US 20140006620A1

(19) **United States**

(12) **Patent Application Publication**

Assuncao et al.

(10) **Pub. No.: US 2014/0006620 A1**

(43) **Pub. Date: Jan. 2, 2014**

(54) **SYSTEM, METHOD AND PROGRAM PRODUCT FOR LOCAL CLIENT DEVICE CONTEXT-AWARE SHARED RESOURCE AND SERVICE MANAGEMENT**

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(21) Appl. No.: **13/534,316**

(22) Filed: **Jun. 27, 2012**

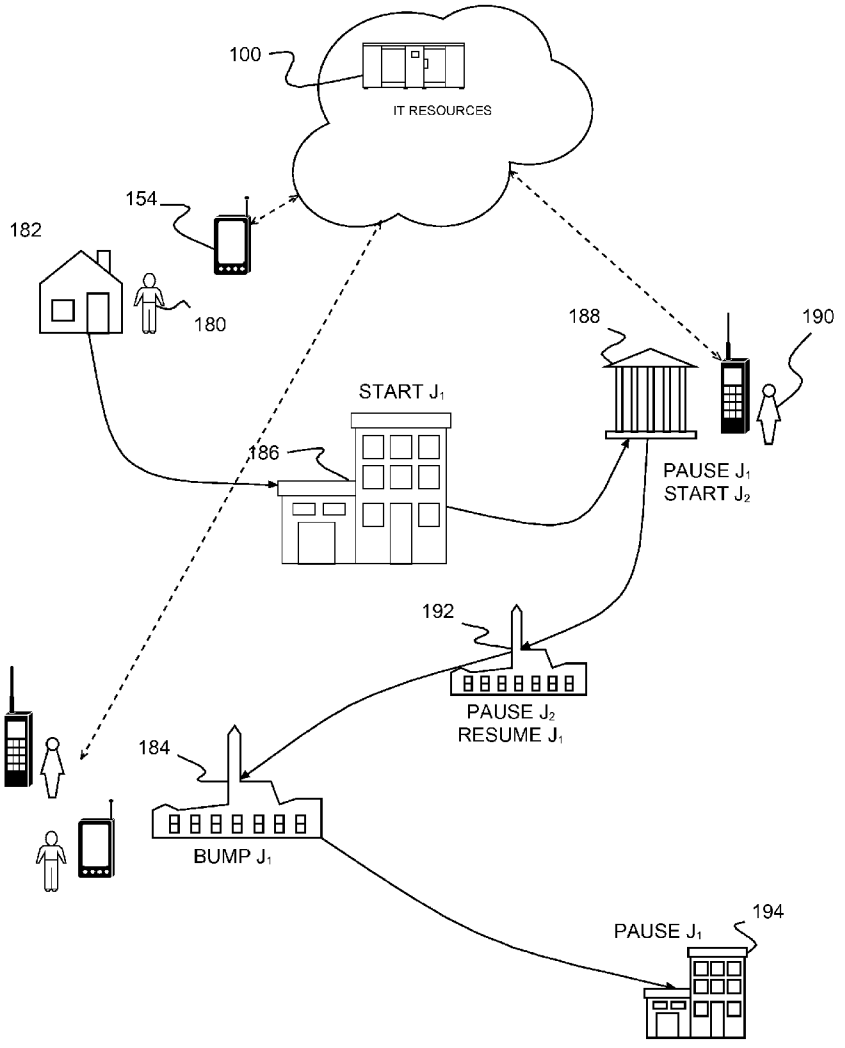
Publication Classification

(51) **Int. Cl.**
G06F 15/173 (2006.01)

(52) **U.S. Cl.**
USPC **709/226**

(57) **ABSTRACT**

A system context aware resource management, method of managing shared resources and services and a computer program product therefor. Client devices, e.g., handheld or mobile devices, request resources from provider computers, e.g., in a cloud environment. The provider computers provide cloud-based personal assistants. Resource requests from client devices may be context related that may be provided in response to a selected context. A resource management system schedules resource processing for requesting mobile client devices, initially, and responds to device context changes by selectively adjusting shared resource job priorities, e.g., creating a new job, pausing or restarting/resuming a respective job.



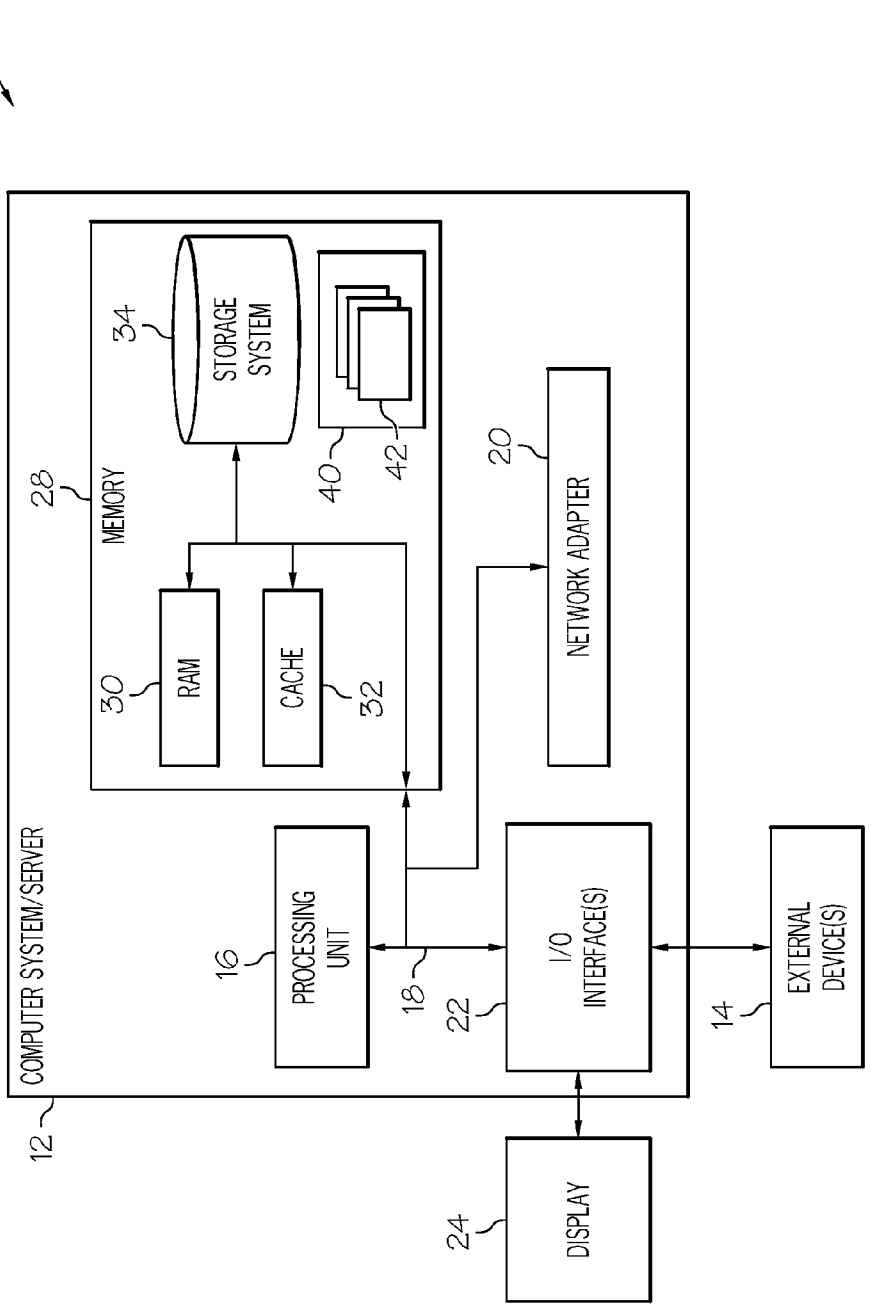

10
COMPUTER SYSTEM/SERVER
12
PROCESSING UNIT
16
MEMORY
28
RAM
30
CACHE
32
STORAGE SYSTEM
34
40
42
NETWORK ADAPTER
20
I/O INTERFACE(S)
22
18
EXTERNAL DEVICE(S)
14
DISPLAY
24

