# Lecture 5

Introduction to Architectural Patterns:
Pipes & Filters, Message Queues, Layers
MVC Design Pattern

# Epigram

"One little incident of LISP beauty happened when Allen Newell visited PARC with his theory of hierarchical thinking and was challenged to prove it. He was given a programming problem to solve . . . given a list of items, produce a list consisting of all the odd indexed items followed by all of the even indexed items. [Newell] got into quite a struggle to do the program [with his IPL-V like language]. In 2 seconds I wrote down oddsEvens(x) = append(oods(x), evens(x)). This characteristic of writing down many solutions in declarative form and have them also be the programs is part of the appeal and beauty of this kind of language. Watching a famous guy much smarter than I struggle for more than 30 minutes to not quite solve the problem his way (there was a bug) made quite an impression. It brought home to me once again that *point of view is worth 80 IQ points*. I wasn't smarter but I had a much better internal thinking tool to amplify my abilities. This incident and others like it made it paramount that any tool for children should have great thinking patterns *and* deep beauty 'built-in'."

--Alan Kay, creator of Smalltalk

# What is Software Architecture

- A Software Architecture provides a fundamental description of a system, detailing the components that make up the system, the significant collaborations between those components, including the data and control flows of the system
- A Software Architecture attempts to provide a sound basis for analysis, decision making, and risk assessment of both design and performance
- Architecture is an asset that constitutes tangible value to the organization that has created it

# What is an Architectural Pattern?

- An enterprise-level solution to common design problems
- A set of design artifacts that together provide mechanisms for solving or avoiding common enterprise-level design problems
- An architectural pattern represents common best practice models for solving problems related to designing enterprise software
- Architectural patterns, like design patterns, promote a common *vocabulary* within which to discuss enterprise design issues, along with constraints on their implementations
- Sometimes, you'll see architectural patterns called "styles" (cf. Shaw and Garlan). They're the same thing.

# Architectural Interlude

Enterprise Messaging Concepts

# Distribution vs. Integration

- N-tier distributed applications tend to be tightly coupled, as:
  - The tiers depend directly on one another
  - The communication tends to be *synchronous*
  - There is a certain performance expectation in terms of timely delivery of information
  - The distributed objects of the system tend to form parts of a single application (although components can be leveraged by several different applications)

# Distribution vs. Integration

- Integrated applications tend to be *loosely coupled*, as:
  - Multiple applications coordinate in a loosely coupled manner, they can be understood to be “disconnected” from one another
  - Each application is discrete, but may need or provide information from other applications
  - Such communication of data tends to be asynchronous
  - Individual applications can continue what they’re doing while waiting on processing from another application

# Messaging

- Technologies such as CORBA, EJB, RPC, Web Services, etc. tend to support n-tier application strategies, and tend to be *synchronous* in their mechanisms
- Messaging Technologies tend to be *asynchronous* and facilitate the integration of separate but collaborating applications
- Messaging technologies are based on the *Mediator Pattern* and use it to provide numerous benefits in terms of integration

# Distribution and Integration

- Nevertheless, distributed and integrated technology strategies do share many of the same features, such as:
  - Reliable communication (exceptions)
  - Multithreaded operation
  - An object façade is available for both strategies

# Types of Messaging Systems

- Operating Systems (MSMQ in Windows XP, System V IPC Message Queues in Unix)
- Application Servers and Message Oriented Middleware (MOM) (JMS as part of J2EE 1.2, now incorporated into almost all J2EE Application Servers)
- Enterprise Application Integration suites which (may) focus on process workflow such as WebSphere MQ, Microsoft BizTalk, TIBCO, WebMethods, Vitria, etc.

