Implementation of Fault Tolerant Atomic Broadcast

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Fault Tolerance

Ability to recover from unexpected situations

ABSTRACT TECHNIQUES

Information redundancy

e.g. Hamming code

Time redundancy

e.g. timeout and retransmission

Physical redundancy

e.g.. redundant array of independent disks

Faults in Distributed Systems

Crash Failure: Process works correctly until it halts

Omission failure: Receive or send omission

Timing failure: does not respond in expected period

Arbitrary failure: unexpected response at arbitrary time

Information Redundancy in Distributed Systems

Active replication

Active replication: A, B, C, replaced by A, AA, AAA …; B, BB, BBB .., C, CC, CCC .., and if A sends message M to B in original, A* send message to B* in new system, and B* chooses majority result

Passive Replication

Passive Replication: A, B, C, augmented with by AA, AAA, …; BB, BBB, …, CC, CCC, … and if A's state changes, the corresponding change is made on AA and AAA. If A fails, AA takes over. If AA fails, AAA takes over ….

Fault Tolerance Problems: Consensus Problem

Set of processes decide on some value

e.g. Who Relays, whether a transaction should be committed, which value to choose

Asynchronous vs. Synchronous Systems

Asynchronous Systems

No bound on the time required to respond to a message

Synchronous Systems

Bound on the time required to a message

Impossibility Results in in Distributed System

Asynchronous Systems

Cannot achieve consensus as long as one faulty process

Do not know if a process is faulty or taking too long

Synchronous Systems

Can achieve consensus as long as ratio of total/faulty processes is above a certain threshold (M faulty in 3M + 1 total processes)

Rounds of communication with timeouts

Consistency Problem in Broadcast

FIFO

Messages Mi1, M2 sent by P are received in order by every receiver Q

Causal Broadcast

If P sends a message M2 after seeing M1 then M2 is received after M1 in every receiver Q

Atomic Broadcast

- Communication History
- Privilege-Based
- Moving Sequencer
- Destination Agreement

Fixed Sequencer

Broadcast-Broadcast

P broadcasts M to sequencer and all destinations. Sequencer sends sequence number and hashcode of M to all destinations. Destinations deliver messages based on sequence number

Unicast-Unicast-Broadcast

P unicasts message to sequencer, which unicasts sequence number to it. P broadcasts message with sequence number

Techniques in Distributed Systems

Active replication

Active replication: A, B, C, replaced by A, AA, AAA …; B, BB, BBB .., C, CC, CCC .., and if A sends message M to B in original, A* send message to B* in new system, and B* chooses majority result

Atomic broadcast without fault means that all processes will have the same state at quiescence

Fault Tolerant Atomic Broadcast

Asynchronous Systems

If we can do fault tolerant atomic broadcast, then we could have consensus, which is impossible

Synchronous Systems

/s unreliable communication

l vs network based broadcast

Fixed Sequencer, Unicast Broadcast: Basic Idea and Assumptions

Assume each message has been sent to each of the current session members– no latecomer

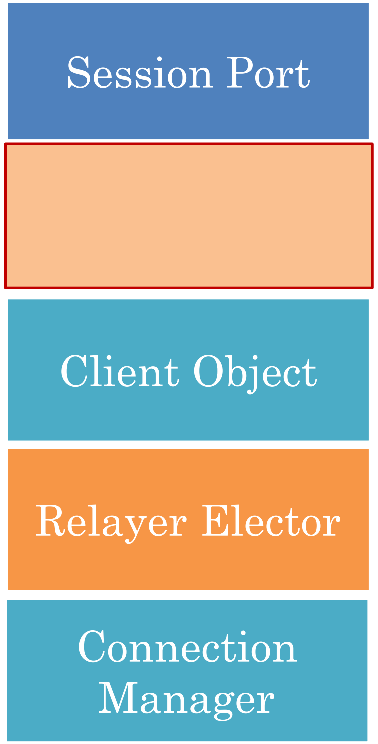
Assume synchronous system, when a process fails, within a specified time (chosen by TCP/IP) period all other processes know because of probe messages, and any in-transit messages are discarded

Next relayer chosen based on purely local information, no expensive synchronization done but it is possible to solve the consensus problem