FIG. 1

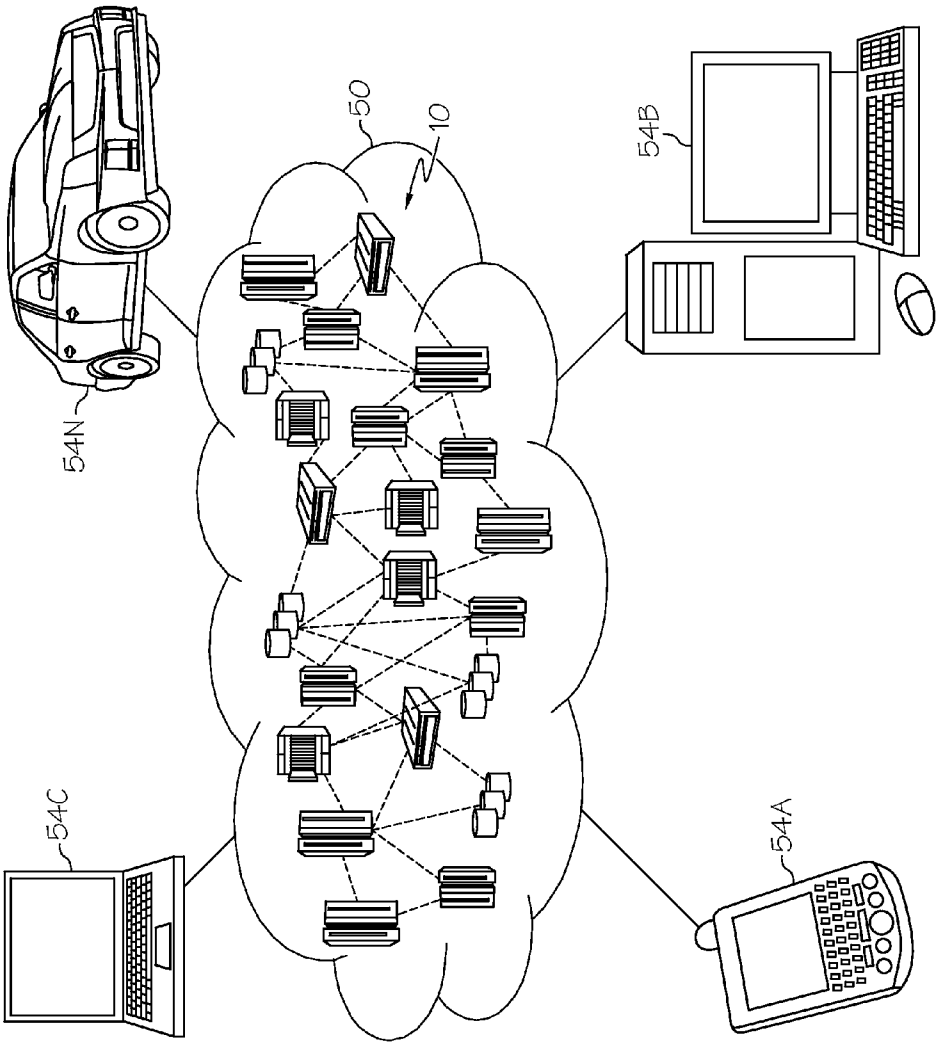


FIG. 2

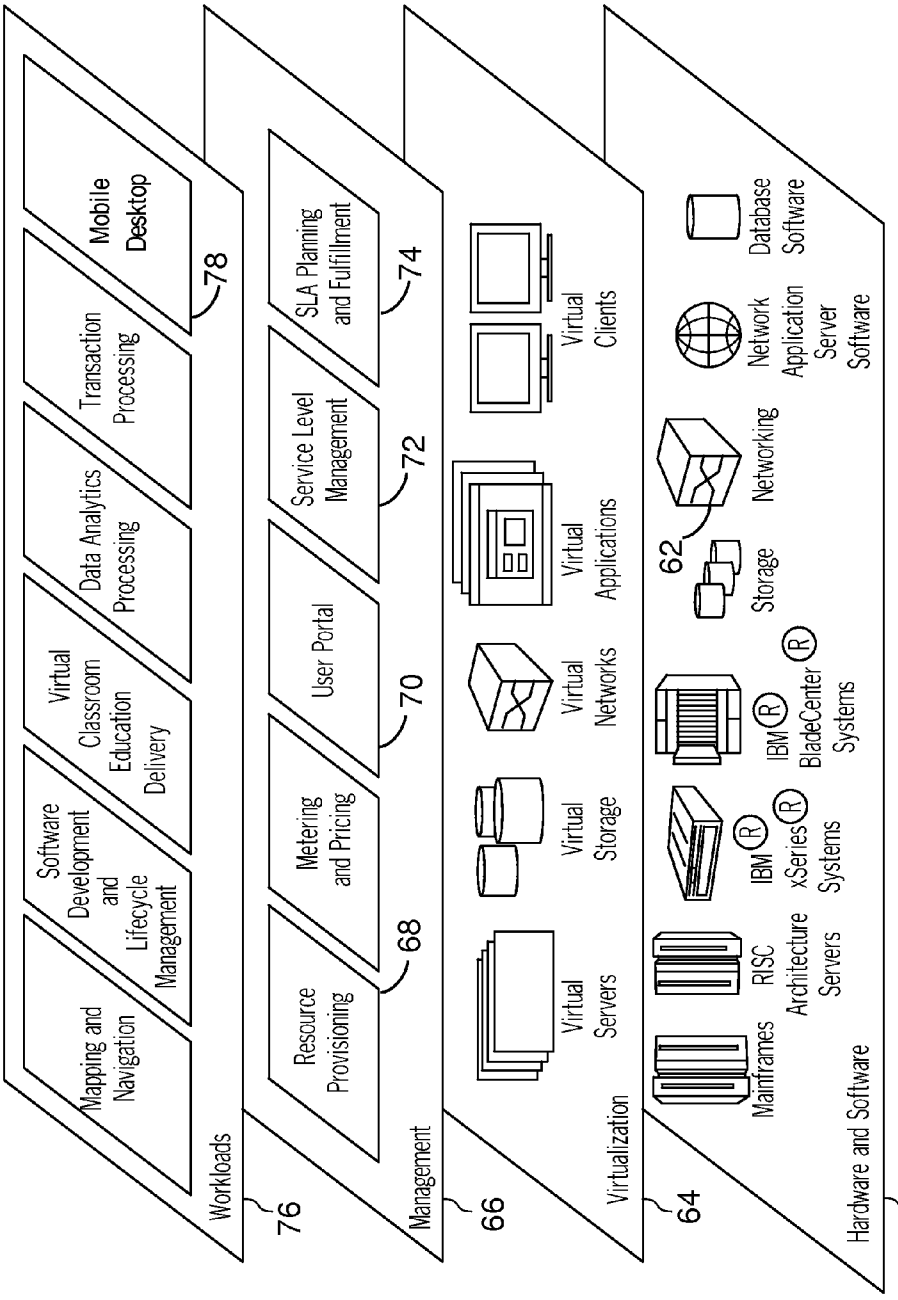

Workloads
76
Mapping and Navigation
Software Development and Lifecycle Management
Virtual Classroom Education Delivery
Data Analytics Processing
Transaction Processing
Mobile Desktop
78
Management
66
Resource Provisioning
Metering and Pricing
User Portal
Service Level Management
SLA Planning and Fulfillment
68
70
72
74
Virtualization
64
Virtual Servers
Virtual Storage
Virtual Networks
Virtual Applications
Virtual Clients
Hardware and Software
60
Mainframes
RISC Architecture Servers
IBM xSeries Systems
IBM BladeCenter Systems
Storage
62
Networking
Network Application Server Software
Database Software

