HKEx Orion Market Data Platform (OMD)
Derivatives Market

Technical Briefing

26 July 2013

Changes are made on 30 July 2013 with highlights on right margin with "|" . (Pages 33 and 61.)

AGENDA

Part 1	
Overview & On-boarding Activities	**By Karen Lam** **Vendor Support & Data Management** **Market Data Department**
Part 2	
Technical Features of OMD and Notes on Feed Handler Development	**By Kelvin Yang** **Market Data Systems** **Information Technology Division**
Part 3	
Network Matters	**By Stephen Mak** **Network Operations & Engineering (SDNet)** **Information Technology Division**
Part 4	
Q&A	**All Speakers**

AGENDA – Part 1

1. Overview
2. On-boarding Activities

Overview

Orion Market Data Platform (OMD)

HKEx Orion

HKEx Orion:

a transformative programme comprising new platforms and facilities designed to revolutionise HKEx's core trading platforms, including connectivity networks, a state-of-the-art data centre, and systems providing order matching, market data dissemination and market access services

Orion Market Data Platform (OMD)

OMD

an integrated low-latency platform delivering market data for all asset classes traded on HKEx markets in a common message format

- OMD Securities Market (OMD-C)
- OMD Derivatives Market (OMD-D)
- OMD Index

OMD Derivatives Market

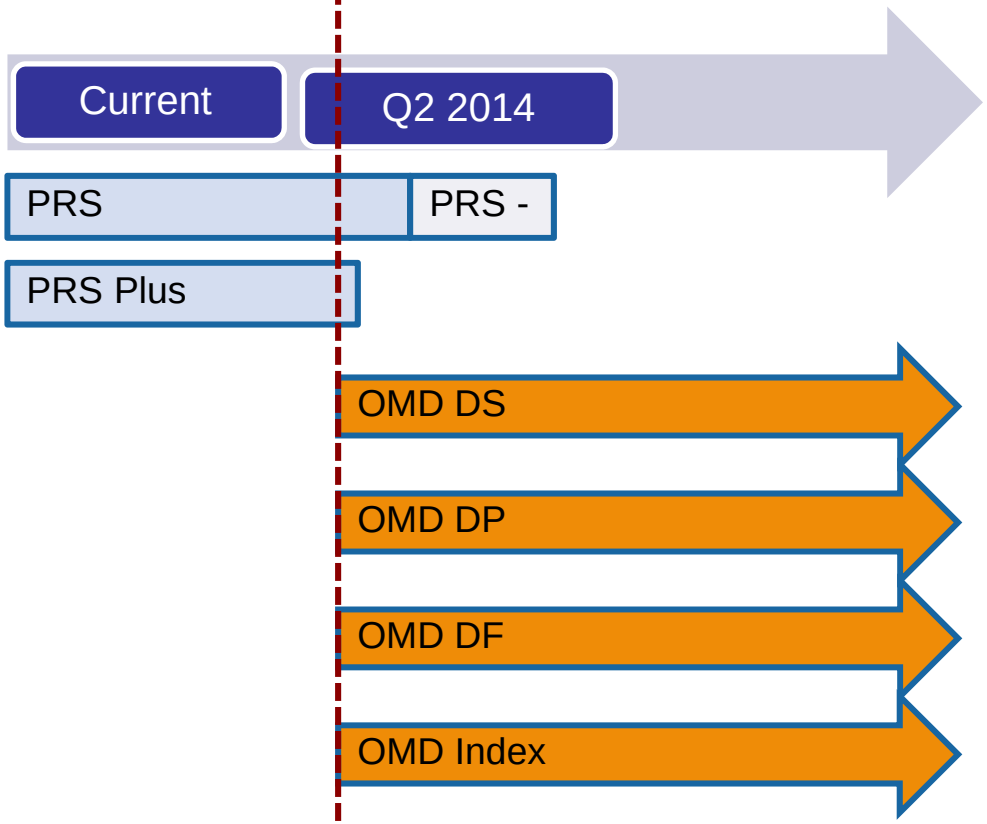
OMD Derivatives Market (OMD-D) comprises three (3) datafeed products:

- Derivatives Standard (DS)
- Derivatives Premium (DP)
- Derivatives FullTick (DF)

Overview

Product Rollout

Derivatives Market Data		
Market by Price	Conflated	Holdback: 0.5s 5 BBO
		Holdback: 0.1s 5 BBO
		Holdback: 0.5s 10 BBO
	Streaming	10 + 1 BBO
Market by Order	Streaming	-
Index Data (HSI, CESC, etc.)		



PRS - : The holdback time of PRS will be increased to cope with the increased trading volume
BBO – Best Bid & Offer prices

Overview

Product Profile

Contents		DS	DP	DF	Index
Reference Data		○	○	○	
Status Data		○	○	○	
Price Queue Update (10)		○			
Price Queue Update (10 +1 BBO)			○		
Order Book Data				○	
Quote Request		○	○	○	
Trade Statistics		○			
Series Statistics			○		
Trade / Trade Cancel		◎	○	○	
Open Interest and Settlement Price		○	○		
Calculated Opening Price		○	○	○	
Implied Volatility (End of Day)			○		
Estimated Average Settlement price		○	○		
Market Alert		○	○		
Index					○
Anticipated Bandwidth (Mbps)	Non SOM	4	7	6	Negligible
	SOM	19	40	34	

○ Contents of feed ◎ Complimentary

SOM Stock Options Market

Overview

Highlights of Differences (Technical)

Feature	PRS / PRS Plus	OMD	Points to Note about OMD
Transmission Protocol (Real-time Data)	Unicast	Multicast	• Detection of data loss and data recovery • Race condition as a result of data transmission from multiple channels
Data Recovery	• From same connection • Retransmission Service (optional)	• Latest image – Refresh (multicast) • Gap filling – Retransmission (unicast)	• Different IP address to receive same data from Refresh channels • Limited number of messages available in cache for retransmission

Overview

Highlights of Differences (OMD-D vs PRS)

Data	PRS / PRS Plus	DS	DP	DF	Points to Note about OMD
Price Depth	5 BBO	10 BBO	10 +1 BBO	All orders	The 11th price level is the for the aggregated quantity of all price levels beyond the best 10
Trade Information	Last Trade at snapshot	Last Trade at snap shot	Individual Trades		Individual Trades also available to DS in the complimentary Trade Feed
Price Queue Update	Full Price Queue Information	Changes only, including new order prices and change of quantity		N/A	Client's system to create order book from the changes, e.g. shifting of queue positions and deleting price queues beyond the top 10 price levels, etc.
Series Definition	Single level at Series	Multiple levels from Market to Series			
Series State	Defined at market or commodity level	Defined down to seriies level			OMD provides information to derive active state of individual series
Quote Request	Not Provided	Provided			

Overview

Highlights of Differences (OMD-D vs OMD-C)

Data	OMD-C	OMD-D	Points to Note about OMD
Price Depth	10 **tick** levels according to the Spread Table	10 **price** levels **11th** price level for the remaining orders beyond the best 10	
Order Book Update from Trade Execution	Aggregated Order Book Update messages will be sent	Aggregated Order Book Update message will **not** be sent	Client's system to update order book in memory from Trade messages
Order Book Position	Order Book Position **not** provided	Order Book Position provided	Client's system can construct the full order book with position of each outstanding order
Market Orders during Auction	No information on market orders if only market orders exist during auction	Market orders will be ranked the best level when the buy and sell sides do not cross	

AGENDA – Part 1

1. Overview
2. **On-boarding Activities**

On Boarding Activities

First Batch Schedule

Q3 2013	Q3 2013	Q4 2013 – Q1 2014	Q4 2013 – Q1 2014	Q2 2014	Q2 2014
Feed Enrolment	Self Test	Open Test	Readiness Test	Market Rehearsal	Post Release Test
• Choice of Feed • Complimentary Feed (Yes/No)	• On-boarding tools provided by HKEx, including real-time multicast simulator, canned data, user guide • First cut canned data for data decoding • Subsequent cut including more test scenarios, e.g. for order book building • Retransmission enabled • Refresh not supported	• Clients to arrange testing line installation • Conducted in HKEx testing environment with OMD Derivatives and Index fully functional, e.g. real-time data transmission via multicast channels, refresh and retransmission are all supported • Loop test with HKATS can be enabled	• Clients enabled to verify and declare their readiness for OMD Derivatives and Index in areas below: 1. message decoding 2. order book building 3. data recovery 4. volume/stress 5. site failover • ReadinessTest Document to be delivered in due course • Expected results to be provided for Clients' self verification • Self Declaration	• Volume test session • Failover test session • Self Declaration	• Self Declaration • 2 weeks' stabilisation period

On Boarding Activities

Special Notes

- **Decommissioning of PRS and PRS Plus**

  In view of the anticipated significant increase in market transaction volume in Q2 2014 under the new HKATS platform which PRS and PRS Plus could no longer support due to their technical limits:

  - **PRS will be terminated in 3 months upon OMD-D rollout possibly with prolonged conflation interval from the current 0.5 second up to 5 seconds**
  - **PRS Plus will be terminated within one month upon OMD-D rollout.**

