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(54) **SYNCHRONIZING CONTENT WITH THIRD-PARTY APPLICATION**

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G06F 16/27 (2019.01)
(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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USPC 707/613
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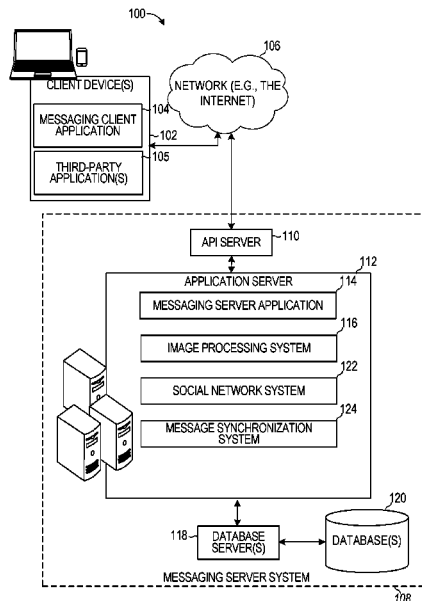
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(57) **ABSTRACT**

Systems and methods are provided for synchronizing messages. The systems and methods include operations for: identifying a difference between a current state of a messaging application and a shared synchronization database, wherein the shared synchronization database is updated via a third-party application in response to the third-party application receiving, from a server, a notification related to the messaging application, the messaging application and the third-party application being implemented on a client device; retrieving information from the shared synchronization database to update the current state of the messaging application based on the identified difference; and transmitting, to the server by the messaging application, a request for content based on the update to the current state of the messaging application.

20 Claims, 7 Drawing Sheets



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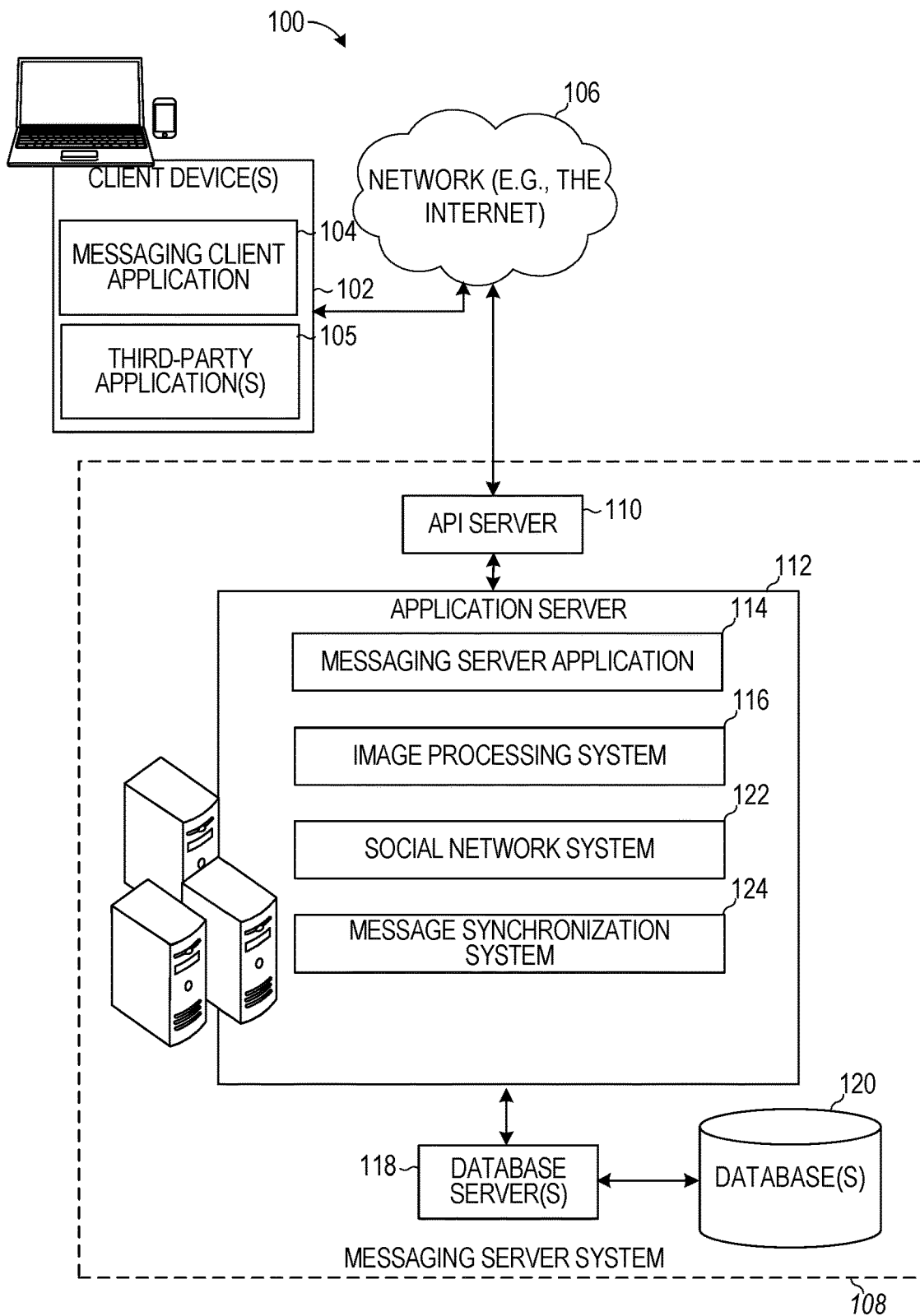


