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Walters et al.

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(54) **SYSTEM AND METHODS FOR VIRTUAL ASSISTANT NETWORKS**

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H04L 29/08 (2006.01)
G06N 5/00 (2006.01)

(52) **U.S. Cl.**
CPC . ***H04L 67/10*** (2013.01); *G06N 5/00* (2013.01)

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

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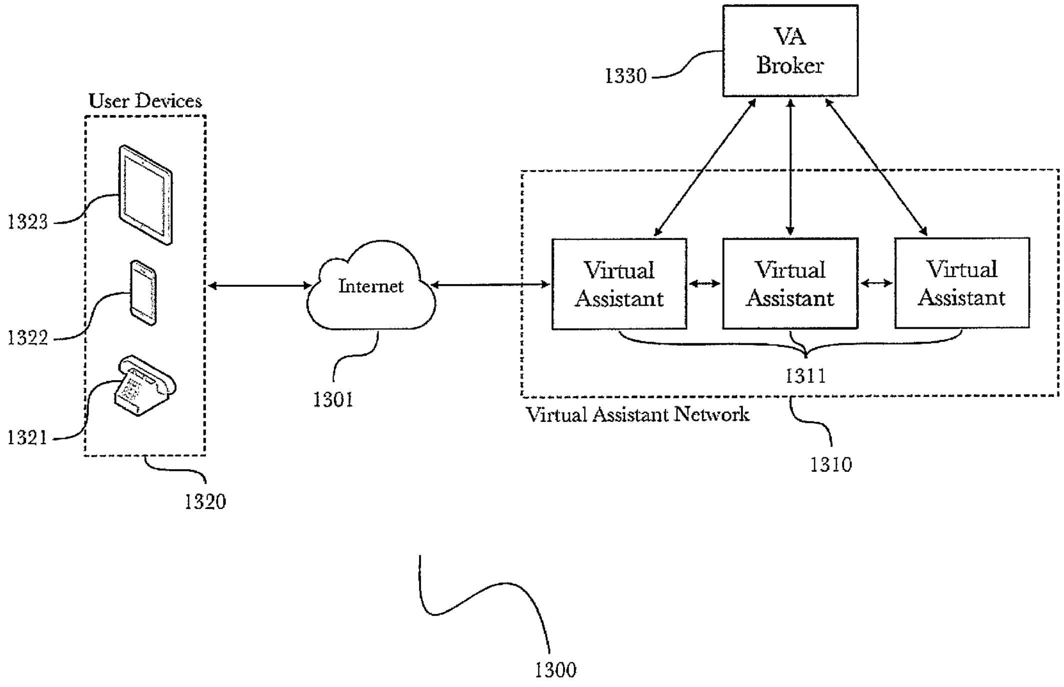
(57) **ABSTRACT**

A system for the operation of a virtual assistant network, comprising a plurality of virtual assistants stored and operating on network-connected devices, and a plurality of virtual assistant brokers stored and operating on network-connected devices, wherein the virtual assistants receive user requests and send the requests to the virtual assistant brokers, and wherein the virtual assistant brokers delegate the requests to other virtual assistants for fulfillment.

6 Claims, 17 Drawing Sheets



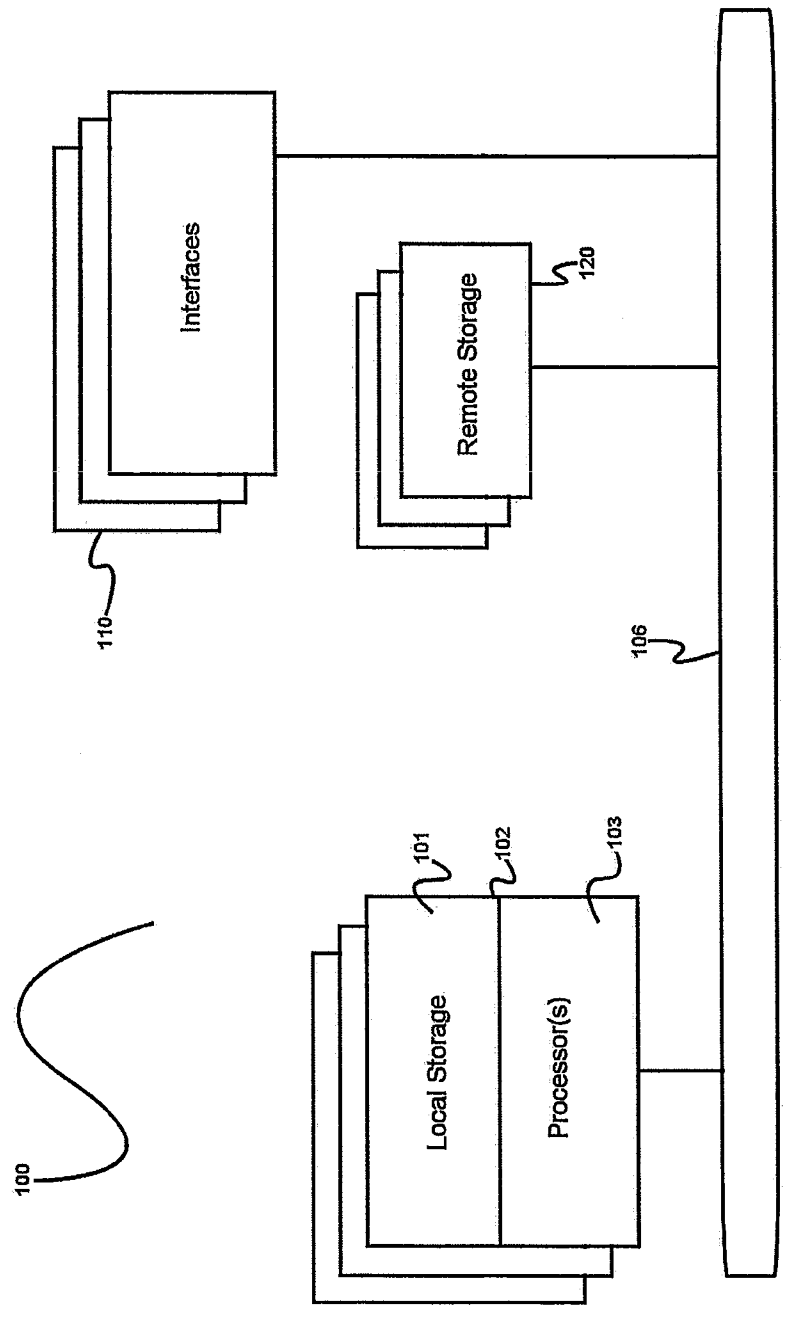

Interfaces
110
Remote Storage
120
106
100
Local Storage
Processor(s)
101
102
103

Fig. 1

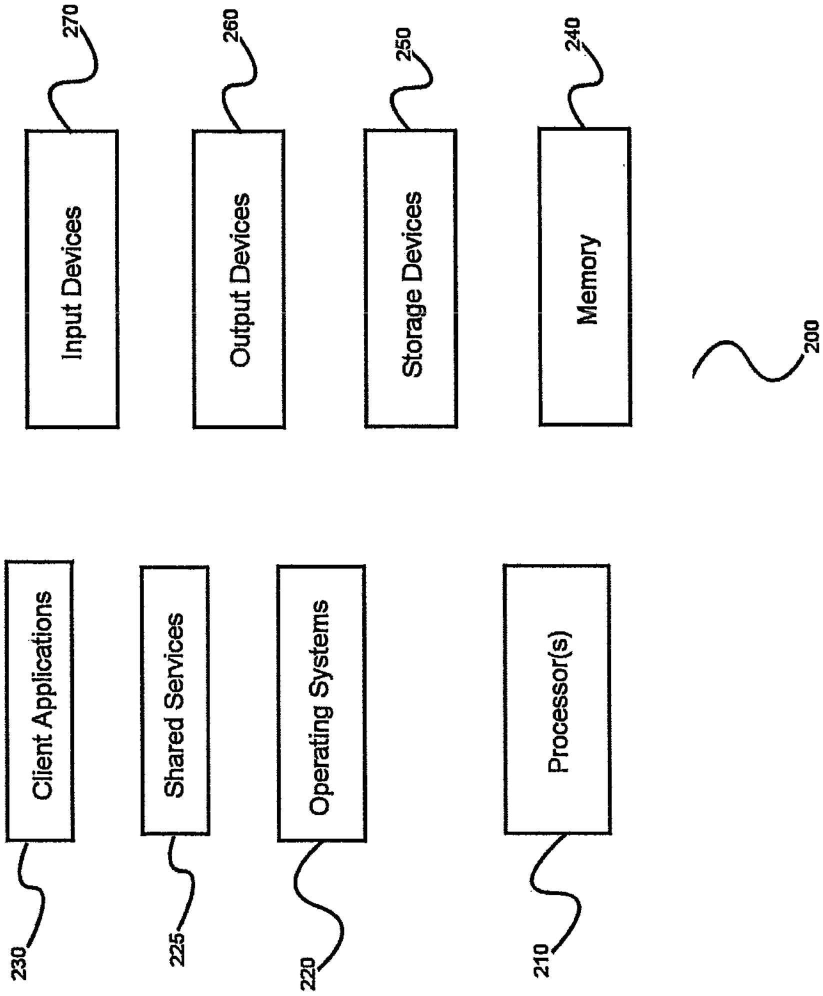

Input Devices
270
Output Devices
260
Storage Devices
250
Memory
240
200
Client Applications
230
Shared Services
225
Operating Systems
220
Processor(s)
210

Fig. 2

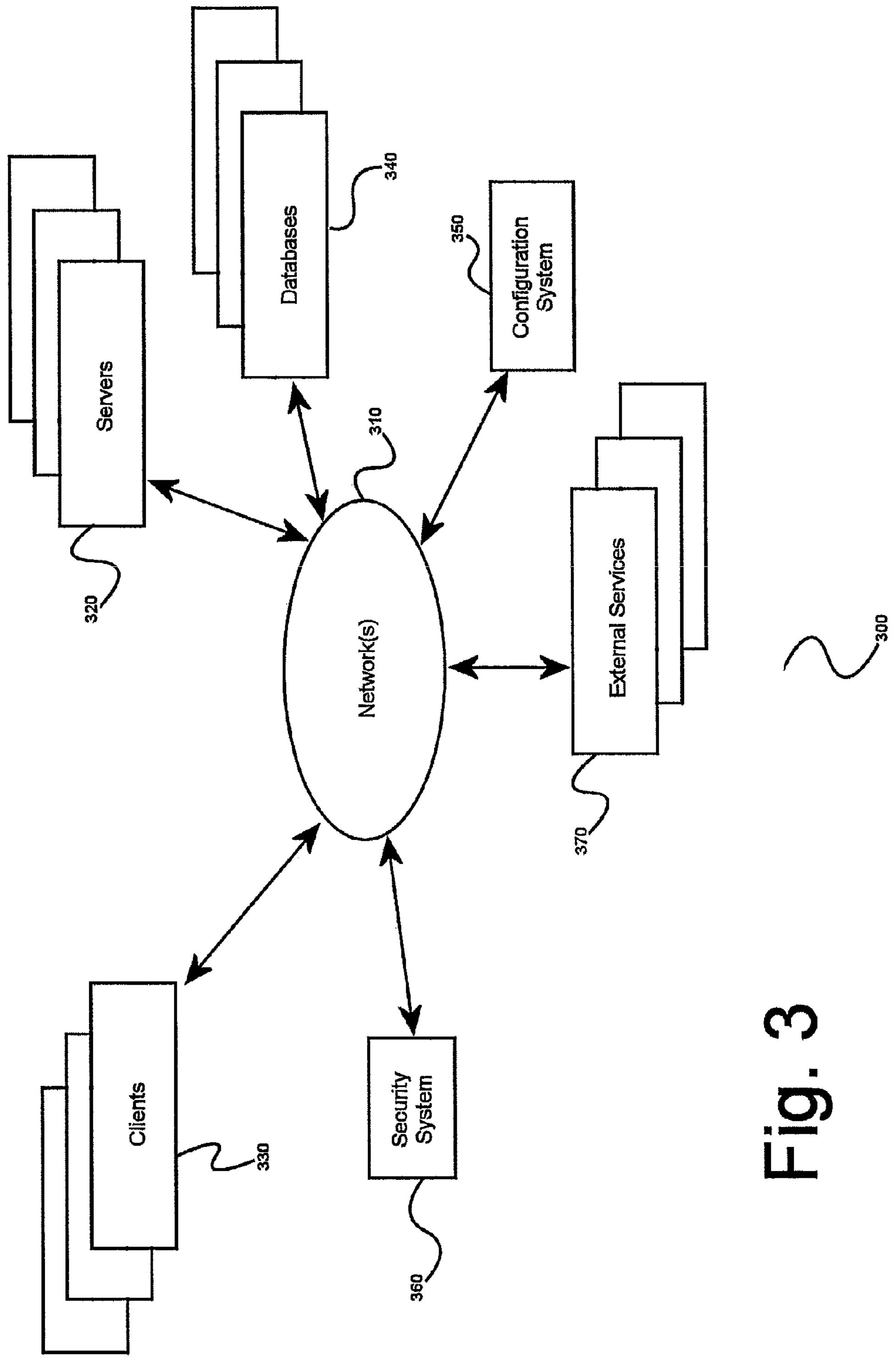
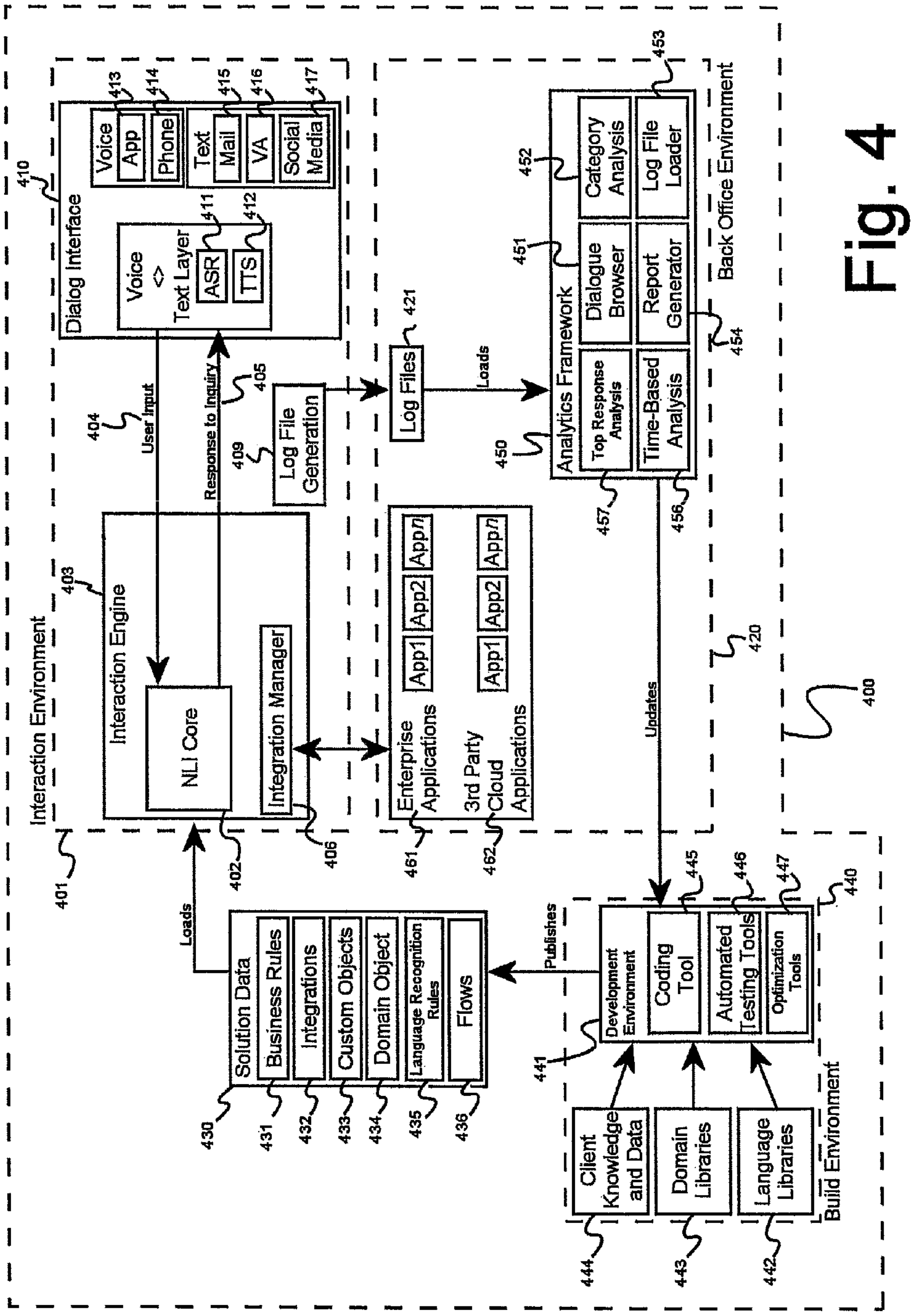

Servers
320
Databases
340
Configuration System
350
Network(s)
310
External Services
370
300
Clients
330
Security System
360

Fig. 3



400
401
Interaction Environment
410
Dialog Interface
Voice
<>
Text Layer
ASR
TTS
411
412
Voice
App
Phone
413
414
Text
Mail
VA
Social Media
415
416
417
403
Interaction Engine
NLI Core
Integration Manager
402
406
404
User Input
Response to Inquiry
405
409
Log File Generation
420
Back Office Environment
Log Files
421
Loads
450
Analytics Framework
Top Response Analysis
Time-Based Analysis
Dialogue Browser
Report Generator
Category Analysis
Log File Loader
451
452
453
454
456
457
Enterprise Applications
App1
App2
Appn
3rd Party Cloud Applications
App1
App2
Appn
461
462
Updates
Loads
Solution Data
Business Rules
Integrations
Custom Objects
Domain Object
Language Recognition Rules
Flows
430
431
432
433
434
435
436
Publishes
440
Build Environment
Development Environment
Coding Tool
Automated Testing Tools
Optimization Tools
441
445
446
447
Client Knowledge and Data
Domain Libraries
Language Libraries
444
443
442

Fig. 4

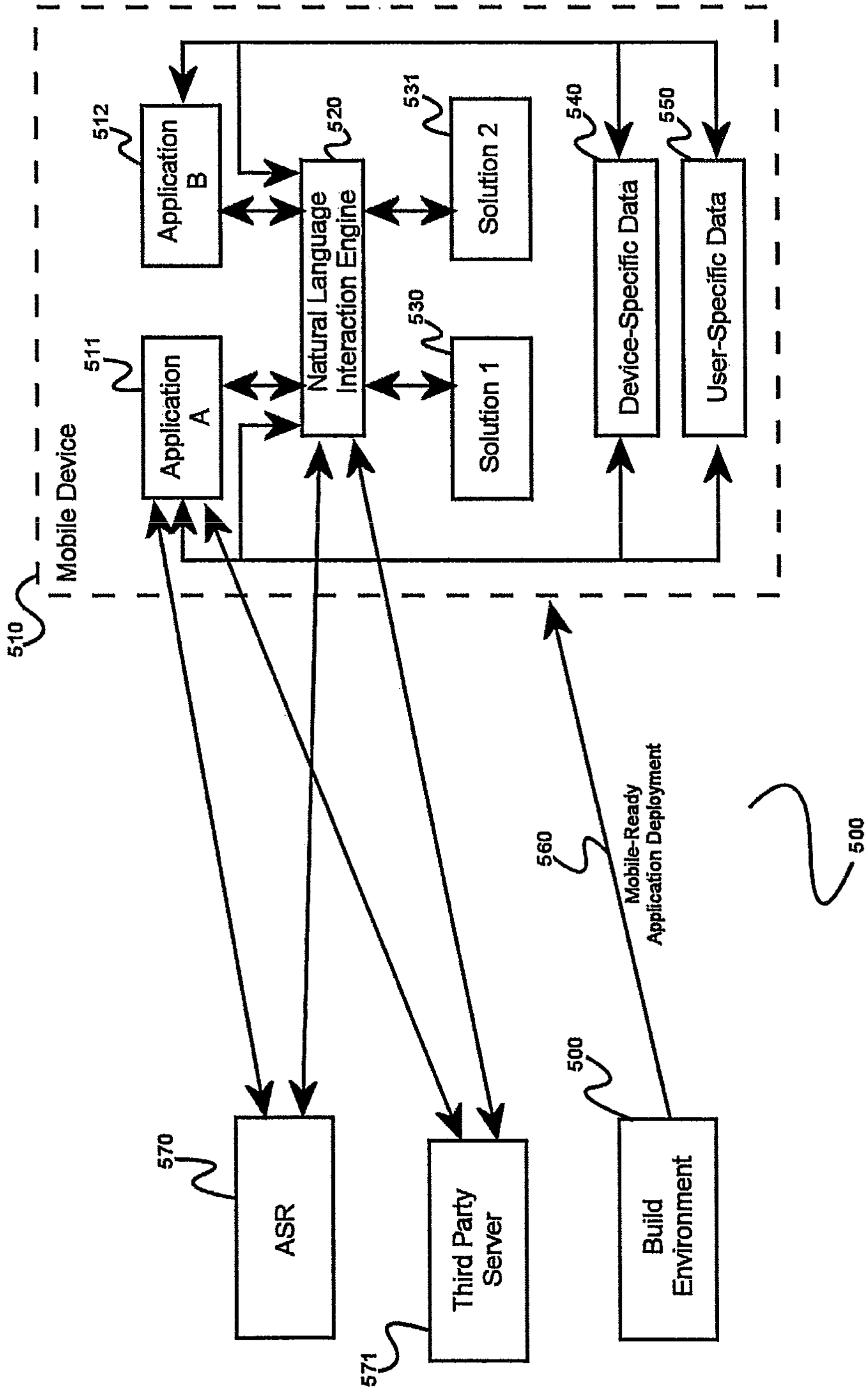

Mobile Device
510
Application A
511
Application B
512
Natural Language Interaction Engine
520
Solution 1
530
Solution 2
531
Device-Specific Data
540
User-Specific Data
550
Mobile-Ready Application Deployment
560
500
ASR
570
Third Party Server
571
Build Environment
500