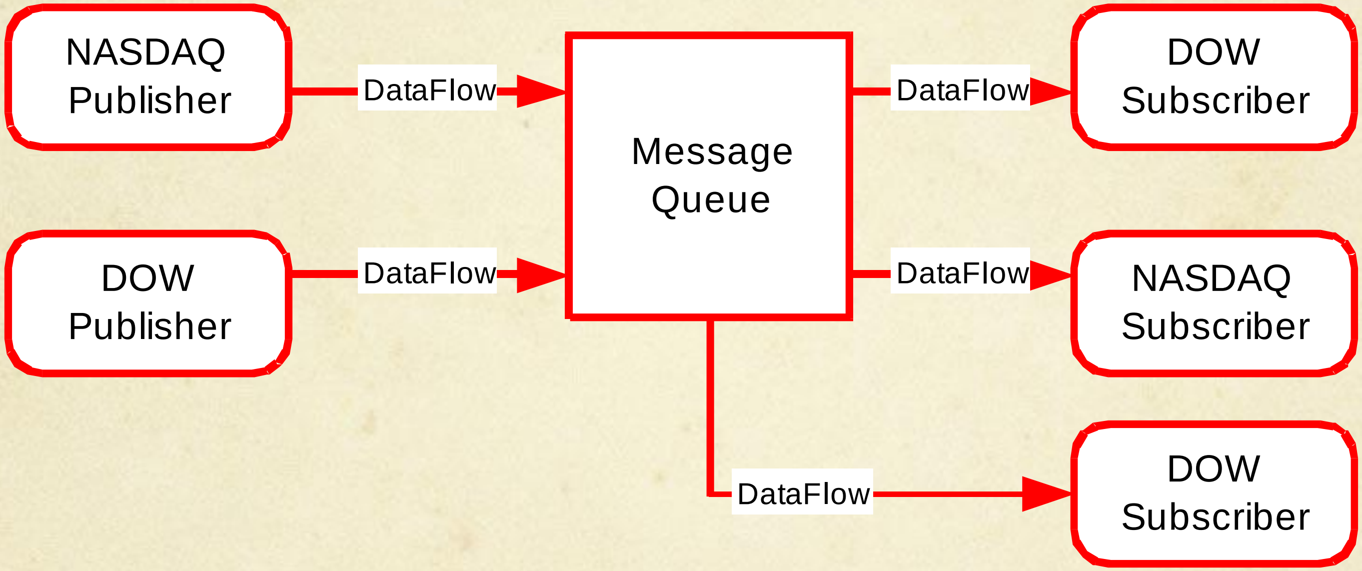
# Fundamental Archetypes

- Delivery Metaphors (Messaging Domains)
  - Publish Subscribe
  - Point to Point
- Pipes and Filters Pattern
- Message Queue Pattern

# Publish Subscribe Delivery

- Sometimes we want to *broadcast* the same message to *more than one* interested recipients (subscriber)
- We *want* a message to be sent to more than one recipient
- Sending applications *publish* messages to the queue (topic), and receiving applications *subscribe* to queues (topics) to receive messages
- Messages are delivered to subscribers via the push method (messages are pushed out to subscribers)
- Example: A price change on an exchange needs to be broadcast to several different brokerage firms interested in that price change

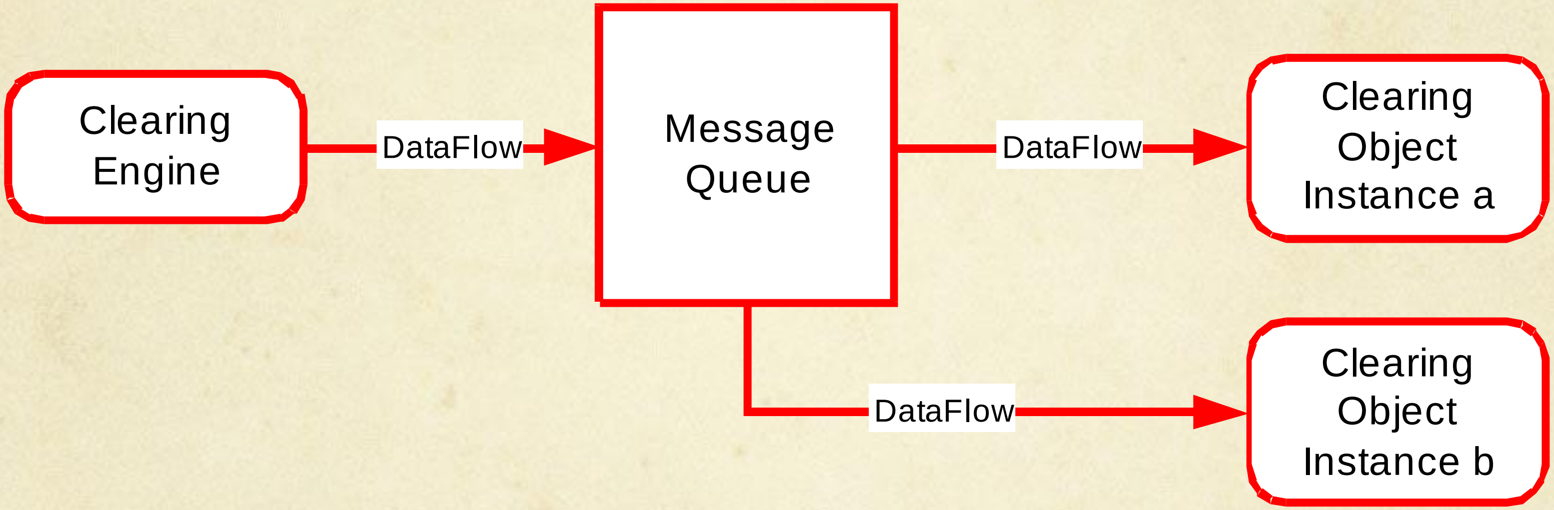
# Publish Subscribe Delivery



# Point To Point Delivery

- Sometimes, we want to ensure that *only one* consumer consumes any given message
- We don't want to broadcast a message to multiple recipients, but rather, want to make sure *only one* recipient receives *each* discrete message
- We can still have multiple (competing) consumers, but P2P guarantees that *only one of them* will get any single message
- Message delivery can either by synchronous (pull via the receive() method) or asynchronous (push via the OnMessage() callback)
- Example:  We have multiple Clearing objects, and only want one Clearing object to clear any given trade (i.e., we don't want trades being cleared *multiple* times)

