

Monitoring System

Field of invention

5 The present invention generally relates to a system and a method for non-intrusive monitoring. The present invention more particularly relates to a system and a method for non-intrusive monitoring at device level to overview technical installations to identify devices that cause loss of resources.

10 Prior art

Waste and overconsumption of resources are a major concern in modern society, because it leads to both environmental and economic problems. A significant part of the wasted resources origins from dysfunctional or inefficient devices. Dysfunctional devices may lead to waste of resources
15 because the intended production is damaged or even lost, whereas inefficient devices may lead to overconsumption of resources to obtain the desired production.

20 From industrial production it is well known that present and emerging problems can be identified, and overconsumption of resources reduced, by continuous monitoring at level of the single production devices. The challenge of the present systems is, however, that the expenses to install and operate the entire set of needed specialised technologies limit the areas of use. Moreover, such monitoring systems are often complicated to
25 retrofit at existing device installations, and difficult to fit acceptable into the designs.

The so-called non-intrusive monitoring (NILM) systems that apply a technique that e.g. determines the electrical load composition of a
30 household through a single point of measurement at the main power feed are well known. The technique is described by G. W. Hart in the paper "Residential energy monitoring and computerized surveillance via utility

power flows" in Technology and Society Magazine, vol. 8, no. 2, pp. 12, 16, June 1989.

5 This technique, however, is unable to handle a complex electrical setup, and to overcome the challenge it has been proposed to add simple sub-metering electricity sensors in the installation, to distinguish devices with similar energy flow. EP2489987A2 discloses a system for non-invasive energy flow monitoring. The system comprises one or more device embodiments that include a transformer configured to couple the device to
10 a circuit conductor that is coupled to an additional device. The system moreover comprises a detection module configured to detect a change in a power signal over the circuit conductor, and a transmission module configured to transmit a unique signal associated with the additional device over the circuit conductor, if the change in the power signal meets or
15 exceeds a particular threshold.

Even such more advanced NILM approaches are, however, often unable to forecast and estimate emerging problems and/or overconsumption of resources. In dynamic systems, such as ventilation, hygienising or food
20 production, it is typically insufficient to know e.g. the flow of electricity, to be able to model the actual performance of the system.

When multiple sources of variation affects the latent (e.g. underlying) dynamic (e.g. evolving) stochastic process it is virtually impossible to model
25 the said stochastic process efficiently by the methods of the prior art. The only alternative is therefore, the expensive and complicated monitoring technologies known e.g. from industry.

To be more specific, there is need for a system that can be retrofitted at an
30 existing installations (in a building by way of example), to give an overview of the performance of critical devices. There is also need for the system to

estimate and predict the activity, energy consumption and/or resource flow (for instance heat, power and/or ventilation) of the critical devices.

5 Accordingly, it is an object of the present invention to provide a system for monitoring resource flow(s) at a number of devices, which system is less expensive and complicated than the prior systems that apply traditional monitoring technologies.

10 It is also an object of the present invention to provide a system that is capable of estimating and predicting the activity, energy consumption and/or resource flow (e.g. heat, power and/or ventilation) of a number of predefined devices.

Summary of the invention

15 The objects of the present invention can be achieved by a system as defined in claim 1 and by a method as defined in claim 10. Preferred embodiments are defined in the dependent sub claims and explained in the following description and illustrated in the accompanying drawings.

20 The system according to the invention is a system for monitoring resource flow(s) at a number of devices, which system comprises a receiving unit configured to receive data from a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and a number of meters configured to measure the overall flow for at least a
25 part of the devices. The system comprises a calculation module configured to receive information from the sensors and the meters and the calculation module comprises a mathematical statistic model configured to estimate and/or predict the flow of resources and/or the performance of at least a selection of the devices.

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Hereby it is achieved that the system can estimate and predict the activity,

estimate and predict the activity, energy consumption and/or resource flow (for instance heat, power and/or ventilation) of the critical devices.

5 Accordingly, it is an object of the present invention to provide a system for monitoring resource flow(s) at a number of devices, which system is less expensive and complicated than the prior systems that apply traditional monitoring technologies.

10 It is also an object of the present invention to provide a system that is capable of estimating and predicting the activity, energy consumption and/or resource flow (e.g. heat, power and/or ventilation) of a number of predefined devices.

Summary of the invention

15 In one aspect, there is provided a system for monitoring resource flow(s) at a number of devices, which system comprises a receiving unit configured to receive data from

A. a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and

20 B. a high precision meter configured to measure the overall flow for at least a part of the devices by a predefined high accuracy, characterised in that the system comprises a calculation module configured to receive information from the sensors and the meter, where the calculation module comprises a mathematical statistic model configured to
25 estimate and/or predict the latent stochastic process, (i.e. flow of resources and/or performance (e.g. activity), of the devices by using data from the sensors and the meter); where the data from the sensors and the meter at time t are given as a vector (Y_t), where the latent stochastic process (flow of resources and/or performance such as percent ventilation efficiency,
30 percent overconsumption of resources, resource flow or device health status) at time t is a vector (θ_t), where the mathematical statistic model uses

a noise vector (ϵ_t) of the data from the sensors and the meter at time t and eventually a noise vector (ϑ_t) of the latent stochastic process at time t , where the statistical distribution of the noise vectors (ϵ_t, ϑ_t) are estimated on the basis of the data from the sensor and the meter.