Fig. 5

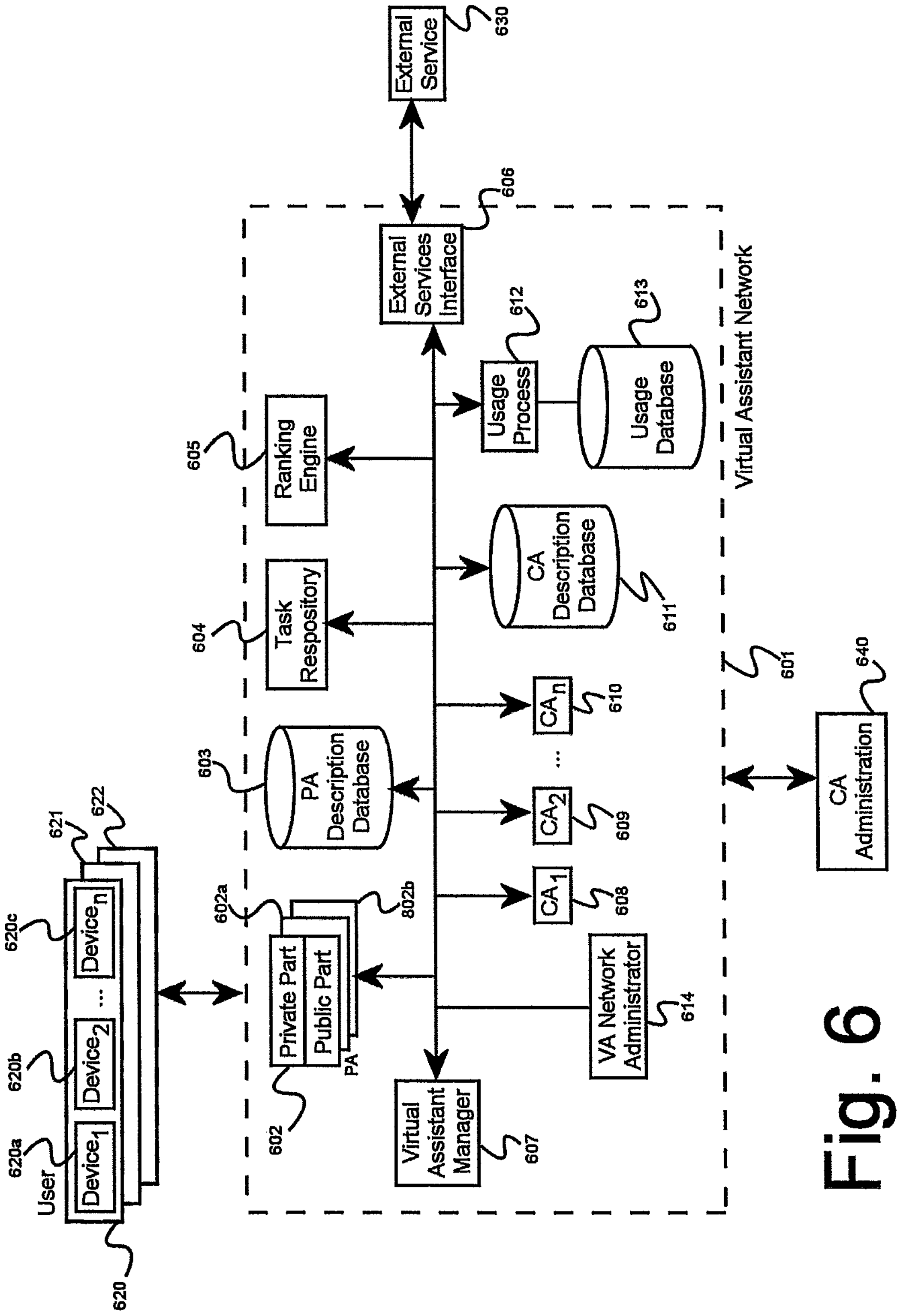

External Service
630
External Services Interface
606
Virtual Assistant Network
601
Ranking Engine
605
Task Respository
604
PA Description Database
603
Usage Process
612
Usage Database
613
CA Description Database
611
CA$_1$
608
CA$_2$
609
...
CA$_n$
610
CA Administration
640
Private Part
Public Part
PA
602
602a
802b
VA Network Administrator
614
Virtual Assistant Manager
607
User
Device$_1$
Device$_2$
...
Device$_n$
620
620a
620b
620c
621
622

Fig. 6

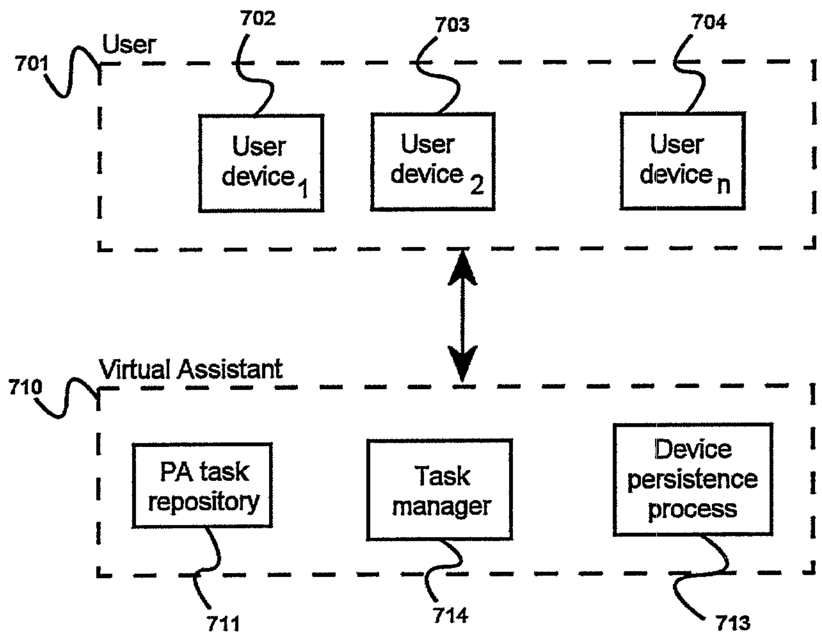

701
User
702
703
704
User device$_1$
User device$_2$
User device$_n$
710
Virtual Assistant
PA task repository
Task manager
Device persistence process
711
714
713

Fig. 7

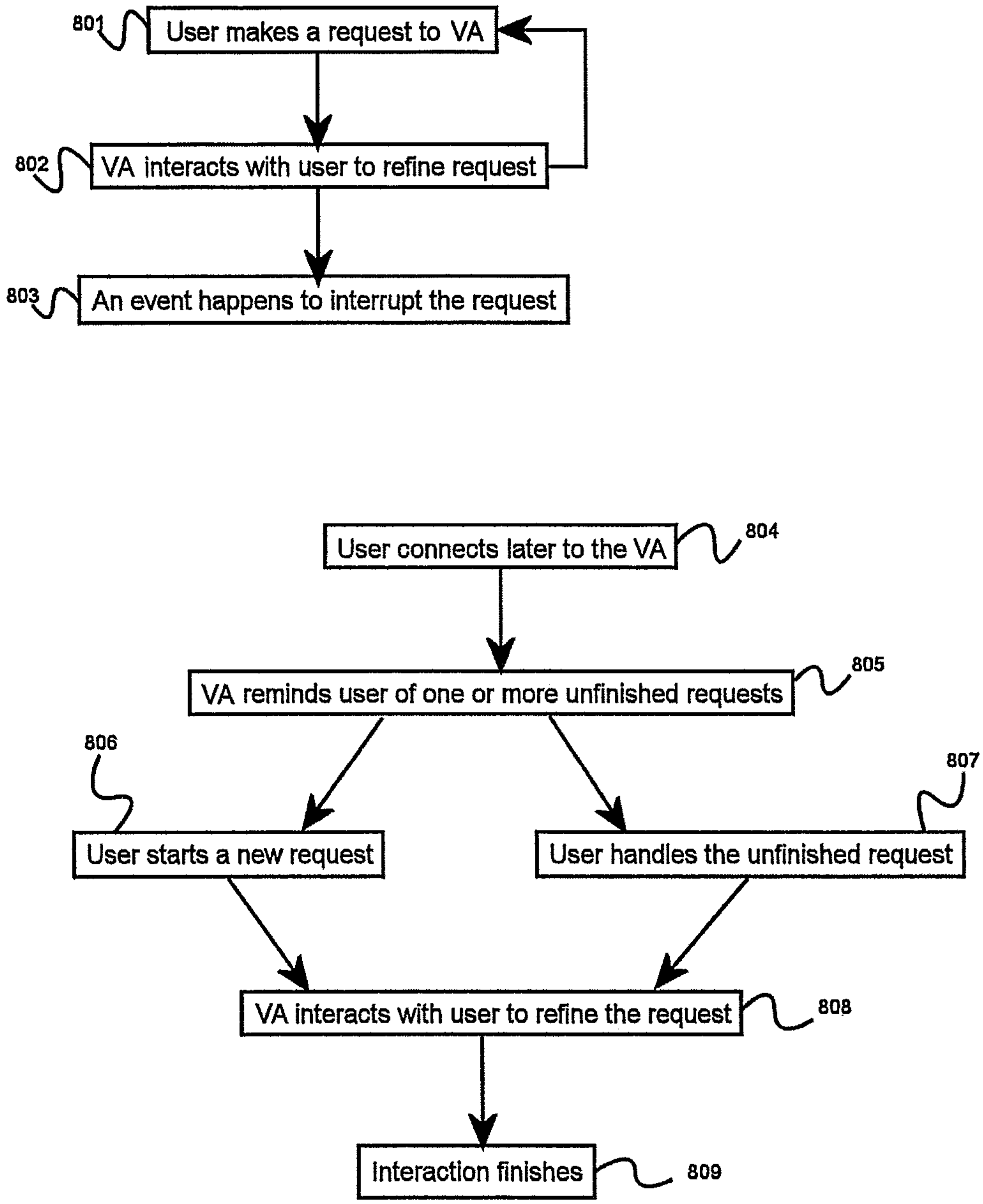

801
User makes a request to VA
802
VA interacts with user to refine request
803
An event happens to interrupt the request
User connects later to the VA
804
VA reminds user of one or more unfinished requests
805
806
807
User starts a new request
User handles the unfinished request
VA interacts with user to refine the request
808
Interaction finishes
809

Fig. 8

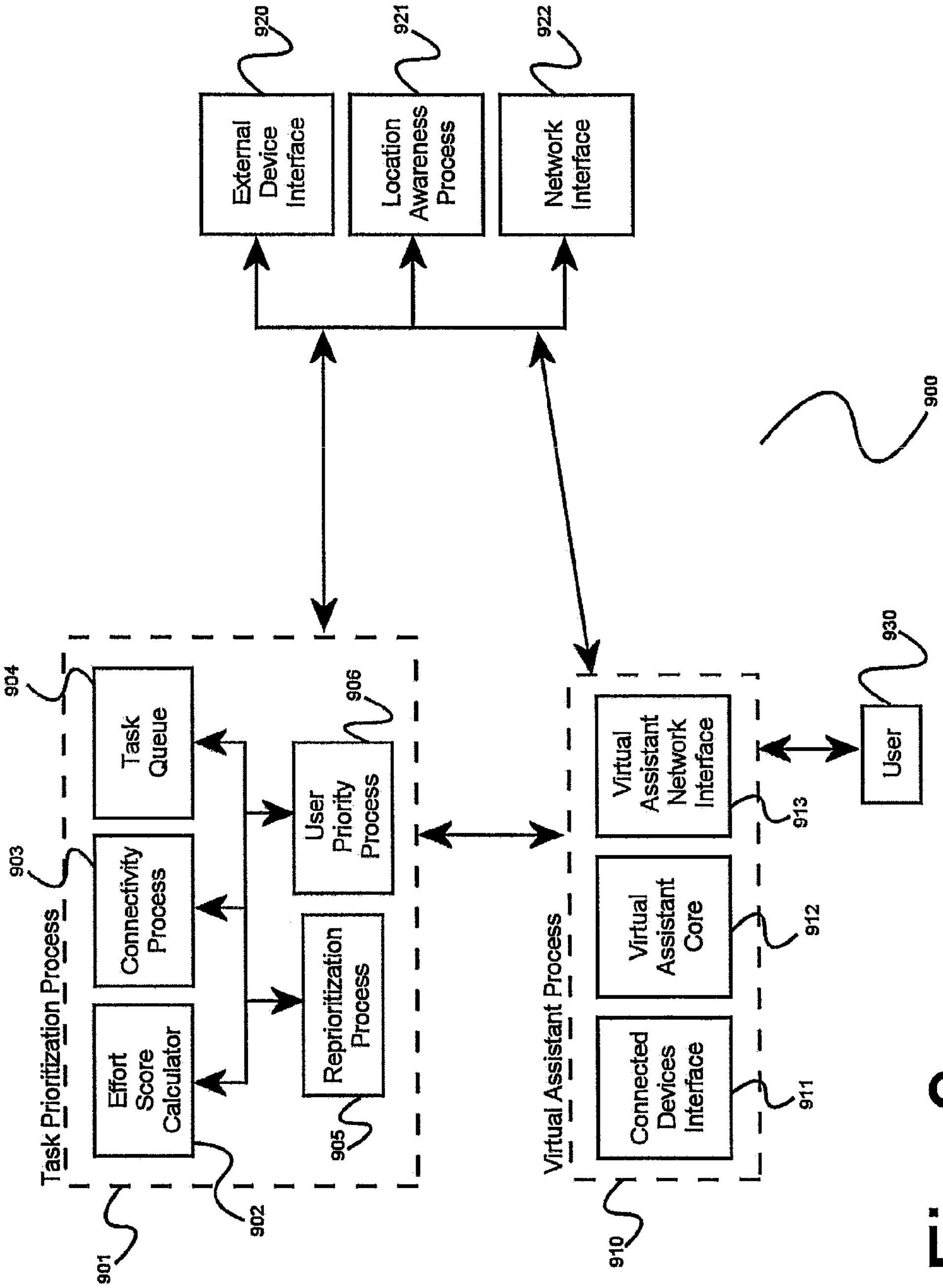

External Device Interface
920
Location Awareness Process
921
Network Interface
922
900
Task Prioritization Process
901
Effort Score Calculator
902
Connectivity Process
903
Task Queue
904
Reprioritization Process
905
User Priority Process
906
Virtual Assistant Process
910
Connected Devices Interface
911
Virtual Assistant Core
912
Virtual Assistant Network Interface
913
User
930

Fig. 9

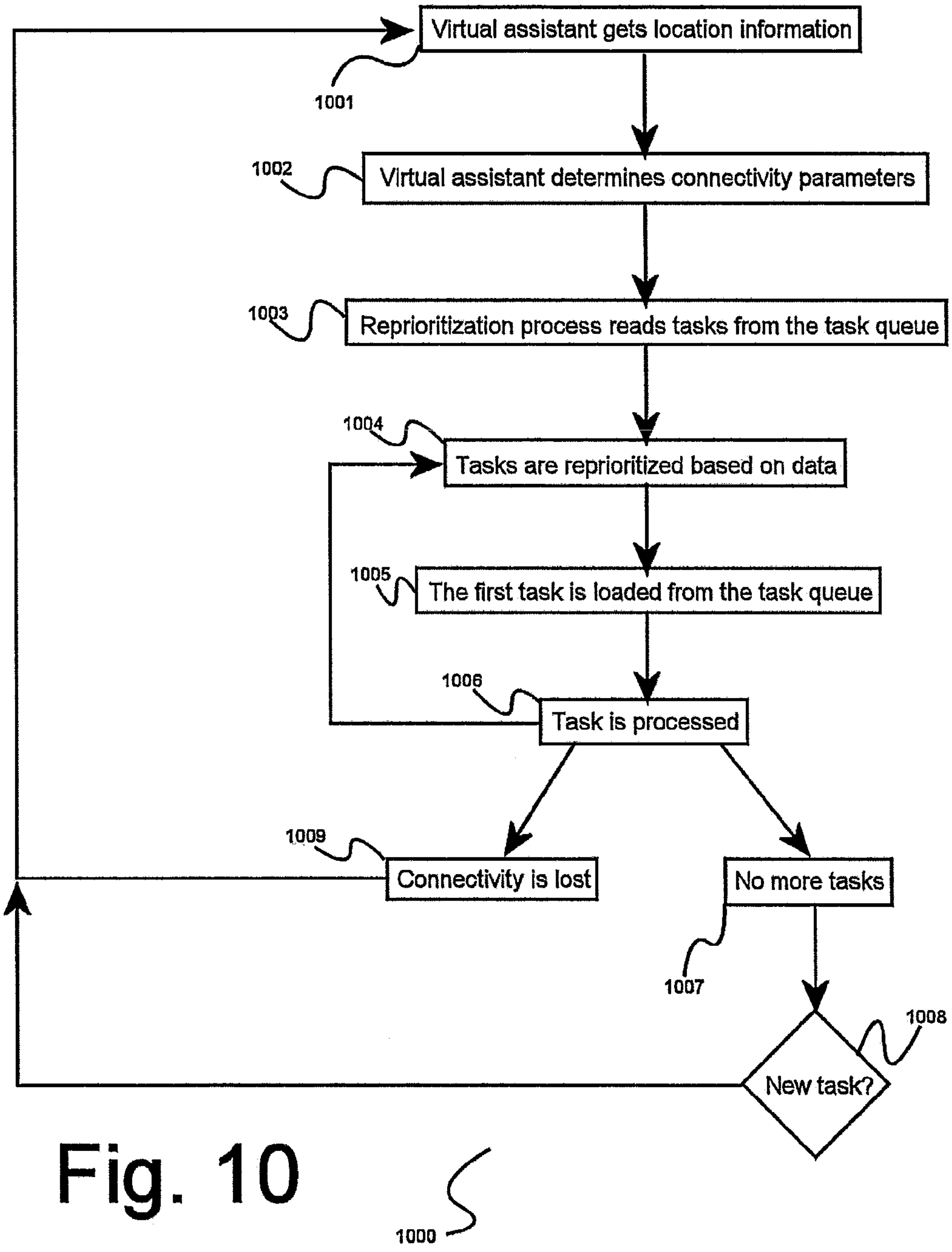

Virtual assistant gets location information
1001
1002
Virtual assistant determines connectivity parameters
1003
Reprioritization process reads tasks from the task queue
1004
Tasks are reprioritized based on data
1005
The first task is loaded from the task queue
1006
Task is processed
1009
Connectivity is lost
No more tasks
1007
1008
New task?
1000

Fig. 10

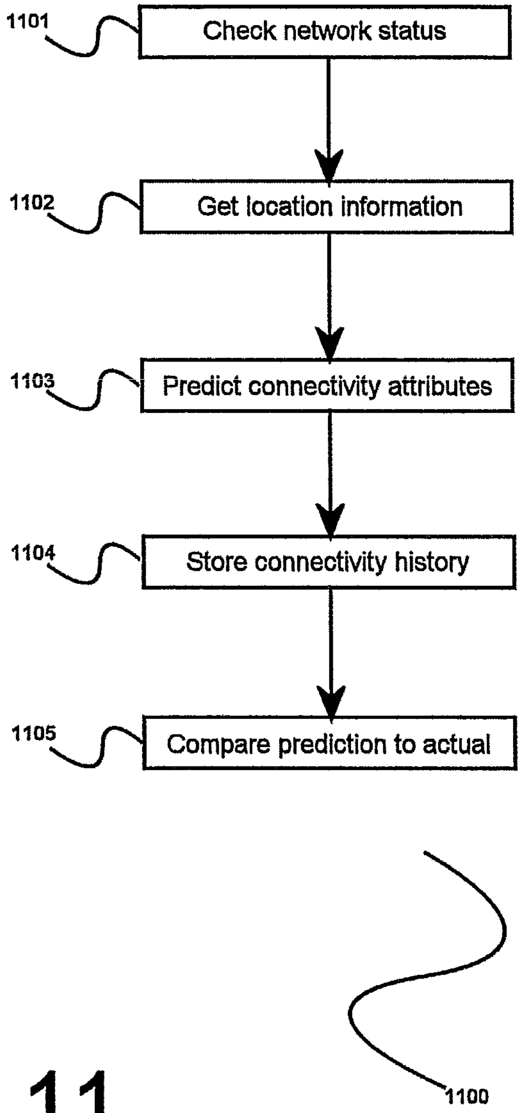

1101
Check network status
1102
Get location information
1103
Predict connectivity attributes
1104
Store connectivity history
1105
Compare prediction to actual
1100

