DATA LOGGER AND SENTINEL PLATFORM FOR SENSOR NETWORK

[0001] The present application relates to a sentinel platform for a sensor network. The application also relates methods for making, assembling, installing, configuring, optimizing, upgrading, dismantling and using the sentinel platform. The sentinel platform is alternatively known as gateway sensor node, which is typically connected between remote sensor(s) and base station(s)/server(s). The sentinel platform may further be known as IoT (Internet of Things) sentinel platform for big data gathering and analytics.

[0002] Known platforms for sensor networks are sometimes deployed for monitoring natural ecosystems, such as forests, plantations and urban environment. These known platforms mainly rely on manual operations for data collection and analysis from geographically distributed sensors such that workers have to travel to these scattered sensors for retrieving data locally. Furthermore, many of the known platforms are designed for specific technical applications. Accordingly, these known platforms have diverse types of hardware, software and communication protocols such that the known platforms are complicated, expensive and difficult to manage, use, configure, modify or upgrade.

[0003] The present inventions aim to provide one or more new and useful devices or methods. Essential features of the inventions are provided by independent claims. Advantageous features are given by dependent claims. The present application further claims the priority of an earlier patent application US61/769,008 titled “Sentinel Platform for Sensor Network”, which was filed with USPTO (United States Patent and Trademark Office) on 25 February 2013. All subject matter or entire content of the earlier priority application is hereby incorporated by reference.

[0004] According to a first aspect, the present application provides a data logger or adaptor for one or more sensor networks. The data logger comprises a central processing unit (e.g. microprocessor) for electronic signal processing, a volatile or non-volatile memory device (or cache) connected to the central processing unit (CPU) for storing the data temporarily or permanently, an electronic circuit on a Printed Circuit Board or an integrated circuit (e.g. semiconductor chip) connected to both the

central processing unit and the memory device, and a power supply/source further connected to the electronic circuit for providing electricity to the data logger. The electronic circuit comprises an universal interface or universal interface module, which is configurable or programmable for connecting two or more different types of sensors simultaneously or sequentially via various communication modes. The universal interface or module is an electrical interface (hardware component) or an electronic interface device. The various communication modes may be encrypted or open. Accordingly, the data logger has the flexibility for adopting different types of sensors and their adaptors using different communication modes. The same data logger is suitable for adoption by wide variety of sensors in diverse industrial or agriculture fields. The adaptor may include a communication module (software program or hardware circuit), a sensor controller (software program or hardware circuit) or a power manager (software program or hardware circuit).

[0005] In the past, researchers and/or engineers have to select specific types or models of sensors from various manufacturers for predetermined applications. These specific types of sensors further require corresponding data logger and software programmmes for downloading data from the sensors in table, chart or pictorial formats. Highly skilled software programmer and electronic engineers are often required for setting up the purpose-dedicated sensor network, which tends to be expensive and technically difficult to implement. If the application requires multiple types of sensors (e.g. moisture sensors, light sensors, temperature sensors) for monitoring an environment (e.g. forest plantation), the researchers or/engineers have to manually connect power sources, the multiple types of sensors, their corresponding data loggers to one or computers. This arrangement is complicated and expensive, which often cannot provide real-time data feeding/input, such as synchronizing temperature, moisture and (solar) lighting condition data. Again, the highly skilled software programmers and electronic engineers tend to require additional working time and high manpower expenditure.

[0006] In contrast, the data logger of the present application can connect different types or models of sensors from various manufacturers of the sensors. The data logger may be connected to and shared by different types of sensor network simultaneously or sequentially. The data logger can be configured and/or calibrated to

operate the different types or models of sensors simultaneously or separately (e.g. sequentially) after connecting the different types or models of sensors to the universal interface. Although the different types or models of sensors may require diverse ranges of supply voltage, ADC resolution (e.g. 10 bit), dynamic range or other parameters, the data logger can be adjusted or configured to accept the different types or models of sensors through software configuration. Since the configuration is guided by the software on the data logger, implementation of the different types or models of sensors demands much less skills from users of the data logger. The highly skilled software programmers or electronic engineers may be avoided, providing wide user base to the different types or models of sensors by adopting the data logger of the present application. The ease of connecting multiple instruments through the plug-n-play data logger (Sentinel Core™) allows “layman” (users with less training on software programming) to implement multi-sensor applications. The data logger can also combine multiple power sources and power management algorithm to allow corresponding sensor networks to be self-powered reliably and work efficiently by increasing power source and decreasing power consumption. The data logger further enhances reliability and data rate (e.g. sampling rate).

[0007] The data logger avoids rigid configuration for providing a single type of communication mode. A data logger with a single type of communication mode is often made for task-specific sensor network. Such type of data logger does not have flexibility or adaptability for serving in one or more sensor network with different types of sensors having various modes of communications. In contrast, the present application provides the data logger that is configurable, modifiable, adaptable or upgradable for diverse types of sensors. For example, the different types of sensors include air temperature (thermocouple), humidity (optical, capacitive or resistive) and light intensity (photo-emissive, photo-conductive, photo-voltaic, photo-junction) sensors that are connected to their respective adaptors for having communication modes of ZigBee (IEEE 802.15 standard) and Wi-Fi (IEEE 802.11 standard).

[0008] In one embodiment, the data logger is installed with an operating system (software program) that scans or detects continuously, periodically or on-demand the presence of ZigBee or Wi-Fi signals from adaptors of the different types of sensors. The data logger identifies appropriate mode(s) of communication such that the data

logger can install or request to install suitable software programmes (e.g. driver software) for the corresponding sensors/adaptors. The suitable software programmes may be installed via internet or onsite. Accordingly, the data logger does not require specially trained or high-skilled computer programmer for installing, configuring or updating relevant programmes for the sensors and their adaptors. When some of the sensors or their adaptors are replaced or modified, the data logger can prompt a user or automatically install relevant software programmes for keeping the sensors at desired performance.

[0009] Since different sensor networks are designed to monitor different parameters with specific types of sensors, the different sensor networks operate independently and are not compatible to each other. In contrast, since the data logger according to the present application can communicate in different modes (e.g. Wi-Fi, ZigBee, Bluetooth), the data logger can serve or be shared by the different sensor networks. Device drivers, which relate to various adaptors for the different types of sensors, can be installed onto or removed from the data logger such that the data logger can serve as gateway nodes for multiple sensor networks concurrently, sequentially or in combination. The device driver (or simply driver) is a computer program that operates or controls a particular type of device that is attached to a computer. The data logger may automatically scan availability of the sensors or their adaptors for selecting, requesting, downloading or configuring corresponding drivers.

[0010] Alternatively speaking, the data logger can provide the function of plug-and-play to a sensor network having the different types of sensors. In computing, a plug and play device or computer bus, is one with a specification that facilitates the discovery of a hardware component in a system without the need for physical device configuration or user intervention in resolving resource conflicts. Plug and play devices can be due to boot-time assignment of device resources and to hotplug systems such as USB (Universal Serial Bus) and FireWire (IEEE 1394 standard).

[0011] The universal interface or module can be configured to detect connection/signal of a sensor for sensor configuration. The universal interface includes hardware components that may comprise antennas (e.g. dipole antenna, fractal antenna, loop antenna) or semiconductor chips (e.g. ZigBee module). Since

the data logger can be installed (e.g. embedded) with an operating system, the universal interface can be adapted to communicate with adaptors of the sensors with suitable communication modes. For example, a smoke sensor (ionization detectors and photoelectric detectors) has an adaptor with Bluetooth and ZigBee communication modes such that the data logger can connect to the smoke sensor via Bluetooth or ZigBee depending on availability.