FIG. 3

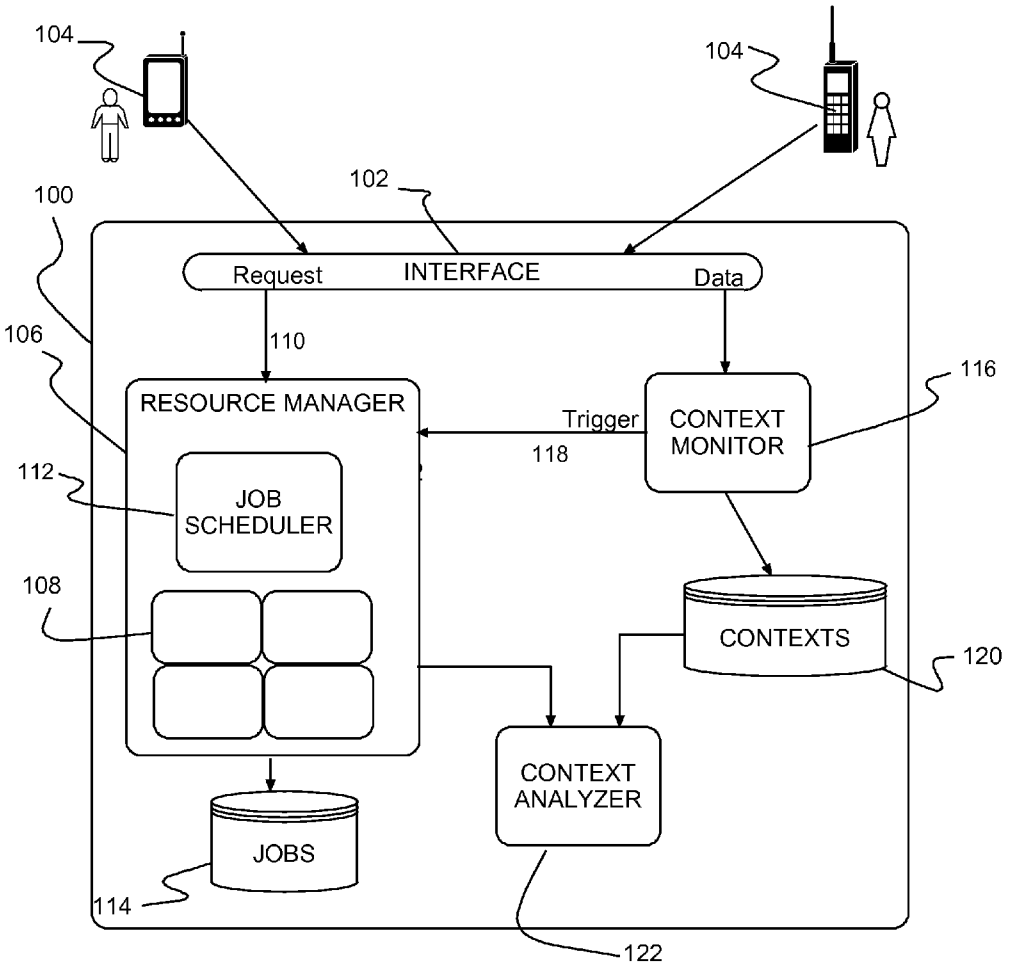

104
104
102
100
Request
INTERFACE
Data
110
106
RESOURCE MANAGER
Trigger
118
CONTEXT MONITOR
116
112
JOB SCHEDULER
108
CONTEXTS
120
CONTEXT ANALYZER
JOBS
114
122

Fig. 4A

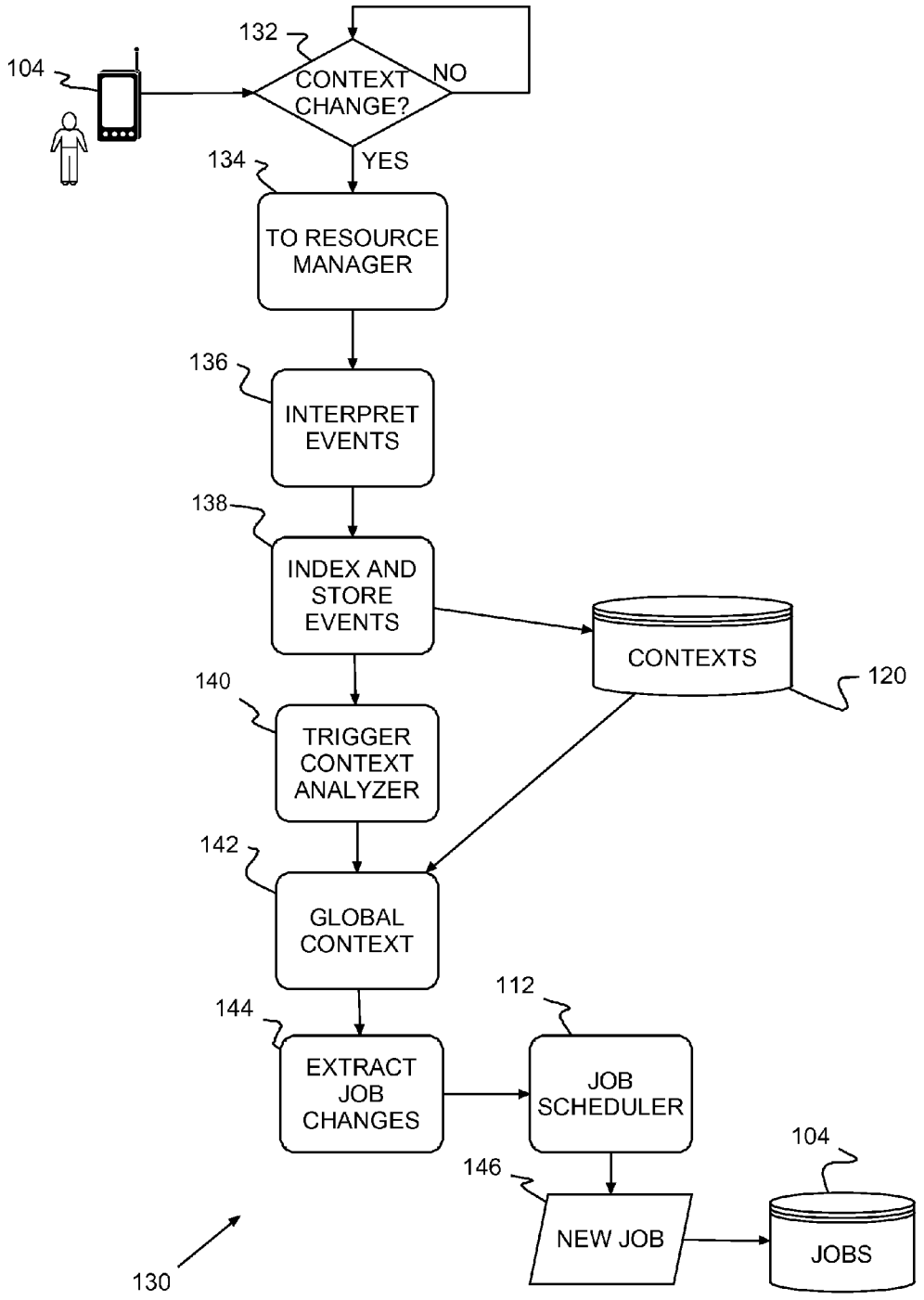

104
132
CONTEXT CHANGE?
NO
YES
134
TO RESOURCE MANAGER
136
INTERPRET EVENTS
138
INDEX AND STORE EVENTS
CONTEXTS
120
140
TRIGGER CONTEXT ANALYZER
142
GLOBAL CONTEXT
112
144
EXTRACT JOB CHANGES
JOB SCHEDULER
104
146
NEW JOB
JOBS
130