FIG. 1

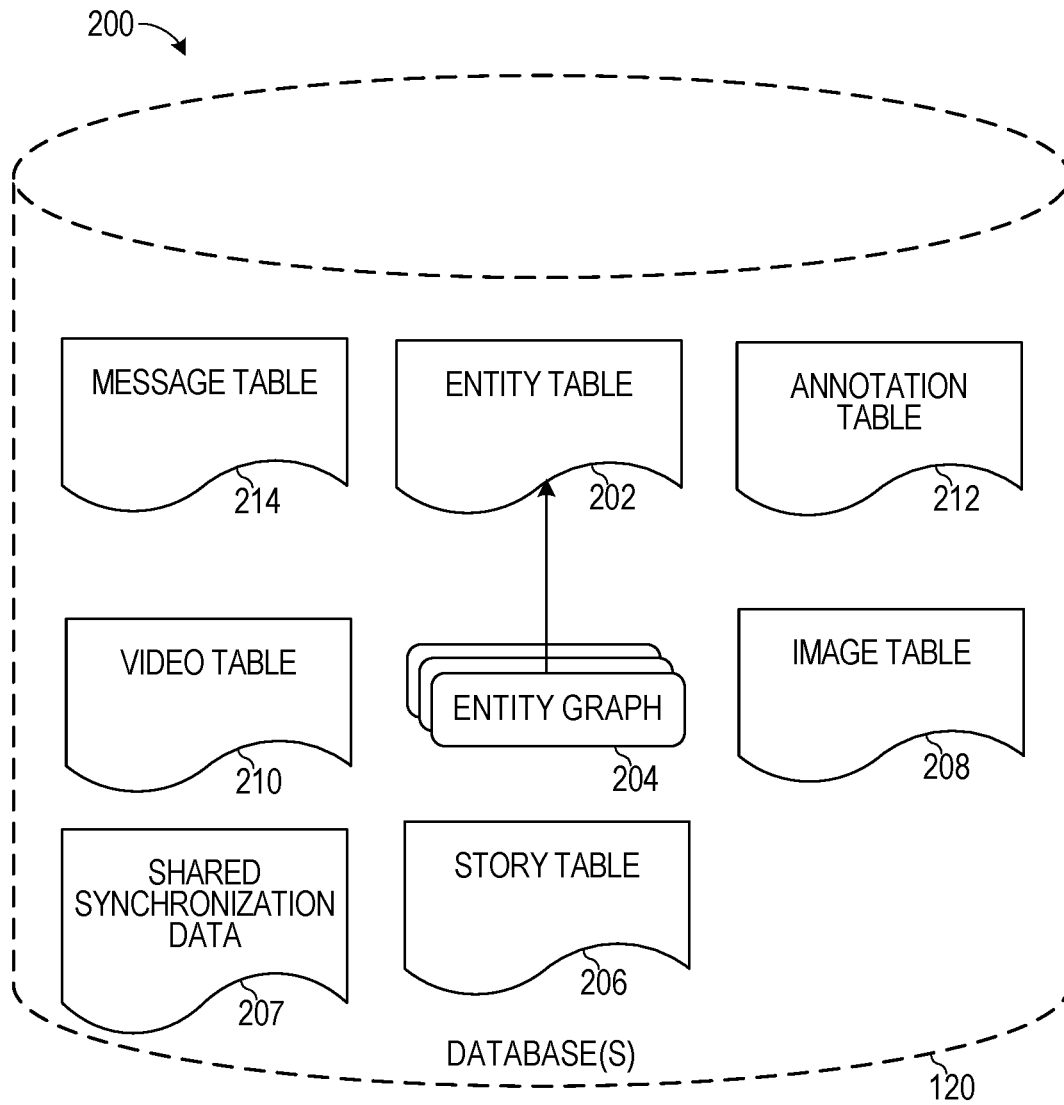


FIG. 2

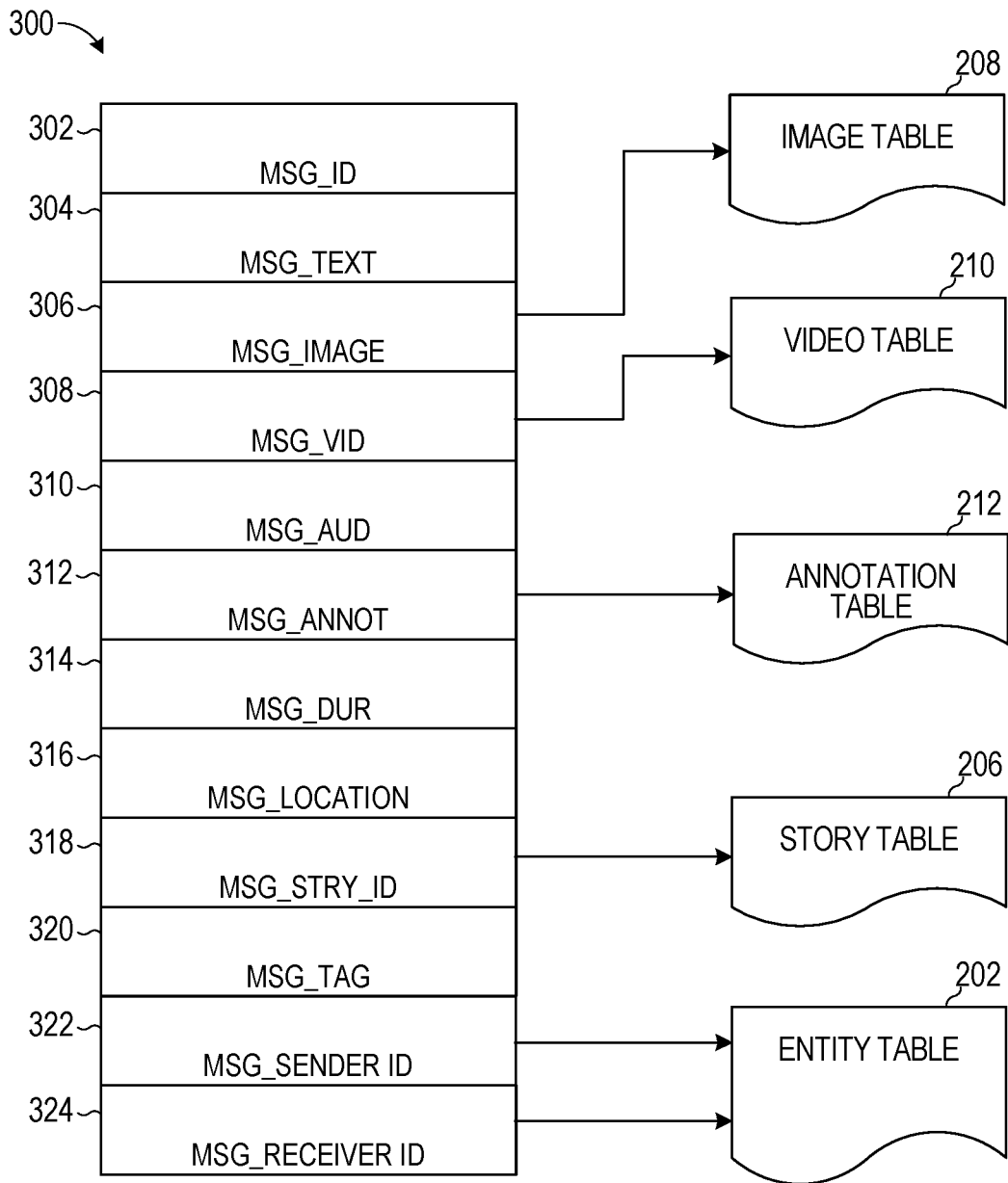


FIG. 3

124 →

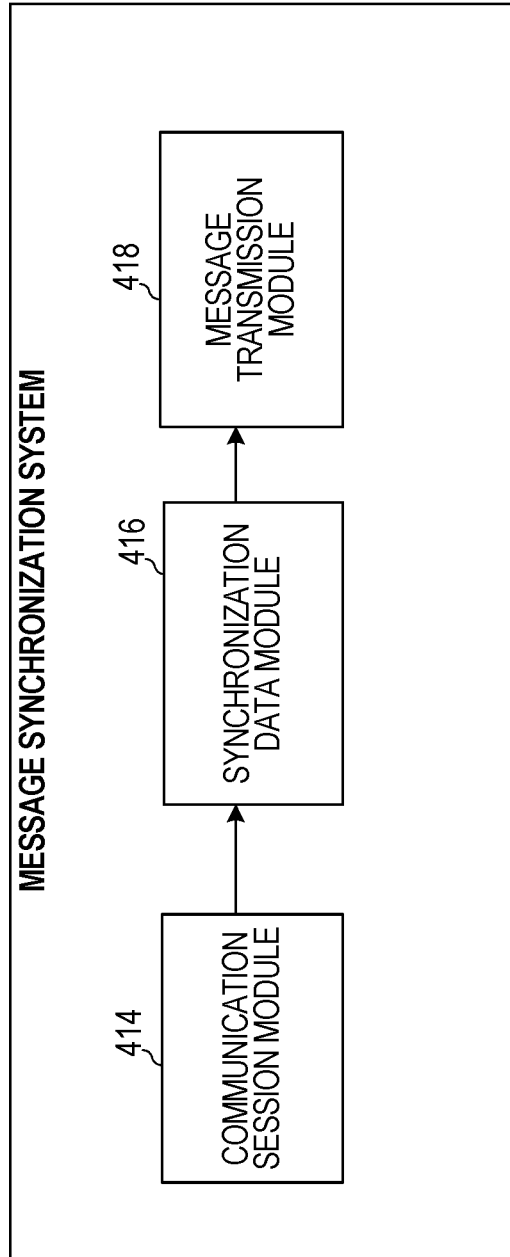


FIG. 4

500 →

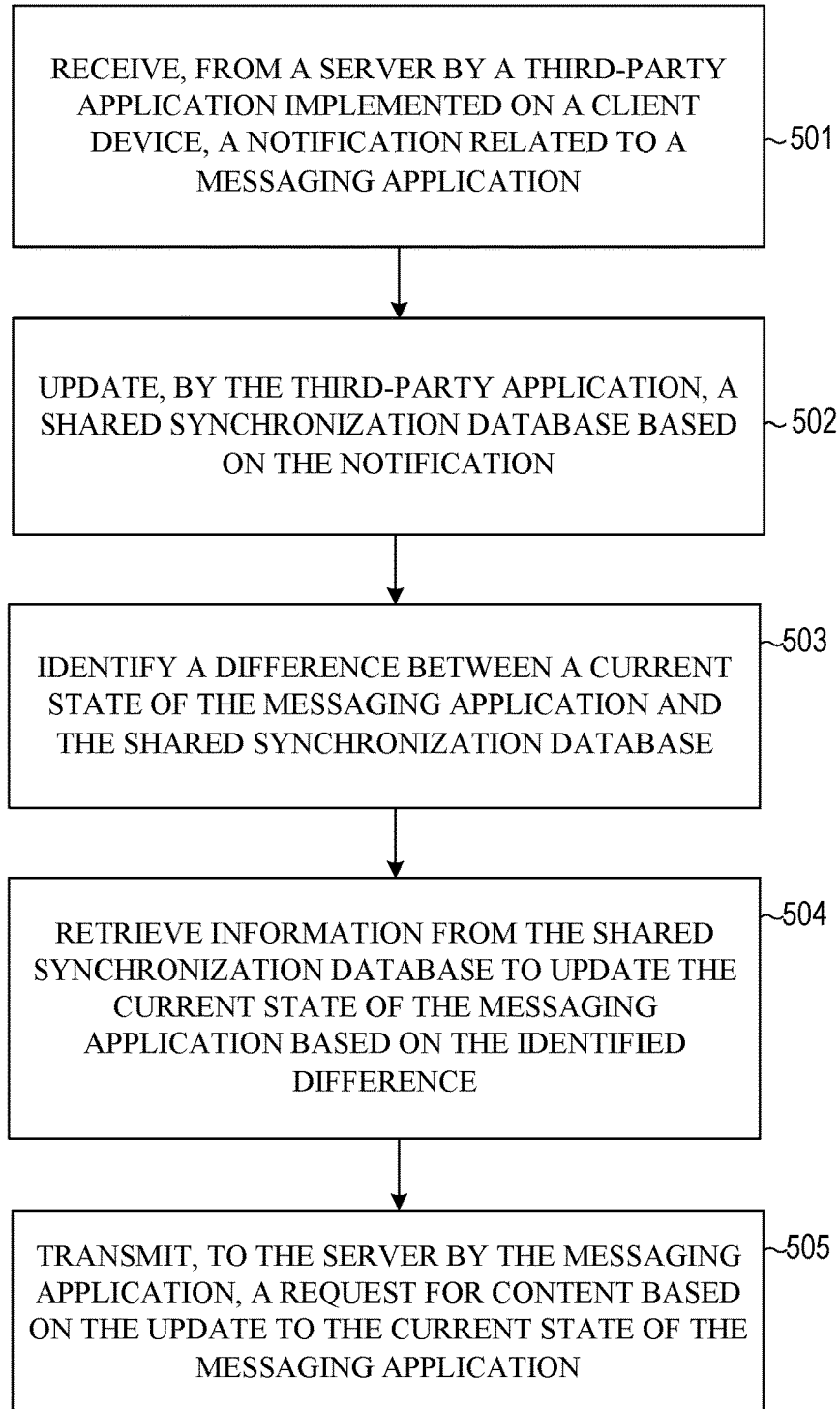


FIG. 5

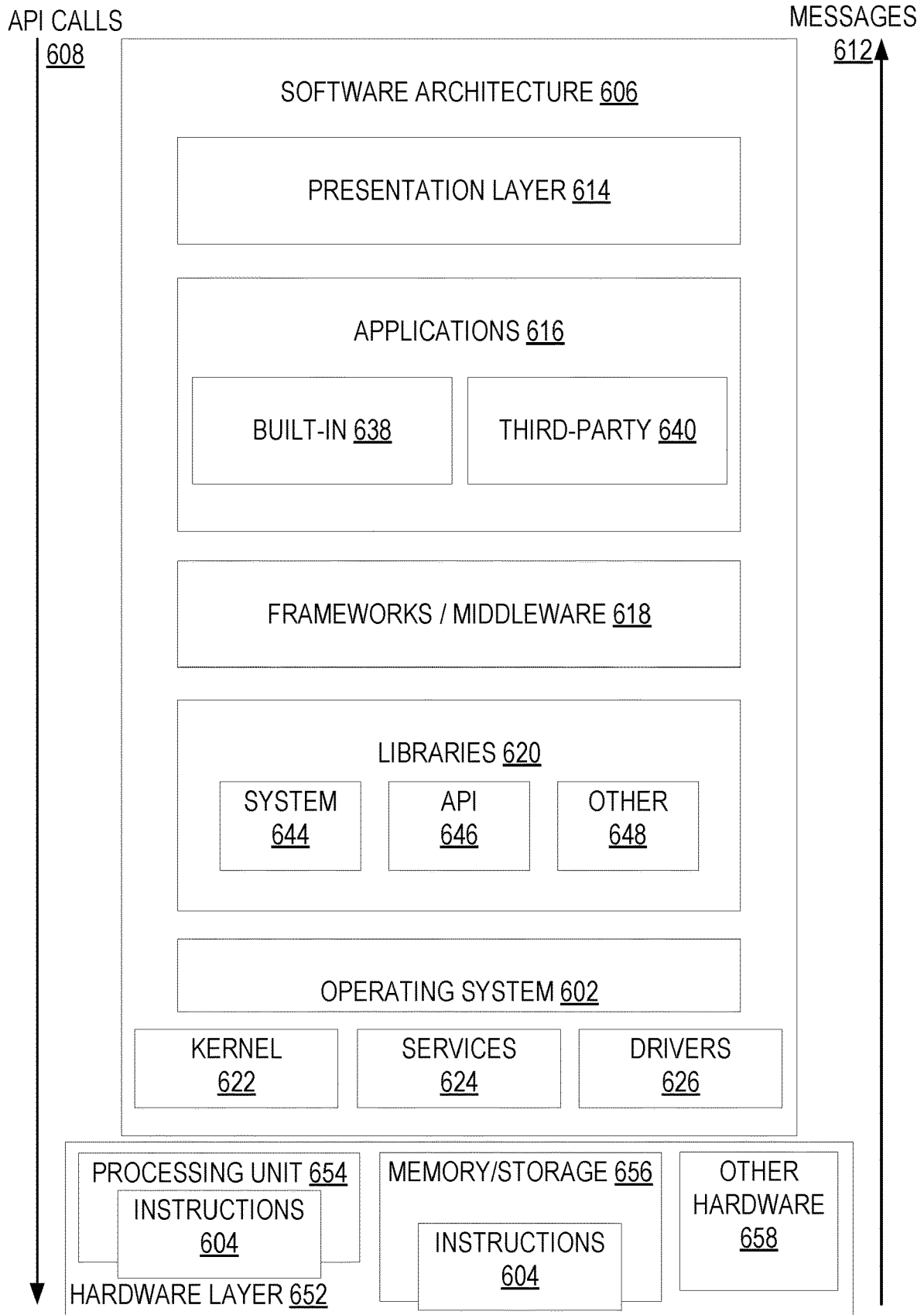


FIG. 6

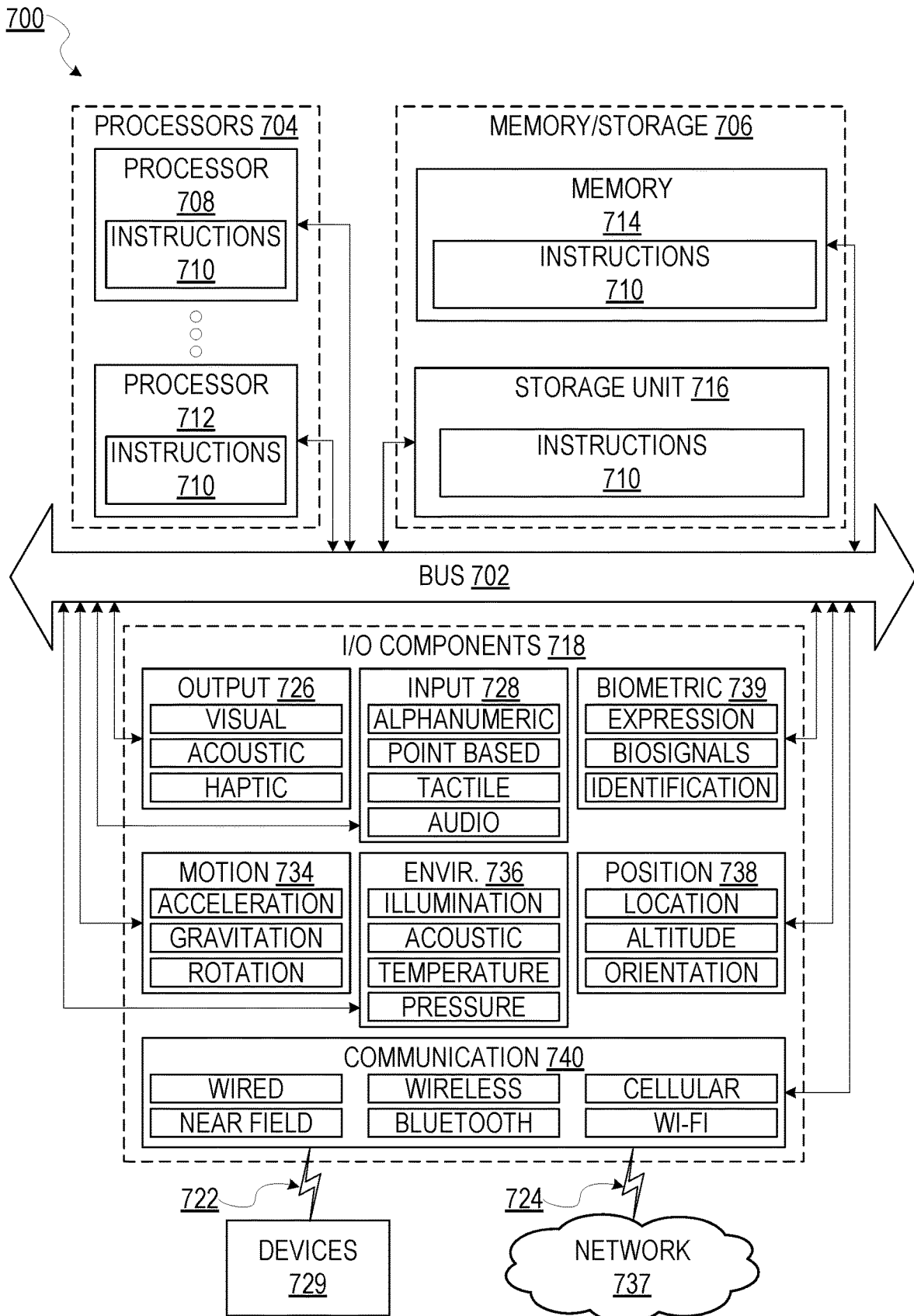


FIG. 7

SYNCHRONIZING CONTENT WITH THIRD-PARTY APPLICATION

CLAIM OF PRIORITY

This application is a continuation of U.S. patent application Ser. No. 16/801,805, filed Feb. 26, 2020, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure generally relates to the technical field of social networks. In particular, the present embodiments are generally directed to managing message synchronization.

BACKGROUND

As the popularity of social networking grows, social networks are expanding their capabilities. To improve ease of use, social networks are integrating more and more functions such that a user may accomplish many or even most of their computer-based tasks within the social network itself. One vision of social networks is that they eventually become a virtual operating system, from which a user seldom finds a need to remove themselves.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. To easily identify the discussion of any particular element or act, the most significant digit or digits in a reference number refer to the figure number in which that element is first introduced. Some embodiments are illustrated by way of example, and not limitation, in the figures of the accompanying drawings in which:

FIG. 1 is a block diagram showing an example messaging system for exchanging data (e.g., messages and associated content) over a network, according to example embodiments.

FIG. 2 is a schematic diagram illustrating data which may be stored in the database of a messaging server system, according to example embodiments.

FIG. 3 is a schematic diagram illustrating a structure of a message generated by a messaging client application for communication, according to example embodiments.

FIG. 4 is a block diagram showing an example message synchronization system, according to example embodiments.

FIG. 5 is a flowchart illustrating example operations of the message synchronization system, according to example embodiments.

FIG. 6 is a block diagram illustrating a representative software architecture, which may be used in conjunction with various hardware architectures herein described, according to example embodiments.

FIG. 7 is a block diagram illustrating components of a machine able to read instructions from a machine-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein, according to example embodiments.

DETAILED DESCRIPTION

The description that follows includes systems, methods, techniques, instruction sequences, and computing machine

program products that embody illustrative embodiments of the disclosure. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide an understanding of various embodiments.

5 It will be evident, however, to those skilled in the art, that embodiments may be practiced without these specific details. In general, well-known instruction instances, protocols, structures, and techniques are not necessarily shown in detail.

10 Often, users consume media content, and specifically videos, on a user device, such as a mobile device. Such media content is typically exchanged in chat sessions between users. Sometimes users log on and log off a server that maintains the contents of the chat sessions. In order to ensure that the latest chat messages, that were exchanged in the chat session while the user device has been disconnected from the server, are presented to the user, a user device synchronizes with the server. Typically, the server will send the content of all the messages that were exchanged while the user device was disconnected from the server. Some of these messages are rich in large-sized content, such as videos and images. Synchronizing such content between a server and a user device consumes a great deal of processing resources and network bandwidth which makes synchronization sessions operate inefficiently. Also, synchronizing such content can take a long time which further delays presenting the latest chat messages to the user and can end up frustrating the users.