[0012] The universal interface may comprise an analogue port (terminal adaptor), a digital port or both the analogue and digital ports for receiving analogue or digital signals from the sensors. For example, the analogue port can communicate signals in NTSC (National Television System Committee), PAL (Phase Alternating Line) or SECAM (Sequential Color with Memory) format. The digital port may be able to communicate with ZigBee, Bluetooth, Wi-Fi or other electronic devices with other standards.

[0013] The universal interface further can comprise a communication module that has a wired terminal (connector or input), a wireless terminal (connector or input) or both the wired and wireless terminal for connecting the sensors via the analogue port, the digital port or both the analogue and digital ports. The wired terminal is often used for data transmission with high transfer rates in a secured manner, whilst the wireless terminal is sometimes used for electronic signal communication for long distance (e.g. 10~100 meters) free from cable interference or entanglement.

[0014] The wired terminal may comprise a USB (Universal Serial Bus) terminal, a PoE (Power over Ethernet) terminal, a RS-232 terminal (serial terminal with 3-wire or 5-wire), a RS-232 express terminal/connector, a RS-485 terminal (TIA-485-A, ANSI/TIA/EIA-485, TIA/EIA-485, EIA-485 or RS-485ANSI/TIA/EIA-485-A-1998 standard), a parallel terminal (IEEE 1284 standard), a coaxial terminal (transmission line for radio frequency signals), an optical terminal (optic fiber), an Ethernet terminal (IEEE 802.3 standard), a FireWire terminal (IEEE 1394 standard), DSL terminal (Digital Subscriber Line), ADSL terminal (Asymmetric Digital Subscriber Line) or a combination of any of these terminals. More terminals or communication modes/modules may be added depending on availability and suitability. Accordingly,

the data logger has expanded capacity for connecting wide range of sensors, which are directly or indirectly (e.g. via adaptors) communicate with the universal interface.

[0015] The wireless terminal can comprise a Near Field Communication Terminal (e.g. radio-frequency identification RFID), a Wi-Fi terminal, a ZigBee terminal, a Bluetooth terminal, a GPRS terminal (General Packet Radio Service), an Edge terminal (1900 MHz (PCS) GSM network by Edge Wireless LLC), a 2G terminal (second-generation wireless telephone technology), a 3G terminal (third generation of mobile telecommunications technology), a 4G terminal (fourth generation of mobile phone mobile communication technology standards), a GSM terminal (Global System for Mobile Communications), a HSPA terminal (High Speed Packet Access), a CDMA terminal (Code Division Multiple Access), a WCDMA terminal (Wideband Code Division Multiple Access, UMTS-FDD, UTRA-FDD, or IMT-2000 CDMA Direct Spread is an air interface standard found in 3G mobile telecommunications networks), an UMTS terminal (Universal Mobile Telecommunications System as a third generation mobile cellular system for networks based on the GSM standard), a radio communication terminal, a LTE terminal (Long Term Evolution, as standard for wireless communication of high-speed data for mobile phones and data terminals), a SATCOM terminal (family of communications satellites originally developed and operated by RCA American Communications), a WiMax terminal (Worldwide Interoperability for Microwave Access as a wireless communication standard designed to provide 30 to 40 megabit-per-second data rates), a satellite network terminal, a VSAT terminal (Very Small Aperture Terminal), a MSAT terminal (Mobile Satellite as a satellite-based mobile telephony service developed by the National Research Council of Canada), a VHF terminal (Very high frequency as the ITU-designated range of radio frequency electromagnetic waves from 30 MHz to 300 MHz, with corresponding wavelengths of one to ten meters.), an UHF terminal (Ultra-high frequency designates the ITU radio frequency range of electromagnetic waves between 300 MHz and 3 GHz, also known as the decimetre band or decimetre wave), DSL, ADSL or a combination of any of these terminals.

[0016] The universal interface may further comprise one or more analogue to digital converters connected to the analogue port for converting analogue signals from the sensors to digital signals. Conversely, the universal interface may further comprise

one or more digital to analogue converters (e.g. modem) connected to the digital port for converting digital signals. The universal interface may further comprise a router for diverting communication among multiple sensors and their adaptors. The converts facilitate communication of the data logger for both analogue and digital signals, thus providing flexibility.

[0017] The power supply can comprise one or more connectors for receiving the electricity from onboard batteries, external power supplies or both. The power supply may provide multiple options for providing electricity to the data logger. For example, the power supply has connectors in the form of cable connections to UPS (uninterruptible power supply, uninterruptible power source, or battery/flywheel backup). The power supply may further incorporate safety features for preventing electric current surge, such as fuse, circuit breaker and lightning rods.

[0018] The data logger may comprise security interface for access, management or modification control. The security interface includes biometric authentication, user name and password control, fingerprint identification, face detection, DNA recognition, Palm print, hand geometry, iris recognition, retina and odour/scent check, which are various measures of computer security.

[0019] The present application provides a Sentinel Platform for a wireless or wired sensor network. The sentinel platform comprises the data logger, a base station having a microcontroller, microprocessor or computer connected to the data logger for managing the data, and a data storage device connected to the data logger, the microcontroller or both for data storage locally at the Sentinel Platform. The sentinel platform may be known as a gateway sensor node in the sensor network. The sensor network often includes spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the sensor network to the base station (computer server). In addition to the base station, the sensor network has sensor node (sensor connected with adaptor) and gateway sensor node (sentinel platform). Since the sentinel platform can communicate in different modes (e.g. USB or ZigBee) via the universal interface, the sentinel platform has the flexibility to be adopted by wide variety of sensor network. The sentinel network having an operating system

makes the sentinel work intelligent such that the sentinel platform can detect, recognize and communicate with the wide variety of sensor network, adaptors of the wide variety of sensor types or the wide variety of sensors directly. The base station may include a cloud manager (software program or hardware circuit), a data controller (software program or hardware circuit), a communication manager (software program or hardware circuit) or a power manager (software program or hardware circuit).

[0020] The Sentinel Platform can comprise a cloud platform that is connected to the microcontroller, microprocessor or computer for transferring data to a remote data storage device. The cloud platform may include a graphic or text user interface, a data analytics (software program), data manager (database software) or a cloud synchronization manager (application software or hardware circuit). The cloud platform enables the sentinel platform to transfer, process or analyze data collected by the sensors a remote place. The cloud platform further allows online or offline access by several users (engineers or scientists), maintenance technicians or network service providers.

[0021] The cloud platform may comprise wired or wireless terminal(s), such as a Near Field Communication Terminal, a Wi-Fi terminal, a ZigBee terminal, a Bluetooth terminal, a GPRS terminal, an Edge terminal, a 3G terminal, a 4G terminal, a GSM terminal, a HSPA terminal, a CDMA terminal, a WCDMA terminal, an UMTS terminal, a radio (communication) terminal, a LTE terminal, a SATCOM terminal, a WiMax terminal, a satellite network terminal, a VSAT terminal, a MSAT terminal, other satellite communication terminals or a combination of any of these terminals for data transmission. The cloud platform thus has the many options for conveying data or electronic signals such that the sentinel platform can work independently or cooperatively with other sentinel platform or sensor network.

[0022] The Sentinel Platform can further comprise a text or graphic user interface for controlling or monitoring the sensors. The user interface is optionally installed onto or accessed by the cloud platform. The graphic user interface provides intuitive operation by third parties (e.g. engineer, technician) such that an untrained or ordinary user (having programing skills) can operate the sentinel platform easily.

[0023] The user interface may comprise a CRT (Cathode Ray Tube), LCD (Liquid-Crystal Display) or touchscreen display, a keyboard, a computing mouse, a barcode or RFID scanner, a memory card reader, a biometric reader, a printer, a gesture recognition device, adaptable and adaptive user interface for disabled or a combination of any of these. The various types of user interface offer convenient access to users with different preference.

