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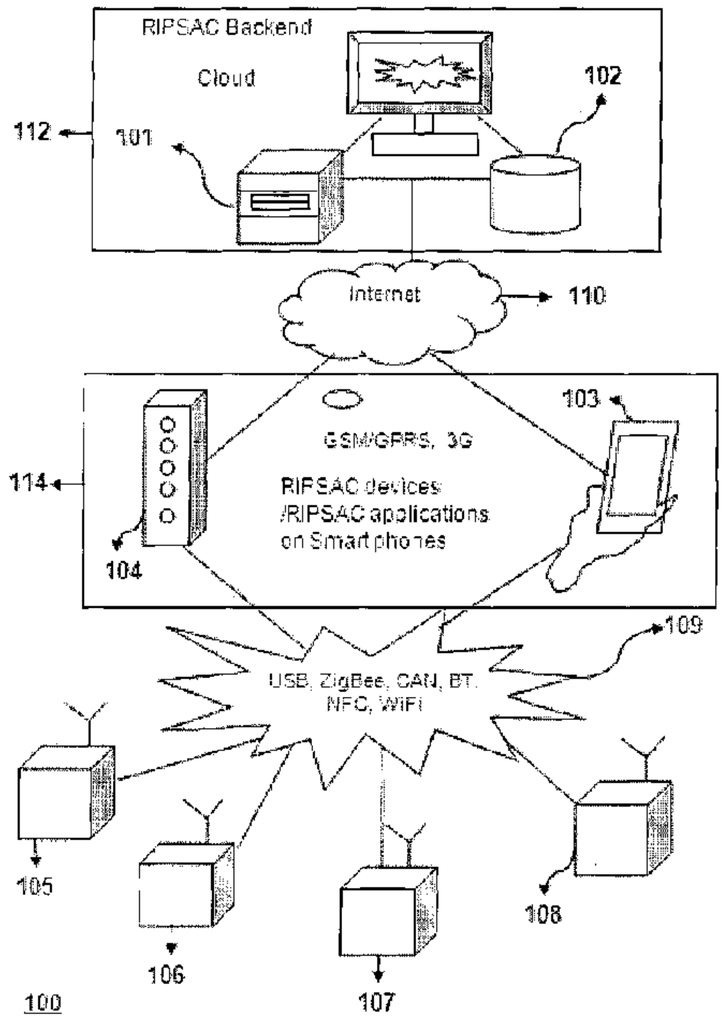

(57) Abrégé/Abstract:
A method and system for real-time analytics of sensor-based data is disclosed. Also disclosed is a Cloud-based Paltform-as-a-Service (PaaS) offering for sensor driven applications with services and features for their complete life-cycle management including prompt development, testing, deployment and so forth. The method of the present invention enables real-time tracking of various physical parameters and attributes related to smart-spaces using sensor devices implemented in the premises of the smart-space environment and using crowd-sourced user input data. Further, the parameters obtained are sent to the cloud-computing server, wherein the analytics is performed in real-time based on the obtained parameters.

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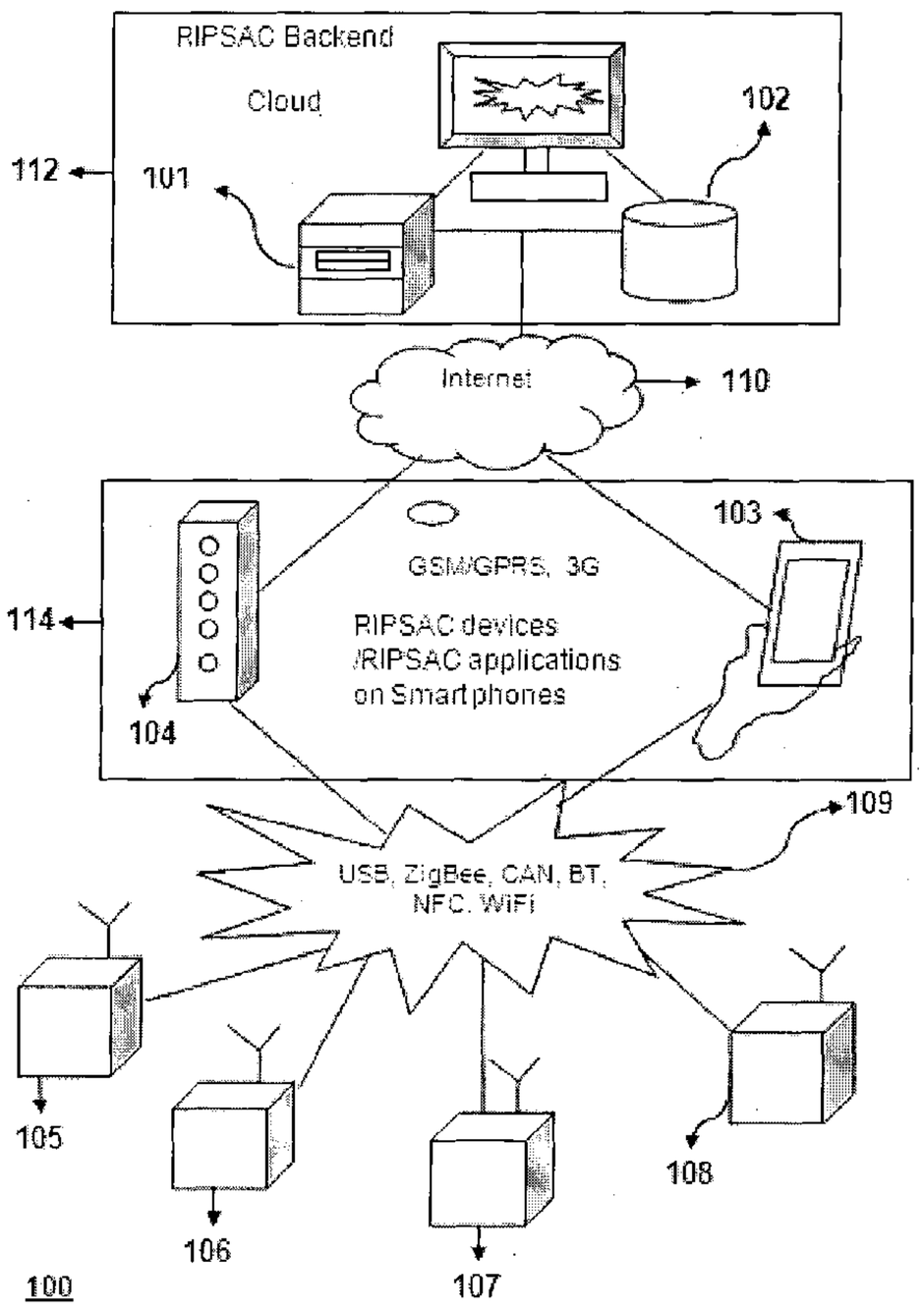
(54) Title: A COMPUTING PLATFORM FOR DEVELOPMENT AND DEPLOYMENT OF SENSOR DATA BASED APPLICATIONS AND SERVICES

(57) Abstract: A method and system for real-time analytics of sensor-based data is disclosed. Also disclosed is a Cloud-based Paltform-as-a-Service (PaaS) offering for sensor driven applications with services and features for their complete life-cycle management including prompt development, testing, deployment and so forth. The method of the present invention enables real-time tracking of various physical parameters and attributes related to smart-spaces using sensor devices implemented in the premises of the smart-space environment and using crowd-sourced user input data. Further, the parameters obtained are sent to the cloud-computing server, wherein the analytics is performed in real-time based on the obtained parameters.



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A COMPUTING PLATFORM FOR DEVELOPMENT AND DEPLOYMENT OF SENSOR DATA BASED APPLICATIONS AND SERVICES

FIELD OF THE INVENTION

The invention generally relates to the field of smart ubiquitous computing systems, cyber-physical systems and the Internet-of-Things (IoT). More particularly, the invention relates to a method and system for enabling a unified platform capable of providing suite of services for development and deployment of sensor-based applications in the smart ubiquitous computing environment.

BACKGROUND OF THE INVENTION

Smart ubiquitous computing systems have been developed and deployed in order to observe, monitor and track the state of various physical infrastructures, state physical objects, environment, human beings and their activities and utilize these observations to provide applications and services that enrich the lives of people and help them in their day-to-day activities. The environments in which such smart ubiquitous systems are deployed are referred to as "smart spaces".

In general, smart spaces includes various categories of sensors adapted for sensing and observation of various parameters in the environment that may enable to perform analytics on them to alert the end-users about the consequence of changes in the state, if any. For example, sensors may be deployed to observe and track location of any physical object, observe weather conditions to monitor natural calamities, observe traffics on the road to enable traffic shaping and vehicle surveillance systems etc.