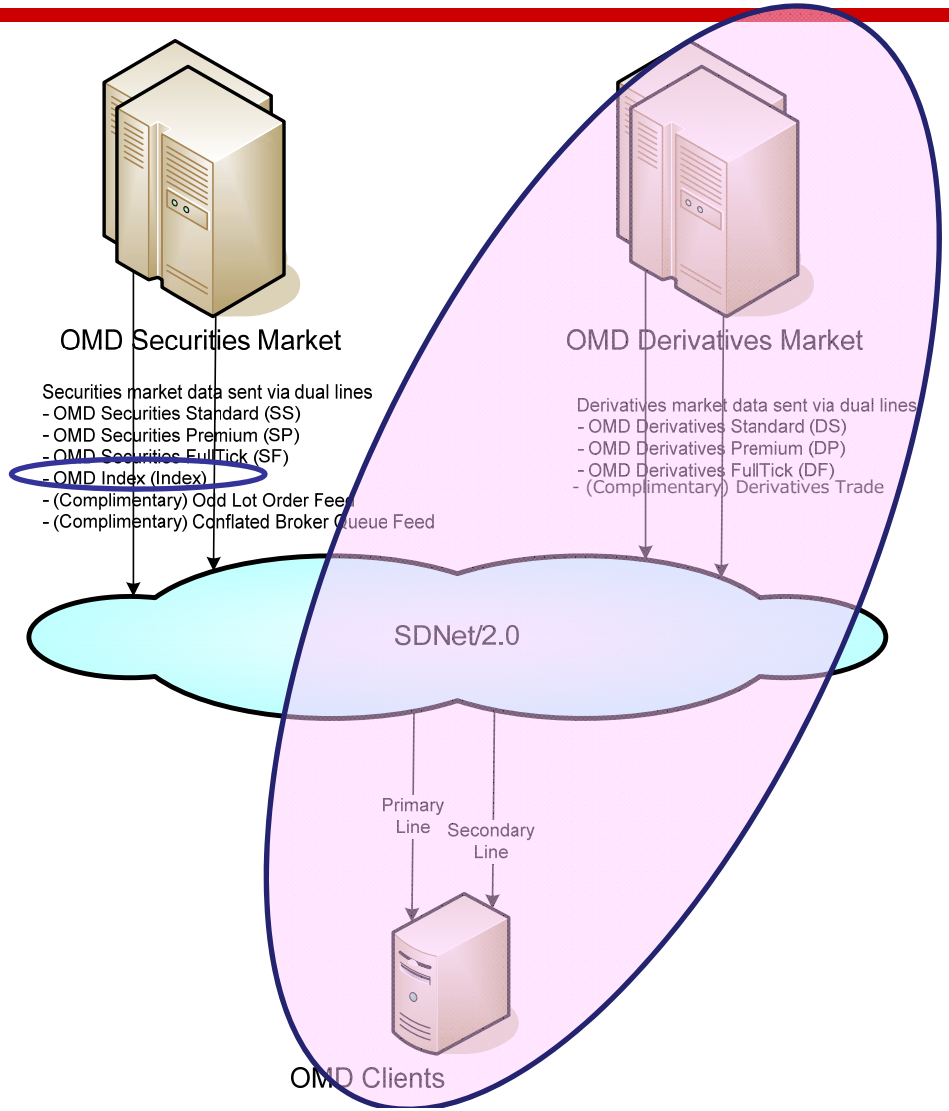
- **Indirect Vendors Readiness**

  - **Feed providing vendors undertake the responsibility for the readiness of indirect connection clients.**
  - **Feed providing vendors should ensure indirect connection clients with OMD original format to pass the same test cases as per OMD direct connection clients.**
  - **Declaration of indirect connection client's readiness via both feed providing vendors and indirect connection client itself.**

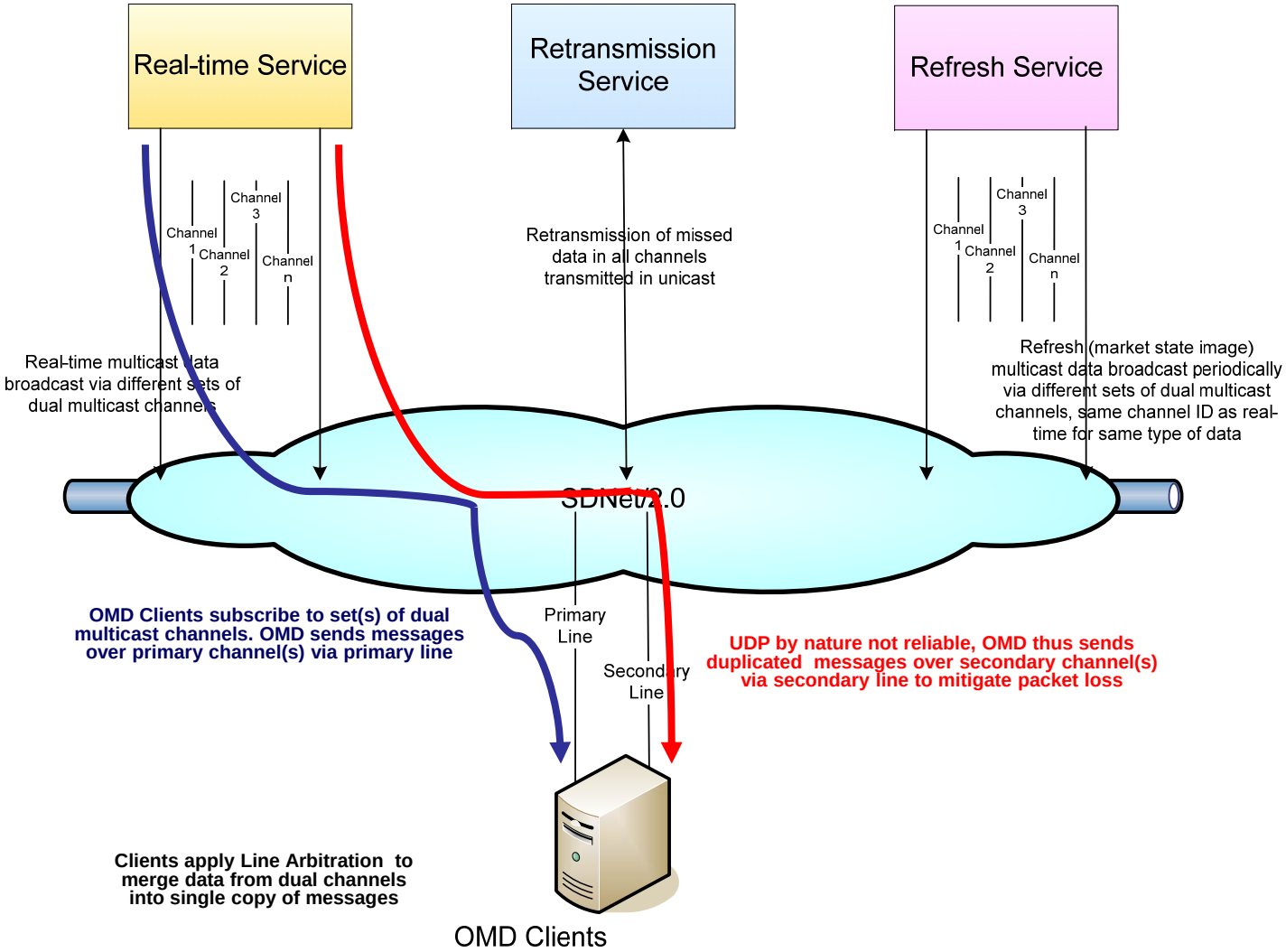
AGENDA – Part 2

1. Overview of OMD
2. Use of Developers Guide
3. Channel Assignment
4. Control Message
5. Recovery Mechanism
6. OMD Failure Recovery
7. Market Data Message
8. Highlights on Aggregate Order Book Management

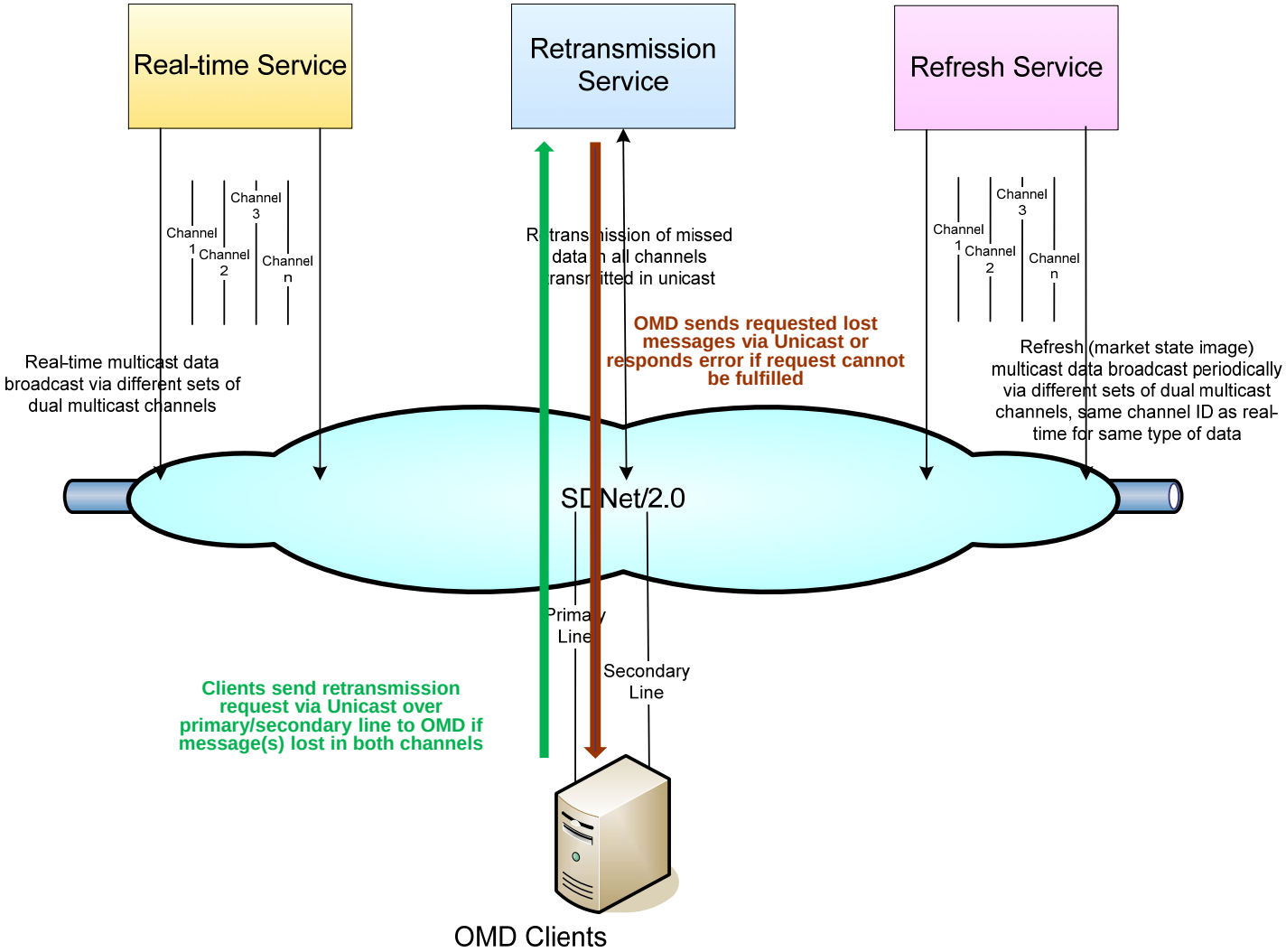
Overview of OMD (Derivatives)



