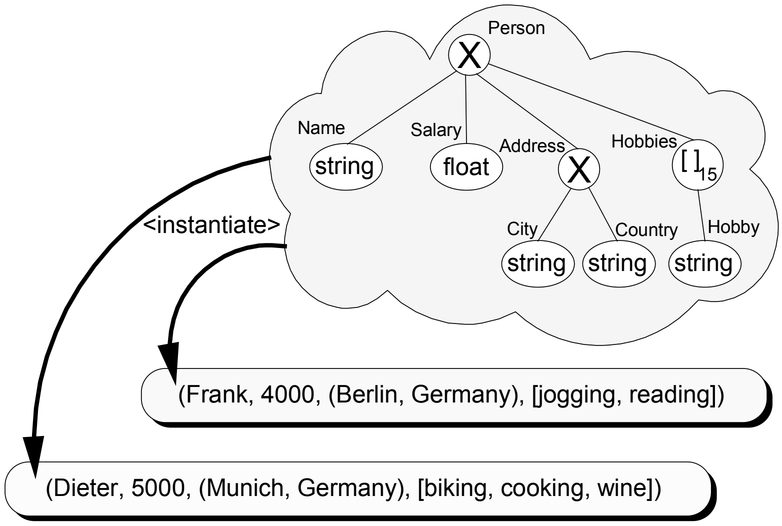
Containers And Their Instances



(Frank, 4000, (Berlin, Germany), [jogging, reading])

(Dieter, 5000, (Munich, Germany), [biking, cooking, wine])

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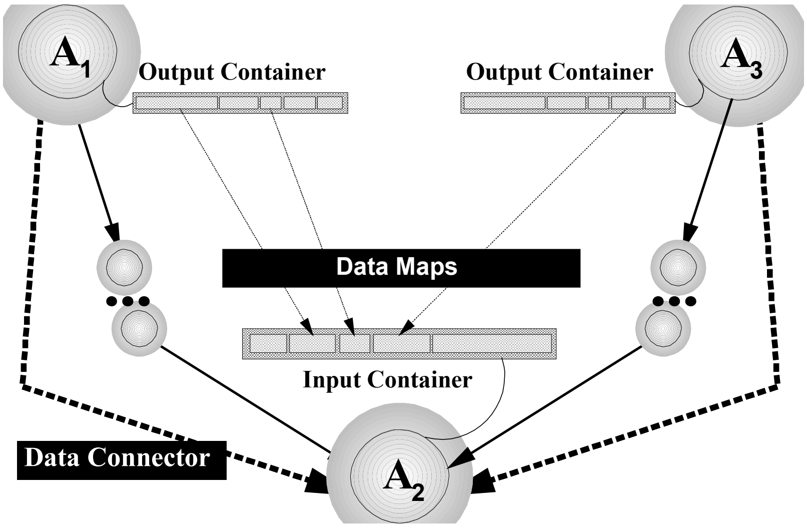
Data Maps



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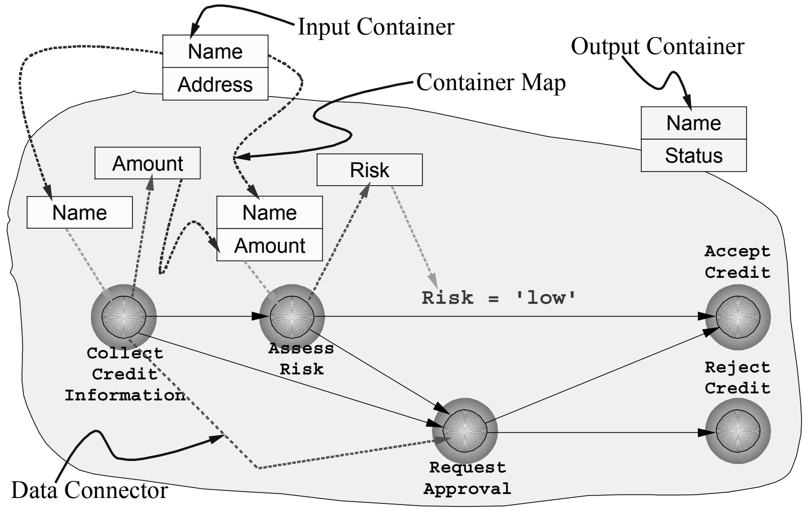
Data Flow Constructs



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Other Approaches To Flow Modelling

- Graph-/PTN-based modeling
  - ...realized in a bunch of products
  - ...standardized by WfMC (see later)
- Many other possible approaches
  - State-Transition Diagrams
  - Calculus-based
    - ...realized on some products
    - ...standard proposals
  - ...

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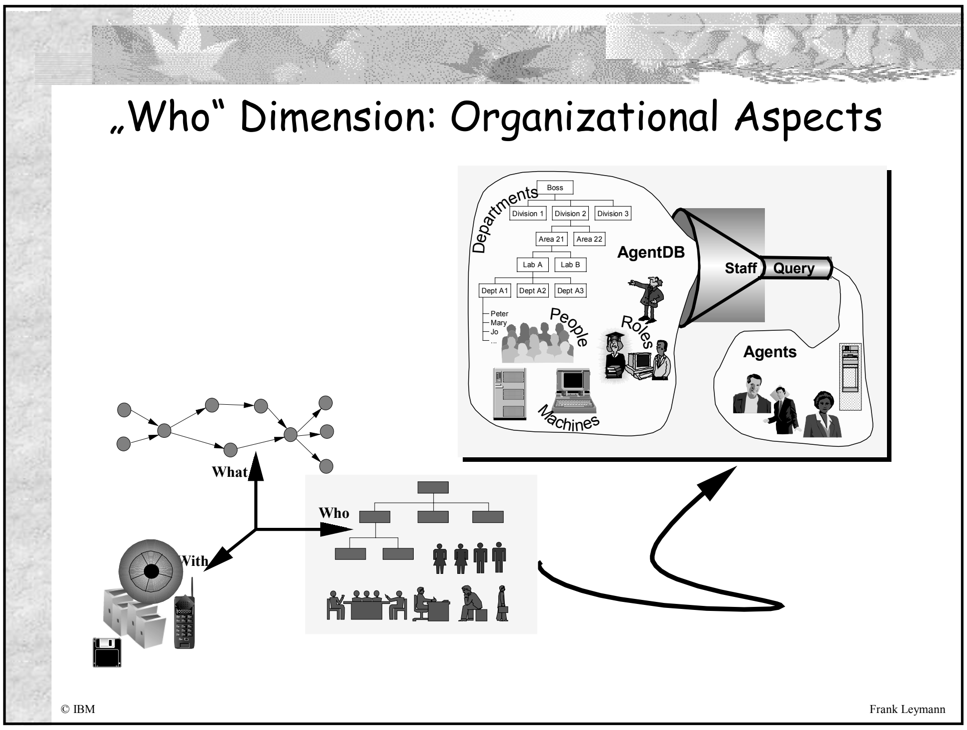

„Who“ Dimension: Organizational Aspects

Boss

Division 1

Division 2

Division 3

Area 21

Area 22

Lab A

Lab B

Dept A1

Dept A2

Dept A3

Peter

Mary

Jo

...

Departments

People

Roles

Machines

AgentDB

Staff

Query

Agents

What

Who

With

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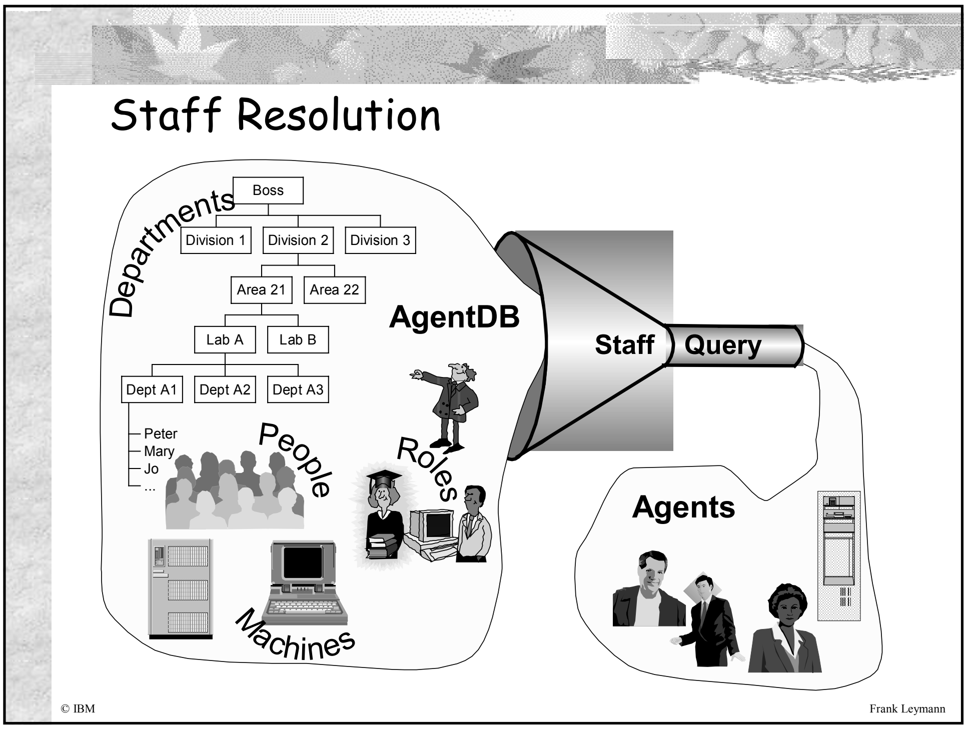

Staff Resolution

Boss

Division 1

Division 2

Division 3

Area 21

Area 22

Lab A

Lab B

Dept A1

Dept A2

Dept A3

Peter

Mary

Jo

...

Departments

People

Roles

Machines

AgentDB

Staff

Query

Agents

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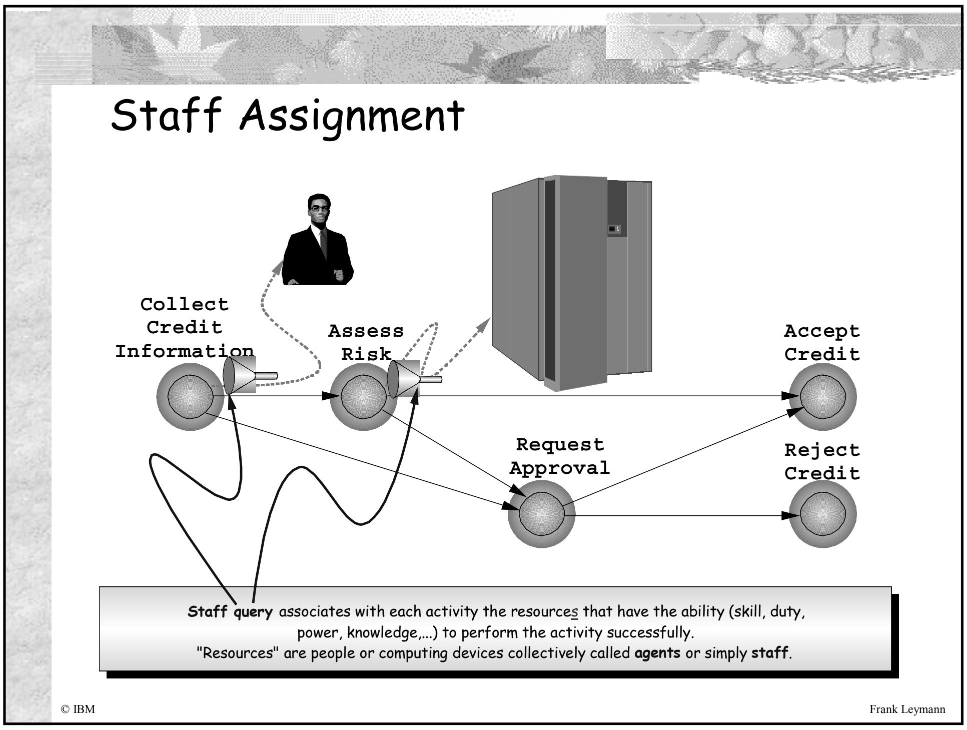

Staff Assignment

Staff query associates with each activity the resources that have the ability (skill, duty, power, knowledge,...) to perform the activity successfully.
"Resources" are people or computing devices collectively called **agents** or simply **staff**.

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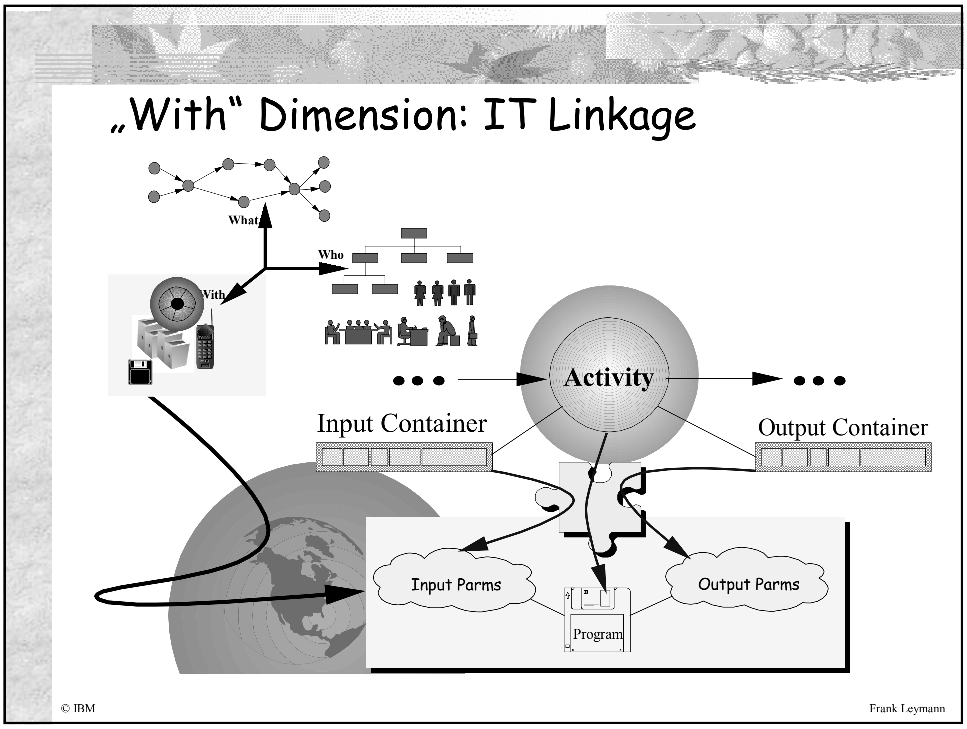

„With“ Dimension: IT Linkage

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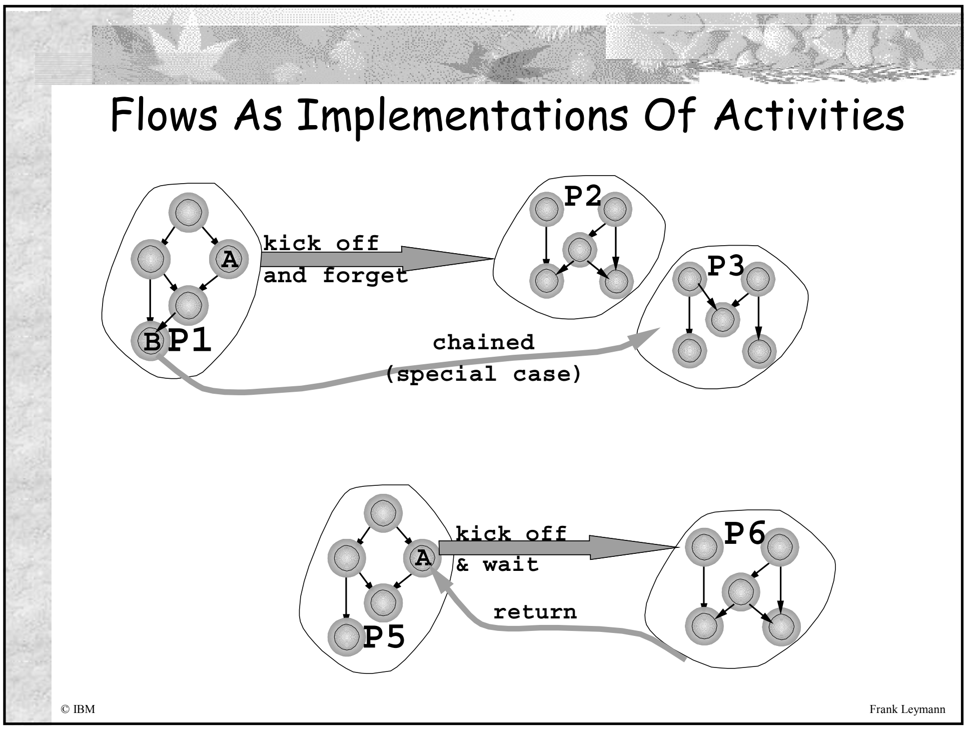

Flows As Implementations Of Activities

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How To Work With Workflows?

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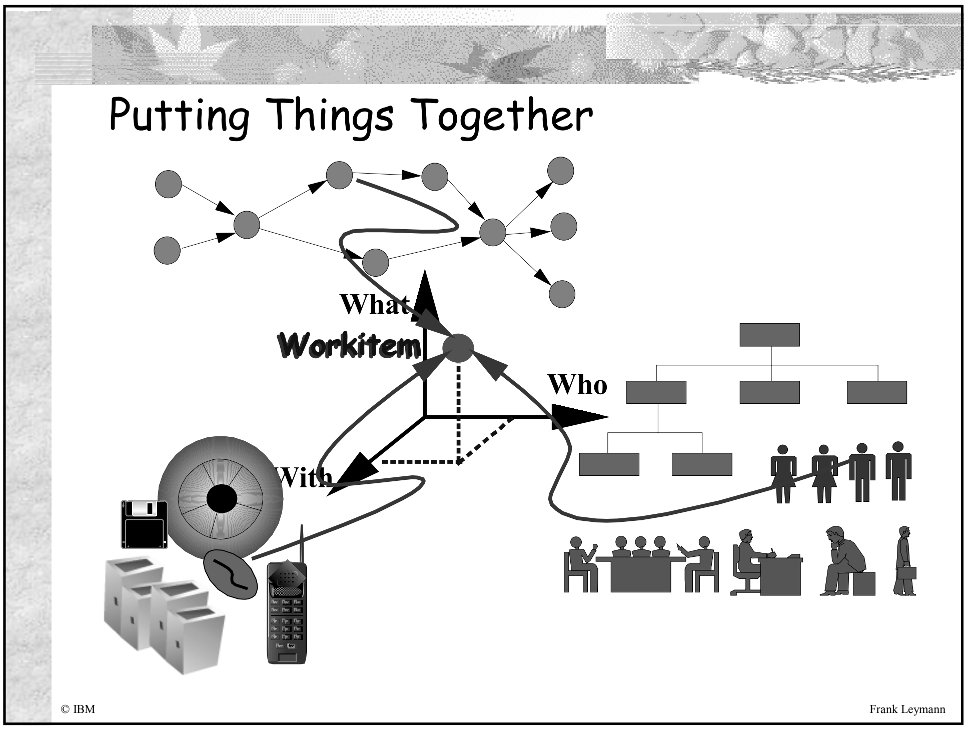

Putting Things Together

What

Workitem

Who

With

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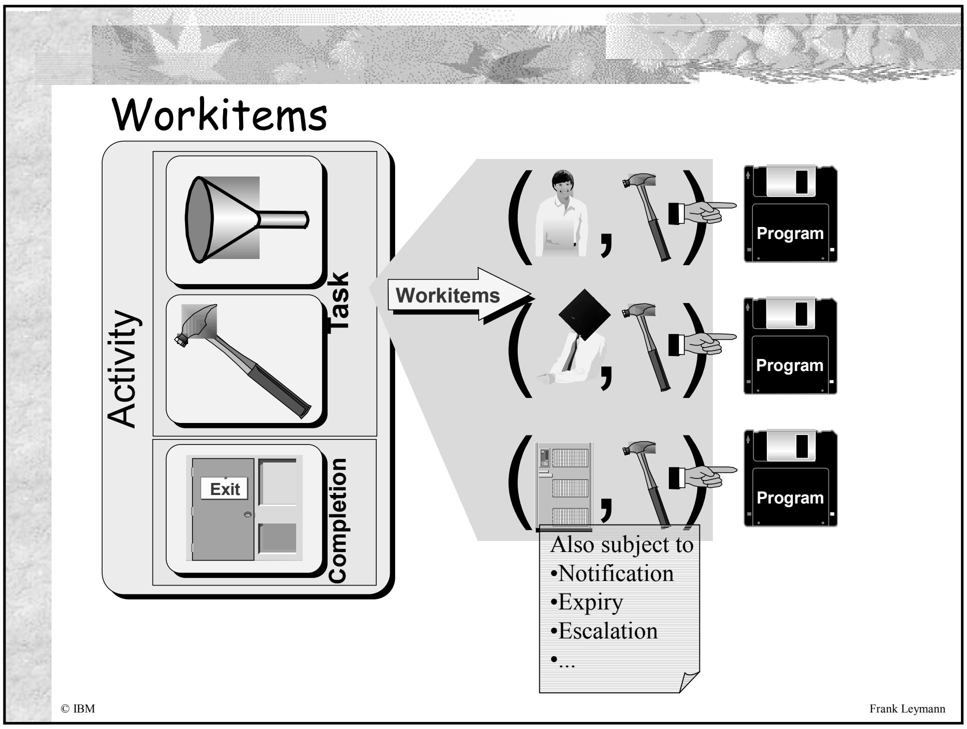

Workitems

Activity

Task

Completion

Exit

Workitems

Program

Program

Program

Also subject to
- Notification
- Expiry
- Escalation
- ...

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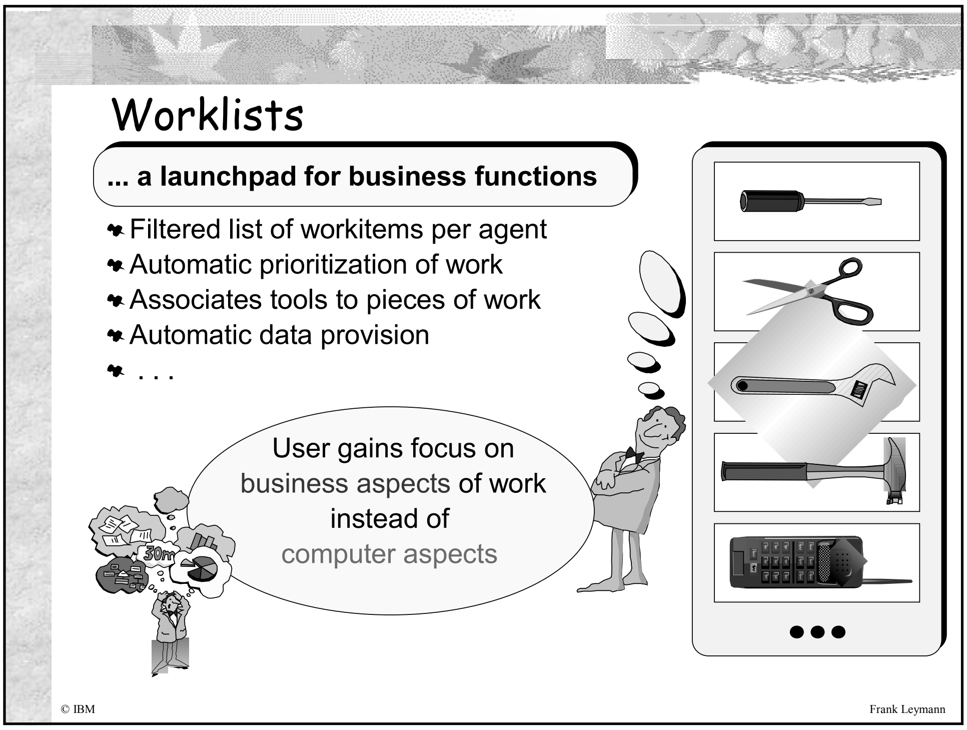

Worklists

... a launchpad for business functions

- Filtered list of workitems per agent
- Automatic prioritization of work
- Associates tools to pieces of work
- Automatic data provision
- . . .

User gains focus on business aspects of work instead of computer aspects

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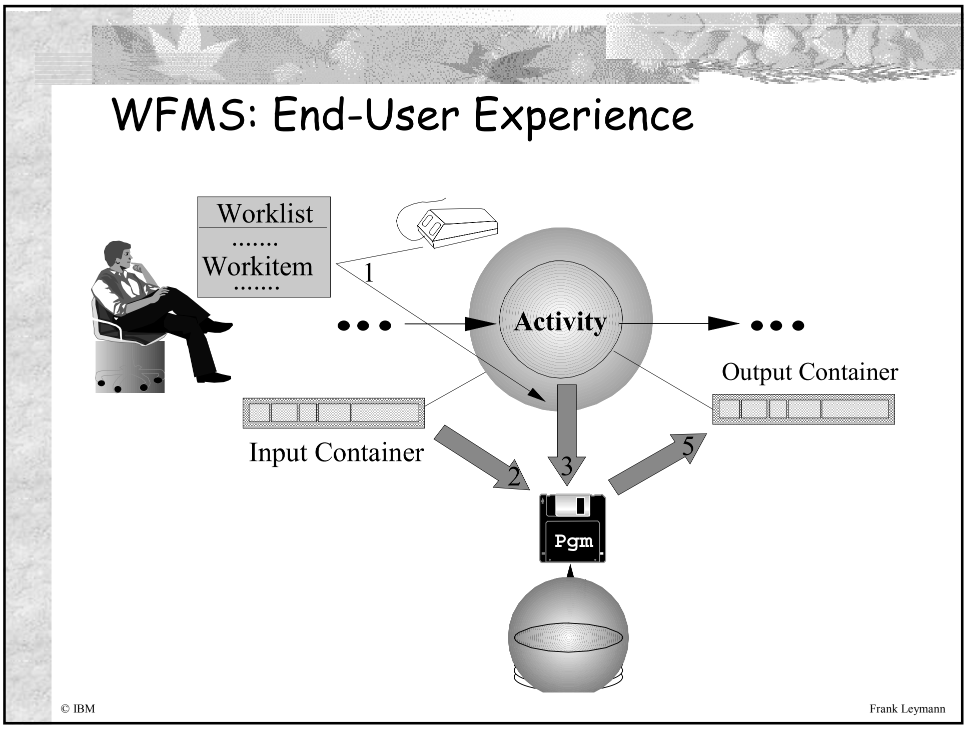

WFMS: End-User Experience

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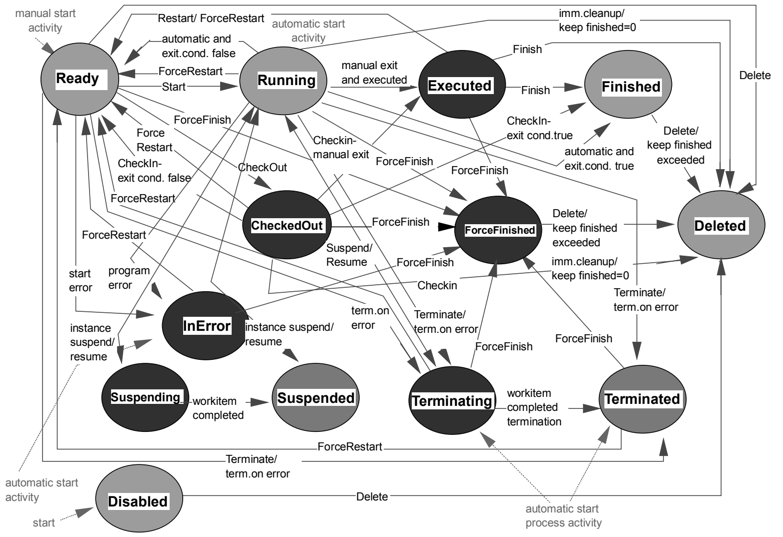
Activity And Workitem Lifecycle



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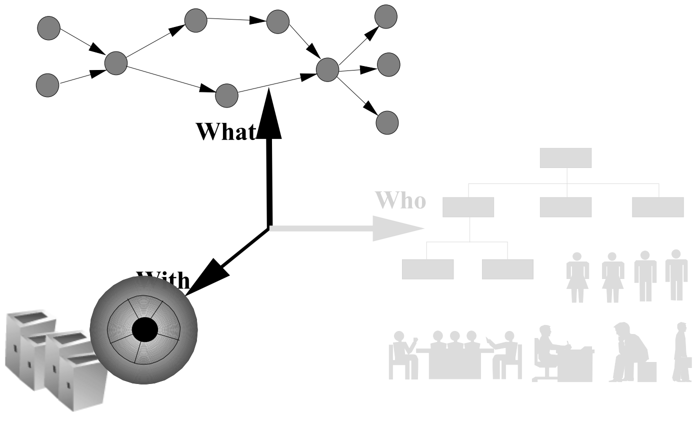
Automatic Workflow, Microflows



- Regular processing of automatic workflows and microflows don‘t involve human beings
- Microflows run often „local“, are „method“ bodies etc

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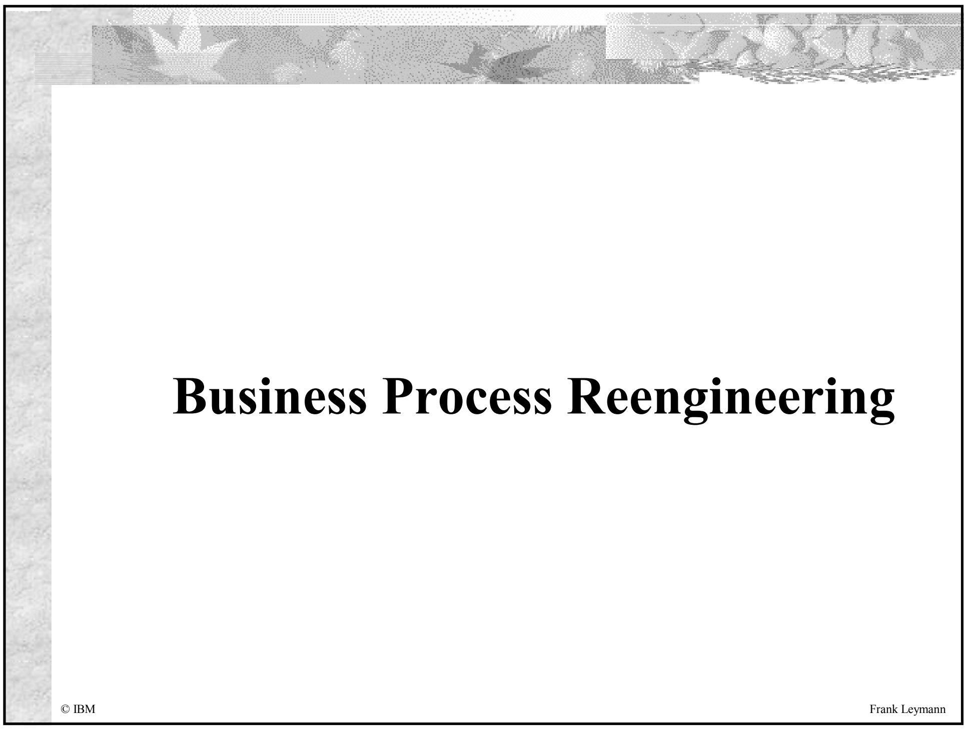

Business Process Reengineering

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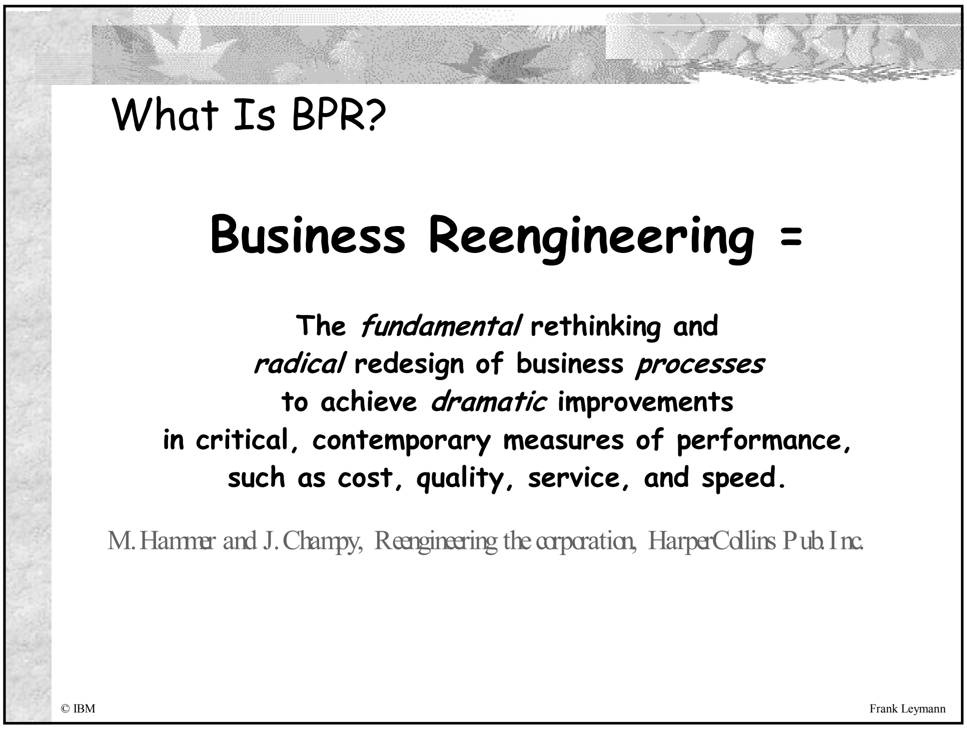

What Is BPR?

Business Reengineering =

The *fundamental* rethinking and
radical* redesign of business *processes
to achieve *dramatic* improvements
in critical, contemporary measures of performance,
such as cost, quality, service, and speed.

M. Hammer and J. Champy, Reengineering the corporation, HarperCollins Pub. Inc.

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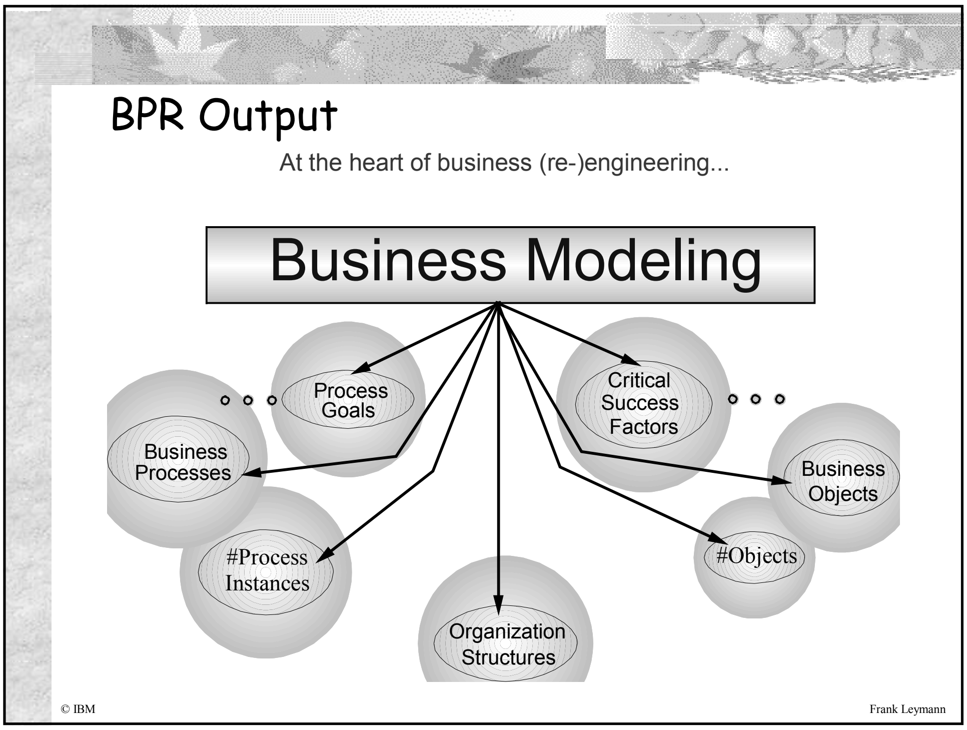

BPR Output

At the heart of business (re-)engineering...

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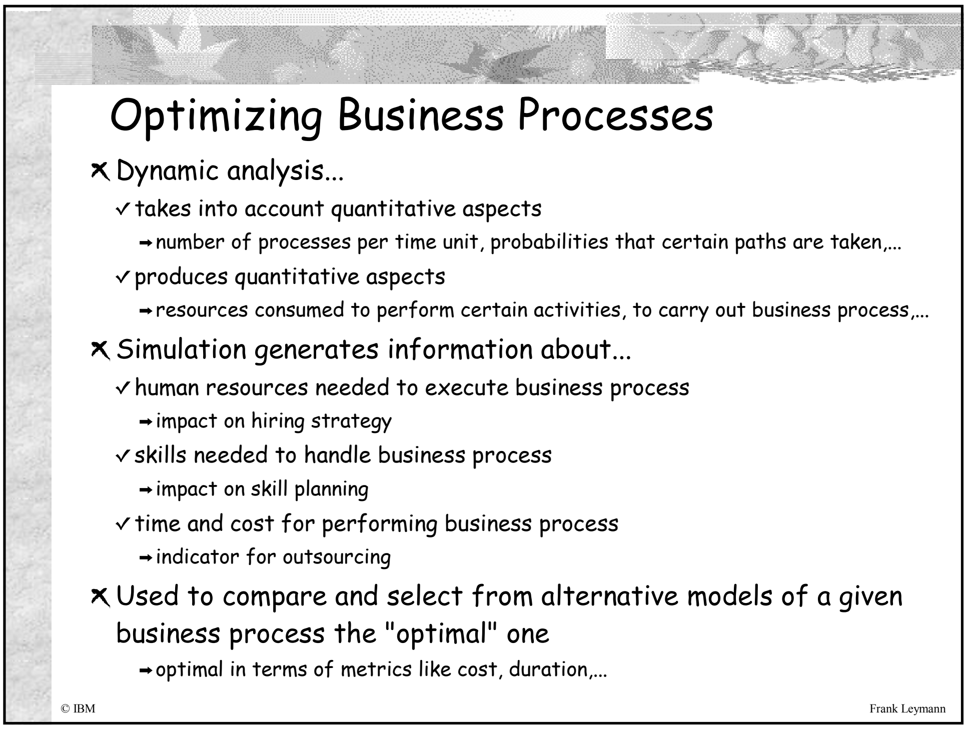

Optimizing Business Processes

- Dynamic analysis...
  - ✓ takes into account quantitative aspects
    - ➡ number of processes per time unit, probabilities that certain paths are taken,...
  - ✓ produces quantitative aspects
    - ➡ resources consumed to perform certain activities, to carry out business process,...
- Simulation generates information about...
  - ✓ human resources needed to execute business process
    - ➡ impact on hiring strategy
  - ✓ skills needed to handle business process
    - ➡ impact on skill planning
  - ✓ time and cost for performing business process
    - ➡ indicator for outsourcing
- Used to compare and select from alternative models of a given business process the "optimal" one
    - ➡ optimal in terms of metrics like cost, duration,...

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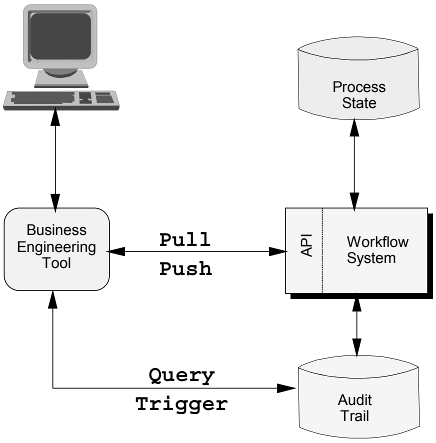
Purpose Of Simulation

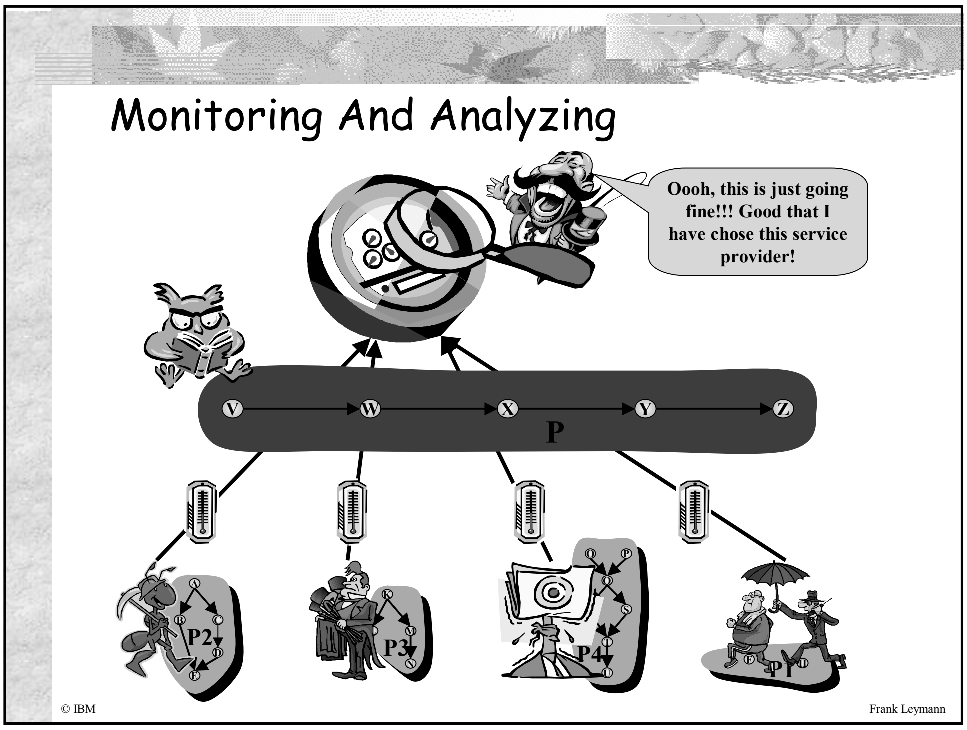
Verify capability of organization to support expected workload

- Performed based on metrical information ("instrumentation")
- Instrumentation requires to specify
  - ✓ Number of processes started per time intervall, i.e. distribution patterns of starts - for example:
    - ➡ constant: same number for each time intervall
    - ➡ exponential: smaller numbers more frequent than large numbers
    - ➡ uniform: numbers random within lower and upper bound
    - ➡ customer defined: 57 between 9AM and 11AM, 341 between 11AM and noon,...
  - ✓ Probability of transition conditions (likelihood of different branches taken)
  - ✓ Probability of activation-, join- and exit conditions (likelihood of repetitions)
  - ✓ Average duration of activities (work time, idle time,...), i.e. their distribution patterns
  - ✓ Processing power of resources, availability (based on calendar, shifts,...)

Monitoring And Auditing



- Business modeling based on assumptions about cardinalities, duration, etc.
- Based on these assumption process characteristics are derived (costs,...) which trigger optimizations
- Thus, incorrect assumptions result in non-optimal process models
- WFMS allows to access actual state (monitoring) as well as history (auditing) of each workflow
- Analyzing audit trail ("vanilla" SQL, OLAP, mining) derives "real data" for optimizing process models (re-engineering)
- Monitoring (manually or automatically) individual processes or instances of the same model allows to detect out-of-line situations and to react accordingly (re-assignment of work,...)



