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(54) RUNTIME SYSTEMS QUERY COORDINATOR

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G06F 16/242	(2019.01)

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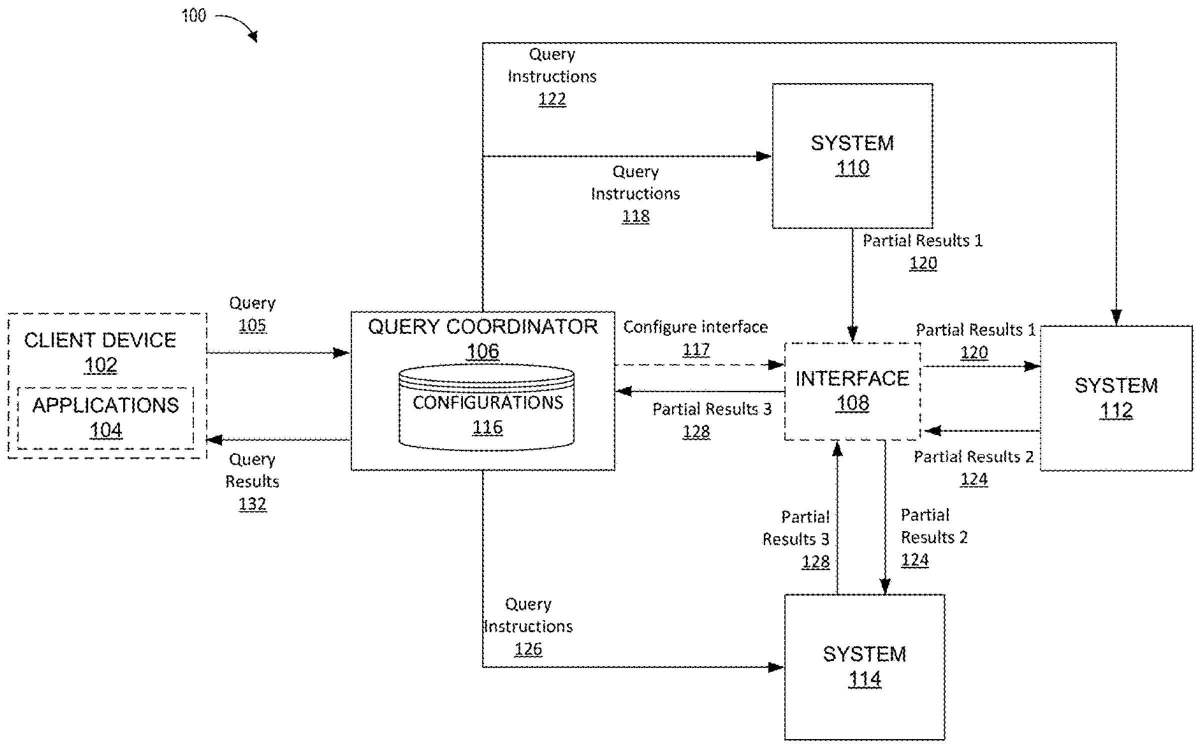
(57) **ABSTRACT**

Systems and methods are disclosed for receiving, at query coordinator, a search query. The query coordinator parses the search query and generates tasks for different runtime systems. The query coordinator configures an interface enabling inter system communication between the runtime systems. The generated tasks are distributed to the runtime systems and partial results of a runtime system are communicated to the interface. The query coordinator retrieves the partial results from the interface, finalizes the partial results, and sends finalized results them to the requestor of the search query.



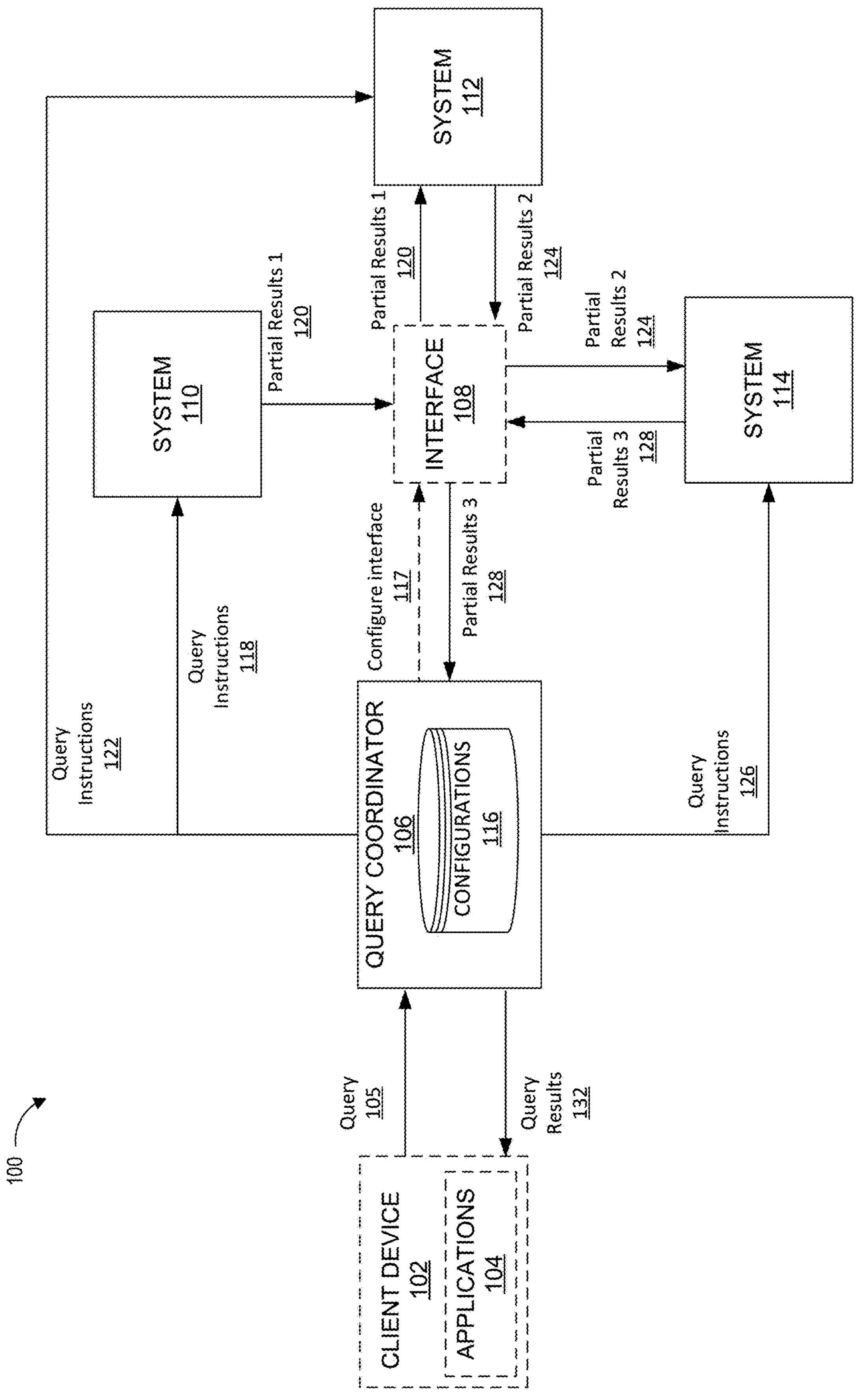

100
CLIENT DEVICE 102
APPLICATIONS 104
Query 105
Query Results 132
QUERY COORDINATOR 106
CONFIGURATIONS 116
Query Instructions 122
Query Instructions 118
Configure interface 117
Partial Results 3 128
Query Instructions 126
SYSTEM 110
Partial Results 1 120
INTERFACE 108
Partial Results 1 120
Partial Results 2 124
SYSTEM 112
Partial Results 2 124
Partial Results 3 128
SYSTEM 114

FIG. 1

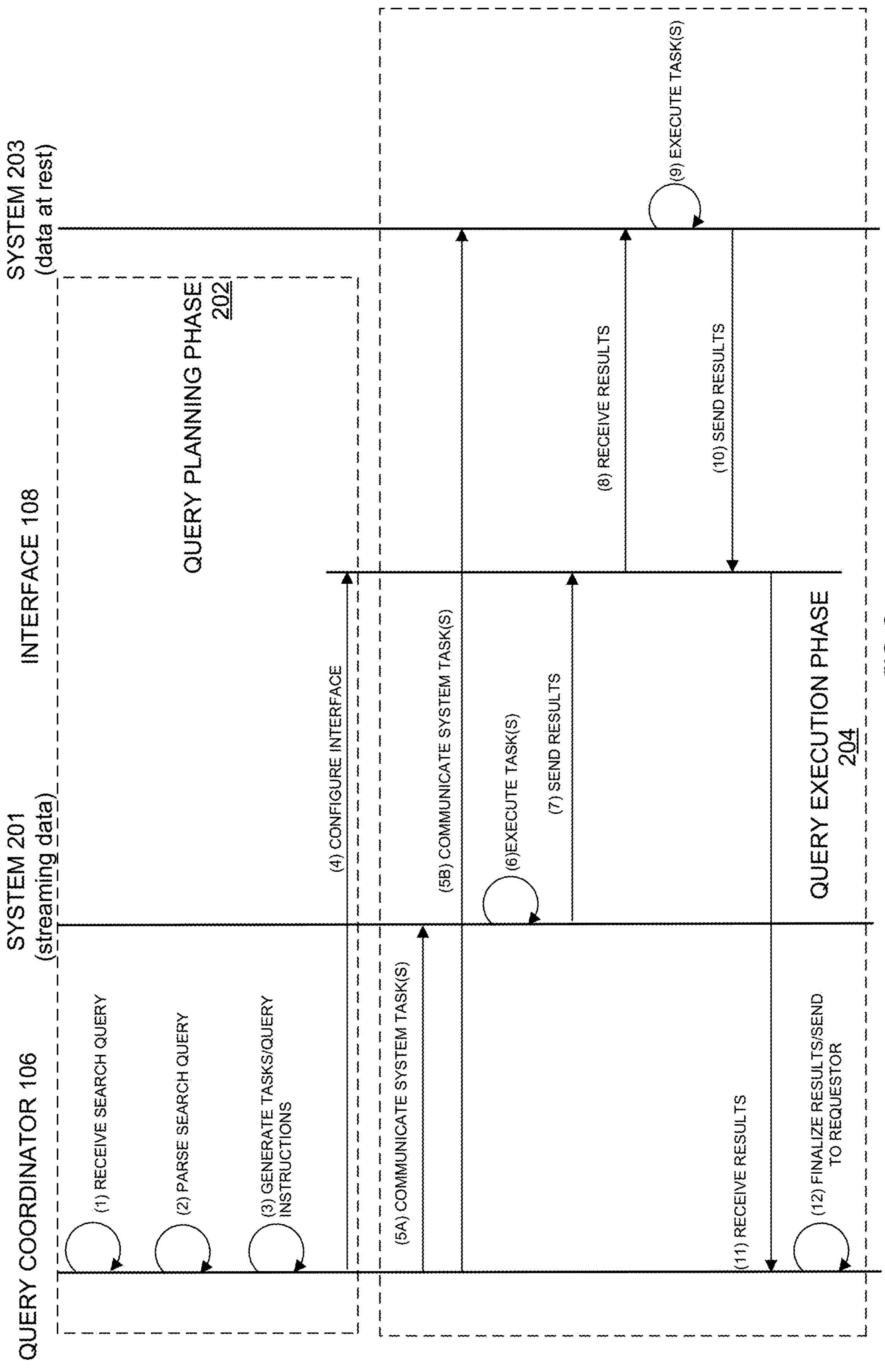

QUERY COORDINATOR 106
SYSTEM 201 (streaming data)
INTERFACE 108
SYSTEM 203 (data at rest)
QUERY PLANNING PHASE 202
QUERY EXECUTION PHASE 204
(1) RECEIVE SEARCH QUERY
(2) PARSE SEARCH QUERY
(3) GENERATE TASKS/QUERY INSTRUCTIONS
(4) CONFIGURE INTERFACE
(5A) COMMUNICATE SYSTEM TASK(S)
(5B) COMMUNICATE SYSTEM TASK(S)
(6)EXECUTE TASK(S)
(7) SEND RESULTS
(8) RECEIVE RESULTS
(9) EXECUTE TASK(S)
(10) SEND RESULTS
(11) RECEIVE RESULTS
(12) FINALIZE RESULTS/SEND TO REQUESTOR

FIG. 2

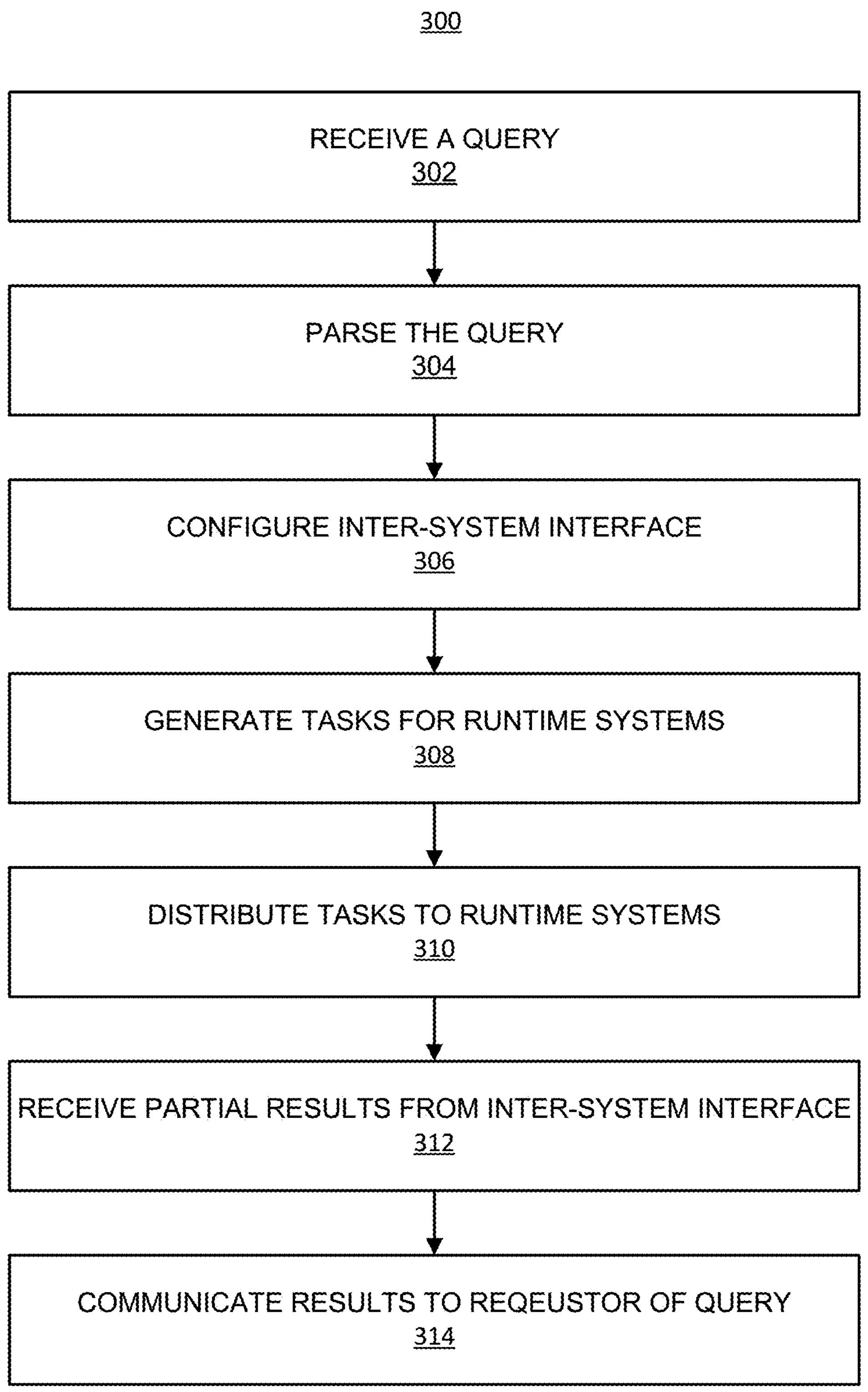

300
RECEIVE A QUERY 302
PARSE THE QUERY 304
CONFIGURE INTER-SYSTEM INTERFACE 306
GENERATE TASKS FOR RUNTIME SYSTEMS 308
DISTRIBUTE TASKS TO RUNTIME SYSTEMS 310
RECEIVE PARTIAL RESULTS FROM INTER-SYSTEM INTERFACE 312
COMMUNICATE RESULTS TO REQEUSTOR OF QUERY 314