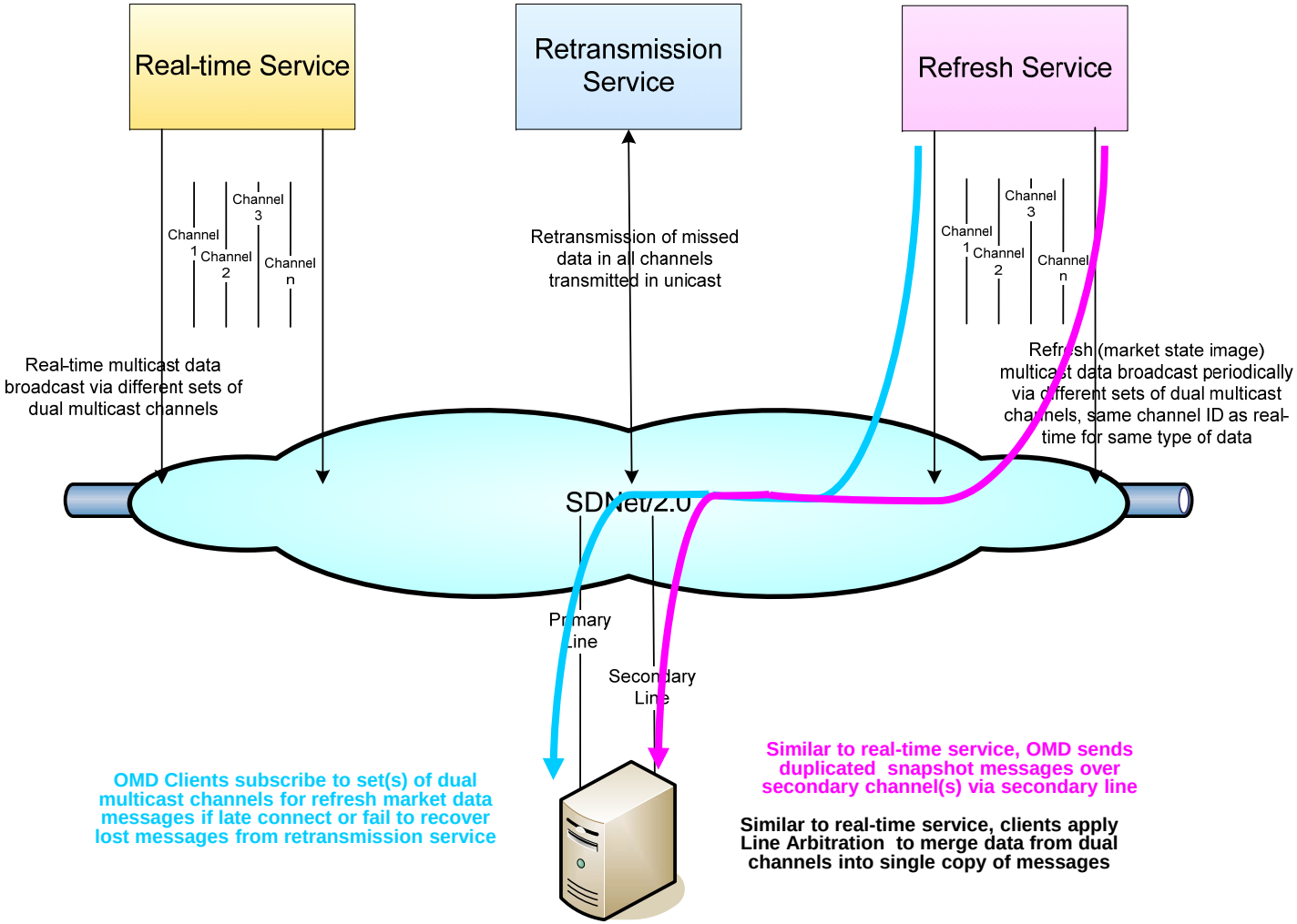
Overview of OMD



Overview of OMD



Overview of OMD



Overview of OMD

- Messages published in one-to-many mode using IP multicast and UDP transport protocols, supported by retransmission & retransmission services
- Duplicated messages sent over dual multicast channels via primary & secondary SDNet/2 lines, line arbitration applied **(Link A 239.1.1.0-255, Link B 239.1.127.0-255)**
- Retransmission service offered for recovery of past ~15s of lost packets in each channel
- Refresh service published snapshot market state using IP multicast and UDP transport protocols, line arbitration applied
- OMD adopt multicast in order to achieve
  - Fairness
  - Low latency

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Use of Developers Guide

- Provide supplementary information to clients to support development of their own feed handler to process OMD messages
- Address potential queries raised by clients after reading OMD Interface Specification
- Help clients to get familiar with multicast message handling
- Cover different topics in deeper level of details to facilitate client development
  - Line Arbitration
  - Packet and message processing
  - Retransmission and refresh mechanism
  - Aggregate order book management and order book maintenance
  - Exception handling

Use of Developers Guide

- **Illustrate with flow diagrams the possible logics in processing**
  - **Retransmitted data from OMD retransmission server**
  - **Refresh snapshot messages from OMD refresh service**
- **Demonstrate with pseudo codes as examples for message processing & exception handling**
  - **Connect and receive multicast channel**
  - **Line Arbitration**
  - **Processing retransmitted data**
  - **Processing refresh snapshot packet**
  - **Processing Aggregate Order Book message**
- **Objectives – use with OMD on-boarding tools to assist clients in OMD on-boarding**

Use of Developers Guide (Processing Data Section 5.2.3)

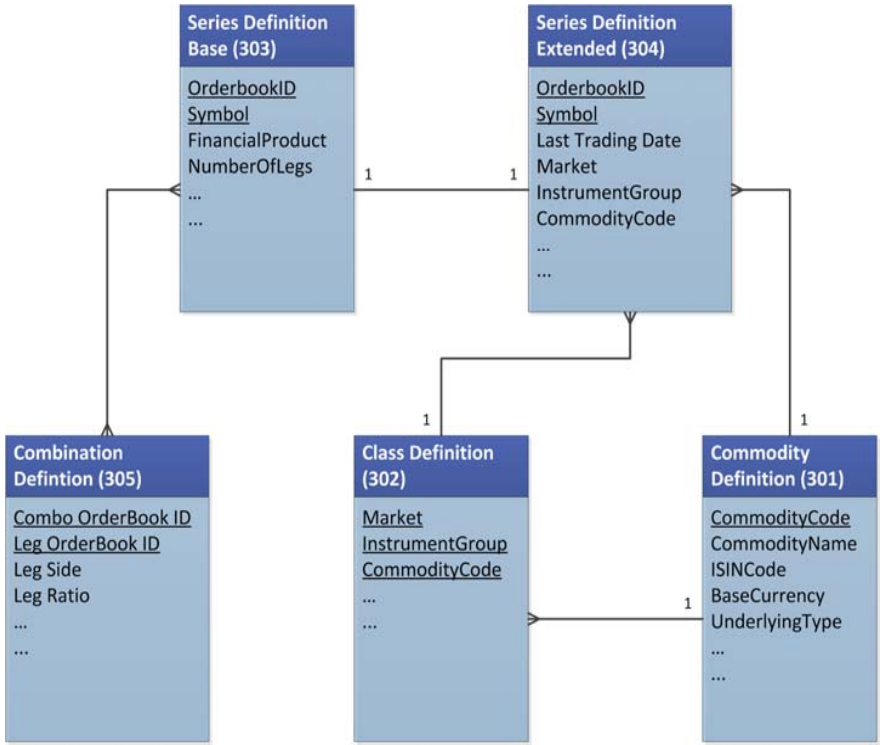
- Building Up Definitions
- Market Status Update Arrangement
- Full Order Book Management
- Partitions in HKATS
- Traded Quantity of a Deal
- Trade Amendment
- Calculated Opening Price reset when Pre-market end
- Next day Tradable Series
- Intra-Day Created Series
- Message Routing for SOM & non-SOM
- After Hours Futures Trading – Clarification on Trading Information
- Expiration Date field in Message 304

Use of Developers Guide (Building Up Definition)

- OMD-D Instrument Key Structure
  - Commodity Definition (301)
    - CommodityCode
  - Class Definition (302)
    - Country /Market /InstrumentType /Modifier /CommodityCode
  - Series Definition Based (303)
    - OrderbookID (unique key of a series)
    - Symbol Name (the reference long name of series)
  - Series Definition Extended (304)
    - OrderbookID (unique key of a series)
    - Symbol Name (the reference long name of series)
    - Country /Market /InstrumentType /Modifier /CommodityCode /Expiration Date
  - Combination Definition (305)
    - ComboGroupID / LegOrderBookID

Use of Developers Guide (Building Up Definition)

- Current day tradable series are provided in Msg304
- If a series is suspended at start of day, NO Msg303 is provided until the series is resumed trading in market
- The key between Msg303 and Msg304 for tradable series is OrderBookID. Symbol name can also be used.
- Msg301 and Msg302 carry the Class and Commodity Levels information