Assume no erroneous or malicious code or hardware

Peer to peer: any process can act as a relayer, no special sequencer

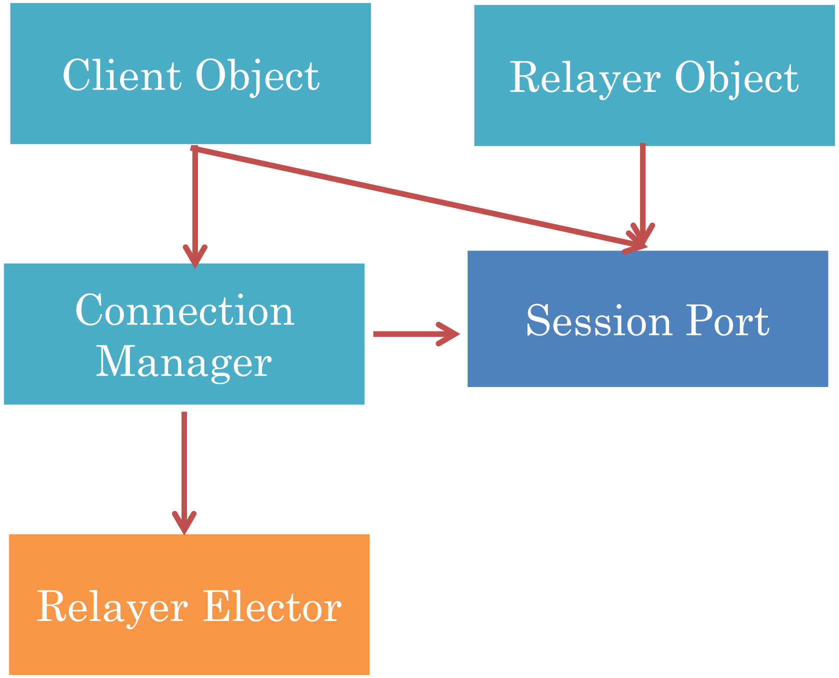
Non Fault Tolerant Architecture with Separation of Concerns



Client object can be composed of model, in and out couplers, reference relayer elector

Awareness?

Connections



Relayer elector is session port unaware

Connection manager responds to join and leave commands and calls relayer elector to get current relayer

Client reference (possibly subclassed) relayer connector if relayer elector is simply a function call

Events

Sent-broadcast: A message sent by a relayer-client to a relayer.

Received-broadcast: A message received by a relayer from a relayer-client.

Sent-relay: A message sent by a relayer to a relayer-client.

Received-relay: A message received by a relayer-client from a relayer.

Process left: A process has left the session.

Process joined: A process has left the session.

Basic Fault-Tolerace Algorithm

Client algorithm

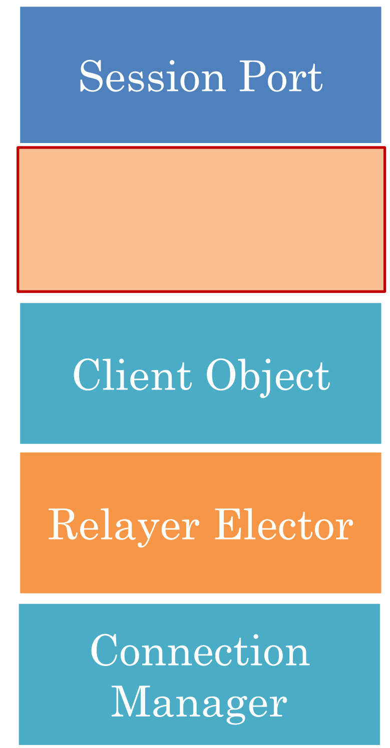
When the leaving of a relayer is detected, the next broadcast is sent to the new relayer

