



Technology  
Solutions

**SOLA®**  
TMX Technology Solutions

An abstract graphic composed of several overlapping, semi-transparent geometric shapes in shades of blue, green, orange, and pink, creating a sense of depth and movement.

# TMX Technology Solutions

## Session 1 - Overall Architecture

### TMX Group

#### Equities

Toronto Stock Exchange  
TSX Venture Exchange  
TMX Select  
Equicom

#### Derivatives

Montréal Exchange  
BOX Options Exchange  
Montréal Climate Exchange  
CDCC

#### Fixed Income

Shorcan

#### Energy

NGX

#### Information Services

TMX Datalinx  
TMX Atrium  
PC Bond

#### Technologies

**TMX Technology  
Solutions**

# Agenda

- General SOLA Overview
- SOLA Trading Performance
- Distributed Architecture
- Infrastructure
- Network
- High Availability
- Order Life Cycle
- SOLA Architecture Overview
- Integrating External Components

# General SOLA® Overview

- SOLA is a TMX brand of software products originally designed and created in 2005 at the Montréal Exchange.
- Today's well established and internationally recognized SOLA brand has continued evolving since its origins by expanding its core product offering and adding more innovative software solutions.
- SOLA's architecture and software products provide highly efficient messaging and increased performance as well as capacity capabilities for derivative products (futures and options) of multiple asset classes.

# General SOLA® Overview

- SOLA's unparalleled technological architecture, design and evolution provide:
  - ✓ high availability,
  - ✓ real time failover,
  - ✓ low cost and operational efficiencies
  - ✓ fast turn around and time to market
- ...while providing the end users the highest standards of performance

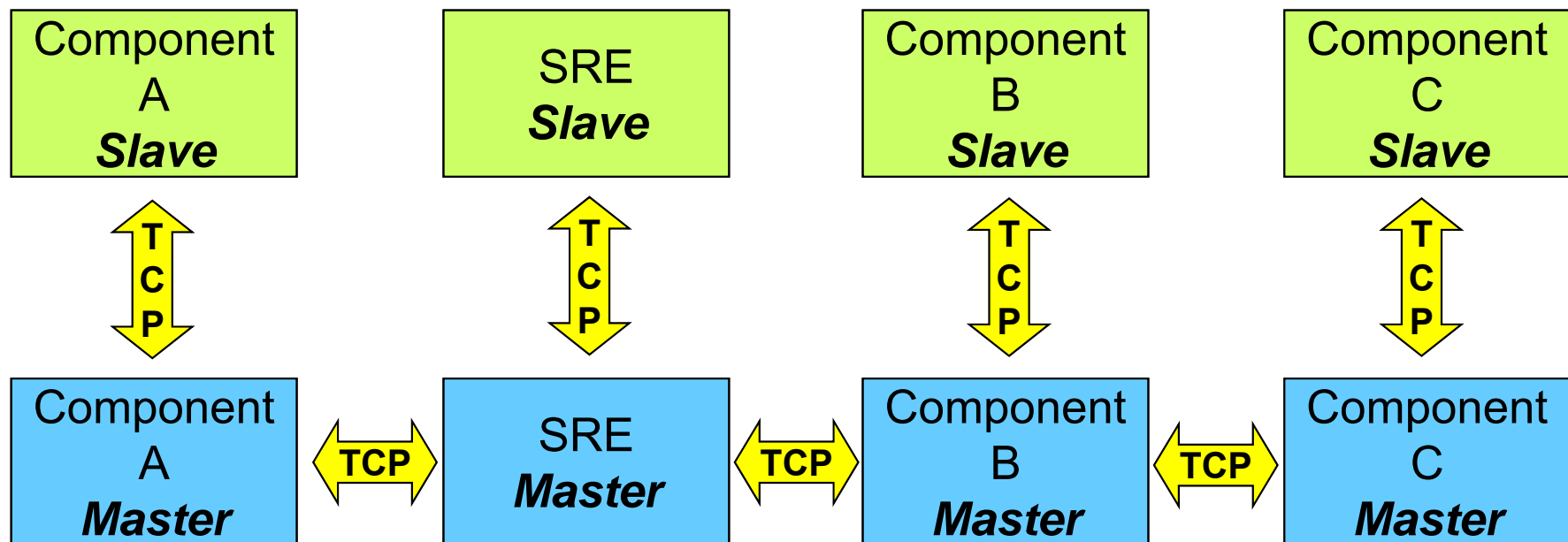


# General SOLA® Overview

- Reliability
  - All communications between Sola components, either through SRE (Sola Routing Engine) or point-to-point, are achieved using TCP that ensure no data will be lost
  - All communications are supported by home-made tools and libraries (No middleware) to maintain total control for optimisation

# General SOLA® Overview

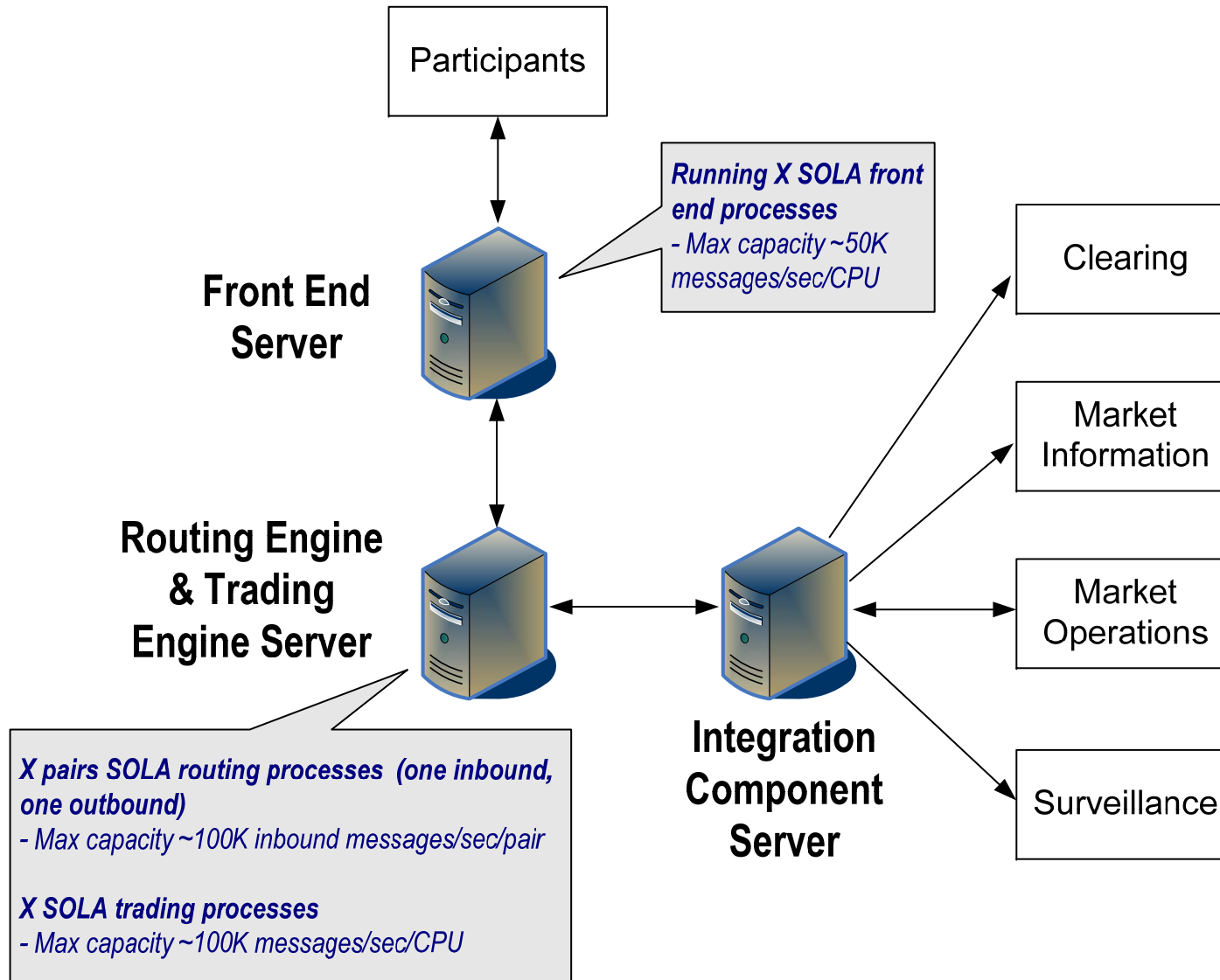
- Master/Slave communications use TCP
- Communications through SRE use TCP
- Point-to-Point communications use TCP



# SOLA® Trading Performance

- SOLA's architecture provides exceptional performance on generic hardware and operating systems delivering an average response time of less than 1 ms.

# SOLA® Trading Performance

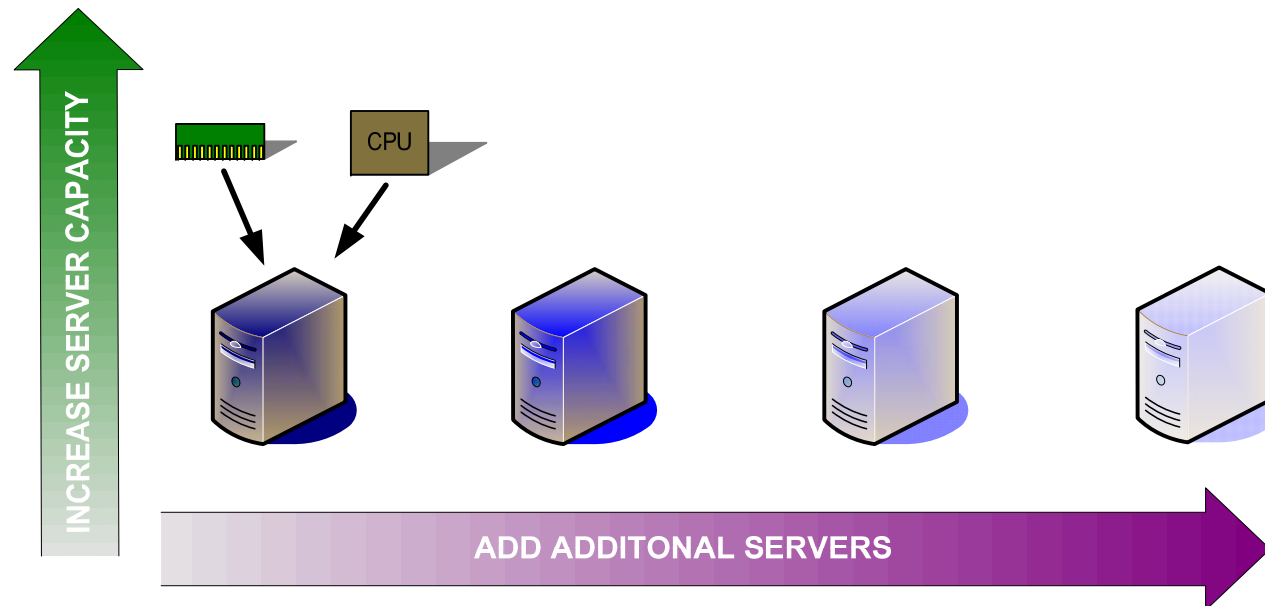




# SOLA® Trading Performance

## Scalability

- Increased capacity can be achieved both by vertical scaling, adding additional capacity to existing servers and horizontally by installing components over multiple servers



# SOLA® Trading Performance

- **Small Scale Exchanges:**

SOLA Can run on as little as 2 servers (8 Cores each), with full hot backup configuration.