# Point To Point Delivery



# Pipes and Filters Pattern

Operative Metaphor:
Conveyer Belt

# Pipes and Filters Pattern

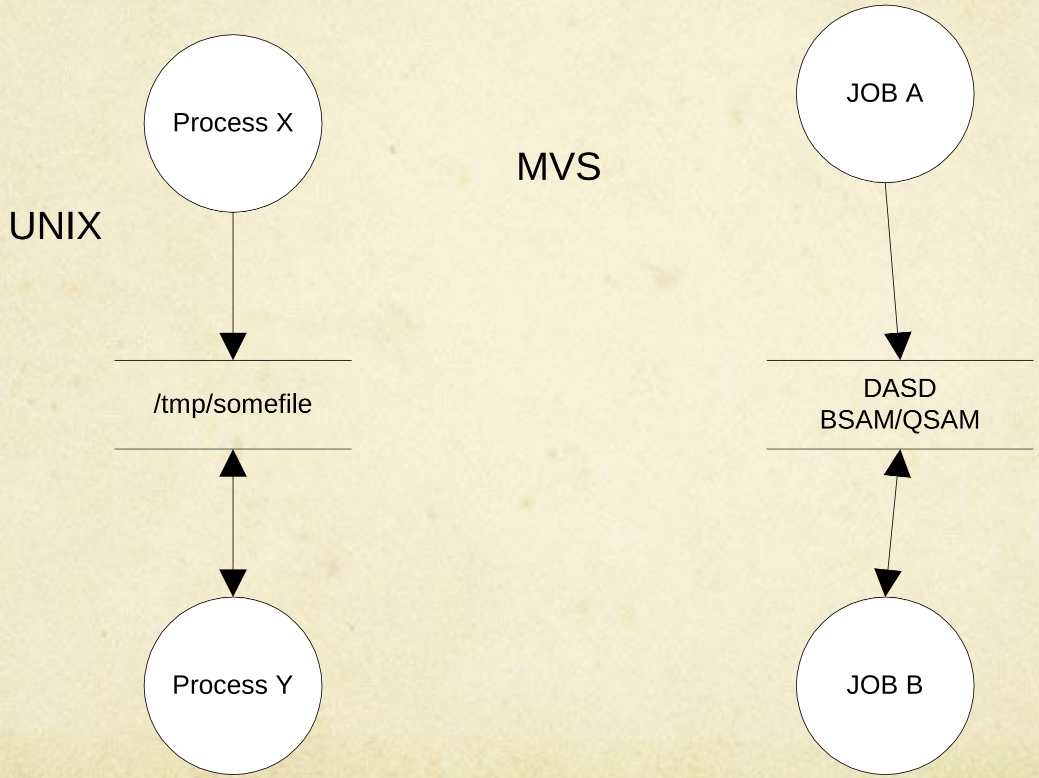
- The Pipes and Filters pattern is a data-flow architectural pattern that views the system as a series of transformations on successive pieces of input data
- Pipes are stateless and serve as conduits for moving streams of data between multiple filters
- Filters are stream modifiers, which process incoming data in some specialized way and send that modified data stream out over a pipe to another filter
- If you are familiar with the decorator design pattern, filters may be seen as decorators.  Java's stream IO is an example of the use of decorators as stream filters

# Details

- Unix background
  - Origination of Pipes and Filters concept with Ken Thompson of Bell Labs
- Active filters (passive *pipes*)
  - filters do the pushing and pulling from a passive pipe (Unix model)
- Passive filters (utilize active *pipes*, push and pull)
  - CORBA Event Services model with Push Consumers and Pull Supplier

# Motivation:
# Batch Sequential Data Processing

- In the beginning, there was a void…




Px >/tmp/somefile
Py < /tmp/somefile

# Batch Sequential Data Processing

- Stand-alone programs would operate on data, producing a file as output
- This file would stand as input to another stand-alone program, which would read the file in, process it, and write another file out
- Each program was dependent on its version of input before it could begin processing
- Therefore processing took place sequentially, where each process in a fixed sequence would run to completion, producing an output file in some new format, and then the next step would begin