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In another aspect, there is provided a method for monitoring resource flow(s) at a number of devices by using a receiving unit which receives data from a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and a high precision meter
 10 configured to measure the flow of at least a selection of the devices by a predefined high accuracy, characterised in that the method comprises the step of estimating and/or predicting loss and/or flow of resource(s) of the devices by using a calculation module configured to receive information from the sensors and the meter, where the estimating and/or predicting of
 15 resource flows is carried out in a calculation module that comprises a mathematical model by using data from the sensors and the meter, where the mathematical model is configured to estimate the latent stochastic process using a mathematical statistic model, where the mathematical statistic model combines data from the sensors and the meter to estimate
 20 the latent stochastic process, where the data from the sensor and the meter at time t are given as a vector (Y_t), where the latent stochastic process (flow of resources and/or performance such as percent ventilation efficiency, percent overconsumption of resources, resource flow or device health status) at time t is a vector (θ_t), where the mathematical statistic model uses
 25 a noise vector (ϵ_t) of the data from the sensors and the meter at time t and eventually a noise vector (ϑ_t) of the latent stochastic process at time t , where the statistical distribution of the noise vectors (ϵ_t, ϑ_t) are estimated on the basis of the data from the sensor and the meter.

30 The objects of the present invention can be achieved by a system as defined in claim 1 and by a method as defined in claim 12. Preferred

embodiments are defined in the dependent sub claims and explained in the following description and illustrated in the accompanying drawings.

5 Herein disclosed is a system for monitoring resource flow(s) at a number of devices, which system comprises a receiving unit configured to receive data from a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and
a number of meters configured to measure the overall flow for at least a part of the devices. The system comprises a calculation module configured
10 to receive information from the sensors and the meters and the calculation module comprises a mathematical statistic model configured to estimate and/or predict the flow of resources and/or the performance of at least a selection of the devices.

15 Hereby it is achieved that the system can estimate and predict the activity,

performance and or resource flow (for instance heat, power or ventilation air flow) of a group of devices, for example a HVAC (heating, ventilation, and air conditioning) system in a commercial building or in a production factory. Moreover, the system can detect if the devices are used and/or
5 working in a manner that leads to overconsumption of resources.

Moreover, it is achieved that the system can be built by means of less complicated and accurate (and thus cheaper) monitoring devices (sensors) than the prior art systems. In fact, it is possible to apply sensors that are
10 unfit for being used in the known systems. By applying a mathematical statistic model, the system according to the invention makes it possible to "calibrate" and/or adjust the measurements from "simple" and "cheap" sensors (having low accuracy compared with a typical meters being used in such systems).

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Devices may be electrical devices, heaters, pipes or other structures through which a flow (electricity, power, heat energy, air, gas, water, or electromagnetic radiation) may pass.

20 By device is meant a single device, a well-defined group of devices, or sub-devices of e.g. complex devices such as a machinery.

By the term sensor is meant a unit capable of detecting one or more parameter such as temperature, light, or flow of water, current, gas, and/or
25 air. The sensor may be configured to detect the flow rate and/or the change in the flow rate of a flow for instance. The detection may be a direct measurement or an estimate.

It is preferred that all the sensors can be retrofitted to an existing installation
30 (a building or a machine by way of example).

It may be an advantage to use sensors that are configured to be attached to the outside of a cable or a pipe. Such sensors may be piezoelectric sensors. The sensors may be mechanically attached at the outside of pipes, tubes and cables of different geometry, dimension, material and medium.

The sensors are configured to send information to the receiving unit and the information may be any suitable type of signal (e.g. a wireless signal). The information may be any type of data detected by the sensors and meter(s).

The calculation module may be any suitable type of calculation module configured to receive information from the sensors and to comprise a mathematical statistic model.

By the term estimate and/or predict is meant a determination by using the mathematical statistic model. The determination may be a forecast based on information from the collected data from the sensors and meters as well as any suitable other information. In any case it may be an advantage to apply a mathematical statistic model that is developed to match the application. In other words, different applications may require different mathematical statistic models.

By the term resource flow is meant flow of heat, power and/or flow of a fluid through a pipe (or another structure) and/or intensity of electromagnetic radiation or a flow of another quantity. The resource flow may be power uptake (energy per time unit) or a flow (e.g. water) through a pipe (volume per unit time) by way of example.

It is preferred that the calculation module comprises a mathematical statistic model configured to estimate and/or predict resource flow of all the devices.

It is preferred that the calculation module comprises a mathematical statistic model configured to estimate and/or predict that a device do not perform as expected.

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It is preferred that the mathematical statistic model can generate warnings and alarms to inform the user if the system does not perform as expected.

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It is preferred that the sensors are configured to communicate wirelessly with the receiving unit.

It is possible to use sensors of simple type, e.g. sensors that are configured to be attached to the outside of a pipe of a cable.

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By the term meter is meant a unit configured to measure the overall resource flow of at least a section of the devices. A meter may be a unit configured to measure the overall resource flow of at least a section of the devices by a predefined accuracy, preferably a high accuracy. Such meter is typically used to perform precise measuring of energy consumption, heat, cooling and electricity by way of example.