In some cases, a dedicated operating system process, such as a push notification application, receives messages or data corresponding to a messaging application. For example, a first user may send a message, via a messaging application of a first user devices of the first user to a second user. A messaging application of a second user device of the second user may be inactive when the first user sends such a message. In such circumstances, the push notification application of the operating system of the second user device may receive and present the message to the second user. Typically, the push notification application does not communicate with the messaging application and works independently of the messaging application. As such, the messaging application is not informed about the receipt of the message from the first user. So when the messaging application ultimately synchronizes its content with the server, the messaging application may request content from the server that may have already been delivered to the second user device through alternate means, such as by way of the push notification application. This results in wasted bandwidth and processing resources in performing duplicative work. In this case, the duplicative work is the receipt of a message that has already been provided to the second user device by other means.

The disclosed embodiments improve the efficiency of using the electronic device by providing a system that efficiently synchronizes content between a server and a user device. According to the disclosed system, only content that differs between the user device and the server and that has not already been sent to a third-party application, such as a push notification application, or a messaging application on the user device is transmitted to the user device in a synchronization session. In this way, if one application, such as a third-party application, on the user device obtained content while a messaging application is offline, such content can be shared with the messaging application, and need not be requested to be provided by the messaging application from the server. As such, the server avoids sending duplicate information to the user device when the messaging

application of the user device ultimately connects back to the server. Specifically, the disclosed system receives, from a server by a third-party application implemented on a client device, a notification related to a messaging application and updates, by the third-party application, a shared synchronization database based on the notification. The disclosed system identifies a difference between a current state of the messaging application and the shared synchronization database and retrieves information from the shared synchronization database to update the current state of the messaging application based on the identified difference. Then, the messaging application transmits, to the server, a request for content based on the update to the current state of the messaging application and does not request content that was already obtained from the shared synchronization database via the third-party application.

Rather than sending the entire contents of the messages exchanged as part of a communication session after a user device disconnected from a server, the disclosed system only sends those messages that the user device did not already obtain using a different application, such as a push notification application. Specifically, a messaging application on the user device may end a connection with a server and may receive a first set of messages from a push application. The push application may update a shared synchronization database with the first set of messages. Later, the messaging application, prior to connecting back to the server to receive a set of synchronization data, identifies a set of data the messaging application is missing that is included in the shared synchronization database. The messaging application updates the missing data and requests from the server any further updates not including the missing data that was obtained from the synchronization database. This increases the efficiencies of the electronic device by reducing processing times and network bandwidth needed to accomplish a task.

FIG. 1 is a block diagram showing an example messaging system 100 for exchanging data (e.g., messages and associated content) over a network 106. The messaging system 100 includes multiple client devices 102, each of which hosts a number of applications, including a messaging client application 104 and a third-party application 105. Each messaging client application 104 is communicatively coupled to other instances of the messaging client application 104, the third-party application 105, and a messaging server system 108 via a network 106 (e.g., the Internet).

