US010007566B1

(12) **United States Patent**
Sweetland

(10) **Patent No.: US 10,007,566 B1**
(45) **Date of Patent: Jun. 26, 2018**

(54) MESSAGE ORDERING AND IDEMPOTENCY ENFORCEMENT PROCESS

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days. days.

(21) Appl. No.: **14/625,679**

(22) Filed: **Feb. 19, 2015**

(51) **Int. Cl.**

G06F 3/00	(2006.01)
G06F 9/44	(2018.01)
G06F 9/46	(2006.01)
G06F 13/00	(2006.01)
G06F 9/54	(2006.01)

(52) **U.S. Cl.**
CPC ***G06F 9/546*** (2013.01); ***G06F 9/544*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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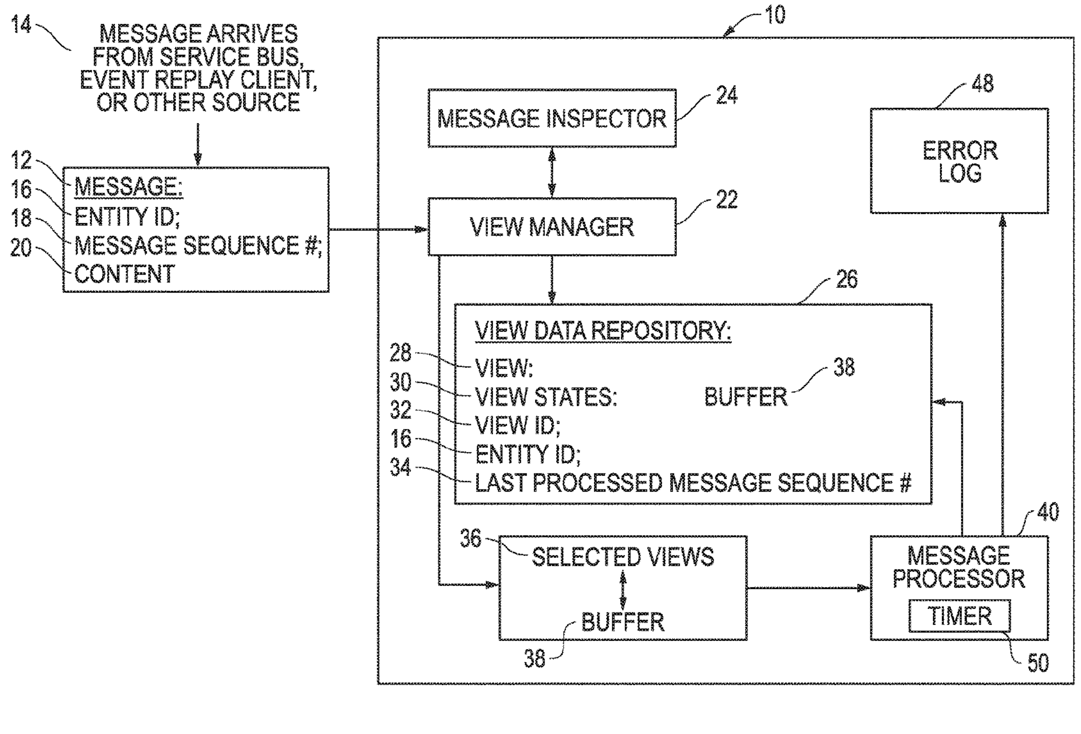
(57) **ABSTRACT**

A message ordering and idempotency enforcement process utilizing at least one computing device ensures the ordered processing of asynchronously received messages and avoids reprocessing of messages that have already been successfully processed, the process receives a message identified by entity ID, message sequence number and content. The process identifies the message according to the entity ID, message sequence number and content and selects selected views of data from a view data repository applicable to the message and then inserts the message in a buffer according to message sequence number for execution of messages in message sequence order. The process then recording the last message processed according to message sequence number for an entity ID within each selected view in the view data repository.

20 Claims, 7 Drawing Sheets



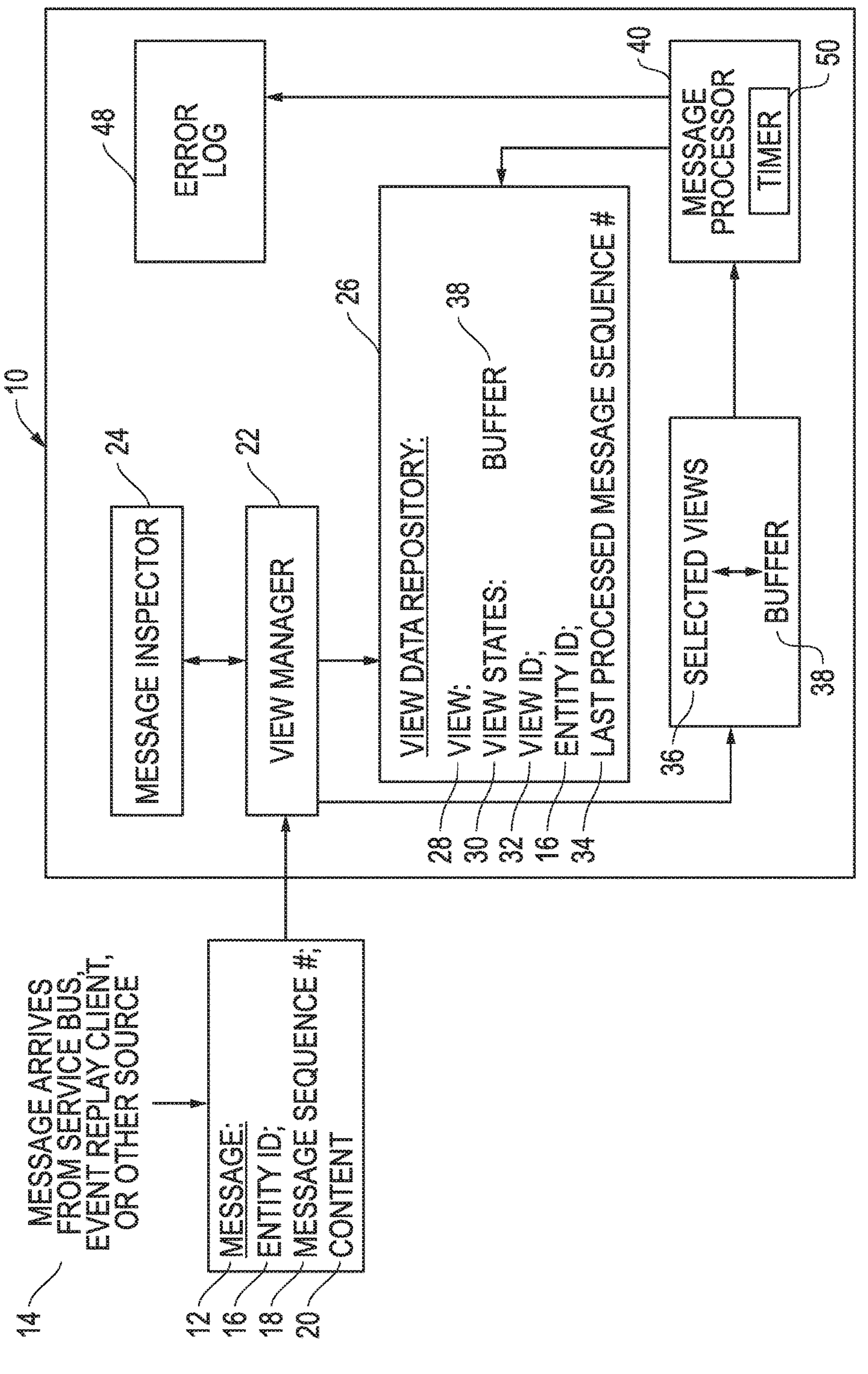

14
MESSAGE ARRIVES FROM SERVICE BUS, EVENT REPLAY CLIENT, OR OTHER SOURCE
12
MESSAGE:
16
ENTITY ID;
18
MESSAGE SEQUENCE #;
20
CONTENT
10
24
MESSAGE INSPECTOR
22
VIEW MANAGER
26
VIEW DATA REPOSITORY:
28
VIEW:
30
VIEW STATES:
32
VIEW ID;
16
ENTITY ID;
34
LAST PROCESSED MESSAGE SEQUENCE #
38
BUFFER
36
SELECTED VIEWS
38
BUFFER
40
MESSAGE PROCESSOR
50
TIMER
48
ERROR LOG