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In a system according to the invention it would be possible to use sensors having significantly lower accuracy than the meter(s) of the system. By using a mathematical statistic model, it is possible to "compensate" for the lower accuracy of the sensors.

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Hereby an overall measure of at least a section of the devices can be provided.

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It may be an advantage that the system comprises a number of meters configured to measure resource flow of all the devices and to send

information to the receiving unit. Hereby the total resource flow can be determined.

5 It may be an advantage that the meters are high precision meters capable of providing a very accurate measurement of the resource flow so that the detected data can be used to provide accurate estimates and/or predictions of resource flow at the devices.

10 It is possible to have a system, in which not all devices are equipped with a sensor and where the meters measure the resource flow of more devices than the devices equipped with a sensor.

15 The mathematical statistic model is preferable configured to estimate and/or predict resource flow of the devices on the basis of the information from the sensors and from the meters even if not all devices are equipped with a sensor.

20 It may be an advantage that the mathematical statistic model is of the specific class that is able to estimate the latent part of each main meter measurement that is associated with each sensor.

It may be beneficial that the mathematical statistic model comprises:
- a mathematical function component modelling the latent mapping from the main meter measurements onto the specific sensor measurements and
25 - a stochastic component modelling the measurement noise and the part of each main meter measurement associated with usage which are not measured by sensor(s), if any.

30 The mathematical statistic model may be of any suitable type capable of estimating the latent part of each main meter measurement that is associated with the sensors. As known from the field of statistical

modelling, several approaches can be used to build a model of the specific class, e.g. time series analysis methods and/or multivariate data-analysis methods, such as Analysis of Variance (ANOVA), Markov models, Generalized Linear Models (GLM), and Multivariate Gaussian Models.

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It may be beneficial that the system comprises a user interface, preferably a remote user interface and that the user interface provides access to generated information such as warnings, alarms and estimated and/or predicted resource flow(s) of at least a selection of the devices.

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Hereby a very simple and user friendly system can be provided.

It may be an advantage that the calculation module is implemented in one or more router. Hereby it is possible to provide a reliable and safe configuration of the system.

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It may be beneficial that one or more of the sensors comprises an energy harvester. Hereby the sensors may be self-sufficient with power so that no battery or external energy is required.

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It may be an advantage that the harvested energy is used to detect resource flow or change resource flow rate of the devices. Herby simple and efficient sensors may be provided and a valid and reliable detection technique may be applied.

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It may be an advantage that the harvested energy is used to detect resource flow or change resource flow rate of the devices and to perform wireless communication with the receiving unit and/or calculation module.

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It may be an advantage that the calculation module and the mathematical statistic model are integrated in an apparatus of the system. Hereby there is

no need for a separate router and very simple system can be provided.

It may be an advantage the calculation module and the mathematical model and the user interface are integrated in an apparatus of the system.

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It may be advantageously that the calculation module and the mathematical statistic model are integrated in a user interface. Such system is simple and requires only few features.

10 It may be an advantage that the user interface is a smartphone or similar smart device.

Moreover it may be an advantage that the calculation module and the mathematical statistic model are integrated in a smartphone.

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In a preferred embodiment according to the invention the calculation module is a cloud service with mathematical statistic model and a data storage. The use of such cloud service makes it possible to connect other systems to the cloud service and hereby get additional data for the mathematical statistic model from other systems. Accordingly, a very complex and accurate mathematical statistic model can be developed. Moreover, trends may be detected faster when the cloud service gets additional data for the mathematical statistic model from other systems.

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25 It may be an advantage that the system comprises a control unit configured to change the activity of one or more of the devices or other apparatuses, e.g. a valve of a main pipe. Hereby it is achieved that the system can perform actions (switch off devices, regulation of speed of a motor or other action) by using a control unit. The control unit may comprise one or more actuators (e.g. an electric valve or an electrically controlled permanent magnet motor by way of example).

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It is preferred that the system is configured to estimate the actual and/or future activity of at least a selection of the devices. Hereby the system can be used to regulate and optimize the activity of the devices in order to save energy and avoid dysfunctional devices from being kept turned on, and to avoid waste of resources and overconsumption of resources.

It may be an advantage that the sensors are configured to be attached as e.g. tape, clip or strips to the devices (e.g. on the power cable of an electrical device). In this way the sensors do not need to have physical contact to the internal of the monitored pipe, cable, container, cooling/heating device of the device.

Herein disclosed is a method for monitoring resource flow(s) of a number of devices by using a receiving unit which receives data from a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and a number of meters configured to measure the flow for at least a part of the devices. The method comprises the step of estimating and/or predicting loss and/or flow of resource(s) of at least a selection of the devices by using a calculation module configured to receive information from the sensors and the meters, where the estimating and/or predicting resource flow is carried out in a calculation module that comprises a mathematical statistic model.

It may be an advantage that the method comprises the step of sending information from a number of meters configured to measure the resource flow of at least a section of the devices to the receiving unit and applying the information from the meters to estimate and/or predict resource flow of at least a selection of the devices.

It is preferred that the method uses a system as defined in claim 1-11 to

estimate and/or predict resource flow of at least a selection of the devices.

It may be an advantage the receiving unit is configured to automatically recognise one or more of the sensors and/or meters of the system. Hereby
5 it becomes easy for the user to install the sensors and/or meters of the system.