Observations as described above are made by sensors and increasingly more and more sensors will be embedded in physical objects and things in the smart spaces. These sensors have transducers that transform a real life event or phenomenon into an electrical signal or digital data. In addition the sensors have computation and networking capabilities. Increasingly many of these sensors will directly or indirectly be connected to the Internet. Many of the sensors will be deployed by organizations, companies or public sector entities such as city governments or utilities or government departments. Also, many of the sensors will actually be owned and operated by private individuals. In case of private individuals, sensors embedded in mobile phones used by individuals will be an important class of sensors.

A critical requirement for development of smart ubiquitous computing environments leading to development of "smart spaces" is the ability to collect data from a large set of diverse sensors, aggregate and store the sensor data, perform specialized analytics on the data and combine and correlate observations from multiple diverse and geographically dispersed sensors. There is a need for scalable computing platforms that are able to provide these capabilities to software developers, including third party software developers, who can use the sensor data and the derived analytics to create new novel applications. Also, such platforms may be made available as web services accessed over the Internet, In such cases, these platforms can be categorized under the class of cloud computing services referred to as Platform-as-a-Service (PaaS).

In the background art, several systems have been implemented that perform the task of analysis of data captured by different category of sensors or telecommunication devices having sensing capabilities which are deployed in any smart space environment. These systems incorporate sensor devices that sense the state of various physical entities in any smart-spaces environments that could be processed

and analyzed further to monitor, administer and control the services catered through these smart-spaces remotely. Though, there has been efforts made in the past for real-time data capture and analysis thereof meant for remote smart-space monitoring, the need for a unified platform that integrates the suite of services capable of provisioning the development of real-time applications and management thereof from sensor data captured through any sensor device still exists in the art.

As of today, there are various Platform-As-A-Services (PaaS) available including Google App Engine, Heroku, and Microsoft Azure etc. However, these are limited to general purpose application development and therefore do not provide specific support for development, deployment and management of sensor-based applications. These platforms do not provide specialized services required in IOT/ Cyber Physical Systems domain. In this domain, there is a need for specialized services to cater to applications that leverages web connected sensors and sensors available as part of smart mobile devices. Sensor discovery, description, interfacing, query and tasking are some of the key requirements. Additionally, the sensor driven applications need to be event driven and therefore require capabilities such as event processing or stream processing. Further, these domains may require support for various types of databases such as RDBMS, NOSQL and Object Stores etc for scalable storage of different types of sensor observations. Also, the diversified domains may require specialized analytics and data visualization for deriving inferences and value addition. None of the above disclosed PaaS platforms provide support for all these features in a single platform.

On the other hand, there are some sensor platforms available as cloud computing services such as Pachube (Cosm), Sun Microsystem Sensor Networks etc. However these platforms mainly focus on sensor data publishing, subscription and storage services with very elementary support for application development. Additionally,

there is very little support in these platforms for location based processing, spatial and spatio-temporal processing. Additionally, these sensor platforms provide no support for crowd sourced applications to be developed and deployed on these platforms.

Further, there are some sensors and gateway device vendors in the market including companies such as Digi, Mobile Devices etc who provide a cloud based web services for remote device monitoring, management and data acquisition. However, these services cater for sensors and devices from a particular vendor only and are therefore not suitable for multi-vendor generic sensor device management, data capture and observation processing. Additionally, these services have very limited support for sensor data storage and analytics and almost no support for application development and deployment.

Additionally, a behavior based machine-to-machine (M2M) platform is known in the art that facilitates communication with global sensor network to enable sensor device management and generate composite applications without direct programming. Another implementation facilitating sensor-device management in the art uses cross APIs for accessing the sensor data across different platforms in a real-time. Further, an activity management system particular to specific domain such as semiconductor manufacturing is known in the art that comprises the steps of data collection, data storage and activation of services enables for improving the operational efficiency of the semiconductor manufacturing plant. An architecture facilitating automatic generation of software code for development of sensor driven applications is disclosed in the art.

Further, a framework facilitating context-aware advertising is known in the art, wherein the framework delivers relevant contents/ads to the end-consumer in context

with the consumers behavior/habits tracked through sensors deployed in a smart-space environment. Further, an application scope management platform is known that works on the aspects of crowd sensing adapted for web-application deployment and management thereof. An enterprise resource management analytics platform enables data integration from remote resources to facilitate remote surveillance, monitoring and real-time events of agencies, organizations and communities to ensure safety and security in their campuses. Further, a system implementing graph pattern query o simplify writing Stream Processing application by application developer is known. Further, systems facilitating efficient resource management in general for processing tasks in virtualized environment are known that utilizes sharing of resources for effective task management.

However, none of the existing systems, methods, platforms or frameworks provide a unified system that facilitates sensor driven distributed application development, testing, deployment, application life cycle management, analytics service, data storage service, sensor services and modeling and simulation for analytics. Also, existing systems lack comprehensive hosting of services such as sensor service, analytics service, identity & access control service, data storage service that are required for prompt and speed-up sensor application development. Further, none of the platforms disclosed in the art facilitates real-time development and deployment of sensor-based applications using a rich suite of services that enables sensor data reusability, data normalizing and data privacy. As most of the platforms lack generic capabilities of sensor data processing, this further leads to increase in costs and effort required for development and deployment of sensor based applications. Further, since the platforms are designed with specific to particular devices thereby bounded with security and privacy policies, there is a little scope of further application developments using third-party resources.

In the background art, there have been efforts made in the past for providing vehicle telemetry applications that enables intelligent transportation services to end-user subscribers. In general, these applications are either provided vertically by the vehicle manufacturers/OEMs etc or made available to the driver's Smartphone. In both cases, the applications development is enabled by using sensor data from various vehicle on-board/off-board sensors such as GPS, accelerometer and the like. Further, there have been efforts made in the art for implementing cloud computing technologies in the vehicle for providing vehicle telemetry applications. Further, there are vehicle to vehicle ad-hoc networks (VANETs) available in the art facilitating the provision of vehicle telemetry applications in a specific transport domain. However, the need for a single unified platform facilitating an intelligent transportation system by way of providing intelligent transport services in the platform for develop, test and deploy various telemetry applications using these services still exists in the art.

Thus, in view of the above, there is a long-felt need for an efficient method and a single unified system/platform design enabling real-time analysis sensor data captured from virtually any kind of sensor device and facilitates sensor-data capture, storage and analytics thereof using a suite of services therefrom said platform. Further, there is a need for a method and system that leverages a cloud computing platform offering a suite of services designed for real-time sensor data analytics, data mining, machine learning, image and video analysis, location based services and context-aware services in a ubiquitous computing environment.

OBJECTS OF THE INVENTION

The principal object of the invention is to provide a Real-Time Integrated Platform for Services & Analytics (RIPSAC) in the form of a Platform-as-a-Service (PaaS) cloud computing platform that allows quick and easy development, deployment and administration of sensor driven applications.

Yet another object of the invention is to provide a method and system for a real-time platform enabling data capture from any ubiquitous device having at least one attached sensor, the said device being connected through a communication network to the Internet.

Yet another object of the invention is to enable a method and system for storing said data with assorted formats captured from various sensor devices in a database connected to the platform.

Yet another object of the invention is to perform a scalable analytics on the stored data in the database to derive insights, inferences and visualized data therefrom thereby allowing stakeholders to take further decisions on the businesses associated with that data.

Yet another object of the invention is to provide a method and system enabling real-time development, testing and deployment of sensor-based applications thereby facilitating crowd sourcing application developments.

Yet another object of the invention is to provide a method and system enabling to develop various sensor-based applications using the suite of services of the platform

by selecting appropriate algorithms, software development kits (SDKs), application program interfaces (APIs) etc bundled in said suite of services.

Yet another object of the invention is to enable a method and system for data analysis by capturing data from user inputs using crowd sourcing, and treating these data as data from software sensors.

Yet another object of the invention is to provide a method and system enabling dissemination of deployed applications on end-user computing devices subscribed to these applications and services thereof.

Still another object of the invention is enabling a method and system for appropriate privacy controls and end-user license agreements while performing the analytics on the data.

Still another object of the invention is enabling a method and system for providing the RIPSAC platform and services thereof for real-time analysis and monitoring of activities in diverse sectors including energy, utility, government, transportation, healthcare, and education etc.