Fig. 4B

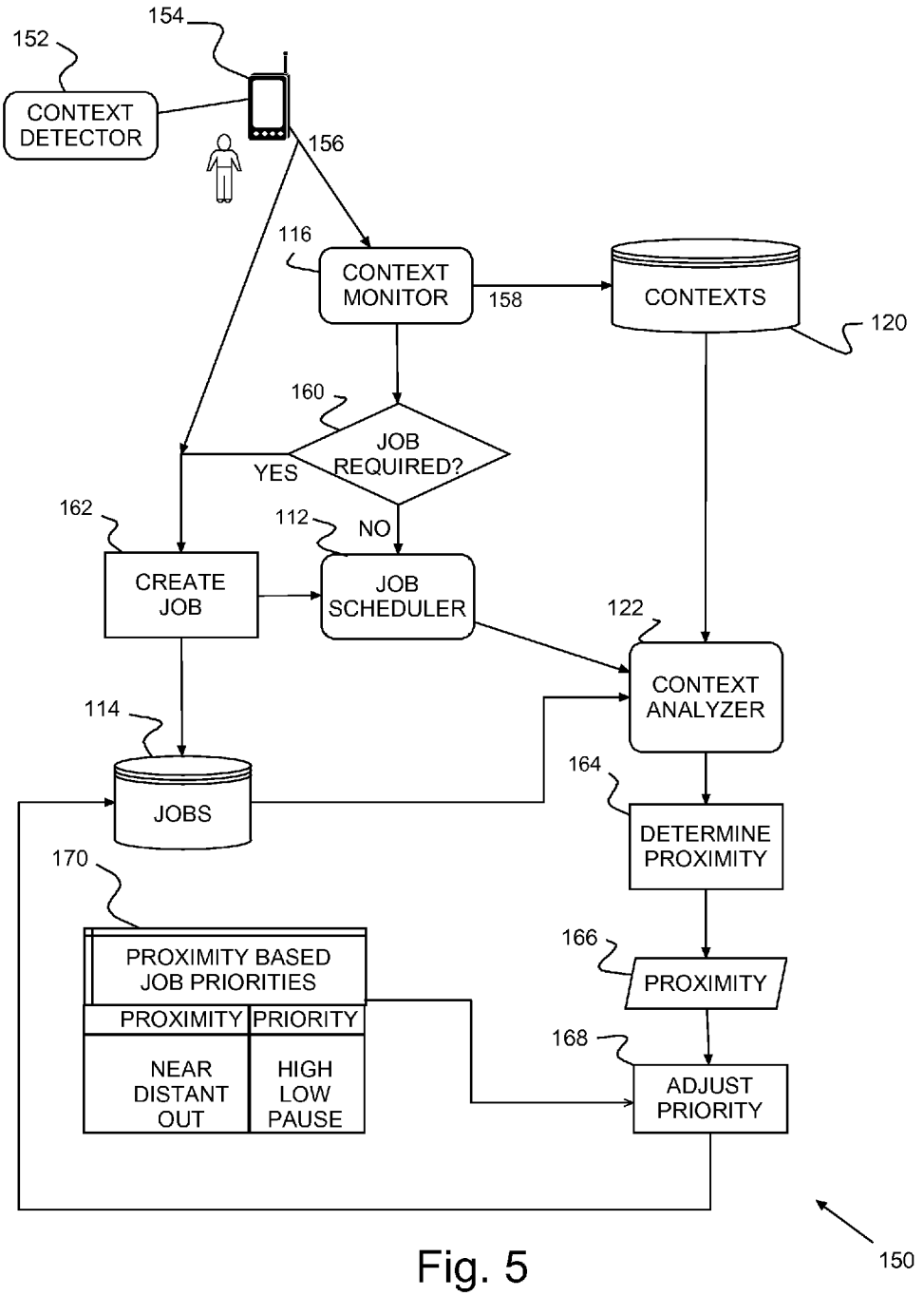

154
152
CONTEXT DETECTOR
156
116
CONTEXT MONITOR
158
CONTEXTS
120
160
JOB REQUIRED?
YES
NO
162
112
CREATE JOB
JOB SCHEDULER
122
CONTEXT ANALYZER
114
JOBS
164
DETERMINE PROXIMITY
170
PROXIMITY BASED JOB PRIORITIES
PROXIMITY
PRIORITY
NEAR
DISTANT
OUT
HIGH
LOW
PAUSE
166
PROXIMITY
168
ADJUST PRIORITY
150

Fig. 5

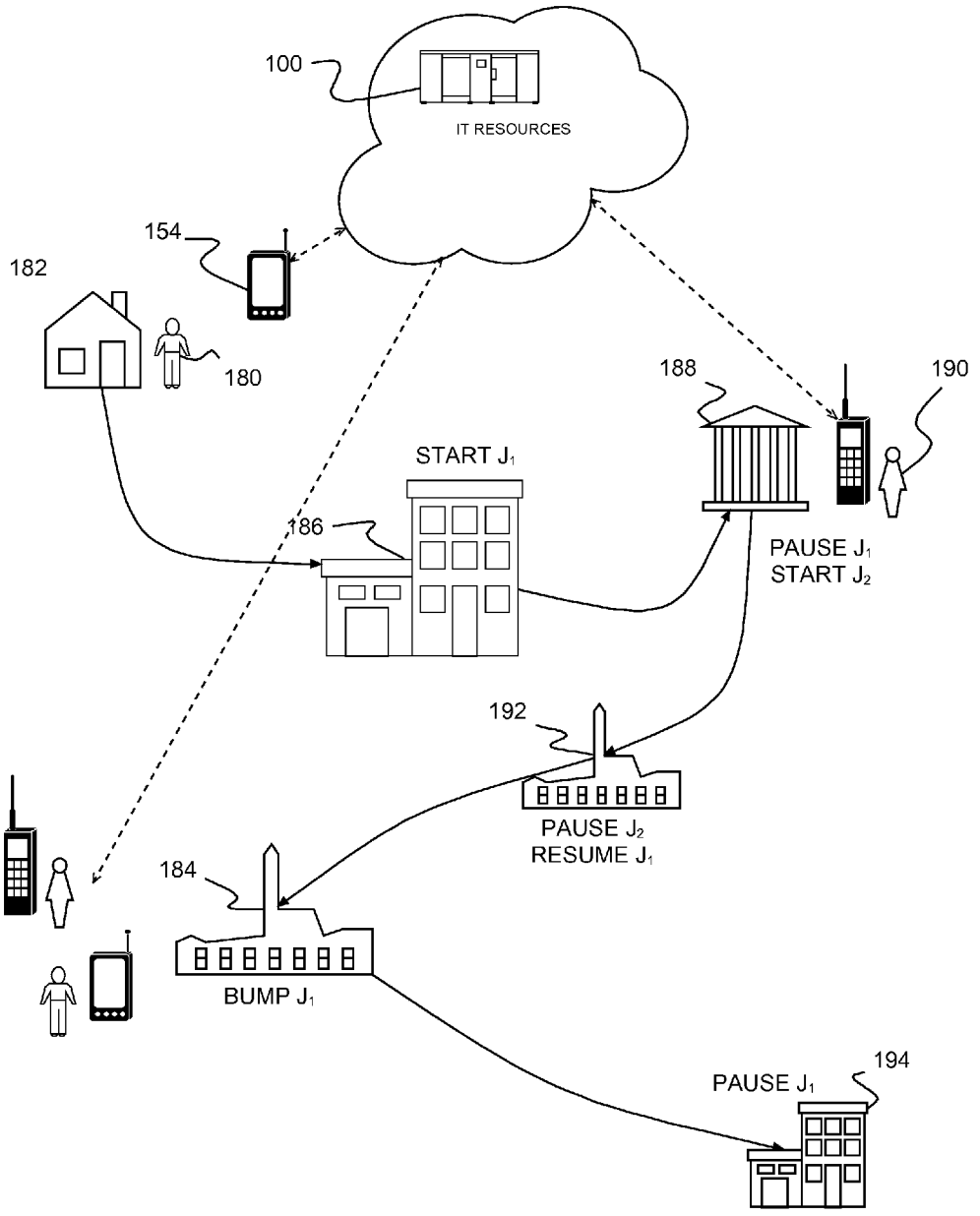

100
IT RESOURCES
154
182
180
188
190
START J1
186
PAUSE J1
START J2
192
PAUSE J2
RESUME J1
184
BUMP J1
194
PAUSE J1

Fig. 6

SYSTEM, METHOD AND PROGRAM PRODUCT FOR LOCAL CLIENT DEVICE CONTEXT-AWARE SHARED RESOURCE AND SERVICE MANAGEMENT

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention is related to allocating resources amongst multiple computers and more particularly to managing and allocating resources for cloud-based personal assistants.

[0003] 2. Background Description

[0004] Recently, cloud computing has offered great opportunities for a broad range of applications. Cloud service providers (e.g., with mainframe computers) share Information Technology (IT) infrastructure with users/clients, connected together over networks in what constitutes a client-cloud system. The shared IT infrastructure (the cloud computers) provides end-user content and support, i.e., supply services and resources and handle data-intensive computing tasks for the clients. This has allowed user client devices to become much more lightweight and mobile and small enough to be hand held. Further, these lightweight, mobile devices still provide users with access to resources managed by the larger shared resource providers, allowing end-users access to cloud services through handheld devices.

[0005] Typically, cloud resources are allocated in response to prior requests. However, clients may request services/resources on the fly, when a need arises. This has resulted in periods of heavy utilization or peaks, e.g., during the workday, and low utilization or valleys, e.g., at night. Thus, service providers have sought to reactively and pro-actively set job priorities context-sensitively to optimize resource utilization, e.g., timing resource production to be available just as they are needed. In a fixed client environment, e.g., personal computers in an office environment, setting priorities for jobs may be a relatively straightforward task. In mobile personal assistance environment, however, targeting timely delivery for end-user support content, imposes mobility, dynamic environment and context-sensitivity issues that impact the timing and relevant context of the delivery area, i.e., what are known as "windows of opportunity."

[0006] For what are commonly referred to as "cloud-based personal assistants" job processing typically refers to processing files (such as documents, graphs or videos), notifications, and any other computing support and communications with demands that exceed handheld device capabilities and efficiency. Processing elements that demand capacity, typically, are delegated to the cloud. Preferably, the cloud delivers the content for these elements in relevant end-user contexts. For example, the cloud may deliver documents for scheduled meetings just prior to, but close to, the scheduled meeting times. Timely delivery, however, not too early and not too late, may overload resources at that time, spiking cloud computing resource utilization and communications requirements. Alternatively, to minimize risk of tardy content deliveries, the cloud may deliver content early, which may unduly burden local resources, e.g., occupying handheld device space that might otherwise be used prior to the meeting for other, more timely matters.

[0007] Some prior approaches have been server centric, focusing on server-based job performance. Jobs, and in particular, complex and intricate jobs were scheduled according to cloud infrastructure (e.g., a server) deadlines, priorities and performance predictions. However, the variations of the end-user local context have not been considered in adjusting server-based job scheduling. Other approaches have focused on using local context reasoning to enhance handheld device processing deliberation and performance. Yet other approaches have extended these local processing performance enhancement approaches to further enhance bandwidth utilization, memory consumption, and connectivity.

[0008] These prior approaches to providing cloud support for handheld devices optimize for cloud requirements, without considering local contexts; or, optimize for local performance and response without considering cloud contexts. Consequently, there may be considerable wasted resources from processing existing job content that, because the mobile user's local context has changed, is no longer relevant in the current local context. For a single mobile device user this waste is insignificant. However, where a large number mobile users are accessing the cloud for one or more personal assistant jobs, they combine for a much more significant effect with a highly dynamicity delivery environment.

[0009] Thus, there is a need for flexibly scheduling and executing jobs in the cloud for local delivery, responding to local context variations, to minimize wasted resources from processing stale job content based on out of date contexts; and in particular, where a large number of personal assistants may have active jobs processing in a highly dynamic delivery environment.