It may be an advantage that the user of the system can add further information about a sensor, meter or control unit through a user interface.
10 The added information can be used in the mathematical statistic model and/or in a user interface.

It may be an advantage that at least some of the sensors and/or meters contain a timestamp module to ensure correct linking of data from the
15 sensors and/or meters.

The data from the sensors and/or meters may be sampled at any suitable sampling rate e.g. once a second, once a minute or once every half hour.

20 It may be an advantage to use one or more repeaters each configured to receive a signal and retransmit it at a higher level or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances.

25 It may be an advantage that the data from the sensor and/or meters are condensed throughout the data collection process, so only sufficient data to determine the latent process is transferred further on to the mathematical statistic model. It may be e.g. by condensing a sequence of homologue status packages from a sensor to a single data package containing only the
30 start and the end time of the actual status of the sensor. The data

condensing may be performed e.g. at one or more routers and/or sensors and/or meters.

5 It may be beneficial that the mathematical statistic model and/or a user interface and/or the control units are operated through a cloud service, which may be hosted on e.g. a central server, a mobile processor, a laptop, an embedded controller, or one or more local routers.

10 The mathematical statistic model may be implemented in computer code, or directly in an integrated circuit.

It may be an advantage that a user interface has remote access to the system.

15 It may be an advantage that wireless data communication is carried out by using a ZigBee and/or WiFi data communication protocol.

Description of the Drawings

20 The invention will become more fully understood from the detailed description given herein below. The accompanying drawings are given by way of illustration only, and thus, they are not limitative of the present invention. In the accompanying drawings:

- 25 Fig. 1 shows a schematic view of a first system according to the invention;
- Fig. 2 shows a schematic view of a second system according to the invention;
- Fig. 3 shows a schematic view of a third system according to the invention;
- 30 Fig. 4 shows a device being monitored by a system according to the invention and

Fig. 5 shows a portion of a system according to the invention.

Detailed description of the invention

5 Referring now in detail to the drawings for the purpose of illustrating preferred embodiments of the present invention, a system 2 according to the present invention is illustrated in Fig. 1.

10 Fig. 1 is a schematic view of a system 2 according to the invention. The system 2 comprises a first sensor S_1 configured to monitor a first device D_1 to which the first sensor S_1 is attached. The system 2 also comprises two further sensors (S_2 and S_3) which are configured to monitor a second device D_2 . The system 2 moreover comprises two further sensors (S_4 and S_5) which are configured to monitor a third device D_3 . The sensors S_1 , S_2 , S_3 , S_4 , S_5 are configured to communicate wirelessly with a router 4.

20 The system 2 comprises meters (M_1 and M_2) that are configured to communicate with the router 4 that is configured to communicate wirelessly with a cloud service 8. The router 4 is communicating wirelessly with a user interface 10 represented by a smartphone 10. The router 4 is also configured to communicate wirelessly with control unit 6. The control unit 6 may be an actuator capable of regulating the activity of one or more of the devices D_1 , D_2 , D_3 , or a fourth device D_4 . Regulation of the activity of one or more of the devices D_1 , D_2 , D_3 , D_4 may be carried out by changing a flow (e.g. by using a valve), changing the speed (of a pump or a motor) or by
25 shutting down one or more of the devices D_1 , D_2 , D_3 , D_4 by way of example.

30 The sensors S_1 , S_2 , S_3 , S_4 , S_5 may monitor the devices D_1 , D_2 , D_3 continuously or in selected time periods such as one minute every hour, one second every minute or another frequency and measurement duration.

The cloud service 8 comprises a data storage 36 that can be used to store information received from the router 4 or data modified or calculated by the cloud service 8. The cloud service 8 moreover comprises a mathematical statistic model 38 that is configured to estimate and/or forecast the activity of one or more of the devices D₁, D₂, D₃ or the flow (e.g. of a fluid, gas, electricity or heat) through the one or more of the devices D₁, D₂, D₃. The mathematical statistic model 38 may be a mathematical statistic model 38 of any suitable type and the mathematical statistic model 38 may conduct inference on combined data from one or more of the sensors S₁, S₂, S₃, S₄, S₅ and from one or more of the meters M₁, M₂, M₃ to estimate and/or forecast the activity of one or more of the devices D₁, D₂, D₃ or the flow (e.g. of a fluid, gas, electricity or heat) through the one or more of the devices D₁, D₂, D₃.

The cloud service 8 may receive inputs from a number of other systems (not shown) and by this way information may be gathered from several systems of equal or different types. By this way it is possible to provide an updated mathematical statistic model 38 according to flow profiles (e.g. resource flows) of the devices D₁, D₂, D₃.

It is preferred that the meters M₁, M₂, M₃ are meters of high precision, however, the sensors S₁, S₂, S₃, S₄, S₅ may be cheap sensors. The data from the meters M₁, M₂, M₃ and from the S₁, S₂, S₃, S₄, S₅ may be used to predict the flow rate(s) of the D₁, D₂, D₃ by using the mathematical statistic model 38.

The sensors S₁, S₂, S₃, S₄, S₅ may be configured to measure flow (e.g. of a fluid in a pipe), electricity, temperature, lux (if the sensor is a lux meter for measuring illuminances in a room or outside by way of example) for example.