FIG. 3

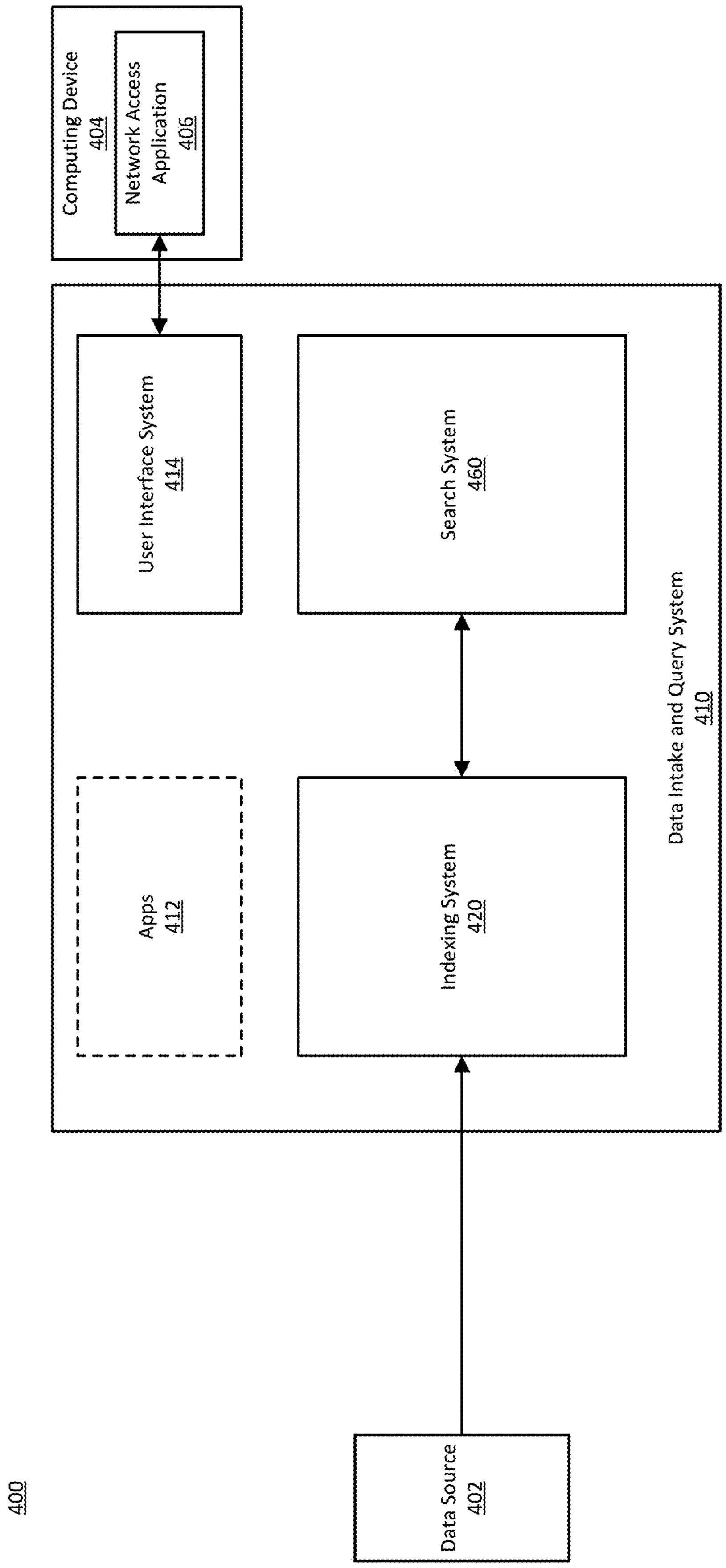

400
Data Source
402
Data Intake and Query System
410
Apps
412
User Interface System
414
Indexing System
420
Search System
460
Computing Device
404
Network Access Application
406

FIG. 4A

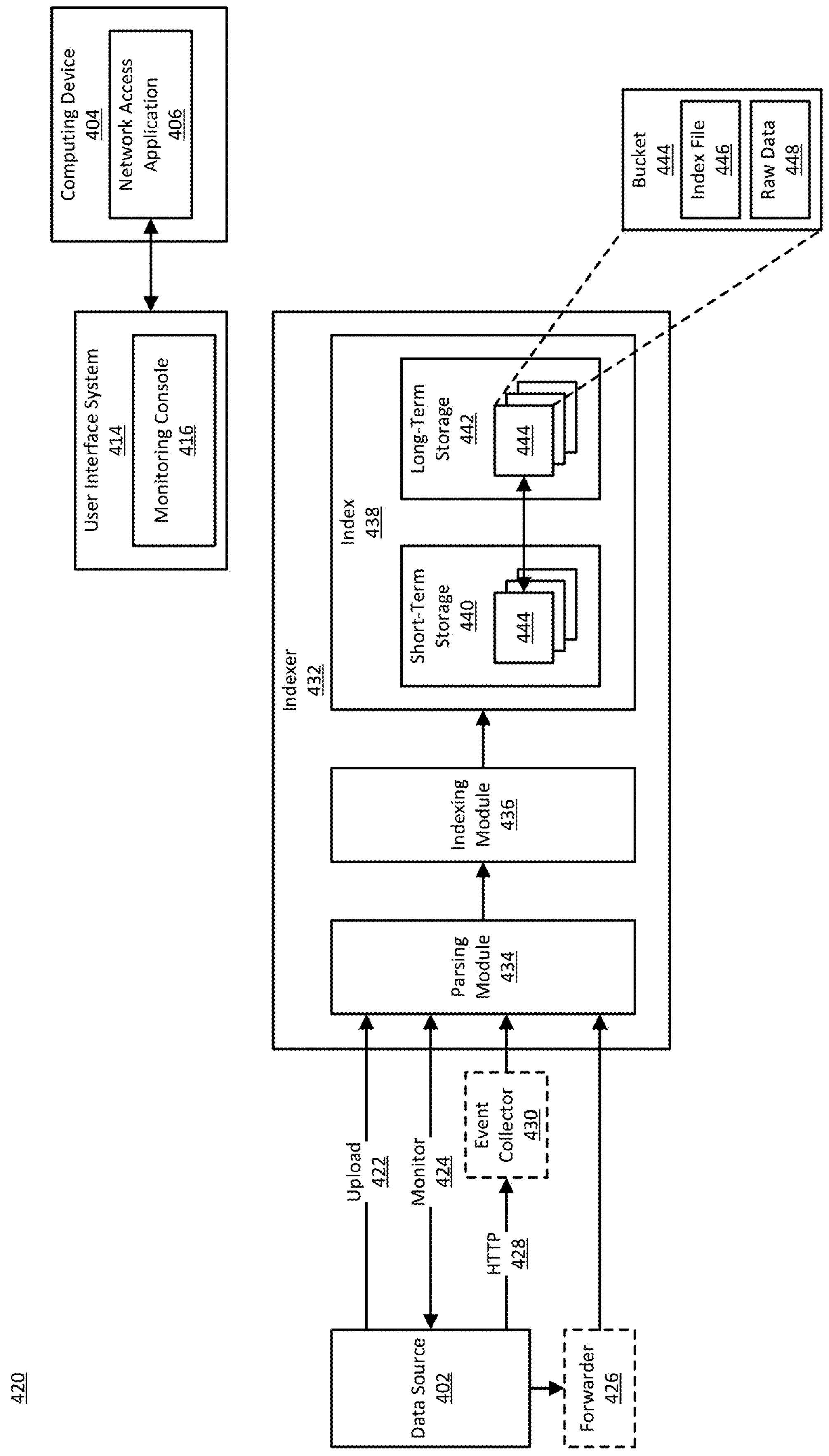

420
Data Source 402
Forwarder 426
Upload 422
Monitor 424
HTTP 428
Event Collector 430
Indexer 432
Parsing Module 434
Indexing Module 436
Index 438
Short-Term Storage 440
444
Long-Term Storage 442
444
Bucket 444
Index File 446
Raw Data 448
User Interface System 414
Monitoring Console 416
Computing Device 404
Network Access Application 406

FIG. 4B

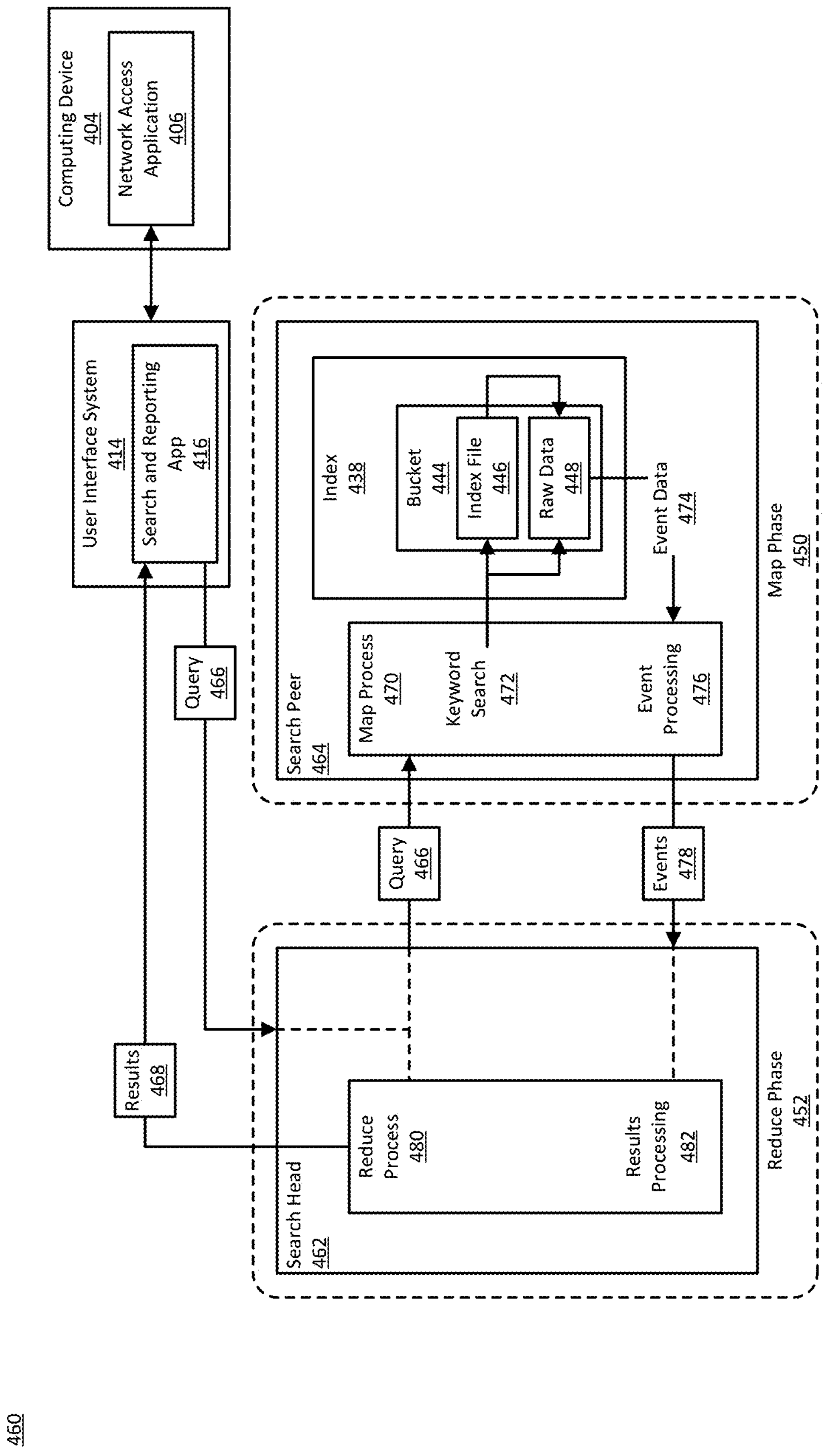
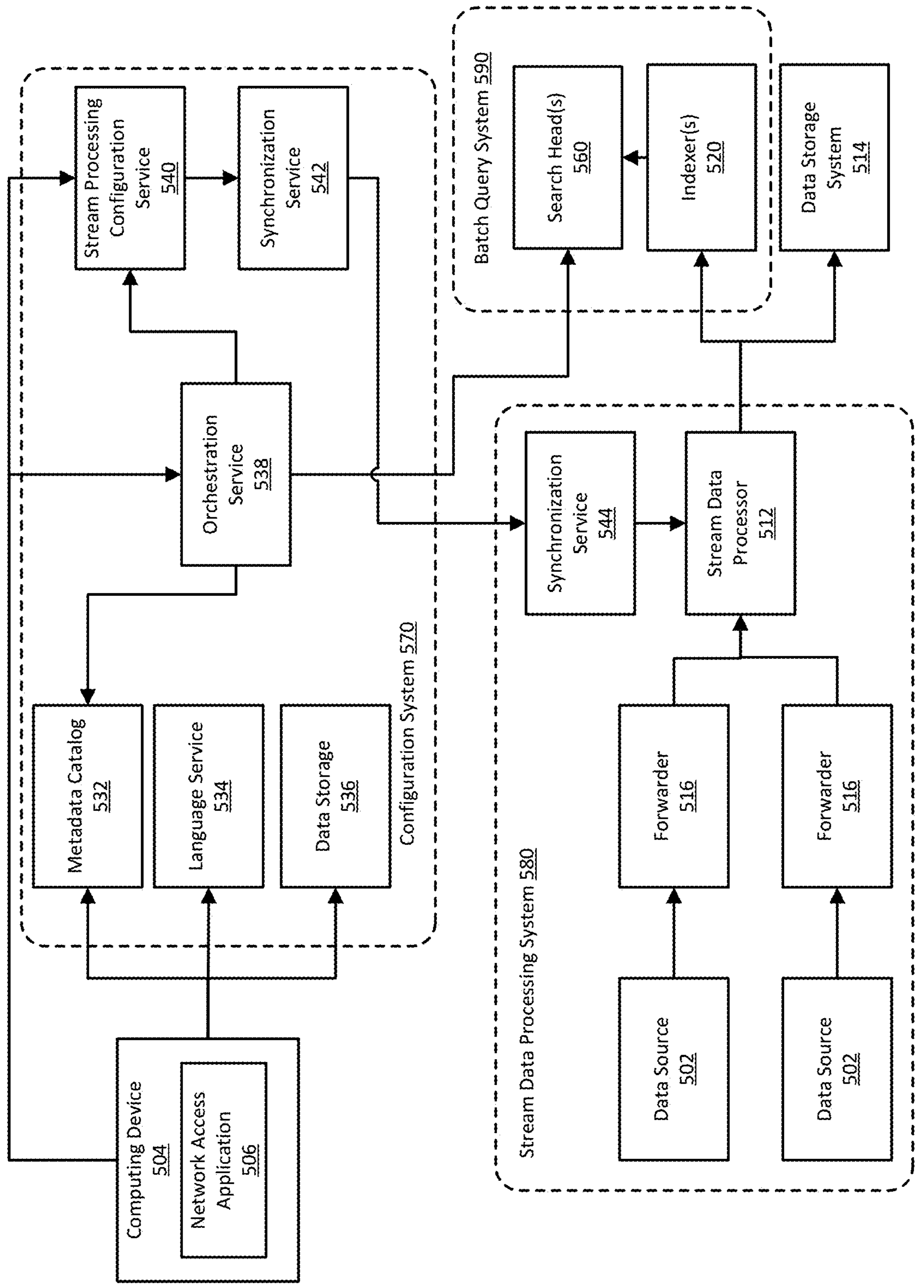

460
Computing Device 404
Network Access Application 406
User Interface System 414
Search and Reporting App 416
Query 466
Results 468
Search Peer 464
Map Process 470
Keyword Search 472
Event Processing 476
Index 438
Bucket 444
Index File 446
Raw Data 448
Event Data 474
Map Phase 450
Query 466
Events 478
Search Head 462
Reduce Process 480
Results Processing 482
Reduce Phase 452

FIG. 4C



Computing Device 504
Network Access Application 506
Metadata Catalog 532
Language Service 534
Data Storage 536
Configuration System 570
Orchestration Service 538
Stream Processing Configuration Service 540
Synchronization Service 542
Batch Query System 590
Search Head(s) 560
Indexer(s) 520
Data Storage System 514
Stream Data Processing System 580
Synchronization Service 544
Stream Data Processor 512
Forwarder 516
Forwarder 516
Data Source 502
Data Source 502

FIG. 5

RUNTIME SYSTEMS QUERY COORDINATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 18/309,596, filed on Apr. 28, 2023, which itself claims priority to U.S. Provisional Application 63/482,530, filed on Jan. 31, 2023, the entire contents of which are fully incorporated herein by reference.

BACKGROUND

[0002] Information technology (IT) environments can include diverse types of data systems that process, manage, or store large amounts of diverse data types generated by numerous devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Illustrative examples are described in detail below with reference to the following figures:

[0004] FIG. **1** is a block diagram of an example environment in which an embodiment may be implemented.

[0005] FIG. **2** is a data flow diagram illustrating an embodiment of communications between various components to process a query involving multiple systems.

[0006] FIG. **3** is a flow diagram illustrating an embodiment of a routine implemented by a query coordinator to process a search query.

[0007] FIG. **4**A is a block diagram illustrating an example computing environment.

[0008] FIG. **4**B is a block diagram illustrating an example of an indexing system of a data intake and query system.

[0009] FIG. **4**C is a block diagram illustrating an example of the search system.

[0010] FIG. **5** illustrates an example of a self-managed network that includes a data intake and query system.