Throughput:

100,000 Market Maker bulk orders/sec and 10,000 orders/sec or 20,000 orders/sec (for orders driven market)

- **Medium Scale Exchanges:**

Can run on as little as 6 servers (8 Cores each), in three layers, with full hot backup configuration.

Throughput:

200,000 Market Maker bulk orders/sec and 20,000 orders/sec or 40,000 orders/sec (for orders driven market)

# SOLA® Trading Performance

- **Large Scale Exchanges:**

Can profit from the product's vertical and horizontal scalability and process millions of order book updates per second, in a three layers configuration with full hot backup configuration, on as little as 20 servers (8 Cores each).

Throughput(\*):

1,000,000 Market Maker bulk orders/sec and 100,000 orders/sec or 200,000 orders/sec (for orders driven market)

**NOTE(\*):** SOLA's features provide the capabilities to expand capacity far beyond the above parameters with increased infrastructure (by adding servers)



# SOLA® Trading Performance

## Montréal Exchanges

	Daily Historical Peak
Volume	701 657
Trades	59 933
Orders/Cxl/Mod	3 316 138
Strategy Orders	136 923
Bulked Orders	184 598 069
All Messages	187 989 593

	Opening Peak	Continuous Trading Peak
Options Orders / sec	2 279	1 007
Options Bulked Orders / sec	119 969	56 785
Futures Orders / sec	1 974	1 608

# SOLA® Trading Performance

## Montréal Exchanges

	Response time < 1 msec	Average (msec)
Options Orders	98.91%	0.15
Options Bulked Orders	99.71%	0.16
Futures Orders	99.85%	0.13

# SOLA® Trading Performance

## Boston Option Exchanges

	Daily Historical Peak
Volume	1 563 472
Trades	121 583
Orders/Cxl/Mod	59 586 565
Strategy Orders	66 509
Bulked Orders	1 589 751 371
All Messages	1 643 561 671

	Opening Peak	Continuous Trading Peak
Orders / sec / slice	7 829	63 561
Bulked Orders / sec / slice	218 328	433 084
Total Orders / sec	16 266	251 526
Total Bulked Orders / sec	1 020 744	873 967

# SOLA® Trading Performance

## Boston Option Exchanges

	Response time < 1 msec	Average (msec)
Orders	98.94%	0.16
Bulked Orders	98.06%	0.22

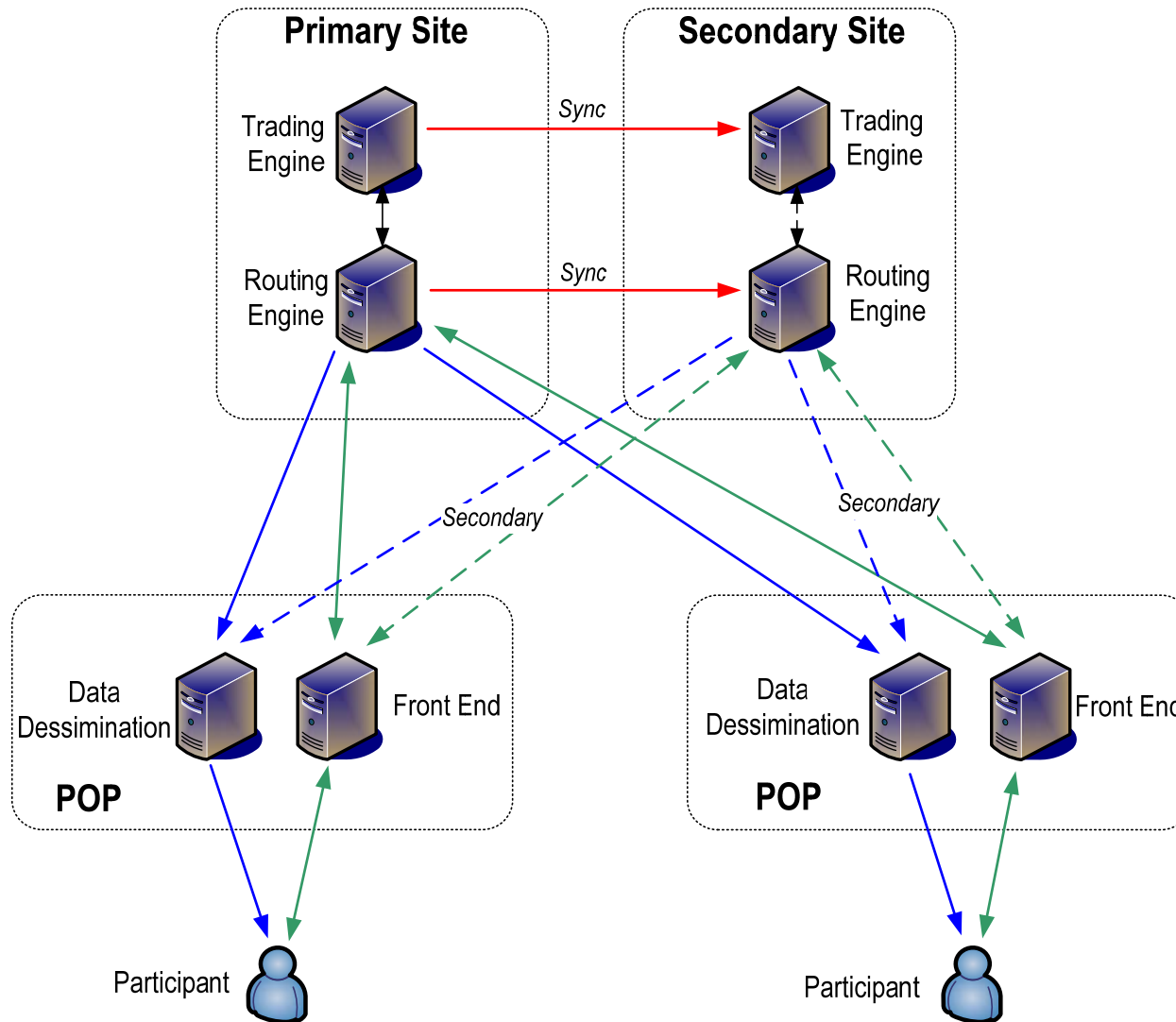
# Distributed Architecture

- Main servers installed at the primary site.
- Load can be distributed among multiple CPU on a server or multiple servers
- Backup servers installed at the DR site.
- Point-of-Presence (POP) deployed close to financial centers:
  - ✓ Offers Market Data
  - ✓ Offers Order Entry