The devices D₁, D₂, D₃ may be various devices having a flow of "resources" such as power, fluid (e.g. a liquid like a coolant, beverage or water or a gas such as natural gas). Accordingly, the devices D₁, D₂, D₃ may be HVAC devices such as heating devices, ventilating devices and air conditioning devices or refrigerators, lamps, radiators, floor heating or electronic devices in general.

The system 2 is easy to retrofit at existing installations. The sensors S₁, S₂, S₃, S₄, S₅ may be added to existing installation e.g. simply by attaching a wireless temperature sensor S₁ to a heating surface or an induction sensor S₂ to an electrical device D₂ by way of example.

The meters M₁, M₂, M₃ may be existing meters M₁, M₂, M₃ in an existing installation. Thus, some of the elements in the system 2 may already exist in the installation, to which the system 2 is to be retrofit.

It is possible to use a repeater in case that the system 2 has to be installed in a large area. One or more repeaters may be configured to receive a signal and retransmits it at a higher level or higher power, or onto the other side of an obstruction, so that the signal can cover longer distances.

Fig. 2 illustrates a schematic view of a system 2 according to the invention. The system 2 comprises a wireless router 4 that is configured to communicate wirelessly with a group of sensors S₁, S₂, S₃, S₄, meters M₁, M₂, M₃, a cloud service 8, a user interface 10 in the form of a smartphone 10 and three control units 20, 22, 40.

The system 2 comprises a first meter M₁ configured to measure the total power flow of group of electrical devices including an air conditioner 24. It is important to underline that the system may comprise a large number of electrical devices even though this is not indicated in Fig. 2.

The first meter M_1 is configured to communicate wirelessly with the router 4 and send information about the total power flow to the router. The first meter M_1 also comprises a power switch 18 that can be controlled wirelessly by the router 4. In case that a power alert is generated the router 4 may shut down the main power line by using the power switch 18.

The system 2 further more comprises a main pipe (for water supply) 14. The main pipe 14 is equipped with a meter M_2 configured to communicate wirelessly with the router 4 and send information to the router 4. The meter M_2 is configured to continuously measure the total water flow through the building into which the system 2 is installed.

A valve 20 is mounted on the main pipe 14 and the valve is configured to communicate wirelessly with the router 4. The router 4 can control the valve 20 and hereby regulate the flow through the main pipe 14. The valve 20 can reduce (e.g. by closing the valve 20) the flow through the main pipe 14, increase the flow through the main pipe 14 or maintain a constant the flow through the main pipe 14.

The system 2 also comprises a third meter M_3 that is configured to communicate wirelessly with the router 4. The router 4 receives wireless information about the total energy flow measured by the energy meter M_3 .

The first sensor S_1 is attached to a first device 16 that is a water pipe 16. The water pipe 16 is provided with a control unit formed as a valve 40. The first sensor S_1 is configured to detect the flow through the pipe 16 or if there is flow through the pipe 16 or if the flow through the pipe 16 is changing and then to send the detected information wirelessly to the router 4. The router 4 is configured to send wireless signals to the valve 40 and hereby control the valve 40 e.g. in order to regulate the flow through the pipe 16. The valve

40 may be closed in order to stop the flow through the pipe 16 in case of leakage (detected by the router 4. The router may compare the flow measured by the first sensor S₁ with the total flow measured by the meter M₂ at the main pipe 14).

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It may be an advantage that the sensor S₁ only is required to detect if there is flow through the pipe 16 or if there is change in the flow through the pipe 16. Hereby a simple a cheap sensor S₁ may be applied to the system 2.

10 The second sensor S₂ is attached to a heater 12. The second sensor S₂ is configured to detect the temperature of the heater 12 and/or flow of water through the heater 12 or to detect if there is flow through the heater 12 and send the detected information wirelessly to the router 4. It may be an advantage that the sensor S₂ only is required to detect if there is flow
15 through the heater 12 or if there is change in the flow through the heater 12 since it then would be possible to apply a simple a cheap sensor S₂ in the system 2.

The third sensor S₃ is attached to the power cable 26 of an air conditioner
20 24. The third sensor S₃ is configured to detect the temperature of the heater 12 and/or flow of water through the heater 12 and send the detected information wirelessly to the router 4. It may be an advantage that the sensor S₃ only is required to detect if there is power at the cable 26. In this way it would be possible to use a simple a cheap sensor S₃ in the system 2.

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The air conditioner 24 comprises a control unit 22 provided on the top of the air conditioner 24. The control unit 22 is capable of regulating the activity of the air conditioner 24. The control unit 22 is controlled wirelessly by the router 4. This means that the router 4 can switch off, turn on and regulate
30 the activity of the air conditioner 24 by communicating wirelessly with the control unit 22.

The system 2 also comprises a sensor S₄ that not is attached to any particular device. The sensor S₄ may be a temperature sensor place in any suitable location e.g. in order to detect the room temperature by way of example. The sensor S₄ may also be a lux sensor configured to measure the inflow of light, since this information may be important when deciding whether to turn on the heater 12 or not.