FIG. 1

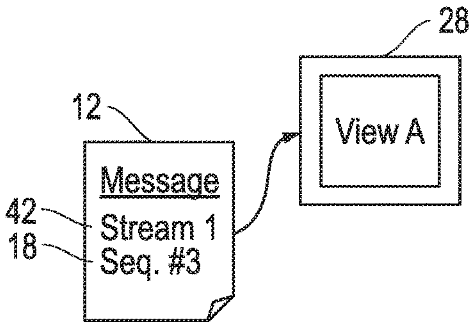


FIG. 2

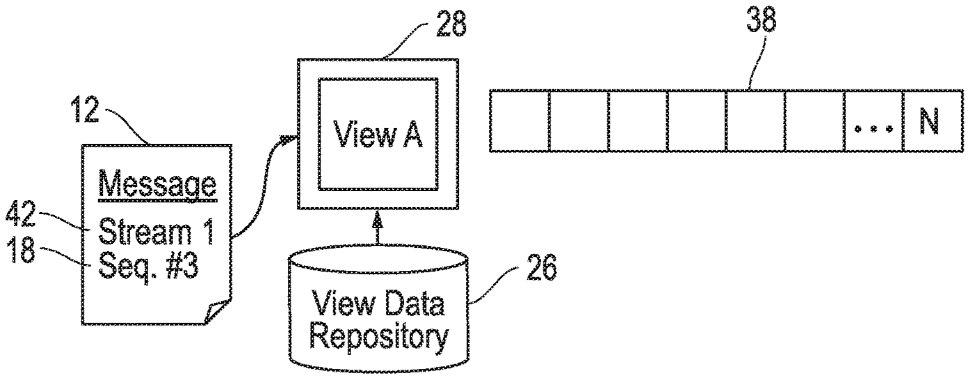


FIG. 3

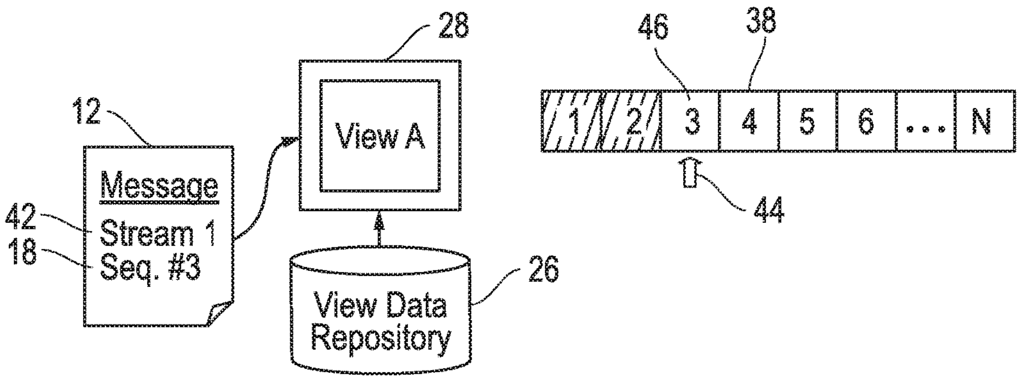


FIG. 4

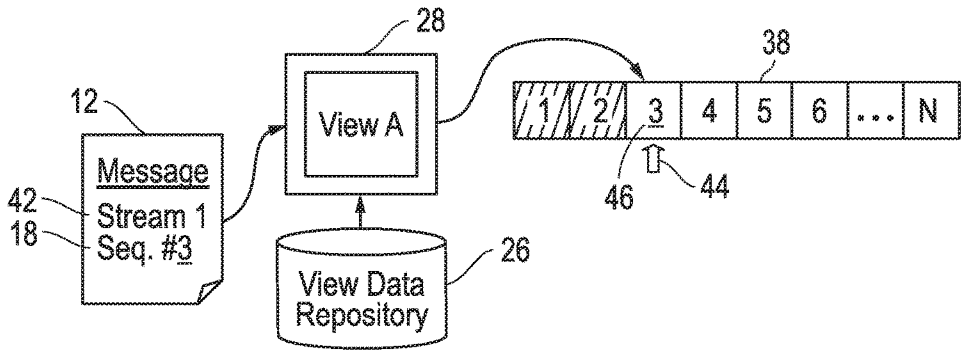


FIG. 5

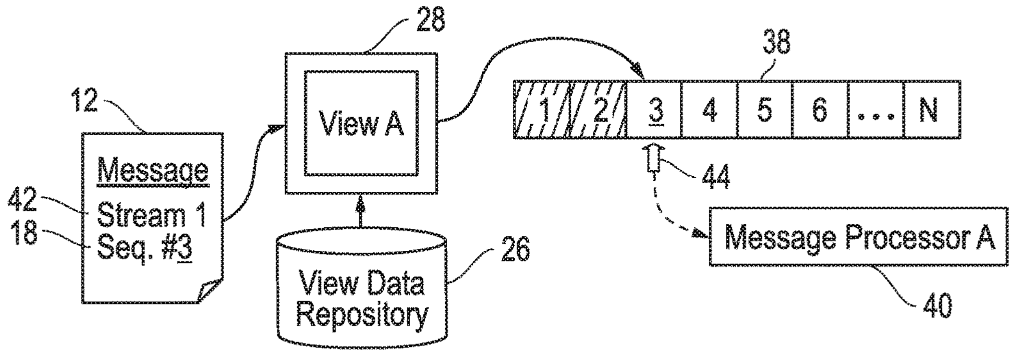


FIG. 6

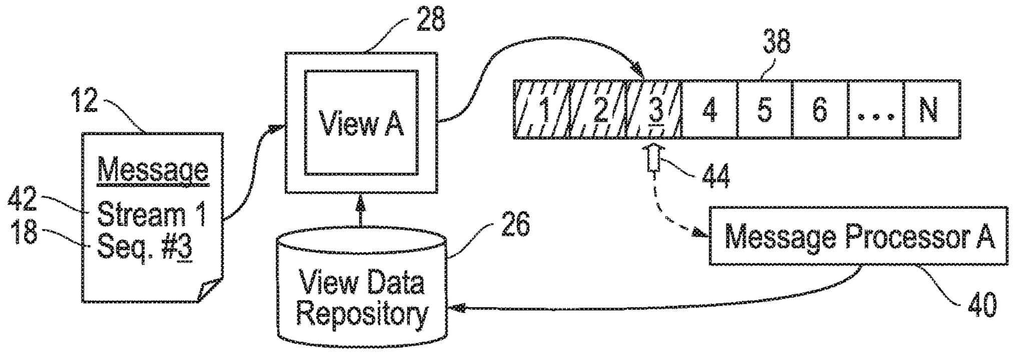


FIG. 7

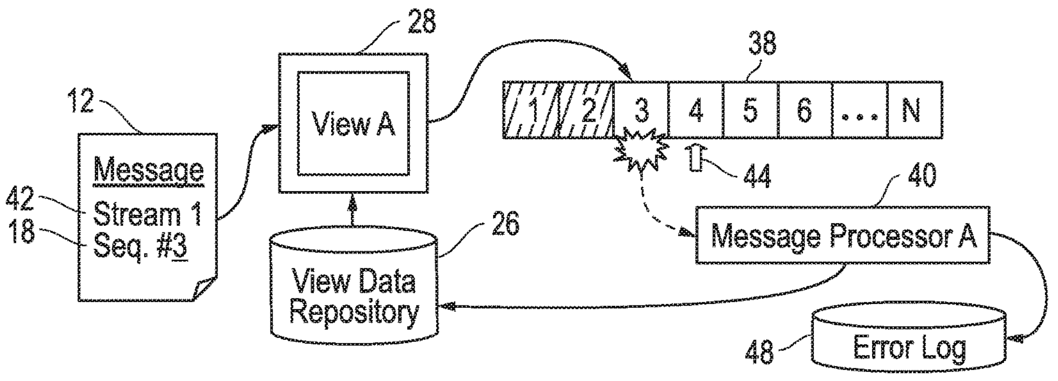

12
Message
Stream 1
Seq. #3
42
18
28
View A
26
View Data Repository
38
1
2
3
4
5
6
...
N
44
40
Message Processor A
48
Error Log