[0024] The sentinel platform can further comprise a power source for providing electricity. The power source may include a power harvester that gleans or stores solar power, thermal energy, wind energy, salinity gradients, and kinetic energy for small, wireless autonomous devices. Thus, the sentinel platform or the sensor network can operate autonomously or have self-diagnose or correction abilities.

[0025] In practice, the power source may comprise one or more batteries, solar panels, electricity generators connected to a wind turbine or water turbine, biomass electricity generators, biofuel electricity generators, geothermal electricity generators, piezoelectric elements or a combination of any of these. The different types of the power sources can be made available to suit operating conditions of the sensor networks or sentinel platforms. For example, a sensor network for forest research can employ solar panels that are installed on a mast above tree canopies.

[0026] The base station can be configured or programmed to manage or supply electricity supply to components of the sentinel platform according to predetermined priority level or sampling rate. For monitoring a specific environment, many different types of seniors are often deployed for data collection. These sensors can be selectively configured for collecting data of the specific environment. For example, in forest research, sensors are installed for observing temperature, moisture, tree sizes, light intensity of the forest. The base station can configure on/off, sampling rate and data transfer rate of these sensors. In case of energy shortage, the base station can turn off some of the sensors for reducing power consumption. The base station can further send signals to remote places for requiring assistance or human onsite service.

[0027] The present application provides a sensor network that comprises geographically scattered sensors for collecting data, and one or more of the data

logger, and one or more of the Sentinel Platform. Multiple sensor networks may share one sentinel platform. Alternatively, multiple sentinel platforms may be shared by different sensor networks. The sensor network can provide area monitoring, healthcare monitoring, air pollution monitoring, forest monitoring, landslide monitoring, water quality monitoring, natural disaster monitoring and machine health monitoring.

[0028] The sensor network may comprise one or more relay node for increasing signal strength of the sensors or their adaptors. The relay node may communicate with other sensors, relay nodes, the sentinel platform, the base station or the cloud platform. Accordingly, the relay node extends communication network of the sensor network.

[0029] The sensor network can further comprise two or more different types of sensors for monitoring. The different types of sensors are suitable for providing diverse type of data for monitoring different environments.

[0030] According to a second aspect, the application provides a method of using a data logger. The data logger may be provided by the application as mentioned in the present application. The method comprises a step of installing, configuring or uninstalling/removing one or more software programs according to designated sensor, and a step of selecting communication channels of the designated sensor. Since the data logger can communicate with different types of sensors or their adaptors, an operating system or device drivers of the data logger may offer options for detecting, selecting, installing or configuring relevant programmes of the sensors or their adaptors. The various operations (e.g. detecting) may be conducted manually, automatically or in combination such that the data logger can be flexibly used for different sensor networks.

[0031] The method further may comprise a step of applying power plan, such as setting priority level or sequence, adjusting sampling scheme or both to designated sensor(s). Different operation parameters of a sensor, sentinel platform or sensor network may be changed manually or automatically to suit operating requirement, resource availability (e.g. battery level) or user preferences.

[0032] According to a third aspect, the present application provides a method of using a sentinel platform. The sentinel platform may be presented as mentioned in the present application. The method comprise a step of determining power plan, communication channels, data recording format, sensor types for the sentinel platform. Accordingly, the sentinel platform can be configured to adapt different user requirements, sensor types and data communication situations.

[0033] The method can comprise one or more steps of installing, configuring, updating or removing drivers for different types of sensors. Since the sentinel platform can accept diverse types of sensors such that the sentinel platform or a sensor network with the sentinel platform can evolve with the progress of sensor technologies.

[0034] According to a fourth aspect, the present application provides a method of installing a sentinel platform or the sentinel platform as described which comprises a step of mounting the sentinel platform on a frame for providing communication of the sentinel platform free from ambient interference such as water, dust or physical blockage (e.g. tree canopy obstructing radio waves). The frame also holds and protects components of the sentinel platform such that the sentinel platform can operate safely. For example, the frame comprises a plastic casing that has Ingress Protection Rating of level 6. External rain or dust is prevented from interfering operation of the sentinel platform.

[0035] The method may further comprise a step of connecting an antenna, a camera, power source, data logger or any of these onto the frame.

[0036] To facilitate research of forests and plantations, the sentinel platform may have data analytics (software programmes), custom sensor integration and device management capabilities.

[0037] According to a fifth aspect, the present application presents a Sentinel platform that may provide real-time monitoring of the environment using wireless sensor networks. The Sentinel platform can comprise a Base Station, a Cloud Platform, an Adaptor, a Sensor and Data analytics. With this platform, researchers can obtain real-

time data from sensors installed at remote locations. The platform offers an interface universal for receiving and analyzing data from multiple sensors of the diverse types. The platform provides the possibility of connecting to an unrestricted number of sensors positioned at long distances, especially in dense vegetation.

[0038] The sentinel platform can comprise a cloud platform for storing data onto a remote data storage device, a base station for managing data flow, and an adaptor having an universal interface to connect one or more types of sensors. The universal interface has variety of ports for connecting to the sensors via cables or wirelessly. The cloud platform, the base station and the adapter are connected to each other for receiving, processing and storing data collected by the sensor.

[0039] Since the universal interface has been introduced, a wide variety of communication modes between the sensors and the sentinel platform have been provided. The communication modes include Wi-Fi (based on IEEE 802.11), ZigBee (based on IEEE 802.15 standard), UHF (Ultra-High Frequency), VHF (Very High Frequency), NFC (Near Field Communication), RFID (Radio-Frequency Identification), satellite communication, and Internet. The sensors can be connected to the sentinel platform via ZigBee, USB, Serial (RS232), Power over Ethernet (PoE). The sentinel platform further is installed with a software package that has data analytics capability. The software package further enables the sentinel platform to monitor and control power distribution, power consumption and data communication.

[0040] The software allows a user to easily add a sensor to the platform, and this data can be viewed in a similar format and interface as the other sensors connected. This consistency facilitates data analysis and further data processing.

[0041] The adaptor can be configured to connect a sensor for monitoring visual or auditory information, a sensor for monitoring atmospheric condition, a sensor for monitoring gaseous samples, a sensor for monitoring soil parameters, a sensor for monitoring plant-related parameters, a sensor for monitoring water-related parameters, or a combination of sensors of any of these.

[0042] The adaptor or the universal interface comprises the ports with a serial interface according to IEEE1394, a parallel interface according to IEEE1284, or a combination of any of both.

[0043] The interfaces may comprise Wi-Fi interface, a ZigBee interface, an Ethernet interface, a FireWire interface, an USB interface, a PoE interface, a VHF (Very high frequency) interface, a UHF (Ultra-high frequency) interface or a combination of any of these interfaces for data transmission.

[0044] The sentinel platform can further comprise one or more relay nodes for increasing signal strength of the sensors for improving data reception by the adaptor. The cloud platform may be configured to communicate with sensors or a central server of the sensors wirelessly. The cloud platform can be configured to communicate to users wirelessly. The cloud platform may comprise an user interface for controlling or monitoring the sensors.

[0045] The adaptor can comprise a data storage device for storing data locally at the sentinel platform. The adaptor may further comprise a data communication port for storing data onto remote storage device. The adaptor can include an internal or external power source for powering the sentinel platform. The power source may be configured to supply electric power to components of the sentinel platform according to predetermined priority level. The power source can comprise a battery, a solar panel, an electricity generator or a combination of any of these.

[0046] The electricity generator can comprise a wind turbine, a hydroelectricity generator, a biomass electricity generator, a biofuel electricity generator, a geothermal electricity generator, or a combination of any of these.

[0047] The application may provide a sensor network that includes the sentinel platform and sensors connected to the sentinel platform.