Fig. 11

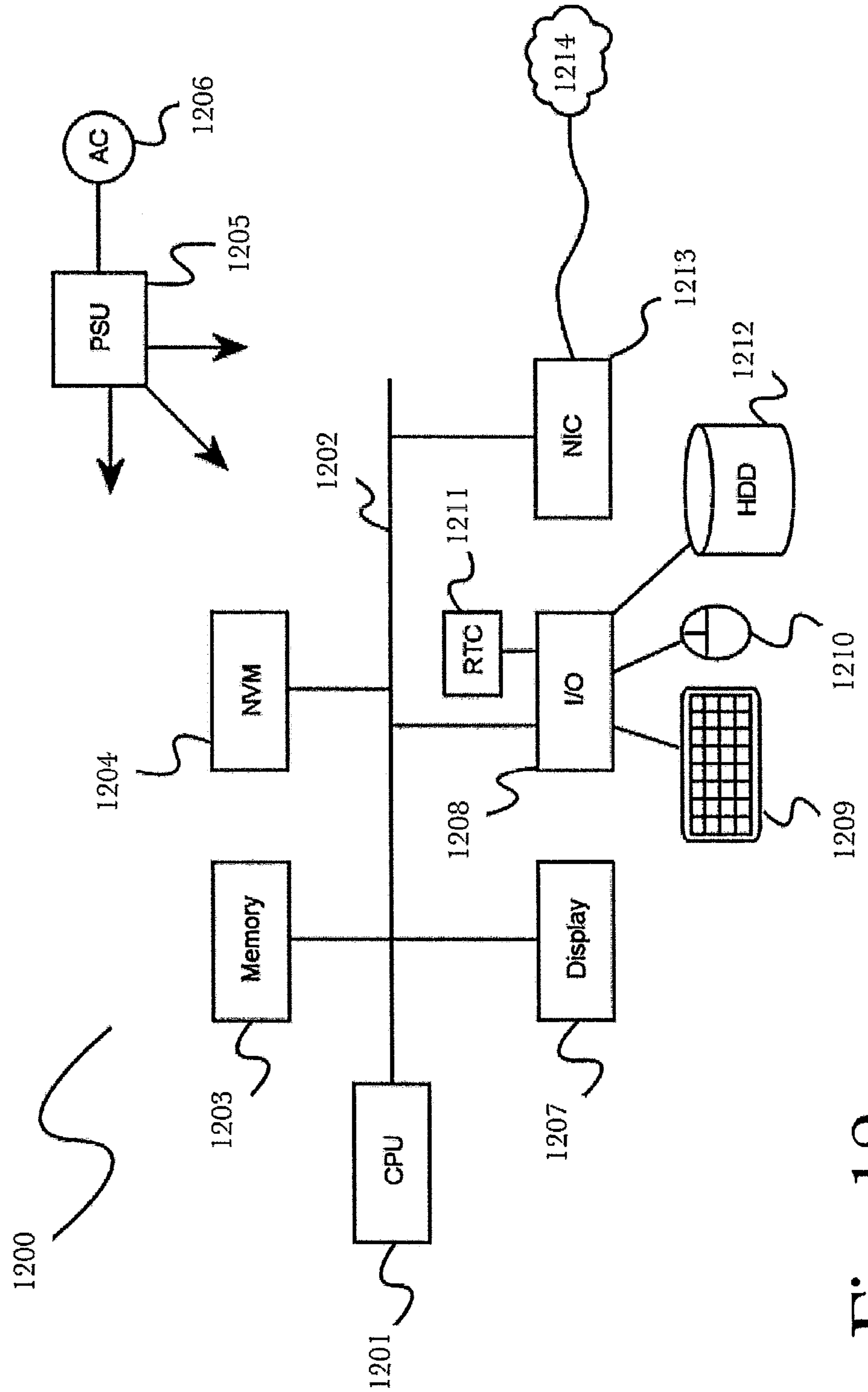

1200
1201
CPU
1202
1203
Memory
1204
NVM
1205
PSU
1206
AC
1207
Display
1208
I/O
1209
1210
1211
RTC
1212
HDD
1213
NIC
1214

Fig. 12

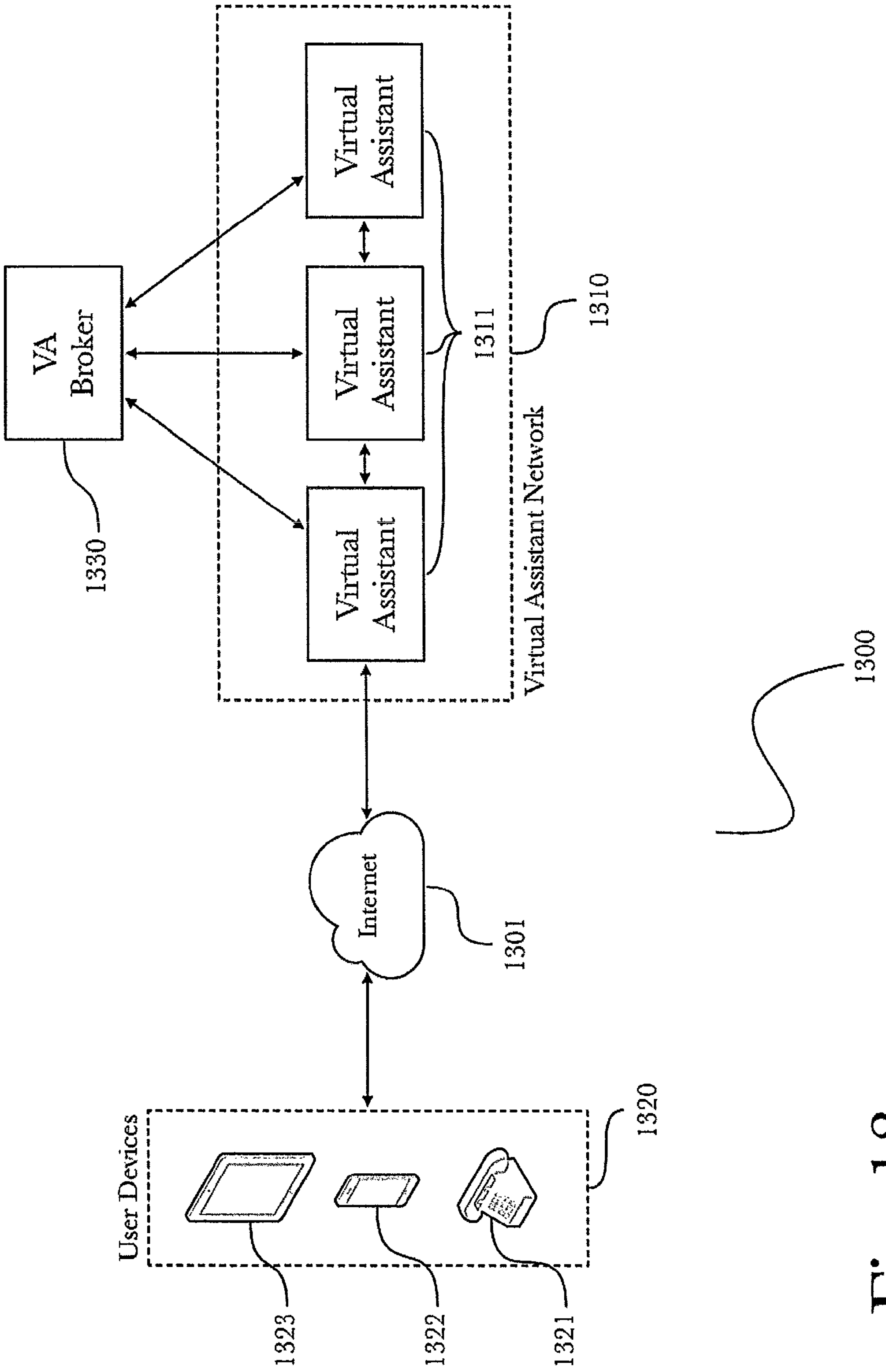

VA Broker
1330
Virtual Assistant
Virtual Assistant
Virtual Assistant
1311
1310
Virtual Assistant Network
Internet
1301
1300
User Devices
1320
1323
1322
1321

Fig. 13

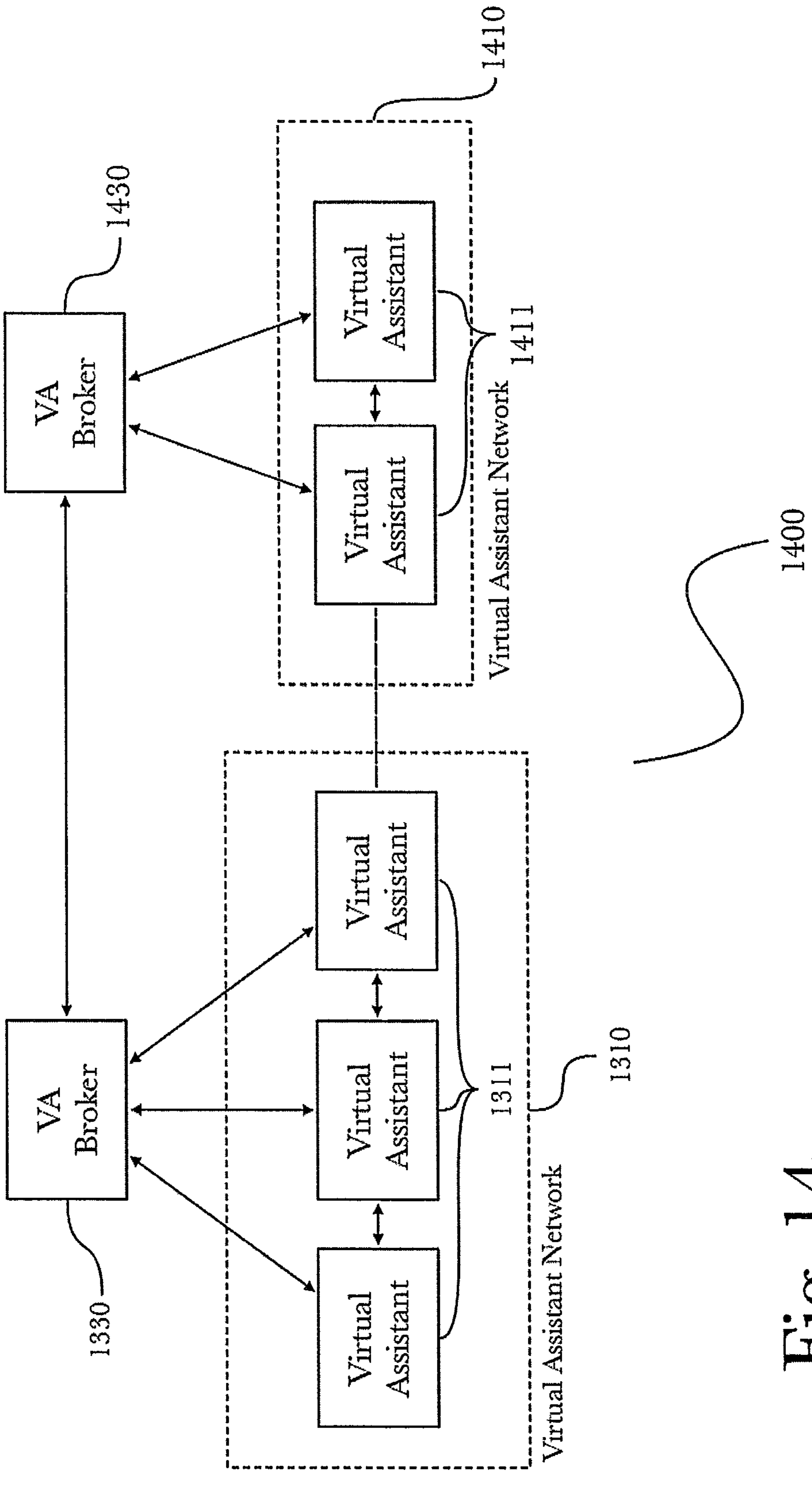

1410
1430
VA Broker
Virtual Assistant
Virtual Assistant
1411
Virtual Assistant Network
1400
Virtual Assistant
Virtual Assistant
Virtual Assistant
VA Broker
1311
1310
1330
Virtual Assistant Network

Fig. 14

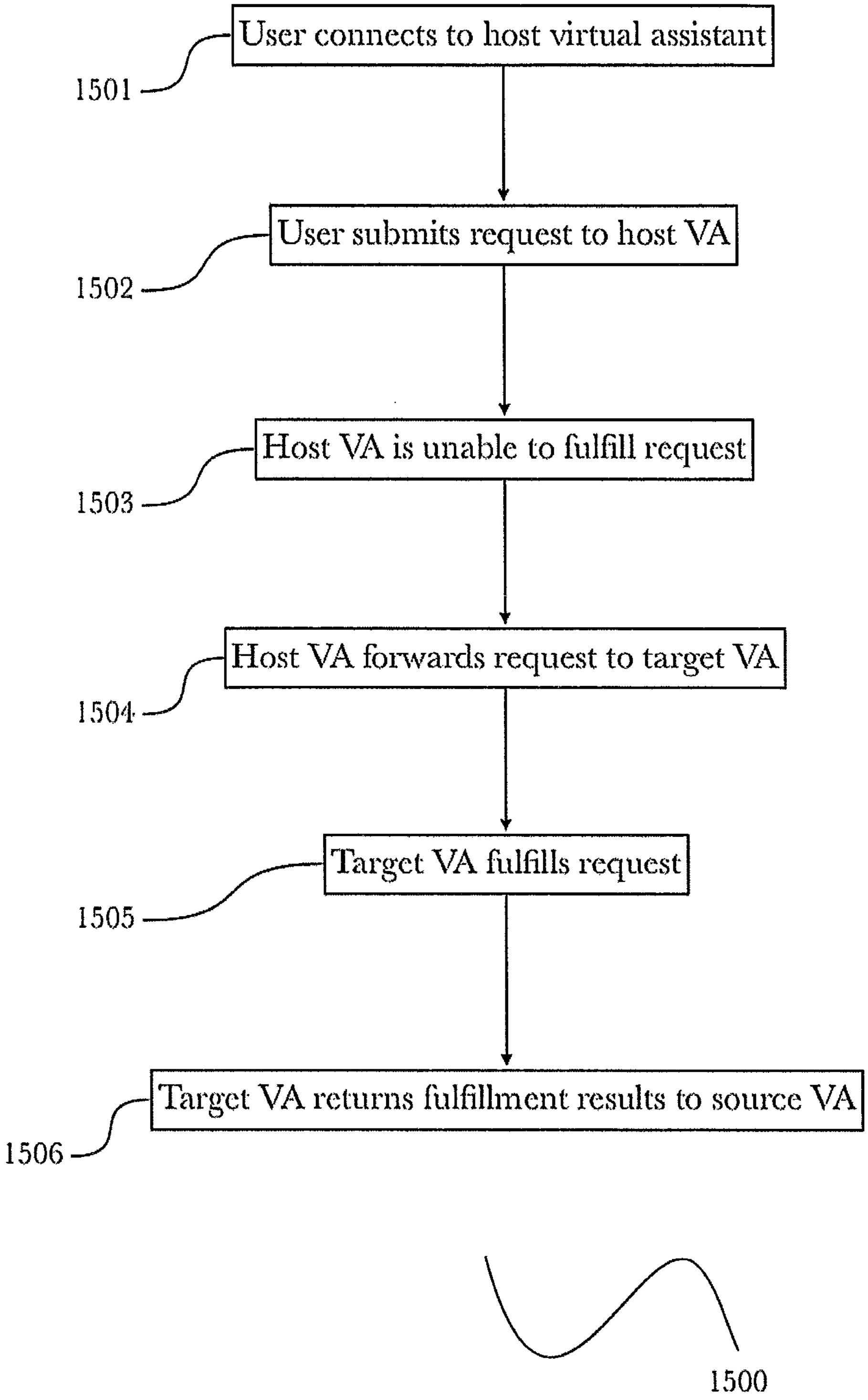

User connects to host virtual assistant
1501
User submits request to host VA
1502
Host VA is unable to fulfill request
1503
Host VA forwards request to target VA
1504
Target VA fulfills request
1505
Target VA returns fulfillment results to source VA
1506
1500

Fig. 15

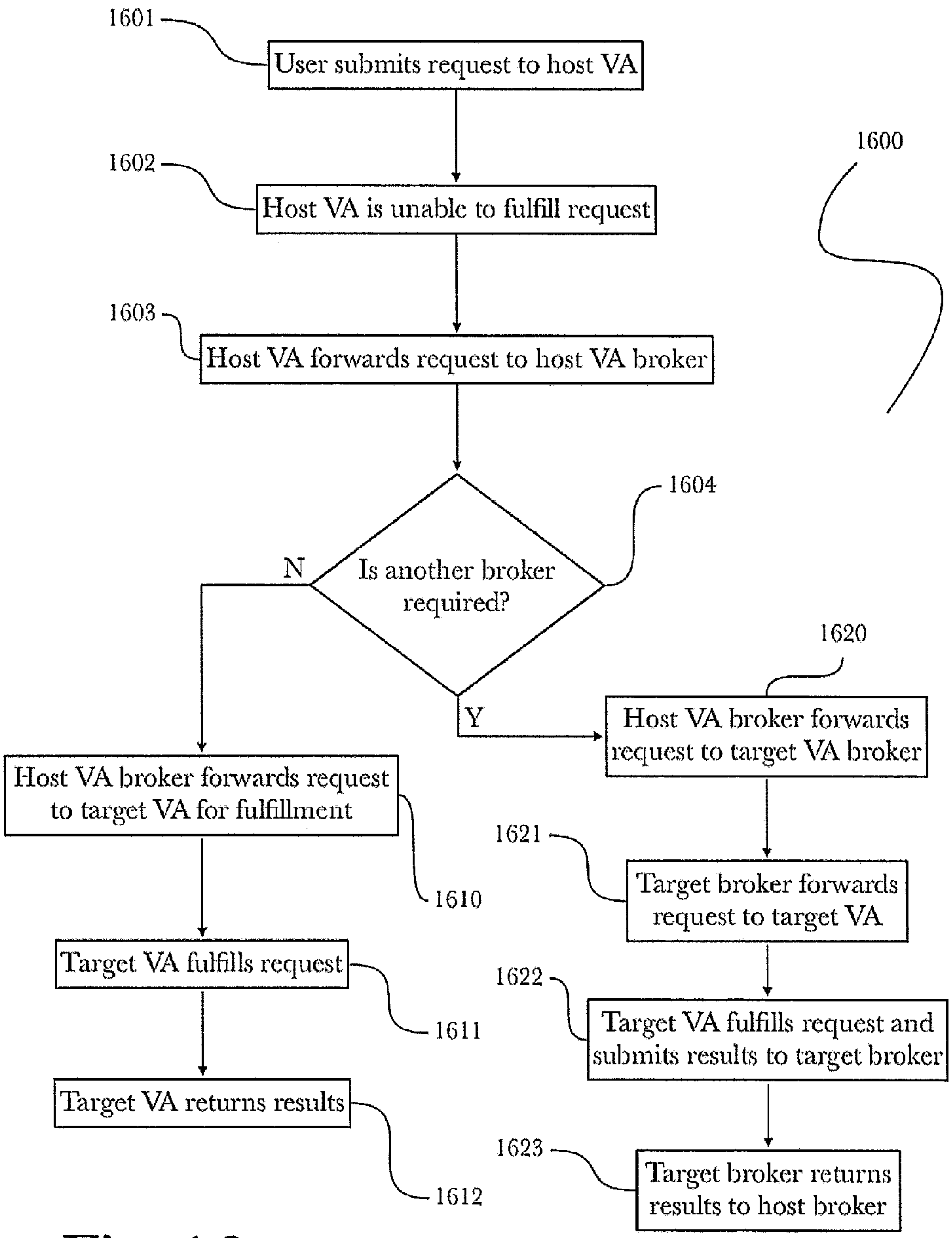

1600
1601
User submits request to host VA
1602
Host VA is unable to fulfill request
1603
Host VA forwards request to host VA broker
1604
Is another broker required?
N
Y
1610
Host VA broker forwards request to target VA for fulfillment
1611
Target VA fulfills request
1612
Target VA returns results
1620
Host VA broker forwards request to target VA broker
1621
Target broker forwards request to target VA
1622
Target VA fulfills request and submits results to target broker
1623
Target broker returns results to host broker

Fig. 16

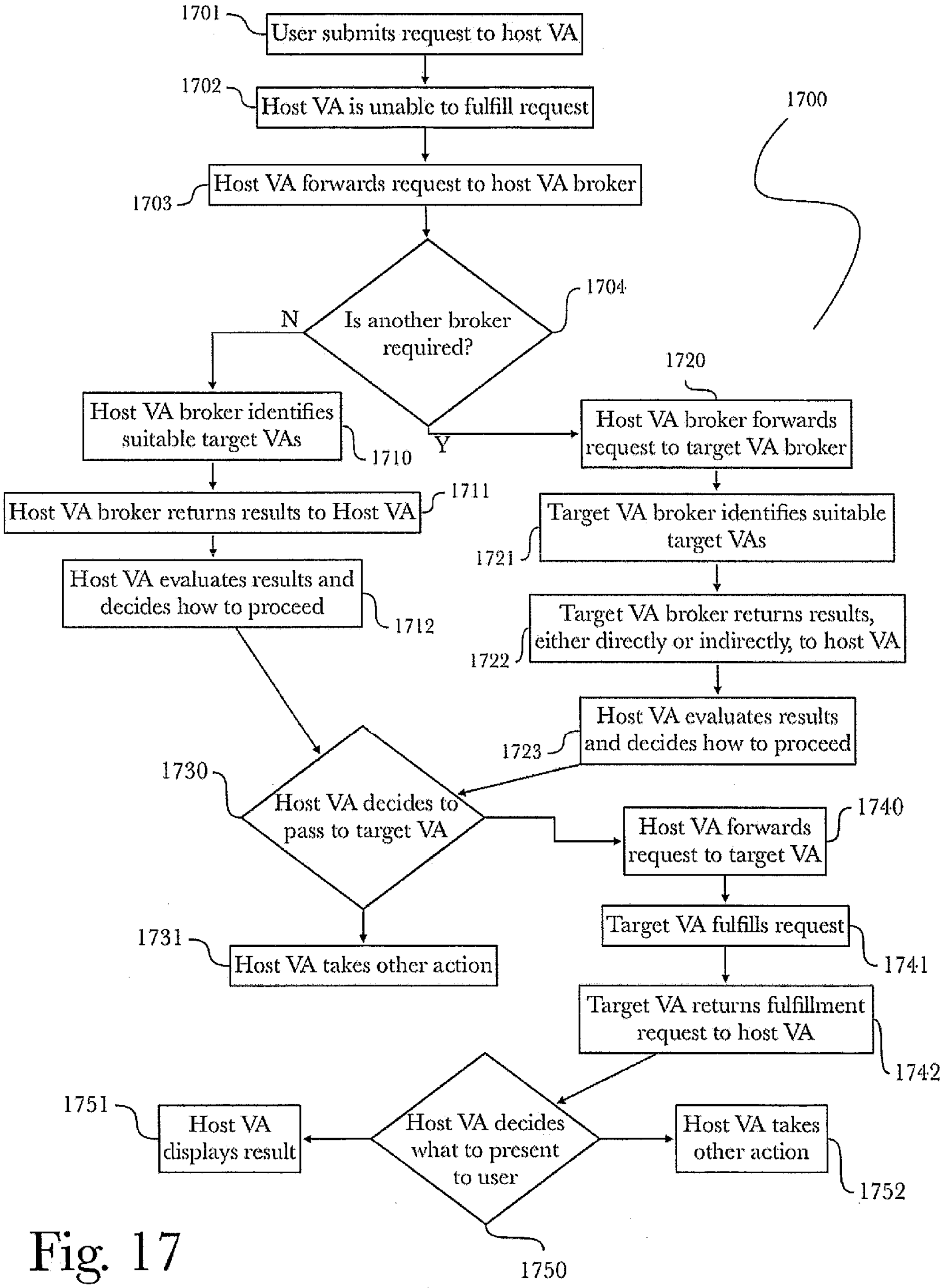

1701
User submits request to host VA
1702
Host VA is unable to fulfill request
1700
1703
Host VA forwards request to host VA broker
1704
Is another broker required?
N
Y
Host VA broker identifies suitable target VAs
1710
1720
Host VA broker forwards request to target VA broker
Host VA broker returns results to Host VA
1711
Target VA broker identifies suitable target VAs
1721
Host VA evaluates results and decides how to proceed
1712
Target VA broker returns results, either directly or indirectly, to host VA
1722
Host VA evaluates results and decides how to proceed
1723
1730
Host VA decides to pass to target VA
Host VA forwards request to target VA
1740
1731
Host VA takes other action
Target VA fulfills request
1741
Target VA returns fulfillment request to host VA
1742
1751
Host VA displays result
Host VA decides what to present to user
Host VA takes other action
1752
1750

Fig. 17

SYSTEM AND METHODS FOR VIRTUAL ASSISTANT NETWORKS

CROSS-REFERENCE TO RELATED APPLICATIONS

The instant application is a continuation of U.S. patent application Ser. No. 14/184,697, titled "SYSTEM AND METHODS FOR VIRTUAL ASSISTANT NETWORKS", filed on Feb. 19, 2014, which claims priority to U.S. provisional patent application Ser. No. 61/769,191, titled "SYSTEM AND METHODS FOR A NETWORK OF VIRTUAL ASSISTANTS", filed on Feb. 25, 2013, the entire specification of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the field of artificial intelligence, and more particularly to the field of natural language interaction-based applications, such as virtual assistants.