Monitoring And Analyzing

Oooh, this is just going fine!!! Good that I have chose this service provider!
V
W
X
Y
Z
P
P2
P3
P4
P1

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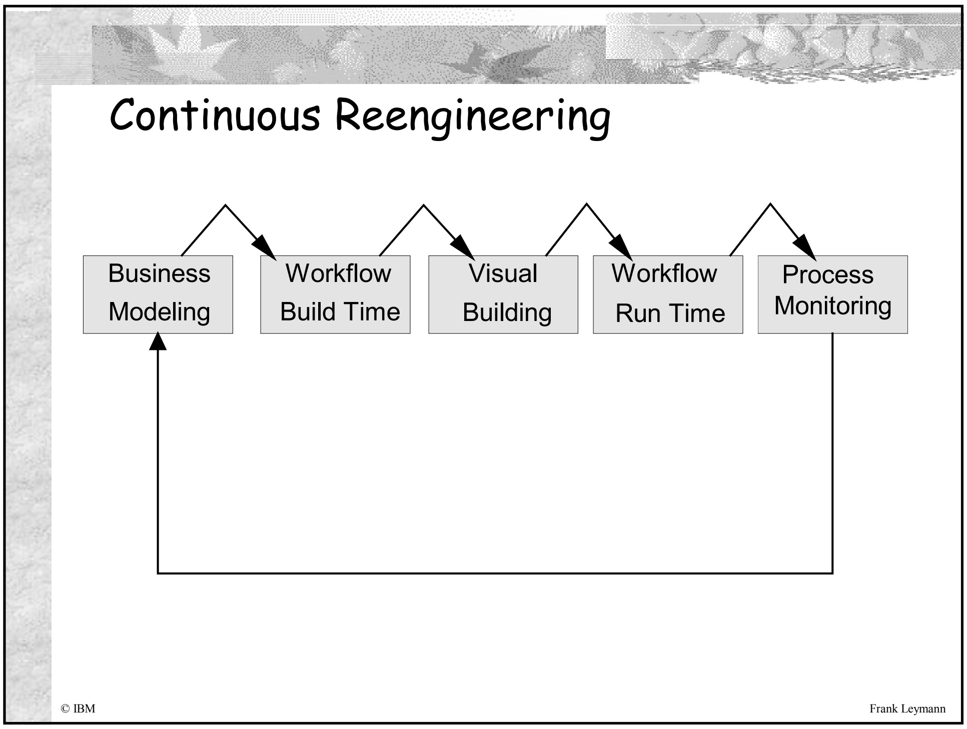

Continuous Reengineering

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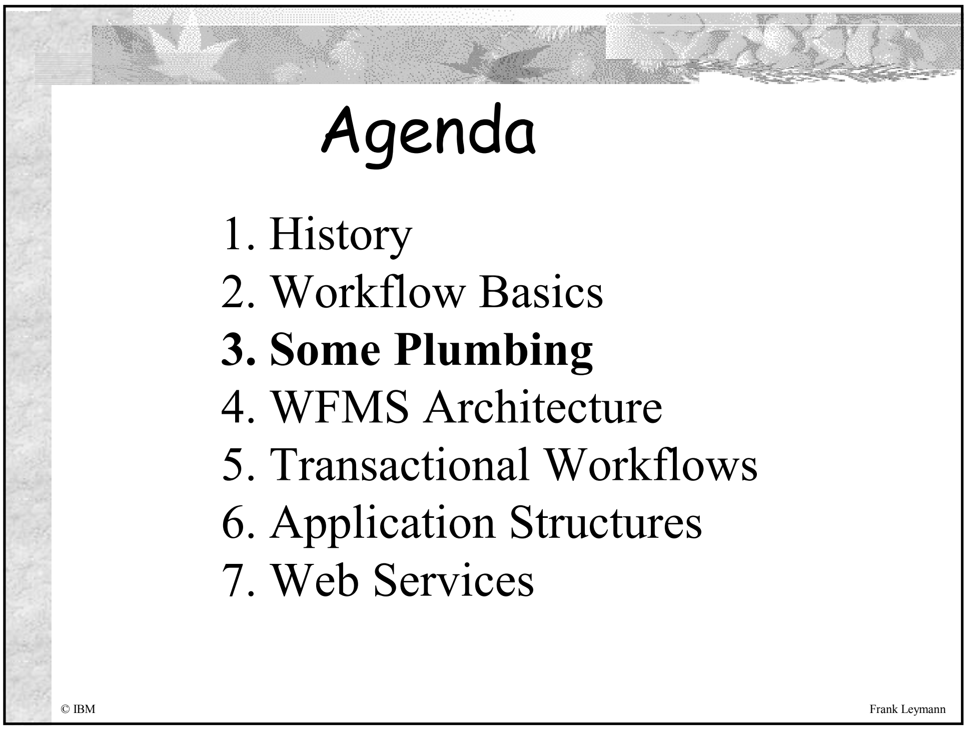

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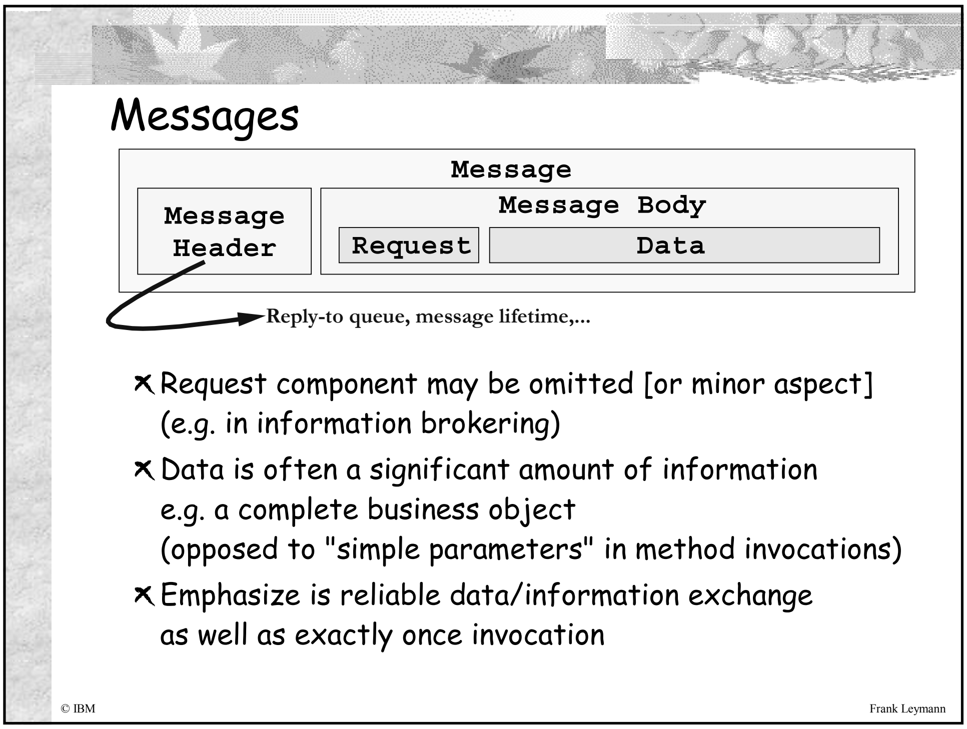

Messages

Message

Message Header

Message Body

Request

Data

Reply-to queue, message lifetime,...

- Request component may be omitted [or minor aspect] (e.g. in information brokering)
- Data is often a significant amount of information e.g. a complete business object (opposed to "simple parameters" in method invocations)
- Emphasize is reliable data/information exchange as well as exactly once invocation

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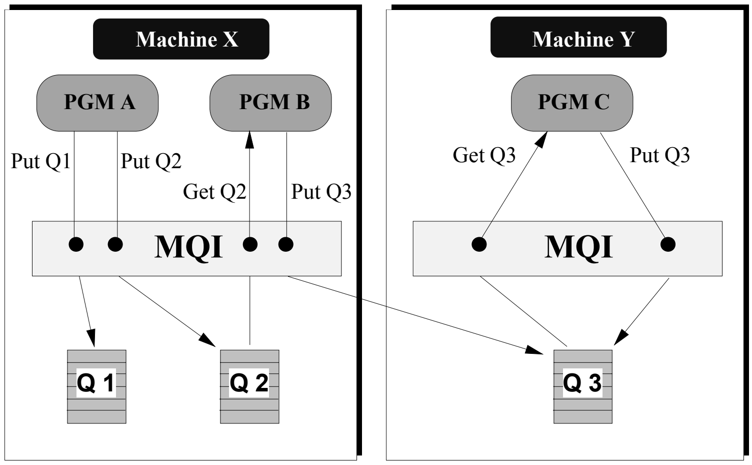
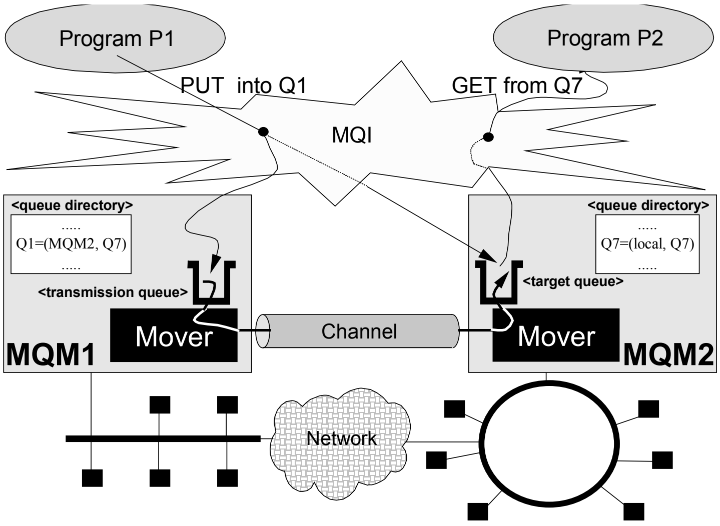
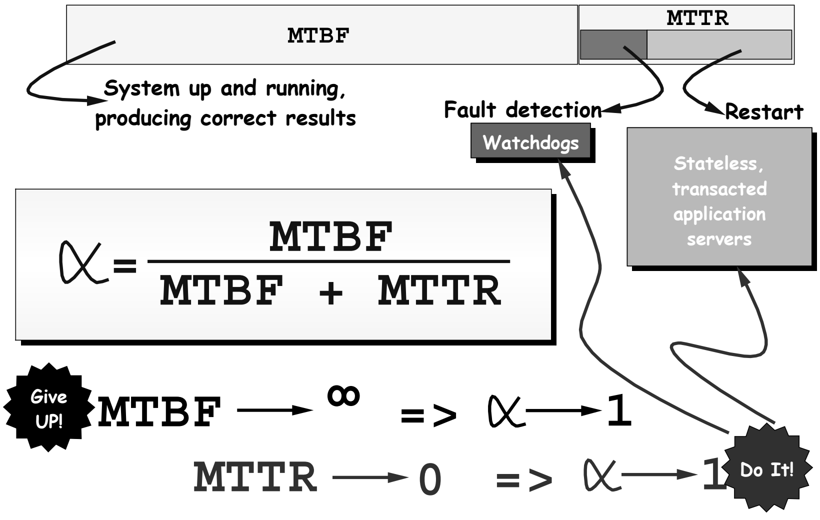
Message Queuing



Hiding Plumbing Complexity



Availability



MTBF

MTTR

System up and running, producing correct results

Fault detection

Watchdogs

Restart

Stateless, transacted application servers

$$\alpha = \frac{MTBF}{MTBF + MTTR}$$

Give UP!

$MTBF \longrightarrow \infty \;\; => \;\; \alpha \longrightarrow 1$

$MTTR \longrightarrow 0 \;\; => \;\; \alpha \longrightarrow 1$

Do It!

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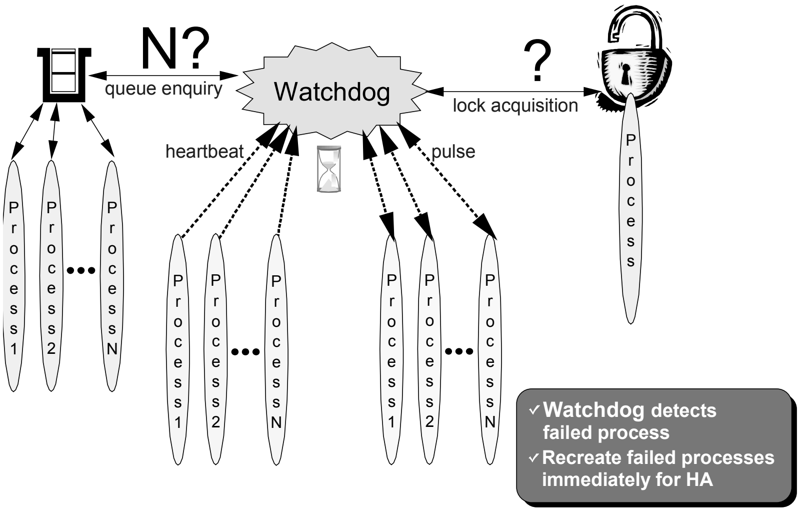
Fault Detection



N?

queue enquiry

Watchdog

?

lock acquisition

heartbeat

pulse

Process 1 Process 2 ••• Process N

Process 1 Process 2 ••• Process N

Process 1 Process 2 ••• Process N

Process

- ✓ Watchdog detects failed process
- ✓ Recreate failed processes immediately for HA

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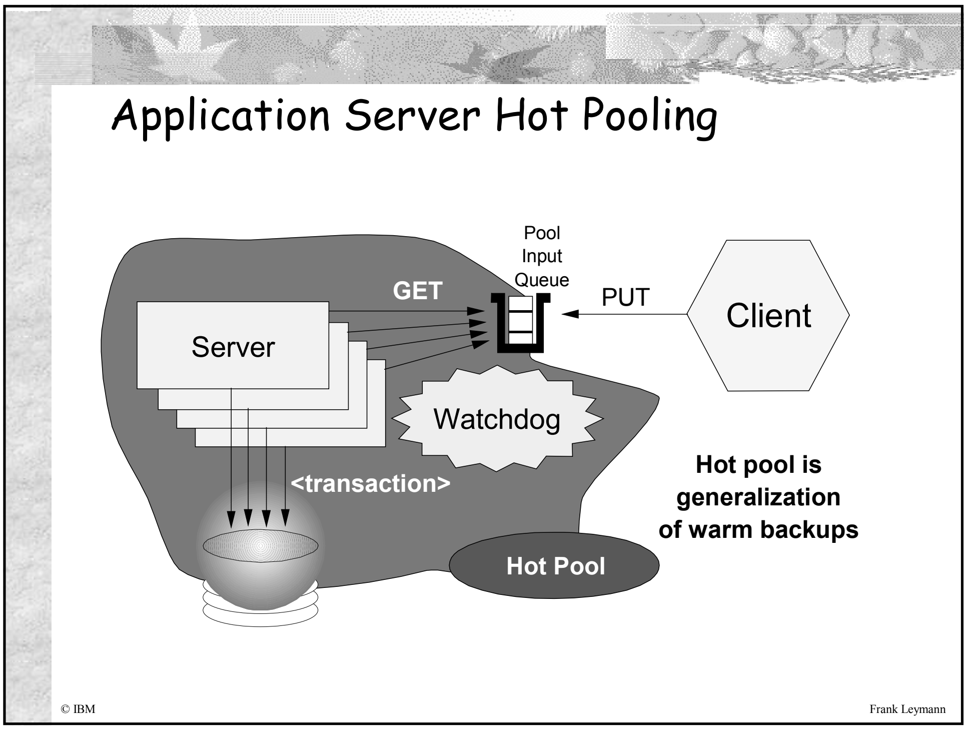

Application Server Hot Pooling

Pool
Input
Queue

GET

PUT

Client

Server

Watchdog

<transaction>

Hot pool is
generalization
of warm backups

Hot Pool

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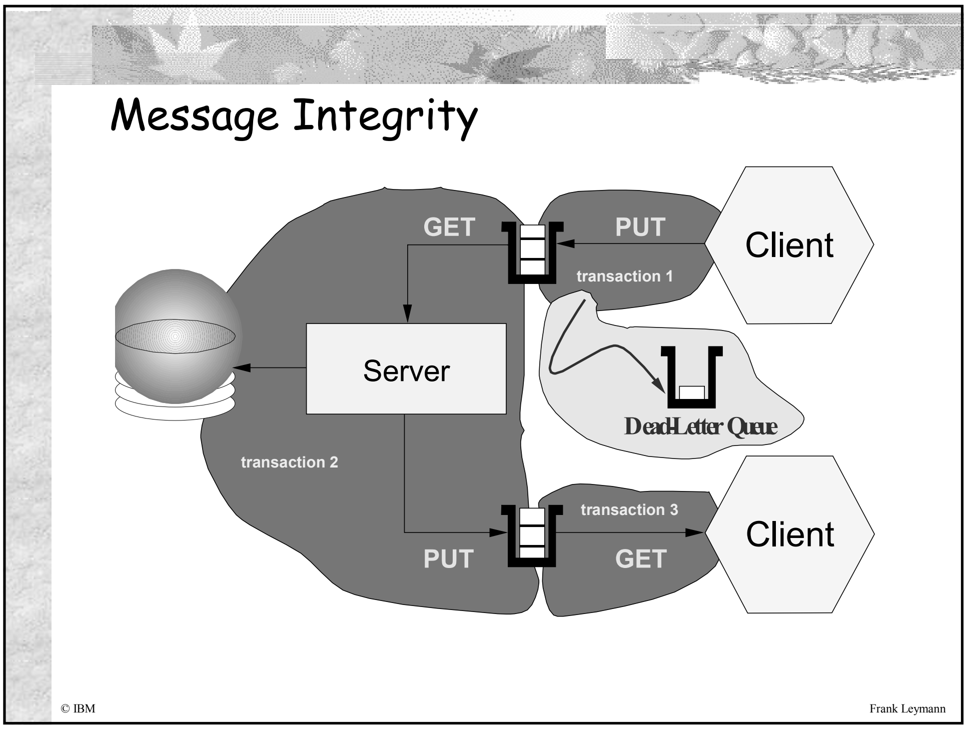

Message Integrity

GET

PUT

Client

transaction 1

Server

Dead-Letter Queue

transaction 2

transaction 3

PUT

GET

Client

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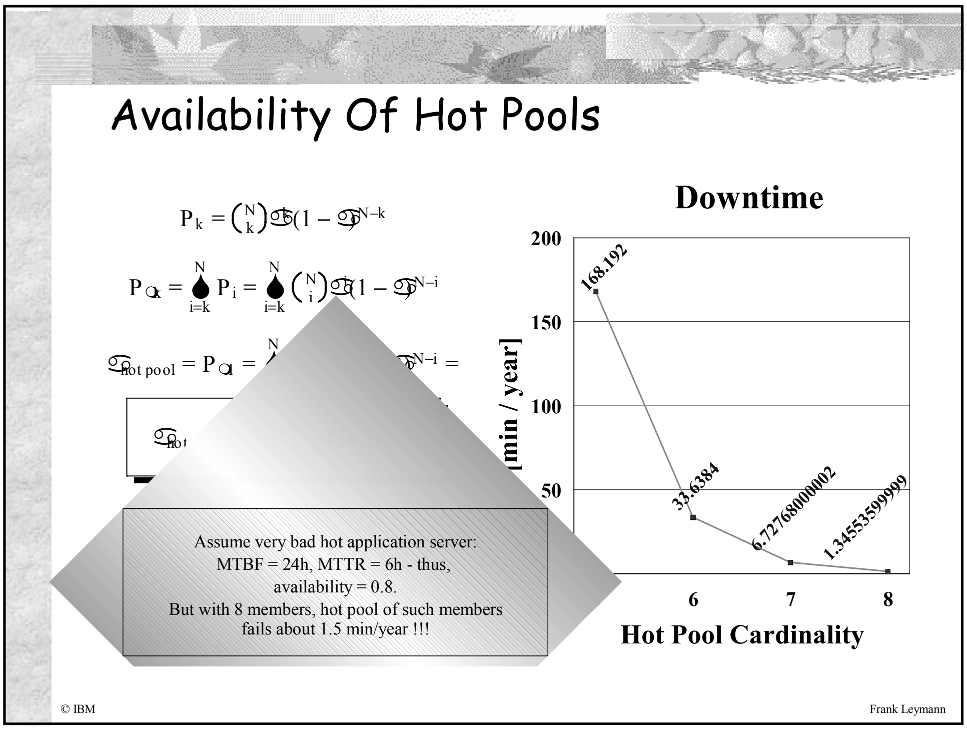

Availability Of Hot Pools

$P_k = \binom{N}{k} \text{♋}^k (1 - \text{♋})^{N-k}$

$P_{\text{♌}k} = \overset{N}{\underset{i=k}{\text{💧}}} P_i = \overset{N}{\underset{i=k}{\text{💧}}} \binom{N}{i} \text{♋}^i (1 - \text{♋})^{N-i}$

$\text{♋}_{\text{hot pool}} = P_{\text{♌}1} = \overset{N}{\text{💧}} \ldots \text{♋})^{N-i} =$

♋_{hot}

Assume very bad hot application server:
MTBF = 24h, MTTR = 6h - thus,
availability = 0.8.
But with 8 members, hot pool of such members fails about 1.5 min/year !!!

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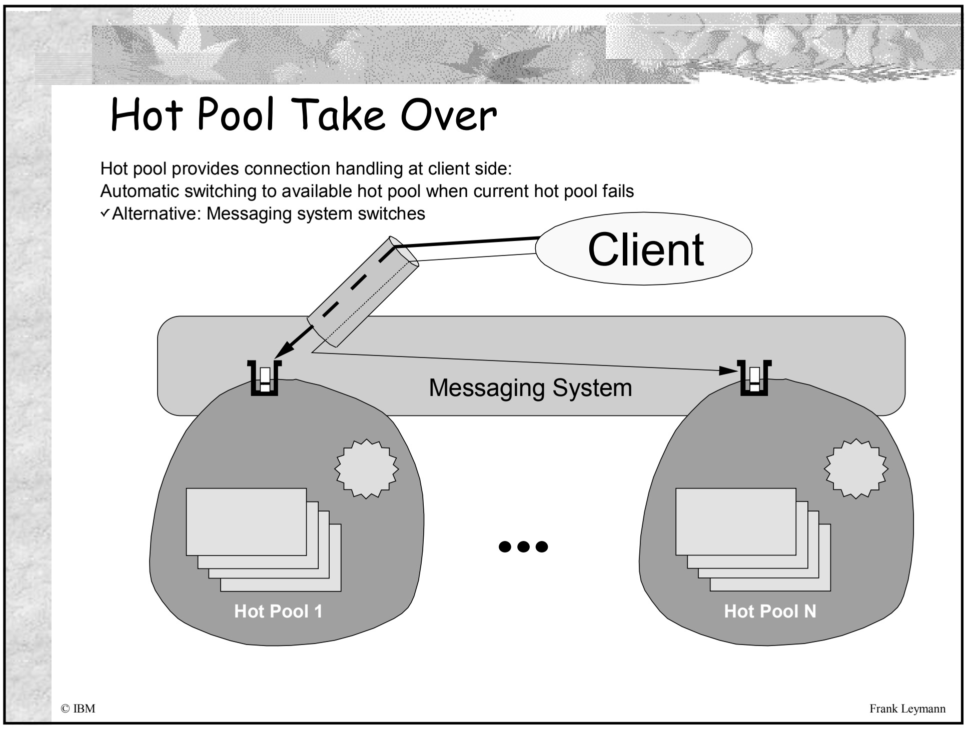

Hot Pool Take Over

Hot pool provides connection handling at client side:
Automatic switching to available hot pool when current hot pool fails
✓Alternative: Messaging system switches

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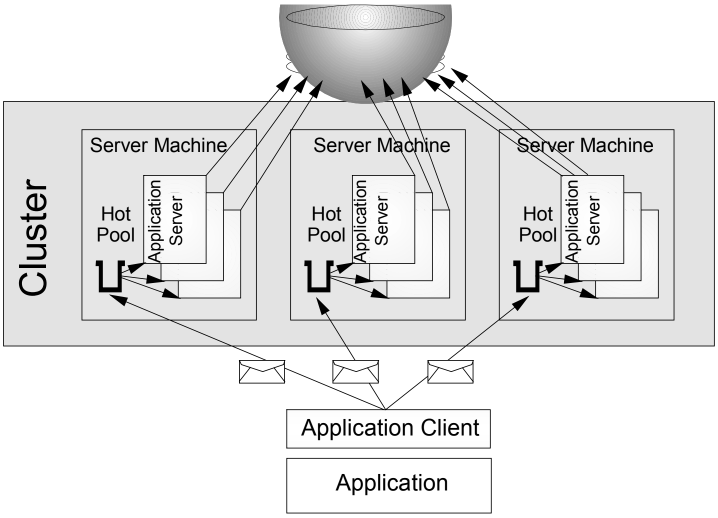
Clustering Hot Pools



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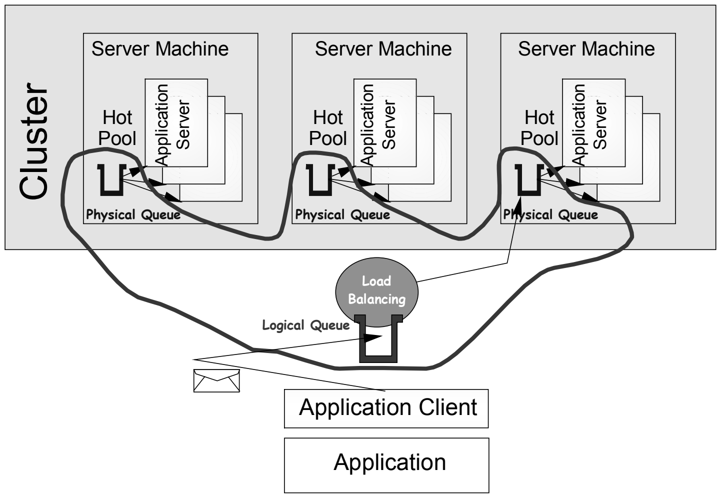
Load Balancing Via Cluster Queues



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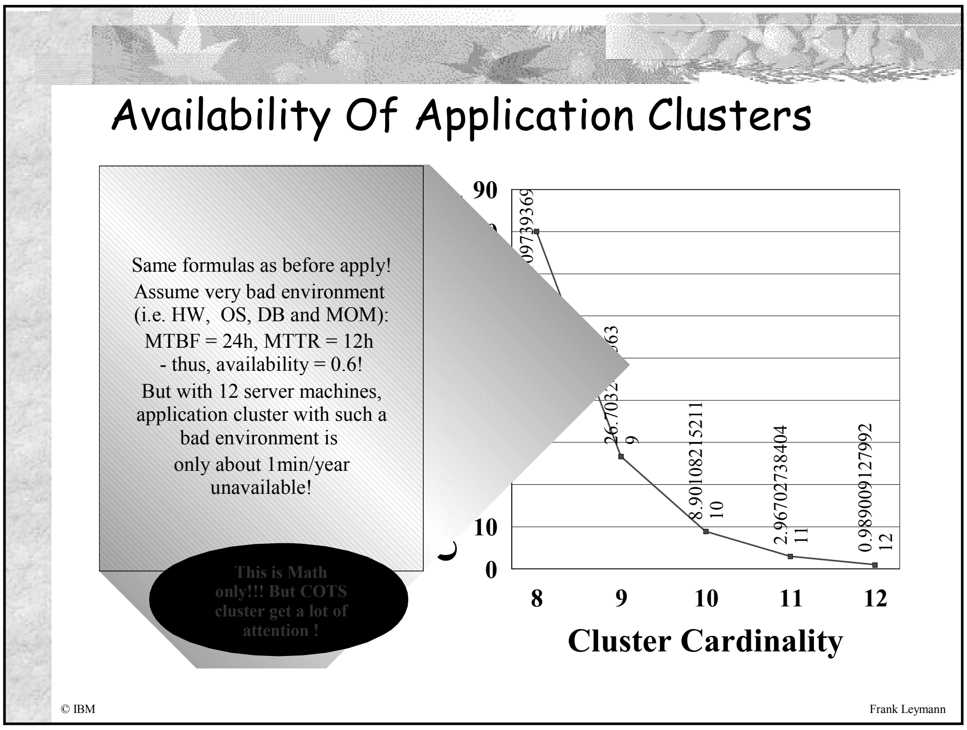

Availability Of Application Clusters

Same formulas as before apply!
Assume very bad environment
(i.e. HW, OS, DB and MOM):
MTBF = 24h, MTTR = 12h
- thus, availability = 0.6!
But with 12 server machines,
application cluster with such a
bad environment is
only about 1min/year
unavailable!

This is Math only!!! But COTS cluster get a lot of attention !

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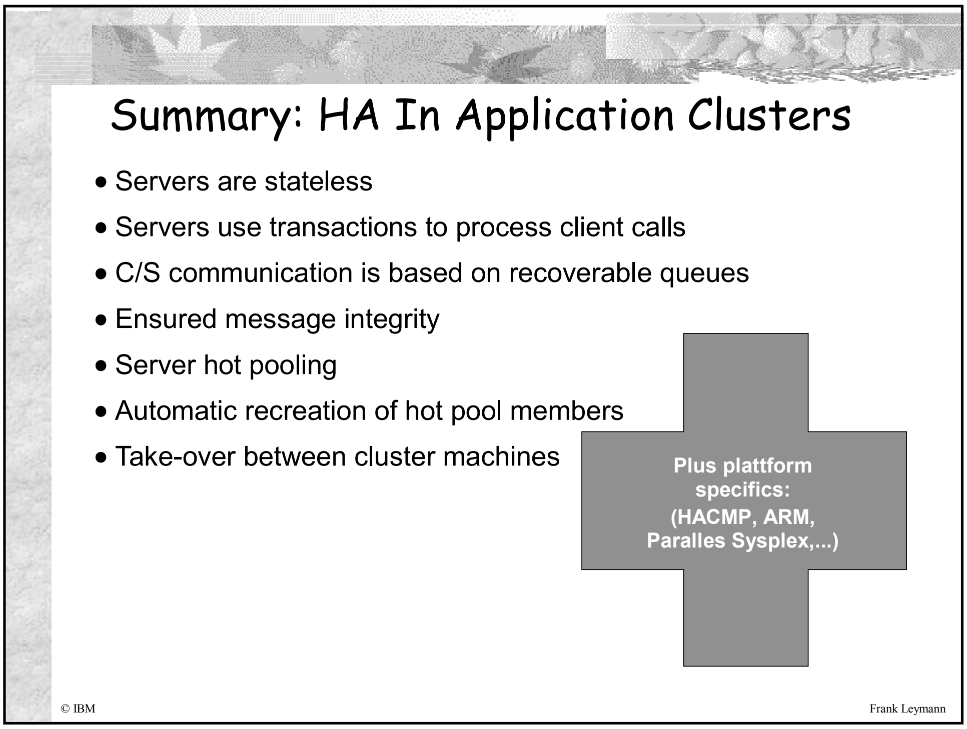

Summary: HA In Application Clusters

- Servers are stateless
- Servers use transactions to process client calls
- C/S communication is based on recoverable queues
- Ensured message integrity
- Server hot pooling
- Automatic recreation of hot pool members
- Take-over between cluster machines

Plus plattform specifics: (HACMP, ARM, Paralles Sysplex,...)

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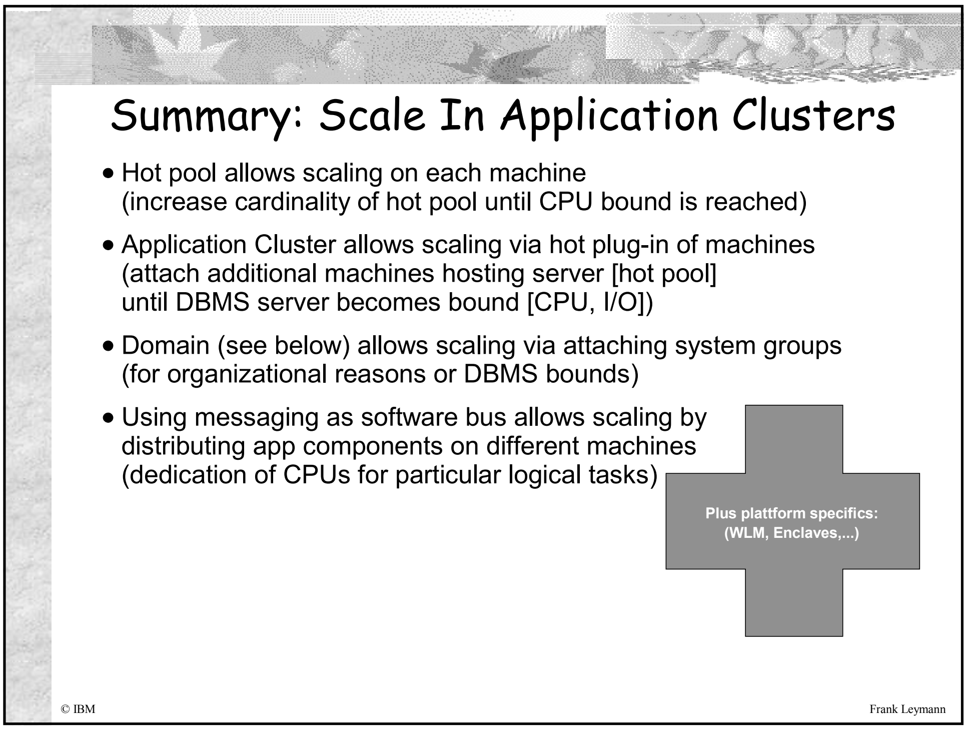

Summary: Scale In Application Clusters

- Hot pool allows scaling on each machine (increase cardinality of hot pool until CPU bound is reached)
- Application Cluster allows scaling via hot plug-in of machines (attach additional machines hosting server [hot pool] until DBMS server becomes bound [CPU, I/O])
- Domain (see below) allows scaling via attaching system groups (for organizational reasons or DBMS bounds)
- Using messaging as software bus allows scaling by distributing app components on different machines (dedication of CPUs for particular logical tasks)

Plus plattform specifics: (WLM, Enclaves,...)

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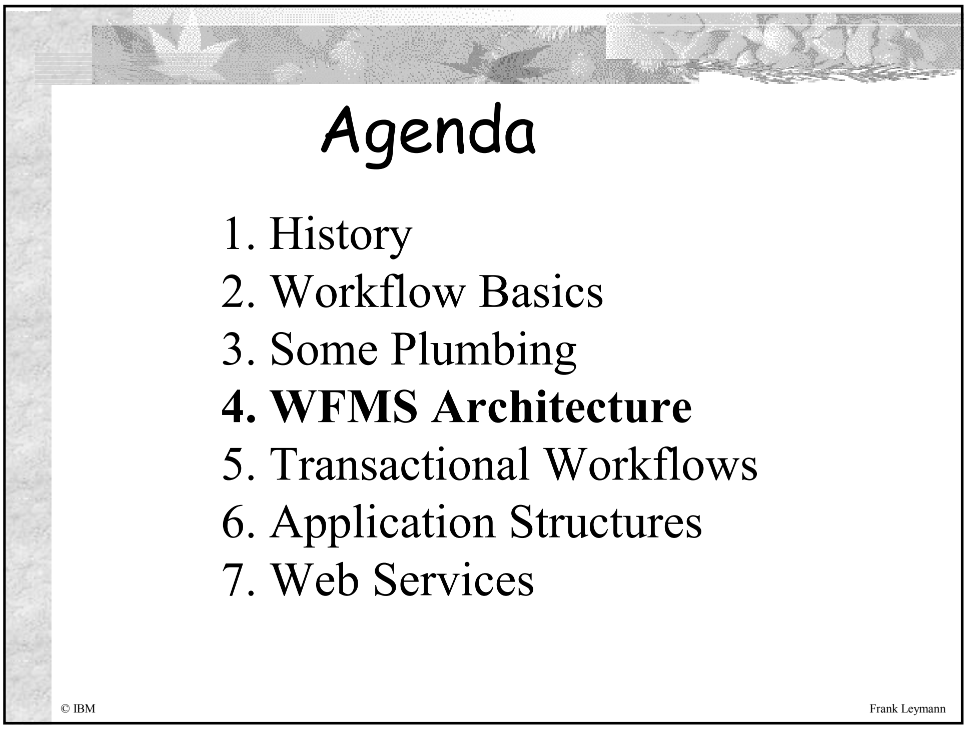

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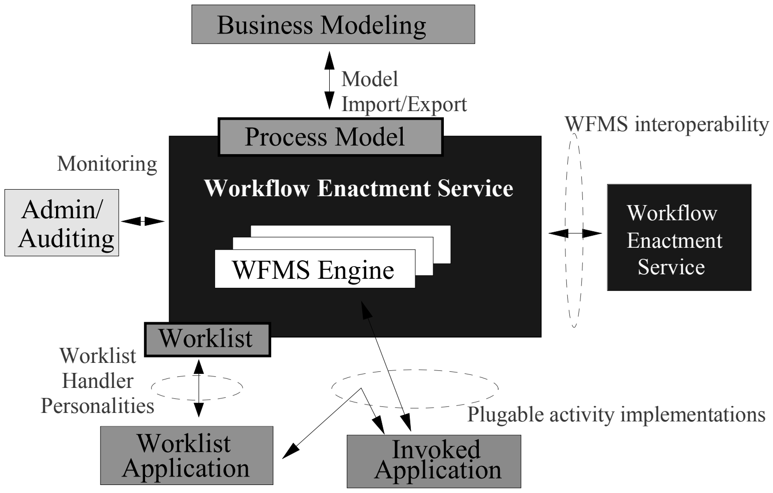
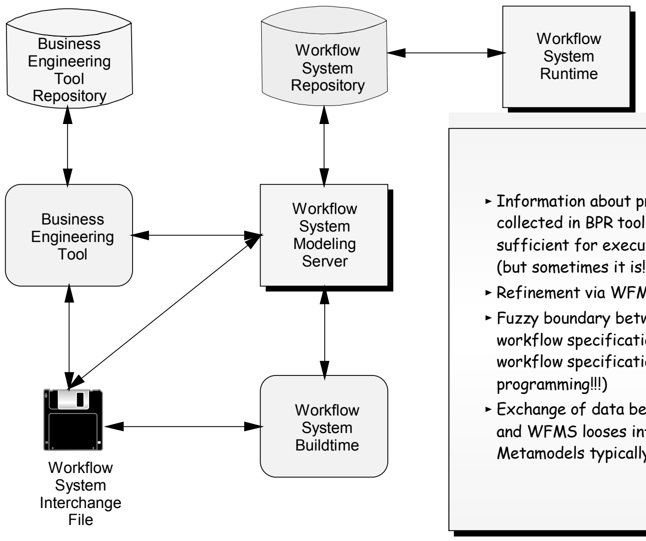
The WfMC Reference Model

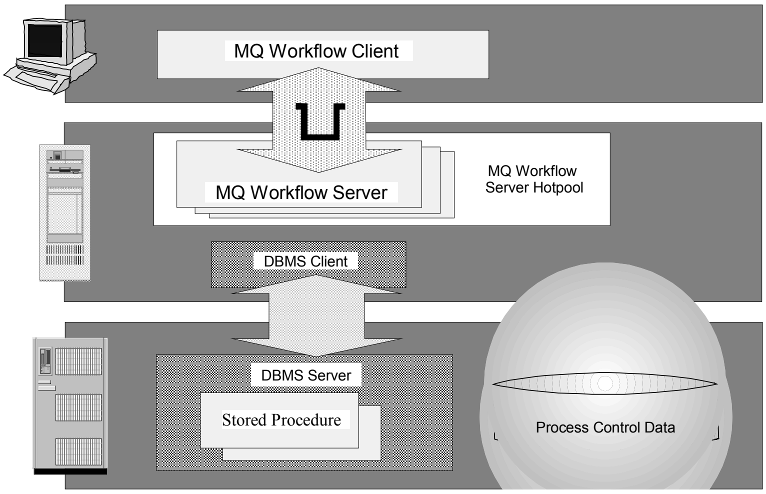


Relation Of BPR Tools And WFMS



- Information about process model collected in BPR tool often not sufficient for execution in WFMS (but sometimes it is!)
- Refinement via WFMS buildtime
- Fuzzy boundary between BPR and workflow specification (similar to workflow specification and programming!!!)
- Exchange of data between BPR tool and WFMS looses information: Metamodels typically different

Three-Tier-Architecture



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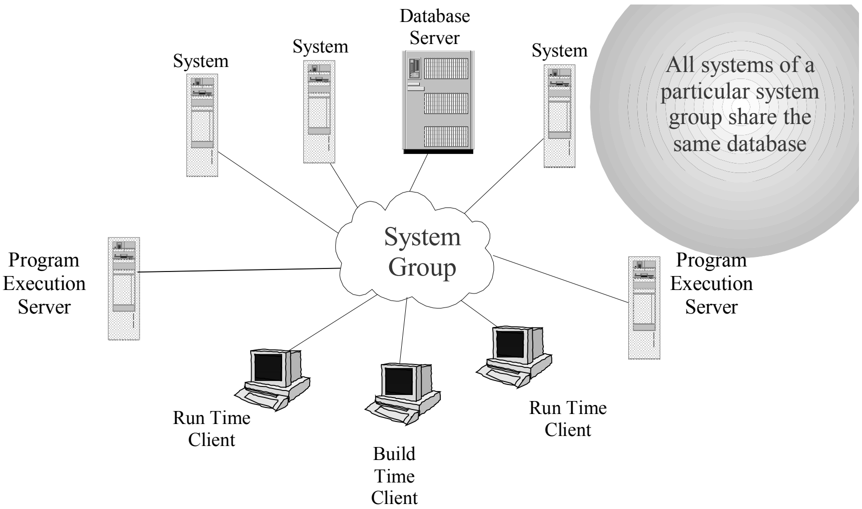
System Groups



All systems of a particular system group share the same database

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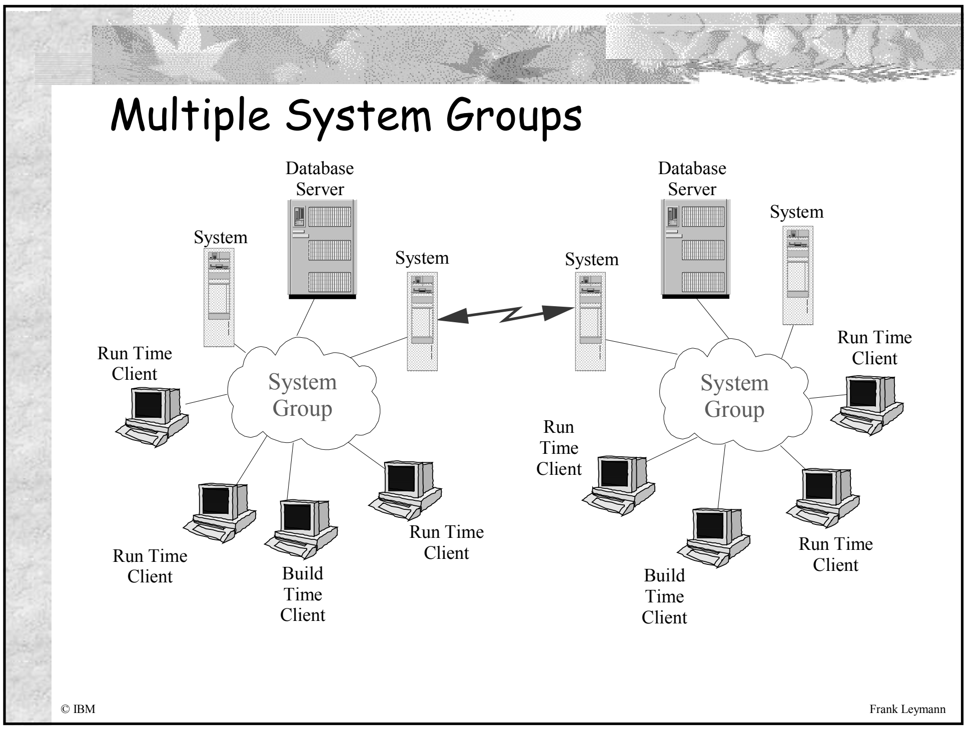

Multiple System Groups

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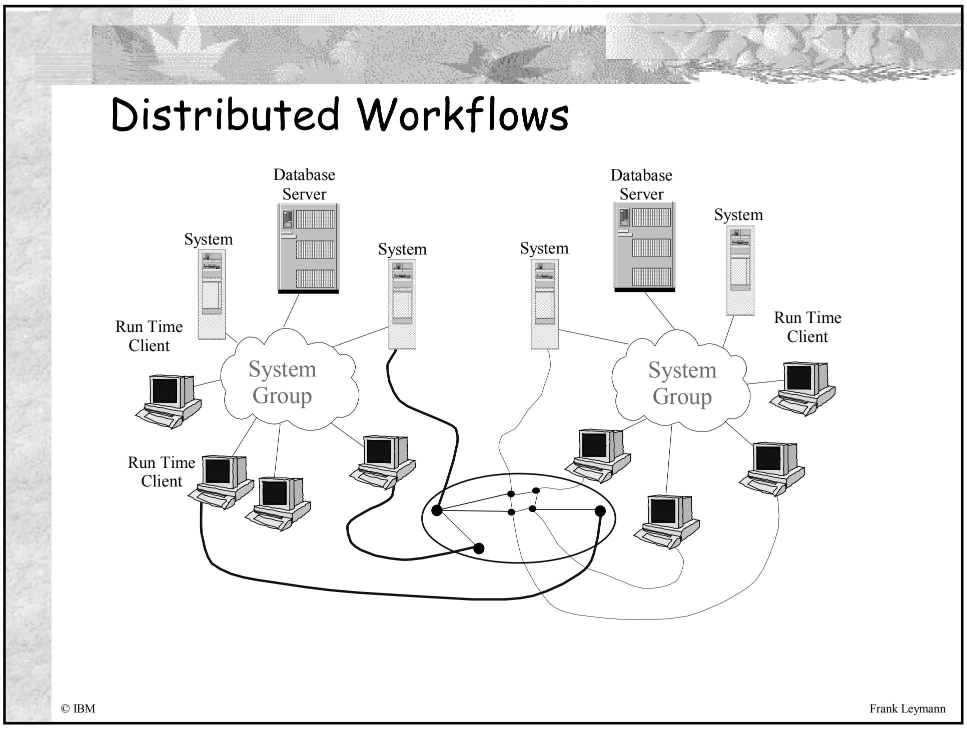

Distributed Workflows

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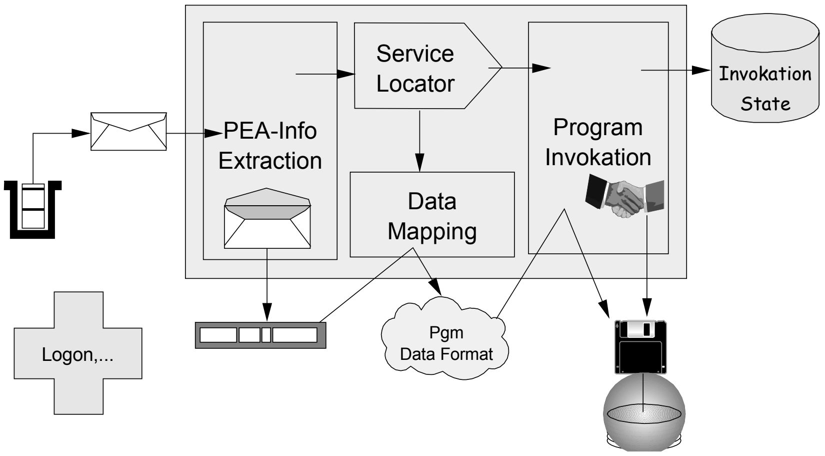
Invoking Activity Implementations



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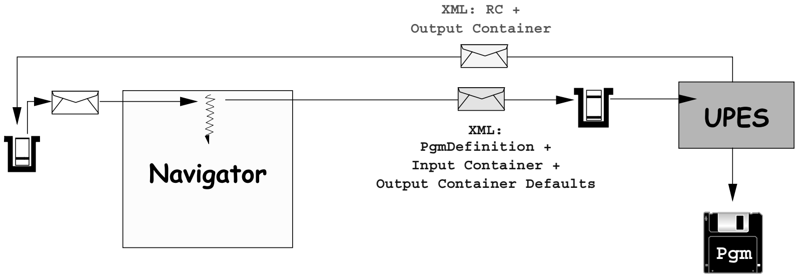
User Provided Invocation



- UPES has to commit certain quality of services like the corresponding PES provided by the WFMS vendor
  - ✓ For example, exactly once invocation for safe activities (see later)
- Otherwise, UPES can be any kind of implementation

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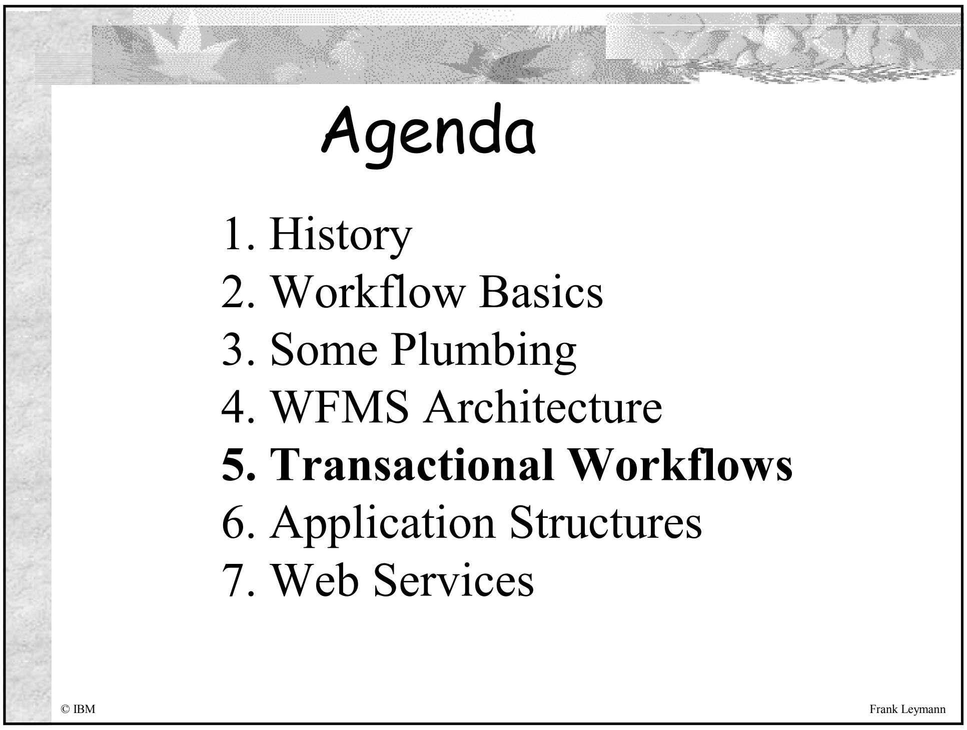

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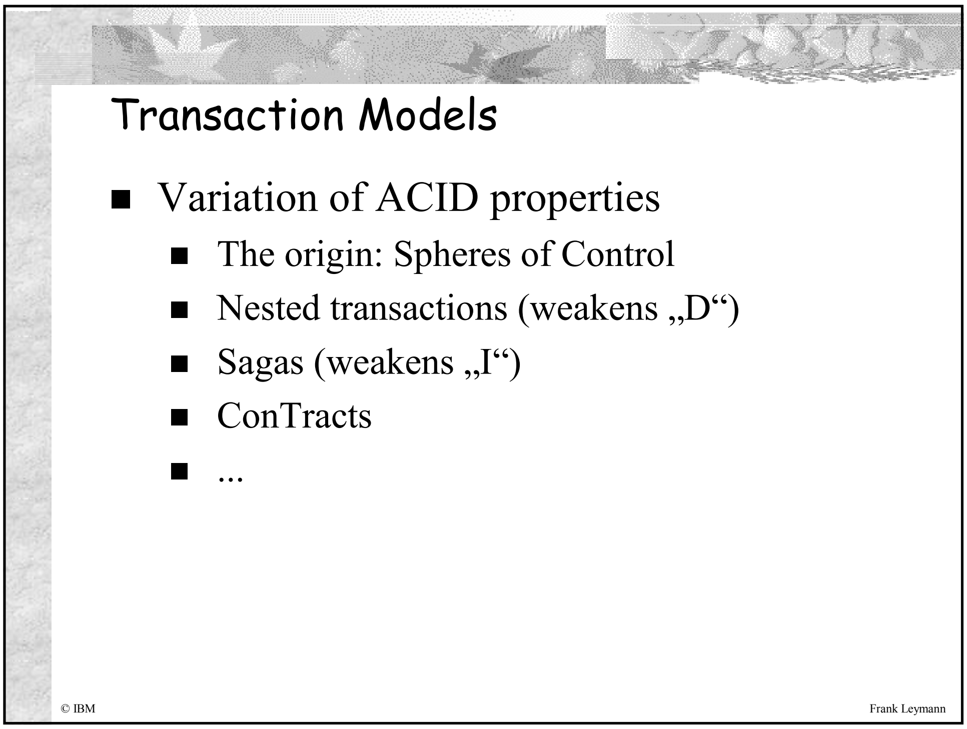

Transaction Models

- Variation of ACID properties
  - The origin: Spheres of Control
  - Nested transactions (weakens „D“)
  - Sagas (weakens „I“)
  - ConTracts
  - ...