FIG. 8

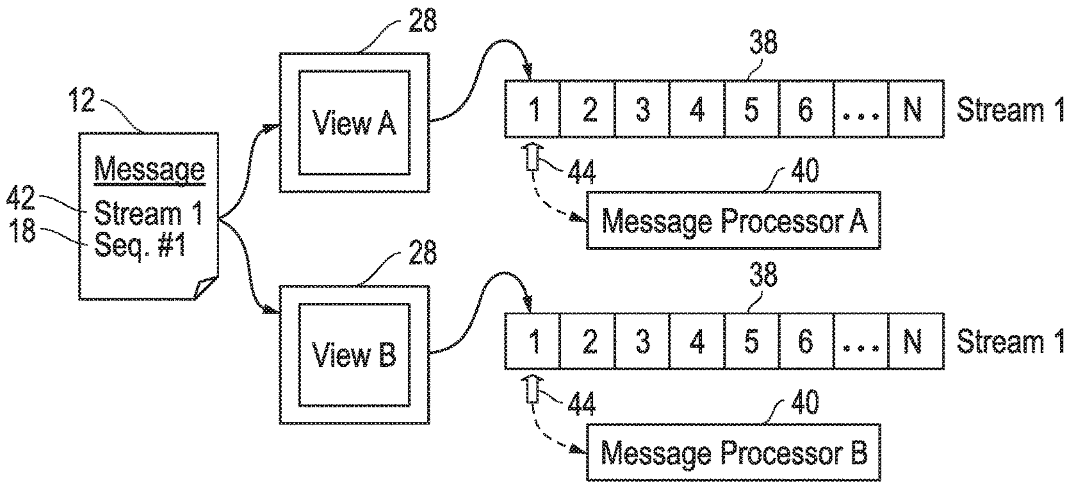

12
Message
Stream 1
Seq. #1
42
18
28
View A
28
View B
38
1
2
3
4
5
6
...
N
Stream 1
44
40
Message Processor A
38
1
2
3
4
5
6
...
N
Stream 1
44
40
Message Processor B

FIG. 9

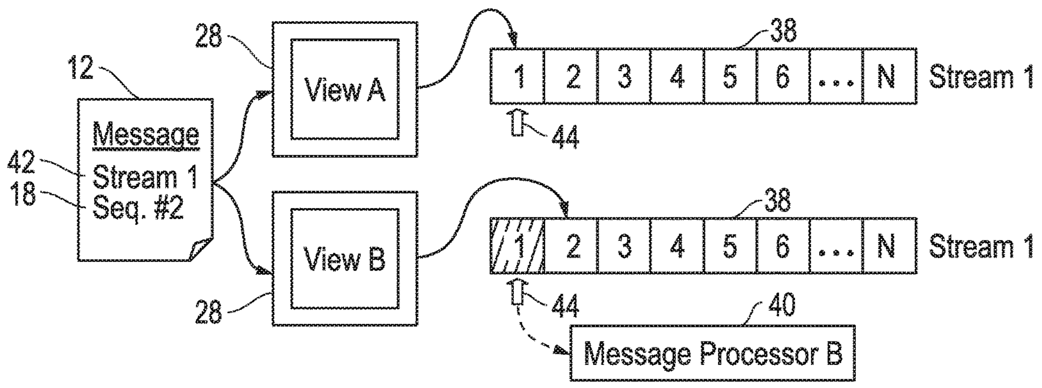

28
12
Message
42
Stream 1
18
Seq. #2
View A
View B
28
38
1 2 3 4 5 6 ... N
Stream 1
44
38
1 2 3 4 5 6 ... N
Stream 1
44
40
Message Processor B

FIG. 10

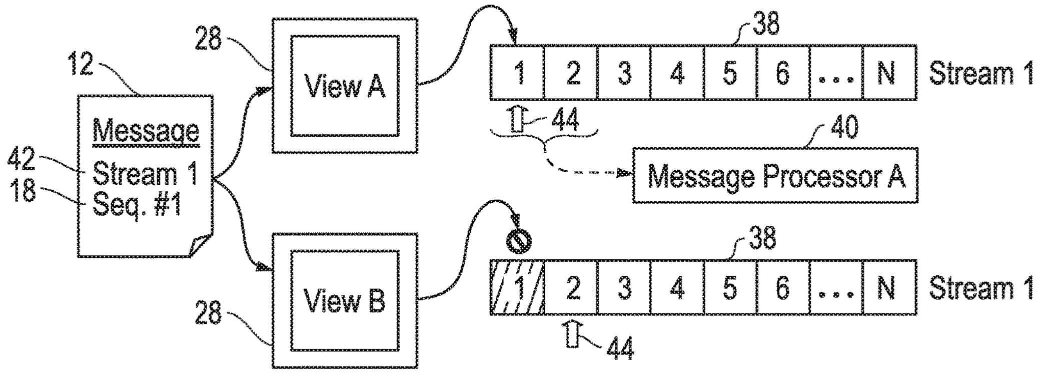

28
12
Message
42
Stream 1
18
Seq. #1
View A
View B
28
38
1 2 3 4 5 6 ... N
Stream 1
44
40
Message Processor A
38
1 2 3 4 5 6 ... N
Stream 1
44

FIG. 11

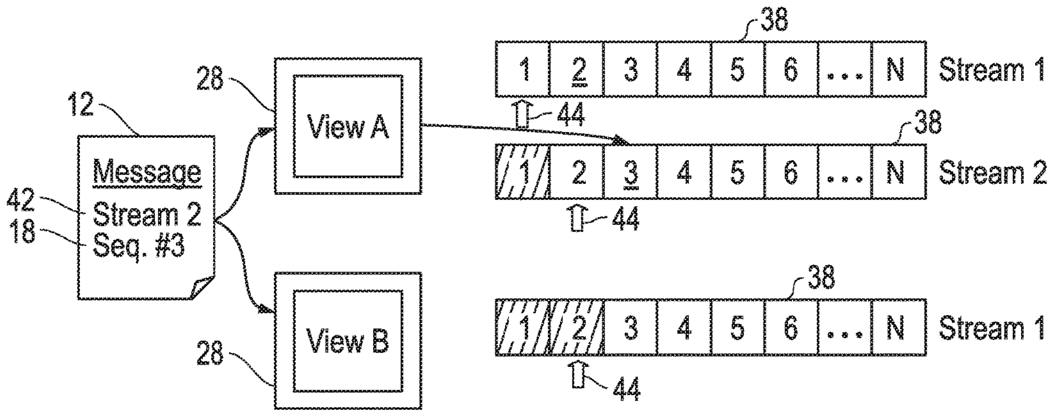

12
Message
42
Stream 2
18
Seq. #3
28
View A
28
View B
38
1 2 3 4 5 6 ... N Stream 1
44
38
1 2 3 4 5 6 ... N Stream 2
44
38
1 2 3 4 5 6 ... N Stream 1
44