2. Discussion of the State of the Art

Virtual assistants are an example of a class of software applications, referred to herein as natural language interaction applications that use natural language to interact with a human user. With respect to virtual assistants in particular, these applications perform functions similar to those provided by human assistants, in that they can engage in conversations with their users in order to for example provide information, carry out routine tasks, or perform other operations as required. Many virtual assistants have been used in association with web sites, with these virtual assistants often featuring the use of graphical images or avatars to simulate the experience of interacting with a human being.

While some natural language interaction applications known in the art may possess rudimentary natural language understanding capabilities, in reality most such applications, and particularly most virtual assistants known in the art, are tightly scripted applications that carry out a limited range of activities. While scripted agents have proven useful in many online scenarios, their acceptance has generally been limited because, when users are restricted in their ways of expressing themselves in natural language, the communication language is not natural. Any notion of the virtual assistant's behaving like a real assistant disappears because too much effort is demanded of the user when the user is expected to know precisely what to say or what to do in order to achieve her goals. Thus there is a distinct need in the art for interpreting fluid and freely expressed natural language in various applications, for example by virtual assistants. This challenge is exacerbated by the fact that, even when equipped with rudimentary natural language interpretation, natural language interaction applications such as virtual assistants that seem to only "know" a small number of facts and who only "talk about" a very limited range of subjects (such as appointment management) do not seem very realistic to humans, who are used to being able to say things in a fluid way, shifting subjects easily and intermixing casual banter with task-oriented speech.

The use of natural language interaction applications generally, and virtual assistants more particularly, has also been hampered by the high degree of complexity and cost associated with developing and deploying virtual assistants, particularly those that have any significant degree of natural language interpretation and interaction capability. As such many of the services used by virtual assistants are housed in the cloud and are connected to using a network such as the internet, a corporate intranet, Bluetooth and other networks. Maintaining a connection to these services is necessary to completing many tasks of virtual assistants. However, given that in the current environment, there are many areas where connectivity is not available or expensive due to, for example, roaming charges or networks requiring a subscription, connectivity to other services may not always be available. Moreover, since typical users have a plurality of devices, maintaining consistency across devices is essential.

Accordingly, what is needed in the art is a system and various methods that enable virtual assistants to operate in a networked fashion with one another, facilitating interaction between virtual assistants as well as the management of a virtual assistant network for efficient task handling.

SUMMARY OF THE INVENTION

Accordingly, the inventor has conceived and reduced to practice, in a preferred embodiment of the invention, various systems and methods for the implementation and operation of virtual assistant networks, including the use of a virtual assistant broker that may be used to manage a number of virtual assistants in a networked fashion.

According to a preferred embodiment of the invention, a system for operating a virtual assistant network (VAN), comprising a plurality of virtual assistants (VAs) such as, for example, SIRI™ or other virtual personal assistants, or other assistive products or services, a plurality of VA brokers (that may be stored and operating on network-connected electronic devices), and a VA communication protocol (such as a standardized markup language or other means of standardizing communication between virtual assistants and brokers), is disclosed. According to the embodiment, VAs may be connected to and in communication with one another (as well as with brokers and human users) via the Internet or another communication network, such as a cellular data network or any other such appropriate means for electronic communication. A VA broker may be in communication with a plurality of VAs for such purposes as to receive requests or information as well as to send requests or other information to VAs, thereby facilitating a VAN by unifying communication between individual virtual assistants in an orderly fashion. For example, a virtual assistant may be assisting a user that is looking for a restaurant in a foreign country, and may send a request to a VA broker for information on local restaurants. The VA broker may then identify another virtual assistant in the network that may be able to process this request (for example, a virtual assistant maintained by a company in the country that is designed to assist local individuals in locating restaurants and placing reservations), and submit the request to that assistant on the user's behalf. The VA broker may then receive the result of the query (such as a list of nearby restaurants and their associated information), and send this back to the originating virtual assistant for presentation to the user. Alternatively, in some embodiments the broker assembles a list of virtual assistants that are likely to be able to satisfy a user's request that was submitted by the user's host virtual assistant, and send this list of possible virtual assistants back to the host virtual assistant. The host virtual assistant may then select one of the virtual assistants from the list provided by the broker and contact that virtual assistant with the request directly (typically, using contact information such as IP address that is provided by the broker with the list of eligible virtual assistants). In other embodiments, the host may exercise more direct control, selecting a virtual assistant and connecting the host virtual assistant to the selected virtual assistant, or even receiving responses to the user's request from a plurality of virtual assistants and returning either a list of responses (with or without information concerning which virtual assistant provided each response) or a single response selected by the broker. In this manner, a network of virtual assistants may be utilized to expand the functionality of any one particular assistant without any additional complication on the part of the user, who may perceive that they are consistently interacting with a single virtual assistant with which they may be familiar, while networked operation takes place "in the background" without their knowledge.

Further according to the embodiment, a VA communication protocol (such as, as envisioned by the inventor, a standardized markup language) may be utilized to facilitate interaction between virtual assistants and brokers. Ordinarily, each particular virtual assistant or broker may have a particular means of interaction, that may not be interchangeable with another. Such behavior is common practice in various corporate technologies in the art, where proprietary technologies may impede interaction between products or services from different vendors. By utilizing a standardized protocol, interaction between these disparate technologies may be facilitated in a structured and reliable manner, such that networking functionality and the use of brokers (that may need to interact with a large variety of different technologies to perform their functions) become possible according to the invention.

According to the embodiment, not all inter-VA communication may need to utilize a broker. For example, it is possible that a particular VA may already be familiar with another VA that is appropriate for a particular request. In such a scenario, a user may interact with their familiar VA that may serve as the "host" for the interaction. As needed, the host VA may communicate with a known "target" VA for assistance with specific requests. The target VA may then fulfill those requests as they would during normal operations (as if the requests had been received directly from a user), and return the results to the host VA for presentation to the user. In this manner, networked functionality may be provided by virtual assistants when no broker is available, or when it may be undesirable to utilize one (such as when the host VA already knows of a specific target VA that may be appropriate for the request).

Further according to the embodiment, a VA broker may communicate with another VA broker as necessary, such as to utilize virtual assistants outside of its own network. For example, a virtual assistant network (VAN) may be maintained for a specific region or country, encompassing a variety of virtual assistant technologies relevant to that specific locale. When a user submits a request for information from another region, such as asking for local news from another country, it may be possible that no particular VA within the network is ideal for handling the request. In this scenario, the originating "host" VA may decide to communicate with a VA broker for assistance in fulfilling the user's request. The VA broker may then reach out to another "target" broker for the specified region to pass the request to their network for handling, and in turn the target VA broker may submit the request to a local virtual assistant (as described previously) for handling. The results of that interaction may then be returned to the host VA for presenting to the user. In this use case, the user may still perceive that they are only interacting with their familiar virtual assistant, while all brokering operations take place without their knowledge.

In another preferred embodiment of invention, a method for providing networked virtual assistant operations is disclosed. According to the embodiment, a user may submit a request to a virtual assistant for fulfillment. According to the nature of the specific request, the VA may identify that another VA is needed to fulfill the request (or that utilizing another VA for assistance may further enhance the fulfillment of the request). The VA may then send a request to a VA broker for assistance, the broker then communicating with another target VA for fulfillment of the request. The results of the request may then be returned to the host VA for presentation to the user. Alternatively, in some embodiments the broker assembles a list of virtual assistants that are likely to be able to satisfy a user's request that was submitted by the user's host virtual assistant, and send this list of possible virtual assistants back to the host virtual assistant. The host virtual assistant may then select one of the virtual assistants from the list provided by the broker and contact that virtual assistant with the request directly (typically, using contact information such as IP address that is provided by the broker with the list of eligible virtual assistants). In other embodiments, the host may exercise more direct control, selecting a virtual assistant and connecting the host virtual assistant to the selected virtual assistant, or even receiving responses to the user's request from a plurality of virtual assistants and returning either a list of responses (with or without information concerning which virtual assistant provided each response) or a single response selected by the broker.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

The accompanying drawings illustrate several embodiments of the invention, and together with the description, serve to explain the principles of the invention according to the embodiments. One skilled in the art will recognize that the particular embodiments illustrated in the drawings are merely exemplary, and are not intended to limit the scope of the present invention.

FIG. **1** is a block diagram illustrating an exemplary hardware architecture of a computing device used in an embodiment of the invention.

FIG. **2** is a block diagram illustrating an exemplary logical architecture for a client device, according to an embodiment of the invention.

FIG. **3** is a block diagram illustrating an exemplary architectural arrangement of clients, servers, and external services, according to an embodiment of the invention.

FIG. **4** is a detailed architecture diagram of a method for natural language processing.

FIG. **5** is a block diagram of a system with a natural language interaction engine residing on a mobile device.

FIG. **6** is a block diagram of a social network of virtual assistants by which virtual assistants interact with each other and with users.

FIG. **7** is a block diagram of a persistent virtual assistant across multiple platforms in a social network of virtual assistants.

FIG. **8** is a high-level process flow diagram illustrating an exemplary method for persistence of a virtual assistant across multiple platforms in a social network of virtual assistants.

FIG. **9** is a block diagram illustrating an exemplary architecture of a system for automated adaptive prioritization of tasks in a virtual assistant environment.

FIG. **10** is a high-level process flow diagram illustrating an exemplary method for automated adaptive prioritization of tasks in an intermittently connected virtual assistant environment.

FIG. **11** is a high-level process flow diagram illustrating an exemplary method for predictive network connectivity in an intermittently connected virtual assistant environment.

FIG. **12** is another block diagram illustrating an exemplary hardware architecture of a computing device used in various embodiments of the invention.

FIG. **13** is a block diagram illustrating an exemplary arrangement of a virtual assistant network, showing the use of multiple virtual assistants with a broker, according to a preferred embodiment of the invention.

FIG. **14** is a block diagram illustrating communication between two virtual assistant brokers, each operating a distinct virtual assistant network.

FIG. **15** is a method flow diagram illustrating an overview method of networked virtual assistant operation, according to a preferred embodiment of the invention.

FIG. **16** is a method flow diagram illustrating a method for networked virtual assistant operation utilizing brokers.

FIG. **17** is a method flow diagram illustrating a further method for networked virtual assistant operation utilizing brokers.

DETAILED DESCRIPTION

The inventor has conceived, and reduced to practice, various systems and methods for operating virtual assistant networks.

One or more different inventions may be described in the present application. Further, for one or more of the inventions described herein, numerous alternative embodiments may be described; it should be understood that these are presented for illustrative purposes only. The described embodiments are not intended to be limiting in any sense. One or more of the inventions may be widely applicable to numerous embodiments, as is readily apparent from the disclosure. In general, embodiments are described in sufficient detail to enable those skilled in the art to practice one or more of the inventions, and it is to be understood that other embodiments may be utilized and that structural, logical, software, electrical and other changes may be made without departing from the scope of the particular inventions. Accordingly, those skilled in the art will recognize that one or more of the inventions may be practiced with various modifications and alterations. Particular features of one or more of the inventions may be described with reference to one or more particular embodiments or figures that form a part of the present disclosure, and in which are shown, by way of illustration, specific embodiments of one or more of the inventions. It should be understood, however, that such features are not limited to usage in the one or more particular embodiments or figures with reference to which they are described. The present disclosure is neither a literal description of all embodiments of one or more of the inventions nor a listing of features of one or more of the inventions that must be present in all embodiments.

Headings of sections provided in this patent application and the title of this patent application are for convenience only, and are not to be taken as limiting the disclosure in any way.

Devices that are in communication with each other need not be in continuous communication with each other, unless expressly specified otherwise. In addition, devices that are in communication with each other may communicate directly or indirectly through one or more intermediaries, logical or physical.

A description of an embodiment with several components in communication with each other does not imply that all such components are required. To the contrary, a variety of optional components may be described to illustrate a wide variety of possible embodiments of one or more of the inventions and in order to more fully illustrate one or more aspects of the inventions. Similarly, although process steps, method steps, algorithms or the like may be described in a sequential order, such processes, methods and algorithms may generally be configured to work in alternate orders, unless specifically stated to the contrary. In other words, any sequence or order of steps that may be described in this patent application does not, in and of itself, indicate a requirement that the steps be performed in that order. The steps of described processes may be performed in any order practical. Further, some steps may be performed simultaneously despite being described or implied as occurring non-simultaneously (e.g., because one step is described after the other step). Moreover, the illustration of a process by its depiction in a drawing does not imply that the illustrated process is exclusive of other variations and modifications thereto, does not imply that the illustrated process or any of its steps are necessary to one or more of the invention (s), and does not imply that the illustrated process is preferred. Also, steps are generally described once per embodiment, but this does not mean they must occur once, or that they may only occur once each time a process, method, or algorithm is carried out or executed. Some steps may be omitted in some embodiments or some occurrences, or some steps may be executed more than once in a given embodiment or occurrence.

When a single device or article is described, it will be readily apparent that more than one device or article may be used in place of a single device or article. Similarly, where more than one device or article is described, it will be readily apparent that a single device or article may be used in place of the more than one device or article.

The functionality or the features of a device may be alternatively embodied by one or more other devices that are not explicitly described as having such functionality or features. Thus, other embodiments of one or more of the inventions need not include the device itself.

Techniques and mechanisms described or referenced herein will sometimes be described in singular form for clarity. However, it should be noted that particular embodiments include multiple iterations of a technique or multiple instantiations of a mechanism unless noted otherwise. Process descriptions or blocks in figures should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process. Alternate implementations are included within the scope of embodiments of the present invention in which, for example, functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those having ordinary skill in the art.

DEFINITIONS

As used herein, “virtual assistant” means a software, hardware, or hybrid hardware/software application that provides assistance to humans analogous to that provided by human assistants, generally using an intuitive user interface, such as one that allows a user to express her needs in natural language.

As used herein, “natural language interpretation” means interpretation, by a machine, of one or a series of utterances made by a human user speaking or writing naturally; in some cases “natural language” may be supplemented by gestural, haptic, or other input combined with natural language input (for example, saying “move this here” while pointing or clicking on an object and a later a location). That is, a “natural language interpreter” generally does not require users to format their requests in simple, fixed patterns (such as a program might be required to do, as for example when invoking a web service or an application programming interface (API)).

As used herein, a "dialog" is a conversational exchange between two or more participants consisting of a generally unstructured sequence of natural language contributions in the form of requests, responses, statements and the like. A dialog is an interaction sequence that actually occurs (i.e., in run-time) during a conversation exchange between a user and a natural language system.

As used herein, a "flow" is a logical task unit comprising a set of related interaction steps required (and preconfigured) in order to perform a task. Typically a flow may comprise one or more transition conditions and operative nodes. A flow is typically defined in a natural language system as a series of predefined steps to perform when some triggering condition is satisfied.

As used herein, an "instructional path" is a sequence of instructions from one or more flows that were invoked or executed during the delivery of a dialog by a natural language system. In effect, an instructional path is the realization of one or more flows that occurs in an actual conversation (or dialog) between a user and a natural language system; it represents the sequence of decisions (or instructions) taken in support of natural language conversation (whereas the corresponding dialog is the actual sequence of what was "said" during the conversation by the parties involved, rather than why it was said).

As used herein, a "natural language interaction system" or a "natural language system" is a computer-based system capable of interacting via dialogs with one or more users using natural language (perhaps augmented by haptics, gestures, or other nonverbal means). Natural language systems carry out their function using dialogs, which can be thought of also as the actual, as executed, sequence of interaction steps between a user and a natural language system. A natural language system may participate in a dialog, by following the instructional steps of flows.

As used herein, a "language object" means an abstract representation of a logical unit of human linguistic expression that has meaning and is suitable for processing by automated systems such as virtual assistants. Language objects, in their simplest form, are represented as single words that represent a plurality of variants of a single common meaning, including inflectional variants and variants connected by synonymy. That is, generally a language object represents all variants and synonyms of the core word that represents it, and language objects may contain grammatical variants of words as well (such as verb tenses, contractions, and so forth).

As used herein, "script" means an executable sequence of instructions, generally stored (or at least rendered for execution) as plain text, which can be executed by an appropriate script interpreter. Scripts may be written in any scripting language known in the art, such as Perl, Python, PHP, Ruby, Groovy, and the like, or in any similar scripting language including proprietary scripting languages. As described variously herein, scripts generally are executed upon occurrence of specific events, such as initiation or termination of a user interaction session, or the triggering of a business rule such as "execute the following script if the number of active sessions exceed a configured number". Scripts can be nodes in flows (in which case they are referred to as "script nodes").

As used herein, "request" or "question" means a user-supplied or automatically supplied input to a natural language interaction-based system such as a virtual assistant, or to a virtual assistant broker.

As used herein, "response" means a system-supplied output from a natural language interaction system (as opposed to a user-supplied or automatically supplied input).

As used herein, "condition" means a rule or logical expression used for interpreting natural language utterances that, if satisfied, will allow for execution of one or more actions or will generate one or more effects. There are several types of conditions envisioned according to the invention, comprising for example: language recognition rules, skip conditions and transition conditions.

As used herein, a "language recognition rule" is a specific type of condition built up from language objects and used for capturing natural language expressions. For example, a language recognition rule can be used to interpret or capture the intention of a user request.

As used herein, "trigger" or a "flow trigger" is a construct which holds a condition, and which makes the system activate and start executing a flow if the condition is fulfilled.

As used herein, "listener" means is a rule construct with a conditional part and an operational part. When the conditional part is fulfilled, the operational part is invoked or executed, whereupon it updates current state based on information present in the current state and in the natural language input (the user request). Listeners may be configured to operate on a global level, on a flow level, or on a transition level, and they are generally evaluated in that order.

As used herein, "transition" or "transition condition" means a condition that determines whether the system should pass a transition to enter a new instructive step or process, a node (or a new transition). Transition may be input consuming (requires user input) or non-input consuming (does not require user input). Transitions may comprise one or more conditions and transitions can follow each other directly.

As used herein, "skip condition" means a condition that is verified prior to executing an instructive step (i.e., entering a node, for example of a flow). If the condition is met (e.g. some values have already been set previous in the system), the system will skip executing the instructional step and will continue as if it has already been executed.

As used herein, "small talk" means generally off-topic conversation elements that may be used to respond to user request. For example, if, during a flow devoted to making an airline reservation, a user asks "do you like to fly yourself?" a preprogrammed response (or a random or other selection from a plurality of possible responses) may be invoked which causes a response such as "I never fly myself, because I live in a machine!".

As used herein, "safety net" means a special flow type which is invoked when a user request fails to satisfy any condition (i.e., no matches were found); it is used to ensure that some form of response is made, after which generally the last active flow is resumed where it left off.