# Pipes and Filters Features

- Incremental delivery:  data is output as work is conducted
- Concurrent (non-sequential) processing, data *flows* through the pipeline in a stream, so multiple filters can be working on different parts of the data stream simultaneously (in different processes or threads)
- Filters work *independently and ignorantly* of one another, and therefore are plug-and-play
- Filters are ignorant of other filters in the pipeline --there are no filter-filter interdependencies
- Maintenance is again isolated to individual filters, which are loosely coupled
- Very good at supporting producer-consumer mechanisms
- Multiple readers and writers are possible

# Benefits

- Fairly simple to understand and implement
- Simple, defined interface reduces complex integration issues
- Filters are substitutable black boxes, and can be plug and played, and thus *reused* in creative ways
- Filters are highly modifiable, since there's no coupling between filters and new filters can be created and added to an existing pipeline

# More Benefits

- Filters and Pipes can be hierarchical and can be composed into a facade mechanism to further simplify client access
- Because filters stand alone, they can be distributed easily and support concurrent execution (the stream is *in process*)
- Multiple filters can be used to design larger complex highly-modifiable algorithms, which may be modified by adding new filters or deleting others

# Limitations

- A batch processing metaphor is not inherently limiting, but this pattern does not facilitate highly dynamic responses to system interaction
- Because filters are black boxes, and are ignorant of one another, they cannot intelligently reorder themselves dynamically
- Once a pipeline is *in progress*, it cannot be altered without corrupting the stream
- Difficult to configure dynamic pipelines, where depending on content, data is routed to one filter or another

# More Limitations

- The "Kiss It Goodbye" scenario: useful for batch-oriented processing, limited support for interactive applications (what happens when already-processed data needs to change? Compare this to a shared-memory solution)
- May force a Lowest Common Denominator for data transmission, forcing some filters to have to modulate the stream before processing (some filters are set to handle XML, others strings, etc.)
- Each filter must internally buffer the data (some *all* of the data), creating memory issues in longer pipelines
- Filters which require all input to be delivered before they can begin processing (uniq, sort) can require significant buffering overhead

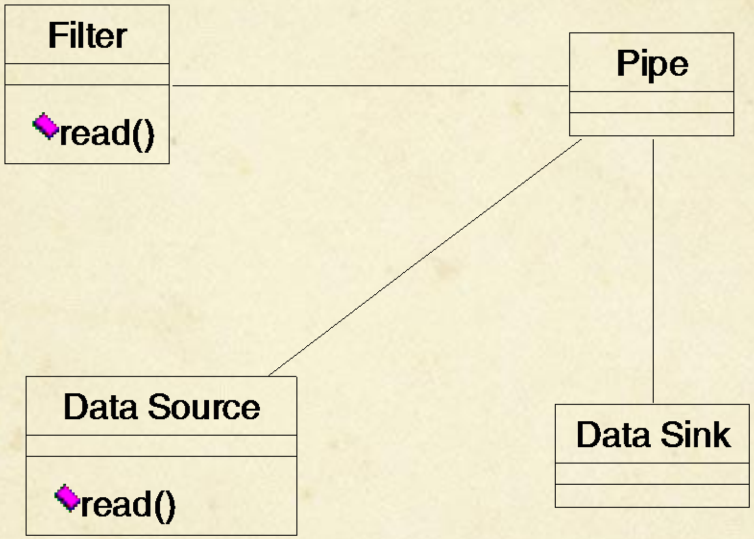
# Performance Issues

- Filters force a lowest common denominator philosophy on data streams, usually forcing an ascii format, which can be inefficient
- If a non-ascii stream is used, often, each filter must pay a price in marshaling and unmarshaling the data
- Each filter is usually represented as a process, which necessarily incurs some overhead (although the use of threads can mitigate this problem)
- Data is no longer "encapsulated", but is rather "distributed"