Accordingly, each messaging client application 104 and third-party application 105 is able to communicate and exchange data with another messaging client application 104 and third-party application(s) 105 and with the messaging server system 108 via the network 106. The data exchanged between messaging client applications 104, third-party applications 105, and the messaging server system 108 includes functions (e.g., commands to invoke functions) and payload data (e.g., text, audio, video, or other multimedia data). Any disclosed communications between the messaging client application 104 and the third-party application(s) 105 can be transmitted directly from the messaging client application 104 to the third-party application(s) 105 and/or indirectly (e.g., via one or more servers) from the messaging client application 104 to the third-party application(s) 105.

The third-party application(s) 105 and the messaging client application 104 are applications that include a set of functions that allow the client device 102 to access a message synchronization system 124. The third-party application 105 is an application that is separate and distinct from the messaging client application 104. The third-party appli-

cation(s) 105 are downloaded and installed by the client device 102 separately from the messaging client application 104. In some implementations, the third-party application(s) 105 are downloaded and installed by the client device 102 before or after the messaging client application 104 is downloaded and installed. The third-party application 105 is an application that is provided by an entity or organization that is different from the entity or organization that provides the messaging client application 104. The third-party application 105 is an application that can be accessed by a client device 102 using separate login credentials than the messaging client application 104. Namely, the third-party application 105 can maintain a first user account and the messaging client application 104 can maintain a second user account. For example, the third-party application 105 can be a social networking application, a dating application, a ride or car sharing application, a shopping application, a trading application, a gaming application, or an imaging application. In some cases, the third-party application 105 is an operating system process (e.g., a push notification application) that handles push notifications for various applications installed on the client device 102. The push notification application is configured to receive messages from one or more servers and automatically present the received messages to the user. The messages may be received out-of-band and without a synchronization or refresh operation being performed by the client device 102.

The messaging server system 108 provides server-side functionality via the network 106 to a particular messaging client application 104. While certain functions of the messaging system 100 are described herein as being performed by either a messaging client application 104 or by the messaging server system 108, it will be appreciated that the location of certain functionality either within the messaging client application 104 or the messaging server system 108 is a design choice. For example, it may be technically preferable to initially deploy certain technology and functionality within the messaging server system 108, but to later migrate this technology and functionality to the messaging client application 104 where a client device 102 has a sufficient processing capacity.

The messaging server system 108 supports various services and operations that are provided to the messaging client application 104. Such operations include transmitting data to, receiving data from, and processing data generated by the messaging client application 104. This data may include message content, client device information, geolocation information, media annotation and overlays, virtual objects, message content persistence conditions, social network information, and live event information, as examples. Data exchanges within the messaging system 100 are invoked and controlled through functions available via user interfaces (UIs) of the messaging client application 104.

Turning now specifically to the messaging server system 108, an API server 110 is coupled to, and provides a programmatic interface to, an application server 112. The application server 112 is communicatively coupled to a database server 118, which facilitates access to a database 120 in which is stored data associated with messages processed by the application server 112.

Dealing specifically with the API server 110, this server 110 receives and transmits message data (e.g., commands and message payloads) between the client device 102 and the application server 112. Specifically, the API server 110 provides a set of interfaces (e.g., routines and protocols) that can be called or queried by the messaging client application 104 and the third-party application 105 in order to invoke

functionality of the application server **112**. The API server **110** exposes various functions supported by the application server **112**, including account registration; login functionality; the sending of messages, via the application server **112**, from a particular messaging client application **104** to another messaging client application **104** or third-party application **105**; the sending of media files (e.g., images or video) from a messaging client application **104** to the messaging server application **114**, and for possible access by another messaging client application **104** or third-party application **105**; the setting of a collection of media data (e.g., story); the retrieval of such collections; the retrieval of a list of friends of a user of a client device **102**; the retrieval of messages and content; the adding and deleting of friends to a social graph; the location of friends within a social graph; access to user conversation data; access to avatar information stored on messaging server system **108**; and opening an application event (e.g., relating to the messaging client application **104**).

The application server **112** hosts a number of applications and subsystems, including a messaging server application **114**, an image processing system **116**, a social network system **122**, and the message synchronization system **124**. The messaging server application **114** implements a number of message processing technologies and functions, particularly related to the aggregation and other processing of content (e.g., textual and multimedia content) included in messages received from multiple instances of the messaging client application **104**. As will be described in further detail, the text and media content from multiple sources may be aggregated into collections of content (e.g., called stories or galleries). These collections are then made available, by the messaging server application **114**, to the messaging client application **104**. Other processor- and memory-intensive processing of data may also be performed server-side by the messaging server application **114**, in view of the hardware requirements for such processing.

The application server **112** also includes an image processing system **116** that is dedicated to performing various image processing operations, typically with respect to images or video received within the payload of a message at the messaging server application **114**. A portion of the image processing system **116** may also be implemented by the message synchronization system **124**.

The social network system **122** supports various social networking functions and services and makes these functions and services available to the messaging server application **114**. To this end, the social network system **122** maintains and accesses an entity graph within the database **120**. Examples of functions and services supported by the social network system **122** include the identification of other users of the messaging system **100** with which a particular user has relationships or is “following” and also the identification of other entities and interests of a particular user. Such other users may be referred to as the user’s friends. Social network system **122** may access location information associated with each of the user’s friends to determine where they live or are currently located geographically. Social network system **122** may maintain a location profile for each of the user’s friends indicating the geographical location where the user’s friends live.

The message synchronization system **124** manages synchronization of messages exchanged in a communication session. For example, the message synchronization system **124** establishes a communication session between a plurality of users (e.g., a chat session in which multiple chat messages are exchanged). The messaging client application **104** implemented on the client device **102** communicates with

the message synchronization system **124** to receive messages transmitted as part of the communication session. Specifically, messages are sent from one user to another via the message synchronization system **124**. The message synchronization system **124** keeps track of all the messages that are exchanged and sends updates to client devices **102** that are connected to the message synchronization system **124**.

In some cases, the message synchronization system **124** stores data relating to the messaging client application **104** in a shared synchronization database. The shared synchronization database may be stored locally on the client device **102** and/or on a remote server. The data may include identifiers of messages that were received by a third-party application **105**. The data may also include identifiers of messages received by the messaging client application **104**.

For example, the messaging client application **104** may go offline (e.g., because a user closed the application and/or because of loss of Internet connectivity). Once the same messaging client application **104** connects back to the message synchronization system **124**, the message synchronization system **124** determines whether the shared synchronization database includes additional messages were exchanged or sent by users in the communication session. Such additional messages may have been received by the third-party application **105** and have been stored in the shared synchronization database. In some cases, the message synchronization system **124** retrieves the timestamp of the last time the messaging client application **104** received an update from the messaging server system **108**. The message synchronization system **124** compares the timestamp to timestamps of messages stored in the shared synchronization database to identify a set of messages that were exchanged after the timestamp of the last time the messaging client application **104** received the update. Namely, the message synchronization system **124** identifies timestamps that follow the timestamp of the last time the messaging client application **104** was synchronized or refreshed.

The message synchronization system **124** obtains the set of messages from the third-party application **105** and/or from the shared synchronization database. The message synchronization system **124** locally updates the current state of the messaging client application **104** with the obtained set of messages.

The message synchronization system **124** then generates synchronization data based on the current state of the messaging client application **104**. Specifically, the message synchronization system **124** generates a request to synchronize messages with the server **108** based on the timestamps of the messages that were stored in the shared synchronization database rather than the last timestamp of when the last time the messaging client application **104** refreshed or synchronized content with the server **108**. The server **108** determines whether additional messages or content were exchanged following the latest timestamp of the messages obtained from the shared synchronization database. The server **108** provides to the messaging client application **104** any messages that are missing from the updated state of the messaging client application **104**, such as any additional messages or content were exchanged following the latest timestamp of the messages obtained from the shared synchronization database. In some cases, the server **108** does not find any messages that are missing from the messaging client application **104**. In such cases, no updated information is provided to the messaging client application **104**. In some cases, after updated content is received by the messaging client application **104** from the server **108**, the shared

synchronization database is updated with this information retrieved from the server **108**.

In some cases, the synchronization data includes a vector of sequence numbers of messages that were exchanged. In some implementations, the vector identifies users who participate in the communication session and sequence numbers of messages sent by such users. In some cases, the vector is a matrix in which columns of the matrix represent different participants of the communication session and rows of the matrix represent sequence numbers of messages sent by the different participants.

The messaging client application **104** obtains the synchronization data including the vector from the shared synchronization database. The messaging client application **104** generates a vector that represents messages already received by the messaging client application **104** that were previously exchanged in the communication session. The messaging client application **104** identifies differences between the vector generated by the messaging client application **104** and the synchronization data received from the shared synchronization database.

As an example, the messaging client application **104** compares the vector of sequence numbers generated by the messaging client application **104** and the vector of sequence numbers received from the shared synchronization database. The messaging client application **104** identifies one or more sequence numbers that are in the vector of sequence numbers received from the shared synchronization database and that are not in the vector generated by the messaging client application **104**. The messaging client application **104** retrieves messages from the third-party application **105** corresponding to the identified one or more sequence numbers. The messaging client application **104** then generates a new vector of sequence numbers that includes the newly retrieved messages from the third-party application **105**. The messaging client application **104** transmits a request to the server **108** to synchronize data based on the new vector of sequence numbers. The server **108** generates a vector of sequence numbers corresponding to a communication session of the messaging client application **104**. The server **108** identifies differences between the vector received from the messaging client application **104** and the vector generated by the server **108**. The server **108** then sends to the messaging client application **104** any messages that are associated with sequence numbers that are in the vector generated by the server **108** and that are not in the vector received from the messaging client application **104**.

In this way, the given client device **102** may employ the techniques described herein to reduce network bandwidth by having the messaging client application **104** compare a vector of sequence numbers of messages exchanged in a communication session received from by the third-party application **105** and that are stored in a shared synchronization database to update the state of the messaging client application **104** before the messaging client application **104** communicates with the server **108** to obtain updates to a communication session.

The application server **112** is communicatively coupled to a database server **118**, which facilitates access to a database **120** in which is stored data associated with messages processed by the messaging server application **114**. Database **120** may be a third-party database. For example, the application server **112** may be associated with a first entity, and the database **120** or a portion of the database **120** may be associated with and hosted by a second, different entity. In some implementations, database **120** stores user data that the first entity collects about various each of the users of a

service provided by the first entity. For example, the user data includes user names, passwords, addresses, friends, activity information, preferences, videos or content consumed by the user, and so forth.

FIG. 2 is a schematic diagram **200** illustrating data, which may be stored in the database **120** of the messaging server system **108**, according to certain example embodiments. While the content of the database **120** is shown to comprise a number of tables, it will be appreciated that the data could be stored in other types of data structures (e.g., as an object-oriented database).