As used herein, an "example input" is a text sample that is used to describe, build, and test language recognition rules, triggers, and flows. Example inputs are typically obtained from text sample corpora, which are often obtained for example from logs of actual interactions between users and service representatives such as agents handling chat interactions or phone calls (which can be transcribed to generate example inputs). Typically, an example input (EI) will belong to at least one group of EIs that are related to a specific part of a natural language solution, such as a trigger and a language recognition rule (the trigger's condition). So an EI may "belong to" a specific trigger of a flow, and represents an example of what type of input should fulfill the language recognition rule of the trigger (in other words, the EI is assigned to a specific language recognition rule; often this occurs automatically because the language recognition rules was auto-generated from a set of example inputs, each of which is then assigned as a positive example input for the language recognition rule by default. Each language recognition rule (which can be linked to a trigger, language object, listener, internal flow transition or a skip condition) typically comprises four sets of assigned EIs: positive local EIs (that should match the language recognition rule when tested in isolation, but may not necessarily trigger it when tested in the context of the whole solution); negative local EIs (that should not match it); positive global EIs (that should both match and trigger it); and negative global EIs (that maybe could match it, but should never trigger it). Those sets may be empty. For example, example input "Insurance" may trigger a general language recognition rule; "Vehicle insurance" may fulfill a more specific language recognition rule; and "Car insurance" may trigger the most specific rule of the three. In this situation, the "car insurance" EI will always match the general "insurance" rule; a designer can solve the implied conflict here by setting an ordering relation that always evaluates the "car insurance" rule before the more general "insurance" rule. In that way, the more general rule is triggered only when the more specific condition isn't fulfilled. Alternatively, systems according to the invention may automatically identify conflicts (such as tangles) and propose a new ordering relation that may be reviewed by a developer.

As used herein, a "dialog hand-over" is when a component that is communicating to a user passes communication control to another component.

As used herein, a "host VA" is a virtual assistant that controls a dialog with a user. All communication with users typically goes via a host VA. In order to find a target VA (virtual assistant), the host may turn to a VA broker in a VA Network. The host may communicate with target VAs and VA brokers using a standardized inter-VA communication protocol. The host decides when to initiate a dialog with a target VA, when to forward a user's input to a target VA or a VA broker, and how to handle a response from a target VA or VA broker (e.g. display natural language response received from the target, respond to a request from the target). The host decides when to drop the dialog with a target. A host VA may also be registered in a VAN as a target VA.

As used herein a "target VA" is a virtual assistant that makes its knowledge available to a network or that performs tasks on behalf of users at the request of a network. The target VA needs to be capable of communicating with other VA's and VA brokers using the inter-VA communication protocol. The target VA informs a VA network of its areas of expertise via a VA Broker. A target may be available/registered in multiple networks.

As used herein a "VA broker" assists host VAs (and possibly other VA brokers) in finding suitable target VAs in VA networks. A VA broker may determine the best suitable target VAs based on various criteria, such as but not limited to the user's natural language input, statistical information about VA targets (user satisfaction, usage patterns etc), structured information provided by the host (user preferences, location details, language preferences). A VA broker may have a register of target VAs with their associated capabilities. Alternatively, in some embodiments the broker assembles a list of virtual assistants that are likely to be able to satisfy a user's request that was submitted by the user's host virtual assistant, and send this list of possible virtual assistants back to the host virtual assistant. The host virtual assistant may then select one of the virtual assistants from the list provided by the broker and contact that virtual assistant with the request directly (typically, using contact information such as IP address that is provided by the broker with the list of eligible virtual assistants). In other embodiments, the host may exercise more direct control, selecting a virtual assistant and connecting the host virtual assistant to the selected virtual assistant, or even receiving responses to the user's request from a plurality of virtual assistants and returning either a list of responses (with or without information concerning which virtual assistant provided each response) or a single response selected by the broker.

As used herein an "inter-VA communication protocol" is a standard protocol used by VAs and VA brokers to exchange information. The protocol makes it possible for VAs of different vendors, built using different technologies and targeted at different devices or interfaces, to exchange relevant data in a structured manner.

Hardware Architecture

Generally, the techniques disclosed herein may be implemented on hardware or a combination of software and hardware. For example, they may be implemented in an operating system kernel, in a separate user process, in a library package bound into network applications, on a specially constructed machine, on an application-specific integrated circuit (ASIC), or on a network interface card.

Software/hardware hybrid implementations of at least some of the embodiments disclosed herein may be implemented on a programmable network-resident machine (which should be understood to include intermittently connected network-aware machines) selectively activated or reconfigured by a computer program stored in memory. Such network devices may have multiple network interfaces that may be configured or designed to utilize different types of network communication protocols. A general architecture for some of these machines may be disclosed herein in order to illustrate one or more exemplary means by which a given unit of functionality may be implemented. According to specific embodiments, at least some of the features or functionalities of the various embodiments disclosed herein may be implemented on one or more general-purpose computers associated with one or more networks, such as for example an end-user computer system, a client computer, a network server or other server system, a mobile computing device (e.g., tablet computing device, mobile phone, smartphone, laptop, and the like), a consumer electronic device, a music player, or any other suitable electronic device, router, switch, or the like, or any combination thereof. In at least some embodiments, at least some of the features or functionalities of the various embodiments disclosed herein may be implemented in one or more virtualized computing environments (e.g., network computing clouds, virtual machines hosted on one or more physical computing machines, or the like). Moreover, in some embodiments one or more aspects, or all aspects, of the invention may optionally be implemented via a specially programmed chip (for instance, an application specific integrated circuit, or ASIC, or an erasable programmable read only memory, or EPROM), or via some other hardware-only approach known in the art.

Referring now to FIG. **1**, there is shown a block diagram depicting an exemplary computing device **100** suitable for implementing at least a portion of the features or functionalities disclosed herein. Computing device **100** may be, for example, any one of the computing machines listed in the previous paragraph, or indeed any other electronic device capable of executing software- or hardware-based instructions according to one or more programs stored in memory. Computing device **100** may be adapted to communicate with a plurality of other computing devices, such as clients or servers, over communications networks such as a wide area network a metropolitan area network, a local area network, a wireless network, the Internet, or any other network, using known protocols for such communication, whether wireless or wired.

In one embodiment, computing device **100** includes one or more central processing units (CPU) **102**, one or more interfaces **110**, and one or more busses **106** (such as a peripheral component interconnect (PCI) bus). When acting under the control of appropriate software or firmware, CPU **102** may be responsible for implementing specific functions associated with the functions of a specifically configured computing device or machine. For example, in at least one embodiment, a computing device **100** may be configured or designed to function as a server system utilizing CPU **102**, local memory **101** and/or remote memory **120**, and interface(s) **110**. In at least one embodiment, CPU **102** may be caused to perform one or more of the different types of functions and/or operations under the control of software modules or components, which for example, may include an operating system and any appropriate applications software, drivers, and the like.

CPU **102** may include one or more processors **103** such as, for example, a processor from one of the Intel, ARM, Qualcomm, and AMD families of microprocessors. In some embodiments, processors **103** may include specially designed hardware such as application-specific integrated circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), field-programmable gate arrays (FPGAs), and so forth, for controlling operations of computing device **100**. In a specific embodiment, a local memory **101** (such as non-volatile random access memory (RAM) and/or read-only memory (ROM), including for example one or more levels of cached memory) may also form part of CPU **102**. However, there are many different ways in which memory may be coupled to system **100**. Memory **101** may be used for a variety of purposes such as, for example, caching and/or storing data, programming instructions, and the like.

As used herein, the term "processor" is not limited merely to those integrated circuits referred to in the art as a processor, a mobile processor, or a microprocessor, but broadly refers to a microcontroller, a microcomputer, a programmable logic controller, an application-specific integrated circuit, and any other programmable circuit.

In one embodiment, interfaces **110** are provided as network interface cards (NICs). Generally, NICs control the sending and receiving of data packets over a computer network; other types of interfaces **110** may for example support other peripherals used with computing device **100**. Among the interfaces that may be provided are Ethernet interfaces, frame relay interfaces, cable interfaces, DSL interfaces, token ring interfaces, graphics interfaces, and the like. In addition, various types of interfaces may be provided such as, for example, universal serial bus (USB), Serial, Ethernet, Firewire™, PCI, parallel, radio frequency (RF), Bluetooth™ near-field communications (e.g., using near-field magnetics), 802.11 (WiFi), frame relay, TCP/IP, ISDN, fast Ethernet interfaces, Gigabit Ethernet interfaces, asynchronous transfer mode (ATM) interfaces, high-speed serial interface (HSSI) interfaces, Point of Sale (POS) interfaces, fiber data distributed interfaces (FDDIs), and the like. Generally, such interfaces **110** may include ports appropriate for communication with appropriate media. In some cases, they may also include an independent processor and, in some in stances, volatile and/or non-volatile memory (e.g., RAM).

Although the system shown in FIG. **1** illustrates one specific architecture for a computing device **100** for implementing one or more of the inventions described herein, it is by no means the only device architecture on which at least a portion of the features and techniques described herein may be implemented. For example, architectures having one or any number of processors **103** may be used, and such processors **103** may be present in a single device or distributed among any number of devices. In one embodiment, a single processor **103** handles communications as well as routing computations, while in other embodiments a separate dedicated communications processor may be provided. In various embodiments, different types of features or functionalities may be implemented in a system according to the invention that includes a client device (such as a tablet device or smartphone running client software) and server systems (such as a server system described in more detail below).

Regardless of network device configuration, the system of the present invention may employ one or more memories or memory modules (such as, for example, remote memory block **120** and local memory **101**) configured to store data, program instructions for the general-purpose network operations, or other information relating to the functionality of the embodiments described herein (or any combinations of the above). Program instructions may control execution of or comprise an operating system and/or one or more applications, for example. Memory **120** or memories **101**, **120** may also be configured to store data structures, configuration data, encryption data, historical system operations information, or any other specific or generic non-program information described herein.

Because such information and program instructions may be employed to implement one or more systems or methods described herein, at least some network device embodiments may include nontransitory machine-readable storage media, which, for example, may be configured or designed to store program instructions, state information, and the like for performing various operations described herein. Examples of such nontransitory machine-readable storage media include, but are not limited to, magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROM disks; magneto-optical media such as optical disks, and hardware devices that are specially configured to store and perform program instructions, such as read-only memory devices (ROM), flash memory, solid state drives, memristor memory, random access memory (RAM), and the like. Examples of program instructions include both object code, such as may be produced by a compiler, machine code, such as may be produced by an assembler or a linker, byte code, such as may be generated by for example a Java™ compiler and may be executed using a Java virtual machine or equivalent, or files containing higher level code that may be executed by the computer using an interpreter (for example, scripts written in Python, Perl, Ruby, Groovy, or any other scripting language).

In some embodiments, systems according to the present invention may be implemented on a standalone computing system. Referring now to FIG. **2**, there is shown a block diagram depicting a typical exemplary architecture of one or more embodiments or components thereof on a standalone computing system. Computing device **200** includes processors **210** that may run software that carry out one or more functions or applications of embodiments of the invention, such as for example a client application **230**. Processors **210** may carry out computing instructions under control of an operating system **220** such as, for example, a version of Microsoft's Windows™ operating system, Apple's Mac OS/X or iOS operating systems, some variety of the Linux operating system, Google's Android™ operating system, or the like. In many cases, one or more shared services **225** may be operable in system **200**, and may be useful for providing common services to client applications **230**. Services **225** may for example be Windows™ services, user-space common services in a Linux environment, or any other type of common service architecture used with operating system **210**. Input devices **270** may be of any type suitable for receiving user input, including for example a keyboard, touchscreen, microphone (for example, for voice input), mouse, touchpad, trackball, or any combination thereof. Output devices **260** may be of any type suitable for providing output to one or more users, whether remote or local to system **200**, and may include for example one or more screens for visual output, speakers, printers, or any combination thereof. Memory **240** may be random-access memory having any structure and architecture known in the art, for use by processors **210**, for example to run software. Storage devices **250** may be any magnetic, optical, mechanical, memristor, or electrical storage device for storage of data in digital form. Examples of storage devices **250** include flash memory, magnetic hard drive, CD-ROM, and/or the like.

In some embodiments, systems of the present invention may be implemented on a distributed computing network, such as one having any number of clients and/or servers. Referring now to FIG. **3**, there is shown a block diagram depicting an exemplary architecture for implementing at least a portion of a system according to an embodiment of the invention on a distributed computing network. According to the embodiment, any number of clients **330** may be provided. Each client **330** may run software for implementing client-side portions of the present invention; clients may comprise a system **200** such as that illustrated in FIG. **2**. In addition, any number of servers **320** may be provided for handling requests received from one or more clients **330**. Clients **330** and servers **320** may communicate with one another via one or more electronic networks **310**, which may be in various embodiments any of the Internet, a wide area network, a mobile telephony network, a wireless network (such as WiFi, Wimax, and so forth), or a local area network (or indeed any network topology known in the art; the invention does not prefer any one network topology over any other). Networks **310** may be implemented using any known network protocols, including for example wired and/or wireless protocols.

In addition, in some embodiments, servers **320** may call external services **370** when needed to obtain additional information, or to refer to additional data concerning a particular call. Communications with external services **370** may take place, for example, via one or more networks **310**. In various embodiments, external services **370** may comprise web-enabled services or functionality related to or installed on the hardware device itself. For example, in an embodiment where client applications **230** are implemented on a smartphone or other electronic device, client applications **230** may obtain information stored in a server system **320** in the cloud or on an external service **370** deployed on one or more of a particular enterprise's or user's premises.

In some embodiments of the invention, clients **330** or servers **320** (or both) may make use of one or more specialized services or appliances that may be deployed locally or remotely across one or more networks **310**. For example, one or more databases **340** may be used or referred to by one or more embodiments of the invention. It should be understood by one having ordinary skill in the art that databases **340** may be arranged in a wide variety of architectures and using a wide variety of data access and manipulation means. For example, in various embodiments one or more databases **340** may comprise a relational database system using a structured query language (SQL), while others may comprise an alternative data storage technology such as those referred to in the art as "NoSQL" (for example, Hadoop, MapReduce, BigTable, and so forth). In some embodiments variant database architectures such as column-oriented databases, in-memory databases, clustered databases, distributed databases, or even flat file data repositories may be used according to the invention. It will be appreciated by one having ordinary skill in the art that any combination of known or future database technologies may be used as appropriate, unless a specific database technology or a specific arrangement of components is specified for a particular embodiment herein. Moreover, it should be appreciated that the term "database" as used herein may refer to a physical database machine, a cluster of machines acting as a single database system, or a logical database within an overall database management system. Unless a specific meaning is specified for a given use of the term "database", it should be construed to mean any of these senses of the word, all of which are understood as a plain meaning of the term "database" by those having ordinary skill in the art.

Similarly, most embodiments of the invention may make use of one or more security systems **360** and configuration systems **350**. Security and configuration management are common information technology (IT) and web functions, and some amount of each are generally associated with any IT or web systems. It should be understood by one having ordinary skill in the art that any configuration or security subsystems known in the art now or in the future may be used in conjunction with embodiments of the invention without limitation, unless a specific security **360** or configuration **350** system or approach is specifically required by the description of any specific embodiment.

FIG. **12** shows an exemplary overview of a computer system **1200** as may be used in any of the various locations throughout the system. It is exemplary of any computer that may execute code to process data. Various modifications and changes may be made to computer system **1200** without departing from the broader spirit and scope of the system and method disclosed herein. CPU **1201** is connected to bus **1202**, to which bus is also connected memory **1203**, nonvolatile memory **1204**, display **1207**, I/O unit **1208**, and network interface card (NIC) **1213**. I/O unit **1208** may, typically, be connected to keyboard **1209**, pointing device **1210**, hard disk **1212**, and real-time clock **1211**. NIC **1213** connects to network **1214**, which may be the Internet or a local network, which local network may or may not have connections to the Internet. Also shown as part of system **1200** is power supply unit **1205** connected, in this example, to ac supply **1206**. Not shown are batteries that could be present, and many other devices and modifications that are well known but are not applicable to the specific novel functions of the current system and method disclosed herein.

In various embodiments, functionality for implementing systems or methods of the present invention may be distributed among any number of client and/or server components. For example, various software modules may be implemented for performing various functions in connection with the present invention, and such modules can be variously implemented to run on server and/or client components.

Conceptual Architecture

FIG. **4** is a block diagram providing a conceptual overview of a method **400** by which human users may interact with a natural language interaction application such as a virtual assistant, according to an embodiment of the invention. According to the embodiment, user input or user request **410** is provided to a natural language interaction engine **403**, which attempts to interpret the intention of the user request **410** and construct one or more appropriate responses to request **410** and provides any resulting responses **430** to user queries (or, analogously, responses or reactions to requests, for example when a virtual system does something as a result of being requested to do it, such as filling in a form or scheduling a meeting) using those constructed responses. Requests **410** to natural language interaction engine **403** may be made using any of a number of user interface means known in the art, including but not limited to use of text-based requests **412** (for instance, generated by typing a question or command into a text entry field in a user interface, such as on a mobile device application, on a consumer device, on a web site, or in an email or other message), spoken requests **411** (for example, if a user speaks a command or a question into a microphone on a mobile device or consumer device, the command or question then being converted into a more computer-usable form—typically but not necessarily a text string that comprises either a full transcription of the spoken command or request, or a standardized text element that is substantially semantically related to the spoken command or request), or even haptic or other user interface means **413** (for instance, taking actions such as pressing a button on a mobile device, or shaking or orienting a mobile device in a specific way, or similar actions). Similarly, in general responses **430** may be rendered as speech **431**, text **432**, graphics **433** (for example, a plurality of images to allow a user to review possible hotel choices), haptics **434** (for example, touch-sensitive or mechanical buttons, slide bars, selection interface elements that allow a user to select a region or a plurality of specific elements of a screen, and so forth), or emotions **435** (for example, an avatar adapted to dynamically display different emotions as appropriate for particular responses **430**). Indeed, response **430** may take any appropriate form or combination of forms (for example, in a multimodal interaction, a response might also be multimodal, comprising for example speech output and approximately simultaneous display of an appropriate image on a device screen). Responses **430** may comprise a natural language response (including for example text-based output, spoken output), or changes in one or more graphical user interface elements (for example, in response to a request, "Please tell me where I can eat near here", a list of selected restaurants might be displayed on a screen of a consumer device or a map with nearby restaurants might be shown on a mobile device), or both, for example. Responses **430** may also be actions directed by natural language interaction application **403** in response to an explicit or implicit request **410** from a user.

In order to formulate one or more appropriate responses to request **410**, natural language interaction engine **403** carries out a process that may be broadly described as taking place in three steps. First, natural language interaction engine **403** analyzes **421** request **410** to determine its meaning (usually, by determining the user's intent). Analysis **421** may require preprocessing, for example to convert a spoken request **411** into a textual form suitable for further analysis (although it should be noted that, in some embodiments, audio data obtained from a spoken request **411** could be analyzed directly using one or more speech analytics technologies known in the art). Analysis **421** typically involves parsing request **410** and then analyzing its semantic content to determine one or more possible user intentions that motivated request **410**. In many cases this may be straightforward (for instance, a request might be "Please set my alarm for 8 am", and accordingly the user's intent would easily be understood once the sentence was parsed), but in other cases it might be anything but straightforward (for instance, a user might say "Get out of here!" which has several possible intentions, depending on context). Thus it could be that output from analysis **421** could involve a certain amount of uncertainty, for instance in cases where an output of analysis step **421** comprises a list of possible user intents, perhaps with weights indicating their likelihood of being the user's actual intention.

Once analysis **421** is completed, natural language interaction engine **403** may undertake a reasoning step **422** to further elaborate or to better determine user intent. Interaction engine **403** may use advanced linguistic interpretation and business rules to simulate "intelligent thinking", allowing interaction engine **403** to appear to reason like a human and to determine a most appropriate way to respond to a user request **410**. During this reasoning process **422**, interaction engine **403** may take into account many contextual factors such as date, time, location of user, entities and facts discussed in a current or recent dialog, active flows, local context, global context, information picked up in previous dialogs, data about a user, and the like. In addition, inferences may be drawn based on data about one or more users (for example, when users do "this" they normally also want to do "that"). For example, if a user inquires about "next year's insurance premium", interaction engine **403** may understand context of "next year", but may need to seek clarification about whether the user is asking about home or motor insurance. In general, the goal of reasoning **422** is to reduce ambiguity about what a user meant in request **410**, and to apply rules or other logical processing to take into account the extended context in which request **410** was made, in order to facilitate the final step of reacting **423**. Once user intent is understood and relevant context has been taken into account, natural language interaction engine **403** may select and execute appropriate actions needed to react **423** to request **410**. Suitable reactions may be to give an appropriate verbal, textual, visual, or haptic response, to ask for more information to disambiguate user intent (when for example disambiguation could not be carried out during reasoning step **422**), to open a webpage, to play a video, to open another application, to automatically fill in a form, to invoke or update or interact with a third party service, to perform some form of multimodal output, or to execute a transaction for example by updating a database or by integrating with one or more backend or e-commerce systems. These three steps analyze **421**, reason **422**, and react **423**) may all happen seamlessly in milliseconds with interaction engine **403** able to handle thousands of interactions simultaneously, or they may occur over an extended period of time, depending on context and the state of the device being used or its connectivity.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. **4** is a block diagram illustrating an exemplary arrangement of components of a system **400** for efficiently delivering natural language interaction applications according to an embodiment of the invention, showing more detail regarding the high-level conceptual architecture. As indicated above, key elements of system **400** typically comprise a natural language interaction engine **401**, one or more solution data repositories **430**, a build environment **440**, and a back office environment **420**. Each of these may in turn be comprised of several components, in varying combinations, as will be described in detail herein.