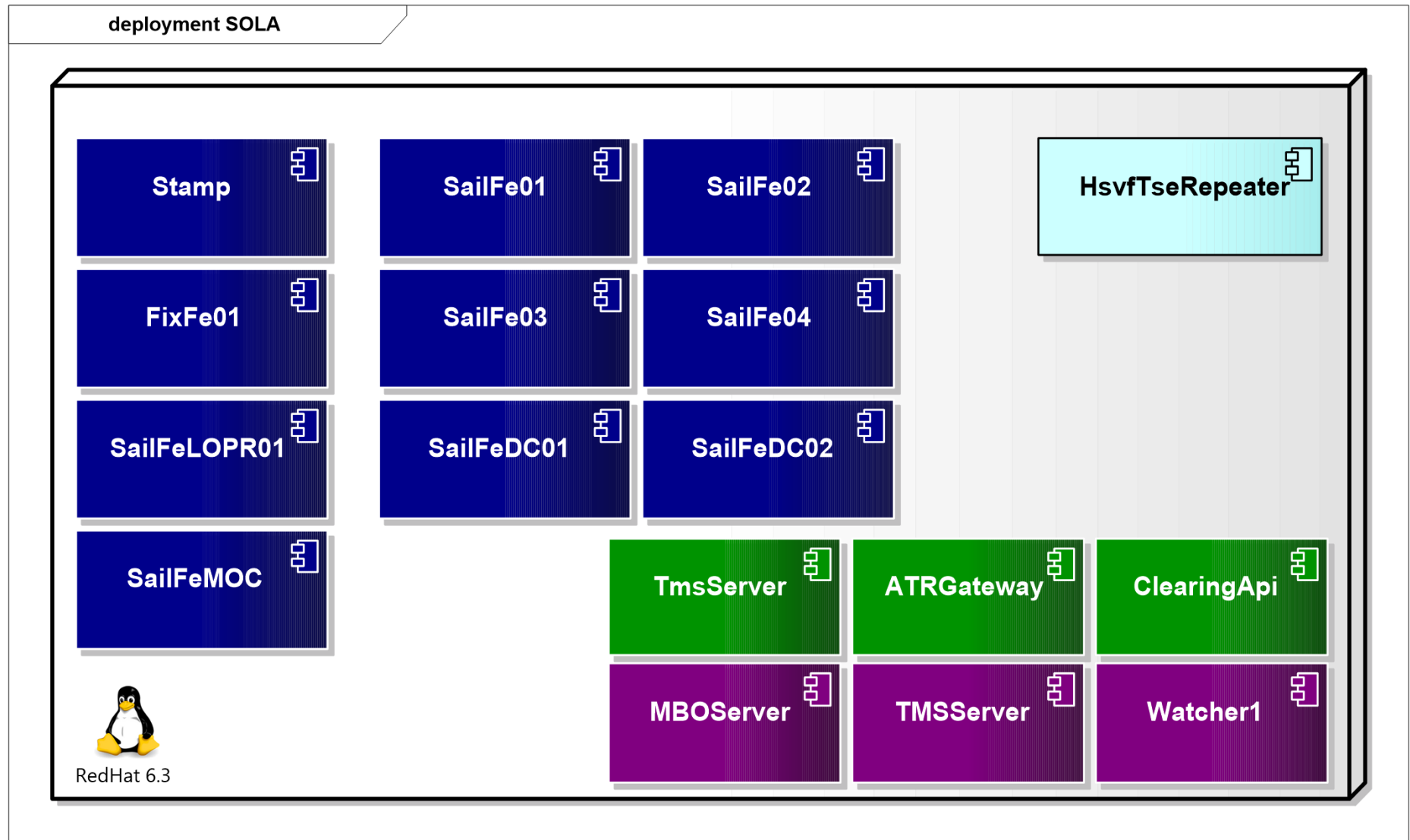
# Distributed Architecture



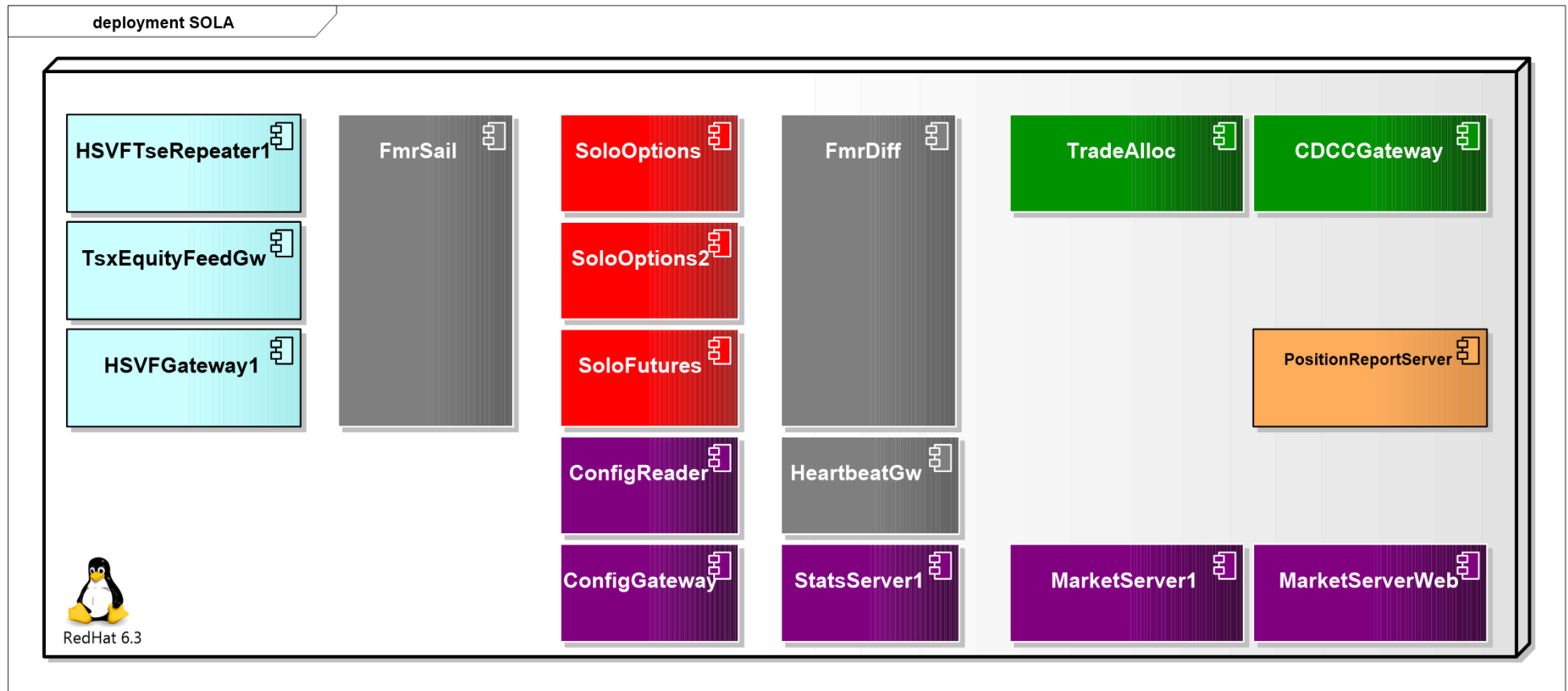
# Infrastructure

- Runs on standard and cost effective technology
  - ✓ Linux and Windows.
  - ✓ More efficient on a real time kernel
- No dependencies on third party software or hardware specific services
  - ✓ No database
  - ✓ No telecom middleware
  - ✓ Fail-over built inside solution
- Performance improved using fast disk
  - ✓ Fusion-I/O recommended for IO intensive components