FIG. 12

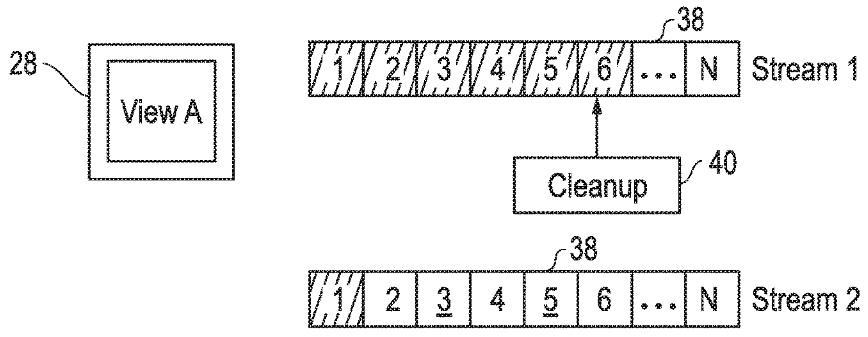

28
View A
38
1 2 3 4 5 6 ... N Stream 1
Cleanup
40
38
1 2 3 4 5 6 ... N Stream 2

FIG. 13

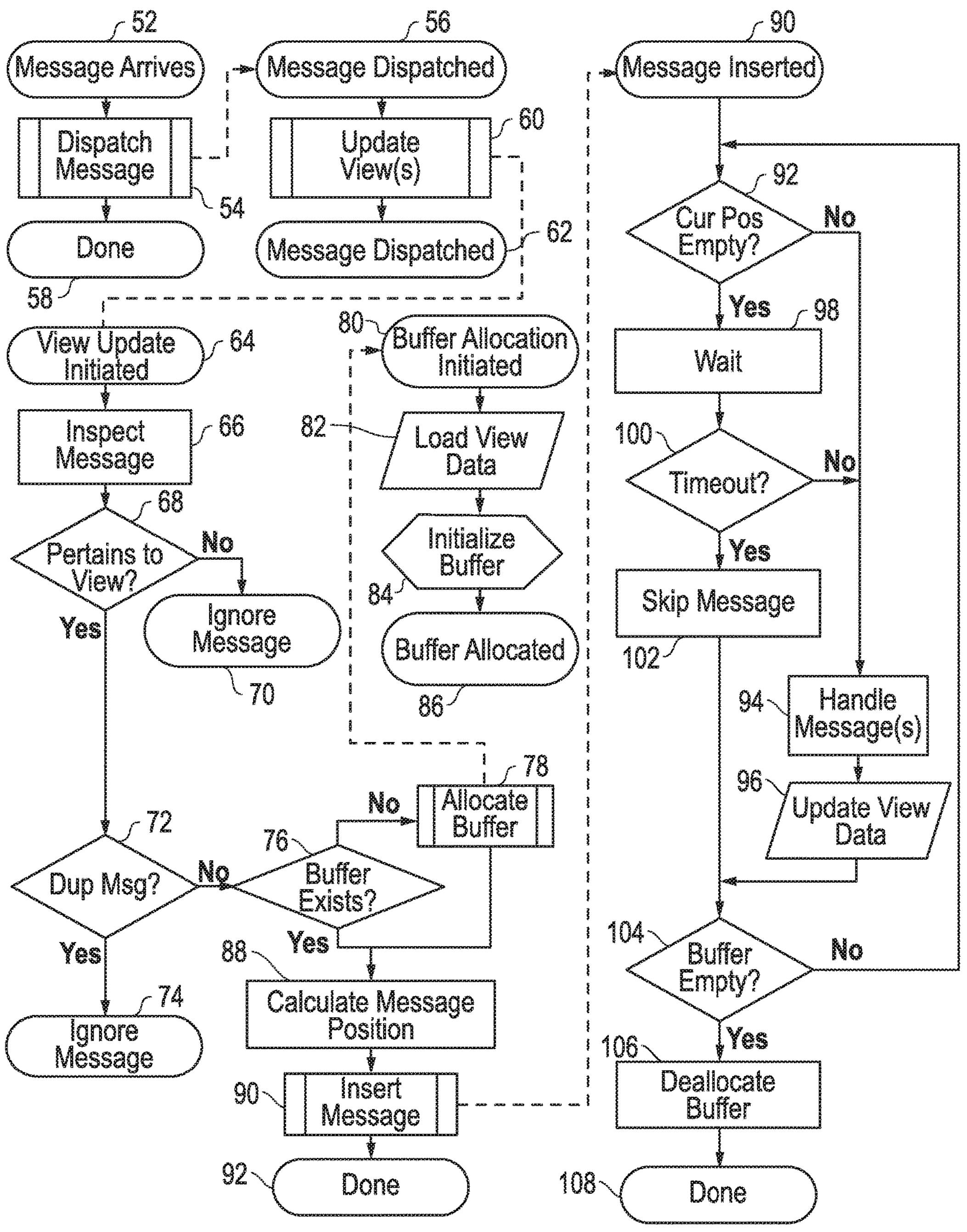

52
Message Arrives
Dispatch Message
54
Done
58
56
Message Dispatched
Update View(s)
60
Message Dispatched
62
View Update Initiated
64
Inspect Message
66
Pertains to View?
68
No
Yes
Ignore Message
70
Dup Msg?
72
No
Yes
Ignore Message
74
Buffer Exists?
76
No
Yes
Allocate Buffer
78
Calculate Message Position
88
Insert Message
90
Done
92
Buffer Allocation Initiated
80
Load View Data
82
Initialize Buffer
84
Buffer Allocated
86
Message Inserted
90
Cur Pos Empty?
92
No
Yes
Wait
98
Timeout?
100
No
Yes
Skip Message
102
Handle Message(s)
94
Update View Data
96
Buffer Empty?
104
No
Yes
Deallocate Buffer
106
Done
108

FIG. 14

MESSAGE ORDERING AND IDEMPOTENCY ENFORCEMENT PROCESS

FIELD OF THE DISCLOSURE

The present invention pertains to a message ordering and idempotency enforcement process that ensures the ordered processing of asynchronously received messages and avoids reprocessing of messages that have already been successfully processed.

BACKGROUND OF THE INVENTION

In systems with user interfaces, commands are sent to a server in order to effect changes to one or more entities within the system. As the command is processed, the server outputs events that describe the changes made to the entities. These events are then transmitted asynchronously over the network to other systems where they are handled.

Certain systems involve read stores. Read stores are used exclusively for querying (reads) and their schemas are optimized for user interfaces. These differ from traditional relational databases in that data in a read store is denormalized (flattened) and there are few if any constraints. In a read store, the same information is often copied into multiple places to reduce the need for joins or complex queries. Accordingly, read store schemas are often partitioned into multiple views, each of which contains different projections of similar data that is customized to suit a particular user interface. A single event may result in updates to many views within a read store. For example, a read store may have a Customer Search view and a Customer Detail View. The Customer Search view may consist of a single Customer Search Result table, whereas the Customer Detail view may contain the tables Customer Detail, Customer Detail Account, Customer Detail Subscription, Customer Detail Domain, and so on. A Customer Created Event may result in an insert into both the Customer Search Result and Customer Detail tables.

While data in local read stores is not guaranteed to be consistent with the source systems at all times, there is an expectation that they will be eventually consistent once all events arrive and have been processed and any compensating commands have been issued. To ensure eventual consistency, the events that are emitted from an event-sourced system must be processed in the order in which they were applied. However, due to the asynchronous nature of message delivery and other contributing factors such as disk and network latency, published events may be substantially delayed and may not arrive at a subscribing application in the order in which they were published.

In addition to the problem of ensuring in-order processing of asynchronous publications, applications subscribing to event-sourcing systems also generally should include a means to:

1. Avoid re-processing messages that have already been processed (idempotency);
2. Influence whether a message will be redelivered if an error occurs;
3. Accommodate the handling of out-of-order messages;
4. Handle unknown messages;
5. Process a single message for one or more views;
6. Extend or substitute framework components to meet application-specific needs; and
7. Function independently of a service bus or other messaging infrastructure.

Thus, there is a need in the art for a process that addresses the aforementioned problems in a manner that is robust and flexible so as to accommodate a full spectrum of message types and user objectives.

It therefore is an object of this invention to provide a message ordering and idempotency enforcement process for ensuring in-order processing of messages and enforcing idempotency at the same time.

SUMMARY

Accordingly, the message ordering and idempotency enforcement process of the present invention, according to one embodiment, includes utilizing at least one computing device for performing the function of ensuring message ordering and idempotency; the process further including:

a. a message receiving step, the process passing a message received from a message source to a view manager, the message including an entity ID and message sequence number, where upon receipt of a message the view manager accesses a view data repository of view states, the view states identified by a view ID, an entity ID and the message sequence number of the last message processed for the view state;
b. a message inspection step, the process identifying the entity ID, the sequence number and message content of the message;
c. a view selection step, the process identifying and selecting which view or views a message pertains to according to the content of the message as determined by the message inspection step;
d. a dispatch step, the process sending the message from the view manager to one or more selected views in accordance with the view selection step;
e. an ordering step, the process including:

(i) a buffer lookup step, the process locating an existing buffer in the view data repository, the existing buffer allocated to store and control the flow of messages related by content to the entity ID and message sequence number to one or more selected views;
(ii) a view data lookup step, the process obtaining data from the view data repository in accordance with the view selection step identifying the last message processed for an entity ID within each selected view;
(iv) a buffer initialization step, the process initializing the existing buffer with the position of the next expected message according to message sequence number for each selected view;
(v) an insertion step, the process inserting the message into the appropriate position according to the message sequence number within the existing buffer for each selected view; and

e. a processing step, the process processing messages inserted in the existing buffer for each selected view in message sequence order until the buffer is empty; and
f. a recording step where the last message processed according to message sequence number for an entity ID within each selected view is recorded in the view data repository;

whereby the message ordering and idempotency enforcement process utilizing the at least one computing device, enforces in sequence processing of the message.