[0048] The accompanying figures (Figs.) illustrate embodiments and serve to explain principles of the disclosed embodiments. It is to be understood, however, that these

figures are presented for purposes of illustration only, and not for defining limits of relevant inventions.

[0049] Fig. 1 illustrates an architectural diagram of a sentinel platform;
Fig. 2 illustrates components of an adaptor;
Fig. 3 illustrates a process diagram of data collection and pre-processing;
Fig. 4 illustrates a flowchart diagram of sentinel data processing and Graphic Unser Interface (GUI);
Fig. 5 illustrates a sentinel power and communication management flowchart diagram;
Fig. 6 illustrates a workflow diagram of Data Analytics;
Fig. 7 illustrates an ambient energy harvester;
Fig. 8 illustrates the sentinel platform;
Fig. 9 illustrates a data logger of the sentinel platform; and
Fig. 10 illustrates the sentinel platform in a sensor network.

[0050] Exemplary, non-limiting embodiments of the present application will now be described with references to the above-mentioned figures.

[0051] Fig. 1 illustrates the architecture diagram of a Sentinel Platform 20. The sentinel platform 20 includes a base station 22, an adaptor 24, a cloud platform 26 and a sensor 28 and data analytics 36. The sentinel platform 20 connects and transmits information between a central server (not shown) and distributed sensors 30. The sensors 30 are scattered in a forest at various geographical places. The base station 22 collects data from the sensors 30 and transmits the data to the central server. The central sever resides on the cloud platform (cloud). Alternatively, the central server is provided by a Personal Computer that can be operated online or offline.

[0052] Here, the cloud platform 26 relates to cloud computing for describing a variety of computing concepts, which involves a large number of computers connected through a real-time communication network such as the Internet. The cloud computing relates to distributed computing over a network, and means the ability to run a program or application on many connected computers at the same time. The

cloud computing further refers to network-based services, which are provided by real server hardware, and are served up by virtual hardware, simulated by software running on one or more real machines. Such virtual servers may not physically exist and can therefore be moved around and scaled up (or down) on the fly without affecting the end user - arguably, rather like a cloud.

[0053] Referring to the sensors 30, the Sentinel platform 20 utilizes the sensors 30 to monitor the overall temperature of the forest and operation conditions of the Sentinel platform 20. The sensors 30 include temperature sensors that are bimetallic or electrical sensors, thermistors and thermocouples. The electrical sensors further include hall-effect sensors, current clamps and resistors.

[0054] The Sentinel platform 20 is connected to the wide variety of external sensors 30 for monitoring corresponding parameters. Examples of the sensors 30 are presented in a non-exhaustive list below:

1. Sensors monitoring visual or auditory information including:
    1) Live subjects under aerial/terrestrial/marine conditions (e.g. Using sound to identify animal species; Camera traps to determine movement habits of animals; Taking underwater videos of fishes);
    2) An area or still subjects, for the purposes of observing any changes of interest (e.g. Observing an area for suspicious activity; Monitoring a structure for seismic changes); and
    3) Any subject of interest using either single or combination of wavelengths from the electromagnetic spectrum, with devices that can capture/receive/record like detector/receiver/cameras, for spectral imaging techniques like radio detection and ranging (radar), light detection and ranging (LIDAR) and moderate-resolution imaging spectro-radiometer (MODIS).

2. Sensors monitoring atmospheric conditions including:
    1) Temperature and heat flux measurements like thermometers and heat flux sensors;
    2) Humidity measurements like hygrometers and psychrometers;

3) Pressure measurements like barometers;
4) Precipitation of rain and snow like tipping bucket rain gauges or flow gauges;
5) Wind speed measurements like anemometers;
6) Wind direction measurements like wind vanes; and
7) Solar radiation measurements, including and not limited to visible light, ultraviolet (UV-A, UV-B, UV-C), infrared (NIR, MIR, FIR), photosynthetic active radiation (PAR), photosynthetic photon flux (PPF) or photosynthetic photon flux density (PPFD) using radiometers, pyranometers, pyrheliometers, solarimeters and quantum sensors.

3. Sensors monitoring gaseous samples including:
1) Concentration and detection of volatile organic compounds, hydrocarbons, carbon dioxide, carbon monoxide, oxygen, water vapour, SOx gases and NOx gases using devices such as non-dispersive infrared (NDIR) spectrometers; and
2) Gaseous flux measurements such as carbon dioxide, hydrocarbons and water vapour fluxes using methods like eddy covariance.

4. Sensors monitoring soil parameters including:
1) Temperature and heat flux measurements like thermometers and heat flux sensors;
2) Water potential or volumetric water content of the soil using methods like frequency domain or time domain reflectometry;
3) Water tension measurements like tensiometers;
4) Groundwater elevation measurements like piezometers;
5) pH measurements like pH electrodes and meters;
6) Nutrient detection of parameters like nitrogen (N), phosphorus (P), potassium (K) using potentiometric electrochemical methods; and
7) Carbon dioxide flux measurements like gas chamber sensors.

5. Sensors monitoring plant-related parameters including:
1) Temperature measurements like thermometers;

2) Water potential measurements like hygrometers and psychrometers;
3) Hydraulic conductance measurements like flow meters;
4) Leaf area index measurements like ceptometers;
5) Leaf wetness measurements using methods like frequency domain, capacitive or resistivity sensing;
6) Leaf porousness measurements like porometers;
7) Leaf physiology such as colour measurement, chlorophyll and plant pigment (e.g. anthocyanin, carotenoids) concentration using devices like spectrometers;
8) Structural integrity using methods like sonic tomographs;
9) Stem and fruit measurement like dendrometers;
10) Plant canopy imaging using methods like hemispherical photography;
11) Photosynthesis measurements using sensor systems which typically contain carbon dioxide and water vapour gas analysers; and
12) Sapflow measurements using methods like thermal dissipation (TD), compensation heat pulse method (CHPM), heat ratio method (HRM) or heat field deformation (HFD).

6. Sensors monitoring water-related parameters including:
1) Temperature measurements like thermometers;
2) Pressure measurements like barometers;
3) Water level or depth measurements using devices like pressure transducers, acoustic or radar sensors and float switches;
4) Area velocity flow measurements using devices like mechanical, pressure, optical, thermal mass, vortex, electromagnetic, acoustic, corolis flow meters;
5) Light intensity measurements like spectrometers;
6) Conductivity/salinity measurements like amperometric, potentiometric or inductive sensors;
7) Dissolved oxygen measurements like optical or electrochemical sensors;
8) pH measurements like pH electrodes and meters or spectrometers
9) Turbidity measurements like turbidimeters, nephelometers or spectrometers;

10) Total suspended solids (TSS) measurements like spectrometers;
11) Colour, coloured dissolved organic matter (CDOM), fluorescent dissolved organic matter (fDOM) measurements like spectrometers
12) Chemical oxygen demand (COD) measurements like electrochemical, photocatalytic sensors or spectrometers;
13) Biochemical oxygen demand (BOD) measurements like manometric sensors or microbial fuel cell type biosensors;
14) Total organic carbon (TOC) measurements using methods such as oxidation (chemical, thermal or photocatalytic) with detectors like conductivity and NDIR spectrometers;
15) Dissolved organic carbon (DOC) measurements like NDIR spectrometers or biosensors;
16) Assimilable organic carbon (AOC) measurements like spectrometers or biosensors; and
17) Concentration and detection of chemical or organic compounds such as potassium ions, fluoride ions, metals and metalloids, free/total chlorine, ozone, hydrogen sulphide, nitrate and nitrites, ammonium, phosphates, benzene, toluene, ethylbenzene, xylene (BTEX), naphthalene, styrene, rhodamine, chlorophyll and organic constituents absorbing UV wavelength 254nm (UV254) using devices such as spectrometers.