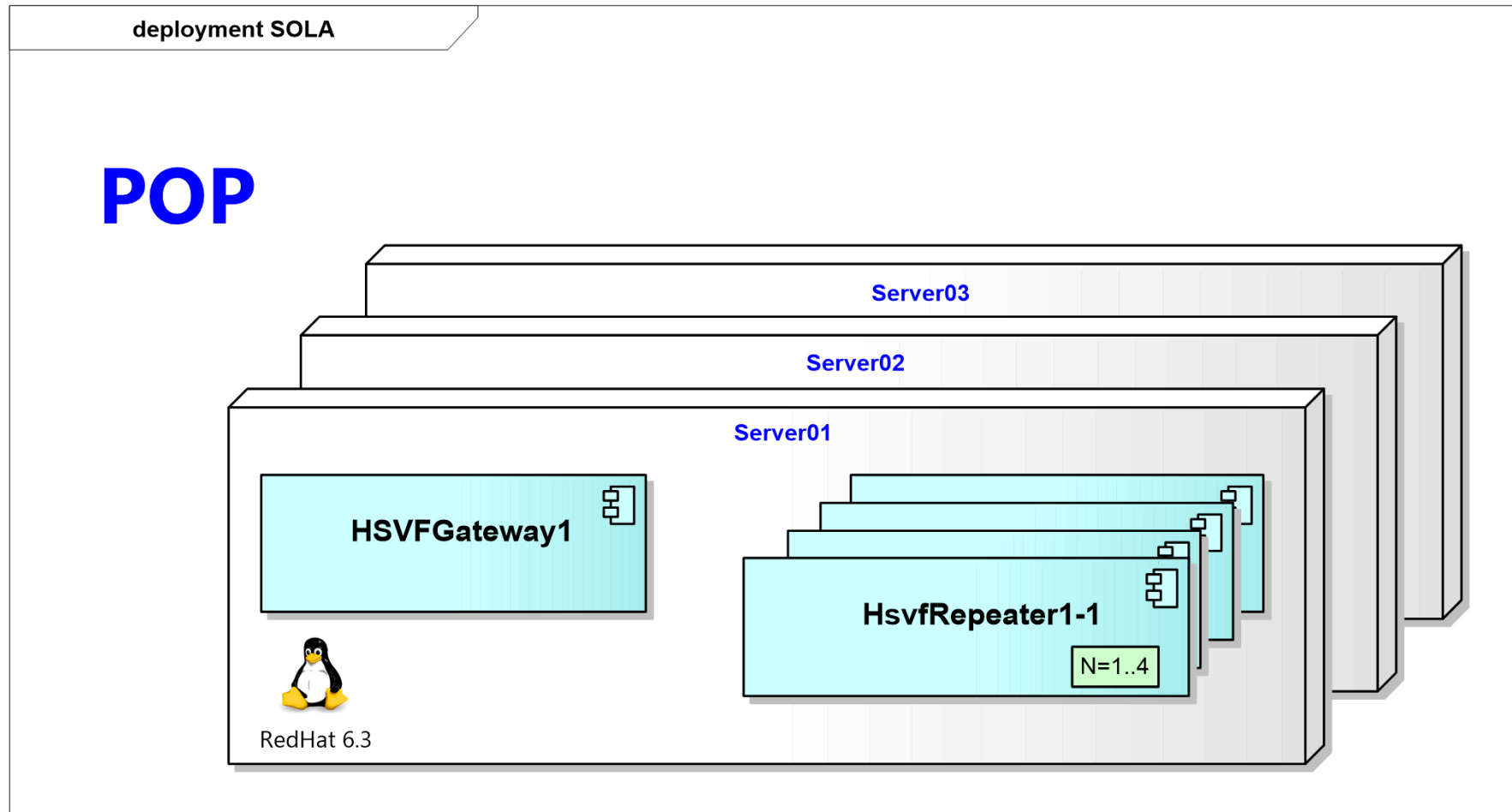
# Infrastructure



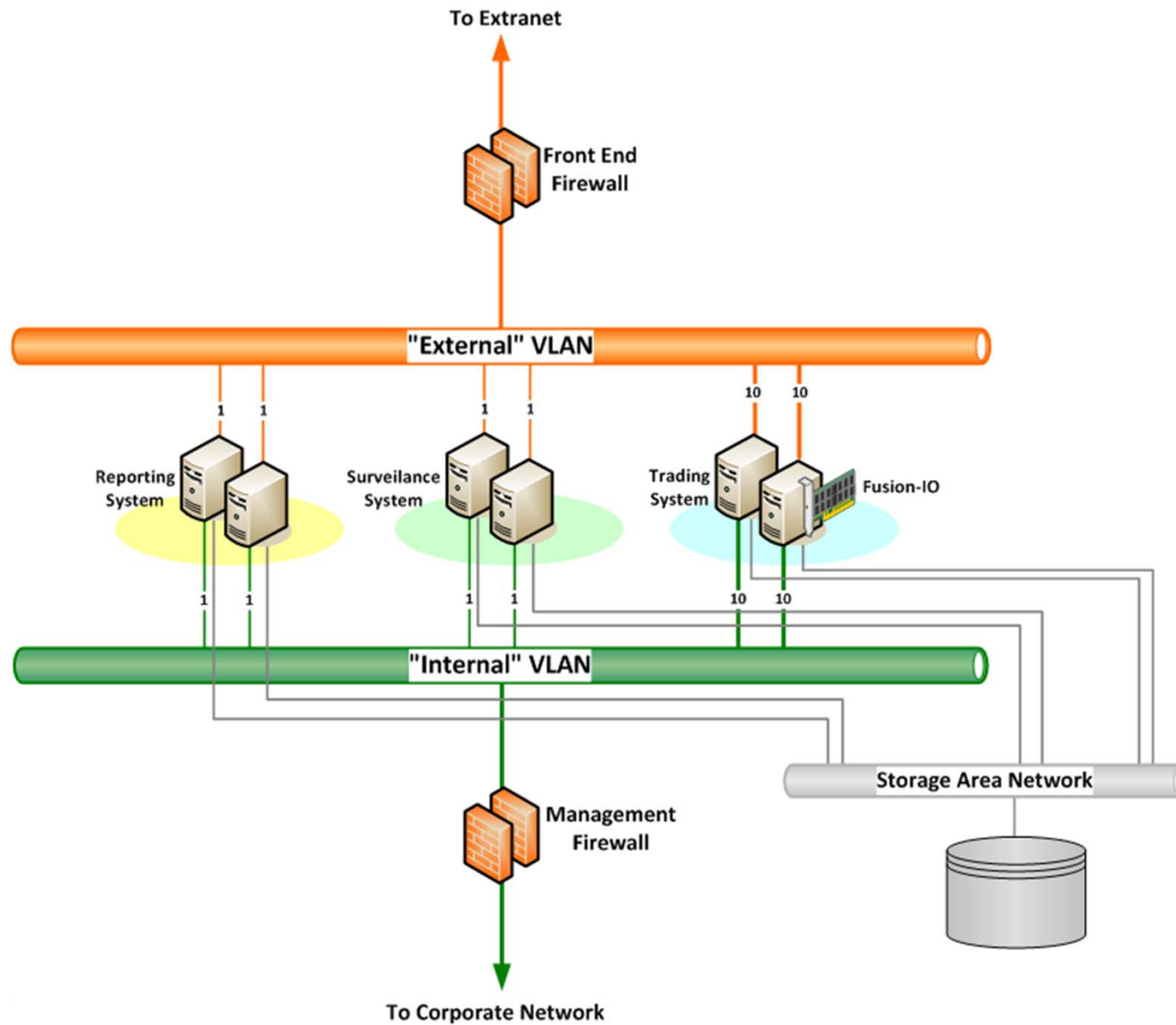
# Infrastructure



# Infrastructure



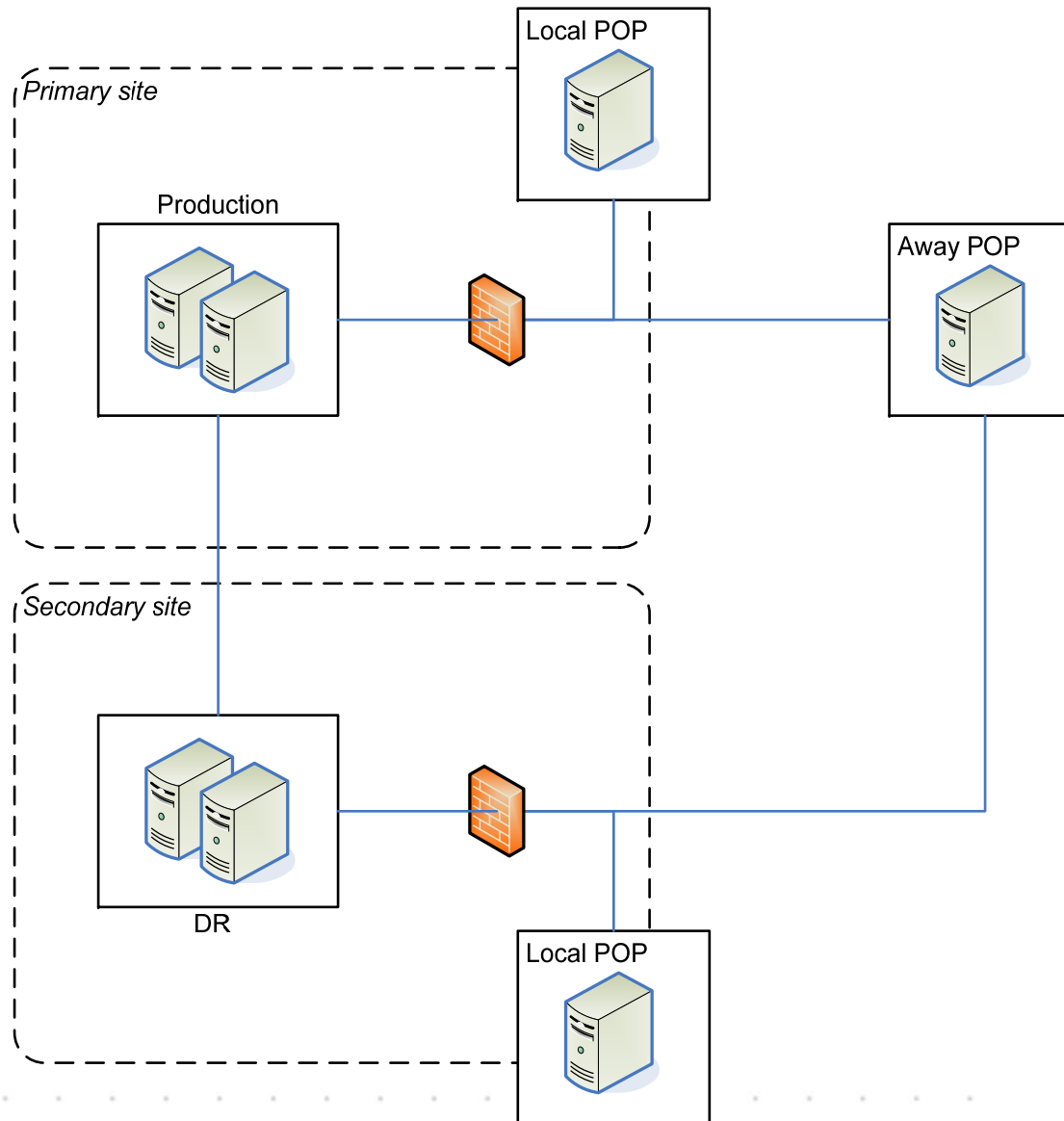
# Infrastructure



# Network

- No specific need related to network
- Use standard load balancer on the data distribution side
- Use internal dynamic IP switching module on the Front End side (Virtual IP)

# Network – Global





# High Availability

- In SOLA, high availability is offer through:
- **Farming**
  - ✓ Multiple instances of the same application are running in parallel and if one instance is failing, the participants using that instance will be disconnected and on reconnection will be redirected to one of the other available instances.
  - ✓ This option is mainly used for market data dissemination.
  - ✓ A load balancer is used to distribute the load on all instances.

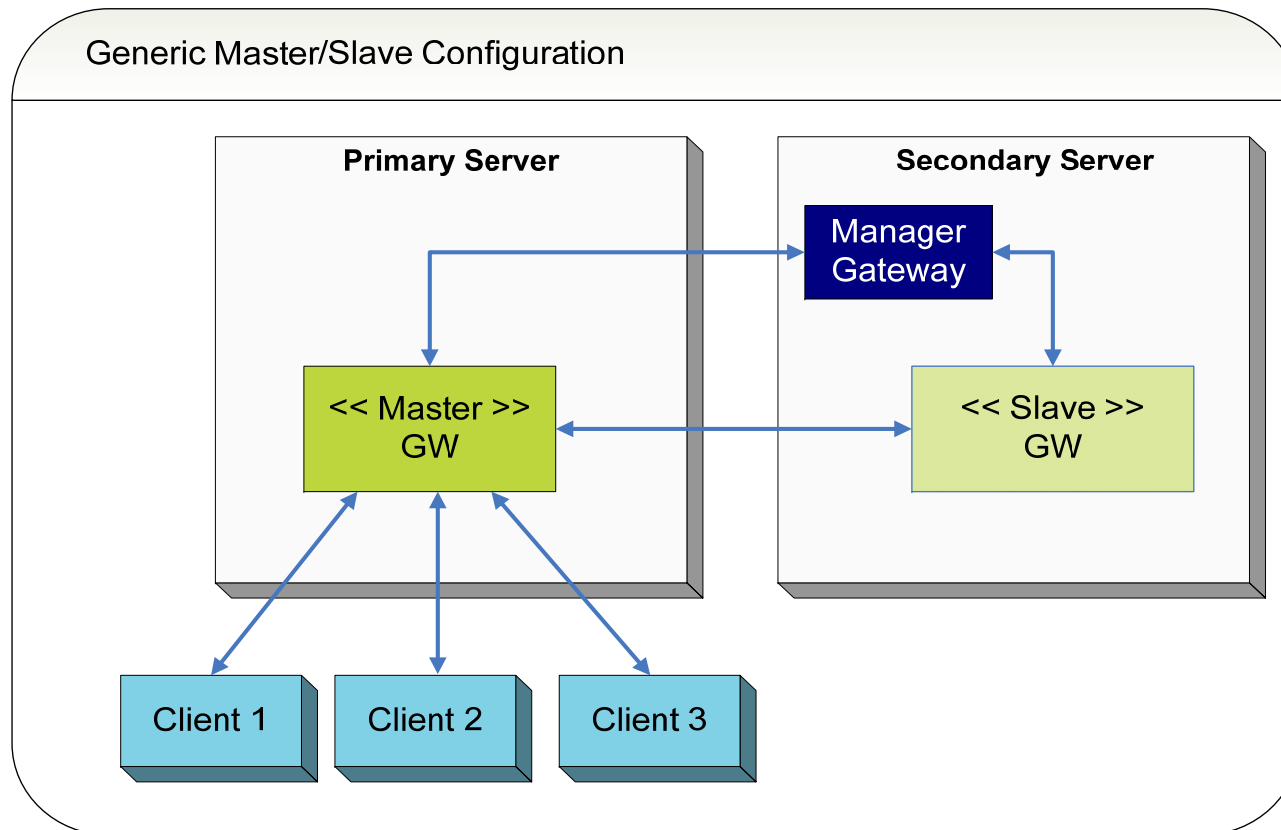
# High Availability

- **Master/Slave**

- Two instances of the same component are running in parallel having only one activated: the Master.
- The Slave is connected to the Master and receives all messages processed by the Master and processes them also to be in perfect synchronization with the Master.
- In case of failure of the Master, the Slave can replace the Master and continue to offer the service as if nothing happened.
- The Manager is in communication with both Master and Slave and will allow the Slave to become Master only if it confirm that the original Master is not running.
- A load balancer is used to direct the client connections to the active component.