SUMMARY OF THE INVENTION

[0010] A feature of the invention is a shared resource system and method for timely managing provisioning to mobile client devices responsive to local contexts;

[0011] Another feature of the invention is a shared resource system and method of providing resources to handheld client devices and monitoring respective local contexts and managing off-line job processing of the handheld client device jobs in response to changes in local context;

[0012] Yet another feature of the invention is a cloud-based shared resource system and method of providing context sensitive cloud-based personal assistants and managing client job processing, wherein handheld clients with pending requests for service are monitored for local context changes and off-line job processing is selectively adjusted in response to local context changes.

[0013] The present invention relates to a context aware resource management system, method of managing shared resources and services and a computer program product therefor. Client devices, e.g., handheld or mobile devices, request resources from provider computers, e.g., in a cloud environment. The provider computers may provide cloud-based personal assistants to the client devices. Resource requests from client devices may be context related that may be provided in response to a selected context. A resource management system schedules resource processing for requesting mobile client devices, initially, and responds to device context changes by selectively adjusting shared resource job priorities, e.g., creating a new job, pausing or restarting/resuming a respective job.

[0014] A method of context aware resource management, said method comprising: receiving requests for shared resource capacity, one or more provider computer providing said shared resource capacity, each request being from a mobile client device within a defined context; queuing a job for provisioning resources within said defined context for said

each request; monitoring mobile client devices for local context changes; and whenever local context changes occur for that respective device analyzing the current local context to determine a global context; extracting job changes from global context; and selectively modifying a respective job responsive to extracted said job changes.

[0015] The provider computers may include a resource management system receiving said requests; monitoring context of said mobile client devices for context variations indicating triggering events; selectively changing shared resource priorities responsive to said triggering events; analyzing local mobile client device activity and related context history; and providing scheduling recommendations responsive to analysis results, e.g., selectively pausing and restarting shared resource processing responsive to provided said scheduling recommendations.

[0016] The resource management system is further: storing local device context history from said context monitor in a context information store, said defined context including time, device location and associated activity; creating jobs responsive to job request from said one or more mobile client devices; queuing said jobs in a job queue; and selectively pausing and restarting queued jobs and creating new jobs, responsive to said provided scheduling recommendations.

[0017] A method of context aware resource management, said method comprising: receiving requests for shared resource capacity in a cloud environment including a plurality of provider computers selectively providing cloud-based personal assistants, each request being for a handheld client device within a defined context, said defined context including time, device location and associated activity; queuing a job for provisioning resources within said defined context for said each request; monitoring handheld client devices for local context changes; and whenever local context changes occur for that respective device analyzing the current local context to determine a global context; extracting job changes from global context; and selectively modifying a respective job responsive to extracted said job changes.

[0018] The cloud environment includes a resource management system receiving said requests, monitoring context of said handheld client devices for context variations indicating triggering events; selectively changing job priorities responsive to said triggering events; analyzing local handheld client device activity and related context history; and providing scheduling recommendations responsive to analysis results, e.g., selectively pausing and restarting shared resource processing responsive to provided said scheduling recommendations.

[0019] The resource management system further: storing local device context history from said context monitor in a context information store; creating jobs responsive to job request from said one or more handheld client devices; queuing said jobs in a job queue; and selectively pausing and restarting queued jobs and creating new jobs, responsive to said provided scheduling recommendations.

[0020] A computer program product for context aware resource management, said computer program product comprising a computer usable medium having computer readable program code stored thereon, said computer readable program code causing one or more computer executing said code to: receive requests for resource capacity, each request from a mobile client device being within a defined context; queue a job for provisioning resources within the defined context for said each request; monitor mobile client devices for local context changes; and whenever local context changes occur for that respective device analyze the current local context to determine a global context; extract job changes from global context; and selectively modify a respective job responsive to extracted said job changes.

[0021] The computer readable program code causes one computer to be a resource management system: receiving said requests; monitoring context of said mobile client devices for context variations indicating triggering events; selectively changing shared resource priorities responsive to said triggering events; analyzing local mobile client device activity and related context history; and providing scheduling recommendations responsive to analysis results, e.g., selectively pausing and restarting shared resource processing responsive to provided said scheduling recommendations.

[0022] The computer readable program code further causes resource management system to be: storing local device context history from said context monitor in a context information store, said defined context including time, device location and associated activity; creating jobs responsive to job request from said one or more mobile client devices; queuing said jobs in a job queue; and selectively pausing and restarting queued jobs and creating new jobs, responsive to said provided scheduling recommendations.

[0023] A computer program product for context aware resource management, said computer program product comprising a computer usable medium having computer readable program code stored thereon, said computer readable program code causing a plurality of computers including provider computers executing said code to: receive requests for shared resource capacity in a cloud environment including a plurality of provider computers selectively providing cloud-based personal assistants, each request being for a handheld client device within a defined context, said defined context including time, device location and associated activity; queue a job for provisioning resources within said defined context for said each request; monitor handheld client devices for local context changes; and whenever local context changes occur for that respective device analyze the current local context to determine a global context; extract job changes from global context; and selectively modify a respective job responsive to extracted said job changes.

[0024] The computer readable program code causes one computer to be a resource management system receiving said requests, and causing said resource management system to: monitor context of said handheld client devices for context variations indicating triggering events; selectively change shared resource priorities responsive to said triggering events; analyze local handheld client device activity and related context history; and provide scheduling recommendations responsive to analysis results.

[0025] The computer program code further causing the resource management system to: store local device context history from said context monitor in a context information store; create jobs responsive to job request from said one or more handheld client devices; and queue said jobs in a job queue; selectively pause and restart queued jobs and creating new jobs, responsive to said provided scheduling recommendations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The foregoing and other objects, aspects and advantages will be better understood from the following detailed

description of a preferred embodiment of the invention with reference to the drawings, in which:

[0027] FIG. **1** depicts a cloud computing node according to an embodiment of the present invention;

[0028] FIG. **2** depicts a cloud computing environment according to an embodiment of the present invention;

[0029] FIG. **3** depicts abstraction model layers according to an embodiment of the present invention;

[0030] FIG. **4**A shows an example of a preferred resource management system in the resource management layer;

[0031] FIG. **4**B shows an example of a preferred resource management system cross-relating shared resource system demands with provisioned mobile personal assistants, and responding to respective user environment context changes;

[0032] FIG. **5** shows an example of information flow in a preferred shared resource system;

[0033] FIG. **6** shows an example of operation of a shared IT infrastructure with a preferred resource management system processing end-user jobs for handheld devices obtaining end-user context and in communication with the shared IT infrastructure.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0034] It is understood in advance that although this disclosure includes a detailed description on cloud computing, implementation of the teachings recited herein are not limited to a cloud computing environment. Rather, embodiments of the present invention are capable of being implemented in conjunction with any other type of computing environment now known or later developed and as further indicated hereinbelow.

[0035] Cloud computing is a model of service delivery for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, network bandwidth, servers, processing, memory, storage, applications, virtual machines, and services) that can be rapidly provisioned and released with minimal management effort or interaction with a provider of the service. This cloud model may include at least five characteristics, at least three service models, and at least four deployment models.

[0036] Characteristics are as follows:

[0037] On-demand self-service: a cloud consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with the service's provider.

[0038] Broad network access: capabilities are available over a network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

[0039] Resource pooling: the provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to demand. There is a sense of location independence in that the consumer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).

[0040] Rapid elasticity: capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

[0041] Measured service: cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

[0042] Service Models are as follows:

[0043] Software as a Service (SaaS): the capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based e-mail). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

[0044] Platform as a Service (PaaS): the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including networks, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

[0045] Infrastructure as a Service (IaaS): the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).

[0046] Deployment Models are as follows:

[0047] Private cloud: the cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on-premises or off-premises.

[0048] Community cloud: the cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on-premises or off-premises.

[0049] Public cloud: the cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

[0050] Hybrid cloud: the cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).

[0051] A cloud computing environment is service oriented with a focus on statelessness, low coupling, modularity, and semantic interoperability. At the heart of cloud computing is an infrastructure comprising a network of interconnected nodes.

[0052] Referring now to FIG. **1**, a schematic of an example of a cloud computing node is shown. Cloud computing node **10** is only one example of a suitable cloud computing node and is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the invention described herein. Regardless, cloud computing node **10** is capable of being implemented and/or performing any of the functionality set forth hereinabove.

[0053] In cloud computing node **10** there is a computer system/server **12**, which is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with computer system/server **12** include, but are not limited to, personal computer systems, server computer systems, thin clients, thick clients, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputer systems, mainframe computer systems, and distributed cloud computing environments that include any of the above systems or devices, and the like.