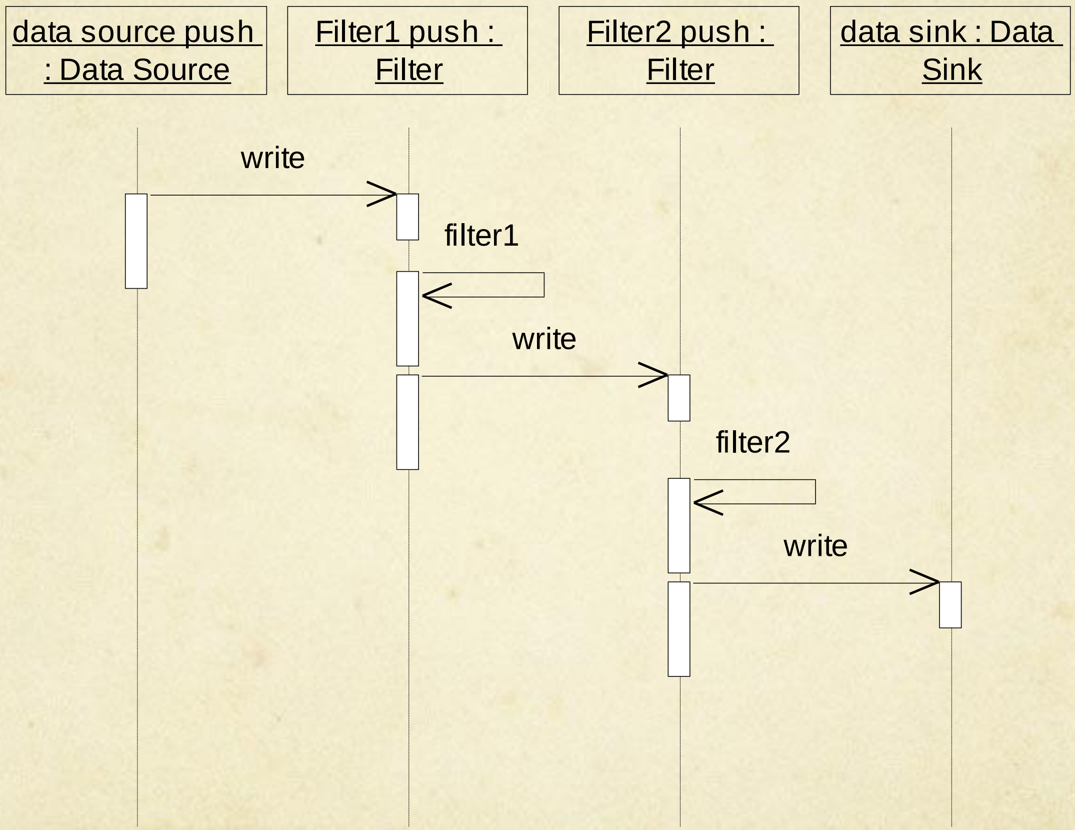
# Participating Classes

- Filters
  - Filters enrich, refine, or otherwise modify streams of data
  - Filters can be seen as complementing the GoF Decorator pattern
- Data Source
  - The original source for incoming data to the pipeline
- Data Sink
  - The final destination for output data from the pipeline