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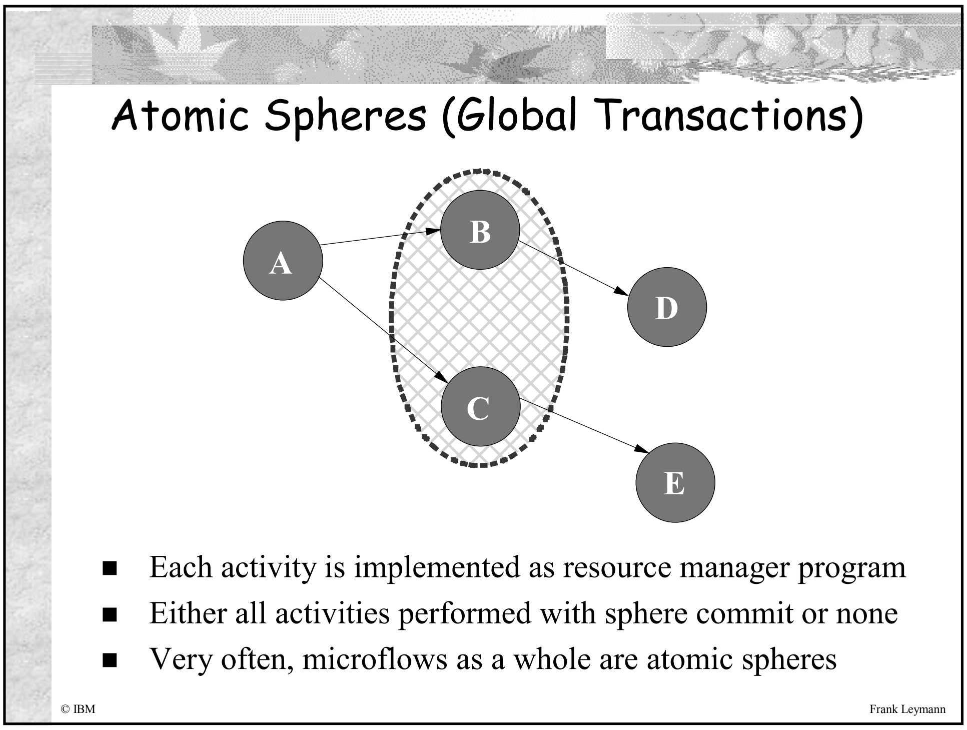

Atomic Spheres (Global Transactions)

- Each activity is implemented as resource manager program
- Either all activities performed with sphere commit or none
- Very often, microflows as a whole are atomic spheres

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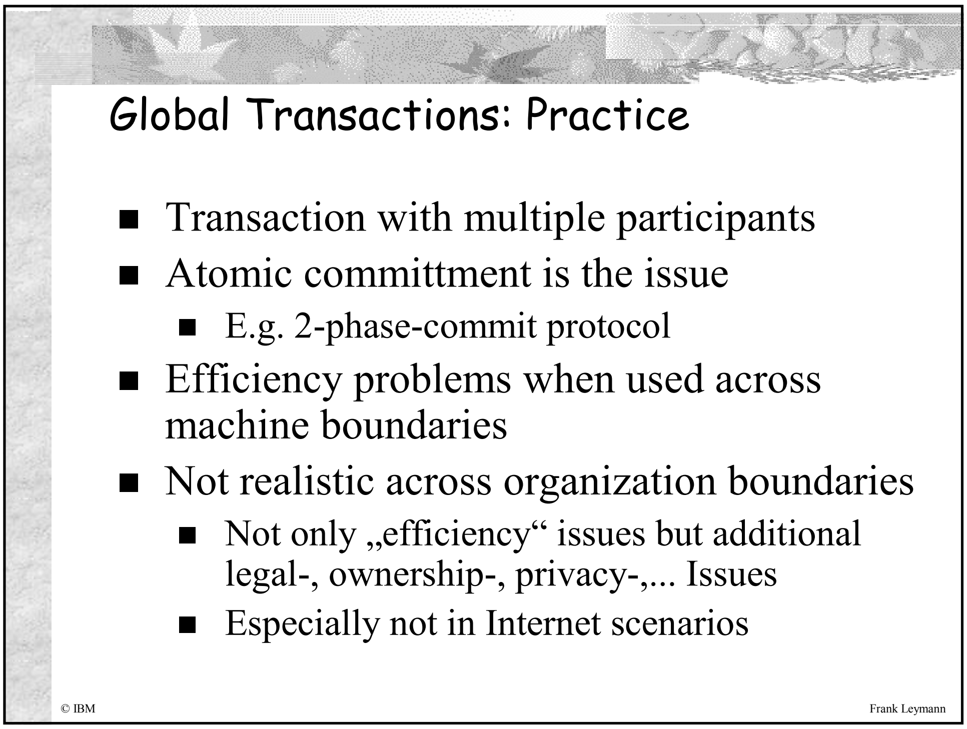

Global Transactions: Practice

- Transaction with multiple participants
- Atomic committment is the issue
  - E.g. 2-phase-commit protocol
- Efficiency problems when used across machine boundaries
- Not realistic across organization boundaries
  - Not only „efficiency“ issues but additional legal-, ownership-, privacy-,... Issues
  - Especially not in Internet scenarios

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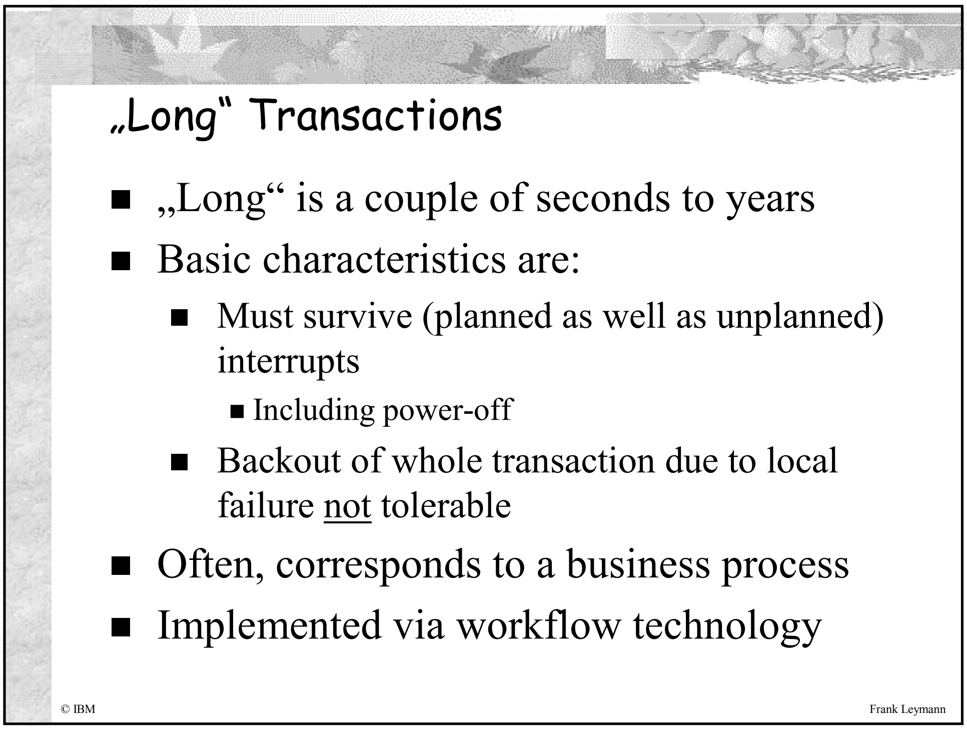

„Long" Transactions

- „Long" is a couple of seconds to years
- Basic characteristics are:
  - Must survive (planned as well as unplanned) interrupts
    - Including power-off
  - Backout of whole transaction due to local failure <u>not</u> tolerable
- Often, corresponds to a business process
- Implemented via workflow technology

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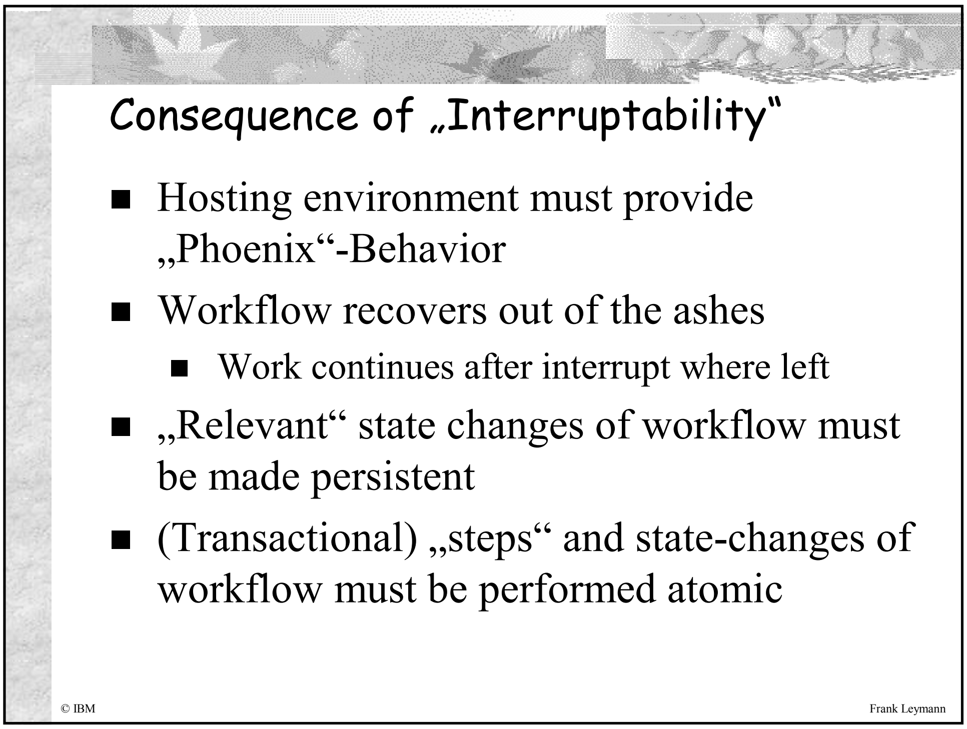

Consequence of „Interruptability"

- Hosting environment must provide „Phoenix"-Behavior
- Workflow recovers out of the ashes
  - Work continues after interrupt where left
- „Relevant" state changes of workflow must be made persistent
- (Transactional) „steps" and state-changes of workflow must be performed atomic

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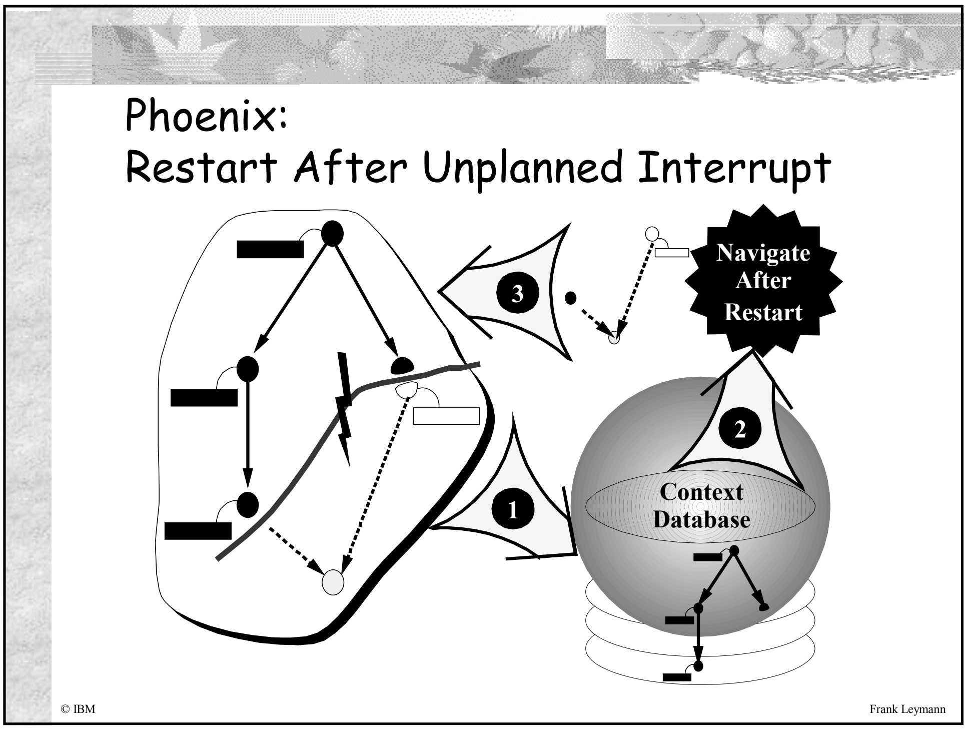

Phoenix: Restart After Unplanned Interrupt

3

Navigate After Restart

2

1

Context Database

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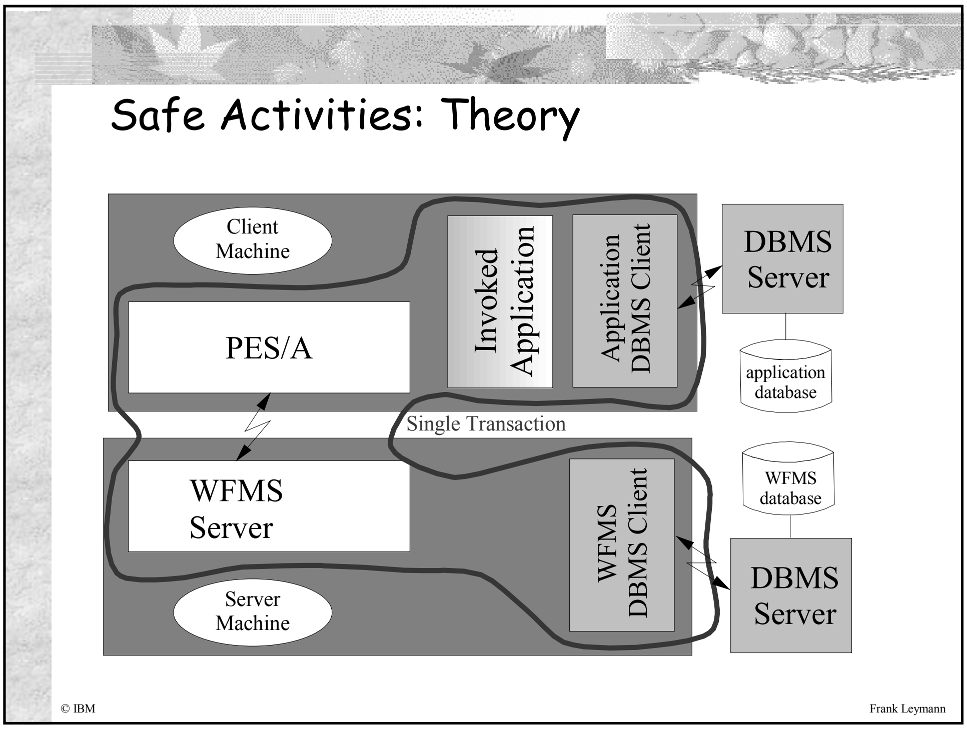

Safe Activities: Theory

Client Machine

PES/A

Invoked Application

Application DBMS Client

DBMS Server

application database

Single Transaction

WFMS Server

WFMS DBMS Client

WFMS database

DBMS Server

Server Machine

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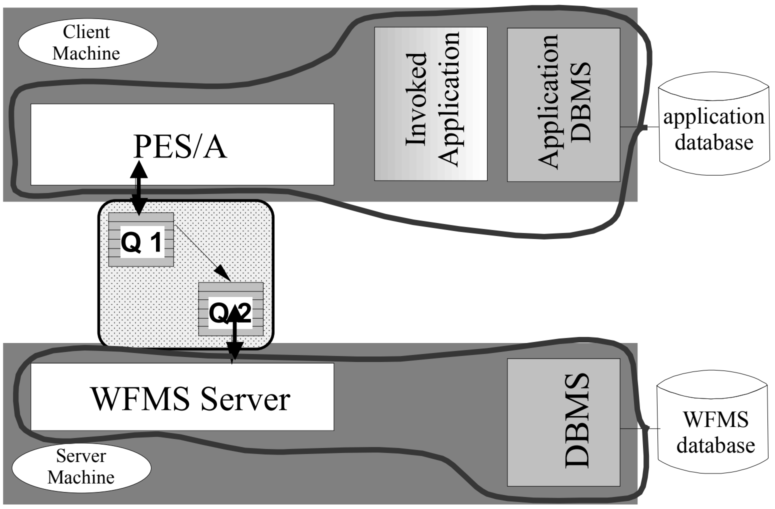
Safe Activities: Practice



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Consequence of „No System Initiated Backout“

- Handling of exceptions is explicitly modeled
    - By means of flow constructs
    - Compensation actions
- System can initiate human intervention to repair erroneous situations
    - Failed steps set in „error“ state
    - Hosting environment stops regular processing
    - Notification to specified personell
    - Fix container content
    - Fix activity implementation
    - Skip, retry,... activity
    - Suspend, resume, terminate, compensate,... Workflow
- Also important for automatic workflows

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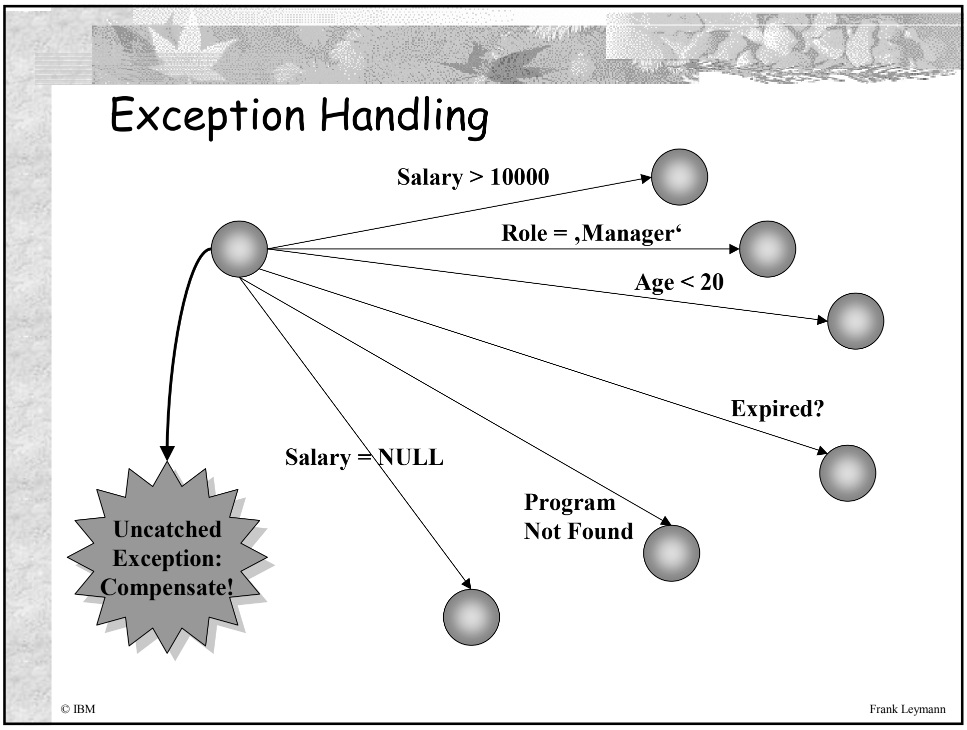

Exception Handling

Salary > 10000

Role = ‚Manager‘

Age < 20

Expired?

Salary = NULL

Program
Not Found

Uncatched
Exception:
Compensate!

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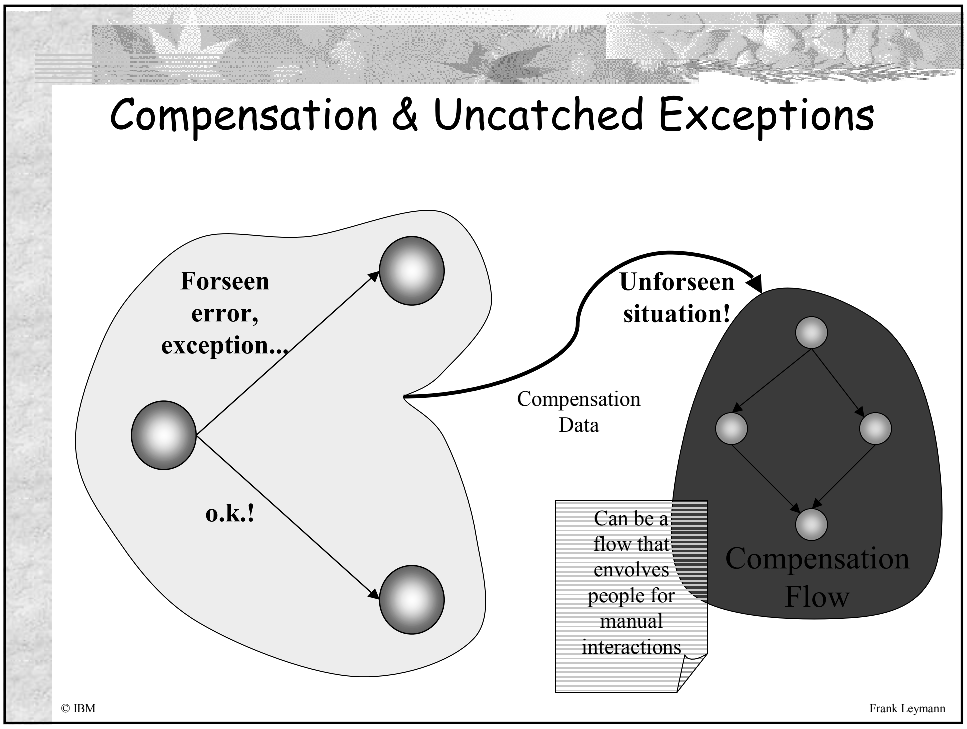

Compensation & Uncatched Exceptions

Forseen
error,
exception...

o.k.!

Unforseen
situation!

Compensation
Data

Can be a
flow that
envolves
people for
manual
interactions

Compensation
Flow

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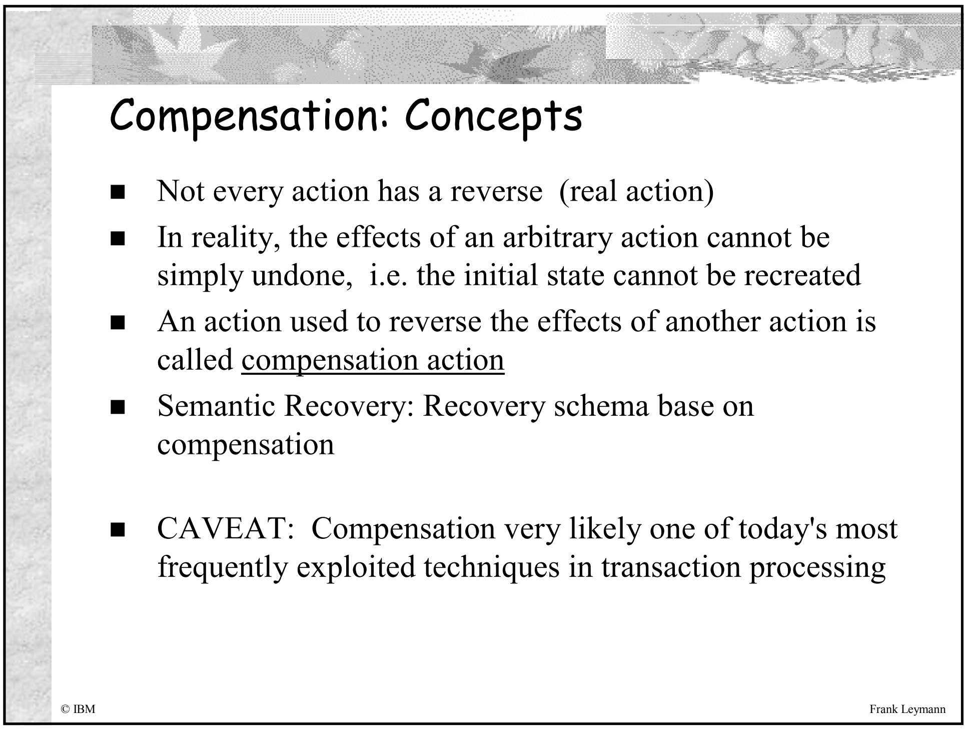

Compensation: Concepts

- Not every action has a reverse (real action)
- In reality, the effects of an arbitrary action cannot be simply undone, i.e. the initial state cannot be recreated
- An action used to reverse the effects of another action is called <u>compensation action</u>
- Semantic Recovery: Recovery schema base on compensation
- CAVEAT: Compensation very likely one of today's most frequently exploited techniques in transaction processing

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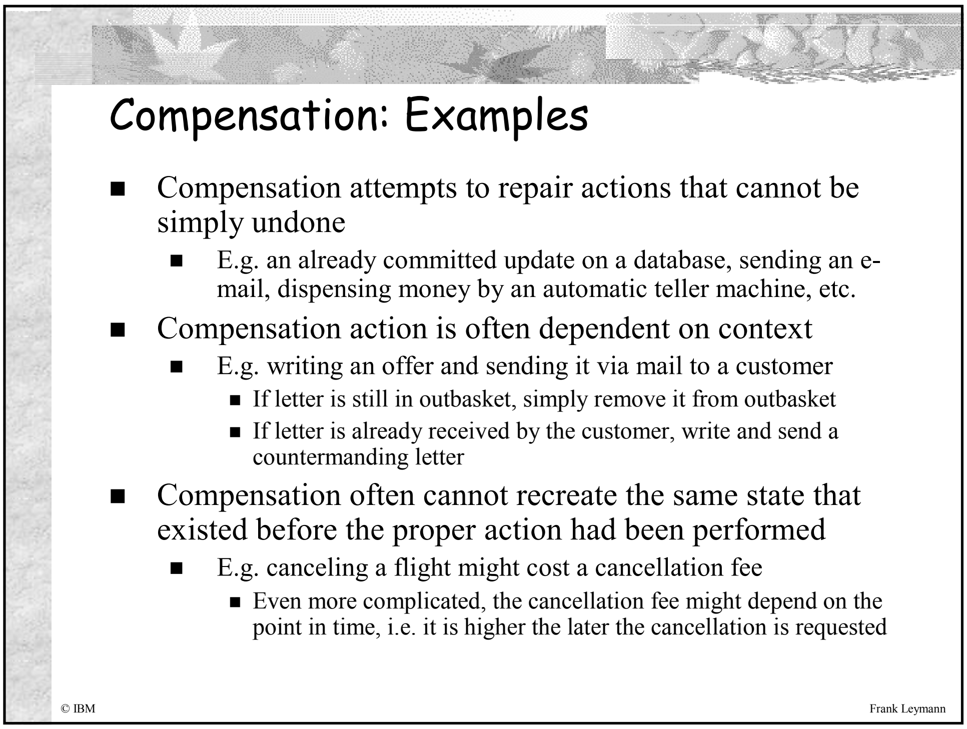

Compensation: Examples

- Compensation attempts to repair actions that cannot be simply undone
  - E.g. an already committed update on a database, sending an e-mail, dispensing money by an automatic teller machine, etc.
- 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

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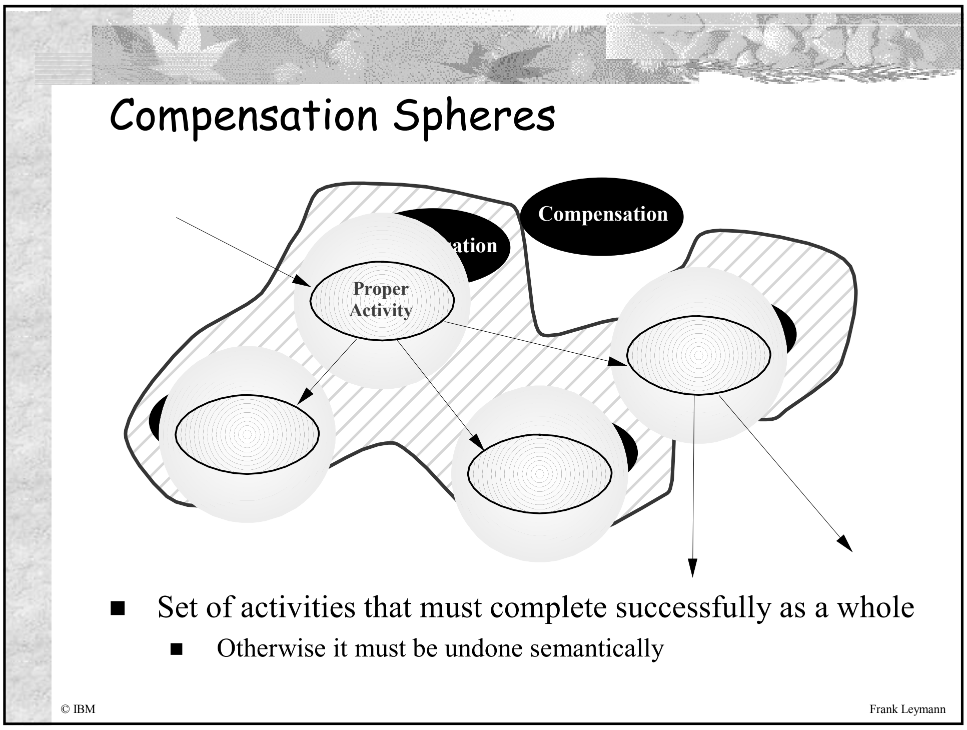

Compensation Spheres

- Set of activities that must complete successfully as a whole
  - Otherwise it must be undone semantically

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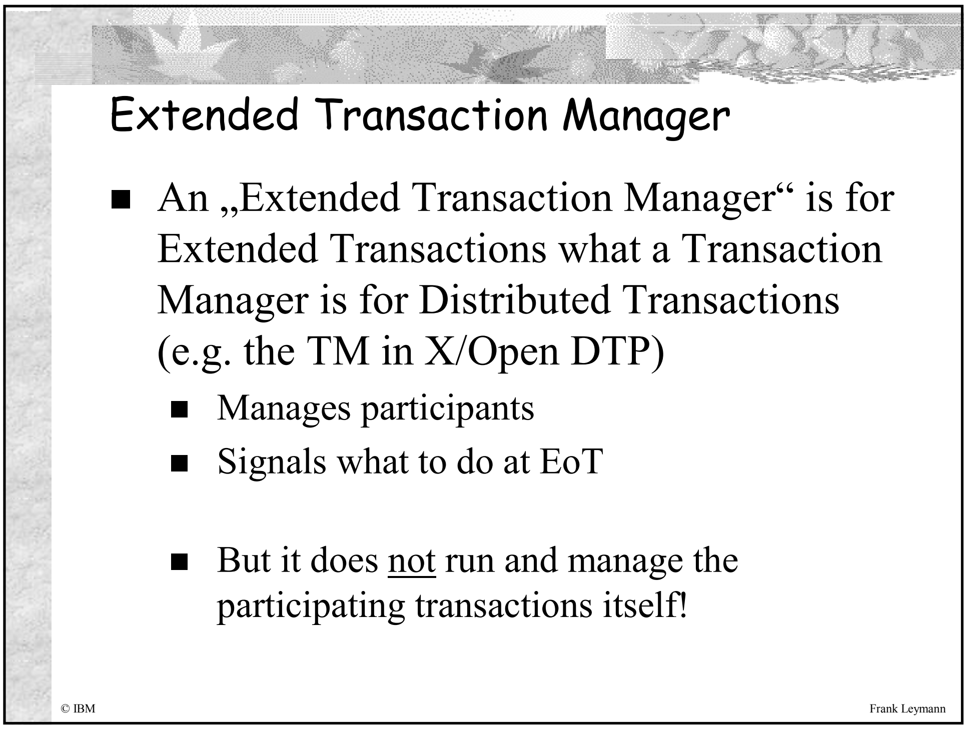

Extended Transaction Manager

- An „Extended Transaction Manager“ is for Extended Transactions what a Transaction Manager is for Distributed Transactions (e.g. the TM in X/Open DTP)
  - Manages participants
  - Signals what to do at EoT
  - But it does not run and manage the participating transactions itself!

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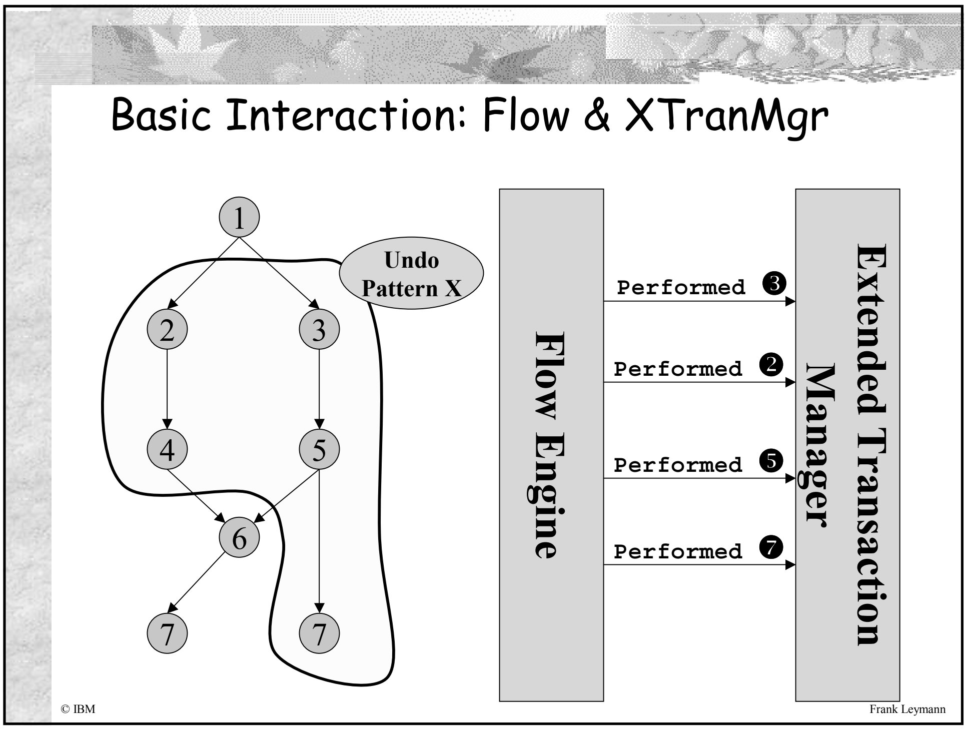

Basic Interaction: Flow & XTranMgr

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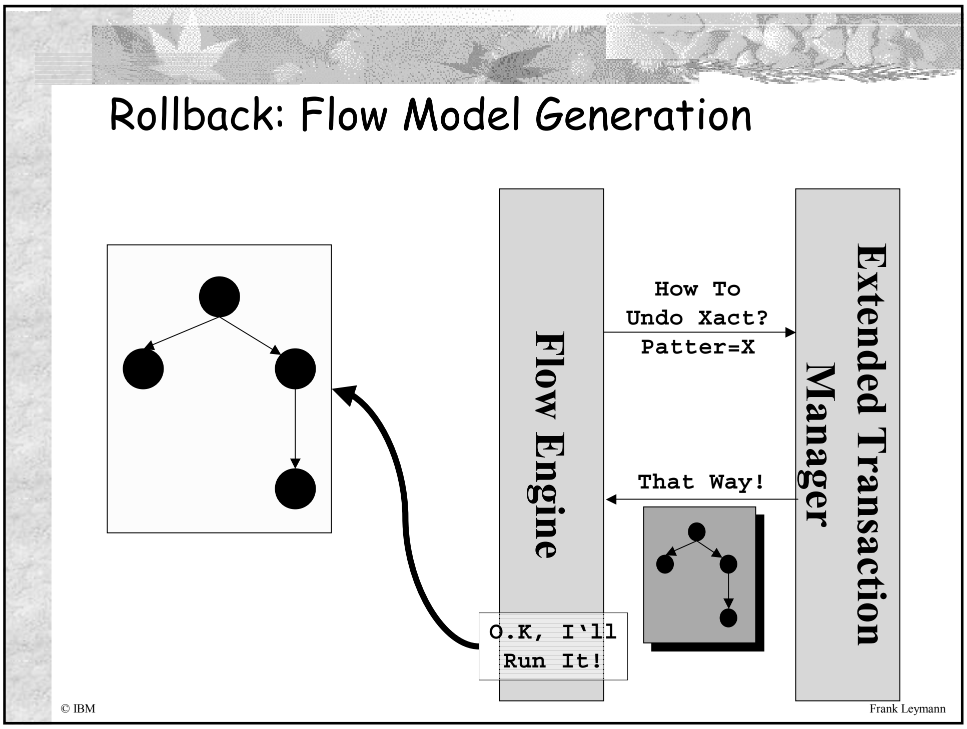

Rollback: Flow Model Generation

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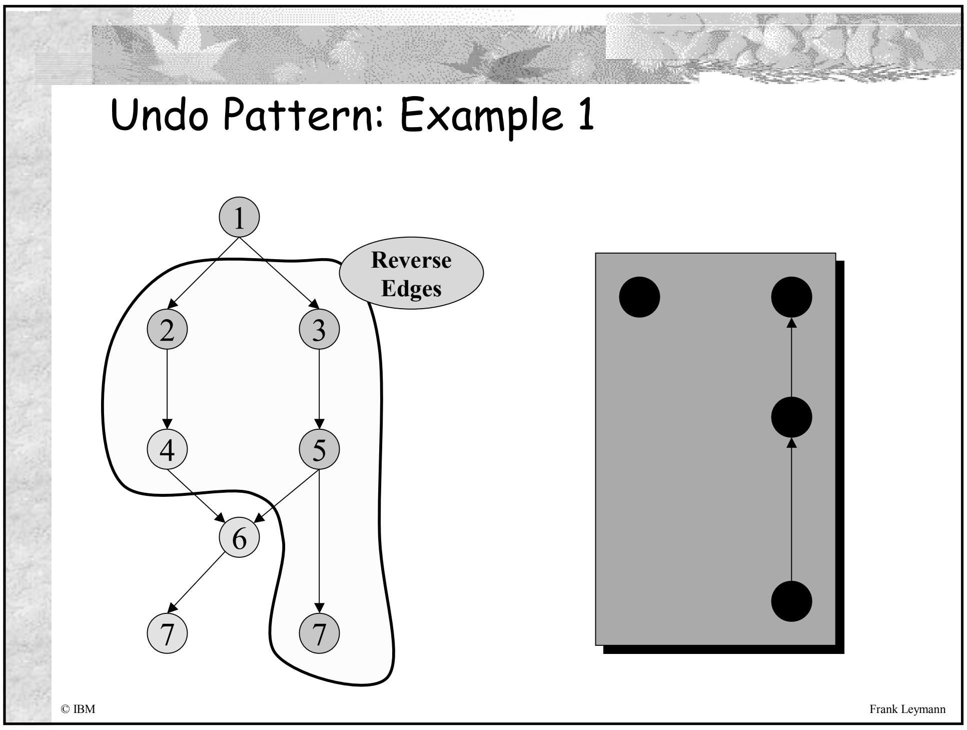