In another aspect, the invention further includes, after the insertion step, a waiting step for each selected view, the process waiting until the next expected message according to the message sequence number arrives before proceeding to the processing step.

In one aspect, the invention includes, after the buffer initialization step, in the event that no existing buffer is found, a buffer creation step, the process creating a buffer for each selected view for which no existing buffer is found.

In another aspect, the invention further includes an error detection step, the process including the creation of an error message log where a message that causes an error is recorded in the error message log and in a further aspect, the message sequence number of the error message is used as the last message processed at the recording step.

In a further aspect, the messages pertaining to multiple views are processed independently and concurrently.

In one aspect, at the insertion step, if the message sequence number is less than or equal to the last processed message sequence number in the existing buffer, the message is discarded.

In another aspect, the view or views include separate buffers for messages according to message content such that the message is processed at each separate buffer independently.

In one aspect, the invention further includes a deallocation step after the recording step, the process including removing buffers which contain no waiting messages.

In another aspect, the invention further includes a timer step, the process commencing at the processing step and providing a discrete amount of time for processing a message before the processing step advances to the next expected message according to message sequence number.

According to another embodiment of the invention, a message ordering and idempotency enforcement process includes:

utilizing at least one computing device for performing the function of ensuring message ordering and idempotency;

the process further including:

a. a message receiving step, the process passing a message received from a message source to a view manager, the message including an entity ID and message sequence number, where upon receipt of a message the view manager accesses a view data repository of view states, the view states identified by a view ID, an entity ID and the message sequence number of the last message processed for the view state;

b. a message inspection step, the process identifying the entity ID, the sequence number and message content of the message;

c. a view selection step, the process identifying and selecting which view or views a message pertains to according to the content of the message as determined by the message inspection step;

d. a dispatch step, the process sending the message from the view manager to one or more selected views in accordance with the view selection step;

e. an ordering step including a process including:

(i) a buffer lookup step, the process locating an existing buffer in the view data repository, the existing buffer allocated to store and control the flow of messages related by content to the entity ID and message sequence number to one or more selected views;

(ii) a view data lookup step, the process obtaining data from the view data repository in accordance with the view selection step identifying the last message processed for an entity ID within each selected view;

(iv) a buffer initialization step, the process initializing the existing buffer with the position of the next expected message according to message sequence number for each selected view;

(v) an insertion step, the process inserting the message into the appropriate position according to the message sequence number within the existing buffer for each selected view if that buffer position is empty wherein if that buffer position is not empty the message is discarded; and

e. a processing step, the process processing messages inserted in the

existing buffer for each selected view in message sequence order until the buffer is empty or a missing message sequence number is encountered wherein upon encountering a missing message sequence number processing stops until receipt of the next expected message according to message sequence number;

f. a recording step where the last message processed according to message sequence number for an entity ID within each selected view is recorded in the view data repository;

whereby the message ordering and idempotency enforcement process utilizing the at least one computing device, enforces in sequence processing of the message.

In another aspect, the invention further includes, after the insertion step, a waiting step for each selected view, the process waiting until the next expected message according to the message sequence number arrives before proceeding to the processing step.

In one aspect, the invention includes, after the buffer initialization step, in the event that no existing buffer is found, a buffer creation step, the process creating a buffer for each selected view for which no existing buffer is found.

In another aspect, the invention further includes an error detection step, the process including the creation of an error message log where a message that causes an error is recorded in the error message log and in a further aspect, the message sequence number of the error message is used as the last message processed at the recording step.

In a further aspect, the messages pertaining to multiple views are processed independently and concurrently.

In one aspect, at the insertion step, if the message sequence number is less than or equal to the last processed message sequence number in the existing buffer, the message is discarded.

In another aspect, the view or views include separate buffers for messages according to message content such that the message is processed at each separate buffer independently.

In one aspect, the invention further includes a deallocation step after the recording step, the process including removing buffers which contain no waiting messages.

In another aspect, the invention further includes a timer step, the process commencing at the processing step and providing a discrete amount of time for processing a message before the processing step advances to the next expected message according to message sequence number.

Other objects, features and advantages of the present invention will become more fully apparent from the following detailed description of the preferred embodiment, the appended claims and the accompanying drawings in which:

FIG. **1** illustrates a block diagram of the inventive process;

FIGS. **2-13** illustrate the inventive process in a step by step manner beginning at FIG. **2** with the receipt of a message and it routing to a View A;

FIG. **3** illustrates the location or creation of a circular buffer;

FIG. **4** illustrates the creation of a pointer to the next expected message sequence number in a buffer;

FIG. **5** illustrates the insertion of a message into the buffer according to its message sequence number;

FIG. **6** illustrates the handling of the message in message sequence order;

FIG. **7** illustrates the updating of the view data repository to reflect the last message sequence number processed;

FIG. **8** illustrates a message processing error and the creation of an error log;

FIG. **9** illustrates the inventive process with more than one view operating concurrently and independently;

FIG. **10** illustrates the processing of a message in order in one view and the storing of an out of sequence message in another view;

FIG. **11** illustrates the discarding by one view of a previously received message by message sequence number;

FIG. **12** illustrates the handling of a single message by multiple views and multiple buffers for a view;

FIG. **13** illustrates the deallocation of buffers after processing of messages is complete; and

FIG. **14** is a flow chart of the inventive process according to FIGS. **1-13**.

DETAILED DESCRIPTION OF EMBODIMENTS

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the invention be regarded as including equivalent constructions to those described herein insofar as they do not depart from the spirit and scope of the present invention.

For example, the specific sequence of the described process may be altered so that certain processes are conducted in parallel or independent, with other processes, to the extent that the processes are not dependent upon each other. Thus, the specific order of steps described herein is not to be considered implying a specific sequence of steps to perform the process. In alternative embodiments, one or more process steps may be implemented by a user assisted process and/or manually. Other alterations or modifications of the above processes are also contemplated. For example, further insubstantial approximations of the process and/or algorithms are also considered within the scope of the processes described herein.

In addition, features illustrated or described as part of one embodiment can be used on other embodiments to yield a still further embodiment. Additionally, certain features may be interchanged with similar devices or features not mentioned yet which perform the same or similar functions. It is therefore intended that such modifications and variations are included within the totality of the present invention.

It should also be noted that a plurality of hardware and software based devices, as well as a plurality of different structural components, may be utilized to implement the invention. Furthermore, and as described in subsequent paragraphs, the specific configurations illustrated in the

drawings are intended to exemplify embodiments of the invention and that other alternative configurations are possible.

One embodiment of the present invention is illustrated by way of example in FIGS. **1-13**. With specific reference to FIG. **1**, message ordering and idempotency enforcement process **10** begins with a message **12** from a message source **14**. Message **12** may be any type of message packet, command, email or the like. Message source **14** may be a Service Bus, event replay client or any other source. The message **12** includes an entity ID **16**, message sequence number **18** and content **20**. Entity ID **16** identifies the entity to whom the message is addressed and may take the form of letters, numbers, characters and the like such that it is possible to discern the addressee of the message. The message sequence number **18** is similar to the entity ID **16** in that it is a number, character or symbol that indicates its position in a stream of consecutive messages. Content **20** is the bulk of the message **12** and may be any form or format.

Message **12** is received by message ordering and idempotency enforcement process **10** by view manager **22**. View manager **22** is connected with message inspector **24** and view data repository **26**. Message **12** is sent to message inspector **24** where message inspector **24** identifies the entity ID **16** to whom message **12** is addressed as well as the message sequence number **18** and the content **20** of the message **12**. With this information view manager **22** consults view data repository **26**. View data repository **26** includes a repository of at least one view **28**. Each view **28** includes a view state **30**. View state **30** includes view ID **32**, entity ID **16** and last processed massage sequence number **34** for one particular view **28**. A view **28** may include other data.