The database **120** includes message data stored within a message table **214**. An entity table **202** stores entity data, including an entity graph **204**. Entities for which records are maintained within the entity table **202** may include individuals, corporate entities, organizations, objects, places, events, and so forth. Regardless of type, any entity regarding which the messaging server system **108** stores data may be a recognized entity. Each entity is provided with a unique identifier, as well as an entity type identifier (not shown).

The entity graph **204** stores information regarding relationships and associations between entities. Such relationships may be social, professional (e.g., work at a common corporation or organization), interest-based, or activity-based, merely for example.

Message table **214** may store a collection of conversations between a user and one or more friends or entities. Message table **214** may include various attributes of each conversation, such as the list of participants, the size of the conversation (e.g., number of users and/or number of messages), the chat color of the conversation, a unique identifier for the conversation, and any other conversation related feature(s).

The database **120** also stores annotation data, in the example form of filters, in an annotation table **212**. Database **120** also stores annotated content received in the annotation table **212**. Filters for which data is stored within the annotation table **212** are associated with and applied to videos (for which data is stored in a video table **210**) and/or images (for which data is stored in an image table **208**). Filters, in one example, are overlays that are displayed as overlaid on an image or video during presentation to a recipient user. Filters may be of various types, including user-selected filters from a gallery of filters presented to a sending user by the messaging client application **104** when the sending user is composing a message. Other types of filters include geolocation filters (also known as geo-filters), which may be presented to a sending user based on geographic location. For example, geolocation filters specific to a neighborhood or special location may be presented within a UI by the messaging client application **104**, based on geolocation information determined by a Global Positioning System (GPS) unit of the client device **102**. Another type of filter is a data filter, which may be selectively presented to a sending user by the messaging client application **104**, based on other inputs or information gathered by the client device **102** during the message creation process. Examples of data filters include current temperature at a specific location, a current speed at which a sending user is traveling, battery life for a client device **102**, or the current time.

Other annotation data that may be stored within the image table **208** is so-called "lens" data. A "lens" may be a real-time special effect and sound that may be added to an image or a video.

As mentioned above, the video table **210** stores video data which, in one embodiment, is associated with messages for which records are maintained within the message table **214**. Similarly, the image table **208** stores image data associated

with messages for which message data is stored in the entity table **202**. The entity table **202** may associate various annotations from the annotation table **212** with various images and videos stored in the image table **208** and the video table **210**.

Shared synchronization data **207** stores various information about messages exchanged in a communication session. Shared synchronization data **207** is a shared data storage that is accessible to the messaging client application **104** and to the third-party application **105**. In some cases, the third-party application **105** receives a notification containing a message associated with the messaging client application **104**. The messaging client application **104** not be informed about this message but the message may still be presented to the user. In response to receiving the message, the third-party application **105** stores an identifier of the message or notification (e.g., one or more sequence numbers or a vector of sequence numbers associated with the message) in the shared synchronization data **207**.

The messaging client application **104** may access the shared synchronization data **207** to determine whether any notifications have been received by the third-party application **105** and which have not been updated or received by the messaging client application **104** (e.g., when the messaging client application **104** was offline, messages may have been received by the third-party application **105**). The messaging client application **104** may update the local state of the communication session of the messaging client application **104** based on the updated information included in the shared synchronization data **207** before the messaging client application **104** requests to synchronize content with a remote source, such as server **108**. After the messaging client application **104** updates its current state, the messaging client application **104** communicates with the server **108** to obtain further updates based on the updated current state of the messaging client application **104**.

In some embodiments, the information stored in the shared synchronization data **207** includes a vector or matrix representing participants to a communication session and/or sequence numbers of messages sent by the respective participants associated with the messaging client application **104**. Such messages may be received by the third-party application **105** but may not be received by the messaging client application **104** (e.g., because the messaging client application **104** is offline). The sequence numbers are associated with the messages and can be used to uniquely identify each respective message that is exchanged in the communication session. As an example, a client device **102** or messaging client application **104** may send a sequence number to the message synchronization system **124** and/or to the shared synchronization data **207** and request content or messages associated with the sequence number. The message synchronization system **124** and/or the shared synchronization data **207** identifies the contents or message associated with the received sequence number and sends the contents or message associated with the sequence number to the client device **102** or messaging client application **104**. In some cases, the message synchronization system **124** uses the shared synchronization data **207** information to identify a set of synchronization data (e.g., a vector of sequence numbers) that includes identifiers of messages with timestamps that were received by the third-party application **105** after the last time the messaging client application **104** received a last message, was last updated, and/or was last connected to the message synchronization system **124**.

A story table **206** stores data regarding collections of messages and associated image, video, or audio data, which

are compiled into a collection (e.g., a story or a gallery). The creation of a particular collection may be initiated by a particular user (e.g., each user for which a record is maintained in the entity table **202**). A user may create a “personal story” in the form of a collection of content that has been created and sent/broadcast by that user. To this end, the UI of the messaging client application **104** may include an icon that is user-selectable to enable a sending user to add specific content to his or her personal story.

A collection may also constitute a “live story,” which is a collection of content from multiple users that is created manually, automatically, or using a combination of manual and automatic techniques. For example, a “live story” may constitute a curated stream of user-submitted content from various locations and events. Users whose client devices **102** have location services enabled and are at a common location event at a particular time may, for example, be presented with an option, via a UI of the messaging client application **104**, to contribute content to a particular live story. The live story may be identified to the user by the messaging client application **104** based on his or her location. The end result is a “live story” told from a community perspective.

A further type of content collection is known as a “location story,” which enables a user whose client device **102** is located within a specific geographic location (e.g., on a college or university campus) to contribute to a particular collection. In some embodiments, a contribution to a location story may require a second degree of authentication to verify that the end user belongs to a specific organization or other entity (e.g., is a student on the university campus).

FIG. 3 is a schematic diagram illustrating a structure of a message **300**, according to some embodiments, generated by a messaging client application **104** for communication to a further messaging client application **104** or the messaging server application **114**. The content of a particular message **300** is used to populate the message table **214** stored within the database **120**, accessible by the messaging server application **114**. Similarly, the content of a message **300** is stored in memory as “in-transit” or “in-flight” data of the client device **102** or the application server **112**. The message **300** is shown to include the following components:

A message identifier **302**: a unique identifier that identifies the message **300**.

A message text payload **304**: text, to be generated by a user via a UI of the client device **102** and that is included in the message **300**.

A message image payload **306**: image data, captured by a camera component of a client device **102** or retrieved from memory of a client device **102**, and that is included in the message **300**.

A message video payload **308**: video data, captured by a camera component or retrieved from a memory component of the client device **102** and that is included in the message **300**.

A message audio payload **310**: audio data, captured by a microphone or retrieved from the memory component of the client device **102**, and that is included in the message **300**.

Message annotations **312**: annotation data (e.g., filters, stickers, or other enhancements) that represents annotations to be applied to message image payload **306**, message video payload **308**, or message audio payload **310** of the message **300**.

A message duration parameter **314**: parameter value indicating, in seconds, the amount of time for which content of the message (e.g., the message image payload **306**, message video payload **308**, message audio

payload **310**) is to be presented or made accessible to a user via the messaging client application **104**.

A message geolocation parameter **316**: geolocation data (e.g., latitudinal and longitudinal coordinates) associated with the content payload of the message. Multiple message geolocation parameter **316** values may be included in the payload, with each of these parameter values being associated with respect to content items included in the content (e.g., a specific image within the message image payload **306**, or a specific video in the message video payload **308**).

A message story identifier **318**: identifier value identifying one or more content collections (e.g., "stories") with which a particular content item in the message image payload **306** of the message **300** is associated. For example, multiple images within the message image payload **306** may each be associated with multiple content collections using identifier values.

A message tag **320**: each message **300** may be tagged with multiple tags, each of which is indicative of the subject matter of content included in the message payload. For example, where a particular image included in the message image payload **306** depicts an animal (e.g., a lion), a tag value may be included within the message tag **320** that is indicative of the relevant animal. Tag values may be generated manually, based on user input, or may be automatically generated using, for example, image recognition.

A message sender identifier **322**: an identifier (e.g., a messaging system identifier, email address, or device identifier) indicative of a user of the client device **102** on which the message **300** was generated and from which the message **300** was sent.

A message receiver identifier **324**: an identifier (e.g., a messaging system identifier, email address, or device identifier) indicative of user(s) of the client device **102** to which the message **300** is addressed. In the case of a conversation between multiple users, the identifier may indicate each user involved in the conversation.

The contents (e.g., values) of the various components of message **300** may be pointers to locations in tables within which content data values are stored. For example, an image value in the message image payload **306** may be a pointer to (or address of) a location within an image table **208**. Similarly, values within the message video payload **308** may point to data stored within a video table **210**, values stored within the message annotations **312** may point to data stored in an annotation table **212**, values stored within the message story identifier **318** may point to data stored in a story table **206**, and values stored within the message sender identifier **322** and the message receiver identifier **324** may point to user records stored within an entity table **202**.

FIG. 4 is a block diagram showing an example message synchronization system **124**, according to example embodiments. Message synchronization system **124** includes a communication session module **414**, a synchronization module **416**, and a message transmission module **418**. The communication session module **414** enables users to engage in a communication session to exchange messages with each other. In some cases, the communication session includes a group of three or more users in which case any message sent by one user is viewable by the other two users in the group. In some cases, the communication session includes only two users where one user sends messages to another user and vice versa.

After initiating a communication session using the communication session module **414**, messages are transferred

between users of the communication session using the communication session module **414**. For example, the communication session module **414** receives a message from a first user in the communication session and marks the message for transmission to a second user in the communication session. The communication session module **414** stores the message along with various information indicating the recipient, the communication session identifier, a sequence number, an identifier of the sender, and a timestamp representing when the message was received. In some cases, in response to receiving a given message from a participant or sender, the communication session module **414** identifies a vector associated with the participant or sender and the value of the last sequence number that is stored in the vector. The communication session module **414** increments the value of the last sequence number that is stored to generate a new sequence number for the given message, associates the new sequence number with the given message, and adds the new sequence number to the vector stored for the sender or participant. In this way, each participant of the communication session is assigned a vector with sequence numbers representing messages sent by the respective participants.

When the second user logs into the message application, the communication session module **414** receives an identifier of the second user and determines whether any messages that have not been delivered yet to the second user and that are intended for the second user to receive. In some cases, the communication session module **414** receives a last update timestamp from the second user. The communication session module **414** searches the receive time of all the messages that are intended for receipt by the second user. The communication session module **414** selects those messages that have a receive time that is later than the last update timestamp. The communication session module **414** then sends all of the selected messages to the user device of the second user for presentation in the communication session of the message client application **104**.

In some embodiments, after a given user of the communication session logs off, the communication session module **414** stores a timestamp indicating the last time an update was sent to the client device **102** of the user. In some embodiments, the communication session module **414** continuously updates the timestamp for a given client device **102** each time an update including new messages of the communication session is sent to the given client device **102**. This way, the timestamp always represents the last time the given client device **102** was connected to and received a message from the communication session module **414**.