7. Sensors monitoring human activities and conditions through their personal electronic devices, such as hand-phones (mobile phone or cellphone), tablet computers or notebook computers by sensing the presence of following electronic signals emitted from these personal electronic devices.
   1) Bluetooth Sensor
   2) WiFi Sensor
   3) 3G Sensor

[0055] The sensors 30 include some sensors with contactless tags, such as a Radio-frequency identification (RFID) Tag. Some of the sensors 30 communicate with the Sentinel platform 20 or the central server directly. Some of the sensors 30 or adaptor

24 has in-built Global Positioning Systems (GPS) respectively. Data transmitted by the sensors 30 are in various formats such as HTTP, PHP, txt, excel, CSV, GIS file formats. The data is compatible with a GIS (Geographic Information Systems) software. The sensors 30 include analog, digital or wireless sensors. Some of the sensors 30 are connected to the adaptor 24 via one or more cables or wires. Some of the sensors 30 are connected to the adaptor 24 via WiFi, ZigBee, serial (RS 232), Bluetooth (2,400~2,483.5 MHz) or USB (Universal Serial Bus). The adaptor 24 includes microcontroller 25, sensor controllers 27 and communications modules 29 and Power Management Module 31. The adaptor 24 transmits the data from the sensors 30 to the cloud platform 26 through the base station 22.

[0056] According to Fig. 1, the Cloud Platform 26 includes a Cloud synchronization manager 32, a data manager 34 for conducting data analysis, a data analytics 36 and a Graphic User Interface (GUI) 38. Communication between the sensors 30 and the adaptor 24 of the Sentinel platform 20 is done via the near field communications, WiFi, ZigBee, USB, POE (Power-Over-Ethernet), Bluetooth or serial port. There exists relay nodes (not shown) between the sensors 30 and the adaptor 24 of the platform 20 for increasing the signal strength of the communication. The Sentinel platform 20 includes a wireless sensor network that comprises a plurality of sensor nodes, relay nodes and platforms. Communication between the wireless sensor network 30 and the central server has been established via GPRS (General Packet Radio Service), Edge (Enhanced Data Rates for Global System for Mobile Communications Evolution), 3G, 4G, UMTS (Universal Mobile Telecommunications System), radio frequencies or similar technologies over cellular network or a wireless broadband data communication service, such as WiMax (Worldwide Interoperability for Microwave Access), or a satellite network such as Inmarsat, VSAT (Very Small Aperture Terminal), MSAT (Mobile Satellite).

[0057] Data over the cellular network is collected and transferred to the Cloud platform 26 using Internet protocols such as TCP (Transmission Control Protocol) and/or UDP (User Datagram Protocol) by a mobile phone operator. The Cloud platform 26 communicates the information to users through computers, mobile phones and laptops. To access the data, users can either install software packages on their laptops or mobile phones, or access the data directly through a website.

[0058] The Cloud Platform 26 is in a form of software or website that enables data display via the User Interface 38 and the Data Analytics 36. The Cloud platform 26 enables the users to develop communication protocols with a sensor. The Cloud Platform 26 has different levels of access for administrator, member and guest. The users can control the functions of the sensors 30 through this Cloud Platform 26, such as switching on/off, changing directions of monitoring, sampling rates of the sensors 30, and logging rates. The logging rates refer to rates at which data points are saved. The logging rates differ from sampling rates at which data points are sampled, but may not be saved. The users can monitor the operating conditions of the sensors 30 such as their temperature, power consumption, current and voltage.

[0059] According to Fig. 1, the base station 22 collects all the information from the sensors 30 and transmits them to the central server. The platform 20 also communicates the information from the central server to the sensors 30.

[0060] The base station 22 includes of the following inter-connected components:

1. Supporting structure
2. Enclosure, cover, housing or casing
3. Solar Panels
4. Antennas
5. Routers
6. Computers
7. Electronic Adaptors
8. Batteries
9. Charge controllers
10. Switch boards
11. Generators
12. POE (Power Over Ethernet) switches
13. Electronic converters and inverters
14. Lightning conductors
15. Wired fence
16. Electrical wiring
17. Global Positioning System

18. Sensors
19. Power Harvester (e.g. solar panel, wind turbine)

[0061] A supporting structure of the Sentinel Platform 20 includes a tower frame made of metal or wood that rises above the canopy of the trees. This enables the solar panels to be placed at a height above a tree canopy such that the solar panels can receive solar power. The frame is rapidly collapsible and portable by a user. The frame further comprises a self-propelled and self-raising mast.

[0062] The Sentinel platform 20 is covered by the housing which forms an enclosure. The housing is made of metallic plates, frames and organic polymer films. Construction materials of the housing include aluminum, steel and stainless steel. The enclosure adheres to an IP (Ingress Protection) rating so that the components of the sentinel platform are protected against external disturbance (e.g. sunshine, rain and falling leaves) for working optimally and continuously. The Sentinel platform 20 has IP66 rating such that components in the enclosure are dust tight and can withstand powerful jets of water. The enclosure could also have temperature management features, such as, louvers, fans, heat panels, air-conditioning and thermostats.

[0063] The solar panels collect and convert solar energy into electrical energy. The energy is used to power the system components or charge the batteries. The solar panels are usually placed at an angle to capture the most solar energy. Examples of batteries are lithium-based, lead acid, alkaline, fuel cells, nickel-based, polymer-based, Sodium-based, Zinc-based. The antenna includes a directional and Omni-directional antenna. The antenna will transmit and receive data between the sensors, adaptors, satellite, base station and internet. The generators help to provide additional power. They can be electric or gas-driven generators. The fence helps prevent intrusion of humans and animals. The components in the sentinel platform 20 are powered by three forms of energy - solar power from the solar panel, battery power and power from the generator. There could be other forms of energy, for instance, piezoelectric energy, wind energy, hydroelectricity, biomass, biofuels, and geothermal energy.

[0064] Fig. 2 shows components of the Adaptor 24. The power harvester regulates the charging drawn by the batteries from the power harvester (e.g. solar panel) and/or other means. Power is also supplied via the charge controller to the 3G (Third Generation) Modem (modulator-demodulator), Microcontroller (MCU), WiFi Access Point and ZigBee. The MCU provides power and communicates data with the connections via Serial (RS232), Serial (RS485) and Analog Sensors.

[0065] The Adaptor 24 accepts the sensors 30 with a standard interface of the following:

Analog sensors which output current or voltage with respect to the measured parameter

1. Serial (RS232/RS485) sensors which send TTL (0-3.3V) and (+-12V) signal as raw data or ModBus protocol
2. ZigBee sensors
3. WiFi sensors
4. PoE sensors
5. Bluetooth sensors
6. Proprietary Sensors from major manufacturer such as:
    1) MEMSIC eKo Series
    2) Onset HOBO Series
    3) Any other commercial proprietary sensors

[0066] The adaptor uses RS232 Express technique for downloading data from some of sensors. This technique implements a simple framed protocol over a serial data line to allow aggregation of the buses in order to increase bandwidth. The protocol also allows the graceful degradation of the link when the physical link layer is affected by inclement weather or electrical interference.

[0067] The advantage of aggregating serial data links is its ready availability through the use of microcontrollers using hardware serial transceivers, software serial libraries, or other “bit-banging” strategies. This allows the ad-hoc scaling of a link’s bandwidth through software methods by aggregating serial links together to fulfil a high bandwidth transmission. The individual serial data links can be turned off to economize on power, or re-allocated to other high-bandwidth transmissions.

[0068] In contrast, the implementation of a high-bandwidth link has significant limitations on costs; requiring costly transceivers, antennae, cables which may have significant range limitations and implementation complexities. Such high bandwidth links cannot be split ad hoc into separate channels, or have its bandwidth scaled back ad-hoc in close to direct proportion to its power draw in order to save power.