View manager **22** selects selected views **36** from the view data repository **26**. Selected views **36** are a view or views **28** to which message **12** pertains according to the content **20** of the message **12** as determined by the message inspector **24**.

View data repository **26** also includes a buffer **38** associated with each view **28**. Buffer **38** may be a circular buffer as will be described more fully hereafter. View manager **26** sends message **12** to a buffer **38** associated with a selected view **36**. Message **12** is inserted into buffer **38** according to message sequence number **18** where messages **12** are processed by message handler **40** in message sequence order until no further messages **12** are left in the buffer **38** to be processed as will be described more fully hereafter.

Message handler **40**, once all the messages **12** have been processed in the buffer **38**, then records the last processed message according to message sequence number **18** in the view data repository **26** as the last processed message sequence number **34** for that view state **30**.

Referring now to FIGS. **2-13** other features, elements and embodiments of the present invention are described. Applicant's message ordering and idempotency enforcement process **10** is better understood by use of the following examples. However, the following examples are exemplary only and are not meant to limit the scope of the invention disclosed herein.

FIG. **2** illustrates the inventive process beginning with the receipt of message **12** with an entity ID **16**. In FIGS. **2-12**, entity ID **16** is indicated as a "stream" **42**. Stream **42** is a combination of entity ID **16** and message content **20** such that "Stream **1**" in FIGS. **2-11** identifies one or more views **28**. Message **12** is received and routed to a view **28**, View A, as described above. View **28** by way of further description is a self contained set of data that is updated based on a subset of messages received, as described and illustrated. A view **28** can be an in-memory cache, documents in a NaSQL data store; flat files on disk; a relational database; or any other collection of data. According to the inventive process, views **28** can be independently refreshed.

FIG. **3** illustrates the location or creation of a circular buffer **38** in view data repository **26**. The first step to create a circular buffer **38** is to retrieve the last processed message sequence number **34** for "Stream **1**" in view A from the view data repository **26**. The view data repository **26** can be backed by an in-memory cache, documents in a NaSQL data store; flat files on disk; a relational database; or any other means of persisting data regarding the relationships between message streams **42** and views **28**. If a view **28** does not currently contain a circular buffer **38**, one is created.

FIG. **4** illustrates the identification of a buffer **38** for Stream **1** and the creation of a pointer **44** to the next expected message sequence number **46** in the buffer **38**. The pointer **44** is initialized to point to the next expected message sequence number **46** in buffer **38**. Here, the next expected sequence number **46** is number "3" and the pointer **44** so identifies it. For the purposes of illustration buffer **38** numbers "1" and "2" are shown filled in or blacked out to indicate that those message sequence number messages have been received and stored in the buffer **38**. Buffer **38** is small relative to the maximum sequence number for each stream **42**. Buffer indices may be calculated by taking the modulus of the message sequence number and buffer size, for example.

FIG. **5** illustrates the insertion of a message **12** into the buffer **38** according to its message sequence number **18**. Thus, message **12** with message sequence number "3" is inserted into the empty buffer space "3". Again, the buffer index may be calculated by taking the modulus of the message sequence number and the buffer size N.

Referring to FIG. **6**, the background processing thread, message handler **40**, identifies that a message **12** has arrived and the next expected message according to message sequence number **18** has been inserted into the buffer **38**. At this point, there is a contiguous sequence of messages in buffer indices "1" to "3" such that the messages **12** are then processed by message handler **40** in message sequence order.

FIG. **7** illustrates the process of the invention in the updating of the view data repository **26** to reflect the last processed message sequence number **34**. In FIG. **7**, the last processed message sequence number **34** for this message **12** is "3".

At this point the operation of the present invention has proceeded according to the description of the inventive process set forth above. Beginning with FIG. **8**, other features of the invention are disclosed and described. FIG. **8** illustrates how the invention accommodates a message processing error. Here an error occurs while message handler **40** is processing this particular message **12** at position "3". In the case of an error, there are two possibilities for handling the error: halt processing until the error is resolved or proceed with processing. If it is supposed that the message that caused the error is more important than the subsequent messages, then the former would be a good strategy. However, by observation and research Applicants believe that it is more probable that the subsequent messages will in aggregate be more important than the message that caused the error. Further, Applicants submit that the typical expectation is that the occurrence of such errors is likely to be low. Finally, Applicants have determined that the cost of correcting such errors is minimal (typically a one-off DB update).

Thus, in one embodiment, Applicants inventive process adopts the second option which is to record the error prominently and in as much detail as possible and then proceed to the next expected message in message sequence number order. The error is recorded in an error log **46**. Further, according to one aspect of the invention, the view data repository **26** is updated to reflect the last processed message sequence number **34** for the stream **42** in the view **28**. In the FIG. **8**, according to one aspect of the invention, the message handler **40** records the last processed message sequence number **34** as sequence number "3" even though the message did not process because of error.

FIG. **9** illustrates the inventive process with more than one view **28** operating concurrently and independently. That is, FIG. **9** illustrates that message **12** stream **42** identifies two separate views **28**, view A and view B. Each includes an associated buffer **38** and is processed by message handler **40**, either one or more, concurrently and independently.

FIG. **10** illustrates the processing of a message **12** in message sequence order in one view **28**, view "B", and the storing of an out of sequence message in another view **28**, view "A". This illustrates the flexibility of the present invention in that, due to their independent and concurrent operation, it is permitted that messages are ready for processing in some views, view "B", but not others, view "A". That is, in FIG. **10**, view "A" receives a message sequence number "2" while it is still waiting for a message with sequence number "1". Meanwhile, view "B" has already received and processed a message with sequence number "1" and may immediately process the message with sequence number "2".

FIG. **11** illustrates the discarding by one view of a previously received message by message sequence number. In this Figure, it is shown that, according to one aspect of the invention, if the sequence number of a message is less than or equal to the last processed message sequence number **34** stored in the view data depository **26**, then the message is considered to be a duplicate and is discarded, as at view "B". Here, view "A" has been waiting for a message with sequence number "1" and upon receipt is now able to process both message "1" and previously received out of order number "2" that had been queued. At the same time, view "B" had already received and processed a message with sequence number "1" as reflected by the last processed message sequence number **34** recorded by the message handler **40** in view data repository **26**. Thus, when buffer **38** was initiated, pointer **44** identified the next expected sequence number **46** to be number "2" and message sequence number "1" is discarded.

FIG. **12** illustrates the handling of a single message by multiple views and multiple buffers for a view. This example shows concurrent message buffers **38** for multiple streams **42**, stream "1" and stream "2", for a single view **28**, view "A".

As has been described, view **28** is represented by a view state **30**. View state **30** consists, at least, of a view ID **32**, and entity ID **16** and a last processed message sequence number **34**. Message **12** consists, at least, of an entity ID **16**, a message sequence number **18** and content **20**. Message inspector **24** identifies appropriate views **28** as selected views **36** by analysis of entity ID **16** and message content **20** or, said another way, by stream **42**. Thus, a particular view **28** may include multiple streams **42**.

In FIG. **12**, view "A" has previously received an out of order message with sequence number "2" for stream "1" and is waiting for a message with sequence number "1" to process. View "A" also had previously received and processed a message with sequence number "1" for stream "2" and is waiting for on sequence number "2". FIG. **12** shows that stream "2" had previously received out of order message sequence number "3" that is stored in the appropriate index pending execution upon the arrival of the next expected sequence number **46**, that is number "2" for stream "2".

As shown, view "B", in this example, is not configured to process this particular message and, therefore, does not have a buffer for stream "2". This can be controlled, for example only, by configuring views with message specifications that determine whether the view should process a particular message.

According to one aspect of the invention, message handler **40** includes a timer **50**. Timer **50** begins timing upon activation of the message handler **40**, for example only and not by way of limitation, and allows message handler **40** a discrete amount of time for processing a message before the message handler **40** processes the next expected message according to message sequence number. Referring to FIG. **12**, stream "2" has received message sequence number "3" and is waiting for the next expected sequence number, number "2". Timer **50** ensures that processing of messages **12** is delayed until messages may be processed in sequence order but only for a certain period of time. Again, the determination may be made that the missing of one message is less important than the in order processing of the majority of messages.