SUMMARY OF THE INVENTION

Before the present methods, systems, and hardware enablement are described, it is to be understood that this invention is not limited to the particular systems, and methodologies described, as there can be multiple possible embodiments of the present invention which are not expressly illustrated in the present disclosure. It is also to be understood that the terminology used in the description is for the purpose

of describing the particular versions or embodiments only, and is not intended to limit the scope of the present invention.

In one embodiment, the present invention enables a Real-Time Integrated Platform for Services & Analytics (RIPSAC) which is a Platform-as-a-Service (PaaS) cloud computing platform that allows quick and easy development, deployment and administration of sensor driven applications. In this embodiment, the RIPSAC interfaces with a heterogeneous set of sensors and devices within a smart computing environment collecting sensor observations, storing the data in a database connected with the platform, performing scalable analytics on the data for the benefit of both the end subscribers as well as authorized third parties such as insurance companies and government regulators either within the vicinity of the smart computing environment on in a cloud, exporting de-personalized samples of that data to third party application developers to enable open software development. In this embodiment, the platform provide a suite of infrastructure services in the form of APIs and SDKs. RIPSAC provides a highly scalable platform for sensor integration, sensor data storage, analytics, rich query capabilities and visualization. The platform comprises a set of services related to sensor description, discovery, integration, sensor observation and measurement capture, storage and query in the form of APIs and libraries. In this embodiment, application developers including third-party software developers are adapted to develop, test, deploy and manage applications in the said cloud-computing platform. In this embodiment, end-users are adapted to download apps, subscribe & unsubscribe to them, control their privacy settings, and view usage history and billing information.

In another embodiment, there is provided a system for providing infrastructure platform in a smart-space environment that facilitates quick and easy development, deployment and management of a plurality of sensor driven applications, said system comprising: a real-time integrated platform for service & analytics (RIPSAC) device configured to: periodically capture sensor data in assorted formats from a plurality of sensor devices deployed in the smart-space environment based on application logic and type of the plurality of sensor devices, transform the captured sensor data and provide the transformed sensor data to a plurality of application developers in order to enable a plurality of application developers to develop and test the plurality of sensor driven applications such that privacy related to the

captured sensor data is protected; pre-process the captured sensor-based data to extract relevant sensor-based information and store the relevant sensor-based information in a database; a telematics device configured to: perform scalable real-time analytics on the relevant sensor-based information using machine learning packages, statistical processing packages, rule engines, complex event and stream processing and knowledge driven processing to derive insights inferences and visualized data of the relevant sensor based information; and the plurality of application developer devices configured to: develop and deploy one or more sensor driven applications using a suite of services in an infrastructure platform based on results of the scalable real-time analytics; wherein the one or more sensor driven applications are further tested using the suite of services in the infrastructure platform.

In another embodiment, there is provided a method for providing an infrastructure platform in a smart-space environment characterized in facilitating quick and easy development, deployment and management of a plurality of sensor driven applications, the method comprising steps of: periodically capturing sensor data in assorted formats from a plurality of sensor devices deployed in the smart-space environment based on application logic and type of the plurality of sensor devices and transform the captured sensor data and provide the transformed sensor data to a plurality of application developers in order to enable the plurality of application developers to develop and test the plurality of sensor driven applications such that privacy related to the captured sensor data is protected; pre-processing the captured sensor-based data to extract relevant sensor-based information and store the relevant sensor-based information in a database; perform scalable real-time analytics on the relevant sensor-based information using machine learning packages, statistical processing packages, rule engines, complex event and stream processing and knowledge driven processing to derive insights inferences and visualized data of the relevant sensor based information; and developing and deploying one or more sensor driven applications using a suite of services in an infrastructure platform based on results of the scalable real-time analytics wherein the one or more sensor driven applications are further tested using the suite of services in the infrastructure platform.

BRIEF DESCRIPTION OF DRAWINGS

The foregoing summary, as well as the following detailed description of preferred embodiments, is better understood when read in conjunction with the appended

drawings. For the purpose of illustrating the invention, there is shown in the drawings exemplary constructions of the invention; however, the invention is not limited to the specific methods and architecture disclosed in the drawings:

Figure 1 schematically illustrates a system architecture diagram (100) displaying various hardware elements configured to perform real-time sensor data analytics in a smart computing environment according to an exemplary embodiment of the invention.

Figure 2 is a block diagram (200) of RIPSAC platform illustrating various application developers/tenants, sensor data providers and subscribers being connected with said RIPSAC platform for accessing RIPSAC services and applications in accordance to an exemplary embodiment of the invention.

Figure 3 is a block diagram illustrating various software layers of the in-car telematics device enabling real-time analytics of telematics data in accordance with an exemplary embodiment of the invention.

Figure 4 is a block diagram illustrating the back-end software platform according to an exemplary embodiment of the invention.

Figure 5 is a flow diagram illustrating steps designed to enable the RIPSAC platform to perform the task of real-time analytics of any smart-space environment according to an exemplary embodiment.

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DETAILED DESCRIPTION:

The description has been presented with reference to an exemplary embodiment of the invention. Persons skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described method and system of operation can be practiced without meaningfully departing from the principle, scope of this invention.

Referring to figure 1 is a system architecture diagram of a Real-Time Integrated Platform for Services and Analytics (RIPSAC) 100 comprising various hardware elements configured to perform real-time data analytics in a smart computing environment according to an exemplary embodiment of the invention.

As illustrated in figure 1, the system architecture (100) comprises a RIPSAC backend cloud (112) that includes a cloud server (101) connected to a database (102). The system further comprises various RIPSAC devices (114) implemented on different smart devices such as Smart phone (103), a telematics device (104) enabling real-time analytics of sensor data. The system further comprises various heterogeneous sensor devices (105), (106), (107) and (108) etc placed in the vicinity of smart computing environment connected with various telecommunication devices such as Smartphone (103), and the telematics device (104) etc. Thus, the sensors along with the telecommunication devices collectively form an intelligent smart environment according to this exemplary embodiment.

Further, as illustrated in figure 1, the system platform (100) supports various connectivity options such as Bluetooth®, USB, ZigBee and other cellular services collectively illustrated as smart computing network (109). In an exemplary embodiment, the system platform interfaces with sensors (105,106, 107, and

108)such as GPS, accelerometers, magnetic compass, audio sensors, camera sensors etc deployed in vicinity of the smart computing environment. The platform enables connection of telecommunication devices such as Smartphone with the server, and accordingly with the database using any communication link including Internet, WAN, MAN referred to as (110) in figure 1.In an exemplary embodiment, the system platform (100) is implemented to work as a stand-alone device. In another embodiment, the system platform (100) may be implemented to work as a loosely coupled device to the smart computing environment.

In one embodiment, the Smartphone as illustrated in figure 1 may include in-built sensors such as accelerometer, compass, GPS, NFC reader, microphone and camera etc. In this embodiment, the system platform (100) may be installed on the Smartphone in the form of a mobile application (App). In such scenario, the inbuilt sensors in the Smartphone feed the data collected by them related to vehicle tracking, traffic measurements, and human driving characteristics etc to the RIPSAC platform (100) acting as mobile app on the Smartphone. In such scenario, the Smartphone is considered to be a ubiquitous telematics platform which may act as a car phone if the Smartphone is located inside the car. Further, based on the data collected from various sensors, the system platform (100) with the help of various hardware and software platforms collectively performs the task of scalable data analytics on the captured sensor data in any smart computing environment.

Referring to figure 2 is a block diagram (200) illustration various user-devices connected to RIPSAC platform for utilizing various RIPSAC services and applications in accordance with an exemplary embodiment of the invention. As illustrated in figure 2, the RIPSAC platform (201) provides various RIPSAC services related to sensors, storage and analytics to different stakeholders connecting with the platform. A plurality of sensor providing devices (205) act as contributors or

publishers that publishes sensor data observed in any smart space environment. The sensor providing devices (205) own the sensor observation data.

A plurality of application developer devices (203) as shown in figure 2 communicates with the platform (201) by means of communication network, preferably by means of an internet connection. The application developers are adapted to access the RIPSAC services on the platform to develop varied sensor-driven application and deploy these on the platform (201) in the form of RIPSAC applications. As illustrated, a plurality of end-user subscriber devices (207) are shown that connects with the platform (201) by internet communication means in order to subscribe with the RIPSAC applications deployed in the RIPSAC platform (201). In an embodiment, the sensor providing devices (205) and the application developer devices (203) can perform the tasks interchangeably. In this exemplary embodiment, platform/PaaS provider (209) is an entity that runs the RIPSAC platform (201) as a hosted service.