[0069] The technique calls for the creation of a simple data frame that supports addressing, frame enumeration, and link enumeration. A simple error control protocol would allow ARQ (Automatic Repeat reQuest) with provisions for ACK and NAK or each packet. Data coding such as Hanning codes would be transparent to and be optionally provided for by the link.

[0070] The signaling protocol for the data link layer varies according to specific applications. An example would be simple RS-232 like protocols implemented at 5V TTL signaling levels by the software serial libraries of a microcontroller. The physical layer might be wireless or wired. In an example wireless implementation, it might be carried over a low-power ZigBee (IEEE 802.15.4) transceiver. In an example wired implementation, it might be carried over twisted pair Cat5e cables using RS-485 signaling.

[0071] The Adaptor 24 consumes very little power and is able to last a few years with the minimum sampling rate. The Adaptor 24 stores the data collected from the sensors 30 on a local storage which may be (SD Card, Micro SD Card, portable USB storage, SATA HDD, or any other form of nonvolatile data storage devices). This data may then be abstracted via a portable storage drive, Ethernet, FTP, HTTP, SD Card. This data may also be sent over wireless means (3G/GPRS/GSM/CDMA/WiMax/LTE/4G/SATCOM) to the internet. This data may also be sent over Ethernet to the tower which will consolidate all data to be sent to the internet. The Adaptor 24 may be powered by battery, solar or any external power source. The adapter 24 uses solar energy during the day and excess power from the solar panels will be used to charge the battery. At night, the adapter will draw power from the battery. Other external power sources are used to charge the battery when necessary. The charge controller regulates the solar power to charge the battery in an

efficient manner. The MCU controls the adapter 24 and collects data from the sensors 30, process it before sending the data to the tower or directly to the internet. The 3G modem provides 3G/HSPA/GSM/WCDMA connection to the internet. An external antenna may be used to provide better signal strength. The WiFi AP provides WiFi a/b/g/n connection to the tower as well as allows the sensors 30 to connect to the AP. The WiFi AP will act as a bridge to connect WiFi sensors to the tower. The Adaptor 24 will also provide power to the sensors 30. The Adaptor 24 also has smart power management to change sampling rate and data transmission rate based on available power resource and bandwidth. The Adaptor 24 can be in resource optimization mode to maximize on time or it can be in data collection mode which will collect as much data as possible up to per minute frequency. The Adaptor 24 can be used either standalone by sending data directly to the cloud via 3G or internet-connected WiFi or it can send data to the Sentinel platform via ZigBee, USB/LAN, Bluetooth, WiFi, etc.

[0072] Fig. 3 illustrates a diagram of data collection and pre-processing by the microcontroller (MCU). The data from the sensors 30 can be sent to the MCU either through the active method or the passive method. In one mode, the sensors 30 keep sending data to the MCU at regular interval. In another mode, the MCU polls the sensors 30 for data at regular interval. The MCU stores the data, the date and time of the data collected and the sensor identification into a local storage. The MCU further checks internet connection regularly. If the internet connection is available, the MCU sends the data to the web server and update the local storage to flag that the data record is uploaded to the web server. The data will be stored on the MCU and once max capacity is reached, the oldest record that was uploaded to the web server will be purged to make storage space for new data. Data will not be deleted unless there is insufficient space on the MCU. Data may be sent via http GET/POST (Request methods of Hypertext Transfer Protocol) or through custom TCP (Transmission Control Protocol) socket programming.

[0073] With reference to Fig. 1, the Cloud Platform 26 hosts the database and the different applications supporting the Graphical User Interface (GUI) 38. The cloud synchronize manager 32 listens for raw data from the remote sensors 30 at a determined periodic rate and insert them into a temporary storage within the cloud (remote data storage device). The communicate link between the cloud and the

remote devices/sensors 30 can be via 3G, Satellite, WiFi or any other commonly used commercially available communication networks. The data manager 34 will then decode the raw data stored into a recognizable format to be inserted into a database.

[0074] The GUI 38 hosted in the cloud platform 26 enables users to access the interface whenever the Internet access is available. As such, the hardware supporting the cloud platform 26 is configured to an optimal level for multiple users logging as well as intensive processing within the GUI 38, such as retrieval of data within a time range from a huge database.

[0075] The GUI 38 has the typical features of login system, backup and print functions, forms entry, graphical displays and tabulations viewing. Fig. 4 provides further details of the flow process of the GUI 38. Some applications supporting the GUI 38 such as periodically checking of inactive logins and computation of data from proven equations will also be run at a pre-determined time for maximum efficiency in cloud server resource usage. Another unique function handled at the cloud platform 26 is the smart management of power and communication at the base station 22. To make use of the limited power and communication available provided on-site, the GUI 38 allows an administrator to set priority and preferred settings according to experimental importance for maximum efficient in power and communication bandwidth usage. The details of the flow process of the power and communication management can be found in Fig. 5.

[0076] The data analytics 36 is a standalone module integrated within the GUI 38. As such, processing from the analytics 36 will be done via the cloud platform 26 upon input of user-defined parameters via the GUI 38.

[0077] In a nutshell, the cloud platform 26 is the “exchange center” between the raw data from different remote devices deployed all over the place, and the processed data displayed in the form of tables and graphs in the GUI 38.

[0078] Fig. 4 illustrates a Data Processing and GUI Flow Diagram of the Sentinel Platform 20. According to Fig. 4, the data processing and flow at the Sentinel Platform 20 has following features:

1. Data collected from the multiple sensors 30 at different intervals depending on the settings;
2. Data stored in local storage for each sensor;
3. Invalid data is removed;
4. Data from local storage sent to the database in the cloud whenever there is communication or whenever the sending to cloud function is activated based on condition met;
5. During data insertion into database in cloud, data is stored according to their tower_id and device_id;
6. Forest Sentinel GUI will be connected to the database in the cloud;
7. Login page upon accessing the Forest Sentinel Web Portal (FSWP);
8. Successful login directs user to main page of FSWP (1_FSWP);
9. 1_FSWP displays tower daily statistic of battery and communication information;
10. 1_FSWP displays tower daily graphs based on daily statistic of battery information;
11. 1_FSWP displays Tree-Like Menu (TLM) of all the connected devices;
12. 1_FSWP displays a permanent Header Navigation Menu (HNM);
13. TLM directs user to the Device's Data Page (DDP) upon clicking a particular device in the TLM;
14. Default data display is for the current time;
15. DDP displays the Device Tabulated Data (DTD) as well as the Device Graph Data (DGD);
16. DTD displayed 20 items per page;
17. DGD allows graphs comparison between any 2 metrics;
18. Both DTD and DGD allows date range input to display data within the time range specified;
19. One of the options in HNM directs user to DDP with the TLM;
20. HNM allows user to logout of the GUI;
21. HNM allows user to install, remove and edit devices to the forest Sentinel;
22. HNM allows direction of user to the location map of the devices connected; and
23. HNM allows direction of user to the Devices Informatory Page (DIP).

[0079] Fig. 5 illustrates a Sentinel Power and Communication Management Flow Diagram. The Sentinel Power and Communication Management have following features:

1. Input power from external power source;
2. Based on different priority level of devices set, the available power is assigned to power those currently active devices;
3. One or more groups of devices may be assigned a dedicated power percentage X% with the rest of the remaining power (100-X)% assigned to the others according to their priority level;
4. Each group with a priority level is assigned a weight Wpow;
5. Based on the weight of each priority group, an algorithm Y is used to assign the corresponding power to all the devices in each group;
6. The power assignment for each device in each group may be done in a round robin fashion (with Wpow = 1);
7. Data may be send to the database in cloud from the local storage of each device based on a certain condition met which is related to the communication signal strength;
8. Based on the priority level of devices which may or may not be the same as compared to that in power assignment, each priority level is assigned a minimum signal strength required for transmission;
9. The minimum signal strength required is determined by taking the difference between the maximum signal strength and the signal strength weight of each priority group;
10. The top priority group weight should be the largest and decreases as the priority of each group decreases; and
11. Data from devices in all priority groups with minimum signal strength required lesser or equal to that of the current signal strength will be sending to the database in the cloud.