DETAILED DESCRIPTION

[0011] Big data environments may include different systems that process different types of data in different ways and/or process data in different states (also referred to herein as different runtime systems). Some example runtime systems include streaming data processing systems that may process streaming data in real-time (e.g., as it is output by/received from a data source and before it is stored in non-volatile memory (e.g., a data store)), batch search systems or database systems that may process data in batches or data at rest (e.g., data pulled from non-volatile memory, such as log data, metrics data, etc.), tracing data processing systems that may process traces corresponding to isolated execution environments (e.g., virtual machines, software containers, etc.) instantiated in a hosted computing environment, and machine learning data processing systems that may process data using a machine learning model (e.g., to identify abnormalities or deviations in the data). Accordingly, the streaming data processing systems, batch search systems/database systems, tracing data processing systems, and machine learning data processing systems may be referred to as different runtime systems.

[0012] The different runtime systems may operate independently and provide users with distinct user interfaces that enable the users to use the respective runtime systems. For example, a user may independently and/or separately process data using a streaming data processing system, batch search system, tracing data processing system, and/or a machine learning data processing system, and then view the results via different user interfaces of the respective systems. As such, the data managed, processed, or stored by the various runtime systems may be siloed from each other and therefore it may not be feasible to execute queries that rely on partial results from multiple different runtime systems.

[0013] The different runtime systems may also use different computer or query languages to process data. For example, a batch search system may use a query processing language, such as Splunk Processing Language (SPL) or SQL, to identify data to be processed and how to process the data, whereas a streaming data processing system may not use a query processing language and/or may use C or some other computer language to determine how to process the streaming data. Similarly, a tracing data processing system and/or a machine learning data processing system may operate using different computer languages. In some cases, if a requestor of a search query wants query results that involve different runtime systems, the requestor may have to write separate queries for each runtime system in the language of the respective runtime systems.

[0014] In addition, as the data from the different runtime systems is managed by the respective runtime systems, a user may be unable to have the different runtime systems process the data in a particular sequence. For example, the user may be unable to use the streaming data processing system to perform some amount of processing on a set of data, use the batch search systems to perform further processing on the set of data (possibly in combination with additional data from the batch search system), and then have the machine learning data processing system perform even more processing on the set of data from the batch search system.

[0015] To address these and other potential issues, a query coordinator may be used to coordinate searches between multiple runtime systems. In some cases, the query coordinator may coordinate searches that involve the sequential processing of data by different runtime systems. In certain cases, to coordinate the processing of searches using multiple runtime systems, the query coordinator may configure an inter-system interface that receives results of one runtime system processing data and enables subsequent runtime systems to pull the results and further process them.

[0016] As described herein, a query coordinator may receive a search query from a user device or requestor. The query coordinator may parse the search query to identify operations and/or commands associated with the search query. Moreover, the query coordinator may identify different (runtime) systems which relate to the operations and/or commands. The query coordinator may also configure an interface to allow inter-system communication between the different (runtime) systems.

[0017] The query coordinator may also distribute tasks to the different (runtime) systems for the different (runtime) systems to execute. Each (runtime) system may participate in the execution of the query based on the tasks received from the query coordinator. In some cases, this may include receiving and processing data from the interface configured by the query coordinator and/or sending partial results to the interface for another (runtime) system or the query coordinator to retrieve. In some cases, the interface may be configured under a publisher subscriber model (pub/sub) and publish results received from one (runtime) system for consumption by another (runtime) system and/or the query coordinator. The query coordinator retrieves results from the interface and finalizes them before communicating the results to the user device or requestor.

[0018] Accordingly, the solutions described herein may enable the (sequential) use of multiple (runtime) systems as part of a single query (also referred to herein as a search query) received from a user. As described herein, the query coordinator may enable a user to send a single search query to process data using multiple runtime systems, rather than the user writing multiple queries in different query languages and manually communicating the results of one query from one runtime system to another runtime system for further processing. Moreover, the solutions described herein enable the requestor to be agnostic to the internal workings of the various runtime systems. This allows for a more simple and straightforward process leaving the technical underpinnings (communications between different runtime systems, multiple query processing, etc.) to the query coordinator.

[0019] FIG. **1** is a block diagram illustrating an example of a data processing environment **100**. In the illustrated example, the environment **100** includes a client device **102**, query coordinator **106**, inter-system interface **108**, and different (runtime) systems **110**, **112**, and **114**, however, it will be understood that the environment **100** may include fewer or more components. For example, the environment **100** may include fewer or more client devices **102**, query coordinators **106**, interfaces **108**, and/or (runtime) systems **110**-**114**.

[0020] The systems illustrated in the environment **100** may be communicatively coupled and communicate via one or more networks, such as a wide area network, local area network, private network, etc. In some cases, the query coordinator **106**, inter-system interface **108**, system **110**, system **112**, and system **114** may be implemented in separate computing devices and/or separate isolated execution environments (e.g., as virtual machines, software containers, etc.). In some cases, such as when the query coordinator **106**, inter-system interface **108**, system **110**, system **112**, and system **114** are implemented as isolated execution environments, the various components may communicate via one or more computer buses.

[0021] The client device **102** may include one or more applications **104** being executed by one or more processors of the client device **102**. An example client device may include a personal computer, laptop, tablet, phone, or other computing device running a network browser application that enables a user of the client device **102** to communicate with the query coordinator **106**.

[0022] The query coordinator **106** may be implemented using one or more processors, isolated execution environments (e.g., virtual machines, software container, etc.) and may be used to coordinate the processing and execution of queries between one or more runtime systems **110**, **112**, and **114**. In this way, the query coordinator **106** may function as a coordinator and/or orchestrator of search queries from devices such as client device **102** to one or more runtime systems **110**, **112**, and **114**.

[0023] The query coordinator **106** may contain configurations **116** which may be stored in one or more data stores. The configurations **116** may store configurations, mappings, setups, or the like, which may enable the query coordinator **106** to determine what operations and/or commands are associated, and/or are to be used with, what systems. Moreover, the configurations **116** may also store configurations, mappings, setups, and the like, of different systems which may be used by the query coordinator **106** in processing and/or completing search queries. As an example, the configurations **116** may provide the query coordinator **106** information about different systems (e.g., systems **110**/**112**/**114**, etc.) such that the query coordinator **106** may use this information to connect to and process queries (also subqueries or partial queries, etc.) at these different systems as a part of completing a single search query, and therefore, may require involvement of multiple systems to provide full results of the single search query.

[0024] As described herein, the query coordinator **106** may receive a search query and process it to generate tasks for the various runtime systems. As part of processing the query, the query coordinator **106** may parse the query to identify sets of data to be processed as part of the query, query commands to be executed as part of processing the sets of data, and (runtime) systems to be used to execute the query.

[0025] In some cases, the commands associated with a search query (e.g., in the query) may correspond to different (runtime) systems that may be separate and distinct from and operate independent of each other and the query coordinator **106**. Accordingly, the query coordinator **106** may parse a search query, identify query commands, and use the identified query commands to identify one or more (runtime) systems associated with the query and/or to be used to execute the query (e.g., to execute the particular query command).

[0026] In certain cases, the query coordinator **106** may identify the (runtime) systems to use for the query based on the sets of data identified in the query. For example, the query coordinator **106** may determine that a particular set of data is accessible (e.g., stored or managed) by a particular runtime system. As such, the query coordinator **106** may identify the particular runtime system as being associated with the query and/or to be used to execute the query (e.g., to retrieve the particular set of data).

[0027] The query coordinator **106** may further generate tasks for the various runtime systems associated with the query. The tasks may include query instructions for the runtime systems. For example, the tasks may indicate the sets of data to be processed by the different runtime systems, where to retrieve the sets of data (e.g., from respective system and/or from the inter-system interface), how to process the retrieved data (e.g., what query commands to perform on the retrieved data), and where to communicate the results (e.g., to the inter-system interface). In some cases, the tasks may include a (sub) search query for the runtime system to execute and/or instructions to communicate the results of the (sub) search query to an (inter-system) interface. In some cases, the query instructions may include a portion of the query received by the query coordinator **106**.

[0028] The query coordinator **106** may also configure the inter-system interface **108** for use during execution of the query. In some cases, configuring the inter-system interface **108** may include setting up one or more buffers, identifying query results or partial query results of the query as a particular topic, identifying publishers and subscribers to a pub/sub, etc.

[0029] Once the query is ready for execution, the query coordinator **106** may initiate execution of the query by sending the query instructions (or tasks) to the various (runtime) systems. During query execution, the query coordinator **106** may monitor the status of the query. For example, the query coordinator **106** may monitor the status of the inter-system interface **108**, and/or the different (runtime) systems. In some cases, the query coordinator **106** may ping the various systems to confirm they are still active and/or request a status update regarding the amount of data processed as part of the query. In certain cases, the query coordinator **106** may monitor the amount of data communicated to/from the inter-system interface **108** and/or determine which (runtime) system is pulling data from the inter-system interface **108**. For example, if the system **114** is retrieving data from (or communicating data to) the inter-system interface **108**, the query coordinator **106** can determine that the query is closer to completion than if the system **110** is communicating data to the inter-system interface **108** and/or if the system **112** is retrieving data from (or communicating data to) the inter-system interface **108**.

[0030] The query coordinator **106** may also retrieve query results from the inter-system interface **108**, finalize the results, and communicate the finalized results to the client device **102** (the requestor of the search query). As described herein, the various (runtime) systems may communicate their results to the inter-system interface **108**. In some such cases, the query coordinator **106** may retrieve the query results from the last system (e.g., system **114**) to send results to the inter-system interface **108**. Upon retrieving the results from the inter-system interface **108**, the query coordinator **106** may perform additional processing on the retrieved results. For example, the query coordinator **106** may have generated one or more tasks for itself, such as taking the partial results from each system (system **110**, **112**, **114**, etc.) and formatting such partial results in a manner for presentation on the client device **102**. Accordingly, the query coordinator **106** may execute the tasks and communicate the results to the client device **102**.

[0031] The inter-system interface **108** may be communicatively coupled with the query coordinator **106** and the different (runtime) systems **110**, **112**, and **114**, and be used to facilitate communications between the query coordinator **106** and the different (runtime) systems **110**, **112**, and **114**. Although reference is made to the inter-system interface **108** facilitating communications between different runtime systems, it will be understood that, in some cases, the inter-system interface **108** may facilitate communications between different systems within the same runtime environment. For example, the inter-system interface **108** may facilitate communications between different batch search systems that store data at rest, between different streaming data processing systems, etc.

[0032] In some cases, the inter-system interface **108** may operate according to a publish-subscribe ("pub-sub") messaging model. In some cases, a query may be represented as one or more "topics" within a pub/sub model, and the partial search results from the different systems **110**, **112**, and **114** may be represented as "messages" within the pub/sub model. For example, during execution of a query (Query1), the system **110** may publish its partial results to the inter-system interface **108** as one or more messages associated with the topic corresponding to Query1. The system **112** may retrieve the messages (generated by system **110**) from the topic Query1, process the retrieved data (according to its own tasks), and publish it as new messages in the topic Query1. The system **114** may retrieve the messages (generated by system **112**), process the retrieved data (according to its own tasks), and publish it as new messages in the topic Query1. The query coordinator **106** may retrieve the messages (generated by system **114**), process the retrieved data (according to its own tasks, such as further processing, formatting, etc.), and communicate the search results to the client device **102**. In some such cases, the various systems that interact with the inter-system interface **108** may be configured as publishers and subscribers to the Query1 topic.

[0033] In certain cases, the query may use multiple "topics" within a pub-sub model. For example, there may be one topic for messages from system **110** to system **112**, another topic for messages from system **112** to system **114**, and another topic for messages from the system **114** to the query coordinator **106**. In certain cases, there may be multiple topics used for communications between systems. As such, the inter-system interface **108** may receive query results from systems, such as systems **110**, **112**, **114**, and publish them for other systems to access. In some such cases, a particular topic may have a first runtime system (e.g., system that places data in the inter-system interface **108** for the topic) as a publisher and another runtime system as a subscriber (e.g., the system that pulls the data from the pub-sub that the first system published).

[0034] In some cases, the inter-system interface **108** may be configured by the query coordinator **106**. For example, as part of a query planning phase, the query coordinator **106** may configure the inter-system interface **108** to include one or more topics for the query, identify the publishers and subscribers for the topic(s), set up a time out policy (e.g., when to determine that a system is not functioning), set up a message retention policy (e.g., how long to retain messages before removing them), etc. In some cases, as part of the message retention policy, the query coordinator **106** may configure the inter-system interface **108** to remove messages once they have been retrieved from a particular system. For example, once system **112** has retrieved messages generated by the system **110**, the inter-system interface **108** may remove the messages generated by the system **110** from the inter-system interface **108**.

[0035] In certain cases, the query coordinator **106** may configure the inter-system interface **108** to retain messages until a query has been completed. For example, the inter-system interface **108** may retain the messages in the topic(s) associated with a particular search query until it receives a notification from the query coordinator **106** that the query has been completed and/or results have been sent to the client device **102**. In some such cases, if a system (e.g., one of systems **110**, **112**, or **114**) goes down during (or communication is lost), the inter-system interface **108** may be used to retrieve messages and partial results that may otherwise be lost. In other words, the inter-system interface **108** may function as a backup or cache for at least messages and/or partial results from systems and/or the query coordinator **106** in the event that any problems and/or issues arise during execution of queries.

[0036] Moreover, by retaining messages (and the partial results) between the systems, the inter-system interface **108** may improve the performance of future queries. For example, the query coordinator **106** may make the inter-system messages in the inter-system interface **108** available for a user. By reviewing the inter-system messages, the user may identify an error in the query logic or how the data is being processed. In this way, the inter-system interface **108** may facilitate a better understanding of how the different parts of the query are working (e.g., to see what data is retrieved from system **110** and/or system **112**).

[0037] The systems **110**, **112**, and **114** may refer to different runtime systems and may be external to the query coordinator **106**. As stated herein, different runtime systems may operate independently and provide users with distinct user interfaces that enable the users to use the respective runtime systems. Moreover, each of systems **110**, **112**, and **114** may manage, process, or store different data from each other. For example, system **110** may be a streaming data processing system, system **112** may be a batch search system, and system **114** may be a tracing data processing system or a machine learning system. As such, the data processed or managed by the various runtime systems may be separate and/or siloed from each other and therefore the data from these different systems may not be easily shared with one another. Also, the nature of the data of each system may also be different, for example, a streaming data processing system may process (e.g., transform, modify, etc.) (but may not store) streaming data, whereas a batch search system may store and process data at rest, and/or a machine learning system may not process data so much as extract or determine patterns from the data.

[0038] A batch search system may correspond to one or more computing devices that conduct batch searches or other batch processing against existing data sets (or data at rest). For example, the batch search system may include an indexing and search system as described below (e.g., the indexing system **420** and search system **460** of FIG. **4**). The batch search system may be configured to accept batch operations, such as queries, from a computing device (e.g., via a user interface system) and apply such queries to a data set, which may for example be stored within a data storage system. Such queries may retrieve relevant data, manipulate the data according to one or more manipulations (e.g., filtering, routing, or transforming the data), and output results, such as by creating a new data set on the data storage system, presenting results to the requesting device via the user interface system, or the like.

[0039] A stream data processing system may correspond to one or more computing devices that obtain data from the data sources, manipulate the data according to one or more defined sets of data stream processing instructions, and output the data to a destination, such as a data storage system. As the data from the data sources may be unbounded—that is, it has no pre-defined size or termination point—the data processed by the data processing system can be considered a data stream or streaming data. Similarly, data output by the stream data processing system can be considered a data stream or streaming data. Accordingly, the manipulations of the stream data processing system are discussed here as stream data processing. In some cases, the stream data processing system implements multiple sets of processing instructions, each associated with intaking a particular set of data (e.g., from one or more specified data sources), implementing one or more manipulations (e.g., including filtering, modifying, routing, or otherwise manipulating the data), and outputting the data (e.g., to one or more specified destinations). Each instruction set may be in some cases be referred to as a "pipeline." For example, each instruction set may be logically viewed as a pipeline through which data moves and is manipulated prior to being output.

[0040] One skilled in the art will recognize that data streams differ from defined or pre-existing data sets (referred to herein as "data sets" for brevity). For example, data streams unlike data sets typically have no fixed size or termination, but can continue (potentially indefinitely) as data is produced. Data streams are sometimes described as "data in motion," whereas data sets are sometimes described as "data at rest." Processing for data sets and data streams can differ. For example, while batch processing of a data set may apply statistical techniques (such as averages, medians, distributions, etc.) to the fixed set, stream data processing may apply such techniques to windows within the stream. Batch processing of data sets may be associated with more latency between data generation and processing than stream processing. For example, batch processing may occur periodically (e.g., every x minutes, hours, etc.), processing a past portion of data created by a data source, with each result being delayed by up to the periodicity. Stream processing may occur continuously, enabling rapid results to be produced. Batch processing of a data set can be preferably for some tasks, such as historical analysis of existing data, while stream data processing can be preferably for other tasks, such as continuous monitoring.