In this exemplary embodiment, the RIPSAC platform (201) provides different services for each of the application developer/tenant device (203), sensor provider device (205), end-user device (207) and a platform provider (209) connected to the platform through internet means. In this exemplary embodiment, the platform provider (209) is provided with the ability to deploy and run the core RIPSAC services such as sensor , Storage and Analytics Services, deploy and run Identity , Security, Privacy and end User License Mgmt services. The platform provider is provided with the ability to deliver targeted advertisements, create a multi-tenant environment with control resource sharing, create separate environments of sandboxes for different tenants and enable operation support systems such as managing, monitoring, billing etc. In this exemplary embodiment, the sensor

providing devices (205) are provided with the services needed to describe feature of interest and different types of phenomenon, sensor & sensor observation description, Feeds & sensor streams definition, services required to publish & share sensor streams to the platform and services needed to define access control and privacy preferences for published sensor streams.

In this exemplary embodiment, the application developer/tenant devices (203) are provided with environments required for development & testing of applications in the form of Sandboxes. Further, Software Development Kits and Application Programming Interfaces (APIs) in form of web services calls or language specific libraries are made available to these devices. Additionally, the platform provides test sensor data to tenants so that they can develop and test applications. The application developer/tenant devices (203) are adapted to register and deploy Apps to the RIPSAC platform (201). The application developer/tenant devices are enabled to define end user license Agreements for their applications and can Start, Stop, upgrade, redeploy and undeploy applications. In this exemplary embodiment, the end-user devices (205) as shown in figure 2 are adapted to download apps, subscribe or unsubscribe to RIPSAC applications and services. Further, these devices are adapted to control the privacy setting of sensor data which they are contributing/publishing with the platform and are enabled to track & view usage history, billing information etc.

In an embodiment, the services provided to various stakeholders in the platform including platform providers (209), application developers/tenants, sensor providers and end-user subscribers etc are facilitated through various hardware/software components in the platform. Figure 3 and 4 refers to software architecture diagrams illustrating different suite of sensor-based services enabling real-time analytics of sensor data in accordance to an exemplary embodiment of the invention. The

software architecture comprises three software platforms enabling the real-time including a sensing device software platform, a backend software platform and a Smartphone platform.

As illustrated in figure 3, the sensing device software platform (300)comprises a real-time operating system (OS), device drivers required for establishing interconnections and network adaptors and providing support for deployment and execution for multiple concurrent telematics services and applications, standard programming languages and development tools for software development, remote deployment, real-time monitoring and management of deployed software components, support for secure deployment of trusted applications and services and fine grained access controls. In an embodiment, considering these requirements for executing various applications and services, the programming language such as JAVA and OSGI as a service delivery platform is utilized.

Referring to figure 4 is a software platform architecture diagram (400) illustrating various backend components in the backend software platform. The backend software platform comprises a scalable sensor service module, a scalable storage service module, a scalable analytics services module, web-based portals facilitating connectivity with end-user mobile computing devices that collectively implements real-time analytics on data received from various sensor devices installed in a smart-space environment. RIPSAC acts as a Platform-as-a-Service (PaaS) cloud computing platform that allows quick and easy development, deployment and administration of sensor driven applications. RIPSAC provides sensor device management, data acquisition, data storage and analytics services. These services are made available to application developers in form of application program interfaces (APIs) and software development kits (SDKs). RIPSAC provides a highly scalable platform for sensor integration, sensor data storage, analytics (including real-time and Big Data

processing), rich query capabilities (including geo-spatial queries and continuous queries) and visualization.

At the core of RIPSAC is a set of services related to sensor description, discovery, integration, sensor observation and measurement capture, storage and query. RIPSAC provides these services in form of APIs and libraries. App developers can develop, test, deploy and manage applications in RIPSAC. RIPSAC supports multi-tenancy and provides secure sandboxes for testing and deployment of applications by each tenant. End users computing devices are configured to download Apps, subscribe & unsubscribe to them, control their privacy settings, and view usage history and billing information.

Thus, the RIPSAC integrates various services, software, libraries, tools in the single infrastructure platform that can be utilized for development and deployment of various sensor-driven applications. In an embodiment of the invention, the RIPSAC enables such integration by utilizing standard information models and access mechanisms such as the Open GeoSpatial Consortium (OGC) standards known as Sensor Web Enablement (SWE) standards. In an embodiment, the RIPSAC sensor services provide access to sensor and sensor observation data using these standards. Further, the RIPSAC platform provides client libraries and web service Application Program Interfaces (APIs) that make it feasible and easy to use the information model and access mechanism. In an embodiment, the RIPSAC platform further enables exchanging sensor related events across different applications and services using a messaging infrastructure that consists of message publish-subscribe mechanisms implementing such exchange of sensor related events.

In an embodiment, integration of any software running on RIPSAC (i.e. applications and services) with Analytics engines is provided by means of analytics engine

specific libraries included in the RIPSAC platform. In this embodiment, a networking protocol enabling data connection facilitates connection of these libraries to analytics engines running on analytics servers. The libraries hide all complexities and details of network connectivity between the end points. Moreover, these libraries also provide load balancing services across the various analytics servers. In an embodiment, the RIPSAC database services are accessed using a combination of web service calls, technologies such as SQL, JDBC and JPA, and specific database client libraries etc. The various services bundled through said scalable sensor service module, scalable storage service module, scalable analytics services module and web-based portals are now described by referring to figure 4.

In an embodiment, as illustrated in figure 4, the presentation services module (401) are catered through portals and user Interfaces. The portal component includes application developer's portal, administrator's portal and an end-user subscriber portal. The application developer's portal is utilized to enable application developer's computing devices to register with the RIPSAC, register the developed applications, create databases, upload and test analytics programs etc. The administrator's portal is used by the RIPSAC administrator computer to manage and monitor the underlying software and hardware infrastructure, monitor, manage and control usage of platform services by tenants.

In an embodiment, the device integration and management services component (413) includes data aggregation and device monitoring and management services for interfacing gateway devices, sensors, mobile devices and their network addresses in RIPSAC. These services provide support for various network protocols for data communication between these devices and RIPSAC. This suite of service enables ability to monitor the health and status of the devices and the ability to deploy software on these devices from RIPSAC. In this embodiment, device specific

software modules, known as Device Sensor Adapters are provided for each type of device that are able to access the sensors attached to these devices and process sensor specific commands. Further, device specific software modules, known as Device Management Adapters are developed for each type of device that facilitates a web service interface for the following type of activities such as device health monitoring, device starting, stopping and restarting and device data structure access, read and update. In this embodiment, the Device management Adapters typically runs on the device itself. Alternatively, for some devices, Device management Adapters may run as a separate cloud based web service. The RIPASAC device management services use Device Management Adapters for each device connected to RIPSAC to manage and monitor devices. Further, software modules called RIPSAC Sensor Integration adapters are used by software running on the devices to invoke the RIPSAC Sensor Services over an internet connection. In addition to use of RIPSAC Sensor Integration Adapters, application software running on devices can also call web service interfaces exposed by RIPSAC applications directly. In such scenario, the RIPSAC Integration Adapters are bypassed in the device, but invoked from the RIPSAC application instead. These devices facilitate sensor data acquisition and integration on the platform using either pull-mode or push-mode.

In one embodiment, in case of a pull-mode sensor data acquisition, the sensor data feed is captured by RIPSAC applications by invoking Device Management Adapters running for the devices whose sensor data is required. In another embodiment, if the sensor data is acquired using push-mode, the sensor data is posted to RIPSAC sensor services by the device software either by invoking RIPSAC Sensor Integration Adapters or by calling the web services exposed by RIPSAC applications. In an embodiment, depending on the application logic and type of sensor, the sensor data acquisition may be continuous (i.e. periodic), or event driven, or on demand initiated

by some user action. The RIPSAC platform can support time series sensor data in any granularity.

In an embodiment, the Messaging & Event Distribution Services (411) provides an infrastructure for passing of messages and events across RIPSAC services and applications. Further, the Data Storage & Query Services (409) enables large scale, distributed sensor data storage and query facility, including support for geo-spatial queries. These services enable the capability of continuous query processing.

In an embodiment, the analytics services component (407) consists of several libraries and servers comprising machine learning packages, statistical processing packages, rule engines, complex event and stream processing, knowledge driven processing that are configured to perform real-time analytics on the stored sensor data. The Application services component (403) incorporates application components, core sensor services, and user interface & visualization services. The core sensor services enable sensor and senor observations description services, sensor discovery, feature description and phenomena, inserting & querying observations etc. In this embodiment, in order to insert observations for a given Sensor Id, observation in terms of <Key, Value> pairs, geo-location coordinates of the observation and the time of observation is specified and then the observation is inserted using RIPSAC services. Similarly, observations are queried using one or more parameters including Sensor Id, Phenomenon, Geo-location parameters (points, boundaries etc), and time parameters. The Observations are used as is or it is passed on to analytics programs and then the output of analytics programs is used for observations. The user interface & visualization services component incorporates libraries and tools for creating rich visualizations and reports from the sensor data.