The system 2 comprises a cloud service 8 comprising a data storage 36 that can be used to store information received from the router 4 or data modified or calculated by the cloud service 8. Besides the cloud service 8 comprises a mathematical statistic model 38 that is configured to estimate and/or forecast the activity (flow of water, power or heat energy) of one or more of the devices 16, 24, 12 of the system. Any suitable mathematical statistic model 38 may be applied and the mathematical statistic model 38 may conduct inference on combined data from one or more of the sensors S₁, S₂, S₃, S₄ and from one or more of the meters M₁, M₂, M₃ to estimate and/or forecast the activity of one or more of the devices 16, 24, 12.

The user interface 10 that is a smartphone 10 communicates wirelessly with the router 4. Hereby the user of the system 2 can have access to information about the estimated or predicted resource flow of at least a selection of the devices 16, 12, 24. The smartphone 10 may also be used to control the control units 22, 40, 20 through the router 4 or to change settings in the router 4 (e.g. upload new structures or parameters to the mathematical statistic model 38).

The system 2 may be used to generate an alert and shout down or regulate the activity of the any of the devices 16, 24, 12 e.g. in order to reduce the total energy flow. By way of example the system 2 will automatically detect if the heater 12 and the air conditioner 24 are activated at the same time.

The system 2 will then either switch off the heater 12 (in case the room temperature is within a predefined comfort zone). If the room temperature is higher than the preferred room temperature the system 2 may increase the activity of the air conditioner 24. If, on the other hand, the room temperature is lower than the preferred room temperature, the system may switch off the air conditioner 24 and turn on the heater 12.

Fig. 3 illustrates a schematic view of a system 2 that is almost similar to the system 2 illustrated in Fig. 2. The wireless router 4 is, however, replaced with a user interface 10 in the form of a smartphone 10. The smartphone 10 is configured to communicate wirelessly with a group of sensors S_1 , S_2 , S_3 , S_4 , meters M_1 , M_2 , M_3 , a cloud service 8 and three control units 20, 22, 40. The function of the system 2 corresponds to the function of the system 2 illustrated in Fig. 2. It is important to point out that the user interface 10 may be any other type of suitable user interface, e.g. a laptop.

Fig. 4 illustrates a schematic view of the air conditioner 24 illustrated in Fig. 2 and in Fig. 3. Fig 4 a) is a schematic close-up cross sectional view of a sensor S_1 attached the power cable 26 of the air conditioner 24. Fig. 4 b) is a perspective view of the air conditioner 24.

In Fig. 4 b) it can be seen that the air conditioner 24 has a power cable 26 to which a sensor S_1 is attached. The sensor S_1 is configured to send a wireless signal 34 to a router or a user interface (not shown).

In Fig. 4 a) it can be seen that the S_1 comprises an energy harvester 28, arranged next to a centrally arranged power manager 30 that is arranged next to a wireless transducer 32. The energy harvester 28 may be any suitable type of energy harvester. The power manager 30 may be any unit capable of generating a signal 34 that can be send by using the wireless transducer 32.

It may be an advantage that the harvested energy is used to detect activity of the air conditioner 24. It would then be possible to provide a sensor S_1 capable of generating a wireless signal 32 when energy is harvested. When
5 the air conditioner 24 is activated the power cable 26 will be current-carrying and thus energy will be harvested.

The sensor S_1 may, however, be provided with a battery and or a number of capacitors or any other suitable energy storage if necessary.

10

The system 2 according to the invention may be used to detect early warning of emerging problems (e.g. leakage of water in a pipe network or emerging disease in an animal herd).

15 The system 2 may also be used to detect overconsumption of resources e.g. if a heater 12 and an air conditioner are activated at the same time. In this case the system 2 may be configured to take care of the situation and switch off or regulate the activity of at least one of the devices.

20 The system 2 may be used to provide general information about the actual flows of resources over time and to generate alarms in case of sudden failures. Besides the system may be used to estimate or predict future resource flow of the devices.

25 The system 2 may also be used to simulate the future resource flow of a new constellation of devices (e.g. if a company considers to increase the number of devices due to an increased production capacity demand).

30 The system 2 may be used to benchmarking similar devices, to perform service surveillance on technical devices, and to allow for remote surveillance.

The sensors S_1 , S_2 , S_3 , S_4 and the meters M_1 , M_2 , M_3 may each contain a unique identifier (e.g. number, signature, description or ID). In this way the route 4 or the user interface 10 is capable of coupling each incoming
5 wireless signal 34 with a specific device. In other words, the use of a unique identifier secures that the wireless signal 34 can be used in an optimum way by the route 4 or the user interface 10.

The sensors S_1 , S_2 , S_3 , S_4 may be configured to detect when the devices
10 D_1 , D_2 , D_3 , 12, 16, 24 are activated (when the devices are switched on or when there is a flow of a resource, e.g. water, gas or current, through the device).

Fig. 5 illustrates a portion of a system 2 according to the invention. Fig. 5
15 illustrates how a system 2 according to the invention can be used to measure water flow in a main pipe 14 and in a number of smaller distribution pipes 16.

The water supplied to the installation is metered by means of one main
20 meter M_1 that provides measurements of high precision (e.g. approved by authorities or within standards for flow measurements). The main pipe 14 is in fluid communication with a plurality of smaller distribution pipes 16, while a number of sensors S_1 , S_2 and S_3 are attached to the outside of some of these smaller distribution pipes 16, 16', 16".