[0054] Computer system/server **12** may be described in the general context of computer system-executable instructions, such as program modules, being executed by a computer system. Generally, program modules may include routines, programs, objects, components, logic, data structures, and so on that perform particular tasks or implement particular abstract data types. Computer system/server **12** may be practiced in distributed cloud computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed cloud computing environment, program modules may be located in both local and remote computer system storage media including memory storage devices.

[0055] As shown in FIG. **1**, computer system/server **12** in cloud computing node **10** is shown in the form of a general-purpose computing device. The components of computer system/server **12** may include, but are not limited to, one or more processors or processing units **16**, a system memory **28**, and a bus **18** that couples various system components including system memory **28** to processor **16**.

[0056] Bus **18** represents one or more of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnects (PCI) bus.

[0057] Computer system/server **12** typically includes a variety of computer system readable media. Such media may be any available media that is accessible by computer system/server **12**, and it includes both volatile and non-volatile media, removable and non-removable media.

[0058] System memory **28** can include computer system readable media in the form of volatile memory, such as random access memory (RAM) **30** and/or cache memory **32**. Computer system/server **12** may further include other removable/non-removable, volatile/non-volatile computer system storage media. By way of example only, storage system **34** can be provided for reading from and writing to a non-removable, non-volatile magnetic media (not shown and typically called a "hard drive"). Although not shown, a magnetic disk drive for reading from and writing to a removable, non-volatile magnetic disk (e.g., a "floppy disk"), and an optical disk drive for reading from or writing to a removable, non-volatile optical disk such as a CD-ROM, DVD-ROM or other optical media can be provided. In such instances, each can be connected to bus **18** by one or more data media interfaces. As will be further depicted and described below, memory **28** may include at least one program product having a set (e.g., at least one) of program modules that are configured to carry out the functions of embodiments of the invention.

[0059] Program/utility **40**, having a set (at least one) of program modules **42**, may be stored in memory **28** by way of example, and not limitation, as well as an operating system, one or more application programs, other program modules, and program data. Each of the operating system, one or more application programs, other program modules, and program data or some combination thereof, may include an implementation of a networking environment. Program modules **42** generally carry out the functions and/or methodologies of embodiments of the invention as described herein.

[0060] Computer system/server **12** may also communicate with one or more external devices **14** such as a keyboard, a pointing device, a display **24**, etc.; one or more devices that enable a user to interact with computer system/server **12**; and/or any devices (e.g., network card, modem, etc.) that enable computer system/server **12** to communicate with one or more other computing devices. Such communication can occur via Input/Output (I/O) interfaces **22**. Still yet, computer system/server **12** can communicate with one or more networks such as a local area network (LAN), a general wide area network (WAN), and/or a public network (e.g., the Internet) via network adapter **20**. As depicted, network adapter **20** communicates with the other components of computer system/server **12** via bus **18**. It should be understood that although not shown, other hardware and/or software components could be used in conjunction with computer system/server **12**. Examples, include, but are not limited to: microcode, device drivers, redundant processing units, external disk drive arrays, RAID systems, tape drives, and data archival storage systems, etc.

[0061] Referring now to FIG. **2**, illustrative cloud computing environment **50** is depicted. As shown, cloud computing environment **50** comprises one or more cloud computing nodes **10** with which local computing devices used by cloud consumers, such as, for example, personal digital assistant (PDA) or cellular telephone **54**A, desktop computer **54**B, laptop computer **54**C, and/or automobile computer system **54**N may communicate. Nodes **10** may communicate with one another. They may be grouped (not shown) physically or virtually, in one or more networks, such as Private, Community, Public, or Hybrid clouds as described hereinabove, or a combination thereof. This allows cloud computing environment **50** to offer infrastructure, platforms and/or software as services for which a cloud consumer does not need to maintain resources on a local computing device. It is understood that the types of computing devices **54**A-N shown in FIG. **2** are intended to be illustrative only and that computing nodes **10** and cloud computing environment **50** can communicate with any type of computerized device over any type of network and/or network addressable connection (e.g., using a web browser).

[0062] Referring now to FIG. **3**, a set of functional abstraction layers provided by cloud computing environment **50** (FIG. **2**) is shown. It should be understood in advance that the components, layers, and functions shown in FIG. **3** are intended to be illustrative only and embodiments of the invention are not limited thereto. As depicted, the following layers and corresponding functions are provided:

[0063] Hardware and software layer **60** includes hardware and software components. Examples of hardware components include mainframes, in one example IBM® zSeries® systems; RISC (Reduced Instruction Set Computer) architecture based servers, in one example IBM pSeries® systems; IBM xSeries® systems; IBM BladeCenter® systems; storage devices; networks and networking components **62**. Examples of software components include network application server software, in one example IBM WebSphere® application server software; and database software, in one example IBM DB2® database software. (IBM, zSeries, pSeries, xSeries, BladeCenter, WebSphere, and DB2 are trademarks of International Business Machines Corporation registered in many jurisdictions worldwide).

[0064] Virtualization layer **64** provides an abstraction layer from which the following examples of virtual entities may be provided: virtual servers; virtual storage; virtual networks, including virtual private networks; virtual applications and operating systems; and virtual clients.

[0065] In one example, management layer **66** may provide the functions described below. Preferred, context aware resource provisioning **68** provides dynamic procurement of computing resources and other resources that are utilized to perform tasks within the cloud computing environment. Metering and Pricing provide cost tracking as resources are utilized within the cloud computing environment, and billing or invoicing for consumption of these resources. In one example, these resources may comprise application software licenses. Security provides identity verification for cloud consumers and tasks, as well as protection for data and other resources. User portal **70** provides access to the cloud computing environment for consumers and system administrators. Preferred, context aware service level management **72** provides cloud computing resource allocation and management such that required service levels are met. Preferred, context-aware Service Level Agreement (SLA) planning and fulfillment **74** provide pre-arrangement for, and procurement of, cloud computing resources for which a future requirement is anticipated in accordance with an SLA.

[0066] Workloads layer **76** provides examples of functionality for which the cloud computing environment may be utilized. Examples of workloads and functions which may be provided from this layer include: mapping and navigation; software development and lifecycle management; virtual classroom education delivery; data analytics processing; transaction processing; and Mobile Desktops **78**.

[0067] FIG. **4**A with reference to FIGS. **1-3** shows an example of a preferred resource management system **100** in resource management layer **64** with like features labeled identically. In particular, a preferred resource management system **100** combines events related to local context variations at mobile devices, e.g., **54**A, **54**C and/or **54**N, with job prioritization in a shared IT infrastructure such as in cloud computing. The present invention cross-relates current end-user local context with context history, infrastructure utilization and resource availability, preferably, for all mobile devices associated with the respective user. Thus, a preferred system optimizes resource utilization by adjusting job priorities either actively responding to, or pro-actively responding to, sensed end-user context variations and thus, ensuring timely material delivery in an appropriate group of contexts or context area with minimal wasted resources.

[0068] So, in this example, user portal **68** includes an interface **102** to handheld devices **104**, e.g., one or more cell phones **54**A, a personal digital assistants, smart phones, tablet computers, laptops/netbooks **54**C and/or automobile computer system **54**N or any other suitable mobile device with mobile desktops **78**. The preferred handheld devices **104** may connect to interface **102**, for example, wired or wirelessly through networking **62**, or in the case of cellular capable devices, e.g., cell phones, smart phones or tablet computers, through the cellular network. A resource manager **106** (e.g., **66** in FIG. **3**) with normal resource management elements **108** (e.g., **68**, **70**, **72**, **74** in FIG. **3**), receives resource requests **110** within a given context from handheld devices **104**. In addition a preferred resource manager **106** includes a client context aware job scheduler **112** that creates and queues **114** requested jobs. A context monitor **116** monitors local context for mobile clients and triggers **118** adjusting shared resource job priorities in response to deviations from specific given contexts. A context repository **120** stores current and past local context information collected from the context monitor **116**. A context analyzer **122** analyzes local client activity and related contexts and provides scheduling recommendations to the job scheduler **112**.

[0069] Thus, as shown in the example **130** of FIG. **4**B, a preferred resource management system **100** of FIG. **4**A cross-relates the shared resource system demands with provisioned mobile personal assistants, responding to context changes in the respective user environment according to a preferred embodiment of the present invention. Thus, the preferred resource management system **100** combines events related to local context variations for each end-user with historical context data in prioritizing shared Information Technology (IT) infrastructure provisions and job processing for mobile users. In particular, the preferred resource management system **100** adjusts selected job priorities for end-user context variations, pro-actively to expected context changes or responsively to changes as they occur. Preferably, the resource management system **100** adjusts job priorities for processing files (such as documents, graphs and videos), notifications, or any other type of support material to ensure delivering request material in the appropriate context or set of contexts (also called "window of opportunity" or context area), and while optimally utilizing shared IT infrastructure.