[0080] Referring to the Data Analytics 36, data acquired from the remote sensors 30 has a lot of practical applications if processed in specific situations. These data are collected on-site using various sensors 30 and are sent to an online database for further processing. By constructing algorithms and software, these data can be used to produce useful output such as research studies or actionable items.

[0081] Fig. 6 illustrates a workflow diagram of the Data Analytics 36. According to Fig. 6, the fate of raw data eventually leads to a specific form of application, but may be used directly or processed and analyzed before application.

[0082] In Fig. 6, Raw Data refers to native data derived from an electronic device such as a sensor, which may include any form of processing that is intrinsically done within the device.

[0083] In Fig. 6, processing refers to manipulation of the raw data derived upstream, directly or indirectly, to transform data with the goal of highlighting useful information, suggesting conclusions, and supporting decision making. Examples of the processing are:

1. Diagnostics of data, including detecting outliers or errors in the readings; interpolation of data to replace errors and missing samples; extrapolation of data to extend dataset beyond existing range;
2. Selection of desired data, including extraction of data (e.g. Extracting data systematically through specific criteria) or filtering to exclude unwanted readings (e.g. Removing all readings with “0” or null);
3. Classification of datasets to specific categories for improved handling;
4. Visualization of data in 2D or 3D involving multiple datasets, resulting in tables, charts, graphs, plots, maps and other visual models;
5. Descriptive Statistics, summarizing and describing collections of data (mean, mode, median, averages, ratio, proportion etc.) which may be used for inferential statistical analysis to draw conclusions from the data;
6. Correlation between datasets, including regression analysis, factor analysis, principal component analysis, correspondence analysis and their derivatives;
7. Trend Estimation, including time series, method of least-squares and goodness-of-fit; and
8. Modeling, conceptualization or realization of mathematical or scientific ideas involving methods such as functions, algorithms and simulations or abstraction and modularization respectively.

[0084] In Fig. 6, Application refers to the deliberate usage of information derived from data to specific purposes. Examples of the application are:

1. Research, to gather data, analyze and generate useful conclusions which may result in a publication;
2. Assessment and validation of methods, equations and models, to use field data derived from sensors to evaluate accuracy, sensitivity and robustness;
3. Forecasting to predict the outcome of future events through statistical methods such as trends, correlations and regression analysis to achieve either probabilistic or ensemble forecasting. Examples include climate conditions, biodiversity parameters like population change, migration studies, physical measurements;
4. Surveying of the site using visual data and other modeling techniques to support mapping, planning and design purposes, including experiment planning and execution;
5. Surveillance, from real-time or periodic data collection in situ to identify changes in trends, which may result in dissemination of information to initiate investigative or control measures. Examples include systematic monitoring (e.g. Early warning system for disasters, security, compliance and productivity) and detection of transient data (e.g. Biodiversity movement, flowering and fruiting);
6. Causality to quantitatively identify causes that increases the probability of effects occurring, in order to derive a strategy or cause of action to achieve desired objectives (e.g. By attributing deforestation to an increase in probability of flood occurrence, logging activities can be taken into consideration and regulated);
7. Valuation usage of mathematical models and functions to estimate the economic value of an asset (e.g. Tree, forest) or a process (e.g. Seed-dispersal, pollination) using approaches such as property value, production function, replacement cost, defensive expenditure, human capital;
8. Risk Management using modeling and forecasting to identify sources of risk and their potential impact, then subsequently developing a strategy or a series of actions to mitigate the risk; (e.g. Understanding how

rainfall and logging could contribute to landslides and flooding, then coming up with countermeasures) and

9. Policy Recommendation using variety of relevant inputs such as from research, assessment, forecasting, surveying, causality, valuation and risk management to influence policy review and change. (e.g. The government would be able to decide how to best implement carbon strategy with a better understanding on how different actions correlate and influence each other resulting in a variety of outcomes with different risk factors).

[0085] Fig. 7 illustrates an ambient energy harvester 702. In an embodiment, the sensors 28 are deployed remotely in a rain forest, which is a solar energy rich and vibration scarce environment. The Sentinel Platform 20 includes the ambient energy harvester 702 to collect solar and wind energy on a daily basis, especially when a mast of the Sentinel Platform 20 holds wind turbine blades (not shown) above a tree canopy (not shown). Additionally, during overcast and rainy days, when solar energy harvesting is reduced, the ambient energy harvester 702 supplement the solar energy harvesting with vibration energy from rainfall and wind.

[0086] In Fig. 7, the ambient energy harvester 702 comprises an array of solar panels 704 that are attached to their supporting frame 706 by piezoelectric elements respectively. The supporting frame 706 is slightly pliant and flexible to allow the individual solar panel-piezoelectric systems to be vibrationally coupled together. Stems 708 of the supporting frame 706 are differently weighted to cause a measured degree of chaotic oscillation to occur. The chaotic behavior of the system 702 allows occasional high amplitude vibrations to occur even at low wind speeds.

[0087] Fig. 8 illustrates the sentinel platform 20 as physically implemented. Fig. 8 comprises parts or components that are similar or identical to those described before. Descriptions of the similar or identical parts are therefore incorporated wherever relevant.

[0088] The sentinel platform 20 comprises solar panels 704a-f, a data logger (Sentinel Core™) 802, a sectional guyed mast 804, a high-gain antenna 806 and a remotely

controlled camera 808. The sectional guyed mast 804 is extendable from 3 meters to 818 meters, which further supports the data logger 802, the solar panels 704, the high-gain antenna 806 and the remotely controlled camera 808. The sectional guyed mast 804 is firmly planted into the ground such that both the high-gain antenna 806 and the remotely controlled camera 808 are above tree-canopies of its neighboring trees. The data logger 802 comprises the base station 22 and the adaptor 24.

[0089] When in use, the sentinel platform 20 provides real-time remote data access. Components of the sentinel platform, including the data logger 802, are enclosed by weatherproof enclosures that ensure reliable performance. The sentinel platform 20 provides flexible power and communications options for its connections. The sentinel platform 20 further has modular data storage units for data backup & retrieval, and allows integration with wide variety of sensors 28 or sensor network 30. The sentinel platform 20 has computer software programmes for dynamic resource monitoring and management. For example, the sentinel platform 20 is implemented with cloud-based software allows customization and alerts.

[0090] Fig. 9 illustrates a data logger 802 of the sentinel platform 20 as implemented. The data logger 802 is installed with the cloud platform 26 (NucleuS^{TM}) for managing sensor-acquired data, users and visualizing the sensor-acquired data using tables, graphs and map resources. The sentinel platform 20 is configured with custom alert to trigger on system conditions, such as when memory or power is running low, or on specific sensor readings to alert an important change. The cloud platform 26 is connected to the base station 22.

[0091] The data logger 802 provides a reliable, utilitarian data logging and control unit that serves as a one-stop solution for sensing. The data logger 802 comprises in-built power storage, cellular capabilities and multi-communication interfaces such that the data logger 802 can be rapidly configured for a wide range of sensing applications. The data logger 802 enables remote monitoring through a web-based software program, known as NucleuS^{TM}.