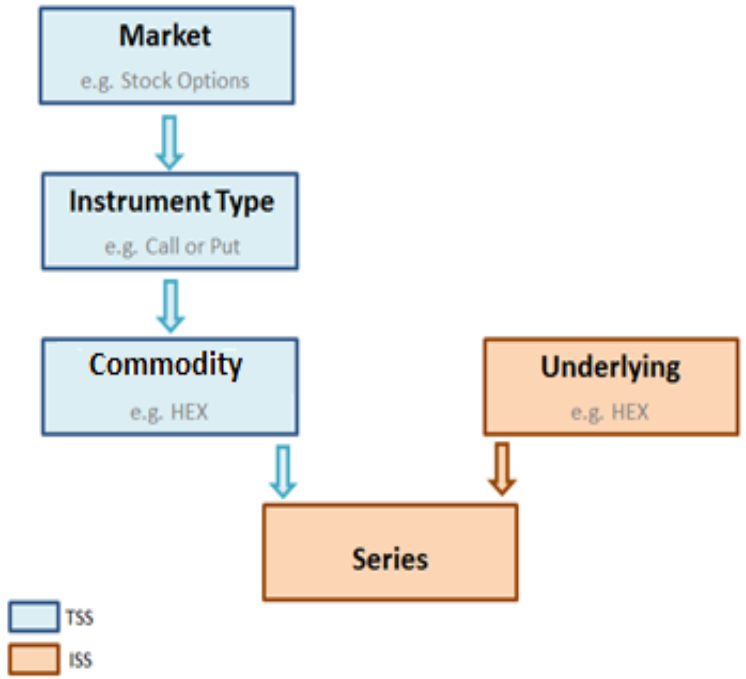
Use of Developers Guide (Market Status Update Arrangement)

- **OMD-D Market Status Key levels**
  - **Market** : TSS level (Statelevel = 1, 2, 3)
  - **InstrumentType** : TSS level (Statelevel = 2, 3)
  - **CommodityCode** : TSS / ISS level (Statelevel = 3, 5)
  - **OrderBookID** : ISS level (Statelevel = 4)

Offset	Field	Format	Len	Description	Values
0	MsgSize	Uint16	2	Size of the message	◄calculated
2	MsgType	Uint16	2	Type of message.	320 Market Status
4	StateLevel	Uint16	2	Indicates the level which a state applies to	1 Market 2 Instrument Type 3 Instrument Class 4 Instrument Series 5 Underlying 99 End of Business Day
6	Market	Uint8	1	Market Code Populated only if StateLevel = 1, 2 or 3	See section 8.4 for a list of possible values
7	Instrument	Uint8	1	Instrument Group Populated only if StateLevel = 2, 3	See section 8.3 for a list of possible values
8	OrderbookID	Uint32	4	Orderbook ID Populated only if StateLevel = 4	
12	CommodityCode	Uint16	2	Commodity Populated only if StateLevel = 3 or 5 eg. 2005 (HKB).	

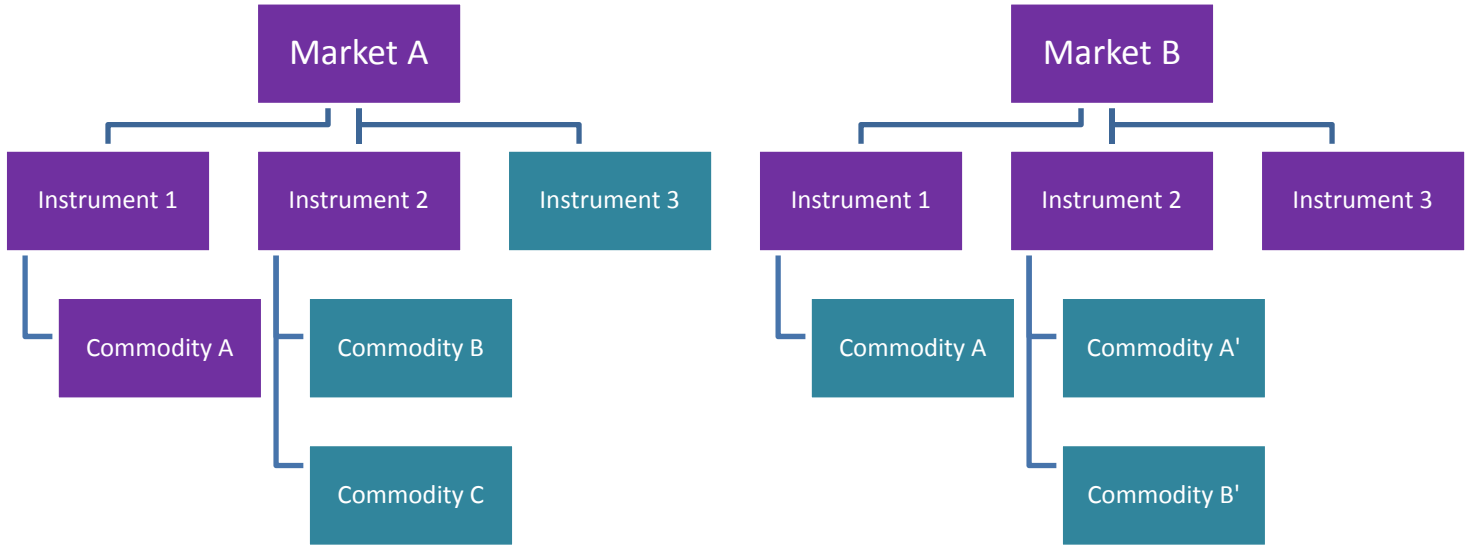
Use of Developers Guide
(Market Status Update Arrangement)

- **Active Instrument State (AIS)**
  - If the priority of ISS is higher than the priority of TSS, then AIS is the ISS, else the AIS is the TSS.
- **Trading Session State (TSS)**
  - All TSS are always declared at the start of business day. No new TSS for undeclared block is created during day time
- **Instrument Session State (ISS)**
  - ISS is not necessarily being sent on a business day



Use of Developers Guide (Market Status Update Arrangement)

- **Trading Session State (TSS)**
  - All TSS are always declared at the start of business day. No new TSS for undeclared block is created during day time
  - Purple blocks is the declared TSS at start of day
  - Green blocks inherit the TSS from upper level



Use of Developers Guide (Full Order Book Management)

- **For Every Trade in OMD-D, the behaviour is different from OMD-C.**
- **Quantity management on order is required in OMD-D**
  - Trade (350) message in OMD-D has implicit logic to remove orders in order book. **No** Modify Order (331) message is sent when order is partially traded. Also, **no** Delete Order (332) is sent when the order is fully traded.
  - Orders in market should be implicitly removed when quantity reached zero.
- **OrderBookPosition**
  - Add order : Insert Order at the specified position. All current orders at or below the position is implicitly shifted down
  - Delete Order : no OrderBookPosition is provided. All orders below the deleted order is implicitly shifted up
  - Modify Order : The Order is removed from the OrderbookID and re-position in the OrderBookID with new specified position. Modify order operation implies a delete and an add operation.

Use of Developers Guide (Partitions & Trade Amendment)

- **OMD-D follows the Partitions arrangement in HKATS. Separated partitions means the relevant markets will be sent in separated channels in OMD-D (i.e. Separated Multicast IP)**

Partition Number	Markets ID
1	1 – 20
2	21 - 255

Note: The above partitioning is subject to change by market operation development.

- **When there is a trade amendment in market,**
  - **Trade Ticker = all trades with the same Trade ID**
  - **OMD-D broadcasts the Trade Amendment (356) message for the cancellation of the Trade Ticker.**
  - **OMD-D broadcasts another Trade Amendment (356) message for rectification to declare the new volume of the Trade Ticker.**

Use of Developers Guide (Next day Series & Message Routing)

- For those next day tradable series, “EffectiveTomorrow” field is defined as ‘True’ in Series Definition Extended (304) message. **Please note that no OrderBookID is provided in Series Definition Extended (304) message for those next day tradable series**, and no calendar spread series is covered in next day tradable series declaration.
  - Please be aware if OrderBookID is used as the key for Msg304
- Below message types are routed to both SOM and non-SOM channels due to the nature of the message. Vendors may receive duplicated information if both SOM and non-SOM are consolidated to single output stream.

	Both channels	Remarks
Commodity Definition (301)	Yes	
Series Definition Base (303)	Yes	For combo series, both channel will receive the same information.
Market Status (320)	OMD-D message types	
Commodity Status (322)	Yes	
Market Alert (323)	Yes	
Estimated Average Settlement Price (365)	Yes	

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Multicast Channel Assignment

OMD Derivatives Standard (DS)

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Series Definition Reference Channel (Partition 1)	Series Definition Base (303) Combination Definition (305)	101	102	601	602
Derivatives Series Definition Reference Channel (Partition 2)	Series Definition Base (303) Combination Definition (305)	201	202	701	702
Derivatives Series Definition Reference Channel	Commodity Definition (301) Class Definition (302) Series Definition Extended (304)	151	152	651	652
Derivatives Series & Market Status Channel	Market Status (320) Series Status (321) Commodity Status (322)	161	162	661	662
Derivatives Quote Request Channel	Quote Request (336)	164	165	NIL	NIL
Derivatives Open Interest Channel	Open Interest (366)	191	192	691	692
Derivatives Level 2 Price and COP (Partition 1)	Calculated Opening Price (364) Aggregate Order Book Update (353)	134	135	634	635
Derivatives Level 2 Price and COP (Partition 2)	Calculated Opening Price (364) Aggregate Order Book Update (353)	234	235	734	735

Multicast Channel Assignment

OMD Derivatives Standard (DS) cont.

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Trade Statistic Channel	Trade Statistic (360)	171	172	671	672
Derivatives Trade Statistic Supplement Channel (Correction)	Trade Statistic (360)	181	182	681	682
Derivatives Market Alert Channel	Market Alert (323)	177	177	677	677
Derivatives EAS Channel	EAS Price (365)	199	199	699	699

Multicast Channel Assignment

OMD Derivatives Premium (DP)

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Series Definition Reference Channel (Partition 1)	Series Definition Base (303) Combination Definition (305)	101	102	601	602
Derivatives Series Definition Reference Channel (Partition 2)	Series Definition Base (303) Combination Definition (305)	201	202	701	702
Derivatives Series Definition Reference Channel	Commodity Definition (301) Class Definition (302) Series Definition Extended (304)	151	152	651	652
Derivatives Series & Market Status Channel	Market Status (320) Series Status (321) Commodity Status (322)	161	162	661	662
Derivatives Quote Request Channel	Quote Request (336)	164	165	NIL	NIL
Derivatives Open Interest Channel	Open Interest (366)	191	192	691	692
Derivatives Level 2 Price and COP (Partition 1)	Calculated Opening Price (364) Aggregate Order Book Update (353) Trade (350)	131	132	631	632

Multicast Channel Assignment

OMD Derivatives Premium (DP) cont.