25 In the following, we take a look at the metering at sensor S_1 . The sensor S_1 is a piezoelectric sensor that comprises simple piezo elements. Thus, the sensor signal changes with the flow in the pipe 16. The signal from the sensor S_1 depends, however, on the material and the dimension of the pipe
30 16, the sensor attachment and the medium (in this example water). Accordingly, and the sensor signal must be "transformed" or

“adjusted/calibrated” to give the actual flow (the flow that would be achieved by using a high precision meter). In a prior art system it would be necessary to apply “a high quality sensor” configured measure flow in the specific environment (the dimensions of the pipe 16, the material of the pipe 16 and attachment type).

Since the present invention applies a mathematical statistic model it is possible to use a simple sensor S_1 to determine the flow at the pipe 16. The use of a mathematical statistic model makes it possible to compensate for the low precision of the sensor S_1 .

The sensor S_1 is attached to the outside of the pipe 16 and hereafter it is possible to sample a series of measurements from the sensor S_1 , over a timespan.

In the same timespan a series of measurements is sampled from the main meter M_1 in the same timespan.

The mathematical statistic model is used to estimate the part of the main meter flow that flows through the pipe 16 having the sensor S_1 attached to it. It is possible to carry out a time-dependent transformation of the measurements of sensor S_1 in order to correct for the actual environment of the sensor S_1 .

A less computer demanding approach can be obtained by using a mathematical statistic model to estimate if a time-independent transformation can be used.

It may be an advantage to use the time-independent transformation, rather than the full mathematical statistic model, on the running measurements from the sensor S_1 .

It may be beneficial from time to time, to test if the precision of the transformation is acceptable, and update it if needed, using the mathematical statistic model.

- 5 The necessary amount of samples needed can be obtained by estimating the measurement error of the transformation. In this manner, the results can be detained until the desired precision is obtained.

10 In the following, one preferred method to estimate the latent stochastic process using a mathematical statistic model 38 is described. The latent stochastic process can be modelled by e.g. a state space model defined by

$$(1) \quad \mathbf{Y}_t = \mathbf{F}_t \boldsymbol{\theta}_t + \boldsymbol{\varepsilon}_t \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{V}_t)$$

$$(2) \quad \boldsymbol{\theta}_t = \mathbf{G}_t \boldsymbol{\theta}_{t-1} + \boldsymbol{\vartheta}_t \quad \boldsymbol{\vartheta}_t \sim \mathcal{N}(\mathbf{0}, \mathbf{W}_t)$$

15 where $\mathbf{Y}_t$ is a vector determines (e.g. describing, or defining) the observed process at time t , comprising observed data from the sensor ($S_1, S_2, \dots, S_n$) and/or the meters $M_1, M_2, \dots, M_k$; $\boldsymbol{\theta}_t$ is a vector determine the said latent stochastic process at time t , comprising latent process data, such as
 20 percent ventilation efficiency, percent overconsumption of resources, resource flow, device health status, etc; $\mathbf{F}_t$ is the regression matrix which determine the linear relation between the latent process and the observed process at time t ; $\mathbf{G}_t$ is the evolve matrix which determine the linear transition from time $t-1$ to time t in the latent process; $\boldsymbol{\varepsilon}_t$ and $\boldsymbol{\vartheta}_t$ are zero
 25 mean multivariate Gaussian distributed noise vectors of the observed process and the latent process respectively; $\mathbf{V}_t$ is the observation variance-covariance matrix; and $\mathbf{W}_t$ is the evolution variance-covariance matrix.

30 The model parameter matrices $\mathbf{F}_t$ and $\mathbf{G}_t$ may be estimated by e.g. the Kalman filter, using prior data from the modelled system and/or similar systems, hereunder the said data provided by the user and/or experts in the field. Standard statistical methods can be used to conduct inference (e.g.

estimate information) on the process. The information can be e.g. an estimated signal (e.g. trend) and/or forecasts (e.g. prognosis) of the process, and the related distributions of the estimates, variance and/or confidence intervals. Using these kinds of estimates, it is easy to e.g. raise
 5 warnings and/or alarms. For example an alarm can be chosen to appear if the probability of an observed deviation in the process is less than 0.1 % probable to occur by change.

The above model framework is a special case of the more general model
 10 framework

$$(3) \quad Y_t = f_t(\theta_t) + \varepsilon_t \quad \varepsilon_t \sim \delta_1(V_t)$$

$$(4) \quad \theta_t = g_t(\theta_{t-1}) + \vartheta_t \quad \vartheta_t \sim \delta_2(W_t)$$

15 where f_t and g_t are general functions, δ_1 and δ_2 are general statistical distributions, and all other terms are as described above.

Inference on this more general model framework can be conducted by e.g.
 20 the extended Kalman filter in cases where the relation between the latent process and the observed process is non-linear, and the Kalman-Bucy filter in cases where the time is defined (e.g. described) on a continuous scale.

Other time series analysis method and/or multivariate data-analysis
 25 methods, such as Analysis of Variance (ANOVA), Markov models, Generalized Linear Models (GLM), and Multivariate Gaussian Models may as well be used to estimate the said latent stochastic process, and infer the said information.