Server algorithm

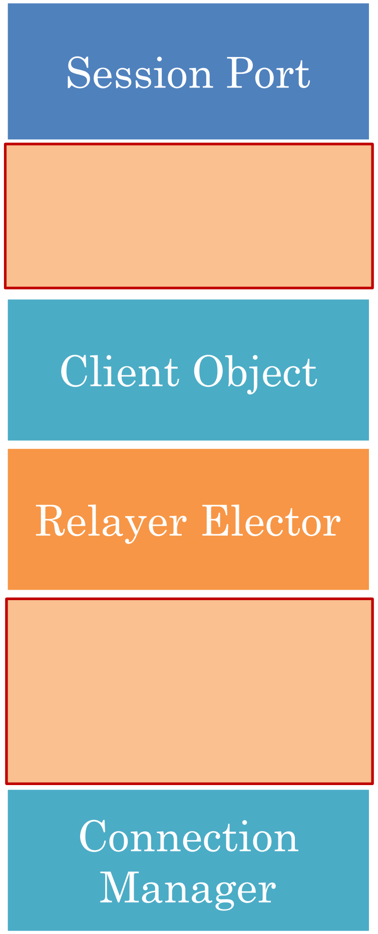
When the leaving of a relayer is detected, the client object is removed from the list of clients

Assumption: A relayer does not die in the middle of sending messages

Passive voice?



Fault Tolerant Architecture with Separation of Concerns



FT Manager responds to leave command by changing destination of broadcasts and updating client map

Can be subclass of Relayer Elector and same connections

Assumption: A relayer does not die in the middle of sending messages

Reacting to Partial Broadcast

Passive Replication Requirements
1. Any message sent by a remote client to the dead relayer should be received by all clients
2. Any message sent by the dead relayer to a remote client should be received by all clients

Key idea: one or more clients has the message(s) that old relayer partially broadcast, which can be rebroadcast using the old relayer
1. →Sent messages must be buffered
2. →Received messages must be buffered

Changes to Basic Algorithm

Client algorithm

When the leaving of a relayer is detected, synchronization phase is entered and one or more messages are rebroadcast

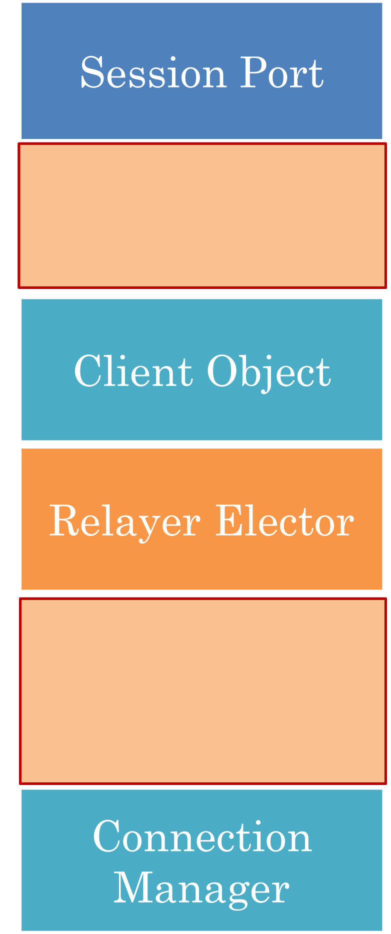
When messages are sent/received, they are buffered and the sequence numbers of received messages used to determine what is rebroadcast

During synchronization phase new messages are buffered and at end of phase they are sent

Server algorithm

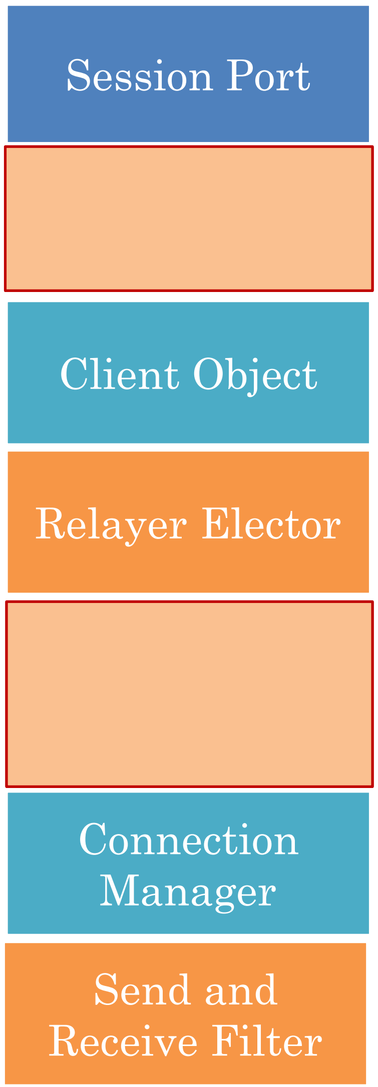
Each relayed message wrapped with current sequence number before being sent to client object