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Level 2 Price and COP (Partition 2)	Calculated Opening Price (364) Aggregate Order Book Update (353) Trade (350)	231	232	731	732
Derivatives Trade Adjustment Channel	Trade Amendment (356) Trade (350)	167	168	Nil	Nil
Derivatives Series Statistic Channel	Series Statistics (363)	174	175	674	675
Derivatives Series Statistic Supplement Channel (Correction)	Series Statistics (363)	184	185	684	685
Derivatives Market Alert Channel	Market Alert (323)	177	177	677	677
Derivatives EAS Channel	EAS Price (365)	199	199	699	699
Derivatives Implied Volatility	Implied Volatility (367)	194	195	694	695

Multicast Channel Assignment

- **OMD Derivatives FullTick (DF)**

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Series Definition Reference Channel (Partition 1)	Series Definition Base (303) Combination Definition (305)	101	102	601	602
Derivatives Series Definition Reference Channel (Partition 2)	Series Definition Base (303) Combination Definition (305)	201	202	701	702
Derivatives Series Definition Reference Channel	Commodity Definition (301) Class Definition (302) Series Definition Extended (304)	151	152	651	652
Derivatives Series & Market Status Channel	Market Status (320) Series Status (321) Commodity Status (322)	161	162	661	662
Derivatives Quote Request Channel	Quote Request (336)	164	165	NIL	NIL
Derivatives Order, COP and Trade (Partition 1)	Calculated Opening Price (364) Add Order (330) Modify Order (331) Delete Order (332) Orderbook Clear (335) Trade (350)	121	122	621	622

Multicast Channel Assignment

- **OMD Derivatives FullTick (DF) cont.**

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Order, COP and Trade (Partition 2)	Calculated Opening Price (364) Add Order (330) Modify Order (331) Delete Order (332) Orderbook Clear (335) Trade (350)	221	222	721	722
Derivatives Trade Adjustment Channel	Trade Amendment (356) Trade (350)	167	168	Nil	Nil
Derivatives Market Alert Channel	Market Alert (323)	177	177	677	677

Multicast Channel Assignment

- **OMD Trade Tick (DT)**

Multicast Service	Contents	Real-time Service Channel ID		Refresh Service Channel ID	
		Non-SOM	SOM	Non-SOM	SOM
Derivatives Trade Channel (Partition 1)	Trade (350)	111	112	Nil	Nil
Derivatives Trade Channel (Partition 2)	Trade (350)	211	212	Nil	Nil
Derivatives Trade Adjustment Channel	Trade Amendment (356) Trade (350)	167	168	Nil	Nil

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4. **Control Message**
5. Recovery Mechanism
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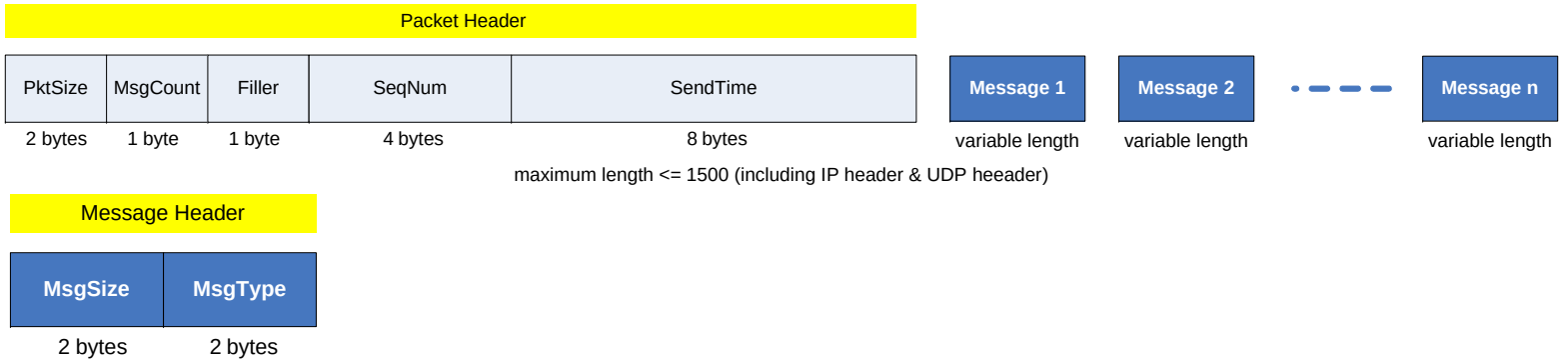
Control Message

- **Multicast packet structured into a Packet Header followed by 0 or more messages, each starts with a 4-byte Message Header**



  - **Same packet structure applied to unicast messages**

- **There are 2 kinds of messages in OMD**
  - **Control message**
    - ***Heartbeat*, *Sequence Reset (100)*, *Refresh Complete (203)*, *Logon (101) & Logon Response (102)*, *Retransmission Request (201) & Retransmission Response (202)***
  - **Market Data message**

Control Message

- **Heartbeat**
  - **Unique message in a packet with MsgCount 0**

Field	Value
PktSize	16
MsgCount	0
Filler	
SeqNum	Sequence number of previous message
SendTime	Send time of the heartbeat

  - **Heartbeat frequency**
    - **Multicast – 2 seconds**
    - **Unicast**
      - **30 seconds**
      - **Need response in 5 seconds otherwise TCP/IP session will be terminated**
      - **Heartbeat response from clients is an exact copy of the incoming heartbeat**

Control Message

- **Sequence Reset (100)**

MsgSize = 8	MsgType = 100	NewSeqNo = 1
2 bytes	2 bytes	4 bytes

  - **Per channel in real-time & refresh**
  - **Once at Start of Day, multiple for resend of Reference data under very rare condition – this apply to real-time channel only**
  - **Possible sent following OMD failure recovery**
  - **Set next expected sequence number to 1**
  - **Processing highlights to be covered in next topic**

Control Message

- **Refresh Complete (203)**

MsgSize = 8	MsgType = 203	LastSeqNum
2 bytes	2 bytes	4 bytes

  - As a marker between successive full refresh snapshots
  - Clients cache real-time data before full refresh snapshots received
  - Process real-time data with sequence number greater than LastSeqNum and discard the rest

- **Logon (101) & Logon Response (102)**

Logon (101)

MsgSize = 16	MsgType = 101	Username
2 bytes	2 bytes	12 bytes

Logon Response (102)

MsgSize = 8	MsgType = 102	SessionStatus	Filler
2 bytes	2 bytes	1 byte	3 bytes

  - Authenticate Username & client IP
  - Reject logon for duplicated logon, invalid username or client IP
  - *Logon* / *Logon Response* timeout – 5 seconds

Control Message

- **Retransmission Request (201) & Retransmission Response (202)**

Retransmission Request (201)

MsgSize = 16	MsgType = 201	ChannelID	Filler	BeginSeqNum	EndSeqNum
2 bytes	2 bytes	2 bytes	2 bytes	4 bytes	4 bytes

Retransmission Response (202)

MsgSize = 16	MsgType = 202	ChannelID	RetransStatus	Filler	BeginSeqNum	EndSeqNum
2 bytes	2 bytes	2 bytes	1 byte	1 byte	4 bytes	4 bytes

- **Requested messages will be sent after successful *Retransmission Response***
- **SeqNum in packet header carries no meaning, simply ignore it**
- **BeginSeqNum & EndSeqNum in *Retransmission Response* copied from *Retransmission Request*, carry no meaning & can be ignored**

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Recovery Mechanism

- UDP protocol is unreliable & exposed to risk of packet loss
- Infrastructure-wise SDNet/2 offers extremely low packet loss rate ➔ compensate UDP shortfall
- Clients may still experience, though some are rare:
  - Late connection
  - Client application restarts
  - OMD restart or node/site failover
- To address the above OMD implements below different recovery mechanisms:
  - Line Arbitration
  - Retransmission Service
  - Refresh Service

Recovery Mechanism – Line Arbitration

- **Data broadcast in different sets of dual multicast channels via primary line (Line A) & secondary line (Line B)**
- **Content comparison for Line A & Line B**

Identical	(Possible) Difference
Sequence number (SN)	Number of message in a packet (MsgCount)
Messages that are sent	SN of 1st message in the packet (SeqNum)
Sequence of the message sent	

- **Contents of Line A & Line B can be**

Line A		
Message	**MsgCount**	**SeqNum**
Add Order 1 Add Order 2 Modify Order 1	3	101
Trade 1 Delete Order 1	2	104
Trade 2 Statistics 1	2	106

Line B		
Message	**MsgCount**	**SeqNum**
Add Order 1 Add Order 2	2	101
Modify Order 1 Trade 1 Delete Order 1	3	103
Trade 2 Statistics 1	2	106

Recovery Mechanism – Line Arbitration

- Listen to both Line A & Line B, set same priority for both lines
- Whenever a gap is detected in Line A or Line B, either
  - Wait some finite time, issue retransmission request if gap cannot be filled from same line (due to out of order) or alternate line
  - Issue retransmission request directly
- Gap detection mechanism may work as follows
  - Set next expected sequence number (NSN) to s+1, assuming
    - Sequence number (SN) of last message in $(n-1)^{th}$ packet = s
    - No gap detected in (n-1) packets
  - For each message in n^{th} packet compare message SN with NSN
    - If SN = NSN, process message, advance SN & NSN by 1
    - Duplicate message if SN < NSN ➔ discard message
    - Gap detected if SN > NSN

Recovery Mechanism – Retransmission Service

- Recover small number of message gap (real-time feed only)
- Primary/secondary retransmission server (RTS) for resilience
- Clients can establish connection to RTS when their system starts up or when retransmission is needed
- Check heartbeat to detect connection drop, reconnect to same RTS or switch to secondary RTS
- Missing messages sent in packets not exceeding 1,500 bytes
- Several limits to take note

System Limit	Value
Available number of messages per channel ID	~15 sec
Maximum sequence range for request per channel ID	10,000
Daily maximum of requests (counting all channel IDs)	1,000

Recovery Mechanism – Retransmission Service

- Cache real-time data & process after gap filled
- Multiple gaps may occur in same channel while a gap awaiting filled or occur in different channels
  - Keep a list of gaps to be filled
  - Process distinct retransmission request/response with RTS to fill gap one by one
  - RTS accepts multiple concurrent requests from same client
    - FIFO
    - May interleave with requests from other clients
    - ***Clients should send new request to RTS only after previous gap is filled***
- Use refresh service if gap size exceeds available number of messages in the channel

Recovery Mechanism – Refresh Service

- **Allow clients to late connect to OMD or recover from significant packet loss**
- **Publish latest market states periodically in for the followings:**
  - **Latest images of all reference data definition**
  - **Latest snapshots for each series and market static**
    - **Series & Market status**
    - **Open Interest, Implied Volatility and EAS**
    - **Trade and series statistics**
    - **All price levels (10 + 1 BBO[1]) in Aggregated Order Book**
    - **Market Alerts (last 400 messages)**
    - **Outstanding orders in full books**

Note 1: 10BBO for DS and 10+1BBO for DP.