List of reference numerals

	2	-	System
	4	-	Router
5	6	-	Control unit
	8	-	Cloud service
	10	-	User interface
	D ₁ , D ₂ , D ₃	-	Device
	S ₁ , S ₂ , S ₃ , S ₄ , ..., S _n	-	Sensor
10	M ₁ , M ₂ , M ₃	-	Meter
	12	-	Heater
	14	-	Main pipe
	16, 16', 16''	-	Pipe
	18	-	Power switch
15	20	-	Valve
	22	-	Control unit
	24	-	Air conditioner
	26	-	Cable
	28	-	Energy harvester
20	30	-	Power manager
	32	-	Wireless transducer
	34	-	Wireless signal
	36	-	Data storage
	38	-	Mathematical statistical model
25	40	-	Valve

Claims

1. A system for monitoring resource flow(s) at a number of devices, which system comprises a receiving unit configured to receive data from

A. a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and

B. a high precision meter configured to measure the overall flow for at least a part of the devices by a predefined high accuracy,

characterised in that the system comprises a calculation module configured to receive information from the sensors and the meter, where the calculation module comprises a mathematical statistic model configured to estimate and/or predict the latent stochastic process, (i.e. flow of resources and/or performance (e.g. activity), of the devices by using data from the sensors and the meter); where the data from the sensors and the meter at time t are given as a vector (Y_t), where the latent stochastic process (flow of resources and/or performance such as percent ventilation efficiency, percent overconsumption of resources, resource flow or device health status) at time t is a vector (θ_t), where the mathematical statistic model uses a noise vector (ε_t) of the data from the sensors and the meter at time t and eventually a noise vector (ϑ_t) of the latent stochastic process at time t , where the statistical distribution of the noise vectors (ε_t , ϑ_t) are estimated on the basis of the data from the sensor and the meter.

2. A system according to claim 1, characterised in that the data from the sensor and the meter at time t are given as a vector, Y_t given by:

$$Y_t = f_t(\theta_t) + \varepsilon_t ,$$

where the latent stochastic process (flow of resources and/or performance such as percent ventilation efficiency, percent overconsumption of resources, resource flow or device health status) at time t is a vector θ_t which eventually can be modelled by the underlying process:

$$\theta_t = g_t(\theta_{t-1}) + \vartheta_t ,$$

where f_t and g_t are mathematical functions.

3. A system according to one of the preceding claims, characterised in that the high precision meter is configured to measure the total power flow for a group of electrical devices or to measure the total water flow or to measure energy consumption.
4. A system according to one of the preceding claims, characterised in that the system comprises a user interface, preferably a remote user interface and that the user interface provides access to the estimated and/or predicted resource flow(s) of at least a selection of the devices.
5. A system according to one of the preceding claims, characterised in that the calculation module is one or more routers.
6. A system according to one of the preceding claims, characterised in that one or more of the sensors comprises an energy harvester.
7. A system according to claim 6, characterised in that the harvested energy is used to detect resource flow or change resource flow rate of the devices.
8. A system according to one of the preceding claims, characterised in that the calculation module and the mathematical model are integrated in an apparatus of the system.
9. A system according to one of the preceding claims, characterised in that the calculation module is a cloud service comprising a mathematical model and a data storage.
10. A system according to one of the preceding claims, characterised in

that the system comprises a control unit configured to change the activity of one or more of the devices or another apparatuses, e.g. a valve of a main pipe.

11. A system according to one of the preceding claims, characterised in that the calculation module is configured to estimate the actual and/or future activity of at least a selection of the devices.

12. A method for monitoring resource flow(s) at a number of devices by using a receiving unit which receives data from a number of sensors configured to detect the flow rate and/or the change in the flow rate at device level, and a high precision meter configured to measure the flow of at least a selection of the devices by a predefined high accuracy, characterised in that the method comprises the step of estimating and/or predicting loss and/or flow of resource(s) of the devices by using a calculation module configured to receive information from the sensors and the meter, where the estimating and/or predicting of resource flows is carried out in a calculation module that comprises a mathematical model by using data from the sensors and the meter, where the mathematical model is configured to estimate the latent stochastic process using a mathematical statistic model, where the mathematical statistic model combines data from the sensors and the meter to estimate the latent stochastic process, where the data from the sensor and the meter at time t are given as a vector (Y_t) , where the latent stochastic process (flow of resources and/or performance such as percent ventilation efficiency, percent overconsumption of resources, resource flow or device health status) at time t is a vector (θ_t) , where the mathematical statistic model uses a noise vector (ϵ_t) of the data from the sensors and the meter at time t and eventually a noise vector (ϑ_t) of the latent stochastic process at time t , where the statistical distribution of the noise vectors $(\epsilon_t, \vartheta_t)$ are estimated on the basis of the data from the sensor and the meter.

13. A method according to claim 12, characterised in that the data from the sensor and the meter at time t are given as a vector, Y_t given by:

$$- \quad Y_t = f_t(\theta_t) + \varepsilon_t ,$$

where the latent stochastic process (flow of resources and/or performance such as percent ventilation efficiency, percent overconsumption of resources, resource flow or device health status) at time t is a vector θ_t which eventually can be modelled by the underlying process:

$$- \quad \theta_t = g_t(\theta_{t-1}) + \vartheta_t ,$$

where f_t and g_t are mathematical functions.

14. A method according to claim 12 or 13, characterised in that the method uses a system as defined in claim 1-11 to estimate and/or predict resource flow of the devices.