Interaction environment **401** normally comprises a dialog interface **410** and an interaction processing core engine **403**. Dialog interface **410** performs functions necessary for media-specific interactions with users. A principal role of dialog interface **410** is to receive input from a user in order that interaction engine core **403** can successfully determine a user's meaning (and the user's intent), and to provide feedback or responses back to the user. For example, when interactions are conducted using speech interfaces, interaction may be either via a phone **414** (for example when a virtual assistant is used in place of a conventional IVR application) or via a dedicated voice application **413** (for example when a user of a mobile application or a web site interacts with a virtual assistant using an application, and no phone is involved). In either case (or indeed in other cases, such as embodiments where other means of exchanging voice communications via audio signals—of which many are known in the art—are used, such as interaction with a building control virtual assistant using an intercom system), it is generally necessary to convert speech input into some form of text, and conversely to convert text output into some form of speech output (although, it should be noted, there are limited means known in the art for analyzing speech signals directly—known in the art as speech analytics technologies—and these could be used directly to infer user meaning and intent). Normally this is done by a voice-to-text conversion layer within dialog interface **410**, comprising an automated speech recognition (ASR) engine **411** and a text-to-speech (TTS) engine **412**. Many of each of these components are well known in the art, such as those available from Nuance™, Acapela™ Ispeech™, Google™ and other vendors; any suitable ASR and TTS engines may be used according to the invention. In some embodiments, ASR **411** and/or TTS **412** are deployed integrally to system **400** (as shown in FIG. **4**), while in others they may be deployed as separate services delivered over a network such as the Internet or a telecommunications network; such external services architectures may employ ASR **411** or TTS **412** provided by one or more third party service providers. Input may also be received (and output sent) via text-based media channels such as **415**, dedicated virtual assistant interfaces **416** (for instance, when a virtual assistant equipped with a graphical avatar is embedded in a web site and, when activated by a user, is interacted with directly), a social media interface **417** such as Facebook™, LinkedIn™ Twitter™, and the like, or any of a number of other text-based media channels known in the art but not shown in FIG. **4** (such as, for example, text-based interaction with a virtual assistant from within a document such as a word processing document, a spreadsheet document, or a presentation document; kiosks such as at airport check-in counters, and so forth).

Once input has been received, it is passed as input **404** to interaction engine core **403**, where it is reacted to and one or more responses **405** may be generated. When responses **405** are generated and sent to dialog interface **401**, they are converted (using TTS **412**) to speech form or spoken output, if required, and delivered to a user via either or both of a voice application **413** or a phone **414**, or if response **405** is already in textual form it is passed directly to a text-based output channel such as email **415**, virtual assistant **416**, social media **416**, and the like. As a further example illustrating how natural language interpretation can be used to enrich multimodal user interactions, consider a combination mobile phone application that proceeds as follows. First, a user presses a button to initiate the application, which displays or plays a welcome prompt (or both) to the user. The user may say an utterance expressing her intent or goal (for example, “I would like to arrange travel to Berlin tomorrow morning.”) The application may then display a selection of radio-button style choices on the screen of the mobile phone, for example comprising “Flights”, “Hotel”, “Car/Transport”, and “Recommended”. At substantially the same time, the application may speak a phrase such as, “Where would you like to start to make travel plans? Select a button or tell me what you want to do.” The user and the application may, throughout the subsequent interaction, use a blend of spoken, text, and haptic interface conventions to exchange information and satisfy the user’s original (and any subsequently arising) intention). Thus it can be seen that many examples of natural language interaction applications envisioned by the inventors may involve multimodal interactions comprising two or more interface modalities (such as speech, text, buttons, images, videos, vibrations, sounds, and so forth).

When input **404** is received by interaction engine core **403**, it is generally first handled by an input interpretation module **407**, which manages the process of handling inputs **405**, making various calls to one or more services of natural language interpreter core (NLI core) **402** (which services and associated processes are described in more detail below), in order to determine one or more meanings of a user’s input **404** and to infer therefrom the user’s intent. That is, a goal of input interpretation module **407** is to “understand” what a user wants, in order that NLI core **402**, in conjunction with input interpretation module **407**, can formulate one or more appropriate responses to input **404**. Once a response type, or the content of a response, is determined, output generation module **408** is tasked with creating an appropriate response **405**, which can then be sent to dialog interface **410** for delivery (in an appropriate medium or via an appropriate channel) to the requesting user. In general, every time input interpretation module **407** receives and processes a user input **404**, and every time output generation module **408** formulates a response **405** and sends it to dialog interface **410**, log file generation module **409** generates one or more log files **421** in order to capture a history of interactions between users and natural language interaction applications. In addition, more or less detailed information pertaining to processes carried out by NLI core **402** is passed to log file generation module **409** as well, in order that not only what transpired is recorded (that is, the inputs **404** and outputs **405**), but also how it was done and why (that is, a history of decisions made, rules and flows executed, variables set, and so forth in NLI core **402** is captured). NLI core **402** may, in order to process user inputs or to create responses, require access to one or more external data sources or external services; such access is provided by one or more connection APIs **406**, which manage interactions between NLI core **402** (and possibly also input interpretation module **407** and output generation module **408**) and external data sources and services. Such external entities may comprise a plurality of enterprise applications **461** such as customer relationship management (CRM) systems, transaction management systems, trouble ticket tracking systems, inventory management systems, and so forth (it will be appreciated by one having ordinary skill in the art that essentially any enterprise or third party applications may be interacted with using standards-based APIs or other integration technologies, and thus any such enterprise applications known in the art may be used by interaction engine **401** as needed to serve users). Such external entities may also comprise a plurality of third-party cloud-based applications **462**, or any other third party services or applications accessible via public or private interfaces (whether standards-based or proprietary), subject only to findability and security constraints.

NLI core **402**, when processing requests received (after preprocessing) from input interpretation module **407**, uses one or more solution data repositories (or simply “solutions”) **430** that it loads as required. Solutions **430** generally comprise various combinations of business rules **431**, integrations **432** (that is, configuration data necessary to carry out communications via connect APIs **406** with enterprise applications **461**, third party cloud applications **462**, and the like), custom objects **433** (such as script objects used to encapsulate frequently used functionality), domain objects **434** (which are collections of ontologies or ontological data sets that represent knowledge about one or more subject domains such as travel, finance, heart health, furniture, and so forth), language recognition rules **435** built up from language objects (which may comprise a large number of formal models of various language elements for one or more languages; language objects will be discussed in detail below), and flows **436**. These solution data **430** components in turn may be preloaded as standardized knowledge bases when a natural language interaction application is created, or they may be hand-crafted by one or more natural language interaction (NLI) developer within build environment **440** (or both; it is quite common to start with a prebuilt set of knowledge base **430** components, and then to add new components or extend the added components from within build environment **440**) or part of it can be automatically generated according to the embodied invention.

Build environment **440** comprises several components, organized in a preferred embodiment into a single application **441** (sometimes referred to as a "studio"), from which an NLI developer may access client knowledge and data **444**, domain libraries **443**, and language libraries **442**. Build environment **441** typically comprises a graphical coding tool **445** and one or more automated testing tools **446**. Thus, in a typical scenario, a developer building a new natural language interaction application such as a virtual assistant would, within a coding tool **445** in build environment **441**, load one or more prebuilt language libraries **442** and domain libraries **443**, edit these based on available client knowledge and data **444**, and then test the resulting knowledge base **430** using one or more automated (or manual) testing tools **446** in order to test the behavior of her new application prior to its use. Once satisfied with a new solution **430** (and with the associated application's behavior), the developer would publish knowledge base **430**, which would then be available for NLI core **402** to load and use in handling user requests **404**. A key benefit of the build environment **440** approach envisioned by the inventors is that it enables NLI developers who are not necessarily research scientists (such as computational linguists) to rapidly prototype, test, refine, and then tune natural language interaction applications for particular domains or business needs. This makes it possible to move natural language interaction application development from being an activity typical of linguistic experts with technical skills to one practiced commonly by user without technical or linguistic skills and users such as businesses (large and small) and other organizations desiring to use natural language interaction applications in production.

According to a preferred embodiment of the invention, the process just described is part of an overall closed-loop process. The loop is made "closed" by the availability of an analytics framework **450**, which can be used to automatically or manually analyze natural language interaction application performance in order to eliminate poorly functioning dialog elements, improve customer satisfaction, and so forth. Analytics framework **450** generally takes as input a plurality of log files **421** generated by log file generation module **409**, although in some embodiments analytics framework **450** may take input directly in real time from interaction engine **410**, for example by receiving requests **404**, responses **405**, raw user inputs, and processed outputs to users as they occur directly from the corresponding components of interaction engine **410** (and of course diagnostic information about decision-making and operational processes occurring within interaction engine **410** could similarly be obtained as they occur). Thus the log file-driven architecture shown and discussed herein should be taken as exemplary and not limiting. In various embodiments, analytics framework may comprise one or more of a top response analysis module **457**, a dialog browser **451**, a category analysis module **452**, a log file loader **453**, a report generator **454**, and a time-based analytics module **456**. In any particular embodiment of the invention, some, most, or all of these components may be present within analytics framework **450**; moreover, in some embodiments one or more of these components (or other analytical components known in the art such as business intelligence engines, datamarts, and the like), may be implemented as standalone components separate from analytics framework, including for example delivery as web-based or cloud-based services from a third party analytics platform provider. It should be apparent to one having ordinary skill in the art that any combination or architecture of these and other analytical components may be used according to the invention, and that the particular arrangement shown in FIG. **4** is intended to be exemplary and not limiting.

Top response analytics module **457** is a software module that computes a ranked list of responses **405** generated by interaction engine **410** to user requests **404**; in many embodiments, a corresponding ranked list of requests **404** that led to a particular response **405** may be provided (often by provision of a "drill-down" capability, so that when viewing a ranked list of responses **405**, a user may right-click or take some other action to see what requests **404** led to that response **405** most commonly). Responses **405** (and corresponding requests **404**) may be ranked according to one of many numerical or qualitative parameters, such as most popular, most used, most often abandoned from, most often viewed, most often complained about, or any other similar ranking metric. Top response analytics module **457** may automatically generate and maintain ranked lists of responses **405**, or may do so on request from an analyst or other authorized user (or both). In some embodiments, users may be allowed to specify one or more custom ranking criteria (as long as they are susceptible of measurement based on data received from interaction engine **410**); such custom rankings may be conducted on an ad hoc basis, although useful rankings may be added to the last of available standard rankings, and could be added to any automated ranking processes as well, if desired.

Dialog browser **451** is a user interface element that allows an analyst or other authorized user to view (or hear) one or more interactions or dialogs between users and natural language interaction applications. Users may be allowed to request random interaction sessions, in which case one or more sessions would be displayed for viewing at a time; such a view would be useful for example to a marketing analyst who wants to "see" how users interact by randomly browsing among user experiences. Users may also select one or more sessions for viewing (or listening), based typically on any of a wide range of filters or selection criteria made available through a user interface of dialog browser **451**. For example, a user could request to view all interactions with a specific user, or with a specific user/application pair, or relating to a particular subject such as a particular product or small talk, and so forth. Users may also request a specific interaction by providing a time, or a session identifier, or a customer name and a time, or any other filtering arrangement that can distinguish the desired session from all others.

Category analysis module **452** is typically a graphical user interface component that allows an analyst or other authorized user to view one or more, or all, sessions or interactions that pertain to a particular category (such as a category within a domain model, for instance by requesting to view a sampling of sessions involving furniture-related questions). Users of category analysis module **452** may be able, for example, to view all or a set of sessions (or to view aggregated numerical data pertaining to such sessions) that were about home equity loans. While viewing such a set of data or sessions, the user might be able to explore for example whether certain questions related to home equity loans are more commonly received from customers that are actually considering taking out such a loan; this might be determined, for example, by displaying columns of data about "probability of loan application being taken" and "probability of closing of loan applications taken", and allowing a user to rank sessions by one or another column in order to understand such patterns. It should be clear to one having ordinary skill in the art of data analytics that there are many ways of viewing and analyzing data of this type, any of which may be included in category analysis module **452** according to the invention.

Time-based analysis module **456** is typically a graphical user interface element that allows an analyst or other authorized user to configure, conduct, schedule, and view the results of various analyses of one or more time-based behaviors of natural language interaction applications and/or their users. For example, time-based analysis module **456** may in some embodiments be used to identify trends in user behavior, such as the emergence of new dominant questions or shifts in linguistic usage over time. Another example, likely to occur quite readily, would be the use of time-based analysis module **456** to study assimilation of new application capabilities upon their introduction in one or more natural language interaction applications. When new capabilities (for instance, new language models, improved business rules, richer interaction modality options, or expansion of domain coverage) are added to an application such as a virtual assistant, their use by those who interact with the modified natural language interaction application is likely to vary over time as more and more users become accustomed to the new capabilities; such user assimilation can be studied to learn how long to wait before expecting changes in user behavior (such knowledge would be quite useful in avoiding for example the premature termination of an experimental feature, which might occur if knowledge engineers misunderstood a normal "uptake curve" for lack of user interest). Similarly, in some embodiments time-based analysis of users' natural language inquiries may uncover emerging linguistic elements, such as the emergence of new "buzzwords", common off-topic questions such as "What do you think of the Avengers movie?", or topics of interest (any of which might suggest modifications to knowledge base to maintain a high degree of user acceptance and virtual assistant fluency).

Report generator **454** is typically a graphical user interface element that allows an analyst or other authorized user to design, configure, schedule, edit, manage distribution of, or view one or more periodic or ad hoc reports regarding operation of interaction engine **410** or virtual assistants hosted by it. Similarly to output from time-based analysis module **456**, reports generally prove very useful in detecting trends or emerging problems with natural language interaction applications, language or domain models, or the infrastructure or applications of interaction engine **410**. For example, a report might provide tabular and graphical data pertaining to the number of occurrences of various types of interactions using one or more applications, and data for each row or category of interaction for each time period might include items such as the number and/or percentage of sessions that terminated either prematurely or in an unexpected way, the number of sessions that resulted in or involved a product sales inquiry, the number of those that resulted in a sale, and so forth. It is common in the art for reports to be useful in understanding such issues as diurnal patterns of user behavior (for example, users might be more likely to conclude purchases during early evening hours, and might engage in a higher level of off-topic "small talk" in the hours after midnight). It should be clear to one having ordinary skill in the art that any of the many infrastructure, data presentation, drill-down and drill-up, filtering, and other options known in the well-developed art of enterprise application reporting may be used according to the invention. Of course, the range of inferences that might be made through use of analytics based on natural language interaction engine **403** data is quite broad. For example, in some implementations it may be desirable to identify particular channels (media types, such as email, phone, kiosk, instant messaging, and so forth), particular operating systems, particular browsers, and similar specifics regarding a plurality of users. As an exemplary use of such data, it may be that users of Macintosh™ computers from Apple™ might be found to demonstrate certain typical habits and preferences, knowledge of which might allow for effective tailoring of natural language interaction engine **403** to better serve those customers.

Log file loader **453** is typically a graphical user interface element that allows an analyst or other authorized user to manage the configuration and scheduling of log file loading (or to configure real time data acquisition, when that approach is taken to gathering data from interaction engine **410**), and to carry out ad hoc log file activities such as log file pruning, exporting of log files to other systems, archiving or configuring archival of log files onto long term storage systems, and so forth.

In most embodiments, the various components of analytics framework **450** are tightly coupled, for instance by allowing an analyst or other user to move directly from one tool or view to another with a simple user interface action such as selecting a button, choosing a tab, or picking a different view from a context-sensitive menu. For example, a user viewing a list of sessions in a category analysis screen **452** might select one or more sessions from a list (for example, by shift-clicking them using a mouse, or using a check button interface element) and then select "browse dialogs" to view the selected sessions in dialog browser **451**. It should be appreciated by one having ordinary skill in the art that many styles of linking of related user interface elements and analytic functionality exist in the art, any of which may be used according to the invention.

FIG. **5** is a block diagram of a system **500** with a natural language interaction engine residing on a mobile device, according to an embodiment of the invention. According to the embodiment, a portion of the functionality of natural language interaction engine **403** and its associated components may be deployed on a mobile device **510**. In particular, natural language interaction engine **520** may be deployed in full or in part on mobile device **510**, which is advantageous at least because, to the extent a fully functional natural language interaction engine **520** is deployed on a mobile device **510**, one or more natural language applications **511**, **512** may be executable on mobile device **510** even when the device lacks network connectivity. Since most mobile devices **510** are at least intermittently disconnected from networks, the ability to operate robust natural language applications such as application A **511** and application B **512** clearly represents a significant usability enhancement over those natural language applications known in the art. For example, Apple's Siri™ virtual assistant product only works when connected via a mobile telephony network to one or more servers operated by Apple, which represents a usability problem for situations where users lose network connectivity (for example, in many places users traveling in cars, trains, or planes may go for significant periods with no network connectivity, and may also experience only degraded or intermittent network connectivity when on a network). Since it is well known in the art that some types of services such as ASR **570** may be too processor-intensive to be deployed entirely onboard mobile device **510**, natural language interaction engine **520** may interact or utilize ASR **570** or other third party services **571** (such as, for example, text-to-speech, search engines, and the like) when connected to a network to augment functionality available to either application A **511** or application B **512** or both (of course, applications **571** and **572** are merely exemplary, and more or fewer applications may be deployed continuously or intermittently on mobile device **510**, according to the invention; for example, some applications may be uploaded temporarily to run on mobile device **510** and then deleted once used until they are needed again). Of course, ASR **570** may be deployed on a mobile device **510** if such a device has sufficient processing power to handle a particular set of speech recognition tasks; it is anticipated that such deployments may become more and more common as the processing power available in mobile devices continues to improve. In other embodiments, some portion of ASR **570** may be deployed on device **510** while others remain on one or more network-connected servers. For example, simple ASR **570** grammars might be used on-device, and unrecognized or poorly-recognized speech might be sent as needed to a server for further ASR **570** processing.

According to the embodiment, build environment **400** may be used to develop and deploy natural language applications such as application A **511** and application B **512**. In some embodiments, natural language interaction engine **520** is a mobile application that is deployed from an application store or downloaded directly from a web site or other source by a user, and that interacts with one or more separate mobile applications **511**, **512** using data from one or more solutions **531**, **532**. In other embodiments, solutions **531** and **532** might be loaded directly into applications **511** and **512**, respectively. In yet other embodiments, a solution **531** and a natural language interaction engine **520** may be embedded fully into a standalone mobile application **511**; while in other embodiments individual solutions **531**, **532** may be deployed either as separate mobile applications **511**, **512** that interact with engine **520** or as modules that are downloaded to device **520** and installed as add-ons to engine **520**. Build environment **400** will typically comprise exemplary features described above with reference to FIG. **4**. When a developer has completed and tested a natural language application such as a virtual assistant, then mobile-ready application deployment **560** may be carried out across one or more data networks or mobile telephony networks, to deliver the resulting application to a plurality of mobile devices **510**, either on demand, as implicitly needed, or via for example the mediation of an "app store" such as are well known in the art (in which case, typically a user of mobile device **510** would explicitly select a mobile-ready natural language application **511**, **512** and upload it to her mobile device **510**. According to the embodiment, natural language applications need not be tightly bound in a one-to-one relationship with solutions such as solution **1 530** and solution **2 531**. For example, solution **1 530** might be a travel-related solution, comprising elements such as those described above with reference to item **730** in FIG. **7**, and solution **2 531** might be a credit card transaction solution. Both solution **1 530** and solution **2 531** may be deployed (either permanently or temporarily under user of system control) on a single mobile device **510** (and indeed a plurality of other solutions may be as well, limited only by available resources on mobile device **510**). Continuing the example, application A **511** might be an airline reservation application (perhaps provided by an airline itself, or by a third party application vendor), which might make use of language recognition rules and flows (among other items) from both solution **1 530** (for travel-related flows) and solution **2 531** (for credit card transaction related flows). Similarly, application B **512** might be a virtual assistant application using natural language user interaction, facilitated by natural language interaction engine **520**. Such a virtual assistant application might only occasionally have need to use solution **1 530** (for example, when the user of mobile device **510** desires to set up a flight itinerary using virtual assistant application **512**); similarly, virtual assistant **512** might also have occasional need for solution **2 531** to conduct credit card transactions (whether or not related to travel). Thus it should be clear to one having ordinary skill in the art that a plurality of solutions **530-531** may be deployed on mobile device **510**, and that these solutions may make their capabilities available to all or a portion of a plurality of natural language applications **511-512** deployed on mobile device **510**. Moreover, natural language applications **511-512** may typically be provided with access (generally subject to application-based or user role-based security restrictions imposed by mobile device **510**) to device-specific data **540** (such as location data, device **510** orientation and other environmental data, map data stored on or accessible via mobile device **510**, and so forth) or user-specific data **550** (such as a user's address, phone number, location history, preferences, or even sign-on data to various online services such as Twitter™, Facebook™, and the like). Thus FIG. **5** shows a valuable embodiment of the invention in which a user of a mobile device **510**, even when only intermittently connected to the Internet or a mobile telephony network, may enjoy rich, natural language-based applications with low latency resulting from their residence on the mobile device **510** itself (while still being able to invoke or utilize any number of network-resident services such as ASR **570** and other third-party services or servers **571**).