In an embodiment, the application components include producer applications component, consumer applications component and producer cum consumer applications component. The producer applications component is configured to publish sensor data to the RIPSAC platform. The consumer applications component is adapted to query and use sensor data from the RIPSAC platform. The producer cum consumer applications component is configured to simultaneously act as both producer applications component and consumer applications components.

In an embodiment, the application support services component (405) includes integration & orchestration services, planners, platform APIs & SDKs that collectively provide support for various RIPSAC service integration and orchestration thereof. The Service Orchestration allows creation of composite applications or composite services. Service Orchestration is itself a platform service that is available to application developers for the purpose of creating composite applications. Access to service orchestration services, like any other RIPSAC services, is controlled using policy driven access controls. The Service Orchestration services in the RIPSAC are implemented using a standard web service orchestration engine. These Services will allow application developers to specify the orchestration logic using standard web service orchestration languages such as Business Process Execution Language (BPEL). RIPSAC Orchestration services make it simpler to use orchestration services by hiding the details of orchestration engines and engine specific complexities. The RIPSAC platform enables these SDKs and APIs to provide support for third party application developers and also provides them access to developer sandboxes and training data. The application developers can test and verify the various applications built on the software platform enabling real-time analytics by utilizing the test data, development sandboxes and device simulators provided by the backend software platform. APIs and SDKs are software

development tools that acts as Web Services and language specific bindings to various RIPSAC services.

In an embodiment, the RIPSAC backend platform further facilitates Software infrastructure that comprise application servers, relational databases and document databases. The application servers act as Containers / Virtual Machines / hosts on which user applications are executed. The relational databases and document databases services enable storage of data and documents in the RIPSAC backend platform. Additionally, the RIPSAC facilitate data center infrastructure services that include Compute, Network & Disk Storage Services, File Services and Firewall Services. The Compute, Network & Disk Storage Service consists of servers, disks and network resources that act as a virtual hardware infrastructure on which RIPSAC components finally run. File storage services are provided to servers using File Services. The Firewall Services are adapted to create secure zones based on policies to separate different tenants from each other.

In one embodiment of the invention, in order to enable flexible, extensible and interoperable platform that can accommodate and interoperate with virtually any sensor type and to allow easy addition of new applications and services, the platform adopts suitable database schemas and message encodings. The database schemas are designed in such a way so that virtually any sensor measurements and observations made in smart-space environment and can be stored for both immediate and historical use. Similarly, suitable XML based encodings and schemas can be used in messages transferred from the sensing device to the backend platform. Apart from proprietary protocols, both the telematics device as well as backend platform will support standard web services and http for accessing sensor observations.

In one embodiment, the RIPSAC platform incorporates Privacy preservation important feature in the software stack of the backend platform. Various sensor-based applications and services require various levels of privacy preservation and the proposed invention enables tailored levels of privacy protection for each application or service. Privacy preservation is achieved via the following four sub-components:

- Policy driven and adaptive access control software layer is configured for allowing fine grained control over who can access various sensors, sensor observation values and sensor database records and fields.
- Robust privacy preserving algorithms configured for anonymizing, diversifying, perturbing and randomizing privacy sensitive data.
- Data transformation algorithms configured for transforming private data to forms suitable for publishing for public consumption and vice versa.
- Use of Trusted Computing concepts and Trusted Platform Modules for secure and trusted storage of keys and algorithms for privacy preservation and data transformations as described above.

In an embodiment, the Smartphone software platform includes a software development kit (SDK) compatible to the Smartphone and an app-store model. The platform (100), if implemented as a Smartphone app is configured to be made compatible with various Smartphone devices in the market built on several operating systems (OS) or simple Java phones supporting J2ME, CLDC,MIDP and Midlets. The hardware platform illustrated in figure 2 in combination with the software platforms such as the sensing device software platform, the backend software platform and the Smartphone platform by virtue of single integrated cloud-computing platform enable the subscribers and other authorized third parties to perform various tasks based on the data analytics results that may be implemented in the cloud or in the vicinity of monitored and analyzed smart-space environment.

Referring to figure 5 is a flow diagram illustrating steps designed to enable the RIPSAC platform to perform the task of real-time analytics of any smart-space environment according to an exemplary embodiment.

At step 501, sensor-based data in assorted formats is captured from one or more sensors deployed in the smart-space environment.

At step 503, the sensor-based data is pre-processed the captured data to extract relevant sensor-based information and enable storage thereof in a database.

At step 505, real-time analytics on the stored sensor-based information is performed to derive insights, inferences and visualized data therefrom.

At step 507, a set-of bundled services and algorithms in the RIPSAC is utilized to develop, test and deploy one or more sensor-based applications based on the results of real-time analytics.

The preceding description has been presented with reference to various embodiments of the invention. Persons skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described structures and methods of operation can be practiced without meaningfully departing from the principle, scope of this invention.

ADVANTAGES OF THE INVENTION

The present invention has following advantages:

- The present invention enables a platform-as-a-service cloud computing platform that allows quick and easy development, deployment and administration of sensor driven applications.
- The present invention provides an integrated platform for sensor data capture, storage, analytics, and visualization etc.
- The present invention enables easy development and deployment of applications developed by many different third party developers using a set of services are made available in form of Application Programming Interfaces (APIs) and Software Development Kits (SDKs).
- The present invention enables multiple sensor data providers, multiple application developers and application end users to connect with the platform in a secure and mutually isolated way for accessing various services and application facilitated by the platform.
- The present invention enables sensor data to be shared across applications and users by facilitating policy driven data privacy and policy driven data on the platform.
- The present invention enables the platform to interface with any kind of sensor and is independent of type of the sensor and sensor data observation.
- The platform of the present invention provides scalable sensor data storage for a wide variety of sensors and sensor observations and provides scalable analytics services.

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CLAIMS:

1. A system for providing infrastructure platform in a smart-space environment that facilitates quick and easy development, deployment and management of a plurality of sensor driven applications, said system comprising:

a real-time integrated platform for service & analytics (RIPSAC) device configured to:

periodically capture sensor data in assorted formats from a plurality of sensor devices deployed in the smart-space environment based on application logic and type of the plurality of sensor devices, transform the captured sensor data and provide the transformed sensor data to a plurality of application developers in order to enable a plurality of application developers to develop and test the plurality of sensor driven applications such that privacy related to the captured sensor data is protected;

pre-process the captured sensor-based data to extract relevant sensor-based information and store the relevant sensor-based information in a database;

a telematics device configured to:

perform scalable real-time analytics on the relevant sensor-based information using machine learning packages, statistical processing packages, rule engines, complex event and stream processing and knowledge driven processing to derive insights inferences and visualized data of the relevant sensor based information; and

the plurality of application developer devices configured to:

develop and deploy one or more sensor driven applications using a suite of services in an infrastructure platform based on results of the scalable real-time analytics; wherein the one or more sensor driven applications are further tested using the suite of services in the infrastructure platform.

2. The system of claim 1, wherein the suite of services comprise one or more of: device integration and management services, analytics services, messaging & event distribution services, data storage and query services, sensor management services, application support services, user interface & visualization services and security, access control & privacy policy services.

3. The system of claim 2, wherein device integration and management is enabled using a set of devices consisting of but not limited to device sensor adapters, device management adapters, sensor integration adapters, web-service interface or combinations thereof.

4. The system of claim 2, wherein the device integration and management services are configured to interface varied sensor devices, facilitate support for networking protocols enabling data communication, monitor the health and status of said sensor devices, deploy software on the sensor devices from the infrastructure platform or combinations thereof.

5. The system of claim 2, wherein the messaging & event distribution services are adapted for passing of messages and events across the infrastructure platform services and applications built therefrom.

6. The system of claim 2, wherein the data storage & query services are configured to enable distributed sensor data storage and querying said sensor data storage.

7. The system of claim 2, wherein said sensor management services are configured to enable sensor device discovery, description of sensor device and sensor data observations, feature description, inserting observations, querying observations or combinations thereof.

8. The system of claim 2, wherein said application support services are configured to provide support for service integration and orchestration thereof.