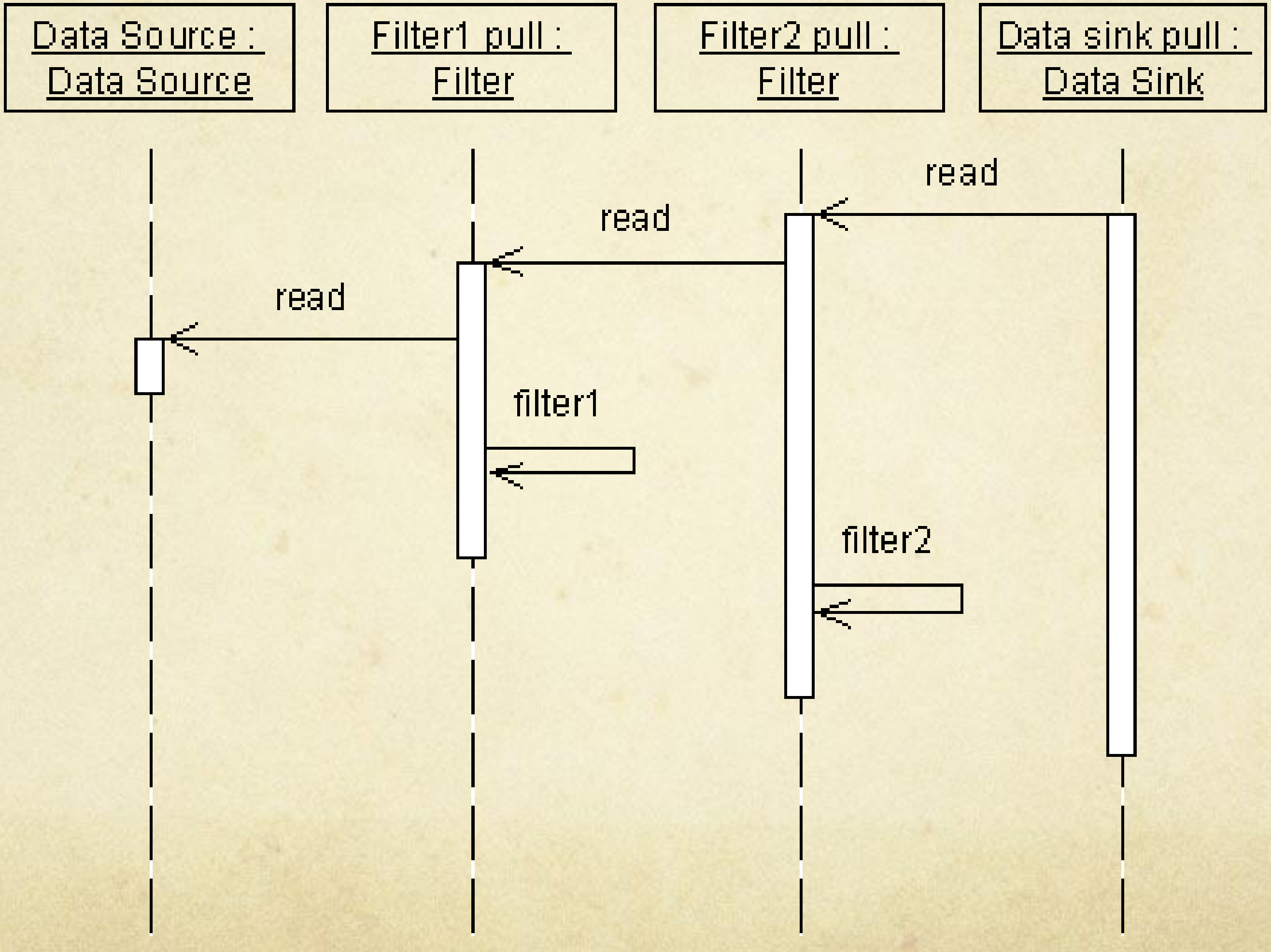
# UML



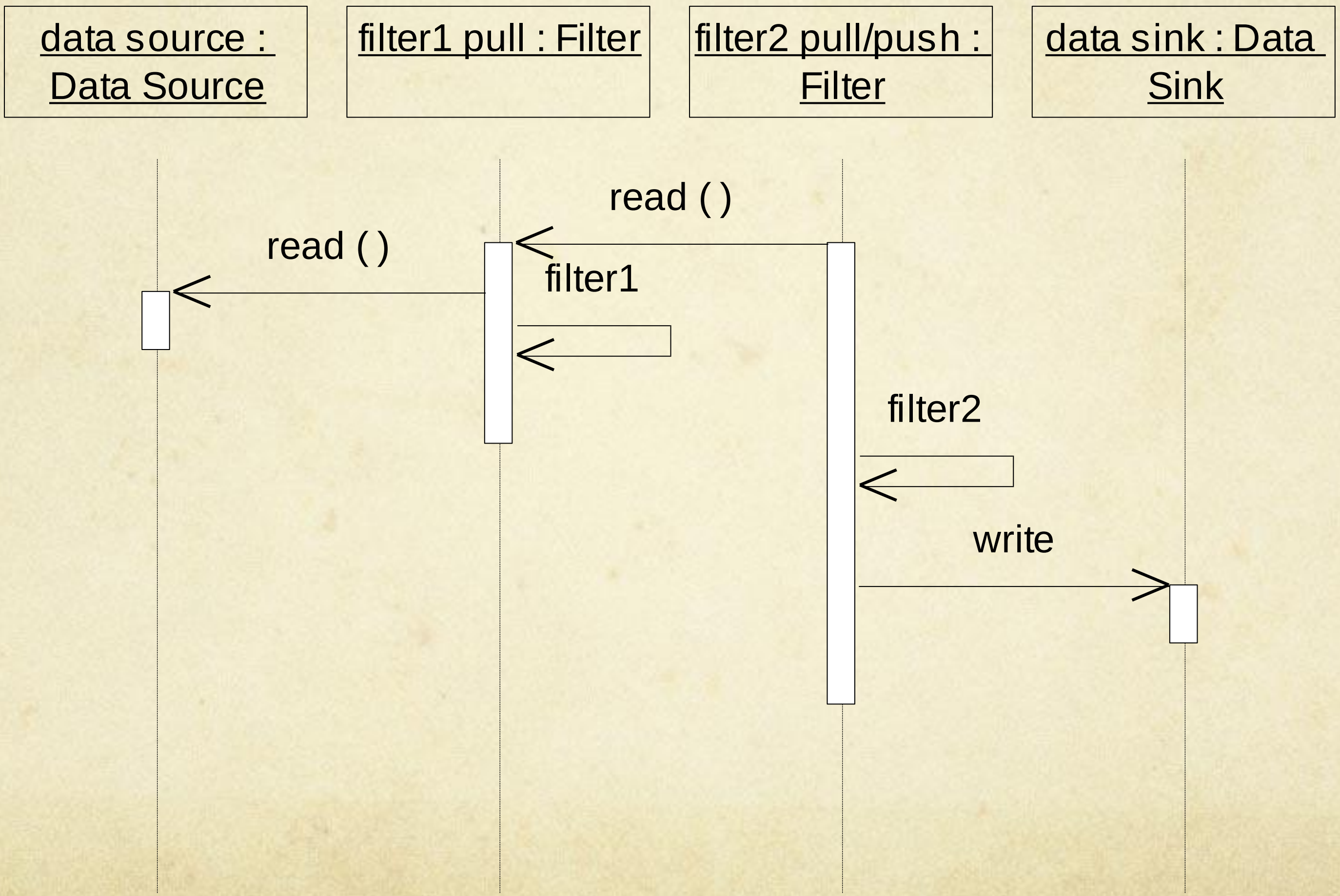
# Push Pipeline Scenario



# Pull Pipeline Scenario



# Push-Pull Scenario



# Push-Pull Methods

- Filters can connect to other filters in either of three ways:
  - Push
    - The server filter will notify the client filter when new data is available and will deliver it
  - Pull
    - The client filter will contact the server filter when it needs new data
    - this is generally a blocking mechanism
  - Try-Pull
    - The client filter will contact the server filter when it needs new data, but will NOT block if no data is available
    - this is a non-blocking mechanism