FIG. **6** is a block diagram of a network of virtual assistants by which virtual assistants interact with each other and with users, according to an embodiment of the invention. Virtual assistant network **601** consists of one or more personal virtual assistants **602** (Herein, referred to as PAs) and one or more common virtual assistants **608**, **609**, and **610** (Herein, referred to as CAs). A PA is an automated virtual assistant by which human users **620** may interact, for example, through natural language interaction between user **620** and PA **602**, to interpret the intention of a user request **410** and construct one or more appropriate responses to request **410** and provides any resulting responses **430** to user **620** queries (or, analogously, responses or reactions to requests, for example when a virtual system does something as a result of being requested to do it, such as checking the status and availability of common services like checking for movie tickets and show times) using those constructed responses. A PA may interface to one or more external services **630**, for example web services from a corporation or service provider over the internet, to one or more other PAs **602**, and/or one or more CAs **608**, **609**, **610** to fulfill requests by user **620**. A CA is an automated virtual assistant that can reside online, on a device, and/or in embedded systems, typically in a corporate or a service provider environment, but may not always be the case, that has an ability to provide responses to requests by other virtual assistants **602** or directly from users **620**, for example, customer service and other informational requests. In some embodiments, CAs **608**,**608**, **610** may be a complement to customer service by humans or replace human-based service altogether. Both PAs **602**, **602***a*, **602***b* and CA **608**, **609**, **610** may be implemented via one or more services (for example, through Twitter™, Instant Messaging services such and Microsoft Lync™, Social Media platforms such as Facebook™ web services, etc.) and/or embedded within a device or system (for example, Mobile telephones, tablet devices, laptop computers, a vehicle's control system, an appliance such as an elevator, etc.) known in the art. Once PA **602** registers with virtual assistant network **601**, a record is created, or updated, in PA description database **603** describing user preferences (for example a user's hobbies, areas of interest such as genres of literature and movies that she likes, other likes and dislikes, other demographical information, personal information, user specific data, payment information, device dependent/independent settings, etc.) as well as privacy settings detailing which information to expose to other PAs **602**, CAs **608**, or external services **630**. PA **602** consists of a public part and a private part. The public part exposes information and functionality that can be accessed by other PAs **602**, CAs **608**, or one or more external services **630**. The private part of PA **602** exposes information which is accessible only to user **620** (that is, the owner of PA **602**). PA **602** can reside physically on one or more devices **620***a*, **620***b*, **620***c* (for example a mobile phone, a personal computer, etc.), within an embedded device **620***b* (for example, a home automations system), in the cloud, etc. as separate instances or as access points to the same instance. Each PA **602** instance holds the information needed to function and any limitations in capabilities (for example, an on-device PA **602***b* may be limited in functionality when no internet access is available; a device, for example in an embedded system, may only have an audio interface (i.e. no video), etc.). Each PA **602** instance may periodically synchronize preferences (for example a new privacy setting, a new connection to a friend's PA **602***b*, etc.), updated information (for example, a change in physical location, calendar setting, etc.), and/or other user-specific data with PA description database **603**. PA description database **603** may also hold information about other PAs **602***a* authorized to use the public part of a PA **602** and task descriptions of services available for authorized PAs **602***b*. Different PAs **602***a* in virtual assistant network **601** may have access to different parts of the public part of a PA **602** based on the configuration and privacy settings. One or more CA **608**, **609**, **610** can be connected to the virtual assistant network **601**. Once connected, a description of CA **608** capabilities is stored in CA description database **611** (for example, CA **609** may have domain-specific capabilities, such as those used in conducting financial transaction such as finding the best mortgage rates, or performing stock purchases and sales) and one or more PAs **602**, and other virtual assistants, may discover capabilities and services available from CA **608** to make use of them.

Virtual assistant mediator VAM **607** facilitates communication between one or more PAs **602**, one or more CAs **608**, and/or one or more external services **630**. To facilitate communications, VAM **607** uses PA descriptions stored in PA description database **603** to understand the preferences (for example, a preferred external service such as Expedia.com™ for travel arrangements), relationships to other PAs **602***b* (for example, virtual assistants of friends and colleagues), preferred CAs **610** (for example, a virtual assistant that relays stock quotes that uses a particular celebrity's voice pattern), and the like. Furthermore, VAM **607** uses CA descriptions stored in CA description database **611** to be informed of what services may be available. Virtual assistant network **601** provides task repository **604** that contains application logic and natural language understanding rules that can be downloaded and/or integrated into one or more PAs **602**, one or more CAs **608**, **609**, **610**, or to external services **630** as needed. VAM **607** auto generates natural language recognition rules for each task and adds it to task repository **604** (for example, product names that are not standard language words may require specific natural language recognition rules). Usage process **612** records details on the usage and interaction of virtual assistant network **601** (for example, which PAs connected to which CAs, survey information about a CA or an external service, trust parameters, satisfaction parameters, connectivity issues, and other information), and saved for analytic purposes to usage database **613**. Communication between one or more PAs **602**, CAs **608**, **609**, **610**, external services interface **606**, and/or other system components, is routed via VAM **607**. In some embodiments, VA network administrator **614** may manually process a request forwarded by VAM **607**. For example, VA network administrator **614** adapts PA **602** natural language recognition rules to user **620**'s profile (for example, adapting to a specific dialect or difference in standard vocabulary), or enables and customizes one or more external services **630** (for example, access to a subscription-only investment brokerage website). In another embodiment, VA network administrator **614** may enable a human process to provide input to aid in a request by PA **602** where an automated process may not be able. For example, if a web service requires "captcha" input (that is, a type of challenge-response test used in computing as an attempt to ensure that the response is generated by a human).

To prevent session hijacking, that is, to gain unauthorized access to information, services, or components in virtual assistant network **601**, PA **602** may disconnect from CA **608** or another PA **602** at any time (for example, by giving a certain command, or based on some alarm or threshold).

In order to facilitate service CA **610** may connect to an external service **630** via one or more external services interface **606**. For example, a request from user **620** for PA **602** to order a pizza may access an online mapping service, such as Google Maps™, to determine which pizza vendor may be closest in proximity. In this example, the vendor has a web services interface that may be used by PA **602** to fulfill the request. In another embodiment, a vendor may already have CA **610** that can be used to interface with PA **602** to fulfill the request or a dialog hand-over happens and user **620** directly with CA **610**.

FIG. **7** is a block diagram of a persistent virtual assistant across multiple platforms in a social network of virtual assistants, according to an embodiment of the invention. In a preferred embodiment, virtual assistant **710** may be independent of device (for example, mobile telephone, laptop computer, television, automobile navigation system, etc.) to provide cross platform support and thereby allowing user **701** to continue a session held on user device **701** on another user device **703**. The ubiquitous nature of virtual assistant **710** is performed by maintaining a persistence of knowledge by preserving dialog sessions and techniques for dialog resumption as well as adaptation to various devices in device persistence **713**. For example, user **701** begins a dialog with virtual assistant **710** on user device **702** (for example, a laptop computer). User **701** desires to transfer the interaction to user device **703** (for example a smart phone) by issuing a command (for example, a verbal statement) to virtual assistant **710**. Virtual assistant **710** sends dialog session information to device persistence process **713**. User **701** interacts with virtual assistant **710** on user device **703**. Virtual assistant **710** checks device persistence process **713** and sees that a session in progress and asks user **701** if she wishes to continue where it left off.

In another embodiment, virtual assistant **710** may handle intermittent connectivity and be able to continue processing requests from user **701** that require connection when connectivity resumes. For example, user **701** may request virtual assistant **710** to block off time in her calendar. In this example this request happens when virtual assistant is unable to connect to user **701**'s calendar. As such, virtual assistant **710** may add the calendar task to task repository **711**. When connectivity resumes, virtual assistant **710** sees the task in the task repository and completes the request.

An exemplary dialog between user **701** and virtual assistant **710** is as follows:

User **701** is in a car interacting with virtual assistant **710** on user device **704** (for example, embedded into the car audio system). User **701** utters, "Can you check flights to Paris for Friday?"

Virtual assistant **710** may assume that the flight is to commence in London where user **710** resides. Furthermore, based on data in virtual assistant description database **603**, virtual assistant **710** may know that user **701** does not prefer to fly low cost. Virtual assistant **710** utters, "I have found ten flights for Friday. When do you need to be there?"

User **701** interrupts the dialog by uttering, "We will have to continue later I am home now." Virtual assistant may place a time stamp on the dialog and store it in task repository **711**.

At some later point in time, user **701** starts user device **702** (for example, a laptop computer). Virtual assistant **710** utters, "Hi, what about that flight? Should we continue?"/In this example, user **701** agrees.

Virtual assistant **710** adapts to device **702** that has a larger screen and utters, "So, I had found ten flights for Friday. Do you want me to show you the list?"

And so on.

In some embodiments, virtual assistant **710** may, for example, be configured with rules as to when to resume a dialog. For example, in the above example, virtual assistant **710** may not have resumed the dialog after the uttered departure date had passed for the intended flight.

In another embodiment, virtual assistant **710** may, for example, simply state that there is an unfinished dialog.

In another embodiment, virtual assistant **710** may, for example, not resume a task based on the capability of user device **704** that may not be capable of enabling the successful outcome of the request.

In another embodiment, virtual assistant may, for example, prioritize unfinished dialogs and present them to user **701** in order of priority or some other desired order.

In another embodiment, virtual assistant **710** may, for example, collect actions that require connections and not revisit those dialogs with user **701** until connectivity is available.

In another embodiment, user **710** may, for example, explicitly tell virtual assistant **710**, in natural language, to postpone the task (for example, "let's talk about that later").

In another embodiment, user **710** may, for example, stop the dialogue with virtual assistant **710** (for example, by uttering a command or interaction via an interface on user device **702**).

In another embodiment, dialogue between user **701** and virtual assistant **710** may be interrupted by some external factor (for example, an incoming call on mobile device **703**)

In another embodiment, dialogue between user **701** and virtual assistant **710** may be interrupted by user **701** being, for example, distracted and not responding to virtual assistant **710**.

In another embodiment, dialogue between user **701** and virtual assistant **710** may be interrupted by the connection between the user **710** and virtual assistant network **601** shuts down.

In a preferred embodiment, tasks and/or dialogs can be resumed by user **701** or virtual assistant network **601**, for example, when:

user **701** has finished a secondary task that it switched to, and a postponed task is still active

when the connectivity between virtual assistant **710** and virtual assistant network **601** has been restored

if user **701** explicitly requests virtual assistant **710** to resume a task (for example, "let's go back to that booking")

if user **701** selects a GUI menu, for example, on user device **703** by clicking to resume a task

when an interruptive factor stops (for example, an incoming call has finished on user device **702**), virtual assistant **710** can resume dialogue with user **701**

when a new session starts on the same user device **702** or another user device **703**

In some embodiments, tasks might be device dependent and may not be resumed on another device. For example, a task started on user device **702** (i.e. a laptop computer) may not be resumed on user device **704** (i.e. automobile navigation system)

A postponed task can be cancelled for several reasons:

Task has passed a pre-configured hibernation period (for example, virtual assistant **710** may be configured such that a task can only be active for a certain amount of time)

Explicitly by user **710** when resumed by a command (for example, user **701** utters, "forget about that")

User **701** can graphically delete the task via a GUI on user device **703**.

Task manager **714** handles user **701**'s active and postponed tasks to:

keep tasks in a data structure (for example, a stack, tree, queue or heap). It will be appreciated by one having ordinary skill in the art that a data structure is a particular way of storing and organizing data in a computer so that it can be used efficiently

set status of tasks (for example, hibernation period, status, time when task was latest active, etc.)

store tasks with task parameters

keep information in virtual assistant network **601** so that it is accessible from different user devices **702**, **703**, **704** to allow for device independent resumption

make use of methods for postponement of tasks, resumption of tasks, cancellation of tasks, etc.

hold resumption strategies and interface to device persistence process described earlier that may adapt to the task conditions, for example, a different strategy may be invoked if a task is resumed after a short interruption as opposed to resuming a task after a day or on a different device or modality. For example, with an interruption of a shorter time period, virtual assistant **710** may utter a specific portion of the dialog, for example, "So, what date did you want to fly?" (It will be appreciated by one having ordinary skill in the art that a shorter time period for an interruption would result in a reduced chance of user **701** forgetting where the dialog left off), whereas for an interruption of a longer time period, virtual assistant **710** may utter a more general statement to refresh the mental state of user **701** for the task, for example, "Should we continue with the flight booking to New York?" (It will be appreciated by one having ordinary skill in the art that a longer time period for an interruption would result in a increased chance of user **701** forgetting where the dialog left off if not forgetting the entire dialog altogether)

Task parameters may be obtained in several ways, for example:

From another dialog flow

From another user **701** in a dialogue

From personal information of user **701**

Task parameters and data may have conditions or constraints, for example:

Local or global in scope (for example, may only be used only in current task or can be used in other tasks)

Life time of a task parameter

Device dependent task parameters

FIG. **13** is a block diagram illustrating an exemplary arrangement **1300** of a virtual assistant network **1310**, showing the use of multiple virtual assistants with a broker, according to a preferred embodiment of the invention. As illustrated, a plurality of virtual assistants **1311** may be connected to the Internet **1301** or another appropriate communications network, such as to receive requests from user devices **1320**. A user device may be any suitable network-connected device, such as a telephone **1321**, smartphone **1322**, tablet computing device **1323**, or any other such device according to the invention. As illustrated, virtual assistants **1311** may be in communication with each other, such as to interact as needed during the fulfillment of a user's request, for example if one virtual assistant (VA) is more suitable for handling the request than another. In such an instance, the request may be sent from the original "host" VA to the more capable "target" VA for fulfillment, and the result then sent back to the host for presentation to the user. In this manner, a virtual assistant network (VAN) **1310** may facilitate more effective fulfillment of user requests without impacting user experience, as the user may perceive that they are only interacting with a single VA as per normal operation.

As further illustrated, a VA broker **1330** may be utilized, such as to facilitate management of a VAN **1310** or to assist in optimal routing of networked operations. For example, a VA broker **1330** may maintain a repository of information related to specific VAs within a network, such as their respective capabilities or knowledge bases, and may use this information to optimally handle requests as needed. As an example, if a host VA is given a request it is unable to fulfill (or, optionally, that it may be capable of fulfilling but to an unacceptable degree, as might be configured to optimize customer satisfaction with assistant interactions), a request complying with the inter-VA communication protocol might be sent to a broker **1330** for assistance. The request may contain a natural language expression and additional structured data. Based on the data in the request and known information about the VAN **1310**, the broker **1330** may then find and return information about one or many suitable VA's for fulfillment. The host VA may decide whether to forward the request to any of the suggested target VAs. If so, the host VA communicates with the target VA using the standardized inter-VA protocol. Alternatively, the VA broker may return a list of target VAs to the host VA, the list comprising target VAs that it determines may be likely to be useful in satisfying the request sent by the host VA. The communication between the user and the target VA is done via the host VA. In this preferred embodiment, the host VA exercises full control over selection of a target VA to fulfill the request. In other embodiments, the host VA may evaluate the suitability of a plurality of target VAs and then select a specific target VA and send the relevant information regarding the selected target VA to the host VA. In yet another embodiment, the VA broker may receive responses from a plurality of target VAs to whom it sent a request received from the host VA, and then select from among the received responses that response which is believed to be most suitable for the received request, and send the selected response to the host VA. Again, it will be seen that the host VA controls the actual user interaction. When a host VA receives a list of eligible target VAs from a broker, the host VA decides when to initiate the dialog with a selected target VA (in this case, selected by the host VA, possibly as a result of user interaction), when to forward a user's input, and how to handle a response from a target (example: display natural language response received from the target, respond to a request from the target). The host VA decides when to drop the dialog with a target, based for example on signals from the user, signals from the target or other reasons decided upon by the host VA. In this manner, it can be appreciated that networked virtual assistant operations may be further optimized through the use of a broker to increase efficiency and relevancy, but that a broker need not be required for a VAN to operate (as the VAs may be able to communicate between themselves, as described previously).

FIG. **14** is a block diagram illustrating communication between two virtual assistant brokers, each operating a distinct virtual assistant network **1310**, **1410**. As illustrated, multiple virtual assistant networks **1310**, **1410** may be served by separate VA brokers **1330**, **1430**, such as to facilitate discrete operation of each network but still allowing for inter-network operation when needed. As illustrated, individual VAs within a network may not be able to find target VAs outside of their respective network, but by interacting with a broker such networking may be made possible. A host VA broker **1330** may interact with a target broker **1430** as needed for request fulfillment, such as to find target VAs that the target broker **1430** has knowledge of. For example, a host VA broker **1330** may wish to utilize the capabilities of a regional VA **1411** for assistance with a particular request, so it may send the request (or the relevant portions of the request) to target VA broker **1430**, which may then pass the request on to VA **1411** for handling, returning the results to host VA broker **1330** upon completion. In this manner, it can be seen that it is possible for individual VAs to find and interact with one another within a (possibly quite extended or extensive) VAN, as well as with a VA broker. It is also possible for a VA broker to interact with various VAs within a network, as well as with other VA brokers as needed, facilitating operation across individual virtual assistant networks as appropriate. In some embodiments, a VA **1311** in one virtual assistant network **1310** may communicate directly with a VA **1411** in another virtual assistant network **1410**, generally after having at least once been referred to each other by a VA broker **1330**, **1430**.

FIG. **8** is a high-level process flow diagram illustrating an exemplary method for persistence of a virtual assistant across multiple platforms in a social network of virtual assistants, according to an embodiment of the invention. In step **801**, user **701** interacts with virtual assistant **710** using user device **702** (for example, a smart phone) to request, for example, to setup an invitation to a dinner party to other users. In step **802**, user **701** interacts with virtual assistant **710** to refine the request from step **701**. For example, virtual assistant **710** may ask who to invite, what location, etc. in step **803**, a command to postpone the request is issued by user **701** and the request is interrupted (for example, user **701** utters the command, "let's finish this later").

A period of time passes (for example, several hours) and in step **804**, user **701** connects to virtual assistant **710** via user device **703** (for example, a tablet device). In step **805**, virtual assistant **710** identifies an unfinished task in task repository

711 and notifies user **701** that there is an unfinished task. For example, virtual assistant **710** utters, "at which location would you like your dinner party. User **701** may, in step **806**, decide to not continue with the unfinished task and utter a new request to virtual assistant **710**. Alternatively, user **701** may choose to continue the unfinished task in step **807**. If so, virtual assistant **710** interacts with user **701** to discover the remaining details of the request (for example, location and time of dinner party, etc.). Virtual assistant **710** may connect to other PA **621**, **622**, CA **608**, **609**, **610**, and or external services **630** to complete the request. When completed, the interaction between user **701** and virtual assistant **710** terminates in step **809**.

FIG. **9** is a block diagram illustrating an exemplary architecture of a system for automated adaptive priority of tasks in a virtual assistant environment, according to an embodiment of the invention. According to the invention, key elements of virtual assistant task environment **900** typically comprise a task prioritization process **901**, a virtual assistant process **910**, external devices interface **920**, location awareness process **921**, and a network interface **923**. Each of these may in turn be comprised of several components, in varying combinations, as will be described in detail herein.

User **930** interfaces to virtual assistant process **910** by means of voice, text, tactile, and/or video input, or a combination of one or more methods, or by some other means to request processing of one or more tasks (herein referred to as, "the task"). For example, a task to book a flight or a task to make dinner reservations. Virtual assistant core **912** understands the task (for example through the use of automatic speech recognition) and determines how best to process the steps to complete the task. In some embodiments, a task may require virtual assistant core **912** to interface to other virtual assistant **808** (for example, a virtual assistant that may be interfaced to expert system with specific or unique capability, such as a virtual assistant for a furniture company with special information on furniture sales information) via virtual assistant network interface **913** and/or external service **830** via external device interface **920** (for example, information from a device connected to the internet, such as a traffic camera) via connected devices interface **911** to process and complete the task. In some embodiments virtual assistant process **910** may not have a suitable connectivity to other elements required to complete the task. For example, in the case where information from an external service **830** via external device interface **920** is required, external service **830** may require internet connectivity to receive the information required to complete a task (for example, images from a traffic camera to determine traffic patterns along a planned route). In another embodiment, a connection to a virtual assistant on a social network of virtual assistants **801** via virtual assistant network interface may be required to complete a task. In the instances where connectivity is not available, virtual assistant core may add a task to task queue **904**. In some embodiments, user **930** may indicate a priority for a task using a one or more interfaces to assign a priority (for example, user **930** is given a choice via a graphical user interface, or via voice command, to indicate low, medium or high priority). User priority process **906** associates a priority to a task record in task queue **904**. Once a task is added task queue **904**, effort score calculator **902** determines what may be required to complete the task. For example, one or more of the following attributes may be stored as parameters of a task to identify effort required to complete a task and assist in determining when and under what conditions tasks may be performed:

Amount of data that may be required to transmit, if any, for a task. For example, a time estimate on how long a task will take to complete may be calculated by a combination of the amount of data required to transmit and connection speed of network interface **923**.

Communication mode required, if any, for a task. For example, a task may require a synchronous or asynchronous communication (or a combination of both) with external service **830** via connected devices interface **911**.

Type of connectivity required. Network interface **923** may be a local area network (LAN) covering a small geographic area, such as a school or company; a wide area network (WAN) providing communication in a broad geographic area covering national and international locations; personal area networks (PAN) such as a wireless LAN with a very short range (up to, for example, a few meters), for example when communicating with external service **830** such as, a refrigerator or automobile enabled to provide relevant information about itself; internet connectivity for example, to connect to external service **830** via external device interface **920** that is also connected to the internet; intranet connectivity, for example, to connect to external service **830** via external device interface **920** that may provide corporate or retail information services; virtual private networking capability, for example to connect securely to external services **830**, and the like.

Location and time awareness. For example, GPS coordinates, GSM localization, location proximity via Wi-Fi (or other wireless) services, and the like. It will be appreciated by one having ordinary skill in the art that any of the many class of computer program-level services used to provide specific controls for location and time data as control features in computer programs will be used to determine location and time.

Time zone of user **930** and/or time zone of required resources that may prevent or enable interface to said resource. For example, time zone of other virtual assistant **809**, time zone of user **820** who may be the owner of other virtual assistant **809**, time zone of external service **830**, and the like.

In addition to the above attributes, connectivity process **903** determines a more detailed connectivity requirement for each task to more accurately assist in determining a priority for a task:

Type of connectivity required for a task. For example, connectivity to a local area network (LAN) covering a small geographic area, such as a school or company where the required service is located; a wide area network (WAN) providing communication in a broad geographic area covering national and international locations; personal area networks (PAN) such as a wireless LAN with a very short range (up to, for example, a few meters); internet connectivity, intranet connectivity, and the like. In some embodiments, one or more types of connectivity may be required

Signal strength of the current LAN, WAN, PAN, or of internet connection. For example, connectivity process **903** may use signal strength to estimate an amount of time that connectivity may last. Weak signal strength may indicate that a connectivity source is far away and thus an assumption can be made that a connection may only last a few minutes or seconds.