9. The system of claim 2, wherein said application support services are configured to enable identity management, policy driven access control, data privacy controls

& data masking and authentication of various category of users accessing the infrastructure platform.

10. The system of claim 1, wherein the plurality of application developer devices comprises an application developer portal adapted to enable various application developers to register with the platform, register their applications, create databases, a administrator developer portal adapted to enable various administrators to monitor, manage & control the usage of underlying software & hardware infrastructure and platform services by the tenants and a subscriber portal adapted to enable various subscribers to download apps, subscribe & unsubscribe to them, control privacy settings, and view usage history and billing information.

11. A method for providing an infrastructure platform in a smart-space environment characterized in facilitating quick and easy development, deployment and management of a plurality of sensor driven applications, the method comprising steps of:

periodically capturing sensor data in assorted formats from a plurality of sensor devices deployed in the smart-space environment based on application logic and type of the plurality of sensor devices and transform the captured sensor data and provide the transformed sensor data to a plurality of application developers in order to enable the plurality of application developers to develop and test the plurality of sensor driven applications such that privacy related to the captured sensor data is protected;

pre-processing the captured sensor-based data to extract relevant sensor-based information and store the relevant sensor-based information in a database;

perform scalable real-time analytics on the relevant sensor-based information using machine learning packages, statistical processing packages, rule engines, complex event and stream processing and knowledge driven processing to derive insights inferences and visualized data of the relevant sensor based information; and

developing and deploying one or more sensor driven applications using a suite of services in an infrastructure platform based on results of the scalable real-time analytics

wherein the one or more sensor driven applications are further tested using the suite of services in the infrastructure platform.

12. The method of claim 11, wherein the suite of services in an infrastructure platform comprise one or more of device integration services, analytics services, messaging and event distribution services, sensor management services, application support services, user interface and visualization services, and security, access control and privacy policy services.

13. The method of claim 11, wherein device integration and management service comprises services for interfacing gateway devices, sensors, mobile devices and corresponding network addresses thereof by means of device specific software modules including device sensor adapters, device management adapters and sensor integration management adapters or combinations thereof.

14. The method of claim 11, wherein plurality of sensor devices are dynamically coupled with the infrastructure platform and are seamlessly integrated for ad-hoc data gathering.

15. The method of claim 11, wherein the plurality of sensor devices are integrated with the platform comprising of soft sensors, physical sensors, and virtual sensors, each being scalable at an instance by means of dynamic addition of servers capable of processing sensor data depending on the load on the present servers handling sensor data.

16. The method of claim 11, wherein the infrastructure platform is configured to continuously/intermittently/upon request receive data from each of the integrated sensors that are pre-registered and authenticated with the platform such that an extent of data usage and dissemination is dynamically governed by owner thereof.

17. The method of claim 16, wherein the observation data from the plurality of sensors can be accessed through synchronous polling based mode or asynchronous notification based mode and filtered by temporal, spatial, spatio-temporal, or value based filtering criteria.