When the leaving of a relayer is detected, the new relayer goes into a synchronization phase before doing new relay

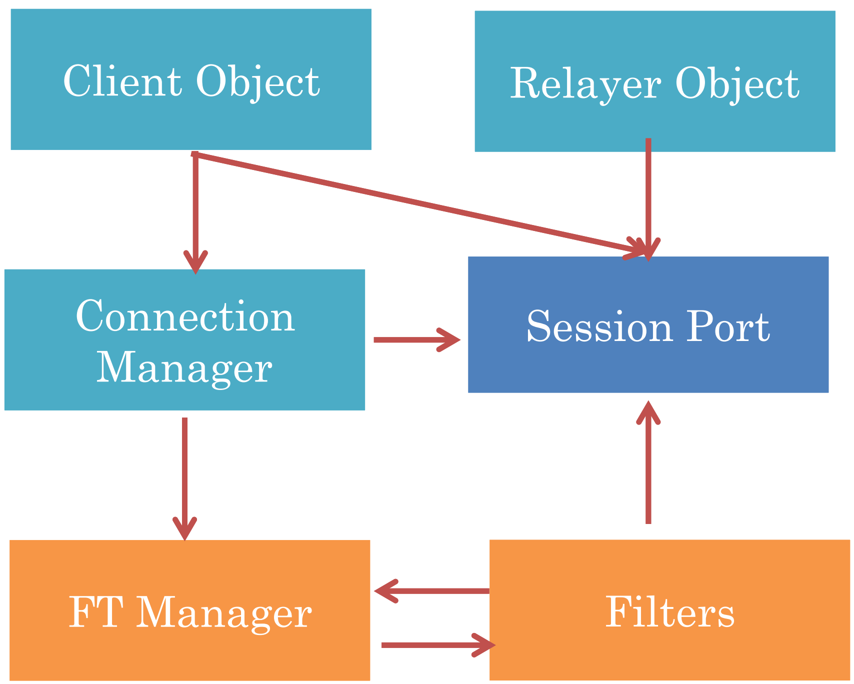


Architecture changes?

Filter Objects



Connections



As Filters are GIPC aware, best to no FT logic in them

Separate receive and send filter

FT manager can be separated into master and slave FT managers

Message Events

Sent-broadcast: A message sent by a relayer-client to a relayer.

Received-broadcast: A message received by a relayer from a relayer-client.

Sent-relay: A message sent by a relayer to a relayer-client.

Received-relay: A message received by a relayer-client from a relayer.

Send finish synchronization message: A message received by the master FT manager to the slave FT manager to indicate synchronization is over

Receive finish synchronization message: A message received by the master FT manager to the slave FT manager to indicate synchronization is over

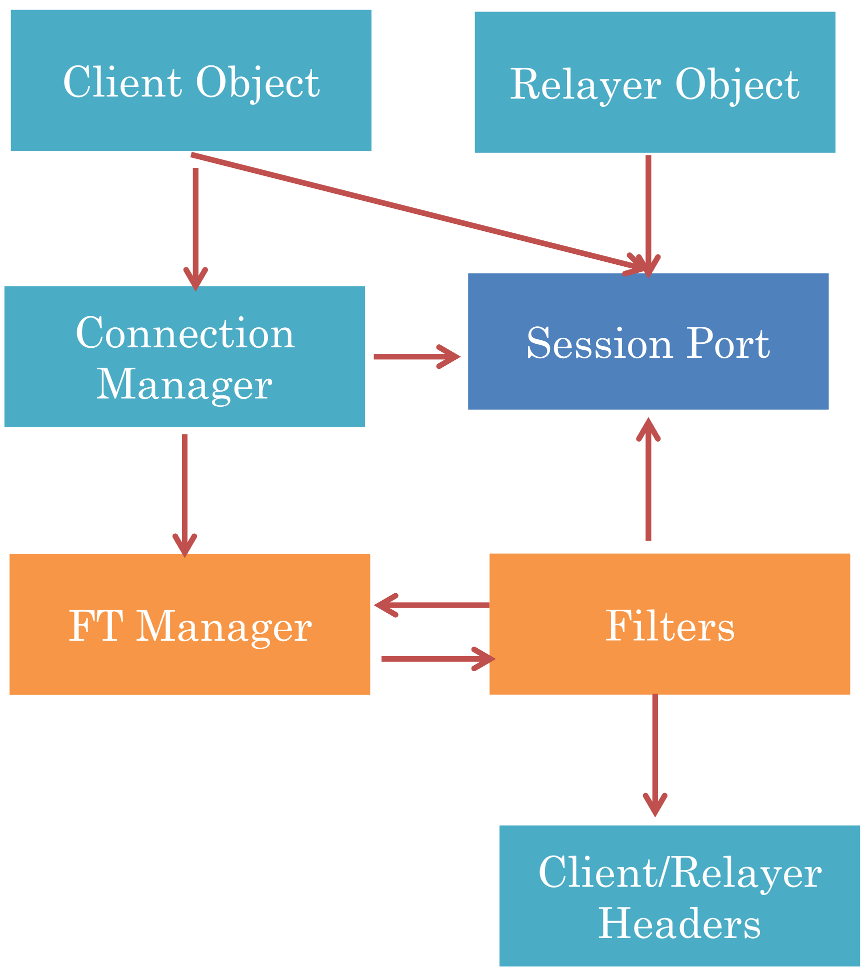
Must somehow generate (application-specific) sent-broadcasts and sent-relay messages and distinguish them from synchronization messages