Undo Pattern: Example 1

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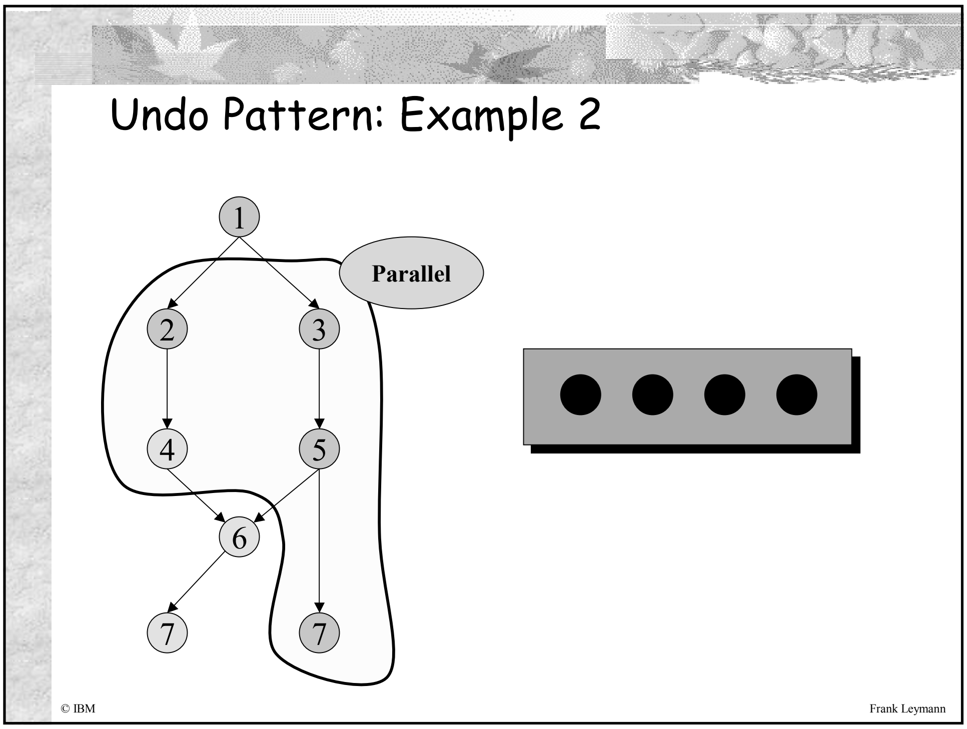

Undo Pattern: Example 2

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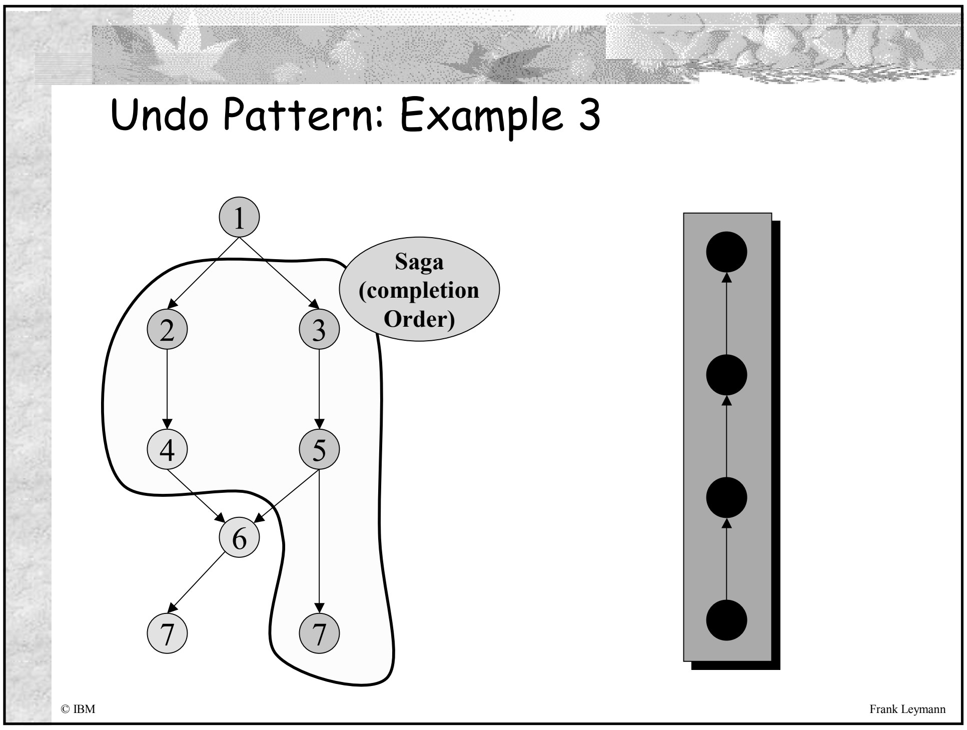

Undo Pattern: Example 3

Saga (completion Order)

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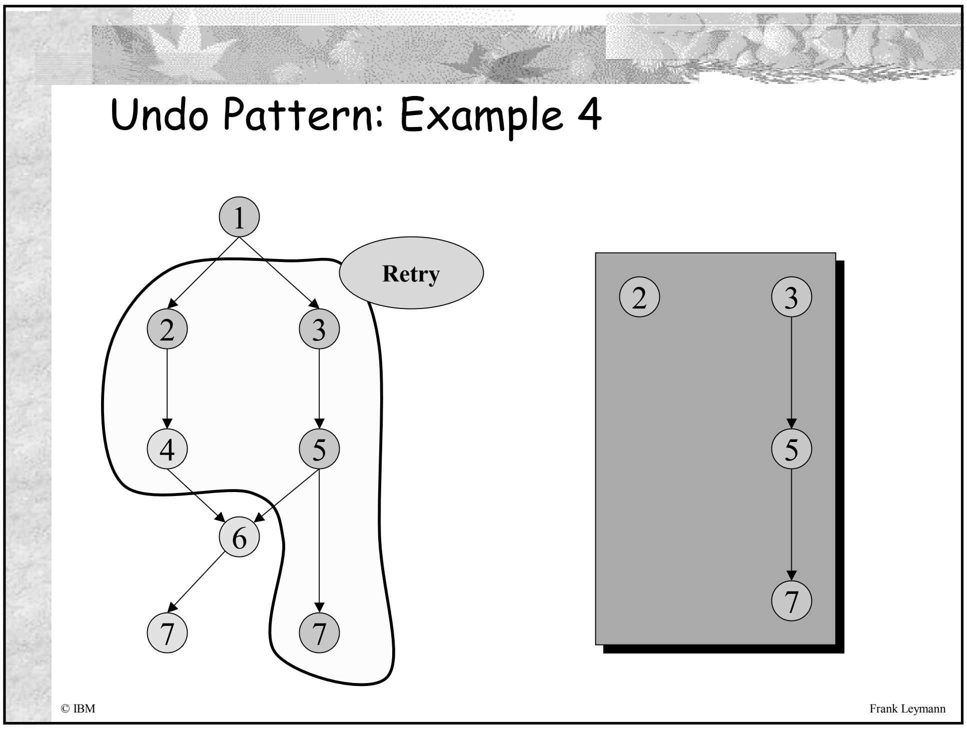

Undo Pattern: Example 4

Retry

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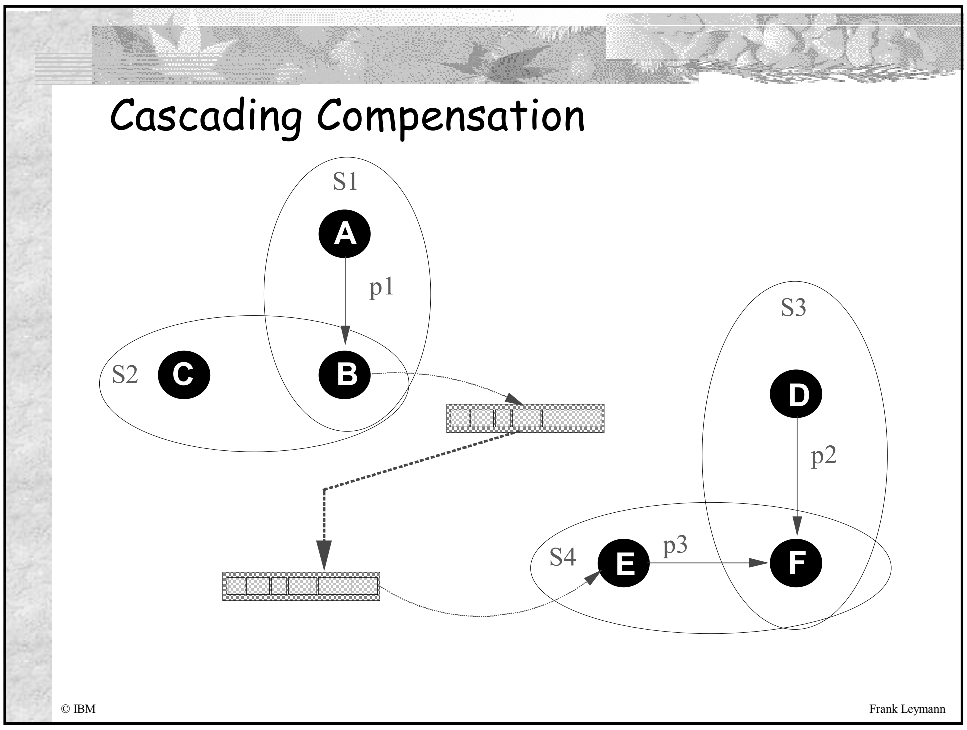

Cascading Compensation

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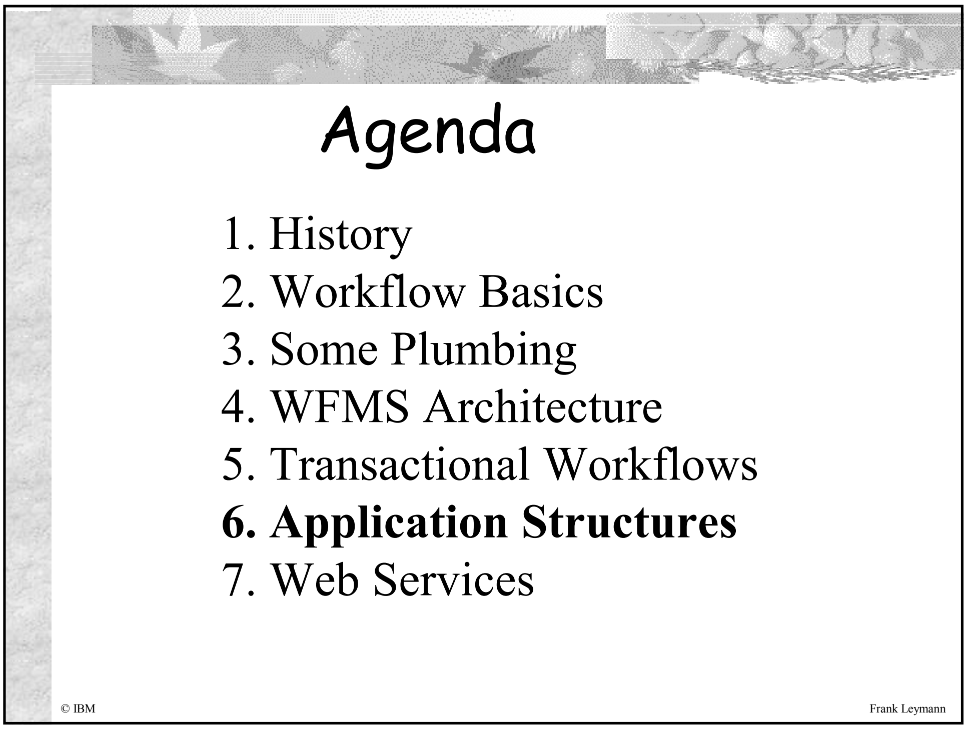

Agenda

1. History
2. Workflow Basics
3. Some Plumbing
4. WFMS Architecture
5. Transactional Workflows
6. **Application Structures**
7. Web Services

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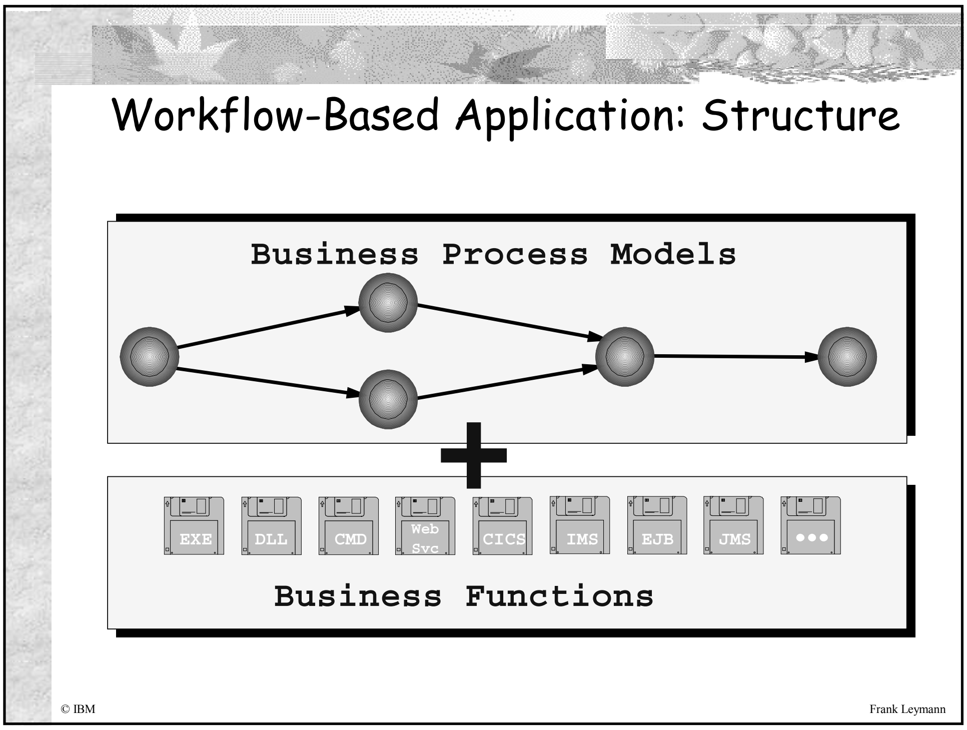

Workflow-Based Application: Structure

Business Process Models

Business Functions

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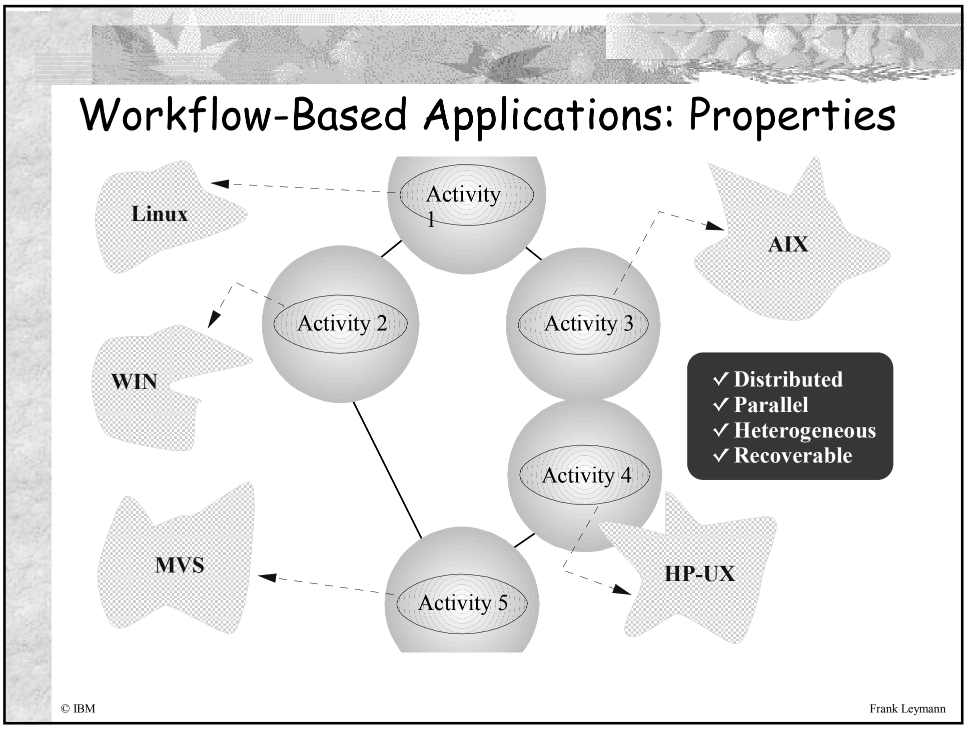

Workflow-Based Applications: Properties

✓ Distributed
✓ Parallel
✓ Heterogeneous
✓ Recoverable

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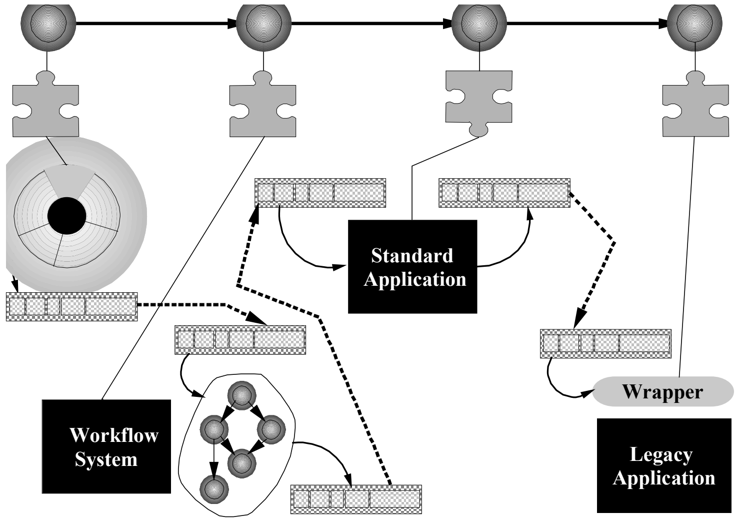
Application Integration



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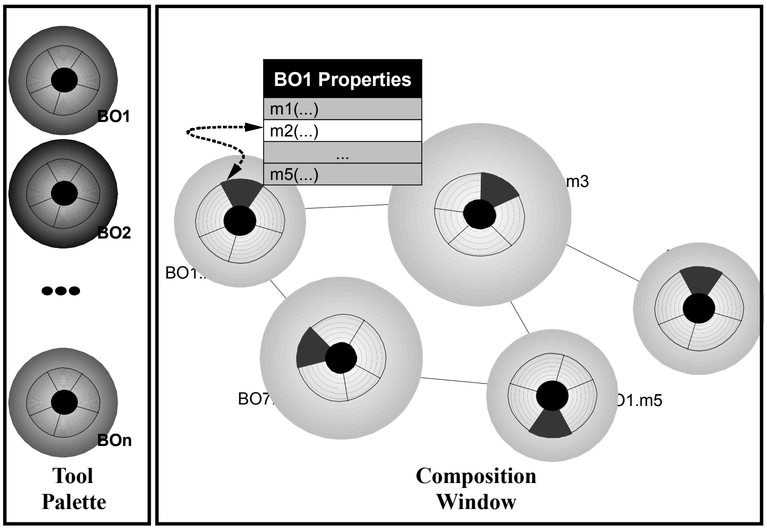
Using „Components" In Workflows



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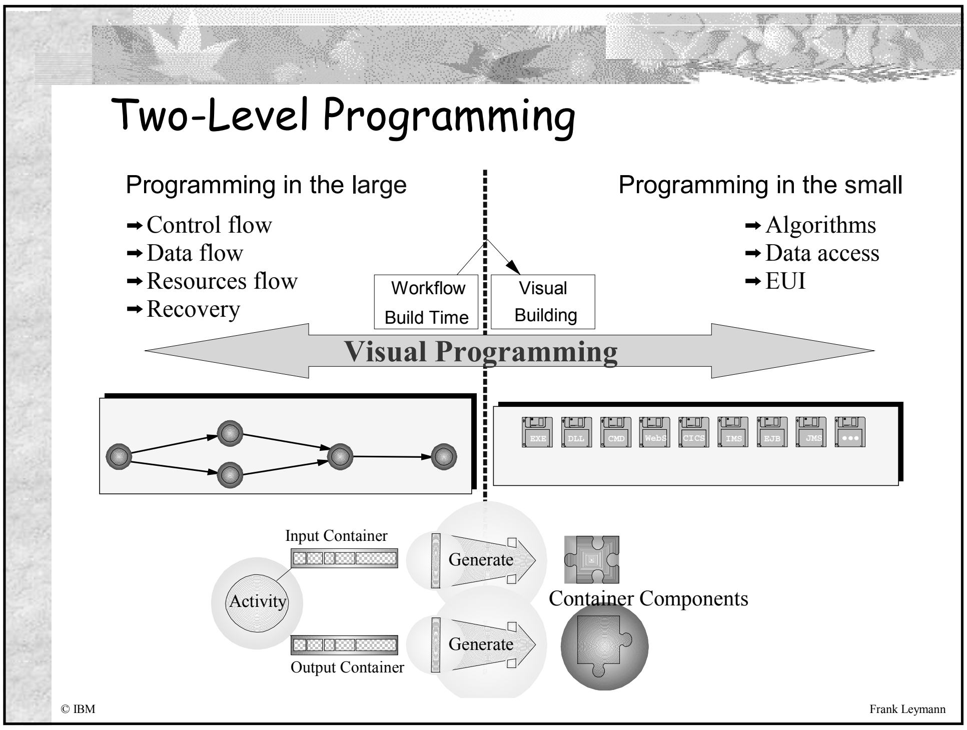

Two-Level Programming

Programming in the large

- ➡Control flow
- ➡Data flow
- ➡Resources flow
- ➡Recovery

Programming in the small

- ➡Algorithms
- ➡Data access
- ➡EUI

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Agenda

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6. Application Structures
7. **Web Services**

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Workflows On The Internet

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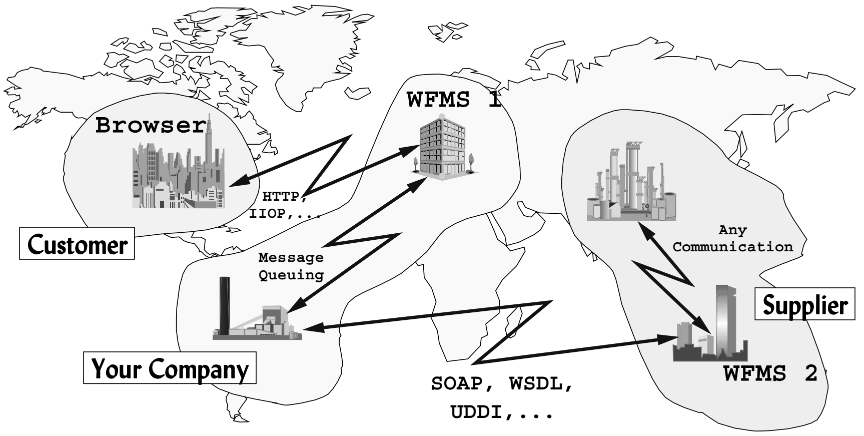
Virtual Enterprise: Scenario



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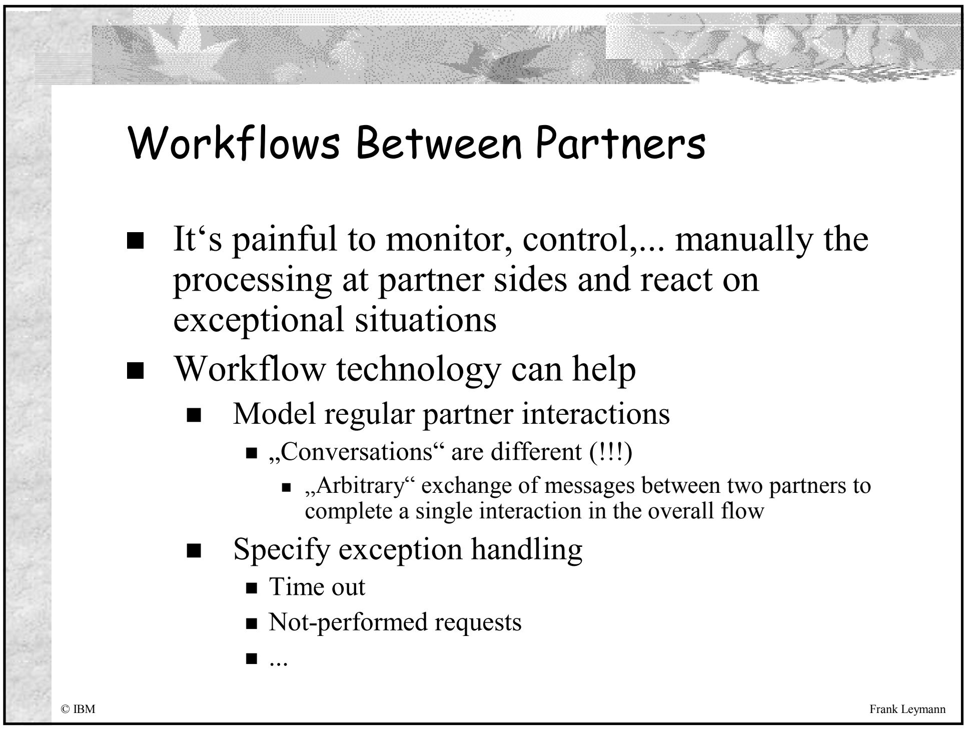

Workflows Between Partners

- It‘s painful to monitor, control,... manually the processing at partner sides and react on exceptional situations
- Workflow technology can help
  - Model regular partner interactions
    - „Conversations“ are different (!!!)
      - „Arbitrary“ exchange of messages between two partners to complete a single interaction in the overall flow
  - Specify exception handling
    - Time out
    - Not-performed requests
    - ...

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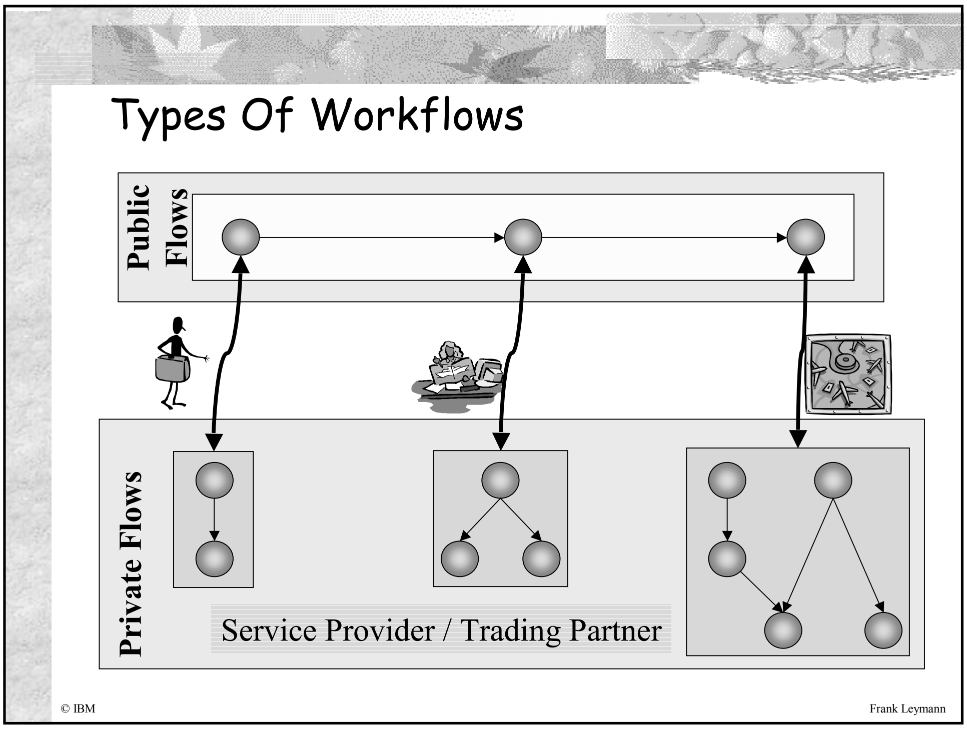

Types Of Workflows

Public Flows

Private Flows

Service Provider / Trading Partner

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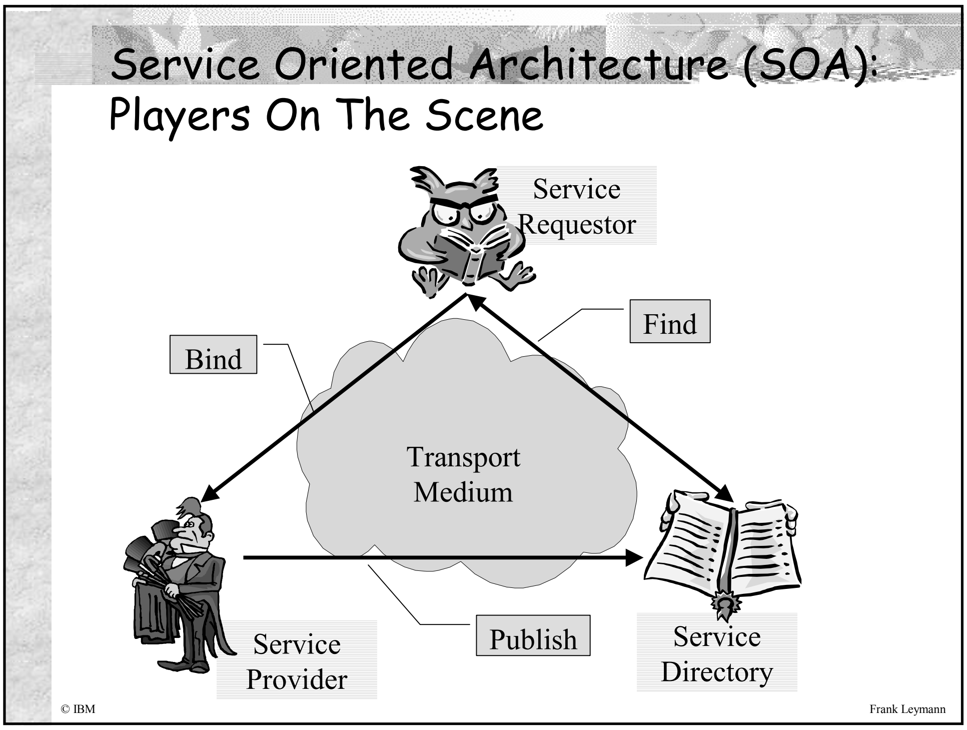

Service Oriented Architecture (SOA): Players On The Scene

Service Requestor

Find

Bind

Transport Medium

Service Provider

Publish

Service Directory

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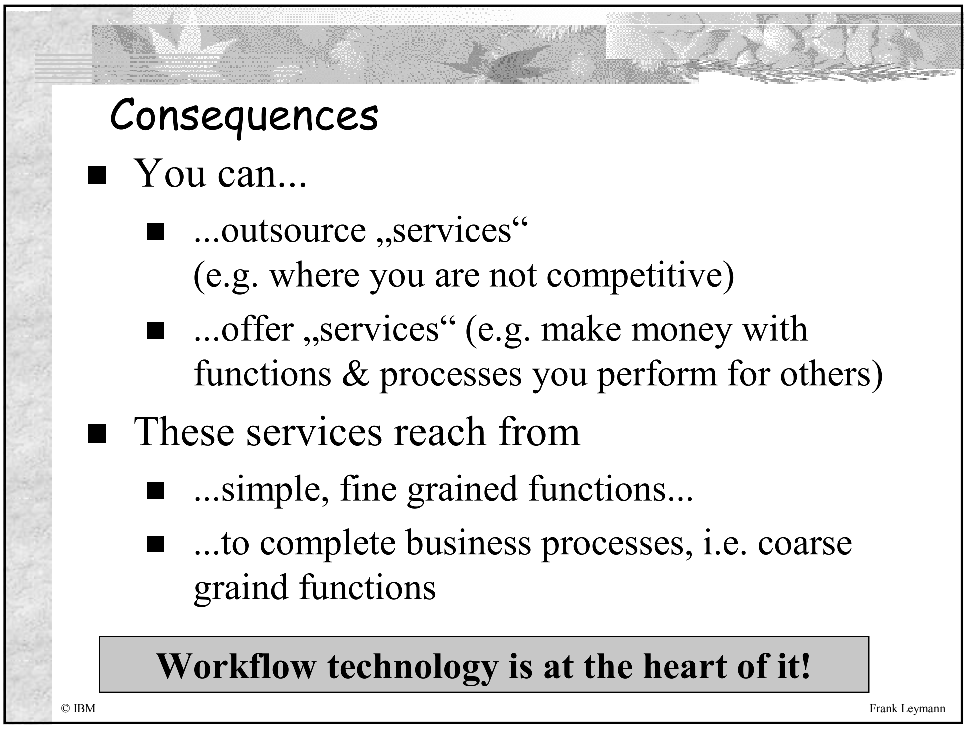

Consequences

- You can...
  - ...outsource „services“ (e.g. where you are not competitive)
  - ...offer „services“ (e.g. make money with functions & processes you perform for others)
- These services reach from
  - ...simple, fine grained functions...
  - ...to complete business processes, i.e. coarse graind functions

Workflow technology is at the heart of it!

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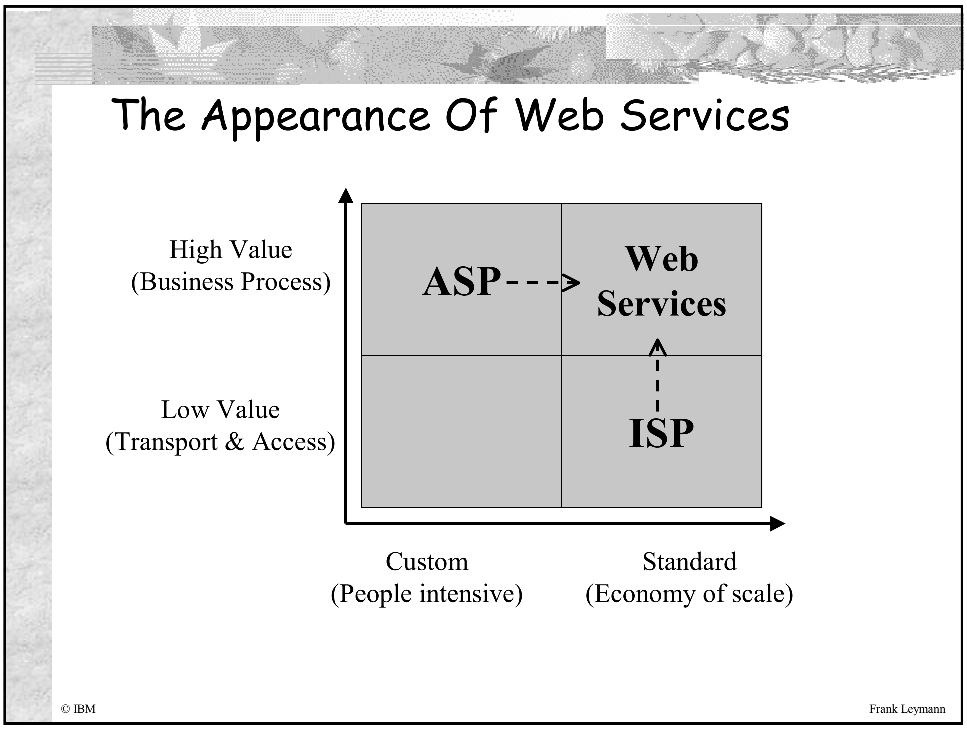

The Appearance Of Web Services

High Value
(Business Process)

Low Value
(Transport & Access)

ASP - - -> Web Services

ISP

Custom
(People intensive)

Standard
(Economy of scale)

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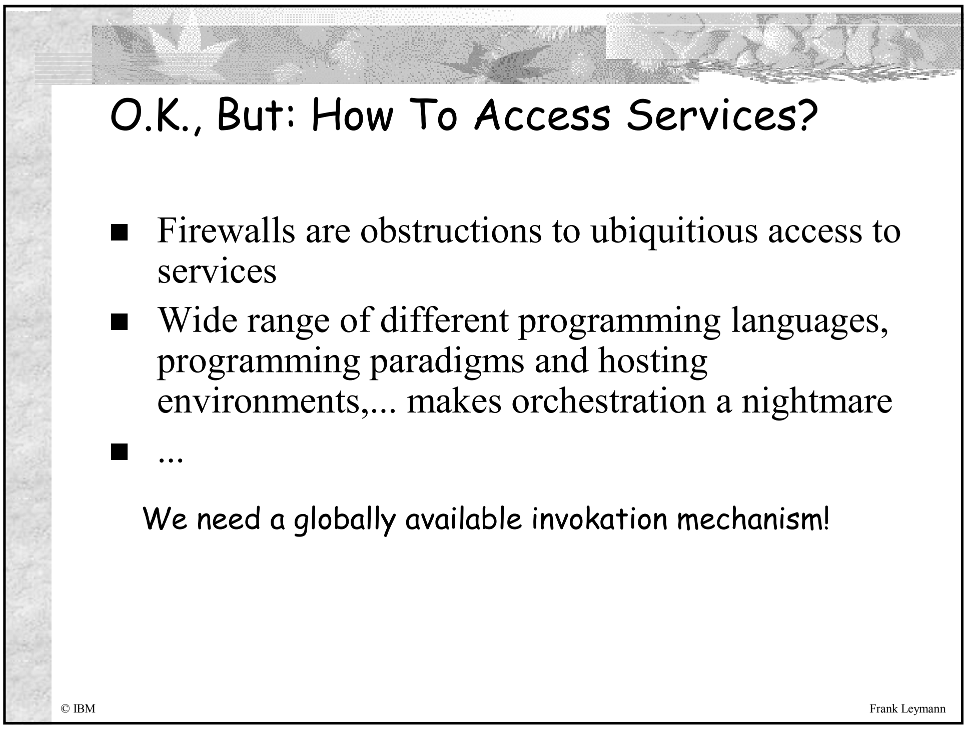

O.K., But: How To Access Services?

- Firewalls are obstructions to ubiquitious access to services
- Wide range of different programming languages, programming paradigms and hosting environments,... makes orchestration a nightmare
- ...

We need a globally available invokation mechanism!

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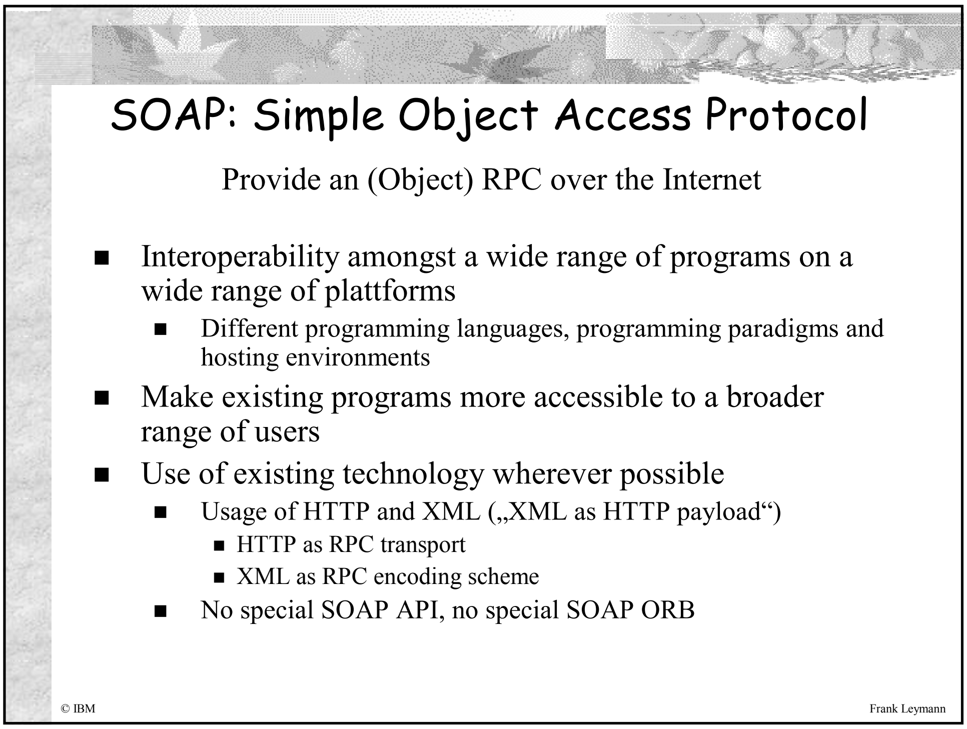
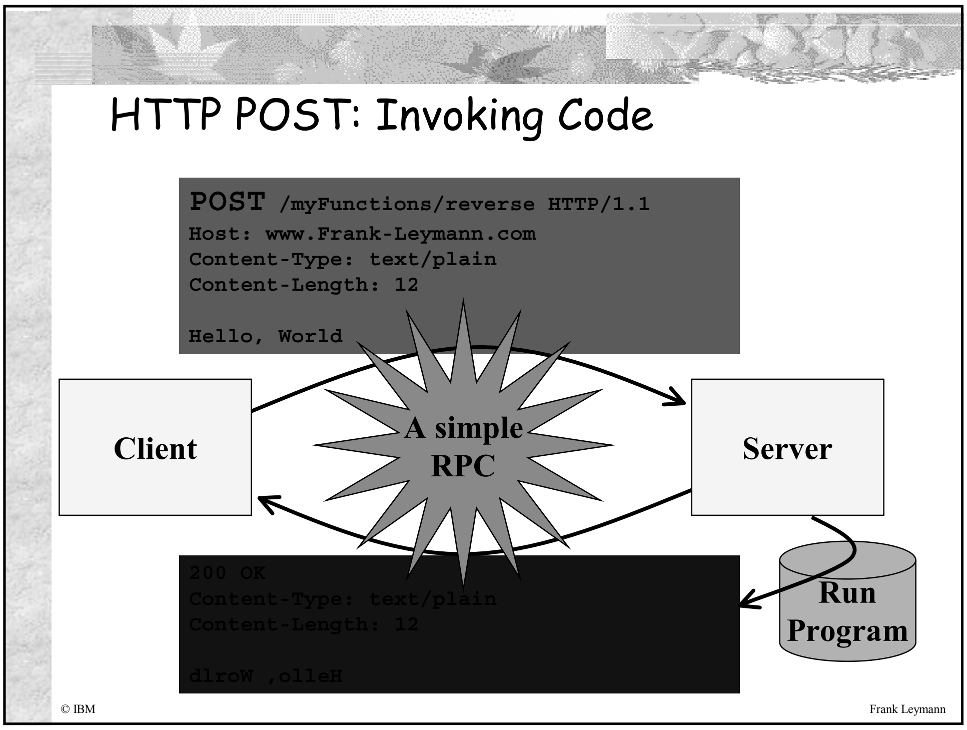
SOAP



SOAP: Simple Object Access Protocol

Provide an (Object) RPC over the Internet

- Interoperability amongst a wide range of programs on a wide range of plattforms
  - Different programming languages, programming paradigms and hosting environments
- Make existing programs more accessible to a broader range of users
- Use of existing technology wherever possible
  - Usage of HTTP and XML („XML as HTTP payload“)
    - HTTP as RPC transport
    - XML as RPC encoding scheme
  - No special SOAP API, no special SOAP ORB



HTTP POST: Invoking Code

```
POST /myFunctions/reverse HTTP/1.1
Host: www.Frank-Leymann.com
Content-Type: text/plain
Content-Length: 12

Hello, World
```

```
200 OK
Content-Type: text/plain
Content-Length: 12

dlroW ,olleH
```

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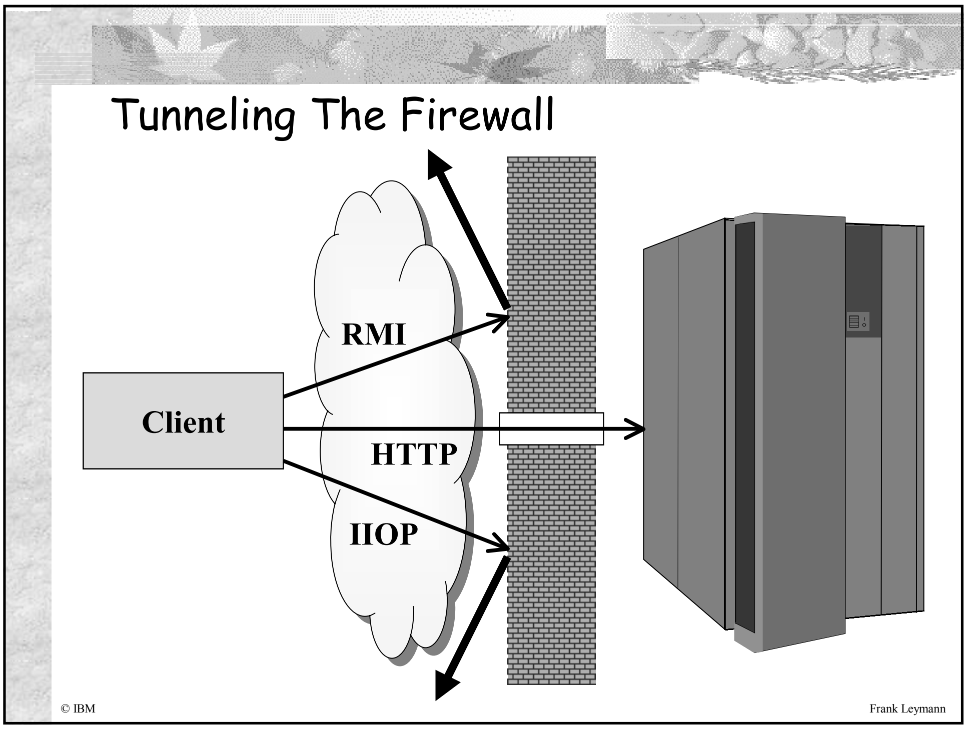

Tunneling The Firewall

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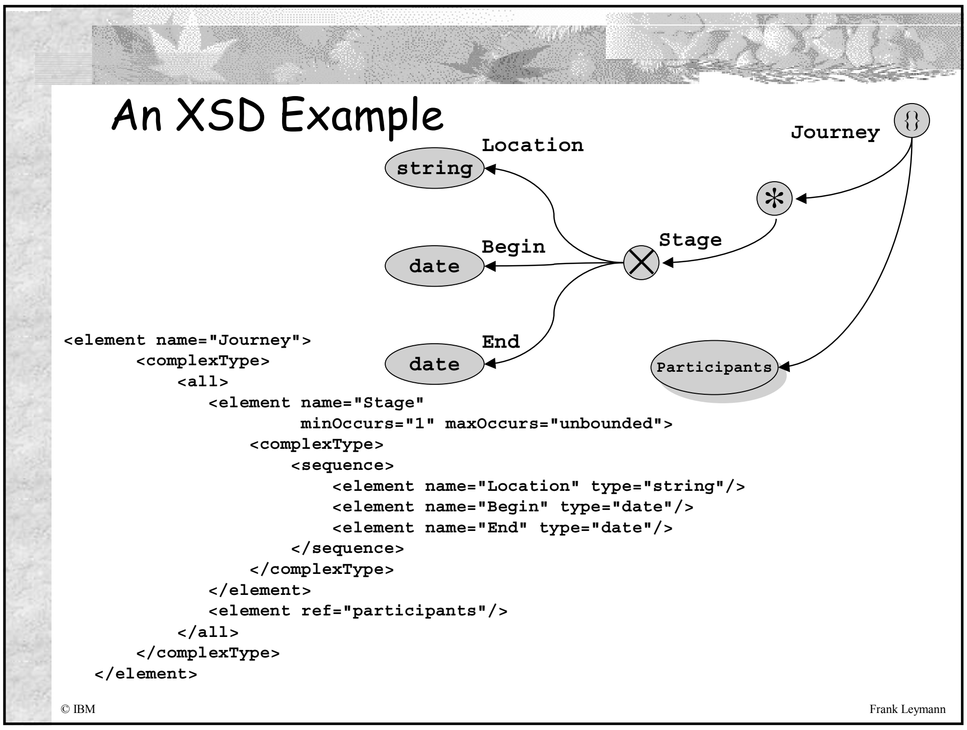

An XSD Example

```
<element name="Journey">
       <complexType>
           <all>
              <element name="Stage"
                       minOccurs="1" maxOccurs="unbounded">
                  <complexType>
                      <sequence>
                          <element name="Location" type="string"/>
                          <element name="Begin" type="date"/>
                          <element name="End" type="date"/>
                      </sequence>
                  </complexType>
              </element>
              <element ref="participants"/>
           </all>
       </complexType>
   </element>
```

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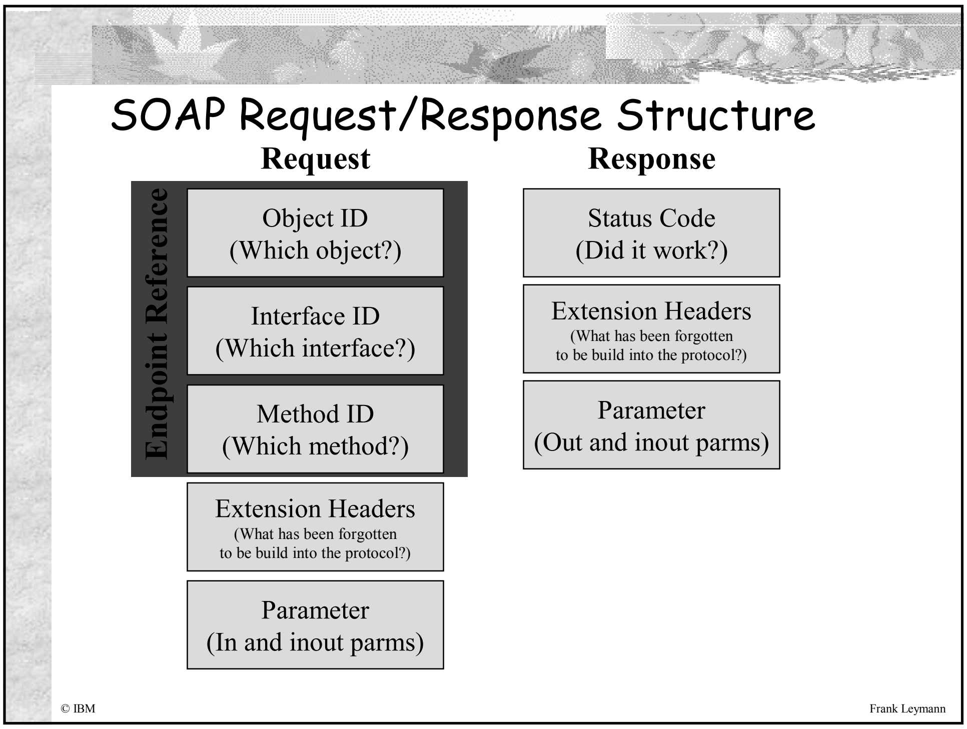

SOAP Request/Response Structure

Request

Endpoint Reference

- Object ID (Which object?)
- Interface ID (Which interface?)
- Method ID (Which method?)