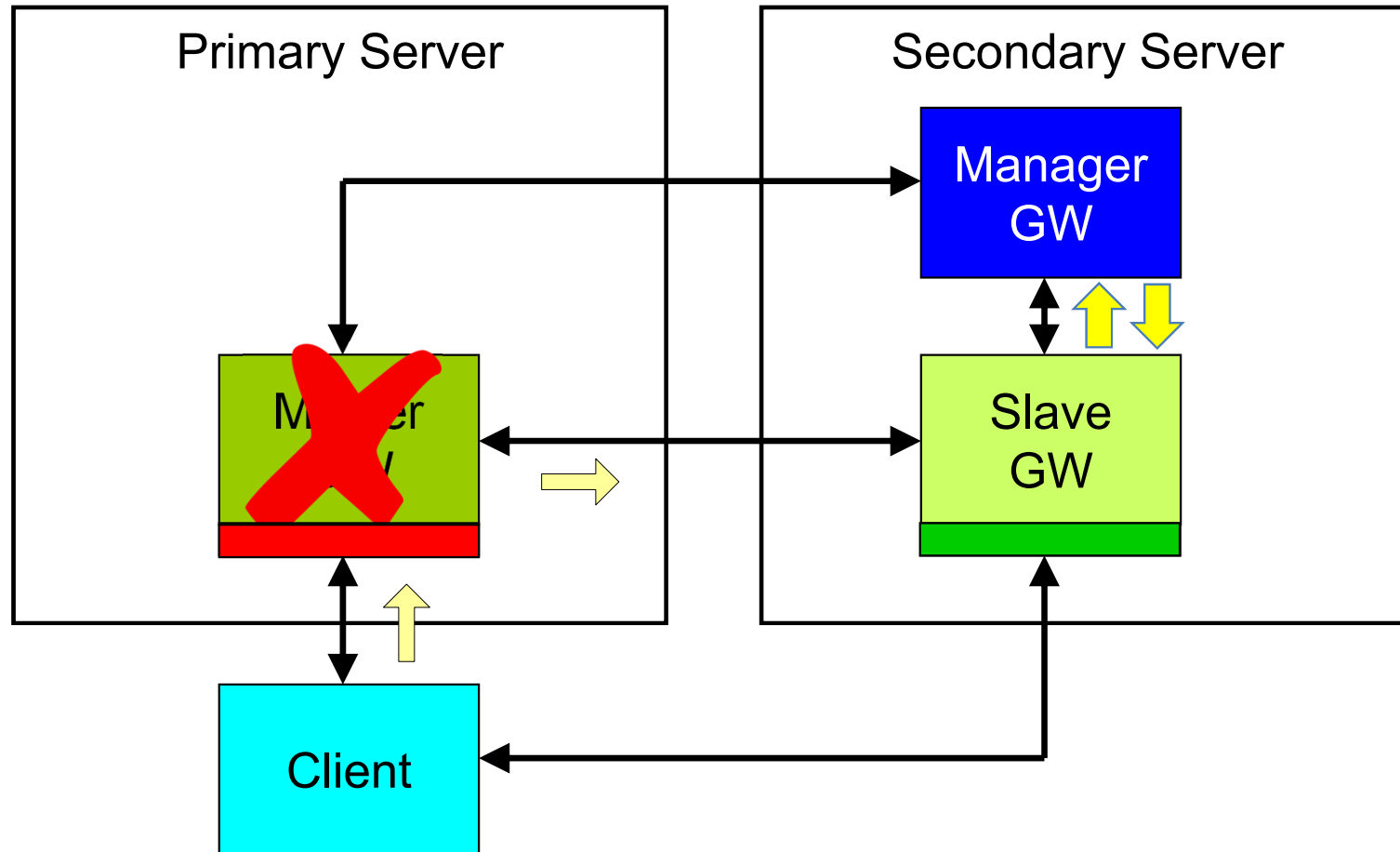
# High Availability

- **Master/Slave**



# High Availability

- **Master/Slave take over scenario**



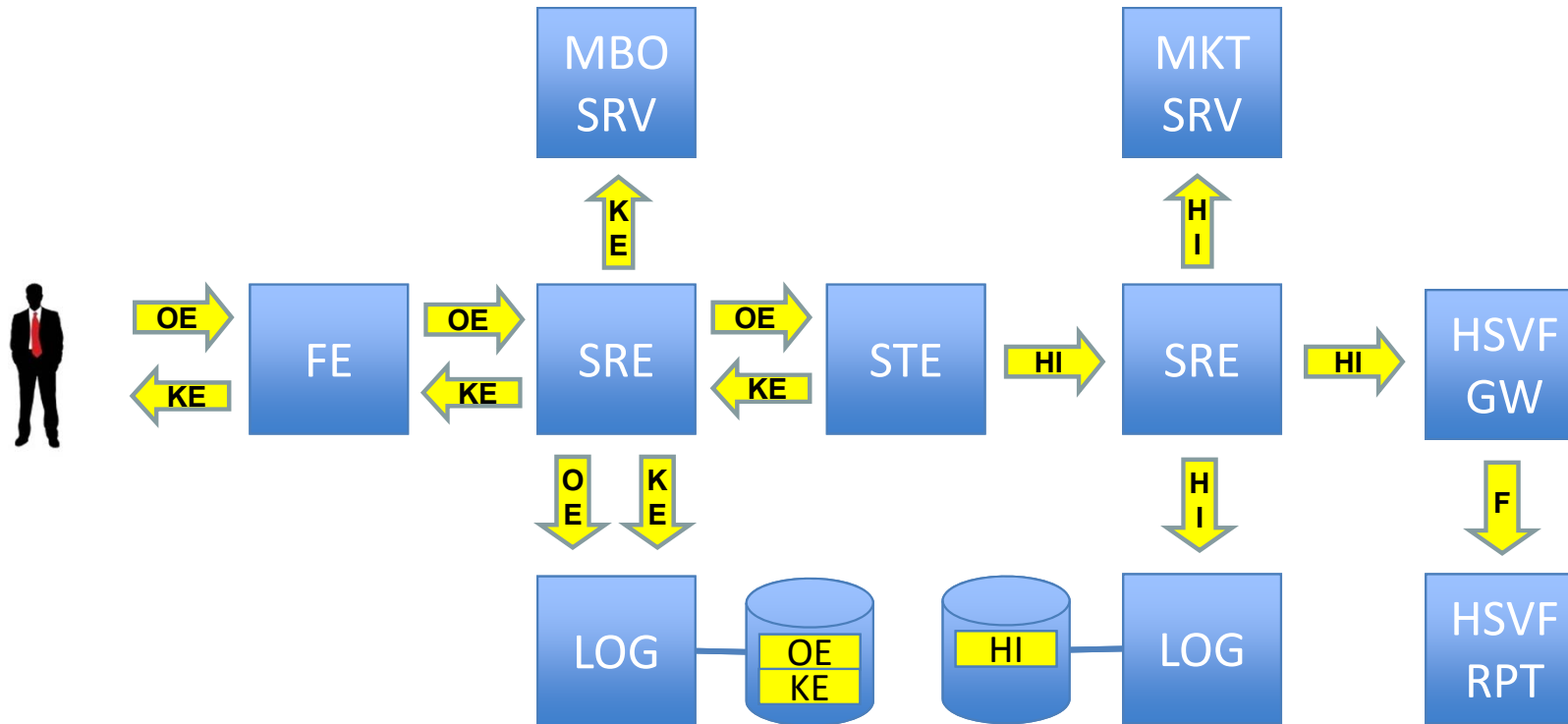
# High Availability

- **Virtual IP**

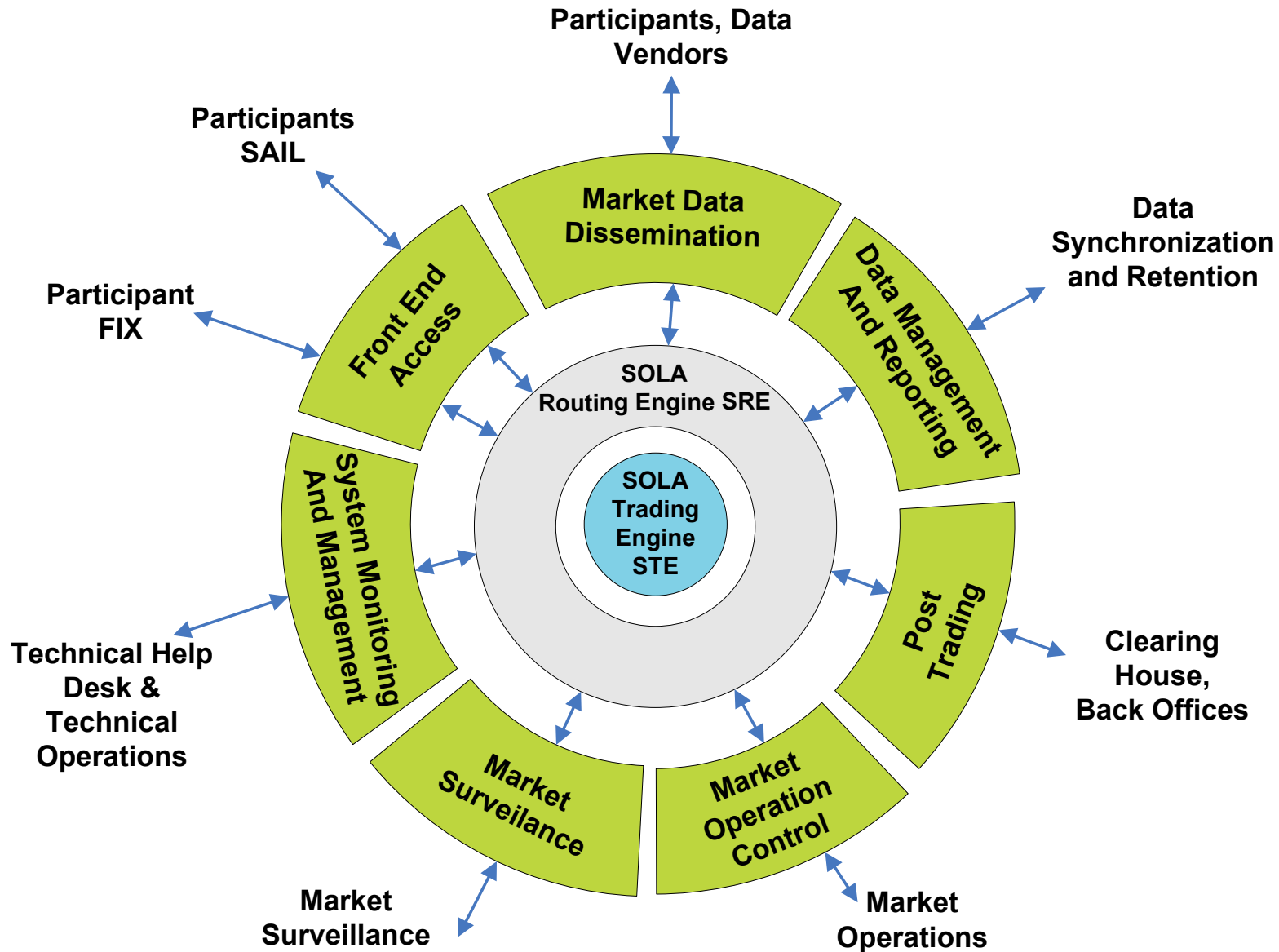
- Internal component replacing the load balancer for Master/Slave environment.
- Allows a unique IP address to be shared by multiple servers with dynamic mounting.
- Only the server running as Master must have the common IP address mounted.
- On failure of the Master component, the Watcher will un-mount the IP address to make it available for the server running the Slave.



# Order Life Cycle



# SOLA Architecture Overview



# SOLA Trading Engine (STE)

- **Manages Central Order “Book”**
  - Performs order validation
  - Generates market information
  - Generates implied market
  - Matches orders and generates trades
  - Manages market schedule
  - Processes market events





# SOLA Routing Engine (SRE)

- Role and Responsibilities of SRE

- Routing

- SRE stores all incoming messages and forwards messages to all clients who are subscribed to receive those messages using FMR Filters

- Data Persistence

- All messages are stored in log files, which can be re-injected in SRE instance in replay mode

- Retransmission of messages to client

- After establishing new connection, SRE re-transmits all messages or messages from the last sequence number

- Recovery

- If SRE is stopped and restarted, it replays its own logs and informs each client as to how many messages were retrieved from the log files and each client is expected to resume data transmission at the requested position.

# SOLA Integration Components (SICs)

- **Role and Responsibilities of SICs**

- Provide services that rely on protocols not recognized or generated by the SOLA® Trading Engine (STE). SICs both translate and enrich the protocols native to STE.
- They allow market participants to interact with the trading system.
  - Participants can use SICs as an access point to the market to manage their orders while retaining the use of protocols not native to STE (FIX).
- They forward market dissemination messages generated by STE to participants and data vendors through the Market Data Dissemination Feed.
- They offer clearing and post-trade management and reporting feeds. Back-offices can use these services to manage risk and manage the clearing information for their trades.
- They provide monitoring and management functionalities for STE, SRE and SICs.

# SOLA Integration Components (SICs)

## Front Ends Gateways

- **Role and Responsibilities of Front Ends**

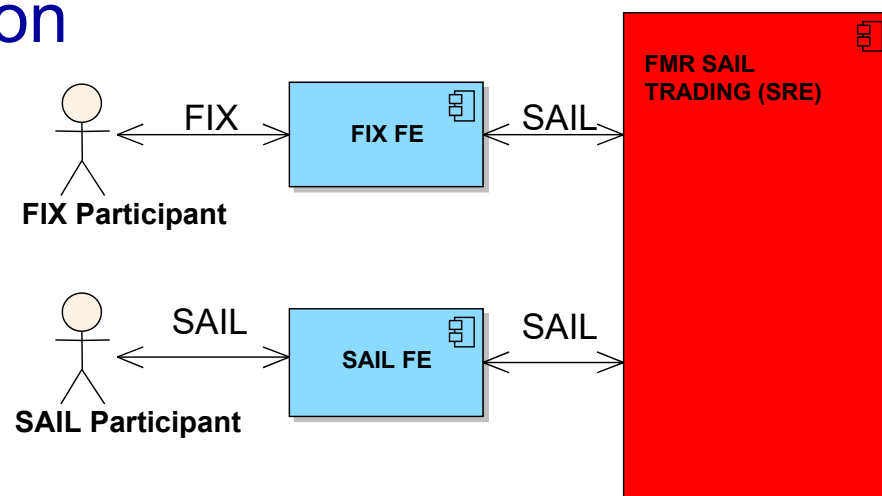
- ✓ Manage participant connection to Trading System
- ✓ Participant Configuration and Profiles
- ✓ Mechanism for Throttling of messages to the Trading System
- ✓ Protect the Trading System from direct external access
- ✓ Support multiple protocols such as native protocol of Trading System (SAIL), and internationally recognised protocols (FIX)
- ✓ Offer protection mechanism to participants connected to the Trading System in case of technical problems on the participant side or from the Trading System itself
  - Disconnection Instruction Management
  - Heartbeat Management

# SOLA Integration Components (SICs)

## Front Ends Gateways

- **SAIL FE - Additional Information**

- Accepts Bulk Quote from MM
- Minimal business validation of incoming business messages



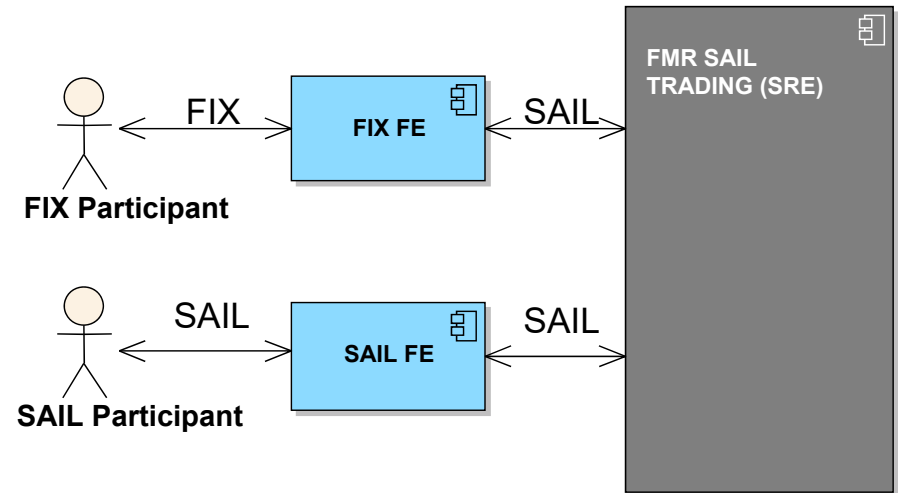
- **SAIL FE DC (Drop Copy)**

- Accepts only connectivity requests
- All outgoing messages from all SAIL/FIX participants within the same firm are sent to the Drop Copy connection (using Sail format)