Recovery Mechanism – Refresh Service

- **Refresh processing may work as follows**
  - **Clear all cached market data before processing refresh data**
  - **Cache real-time data to be processed after refresh complete**
  - **First build series and market static images from refresh channels for reference data before listen to other channels**
  - **Line Arbitration for real-time data applies to refresh data except**
    - **No retransmission service**
    - **No need to check any message gap before first arrived packet**
  - **Any gap cannot be filled from same/alternate line ➔ discard the cached data & wait for next 'full' refresh snapshot**

AGENDA – Part 2

1. Overview of OMD
2. Use of Developers Guide
3. Channel Assignment
4. Control Message
5. Recovery Mechanism
6. **OMD Failure Recovery**
7. Market Data Message
8. Highlights on Aggregate Order Book Management

OMD Failure Recovery

- OMD builds different levels of resilience to address the followings:
  - SDNet/2 client line failure – dual client lines
  - SDNet/2 host line failure – multiple host lines
  - OMD node failure – dual nodes for node restart/failover
  - OMD site failure – primary & DR sites for site failover
- Apply below recovery mechanisms for SDNet/2 client/host line failure or OMD node restart
  - Line Arbitration
  - Retransmission Service
  - Refresh Service

OMD Failure Recovery

- **Clients may receive *Sequence Reset* messages when OMD node restarts or fails over to DR site**
  - **Sequence reset processing may work as follows:**
    - **Receive *Sequence Reset* message from any multicast channel, ignore subsequent *Sequence Reset* messages from other channels**
    - **Reset next expected sequence number to 1 for all channels**
    - **Clear all cached data for all instruments**
    - **Subscribe to refresh channels for latest market states**
    - **Resume to process real-time messages**

AGENDA – Part 2

1. Overview of OMD
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4. Control Message
5. Recovery Mechanism
6. OMD Failure Recovery
7. **Market Data Message**
8. Highlights on Aggregate Order Book Management

Market Data Message

Message Overview

Reference Data
Commodity Definition (301)
Class Definition (302)
Series Definition Base (303)
Series Definition Extended (304)
Combination Definition (305)

Order Book Data
Add Order (330)
Modify Order (331)
Delete Order (332)
Orderbook Clear (335)
Aggregate Order Book Update (353)

Value Added Data
Open Interest (366)
Quote Request (336)
Implied Volatility (367)
EAS Price (365)

Status Data
Market Status (320)
Series Status (321)
Commodity Status (322)

Trade and Price Data
Trade (350)
Calculated Opening Price (364)
Trade Amendment (356)
Trade Statistics (360)
Series Statistics (363)

News
Market Alert (323)

AGENDA – Part 2

1. Overview of OMD
2. Use of Developers Guide
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6. OMD Failure Recovery
7. Market Data Message
8. **Highlights on Aggregate Order Book Management**

Highlights on Aggregate Order Book Management

- **Tick Level vs Price Level**

Tick Level (OMD-C)	Price Level (OMD-D)
Defined as how many spreads from the best bid/ask price	**Assigned to each price existing in the OMD order book**
A tick level of 10 means the order price is 9 spreads from the best price	**A price level of 10 means the order price is the 10th best prices in the order book**
Used in OMD-C	**Widely used in other Exchanges**
OMD-C sends tick level	**OMD-D sends price level in message (353)**
Empty tick level is possible	**No empty price level**

Highlights on Aggregate Order Book Management

- **Illustration of different techniques used for processing *Aggregate Order Book Update*, take DP as reference**

  - **At time T we have the following OMDD book image**

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	250	9.730	9.800	700	1
2	50	9.720	9.810	350	2
3	700	9.710	9.820	150	3
4	350	9.700	9.840	250	4
5	150	9.690	9.850	100	5
6	250	9.680	9.870	400	6
7	100	9.670	9.880	200	7
8	150	9.660	9.890	300	8
9	50	9.650			
10	150	9.640			
255	100	NIL			

The 11th level is only applicable to DP

  - **At time T+1 we have the following sequence events:**
    - **(1) An aggressing ask order @ 9.730 completely matched resting bid order @ price level 1;**
    - **(2) A modify order to reduce resting order quantity @ price level 3 from 700 to 300;**
    - **(3) New ask orders at 3 different prices (9.740, 9.750 & 9.760) arrived**

Highlights on Aggregate Order Book Management

➢ **OMD sends the following Aggregate Order Book Update message**

Offset	Field Name	Value
0	MsgSize	201
2	MsgType	353
4	OrderBookID	1234
8	Filler	NULL
11	NoEntries	8
12	AggregateQuantity	250
20	Price	9.730
24	NumberOfOrders	1
28	Side	0 (Bid)
30	PriceLevel	1
31	UpdateAction	2
32	Filler	NULL
36	AggregateQuantity	300
44	Price	9.710
48	NumberOfOrders	1
52	Side	0 (Bid)
54	PriceLevel	2
55	UpdateAction	1
56	Filler	NULL
60	AggregateQuantity	10
68	Price	9.630
72	NumberOfOrders	1
76	Side	0 (Bid)
78	PriceLevel	10
79	UpdateAction	0
80	Filler	NULL
84	AggregateQuantity	90
92	Price	NULL
96	NumberOfOrders	5
100	Side	0 (Bid)
102	PriceLevel	255
103	UpdateAction	1
104	Filler	NULL
108	AggregateQuantity	450
116	Price	9.740
120	NumberOfOrders	1
124	Side	1 (Offer)
126	PriceLevel	1
127	UpdateAction	0
128	Filler	NULL
132	AggregateQuantity	550
140	Price	9.750
144	NumberOfOrders	1
148	Side	1 (Offer)
150	PriceLevel	2
151	UpdateAction	0
152	Filler	NULL
156	AggregateQuantity	650
164	Price	9.760
168	NumberOfOrders	1
172	Side	1 (Offer)
174	PriceLevel	3
175	UpdateAction	0
176	Filler	NULL
180	AggregateQuantity	300
188	Price	NIL
192	NumberOfOrders	1
196	Side	1 (Offer)
198	PriceLevel	255
199	UpdateAction	1
200	Filler	NULL

** Please note that all the update Actions are not necessarily contain in one 353 message.

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1			9.800	700	1
2	50	9.720	9.810	350	2
3	700	9.710	9.820	150	3
4	350	9.700	9.840	250	4
5	150	9.690	9.850	100	5
6	250	9.680	9.870	400	6
7	100	9.670	9.880	200	7
8	150	9.660	9.890	300	8
9	50	9.650			
10	150	9.640			
255	100	NIL			

12	AggregateQuantity	250
20	Price	9.730
24	NumberOfOrders	1
28	Side	0 (Bid)
30	PriceLevel	1
31	UpdateAction	2
32	Filler	NULL

1st aggregate book order update entry

Explicit Deletion

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	700	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
255	100	NIL			

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1			9.800	700	1
2	50	9.720	9.810	350	2
3	700	9.710	9.820	150	3
4	350	9.700	9.840	250	4
5	150	9.690	9.850	100	5
6	250	9.680	9.870	400	6
7	100	9.670	9.880	200	7
8	150	9.660	9.890	300	8
9	50	9.650			
10	150	9.640			
255	100	NIL			

12	AggregateQuantity	250
20	Price	9.730
24	NumberOfOrders	1
28	Side	0 (Bid)
30	PriceLevel	1
31	UpdateAction	2
32	Filler	NULL

1st aggregate book order update entry

Explicit Deletion

Implicit Level Adjustment
Change Price Levels
from 2 – 10 to 1 – 9 (by clients)

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	700	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
255	100	NIL			

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	700	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
255	100	NIL			

Order Reduction

2nd aggregate book order update entry

36	AggregateQuantity	300
44	Price	9.710
48	NumberOfOrders	1
52	Side	0 (Bid)
54	PriceLevel	2
55	UpdateAction	1
56	Filler	NULL

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	300	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
255	100	NIL			

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	700	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
255	100	NIL			

3rd aggregate book order update entries

60	AggregateQuantity	10
68	Price	9.630
72	NumberOfOrders	1
76	Side	0 (Bid)
78	PriceLevel	10
79	UpdateAction	0
80	Filler	NULL

Price level Added

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	300	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
10	10	9.630			
255	100	NIL			

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	700	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
10	10	9.630			
255	90	NIL			

4th aggregate book order update entries

84	AggregateQuantity	90
92	Price	NULL
96	NumberOfOrders	5
100	Side	0 (Bid)
102	PriceLevel	255
103	UpdateAction	1
104	Filler	NULL

Price Level 11 update on Qty & Number of Orders

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	300	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
10	10	9.630			
255	90	NIL			