In some embodiments, after the messaging client application **104** logs off, the given client device **102** of the given user may receive messages that are part of the communication session using a third-party application **105**. For example, the third-party application **105** may be a push notifications application that is configured to receive messages out-of-band. Such an application may receive a message and present the message to the user while the messaging client application **104** is logged off. The third-party application **105** may store an indication of the received message in the shared synchronization data **207**. For example, the third-party application **105** may store a participant identifier and one or more sequence numbers of the message received from the participant.

At a later time, the messaging client application **104** may determine a need to synchronize its content (e.g., when a polling period is reached or when a user requests to refresh the data of the messaging client application **104**). At that

time, the communication session module **414** instructs the synchronization module **416** to send the shared synchronization data **207** to the messaging client application **104** verify whether the messaging client application **104** has all of the messages that are part of the communication session before the messaging client application **104** communicates with the remote server to obtain updated messages.

In some embodiments, the synchronization module **416** generates a vector of sequence numbers and participant identifiers using the set of messages stored in the shared synchronization data **207**. Namely, the synchronization module **416** generates a vector that includes sequence numbers or identifiers of messages that the synchronization module **416** identifies were exchanged during the period of time following the last time the messaging client application **104** last received an update or was last connected to the communication session module **414**. The synchronization module **416** sends the synchronization data (e.g., the vector of sequence numbers) to the messaging client application **104**.

The messaging client application **104** generates a local data set representing messages exchanged in the communication session that are locally stored. In some cases, the messaging client application **104** generates a vector that represents participants to the communication session and the sequence numbers of the messages sent by the participants that are stored on the messaging client application **104**. The messaging client application **104** compares the received synchronization data with the current state of (e.g., a vector of sequence numbers of the communication session currently stored by) the messaging client application **104** to identify differences. For example, the messaging client application **104** compares the vector of sequence numbers received from the synchronization module **416** that are in the shared synchronization data **207** (including messages received by the third-party application **105**) to the locally generated vector of sequence numbers of messages currently stored in the messaging client application **104**. The synchronization module **416** compares the vector of sequence numbers received from the shared synchronization data **207** with a vector of sequence numbers generated by the messaging client application **104**. The synchronization module **416** identifies any differences and automatically sends content or messages corresponding to the differences (e.g., sends messages corresponding to sequence numbers that are in the vector obtained from the shared synchronization data **207** that are not also in the vector received from the messaging client application **104**). Namely, the messaging client application **104** updates the current state of the communication session with the updated content or messages corresponding to the differences.

The messaging client application **104** sends a request to the synchronization module **416** to obtain content from a remote server, such as server **108**, for content associated with differences between the updated state of the messaging client application **104** and the current state maintained by the server **108**. Specifically, the messaging client application **104** generates a new vector of sequence numbers representing the updated state of the messaging client application **104**. The messaging client application **104** sends to the server **108** a request for messages associated with a set of sequence numbers that are not already included in the new vector of sequence numbers. Namely, the messaging client application **104** requests that the server **108** provide any messages exchanged in the communication session that were not

previously stored by the messaging client application **104** and that were not previously received by the third-party application **105**.

In response to receiving the request from the messaging client application **104**, the server **108** sends via the message transmission module **418** one or more messages corresponding to the received request. For example, the synchronization module **416** instructs the message transmission module **418** to retrieve messages associated with the sequence numbers that are stored by the server **108** in connection with the communication session and that are not in the new vector of sequence numbers received from the messaging client application **104**. The message transmission module **418** obtains the messages and updates the communication session that is stored and maintained locally and displayed to the user with the messages obtained from the message transmission module **418**.

FIG. 5 is a flowchart illustrating example operations of the message synchronization system **124** in performing process **500**, according to example embodiments. The process **500** may be embodied in computer-readable instructions for execution by one or more processors such that the operations of the process **500** may be performed in part or in whole by the functional components of the messaging server system **108**, client device **102**, and/or third-party application **105**; accordingly, the process **500** is described below by way of example with reference thereto. However, in other embodiments, at least some of the operations of the process **500** may be deployed on various other hardware configurations. The process **500** is therefore not intended to be limited to the messaging server system **108** and can be implemented in whole, or in part, by any other component. Some or all of the operations of process **500** can be in parallel, out of order, or entirely omitted.

At operation **501**, the computing system (e.g., client device **102**) receives, from a server, by a third-party application implemented on the computing system a notification related to a messaging application. For example, the third-party application **105** receives a message from a server that includes a participant identifier of a user involved in a communication session and a sequence number of the message.

At operation **502**, the computing system updates, via the third-party application, a shared synchronization database based on the notification. For example, the third-party application **105**, such as the push notification application or process of the operating system of the computing system, presents a notification to the user of the computing system with the received message and updates the shared synchronization data **207** with information, such as the participant identifier and the sequence number of the message.

At operation **503**, the computing system identifies a difference between a current state of the messaging application and the shared synchronization database. For example, the messaging client application **104** retrieves notification information from the shared synchronization data **207** (that was provided by the third-party application **105**) and generates a vector of sequence numbers of messages currently stored in the messaging client application **104**. The messaging client application **104** determines whether the sequence numbers in the shared synchronization data **207** are different (and are earlier or later) than the sequence numbers in the vector previously generated by the messaging client application **104**.

At operation **504**, the computing system, such as the client device **102**, retrieves information from the shared synchronization database to update the current state of the messag-

ing application based on the identified difference. For example, the messaging client application 104 on the client device 102 retrieves one or more messages corresponding to sequence numbers that are stored in the shared synchronization data 207 (as provided by the third-party application 105) but that are not in the vector of sequence numbers generated by the messaging client application 104.

At operation 505, the computing system transmits via the messaging application to the server, a request for content based on the update to the current state of the messaging application. For example, the messaging client application 104 requests that the server provide messages with sequence numbers that are not in the updated messaging client application 104. Specifically, the messaging client application 104 requests that the server provide updates or synchronize content of the messaging client application 104 that has not been provided already to the client device 102 by other means, such as via the third-party application 105. Namely, if the third-party application 105 received third and fourth messages in a communication session that have not been received by the messaging client application 104, the messaging client application 104 can retrieve such third and fourth messages from the local shared synchronization data 207. Then, the messaging client application 104, when performing a synchronization operation with the server, need not request that the third and fourth messages be provided. Instead, the messaging client application 104 requests that the server provide any messages that came after the third and fourth messages. In short, the messaging client application 104 performs two synchronization operations. First, the messaging client application 104 updates its state by synchronizing its content based on a local synchronization operation using content stored in the shared synchronization data 207. Second, the messaging client application 104 synchronizes its state (as updated by the first synchronization operation) by performing a remote synchronization operation with the server, such as the messaging server system 108, to synchronize content with content stored on the server.

FIG. 6 is a block diagram illustrating an example software architecture 606, which may be used in conjunction with various hardware architectures herein described. FIG. 6 is a non-limiting example of a software architecture and it will be appreciated that many other architectures may be implemented to facilitate the functionality described herein. The software architecture 606 may execute on hardware such as machine 700 of FIG. 7 that includes, among other things, processors 704, memory 714, and input/output (I/O) components 718. A representative hardware layer 652 is illustrated and can represent, for example, the machine 700 of FIG. 7. The representative hardware layer 652 includes a processing unit 654 having associated executable instructions 604. Executable instructions 604 represent the executable instructions of the software architecture 606, including implementation of the methods, components, and so forth described herein. The hardware layer 652 also includes memory and/or storage modules memory/storage 656, which also have executable instructions 604. The hardware layer 652 may also comprise other hardware 658.

In the example architecture of FIG. 6, the software architecture 606 may be conceptualized as a stack of layers where each layer provides particular functionality. For example, the software architecture 606 may include layers such as an operating system 602, libraries 620, frameworks/middleware 618, applications 616, and a presentation layer 614. Operationally, the applications 616 and/or other components within the layers may invoke API calls 608 through

the software stack and receive messages 612 in response to the API calls 608. The layers illustrated are representative in nature and not all software architectures have all layers. For example, some mobile or special purpose operating systems may not provide a frameworks/middleware 618, while others may provide such a layer. Other software architectures may include additional or different layers.

The operating system 602 may manage hardware resources and provide common services. The operating system 602 may include, for example, a kernel 622, services 624, and drivers 626. The kernel 622 may act as an abstraction layer between the hardware and the other software layers. For example, the kernel 622 may be responsible for memory management, processor management (e.g., scheduling), component management, networking, security settings, and so on. The services 624 may provide other common services for the other software layers. The drivers 626 are responsible for controlling or interfacing with the underlying hardware. For instance, the drivers 626 include display drivers, camera drivers, Bluetooth® drivers, flash memory drivers, serial communication drivers (e.g., Universal Serial Bus (USB) drivers), Wi-Fi® drivers, audio drivers, power management drivers, and so forth depending on the hardware configuration.

The libraries 620 provide a common infrastructure that is used by the applications 616 and/or other components and/or layers. The libraries 620 provide functionality that allows other software components to perform tasks in an easier fashion than to interface directly with the underlying operating system 602 functionality (e.g., kernel 622, services 624 and/or drivers 626). The libraries 620 may include system libraries 644 (e.g., C standard library) that may provide functions such as memory allocation functions, string manipulation functions, mathematical functions, and the like. In addition, the libraries 620 may include API libraries 646 such as media libraries (e.g., libraries to support presentation and manipulation of various media format such as MPEG4, H.264, MP3, AAC, AMR, JPG, PNG), graphics libraries (e.g., an OpenGL framework that may be used to render two-dimensional and three-dimensional in a graphic content on a display), database libraries (e.g., SQLite that may provide various relational database functions), web libraries (e.g., WebKit that may provide web browsing functionality), and the like. The libraries 620 may also include a wide variety of other libraries 648 to provide many other APIs to the applications 616 and other software components/modules.

The frameworks/middleware 618 (also sometimes referred to as middleware) provide a higher-level common infrastructure that may be used by the applications 616 and/or other software components/modules. For example, the frameworks/middleware 618 may provide various graphical user interface functions, high-level resource management, high-level location services, and so forth. The frameworks/middleware 618 may provide a broad spectrum of other APIs that may be utilized by the applications 616 and/or other software components/modules, some of which may be specific to a particular operating system 602 or platform.

The applications 616 include built-in applications 638 and/or third-party applications 640. Examples of representative built-in applications 638 may include, but are not limited to, a contacts application, a browser application, a book reader application, a location application, a media application, a messaging application, and/or a game application. Third-party applications 640 may include an application developed using the ANDROID™ or IOS™ software

development kit (SDK) by an entity other than the vendor of the particular platform, and may be mobile software running on a mobile operating system such as IOS™, ANDROID™, WINDOWS® Phone, or other mobile operating systems. The third-party applications 640 may invoke the API calls 608 provided by the mobile operating system (such as operating system 602) to facilitate functionality described herein.