# Intermediate Buffering and Persistence

- Buffering Pipe (e.g., CORBA Event Service)
- Issues
  - Persistence
  - Redundancy
  - Efficiency
  - Non-queuing

# Message Queue Pattern

Operative Metaphor:
Buffered Publish Subscribe

# Message Queues in Unix System V Interprocess Communication

- Message Queues got their start in System V IPC which was first introduced in AT&T Unix SVR2, but is available now in most versions of unix
- Microsoft Message Queue is an implementation of message queues on the Windows platform
- IBM's MQSeries is another example of a message queue
- Vitria's 2 layer approach is built upon message queues (message queues as *filters* via translators)
- Message Queues represent linked lists of messages, which can be written to and read from

# Unix Message Queues

- A Message Queue is a linked list of message structures stored inside the kernel's memory space and accessible by multiple processes
- Synchronization is provided automatically by the kernel, so things like semaphores and other controls mechanisms are not necessary
- New messages are added at the end of the queue in a FIFO manner
- Each message structure has a long *message type* which allows for selective filtering of messages (typed access)
- Messages may be obtained from the queue either in a FIFO manner (default) or by requesting a specific *type* of message (based on *message type*)

# Message Structs

- Each message structure must start with a long message type:

```
struct mymsg {
	long msg_type;
	char mytext[512]; /* rest of message */
	int somethingelse;
	float dollarval;
};
```

# Message Queue Limits

- Each message queue is limited in terms of both the maximum number of messages it can contain and the maximum number of bytes it may contain
- New messages cannot be added if *either* limit is hit (new writes will normally block)
- On Linux, for example, these limits are defined as (in /usr/include/linux/msg.h):
  - MSGMAX 8192 /*total number of messages */
  - MSBMNB 16384 /* max bytes in a queue */

# Microsoft MSMQ (Falcon)

- Integrated into XP and XP Server, Windows 7 and 8
- Provides Internet messaging which offers
  - reliable delivery (theoretical 1 terabyte buffering)
  - authentication via digital signatures
  - delivery notification and confirmation
- One-to-Many messaging model
- Message Queuing Triggers (associate a queue with a COM component or executable) (danger Will Robinson)
- Load balancing
- HTTP protocol support for delivery (firewall bypass) or HTTPS support over SSL
- URLs can be mapped to a particular queue

# Event-Driven Features

- Message Queues are often used to implement *event-driven* (*implicit invocation*) systems
- Consumers of events register *interest*, and producers of events *broadcast* events as they arise
- Implementations can be either priority based (on message type) or interest based (based on registration which requires *observers* or a type-aware active queue)

# CORBA COS Event Service

OMG COS Event Service Specification

# The CORBA Event Service

- The COS Event Service allows to *decouple* publishers and subscribers, via an asynchronous message transfer between CORBA distributed objects
- The Event Service acts as a well-known intermediary between objects that wish to communicate, but do not wish to be tightly coupled
- Senders of events are called *suppliers*, and receivers of events are called *consumers*.
- The COS Event Service implements the Mediator and Proxy Patterns (GoF)
- The COS Event Service offers what is commonly referred to as the Producer-Consumer model

# Characteristics

- Messages can be accessed by either a Push or Pull metaphor
- Message passing takes place asynchronously (non-blocking model)
- The COS Event Service delivery can be set up to be typed or untyped
- The COS Event Service will automatically buffer received events, offering semi-persisted messaging
- Communication can follow either a Push or Pull model
- Consumers can either synchronously (Pull) or asynchronously (tryPull) obtain messages from the Event Services, or have the Event Service deliver events to them (Push model)
- A 1-1 correspondence between Producers and Consumers is not necessary

# The Connection Process

- Regardless of the model, the following steps must be taken to connect to an event channel:
  - The client must bind to the Event Channel, which must already have been created by someone, perhaps the client
  - The client must get and Admin object from the Event Channel
  - The client must obtain a proxy object from the Admin object (a Consumer Proxy for a Supplier client and a Supplier Proxy for a Consumer client)
  - Add the Supplier or Consumer client to the event channel via a connect() call
  - Transfer data between the client and the Event Channel via a push(), pull(), or try_pull() call