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.800	700	1
2	300	9.710	9.810	350	2
3	350	9.700	9.820	150	3
4	150	9.690	9.840	250	4
5	250	9.680	9.850	100	5
6	100	9.670	9.870	400	6
7	150	9.660	9.880	200	7
8	50	9.650	9.890	300	8
9	150	9.640			
10	10	9.630			
11	90	NIL			

Explicit Additions

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	**9.740**	**450**	**1**
2	300	9.710	9.800	700	**2**
3	350	9.700	9.810	350	**3**
4	150	9.690	9.820	150	4
5	250	9.680	9.840	250	5
6	100	9.670	9.850	100	6
7	150	9.660	9.870	400	7
8	50	9.650	9.880	200	8
9	150	9.640	9.890	300	**9**
10	10	9.630			
11	90	NIL			

5th aggregate book order update entries

108	AggregateQuantity	450
116	Price	9.740
120	NumberOfOrders	1
124	Side	1 (Offer)
126	PriceLevel	1
127	UpdateAction	0
128	Filler	NULL

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.740	450	1
2	300	9.710	9.800	700	2
3	350	9.700	9.810	350	3
4	150	9.690	9.820	150	4
5	250	9.680	9.840	250	5
6	100	9.670	9.850	100	6
7	150	9.660	9.870	400	7
8	50	9.650	9.880	200	8
9	150	9.640	9.890	300	9
10	10	9.630			
11	90	NIL			

6th aggregate book order update entries

Explicit Additions

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.740	450	1
2	300	9.710	9.750	550	2
3	350	9.700	9.800	700	3
4	150	9.690	9.810	350	4
5	250	9.680	9.820	150	5
6	100	9.670	9.840	250	6
7	150	9.660	9.850	100	7
8	50	9.650	9.870	400	8
9	150	9.640	9.880	200	9
10	10	9.630	9.890	300	10
11	90	NIL			

132	AggregateQuantity	550
140	Price	9.750
144	NumberOfOrders	1
148	Side	1 (Offer)
150	PriceLevel	2
151	UpdateAction	0
152	Filler	NULL

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.740	450	1
2	300	9.710	9.750	550	2
3	350	9.700	9.800	700	3
4	150	9.690	9.810	350	4
5	250	9.680	9.820	150	5
6	100	9.670	9.840	250	6
7	150	9.660	9.850	100	7
8	50	9.650	9.870	400	8
9	150	9.640	9.880	200	9
10	10	9.630	9.890	300	10
11	90	NIL			

7th aggregate book order update entries

Explicit Additions

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.740	450	1
2	300	9.710	9.750	550	2
3	350	9.700	9.760	650	3
4	150	9.690	9.800	700	4
5	250	9.680	9.810	350	5
6	100	9.670	9.820	150	6
7	150	9.660	9.840	250	7
8	50	9.650	9.850	100	8
9	150	9.640	9.870	400	9
10	10	9.630	9.880	200	10
11	90	NIL	9.890	300	11

Implicit Deletion

156	AggregateQuantity	650
164	Price	9.760
168	NumberOfOrders	1
172	Side	1 (Offer)
174	PriceLevel	3
175	UpdateAction	0
176	Filler	NULL

Highlights on Aggregate Order Book Management

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.740	450	1
2	300	9.710	9.750	550	2
3	350	9.700	9.760	650	3
4	150	9.690	9.800	700	4
5	250	9.680	9.810	350	5
6	100	9.670	9.820	150	6
7	150	9.660	9.840	250	7
8	50	9.650	9.850	100	8
9	150	9.640	9.870	400	9
10	10	9.630	9.880	200	10
11	90	NIL			

Bid Side			Ask Side		
PriceLevel	AggregateQuantity	Price	Price	AggregateQuantity	PriceLevel
1	50	9.720	9.740	450	1
2	300	9.710	9.750	550	2
3	350	9.700	9.760	650	3
4	150	9.690	9.800	700	4
5	250	9.680	9.810	350	5
6	100	9.670	9.820	150	6
7	150	9.660	9.840	250	7
8	50	9.650	9.850	100	8
9	150	9.640	9.870	400	9
10	10	9.630	9.880	200	10
11	90	NIL	NIL	300	255

Add new on 11th level

8th aggregate book order update entries

180	AggregateQuantity	300
188	Price	NIL
192	NumberOfOrders	1
196	Side	1 (Offer)
198	PriceLevel	255
199	UpdateAction	0
200	Filler	NULL

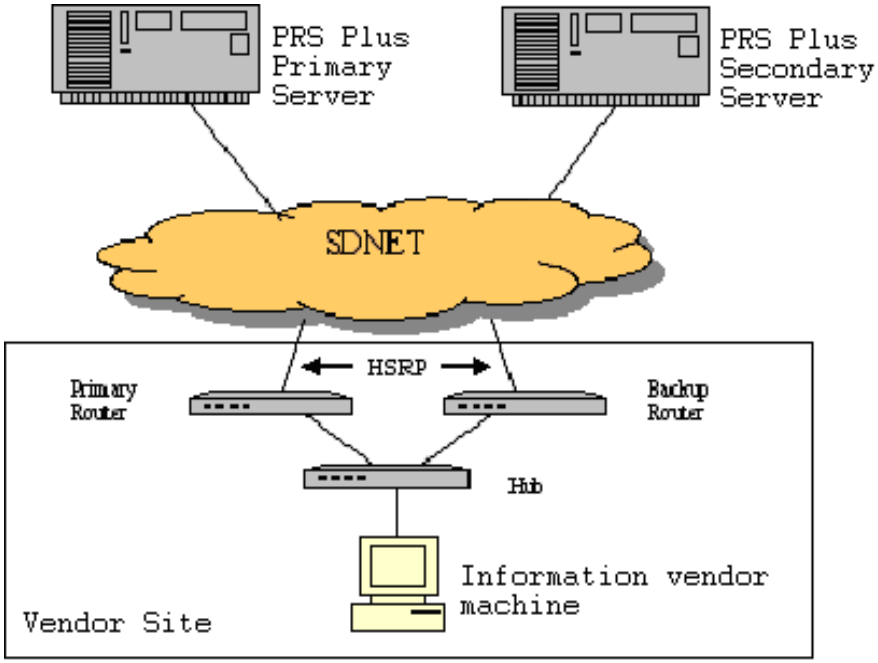
Highlights on Aggregate Order Book Management

- **Strictly follow the sequence in the book entry list of the *Aggregate Order Book Update (353)* to apply changes to 10BBO**
- **Apply implicit level adjustment to PriceLevels following addition/deletion of aggregate order book entry**
- **OMD sends explicit deletion/addition for book entries within 10 PriceLevel**
- **Clients perform implicit deletion for book entries beyond 10 PriceLevel**
- **Techniques used in aggregate order book management:**
  - **Explicit Deletion/Addition**
  - **Quantity Reduction**
  - **Implicit Deletion**
  - **Implicit Level Adjustment**

AGENDA – Part 3

1. Existing PRS Network
2. Network for OMD

Existing PRS Network



Existing PRS Network

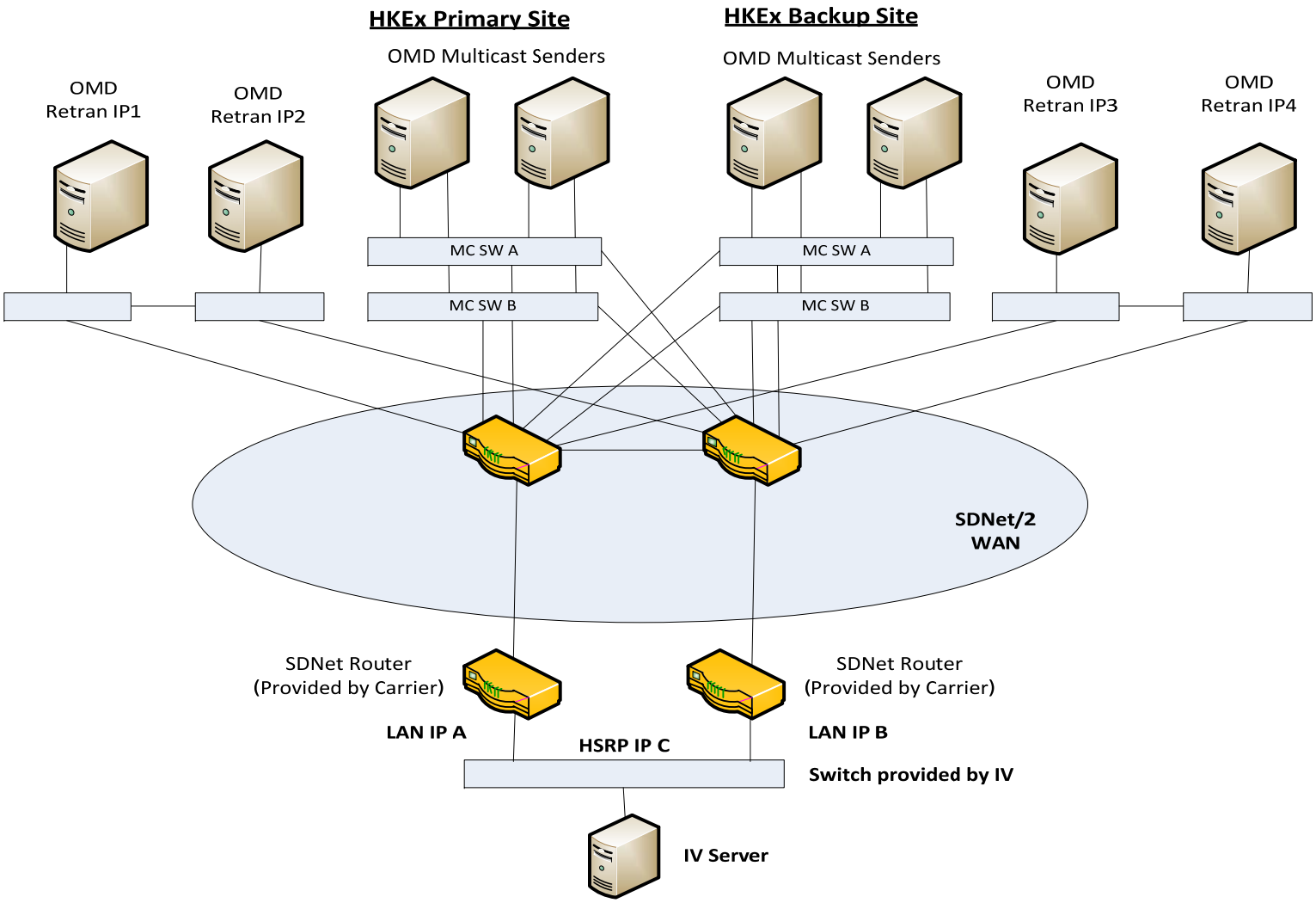
- Two separate networks for two links
- Unicast only
- No network failover mechanism built-in, application need to detect TCP session disconnection and call to another host IP.