The applications 616 may use built-in operating system functions (e.g., kernel 622, services 624, and/or drivers 626), libraries 620, and frameworks/middleware 618 to create UIs to interact with users of the system. Alternatively, or additionally, in some systems, interactions with a user may occur through a presentation layer, such as presentation layer 614. In these systems, the application/component “logic” can be separated from the aspects of the application/component that interact with a user.

FIG. 7 is a block diagram illustrating components of a machine 700, according to some example embodiments, able to read instructions from a machine-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 7 shows a diagrammatic representation of the machine 700 in the example form of a computer system, within which instructions 710 (e.g., software, a program, an application, an applet, an app, or other executable code) for causing the machine 700 to perform any one or more of the methodologies discussed herein may be executed. As such, the instructions 710 may be used to implement modules or components described herein. The instructions 710 transform the general, non-programmed machine 700 into a particular machine 700 programmed to carry out the described and illustrated functions in the manner described. In alternative embodiments, the machine 700 operates as a standalone device or may be coupled (e.g., networked) to other machines. In a networked deployment, the machine 700 may operate in the capacity of a server machine or a client machine in a server-client network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine 700 may comprise, but not be limited to, a server computer, a client computer, a personal computer (PC), a tablet computer, a laptop computer, a netbook, a set-top box (STB), a personal digital assistant (PDA), an entertainment media system, a cellular telephone, a smart phone, a mobile device, a wearable device (e.g., a smart watch), a smart home device (e.g., a smart appliance), other smart devices, a web appliance, a network router, a network switch, a network bridge, or any machine capable of executing the instructions 710, sequentially or otherwise, that specify actions to be taken by machine 700. Further, while only a single machine 700 is illustrated, the term “machine” shall also be taken to include a collection of machines that individually or jointly execute the instructions 710 to perform any one or more of the methodologies discussed herein.

The machine 700 may include processors 704, memory/storage 706, and I/O components 718, which may be configured to communicate with each other such as via a bus 702. In an example embodiment, the processors 704 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 708 and a processor 712 that may execute the instructions

710. The term “processor” is intended to include multi-core processors 704 that may comprise two or more independent processors (sometimes referred to as “cores”) that may execute instructions 710 contemporaneously. Although FIG. 7 shows multiple processors 704, the machine 700 may include a single processor 708 with a single core, a single processor 708 with multiple cores (e.g., a multi-core processor), multiple processors 708, 712 with a single core, multiple processors 708, 712 with multiple cores, or any combination thereof.

The memory/storage 706 may include a memory 714, such as a main memory, or other memory storage, and a storage unit 716, both accessible to the processors 704 such as via the bus 702. The storage unit 716 and memory 714 store the instructions 710 embodying any one or more of the methodologies or functions described herein. The instructions 710 may also reside, completely or partially, within the memory 714, within the storage unit 716, within at least one of the processors 704 (e.g., within the processor’s cache memory), or any suitable combination thereof, during execution thereof by the machine 700. Accordingly, the memory 714, the storage unit 716, and the memory of processors 704 are examples of machine-readable media.

The I/O components 718 may include a wide variety of components to receive input, provide output, produce output, transmit information, exchange information, capture measurements, and so on. The specific I/O components 718 that are included in a particular machine 700 will depend on the type of machine. For example, portable machines such as mobile phones will likely include a touch input device or other such input mechanisms, while a headless server machine will likely not include such a touch input device. It will be appreciated that the I/O components 718 may include many other components that are not shown in FIG. 7. The I/O components 718 are grouped according to functionality merely for simplifying the following discussion and the grouping is in no way limiting. In various example embodiments, the I/O components 718 may include output components 726 and input components 728. The output components 726 may include visual components (e.g., a display such as a plasma display panel (PDP), a light emitting diode (LED) display, a liquid crystal display (LCD), a projector, or a cathode ray tube (CRT)), acoustic components (e.g., speakers), haptic components (e.g., a vibratory motor, resistance mechanisms), other signal generators, and so forth. The input components 728 may include alphanumeric input components (e.g., a keyboard, a touch screen configured to receive alphanumeric input, a photo-optical keyboard, or other alphanumeric input components), point-based input components (e.g., a mouse, a touchpad, a trackball, a joystick, a motion sensor, or other pointing instrument), tactile input components (e.g., a physical button, a touch screen that provides location and/or force of touches or touch gestures, or other tactile input components), audio input components (e.g., a microphone), and the like.

In further example embodiments, the I/O components 718 may include biometric components 739, motion components 734, environmental components 736, or position components 738 among a wide array of other components. For example, the biometric components 739 may include components to detect expressions (e.g., hand expressions, facial expressions, vocal expressions, body gestures, or eye tracking), measure biosignals (e.g., blood pressure, heart rate, body temperature, perspiration, or brain waves), identify a person (e.g., voice identification, retinal identification, facial identification, fingerprint identification, or electroencephalogram based identification), and the like. The motion com-

ponents **734** may include acceleration sensor components (e.g., accelerometer), gravitation sensor components, rotation sensor components (e.g., gyroscope), and so forth. The environmental components **736** may include, for example, illumination sensor components (e.g., photometer), temperature sensor components (e.g., one or more thermometer that detect ambient temperature), humidity sensor components, pressure sensor components (e.g., barometer), acoustic sensor components (e.g., one or more microphones that detect background noise), proximity sensor components (e.g., infrared sensors that detect nearby objects), gas sensors (e.g., gas detection sensors to detection concentrations of hazardous gases for safety or to measure pollutants in the atmosphere), or other components that may provide indications, measurements, or signals corresponding to a surrounding physical environment. The position components **738** may include location sensor components (e.g., a GPS receiver component), altitude sensor components (e.g., altimeters or barometers that detect air pressure from which altitude may be derived), orientation sensor components (e.g., magnetometers), and the like.

Communication may be implemented using a wide variety of technologies. The I/O components **718** may include communication components **740** operable to couple the machine **700** to a network **737** or devices **729** via coupling **724** and coupling **722**, respectively. For example, the communication components **740** may include a network interface component or other suitable device to interface with the network **737**. In further examples, communication components **740** may include wired communication components, wireless communication components, cellular communication components, near field communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components to provide communication via other modalities. The devices **729** may be another machine **700** or any of a wide variety of peripheral devices (e.g., a peripheral device coupled via a USB).

Moreover, the communication components **740** may detect identifiers or include components operable to detect identifiers. For example, the communication components **740** may include radio frequency identification (RFID) tag reader components, NFC smart tag detection components, optical reader components (e.g., an optical sensor to detect one-dimensional bar codes such as Universal Product Code (UPC) bar code, multi-dimensional bar codes such as Quick Response (QR) code, Aztec code, Data Matrix, Dataglyph, MaxiCode, PDF417, Ultra Code, UCC RSS-2D bar code, and other optical codes), or acoustic detection components (e.g., microphones to identify tagged audio signals). In addition, a variety of information may be derived via the communication components **740**, such as location via Internet Protocol (IP) geolocation, location via Wi-Fi® signal triangulation, location via detecting a NFC beacon signal that may indicate a particular location, and so forth.

Glossary:

“CARRIER SIGNAL,” in this context, refers to any intangible medium that is capable of storing, encoding, or carrying transitory or non-transitory instructions **710** for execution by the machine **700**, and includes digital or analog communications signals or other intangible medium to facilitate communication of such instructions **710**. Instructions **710** may be transmitted or received over the network **106** using a transitory or non-transitory transmission medium via a network interface device and using any one of a number of well-known transfer protocols.

“CLIENT DEVICE,” in this context, refers to any machine **700** that interfaces to a communications network **106** to obtain resources from one or more server systems or other client devices **102**. A client device **102** may be, but is not limited to, a mobile phone, desktop computer, laptop, PDAs, smart phones, tablets, ultra books, netbooks, laptops, multi-processor systems, microprocessor-based or programmable consumer electronics, game consoles, set-top boxes, or any other communication device that a user may use to access a network **106**.

“COMMUNICATIONS NETWORK,” in this context, refers to one or more portions of a network **106** that may be an ad hoc network, an intranet, an extranet, a virtual private network (VPN), a local area network (LAN), a wireless LAN (WLAN), a wide area network (WAN), a wireless WAN (WWAN), a metropolitan area network (MAN), the Internet, a portion of the Internet, a portion of the Public Switched Telephone Network (PSTN), a plain old telephone service (POTS) network, a cellular telephone network, a wireless network, a Wi-Fi® network, another type of network, or a combination of two or more such networks. For example, a network **106** or a portion of a network may include a wireless or cellular network and the coupling may be a Code Division Multiple Access (CDMA) connection, a Global System for Mobile communications (GSM) connection, or other type of cellular or wireless coupling. In this example, the coupling may implement any of a variety of types of data transfer technology, such as Single Carrier Radio Transmission Technology (1xRTT), Evolution-Data Optimized (EVDO) technology, General Packet Radio Service (GPRS) technology, Enhanced Data rates for GSM Evolution (EDGE) technology, third Generation Partnership Project (3GPP) including 3G, fourth generation wireless (4G) networks, Universal Mobile Telecommunications System (UMTS), High Speed Packet Access (HSPA), Worldwide Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE) standard, others defined by various standard setting organizations, other long range protocols, or other data transfer technology.

“EPHEMERAL MESSAGE,” in this context, refers to a message **300** that is accessible for a time-limited duration. An ephemeral message may be a text, an image, a video, and the like. The access time for the ephemeral message may be set by the message sender. Alternatively, the access time may be a default setting or a setting specified by the recipient. Regardless of the setting technique, the message **300** is transitory.

“MACHINE-READABLE MEDIUM,” in this context, refers to a component, device, or other tangible media able to store instructions **710** and data temporarily or permanently and may include, but is not limited to, random-access memory (RAM), read-only memory (ROM), buffer memory, flash memory, optical media, magnetic media, cache memory, other types of storage (e.g., erasable programmable read-only memory (EEPROM)) and/or any suitable combination thereof. The term “machine-readable medium” should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, or associated caches and servers) able to store instructions **710**. The term “machine-readable medium” shall also be taken to include any medium, or combination of multiple media, that is capable of storing instructions **710** (e.g., code) for execution by a machine **700**, such that the instructions **710**, when executed by one or more processors **704** of the machine **700**, cause the machine **700** to perform any one or more of the methodologies described herein. Accordingly, a “machine-readable medium” refers to a single storage apparatus or

device, as well as “cloud-based” storage systems or storage networks that include multiple storage apparatus or devices. The term “machine-readable medium” excludes signals per se.