Filter Object

Needs a way to distinguish between messages are internally communicated by GIPC and those generated by client and relay object

We can specify the messages generated by client and relay objects

Connections



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Separate receive and send filter

FT manager can be separated into master and slave FT managers

Gipc and RPC Calls

Assume that client and relay objects make remote procedure calls

The messages passes to filter objects are instances of SerializableCall

The toHeader() method of such a call tells its signature which can be specified in a list

GIPC AND RPC CALLS

Server algorithm

Each relayed message wrapped with current sequence number before being sent to client object

Each sent-relay in response to a received-broadcast must be assigned the same sequence number

Server FT manager Keeps track of N, the number of clients

Assigns sequence number on received-broadcast and wraps the next N sent-relay messages with N

Concurrency Issues

Server algorithm

During synchronization phase new messages are buffered and at end of phase they are sent

Synchronized method can broadcast,

THREADS

Sent-broadcast: A message sent by a relayer-client to a relayer.

App thread

Received-broadcast: A message received by a relayer from a relayer-c

RPC thread

Sent-relay: A message sent by a relayer to a relayer-client.

RPC thread

Received-relay: A message received by a relayer-client from a relay

RPC thread

Send finish synchronization message: A message received by the mast
manager to the slave FT manager to indicate synchronization is ov

Select Thread

Receive finish synchronization message: A message received by the master FT
manager to the slave FT manager to indicate synchronization is over

Original transmission and retransmission can occur in different threads

Retransission in select thread

Buffering

Client algorithm

Sent/received messages are buffered and the sequence numbers of received messages used to determine what is rebroadcast

Replicated vs. Distributed Buffering

Replicated Buffering

A client buffers all received messages and unbuffers messages it knows have been

Unbuffers messages it knows have been received by all sites

Last sequence number sent with every broadcast and periodically a special synchronization message sent with sequence number

Distributed Buffering

A client buffers messages it has sent and at most one message from te current relayer

When a message is echoed back or a relayer message is received, previous message is unbuffered..

Effcient but less flexible: assumes synchronized broadcast (GIPC group function call)	No fault occurs during synchronization phase – one fault at a time assumption

More Wrapping

Distributed Buffering

Need a way to know its message has been bounced back or that a relayer message has been received

Wrap message with message with unique (host and local sequence number) which must be unwrapped

Distributed Buffering

Client algorithm

When the leaving of relayer is detected, the slave FT Manager sends the buffered message with the highest sequence number (relayer or local)

A relayed message is discarded if its sequence number is not expected

Server algorithm

When the leaving of a relayer is detected, the master FT manager chooses the maximum received message and sends it to all clients that have not received the message or all sites and sends a finish synchronization message

Key Ideas

Synchronous Systems

Passive Replication

Client, Relayer, FT Manager, Filter, Connection Manager Architecture

Partial vs. Complete Broadcast

Distributed vs. Replicated Buffering