[0041] The stream data processing system can output data streams to a variety of destinations. For example, where the batch search system provides for indexing of data, the stream data processing system may output a data stream to the batch search system for indexing as a data set, as described in more detail below. As another example, a user interface system may enable real-time review of data processing by the stream data processing system, and as such the stream data processing system may output a data stream to the user interface system for display on a computing device. As yet another example, the stream data processing system may output a data stream to a data storage system for storage.

[0042] A tracing data processing system may correspond to one or more computing devices that obtain data from the data sources in a hosted computing environment. The data from these data sources may include information related to the operation of software in one or more isolated execution environments (e.g., virtual machines, software containers, etc.) instantiated on a host device that shares compute resources between multiple isolated execution environments.

[0043] A machine learning data processing system may correspond to one or more computing devices that ingest shaped and/or annotated machine data and use one or more machine learning models to process the annotated machine data. In processing the annotated machine data, the machine learning data processing system may extract one or more features from the annotated machine data, identify one or more patterns in the machine data, identify deviations from the patterns and/or abnormalities from the machine generated data, etc.

[0044] With continued reference to FIG. **1**, as a part of a query planning phase, as stated herein, the query coordinator **106** may create and/or generate tasks for systems, such as the systems **110**, **112**, and **114**. The systems **110**, **112**, and **114** may receive tasks from the query coordinator **106**, or via the inter-system interface **108**, and instructions to process the tasks at a certain point in time. The tasks themselves may cover a myriad of instructions for each of the systems. For example, tasks may themselves be search queries for a particular system to execute (written in the query language of the particular system). The tasks may additionally include instructions for a particular system to obtain partial results from another runtime system and process the partial results with the particular system's own data. Moreover, the tasks may include instructions for a system to send its query results (also known as partial results since its coming from one system of possibly many systems required to satisfy a single general search query) to another system or to the query coordinator **106** (e.g., directly or via the inter-system interface **108**). As such, the tasks may appear to each system as normal query processing statements that the respective runtime system understands and processes, with potentially added instructions within those tasks on where to distribute results of a query and/or what to do with those results.

[0045] The tasks that are at least created by the query coordinator **106** may include many actions and/or instructions for systems to perform and/or accomplish. Some non-limiting examples of tasks are described, however, it should be noted that such examples are not limited to the example systems described. A task may include instructions for the system **110** to retrieve data from its own data stores and process the data according to query commands written in a language (e.g., SPL) that the system **110** understands. Another task may include instructions for the system **112** to wait for partial results from the system **110** to be available in the inter-system interface **108**. As another example, a task may include instructions for the system **112** to retrieve and process partial results from the inter-system interface **108**. In some cases, a task may include instructions for a system, such as the system **112**, to combine and process (or at least concurrently process) data retrieved from the inter-system interface **108** and from its own system (e.g., a data store of the system **112**). As shown in this specific example, the system **112** (and any system connected to the query coordinator **106** via the inter-system interface **108**) may have the ability to process a query involving data that it manages or stores and also data from another runtime system. Moreover, as described herein, a system that performs tasks for at least the query coordinator **106** may send its partial results to the inter-system interface **108**, in some cases, under a topic associated with a search query from the client device **102**. The inter-system interface **108** may then make available and/or communicate the partial results (e.g., the result of multiple runtime systems processing the data) to the query coordinator **106**. Alternatively, one or more of the systems (system **110**, **112**, **114**, etc.) may send their partial results directly to the query coordinator **106** as per task instructions.

[0046] As a non-limiting example, and as shown in FIG. **1**, the client device **102** may send a query **105** to the query coordinator **106**. The query coordinator **106** may receive the query **105** from the client device **102** and process it according to at least instructions within the query **105**, configurations associated with the query coordinator **106**, and/or setup associated with the query coordinator **106**. As described herein, the query coordinator **106** may utilize the inter-system interface **108** to the process query **105** in association with at least one or more external data systems.

[0047] In some cases, the query coordinator **106** may parse the query **105** to determine which systems should receive which operations and/or commands of the query **105**. In certain cases, the query coordinator **106** may parse the query **105** to identify data that should be processed, how the data should be processed, and also which systems should process the data. The query coordinator **106** may determine the location of the data and/or the system that processes (or can access) the data to be processed by identifying the commands to perform on the data, the data sources identified in the query, etc. In some cases, the query coordinator **106** may use a lookup or a configuration file to identify the location of the data and/or the system configured to access the data.

[0048] As part of processing the query, the query coordinator **106** may also identify the commands and/or operations to be performed on the data. The query coordinator **106** may determine particular systems are configured to perform these commands and/or operations. For example, the query coordinator **106** may determine that a particular command is associated with streaming data (thereby implicating a streaming data processing system) or that an abnormality_ detection command is associated with a machine learning processing system.

[0049] At **117**, the query coordinator **106** configures the inter-system interface **108** to receive partial results from one runtime system (e.g., systems **110**, **112**, **114**) and make the partial results available to another runtime system (e.g., another of the systems **110**, **112**, **114**).

[0050] In some cases, the query coordinator **106** may configure the inter-system interface **108** to operate under a pub/sub model with topics. As stated herein, the query coordinator **106** may configure the inter-system interface **108** to include one or more topics for the query **105**. The partial search results from the different systems **110**, **112**, and **114** may be published to the same or different topics as "messages." In addition, the query coordinator **106** may configure the inter-system interface **108** to receive data from the systems **110**, **112**, **114**, publish the received data to the one or more topics and permit the systems **110**, **112**, **114** to subscribe to the different topics (and retrieve the messages of the topics) associated with the query **105**.

[0051] As described herein, the query coordinator **106** may also create and/or generate tasks. The tasks may include instructions for the systems **110**, **112**, **114** to be used in executing the query **105**. The tasks for the respective systems may identify the data to process and how to process that data. For example, a first task may have instructions for the system **110** (implemented as a data stream processing system) to process streaming data and include commands and/or operations to be performed on the streaming data. The tasks may also include instructions on what to do with the results of data processed by a system. For example, a task may include instructions for the system **112** to communicate and/or publish its partial query results to the inter-system interface **108**. In some cases, the query coordinator **106** may generate tasks for itself. For example, once the query coordinator **106** receives partial results from the systems **110**, **112**, **114**, whether via the inter-system interface **108** or directly from the systems, the query coordinator **106** may finalize the partial results as a single finalized result for the client device **102**. Finalizing the partial results may include formatting and/or other changes to the partial results which may make them presentable to the client device **102** in a format which the client device **102** is expecting.

[0052] As further shown in FIG. **1**, the query coordinator **106** may execute the query **105**. As part of executing the query, the query coordinator **106** may (concurrently or serially) send query instructions **118** to the system **110**, the query instructions **122** to the system **112**, and the query instructions **126** to the system **114**. As described herein, the query instructions **118**, **122**, **126** may include the respective tasks generated by the query coordinator **106** for the different systems **110**, **112**, and **114**.

[0053] The query instructions **118** may instruct the system **110** to process certain data and communicate the partial results **120** of processing the data to the inter-system interface **108**. In some cases, the query instructions **118** may include a (first) portion of the query received by the query coordinator **106**. As described herein, in some cases, the system **110** may be a streaming data processing system and the data processed as part of the query may be streaming data.

[0054] The query instructions **122** may include instructions for the system **112** to obtain the partial results **120** from the inter-system interface **108** and process the partial results **120**. In some cases, the query instructions **122** may include a (second) different portion of the query received by the query coordinator **106**. The second portion of the query may have some or no overlap with the first portion of the query (communicated to the system **110** as part of the query instructions **118**). In some cases, the query instructions **122** may further instruct the system **112** to combine the partial results **120** with additional data accessible (or stored) by the system **112** and/or process the combined data. In certain cases, the query instructions **122** may also instruct the system **112** to communicate and/or publish its results to the inter-system interface **108** as partial results **124**.

[0055] The query instructions **126** may instruct the system **114** to obtain the partial results **124** from the inter-system interface **108** and process the partial results **124** according to one or more query commands. In some cases, the query instructions **122** may include a (third) different portion of the query received by the query coordinator **106**. The third portion of the query may have some or no overlap with the first portion and/or second portion of the query (communicated to the systems **110**, **112** as part of the query instructions **118**, **122**, respectively). In some cases, the query instructions **126** may further instruct the system **114** to combine the partial results **124** with additional data accessible (or stored) by the system **114** and/or process the combined data. In certain cases, the query instructions **126** may also instruct the system **114** to communicate and/or publish its results to the inter-system interface **108** as partial results **128**.

[0056] As described herein, the query coordinator **106** may also generate one or more instructions for itself. These instructions may cause the query coordinator **106** to obtain the partial results **128** from the inter-system interface **108**, process the partial results **128** according to one or more query commands, and communicate the query results **132** to the client device **102**.

[0057] In some cases, the query coordinator **106** may obtain and/or process the partial results **120**, partial results **124**, and partial results **128** from the inter-system interface **108**. For example, as described herein, in some cases, the inter-system interface **108** may be configured to retain the partial results **120**, partial results **124**, and partial results **128** to enable the query coordinator **106** to retrieve them. In certain cases, the inter-system interface **108** is configured to remove or delete the partial results **120**, partial results **124**, and/or partial results **128** once they are retrieved by the next downstream system (or once the query results **132** are sent to the client device **102**). By retrieving the partial results **120**, partial results **124**, and/or partial results **128**, the query coordinator **106** may enable troubleshooting and/or deeper analysis of the query. For example, by analyzing the partial results **120**, a user may identify issues with the system **110** and/or with the query **105**.

[0058] It should be understood that the disclosed techniques can extend the search, extraction, execution, and analytics capabilities of a search query system to use multiple external or runtime data systems to process data (sequentially). For example, the query coordinator **106** may send query instructions to the different external systems to perform parts of a query, send the results of processing the part of the query (e.g., the partial results) to an inter-system interface, and enable a downstream external system (in terms of how the query is processed) to retrieve the partial results generated by the upstream system (in terms of how the query is processed), perform additional processing, and return the updated partial results to the inter-system interface for another system or the query coordinator to retrieve. Although the example primarily references the use of different runtime systems, it will be understood that the description herein may also be used to facilitate the sequential processing of data using multiple internal or external systems from the same runtime (e.g., using multiple batch search query systems, multiple data stream processing systems, and/or multiple tracing data systems).

[0059] In some cases, to access or process data from a particular data source (or another component) as part of executing a query, a runtime system may use (or require) system credentials associated with the data source. For example, to access a data store of a shared storage system, the shared storage system may require credentials from a runtime system before allowing the runtime system to access the data store. Moreover, before a runtime system or other component accesses a particular data source there may be multiple communications between different components and the system credential for the data source may be shared with the various components. For example, the query coordinator **106** may communicate a copy of the query instructions to each runtime system involved in the query (e.g., with indications of which runtime system is to process which query instructions). In some such cases, each runtime system may receive a copy of the system credential of a particular data source even if only one of the runtime systems will be accessing the particular data source. Similarly, multiple (distributed) components within a particular runtime system may receive a copy of a credential for a particular data source. The more components that receive a copy of system credentials for a particular component or system, the greater the likelihood that a breach will result in the system credential being compromised by a bad actor.

[0060] To address this issue, the query coordinator **106** (or another component) may store credential information to access one or more runtime systems. Instead of providing different systems with copies of a particular credential, the query coordinator **106** may provide the systems with a reference to the stored system credentials (e.g., via a universal resource identifier or "URI"). In this way, copies of the credential are not communicated to multiple systems that will not be accessing the component.

[0061] When a particular system (or component of a system) is ready to access the particular component (e.g., a data store), it can use the reference to retrieve the credential (e.g., communicate with the query coordinator **106** to determine the credential). For example, a runtime system may identify the location of a version of the credential by parsing a URI for a path location to the credential. The runtime system may use the path location to access the location where the credential is stored. In some cases, the query coordinator **106** (or other component) may validate the requesting runtime system (or component thereof) prior to granting access to the credential.

[0062] FIG. **2** is a data flow diagram illustrating an example of communications between various components sequentially processing data using different runtime systems **201**, **203**, a query coordinator **106** and an inter-system interface **108**. Although FIG. **2** references different runtime systems, it will be understood that the description herein may also be used to facilitate the sequential processing of data using multiple internal or external systems from the same runtime (e.g., using multiple batch search query systems, multiple data stream processing systems, and/or multiple tracing data systems).

[0063] As described above, the query coordinator **106** may receive a (single) search query from the client device **102**. The client device **102** may be agnostic to the number of external systems involved in providing results to the single search query and may only seek the results from the query coordinator **106**. As such, the query coordinator **106** may enable the abstraction of the inter-system communications and processing to execute the query.

[0064] The processing and execution of the query may involve two general phases: a query planning phase **202** and a query execution phase **204**. The query planning phase **202** may include various steps or internal processes of the query coordinator **106** as it determines what data is to be retrieved/processed, identifies the location of the data to be retrieved/processed, determines the systems that will retrieve and process the data, and determines the commands for the different systems to execute the query, etc. As such, during the query planning phase **202**, the query coordinator **106** may generate tasks or instructions for itself and other systems that will be involved in the execution of the query.

[0065] The query execution phase **204** may include various steps or communications between the query coordinator **106** and the systems or components that will be used to retrieve the data to be processed and process the data. As part of the query execution phase **204**, the query coordinator **106** may distribute tasks and/or instructions to different systems and/or components (including itself), and the relevant components may execute the received tasks.

[0066] Although illustrated in a particular order, it will be understood that in some cases one or more portions of the query planning phase **202** and/or query execution phase **204** may be performed in a different order and/or performed concurrently.

[0067] At (1), the query coordinator **106** receives a search query from the client device **102**. As stated above, the search query may have been sent and/or communicated by a requestor (e.g., client device **102**) to the query coordinator **106**. Moreover, the client device **102** may be agnostic as to how many external systems are required to provide the results to the search query. As such, the requestor may send the search query in one language or communication protocol and rely on query coordinator **106** to create different queries to different external systems in each of the external systems' respective languages and/or communication protocols.

[0068] At (2), the query coordinator **106** parses the search query. As described herein, as part of parsing the query, the query coordinator **106** can determine that the search query to be executed is a multi-system query, or involves data managed, processed, and/or stored by different runtime systems, such as a streaming data system that processes streaming data and a batch search system that processes data in batches. In some cases, the query coordinator **106** can determine that the search query to be executed is a multi-system query based on commands, function calls, or terms in the search query that map to different runtime systems. For example, the query coordinator **106** may have certain search query operations and/or commands mapped to runtime system **201**, while other search query operations and/or commands may be mapped to runtime system **203**. For example, the query coordinator **106** may identify the command "select streaming data" as related to a streaming external data system and map the command to be distributed to external system **201**, which may be identified as a streaming system (e.g., by at least evaluating mapping stored in the configurations **116**). As another example, the query coordinator **106** may identify the command "select at rest data" as related to a system storing at rest data and map the command to be distributed to external system **203**, which may be identified as a batch search system. However, it will be understood that a variety of methods can be used to indicate that a search query is a multi-system query. In some cases, the search query can include details of a subquery for either system **201** or system **203**. For example, the search query can include a search string for the subquery, access information to access the system **201** or system **203**, and/or other relevant information to enable the query coordinator **106** to generate a subquery for either system **201** or system **203**.

[0069] At (3), the query coordinator **106** generates tasks and/or query instructions based on operations and/or commands within the search query received from the requestor. As stated above, the query coordinator **106** may access configurations **116** which map operations and/or commands to certain systems such that when query coordinator **106** identifies those operations and/or commands, it knows to associate those operations or commands with a certain system. Moreover, because the search query may be in a single language, the query coordinator **106** may convert or translate operations or commands from the language used in the search query to operations or commands in a different language for different systems. As an example, the command or operation "select1" may be mapped to a select statement of system **201** in one query language, whereas "select2" may be mapped to a select statement of system **203** in a different query language.

[0070] Using the operations and/or commands from the search query, the query coordinator **106** may generate query instructions for system **201** and system **203**. As stated above, the query coordinator **106** may know how to segregate commands and/or operations of system **201** and system **203**. Therefore, the query coordinator **106** may intelligently determine what partial results will be generated by system **201** and generate query instructions for system **201** (e.g., in system **201**'s processing language). Similarly, the query coordinator **106** may intelligently determine what partial results will be generated by system **203** and generate query instructions for system **203** (e.g., in system **203**'s language). Moreover, the query instructions (or tasks) generated by the query coordinator **106** may provide instructions to systems **201** and **203** to retrieve data to process and/or dictate how a query is run in that system. For example, the query coordinator **106** may instruct system **203** to retrieve system **201**'s partial results from the inter-system interface **108** and use those partial results in system **203**'s query processing.

[0071] At (4), the query coordinator **106** configures the inter-system interface **108** to: receive partial results from the system **201**, enable the system **203** to retrieve the partial results from the system **201**, receive updated partial results from the system **203**, and enable the query coordinator **106** to retrieve the updated partial results from the system **203**. In certain cases, the query coordinator **106** may configure the inter-system interface **108** in a pub-sub model identifying the system **201**, the system **203**, and/or the query coordinator **106** as publishers and/or subscribers to different topics as the case may be.