Extension Headers (What has been forgotten to be build into the protocol?)

Parameter (In and inout parms)

Response

Status Code (Did it work?)

Extension Headers (What has been forgotten to be build into the protocol?)

Parameter (Out and inout parms)

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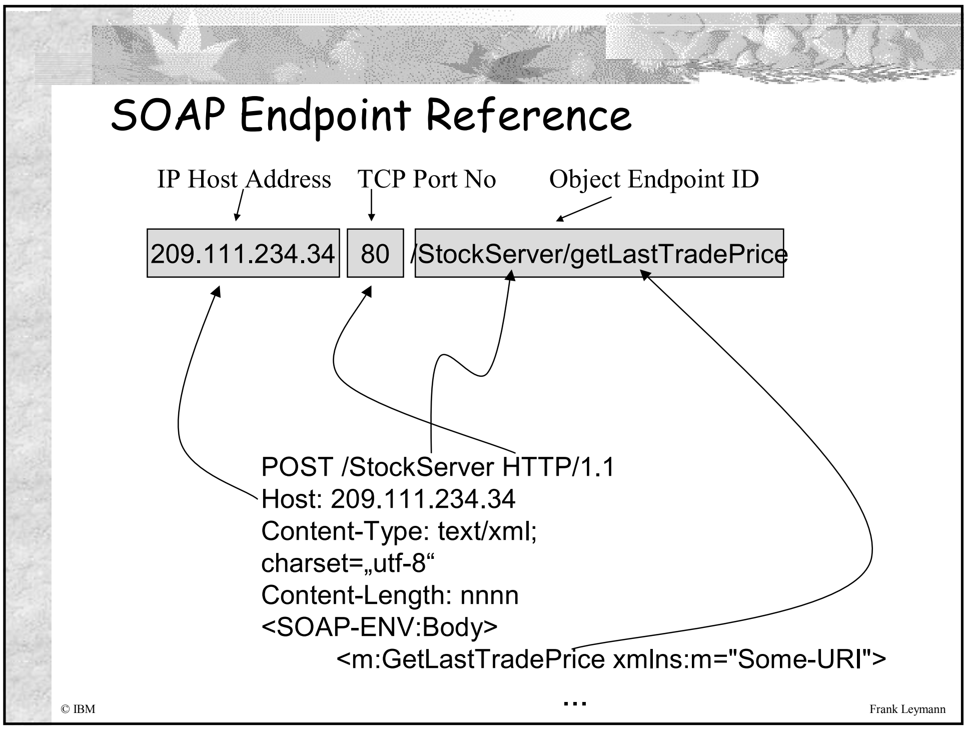

SOAP Endpoint Reference

IP Host Address

TCP Port No

Object Endpoint ID

209.111.234.34

80

/StockServer/getLastTradePrice

```
POST /StockServer HTTP/1.1
Host: 209.111.234.34
Content-Type: text/xml;
charset=„utf-8“
Content-Length: nnnn
<SOAP-ENV:Body>
        <m:GetLastTradePrice xmlns:m="Some-URI">
                    ...
```

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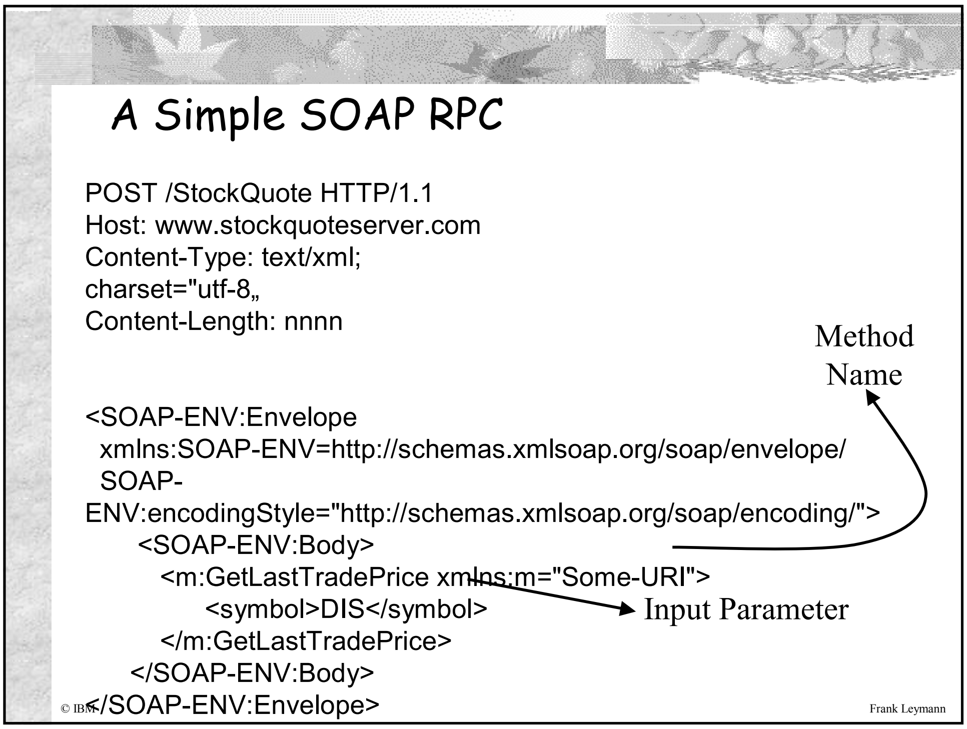

A Simple SOAP RPC

```
POST /StockQuote HTTP/1.1
Host: www.stockquoteserver.com
Content-Type: text/xml;
charset="utf-8„
Content-Length: nnnn


<SOAP-ENV:Envelope
  xmlns:SOAP-ENV=http://schemas.xmlsoap.org/soap/envelope/
  SOAP-
ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
       <SOAP-ENV:Body>
          <m:GetLastTradePrice xmlns:m="Some-URI">
                <symbol>DIS</symbol>
          </m:GetLastTradePrice>
      </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Method
Name
Input Parameter

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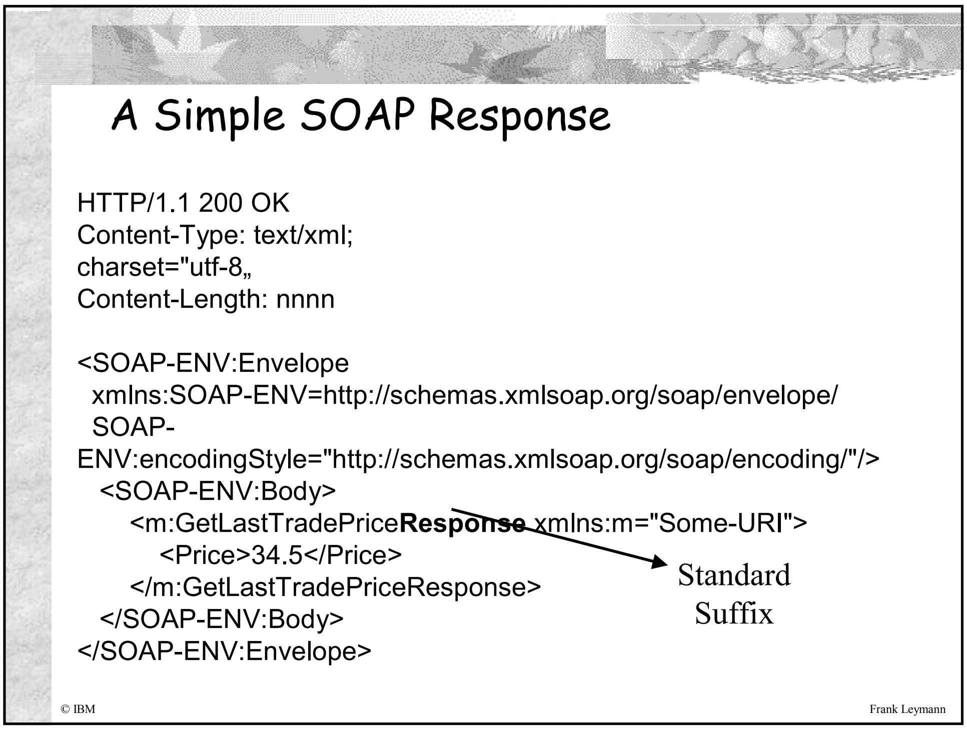

A Simple SOAP Response

```
HTTP/1.1 200 OK
Content-Type: text/xml;
charset="utf-8„
Content-Length: nnnn

<SOAP-ENV:Envelope
  xmlns:SOAP-ENV=http://schemas.xmlsoap.org/soap/envelope/
  SOAP-
ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
   <SOAP-ENV:Body>
       <m:GetLastTradePriceResponse xmlns:m="Some-URI">
           <Price>34.5</Price>
       </m:GetLastTradePriceResponse>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Standard Suffix

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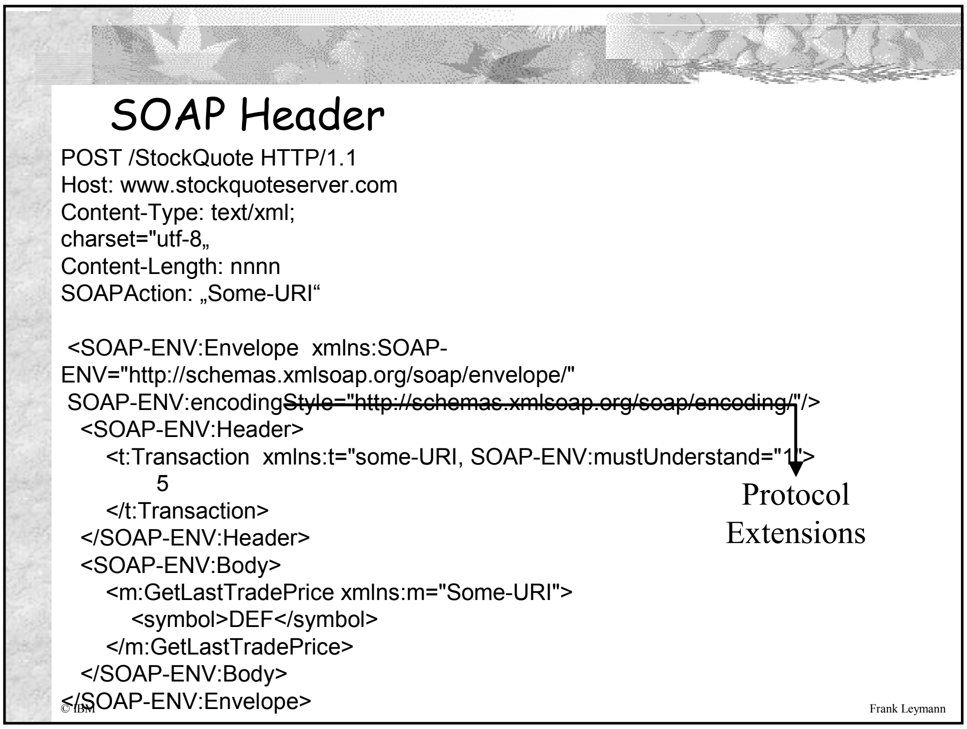

SOAP Header

```
POST /StockQuote HTTP/1.1
Host: www.stockquoteserver.com
Content-Type: text/xml;
charset="utf-8„
Content-Length: nnnn
SOAPAction: „Some-URI“

 <SOAP-ENV:Envelope  xmlns:SOAP-
ENV="http://schemas.xmlsoap.org/soap/envelope/"
 SOAP-ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
   <SOAP-ENV:Header>
       <t:Transaction  xmlns:t="some-URI, SOAP-ENV:mustUnderstand="1">
            5
       </t:Transaction>
   </SOAP-ENV:Header>
   <SOAP-ENV:Body>
       <m:GetLastTradePrice xmlns:m="Some-URI">
           <symbol>DEF</symbol>
       </m:GetLastTradePrice>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Protocol Extensions

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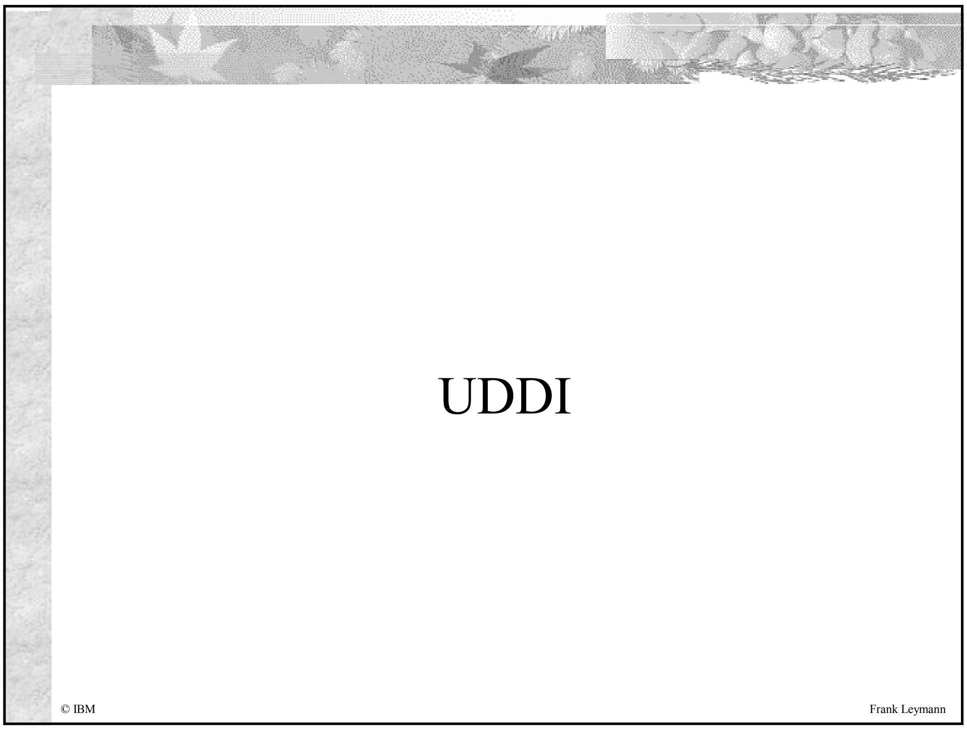

UDDI

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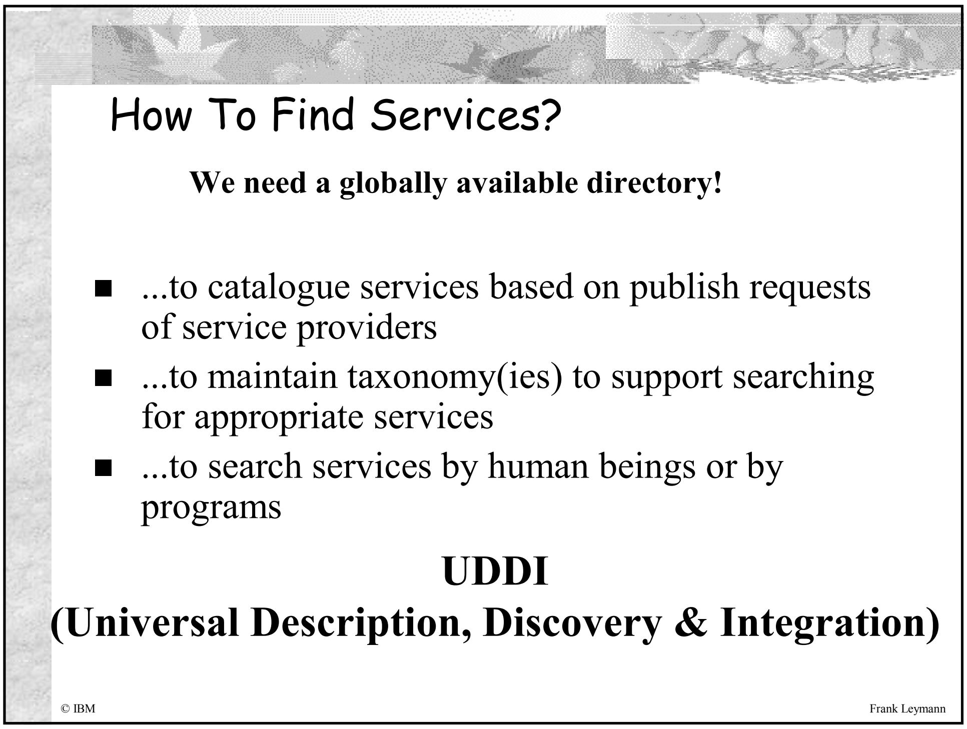

How To Find Services?

We need a globally available directory!

- ...to catalogue services based on publish requests of service providers
- ...to maintain taxonomy(ies) to support searching for appropriate services
- ...to search services by human beings or by programs

UDDI
(Universal Description, Discovery & Integration)

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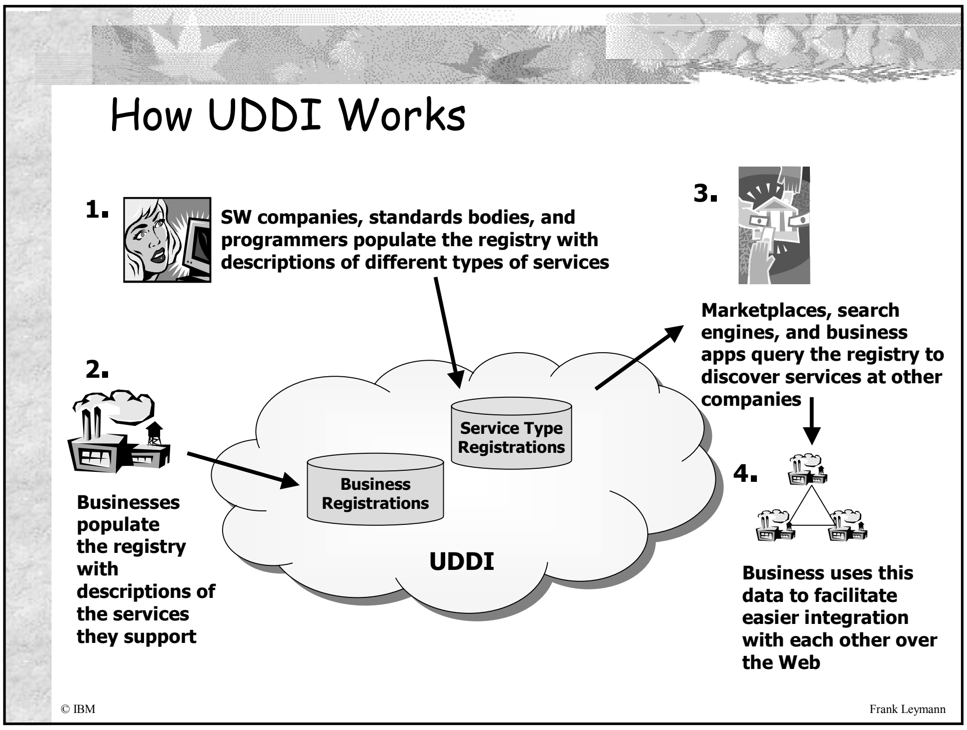

How UDDI Works

1. SW companies, standards bodies, and programmers populate the registry with descriptions of different types of services

2. Businesses populate the registry with descriptions of the services they support

3. Marketplaces, search engines, and business apps query the registry to discover services at other companies

4. Business uses this data to facilitate easier integration with each other over the Web

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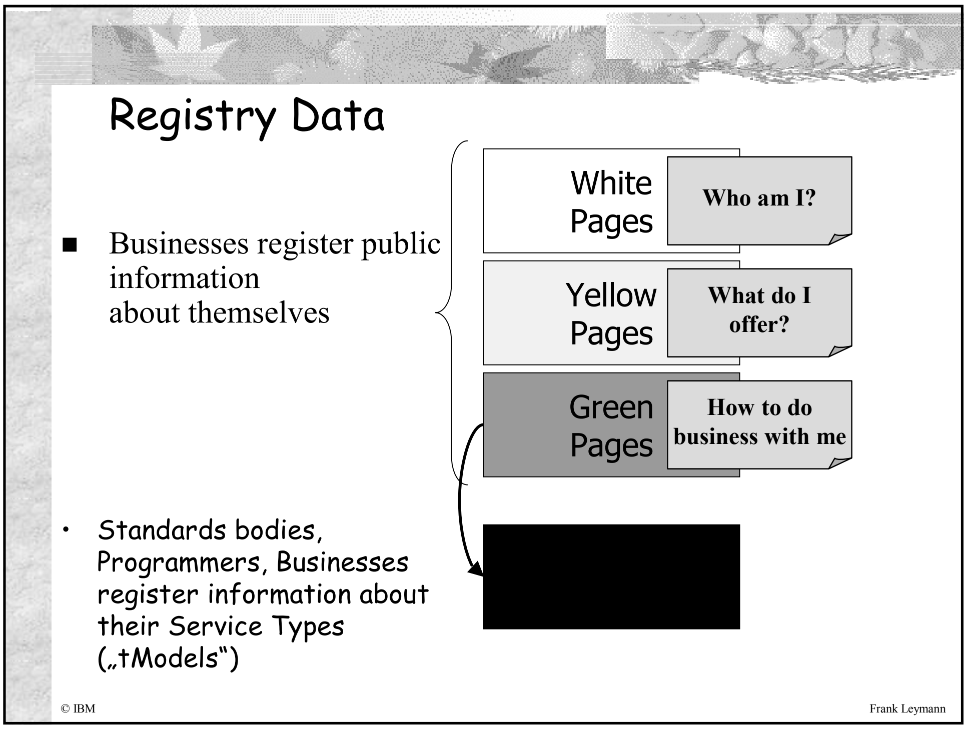

Registry Data

- Businesses register public information about themselves

- Standards bodies, Programmers, Businesses register information about their Service Types („tModels")

[redacted]

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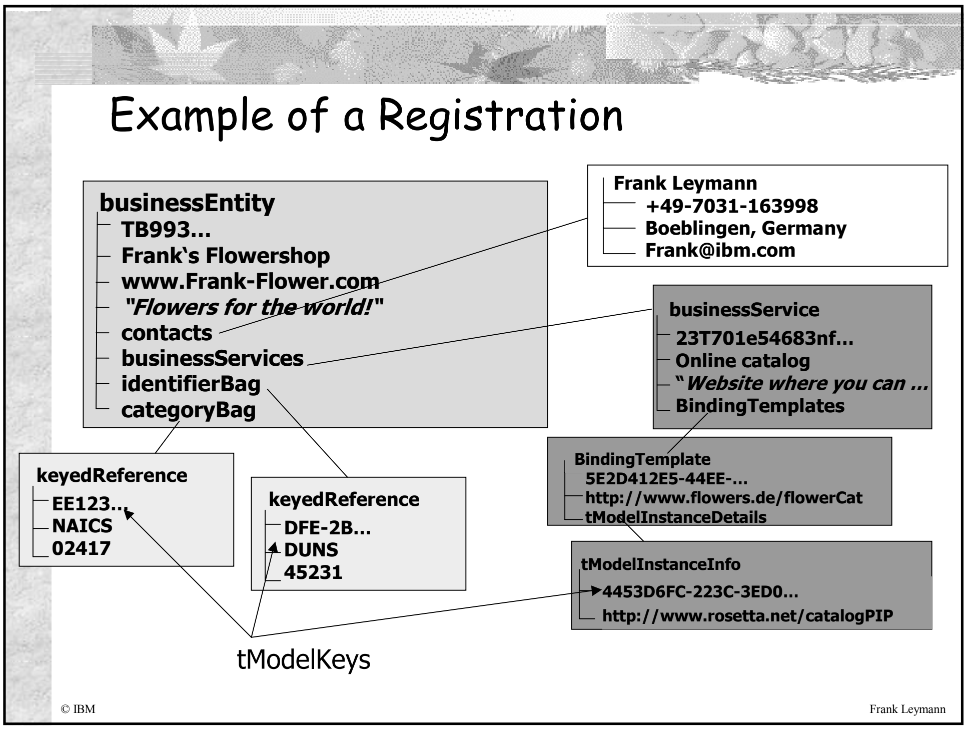

Example of a Registration

businessEntity
- TB993...
- Frank's Flowershop
- www.Frank-Flower.com
- *"Flowers for the world!"*
- contacts
- businessServices
- identifierBag
- categoryBag

Frank Leymann
- +49-7031-163998
- Boeblingen, Germany
- Frank@ibm.com

businessService
- 23T701e54683nf...
- Online catalog
- "*Website where you can ...*
- BindingTemplates

BindingTemplate
- 5E2D412E5-44EE-...
- http://www.flowers.de/flowerCat
- tModelInstanceDetails

tModelInstanceInfo
- 4453D6FC-223C-3ED0...
- http://www.rosetta.net/catalogPIP

keyedReference
- EE123...
- NAICS
- 02417

keyedReference
- DFE-2B...
- DUNS
- 45231

tModelKeys

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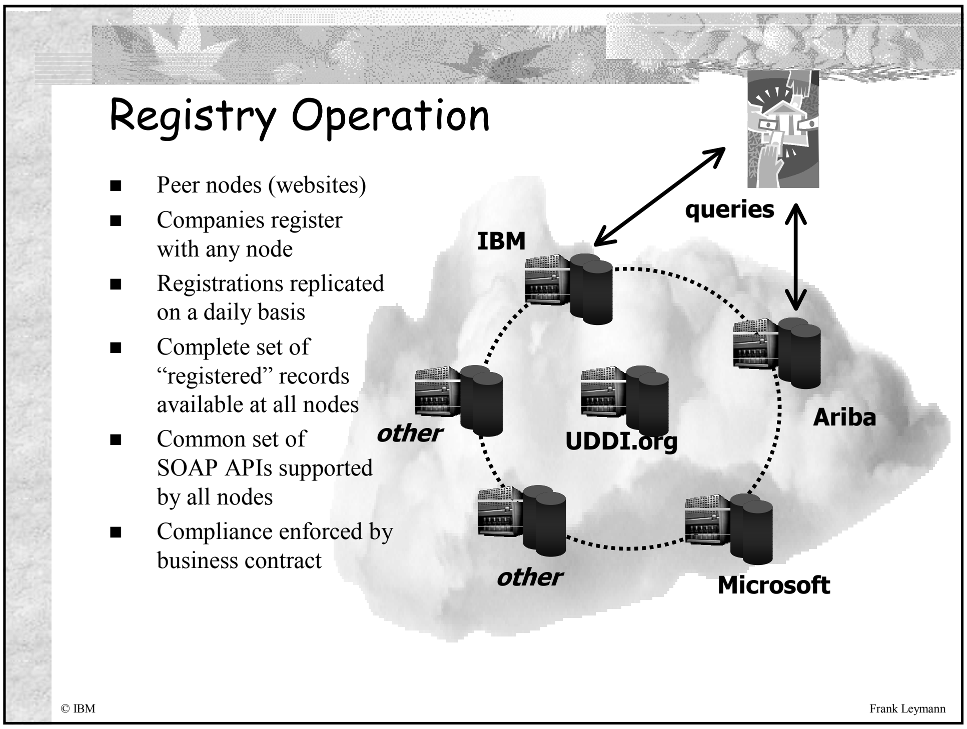

Registry Operation

- Peer nodes (websites)
- Companies register with any node
- Registrations replicated on a daily basis
- Complete set of "registered" records available at all nodes
- Common set of SOAP APIs supported by all nodes
- Compliance enforced by business contract

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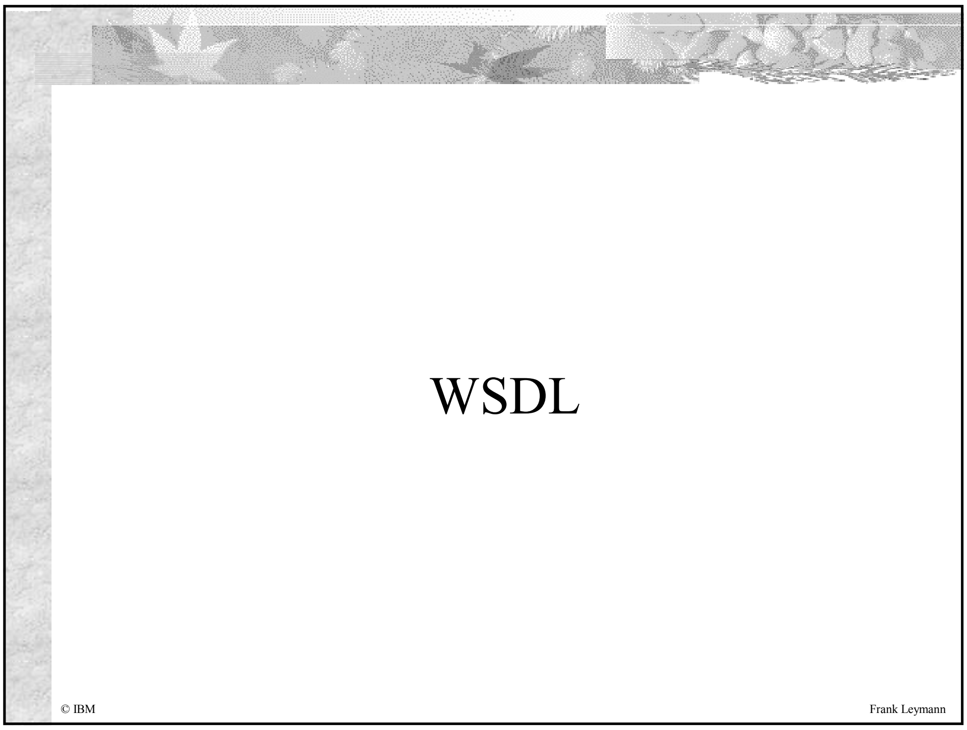

WSDL

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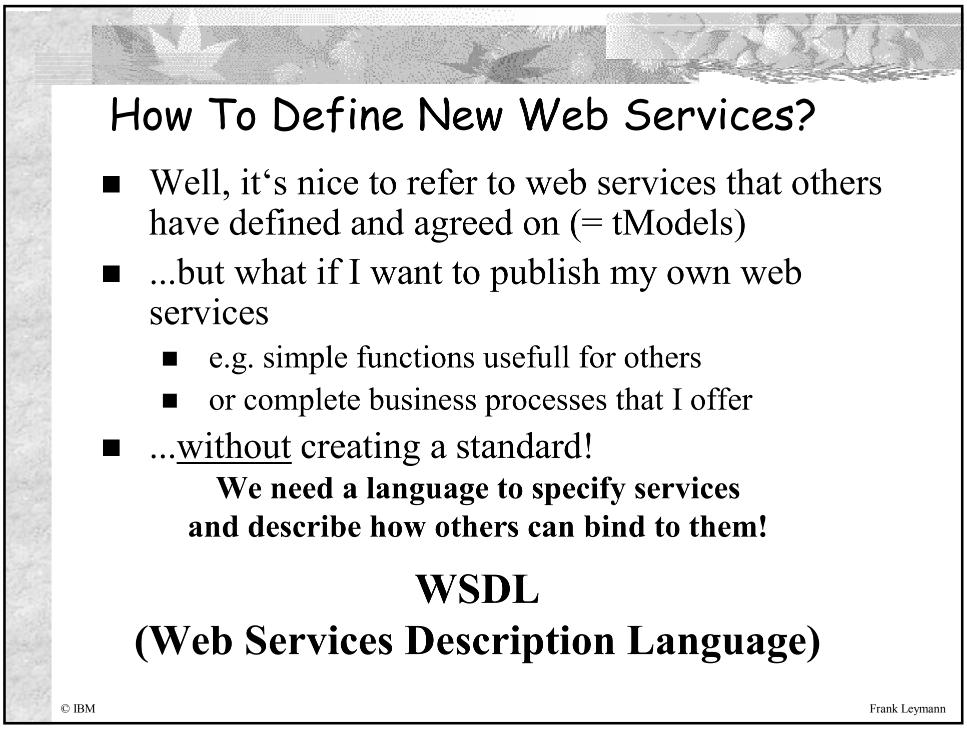

How To Define New Web Services?

- Well, it‘s nice to refer to web services that others have defined and agreed on (= tModels)
- ...but what if I want to publish my own web services
  - e.g. simple functions usefull for others
  - or complete business processes that I offer
- ...without creating a standard!

We need a language to specify services and describe how others can bind to them!

WSDL
(Web Services Description Language)

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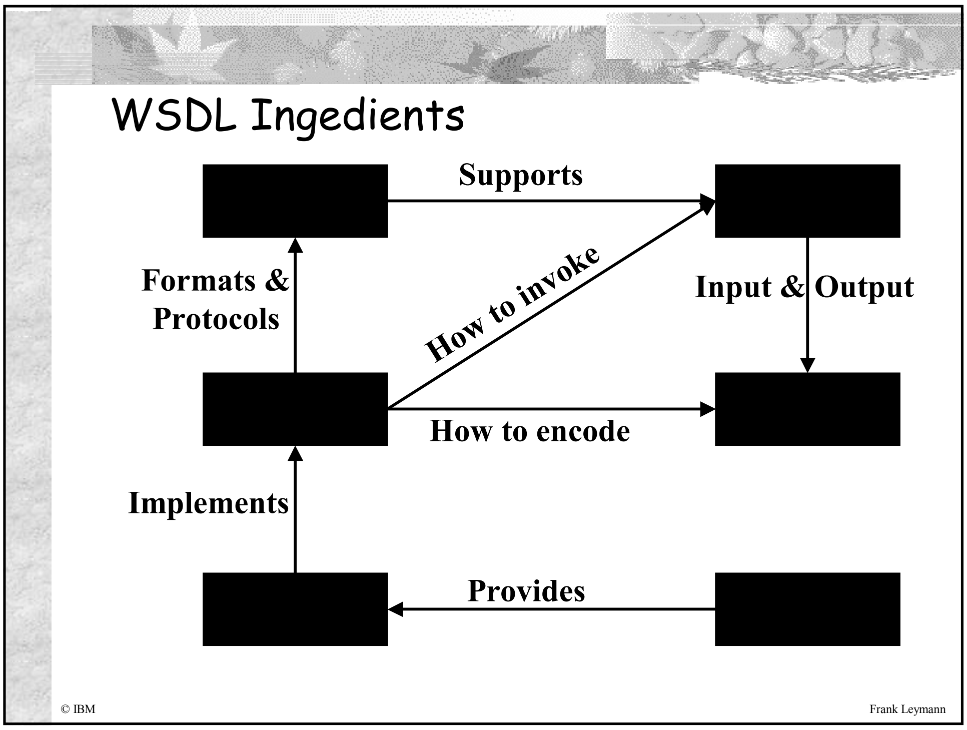

WSDL Ingedients

Supports

Formats & Protocols

How to invoke

Input & Output

How to encode

Implements

Provides

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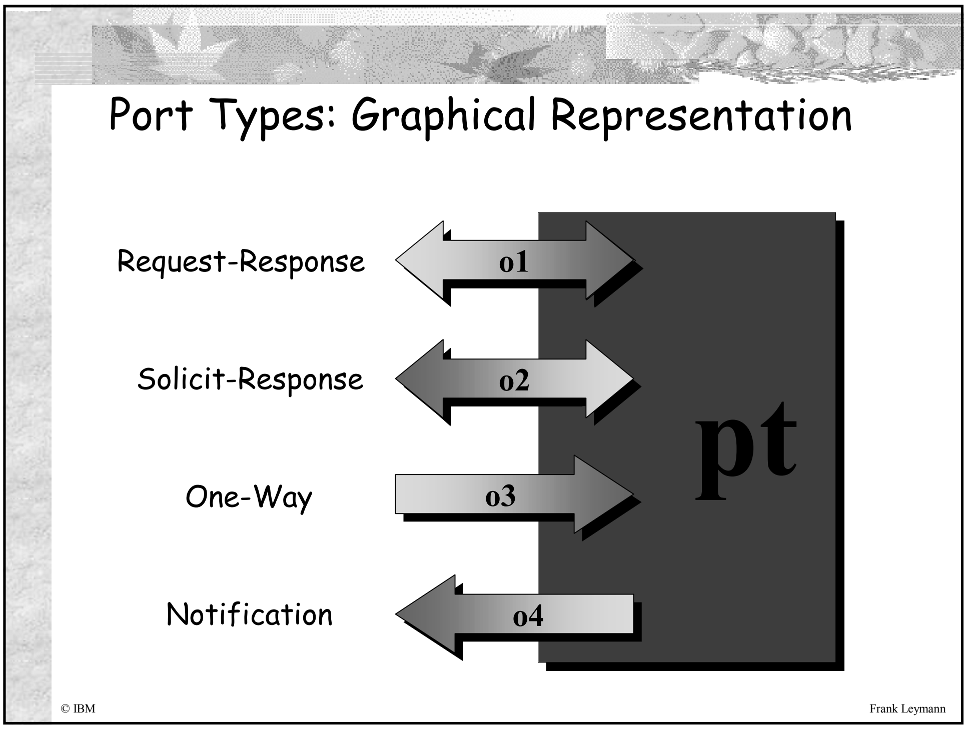

Port Types: Graphical Representation

Request-Response

o1

Solicit-Response

o2

One-Way

o3

Notification

o4

pt

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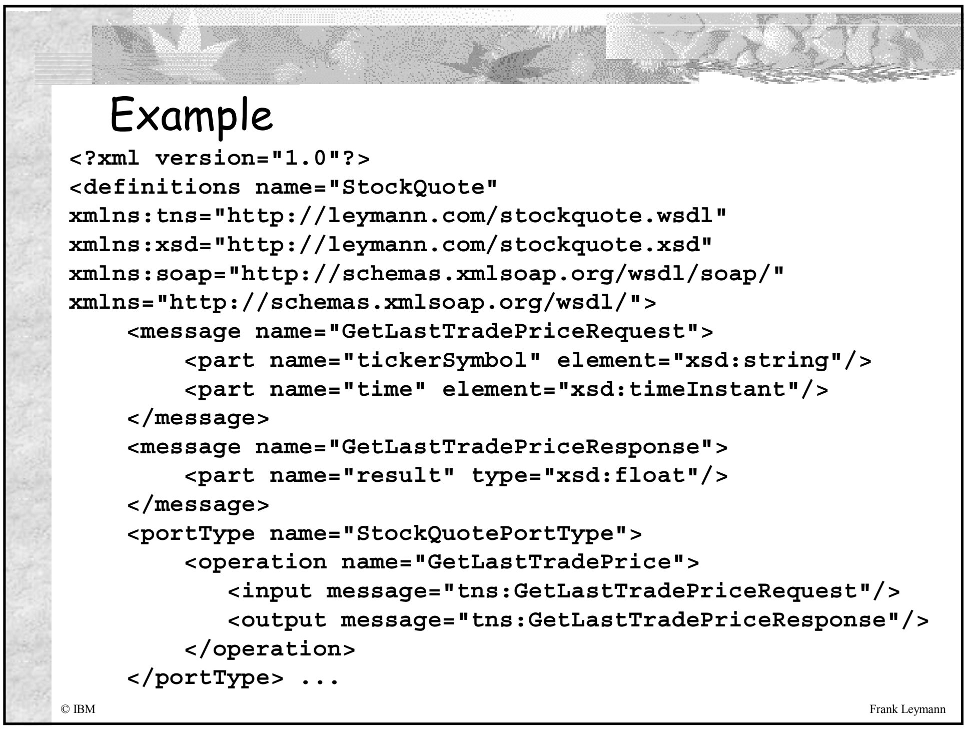

Example