FIG. **13** illustrates the deallocation of buffers **38** after processing of messages **12** is complete. According to this aspect of the inventive process, once the processing step, message handler **40**, has completed, buffers that contain no waiting messages are deallocated by a cleanup process. In the Figure, view "A", stream "1" has fully processed message numbers "1", "2" and "3" and no further messages are stored or pending and it is deallocated. In practice, this means that references to the buffer are removed and the runtime garbage collection released memory used for the buffer. Although messages for stream "1" may arrive at some point in the future, there are none waiting now and is it deallocated. As shown, however, stream "2" has messages that have not yet been processed and it remains allocated.

Referring now to FIG. **14**, for clarification purposes, a flow chart summarizes the inventive process as set forth in detail above and in reference to FIGS. **1-13**. The process begins at block **52** with the arrival of a message **12**. At block **54** the message **12** is dispatched to block **56** and is done at block **58**. At block **60** the view manager **22** identifies view or views **28** that need to be updated and signals each view **28** to perform updates according to the contents of the message **12** and then is dispatched at block **62**.

At block **64** view update is initiated in which at block **66** the message is inspected by message inspector **24** to obtain a stream ID **42** and sequence number **18** from the message **12**. Each message source **14**, again, may implement different mechanisms for identifying and encoding the stream ID **42** and sequence number **18** in its messages.

The stream ID **42** as set forth in detail above, uniquely identifies a series of related messages **12**. Within the series of messages, sequence numbers **18** are used to identify the order in which the messages occur relative to that stream ID **42**. In one embodiment, a stream ID **42** may correspond to an entity in a database. In another embodiment, the stream ID **42** may identify an aggregate root consisting of multiple entities governed by the same invariant conditions and consistency requirements. Message sources **14** may use Globally Unique Identifiers (GUIDs), integers, strings, or combinations of fields, for example again and not by limitation, to correlate related messages **12**. Message sources **14** may, for example again only, use monotonically incrementing integer values, time stamps, or other values with natural or prescribed ordering to identify the ordering of its messages **12**.

The message inspector **24** extracts and normalizes these correlation and ordering values from diverse message source **14** formats and produces a standard stream ID **42** and sequence number **18** used to order messages **12** and perform idempotency checks.

At block **68** if the message does not pertain to a view **28** it is ignored at block **70**. If it does pertain but is a duplicate message at block **72** it is ignored at block **74**. If it is not a duplicate message it is determined at block **76** if a buffer **38** exists. If not, at block **78**, a buffer allocation is initiated at block **80**. Within each view **28** a buffer **38** is allocated per stream ID **42** to store messages until all preceding messages are received or a timeout **50** occurs thus enabling views **28** to be updated concurrently and at different rates according to the relevance of messages and the order in which they are received.

To initialize a buffer **38**, a view **28** must determine the last (highest) sequence number **18** processed for a particular stream ID **42**. A View Data Repository **26** provides access to a persistent store of this information at block **82**.

A buffer **38** of a configurable size is created and initialized at block **84** and allocated at block **86** so that its current position corresponds to the next sequence number **18** that is expected for the stream ID **42**. At block **88**, using the output of the message inspector **24** the view **28** determines the position in the buffer **38** at which the message **12** belongs. This position may be at the current position of the buffer **38** or in any position after. At block **90**, messages **12** are inserted at block **90**, and when that is done finishes at block **92**, into a buffer **38** at the calculated position and held until all preceding messages for that stream ID **42** are received or skipped due to timeouts.

According to the inventive process, also included is the process through which messages **12** are removed from the buffer **38** and processed through the configured message handler **40**. It may execute in a separate thread from the threads in which messages **12** are inserted into the buffer **38**. At block **92**, if the current position of the buffer **38** is not empty then the message **12** at that position is handled at block **94** and at block **96** the view data is updated and the buffer position is incremented. That is, upon successful processing of a message **12** the view data repository **26** is used to update the highest or last sequence number **34** processed for the stream ID **42** in that view **28**.

If the current position of the buffer **38** is empty then at block **98** processing of the message **12** will be delayed until the missing message **12** is received or a timeout occurs at block **100**. If a timeout occurs then the position of the buffer **38** will be incremented at block **102** and the message **12** skipped. If, at block **104**, the buffer **38** is empty then, at block **106**, the buffer **38** is deallocated at block **106** and message processing concludes at block **108**. When a buffer **38** becomes empty then it is deallocated and its resources are reclaimed. If, at block **106**, the buffer **38** is not empty the processing continues at block **92** as just described.

The present invention is completely configurable to meet various message processing needs. By way of further description, the present invention addresses several message management issues: transaction management; recovery and message sequencing

Transaction Management

Previous message management solutions rely on nested transactions to isolate the global application lock concerns from database writes that occur within the message processor. There are a few of drawbacks to this:

A distributed transaction manager, e.g. Microsofts' MS DTC (Distributed Transaction Coordinator) or IBM's XA Transaction, for example, is needed to handle the distributed transaction, which incurs a performance penalty.

The same data source/connection cannot be used for both the idempotency lookups and the actual message processing.

The transactional semantics of the exterior message delivery system (e.g. service bus) are conflated with the transactional semantics of the message idempotency and processing logic, which can have unintended side-effects, such as:

a. If a single message is routed to multiple views, and redelivery is requested by one of those views, then the message will be redelivered to all views due to the nature of the external transaction. Although the messages will not be processed more than once, global locks and queries need to detect the duplicate message delivery have a significant impact on performance.

b. Failures in other message handlers exterior to the denormalization framework can cause redelivery to the denormalizers which incurs the same performance penalty.

c. Conversely, redelivery requests in denormalizers can cause messages to be redelivered to other external handlers which may not be set up to handle multiple deliveries of the same message.

The present invention places a message in a buffer and allows the external transaction to complete. If a message happens to be redelivered it will be discarded immediately since that position in the buffer is already filled. Processing of messages takes place in a separate thread with no ambient transaction, allowing the message processor to enforce its own transaction semantics. In addition, processing of messages does not commence until all intermediate messages have been received. Processing then occurs sequentially until the next empty slot in the buffer is reached. There is no need for redelivery and the overhead involved.

Recovery

Previous message management systems have relied on retry policies to control when and how messages should be redelivered in the event of an error. However in practice Applicants have noticed that there is very rarely a situation in which an error was resolved with a simple retry. The result is that messages would be retried several times over the span of many minutes or hours (depending on the policy) before ultimately giving up and proceeding to the next message. No situation has been identified in which it would be valuable to stop processing messages until the error was identified and correct. On the contrary, Applicants have found that more often than not it is preferable that processing to continue in order to avoid skewing data in the read store even further.

Therefore according to the present invention, a preferred process is to log the failure and continue immediately on to the next message. In the event of an error the options are:

Issue a compensating action so that another message is published and the data corrects itself (basically re-do the missed change). For example, if a CustomerNameChangedEvent fails and the customer record is not updated with the new name, the error can be corrected by changing the customer's name again once the underlying issue has been fixed.

Identify the discrepancy and issue a manual DML query to correct it. As in the example above, the affected tables can be updated with the correct name.

Truncate data in the affected view and replay messages from the source (for event-sourced systems)

These are simple and straightforward fixes that are expected to happen infrequently and will have low impact given that a read store is simply a persistent projection/cache. In exchange the present invention results in performance gains and more consistent throughput of messages.

Message Sequencing Strategies

An important advantage of the present invention relates to the method used to sequence messages. Whereas prior art systems may use nested transactions, global application locks, and constant database reads to enforce message idempotency, the present invention uses a system of buffers, timers, and background processing tasks to achieve the same effect without all the overhead.

By way of comparison, in prior art systems, by way of example, the following representative steps may be found:

1. For each message that arrives:

a. Obtain a global lock representing the combined Stream ID and View ID. This was accomplished by concatenating the two values and requesting an application lock from SQL Server (sp_getapplock).

b. Issue a query against a table to get the last sequence number that was processed.

c. Compare the result of the query to the sequence number of the message.

d. If the message was received out of order, ignore it or request that the message be redelivered at some future time (generally 500 ms-1500 ms delay) depending on the deferral strategy.

e. Otherwise, process the message. If an error occurs, either ignore it or request redelivery depending on the retry strategy.

f. If the message processes without errors, update the database with the sequence number of the message and release the global application lock.