[0072] At (5A) and (5B), the query coordinator **106** distributes the generated tasks or query instruction to the respective systems **201** and **203**. As stated above, the tasks may include query commands that were translated from one language to another language. For example, in FIG. **2**, the system **201** is a streaming data processing system that processes streaming data. Therefore, the query coordinator **106** may generate tasks or include commands or query instructions specific to streaming data, and communicate those tasks to the system **201** at (5A). As another non-limiting example, in the illustrated example, the system **201** is a batch search system. Therefore, the query coordinator **106** may generate tasks or include commands or query instructions specific to streaming data, and communicate those tasks to the system **203** at (5B).

[0073] At (6), the system **201** executes the tasks (query instructions) received from the query coordinator **106**. The tasks may include retrieving data and/or processing it according to one or more query commands. As described herein, the tasks or query commands may be in a query language particular to the system **201** (and translated by the query coordinator **106** from a different query language).

[0074] At (7), the system **201** sends the results of processing the tasks (e.g., results of processing data according to one or more commands in the tasks) or partial results to the inter-system interface **108**. In some cases, the query instructions received at (5A) may include an instruction to send the partial results to the inter-system interface **108**. As described herein, in some cases, in communicating and/or sending the partial results, the system **201** may "publish" the partial results to a particular topic associated with the search query (and/or associated specifically with communications between the system **201** and the system **203**).

[0075] At (8), the system **203** retrieves the partial results (generated by the system **201**) from the inter-system interface **108**. As described herein, the tasks or query instructions sent to the system **203** at (5B) may include instructions to retrieve the partial results from the inter-system interface **108**. Accordingly, based on the received query instructions, the system **203** can retrieve the partial results from the inter-system interface **108**.

[0076] At (9), the system **203** executes the tasks (query instructions) sent to it by query coordinator **106** at (5B). As described herein, the system **203** may, according to the query instructions process the partial results from system **201** and/or process data retrieved from its own system. In the illustrated example, as the system **203** is shown as a batch search system, the query instructions may include query commands to retrieve and process data at rest alone or in combination with the partial results generated by a streaming data processing system (e.g., system **201**).

[0077] At (10), the system **203** sends the results of processing its tasks (e.g., results of processing data according to the one or more commands in the tasks) or partial results to the inter-system interface **108**. In some cases, the query instructions received at (5B) may include an instruction to send the partial results to the inter-system interface **108**. As described herein, in some cases, in communicating and/or sending the partial results, the system **203** may "publish" the partial results to a particular topic associated with the search query (and/or associated specifically with communications between the system **203** and the query coordinator **106**).

[0078] At (11), the query coordinator **106** retrieves the partial results (generated by the system **203**) from the inter-system interface **108**. As described herein, the tasks or query instructions generated by the query coordinator **106** may include instructions to retrieve the partial results generated by the system **203** from the inter-system interface **108**. Accordingly, based on the generated query instructions, the query coordinator **106** can retrieve the partial results from the inter-system interface **108**. In certain cases, the query coordinator **106** may be configured to also retrieve the partial results generated by system **201** for debugging or another analysis.

[0079] At (12), the query coordinator **106** processes (or finalizes) the partial results pulled from the inter-system interface **108**. Further processing and/or finalizing the partial results may include formatting them into a presentable and readable format which the client device **102** can understand.

[0080] It will be understood that the multi-system data flow can include fewer or more steps. For example, in some cases, the query may include processing by three or more different runtime systems and/or different systems in the same runtime. Moreover, it will be understood that the various functions described can be performed concurrently or in any order. For example, the query coordinator **106** may generate and communicate the query instructions to system **201** before, after, or concurrently with the query instructions for system **203**.

[0081] As described herein, the query coordinator may use multiple runtimes to sequentially execute different portions of a query (e.g., one runtime to retrieve and process data and a machine learning runtime to further process or transform the data). As a non-limiting example, consider the scenario in which the query coordinator **106** receives the following query from a client device **102**: "$output=|from main|head limit=10|fit 'DensityFunction' bytes split_by=[field1, field2] into model." Based on the query, the query coordinator **106** may send a (first) portion of the query (e.g., "from main-|head limit=10") to a batch search runtime system and receive results from such runtime (e.g., receive the results itself or the results may be communicated to the interface **108**). The query coordinator **106** may take those results and send them to a machine learning runtime (e.g., itself or by sending an instruction to the machine learning runtime to retrieve the results from the interface **108**) along with another (second portion) of the query such that a machine learning model processes the results from the batch search runtime system according to the command "fit 'DensityFunction' bytes split_by=[field1, field2]." Some or all of the results from the machine learning runtime may be communicated to the query coordinator **106** or another runtime system (e.g., directly or via the inter-system interface **108**).

[0082] As yet another non-limiting example, the query coordinator **106** may receive the following query from the client device **102**: "$output=|from supermarket|apply example_soda_supermarket show_density=True sample=True." The query coordinator **106** may send a (first) portion of the receive query (e.g., "from supermarket") to a batch search runtime system and receive results from such runtime system (e.g., receive the results itself or the results may be communicated to the interface **108**). The query coordinator **106** may cause the results received from the batch search runtime system to be communicated to a machine learning runtime (e.g., directly or via the inter-system interface **108**). The query coordinator **106** may also communicate another (second) portion of the query to machine learning runtime (e.g., "apply example_soda_supermarket show_density=True sample=True"). The machine learning runtime may process the results from the batch search runtime system according to the received second portion of the query. Some or all of the results from the machine learning runtime may be communicated to the query coordinator **106** or another runtime system (e.g., directly or via the inter-system interface **108**).

[0083] In some cases, the query coordinator **106** may concurrently send tasks to multiple runtime systems (e.g., system **201**, system **203**, etc.) for parallel processing, aggregate the results from each runtime system as a union dataset, and perform additional processing on the union dataset. For example, the query coordinator **106** may receive the following query from the client device **102**: "$multi_runtime_search=FROM [main_index, bucket]|SEARCH "error"|stats count ( )" Based on this example query, the query coordinator **106** may concurrently instruct a first runtime system with a source "main_index" and a second runtime system with a source "bucket") to retrieve data (in parallel).

[0084] In response, each runtime system may concurrently or asynchronously return its results to the query coordinator **106** (e.g., directly to the query coordinator **106** or via the inter-system interface **108**). For example, the first runtime system and the second runtime system may return results concurrently (e.g., without sequential dependence on one another). As such, the results from the first runtime system may be a first dataset and the results from the second runtime system may be a second dataset.

[0085] The query coordinator **106** may combine the first and second datasets to form a union dataset. The query coordinator **106** may perform one or more tasks or a second portion of the query (e.g., "SEARCH "error"|stats count( )") on the union dataset. For example, the query coordinator **106** may search for the "error" string within the union dataset and then conduct a stats count ( ) aggregation of the search. The results of the query may be communicated and/or published to a client device **102** of the query or even published to the inter-system interface **108** for retrieval by other systems or users, and the like.

[0086] FIG. **3** is a flow diagram illustrative of an example of a routine **300** implemented by the query coordinator **106** to execute a search query using multiple (runtime) systems. Although described as being implemented by the query coordinator **106**, it will be understood that one or more elements outlined for routine **300** can be implemented by one or more computing devices/components that are associated with the query coordinator **106**, such as the inter-system interface **108**. Thus, the following illustrative embodiment should not be construed as limiting. The example routine **300** can be implemented, for example, by a computing device that comprises a processor and a non-transitory computer-readable medium. The non-transitory computer readable medium can be storing instructions that, when executed by the processor, can cause the processor to perform the operations of the illustrated routine **300**. Alternatively, or additionally, the routine **300** can be implemented using a non-transitory computer-readable medium storing instructions that, when executed by one or more processors, cause the one or more processors to perform the operations of the process **300** of FIG. **3**.

[0087] At block **302**, the query coordinator **106** receives a search query. As described herein, the query coordinator **106** may receive the search query from the client device **102**. In receiving the search query, the query coordinator **106** may perform pre-processing on the search query to confirm that the client device **102** has appropriate authorizations to request the query be executed. The query coordinator **106** may also perform a semantic or syntax review of the query to verify that the query is a valid query.

[0088] At block **304**, the query coordinator **106** parses the query. As part of processing the query, the query coordinator **106** may identify sets of data to be processed, operations to be performed on the sets of data, and runtime systems to execute the commands (or portions of the query). As described herein, in some cases, the query coordinator **106** may identify the sets of data by parsing the search query to identify dataset identifiers, identify the operations to perform on the datasets by parsing the search query to identify query commands, and identify the runtime systems associated with the search query by identifying the runtime systems that include, control access to, or store the sets of data to be processed, and/or the runtime systems that are configured to perform the operations corresponding to the query commands.

[0089] The sets of data may include data accessible via, stored on, or managed by runtime systems, partial results received from runtime systems, and/or any set of data which is involved with processing the search query. For example, the query coordinator **106** may identify sets of data as data stored in more than one system, such as a first data set as streaming data processed by a streaming system, and a second data set as at rest data on a batch search system.

[0090] In some cases, the sets of data may correspond to different types of data, such as streaming data, data at rest, trace data, and/or the results of processing any one or any combination of the aforementioned types of data. In certain cases, some or all of the sets of data may be associated with one of the runtime systems. For example, one set of data may include streaming data associated with a streaming data processing system, another set of data may include data at rest associated with a batch search system, another set of data may include trace data at rest associated with a tracing data processing system, etc.

[0091] The operations may include commands that runtime systems may perform to process a part of the search query. For example, the query coordinator **106** may identify operations for a streaming system in some parts of the search query and then identify operations for a batch search system in other parts of the search query.

[0092] The runtime systems may include systems that store and/or process different types of data or data in different states. As described herein, different runtime systems may store and process different types of data such as streaming data, at rest data, audio data, machine learning applied data, etc. As such, the query coordinator **106** may parse the search query and identify the different runtime systems that will be used to process the query.

[0093] At block **306**, the query coordinator **106** configures an interface, such as the inter-system interface **108**, for the different runtime systems. In some cases, the configured interface enables the communication of partial results between different runtime systems and/or the query coordinator **106**. In some cases, the query coordinator **106** may configure the interface by implementing a pub-sub model that enables the runtime systems to publish messages to one or more topics and/or subscribe to the topics to receive messages. As described herein, the query coordinator **106** may configure the interface to include one or more topics for the search query such that the communication of partial results between runtime systems occurs on one or multiple topics.

[0094] At block **308**, the query coordinator **106** generates tasks for at least one of the runtime systems. In certain cases, the query coordinator **106** generates task(s) for some or all of the runtime systems (and/or for itself). For example, based on a first query command, the query coordinator **106** may generate a first task for a first runtime system and based on a second query command, the query coordinator **106** may generate a second task for a second runtime system to process data, etc.

[0095] In some cases, the tasks may include query commands or instructions for the runtime system (or the query coordinator **106**). As described above, the query commands may be in a query language that is different from the query language of the search query received by the query coordinator **106**. In some cases, the commands or instructions may include instructions to process a (first) set of data to generate partial results (a second set of data), communicate (e.g., publish) the partial results to the inter-system interface **108**, retrieve partial results from a previous runtime system from the inter-system interface **108**, process the retrieved partial results (alone or in combination with additional data from the system (e.g., a third set of data)) to generate updated partial results (a fourth set of data), communicate the updated partial results to the inter-system interface **108**, etc.

[0096] As described herein, in certain cases, the query coordinator **106** may generate one or more query instructions for itself to retrieve partial results from one or more of the runtime systems, process the retrieved results to generate query results (e.g., a fifth set of data), and communicate the results to a client device.

[0097] At block **310**, the query coordinator **106** distributes the generated tasks to one or more runtime systems. As described herein, a task may include one or more instructions for a runtime system to process a set of data, communicate partial results to the inter-system interface **108**, retrieve partial results from the inter-system interface **108**, process retrieved partial results from the inter-system interface **108** (alone or in combination with additional data) to generate second partial results, and/or communicate the second partial results to the inter-system interface **108**.

[0098] Accordingly, when a particular runtime system receives its tasks from the query coordinator **106**, it may perform query processing without receiving data from the inter-system interface **108** and/or wait for another system to send their partial results to the inter-system interface **108** and pull those partial query results for processing. If a system uses partial query results from another runtime system, such system may utilize such partial results as input into its own query processing.

[0099] At block **312**, the query coordinator **106** receives partial results (from at least one of the runtime systems) from the inter-system interface **108**. After receiving the partial results from the inter-system interface **108**, the query coordinator **106** may further process the partial results by modifying and/or formatting them into one finalized result that is deliverable to the initial requestor (e.g., the client device **102**) of the search query.

[0100] At block **314**, the query coordinator **106** communicates the results of the search query to the requestor. As described herein, the results may be a finalized version of all the partial results received from the externals systems identified at block **304**. The finalized results may be an aggregation and/or modified version of the partial results.

Data Intake and Query System

[0101] Entities of various types, such as companies, educational institutions, medical facilities, governmental departments, and private individuals, among other examples, operate computing environments for various purposes. Computing environments, which can also be referred to as information technology environments, can include inter-networked, physical hardware devices, the software executing on the hardware devices, and the users of the hardware and software. As an example, an entity such as a school can operate a Local Area Network (LAN) that includes desktop computers, laptop computers, smart phones, and tablets connected to a physical and wireless network, where users correspond to teachers and students. In this example, the physical devices may be in buildings or a campus that is controlled by the school. As another example, an entity such as a business can operate a Wide Area Network (WAN) that includes physical devices in multiple geographic locations where the offices of the business are located. In this example, the different offices can be inter-networked using a combination of public networks such as the Internet and private networks. As another example, an entity can operate a data center at a centralized location, where computing resources (such as compute, memory, and/or networking resources) are kept and maintained, and whose resources are accessible over a network to users who may be in different geographical locations. In this example, users associated with the entity that operates the data center can access the computing resources in the data center over public and/or private networks that may not be operated and controlled by the same entity. Alternatively or additionally, the operator of the data center may provide the computing resources to users associated with other entities, for example on a subscription basis. Such a data center operator may be referred to as a cloud services provider, and the services provided by such an entity may be described by one or more service models, such as to Software-as-a Service (SaaS) model, Infrastructure-as-a-Service (IaaS) model, or Platform-as-a-Service (PaaS), among others. In these examples, users may expect resources and/or services to be available on demand and without direct active management by the user, a resource delivery model often referred to as cloud computing.

[0102] Entities that operate computing environments need information about their computing environments. For example, an entity may need to know the operating status of the various computing resources in the entity's computing environment, so that the entity can administer the environment, including performing configuration and maintenance, performing repairs or replacements, provisioning additional resources, removing unused resources, or addressing issues that may arise during operation of the computing environment, among other examples. As another example, an entity can use information about a computing environment to identify and remediate security issues that may endanger the data, users, and/or equipment in the computing environment. As another example, an entity may be operating a computing environment for some purpose (e.g., to run an online store, to operate a bank, to manage a municipal railway, etc.) and may want information about the computing environment that can aid the entity in understanding whether the computing environment is operating efficiently and for its intended purpose.

[0103] Collection and analysis of the data from a computing environment can be performed by a data intake and query system such as is described herein. A data intake and query system can ingest and store data obtained from the components in a computing environment, and can enable an entity to search, analyze, and visualize the data. Through these and other capabilities, the data intake and query system can enable an entity to use the data for administration of the computing environment, to detect security issues, to understand how the computing environment is performing or being used, and/or to perform other analytics.

[0104] FIG. **4**A is a block diagram illustrating an example computing environment **400** that includes a data intake and query system **410**. The data intake and query system **410** obtains data from a data source **402** in the computing environment **400**, and ingests the data using an indexing system **420**. A search system **460** of the data intake and query system **410** enables users to navigate the indexed data. Though drawn with separate boxes in FIG. **4**A, in some implementations the indexing system **420** and the search system **460** can have overlapping components. A computing device **404**, running a network access application **406**, can communicate with the data intake and query system **410** through a user interface system **414** of the data intake and query system **410**. Using the computing device **404**, a user can perform various operations with respect to the data intake and query system **410**, such as administration of the data intake and query system **410**, management and generation of "knowledge objects," (user-defined entities for enriching data, such as saved searches, event types, tags, field extractions, lookups, reports, alerts, data models, workflow actions, and fields), initiating of searches, and generation of reports, among other operations. The data intake and query system **410** can further optionally include apps **412** that extend the search, analytics, and/or visualization capabilities of the data intake and query system **410**.

[0105] The data intake and query system **410** can be implemented using program code that can be executed using a computing device. A computing device is an electronic device that has a memory for storing program code instructions and a hardware processor for executing the instructions. The computing device can further include other physical components, such as a network interface or components for input and output. The program code for the data intake and query system **410** can be stored on a non-transitory computer-readable medium, such as a magnetic or optical storage disk or a flash or solid-state memory, from which the program code can be loaded into the memory of the computing device for execution. "Non-transitory" means that the computer-readable medium can retain the program code while not under power, as opposed to volatile or "transitory" memory or media that requires power in order to retain data.