# The COS Event Service Design

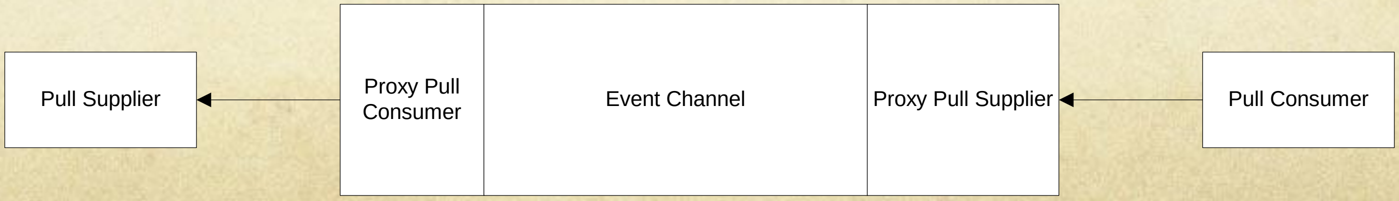
- Suppliers and Consumers each connect to the event service, via a particular *channel.*
- Each channel can have multiple consumers and suppliers, and all events delivered by a supplier are made available to all consumers
- An event channel can be thought of as a repository of common interest, the Usenet model is available as a metaphor
- Suppliers and consumers connect to an event channel, and begin communication through the channel

# Interaction Models

- The Event Channel supports two models of interaction:  Push and Pull
  - Push Model:  The sender initiates the delivery of the message to the recipient
  - Pull Model:  The recipient initiates the delivery of the message from the sender by request
- The Event Channel plays roles on behalf of suppliers and consumers
  - For consumers, it plays the role of a supplier
  - For suppliers, it plays the role of a consumer
- Through this role playing, the Event Channel can decouple the communication between the two interested parties

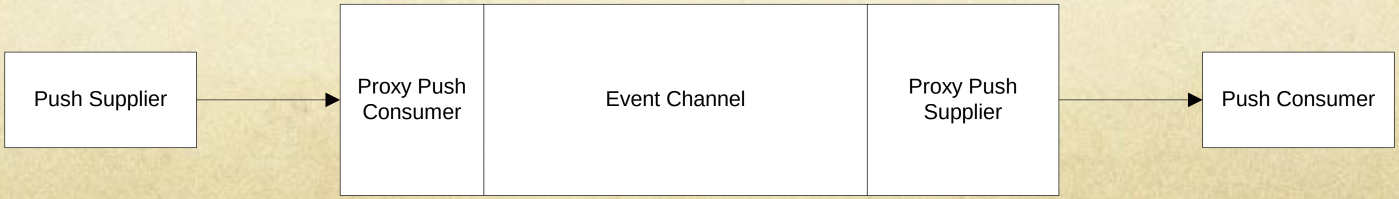
# The Pull Model

- In the Pull Model, the consumer initiates the flow of events from the supplier
- When a Pull supplier wants to connect to the event channel, the event channel will "pretend" it is a Pull consumer, by creating a *consumer proxy* for the supplier to talk to
- The supplier is none the wiser, and simply delivers messages on request to its "consumer", which is a proxy object within the event channel
- When a Pull consumer wants to connect to the event channel, the event channel will "pretend" it is a supplier, by creating a *supplier proxy* for the consumer to talk to.
    - In the Pull Consumer scenario, the Pull Consumer *pulls* (or *tries* to pull) events from the Proxy Pull Supplier
    - In the Pull Supplier scenario, the Proxy Pull Consumer *pulls* events from the Pull Supplier.



# The Push Model

- In the Push Model, the supplier initiates the flow of events to the consumer
- When a Push Supplier wants to connect to the event channel, the event channel will "pretend" it is a consumer, by creating a *consumer proxy* for the supplier to talk to
- The supplier is none the wiser, and simply delivers messages to its "consumer", which is a proxy object within the event channel
- When a Push Consumer wants to connect to the event channel, the event channel will "pretend" it is a supplier, by creating a *supplier proxy* for the consumer to talk to.
  - In the Push Consumer scenario, the event channel *pushes* events out to the consumer via the *push supplier proxy*
  - In the Push Supplier scenario, the supplier *pushes* events out to the event channel via its *push consumer proxy*.



# The Hybrid Model

- Push Supplier/Push Consumer:  Push suppliers *push* events onto the channel, which in turn *pushes* them out to consumers
- Push Supplier/Pull Consumer:  Push suppliers *push* events onto the channel, and pull consumers *pull* events (or try to pull) from the channel when they need one
- Pull Supplier/Push Consumer:  The event channel *pulls* events from the Pull Supplier, and then it *pushes* these events out to the Push Consumers
- Pull Supplier/Pull Consumer:  The Pull Consumers *pull* events from the event channel, which in turn *pulls* them from the Pull Suppliers.