[0092] Accordingly, the sentinel platform 20 provides real-time remote data access. Components of the sentinel platform 20 have weatherproof enclosure that ensures

reliable performance. The sentinel platform 20 further has flexible power options and communications sources. The sentinel platform 20 also has modular data storages for data backup and retrieval. The data logger 802 of the sentinel platform 20 is compatible with a wide range of sensors 30. The data logger 802 is portable, compact and easy to setup.

[0093] An embodiment of the data logger 802 has an ARM9 Single Board Computer (Central Processing Unit) which runs on a Linux Operating System. The data logger 802 further has a1 GB solid-state drive (SSD, solid-state disk or Data Storage), expandable via SD card. The data logger 802 further has cellular and satellite data transmission capabilities. In the embedment, the data logger 802 comprises twelve data communication channels. Wired communication interfaces of the data logger 802 include serial, Analog, USB and PoE, whilst wireless communication interface Wi-Fi and ZigBee. Range Extenders of the sentinel platform 20 contains the high-gain directional antenna 806, which are connected to the data logger 802. The data logger 802 has an inbuilt battery of 12V and 18AH. The data logger 802 further has a socket (not shown) for receiving an input voltage of 24V (Direct Current) or 110/240V (Alternating Current). Output voltages of the data logger 802 are 5V, 12V, 24V & 48V for DC and 110/240V for AC. Operating Temperature of the data logger 802 and the sentinel platform 20 is -25 to 50°C. Physical dimensions of the data logger 802 are 559mm (length), 351 (width) and 229mm (millimeter) height. The data logger 802 as described has physical mass of 5kg (kilogram). Enclosure or casing of the data logger 802 is made of polypropylene copolymer with polyurethane wheels and stainless steel parts. The enclosure has an Ingress Protection Rating of IP65 (Dustproof; Water jet protected). Mounting Options of the data logger 802 include pole-mounting, tripod-mounting and trees-mounting with accessories.

[0094] Fig. 10 illustrates the sentinel platform 20 in a sensor network 1002. The Sentinel Platform™ 20 provides power, communications and intelligence to remote locations. The data logger 802 (Sentinel Core™) serves as an enabler for the sentinel platform 20, allowing virtually a wide variety of devices to be integrated, providing flexibility for applications (software programs) while keeping costs low. The sentinel platform 20 facilities forestry research, sustainable agriculture and Crop Science,

environmental monitoring, meteorological forecasting, geotechnical surveillance, water resource studies and sensor development.

[0095] In the application, unless specified otherwise, the terms "comprising", "comprise", and grammatical variants thereof, intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, non-explicitly recited elements.

[0096] As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

[0097] Throughout this disclosure, certain embodiments may be disclosed in a range format. The description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0098] It will be apparent that various other modifications and adaptations of the application will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the application and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. Data logger for sensor network, the data logger comprising
   - a central processing unit for signal processing,
   - a memory device connected to the central processing unit for storing the data,
   - an electronic circuit connected to both the central processing unit and the memory device, and
   - a power supply further connected to the electronic circuit for providing electricity to the data logger, the electronic circuit comprising an universal interface for connecting different types of sensors via various communication modes;

   wherein the data logger is configured to provide power management algorithm to allow the corresponding sensor network to be self-powered reliably or work efficiently.

2. Data logger of Claim 1, wherein
   the universal interface is configured to detect availability of a sensor for configuration or connection.

3. Data logger of Claim 1 or 2, wherein
   the universal interface comprises an analogue port, a digital port or both for receiving analogue or digital signals from the sensors via the various communication modes.

4. Data logger of any of the preceding Claims, wherein
   the universal interface further comprises a communication module, the communication module having a wired terminal, a wireless terminal or both for connecting the sensors via the various communication modes.

5. Data logger of Claim 4, wherein
   the wired terminal comprises a USB terminal, a PoE terminal, a RS-232 terminal, a RS-232 express terminal, a RS-485 terminal, a parallel terminal, a coaxial terminal, an optical terminal, an Ethernet terminal, a FireWire terminal,

a DSL terminal an ADSL terminal or a combination of any of these terminals for providing the various communication modes.

6. Data logger of Claim 4, wherein
the wireless terminal comprises a Near Field Communication Terminal, a Wi-Fi terminal, a ZigBee terminal, a Bluetooth terminal, a GPRS terminal, an Edge terminal, a 3G terminal, a 4G terminal, a GSM terminal, a HSPA terminal, a CDMA terminal, a WCDMA terminal, an UMTS terminal, a radio (communication) terminal, a LTE terminal, a SATCOM terminal, a WiMax terminal, a satellite network terminal, a VSAT terminal, a MSAT terminal, a VHF terminal, an UHF terminal, a DSL terminal, an ADSL terminal or a combination of any of these terminals for providing the various communication modes.

7. Data logger of any of the preceding Claims, wherein
the universal interface further comprises at least one analogue to digital converter connected to the analogue port for converting analogue signals to digital signals.

8. Data logger of any of the preceding Claims, wherein:
the power supply comprises at least one connector for receiving the electricity from onboard batteries, external power supplies or both.

9. Sentinel platform for sensor network, the sentinel platform comprising:
- the data logger of any of the preceding claims,
- a base station having a microcontroller connected to the data logger for data processing, and
- a data storage device connected to the data logger, the microcontroller or both for data storage.

10. Sentinel platform of Claim 9 further comprising:
a cloud platform connected to the microcontroller for transferring data to a remote data storage device.

11. Sentinel platform of Claim 10, wherein
the cloud platform comprises at least one wireless terminal for data transmission.

12. Sentinel platform of any of the preceding Claims 9 to 11 further comprising
an user interface for controlling or monitoring the sensors.

13. Sentinel platform of Claim 12, wherein
the user interface comprises a display unit, a keyboard, a computing mouse, a scanner, a memory card reader, a biometric reader, a printer or a combination of any of these.

14. Sentinel platform of any of the preceding Claims 9 to 13 further comprising
a power source for providing electricity.

15. Sentinel platform of Claim 14, wherein
the power source comprises a battery, a solar panel, an electricity generator, a biomass electricity generator, a biofuel electricity generator, a geothermal electricity generator, a piezoelectric element or a combination of any of these.

16. Sentinel platform of any of the preceding Claims 9 to 15, wherein
the base station is configured to manage electricity supply to components of the sentinel platform according to predetermined priority level, power consumption requirement, sampling rate or a combination of any of these.

17. Sensor network comprising:
sensors for collecting data, and
the data logger of any of the preceding Claims 1 to 8,
the sentinel platform of any of the preceding Claims of 9 to 16, or
both the data logger of any of the preceding Claims 1 to 8 and the sentinel platform of any of the preceding Claims of 9 to 16.

18. Sensor network of Claim 17 further comprising
at least one relay node for increasing signal strength of the sensors.

19. Sensor network of Claim 17 or 18 further comprising
two or more different types of sensors having the various communication modes.

20. Method of using a data logger comprising:
- installing an operating system for sensor network,
- selecting sensor type or communication mode of the sensor,
- loading at least one driver software program according to the sensor type, the communication mode or both, and
- applying power plan, sampling scheme, data transmission rate or a combination of any of these.

21. Method of Claim 20 further comprising:
selecting at least one communication mode or channel according to the sensor type, communication mode, or both.

22. Method of using the sentinel platform according to any of the preceding Claims 8 to 16 comprising:
determining power plan, communication channels, data recording format, sensor types for the sentinel platform.

23. Method of Claim 22 further comprising:
installing, configuring, updating or uninstalling at least one device driver or operating systems.

24. Method of installing the sentinel platform according to any of the preceding Claims 9 to 16 comprising:
mounting the sentinel platform on a frame for providing communication of the sentinel platform with less ambient interference.

25. Method of Claim 24 further comprising:
connecting an antenna, a camera, power source, data logger or any of these onto the frame.