In contrast, Applicants' inventive process does the following:

1. When a message arrives, route it to each view.

2. Within each view, locate the buffer corresponding to the Stream ID on the message. If a buffer does not exist, allocate one:

a. Read the last sequence number processed for the Stream ID+View ID from the View Data Repository.

b. Compute the next buffer position: Add 1 to the value read from the View Data Repository and take the modulus of the result and the length of the buffer.

c. Initialize the next position in the buffer to the result of the modulus operation.

d. Example: Given a buffer with 16 slots and last sequence number of 42, the next position would be: (42+1) % 16=43%16=11.

3. Compute the position of the message within the buffer by taking the modulus of the sequence number and the length of the buffer. If the buffer is currently full (rare, depending on the size of the buffers) request redelivery of the message with some delay.

a. Example: Given a buffer with 16 slots and a message with sequence number **45**, the message would be inserted into position: 45% 16=13.

4. Insert the message into the buffer and notify the processor thread that a message has arrived. Concurrently, the processor thread does the following:
1. For each buffer:
a. While there is a message in the next position of the buffer, process the message.
b. Catch and log all errors.
c. Increment the next position in the buffer.
d. Repeat until there is no message waiting in the next position.
e. When all ready messages have been processed for all buffers, de-allocate and free resources for any empty buffers.
f. Yield and wait for a notification that a new message has arrived.

In one aspect, in addition, there is a separate timer that will automatically advance the next position in the buffer after a timeout to ensure that processing of a message stream can continue if a message is lost in transit.

The description of the present embodiments of the invention has been presented for purposes of illustration, but is not intended to be exhaustive or to limit the invention to the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. As such, while the present invention has been disclosed in connection with an embodiment thereof, it should be understood that other embodiments may fall within the spirit and scope of the invention as defined by the following claims.

What is claimed is:

1. A message ordering and idempotency enforcement process comprising:

utilizing at least one computing device for performing the function of ensuring message ordering and idempotency;

said process further comprising:

a. a message receiving step, said process passing a message received from a message source to a view manager, said message including an entity ID and message sequence number, wherein upon receipt of said message said view manager accesses a view data repository of views, said views identified by a view ID, an entity ID and the message sequence number of the last message processed for a view;

b. a message inspection step, said process identifying the entity ID, the sequence number and message content of said message;

c. a view selection step, said process identifying and selecting which view or views said message pertains to according to the content of the message as determined by the message inspection step;

d. a dispatch step, said process sending said message from said view manager to one or more selected views in accordance with said view selection step;

e. an ordering step including a process comprising:

(i) a buffer lookup step, said process locating an existing buffer in said view data repository, said existing buffer allocated to store and control the flow of messages related by content to the entity ID and message sequence number to one or more selected views;

(ii) a view data lookup step, said process obtaining data from said view data repository in accordance with said view selection step identifying the last message processed for an entity ID within each selected view;

(iii) a buffer initialization step, said process initializing said existing buffer with the position of the next expected message according to message sequence number for each selected view;

(iv) an insertion step, said process inserting said message into the appropriate position according to said message sequence number within said existing buffer for each selected view;

f. a processing step, said process processing messages inserted in said existing buffer for each selected view in message sequence order until the buffer is empty; and

g. a recording step wherein the last message processed according to message sequence number for an entity ID within each selected view is recorded in said view data repository;

whereby said message ordering and idempotency enforcement process utilizing said at least one computing device, enforces in sequence processing of said message.

2. The ordering and idempotency process of claim **1** further including after said insertion step, a waiting step for each selected view, said process waiting until the next expected message according to said message sequence number arrives before proceeding to said processing step.

3. The ordering and idempotency process of claim **1** further including after said buffer initialization step, in the event that no existing buffer is found, a buffer creation step, said process creating a buffer for each selected view for which no existing buffer is found.

4. The ordering and idempotency process of claim **1** further including an error detection step, said process including the creation of an error message log wherein a message that causes an error is recorded in said error message log.

5. The ordering and idempotency process of claim **4** wherein the message sequence number of said error message is used as the last message processed at said recording step.

6. The ordering and idempotency process of claim **1** wherein messages pertaining to multiple views are processed independently and concurrently.

7. The ordering and idempotency process of claim **1** wherein at said insertion step, if said message sequence number is less than or equal to the last processed message sequence number in said existing buffer, the message is discarded.

8. The ordering and idempotency process of claim **1** wherein said view or views include separate buffers for messages according to message content such that said message is processed at each separate buffer independently.

9. The ordering and idempotency process of claim **1** further including a deallocation step after said recording step, said process including removing buffers which contain no waiting messages.

10. The ordering and idempotency process of claim **1** further including a timer step, said process commencing at said processing step and providing a discrete amount of time for processing a message before said processing step advances to the next expected message according to message sequence number.

11. A message ordering and idempotency enforcement process comprising:

utilizing at least one computing device for performing the function of ensuring message ordering and idempotency;

said process further comprising:

a. a message receiving step, said process passing a message received from a message source to a view manager, said message including an entity ID and message sequence number, wherein upon receipt of said message said view manager accesses a view data repository of views, said views identified by a view ID, an entity ID and the message sequence number of the last message processed for a view;

b. a message inspection step, said process identifying the entity ID, the sequence number and message content of the message;

c. a view selection step, said process identifying and selecting which view or views said message pertains to according to the content of the message as determined by the message inspection step;

d. a dispatch step, said process sending said message from said view manager to one or more selected views in accordance with said view selection step;

e. an ordering step including a process comprising:

(i) a buffer lookup step, said process locating an existing buffer in said view data repository, said existing buffer allocated to store and control the flow of messages related by content to the entity ID and message sequence number to one or more selected views;

(ii) a view data lookup step, said process obtaining data from said view data repository in accordance with said view selection step identifying the last message processed for an entity ID within each selected view;

(iii) a buffer initialization step, said process initializing said existing buffer with the position of the next expected message according to message sequence number for each selected view;

(iv) an insertion step, said process inserting the message into the appropriate position according to said message sequence number within said existing buffer for each selected view if that buffer position is empty wherein if that buffer position is not empty the message is discarded;

f. a processing step, said process processing messages inserted in said existing buffer for each selected view in message sequence order until the buffer is empty or a missing message sequence number is encountered wherein upon encountering a missing message sequence number processing stops until receipt of the next expected message according to message sequence number, and

g. a recording step wherein the last message processed according to message sequence number for an entity ID within each selected view is recorded in said view data repository;

whereby said message ordering and idempotency enforcement process utilizing said at least one computing device, enforces in sequence processing of said message.

12. The ordering and idempotency process of claim **11** further including after said insertion step, a waiting step for each selected view, said process waiting until the next expected message according to said message sequence number arrives before proceeding to said processing step.

13. The ordering and idempotency process of claim **1** further including after said buffer initialization step, in the event that no existing buffer is found, a buffer creation step, said process creating a buffer for each selected view for which no existing buffer is found.

14. The ordering and idempotency process of claim **11** further including an error detection step, said process including the creation of an error message log wherein a message that causes an error is recorded in said error message log.

15. The ordering and idempotency process of claim **14** wherein the message sequence number of said error message is used as the last message processed at said recording step.

16. The ordering and idempotency process of claim **11** wherein messages pertaining to multiple views are processed independently and concurrently.

17. The ordering and idempotency process of claim **11** wherein at said insertion step, if said message sequence number is less than or equal to the last processed message sequence number in said existing buffer, the message is discarded.

18. The ordering and idempotency process of claim **11** wherein said view or views include separate buffers for messages according to message content such that said message is processed at each separate buffer independently.

19. The ordering and idempotency process of claim **11** further including a deallocation step after said recording step, said process including removing buffers which contain no waiting messages.

20. The ordering and idempotency process of claim **11** further including a timer step, said process commencing at said processing step and providing a discrete amount of time for processing a message before said processing step advances to the next expected message according to message sequence number.

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