# SOLA Integration Components (SICs)

## Front Ends Gateways

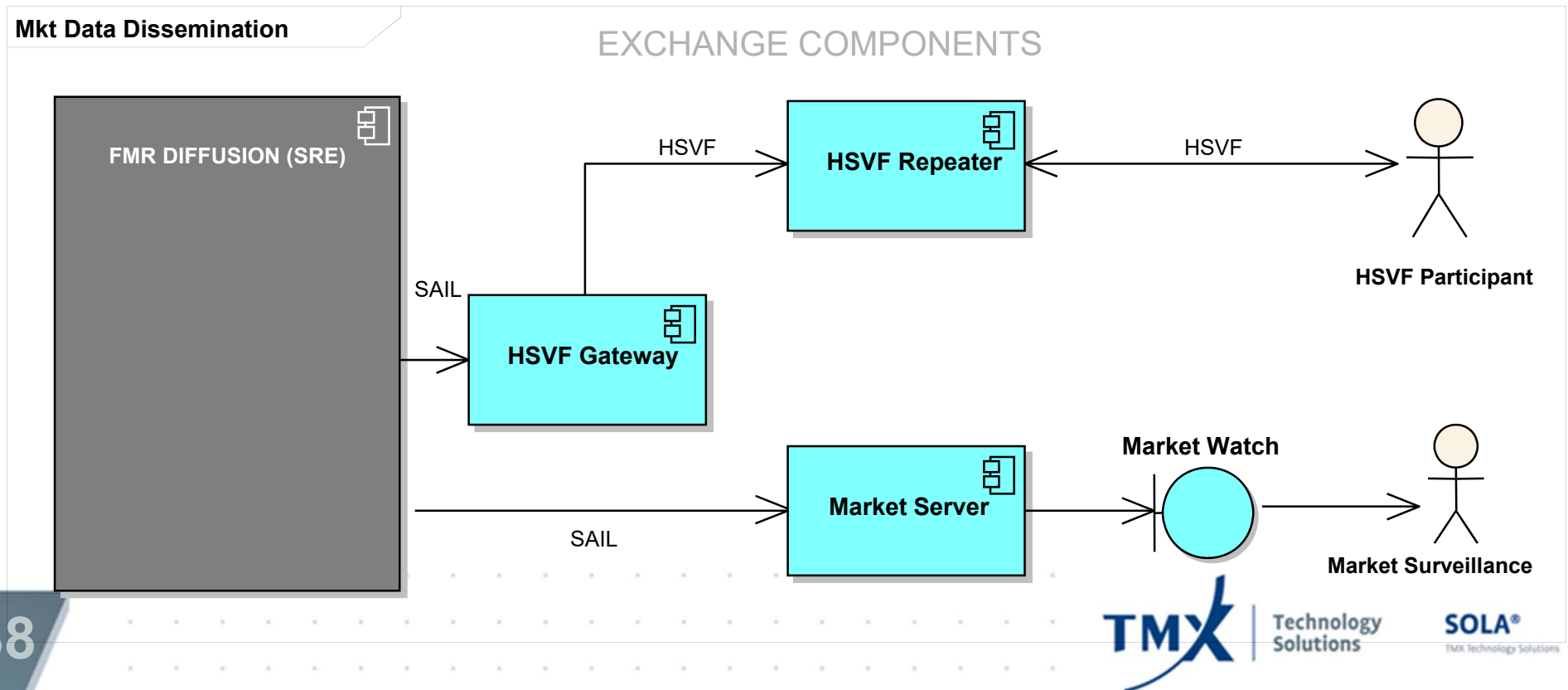
- **FIX FE - Additional Information**
  - Translation of messages from FIX to SAIL and vice-versa
  - Stores order information to compute FIX-related fields which are not present in SAIL e.g. CumQty, AvgPx etc.
  - Performs some business validation of incoming messages e.g. range check



# SOLA Integration Components (SICs)

## Market Data Dissemination Components

- The HSVF Gateways broadcasts real-time trading and statistical information using the HSVF protocol
- Its feed is comprised of trades, quotes, five-level market depth, one-level market depth for implied, referential data (security definitions), bulletins, summaries and other statistics.



# SOLA Integration Components (SICs)

## Market Data Dissemination Components

- HSVF Gateway
  - Generates market data information on Options, Futures, Future Options and Strategies for ISVs, Market Participants and Information Providers.
  - Generates the following types of business information
    - Trade and Trade Cancellation messages
    - Market Depth messages – up to 5 levels + **1 Level for Implied**
    - Request for Quote messages
    - Instrument Keys (Security Definition) messages
    - Summary messages
    - Bulletins from the Market Surveillance
    - Market Status messages



# SOLA Integration Components (SICs)

## Market Data Dissemination Components

- HSVF Repeater
  - Manages the connection of market participants
  - Receives HSVF Market Data Dissemination messages from the HSVF Gateway and forwards them to market participants
  - Feed can be customized per client request on connection allowing for protocol optimization request
  - Manages recovery of a client on re-connection
    - Client can request all messages sent for the day or
    - Client can request all messages from the last sequence received or
    - Client can request all messages from the current one





# SOLA Integration Components (SICs)

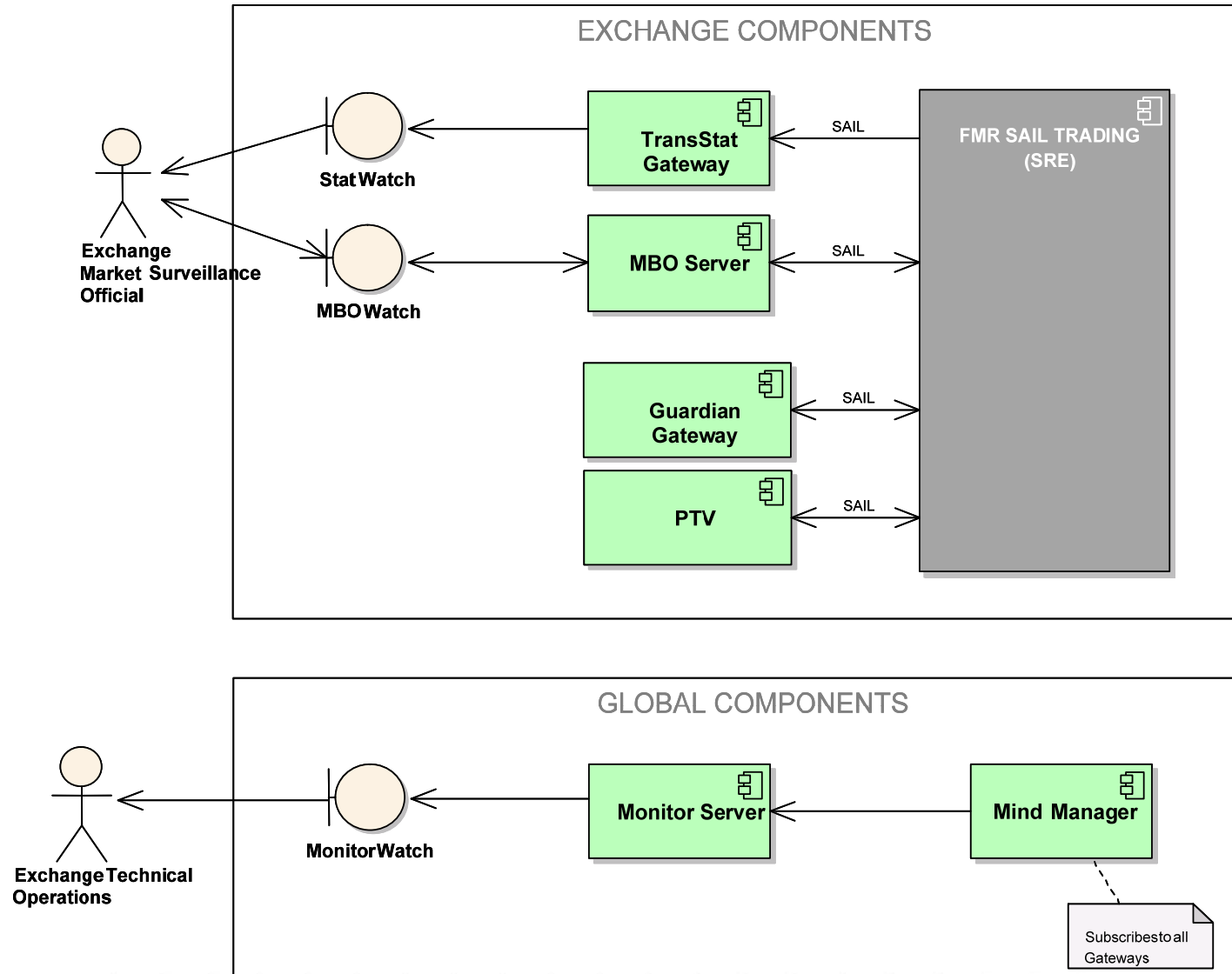
## Market Data Dissemination Components

- **Market Server**
  - Maintains up-to-date market information.
  - Provide (with real-time refresh) market information to Market Watch
- **Market Watch**
  - Market Watch is the client application of the Market Server
  - It is a GUI used by the Market Operation to:
    - Monitor in real time the market information (first limit or 5 best limits)
    - View list of trades and trade cancellations
    - View list of Request for Quotes (RFQ)



# SOLA Integration Components (SICs)

## System Monitoring and Management



# SOLA Integration Components (SICs)

## System Monitoring and Management

- The Gateways concerned provide:
  - Real-time and historical data on orders and quotes to teams involved in the reconstruction of market events, either for same-day information requests from participants, or inquiries following suspect market events
  - Live monitoring of Market Makers quoting performance and obligations
  - Real-time monitoring of the internal state of all SICs including the Trading Engine and Routing Engine
  - Statistical information on orders and quotes in real-time
  - Live monitoring of firms and traders limits

# SOLA Integration Components (SICs)

## System Monitoring and Management

- **MBO Server**

- MBO Server offers dynamic views of the order book for a given instrument or firm (as computed from order messages, bulk quotes messages and their confirmations, as well as any other market events which can modify an order).
- The MBO Server sends the order information to the MBO Watch.

- **MBO Watch**

- Displays all live and historical orders by firm or instrument
- Allows the Market Surveillance to cancel orders/quotes for a given firm or trader



# SOLA Integration Components (SICs)

## System Monitoring and Management

- **Monitor Server and Manager**

- The Monitors application offers an operational monitoring system for the Trading System and perform the following functions:
  - Alarm/Warning System for errors occurring on the trading system
  - Provide a real-time state of all connection through the trading system
  - Provide a real-time internal state of each application of the trading system.
- The Monitor Server forwards the real-time monitoring information to the Monitor Watch GUI.