[0106] In various examples, the program code for the data intake and query system **410** can be executed on a single computing device, or execution of the program code can be distributed over multiple computing devices. For example, the program code can include instructions for both indexing and search components (which may be part of the indexing system **420** and/or the search system **460**, respectively), which can be executed on a computing device that also provides the data source **402**. As another example, the program code can be executed on one computing device, where execution of the program code provides both indexing and search components, while another copy of the program code executes on a second computing device that provides the data source **402**. As another example, the program code can be configured such that, when executed, the program code implements only an indexing component or only a search component. In this example, a first instance of the program code that is executing the indexing component and a second instance of the program code that is executing the search component can be executing on the same computing device or on different computing devices.

[0107] The data source **402** of the computing environment **400** is a component of a computing device that produces machine data. The component can be a hardware component (e.g., a microprocessor or a network adapter, among other examples) or a software component (e.g., a part of the operating system or an application, among other examples). The component can be a virtual component, such as a virtual machine, a virtual machine monitor (also referred as a hypervisor), a container, or a container orchestrator, among other examples. Examples of computing devices that can provide the data source **402** include personal computers (e.g., laptops, desktop computers, etc.), handheld devices (e.g., smart phones, tablet computers, etc.), servers (e.g., network servers, compute servers, storage servers, domain name servers, web servers, etc.), network infrastructure devices (e.g., routers, switches, firewalls, etc.), and "Internet of Things" devices (e.g., vehicles, home appliances, factory equipment, etc.), among other examples. Machine data is electronically generated data that is output by the component of the computing device and reflects activity of the component. Such activity can include, for example, operation status, actions performed, performance metrics, communications with other components, or communications with users, among other examples. The component can produce machine data in an automated fashion (e.g., through the ordinary course of being powered on and/or executing) and/or as a result of user interaction with the computing device (e.g., through the user's use of input/output devices or applications). The machine data can be structured, semi-structured, and/or unstructured. The machine data may be referred to as raw machine data when the data is unaltered from the format in which the data was output by the component of the computing device. Examples of machine data include operating system logs, web server logs, live application logs, network feeds, metrics, change monitoring, message queues, and archive files, among other examples.

[0108] As discussed in greater detail below, the indexing system **420** obtains machine date from the data source **402** and processes and stores the data. Processing and storing of data may be referred to as "ingestion" of the data. Processing of the data can include parsing the data to identify individual events, where an event is a discrete portion of machine data that can be associated with a timestamp. Processing of the data can further include generating an index of the events, where the index is a data storage structure in which the events are stored. The indexing system **420** does not require prior knowledge of the structure of incoming data (e.g., the indexing system **420** does not need to be provided with a schema describing the data). Additionally, the indexing system **420** retains a copy of the data as it was received by the indexing system **420** such that the original data is always available for searching (e.g., no data is discarded, though, in some examples, the indexing system **420** can be configured to do so).

[0109] The search system **460** searches the data stored by the indexing **420** system. As discussed in greater detail below, the search system **460** enables users associated with the computing environment **400** (and possibly also other users) to navigate the data, generate reports, and visualize search results in "dashboards" output using a graphical interface. Using the facilities of the search system **460**, users can obtain insights about the data, such as retrieving events from an index, calculating metrics, searching for specific conditions within a rolling time window, identifying patterns in the data, and predicting future trends, among other examples. To achieve greater efficiency, the search system **460** can apply map-reduce methods to parallelize searching of large volumes of data. Additionally, because the original data is available, the search system **460** can apply a schema to the data at search time. This allows different structures to be applied to the same data, or for the structure to be modified if or when the content of the data changes. Application of a schema at search time may be referred to herein as a late-binding schema technique.

[0110] The user interface system **414** provides mechanisms through which users associated with the computing environment **400** (and possibly others) can interact with the data intake and query system **410**. These interactions can include configuration, administration, and management of the indexing system **420**, initiation and/or scheduling of queries that are to be processed by the search system **460**, receipt or reporting of search results, and/or visualization of search results. The user interface system **414** can include, for example, facilities to provide a command line interface or a web-based interface.

[0111] Users can access the user interface system **414** using a computing device **404** that communicates with data intake and query system **410**, possibly over a network. A "user," in the context of the implementations and examples described herein, is a digital entity that is described by a set of information in a computing environment. The set of information can include, for example, a user identifier, a username, a password, a user account, a set of authentication credentials, a token, other data, and/or a combination of the preceding. Using the digital entity that is represented by a user, a person can interact with the computing environment **400**. For example, a person can log in as a particular user and, using the user's digital information, can access the data intake and query system **410**. A user can be associated with one or more people, meaning that one or more people may be able to use the same user's digital information. For example, an administrative user account may be used by multiple people who have been given access to the administrative user account. Alternatively or additionally, a user can be associated with another digital entity, such as a bot (e.g., a software program that can perform autonomous tasks). A user can also be associated with one or more entities. For example, a company can have associated with it a number of users. In this example, the company may control the users' digital information, including assignment of user identifiers, management of security credentials, control of which persons are associated with which users, and so on.

[0112] The computing device **404** can provide a human-machine interface through which a person can have a digital presence in the computing environment **400** in the form of a user. The computing device **404** is an electronic device having one or more processors and a memory capable of storing instructions for execution by the one or more processors. The computing device **404** can further include input/output (I/O) hardware and a network interface. Applications executed by the computing device **404** can include a network access application **406**, such as a web browser, which can use a network interface of the client computing device **404** to communicate, over a network, with the user interface system **414** of the data intake and query system **410**. The user interface system **414** can use the network access application **406** to generate user interfaces that enable a user to interact with the data intake and query system **410**. A web browser is one example of a network access application. A shell tool can also be used as a network access application. In some examples, the data intake and query system **410** is an application executing on the computing device **406**. In such examples, the network access application **406** can access the user interface system **414** without going over a network.

[0113] The data intake and query system **410** can optionally include apps **412**. An app of the data intake and query system **410** is a collection of configurations, knowledge objects (a user-defined entity that enriches the data in the data intake and query system **410**), views, and dashboards that may provide additional functionality, different techniques for searching the data, and/or additional insights into the data. The data intake and query system **410** can execute multiple applications simultaneously. Example applications include an information technology service intelligence application, which can monitor and analyze the performance and behavior of the computing environment **400**, and an enterprise security application, which can include content and searches to assist security analysts in diagnosing and acting on anomalous or malicious behavior in the computing environment **400**.

[0114] Though FIG. **4**A illustrates only one data source, in practical implementations, the computing environment **400** contains many data sources spread across numerous computing devices. The computing devices may be controlled and operated by a single entity. For example, in an "on the premises" or "on-prem" implementation, the computing devices may physically and digitally be controlled by one entity, meaning that the computing devices are in physical locations that are owned and/or operated by the entity and are within a network domain that is controlled by the entity. In an entirely on-prem implementation of the computing environment **400**, the data intake and query system **410** executes on an on-prem computing device and obtains machine data from on-prem data sources. An on-prem implementation can also be referred to as an "enterprise" network, though the term "on-prem" refers primarily to physical locality of a network and who controls that location while the term "enterprise" may be used to refer to the network of a single entity. As such, an enterprise network could include cloud components.

[0115] "Cloud" or "in the cloud" refers to a network model in which an entity operates network resources (e.g., processor capacity, network capacity, storage capacity, etc.), located for example in a data center, and makes those resources available to users and/or other entities over a network. A "private cloud" is a cloud implementation where the entity provides the network resources only to its own users. A "public cloud" is a cloud implementation where an entity operates network resources in order to provide them to users that are not associated with the entity and/or to other entities. In this implementation, the provider entity can, for example, allow a subscriber entity to pay for a subscription that enables users associated with subscriber entity to access a certain amount of the provider entity's cloud resources, possibly for a limited time. A subscriber entity of cloud resources can also be referred to as a tenant of the provider entity. Users associated with the subscriber entity access the cloud resources over a network, which may include the public Internet. In contrast to an on-prem implementation, a subscriber entity does not have physical control of the computing devices that are in the cloud, and has digital access to resources provided by the computing devices only to the extent that such access is enabled by the provider entity.

[0116] In some implementations, the computing environment **400** can include on-prem and cloud-based computing resources, or only cloud-based resources. For example, an entity may have on-prem computing devices and a private cloud. In this example, the entity operates the data intake and query system **410** and can choose to execute the data intake and query system **410** on an on-prem computing device or in the cloud. In another example, a provider entity operates the data intake and query system **410** in a public cloud and provides the functionality of the data intake and query system **410** as a service, for example under a Software-as-a-Service (SaaS) model, to entities that pay for the user of the service on a subscription basis. In this example, the provider entity can provision a separate tenant (or possibly multiple tenants) in the public cloud network for each subscriber entity, where each tenant executes a separate and distinct instance of the data intake and query system **410**. In some implementations, the entity providing the data intake and query system **410** is itself subscribing to the cloud services of a cloud service provider. As an example, a first entity provides computing resources under a public cloud service model, a second entity subscribes to the cloud services of the first provider entity and uses the cloud computing resources to operate the data intake and query system **410**, and a third entity can subscribe to the services of the second provider entity in order to use the functionality of the data intake and query system **410**. In this example, the data sources are associated with the third entity, users accessing the data intake and query system **410** are associated with the third entity, and the analytics and insights provided by the data intake and query system **410** are for purposes of the third entity's operations.

[0117] FIG. **4**B is a block diagram illustrating in greater detail an example of an indexing system **420** of a data intake and query system, such as the data intake and query system **410** of FIG. **4**. The indexing system **420** of FIG. **4** uses various methods to obtain machine data from a data source **402** and stores the data in an index **438** of an indexer **432**. As discussed previously, a data source is a hardware, software, physical, and/or virtual component of a computing device that produces machine data in an automated fashion and/or as a result of user interaction. Examples of data sources include files and directories; network event logs; operating system logs, operational data, and performance monitoring data; metrics; first-in, first-out queues; scripted inputs; and modular inputs, among others. The indexing system **420** enables the data intake and query system to obtain the machine data produced by the data source **402** and to store the data for searching and retrieval.

[0118] Users can administer the operations of the indexing system **420** using a computing device **404** that can access the indexing system **420** through a user interface system **414** of the data intake and query system. For example, the computing device **404** can be executing a network access application **406**, such as a web browser or a terminal, through which a user can access a monitoring console **416** provided by the user interface system **414**. The monitoring console **416** can enable operations such as: identifying the data source **402** for data ingestion; configuring the indexer **432** to index the data from the data source **432**; configuring a data ingestion method; configuring, deploying, and managing clusters of indexers; and viewing the topology and performance of a deployment of the data intake and query system, among other operations. The operations performed by the indexing system **420** may be referred to as "index time" operations, which are distinct from "search time" operations that are discussed further below.

[0119] The indexer **432**, which may be referred to herein as a data indexing component, coordinates and performs most of the index time operations. The indexer **432** can be implemented using program code that can be executed on a computing device. The program code for the indexer **432** can be stored on a non-transitory computer-readable medium (e.g., a magnetic, optical, or solid state storage disk, a flash memory, or another type of non-transitory storage media), and from this medium can be loaded or copied to the memory of the computing device. One or more hardware processors of the computing device can read the program code from the memory and execute the program code in order to implement the operations of the indexer **432**. In some implementations, the indexer **432** executes on the computing device **404** through which a user can access the indexing system **420**. In some implementations, the indexer **432** executes on a different computing device than the illustrated computing device **404**.

[0120] The indexer **432** may be executing on the computing device that also provides the data source **402** or may be executing on a different computing device. In implementations wherein the indexer **432** is on the same computing device as the data source **402**, the data produced by the data source **402** may be referred to as "local data." In other implementations the data source **402** is a component of a first computing device and the indexer **432** executes on a second computing device that is different from the first computing device. In these implementations, the data produced by the data source **402** may be referred to as "remote data." In some implementations, the first computing device is "on-prem" and in some implementations the first computing device is "in the cloud." In some implementations, the indexer **432** executes on a computing device in the cloud and the operations of the indexer **432** are provided as a service to entities that subscribe to the services provided by the data intake and query system.

[0121] For a given data produced by the data source **402**, the indexing system **420** can be configured to use one of several methods to ingest the data into the indexer **432**. These methods include upload **422**, monitor **424**, using a forwarder **426**, or using Hypertext Transfer Protocol (HTTP **428**) and an event collector **430**. These and other methods for data ingestion may be referred to as "getting data in" (GDI) methods.

[0122] Using the upload **422** method, a user can specify a file for uploading into the indexer **432**. For example, the monitoring console **416** can include commands or an interface through which the user can specify where the file is located (e.g., on which computing device and/or in which directory of a file system) and the name of the file. The file may be located at the data source **402** or maybe on the computing device where the indexer **432** is executing. Once uploading is initiated, the indexer **432** processes the file, as discussed further below. Uploading is a manual process and occurs when instigated by a user. For automated data ingestion, the other ingestion methods are used.

[0123] The monitor **424** method enables the indexing system **420** to monitor the data source **402** and continuously or periodically obtain data produced by the data source **402** for ingestion by the indexer **432**. For example, using the monitoring console **416**, a user can specify a file or directory for monitoring. In this example, the indexing system **420** can execute a monitoring process that detects whenever the file or directory is modified and causes the file or directory contents to be sent to the indexer **432**. As another example, a user can specify a network port for monitoring. In this example, a monitoring process can capture data received at or transmitting from the network port and cause the data to be sent to the indexer **432**. In various examples, monitoring can also be configured for data sources such as operating system event logs, performance data generated by an operating system, operating system registries, operating system directory services, and other data sources.

[0124] Monitoring is available when the data source **402** is local to the indexer **432** (e.g., the data source **402** is on the computing device where the indexer **432** is executing). Other data ingestion methods, including forwarding and the event collector **430**, can be used for either local or remote data sources.

[0125] A forwarder **426**, which may be referred to herein as a data forwarding component, is a software process that sends data from the data source **402** to the indexer **432**. The forwarder **426** can be implemented using program code that can be executed on the computer device that provides the data source **402**. A user launches the program code for the forwarder **426** on the computing device that provides the data source **402**. The user can further configure the forwarder **426**, for example to specify a receiver for the data being forwarded (e.g., one or more indexers, another forwarder, and/or another recipient system), to enable or disable data forwarding, and to specify a file, directory, network events, operating system data, or other data to forward, among other operations.

[0126] The forwarder **426** can provide various capabilities. For example, the forwarder **426** can send the data unprocessed or can perform minimal processing on the data before sending the data to the indexer **432**. Minimal processing can include, for example, adding metadata tags to the data to identify a source, source type, and/or host, among other information, dividing the data into blocks, and/or applying a timestamp to the data. In some implementations, the forwarder **426** can break the data into individual events (event generation is discussed further below) and send the events to a receiver. Other operations that the forwarder **426** may be configured to perform include buffering data, compressing data, and using secure protocols for sending the data, for example.

[0127] Forwarders can be configured in various topologies. For example, multiple forwarders can send data to the same indexer. As another example, a forwarder can be configured to filter and/or route events to specific receivers (e.g., different indexers), and/or discard events. As another example, a forwarder can be configured to send data to another forwarder, or to a receiver that is not an indexer or a forwarder (such as, for example, a log aggregator).

[0128] The event collector **430** provides an alternate method for obtaining data from the data source **402**. The event collector **430** enables data and application events to be sent to the indexer **432** using HTTP **428**. The event collector **430** can be implemented using program code that can be executing on a computing device. The program code may be a component of the data intake and query system or can be a standalone component that can be executed independently of the data intake and query system and operates in cooperation with the data intake and query system.

[0129] To use the event collector **430**, a user can, for example using the monitoring console **416** or a similar interface provided by the user interface system **414**, enable the event collector **430** and configure an authentication token. In this context, an authentication token is a piece of digital data generated by a computing device, such as a server, that contains information to identify a particular entity, such as a user or a computing device, to the server. The token will contain identification information for the entity (e.g., an alphanumeric string that is unique to each token) and a code that authenticates the entity with the server. The token can be used, for example, by the data source **402** as an alternative method to using a username and password for authentication.

[0130] To send data to the event collector **430**, the data source **402** is supplied with a token and can then send HTTP **428** requests to the event collector **430**. To send HTTP **428** requests, the data source **402** can be configured to use an HTTP client and/or to use logging libraries such as those supplied by Java, JavaScript, and .NET libraries. An HTTP client enables the data source **402** to send data to the event collector **430** by supplying the data, and a Uniform Resource Identifier (URI) for the event collector **430** to the HTTP client. The HTTP client then handles establishing a connection with the event collector **430**, transmitting a request containing the data, closing the connection, and receiving an acknowledgment if the event collector **430** sends one. Logging libraries enable HTTP **428** requests to the event collector **430** to be generated directly by the data source. For example, an application can include or link a logging library, and through functionality provided by the logging library manage establishing a connection with the event collector **430**, transmitting a request, and receiving an acknowledgement.