```
<?xml version="1.0"?>
<definitions name="StockQuote"
xmlns:tns="http://leymann.com/stockquote.wsdl"
xmlns:xsd="http://leymann.com/stockquote.xsd"
xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
xmlns="http://schemas.xmlsoap.org/wsdl/">
    <message name="GetLastTradePriceRequest">
        <part name="tickerSymbol" element="xsd:string"/>
        <part name="time" element="xsd:timeInstant"/>
    </message>
    <message name="GetLastTradePriceResponse">
        <part name="result" type="xsd:float"/>
    </message>
    <portType name="StockQuotePortType">
        <operation name="GetLastTradePrice">
           <input message="tns:GetLastTradePriceRequest"/>
           <output message="tns:GetLastTradePriceResponse"/>
        </operation>
    </portType> ...
```

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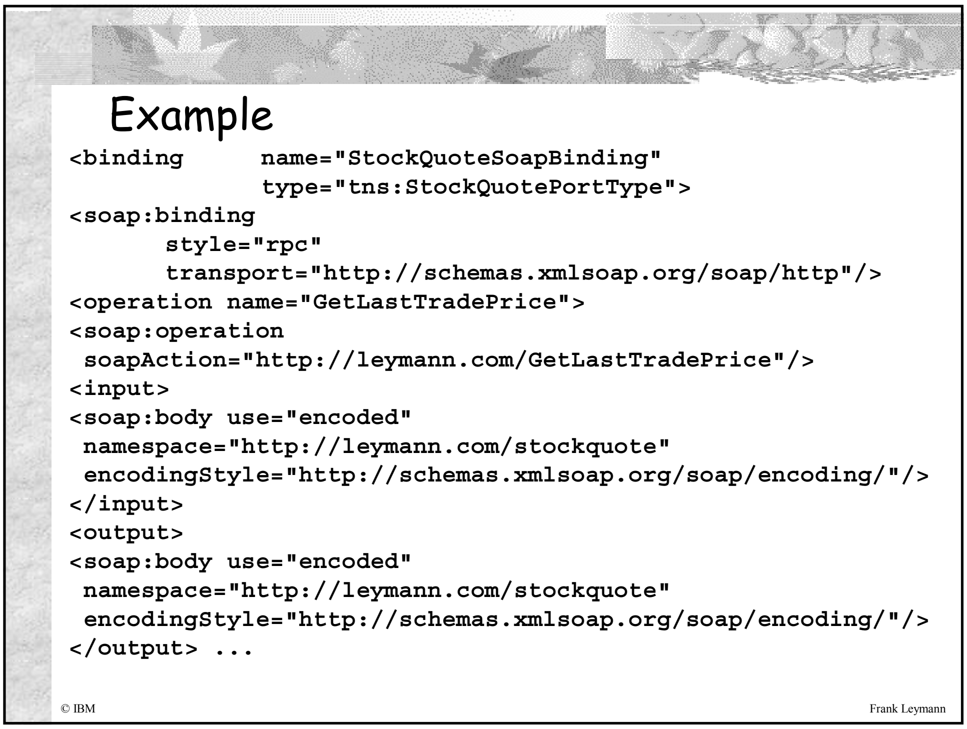

Example

```
<binding      name="StockQuoteSoapBinding"
              type="tns:StockQuotePortType">
<soap:binding
       style="rpc"
       transport="http://schemas.xmlsoap.org/soap/http"/>
<operation name="GetLastTradePrice">
<soap:operation
 soapAction="http://leymann.com/GetLastTradePrice"/>
<input>
<soap:body use="encoded"
 namespace="http://leymann.com/stockquote"
 encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
</input>
<output>
<soap:body use="encoded"
 namespace="http://leymann.com/stockquote"
 encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
</output> ...
```

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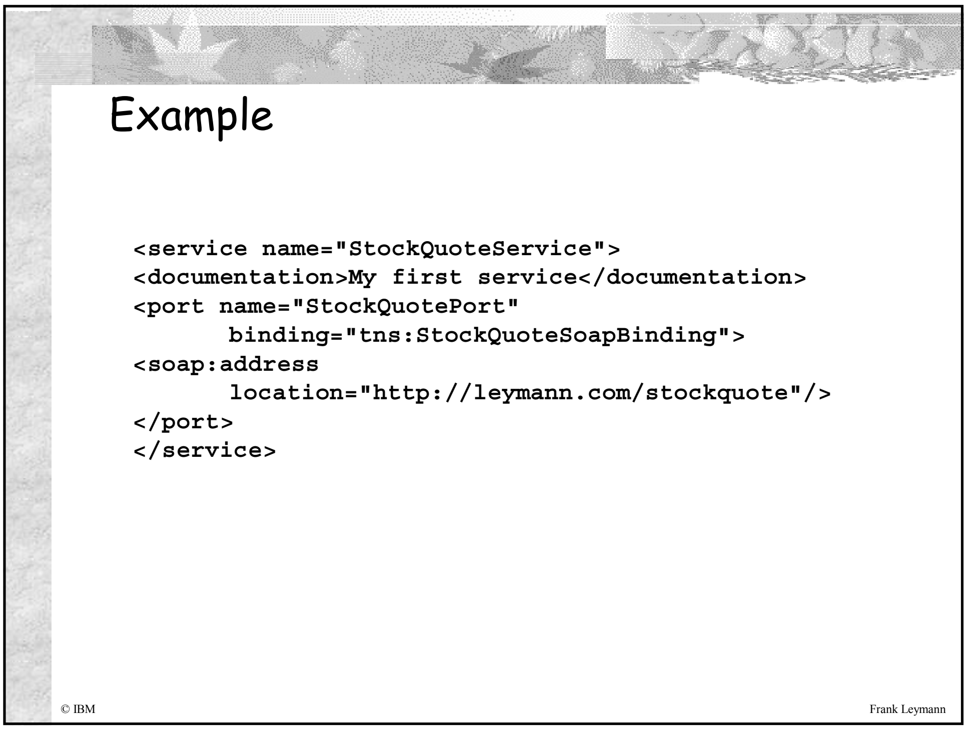

Example

```
<service name="StockQuoteService">
<documentation>My first service</documentation>
<port name="StockQuotePort"
       binding="tns:StockQuoteSoapBinding">
<soap:address
       location="http://leymann.com/stockquote"/>
</port>
</service>
```

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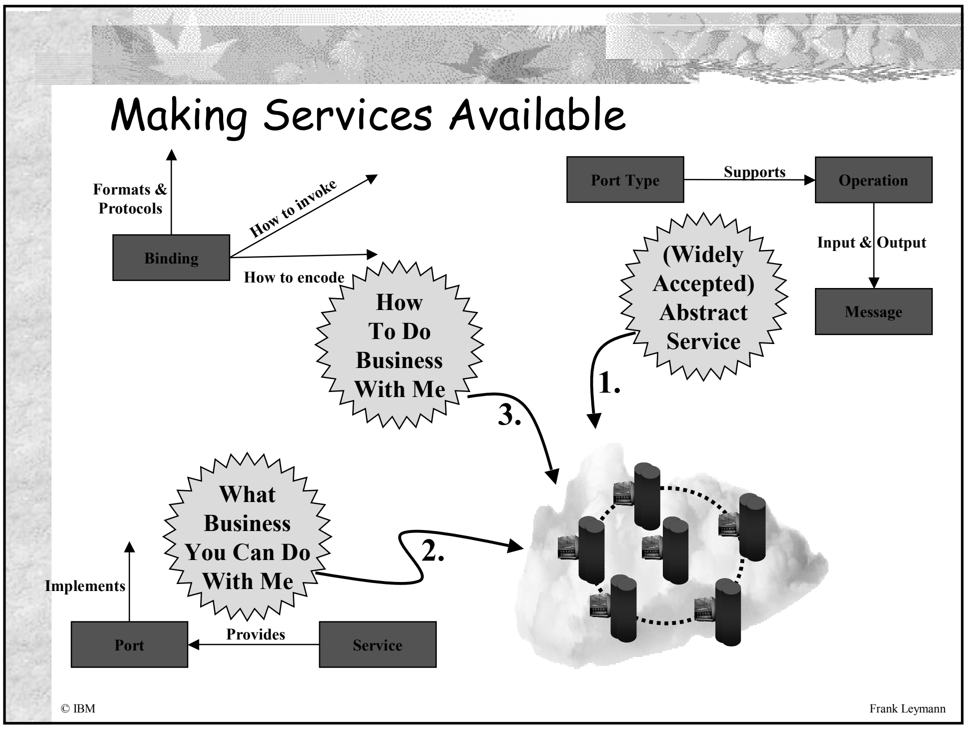

Making Services Available

Port Type

Supports

Operation

Input & Output

Message

Formats & Protocols

Binding

How to invoke

How to encode

How To Do Business With Me

(Widely Accepted) Abstract Service

1.

2.

3.

What Business You Can Do With Me

Implements

Port

Provides

Service

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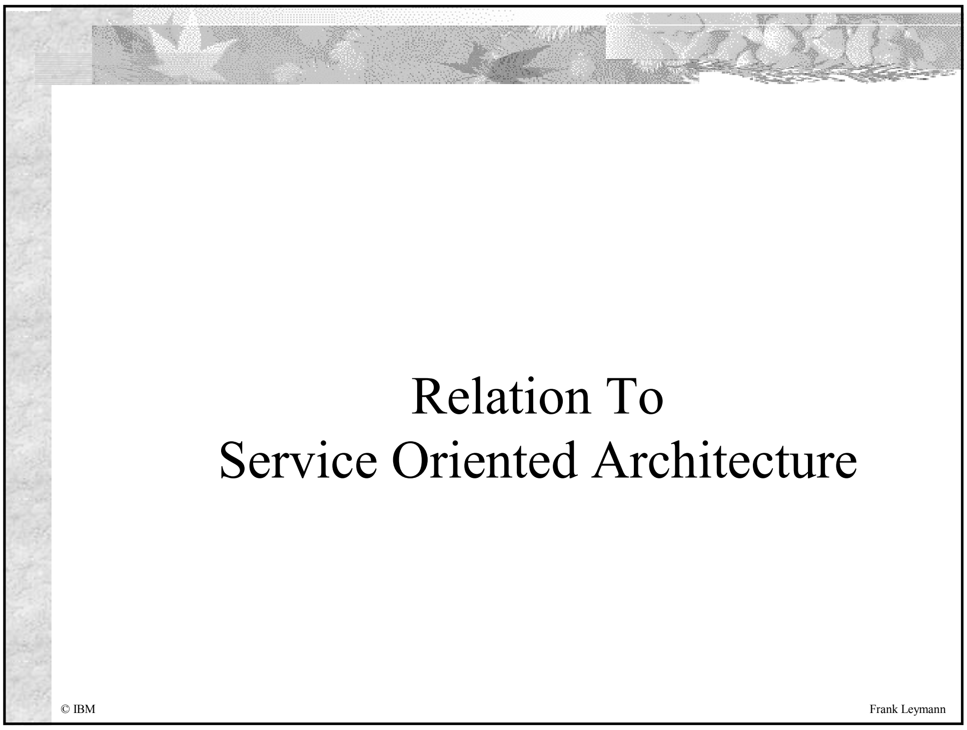

Relation To Service Oriented Architecture

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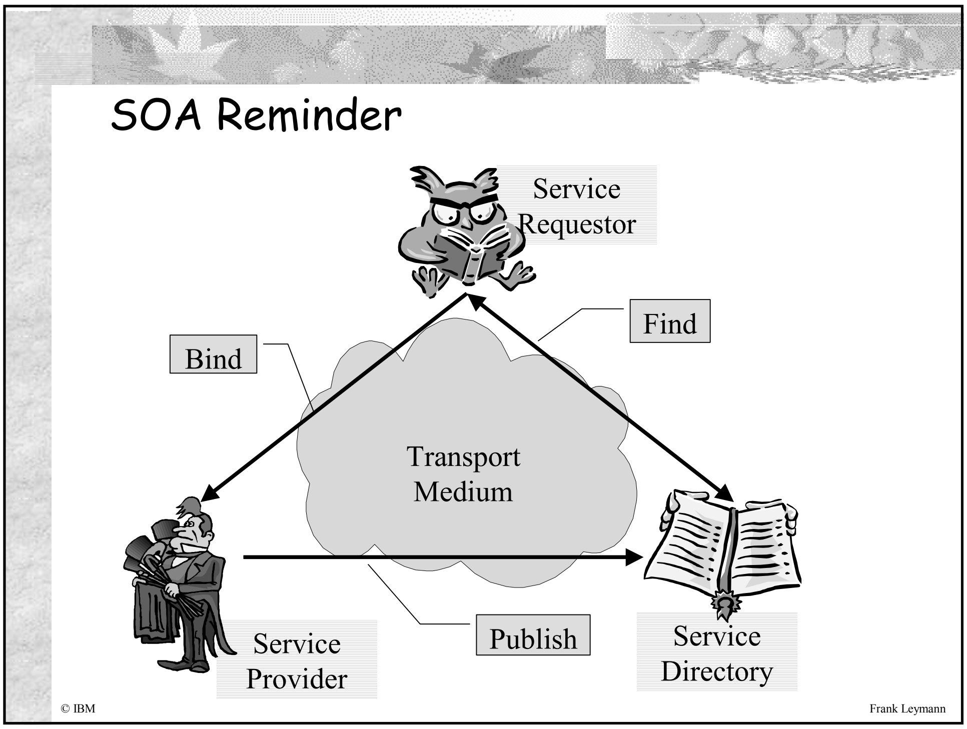

SOA Reminder

Service Requestor

Find

Bind

Transport Medium

Service Provider

Publish

Service Directory

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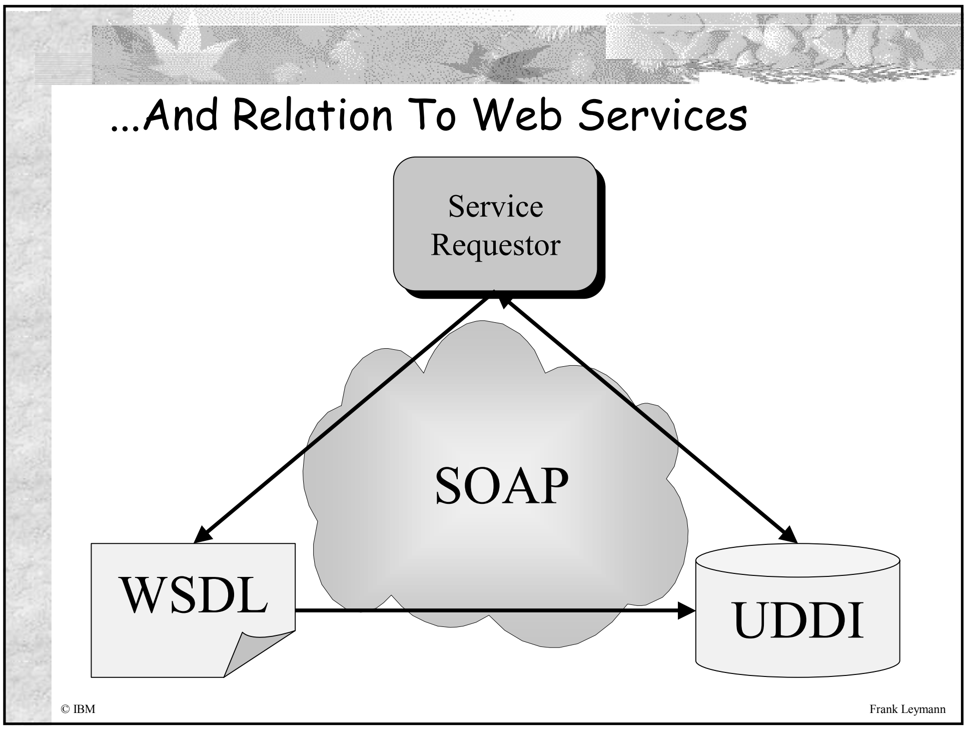

...And Relation To Web Services

Service Requestor

SOAP

WSDL

UDDI

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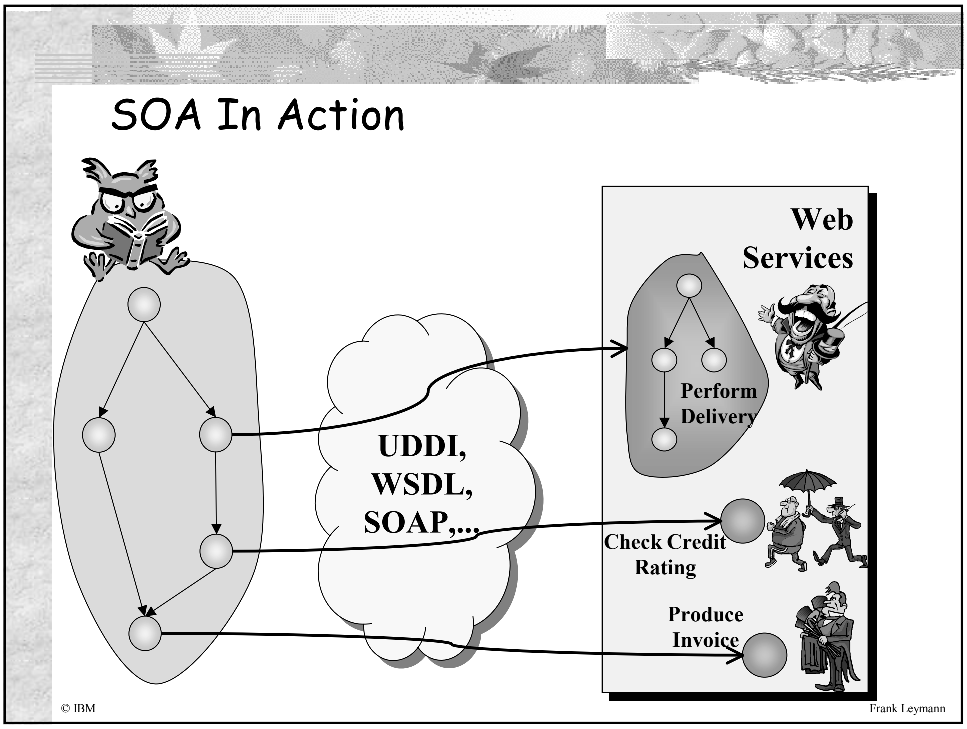

SOA In Action

UDDI, WSDL, SOAP,...

Web Services

Perform Delivery

Check Credit Rating

Produce Invoice

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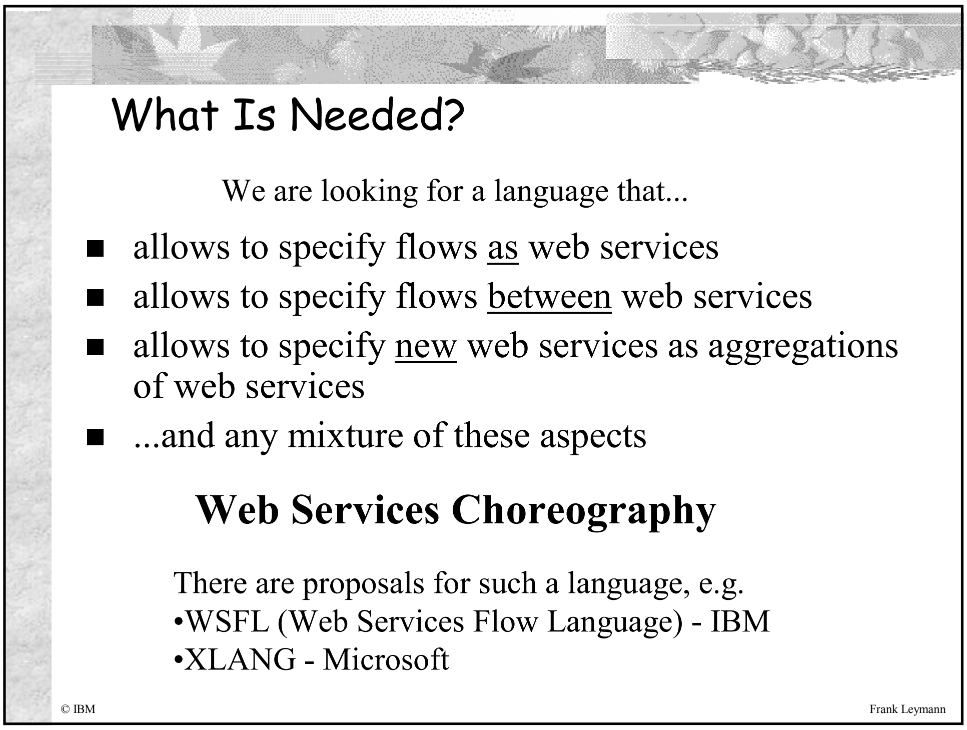

What Is Needed?

We are looking for a language that...

- allows to specify flows as web services
- allows to specify flows between web services
- allows to specify new web services as aggregations of web services
- ...and any mixture of these aspects

Web Services Choreography

There are proposals for such a language, e.g.
•WSFL (Web Services Flow Language) - IBM
•XLANG - Microsoft

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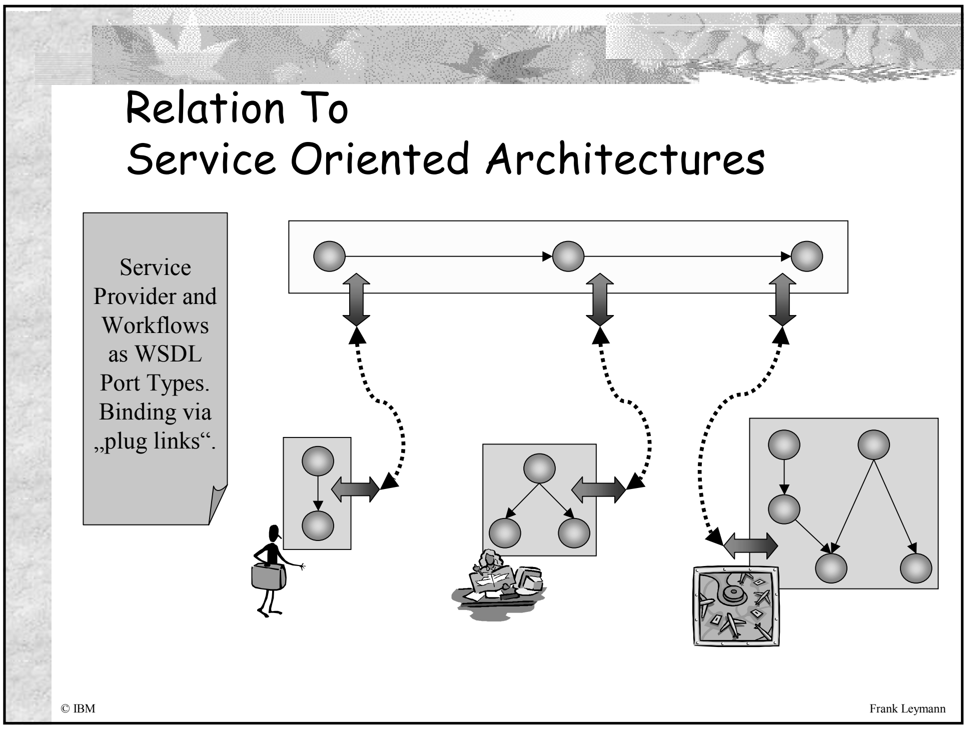

Relation To Service Oriented Architectures

Service Provider and Workflows as WSDL Port Types. Binding via „plug links“.

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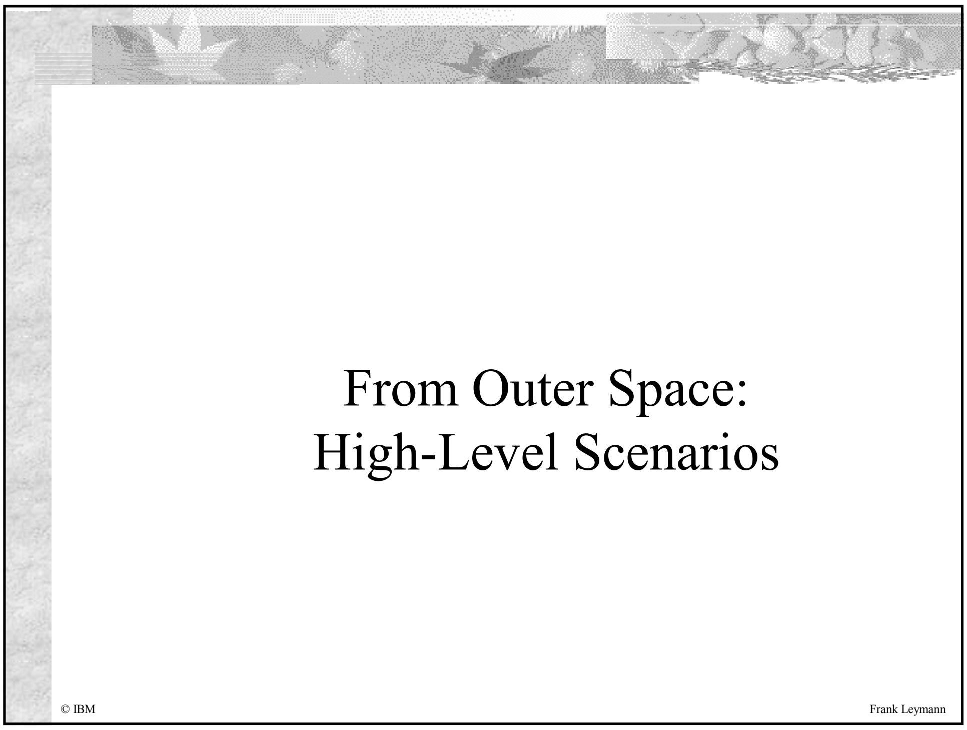

From Outer Space: High-Level Scenarios

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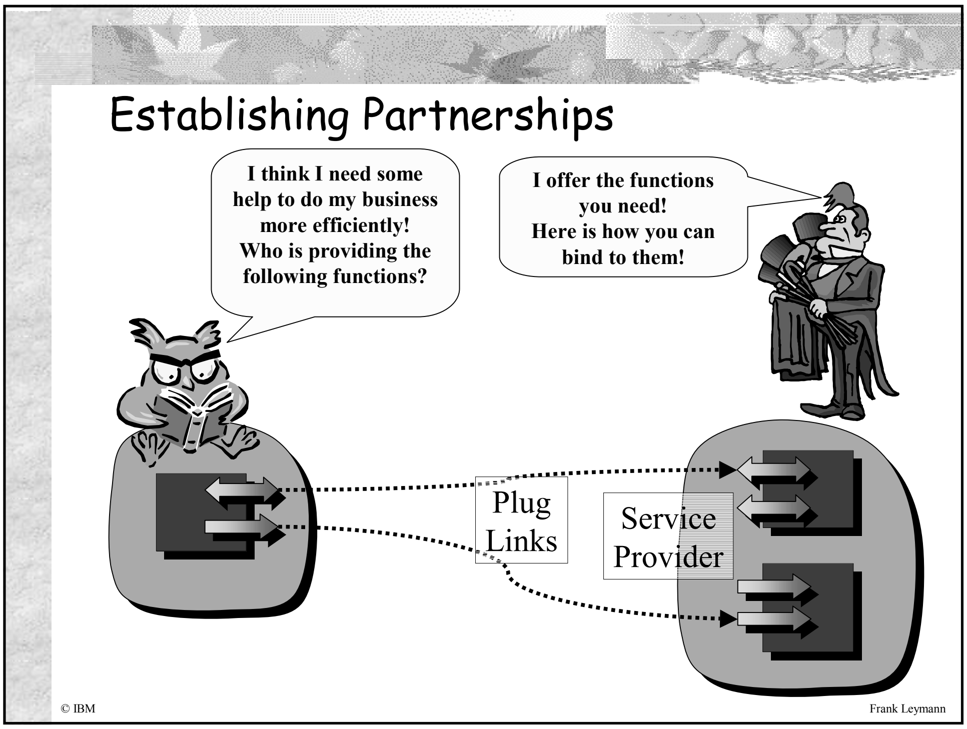

Establishing Partnerships

I think I need some help to do my business more efficiently! Who is providing the following functions?