Signal (for example, a mobile network signal) strength trend. That is, determining, using recent historical metrics, if the signal may be getting stronger or weaker.

Signal strength (for example, the magnitude of the electric field at a reference point corresponding to virtual assistant process **910** that is a significant distance from the transmitting apparatus) trend. For example, when user **930** is in motion, signal strength may be fluctuating. Using recent historical metrics, signal strength of the apparatus that may be providing connectivity to complete certain tasks for virtual assistant process **910** may be on a progression where strength is increasing or decreasing. Connectivity process **903** may determine that when an increasing signal strength trend is present, connectivity may last longer, whereas on a decreasing signal strength trend, connectivity may not, for example, last long. In some embodiments, signal strength trends may be used in conjunction with location information from location awareness process **921**. For example, connectivity process **903** may cross-reference signal strength trend with proximity to, for example, a nearby city where the likelihood of a signal transmitting device is high. In this example, if the signal strength trend is intensifying coupled with location information that user **930** is approaching a large metropolitan area, connectivity process may determine that the likelihood of a long duration of connectivity may be probable. In this example, virtual assistant core **912** may be able to complete high-effort tasks, that is tasks that are deemed to require a larger than typical effort as determined by effort score calculator **902**. For example, booking a flight with other virtual assistant **810** that may require a back and forth dialog with user **930**. As such, reprioritization process **905** may reprioritize tasks in task queue **904** accordingly.

Connection type selection. Connectivity process **903**, may determine that certain tasks may only be performed on certain types of connections. For example, if a task that may require a large transmittal of data which may, in some connectivity types cost more (for example, on a cellular network where user **930** is roaming), connectivity process **903** may require that a task only use, for example, a lower cost network, such as a Wi-Fi network.

Privacy of tasks. If a task has privacy requirements, connectivity process **903** may require that a certain type of connection be available on network interface **923**. For example, a network capable of supporting a VPN connection.

In a particular embodiment, connectivity process **903** may predict when connectivity may be available next by using location information from location awareness process **921**. For example, in the case where user **930** may be currently offline but requesting tasks from virtual assistant process **910** and may be in a state of motion (for example, user **930** may be on a train headed towards a metropolitan area), connectivity process **903**, may use location information to determine the amount of time to be within range of known mobile of Wi-Fi networks, or some other form of connectivity, in order to start or continue processing tasks that may have been requested while user virtual assistant process **910** was not connected or continue processing a task that virtual assistant process **910** may have been processing previously and connection lost. In some embodiments, connectivity process **903** may assume that there will be connectivity available, given location information from location awareness process **921**, even if it may not known for sure that connection may become available. In a particular embodiment, location awareness process **921** may use other information (for example, speed, direction, and the like) to estimate when connectivity on network interface **923** may be available. In some embodiments, virtual assistant process **910** may notify user **930** of a predicted time-to-connectivity (that is, how long it may be until virtual assistant process **910** may establish a connection to one or more networks required to complete tasks).

Once effort score calculator **902** has determined details and environment that may be required to perform and complete a task, effort score calculator **902** computes an effort score, for example, how long a task may take to complete, what type of connection is required, etc. Effort score calculator **902** may store an effort score for each task in task queue **904**. In some embodiments, a duration required to complete a task may be stored for each task in task queue **904**. In a particular embodiment, effort score calculator will may be required for a task where a priority was set by user **930** using user priority process **906**.

Once a plurality of tasks are stored in task queue **904**, reprioritization process **905** may determine that a reprioritization of tasks may be required. For example, if connectivity is intermittent through network interface **923** (for example, connectivity availability is unpredictable and may connect and disconnect at unpredictable periods), reprioritization process **905** may reprioritize tasks so that tasks with lowest effort scores may be attempted first. For example, a task where a length of time to complete is minimal and/or where minimum amounts of data transfer may be required may be prioritized.

In a particular embodiment, user priority process **906** may override reprioritization process **905** with an urgent task. For example, if user **930** requests virtual assistant process **910** to prioritize a task (herein, referred to "priority task") to completion before all other tasks, reprioritization process will keep priority task in the first position, that is, the current task to attempt to complete by virtual assistant process **910**. In a particular embodiment, a priority task may be set to a high priority. In this case, user priority process may increase the priority of priority task so that it gets the majority of processing time, while still allowing reprioritization process to process other tasks based on attributes of all tasks in task queue **904** and current environment parameters (for example, time left until next connectivity with a long duration).

In a particular embodiment reprioritization process may prioritize tasks in task queue **904** based on connectivity speeds. For example, if there are tasks with low data requirements, said tasks would be prioritized before tasks that may require a large amount of data to be transferred.

In a preferred embodiment, when a task is not complete and network interface **923** loses connectivity to the required network, the task will be marked as incomplete in task queue **904**. When connectivity is re-established on network interface **923**, reprioritization process **905** may keep said task as top priority or in some situations, another task may take priority based on environmental parameters. For example, a connection where it is predicted that connectivity may not be active for the duration required for an unfinished task, a task with a low effort score may then be prioritized. The unfinished task may be attempted again when a suitable connection via network interface **923** is available.

In a particular embodiment, virtual assistant core **912** may provide a report to user **930** on the status of tasks in task queue **904**. For example, a list may be presented with a list (for example via a graphical user interface such as a screen of a tablet device) of tasks that may have been completed, a percentage completion on tasks that may only be partially complete, and a list of tasks that where processing may not have been attempted.

In a another embodiment, virtual assistant core **912** may present estimations on when tasks can be completed and presented to user **930** (for example by uttering voice signifying as such).

In a preferred embodiment, reprioritization process **905** may be continuously adapting and reprioritizing tasks based on data available about tasks and the current environment (such as the status of connectivity. For example, using predictive elements such as when the next time network interface **923** will have a connection to a required network and types of connectivity available (for example, Wi-Fi, GSM, and the like).

FIG. **10** is a high-level process flow diagram illustrating an exemplary method for automated adaptive priority of tasks in an intermittently connected virtual assistant environment, according to an embodiment of the invention. In step **1001**, virtual assistant core **912** gets the current location of user **930**. For example, user **930** is travelling on a train in northern Europe and may be in close proximity to a small town. In step **1002**, virtual assistant core **912** determines that within an estimated amount of time, virtual assistant process **910** may establish connectivity via a cellular telephone site that is Internet capable. For example, given the speed of the train and the direction in which it is heading, it is determined that connectivity may last four minutes. In step **1003**, reprioritization process **905** reads tasks from task queue **904** including associated information (for example task effort score as determined by effort score calculator **902**, time required to process task, etc.), reprioritization process **905** then rearranges tasks in task queue **904** to add a higher priority to tasks that take less than four minutes to process while taking into account any prioritizations set by user **930** via user priority process **906**. As such, tasks are reprioritized in an order where the priority is tasks that may require four minutes or less to process. In step **1004**, the first task is loaded and processed in step **1005**. For example, a task may require an interface to another virtual assistant **809** via network interface **913** or receive data via connected devices interface **911**. Once the task processing is complete, control returns to step **1003** and tasks are reprioritized again based on remaining tasks in task queue **904** and environment parameters. For example, given the time to process the previous task and the estimated time until connectivity is lost (for example, through updated location from location awareness process **921**, connectivity trends, that is, signal strength may be getting stronger or weaker as determined by connectivity process **903** and other parameters) and the time duration of remaining tasks in task queue **904**. Once tasks in task queue **904** are reprioritized by reprioritization process **905**, the process continues in a similar fashion through steps **1004** to **1006** as above until all tasks have been successfully completed in step **1006**, or when connectivity is lost in step **1005**. If there are no more tasks, the process will restart at step **1001** when a new task is added. If connectivity is lost, virtual assistant core **912** will check the status of the current task, if it did not complete successfully due to lost connectivity from network interface **923**, then the task will be marked as incomplete in task queue **904**. Information so that the task can continue to be processed is stored. The process will continue at step **1001** and continue in a similar fashion as outlined above.

FIG. **11** is a high-level process flow diagram illustrating an exemplary method for predictive network connectivity in an intermittently connected virtual assistant environment, according to an embodiment of the invention. In step **1101**, virtual assistant process **910** checks network interface **923** for an active connection to a required network to complete a task. In step **1102**, virtual assistant process **910** reads location information from location awareness process **921**. In this example, user **930** may be travelling in an automobile with intermittent connectivity. If an active connection to a network via network interface **923** is present, then connectivity process **903** may predict how long the connection will remain active on network interface **923**, for example by analyzing the recent historical trend of the signal strength or by determining a proximity to known connection apparatuses (for example a metropolitan area network). By using location information obtained in step **1102**, virtual assistant core **912** may determine that user **930** may be headed away from the area where connectivity was established. Using, for example, speed of travel, signal strength progression (that is, signal strength may be getting weaker), connectivity process **903** may determine, in step **1103**, an estimated time until connectivity may no longer available. Using one or more of these attributes (or other information available to task process **901**), reprioritization process **905** may use the time left with an active connection on network interface **923** to reprioritize tasks in task queue **904** in order to complete tasks that can be completed within the remaining time left until a disconnect (which may be a theoretical amount of time predicted until a connection will be lost). In some embodiments, reprioritization process **905** may decide to complete high priority tasks even if said tasks may take longer than a predicted amount of time of a duration when connectivity may remain active. In step **1104** connectivity history (that is, duration of active connectivity, signal strength, location, etc.) is recorded in usage database **813** via usage process **812** (in some cases, usage database **813** may be a local database on the same device as virtual assistant process **910**, for example, a mobile phone, a tablet, or an embedded device such as a virtual assistant equipped automobile, etc. so that connectivity behavior can be understood and referenced for future tasks in the same location. After connection is lost by network interface **923**, step **1105** compares the predicted time until connectivity was predicted to be lost to when connectivity was actually lost. As such, prediction algorithms are updated as necessary with any discrepancies from predicted durations and actual durations. In a particular embodiment, historical data will be looked up as needed to predict connectivity attributes for said location for future task by task process **901**.

Referring back to step **1101**, if it is determined that there is no connectivity on network interface **923**, using location data obtained in step **1102**, connectivity process **903** may calculate, in step **1103**, a predicted time to when network interface **923** may have connectivity. In this example, reprioritization process **905** may reprioritize tasks in task queue **904** based on the predicted connectivity attributes (for example, connectivity process **903** may have predicted that network interface **923** may have connection in five minutes and based on location information from location awareness process **921**, connection will stay active for only several minutes. In this example, reprioritization process **905** may reprioritize tasks in task queue **904** as more information becomes available. In step **1104**, connectivity predictions are stored in usage database **813** via usage process **812**. In a particular embodiment, usage database **813** may reside on a laptop that may also be executing a virtual assistant process **910** or some other portable device). Once connectivity is established on network interface **923**, step **1105** compares predictions made in step **1103** to actual data of when connectivity was established, duration of connectivity and any other predictions that were made by connection process **903**. As such, prediction algorithms are updated as necessary. In a particular embodiment, historical data will be looked up as needed and used to predict connectivity attributes for said location for future task processing requirements by task process **901**.

FIG. **15** is a method flow diagram illustrating an overview method **1500** of networked virtual assistant operation, according to a preferred embodiment of the invention. As illustrated, in an initial step **1501** a user may connect to a virtual assistant by any appropriate means (such as by calling a special dialing number for an assistant service, or using a virtual assistant software application on a smartphone or other computing device). In a next step **1502**, the user may submit a query or request, such as a request for information, to the virtual assistant. Ordinarily, the virtual assistant would process and fulfill the request, returning the results to the user (as is common in the art). According to the invention, in a next step **1503** the virtual assistant may determine that it is unable to fulfill the request on its own (or perhaps is unable to fulfill it to a satisfactory degree), and may then decide to forward the request to another virtual assistant in a next step **1504**. The second, or "target", virtual assistant may then fulfill the request in step **1505**, as if it had originated from a user (that is, no special operation may be required for fulfillment, and operation on the part of the target VA should be similar regardless of the request's origin). In a final step **1506**, the results of the request fulfillment may then be sent back to the host VA for presentation to the user. In this manner it can be appreciated that form the user's perspective, they only interacted with the host VA and may not be aware that networked operation is occurring, only that their request was fulfilled. This can be appreciated to facilitate improved assistance operations through the use of inter-VA communication within a network, without impacting user experience or detracting from overall performance.

FIG. **16** is a method flow diagram illustrating a method **1600** for networked virtual assistant operation utilizing brokers. According to the embodiment, networked virtual assistant operations may be carried out between multiple VAs using a VA broker as an intermediary (such as to maintain a knowledge base pertaining to individual VA suitability for various requests, such as their individual capabilities or access to knowledge bases relevant to specific requests), or between multiple VA brokers (such as to facilitate communication across VA networks as needed, or to use another broker's knowledge base for improved routing to a VA within a network), as needed in addition to the previously described (referring to FIG. **15**, above) operation between individual virtual assistants directly. In an initial step **1601**, a user may submit a request to a host VA, as previously described. According to the brokered operation described presently, in a next step **1602** the host VA may determine that it is unable to fulfill the request adequately, and may send the request to a VA broker in a next step **1603** for help with finding suitable target VAs. The VA broker may then decide how to proceed in a next step **1604**, optionally directly returning suitable target VAs in a list to the host VA (in a first branching step **1610**), or to forward the request to another VA broker (in a second branching step **1620**). If the VA broker returned suitable targets VAs directly to the host VA (**1611**), the host VA evaluates the results and decides whether to initiate communication with any of the target VAs (as described in FIG. **15**). In step **1611** the target VA fulfills the request and in step **1612** it send the results back to the host VA for presentation (in a manner controlled by the host VA) to the user that originated the request. If the request instead was forwarded to another VA broker, as might be needed to identify suitable target VAs within a separate network (i.e., a VA not serviced by the host VA broker), the target VA broker may then identify suitable target VAs in step **1621**, at which point a target VA fulfills the request and submits results in step **1622** to the target broker, which then sends the results to the host broker in step **1623**, thus returning information about these results to the host VA either directly or indirectly. The host VA then decided how to proceed with the suggestions (if any were found). It should be appreciated that it is also possible for the target VA broker to then determine that another VA broker is needed for optimal fulfillment, continuing to route the request to another target VA broker as needed, and that only a single broker-to-broker interaction is illustrated for brevity. It will be appreciated by one having ordinary skill in the art that other modes of communication and control are possible. For example, while normally a host VA is in control throughout the process, selecting a target VA from a list provided by a VA broker, controlling the user dialog, and determining precisely how a response received from another VA (i.e., a target VA) is actually presented to the user, and so forth. Alternatively, a VA broker may send to the host VA, instead of a list of target VAs, a list of responses received from a plurality of target VAs, and the host VA can then select the response it prefers. Or, the VA broker can evaluate a set of responses to a request that is received from a plurality of target VAs, and the VA broker makes the selection of the best response, then sending only the selected response to the host VA. Many variations are possible, as should be evident.

FIG. **17** is a method flow diagram illustrating a further method **1700**, according to a preferred embodiment of the invention, for networked virtual assistant operation utilizing brokers. According to the embodiment, networked virtual assistant operations may be carried out between multiple VAs using a VA broker as an intermediary (such as to maintain a knowledge base pertaining to individual VA suitability for various requests, such as their individual capabilities or access to knowledge bases relevant to specific requests), or between multiple VA brokers (such as to facilitate communication across VA networks as needed, or to use another broker's knowledge base for improved routing to a VA within a network), as needed in addition to the previously described (referring to FIG. **15**, above) operation between individual virtual assistants directly. In an initial step **1701**, a user may submit a request to a host VA, as previously described. According to the brokered operation described presently, in a next step **1702** the host VA may determine that it is unable to fulfill the request adequately, and may send the request to a VA broker in a next step **1703** for help with finding suitable target VAs. The VA broker may then decide how to proceed in a next step **1704**, optionally generating a list of suitable target VAs in a list (in a first branching step **1710**), or forwarding the request to another (target) VA broker (in a second branching step **1720**). If the host VA broker identified a list of suitable target VAs in step **1710**, then in step **1711** the host VA broker returns those results (i.e., the list of target VAs) directly to the host VA, whereupon the host VA evaluates the results in step **1712** and decides whether to initiate communication with any of the target VAs (as described in FIG. **15**). If it decides not to do so, then in step **1751** the host VA takes some other action, such as for example telling the user it cannot fulfill the request, or asking the user to provide more information. Otherwise, in step **1740** the host VA forward the request to a selected target VA, whereupon in step **1741** the target VA fulfills the request, returning the fulfilled request to the host VA in step **1742**. Thereupon, the host VA in step **1750** decides how to present the information provided in the response to the user, and in step **1751** displays the results to the user. Also, in some cases after step **1750** the host VA may also take other actions in step **1752**, such as initiating a new dialog turn with the user. If execution moved in step **1704** to step **1720**, then in step **1721** the target VA broker identifies one or more suitable target VAs. Of course, it is possible that a first target broker would fail to identify any suitable VAs, at which point operation could loop back to step **1720** with a new target VA broker, until there are no more available target VA brokers to send the request to (at which point execution would jump to step **1731** for some sort of error handling, since there would be no target VA anywhere available to satisfy the request sent in step **1701**). Once suitable target VAs are identified in step **1721**, in step **1722** the target VA broker returns the results (i.e., a list of suitable target VAs) to the host VA (either directly, or indirectly via the host VA broker and possibly one or more other target VA brokers). As in step **1712**, in step **1723** the host VA evaluates the results and decides how to proceed abd execution continues in step **1730** as described above.

It will be appreciated by one having ordinary skill in the art that other modes of communication and control are possible. For example, while normally a host VA is in control throughout the process, selecting a target VA from a list provided by a VA broker, controlling the user dialog, and determining precisely how a response received from another VA (i.e., a target VA) is actually presented to the user, and so forth. Alternatively, a VA broker may send to the host VA, instead of a list of target VAs, a list of responses received from a plurality of target VAs, and the host VA can then select the response it prefers. Or, the VA broker can evaluate a set of responses to a request that is received from a plurality of target VAs, and the VA broker makes the selection of the best response, then sending only the selected response to the host VA. Many variations are possible, as should be evident.

It should also be apparent that, among other things, a plurality of virtual assistant networks operating as described herein may in effect provide a “network of knowledge”, wherein a user can interact with a host VA by querying it for information, and the host VA can access a potentially very extensive network of VAs, each of which possesses at least a knowledge base, thereby making the entire network of knowledge bases accessible in a natural way to a user via a single virtual assistant user interface.

The skilled person will be aware of a range of possible modifications of the various embodiments described above. Accordingly, the present invention is defined by the claims and their equivalents.

What is claimed is:

1. A system for operating a network dialog-based virtual assistants, comprising:

a plurality of dialog-based virtual assistants each comprising programmable instructions stored and operating on a network-connected computing device comprising a memory and a processor and adapted to interact with users using conversational request and response dialog flows; and

a plurality of virtual assistant brokers each comprising programmable instructions stored and operating on a network-connected computing device comprising a memory and a processor;

wherein a first dialog-based virtual assistant receives a natural-language dialog request from a user via a communications network;

wherein the first dialog-based virtual assistant interprets the natural-language dialog request, determines that it cannot fulfill the natural-language dialog request, and forwards the natural language dialog request to a first virtual assistant broker;

wherein the first virtual assistant broker identifies a plurality of second dialog-based virtual assistants that may be capable of fulfilling the natural language dialog request;

wherein the first virtual assistant broker sends a list of the plurality of second dialog-based virtual assistants to the first dialog-based virtual assistant;

wherein the first dialog-based virtual assistant selects a third dialog-based virtual assistant from among the plurality of second dialog-based virtual assistants and forwards the natural language dialog request to the third dialog-based virtual assistant;

wherein the first dialog-based virtual assistant receives a natural language dialog response from the third dialog-based virtual assistant; and

wherein the first dialog-based virtual assistant presents the natural language dialog response in a suitable format to the user.

2. The system of claim **1**, wherein communications between dialog-based virtual assistants and virtual assistant brokers is carried out using a virtual assistant markup language, wherein the virtual assistant markup language allows for standardized communication between the dialog-based virtual assistants, between dialog-based virtual assistants and virtual assistant brokers, and between the virtual assistant brokers.

3. The system of claim **1**, further wherein the first dialog-based virtual assistant forwards the natural language dialog request directly to the third dialog-based virtual assistant based on information received in a prior interaction from the first virtual assistant broker.

4. The system of claim **1**, further wherein the first virtual assistant broker forwards the natural language request to a second virtual assistant broker.

5. A method for operating a network of dialog-based virtual assistants, comprising the steps of:

receiving a natural language dialog request, at a first dialog-based virtual assistant comprising programmable instruction stored and operating on a computing device comprising a memory and a processor and adapted to interact with users using conversational request and response dialog flows, from a user;

determining that the first dialog-based virtual assistant cannot fulfill the natural language dialog request;

forwarding the natural language dialog request to a first virtual assistant broker comprising programmable instructions stored and operating on a computing device comprising a memory and a processor;

identifying, by the first virtual assistant broker, a plurality of second dialog-based virtual assistants that may be capable of fulfilling the natural language dialog request;

sending a list of the plurality of second dialog-based virtual assistants from the first virtual assistant broker to the first dialog-based virtual assistant;

selecting a third dialog-based virtual assistant from among the plurality of second dialog-based virtual assistants;

forwarding the natural language dialog request from the first dialog-based virtual assistant to the third dialog-based virtual assistant;

receiving a natural language dialog response from the third dialog-based virtual assistant; and

presenting the response in a suitable format to the user.

6. The method of claim **5**, further comprising the step of forwarding the natural language dialog request to a second virtual assistant broker.

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