- **Monitor Watch GUI**

- This application is the GUI which displays the information from the Monitor Server to System Operators

# SOLA Integration Components (SICs)

## System Monitoring and Management

- **Guardian Gateway**

- The Guardian Gateway is responsible for the monitoring of Market Makers in term of their quoting obligations
- The Guardian Gateway receives Underlying Price (from external Data vendor), Bulk Quote acknowledgements, trade, global quote cancellation, instrument or group status change from the FMR Trading SRE
- It calculates in real-time the monitoring space for a given market maker and generates two levels of alerts – Warning and Infraction
- Warnings alerts are sent to the MBO Server and MBO Watch and can be monitored by Market Operations
- Infraction alerts, generated after expiry of a configured grace period, are sent both to MBO Watch and the MM in infraction

# SOLA Integration Components (SICs)

## System Monitoring and Management

- **PTV (Pre-Trade Validation)**
  - SOLA controls limits on trading activities
  - Various limits can be configured per group, at the Firm and/or Trader Team
    - Maximum Order Quantity
    - Position Limits
    - Credit Control
  - A Global Credit Control can be configured, cumulating the Net Exposure across all groups, at the Firm and/or Trader Team levels
  - When a limit is reached, various actions can be performed
    - Rejection of incoming orders and quotes
    - Cancellation of booked orders and quotes
    - Emission of a notification message

# SOLA Integration Components (SICs)

## System Monitoring and Management

- PTV (Pre-Trade Validation)
  - SOLO
    - performs the limit calculation and apply configured rules
  - PTV
    - Perform same limit calculation
    - Perform netting calculation and advise Solo of adjustment required
    - Perform global limit calculation (inter-CPU)
    - Notify of limit usage



# SOLA Integration Components (SICs)

## System Monitoring and Management

- TransStat Gateway

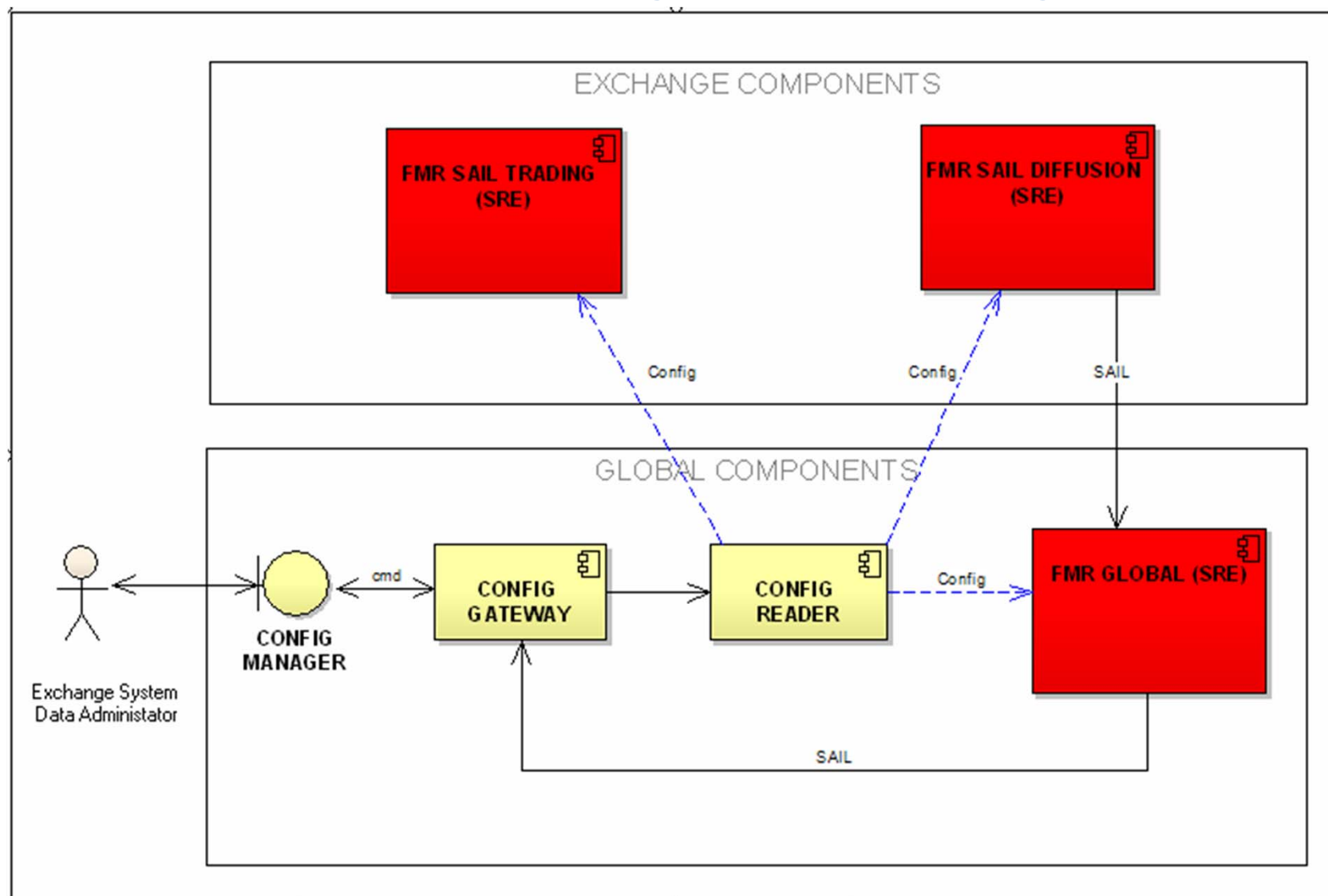
- The TransStats Gateway calculates real-time order and bulk quote statistics such as minimum and maximum response times, number of messages received by instrument group and/or participant and sends the information to be displayed on the Stats Watch GUI

- Stats Watch GUI

- Receives orders/quotes statistical information by instrument group or participant
- Received technical connection/disconnection statistical information by participant only.
- Displays a summary/cumulative representation record by record or in graphical form

# SOLA Integration Components (SICs)

## Market Surveillance – Configuration Management



# SOLA Integration Components (SICs)

## Market Surveillance – Configuration Management

- **Config Gateway**
  - Responsible for the management of all configuration business objects of the Trading System. Config Information sent to Config Reader
  - Receives trades and trade cancellations from FMR Global SRE and sends them to the Config Manager for display
  - Responsible for Automatic Creation of Instruments
- **Config Reader**
  - Responsible for diffusion all configuration information to all SREs (Trading, Dissemination, Global), where all subsystems in turn subscribe to receive some or all config information
- **Config Manager**
  - Config Manager is the GUI Interface used by the Market Surveillance to configure all business objects and other objects (e.g. CPU)
  - It also displays all trades in the system, and allows the Market Surveillance to cancel trades and manually create trades

# SOLA Integration Components (SICs)

## Data Management and Reporting

- Overview

- The applications involved in this business domain are responsible for management of data in the Trading System.
- Loggers log live data from the SREs in specific log files which safe keep all orders of all types, all market data, trading and management data, and all incoming and outgoing messages.
- All the log files are compressed flat files using an optimized compression algorithm, hence minimizing disk space usage for capacity management.
- All log files are retained on disk or tape for live and historical data querying

# SOLA Integration Components (SICs)

## Data Management and Reporting

- **Sail Logger**
  - These loggers log order, quote and trade related information as well as group and instrument status information etc
  - All configuration information diffused by Config Reader are also logged in the SailLoggerConfig files
  - Bulk Quote information and Market Depth information are logged in the SailLoggerQuote and RLCLoggerQuote file repository.
  - The RLCLoggerSummary contains end-of-day summary information (e.g. closing prices, total volume, etc)

# SOLA Integration Components (SICs)

## Data Management and Reporting

- **SasHistoric**
  - The **SasHistoric** processes queries from the **SurvServer**, accesses the above log files and returns the results back to the **SurvServer**
- **SurvMan**
  - The **SurvManager** is a GUI which enables users to build customized queries about all types of market activities.
  - The **SurvManager** also allows the user to iteratively query the results of a query, thus enabling Monitoring teams to “drill down” on all activities leading to a given market event.
- **SurvServer**
  - The **SurvServer** relays queries from the **SurvManager** to the **SasHistoric** and returns the results of a given query to be displayed on the **SurvMan** screen.

# SOLA Integration Components (SICs)

## Data Management and Reporting

- **Order Reporter**

- This gateway receives all messages which pertain to order management such as
  - OrderEntry and Acknowledgements
  - OrderModification and Acknowledgments
  - OrderCancellation and Acknowledgments
  - Trade and Trade Cancellation
- It produces an Order report by Firm for all orders which remain in the book at EOD

- **Trade Reporter**

- This gateway retrieves all trades and trade cancellations for the day from log files and produces an end-of-day report by firm

# SOLA Integration Components (SICs)

## Post-Trading

- **TradeAlloc** - This gateway is generating the trade allocations with all the default clearing information. It converts trades of instruments to be cleared from the SAIL format into allocations in BTA format.
- **CLR** - This gateway is responsible for sending trade allocations (and trade give-ups) to the Clearing House
- **TMS Server** - This gateway allows participants to perform post-trade allocations and give-ups to other clearing firms.
- **TMS** - This is the GUI part.



# SOLA Integration Components (SICs)

## Post-Trading

- **TMS Hist-Server** - This gateway allows participants to consult allocations and give-ups performed before today.
- **Clearing API** - This gateway is allows participants to perform post-trade allocations and give-ups through an API.
- **BTA Logger** - This gateway reads all the allocation messages and save them in a file using a tag log format.