[0131] An HTTP **428** request to the event collector **430** can contain a token, a channel identifier, event metadata, and/or event data. The token authenticates the request with the event collector **430**. The channel identifier, if available in the indexing system **420**, enables the event collector **430** to segregate and keep separate data from different data sources. The event metadata can include one or more key-value pairs that describe the data source **402** or the event data included in the request. For example, the event metadata can include key-value pairs specifying a timestamp, a hostname, a source, a source type, or an index where the event data should be indexed. The event data can be a structured data object, such as a JavaScript Object Notation (JSON) object, or raw text. The structured data object can include both event data and event metadata. Additionally, one request can include event data for one or more events.

[0132] In some implementations, the event collector **430** extracts events from HTTP **428** requests and sends the events to the indexer **432**. The event collector **430** can further be configured to send events to one or more indexers. Extracting the events can include associating any metadata in a request with the event or events included in the request. In these implementations, event generation by the indexer **432** (discussed further below) is bypassed, and the indexer **432** moves the events directly to indexing. In some implementations, the event collector **430** extracts event data from a request and outputs the event data to the indexer **432**, and the indexer generates events from the event data. In some implementations, the event collector **430** sends an acknowledgement message to the data source **402** to indicate that the event collector **430** has received a particular request form the data source **402**, and/or to indicate to the data source **402** that events in the request have been added to an index.

[0133] The indexer **432** ingests incoming data and transforms the data into searchable knowledge in the form of events. In the data intake and query system, an event is a single piece of data that represents activity of the component represented in FIG. **4**B by the data source **402**. An event can be, for example, a single record in a log file that records a single action performed by the component (e.g., a user login, a disk read, transmission of a network packet, etc.). An event includes one or more fields that together describe the action captured by the event, where a field is a key-value pair (also referred to as a name-value pair). In some cases, an event includes both the key and the value, and in some cases the event includes only the value and the key can be inferred or assumed.

[0134] Transformation of data into events can include event generation and event indexing. Event generation includes identifying each discrete piece of data that represents one event and associating each event with a timestamp and possibly other information (which may be referred to herein as metadata). Event indexing includes storing of each event in the data structure of an index. As an example, the indexer **432** can include a parsing module **434** and an indexing module **436** for generating and storing the events. The parsing module **434** and indexing module **436** can be modular and pipelined, such that one component can be operating on a first set of data while the second component is simultaneously operating on a second sent of data. Additionally, the indexer **432** may at any time have multiple instances of the parsing module **434** and indexing module **436**, with each set of instances configured to simultaneously operate on data from the same data source or from different data sources. The parsing module **434** and indexing module **436** are illustrated in FIG. **4**B to facilitate discussion, with the understanding that implementations with other components are possible to achieve the same functionality.

[0135] The parsing module **434** determines information about incoming event data, where the information can be used to identify events within the event data. For example, the parsing module **434** can associate a source type with the event data. A source type identifies the data source **402** and describes a possible data structure of event data produced by the data source **402**. For example, the source type can indicate which fields to expect in events generated at the data source **402** and the keys for the values in the fields, and possibly other information such as sizes of fields, an order of the fields, a field separator, and so on. The source type of the data source **402** can be specified when the data source **402** is configured as a source of event data. Alternatively, the parsing module **434** can determine the source type from the event data, for example from an event field in the event data or using machine learning techniques applied to the event data.

[0136] Other information that the parsing module **434** can determine includes timestamps. In some cases, an event includes a timestamp as a field, and the timestamp indicates a point in time when the action represented by the event occurred or was recorded by the data source **402** as event data. In these cases, the parsing module **434** may be able to determine from the source type associated with the event data that the timestamps can be extracted from the events themselves. In some cases, an event does not include a timestamp and the parsing module **434** determines a timestamp for the event, for example from a name associated with the event data from the data source **402** (e.g., a file name when the event data is in the form of a file) or a time associated with the event data (e.g., a file modification time). As another example, when the parsing module **434** is not able to determine a timestamp from the event data, the parsing module **434** may use the time at which it is indexing the event data. As another example, the parsing module **434** can use a user-configured rule to determine the timestamps to associate with events.

[0137] The parsing module **434** can further determine event boundaries. In some cases, a single line (e.g., a sequence of characters ending with a line termination) in event data represents one event while in other cases, a single line represents multiple events. In yet other cases, one event may span multiple lines within the event data. The parsing module **434** may be able to determine event boundaries from the source type associated with the event data, for example from a data structure indicated by the source type. In some implementations, a user can configure rules the parsing module **434** can use to identify event boundaries.

[0138] The parsing module **434** can further extract data from events and possibly also perform transformations on the events. For example, the parsing module **434** can extract a set of fields (key-value pairs) for each event, such as a host or hostname, source or source name, and/or source type. The parsing module **434** may extract certain fields by default or based on a user configuration. Alternatively or additionally, the parsing module **434** may add fields to events, such as a source type or a user-configured field. As another example of a transformation, the parsing module **434** can anonymize fields in events to mask sensitive information, such as social security numbers or account numbers. Anonymizing fields can include changing or replacing values of specific fields. The parsing component **434** can further perform user-configured transformations.

[0139] The parsing module **434** outputs the results of processing incoming event data to the indexing module **436**, which performs event segmentation and builds index data structures.

[0140] Event segmentation identifies searchable segments, which may alternatively be referred to as searchable terms or keywords, which can be used by the search system of the data intake and query system to search the event data. A searchable segment may be a part of a field in an event or an entire field. The indexer **432** can be configured to identify searchable segments that are parts of fields, searchable segments that are entire fields, or both. The parsing module **434** organizes the searchable segments into a lexicon or dictionary for the event data, with the lexicon including each searchable segment (e.g., the field "src=10.10.1.1") and a reference to the location of each occurrence of the searchable segment within the event data (e.g., the location within the event data of each occurrence of "src=10.10.1.1"). As discussed further below, the search system can use the lexicon, which is stored in an index file **446**, to find event data that matches a search query. In some implementations, segmentation can alternatively be performed by the forwarder **426**. Segmentation can also be disabled, in which case the indexer **432** will not build a lexicon for the event data. When segmentation is disabled, the search system searches the event data directly.

[0141] Building index data structures generates the index **438**. The index **438** is a storage data structure on a storage device (e.g., a disk drive or other physical device for storing digital data). The storage device may be a component of the computing device on which the indexer **432** is operating (referred to herein as local storage) or may be a component of a different computing device (referred to herein as remote storage) that the indexer **438** has access to over a network. The indexer **432** can manage more than one index and can manage indexes of different types. For example, the indexer **432** can manage event indexes, which impose minimal structure on stored data and can accommodate any type of data. As another example, the indexer **432** can manage metrics indexes, which use a highly structured format to handle the higher volume and lower latency demands associated with metrics data.

[0142] The indexing module **436** organizes files in the index **438** in directories referred to as buckets. The files in a bucket **444** can include raw data files, index files, and possibly also other metadata files. As used herein, "raw data" means data as when the data was produced by the data source **402**, without alteration to the format or content. As noted previously, the parsing component **434** may add fields to event data and/or perform transformations on fields in the event data. Event data that has been altered in this way is referred to herein as enriched data. A raw data file **448** can include enriched data, in addition to or instead of raw data. The raw data file **448** may be compressed to reduce disk usage. An index file **446**, which may also be referred to herein as a "time-series index" or tsidx file, contains metadata that the indexer **432** can use to search a corresponding raw data file **448**. As noted above, the metadata in the index file **446** includes a lexicon of the event data, which associates each unique keyword in the event data with a reference to the location of event data within the raw data file **448**. The keyword data in the index file **446** may also be referred to as an inverted index. In various implementations, the data intake and query system can use index files for other purposes, such as to store data summarizations that can be used to accelerate searches.

[0143] A bucket **444** may include event data for a particular range of time. The indexing module **436** may arrange buckets in the index **438** according to the age of the buckets, such that buckets for more recent ranges of time are stored in short-term storage **440** and buckets for less recent ranges of time are stored in long-term storage **442**. Short-term storage **440** may be faster to access while long-term storage **442** may be slower to access. Buckets may be moves from short-term storage **440** to long-term storage **442** according to a configurable data retention policy, which can indicate at what point in time a bucket is old enough to be moved.

[0144] A bucket's location in short-term storage **440** or long-term storage **442** can also be indicated by the bucket's status. As an example, a bucket's status can be "hot," "warm," "cold," "frozen," or "thawed." In this example, hot bucket is one to which the indexer **432** is writing data and the bucket becomes a warm bucket when the index **432** stops writing data to it. In this example, both hot and warm buckets reside in short-term storage **440**. Continuing this example, when a warm bucket is moved to long-term storage **442**, the bucket becomes a cold bucket. A cold bucket can become a frozen bucket after a period of time, at which point the bucket may be deleted or archived. An archived bucket cannot be searched. When an archived bucket is retrieved for searching, the bucket becomes thawed and can then be searched.

[0145] The indexing system **420** can include more than one indexer, where a group of indexers is referred to as an index cluster. The indexers in an index cluster may also be referred to as peer nodes. In an index cluster, the indexers are configured to replicate each other's data by copying buckets from one indexer to another. The number of copies of a bucket can be configured (e.g., three copies of each buckets must exist within the cluster), and indexers to which buckets are copied may be selected to optimize distribution of data across the cluster.

[0146] A user can view the performance of the indexing system **420** through the monitoring console **416** provided by the user interface system **414**. Using the monitoring console **416**, the user can configure and monitor an index cluster, and see information such as disk usage by an index, volume usage by an indexer, index and volume size over time, data age, statistics for bucket types, and bucket settings, among other information.

[0147] FIG. **4**C is a block diagram illustrating in greater detail an example of the search system **460** of a data intake and query system, such as the data intake and query system **410** of FIG. **4**. The search system **460** of FIG. **4**C issues a query **466** to a search head **462**, which sends the query **466** to a search peer **464**. Using a map process **470**, the search peer **464** searches the appropriate index **438** for events identified by the query **466** and sends events **478** so identified back to the search head **462**. Using a reduce process

482, the search head **462** processes the events **478** and produces results **468** to respond to the query **466**. The results **468** can provide useful insights about the data stored in the index **438**. These insights can aid in the administration of information technology systems, in security analysis of information technology systems, and/or in analysis of the development environment provided by information technology systems.

[0148] The query **466** that initiates a search is produced by a search and reporting app **416** that is available through the user interface system **414** of the data intake and query system. Using a network access application **406** executing on a computing device **404**, a user can input the query **466** into a search field provided by the search and reporting app **416**. Alternatively or additionally, the search and reporting app **416** can include pre-configured queries or stored queries that can be activated by the user. In some cases, the search and reporting app **416** initiates the query **466** when the user enters the query **466**. In these cases, the query **466** maybe referred to as an "ad-hoc" query. In some cases, the search and reporting app **416** initiates the query **466** based on a schedule. For example, the search and reporting app **416** can be configured to execute the query **466** once per hour, once per day, at a specific time, on a specific date, or at some other time that can be specified by a date, time, and/or frequency. These types of queries maybe referred to as scheduled queries.

[0149] The query **466** is specified using a search processing language. The search processing language includes commands or search terms that the search peer **464** will use to identify events to return in the search results **468**. The search processing language can further include commands for filtering events, extracting more information from events, evaluating fields in events, aggregating events, calculating statistics over events, organizing the results, and/or generating charts, graphs, or other visualizations, among other examples. Some search commands may have functions and arguments associated with them, which can, for example, specify how the commands operate on results and which fields to act upon. The search processing language may further include constructs that enable the query **466** to include sequential commands, where a subsequent command may operate on the results of a prior command. As an example, sequential commands may be separated in the query **466** by a vertical line ("|" or "pipe") symbol.

[0150] In addition to one or more search commands, the query **466** includes a time indicator. The time indicator limits searching to events that have timestamps described by the indicator. For example, the time indicator can indicate a specific point in time (e.g., 10:00:00 am today), in which case only events that have the point in time for their timestamp will be searched. As another example, the time indicator can indicate a range of time (e.g., the last 24 hours), in which case only events whose timestamps fall within the range of time will be searched. The time indicator can alternatively indicate all of time, in which case all events will be searched.

[0151] Processing of the search query **466** occurs in two broad phases: a map phase **450** and a reduce phase **452**. The map phase **450** takes place across one or more search peers. In the map phase **450**, the search peers locate event data that matches the search terms in the search query **466** and sorts the event data into field-value pairs. When the map phase **450** is complete, the search peers send events that they have found to one or more search heads for the reduce phase **452**. During the reduce phase **452**, the search heads process the events through commands in the search query **466** and aggregate the events to produce the final search results **468**.

[0152] A search head, such as the search head **462** illustrated in FIG. **4**C, is a component of the search system **460** that manages searches. The search head **462**, which may also be referred to herein as a search management component, can be implemented using program code that can be executed on a computing device. The program code for the search head **462** can be stored on a non-transitory computer-readable medium and from this medium can be loaded or copied to the memory of a computing device. One or more hardware processors of the computing device can read the program code from the memory and execute the program code in order to implement the operations of the search head **462**.

[0153] Upon receiving the search query **466**, the search head **462** directs the query **466** to one or more search peers, such as the search peer **464** illustrated in FIG. **4**C. "Search peer" is an alternate name for "indexer" and a search peer may be largely similar to the indexer described previously. The search peer **464** may be referred to as a "peer node" when the search peer **464** is part of an indexer cluster. The search peer **464**, which may also be referred to as a search execution component, can be implemented using program code that can be executed on a computing device. In some implementations, one set of program code implements both the search head **462** and the search peer **464** such that the search head **462** and the search peer **464** form one component. In some implementations, the search head **462** is an independent piece of code that performs searching and no indexing functionality. In these implementations, the search head **462** may be referred to as a dedicated search head.

[0154] The search head **462** may consider multiple criteria when determining whether to send the query **466** to the particular search peer **464**. For example, the search system **460** may be configured to include multiple search peers that each have duplicative copies of at least some of the event data and are implanted using different hardware resources q. In this example, the sending the search query **466** to more than one search peer allows the search system **460** to distribute the search workload across different hardware resources. As another example, search system **460** may include different search peers for different purposes (e.g., one has an index storing a first type of data or from a first data source while a second has an index storing a second type of data or from a second data source). In this example, the search query **466** may specify which indexes to search, and the search head **462** will send the query **466** to the search peers that have those indexes.

[0155] To identify events **478** to send back to the search head **462**, the search peer **464** performs a map process **470** to obtain event data **474** from the index **438** that is maintained by the search peer **464**. During a first phase of the map process **470**, the search peer **464** identifies buckets that have events that are described by the time indicator in the search query **466**. As noted above, a bucket contains events whose timestamps fall within a particular range of time. For each bucket **444** whose events can be described by the time indicator, during a second phase of the map process **470**, the search peer **464** performs a keyword search **474** using search terms specified in the search query **466**. The search terms can be one or more of keywords, phrases, fields, Boolean expressions, and/or comparison expressions that in combination describe events being searched for. When segmentation is enabled at index time, the search peer **464** performs the keyword search **472** on the bucket's index file **446**. As noted previously, the index file **446** includes a lexicon of the searchable terms in the events stored in the bucket's raw data **448** file. The keyword search **472** searches the lexicon for searchable terms that correspond to one or more of the search terms in the query **466**. As also noted above, the lexicon incudes, for each searchable term, a reference to each location in the raw data **448** file where the searchable term can be found. Thus, when the keyword search identifies a searchable term in the index file **446** that matches a search term in the query **466**, the search peer **464** can use the location references to extract from the raw data **448** file the event data **474** for each event that include the searchable term.

[0156] In cases where segmentation was disabled at index time, the search peer **464** performs the keyword search **472** directly on the raw data **448** file. To search the raw data **448**, the search peer **464** may identify searchable segments in events in a similar manner as when the data was indexed. Thus, depending on how the search peer **464** is configured, the search peer **464** may look at event fields and/or parts of event fields to determine whether an event matches the query **466**. Any matching events can be added to the event data **474** read from the raw data **448** file. The search peer **464** can further be configured to enable segmentation at search time, so that searching of the index **438** causes the search peer **464** to build a lexicon in the index file **446**.

[0157] The event data **474** obtained from the raw data **448** file includes the full text of each event found by the keyword search **472**. During a third phase of the map process **470**, the search peer **464** performs event processing **476** on the event data **474**, with the steps performed being determined by the configuration of the search peer **464** and/or commands in the search query **466**. For example, the search peer **464** can be configured to perform field discovery and field extraction. Field discovery is a process by which the search peer **464** identifies and extracts key-value pairs from the events in the event data **474**. The search peer **464** can, for example, be configured to automatically extract the first **100** fields (or another number of fields) in the event data **474** that can be identified as key-value pairs. As another example, the search peer **464** can extract any fields explicitly mentioned in the search query **466**. The search peer **464** can, alternatively or additionally, be configured with particular field extractions to perform.

[0158] Other examples of steps that can be performed during event processing **476** include: field aliasing (assigning an alternate name to a field); addition of fields from lookups (adding fields from an external source to events based on existing field values in the events); associating event types with events; source type renaming (changing the name of the source type associated with particular events); and tagging (adding one or more strings of text, or a "tags" to particular events), among other examples.