“COMPONENT,” in this context, refers to a device, physical entity, or logic having boundaries defined by function or subroutine calls, branch points, APIs, or other technologies that provide for the partitioning or modularization of particular processing or control functions. Components may be combined via their interfaces with other components to carry out a machine process. A component may be a packaged functional hardware unit designed for use with other components and a part of a program that usually performs a particular function of related functions. Components may constitute either software components (e.g., code embodied on a machine-readable medium) or hardware components. A “hardware component” is a tangible unit capable of performing certain operations and may be configured or arranged in a certain physical manner. In various example embodiments, one or more computer systems (e.g., a standalone computer system, a client computer system, or a server computer system) or one or more hardware components of a computer system (e.g., a processor or a group of processors) may be configured by software (e.g., an application or application portion) as a hardware component that operates to perform certain operations as described herein.

A hardware component may also be implemented mechanically, electronically, or any suitable combination thereof. For example, a hardware component may include dedicated circuitry or logic that is permanently configured to perform certain operations. A hardware component may be a special-purpose processor, such as a field-programmable gate array (FPGA) or an ASIC. A hardware component may also include programmable logic or circuitry that is temporarily configured by software to perform certain operations. For example, a hardware component may include software executed by a general-purpose processor **708** or other programmable processor. Once configured by such software, hardware components become specific machines (or specific components of a machine **700**) uniquely tailored to perform the configured functions and are no longer general-purpose processors **708**. It will be appreciated that the decision to implement a hardware component mechanically, in dedicated and permanently configured circuitry, or in temporarily configured circuitry (e.g., configured by software) may be driven by cost and time considerations. Accordingly, the phrase “hardware component” (or “hardware-implemented component”) should be understood to encompass a tangible entity, be that an entity that is physically constructed, permanently configured (e.g., hardwired), or temporarily configured (e.g., programmed) to operate in a certain manner or to perform certain operations described herein. Considering embodiments in which hardware components are temporarily configured (e.g., programmed), each of the hardware components need not be configured or instantiated at any one instance in time. For example, where a hardware component comprises a general-purpose processor **708** configured by software to become a special-purpose processor, the general-purpose processor **708** may be configured as respectively different special-purpose processors (e.g., comprising different hardware components) at different times. Software accordingly configures a particular processor **708** or processors **704**, for example, to constitute a particular hardware component at one instance of time and to constitute a different hardware component at a different instance of time.

Hardware components can provide information to, and receive information from, other hardware components. Accordingly, the described hardware components may be regarded as being communicatively coupled. Where multiple hardware components exist contemporaneously, communications may be achieved through signal transmission (e.g., over appropriate circuits and buses) between or among two or more of the hardware components. In embodiments in which multiple hardware components are configured or instantiated at different times, communications between such hardware components may be achieved, for example, through the storage and retrieval of information in memory structures to which the multiple hardware components have access. For example, one hardware component may perform an operation and store the output of that operation in a memory device to which it is communicatively coupled. A further hardware component may then, at a later time, access the memory device to retrieve and process the stored output.

Hardware components may also initiate communications with input or output devices, and can operate on a resource (e.g., a collection of information). The various operations of example methods described herein may be performed, at least partially, by one or more processors **704** that are temporarily configured (e.g., by software) or permanently configured to perform the relevant operations. Whether temporarily or permanently configured, such processors **704** may constitute processor-implemented components that operate to perform one or more operations or functions described herein. As used herein, “processor-implemented component” refers to a hardware component implemented using one or more processors **704**. Similarly, the methods described herein may be at least partially processor-implemented, with a particular processor **708** or processors **704** being an example of hardware. For example, at least some of the operations of a method may be performed by one or more processors **704** or processor-implemented components. Moreover, the one or more processors **704** may also operate to support performance of the relevant operations in a “cloud computing” environment or as a “software as a service” (SaaS). For example, at least some of the operations may be performed by a group of computers (as examples of machines **700** including processors **704**), with these operations being accessible via a network **106** (e.g., the Internet) and via one or more appropriate interfaces (e.g., an API). The performance of certain of the operations may be distributed among the processors, not only residing within a single machine **700**, but deployed across a number of machines. In some example embodiments, the processors **704** or processor-implemented components may be located in a single geographic location (e.g., within a home environment, an office environment, or a server farm). In other example embodiments, the processors **704** or processor-implemented components may be distributed across a number of geographic locations.

“PROCESSOR,” in this context, refers to any circuit or virtual circuit (a physical circuit emulated by logic executing on an actual processor **708**) that manipulates data values according to control signals (e.g., “commands,” “op codes,” “machine code,” etc.) and which produces corresponding output signals that are applied to operate a machine **700**. A processor **708** may, for example, be a CPU, a RISC processor, a CISC processor, a GPU, a DSP, an ASIC, a RFIC or any combination thereof. A processor **708** may further be a multi-core processor having two or more independent processors **704** (sometimes referred to as “cores”) that may execute instructions **710** contemporaneously.

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“TIMESTAMP,” in this context, refers to a sequence of characters or encoded information identifying when a certain event occurred, for example giving date and time of day, sometimes accurate to a small fraction of a second.

Changes and modifications may be made to the disclosed embodiments without departing from the scope of the present disclosure. These and other changes or modifications are intended to be included within the scope of the present disclosure, as expressed in the following claims.

What is claimed is:

1. A method comprising:
 - establishing a communication session between a plurality of user devices; and
 - identifying a difference between a current state of an application and a shared synchronization database, the shared synchronization database storing identifiers of one or more content items exchanged in the communication session, the shared synchronization database storing a matrix comprising a plurality of vectors, a first vector of the plurality of vectors being associated with a first user device of the plurality of user devices, the first vector storing a first set of sequence numbers of content items sent by the first user device, a second vector of the plurality of vectors being associated with a second user device of the plurality of user devices, the second vector storing a second set of sequence numbers of content items sent by the second user device.
2. The method of claim 1, further comprising:
 - receiving, by an external application from a server, as a notification, a content item corresponding to the communication session of the application implemented on the first user device; and
 - presenting, by the external application, the content item on the first user device while the application is inactive, the application not being informed about the content item that has been presented on the first user device.
3. The method of claim 1, further comprising:
 - retrieving information from the shared synchronization database to update the current state of the application based on the identified difference; and
 - transmitting, to a server by the application, a request for content based on the update to the current state of the application.
4. The method of claim 1, wherein the shared synchronization database is stored locally on the first user device.
5. The method of claim 1, wherein a first dimension of the matrix represents the plurality of user devices, and wherein a second dimension of the matrix represents sequence numbers of the content items sent by the plurality of user devices, respectively.
6. The method of claim 1, wherein the difference identifies a given content item exchanged in the communication session, further comprising:
 - obtaining the given content item from the shared synchronization database; and
 - adding the given content item to the communication session of the application.
7. The method of claim 1, further comprising:
 - transmitting, to a server, a synchronization request from the application;
 - causing the server to identify version information representing an update to the current state of the application;
 - causing the server to retrieve current version information of content stored by the server;
 - causing the server to identify a set of versions that are later than the version information representing the update to the current state of the application; and

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receiving, from the server, the content corresponding to the set of versions.

8. The method of claim 7, further comprising updating the shared synchronization database based on the received content by updating version information stored in the shared synchronization database.

9. The method of claim 1, wherein identifying the difference comprises:

- generating, by the application, a first vector of sequence numbers;
- retrieving, by the application from the shared synchronization database, a second vector of sequence numbers; and
- identifying one or more sequence numbers that differ between the first and second vectors.

10. The method of claim 9, further comprising accessing an external application to retrieve one or more content items corresponding to the one or more sequence numbers that differ between the first and second vectors.

11. The method of claim 9, wherein each sequence number represents a respective content item sent by a participant in the communication session, and wherein each sequence number is associated with a participant identifier of the participant that sent the respective content item.

12. The method of claim 1, further comprising:

- establishing, at a previous time, the communication session on the first user device comprising a first set of content items received from a server;
- ending a synchronization session with the server after establishing the communication session at the previous time;
- receiving, by the first user device, as a notification, a second set of content items in the communication session by an external application;
- identifying, as the difference, identifiers of a third set of content items exchanged in the communication session after the previous time, the third set of content items corresponding to a subset of the second set of content items that is different from the first set of content items; and
- updating the current state of the application using the identifiers of the third set of content items.

13. The method of claim 12, further comprising:

- causing the server to identify a fourth set of content items that differ from the first set of content items and the second set of content items; and
- receiving, from the server, the fourth set of content items.

14. The method of claim 1, wherein an external application comprises a dedicated application on an operating system of the first user device configured to receive push notifications for a plurality of applications implemented on the first user device, the plurality of applications including the application.

15. The method of claim 1, further comprising:

- receiving a new content item from a given user;
- identifying a given vector of the plurality of vectors associated with the given user;
- generating a new sequence number for the new content item by incrementing a value of a last sequence number stored in the given vector; and
- storing the new sequence number in the given vector for the given user.

16. A system comprising:

- at least one processor configured to perform operations comprising:
 - establishing a communication session between a plurality of user devices; and

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identifying a difference between a current state of an application and a shared synchronization database, the shared synchronization database storing identifiers of one or more content items exchanged in the communication session, the shared synchronization database storing a matrix comprising a plurality of vectors, a first vector of the plurality of vectors being associated with a first user device of the plurality of user devices, the first vector storing a first set of sequence numbers of content items sent by the first user device, a second vector of the plurality of vectors being associated with a second user device of the plurality of user devices, the second vector storing a second set of sequence numbers of content items sent by the second user device.

17. The system of claim 16, the operations comprising: receiving, by an external application from a server, as a notification, a content item corresponding to the communication session of the application implemented on the first user device; and

presenting, by the external application, the content item on the first user device while the application is inactive, the application not being informed about the content item that has been presented on the first user device.

18. The system of claim 16, further comprising operations for:

retrieving information from the shared synchronization database to update the current state of the application based on the identified difference; and

transmitting, to a server by the application, a request for content based on the update to the current state of the application.

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19. The system of claim 16, wherein the difference identifies a given content item exchanged in the communication session, and the operations comprise:

obtaining the given content item from the shared synchronization database; and

adding the given content item to the communication session of the application.

20. A non-transitory machine-readable storage medium that includes instructions that, when executed by one or more processors of a machine, cause the machine to perform operations comprising:

establishing a communication session between a plurality of user devices; and

identifying a difference between a current state of an application and a shared synchronization database, the shared synchronization database storing identifiers of one or more content items exchanged in the communication session, the shared synchronization database storing a matrix comprising a plurality of vectors, a first vector of the plurality of vectors being associated with a first user device of the plurality of user devices, the first vector storing a first set of sequence numbers of content items sent by the first user device, a second vector of the plurality of vectors being associated with a second user device of the plurality of user devices, the second vector storing a second set of sequence numbers of content items sent by the second user device.

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