Sheet No: 1/5

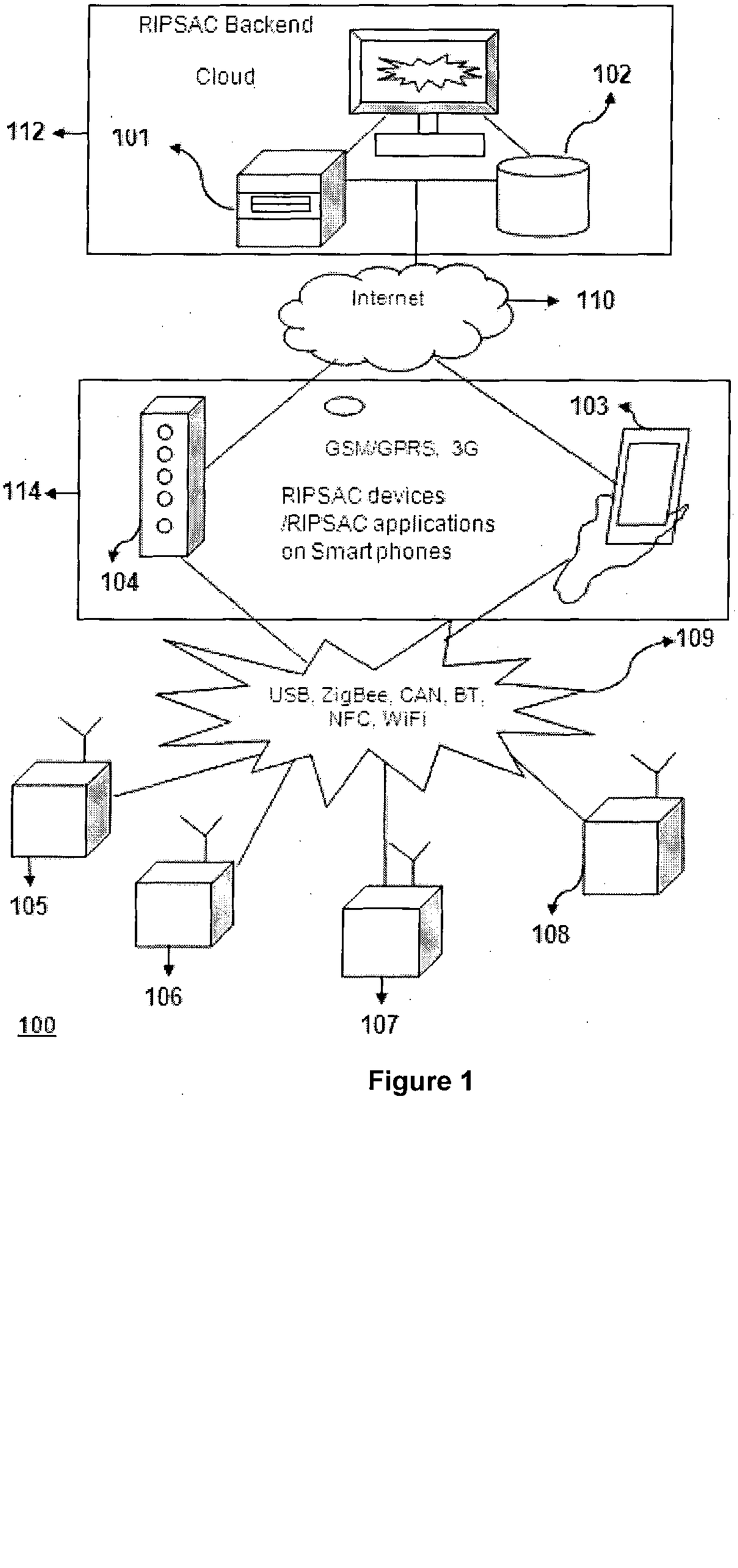


Figure 1

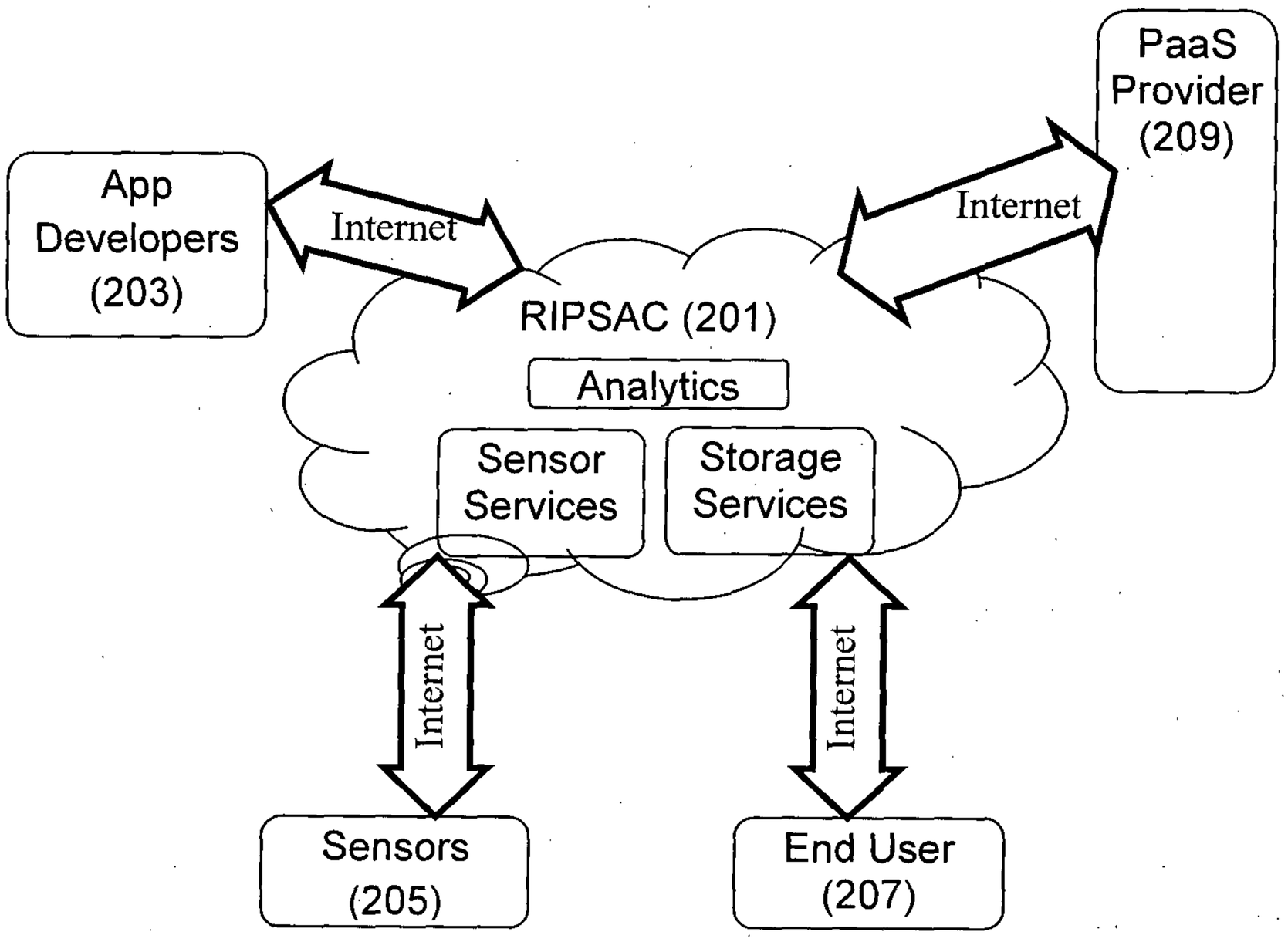

App Developers (203)
Internet
RIPSAC (201)
Analytics
Sensor Services
Storage Services
Internet
PaaS Provider (209)
Internet
Internet
Sensors (205)
End User (207)

Figure 2

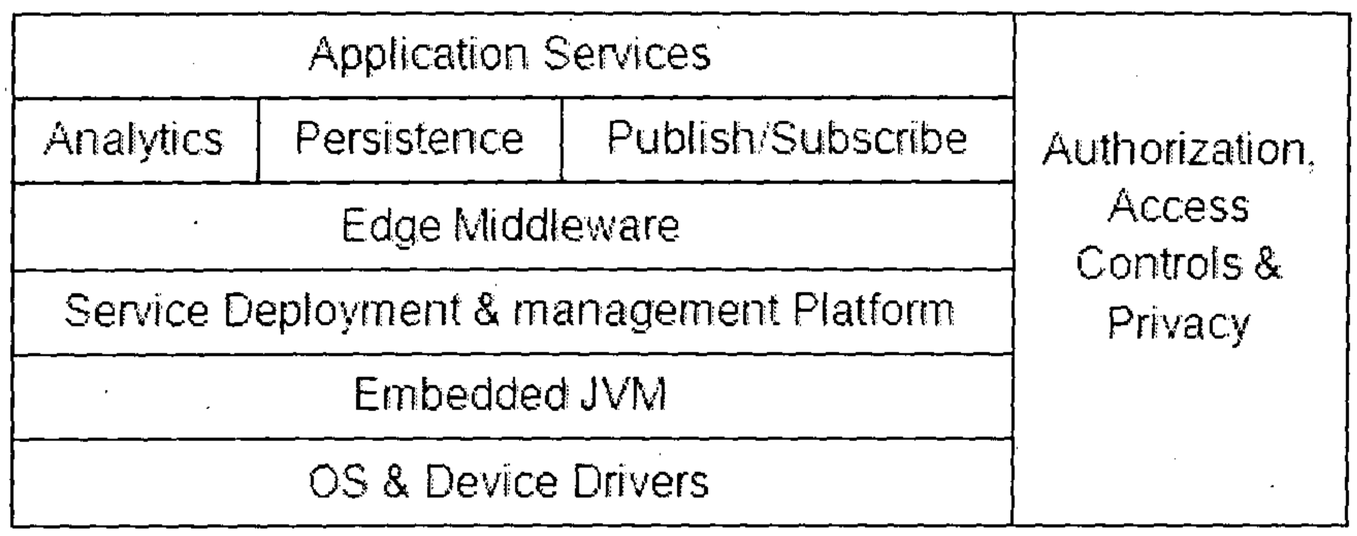

Application Services
Analytics
Persistence
Publish/Subscribe
Edge Middleware
Service Deployment & management Platform
Embedded JVM
OS & Device Drivers
Authorization, Access Controls & Privacy
300