[0159] The search peer **464** sends processed events **478** to the search head **462**, which performs a reduce process **480**. The reduce process **480** potentially receives events from multiple search peers and performs various results processing **482** steps on the received events. The results processing **482** steps can include, for example, aggregating the events received from different search peers into a single set of events, deduplicating and aggregating fields discovered by different search peers, counting the number of events found, and sorting the events by timestamp (e.g., newest first or oldest first), among other examples. Results processing **482** can further include applying commands from the search query **466** to the events. The query **466** can include, for example, commands for evaluating and/or manipulating fields (e.g., to generate new fields from existing fields or parse fields that have more than one value). As another example, the query **466** can include commands for calculating statistics over the events, such as counts of the occurrences of fields, or sums, averages, ranges, and so on, of field values. As another example, the query **466** can include commands for generating statistical values for purposes of generating charts of graphs of the events.

[0160] The reduce process **480** outputs the events found by the search query **466**, as well as information about the events. The search head **462** transmits the events and the information about the events as search results **468**, which are received by the search and reporting app **416**. The search and reporting app **416** can generate visual interfaces for viewing the search results **468**. The search and reporting app **416** can, for example, output visual interfaces for the network access application **406** running on a computing device **404** to generate.

[0161] The visual interfaces can include various visualizations of the search results **468**, such as tables, line or area charts, Chloropleth maps, or single values. The search and reporting app **416** can organize the visualizations into a dashboard, where the dashboard includes a panel for each visualization. A dashboard can thus include, for example, a panel listing the raw event data for the events in the search results **468**, a panel listing fields extracted at index time and/or found through field discovery along with statistics for those fields, and/or a timeline chart indicating how many events occurred at specific points in time (as indicated by the timestamps associated with each event). In various implementations, the search and reporting app **416** can provide one or more default dashboards. Alternatively or additionally, the search and reporting app **416** can include functionality that enables a user to configure custom dashboards.

[0162] The search and reporting app **416** can also enable further investigation into the events in the search results **416**. The process of further investigation may be referred to as drilldown. For example, a visualization in a dashboard can include interactive elements, which, when selected, provide options for finding out more about the data being displayed by the interactive elements. To find out more, an interactive element can, for example, generate a new search that includes some of the data being displayed by the interactive element, and thus may be more focused than the initial search query **466**. As another example, an interactive element can launch a different dashboard whose panels include more detailed information about the data that is displayed by the interactive element. Other examples of actions that can be performed by interactive elements in a dashboard include opening a link, playing an audio or video file, or launching another application, among other examples.

[0163] In some implementations, a data intake and query system as described above may further include a stream data processing system. The stream data processing system can illustratively be configured to operate on the basis of data streams, rather than data sets, such as by manipulating the data streams according to one or more data sets of data processing instructions, sometimes referred to as pipelines.

[0164] In one example, the data intake and query system provides a unified query language that can be applied to both conduct batch queries and implement data stream processing instruction set. In another example, the data intake and query system provides graphical user interfaces to design data stream processing instruction set, and is configured to convert graphically designated data stream processing instruction sets into textual query language representations of the data stream processing instruction sets. In some cases, the data intake and query system may be configured to programmatically implement a given query command as a batch query, a data stream processing instruction set, or a combination thereof. For example, a query specifying a time range may be execute as a batch query if the time range is prior to a present time, as a data stream processing instruction set if the time range is at or past a present time, or as a combination if the range spans both past and present (e.g., with the batch query executed from the portion of the range in the past and the data stream processing instruction set executed on the portion of the range at or past a current time).

[0165] One example implementation of a data intake and query system including a stream data processing system is shown in FIG. **5**. The data intake and query system of FIG. **5** includes a batch query system **590**, including a search head **560** and an indexer **520**. The search head **560** and indexer **520** may operate similarly to the various search heads and indexers described above, such as the search heads **960** and indexers **920** of FIG. **9**.

[0166] As shown in FIG. **5**, the search head **560** and indexer **520** can (in addition or alternatively to obtaining from data sources **502**) obtain data from a stream data processor **512** of a stream data processing system **580**. The stream data processor **512**, in turn, can be configured to obtain data from data sources **502** as an input data stream, manipulate the data according to one or more data stream processing instruction set, and output the resulting data stream to indexers **520** or other network-accessible storage, such as the data storage system **514**. For example, the stream data processing system **580** can include one or more forwarders **516** configured to obtain data from data sources **502** and forward the data to the stream data processor **512**. In one example, the stream data processor **512** conducts filtering prior to data moving to indexers **520**. Illustratively, the stream data processor **512** may identify high value data and route such data to indexers **520**, while routing remaining data to the data storage system **514**. In another example, the stream data processor **512** conducts other manipulations, such as re-formatting data, compressing data, or the like.

[0167] Illustratively, forwarders **516** may be configured to support a variety of protocols, transmission formats, and data formats that may be used by various data sources **502**, and to forward such data to a stream data processor **512** in a format acceptable to the process **512**. In some implementations, the stream data processor **512** may obtain data directly from data sources **502** and forwarders **516** may be omitted.

[0168] The data intake and query system of FIG. **5** can further include a configuration system **570** enabling user configuration of the stream data processing system **580**, the batch query system **590**, or both. Illustratively, a user may utilize a network access application **506**, such as a web browser, executing on a computing device **504** to interact with the configuration system **570** and appropriately configure the stream data processing system **580**, the batch query system **590**, or both. The configuration system **570** can include a variety of elements facilitating such configuration. For example, the configuration system **570** can include data storage **536** for storage of information used by the network access application **506**, such as web pages renderable on the application **506** to display interfaces facilitating configuration. The configuration system **570** can further include a language service **534** to facilitate creation of batch queries and/or pipelines implementable on the data intake and query system. For example, the language service **534** may be configured to interpret textual queries as either or both batch queries and pipelines, and generate computer executable instructions executable by the respective stream data processing system **580** and batch query system **590** to implement the textual queries. The configuration system **570** can further include a metadata catalog **532** storing information regarding the data intake and query system, such as groups (e.g., buckets) of data stored on the batch query system **590**, identifiers for such groups, indexes of such groups, etc. and a configuration of the stream data processing system **580**, such as data stream processing instruction sets deployed to the system **580** or metadata regarding such pipelines. Illustratively, the network access application **506** may utilize metadata stored within the metadata catalog **532** to enable a user of the computing device **504** to browse data on the data intake and query system, form queries against that data, configure or reconfigure pipelines, and the like.

[0169] The configuration system **570** shown in FIG. **5** further includes an orchestration service **538** configured to orchestrate operation of the data intake and query system. For example, the orchestration service **538** can be configured to determine whether to implement a query statement on the stream data processing system **580**, the batch query system **590**, or both (based, e.g., on a time range specified within the query, a source or destination specified in the query, etc.). The orchestration service **538** can further maintain the metadata catalog **532** based on results of such queries.

[0170] The configuration system **570** in FIG. **5** further includes a stream processing configuration service **540** enabling configuration of the stream data processing system **580**. For example, the stream processing configuration service **540** may obtain configuration instructions from the computing device **504** and/or from the orchestration service **538** and generate a configuration for the stream data processing system **580** from such instructions. For example, the stream processing configuration service **540** may generate instructions to implement a data stream processing instruction set based on input from the computing device **504** and/or the orchestration service **538**. The stream processing configuration service **540** can illustratively interact with a synchronization service **542** to provide configuration data to the stream data processing system **580**. For example, the synchronization service **542** of the configuration system **570** may interact with a synchronization service **544** of the stream data processing system **580** to synchronize a configuration of the stream data process **512** with that generated at the stream processing configuration service **540**.

[0171] Accordingly, by use of the configuration system **570**, a user at a computing device **504** may configure and utilize either or both the stream data processing system **580** and batch query system **590**.

[0172] In one embodiment, each of the configuration system **570**, stream data processing system **580**, and batch query system **590** is implemented within a distinct computing environment. For example, the configurations system **570** may be implemented within a multi-tenant hosted computing environment (which hosted computing environment is sometimes referred to as a "cloud computing environment"). The stream data processing system **580** may be implemented within a private computing environment, such as a private data center of an end user of the data intake and query system, which private computing environment may be referred to in some cases as an "on premises" environment. The batch query system **590** may be implemented within a single tenanted hosted computing environment, such as a cloud-hosted environment dedicated to the end user associated with the batch query system **590**. Each of the elements of FIG. **5** may be in communication with one another via one or more networks, including private networks and/or public networks. Lines within FIG. **5** should be understood to depict illustrative logical interactions between elements; however, elements may interact in ways not depicted within FIG. **5**.

[0173] Various examples and possible implementations have been described above, which recite certain features and/or functions. Although these examples and implementations have been described in language specific to structural features and/or functions, it is understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or functions described above. Rather, the specific features and functions described above are disclosed as examples of implementing the claims, and other equivalent features and acts are intended to be within the scope of the claims. Further, any or all of the features and functions described above can be combined with each other, except to the extent it may be otherwise stated above or to the extent that any such embodiments may be incompatible by virtue of their function or structure, as will be apparent to persons of ordinary skill in the art. Unless contrary to physical possibility, it is envisioned that (i) the methods/steps described herein may be performed in any sequence and/or in any combination, and (ii) the components of respective embodiments may be combined in any manner.

[0174] Processing of the various components of systems illustrated herein can be distributed across multiple machines, networks, and other computing resources. Two or more components of a system can be combined into fewer components. Various components of the illustrated systems can be implemented in one or more virtual machines or an isolated execution environment, rather than in dedicated computer hardware systems and/or computing devices. Likewise, the data repositories shown can represent physical and/or logical data storage, including, e.g., storage area networks or other distributed storage systems. Moreover, in some embodiments the connections between the components shown represent possible paths of data flow, rather than actual connections between hardware. While some examples of possible connections are shown, any of the subset of the components shown can communicate with any other subset of components in various implementations.

[0175] Examples have been described with reference to flow chart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products. Each block of the flow chart illustrations and/or block diagrams, and combinations of blocks in the flow chart illustrations and/or block diagrams, may be implemented by computer program instructions. Such instructions may be provided to a processor of a general purpose computer, special purpose computer, specially-equipped computer (e.g., comprising a high-performance database server, a graphics subsystem, etc.) or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor(s) of the computer or other programmable data processing apparatus, create means for implementing the acts specified in the flow chart and/or block diagram block or blocks. These computer program instructions may also be stored in a non-transitory computer-readable memory that can direct a computer or other programmable data processing apparatus to operate in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means which implement the acts specified in the flow chart and/or block diagram block or blocks. The computer program instructions may also be loaded to a computing device or other programmable data processing apparatus to cause operations to be performed on the computing device or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computing device or other programmable apparatus provide steps for implementing the acts specified in the flow chart and/or block diagram block or blocks.

[0176] In some embodiments, certain operations, acts, events, or functions of any of the algorithms described herein can be performed in a different sequence, can be added, merged, or left out altogether (e.g., not all are necessary for the practice of the algorithms). In certain embodiments, operations, acts, functions, or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially.

1. (canceled)

2. A computer-implemented method, comprising:

receiving a search query;

responsive to receiving the search query, configuring an inter-system interface for a plurality of runtime systems;

generating a plurality of tasks for the plurality of runtime systems to execute the search query, wherein a particular task for a particular runtime system:

includes an instruction for the particular runtime system to retrieve at least a portion of a set of data from the inter-system interface, wherein the at least the portion of the set of data corresponds to a result of processing another set of data by another runtime system, and

identifies a particular operation of a plurality of operations that the particular runtime system is to perform on the set of data;

distributing the plurality of tasks to the plurality of runtime systems; and

receiving, from the inter-system interface, results associated with completion of the plurality of tasks.

3. The computer-implemented method of claim **2**, wherein the set of data includes data stored or controlled by the particular runtime system and partial search query results generated by another runtime system.

4. The computer-implemented method of claim **2**, further comprising identifying the plurality of operations to be performed based on the search query, wherein identifying the plurality of operations comprises:

parsing the search query to identify query commands within the search query, and

determining the plurality of operations based on the identified query commands.

5. The computer-implemented method of claim **2**, further comprising identifying the plurality of runtime systems to execute at least a portion of the search query, wherein identifying the plurality of runtime systems comprises:

identifying runtime systems configured to store or control access to at least a portion of at least one set of data of the plurality of sets of data, and

identifying runtime systems configured to perform at least one operation of the plurality of operations.

6. The computer-implemented method of claim **2**, further comprising identifying a plurality of sets of data to be processed based on the search query, wherein each set of data of the plurality of sets of data is associated with at least one runtime system of the plurality of runtime systems.

7. The computer-implemented method of claim **2**, wherein each operation of the plurality of operations is associated with at least one runtime system of the plurality of runtime systems.

8. The computer-implemented method of claim **2**, wherein the inter-system interface enables communications of partial search results between the plurality of runtime systems.

9. The computer-implemented method of claim **2**, wherein configuring the inter-system interface comprises instantiating a publisher subscriber model.

10. The computer-implemented method of claim **2**, wherein the particular runtime system is a first runtime system, the particular task is a first task, the set of data is a first set of data, and the particular operation is a first operation, wherein a second task of the plurality of tasks:

identifies a second set of data of the plurality of sets of data to be processed by a second runtime system of the plurality of runtime systems, wherein the second set of data includes the results of performing the first operation on the first set of data,

identifies a second operation of the plurality of operations that the second runtime system is to perform on the second set of data, and

includes instructions for the second runtime system to retrieve the results of performing the first operation on the first set of data from the inter-system interface, process the results of performing the first operation on the first set of data according to the second operation, and communicate results of performing the second operation on the second set of data to the inter-system interface.

11. The computer-implemented method of claim **2**, wherein the particular runtime system is a first runtime system, the particular task is a first task, the set of data is a first set of data, and the particular operation is a first operation, wherein a second task of the plurality of tasks:

identifies a second set of data of the plurality of sets of data to be processed by a second runtime system of the plurality of runtime systems, wherein the second set of data includes the results of performing the first operation on the first set of data and data stored or controlled by the second runtime system,

identifies a second operation of the plurality of operations that the second runtime system is to perform on the second set of data, and

includes instructions for the second runtime system to retrieve the results of performing the first operation on the first set of data from the inter-system interface, process the results of performing the first operation on the first set of data and the data stored or controlled by the second runtime system according to the second operation, and communicate results of performing the second operation on the second set of data to the inter-system interface.

12. The computer-implemented method of claim **2**, wherein the particular task for the particular runtime system further identifies the set of data from a plurality of sets of data to be processed by the particular runtime system of the plurality of runtime systems and includes instructions for the particular runtime system to communicate results of performing the particular operation on the set of data to the inter-system interface.

13. A system, comprising:

a data store; and

one or more processors configured to:

receive a search query;

responsive to receiving the search query, configure an inter-system interface for a plurality of runtime systems;

generate a plurality of tasks for the plurality of runtime systems to execute the search query, wherein a particular task for a particular runtime system:

includes an instruction for the particular runtime system to retrieve at least a portion of a set of data from the inter-system interface, wherein the at least the portion of the set of data corresponds to a result of processing another set of data by another runtime system, and

identifies a particular operation of a plurality of operations that the particular runtime system is to perform on the set of data;

distribute the plurality of tasks to the plurality of runtime systems; and

receive, from the inter-system interface, results associated with completion of the plurality of tasks.

14. The system of claim **13**, wherein the set of data includes data stored or controlled by the particular runtime system and partial search query results generated by another runtime system.

15. The system of claim **13**, further comprising identifying the plurality of operations to be performed based on the search query, wherein identifying the plurality of operations comprises:

parse the search query to identify query commands within the search query, and

determine the plurality of operations based on the identified query commands.

16. The system of claim **13**, further comprising identifying the plurality of runtime systems to execute at least a portion of the search query, wherein identifying the plurality of runtime systems comprises:

identify runtime systems configured to store or control access to at least a portion of at least one set of data of the plurality of sets of data, and identify runtime systems configured to perform at least one operation of the plurality of operations.

17. Non-transitory computer-readable media including computer-executable instructions that, when executed by a computing system, cause the computing system to:

receive a search query;

responsive to receiving the search query, configure an inter-system interface for a plurality of runtime systems;

generate a plurality of tasks for the plurality of runtime systems to execute the search query, wherein a particular task for a particular runtime system:

includes an instruction for the particular runtime system to retrieve at least a portion of a set of data from the inter-system interface, wherein the at least the portion of the set of data corresponds to a result of processing another set of data by another runtime system, and

identifies a particular operation of a plurality of operations that the particular runtime system is to perform on the set of data;

distribute the plurality of tasks to the plurality of runtime systems; and

receive, from the inter-system interface, results associated with completion of the plurality of tasks.

18. The non-transitory computer-readable media of claim **17**, further comprising identifying a plurality of sets of data to be processed based on the search query, wherein each set of data of the plurality of sets of data is associated with at least one runtime system of the plurality of runtime systems.

19. The non-transitory computer-readable media of claim **17**, wherein each operation is associated with at least one runtime system of the plurality of runtime systems.

20. The non-transitory computer-readable media of claim **17**, wherein the inter-system interface enables communications of partial search results between the plurality of runtime systems.

21. The non-transitory computer-readable media of claim **17**, wherein configuring the inter-system interface comprises instantiating a publisher subscriber model.

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