[0070] Each handheld device **104** senses **132** local context variations and captures context changes as they occur. Then, the handheld device **104** relays **134** those captured changes through communication structure, e.g., through a wired or wireless network **62**, to the interface **102** in resource management system **100**. The context monitor **116** interprets the context variations/changes to determine handheld device events **136**. Then, the context monitor **116** indexes and stores **138** identified events in the context repository **120** and triggers **140** the context analyzer **122**. The context analyzer **122** analyzes the events, forming a "global context" **142** from which it extracts job priority alteration recommendations **144**. Finally, the context analyzer **122** sends the recommendations to the job scheduler **112**, which processes the recom-

mendations, creating a new job **146**, pausing or restarting jobs, each time a priority is changed. Finally, any new jobs are queued **104**.

[0071] Preferably, the context analyzer **122** forms an eight dimensional global context for each event, such as described by Graham et al., "Indexical Representations for Context-Aware Mobile Devices" (2003). The eight dimensions include time, absolute location, relative location (absolute and relative can be the same variable), object presence, activity, social setting, environment and culture. Preferably, each handheld device **104** module calculates context proximity conditions for each dimension in response to yes-no questions. Examples of such questions include

[0072] For time: "Is the task still feasible in time?"

[0073] For absolute location: "Is the position still valid?"

[0074] For relative location: "Is the position still valid?"

[0075] For object presence: "Are objects $o_1, \ldots, o_n$ present?"

[0076] For activity: "Is the user engaged in activities $a_1, \ldots, a_n$?"

[0077] For social setting: "Is the user in any of social setting segments $ss_1, \ldots, ss_n$?"

[0078] For environment: "Are conditions $c_1, \ldots, c_n$ valid?"

[0079] For culture: "Is the user immersed in any of cultural setting $cs_1, \ldots, cs_n$?"

[0080] So, the context analyzer **122** cross-relates each current event with relevant, available situational information. The relevant, available situational information may include, for example, historical data, e.g., from context repository **120**, system/server-based event context information $<G_1, \ldots, G_n>$, and existing jobs $<J_1, \ldots, J_n>$. System/server-based event context information may include, for example, personal information stored on shared information handling infrastructure, e.g., cloud infrastructure. The context analyzer **122** uses the information to calculate context proximity. This may include, for example, inferring if the current context is "near", "distant", or "out" the window of opportunity for notification delivery.

[0081] When the job scheduler **112** receives recommendations, it alters job priorities accordingly. So, if a recommendation is to change priority or create a new job, the job scheduler **112** may use any suitable state of the art algorithms and strategies to advance or slow execution. For example, the job scheduler **112** can sort jobs for execution by priority and re-sort after any priority changes. Moreover, the job scheduler **112** may designate available resources for higher priority jobs, with lower priority jobs designated to spare computing resources. Alternatively, the system may provision more resources for executing high priority jobs.

[0082] FIG. **5** shows an example of information flow **150** according to a preferred embodiment of the present invention with reference to FIGS. **4**A-B. In this embodiment a local context detector **152** resides in each local client device **154**, and detects changes/variations in the local context. An example of a suitable context monitor is described by Koch et al., "Enhanced Deliberation Behaviour for BDI-Agents in Mobile Services" *Proceeding of the* 8*th International Conference on Practical Applications of Agents and Multi-Agent Systems* (PAAMS10), *Advances in Intelligent and Soft Computing* 70 (2010). Koch et al. describes a context monitor module specialized in observing environmental events, filtering relevant changes, and coordinating application processing.

[0083] Upon a change the local context detector **152** notifies **156** the shared IT infrastructure. The context monitor **116** intercepts notifications **156** and stores **158** related information in the context information repository **120**. Using a simple compare, for example, the context monitor **116** also determines **160** whether the context change in each notification **156** triggers **118** an event potentially influencing currently scheduled jobs.

[0084] If so, the context analyzer **122** determines whether the context change is such as to require creating a new job. Whenever a client device makes an explicit request **110** or, when the context analyzer **122** determines whether a new job is required, the resource manager **106** creates a new job **162**, defaulting to low priority. The job scheduler **112** adds the new job to the queue **114**, e.g., in a job database. Even if detected context changes do not warrant creating **162** a new job, the events may affect resource scheduling. So, the context analyzer **122** notifies/triggers job scheduler **112**. Upon receiving each triggering event, the job scheduler **112** iterates the respective user jobs, re-setting each job priority according to proximity. After the context analyzer **122** has re-defined priorities for all jobs, the job scheduler **112** schedules or re-schedules each job according to priority guided by a selected scheduling policy, e.g., High-Priority Job First (HPJF).

[0085] Iterating the respective user jobs begins by invoking the context analyzer **122**, which gathers information from the repository **114** about the current context for the respective user. The context analyzer **122** determines **164** user proximity **166** to the job window of opportunity, e.g., how close the user is to the window. The context analyzer **122** sets/adjusts job priority **168** according to proximity based on a job priority table **170**. The job priority table **170** of this example has three defined qualitative proximity levels: near, distant and out; and corresponding assignable priorities of high, low and pause. The system and method of the present invention have many real world applications.

[0086] So, in a large social setting, such as the World Cup for example, people with different nationalities may try to communicate. In such a setting there is the need for "Universal Translators." Handheld devices may be used as cloud-based universal translators with translation running on shared IT infrastructure. Thus, these handheld devices provide a local interface and may be equipped with sensors sensing the local context, e.g., what translation is needed. Thus, the preferred resource management system **100** starts translator jobs by a combination of both necessity and proximity.

[0087] So, in this example, it may be necessary to translate between languages A, B, and C. Also, the proximity requirement may be for individuals communicating in the same room with one individual speaking language C. A context variation for this example may be that sole individual leaving the room. The preferred system automatically reacts to this variation when that individual's device sends an event notification to the preferred resource manager **100** causing the job scheduler **112** to pause jobs associated with translating A to C and B to C and vice versa, reducing the workload by two thirds. Thus, the present invention captures the change of context, based on inference upon the variation of location and social setting, and influences job processing for other users.

[0088] In another example, a police officer is assigned a low priority information-gathering task for completion in a selected window, e.g., at any time within the next eight (8) hours. En route, the officer gets a call, that shots were fired in a nearby area, and the officer is diverted to that area. The

preferred system is notified by the police dispatch system of the reassignment. The social context changes from a low risk to a high-risk activity, with an armed and dangerous suspect. The preferred system pauses the first task and initiates a high priority examination of the local area, providing the officer with available information, e.g., location maps, known potential police suspects, pictures of suspects and details about any victims. Thus, the preferred system adjusts to social setting and location, and initiates high priority cloud computing tasks to provide a photographic, social hierarchy, and danger analysis. Thus, officer safety and effectiveness are increased, and prior task assignment priority is changed automatically in real time for subsequent processing.

[0089] FIG. **6** shows an example of operation of a shared IT infrastructure with a preferred resource management system (**100** in FIG. **4**A) processing end-user jobs for handheld devices (**154** in FIG. **5**), obtaining end-user context (C_t), and managing communication with the shared IT infrastructure. So, in this example, the device user **180** at location **182** has an activity (A_t), e.g., a meeting, scheduled at a future time (T_t) and at established location (L_t) **184**. At that scheduled time the preferred shared resource system is to deliver to device user **180** content related to that scheduled event, e.g., reports and information material required for the meeting. Initially, the context is $<C_0:L_0,T_0,A_0, \ldots >$ with the user outside the area of interest. There is nothing yet to be done by the preferred shared resource system.

[0090] Next, the user **180** moves into location (L_1) **186** at time (T_1) with context $<C_1:L_1,T_1,A_1 \ldots >$. The preferred system concludes from the context that it is time to start a Job J_1 that produces the required material for the meeting. However, the system further considers a time lag for the scheduled event, and starts the job J_1 at low priority. When the user **180** next moves into location (L_2) **188** at time (T_2) with context $<C_2:L_2,T_2,A_2 \ldots >$, the user **180** is again out of the relevant area **182**, e.g. because of absolute distance to the scheduled event at location **184**. Consequently, rather than waste resources preparing for the meeting, the preferred system pauses processing J_1.

[0091] Also in this example at this new position **188**, the user **180** engages in a conversation with a co-worker **190** and requests material for demonstration ASAP. In response to this urgent request, the system to trigger a new job J_2, which starts with high priority. Prior to completion of job J_2, however, the user **180** moves to location (L_3) **192**, distant from co-worker **190**, in the vicinity of the meeting place **184** with context $<C_3:L_3,T_3,A_3, \ldots >$. In response, considering the proximity with the target delivery point (i.e., co-worker **190** and the meeting's venue **184**), the job spooler both pauses processing J_2 and resumes J_1, still at a low priority.

[0092] If the user **180** continues to move towards the meeting venue, at the location **184** with context $<C_4:L_4,T_4,A_4, \ldots >$, the system may assign J_1 a new priority, e.g., bumping it higher to complete for delivery at the meeting. Optionally, the system may keep J_1 at its current priority and deliver partial contents (i.e. completed pieces), if the nature of J_1 permits it. If the user **180** again moves away from the meeting venue **184**, at location **194** with context $<C_5:L_5,T_5,A_5, \ldots >$, the user is out of proximity of the relevant context area **184**; and the system suspends J_1. Thus, the preferred system captures events related to context changes in real time. Each preferred handheld device and the shared IT infrastructure cooperate to capture, communicate and interpret the real time user events, as well as prioritize and process jobs accordingly.