I offer the functions you need! Here is how you can bind to them!
Plug Links
Service Provider

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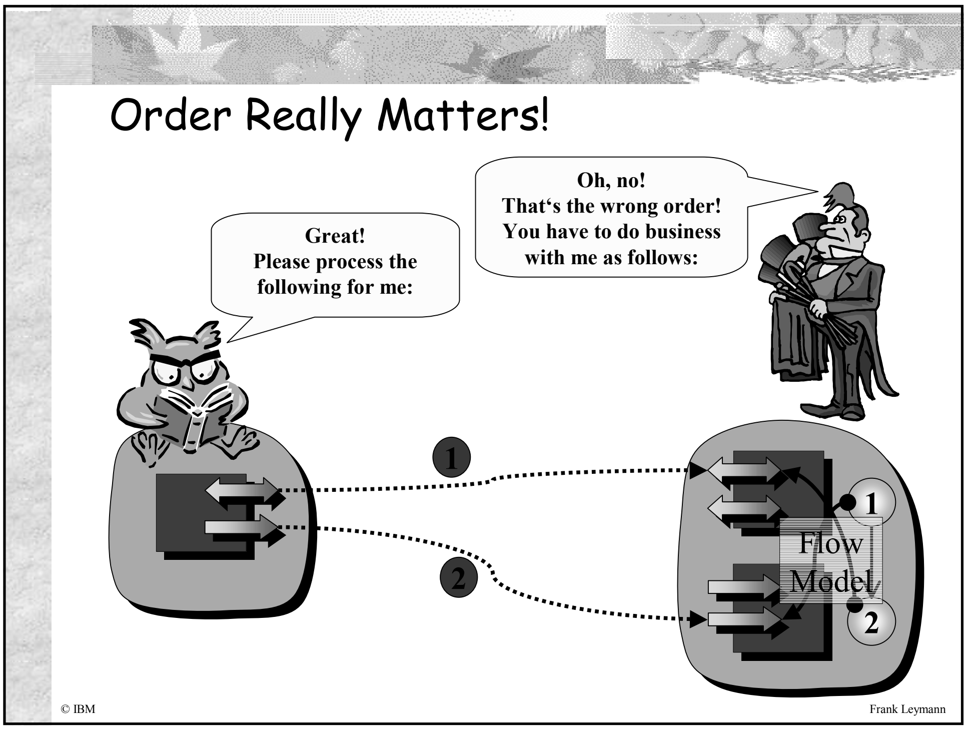

Order Really Matters!

Great!
Please process the following for me:

Oh, no!
That‘s the wrong order!
You have to do business with me as follows:

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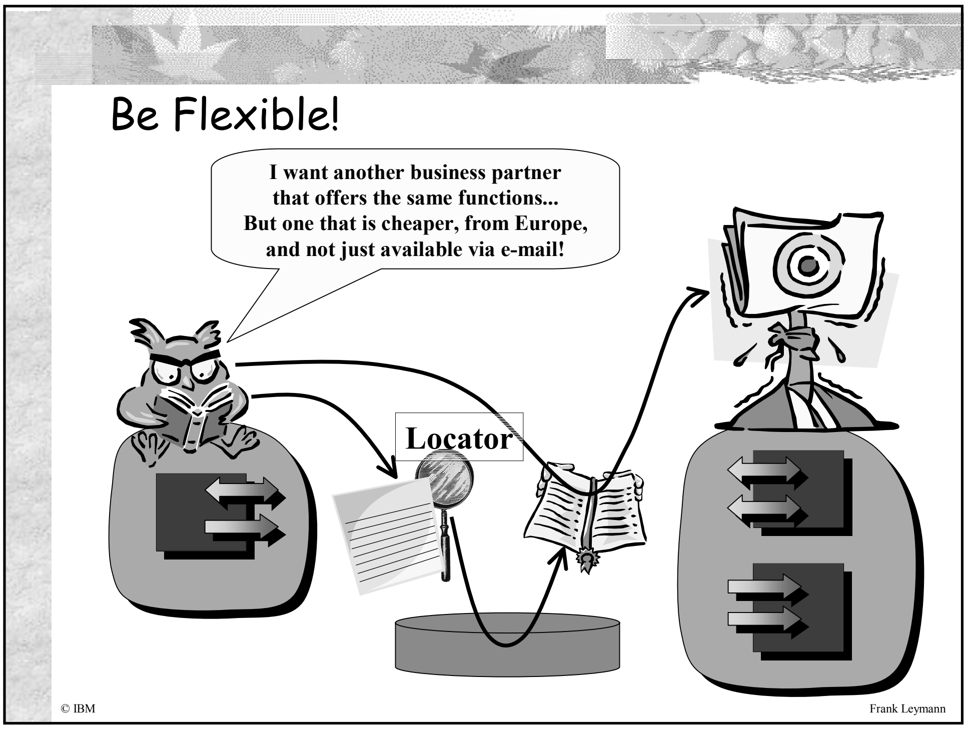

Be Flexible!

I want another business partner that offers the same functions...
But one that is cheaper, from Europe, and not just available via e-mail!

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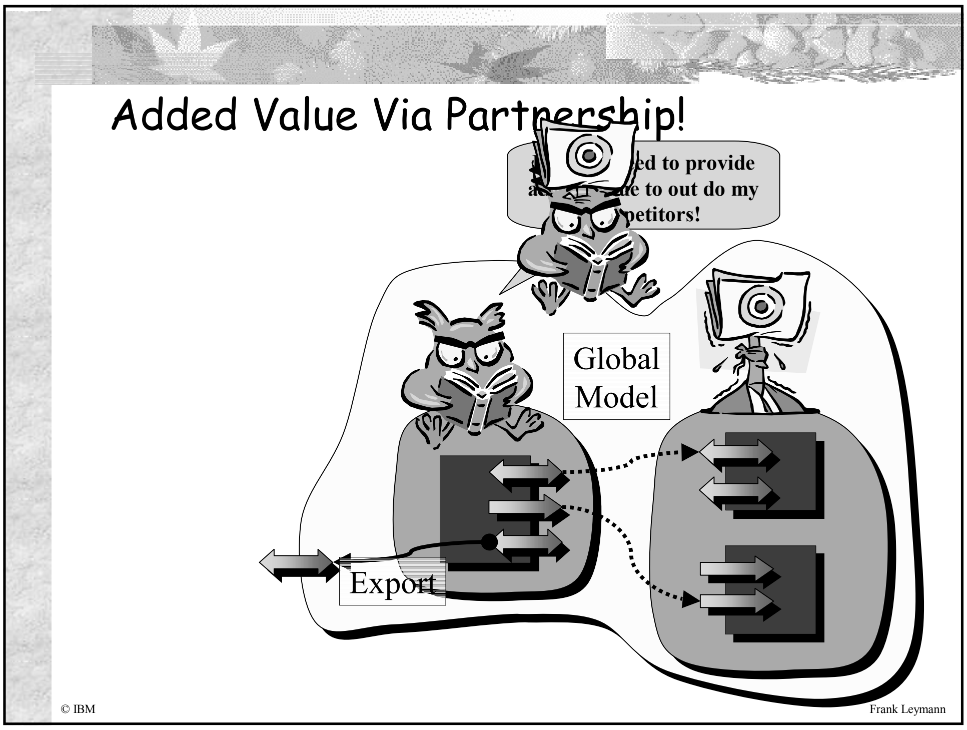

Added Value Via Partnership!

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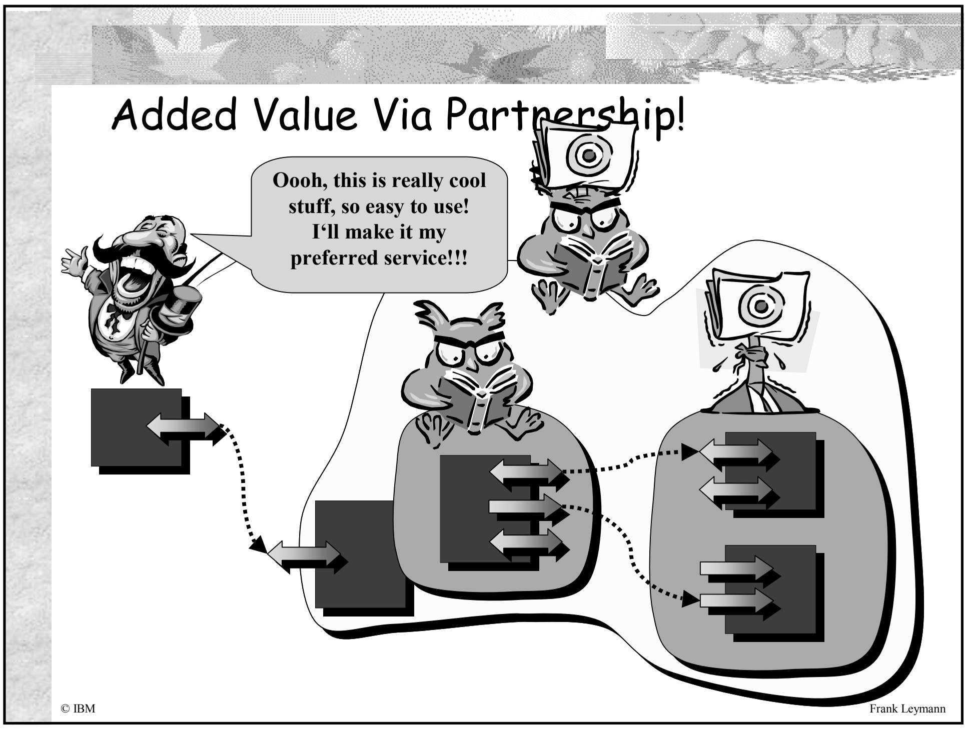

Added Value Via Partnership!

Oooh, this is really cool stuff, so easy to use! I'll make it my preferred service!!!

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From The Orbit:
An Overview Example

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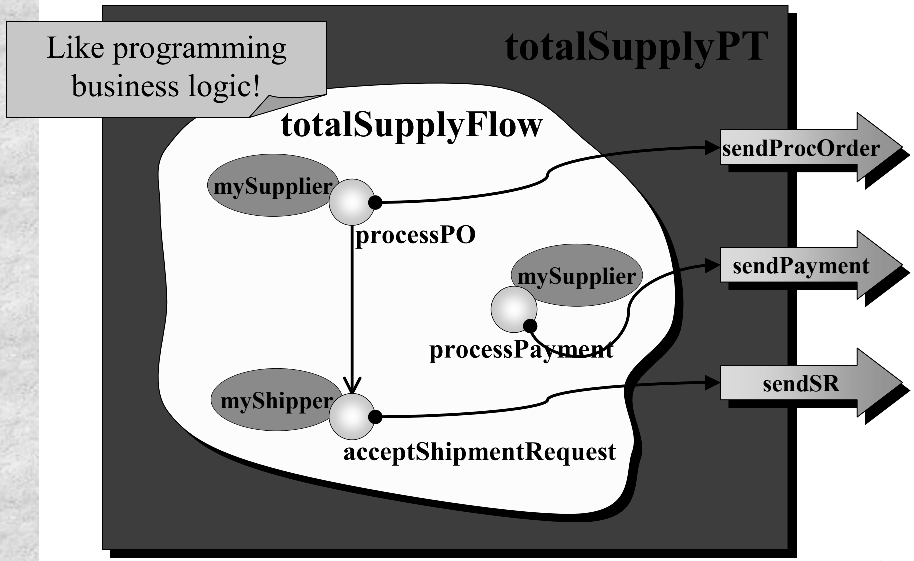
Sample Flow Model



Like programming business logic!

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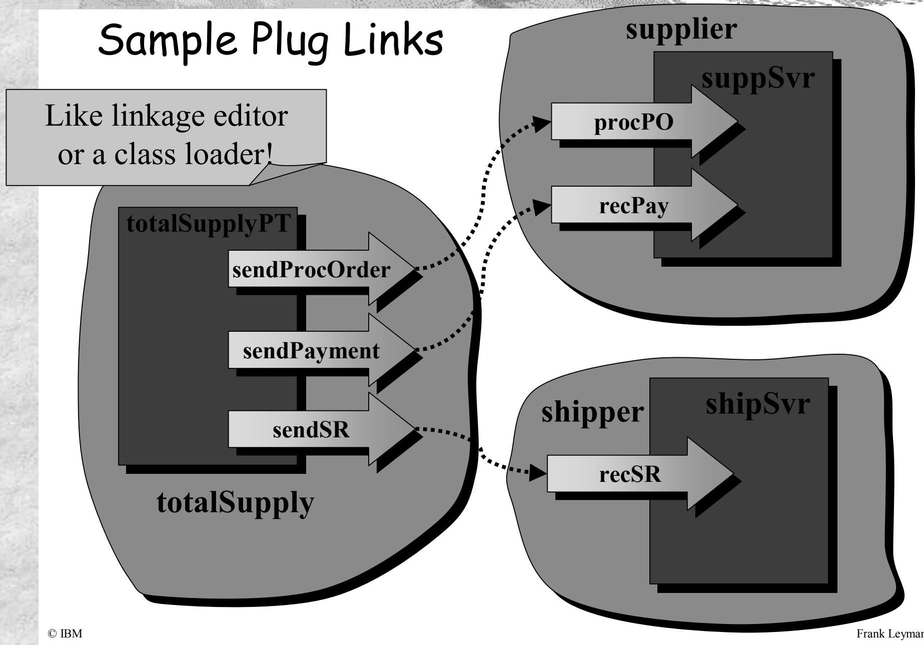
Sample Plug Links



Like linkage editor or a class loader!

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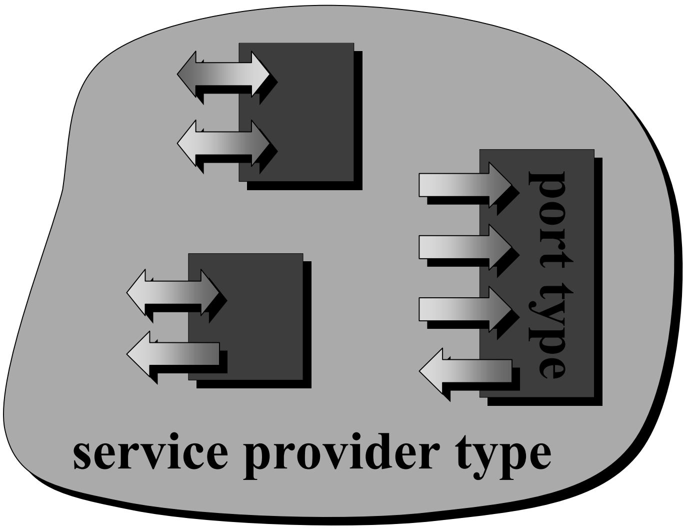
Service Provider Type



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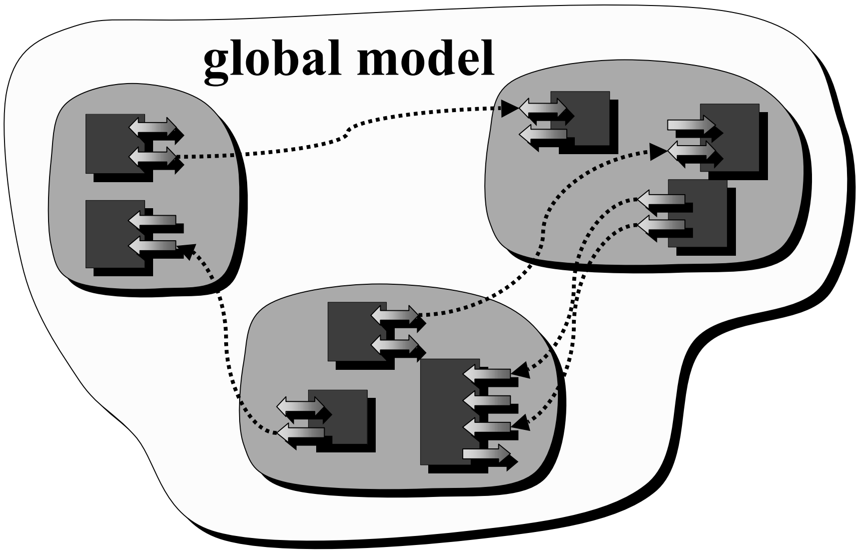
Global Model



global model

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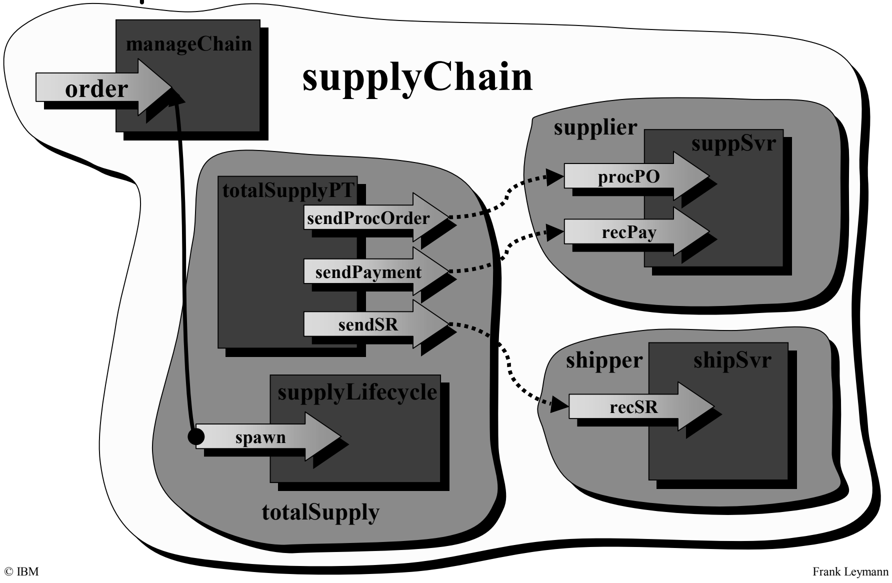
Sample Global Model



manageChain

order

supplyChain

supplier

suppSvr

procPO

recPay

totalSupplyPT

sendProcOrder

sendPayment

sendSR

shipper

shipSvr

recSR

supplyLifecycle

spawn

totalSupply

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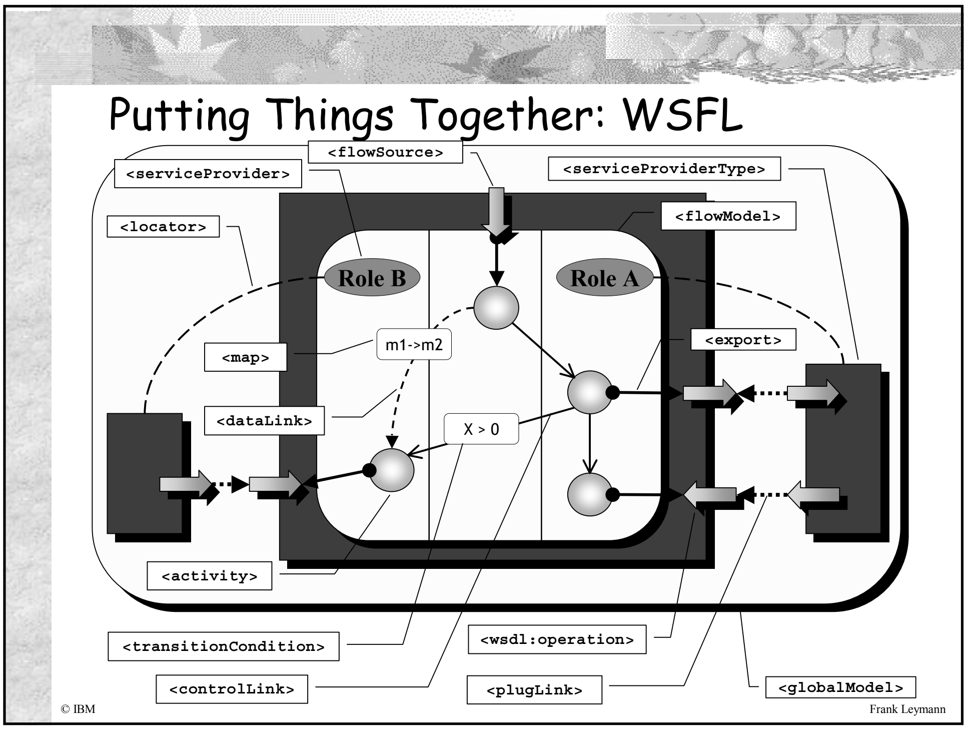

Putting Things Together: WSFL

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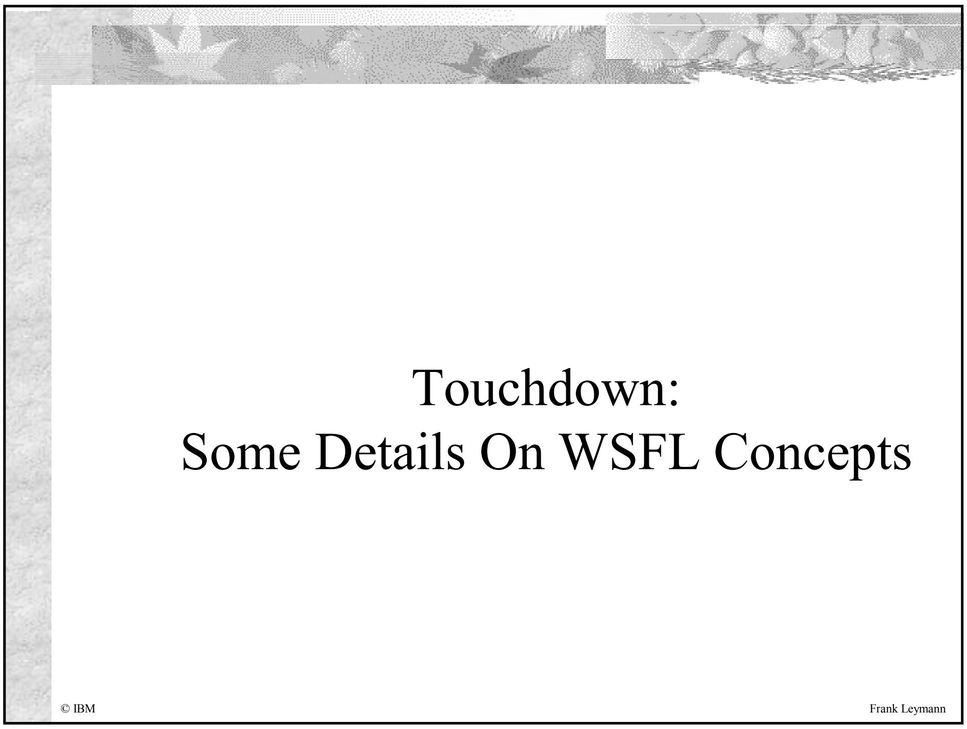

Touchdown:
Some Details On WSFL Concepts

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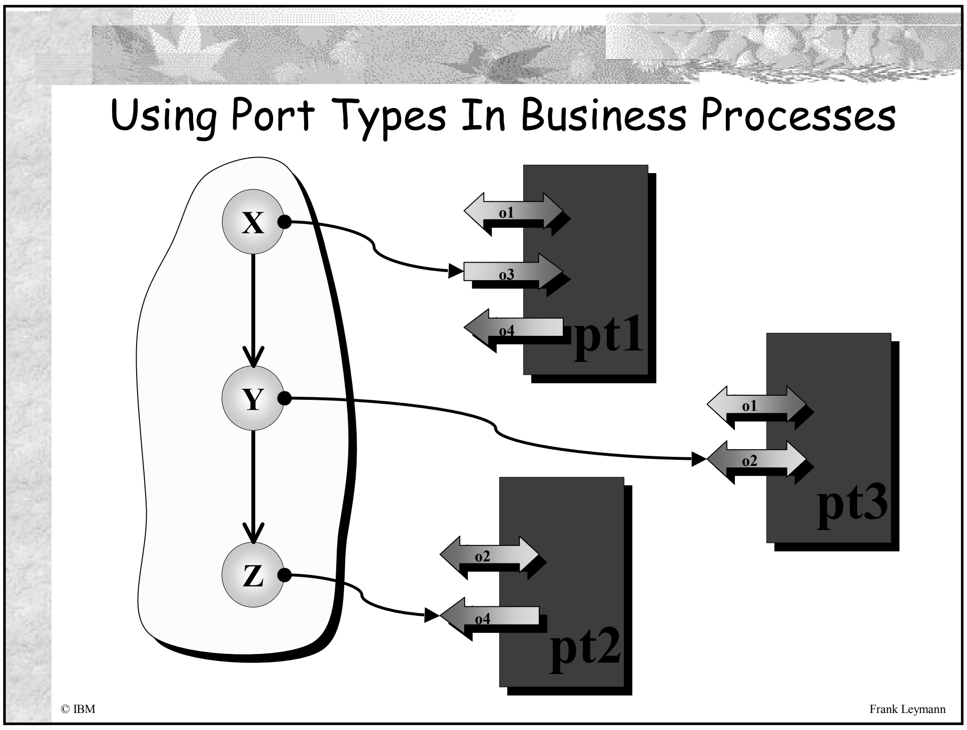

Using Port Types In Business Processes

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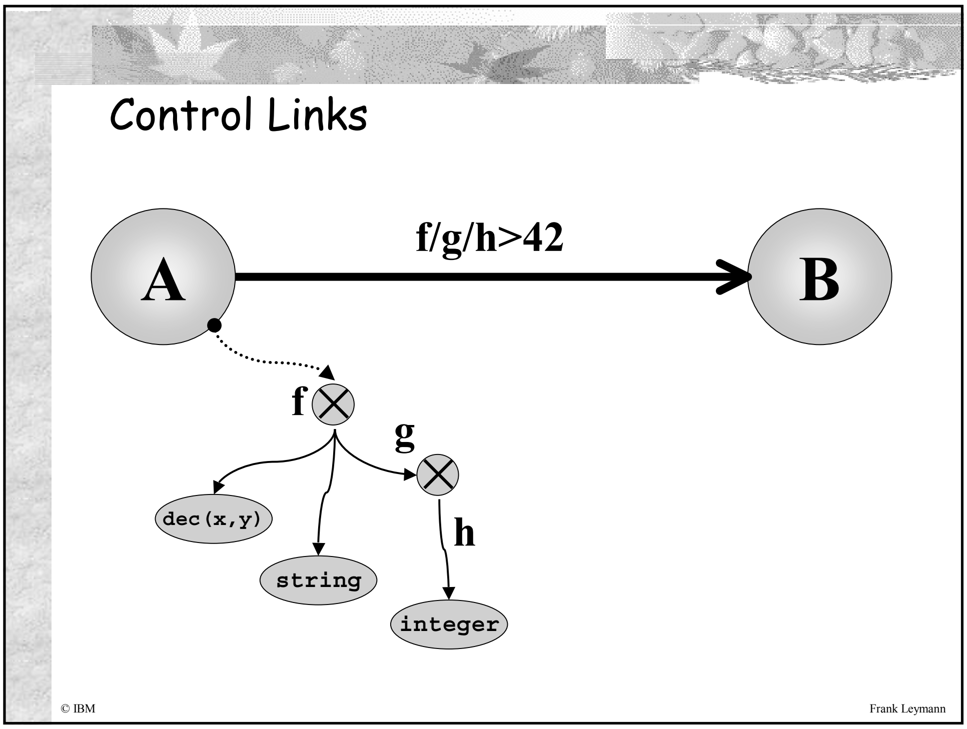

Control Links

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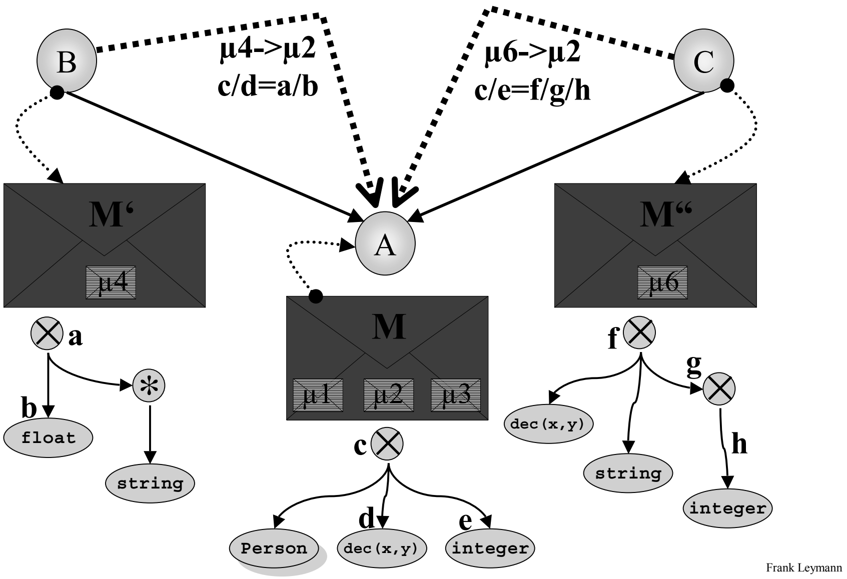
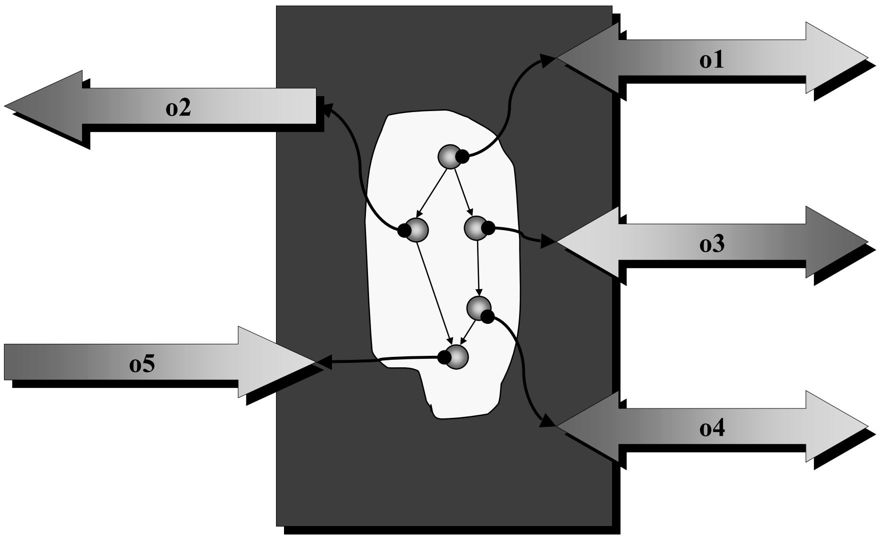
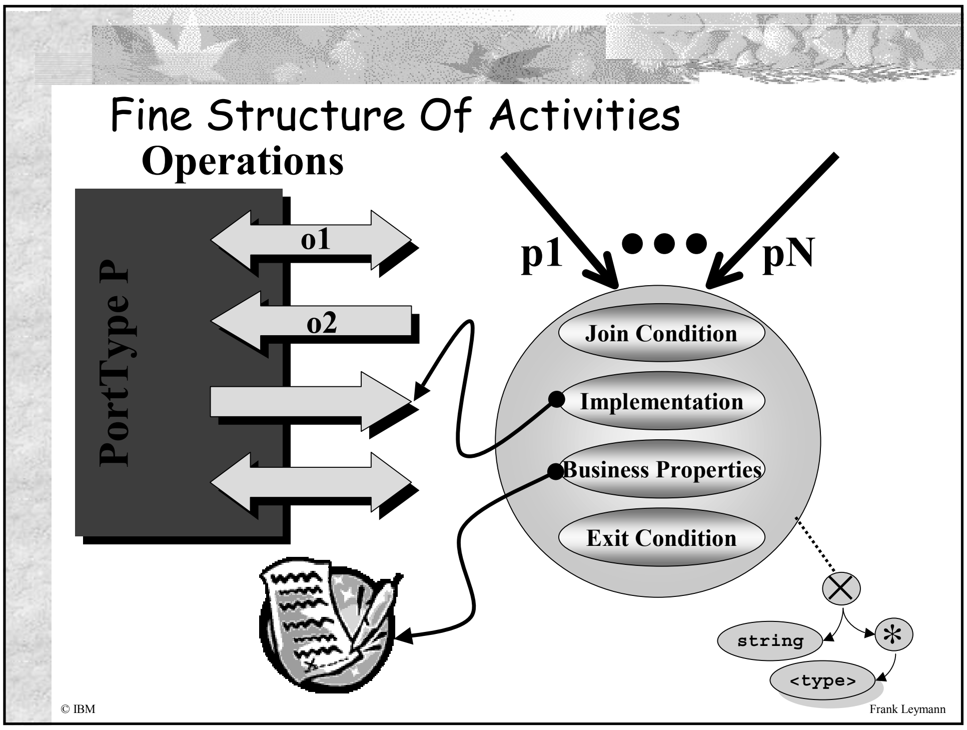
Data Links



Constraining Invokation Orders





Fine Structure Of Activities

Operations

PortType P

o1

o2

p1

pN

Join Condition

Implementation

Business Properties

Exit Condition

string

<type>

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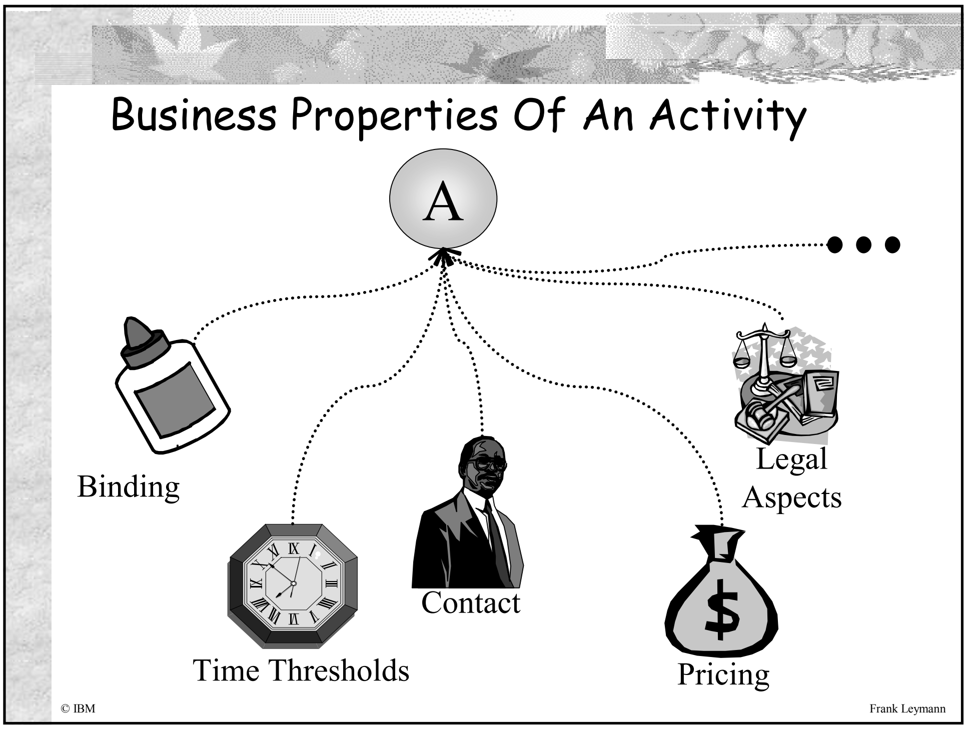

Business Properties Of An Activity

A

Binding

Time Thresholds

Contact

Pricing

Legal Aspects

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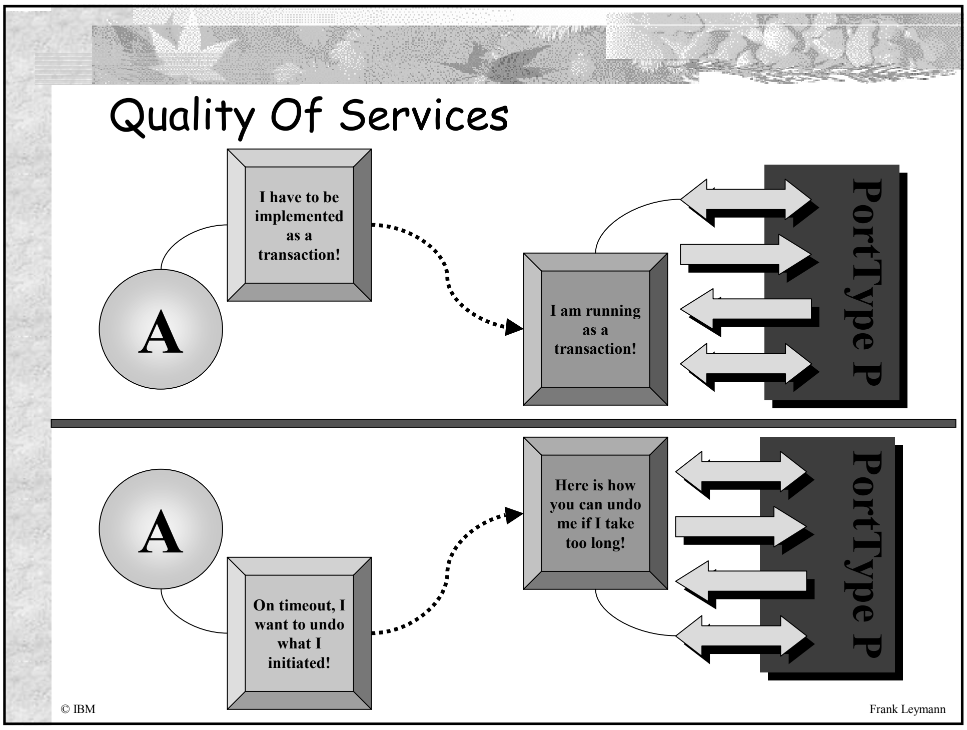

Quality Of Services

I have to be implemented as a transaction!
A
I am running as a transaction!
PortType P
Here is how you can undo me if I take too long!
A
On timeout, I want to undo what I initiated!
PortType P
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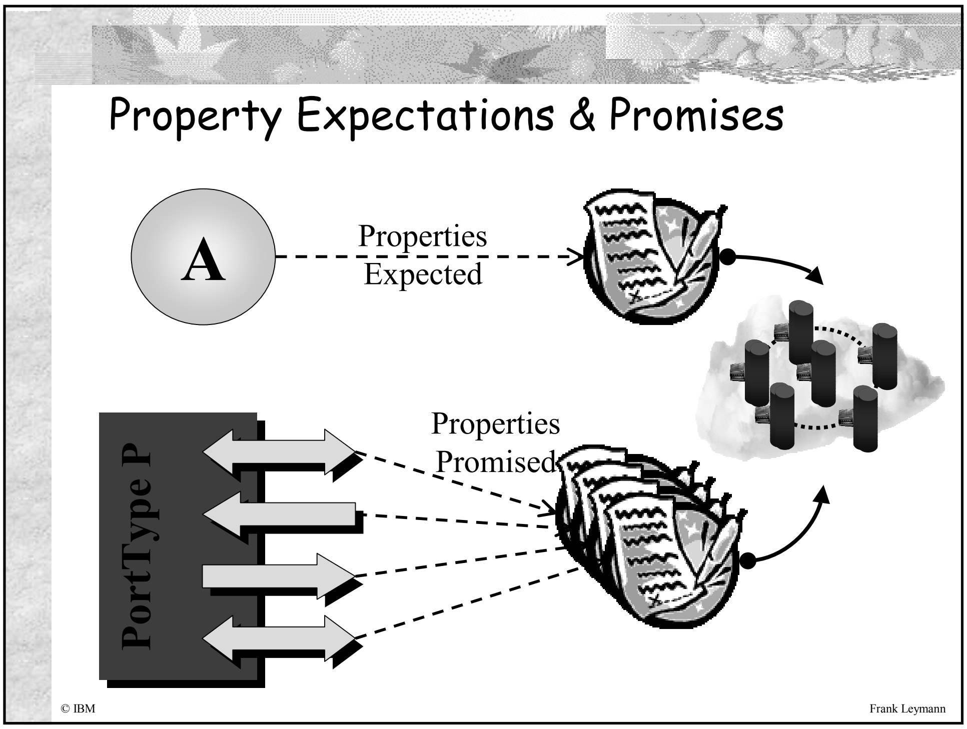
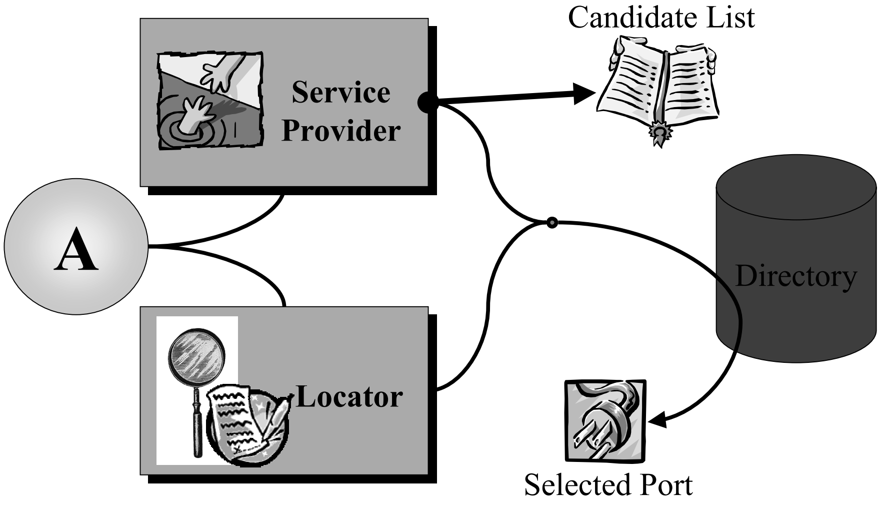
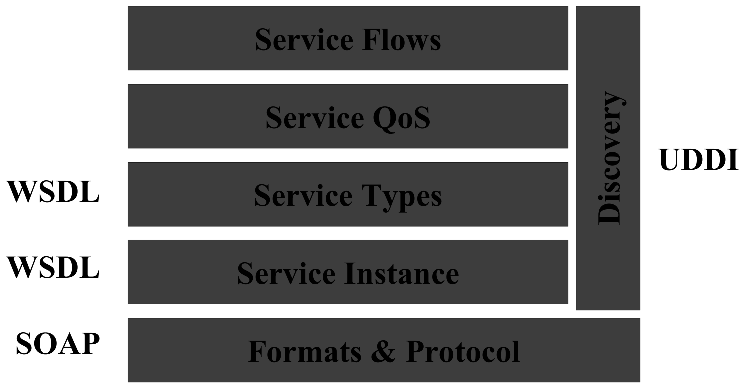


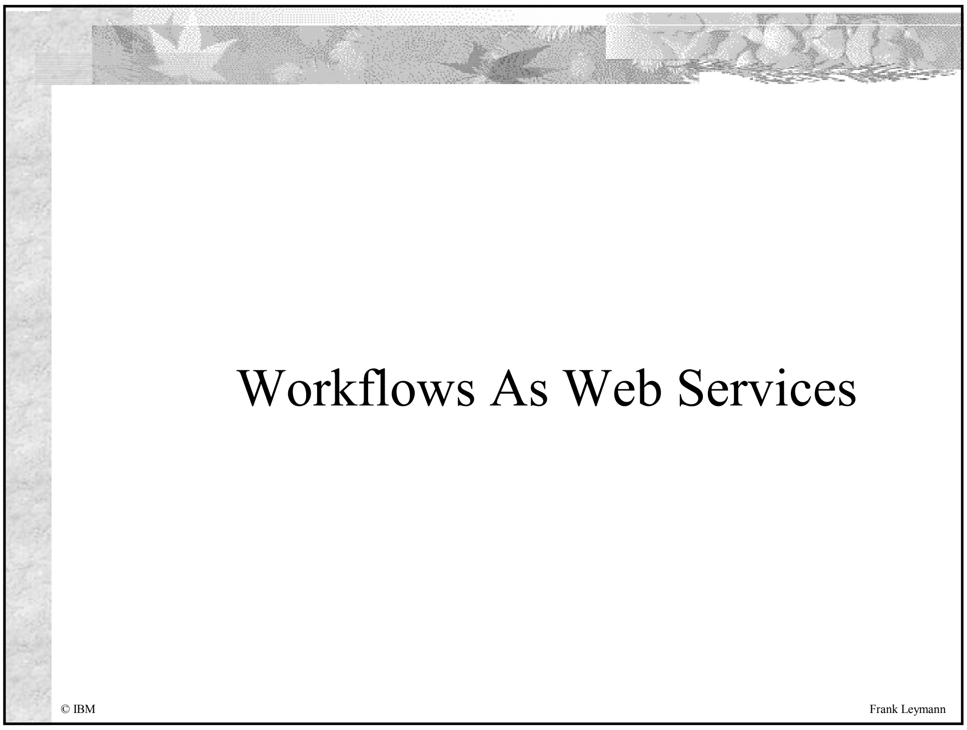
Property Expectations & Promises

Matching Endpoints



The Web Services Stack





Workflows As Web Services

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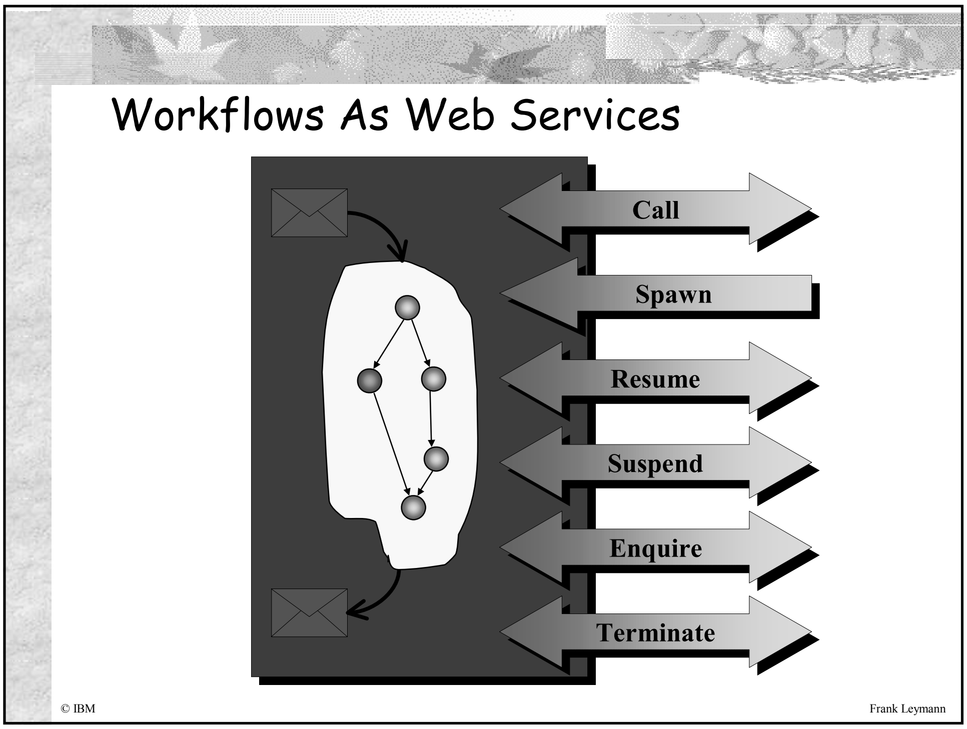

Workflows As Web Services

Call

Spawn

Resume

Suspend

Enquire

Terminate

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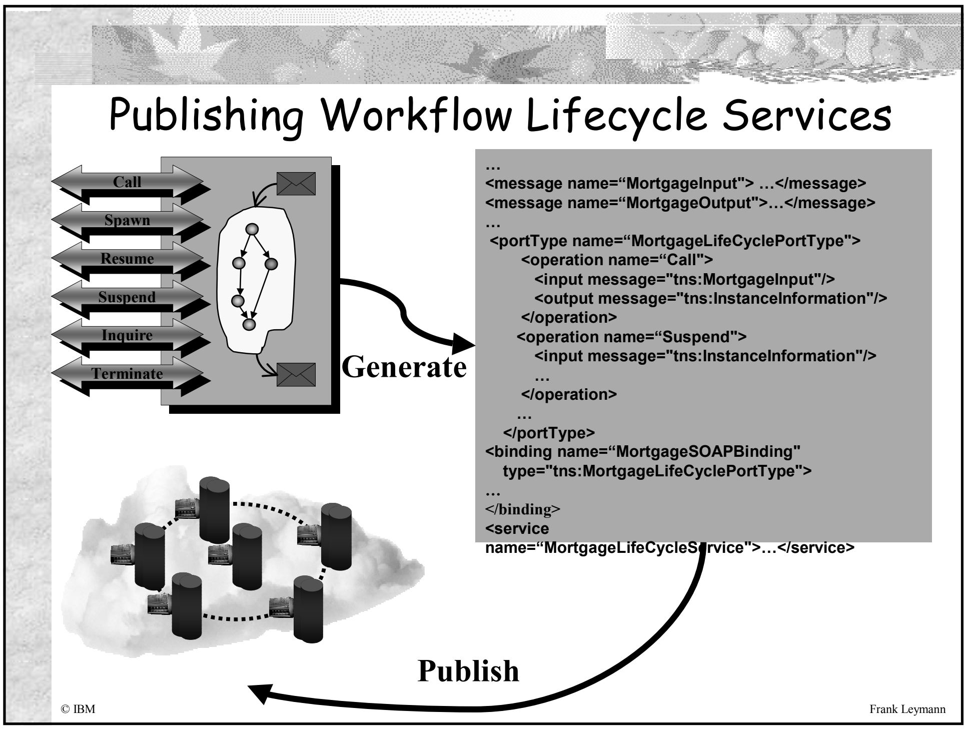

Publishing Workflow Lifecycle Services