Figure 3

Sheet No: 4/5

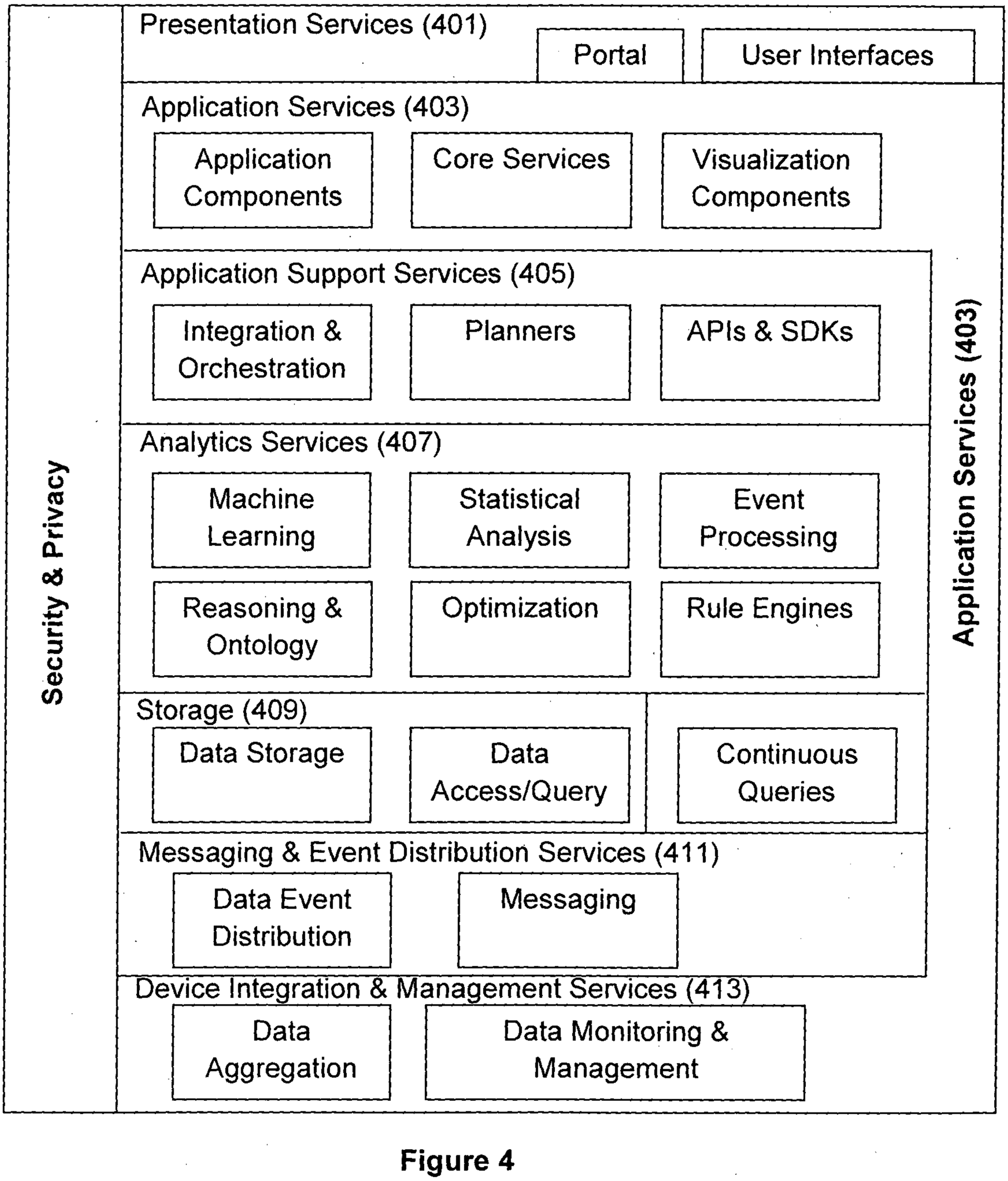


Figure 4

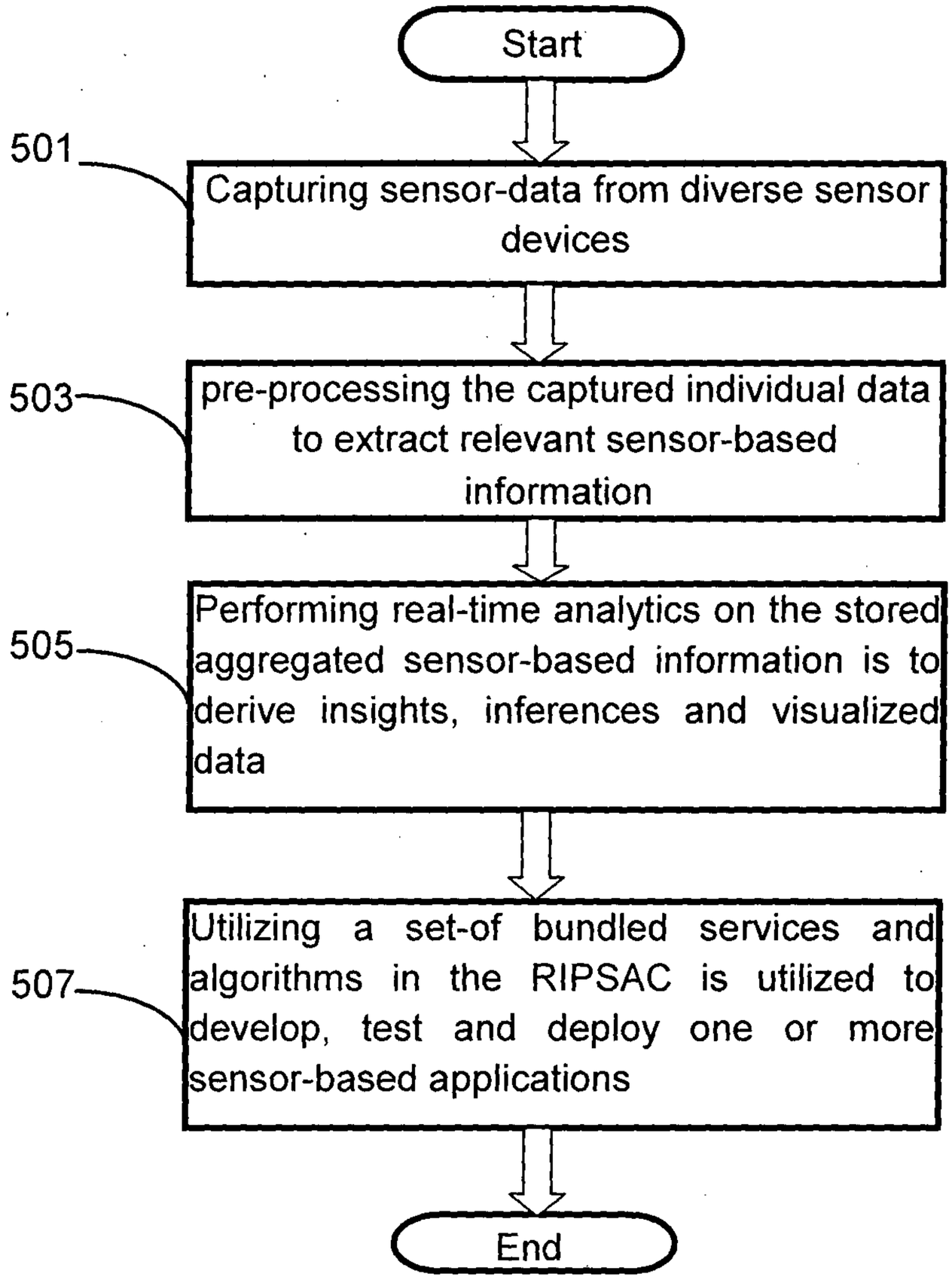
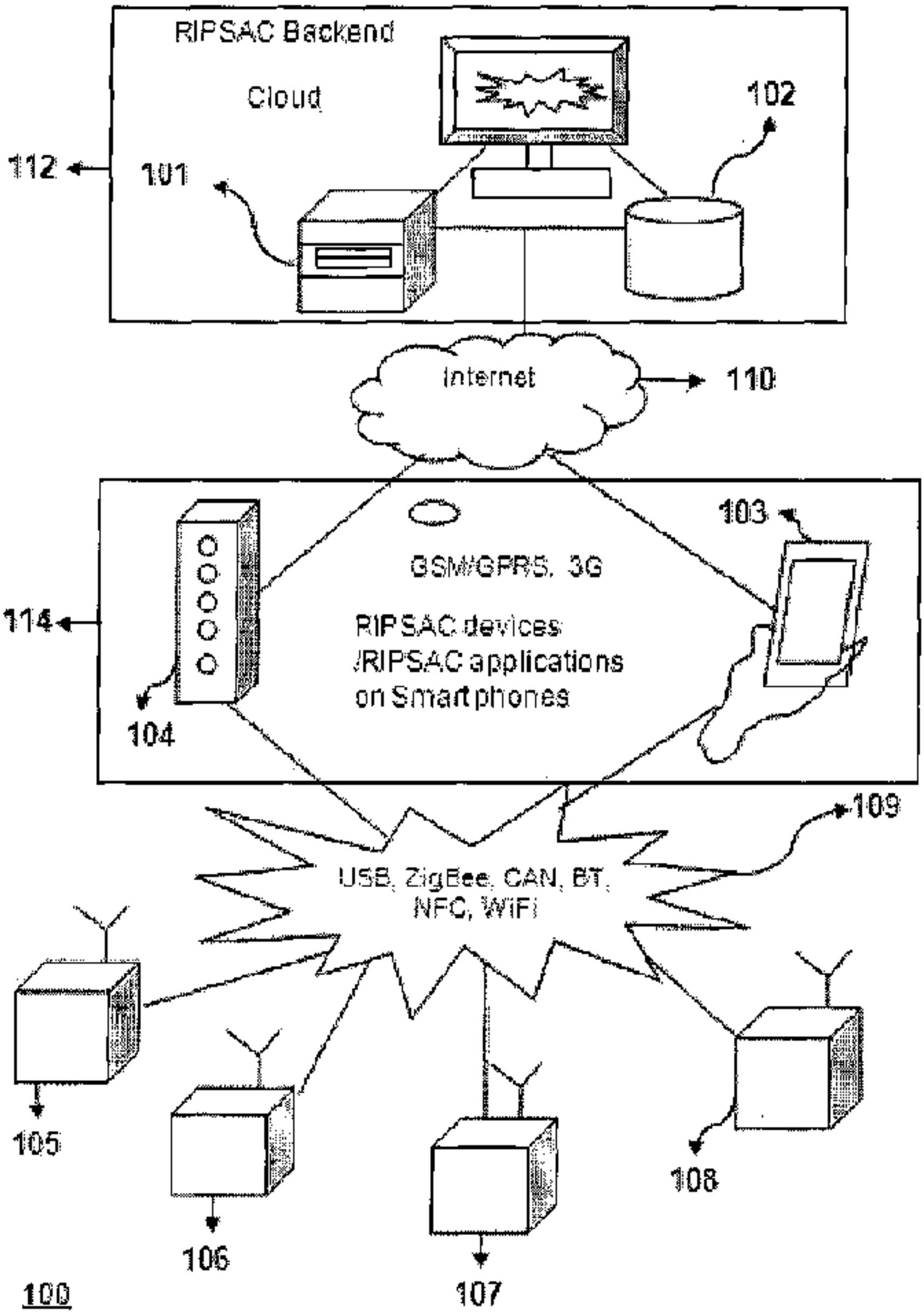

Start
501
Capturing sensor-data from diverse sensor devices
503
pre-processing the captured individual data to extract relevant sensor-based information
505
Performing real-time analytics on the stored aggregated sensor-based information is to derive insights, inferences and visualized data
507
Utilizing a set-of bundled services and algorithms in the RIPSAC is utilized to develop, test and deploy one or more sensor-based applications
End

Figure 5


RIPSAC Backend
Cloud
102
112
101
Internet
110
103
GSM/GPRS, 3G
114
RIPSAC devices
/RIPSAC applications
on Smartphones
104
109
USB, ZigBee, CAN, BT,
NFC, WiFi
105
106
107
108
100