AGENDA – Part 3

1 Existing MDS Network

2 **Network for OMD**

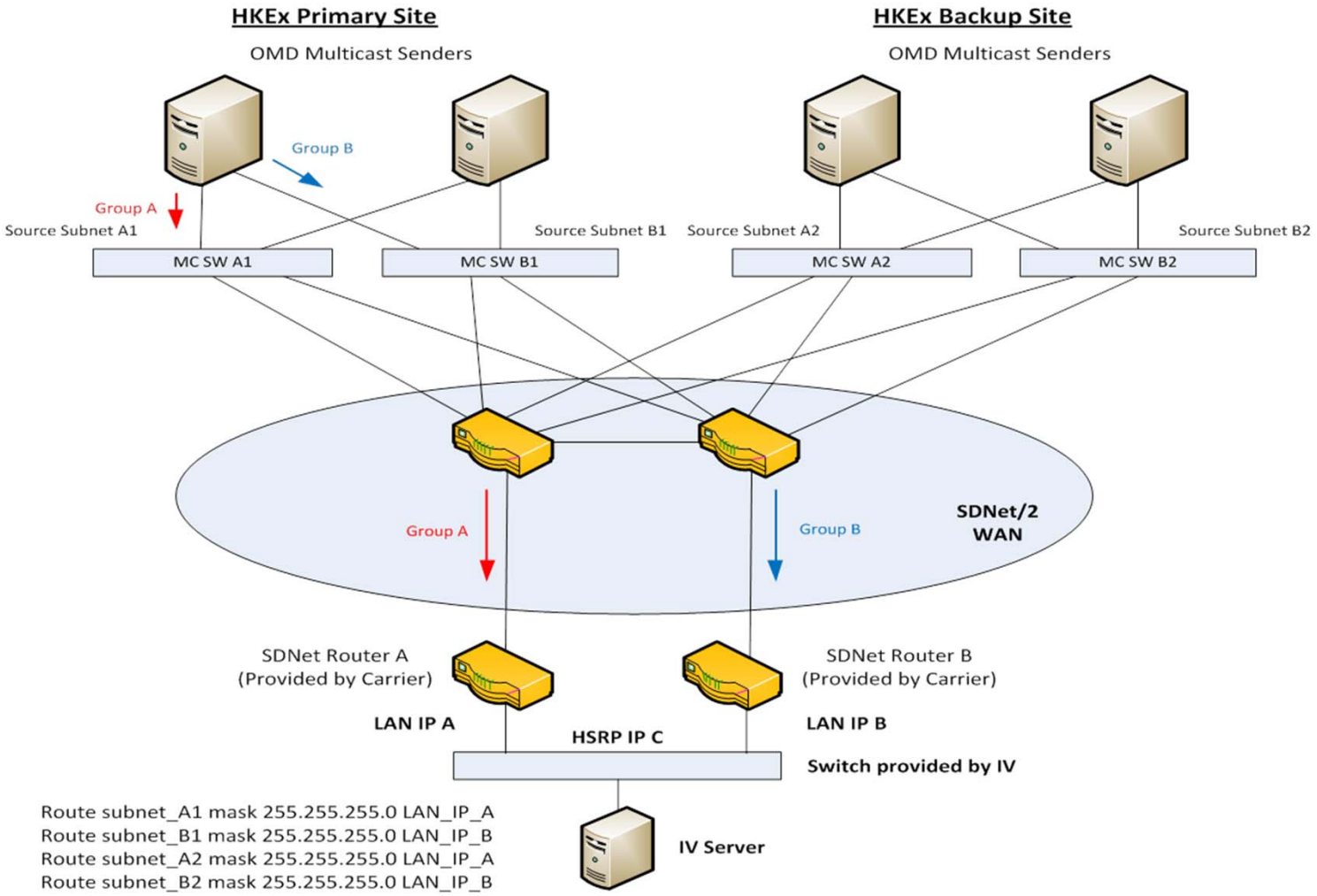
Network for OMD



Network for OMD

- Support both Unicast and Multicast Traffic
- Separate bandwidth for Multicast and Unicast Traffic
- With network failover mechanism built-in
- Two circuits are required to install in a single site
- New subnet for OMD at IV end will be provided

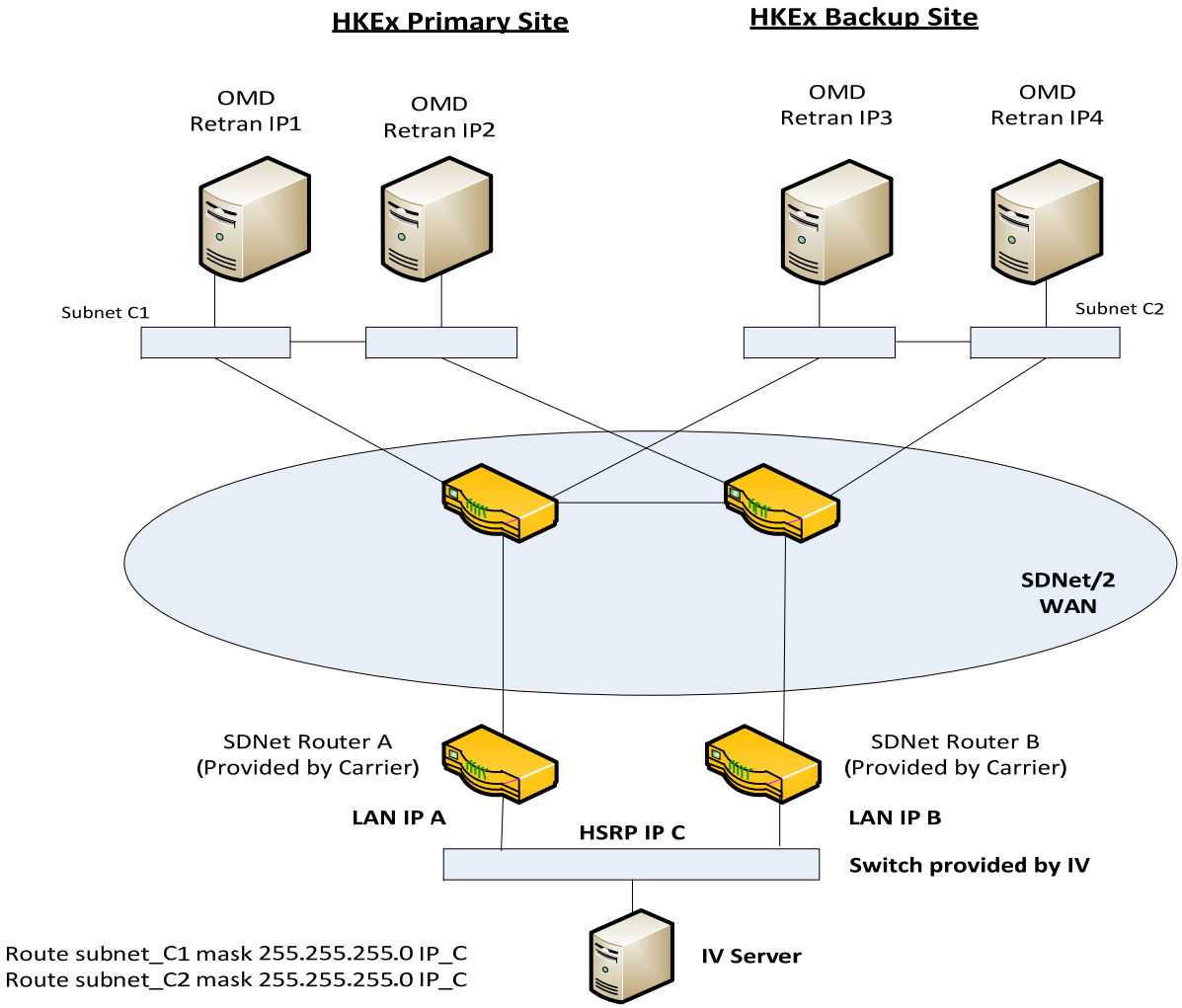
Network for OMD - Multicast



Network for OMD – Multicast

- Multicast Traffic is sent in pair of multicast group IPs (A & B)
  - Eg. (239.0.1.1 and 239.0.127.1)
  - A&B carries same information with different destination address (group address)
- Different paths for two multicast streams:
  - A: via router A; B: via router B
- IV applications need to join both A&B multicast groups with IGMP version 2
- IV applications will receive both A&B multicast traffic under normal condition. If one router or one link fails, there will be only one (either A or B) will be received
- Multicast will check reverse path, therefore, IV servers need to add route for the IP multicast sources

Network for OMD - Unicast



Network for OMD – SDNet/2

- **To support OMD, SDNet/2 comes with a High Performance Option, where the circuits can support high data throughput for bandwidth >= 30Mbps**

Bandwidth	PCCW (<= HKD)	HGC (<= HKD)	WTT (<= HKD)
30M	10,560	N/A	6,410
40M	12,540	N/A	7,310
50M	14,520	N/A	8,210
60M	16,350	N/A	8,440
70M	18,150	N/A	8,970
80M	19,950	N/A	9,500
90M	21,900	N/A	10,030
100M	23,700	N/A	10,560
1G	63,300	N/A	15,560

OMD Derivatives Market

Technical Briefing

Q&A

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THANK YOU