```
…
<message name=“MortgageInput"> …</message>
<message name=“MortgageOutput">…</message>
…
 <portType name=“MortgageLifeCyclePortType">
       <operation name=“Call">
          <input message="tns:MortgageInput"/>
          <output message="tns:InstanceInformation"/>
       </operation>
      <operation name=“Suspend">
          <input message="tns:InstanceInformation"/>
          …
       </operation>
      …
    </portType>
<binding name=“MortgageSOAPBinding"
   type="tns:MortgageLifeCyclePortType">
…
</binding>
<service
name=“MortgageLifeCycleService">…</service>
```

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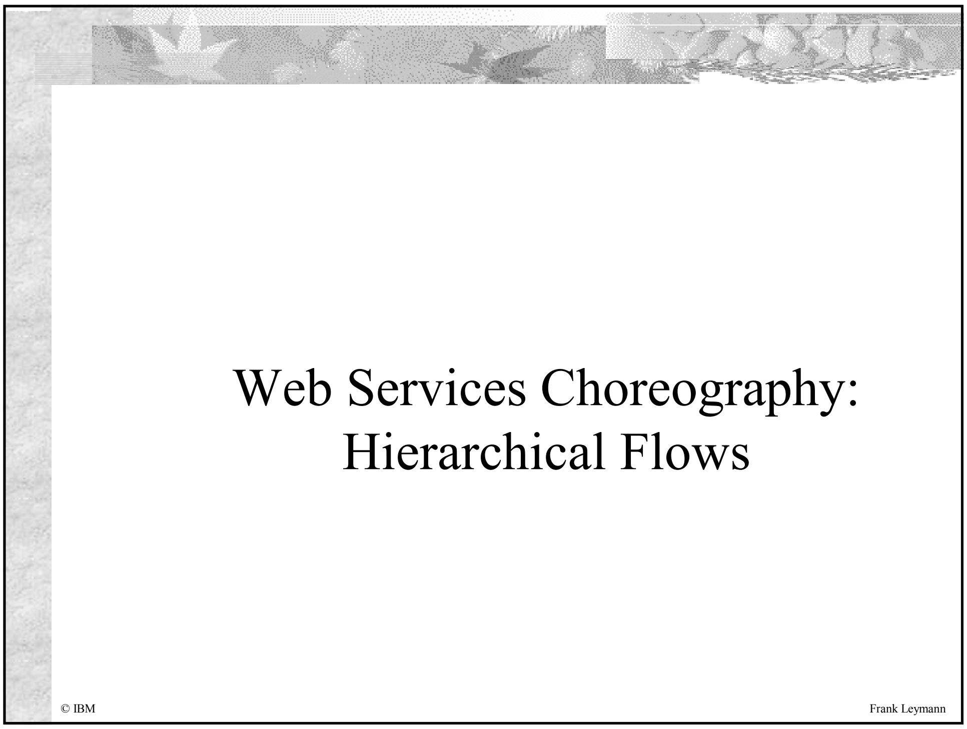

Web Services Choreography: Hierarchical Flows

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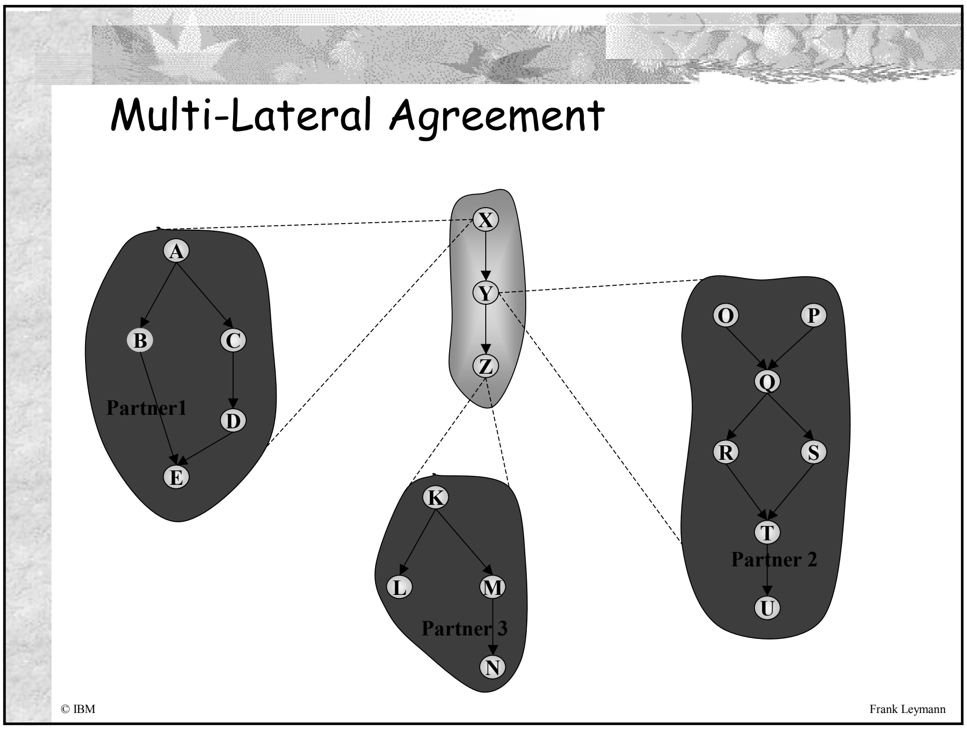

Multi-Lateral Agreement

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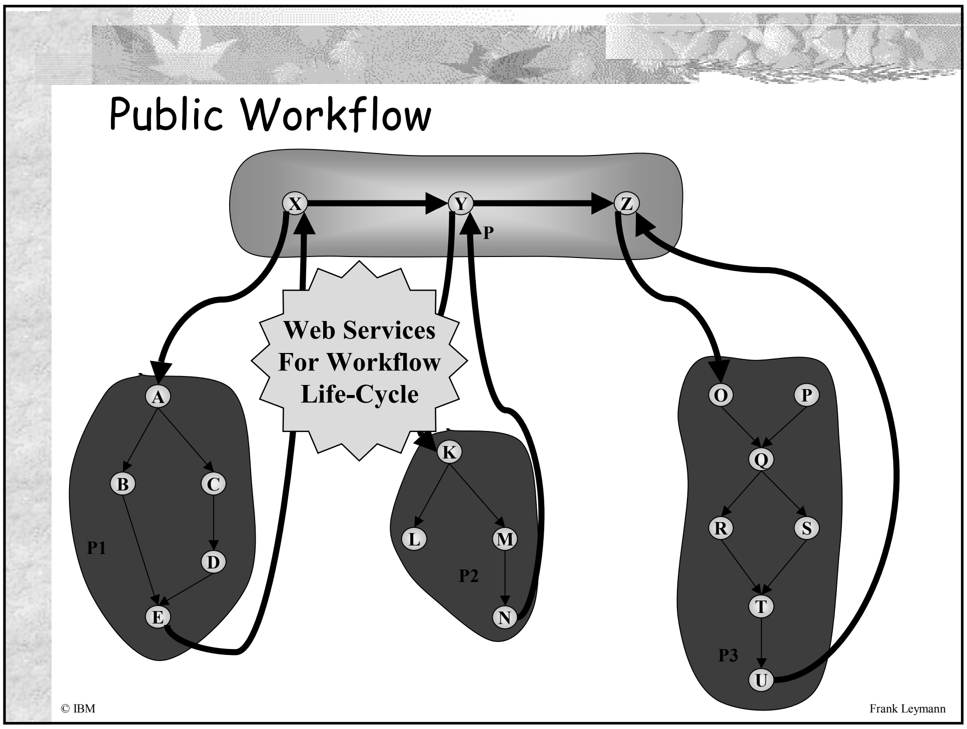

Public Workflow

Web Services For Workflow Life-Cycle

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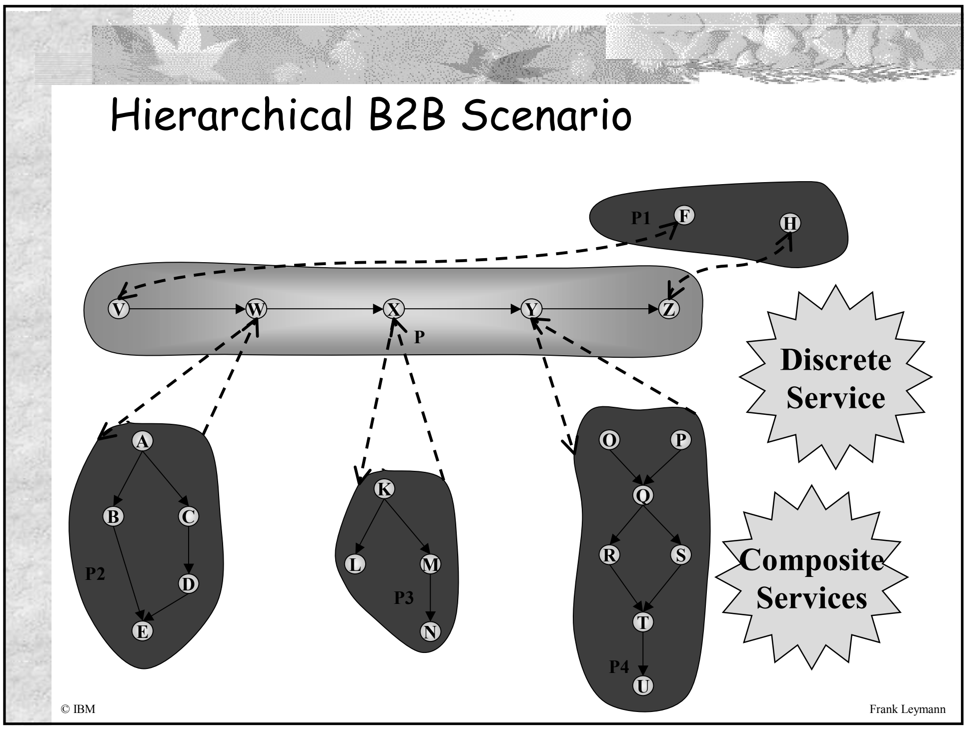

Hierarchical B2B Scenario

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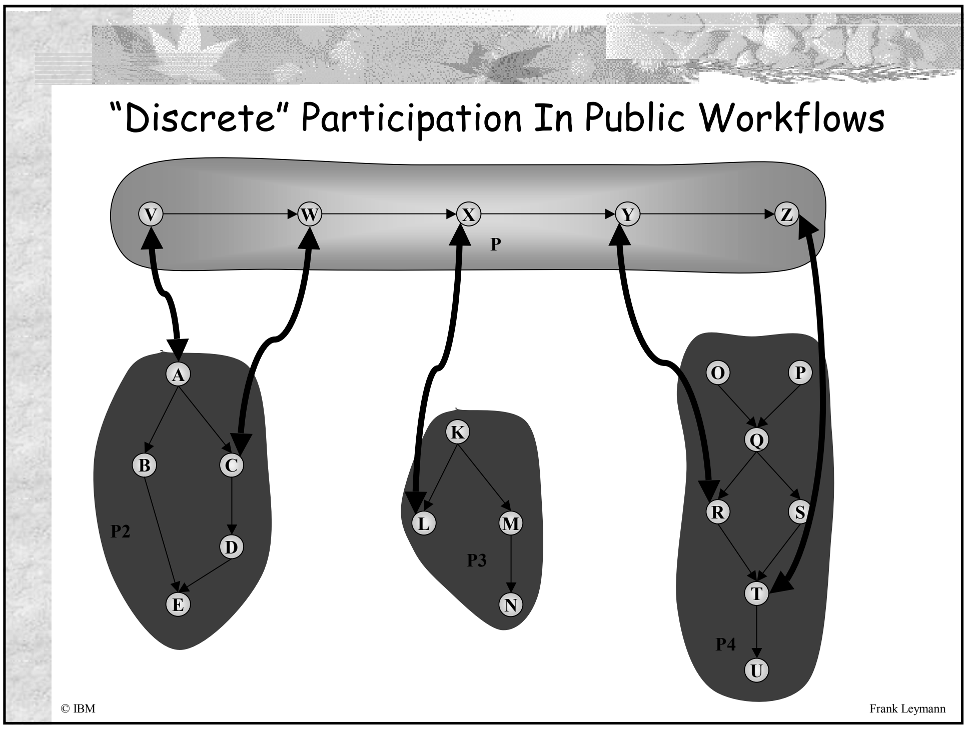

“Discrete” Participation In Public Workflows

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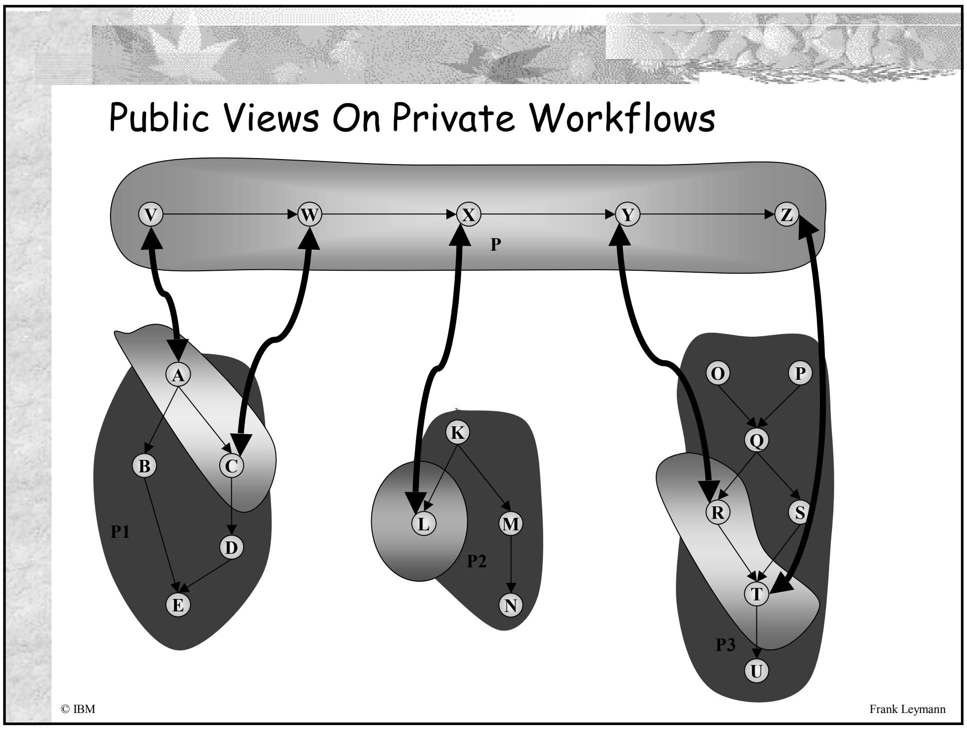

Public Views On Private Workflows

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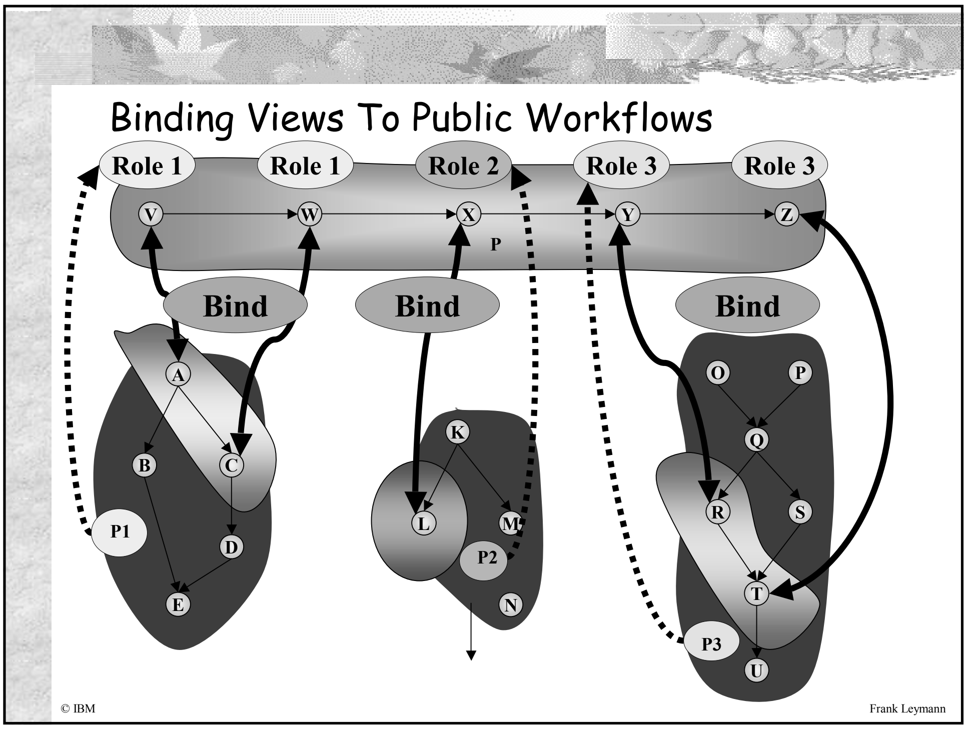

Binding Views To Public Workflows

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Web Services Choreography: Peer-To-Peer Flow

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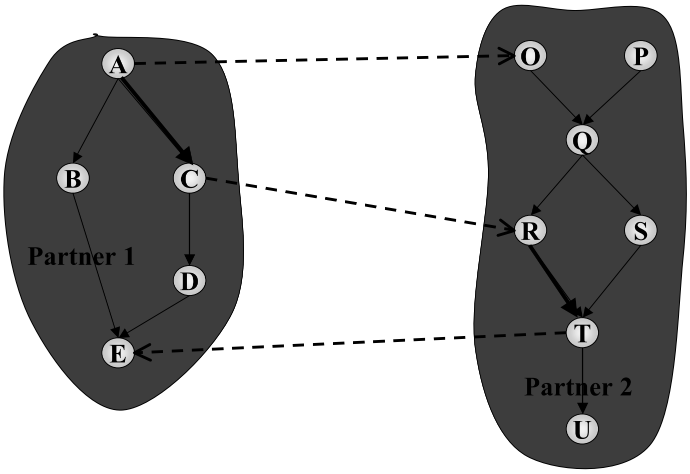
Peer-To-Peer B2B Scenario



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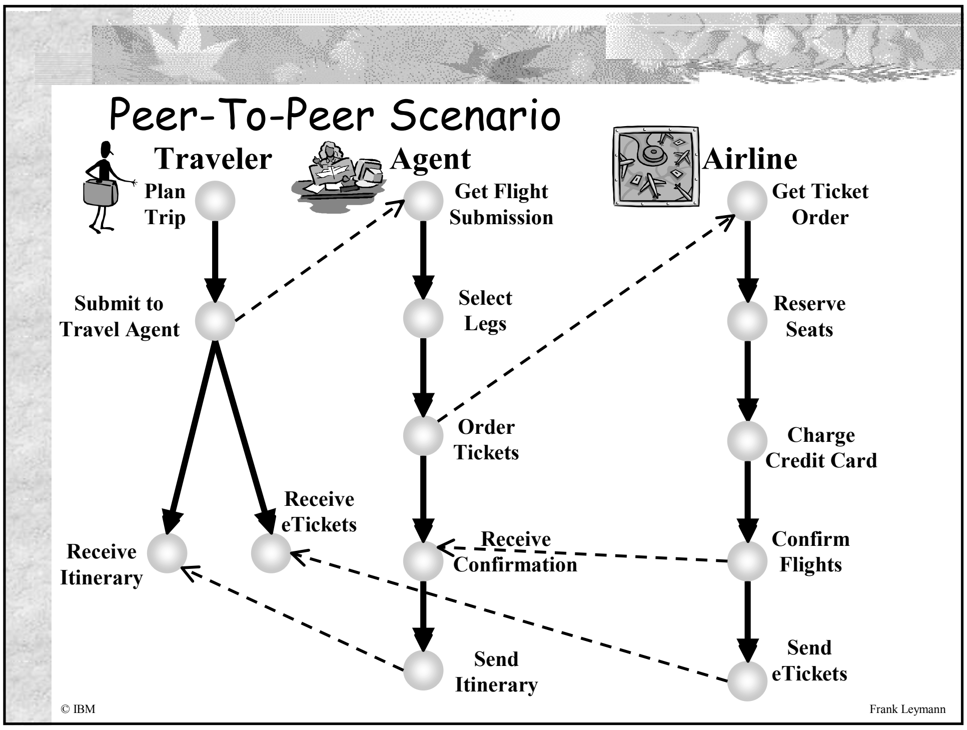

Peer-To-Peer Scenario

Traveler

Plan Trip

Submit to Travel Agent

Receive Itinerary

Receive eTickets

Agent

Get Flight Submission

Select Legs

Order Tickets

Receive Confirmation

Send Itinerary

Airline

Get Ticket Order

Reserve Seats

Charge Credit Card

Confirm Flights

Send eTickets

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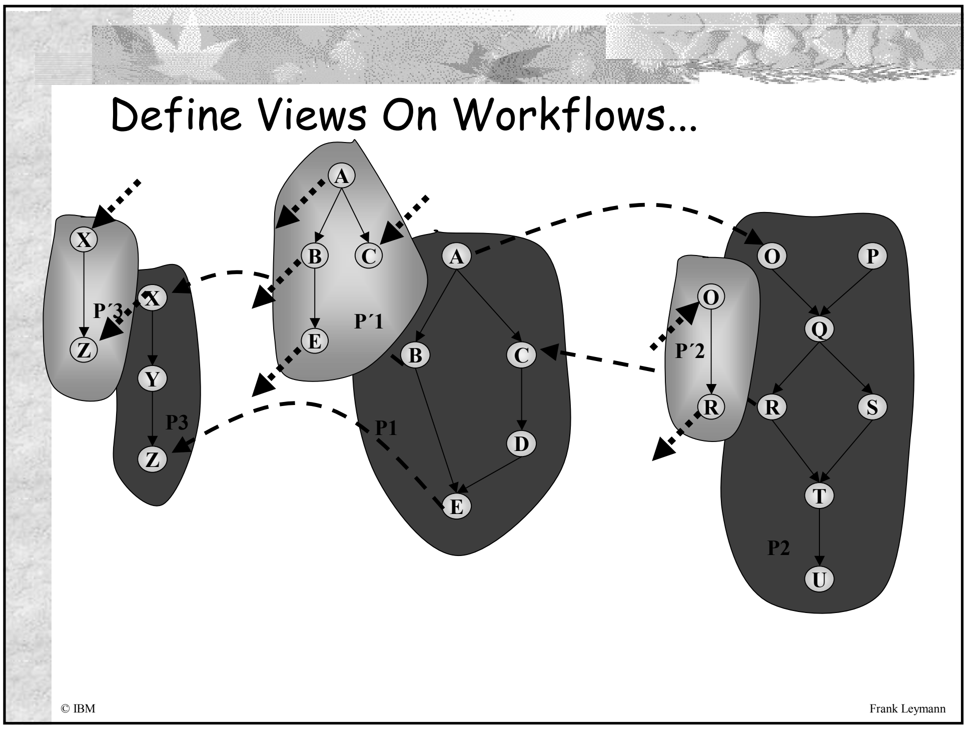

Define Views On Workflows...

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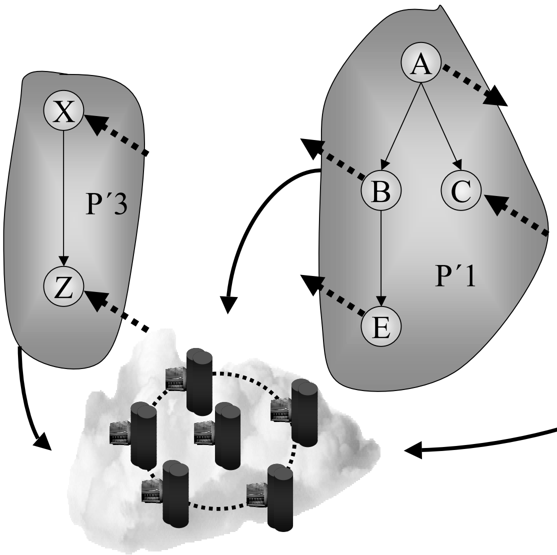
...And Publish Them As Web Services



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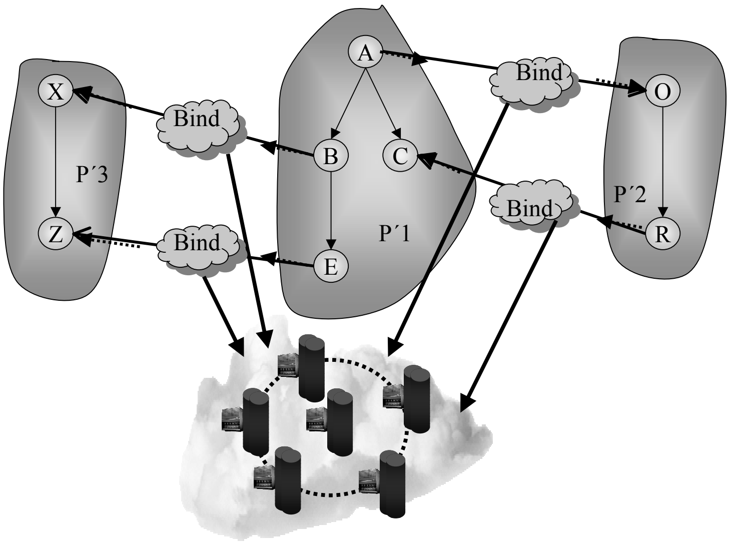
Dynamically Bind To Them At Run Time



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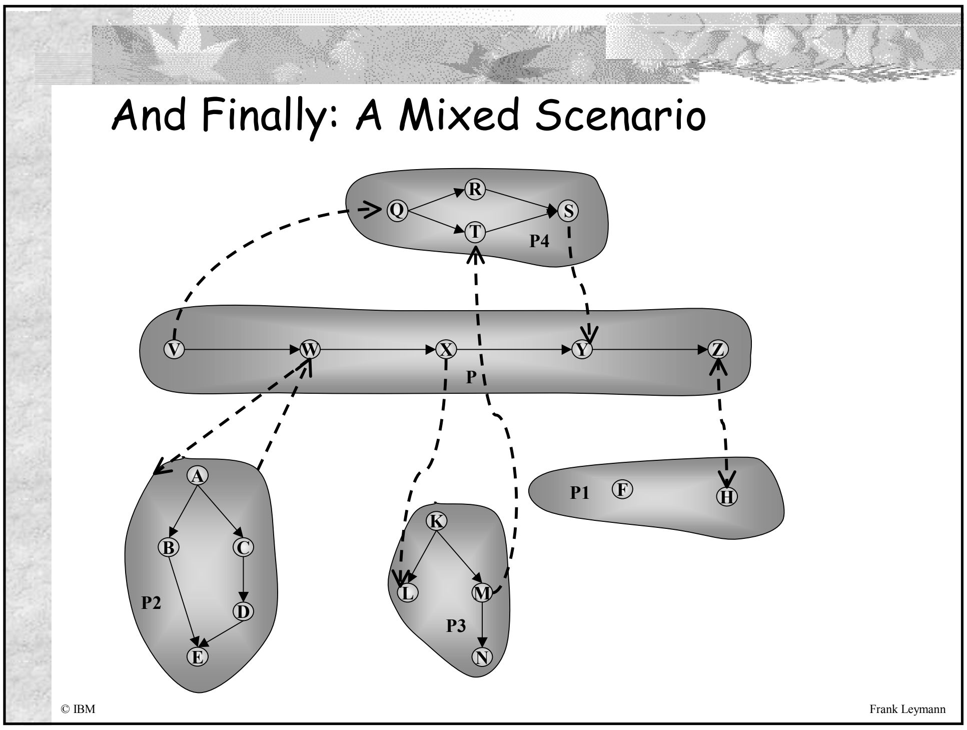

And Finally: A Mixed Scenario

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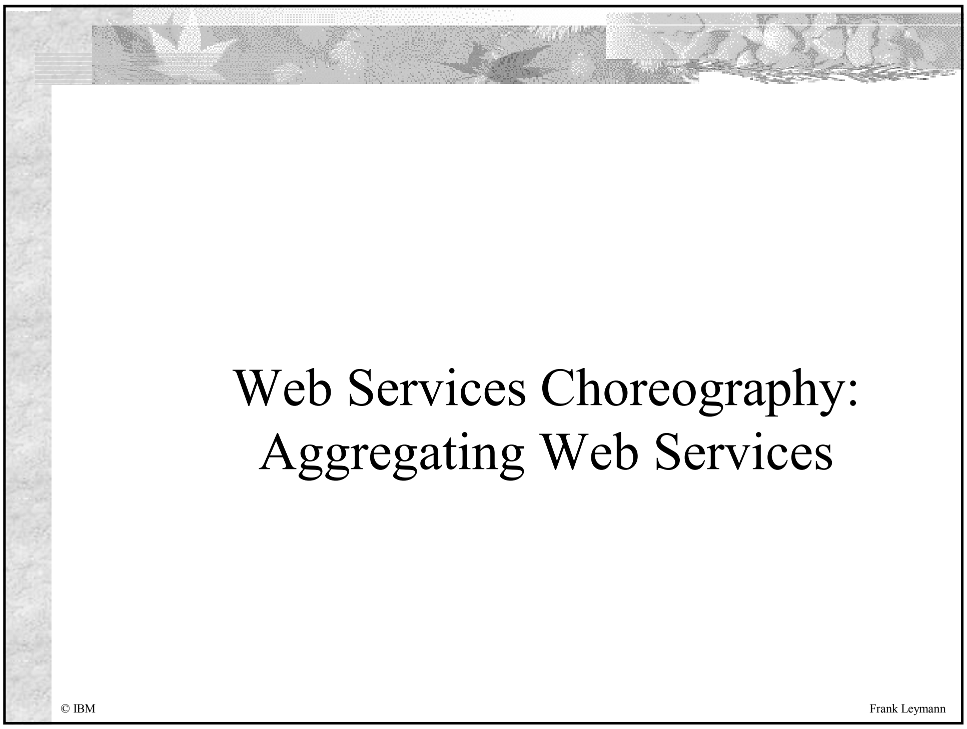

Web Services Choreography: Aggregating Web Services

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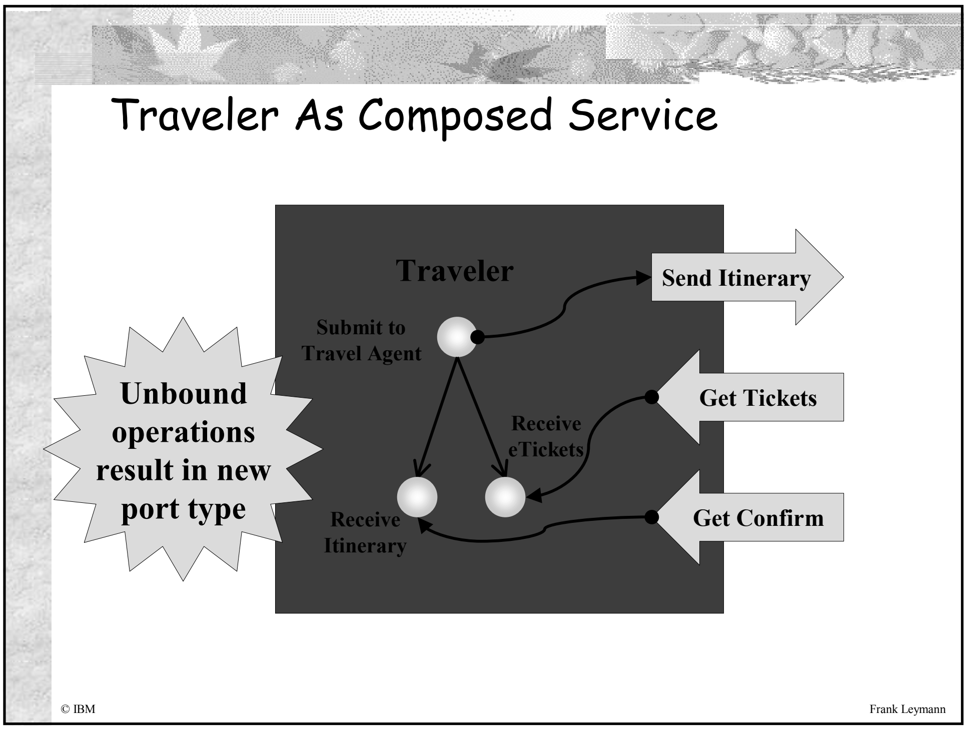

Traveler As Composed Service

Unbound operations result in new port type

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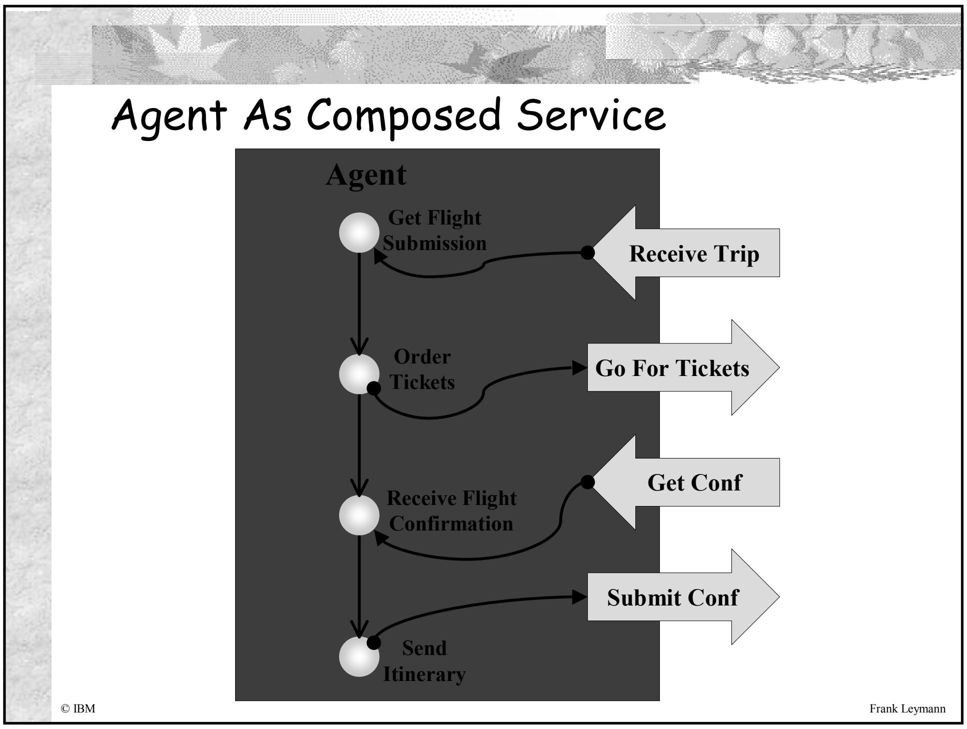

Agent As Composed Service

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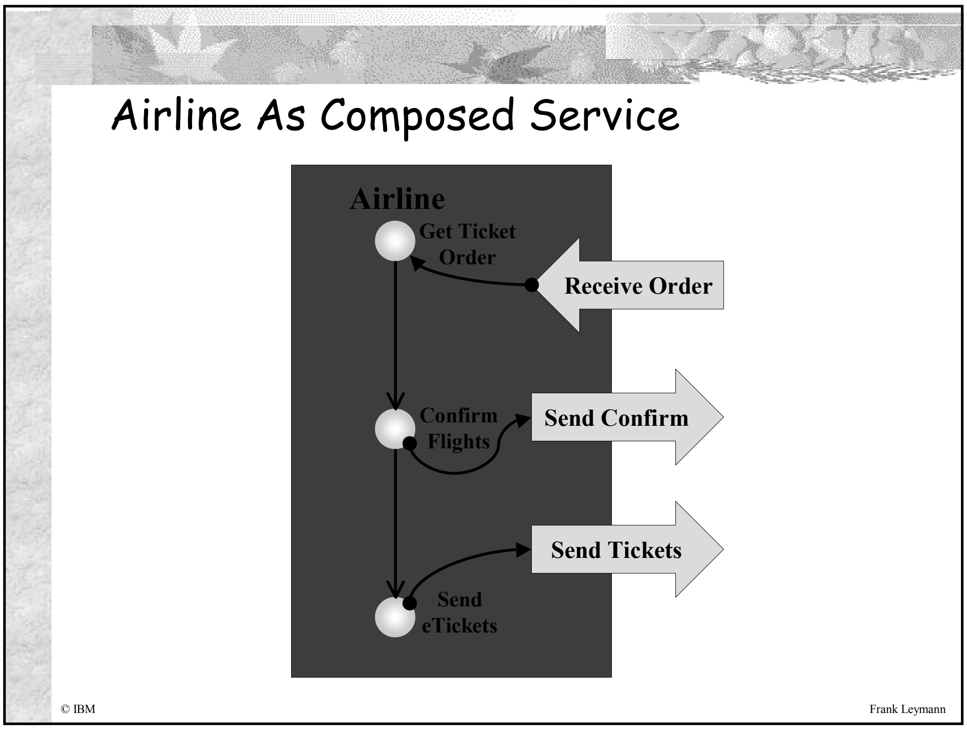

Airline As Composed Service

Airline

Get Ticket Order

Receive Order

Confirm Flights

Send Confirm

Send Tickets

Send eTickets

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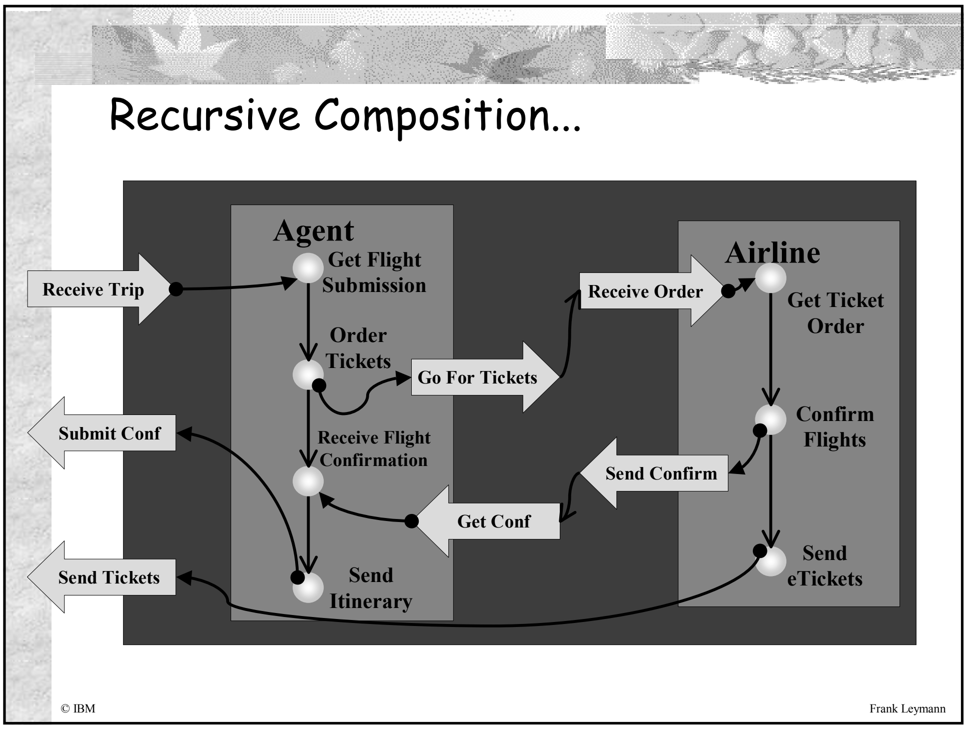

Recursive Composition...

Agent

Receive Trip

Get Flight Submission

Order Tickets

Go For Tickets

Receive Flight Confirmation

Submit Conf

Get Conf

Send Tickets

Send Itinerary

Airline

Receive Order

Get Ticket Order

Confirm Flights

Send Confirm

Send eTickets

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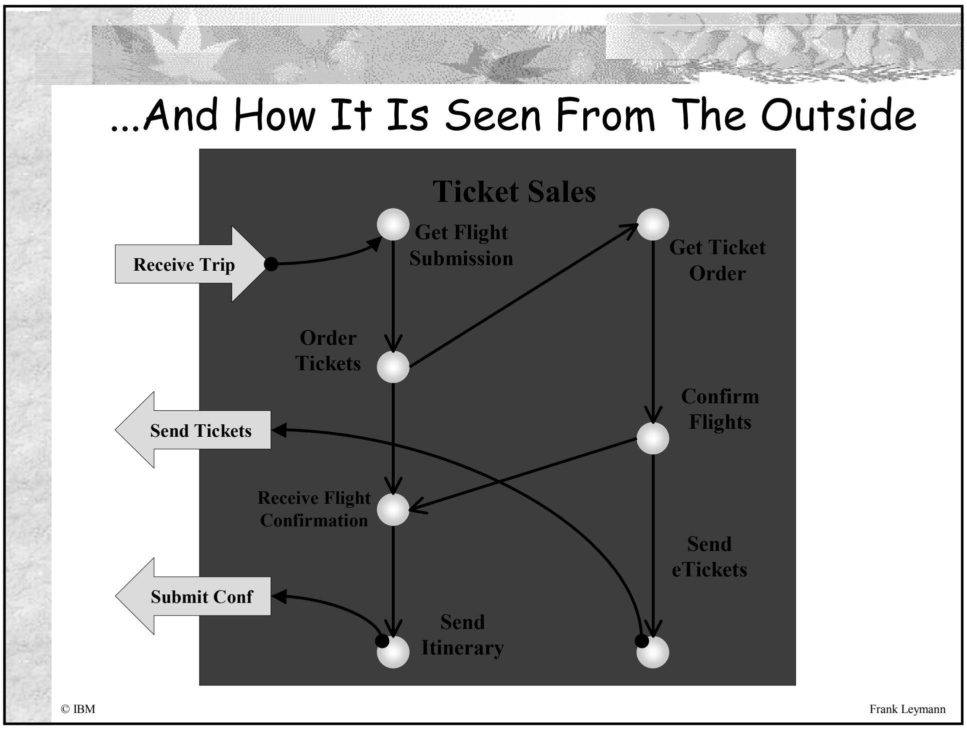

...And How It Is Seen From The Outside

Ticket Sales

Receive Trip

Get Flight Submission

Get Ticket Order

Order Tickets

Confirm Flights

Send Tickets

Receive Flight Confirmation

Send eTickets

Submit Conf

Send Itinerary

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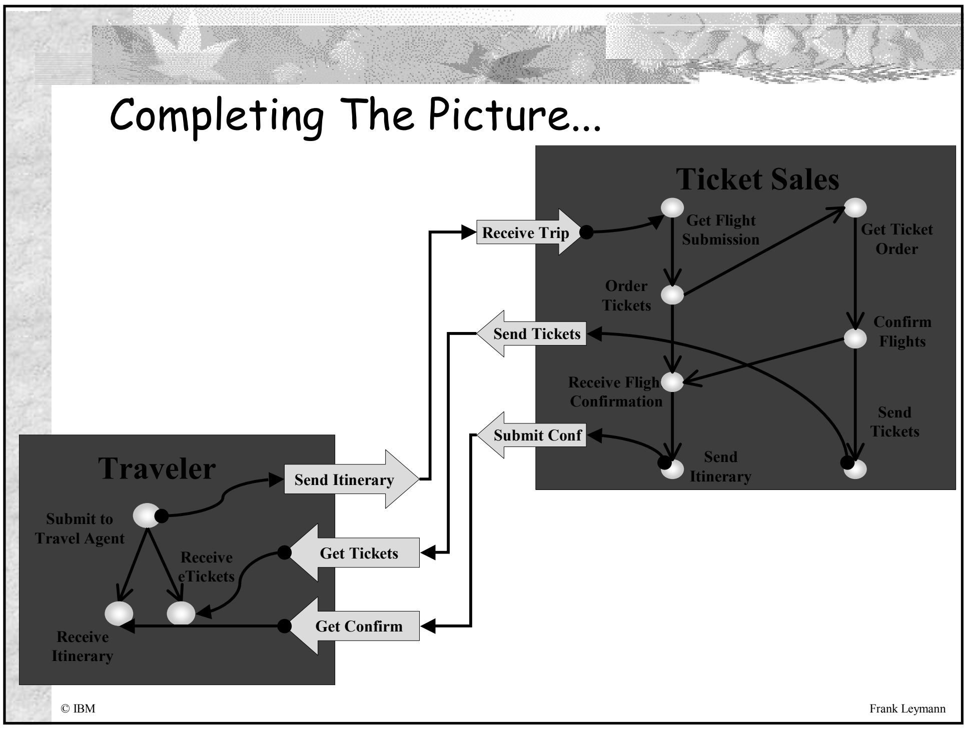

Completing The Picture...

Ticket Sales

Receive Trip

Get Flight Submission

Get Ticket Order

Order Tickets

Send Tickets

Confirm Flights

Receive Fligh Confirmation

Submit Conf

Send Tickets

Send Itinerary

Traveler

Send Itinerary

Submit to Travel Agent

Receive eTickets

Get Tickets

Receive Itinerary

Get Confirm

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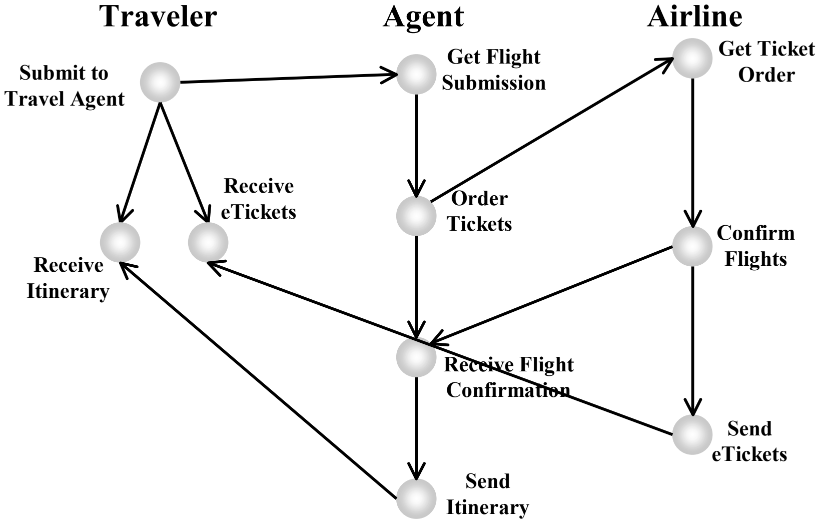
…Should Be a Deja Vu



Traveler

Agent

Airline

Submit to Travel Agent

Get Flight Submission

Get Ticket Order

Receive eTickets

Order Tickets

Receive Itinerary

Confirm Flights

Receive Flight Confirmation

Send eTickets

Send Itinerary

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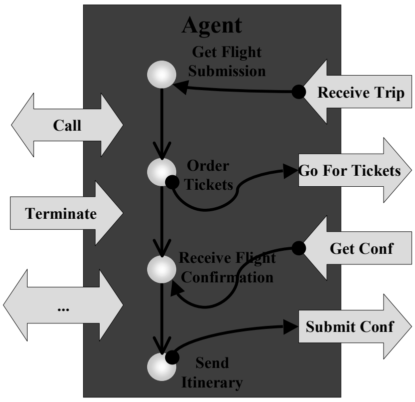
Completing The Picture

- A Web service flow may offer two kinds of operations
  - The exported „dangling“ operations requiring binding
  - The lifecycle operations for the flow as a whole



Agent

Get Flight Submission

Receive Trip

Call

Order Tickets

Go For Tickets

Terminate

Receive Flight Confirmation

Get Conf

...

Submit Conf

Send Itinerary

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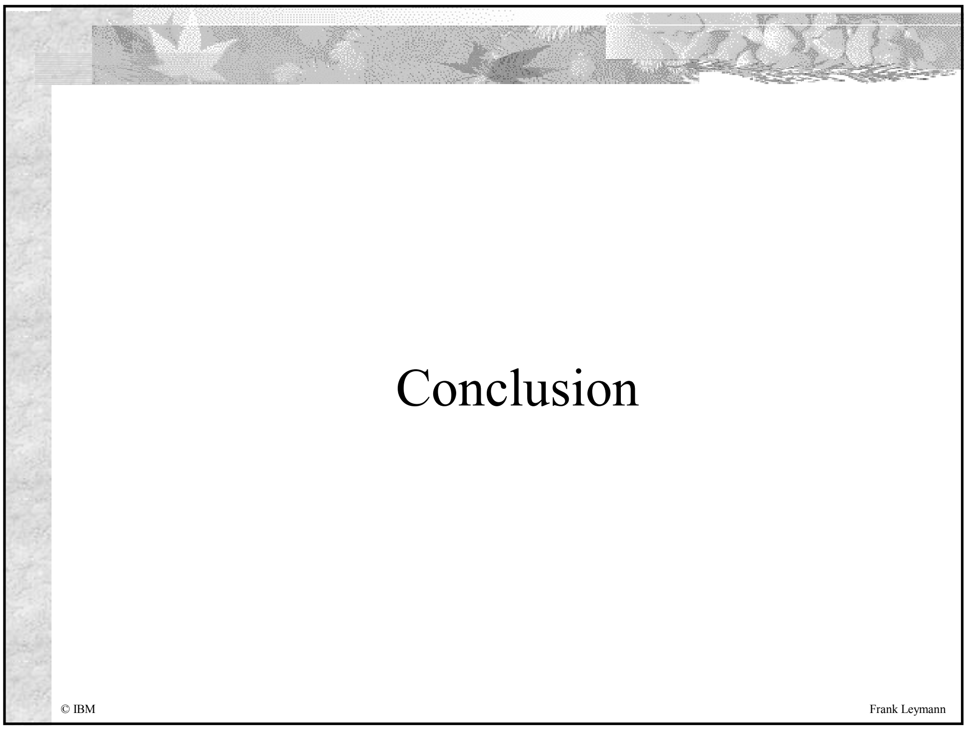

Conclusion

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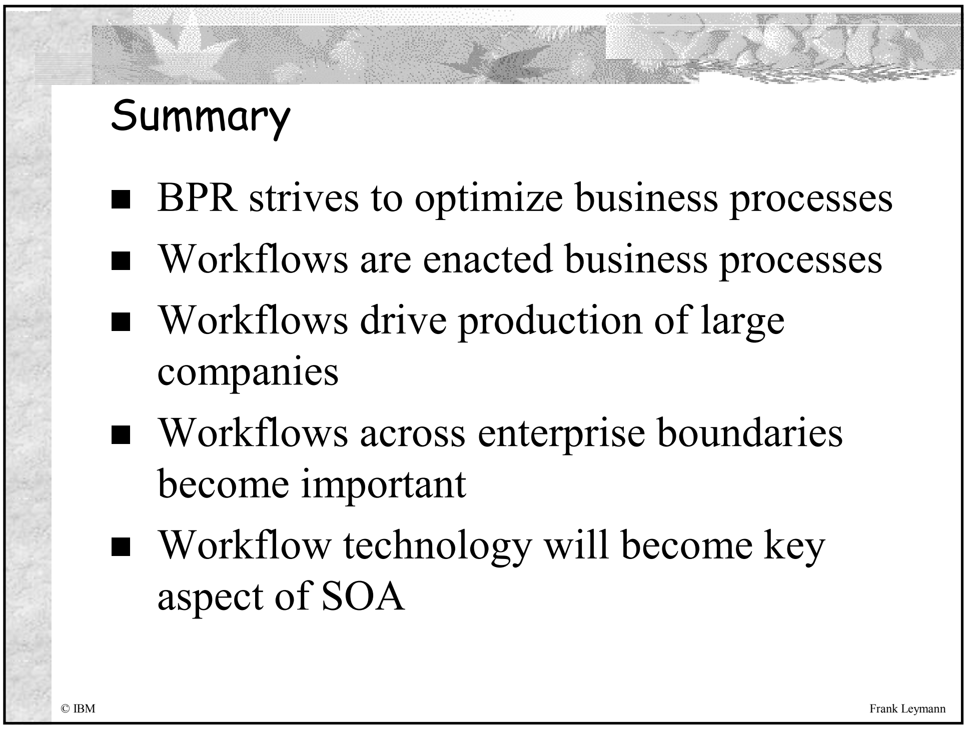

Summary

- BPR strives to optimize business processes
- Workflows are enacted business processes
- Workflows drive production of large companies
- Workflows across enterprise boundaries become important
- Workflow technology will become key aspect of SOA

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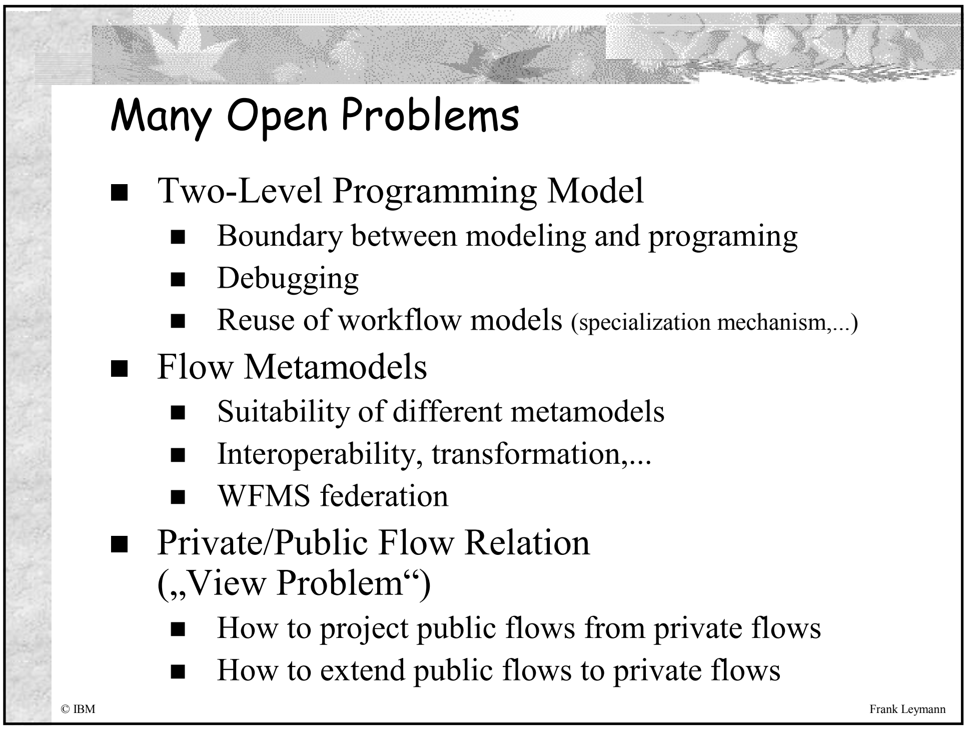

Many Open Problems

- Two-Level Programming Model
  - Boundary between modeling and programing
  - Debugging
  - Reuse of workflow models (specialization mechanism,...)
- Flow Metamodels
  - Suitability of different metamodels
  - Interoperability, transformation,...
  - WFMS federation
- Private/Public Flow Relation („View Problem“)
  - How to project public flows from private flows
  - How to extend public flows to private flows

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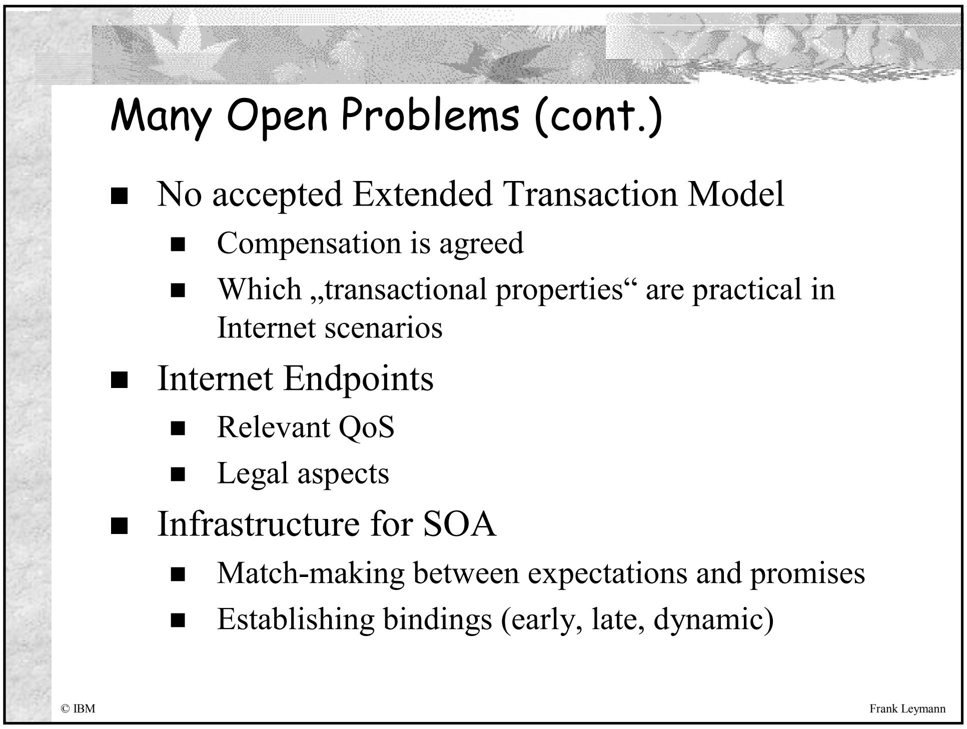

Many Open Problems (cont.)

- No accepted Extended Transaction Model
  - Compensation is agreed
  - Which „transactional properties“ are practical in Internet scenarios
- Internet Endpoints
  - Relevant QoS
  - Legal aspects
- Infrastructure for SOA
  - Match-making between expectations and promises
  - Establishing bindings (early, late, dynamic)

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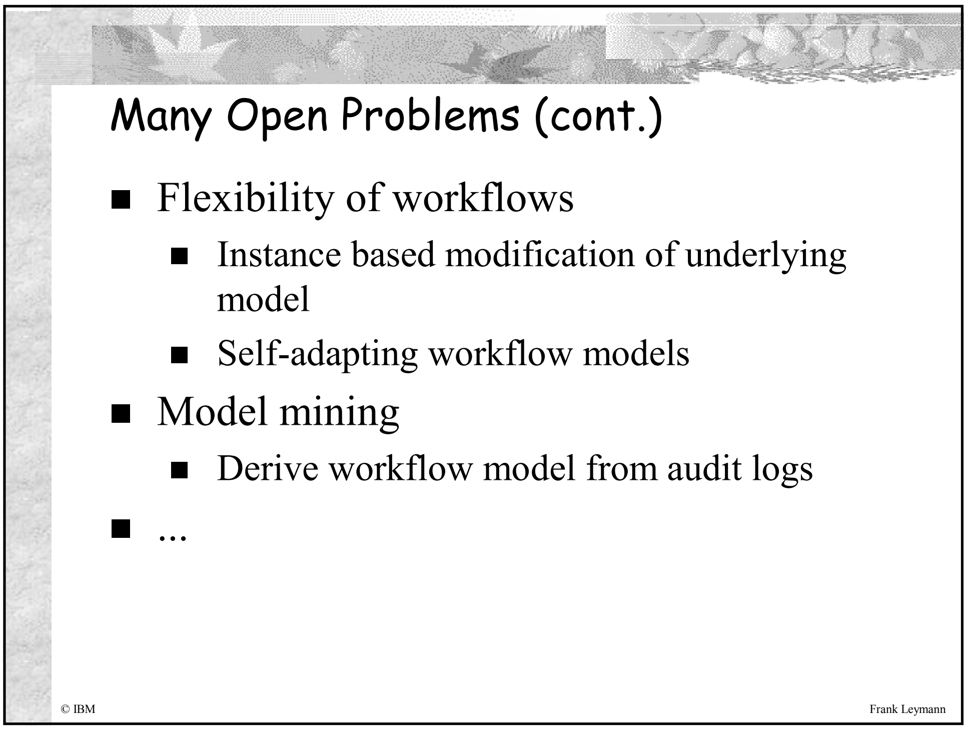

Many Open Problems (cont.)

- Flexibility of workflows
  - Instance based modification of underlying model
  - Self-adapting workflow models
- Model mining
  - Derive workflow model from audit logs
- ...

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The End

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