# SOLA Integration Components (SICs)

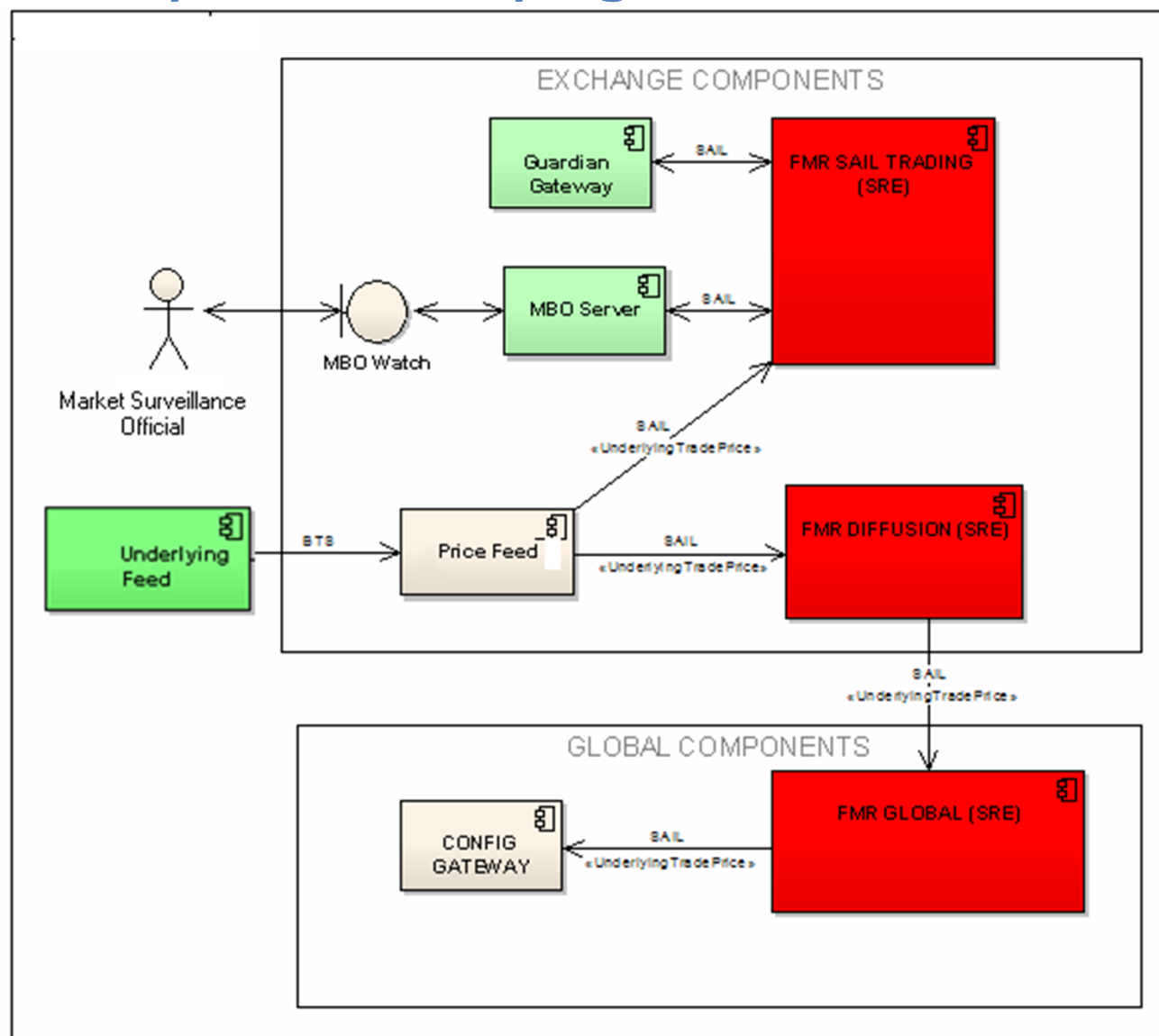
## Post-Trading

- **Billing Reporter** - This gateway generates a trade log file (journal) with all the information required to perform the billing.
- **Billing Manager** - This gateway parses the trade log file and applies the fee programs to calculate the fees to be bill to participants.
- **ATR** - This gateway generates in real-time allocation messages to participants performing trade reconciliation.



# SOLA Integration Components (SICs)

## Other Gateways – Underlying Price Feed



# SOLA Integration Components (SICs)

## Other Gateways – Underlying Price Feed

- Underlying Price Feed Gateway
  - This gateway is responsible for receiving Underlying Feed in real-time from a data vendor such as **Thomson, Reuters or Bloomberg**.
  - Underlying Closing Price are sent to the Config Manager
  - Underlying Trades are also required by the Guardian Gateway in real-time to calculate or re-assess the monitoring space of all options series

# SOLA Integration Components (SICs)

## Other Gateways – RTF Gateway

- RTF Gateway (Real Time Feed)
  - This gateway is providing all messages received by an FMR to downstream systems.
  - Messages are disseminated on up to 62 lines
  - Bulk messages are un-bulked
  - It allows the breakdowns of a high volume message (like price update) on multiple lines by configuring ranges of groups



# Data Communications Protocols

- Incoming
  - FIX (for trading)
  - SAIL (for trading)
  - Clearing API (for allocation)
- Internal
  - SAIL (wrapped inside FMR)
  - BTA (wrapped inside FMR)
  - Message Format
    - Configuration (wrapped inside FMR)
    - GUI/Server (Point-to-Point)
- Outgoing
  - HSVF
  - RTF
  - ATR

# Integrating External Components

- **Public API**

- Use of the shelf standard interface to integrate external components: FIXFE, SailFE, SailFE-DropCopy, HSVF, ClearingAPI, ATR.

- **RTF**

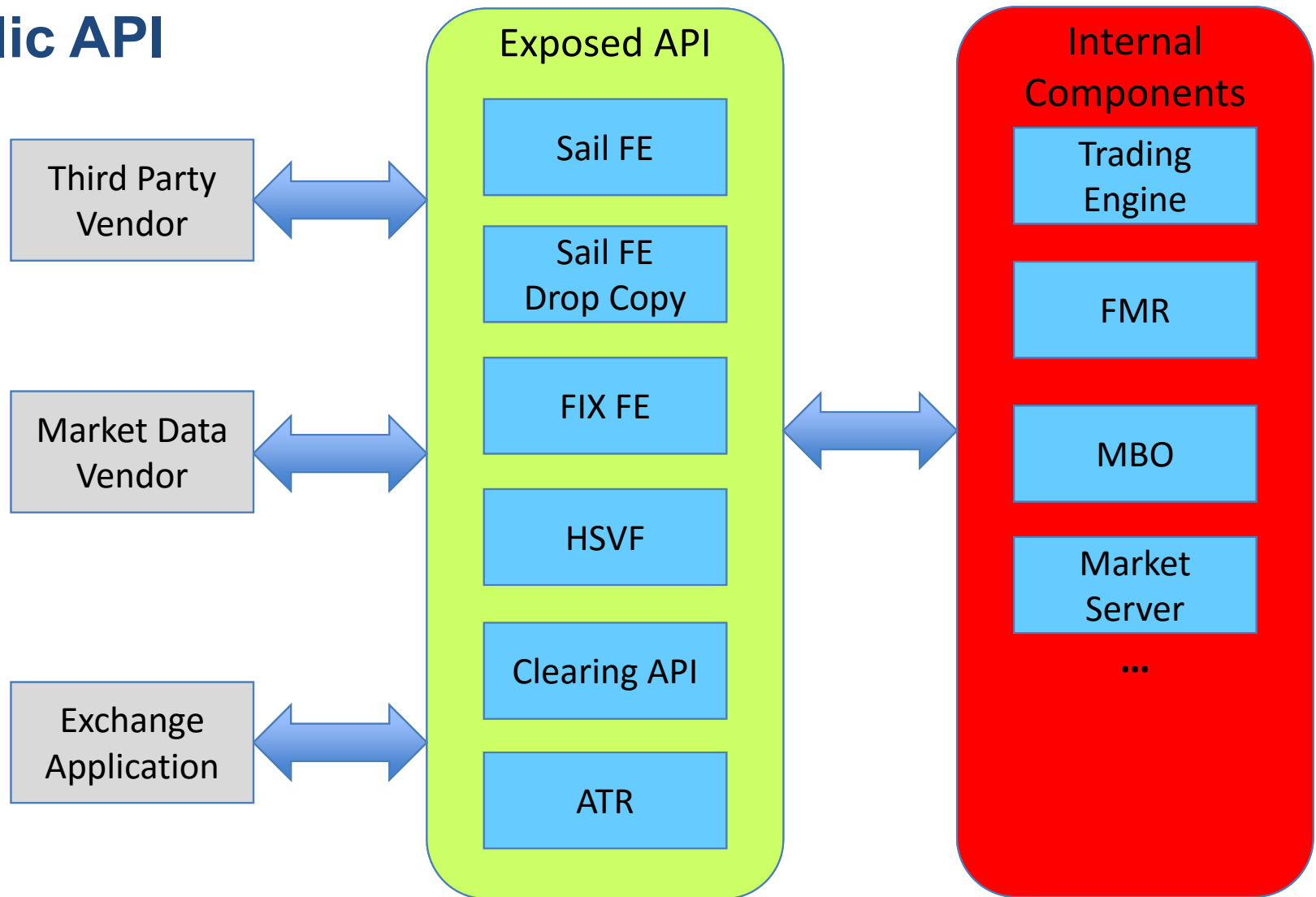
- RTF offers an isolation layer between external components and the trading system.
  - This layer allows external components to have a light delay in processing incoming messages.
  - Major delay (like requiring message from the start of the day) might slightly impact other external components but not the trading environment.

- **FMR**

- Components linked to FMR must absolutely follow the pace of messages.
  - Any delay in reading FMR messages can degrade overall system performance.

# Integrating External Components

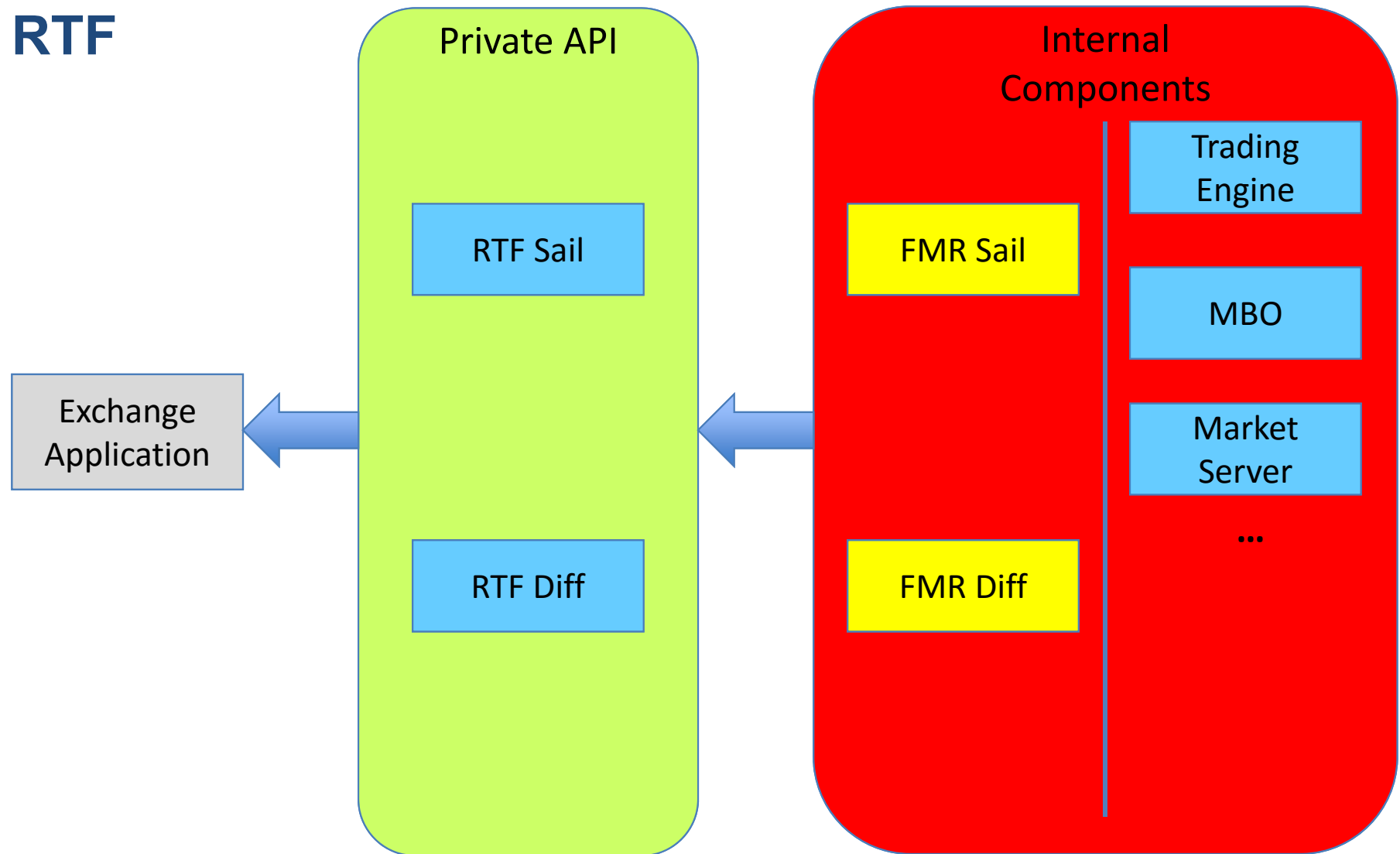
- **Public API**





# Integrating External Components

- **RTF**



# Integrating External Components

- **FMR**