[0093] Thus advantageously, a preferred resource management system **100** adjusts job execution based on local context variations at mobile user devices, improving the quality of service and overall end-user experience. The preferred resource management system **100** does not waste resources processing stale job content, no longer relevant in the current context. These advantages become even more beneficial with larger and larger numbers of personal assistant jobs provisioned for devices in a highly dynamic delivery environment. Further, unlike prior approaches to context-aware processing, the present invention focuses on enhancing local processing performance with context-awareness applied to coordinating server-based task prioritization.

[0094] While the invention has been described in terms of preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims. It is intended that all such variations and modifications fall within the scope of the appended claims. Examples and drawings are, accordingly, to be regarded as illustrative rather than restrictive.

1. A shared resource system comprising:

one or more client devices;

at least one provider computer, said one or more client devices requesting shared resource capacity from said at least one provider computer, a plurality of resource requests being context related, shared resources for context related said resource requests being provided to each respective requesting client device further responsive to a selected context; and

a resource management system receiving context changes from each of said client devices and selectively adjusting shared resource job priorities responsive to said received context changes.

2. A shared resource system as in claim **1** wherein said at least one provider computer is a plurality of provider computers in a cloud environment providing cloud-based personal assistants.

3. A shared resource system as in claim **1** wherein said at least one provider computer includes said resource management system and said one or more client devices includes at least one mobile client device, said resource management system comprising:

a context monitor monitoring context of mobile client devices for context variations indicating triggering events;

a resource manager assigning said shared resource job priorities to jobs and changing said shared resource priorities responsive to triggers from said context monitor; and

a context analyzer analyzing local mobile client device activity and related context history and providing scheduling recommendations to said resource manager.

4. A shared resource system as in claim **3** wherein said resource manager includes a job scheduler selectively pausing and restarting shared resource processing responsive to provided said scheduling recommendations.

5. A shared resource system as in claim **4** wherein said resource management system further comprises:

a context information store storing local device context history from said context monitor, context including time, device location and associated activity; and

a job queue, said jobs being queued in said job queue according to said assigned shared resource job priority, said job scheduler creating jobs responsive to job

requests from said at least one mobile client device, said job scheduler selectively pausing and restarting queued jobs and creating new jobs, responsive to said provided scheduling recommendations.

6. A shared resource system as in claim **5** wherein said one or more client devices include a plurality of handheld devices comprising a cell phone, a personal digital assistant, and a tablet computer.

7. A shared resource system as in claim **6** wherein said job scheduler sorts queued jobs queue according to said assigned shared resource job priority and resorts according to adjusted priorities, said cell phone is a smart phone including said personal digital assistant.

8. A shared resource system comprising:

a plurality of mobile client devices;

a plurality of provider computers, said plurality of mobile client devices requesting shared resource capacity from said plurality of provider computers, a plurality of resource requests being context related, shared resources for context related said resource requests being assigned a shared resource job priority, and provided to each respective requesting mobile client device further responsive to a selected context; and

one provider computer being a resource management system assigning shared resource job priorities and provisioning resources to requesting mobile client devices according to said assigned shared resource job priority, receiving context changes from each of said requesting mobile client devices, selectively changing said assigned shared resource job priorities responsive to said received context changes, and managing shared resource processing responsive to said priority changes.

9. A shared resource system as in claim **8** wherein said plurality of provider computers are computers in a cloud environment providing cloud-based personal assistants to said plurality of mobile client devices, said plurality of mobile client devices requesting shared resource capacity in said cloud environment, said resource management system comprising:

a context monitor monitoring context of said mobile client devices for context variations indicating triggering events;

a resource manager changing said shared resource priorities responsive to triggers from said context monitor;

a context analyzer analyzing local mobile client device activity and related context history and providing scheduling recommendations; and

a job scheduler scheduling and selectively re-scheduling shared resource processing responsive to said scheduling recommendations.

10. A shared resource system as in claim **9** wherein said job scheduler adds jobs responsive to resource requests from said requesting mobile client devices according to said assigned shared resource job priority and selectively pauses and resumes shared resource processing responsive to said scheduling recommendations.

11. A shared resource system as in claim **10** wherein said resource management system further comprises:

a context information store storing local device context history from said context monitor, context including time, device location and associated activity; and

a job queue, said job scheduler sorting queued jobs queue according to said assigned shared resource job priority and resorting according to adjusted priorities, said job scheduler creating and queuing jobs responsive to resource requests, said job scheduler selectively pausing and restarting queued jobs and, responsive to said provided scheduling recommendations, creating new jobs.

12. A shared resource system as in claim **9** wherein said plurality of mobile client devices include a plurality of handheld devices comprising a cell phone, a personal digital assistant, and a tablet computer.

13. A shared resource system as in claim **12** wherein said cell phone is a smart phone including said personal digital assistant.

14. A computer program product for context aware resource management, said computer program product comprising a non-transitory computer usable medium having computer readable program code stored thereon, said computer readable program code comprising:

computer readable program code for managing a plurality of computers selectively sharing resource capacity;

computer readable program code for interfacing with client devices requesting shared resource capacity for a specified context, each context including a time, a location and an associated activity;

computer readable program code for assigning a job priority for each request for resource capacity;

computer readable program code for scheduling provisioned resource capacity for requesting client devices responsive to assigned job priority;

computer readable program code for monitoring context of interfaced said client devices for context variations;

computer readable program code for triggering adjusting shared resource job priorities responsive to said context variations; and

computer readable program code for selectively adjusting shared resource job priorities, scheduling being adjusted responsive to adjusted priorities.

15. A computer program product for context aware resource management as in claim **14**, wherein said computer readable program code for managing said plurality of computers manages provider computers in a cloud environment providing cloud-based personal assistants.

16. A computer program product for context aware resource management as in claim **15** wherein said computer readable program code for managing said plurality of computers comprises:

computer readable program code for monitoring context of said client devices for context variations;

computer readable program code for generating triggers responsive to events indicated by said context variations;

computer readable program code for changing shared resource priorities responsive to triggers; and

computer readable program code for analyzing local mobile client device activity and related context history and providing scheduling recommendations responsive to changed priorities.

17. A computer program product for context aware resource management as in claim **16** further comprising computer readable program code for selectively pausing and restarting shared resource processing responsive to provided said scheduling recommendations.

18. A computer program product for context aware resource management as in claim **17** wherein said computer readable program code for managing said plurality of computers further comprises:

computer readable program code for storing local device context history from said context monitor;

computer readable program code for creating jobs responsive to job requests from said one or more mobile client devices;

computer readable program code for queuing jobs according to said assigned job priorities and re-sorting queued jobs according to adjusted said assigned job priorities; and

computer readable program code for selectively pausing and restarting queued jobs responsive to context variations and context history, said computer readable program code for creating jobs further creating new jobs responsive to said provided scheduling recommendations.

19. A computer program product for context aware resource management as in claim **15** wherein said client devices include a plurality of handheld devices comprising a cell phone, a personal digital assistant, and a tablet computer.

20. A computer program product for context aware resource management as in claim **19** wherein said cell phone is a smart phone including said personal digital assistant.

21. A computer program product for context aware resource management, said computer program product comprising a computer usable medium having computer readable program code stored thereon, said computer readable program code comprising:

computer readable program code for managing a plurality of computers selectively sharing resource capacity according to a job priority assigned for each request for resource capacity;

computer readable program code for interfacing with client devices requested shared resource capacity for a specified context from said plurality of computers, said specified context including a specified time, a client device location and an associated activity;

computer readable program code for monitoring context of interfaced said client devices for context variations indicating triggering events;

computer readable program code for changing shared resource priorities responsive to triggers from said context monitor;

computer readable program code for analyzing local client device activity and related context history and providing scheduling recommendations; and

computer readable program code for initially scheduling responsive to device requests and assigned job priority, and for selectively re-scheduling shared resource processing responsive to said scheduling recommendations and changed said job priorities.

22. A computer program product for context aware resource management as in claim **21**, wherein said computer readable program code for scheduling selectively pauses and resumes shared resource processing responsive to said scheduling recommendations.

23. A computer program product for context aware resource management as in claim **21** wherein said plurality of mobile client devices include a plurality of handheld devices with cloud-based personal assistants, said handheld devices comprising a cell phone, a personal digital assistant, and a tablet computer.

24. A computer program product for context aware resource management as in claim **23** wherein said cell phone is a smart phone including said personal digital assistant.

25. A computer program product for context aware resource management as in claim **21** wherein said plurality of computers are computers in a cloud environment selectively providing cloud-based personal assistants.

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